Northfield Downtown Flood Study

Phase 1— Flood Mitigation Options

Prepared for

City Of Northfield Minnesota

Rev 0	April 26, 2022	
Rev 1	6/19/23	Updated hydrology and hydraulics. Added Carleton Alts.

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Contents

List of Tables

List of Figures

List of Attachments

Certifications

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Digitally signed by Joseph J. Waln
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6/19/2023
Date

Abbreviations

AEP	annual exceedance probability
BCA	benefit-cost analysis
BCR	benefit-cost ratio
BFE	base flood elevation
cfs	cubic feet per second
CRS	Community Rating System
DHS	Department of Homeland Security
MDNR	Minnesota Department of Natural Resources
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FEMA	Federal Emergency Management Agency
GIS	geographic information system
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
LiDAR	light detection and ranging
LOMR	Letter of Map Revision
SFHA	Special Flood Hazard Area
USGS	United States Geological Survey
NFIP	National Flood Insurance Program
USACE	United States Army Corps of Engineers

1 Introduction

The purpose of this study is to evaluate flood risk reduction options to reduce future flood damages for properties adjacent to the Cannon River in downtown Northfield, Minnesota. The results of this study will be used to identify preferred mitigation options and develop the information needed to apply for grant funding to design and implement the mitigation measures.

Table 1-1 lists the locations evaluated in the study. There are three areas in downtown Northfield, three city parks along the river, and five locations on the Carleton College campus.

Table 1-1 Northfield and Carleton College Flood Mitigation Locations

Northfield				Carleton College
Area 1	Area 2	Area 3	Parks	
205 Water Street S	11 Bridge Square	500 Water Street S	Ames Park	Student Houses
207 Water Street S	13 Bridge Square	516 Water Street S	Riverside Lions Park	Stadium
301 Water Street S	—	630 Water Street S	Babcock Park	West Gym
—	—	—	—	Pump House
—	—	—	—	West Practice Fields

These locations have experienced repeated flooding in recent years. Seven of the ten largest recorded flood events for the City have occurred since 2010. The City and private property owners have taken some measures to reduce flood risk by constructing both temporary and permanent barriers and elevating equipment. While these measures help, responding to flood events still requires sandbags and pumps in multiple areas. The goal of this study is to identify viable options for more reliable flood mitigation measures that are less labor-intensive.

The parks listed in Table 1-1 are along the Cannon River and near the heart of the city. They have low areas that frequently flood during major flood events. The City is interested in reducing the frequency and extent of flooding in these parks.

After the 2010 flood, Carleton College retrofitted the Stadium and West Gym to allow for the quick installation of temporary barriers in front of doorways during floods. This study explores options for further reducing flood risk on this part of Carleton's campus.

2 Data Gathering and Analysis

The project team gathered data from a field survey, City staff, Carleton College, the Federal Emergency Management Agency (FEMA), the Minnesota Department of Natural Resources (MDNR), and other public data sets.

2.1 Data Gathering

2.1.1 Field Survey

The study team collected field survey data along the Cannon River adjacent to the subject properties. The field survey captured ground elevations along the riverwalk. Surveyors also collected low opening elevations for doors and windows of the subject properties. First floor elevations were inferred based on doorway sill elevations and measurements made by City staff.

2.1.2 City of Northfield

The study team obtained the following data from the City.

- Geographic information system (GIS) database with property boundaries, utilities, elevation contours
- Photos and video from the 2010 and 2016 flood events
- Northfield Climate Action Plan (adopted November 5, 2019) (reference [1])
- Riverfront Enhancement Action Plan (reference [2])

2.1.3 Carleton College

The study team obtained the following data from Carleton College staff.

- Photos and video from the 2010 flood
- Verbal accounts of flood levels and flood fighting efforts during the 2010 flood and subsequent flood events

2.1.4 Federal Emergency Management Agency (FEMA)

The study team obtained the following data from FEMA.

- Geodatabase with regulatory floodplain layers used to create the Flood Insurance Rate Maps (FIRMs) for the study area
- Effective Flood Insurance Study (FIS) for Rice County (adopted April 3, 2012) (reference [3])
- Preliminary FIS for Rice County (issued November 15, 2019) (reference [4])
- Letter of Map Revision (LOMR) Case No.: 12-05-1809P revising the effective FIS (effective October 2, 2012)

2.1.5 Minnesota Department of Natural Resources (MDNR)

The study team obtained the following data from the MDNR.

- Effective HEC-RAS model used by the MDNR to prepare the LOMR Case No.: 12-05-1809P
- Memo documenting changes made to the model for the above LOMR (reference [5])

2.1.6 Public Engagement

The City held an open house meeting on September 15, 2021 at City Hall. During the meeting, City staff and Barr staff described the scope of the study and solicited input from community members regarding their experiences during past floods and ideas for mitigating future flood risk. Eleven people attended the meeting. Most attendees were property owners in the study area. Two people from Carleton College also attended. Attendees were supportive of the goals of the study.

The City held an open house on April 7, 2022, at City Hall. During the meeting, City staff and Barr staff described the findings from the feasibility study and the potential flood risk reduction projects that are recommended for further consideration, as documented in this report, for City of Northfield locations. Ten people attended the meeting. Most attendees were property owners in the study area. Attendees were generally supportive of the recommendations from the feasibility study.

The City held an open house on April 26, 2023, at City hall. During the meeting, City staff and Barr staff described updates to the feasibility study to incorporate mitigation alternatives at Carleton College and preliminary results of the benefit cost analysis. Approximately ten people attended the meeting. Most attendees were property owners in the study area. Attendees were generally supportive of the recommendations from the revised feasibility study.

2.1.7 Other Data Sources

The study team obtained data from several other sources to inform the analysis and mitigation evaluation.

- Light detection and ranging (LiDAR) data for the state of Minnesota
- Aerial imagery for maps and figures
- Flood history from the National Weather Service
- Data from United States Geological Survey (USGS) stream gage 05355024 (Cannon River at Northfield, Minnesota)

2.2 Data Analysis

Barr reviewed the data gathered for the study to understand the history of Cannon River flooding in the study area.

2.2.1 Floodplain Regulations

The study area involves properties in the regulatory floodplain. Work in the regulatory floodplain requires a floodplain development permit per the City of Northfield's local floodplain ordinance. The floodplain ordinance helps the City of Northfield meet state and federal requirements for community participation in the National Flood Insurance Program (NFIP) administered by FEMA.

FEMA develops Flood Insurance Rate Maps (FIRMs) to identify properties and structures that are within the inundation extents of the base flood (1%-annual-exceedance probability (AEP) or 100-year flood). The NFIP requires flood insurance for structures within the extents of the base flood. FEMA recently updated its risk rating system to better account for a structure's flood risk when setting insurance rates.

Flood insurance can be expensive, especially for structures mapped in the regulatory floodplain. Communities have options for helping reduce property owner flood insurance premiums. The Community Rating System (CRS) is a voluntary incentive program run by FEMA that allows communities to earn points for taking steps to reduce flood risk. These points bring down flood insurance rates for the community.

While the City of Northfield is not currently in the CRS program, some of the alternatives evaluated in this report could affect insurance rates and requirements. Eliminating a flood insurance requirement for a property would mean providing flood protection that is certified by a professional engineer as meeting FEMA requirements.

2.2.2 Flooding History

The USGS gage 05355028 for the Cannon River at Northfield, Minnesota, is near Second Street. Figure 2-1 shows the highest annual flows recorded at the gage from 1980-2021 (reference [6]). Seven of the 10 largest flood events in this period of record have happened since 2010.

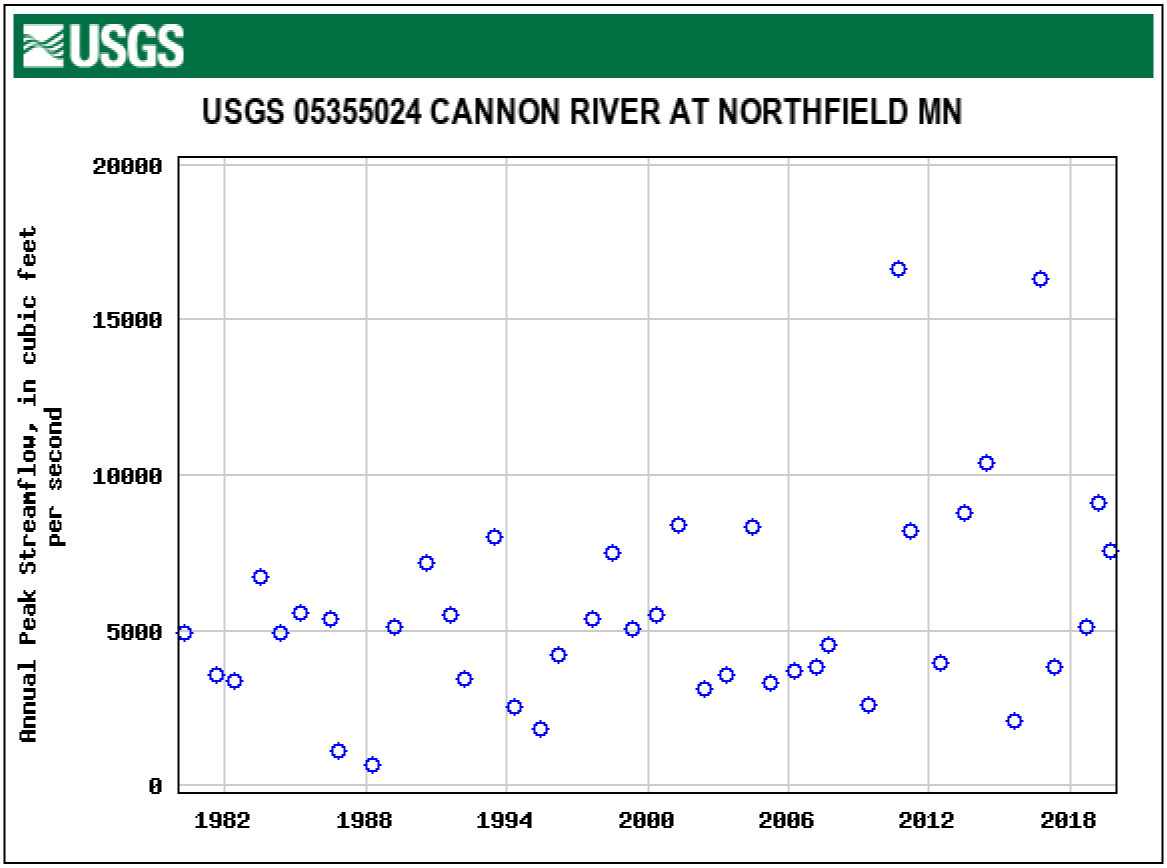


Figure 2-1 Annual Peak Streamflow at the USGS Stream Gage in Northfield, MN

2.2.3 Flood Frequency

The FEMA preliminary Flood Insurance Study (FIS) for Rice County documents the hydrologic methods used to define discharge frequency relationships for the Cannon River in the City of Northfield (reference [4]). The discharge frequency was developed using a Bulletin 17B analysis on 17 years of stream gage data from 1980 to 1996. Although this is a brief period of record on which to base a discharge frequency analysis, it was the best available information at the time.

Barr completed an updated discharge frequency analysis with additional data from the USGS stream gage for the Cannon River at Northfield, Minnesota (reference [7]). Barr's analysis built on a recent study by the USACE (United States Army Corps of Engineers) for the larger Cannon River watershed (reference [8]). The analysis used peak streamflow data from 1980 through 2020. The analysis was completed using the Bulletin 17C methodology in the software HEC-SSP. Table 2-1 provides the results of the analysis.

Table 2-1 Discharge Frequency Analysis Comparison

Annual Exceedance Probability (AEP)	Return Period	FIS Discharge (cfs) Period of Record 1980 to 1996	Preliminary Updated Discharge (cfs) Period of Record 1980 to 2020	% Change in Discharge
0.2%	500-year	14,200	22,800	+52%
1%	100-year	11,800	16,200	+37%
2%	50-year	10,700	14,000	+31%
10%	10-year	7,780	9,200	+18%

The updated discharge values for a given annual exceedance probability are significantly higher than the discharges listed in the preliminary and effective FIS documents. This is not a surprise given that the largest flood events in the period of record occurred after 1996. There have been nine events with flows greater than the 10% AEP (10-year) FIS discharge in the past 28 years and three events greater than the 1% AEP (100-year) FIS discharge in the last 12 years.

The discharge frequency analysis indicates that

- the 2010 and 2016 floods have a 1% AEP (100-year flood) instead of a 0.2% AEP (500-year flood)
- the updated 1% AEP discharge would be larger than FEMA's current 0.2% AEP discharge

The updated discharge frequency data has been shared with the Interagency Hydrologic Review Committee. This means that the data could be used in the future for updates to regulatory flood mapping. In the interim, Barr used this information as the basis for evaluating flood mitigation options for Northfield.

2.2.4 Potential Future Flood Risk

Why consider potential future flood risk?

We live in an era of uncertainty about how global climate change may affect severe weather in our region. The investments Northfield makes today should enhance the resiliency of its infrastructure to floods and other natural hazards. There is a reasonable chance that large flood events on the Cannon River could become more frequent in the coming decades. Therefore, it is prudent to consider how larger flood events could impact the community and use that knowledge to inform flood mitigation investment decisions today.

What do we think we know?

Scientists from around the world have developed many different models to simulate what might happen to our global climate based on different carbon emission scenarios. Models are simplifications of large complex systems. Few systems are more complex than our planet. The benefit of having many models is that together they can compensate for the various shortcomings in any one model. However, a remaining shortcoming is that these models pertain to the planet as a whole. They do not provide detailed information for the United States, let alone a relatively small watershed in southeast Minnesota.

There have been recent attempts by others to use the global climate models to develop regional models that can inform us about potential effects of climate change in our region. Barr reviewed the data from regional climate change models and concluded those models are not useful for predicting extreme weather events like the 1% AEP flood. When calibrated to historic data, these models accurately predict annual average precipitation, but underpredict the magnitude of extreme weather events that cause flooding. Barr documented this analysis in a memorandum titled Cannon River Future Flood Risk Analysis Memorandum (reference [9]).

Initial results from regional climate models suggest that total annual precipitation may not change significantly for southeast Minnesota over the next century. If there is an increase, it is expected to be less than 20 percent. The concern is that this additional precipitation could come from larger and more intense storm events than we have experienced in the past.

What should be done with this information?

Predicting the future is exceedingly difficult, but we can use the available data to define likely boundaries for how much change we could see over the next century. Based on potential increases in total precipitation, peak flows for the 1% AEP event are likely to be within the bounds of the upper and lower bounds of the 90% confidence limits for the current flood frequency estimate for the Cannon River at Northfield (reference [7]). Barr's flood frequency analysis determined that there is a 90% chance that the 1% AEP peak discharge is between approximately 13,000 cfs and 24,000 cfs, with a median value of 16,200 cfs. If climate change causes larger floods on the Cannon River in the future, Barr does not expect the median value for the 1% AEP peak discharge to increase beyond 24,000 cfs. For the feasibility analysis, alternatives are designed for a 1% AEP median discharge of 16,200 cfs, equivalent to the 2010 flood event, but are checked to see how they would perform during a 24,000-cfs flood event.

2.2.5 Hydraulics

Barr updated a copy of the MDNR HEC-RAS hydraulic model for the Cannon River to add missing bridges and calibrate the model to recent flood events. These updates are documented in memorandum titled Cannon River Hydraulic Model Updates (reference [10]). The calibrated model was used to simulate flood profiles for a range of annual exceedance probability flood events.

The model results are useful for showing how regulatory flood profiles for a given flood frequency will increase if the Interagency Hydrology Review Committee approves the updated discharge frequency and the Rice County Flood Insurance Study is updated to incorporate that technical analysis.

3 Potential Flood Risk Reduction Strategies

There are many strategies for mitigating flood risk, but only some apply to the Northfield downtown and Carleton College areas. Barr evaluated these strategies in the alternatives analysis. Other strategies were considered but not evaluated because they are unlikely to be economically viable.

3.1 Flood Mitigation Strategies Evaluated

Barr evaluated the following flood mitigation strategies for the study area properties.

3.1.1 Structural Flood Barriers

Structural flood barriers are typically floodwalls and levees. Floodwalls are structurally engineered walls designed to withstand the forces of floodwaters. Levees are typically earthen berms designed to withstand erosive forces from moving water and manage seepage through or under the berm.

3.1.2 Temporary Flood Barriers

Temporary flood barriers can be sandbags, earthen fill, or any number of proprietary devices installed in anticipation of a flood event and removed once the flood is over. These include temporary closures for openings in structural flood barriers, such as metal plates, stoplogs, sandbags, and other devices designed to withstand forces from moving water.

3.1.3 Dry Flood Proofing

Dry floodproofing of non-residential structures is a combination of building modifications that reduce or eliminate the potential for flood damage. This may involve anchoring the structure to resist movement or flotation; installing water-tight closures over doors, windows, and other openings; using sealants or membranes to reduce or eliminate seepage through the walls of the building; installing sump pumps to control interior water levels; installing check-valves to prevent backflow through utility conduits; and elevating electrical, mechanical, and other sensitive equipment above the expected flood level. FEMA Technical Bulletin 3-93 defines certification requirements for the dry floodproofing of non-residential structures.

3.1.4 Wet Flood Proofing

Wet floodproofing of existing structures is a combination of building modifications that allow the lower portion of the structure to be inundated in a flood with minimal damage to the structure or its contents. This may involve anchoring the structure, using flood-resistant materials, protecting or elevating sensitive equipment, and providing openings for water to pass into and out of the structure.

3.1.5 Buyouts

Voluntary buyouts are one of the most effective flood mitigation strategies because they remove a structure from the floodplain. FEMA Hazard Mitigation Grant Program (HMGP) funds may be available through Minnesota Homeland Security and Mitigation Management. The community must apply for the

HMGP grant funding. If approved, FEMA covers 75 percent of the acquisition cost. Use of FEMA funds means acquired properties must be deed-restricted to remain open space forever.

3.2 Flood Mitigation Strategies Considered but Not Evaluated

Some potential flood risk reduction strategies were not carried forward for full evaluation because they are unlikely to be viable. These strategies are discussed below.

Upstream flood storage

- The goal of upstream flood storage would be to retain floodwater in the upstream watershed and release it slowly to reduce the severity of flooding in Northfield. This is accomplished by constructing dams to create reservoirs that are designed to fill up during a flood. For example, the Natural Resources Conservation Service built several reservoirs on tributaries to the South Fork Zumbro River as part of the Rochester flood protection project constructed in the 1980s.
- For upstream flood storage to be effective, reservoirs need to be strategically positioned within the watershed to intercept flood flows, and outflows from the reservoirs must be managed to keep enough storage volume available to absorb the peak of the flood.
- During the 2016 flood event, reducing the flood elevation between the Water Street and Second Street Bridges by 1.5 feet would have required storing approximately 20,000 acre-feet of water from the peak of the flood hydrograph—this is equivalent to a 2,000-acre (3 square-mile), 10-foot-deep reservoir.
- This mitigation strategy is unlikely to be viable. It likely would be cost-prohibitive to acquire the land and construct and maintain the dams necessary to significantly reduce the flood risk in Northfield. It could take decades to implement this strategy.

Channel modification

- The channel modification strategy would involve lowering the river channel downstream of the Ames Mill Dam by approximately 3 feet to create additional conveyance capacity in the channel and lower peak flood levels.
- The channel bottom in this area is bedrock at approximately elevation 888. Lowering the channel bottom to 885 would require rock removal for roughly 3,000 feet of channel.
- This mitigation strategy is unlikely to be viable. It would be expensive to construct, difficult to permit, and might have structural implications for the Second Street Bridge.

Structure Relocation

- The structure relocation strategy would involve lifting structures off their foundations and moving them to higher ground.
- This mitigation strategy is unlikely to be viable because the buildings in this study do not appear to be structurally well-suited for relocation. It is unlikely that they could be easily separated from their foundations.

4 Northfield Mitigation Alternatives Analysis

Flood mitigation strategies in downtown Northfield are organized into three areas, with the three parks considered separately. Areas 1 and 2 are downstream of the Ames Mill Dam and Water Street Bridge. Area 3 is upstream of Fifth Street Bridge. Each area and the corresponding flood risk reduction alternatives considered are described in the sections below. Figures in Attachment A illustrate the structural alternatives for each of the study areas and parks.

Barr updated existing-conditions flood inundation maps for the 50-year, 100-year, and 500-year flood events. Mapped flood levels are based on flood elevations from the updated flood frequency analysis by Barr (reference [7]). Mapping is based on LiDAR topography for Rice County and survey data collected in Area 1, Area 2, and Area 3 for this study. Figures in Attachment B show existing and proposed conditions inundation extents for structural alternatives that would block a portion of the existing floodplain.

Table 4-1 lists structure low floor and low opening elevations compared to the 1% AEP flood elevation for the downtown Northfield properties.

Table 4-1 Northfield Property Low Floor and Low Opening Elevations vs. 1% AEP Flood

Location	Address	Low Floor (1) (feet)	Low Opening (2) (feet)	1% AEP Flood Elevation (3) (feet)
Area 1	205 Water Street S	900.8 (4)	900.8	902.5
Area 1	207 Water Street S	897.4	897.4	903.0
Area 1	301 Water Street S	897.4	902.6	903.5
Area 2	11 Bridge Square	900.2	900.2	903.5
Area 2	13 Bridge Square	902.4	902.4	903.5
Area 3	500 Water Street S	910.2	910.2	908.0
Area 3	516 Water Street S	910.2	910.2	908.0
Area 3	630 Water Street S	911.2	911.2	908.5

(1) Low floor elevations were surveyed or calculated based on a measurement from the low opening survey elevation
(2) Low opening elevations were surveyed in 2021
(3) 1% AEP flood elevations were calculated using the updated Cannon River hydraulic model
(4) Red text indicates value is lower than the 1% AEP flood elevation at that location

4.1 Area 1 Flood Risk Reduction Alternatives

Area 1 covers the study area properties on the west bank of the Cannon River between the Water Street and Second Street Bridges. Figure 4-1 and Figure 4-2 show the three property addresses in Area 1.

Figure 4-1 West Bank Riverwalk Properties Upstream of Pedestrian Bridge

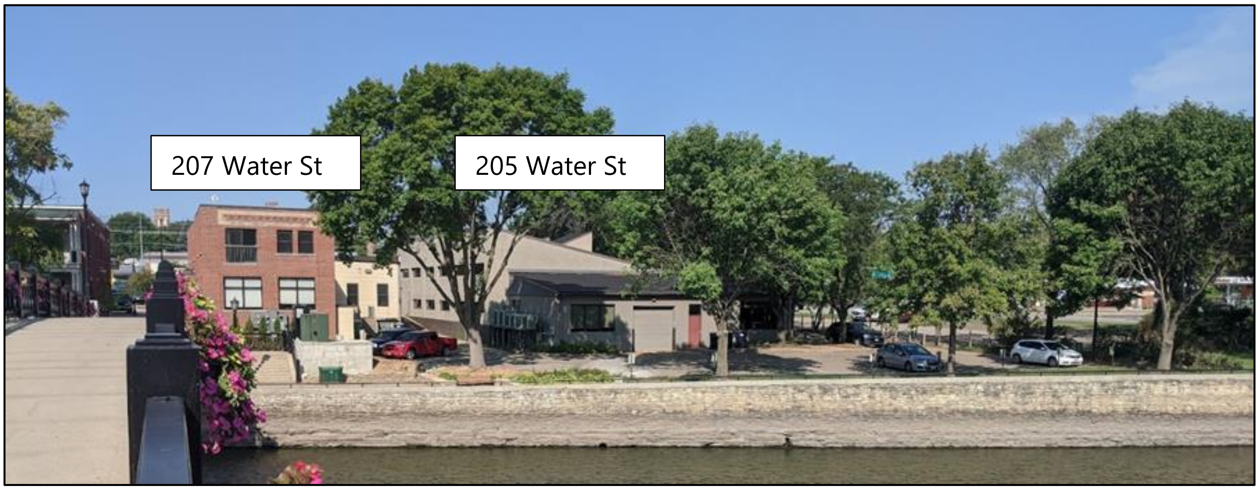


Figure 4-2 West Bank Riverwalk Properties Downstream of Pedestrian Bridge

Figure 4-3 shows the west riverwalk near 301 Water Street during a flood event and water flowing over the top of the channel wall (top left of the picture). The top of the channel wall is at elevation 902.

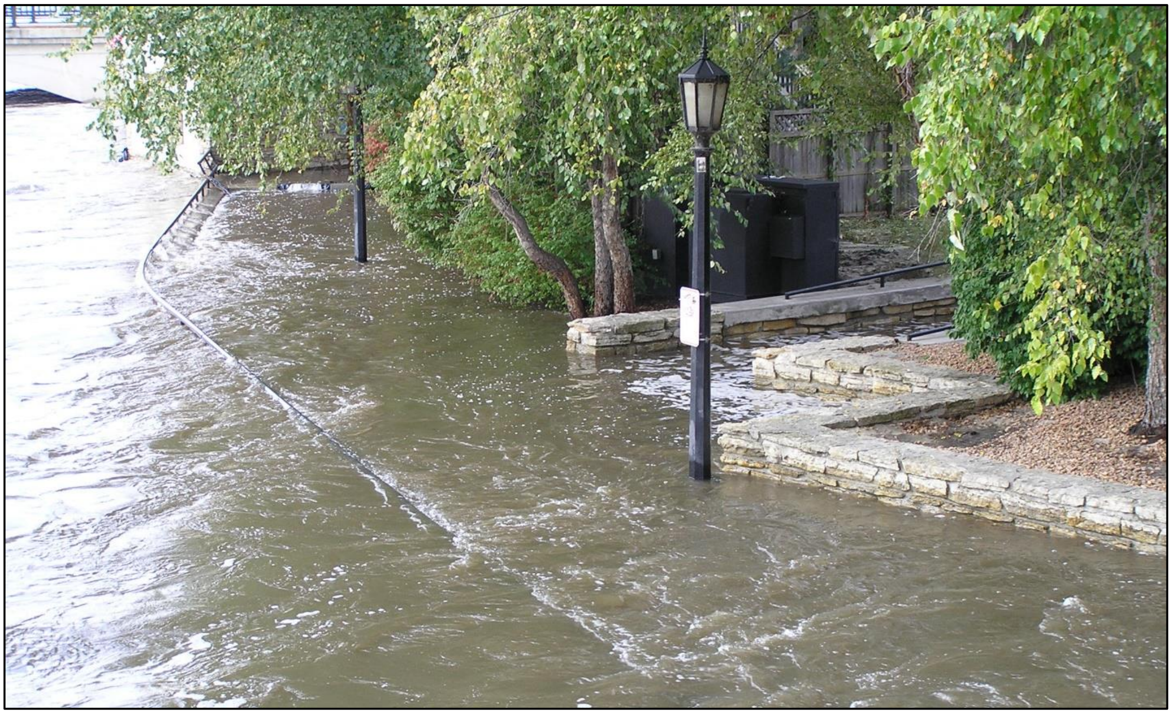


Figure 4-3 Channel Wall Overtopping near 301 Water Street in 2010

Table 4-2 lists the flood risk reduction alternatives evaluated for the study area for properties in Area 1. Figure A-1 in Attachment A shows a schematic plan and profile for Alt 1-2, Alt 1-3, and Alt 1-4.

Table 4-2 Area 1 Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt 1-1	No Change	Continue to use emergency measures such as sandbags and pumps to protect individual properties during a flood response.
Alt 1-2	Floodwall Extension	Extend the existing flood wall from 303 Water Street to high ground near the Second Street Bridge.
Alt 1-3	Channel Floodwall	Replace the top portion of the west channel wall along the west riverwalk with a floodwall between the Froggy Bottoms properties and the Second Street Bridge.
Alt 1-4	Two Floodwalls	Floodwall A—Extend the existing floodwall near Froggy Bottoms 135 feet to protect 301 Water Street on the east and north sides. Floodwall B—Construct a floodwall from the north side of the pedestrian bridge to protect the 205 and 207 Water Street properties. Provide a temporary closure through the parking lot for 205 Water Street.
Alt 1-5	Property Buyout	Conduct a voluntary buyout of the properties in this area and convert the space into an area that can be flooded without causing significant damage to structures and the local economy.

4.1.1 Alt 1-1 No Change

The no-change alternative considers the benefits and drawbacks of not implementing a project for Area 1 and continuing existing emergency flood response measures when needed. During the 2010 flood, water inundated the lower levels of properties in Area 1. The City and individual property owners were better prepared for the 2016 flood, and flood levels in 2016 were lower than in 2010. Railing plates, a new floodwall near Froggy Bottoms Pub (constructed after the 2010 flood), sandbags, and pumps were used to limit the inundation of lower levels. Electrical and HVAC equipment were elevated higher than the 2016 flood levels.

Benefits

- Minimal upfront public investment
- Flood response strategy is already in place

Drawbacks

- Does not reduce flood risk to the subject properties.
- Flood response actions require significant effort by the property owners, the City, and volunteers.
- The existing flood-response strategy was not effective in 2010 and would not be effective for future floods of similar or larger magnitude.
- Prolonged business interruption to prepare for, implement, and clean up after a flood response.
- Recurring costs associated with flood response and damages.

4.1.2 Alt 1-2 Floodwall Extension

The floodwall extension alternative would create a continuous flood barrier along the west side of the river between the Froggy Bottoms properties and the Second Street bridge. The existing floodwall near Froggy Bottoms is approximately 36 feet long, including a 30-inch opening for a temporary closure. The top of the wall is at elevation 904.

The proposed extension would maintain the 904 top elevation and be approximately 415 feet long, plus a 15-foot temporary closure for the walkway north of 301 Water Street. The alignment for the proposed floodwall extension would roughly follow the existing retaining wall along the backside of the riverwalk. The above-grade height of the wall will range from 4 to 7 feet (see Attachment A, Figure A-1).

Design Considerations and Assumptions

- Interior drainage during normal conditions and during a flood
- Groundwater seepage impacts from floodwall foundation
- Mature tree impacts should be avoided or minimized
- Utility coordination and relocates, including light posts
- Pedestrian bridge has a low vertical clearance

- Aesthetics will be important for the floodwall façade
- Temporary closure storage location and maintenance
- Emergency action plan for installing temporary closure
- Assumes City would not pursue FEMA accreditation of the floodwall

Benefits

- Continuous line of protection would benefit all properties in Area 1.
- The temporary closure effort would be small relative to existing the flood response.
- The top-of-wall elevation at 904, about 1 foot above the flood of record in 2010, would provide additional flood protection.

Drawbacks

- Materials for the temporary closure need to be stored and maintained to be available and in good condition when there is a flood.
- Temporary closures require installation; they are not automatic or passive. The City's emergency action plan should include installation triggers for all closures.
- Floodwalls are expensive.
- Interior drainage behind the floodwall will need to be managed.
- Floodwall construction may require the removal of some mature trees along the riverwalk.

4.1.3 Alt 1-3 Channel Floodwall

This alternative would reconstruct the top portion of the channel wall as a floodwall to create a continuous flood barrier along the west side of the river between Froggy Bottoms and the Second Street Bridge. The existing wall is 2.5 to 3 feet higher than the adjacent sidewalk, allowing views of the river. The existing top-of-wall elevation ranges from 899 to 901. The sidewalk elevation ranges from 897 to 899. A floodwall with a top elevation of 904 would be 3 to 5 feet higher than the existing floodwall. This alternative would include elevating the riverwalk to maintain a 30-inch difference between the sidewalk and the top of the wall. Elevating the riverwalk would not be feasible under the pedestrian bridge. Closures would be used on either side of the pedestrian bridge to provide a continuous line of protection (See Attachment A, Figure A-1).

Design Considerations and Assumptions

- Interior drainage during normal conditions and during a flood.
- Groundwater seepage impacts from floodwall foundation.
- Pedestrian bridge—The low chord of the bridge is below elevation 904, where it crosses the existing wall. The proposed floodwall would need to tie into the pedestrian bridge abutment.

- ADA accessibility for the riverwalk.
- Floodwall tie-in at Second Street would likely mean eliminating the canoe launch area.
- Assumes City would not pursue FEMA accreditation of the floodwall.

Benefits

- Continuous line of protection would benefit all properties in Area 1.
- The top-of-wall elevation at 904, about 1-foot above the flood of record in 2010, would provide additional flood protection

Drawbacks

- Design may require a seepage mitigation system to intercept groundwater seepage from the west.
- Design would require an interior drainage system to collect and discharge surface runoff behind the wall to the river.
- Elevating the riverwalk in most areas but not under the pedestrian bridge would be difficult to design to remain ADA accessible.
- Materials for the temporary closure need to be stored and maintained to be available and in good condition when there is a flood.
- Temporary closures require installation; they are not automatic or passive. The City's emergency action plan should include installation triggers for all closures.

4.1.4 Alt 1-4 Two Floodwalls

This alternative is similar to Alt 1-2 but with two shorter floodwall segments. Floodwall A would be an extension of the existing floodwall near Froggy Bottoms. It would terminate at high ground on the north side of 301 Water Street. Floodwall B would extend from the pedestrian bridge north. It would tie into high ground on the north side of 205 Water Street. This alignment would use a closure where the wall passes through the existing parking lot for 205 Water Street.

Design Considerations and Assumptions

- Interior drainage during normal conditions and during a flood
- Groundwater seepage impacts from floodwall foundation
- Mature tree impacts should be avoided or minimized
- Utility coordination and relocates, including light posts
- Stair modification
- Stoplog storage location
- Emergency action plan for installing temporary closure
- Assumes City would not pursue FEMA accreditation of the floodwall

Benefits

- Shorter length of floodwall than Alt 1-2
- Avoids a temporary closure for the walkway near 301 Water Street accessing the riverwalk
- The top-of-wall elevation at 904, about 1-foot above the flood of record in 2010, would provide additional flood protection

Drawbacks

- Materials for the temporary closure need to be stored and maintained to be available and in good condition when there is a flood.
- Temporary closures require installation; they are not automatic or passive. The City's emergency action plan should include installation triggers for all closures.
- Wall construction near the pedestrian bridge, stairway, and elevated utility pad will be complicated.

4.1.5 Alt 1-5 Property Buyout

Voluntary acquisition of properties would allow the City to purchase and remove structures at risk of flooding.

Benefits

- Removing at-risk structures from the floodplain is one of the most effective means of reducing flood risk. There is always residual risk of a flood barrier overtopping. Removing a structure from the floodplain eliminates the risk.
- Removing the structure could provide an opportunity to create a public space that enhances the destination aspects of the riverwalk area.

Drawbacks

- Buyouts can be disruptive to lives and businesses.
- Buyouts may reduce the tax base for the community.
- Removing structures along the riverwalk may change the historic character of the area.
- Some property owners may not be willing to sell.
- FEMA funded buyouts prohibit the future construction of a new structure on the property.

4.1.6 Area 1 Hydraulic Profiles

Figure A-7 in Attachment A shows hydraulic profiles for a range of flood events between Fifth Street bridge and Second Street bridge. Area 1 structures and recommended flood mitigation measures are shown on the figure. The figure shows the proposed levels of protection relative to the different expected annual exceedance probability flood levels.

4.1.7 Area 1 Inundation Mapping

Figure B-1 in Attachment B is the existing-conditions flood inundation map for Areas 1 and 2. Proposed-conditions flood inundation maps were created for alternatives that would modify the extents of the three mapped flood events. Figures B-2, B-3, and B-4 in Attachment B show the impact to flood inundation extents for Alt 1-2, Alt 1-3, and Alt 1-4, respectively.

4.2 Area 2 Flood Mitigation Alternatives

Area 2 covers the study area properties on the east bank of the Cannon River downstream of the Water Street bridge. Figure 4-4 shows the Bridge Square properties in Area 2. Figure 4-5 shows the Cannon River overtopping the channel wall adjacent to these structures in the 2010 flood. The top of the wall is about elevation 902.7, suggesting the peak flood elevation in 2010 was at least 903.

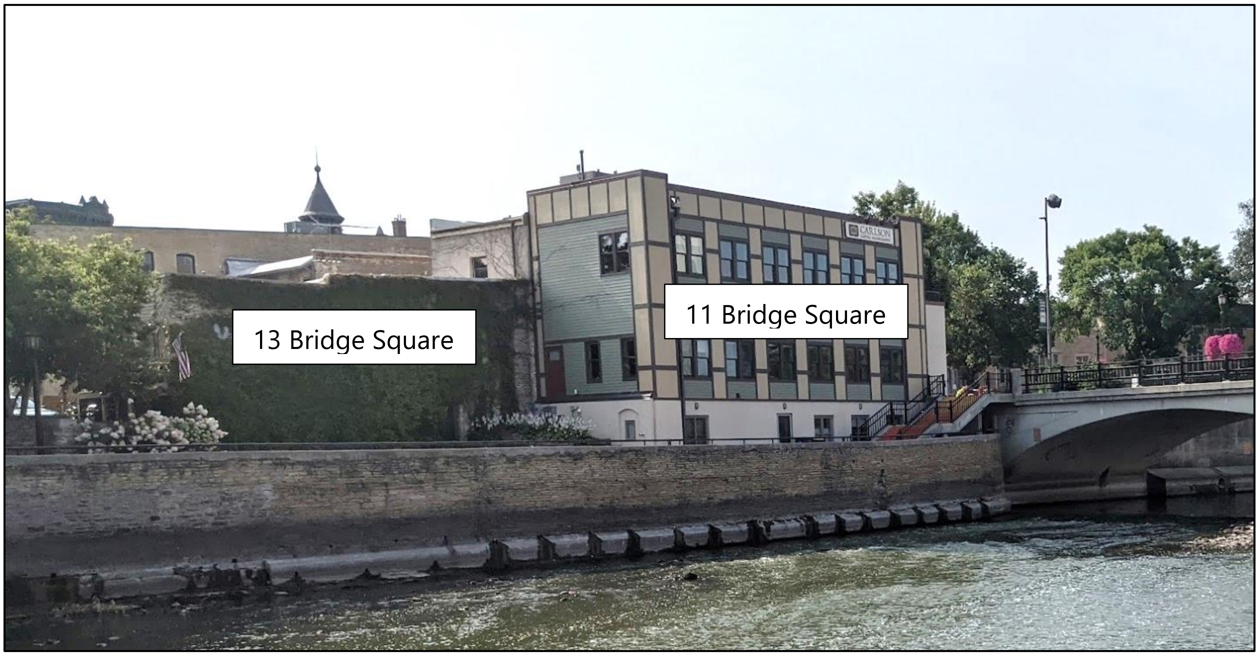


Figure 4-4 Bridge Square Properties

Figure 4-5 Cannon River Overtopping Channel Wall at 11 Bridge Square September 24, 2010

Table 4-3 lists the flood risk reduction alternatives evaluated for properties in Area 2. Figure A-2 in Attachment A shows a schematic plan and profile for Alt 2-2.

Table 4-3 Area 2 Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt 2-1	No Change	Continue to use emergency measures such as sandbags and pumps to protect individual properties during a flood response.
Alt 2-2	Dry Floodproofing	Retrofit exterior of buildings to allow for rapid installation of temporary barriers in front of building openings.
Alt 2-3	Wet Floodproofing	Voluntary partial buyout of the lower level of the two properties. Convert the lower levels to uses that allow flooding to occur without damaging the remaining structure or its contents.
Alt 2-4	Property Buyout	Voluntary buyout of the properties in this area. Convert the space into an area that can be flooded without causing significant damage to structures and the local economy.

4.2.1 Alt 2-1 No Change

The no-change alternative considers the benefits and drawbacks of making no changes to managing flood risk for the properties in Area 2. During the 2010 flood, floodwaters were directly against the walls and openings of the two structures in Area 2. During the 2016 flood, sandbags and pumps were used to minimize the inundation of the two structures. For floods larger than the 2016 event, the no-change approach may not effectively keep river water out of structures.

Benefits

- Limited up-front public investment.

Drawbacks

- Does not reduce flood risk to the subject properties.
- Flood response actions require significant effort by the property owners, the City, and volunteers.
- Existing flood-response strategy was not effective in 2010 and would not be effective for future floods of similar magnitude or larger.
- Prolonged business interruption to prepare for, implement, and clean up after a flood response.
- Recurring costs associated with flood response and damages.

4.2.2 Alt 2-2 Dry Floodproofing

The dry floodproofing alternative considers the benefits and drawbacks of sealing the building envelope up to elevation 904 to minimize the ability for water to enter the structure. This would be accomplished by sealing cracks in the building envelope, using structural covers to block floodwaters from coming through door and window openings, and verifying that the walls are structurally capable of withstanding the hydrostatic pressure of water against the sides of the building.

Design Considerations

General Assumptions

- Barriers can be installed quickly without special training.
- Barriers would be small and could be stored on-site for installation by the property owner. Alternatively, barriers could be stored and installed by City staff.
- Temporary barriers for the openings would extend to at least elevation 904.
- Some sealing of cracks will be required to make the building envelope impermeable. This assumption needs confirmation if this alternative is advanced to preliminary design.
- Structures withstood water against the exterior in 2010. We assumed that no structural reinforcement would be necessary to keep water from pushing in the walls of the buildings. This assumption needs confirmation if this alternative is advanced to preliminary design.

11 Bridge Square

- This structure would include six opening covers for the door and windows on the lower level. The sill elevations for the openings are:
    - 900.2 one door
    - 901.0 four large windows
    - 903 one small window
- The lower-level exterior appears to be painted concrete in good condition. Sealing cracks may be necessary but not expected to be a major retrofit.
- A sump pump would need to be installed inside the building (if it does not already have one) to manage residual seepage through the building envelope.

13 Bridge Square

- The low openings for this structure are doorways with sill elevations of 902.4 and 902.6.
- The lower-level exterior of this building is brick and mortar. Installing the opening covers may require modifications to the small retaining wall next to the south door.
- Sealing the brick-and-mortar exterior of this structure may be difficult.

- A sump pump would need to be installed inside the building (if it does not already have one) to manage residual seepage through the building envelope.

Benefits

- Opening covers are relatively small and could be stored on-site.
- Installation of covers is quick and does not require specialized training or expertise. Property owners could store, install, and remove the covers.

Drawbacks

- Opening covers require installation; they are not automatic or passive. The City's emergency action plan should include installation triggers for all closures, including building opening covers.
- Opening covers must be stored in a known location accessible on short notice. They also require maintenance.
- The building may or may not be structurally capable of withstanding the impact of floodwaters.
- The building envelope may not be water-tight. There could be gaps or cracks that allow water to seep into the structure.

4.2.3 Alt 2-3 Wet Floodproofing

The wet floodproofing alternative considers the benefits and drawbacks of retrofitting the lower levels of these structures so they are designed to be inundated during floods.

Design Considerations

- Voluntary partial buyout of the lower level of the structure.
    - 1,200 square feet for 11 Bridge Square
    - 1,000 square feet for 13 Bridge Square
- Retrofit each structure to seal off the upper level from the lower level.
- Convert the lower level into a storage area designed to inundate when the riverwalk floods. This would involve removing doors and windows and converting them to flood vents to allow air and water to enter and leave the converted space.

Benefits

- Passive system for reducing flood risk—nothing to install or construct during a flood response
- Removes the at-risk property elements without eliminating the entire structure

Drawbacks

- The value of structures will go down with the loss of square footage. This would reduce the tax base.
- It may be difficult to retrofit the structures to protect the upper stories when the lower level floods.

- Property owners may not be interested in this alternative.

4.2.4 Alt 2-4 Property Buyout

Voluntary acquisition of properties would allow the City to purchase and remove structures at risk of flooding.

Benefits

- Removing the structure could be an opportunity to create a public space that enhances the destination aspect of the riverwalk area.
- There is always residual risk of a flood barrier overtopping. Removing at-risk structures from the floodplain is one of the most effective means of reducing flood risk because it eliminates the residual risk.

Drawbacks

- Buyouts can be disruptive to lives and businesses.
- May reduce the tax base for the community.
- Removing structures along the riverwalk may change the historic character of the area.
- Some property owners may not be willing to sell.
- FEMA funded buyouts prohibit the construction of a new structure on the property.

4.2.5 Area 2 Hydraulic Profiles

Figure A-8 in Attachment A shows hydraulic profiles for a range of flood events between Fifth Street bridge and Second Street bridge. Area 2 structures and recommended flood mitigation measures are shown on the figure. The figure shows the proposed levels of protection relative to the different expected annual exceedance probability flood levels.

4.2.6 Area 2 Inundation Mapping

Figure B-1 in is the existing-conditions flood inundation map for Areas 1 and 2. Proposed-conditions flood inundation maps were only created for alternatives that would modify the extents of the three mapped flood events. None of the Area 2 alternatives would modify flood extents.

4.3 Area 3 Flood Mitigation Alternatives

Area 3 covers the study area properties along the east bank of the Cannon River between Seventh Street and Fifth Street. The properties in Area 3 are shown in Figure 4-6, Figure 4-7, and Figure 4-8. Figure 4-9 shows flood-response measures from the 2010 flood between 500 and 516 Water Street. Flood levels in this photo appear to have reached approximately elevation 908. The doorways for these three structures are generally higher than elevation 910.

Figure 4-6 Family Hair Building Looking North

Figure 4-7 Just Food Co-Op Building Looking South

Figure 4-8 River Park Mall Property Looking South

Figure 4-9 Flood Response During 2010 Flood (September 25, 2010)

Table 4-4 lists the flood risk reduction alternatives evaluated for properties in Area 3. Figure A-3 in Attachment A shows a schematic plan and profile for Alt 3-2, Alt 3-3, and Alt 3-4.

Table 4-4 Area 3 Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt 3-1	No Change	Continue to use emergency measures, such as sandbags, to protect the structures in this area during large flood events.
Alt 3-2	Dry Floodproofing	Retrofit the exterior of buildings to allow for rapid installation of temporary barriers in front of building openings.
Alt 3-3	Floodwall	Construct a floodwall from the intersection of Fifth Street and Water Street to high ground behind 630 Water Street. Design requires a 2-foot-tall temporary closure across Water Street and assumes three temporary closures along the trail.
Alt 3-4	Temporary Barrier	Purchase temporary barriers that can be installed quickly and are less labor-intensive than sandbags.
Alt 3-5	Property Buyout	Voluntary buyout of the properties in this area and convert the space into an area that can be flooded without causing significant damage to structures and the local economy.

4.3.1 Alt 3-1 No Change

The no-change alternative considers the benefits and drawbacks of making no changes to how flood risk is managed for the properties in Area 3. Flood photos from 2010 and 2016 suggest that floodwaters did not reach the lower levels of the three structures in this area. Sandbags were used as a precaution.

Benefits

- Minimal up-front public investment

Drawbacks

- Does not reduce flood risk to the subject properties.
- Emergency flood-response with sandbags is time- and labor-intensive. There is typically less than 24 hours to prepare a flood response in Northfield. This would not make the flood response easier for City staff and property owners.

4.3.2 Alt 3-2 Dry Floodproofing

The dry floodproofing alternative considers the benefits and drawbacks of making the building envelopes for the three structures in Area 3 impermeable up to elevation 912, about 4-feet above the high-water level in this area during the 2010 flood. This would be accomplished by sealing cracks in the building envelope, using structural covers to block floodwaters from coming through door openings, and verifying that the walls are structurally capable of withstanding the hydrostatic pressure of water against the sides of the building. Figure A-3 in Attachment A shows a schematic plan and elevation for this alternative.

Design Assumptions and Considerations

General Assumptions

- The building would be retrofitted around openings for windows and doors to install the hardware for attaching temporary flood barriers during a flood response. Examples of such barriers are stoplogs and the Flex-Cover Door by ILC Dover.
- Low openings for the structures in Area 3 are above elevation 910.
- Two-foot-tall barriers extending to elevation 912 or higher.
- Installation of sump pumps in each structure (if they do not already have them) to manage residual seepage during a flood event.
- The structures in Area 3 appear to be masonry construction, which typically can withstand a few feet of water structurally and may be sufficiently impermeable. This will need confirmation if this alternative is advanced to preliminary design.

500 Water Street

- This structure would have five opening covers for doors on the building's west, south, and east sides.
- Seal approximately 330 feet around the perimeter of the structure.

516 Water Street

- This structure would have three opening covers for doors on the building's west, north, and south sides.
- Seal approximately 460 feet around the perimeter of the structure.

630 Water Street

- This structure would have four opening covers for doors. Assumes doors on the south and east sides of the building are at or above elevation 912.
- Seal approximately 520 feet around the structure's perimeter below elevation 912.

Benefits

- Limited investment to protect structures that were not inundated during the 2010 flood.
- Opening covers can be installed quickly without special training.
- Opening covers can be stored on-site for installation by the property owner. Alternatively, opening covers could be stored and installed by City staff.

Drawbacks

- Materials for opening covers need to be stored and maintained to be available and in good condition when there is a flood.
- Temporary closures require installation; they are not automatic or passive. The City's emergency action plan should include installation triggers for all closures, including building opening covers.

4.3.3 Alt 3-3 Floodwall

The floodwall alternative considers the benefits and drawbacks of using a 920-foot-long concrete floodwall along the east side of the trail to block floodwaters from reaching the existing structures. The floodwall would have a top elevation of 912, about 4 feet above the high-water level in this area during the 2010 flood. The wall would have an 80-foot temporary closure across Water Street at its intersection with Fifth Street. There would be three additional 8-foot closures where the wall parallels the trail. Figure A-3 in Attachment A shows a schematic plan view alignment for this alternative.

Design Assumptions and Considerations

- Interior drainage during normal conditions and during a flood
- Groundwater seepage impacts from floodwall foundation
- Mature tree impacts should be avoided or minimized
- Utility coordination and relocates
- Temporary closure storage location
- Emergency action plan for installing temporary closure

Benefits

- Floodwalls are passive flood barriers that do not require setup and removal.
- Floodwaters would be kept away from the structures, which would reduce the potential for lateral seepage through the walls of the structure.
- Openings in the floodwall for temporary closures will allow surface runoff to drain to the river under normal conditions.

Drawbacks

- Tying into high ground at the downstream end requires crossing Water Street with a temporary barrier.
- Floodwalls require deep foundations, which could affect groundwater levels for the structures in the study area.
- The wall would limit access points to the river trail.
- The wall may block some views of the river from adjacent properties.

4.3.4 Alt 3-4 Temporary Barrier

The temporary barrier alternative considers the benefits and drawbacks of using a deployable barrier to keep water away from the base of structures up to a flood elevation of 910. This is about 2 feet higher than the 2010 flood peak in this area. About 270 feet of barrier would be needed to connect elevation 910 contours at the southwest corner of 500 Water Street to the northwest corner of 630 Water Street. Figure A-3 in Attachment A shows a plan view alignment for this alternative.

Design Considerations

- Select a product that provides at least 2 feet of barrier height
- Select a product that is collapsible or stackable so it can be stored without taking up much space

Benefits

- Low cost
- Avoids interior drainage and potential groundwater issues
- Easier to deploy and remove than sandbags

Drawbacks

- Materials for the temporary barrier need to be stored and maintained to be available and in good condition when there is a flood.
- Temporary barriers require installation; they are not automatic or passive. The City's emergency action plan should include installation triggers for all closures.
- Temporary barriers would only protect up to elevation 910. Low openings for the three buildings in the study area are already 910 or higher. Temporary barriers would limit parking lot flooding only.

4.3.5 Alt 3-5 Property Buyout

Voluntary acquisition of properties would allow the City to purchase and remove structures at risk of flooding.

Benefits

- Removing at-risk structures from the floodplain is one of the most effective means of reducing flood risk. There is always residual risk of a flood barrier overtopping. Removing a structure from the floodplain eliminates the risk entirely.
- Removing the structure could create an opportunity to create a public space that enhances the destination aspect of the riverwalk area.

Drawbacks

- Buyouts of residences and businesses may disrupt lives and businesses.
- Reduces the tax base for the community.
- Removing structures along the riverwalk may change the historic character of the area.
- Buyouts are voluntary, and some property owners might not be willing to sell.
- FEMA funded buyouts prohibit the future construction of a new structure on the property.

4.3.6 Area 3 Hydraulic Profiles

Figure A-9 in Attachment A shows hydraulic profiles for a range of flood events between the upstream end of Babcock Park and Fifth Street bridge. Area 3 structures and recommended flood mitigation measures are shown on the figure. The figure shows the proposed levels of protection relative to the different expected annual exceedance probability flood levels.

4.3.7 Area 3 Inundation Mapping

Figure B-5 in Attachment B shows existing floodplain mapping for Area 3. Proposed conditions flood inundation maps were created for alternatives that would modify the extents of the three mapped flood events. Figures B-6 and B-7 in Attachment B show the impact to flooding extents for Alt 3-3 and Alt 3-4, respectively.

4.4 Parks Flood Mitigation Alternatives

City-owned parks along the river have experienced frequent flooding in recent years. This section discusses alternatives for reducing the frequency of flooding in the park areas. Table 4-5 lists the flood risk reduction alternatives evaluated for the three parks. In Attachment A, Figure A-4 shows the Ames Mill Park alternatives, Figure A-5 shows the Riverside Lions Park alternatives, and Figure A-6 shows the Babcock Park alternatives.

Table 4-5 Parks Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt 4-1 Ames Alt 5-1 Riverside Alt 6-1 Babcock	No Change	Continue to allow floodwaters to regularly inundate the three parks. Future renovations to the parks should allow for frequent flooding.
Alt 4-2 Ames Alt 5-2 Riverside Alt 6-2 Babcock	Fill	Bring in fill to raise the ground elevation within the parks to reduce the frequency of flooding.
Alt 4-3 Ames Alt 5-3 Riverside Alt 6-3 Babcock	Levee	Construct a berm between the park area and the river to reduce the frequency of riverine flooding.
Alt 4-4 Ames Alt 5-4 Riverside Alt 6-4 Babcock	Floodwall	Same as the levee option but use a floodwall to reduce the footprint.

4.4.1 Alt 4-1 No Change

The no-change alternative considers the benefits and drawbacks of making no changes to how flood risk is managed for the three parks. Recent flood history and the updated discharge frequency estimates suggest that some flooding in the parks is likely to occur every few years. Table 4-6 lists the estimated expected inundation frequency of each park for a given elevation.

Table 4-6 Estimated Annual Flood Risk Based on Ground Elevation in the Parks

Flood Frequency (based on FEMA hydrology)	Recurrence Interval	Approximate Flood Elevation (1) (feet)		
Annual Chance of Exceedance	**(years)**	**Ames Mill Park**	**Riverside Lions Park**	**Babcock Park**
10%	10	905.5	906.3	906.5
2%	50	906.6	907.6	907.7
1%	100	907.1	908.4	908.5

(1) Existing Ground Elevations Range from 904 to 910

Benefits

- Minimal up-front public investment.
- Parks provide floodwater storage during flood events which helps keep flood levels in the immediate area lower and attenuate peak flood flows downstream.

Drawbacks

- Park areas will continue to flood regularly.
- Recurring maintenance costs associated with maintenance and clean-up after flood events.
- Limits the available uses of the park areas to structures and landscaping that are resilient to regular flooding.

4.4.2 Alt 4-2 Fill

The fill alternative considers the benefits and drawbacks of using fill to raise the ground elevation within the parks, so those areas flood less frequently. Filling in the floodplain is generally discouraged because it reduces flood storage in the floodplain. Fill in the floodplain can sometimes be offset with compensatory storage, meaning excavating an equivalent amount of fill in the immediate vicinity.

Design Assumptions and Considerations

- Add fill to bring park areas up to the highest adjacent grade surrounding the park.
- Portions of each site could be elevated higher than the surrounding area.
- Grading would need to allow for gravity drainage of surface runoff.
- Fill elevation selected based on adjacent high ground and with the goal of reducing the frequency of flooding to the 25-year to 50-year flood event.

Table 4-7 lists proposed fill elevations and how that would change the annual chance of flooding for the fill areas within the park.

Table 4-7 Fill Elevation Needed to Reduce Annual Flood Risk to 10% or Less in the Parks

Design Dimension	Ames Mill Park	Riverside Lions Park	Babcock Park
Existing Ground Elevation (feet)	904 to 908	905 to 908	906 to 910
Existing Annual Flood Risk	>10%	>10%	>10%
Fill Elevation (feet)	907	908	908
Proposed Annual Flood Risk	<2%	<2%	~2%

Permitting

- Floodplain permitting—Filling in the floodplain means the projects would need to meet the City of Northfield's local floodplain ordinance requirements. The proposed fill areas in the parks are in the flood-fringe portion of the FEMA regulatory floodplain. This means fill could be placed without requiring a no-rise certification.

Benefits

- Reduces the frequency of flooding in the park areas

Drawbacks

- Fill in the floodplain reduces flood storage, which can cause flood elevations and downstream peak flood flows to increase. One project usually does not have a significant impact, but the cumulative impacts of many such projects increase the flood risk for other properties.
- It is unlikely suitable locations are available to provide compensatory storage to offset the proposed fill in the floodplain.

4.4.3 Alt 4-3 Levee

The levee alternative considers the benefits and drawbacks of using an earthen berm to reduce the frequency of park area flooding. A levee would reduce the frequency of flooding from smaller, more frequent flood events. It would require less fill to construct than Alt 4-2.

Design Assumptions and Considerations

The design would need to account for interior drainage. This could be accomplished by (1) leaving a gap in the existing levee that is closed during a flood response, (2) constructing gravity inlets and pipes with back-flow preventers, or (3) constructing pump stations.

Table 4-8 lists the design parameter assumptions for levees protecting each park. The levee alternatives would provide similar levels of flood protection as the fill alternatives. The river would overtop the levees at about the 50-year event, and the area behind the levees would become available for flood storage.

Table 4-8 Levee Dimension Assumptions for Each Park

Design Dimension	Ames Mill Park	Riverside Lions Park	Babcock Park
Length (feet)	360	350	460
Top Elevation (feet)	907	908	908
Max Height (feet)	2	3	3
Side Slopes (H:V, feet/feet)	3:1	3:1	3:1
Top Width (feet)	8	8	8
Max Bottom Width (feet)	20	26	26

Permitting

- Floodplain permitting—levees are fill in the floodplain, which means the projects would need to meet the City of Northfield's local floodplain ordinance requirements. The proposed levee fill areas in the parks are in the flood-fringe portion of the FEMA regulatory floodplain. This means fill could be placed without no-rise certification.

Benefits

- Reduces the frequency of flooding in the park areas
- Would require less soil to construct than Alt 4-2
- Would retain most of the available flood storage within the parks for larger flood events

Drawbacks

- The levee would be fill in the floodplain, which reduces the available flood storage.
- It is unlikely suitable locations are available to provide compensatory storage to offset the proposed fill in the floodplain.
- The levee would need to be maintained.
- Levees create interior drainage challenges by blocking surface runoff from draining to the river.

4.4.4 Alt 4-4 Floodwall

The floodwall alternative considers the benefits and drawbacks of using a wall to reduce the frequency of park area flooding. A floodwall would reduce the frequency of flooding from smaller, more frequent flood events. It would have a smaller footprint than Alt 4-2 and Alt 4-3.

Design Assumptions and Considerations

The design would need to account for interior drainage. This could be accomplished by (1) leaving a gap in the wall that is closed during a flood response, (2) constructing gravity inlets and pipes with back-flow preventers, or (3) constructing pump stations.

Table 4-9 lists the design parameter assumptions for floodwalls protecting each park. The floodwall alternatives would provide similar levels of flood protection as the levee and fill alternatives. The river would overtop the floodwalls at about the 50-year event, and the area behind the levees would become available for flood storage.

Table 4-9 Floodwall Dimension Assumptions for Each Park

Design Dimension	Ames Mill Park	Riverside Lions Park	Babcock Park
Length (feet)	360	350	460
Top Elevation (feet)	907	908	908
Max Height (feet)	2	3	3

Permitting

- Floodplain permitting—Constructing a wall in the floodplain means the projects would need to meet the City of Northfield's local floodplain ordinance requirements. The wall locations in the parks are in the flood-fringe portion of the FEMA regulatory floodplain. This means no-rise certification would not be required.

Benefits

- Reduces the frequency of flooding in the park areas
- Would require less soil to construct than Alt 4-2
- Would retain most of the available flood storage within the parks for larger flood events

Drawbacks

- The wall would add some fill in the floodplain, which reduces the available flood storage.
- Wall system would need to be designed to overtop without scouring the ground behind the wall.
- The wall would need to be maintained.
- Floodwalls create interior drainage challenges by blocking surface runoff from draining to the river.

4.4.5 Parks Hydraulic Profiles

Figure A-7 and Figure A-9 in Attachment A show hydraulic profiles for a range of flood events. Ames Park is shown on Figure A-7. Riverside Lions and Babcock Park are shown on Figure A-9. The figures show the proposed level of protection needed to limit flooding in the parks to less than the 10% AEP (10-year) flood event.

4.4.6 Parks Inundation Mapping

Figure B-8 in Attachment B is the existing-conditions flood inundation map for the three parks. Figure B-9 shows proposed inundation extents for the park fill alternatives Alt 4-2, Alt 5-2, and Alt 6-2. Figure B-10 shows the proposed inundation extents for the park levee and floodwall alternatives. Both figures show that the 50-year floodplain is reduced but the 100-year and 500-year floodplains are not.

5 Carleton College Mitigation Alternatives Analysis

Barr, City, and College staff identified potential flood mitigation strategies for five locations during the Carleton College site visit in August 2022. These locations are listed below. Figures in Attachment C illustrate the structural alternatives for each location. Figure C-1 is a location map for the area of Carleton College included in the study.

- Area CC1 Student Houses (Figure C-2)
- Area CC2 Stadium Area (Figure C-3 and Figure C-4)
- Area CC3 West Gym (Figure C-5)
- Area CC4 Pump House (Figure C-6)
- Area CC5 Practice Fields (Figure C-7)

Table 5-1 lists the low floor and low opening elevations for each property in the study.

Table 5-1 Carleton College Structure Low Floor and Low Opening Elevations vs 1% AEP Flood

Name	Low Floor (1) (feet)	Low Opening (2) (feet)	1% AEP Flood Elevation (3) (feet)
Prentice House	899.0 (4)	906.0	901.5
Allen House	899.0	902.0	901.0
Wilson House	898.0	903.0	901.0
Stadium	900.0	900.0	901.0
West Gym	898.5	898.5	900.0
Pump House	902.0	902.0	900.5

(1) Low floor elevations were estimated to the nearest half-foot based on LiDAR, site photos, and assuming 9 feet between first floor and basement floor.
(2) Low opening elevations were estimated to the nearest half-foot based on LiDAR topography and site photos.
(3) 1% AEP flood elevations were calculated using the updated Cannon River hydraulic model
(4) Red text indicates value is lower than the 1% AEP flood elevation at that location

5.1 Area CC1 Student Houses

The three student houses are between Colvill Memorial Highway (Highway 19) and the river, just upstream of the Stadium. The basements of the three houses are 2 to 3 feet below the 1% AEP flood elevation. However, the low openings for the houses are above the 1% AEP flood elevation. This means the structures are more susceptible to basement flooding from groundwater seepage than from overland flows. Flood damage to the structures could occur from groundwater seepage into the basement or from a larger flood that reaches the low openings. Figure 5-1 shows the three student houses along Highway 19, south of the Stadium.

Figure 5-1 Student Houses (left to right: Wilson House, Allen House, Prentice House)

Table 5-2 lists the flood risk reduction alternatives evaluated for the student houses.

Table 5-2 Area CC1 Student Houses Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt CC1-1	No Change	Continue to use emergency measures such as sandbags and pumps to protect individual properties during a flood response.
Alt CC1-2	Temporary Barrier	Using temporary barriers to block floodwaters from reaching the structures.
Alt CC1-3	Remove Structures	Demolish or relocate structures and convert the space into an area that can be flooded without causing significant damage to infrastructure.

Other alternative(s) considered but not evaluated:

- **Dry Floodproofing** – Retrofit to make building exteriors impermeable and allow for rapid installation of temporary flood barrier panels in front of building openings. The college plans to remove these structures in the next 5 to 10 years due to safety issues with students having to cross Highway 19 daily to reach campus. Investing in structural improvements to the structures is unlikely to be a worthwhile investment.

- **Levee/Floodwall** – Constructing an earthen berm or concrete wall between the river and the houses would keep floodwaters away from the structures. A seepage cutoff would likely be needed to prevent groundwater seepage. The cost of this alternative is several times the value of the structures. Therefore, it was not carried forward for evaluation.
- Buyouts – The community could get FEMA funding to buyout the properties. This would put deed restrictions on the property that would limit future use of this space. This is not consistent with the expressed interests of Carleton College for future use of this area. Therefore, it was not carried forward for evaluation.

5.1.1 Alternative CC1-1 No Change

The no-change alternative considers the benefits and drawbacks of making no changes to managing flood risk for the student houses. For the 1% annual chance flood, floodwaters may not reach the structures above ground, but there could be basement flooding from groundwater seepage.

Benefits

- Minimal up-front investment

Drawbacks

- Does not reduce flood risk to the structures
- Flood response actions could require significant effort by the college
- Disruptions associated with relocating students during and after a flood
- Recurring costs associated with flood response and damages

5.1.2 Alternative CC1-2 Temporary Barrier

The temporary barrier alternative considers the benefits and drawbacks of using a deployable barrier to keep water away from the base of structures up to a flood elevation of 904. This is about 2 to 3 feet higher than the 2010 flood peak in this area. About 250 feet of barrier would be needed to protect the three houses. Figure C-2 in Attachment C shows a schematic plan view alignment for this alternative.

Design Considerations

- Select a product that provides at least 2 feet of barrier height
- Select a product that is collapsible or stackable for ease of storage
- Identify a storage location for the barrier
- Consider installation time relative to advanced warning time

Benefits

- Low cost
- Easier to deploy and remove than sandbags

Drawbacks

- Materials for the temporary barrier need to be stored and maintained to be available and in good condition when there is a flood.
- Temporary barrier requires installation; they are not automatic or passive. The City's and/or College’s emergency action plan would need to define installation triggers. There needs to be enough time and personnel available to complete the installation before floodwater arrive.
- Temporary barrier would not prevent or inhibit basement flooding from groundwater seepage.

5.1.3 Alternative CC1-3 Remove Structures

The remove structures alternative would vacate residents from the three houses and demolish the structures.

Benefits

- Eliminates flood risk for the current structures.
- Addresses safety concerns associated with student residents having to frequently cross Highway 19 to travel between their residence and the main campus.

Drawbacks

- Reduces the available on-campus housing for the college.

5.2 Area CC2 Stadium Area

The Stadium area consists of a track, football field, and structure with bleacher seating over locker rooms and other Stadium facilities. The structure is between the field and the river. There is a narrow access road that runs between the structure and the river. The low floor of the Stadium structure (Table 5-1) is approximately 1 foot below the peak elevation of the 1% AEP flood. The Stadium area flooded in 2010 and 2016. Figure 5-2 shows the Stadium during the 2010 flood. The rubberized track can be seen bulging up through the floodwaters.

Figure 5-2 Stadium Flooding September 25, 2010

Flood mitigation efforts deployed after the 2010 flood and a lower flood peak in 2016 significantly reduced the extent of damages during the 2016 flood relative to the 2010 flood. Post-2010 flood mitigation measures included installing posts for flood barrier panels for exterior Stadium doors, elevation of electrical and mechanical equipment within the structure, and flood proofing an interior room with electrical and mechanical equipment with posts for temporary flood barrier and sumps. Figure 5-3 shows the south Stadium entrance. The metal channels on either side of the double doors are in place to hold a stoplog temporary closure during a flood. Figure 5-4 shows the internal door to the electrical room within the Stadium, which has its own temporary stoplog closure.

Figure 5-3 Stadium South Entrance with Posts for Stoplog Temporary Closure

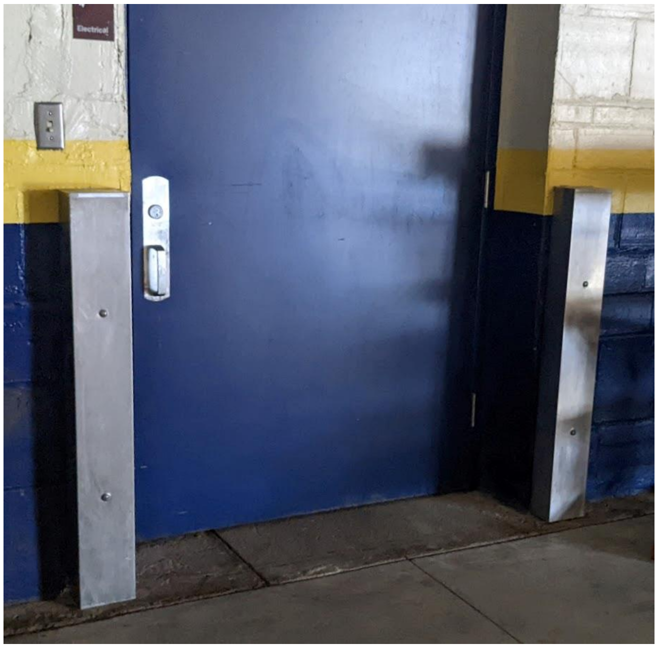


Figure 5-4 Stadium Electrical Room Flood Door with Posts for Stoplog Temporary Closure

Residual flood risk for the Stadium structure is from seepage through the structure membrane and inundation to the track and field area.

Table 5-3 lists the flood risk reduction alternatives evaluated for the Stadium area.

Table 5-3 Area CC2 Stadium Area Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt CC2-1	No Change	Continue to use temporary flood barrier panels in front of doorways (installed post-2010 flood) to protect the property during a flood response.
Alt CC2-2	Dry Floodproofing	Retrofit to make building exterior impermeable.
Alt CC2-3	Dry Floodproofing and Temporary Barriers	In addition to dry floodproofing the Stadium structure, use temporary barriers to limit inundation of the track and field area.
Alt CC2-4	Dry Floodproofing and Floodwalls	In addition to dry floodproofing the Stadium structure, construct floodwalls extending from the Stadium around the track and field area to high ground.

Other alternative(s) considered by not evaluated:

- **Full Levee/Floodwall** – Constructing an earthen berm and/or concrete wall between the river and Stadium area would keep floodwaters away from the structures. This would require up to 1500 feet of levee/floodwall. The space between the back side of the Stadium and the river is too narrow for a levee. A floodwall in this location would eliminate the access road around the back side of the Stadium, which would require creating a new access point to the parking lot near the West Gym. The cost of a levee/floodwall system would be in the 10’s of millions of dollars, which far exceeds the potential benefits. Therefore, this alternative was not carried forward for evaluation.

5.2.1 Alternative CC2-1 No Change (Stadium)

The no-change alternative considers the benefits and drawbacks of making no changes to managing flood risk for the Stadium area. For the 1% annual chance flood, the college would install its temporary flood barrier panels over Stadium doorways. Floodwaters would press against the sides of the structure. Seepage through the structure membrane would cause interior flooding. Sumps in the structure may or may not be able to keep up with the seepage. Building contents could be damaged. The track and field area would inundate, potentially delaminating the track (as occurred in 2010), requiring it to be replaced.

Benefits

- Minimal up-front investment

Drawbacks

- Does not reduce flood risk to the structure or track and field area
- Flood response actions require significant effort by the college
- Disruptions associated with canceling/rescheduling events during post-flood repairs
- Recurring costs associated with flood response and damages

5.2.2 Alternative CC2-2 Dry Floodproofing (Stadium)

The dry floodproofing alternative considers the benefits and drawbacks of sealing the building envelope up to elevation 903.0 to minimize the ability for water to enter the Stadium structure. This would provide approximately 2 feet of freeboard above the 1% AEP flood elevation. Dry floodproofing would be accomplished by sealing cracks in the building envelope and verifying that the walls are structurally capable of withstanding the hydrostatic pressure of water against the sides of the building. The Stadium already has stoplog temporary closures that can be installed in front of exterior doors.

Design Considerations

- Sealing the building envelope will involve applying a waterproof coating to the masonry exterior of the structure.
- Structural reinforcement of the walls may be necessary.
- The 2010 floodwaters were about 1 foot below the windowsills on the east side of the Stadium (see Figure 5-2). Alternative assumes no temporary flood barrier panels over the windows.

Benefits

- Reduces flood risk for the Stadium structure and its contents

Drawbacks

- Does not prevent floodwaters from reaching the structure

- Structure would not be accessible during a flood event
- Does not reduce flood risk to the track and field area
- May require significant retrofitting of structure
- Dry floodproofing is not recommended for flood depths greater than 3 feet

5.2.3 Alternative CC2-3 Temporary Barriers and Dry Floodproofing (Stadium)

The temporary barriers and dry floodproofing alternative builds on Alternative CC2-2 by adding temporary barriers to protect the track and field area. This would require approximately 750 feet of temporary barrier. Figure C-3 in Attachment C show the temporary barrier alignments extending from the Stadium steps to high ground.

Design Considerations

- Same dry flood proofing considerations as Alternative CC2-1.
- Temporary barriers will need a storage location.
- Emergency action plan will need to be updated to establish triggers for when to deploy the barriers.
- Adequate staff resources need to be on-hand to deploy the barriers within the advanced warning time for a flood.

Benefits

- Provides flood risk reduction for both the Stadium and the track and field area
- Structure would be accessible during a 1% annual chance flood event

Drawbacks

- Does not prevent floodwaters from reaching the Stadium structure
- May require significant retrofitting of structure
- System is not passive—requires time and human resources to deploy the temporary barriers
- Dry floodproofing is not recommended for flood depths greater than 3 feet

5.2.4 Alternative CC2-4 Floodwalls and Dry Floodproofing (Stadium)

The floodwalls and dry floodproofing alternative builds on Alternative CC2-3 by adding floodwalls and temporary closures to protect the track and field area. This would require approximately 750 feet of floodwall and five temporary closures. Figure C-4 in Attachment C shows the floodwall alignments extending from the Stadium steps to high ground.

Design Considerations

- Same dry flood proofing considerations as Alternative CC2-1.

- Assumes floodwall is constructed along the alignment for the perimeter fence. New, shorter fence would be constructed on top of the floodwall.
- Temporary closure stoplogs will need a storage location.
- Emergency action plan will need to be updated to establish triggers for when to deploy the temporary closures.
- Adequate staff resources need to be on-hand to deploy the barriers within the advanced warning time for a flood.

Benefits

- Provides flood risk reduction for both the Stadium and the track and field area
- Structure would be accessible during a 1% annual chance flood event
- Limited installation required, relative to the Temporary Barriers and Dry Floodproofing alternative

Drawbacks

- Does not prevent floodwaters from reaching the Stadium structure
- May require significant retrofitting of structure
- System is not passive—requires time and human resources to deploy stoplog closures
- Dry floodproofing is not recommended for flood depths greater than 3 feet
- May require removal and reconstruction of scoreboard at south end of Stadium

5.3 Area CC3 West Gym Basement

The West Gym basement is accessed from the west side of the building. It contains mechanical and electrical equipment as well as storage for materials used for operating and maintaining the facility. The floor of the basement (Table 5-1) is below the 1% chance flood elevation. During the 2010 flood there was approximately 18 inches of water in the basement area. Figure 5-5 shows the two access doors for the West Gym basement. The metal channels on either side of both doors are in place to hold stoplog temporary closures during a flood.

Figure 5-5 West Gym Doors

Residual flood risk for the West Gym basement is from seepage through the structure membrane. Because the basement is only accessible from the two exterior doors, there is no access to the basement once the temporary closures are installed. This prevents staff from monitoring and mitigating interior flooding during a flood event.

Table 5-4 lists the flood risk reduction alternatives evaluated for the West Gym basement

Table 5-4 Area CC3 West Gym Basement Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt CC3-1	No Change	Continue to use emergency measures such as stoplog temporary closures, sandbags and pumps to protect the property during a flood response.
Alt CC3-2	Temporary Closure	Construct a temporary closure that is offset from the entry points for the basement to allow for egress during flood events and prevent floodwaters from pressing up against the building.

5.3.1 Alternative CC3-1 No Change (West Gym)

The no-change alternative considers the benefits and drawbacks of making no changes to managing flood risk for the West Gym basement. For floods that reach the structure, the college installs temporary flood barriers over the two doorways and floodwaters press against the walls adjacent to the doors. Seepage through the structure membrane would cause interior flooding. Sumps in the structure may or may not keep up with the seepage. Building contents could be damaged.

Benefits

- Minimal up-front investment

Drawbacks

- Does not reduce flood risk to structure and its contents
- Recurring costs associated with flood response and damages

5.3.2 Alternative CC3-2 Setback Temporary Closure (West Gym)

The setback temporary closure alternative considers the benefits and drawbacks of constructing a new closure that is away from the building and an egress route so that staff can access the basement during a flood. Figure C-5 in Attachment C shows a schematic of the proposed closure.

Design Considerations

- New closure would be approximately 15-feet wide and 4-feet tall.
- Reconstruct pavement at base of closure to provide a smooth sill for the closure to rest on.
- Construct concrete wing walls that tie into the existing embankment on either side of the driveway in front of the gym basement doors.
- Construct stairs and a sidewalk behind the closure to provide access to the gym doors when the closure is installed. May require fill to create enough space for the walkway.

Benefits

- Setback closure would keep floodwaters from pushing against the side of the building.
- Staff would have access to the basement area during a flood.

Drawbacks

- Temporary closure is not passive—requires time and human resources to deploy the closure.

5.4 Area CC4 Pump House

The Pump House is a small building on the west side of Highway 19, between the track and field area and the West Gym; the building houses mechanical and electrical equipment. The Pump House provides access to a tunnel under Highway 19 that connects to the Facilities Building. The college has constructed a 2-foot-high berm around the entrance to the pump house. The top of the berm is at approximately elevation 904. The 1% AEP flood elevation is 901. The low opening is approximately 902. The low floor of the Pump House is approximately elevation 898. There is a high-voltage electrical panel in the pump house, the bottom of which is about 1-foot above the floor. Figure 5-6 shows four images of the Pump House. From left to right, the first image shows the entry door; the second shows the tunnel under the highway; the third shows the stairs leading down from the doorway into the pump house; and the fourth shows the electrical panel at the base of the entrance stairs.

Figure 5-6 Pump House Door, Tunnel, Entrance Stairs, and Electrical Panel (left to right)

The college can use portable pumps to remove water from the Pump House. If water enters the Pump House too quickly, the high-voltage electrical panel would have to be de-energized. If water gets several feet deep it could flow through the tunnel and into the basement of the Facilities Building, which could affect heating operations for other parts of campus.

Table 5-5 lists the flood risk reduction alternatives evaluated for the Pump House.

Table 5-5 Area CC4 Pump House Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt CC4-1	No Change	Continue to use existing flood risk mitigation strategies.
Alt CC4-2	Temporary Flood Barrier Panel	Install hardware for a temporary flood barrier in front of the Pump House door, similar to what exists for the West Gym and the Stadium.
Alt CC4-3	Elevate Electrical Panel	Replace the electrical panel inside the Pump House so it is at least one foot higher than the low opening.
Alt CC4-4	Sump Pump	Install a sump pump in the floor of the Pump House to automatically dewater the building if water gets into the structure.

Other alternative(s) considered but not evaluated:

- **Flood Door**—This would involve replacing the existing door with a flood door that is designed to be watertight. They require activation for them to be watertight. Flood doors are more expensive than temporary flood barrier panels for similar benefits. Therefore, this alternative was not evaluated.

5.4.1 Alternative CC4-1 No Change (Pump House)

The no-change alternative considers the benefits and drawbacks of making no changes to managing flood risk for the Pump House. The berm in front of the entrance to the Pump House is high enough that it should prevent the 1% AEP flood event from reaching the door of the Pump House.

Benefits

- Minimal up-front investment

Drawbacks

- Does not reduce flood risk to the electrical panel and Pump House

5.4.2 Alternative CC4-2 Temporary Stoplog Closure (Pump House)

The temporary stoplog closure alternative evaluates the benefits and drawbacks of using a stoplog closure in front of the Pump House door to keep water from seeping through the door if the berm is overtopped or water comes through the drain pipe through the berm.

Design Considerations

- Stoplogs would be small and could be stored on-site
- Install metal slots on either side of the door to receive stoplogs during a flood event
- Use the same flood barrier panel system as used on West Gym and the Stadium

Benefits

- Small up-front investment
- Stoplogs can be installed quickly without special training
- Increases the elevation of flood protection elevation to approximately 905
- College staff are already familiar with this type of temporary barrier

Drawbacks

- Active system that requires staff resources to install flood barrier panels ahead of the flood peak
- Only access to the Pump House once the flood barrier panel is installed is through the tunnel
- Sealing the doorway would block the closest outlet point for pumping water out of the structure

5.4.3 Alternative CC4-3 Elevate Electrical Panel (Pump House)

The elevate electrical panel alternative evaluates the benefits and drawbacks of modifying the high-voltage-electrical panel so it is less likely to be inundated if floodwater gets into the Pump House.

Design Considerations

- Confirm feasibility of modifying the panel
- Confirm access requirements for the panel

Benefits

- Reduces the risk of a de-energizing event
- Reduces the risk of a life safety event if staff are working in the Pump House during a flood

Drawbacks

- Panel remains in the structure and could still be impacted during flood larger than the 1% annual chance flood event.

5.4.4 Alternative CC4-4 Sump Pump (Pump House)

The sump pump alternative evaluates the benefits and drawbacks of installing a sump pump in the basement of the Pump House that can automatically dewater the floor of the Pump House if flooded.

Design Considerations

- Determine the size of pump needed to keep water from getting more than 6 inches deep on the floor of the Pump House
- Determine discharge point for the sump. Does it need to go to the sanitary sewer? Or can it be discharged onto the ground adjacent to the structure?

Benefits

- Provides a passive means of managing water that seeps into the Pump House
- Reduces the risk of a life safety event if staff are working in the Pump House during a flood

Drawbacks

- Pumps need to be maintained

5.5 Area CC5 West Practice Fields

The West Practice Fields are 7.5 acres of turf north of the West Gym that are used for open field athletic practices and occasional event parking. During flood events, floodwaters from the Cannon River back up into the area. Slow moving water deposits a significant volume of sediment. Restoration of the practice field requires removal of this sediment and seeding or sodding to reestablish the turf. This has happened at least three times since 2010. Field elevations range from roughly 894 to 897. This elevation range is lower than the 10% annual chance flood event in the hydraulic model, meaning the fields have a greater than a 10% chance of flooding in a given year. Roughly two-thirds of the area is delineated as regulatory floodway. Figure C-1 and Figure C-7 in Attachment C show the mapped regulatory floodplain for the West Practice Fields area.

Figure 5-7 shows the West Practices Fields during the 2010 flood. The top of the soccer goal in the background of the photo suggests that there was approximately 7 feet of water at that location. Table 5-6 lists the flood risk reduction alternatives evaluated for the West Practice Fields.

Figure 5-7 West Practice Fields During the 2010 Flood Looking North

Table 5-6 Area CC5 West Practice Fields Flood Risk Reduction Alternatives

Alternative	Name	Description
Alt CC5-1	No Change	Continue to use existing flood risk mitigation strategies.
Alt CC5-2	Berm	Construct a low berm along the perimeter of the fields adjacent to the river that prevents flooding from the 10-year flood event.

Alternatives considered but not evaluated

- **Fill Outside of the Floodway** – The college could use fill to raise up a portion of the practice field area. While this would reduce the frequency of flooding for about one-third of the field area, it would create a tiered practice field area with an irregular shape that would require a reconfiguration of the fields as they are currently used. The college would not be able to fit as many different separate full fields (soccer, football, etc.) in the same space. The remaining area would still be flood prone and require costly cleanup after flood events.

5.5.1 Alternative CC5-1 No Change (West Practice Fields)

The no-change alternative considers the benefits and drawbacks of making no changes to managing flood risk for the West Practice Fields.

Benefits

- Minimal up-front investment
- No impacts to the regulatory floodplain

Drawbacks

- Continued operation and maintenance expenses related to periodic cleanup and restoration of the fields after flood events.

5.5.2 Alternative CC5-2 Berm (West Practice Fields)

The berm alternative considers the benefits and drawbacks of using a low berm between the river and the practice fields to block floodwaters from inundating the fields during smaller flood events up to about the 10% AEP (10-year) flood. Larger flood events would continue to have access to the broader floodplain.

Design Considerations

- Hydraulic modeling would be needed to verify that a berm could be constructed without causing a rise in base flood elevation.
- Assumes interior drainage will need to be managed by leaving a gap in the berm that could be filled temporarily with sandbags or soil when flooding is expected.

Benefits

- Reduces frequency of flooding for the entire area.
- Retains most of the existing field area for full sized practice fields.

Drawbacks

- Additional operations and maintenance associated with managing interior drainage.
- May increase channel velocities during smaller flood events, which may require mitigation against bank erosion.
- Would require permitting of fill in the floodplain.

5.5.3 Carleton College Hydraulic Profiles

Figure C-8 in Attachment C shows hydraulic profiles for a range of flood events at Carleton College. The figure shows structures and recommended flood mitigation measures relative to the different expected annual exceedance probability flood levels.

5.5.4 Carleton College Inundation Mapping

Figure D-1 in Attachment D shows existing floodplain mapping for the Carleton College study area. Proposed-conditions flood inundation maps were created for alternatives that would modify the flooding extents. The mitigation alternatives for the Student Houses, Pump House and West Practice Fields would not affect 100-year inundation extents. Figures D-2, D-3, and D-4 show the effect of the three different alternatives for the Stadium and the West Gym alternative.

6 Cost Estimating

6.1 Estimator's Qualification of Estimated Construction Cost

The feasibility-level construction cost estimate provided in this report is based on Barr's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. This opinion is based on the project-related information available to Barr at this time, current information about probable future costs, and a concept-level design for the Project. The opinion of construction cost will likely change as more information becomes available and further design is completed. In addition, because we have no control over the eventual cost of labor, materials, equipment, or services furnished by others, or over a contractor's methods of determining prices, or over competitive bidding or market conditions, Barr cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from the opinion of probable construction cost presented in this report. Greater assurance as to the probable construction cost can be achieved through additional design to provide more complete project definition.

6.2 Estimate Type

These construction cost estimates, documentation, and discussion are intended to provide background information for initial feasibility assessment and preliminary analysis purposes. These cost estimates correspond to a Class 4 estimate class (AACE International Recommended Practice No. 18R-97 and ASTM E 2516-06 Standard Classification for Cost Estimate Classification System). This estimate classification is characterized by limited project definition and the wide-scale use of parametric models and engineering judgment to calculate costs.

6.3 Cost Estimate Summary

Table 6-1 lists the estimated total project cost for each of the Northfield alternatives, as well as a low and high estimate for the total project cost. Table 6-2 lists similar cost data for the Carleton College alternatives. Attachment E contains a breakdown of the components of the total project cost and cost comparison charts.

Table 6-1 Northfield Alternative Cost Estimate Summary

Alternative	Name	Estimated Total Project Cost	Cost Range Low End (-25%)	Cost Range High End (+50%)
Alt 1-1	No Change	N/A	N/A	N/A
Alt 1-2	Floodwall Extension	$2,619,000	$1,970,000	$3,930,000
Alt 1-3	Channel Floodwall	$3,806,000	$2,860,000	$5,710,000
Alt 1-4	Two Floodwalls	$1,199,000	$900,000	$1,800,000
Alt 1-5	Buyouts	$2,830,000	$2,550,000	$3,400,000
Alt 2-1	No Change	N/A	N/A	N/A
Alt 2-2	Dry Floodproofing	$544,000	$410,000	$820,000
Alt 2-3	Wet Floodproofing	$1,376,000	$1,040,000	$2,070,000
Alt 2-4	Buyouts	$1,900,000	$1,710,000	$2,280,000
Alt 3-1	No Change	N/A	N/A	N/A
Alt 3-2	Dry Floodproofing	$196,000	$150,000	$300,000
Alt 3-3	Floodwall	$2,871,000	$2,160,000	$4,310,000
Alt 3-4	Temporary Barriers	$85,000	$64,000	$128,000
Alt 3-5	Buyouts	$8,230,000	$7,410,000	$9,880,000
Alt 4-1	No Change	N/A	N/A	N/A
Alt 4-2	Ames Park Fill	$176,000	$140,000	$270,000
Alt 4-3	Ames Park Levee	$204,000	$160,000	$310,000
Alt 4-4	Ames Park Floodwall	$994,000	$750,000	$1,500,000
Alt 5-1	No Change	N/A	N/A	N/A
Alt 5-2	Riverside Lions Park Fill	$167,000	$130,000	$260,000
Alt 5-3	Riverside Lions Park Levee	$211,000	$160,000	$320,000
Alt 5-4	Riverside Lions Park Floodwall	$962,000	$730,000	$1,450,000
Alt 6-1	No Change	N/A	N/A	N/A
Alt 6-2	Babcock Park Fill	$378,000	$290,000	$570,000
Alt 6-3	Babcock Park Levee	$281,000	$220,000	$430,000
Alt 6-4	Babcock Park Floodwall	$1,256,000	$950,000	$1,890,000

Table 6-2 Carleton College Alternative Cost Estimate Summary

Alternative	Name	Estimated Total Project Cost	Cost Range Low End (-25%)	Cost Range High End (+50%)
Alt CC1-1	No Change	N/A	N/A	N/A
Alt CC1-2	Temporary Barriers	$24,000	$20,000	$40,000
Alt CC1-3	Remove Structures	$1,010,000	$760,000	$1,520,000
Alt CC2-1	No Change	N/A	N/A	N/A
Alt CC2-2	Dry Floodproofing	$295,000	$230,000	$450,000
Alt CC2-3	Temporary Barrier	$277,000	$210,000	$420,000
Alt CC2-4	Floodwall	$1,622,000	$1,220,000	$2,440,000
Alt CC3-1	No Change	N/A	N/A	N/A
Alt CC3-2	Temporary Closure	$161,000	$130,000	$250,000
Alt CC4-1	No Change	N/A	N/A	N/A
Alt CC4-2	Temporary Closure	$4,000	$3,000	$6,000
Alt CC4-3	Elevate Electrical Panel	$169,000	$130,000	$260,000
Alt CC4-4	Sump Pump	$26,000	$20,000	$40,000
Alt CC5-1	No Change	N/A	N/A	N/A
Alt CC5-2	Practice Field Berm	$65,000	$50,000	$100,000

6.4 Basis for Cost Estimate

The basis and methodology used to develop the cost estimates are described below.

- Mobilization is assumed to be 5% of construction costs for projects over $500,000 and 10% for project under $500,000.
- Erosion and sediment control are assumed to be 2% of construction costs for projects over $500,000 and 5% for projects under $500,000.
- Contingency is assumed to be 25% of construction costs, including mobilization.
- Planning, engineering, and design are assumed to be 25% of construction costs with contingency.
- Permitting and regulatory approvals are assumed to be 10% of construction costs with contingency.
- Acquisition cost estimates are based on 135% of a typical cost per square foot for commercial office space. For the smaller buildings downstream of the dam, Barr assumed $160 per square foot. For the larger buildings upstream of the dam Barr assumed $100 per square foot. These

value estimates are all higher than the market value estimate on the Rice County property tax website.

- Demolition costs for acquired commercial structures account for demolition of the structure, abatement of hazardous substances, utility excavation, and backfilling.
- The estimated accuracy range for the total project cost is -25% and +50% for construction projects and -10% to +20% for acquisition alternatives.

6.5 Operations and Maintenance Costs

Most alternatives would require ongoing operations and maintenance costs. Table 6-3 lists the estimated annual operations and maintenance costs of each alternative. These are order-of-magnitude estimates based on anticipated labor during a flood response, anticipated frequency of flood events, storage costs, annual maintenance labor and expenses, and interior drainage system operation costs. These estimates should be refined during the design of a selected alternative. Buyout areas are assumed to require operation and maintenance costs similar to parks in the floodplain.

Table 6-3 Annual Operation and Maintenance Cost Estimates

Alternative	Name	Estimated Annual Cost
Alt 1-1	No Change	$16,000
Alt 1-2	Floodwall Extension	$11,000
Alt 1-3	Channel Floodwall	$11,000
Alt 1-4	Two Floodwalls	$11,000
Alt 1-5	Buyouts	$1,000
Alt 2-1	No Change	$17,000
Alt 2-2	Dry Floodproofing	$12,000
Alt 2-3	Wet Floodproofing	$13,000
Alt 2-4	Buyouts	$1,000
Alt 3-1	No Change	$6,000
Alt 3-2	Dry Floodproofing	$13,000
Alt 3-3	Floodwall	$21,000
Alt 3-4	Temporary Barriers	$9,000
Alt 3-5	Buyouts	$1,000
Alt 4-1	No Change	$6,000
Alt 4-2	Ames Park Fill	$1,000
Alt 4-3	Ames Park Levee	$8,000
Alt 4-4	Ames Park Floodwall	$12,000
Alt 5-1	No Change	$6,000
Alt 5-2	Riverside Lions Park Fill	$1,000
Alt 5-3	Riverside Lions Park Levee	$8,000
Alt 5-4	Riverside Lions Park Floodwall	$12,000
Alt 6-1	No Change	$6,000
Alt 6-2	Babcock Park Fill	$1,000
Alt 6-3	Babcock Park Levee	$8,000
Alt 6-4	Babcock Park Floodwall	$12,000

Table 6-4 Carleton College Annual Operation and Maintenance Cost Estimates

Alternative	Name	Estimated Annual Cost
Alt CC1-1	No Change	$1,000
Alt CC1-2	Temporary Barriers	$7,000
Alt CC1-3	Remove Structures	$4,000
Alt CC2-1	No Change	$5,000
Alt CC2-2	Dry Floodproofing	$5,000
Alt CC2-3	Temporary Barrier	$19,000
Alt CC2-4	Floodwall	$4,000
Alt CC3-1	No Change	$6,000
Alt CC3-2	Setback Temporary Barrier	$3,000
Alt CC4-1	No Change	$1,000
Alt CC4-2	Temporary Barriers	$5,000
Alt CC4-3	Elevate Electrical Panel	$5,000
Alt CC4-4	Sump Pump	$3,000
Alt CC5-1	No Change	$50,000
Alt CC5-2	Practice Field Berm	$11,000

7 Recommendations

Barr scored the alternatives based on whether they align with the Riverfront Plan, meet City goals, meet property owner goals, and provide effective flood protection for the flood of record. This score was divided into the total project cost and the estimated annual maintenance cost times a 50-year design life. Lower values in these calculations mean a more cost-effective project. These scores were used to make recommendations about whether each alternative should be considered further. Attachment F contains the tables used to score each alternative.

Table 7-1 lists the alternatives for Area 1 with the recommended alternative in **bold**. Table 7-2 lists the alternatives for Area 2, with the recommended alternative in **bold**. Table 7-3 lists the alternatives for Area 3, with the recommended alternative in **bold**. Table 7-4 shows the alternatives for the three parks; no recommendation is given. Table 7-5 lists the Carleton College alternatives, with the recommended alternatives in **bold**.

The information and recommendations presented in this report are intended to provide the basis for the City of Northfield to select preferred alternatives that can be advanced to a second phase involving a FEMA benefit-cost analysis.

Table 7-1 Area 1 Alternatives Recommendations

Alternative	Name	Aligns with Riverfront Plan	Consider Further	Notes
Alt 1-1	No Change	No	No	Does not meet goals of the project
Alt 1-2	**Floodwall Extension**	**Yes**	**Yes**	**Provides robust protection with low effort for operation and maintenance**
Alt 1-3	Channel Floodwall	Maybe	No	Would be expensive to maintain river access views
Alt 1-4	Two Floodwalls	No	No	Most cost-effective structural alternative. Does not protect lot near 2nd Street Bridge
Alt 1-5	Buyouts	No	No	Does not meet goals of the project

Table 7-2 Area 2 Alternatives Recommendations

Alternative	Name	Aligns with Riverfront Plan	Consider Further	Notes
Alt 2-1	No Change	No	Maybe	Does not meet goals of the project
Alt 2-2	**Dry Floodproofing**	**Yes**	**Maybe**	**Dry floodproofing is difficult to achieve and will require active management by property owner.**
Alt 2-3	Wet Floodproofing	Maybe	No	Alt 2-2 and Alt 2-4 are more cost-effective
Alt 2-4	Buyouts	Maybe	Maybe	Consider if property owners are willing

Table 7-3 Area 3 Alternatives Recommendations

Alternative	Name	Aligns with Riverfront Plan	Consider Further	Notes
Alt 3-1	**No Change**	**Maybe**	**Yes**	**Low openings for buildings are 2 feet above the flood of record**
Alt 3-2	Dry Floodproofing	Yes	No	Unnecessary based on flood history
Alt 3-3	Floodwall	Maybe	No	Unnecessary based on flood history.
Alt 3-4	Temporary Barriers	Maybe	No	Unnecessary based on flood history
Alt 3-5	Buyouts	Maybe	No	Unnecessary based on flood history

Table 7-4 Park Alternatives Recommendations

Alternatives	Name	Aligns with Riverfront Plan	Consider Further	Description
Alt 4-1 Ames Alt 5-1 Riverside Alt 6-1 Babcock	No Change	Maybe	Maybe	Preserves floodplain storage
Alt 4-2 Ames Alt 5-2 Riverside Alt 6-2 Babcock	Fill	Yes	Maybe	Filling in the flood fringe for parks is generally not a good floodplain management policy
Alt 4-3 Ames Alt 5-3 Riverside Alt 6-3 Babcock	Levee or Floodwall	Maybe	Maybe	Reduces flood frequency in park areas without significantly reducing flood storage

Table 7-5 Carleton College Alternatives Recommendations

Alternative	Name	Aligns with Riverfront Plan	Aligns with College Goals	Consider Further	Notes
Alt CC1-1	**No Change**	**N/A**	**Yes**	**Yes**	**College plans to remove houses within 5 years**
Alt CC1-2	Temporary Barrier	N/A	Maybe	No	Not worth the investment given plans to remove houses within 5 years.
Alt CC1-3	Buyouts	N/A	No	No	Deed restrictions for FEMA buyouts are undesirable.
Alt CC2-1	No Change	N/A	No	Maybe	Track and structure at risk
Alt CC2-2	Dry Floodproofing	N/A	Yes	Maybe	Only protects structure
Alt CC2-3	Temporary Barrier	N/A	Maybe	Maybe	Labor intensive to install, protects track. Less expensive than floodwall.
Alt CC2-4	**Floodwall**	**N/A**	**Yes**	**Yes**	**Low maintenance, protects track**
Alt CC3-1	No Change	N/A	No	No	Current temporary closures do not allow for egress
Alt CC3-2	**Temporary Closure**	**N/A**	**Yes**	**Yes**	**Preferred alternative for college because it maintains egress for emergency exit.**
Alt CC4-1	**No Change**	**N/A**	**Maybe**	**Yes**	**Current mitigation may be sufficient**
Alt CC4-2	Temporary Closure	N/A	Yes	No	Unlikely to be cost effective
Alt CC4-3	Elevate Electrical Panel	N/A	Yes	Maybe	Unlikely to be cost effective
Alt CC4-4	Sump Pump	N/A	Yes	Maybe	Unlikely to be cost effective
Alt CC5-1	No Change	N/A	No	Maybe	May not be able to reduce flood risk due to floodway designation
Alt CC5-2	**Berm**	**N/A**	**Yes**	**Yes**	**Reducing backwater flooding from Spring Creek could significantly reduce post-flood restoration costs**

8 References

[1] City of Northfield, "Northfield Climate Action Plan, Carbon Free 2040," 2019.

[2] City of Northfield, "Riverfront Enhancement Action Plan, Northfield Minnesota," 2020.

[3] FEMA, "Effective Flood Insurance Study for Rice County," 2012.

[4] FEMA, "Preliminary Flood Insurance Study, Rice County, Minnesota and Incorporated Areas, 27131CV000B," 2019.

[5] FEMA, "Letter of Map Revision 12-05-1809P," 2012.

[6] USGS, "Water Data, Cannon River at Northfield MN Gage 05355024," [Online]. Available: https://waterdata.usgs.gov/monitoring-location/05355024/#parameterCode=00065&period=P7D. [Accessed 2021].

[7] Barr Engineering Co., "Cannon River Flood-Frequency Analysis Update," 2022.

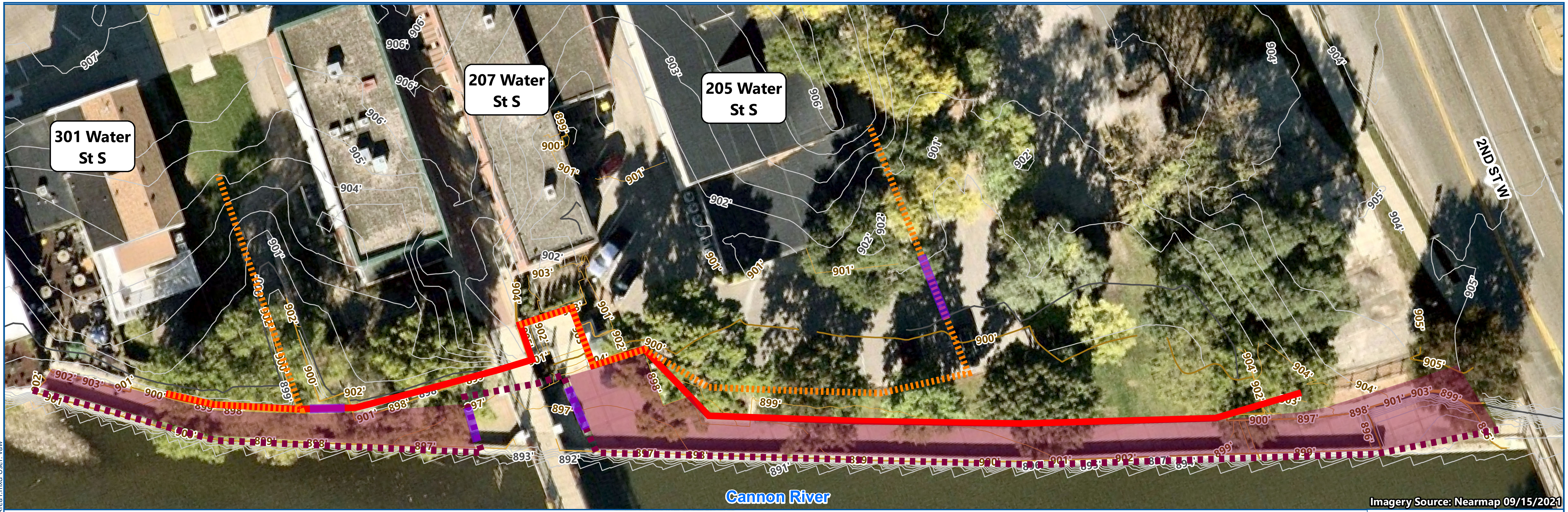
[8] USACE, "Cannon River Basin, Hydrology Study and Report," St. Paul District, St. Paul, 2015.

[9] Barr Engineering Co., "Cannon River Future Flood Risk Analysis Memorandum," Minneapolis, 2023.

[10] Barr Engineering Co., "Cannon River Hydraulic Model Updates," Barr, Minneapolis, 2022.

Attachment A

Northfield Alternatives Conceptual Design Figures



Alt 1-2 Floodwall Extension

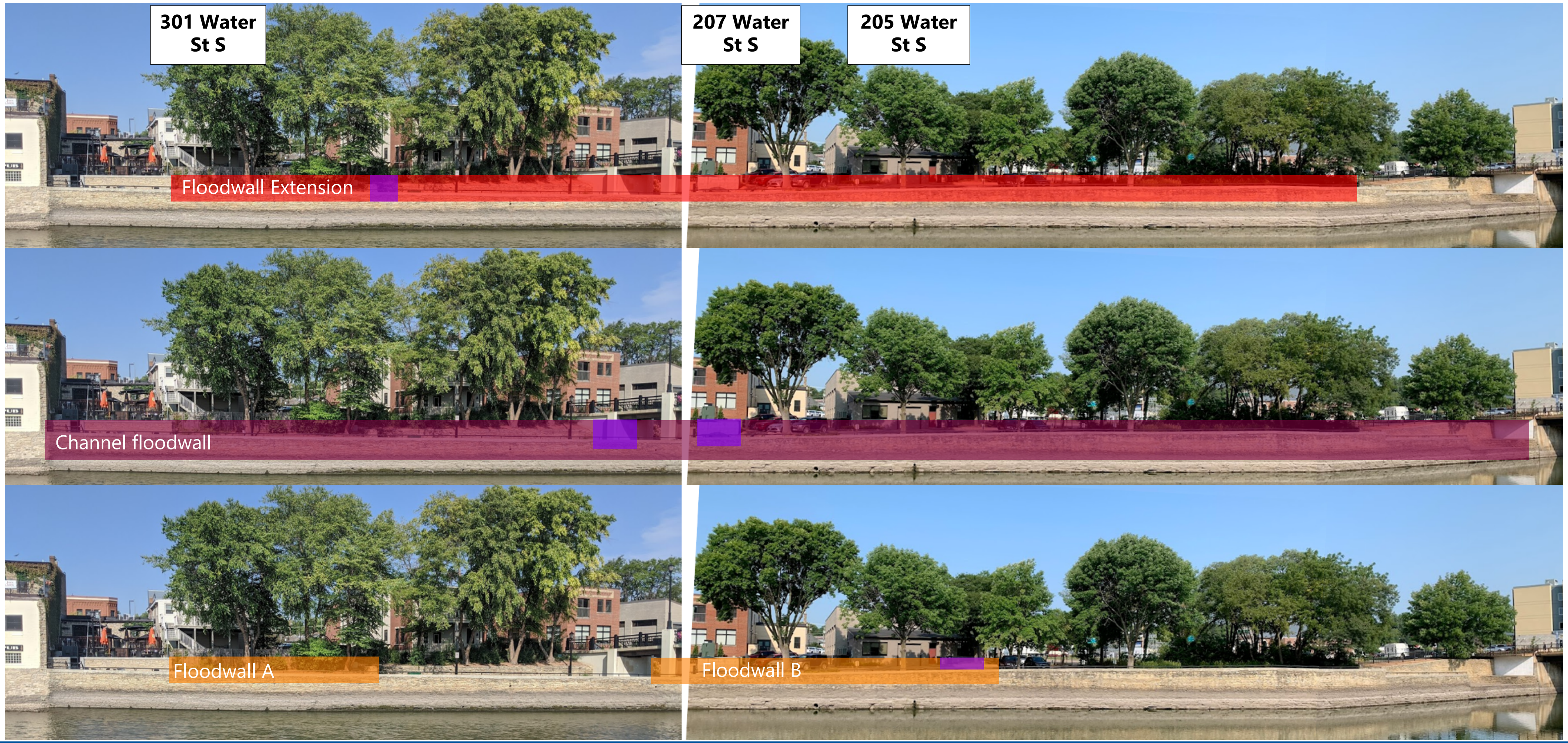
Top of Wall = 904
Length = 415 feet
Temporary Closures = 1

Alt 1-3 Channel Floodwall

Elevate Riverwalk = 901.5
Top of Wall = 904
Length = 500 feet
Temporary Closures = 2

Alt 1-4 Two Floodwalls

Top of Wall = 904
Length A = 135 feet
Length B = 230 feet
Temporary Closures = 1



Survey Contours

Index (10-Foot Interval)
Intermediate (1-Foot Interval)

LiDAR Contours

Index (10-Foot Interval)
Intermediate (1-Foot Interval)

0 25 50
Feet

Note: Legend, Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY

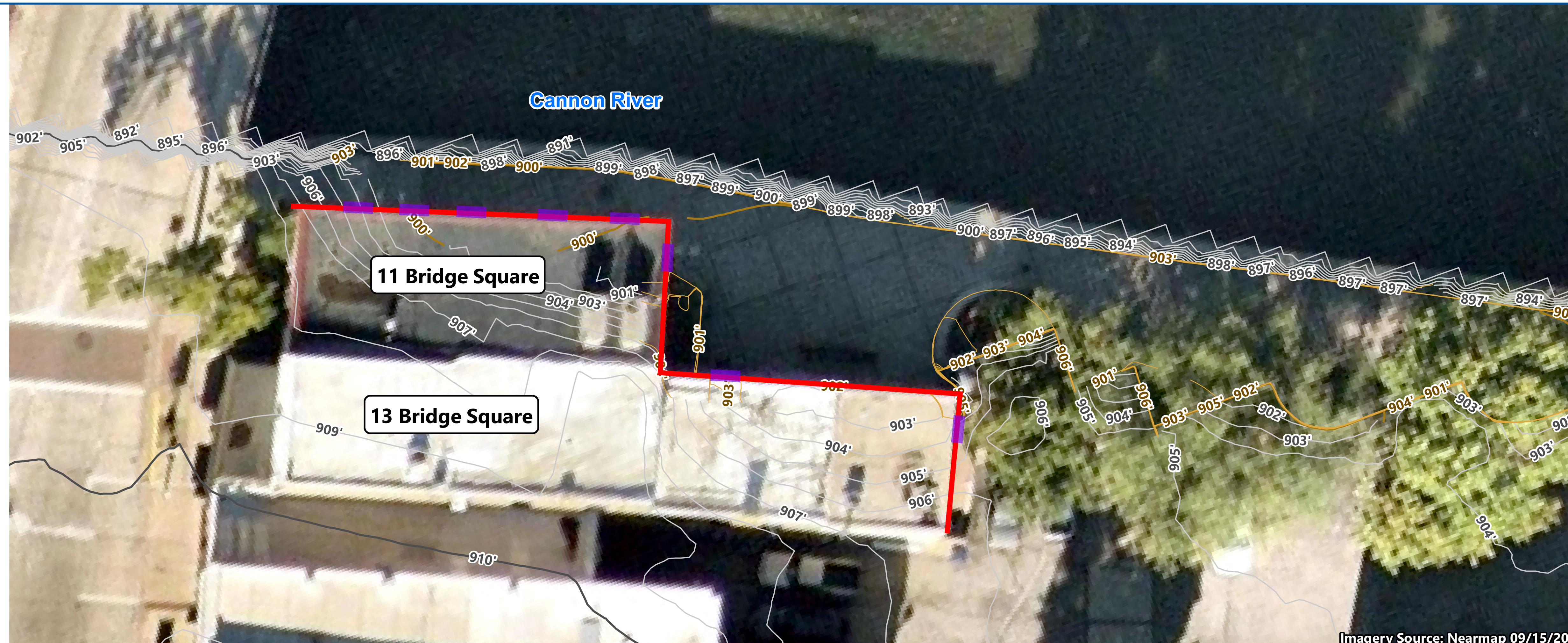
Area 1 Alternatives
205-301 Water St.

FIGURE A-1

BARR

Alt 2-2 Dry Floodproofing
Protection Elevation = 904
Seal Building Envelope
Opening Covers = 8

Alt 2-3 Wet Flood Proofing
Voluntary buyout of lower levels of both structures
Install openings to allow water to enter and leave the structures.
Retrofit interior of lower level so flooding does not damage the structures.



Survey Contours
Index (10-Foot Interval)
Intermediate (1-Foot Interval)

LiDAR Contours
Index (10-Foot Interval)
Intermediate (1-Foot Interval)

0 10 20
Feet

Note: Legend, Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
Area 2 Alternatives
11 & 13 Bridge Square

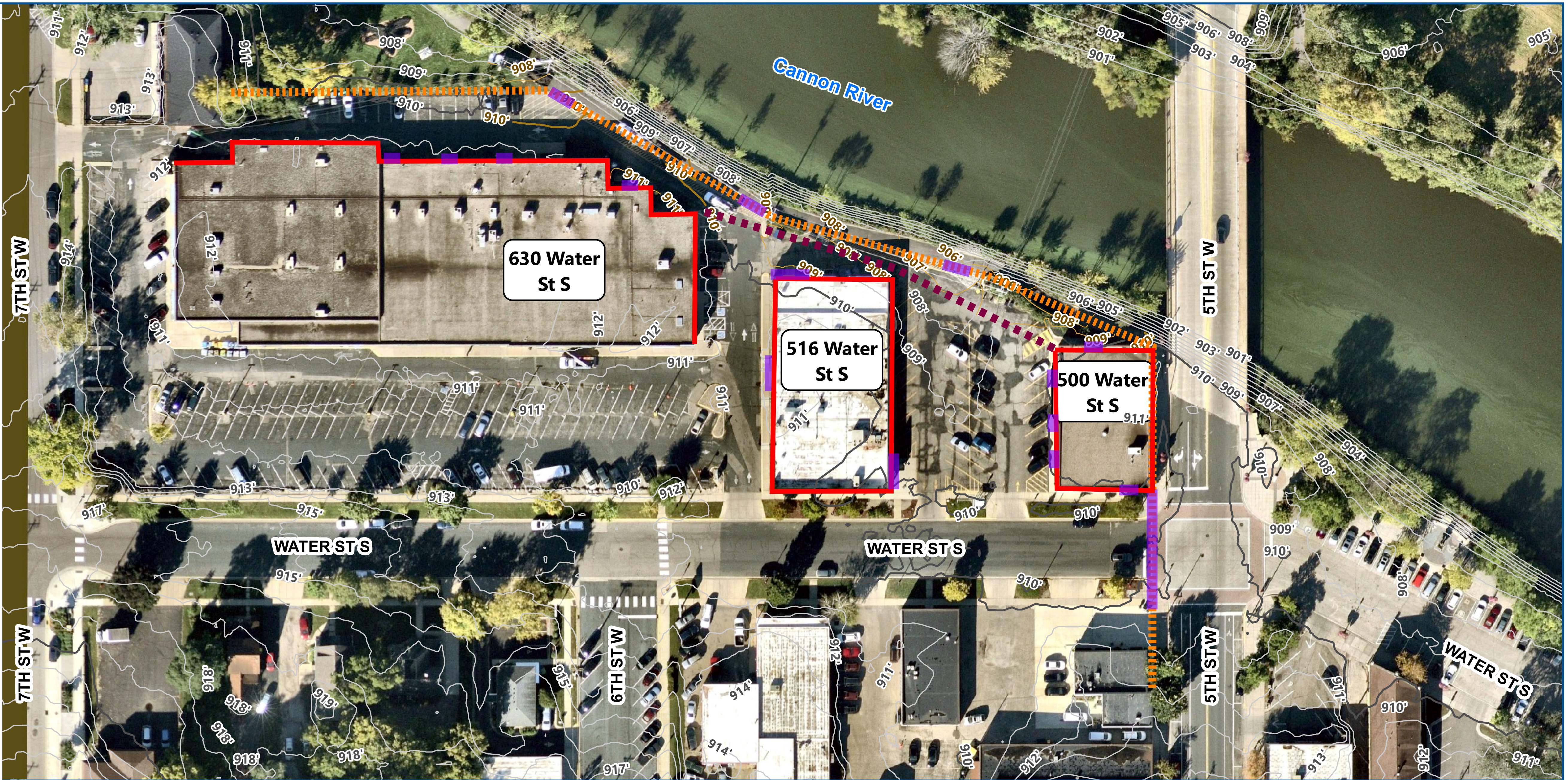
FIGURE A-2

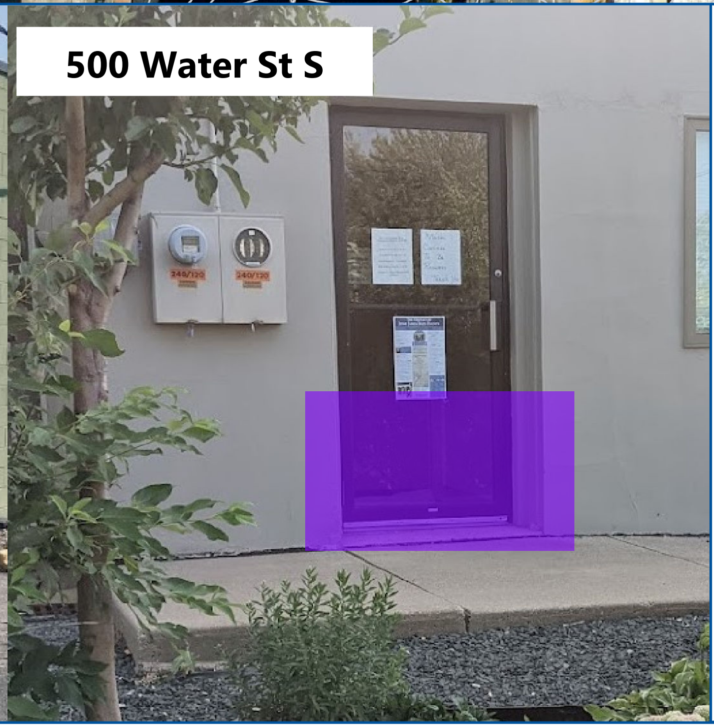
BARR

Alt 3-2 Dry Floodproofing
Protection Elevation = 912
Seal Building Envelope
630 Water St = 520 feet
516 Water St = 460 feet
500 Water St = 330 feet
Door Covers
630 Water St = 4
516 Water St = 3
500 Water St = 5

Alt 3-3 Floodwall
Top of Wall = 912
Length = 920 feet
Temporary Closures
8' Closures (3)
80' Closure across Water St

Alt 3-4 Temporary Barrier
Top of Barrier = 910
Length = 270 feet





Survey Contours
Index (10-Foot Interval)
Intermediate (1-Foot Interval)
LiDAR Contours
Index (10-Foot Interval)
Intermediate (1-Foot Interval)

0 70 140
Feet

Note: Legend, Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
Area 3 Alternatives
500-516 Water St.
FIGURE A-3

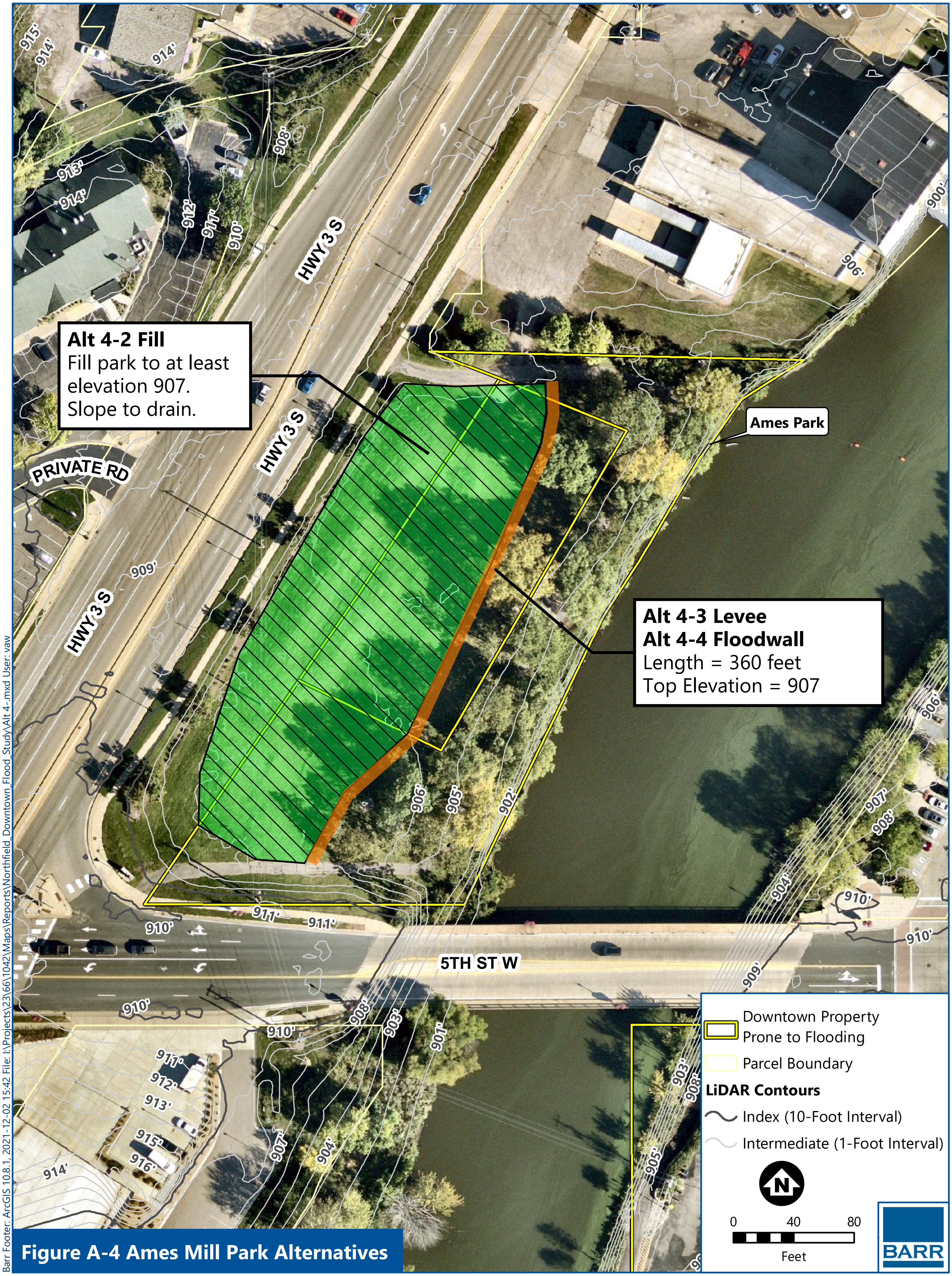


Figure A-4 Ames Mill Park Alternatives

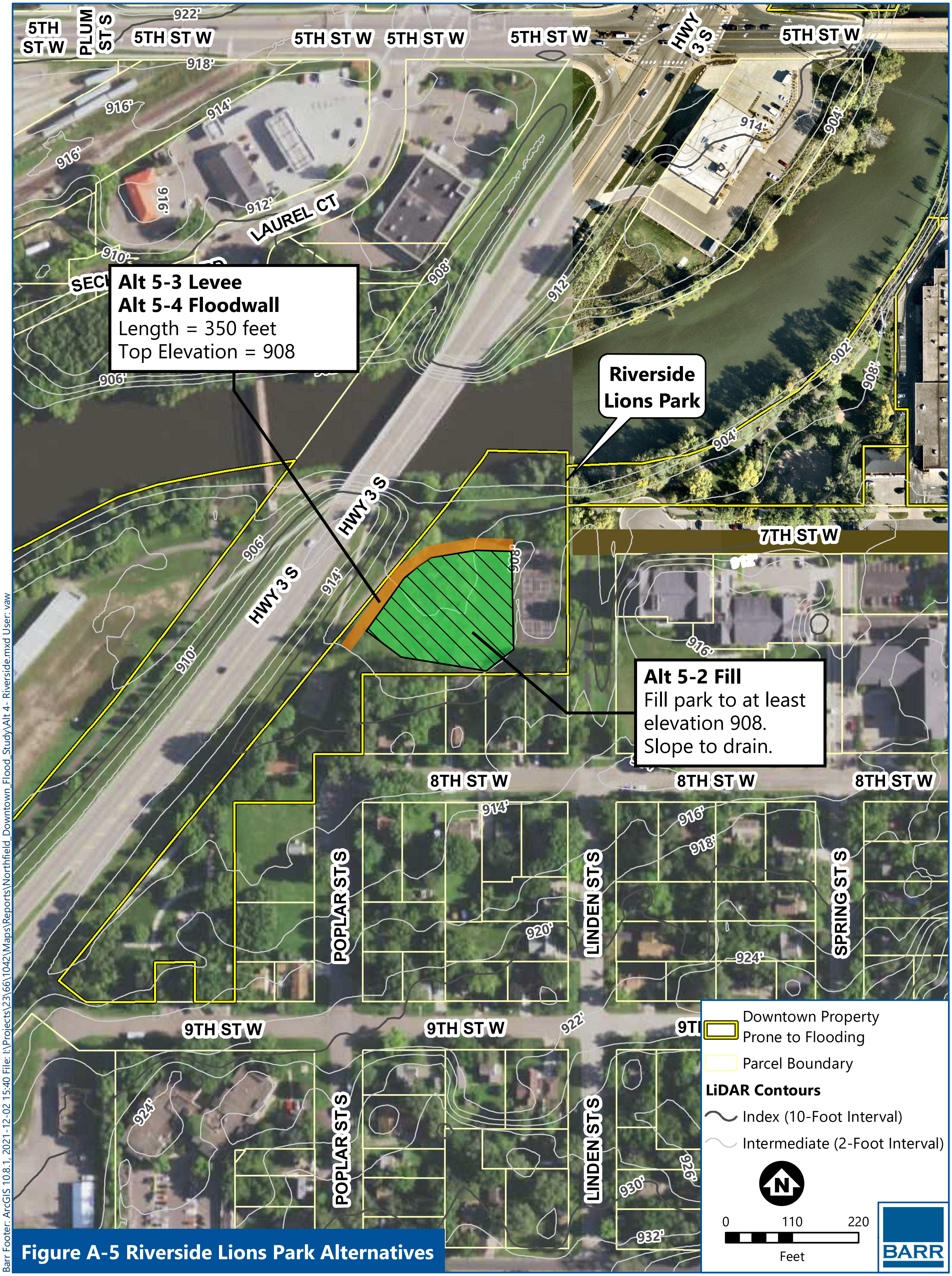


Figure A-5 Riverside Lions Park Alternatives

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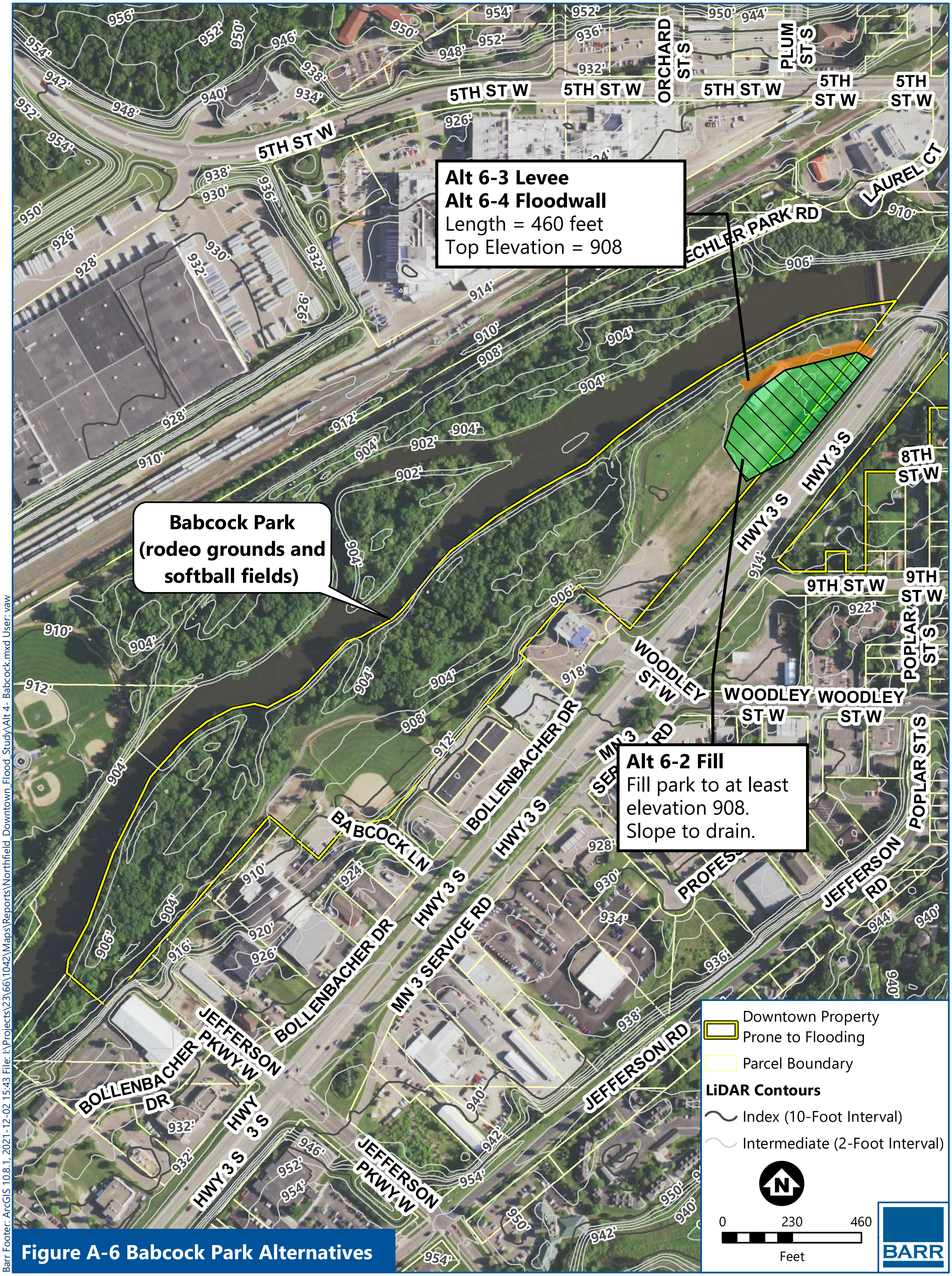


Figure A-6 Babcock Park Alternatives

Barr Footer: ArcGIS 10.8.1, 2021-12-02 15:43 File: I:\Projects\23\66\1042\Maps\Reports\Northfield_Downtown_Flood_Study\Alt 4- Babcock.mxd User: vaw

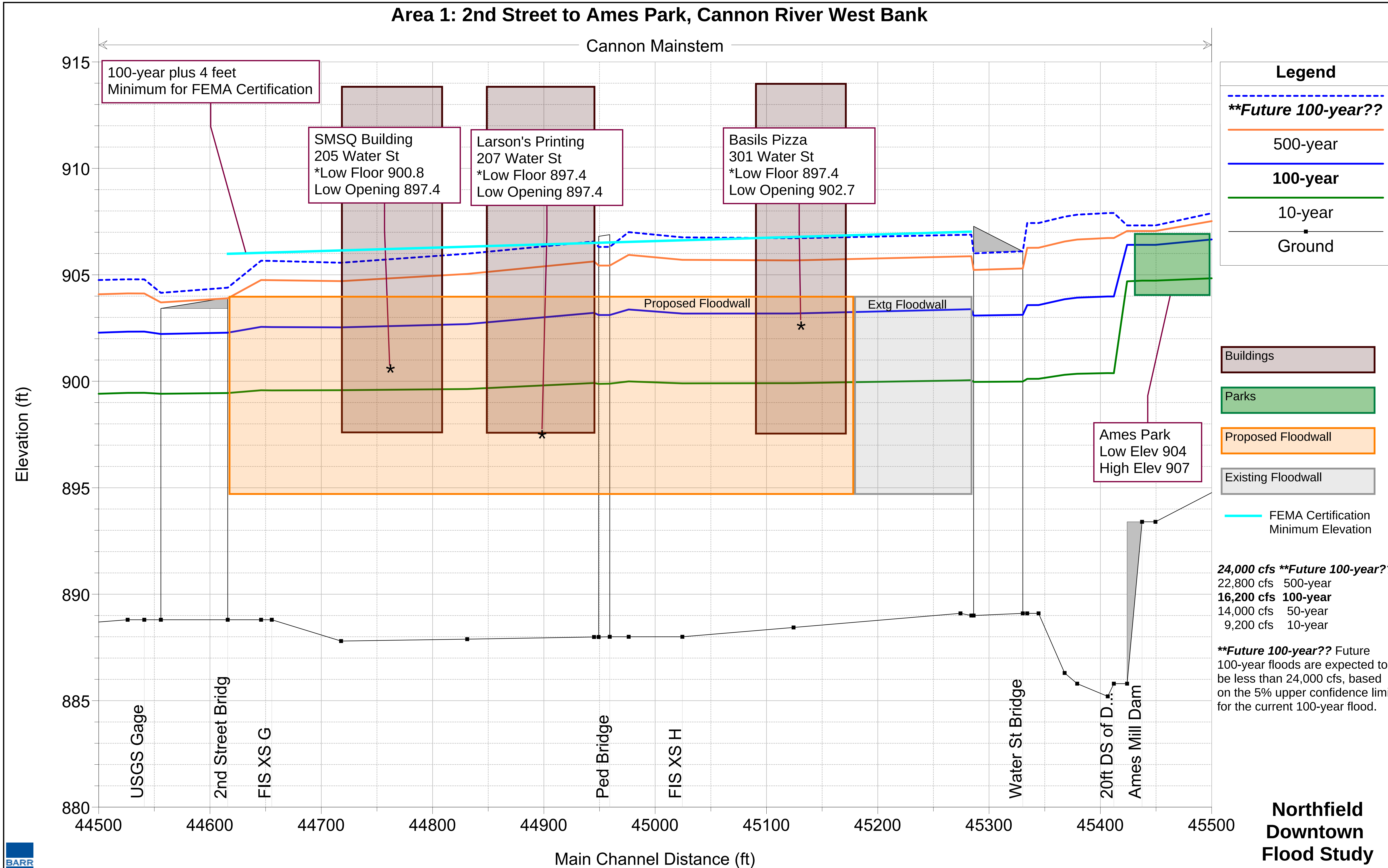


Figure A-7 Cannon River Flood Profiles for Area 1 and Ames Park

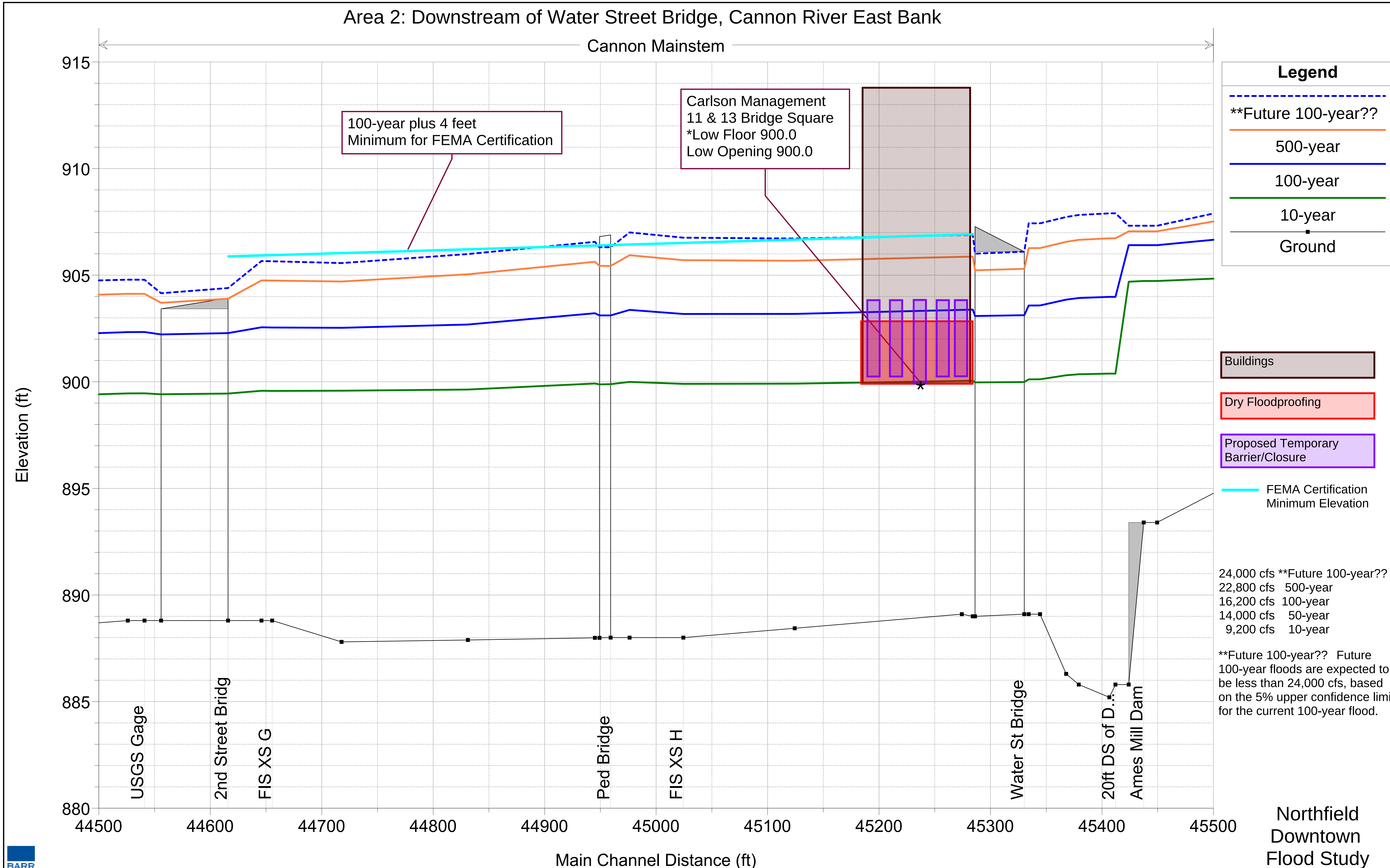


Figure A-8 Cannon River Flood Profiles for Area 2

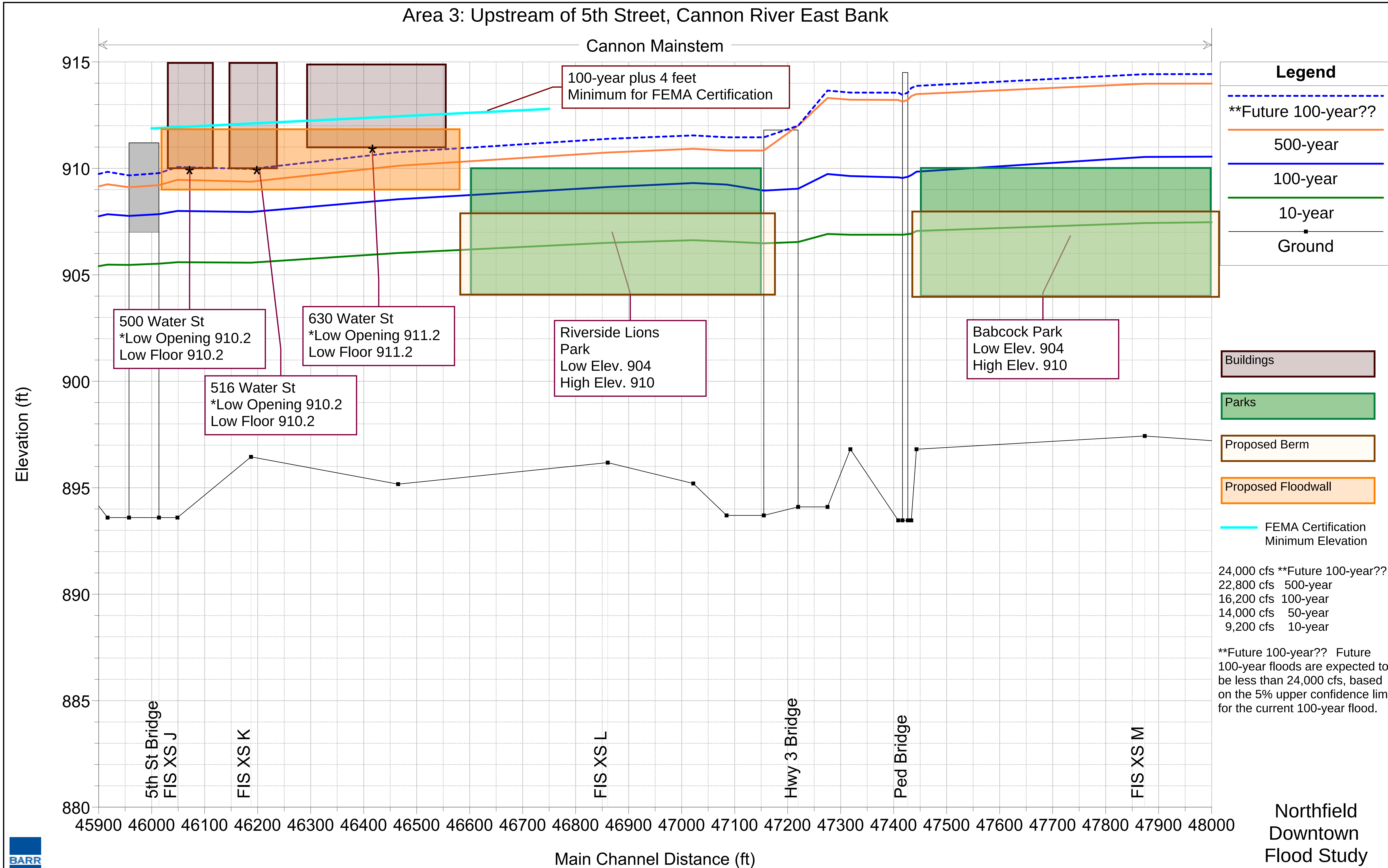
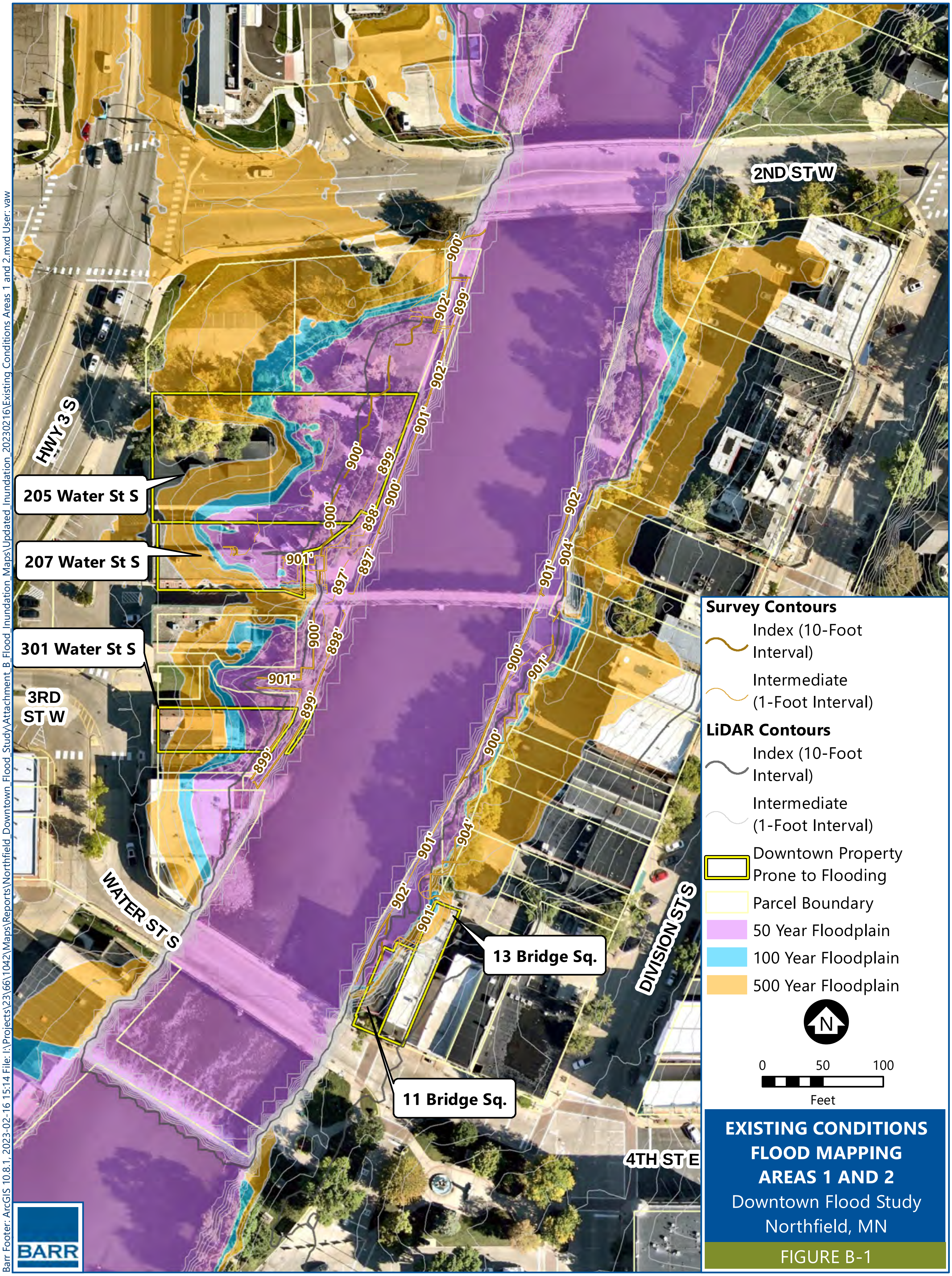


Figure A-9 Cannon River Flood Profiles for Area 3, Riverside Lions Park, and Babcock Park

Attachment B

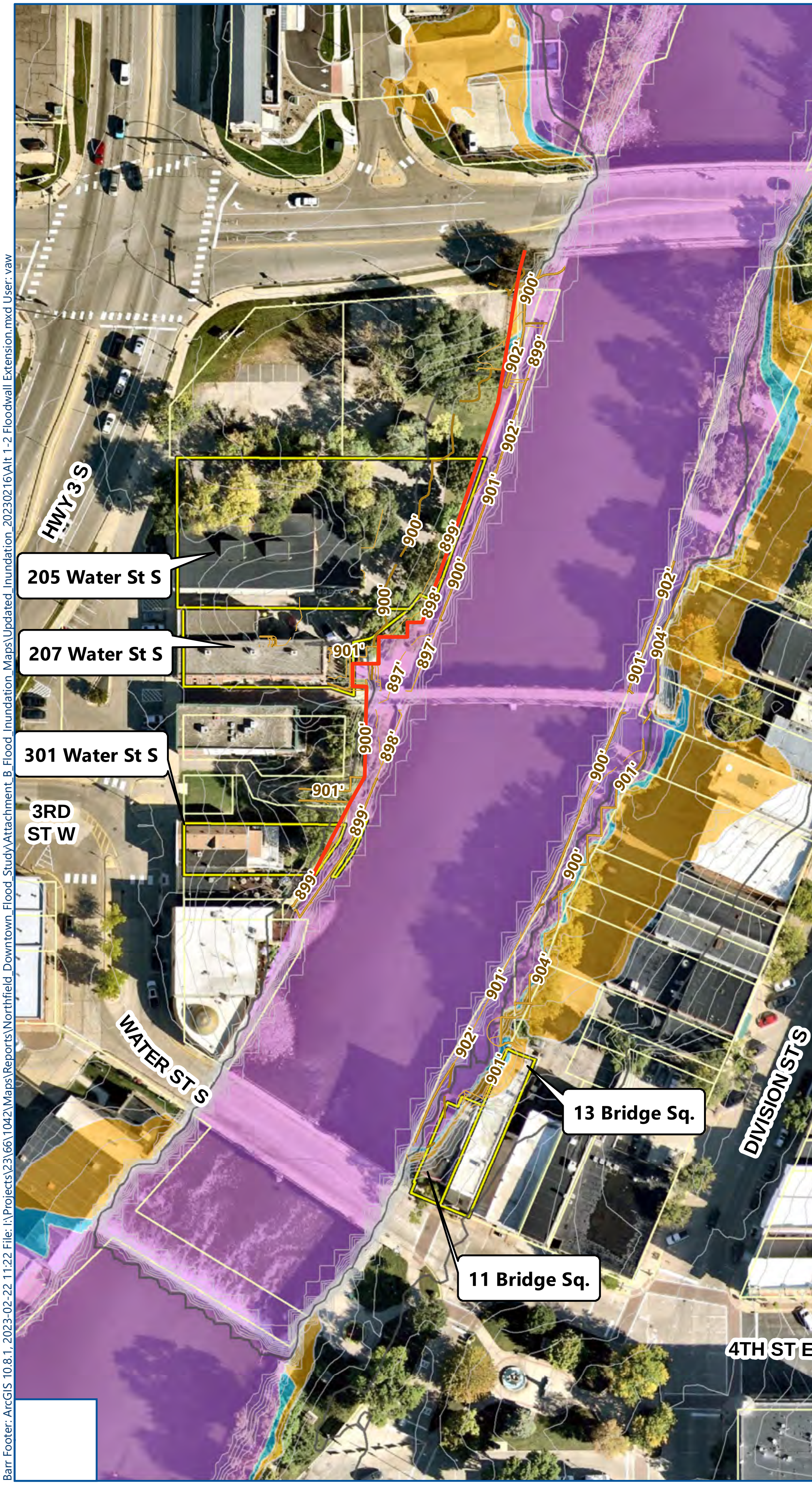
Northfield Alternatives Flood Inundation Maps



EXISTING CONDITIONS FLOOD MAPPING AREAS 1 AND 2

Downtown Flood Study
Northfield, MN

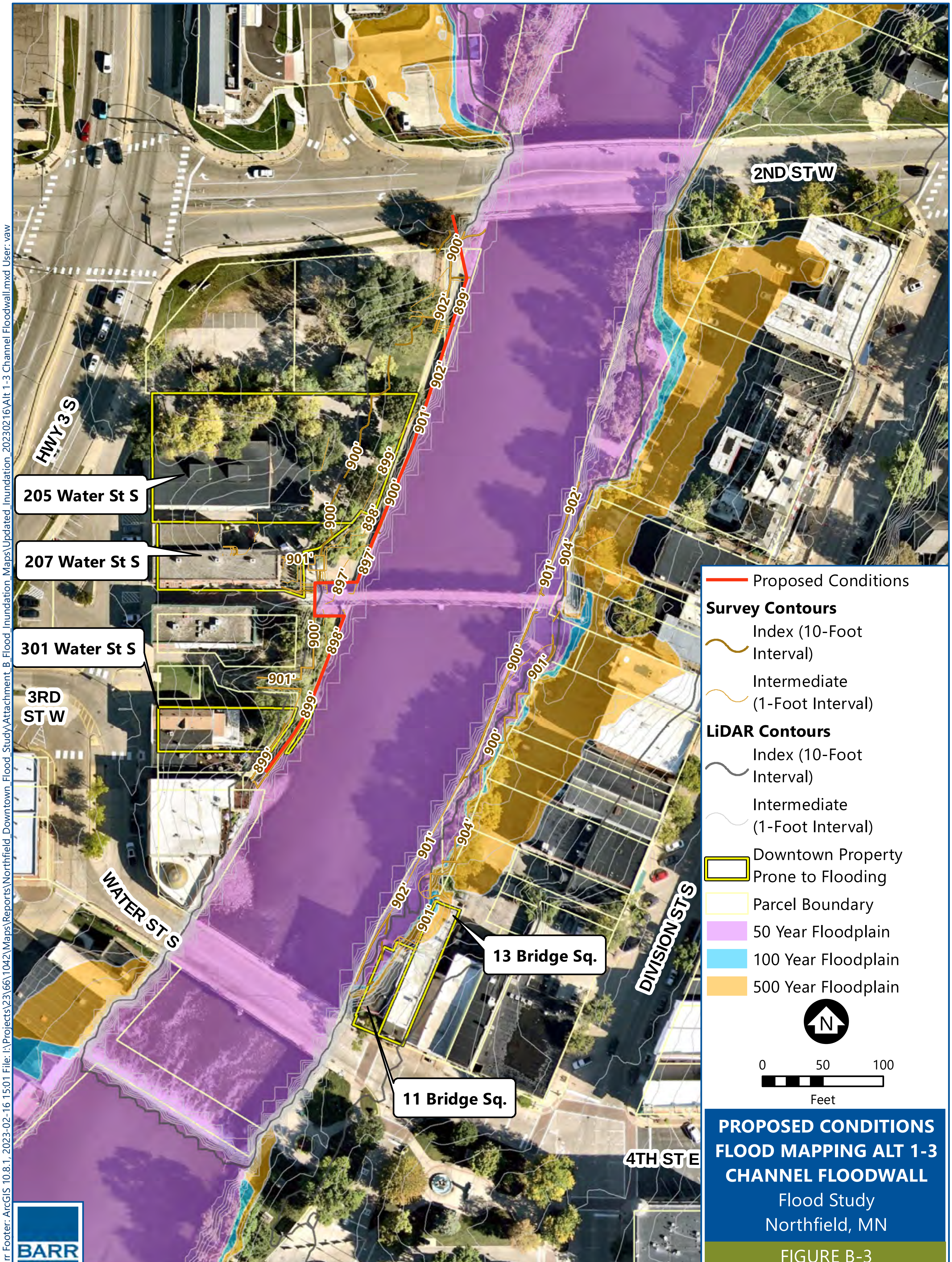
FIGURE B-1



PROPOSED CONDITIONS FLOOD MAPPING ALT 1-2 FLOODWALL EXTENSION

Downtown Flood Study
Northfield, MN

FIGURE B-2



PROPOSED CONDITIONS FLOOD MAPPING ALT 1-3 CHANNEL FLOODWALL

Flood Study
Northfield, MN

FIGURE B-3

BARR

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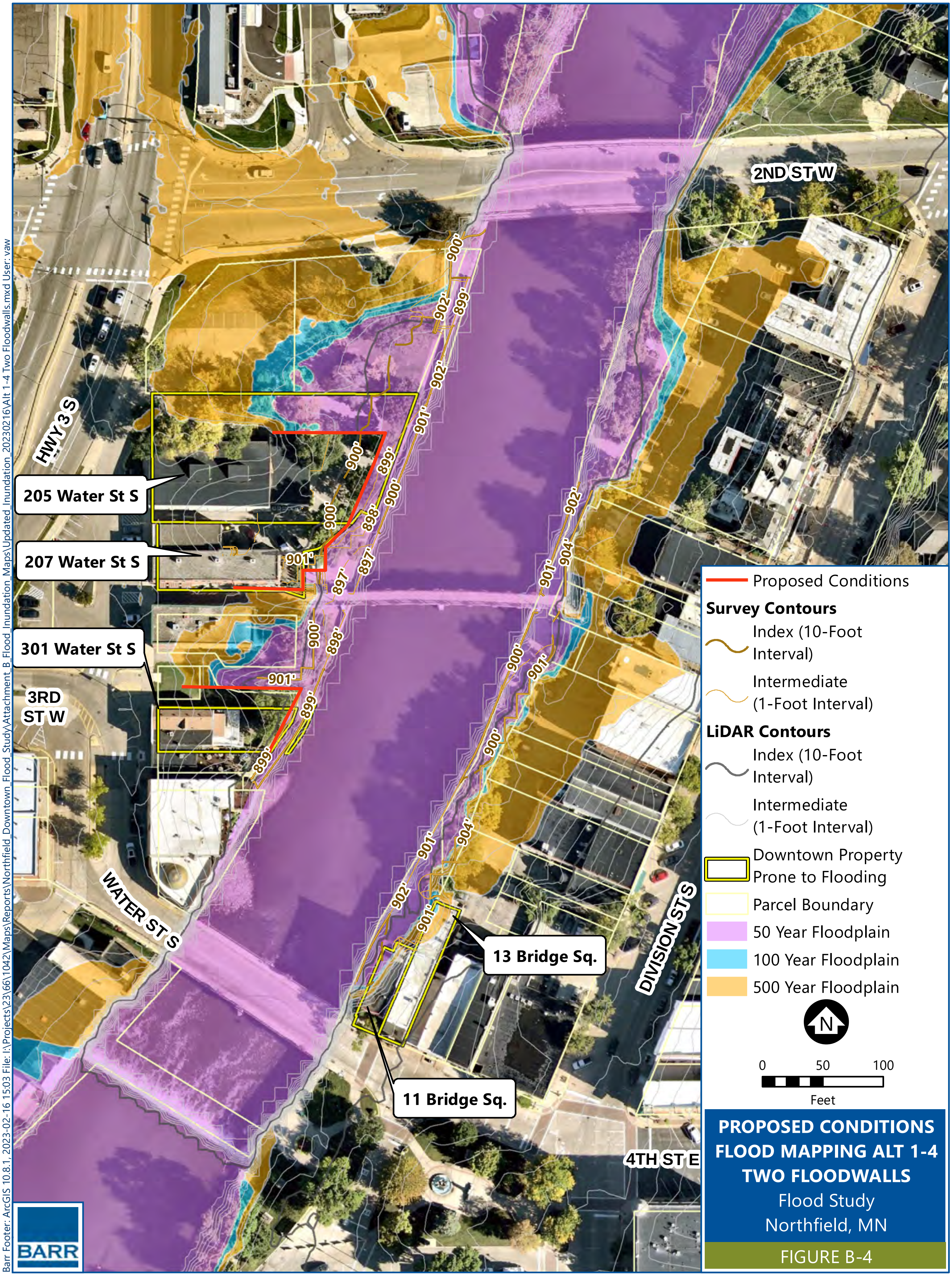
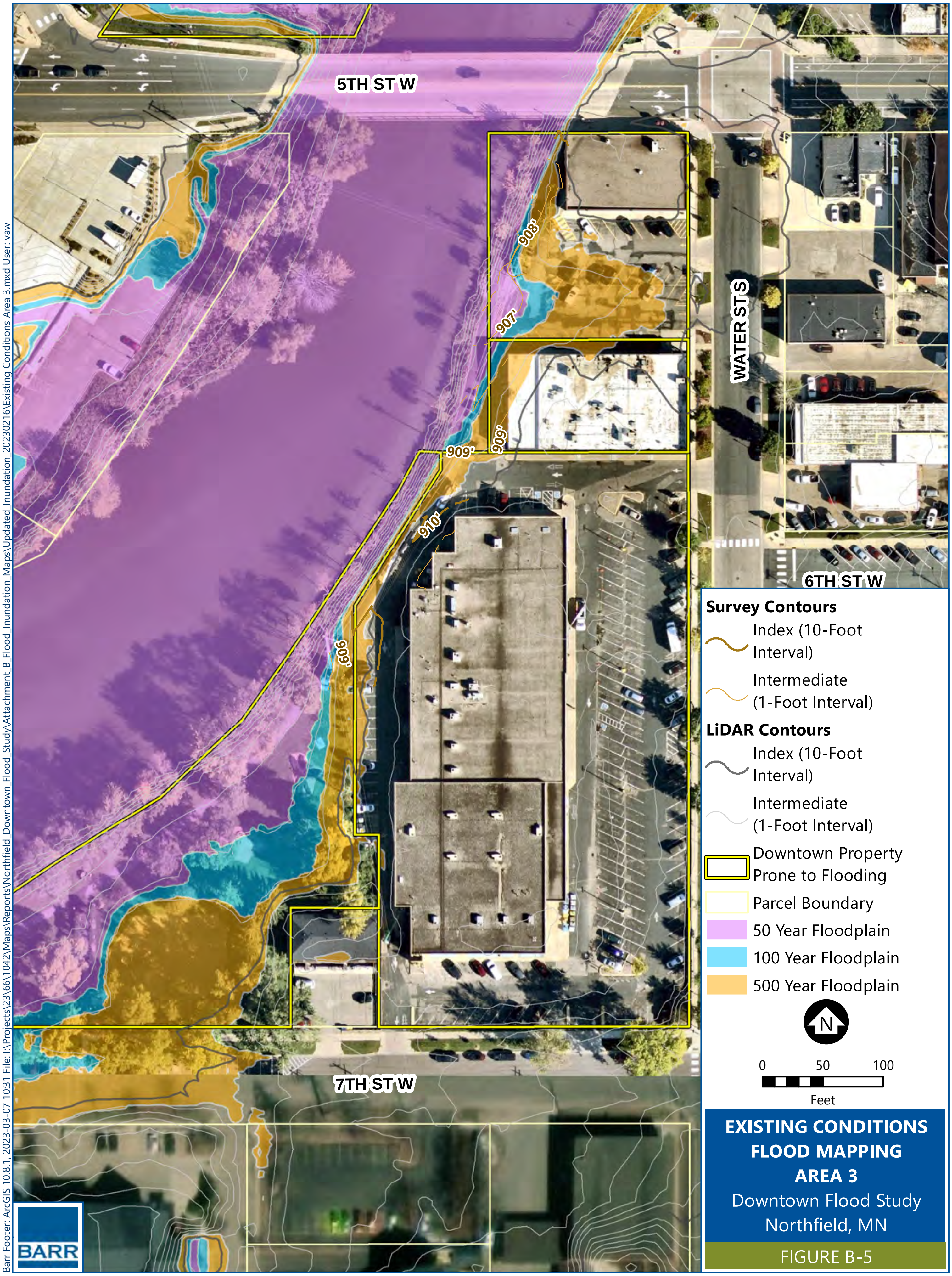


PROPOSED CONDITIONS FLOOD MAPPING ALT 1-4 TWO FLOODWALLS

Flood Study

Northfield, MN

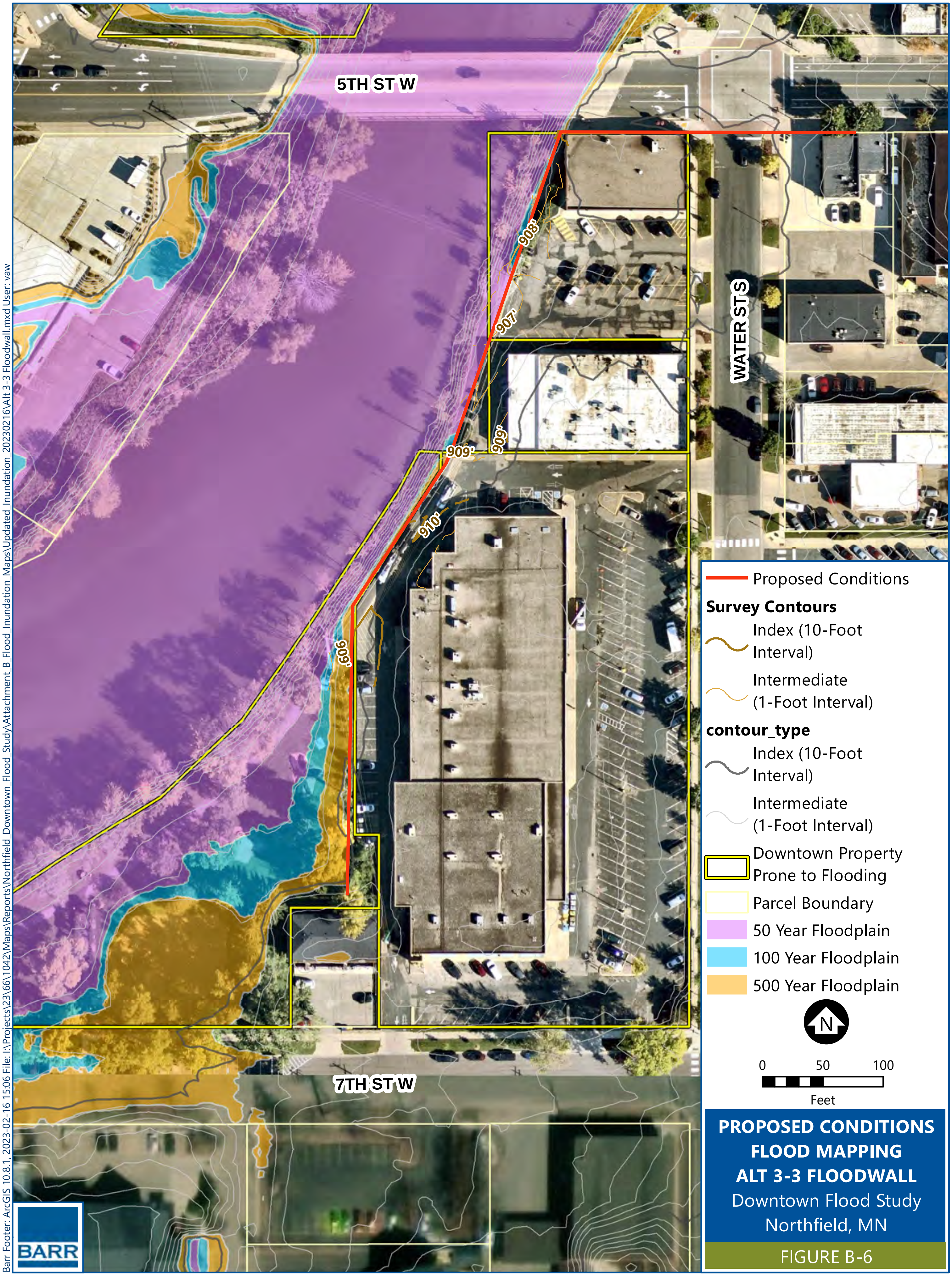
FIGURE B-4



EXISTING CONDITIONS FLOOD MAPPING AREA 3

Downtown Flood Study
Northfield, MN

FIGURE B-5



5TH ST W
WATER ST S
7TH ST W
908'
907'
909'
909'
910'
909'
Proposed Conditions
Survey Contours
Index (10-Foot Interval)
Intermediate (1-Foot Interval)
contour_type
Index (10-Foot Interval)
Intermediate (1-Foot Interval)
Downtown Property Prone to Flooding
Parcel Boundary
50 Year Floodplain
100 Year Floodplain
500 Year Floodplain
N
0 50 100
Feet
PROPOSED CONDITIONS
FLOOD MAPPING
ALT 3-3 FLOODWALL
Downtown Flood Study
Northfield, MN
FIGURE B-6
BARR
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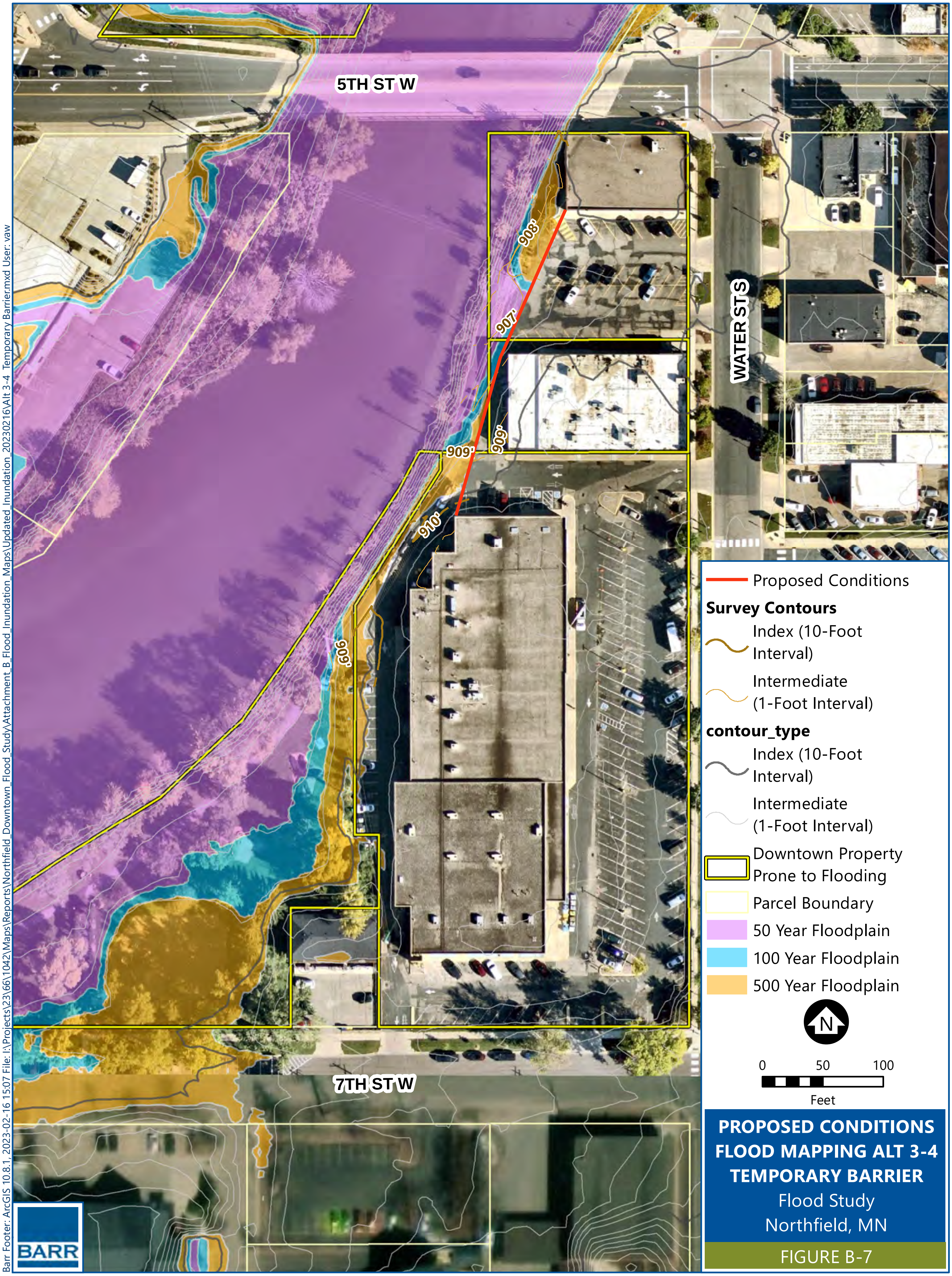
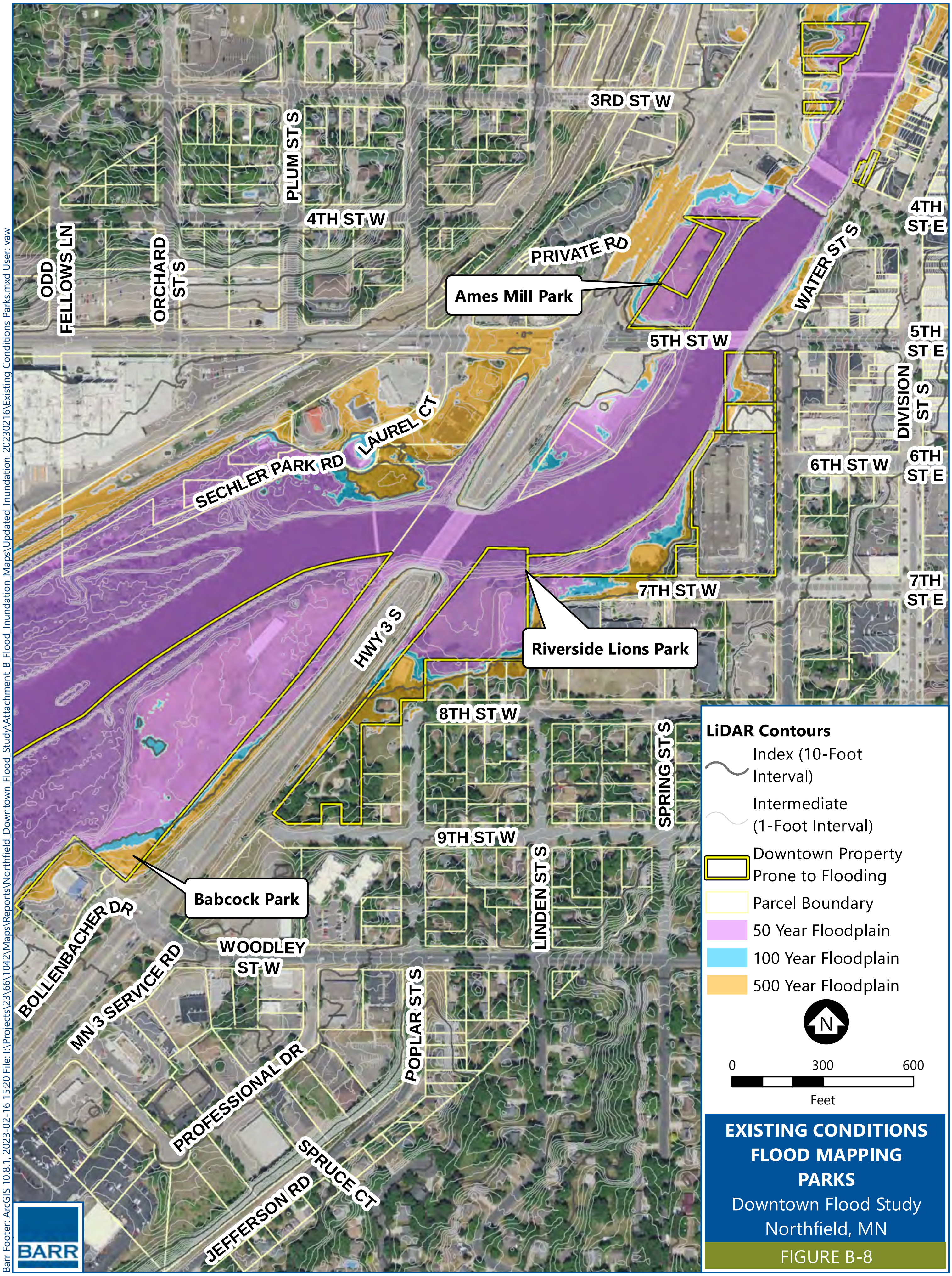


PROPOSED CONDITIONS FLOOD MAPPING ALT 3-4 TEMPORARY BARRIER

Flood Study

Northfield, MN

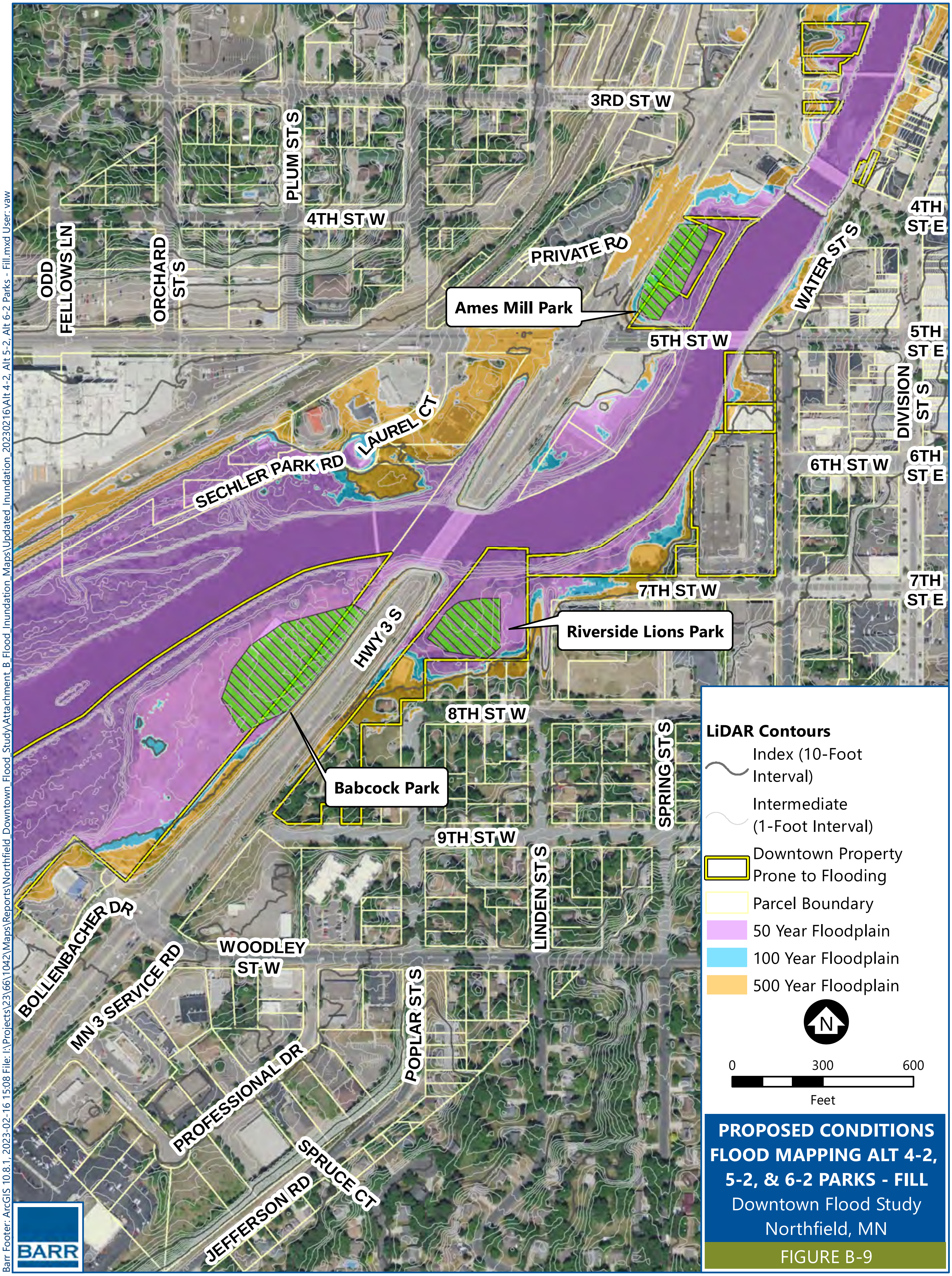
FIGURE B-7



EXISTING CONDITIONS FLOOD MAPPING PARKS

Downtown Flood Study
Northfield, MN

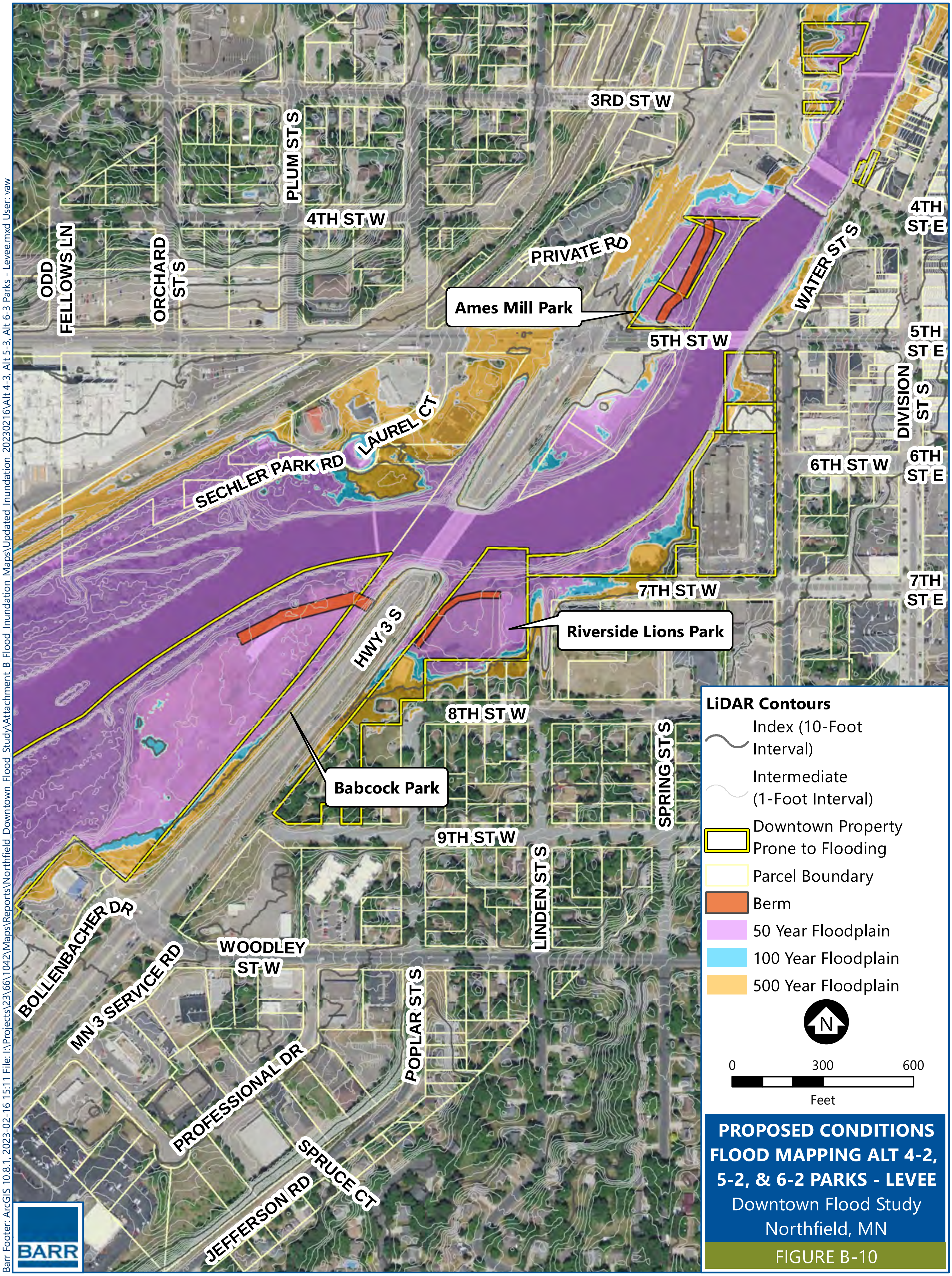
FIGURE B-8



PROPOSED CONDITIONS FLOOD MAPPING ALT 4-2, 5-2, & 6-2 PARKS - FILL

Downtown Flood Study
Northfield, MN

FIGURE B-9



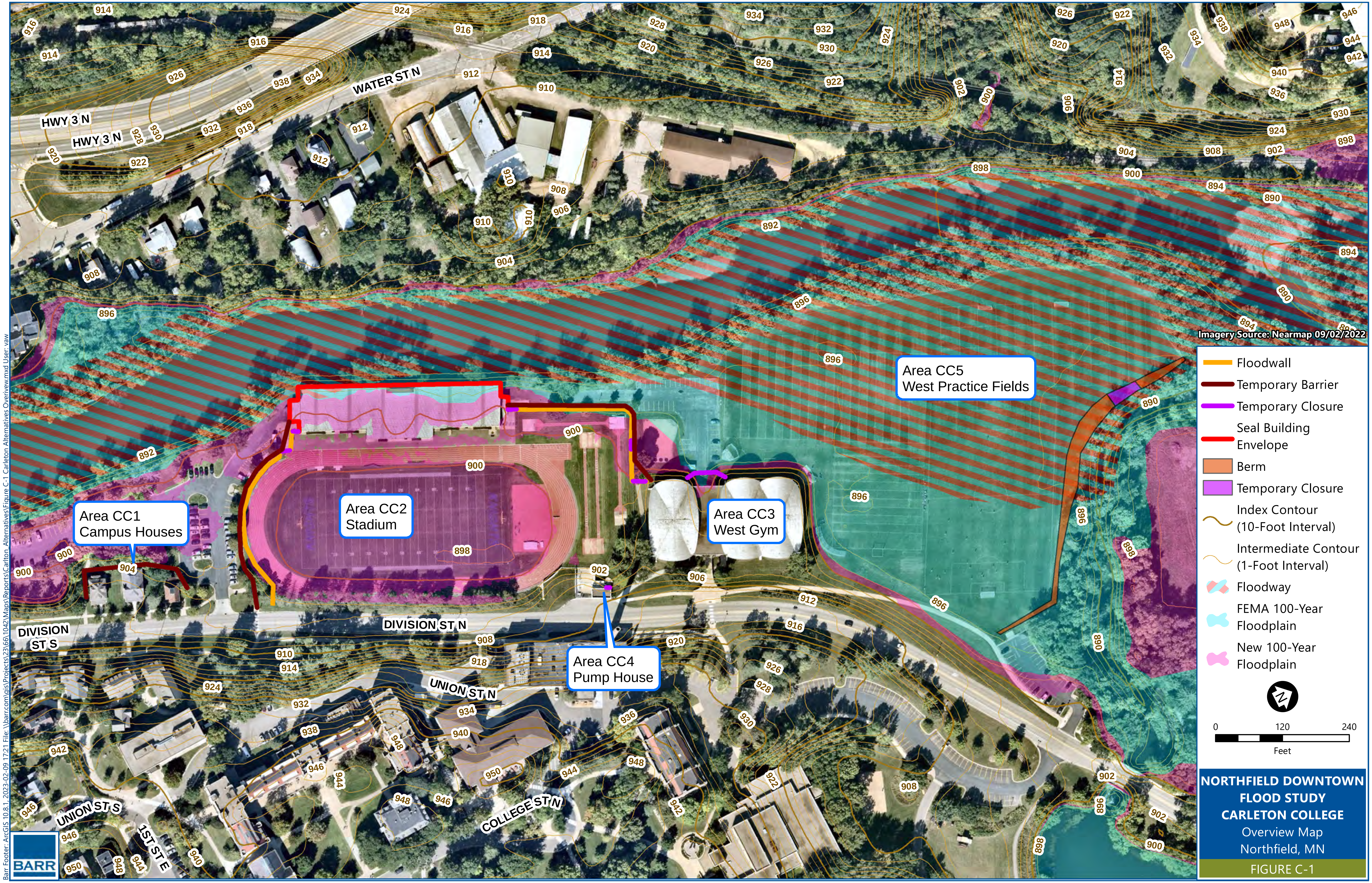
PROPOSED CONDITIONS FLOOD MAPPING ALT 4-2, 5-2, & 6-2 PARKS - LEVEE

Downtown Flood Study
Northfield, MN

FIGURE B-10

Attachment C

Carleton College Alternatives Concept Design Figures



Barr Footer: ArcGIS 10.8.1, 2023-02-09 17:21 File: \\barr.com\gis\Projects\23\66\1042\Maps\Reports\Carlton_Alternatives\Figure C-1 Carleton Alternatives Overview.mxd User: vaw

Temporary Barrier

Index Contour (10-Foot Interval)

Intermediate Contour (1-Foot Interval)

Temporary Barrier

0 25 50

Feet

Note: Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY CARLETON COLLEGE

Area CC1 Student Houses

Alt CC1-2 Temporary Barrier

Northfield, MN

FIGURE C-2

BARR

Barr Footer: ArcGIS 10.8.1, 2023-02-09 17:41 File: \\barr.com\gis\Projects\23\60\1042\Maps\Reports\Carlton_Alternatives\Figure C-2 Area CC1 AltCC1-2.mxd User: vaw

Temporary Barrier
Seal Building Envelope
Index Contour (10-Foot Interval)
Intermediate Contour (1-Foot Interval)
Temporary Barrier

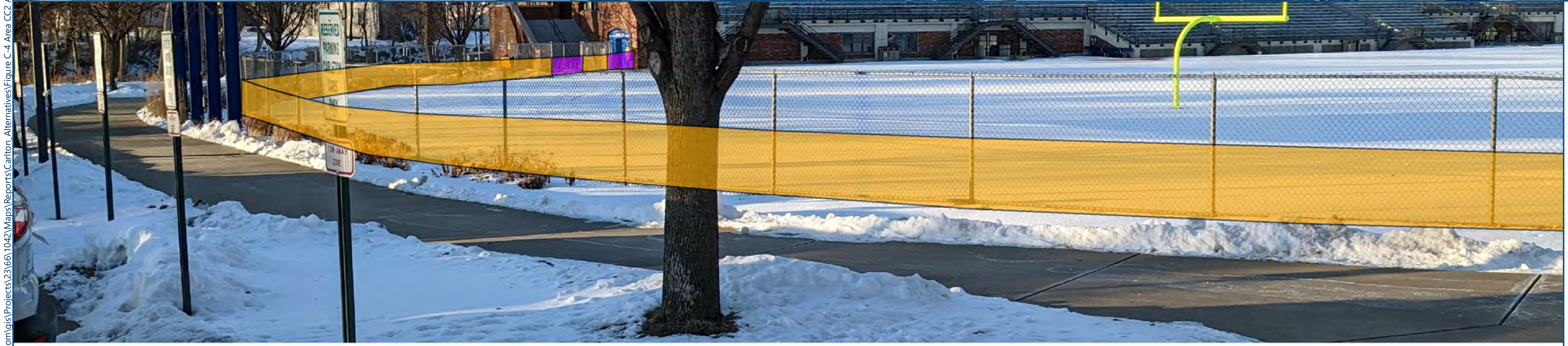
0 90 180
Feet

Note: Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
CARLETON COLLEGE
Area CC2 Stadium
Alt CC2-3 Temporary Barrier
Northfield, MN

FIGURE C-3

BARR



Floodwall
Temporary Closure
Seal Building Envelope
Index Contour (10-Foot Interval)
Intermediate Contour (1-Foot Interval)
Floodwall
Temporary Closure

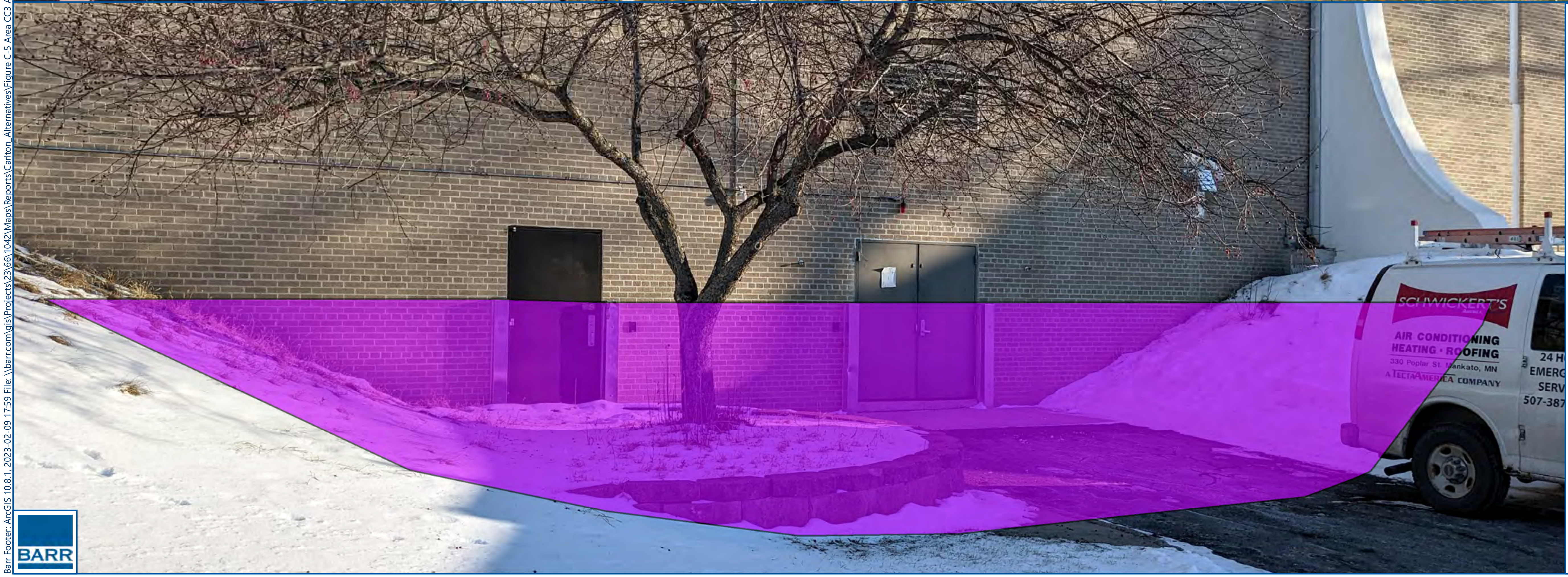
0 90 180
Feet

Note: Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
CARLETON COLLEGE
Area CC2 Stadium
Alt CC2-4 Floodwall
Northfield, MN

FIGURE C-4

BARR



- Temporary Closure
- Sidewalk Access
- Index Contour (10-Foot Interval)
- Intermediate Contour (1-Foot Interval)
- Temporary Closure

N

0 50 100

Feet

Note: Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
CARLETON COLLEGE

Area CC3 West Gym
Alt CC3-2 Temporary Closure
Northfield, MN

FIGURE C-5

Temporary Closure

Index Contour (10-Foot Interval)

Intermediate Contour (1-Foot Interval)

Temporary Closure

0 10 20

Feet

Note: Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
CARLETON COLLEGE
Area CC4 Pump House
Alt C4-2
Northfield, MN

FIGURE C-6

BARR

Surface Flow Direction

Berm

Temporary Closure

Index Contour (10-Foot Interval)

Intermediate Contour (1-Foot Interval)

Floodway

FEMA 100-Year Floodplain

0 120 240

Feet

Note: Scale, and North Arrow reference the plan view only.

NORTHFIELD DOWNTOWN FLOOD STUDY
CARLETON COLLEGE

Area CC5 Practice Fields

Alt CC5-2 Berm

Northfield, MN

FIGURE C-7

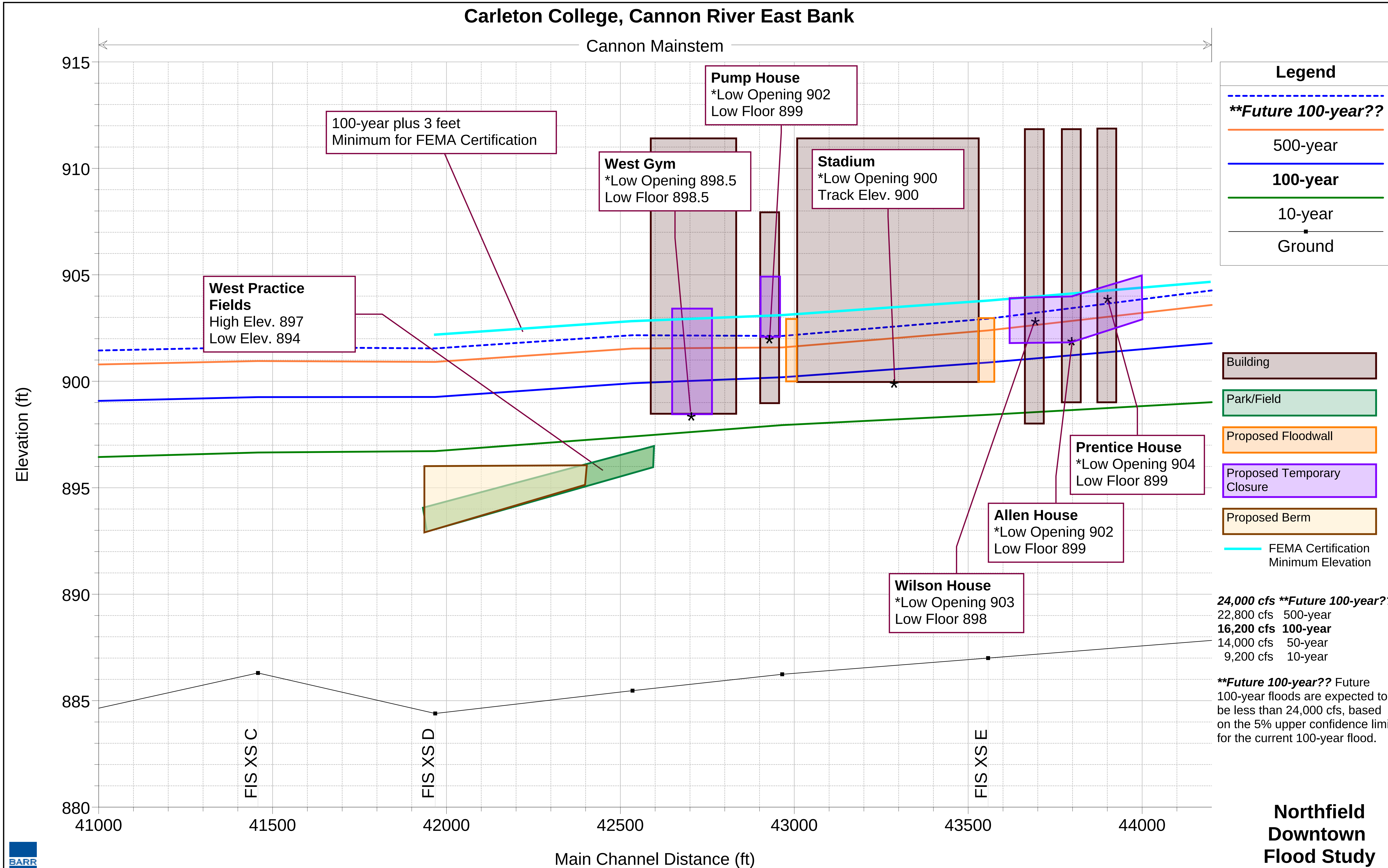
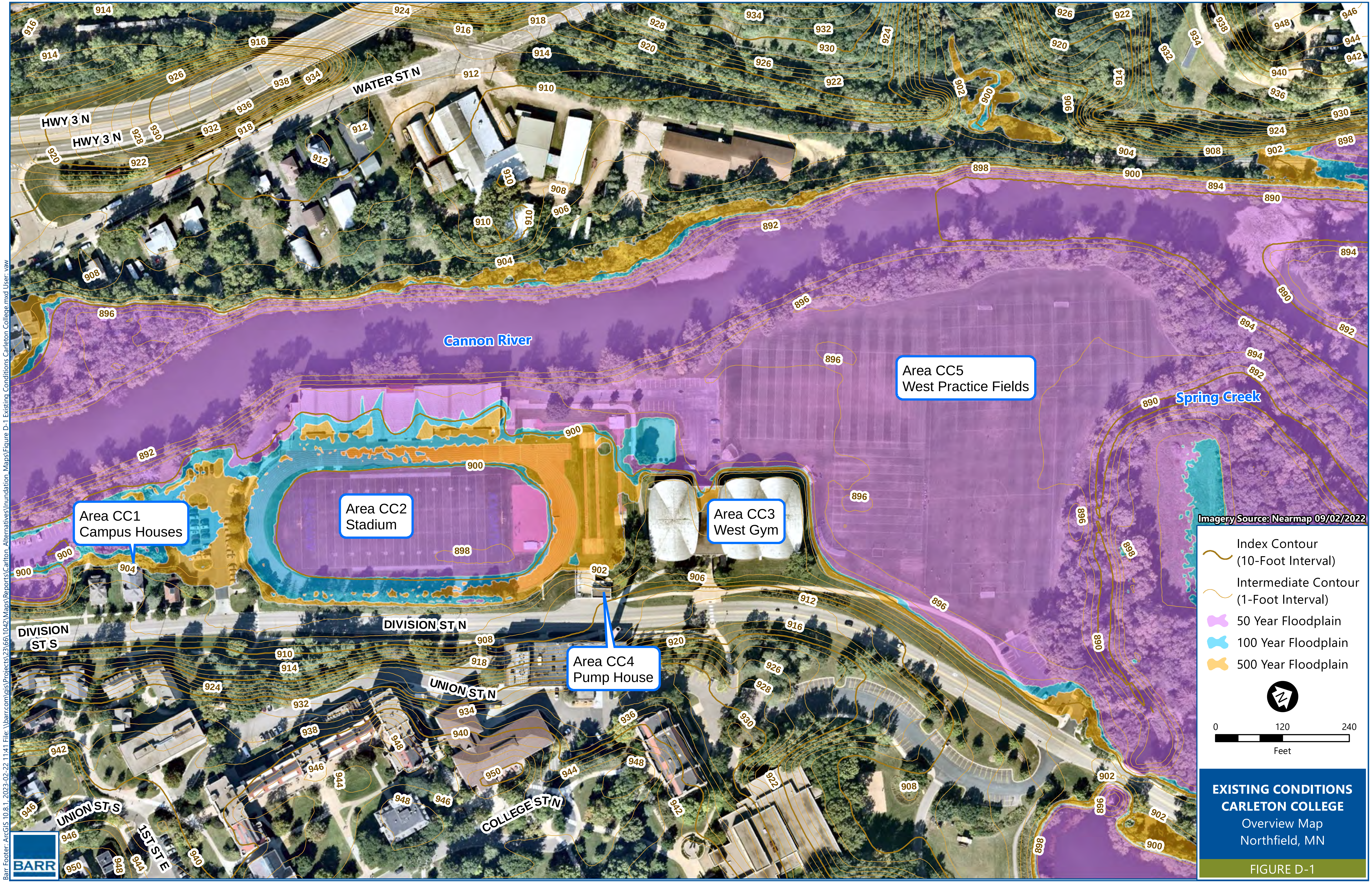


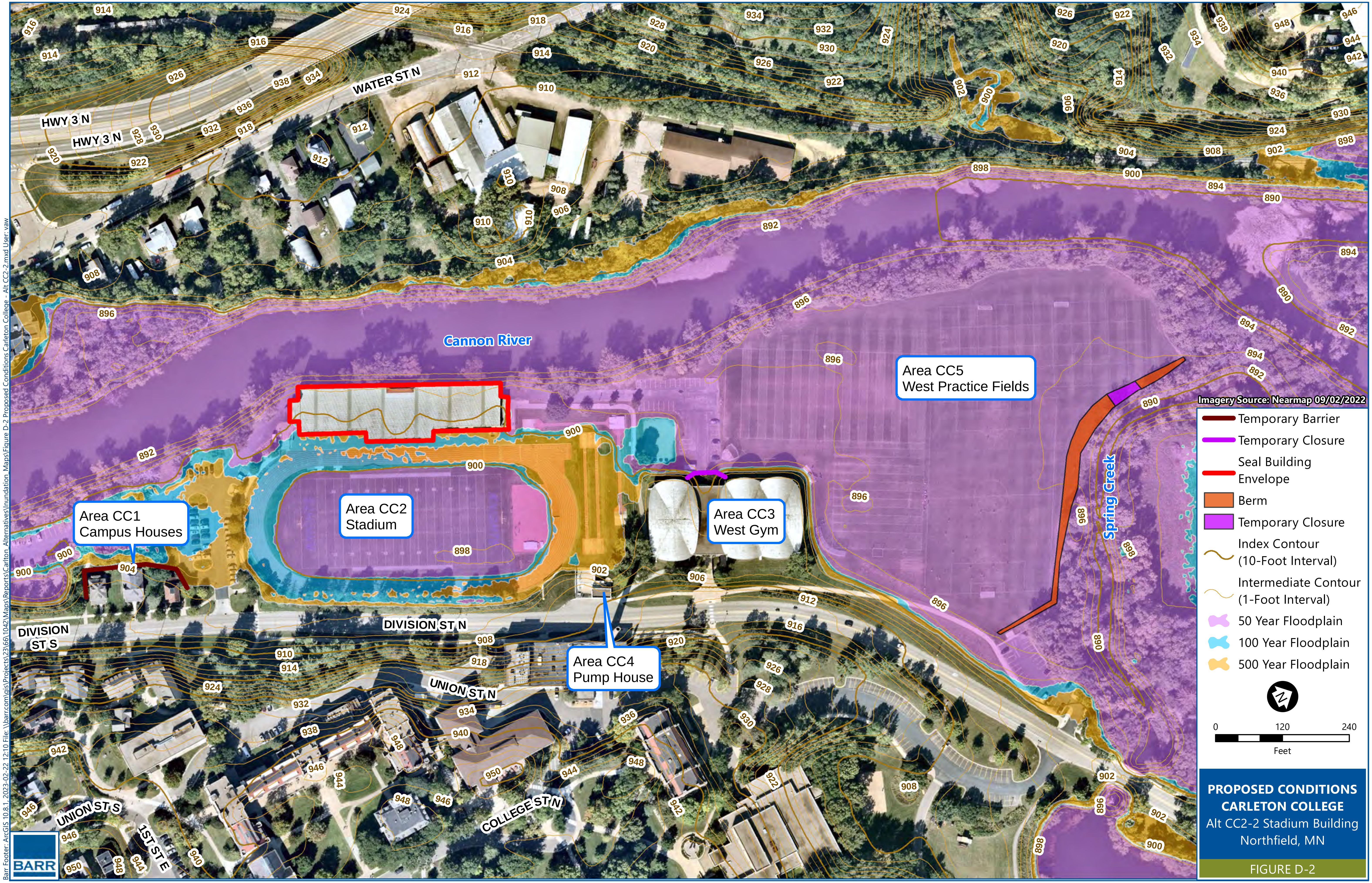
Figure C-8 Cannon River Flood Profiles at Carleton College

Attachment D

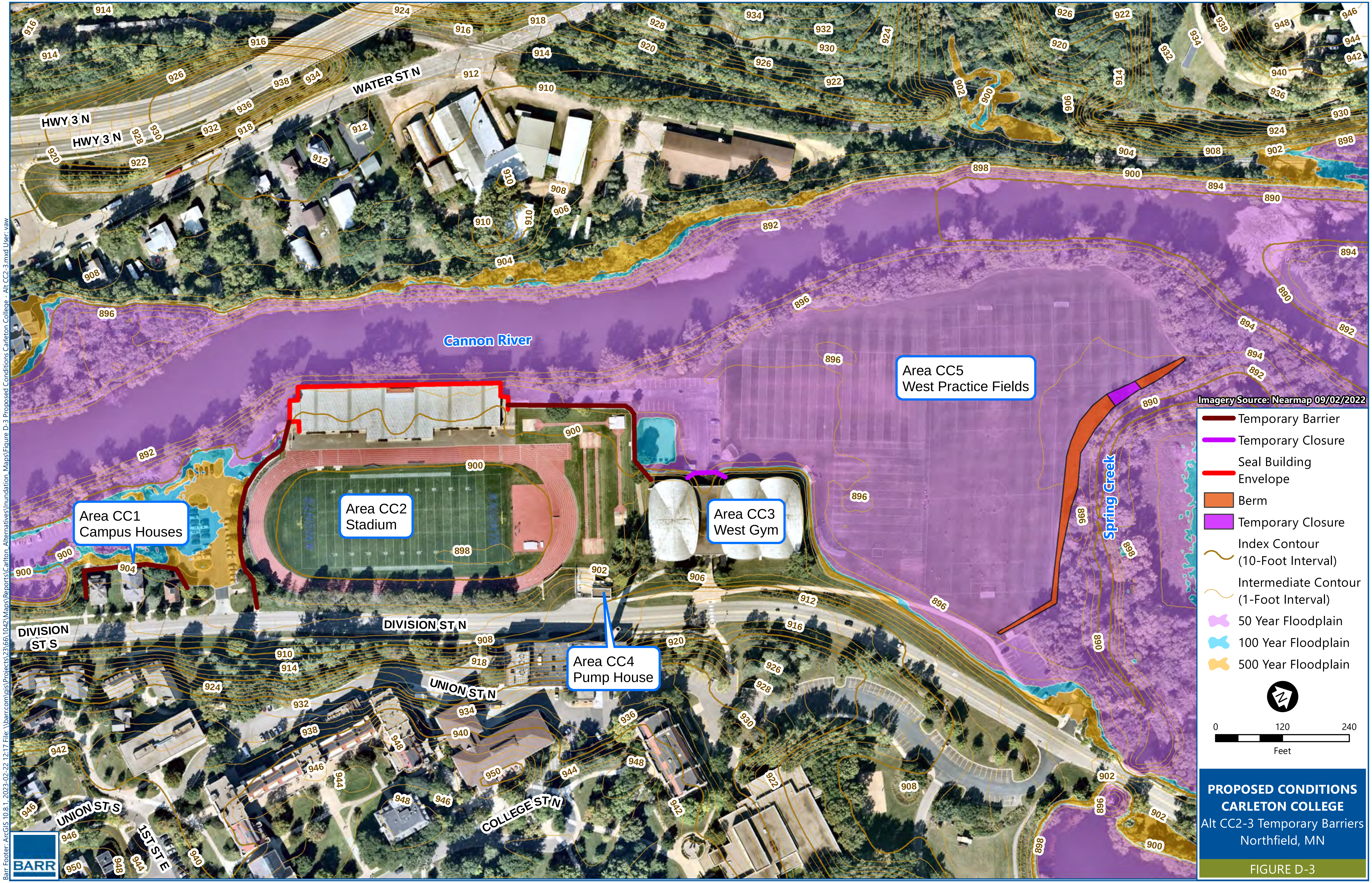
Carleton College Alternatives Flood Inundation Maps



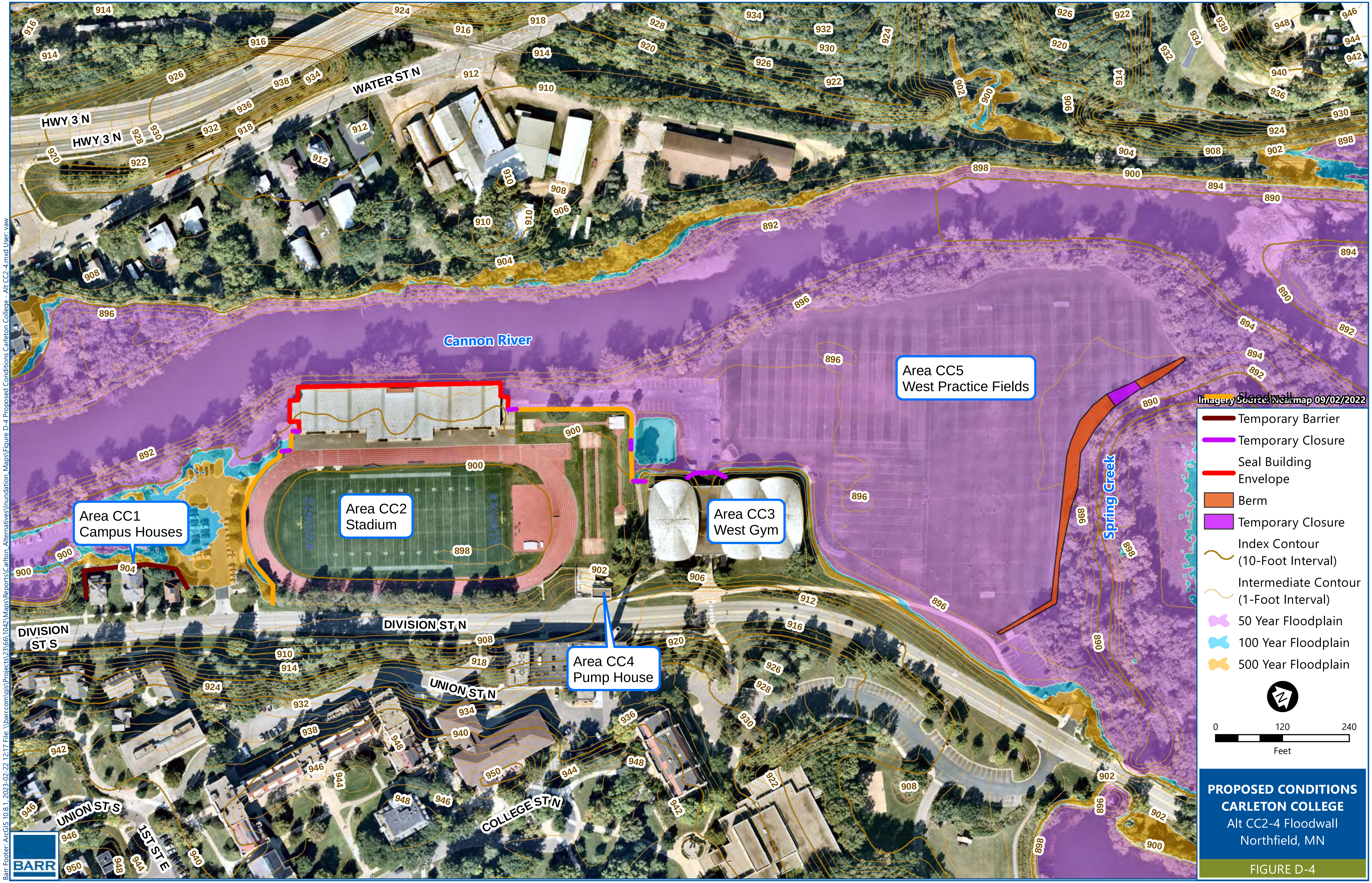
Barr Footer: ArcGIS 10.8.1, 2023-02-22 11:41 File: \\barr.com\gis\Projects\23\66\1042\Maps\Reports\Carlton Alternatives\Inundation Maps\Figure D-1 Existing Conditions Carleton College.mxd User: vaw



HWY 3 N
WATER ST N
Cannon River
Area CC1
Campus Houses
Area CC2
Stadium
Area CC3
West Gym
Area CC4
Pump House
Area CC5
West Practice Fields
Spring Creek
DIVISION ST S
DIVISION ST N
UNION ST N
UNION ST S
1ST ST E
COLLEGE ST N
Imagery Source: Nearmap 09/02/2022
Temporary Barrier
Temporary Closure
Seal Building Envelope
Berm
Temporary Closure
Index Contour (10-Foot Interval)
Intermediate Contour (1-Foot Interval)
50 Year Floodplain
100 Year Floodplain
500 Year Floodplain
0
120
240
Feet
PROPOSED CONDITIONS
CARLETON COLLEGE
Alt CC2-2 Stadium Building
Northfield, MN
FIGURE D-2
BARR



HWY 3 N
WATER ST N
Cannon River
Area CC1
Campus Houses
Area CC2
Stadium
Area CC3
West Gym
Area CC4
Pump House
Area CC5
West Practice Fields
Spring Creek
DIVISION ST N
DIVISION ST S
UNION ST N
UNION ST S
COLLEGE ST N
1ST ST E
Imagery Source: Nearmap 09/02/2022
Temporary Barrier
Temporary Closure
Seal Building Envelope
Berm
Temporary Closure
Index Contour (10-Foot Interval)
Intermediate Contour (1-Foot Interval)
50 Year Floodplain
100 Year Floodplain
500 Year Floodplain
0 120 240
Feet
PROPOSED CONDITIONS
CARLETON COLLEGE
Alt CC2-3 Temporary Barriers
Northfield, MN
FIGURE D-3
BARR



PROPOSED CONDITIONS
CARLETON COLLEGE
Alt CC2-4 Floodwall
Northfield, MN

FIGURE D-4

Attachment E

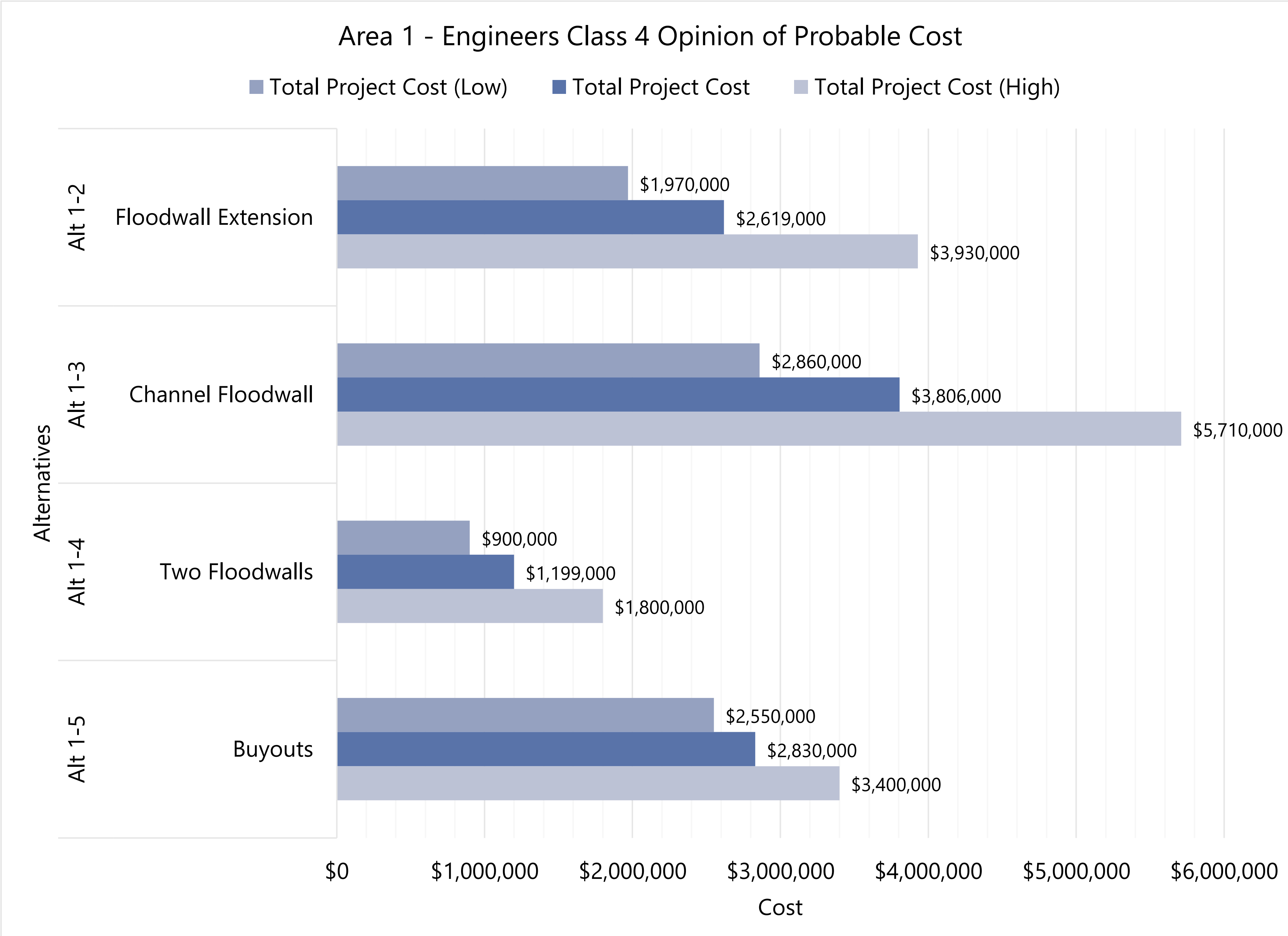
Engineer's Opinion of Probable Costs

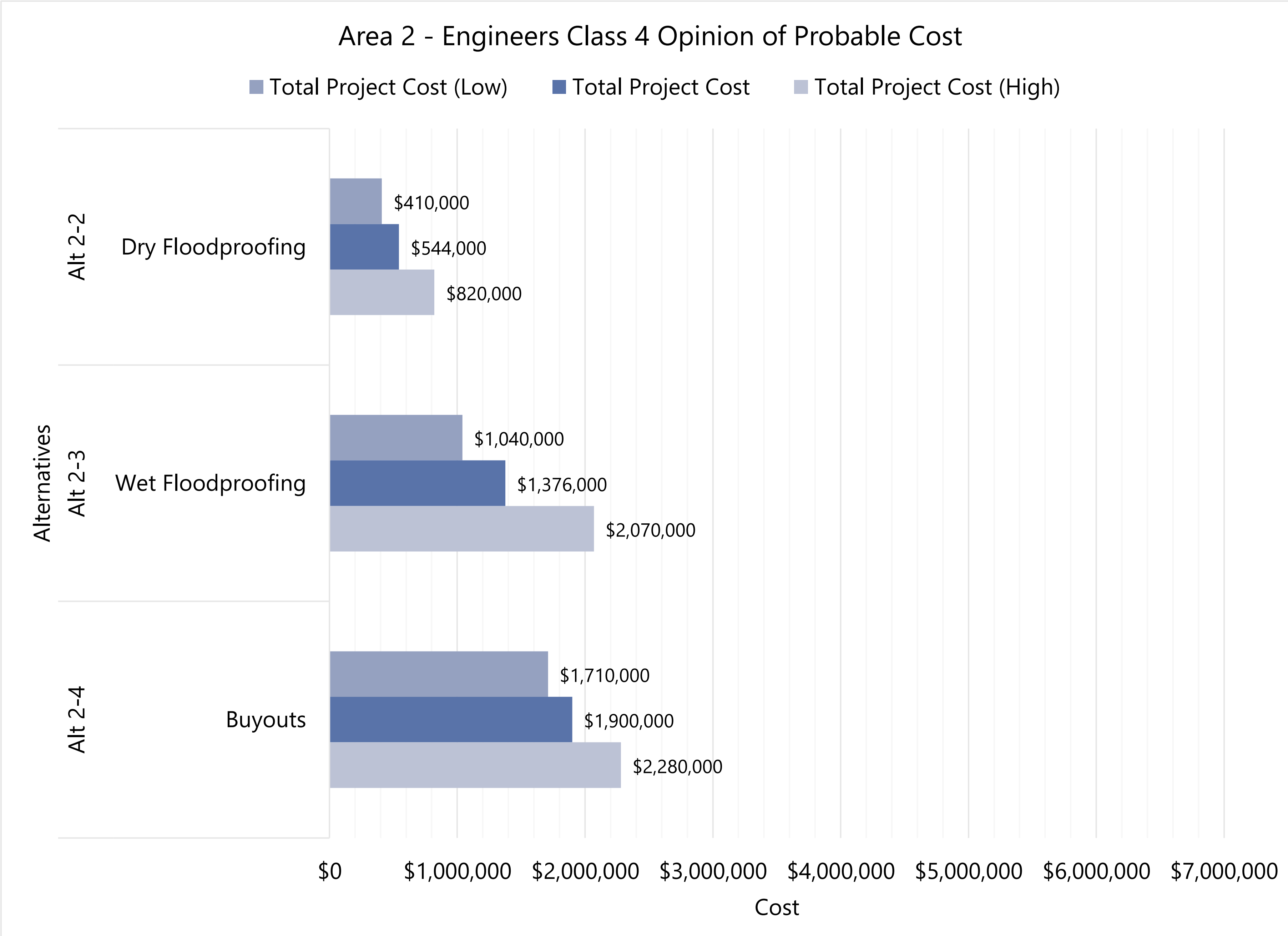
Northfield Downtown Flood Study - Class 4 Opinion of Probable Cost

Alternative	Name	Estimated Construction Cost	Engineering	Permitting	Total Project Cost	Total Project Cost (Low)	Total Project Cost (High)
Alt 1-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt 1-2	Floodwall Extension	$1,940,000	$485,000	$194,000	$2,619,000	$1,970,000	$3,930,000
Alt 1-3	Channel Floodwall	$2,819,000	$705,000	$282,000	$3,806,000	$2,860,000	$5,710,000
Alt 1-4	Two Floodwalls	$888,000	$222,000	$89,000	$1,199,000	$900,000	$1,800,000
Alt 1-5	Buyouts	$0	$0	$0	$2,830,000	$2,550,000	$3,400,000
Alt 2-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt 2-2	Dry Floodproofing	$403,000	$101,000	$40,000	$544,000	$410,000	$820,000
Alt 2-3	Wet Floodproofing	$1,019,000	$255,000	$102,000	$1,376,000	$1,040,000	$2,070,000
Alt 2-4	Buyouts	$1,900,000	$0	$0	$1,900,000	$1,710,000	$2,280,000
Alt 3-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt 3-2	Dry Floodproofing	$145,000	$36,000	$15,000	$196,000	$150,000	$300,000
Alt 3-3	Floodwall	$2,126,000	$532,000	$213,000	$2,871,000	$2,160,000	$4,310,000
Alt 3-4	Temporary Barriers	$85,000	$0	$0	$85,000	$64,000	$128,000
Alt 3-5	Buyouts	$8,230,000	$0	$0	$8,230,000	$7,410,000	$9,880,000
Alt 4-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt 4-2	Ames Park Fill	$130,000	$33,000	$13,000	$176,000	$140,000	$270,000
Alt 4-3	Ames Park Levee	$151,000	$38,000	$15,000	$204,000	$160,000	$310,000
Alt 4-4	Ames Park Floodwall	$736,000	$184,000	$74,000	$994,000	$750,000	$1,500,000
Alt 5-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt 5-2	Riverside Lions Park Fill	$124,000	$31,000	$12,000	$167,000	$130,000	$260,000
Alt 5-3	Riverside Lions Park Levee	$156,000	$39,000	$16,000	$211,000	$160,000	$320,000
Alt 5-4	Riverside Lions Park Floodwall	$713,000	$178,000	$71,000	$962,000	$730,000	$1,450,000
Alt 6-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt 6-2	Babcock Park Fill	$280,000	$70,000	$28,000	$378,000	$290,000	$570,000
Alt 6-3	Babcock Park Levee	$208,000	$52,000	$21,000	$281,000	$220,000	$430,000
Alt 6-4	Babcock Park Floodwall	$930,000	$233,000	$93,000	$1,256,000	$950,000	$1,890,000

Northfield Downtown Flood Study Carleton College Alts - Class 4 Opinion of Probable Cost

Alternative	Name	Estimated Construction Cost	Engineering	Permitting	Total Project Cost	Total Project Cost (Low)	Total Project Cost (High)
Alt CC1-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt CC1-2	Temporary Barriers	$24,000	$0	$0	$24,000	$20,000	$40,000
Alt CC1-3	Buyouts	$1,000,000	$0	$10,000	$1,010,000	$760,000	$1,520,000
Alt CC2-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt CC2-2	Dry Floodproofing	$275,000	$14,000	$6,000	$295,000	$230,000	$450,000
Alt CC2-3	Temporary Barrier	$259,000	$13,000	$5,000	$277,000	$210,000	$420,000
Alt CC2-4	Floodwall	$1,410,000	$141,000	$71,000	$1,622,000	$1,220,000	$2,440,000
Alt CC3-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt CC3-2	Temporary Closure	$119,000	$30,000	$12,000	$161,000	$130,000	$250,000
Alt CC4-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt CC4-2	Temporary Closure	$3,000	$800	$300	$4,000	$3,000	$6,000
Alt CC4-3	Elevate Electrical Panel	$125,000	$31,000	$13,000	$169,000	$130,000	$260,000
Alt CC4-4	Sump Pump	$19,000	$5,000	$2,000	$26,000	$20,000	$40,000
Alt CC5-1	No Change	N/A	N/A	N/A	N/A	N/A	N/A
Alt CC5-2	Practice Field Berm	$46,000	$12,000	$7,000	$65,000	$50,000	$100,000


Area 1 - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt 1-2
Floodwall Extension
$1,970,000
$2,619,000
$3,930,000
Alt 1-3
Channel Floodwall
$2,860,000
$3,806,000
$5,710,000
Alt 1-4
Two Floodwalls
$900,000
$1,199,000
$1,800,000
Alt 1-5
Buyouts
$2,550,000
$2,830,000
$3,400,000
$0
$1,000,000
$2,000,000
$3,000,000
$4,000,000
$5,000,000
$6,000,000
Cost



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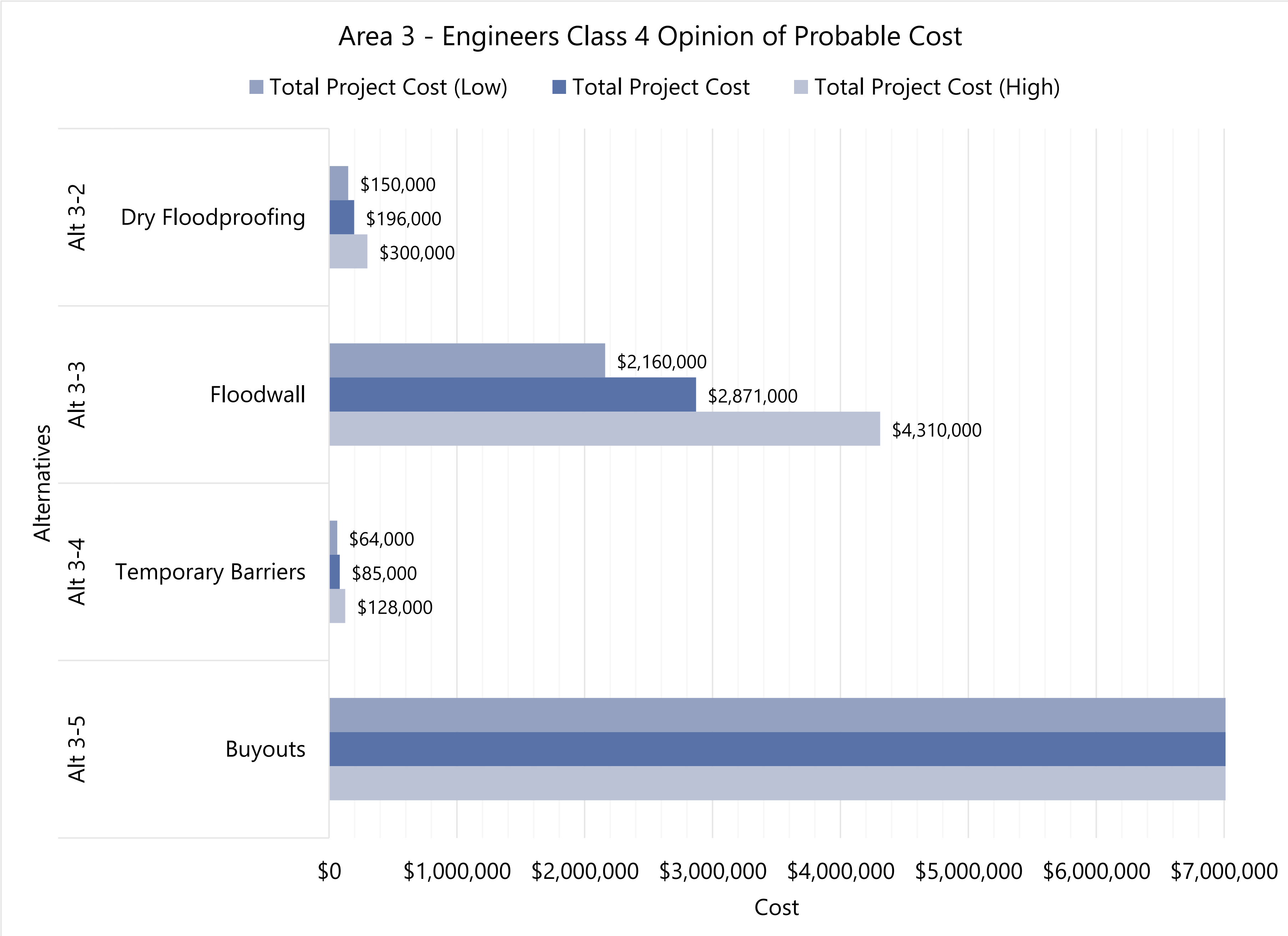
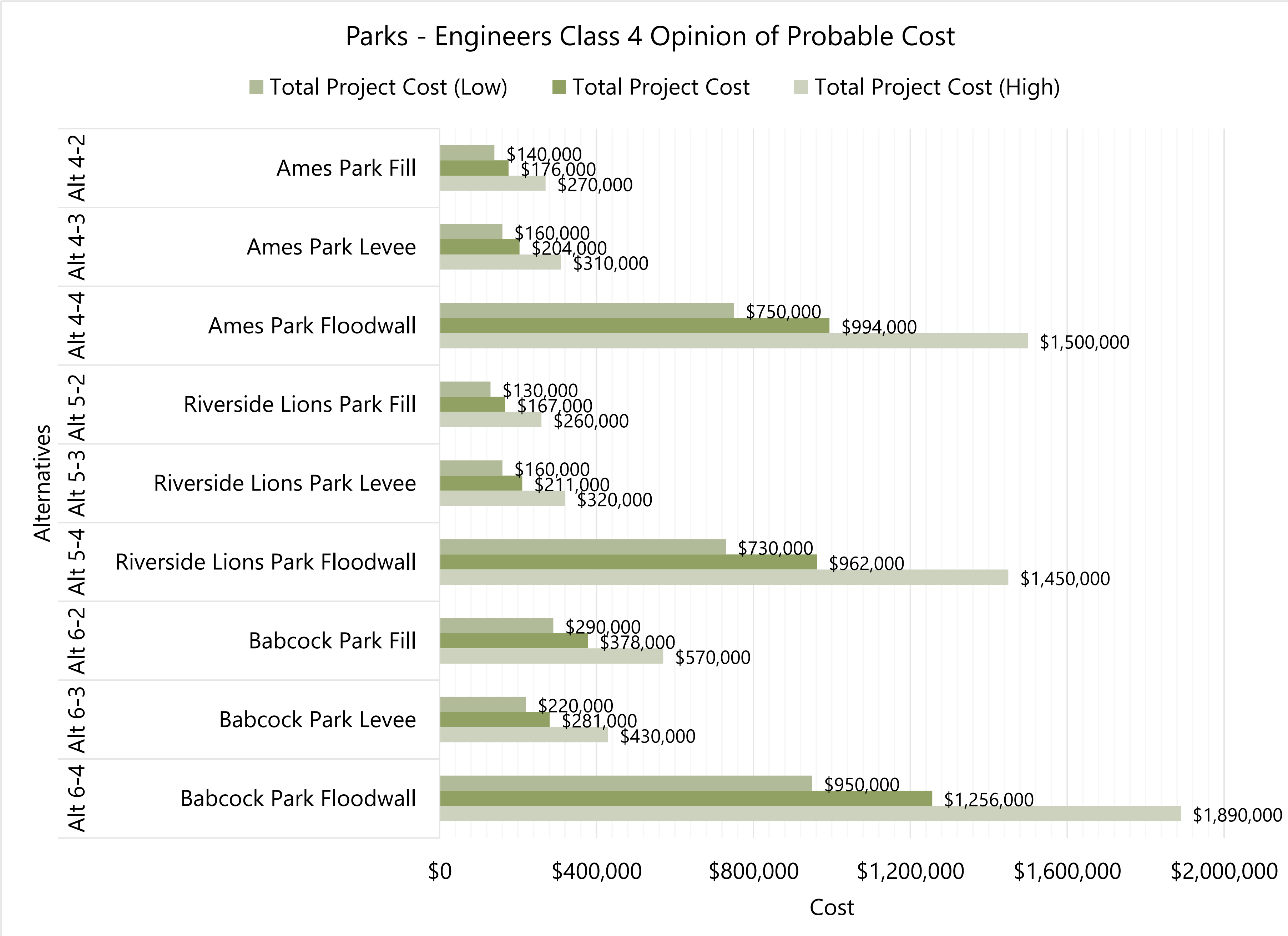
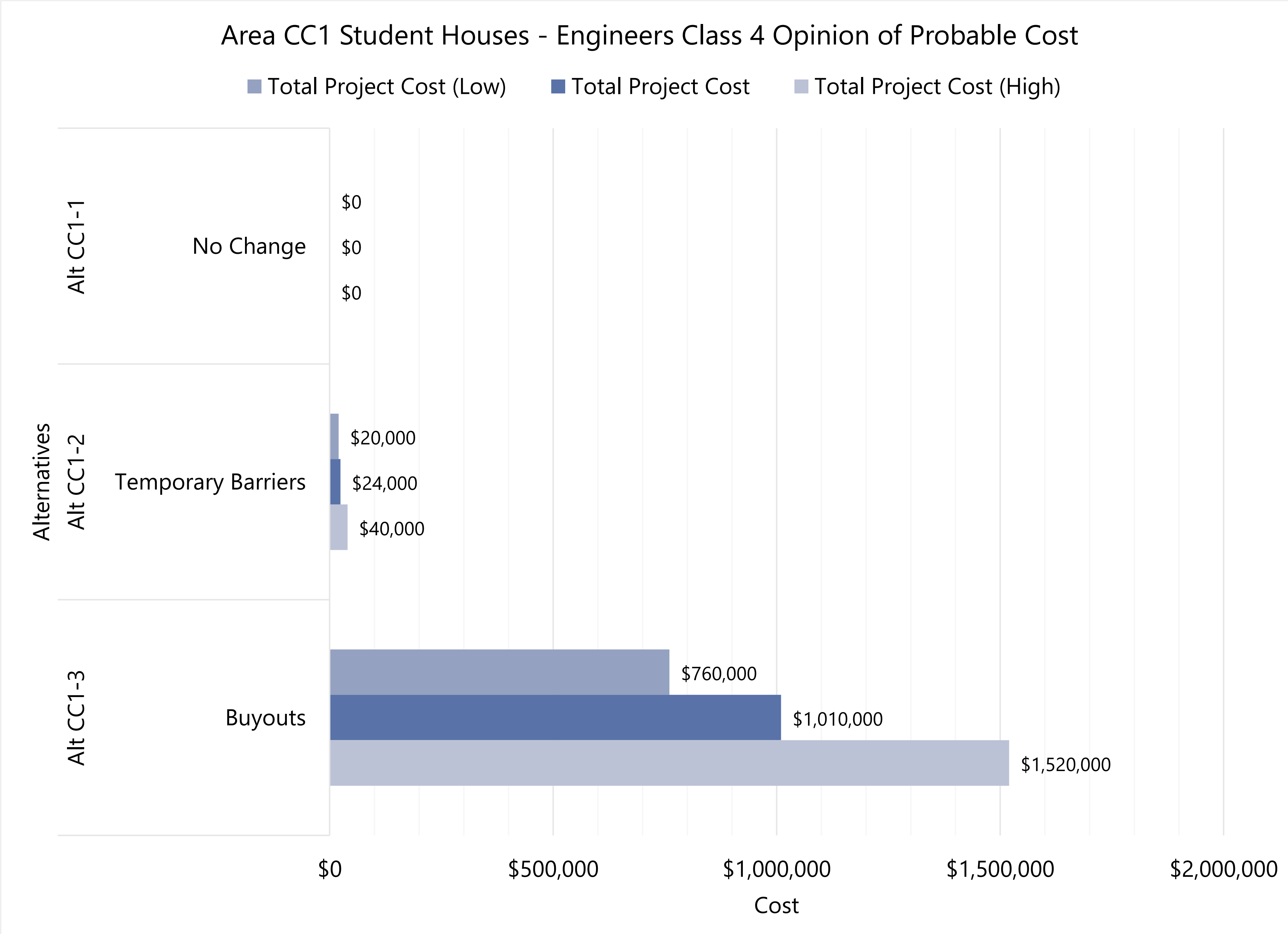
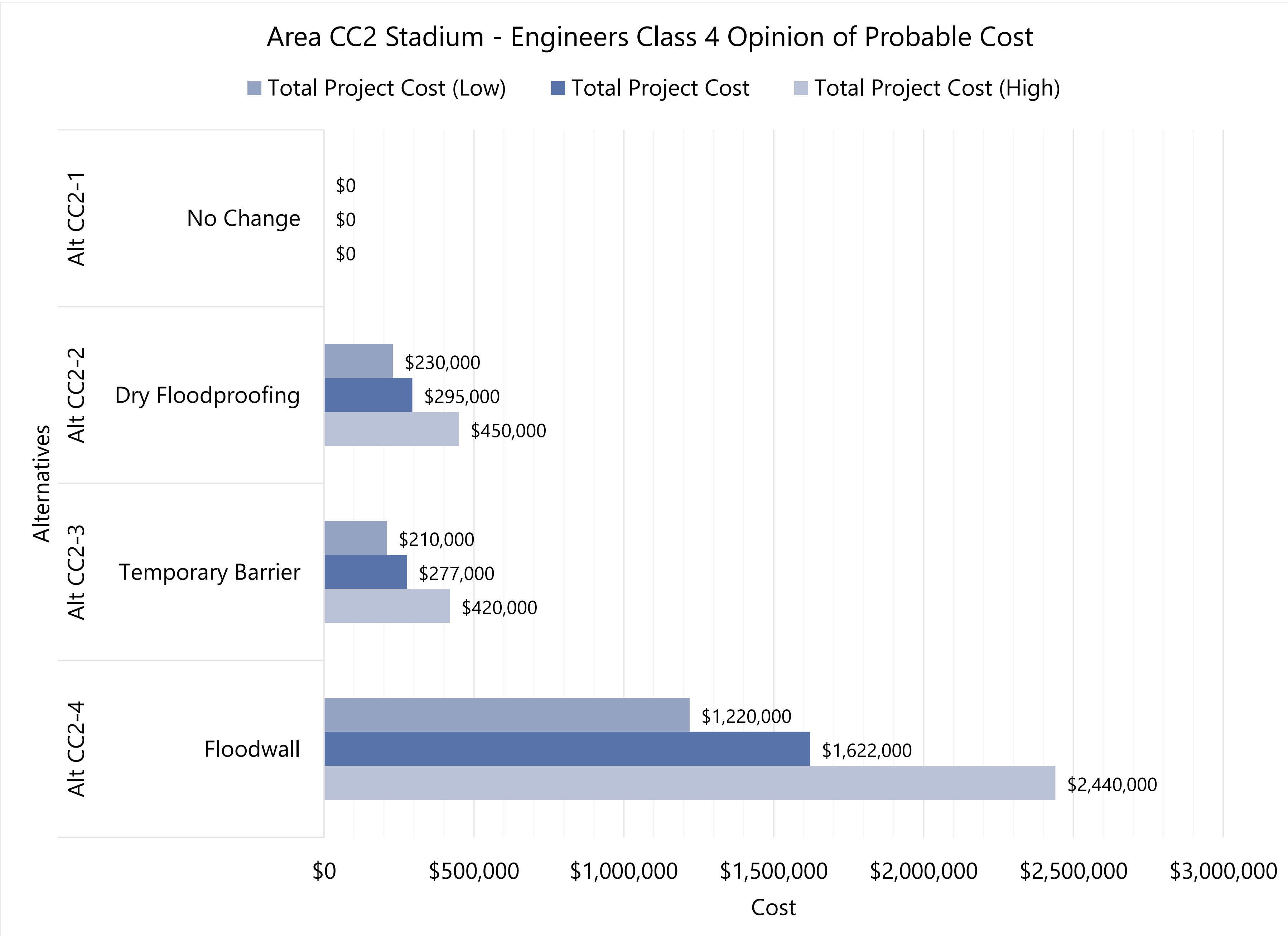


Area 3 - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt 3-2
Dry Floodproofing
$150,000
$196,000
$300,000
Alt 3-3
Floodwall
$2,160,000
$2,871,000
$4,310,000
Alt 3-4
Temporary Barriers
$64,000
$85,000
$128,000
Alt 3-5
Buyouts
$0
$1,000,000
$2,000,000
$3,000,000
$4,000,000
$5,000,000
$6,000,000
$7,000,000
Cost

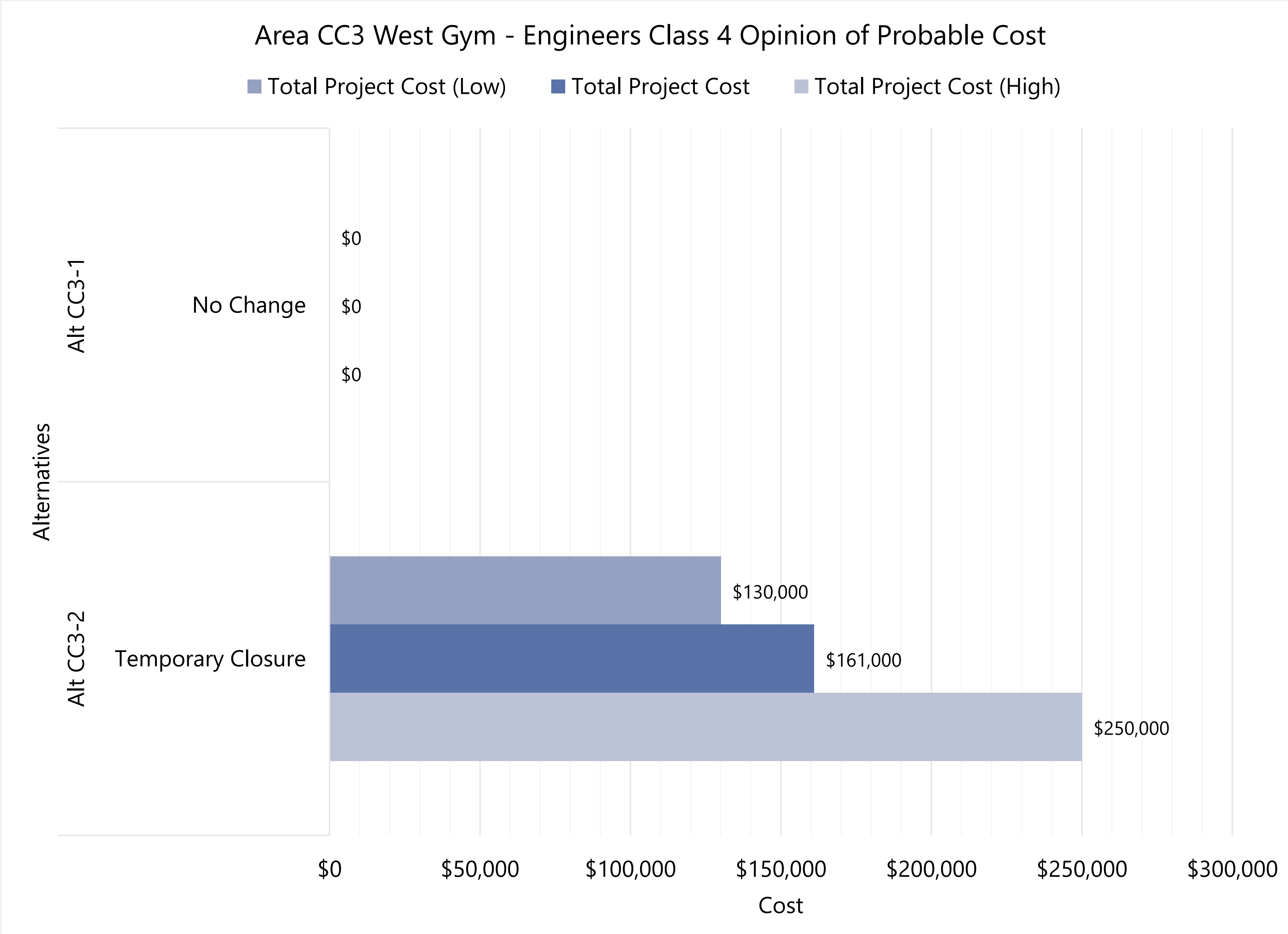


Parks - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt 4-2
Ames Park Fill
$140,000
$176,000
$270,000
Alt 4-3
Ames Park Levee
$160,000
$204,000
$310,000
Alt 4-4
Ames Park Floodwall
$750,000
$994,000
$1,500,000
Alt 5-2
Riverside Lions Park Fill
$130,000
$167,000
$260,000
Alt 5-3
Riverside Lions Park Levee
$160,000
$211,000
$320,000
Alt 5-4
Riverside Lions Park Floodwall
$730,000
$962,000
$1,450,000
Alt 6-2
Babcock Park Fill
$290,000
$378,000
$570,000
Alt 6-3
Babcock Park Levee
$220,000
$281,000
$430,000
Alt 6-4
Babcock Park Floodwall
$950,000
$1,256,000
$1,890,000
$0
$400,000
$800,000
$1,200,000
$1,600,000
$2,000,000
Cost

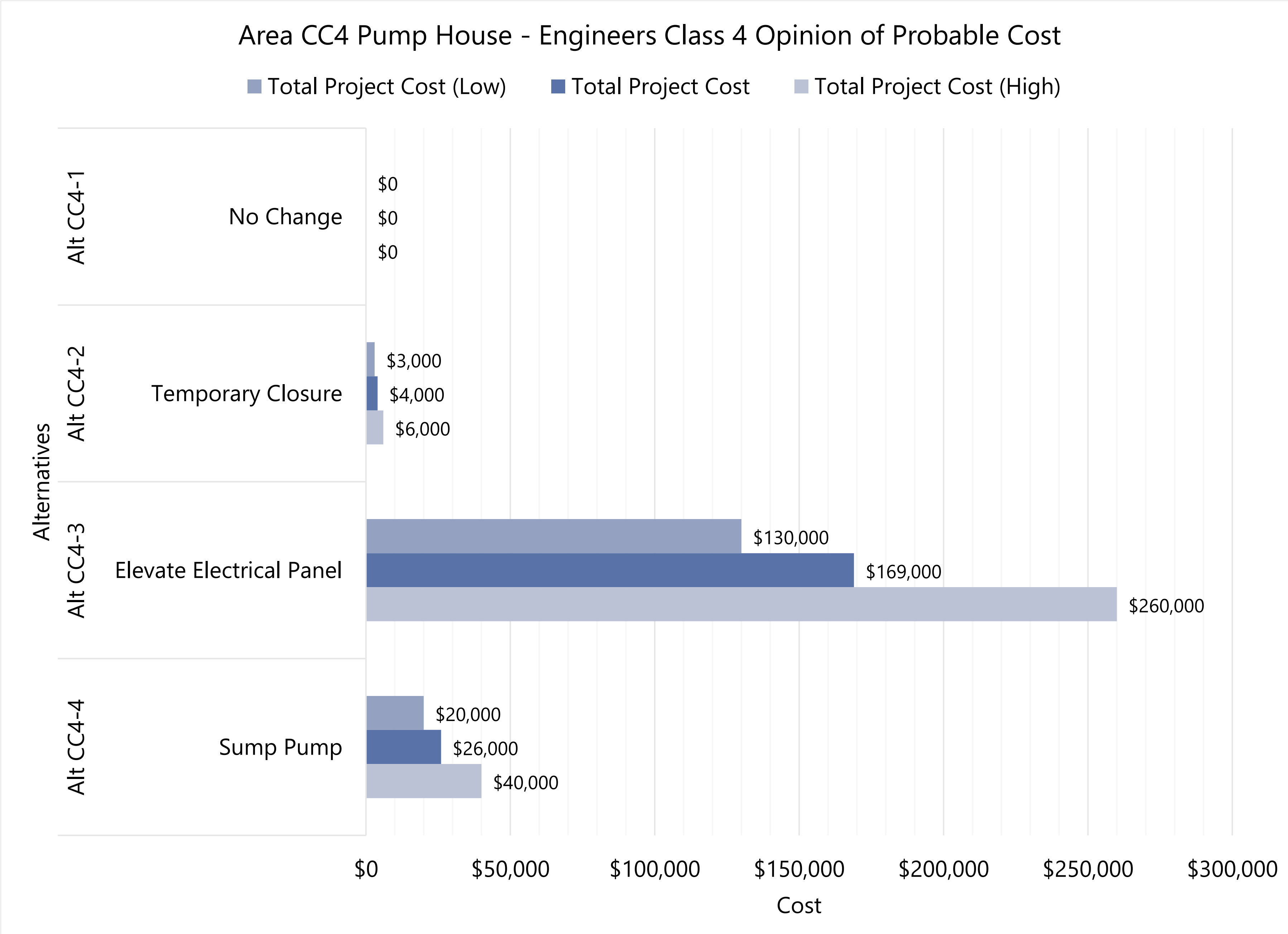

Area CC1 Student Houses - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt CC1-1
No Change
$0
$0
$0
Alt CC1-2
Temporary Barriers
$20,000
$24,000
$40,000
Alt CC1-3
Buyouts
$760,000
$1,010,000
$1,520,000
$0
$500,000
$1,000,000
$1,500,000
$2,000,000
Cost



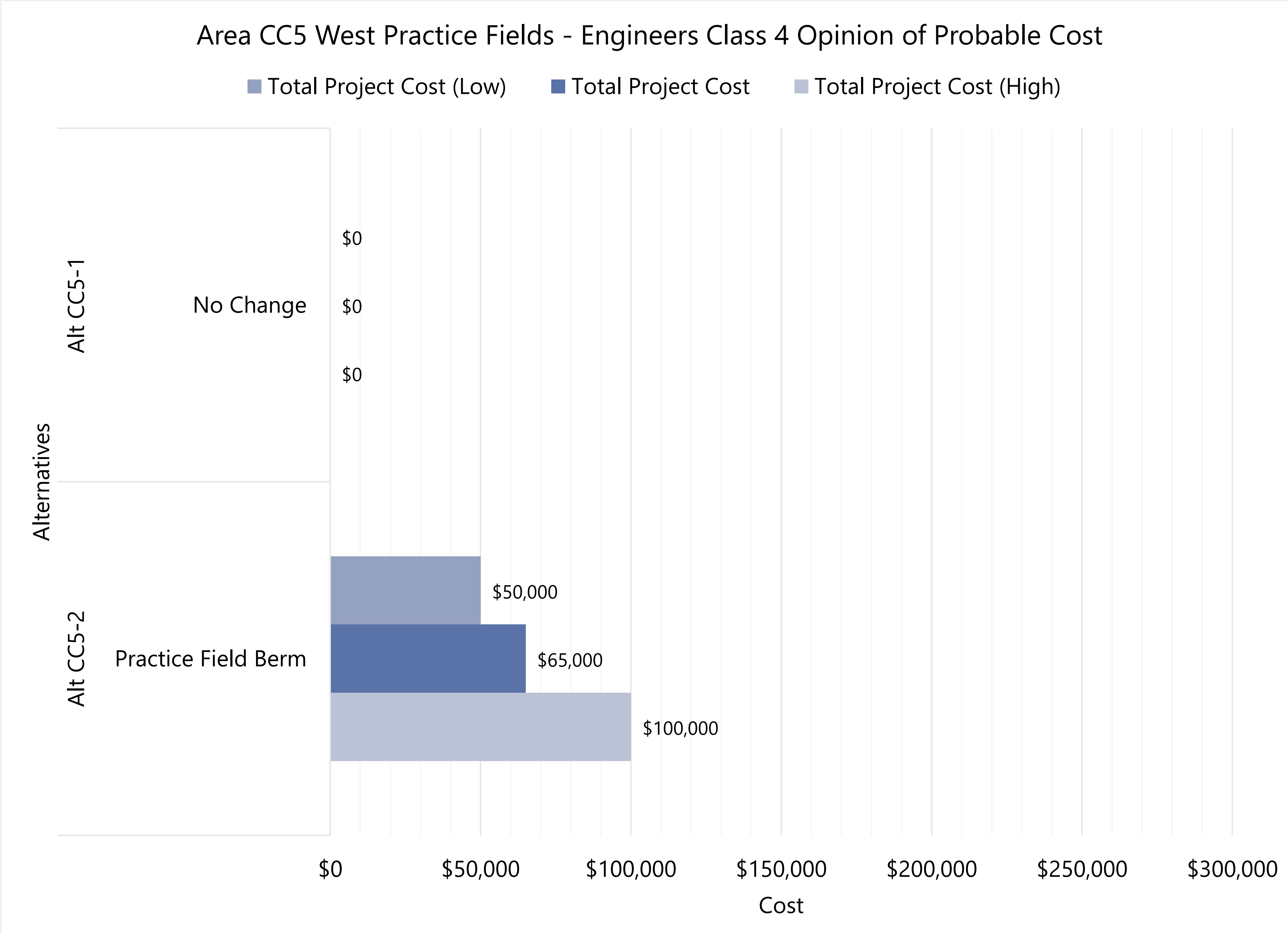
Area CC2 Stadium - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt CC2-1
No Change
$0
$0
$0
Alt CC2-2
Dry Floodproofing
$230,000
$295,000
$450,000
Alt CC2-3
Temporary Barrier
$210,000
$277,000
$420,000
Alt CC2-4
Floodwall
$1,220,000
$1,622,000
$2,440,000
$0
$500,000
$1,000,000
$1,500,000
$2,000,000
$2,500,000
$3,000,000
Cost



Area CC3 West Gym - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt CC3-1
No Change
$0
$0
$0
Alt CC3-2
Temporary Closure
$130,000
$161,000
$250,000
$0
$50,000
$100,000
$150,000
$200,000
$250,000
$300,000
Cost



Area CC4 Pump House - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt CC4-1
No Change
$0
$0
$0
Alt CC4-2
Temporary Closure
$3,000
$4,000
$6,000
Alt CC4-3
Elevate Electrical Panel
$130,000
$169,000
$260,000
Alt CC4-4
Sump Pump
$20,000
$26,000
$40,000
$0
$50,000
$100,000
$150,000
$200,000
$250,000
$300,000
Cost


Area CC5 West Practice Fields - Engineers Class 4 Opinion of Probable Cost
Total Project Cost (Low)
Total Project Cost
Total Project Cost (High)
Alternatives
Alt CC5-1
No Change
$0
$0
$0
Alt CC5-2
Practice Field Berm
$50,000
$65,000
$100,000
$0
$50,000
$100,000
$150,000
$200,000
$250,000
$300,000
Cost

Attachment F

Alternative Scoring and Recommendations

Northfield Downtown Flood Study - Alternative Scoring

Alternative	Name	Estimated Total Project Cost	O&M Cost Estimate	50-year Lifecycle Cost Estimate	Aligns with Riverfront Plan	Meets City Goals	Meets Property Owner Goals	Effective for flood of Record	Effective for flood of record +1 ft	Effective for flood of record + 2 ft	Effective for flood of record + 4 ft	O&M Cost Score	Weighted Effectiveness Score	Lifecyle Cost/ Weighted Effectiveness Score	Consider Further	Basis for Recommendation
				values	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1				
				weight	50	50	50	100	80	50	20	50				
Alt 1-1	No Change	$0	$16,000	$800,000	0.3	0.1	0.0	0.5	0.0	0.0	0.0	0.76	108	7,401	No	Does not meet City goals
Alt 1-2	Floodwall Extension	$2,619,000	$11,000	$3,169,000	0.9	0.9	1.0	1.0	0.6	0.0	0.0	0.52	314	10,086	Yes	Meets City goals
Alt 1-3	Channel Floodwall	$3,806,000	$11,000	$4,356,000	0.5	0.7	1.0	1.0	0.6	0.0	0.0	0.52	284	15,328	No	Alt 1-4 is more cost effective
Alt 1-4	Two Floodwalls	$1,199,000	$11,000	$1,749,000	0.3	0.3	1.0	1.0	0.6	0.0	0.0	0.52	254	6,881	No	Does not meet City goals
Alt 1-5	Buyouts	$2,830,000	$1,000	$2,880,000	0.3	0.3	0.0	1.0	1.0	1.0	1.0	0.05	282	10,199	Maybe	Does not meet City goals
Alt 2-1	No Change	$0	$17,000	$850,000	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.81	60	14,055	No	Does not meet City goals
Alt 2-2	Dry Floodproofing	$544,000	$12,000	$1,144,000	0.9	0.8	0.9	1.0	1.0	0.0	0.0	0.57	339	3,379	Maybe	Dry Floodproofing is difficult to achieve
Alt 2-3	Wet Floodproofing	$1,376,000	$13,000	$2,026,000	0.8	0.7	0.4	1.0	1.0	1.0	1.0	0.62	376	5,389	No	Not cost effective
Alt 2-4	Buyouts	$1,900,000	$1,000	$1,950,000	0.3	0.3	0.2	1.0	1.0	1.0	1.0	0.05	292	6,669	Maybe	Property owners unlikely to accept
Alt 3-1	No Change	$0	$6,000	$300,000	0.9	0.3	0.3	1.0	1.0	1.0	0.2	0.29	323	928	Yes	Low openings 2 feet above flood of record
Alt 3-2	Dry Floodproofing	$196,000	$13,000	$846,000	0.9	0.8	0.8	1.0	1.0	1.0	0.5	0.62	396	2,137	No	Unnecessary based on flood history
Alt 3-3	Floodwall	$2,871,000	$21,000	$3,921,000	0.6	0.9	0.8	1.0	1.0	1.0	1.0	1.00	415	9,448	No	Unnecessary based on flood history
Alt 3-4	Temporary Barriers	$85,000	$9,000	$535,000	0.6	0.1	0.1	1.0	1.0	0.8	0.0	0.43	281	1,901	No	Unnecessary based on flood history
Alt 3-5	Buyouts	$8,230,000	$1,000	$8,280,000	0.3	0.3	0.0	1.0	1.0	1.0	1.0	0.05	282	29,322	No	Unnecessary based on flood history

Northfield Downtown Flood Study - Parks Alternative Scoring

Alternative	Name	Estimated Total Project Cost	O&M Cost	50-year Lifecycle Cost	Aligns with Riverfront Plan	Meets City Goals	Meets Property Owner Goals	Effective 2-year flood	Effective 10-year flood	Effective 25-year flood	Effective 50-year flood	O&M Cost Score	Weighted Effectiveness Score	Lifecycle Cost/ Weighted Effectiveness Score	Consider Further	Basis for Recommendation
				values	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1				
				weight	50	50	50	100	80	50	20	50				
Alt 4-1	No Change	$ -	$ 6,000	$ 800,000	0.3	0.3	1.0	1.0	0.0	0.0	0.0	0.76	93	7,401	Maybe	Preserves floodplain storage
Alt 4-2	Ames Park Fill	$ 176,000	$ 1,000	$ 226,000	0.8	0.9	1.0	1.0	1.0	1.0	1.0	0.08	349	647	Maybe	Filling in the flood fringe for parks is not good
Alt 4-3	Ames Park Levee	$ 204,000	$ 8,000	$ 604,000	0.7	0.8	1.0	1.0	1.0	1.0	1.0	0.67	373	1,618	Maybe	Reduces flood frequency in park areas without
Alt 4-4	Ames Park Floodwall	$ 994,000	$ 12,000	$ 1,594,000	0.7	0.8	1.0	1.0	1.0	1.0	1.0	1.00	390	4,087	No	high cost
Alt 5-1	No Change	$ -	$ 6,000	$ 300,000	0.3	0.3	1.0	1.0	0.0	0.0	0.0	0.50	190	1,579	Maybe	Preserves floodplain storage
Alt 5-2	Riverside Lions Park Fill	$ 167,000	$ 1,000	$ 217,000	0.8	0.9	1.0	1.0	1.0	1.0	1.0	0.08	349	621	Maybe	Filling in the flood fringe for parks is not good
Alt 5-3	Riverside Lions Park Levee	$ 211,000	$ 8,000	$ 611,000	0.7	0.8	1.0	1.0	1.0	1.0	1.0	0.67	373	1,637	Maybe	Reduces flood frequency in park areas without
Alt 5-4	Riverside Lions Park Floodwall	$ 962,000	$ 12,000	$ 1,562,000	0.7	0.8	1.0	1.0	1.0	1.0	1.0	1.00	390	4,005	No	high cost
Alt 6-1	No Change	$ -	$ 6,000	$ 300,000	0.3	0.3	1.0	1.0	0.0	0.0	0.0	0.50	190	1,579	Maybe	Preserves floodplain storage
Alt 6-2	Babcock Park Fill	$ 378,000	$ 1,000	$ 428,000	0.8	0.9	1.0	1.0	1.0	1.0	1.0	0.08	349	1,226	Maybe	Filling in the flood fringe for parks is not good
Alt 6-3	Babcock Park Levee	$ 281,000	$ 8,000	$ 681,000	0.7	0.8	1.0	1.0	1.0	1.0	1.0	0.67	373	1,824	Maybe	Reduces flood frequency in park areas without
Alt 6-4	Babcock Park Floodwall	$ 1,256,000	$ 12,000	$ 1,856,000	0.7	0.8	1.0	1.0	1.0	1.0	1.0	1.00	390	4,759	No	high cost

Northfield Downtown Flood Study - Carleton College Alternative Scoring

Alternative	Name	Estimated Total Project Cost	O&M Cost Estimate	50-year Lifecycle Cost Estimate	Meets College Goals	Flood Protection for 10yr	Flood Protection for 50yr	Flood Protection for 100 yr	Flood Protection for 500 yr	O&M Cost Score	Weighted Effectiveness Score	Lifecycle Cost/ Weighted Effectiveness Score	Consider Further	Basis for Recommendation
				values	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1				
				weight	300	100	80	50	20	50				
Alt CC1-1	No Change	$0	$1,000	$50,000	0.0	0.5	0.5	0.5	0.0	0.02	116	431	Yes	College plans to remove houses within 5 years
Alt CC1-2	Temporary Barriers	$24,000	$7,000	$374,000	1.0	0.5	0.5	0.5	1.0	0.14	442	846	No	Not worth the investment given plans to remove houses within 5 years.
Alt CC1-3	Buyouts	$1,010,000	$4,000	$1,210,000	1.0	0.5	0.5	0.5	1.0	0.08	439	2,756	No	Deed restrictions for FEMA buyouts are undesirable.
Alt CC2-1	No Change	$0	$5,000	$250,000	0.0	0.5	0.5	0.0	0.0	0.10	95	2,632	Maybe	Track and structure at risk
Alt CC2-2	Dry Floodproofing	$295,000	$5,000	$545,000	1.0	0.5	0.5	1.0	1.0	0.10	465	1,172	Maybe	Only protects structure
Alt CC2-3	Temporary Barrier	$277,000	$19,000	$1,227,000	1.0	0.5	0.5	1.0	1.0	0.38	479	2,562	Maybe	Labor intensive to install, protects track. Less expensive than floodwall.
Alt CC2-4	Floodwall	$1,622,000	$4,000	$1,822,000	1.0	0.5	0.5	1.0	1.0	0.08	464	3,927	Yes	Low maintenance, protects track
Alt CC3-1	No Change	$0	$6,000	$300,000	0.0	0.5	0.0	0.0	0.0	0.12	56	5,357	No	Current temporary closures do not allow for egress
Alt CC3-2	Temporary Closure	$161,000	$3,000	$311,000	1.0	0.5	1.0	1.0	1.0	0.06	503	618	Yes	Preferred alternative for college because it maintains egress for emergency exit.
Alt CC4-1	No Change	$0	$1,000	$50,000	0.0	0.5	0.5	0.5	0.5	0.02	126	397	Yes	Current mitigation may be sufficient
Alt CC4-2	Temporary Closure	$4,000	$5,000	$254,000	0.5	0.5	0.5	0.5	0.5	0.10	280	907	No	Unlikely to be cost effective
Alt CC4-3	Elevate Electrical Pane	$169,000	$5,000	$419,000	1.0	0.5	0.5	0.5	0.5	0.10	430	974	Maybe	Unlikely to be cost effective
Alt CC4-4	Sump Pump	$26,000	$3,000	$176,000	0.5	0.5	0.5	0.5	0.5	0.06	278	633	Maybe	Unlikely to be cost effective
Alt CC5-1	No Change	$0	$50,000	$2,500,000	0.0	0.0	0.0	0.0	0.0	1.00	50	50,000	Maybe	May not be able to reduce flood risk due to floodway designation
Alt CC5-2	Practice Field Berm	$65,000	$11,000	$615,000	1.0	1.0	0.0	0.0	0.0	0.22	411	1,496	Yes	Reducing backwater flooding from Spring Creek could significantly reduce post-flood restoration costs

Notes

Lifecyle Cost divided by Weighted Effectiveness Score is a measure of cost per quantitative estimate of value. Lower numbers generally indicate a more cost effective project.