# Loss Avoidance Study

## Iowa, Flood Reduction Projects

*May 2010*

FEMA

**Federal Emergency Management Agency**
**U.S. Department of Homeland Security**
500 C Street, Southwest
Washington, DC 20472

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# Executive Summary

Every year, Federal, State, and local government agencies and private entities fund mitigation projects that are intended to reduce or eliminate the risk of damage and loss of life from natural disasters. Natural disasters are a threat to health and safety, the built environment, and the economy. Some of the funding for mitigation comes from mitigation grants awarded by the Department of Homeland Security's Federal Emergency Management Agency (FEMA), which uses cost-effectiveness as a grant eligibility requirement.

To determine the cost-effectiveness of mitigation projects before funding them, FEMA uses tools that predict damage from probabilistic hazard events. However, because the investment in mitigation is significant, the economic performance of mitigation during actual hazard events is important, particularly to policymakers. Over the last decade, FEMA has developed and refined a methodology for determining the performance of mitigation projects in actual post-project hazard events. The flood methodology is detailed in FEMA's *Loss Avoidance Study: Riverine Flood Methodology Report* (FEMA, 2009d).

Iowa has a long history of flooding accompanied by severe damage. The Great Flood of 1993 spanned nine Midwestern states, including Iowa, and caused $15 billion in damage. The extensive damage in Iowa provided the State with an incentive to implement a large number of flood mitigation projects. After the devastating floods in the summer of 2008, which affected much of Iowa, FEMA partnered with the State of Iowa to conduct a loss avoidance study to determine the economic benefit of minor localized flood reduction projects that had been implemented before the 2008 floods. The projects were implemented to reduce the risk of flooding in the communities of Burlington, Cedar Falls, Des Moines, Coralville, Elkader, Forest City, Manning, McGregor, and Montrose.

Nine projects were included in the study. Two were eliminated after it was determined that they had not yet resulted in any losses avoided. The value of the total losses avoided for the remaining seven projects was calculated at $52,863,381, and the total cost of the projects was $2,590,042, resulting in a Return on Investment of 2,041%. Minor localized flood reduction projects are estimated to have an average useful life of 50 years. Because the projects in this study were implemented between 3 and 14 years ago, the value of the losses avoided, and therefore the Return on Investment, will increase as other flood events occur.

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# Section One:

## Introduction

Frequent flooding in Iowa has jeopardized public health and safety and caused severe damage to property. With support from the State of Iowa and the Department of Homeland Security's Federal Emergency Management Agency (FEMA), Iowa communities have sought to reduce the risk of flood damage through mitigation. The effort has included a number of minor localized flood reduction projects throughout the state.

The June 2008 flood event affected most of Iowa. Following this flood, FEMA partnered with the State of Iowa to initiate a loss avoidance study (LAS or study) to assess the cost-effectiveness of nine minor localized flood reduction projects in areas that had been affected by the flood. **Table 1.1** provides a general description of the projects. The study was conducted to determine the Return on

*Table 1.1*

**Description of the Minor Localized Flood Reduction Projects in the Iowa Study**

| Project Name | Description |
|---|---|
| ***Burlington Municipal Water Works Project*** | Installation of retaining walls and stop logs to fill a gap in the earthen levee at the entrance of the Burlington Municipal Water Works Project. The walls and stop logs provide flood protection to above the 500-year WSE. |
| ***Cedar Falls Utilities Flood Protection Project*** | Construction of a floodwall to protect the Cedar Falls Utilities to the 100-year WSE with 3 feet of freeboard. |
| ***Coralville Flood Control Project*** | Installation and incorporation of three pump stations and a water detention pond in the existing City of Coralville storm sewer system, which normally drains by gravity to the river. During flood events, the pumps expel interior runoff until the river recedes. The project provides flood protection to the 100-year WSE. |
| ***Des Moines, Central Campus Floodgates Project*** | Installation of floodgates to close a railroad opening in the USACE levee system to protect the Riverfront Area business district to the 100-year WSE. |
| ***Elkader Flood Protection Project*** | An increase in the height of the existing berm surrounding the Elkader Sewage Treatment Plant aeration lagoons and construction of a floodwall to protect the Main Sanitary Lift Station. The project provides flood protection to the 100-year WSE with between 2 and 4 feet of freeboard. |
| ***Forest City Flood Protection Project*** | Construction of a ring levee on three sides of the Forest City Water Treatment Plant to protect the facility to the 500-year WSE plus 1 foot of freeboard. |
| ***Manning Well Head Project*** | Elevation of two municipal well heads in the City of Manning to the 500-year WSE. |
| ***McGregor Floodwall Project*** | Construction of a floodwall with stop log floodgates and a berm to protect the McGregor Municipal Utilities to the 500-year WSE. |
| ***Montrose Floodproofing Project*** | Demolition of the old control building and construction of a new control building on fill to protect the building to above the 500-year WSE. Raising of the wet well for protection to above the 500-year WSE. |

USACE = U.S. Army Corps of Engineers
WSE = water surface elevation

Investment (ROI)[1] of the nine projects by comparing the cost of the projects to the losses avoided in all floods that have occurred since the projects were completed. The study is referred to in this report as the "Iowa study." This report contains the results of the study.

## 1.1 Hazard Mitigation

FEMA defines mitigation as any sustained action taken to reduce or eliminate long-term risk to people and property from hazards and their effects. Every year, FEMA provides States and communities with substantial financial assistance for projects that will reduce or eliminate risks from natural hazards through Hazard Mitigation Assistance (HMA) grants, which include post-disaster grants under the Hazard Mitigation Grant Program (HMGP) and pre-disaster grants under the Pre-Disaster Mitigation (PDM) Program, the Flood Mitigation Assistance (FMA) Program, the Repetitive Flood Claims (RFC) Program, and the Severe Repetitive Loss (SRL) Program.

With significant investment being made in mitigation, demonstrating cost-effectiveness is crucial for continued support. In order to evaluate the cost-effectiveness of mitigation projects, FEMA has developed and refined the LAS methodology, which is used to determine the performance of mitigation projects in actual post-project hazard events. The methodology is based on the analysis of actual hazard events that have occurred in a study area since the completion of a mitigation project. The methodology provides a way to assess the benefits of a mitigation project in terms of its actual performance. Losses avoided are determined by comparing damage that would likely have been caused by the same events without the project (Mitigation Project Absent [$MP_A$]) with damage that actually occurred with the project in place (Mitigation Project Complete [$MP_C$]).

The LAS methodology used for this study is consistent with the methodology described in *Loss Avoidance Study: Riverine Flood Methodology Report* (FEMA, 2009d).

## 1.2 Methodology Overview

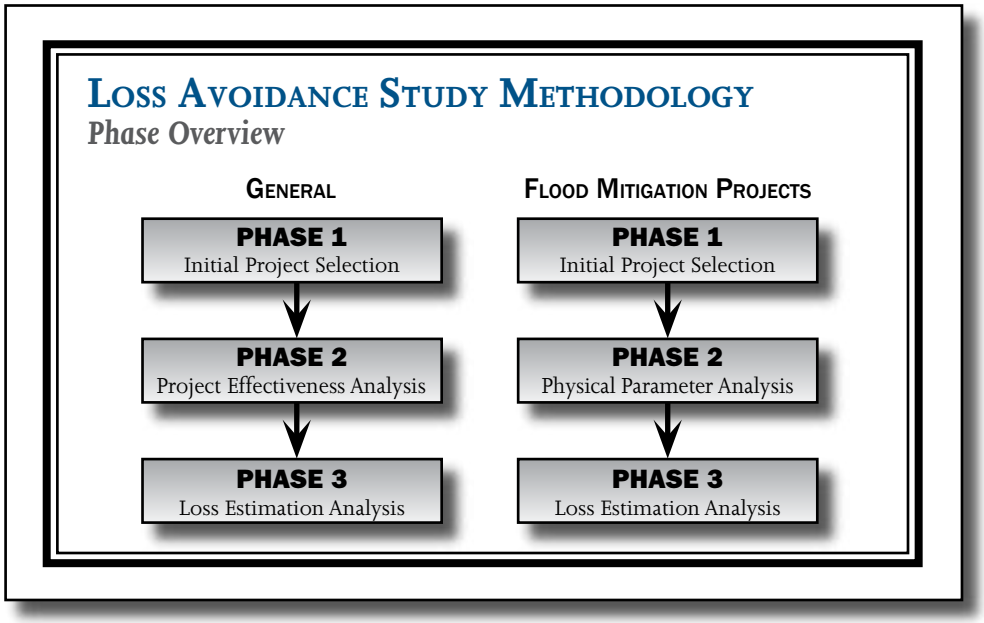
Loss avoidance methodology can be applied to the mitigation of any type of natural hazard (e.g., flood, wildfire, seismic, wind). Flood hazard mitigation projects can be classified as either building

1 An ROI of >1 indicates that project benefits have exceeded project costs, and the project is therefore considered cost-effective. Note that the FEMA measure of ROI is not the same as a financial ROI. A financial ROI is a measure of net profit, expressed relative to the dollars invested.

modification or minor localized flood reduction projects. Building modification projects mitigate damage by modifying a building to reduce its risk of flood damage through acquisition/demolition, acquisition/relocation, elevation, or floodproofing. Acquisition/demolition projects are referred to as "acquisition projects," and acquisition/relocation projects are referred to as "relocation projects." Minor localized flood reduction projects, referred to as "flood reduction projects," mitigate damage by reducing the hazard itself and include stormwater drainage system improvements, channel modifications, flood walls/barriers, and other projects that reduce the severity of flooding. This study is focused on the performance of flood reduction projects.

An LAS consists of three phases. These phases are summarized in **Figure 1.1**, and the steps included in each phase of an LAS for a flood reduction project are shown in **Figure 1.2**. Although Phases 1 and 3 are similar regardless of the type of hazard and type of mitigation project, Phase 2 varies considerably depending on the hazard and the mitigation project. In flood-related studies, Phase 2 is called "Physical Parameter Analysis."

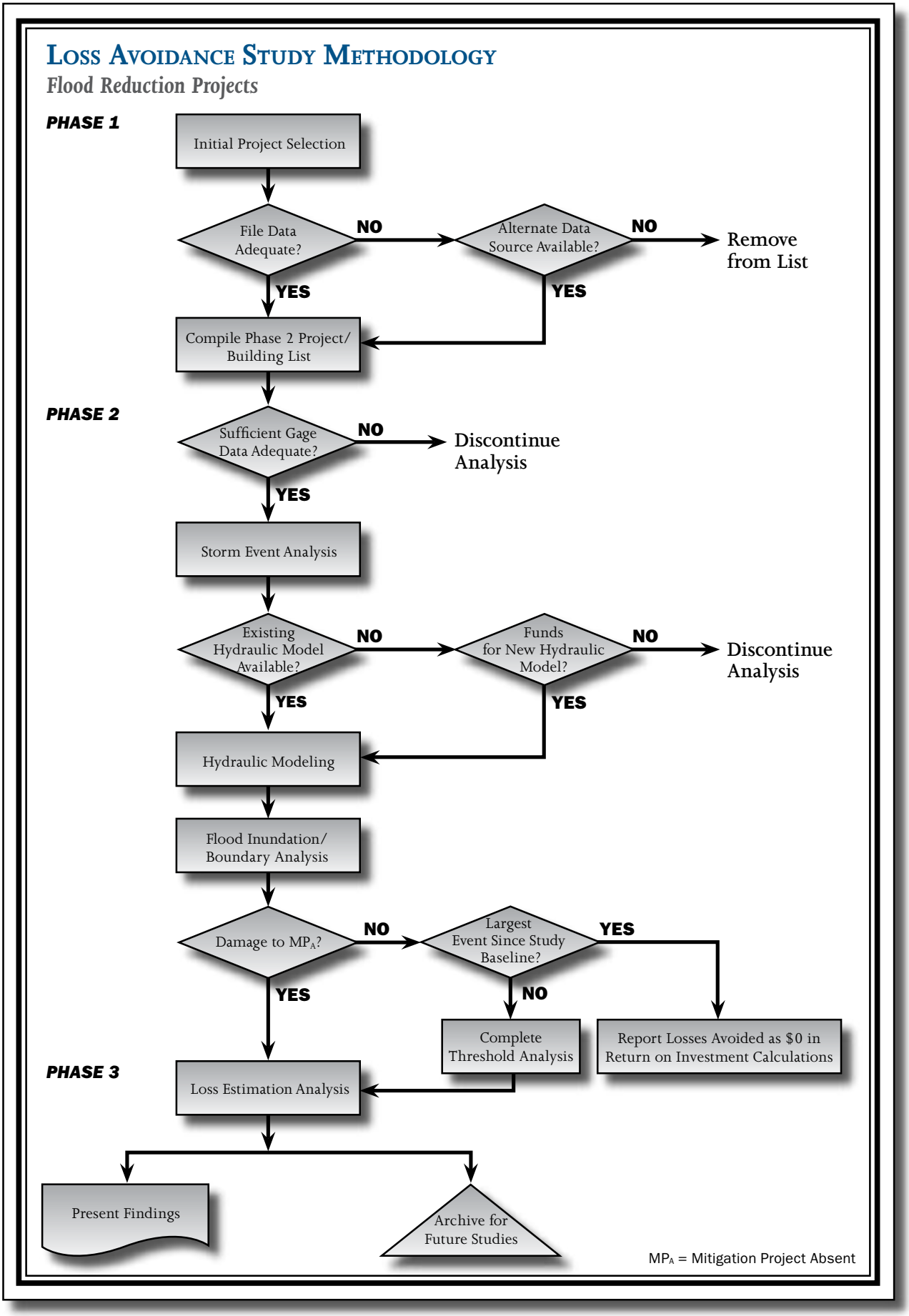
***Figure 1.1***




Phase 1 consists of the development of the initial project list. Projects are selected based on criteria determined by the sponsoring agency. The initial list of projects is screened based on the availability of data required for completion of all phases of the study. Projects with adequate data advance to Phase 2.

Phase 2 is composed of three analyses—Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis. A Storm Event

**Figure 1.2**


Loss Avoidance Study Methodology
Flood Reduction Projects
PHASE 1
Initial Project Selection
File Data Adequate?
NO
Alternate Data Source Available?
NO
Remove from List
YES
YES
Compile Phase 2 Project/ Building List
PHASE 2
Sufficient Gage Data Adequate?
NO
Discontinue Analysis
YES
Storm Event Analysis
Existing Hydraulic Model Available?
NO
Funds for New Hydraulic Model?
NO
Discontinue Analysis
YES
YES
Hydraulic Modeling
Flood Inundation/ Boundary Analysis
Damage to MPA?
NO
Largest Event Since Study Baseline?
YES
YES
NO
Complete Threshold Analysis
Report Losses Avoided as $0 in Return on Investment Calculations
PHASE 3
Loss Estimation Analysis
Present Findings
Archive for Future Studies
MPA = Mitigation Project Absent

Analysis is performed to determine whether any storm event occurred since the mitigation project was implemented that would have caused damage in the $MP_A$ scenario. A Hydraulic Analysis is performed to determine the extent and elevation of flooding in the event(s) for the $MP_A$ and $MP_C$ scenarios. The results of the Hydraulic Analysis are used in the Flood Boundary Analysis, which is conducted to inventory the affected buildings and infrastructure within the extent of the flooding. If the limit of inundation determined for the $MP_A$ scenario indicates that damage would have occurred if the project had not been implemented, the project advances to Phase 3 for a Loss Estimation Analysis.

In Phase 3, damage is calculated for the $MP_A$ and $MP_C$ scenarios, and the difference between the two scenarios is determined, which equals the losses avoided. The ROI is calculated by comparing the losses avoided to the project investment.

# Section Two:
## Mitigation Project Information

Because Iowa is highly susceptible to flooding, the State of Iowa initiated a number of flood mitigation projects from 1993 to 2008 to reduce the risk of property damage, the threat to life and public health and safety, and the cost of emergency response. Nine flood reduction projects were considered for this study. The projects are located in the communities of Burlington, Cedar Falls, Des Moines, Coralville, Elkader, Forest City, Manning, McGregor, and Montrose. See **Appendices A through I** for more information about each project.

## 2.1 History

Iowa has long been vulnerable to severe storms and flooding. Every year, flooding causes residents, businesses, and taxpayers millions of dollars in repairs. From 1953 to 2008, the President declared 32 disasters for flooding events in Iowa.

The Great Flood of 1993 spanned nine Midwestern states, caused $15 billion in damage, and had devastating effects in Iowa. The flood prompted Iowa to complete a large number of flood mitigation projects. Three of the projects in this study were funded as a direct result of the damage caused by this flood.

The two most recent, significant floods in Iowa occurred in 2001 and 2008. In the spring of 2001, rapid snowmelt and heavy storms caused flooding, and 13 counties were designated as disaster areas. The 2008 flood disaster, which affected much of the Midwest, resulted from a winter in which precipitation was far above normal, followed by extreme rain events in June 2008. According to the National Climatic Data Center (NCDC), precipitation across the Upper Mississippi Basin from December 2007 through May 2008 was the second-highest total since recordkeeping began in 1895, and over 1,100 daily precipitation records were broken across the Midwest during the month of June (NCDC, 2008). The resulting floods affected most of Iowa; the President designated 85 of Iowa's 99 counties as disaster areas.

## 2.2 Funding and Timeline

See **Table 2.1** for the cost and completion dates of the nine flood reduction projects included in this study. The projects all received

*Table 2.1*

**Project Funding and Timeline Summary**

| Project Name | Community | Funding Grant | Grant Approval Year | FEMA Project Number | FEMA Disaster | Project Cost at Date of Project Completion | Percentage of Project Cost Provided by Federal Grants | Project Completion Date |
|---|---|---|---|---|---|---|---|---|
| ***Burlington Municipal Water Works Project*** | Burlington | 404 HMGP | 1997 | 1121-0001 | FEMA-1121-DR-IA | $295,962 | 75% | 5/13/99 |
| ***Cedar Falls Utilities Flood Protection Project*** | Cedar Falls | PDMC | 2004 | PDMC-PJ-07-IA-2003-001 | N/A | $644,162 | 70% | 11/20/07 |
| ***Coralville Flood Control Project*** | Coralville | 404 HMGP | 1999 | 0868-0023/ 0911-0009/ 0928-0015 | FEMA-0868/0911/ 0928-DR-IA | $1,364,111 | 50% | 11/18/02 |
| ***Des Moines, Central Campus Floodgates Project*** | Des Moines | 404 HMGP | 1994 | 0996-0003 | FEMA-0996-DR-IA | $342,092 | 75% | 3/25/96 |
| ***Elkader Flood Protection Project*** | Elkader | 404 HMGP | 1998 | 0928-0018/ 0965-0003 | FEMA-0928/ 0965-DR IA | $134,917 | 50% | 10/9/00 |
| ***Forest City Flood Protection Project*** | Forest City | PDMC | 2005 | PDMC-PJ-07-IA-2005-003 | N/A | $57,600 | 75% | 11/2/06 |
| ***Manning Well Head Project*** | Manning | 404 HMGP | 1998 | 0928-0013 | FEMA-0928-DR-IA | $24,000 | 50% | 11/8/99 |
| ***McGregor Floodwall Project*** | McGregor | 404 HMGP | 1998 | 0996-0062 | FEMA-0996-DR-IA | $173,322 | 75% | 6/24/99 |
| ***Montrose Floodproofing Project*** | Montrose | 404 HMGP | 1999 | 0928-0019/ 0996-0091 | FEMA-0928/ 0996-DR IA | $434,033 | 62% | 12/2/04 |

*Sources: FEMA Project Files (FEMA, 1996b; 1999a; 1999b; 2000; 2001; 2003a; 2003b; 2005a; 2005b)*

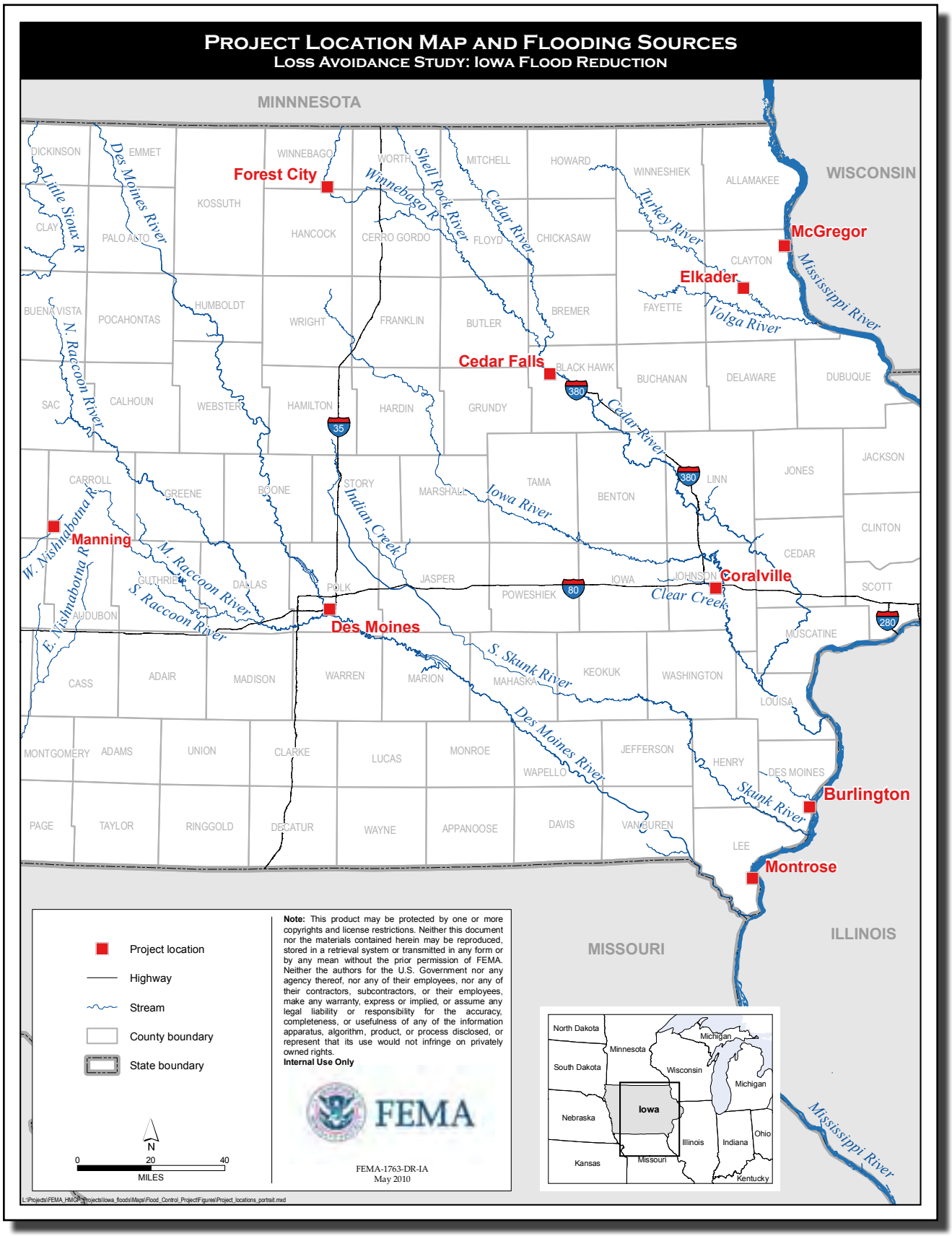
FEMA = Federal Emergency Management Agency
HMGP = Hazard Mitigation Grant Program
N/A = Not Applicable
PDMC = Pre-Disaster Mitigation – Competitive

FEMA mitigation funding. Seven were funded through HMGP grants and two through PDM Program grants. The Federal grants provided between 50% and 75% of the project cost, and the community provided the remainder. The projects were completed between March 1996 and November 2007. See **Appendices A through I** for more information about the cost and timeline of each project.

## 2.3 Location

The nine projects are dispersed throughout the state. See **Figure 2.1** for the project locations and flooding sources. See **Appendices A through I** for information about the project sites.

***Figure 2.1***


Project Location Map and Flooding Sources
Loss Avoidance Study: Iowa Flood Reduction
MINNNESOTA
WISCONSIN
MISSOURI
ILLINOIS
Forest City
McGregor
Elkader
Cedar Falls
Manning
Coralville
Des Moines
Burlington
Montrose
Little Sioux R
Des Moines River
Winnebago R
Shell Rock River
Cedar River
Turkey River
Mississippi River
Volga River
N. Raccoon River
Cedar River
Iowa River
Indian Creek
W. Nishnabotna R
E. Nishnabotna R
M. Raccoon River
S. Raccoon River
Clear Creek
S. Skunk River
Des Moines River
Skunk River
Mississippi River
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
CLAYTON
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
FAYETTE
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
CEDAR
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
SCOTT
AUDUBON
MUSCATINE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
35
380
80
280
Project location
Highway
Stream
County boundary
State boundary
N
0
20
40
MILES
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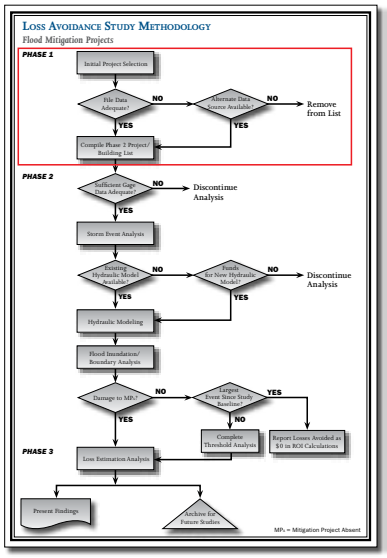
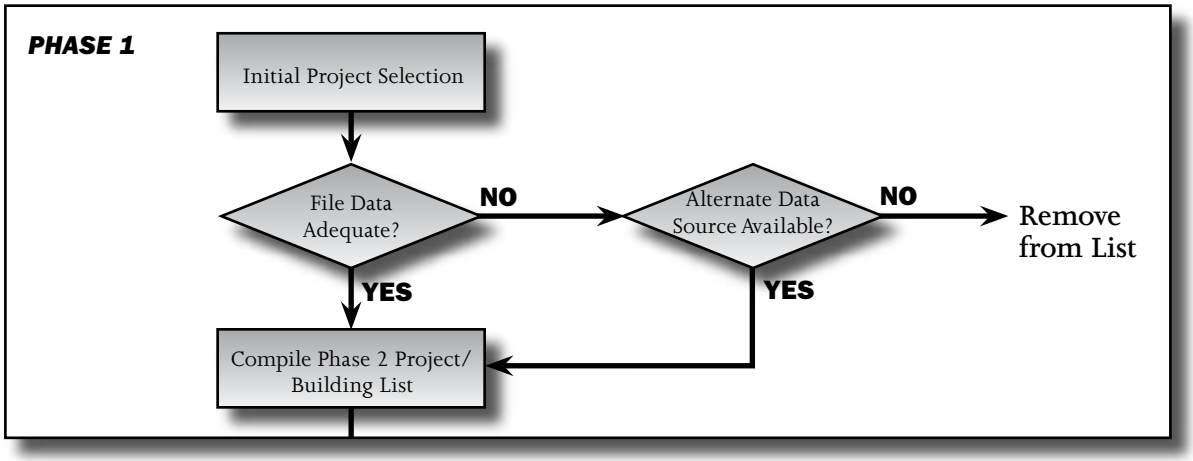
# Section Three:

## Phase 1 – Initial Project Selection and Screening




This section contains a discussion of Phase 1 (Initial Project Selection and Screening) for flood reduction projects. The steps included in Phase 1 for a flood reduction project are shown in **Figure 3.1**. In Phase 1, an initial list of candidate projects is compiled, and data are collected for analysis of the projects. Each project is screened. If the data required to analyze a project are unavailable or inadequate, that project is eliminated from the study. The projects for which adequate data are available are advanced to Phase 2.

***Figure 3.1***




## 3.1 Initial Project Selection

Project selection criteria are defined for each LAS, and the initial projects are selected based on the criteria. The criteria may include but are not limited to:

- **Area of Interest** – The area of interest is the geographic boundary of a study. The boundary can be a reach of a river or channel, a single community or watershed, a region, a jurisdictional boundary (e.g., city, county, state, special district), or any other area. The boundary must be defined by the agency sponsoring the study.
- **Hazard Type** – Projects in an LAS are selected based on the type of hazard they are mitigating. Examples of hazard types are riverine flood and coastal flood.
- **Project Type** – Many project types can be analyzed in an LAS. Flood-related projects include building modification projects

(elevation, acquisition, relocation, and floodproofing) and flood reduction projects (stormwater drainage system improvements, channel modifications, flood walls/barriers, and other projects that would reduce the severity of flooding).

- **Study Baseline** – The study baseline is the date a mitigation activity was completed. Only storm events that occurred after the study baseline should be evaluated. Mitigation activities that were completed long before the LAS have a higher likelihood of being tested by a potentially damaging event than those with more recent completion dates. Consequently, it is more likely that losses avoided can be assessed for projects with earlier construction dates. Although a flood reduction project may include multiple tasks, the study baseline is the date the entire project became functional.

## 3.2 Project Screening

In an LAS for a flood reduction project, losses are calculated or estimated for all buildings and infrastructure affected by the project in both the $MP_A$ and $MP_C$ scenarios. Projects should be removed from the analysis during Phase 1 if required data are not available, are inadequate, or cannot be easily estimated. Projects may also be eliminated from the study if the quality of the available data is insufficient.

### 3.2.1 Project Files and Other Sources of Data

The data required for an HMA grant application are similar to the data required for an LAS. Therefore, if a flood reduction project was funded through one of the HMA grant programs, much of the required data should be available in the project file.

The data required to complete an LAS for a flood reduction project are:

- Actual project costs
- Project completion dates for each project to establish the study baseline
- Detailed design plans or drawings for the mitigation project
- Hydraulic modeling for the $MP_A$ and $MP_C$ scenarios
- Detailed topographic data
- First floor elevations (FFEs) for any buildings within the flooding extent, preferably in the form of FEMA elevation certificates. FFEs can be estimated in the absence of surveyed

FFEs, but the accuracy of the estimate can greatly affect loss calculations.

- Building location information in the form of latitude/longitude data, address, and/or assessor parcel number
- Building information, including building type (i.e., residential, commercial, industrial, or municipal), basement information (finished versus unfinished and square footage), number of floors, living space square footage, foundation type, number of stories, and building replacement value (BRV)
- Functional downtime of affected utilities and roads
- Number of connections to affected utilities
- Traffic counts, detour times, and distances for affected roads

The data obtained from project files should be verified as being the most current and accurate data available. Other sources of data include site visits, local governments, consulting engineers, resource documents, and third-party vendors.

### 3.2.2 Initial Site Visit and Additional Data Collection

An initial site visit should be completed in order to meet State and local officials and to initiate the more detailed data collection required for Phases 2 and 3. Data collected in the field are used to verify and supplement data in the project files and assess the conditions of the project site.

A field visit is also an excellent source of information about the actual storm events that occurred since the project was completed. The community may have recorded high water marks (HWMs), and local officials and residents may be able to provide eyewitness accounts of the flood levels during those events. This information can be useful in the Storm Event Analysis and the Hydraulic Analysis of Phase 2 because it provides an indicator of which storm events should be included in the scope of the study and calibration information that can be used to verify the accuracy of the modeling of those storm events.

Initial data collection efforts and general project knowledge should provide sufficient information to determine the potential for a project to advance to Phase 2. If data are not readily available or are difficult to estimate, the analysis should be discontinued for that project.

## 3.3 Iowa Study: Phase 1 – Initial Project Selection and Screening

FEMA initiated the Iowa study in 2009 with the cooperation of Iowa Homeland Security & Emergency Management. The two agencies worked together to develop a project list for the study based on the following:

- **Area of Interest** – Black Hawk, Carroll, Clayton, Des Moines, Hancock, Johnson, Lee, Polk, and Winnebago counties
- **Hazard Type** – Riverine flooding
- **Project Type** – Minor localized flood reduction projects
- **Study Baseline Date** – Mitigation projects completed between March 1996 and November 2007

FEMA and the State selected the nine projects for the Iowa study (see **Table 1.1**). The projects were screened for data availability, and their potential for proceeding through all three phases of the LAS was determined to be high. Project files available from the State included historical damage, project costs, and building data. The State also identified local contacts who could lead site visits and provide information not available in the project files.

Site visits were conducted in February 2010. During the site visits, an inventory of facilities inundated by previous flooding events was developed. Photographs of the project areas were gathered, elevations of HWMs were obtained, and first-hand accounts of the damage were noted. The physical conditions of the project sites were noted for use in the Storm Event Analysis (see **Section 4.1**) and Hydraulic Analysis (see **Section 4.2**). Contact information for commercial building managers and residential building owners was collected in case more data were needed during Phases 2 and 3.

# Section Four:

## Phase 2 – Physical Parameter Analysis

Phase 2 (Physical Parameter Analysis) consists of a Storm Event Analysis, a Hydraulic Analysis, and a Flood Boundary Analysis. The steps for completing Phase 2 are shown in **Figure 4.1**.

- **Storm Event Analysis** – Conducted to identify potentially damaging storm events that have occurred since the study baseline and to assess data availability. Data include HWMs or stream/precipitation gage readings. If precipitation gages are used, a hydrologic analysis must be completed as part of this analysis to convert rainfall data to flow at the project site.
- **Hydraulic Analysis** – Conducted to determine flow characteristics in the project area and the water surface elevations (WSEs) from known storm events.

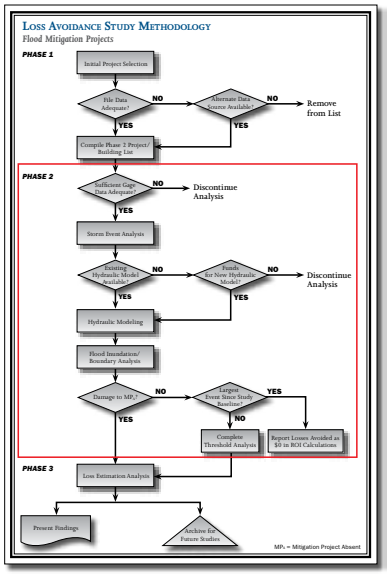
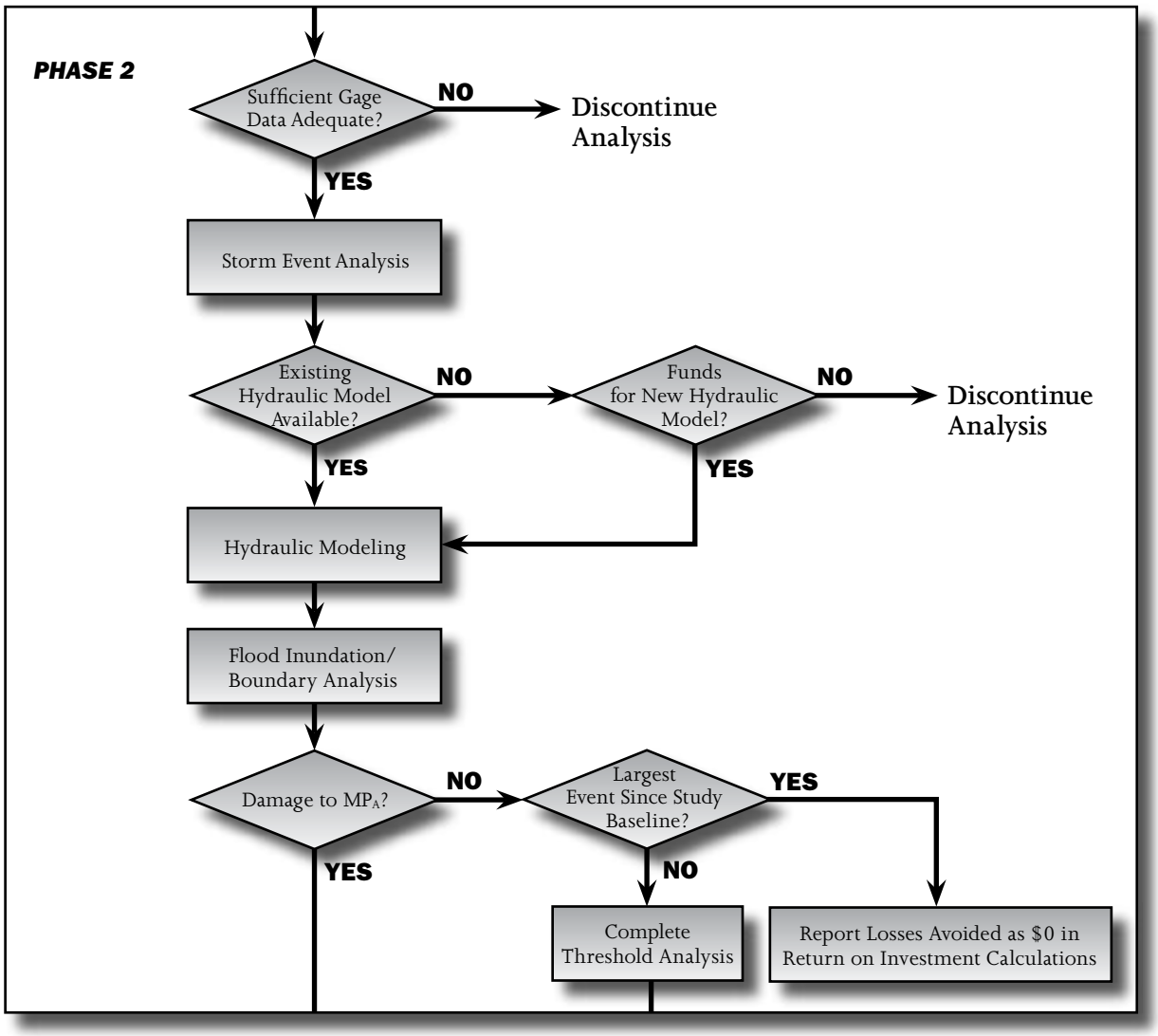



*Figure 4.1*

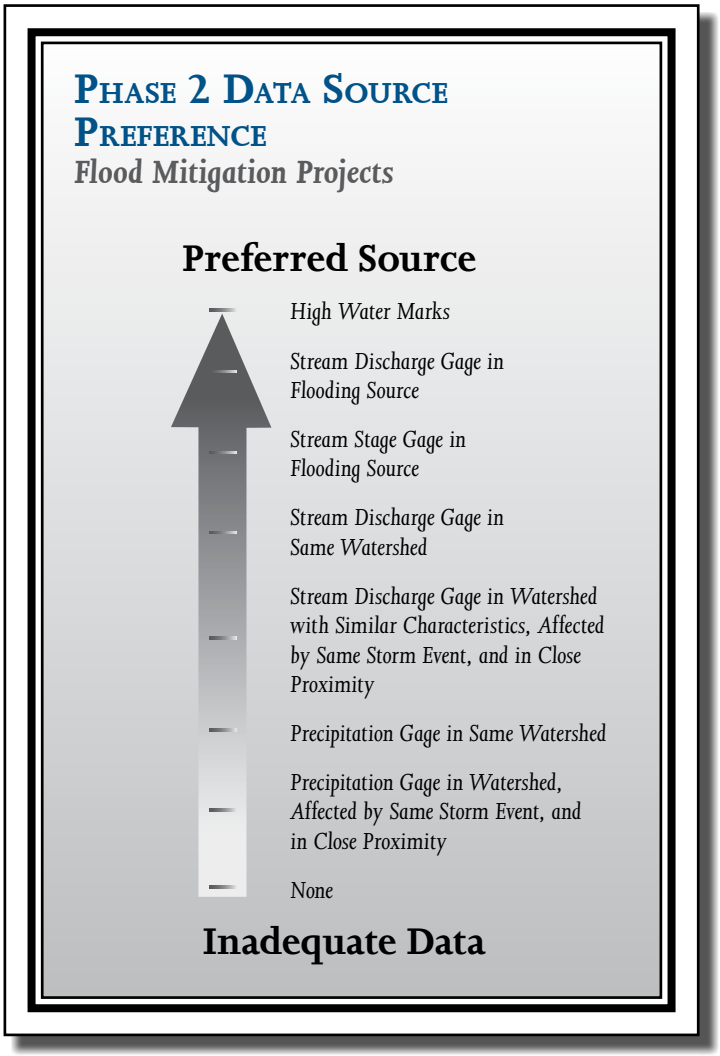


- **Flood Boundary Analysis** – Conducted to delineate the extent and depth of flooding for the storm events being analyzed in the $MP_A$ and $MP_C$ scenarios.

## 4.1 Storm Event Analysis

An LAS of a flood mitigation project can be conducted only if at least one storm event severe enough to have caused damage in the $MP_A$ scenario has occurred since the study baseline (completion date) for that project. The purposes of the Storm Event Analysis are to identify the storm events since project completion and to determine the availability of relevant storm event data. Data can include HWMs from floods, stream gage discharge data, stream gage stage data, and precipitation gage data. See **Figure 4.2** for the sources of storm event data for flood mitigation projects, listed in order of preference.

*Figure 4.2*



After HWMs, stream gage data are the next best source of data. If no HWMs were recorded, the availability of sufficient stream gage data should be determined. The stream gage should be in or near the study area and have a period of record covering the event(s) of interest. Stream gage data may include measurements of stage (WSE), discharge (flow rate), or both. When no stream gage data are available, precipitation gages must be located. If precipitation gages are used, a hydrologic analysis must be completed to convert rainfall data to flow at the project site.

If no storm event data for a flooding source are available, the projects affected by the flooding source may be eliminated from the study. A list of peak events since the first mitigation activity was completed can be compiled from the gage data during this phase if the scope of the study calls for the analysis of more than one event.

## 4.2 Hydraulic Analysis

A Hydraulic Analysis is used to determine the WSE at locations of interest for both the $MP_A$ and $MP_C$ scenarios. When hydraulic modeling is used, peak flows determined in the Storm Event Analysis (see **Section 4.1**) are used for the discharges in the hydraulic model. The hydraulic model is used to estimate WSEs at a series of cross sections for the event(s) of interest. A hydraulic model for each event may not be necessary if available HWMs (for the $MP_C$ scenario) or WSE profiles developed from existing hydraulic models (for the $MP_A$ scenario) are sufficient to determine the WSE for the storm events of interest.

A hydraulic model for the study area may already exist. If a flooding source has been studied in sufficient detail for a Flood Insurance Study (FIS), it may be possible to obtain a copy of the hydraulic model used to develop the FIS. Results from the hydraulic model can be used to interpolate actual storm events, or the model may be able to be modified simply by replacing the original discharges with discharges for the events of interest. However, only portions of the original model may be applicable, especially if a channel has migrated or other physical modifications have occurred since the model was developed.

When an existing hydraulic model is not available, a model of the flooding source in the project area may need to be created. The required parameters would be cross-section elevation data, roughness coefficients, boundary conditions, discharges (from the Storm Event Analysis), and data for any hydraulic structures in the model area. Detailed topographic data for the project area

are necessary for the creation of channel cross sections. Outlier projects or projects located where adequate topographic data are not available should be removed from the study. Projects located on flooding sources with available hydraulic modeling or located on flooding sources that can be modeled appropriately can proceed to the Flood Boundary Analysis.

## 4.3 Flood Boundary Analysis

In LASs for flood reduction projects, the Flood Boundary Analysis is the final step of Phase 2. The purpose is to delineate the floodplain and associated flood depths to determine whether buildings and infrastructure would have been affected during the event(s) of interest for both the $MP_A$ and $MP_C$ scenarios.

Most Flood Boundary Analyses are conducted using Geographic Information System (GIS) software. The cross sections from the hydraulic model are digitized and attributed with peak $MP_A$ and $MP_C$ WSEs for each flood event of interest. Flood elevations are then interpolated and converted to a water surface layer to account for flood elevations in all areas between the cross sections. The water surface layer is extended until it intersects with surrounding topography. All buildings and infrastructure within the $MP_A$ and $MP_C$ flood boundaries are then inventoried.

If buildings are found within the flood boundary and FFE data are available, the WSE is extracted from the flood elevation surface at the building location, and the FFE is subtracted from the WSE to determine the depth of flooding in the building. When the FFE is unknown, detailed topographic information is needed to calculate the flood depth between the ground and the WSE. The FFE is first estimated by adding a standard offset value to the ground elevation at the building determined from detailed topographic information. The standard offset value depends on the type of building foundation and is based on FEMA's Hazards U.S. – Multi-Hazard (HAZUS-MH) guidance (FEMA, 2009b). The flood depth at each building is then calculated by subtracting the estimated FFE from the WSE.

## 4.4 Iowa Study: Phase 2 – Physical Parameter Analysis

The Physical Parameter Analysis for the Iowa study is described in this section. See **Appendices A through I** for additional information regarding the Physical Parameter Analysis for each project.

### 4.4.1 Storm Event Analysis

As stated in **Section 3.3**, HWM data and information about flooding events since the study baseline were collected during the February 2010 site visits. See **Table 4.1** for the types of data collected for each project and used in the Physical Parameter Analysis. The projects with applicable stream gages in the project watershed were identified, and daily and annual peak data were obtained for the entire period of record since the completion date for each project. For projects without a stream gage in the project watershed, gages in nearby watersheds were used to compute an equivalent flow using basin transfer techniques adapted from methods provided in *Techniques for Estimating Flood Frequency Discharges for Streams in Iowa* (USGS, 2001). Basin transfer techniques were also used for ungaged sites on gaged flooding sources. When stream gage data were not available, the runoff was calculated from rainfall data collected from precipitation gages using an appropriate hydrologic analysis method. The information was reviewed to identify the storm events occurring after the study baseline that could have caused

***Table 4.1***

**Data Sources for the Physical Parameter Analysis in the Iowa Study**

| Project Name | Flooding Source | Type of Data Collected | Gage Name or Number |
|---|---|---|---|
| ***Burlington Municipal Water Works Project*** | Mississippi River | • HWM<br>• Stream Gage – stage and discharge | USACE gage: Mississippi River at Burlington and numerous USGS gages in adjacent watersheds |
| ***Cedar Falls Utilities Flood Protection Project*** | Cedar River | • HWM<br>• Stream Gage – stage | USACE gage: Cedar River at Cedar Falls<br>USGS gage #05463050 |
| ***Coralville Flood Control Project*** | Iowa River, Clear Creek | • HWM<br>• Stream Gage – discharge<br>• Precipitation Gage | USGS gages #05454300, #05454500, and #05453600 |
| ***Des Moines, Central Campus Floodgates Project*** | Raccoon River | • HWM<br>• Stream Gage – stage | USGS gage #05484900 |
| ***Elkader Flood Protection Project*** | Turkey River | • HWM<br>• Stream Gage – stage and discharge | USGS gages #05412020 and #05412500 |
| ***Forest City Flood Protection Project*** | Winnebago River | • Stream Gage – discharge | USGS gage #05459500 |
| ***Manning Well Head Project*** | West Nishnabotna River | • Stream Gage – discharge | USGS gage #06807410 |
| ***McGregor Floodwall Project*** | Mississippi River | • Stream Gage – stage and discharge<br>• Precipitation Gage | USGS gage #05389500, NOAA Gage #135315 |
| ***Montrose Floodproofing Project*** | Mississippi River | • HWM<br>• Stream Gage – stage | USACE gage: Mississippi River at Fort Madison |

HWM = high water mark
NOAA = National Oceanic and Atmospheric Administration
USACE = U.S. Army Corps of Engineers
USGS = U.S. Geological Survey

damage in the $MP_A$ scenario or that actually caused damage in the $MP_C$ scenario.

### 4.4.2 Hydraulic Analysis

Hydraulic data collected for the Iowa study included design drawings, as-built drawings, flood studies, and flood maps. All hydraulic data provided in the project files were hardcopy reproductions of drawings, drainage master plans, or other drainage studies.

Hydraulic model computations were performed only for the Hydraulic Analysis of the Forest City Flood Protection Project. For other projects, when FIS or U.S. Army Corps of Engineers (USACE) flood profiles were available, WSEs were found through interpolation of the profiles (typically for the 10-, 50-, 100-, and 500-year events).

Many flood reduction projects alter flooding conditions at the project site and require separate hydraulic models for the $MP_A$ and $MP_C$ scenarios in an LAS. However, the projects in the Iowa study are not extensive enough to affect WSEs in the project area; the projects protect either one building or a few facilities, such as a building and lagoons. Creating a separate hydraulic model for the two scenarios was therefore unnecessary. See **Section 4.4.3** for more information about why the flood levels could be the same in the $MP_A$ and $MP_C$ scenarios for the projects in this study.

See **Table 4.2** for information about the methods that were used to estimate WSEs on the flooding sources for the nine projects. See **Appendices A through I** for additional information regarding the Hydraulic Analyses conducted in this study.

### 4.4.3 Flood Boundary Analysis

In general, building modification projects remove a building from a flood hazard while flood reduction projects reduce the flood hazard at the project site. In an LAS for a building modification project, the final step of Phase 2 is a Flood Inundation Analysis, but in an LAS for a flood reduction project, the final step is a Flood Boundary Analysis. For building modification projects, the flood levels, and therefore the flood boundaries, are the same in both the $MP_A$ and $MP_C$ scenarios. The Flood Inundation Analysis is performed to compare the building location and elevation in each scenario to the WSE at the property location.

*Table 4.2*

**Hydraulic Analysis Methodology for the Iowa Study**

| Project Name | Flooding Source | Hydraulic Analysis Methodology |
|---|---|---|
| ***Burlington Municipal Water Works Project*** | Mississippi River | WSE interpolated using USACE flood profiles and Upper Mississippi River Flow Frequency Query (USACE, 2004) |
| | Flint Creek | WSE interpolated using FIS flood profiles (FEMA, 1985) |
| ***Cedar Falls Utilities Flood Protection Project*** | Cedar River | WSE interpolated using FIS flood profiles (FEMA, 1984); HWM compared directly to FFEs |
| ***Coralville Flood Control Project*** | Iowa River | WSE interpolated using FIS flood profiles (FEMA, 2007a) |
| | Clear Creek | Flooding controlled by Iowa River |
| ***Des Moines, Central Campus Floodgates Project*** | Raccoon River | WSE interpolated using USACE flood profiles (USACE, 2005) |
| ***Elkader Flood Protection Project*** | Turkey River | WSE interpolated using FIS flood profiles (FEMA, 1996a) |
| ***Forest City Flood Protection Project*** | Winnebago River | WSE determined using HEC-RAS model with event discharge as input; HEC-RAS model constructed using hard-copy HEC-2 model (FEMA, 2009c) |
| ***Manning Well Head Project*** | West Nishnabotna River | WSE computed using normal depth equation |
| ***McGregor Floodwall Project*** | Mississippi River | WSE interpolated using USACE flood profiles and Upper Mississippi River Flow Frequency Query (USACE, 2004) |
| | Non-riverine flash flooding | WSE computed using normal depth equation |
| ***Montrose Floodproofing Project*** | Mississippi River | WSE interpolated using USACE flood profiles and Upper Mississippi River Flow Frequency Query (USACE, 2004) |

FEMA = Federal Emergency Management Agency
FFE = first floor elevation
FIS = Flood Insurance Study
HEC = Hydrologic Engineering Center
HEC-RAS = Hydrologic Engineering Center River Analysis System
HWM = high water mark
USACE = U.S. Army Corps of Engineers
WSE = water surface elevation

This study was unusual because a Flood Inundation Analysis, rather than a Flood Boundary Analysis, was conducted for seven of the nine flood reduction projects. Two of these projects consisted of modifications to the existing facilities (raising well heads in Manning and construction of a new control building on higher ground in Montrose), and the other five consisted of flood barrier projects (e.g., berms, levees, floodwalls). Although flood barrier projects are considered flood reduction projects, for the projects in this study, the flood barriers would protect only a single building or a small number of facilities, and the flood levels outside the flood barrier would likely be the same in both scenarios. Therefore, it was not necessary to determine flood boundaries for both the $MP_A$ and $MP_C$ scenarios. Consequently, these projects could be analyzed using the same method as the analysis for a building modification project, and only a Flood Inundation Analysis was needed to determine whether a flood event had occurred that would have breached the flood barrier and inundated the protected facility.

**Table 4.3** lists the nine projects included in this study and whether a Flood Boundary Analysis or a Flood Inundation Analysis was performed in Phase 2. The table also lists the projects that were

*Table 4.3*

**Flood Inundation and Flood Boundary Analyses in the Iowa Study**

| Project Name | Type of Analysis | Project Advanced to Phase 3? |
|---|---|---|
| *Burlington Municipal Water Works Project* | Flood Inundation | Yes |
| *Cedar Falls Utilities Flood Protection Project* | Flood Inundation | Yes |
| *Coralville Flood Control Project* | Flood Boundary | No |
| *Des Moines, Central Campus Floodgates Project* | Flood Boundary | Yes |
| *Elkader Flood Protection Project* | Flood Inundation | Yes |
| *Forest City Flood Protection Project* | Flood Inundation | No |
| *Manning Well Head Project* | Flood Inundation | Yes |
| *McGregor Floodwall Project* | Flood Inundation | Yes |
| *Montrose Floodproofing Project* | Flood Inundation | Yes |

advanced to Phase3 because the facilities protected by the projects would have sustained greater damage in the $MP_A$ scenario than in the $MP_C$ scenario.

Based on the results of Phase 2, all projects except the Coralville Flood Control and Forest City Flood Protection projects advanced to Phase 3 (see **Table 4.3**). For these two projects, it was determined that losses were not avoided, and the ROI was zero.

The data collected during the site visit for the Coralville Flood Control Project indicated that the three pumps that were installed as part of the project have operated for only 30 hours since project completion and have sometimes activated without a reason. The Phase 2 results also indicated that since implementation, only one significant rain event has coincided with high river flows, preventing drainage by gravity and potentially requiring the use of the pumps. However, the river levels were so high in this event that the levees overtopped, which completely flooded the area and overwhelmed the pumps, rendering them ineffective. Therefore, although an event large enough to have caused damage in the $MP_A$ scenario occurred, the damage sustained in the $MP_C$ scenario would have been identical since the project was ineffective. No losses would have been avoided. Therefore, detailed topographic data used to estimate flood depths within the flood boundary were not required. See **Appendix C** for more information.

The Phase 2 results for the Forest City Flood Protection Project indicated that an event large enough to have caused damage in the

$MP_A$ scenario had not occurred since implementation of the project. See **Appendix F** for more information.

Detailed topographic data were required only for the Flood Boundary Analysis performed for the Des Moines, Central Campus Floodgates Project. The ground elevation data were obtained from the Iowa LiDAR Consortium (GeoTREE, n.d.). The ground elevations were represented as a bare-earth digital elevation model (DEM) derived from LiDAR data. See **Appendix D** for more information.

# Section Five:

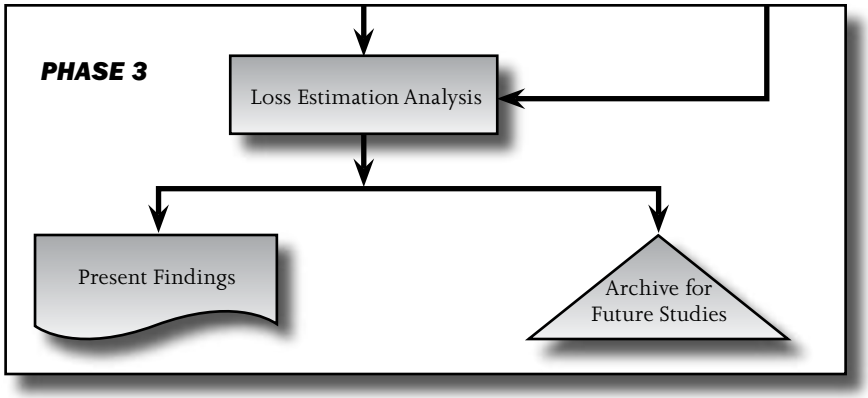
## Phase 3 – Loss Estimation Analysis

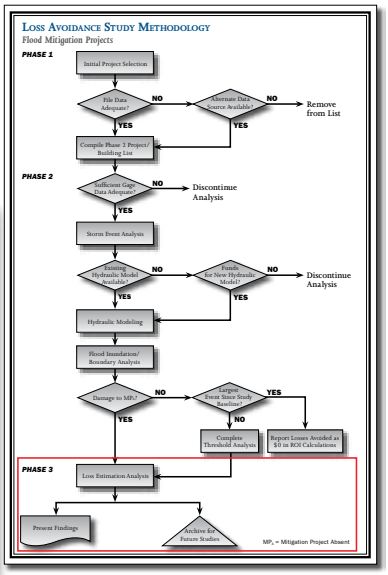
The final phase of an LAS consists of a Loss Estimation Analysis, in which the value of the losses avoided are estimated, based on the effectiveness of the mitigation project in storm events since the study baseline. The methodology is illustrated in **Figure 5.1**.

The two major tasks in Phase 3 are:

- Calculating losses avoided
- Calculating the ROI

*Figure 5.1*




## 5.1 Approach for Calculating Losses Avoided

During Phases 1 and 2 of the LAS, the following information is determined:

- The storm events that have occurred since the study baseline that would have caused damage in the $MP_A$ scenario
- The number and type of buildings and infrastructure affected by the storm events being analyzed in the $MP_A$ and $MP_C$ scenarios
- The depth and extent of flooding in the $MP_A$ and $MP_C$ scenarios, estimated during the Flood Boundary Analysis

In Phase 3, the dollar value estimate of the damage that would have occurred if the mitigation project not been completed ($MP_A$) and the damage that did occur after the mitigation project was implemented ($MP_C$) must be determined.

The losses for buildings and infrastructure are calculated for both the $MP_A$ and $MP_C$ scenarios for each flood event studied in Phase 2.

Losses avoided (in dollars) are then calculated by subtracting $MP_C$ damage from the $MP_A$ damage, using the formula shown in **Figure 5.2**.

*Figure 5.2*

**Loss Estimation Analysis**

$$MP_A - MP_C = LA$$

Where $MP_A$ = Mitigation Project Absent
Where $MP_C$ = Mitigation Project Complete
Where **LA** = Losses Avoided

$MP_C$ damage may not exist if no events occurred that exceeded the capacity of the flood reduction project. When losses are calculated, all of the losses should be given in 2010 values. If historical losses from similar events are used as estimates, they should be adjusted to 2010 values.

### 5.1.1 Loss Categories

Once the Flood Boundary Analysis is complete and the potentially affected buildings and infrastructure have been inventoried, flood damage must be evaluated. As shown in **Table 5.1**, potential damage is divided into loss categories. Loss categories generally include physical damage, loss of function, emergency protective measures, and nontraditional benefits, all of which contain multiple loss types. **Table 5.1** reflects the potential damage types for any flood mitigation project.

When possible, data regarding actual damage should be used for the $MP_C$ scenario. However, because the $MP_A$ scenario is theoretical, damage from prior similar events or other methods of estimating losses must be used. The approach used for estimating flood damage is based on the FEMA Benefit-Cost Analysis (BCA) Tool Version 4.5[2] unless stated otherwise. For more information regarding loss calculations, see *Loss Avoidance Study: Riverine Flood Methodology Report* (FEMA, 2009d).

2 All references to the FEMA BCA Tool in this document are to the Benefit-Cost Analysis Tool, Version 4.5 (FEMA, 2009a)

*Table 5.1*

**Loss Estimation Categories and Types**

| Loss Category | Loss Type |
|---|---|
| ***Physical Damage*** | • Buildings<br>• Contents<br>• Roads and Bridges<br>• Infrastructure<br>• Landscaping<br>• Environmental Impacts<br>• Vehicles/Equipment |
| ***Loss of Function*** | • Displacement Expense<br>• Loss of Rental Income<br>• Loss of Business Income<br>• Lost Wages<br>• Disruption Time for Residents<br>• Loss of Public Services<br>• Economic Impact of Utility Loss<br>• Economic Impact of Road/Bridge Closure |
| ***Emergency Protective Measures*** | • Debris Cleanup<br>• Governmental Expense |
| ***Nontraditional Benefits*** | • Emergency Response Services<br>• Avoidance of Mental Stress and Anxiety<br>• Fire Suppression<br>• Hazardous Materials Cleanup<br>• Historic and Cultural Heritage Preservation<br>• Floodplain and Wetland Protection<br>• Recreational Activities<br>• Volunteers and Non-Governmental Organizations<br>• Reduced Insurance Transaction Costs Including Project Worksheets |

*Source: FEMA (2007b)*

### 5.1.2 Depth-Damage Functions

Established depth-damage relationships are commonly used for determining losses caused by flood hazards. These relationships, which have been developed by FEMA, USACE, and other agencies using observed data from historical events and expert elicitation, generally identify the loss that is likely to occur at certain intervals (e.g., flood depths). See **Appendix J** for the depth-damage functions (DDFs) used in this study.

For example, the FEMA BCA Tool was developed to standardize determinations of cost-effectiveness for mitigation projects and includes damage curves for determining damage based on the severity of an event. The damage curves included in the FEMA BCA Tool can be adapted to an LAS. For the flood module of the FEMA BCA Tool, default DDFs are included for various residential, public, and commercial types of buildings based on information from FEMA's expert elicitation and the USACE. The modules include curves for building damage, building contents damage,

displacement time, and loss of public services. No standardized curve currently exists in the FEMA BCA Tool for disruption time for residents, and the time must therefore be estimated.

The USACE St. Paul District has also developed DDFs based on regional conditions. The regional DDFs are currently being used by both the USACE St. Paul and Rock Island districts, which cover the majority of Iowa. Because Iowa building stock is similar to the buildings used to develop the regional DDFs, these DDFs are appropriate for use in Iowa and therefore were used for this study. The USACE St. Paul District DDFs were used as input files for the USACE Hydrologic Engineering Center Flood Damage Analysis Program (HEC-FDA) and include curves for various residential, public, and commercial types of buildings. An advantage of the USACE St. Paul District DDFs is that they also include DDFs for commercial building basement damage, which are not available in many of the FEMA BCA Tool DDFs for nonresidential buildings. The USACE St. Paul District DDFs use a separate DDF for basement damage, which can be combined with another DDF that addresses the first floor damage. However, unlike the FEMA BCA Tool DDFs, only physical damage (i.e., building damage and building contents damage) are included. Because the USACE St. Paul District functions are applicable to Iowa, they were used in this LAS to estimate building and building contents damage.

## 5.2 Loss Categories

The loss categories listed in **Table 5.1** that are relevant to the Iowa study and the methods that were used to estimate damage in each category are described in this section.

### 5.2.1 Physical Damage

For an LAS for a flood reduction project, physical damage includes the direct damage to a building and its contents and direct damage to infrastructure. Physical damage can be estimated using:

- Historical damage from events of similar size
- DDFs and known flood depths (developed during the Flood Boundary Analysis) for buildings
- Engineering analysis or professional judgment to estimate damage for infrastructure

When available, actual repair costs (or replacement costs if the facility was substantially damaged) should be used to estimate losses, especially if similar flood events have occurred in the past.

Historical damage data may be obtained from various sources such as homeowners' insurance claims, the National Flood Insurance Program BureauNet database, Small Business Administration loan application data, local contractors, and interviews of homeowners. The BCA that was performed for the HMA grant application of the mitigation project may also contain historical damage data.

Additionally, for events that were Presidentially declared major disasters, FEMA may have provided grants under the Public Assistance Program for repairs to buildings and other facilities owned by public entities and certain private, nonprofit organizations. Damage and repair information may be obtained from Damage Survey Reports (DSRs) or Project Worksheets that FEMA prepared to document eligible costs under the Public Assistance Program.

If historical information is not available, the losses must be estimated. The USACE St. Paul District functions described above provide standardized DDFs relating depth of flooding to building and contents damage (calculated as a percentage of the BRV). The BRV used with basement curves is the value of the entire building, including the value of the basement. The BRV used with other building type curves (without basement) is the value of the first floor area only. Damage to other facilities must be based on engineering analysis or professional judgment.

In the Iowa study, physical damage to buildings, their contents, and utilities were included. A description for estimating damage to those types of facilities is therefore provided below.

#### 5.2.1.1 Building Damage

If historical damage information from similar events is not available, the damage must be estimated. To evaluate the building damage, the following steps must be followed for each building:

- An inventory of the building must be completed to determine characteristics such as type of building, number of floors, and FFE. This type of information is generally obtained from project files, site visits, or by searching community databases such as tax assessment and parcel data.
- A determination of the BRV for each inundated building must be made. Only the BRV, and not the fair market value of the building, should be used. The BRV can be estimated based on values provided by local officials or local contractors or by using nationally recognized cost-estimating guides.

Once the BRV and building type are known, damage for various flood scenarios can be estimated using the flood depth-damage relationships discussed previously. To do so, the following steps should be taken:

- A selection of the appropriate DDF for the building type must be made. Then, the flood depth (determined through the Flood Boundary Analysis) must be correlated with the appropriate percent damage ratio from the depth-damage curve to estimate the percent damage to each building.
- The percent damage ratio must be multiplied by the BRV to calculate the building damage for the flood event.

If the percent damage determined from the depth-damage curve exceeds 50% for a typical building, the building should be assumed to be substantially damaged and would be replaced rather than repaired. In those instances, the building damage should be calculated as equal to the total BRV. It should be noted that the substantial damage threshold can vary. For example, if the building is extremely substandard, the threshold would be lower, or if the building is historic, the threshold may be higher.

#### 5.2.1.2 Contents Damage

If historical damage information from similar events is not available, the damage must be estimated. The process used to calculate damage to contents within each building is similar to calculating damage to the building.

- The value of the contents may be determined through owner interviews, insurance information, and tax records. The estimation of contents damage should include a consideration of the depth of flooding in relation to the damage. For specialized facilities such as water treatment plants, wastewater treatment plants, and power plants, this method should be used because the value of contents is usually specific to the facility being studied. For example, a sewage lift station may have a certain number of pumps, depending on the population served by the station, and an electrical cabinet may be completely damaged and lose functionality from a flood depth of only a few inches.
- When the actual value of the contents is unknown, damage to the contents can be estimated. However, this method should not be used for specialized facilities. For general facilities, the contents damage may be estimated based on the BRV and an appropriate contents-to-building ratio. For the USACE St. Paul District DDFs, the contents-to-building ratios are either 50% or 100%, based on the building type. When the appropriate ratio has been determined, the ratio is multiplied by the BRV to find

the value of the contents. The flood depth (determined through the Flood Boundary Analysis) must be correlated with the appropriate percent damage ratio from the depth-damage curve to estimate the percent damage to the contents. The percent damage ratio must be multiplied by the total contents value to calculate the contents damage for the flood event.

#### 5.2.1.3 Utilities

Water, wastewater, electric transmission, gas transmission, and telecommunications systems are considered utilities. Since depth-damage curves do not apply to utilities, damage to utilities is estimated using actual costs from past events and evaluations by subject matter experts.

When available, actual damage costs for previous similar events should be used to estimate utilities damage. Local officials and utility owners, such as special districts and private utility companies, can provide information about damage from previous events. Further, repairs to disaster-related damage may have been funded under the Public Assistance Program, and DSRs or Project Worksheets documenting damage to utilities may be available.

If actual damage information is not available, losses may be based on engineering estimates or professional judgment of expected damage. Using flood depths determined in the Flood Boundary Analysis, the utility must be analyzed to determine which components of the system would be vulnerable to flooding and the damage that would occur to those components if flooded. The cost to repair or replace those components can then be determined. Chapter 7 of the *HAZUS-MH MR4 Technical Manual* provides further guidance for direct damage estimates to utility components (FEMA, 2009b).

### 5.2.2 Loss of Function

For an LAS, loss-of-function damage is the economic impact to an individual or the community that occur when a facility is damaged, and the normal function of the facility is disrupted because of the flood. Loss-of-function damage can vary extensively depending on the type of facility damaged.

As with physical depth-damage relationships, published relationships between flood depth and functional downtime and loss-of-function costs can be used to calculate these costs for buildings. For infrastructure, standard unit values for the loss of service are available. For example, the FEMA BCA Tool contains

methodologies and values that can be used to calculate loss of function. The *HAZUS-MH MR4 Technical Manual* (FEMA, 2009b) contains methods similar to the FEMA BCA Tool, with regional adjustments to various loss-of-function methods. Additionally, USACE publications on post-disaster impacts from flooding contain information about loss of function in specific locations.

Communities may also provide costs from past events that demonstrate the impact of the events. In these cases, local values provide a more accurate representation of a project area than the national or regional values from tools such as the FEMA BCA Tool or HAZUS-MH.

Loss of function may include displacement expenses, loss of business income, loss of public services for public buildings, and loss of utility services. These loss types are discussed in the following subsections. Not all of the loss-of-function types that are discussed apply to every project in this study. Refer to the **Appendices A through I** for information about which loss-of-function types apply to each project, if any.

#### 5.2.2.1 Displacement Expense

Displacement time is the period during which occupants are displaced from a building in order for repairs to be made. The loss is therefore associated with the cost of renting a temporary space during the displacement. Displacement should be included in the analysis only if a temporary alternate location is necessary to continue the function of the damaged building while it is being repaired.

The losses associated with displacement can be calculated once a determination of per-unit costs for the displacement of occupants is made. The FEMA BCA Tool provides standard values that can be used to calculate costs for displacement, based on a national average of rental costs per unit area. For example, the costs for residential displacement include rental costs for temporary facilities, which are estimated as $1.44 per square foot per month. If area-specific rental costs are available, they will produce a more appropriate estimate of the actual displacement expense and should be used. Area-specific values can be determined through historical information, information from real estate agents and rental companies, or from emergency assistance organizations such as the American Red Cross. The FEMA BCA Tool also provides standard values for one-time displacement costs. These costs are based on building use and include one-time costs such as moving fees and utility hookup fees.

Flood depths must be correlated with the appropriate displacement time in the depth-damage curve, and the number of displaced days must be multiplied by the displacement expense for each day to calculate the loss.

#### 5.2.2.2 Loss of Business Income

A loss of business income may occur for commercial buildings when damage is severe enough to result in temporary loss of function of a building. The proper measure of loss of business income is the net income, not the gross income, because expenses as well as receipts are lower when a business is closed.

Business losses can be estimated using the following methods. The results should be validated through field observation and discussion with local representatives.

- The economic impact of each lost day of operation must be calculated by dividing annual net income by 365.
- The number of days the business would be interrupted because of flooding should be obtained from historical losses (closure time) from similar events, if available. If this information is not available, the number of days must be estimated. The standard curve for loss-of-function time provided in the FEMA BCA Tool can be used to calculate business interruption. The *HAZUS-MH MR4 Technical Manual* (FEMA, 2009b) also provides guidance for determining business interruption time based on percentage of building damage.
- The number of days the business would be interrupted must then be multiplied by the economic impact of each lost day.

#### 5.2.2.3 Loss of Public Service

If a building is a public building that would temporarily close in a flooding event, there is a potential for a loss of public service. Even if the function of the building would be relocated to a temporary facility, there may be loss of function until the temporary facility is activated. Public services include public works departments, police stations, fire departments, and libraries. Additionally, private, nonprofit organizations, such as schools and hospitals that are essentially providing public services, are classified as public services. The FEMA BCA Tool includes a standard curve that correlates loss of function and depth of flooding; the curve is similar to the one that is used for displacement times.

FEMA makes a simple and direct assumption that at a minimum, noncritical public services are worth what it costs to provide the

services to the public. Therefore, the following steps are necessary to calculate the loss of function to a public building:

- The economic impact of each lost day of operation must be established. A loss of public service is assigned an economic value that is equal to the costs necessary to provide that public service. The daily cost of services is estimated from the annual operating budget for the agencies occupying a building. The annual operating budget includes all of the direct costs necessary to provide the public services, including salaries and benefits, materials, supplies, utilities, equipment costs, and rent or the annual cost of owning the building. Local officials or the operators of private, nonprofit entities can provide information about the annual operating budget. This information may also be available on the agency's website.
- The number of days the public service would be interrupted because of flooding should be obtained from historical losses (closure time) from similar events, if available. If this information is not available, the flood depth (determined through the Flood Boundary Analysis) must be correlated with the appropriate loss-of-function time in the depth-damage curve.
- The number of lost days must then be multiplied by the daily cost of services.

The FEMA BCA Tool also provides guidance for calculating loss of function for critical services. Within this guidance, the estimation of the value to society of lost police services has two components. The first component is to measure how a reduced police presence would affect the population of the affected area. The second component is to assign a dollar value to those effects. For fire and medical services, this guidance assumes that a fire station or hospital can substitute for a nearby facility if that facility is unable to function. Many evaluations of public safety functions are based on response time—a faster response is assumed to lead to a better outcome. Closed stations and longer response times should thus lead to increased fire and medical losses.

#### 5.2.2.4 Impact of Utility Loss

Utility services include services such as electric power, potable water, wastewater services, and gas transmission. The economic impact of utility loss is the economic value assigned when a utility service is unable to operate as a result of a flooding event. Because of the importance of these services, the economic impact of utility loss may be much greater than the physical damage to the facility. However, it is important to note that if the project already counts

displacement costs for residential or other facilities, it would be double counting to include loss of utilities for the same customers because it is assumed that the utilities will be operational at the temporary facility.

The following steps are necessary to calculate the economic impact of utility loss:

- The type of utility is determined. The loss of service calculation varies slightly depending on the type of utility. Currently, the FEMA BCA Tool provides loss estimates for electricity, potable water, and wastewater.
- The economic impact of each lost day of operation is determined. This value can be expressed as a dollar value per capita per day or a dollar value per day. The FEMA BCA Tool provides the following values for the economic impact per capita per day:
  - Loss of electricity: $126 per person per day of lost service
  - Loss of potable water service: $93 per person per day of lost service
  - Loss of wastewater service $41 per person per day of lost service

These values are for a complete loss of service only, and it should therefore be determined whether there are redundancies in the utility system before losses are included. If a FEMA standard value is not available for a utility, a value for that service must be estimated.

- The number of days of lost service because of flooding is determined.
- The number of people serviced by the utility is determined. Interviews with utility providers can provide information on the number of people serviced by a particular utility (in most instances, the entire utility service area should not be used, only the percentage of the area protected by the mitigation project). It is important to determine a value based on the number of people being affected rather than on number of customers, as often recorded by utility agencies, if using the FEMA standard values for loss.
- The economic impact of the loss of utility service is multiplied by the number of lost days (and the number of people serviced by the utility, when appropriate).

### 5.2.3 Emergency Protective Measures

The cost of emergency protective measures include the costs related to response and recovery activities conducted by local, State, and

Federal government agencies as a result of a hazard event. For example, the community experiences costs for ensuring public safety. These costs are obtained primarily from historical damage records, such as DSRs or Project Worksheets prepared by FEMA under the Public Assistance Program following Presidentially declared major disasters. If actual costs from previous events are known, they should be used. The following steps can be used to calculate the impacts of other emergency protective measures:

- Local representatives can be interviewed to identify the types of services required and the level of effort required in delivering those services.
- The duration of the flood and the appropriate salary categories can be used to estimate the costs for first responders.
- The estimated flood recovery time and the appropriate salary categories can be used to estimate the impact to other municipal employees. The impact may include cleanup and costs associated with implementing repairs.

If the flood reduction project significantly reduces the costs for emergency protective measures, the benefits of reduced costs for emergency protective measures should be counted.

### 5.2.4 Avoidance of Mental Stress and Anxiety

People can experience acute and chronic psychological problems such as stress, exhaustion, nightmares, depression, and despair following a disaster. Unfortunately, little research has been conducted on the economic impact of these problems.

Parker et al. (1987) found that flood victims in Swalecliffe, England, were more concerned about intangible impacts than direct damage. The intangible impacts were long-term health effects, loss of irreplaceable memorabilia, stress, and worry about future flooding. These results suggest that the unpriced (non-market) values of flood losses may be greater than those that are priced.

Bennet (1970) conducted an often-quoted study of the health effects of a flood in Bristol, England, in 1968. The results of the study include the finding that:

> Surgery attendances rose by 53 per cent, referrals to hospital and hospital admissions more than doubled. In all respects the men appeared less able to cope with the experience of disaster than the women did (p. 454).

A number of studies have found significant mental health impacts associated with floods, wildfires, and hurricanes (Chamberlain et al., 1981; Mental Health Research and Evaluation Centre, 1985; Smith et al., 1990). The studies used surveys to estimate the proportion of the disaster-affected population that was adversely affected and the number of the days of debilitation. The monetary value of the number of days lost through debilitation is usually not provided.

Disasters have a substantial impact on mental health despite the provision of welfare teams to assist the affected population. According to Read Sturgess and Associates (2000), residents of Benalla, Australia, were still traumatized 18 months after the 1993 Benalla Floods despite intensive support to the community.

Expenditures on mental health after disasters are documented in the following studies:

- Following Hurricane Floyd in South Carolina in 1999, FEMA awarded a grant of $100,000 for crisis counseling for the approximately 6,500 persons who were affected by the storm, the equivalent of an average of approximately $15.38 per person ($21.29 per person in 2010 dollars).
- After the terrorist attacks in New York City in September 2001, Project Liberty, the largest federally funded crisis counseling program in history, was launched to assist victims and their families. With funding of approximately $154.7 million, the program is estimated to have reached 2.5 million people for an average expenditure of $61.88 per person, equivalent to $80.73 per person in 2010 dollars.
- Following Hurricane Katrina in 2005, the Substance Abuse and Mental Health Services Administration awarded approximately $20 million to the State of Mississippi to provide crisis counseling services to the population (more than 300,000 persons) in 47 counties, resulting in an average expenditure of approximately $66.58 per person, which is equivalent to $77.19 in 2010 dollars.

The mental stress and anxiety benefit may apply to flood, earthquake, wildfire, and tornado wind hazards. Cost data for crisis counseling can be obtained from FEMA Crisis Counseling program data, local governments, community-based organizations, faith-based organizations, other non-governmental organizations, and private-sector entities that provide crisis counseling services.

## 5.3 Iowa Study: Loss Estimation Analysis

The Iowa study included an evaluation of the following loss categories:

- Physical damage (damage to buildings and building contents)
- Loss of function (displacement costs, loss of public service, loss of utility service, and loss of business income)
- Emergency protective measures (debris removal and cleanup)
- Nontraditional benefits (emergency response costs and avoidance of mental stress and anxiety)

See **Sections 5.3.1** through **5.3.3** for a discussion of the loss categories evaluated in the Iowa study and **Appendices A through I** for information about the loss categories and loss calculations for each project.

### 5.3.1 Iowa Study: Physical Damage

Physical damage generally involved damage to buildings and building contents at each facility. When historical data for building damage or building contents damage were not available, the USACE St. Paul District DDFs were used to estimate the building damage associated with certain flood depths. These DDFs were used in place of the FEMA BCA Tool nonresidential DDFs in order to account for basement damage appropriately. The USACE St. Paul District DDFs are specific to the region that includes Iowa, and are therefore appropriate for this study. These functions were applied to the buildings in the Des Moines, McGregor, and Montrose projects and the Main Sanitary Lift Station at the Elkader project.

Many of the projects considered in the Iowa study involve facilities such as water treatment plants, wastewater treatment plants, and electrical plants with specialized contents and equipment. To estimate building contents damage for these facilities, actual contents costs were obtained from discussions with local representatives during site visits, and equipment values were obtained from FEMA project closeout files. The damage estimates included a consideration of the severity and depth of flooding required to yield certain levels of damage. For example, at the Elkader lagoon control building, a flood depth of only a few inches would damage the control equipment severely and require it to be replaced. Building content costs were inflated to 2010 values when appropriate.

For certain projects, physical damage included damage to nonbuilding facilities, such as the aeration equipment in the lagoons

for the Elkader Flood Protection Project. Damage estimates for such facilities were obtained from discussions with local representatives during site visits and also included a consideration of the level of damage associated with certain depths of flooding.

### 5.3.2 Iowa Study: Loss of Function

The types of loss of function that applied to the projects in the Iowa study were displacement costs, loss of public service, loss of utility service, and loss of business income. The types of loss of function varied from project to project.

For the projects involving public utilities, such as the McGregor Floodwall Project and the Elkader Flood Protection Project, loss of function in general related to the loss of utility service for the population served by the utility. The loss occurred or would have occurred if service equipment could not function properly because of the flooding. The value of the loss of utility service was determined using the FEMA standard values for loss of service, the population served by the utility, and the number of days of lost service. The number of days of lost service was obtained from discussions with local representatives during the site visit or estimated from the days of lost service incurred for comparable facilities during a flood event of similar size.

Displacement costs and loss of business income applied only to the Des Moines project because the buildings affected by this project were mostly private businesses, several which would be able to displace to a temporary facility to continue normal operations. However, displacement costs and lost income were not calculated for the Des Moines project because the value of the physical damage by itself yielded a high ROI. In contrast, displacement costs and loss of business income did not apply to the other projects because loss of function is usually measured in terms of a public service lost to the community for most utility facilities. It is usually difficult to find a temporary building that serves the same purpose as the original building for utility facilities.

### 5.3.3 Iowa Study: Emergency Protective Measures

The emergency protective measures considered in the Iowa study were debris removal and cleanup. The costs for these activities were obtained from FEMA project closeout files or discussions with local representatives during the site visit. In general, the labor costs involved in cleanup were estimated based on the FEMA standard value of labor ($28.11 per hour) and the number of laborers and hours required for the cleanup. For the Manning Well Head

Project, a specialized contractor would be required for the cleanup of contaminated wells. The labor rate for the specialized contractor was obtained from discussions with engineers familiar with well contamination.

### 5.3.4 Iowa Study: Nontraditional Benefits

The nontraditional benefits considered in the Iowa study were emergency response costs and the avoidance of mental stress and anxiety. Emergency response costs included the costs for materials and labor involved with procedures such as sandbagging or the installation of temporary flood barriers. If actual labor and material costs were available from FEMA Project Worksheets, these costs were used for $MP_C$ damage if the Project Worksheet was for the particular flood event being studied. In addition, if actual emergency response efforts were performed for certain flood events, as determined through discussions with local representatives during the site visit, these costs were also included in the loss calculations.

The avoidance of mental stress and anxiety is applicable only to the Burlington Municipal Water Works Project. In both the $MP_A$ and $MP_C$ scenarios, no building damage, contents damage, or loss-of-function costs were incurred because the floodwaters would not have reached the water treatment building. However, many workers expressed a sense of relief knowing that the facility would be protected with the new stop logs and pumps. The mental stress and anxiety costs were measured in terms of the additional workers who would need to stay overnight at the facility when a flood was approaching. The FEMA standard value of labor ($28.11 per hour) was used to represent the opportunity cost of the time the workers spent at the facility. This value does not represent an actual labor cost but instead the loss in welfare from being away from family and friends.

## 5.4 Calculating Return on Investment

After calculating the losses for each event considered for each project, the cumulative amount of losses are calculated for both the $MP_A$ and $MP_C$ scenarios. The total losses in the $MP_C$ scenario are then subtracted from the total losses in the $MP_A$ scenario to determine the total losses avoided.

Calculating the ROI is the final task in determining losses avoided. The results vary depending on the number of events evaluated for each project and the resulting level of damage. The formula used in calculating the ROI is shown in **Figure 5.3**.

*Figure 5.3*

**Calculating Return on Investment**

$$\frac{\$\ LA}{\$\ PI} = \%ROI$$

Where **LA** = Losses Avoided
Where PI = Project Investment
Where ROI = Return on Investment

The denominator, Project Investment (PI), is the total project investment for the mitigation project being evaluated. PI does not represent the Federal investment alone. Rather, it is the total investment for the project made by all parties involved. Also, all of the losses avoided are calculated in 2010 values; therefore, the actual costs associated with the mitigation project should also be adjusted to 2010 values.

The numerator, Losses Avoided (LA), represents the total losses avoided for the mitigation project being evaluated. The ROI may be calculated for one or multiple flood events. If multiple events are being evaluated for each mitigation project, then the LA would represent the total losses avoided for all the flood events. Therefore, the ROI would represent the cumulative ROI.

An ROI can be calculated for each mitigation project, by storm event, or for the whole study area (which could include multiple projects). If an ROI is calculated for multiple projects, taking an average of the ROI for each project is not appropriate. The total losses avoided for all of the projects should be added and divided by the total investment costs. This is referred to as aggregation.

## 5.5 Iowa Study: Calculating Return on Investment

In the Iowa study, the ROI was calculated in various ways to provide a series of data.

- An ROI was calculated for each peak storm event considered under each project. See the Summary of Damage sections in **Appendices A through I** for the peak storm event ROIs.

- A total ROI was calculated for each project, which involved determining the total losses avoided over all peak storm events considered for that project. See **Table 5.2** for the project ROIs.
- A total ROI was calculated for the study as a whole, based on the total cumulative losses for all projects and all peak storm events. See **Table 5.2** for the total ROI.

The actual cost of project construction, available from FEMA project files, was adjusted from the project completion data to 2010 values because all of the losses were calculated in 2010 values.

As shown in **Table 5.2**, the Des Moines, Central Campus Floodgates Project has the highest project ROI (9,758%), followed by the McGregor Floodwall Project (641%), Elkader Flood Protection Project (543%), Montrose Floodproofing Project (224%), and Manning Well Head Project (46%). The Burlington Municipal Water Works Project and Cedar Falls Utilities Flood Protection Project had ROIs of 1% or less because the losses avoided were small compared to the project cost. For the Burlington Municipal Water Works Project, the only losses avoided were cleanup costs, avoidance of mental stress and anxiety, and emergency response costs. For the Cedar Falls Utilities Flood Protection Project, the floodwall was overtopped in June 2008 and that event exceeded the design capacity of the wall. Similar losses would have been incurred whether or not the floodwall had been constructed. The only losses avoided were minor cleanup costs and loss of function for the parking lot during the April 2008 event.

The total value of the losses avoided for all projects is $52,863,381, and the total project investment is $2,590,042. The overall project ROI is therefore 2,041%. An ROI of over 100% indicates that the project costs have been recovered based on losses avoided after the project was completed. For a BCA, FEMA estimates that minor local flood reduction projects have a useful life of 50 years (FEMA, 2009a), which means that a project is expected to reduce loss over 50 years from the time it is implemented. The projects in this study have already demonstrated a collective ROI of 2,041% less than 15 years into their useful lives. Thus, it is anticipated that as additional flood events occur, the total losses avoided and consequently the ROI will increase.

*Table 5.2*

## Iowa Flood Reduction Projects Return on Mitigation Investment

| General Project Information | | | Losses Avoided by Loss Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Emergency Protective Measures | | Nontraditional Benefits | | | | |
| Project Name | County | Date of Project Completion | Physical Damage | Loss of Function | Debris Removal | Cleanup Costs | Emergency Response | Avoidance of Mental Stress & Anxiety | Losses Avoided | Project Investment | ROI |
| ***Burlington Municipal Water Works Project*** | Des Moines | 5/13/99 | — | — | — | $339 | –$4,241 | $6,072 | $2,170 | $409,681 | 1% |
| ***Cedar Falls Utilities Flood Protection Project*** | Blackhawk | 11/20/07 | — | $2,952 | — | $225 | –$28 | — | $3,148 | $703,893 | 0% |
| ***Des Moines, Central Campus Floodgates Project*** | Clayton | 3/25/96 | $49,156,969 | — | — | — | — | — | $49,156,969 | $503,752 | 9,758% |
| ***Elkader Flood Protection Project*** | Clayton | 10/9/00 | $343,602 | $600,650 | $41,055 | — | — | — | $985,308 | $181,317 | 543% |
| ***Manning Well Head Project*** | Carroll | 11/8/99 | — | — | — | $15,300 | — | — | $15,300 | $33,222 | 46% |
| ***McGregor Floodwall Project*** | Clayton | 6/24/99 | $799,123 | $738,984 | — | — | — | — | $1,538,107 | $239,918 | 641% |
| ***Montrose Floodproofing Project*** | Lee | 12/2/04 | $108,516 | $1,053,864 | — | — | — | — | $1,162,380 | $518,258 | 224% |
| | | **Total** | **$50,408,210** | **$2,396,450** | **$41,055** | **$15,864** | **–$4,269** | **$6,072** | **$52,863,381** | **$2,590,042** | **2,041%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
ROI = Return on Investment

# Section Six:

## Considerations and Recommended Practices

The Iowa study yielded findings with potential value to future LASs. The considerations and recommended practices that resulted from this study in regard to data collection and availability and to analysis methodology are described below.

## 6.1 Data Collection and Availability

Historical data indicating past emergency response behavior and actual damage are preferred to modeled or estimated data for an LAS because historical data provide the most accurate account of what occurred during a flood event. For all projects in the Iowa study, attempts were made to include losses to facilities and equipment that were determined using historical data. Losses to water treatment plants, aeration lagoons, power plants, electrical equipment, water wells, and water pumps were estimated using historical damage data obtained from the project files and in Project Worksheets for the Public Assistance Program under Presidentially declared disasters. Project Worksheets from the 2008 flood event (FEMA-1763-DR-IA) were used to determine $MP_C$ damage for multiple facilities. The data reported in the project files were verified during site visits.

When historical data for building damage were not available, the value of the building damage was estimated using the USACE St. Paul District DDFs. This approach was used for the buildings in the McGregor Floodwall Project, Elkader Flood Protection Project, Montrose Floodproofing Project, and the Des Moines, Central Campus Floodgates Project. The USACE St. Paul District DDFs were also used to determine building contents damage in the Des Moines, Central Campus Floodgates Project because historical building contents data were not available.

## 6.2 Analysis Methodology

The Iowa study is unusual in that it involved not only a Flood Boundary Analysis, which is normally used in the analysis of flood reduction projects, but also a Flood Inundation Analysis, which is not typically used in the analysis of flood reduction projects but in building modification projects instead. The Flood Inundation

Analysis was used in the Iowa study for the projects that do not alter the flood hazard. The majority of the projects in the Iowa study are flood barrier projects, and although flood barriers are considered flood reduction projects, the flood barrier projects analyzed in this study protect only one building or a small number of facilities. In these projects, the flood hazard is not actually altered, and flood elevations at each project site were the same in the $MP_A$ and $MP_C$ scenarios. The flood elevation of the event of interest was determined for both the $MP_A$ and $MP_C$ scenarios using the existing conditions of the site and compared to the physical condition of the buildings and infrastructure protected by the mitigation project. A Flood Inundation Analysis was necessary to determine whether a flood event had occurred that would have breached the flood barrier and inundated the protected buildings and infrastructure.

For an assessment of losses avoided that was as accurate as possible, the Iowa study considered two types of nontraditional benefits—emergency response and the avoidance of mental stress and anxiety. Emergency response costs included actual costs from Project Worksheets that were relevant for the $MP_C$ scenario. For example, Project Worksheets for the Burlington Municipal Water Works Project included additional labor costs, material costs for sandbags and rocks, and additional run time for pumps. Other emergency response costs were obtained from discussions with local representatives who described the efforts required to prepare for a flood. For example, for the Cedar Falls Utilities Flood Protection Project, these costs accounted for the efforts to gather bladders in preparation for deployment. The historical data reflect the actual efforts performed by a community during a flood rather than estimated damage from emergency response efforts that might have occurred.

Disasters often have a substantial impact on mental health. Victims of disaster may experience chronic psychological problems such as stress, exhaustion, nightmares, depression, and despair following a disaster. For the Burlington Municipal Water Works Project, discussions with plant staff during the site visit indicated that workers felt a sense of relief after the mitigation project was complete and were able to sleep better knowing that they would not have to sandbag the facility. The reduction in mental stress and anxiety was quantified in terms of the opportunity cost associated with additional workers required to stay overnight at a facility that was vulnerable to flooding. The opportunity cost represented the loss in welfare from being away from family and friends.

# Appendix A

## Burlington Municipal Water Works Project

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# Appendix A:

## Burlington Municipal Water Works Project

### A1 Introduction

Burlington Municipal Water Works (BMWW), the water treatment plant for the City of Burlington (City) in Des Moines County, Iowa, is located near the confluence of Flint Creek and the Mississippi River. The facility can experience flooding from both sources. The location of the facility is shown in **Figure A.1**.

The facility experienced flooding in 1990, 1993, and 1996. In 1993, flooding was so severe that access to the facility was by boat only. After this flood, BMWW developed a mitigation plan that included construction of an earthen levee around the facility; and installation of retaining walls, stop logs, three permanent pumps with electrical feed to manage internal drainage, one portable pump, and three lime sludge lagoons. Construction of the earthen levee was completed in 1996 and included an opening for the access road. The opening would be protected by sandbags in the event of a flood. **Figures A.2** and **A.3** are photographs of the BMWW facility and the opening through the earthen levee.

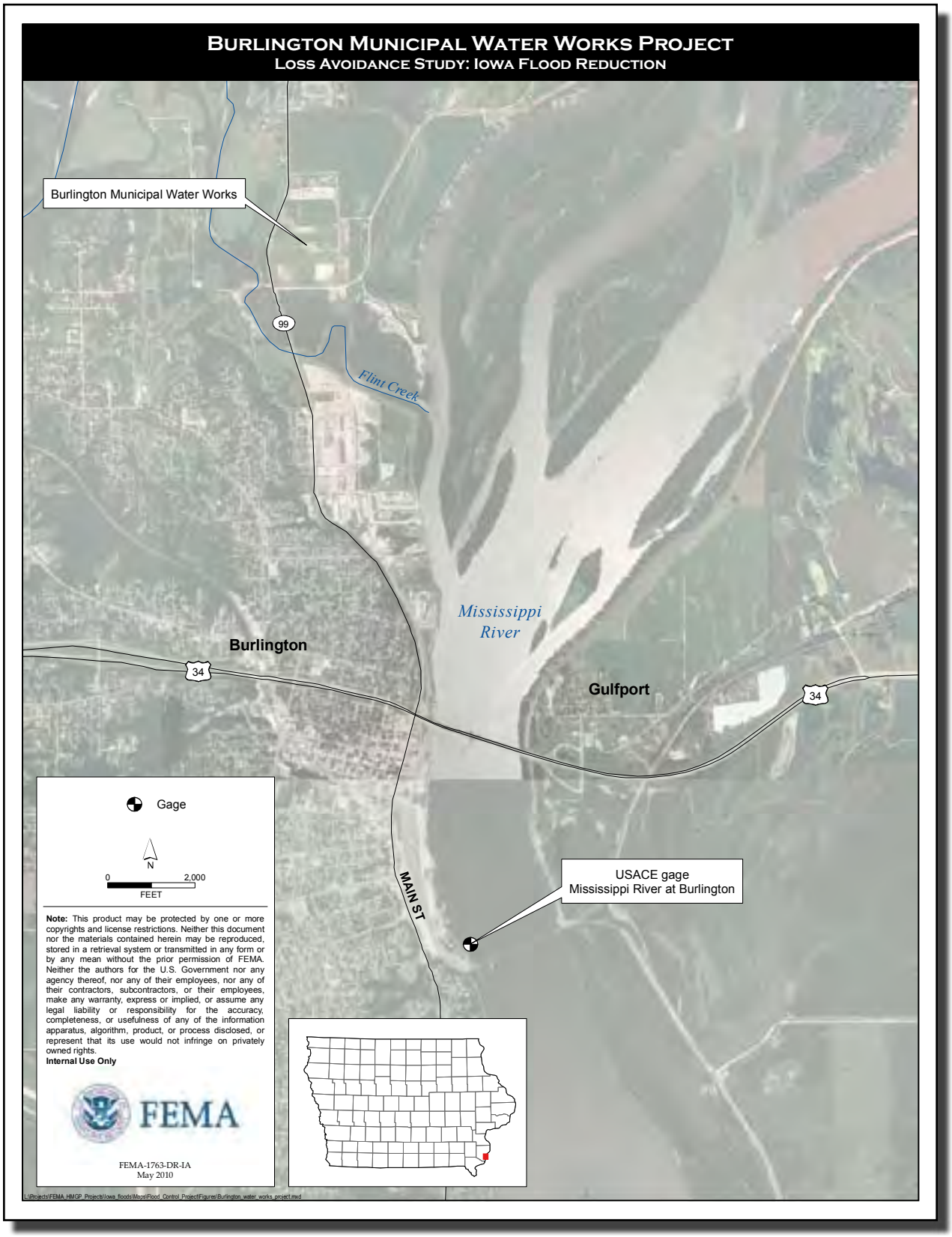
In 1997, BMWW applied for Hazard Mitigation Grant Program (HMGP) funding to complete the mitigation plan. However, the State of Iowa concluded that only the retaining walls, stop logs, and the three permanent pumps were eligible mitigation measures. The stop logs and earthen levee would provide protection up to the 500-year flood with freeboard. The approved components of the project were completed on May 13, 1999,[1] at a total cost of $295,962. The City received 75% ($221,972) of the project cost from HMGP funding and provided the local match of $73,990. The total project cost, in 2010 dollars, is $409,681. Because of limited funding, the remaining components of the project were postponed.

The elevation of the top of the earthen levee is 544 feet National Geodetic Vertical Datum of 1929 (NGVD29),[2] as determined from discussions with the facility staff during the site visit. According to the construction plans reviewed during the site visit, the access road that breaches the levee is at an elevation of 536.2 feet. The building

1 This is the date of the final inspection of by the Iowa Department of Public Defense, Emergency Management Division (FEMA, 1999).

2 All elevations in this paragraph are referenced to NGVD29.

**Figure A.1**


Burlington Municipal Water Works Project
Loss Avoidance Study: Iowa Flood Reduction
Burlington Municipal Water Works
99
Flint Creek
Mississippi River
Burlington
34
Gulfport
34
MAIN ST
USACE gage
Mississippi River at Burlington
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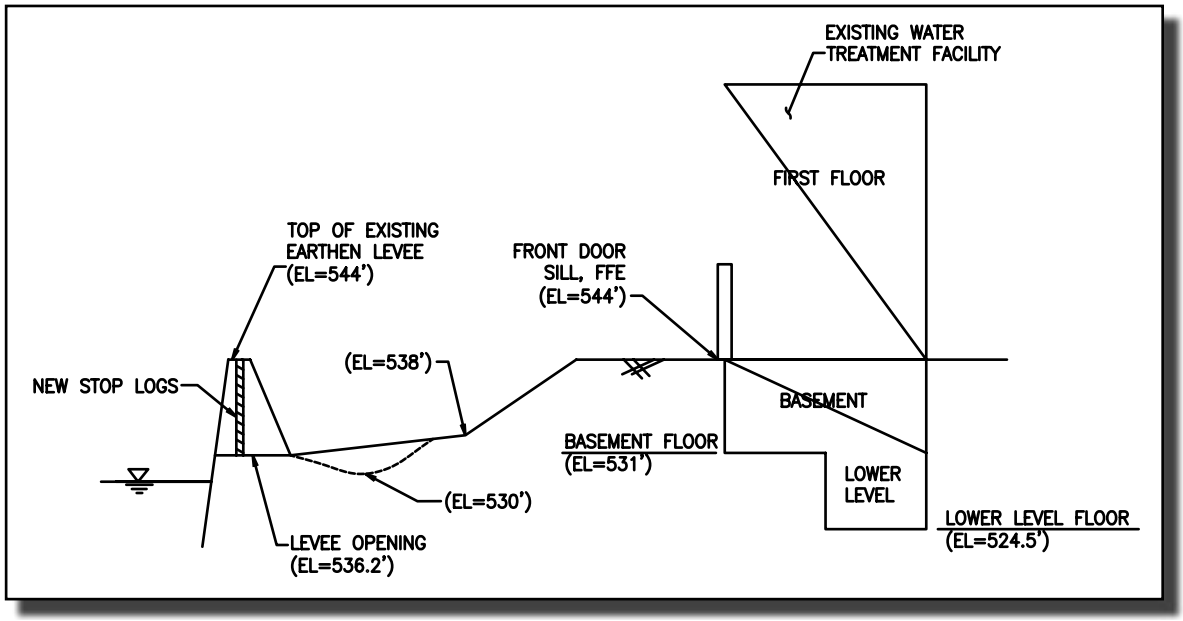
FEMA
FEMA-1763-DR-IA
May 2010
L:\Projects\FEMA_HMGP_Projects\Iowa_floods\Maps\Flood_Control_Project\Figures\Burlington_water_works_project.mxd

***Figure A.2*** *Burlington Municipal Water Works, June 21, 2008 (photo by Tim Powers, Burlington Municipal Water Works; used with permission)*

***Figure A.3*** *Earthen Levee with Opening for Access Road, February 5, 2010 (photo by Jane Branson, URS Group, Inc.)*

houses equipment in the basement at elevations of 531 feet and 524.5 feet. Water can enter the building at the first floor elevation (FFE) at an elevation of 544 feet. The lowest grade adjacent to the access road is at an elevation of 530 feet. If floodwaters reached the opening of the earthen levee at elevation 536.2 feet, the low areas adjacent to the access road would flood and require cleanup. **Figure A.4** is a schematic of the project area.

***Figure A.4*** *Schematic of Burlington Municipal Water Works Facility*




## A2 Phase 1 – Data Collection

The HMGP application and project files were reviewed for data necessary for the loss avoidance study. In late 2009, collection of the remaining data was initiated. Hydrologic data were obtained from the U.S. Army Corps of Engineers (USACE) gage at Burlington for the Mississippi River (the location of which is shown in **Figure A.1**), and additional gage data were collected from multiple U.S. Geological Survey (USGS) gages for Flint Creek. The Upper Mississippi River Flow Frequency Query website was accessed for Mississippi River hydraulic data, and the FEMA Flood Insurance Study (FIS) provided information regarding Flint Creek. A preliminary Storm Event Analysis was completed using this data prior to a site visit on February 5, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. Information about past storm events was obtained, and an understanding of the project was confirmed. High water marks (HWMs) that were observed on the levee following the June

2008 flood event were measured. The plant supervisor explained the daily operation of the facility and the damage that could be expected if to the facility flooded. Information about the elevation of the levee opening, the building and equipment, and design plans from Veenstra & Kimm, Inc., were obtained (Veenstra & Kimm, Inc., n.d.).

## A3 Phase 2 – Physical Parameter Analysis

The following section details the Phase 2 methodology for the Burlington Municipal Water Works Project. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

### A3.1 Storm Event Analysis

The USACE gage on the Mississippi River at Burlington measures river stage. The gage became operational in 1917 (USACE, 2004a). This gage is located at River Mile 403.1, approximately 3 miles downstream of the BMWW facility (see **Figure A.1**). Stage data are recorded hourly, but only stage data measured each day at 6 AM are archived. In addition, the ten highest stages are recorded.

Two Mississippi River flooding events have occurred since the Burlington Municipal Water Works Project was completed. These events are listed in **Table A.1**, in order of decreasing magnitude.

The site could also be subject to flood events from Flint Creek, which is ungaged. According to discussions with facility staff, a flooding event did occur on Flint Creek in September 2008. Review of stream gages in adjacent basins showed that annual peak high flows did occur on September 13-14, 2008, for nearby watersheds

*Table A.1*

**Record High Stages Since Completion of Burlington Municipal Water Works Project, Mississippi River at Burlington, Iowa**

| Date | Peak Gage Height (feet) | Peak Gage Height (feet MSL 1912)[1] | Peak Gage Height (feet NGVD29)[2] |
|---|---|---|---|
| *June 17, 2008* | 25.73 | 537.18 | 536.73 |
| *May 14, 2001* | 21.82 | 533.27 | 532.82 |

1 Gage datum elevation is 511.45 MSL 1912 (USACE, 2004a).
2 NGVD29 = MSL 1912 – 0.45 (USACE, 1979).

MSL = mean sea level
NGVD29 = National Geodetic Vertical Datum of 1929

with areas of 500 square miles or less. A discharge for Flint Creek for this event was computed using regression equations and basin transfer methods published in *Techniques for Estimating Flood Frequency Discharges for Streams in Iowa* (USGS, 2001). Two methods were used to calculate discharges for the watersheds, and the values were used to estimate the discharge for Flint Creek. The equations used in the basin transfer calculations are shown below.

One-variable equation method:

$$Q_{transferred} = Q_{observed}\left(\frac{DA_{transferred}}{DA_{observed}}\right)^{0.465}$$

Two-variable equation method:

$$Q_{transferred} = Q_{observed}\left(\frac{DA_{transferred}}{DA_{observed}}\right)^{0.590}\left(\frac{MCS_{transferred}}{MCS_{observed}}\right)^{0.306}$$

Where:

$Q_{transferred}$ = peak discharge in cubic feet per second (cfs) at the ungaged site

$Q_{observed}$ = peak discharge (cfs) measured at the gage location

$DA_{transferred}$ = drainage area (square miles) at the ungaged site

$DA_{observed}$ = drainage area (square miles) at the gage location

$MCS_{transferred}$ = main channel slope (ft/mile) at the ungaged site

$MCS_{observed}$ = main channel slope (ft/mile) at the gaged site

These computations are shown in **Table A.2**.

These computed discharges approximately equal the 10-year peak discharge for Flint Creek according to the FIS value of 7,400 cfs, indicating that the September flood event on Flint Creek was approximately the 10-year flood (FEMA, 1985).

## A3.2 Hydraulic Analysis

Water surface elevations (WSEs) measured at the gage at River Mile 403.1 were interpolated upstream to the project site at River Mile 406.5 for the June 2008 and May 2001 flood events. This was done using the USACE flood profiles and the query website (USACE, 2004b).

The WSE for the September 2008 flood event on Flint Creek was estimated using the flood profiles published in the FIS. Since the discharge estimate for the flood event was estimated to be the 10-

*Table A.2*

**Peak Flood Discharges – Flint Creek, September 13–14, 2008**

| Flooding Source | USGS Gage Number[1] | Watershed Area (sq mi) | Watershed Slope (ft/mi) | Peak Discharge Observed September 13–14, 2008 (cfs) | Computed Flint Creek Peak Discharge: One-variable equation (cfs) | Computed Flint Creek Peak Discharge: Two-variable equation (cfs) |
|---|---|---|---|---|---|---|
| *Pope Creek* | 5467000 | 174 | 3.59 | 4,870 | 4,520 | 5,670 |
| *Henderson Creek* | 5469000 | 432 | 3.97 | 10,600 | 6,440 | 7,000 |
| *Cedar Creek* | 5473400 | 530 | 2.57 | 14,100 | 7,790 | 9,420 |
| *Big Creek* | 5469450 | 58 | 5.32 | 4,520 | 6,990 | 8,910 |
| *Haight Creek* | 5469350 | 3 | N/A | 1,740 | 11,200 | N/A |
| *Edwards River* | 5466500 | 445 | N/A | 10,300 | 6,160 | N/A |
| Average Discharge Computed Flint Creek | | | | | 7,180 | 7,750 |

1 USGS (n.d.)

Flint Creek Watershed Area = 148 square miles
Flint Creek Watershed Slope = 8.04 feet/mile
cfs = cubic feet per second
ft/mi = feet per mile
sq mi = square mile(s)
N/A = not available

year flood event, the 10-year flood profile for Flint Creek was used. At the BMWW facility, the WSE is 535 feet NGVD29 during the 10-year event. **Table A.3** shows the WSEs for the three studied events at the project site.

The WSE for the June 2008 flood event was compared to the HWM recorded during the site visit and found to be consistent. The HWM was measured at 2.3 feet above the low levee opening. The flood elevation is therefore 536.2 feet + 2.3 feet = 538.5 feet.

HWMs were also surveyed by FEMA after the June 2008 flood event (FEMA, 2008). Two HWMs were taken in the vicinity of the BMWW facility, both indicating flood elevations of 1.5 to 1.8 feet

*Table A.3*

**Water Surface Elevations at the Burlington Municipal Water Works Facility**

| Event Date | Flooding Source | Peak Gage Height (feet NGVD29) |
|---|---|---|
| *June 17, 2008* | Mississippi River | 538.5[1] |
| *May 14, 2001* | Mississippi River | 534.2[1] |
| *September 13–14, 2008* | Flint Creek | 535.0[2] |

1 WSEs interpolated from gage data and USACE flood profiles
2 WSE is the 10-year flood event elevation at the project site

NGVD29 = National Geodetic Vertical Datum of 1929
WSE = water surface elevation

lower than the WSE computed using the downstream gage elevation with the USACE flood profile information and the HWM obtained during the site visit. The HWMs surveyed by FEMA were based on the line of dead or dying vegetation, but for turf vegetation to die, it must be submerged for approximately 4 days. Examination of the gage data indicates that the flood elevation dropped about 2 feet from the peak within 6 days. For these reasons, these two HWMs likely underestimated the peak flood elevation and were therefore not used in the analysis.

### A3.3 Flood Boundary Analysis

Because the levee protects only one facility and does not affect flood elevations in the adjacent flooding sources, the Flood Boundary Analysis resembled a Flood Inundation Analysis. The WSEs were compared directly to the FFE of the building to determine depth of flooding. The largest event studied (the June 2008 flood event, which had a WSE of 538.5 feet NGVD29) was well below the FFE of 544.0 feet NGVD29. No building damage was therefore sustained in either the Mitigation Project Absent ($MP_A$) or the Mitigation Project Complete ($MP_C$) scenario.

The levee opening is at elevation 536.2 feet NGVD29. Therefore, the June 2008 flood event was large enough to enter the facility grounds and cause nuisance flooding. Some losses might have been avoided for this event. Consequently, the project was advanced to Phase 3.

## A4 Phase 3 – Loss Estimation Analysis

The losses calculated for the Burlington Municipal Water Works Project were cleanup costs, the avoidance of mental stress and anxiety, and emergency response costs. Other potential costs including physical damage to carbon dioxide tanks, reduced access to the plant by workers, and the inability to deliver chemicals and materials were not assessed. However, according to the plant staff, these potential costs did not apply to the flood events studied and would only be associated with larger floods on the Mississippi River.

The results of the Flood Boundary Analysis showed that the WSEs for all the flood events considered would not reach the FFE of the water treatment facility in either the $MP_A$ or $MP_C$ scenario for all flood events considered. Therefore, no building damage, contents damage, or loss of service would be incurred. In the $MP_A$ scenario, for all flood events considered, floodwaters would be expected to enter the earthen levee surrounding the water treatment facility,

resulting in flood water ponding in the front yard and low areas of the facility grounds. However, at no point would the water reach the FFE of the water treatment facility.

## A4.1 Cleanup Costs

The costs for cleanup of the front yard and low areas of the facility grounds would require the use of a mobile pump and manual labor to pick up trash and debris carried by the floodwaters. It is assumed that BMWW owns a mobile pump. In assessing costs, the staff at BMWW estimated that an additional 4 hours of pumping for each of the three pumps at the facility would be required. The cost of pump operation is estimated at $0.10 per kilowatt (kW) per pump hour. The pumps are estimated to have a capacity of 0.5 horsepower (0.37 kW). In addition, it was estimated that the cleanup would require 2 hours of labor per person for two staff members to clean up trash and debris. The FEMA standard value for labor of $28.11 per hour was used to calculate the labor costs. See **Attachment 1** for detailed loss calculations.

## A4.2 Avoidance of Mental Stress and Anxiety

Prior to installation of the floodgates and permanent pumps, BMWW typically used sandbagging around the facility to provide protection from floodwaters. The wide opening at the levee entrance would be sandbagged prior to a flood. However, because Flint Creek is unregulated and flooding is unpredictable with minimal warning time, localized rainfall events would increase the mental stress and anxiety of workers at the water treatment plant because of the quick response required.

In severe cases, mental stress and anxiety can result in chronic psychological problems such as stress, exhaustion, nightmares, and depression. However, limited studies have been done to quantify the economic impacts of these problems. The economic impact of mental health issues are manifested in medical costs and disruption of work activities, but data on these impacts are not readily available.

Workers at the facility described how prior to the installation of floodgates, staff members lived at the plant to ensure sufficient personnel were onsite for any unexpected emergency response that was needed during rainfall or flooding events. Plant policy requires that when the river reaches a certain flood stage, the plant supervisor must remain at the plant until the threat has passed (in addition to the two shift workers required to operate the plant). The floodgates provide a level of confidence that reduces the need for multiple people to be at the facility during the rainfall and flooding

events. Representatives at the treatment facility expressed a sense of relief since the floodgates became available. Many described an ease of mind from the relief of not having to sandbag under extreme time constraints to protect the treatment facility from damage and loss of service.

For the $MP_C$ scenario, the general manager camped at the facility for 7 days in a motor home at during the June 2008 flood event. The cost was calculated by multiplying 7 days by 24 hours at $28.11 per hour, which is the FEMA standard value for labor.

For the $MP_A$ scenario, according to the plant staff, two additional staff members would stay at the facility overnight during the June 2008 flood event because of the size of the event. For the September 2008 and May 2001 events, one additional staff member would stay at the facility overnight. The costs were determined by multiplying the time that each additional staff member was required to stay overnight by $28.11 per hour.

## A4.3 Emergency Response

For the June 2008 flood event, actual emergency response costs were obtained from FEMA Public Assistance Program Project Worksheet #1432. The Project Worksheet indicated that approximately 250 hours of additional pump run time, 69 hours of labor, and $2,062 in materials (including sandbags and rocks) were spent on emergency response during this event. The $MP_C$ emergency response costs were calculated using these hours and material costs, an operational cost for pumping of $0.10 per kW per hour, and the FEMA standard value of $28.11 per hour for labor.

## A4.4 Summary of Damage

The $MP_A$ and $MP_C$ damage for Burlington is summarized in **Table A.4**. For the Return on Investment (ROI) calculation, the total project cost of $295,962 was inflated to 2010 dollars for a total of $409,681.

**Table A.4** shows that the value of the total losses avoided is only $2,170, and the total ROI for the Burlington Municipal Water Works Project is only 0.53%. The only significant losses avoided were a reduction in the stress and anxiety of staff working at the facility. However, even these impacts are extremely low relative to the project investment.

*Table A.4*

## Burlington Municipal Water Works Project Loss Estimation Analysis Results and Return on Mitigation Investment (ROI)

| Event Date | Results by Loss Category | | | | | | Losses Avoided | Project Investment | ROI |
|---|---|---|---|---|---|---|---|---|---|
| | $MP_A$ Scenario Damage | | | $MP_C$ Scenario Damage | | | | | |
| | Emergency Protective Measures | Nontraditional Benefits | | Emergency Protective Measures | Nontraditional Benefits | | | | |
| | Cleanup Costs | Avoidance of Mental Stress and Anxiety | Emergency Response | Cleanup Costs | Avoidance of Mental Stress and Anxiety | Emergency Response | | | |
| ***June 17, 2008*** | $113 | $9,445 | $0 | $0 | $4,722 | $4,241 | $595 | $409,681 | 0.15% |
| ***September 14, 2008*** | $113 | $675 | $0 | $0 | $0 | $0 | $788 | $409,681 | 0.19% |
| ***May 14, 2001*** | $113 | $675 | $0 | $0 | $0 | $0 | $788 | $409,681 | 0.19% |
| **Total** | **$339** | **$10,794** | **$0** | **$0** | **$4,722** | **$4,241** | **$2,170** | **$409,681** | **0.53%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

## A5 References

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Veenstra & Kimm, Inc. n.d. Design plans for Project #29621. Engineers William Forbes and Morris Rosen.

# Attachment 1

## Loss Calculations

## Table Att-1

| Burlington Municipal Water Works Project, May 2001 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Cleanup Costs | Additional Hours of Pumping Required Per Pump: | 4 | Discussion with Burlington representatives | *No Cleanup Costs* | | |
| | Number of Pumps: | 3 | Site visit observations | | | |
| | Cost of Pump Operation ($/hour): | $0.037 | Based on $0.10 per kW*hour and a 0.5 horsepower (0.37 kW) pump | | | |
| | Number of Staff Members Needed for Cleanup Labor: | 2 | Discussion with Burlington representatives | | | |
| | Number of Hours of Labor Required for Cleanup: | 2 | Discussion with Burlington representatives | | | |
| | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor | | | |
| | **Cleanup Costs (2010 Dollars):** | **$113** | | **Cleanup Costs (2010 Dollars):** | **$0** | |
| Avoidance of Mental Stress and Anxiety | Number of Staff Workers that Needed to Stay at Plant Overnight | 1 | Two additional workers would need to stay overnight at the plant (in additional the two shift workers required to operate plant) if the project was not in place | *No Avoidance of Mental Stress and Anxiety Costs* | | |
| | Number of Hours Each Worker Stayed at the Plant: | 24 | Assumed that each worker spent 24 hours overnight | | | |
| | FEMA Standard Labor Rate ($/hour): | $28.11 | FEMA standard value for labor | | | |
| | **Costs for Avoidance of Mental Stress and Anxiety (2010 Dollars):** | **$675** | | **Costs for Avoidance of Mental Stress and Anxiety (2010 Dollars):** | **$0** | |

FEMA = Federal Emergengy Management Agency
kW = kilowatt
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete

## Table Att-2

**Burlington Municipal Water Works Project, June 2008 Event**

| Damage Category | $MP_A$ Scenario: Description | Value | Source | $MP_C$ Scenario: Description | Value | Source |
|---|---|---|---|---|---|---|
| Cleanup Costs | Additional Hours of Pumping Required Per Pump: | 4 | Discussion with Burlington representatives | *No Cleanup Costs* | | |
| | Number of Pumps: | 3 | Site visit observations | | | |
| | Cost of Pump Operation ($/hour): | $0.037 | Based on $0.10 per kW*hour and a 0.5 horsepower (0.37 kW) pump | | | |
| | Number of Staff Members Needed for Cleanup Labor: | 2 | Discussion with Burlington representatives | | | |
| | Number of Hours of Labor Required for Cleanup: | 2 | Discussion with Burlington representatives | | | |
| | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor | | | |
| | **Cleanup Costs (2010 Dollars):** | **$113** | | **Cleanup Costs (2010 Dollars):** | **$0** | |
| Avoidance of Mental Stress and Anxiety | Number of Staff Workers that Needed to Stay at Plant Overnight | 2 | Two additional workers would need to stay overnight at the plant (in additional the two shift workers required to operate plant) if the project was not in place | Number of Hours that General Manager Camped Out at Plant: | 168 | Discussion with Burlington representatives |
| | Number of Hours Each Worker Stayed at the Plant: | 168 | Assumed that each worker spent 24 hours overnight | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor |
| | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor | | | |
| | **Costs for Avoidance of Mental Stress and Anxiety (2010 Dollars):** | **$9,445** | | **Costs for Avoidance of Mental Stress and Anxiety (2010 Dollars):** | **$4,722** | |
| Emergency Response | *No Emergency Response Costs* | | | Total Additional Hours of Pumping Required[1]: | 250 | PW #1432 |
| | | | | Cost of Pump Operation ($/hour)[1]: | $0.037 | Based on $0.10 per kW*hour and a 0.5 horsepower (0.37 kW) pump |
| | | | | Total Additional Labor Hours Required[1]: | 68.5 | PW #1432 |
| | | | | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor |
| | | | | Emergency Response Material Costs ($)[1]: | $2,062.36 | PW #1432 |
| | | | | Base Year of Costs: | 2008 | PW #1432 |
| | | | | Inflation Multiplier: | 1.0609 | BCA Inflation Calculator |
| | **Emergency Response Costs (2010 Dollars):** | **$0** | | **Emergency Response Costs (2010 Dollars):** | **$4,241** | |

[1] Emergency response costs were outlined in PW #1432 for the June 2008 event. Costs include additional run time for pumps, labor hours, and material costs for emergency response.

***(1) Additional Run Time for Pumps:***

According to PW #1432:

"The efforts included ...utilizing three (3) on-site pumps for an extra two (2) minutes, two (2) times per hour for 29 days. An additional on-site pump was used an extra two (2) minutes, two (2) times per hour for 69 straight days."

(a) Three on-site pumps — Additional run time = (2 minutes)*(2 times per hour)*(24 hours per day)*(29 days): 8352 minutes; OR 139 hours

(b) One Additional On-Site Pump: — Additional run time = (2 minutes)*(2 times per hour)*(24 hours per day)*(69 days): 6624 minutes; OR 110.4 hours

Total additional run time: **250 hours**

A 0.5 horsepower pump is equivalent to 0.37 kW. Using a cost of $0.10 per kW per hour, the cost of runtime per hour would be 0.37*$0.10 = $0.037 per kW per hour.

Cost of Pump Operation ($/hr): $0.04

**Total Cost of Additional Run Time: $9.24**

***(2) Total Work Hours Associated with Sandbagging:***

According to PW #1432, the labor hours associated with emergency response includes:

(a) Person #1 worked a total of 34 hours between 6/10/08 and 7/31/08 on the backhoe loading and unloading sandbags and spreading rock on the back driveway.
(b) Person #2 worked 4 hours on 6/15/08 loading sandbags and filling the hesco barriers with sand using the backhoe. On 7/1/08 he spend an 4 hours removing the sand from the Hesco Barriers.
(c) Person #3 worked 2.5 hours on 6/11/08 on the backhoe installing the flood gate at the plant.
(d) Both Person #4 and Person #5 spent 2 hours each on 6/15/08 using the backhoe to load sandbags, placing the sandbags at the flood gate, as well as filling the Hesco Barriers with sand.
(e) Person #6 spent 14 hours between 6/10/08 and 8/6/08 hauling sand, sandbags and rock to and from the plant in the dumptruck.
(f) Person #4 spent 2 hours on 6/15/08 hauling sandbags to the plant.
(g) Person #4 used the pickup truck for a total of 4 hours between 6/15/08 and 6/17/08 picking up and delivering sandbags as well as staking the road behind the plant.

**Total Work Hours Associated with Sandbagging: 68.5 hours**

***(3) Material Costs:***

According to PW #1432:

"Materials such as rock, sand, pictures, etc. costing a total of $2,062.36."

**Total Material Costs: $2,062.36**

BCA = Benefit-cost analysis
FEMA = Federal Emergency Management Agency
kW = kilowatt
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete
PW = Project Worksheet

## Table Att-3

| Burlington Municipal Water Works Project, September 2008 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Cleanup Costs | Additional Hours of Pumping Required Per Pump: | 4 | Discussion with Burlington representatives | *No Cleanup Costs* | | |
| | Number of Pumps: | 3 | Site visit observations | | | |
| | Cost of Pump Operation ($/hour): | $0.037 | Based on $0.10 per kW*hour and a 0.5 horsepower (0.37 kW) pump | | | |
| | Number of Staff Members Needed for Cleanup Labor: | 2 | Discussion with Burlington representatives | | | |
| | Number of Hours of Labor Required for Cleanup: | 2 | Discussion with Burlington representatives | | | |
| | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor | | | |
| | **Cleanup Costs (2010 Dollars):** | **$113** | | **Cleanup Costs (2010 Dollars):** | **$0** | |
| Avoidance of Mental Stress and Anxiety | Number of Staff Workers that Needed to Stay at Plant Overnight | 1 | Two additional workers would need to stay overnight at the plant (in additional the two shift workers required to operate plant) if the project was not in place | *No Avoidance of Mental Stress and Anxiety Costs* | | |
| | Number of Hours Each Worker Stayed at the Plant: | 24 | Assumed that each worker spent 24 hours overnight | | | |
| | Labor Rate ($/hour): | $28.11 | FEMA standard value for labor | | | |
| | **Costs for Avoidance of Mental Stress and Anxiety (2010 Dollars):** | **$675** | | **Costs for Avoidance of Mental Stress and Anxiety (2010 Dollars):** | **$0** | |

FEMA = Federal Emergengy Management Agency
kW = kilowatt
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete

# Appendix B

## Cedar Falls Utilities Flood Protection Project

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# Appendix B:

## Cedar Falls Utilities Flood Protection Project

### B1 Introduction

The Cedar Falls Utilities (CFU) facility is adjacent to the Cedar River in the City of Cedar Falls (City) in Black Hawk County, Iowa. The location of the facility is shown in **Figure B.1**.

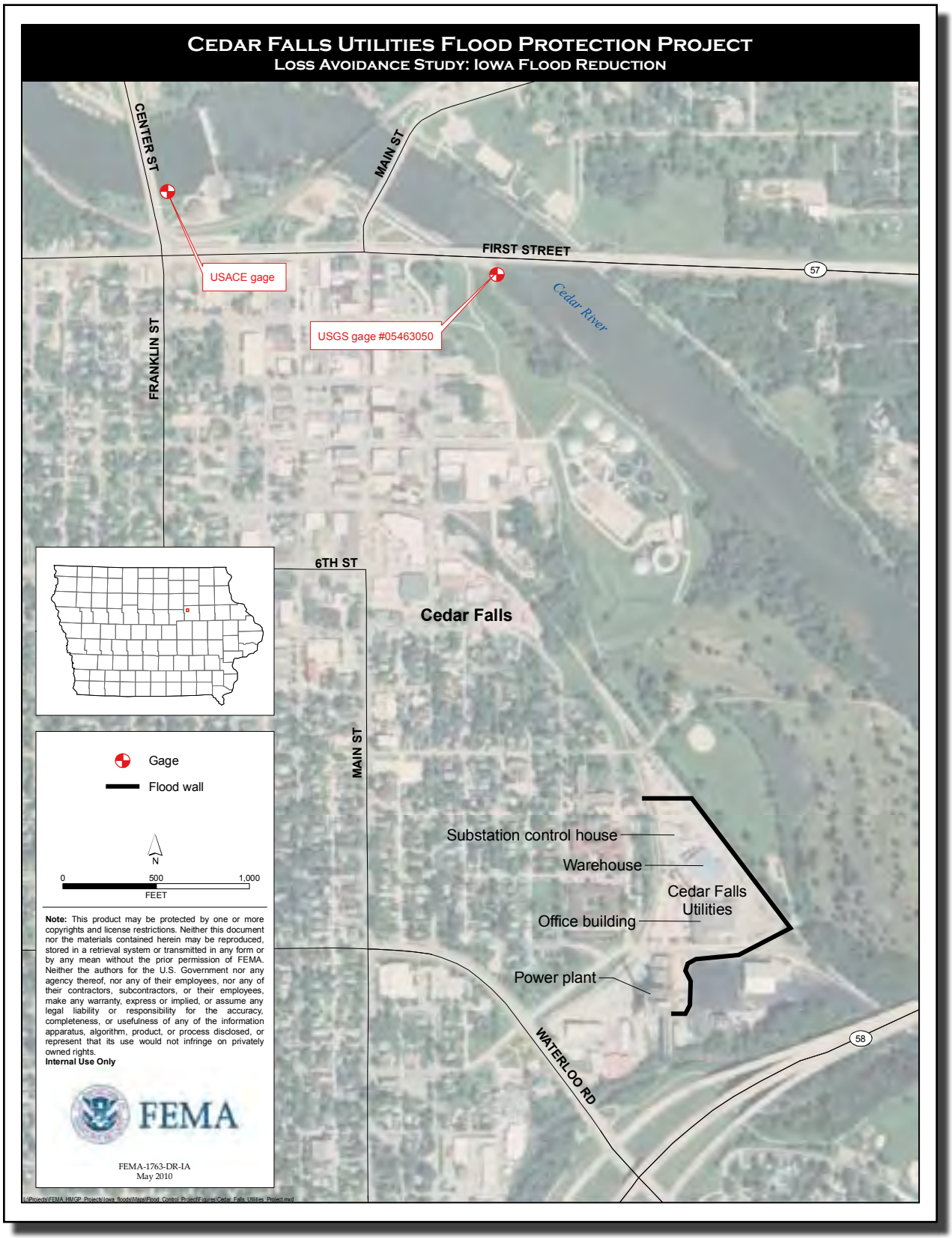
CFU has operated in the floodplain of the Cedar River since 1888. CFU facilities at the site include a two-story office complex, various warehouses, a power plant, two substations, and a substation control house. Historically, the buildings have been threatened by frequent rising of the Cedar River, which has triggered flood preparations including sandbagging doorways, moving files, elevating contents, and 24-hour flood watches.

In 2003, with assistance of the City, CFU applied for and received a Pre-Disaster Mitigation (PDM) grant from the Federal Emergency Management Agency (FEMA) to construct a concrete floodwall to protect its facilities from the 100-year flood. The project consisted of (1) the installation of a floodwall with a crest 3 feet above the 100-year flood elevation and (2) the purchase of temporary flood barriers that are used to close the 7 openings in the floodwall. The project protects the CFU office, warehouse, power plant, and substation control house. The floodwall does not intersect with high ground; consequently, the protection provided by the floodwall is supplemented through use of "water bladders" that are needed to close the area to floodwaters. **Figure B.2** is a photograph of the floodwall showning an opening in the floodwall that requires temporary flood barriers. **Figure B.3** shows the "water bladders" that are used to close the area to floodwaters.

The top of the floodwall is at an elevation of 864.05 feet National Geodetic Vertical Datum of 1929 (NGVD29). **Table B.1** contains the first floor elevations (FFEs) of the protected buildings. **Figure B.4** is a schematic of these buildings and their FFEs in relation to the height of the floodwall.

The project was completed on November 20, 2007, at a total project cost of $644,162. This figure includes the 30% local match of $193,249. The total project cost, in 2010 dollars, is $703,893. This cost does not include the cost of the water bladders.

***Figure B.1***


Cedar Falls Utilities Flood Protection Project
Loss Avoidance Study: Iowa Flood Reduction
CENTER ST
MAIN ST
FIRST STREET
57
USACE gage
USGS gage #05463050
Cedar River
FRANKLIN ST
6TH ST
Cedar Falls
MAIN ST
Substation control house
Warehouse
Cedar Falls Utilities
Office building
Power plant
WATERLOO RD
58
Gage
Flood wall
N
0
500
1,000
FEET
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May 2010

***Figure B.2*** *Cedar Falls Utilities Floodwall, February 4, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure B.3*** *Water Bladders Used with Floodwall at Cedar Falls Utilities during Flood Event (photo by Ed Olthoff, Cedar Falls Utilities, June 10, 2008; used with permission)*

**Figure B.4** *Schematic of First Floor Elevations of Cedar Falls Utilities Buildings in Relation to Floodwall*

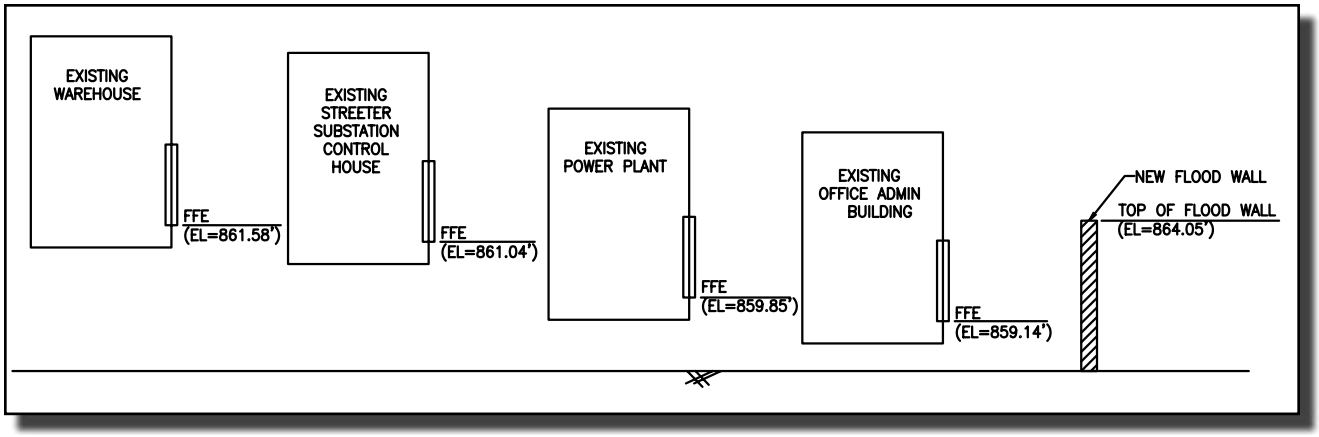


**Table B.1**

**Buildings Protected by Cedar Falls Utilities Flood Protection Project**

| Building | Latitude (degrees) | Longitude (degrees) | FFE (feet NGVD29) |
|---|---|---|---|
| ***Power Plant*** | 42.5281 | –92.4392 | 859.85 |
| ***Office Building*** | 42.5281 | –92.4392 | 859.14 |
| ***Warehouse*** | 42.5281 | –92.4392 | 861.58 |
| ***Substation Control House*** | 42.5281 | –92.4392 | 861.04 |

Project completed on November 20, 2007

FFE = first floor elevation
NGVD29 = National Geodetic Vertical Datum of 1929

## B2 Phase 1 – Data Collection

The PDM application and project files (FEMA, 2003) were reviewed for data that were necessary for the loss avoidance study (LAS). The following information was reviewed and used to conduct the Storm Event Analysis:

- Hydrologic data from a U.S. Geological Survey (USGS) gage at Cedar Falls (the location of the gage is shown in **Figure B.1**)
- Flood Insurance Study (FIS) for Cedar Falls (FEMA, 1984)
- Floodplain boundaries shown on the Flood Insurance Rate Map for Cedar Falls (FEMA, 1984)
- U.S. Army Corps of Engineers (USACE) data on flood stages for the Cedar River (USACE, 2010)

On February 4, 2010, a site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. The preliminary Storm Event Analysis and Hydraulic Analysis showed that the Flood

Protection Project had been tested by a 2008 flood event and that the water surface elevation (WSE) of the flood had overtopped the floodwall. According to CFU staff, there were two flood events in 2008—a smaller event that peaked on April 26, 2008, and did not overtop the floodwall; and a much larger event that peaked on June 11, 2008, and overtopped the floodwall by 1.1 feet. The power plant was rendered inoperable by the June 2008 flood event, and administration building operations were displaced for 6 months (WCF Courier, 2008). However, because the power plant is a supplementary power source that is used only during periods of peak demand, the City experienced negligible loss of power.

The information obtained during the site visit included high water marks (HWMs), the value of the insured building and contents, the operating budget, and project plans for the floodwall. Much of the discussion during the site visit involved gaining an understanding of the losses that would occur if the power plant is flooded.

The June 2008 flood event was declared a disaster by the President (FEMA-1763-DR-IA). CFU requested funding under the Public Assistance Program for emergency response costs and repairs to flood damage. Project Worksheets that FEMA prepared for CFU were obtained from the National Emergency Management Information System database. Costs for emergency response, displacement, and damage repair claimed by CFU are summarized in **Table B.2**. A list of the Project Worksheets for CFU is provided in **Attachment 1, Table Att1-1**.

*Table B.2*

**Summary of Project Worksheets for Cedar Falls Utilities, June 2008 Flood Event**

| Type of Loss | Cost (2008 dollars) | Cost (2010 dollars) |
|---|---|---|
| *Emergency Protective Measures* | $487,801 | $517,508 |
| *Displacement Costs* | $232,952 | $247,139 |
| *Repairs to Damage* | $12,283,411 | $13,031,471 |
| **Total** | **$13,004,164** | **$13,796,118** |

# B3 Phase 2 – Physical Parameter Analysis

The following section describes the completion of Phase 2 of the LAS for the CFU Flood Protection Project. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

## B3.1 Storm Event Analysis

The USGS gage on the Cedar River (USGS gage #05463050) at Cedar Falls is located at State Highway 57/First Street Bridge, formerly U.S. Highway 20 (the location is shown on **Figure B.1**). The gage records river stage data, and the available information includes mean daily stages recorded since 2001 (USGS, n.d.). In addition, the USACE records daily stage information for the Cedar River and has archived the ten highest stages since 1961 (USACE, 2010). USACE peak gage elevations recorded for the April and June 2008 flood events are shown in **Table B.3**.

*Table B.3*

**Peak Gage Elevation on the Cedar River at Cedar Falls**

| Event Date | Peak Gage Height (feet NGVD29)[1] |
|---|---|
| *April 26, 2008* | 856.37 |
| *June 11, 2008* | 865.13 |

1 Peak gage height from USACE (2010)
NGVD29 = National Geodetic Vertical Datum of 1929

The June 2008 flood event resulted in the highest stage on record. Based on a comparison with the flood elevations provided in the FIS for the City (FEMA, 1984), the June 2008 flood event was larger than a 500-year event.

## B3.2 Hydraulic Analysis

The reach of the Cedar River adjacent to the CFU Flood Protection Project was studied in detail for the FIS and FIRM. The FIS contains flood profiles for the 10-, 50-, 100-, and 500-year floods (FEMA, 1984). However, the hydraulic model used to prepare the FIS and FIRM could not be obtained for the LAS.

HWMs collected during the site visit were used to determine the WSE for June 2008 flood event. The WSE for the April 2008 flood event was found through interpolation of the FIS flood profiles and the gage height. **Table B.4** summarizes the results of this analysis.

HWMs were surveyed by FEMA after the June 2008 flood event (FEMA, 2008). A HWM in the vicinity of the CFU facility is approximately 0.15 foot higher than the flood elevation estimated by the facility staff. However, the surveyed HWM is reported to have a vertical accuracy of 0.25 foot (FEMA, 2008). This means that the HWMs are essentially the same HWMs provided by the facility staff that were used in this analysis.

*Table B.4*

**Cedar Falls Water Surface Elevations**

| Event Date | Peak WSE (feet NGVD29) |
|---|---|
| *April 26, 2008* | 855.9[1] |
| *June 11, 2008* | 865.1[2] |

1 WSE interpolated using Flood Insurance Study flood profile
2 Flood elevation based on high water marks collected during site visit
NGVD29 = National Geodetic Vertical Datum of 1929
WSE = water surface elevation

## B3.3 Flood Boundary Analysis

To calculate the depth of flooding inside each building, the WSEs were compared directly to the FFEs. **Table B.5** summarizes the depth of flooding for the two events.

The peak elevation of the April 2008 flood did not reach the FFEs for the buildings at the CFU site. Therefore, no losses would have been avoided for the Mitigation Project Absent ($MP_A$) scenario. Additionally, the flood did not overtop the floodwall, so the flood depths for the Mitigation Project Complete ($MP_C$) scenario are zero. However, anecdotal evidence indicated that the flood reached the

*Table B.5*

**Flood Depths at Cedar Falls Utilities**

| Event Date | Depth of Flooding (feet) | | | |
|---|---|---|---|---|
| | Power Plant | Office Building | Warehouse | Substation Control House |
| *April 26, 2008* | 0 | 0 | 0 | 0 |
| *June 11, 2008* | 5.3 | 6.0 | 3.5 | 4.1 |

parking lot and caused nuisance flooding. Because some losses were avoided, this project was advanced to Phase 3.

Because the June 2008 flood event overtopped the floodwall, the floodwall did not provide protection of the buldings. Therefore, the flood depths inside the buildings are the same for both the $MP_A$ and the $MP_C$ scenarios.

## B4 Phase 3 – Loss Estimation Analysis

For the April 2008 flood event, the only potential losses were cleanup costs, inconvenience, and increased travel time for workers to park and walk to work. The floodwall, which was designed to provide protection up to the 100-year flood event with 3 feet of freeboard, did not provide protection during the June 2008 flood event. Therefore, no losses were avoided for this event.

### B4.1 Cleanup Costs

For the April 2008 flood event, costs would have been incurred for the $MP_A$ scenario to clean up mud and debris from the floodwaters, once the floodwaters receded. According to the CFU operations manager, the cleanup costs were estimated at 4 hours of labor per person for two staff members, with a negligible cost for equipment. Using the FEMA standard value for labor of $28.11 per hour, cleanup costs were estimated at $225 for the April 2008 flood event. No cleanup costs are incurred for the $MP_C$ scenario.

### B4.2 Loss of Function – Parking Lot

For the April 2008 flood event, the primary outcome of flooding of the parking lot would have been the inconvenience to employees. The parking lot is located on the west side of the CFU facility, adjacent to the main administrative building. The main administrative building is built on a concrete slab at an approximate elevation of 859.07 mean sea level (MSL). Based on discussions with plant staff, the parking lot is used by an 150 employees who work in the main administrative building. When the parking lot is flooded, the employees have to park a short distance from the office and then walk to the office. The extra distance is estimated at 500 yards, which corresponds to approximately 7 minutes at a walking speed of 2.5 miles per hour or a total additional commute of 14 minutes per person per day. For the April 2008 event, the parking lot would not be available for use for approximately 3 days.

For the $MP_A$ scenario, the loss-of-function costs were calculated by multiplying 150 employees by 14 minutes, the FEMA standard value for labor of $28.11 per hour, and the assumed 3 days that the parking lot is not available for use. The total $MP_A$ cost is therefore $2,952. No loss of function was experienced for the $MP_C$ scenario.

## B4.3 Emergency Response

Minimal emergency response efforts occurred during the April 2008 event. According to discussions with plant staff, it took 1 hour for one person to forklift bladders out of storage to prepare for the possibility of deployment, although the bladders were not actually deployed. The $MP_C$ scenario damage was taken to be $28.11, using the FEMA standard value for labor of $28.11 per hour. In the $MP_A$ scenario, without the floodwall, no emergency response was assumed to occur.

## B4.4 Summary of Damage

The $MP_A$ and $MP_C$ losses for the CFU Flood Protection Project are summarized in **Table B.6** on the next page. Detailed calculations are provided in **Attachment 2**.

For the Return on Investment (ROI) calculation, the total project cost of $644,162 was inflated to 2010 dollars for a total of $703,893. As shown in **Table B.6**, the ROI for the project is 0.45%. The low ROI can be attributed to the fact that the project was completed recently (the potential for additional floods increases with the age of the project) and the June 2008 flood event far exceeded the design level of protection for the project. The value of the total losses avoided is $3,148 and is associated primarily with cleanup costs and the loss of function of the parking lot. The only damage in the $MP_C$ scenario is the cost associated with emergency response, which is minimal compared to the project cost.

*Table B.6*

## Cedar Falls Utilities Flood Protection Project Loss Estimation Analysis Results and Return on Mitigation Investment (ROI)

| Event Date | Results by Loss Category | | | | | | Losses Avoided | Project Investment | ROI |
|---|---|---|---|---|---|---|---|---|---|
| | $MP_A$ Scenario Damage | | | $MP_C$ Scenario Damage | | | | | |
| | Emergency Protective Measures | Loss of Function | Nontraditional Benefits | Emergency Protective Measures | Loss of Function | Nontraditional Benefits | | | |
| | Cleanup Costs | Loss of Function of Parking Lot | Emergency Response | Cleanup Costs | Loss of Function of Parking Lot | Emergency Response | | | |
| ***April 26, 2008*** | $225 | $2,952 | $0 | $0 | $0 | $28 | $3,148 | $703,893 | 0.45% |
| **Total** | **$225** | **$2,952** | **$0** | **$0** | **$0** | **$28** | **$3,148** | **$703,893** | **0.45%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

## B5 References

FEMA (Federal Emergency Management Agency). 1984. Flood Insurance Study and Flood Insurance Rate Map, City of Cedar Falls, Iowa, Black Hawk County.

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———. 2008. Iowa June 2008 Rapid Response Riverine High Water Mark Collection. Washington, DC.

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# Attachment 1

## Project Worksheets for Cedar Falls Utilities, June 2008 Flood (DR-1763)

*Table Att1-1*

**Project Worksheets For Cedar Falls Utilities, June 2008 Flood (DR-1763)**

| Project Worksheet Number | Category[1] | Damaged Facility | Damage Type | Hazard Mitigation | Force Account | Project Cost |
|---|---|---|---|---|---|---|
| 9822 | F | N/A | N/A | Raise flood barrier by 4 feet | N/A | $4,885,496.04 |
| 2682 | C | Main Access Roadway | Driveway | N/A | 16 labor hrs | $9,160.86 |
| 2018 | E | Business Development Center Building | Building | N/A | N/A | $192,467.00 |
| 2082 | E | Annex Warehouse Building | Building | N/A | N/A | $3,295.18 |
| 2043 | E | Viking Building & Fitness Club | Building | N/A | N/A | $42,138.13 |
| 9926 | E | Contents at Administration Building | Contents - Supplies, Tools & Equipment | N/A | N/A | $220,829.19 |
| 9414 | B | Administration Building Services | Temp relocation of essential services | N/A | Overtime labor = $31,138 | $232,951.85 |
| 9348 | F | Electrical Poles | Erosion & destabilization | Relocate poles & replace with different types | $5,417 in labor | $14,506.37 |
| 8521 | E | Contents at Admin, Warehouse & Power Plant Bldgs | Contents - IT Equipment | N/A | N/A | $38,772.21 |
| 7800 | B | Cedar Falls Utility Assets | Emergency Protective Measures: sandbagging, pumping, shoring & rodent control | N/A | $136,315 in labor | $225,645.85 |
| 7463 | E | Contents at Administration Building | Contents - Furniture & Surveillance equip. | N/A | N/A | $564,056.39 |
| 6603 | E | Contents at Administration Building | Contents - Digital phone system/equip | N/A | N/A | $25,704.75 |
| 6288 | F | Equipment - Cable TV Headend | Loss of power supply, replace UPS batteries | N/A | $450 in labor | $8,692.49 |
| 6227 | E | Fuel Dispenser Pump & Monitoring System | Equipment - Pump & Tank replaced | N/A | 16 labor hrs = $544 | $61,964.93 |
| 6096 | E | Administration Building | Power supply unit - replaced | N/A | $1,000 | $41,205.00 |
| 5910 | E | Contents - Streeter Power Generating Plant Office | Office Contents | N/A | 144 labor hrs = $4896 | $56,764.26 |
| 5849 | E | Contents - Administration Building | Contents - Inventory & Spare Parts | N/A | N/A | $132,193.86 |
| 5832 | A | Coal Storage Facility | Underground gas/diesel removal | N/A | N/A | $24,582.66 |
| 5643 | B | Coal Storage Facility | Coal removal from tank | N/A | N/A | $29,203.26 |
| 5860 | E | Administration Building | Electric, water & gas meters - replaced | N/A | N/A | $262,158.03 |
| 5165 | F | Cedar Falls Utilities | Equipment - replace switches, breakers, terminal blocks, etc. | N/A | $226,180 in labor | $769,367.62 |
| 4361 | E | Administration Building | Equipment - replace 2 stand-by generators & 2 transfer switches | Raise equipment above flood levels | N/A | $145,966.22 |
| 1224 | E | Administration Building | Building structure, interior/exterior repair | Raise equipment & place in enclosure | N/A | $2,428,939.00 |
| 1194 | F | Streeter Power Generating Plant | Equipment - motors, switches, batteries, control panels, transformers etc. | Numerous equipment mitigation, detailed in site sheets, not available | $320,832 in labor | $5,406,784.00 |
| 1181 | E | Administration, Warehouse, Annex, Viking & BDC Bldgs | Restore power by replacing numerous materials & equipment | N/A | N/A | $522,946.17 |
| 133 | E | Streeter Power Plant & Admin Bldg | Building and contents damages | N/A | N/A | $1,112,475.50 |
| 1063 | E | Streeter Power Plant Offices | Building damages | N/A | N/A | $198,441.13 |
| | | | | | **Total Physical Damage** | **$12,283,410.95** |
| | | | | | **Total Cost of Emergency Protective Measures** | **$487,800.96** |
| | | | | | **Total Displacement Costs** | **$232,951.85** |

[1] Category A: Debris Removal; Category B: Emergency Protective Measures; Category C: Roads and Bridges, Category E: Buildings and Equipment; Category F: Utilities; Category G: Parks, Recreational Facilities, and Other Items

N/A = Not Applicable

# Attachment 2

## Loss Calculations

*Table Att2-1*

| Cedar Falls Utilities Flood Protection Project, April 2008 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Cleanup Costs | Number of Staff Members Needed to Clean Up Mud and Debris: | 2 | FEMA standard value for loss of potable water service | *No Cleanup Costs* | | |
| | Number of Labor Hours per Staff Member (hours): | 4 | Discussions during site visit | | | |
| | FEMA Standard Value of Labor ($/hour): | $28.11 | FEMA standard value | | | |
| | **Cleanup Costs (2010 Dollars):** | **$225** | | **Cleanup Costs (2010 Dollars):** | **$0** | |
| Loss of Function - Parking Lot | Number of Employees Residing in the Main Administrative Building: | 150 | Discussions with Cedar Falls staff | *No Loss of Function for Parking Lot* | | |
| | Additional Commute as a Result of Flooded Parking Lot (minutes): | 14 | Discussions with Cedar Falls staff | | | |
| | Number of Days the Parking Lot is Not Available for Use: | 3 | Discussions with Cedar Falls staff | | | |
| | FEMA Standard Value of Labor ($/hour): | $28.11 | FEMA standard value | | | |
| | **Costs for Loss of Function of Parking Lot (2010 Dollars):** | **$2,952** | | **Costs for Loss of Function of Parking Lot (2010 Dollars):** | **$0** | |
| Emergency Response | *No Emergency Response Costs* | | | Number of People Required to Forklift Bladders in Preparation for Deployment: | 1 | Discussions with Cedar Falls staff |
| | | | | Number of Hours Required to Forklift Bladders: | 1 | Discussions with Cedar Falls staff |
| | | | | FEMA Standard Value of Labor ($/hour): | $28.11 | FEMA standard value |
| | **Emergency Response Costs (2010 Costs):** | **$0** | | **Emergency Response Costs (2010 Costs):** | **$28** | |

FEMA = Federal Emergency Management Agency
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete

# Appendix C

## Coralville Flood Control Project

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# Appendix C:

## Coralville Flood Control Project

### C1 Introduction

In 1994, the City of Coralville (City) in Johnson County, Iowa, worked with the U.S. Army Corps of Engineers (USACE) to design a levee system on Clear Creek to increase floodway capacity and to protect the U.S. Route 6/1st Avenue area. The levees were completed in 1996. However, because of limited funding, the installation of three pumping stations, flood control structures, and pipes with gate valves was postponed. Without these features, the levees prevent surface runoff from reaching the Clear Creek channel, and local runoff that is trapped behind the levees could cause flooding in Coralville.

In 1998, the City applied through the State of Iowa to the Federal Emergency Management Agency (FEMA) for Hazard Mitigation Grant Program (HMGP) funds to complete the levee project. Project components included installing permanent pumps and controls, flood control structures, flap gates, and backflow protection at three sites. In 2001, the project was amended to include a detention basin to handle the runoff from the Hawkeye Court area and alleviate the need to expand the capacity of the 1st Avenue pump station. As stated in the project files (FEMA, 2003), the purpose of the project was to "eliminate or substantially reduce localized flooding to 14 commercial buildings in the study area with an estimated building replacement value of $12.3 million in 1997."

The pump stations were incorporated into the existing storm sewer system, which normally drains by gravity to the river. During coincident rainfall and river flooding events, the pumps are intended to expel any stormwater runoff that backs up behind the levees until the river flooding recedes and the storm sewer system can operate by gravity again. The locations of the facilities are shown in **Figure C.1**. **Figure C.2** is a schematic of one of the pump stations. **Table C.1** provides basic components of the project.

The Coralville Flood Control Project was completed on November 18, 2002, at a total project cost of $1,364,111. HMGP funding provided approximately 50% ($682,055), and the City provided the remaining $682,056. The total project cost, in 2010 dollars, is $1,728,015.

***Figure C.1***

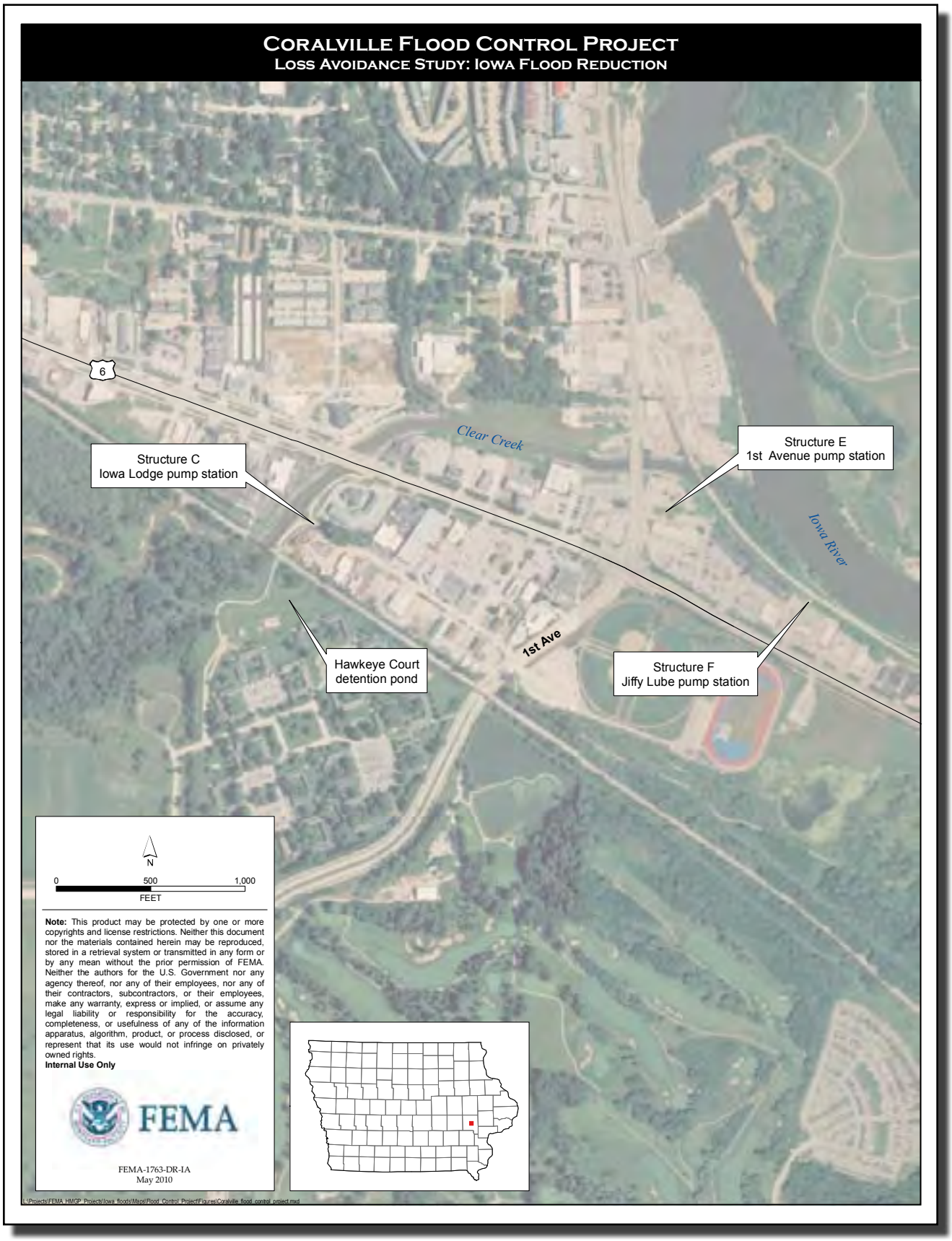
Coralville Flood Control Project
Loss Avoidance Study: Iowa Flood Reduction
6
Clear Creek
Structure C
Iowa Lodge pump station
Structure E
1st Avenue pump station
Iowa River
1st Ave
Hawkeye Court
detention pond
Structure F
Jiffy Lube pump station
N
0
500
1,000
FEET
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***Figure C.2*** *Schematic of Coralville Flood Control Project at Iowa Lodge Pump Station*

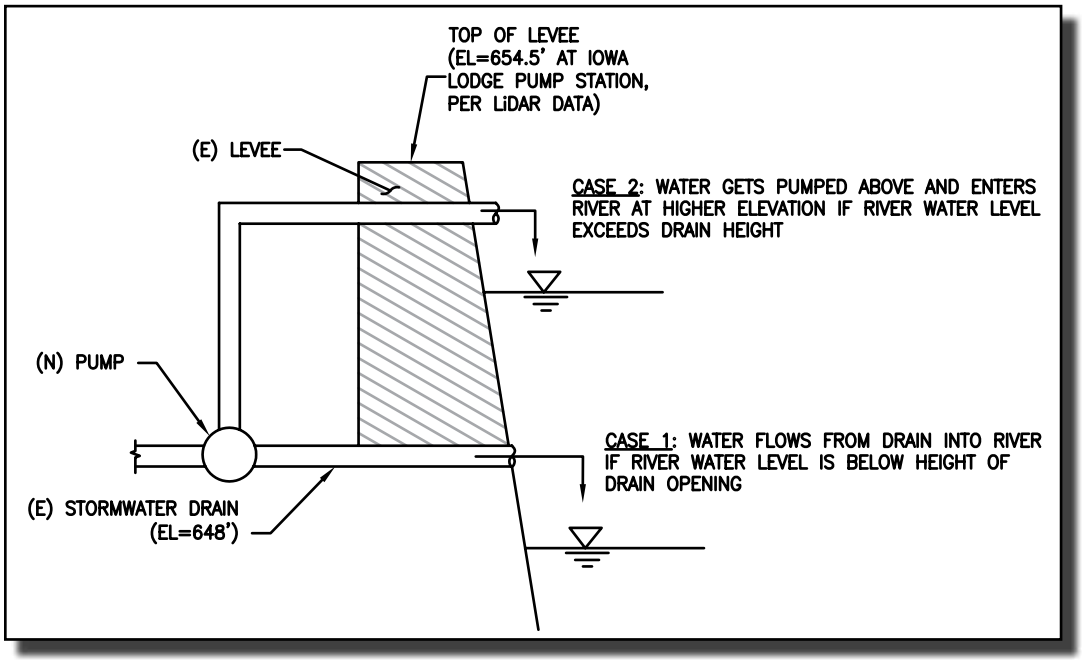


***Table C.1***

**Coralville Flood Control Project Components**

| Description | Latitude | Longitude | Project Construction Completion Date |
|---|---|---|---|
| ***Structure C – Iowa Lodge Pump Station*** | 41.670° | –91.572° | 11/18/2002 |
| ***Structure E – 1st Avenue Pump Station*** | 41.670° | –91.565° | 11/18/2002 |
| ***Structure F – Jiffy Lube Pump Station*** | 41.668° | –91.562° | 11/18/2002 |
| ***Hawkeye Court Detention Pond*** | 41.669° | –91.572° | 11/18/2002 |

## C2 Phase 1 – Data Collection

The HMGP project files were reviewed (FEMA, 2003) for data necessary for the loss avoidance study. Hydrologic data were obtained for two U.S. Geological Survey (USGS) gages: (1) on Clear Creek 1 mile upstream of the project site and (2) on the Iowa River at Iowa City. In addition, Hydrologic Engineering Center 2 (HEC-2) hydraulic modeling for Clear Creek used to prepare the Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM) was obtained from the FEMA Map Service Center (FEMA, 2007). Using this data, a preliminary Storm Event Analysis was completed prior to a site visit on February 5, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. During the site visit, the design and operation of

the pump stations were discussed in relation to recent flood events. The pumps were completely overwhelmed during the June 2008 flood event, during which flood waters overtopped the flood control levees on the Iowa River.

The City engineers explained that the pump stations are designed to operate when stormwater runoff from the local catchment is unable to discharge into Clear Creek by gravity due to high water on Clear Creek. Figure C.2 shows a schematic of the Coralville Flood Control Project at the Iowa Lodge Pump Station, where elevations are in shown in North American Vertical Datum of 1988 (NAVD88). The engineers also indicated that although a record of pump activation is not kept, the pumps have operated only for an estimated 30 hours since their implementation, and activation has often been a result of a malfunction of the mechanism that should automatically activate the pumps during high water.

During the site visit, airborne Light Detection and Ranging System (LiDAR) data with a vertical accuracy of approximately 18 centimeters and based on 1.4-meter average point spacing were obtained for the project site. Aerial photographs showing the inundation of commercial buildings during the June 2008 flood event were reviewed. Hydrologic and hydraulic data were reviewed and the design drawings for the new pump stations accessed.

## C3 Phase 2 – Physical Parameter Analysis

The three pump stations, detention basin, and the area protected by these facilities are at the confluence of the Iowa River and Clear Creek, an area that is hydraulically complex because of the effects of flooding in the separate watersheds of the Iowa River and Clear Creek. The USACE controls releases from the Coralville Reservoir on the Iowa River; the releases affect the flow in the Iowa River. Clear Creek is a narrow watershed that can reach flood stage with limited warning. Consequently, flooding at the project site can occur through increased discharges in the Iowa River, backwater in Clear Creek from the Iowa River, or separate storm events in the Clear Creek basin.

The project improvements expel stormwater and seepage water from precipitation events occurring coincidentally with riverine flooding. The pumps are required to operate only when both a significant rainfall event and a high river level occur at the same time. Therefore, the purpose of the Physical Parameter Analysis was to determine whether any large riverine events had occurred

since the project completion date and if a coincident precipitation peak had occurred.

## C3.1 Storm Event Analysis

Examination of topographic data for the area protected by the pump stations and detention pond indicated that the elevation of the lowest grade is approximately 648 feet (NAVD88) (City of Coralville, 2006). According to the FIS (FEMA, 2007), this is approximately the elevation of the 10-year flood event on the Iowa River and on Clear Creek. Therefore, it was assumed that the storm sewer system would not be able to drain and the pump stations would activate if the Iowa River or Clear Creek flooded to the elevation of the 10-year flood or greater.

A gage on Clear Creek (USGS gage #05454300) near Coralville has been used to measure and record daily discharges on Clear Creek since 1952 and has recorded daily stages since 1988 (USGS, n.d.a). This gage is located approximately 1 mile upstream of the project site, as shown on **Figure C.3**. During the life of the project, the gage has not recorded a daily or peak discharge greater than the 10-year flood event (5,400 cubic feet per second [cfs], based on the FIS). It was therefore assumed that no Clear Creek flood events have occurred that would have resulted in activation of the pump stations.

A gage on the Iowa River (USGS gage #05454500) at Iowa City has been used to measure and record daily discharges on the Iowa River since 1903 and daily stages since 1989 (USGS, n.d.b.). This gage is located approximately 3 miles downstream of the site. Examination of the gage data indicated that from June 8, 2008, to July 5, 2008, the Iowa River discharge exceeded the 10-year flood event discharge of 14,000 cfs, based on the FIS, and that the pump stations should have activated if a coincident rainfall event occurred during this time. **Table C.2** shows the peak water surface elevation (WSE) and discharge of the event. The event is estimated to be greater than the 100-year flood but less than the 500-year flood, based on discharges provided in the FIS (FEMA, 2007).

Examination of the precipitation record for a nearby gage (USGS gage #05453600 Rapid Creek below Morse, Iowa) indicated that rainfall did occur during this period with a total rainfall of 4.36 inches (USGS, n.d.c.). The Soil Conservation Service Runoff Curve Number (CN) method was used to estimate the amount of runoff that could have been produced (USDA, 1986).The contributory watershed area of the storm sewer and three pump stations is approximately 260 acres. Assuming 60 acres is

**Figure C.3**

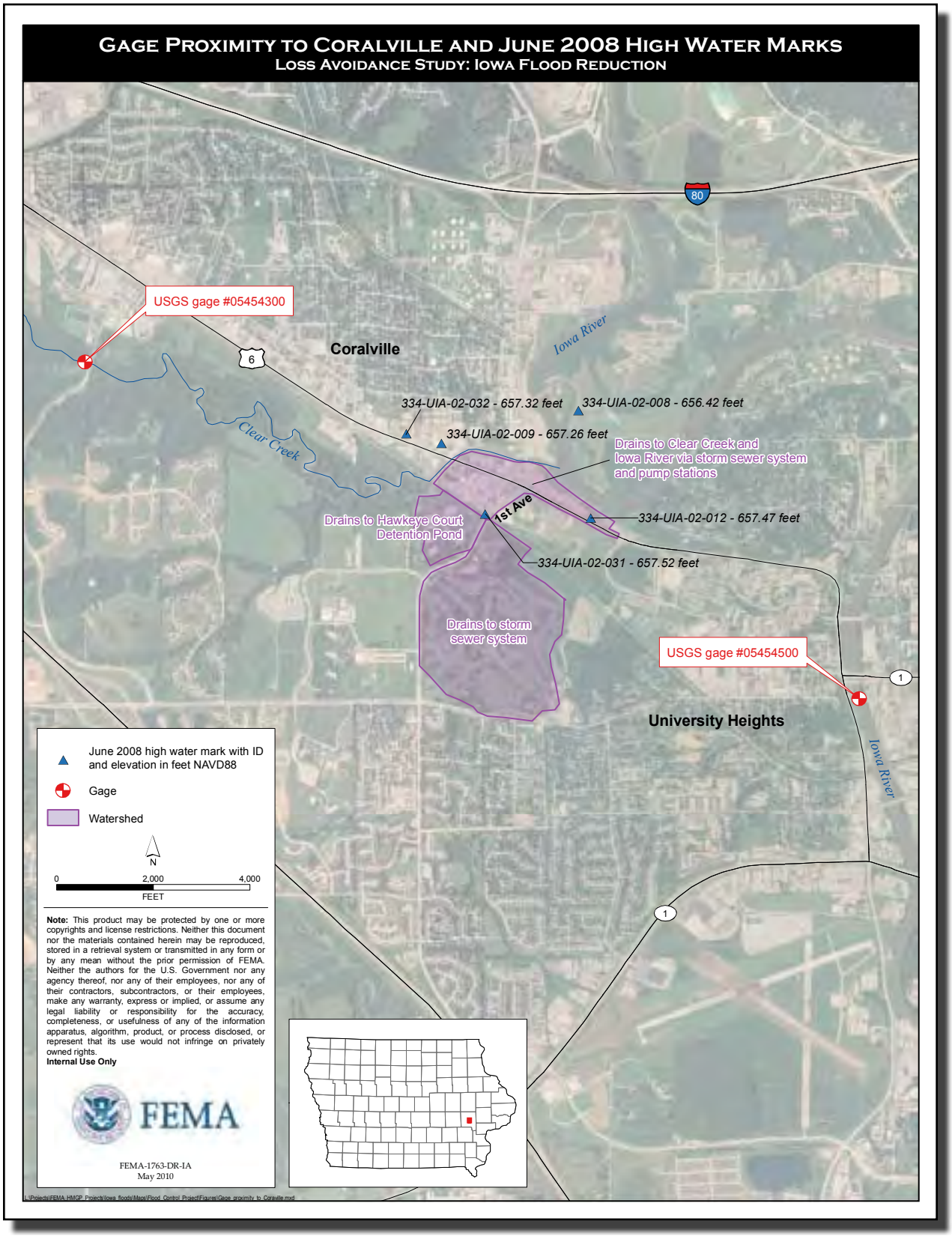
Gage Proximity to Coralville and June 2008 High Water Marks
Loss Avoidance Study: Iowa Flood Reduction
USGS gage #05454300
Coralville
Iowa River
Clear Creek
334-UIA-02-032 - 657.32 feet
334-UIA-02-008 - 656.42 feet
334-UIA-02-009 - 657.26 feet
Drains to Clear Creek and Iowa River via storm sewer system and pump stations
Drains to Hawkeye Court Detention Pond
1st Ave
334-UIA-02-012 - 657.47 feet
334-UIA-02-031 - 657.52 feet
Drains to storm sewer system
USGS gage #05454500
University Heights
Iowa River
June 2008 high water mark with ID and elevation in feet NAVD88
Gage
Watershed
N
0 2,000 4,000
FEET
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*Table C.2*

**Peak Gage Data on the Iowa River at Iowa City, Iowa**

| Event Date | Peak Gage Height (feet) | Peak WSE (feet NGVD29)[1] | Peak Discharge (cfs) |
|---|---|---|---|
| *June 15, 2008* | 31.53 | 648.8 | 41,100 |

1 Gage datum elevation is 617.27 feet NVGD29

cfs = cubic foot (feet) per second
NGVD29 = National Geodetic Vertical Datum of 1929
WSE = water surface elevation

commercial (CN 92) and the remaining 200 acres is golf course and residential (CN 65), the volume of runoff over this period could have been as much as 1.66 million cubic feet, which is enough water to cover the commercial area protected by the internal drainage system to an average depth of 8 inches.

## C3.2 Hydraulic Analysis

The peak WSE of the June 2008 flood event at the project site was transferred upstream from the gage at Iowa City by interpolating between the Iowa River 100-year and 500-year FIS flood profiles. The interpolated WSE at the project site was 656.4 feet National Geodetic Vertical Datum of 1929 (NGVD29). **Table C.3** summarizes the results of this analysis.

Furthermore, HWMs were surveyed by FEMA after the June 2008 flood event (FEMA, 2008). HWMs in the vicinity of the flood control facilities in Coralville are listed in **Table C.4** and shown on **Figure C.3**.

The WSE estimated using gage information and the FIS flood profile (see **Table C.3**) is approximately 1 foot lower than that estimated using the HWMs. This is likely because the gage is downstream

*Table C.3*

**Water Surface Elevations on the Iowa River for the June 15, 2008, Event**

| WSE at Iowa City Gage (feet NGVD29) | WSE at Commercial Subdivision | |
|---|---|---|
| | Feet NGVD29 | Feet NAVD88 |
| *648.8* | 656.4 | 656.3 |

Note: The difference between NAVD88 and NGVD29 is –0.11 ft (VERTCON, n.d.)

NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929
WSE = water surface elevation

*Table C.4*

**Surveyed High Water Marks for the June 15, 2008, Event**

| HWM Identification | HWM Elevation | | Location |
|---|---|---|---|
| | Feet NGVD29 | Feet NAVD88 | |
| 334-UIA-02-008 | 656.5 | 656.4 | On the Iowa River upstream of the confluence with Clear Creek |
| 334-UIA-02-009 | 657.4 | 657.3 | On Clear Creek just downstream of the U.S. Route 6 Bridge |
| 334-UIA-02-012 | 657.6 | 657.5 | On U.S. Route 6 near the Jiffy Lube pump station |
| 334-UIA-02-031 | 657.6 | 657.5 | Intersection of 1st Avenue and railroad tracks |
| 334-UIA-02-032 | 657.4 | 657.3 | On Clear Creek near U.S. Route 6 and 6th Avenue |

Note: The difference between NAVD88 and NGVD29 is –0.11 ft (VERTCON, n.d.)

HWM = high water mark
NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929

of a water control structure. Although the HWMs are the best source of flood information for the June 2008 flood event, both analyses show the levee (top elevation 654.5 feet NAVD88 or 654.6 NGVD29) being overtopped.

Because the surface drainage system was overwhelmed and the pump stations did not have the capacity to reduce flooding during the June 2008 flood event, the flood damage for the Mitigation Project Absent ($MP_A$) and Mitigation Project Complete ($MP_C$) scenarios are equivalent. In other words, the commercial area would have been flooded regardless of whether the project had been implemented. Because no losses were avoided, the project was not advanced to Phase 3.

## C4 Phase 3 – Loss Estimation Analysis

The results of the Physical Parameter Analysis showed that the only event that occurred since the project completion in which the pumps could have avoided flood losses was the June 2008 flood event. However, information obtained during the data collection process showed that because of the overtopping of the levee, the pumps were overwhelmed and no losses were avoided for this event. For this reason, no losses calculations were performed for the Coralville Flood Control Project. The Return on Investment for this project is therefore zero.

## C5 References

City of Coralville. 2006. Topographic information based on 2006 Aerial Photography. NAVD 88, US Survey Feet, Iowa State Plane South. Information obtained from Eric Fischer, City of Coralville.

FEMA (Federal Emergency Management Agency). 2003. Hazard Mitigation Grant Program, Coralville Project File, Project #0868-0023/0911-0009/0928-0015. Closeout Date: October 20, 2003.

_____. 2007. *Flood Insurance Study and Flood Insurance Rate Map, Johnson County, Iowa, and Incorporated Areas.*

———. 2008. Iowa June 2008 Rapid Response Riverine High Water Mark Collection. Washington, DC.

USDA (U.S. Department of Agriculture). 1986. *Urban Hydrology for Small Watersheds.* Technical Release 55. Soil Conservation Service.

USGS (U.S. Geological Survey). n.d.a. Information for gage #05454300 Clear Creek near Coralville, Iowa.

_____. n.d.b. Information for gage #05454500 Iowa River at Iowa City, Iowa.

_____. n.d.c. Information for gage #05453600 Rapid Creek below Morse, Iowa.

VERTCON. n.d. VERTCON datum conversion. Available at http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html. Accessed December 2009.

# Appendix D

## Des Moines, Central Campus Floodgates Project

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# Appendix D:

## Des Moines, Central Campus Floodgates Project

## D1 Introduction

The Des Moines, Central Campus Floodgates Project is located in a large business area in the heart of the City of Des Moines (City) in Polk County, Iowa, on the banks of the Raccoon River. The business area, commonly referred to as the Riverfront Area, is a major industrial and commercial area in the City and includes approximately 200 businesses. The majority of the businesses are warehouses, retail stores, offices, light industrial buildings, and public buildings. See **Figures D.1** and **D.2** for photographs of typical buildings in the project area. The location of the project site is shown in **Figure D.3**.

The Riverfront Area is partially surrounded by a U.S. Army Corps of Engineers (USACE) levee system that was built in 1969 and that protects the area from flooding on the Raccoon River. The original USACE design for the levee system included an opening at the rail yard to allow trains to pass through the City. The rail yard is between Grand Avenue and the Raccoon River behind Central

***Figure D.1*** *Typical Warehouse in the Riverfront Area, February 2, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure D.2*** *Typical Office Building in the Riverfront Area, February 2, 2010 (photo by Jane Branson, URS Group, Inc.)*

Campus Technical High School at the intersection of Grand Avenue and Fleur Drive.

Without floodgates, the opening is closed by sandbags when a flood event is expected. Sandbagging normally takes 2 days and is therefore dependent on adequate warning. When in place, the sandbag barrier blocks railroad traffic until the floodwaters subside enough to dismantle the sandbag barrier. During the Great Flood of 1993, the City experienced flooding in the Riverfront Area because the floodwaters rose quickly and the warning was insufficient for construction of the sandbag barrier.

Recognizing the difficulties involved in sandbagging, the City applied through the State of Iowa to the Federal Emergency Management Agency (FEMA) for Hazard Mitigation Grant Program (HMGP) funding in 1993 to construct a floodwall and two floodgates at the rail yard opening. The project involved the construction of 55 feet of floodwall and two 20-foot floodgates across the rail yard opening (City of Des Moines, 1994). **Figure D.4** is a photograph of one of the floodgates and the floodwall, and **Figure D.5** is a schematic of the project. The default gate position is open, and the gate can be closed with a 20-minute warning.

**Figure D.3**

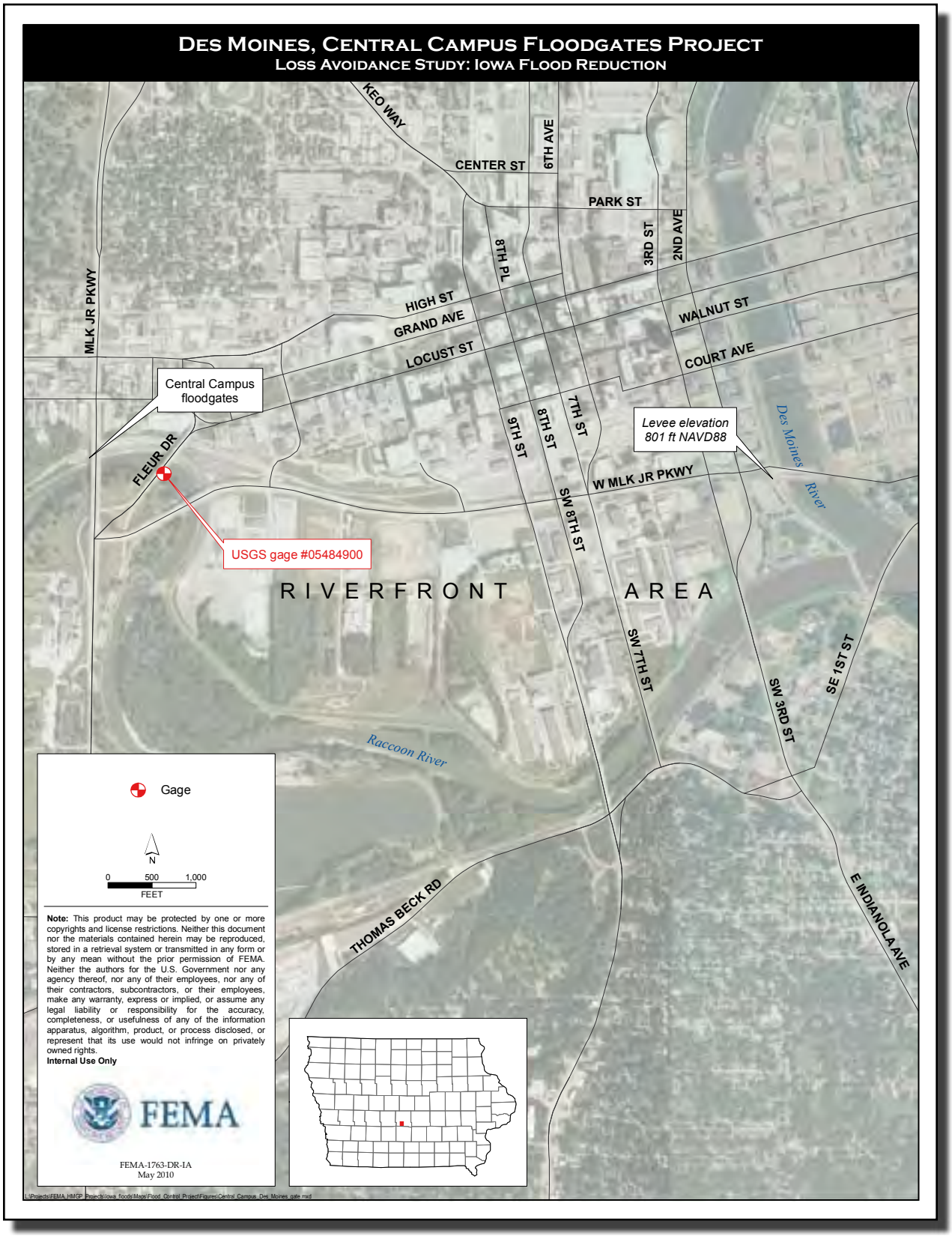
Des Moines, Central Campus Floodgates Project
Loss Avoidance Study: Iowa Flood Reduction
KEO WAY
CENTER ST
6TH AVE
PARK ST
3RD ST
2ND AVE
8TH PL
MLK JR PKWY
HIGH ST
GRAND AVE
WALNUT ST
LOCUST ST
COURT AVE
Central Campus floodgates
FLEUR DR
9TH ST
8TH ST
7TH ST
Levee elevation 801 ft NAVD88
Des Moines River
W MLK JR PKWY
SW 8TH ST
USGS gage #05484900
RIVERFRONT AREA
SW 7TH ST
SE 1ST ST
SW 3RD ST
Raccoon River
THOMAS BECK RD
E INDIANOLA AVE
Gage
N
0 500 1,000
FEET
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***Figure D.4*** *Central Campus Floodwall and One of Two Floodgates, February 2, 2010 (photo by Jane Branson, URS Group, Inc.)*

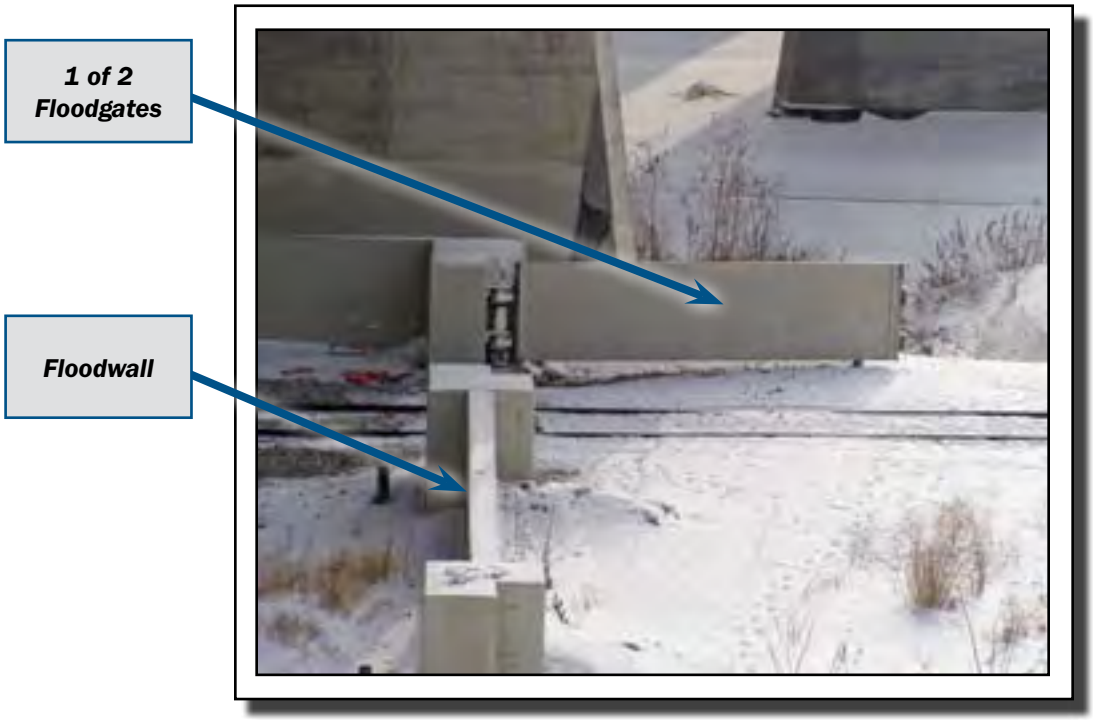
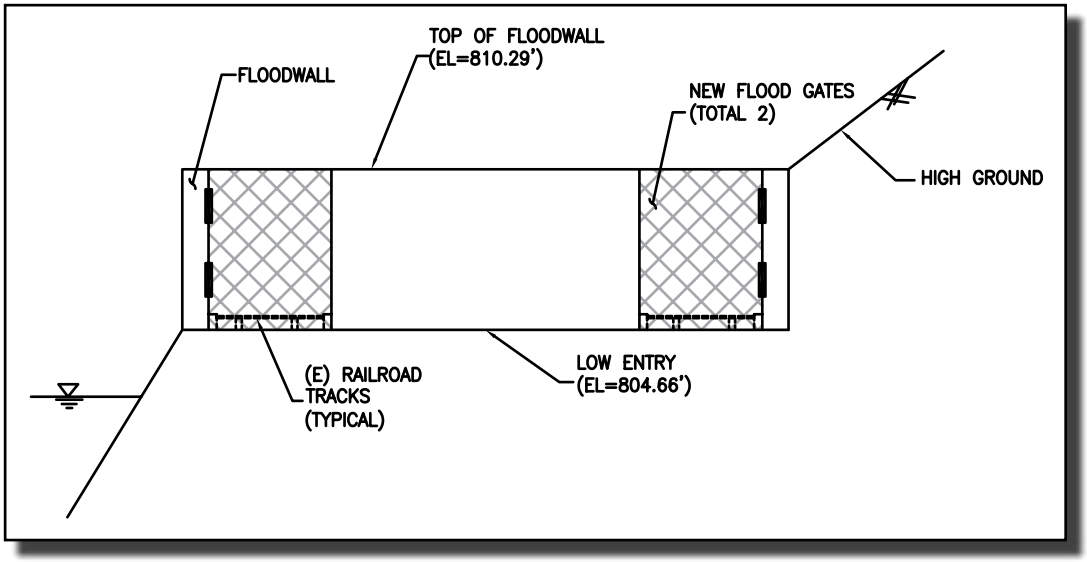



***Figure D.5*** *Schematic of Des Moines, Central Campus Floodgates Project*



The project was completed on March 25, 1996, at a cost of $342,092 ($503,752 in 2010 dollars). HMGP funds provided 75% ($256,569), and the City provided the remaining 25% ($85,523).

## D2 Phase 1 – Data Collection

The HMGP project files (FEMA, 1996) were reviewed for data necessary to complete the loss avoidance study (LAS). The data included project cost, project completion date, design plans or drawings for the project, topographic data, hydraulic modeling, topographic data, and building information.

To complete the Physical Parameter Analysis, hydrologic and hydraulic data for the Raccoon River used to prepare the Flood Insurance Study (FIS) and the Flood Insurance Rate Map (FIRM) for the City (FEMA, 1988) were reviewed. Hydraulic data from a Letter of Map Revision for the Martin Luther King Jr. Parkway bridges was reviewed (see **Section D3.2**). The USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) model (USACE, 2005) of various floods for the reach of interest on the Raccoon River was also obtained. A preliminary Storm Event Analysis was completed using these data prior to a site visit on February 2, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. Much of the discussion during the site visit involved gaining an understanding of the operation of the railroad, floodgates and floodwall, sandbagging efforts, and the effect of flooding on business in the Riverfront Area. Information about business closures and railroad fees were also discussed. A tour of the Riverfront Area businesses was conducted to gather building information such as the building type, number of stories, and building use. During the site visit, City representatives explained that businesses in the Riverfront Area were advised to close for 1 day during the June 2008 flood event because of the fear that the USACE levees protecting the area would breach.

Following the site visit, phone calls were made to the City and several businesses to confirm building use. The Des Moines Floodplain Administrator was contacted to inquire about the availability of elevation certificates for buildings within the area protected by the project. The Floodplain Administrator explained that the Riverfront Area is a levee-protected area and that the City does not maintain elevation certificates for such areas. However, the City suggested that Hubbell Realty could possibly provide first floor elevations (FFEs) for several of the Riverfront Area buildings.

Hubbell Realty was able to provide FFEs for 15 of the Riverfront Area buildings.

The ground elevation data were obtained from the Iowa Airborne Light Detection and Ranging Systems (LiDAR) Consortium. Ground elevations were represented as a bare-earth digital elevation model (DEM) derived from LiDAR data and are the most detailed elevation data available for the project area.

## D3 Phase 2 – Physical Parameter Analysis

The LAS Phase 2 methodology that was used for the Des Moines, Central Campus Floodgates Project is described in the following subsections. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

### D3.1 Storm Event Analysis

A U.S. Geological Survey (USGS) gage for the Raccoon River (USGS gage #05484900) at Fleur Drive has been used to measure and record stage and discharge information since it became operational in 1984 (USGS, n.d.). The location of the gage is shown on **Figure D.3**. Two large flood events have occurred since the project completion date. These events are listed in **Table D.1** in order of decreasing magnitude and the annual peak events for the respective water year. The record of daily mean stream flow was examined to determine whether other large events occurred during the same years as these large events, and no other significant events were found.

Results of flood-frequency studies were used to provide an estimate of the recurrence interval for the events listed in **Table D.1**. According to the FIS, both events are greater than the 100-year

*Table D.1*

**Peak Gage Data on the Raccoon River, Des Moines, Iowa**

| Event Date | Peak Gage Height (feet) | Peak Gage Height (feet NGVD29)[1] | Peak Discharge (cfs) |
|---|---|---|---|
| *June 13, 2008* | 24.66 | 805.36 | 56,300 |
| *June 16, 1998* | 20.45 | 801.15 | 45,000 |

1 Gage datum elevation is 780.70 NVGD29 (USGS, n.d.)
cfs = cubic feet per second
NGVD29 = National Geodetic Vertical Datum of 1929

flood but less than the 500-year flood. A USACE report (USACE, 2005) indicates that the discharge of the June 2008 flood event is between the 50-year and 100-year flood event, while the discharge of the June 1998 flood event is between the 25-year and 50-year flood event.

## D3.2 Hydraulic Analysis

The FIS and FIRM for the City show that this reach of the Raccoon River was studied in detail. However, the HEC-2 model used to create the published flood profile (FEMA, 1988) does not include the recently constructed Martin Luther King Jr. Parkway bridges. A Letter of Map Revision (#09-07-1717P, which FEMA is currently reviewing) will incorporate the effects of the Martin Luther King Jr. Parkway bridges into the existing FIS flood profile.

Separately, the USACE developed a HEC-RAS model of various floods for the reach of the Raccoon River associated with the Riverfront Area, which includes the Martin Luther King Jr. Parkway bridges (USACE, 2005). The flood profiles from this hydraulic model were used to interpolate the gage elevations upstream to the project site. **Table D.2** summarizes the results of this analysis.

*Table D.2*

**Water Surface Elevations at the Des Moines, Central Campus Floodgates Project Site**

| Event Date | WSE (feet, NGVD29)[1] |
|---|---|
| *June 13, 2008* | 805.6 |
| *June 16, 1998* | 801.7 |

1 WSE interpolated from existing U.S. Army Corps of Engineers flood profiles
NGVD29 = National Geodetic Vertical Datum of 1929
WSE = water surface elevation

FEMA surveyed HWMs after the June 2008 flood event (FEMA, 2008). Surveyed HWMs in the vicinity of the project provided flooding information for the Des Moines River even though the project is located on the Raccoon River nearly 14,000 feet upstream of the confluence with the Des Moines River. One HWM on the Raccoon River was surveyed, but the HWM is nearly 8,000 feet upstream of the gage on Fleur Drive. Gage data were therefore determined to be the most appropriate water surface elevation (WSE) information at the project site.

## D3.3 Flood Boundary Analysis

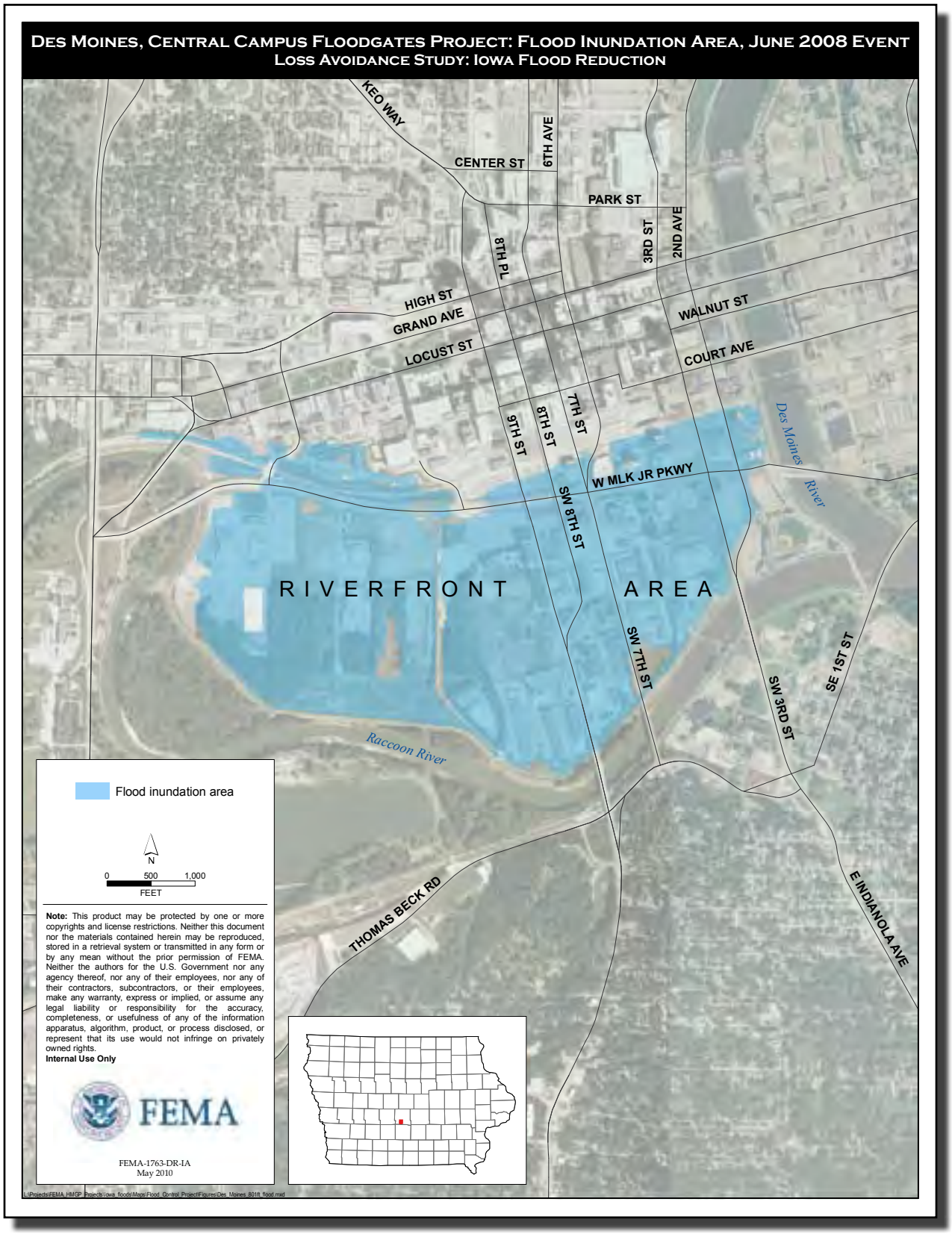
A Flood Boundary Analysis was performed to determine the extent of flooding if water entered the levee opening at the rail yard. It was determined that because the WSE of the June 1998 flood event was below the low entry elevation of the levee opening at 804.66 feet National Geodetic Vertical Datum of 1929 (NGVD29), that no flooding would have been sustained for either the $MP_A$ or Mitigation Project Complete ($MP_C$) scenario. However, the June 2008 flood event would have been high enough to pass through the levee opening in the $MP_A$ scenario. Because the flood elevation is lower than the elevation at the top of the floodgates (810.29 feet NGVD29), no $MP_C$ damage was sustained. This is consistent with information gathered during the site visit.

During the site visit, the City Engineer pointed out that during the Great Flood of 1993, the Raccoon River floodwaters that entered the Riverfront Area through the levee opening flowed east through the industrial area and discharged over the levee and into the Des Moines River. Therefore, it was determined that the top of the Des Moines River levee controlled the WSE within the Riverfront Area. The elevation of this levee is approximately 801 feet North American Vertical Datum of 1988 (NAVD88) (GeoTREE, 2009). The datum shift between NAVD88 and NGVD29 at the project location is 0.125 feet. Therefore, the flood boundary was mapped with a constant elevation of 801 feet NAVD88, which is equivalent to 800.88 feet NGVD29. This boundary is shown in **Figure D.6**.

The flood boundary was determined using Geographic Information System (GIS) software and LiDAR data. The estimated area of inundation was mapped where the ground elevations were below the WSE of 801 feet NAVD88. The ground elevations were represented as a bare-earth DEM derived from LiDAR data obtained from the Iowa LiDAR Consortium (GeoTREE, 2009), which is the most detailed elevation data available for the study area. It was assumed that the flooding from the Raccoon River would not inundate the ballpark or the area approximately a block north of the West Martin Luther King, Jr. Parkway, based on information obtained during the site visit.

Flood depths for buildings in the study area were calculated as the difference between the flood WSE and either (1) the FFE determined from building elevation certificates or (2) the FFE estimated from LiDAR ground-surface elevations combined with Hazards U.S. – Multi-Hazard (HAZUS-MH) standard offsets. The HAZUS-MH standard offsets depend on the building foundation

*Figure D.6*


DES MOINES, CENTRAL CAMPUS FLOODGATES PROJECT: FLOOD INUNDATION AREA, JUNE 2008 EVENT
LOSS AVOIDANCE STUDY: IOWA FLOOD REDUCTION
KEO WAY
CENTER ST
6TH AVE
PARK ST
3RD ST
2ND AVE
8TH PL
HIGH ST
GRAND AVE
WALNUT ST
LOCUST ST
COURT AVE
9TH ST
8TH ST
7TH ST
W MLK JR PKWY
SW 8TH ST
Des Moines River
RIVERFRONT AREA
SW 7TH ST
SE 1ST ST
SW 3RD ST
Raccoon River
THOMAS BECK RD
E INDIANOLA AVE
Flood inundation area
N
0 500 1,000
FEET
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May 2010

type. For example, the standard offset is 4 feet for buildings with a basement and 1 foot for buildings with slab-on-grade.

Based on the Flood Boundary Analysis, it was determined that 78 commercial businesses and public buildings in the Riverfront Area would have been flooded in the $MP_A$ scenario of the June 2008 flood event. **Attachment 1** includes a list of addresses for the buildings affected by this event and the depth of flooding experienced by each building. For the $MP_C$ scenario, the Flood Boundary Analysis showed that no buildings would have been flooded by any of the flood events that were considered. Because damage would have been caused in the $MP_A$ scenario in the June 2008 flood event, the project advanced to Phase 3 of the LAS.

## D4 Phase 3 – Loss Estimation Analysis

The losses avoided for the project include physical damage such as building and contents damage to the Riverfront Area businesses and loss of function for these businesses. The loss-of-function costs include displacement costs for affected buildings, loss of business income for commercial businesses, and loss of public service for public buildings. In addition, the mitigation project also affects the function of the Union Pacific Railroad, which has trains that pass through the rail yard where the floodgates are located.

Physical damage for the Des Moines, Central Campus Floodgates Project would have been significant for the June 2008 flood event in the $MP_A$ scenario. Loss-of-function costs and emergency management costs are also discussed, but these costs were not estimated because of the significant Return on Investment (ROI) calculated from quantifying physical damage alone (see **Section D4.4**).

### D4.1 Physical Damage

The physical damage consists of building and building contents damage. The methodology for determining physical damage is discussed in the following subsections.

#### D4.1.1 Building Damage

Building data such as building use, construction type, and number of stories were collected during the site visit. Building replacement values (BRVs) and building square footage (including square footages of first floor area and basement) were obtained from parcel data available from the Polk County Assessor's website. Although

the BRVs were fair market values rather than the actual costs to construct buildings of similar use, these BRVs are conservative when compared to the BRVs estimated from national cost estimation guides. Only when building values were not available from the assessor's website were the estimated values from national cost estimation guides used.

The BRV, considering only the first floor area, was used in conjunction with depth-damage functions (DDFs) from the USACE St. Paul District to determine the building damage for the loss calculations. Only the first floor area was considered because the floors above the first floor do not get flooded and would not incur building damage. The USACE St. Paul District DDFs were used in place of the FEMA Benefit-Cost Analysis (BCA) Tool Version 4.5 nonresidential depth-damage curves (FEMA, 2009) because the USACE St. Paul District DDFs account for basement damage while many of the FEMA BCA Tool nonresidential DDFs do not.

The flood depths for each flooded building were correlated with the appropriate building damage percentage from the USACE St. Paul District DDFs. Linear interpolation between flood depths was used when necessary. Finally, the building damage percentage was multiplied by the BRV to determine the building damage for the June 2008 flood event. The assumptions behind estimated building damage are provided in **Attachment 2**.

The DDFs for the following nonresidential buildings were used:

- Drug, grocery chain stores
- Hardware, paint, sporting goods, auto parts stores
- Restaurants, larger fast foods
- Warehouse, storage building (warehouse non-refrigerated)
- General office (e.g., doctor, realtor, bank)
- Warehouse/office combo (warehouse non-refrigerated)
- Machine shop, small manufacturing (light manufacturing)
- Apartment on slab (apartment one-story)
- Public property – less damageable type
- Public property – more damageable type

For more information regarding the DDFs, see **Appendix J**.

There is one homeless shelter among the affected buildings. The shelter is categorized as an "Apartment on Slab (Apartment one-story)" because it is the most comparable building use. This is a reasonable approach because the homeless shelter is a one-story building and has many of the same amenities as an apartment,

including office areas, beds, supplies, laundry facilities, and a kitchen area.

Several of the light industrial buildings and warehouses have basements. For these buildings, the "Downtown Commercial Basements Unfinished" DDF was used to assess building damage. This percentage damage for this DDF was applied to the BRV associated with the entire building, including the basement.

#### D4.1.2 Building Contents Damage

The USACE St. Paul District DDFs were also used to determine building contents damage. Using the appropriate contents-to-building ratio for each flooded building, this ratio was multiplied by the BRV to determine the value of contents. The flood depths for each flooded building were then correlated with the appropriate DDFs to find the damage percentage for contents. Finally, the percentage contents damage was multiplied by the value of contents to determine the contents damage.

### D4.2 Loss of Function

Loss-of-function damage for the $MP_A$ scenario during the June 2008 flood event include displacement costs for businesses and residents living in the Riverfront Area that would be displaced to temporary quarters for continued operation or living. They also include loss of business income for commercial businesses and loss of public services for public buildings.

Another cost from loss of function is the cost incurred because Union Pacific trains, which pass through the floodgates, must be rerouted. However, this damage is incurred for both the $MP_A$ and $MP_C$ scenarios and would therefore have limited impact on the calculation of losses avoided.

No damage was calculated from loss of function in the $MP_A$ sceanrio for June 2008 flood event because the estimated losses avoided for physical damage by itself is sufficient to exceed the project investment costs by almost 100 times (see **Section D4.3**).

### D4.3 Summary of Damage

The $MP_A$ and $MP_C$ damage for the Des Moines, Central Campus Floodgates Project is shown in **Table D.3**. The results of the loss calculations showed that considering only the losses associated with physical damage results in a significant ROI. Thus, considering

**Table D.3**

**Des Moines, Central Campus Floodgates Project Loss Estimation Analysis Results and Return on Mitigation Investment (ROI)**

| | Results by Loss Category | | | | | | |
|---|---|---|---|---|---|---|---|
| | $MP_A$ Scenario Damage | | $MP_C$ Scenario Damage | | | | |
| | Physical Damage | | Physical Damage | | | | |
| Event Date | Damage to Building | Damage to Contents | Damage to Structure | Damage to Contents | Losses Avoided | Project Investment | ROI |
| *June 9, 2008* | $19,061,513 | $30,095,456 | $0 | $0 | $49,156,969 | $503,752 | 9,758% |
| **Total** | **$19,061,513** | **$30,095,456** | **$0** | **$0** | **$49,156,969** | **$503,752** | **9,758%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

additional losses associated with loss of function would increase the ROI.

As shown in **Table D.3**, the losses avoided including only physical damage to buildings and contents results in an ROI of 9,758%, almost 100 times the project investment cost. If damage from loss of function were estimated and included, the ROI would be substantially higher.

## D5 References

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# Attachment 1

## Buildings Affected by Flooding, June 2008 Flood Event

**Table Att1-1**

| Des Moines, Central Campus Floodgates Project: Buildings Affected by Flooding, June 2008 Event | | |
|---|---|---|
| BUILDING NUMBER | ADDRESS | FINAL FLOOD DEPTH (ft) |
| 1 | 700 SW 9TH ST, DES MOINES | 4.5 |
| 2 | 629 SW 9TH ST, DES MOINES | 4.6 |
| 3 | 630 SW 9TH ST, DES MOINES | 4.0 |
| 4 | 510 MURPHY ST, DES MOINES | -0.4 |
| 5 | 501 SW 7TH ST, DES MOINES | 0.6 |
| 6 | 400 SW 8TH ST, DES MOINES | 1.5 |
| 7 | 401 SW 8TH ST, DES MOINES | 2.0 |
| 8 | 401 SW 7TH ST, DES MOINES | 1.1 |
| 9 | 512 TUTTLE ST, DES MOINES | 1.2 |
| 10 | 315 SW 14TH ST, DES MOINES | 2.6 |
| 11 | 338 SW 6TH ST, DES MOINES | 2.4 |
| 12 | 320 SW 9TH ST, DES MOINES | 4.1 |
| 13 | 339 SW 6TH ST, DES MOINES | 1.2 |
| 14 | 334 SW 8TH ST, DES MOINES | 0.6 |
| 15 | 333 SW 9TH ST, DES MOINES | 4.0 |
| 16 | 326 SW 5TH ST, DES MOINES | -1.3 |
| 17 | 323 SW 6TH ST, DES MOINES | -0.3 |
| 18 | 702 ELM ST, DES MOINES | 0.4 |
| 19 | 319 SW 5TH ST, DES MOINES | -0.1 |
| 20 | 316 SW 5TH ST, DES MOINES | -1.4 |
| 21 | 512 ELM ST, DES MOINES | 1.0 |
| 22 | 600 SW 7TH ST, DES MOINES | 1.1 |
| 23 | N/A SW 11TH ST, DES MOINES | 2.4 |
| 24 | N/A SW 14TH ST, DES MOINES | 2.3 |
| 25 | N/A SW 5TH ST, DES MOINES | 3.0 |
| 26 | 300 SW 6TH ST, DES MOINES | 0.3 |
| 27 | 300 SW 5TH ST, DES MOINES | 0.1 |
| 28 | 313 SW 5TH ST, DES MOINES | -0.1 |
| 29 | 101 SW 16TH ST, DES MOINES | -1.0 |
| 30 | 106 SW 7TH ST, DES MOINES | -4.2 |
| 31 | 113 SW 8TH ST, DES MOINES | -1.9 |
| 32 | 2 SW 9TH ST, DES MOINES | -8.2 |
| 33 | 204 SW 2ND ST, DES MOINES | -3.3 |
| 34 | 110 SW 5TH ST, DES MOINES | 1.3 |
| 35 | 200 SW 2ND ST, DES MOINES | -0.8 |
| 36 | 1526 WALNUT ST, DES MOINES | -1.1 |
| 37 | 1514 WALNUT ST, DES MOINES | -4.4 |
| 38 | 1314 MULBERRY ST, DES MOINES | -0.2 |
| 39 | 401 W MARTIN LUTHER KING JR PKWY, DES MOINES | 0.5 |
| 40 | 1440 WALNUT ST, DES MOINES | -23.0 |
| 41 | 123 SW 3RD ST, DES MOINES | -2.4 |
| 42 | 112 SW 2ND ST, DES MOINES | -2.7 |
| 43 | 121 SW 2ND ST, DES MOINES | -0.7 |
| 44 | 101 SW 4TH ST, DES MOINES | 1.0 |
| 45 | 100 SW 2ND ST, DES MOINES | 1.3 |
| 46 | 100 MARKET ST, DES MOINES | 4.2 |
| 47 | N/A SW 2ND ST, DES MOINES | 3.2 |
| 48 | 101 SW 2ND ST, DES MOINES | -4.0 |
| 49 | 309 SW 8TH ST, DES MOINES | 1.1 |
| 50 | 322 SW 3RD ST, DES MOINES | 0.4 |
| 51 | 510 SW 9TH ST, DES MOINES | 1.7 |
| 52 | 817 SW 9TH ST, DES MOINES | 3.1 |
| 53 | 200 SW 16TH ST, DES MOINES | -2.9 |
| 54 | N/A SW 16TH ST, DES MOINES | 5.7 |
| 55 | 328 SW 5TH ST, DES MOINES | -0.6 |
| 56 | 815 SW 9TH ST, DES MOINES | 4.7 |
| 57 | 920 MORGAN ST, DES MOINES | 4.5 |
| 58 | 1100 DART WAY, DES MOINES | 7.4 |
| 59 | 1100 DART WAY, DES MOINES | 8.2 |
| 60 | 1100 DART WAY, DES MOINES | 7.7 |
| 61 | 1350 TUTTLE ST, DES MOINES | 4.7 |
| 62 | 1300 TUTTLE ST, DES MOINES | 7.0 |
| 63 | 1350 W MARTIN LUTHER KING JR PKWY, DES MOINES | 2.1 |
| 64 | 1350 W MARTIN LUTHER KING JR PKWY, DES MOINES | 1.1 |
| 65 | 104 SW 4TH ST, DES MOINES | -3.7 |
| 66 | 601 SW 9TH ST, DES MOINES | 4.6 |
| 67 | 520 SW 5TH ST, DES MOINES | 1.1 |
| 68 | 535 SW 7TH ST, DES MOINES | 1.6 |
| 69 | 500 SW 7TH ST, DES MOINES | 2.4 |
| 70 | 525 SW 5TH ST, DES MOINES | 1.2 |
| 71 | 525 SW 5TH ST, DES MOINES | 1.2 |
| 72 | 525 SW 5TH ST, DES MOINES | 1.2 |
| 73 | 525 SW 5TH ST, DES MOINES | 1.2 |
| 74 | 226 ELM ST, DES MOINES | -0.9 |
| 75 | 101 SW 5TH ST, DES MOINES | 0.3 |
| 76 | 120 SW 5TH ST, DES MOINES | -2.3 |
| 77 | 120 SW 6TH ST, DES MOINES | -1.7 |
| 78 | 1716 LOCUST ST, DES MOINES | -19.0 |

# Attachment 2

## Loss Calculations

***Table Att2-1*** *(part 1 of 3)*

## Summary of Losses Avoided and ROI Calculation for Des Moines, Central Campus Floodgates Project, June 2008 Event

| No. | Address | Business Type | Basement Square Footage | Ground Floor Square Footage | Building Square Footage (Gross Area) | BRV (2010$) | FFE (ft, NAVD) | WSE for Jun 08 Event (ft, NAVD) | Final Flood Depth (ft) | Building Damage (%) | Content Damage (%) | Basement Building Damage (%) | Basement Content Damage (%) | Building Damage ($) | Contents Damage ($) | Total Losses Avoided ($) | Total Project Investment (2010$) | ROI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 700 SW 9TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 35,590 | 35,590 | $ 950,999.0 | 796.47 | 801.00 | 4.53 | 32.14 | 61.34 | 0.00 | 0.00 | $ 305,658.7 | $ 583,354.2 | $ 889,012.9 | | |
| 2 | 629 SW 9TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 42,520 | 42,520 | $ 1,323,550.0 | 796.40 | 801.00 | 4.60 | 32.44 | 61.96 | 0.00 | 0.00 | $ 429,391.3 | $ 820,137.1 | $ 1,249,528.4 | | |
| 3 | 630 SW 9TH ST, DES MOINES | Drug, grocery chain stores (Grocery ) | 0 | 842 | 842 | $ 842,540.0 | 797.00 | 801.00 | 4.00 | 30.61 | 64.18 | 0.00 | 0.00 | $ 257,929.5 | $ 540,758.0 | $ 798,687.5 | | |
| 4 | 510 MURPHY ST, DES MOINES | Hardware, paint, sporting goods, auto parts stores | 0 | 15,141 | 15,141 | $ 464,530.0 | 801.41 | 801.00 | -0.41 | 0.00 | 7.72 | 0.00 | 0.00 | $ - | $ 17,932.8 | $ 17,932.8 | | |
| 5 | 501 SW 7TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 50,125 | 50,125 | $ 3,485,108.0 | 800.44 | 801.00 | 0.56 | 8.24 | 12.04 | 0.00 | 0.00 | $ 287,179.9 | $ 209,873.2 | $ 497,053.1 | | |
| 6 | 400 SW 8TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 40,080 | 40,080 | $ 2,890,180.0 | 799.55 | 801.00 | 1.46 | 16.18 | 26.51 | 0.00 | 0.00 | $ 467,761.2 | $ 383,042.8 | $ 850,804.0 | | |
| 7 | 401 SW 8TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 28,772 | 28,772 | $ 861,080.0 | 799.01 | 801.00 | 1.99 | 19.33 | 34.13 | 0.00 | 0.00 | $ 166,439.9 | $ 146,936.4 | $ 313,376.3 | | |
| 8 | 401 SW 7TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 37,770 | 37,770 | $ 2,889,150.0 | 799.95 | 801.00 | 1.05 | 13.82 | 20.79 | 0.00 | 0.00 | $ 399,410.5 | $ 300,276.6 | $ 699,687.1 | | |
| 9 | 512 TUTTLE ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 31,000 | 31,000 | $ 396,241.0 | 799.78 | 801.00 | 1.22 | 13.55 | 23.50 | 0.00 | 0.00 | $ 53,677.3 | $ 93,129.5 | $ 146,806.8 | | |
| 10 | 315 SW 14TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 31,148 | 31,148 | $ 560,320.0 | 798.45 | 801.00 | 2.55 | 22.95 | 41.30 | 0.00 | 0.00 | $ 128,601.1 | $ 231,415.9 | $ 360,017.0 | | |
| 11 | 338 SW 6TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 8,052 | 8,052 | $ 400,979.0 | 798.58 | 801.00 | 2.42 | 22.20 | 39.42 | 0.00 | 0.00 | $ 89,009.6 | $ 158,083.2 | $ 247,092.9 | | |
| 12 | 320 SW 9TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 18,515 | 18,515 | $ 306,940.0 | 796.90 | 801.00 | 4.10 | 30.24 | 57.41 | 0.00 | 0.00 | $ 92,824.8 | $ 176,227.0 | $ 269,051.8 | | |
| 13 | 339 SW 6TH ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 0 | 9,977 | 9,977 | $ 416,120.0 | 799.79 | 801.00 | 1.21 | 13.56 | 21.76 | 0.00 | 0.00 | $ 56,417.1 | $ 90,528.5 | $ 146,945.6 | | |
| 14 | 334 SW 8TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 31,080 | 33,390 | 76,020 | $ 1,030,309.0 | 800.37 | 801.00 | 0.63 | 7.89 | 13.49 | 5.00 | 12.00 | $ 87,202.0 | $ 122,882.2 | $ 210,084.1 | | |
| 15 | 333 SW 9TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 25,800 | 25,800 | $ 881,268.0 | 796.98 | 801.00 | 4.02 | 29.90 | 56.70 | 0.00 | 0.00 | $ 263,470.9 | $ 499,680.7 | $ 763,151.6 | | |
| 16 | 326 SW 5TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 8,107 | 9,507 | 17,614 | $ 233,295.0 | 802.29 | 801.00 | -1.29 | 0.00 | 0.00 | 3.71 | 10.71 | $ 8,649.5 | $ 12,490.1 | $ 21,139.6 | | |
| 17 | 323 SW 6TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 4,975 | 8,811 | 9,611 | $ 194,052.0 | 801.25 | 801.00 | -0.25 | 0.00 | 0.00 | 4.75 | 11.75 | $ 9,210.0 | $ 11,396.8 | $ 20,606.9 | | |
| 18 | 702 ELM ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 14,760 | 14,760 | 59,040 | $ 178,808.0 | 800.64 | 801.00 | 0.36 | 4.91 | 8.01 | 5.00 | 12.00 | $ 11,133.1 | $ 14,307.2 | $ 25,440.3 | | |
| 19 | 319 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 7,986 | 7,986 | 23,958 | $ 160,062.0 | 801.07 | 801.00 | -0.07 | 0.00 | 0.00 | 4.93 | 11.93 | $ 7,891.0 | $ 9,547.7 | $ 17,438.7 | | |
| 20 | 316 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 8,319 | 9,425 | 42,701 | $ 682,375.0 | 802.37 | 801.00 | -1.37 | 0.00 | 0.00 | 3.63 | 10.63 | $ 24,800.5 | $ 36,283.4 | $ 61,083.9 | | |
| 21 | 512 ELM ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 9,900 | 9,900 | $ 447,226.0 | 799.97 | 801.00 | 1.03 | 12.06 | 21.11 | 0.00 | 0.00 | $ 53,915.5 | $ 94,409.9 | $ 148,325.4 | | |
| 22 | 600 SW 7TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 52,920 | 52,920 | $ 1,835,460.0 | 799.91 | 801.00 | 1.09 | 12.55 | 21.90 | 0.00 | 0.00 | $ 230,262.1 | $ 401,892.3 | $ 632,154.4 | | |
| 23 | N/A SW 11TH ST, DES MOINES | Public property - more damageable type | 0 | 1,659 | 1,659 | $ 727,180.0 | 798.55 | 801.00 | 2.45 | 19.34 | 44.45 | 0.00 | 0.00 | $ 140,665.8 | $ 161,627.9 | $ 302,293.7 | | |
| 24 | N/A SW 14TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 29,704 | 29,704 | $ 757,050.0 | 798.72 | 801.00 | 2.28 | 21.47 | 37.60 | 0.00 | 0.00 | $ 162,501.4 | $ 284,639.2 | $ 447,140.6 | | |
| 25 | N/A SW 5TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 559 | 559 | $ 7,982.5 | 798.02 | 801.00 | 2.98 | 25.31 | 47.17 | 0.00 | 0.00 | $ 2,020.1 | $ 3,765.2 | $ 5,785.3 | | |
| 26 | 300 SW 6TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 10,769 | 10,769 | 97,405 | $ 1,124,193.5 | 800.70 | 801.00 | 0.30 | 4.28 | 6.16 | 5.00 | 12.00 | $ 61,532.5 | $ 75,104.2 | $ 136,636.7 | | |
| 27 | 300 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 10,800 | 11,837 | 59,185 | $ 696,486.0 | 800.95 | 801.00 | 0.05 | 1.65 | 2.02 | 5.00 | 12.00 | $ 37,127.2 | $ 44,600.9 | $ 81,728.1 | | |
| 28 | 313 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 6,534 | 6,534 | 26,870 | $ 675,371.0 | 801.14 | 801.00 | -0.14 | 0.00 | 0.00 | 4.86 | 11.86 | $ 32,853.8 | $ 40,064.9 | $ 72,918.8 | | |
| 29 | 101 SW 16TH ST, DES MOINES | Public property - more damageable type | 0 | 1,353 | 1,353 | $ 260,601.3 | 801.98 | 801.00 | -0.98 | 0.00 | 0.00 | 0.00 | 0.00 | $ - | $ - | $ - | | |
| 30 | 106 SW 7TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 11,704 | 11,704 | 46,816 | $ 225,055.0 | 805.17 | 801.00 | -4.17 | 0.00 | 0.00 | 1.92 | 7.66 | $ 4,310.0 | $ 8,619.9 | $ 12,929.9 | | |
| 31 | 113 SW 8TH ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 5,896 | 8,896 | 19,520 | $ 227,630.0 | 802.88 | 801.00 | -1.88 | 0.00 | 0.00 | 3.12 | 10.12 | $ 7,094.5 | $ 11,514.3 | $ 18,608.8 | | |
| 32 | 2 SW 9TH ST, DES MOINES | Apt on slab (Apartment - one story) | 17,100 | 17,100 | 51,300 | $ 316,725.0 | 809.16 | 801.00 | -8.16 | 0.00 | 0.00 | 0.42 | 0.84 | $ 1,325.6 | $ 1,325.6 | $ 2,651.2 | | |
| 33 | 204 SW 2ND ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 4,393 | 3,264 | 17,377 | $ 157,095.6 | 804.26 | 801.00 | -3.26 | 0.00 | 0.00 | 2.37 | 8.74 | $ 3,723.5 | $ 6,865.5 | $ 10,589.0 | | |
| 34 | 110 SW 5TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 1,172 | 1,172 | $ 82,915.0 | 799.72 | 801.00 | 1.28 | 15.18 | 24.07 | 0.00 | 0.00 | $ 12,585.0 | $ 9,977.8 | $ 22,562.8 | | |
| 35 | 200 SW 2ND ST, DES MOINES | Rest., larger fast foods - McDon's, etc. | 0 | 5,984 | 5,984 | $ 148,011.0 | 801.83 | 801.00 | -0.83 | 0.46 | 0.00 | 0.00 | 0.00 | $ 676.3 | $ - | $ 676.3 | | |

***Table Att2-1*** *(part 2 of 3)*

## Summary of Losses Avoided and ROI Calculation for Des Moines, Central Campus Floodgates Project, June 2008 Event

| No. | Address | Business Type | Basement Square Footage | Ground Floor Square Footage | Building Square Footage (Gross Area) | BRV (2010$) | FFE (ft, NAVD) | WSE for Jun 08 Event (ft, NAVD) | Final Flood Depth (ft) | Building Damage (%) | Content Damage (%) | Basement Building Damage (%) | Basement Content Damage (%) | Building Damage ($) | Contents Damage ($) | Total Losses Avoided ($) | Total Project Investment (2010$) | ROI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 1526 WALNUT ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 7,920 | 7,920 | $ 87,035.0 | 802.14 | 801.00 | -1.14 | 0.49 | 0.39 | 0.00 | 0.00 | $ 426.6 | $ 341.3 | $ 767.9 | | |
| 37 | 1514 WALNUT ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 7,920 | 7,920 | 15,840 | $ 285,516.0 | 805.36 | 801.00 | -4.36 | 0.00 | 0.00 | 1.82 | 7.27 | $ 5,190.5 | $ 10,380.9 | $ 15,571.4 | | |
| 38 | 1314 MULBERRY ST, DES MOINES | Apt on slab (Apartment - one story) | 0 | 9,016 | 9,016 | $ 390,370.0 | 801.25 | 801.00 | -0.25 | 0.75 | 0.00 | 0.00 | 0.00 | $ 2,946.9 | $ - | $ 2,946.9 | | |
| 39 | 401 W MARTIN LUTHER KING JR PKWY, DES MOINES | Public property - more damageable type | 0 | 70,885 | 111,700 | $ 27,574,130.0 | 800.45 | 801.00 | 0.55 | 5.45 | 18.00 | 0.00 | 0.00 | $ 954,535.0 | $ 1,574,982.8 | $ 2,529,517.8 | | |
| 40 | 1440 WALNUT ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 18,956 | 8,160 | 42,732 | $ 1,030.0 | 823.96 | 801.00 | -22.96 | 0.00 | 0.00 | 0.00 | 0.00 | $ - | $ - | $ - | | |
| 41 | 123 SW 3RD ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 2,300 | 17,377 | 34,754 | $ 221,089.5 | 803.36 | 801.00 | -2.36 | 0.00 | 0.00 | 2.82 | 9.64 | $ 6,237.7 | $ 10,659.5 | $ 16,897.2 | | |
| 42 | 112 SW 2ND ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 2,480 | 11,616 | 30,032 | $ 158,311.0 | 803.66 | 801.00 | -2.66 | 0.00 | 0.00 | 2.67 | 9.34 | $ 4,225.3 | $ 7,391.6 | $ 11,616.9 | | |
| 43 | 121 SW 2ND ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 12,976 | 12,976 | $ 140,698.0 | 801.69 | 801.00 | -0.69 | 0.69 | 0.59 | 0.00 | 0.00 | $ 964.6 | $ 823.9 | $ 1,788.5 | | |
| 44 | 101 SW 4TH ST, DES MOINES | Public property - less damageable type | 0 | 39,754 | 116,168 | $ 3,941,810.0 | 800.05 | 801.00 | 0.95 | 3.80 | 12.35 | 0.00 | 0.00 | $ 51,267.5 | $ 83,309.7 | $ 134,577.3 | | |
| 45 | 100 SW 2ND ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 10,400 | 10,400 | $ 232,265.0 | 799.66 | 801.00 | 1.34 | 14.54 | 25.10 | 0.00 | 0.00 | $ 33,769.4 | $ 58,289.6 | $ 92,059.0 | | |
| 46 | 100 MARKET ST, DES MOINES | Apt on slab (Apartment - one story) | 0 | 29,070 | 145,350 | $ 20,959,470.0 | 796.77 | 801.00 | 4.23 | 32.12 | 45.67 | 0.00 | 0.00 | $ 1,346,305.2 | $ 1,914,506.1 | $ 3,260,811.3 | | |
| 47 | N/A SW 2ND ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 13,500 | 13,500 | $ 1,446,120.0 | 797.84 | 801.00 | 3.16 | 26.09 | 48.83 | 0.00 | 0.00 | $ 377,346.9 | $ 706,209.6 | $ 1,083,556.5 | | |
| 48 | 101 SW 2ND ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 6,886 | 1,320 | 23,761 | $ 97,850.0 | 805.00 | 801.00 | -4.00 | 0.00 | 0.00 | 2.00 | 7.99 | $ 1,955.7 | $ 3,911.3 | $ 5,867.0 | | |
| 49 | 309 SW 8TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 28,681 | 30,592 | 107,904 | $ 367,710.0 | 799.86 | 801.00 | 1.14 | 12.91 | 22.48 | 5.00 | 12.00 | $ 31,840.3 | $ 45,493.3 | $ 77,333.6 | | |
| 50 | 322 SW 3RD ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 12,012 | 53,768 | 101,272 | $ 197,348.0 | 800.55 | 801.00 | 0.45 | 5.86 | 8.61 | 5.00 | 12.00 | $ 16,007.5 | $ 20,857.6 | $ 36,865.1 | | |
| 51 | 510 SW 9TH ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 18,404 | 30,158 | 49,356 | $ 596,370.0 | 799.33 | 801.00 | 1.67 | 17.21 | 27.16 | 5.00 | 12.00 | $ 92,521.9 | $ 134,753.9 | $ 227,275.8 | | |
| 52 | 817 SW 9TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 2,352 | 2,352 | $ 70,349.0 | 797.95 | 801.00 | 3.05 | 25.62 | 45.90 | 0.00 | 0.00 | $ 18,022.9 | $ 16,145.4 | $ 34,168.3 | | |
| 53 | 200 SW 16TH ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 600 | 18,160 | 186,631 | $ 229,278.0 | 803.86 | 801.00 | -2.86 | 0.00 | 0.00 | 2.57 | 9.14 | $ 5,889.4 | $ 10,475.0 | $ 16,364.4 | | |
| 54 | N/A SW 16TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 1,396 | 1,396 | $ 225,747.2 | 795.28 | 801.00 | 5.72 | 36.73 | 69.65 | 0.00 | 0.00 | $ 82,915.9 | $ 157,226.7 | $ 240,142.5 | | |
| 55 | 328 SW 5TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 12,473 | 8,228 | 79,196 | $ 1,472,900.0 | 801.65 | 801.00 | -0.65 | 0.00 | 0.00 | 4.35 | 11.35 | $ 64,125.0 | $ 83,614.0 | $ 147,739.0 | | |
| 56 | 815 SW 9TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 2,520 | 2,520 | $ 36,050.0 | 796.28 | 801.00 | 4.72 | 32.95 | 63.02 | 0.00 | 0.00 | $ 11,879.0 | $ 22,717.9 | $ 34,596.8 | | |
| 57 | 920 MORGAN ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 72,000 | 72,000 | $ 1,795,290.0 | 796.52 | 801.00 | 4.48 | 31.40 | 59.11 | 0.00 | 0.00 | $ 563,758.8 | $ 530,584.5 | $ 1,094,343.3 | | |
| 58 | 1100 DART WAY, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 19,760 | 19,760 | $ 1,933,516.0 | 793.61 | 801.00 | 7.39 | 42.57 | 78.98 | 0.00 | 0.00 | $ 823,004.6 | $ 1,527,174.0 | $ 2,350,178.6 | | |
| 59 | 1100 DART WAY, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 46,370 | 46,370 | $ 3,773,126.9 | 792.84 | 801.00 | 8.16 | 45.28 | 83.32 | 0.00 | 0.00 | $ 1,708,338.5 | $ 3,143,857.8 | $ 4,852,196.3 | | |
| 60 | 1100 DART WAY, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 53,370 | 53,370 | $ 4,232,774.7 | 793.29 | 801.00 | 7.71 | 43.67 | 80.75 | 0.00 | 0.00 | $ 1,848,370.1 | $ 3,417,918.0 | $ 5,266,288.0 | | |
| 61 | 1350 TUTTLE ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 4,050 | 44,906 | $ 922,880.0 | 796.26 | 801.00 | 4.74 | 33.04 | 63.21 | 0.00 | 0.00 | $ 27,502.6 | $ 52,609.0 | $ 80,111.6 | | |
| 62 | 1300 TUTTLE ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 0 | 5,040 | 5,040 | $ 265,946.0 | 793.96 | 801.00 | 7.04 | 42.37 | 74.72 | 0.00 | 0.00 | $ 112,685.8 | $ 198,720.2 | $ 311,406.1 | | |
| 63 | 1350 W MARTIN LUTHER KING JR PKWY, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 0 | 152,700 | 152,700 | $ 12,582,480.0 | 798.91 | 801.00 | 2.09 | 20.34 | 32.03 | 0.00 | 0.00 | $ 2,558,950.2 | $ 4,030,076.6 | $ 6,589,026.8 | | |
| 64 | 1350 W MARTIN LUTHER KING JR PKWY, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 0 | 87,970 | 87,970 | $ 7,520,555.3 | 799.95 | 801.00 | 1.05 | 12.32 | 19.92 | 0.00 | 0.00 | $ 926,346.2 | $ 1,497,971.1 | $ 2,424,317.3 | | |
| 65 | 104 SW 4TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 15,903 | 13,699 | 82,194 | $ 738,510.0 | 804.69 | 801.00 | -3.69 | 0.00 | 0.00 | 2.15 | 8.31 | $ 15,908.9 | $ 30,679.1 | $ 46,588.0 | | |
| 66 | 601 SW 9TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 51,685 | 51,685 | $ 1,041,845.0 | 796.42 | 801.00 | 4.58 | 32.36 | 61.80 | 0.00 | 0.00 | $ 337,149.4 | $ 643,820.6 | $ 980,970.0 | | |
| 67 | 520 SW 5TH ST, DES MOINES | Mach. shop, small mnfctrg (Light mnftrg) | 0 | 10,550 | 10,550 | $ 27,810.0 | 799.87 | 801.00 | 1.13 | 12.95 | 20.85 | 0.00 | 0.00 | $ 3,600.5 | $ 5,798.4 | $ 9,398.9 | | |
| 68 | 535 SW 7TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 36,082 | 36,082 | $ 2,968,460.0 | 799.44 | 801.00 | 1.56 | 16.79 | 27.98 | 0.00 | 0.00 | $ 498,469.7 | $ 415,278.6 | $ 913,748.4 | | |
| 69 | 500 SW 7TH ST, DES MOINES | General office - doctor, realtor, bank, etc. | 0 | 34,677 | 95,115 | $ 5,512,766.0 | 798.56 | 801.00 | 2.44 | 22.03 | 39.16 | 0.00 | 0.00 | $ 442,728.1 | $ 393,545.3 | $ 836,273.4 | | |
| 70 | 525 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 26,400 | 26,400 | $ 2,904,000.0 | 799.76 | 801.00 | 1.24 | 13.76 | 23.85 | 0.00 | 0.00 | $ 399,596.2 | $ 692,487.8 | $ 1,092,084.0 | | |

***Table Att2-1*** *(part 3 of 3)*

**SUMMARY OF LOSSES AVOIDED AND ROI CALCULATION FOR DES MOINES, CENTRAL CAMPUS FLOODGATES PROJECT, JUNE 2008 EVENT**

| No. | Address | Business Type | Basement Square Footage | Ground Floor Square Footage | Building Square Footage (Gross Area) | BRV (2010$) | FFE (ft, NAVD) | WSE for Jun 08 Event (ft, NAVD) | Final Flood Depth (ft) | Building Damage (%) | Content Damage (%) | Basement Building Damage (%) | Basement Content Damage (%) | Building Damage ($) | Contents Damage ($) | Total Losses Avoided ($) | Total Project Investment (2010$) | ROI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 525 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 84,980 | 84,980 | $ 6,798,400.0 | 799.76 | 801.00 | 1.24 | 13.76 | 23.85 | 0.00 | 0.00 | $ 935,473.4 | $ 1,621,146.5 | $ 2,556,619.9 | | |
| 72 | 525 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 25,860 | 25,860 | $ 2,844,600.0 | 799.76 | 801.00 | 1.24 | 13.76 | 23.85 | 0.00 | 0.00 | $ 391,422.6 | $ 678,323.3 | $ 1,069,746.0 | | |
| 73 | 525 SW 5TH ST, DES MOINES | Wrhse/off comb, (Wrhse non-refrig) | 0 | 26,210 | 26,210 | $ 2,883,100.0 | 799.76 | 801.00 | 1.24 | 13.76 | 23.85 | 0.00 | 0.00 | $ 396,720.3 | $ 687,504.0 | $ 1,084,224.4 | | |
| 74 | 226 ELM ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 13,370 | 12,554 | 37,662 | $ 1,110,752.0 | 801.85 | 801.00 | -0.85 | 0.00 | 0.00 | 4.15 | 11.15 | $ 46,065.3 | $ 61,909.0 | $ 107,974.2 | | |
| 75 | 101 SW 5TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 11,834 | 11,834 | $ 19,055.0 | 800.68 | 801.00 | 0.32 | 4.55 | 6.67 | 0.00 | 0.00 | $ 866.8 | $ 1,271.5 | $ 2,138.3 | | |
| 76 | 120 SW 5TH ST, DES MOINES | Apt on slab (Apartment - one story) | 0 | 9,264 | 83,376 | $ 14,599,137.6 | 803.28 | 801.00 | -2.28 | 0.00 | 0.00 | 0.00 | 0.00 | $ - | $ - | $ - | | |
| 77 | 120 SW 6TH ST, DES MOINES | Wrhse, storage bldg (Wrhse - non-refrig) | 0 | 51,380 | 51,380 | $ 4,180,790.6 | 802.66 | 801.00 | -1.66 | 0.45 | 0.00 | 0.00 | 0.00 | $ 18,930.1 | $ - | $ 18,930.1 | | |
| 78 | 1716 LOCUST ST, DES MOINES | General office - doctor, realtor, bank, etc. | 118,800 | 107,500 | 419,660 | $ 9,655,220.0 | 819.95 | 801.00 | -18.95 | 0.00 | 0.00 | 0.00 | 0.00 | $ - | $ - | $ - | $ 503,752.3 | 9758.2% |
| | | | | | | | | | ***TOTAL*** | | | | | **$ 19,061,512.6** | **$ 30,095,456.2** | **$ 49,156,968.8** | **$ 503,752.3** | **9758.2%** |

# Appendix E

## Elkader Flood Protection Project

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# Appendix E:

## Elkader Flood Protection Project

### E1 Introduction

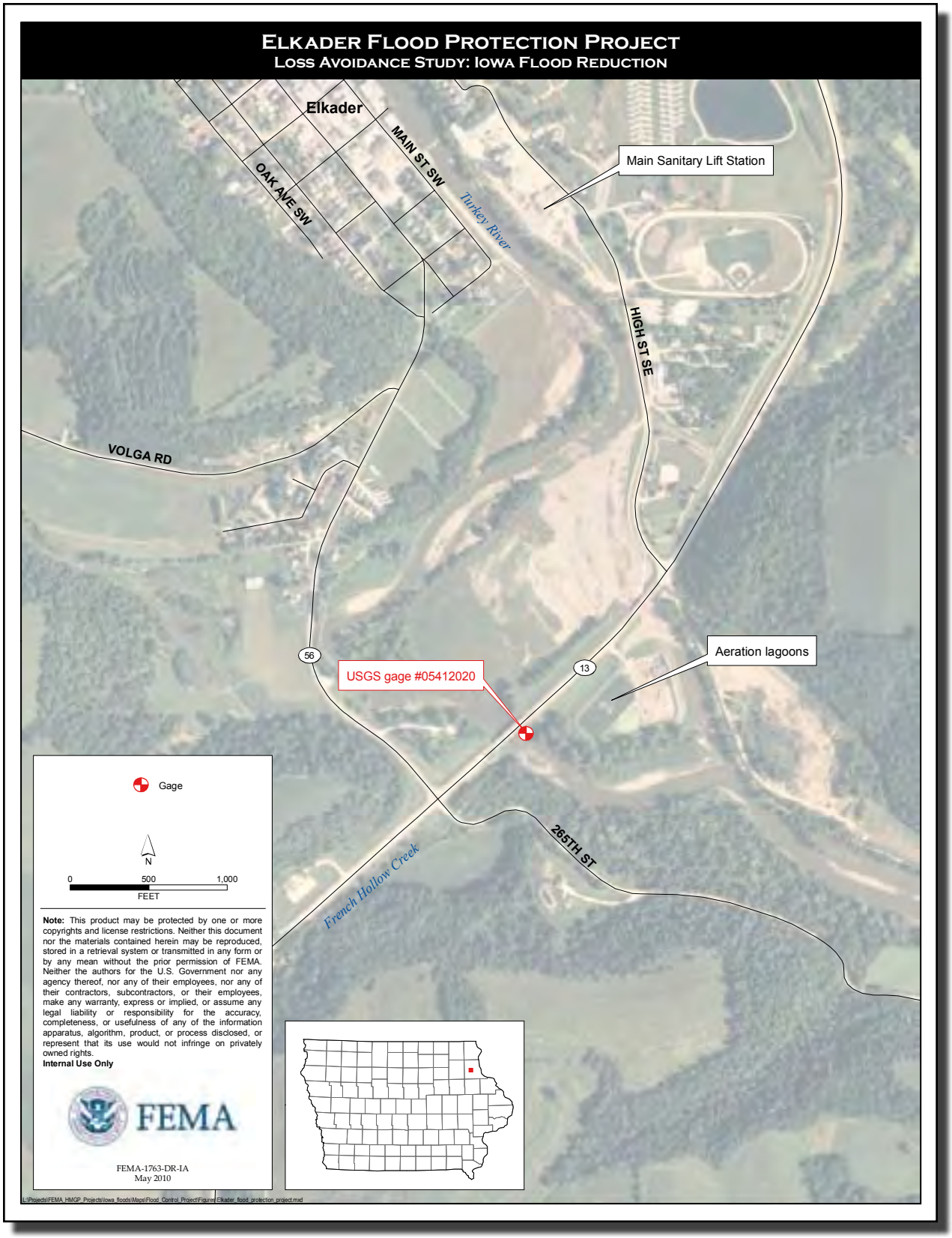
The City of Elkader (City) in Clayton County, Iowa, is highly vulnerable to flooding from the Turkey River. In the past, flooding has damaged components of the Elkader Sewage Treatment Plant—the Main Sanitary Lift Station and the sewage aeration lagoon system. The location of the treatment plant is shown in **Figure E.1**.

The Main Sanitary Lift Station is a 16-foot by 20-foot building that houses three pumps on the lower basement level and the pump controls on the ground level (see **Figures E.2** and **E.3**). Failure of the Main Sanitary Lift Station or overtopping of the berm at the aeration lagoons would cause the City to lose wastewater service, a serious threat to the health and safety of City residents. If the Main Sanitary Lift Station stops operating, raw sewage can back up into homes and businesses. If the berm at the aeration lagoons is overtopped, operation of the sewer system may have to be suspended because of potential contamination of the river.

The pumps move sewage from the City to the aeration lagoons, which are approximately 0.25 mile from the Main Sanitary Lift Station. As shown in **Figure E.1**, the aeration lagoons are southeast of the City, adjacent to the Turkey River, and south of State Route 13. See **Figure E.4** for a photograph of the aeration lagoons. The control building at the lagoon site houses the controls and the compressors that supply air to the aeration equipment. The equipment is approximately 1 foot off the floor. See **Figure E.5** for a photograph of the lagoon control building.

Before the implementation of the Elkader Flood Protection Project, the aeration lagoons and control building at the aeration lagoon site had been protected by a berm with a top elevation of 721 feet North American Vertical Datum of 1988 (NAVD88). In December 1997, the City applied through the State of Iowa to the Federal Emergency Management Agency (FEMA) for Hazard Mitigation Grant Program (HMGP) funding to implement the Elkader Flood Protection Project. The project consisted of increasing the height of the berm by 3.5 feet, constructing a floodwall, and installing a new door and seals at the Main Sanitary Lift Station. The project was completed on October 9, 2000, at a total cost of $134,917 ($181,317 in 2010 dollars). The City provided a 50% match to the HMGP funds.

***Figure E.1***


ELKADER FLOOD PROTECTION PROJECT
LOSS AVOIDANCE STUDY: IOWA FLOOD REDUCTION
Elkader
MAIN ST SW
OAK AVE SW
Turkey River
Main Sanitary Lift Station
HIGH ST SE
VOLGA RD
56
13
USGS gage #05412020
Aeration lagoons
265TH ST
French Hollow Creek
Gage
N
0
500
1,000
FEET
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Internal Use Only
FEMA
FEMA-1763-DR-IA
May 2010
L:\Projects\FEMA_HMGP_Projects\Iowa_floods\Maps\Flood_Control_Project\Figure\Elkader_food_protection_project.mxd

***Figure E.2*** *Main Sanitary Lift Station, February 3, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure E.3*** *Pump Controls at Main Sanitary Lift Station, February 3, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure E.4*** *Aeration Lagoons, February 3, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure E.5*** *Aeration Lagoon Control Building, February 3, 2010 (photo by Jane Branson, URS Group, Inc.)*

**Table E.1** lists the location and first floor elevations (FFEs) of the two buildings included in the Elkader Flood Protection Project. **Table E.2** lists the Mitigation Project Absent ($MP_A$) and Mitigation Project Complete ($MP_C$) elevations of the berm and floodwall. **Figure E.6** is a schematic of the Main Sanitary Lift Station, and **Figure E.7** is a schematic of the aeration lagoons and control building.

*Table E.1*

**Elkader Flood Protection Project Components**

| Project Component | Latitude (Degrees) | Longitude (Degrees) | First Floor Elevation of Building (feet NAVD88) | Project Completion Date[1] |
|---|---|---|---|---|
| ***Main Sanitary Lift Station*** | 42.8508 | –91.3984 | 720 | 10/9/2000 |
| ***Aeration Lagoon Control Building*** | 42.8440 | –91.3979 | 721.5 | 10/9/2000 |

1 Date of Tri-State Engineers letter of completion (FEMA, 2001b)
NAVD88 = North American Vertical Datum of 1988

*Table E.2*

**Top of Berm and Floodwall Elevations**

| Scenario | Top of Aeration Lagoon Site Berm (feet NAVD88) | Top of Main Sanitary Lift Station Floodwall (feet NAVD88) |
|---|---|---|
| ***$MP_A$ Scenario*** | 721[1] | N/A |
| ***$MP_C$ Scenario*** | 724.5[2] | 724.5[3] |

1 Pre-project lagoon berm elevation
2 Post-project lagoon berm elevation per Tri-State Engineers 10/9/2000 letter of completion
3 Top of floodwall per Tri-State Engineers 10/9/2000 letter of completion (FEMA, 2001b)

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
N/A = not applicable (floodwall did not exist prior to project completion date)
NAVD88 = North American Vertical Datum of 1988

***Figure E.6*** *Schematic of the Elkader Flood Protection Project: Main Sanitary Lift Station*

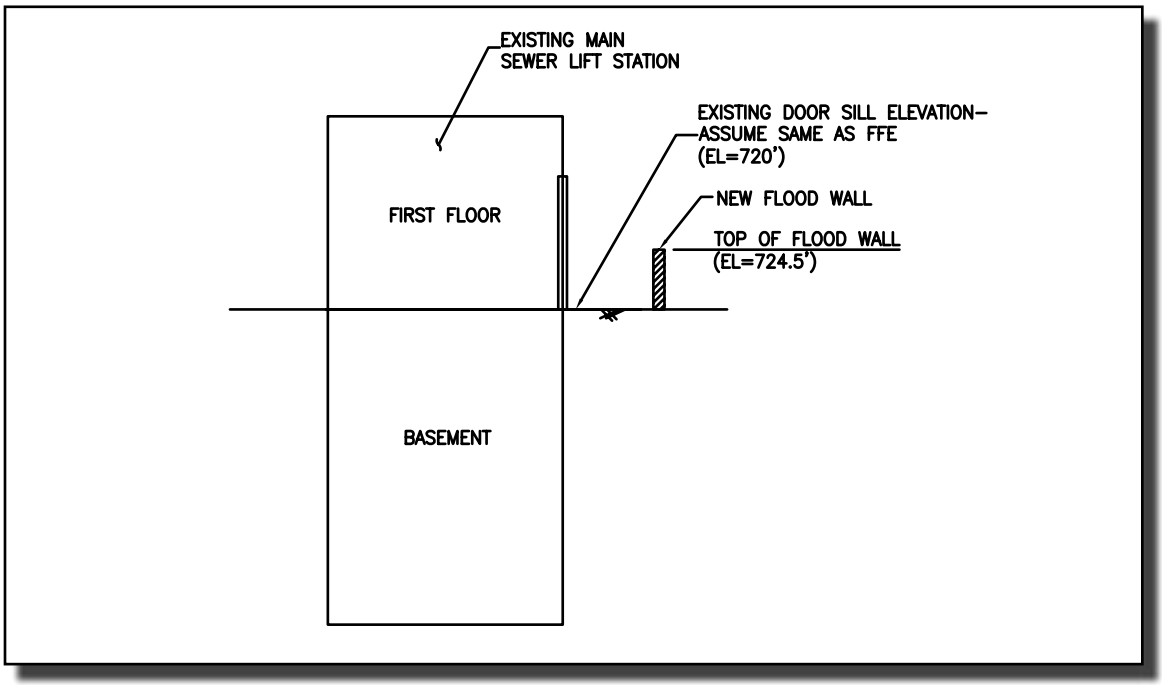
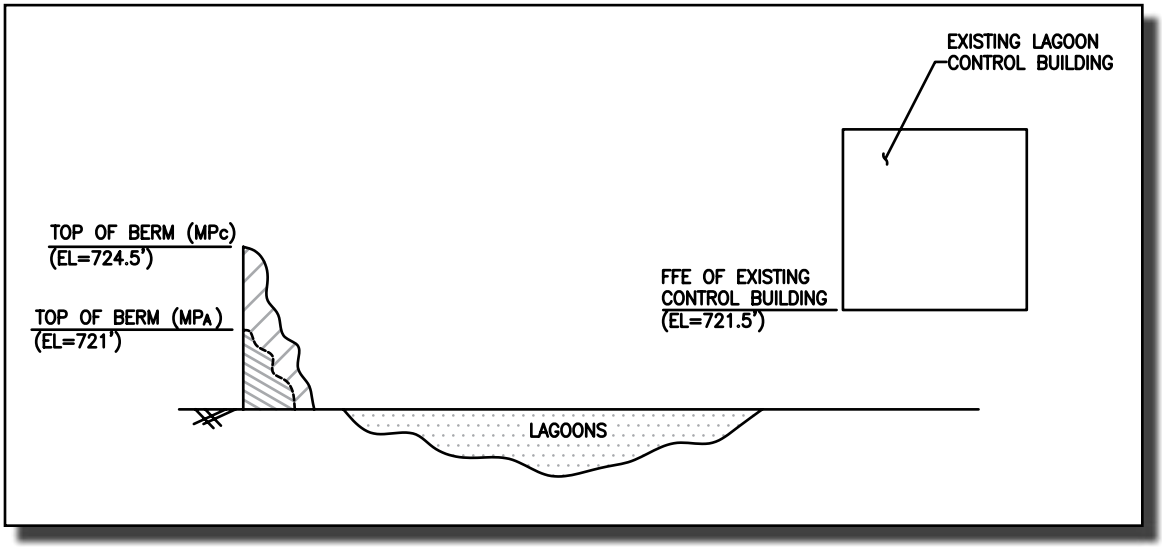



***Figure E.7*** *Schematic of the Elkader Flood Protection Project: Aeration Lagoon Site and Control Building*



## E2 Phase 1 – Data Collection

The HMGP project files were reviewed for data that were required for the study (FEMA, 2001a). Hydrologic data were obtained from a U.S. Geological Survey (USGS) gage for Turkey River (USGS, 2009b) and the FEMA Flood Insurance Study (FIS) for the City of Elkader (FEMA, 1996). A preliminary Storm Event Analysis and a Hydraulic Analysis were completed using the data prior to a site visit conducted on February 3, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. The preliminary Storm Event Analysis and Hydraulic Analysis showed that the Elkader Flood Protection Project had been tested since project completion in 2000 by flooding in May 2004 and June 2008. During the site visit, the staff explained how the project components operated during the two events. Other data collected during the site visit included high water marks (HWMs), design drawings, elevation of project components, and the plant operating budget. After the site visit, data on likely $MP_A$ damage and actual $MP_C$ costs were obtained in phone calls with the staff. Additionally, damage and cost data were obtained from a Project Worksheet (#4096) that FEMA prepared for the Public Assistance Program following the Presidential Disaster Declaration for the June 2008 flood event (FEMA-1763-DR-IA).

## E3 Phase 2 – Physical Parameter Analysis

The Phase 2 methodology that was used for the Elkader Flood Protection Project is described in the following subsections. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

### E3.1 Storm Event Analysis

The gage on Turkey River (USGS gage #05412020) is above French Hollow Creek at Elkader and downstream of State Route 13 (see **Figure E.1**). The gage has been used to measure and record the local water surface stage and discharge information for Turkey Creek since September 2001 (FEMA, 2009b), approximately 1 year after the project was completed. The next downstream gage (USGS gage #05412500 on Turkey River at Garber, Iowa) did not record a large flood event during 2000 or 2001 (USGS, 2009a) so it was assumed that no large flood events occurred at the project site during that time.

Three large flow events have occurred since the project was completed and are listed in **Table E.3** in order of decreasing magnitude. The June 10, 2008, and May 23, 2004, events are annual peak events for their respective water year. When the record of daily mean stream flow was reviewed to determine whether any other large events had occurred during the same year, the event on April 26, 2008, was found.

Based on a review of the discharge data provided in the FIS (FEMA, 1996):

- June 26, 2008, flood event was between a 100- and 500-year event
- May 2004 event was between a 50- and 100-year event
- April 2 event was smaller than a 10-year event

*Table E.3*

**Peak Gage Height and Discharges on the Turkey River at Elkader, Iowa**

| Date | Peak Gage Height (feet) | Peak Gage Height (feet NGVD29)[1] | Peak Gage Height (feet NAVD88)[2] | Peak Discharge (cfs) |
|---|---|---|---|---|
| *June 10, 2008* | 27.7 | 722.7 | 722.54 | 40,500 |
| *May 23, 2004* | 25.57 | 720.5 | 720.34 | 33,330 |
| *April 26, 2008* | 18.16 | 713.09 | 712.93 | 1,600 |

1 Gage datum elevation is 694.93 feet NGVD29 (USGS, 2009b).
2 The difference between NAVD88 and NGVD29 is –0.16 foot (VERTCON, n.d.)

cfs = cubic feet per second
NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929

## E3.2 Hydraulic Analysis

The FIS and Flood Insurance Rate Map (FIRM) for the City indicate that the Turkey River in the vicinity of the lift station and aeration lagoons was studied in detail, but the published profile shows only the 100-year flood profile. No hydraulic model was available from the FEMA Map Service Center for the current study.

Because the gage is adjacent to the aeration lagoons, the gage stage measurements were used to determine the flood elevation at the aeration lagoons. However, at the Main Sanitary Lift Station, using the 100-year FIS profile as guidance, it was determined that the water surface elevation (WSE) would be approximately equal to the stage readings at the gage plus 1.2 feet. An HWM recorded during the site visit was measured as 0.8 foot above the floodwall and was used as the flood elevation at the Main Sanitary Lift Station for the

June 10, 2008, event. **Table E.4** is a summary of the results of the Hydraulic Analysis.

HWMs were also surveyed by FEMA after the June 2008 flood event in the vicinity of the Main Sanitary Lift Station and the aeration lagoons (FEMA, 2008). The two HWMs in the vicinity of the lift station were between 0.6 and 0.8 foot lower than the HWM obtained during the site visit. The HWM in the vicinity of the aeration lagoons was 5 feet lower than the WSE measured by the adjacent USGS gage. Therefore, these additional HWMs were not used in the analysis.

***Table E.4***

**Water Surface Elevations at the Elkader Sewage Treatment Plant**

| Event Date | Water Surface Elevation (feet NAVD88) | |
|---|---|---|
| | Aeration Lagoons and Control Building Site | Main Sanitary Lift Station Site |
| ***June 10, 2008*** | 722.5[1] | 725.3[2] |
| ***May 23, 2004*** | 720.3[1] | 721.5[3] |
| ***April 26, 2008*** | 712.9[1] | 714.1[3] |

1 Gage height; gage is adjacent to lagoon site
2 High water at the Main Sanitary Lift Station was 0.8 foot above the floodwall
3 Water surface elevation at lift station = gage height + 1.2 feet, based on FIS profiles

FIS = Flood Insurance Study
NAVD88 = North American Vertical Datum of 1988

## E3.3 Flood Boundary Analysis

Because the project protects a single site and does not affect the water levels in the Turkey River, the Flood Boundary Analysis resembled a Flood Inundation Analysis. At the aeration lagoon site, WSEs determined during the Physical Parameter Analysis were compared to the $MP_A$ and $MP_C$ scenario lagoon berm heights to determine whether the floodwaters would have overtopped them. As shown in **Table E.5**, the only flood event in which the berm surrounding the aeration lagoons has been overtopped is the June 2008 flood event for the $MP_A$ scenario.

At the Main Sanitary Lift Station, the WSEs were compared to the FFE of the lift station to determine the depth of flooding in the $MP_A$ scenario. For the $MP_C$ scenario, the WSEs were high enough to overtop the floodwall in the June 2008 flood event. However, the door seals replaced as part of the project reduced the volume of water entering the lift station such that flooding on the first

floor was limited to a depth of one foot. In the May 2004 and April 2008 flood events, the WSEs were not high enough to overtop the floodwall, so there were no losses in the $MP_C$ scenario for these events.

The depth of flooding at the lagoon control building and Main Sanitary Lift Station for the $MP_A$ and $MP_C$ scenarios are shown in **Table E.6**.

The results of the Physical Parameter Analysis indicate that both of the buildings and aeration lagoons would have been flooded during the June 2008 flood event for the $MP_A$ scenario. During the May flood event, only the lift station would have experienced flooding and only in the $MP_A$ scenario.

Since damage would have been caused in the $MP_A$ and $MP_C$ scenarios in the June 2008 flood event and in the $MP_A$ scenario in the May 2004 flood event, the project advanced to Phase 3 – Loss Estimation Analysis.

*Table E.5*

**Overtopping of the Aeration Lagoons Berm in the $MP_A$ and $MP_C$ Scenarios**

| Event Date | $MP_A$ Scenario Berm (721.0 feet NAVD88) Overtopped? | $MP_C$ Scenario Berm (724.5 feet NAVD88) Overtopped? |
|---|---|---|
| *June 10, 2008* | Yes | No |
| *May 23, 2004* | No | No |
| *April 26, 2008* | No | No |

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
NAVD88 = North American Vertical Datum of 1988

*Table E.6*

**Flood Depths for the Main Sanitary Lift Station and Lagoon Control Building**

| Event Date | $MP_A$ Scenario Depth of Flooding (feet) | | $MP_C$ Scenario Depth of Flooding (feet) | |
|---|---|---|---|---|
| | Main Sanitary Lift Station | Lagoon Control Building | Main Sanitary Lift Station | Lagoon Control Building |
| *June 10, 2008* | 5.3 | 1.0 | 1.0[1] | 0.0 |
| *May 23, 2004* | 1.5 | 0.0 | 0.0 | 0.0 |
| *April 26, 2008* | 0.0 | 0.0 | 0.0 | 0.0 |

1 Depth of flooding above the lift station finished floor elevation obtained during the February 3, 2010, site visit

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

# E4 Phase 3 – Loss Estimation Analysis

The losses calculated for the Elkader Flood Protection Project include building damage to the lagoon control building and Main Sanitary Lift Station, physical damage to the equipment contained in these buildings and aeration equipment, loss of wastewater service, and potential U.S. Environmental Protection Agency (EPA) fines for sewage spilling into the Turkey River.

## E4.1 Physical Damage

The physical damage consists of building damage and building contents damage at the Main Sanitary Lift Station and the lagoon control building at the aeration lagoons and physical damage to the aeration equipment in the aeration lagoons.

### E4.1.1 Building Damage

#### Main Sanitary Lift Station

The results of the Flood Boundary Analysis and discussions with City officials confirmed that even with the floodwall present ($MP_C$ scenario), building damage to the Main Sanitary Lift Station occurred during the June 2008 flood event. However, for the May 2004 flood event, the floodwall worked as expected and no building damage was incurred. For the $MP_A$ scenario, the Flood Boundary Analysis showed that the Main Sanitary Lift Station would have been flooded during both the June 2008 and May 2004 flood events.

Building damage was estimated using the building replacement value (BRV), which was calculated using the building square footage and the replacement value per square foot. The BRV was estimated from a current cost estimating guide and is listed in **Attachment 1**. The loss calculations for building damage used two U.S. Army Corps of Engineers (USACE) St. Paul District depth-damage functions (DDFs): (1) the Downtown Commercial Basement Unfinished function for the basement portion of the building, and (2) the Machine Shop, Small Manufacturing (Light Manufacturing) function for the first floor of the building. The DDFs were used in place of the FEMA Benefit-Cost Analysis (BCA) Tool Version 4.5 (FEMA, 2009)[1] nonresidential DDFs in order to appropriately account for basement damage.

1 All references to the FEMA BCA Tool in this document are to the Benefit-Cost Analysis Tool, Version 4.5 (FEMA, 2009).

Because the floodwaters would have flooded the entire basement of the lift station in both the May 2004 and June 2008 flood events, the maximum percent building damage from the Downtown Commercial Basement Unfinished function of 5% was applied. The building damage associated with the flooding of the basement were calculated by multiplying 5% by the full BRV of the building because the USACE St. Paul District DDFs for buildings with basements use the full BRV including the value of the basement.

The building damage for the first floor was determined by linearly interpolating the building percent damage available for certain flood depths of the Machine Shop, Small Manufacturing (Light Manufacturing) curve. The building damage associated with the flooding of the first floor was calculated by multiplying the percent building damage by the BRV associated with the first floor of the building because the USACE St. Paul District DDFs for the first floor of the building use only the first floor BRV. The assumptions behind estimated building damage are provided in **Attachment 1**. The total building damage includes the damage for the basement and the first floor.

#### Lagoon Control Building

The results of the Flood Boundary Analysis show that for the $MP_C$ scenario, the lagoon control building would not have been flooded by any of the flood events studied because the WSE would not have overtopped the elevation of the new berm. For the $MP_A$ scenario, the lagoon control building would have been flooded during the June 2008 flood event only. For this event, the lagoon control building would have experienced 1 foot of flooding.

The control building is a 1-story building with approximately 600 square feet and is constructed of pre-fabricated concrete. The BRV for a typical building of this construction type was obtained from current cost estimating guides. The loss calculations for building damage used the USACE St. Paul District DDF for a Machine Shop, Small Manufacturing (Light Manufacturing) building. The percent building damage corresponding to a 1-foot flooding depth was then multiplied by the full BRV of the building. The assumptions behind the estimation of building damage are provided in **Attachment 1**.

### E4.1.2 Building Contents Damage

#### Main Sanitary Lift Station

For the $MP_C$ scenario for the June 2008 flood event, HWMs inside the lift station obtained during the site visit confirmed that there

was 1 foot of flooding above the FFE of the building. Door seals replaced as part of the project reduced the volume of water entering the lift station, reducing the potential for damage to contents.

The contents of the Main Sanitary Lift Station include pumps, motors, electrical control panels, and other equipment. The equipment is in the deep well (basement) and also on the first floor. The basement houses three submersible pumps, which move sewage from Elkader to the aeration lagoons, located approximately 0.25 mile from the lift station.

According to the City's Chief Engineer, if the lift station floods substantially, the cost to repair the damage to the equipment would be as follows:

- Electrical controls: $45,000
- Pumps/motors: $50,000
- Sump pump: $10,000
- Office and other miscellaneous equipment: $5,000

The total estimated damage to the contents of the lift station from flooding is $110,000. In the $MP_A$ scenario for the June 2008 and May 2004 events, floodwaters would be expected to enter the lift station at the first level and flow down to the basement. Maximum damage of $110,000 to the equipment would be incurred for both flood events. The assumptions behind estimated contents damage are provided in **Attachment 1**.

The Elkader Flood Protection Project involved building a floodwall and installing a new door on the pumping station. The new door and seals provide an additional form of flood protection in that they slow the movement of water into the structure.

Plant engineers explained that for the June 2008 flood event $MP_C$ scenario, the electrical wiring on one of the three pumps was damaged during the flood, but the other two pumps remained in working condition. Because a sewer pipe broke upstream of the Main Sanitary Lift Station, essentially reducing the flow of sewage to the station, the two remaining pumps were adequate to maintain wastewater service. The only physical damage to the equipment was to the electrical wiring, which cost $1,100 to replace. Additional expenses were cleanup costs that were estimated at $500.

#### Lagoon Control Building

As stated above, the only event in which damage could have occurred in the lagoon control building was the $MP_A$ scenario

for the June 2008 flood event. For this event, the lagoon control building would have experienced 1 foot of flooding.

The contents in the lagoon control building include electrical controls and compressors to supply air to the aeration equipment and other miscellaneous equipment. The motors for the controls and compressors are approximately 14 inches off the floor. Because the WSE of the June 2008 flood event in the lagoon control building was below the elevation of the motors and controls, it is assumed that no substantial damage to contents would have occurred. However, some miscellaneous damage and cleanup costs would have been incurred, which are estimated at $500. The assumptions behind estimated contents damage are provided in **Attachment 1**.

Physical damage to the aeration equipment in the aeration lagoons would be incurred if floodwaters overtop the berm and enter the aeration lagoons. According to the Flood Boundary Analysis, the berm would have been overtopped for the $MP_A$ scenario in the June 2008 flood event only. The cost to repair the aeration system was estimated by the Chief Wastewater Engineer at $100,000.

## E4.2 Loss of Function

Loss of function affects the Main Sanitary Lift Station and the aeration lagoons. If the Main Sanitary Lift Station fails, sewage can back up in the community serviced by the station. If the aeration lagoons are overtopped and unable to function, sewage can flow into Turkey River.

### E4.2.1 Main Sanitary Lift Station

Loss of wastewater service would result if any of the pump equipment is damaged. If any of the pumps are not operating, sewage would back up into businesses and residences or directly into streets. Raw sewage would mix with floodwaters and discharge directly into the Turkey River where it could affect the health of the residents and health and the environmental downstream. The City would have a complete loss of wastewater service that was valued using the FEMA BCA Tool standard value of $41 per person per day for loss of wastewater function. A population of 1,465 was used for assessing loss of function (U.S. Census Bureau, n.d.).

### E4.2.2 Aeration Lagoons

If the Main Sanitary Lift Station is operating but the aeration lagoons are inundated, the sewage from Elkader would make it to

the aeration lagoons but rather than being treated, it would flow directly into the river. The losses from the event would be the potential downstream impacts to other users and the environment. No loss of service would be experienced in the City. The only event in which the aeration lagoons would be inundated with floodwater is the $MP_A$ scenario in the June 2008 flood event. However, for this event, it is assumed that the Main Sanitary Lift Station would also not be functioning.

## E4.3 Hazardous Materials Cleanup

The earthen berm surrounding the Elkader Sewage Treatment Plant is intended to stop water from spilling into the aeration lagoons and prevent untreated or partially treated wastewater from discharging to the Turkey River. The Turkey River has been classified by the Iowa Department of Natural Resources (DNR) as a High Quality (HQ) water body. Waters designated as HQ receive additional protection because of their unique physical, biological, and chemical features. HQ waters have exceptional recreational and ecological importance. The discharged wastewater, while likely to be diluted by the flood waters, may have consequences for human health and or the environment.

The economic impact of the spill may include reduced water-based activities, recreational fishing, and tourism, and irreversible damage to the environment. Assessing these impacts individually would require substantial data on recreational use, the values associated with the use, and knowledge of any environmental effects caused by the discharge. Most of these data are unknown or not available. A proxy financial measure for hazardous materials cleanup is the EPA or Iowa DNR fines that would be charged to the City because of noncompliance of State and Federal regulations for fecal bacterial limits in the Turkey River.

### E4.3.1 Environmental Protection Agency Fines

If raw sewage is discharged to the Turkey River, the EPA would issue the City a variance, which would essentially warn all downstream users of the event and the potential risks involved with recreational use. If the City's response time in achieving compliance with regulations for discharge were deemed unsatisfactory after the flood event, a fine of $10,000 per day could be imposed by the EPA. No EPA fines were assumed in this analysis.

## E4.4 Debris Removal Services

If the Turkey River overtops the berm protecting the aeration lagoons, material deposited by the flood must be dredged from the lagoons. This condition occurred in 1991, when a flood on the Turkey River overtopped the berms. The silt and mud caused severe damage to the lagoon system and aeration equipment. According to a FEMA Damage Survey Report (#28762) prepared for the Public Assistance Program following the Presidential disaster declaration for the 1991 flood (FEMA-911-DR-IA), dredging costs were valued at $24,200 in 1991 dollars ($41,055 in 2010 dollars).

For the $MP_A$ scenario, the berm would be overtopped only in the June 2008 flood event. Assuming similar costs as in the 1991 flood event, the dredging costs for this event would be $41,055 in 2010 dollars. For the $MP_C$ scenario, the results of the Hydraulic Analysis show that the water level would not exceed the top of the raised berm for any of the events studied. Therefore, no dredging costs would be incurred.

## E4.5 Summary of Damage

The summary of damage for the Elkader Flood Protection Project is shown in **Table E.7**. For both flood events, the total losses avoided are more than two times greater than the project investment costs. The total losses avoided for the project as a whole is $985,308, and the project investment is $181,317, resulting in a project ROI of 543%. An ROI of over 100% indicates that the project costs have been recovered based on losses avoided after the project were completed.

*Table E.7*

## Elkader Flood Protection Project Loss Estimation Analysis Results and Return on Mitigation Investment

| Event Date | Results by Loss Category: $MP_A$ Scenario Damage | | | | | | |
|---|---|---|---|---|---|---|---|
| | Physical Damage | | | | | Emergency Protective Measures | Loss of Function |
| | Damage to Lagoon Control Building | Damage to Lagoon Control Building Contents | Physical Damage to Lagoon Aeration Equipment | Damage to Main Sanitary Lift Station | Damage to Main Sanitary Lift Station Contents | Dredging Costs | Loss of Wastewater Service |
| *June 9, 2008* | $16,779 | $500 | $100,000 | $7,291 | $110,000 | $41,055 | $300,325 |
| *May 23, 2004* | $0 | $0 | $0 | $4,136 | $110,000 | $0 | $300,325 |
| **Total** | **$16,779** | **$500** | **$100,000** | **$11,427** | **$220,000** | **$41,055** | **$600,650** |

| Event Date | Results by Loss Category: $MP_C$ Scenario Damage | | | | | | |
|---|---|---|---|---|---|---|---|
| | Physical Damage | | | | | Emergency Protective Measures | Loss of Function |
| | Damage to Lagoon Control Building | Damage to Lagoon Control Building Contents | Physical Damage to Lagoon Aeration Equipment | Damage to Main Sanitary Lift Station | Damage to Main Sanitary Lift Station Contents | Dredging Costs | Loss of Wastewater Service |
| *June 9, 2008* | $0 | $0 | $0 | $3,504 | $1,600 | $0 | $0 |
| *May 23, 2004* | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Total** | **$0** | **$0** | **$0** | **$3,504** | **$1,600** | **$0** | **$0** |

| Event Date | Losses Avoided | Project Investment | ROI |
|---|---|---|---|
| *June 9, 2008* | $570,847 | $181,317 | 315% |
| *May 23, 2004* | $414,461 | $181,317 | 229% |
| **Total** | **$985,308** | **$181,317** | **543%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
ROI = Return on Investment

## E5 References

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# Attachment 1

## Loss Calculations

## Table Att-1

| Elkader Flood Protection Project, May 2004 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Damage to Main Sewer Lift Station | Facility Type: | Pumping Station | FEMA Project Closeout Files | *No Building Damage* | | |
| | Model Depth-Damage Curve: | Downtown Commercial Basements Unfinished | USACE St. Paul District Depth-Damage Curves | | | |
| | Height of Basement (ft): | 10 | Approximate height from field visit | | | |
| | Depth of Flooding with Respect to Basement (ft): | 11.5 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type: | 5 | USACE St. Paul District Depth-Damage Curves. Note: The entire basement is flooded and in addition, 1.5 feet of the upper floor is flooded. The basement is approximately 10 feet tall. The USACE St. Paul District Depth-Damage Curves account for basement damages up to 9 feet tall basements only. The percent damage is taken a 5%, since this is the maximum percentage of damage that can be achieved when the basement is completely filled with floodwaters. | | | |
| | Model Depth-Damage Curve for Upper Floor: | Machine Shop, Small Manufacturing (Light Manufacturing) | USACE St. Paul District Depth-Damage Curves | | | |
| | Depth of Flooding in Upper Floor (ft): | 1.5 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type for Upper Floor: | 15.85 | USACE St. Paul District Depth-Damage Curves | | | |
| | Building Replacement Value ($/sqft): | $50.00 | National Cost Estimating Guide | | | |
| | First Floor Area (sqft): | 320 | BCA in FEMA Project Closeout Files | | | |
| | Total Floor Area (sqft): | 640 | Basement floor same footprint as first floor | | | |
| | Building Replacement Value Base Year: | 2010 | | | | |
| | **Building Damage to Lift Station (2010 Dollars):** | **$4,136** | | **Building Damage to Lift Station (2010 Dollars):** | **$0** | |
| Damage to Main Sewer Lift Station Contents | Depth of Flooding with Respect to FFE (ft): | 1.5 | H&H analysis | *No Building Contents Damage* | | |
| | Damage to Electrical Controls (2010 dollars): | $45,000 | Discussions with engineers at Elkader | | | |
| | Damage to Pumps/Motors (2010 dollars): | $50,000 | Discussions with engineers at Elkader | | | |
| | Damage to Sump Pump (2010 dollars): | $10,000 | Discussions with engineers at Elkader | | | |
| | Damage to Misc. Office and Other Equipment (2010 dollars): | $5,000 | Discussions with engineers at Elkader | | | |
| | **Building Contents Damage to Lift Station (2010 Dollars):** | **$110,000** | Discussions with engineers at Elkader confirmed maximum damages of $110,000 to the building's equipment would be incurred for May 2004 event. | **Building Contents Damage to Lift Station (2010 Dollars):** | **$0** | |
| Loss of Wastewater Service due to Main Sewer Lift Station Equipment Damages | FEMA Standard Value for Loss of Wastewater Service ($/person/day): | $41.00 | FEMA standard value | *No Loss of Wastewater Service* | | |
| | Number of Days of Lost Wastewater Service: | 5 | Assumption | | | |
| | Population: | 1,465 | Averaged 2008 and 2000 populations for Elkader from U.S. Census Bureau | | | |
| | **Costs for Loss of Wastewater Service (2010 Dollars):** | **$300,325** | | **Costs for Loss of Wastewater Service (2010 Dollars):** | **$0** | |

BCA = benefit-cost analysis
FEMA = Federal Emergency Management Agency
FFE = first floor elevation
ft = feet
H&H = hydrologic and hydraulic
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete
sqft = square feet
USACE = U.S. Army Corps of Engineers

***Table Att-2*** *(part 1 of 2)*

| Elkader Flood Protection Project, June 2008 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Damage to Main Sewer Lift Station | Facility Type: | Sewage Lift Station | FEMA Project Closeout Files | Facility Type: | Sewage Lift Station | FEMA Project Closeout Files |
| | Model Depth-Damage Curve for Basement: | Downtown Commercial Basements Unfinished | USACE St. Paul District Depth-Damage Curves | Model Depth-Damage Curve: | Downtown Commercial Basements Unfinished | USACE St. Paul District Depth-Damage Curves |
| | Height of Basement (ft): | 10 | Approximate height from field visit | Height of Basement (ft): | 10 | Approximate height from field visit |
| | Depth of Flooding with Respect to Basement (ft): | 15.3 | H&H analysis, basement is approximately 10 feet high | Depth of Flooding with Respect to Basement (ft): | 11 | High water marks from field visit, basement is approximately 10 feet high |
| | Percent Damaged (% of Building Value) by Building Type for Basement: | 5 | USACE St. Paul District Depth-Damage Curves. Note: The entire basement is flooded and in addition, 5.3 feet of the upper floor is flooded. The basement is approximately 10 feet tall. The USACE St. Paul District Depth-Damage Curves account for basement damages up to 9 feet tall basements only. The percent damage is taken a 5%, since this is the maximum percentage of damage that can be achieved when the basement is completely filled with floodwaters. | Percent Damaged (% of Building Value) by Building Type for Basement: | 5 | USACE St. Paul District Depth-Damage Curves. Note: The entire basement is flooded and in addition, 1.0 feet of the upper floor is flooded. The basement is approximately 10 feet tall. The USACE St. Paul District Depth-Damage Curves account for basement damages up to 9 feet tall basements only. The percent damage is taken a 5% since this is the maximum percentage of damage that can be achieved when the basement is completely filled with floodwaters. |
| | Model Depth-Damage Curve for Upper Floor: | Machine Shop, Small Manufacturing (Light Manufacturing) | USACE St. Paul District Depth-Damage Curves | Model Depth-Damage Curve for Upper Floor: | Machine Shop, Small Manufacturing (Light Manufacturing) | USACE St. Paul District Depth-Damage Curves |
| | Depth of Flooding in Upper Floor (ft): | 5.3 | H&H analysis | Depth of Flooding in Upper Floor (ft): | 1 | H&H analysis |
| | Percent Damaged (% of Building Value) by Building Type for Upper Floor: | 35.57 | USACE St. Paul District Depth-Damage Curves | Percent Damaged (% of Building Value) by Building Type for Upper Floor: | 11.9 | USACE St. Paul District Depth-Damage Curves |
| | Building Replacement Value ($/sqft): | $50.00 | National Cost Estimating Guide | Building Replacement Value ($/sqft): | $50.00 | National Cost Estimating Guide |
| | First Floor Area (sqft): | 320 | BCA in FEMA Project Closeout Files | First Floor Area (sqft): | 320 | BCA in FEMA Project Closeout Files |
| | Total Building Area (sqft): | 640 | Basement floor same footprint as first floor | Total Building Area (sqft): | 640 | Basement floor same footprint as first floor |
| | Building Replacement Value Base Year: | 2010 | BCA in FEMA Project Closeout Files | Building Replacement Value Base Year: | 2010 | BCA in FEMA Project Closeout Files |
| | **Building Damage to Lift Station (2010 Dollars):** | **$7,291** | | **Building Damage to Lift Station (2010 Dollars):** | **$3,504** | |
| Damage to Lagoon Control Building | Facility Type: | Control Building | FEMA Project Closeout Files | *No Building Damage* | | |
| | Model Depth-Damage Curve: | Machine Shop, Small Manufacturing (Light Manufacturing) | USACE St. Paul District Depth-Damage Curves | | | |
| | Depth of Flooding with Respect to FFE (ft): | 1 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type: | 11.9 | USACE St. Paul District Depth-Damage Curves | | | |
| | Building Replacement Value ($/sqft): | $235.00 | National Cost Estimating Guide | | | |
| | First Floor Area (sqft): | 600 | Discussions with engineers at Elkader | | | |
| | Building Replacement Value Base Year: | 2010 | | | | |
| | **Building Damage to Lagoon Control Building (2010 Dollars):** | **$16,779** | | **Building Damage to Lagoon Control Building (2010 Dollars):** | **$0** | |
| Damage to Main Sewer Lift Station Contents | Depth of Flooding with Respect to FFE (ft): | 15.3 | H&H analysis | Physical Damages to Pump Wiring (2010 dollars): | $1,100 | Discussions with engineers at Elkader |
| | Damage to Electrical Controls (2010 dollars): | $45,000 | Discussions with engineers at Elkader | Additional Cleanup Costs (2010 dollars): | $500 | Discussions with engineers at Elkader |
| | Damage to Pumps/Motors (2010 dollars): | $50,000 | Discussions with engineers at Elkader | | | |
| | Damage to Sump Pump (2010 dollars): | $10,000 | Discussions with engineers at Elkader | | | |
| | Damage to Misc. Office and Other Equipment (2010 dollars): | $5,000 | Discussions with engineers at Elkader | | | |
| | **Building Contents Damage to Lift Station (2010 Dollars):** | **$110,000** | Discussions with engineers at Elkader confirmed maximum damages of $110,000 to the building's dquipment would be incurred for June 2008 event | **Building Contents Damage to Lift Station (2010 Dollars):** | **$1,600** | |
| Damage to Lagoon Control Building Contents | Depth of Flooding with Respect to FFE (ft): | 1 | H&H analysis | *No Building Contents Damage* | | |
| | Miscellaneous Cleanup (2010 dollars): | $500 | Discussions with engineers at Elkader | | | |
| | **Building Contents Damage to Lagoon Control Building (2010 Dollars):** | **$500** | Discussions with engineers at Elkader confirmed that the motors for the controls and compressors are located about 14 inches off the floor. Since only one foot of flooding is expected, no damage is assumed to have occurred to the equipment. | **Building Contents Damage to Lagoon Control Building (2010 Dollars):** | **$0** | |

BCA = benefit-cost analysis
FEMA = Federal Emergency Management Agency
FFE = first floor elevation
ft = feet
H&H = hydrologic and hydraulic

$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete
sqft = square feet
USACE = U.S. Army Corps of Engineers

***Table Att-2*** *(part 2 of 2)*

| Elkader Flood Protection Project, June 2008 Event (Cont.) | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Physical Damages to Aeration Equipment | Cost to Replace Aeration System (2010 dollars): | $100,000.00 | Discussions with Chief Wastewater Operator at Lagoons | *No Damage to Aeration Equipment* | | |
| | **Damage to Aeration Equipment (2010 Dollars):** | **$100,000** | | **Damage to Aeration Equipment (2010 Dollars):** | **$0** | |
| Loss of Wastewater Service due to Main Sewer Lift Station Equipment Damages | FEMA Standard Value for Loss of Wastewater Service ($/person/day): | $41.00 | FEMA standard value | *No Loss of Wastewater Service* | | According to engineers at Elkader, two remaining pumps were sufficient to handle sewage load |
| | Number of Days of Lost Wastewater Service: | 5 | Assumption | | | |
| | Population: | 1,465 | 2008 U.S. Census Bureau, population of Elkader | | | |
| | **Costs for Loss of Wastewater Service (2010 Dollars):** | **$300,325** | | **Costs for Loss of Wastewater Service (2010 Dollars):** | **$0** | |
| Dredging Costs | Dredging Costs: | $24,200.00 | DSR 298762 FEMA PA estimated damage, according to FEMA Project Closeout Files | *No Dredging Costs* | | |
| | Base Year: | 1991 | DSR 298762 FEMA PA estimated damage, according to FEMA Project Closeout Files | | | |
| | Inflation Multiplier: | 1.6965019534 | BCA Inflation Calculator | | | |
| | **Dredging Costs (2010 Dollars):** | **$41,055** | | **Dredging Costs (2010 Dollars):** | **$0** | |

BCA = benefit-cost analysis
DSR = damage survey report
FEMA = Federal Emergency Management Agency
ft = feet
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete
PA = public assistance
sqft = square feet

# Appendix F

## Forest City Flood Protection Project

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# Appendix F:

## Forest City Flood Protection Project

### F1 Introduction

The Forest City Water Treatment Plant in Forest City, Winnebago County, Iowa, is vulnerable to flooding of the Winnebago River. See **Figures F.1** and **F.2** for a map showing the location of the water treatment plant and a photo of the plant, respectively. Flooding at the water treatment plant could affect the entire community because city wells could be contaminated and the delivery of safe drinking water to residents could be jeopardized.

In 2005, Forest City applied through the State of Iowa to the Federal Emergency Management Agency (FEMA) for a Pre-Disaster Mitigation (PDM) grant to construct the Forest City Flood Protection Project. The project consisted of a ring levee around three sides of the facility that would connect to high ground on the fourth side. The ring levee would provide 500-year flood protection with 1 foot of freeboard. The project was completed on November 2, 2006, at a total cost of $57,600 ($64,829 in 2010 dollars). PDM funding provided 75% of the cost ($43,200), and Forest City provided 25% in matching funds ($14,400).

**Table F.1** provides information about the project components. **Figure F.3** is a schematic drawing of the facility and project.

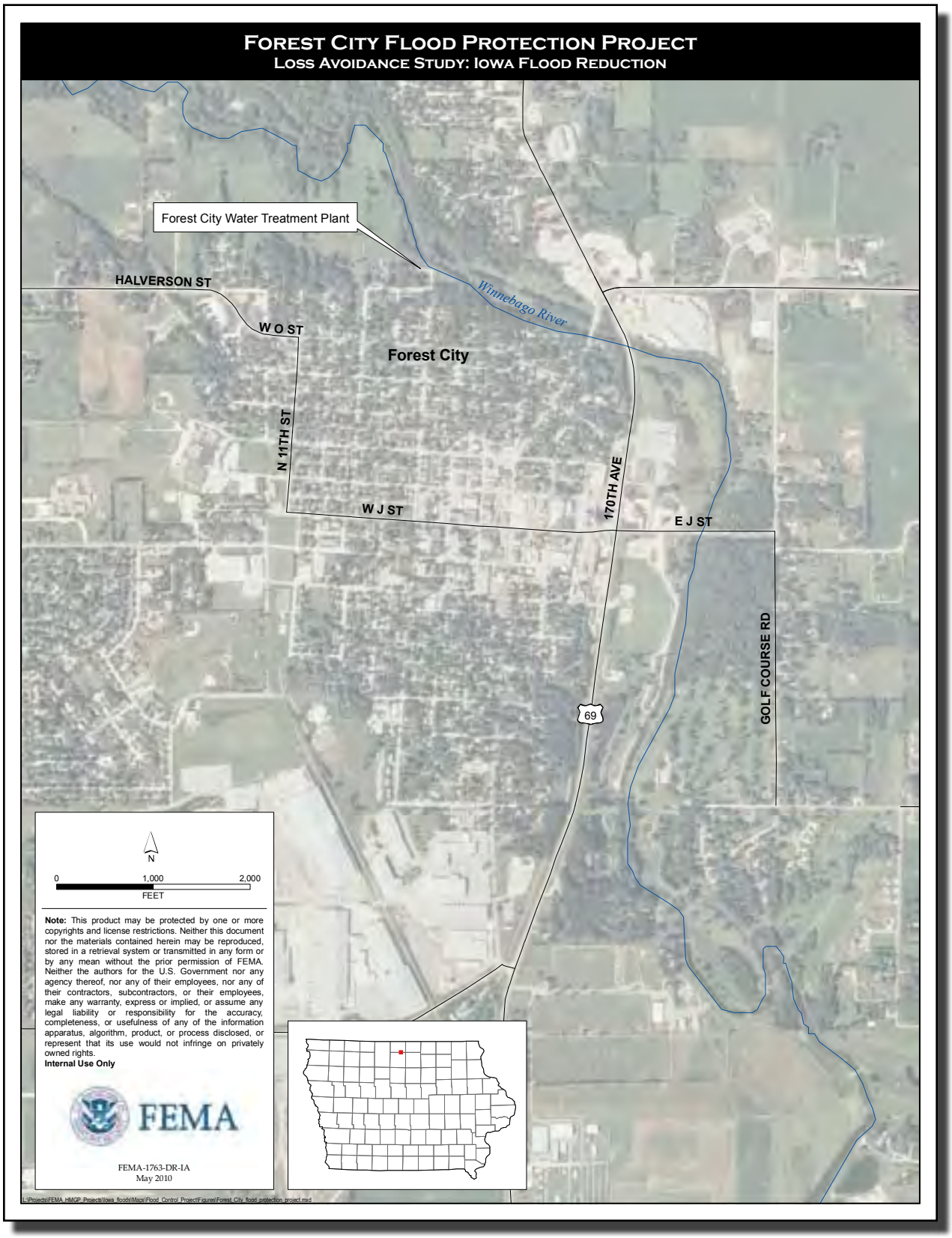
*Table F.1*

**Components of the Forest City Flood Protection Project at the Forest City Water Treatment Plant**

| Category | Data |
|---|---|
| Latitude | 43.2707 degrees |
| Longitude | –93.6406 degrees |
| First Floor Elevation | 1210.8 feet[1,2] |
| Elevation of Top of Well Bearings | 1212.2 feet[1,2] |
| Top of Levee Elevation | 1213.0 feet[1,2] |
| Construction Completion Date | November 2, 2006 |

1 National Geodetic Vertical Datum of 1929 (NGVD29)
2 Elynn Charlson, Water/Wastewater Superintendent of Forest City, February 2, 2010

**Figure F.1**


Forest City Flood Protection Project
Loss Avoidance Study: Iowa Flood Reduction
Forest City Water Treatment Plant
HALVERSON ST
W O ST
Winnebago River
Forest City
N 11TH ST
W J ST
170TH AVE
E J ST
GOLF COURSE RD
69
N
0
1,000
2,000
FEET
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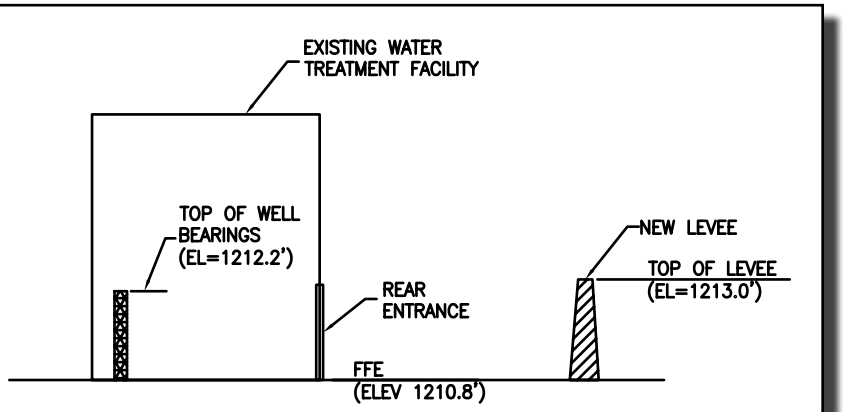
May 2010

***Figure F.2*** *Forest City Water Treatment Plant, February 2, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure F.3*** *Schematic of Forest City Water Treatment Plant and Flood Protection Project*




## F2 Phase 1 – Data Collection

The PDM application and project files (FEMA, 2005) were reviewed for data that could be used in the Iowa flood reduction loss avoidance study.

Hydrologic data were gathered from a U.S. Geological Survey (USGS) gage (USGS, 2010). Hydrological Engineering Center 2 (HEC-2) hydraulic modeling for the Winnebago River used to prepare the Flood Insurance Study (FIS) was obtained from the FEMA Map Service Center (FEMA, 2009). Airborne Light Detection and Ranging Systems (LiDAR) data with a vertical

accuracy of approximately 18 centimeters and 1.4 meter average point spacing were obtained from the Iowa LiDAR Consortium. A preliminary Storm Event Analysis was completed using the data prior to site visit on February 2, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. A project site tour was conducted, information about past storm events was obtained, and an understanding of the project was confirmed. The superintendent explained the daily operation of the plant and the damage that would be expected from flooding. Information was obtained about the elevation of the building, levee, and the well bearings, which are critical to the function of the water treatment plant.

## F3 Phase 2 – Physical Parameter Analysis

The Phase 2 methodology that was used for the Forest City Flood Protection Project is described in the following subsections. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

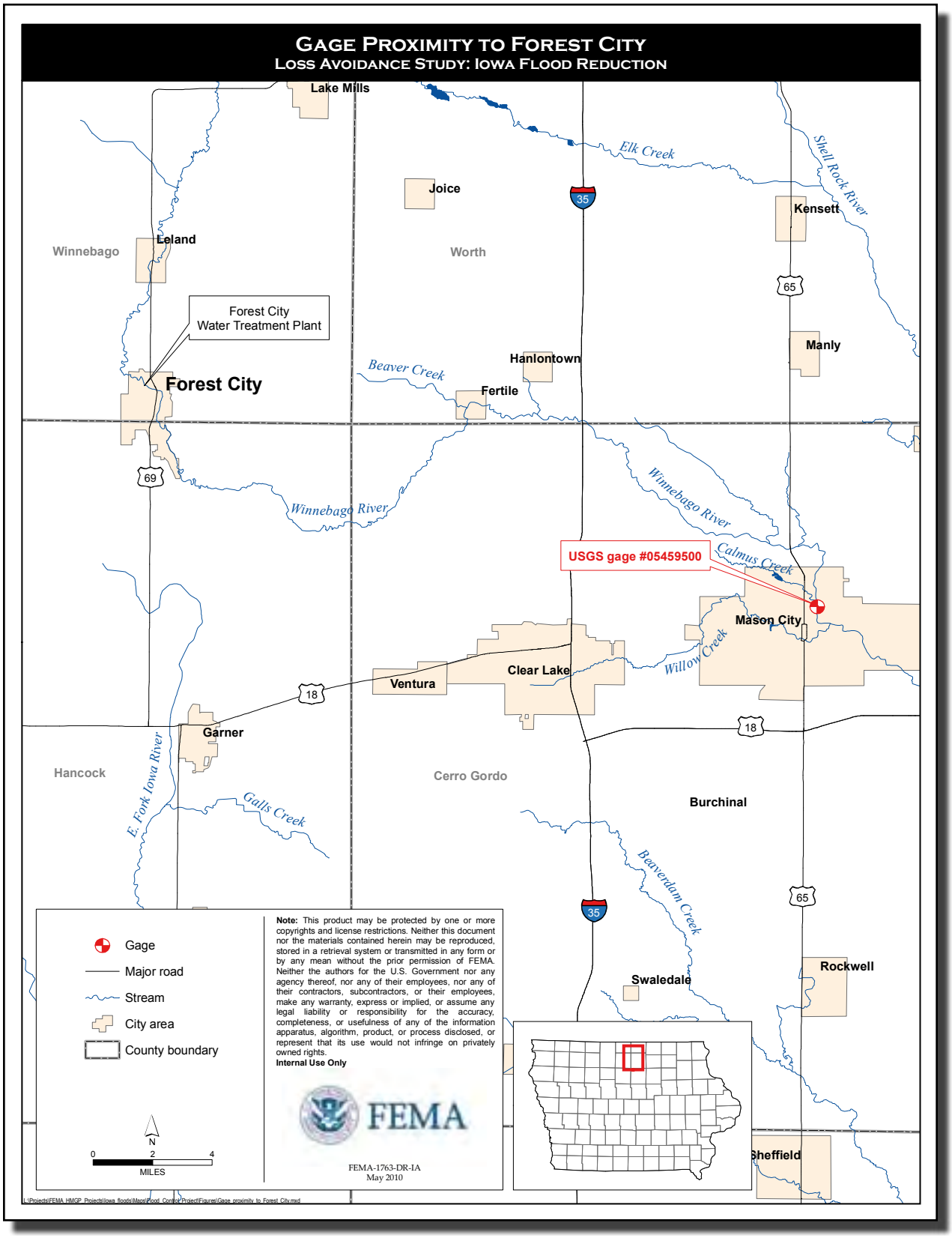
### F3.1 Storm Event Analysis

The gage on the Winnebago River that is closest to the water treatment plant (USGS gage #05459500) is approximately 30 miles downstream at Mason City, Iowa, as shown on **Figure F.4**. This gage has been used to measure annual peak and daily discharges since 1933 (USGS, 2010).

Peak annual discharges since the project completion date are provided in **Table F.2** in descending order of magnitude. The mean daily discharge record was evaluated to determine whether additional secondary peaks occurred during 2007 and 2008 (USGS, 2010); no significant secondary peaks were found.

Because of the distance of the gage from the project site, the peak discharges were transferred upstream, first to the border of Hancock and Cerro Gordo counties, and then to the project site at Forest City using basin transfer techniques for ungaged sites on gaged streams in *Techniques for Estimating Flood Frequency Discharges for Streams in Iowa* (USGS, 2001). The peak discharge was calculated at the county border to be consistent with the discharge locations used in the FIS hydraulic model described in **Section F.2.2**.

**Figure F.4**


Gage Proximity to Forest City
Loss Avoidance Study: Iowa Flood Reduction
Lake Mills
Elk Creek
Shell Rock River
Joice
35
Kensett
Leland
Winnebago
Worth
65
Forest City
Water Treatment Plant
Manly
Hanlontown
Beaver Creek
Forest City
Fertile
69
Winnebago River
Winnebago River
USGS gage #05459500
Calmus Creek
Mason City
Willow Creek
Clear Lake
Ventura
18
18
Garner
Hancock
E. Fork Iowa River
Cerro Gordo
Galls Creek
Burchinal
Beaverdam Creek
35
65
Gage
Major road
Stream
City area
County boundary
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May 2010
Sheffield

**Table F.2**

**Peak Discharges at Mason City and Calculated Peak Discharges at the Hancock/Cerro County Border and Forest City Water Treatment Plant**

| Event Date | Peak Discharge | | |
|---|---|---|---|
| | Mason City Gage | Hancock/Cerro Gordo County Border (Calculated) | Project Site (Calculated) |
| *June 8, 2008* | 13,100 cfs | 8,780 cfs | 8,510 cfs |
| *March 15, 2007* | 4,270 cfs | 2,860 cfs | 2,770 cfs |

cfs = cubic feet per second

For the basin transfer calculations, the following equation was used:

$$Q_{transferred} = Q_{observed}\left(\frac{DA_{transferred}}{DA_{observed}}\right)^{0.665}$$

Where

$Q_{transferred}$ = peak discharge at the ungaged site

$Q_{observed}$ = peak discharge measured at the gage location

$DA_{transferred}$ = drainage area at the ungaged site

$DA_{observed}$ = drainage area at the gage location

The drainage areas were determined to be 526 square miles at Mason City (FEMA, 1995), 288 square miles at the border between Hancock and Cerro Gordo counties, and 275 square miles at Forest City (FEMA, 1980). The calculated discharges are shown in **Table F.2**. Based a review of the discharges provided in the FIS, the discharge for the June 2008 flood event at Forest City was approximately a 100-year flood, and the discharge for the March 2007 flood event was less than a 10-year flood.

## F3.2 Hydraulic Analysis

A Hydrologic Engineering Center River Analysis System (HEC-RAS) model was developed from the HEC-2 model used to prepare the FIS. A railroad bridge just downstream of the project site had been removed since the creation of the HEC-2 model, and the bridge was therefore removed from the HEC-RAS model, although the

removal did not affect water surface elevations (WSEs) at the water treatment plant (located at Cross Section R in the FIS).

The discharges found during the Storm Event Analysis for the two events were routed through the HEC-RAS model. The WSEs that were calculated for the Forest City Water Treatment Plant are listed in **Table F.3**.

*Table F.3*

**Calculated Water Surface Elevations at the Forest City Water Treatment Plant**

| Event Date | Peak Discharge at Project Site | Calculated Water Surface Elevation |
|---|---|---|
| *June 8, 2008* | 8,510 cfs | 1210.4 feet[1,2] |
| *March 15, 2007* | 2,770 cfs | 1205.6 feet[1,2] |

1 National Geodetic Vertical Datum of 1929 (NGVD29)
2 Elevation from Cross Section R, computed by the Hydrologic Engineering Center-River Analysis System (HEC-RAS) model

cfs = cubic feet per second

### F3.3 Flood Boundary Analysis

Because the ring levee protects only one facility and does not affect the water level in the Winnebago River, the Flood Boundary Analysis resembled a Flood Inundation Analysis. The WSE for the June 2008 event (the larger of the two studied events) was calculated at 0.4 foot below the FFE of the building. No damage would therefore have occurred in the Mitigation Project Absent ($MP_A$) scenario. The flood elevation was calculated as 2.6 feet below the top of the levee and would have not resulted in damage in the Mitigation Project Complete ($MP_C$) scenario, which was confirmed during the site visit when the superintendent of the water treatment plant stated that the June 2008 flood event had reached the toe of the levee.

The results of the Physical Parameter Analysis for the Forest City Flood Protection Project indicated that the plant would not have been flooded by the June 2008 flood event in either the $MP_A$ or $MP_C$ scenario, and no losses were avoided. Therefore, the project was not advanced to Phase 3.

## F4 Phase 3 – Loss Estimation Analysis

Because the project was not advanced to Phase 3, no loss calculations were performed, and the Return on Investment for the Forest City Flood Protection Project was zero.

## F5 References

FEMA (Federal Emergency Management Agency). 1980. Flood Insurance Study, City of Forest City, Iowa, Winnebago and Hancock Counties.

———. 1995. Flood Insurance Study, City of Mason City, Iowa, Cerro Gordo County, revised March 16.

———. 2005. Pre-Disaster Mitigation Competitive Grant Program, Forest City Project File, Project #PDMC-PJ-07-IA-2005-003. Closeout Date: December 6, 2006.

———. 2009. HEC-2 Model with T1card labels "FIS – Forest City, Iowa – Winnebago River, 100-year flood, elevations in feet above MSL datum of 1929, Schroder – May 1978 – Encr. Var." from scanned model input and output in "Winnebago_River_HEC_2_match_to_eff_ floodway_ tableR.pdf" obtained from FEMA Engineering Library on November 6, 2009.

USGS (U.S. Geological Survey). 2001. *Techniques for Estimating Flood Frequency Discharges for Streams in Iowa*. Water Resources Investigations Report 00-4233.

———. 2010. USGS Surface-Water Data for Iowa. Information for Gage #05459500, Winnebago River at Mason City Iowa. Available at http://waterdata.usgs.gov/ia/nwis/sw. Accessed December 2009.

# Appendix G

## Manning Well Head Project

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# Appendix G:

## Manning Well Head Project

### G1 Introduction

The City of Manning (City) in Carroll County, Iowa, experienced flooding from the West Nishnabotna River in 1990, 1991, 1993, and 1996. These floods damaged several critical facilities and residential, commercial, and industrial buildings. The City's water wells, which supply potable water, were contaminated during the floods. Because of the lack of clean water, residents were advised to conserve water and boil it before use. The wells had to be dewatered, tested, and flushed to check for contamination.

In December 1997, the City applied through the State of Iowa to the Federal Emergency Management Agency (FEMA) for Hazard Mitigation Grant Program (HMGP) funding to elevate Well #5 and Well #6 to the 500-year flood level. **Figure G.1** shows the location of the two wells.

As part of the project, well houses were constructed to house the wells and protect the well casings from floodwaters, which could contaminate the water. The total project cost was $24,000 ($33,222 in 2010 dollars). HMGP funding provided 50% ($12,000), and the City provided the remaining 50%. The project was completed on November 8, 1999.

**Table G.1** provides the Mitigation Project Absent ($MP_A$) and Mitigation Project Complete ($MP_C$) elevations of the top of the well casings and the first floor elevations (FFEs) of the well houses. **Figure G.2** is a schematic of the wells and well houses.

*Table G.1*

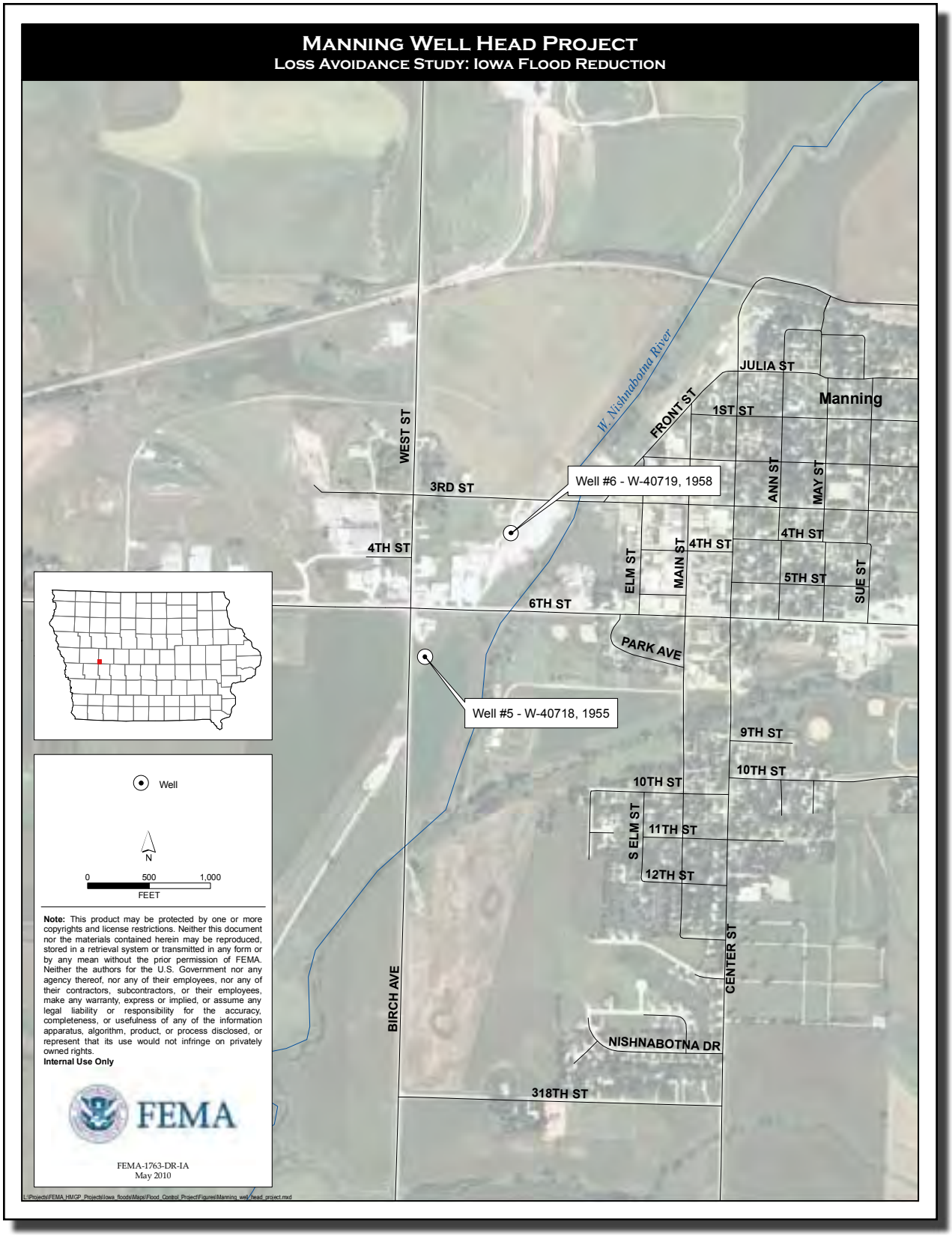
**Manning Well Head Project Components**

| Components | Latitude (degrees) | Longitude (degrees) | $MP_A$ Elevation (feet datum unknown)[1] | $MP_C$ Elevation (feet datum unknown)[1] | Project Construction Completion Date |
|---|---|---|---|---|---|
| *Top of Well Casing #5* | 41.9056 | –95.0731 | 1323.13[2] | 1329.01[2] | 11/8/1999 |
| *Top of Well Casing #6* | 41.9084 | –95.0705 | 1326.68[2] | 1332.36[2] | 11/8/1999 |
| *Well House #5 FFE* | 41.9056 | –95.0731 | N/A[4] | 1328.01[3] | 11/8/1999 |
| *Well House #6 FFE* | 41.9084 | –95.0705 | N/A[4] | 1332.36[3] | 11/8/1999 |

1 The possible difference between the North American Vertical Datum of 1988 and the National Geodetic Vertical Datum of 1929 in the vicinity of Manning is 0.43 foot
2 FEMA (2000)
3 Elevation of well house floor (FEMA, 2000)
4 N/A = Not applicable (well houses did not exist in the $MP_A$ scenario)

FFE = first floor elevation
$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

**Figure G.1**


Manning Well Head Project
Loss Avoidance Study: Iowa Flood Reduction
W. Nishnabotna River
Manning
JULIA ST
1ST ST
FRONT ST
WEST ST
3RD ST
Well #6 - W-40719, 1958
ANN ST
MAY ST
4TH ST
4TH ST
4TH ST
ELM ST
MAIN ST
5TH ST
SUE ST
6TH ST
PARK AVE
Well #5 - W-40718, 1955
9TH ST
10TH ST
10TH ST
S ELM ST
11TH ST
12TH ST
CENTER ST
BIRCH AVE
NISHNABOTNA DR
318TH ST
Well
N
0
500
1,000
FEET
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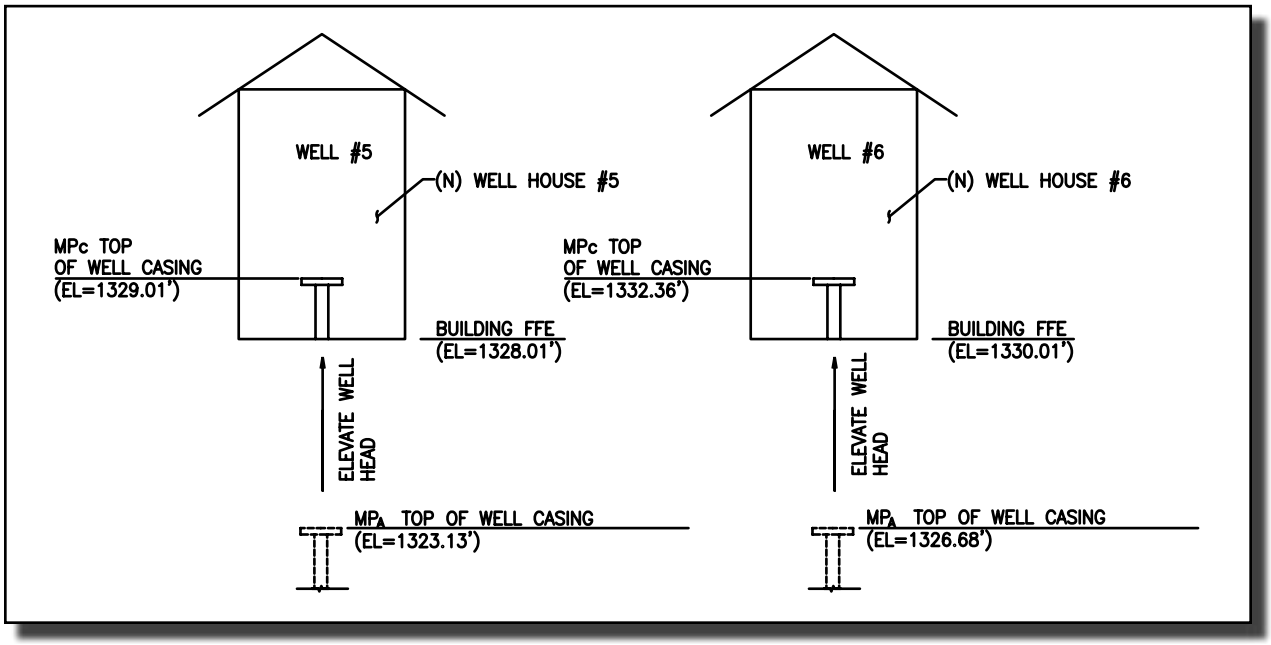
May 2010
L:\Projects\FEMA_HMGP_Projects\Iowa_floods\Maps\Flood_Control_Project\Figures\Manning_well_head_project.mxd

***Figure G.2*** *Schematic of Manning Well Head Project*




## G2 Phase 1 – Data Collection

The data collection process for the loss avoidance study (LAS) was initiated in late 2009. The HMGP project files were reviewed for data necessary to complete the LAS. The data included the project cost, project completion date, design plans or drawings for the project, location maps, and building information for the well houses.

Relevant information gathered for the LAS included data from the only gage on the West Nishnabotna River, which is more than 40 miles downstream of the City. No Flood Insurance Study (FIS) or Flood Insurance Rate Map (FIRM) exists for the City, and other detailed hydraulic studies were not available.

A site visit to the Manning Well Head Project was not performed primarily because it was not feasible to visit this site within the timeframe established for conducting site visits, given its remote location. Instead, phone contact was made with local agencies to confirm data in the project files and collect further information regarding the wells, their condition, and their function in providing potable water to the community. Discussions with the Iowa Department of Natural Resources (DNR) Compliance Office provided information on the number of active (three) and inactive wells (four) and likely damage if one active well is contaminated. In addition, discussions with Test America in Des Moines, Iowa, provided information regarding testing procedures if wells are contaminated.

Topographic data were not available for the project site. The available topography was limited to 10-meter National Elevation Dataset (NED) data, which showed a wide, flat floodplain at an approximate elevation of 1,320 feet North American Vertical Datum of 1988 (NAVD88).

## G3 Phase 2 – Physical Parameter Analysis

The following sections explain the detailed methodology of Phase 2 for the Manning Well Head Project. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

### G3.1 Storm Event Analysis

The U.S. Geological Survey (USGS) gage on the West Nishnabotna River (USGS gage #06807410) at Hancock, Iowa, is the only gage on the river and is more than 40 miles downstream of Manning. The gage has measured peak and daily streamflow since 1960 (USGS, 2001).

The annual peak streamflow data from the gage at Hancock were analyzed to estimate the number of flood events that have occurred since the project completion date. The four largest events are listed in **Table G.2** in order of decreasing magnitude. Additionally, the record of daily mean streamflow was examined to determine whether other large events had occurred during the same year the large events occurred. No other peaks were found.

These four peak discharges were transferred upstream using methodology for determining discharges for ungaged sites on gaged

*Table G.2*

**Peak Discharges on the West Nishnabotna River**

| Event Date | Peak Discharge at Hancock Gage (cfs) | Return Period of Discharge[1] | Exponent Applied to Ratio of | | |
|---|---|---|---|---|---|
| | | | Drainage Areas (x1) | Main Channel Slope (x2) | Calculated Discharge at Manning (cfs)[2] |
| *May 6, 2007* | 19,800 | 10-year | 0.590 | 0.306 | 4,347 |
| *June 12, 2008* | 16,600 | < 10-year | 0.590 | 0.306 | 3,645 |
| *May 25, 2004* | 14,400 | < 5-year | 0.616 | 0.305 | 2,948 |
| *March 15, 2001* | 8,230 | < 2-year | 0.677 | 0.316 | 1,434 |

1 Return period based on flood frequency estimates at Hancock provided in USGS (2001)
2 Discharge computed using regression equations and basin transfer methods adapted from USGS (2001)
cfs = cubic feet per second
USGS = U.S. Geological Survey

flooding sources in *Techniques for Estimating Flood Frequency Discharges for Streams in Iowa* (USGS, 2001).

The equation used in the basin transfer calculations is as follows:

$$Q_{transferred} = Q_{observed}\left(\frac{DA_{transferred}}{DA_{observed}}\right)^{x1}\left(\frac{MCS_{transferred}}{MCS_{observed}}\right)^{x2}$$

Where:

$Q_{transferred}$ = peak discharge (cubic feet per second [(cfs]) at the ungaged site

$Q_{observed}$ = peak discharge (cfs) measured at the gage location

$DA_{transferred}$ = drainage area (square miles) at the ungaged site

$DA_{observed}$ = drainage area (square miles) at the gage location

$MCS_{transferred}$ = main channel slope (ft/mile) at the ungaged site

$MCS_{observed}$ = main channel slope (ft/mile) at the gaged site

*x1, x2* = Coefficients dependent on recurrence interval (see **Table G.2)**

For the purposes of calculations, the contributing watersheds at Hancock and Manning were estimated to be 609 and 41.6 square miles, respectively. The computed peak discharges for Manning are shown in order of descending magnitude in **Table G.2**.

There may be substantial error in transferring the discharge in such a manner because the contributory area at the gage is nearly 15 times larger than the watershed at the site. Closer stream gages on nearby flooding sources were not available.

## G3.2 Hydraulic Analysis

As stated above, there is no current FIS or FIRM for the City of Manning. Preliminary maps in the FEMA Engineering Library files show the floodprone areas and the approximate 100-year floodplain boundary, but no flood elevations are indicated. Available topography is limited to 10-meter NED data, which show a wide, flat floodplain at an approximate elevation of 1,320 feet NAVD88. The topographic data is not of sufficient accuracy to estimate a channel cross section in order to create a new hydraulic model.

According to the limited topographic information, the channel slope at the site is approximately 0.1%. The determination of the floodplain width at elevation 1,320 feet NAVD88 adjacent to each of the wells was based on effective flow limits. The flood elevations for each of the discharge events were determined using the normal

*Table G.3*

**Flood Depths Calculated for the Manning Well Head Project**

| Event Date | Calculated WSE[1] (feet NAVD88) | |
|---|---|---|
| | At Well #5 Location | At Well #6 Location |
| *May 6, 2007* | 1,324.2 | 1,324.2 |
| *June 12, 2008* | 1,323.7 | 1,323.7 |
| *May 25, 2004* | 1,323.3 | 1,323.3 |
| *March 15, 2001* | 1,322.1 | 1,322.1 |

1 Elevation based on normal depth computation

NAVD88 = North American Vertical Datum of 1988
WSE = water surface elevation

depth equation and are shown in **Table G.3**. The normal depth computations are based on a rectangular channel with a bottom width of 350 feet at an elevation of 1,320 feet NAVD88, a channel slope of 0.001 foot/foot, and a Manning's roughness coefficient of 0.04. Backwater effects from bridges and downstream portions of the channel and the conveyance of the channel below elevation 1,320 feet NAVD88 were not considered.

## G3.3 Flood Boundary Analysis

Because the Manning Well Head Project does not affect the water surface elevations (WSEs) in the West Nishnabotna River, the Flood Boundary Analysis resembled a Flood Inundation Analysis. The WSE was compared to the $MP_A$ and $MP_C$ well casing elevation and

*Table G.4*

**Depth of Flooding at Well #5 and Well #6 Locations for the $MP_A$ and $MP_C$ Scenarios**

| Event Date | $MP_A$ Scenario Depth of Flooding (feet) | | | | $MP_C$ Scenario Depth of Flooding (feet) | | | |
|---|---|---|---|---|---|---|---|---|
| | Well Casing #5 | Well Casing #6 | Well House #5[1] | Well House #6[1] | Well Casing #5 | Well Casing #6 | Well House #5 | Well House #6 |
| *May 6, 2007* | 1.1 | 0 | N/A | N/A | 0 | 0 | 0 | 0 |
| *June 12, 2008* | 0.6 | 0 | N/A | N/A | 0 | 0 | 0 | 0 |
| *May 25, 2004* | 0.2 | 0 | N/A | N/A | 0 | 0 | 0 | 0 |
| *March 15, 2001* | 0 | 0 | N/A | N/A | 0 | 0 | 0 | 0 |

1 N/A = Not applicable (well houses did not exist in the $MP_A$ scenario)

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

well house FFE to determine depth of flooding. **Table G.4** shows the results of the analysis.

The results of the Flood Boundary Analysis show that neither of the well heads would be contaminated in the $MP_C$ scenario for any of the events studied. The raising of the well heads to the 500-year flood elevation and construction of well houses around the well heads was effective toward flood protection in the $MP_C$ scenario. The WSEs for the events studied would not have reached the post-project FFEs for either of the well houses.

For the $MP_A$ scenario, the results of the Hydraulic Analysis show that Well #6 would not have been contaminated because the WSEs for the flood events considered would not have reached the pre-project elevation corresponding to the top of the well casing. However, floodwaters would have risen above the well casing for Well #5 in the $MP_A$ scenario in the May 2007, June 2008, and May 2004 flood events.

Because potential losses occurred in the $MP_A$ scenario, the Manning Well Head Project was advanced to Phase 3.

## G4 Phase 3 – Loss Estimation Analysis

The losses calculated for the Manning Well Head Project include the costs to take the well offline if floodwaters rise above the well head casing. The purpose of taking the well offline is to check for potential contamination of potable water and to restore water to acceptable drinking water standards. The Flood Inundation Analysis showed that only one of the active water wells is likely to be affected in the $MP_A$ scenario. Acording to Iowa DNR, this would not result in a loss of water supply. The other two wells would be sufficient to provide the full demand of potable water to the community. This damage was therefore not calculated. The assumptions underlying the loss avoidance calculations are provided in **Attachment 1**.

### G4.1 Cleanup Costs

According to the Iowa DNR, the three active water wells have a common distribution system into the Manning Water Treatment Plant and several protective measures to reduce the threat of contaminating the City's water supply. The system has a separate valve device at each well location for emergency purposes. If a single well is affected by contaminated waters, the valve associated with the single well can be shut off with minimal effort. City water

employees can easily shut the valve within minutes, preventing contaminated water from affecting the rest of the system.

Another protective measure that the State of Iowa implements is a Sanitary Site Survey of each well in Iowa every 3 years. The wells are inspected for good condition and proper sealing at the well head termination to prevent floodwaters from entering. If a well is determined to be deficient, 30 days are allowed for rehabilitation of the well. If the rehabilitation exceeds 30 days, the well is taken offline. According to the Iowa DNR Compliance Office, all three active Manning wells were determined to be in good condition during the most recent Sanitary Site Survey.

Floodwaters rise above the well casing for Well #5 during the $MP_A$ scenario of the May 2007, June 2008, and May 2004 flood events. For each of these events, there is a potential for contamination of potable water. To ensure safe water supply, the Manning Water Treatment Plant would require proper procedures to test the well for contamination. According to the Iowa DNR, the valve associated with Well #5 would first be closed. The well cap would be removed from the well head and the well distribution pipe brought to the ground surface.

After the floodwaters recede, the well water would be dewatered and the electrical equipment inspected for proper functioning. Next, chemicals would be added to the well water to allow for disinfection of waterborne debris and bacteria. The disinfection would take approximately 72 hours. After disinfection, the well water would again be dewatered to ensure that residual chemicals had been removed. Finally, the water would be tested to ensure that drinking water was safe.

The process of restoring safe drinking water varies with the condition of the existing well and the extent of contamination. A community that has taken good care of its wells, performed periodic testing, and implemented protective measures to the best of its ability will likely have wells that are in good condition. If the community has not maintained its wells, restoration may take weeks or months to restore the wells to an acceptable condition. Given that Well #5 was in compliance with the Sanitary Site Survey and that any deficiencies had been addressed, it is likely that the well was in good condition at the time of the May 2007, June 2008, and May 2004 flood events. It is therefore estimated that the well could be restored within 1 week.

The total cost of taking Well #5 offline, performing testing procedures, and restoring the well to good condition involves

labor costs, pumping costs, and the cost of contamination testing. To conduct the analysis, it was estimated that the maximum time required to pump the water to waste would be 1 day (24 hours). In addition, it was assumed that water would be pumped away for 8 hours to ensure that no residuals were present after disinfection.

Assuming that a contractor is onsite for 4 hours each day for the week-long period that the well was being restored, the costs associated with labor can be calculated by multiplying the hourly rate of the contractor by the total number of hours spent at the well site. Using a typical hourly rate of $75 per hour for a contactor, the labor costs are therefore estimated to be $2,100. No costs are assumed for pump rental or pump operation because these costs would be negligible.

The cost associated with testing varies depending on the type of contaminants being tested. For loss calculations, it was assumed that the cost of testing the well contaminants would be $3,000.

## G4.2 Summary of Damage

The $MP_A$ and $MP_C$ scenario damage for the Manning Well Head Project is shown in **Table G.5**.

The total losses avoided include only $MP_A$ damage because the WSEs for the flood events studied would have been below the top of the well casings and the first floor elevations of the well houses. The total losses avoided are $15,300, and the total project Return on Investment (ROI) is 46%. **Table G.5** shows that the total losses

*Table G.5*

**Manning Well Head Project Loss Estimation Analysis Results and Return on Mitigation Investment (ROI)**

| Event Date | Results by Loss Category: $MP_A$ Scenario Damage – Emergency Protective Measures / Cleanup Costs for Well #5 | Results by Loss Category: $MP_C$ Scenario Damage – Emergency Protective Measures / Cleanup Costs for Well #5 | Losses Avoided | Project Investment | ROI |
|---|---|---|---|---|---|
| *May 6, 2007* | $5,100 | $0 | $5,100 | $33,222 | 15% |
| *June 12, 2008* | $5,100 | $0 | $5,100 | $33,222 | 15% |
| *May 25, 2004* | $5,100 | $0 | $5,100 | $33,222 | 15% |
| **Total** | **$15,300** | **$0** | **$15,300** | **$33,222** | **46%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete

avoided are presently lower than the project investment, but this project will continue to provide benefits to both Well #5 and #6 for a number of years. Because floodwaters did not exceed the top of the Well #6 casing in any of the events studied, the ROI could be considered 92% for Well #5 (which is twice the ROI of 46%) and 0% for Well #6.

For Well #5, floodwaters would have exceeded the top of the casing in the $MP_A$ scenario for three of the events studied. If the well had been contaminated, discussions with the Iowa DNR confirmed that other two active wells would have been sufficient to provide drinking water to the community, and there would have been no interruption in potable water service. Therefore, the only losses avoided would have been cleanup costs associated with taking Well #5 offline temporarily and restoring water quality in that well through pumping and testing procedures.

## G5 References

FEMA (Federal Emergency Management Agency). 2000. Hazard Mitigation Grant Program, Manning Well Head Project File, Project #0928-0013. Closeout Date: February 24, 2000.

USGS (U.S. Geological Survey). 2001. *Techniques for Estimating Flood Frequency Discharges for Streams in Iowa*. Water Resources Investigations Report 00-4233.

———. 2010. Information for gage #0680741 West Nishnabotna River at Hancock, Iowa.

# Attachment 1

## Loss Calculations

### Table Att-1

| Manning Well Head Project, May 2004 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Cleanup Costs for Well #5 | Number of Labor Hours for Contractor: | 28 | Based on 4 hour working day and 7 days to restore well | *No Cleanup Costs* | | |
| | Labor Rate for Contractor ($/hour) | $75.00 | Contractor labor rate, based on discussions with water engineers | | | |
| | Water Contamination Testing: | $3,000 | Testing cost based on discussions with water engineers | | | |
| | **Cleanup Costs (2010 Dollars):** | **$5,100** | | **Cleanup Costs (2010 Dollars):** | **$0** | |

$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete

### Table Att-2

| Manning Well Head Project, May 2007 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Cleanup Costs for Well #5 | Number of Labor Hours for Contractor: | 28 | Based on 4 hour working day and 7 days to restore well | *No Cleanup Costs* | | |
| | Labor Rate for Contractor ($/hour) | $75.00 | Contractor labor rate, based on discussions with water engineers | | | |
| | Water Contamination Testing: | $3,000 | Testing cost based on discussions with water engineers | | | |
| | **Cleanup Costs (2010 Dollars):** | **$5,100** | | **Cleanup Costs (2010 Dollars):** | **$0** | |

$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete

### Table Att-3

| Manning Well Head Project, June 2008 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Cleanup Costs for Well #5 | Number of Labor Hours for Contractor: | 28 | Based on 4 hour working day and 7 days to restore well | *No Cleanup Costs* | | |
| | Labor Rate for Contractor ($/hour) | $75.00 | Contractor labor rate, based on discussions with water engineers | | | |
| | Water Contamination Testing: | $3,000 | Testing cost based on discussions with water engineers | | | |
| | **Cleanup Costs (2010 Dollars):** | **$5,100** | | **Cleanup Costs (2010 Dollars):** | **$0** | |

$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete

# Appendix H

## McGregor Floodwall Project

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# Appendix H:

## McGregor Floodwall Project

### H1 Introduction

The McGregor Municipal Utilities power plant is located in the City of McGregor (City) in Clayton County, Iowa. The plant, which was built in 1942, serves as a distribution substation and as a peak and backup generating facility. It is located in the 100-year floodplain of the Mississippi River and 150 yards from the riverbank. The location of the power plant is shown in **Figure H.1**. Floodwaters typically reach the plant indirectly through sewer lines and subterranean channels that permeate the floodplain, eventually ponding around the power plant. In the past, emergency sandbagging efforts have been necessary to protect the plant from flooding.

In 1995, the City applied through the State of Iowa to the Federal Emergency Management Agency (FEMA) for Hazard Mitigation Grant Program (HMGP) funding to protect the power plant from flood damage. The resulting project, the McGregor Floodwall Project, consisted of construction of a floodwall with stop log floodgates and a berm to protect the plant. **Table H.1** shows the basic components of the project. The project was designed to protect the facility to the 500-year flood level and was completed on June 24, 1999, at a total project cost of $173,322. HMGP funded 75% ($129,992) of the project cost, and the City provided the local match of $43,330. The total project cost, in 2010 dollars, is $239,918. **Figures H.2** and **H.3** are photographs of the floodwall and the wall openings where stop logs would be placed in the event of a flood.

*Table H.1*

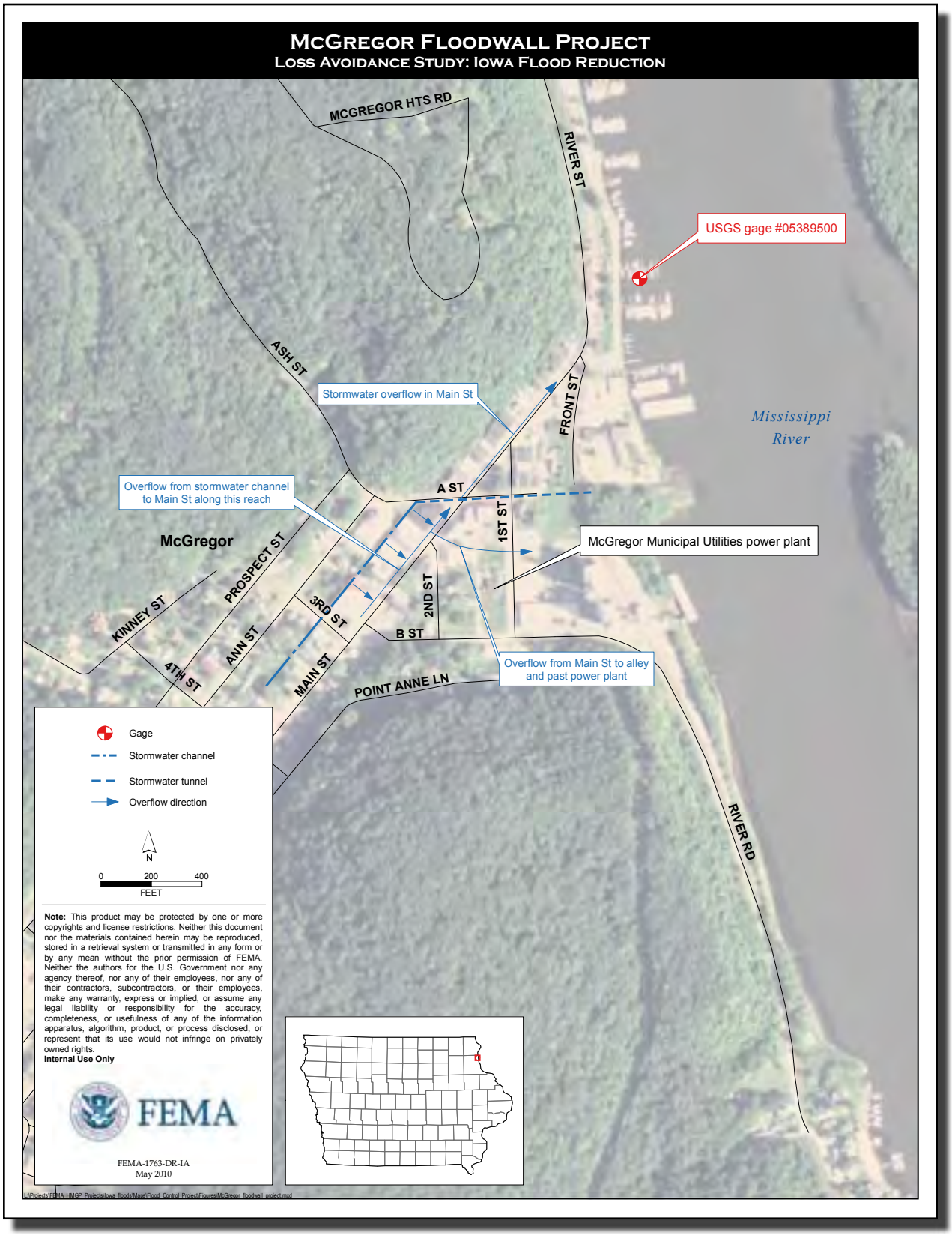
**McGregor Floodwall Project Components**

| Description | Latitude (degrees) | Longitude (degrees) | Overflow Elevation (feet NAVD88) | Access Door Elevation (feet NAVD88) | Floodwall Elevation (feet NAVD88) | Project Construction Completion Date |
|---|---|---|---|---|---|---|
| ***Power Plant*** | 43.0237 | –91.1749 | 628.9[1] | 624.3[2] | 632.9[3] | 6/24/1999 |

1 $MP_A$ overflow lowest point of entry for outside waters, from project plans reviewed during site visit
2 Bottom of basement access door, from project plans (FEMA, 1999)
3 Top of floodwall, from project plans (FEMA, 1999)

FEMA = Federal Emergency Management Agency
$MP_A$ = Mitigation Project Absent
NAVD88 = North American Vertical Datum of 1988

**Figure H.1**


McGregor Floodwall Project
Loss Avoidance Study: Iowa Flood Reduction
MCGREGOR HTS RD
RIVER ST
USGS gage #05389500
ASH ST
Stormwater overflow in Main St
FRONT ST
Mississippi River
Overflow from stormwater channel to Main St along this reach
A ST
1ST ST
McGregor
McGregor Municipal Utilities power plant
PROSPECT ST
KINNEY ST
3RD ST
2ND ST
ANN ST
B ST
4TH ST
MAIN ST
POINT ANNE LN
Overflow from Main St to alley and past power plant
RIVER RD
Gage
Stormwater channel
Stormwater tunnel
Overflow direction
N
0 200 400
FEET
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May 2010

***Figure H.2*** *Floodwall Openings at the Front Entrance to the McGregor Municipal Utilities Power Plant, February 3, 2010 (photo by Jane Branson, URS Group, Inc.)*

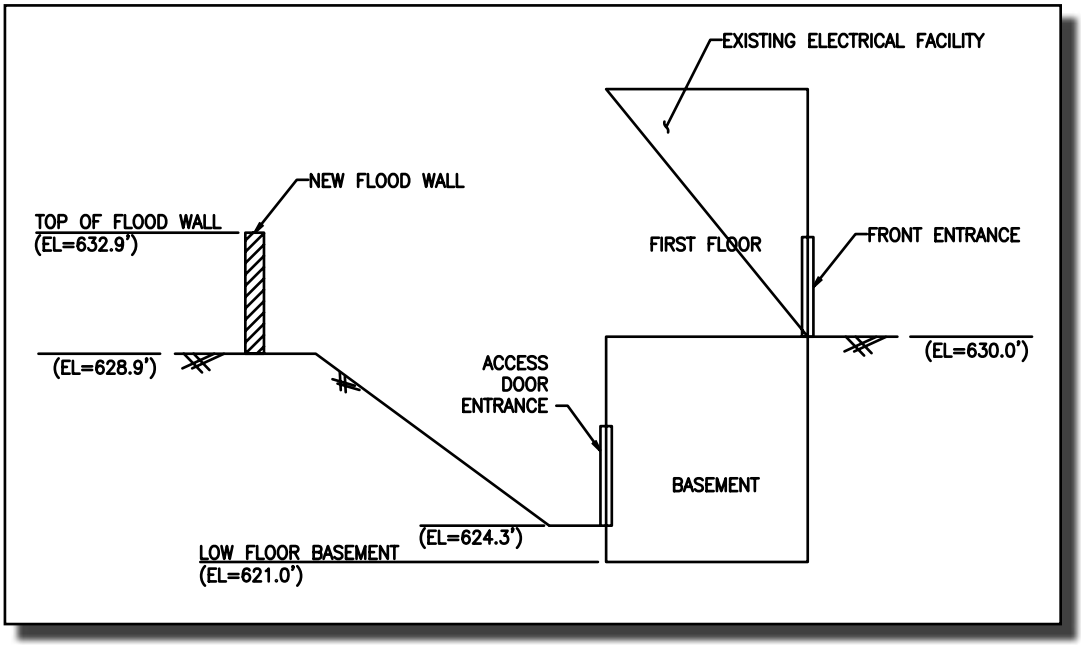
***Figure H.3*** *McGregor Floodwall at the Rear of the Building Showing the Floodwall Opening, February 3, 2010 (photo by Jane Branson, URS Group, Inc.)*

**Figure H.4** is a schematic of the power plant and floodwall at the rear of the building. The adjacent street grade is at an elevation of 628.9 feet North American Vertical Datum of 1988 (NAVD88). This elevation is the lowest point of entry for outside waters. Floodwaters have to be at least this high to flood the lower ground elevations including the power plant basement.

The plant's basement contains generating equipment and electrical controls critical to the operation of the plant are located. Equipment on the basement floor includes 3 diesel engines, electrical switchgear and meters, fuel pumps, substation equipment, and tools and supplies. The first floor has primarily office equipment. A transformer and tank pumps are also located at the same elevation as the first floor, but are external to the building and protected by the floodwall.

The slab of the basement is at an elevation of 621.0 feet NAVD88. Floodwaters could enter the basement at an access door elevation of 624.3 feet NAVD88. The files and project plans indicate that the top of the floodwall protecting the plant is at an elevation of 632.9 feet NAVD88.

***Figure H.4*** *Schematic of McGregor Floodwall Project*



## H2 Phase 1 – Data Collection

The HMGP application and project files were reviewed for data necessary to complete the loss avoidance study.

Data were obtained for the U.S. Geological Survey (USGS) gage #05389500 on the Mississippi River near the City (see **Figure H.1**) (USGS, n.d.). Additionally, hydrologic and hydraulic data used to prepare the Flood Insurance Study (FIS), and Flood Insurance Rate Map (FIRM) were obtained. Using this data, a preliminary Storm Event Analysis was completed prior to a site visit on February 3, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. The preliminary Storm Event Analysis and Hydraulic Analysis showed that the McGregor Floodwall Project had not been tested by Mississippi River flood events since project completion. However, during the site visit, the power plant managers described an unanticipated benefit of the floodwall in that it had been effective in protecting the facility against flash flooding from local catchment runoff.

After the site visit, hourly precipitation data were obtained for the site from a gage maintained by the National Climatic Data Center (National Oceanic and Atmospheric Administration [NOAA] Gage ID #135315). The data were used to develop a Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model to analyze the runoff from the local watershed, which could cause flash flooding at the plant.

The information obtained during the site visit included the insured building and contents values of the facility and project plans for the floodwall. Much of the discussion during the site visit involved gaining an understanding of the avoided losses that would occur if the power plant flooded. The operation of the stormwater system was described, and site plans for the lining/rehabilitation of 430 feet of a nearby storm tunnel structure were obtained. Airborne Light Detection and Ranging System (LiDAR) data for McGregor were obtained (GeoTREE, 2009).

Following discussions of potential flood damage during the site visit, substation vendors and electrical companies were contacted to determine the costs of delivering, constructing, connecting, and securing a temporary substation for several weeks if the system is damaged during a flood event.

## H3 Phase 2 – Physical Parameter Analysis

The following sections detail the Phase 2 methodology for the project. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

### H3.1 Storm Event Analysis

The USGS gage on the Mississippi River (USGS gage #05389500) is used to measure river stage and discharge and became operational in 1936 (USGS, n.d.). The gage records peak stage and discharge events and daily mean stage and discharge information. The two largest river flood events that have occurred since the floodwall was constructed are shown in **Table H.2**. These events are peak stage events for specific water years. The daily mean data were examined to determine whether other peak events that occurred during 2001 exceeded the June 2004 flood event (USGS, n.d.). No such events occurred.

In addition to flooding from the Mississippi River, the facility is subject to flooding from heavy localized rainfall events and flash flooding. Facility staff noted that during a rainfall event on July 17–18, 2007, the stop logs held back floodwaters to a depth of approximately 2 feet (1½ stop logs at 16 inches each). This would indicate a flood elevation of 631.4 feet (NAVD88) based on the project plans. In addition, facility staff indicated that the stop logs had been deployed on May 22–23, 2004, and June 13, 2005, in anticipation of flash flood events.

Hourly precipitation data were obtained for the City from a gage maintained by the National Climatic Data Center (NOAA Gage ID#135315). The data were analyzed for the events that the facility

*Table H.2*

**Peak Gage Data for the Mississippi River at McGregor**

| Event Date | Peak Gage Height (feet) | Peak WSE (feet NGVD29) | Peak WSE (feet NAVD88) | Peak Discharge (cfs) |
|---|---|---|---|---|
| *April 21, 2001* | 23.75 | 628.59[1] | 628.44[1] | 248,000 |
| *June 18, 2004* | 17.30 | 622.14[2] | 621.99[2] | 115,000 |

1 Gage datum elevation is 604.84 feet NVGD 29 (USGS, n.d.)
2 Datum conversion: NAVD – NGVD = –0.151 feet from VERTCON (NCDC, n.d.)

cfs = cubic feet per second
NAVD88 = North American Vertical Datum of 1988
NCDC = National Climatic Data Center
NGVD29 = National Geodetic Vertical Datum of 1929
USGS = U.S. Geological Survey
WSE = water surface elevation

staff mentioned during the site visit. The data indicated that the total rainfall during the July 17–18 event was 10.1 inches. More importantly, after an initial 0.8 inches of rainfall, 9 inches of rain fell within a 7-hour period with intensities as high as 2.3 inches per hour (NCDC, n.d.).

The precipitation data indicate that during the May 2004 rainfall event, more than 6 inches of rain fell with intensities as great at 1.2 inches per hour. This event occurred with high antecedent soil moisture conditions because 1.2 inches of rain had fallen a few days earlier, greatly increasing the potential for runoff. The precipitation gage data did not indicate extraordinary rainfall during the June 2005 rainfall event.

An HEC-HMS model was developed to model runoff from the local watershed that could cause flash flooding in the City. Watershed parameters were developed using digital elevation data and ortho-imagery. Rainfall data from the McGregor precipitation gage were input into the HEC-HMS model to determine peak runoff discharge for several intense rainfall events. **Table H.3** shows the results of the HEC-HMS modeling effort in descending order of total rainfall.

*Table H.3*

**Flash Flood Discharge Events in the City of McGregor**

| Date | Total rainfall (inches) | Maximum rainfall intensity (inches/hour) | Peak discharge (cfs) |
|---|---|---|---|
| *July 17–18, 2007* | 10.1 | 2.3 | 2,970 |
| *May 22–23, 2004* | 6.1 | 1.2 | 1,030 |
| *August 18–20, 2007* | 4.1 | 0.8 | 480 |
| *August 1, 2001* | 2.4 | 1.7 | 340 |

cfs = cubic feet per second

Watershed characteristics used in calculations:
Watershed size = 3.64 square miles
Initial abstraction = 0.7 inch
Runoff curve number = 74
Time of concentration = 166 minutes

## H3.2 Hydraulic Analysis

The FIRM for Clayton County indicate that this reach of the Mississippi River has been studied by approximate methods. Therefore, no hydraulic model for the FIS and FIRM exists. The USACE 2004 Flow Frequency Study for the Mississippi includes the 2-, 5-, 10-, 25-, 50-, 100-, 200- and 500-year flood profiles (USACE, 2004). The profiles and the Upper Mississippi River Flow

Frequency Query (USACE, n.d.) indicate that the change in water surface elevation (WSE) between the project location and the gage location is negligible for all size events. Therefore, the gage reading is used as the flood elevation at the site for river flooding events.

Discharge from flash flooding caused by heavy rainfall events is usually collected in a stormwater channel northwest of Main Street. This channel discharges into a storm sewer tunnel that is constructed of corrugated metal with a concrete bottom. Topographic information developed using LiDAR indicates that the storm tunnel is approximately 650 feet long. The storm tunnel was originally constructed of stone blocks. The project plans for the lining/rehabilitation of 430 feet of the storm tunnel indicate that the rehabilitated section of the storm tunnel is somewhat smaller than the original tunnel. The approximate location of the stormwater tunnel, stormwater channel and overflow paths are shown on **Figure H.1**.

Based on the LiDAR data, if the capacity of the storm tunnel is exceeded, stormwater will overflow the stormwater channel onto Main Street at an elevation of approximately 631 feet. Based on the project plans, the storm tunnel has the capacity of about 930 cubic feet per second (cfs) before the stormwater overflows to the street. Subtracting 930 cfs from the total runoff indicates that approximately 2040 cfs was discharged to the street during the July 2007 rainfall event and approximately 100 cfs was discharged to the street during the May 2004 rainfall event. Other rainfall events that have occurred during the project life should have been contained in the storm tunnel.

Some of the overflow would continue northeast on Main Street and eventually discharge into the Mississippi River. Some of the stormwater could leave Main Street and pass through an alley next to the McGregor Municipal Utilities (see **Figure H.1**).

The approximate percentage of the overflow from Main Street that passes through the alley and across the control section was estimated using normal depth computations and an assumed WSE of 631.4 feet NAVD88, based on the facility operator's estimate of the depth of flooding at the stop logs in the July 2007 flood event. From this calculation, it was estimated that approximately half the overflow would have passed through the alley adjacent to the electrical facility. The flood elevation for the May 2004, event could then be determined using normal depth calculations at the control section by assuming that half of the 100 cfs overflow (50 cfs) was discharged down the alley adjacent to the facility.

**Table H.4** summarizes the WSEs for two flash flood events and two river flood events that have occurred since the McGregor Floodwall Project was constructed.

## H3.3 Flood Boundary Analysis

Because the floodwall protects only one facility and does not affect the WSEs in the Mississippi River, the Flood Boundary Analysis resembled a Flood Inundation Analysis. The historical river gage information for the Mississippi River indicates that the facility would likely not have been flooded from river flood events after the floodwall was installed. However, anecdotal evidence indicates that the floodwall has also protected the facility from flooding from flash flood events on other flooding sources.

The flood depths inside the building (with respect to the basement floor) for two flash flood events have been calculated for the Mitigation Project Absent ($MP_A$) scenario and are shown in **Table H.5**. Given the layout of the facility, any breach of the perimeter would result in substantial flooding of the basement and

*Table H.4*

**Calculated Water Surface Elevations at the McGregor Municipal Utilities Power Plant**

| Event Date | Flood Type/Source | WSE (feet NAVD88) |
|---|---|---|
| *July 17–18, 2007* | Flash flood | 631.4[1] |
| *May 22–23 2004* | Flash flood | 629.0[2] |
| *April 21, 2001* | Mississippi River | 628.4[3] |
| *June 18, 2004* | Mississippi River | 622.0[3] |

1 Based on anecdotal account from facility operator and project plans during the site visit
2 Based on normal depth computations
3 Based on gage stage

NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929
WSE = water surface elevation

*Table H.5*

**Flood Depths at the McGregor Municipal Utilities Power Plant**

| Event Date | Flood Type/ Source | $MP_A$ Scenario Depth of Flooding (feet) | $MP_C$ Scenario Depth of Flooding (feet) |
|---|---|---|---|
| *July 17–18, 2007* | Flash flood | 10.4[1] | 0 |
| *May 22–23 2004* | Flash flood | 8.0[1] | 0 |
| *April 21, 2001* | Mississippi River | 0.0[2] | 0 |
| *June 18, 2004* | Mississippi River | 0.0[2] | 0 |

1 Depth of flooding in relation to basement floor
2 WSE was below the $MP_A$ scenario street grade overflow elevation

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
WSE = water surface elevation

equipment. Because some losses have been shown to have been avoided, the project advanced to Phase 3.

## H4 Phase 3 – Loss Estimation Analysis

The losses avoided by the McGregor Floodwall Project include physical damage and loss of electric service. The assumptions underlying the loss avoidance calculations are provided in **Attachment 1**.

### H4.1 Physical Damage

Physical damage includes damage to the power plant building and equipment. Loss of electric service is incurred if the existing substation or controls are damaged by flooding.

#### H4.1.1 Building Damage

The results of the Flood Boundary Analysis showed that for the $MP_A$ scenario, the power plant would have flooded in the May 2004 and July 2007 flood events. During the May 2004 flood event, the depth of flooding at the power plant would have been 8 feet. Therefore, water would have inundated most of the basement, which has a height of 9 feet. During the July 2007 flood event, the depth of flooding would have been 10.4 feet, which is enough to completely inundate the entire basement and 1.4 feet of the first floor. For the Mississippi River flood events (April 2001 and June 2004), the WSE would have been below the lowest point of entry into the power plant facility. Therefore, the building would not have been flooded and no physical damage would have occurred.

To estimate the building damage in the $MP_A$ scenario, building data for the power plant were obtained from various sources including the original HMGP grant application, documentation for the 2009 insured value of the facility obtained from the plant staff, and photographs taken during a site visit. The insured value of the building and contents is $3,796,800 (in 2010 dollars). In the HMGP grant application, the ratio between building value and contents value was approximately 2:1. The same ratio was therefore applied to the current insured value to determine a building replacement value (BRV) of $2,531,200.

The HMGP grant application specified a total building footprint of 4,750 square feet. The BRV is therefore $532.88/square foot. Aerial photography and online measurement software was used to calculate the area of the first floor of the power plant, which

was estimated at 2,731 square feet. The area of the basement was calculated by subtracting 2,731 square feet from the total building size, which is 1,839 square feet.

The loss calculations for building damage used two USACE St. Paul District depth-damage functions (DDFs): (1) "Downtown Commercial Basement Unfinished" function for the basement portion of the building, and (2) "Machine Shop, Small Manufacturing (Light Manufacturing)" function for the first floor of the building. These DDFs were used in place of the FEMA Benefit-Cost Analysis (BCA) Tool Version 4.5 nonresidential DDFs (FEMA, 2009) in order to appropriately account for basement damage.

For the May 2004 event, floodwaters would have filled 8 feet of the basement, which has a height of 9 feet. This corresponds to a flood depth of –1 foot and a percent building damage of 4%, according to the USACE St. Paul District DDFs for a "Downtown Commercial Basement Unfinished." The basement damage was calculated by multiplying 4% by the full BRV of the building because the USACE St. Paul District DDFs for buildings with basements use the full BRV including the value of the basement. The resulting basement damage was estimated to be $97,411 (in 2010 dollars) for the May 2004 flood event.

Because the floodwaters would have flooded the entire basement of the electrical facility in the July 2007 flood event, the maximum percent building damage of 5% from the "Downtown Commercial Basement Unfinished" curve was applied for the basement. The basement damage were calculated by multiplying 5% by the full BRV of the building. The building damage for the first floor was determined by linearly interpolating between the building percent damage for 1 foot and 2 feet of flooding because the first floor would have experienced 1.4 feet of flooding. It was estimated that building damage on the first floor would be 15.1% of the BRV associated with the first floor of the building. The total building damage for the basement and first floor were therefore estimated at $340,933 (in 2010 dollars) for the July 2007 flood event.

For the Mitigation Project Complete ($MP_C$) scenario, the Flood Boundary Analysis showed that the WSEs would not have exceeded the top of the floodwall in any of the events studied. Therefore, no losses were incurred for the $MP_C$ scenarios.

### H4.1.2 Contents Damage

Damage estimates for contents were included in the FEMA project closeout files. According to the files, damage to the plant's primary

functional equipment would account for the bulk of the contents damage to the plant if flooded. This equipment is located mainly on the basement level of the facility and includes 3 diesel engines, electrical switch gear and meters, fuel pumps, and substation equipment. If the basement level were completely inundated, the total value of the damage was estimated at $110,000 in 1996 dollars ($161,982 in 2010 dollars). If floodwaters rose above the first floor of the facility, additional damage would be incurred. Equipment on the first floor includes a transformer, tank pumps, and office equipment. According to information provided in the project files, damage to the first floor equipment is estimated to be $25,000 in 1996 dollars ($36,814 in 2010 dollars).

Using these estimates of damage, the damage to contents for the $MP_A$ scenario during the May 2004 event would have been $161,982 (assuming 8 feet of flooding in the basement would yield the same damage as if it were completely inundated). For the $MP_A$ scenario during the July 2007 flood event, the contents damage would have been $198,796.

## H4.2 Loss of Function

Loss of function consists of loss of electrical power, which occurs when the substation or controls are damaged by flooding. According to the discussion with the representatives at McGregor Municipal Utilities, if the existing substation and or controls are damaged by flooding, continuing the delivery of electricity to the community would require the purchase of a temporary 2- to 2.5-megawatt substation. According to vendors, the costs of delivering, constructing, connecting, and securing a temporary substation are estimated at $150,000. This cost would be incurred for the May 2004 and the July 2007 flood events.

According to the plant staff, the City would also likely be without power for 1 or 2 days while the temporary substation was made operational. Using the FEMA standard value for loss of electricity service ($126 per person per day of lost service), the loss of function cost was determined by multiplying this value by the population served by the plant and the estimated loss of service for 2 days. The population of the City according to the 2000 U.S. Census is 871 (U.S. Census Bureau, n.d.).

## H4.3 Summary of Damage

The $MP_A$ and $MP_C$ scenario damage for the McGregor Floodwall Project is summarized in **Table H.6**. For the Return on Investment (ROI) calculation, the total project cost of $173,322 was inflated

*Table H.6*

## McGregor Floodwall Project Loss Estimation Analysis Results and Return on Mitigation Investment

| Event Date | Results by Loss Category | | | | | | Losses Avoided | Project Investment | ROI |
|---|---|---|---|---|---|---|---|---|---|
| | $MP_A$ Scenario Damage | | | $MP_C$ Scenario Damage | | | | | |
| | Physical Damage | | Loss of Function | Physical Damage | | Loss of Function | | | |
| | Damage to Building | Damage to Contents | Loss of Electric Power | Damage to Building | Damage to Contents | Loss of Electric Power | | | |
| ***May 22–23, 2004*** | $97,411 | $161,982 | $369,492 | $0 | $0 | $0 | $628,885 | $239,918 | 262% |
| ***July 17–18, 2007*** | $340,933 | $198,796 | $369,492 | $0 | $0 | $0 | $909,221 | $239,918 | 379% |
| **Total** | **$438,344** | **$360,778** | **$738,984** | **$0** | **$0** | **$0** | **$1,538,107** | **$239,918** | **641%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
ROI = Return on Investment

to 2010 dollars for a total of $239,918. The total losses avoided are $1,538,107, and the total project ROI is 641%. An ROI of greater than 100% indicates that the project costs have been recovered based on the losses avoided since the project completion date. As additional flood events occur, the ROI is expected to increase even further.

## H5 References

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# Attachment 1

## Loss Calculations

## Table Att-1

| McGregor Floodwall Project, May 2004 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| DAMAGE TO BUILDING | Facility Type: | Electrical Facility | FEMA Project Closeout Files | *No Building Damage* | | |
| | Model Depth-Damage Curve for Basement: | Downtown Commercial Basements Unfinished | USACE St. Paul District Depth-Damage Curves | | | |
| | Depth of Flooding with Respect to Basement (ft): | 8 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type for Basement: | 4 | USACE St. Paul District Depth-Damage Curves. Note: The depth of flooding is 8 ft. Since the basement is 9 feet tall, floodwaters would fill most of the basement. Therefore, the % basement damage would correspond to flood depth of -1 ft for the USACE St. Paul District Depth-Damage Curves. | | | |
| | Building Replacement Value ($/sqft): | $532.88 | See [1] below | | | |
| | Total Building Area (sqft): | 4,570 | Total Building Area from BCA in FEMA Project Closeout Files. USACE St. Paul District Depth-Damage Curve for "Downtown Commercial Basements Unfinished" call for BRV of entire building including basement. | | | |
| | Upper Floor Area (sqft): | 2,731 | Area mapping tool | | | |
| | **Building Damage (2010 Dollars):** | **$97,411** | | **Building Damage (2010 Dollars):** | **$0** | |
| | Depth of Flooding with Respect to Basement (ft): | 8 | H&H analysis | *No Building Contents Damages* | | |
| | Height of Basement (ft): | 9 | Field visit observations | | | |
| | Value of Contents in Basement | $110,000 | FEMA Project Closeout Files | | | |
| | Value of Contents in First Floor: | $25,000 | FEMA Project Closeout Files | | | |
| | Contents Value Base Year: | 1996 | FEMA Project Closeout Files | | | |
| | Inflation Multiplier: | 1.472563696 | BCA Cost Inflator | | | |
| | **Building Contents Damage (2010 Dollars):** | **$161,982** | Assume 8 feet of flooding in the basement will damage all contents in basement. | **Building Contents Damage (2010 Dollars):** | **$0** | |
| LOSS OF ELECTRIC POWER | Temporary Sub-Station Costs: | $150,000 | Current day cost as discussed with Schneider Engineering | *No Loss of Electric Power* | | |
| | Number of Days of Loss of Function (days): | 2 | Field visit discussions | | | |
| | FEMA Standard Value for Loss of Electric Power ($/person/day): | $126 | FEMA standard value | | | |
| | Population of McGregor (people): | 871 | 2008 U.S. Census Data | | | |
| | **Damage for Loss of Electric Power (2010 Dollars):** | **$369,492** | | **Damage for Loss of Electric Power (2010 Dollars):** | **$0** | |

[1] The Building Replacement Value (BRV) from the BCA was compared to the contents value in the BCA. It was determined that the BRV was two times the contents value. Assuming the same ratio of building value to contents value, the insured value of building and contents (taken from the insurance statement provided by Elkader) was multiplied by (2/3) to get the present day building replacement value. This value was then divided by the square footage of the building to get a $/sqft value of $532.88/sq

| | |
|---|---|
| (1) Insured Value from McGregor Insurance Statement: | $3,796,800.00 |
| (2) Insured Value from McGregor Insurance Statement, Times 2/3 | $2,531,200.00 |
| (3) Item (2), Divided by Building Sqft of 4,750 sqft: | $532.88 |
| | Therefore, BRV = **$532.88/sqft** |

| | |
|---|---|
| BCA = Benefit-cost analysis | H&H = Hydrologic and Hydraulic |
| BRV = Building replacement value | $MP_A$ = mitigation project absent |
| FEMA = Federal Emergency Management Agency | $MP_C$ = mitigation project complete |
| FFE = First floor elevation | sqft = square feet |
| ft = feet | USACE = U.S. Army Corps of Engineers |

## Table Att-2

| McGregor Floodwall Project, June 2007 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| DAMAGE TO BUILDING | Facility Type: | Electrical Facility | FEMA Project Closeout Files | *No Building Damages* | | |
| | Model Depth-Damage Curve: | Downtown Commercial Basements Unfinished | USACE St. Paul District Depth-Damage Curves | | | |
| | Depth of Flooding with Respect to Basement (ft): | 10.4 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type: | 5 | USACE St. Paul District Depth-Damage Curves. Note: The depth of flooding is 10.4 ft. Since the basement is 7.9 feet tall, floodwaters would actually fill the entire basement. The USACE St. Paul Distric Depth-Damage Curves account for basement damages up to 9 feet tall basements only. The percent damage is taken a 5%, since this is the maximum percentage of damage that can be achieved when the basement is completely filled with floodwaters. | | | |
| | Model Depth-Damage Curve for Upper Floor: | Machine Shop, Small Manufacturing (Light Manufacturing) | USACE St. Paul District Depth-Damage Curves | | | |
| | Depth of Flooding in Upper Floor (ft): | 1.4 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type fo Upper Floor: | 15.06 | USACE St. Paul District Depth-Damage Curves | | | |
| | Building Replacement Value ($/sqft): | $532.88 | See [1] below | | | |
| | Total Building Area (sqft): | 4,570 | Total Building Area from BCA in FEMA Project Closeout Files. USACE St. Paul District Depth-Damage Curve for "Downtown Commercial Basements Unfinished" call for BRV of entire building including basement. | | | |
| | Upper Floor Area (sqft): | 2,731 | Area mapping tool | | | |
| | **Building Damage (2010 Dollars):** | **$340,933** | | **Building Damage (2010 Dollars):** | **$0** | |
| DAMAGE TO CONTENTS | Depth of Flooding with Respect to Basement (ft): | 10.4 | H&H analysis | *No Building Contents Damages* | | |
| | Height of Basement (ft): | 9 | Field visit observations | | | |
| | Value of Contents in Basement | $110,000 | FEMA Project Closeout Files | | | |
| | Value of Contents in First Floor: | $25,000 | FEMA Project Closeout Files | | | |
| | Contents Value Base Year: | 1996 | FEMA Project Closeout Files | | | |
| | Inflation Multiplier: | 1.472563696 | BCA Cost Inflator | | | |
| | **Building Contents Damage (2010 Dollars):** | **$198,796** | Assuming 1.4 feet of flooding will damage all contents in first floor | **Building Contents Damage (2010 Dollars):** | **$0** | |
| LOSS OF ELECTRIC POWER | Temporary Sub-Station Costs: | $150,000 | Current day cost as discussed with Schneider Engineering | *No Loss of Electric Power* | | |
| | Number of Days of Loss of Function (days): | 2 | Field visit discussions | | | |
| | FEMA Standard Value for Loss of Electric Power ($/person/day): | $126 | FEMA standard value | | | |
| | Population of McGregor (people): | 871 | 2008 U.S. Census Data | | | |
| | **Damage for Loss of Electric Power (2010 Dollars):** | **$369,492** | | **Damage for Loss of Electric Power (2010 Dollars):** | **$0** | |

[1] The Building Replacement Value (BRV) from the BCA was compared to the contents value in the BCA. It was determined that the BRV was two times the contents value. Assuming the same ratio of building value to contents value, the insured value of building and contents (taken from the insurance statement provided by Elkader) was multiplied by (2/3) to get the present day building replacement value. This value was then divided by the square footage of the building to get a $/sqft value of $532.88/sc

| | |
|---|---|
| (1) Insured Value from McGregor Insurance Statement: | $3,796,800.00 |
| (2) Insured Value from McGregor Insurance Statement, Times 2/3 | $2,531,200.00 |
| (3) Item (2), Divided by Building Sqft of 4,750 sqft: | $532.88 |
| | Therefore, BRV = **$532.88/sqft** |

| | |
|---|---|
| BCA = Benefit-cost analysis | H&H = Hydrologic and Hydraulic |
| BRV = Building replacement value | $MP_A$ = mitigation project absent |
| FEMA = Federal Emergency Management Agency | $MP_C$ = mitigation project complete |
| FFE = First floor elevation | sqft = square feet |
| ft = feet | USACE = U.S. Army Corps of Engineers |

# Appendix I

## Montrose Floodproofing Project

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# Appendix I:

## Montrose Floodproofing Project

### I1 Introduction

The Montrose Wastewater Treatment Facility in the City of Montrose (City) in Lee County, Iowa, is within 50 feet of the Mississippi River. The facility is located along Main Street and adjacent to the Chicago, Burlington & Quincy Railroad (see **Figure I.1**). It is in the middle of the business district and has minimal room for flood protection and expansion. The facility experienced losses during the Great Flood of 1993, but substantial environmental damage from raw sewage spills into the Mississippi River was prevented by emergency response efforts that were successful in protecting the facility.

In November 1999, the State of Iowa applied to the Federal Emergency Management Agency (FEMA) for Hazard Mitigation Grant Program (HMGP) funding to construct a control building. The project consisted of demolishing the old control building and constructing a new control building on fill for protection to the 500-year flood elevation level. The wet well was also raised to protect to the 500-year flood elevation level. **Figure I.2** is a photograph of the elevated building.

The Montrose Floodproofing Project received $267,337 in HMGP funding toward the total project cost of $434,033. The City provided the remaining $166,696 for the local match. The total project cost, in 2010 dollars, is $518,258. The project was completed on December 2, 2004. **Table I.1** provides basic components of the project. **Figure I.3** is a schematic of the project.

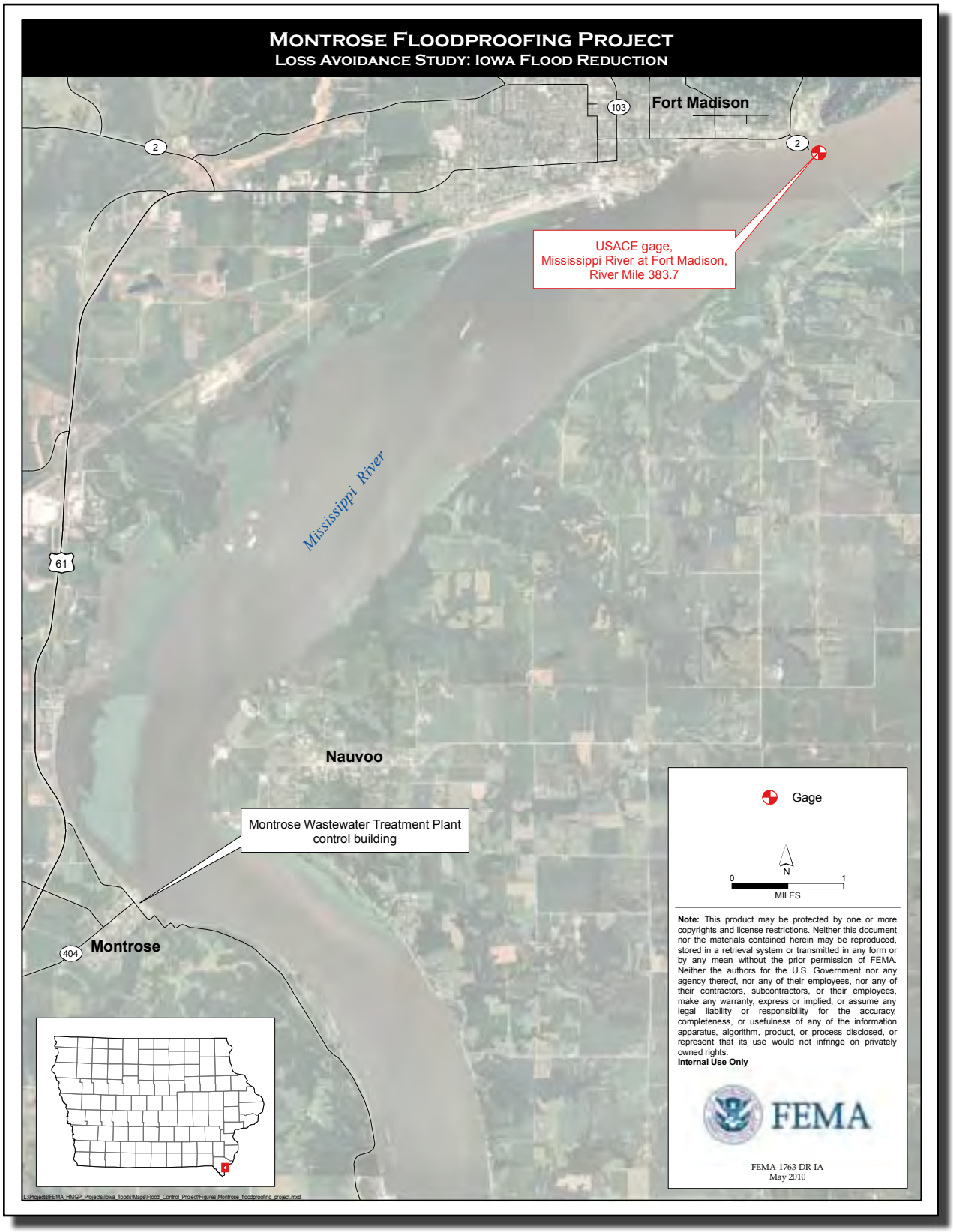
*Table I.1*

**Montrose Floodproofing Project Components**

| Component | Latitude (degrees) | Longitude (degrees) | $MP_A$ Scenario FFE (feet NGVD29) | $MP_C$ Scenario FFE (feet NGVD29) | Project Completion Date |
|---|---|---|---|---|---|
| *Wastewater Treatment Facility Control Building* | 40.5323 | –91.4137 | 523.55 | 532.5 | December 2, 2004 |

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
FFE = first floor elevation
NGVD29 = National Geodetic Vertical Datum of 1929

***Figure I.1***


Montrose Floodproofing Project
Loss Avoidance Study: Iowa Flood Reduction
Fort Madison
103
2
2
USACE gage,
Mississippi River at Fort Madison,
River Mile 383.7
Mississippi River
61
Nauvoo
Montrose Wastewater Treatment Plant
control building
404
Montrose
Gage
N
0
1
MILES
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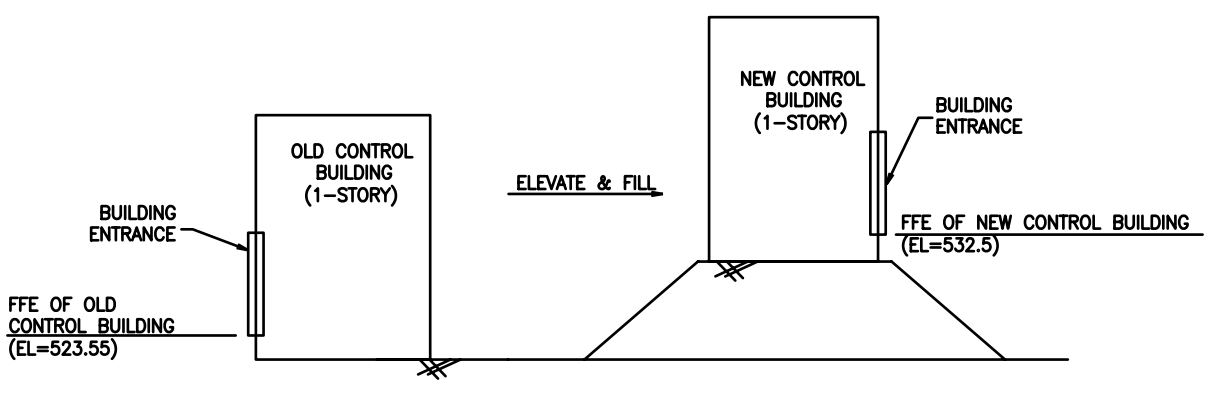
FEMA-1763-DR-IA
May 2010

***Figure I.2*** *Elevated Control and Blower Building, February 5, 2010 (photo by Jane Branson, URS Group, Inc.)*

***Figure I.3*** *Schematic of Old and New Control Buildings at Montrose Wastewater Treatment Facility*



## I2 Phase 1 – Data Collection

The HMGP project files were reviewed for data necessary to conduct the loss avoidance study (FEMA, 2005). However, the project files included a feasibility study for the floodproofing project, and information regarding the old control building, which no longer exists, was used. Hydrologic data were gathered from the U.S. Army Corps of Engineers (USACE) gage at Fort Madison (see **Figure I.1**), and Hydrologic Engineering Center 2 (HEC-2) hydraulic modeling for the Mississippi River was obtained from the FEMA Map Service Center. Using this data, a preliminary Storm Event Analysis was completed prior to a site visit on February 5, 2010.

The site visit was conducted to assess the conditions of the project site and initiate the more detailed data collection required for Phases 2 and 3. Hydrologic and hydraulic data were reviewed, and the design drawings for the new control building were accessed. City employees had all been hired since project completion in 2004. Data regarding the 1993 flood event and likely damage during the 2008 flood event that were not in the project files were obtained during phone calls with the previous Director of Public Works, who had led the 1993 emergency response effort.

## I3 Phase 2 – Physical Parameter Analysis

The following sections detail the Phase 2 methodology for the Montrose Floodproofing Project. Phase 2 consists of the Storm Event Analysis, Hydraulic Analysis, and Flood Boundary Analysis.

### I3.1 Storm Event Analysis

The USACE gage on the Mississippi River at Fort Madison, Iowa (River Mile [RM] 383.7), is operated by the USACE Rock Island District (the location of the gage is shown on **Figure I.1**). The gage is used to measure river stage and has been operational since 1900 (USACE, n.d.a.). The gage is approximately 8.7 miles upstream of Montrose. The gage records river stage daily at 6:00 AM in addition to the top ten record peak stages since the gage has been operational.

The three highest flood stages that have occurred since the project completion date are listed in **Table I.2** in order of decreasing magnitude. The gage data were collected in a local datum called the Memphis Datum, which was initially converted to mean sea level 1912 (MSL) and finally to National Geodetic Vertical Datum of 1929 (NGVD29) so that flood stage could be used to compute

**Table I.2**

**Peak Stages on the Mississippi River at Fort Madison, Iowa**

| Event Date | Peak Gage Height (feet Memphis Datum) | Peak Gage Height (feet MSL)[1] | Peak Gage Height (feet NGVD29)[2] |
|---|---|---|---|
| *June 17, 2008* | 534.85 | 528.05 | 527.62 |
| *May 3, 2008* | 531.70 | 524.90 | 524.47 |
| *March 13, 2009* | 529.33 | 522.53 | 522.10 |

1 Gage datum is –6.80 feet 1912 MSL (USACE, n.d.a.)
2 Elevation 1912 MSL = Elevation 1929 NGVD + 0.43 feet (USACE, 1979)

MSL = mean sea leve
NGVD29 = National Geodetic Vertical Datum of 1929
USACE = U.S. Army Corps of Engineers

flood damage and therefore the losses avoided associated with this project.

The June 2008 flood event is the annual peak for 2008. The May 2008 and March 2009 flood events are the next two highest archived stages measured since project implementation (USACE, n.d.a).

## I3.2 Hydraulic Analysis

In 2004, the USACE re-evaluated the flood return frequencies for the Mississippi River (USACE, 2004). The study resulted in the creation of flood profiles along the entire length of the river. The Montrose Wastewater Treatment Plant is located at RM 375. The USACE flood profiles indicate the 200-year flood at Montrose has an elevation of 523.6 feet (NGVD29), which is approximately the same elevation as the Mitigation Project Absent ($MP_A$) scenario first floor elevation (FFE) of the old control building (523.55 feet NGVD29). This similarity indicates that the control building is in an area of minimal flood hazard with about a 0.5% annual chance of flooding.

The profiles from the 2004 USACE study and the Upper Mississippi River Flow Frequency Query website (USACE, n.d.b.) were also used to interpolate the gage data at Fort Madison downstream of Montrose. The Fort Madison gage is at RM 383.7 or 8.7 miles upstream of the Montrose Wastewater Treatment Plant (RM 375). **Table I.3** contains the results of the interpolation.

The 2004 USACE study indicates that the 500-year flood elevation at Montrose is 524.2 feet NGVD29. Therefore, the June 2008 flood event was greater than a 500-year flood event at the project site. The recorded WSE of the 1993 flood event was 0.35 foot higher at

*Table I.3*

**Interpolated Water Surface Elevation at the Montrose Wastewater Treatment Facility**

| Event Date | Peak Gage Height (feet NGVD29) | Interpolated WSE at Project Site (feet NGVD29) |
|---|---|---|
| *June 17, 2008* | 527.62 | 524.5 |
| *May 3, 2008* | 524.47 | 521.9 |
| *March 13, 2009* | 522.10 | 520.1 |

NGVD29 = National Geodetic Vertical Datum of 1929 WSE = water surface elevation

the gage than the June 2008 flood event (or approximately 524.85 feet NGVD29 at the project site), indicating that the 1993 flood event was also greater than a 500-year flood event.

FEMA obtained HWMs in the City of Montrose near the Montrose Wastewater Treatment Plant after the June 2008 event (FEMA, 2008). The elevation of one of the HWMs was 0.7 foot lower than that computed using gage information and the USACE river profiles. A second HWM was obtained in the vicinity of the Fort Madison River gage. The HWM elevation was 0.36 foot lower than the peak gage elevation during the June 2008 event. Because the HWM elevations appeared to be consistently lower than gage elevations, they were not used in this analysis.

## I3.3 Flood Boundary Analysis

When the water surface elevation (WSE) is at least as high as the FFE, the depth of flooding in the building is calculated by subtracting the FFE from the WSE. Otherwise, there is no flooding calculated. **Table I.4** shows the depth of flooding in the $MP_A$ and Mitigation Project Complete ($MP_C$) scenarios, using the interpolated WSEs provided in **Table I.3**.

*Table I.4*

**Depth of Flooding in the Control Building in the $MP_A$ and $MP_C$ Scenarios**

| Event Date | Depth of Flooding in $MP_A$ Scenario (feet) | Depth of Flooding in $MP_C$ Scenario (feet) |
|---|---|---|
| *June 17, 2008* | 0.95 | 0 |
| *May 3, 2008* | 0 | 0 |
| *March 13, 2009* | 0 | 0 |

$MP_A$ = Mitigation Projection Absent
$MP_C$ = Mitigation Project Complete

The Physical Parameter Analysis indicates that the construction of the Wastewater Treatment Facility control and blower building on fill has protected the building from one event since its construction in 2004. Because some losses were avoided during the June 2008 flood event, this project advanced to Phase 3.

## I4 Phase 3 – Loss Estimation Analysis

The Montrose Floodproofing Project was designed to protect only the control building at the plant. Therefore, the loss types included in the analysis were building damage to the old control building, physical damage to the old control building equipment, and loss of wastewater service due to damage of the controls and electrical equipment.

The results of the Physical Parameter Analysis show that the new control building would not be flooded in the $MP_C$ scenario for any of the flood events studied because the WSE would not have reached the FFE of the new control building. However, in the $MP_A$ scenario, the old control building would have experienced 0.95 foot of flooding in the June 2008 flood event. For the May 2008 and March 2009 flood events, the old control building would not have flooded.

### I4.1 Physical Damage

Physical damage consists of damage to the building and damage to contents. Contents includes control systems and equipment.

#### I4.1.1 Building Damage

Building damage for the $MP_A$ scenario of the June 2008 flood event was estimated using the building replacement value (BRV) of the control building, which was calculated by multiplying the building square footage by the replacement value ($/square foot) determined from a current national cost estimating guide. The loss calculations for building damage were based on the USACE St. Paul District depth-damage function for a "Machine Shop, Small Manufacturing (Light Manufacturing)" building. This building type most closely matches the building type of the old control building.

The building damage corresponding to a flood depth of 0.95 foot was determined by linearly interpolating between the building damage percentages associated with flood depths of 0 and 1 foot for the "Machine Shop, Small Manufacturing (Light Manufacturing)" building. The resulting percentage was multiplied by the BRV of

the building. The assumptions underlying the estimated value of the building damage are provided in **Attachment 1**.

### I4.1.2 Building Contents Damage

The old control building contained equipment such as air compressors, a four-bucket motor control center, and control panels. The project files included a value for building contents that were thought to include considerably more than the contents of the control building. After a review of this value, a revised value was developed based on photos contained in the projects files. The revised value of contents was estimated at $100,000.

For the $MP_A$ scenario, during the June 2008 flood event, floodwaters with a depth of 0.95 foot would have damaged the contents beyond repair. Therefore, building contents damage is estimated at $100,000 for this flood event.

## I4.2 Loss of Function

Loss of function consists of loss of wastewater service. If the control building at the wastewater plant is damaged, the entire plant cannot function and the City of Montrose loses all wastewater service. According to discussions with wastewater engineers, it would take approximately 3 or 4 weeks to restore the wastewater plant and bring it back into service. For the $MP_A$ scenario, the loss of wastewater services was estimated by multiplying the FEMA standard value for loss of wastewater service, $41 per person per day (FEMA, 2009), by 918 (U.S. Census Bureau, n.d.), which is the population of Montrose and a loss of service time of 28 days. The loss of wastewater service is therefore estimated to be $1,053,864. This value represents a complete loss of service in which the controls and/or wetwells are damaged. The value is conservative because it does not include the cost of hauling wastewater in tank trucks to another facility for treatment.

For the $MP_C$ scenario, the new control building would have not been flooded by any of the flood events studied because the floodwaters would not have reached the FFE of the new control building. Therefore, no equipment in the building would be damaged and no loss of wastewater service would be incurred.

## I4.3 Summary of Damage

The $MP_A$ and $MP_C$ damage for Montrose is summarized in **Table I.5**. For the Return on Investment (ROI) calculations, the total project cost of $434,033 was inflated to 2010 dollars for a total of $518,258.

*Table I.5*

## Montrose Floodproofing Project Loss Estimation Analysis Results and Return on Mitigation Investment

| Event Date | Results by Loss Category | | | | | | Losses Avoided | Project Investment | ROI |
|---|---|---|---|---|---|---|---|---|---|
| | $MP_A$ Scenario Damage | | | $MP_C$ Scenario Damage | | | | | |
| | Physical Damage | | Loss of Function | Physical Damage | | Loss of Function | | | |
| | Damage to Building | Damage to Contents | Loss of Wastewater Service | Damage to Building | Damage to Contents | Loss of Wastewater Service | | | |
| ***June 13, 2008*** | $8,516 | $100,000 | $1,053,864 | $0 | $0 | $0 | $1,162,380 | $518,258 | 224% |
| **Total** | **$8,516** | **$100,000** | **$1,053,864** | **$0** | **$0** | **$0** | **$1,162,380** | **$518,258** | **224%** |

Note: All dollar amounts in this table have been adjusted for 2010 dollars

$MP_A$ = Mitigation Project Absent
$MP_C$ = Mitigation Project Complete
ROI = Return on Investment

The value of the total losses avoided is $1,162,380, and the total project ROI is 224% after only one flood event. The ROI for this project will increase if flood levels exceed the elevation of a 200-year event, which is the approximate elevation of the old control building. In this case, there would be significant $MP_A$ damage, such as building damage and building contents damage. However, since the 200-year event does not occur frequently and has already occurred twice in the last 7 years, it is unlikely that another event of this size will occur over the project's useful life that would cause damage in the $MP_A$ scenario.

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# Attachment 1

## Loss Calculations

## Table Att-1

| Montrose Floodproofing Project, June 2008 Event | | | | | | |
|---|---|---|---|---|---|---|
| Damage Category | $MP_A$ Scenario: | | | $MP_C$ Scenario: | | |
| | Description | Value | Source | Description | Value | Source |
| Damage to Building | Facility Type: | Wastewater Treatment Facility | FEMA Project Closeout Files | *No Building Damages* | | |
| | Model Depth-Damage Curve: | Machine Shop, Small Manufacturing (Light Manufacturing) | USACE St. Paul District Depth-Damage Curves | | | |
| | Depth of Flooding (ft): | 0.95 | H&H analysis | | | |
| | Percent Damaged (% of Building Value) by Building Type: | 11.355 | USACE St. Paul District Depth-Damage Curves | | | |
| | Building Replacement Value ($/sqft): | $50.00 | National Cost Estimating Guide | | | |
| | First Floor Area (sqft): | 1,500 | FEMA Project Closeout Files | | | |
| | **Building Damage (2010 Dollars):** | **$8,516** | | **Building Damage (2010 Dollars):** | **$0** | |
| Damage to Contents | Depth of Flooding (ft): | 0.95 | H&H analysis | *No Building Contents Damages* | | |
| | Value of Building Contents: | $100,000.00 | Discussions with wastewater engineers | | | |
| | **Building Contents Damage (2010 Dollars):** | **$100,000** | Assume complete contents damage at flooding of approximately 1 foot | **Building Contents Damage (2010 Dollars):** | **$0** | |
| Loss of Wastewater Service | FEMA Standard Value for Loss of Wastewater Service ($/person/day): | $41.00 | FEMA standard value for loss of wastewater service | *No Loss of Wastewater Service* | | |
| | Number of People Affected by Loss of Wastewater Service: | 918 | 2008 U.S. Census, population of Montrose | | | |
| | Number of Days of Loss of Wastewater Service: | 28 | Discussions with wastewater engineers | | | |
| | **Costs for Loss of Wastewater Service (2010 Dollars):** | **$1,053,864** | | **Costs for Loss of Wastewater Service (2010 Dollars):** | **$0** | |

FEMA = Federal Emergency Management Agency
H&H = hydrologic and hydraulic
ft = feet
$MP_A$ = mitigation project absent
$MP_C$ = mitigation project complete
sqft = square feet
USACE = U.S. Army Corps of Engineers

# Appendix J

## Depth Damage Curves

# Table of Contents

## List of Tables

**Table J.1:** USACE St. Paul District Depth-Damage Curves: Nonresidential.....J-3

## Table J.1

**USACE St. Paul District Depth-Damage Curves: Nonresidential**

| | Damage Curve | Source | Type | -9 ft | -7 ft | -5 ft | -3 ft | -1 ft | 0 ft | 1 ft | 3 ft | 5 ft | 7 ft | 9 ft | 11 ft | 13 ft | 15 ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BUILDING (%) | 1 | USACE St. Paul District | Drug, grocery chain stores (Grocery ) | 0.00 | 0.07 | 0.21 | 0.36 | 0.50 | 1.30 | 11.6 | 25.9 | 35.3 | 42.3 | 49.4 | 57.3 | 66.2 | 75.0 |
| | 2 | USACE St. Paul District | Hardware, paint, sporting goods, auto parts stores | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.0 | 26.0 | 29.0 | 35.8 | 42.6 | 46.8 | 48.4 | 50.0 |
| | 3 | USACE St. Paul District | Rest., larger fast foods - McDon's, etc. | 0.00 | 0.04 | 0.13 | 0.21 | 0.30 | 1.20 | 17.6 | 39.2 | 54.2 | 61.7 | 69.2 | 76.3 | 83.2 | 90.0 |
| | 4 | USACE St. Paul District | Wrhse, storage bldg (Wrhse - non-refrig) | 0.00 | 0.07 | 0.21 | 0.36 | 0.50 | 1.10 | 11.8 | 25.4 | 34.2 | 41.2 | 48.2 | 56.4 | 65.7 | 75.0 |
| | 5 | USACE St. Paul District | General office - doctor, realtor, bank, etc. | 0.00 | 0.11 | 0.34 | 0.57 | 0.80 | 1.60 | 13.5 | 25.4 | 33.5 | 43.7 | 54.0 | 62.3 | 68.6 | 75.0 |
| | 6 | USACE St. Paul District | Wrhse/off comb, (Wrhse non-refrig) | 0.00 | 0.07 | 0.21 | 0.36 | 0.50 | 1.10 | 11.8 | 25.4 | 34.2 | 41.2 | 48.2 | 56.4 | 65.7 | 75.0 |
| | 7 | USACE St. Paul District | Mach. shop, small mnfctrg (Light mnftrg) | 0.00 | 0.07 | 0.21 | 0.36 | 0.50 | 1.00 | 11.9 | 25.7 | 34.4 | 42.2 | 50.0 | 57.1 | 63.6 | 70.0 |
| | 8 | USACE St. Paul District | Apt on slab (Apartment - one story) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 12.5 | 25.9 | 33.5 | 39.4 | 45.0 | 45.0 | 45.0 | 45.0 |
| | 9 | USACE St. Paul District | Public property - less damageable type | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.0 | 10.0 | 12.0 | 14.4 | 16.8 | 18.4 | 19.2 | 20.0 |
| | 10 | USACE St. Paul District | Public property - more damageable type | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.0 | 26.0 | 29.0 | 35.8 | 42.6 | 46.8 | 48.4 | 50.0 |
| | Basement | USACE St. Paul District | Dwntwn comml bsmts unfinished | 0.0 | 0.8 | 1.5 | 2.5 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| | **Damage Curve** | **Source** | **Type** | **-9 ft** | **-7 ft** | **-5 ft** | **-3 ft** | **-1 ft** | **0 ft** | **1 ft** | **3 ft** | **5 ft** | **7 ft** | **9 ft** | **11 ft** | **13 ft** | **15 ft** |
| CONTENTS (%) | 1 | USACE St. Paul District | Drug, grocery chain stores (Grocery ) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.0 | 52.9 | 75.4 | 85.2 | 95.1 | 100.0 | 100.0 | 100.0 |
| | 2 | USACE St. Paul District | Hardware, paint, sporting goods, auto parts stores | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.00 | 48.0 | 90.0 | 111.0 | 119.0 | 127.0 | 131.0 | 131.0 | 131.0 |
| | 3 | USACE St. Paul District | Rest., larger fast foods - McDon's, etc. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.5 | 55.0 | 76.4 | 84.2 | 92.1 | 96.8 | 98.4 | 100.0 |
| | 4 | USACE St. Paul District | Wrhse, storage bldg (Wrhse - non-refrig) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.7 | 47.4 | 65.6 | 76.8 | 88.0 | 94.9 | 97.4 | 100.0 |
| | 5 | USACE St. Paul District | General office - doctor, realtor, bank, etc. | 0.00 | 0.10 | 0.30 | 0.50 | 0.70 | 2.00 | 20.0 | 45.4 | 63.9 | 74.9 | 85.9 | 93.1 | 96.6 | 100.0 |
| | 6 | USACE St. Paul District | Wrhse/off comb, (Wrhse non-refrig) | 0.00 | 0.06 | 0.17 | 0.29 | 0.40 | 1.00 | 20.7 | 47.4 | 65.6 | 76.8 | 88.0 | 94.9 | 97.4 | 100.0 |
| | 7 | USACE St. Paul District | Mach. shop, small mnfctrg (Light mnftrg) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 19.3 | 42.3 | 60.7 | 74.4 | 88.1 | 96.0 | 98.0 | 100.0 |
| | 8 | USACE St. Paul District | Apt on slab (Apartment - one story) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 21.7 | 39.0 | 47.9 | 55.7 | 60.6 | 60.6 | 60.6 | 60.6 |
| | 9 | USACE St. Paul District | Public property - less damageable type | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.0 | 20.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| | 10 | USACE St. Paul District | Public property - more damageable type | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 33.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| | Basement | USACE St. Paul District | Dwntwn comml bsmts unfinished | 0.0 | 2.5 | 6.0 | 9.0 | 11.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |

**Notes:**
**Only the first floor area is considered for estimating building and content damage, with the exception of basement curves, which consider the total building area including the basement.**

**The standard value for contents is a percentage of the Building Replacement Value.**
1. Drug, grocery chain stores (Grocery ) have a BRV-to-Contents ratio of 100%.
2. Hardware, paint, sporting goods, auto parts stores have a BRV-to-Contents ratio of 50%.
3. Rest., larger fast foods - McDon's, etc. have a BRV-to-Contents ratio of 100%.
4. Wrhse, storage bldg (Wrhse - non-refrig) have a BRV-to-Contents ratio of 100%.
5. General office - doctor, realtor, bank, etc. have a BRV-to-Contents ratio of 50%.
6. Wrhse/off comb, (Wrhse non-refrig) have a BRV-to-Contents ratio of 100%.
7. Mach. shop, small mnfctrg (Light mnftrg) have a BRV-to-Contents ratio of 100%.
8. Apt on slab (Apartment - one story) have a BRV-to-Contents ratio of 100%.
9. Public property - less damageable type have a BRV-to-Contents ratio of 50%.
10. Public property - more damageable type have a BRV-to-Contents ratio of 50%.
Dwntwn comml bsmts unfinished have a BRV-to-Contents ratio of 50%.

# Acronyms

**BCA**
Benefit-Cost Analysis

**BMWW**
Burlington Municipal Water Works

**BRV**
building replacement value

**cfs**
cubic foot (feet) per second

**CFU**
Cedar Falls Utilities

**CN**
curve number

**DDF**
depth-damage function

**DEM**
digital elevation model

**DNR**
Iowa Department of Natural Resources

**DSR**
Damage Survey Report

**EPA**
U.S. Environmental Protection Agency

**FEMA**
Federal Emergency Management Agency

**FFE**
first floor elevation

**FIRM**
Flood Insurance Rate Map

**FIS**
Flood Insurance Study

**FMA**
Flood Mitigation Assistance

**ft/mile**
foot (feet) per mile

**GIS**
Geographic Information System

**HAZUS-MH**
Hazards U.S. – Multi-Hazard

**HEC-2**
Hydrologic Engineering Center 2

**HEC-FDA**
Hydrologic Engineering Center Flood Damage Analysis

**HEC-HMS**
Hydrologic Engineering Center Hydrologic Modeling System

**HEC-RAS**
Hydrologic Engineering Center River Analysis System

**HMA**
Hazard Mitigation Assistance

**HMGP**
Hazard Mitigation Grant Program

**HQ**
high quality

**HWM**
high water mark

**kW**
kilowatt

**LA**
losses avoided

**LAS**
loss avoidance study

**LiDAR**
Light Detection and Ranging System

**$MP_A$**
Mitigation Project Absent

**$MP_C$**
Mitigation Project Complete

**MSL**
mean sea level

**n.d.**
no date

### NAVD88
North American Vertical Datum of 1988

### NCDC
National Climatic Data Center

### NED
National Elevation Dataset

### NGVD29
National Geodetic Vertical Datum of 1929

### NOAA
National Oceanic and Atmospheric Administration

### PDM Program
Pre-Disaster Mitigation Program

### PDMC
Pre-Disaster Mitigation – Competitive

### PI
Project Investment

### RFC Program
Repetitive Flood Claims Program

### RM
River Mile

### ROI
Return on Investment

### sq mi
square mile(s)

### SRL Program
Severe Repetitive Loss Program

### USACE
U.S. Army Corps of Engineers

### USGS
U.S. Geological Survey

### WSE
water surface elevation

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