Reducing Losses through Higher Regulatory Standards

2013 Colorado Floods Case Study

FEMA-DR-4145-CO

March 30, 2015

FEMA

Federal Emergency Management Agency
Department of Homeland Security
500 C Street, SW
Washington, DC 20472

This document was prepared by
Dewberry Consultants LLC
8401 Arlington Boulevard
Fairfax, VA 22031

Contract No.: HSFEHQ-09-D-1129
Task Order: 14-J-0003

Acknowledgements

Federal Emergency Management Agency:
Doug Bausch (FEMA Region VIII), Project Monitor
Brooke Buchanan, PE (FEMA Region VIII), Technical Monitor
Michael Gease (FEMA Region VIII)
Jesse Rozelle (FEMA Region VIII)
Casey Zuzak (FEMA Region VIII)

Dewberry:
Catherine Bohn
John Squerciati, PE
Kelly Clark, EIT

ACRONYMS AND ABBREVIATIONS I

EXECUTIVE SUMMARY 1

SECTION ONE INTRODUCTION 1-1
- 1.1 Purpose of the Study 1-1
- 1.2 Losses Avoided Study Methodology 1-1
- 1.3 Intended Audience 1-2
- 1.4 Background 1-2
  - 1.4.1 Overview of the 2013 Colorado Floods 1-2
  - 1.4.2 Description of Study Area 1-4
- 1.5 Layout of Report and Instructions for Use 1-4

SECTION TWO STUDY AREA 2-1
- 2.1 Site Selection Criteria 2-1
- 2.2 Overview of NFIP, CRS, and UDFCD 2-2
  - 2.2.1 National Flood Insurance Program 2-2
  - 2.2.2 Community Rating System 2-2
  - 2.2.3 Urban Drainage Flood Control District 2-3
- 2.3 County and Jurisdiction Overview 2-3
  - 2.3.1 CRS Status 2-5

SECTION THREE REGULATORY LOSSES AVOIDED DATA AND TOOLS 3-1
- 3.1 Data Description 3-1
- 3.2 Data Preparation and Assumptions 3-5

SECTION FOUR LOSS SUMMARIES 4-1
- 4.1 Event Losses 4-1
- 4.2 IA Event Losses Summary 4-2
- 4.3 SBA Event Loss Summary 4-3
- 4.4 NFIP Losses Summary 4-4
- 4.5 Basement-Only Losses 4-5
- 4.6 Likely Soil Erosion Losses 4-6
- 4.7 Letter of Map Amendment and Letter of Map Revision Based on Fill Policy Losses 4-6

SECTION FIVE REGULATORY LOSSES AVOIDED SCENARIO DESCRIPTION AND METHODOLOGY 5-1
- 5.1 Floodway and Floodplain Development Restrictions 5-1
- 5.2 Freeboard 5-3
- 5.3 Critical Facility Regulated in SFHA 5-5
- 5.4 Erosion Setback Assessment 5-6
- 5.5 Benchmark Years 5-6
- 5.6 NFIP Claims 5-6
- 5.7 Categories of Benefits 5-7
  - 5.7.1 Event Losses 5-7
  - 5.7.2 Description of Benefit Categories 5-8
  - 5.7.3 Benefit Categories Used for Scenarios 5-10

SECTION SIX SCENARIO RESULTS 6-1
6.1 Floodplain and Floodway Development Restrictions 6-1
6.1.1 Floodplain Development Regulations in the SFHA Adopted Earlier 6-1
6.1.2 Longmont Mitigation Project Case Study 6-8
6.1.3 Floodway Development Regulations Adopted Earlier .. 6-10
6.2 Freeboard 6-13
6.2.1 Freeboard Adopted Earlier 6-14
6.2.2 Freeboard Never Adopted 6-20
6.2.3 Freeboard Regulated to a Higher or Lesser Standard 6-26
6.3 Critical Facilities Regulated in SFHA 6-32
6.4 Erosion Setback Assessment 6-35
6.5 Benchmark Years 6-36
6.6 NFIP Claims 6-38

SECTION SEVEN CONCLUSION 7-1

SECTION EIGHT REFERENCES 8-1

Figures

Figure 1-1: Map depicting the rainfall amounts across the impacted area for the entire event. Source: NOAA NWS: http://www.nws.noaa.gov/om/assessments/pdfs/14colorado_floods.pdf ... 1-3

Figure 1-2: Figure 2.X: Map depicting the annual exceedance probabilities for worst case 24-hour rainfall. Source: NOAA NWS: http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/8_Colorado_2013.pdf 1-4

Figure 2-1: NFIP and CRS Status for Study Area 2-4

Figure 4-1: Total Event Losses for NFIP, IA, and SBA 4-1

Figure 4-2: Total IA Losses 4-2

Figure 4-3: Total SBA Losses 4-3

Figure 4-4: Total NFIP Losses 4-4

Figure 4-5: Basement Only Losses 4-5

Figure 5-1: Typical Riverine Floodplain Cross Section Showing the Floodway (Source: FEMA P-259, Figure 2-3) 5-2

Figure 5-2: Concept of Freeboard (Source: FEMA P-259, Figure 4-5) 5-4

Figure 6-1: 100-year Event Losses by County to SFHA Structures 6-1

Figure 6-2: MP_A and Losses Avoided in the 100-year Event in SFHA Structures 6-2

Figure 6-3: Boulder County Total Losses (MP_A) in SFHA Structures in the 100-year Event 6-3

Figure 6-4: Larimer County Total Losses (MP_A) in SFHA Structures in the 100-year Event 6-4

Figure 6-5: Weld County Total Losses (MP_A) in SFHA Structures in the 100-year Event 6-4

Figure 6-6: 2013 Event Losses by County to SFHA Structures 6-5

Figure 6-7: MP_A and Losses Avoided in the 2013 Event in SFHA Structures 6-6

Figure 6-8: Boulder County Total Losses (MP_A) in SFHA Structures in the 2013 Event. 6-7

Figure 6-9: Larimer County Total Losses (MP_A) in SFHA Structures in the 2013 Event. 6-7

Figure 6-10: Weld County Total Losses (MP_A) in SFHA Structures in the 2013 Event. 6-8

Figure 6-11: 100-year Event Losses by County to Floodway Structures 6-10

Figure 6-12: MP_A and Losses Avoided in the 100-year Event in Floodway Structures 6-11

Figure 6-13: Boulder County Total Losses (MP_A) in Floodway Structures in the 100-year Event 6-12

Figure 6-14: Larimer County Total Losses (MP_A) in Floodway Structures in the 100-year Event 6-12

Figure 6-15: Weld County Total Losses (MP_A) in Floodway Structures in the 100-year Event 6-13

Figure 6-16: 100-year Event Losses by County to Structures with Freeboard (MPA).. 6-14

Figure 6-17: Losses Avoided in the 100-year Event if Freeboard was Adopted Earlier6-15

Figure 6-18: Boulder County Total Losses (MP_C) in the 100-year Event if Freeboard was Adopted Earlier..... 6-16

Figure 6-19: Larimer County Total Losses (MP_C) in the 100-year Event if Freeboard was Adopted Earlier..... 6-16

Figure 6-20: Weld County Total Losses (MP_C) in the 100-year Event if Freeboard was Adopted Earlier..... 6-17

Figure 6-21: 2013 Event Losses by County to Structures with Freeboard (MP_A) 6-17

Figure 6-22: Losses Avoided in the 2013 Event if Freeboard was Adopted Earlier 6-18

Figure 6-23: Boulder County Total Losses (MP_C) in the 2013 Event if Freeboard was Adopted Earlier..... 6-19

Figure 6-24: Larimer County Total Losses (MP_C) in the 2013 Event if Freeboard was Adopted Earlier..... 6-19

Figure 6-25: Weld County Total Losses (MP_C) in the 2013 Event if Freeboard was Adopted Earlier..... 6-20

Figure 6-26: 100-year Event Losses by County if Freeboard was Never Adopted (MP_C) 6-20

Figure 6-27: Losses Avoided in the 100-year Event in SFHA Structures if Freeboard was Never Adopted..... 6-21

Figure 6-28: Boulder County Total Losses (MP_C) if Freeboard was Never Adopted in the 100-year Event..... 6-22

Figure 6-29: Larimer County Total Losses (MP_C) if Freeboard was Never Adopted in the 100-year Event..... 6-22

Figure 6-30: Weld County Total Losses (MP_C) if Freeboard was Never Adopted in the 100-year Event..... 6-23

Figure 6-31: 2013 Event Losses by County if Freeboard was Never Adopted (MP_C) .. 6-23

Figure 6-32: Losses Avoided in the 2013 Event in SFHA Structures if Freeboard was Never Adopted..... 6-24

Figure 6-33: Boulder County Total Losses (MP_C) if Freeboard was Never Adopted in the 2013 Event..... 6-25

Figure 6-34: Larimer County Total Losses (MP_C) if Freeboard was Never Adopted in the 2013 Event..... 6-25

Figure 6-35: Weld County Total Losses (MP_C) if Freeboard was Never Adopted in the 2013 Event..... 6-25

Figure 6-36: 100-year Event Losses by County if Freeboard was Regulated 2 Feet Higher or Lower (MP_C) 6-26

Figure 6-37: Losses Avoided in the 100-year Event if Freeboard was Regulated to a Higher or Lesser Standard..... 6-27

Figure 6-38: Boulder County Total Losses (MP_C) in the 100-year Event if Freeboard is Increased..... 6-28

Figure 6-39: Larimer County Total Losses (MP_C) in the 100-year Event if Freeboard is Increased..... 6-28

Figure 6-40: Weld County Total Losses (MP_C) in the 100-year Event if Freeboard is Increased..... 6-29

Figure 6-41: 2013 Event Losses by County if Freeboard was Regulated Two Feet Higher or Lower (MP_C) 6-29

Figure 6-42: Losses Avoided in the 2013 Event if Freeboard was Regulated to a Higher or Lesser Standard 6-30

Figure 6-43: Boulder County Total Losses (MP_C) in the 2013 Event if Freeboard is Increased..... 6-31

Figure 6-44: Larimer County Total Losses (MP_C) in the 2013 Event if Freeboard is Increased..... 6-31

Figure 6-45: Weld County Total Losses (MP_C) in the 2013 Event if Freeboard is Increased..... 6-32

Figure 6-46. 100-year Event Losses by County in Critical Facilities in the SFHA (MP_A) 6-32

Figure 6-47: Losses Avoided in the 100-year Event in Critical Facilities 6-33

Figure 6-48: Boulder County Total Losses (MP_A) in Critical Facilities in the 100-year Event 6-34

Figure 6-49: Larimer County Total Losses (MP_A) in Critical Facilities in the 100-year Event 6-34

Figure 6-50: Weld County Total Losses (MP_A) in Critical Facilities in the 100-year Event 6-35

Figure 6-51: Damage-to-Replacement Cost for Various Jurisdiction Regulatory Standards, 1998-2013 6-37

Figure 6-52: Damage-to-Replacement Cost for Various Jurisdiction Regulatory Standards, 1998 – 2013 (Jurisdictions with 10 or More Post-1998 Structures Damaged) 6-38

Figure 6-53: NFIP Policies Inside / Outside SFHA 6-39

Figure 6-54: NFIP Claims Inside/Outside the SFHA 6-40

Tables

Table 2-1: Regulatory Site Selection Criteria 2-1

Table 2-2: CRS Communities in Study Area 2-5

Table 3-1: Data Overview 3-2

Table 4-1: IA Total of Applications and % Inside/Outside SFHA 4-3

Table 4-2: SBA Total and % Inside/Outside SFHA 4-3

Table 4-3: NFIP Claim Total of Applications, % Inside/Outside SFHA, and Average Loss 4-4

Table 4-4: NFIP Policy Summary 4-5

Table 4-5: Basement Only Losses, % Inside/Outside SFHA, and % of IA Loss 4-5

Table 4-6: Likely Soil Erosion Loss Summary 4-6

Table 4-7: LOMC Type Used for Study 4-7

Table 4-8: County Summary of LOMAs and LOMR-F 4-7

Table 5-1: Loss Categories and Loss Avoided Benefits 5-8

Table 5-2: 2014-15 GSA Displacement Costs 5-9

Table 5-3: Environmental Benefits 5-10

Table 5-4: General Benefits Applied to Scenarios 5-11

Table 5-5: Social and Environmental Benefits Applied to Scenarios 5-11

Table 6-1: 2013 Colorado Floods Erosion Setback Assessment 6-35
Table 7-1: Summary of the Regulatory Losses Avoided Analysis 7-1

Appendices

Appendix A Data Preparation Tool User Guide
Appendix B Data Export Tool User Guide
Appendix C Data Analysis Tool User Guide
Appendix D Structure Inventory Assumptions
Appendix E Regulatory Standards
Appendix F Depth Damage Functions Used by Occupancy
Appendix G Case Study: Longmont, Colorado Mitigation Project
Appendix H Scenario Methodology
Appendix I Loss of Function Values

ACRONYMS AND ABBREVIATIONS

BFE	Base Flood Elevation
BRV	Building Replacement Value
CRS	Community Rating System
CRV	Contents Replacement Value
DDF	Depth Damage Function
FEMA	Federal Emergency Management Agency
FFE	First Floor Elevation
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GIS	Geographic Information System
GSA	General Services Administration
IA	Individual Assistance
LA	Losses Avoided
LAS	Loss Avoidance Studies
LOMA	Letter of Map Amendment
LOMC	Letter of Map Change
LOMR-F	Letters of Map Revision Based On Fill
LP	Loss of Productivity
MIP	Mapping Information Platform
MP_A	Mitigation Project Absent
MP_C	Mitigation Project Complete
NFIP	National Flood Insurance Program
ODBC	Open Database Connectivity
PA	Public Assistance
PDM	Pre-Disaster Mitigation
PI	Project Investment
PVC	Present Value Coefficient
PW	Project Worksheets
ROI	Return on Investment
SBA	U.S. Small Business Association
SFHA	Special Flood Hazard Area
UDFCD	Urban Drainage and Flood Control District
WSE	Water Surface Elevation

EXECUTIVE SUMMARY

In September 2013, an unprecedented rainfall event occurred along Colorado's Front Range of the Rocky Mountains, resulting in catastrophic flooding that impacted 18 Colorado counties and 132 jurisdictions. After an event of this magnitude, the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) would typically conduct a loss avoidance study (LAS) to assess the cost-effectiveness of mitigation measures such as acquisition of properties in the floodplain and implementing flood control measures. However, the September 2013 floods provided a unique opportunity to evaluate the losses avoided through a non-traditional approach. The primary focus of this study is to evaluate the impacts of floodplain management through higher regulatory standards and policy actions. Additionally, the LAS examined a more traditional mitigation project in Longmont, Colorado.

While 18 counties experienced significant damages from the September 2013 floods, the most substantial and severe damages were in Boulder, Larimer, and Weld Counties. These counties also have some of highest-rated National Flood Insurance Program (NFIP) Community Rating System (CRS) jurisdictions in Colorado. Conversely, several jurisdictions in these counties do not participate in the NFIP, providing a natural laboratory for comparison.

While the CRS concepts of adopting higher regulatory standards and floodplain management principles are advocated as best practices, there is little empirical data to demonstrate the return on investment for these regulatory or policy actions. The goal of the study was to quantify these benefits and demonstrate what types of regulations and policies could have the most substantial impact on reducing future damages. This is the first time FEMA has been able to take advantage of existing geospatial data (such as parcels, building footprints, and floodplain data), combined with 2013 loss data from several federal programs (i.e., NFIP, FEMA Individual Assistance, and Small Business Administration) to perform a detailed analysis of the impacts at the structure level.

This study evaluated scenarios including regulating freeboard, restricting building of residences and critical facilities in regulatory floodplains, and controlling development in erosion zones. In addition to regulations, the study investigated how the adoption of regulations over time affected losses, and how CRS scores affected NFIP claims and policies.

The regulatory LAS quantitatively analyzes regulations that are, or would be, successful if implemented, as well as "what if" scenarios if regulations were not implemented. For example, for the 100-year and 2013 events, **if freeboard was increased by two feet**, there would be a decrease in estimated losses in Boulder, Larimer, and Weld Counties by **more than 70 percent**. In Boulder County, **if freeboard had never been adopted**, there would be a **331 percent increase in losses and $1.5 billion in additional losses** for the 100-year event.

As demonstrated by this freeboard scenario, the conclusive results of this study continue to demonstrate that higher floodplain regulations result in benefits reflected by a reduction in flood-related losses. Furthermore, jurisdictions not implementing higher regulatory standards may observe substantial increases in future flood losses. This information, in addition to traditional

mitigation actions, can be used by floodplain managers and community officials to support the case for implementing higher regulatory standards for flood mitigation and protection.

SECTION ONE INTRODUCTION

In March 2014, FEMA Region VIII and Dewberry Consultants LLC began evaluating the impacts of enhanced floodplain regulation and policies and the resulting losses avoided from the 2013 Colorado floods. While flooding occurred in many counties throughout Colorado, the LAS primarily focuses on Larimer, Boulder, and Weld Counties. In addition to the regulatory assessment, a traditional LAS was conducted on a 2012 flood control project built in Longmont, Colorado.

This section describes the purpose of this report, its intended audience, and instructions for its use.

1.1 PURPOSE OF THE STUDY

The purpose of this study was to review and quantify the benefits achieved from regulating to higher floodplain standards as opposed to the minimum requirements under the NFIP. Additionally, the benefits of the CRS program were measured to identify whether the program created more flood-resilient communities. While these concepts are continually advocated as best practices, there is little empirical data to demonstrate the return on investment for regulatory or policy actions. The goal of this study was to demonstrate that regulations and policies could have a significant impact on reducing future flood losses. The September 2013 flood provided an opportunity to assess the CRS, NFIP, and local regulations in this capacity.

1.2 LOSSES AVOIDED STUDY METHODOLOGY

The approach taken to performing this regulatory losses avoided analysis uses an adaptation of FEMA's standard LAS methodology outlined in FEMA's *Loss Avoidance Study: Riverine Flood Methodology Report* (FEMA, 2010a). The standard LAS methodology was adapted to address the difference between evaluating regulations and "hard" mitigation projects. There are three phases to a standard LAS:

- **Phase 1: selection of a study area and development of the project.** To develop the project for this regulatory and policy LAS, various regulatory scenarios and the timelines of their implementation were identified and mapped to study areas. In Phase 1, the methodology was further developed (Sections Two and Five)
- **Phase 2: physical parameter analysis.** The physical parameter analysis evaluates the scenarios chosen in Phase 1 to determine the effectiveness of the policies and regulations. The physical parameters for the study were determined based on available data
- **Phase 3: loss estimation analysis.** Damages were calculated for the project areas as if the regulations had not been enacted and were then compared to the actual damages that occurred in those areas. The difference between the two scenarios is the losses avoided (Sections Five and Six)

As part of this study, geospatial modeling tools were created to analyze the regulatory losses avoided. The Loss Avoidance Model Tools (the Tools – Appendix A, B, and C) were created

with standard input and output variables so that the Tools can be used for future events and in other geographies.

1.3 INTENDED AUDIENCE

The results of this study demonstrate a clear relationship between higher regulatory standards and losses avoided that supports the hard work associated with implementing these higher standards in each jurisdiction. The results, methodology, and tools developed for this study can be used by floodplain administrators, planning districts, and jurisdiction officials throughout Colorado and beyond to evaluate their own jurisdiction's flood risk exposure and assess what potential additional floodplain management activities would provide the greatest benefits to their jurisdiction. FEMA and state hazard mitigation program officials are a secondary audience.

1.4 BACKGROUND

This section provides an overview of the 2013 Colorado floods and a description of the study area and datasets associated with the LAS.

1.4.1 Overview of the 2013 Colorado Floods

On September 9, 2013, a slow-moving cold front stalled over Colorado and collided with warm, humid air from the south, generating heavy rainfall for several days in Boulder County and expanding to surrounding counties. Statistics from the Colorado Climate Center show that over 17 inches of rainfall between September 11, 2013 and September 15, 2013 was recorded in Boulder County as depicted in Figure 1-1. This shattered the previous record and approached Boulder County's average annual precipitation of 20.7 inches. According to the NOAA Hydrological Design Studies Center, this amounted to a maximum 1,000-year rainfall event (0.1% annual probability), as depicted in Figure 1-2.

The unprecedented rainfall resulted in widespread catastrophic flooding in the various watersheds along Colorado's Front Range of the Rocky Mountains, resulting in an Emergency Disaster Declaration (FEMA-EM-3365-CO) by the President on September 12, 2013. A Presidential Disaster Declaration (FEMA-DR-4145-CO) followed on September 14, 2013, and

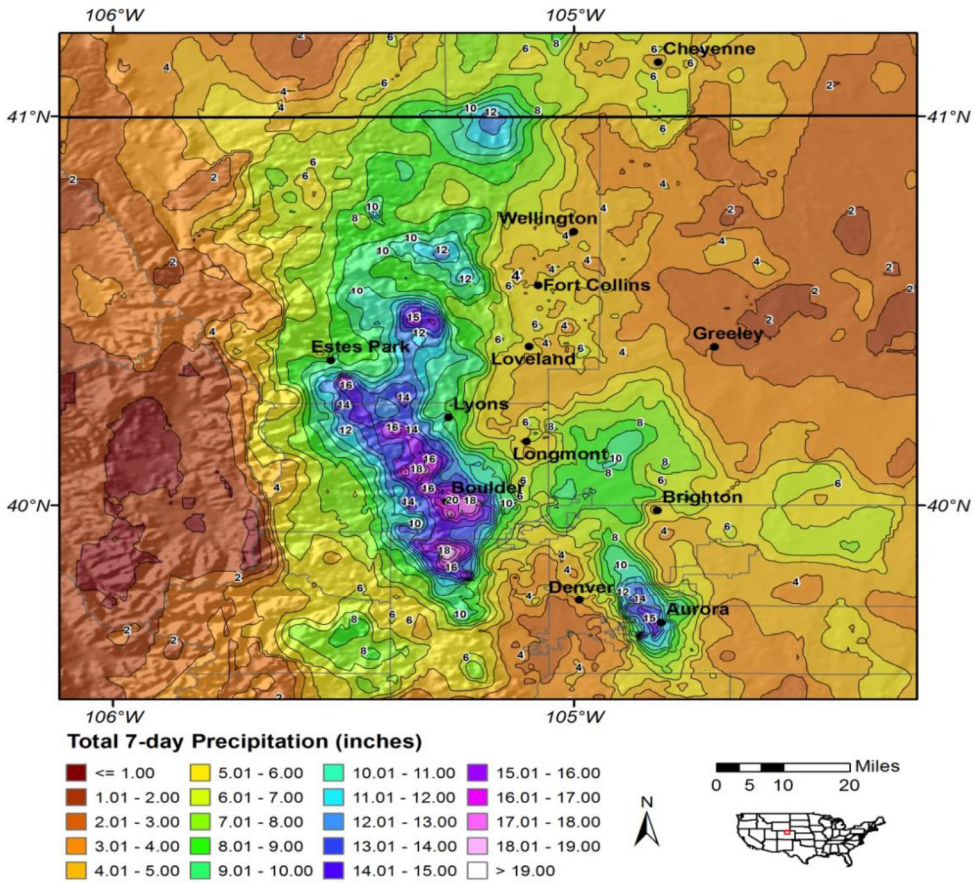

Figure 1-1: Map depicting the rainfall amounts across the impacted area for the entire event. Source: NOAA NWS: http://www.nws.noaa.gov/om/assessments/pdfs/14colorado_floods.pdf

was eventually expanded to encompass 18 Colorado counties including Boulder, Larimer, and Weld Counties. In all, 132 jurisdictions were impacted; Jamestown, Lyons, and the City of Boulder were the most impacted.[1]

The Colorado Front Range and adjacent plains are composed of varying landscapes; as a result, flash flooding, alluvial fan flooding, and riverine flooding occurred throughout the study area. In addition, several dams either overtopped or failed. According to the National Weather Services (NWS), the September 2013 flood recurrence intervals ranged from 50 years up to 1,000 years.[2] This broad range of flood recurrence intervals can be attributed to the complex relationship between rainfall and watershed dynamics. Rainfall recurrence intervals are determined by the amount and duration of the precipitation event over a given region. Flood recurrence intervals are determined by examining rainfall in conjunction with other factors including watershed size

[1] To determine the most impacted jurisdictions, the highest loss ratio was used as defined in FEMA's 2013 Colorado Floods Situational Awareness Viewer (http://fema.maps.arcgis.com/home/item.html?id=16055a012a4c4bfdb972c90e20b5e7b8). The highest loss ratio is the number of directly damaged households divided by the total households for each jurisdiction.

[2] http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/8_Colorado_2013.pdf

and shape, topography, ground surface conditions, and level of development. Because of this, flood recurrence intervals cannot be directly equated to rainfall recurrence intervals and are subject to wide variations based on local conditions.

1.4.2 Description of Study Area

While 18 counties were included in the FEMA Disaster Declaration, the most severe damages occurred in Boulder, Larimer, and Weld Counties. The study area for this analysis focuses on these three counties and the jurisdictions within. The LAS study area also encompasses some of highest-rated NFIP CRS jurisdictions as well as jurisdictions that do not participate in the NFIP. Significant losses occurred both inside and outside regulatory floodplains as a direct result of riverine and flash flooding, soil erosion, and dam failures. By focusing on these areas, the study was able to evaluate a broad range of regulatory standards and complete a comprehensive assessment of the event losses as related to the local regulatory framework.

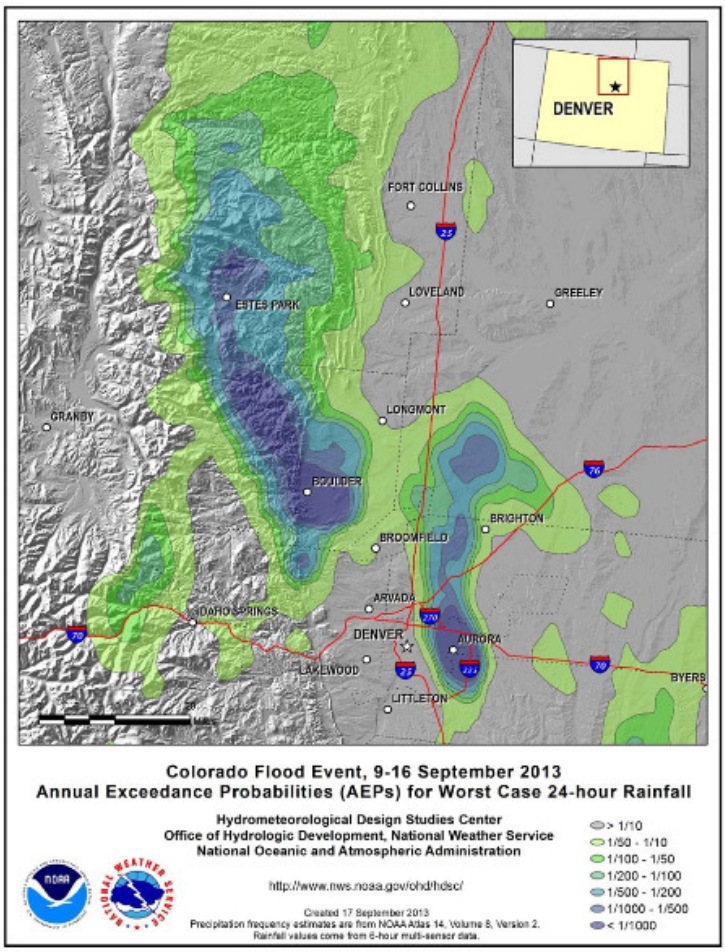

Figure 1-2: Figure 2.X: Map depicting the annual exceedance probabilities for worst case 24-hour rainfall. Source: NOAA NWS: http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/8_Colorado_2013.pdf

1.5 LAYOUT OF REPORT AND INSTRUCTIONS FOR USE

This report comprises eight sections and nine appendices.

Executive Summary – summarizes the main points of the report, including highlights of the regulatory and policy losses avoided analysis and the conclusions.

Section 1 – Introduction describes the purpose of the report, its intended audience, and instructions for use.

Section 2 – Study Area describes the site selection criteria for the study area and the county and jurisdiction participation and location in the NFIP, CRS, and Urban Drainage and Flood Control District (UDFCD).

Section 3 – Regulatory Losses Avoided Data and Tools describes the data used for this study and the assumptions applied to the data during the analyses performed for this study.

Section 4 – Event Loss Summaries summarizes the event losses.

Section 5 – Regulatory Losses Avoided Scenario Description and Methodology describes the scenarios, methodology, and categories of benefits used for the regulatory losses avoided analyses.

Section 6 – Regulatory Losses Avoided by Scenario for Counties examines by county the regulatory losses avoided for each scenario evaluated.

Section 7 – Conclusion discusses the benefits of implementing higher regulations based on the regulatory losses avoided results.

Section 8 – References lists the references used in this study.

Appendices include the following:

Appendix A: Data Preparation Tool User Guide provides detailed instructions on data preparation for the models and how to use the tool.

Appendix B: Data Export Tool User Guide

Appendix C: Data Analysis Tool User Guide

Appendix D: Structure Inventory Assumptions

Appendix E: Regulatory Standards

Appendix F: Depth Damage Functions Used by Occupancy

Appendix G: Case Study: Longmont, Colorado Mitigation Project

Appendix H: Scenario Methodology

Appendix I: Loss of Function Values

SECTION TWO STUDY AREA

This section describes the site selection criteria for the study area and an overview of the NFIP, CRS, and UDFCD. The section concludes with a description of county and jurisdiction participation in the NFIP and CRS, and if the jurisdiction is located in the UDFCD.

2.1 SITE SELECTION CRITERIA

The initial list of potential study areas consisted of five counties. Based on a review of the criteria described in Table 2-1, including data availability, the study area was narrowed to Boulder, Larimer, and Weld Counties.

Table 2-1: Regulatory Site Selection Criteria

	LAS criteria	Reason for selection for study
Area of Interest	Large geographic area spanning multiple counties in Colorado affected by the September 2013 floods	Boulder, Larimer, and Weld Counties were each impacted by the September 2013 floods. Together, the three counties make up a large geographic region that was impacted by the disaster.
Hazard Type	Alluvial, flash, and riverine flooding	Riverine flooding occurred in Weld County. Boulder and Larimer Counties experienced alluvial, flash, and riverine flooding. Event data were available for all three counties.
Project Type	Communities with varying regulations and policies on floodplain management and varying flood hazard risk	The governments of Boulder, Larimer, and Weld Counties each regulate their floodplains and participate in the NFIP; however, not all of the cities or towns in the study area participate in the NFIP. There is a wide variety of policies, ordinances, and regulations in place pertaining to floodplain management in the three counties, and the communities have a varying degree of flood hazard risk.
Study Baseline	The first day of the September 2013 Colorado floods	Jurisdiction census data, regulations, and other GIS data were readily available in the three counties selected, including data provided by the State of Colorado and impacted communities. The data include regulatory conditions immediately preceding the September 2013 flooding event.

The availability of data was a key factor in site selection. Pertinent Geographic Information Systems (GIS) data were essential for estimating losses that would have occurred if earlier actions had not been taken to regulate the floodplain. The data resources used in this study are described in Section Three.

2.2 OVERVIEW OF NFIP, CRS, AND UDFCD

This section provides an overview of the NFIP, the CRS, and the UDFCD. Each of these programs encourages flood hazard mitigation actions at the jurisdiction level and is designed to prevent future flood losses. One of the goals of this study is to identify if flood losses avoided are greater in jurisdictions that participate in these programs and implement flood hazard mitigation actions. Moreover, it seeks to identify if losses avoided are greater in jurisdictions that participate in the NFIP and adopt minimum floodplain management ordinances, and if they are even greater in CRS jurisdictions providing an extra discount to NFIP policy holder premiums that go above and beyond the minimum NFIP floodplain management requirements.

2.2.1 National Flood Insurance Program

Established by Congress on August 1, 1968, the NFIP is a federal program administered by FEMA designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods. The purpose of the NFIP is to mitigate future flood losses nationwide through sound, community-enforced floodplain management regulations and building and zoning ordinances, and to provide access to affordable, federally-backed flood insurance protection for property owners.

Participation in the NFIP is based on an agreement between jurisdictions and the Federal Government stating that if a jurisdiction will adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction and substantial improvements in federally-identified Special Flood Hazard Areas (SFHAs), the Federal Government will make flood insurance available in the jurisdiction as a financial protection against flood losses.

NFIP policies and claims data were used as part of this study to assess jurisdictions' outreach about the NFIP and to evaluate the losses as a result of the 2013 Colorado floods.

2.2.2 Community Rating System

The CRS was implemented by the NFIP in 1990 as a voluntary program for recognizing and encouraging community floodplain management activities exceeding the minimum NFIP standards. The CRS rewards policy holders in jurisdictions with higher standards through discounts on their premiums ranging from 5 to 45 percent. Any jurisdiction in full compliance with the minimum NFIP floodplain management requirements may apply to join the CRS. Nearly 1,300 jurisdictions participate in the CRS by implementing local mitigation, floodplain management, and outreach activities that exceed minimum NFIP requirements.

The CRS uses a class rating system to determine flood insurance premium reductions for residents. CRS classes are rated from 9 to 1 with 1 being the highest. Today, most jurisdictions enter the program at a CRS Class 9 or Class 8 rating, which entitles residents in SFHAs to a 5 percent discount on their flood insurance premiums for a Class 9, or a 10 percent discount for a Class 8. As a jurisdiction engages in additional activities, residents become eligible for increased NFIP policy premium discounts. Each CRS class improvement produces a 5 percent greater

discount on flood insurance premiums for properties in the SFHA. Jurisdictions also receive discounts from 5 to 10 percent on policies for properties located outside SFHAs.

A jurisdiction accrues points to improve its CRS class rating and receive increasingly higher discounts. Points are awarded for engaging in any of 19 creditable activities, organized under four categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Warning and response

This study evaluates the CRS ratings and losses from the 2013 Colorado floods to assess community outreach related to the NFIP participation both in and outside the SFHA where policies are purchased voluntarily, as well as the effectiveness of higher regulatory standards.

2.2.3 Urban Drainage Flood Control District

The UDFCD was established by the Colorado legislature in 1969 to assist local governments in the Denver metropolitan area with multi-jurisdictional drainage and flood control problems. The UDFCD covers 1,608 square miles and includes Denver, parts of the six surrounding counties, and all or parts of 32 incorporated jurisdictions. For a map of the UDFCD area, refer to the UDFCD website at http://www.udfcd.org/.

The UDFCD operates four programs:

- Master planning
- Design, construction, and maintenance
- Floodplain management
- Information services and flood warning

The UDFCD floodplain management program was established in 1974 to prevent new flood damage potential from being introduced into 100-year floodplains while encouraging the use of non-structural methods of flood damage mitigation. The UDFCD has the authority to regulate floodplains but has chosen not to do so as long as local governments implement their own regulations. Most of the Flood Insurance Rate Maps (FIRMs) for jurisdictions in the UDFCD are based on Flood Hazard Area Delineations created by UDFCD.

2.3 COUNTY AND JURISDICTION OVERVIEW

The study area includes 43 jurisdictions in three counties in Colorado. Figure 2-1 shows community paticipation in the NFIP, CRS, and UDFCD.

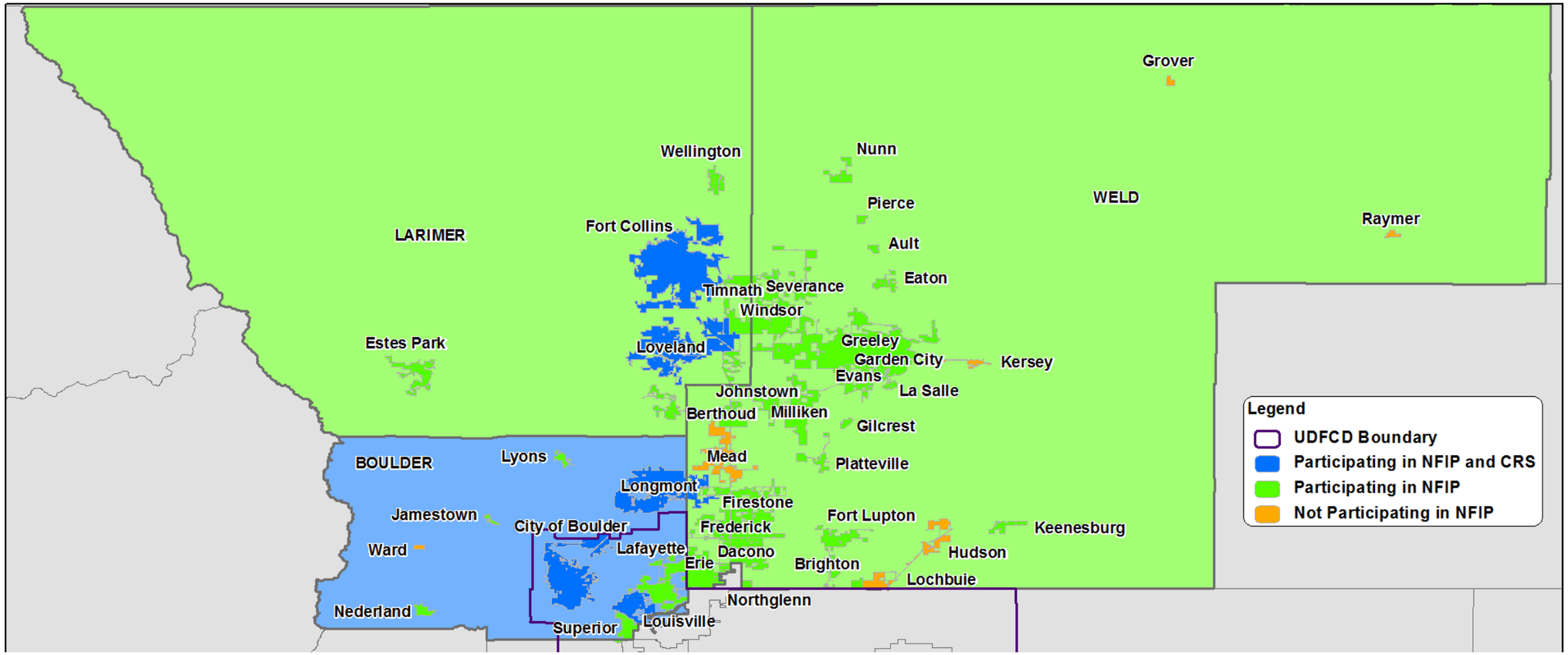

Figure 2-1: NFIP and CRS Status for Study Area

The blue jurisdictions participate in the NFIP in addition to CRS. The green jurisdictions participate in just the NFIP. The orange jurisdictions do not participate in the NFIP. Hudson joined the NFIP under the emergency program on 8/20/97 but does not have a published FIRM. Ault, Gilcrest, and La Salle participate in the NFIP but have no SFHAs identified within their jurisdiction. Boulder County, City of Boulder, Erie, Lafayette, Louisville, and Superior are also part of the UDFCD.

There are jurisdictions in the study area that did not have data available for the 100-year event and/or the 2013 Colorado flood event. Brighton, Northglenn, Grover, and Nunn do not have data for the 100-year event or Individual Assistance claims for the 2013 Colorado flood event. Timnath and Ward did not have data available for the 2013 Colorado flood event. Ault, Berthoud, Eaton, Frederick, Garden City, Gilcrest, Hudson, Johnstown, Keenesburg, Kersey, La Salle, Lochbuie, Mead, Pierce, Platteville, Raymer, Severance, Thornton, and Wellington did not have data available for the 100-year flood event.

2.3.1 CRS Status

Six jurisdictions in the study area participate in the CRS. These jurisdictions, their CRS class, and their flood insurance premium discounts are shown in Table 2-2.

Table 2-2: CRS Communities in Study Area

Jurisdiction	County	CRS class	Premium Reduction In SFHA	Premium Reduction Outside SFHA
Unincorporated Boulder County	Boulder	7	15%	5%
City of Boulder	Boulder	5	25%	10%
Longmont	Boulder	8	10%	5%
Louisville	Boulder	8	10%	5%
Fort Collins	Larimer	4	30%	10%
Loveland	Larimer	7	15%	5%

For more information on CRS classes and flood insurance premium discounts, refer to FEMA's NFIP CRS website: https://www.fema.gov/national-flood-insurance-program-community-rating-system.

SECTION THREE REGULATORY LOSSES AVOIDED DATA AND TOOLS

Section Three describes the data used for this study, how the data were prepared, and the assumptions applied to the data during the analyses performed for this study.

3.1 DATA DESCRIPTION

Table 3-1 provides an overview of the data provided and used for this study.

Remainder of Page Intentionally Left Blank

Table 3-1: Data Overview

Data Type	Data Description	Data Source	Data Acquisition Date	Contribution to Study
	Base Map Data			
Imagery	Post-event imagery for the 2013 Colorado Flood event.	Colorado Department of Transportation, Colorado Water Conservation Board, Digital Globe, and Civil Air Patrol	2013	Assisted in evaluating preliminary 2013 Colorado flood extent, areas of erosion, and damage confirmations
Political Boundaries	Derived from FEMA FIRM Databases	FEMA Flood Map Service Center	2013	Jurisdiction boundaries
Parcels	Boulder, Larimer, and Weld County parcels	County Tax Assessors' office and City of Boulder	2013	Structure points, occupancy type, square footage, basement, year built, critical facilities, and foundation type
Building Footprints	Boulder County building footprints	Boulder County and Longmont	2013	Used in in addition to parcel data for Boulder County
	Flood Data			
FIRM Databases	FEMA SFHAs and cross sections	FEMA Flood Map Service Center	2013	100- and 500-year floodplain boundaries and associated flood zones and cross sections for depth grid development
2013 Flood Extents	Preliminary 2013 Colorado flood extents	FEMA Region VIII	2013	Used to assess 2013 Colorado flood damages. 100-year flood zone depth grids were only created in surveyed (AE/AH/AO) flood zones
Regulatory Depth Grids	100-year frequency	FEMA Region VIII	2013	Used to assess regulatory flood damages
High Water Marks	Event high water marks	City of Boulder, Longmont, Fort Collins, and Estes Park	2013	Used to create event-based depth grids
Event Depth Grids	Event depth grids	FEMA Region VIII	2013	Used to assess 2013 Colorado flood damages
Pre- and Post-event Ground Surface Elevation Grids	Difference grids showing pre- and post-2013 Colorado Flood event LiDAR elevation changes	USACE	2013	Used to assist in identifying potential post-event erosion and deposition areas.

Data Type	Data Description	Data Source	Data Acquisition Date	Contribution to Study
	Structure Location Data			
NFIP Policies	NFIP Policies in Force (Privacy Act Protected)	FEMA	December 2012	Insurance company, premium, status, length of policy and effective dates, jurisdiction information, flood map information, building description and address, insurance coverage and deductibles for building and contents, and specific structural and site elevation data, where available.
NFIP Claims	NFIP claims from 2013 Colorado Floods (Privacy Act Protected)	FEMA	February 13, 2014	NFIP claims used to quantify actual 2013 flood losses.
Individual Assistance (IA) Claims	IA inspections data, with corrected geographical locations (Privacy Act Protected)	FEMA	February 13, 2014	Water depth and FEMA-verified losses
Public Assistance (PA) Project Worksheets	PA Project Worksheets for Disaster Declaration 4145 and PA Project Sites within PA Project Worksheets.	FEMA Project Worksheets and EMMIE Database	December 12, 2014	Used to determine channel maintenance losses. Attributes include facility name, damage category number, project size, cost share status, percent complete, funding status, project completion date, cost share percentage, federal share eligible, federal share obligated, project amount, and total obligated.
Small Business Administration (SBA) Loans	SBA loan information (Privacy Act Protected)	Obtained from SBA by FEMA VIII	February 13, 2014	SBA verified losses used to quantify actual 2014 flood losses.
Longmont Pre-Disaster Mitigation (PDM) data	Longmont mitigation project data	FEMA	2013	Used for traditional LAS study performed for Longmont project

Data Type	Data Description	Data Source	Data Acquisition Date	Contribution to Study
	Other Data			
Erosion Setbacks	St. Vrain Creek erosion zones	St. Vrain Creek coalition lead in Boulder County	2013	Used to evaluate potential losses avoided from erosion zones
	Non-spatial Data			
Regulatory Standards	The current and historical regulatory standards for the jurisdictions and state.	Jurisdictions and state website, and FEMA	2013	Used to assess regulatory losses
NFIP Community Status Book	Community status book that contains the NFIP entry date	FEMA	2013	NFIP Entry Date used as community baseline date
Depth Damage Functions (DDFs)	DDF curves	Refer to Appendix F	Various	Used to determine structure and contents losses
CRS	Community CRS classes and applications	FEMA	2013	Used to determine community CRS classes and specific community CRS activities

3.2 DATA PREPARATION AND ASSUMPTIONS

This study required a significant amount of data preparation prior to the analysis. As part of this study, tools were developed to assist in preparing the data and performing the analysis. The tools were developed using ESRI ArcGIS 10.2 software and include:

- **Data Preparation Tool:** prepares the data for analysis and if structure data are incomplete, uses assumptions to estimate values for foundation type and building square footage. These assumptions are documented in Appendix D.
- **Data Export Tool:** prepares the dataset to have the attributes necessary for FEMA's User Defined Facility (UDF) database.
- **Data Analysis Tool:** runs scenarios using 100-year flood and 2013 flood event data plus regulatory information to estimate regulatory losses avoided.

Descriptions and instructions for use of the Data Preparation Tool, Data Export Tool, and Data Analysis Tool can be found in Appendix A, B, and C, respectively. Please contact Doug Bausch (Douglas.Bausch@fema.dhs.gov) at FEMA Region VIII for more information about the tools and the installation package.

Individual structure locations and associated attributes were derived from local parcel and building footprint data. If the attribute data were incomplete, estimates for building square footage, foundation type, number of stories, and building and contents replacement costs were used in lieu of verified values. These assumptions and estimates are described in Appendix F – Structure Inventory Assumptions.

SECTION FOUR LOSS SUMMARIES

Section Four summarizes specific 2013 Colorado flood losses to support the regulatory scenario assessments, as well as the best practices report, *Best Practices and Cost Effective Strategies – 2013 Colorado Floods Case Study*. The loss summaries include event losses, basement-only losses, likely soil erosion losses, NFIP policies with and without claims, and Letter of Map Amendment (LOMA) and Letter of Map Revision Based on Fill (LOMR-F) property losses.

4.1 EVENT LOSSES

Figure 4-1 depicts the total event losses for the 2013 Colorado floods for the IA, SBA, and NFIP programs in Boulder, Larimer, and Weld Counties. Each of these are separate federal assistance programs available to support recovery efforts. NFIP losses accounted for 28 percent of the total losses, IA was 27 percent, and SBA was 45 percent. Combining the losses for NFIP, IA, and SBA programs is not comprehensive of the total event losses. The sum of the NFIP, IA, and SBA losses does not duplicate or double-count losses since each program has mutually exclusive requirements that prevent duplication of benefits. This information is current as of the date the loss data were acquired, as explained in Section 3.1.

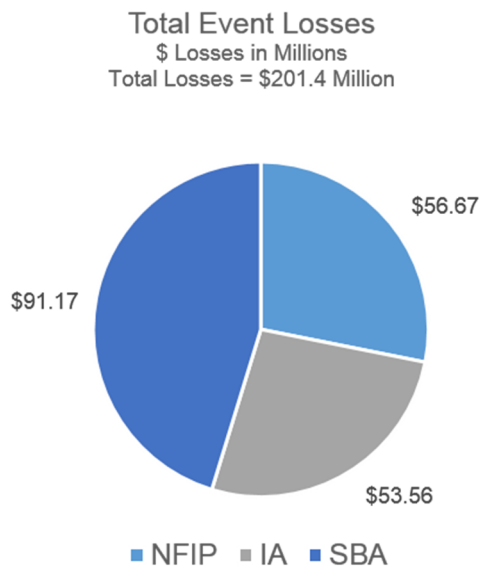

Figure 4-1: Total Event Losses for NFIP, IA, and SBA

Following is an overview of the IA, SBA, and NFIP programs. The linked websites provide more information about each program's specific focus and requirements.

- **FEMA Individual Assistance (IA).** The IA loss information is from the Individuals and Households Program (IHP) that provides financial help or direct services to those who have necessary expenses and serious needs if they are unable to meet the needs through other means. Available forms of help are: Housing Assistance (including temporary housing, repair, replacement, and semi-permanent or permanent housing construction) and Other Needs Assistance (including personal property and other items). For more information on housing assistance, other needs, and conditions and limitations of IHP assistance, refer to FEMA's IHP website: https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit/recovery-directorate/assistance-individuals-and.
- **Small Business Administration (SBA).** The SBA provides low-interest, long-term loans for physical and economic damage caused by a declared disaster. The types of SBA disaster loans include home and personal property loans, business physical disaster loans, economic injury disaster loans, and military reservist economic injury loans. This report focuses on the home and personal property loans. Homeowners may apply for up to $200,000 to replace or repair their primary residence and borrow up to $40,000 to replace

or repair personal property such as clothing, furniture, cars, and appliances. Proceeds from insurance coverage on the home or property are deducted from the total damage estimate to determine the eligible loan amount. In addition, a homeowner can receive up to the IHP maximum for home repair; then, the homeowner may apply for an SBA disaster loan for additional repair assistance. For more information on SBA loans, refer to SBA's disaster loans website: https://www.sba.gov/category/navigation-structure/loans-grants/small-business-loans/disaster-loans.

- **National Flood Insurance Program (NFIP).** Standard homeowner's insurance does not cover flooding associated with heavy rains, tropical storms, hurricanes, and other conditions that result in flooding. In 1968, Congress created the NFIP to help provide a means for property owners to financially protect themselves. The NFIP offers flood insurance to homeowners, renters, and business owners if their community participates in the NFIP. Participating communities agree to adopt and enforce ordinances that meet or exceed FEMA requirements to reduce the risk of flooding. For more information on the NFIP, refer to FEMA's NFIP website: https://www.fema.gov/national-flood-insurance-program.

4.2 IA EVENT LOSSES SUMMARY

Figure 4-2 depicts the total IA event losses by county with Boulder accounting for 61 percent of the losses, Larimer 15 percent, and Weld 24 percent.

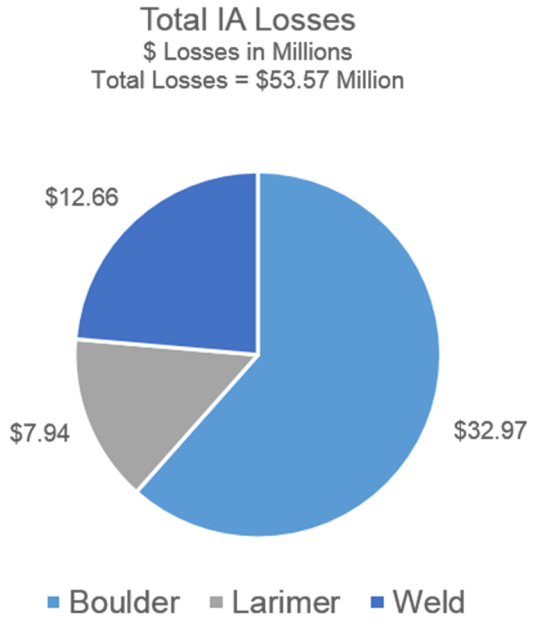

Figure 4-2: Total IA Losses

In total, 13,237 applications were submitted for IA with a significant percentage located outside the SFHA, as depicted in Table 4-1.

Table 4-1: IA Total of Applications and % Inside/Outside SFHA

County	Total	% Inside SFHA	% Outside SFHA
Boulder	10,446	13%	87%
Larimer	1,549	13%	87%
Weld	1,242	29%	71%

There was a high percentage of applicants outside the SFHA, which indicates that properties, located outside the SFHA are still at risk for flooding.

4.3 SBA EVENT LOSS SUMMARY

Figure 4-3 depicts the total SBA event loss by county with Boulder accounting for 46 percent of the loss, Larimer 35 percent, and Weld 19 percent.

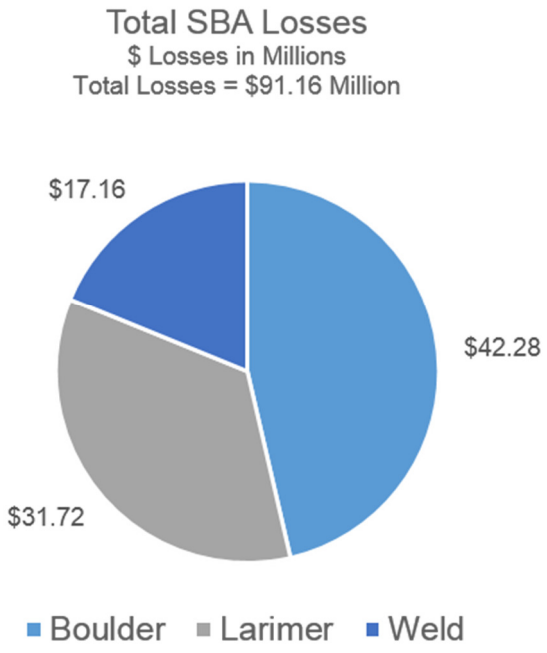

Figure 4-3: Total SBA Losses

In total, 1,832 applications were submitted for SBA loans with a significant percentage located outside the SFHA, as depicted in Table 4-2.

Table 4-2: SBA Total and % Inside/Outside SFHA

County	Total	% Inside SFHA	% Outside SFHA
Boulder	1,116	16%	84%
Larimer	476	20%	80%
Weld	240	32%	68%

The high percentage of SBA applications outside the SFHA may indicate that high rates of property owners were uninsured for flood losses outside of the SFHA and, therefore, were more likely to apply for SBA assistance.

4.4 NFIP LOSSES SUMMARY

Figure 4-4 depicts the total NFIP claims by county with Boulder accounting for 74 percent of the loss, Larimer 19 percent, and Weld 7 percent.

In total, 1,769 applications were submitted for NFIP claims with the breakdown by county and percent inside and outside the SFHA, depicted in Table 4-3.

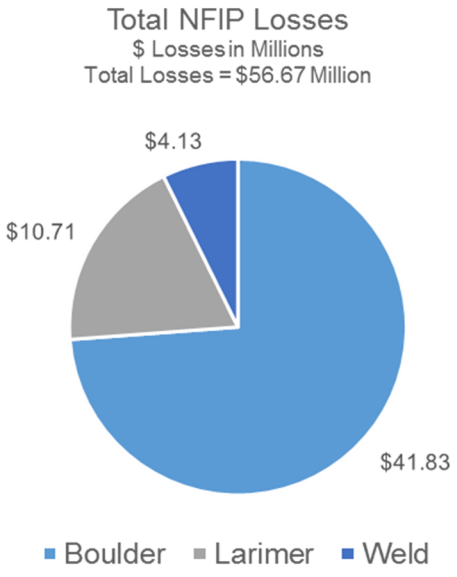

Figure 4-4: Total NFIP Losses

Table 4-3: NFIP Claim Total of Applications, % Inside/Outside SFHA, and Average Loss

County	Total	% Inside SFHA	% Outside SFHA	Average Loss per Claim
Boulder	1,416	55%	45%	$29,542
Larimer	268	57%	43%	$39,948
Weld	85	73%	27%	$48,572

Boulder and Larimer have a similar ratio of NFIP claim applicants inside and outside the SFHA. Weld had the highest percentage of applications inside the SFHA (73 percent) and the highest average loss per claim.

NFIP policies were analyzed in order to better understand the distribution of NFIP claims made inside and outside the SFHA. There are a total of 4,845 NFIP policies in the study area. Table 4-4 summarizes the NFIP policies, percentage of NFIP policies for each county that had a claim, and the percentage of policies inside and outside the SFHA.

Table 4-4: NFIP Policy Summary

County	Total	% Inside SFHA	% Outside SFHA	% policy holders in county that made claims in 2013 Colorado flood
Boulder	3,070	52%	48%	46%
Larimer	1,284	33%	67%	21%
Weld	491	50%	50%	17%

Boulder has the highest percentage of claims out of the total policies for the county. NFIP policies outside the SFHA are voluntary purchases and an indicator of successful risk communication and outreach in the community, including some of the recent post-wildfire flood potential outreach following large fires in both Boulder and Larimer Counties. Based on this, Larimer appears to be successful in encouraging voluntary purchases of NFIP policies.

4.5 BASEMENT-ONLY LOSSES

Figure 4-5 depicts the basement-only losses by county, with Boulder accounting for 84 percent of the loss, Larimer 9 percent, and Weld 7 percent.

The basement-only losses were determined by selecting the structures where the IA High Water Mark (HWM) was located in the basement. Then, the IA-verified losses for the structure and personal property were summarized. Additional basement losses occurred throughout the study area; however, this subset includes only structures where just the basement was flooded, as measured by the IA program. In Boulder alone, this represented over 30 percent of the total IA program losses, with 95 percent of these outside the SFHA.

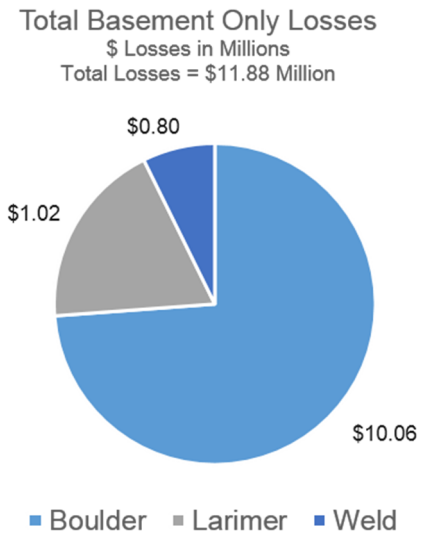

Figure 4-5: Basement Only Losses

There were a total of 6,757 basement only losses with a significant portion located outside the SFHA, as identified in Table 4-5.

Table 4-5: Basement Only Losses, % Inside/Outside SFHA, and % of IA Loss

County	Total	% Inside SFHA	% Outside SFHA	Basement loss for County / IA loss for County
Boulder	5,767	5%	95%	31%
Larimer	595	6%	94%	13%
Weld	395	7%	93%	6%

Overall, the basement-only losses accounted for 22 percent of the total IA losses, and the majority of these losses were outside the SFHA. Basements may be flooded by localized drainage or runoff, as well as sewer backflow. The significant amount of basement-only losses

and the fact that the International Building Code allows for addressing basements in flood-prone areas, should embolden floodplain managers to take the following actions:

1. Identify flood prone areas outside the SFHA to regulate basement development, including using the location of the significant 2013 losses.
2. Encourage basement mitigation strategies such as flood proofing, positive drainage, and backflow prevention to reduce basement losses.

4.6 LIKELY SOIL EROSION LOSSES

FEMA Region VIII identified 34 structures with losses after the 2013 Colorado floods that were likely due to erosion based on aerial imagery. Table 4-6 summarizes the number of likely erosion-impacted structures by jurisdiction and the number of structures inside and outside the SFHA, and sums the FEMA-verified real and personal property losses.

Table 4-6: Likely Soil Erosion Loss Summary

Jurisdiction	Total	Inside SFHA	Outside SFHA	FEMA IA verified losses
City of Boulder	1	1	0	$20,217
Unincorporated Boulder County	13	5	8	$700,857
Estes Park	1	0	1	$19,612
Fort Collins	1	0	1	$26,590
Jamestown	8	7	1	$481,623
Larimer	4	1	3	$53,821
Lyons	3	3	0	$52,243
Weld	3	0	3	$125,276
Total	**34**	**17**	**17**	**$1,480,243**

Unincorporated Boulder County saw the highest amount of FEMA IA verified losses and number of structures impacted by erosion in the study area. While Jamestown exhibited significant FEMA Verified Losses (FVL) and structures impacted considering the size of the town.

4.7 LETTER OF MAP AMENDMENT AND LETTER OF MAP REVISION BASED ON FILL POLICY LOSSES

If a property owner thinks their property has been inadvertently mapped in a SFHA, they may submit a request to FEMA for a Letter of Map Change (LOMC). A LOMC reflects an official revision/amendment to an effective FIRM. If the LOMC request is granted, property owners may be eligible for lower flood insurance premiums or the option to not purchase flood insurance.

This study reviewed the losses associated with properties that had received LOMR-Fs and LOMAs as a result of the 2013 Colorado floods. A list of LOMR-Fs and LOMAs was generated from FEMA's Mapping Information Platform (MIP). The list was filtered based on the type of LOMC and determination type as detailed in Table 4-7.

Table 4-7: LOMC Type Used for Study

LOMC type	Description
eLOMA	Web-based application in the MIP that provides licensed land surveyors and professional engineers (Licensed Professionals) with a system to submit simple Letter of Map Amendment (LOMA) requests to FEMA.
LOMA	Letter from FEMA stating that an existing structure or parcel of land that has not been elevated by the placement of fill is not expected to be inundated by the 100-year flood (the base flood). LOMAs are usually issued because a property is inadvertently mapped as being in the floodplain, but is actually on natural high ground above the base flood elevation.
LOMR-F	Modification of the SFHA shown on the FIRM based on the placement of fill outside the existing regulatory floodway.
LOMR-FW	Requests involving inadvertent inclusions of structures in the regulatory floodway.

The project identification field in the LOMC includes descriptive text about the location of the LOMC, such as an address, parcel block and lot numbers, or other text (e.g. Portion Tract C, The Meadows). For the list, project identification information was reviewed to determine if there was enough information to locate the address in the IA, SBA, and NFIP datasets. If the information contained in the project identification field was insufficient to locate the address, the LOMC was marked as "unable to determine address location". For LOMCs with usable addresses, the addresses were compared to the addresses in the IA, SBA, and NFIP loss data from the 2013 Colorado floods. If a match was found, the dollar damages were recorded for that LOMC. This information is summarized for each county in Table 4-8.

Table 4-8: County Summary of LOMAs and LOMR-F

County	Total	% Unable to Locate	% with IA Loss	IA Verified Loss *	% with SBA Verified Loss	SBA Verified Loss*	% with NFIP Loss	NFIP Loss Amount*	Total Dollars*
Boulder	429	15%	17%	$460	2%	$ 531	7%	$ 600	$ 1,591
Larimer	199	26%	6%	$ 79	5%	$ 953	5%	$ 213	$ 1,244
Weld	130	30%	8%	$ 58	2%	$ 196	2%	$ 79	$ 333

* In thousands

Overall, Boulder County has the most LOMCs and the highest percentage of LOMCs with IA and NFIP claims, while Larimer County saw the most SBA claims and highest SBA losses. Based on Table 4-8, losses are not eliminated for properties that receive LOMCs; however, the average losses trend lower when compared to the properties that have not received or did not apply for a LOMC. This indicates that these properties would benefit from preferred insurance rate as opposed to being removed from the SFHA.

SECTION FIVE REGULATORY LOSSES AVOIDED SCENARIO DESCRIPTION AND METHODOLOGY

A traditional loss avoidance study is used to identify the effectiveness of a mitigation project by analyzing the losses of similar-magnitude events before and after the completion of the project. Typically, a clear conditional change is needed to fully evaluate a project's effectiveness.

Following the completion of a mitigation project, the losses that would have occurred if the project had not been undertaken are called the Mitigation Project Absent (MP_A) losses. The losses that have or may still occur after the mitigation project was fully implemented are known as the Mitigation Project Complete (MP_C) losses. The losses avoided are equal to the difference between MP_C and MP_A.

This regulatory loss avoidance study evaluates jurisdiction floodplain management regulations as the mitigation project. Current jurisdiction regulations were compared to past or alternative regulations to estimate MP_A and MP_C losses and the resulting losses avoided.

Jurisdiction regulations assessed in this study include:

- Freeboard
- Floodway and floodplain development restrictions
- Critical facility siting restrictions
- Erosion setbacks

This section provides an overview and describes the scenarios analyzed for each of the studied regulations. The description includes the questions asked for each scenario and outlines the information required to analyze the scenario. The full methodology used for the scenario analysis, including the criteria for structure selection, the baseline scenario, the regulatory change, and procedure are further described in Appendix H – Scenario Methodology.

In addition to jurisdiction regulations, Sections 5.5 and 5.6 describe analyses that evaluated how the adoption of jurisdiction regulations over time affect losses and how adoption of jurisdiction regulations as reflected in CRS scores affect NFIP claims and policies. The full methodology for these analyses is also detailed in Appendix H – Scenario Methodology.

The last part of this section details the categories of benefits used for the regulatory losses avoided study. Examples of benefit categories are: physical damages, displacement, loss of function, and social and environmental benefits. Descriptions of the benefits are given in Section 5.7. Each scenario evaluates a specific set of benefit categories. A table of the benefit categories used in each scenario is included in Section 5.7.

5.1 FLOODWAY AND FLOODPLAIN DEVELOPMENT RESTRICTIONS

FEMA defines the "regulatory floodway" in 44 CFR 59.1 as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood

without cumulatively increasing the water surface elevation more than a designated height. Figure 5-1 represents a typical floodplain cross-section showing the floodway.

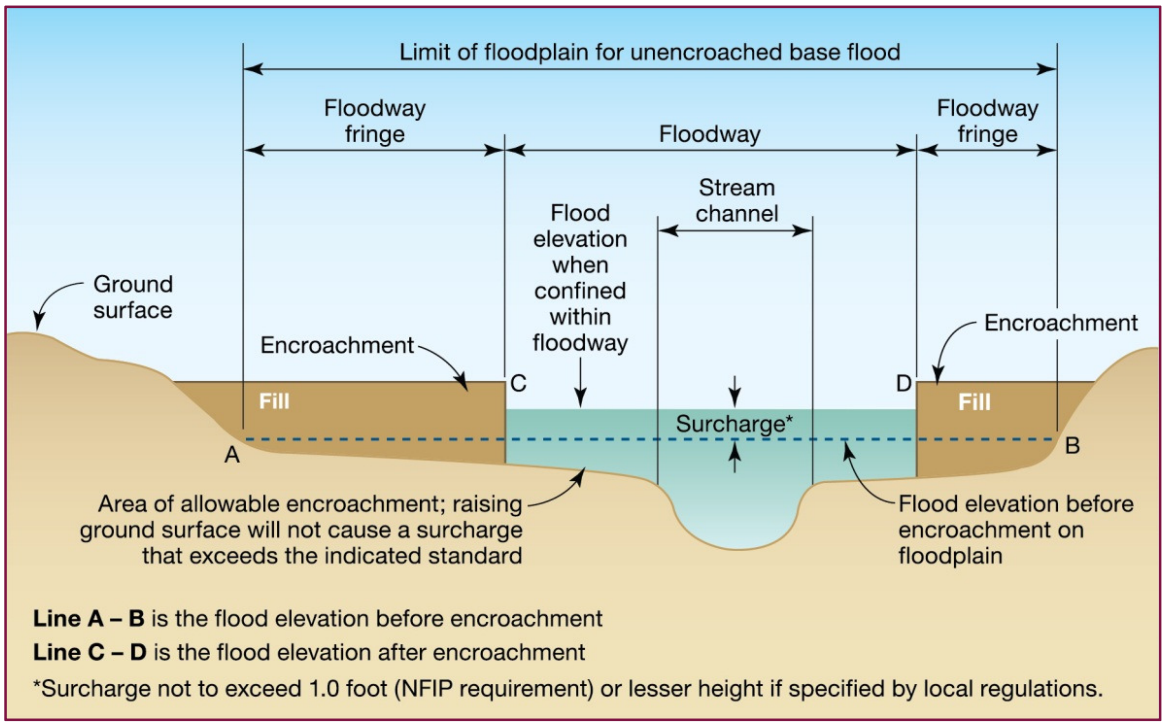

Figure 5-1: Typical Riverine Floodplain Cross Section Showing the Floodway (Source: FEMA P-259, Figure 2-3)

Jurisdictions participating in the NFIP must adopt regulations to restrict or prohibit development in the floodway to ensure there are no increases in upstream flood elevations. The regulatory floodway is designated on the FIRM and is based on a hydraulic analysis of a waterway to determine the area needed to discharge the base flood without impact to the base flood elevation. Restrictions on floodway development may prohibit floodway encroachment or prohibit all development in the floodway. By regulating development in the floodway, jurisdictions may reduce losses across the entire floodplain.

Floodplain development regulations may include restrictions on development in the SFHA, such as limitations on land use or building size, type, and occupancy; or, development in the SFHA may be entirely restricted. Floodway and floodplain development scenarios analyze the regulation scenarios in which floodway or floodplain development is restricted. The baseline floodplain and floodway boundaries used for this scenario were the effective FIRMs for the study area. The scenarios analyzed what the losses would have been in both the 100-year event and the September 2013 Colorado flood event if the current effective FIRMs had been delineated and regulated by the jurisdictions when they first entered the NFIP rather than with the most current effective map.

Two development regulation scenarios were analyzed. These scenarios asked:

1. What would the losses and losses avoided be if all development in the floodway was restricted upon entry into the NFIP?

2. What would the losses and losses avoided be if **all** development in the 100-year floodplain was restricted upon entry into the NFIP?

The following information was required for the analysis:

- The jurisdiction's NFIP emergency entry date: the NFIP emergency entry date is the first date on which a jurisdiction would have joined the NFIP and adopted minimum floodplain management standards to control future use of its floodplains
- The construction date of each structure
- The flood zone for each structure
- The floodway boundaries
- The regulatory depth grid depth at each structure
- The IA event-verified loss at each structure

5.2 FREEBOARD

FEMA defines freeboard as a factor of safety usually expressed in feet above a flood level for purposes of floodplain management. "Freeboard" tends to compensate for the many unknown factors such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed that could contribute to actual flood heights being greater than the modeled regulatory flood event and floodway conditions. Freeboard is not required by the NFIP, but jurisdictions are encouraged to adopt at least a one-foot freeboard. Freeboard results in significantly lower flood insurance rates for homes built to this standard due to their resulting lowered flood risk. Figure 5-2 represents the concept of freeboard.

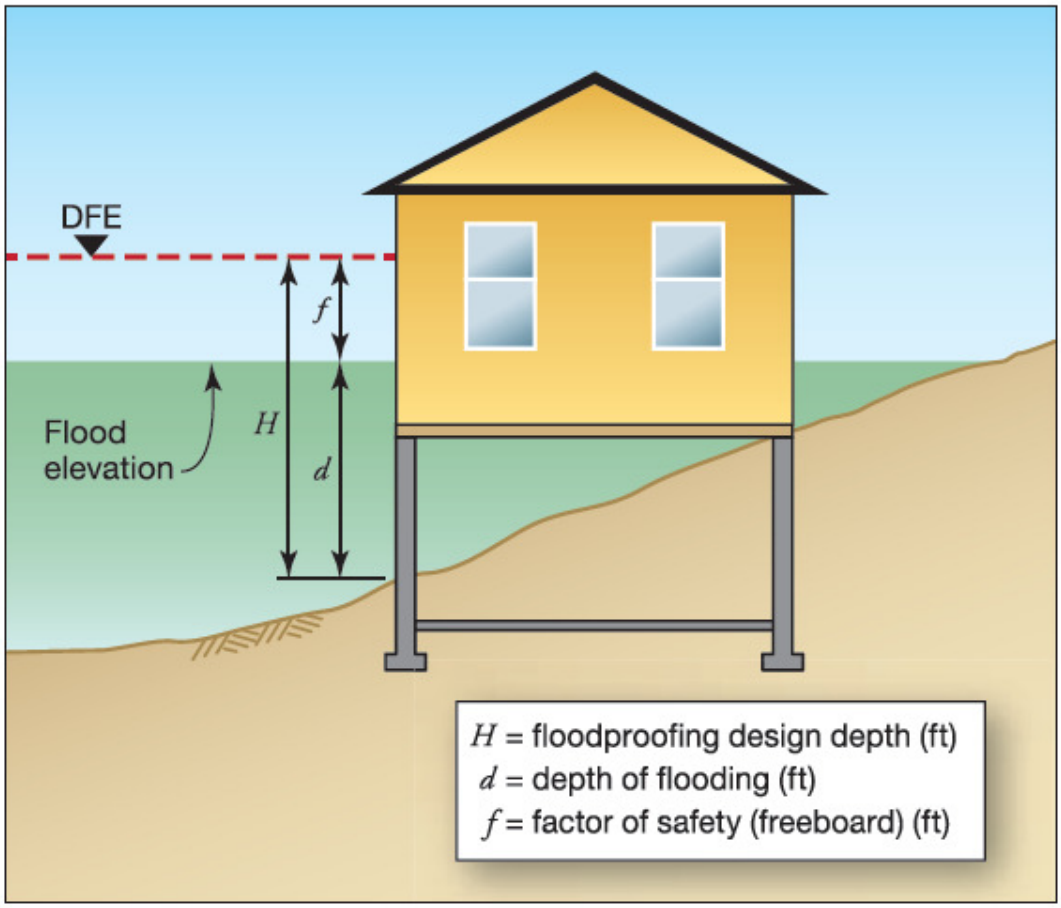

Figure 5-2: Concept of Freeboard (Source: FEMA P-259, Figure 4-5)

When adopted by jurisdictions, freeboard regulations require that the first floor elevation (FFE) be built to an additional height above the base flood elevation (BFE) for structures in a flood hazard zone. These requirements are specified at the jurisdiction level. The state of Colorado requires a one-foot minimum freeboard for new and substantially changed structures.[3] Individual counties may require a greater level of freeboard. Appendix E lists the freeboard regulations in effect and date of adoption in the jurisdictions included in this study.

Freeboard regulations apply to new, substantially damaged, and/or substantially improved structures. Structure and contents losses are expected to occur at or below the FFE for some structures depending on foundation type. The probability of flood depths reaching the FFE is less when the freeboard regulation is implemented because the FFE is higher. Increasing the height of the FFE should result in fewer damages during the base flood event.

Three freeboard regulation scenarios for residential and non-residential structures were analyzed. These scenarios asked:

[3] This is according to the Department of Natural Resources Colorado Water Conservation Board, "*Rules and Regulations for Regulatory Floodplains in Colorado*" that can be accessed at http://cwcb.state.co.us/legal/pages/cwcbfloodplainrulesandregulationsprocess.aspx.

1. What are the losses and losses avoided if no freeboard regulations were adopted?
2. What are the losses and losses avoided if the freeboard regulations were adopted earlier?
3. What are the losses and losses avoided for having imposed a higher (increasing by one foot or two feet), or lesser (decreasing by one foot or two feet), freeboard regulation?

The following information was required for the analysis:

- The jurisdiction's NFIP entry date
- The current freeboard regulation per jurisdiction
- The flood zone for each structure
- The construction date of each structure
- The FFE of each structure
- The regulatory depth grid depth at each structure
- The IA event-verified loss at each structure

5.3 CRITICAL FACILITY REGULATED IN SFHA

Critical facilities are structures whose operations are essential to public safety. Examples of critical facilities include police stations, emergency operations centers, hospital emergency rooms, fire stations, and schools. The location of a critical facility in the SFHA increases the risk of losses to the facility and to the community at large.

Regulations to reduce the risk to critical facilities may include increasing the freeboard requirements, locating critical facilities outside of the SFHA and the 500-year floodplain, providing emergency generators, and elevating utilities. In the critical facilities scenario, the removal of all critical facilities from the SFHA is analyzed.

One critical facility development regulation is analyzed in this scenario:

1. What would the losses and losses avoided be if all development of critical facilities in the 100-year floodplain had been prohibited?

The following information was required for the analysis:

- The structure occupancy type and description to determine if the structure is a critical facility
- The flood zone for each structure
- The regulatory depth grid depth at each structure
- The IA event-verified loss at each structure

5.4 EROSION SETBACK ASSESSMENT

While the damages from the 2013 Colorado floods were mostly as a result of flooding, there were also damages as a result of erosion (outlined in Table 4-6). One way to reduce erosion losses is to identify erosion zones and regulate development in those zones. Erosion zone regulations include identifying required setback distances from erosion areas to protect new structures and renovated structures from erosion. The St. Vrain Creek Coalition in Boulder County is in the process of identifying new erosion zones for St. Vrain Creek, and this preliminary product (November 2014) was used for this study.

One erosion setback assessment was analyzed in this scenario:

1. What would the losses and losses avoided from the 2013 Colorado floods have been if development in the St. Vrain Creek erosion zone had been prohibited?

The following information was required for the analysis:

- The structures located in the St. Vrain Creek erosion zone.
- The IA event-verified loss at each structure.

5.5 BENCHMARK YEARS

In theory, as higher regulatory standards are implemented over time, damages should decrease. This scenario analyzed how the adoption of community regulations over time affects losses. This scenario was limited to the CRS jurisdictions that are within the study area, including Unincorporated Boulder County, City of Boulder, Fort Collins, Longmont, Louisville, and Loveland.

One question was analyzed in this scenario:

1. Do increased regulations, over time, result in fewer damages?

The following information was required for the analysis:

- CRS higher regulatory standard scores from 1998-2013
- Structures located in the CRS communities for Boulder, Larimer, and Weld Counties and associated losses from the 2013 Colorado flood event

5.6 NFIP CLAIMS

As a result of the 2013 Colorado floods, there were a number of NFIP claims outside the SFHA. Since policies purchased and maintained outside the SFHA are voluntary, the presence of these policies and claims outside the SFHA may be an indicator of successful risk communication and outreach by the impacted jurisdiction. This scenario attempts to determine if there is a relationship between the number of NFIP claims and the outreach performed by a jurisdiction. To do this examination, the CRS participating jurisdictions (Unincorporated Boulder County, City of Boulder, Fort Collins, Longmont, Louisville, and Loveland) were compared with the CRS outreach scores for those communities.

One NFIP question was analyzed in this scenario:

1. Is there a correlation between the NFIP policies outside of the SFHA, 2013 NFIP claims, and the CRS outreach score?

The following information was required for the analysis:

- Pre-event NFIP policies locations
- NFIP claims from the 2013 Colorado floods in the study area
- CRS outreach scores

5.7 CATEGORIES OF BENEFITS

This section introduces the categories of damages evaluated. In a losses avoided study, the benefits are the losses or damages that were avoided or not experienced due to implementation of a particular mitigation action.

There are three parts to this section. The first part describes the damages from the 2013 floods, as observed in the field and recorded in the Colorado Action Plan, which were used to select benefit categories for the analysis. The second part outlines each of the benefit categories and includes the losses avoided calculation methodology. The third part shows which benefit categories are applied to the scenarios previously outlined in Section 5.

5.7.1 Event Losses

The State of Colorado Action Plan for Disaster Recovery was written following the September 2013 floods. It divides the impact and unmet needs into three categories:

- Housing impact
- Infrastructure impact
- Economic impact

The housing impact category included an analysis of the structural damage of homes; the damage to roads, driveways, and bridges on private property; and contents damages filed through private insurance claims. The loss categories summarized in the State of Colorado Action Plan for Disaster Recovery included the impact to homeowners, rental stock, and public housing.

The infrastructure impact category analyzed the damages to roads, water and wastewater systems, public facilities and parks, and natural resources. Schools were included in the public facility category. Critical facilities as well as critical roadways were analyzed for impact and future planning.

The economic impact category analyzed business losses across a wide spectrum, both for employers and employees. The impacts to the economic sectors of agriculture, tourism, and oil and gas were also analyzed. The business impacts included structural damage, infrastructure damage, and utility damage. The economic effect of unemployment was also analyzed.

5.7.2 Description of Benefit Categories

The loss estimation analysis includes up to seven benefit categories for each scenario shown in Table 5-1. The loss calculation methods were modeled after those used in the Flood Module of the FEMA Benefit Cost Analysis (BCA) Toolkit (Version 5.1) and are described in this section. The FEMA BCA Toolkit Flood Module computes the benefits of flood mitigation projects by establishing the probabilities of various flood events based on flood hazard profile data from a flood insurance study (FIS) and estimating damages and losses at various flood depths based on depth-damage functions (DDFs) developed for various structure types. The benefit categories analyzed for each scenario are included in Section 5.7.3.

Table 5-1: Loss Categories and Loss Avoided Benefits

	Loss categories	Losses avoided benefits
1	Physical Damage	Building Damage
2	Physical Damage	Contents Damage
3	Loss of Function	Displacement Costs
4	Loss of Function	Loss of Business Income
5	Loss of Productivity	Lost Wages
6	Social Benefits	Avoidance of Mental Stress and Anxiety
7	Environmental Benefits	Restoration of Floodplain

Physical Damage

Building damage and contents damage are computed using DDFs. The source and description of the DDFs is provided in Appendix F. The DDFs assign a percentage of damage to the structure or contents based on the flood depth at the structure. There is one DDF for every building occupancy type and the damage estimates are defined in one foot increments of flood depth relative to the FFE from -2 feet (damages to the utilities and/or floor joints) to +14 feet.

Buildings

To calculate building losses, the structure DDF damage percent is multiplied by the Building Replacement Value (BRV).

$$MP_A\ structure = sDDF_d * BRV$$

Where:

$sDDF_d$ = The structure DDF damage percentage associated with the flood depth, d_A, of the MP_A scenario

Contents

To calculate contents losses the structure DDF damage percent is multiplied by the Contents Replacement Value (CRV).

$$MP_A\ contents = cDDF_d * CRV$$

Where:

$cDDF_d$ = The contents DDF damage percentage associated with the flood depth, d_A, of the MP_A scenario

Displacement

The displacement cost is calculated by multiplying the daily displacement cost by the number of people in the home and the estimated number of days of their displacement. The total displacement cost is the sum of the General Services Administration (GSA) per diem for lodging and the GSA daily meal allowance, which vary by county. Table 5-2 shows the 2014-2015 rates. This method was chosen to estimate displacement because it matches the method used in the BCA toolkit.

Table 5-2: 2014-15 GSA Displacement Costs

County	GSA lodging/ day	GSA meals/ day	Daily displacement cost/ person
Boulder	$114	$61	$175
Larimer	$98	$56	$154
Weld	$83	$46	$129

The displacement losses are calculated as:

$$MP_A \text{ Displacement} = \text{Daily displacement cost} * dDDF_d * \text{Number of persons per household}$$

Where:

$dDDF_d$ = The displacement DDF percentage, as identified by FEMA's BCA Tool, associated with the flood depth, d_A, of the MP_A scenario

The displacement DDF is provided in Appendix F. All structures, regardless of occupancy type, use the same displacement DDF.

Loss of Function

Loss of function, or loss of business income, is a benefit category that is associated with the loss of income for non-residential structures. The value of the net business income per day is multiplied by the loss of function DDF, identified in FEMA's BCA Tool and the number of days the loss of function is experienced. The net business income per square foot is obtained from Table 15.15 of the Hazus-MH MR4 Technical Manual and is listed in Appendix I. This is multiplied by the area of the commercial building to obtain a Daily Business Income.

$$\text{Loss of Business Income} = fDDF_d * \text{Daily Business Income} * \text{Days}$$

Where:

$fDDF_d$ = The loss of function DDF percentage associated with the flood depth, d_A, of the MP_A scenario

Daily Business Income = Net business income (per square foot per day) times the square footage of the commercial structure

Days = Number of days loss of function is experienced.

The Loss of Function DDF is provided in Appendix F. All non-residential structures, regardless of occupancy type, use the same Loss of Function DDF.

Loss of Productivity
The loss of productivity (lost wages) benefit, applies to all full-time wage earners living in a residential structure. The loss of productivity (LP) value is from the FEMA BCA Toolkit (Version 5.1). The LP cost is $8,736 per person. The LP benefit is calculated as follows:

*Loss of Productivity = LP value * Number of persons per household*

Where:
LP value = $8,736/person

Mental Stress and Anxiety
The avoidance of mental stress and anxiety benefit is applied to all full time occupants of a residential structure. The mental stress and anxiety value (MSA value) used in this study is from the FEMA BCA Toolkit (Version 5.1). The MSA value is $2,443 per person. The Mental Stress and Anxiety Loss is calculated as follows:

*Mental Stress and Anxiety Loss = MSA Cost * Number of persons per household*

Where:
MSA value = $2,443/person

Environmental
The environmental benefit applies to acquisition mitigation projects. This benefit takes into account the restoration of a parcel of land to a natural condition. FEMA's BCA Toolkit (Version 5.1) identifies a methodology to determine environmental benefits using an annual per acre benefit that can be considered if the general benefits of the hazard mitigation project yield a Benefit Cost Ratio of 0.75-1.0.

The scenarios that analyze the environmental benefit are discussed in Section 5.9.3. To apply this benefit, the acreage of the restored parcel is needed. If the parcel is touching a river, the environmental benefit is considered a riparian benefit. If the parcel is one or more parcels away from a river and is located in the SFHA, the environmental benefit is called a green open space benefit. The environmental factors for a riparian restoration and for a green open space restoration are given in Table 5-3.

Table 5-3: Environmental Benefits

Environmental benefit category	Benefit factor	Unit
Riparian	$37,493	per acre
Green open space	$7,853	per acre

5.7.3 Benefit Categories Used for Scenarios

This section describes the benefit categories analyzed for each scenario. The general benefit categories are shown in Table 5-4. General benefits are building damages, contents damages, displacement costs, and loss of function. The general benefit categories are included in the freeboard, floodway and floodplain development, critical facilities, and erosion setback assessment.

The general benefits are calculated using DDF curves. As described previously, the DDF is assigned based on the flood depth, a percent damage of the building and contents, and number of days for displacement and loss of function.

Table 5-4: General Benefits Applied to Scenarios

Scenario Description	Building Damages	Contents Damages	Displacement Costs	Loss of Function
Freeboard	Yes	Yes	Yes	Yes
Floodway and floodplain development	Yes	Yes	Yes	Yes
Critical facilities	Yes	Yes	Yes	Yes
Erosion setback assessment	Yes	Yes	No	No

The social and environmental benefits are benefit categories that may not always apply. The benefits may be specific to a building function or to a mitigation activity. The social and environmental benefits used in this analysis are loss of productivity, mental stress and anxiety, and the environmental benefit. Table 5-5 shows the social and environmental benefits applied to each regulatory losses avoided scenario.

Table 5-5: Social and Environmental Benefits Applied to Scenarios

Scenario description	Loss of Productivity	Mental Stress and Anxiety	Environmental
Freeboard	No	Yes	No
Floodway and floodplain development	Yes	Yes	Yes
Critical facilities	No	No	Yes
Erosion setback assessment	No	No	No

The loss of productivity benefit, which applies to non-residential projects, was not analyzed for the freeboard scenario or erosion setback scenario because these scenarios focus on residential buildings and do not significantly impact non-residential and critical facilities where residents work.

The environmental benefit is only applied to regulatory standards that would result in undeveloped parcels. For this reason, the environmental benefit is analyzed in the floodway scenario and floodplain development and critical facility development in the floodplain scenarios.

SECTION SIX SCENARIO RESULTS

Section Six presents the losses avoided results for a 100-year event and in the 2013 Colorado flood event as estimated for each of the scenarios described in Section Five. The 100-year regulatory depth grid data was used to analyze the 100-year event losses. The 2013 Colorado flood event data was used to analyze the 2013 event losses. The MP_A and MP_C and Losses Avoided results are provided for each scenario, first for the 100-year scenario and then for the 2013 event. MP_A is the existing condition and MP_C is what would have happened if the scenario change was implemented.

6.1 FLOODPLAIN AND FLOODWAY DEVELOPMENT RESTRICTIONS

The floodway and floodplain development scenarios analyze the regulation scenarios where floodway or floodplain development is restricted.

6.1.1 Floodplain Development Regulations in the SFHA Adopted Earlier

This scenario analyzed the losses to structures located in the SFHA. Many of the impacted jurisdictions entered the NFIP as early as the 1970s; however, they often regulated with incomplete mapping. Through the FEMA Map Modernization program and now Risk MAP, updated and often more comprehensive flood hazard mapping is now available. Therefore, this scenario asks:

> *If no development in the current effective SFHA was allowed when the jurisdiction first entered the NFIP, what losses would this regulation have avoided in the 100-year event?*

Figure 6-1 depicts the total losses of structures in the SFHA due to the 100-year event. The total losses are the MP_A results. The losses shown are the expected losses from a 100-year base flood. The losses avoided are computed after the regulatory change is applied. In this scenario the regulatory change is the restriction of development in the floodplain. Boulder County accounts for 68 percent of the total losses, Larimer 20 percent, and Weld 12 percent. The percentage of losses for Boulder is higher than Larimer and Weld for two primary reasons:

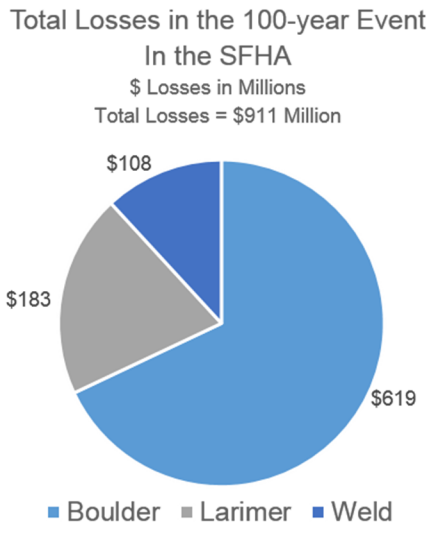

Figure 6-1: 100-year Event Losses by County to SFHA Structures

1. **Exposure**. Boulder has a higher number of structures in the SFHA than Larimer and Weld.
2. **Replacement Costs**. Boulder has higher building and contents replacement costs than Larimer and Weld, which results in higher losses.

Figure 6-2 shows the total losses and losses avoided in the 100-year event. The losses avoided are the difference between the MP_A and the MP_C. The total MP_A losses are $911 million and MP_C losses are $425 million, giving a total losses avoided of $486 million.

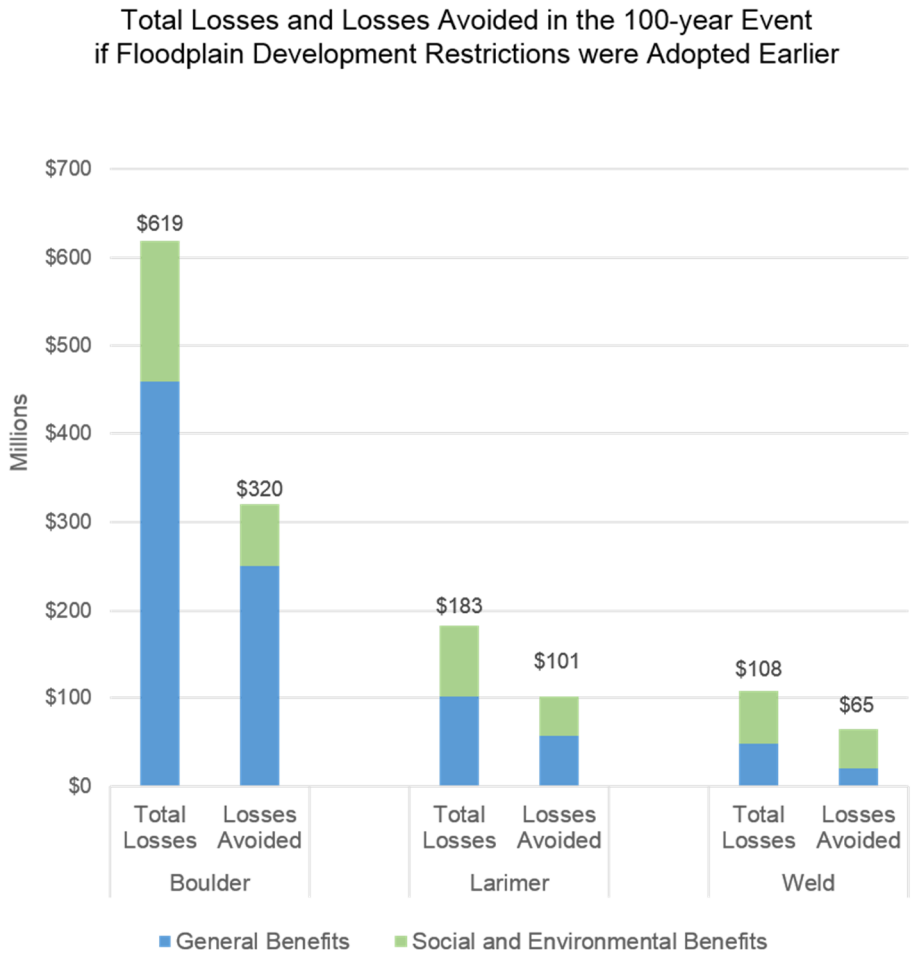

Figure 6-2: MP_A and Losses Avoided in the 100-year Event in SFHA Structures

The losses avoided in this scenario are the losses that occurred to the structures built in the SFHA after the jurisdiction joined the NFIP. These structures are referred to as post-regulatory structures, while structures built before the jurisdiction entered the NFIP are referred to as pre-regulatory structures.

Weld County had the highest percentage (60 percent) of losses avoided compared to total losses because the losses in the pre-regulatory structures are lower. Boulder County has the highest dollar value of total losses and losses avoided at $619 million and $320 million, respectively, because more structures were impacted and the total replacement costs of the exposed buildings in Boulder County are ten times that of either Larimer or Weld Counties.

The social and environmental benefits make up a sizable component of the losses and losses avoided because the environmental benefit is based on acreage. The acreage and the

environmental benefit factor, up to $37,493 per acre for parcels adjacent to a river, may be large compared with the other loss categories. When only the general benefit category results are compared in Figure 6-2 to the total losses, the losses avoided in Boulder County are 55 percent, 56 percent losses avoided in Larimer County, and 41 percent losses avoided in Weld County. The lower percentage for Weld indicates the greater extent to which the social and environmental benefits contributed to the losses avoided in that county.

Figures 6-3, 6-4, and 6-5 provide a summary overview of the 100-year event impacts by county. The event impacts include the number of SFHA structures, the number of impacted structures, and the event losses. The number of structures that were estimated to have physical losses (structure or contents) due to the 100-year flood depth exceeding or being within -2 feet of the FFE are referred to as impacted structures.

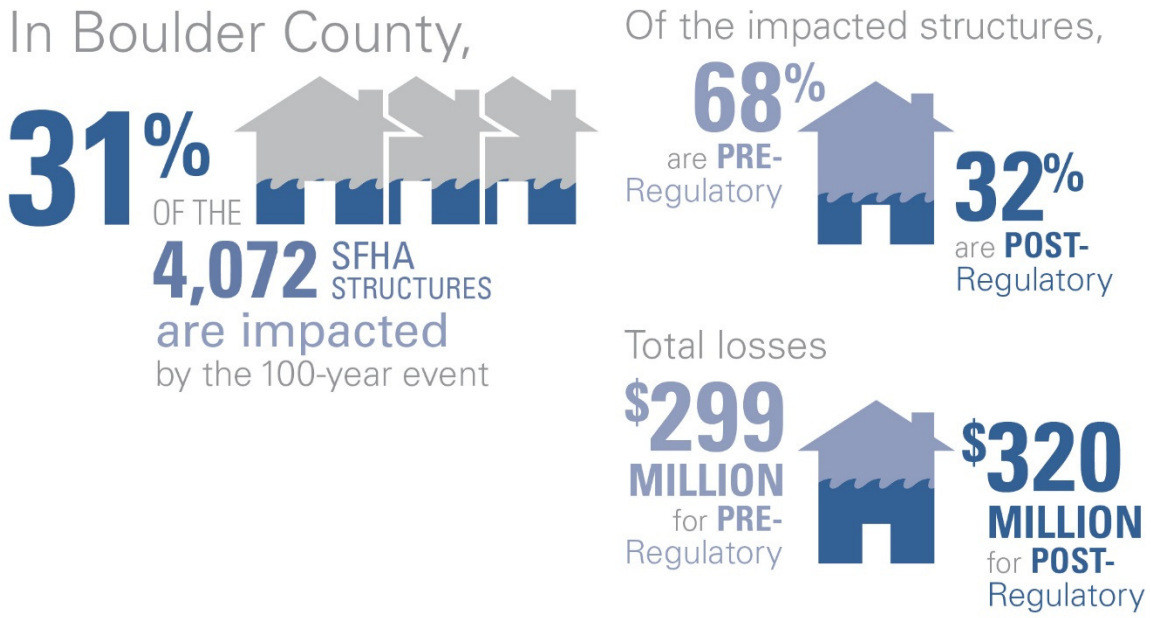

Figure 6-3: Boulder County Total Losses (MP_A) in SFHA Structures in the 100-year Event

The highest number of impacted structures and the greatest number of structures in the SFHA are in Boulder County. The percentage of SFHA structures impacted by the 100-year event in Boulder County is less than one third, as depicted in Figure 6-3. The majority of the impacted structures in Boulder County are pre-regulatory structures, defined as built prior to the communities' entry into the NFIP. Post-regulatory structures are defined as being built after the NFIP entry date; however, they may have been regulated to an older map or Base Flood Elevation than that based on the current effective 100-year SFHA. This contributes to higher post-regulatory total losses driven, in part, by the higher replacement costs of newer and often larger structures in Boulder County.

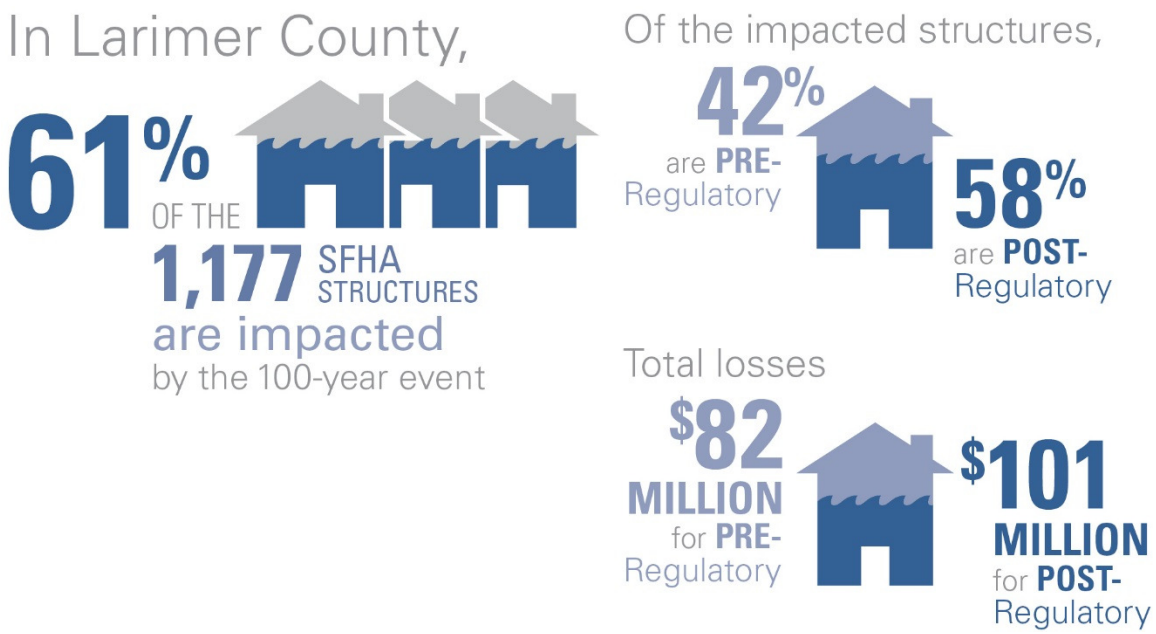

Figure 6-4: Larimer County Total Losses (MP_A) in SFHA Structures in the 100-year Event

It was estimated that in the 100-year event, 722 SFHA structures would be impacted in Larimer County, as depicted in Figure 6-4. The percentage of pre- and post-regulatory losses follows a similar trend to the total pre- and post-regulatory impacted structures. The pre-regulatory losses are 42 percent of the total losses and the post-regulatory losses are 58 percent of the total.

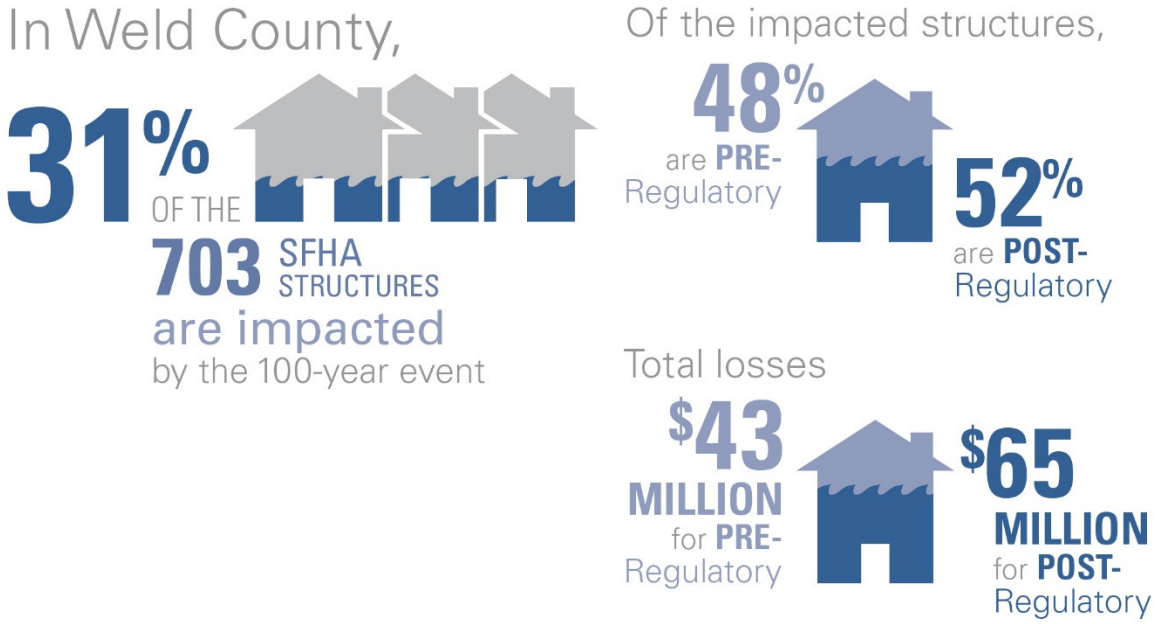

Figure 6-5: Weld County Total Losses (MP_A) in SFHA Structures in the 100-year Event

Weld County had the fewest number of structures impacted by the 100-year event, as depicted in Figure 6-5. It also has the fewest number of structures in the SFHA. Of the impacted structures, 52 percent are post-regulatory. The impacted post-regulatory structures account for 60 percent of the total losses, which is a higher percentage than in Larimer or Boulder. The higher percentage

may be due to higher replacement costs in newer buildings, or it may also be a result of the environmental benefits. The environmental benefits rely on acreage and in Weld County, and the post-regulatory acreage is 1.7 times the pre-regulatory acreage; in other words, the post-regulatory lots are larger, resulting in a higher benefit calculation.

The percent of structures impacted for Boulder and Weld Counties is lower than Larimer County in the 100-year event because there are more structures in the SFHA in Boulder and Weld Counties that have a FFE above the BFE. Not all structures in the SFHA are impacted with physical damages, building or contents, even though all structures in the SFHA are in the 100-year floodplain.

2013 Event Results

This scenario analyzes the losses to structures located in the SFHA as a result of the 2013 Colorado flood event. The losses are obtained from FEMA IA reports and FVL. The following question was addressed:

> *If no development in the SFHA was allowed when the jurisdiction first entered the NFIP, what losses would this regulation have avoided in the 2013 Colorado flood event?*

Figure 6-6 depicts the MP_A or total losses of structures in the SFHA due to the 2013 event. Boulder County accounts for 86 percent of the total losses, Larimer 12 percent, and Weld 3 percent. The total losses for Boulder are higher than Larimer and Weld because of the exposure and higher replacement costs.

Figure 6-7 shows the total losses and losses avoided in the 2013 event. The losses avoided are represented by the difference between the MP_A and the MP_C. The total MP_A losses are $113 million and the MP_C losses are $60 million, giving a total Losses Avoided of $53 million.

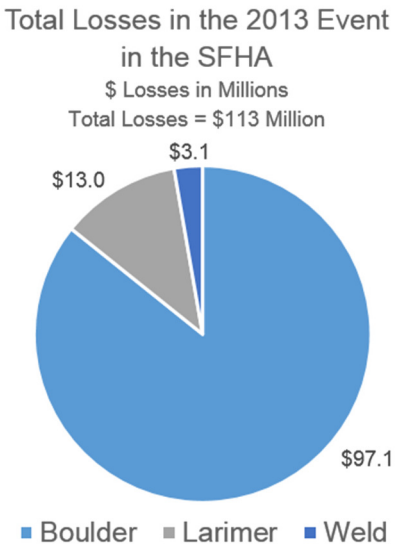

Figure 6-6: 2013 Event Losses by County to SFHA Structures

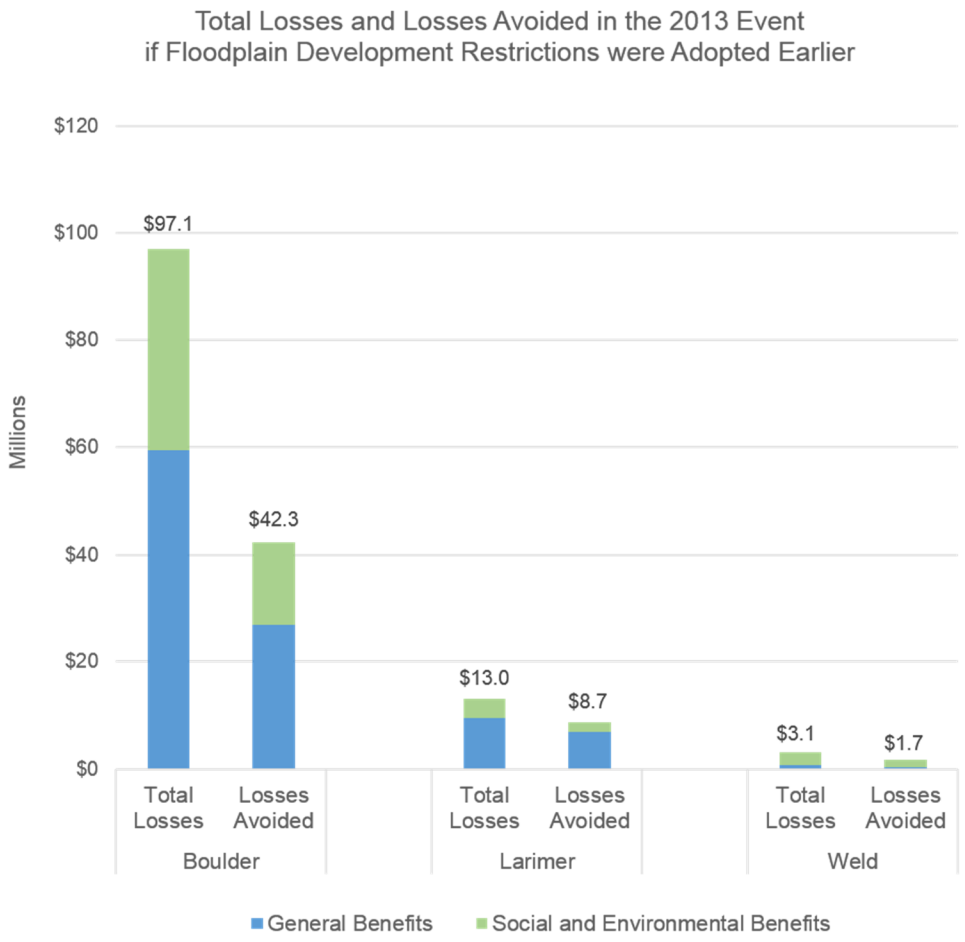

Figure 6-7: MP_A and Losses Avoided in the 2013 Event in SFHA Structures

The losses avoided in this scenario are the losses to the post-regulatory structures. The percent losses avoided to total losses are 44 percent in Boulder, 67 percent in Larimer, and 55 percent in Weld, meaning that this is the percentage of post-regulatory losses to all of the structures in the floodplain. In Larimer County, where the percent losses avoided is the highest, the post-regulatory SFHA structures account for 67 percent of the damages.

Total losses are the highest in Boulder County, as is the greatest number of impacted structures in the 2013 event analysis. More than eight times as many SFHA structures are impacted in Boulder as in Larimer or Weld Counties combined. An “impacted structure” is one that has a FVL report of either building or contents damages in the FEMA IA program.

Figures 6-8, 6-9, and 6-10 provide a summary overview of the 2013 event impacts by county. The losses in Boulder County are higher in the pre-regulatory structures. In Larimer and Weld Counties the losses are higher in the post-regulatory structures.

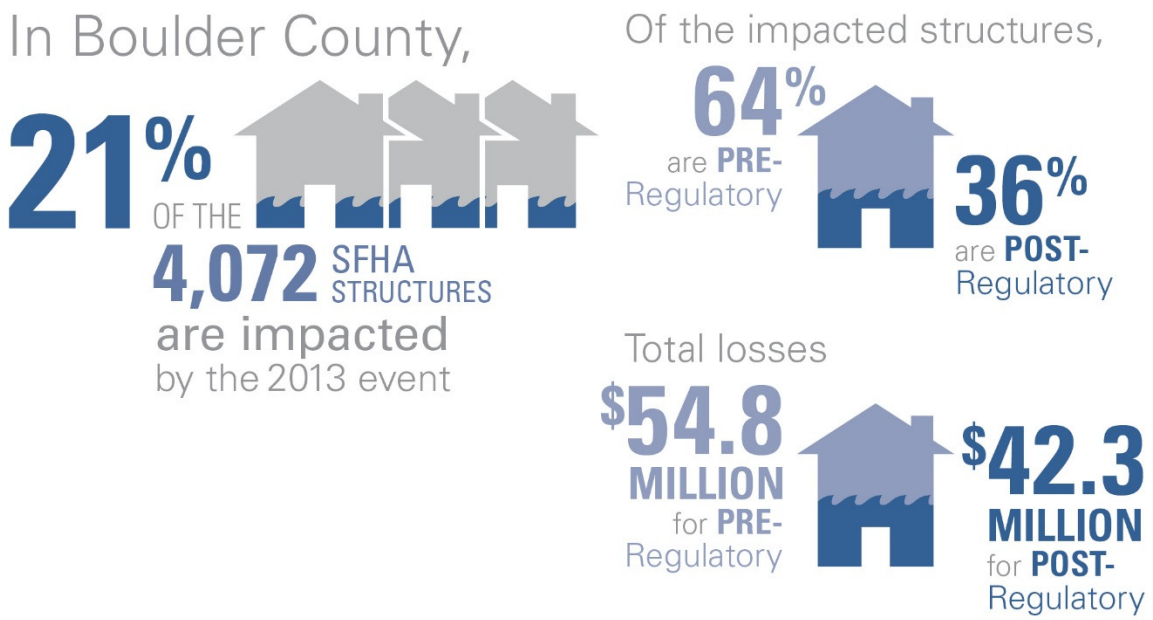

Figure 6-8: Boulder County Total Losses (MP_A) in SFHA Structures in the 2013 Event

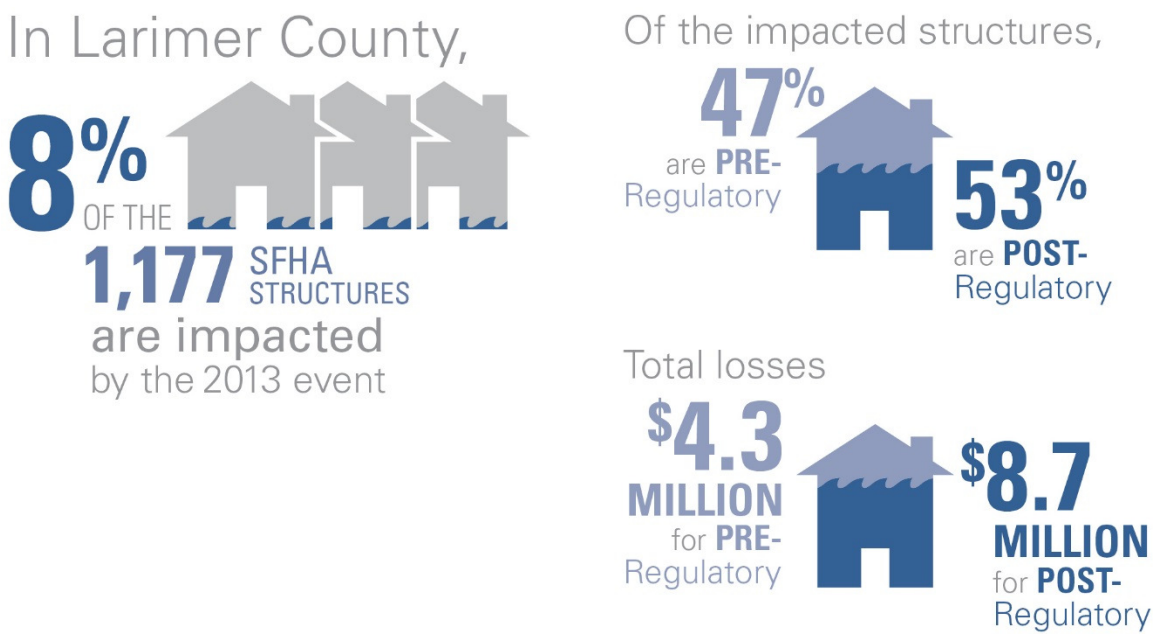

Figure 6-9: Larimer County Total Losses (MP_A) in SFHA Structures in the 2013 Event

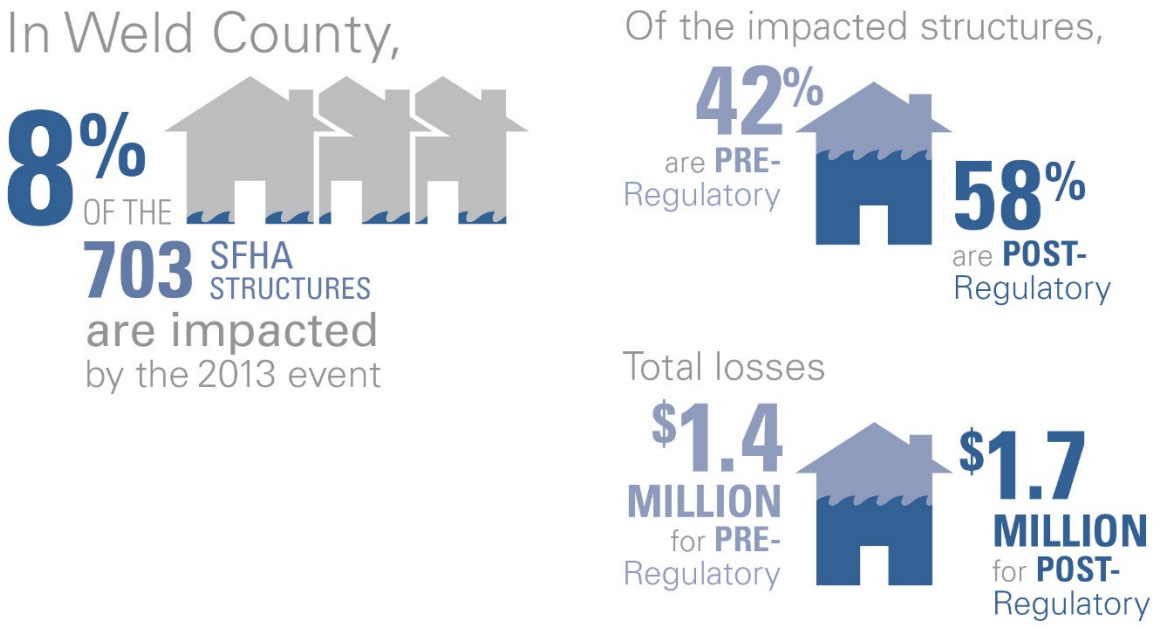

Figure 6-10: Weld County Total Losses (MP_A) in SFHA Structures in the 2013 Event

6.1.2 Longmont Mitigation Project Case Study

The regulatory change analyzed in this scenario is the restriction on development in the SFHA. In Longmont, a channel improvement mitigation project removed structures from the SFHA and redefined the boundaries of the SFHA. This project saved the jurisdiction an estimated $22 million in the 2013 event. See the insert on the following page for more information.

Case Study (CS): Left Hand Creek Channel Improvement – City of Longmont, CO

Point of Contact: David Hollingsworth, Floodplain Administrator, CFM

CRS Activities: 420 – Open Space Preservation, 520 – Acquisition

Description: In 2010, the City of Longmont Left Hand Creek Flood Project was proposed as a Pre-Disaster Mitigation (PDM) Program project at a cost of $5.7 million. It was awarded and completed in 2012. The mitigation project was designed to increase the flow capacity of the Left Hand Creek channel through a mixed-use area. The Left Hand Creek Flood Project improved the Left Hand Creek channel design and updated and resized two bridge culverts (see Figure CS-1). The proposal identified 110 structures that would be removed from the SFHA as depicted on the FIRM.

Subsequent to the completion of the PDM project, two LOMRs were issued, one on August 21, 2014 and another on October 22, 2014, to reflect the construction of the project and revise the FIRM in the project area. In September of 2013, a flood that closely aligned to the SFHA as depicted on the LOMR occurred in Left Hand Creek. According to the City of Longmont Floodplain Administrator, the 2013 flood event in Left Hand Creek channel was approximately a 100-year flood event.

As part of this report, a traditional LAS was conducted for the Left Hand Creek Channel Improvement. The study included 204 structures – the 110 designated project structures plus an additional 94 structures surrounding the project area. As indicated in Table CS-1, the project avoided $22.4 million in damages and losses during a 100-year flood event for a return on investment of 3.91. Refer to Appendix G of this report for additional details on the loss avoidance study for this project.

Table CS-1: Losses Avoided Results for the Left Hand Creek Channel Improvement in Longmont, CO

100-year Flood Event Pre-Project Losses	100-year Flood Event Post-Project Losses	100-Year Event Project Losses Avoided	Project Cost (Including Annual Maintenance)	Project Return on Investment (ROI) = [(22,453,091)/(5,744,858)] = **3.91**
$23,449,720	$996,629	$22,453,091	$5,744,858	

Figure CS-1: Left Hand Creek Channel Improvement Projects Protected Nearby Residences From September 2013 Flood Damage. (Source: FEMA Contractor, June 2014)

In addition to preserving large tracts of open space, the city's Stormwater Department, in coordination with the Natural Areas Department, purchased several properties in the College Avenue and Vine Drive area as part of a Willing Seller-Willing Buyer program. There have been two commercial structures and one residential structure removed. At the time of the flood, a second residential structure had been purchased, but the building had not yet been demolished. That structure had 8-10 inches of water in the basement from the flood and is expected to be removed in the near future.

6.1.3 Floodway Development Regulations Adopted Earlier

This scenario analyzes the losses avoided due to restrictions on structures built in the floodway. The following question was addressed:

> *If no development in the floodway was allowed when the jurisdiction first entered the NFIP, what losses would this regulation have avoided in the 100-year event?*

The total losses in the 100-year event in floodway structures, which are the MP_A results, show that the greatest losses occurred in Larimer County (Figure 6.11). The losses avoided are computed after the regulatory change is applied. The regulatory change in this scenario is the restriction of development in the floodway. Larimer County accounts for 49 percent of the total losses, Boulder 38 percent, and Weld 13 percent. The percentage of losses for Larimer is higher than Boulder and Weld for two reasons:

1. **Location**. The highest percentage of impacted structures in the floodway is in Larimer.
2. **Environmental**. There are twice as many acres in the Larimer floodway parcels then in Weld or Boulder.

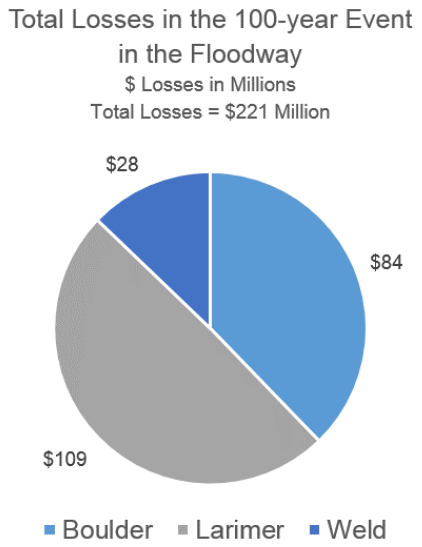

Figure 6-11: 100-year Event Losses by County to Floodway Structures

Figure 6-12 shows the total losses and losses avoided in floodway structures in the 100-year event. The losses avoided are represented by the difference between the MP_A and the MP_C. The total MP_A losses are $221 million and MP_C losses are $113 million, with a Losses Avoided of $107 million.

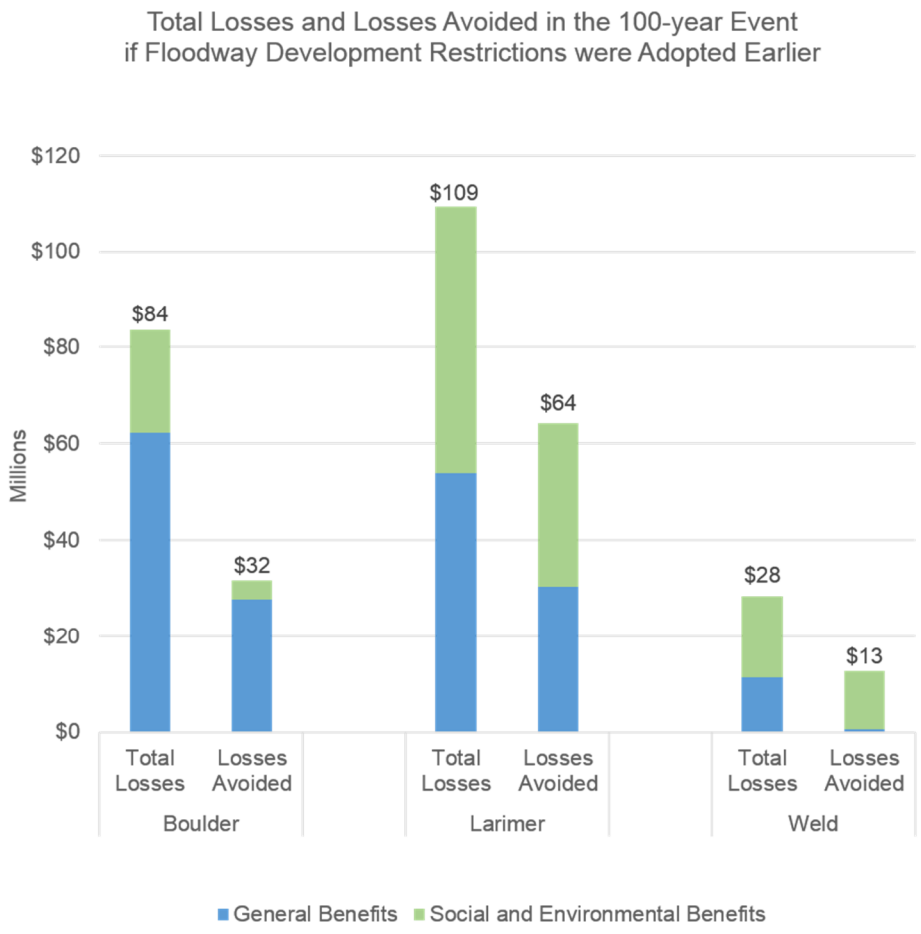

Figure 6-12: MP_A and Losses Avoided in the 100-year Event in Floodway Structures

The losses avoided in this scenario represent the losses in post-regulatory structures. In Larimer County the losses avoided equal 59 percent of the total losses. In Weld County, the losses avoided are 44 percent, and in Boulder County the losses avoided are 38 percent of the total.

The social and environmental benefits have an impact on the total losses. In Larimer and Weld Counties these benefits account for nearly half of the total losses. In Boulder that is not the case, particularly in the losses avoided. The lower environmental benefit indicates that the structures in the floodway in Boulder have smaller parcel sizes. In Figure 6-12, the general benefits are $62 million in Boulder, $54 million in Larimer, and $11 million in Weld.

Figures 6-13, 6-14 and 6-15 provide a summary overview of the 100-year event impacts by county. The event impacts include the number of floodway structures, the number of impacted structures, and the event losses.

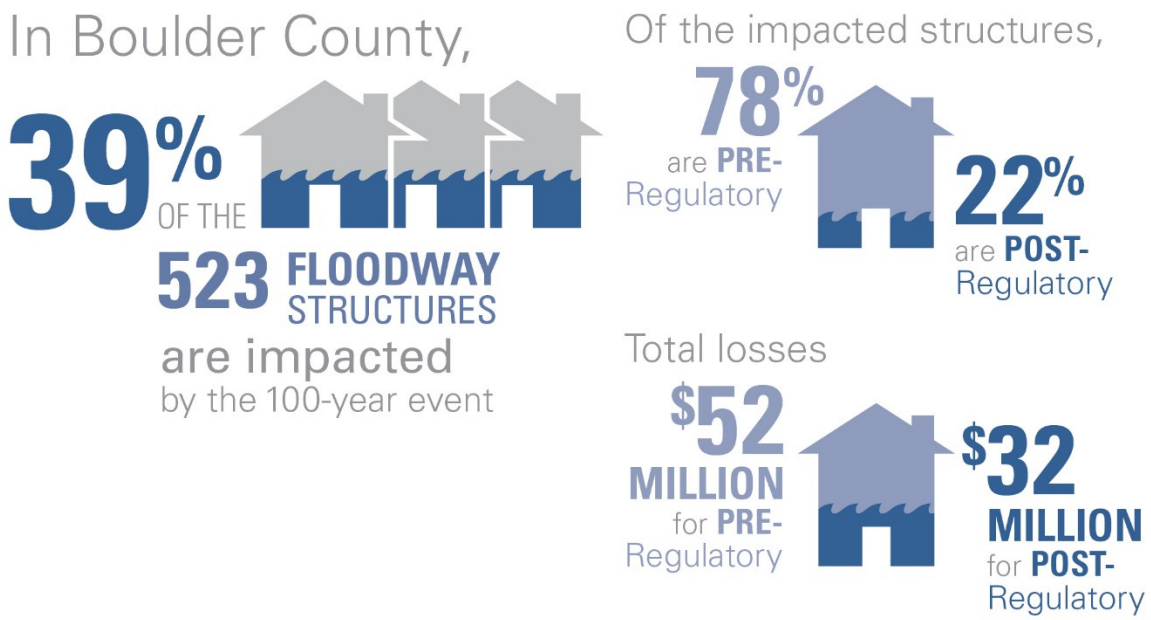

Figure 6-13: Boulder County Total Losses (MP_A) in Floodway Structures in the 100-year Event

In Boulder County, the majority of impacted structures, as well as the majority of the losses, are pre-regulatory structures. The post-regulatory losses are lower than the 100-year event because the higher replacement costs are fewer in the floodway development restriction scenario in Boulder County.

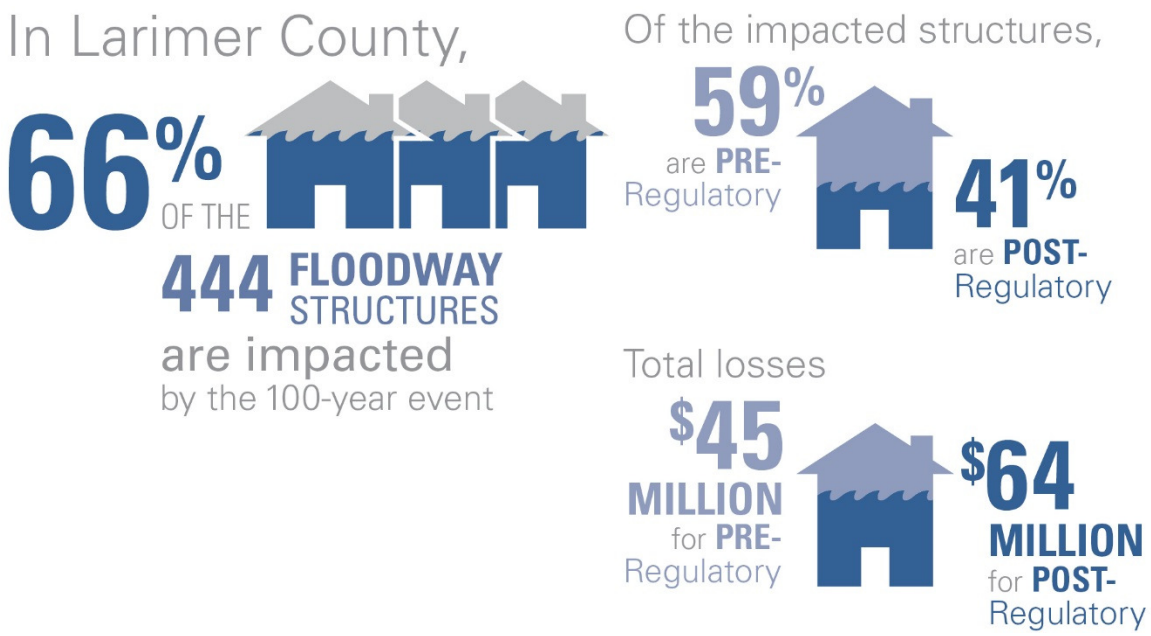

Figure 6-14: Larimer County Total Losses (MP_A) in Floodway Structures in the 100-year Event

Larimer County has the highest percentage of impacted floodway structures and the greatest total losses in this scenario. The total losses are higher in the post-regulatory structures. This is because the environmental benefits in the losses avoided for floodway structures in Larimer

County are greater than in Boulder or Weld Counties. The total acreage of the sites impacted in Larimer County increase from pre- to post-regulatory structures by 150%.

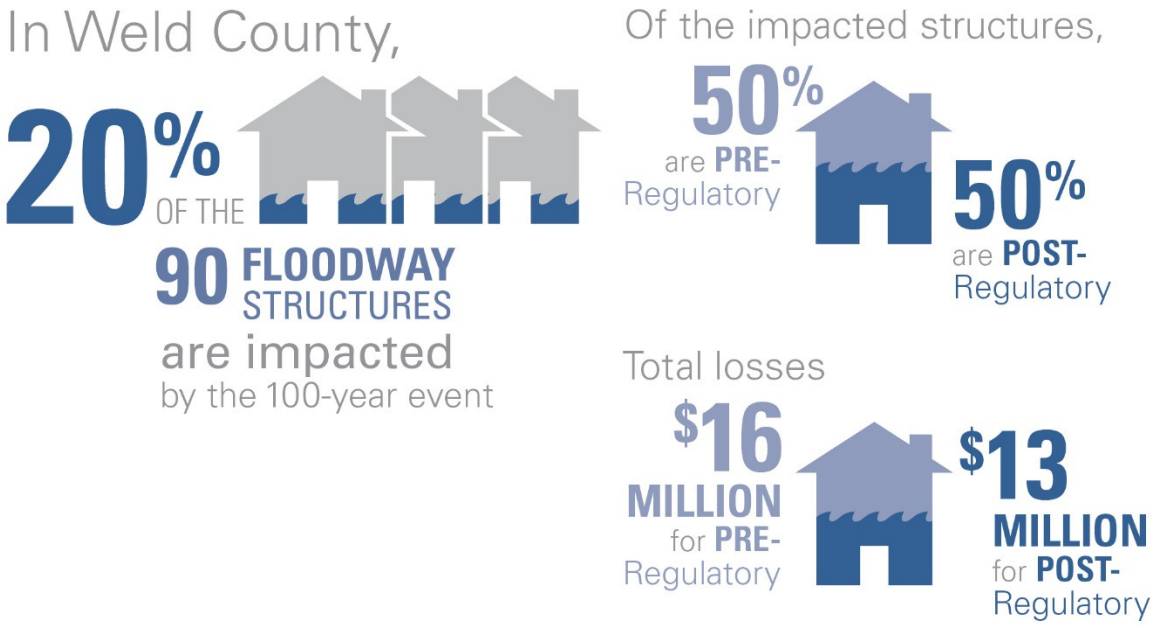

Figure 6-15: Weld County Total Losses (MP_A) in Floodway Structures in the 100-year Event

The exposure in Weld County for this scenario is much lower. There are only 18 impacted structures out of a total of 90 in the floodway. This may be because not all areas of Weld County are participating in the NFIP and so do not have mapped floodways. For the floodway scenario, the 2013 event was not analyzed due to the unavailability of 2013 flood event depth grids for floodway areas.

6.2 FREEBOARD

The freeboard scenarios analyze losses given existing freeboard regulations and the regulatory change of raising, lowering, or adopting current freeboard regulations at an earlier time. The baseline, or MP_A, for every scenario analyzes the current freeboard regulations in a jurisdiction. A regulatory change is incorporated into the model and then analyzed. The new results are presented as the MP_C. The effect of implementing the regulatory change is the difference between the MP_C and the MP_A models, or the losses avoided. The losses avoided can be negative. This means that the total losses increase after the regulation is changed.

The implementation of freeboard lowers the hazard risk of structures in a floodplain by further separating the FFE from the BFE. It would take greater flood depths to cause the same damage to a structure built with freeboard as it would to a structure without freeboard.

The analysis results show that a greater freeboard value and the implementation of freeboard versus no freeboard leads to a reduction in losses. This has a positive losses avoided value. Conversely, if the freeboard regulation was not adopted or if the FFE elevation were allowed to be at a lower elevation, then the losses increase. This has a negative losses avoided value.

6.2.1 Freeboard Adopted Earlier

This scenario analyzes the length of time the freeboard regulation has been implemented. The assumption is that the current freeboard level was not adopted when the jurisdiction first entered the NFIP. The following question was addressed:

> *If today's freeboard (each jurisdiction's current regulation) was regulated when the jurisdiction first joined the NFIP, what losses would this regulation have avoided in the 100-year event?*

The total losses in the 100-year event, using the overall MP_A losses for all of the freeboard scenarios, are shown in Figure 6-16.

Boulder County accounts for 75 percent of the total losses, Larimer County is 17 percent, and Weld County is 8 percent. Figure 6-16 shows the total MP_A losses in the SFHA structures; however, there are no environmental benefits considered because structures are not removed from the floodplain in this scenario. When the environmental benefits are not added to the total losses, the higher exposure and replacement costs in Boulder County are more pronounced.

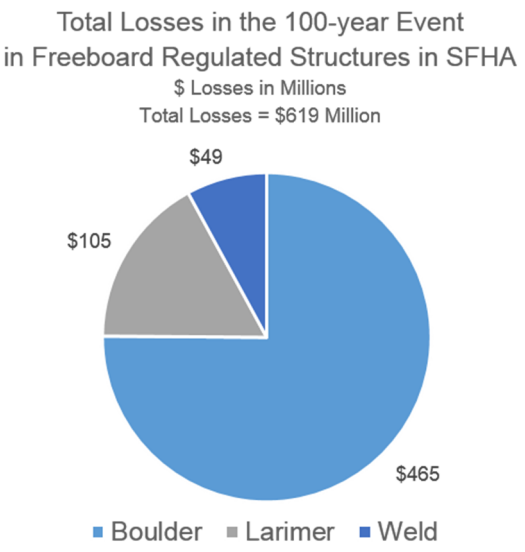

Figure 6-16: 100-year Event Losses by County to Structures with Freeboard (MPA)

Figure 6-17 shows the total losses and losses avoided in freeboard regulated structures in the 100-year event. The losses avoided are the difference between the MP_A and the MP_C. The total MP_A losses are $619 million. The total MP_C losses are $413 million.

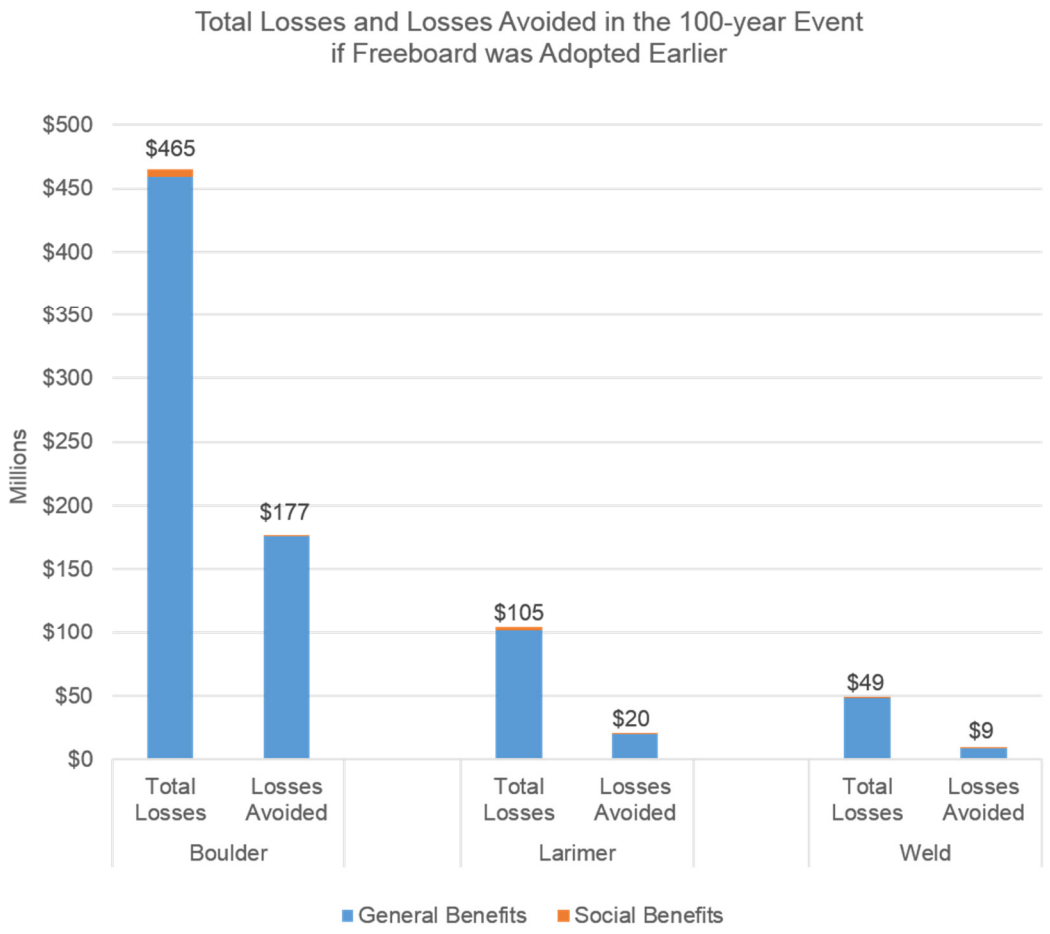

Figure 6-17: Losses Avoided in the 100-year Event if Freeboard was Adopted Earlier

The losses avoided are the losses in the post-regulatory structures that could have been avoided with a higher freeboard. There would have been a 33 percent reduction in total losses in the study area in the 2013 event if this regulation had been implemented earlier.

In Boulder County the losses avoided equal 38 percent of the total losses. In Larimer County, the losses avoided are 19 percent, and in Weld County the losses avoided are 18 percent of the total. The current freeboard of two feet in unincorporated Boulder County is higher than what is regulated at the county level in Larimer or Weld Counties at Base Flood Elevation and one-foot, respectively. Therefore, the losses avoided are higher and the percentage of losses avoided indicates that more savings would have been obtained if the higher standard was implemented earlier.

The freeboard in Larimer County may be lower, but the total losses in Larimer are also lower. This may be due to Boulder County's greater exposure compared to Larimer, or the higher replacement costs, and is illustrated by the number of impacted structures will support this better in the following graphics.

Figures 6-18, 6-19 and 6-20 provide a summary overview of the 100-year event impacts in freeboard-regulated structures by county if freeboard had been adopted earlier. These results are

the MP_C results. The event impacts include the number of structures with reduced and/or no damages and the overall impact on the event losses.

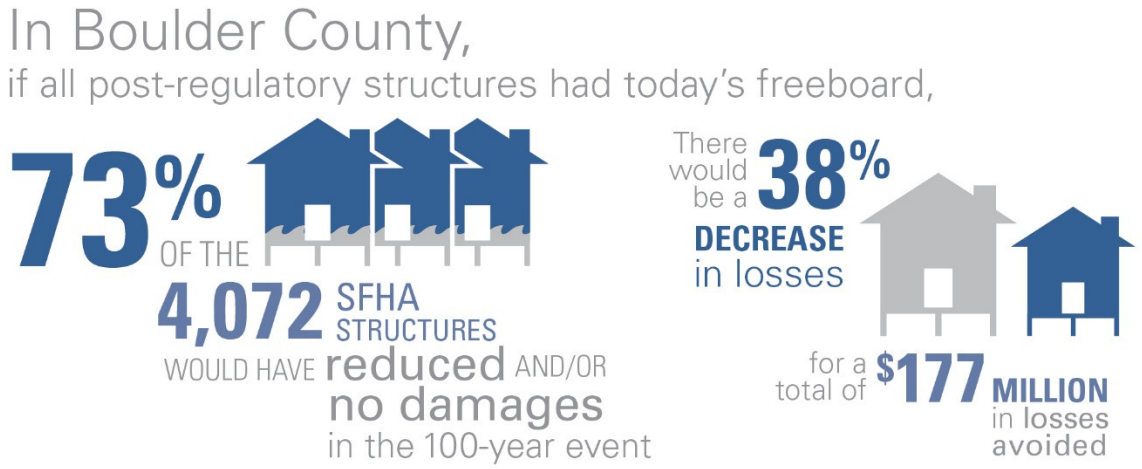

Figure 6-18: Boulder County Total Losses (MP_C) in the 100-year Event if Freeboard was Adopted Earlier

The highest decrease in losses is in Boulder County.

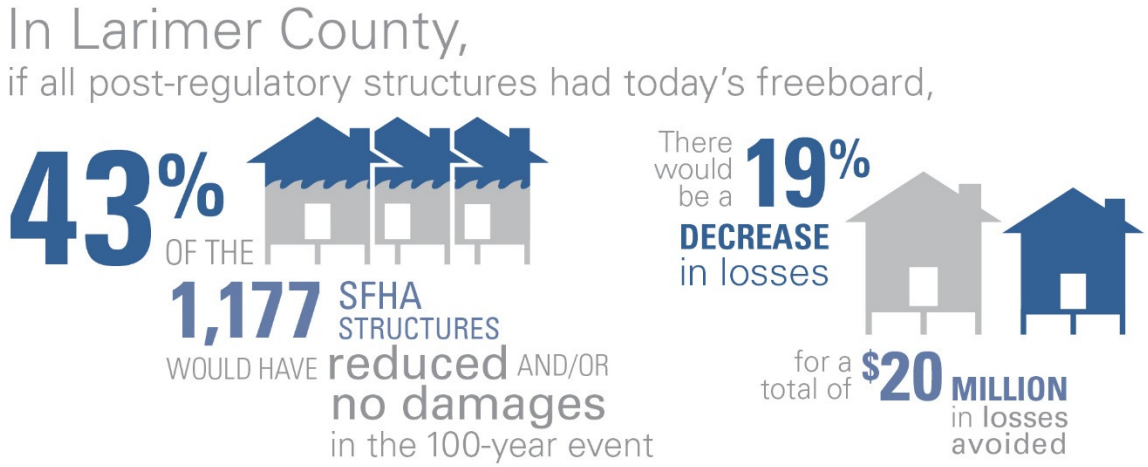

Figure 6-19: Larimer County Total Losses (MP_C) in the 100-year Event if Freeboard was Adopted Earlier

In Larimer County, there is a higher percentage of structures impacted than any other county; however, the total number of impacted structures is still greater in Boulder because the total exposure is greater in Boulder. There are 673 impacted structures in Larimer, 1,081 in Boulder, and 130 in Weld. In Larimer, the number of impacted structures compared to Boulder is 62 percent; however, the total losses are 23 percent of Boulder's total losses. This indicates that the replacement costs are significantly higher in Boulder than in Larimer.

If freeboard were higher, it would be expected that the losses avoided would be a greater percentage of the total in Larimer County.

Figure 6-20: Weld County Total Losses (MP_C) in the 100-year Event if Freeboard was Adopted Earlier

Weld County has the highest percentage of the SFHA structures with reduced and/or no damages.

2013 Event Results

This scenario analyzes the losses to freeboard-regulated structures as a result of the 2013 Colorado flood event. The losses are obtained from the FEMA IA reports and the FEMA verified losses. The following question was addressed:

> *If today's freeboard was regulated when the jurisdiction first joined the NFIP, what losses would this regulation have avoided in the 2013 event?*

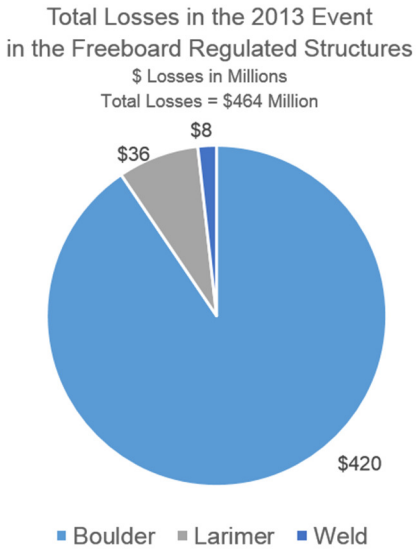

Figure 6-21: 2013 Event Losses by County to Structures with Freeboard (MP_A)

Figure 6-21 depicts the total losses in the 2013 event. The total losses are the MP_A results. Boulder County accounts for 91 percent of the total losses, Larimer 8 percent, and Weld 2 percent.

Figure 6-22 shows the total losses and losses avoided in the 2013 event. The losses avoided are the difference between the MP_A and the MP_C. The total MP_A losses are $13.3 million. The total MP_C losses are $8.9 million.

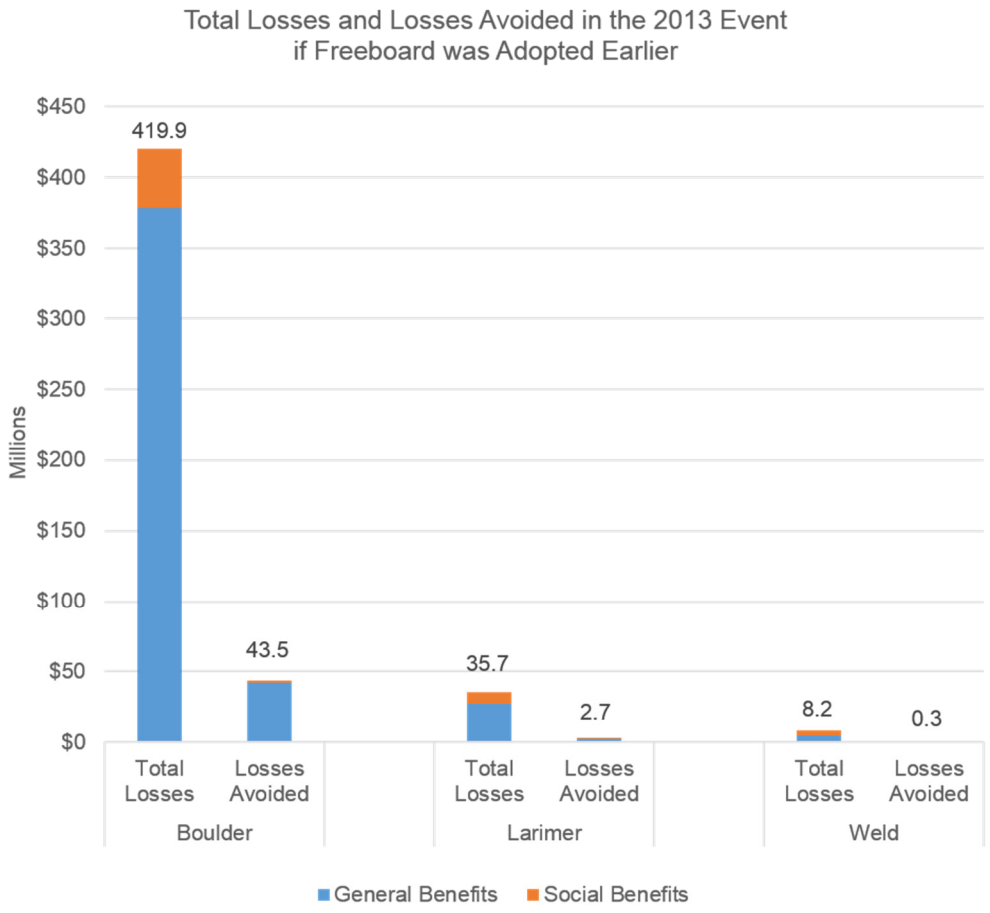

Figure 6-22: Losses Avoided in the 2013 Event if Freeboard was Adopted Earlier

Figures 6-23, 6-24 and 6-25 provide a summary overview of the 2013 event impacts in freeboard-regulated structures by county if freeboard was adopted earlier.

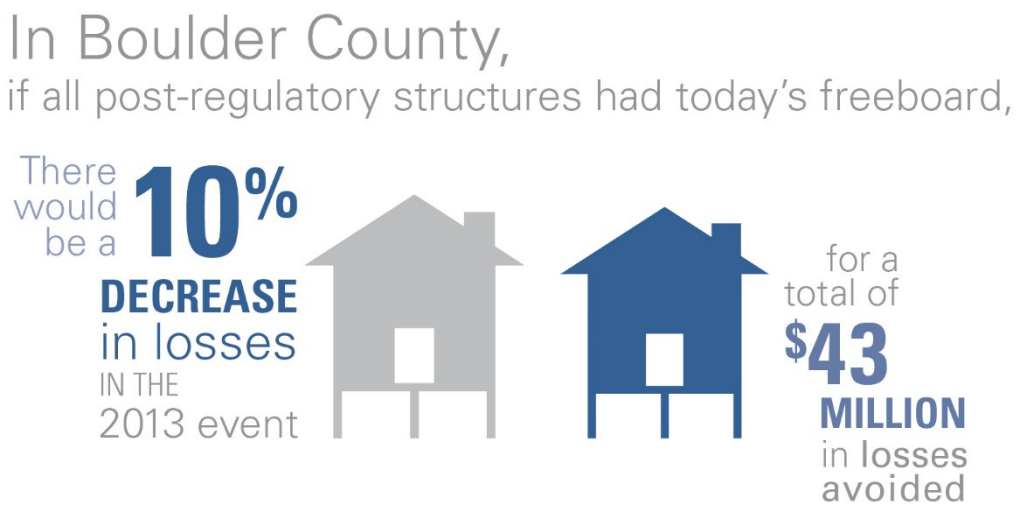

Figure 6-23: Boulder County Total Losses (MP_C) in the 2013 Event if Freeboard was Adopted Earlier

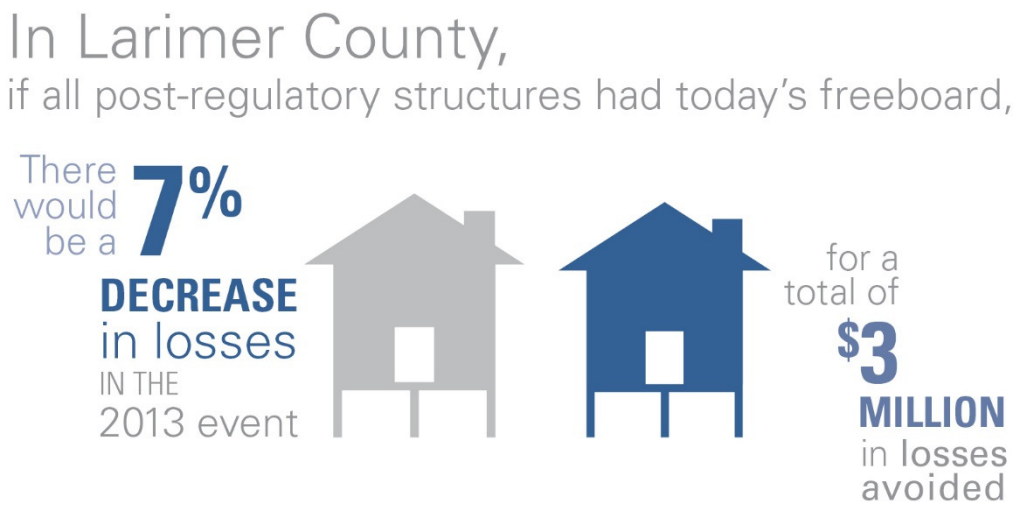

Figure 6-24: Larimer County Total Losses (MP_C) in the 2013 Event if Freeboard was Adopted Earlier

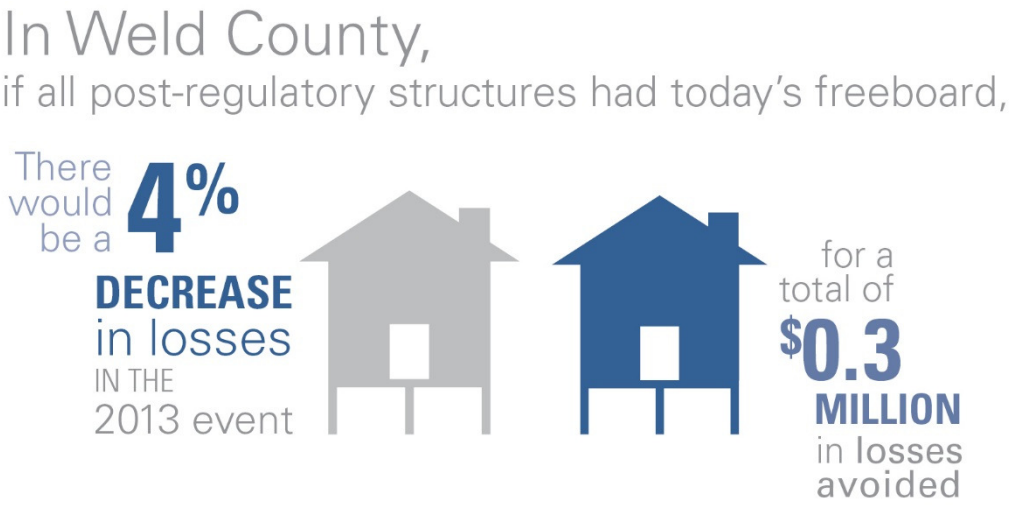

Figure 6-25: Weld County Total Losses (MP_C) in the 2013 Event if Freeboard was Adopted Earlier

6.2.2 Freeboard Never Adopted

This scenario analyzes the total losses in structures in the SFHA when the existing freeboard is removed. The following question was addressed:

If freeboard was never regulated what would the losses be in the 100-year event?

The total MP_C losses are the losses that would have occurred if freeboard regulations never had been adopted. The total MP_C losses in the 100-year event are shown in Figure 6-26.

Figure 6-26 may be compared to the MP_A results shown in the pie chart in Figure 6-16. The total losses increase from $619 million to $2.3 billion if freeboard had never been adopted. Eighty-seven percent of the total losses are in Boulder County. The losses are $2 billion in Boulder County alone compared to the total losses of $465 million that occur when freeboard is adopted. In Boulder County the losses are more than four times greater.

In Larimer and Weld Counties the total losses are also greater. In both counties the losses are almost double the 100-year event results, MP_A, when freeboard is removed.

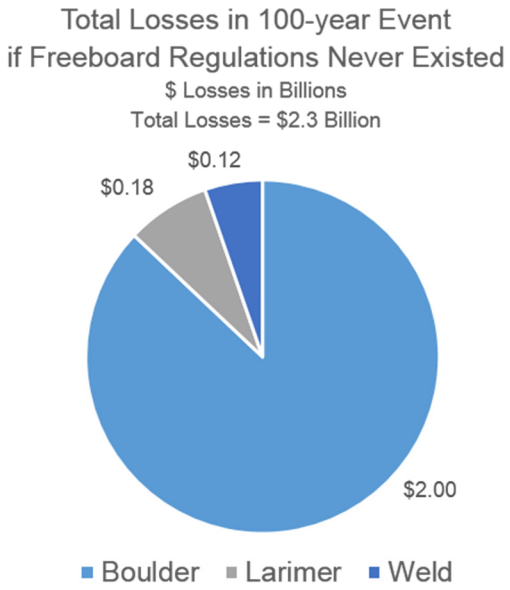

Figure 6-26: 100-year Event Losses by County if Freeboard was Never Adopted (MP_C)

Figure 6-27 shows the total losses to SFHA structures in the 100-year event and the losses avoided if freeboard had never been adopted. The losses avoided are the difference between the MP_A and the MP_C. The total MP_A losses are $619 million. The total MP_C losses are $2.3 billion. The negative losses avoided shows that there are more losses when there is no freeboard.

Figure 6-27: Losses Avoided in the 100-year Event in SFHA Structures if Freeboard was Never Adopted

The percent losses avoided to total losses shows the percent increase or decrease. When it is negative, there are more losses after the regulation is implemented then when it is not. By removing freeboard, the total losses increase.

In Boulder County the losses avoided equal -331 percent of the total MP_A losses. The existing freeboard regulation reduces damages by $1.5 billion in Boulder in a 100-year event. In Larimer County, the losses avoided are -68 percent; the existing freeboard reduces damages by $71 million in the 100-year event. In Weld County the losses avoided are -148 percent of the total. The existing freeboard reduces damages in Weld County by $73 million in the 100-year event.

Figures 6-28, 6-29, and 6-30 provide a summary overview of the 100-year event impacts by county if freeboard had never been adopted. These results are the MP_C results. The event impacts

include the number of structures with reduced and/or no damages and the overall impact on the event losses.

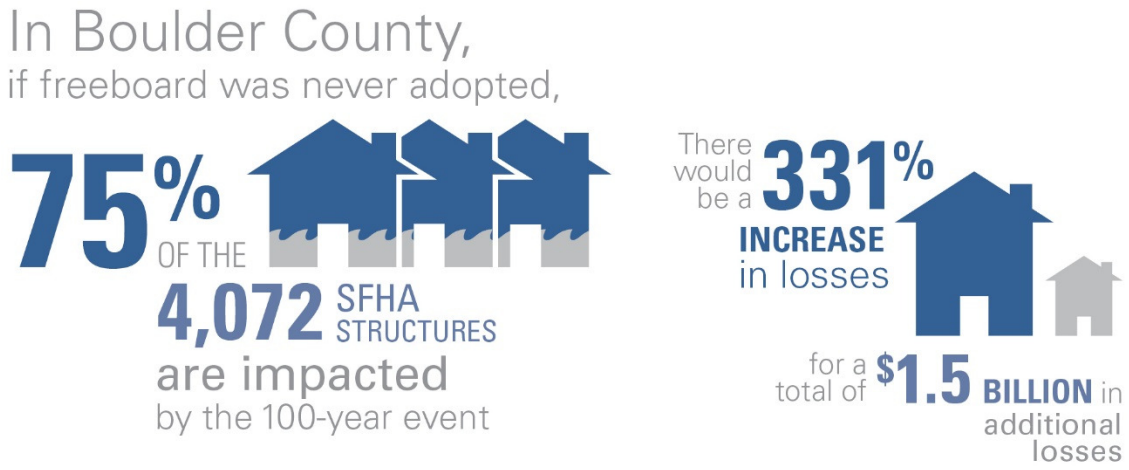

Figure 6-28: Boulder County Total Losses (MP_C) if Freeboard was Never Adopted in the 100-year Event

The increase in losses in Boulder County is greater than 300% if freeboard regulations had never been adopted. The number of impacted SFHA structures is 75 percent. This is why the MP_C losses are the highest in Boulder County in this scenario. There are an additional 1,783 structures impacted in Boulder if freeboard was never adopted from the floodplain scenario. In other words, the freeboard regulations have reduced damages in over 1,500 structures and reduced potential losses by $1.5 billion.

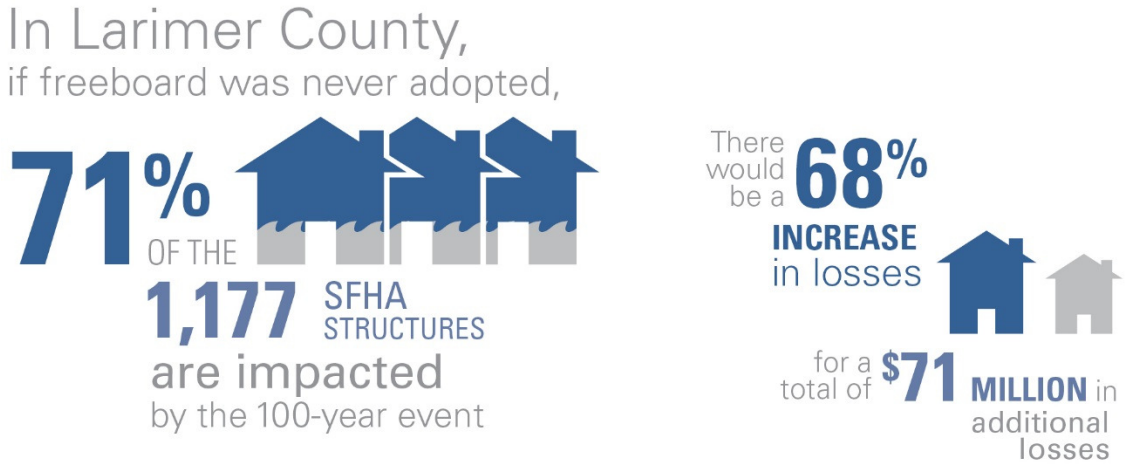

Figure 6-29: Larimer County Total Losses (MP_C) if Freeboard was Never Adopted in the 100-year Event

The increase in losses in Larimer County is 68 percent if freeboard regulations were never adopted. This totals $71 million in losses avoided. The freeboard in Larimer protects fewer structures from 100-year event impacts than the freeboard in Boulder.

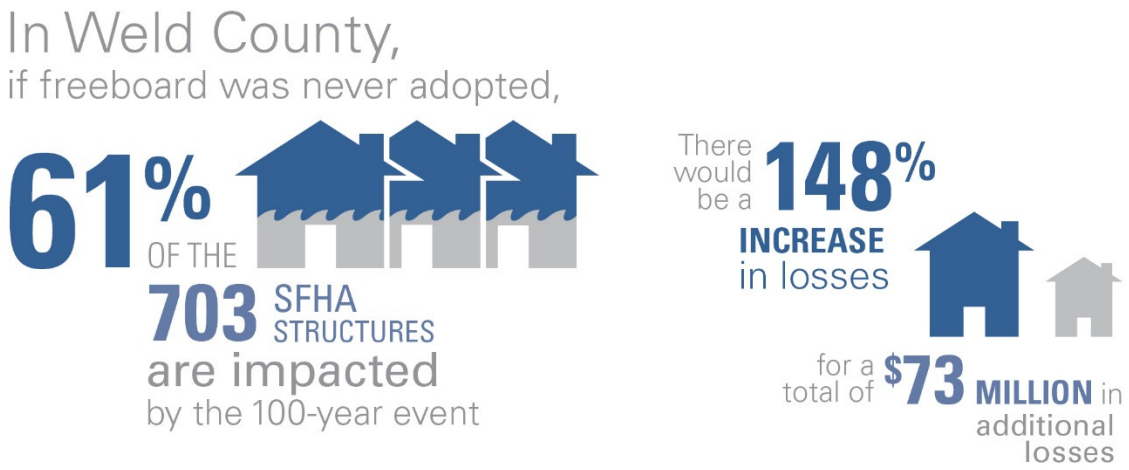

Figure 6-30: Weld County Total Losses (MP_C) if Freeboard was Never Adopted in the 100-year Event

The increase in losses in Weld County is greater than 148 percent if freeboard regulations had never been adopted. The percent of impacted structures increases from 31 percent to 61 percent when no freeboard regulations are adopted.

2013 Event Results

This scenario analyzes the losses to freeboard-regulated structures as a result of the 2013 Colorado flood event if freeboard was removed. The losses are obtained from the FEMA IA reports and the FVL. The following question was addressed:

If freeboard was never regulated, what would the losses have been in the 2013 event?

Figure 6-31 depicts the total losses in the 2013 event. The total losses are the MP_C results. Boulder County accounts for 92 percent of the total losses, Larimer 6 percent, and Weld 1 percent.

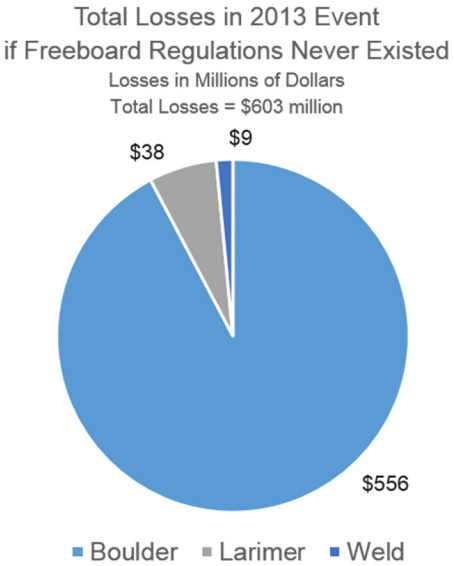

Figure 6-31: 2013 Event Losses by County if Freeboard was Never Adopted (MP_C)

Figure 6-32 shows the total losses and losses avoided in the 2013 event. The losses avoided are the difference between the MP_A and the MP_C. The total MP_A losses are $619 million. The total MP_C losses are $480 million.

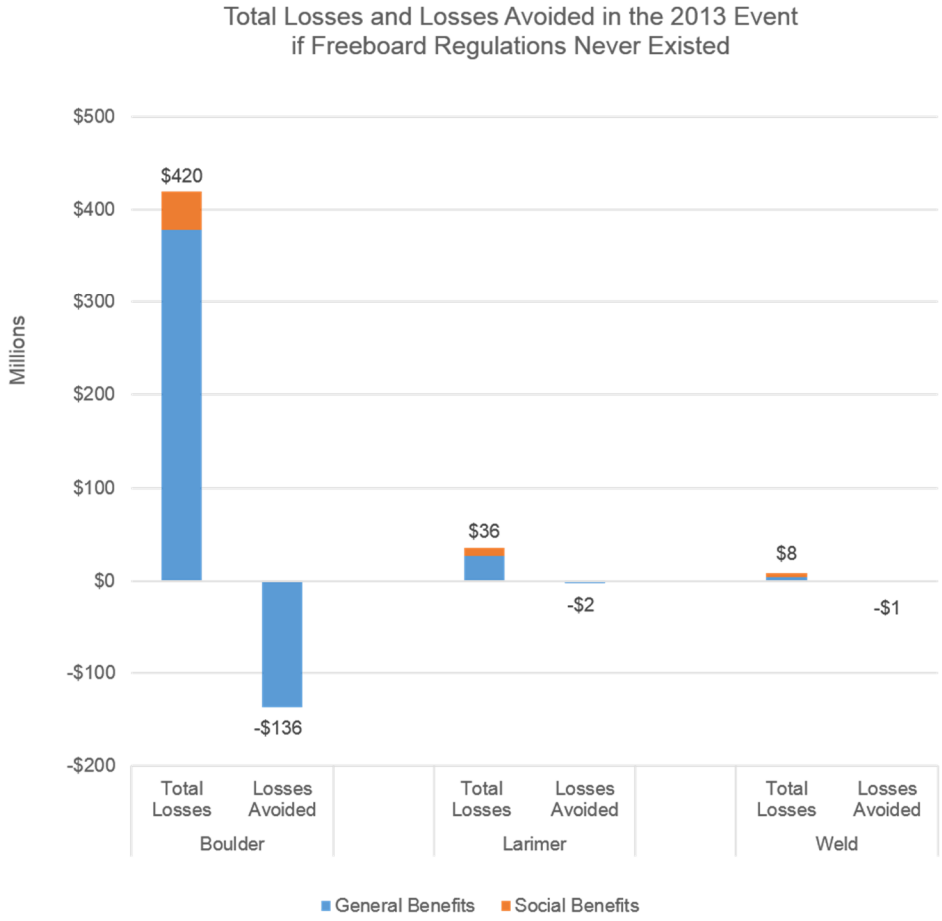

Figure 6-32: Losses Avoided in the 2013 Event in SFHA Structures if Freeboard was Never Adopted

The negative losses avoided in Figure 6-37 shows that there are more losses when there is no freeboard. The negative losses avoided in all three counties means that the losses would have increased in the 2013 event if freeboard was not regulated. The estimated amount that was saved in Boulder due to the existing freeboard regulation is $136 million. In Larimer, $2 million is the avoided losses in the 2013 event and in Weld $1 million is the avoided losses.

Figures 6-33, 6-34 and 6-35 provide a summary of the 2013 event impacts by county if freeboard had never been adopted. These results are the MP_C results and show the percent increase and total losses avoided for the scenario in each county.

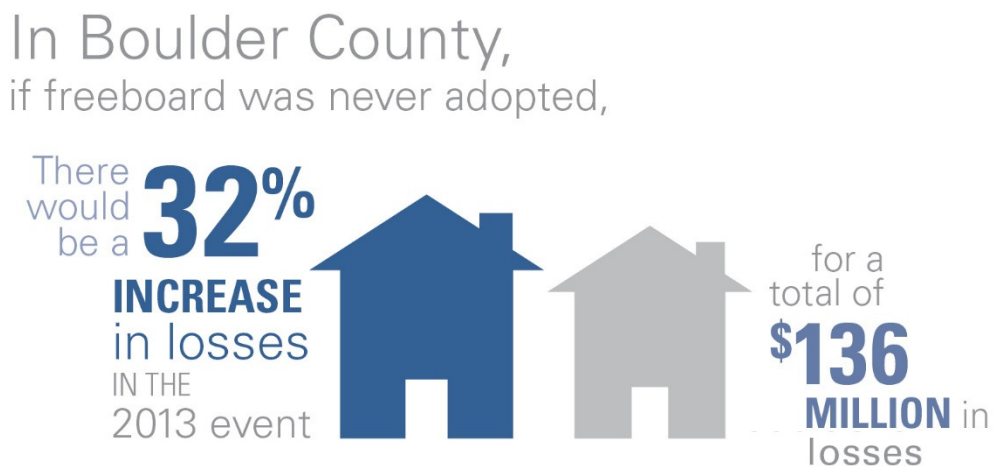

Figure 6-33: Boulder County Total Losses (MP_C) if Freeboard was Never Adopted in the 2013 Event

Figure 6-34: Larimer County Total Losses (MP_C) if Freeboard was Never Adopted in the 2013 Event

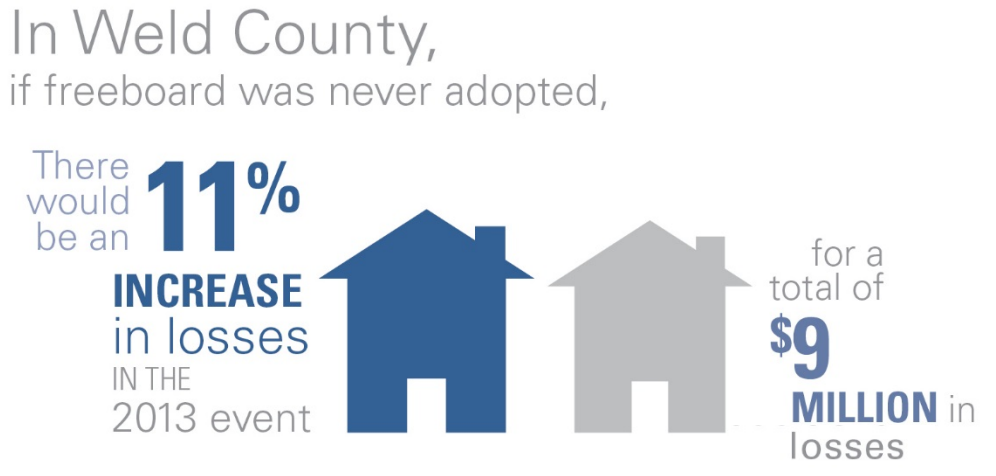

Figure 6-35: Weld County Total Losses (MP_C) if Freeboard was Never Adopted in the 2013 Event

6.2.3 Freeboard Regulated to a Higher or Lesser Standard

This freeboard scenario analyzes the effect of adopting a higher or lesser freeboard standard. The MP_C results are the results of modeling a regulatory change of -2, -1, +1, and +2 feet below and above the existing freeboard in each jurisdiction. The following question was addressed:

> *What are the losses and losses avoided for having imposed a higher, or lesser, freeboard regulation in the 100-year event?*

This scenario analyzes the losses to freeboard regulated structures if the freeboard were increased or decreased. The total losses in the 100-year event if freeboard was two feet higher (+2) and if freeboard was two feet lower (-2) are shown in Figure 6-36.

The total MP_A losses, from Figure 6-16, are $619 million. If freeboard is increased by two feet then the total losses reduce to $153 million. If freeboard is decreased by two feet, the total losses are $2.8 billion.

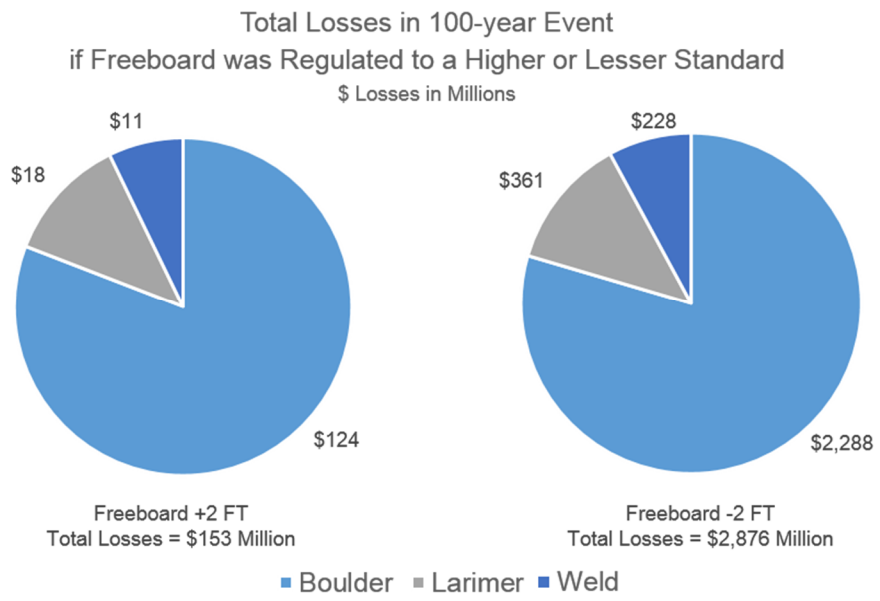

Figure 6-36: 100-year Event Losses by County if Freeboard was Regulated 2 Feet Higher or Lower (MP_C)

Figure 6-37 shows the percent losses avoided in the 100-year event if the existing freeboard regulations were changed. The percent losses avoided is the total losses avoided divided by the total MP_A losses. The total MP_A losses are $221 million for all cases. The total MP_C losses after an increase of two feet of freeboard are $153 million. After an increase of one foot of freeboard, the MP_C is $307 million. The MP_C losses when freeboard is reduced are $1.5 billion for a one-foot reduction in freeboard and $2.9 billion for a two-foot reduction in freeboard.

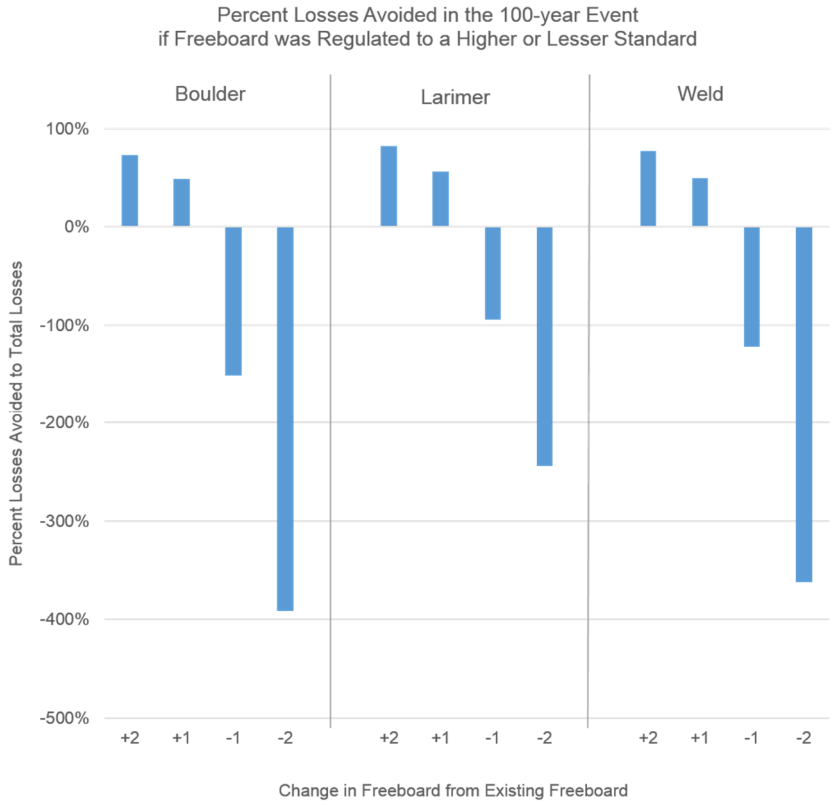

Figure 6-37: Losses Avoided in the 100-year Event if Freeboard was Regulated to a Higher or Lesser Standard

The sign of the percent losses avoided demonstrates whether the regulatory change had a positive or negative effect on the MP_C losses. When the percentage is positive it shows that there are fewer losses due to the regulatory change; when it is negative there are more losses. The freeboard increases of +2 feet and +1 foot reduce the total losses. The freeboard decreases of -2 feet and -1 foot increase the total losses.

Overall, when freeboard is increased by one or two feet, the losses avoided percentage is between 49 and 100 percent. That means that the total losses with the existing freeboard regulation would be reduced by nearly half (or more) in the 100-year event if freeboard was increased. However, when freeboard is reduced by one or two feet, the effect on the total losses is much greater. For a reduction in freeboard of one foot (-1), the percent losses avoided are between -95 and -151 percent of the MP_A total losses. This means that the MP_C losses are double (or nearly double) the MP_A losses when one foot of freeboard is removed. When there is a reduction of freeboard of two feet (-2), the percent losses avoided are higher. In Boulder County, the percent losses avoided are -392 percent of the total MP_A losses. In Larimer County, they are -244 percent and in Weld County they are -362 percent. In terms of the change in total losses, the MP_A losses in Boulder are $465 million and the MP_C losses due to a two foot reduction in freeboard is $2.29 billion. In Larimer this change is $105 million MP_A to $361 million MP_C. In Weld the change is $49 million MP_A to $228 million MP_C.

Figures 6-38, 6-39 and 6-40 provide a summary of the 100-year event impacts by county if freeboard was increased by two feet. These results are the MP_C results. The event impacts include the number of structures with reduced and/or no damages and the overall impact on the event losses.

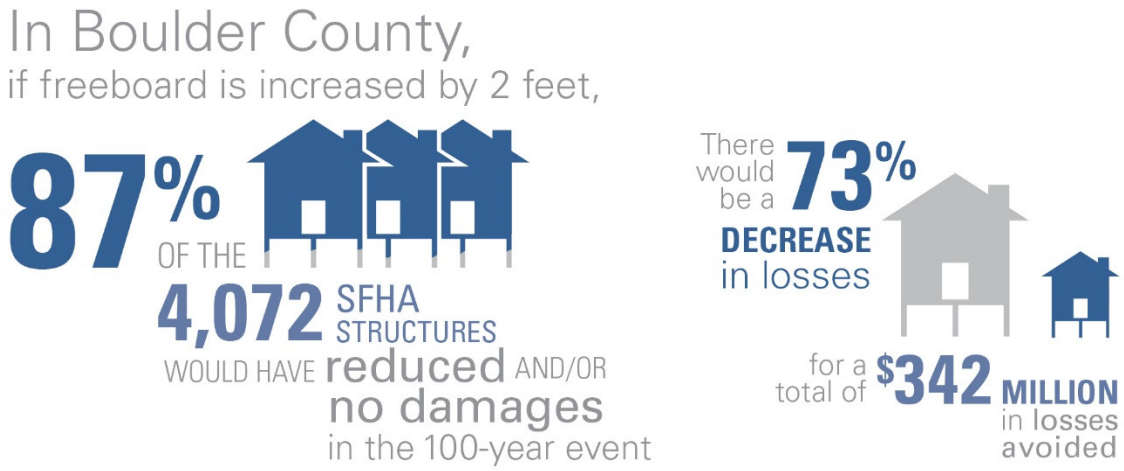

Figure 6-38: Boulder County Total Losses (MP_C) in the 100-year Event if Freeboard is Increased

An additional two feet of freeboard in Boulder County would decrease the number of impacted structures from 31 percent to 13 percent in the 100-year event.

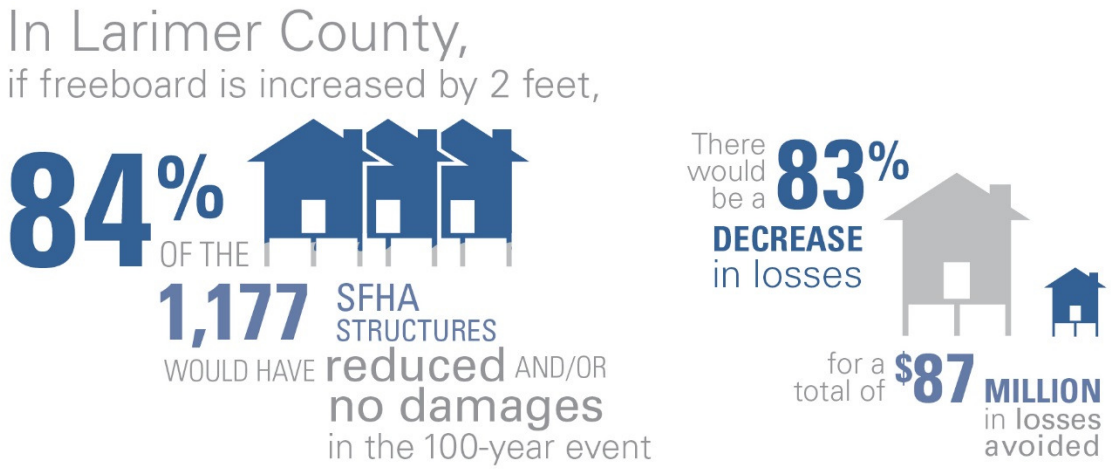

Figure 6-39: Larimer County Total Losses (MP_C) in the 100-year Event if Freeboard is Increased

An additional two feet of freeboard in Larimer County would decrease the number of impacted structures from 61 percent to 16 percent in the 100-year event.

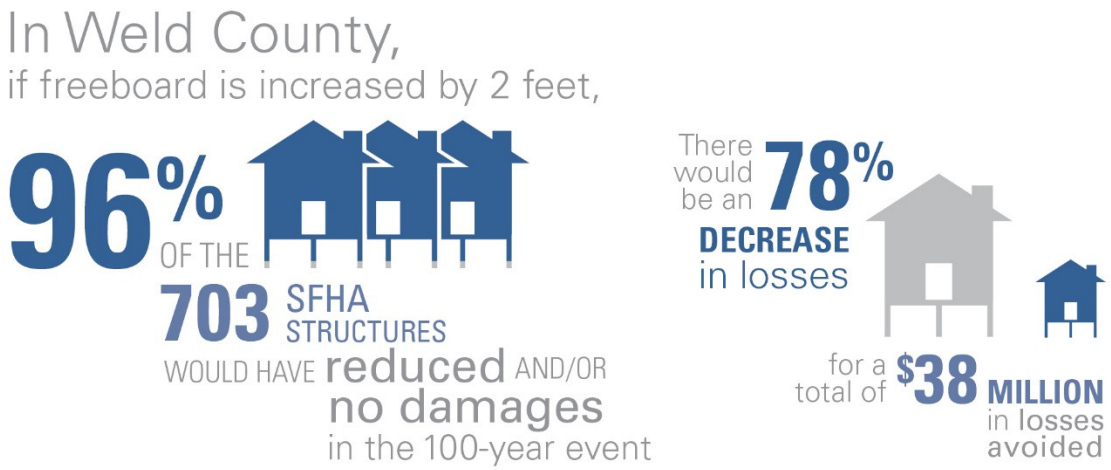

Figure 6-40: Weld County Total Losses (MP_C) in the 100-year Event if Freeboard is Increased

An additional two feet of freeboard in Weld County would decrease the number of impacted structures from 31 percent to 4 percent in the 100-year event.

2013 Event Results

This freeboard scenario analyzes the effect of adopting a higher or lesser freeboard standard. The MP_C is the result of modeling a regulatory change of -2, -1, +1, and +2 feet below and above the existing freeboard in each jurisdiction. The following question was addressed:

> *What are the losses and losses avoided for having imposed a higher, or lesser, freeboard regulation on the 2013 event results?*

Figure 6-41 depicts the total losses in the 2013 event if freeboard was increased by two feet and if freeboard was reduced by two feet. The total losses are the MP_C results.

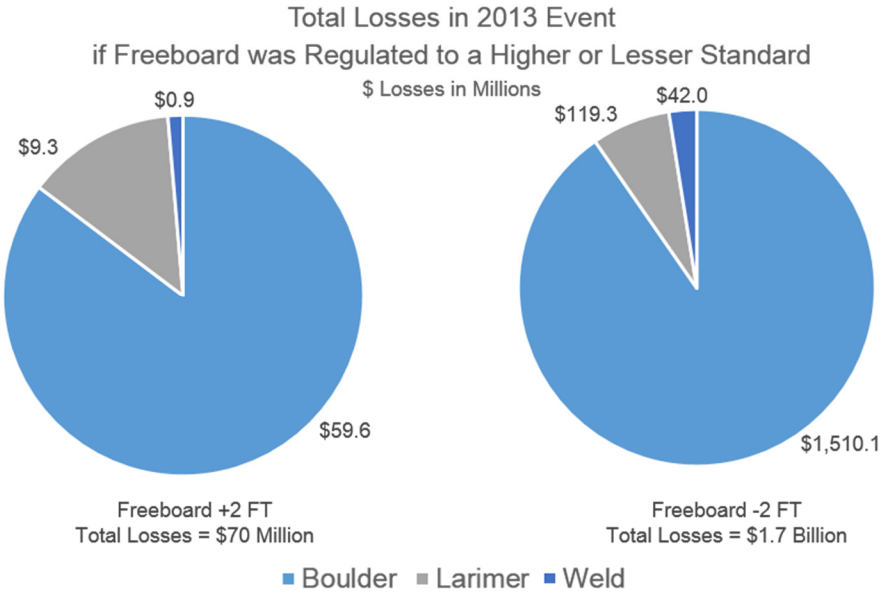

Figure 6-41: 2013 Event Losses by County if Freeboard was Regulated Two Feet Higher or Lower (MP_C)

The total MP_A losses for the 2013 event, shown in Figure 6-21, are $464 million. If freeboard is increased by two feet then the total losses reduce to $70 million. If freeboard is decreased by two feet, the total losses are $1.7 billion.

Figure 6-42 shows the percent losses avoided in the 2013 event if the existing freeboard regulations were changed. The percent losses avoided is the total losses avoided divided by the total MP_A losses. The total MP_A losses are $464 million for all cases. The total MP_C losses after an increase of two feet of freeboard are $70 million and after an increase of one foot of freeboard the MP_C is $204 million. The MP_C losses when freeboard is reduced are $1.0 billion for a one foot reduction in freeboard and $1.7 billion for a two-foot reduction in freeboard.

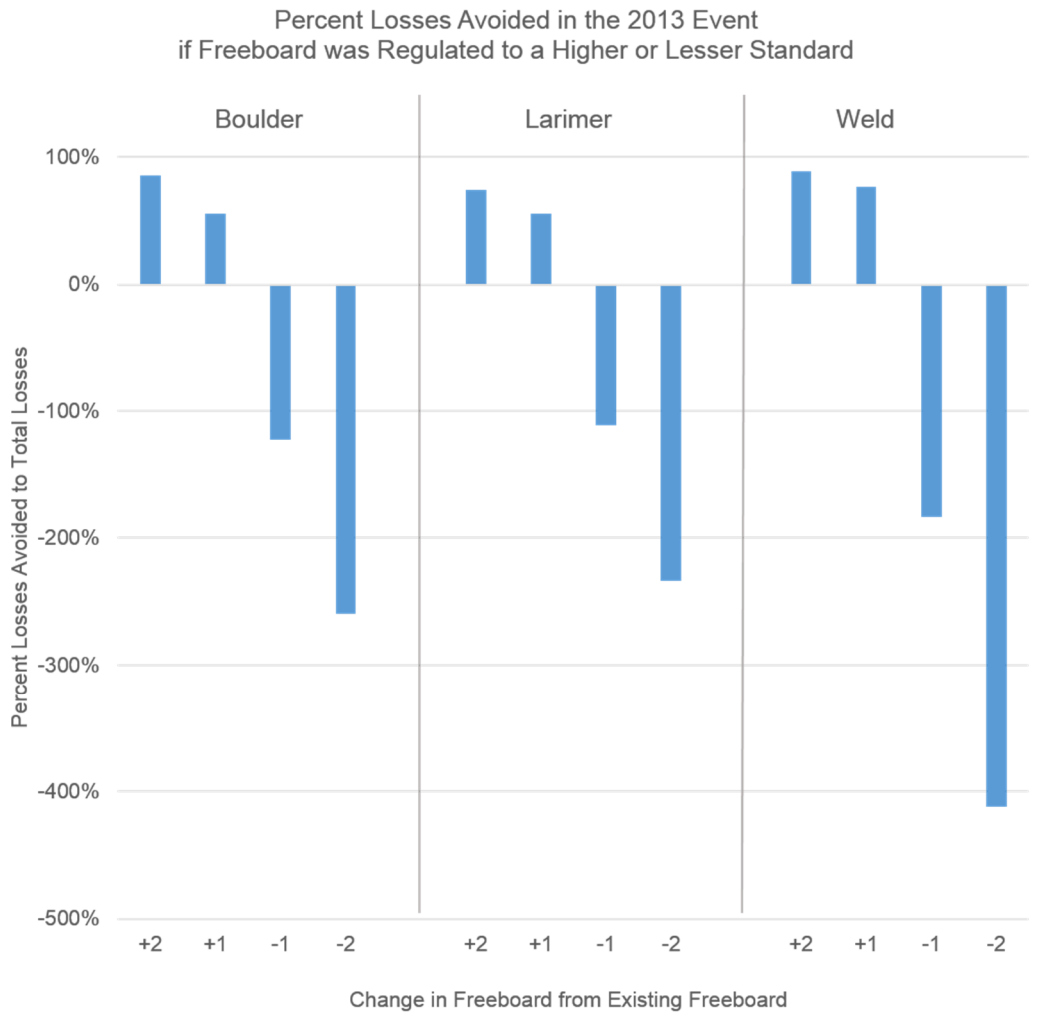

Figure 6-42: Losses Avoided in the 2013 Event if Freeboard was Regulated to a Higher or Lesser Standard

Overall, when freeboard is increased by one or two feet, the losses avoided percentage is between 50 and 100 percent. The total losses in the 2013 event would have been cut in half if freeboard was increased by either one or two feet. The one- or two-foot reduction in freeboard

increases the losses. For a reduction in freeboard of one foot (-1), the percent losses avoided are greater than 100 percent. The 2013 losses would have been at least double if freeboard was one foot lower. When there is a reduction of freeboard of two feet (-2), the percent losses avoided are 200 to 400 percent. The losses would have been much greater with a reduction in freeboard.

In Weld County, the percent losses avoided in the two foot reduction in freeboard case is 412 percent. The total losses in the 2013 event are estimated to be $8 million. With this reduction in freeboard the losses would have been $42 million. The higher percent of losses avoided in Weld County in the two freeboard reduction cases indicates the current freeboard may not be high enough.

Figures 6-43, 6-44 and 6-45 provide a summary overview of the 2013 event impacts by county if freeboard was increased by two feet. These results are the MP_C results.

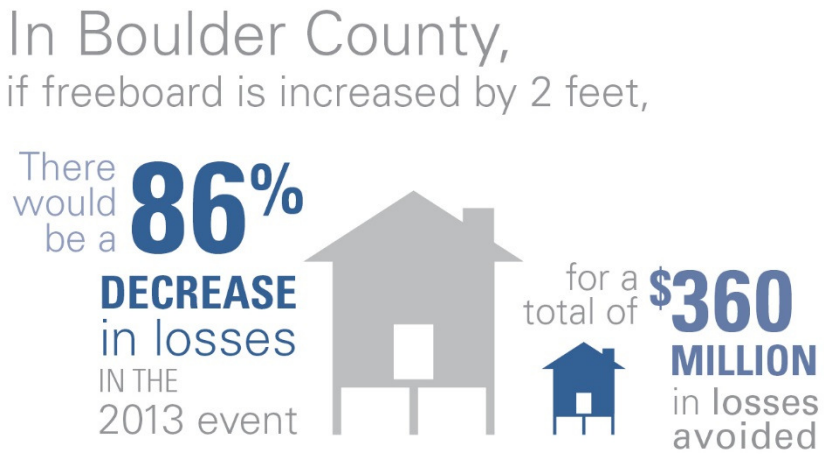

Figure 6-43: Boulder County Total Losses (MP_C) in the 2013 Event if Freeboard is Increased

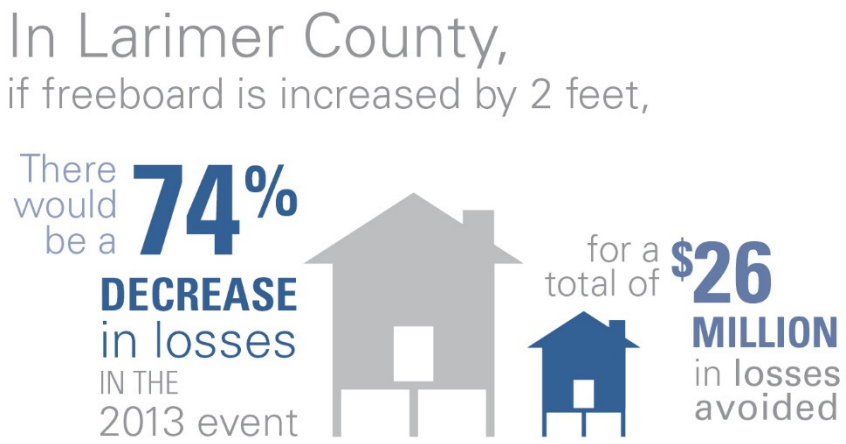

Figure 6-44: Larimer County Total Losses (MP_C) in the 2013 Event if Freeboard is Increased

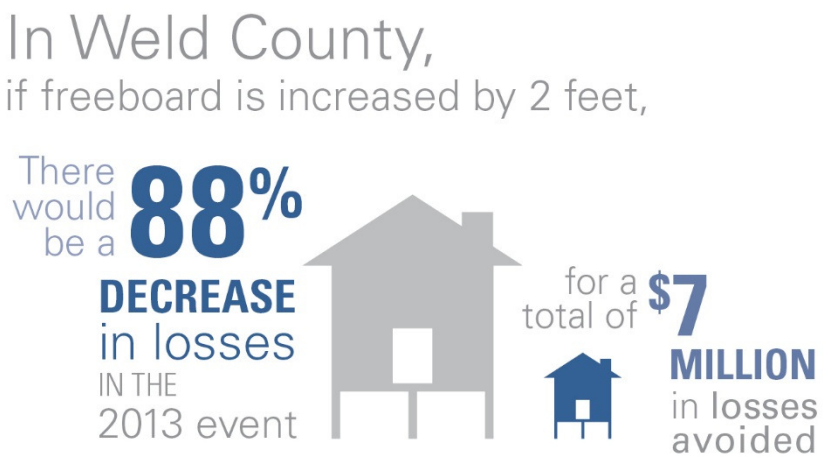

Figure 6-45: Weld County Total Losses (MP_C) in the 2013 Event if Freeboard is Increased

6.3 CRITICAL FACILITIES REGULATED IN SFHA

This scenario analyzes the regulatory standard of prohibiting all critical facility development in the SFHA. Critical facilities are identified and analyzed in this scenario if the critical facility is located in the SFHA, regardless of the year built. In this scenario, the following question is asked:

> *What would the losses and losses avoided be if all development of critical facilities in the SFHA had never been permitted?*

The total losses are of the critical facilities located in the SFHA. Boulder has the highest total losses in the 100-year event as depicted in Figure 6-46. These are the MP_A losses. Boulder County accounts for 94 percent of the total losses, Larimer County 7 percent, and Weld County less than 1 percent.

Figure 6-47 shows the total losses and losses avoided in the 100-year event. This scenario analyzes the removal of all critical facilities from the SFHA. Therefore, the losses avoided are equal to the total losses. The total MP_A losses are $23 million. The total MP_C losses are $0.

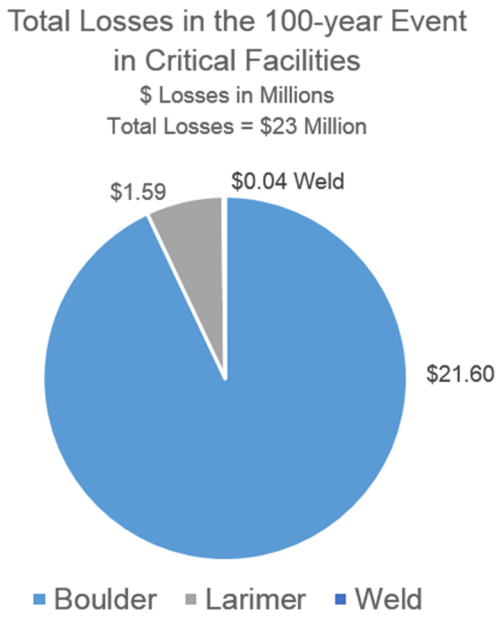

Figure 6-46. 100-year Event Losses by County in Critical Facilities in the SFHA (MP_A)

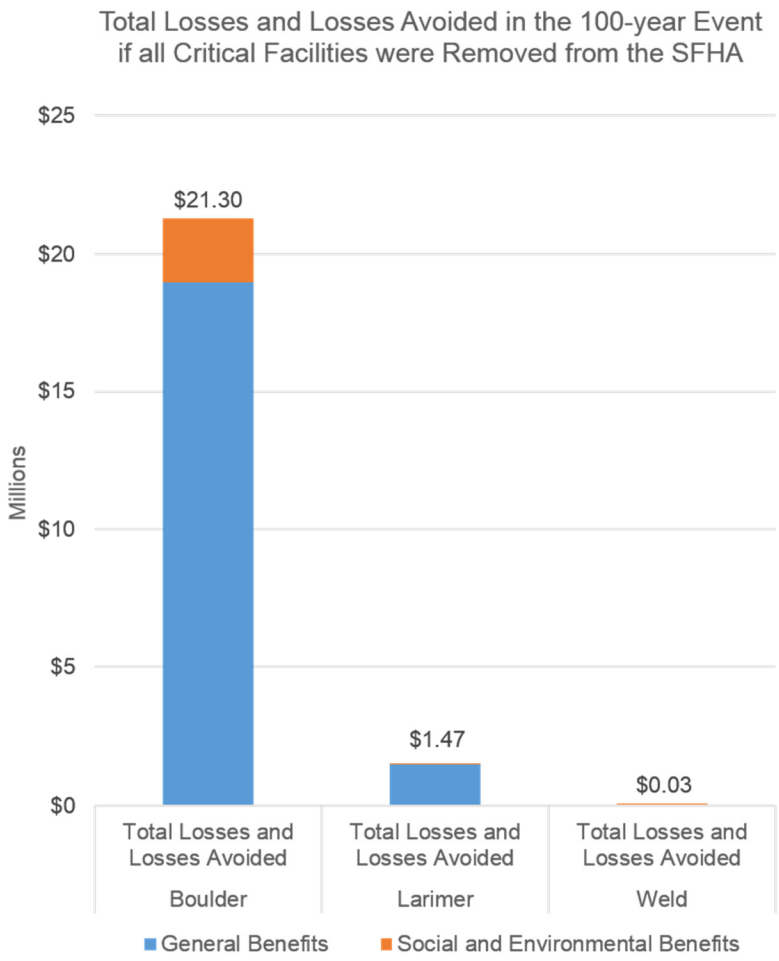

Figure 6-47: Losses Avoided in the 100-year Event in Critical Facilities

The highest total losses are in Boulder County. If critical facilities are removed from the SFHA then the percent of losses avoided is 100%. The regulatory measure to place siting restrictions on critical facilities in the SFHA would reduce losses and could result in an MP_C of $0 to the most critical facilities. In addition, there is an environmental benefit to removing structures from the SFHA. The environmental benefit is a smaller percentage of the total benefit in Figure 6-47 because the total acreage and the number of impacted structures is smaller.

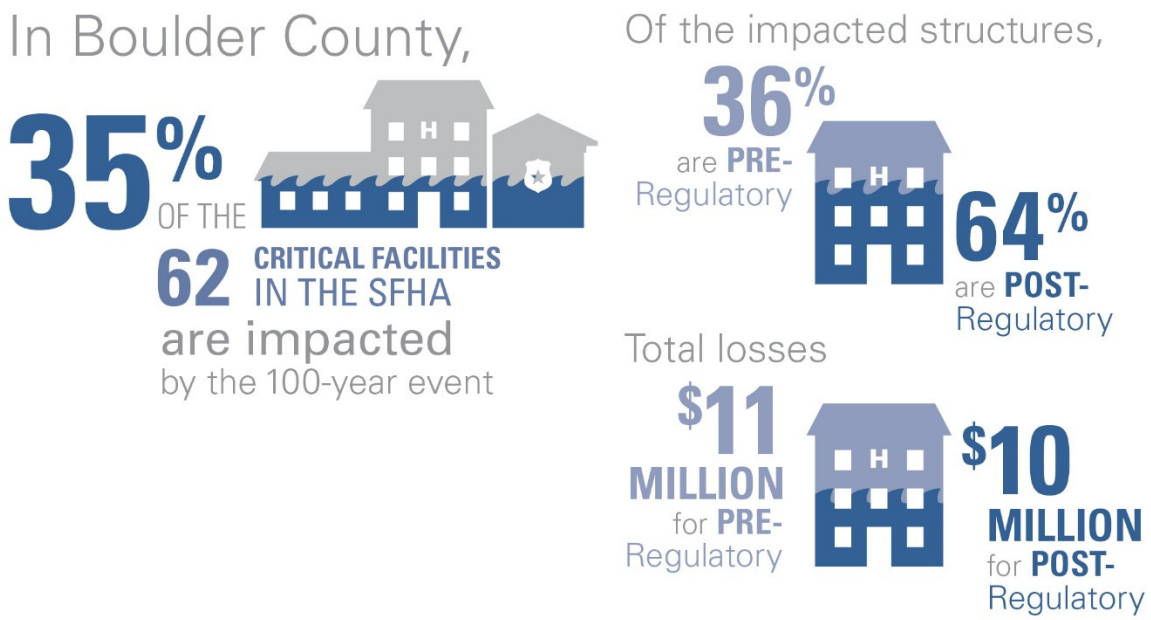

Figure 6-48: Boulder County Total Losses (MP_A) in Critical Facilities in the 100-year Event

If critical facility siting restrictions had been implemented when Boulder communities first joined the NFIP, the losses avoided would be $10 million. There are more post-regulatory critical facilities than pre-regulatory.

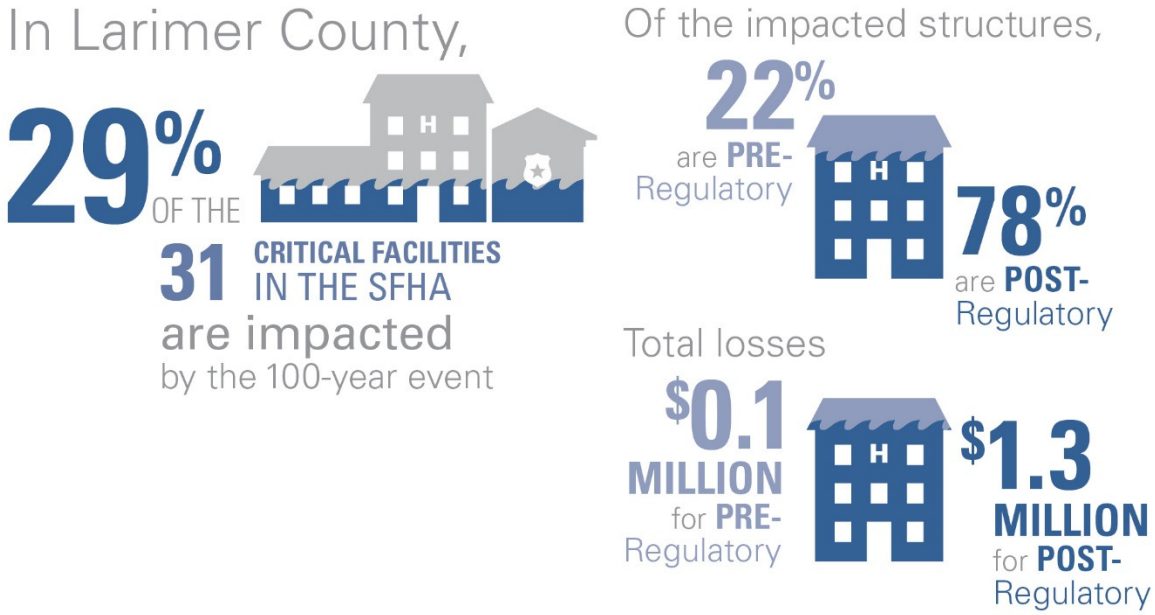

Figure 6-49: Larimer County Total Losses (MP_A) in Critical Facilities in the 100-year Event

If critical facility siting restrictions had been implemented when Larimer jurisdictions first joined the NFIP, then the losses avoided would be $1.3 million.

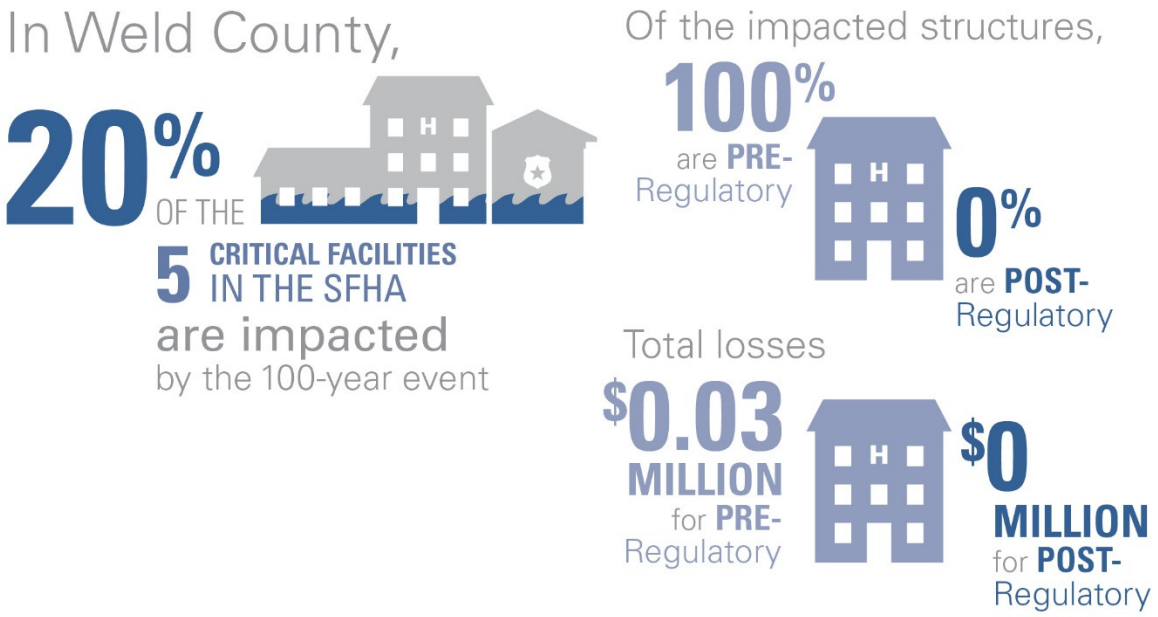

Figure 6-50: Weld County Total Losses (MP_A) in Critical Facilities in the 100-year Event

In Weld County, the critical facilities in the SFHA are pre-regulatory. If critical facility siting restrictions had been implemented when Weld jurisdictions first joined the NFIP, there would have been no losses avoided. The pre-regulatory structures would have to have a different regulation applied to mitigate the losses that would occur in the 100-year event.

2013 Event Results

There are no FEMA IA-impacted structures in the critical facilities scenario structures. This section does not include 2013 event results.

6.4 EROSION SETBACK ASSESSMENT

These results are for the erosion setback of structures in the St. Vrain Creek erosion hazard area. The MP_A was estimated as the total of the IA FVL from the 2013 Colorado floods in the study area. The MP_C was estimated as the FEMA IA-verified losses from the 2013 Colorado floods for those structures in the study area but not in the erosion zone. Of the 363,335 structures in the study area, 698 were found to be in the St. Vrain Creek erosion hazard area, as depicted in Table 6-1.

Table 6-1: 2013 Colorado Floods Erosion Setback Assessment

St. Vrain Erosion Hazard Area Structures	2013 Flood Event Impacted Structures	Losses Avoided (MP_C)
698	153	$1,431,876

Of those 698, 153 structures had FEMA-verified losses as a result of the 2013 Colorado floods. The total FEMA IA-verified losses, which equates to the losses avoided if these structures were removed from the erosion zone, were $1,431,876. This scenario used IA data for the losses avoided; however, analyzing the count of NFIP claims and policies provides additional

information about the losses: 39 structures in the erosion zone had NFIP policies and 36 made NFIP claims.

6.5 BENCHMARK YEARS

This section details the results of how the adoption of jurisdiction regulations over time affects losses. The discussion in this section reviews the data analysis as opposed to the previous sections that are scenario-based and present losses avoided.

- **The overall ratio of damage cost to replacement value declines over time** (see Figure 6-51). This ratio is calculated as the total reported damage cost divided by the total replacement value of all structures for a given jurisdiction and building-year. Each data point in Figure 6-51 represents the damage-to-replacement cost ratio for structures built during a period of stable regulatory standards in each jurisdiction (i.e., a period of time where the jurisdiction's CRS c430 [higher regulatory standards] score remained constant). The downward-sloping trend line suggests that the cost of flood damages as a percentage of the potential cost decreases as regulatory standards become more stringent. One limitation for this analysis is that the 2013 event severity was not the same in each jurisdiction.

- **The cost of damage per building generally increases over time**. This result may seem counterintuitive given that regulatory standards in the analyzed jurisdictions generally become more stringent over time; however, it is likely caused by newer homes having a higher replacement cost because they are generally larger and of higher-quality construction. For this reason, the ratio of damage to replacement cost for each damaged structure is a more reliable measure of the effectiveness of a jurisdiction's regulatory standards on reducing flood loss.

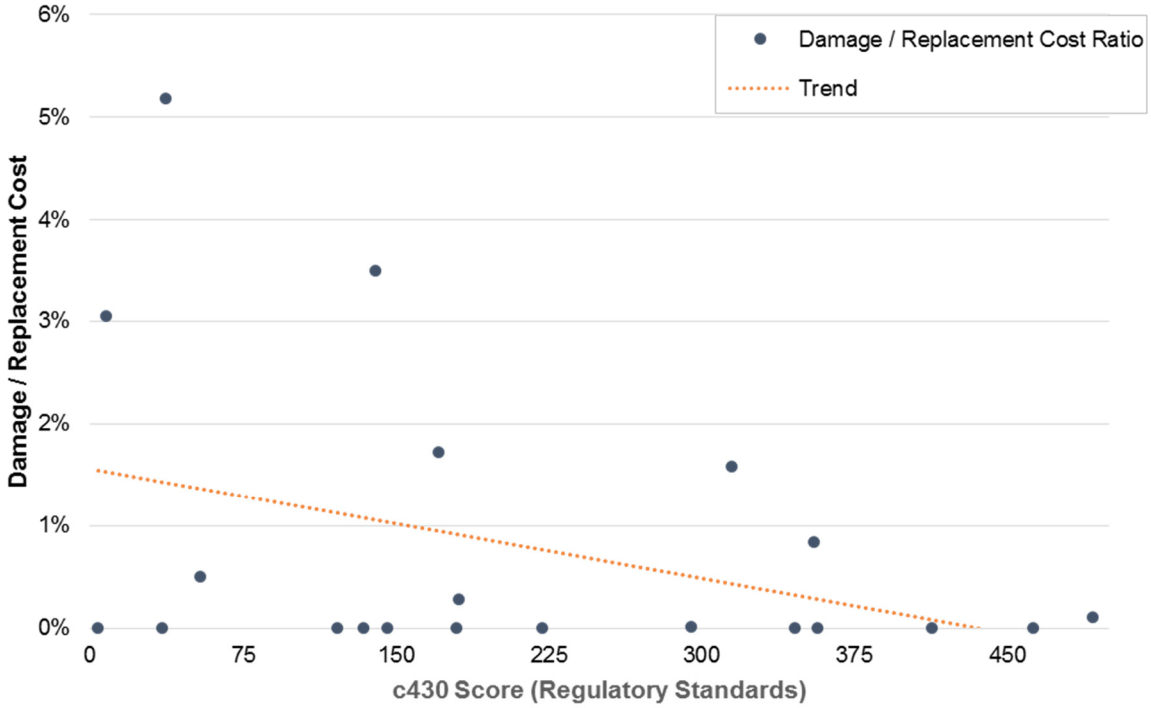

Figure 6-51: Damage-to-Replacement Cost for Various Jurisdiction Regulatory Standards, 1998-2013

Other Observations & Considerations

- This analysis used a subset of the main study area to include five jurisdictions: Unincorporated Boulder County, City of Boulder, Fort Collins, Longmont, and Louisville. Of the nearly 11,000 structures that suffered damage from the 2013 floods, over 8,900 of them are located in the five jurisdictions included in this analysis, but just 399 were built after 1998 (the first year CRS scores for regulatory standards are available).

- According to the data, only 45 structures were built in Louisville between 1999 and 2013, and none suffered damage in the 2013 floods.

- Of the nearly 14,000 structures built in Fort Collins from 1998-2013, just eight were damaged in the flood according to the data.

- As shown in Figure 6-52, if jurisdictions that suffered little damage among post-1998 structures are removed from the analysis, the downward trend in damage-to-replacement cost as c430 scores increase is even more pronounced.

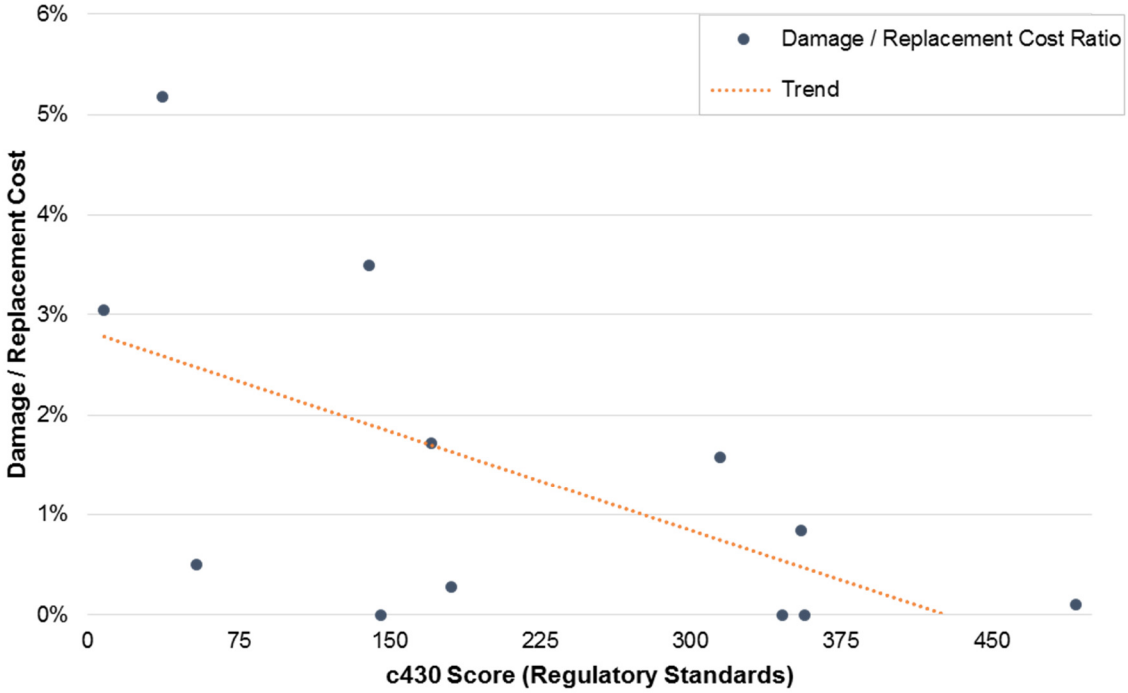

Figure 6-52: Damage-to-Replacement Cost for Various Jurisdiction Regulatory Standards, 1998 – 2013 (Jurisdictions with 10 or More Post-1998 Structures Damaged)

- Although the damage-to-replacement cost ratio generally declines as CRS c430 scores increase, the statistical significance of the association between these two variables was not assessed. The relationship may or may not be causal in nature; there are other factors that could play a role in the correlation. For example, building practices and the quality of materials have likely improved since 1998, and this improvement, as opposed to changes in regulatory standards, could be a primary driver of reduced flood damage as a percentage of replacement cost.

6.6 NFIP CLAIMS

This section describes how the adoption of jurisdiction regulations, as reflected in CRS scores, affects NFIP claims and policies. The discussion in this section is similar to the "Benchmark Years" section, analyzing specific conditions as opposed to losses avoided. Communities with positive CRS "Outreach Projects" (c330) scores are collectively referred to as "high-outreach communities," while communities with a score of 0 for c330 are grouped together as "low-outreach communities."

NFIP Policies: The analysis, as depicted in Figure 6-53, suggests that communities with positive outreach scores in CRS (Fort Collins, City of Boulder, and Unincorporated Boulder County) are more successful in enrolling structures in the NFIP — both inside and outside the SFHA.

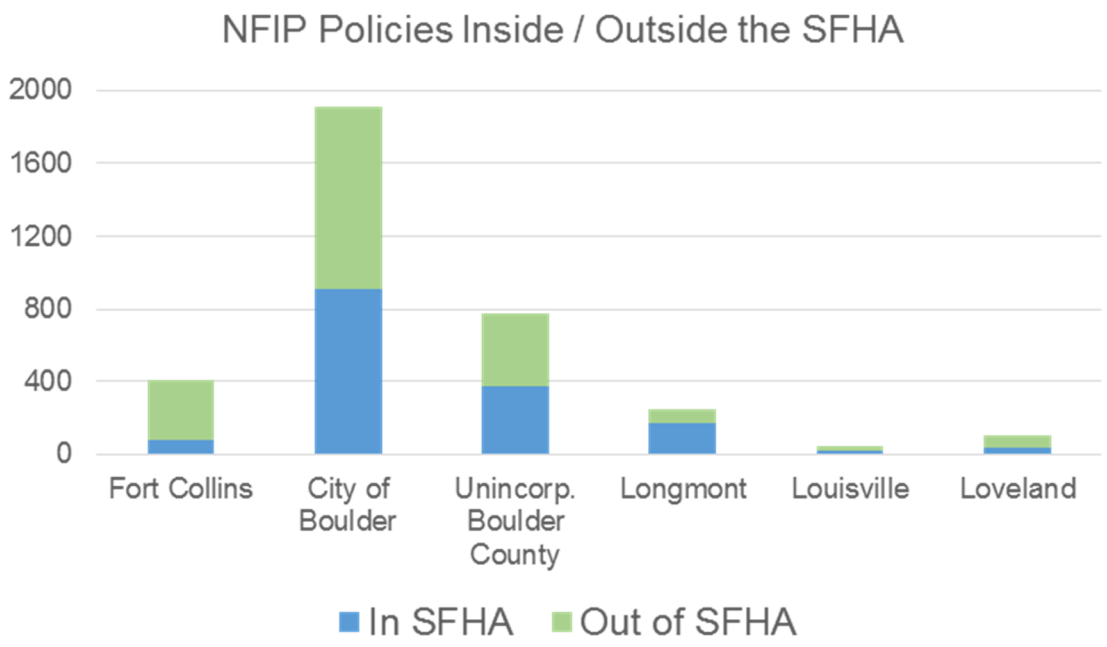

Figure 6-53: NFIP Policies Inside / Outside SFHA

- Structures in high-outreach communities comprise nearly 90 percent of total policies in the study area; more than half of these policies (56 percent) are for structures outside the SFHA.[4] In communities with low CRS outreach scores (i.e., Longmont, Louisville, and Loveland), a substantially lower percentage of policies (42 percent) cover non-SFHA structures. This is consistent with the theory that improved community outreach can encourage people who live outside the SFHA (and, as such, are generally not required to purchase flood insurance) to be more aware of their risk and to participate in the NFIP.

- The share of total structures that are (1) located in high-outreach communities and (2) covered by an NFIP policy is more than four times larger than the corresponding share in low-outreach communities. This result provides further evidence that high-outreach communities are more successful at understanding risk and encouraging NFIP participation than low-outreach communities.

[4] Although the three high-outreach communities contain nearly twice as many structures as the three low-outreach communities according to the full structure database, (114,000 vs. 60,000), this difference does not fully explain the NFIP enrollment discrepancy.

NFIP Claims: High-outreach communities generally benefitted from NFIP coverage more than low-outreach communities, as depicted in Figure 6-54. For more information on outreach strategies, refer to this study's companion report, *Best Practices and Cost Effective Strategies – 2013 Colorado Floods Case Study*. This result is unsurprising given that structures in high-outreach communities are more likely to participate in the NFIP, but it is also possible that these communities were harder hit by the flood than low-outreach communities. Outreach may also give citizens a better understanding of their individual risk, making them more likely to purchase insurance or implement mitigation measures as a result of the high-outreach efforts.

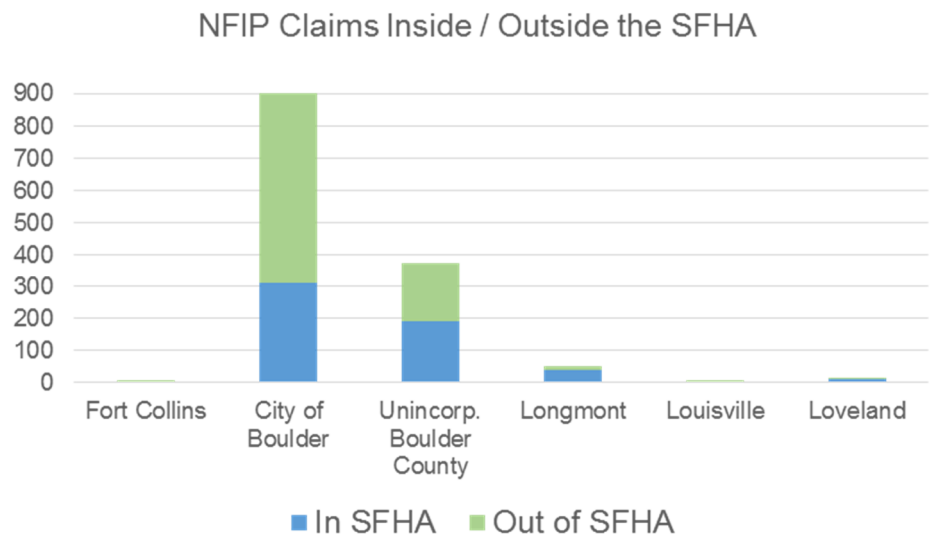

Figure 6-54: NFIP Claims Inside/Outside the SFHA

- Nearly 95 percent of the total number of structures that received an insurance claim are located in high-outreach communities (primarily City of Boulder and Boulder County). These structures received 85 percent of the total insurance payouts following the 2013 floods.

- Structures located in high-outreach communities that were insured through the NFIP were more than twice as likely to suffer damage and receive an insurance claim as insured structures in low-outreach communities.

- In high-outreach communities, 61 percent of structures that received claims are located outside the SFHA, and these structures received an average payout of nearly $19,000. In low-outreach communities, just 24 percent of structures receiving claims are outside the SFHA, but they received an average payout of over $33,000. These results can be inferred to mean that people who purchased insurance in the high-outreach jurisdiction were actually at a lower risk, or the jurisdiction had mitigated some of their risk, whereas the low-outreach communities had some high risk and a lower overall understanding of their risk.

- In high-outreach communities, more than two-thirds of structures receiving claims were pre-FIRM structures, whereas in low-outreach communities, structures receiving claims were evenly split between pre-FIRM and post-FIRM. This is possibly due to continual outreach efforts by high-outreach communities as opposed to only looking at the risk when new FIRMs are published.

SECTION SEVEN CONCLUSION

The September 2013 flood provided a unique opportunity to assess losses avoided due to floodplain regulation and policy. Additionally, the flood event created an ideal environment for comparison, as it impacted both jurisdictions that are highly rated under the CRS and others with less strict regulations.

The regulatory LAS quantitatively identified regulations that are, or would be, successful if implemented, as well as "what if" scenarios considering what would have happened had if regulations were not implemented. As a result, the regulatory LAS demonstrated what types of regulations and policies could have the biggest impact on reducing future damages. The scenarios use either the 2013 Colorado flood event, the 100-year base flood, or in many cases, both flood events to determine the losses avoided and resulting benefits. Table 7-1 lists the events used for each scenario and summarizes the highlights of the results.

Table 7-1: Summary of the Regulatory Losses Avoided Analysis

100-Year Flood	Best Practice/Scenario	2013 Colorado Floods
Regulating floodplain development when the community entered the NFIP (referred to as "earlier") would have resulted in **32% estimated losses avoided in Boulder and more than 52% estimated losses avoided in Larimer and Weld**	**Floodplain development regulations adopted earlier**	Regulating floodplain development earlier would have resulted in **36% estimated losses avoided in Boulder and more than 53% estimated losses avoided in Larimer and Weld**
Regulating floodway development earlier would have resulted in estimated losses avoided of **$32 million for Boulder, $64 million for Larimer, $13 million for Weld**	**Floodway development regulations adopted earlier**	N/A
Adopting freeboard earlier would have resulted in a **38% decrease in estimated losses for Boulder and an over 18% decrease in losses for Larimer and Weld**	**Freeboard adopted earlier**	Adopting freeboard earlier would have resulted in a **10% decrease in estimated losses for Boulder and an over 4% decrease in losses for Larimer and Weld**
If freeboard had never been adopted, there would be a **331% increase in estimated losses for Boulder, 68% increase in losses for Larimer, and 148% increase in losses for Weld**	**Freeboard never adopted**	If freeboard had never been adopted, there would be a **32% increase in estimated losses for Boulder, 5% increase in losses for Larimer, and 11% increase in losses for Weld**
If freeboard was increased by two feet, there would be a decrease in estimated losses in Boulder, Larimer, and Weld Counties of **more than 70%**	**Freeboard regulated to a higher or lesser standard**	If freeboard was increased by two feet, there would be a decrease in estimated losses in Boulder, Larimer, and Weld Counties of **more than 74%**

100-Year Flood	Best Practice/Scenario	2013 Colorado Floods
If critical facilities had been regulated earlier, there would have been a decrease in estimated losses in Boulder, Larimer, and Weld Counties of **more than 64%**	**Critical facilities regulated**	N/A
N/A	**Erosion setback (St. Vrain Creek)**	If development of new structures were regulated in the new St. Vrain Creek erosion zone, there would have been an estimated losses avoided of $1.4 million based on IA losses.
N/A	**Benchmark years**	The overall ratio of damage costs to replacement costs declines over time demonstrating a reduction in severity of losses with improvements in regulatory standards. The cost of damage per building generally increases over time as a result of overall higher replacement cost exposures.
N/A	**NFIP claims and CRS outreach**	High CRS outreach communities benefit from more extensive NFIP coverage both inside and outside the SFHA more than low-outreach communities
N/A	**Basements**	Basement-only losses for the 2013 event were mostly outside the SFHA and accounted for 22% of all the IA losses, demonstrating the need to address or develop mitigation strategies for basements in all floodprone areas.

The results of this study demonstrate that higher floodplain regulations result in benefits to jurisdictions, and not implementing regulations can result in an enormous increase in losses. This information can be used by floodplain managers and communities to support the case for implementing higher regulatory standards, in addition to conducting standard mitigation projects like acquisition and elevation.

For more information on best practices and cost effective strategies, including ideas on implementing and accomplishing mitigation, refer to this study's companion best practices report, *Best Practices and Cost Effective Strategies – 2013 Colorado Floods Case Study*. The best practices report uses the losses avoided information from the scenarios and best practices in this study to evaluate the most cost effective mitigation strategies.

SECTION EIGHT REFERENCES

This section lists the references used in the study.

American Society of Civil Engineers. Flood Resistant Design and Construction (ASCE/SEI 24-05). Available at http://ascelibrary.org/doi/book/10.1061/9780784408186. Accessed December 2014.

Colorado Climate Center's Website: Colorado Flood 2013. Available at http://coflood2013.colostate.edu/. Accessed November 2014.

Department of Natural Resources Colorado Water Conservation Board, "*Rules and Regulations for Regulatory Floodplains in Colorado.*" Available at http://cwcb.state.co.us/legal/pages/cwcbfloodplainrulesandregulationsprocess.aspx. Accessed November 2014.

FEMA. 2015. *Best Practices and Cost Effective Strategies – 2013 Colorado Floods Case Study.*

FEMA. 2010a. *Loss Avoidance: Riverine Flood Methodology Report.*

FEMA's 2013 Colorado Floods Situational Awareness Viewer. Available at http://fema.maps.arcgis.com/home/item.html?id=16055a012a4c4bfdb972c90e20b5e7b8. Accessed December 2014.

State of Colorado. 2013. *Colorado Action Plan for Disaster Recovery*. Available at http://dola.colorado.gov/cdbg-dr/sites/dola.colorado.gov.cdbg-dr/files/cdbg-dr_docs/revised-action-plan.pdf . Accessed November 2014.

APPENDIX A: DATA PREPARATION TOOL USER GUIDE

Appendix A provides detailed instructions on the installation and use of the Data Preparation Tool. Section 1 includes an introduction of the Tool; Section 2 offers specifications for minimum software requirements; Section 3 describes the data required to run the Tool; and Section 4 details the process of running the Tool.

A.1 INTRODUCTION

The Data Preparation Tool was created for this study to prepare data for analysis in the Data Analysis Tool described in Appendix C and the Hazus User Defined Facility (UDF) Tool described in Appendix B. These tools are available for download here: https://content.femadata.com/Hazus/Tools/Colorado_LAS.zip. Please contact Doug Bausch (Douglas.Bausch@fema.dhs.gov) at FEMA Region VIII with questions.

Prior to the creation of this Tool, data preparation was conducted manually and proved to be a time-consuming exercise. The Data Preparation Tool consolidates data from Access and Excel datasets. If structure data are incomplete, the Data Preparation Tool uses assumptions to estimate values for fields such as foundation type and building square footage. These assumptions are documented in Appendix D. The resulting dataset contains fields required for the FEMA Hazus UDF Tool and the Data Analysis Tool.

A.2 INSTALLATION

This section details the minimum system requirements and installation instructions. In order to install the Tools, the user needs the Colorado_LAS_Tools folder from FEMA Region VIII.

A.2.1 Minimum System Requirements

Minimum system requirements to run the Data Preparation Tool are as follows:

- ArcGIS 10.2 (includes Python 2.7)
- Python Library XLRD and PYODBC. Installation instructions are detailed in A.2.3.
- Access 2007 or later

A.2.2 Description of System Requirements

The Data Preparation Tool may be accessed in ArcGIS Version 10.2. ArcGIS Version 10.2 automatically installs Python 2.7. Access 2007 or newer is required to map data to the Data Preparation Tool.

A.2.3 Installing Python Libraries

Prior to running the Tool, the Python extension libraries must be copied into the Python site packages folder.

- The **Python Library XLRD** is used to extract data from Excel spreadsheet files (.xls, .xlsx, versions 2.0 and later).
- The **Python Library PYODBC** is a Python 2.x and 3.x module that enables users to utilize Open Database Connectivity (ODBC) to connect to various databases from Windows, Linux, and OS/X. This specific library is used to connect to Microsoft Access.
- To install the python libraries, navigate to the Library_Installation folder (Colorado_LAS_Tools\Library_Installation). Copy the **xlrd** folder, the **pyodbc.pyd** file, and the **pyodbc-3.0.7-py2.7egg-info** file and paste into the Python site-packages directory folder on your computer (C:\Python27\ArcGIS10.2\Lib\site-packages)

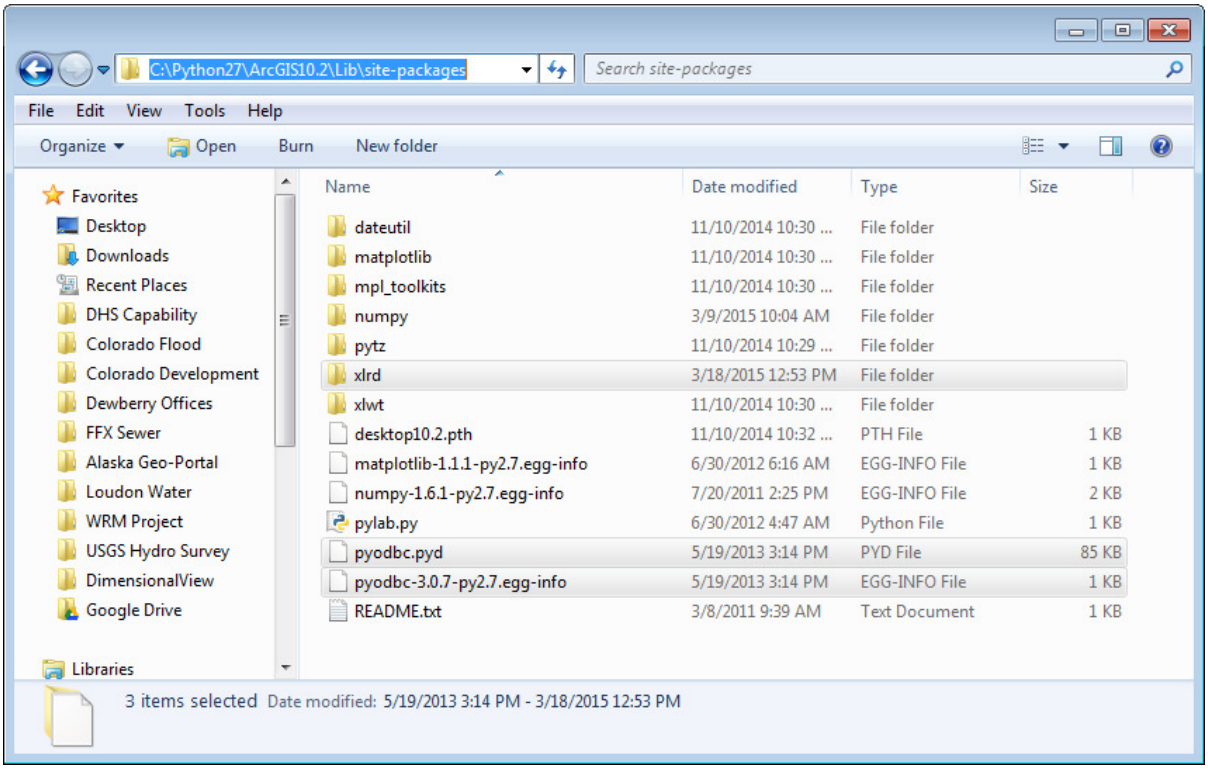

Figure A-1: Python site-packages folder

A.2.4 Data Preparation Tool Location

The Data Preparation Tool is located in the Colorado_LAS_Tools folder as depicted in Figure A-2. This folder contains the files needed to run the Data Preparation Tool.

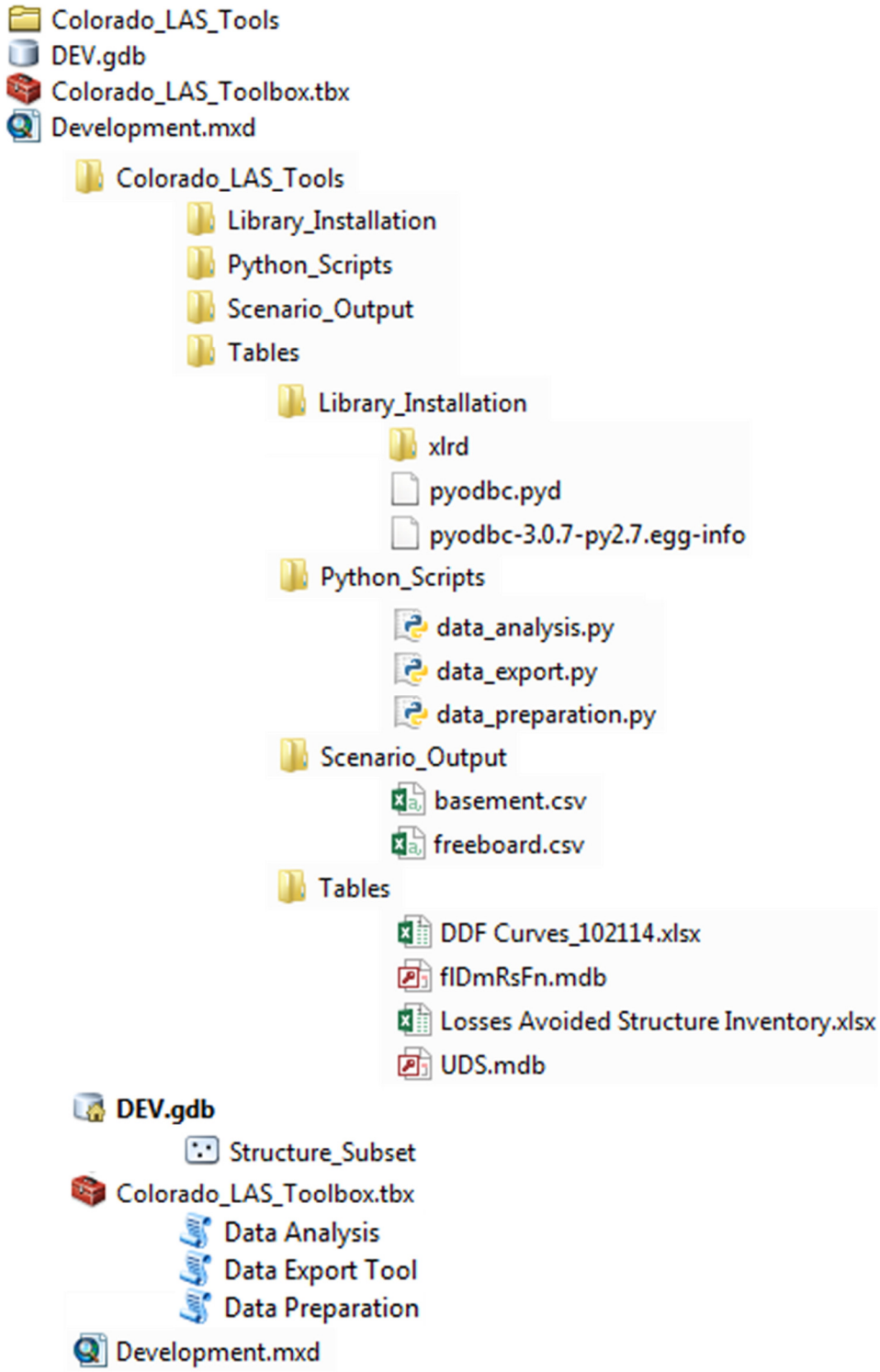

Figure A-2: Installation Folder

The following details the contents of each folder represented in Figure A-2 to support the installation and operation of the Data Preparation Tool.

Colorado_LAS_Tools – file folder

- Library_Installation – Python libraries used by the Tools
- Python_Scripts – Python scripts used by the Tools
- Scenario_Output – Output for the Data Analysis Tool, which will be described in Appendix C
- Tables – Source data that will be read by the Tool (Excel and Access)

Dev.gdb - File Folder

- Development geodatabase that contains the geospatial structure data used by the Tool

Colorado_LAS_Toolbox.tbx - ArcGIS Toolbox

- Tools to be used in ArcGIS

Development.mxd - ArcGIS ArcMAP Document

- Sample ArcGIS map document used by the Tool

A.3 DATA PREPARATION

Specific steps have been completed to prepare data for use in the Data Preparation Tool, including creating necessary fields for the Tool and joining jurisdiction data. These steps must be completed before running the Tool.

A.3.1 Creating Necessary Fields

Table A-1 shows the five fields containing information about the structures required in the input structure data layer to run the Tool. If the structure dataset does not have these required fields, they must be manually added and populated to the dataset by the user.

Table A-1: Required Fields

Field	Field Name	Type	Width
Occupancy Type	OCCUPANCY_1	String	5
Foundation Type	FOUNDATION TYPE	String	1
Building Square Footage	BLDGSQFT	Long	N/A
Number of Stories	NUMSTORIES	Short	N/A
First-floor Elevation	FFE_FT	Short	N/A

A.3.2 Joining Community Data

The following steps must be completed to join jurisdiction data to the user's structure database so the structure data has the jurisdiction name and NFIP emergency entry year. For this study, FEMA Region VIII decided to use the NFIP emergency entry year as the date of entry into the NFIP.

Jurisdiction Data: Create shapefile with target jurisdictions including NFIP entry year (string field should be named NFIP_Emerg_Entry with width of 4) and jurisdiction name (Community_Name with width of 255)

a. Spatially join structure points based on jurisdiction boundaries to append jurisdiction data

b. Export to new structure point shapefile or feature dataset

c. Use this dataset for input into the Data Preparation Tool

A.4 MAPPING DATA SOURCES TO TOOL

The Data Preparation Tool is shown in Figure A-3. Below the figure is the list of datasets used as input to the Data Preparation Tool.

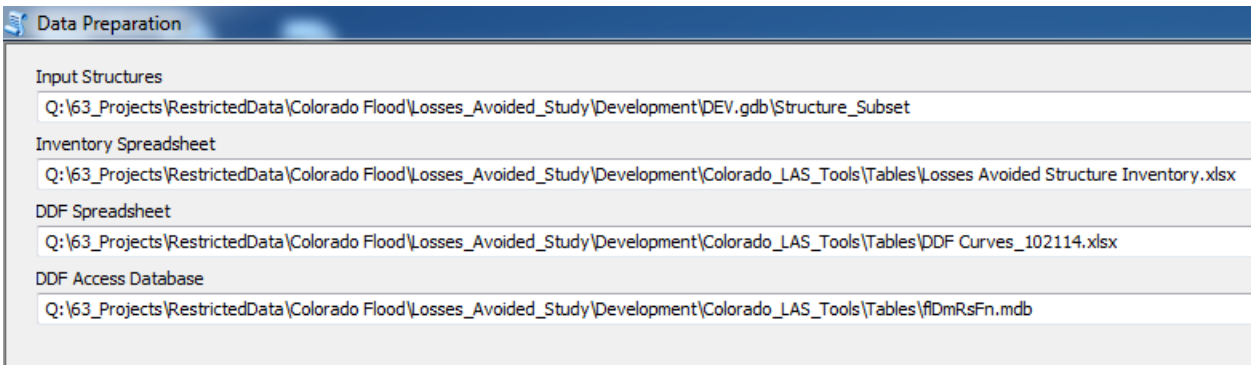

Figure A-3: Data Preparation Diagram

1. Input Structures: Point feature class or shapefile that contains structure data with the following required fields:

   a. OCCUPANCY_1, FOUNDATIONTYPE, BLDGSQFT, NUMSTORIES, FFE_FT

2. Inventory Spreadsheet: Losses Avoided Structure Inventory.xlsx - Inventory Spreadsheet. Spreadsheet with various tables that are linked to the structure data and used to make assumptions to populate null data as detailed in Appendix D. These spreadsheets incorporate assumptions that can be modified:

   a. AvgSqFootage – makes assumptions on square footage based on occupancy type

   b. FoundationType – populates first-floor elevation (FFE) using foundation type and pre-FIRM / post-FIRM SFHA table

   c. ContentValuations – populates Content Replacement Value using Replacement Value

   d. NonRES1Costs_CountyMod – populates Replacement Value using non-RES1 Occupancy Types

   e. BoulderRES1_CostsbyIncome – populates Replacement Value using RES1 Occupancy Types for Boulder County

f. LarimerRES1_CostsbyIncome – populates Replacement Value using RES1 Occupancy Types for Larimer County

g. WeldRES1_CostsbyIncome – populates Replacement Value using RES1 Occupancy Types for Weld County

3. Depth Damage Function (DDF) Spreadsheet: DDF Curves_102114.xslx - DDF Spreadsheet. This spreadsheet provides the DDF Curves based on Occupancy Type. Provides source and description for each depth damage function (DDF) for structure and contents.

4. DDF Access Database: FlDmRsFn.mdb - DDF Access Database. Once the DDFs are populated from the DDF Spreadsheet, the DDF Access Database is linked to get the specific percent of damage based on the high water mark from the 2013 floods and the 100-year floods.

A.5 RUNNING THE TOOL

Open ArcGIS, navigate to ArcCatalog, open Colorado_LAS_Toolbox.tbx and double click "Data Preparation." A dialogue box will appear as depicted in Figure A-4. This screen displays the steps executed by the Tool and indicates the Tool's progress.

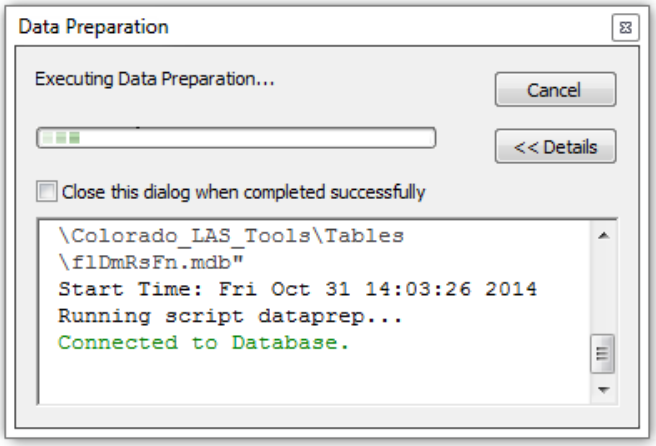

Figure A-4: Data Preparation screen

The script populates data into predefined fields based on input structure information, the Excel spreadsheets, and the Access database.

The following section details the steps performed by the Data Preparation Tool:

1. **Initial Tool Setup**

   a. Connected to Database. The PYODBC library is used to connect to the Access database.

   b. Fields Deleted. If fields created by the Tool exist in the database, these fields are deleted.

   c. Fields Added. Tool required fields are added.

i. FND_TYPE_1, type: TEXT, width: 200
ii. FNDTYPEMERGE, type: TEXT, width: 200
iii. BLDGSQFT_1, type: LONG, width: 200
iv. BLDGSQFTMERGE, type: LONG, width: 200
v. NUMSTORY_1, type: SHORT, width: 200
vi. NUMSTORYMERGE, type: SHORT, width: 200
vii. FFE_1, type: SHORT, width: 200
viii. FFEMERGE, type: SHORT, width: 200
ix. REPVAL_1, type: DOUBLE, width: 200
x. CONTREPVAL_1, type: DOUBLE, width: 200
xi. DDFNUM_STRUCT, type: LONG, width: 50
xii. SOURCE_STRUCT, type: TEXT, width: 50
xiii. DESCRIPTION_STRUCT, type: TEXT, width: 100
xiv. DDFNUM_CONT, type: LONG, width: 50
xv. SOURCE_CONT, type: TEXT, width: 50
xvi. DESCRIPTION_CONT, type: TEXT, width: 100

2. Foundation Type

a. Null FOUNDATION TYPES Populated. Structures lacking foundation type values are populated based on occupancy type (e.g. RES1, RES2, RES3), whether or not the structure is in the SFHA, and if the structure was built before or after the NFIP entry date.

b. FOUNDATION TYPE Merged. Foundation types with pre-assigned values and Tool-populated values are merged.

3. Square Footage

a. Null SQUARE FEET Populated. Structures lacking square footage values are populated based on occupancy type using the average square footage Excel spreadsheet in the losses avoided structure inventory Excel workbook. Note: For structures in Larimer or Weld Counties with a building square footage of less than 500 square feet, the local average of 2,374 square feet is applied, since the low square footage value indicates a potential error in the data.

b. BUILDING SQUARE FOOTAGE Merged. Building square footage values that are pre-assigned are merged with tool-populated values.

4. **Number of Stories**
    a. Null NUMBER OF STORIES Populated. Structures lacking number of stories are populated based on occupancy type (e.g., RES1, RES2, RES3), square footage greater than or less than 3,000 square feet, and square footage greater than or less than 8,000 square feet as defined in Appendix D.
    b. NUMBER OF STORIES Merged. Number of stories with values that are pre-assigned are merged with Tool-populated values.
5. **First Floor Elevation**
    a. Null FFE Populated. Structures lacking FFE are populated based on foundation type and if the structure was built before or after the NFIP entry date using the foundation type Excel spreadsheet and the losses avoided structure inventory workbook.
    b. FFE Merged. FFE with values that are pre-assigned are merged with Tool-populated values.
6. **Replacement and Content Costs**
    a. Replacement Value Calculated. Structure replacement value is calculated using county location, building square footage, and occupancy type using the Res1_costbyincome spreadsheets in the losses avoided structure inventory workbook.
    b. Content Replacement Value Calculated. Content replacement value is calculated using county location, building square footage, and occupancy type using the content valuation spreadsheet in the losses avoided structure inventory workbook.
    c. SOURCE (STRUCTURE) Populated. For all structures the DDF source for structures is populated using occupancy type and basement type in the DDF Curves_102114 Excel workbook.
    d. DESCRIPTION (STRUCTURE) Populated. For all structures the DDF description for structures is populated using occupancy type and basement type in the DDF Curves_102114 Excel workbook.
    e. SOURCE (CONTENTS) Populated. For all structures, the DDF source for contents is populated using occupancy type in the DDF Curves_102114 Excel workbook.
    f. DESCRIPTION (CONTENTS) Populated. For all structures, the DDF description for contents is populated using occupancy type in the DDF Curves_102114 Excel workbook.
    g. DDF Numbers Populated. For all structures, the DDF for contents and replacement are calculated using the Excel file titled DDF Curves_102114.xls

Once the DDF curves are identified, the information from Excel is matched to the access database of DDF curves to get the DDF number.

Figure A-5 and Figure A-6 illustrate the steps taken to prepare the data.

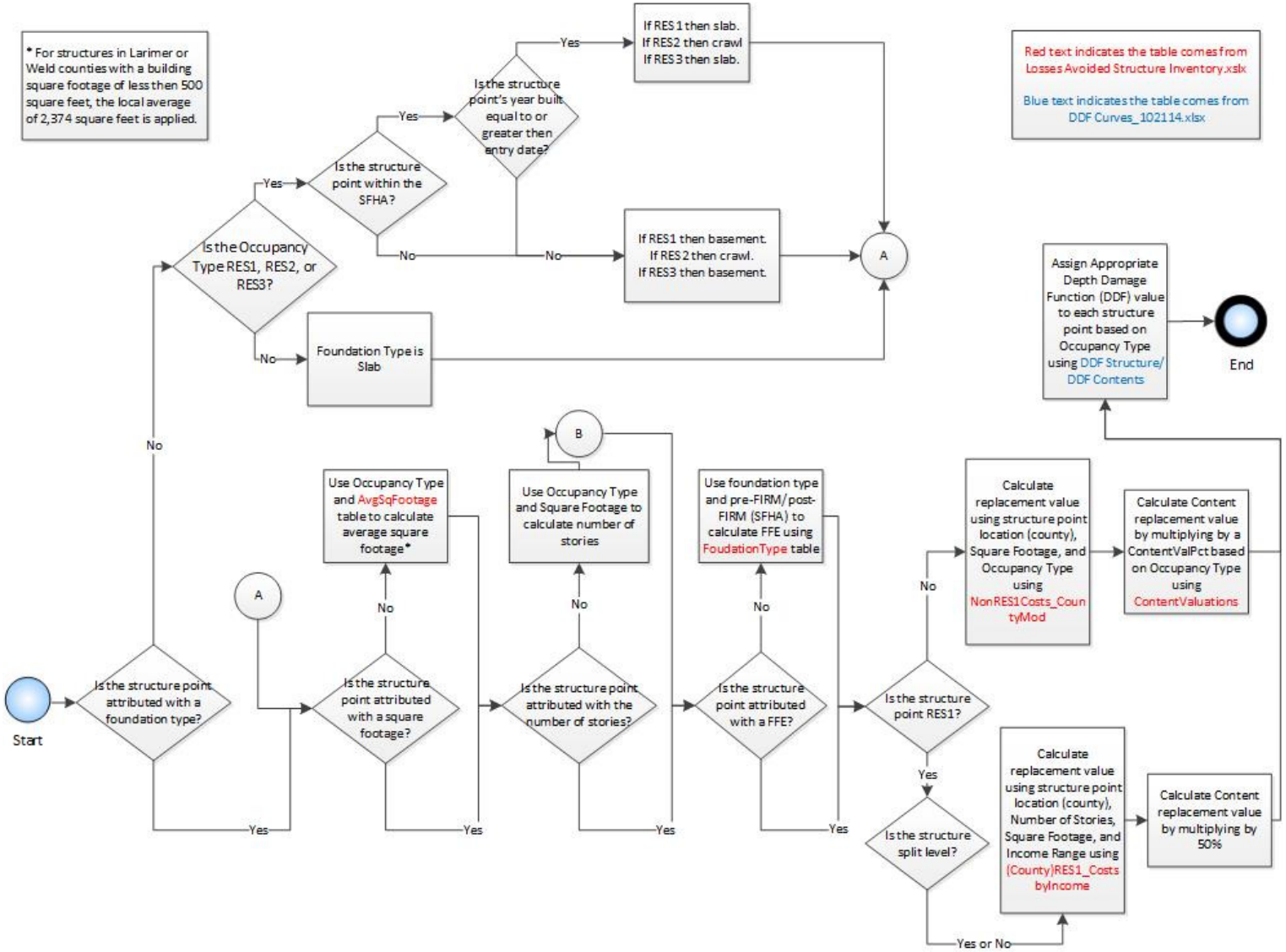

Figure A-5: Data Preparation Flow Chart

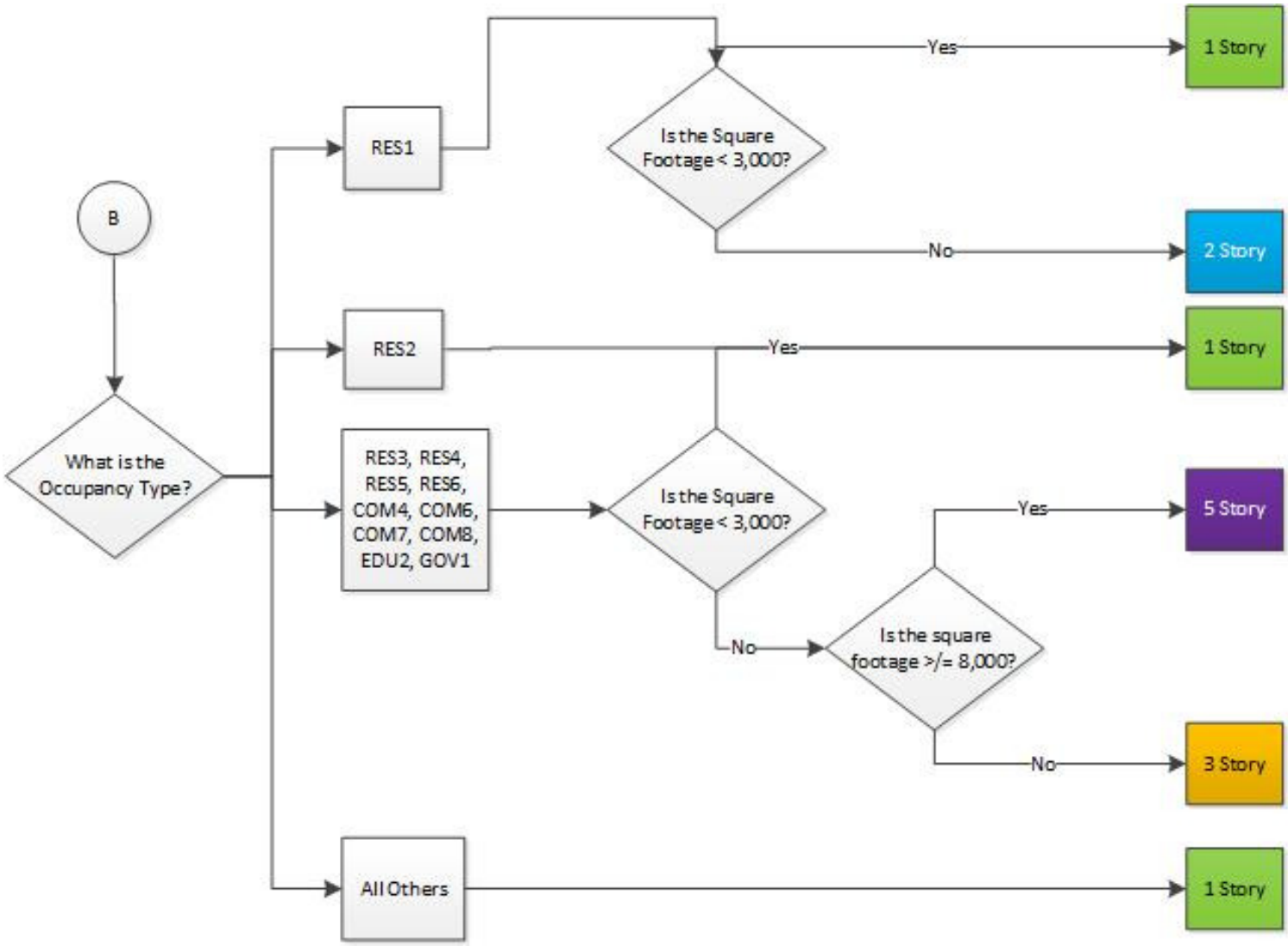

Figure A-6: Data Preparation Flow Chart B

Once the dialogue box displays “Completed” as shown in Figure A-7, the Tool has completed preparation of the data.

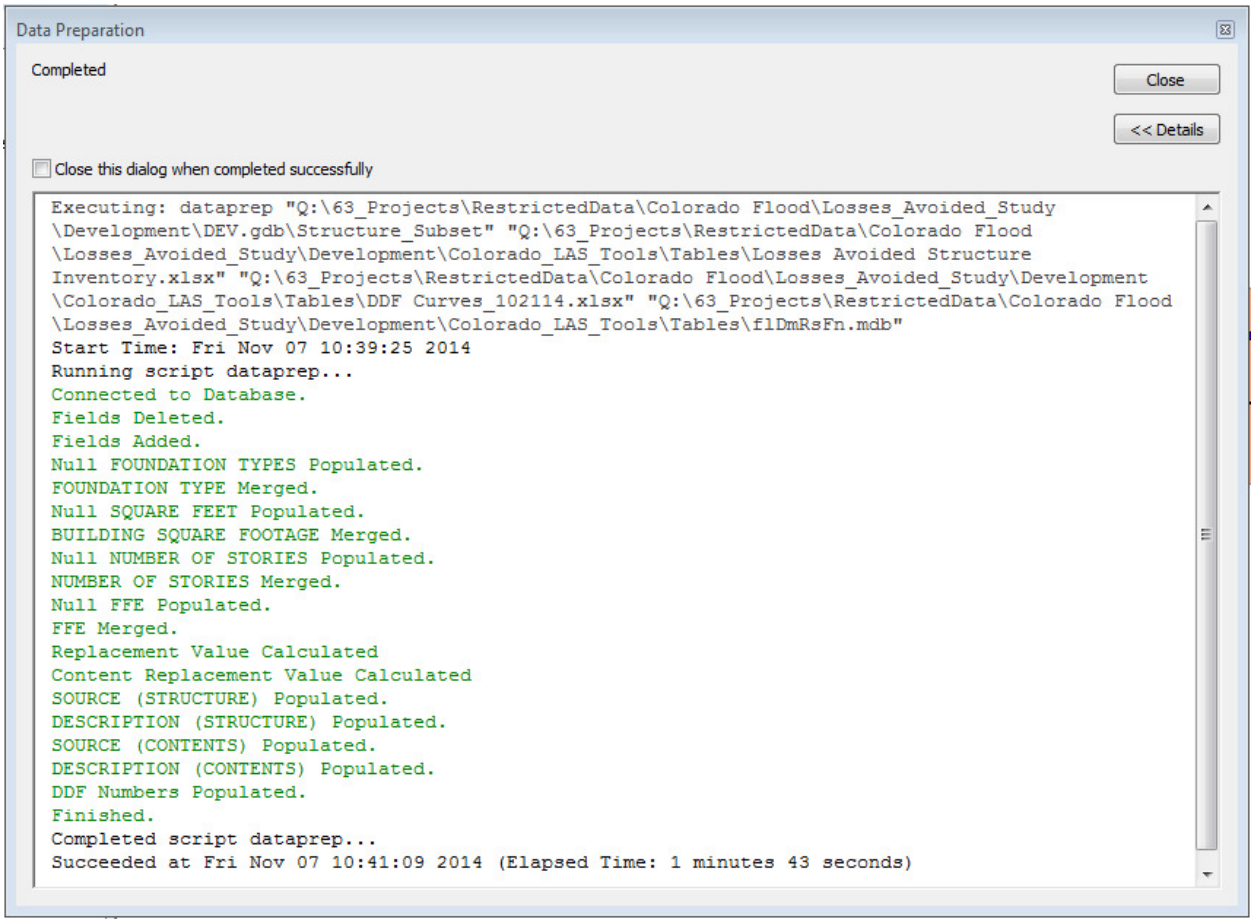

Figure A-7: Completed Tool Display

The output dataset has the fields added and the data populated directly to the dataset that was used for the input parameters. The results may be viewed in the input structures feature dataset and/or shapefile. An example is shown in Figure A-8.

Structure_Subset

FND_TYPE_1	FNDTYPE	BLDGSQFT	BLDGSQFT	NUMSTORY_1	NUMSTORYMERGE	FFE_1	FFEMERGE	REPVAL_1	CONTREPVAL_1	DDFNUM_STRUCT	SOURCE_STRUCT	DESCRIPTION_S
4	4	<Null>	1674	<Null>	1	4	4	227411.7030	113705.851545	129	USACE - IWR	one story, no bas
<Null>	5	<Null>	1892	<Null>	1	3	3	218389.4433	109194.721693	129	USACE - IWR	one story, no bas
<Null>	5	<Null>	3471	<Null>	1	3	3	400649.9777	200324.988899	129	USACE - IWR	one story, no bas
<Null>	4	<Null>	3336	<Null>	1	4	4	276273.7756	276273.77568	616	USACE - Galveston	Average Agricult
<Null>	4	<Null>	5150	<Null>	2	4	4	599986.1960	299993.098041	683	USACE Generic Rive	2 sty finished wa
<Null>	5	<Null>	1309	<Null>	1	3	3	151095.0218	75547.510939	129	USACE - IWR	one story, no bas
<Null>	4	<Null>	3503	<Null>	1	4	4	290104.0276	290104.02764	616	USACE - Galveston	Average Agricult

Figure A-8: Output Dataset

APPENDIX B: DATA EXPORT TOOL USER GUIDE

B.1 INTRODUCTION

Appendix B provides detailed instructions on the use of the Data Export Tool. When the Tool is run, the dataset will have the attributes necessary for FEMA's User Defined Facility (UDF) database. The UDF database uses parcel data attributes to run a more refined loss estimation in Hazus. The Data Export Tool process will prepare the data for seamless use in FEMA's UDF Database.

B.2 RUNNING THE TOOL

In order to access the Tool, the user must have access to the Data Preparation Tool and Data Analysis Tool. Please refer to Appendix A and C for more detailed installation instructions. Open ArcGIS, navigate to ArcCatalog, open Colorado_LAS_Toolbox.tbx and double click "Hazus Output." Refer to figure B-1 for a screenshot of the Tool.

- Name the output Access dataset.
- Select "run."
- Close the dialogue box. The data has been exported to the UDF standard.

Please note, a user may map the fields selected to be exported in the Data Export Tool using the dropdown feature for each field.

The Tool maps the input data into fields required for the UDF Database. Each field will appear in a series of drop-down boxes in the dialogue box as illustrated below.

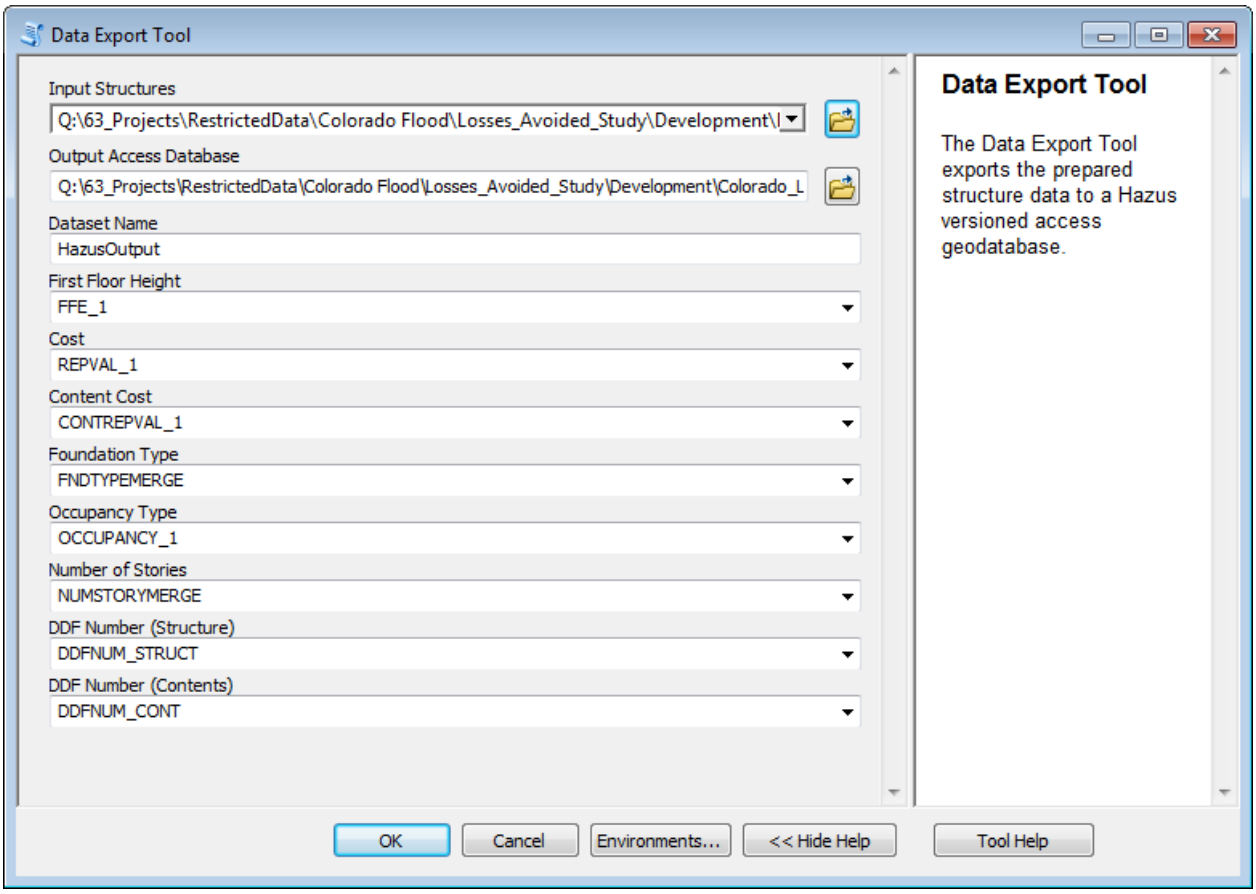

Figure B-1 Hazus Output Dialogue Box

Below is a description of the output results of the Tool:

FIRSTFLOORHT Number, integer

COST Number, long integer

CONTENTCOST Number, long integer

FOUNDATIONTYPE Text, field size 1

OCCUPANCY Text, field size 5

NUMSTORIES Number, byte

COMMENT (optional) Text, field size 40

DDFNUMSTRUCT Number, long integer

DDFNUMCONT Number, long integer

The data are now ready for use in Access. Open the UDS.mdb file (the Tool is making a UDF database; however, the actual database name is UDS.mdb) in the “tables” folder. Once Access is open, navigate to the output table on the table toolbar in order to view the data.

OBJECTID	Shape	FIRSTFLOOR	COST	CONTENTCOST	FOUNDATIONTYPE	OCCUPANCY	NUMSTORIES	DDFNUMSTRUCT	DDFNUMCONT
1	Long binary data	4	462091	231045	4	RES1	1	673	508
2	Long binary data	3	612806	306403	5	RES1	1	129	45
3	Long binary data	4	840762	420381	4	RES1	2	674	509
4	Long binary data	3	1197510	598755	5	RES1	2	130	46
5	Long binary data	3	578871	289435	5	RES1	1	129	45
6	Long binary data	4	449618	224809	4	RES3A	2	130	46
7	Long binary data	4	896156	448078	5	RES1	2	130	46
8	Long binary data	3	249209	124604	5	RES1	1	129	45
9	Long binary data	4	2767227	1383613	4	RES3D	2	130	46
10	Long binary data	4	197528	98764	4	RES1	1	679	514
11	Long binary data	4	494812	247406	4	RES1	2	683	518
12	Long binary data	4	727007	363504	4	RES1	2	674	509
13	Long binary data	4	470296	235148	4	RES1	1	673	508
14	Long binary data	4	444799	222400	4	RES1	1	679	514
15	Long binary data	3	265591	265591	5	AGR1	1	616	460
16	Long binary data	4	1225296	612648	5	RES1	2	130	46
17	Long binary data	4	827985	413993	4	RES1	2	680	515
18	Long binary data	4	721452	360726	4	RES1	1	684	519
19	Long binary data	3	95901	95901	5	AGR1	1	616	460
20	Long binary data	4	1155784	577892	4	RES1	2	680	515
21	Long binary data	4	908106	454053	4	RES1	2	674	509
22	Long binary data	4	593649	296824	4	RES1	2	674	509

Figure B-2: Data Export Tool Access Table

APPENDIX C: DATA ANALYSIS TOOL USER GUIDE

Appendix C provides detailed instructions on the installation and use of the Data Analysis Tool. Section 1 includes an introduction to the Tool; Section 2 offers specifications for minimum software requirements; Section 3 describes the data required to run the Tool; and Section 4 details the process of running the Tool.

C.1 INTRODUCTION

The Data Analysis Tool was created as part of this study to model "what-if" scenarios using actual flood event data and regulatory data. Please contact FEMA Region VIII to obtain the installation package for these Tools. Prior to using the Data Analysis Tool, data must be prepared using the Data Preparation Tool described in Appendix A. The Data Export Tool described in Appendix B is not required to be run for the Data Analysis Tool. The Data Analysis Tool can be run on all structures, structures in a specific county, or structures in a specific jurisdiction or series of jurisdictions. The user may run all or some of the scenarios every time the tool is executed.

C.2 INSTALLATION

This section details the minimum system requirements and installation instructions. In order to install the Tools, the user needs the Colorado_LAS_Tools folder from FEMA Region VIII.

C.2.1 MINIMUM SYSTEM REQUIREMENTS

Minimum system requirements to run the Data Preparation Tool are as follows:

- ArcGIS 10.2 (includes Python 2.7)
- Python Library XLRD and PYODBC. Installation instructions are detailed in C.2.3.
- Access 2007 or later

C.2.2 DESCRIPTION OF SYSTEM REQUIREMENTS

The Data Preparation Tool may be accessed in ArcGIS Version 10.2, which automatically installs Python 2.7. Access 2007 or later is required to map data using the Data Preparation Tool.

C.2.3 INSTALLING PYTHON LIBRARIES

Prior to running the Tool, the Python extension libraries must be copied into the Python site-packages folder.

- The **Python Library XLRD** is used to extract data from Excel spreadsheet files (.xls, .xlsx, versions 2.0 and later).
- The **Python Library PYODBC** is a Python 2.x and 3.x module that enables users to utilize Open Database Connectivity (ODBC) to connect to various databases from Windows, Linux, and OS/X. This specific library is used to connect to Microsoft Access.

- To install the Python libraries, navigate to the Library_Installation folder (Colorado_LAS_Tools\Library_Installation). Copy the **xlrd** folder, the **pyodbc.pyd** file, and the **pyodbc-3.0.7-py2.7egg-info** file and paste into the Python site-packages directory folder on your computer (C:\Python27\ArcGIS10.2\Lib\site-packages)

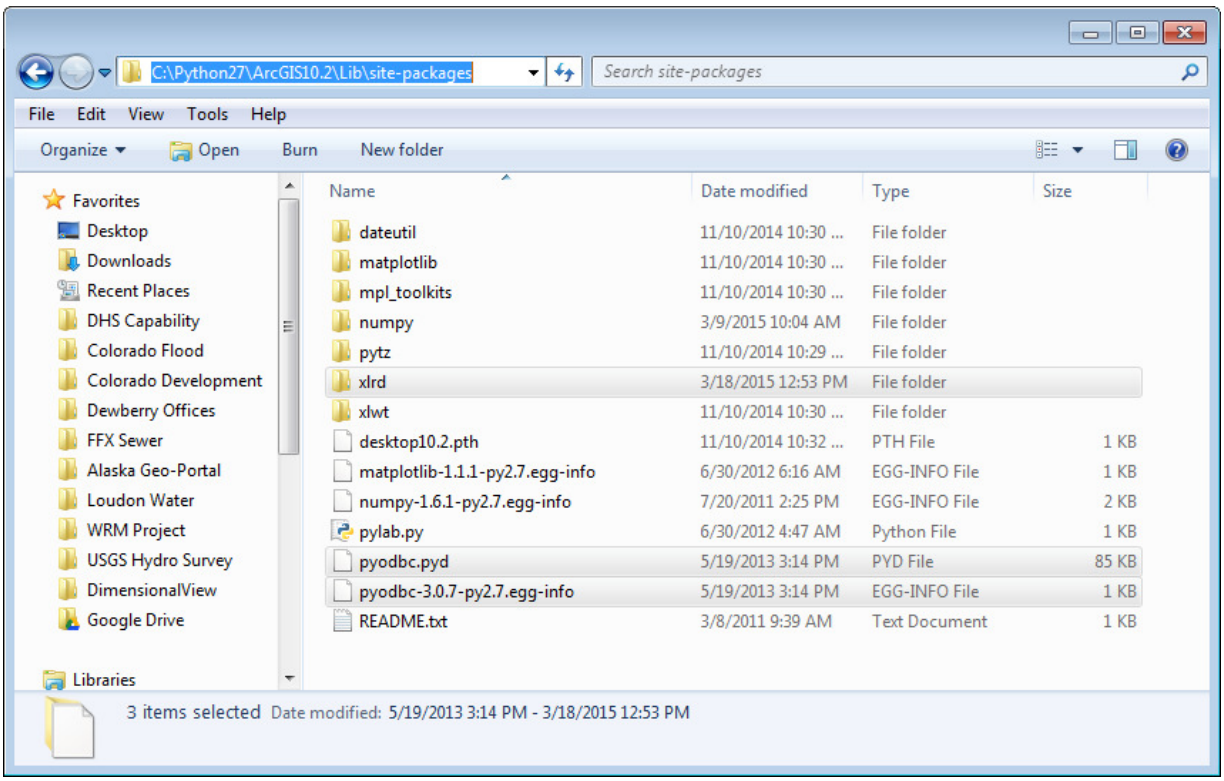

Figure C-1: Python site-packages folder

C.2.4 DATA ANALYSIS TOOL LOCATION

The Data Analysis Tool is located in the Colorado_LAS_Toolbox as depicted in Figure C-2. This folder contains the files to install and run the Data Analysis Tool.

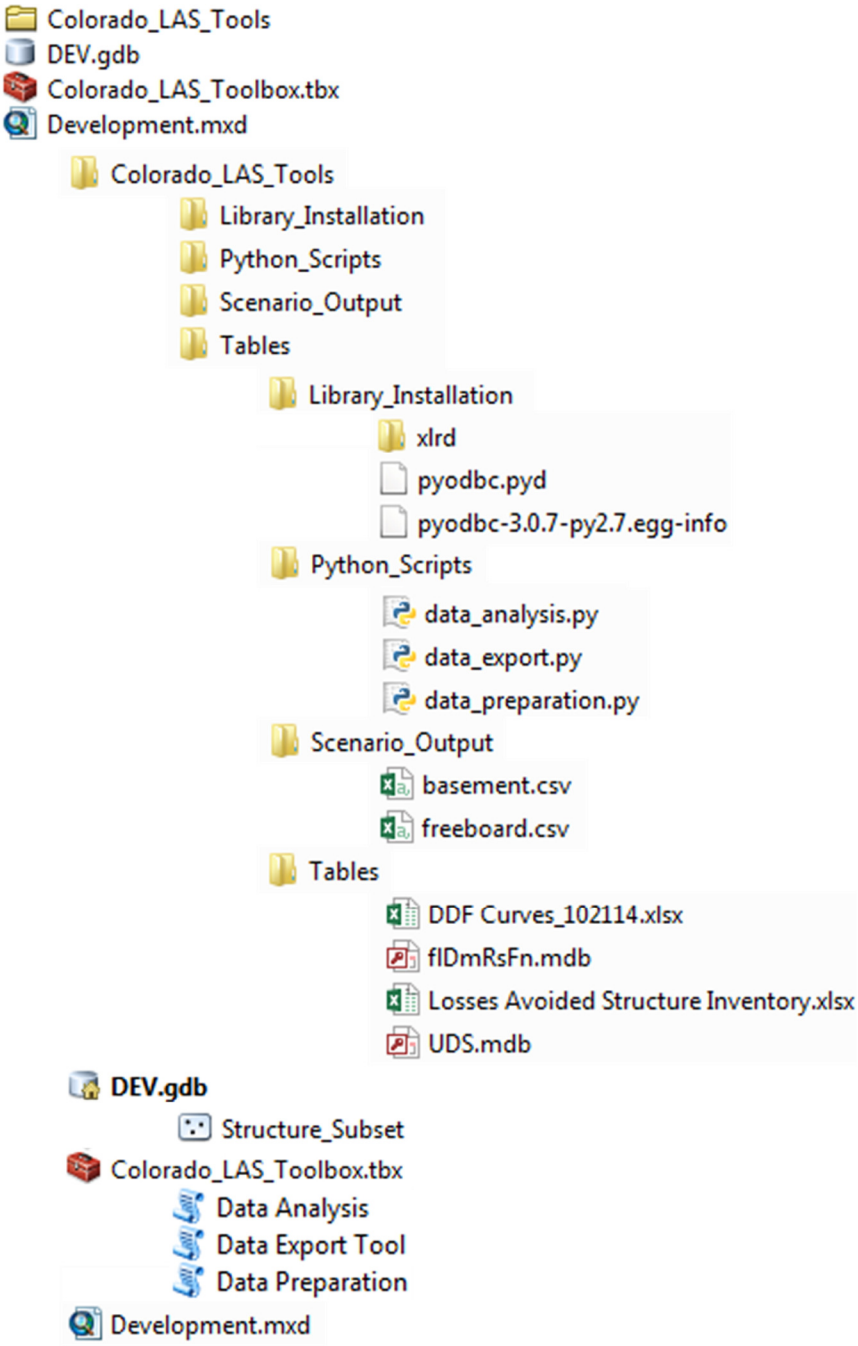

Figure C-2: Installation Folder

The following details the contents of each folder represented in Figure C-2 to support the installation and operation of the Data Analysis Tool.

Colorado_LAS_Tools – file folder

- Library_Installations – Python libraries used by the Tool
- Python_Scripts – Python scripts used by the Tool

- Scenario_Output – Output for the Data Analysis Tool
- Tables – Data sources that will be read by the Tool (Excel and Access)

DEV.gdb - File Folder

- Development geodatabase that contains the geospatial structure data used by the Tool

Colorado_LAS_Toolbox.tbx - ArcGIS Toolbox

- Tools to be used in ArcGIS

Development.mxd - ArcGIS ArcMAP Document

- Sample ArcGIS map document used by the Tool

C.3 MAPPING DATA SOURCES TOOL

The Data Analysis Tool is shown in C-3. Below the figure is a description of the datasets used in the Data Analysis Tool.

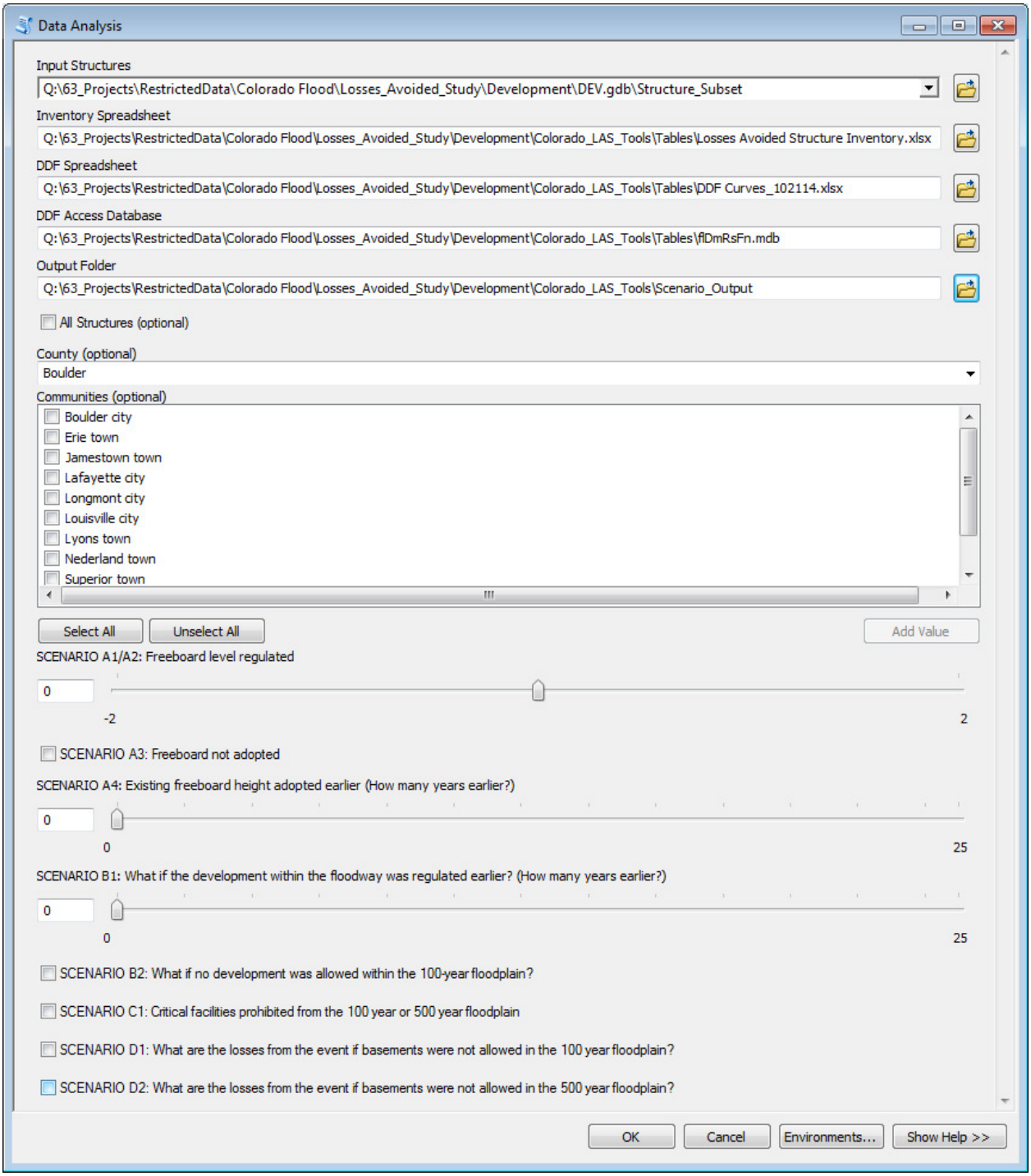

Figure C-3: Data Analysis User Interface

1. Input Structures: Point feature class or point shapefile that contains structure data with the following required fields:

    a. OCCUPANCY_1, FOUNDATIONTYPE, BLDGSQFT, NUMSTORIES, FFE_FT

2. Inventory Spreadsheet: Losses Avoided Structure Inventory.xlsx. Spreadsheet with various tables that are linked to the structure data and used to make assumptions to populate null data identified in Appendix D. These spreadsheets incorporate assumptions that can be modified:
    a. FFE_Adjusted – Adjusts FFE to correct values using Occupancy type, foundation type, and basement type.
    b. IA_HWM_Datum – Adjusts IA High Water Mark values to be relative to the FFE using Occupancy type, foundation type, IA foundation description, parcel data basement description, and high water mark location.
    c. IA_HWM_Assump – IA Report depth assumption table and IA FFE table.
    d. RDG_EDG – Adjusts regulatory depth values to be relative to the FFE using occupancy type, foundation type, and whether or not the structure is pre-FIRM or post-FIRM.
3. DDF Spreadsheet: DDF Curves_102114.xslx. This spreadsheet provides the DDF Curves based on Occupancy Type. It provides the source and description for each DDF for structure and contents.
4. DDF Access Database: FlDmRsFn.mdb. Once DDFs are populated from the DDF Spreadsheet, the DDF Access Database is linked to get the specific percent of damage based on the high water mark.
5. Output Folder: Scenario_Output. This is the default location for the exported scenario spreadsheets. When the Data Analysis Tool is run, the results will be placed in this folder.
6. All Structures (checkbox). If clicked, the analysis will be run on all input structures. Note: If “All structures” is checked, the County and Communities options will be greyed out.
7. County (dropdown menu). The user may select to only analyze the structures in a specific county. Note: If no communities are chosen, all structures in the specified county will be included in the analysis.
8. Communities (multiple checkboxes). The user may select to only analyze the structures in a specific community or series of communities in a county. Note: Below the checkboxes there is an option to “Select All” that will select all of the checkboxes. “Unselect all” will unselect all of the checkboxes.
9. Scenario A.1/A.2: Freeboard level regulated (slider). The user can slide the value to -2, -1, 1, or 2 feet and the Tool calculates values for the chosen freeboard scenario. Note: If the slider is left at a value of 0, no results will be created because there would be no comparison to the baseline freeboard values.
10. Scenario A.3: Freeboard not adopted (checkbox). If checked, the Tool calculates values for a scenario where freeboard was not adopted using the community’s NFIP emergency entry date and the structure’s year built.

11. Scenario A.4: Existing freeboard height adopted earlier (checkbox). If the user checks the box, the Tool calculates values for a scenario where the existing freeboard height was adopted earlier as determined by the jurisdiction's NFIP emergency entry date and the structure's year built.
12. Scenario B.1: What if development in the floodway was regulated earlier? (checkbox). If the user checks the box, the Tool calculates values for a scenario where the development in the floodway was regulated earlier, determined by whether the structure is in the floodway or not, the jurisdictions NFIP emergency entry date, and the structure's year built.
13. Scenario B.2: What if no development was allowed in the 100-year floodplain? (checkbox). The Tool calculates values for a scenario where the development in the 100-year floodplain was regulated earlier determined by whether the structure is in the 100-year floodplain or not.
14. Scenario C.1: Critical facilities prohibited from the 100-year floodplain (checkbox). If checked, the Tool calculates values for a scenario where critical facilities are prohibited from the 100-year floodplain. Critical facilities were selected based on a building description field in the parcel data.

C.4 RUNNING THE TOOL

Open ArcGIS, navigate to ArcCatalog, open the Colorado_LAS_Toolbox.tbx and double click "Data Analysis." A status window will appear as depicted in Figure C-4. This window displays the steps executed by the Tool and indicates the Tool's progress.

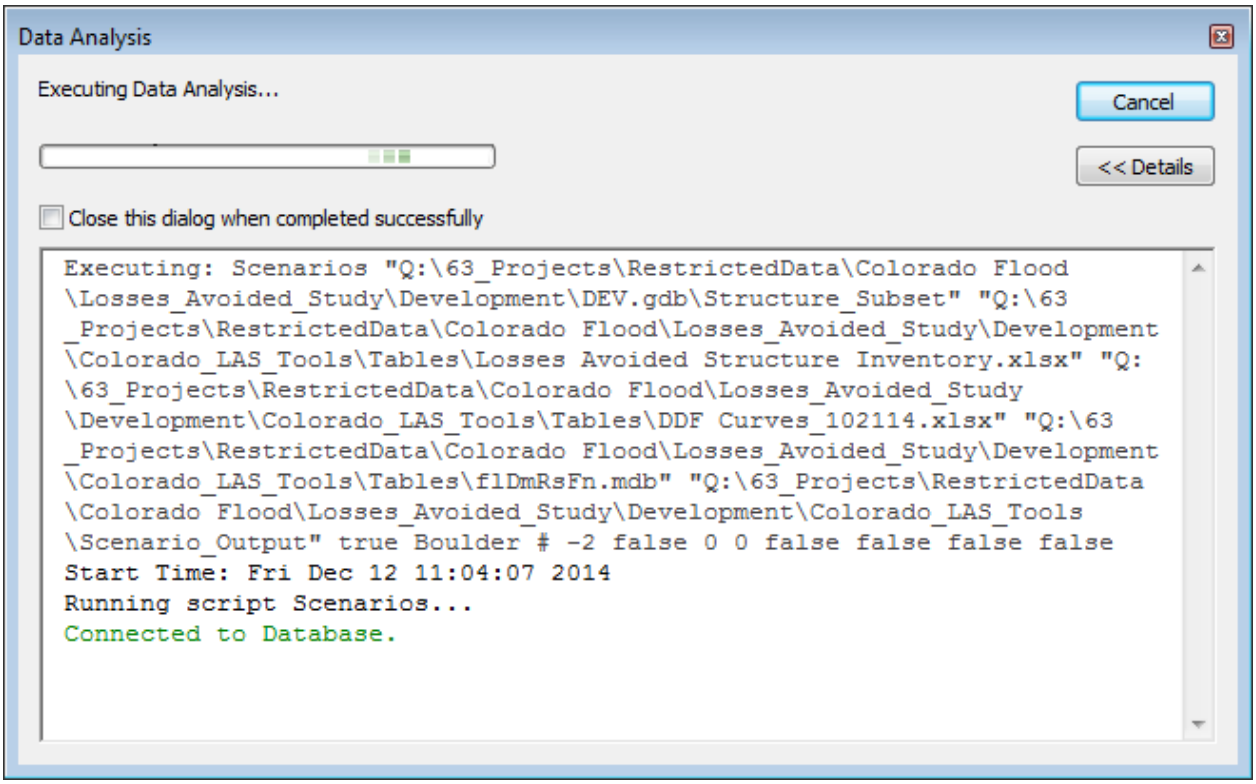

Figure C-4: Data Analysis Running Screenshot

The script populates data into predefined fields based on the input structure information, the Excel spreadsheets, and the Access database.

The following section details the steps of the Data Analysis Tool:

1. **Initial Tool Setup**
    a. Connected to Database. Using PYODBC, the library is used to connect to the Access database.
    b. Fields Deleted. If fields created by the Tool pre-exist in the database, these fields are deleted.
    c. Fields Added. Tool required fields are added.
        i. Wdepth_FT, type: DOUBLE, width: 10
        ii. HWM_Datum, type: DOUBLE, width: 10
        iii. WL_FT, type: DOUBLE, width: 10
        iv. FFE_Adj, type: DOUBLE, width: 10
        v. DDF_Depth, type: DOUBLE, width: 10
        vi. HWM_MERGE, type: DOUBLE, width: 10
        vii. HWM_RDG, type: DOUBLE, width: 10

viii. PCT_STRUCT, type: DOUBLE, width: 10
ix. PCT_CONT, type: DOUBLE, width: 10
x. DISPLACE_DAYS_100, type: LONG, width: 10
xi. DISPLACEMENT_100, type: DOUBLE, width: 10
xii. LOF_100, type: DOUBLE, width: 10
xiii. DISPLACE_DAYS_100_MPC, type: LONG, width: 10
xiv. DISPLACEMENT_100_MPC, type: DOUBLE, width: 10
xv. LOF_100_MPC, type: DOUBLE, width: 10
xvi. DISPLACE_DAYS_2013, type: LONG, width: 10
xvii. DISPLACEMENT_2013, type: DOUBLE, width: 10
xviii. LOF_2013, type: DOUBLE, width: 10
xix. DISPLACE_DAYS_2013_MPC, type: LONG, width: 10
xx. DISPLACEMENT_2013_MPC, type: DOUBLE, width: 10
xxi. LOF_2013_MPC, type: DOUBLE, width: 10

2. Depth Value Modifications

a. Wdepth_FT Populated – IA depth data from TwaterL_IN is converted to feet.
b. HWM_Datum Populated – Assumptions for high water mark depth are used to populate this field to include FFE relative to ground surface using occupancy type, foundation type, IA foundation type, basement description from parcel data, and high water location. The assumptions are located in Appendix D.
c. WL_FT Populated – Wdepth_FT and HWM_Datum are summed.
d. FFE_Adj Populated – FFE values are adjusted using occupancy type, foundation type, basement description, and whether or not the structure is pre-FIRM or post-FIRM. This determines whether the location of the FFE should be at the basement level or the first floor.
e. DDF_Depth Populated – FFE_Adj is subtracted from WL_FT.
f. Depth of Flooding Merged – Merges depth grid values and IA depth values. HWM_RDG is populated by subtracting FFE_Adj from RDG_FT.

3. Depth Damage Function Operations

a. DDF Numbers Populated. The HWM_Merge field uses the depth of flooding along with the DDF to get a percent of damage based on occupancy type, building description, number of stories, and whether or not the structure has a basement.

b. SOURCE (STRUCTURE) Populated. For all structures, the DDF source is populated for structures using occupancy type and basement type in the DDF Curves_102114 Excel workbook.

c. DESCRIPTION (STRUCTURE) Populated. For all structures, the DDF description for structures is populated using occupancy type and basement type in the DDF Curves_102114 Excel workbook.

d. SOURCE (CONTENTS) Populated. For all structures, the DDF source for contents is populated using occupancy type in the DDF Curves_102114 Excel workbook.

e. DESCRIPTION (CONTENTS) Populated. For all structures the DDF description for contents is populated using occupancy type in the DDF Curves_102114 Excel workbook.

4. Study Structures

a. QUERY: xxxx. Shows the user which structures in the dataset are being used in the data analysis.

b. xxxx Records. Shows the user how many structures were assessed in the study.

5. Scenario Output

a. For all scenarios

i. Scenario xx results exported to CSV. The Data Analysis Tool successfully exported the scenario results to a CSV file in the Scenario_Output folder as shown in C.2.4.

ii. No Scenario xx Output. There is no output for the specified scenario since it was not checked or a value was not given as an input.

Figure C-5 illustrates the steps taken to analyze the data.

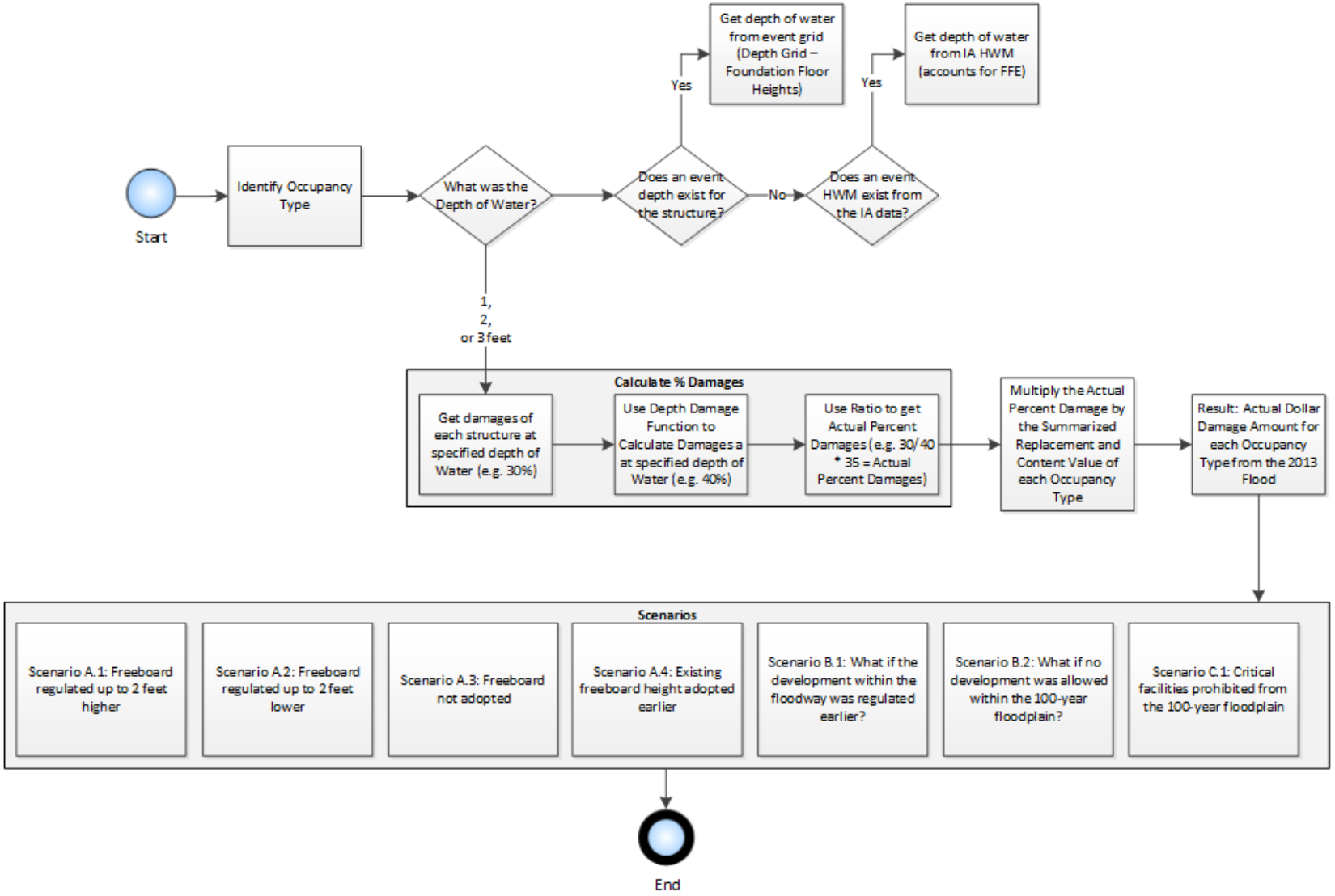

Figure C-5: Data Analysis Flow Chart

Once the dialogue box displays “Completed” as displayed in C-6 the Tool has completed the analysis of data.

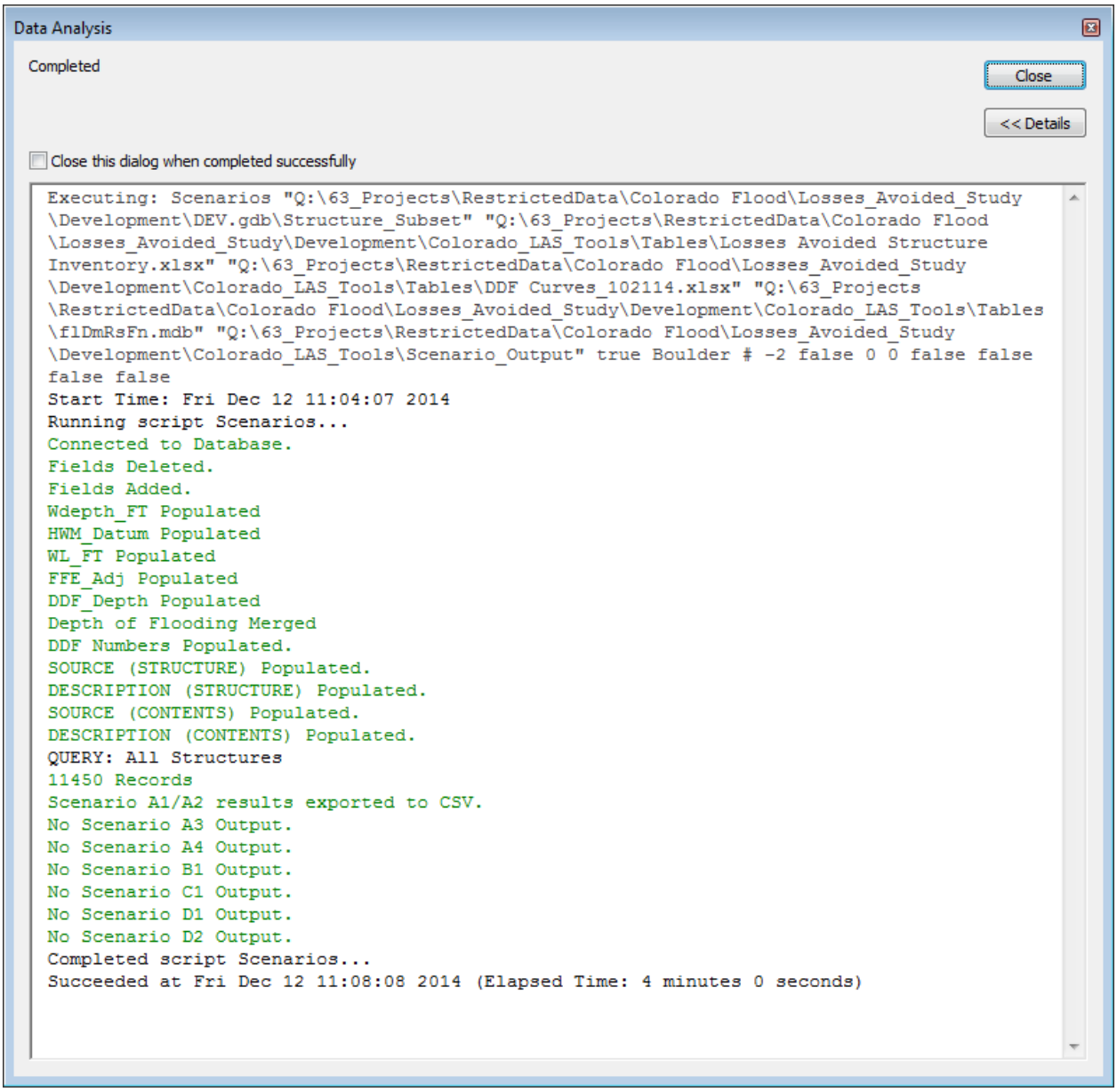

Figure C-6: Completed Tool Display

The output of the Data Analysis Tool is the scenario CSV files. The results are located in the Scenario_Output folder as shown in Figure C-7. Each scenario produces a unique CSV file that can be viewed in Excel. An example of a scenario output of a CSV file viewed in Excel is shown in Figure C-8.

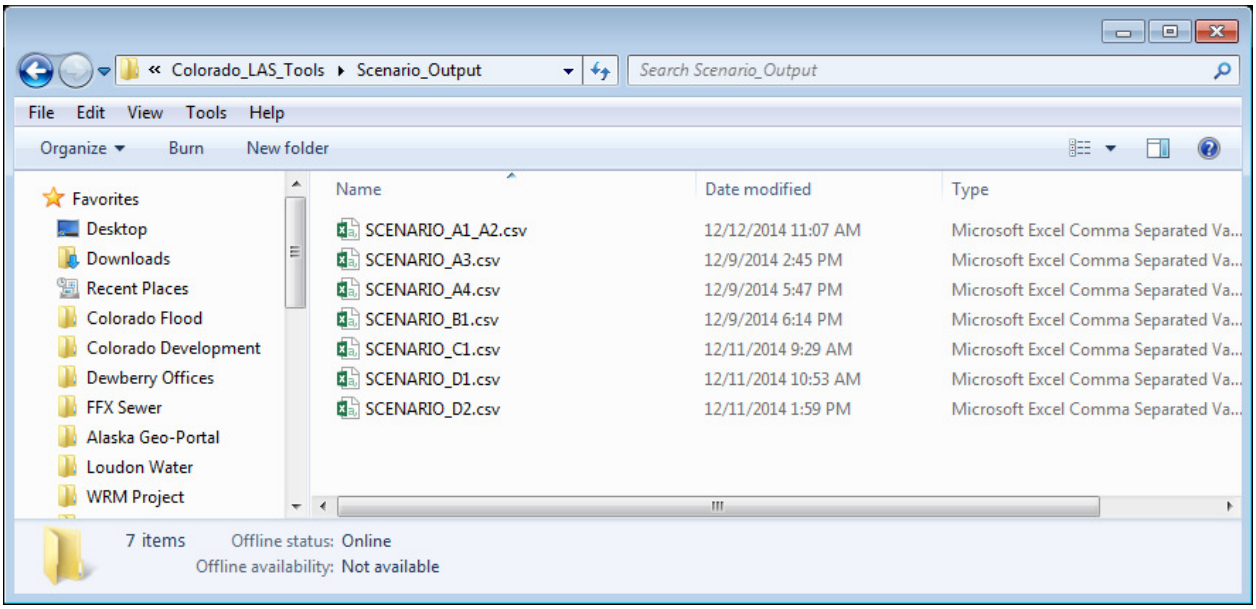

Figure C-7: Scenario Output Folder

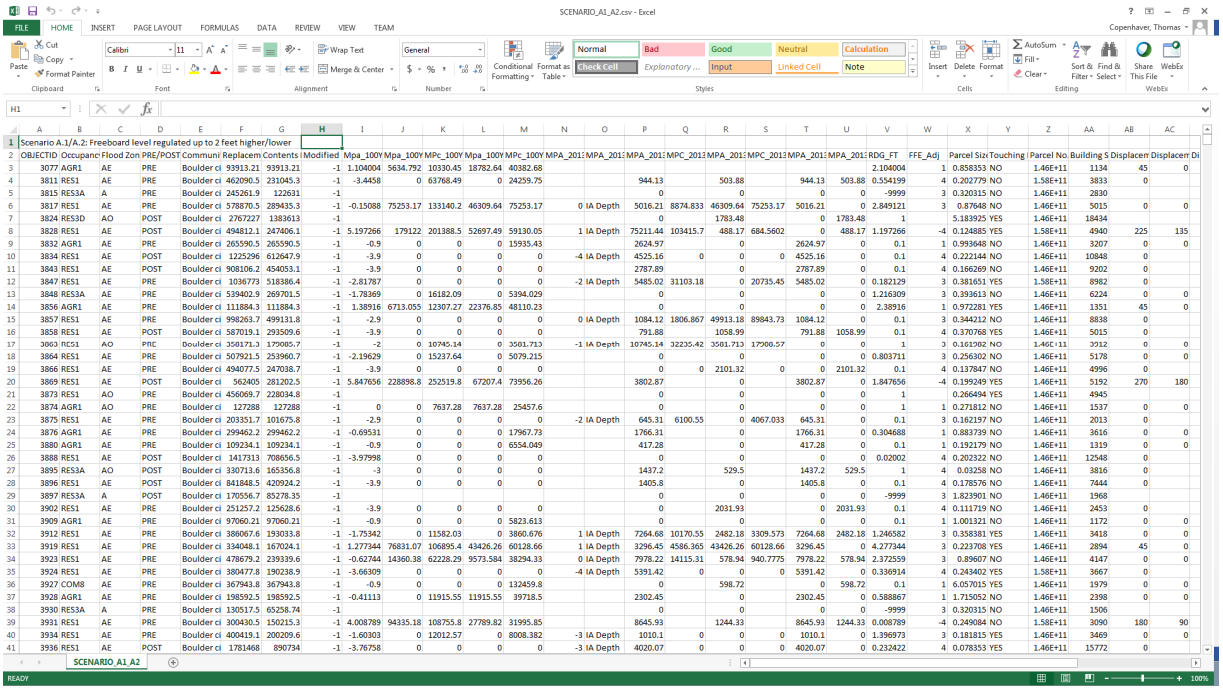

Figure C-8: Scenario Output Example

C.5 UNDERSTANDING THE RESULTS

Each scenario will produce unique results depending on the number and location of structures in the analysis and the parameters selected. While each scenario will produce different results, all scenarios will have a series of common field names and some will have additional unique fields as described in Table C-1.

Table C-1: Scenario Fields

Field	Description
OBJECTID	Unique identifier attributed to every structure, 1 to 363,335.
Occupancy Type	Parcel data occupancy type derived from the field OCCUPANCY_1
Flood Zone	Parcel data flood zone derived from the field FLD_ZONE
PRE/POST	Indicates whether a structure is PRE or POST NFIP based on whether the structure's YEARBUILT is greater than or less than the NFIP Emergency Entry date.
Community	Lists the community name in which the structure falls.
Replacement Value	The replacement value calculated in the Data Preparation Tool from the field REPVAL_1. Refer to section A.5 to see how REPVAL_1 was calculated.
Contents Replacement Value	The contents replacement value calculated in the Data Preparation Tool from the field CONTREPVAL_1. Refer to section A.5 to see how CONTREPVAL_1 was calculated.
MPA_100YR depth	100-year regulatory flood event depth (in feet)
MPA_100YR (structure)	100-year regulatory flood event damage to structure/real property calculated at baseline depth of flooding. (% Damage based on baseline depth of flooding * Replacement Value)
MPC_100YR (structure)	100-year regulatory flood event damage to structure/real property calculated at modified depth of flooding. (% Damage based on modified depth of flooding * Replacement Value)
MPA_100YR (contents)	100-year regulatory flood event damage to contents/personal property calculated at baseline depth of flooding. (% Damage based on baseline depth of flooding * Contents Replacement Value)
MPC_100YR (contents)	100-year regulatory flood event damage to contents/personal property calculated at modified depth of flooding. (% Damage based on modified depth of flooding * Contents Replacement Value)
MPA_2013 depth	2013 flood event depth (in feet)
MPA_2013 depth type	Shows where the depth data came from: IA Depth or Event Depth Grid.
MPA_2013 (structure)	If (FEMA Real Property Verified Loss = 0) Then = (% Damage based on baseline depth of flooding * Replacement Value) Otherwise = FEMA Real Property Verified Loss
MPC_2013 (structure)	If (FEMA Real Property Verified Loss = 0) Then = (% Damage based on baseline depth of flooding * Replacement Value) Otherwise Refer to C.5.1
MPA_2013 (contents)	If (FEMA Personal Property Verified Loss = 0) Then = (% Damage based on baseline depth of flooding * Contents Replacement Value) Otherwise

Field	Description
	= FEMA Personal Property Verified Loss
MPC_2013 (contents)	If (FEMA Personal Property Verified Loss = 0) Then = (% Damage based on baseline depth of flooding * Contents Replacement Value) Otherwise Refer to C.5.1
MPC_2013 (structure)	From IA data, FEMA Real Property Verified Loss (RP_FVL)
MPC_2013 (contents)	From IA data, FEMA Personal Property Verified Loss (PP_FVL)

C.5.1 ADJUSTED DEPTH DAMAGE FUNCTION CALCULATION

To calculate the modified MP_C loss, values must be adjusted to FEMA Verified Loss. To do this, the equation below is calculated where *MdlPctDDF* is Modeled Percent Depth Damage Function and *FrbrdMdlPctDDF* is Freeboard Modeled Percent Depth Damage Function:

$$((\frac{FemaVerifiedLoss}{ReplacementValue})/MdlPctDDF)*FrbrdMdlPctDDF = AdjPctDDF$$

This provides an adjusted depth damage function percentage that is applied to the Replacement Value (REPVAL_1).

$$AdjPctDDF * ReplacementValue = MpcStructure/Contents$$

Example of a RES1 2 story unfinished walkout:

Replacement Value = $403,931

Real Property FEMA Verified Loss = $30,145.15

DDF Percentage at Baseline (9ft) = 22.3

DDF Percentage at Freeboard Adjusted by -2 (11ft) = 31.9 (Note: we are subtracting 2 feet from freeboard so we added 2 feet of flooding)

$$((\frac{30,145.15}{403,931})/0.223) * 0.319 = 0.106$$

AdjPctDDF (Adjusted Percent Depth Damage Function) = 10.6%

$$.106 * 403,931 = 42,816.69$$

APPENDIX D: STRUCTURE INVENTORY ASSUMPTIONS

Appendix D provides detailed structure inventory assumptions used as part of this study. Please refer to the Excel file named Losses Avoided Structure Inventory20141229.xlsx for the structure inventory assumptions. This Excel file was included with the delivery of the report.

APPENDIX E: REGULATORY STANDARDS

Appendix E provides detailed regulatory standards by jurisdiction used as part of this study. Please refer to the Excel files named CRSandUDFCD_HistoricalRegulations_20140916.xlsx, Current_FloodRegulations_ByJurisdiction_10242014.xlsx, and State Regulation History.xlsx for the regulatory standards. The Excel files were included with the delivery of the report.

APPENDIX F: DEPTH DAMAGE FUNCTIONS USED BY OCCUPANCY

Appendix F provides the Depth Damage Functions (DDF) used by occupancy for structure (Table F-1) and contents (Table F-2).

Depth Damage Functions Used by Occupancy

Table F-1: Structure DDF Damage Functions

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
RES1	1-Story Single Family Dwelling	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	2%
RES1	1-Story Single Family Dwelling	With Unfinished Enclosed Basement	USACE Riverine Generic, One story with basement	Matches USACE Generic (Default)	0%
RES1	1-Story Single Family Dwelling	With Finished Enclosed Basement	USACE Riverine Generic, two or more stories, no basement, modified	Modified from USACE Generic (Default)	n/a
RES1	1-Story Single Family Dwelling	With Unfinished Walkout Basement	USACE Riverine Generic, One story with basement, modified	Modified from USACE Generic (Default)	n/a
RES1	1-Story Single Family Dwelling	With Finished Walkout Basement	USACE Riverine Generic, two or more stories, no basement	Modified from USACE Generic (Default)	n/a
RES1	Split Level Single Family Dwelling	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	2%
RES1	Split Level Single Family Dwelling	With Unfinished Enclosed Basement	USACE Riverine Generic, Split level with basement	Matches USACE Generic (Default)	0%
RES1	Split Level Single Family Dwelling	With Finished Enclosed Basement	USACE Riverine Generic, two or more stories, no basement, modified	Modified from USACE Generic (Default)	n/a
RES1	Split Level Single Family Dwelling	With Unfinished Walkout Basement	USACE Riverine Generic, Split level with basement, modified	Modified from USACE Generic (Default)	n/a
RES1	Split Level Single Family Dwelling	With Finished Walkout Basement	USACE Riverine Generic, two or more stories, no basement	Modified from USACE Generic (Default)	n/a
RES1	2-Story Single Family Dwelling	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES1	2-Story Single Family Dwelling	With Unfinished Enclosed Basement	USACE Riverine Generic, two or more stories with basement	Matches USACE Generic (Default)	0%

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
RES1	2-Story Single Family Dwelling	With Finished Enclosed Basement	USACE Riverine Generic, two or more stories, no basement, modified	Modified from USACE Generic (Default)	n/a
RES1	2-Story Single Family Dwelling	With Unfinished Walkout Basement	USACE Riverine Generic, two or more stories with basement, modified	Modified from USACE Generic (Default)	n/a
RES1	2-Story Single Family Dwelling	With Finished Walkout Basement	USACE Riverine Generic, two or more stories, no basement	Modified from USACE Generic (Default)	n/a
RES2	Mobile Home	Mobile Home	FEMA FIA, Mobile home, structure, A Zone	Closest to FEMA FIA (Default)	4%
RES3	Multifamily Dwelling	Apartment/ Condominium	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3A	Duplex	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3B	3–4 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3C	5–9 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3D	10–19 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3E	20–49 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3F	50+ Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES4	Temporary Lodging	Hotel/Motel	USACE Galveston, Motel Unit, structure	Closest to Hotel (Default)	37%
RES5	Institutional Dormitory	Group Housing (military, college), Jails	USACE Galveston, Nursing Home, structure	Closest to Correctional Facility (Default)	63%
RES6	Nursing Home		USACE Galveston, Nursing Home, structure	Closest to Correctional Facility (Default)	63%

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
COM1	Retail Trade	Store	USACE Galveston, Average Retail, structure	Closest to Retail-Clothing (Default)	20%
COM2	Wholesale Trade	Warehouse	USACE Galveston, Sporting Goods Warehouse, structure	Closest to Warehouse, Non-Refrig (Default)	12%
COM3	Personal and Repair Services	Service Station/Shop	USACE Galveston, Beauty Shop, structure	Closest to Service Station (Default)	14%
COM4	Professional/Technical Services	Offices	USACE St. Paul, Professional, structure	Closest to Offices One-Story (Default)	72%
COM5	Banks		USACE Galveston, Bank, structure	Closest to Offices One-Story (Default)	58%
COM6	Hospitals		USACE Galveston, Hospital, structure	Closest to Hospital (Default)	46%
COM7	Medical Office/Clinic		USACE Galveston, Average Medical Office, structure	Closest to Medical Office (Default)	58%
COM8	Entrainment & Recreation	Restaurants/ Bars	USACE Galveston, Tavern, structure	Closest to Recreation (Default)	20%
COM9	Theaters		USACE Galveston, Average Entertainment/Recreation, structure	Closest to Recreation (Default)	38%
COM10	Parking	Garages	USACE Galveston, Sporting Goods Warehouse, structure	Closest to Warehouse, Non-Refrig (Default)	12%
IND1	Heavy	Factory	USACE Galveston, Average Metals/Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND2	Light	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND3	Food/Drugs/ Chemicals	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND4	Metals/Minerals Processing	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND5	High Technology	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND6	Construction	Office	USACE Galveston, Contractor Roofing, structure	Closest to Offices One-Story (Default)	40%

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
AGR1	Agriculture		USACE Galveston, Average Agriculture, structure	Closest to Warehouse, Non-Refrig (Default)	14%
REL1	Church/Non-Profit		USACE Galveston, Church, structure	Closest to Religious Facilities (Default)	51%
GOV1	General Services	Office	USACE Galveston, Post Office, structure	Closest to Office One-Story (Default)	40%
GOV2	Emergency Response	Police/Fire Station/EOC	USACE Galveston, Police Station, structure	Closest to Protective Services (Default)	8%
EDU1	Grade Schools		USACE Galveston Commercial School, structure	Closest to Schools (Default)	37%
EDU2	Colleges/ Universities	Does not include group housing	USACE Galveston Commercial School, structure	Closest to Schools (Default)	37%

Table F-2: Contents DDF Damage Functions

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
RES1	1-Story Single Family Dwelling	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	2%
RES1	1-Story Single Family Dwelling	With Unfinished Enclosed Basement	USACE Riverine Generic, One story with basement	Matches USACE Generic (Default)	0%
RES1	1-Story Single Family Dwelling	With Finished Enclosed Basement	USACE Riverine Generic, two or more stories, no basement, modified	Modified from USACE Generic (Default)	n/a
RES1	1-Story Single Family Dwelling	With Unfinished Walkout Basement	USACE Riverine Generic, One story with basement, modified	Modified from USACE Generic (Default)	n/a
RES1	1-Story Single Family Dwelling	With Finished Walkout Basement	USACE Riverine Generic, two or more stories, no basement	Modified from USACE Generic (Default)	n/a

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
RES1	Split Level Single Family Dwelling	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	2%
RES1	Split Level Single Family Dwelling	With Unfinished Enclosed Basement	USACE Riverine Generic, Split level with basement	Matches USACE Generic (Default)	0%
RES1	Split Level Single Family Dwelling	With Finished Enclosed Basement	USACE Riverine Generic, two or more stories, no basement, modified	Modified from USACE Generic (Default)	n/a
RES1	Split Level Single Family Dwelling	With Unfinished Walkout Basement	USACE Riverine Generic, Split level with basement, modified	Modified from USACE Generic (Default)	n/a
RES1	Split Level Single Family Dwelling	With Finished Walkout Basement	USACE Riverine Generic, two or more stories, no basement	Modified from USACE Generic (Default)	n/a
RES1	2-Story Single Family Dwelling	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES1	2-Story Single Family Dwelling	With Unfinished Enclosed Basement	USACE Riverine Generic, two or more stories with basement	Matches USACE Generic (Default)	0%
RES1	2-Story Single Family Dwelling	With Finished Enclosed Basement	USACE Riverine Generic, two or more stories, no basement, modified	Modified from USACE Generic (Default)	n/a
RES1	2-Story Single Family Dwelling	With Unfinished Walkout Basement	USACE Riverine Generic, two or more stories with basement, modified	Modified from USACE Generic (Default)	n/a
RES1	2-Story Single Family Dwelling	With Finished Walkout Basement	USACE Riverine Generic, two or more stories, no basement	Modified from USACE Generic (Default)	n/a
RES2	Mobile Home	Mobile Home	FEMA FIA, Mobile home, structure, A Zone	Closest to FEMA FIA (Default)	4%
RES3	Multifamily Dwelling	Apartment/ Condominium	USACE Riverine Generic	Matches USACE Generic (Default)	1%

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
RES3A	Duplex	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3B	3–4 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3C	5–9 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3D	10–19 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3E	20–49 Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES3F	50+ Units	No Basement	USACE Riverine Generic	Matches USACE Generic (Default)	1%
RES4	Temporary Lodging	Hotel/Motel	USACE Galveston, Motel Unit, structure	Closest to Hotel (Default)	37%
RES5	Institutional Dormitory	Group Housing (military, college), Jails	USACE Galveston, Nursing Home, structure	Closest to Correctional Facility (Default)	63%
RES6	Nursing Home		USACE Galveston, Nursing Home, structure	Closest to Correctional Facility (Default)	63%
COM1	Retail Trade	Store	USACE Galveston, Average Retail, structure	Closest to Retail-Clothing (Default)	20%
COM2	Wholesale Trade	Warehouse	USACE Galveston, Sporting Goods Warehouse, structure	Closest to Warehouse, Non-Refrig (Default)	12%
COM3	Personal and Repair Services	Service Station/Shop	USACE Galveston, Beauty Shop, structure	Closest to Service Station (Default)	14%
COM4	Professional/Technical Services	Offices	USACE St. Paul, Professional, structure	Closest to Offices One-Story (Default)	72%
COM5	Banks		USACE Galveston, Bank, structure	Closest to Offices One-Story (Default)	58%
COM6	Hospitals		USACE Galveston, Hospital, structure	Closest to Hospital (Default)	46%

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
COM7	Medical Office/Clinic		USACE Galveston, Average Medical Office, structure	Closest to Medical Office (Default)	58%
COM8	Entrainment & Recreation	Restaurants/ Bars	USACE Galveston, Tavern, structure	Closest to Recreation (Default)	20%
COM9	Theaters		USACE Galveston, Average Entertainment/Recreation, structure	Closest to Recreation (Default)	38%
COM10	Parking	Garages	USACE Galveston, Sporting Goods Warehouse, structure	Closest to Warehouse, Non-Refrig (Default)	12%
IND1	Heavy	Factory	USACE Galveston, Average Metals/Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND2	Light	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND3	Food/Drugs/ Chemicals	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND4	Metals/Minerals Processing	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND5	High Technology	Factory	USACE Galveston, Average Metals/ Minerals Processing, structure	Closest to Industrial Light (Default)	7%
IND6	Construction	Office	USACE Galveston, Contractor Roofing, structure	Closest to Offices One-Story (Default)	40%
AGR1	Agriculture		USACE Galveston, Average Agriculture, structure	Closest to Warehouse, Non-Refrig (Default)	14%
REL1	Church/Non-Profit		USACE Galveston, Church, structure	Closest to Religious Facilities (Default)	51%
GOV1	General Services	Office	USACE Galveston, Post Office, structure	Closest to Office One-Story (Default)	40%
GOV2	Emergency Response	Police/Fire Station/EOC	USACE Galveston, Police Station, structure	Closest to Protective Services (Default)	8%
EDU1	Grade Schools		USACE Galveston Commercial School, structure	Closest to Schools (Default)	37%

Depth Damage Functions Used by Occupancy

Occupancy	Occupancy Class	Example Description	Representative Depth Damage Function (DDF) - Description	Justification for DDF Selection – Relation to FEMA BCA Tool	% Error in Curves
EDU2	Colleges/ Universities	Does not include group housing	USACE Galveston Commercial School, structure	Closest to Schools (Default)	37%

APPENDIX G: CASE STUDY: LONGMONT, COLORADO MITIGATION PROJECT

In 2010, the City of Longmont Left Hand Creek Flood Project was proposed as a Pre-Disaster Mitigation (PDM) program project. It was awarded and completed in 2012. The mitigation project was designed to increase the flow capacity of the Left Hand Creek channel through a mixed-use area. The Left Hand Creek Flood Project improved the Left Hand Creek channel design and updated and resized two bridge culverts. The proposal identified 110 structures the flood project would remove from the Special Flood Hazard Area (SFHA) as depicted on the Flood Insurance Rate Map (FIRM).

Subsequent to the completion of the PDM project, two Letters of Map Revisions (LOMRs) were issued in 2014 to reflect the construction of the project and revise the FIRM in the project area. The SFHA depicted on the LOMRs closely matched the flood event that occurred in Left Hand Creek in September 2013. The City of Longmont Floodplain Administrator determined that this had been a 100-year recurrence interval flood.

As a result of the mitigation project, the structures that were removed from the SFHA on the FIRM avoided losses during the 2013 flood event. The losses avoided included physical damages to the buildings and contents; displacement costs and the mental stress and anxiety of residents; loss of business income for stores, businesses, and commercial properties; and loss of income for the affected residents who were unable to attend work.

This appendix evaluates the effectiveness of the Left Hand Creek Flood Project by measuring the losses avoided in the 2013 flood event. A traditional loss avoidance study (LAS) was used. A LAS includes the analysis of a flood event or events before and after a mitigation project is completed. Losses are calculated in two scenarios: (1) as if the mitigation project was never performed, which is the mitigation project absent or MP_A scenario; and (2) post-mitigation project, which is the mitigation project complete or MP_C scenario. Losses avoided are the project benefits and are calculated as the difference between the MP_A and the MP_C losses.

This case study was able to be performed because:

- The 2013 flood event in Left Hand Creek was equivalent to a 100-year recurrence interval flood, for which a FIS was already prepared.
- GIS data were available.
- Event data were available.

The results of this study found that:

- The mitigation project losses avoided resulted in a return on investment (ROI) of the Left Hand Creek Flood Project of ROI 3.9 in one 100-year event.
- The overall losses avoided during the 2013 event were $22 million.
- Basement losses were reduced by 96 percent.
- Post-regulatory structure losses were reduced by 100 percent.

- Almost all (91 percent) of the impacted structures in the 100-year flood event were pre-regulatory. Of the impacted structures in the 2013 event, 100 percent were pre-regulatory.
- Physical building and contents losses account for 73 percent of the total losses avoided.

This appendix summarizes the analysis and results of the LAS. It is organized into the three phases of the LAS, a results section, and a summary. The structure of the report is:

Section G1 – Project Selection (LAS Phase 1)

Section G2 – Physical Parameter Analysis (LAS Phase 2)

Section G3 – Loss Estimation Analysis (LAS Phase 3)

Section G4 – Results

Section G5 – Summary

G.1 PROJECT SELECTION

The Left Hand Creek Flood Project in Longmont, Colorado was completed in 2012; in 2013 a 100-year recurrence interval flood occurred in Left Hand Creek. This flood provided an opportunity to evaluate the effectiveness of the mitigation project by performing a traditional LAS on the project area. The LAS attempts to answer the question, "What would have happened if the mitigation project was never performed?"

G.1.1 PROJECT AREA SELECTION

The project area was originally derived from the Left Hand Creek Flood Project proposal. The 110 structures removed from the SFHA in the project proposal are shown in Figure G-1. The area of the flood project is circled in red.

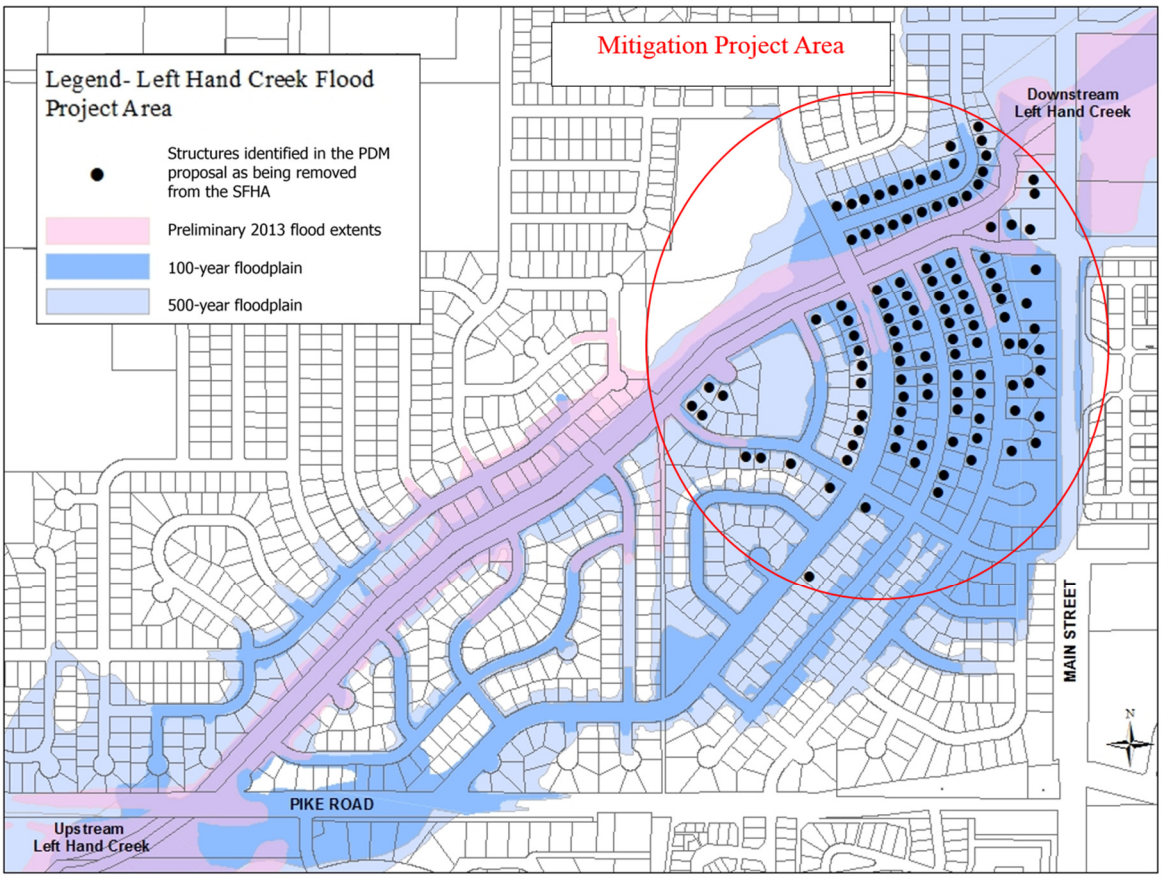

Figure G-1: Structures to be removed from SFHA in the Left Hand Creek Flood Project Proposal

Figure G-1 also shows the 100- and 500-year floodplains of the regulated FIRM, dated December 18, 2013, which reflects the MP_A condition of the LAS. The 2014 LOMRs are not included. The preliminary draft of the 2013 flood extents is shown; the event was determined to be a 100-year event. For the purposes of the LAS, the preliminary 2013 flood extent is the MP_C condition of the 100-year floodplain.

In reviewing the 2013 floods and the effective FIRM around the Left Hand Creek Flood Project area, more structures than were originally identified appear to have been positively impacted by the project. The alignment of the 2013 floods with the SFHA between Pike Road and Main Street allows for a bounded area to study. In this area, a total of 204 structures that are in or partially in the SFHA or 500-year floodplain may be considered for project benefits. These structures are shown in Figure G-2.

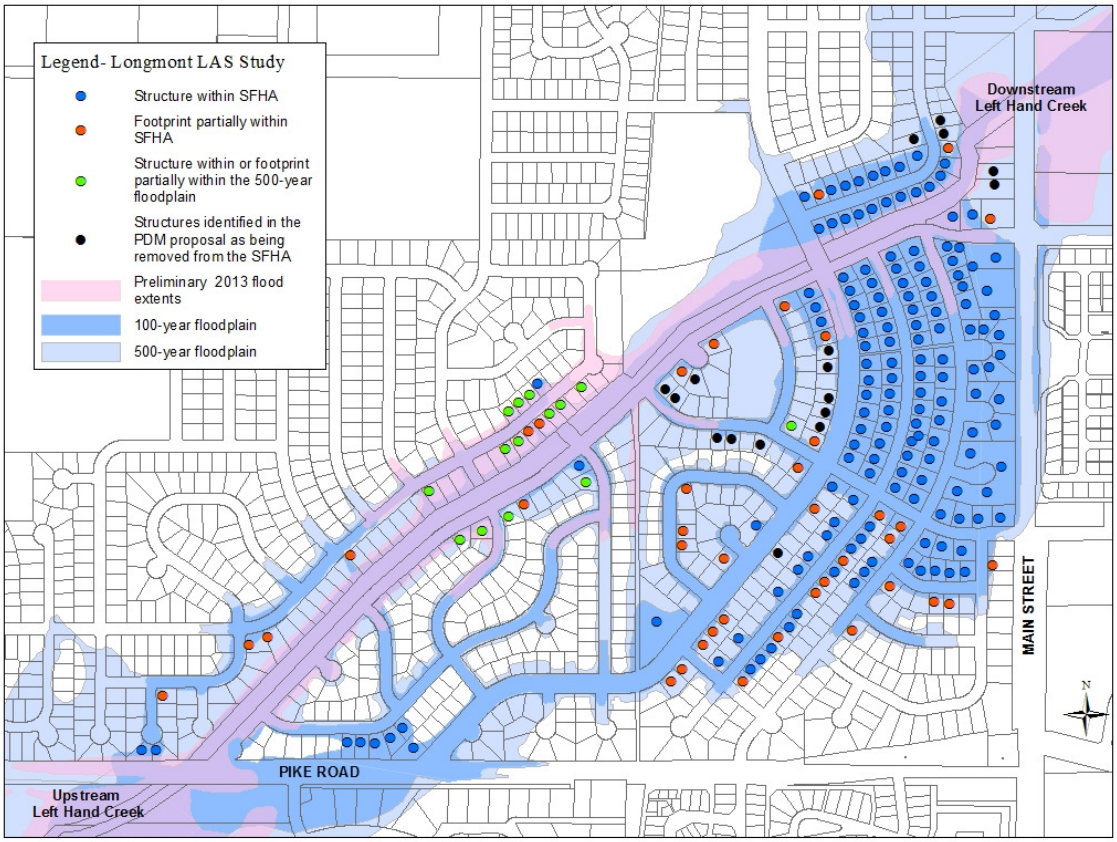

Figure G-2: Left Hand Creek LAS Project Area Map

In order to properly capture whether or not a structure is located in the SFHA, this study used both building centroids and building footprints to make the following distinctions:

- A structure is considered in the SFHA or 500-year floodplain if the centroid of the structure is in the area.
- A structure was considered partially in the SFHA or 500-year floodplain if the structure's footprint intersects the area.

Only the structure points with enough data to complete a losses avoided analysis are included in the study. Table G-1 quantifies the number of structures by flood zone and whether the structures suffered damages in the 100-year estimated event or in the 2013 floods.

Table G-1: Flood Hazard Risk of Structures in the LAS Project Area

Flood zone	Structures in LAS Project Area	Impacted Structures	
		MP_A	MP_C
SFHA Zone AE	151	107	9
500-year floodplain	50	0	14
Outside of 500-year floodplain	3	0	3
Total	**204**	**107**	**26**

Table G-1 shows the number of impacted structures for the MP_A and the MP_C conditions. Impacted structures in the MP_A condition are structures that have a base flood elevation (BFE) greater than the first floor elevation (FFE). The BFE is taken from the base flood depth grid. Impacted structures in the MP_C condition are structures that reported verified losses following the 2013 flood. No depth information is available for the 2013 floods.

In total, 107 structures are estimated to be impacted in the MP_A condition. There are 44 structures in the SFHA that have flood depths greater than zero, but these structures are not impacted, as the FFE is greater than the BFE. In the MP_C condition a total of 26 structures were impacted. The losses were recorded in the Individual Assistance (IA), National Flood Insurance Program (NFIP), and Small Business Administration (SBA) disaster assistance programs.

The LAS project area selection criteria is summarized in Table G-2.

Table G-2: LAS Project Area Criteria Summary

Area of interest	Left Hand Creek 100-year floodplain, 500-year floodplain, and 2013 flood extents from Main Street to Pike Road, Longmont, CO
Hazard type	Riverine flooding, Left Hand Creek channel
Project type	Flood reduction project: channel improvement and upsized culverts
Study baseline	December 2012

Only events occurring after the baseline date of December 2012 (when the Left Hand Creek project was completed) may be considered. This study focused only on one event, the 2013 flood; however, if additional events occur after the baseline date, they could be considered in a future analysis.

G.1.2 DATA ANALYSIS

This case study shares the same dataset as the base report, *Reducing Losses through Higher Regulatory Standards.* Detailed information on the data used is included in all of the report appendices. Table G-3 lists the parameters used in the case study.

Table G-3: Parameters Used

Building Information	
Building Replacement Cost	Year built
Contents Replacement Cost	Regulatory depth grid, depth in feet
Foundation type	Event depth, depth in feet
Basement type	First floor elevation, feet above ground
Occupancy type	Flood hazard zone
Flood Map Information	
500-year floodplain	
SFHA extents	

Area outside of the SFHA and 500-year floodplains
2013 Colorado Floods Preliminary Flood Extents
Area within 2013 flood event extents
Individual Assistance (IA)
Personal property FEMA-verified loss
Real property FEMA-verified loss
Total FEMA-verified loss
National Flood Insurance Program (NFIP)
Building damage verified replacement value
Content damage verified replacement value
U.S. Small Business Association (SBA)
Real estate verified replacement value

The data preparation steps taken are described in the following sections. They were:

- Left Hand Creek Flood Project mitigation cost
- Building location data joins
- Building information data joins
- First floor elevation (FFE) adjustments
- Depth damage function (DDF) selection

G.1.2.1 MITIGATION PROJECT COST

The mitigation project cost was used to analyze the ROI. The City of Longmont Left Hand Creek Flood Project cost $5,689,013 as reported in the PDM mitigation project proposal.

G.1.2.2 BUILDING LOCATION

Location data was collected for each structure in the study. The building location information—centroids in a GIS-compatible format—was provided by FEMA Region VIII and was joined with other data to produce the data necessary for this study. The data necessary for this study includes the GPS coordinates for the centroid of the structure; the county and NFIP jurisdiction regulatory information; the FIRM flood hazard zone; the 100-year, 500-year, and 2013 event flood boundaries; the depth of water in the Regulatory Depth Grid and the Event Depth Grids; and the location of structures with IA program claims, NFIP claims, and SBA disaster assistance reports.

G.1.2.3 BUILDING-SPECIFIC INFORMATION

This section describes the building and contents replacement value and the basement information. The Data Preparation Tool, developed as part of this study and documented in Appendix A, was used to compute the Building Replacement Value (BRV) and the Contents Replacement Value (CRV) for the structures. These values represent the estimated cost to replace the building or the contents after damages.

The presence of a basement in a residential structure is important information for the physical parameter analysis. The building data obtained from Boulder County included information on whether or not a basement existed for the structure and the basement type. The presence of a basement and the specific basement type were joined to the structure points. There are basements in 79 percent of the structures in the study area, as shown in Figure G-3.

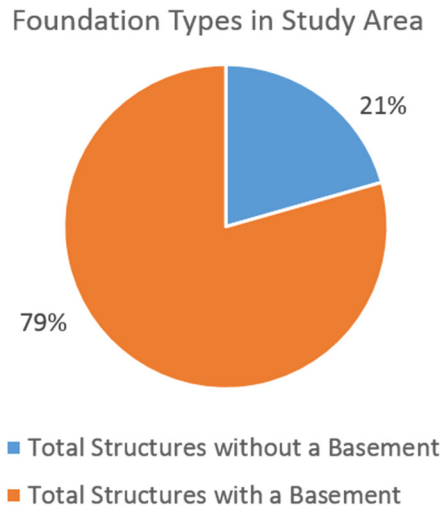

Figure G-3: Structures with Basements

G.1.2.4 FIRST FLOOR ELEVATIONS

This section details the methodology used to adjust the FFE data to account for basements and building age. The FFE is required data to perform a loss estimation analysis. In this study, the FFE is not an elevation but a height in feet above grade.

When there was no FFE available for a structure, the Data Preparation Tool (Appendix A) was used to generate default FFE values. The adjusted FFE values relied on two factors:

1. Construction date
2. Basement foundation type

If the structure was post-FIRM, meaning the structure was built after the FIRM was adopted by the jurisdiction, then a post-FIRM adjustment factor was applied. If the structure had a basement foundation type, then a basement adjustment factor was applied. The basement adjustment factor is used to move the FFE from the top of the first floor to the top of the basement floor when applicable. Figure G-4 shows the FFE adjustment factors used for all occupancy types.

Table G-4: FFE Adjustment

Occupancy Class	Foundation	Default FFE (feet)	Adjustment factors (feet)		Adjusted FFE (feet)	
		Pre-FIRM	Post-FIRM adjustment	Basement adjustment	Pre-FIRM	Post-FIRM
	Pile	7	1	0	7	8

Occupancy Class	Foundation	Default FFE (feet)	Adjustment factors (feet)		Adjusted FFE (feet)	
		Pre-FIRM	Post-FIRM adjustment	Basement adjustment	Pre-FIRM	Post-FIRM
Single family home	Pier	5	1	0	5	6
	Solid Wall	7	1	0	7	8
	Crawlspace	3	1	0	3	4
	Fill	2	0	0	2	2
	Slab	1	0	0	1	1
	Unfinished Enclosed Basement	4	0	0	4	4
	Finished Enclosed Basement	4	0	-8	-4	-4
	Unfinished Walkout Basement	4	0	-8	-4	-4
	Finished Walkout Basement	4	0	-8	-4	-4
Mobile home	Pier	3	1	0	3	4
	Crawlspace	3	1	0	3	4
Multi-family	Unfinished Enclosed Basement	4	0	0	4	4
	Pier	5	1	0	5	6
	Crawlspace	3	1	0	3	4
Other residential	Slab (Assume slab for all foundation types)	1	0	0	1	1
Non-residential	Slab (Assume slab for all foundation types)	1	0	0	1	1

The adjusted FFE is the height in feet above grade. A negative value indicates that the structure has a basement. The formula for determining the Adjusted FFE is:

Adjusted FFE = Default FFE + Post-FIRM Adjustment Factor + Basement Adjustment Factor

The building-specific information and the FFE information includes the following assumptions:

- Bi-level residential one-category homes are the same as split level.
- The FFE for split level homes is assumed to be the lower of the first floor levels, unless there is a basement.
- The FFE height below grade for structures with basements is based on a basement-to-first floor elevation difference of 8 feet.
- The adjusted FFE of structures with walkout basements is not considered to be at grade. It is assumed to be at 8 feet below the first floor elevation regardless of grade.

G.1.2.5 DEPTH DAMAGE FUNCTION

DDF curves identify damages as a percentage of replacement cost based on the depth of flooding at a structure. The DDF curves are based on the generic functions in the BCA Toolkit (Version 5.1). Every structure or occupancy type is assigned a DDF. These functions are used to determine the building damage percent, the contents damage percent, the displacement number of days impacted, and the loss of function number of days impacted. The DDF curves used in this case study are the same as those used in the main report. Appendix F provides the DDF tables.

G.2 PHYSICAL PARAMETER ANALYSIS

The physical parameter analysis is the second phase of a LAS. There are three parts of a physical parameter analysis:

- Storm event analysis
- Hydraulic analysis
- Flood inundation analysis

G.2.1 STORM EVENT ANALYSIS

The 2013 preliminary flood extents were used for MP_C conditions, and impacts were obtained from multiple datasets. The actual structure and contents damages were obtained from IA program claim reports, NFIP claim reports, and SBA disaster assistance reports. The values taken from the reports were the verified losses for structure and contents damages.

G.2.2 HYDRAULIC ANALYSIS

The MP_A scenario relied on FIRM data (December 18, 2013). The regulatory depth grid data was used to determine water depth at each structure for a 100-year base flood. The regulatory depth grid provided flood depths only for the 151 structures located in the SFHA.

G.2.3 FLOOD INUNDATION ANALYSIS

The flood inundation analysis determines the depth of flooding at the structure in a flood scenario. The flooding information for this analysis was converted into a water surface elevation (WSE) relative to the grade in feet. The adjusted FFE was used, based on Table G-5. A flood inundation analysis compares the WSE to the FFE to determine the depth of flooding inside or beneath the building. The formula is:

Flood depth (relative to the first floor elevation) = d = WSE - Adjusted FFE

If the flood depth calculation results in a negative value, the elevation of the FFE is greater than the elevation of the WSE and flooding occurs beneath the adjusted first floor. If the flood depth is a positive value, the elevation of the FFE is less than the elevation of the WSE, and flooding occurred in the building.

The flood inundation analysis identified 107 impacted structures in the MP_A condition. The impacted structures are shown in Figure G-4.

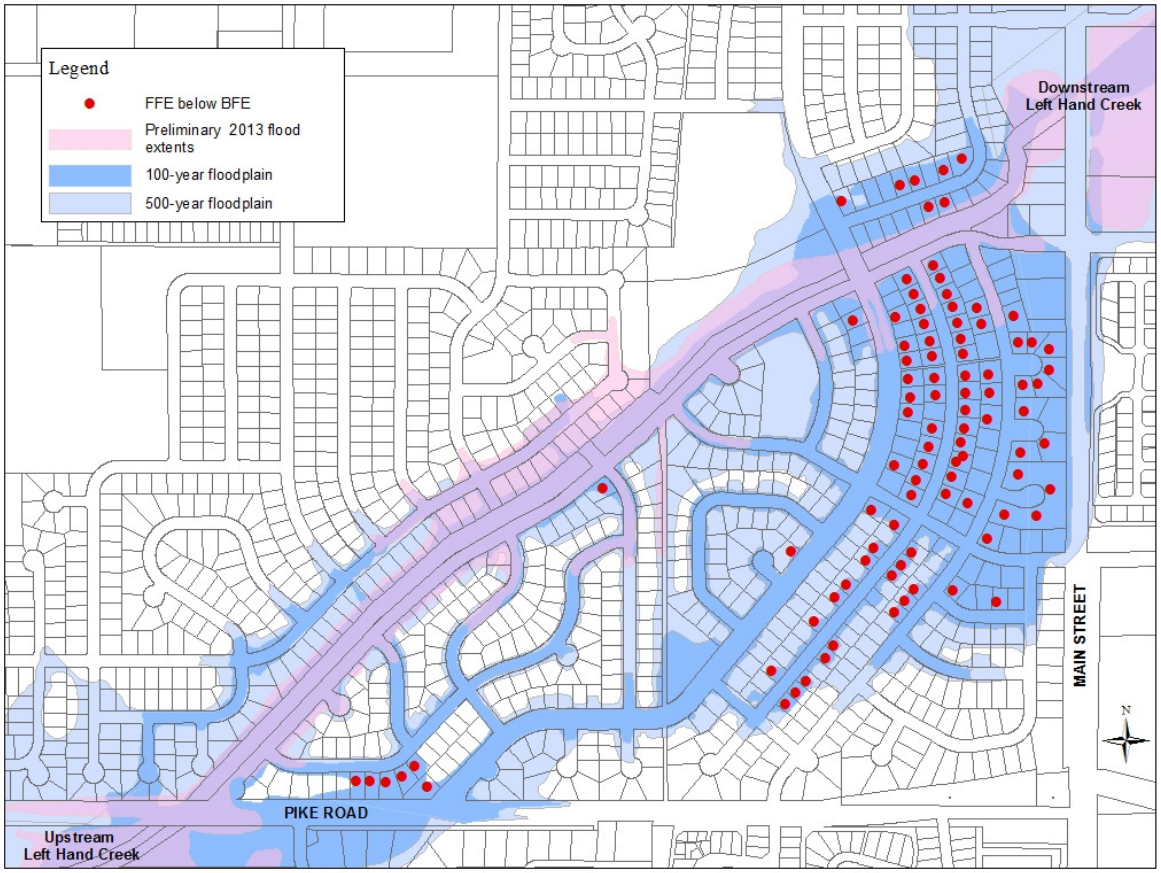

Figure G-4: MP_A Flood Inundation Analysis Results

G.3 LOSS ESTIMATION ANALYSIS

The loss estimation analysis compares the losses avoided in the project area before and after completion of a mitigation project. In this phase, the losses avoided were calculated for various benefit categories and added together for a total project losses avoided. The ROI was computed based on the total savings, or total losses avoided.

The losses avoided for the mitigation project are calculated by subtracting losses in the MP_C condition from the losses in the MP_A condition. The formula is:

$$LA = LMP_A - LMP_C$$

Where:

LA = Total Losses Avoided

LMP_A = Total Losses in MP_A scenario

LMP_C = Total Losses in MP_C scenario

The ROI of the mitigation project is based on the losses avoided. The total investment or actual costs of the mitigation project, including maintenance costs adjusted to present day values, is referred to as the mitigation project investment. The ROI formula is:

$$ROI = LA / PI$$

Where:

ROI = Return on Investment

LA = Total Losses Avoided

PI = Project Investment

G.3.1 LOSS CATEGORIES AND TYPES

The loss estimation analysis looks at the benefits for both the MP_A and the MP_C scenarios in the categories of physical damage, loss of function, and social and environmental benefits. The list of benefits evaluated is in Table G-5.

Table G-5: Loss Categories and Loss Avoided Benefits

Loss categories	Losses Avoided Benefits
Physical damage	Building damage
Physical damage	Contents damage
Loss of function	Displacement costs
Loss of function	Loss of business income
Social	Lost wages
Social	Avoidance of mental stress and anxiety
Environmental	Restoration of floodplain

G.3.1.1 PHYSICAL DAMAGE

The physical damages analyzed are the structure and contents losses. The physical damages are calculated using the DDF. The DDF is a function that graphs damage as a percentage of the replacement value for one foot increments of flood depth. (The flood depth is computed in the flood inundation analysis in Section G.2.3). There is a different replacement value and DDF curve for structure and contents.

The flood depth was interpolated to identify a specific damage percentage on the DDF for the greater than one-foot accuracy of the flood depth data. The DDF interpolation may be calculated as shown in the example of Figure G-5.

If d= 2.1 feet, obtain the DDF percentage at 2 feet and the DDF percent at 3 feet for the DDF that corresponds to the occupancy and basement type of the building.

The DDF interpolation formula is:

$$DDF_d = (d - DDF_2) \times ((DDF_3 - DDF_2) / (d_3 - d_2)) + DDF_2$$

Where:
DDF_2 = The DDF damage percent at 2 feet
DDF_3 = The DDF damage percent at 3 feet

Figure G-5: Example of a Depth Damage Function Interpolation

To calculate building damage losses, the structure DDF damage percent is multiplied by the BRV.

$$MP_A \text{ structure} = sDDF_d \times BRV$$

Where:

$sDDF_d$ = The damage percentage associated with the flood depth, d_A, of the MP_A condition on the structure DDF

To calculate contents damage losses, the contents DDF damage percent is multiplied by the CRV.

$$MP_A \text{ contents} = cDDF_d \times CRV$$

Where:

$cDDF_d$ = The damage percentage associated with the flood depth, d_A, of the MP_A condition on the contents DDF

The flood depth, d_C, in the MP_C condition is unknown, so the actual 2013 event damages were used. The actual event damages are the FEMA-verified losses in the IA, NFIP, and SBA reports.

$$MP_C \text{ structure} = \text{IA Structure Losses} + \text{NFIP Structure Losses} + \text{SBA Structure Losses}$$

$$MP_C \text{ contents} = \text{IA Contents Losses} + \text{NFIP Contents Losses}$$

G.3.1.2 DISPLACEMENT

Damage to the structure or contents may result in displacement of the residents while repairs are made. For this study, we will use the assumptions in Table G-6 to be the number of people residing in each home based on U.S. Census data. The DDF displacement and loss of function curves are interpolated based on flood depth to provide a specific number of days for which the residents are displaced.

Table G-6: Loss Category Assumptions

Losses avoided	Assumed number of persons per household
Displacement costs	2
Loss of productivity	1
Mental stress and anxiety	2

For Boulder County, the daily displacement cost is $175 per person per day. The total displacement cost was determined from the 2014-2015 General Services Administration (GSA) rate at the time of publication of this study. It is the sum of the GSA per diem lodging cost of $114/day and the meals cost of $61/day. This method was chosen to estimate displacement because it matches the method used in the BCA Toolkit (Version 5.1.)

The displacement costs are calculated by multiplying the daily displacement cost by the assumed number of people in the home and the estimated number of days of their displacement.

$$MP_A \text{ Displacement} = \text{Daily displacement cost} \times dDDF_d \times \text{Number of persons per household}$$

Where:

$dDDF_d$ = The displacement DDF damage percentage associated with the flood depth, d_A, of the MP_A scenario

The loss of rental income is sometimes calculated instead of displacement costs when a structure is rented out. This value is estimated by determining a daily rental income for the homeowner and multiplying this loss by the number of days the tenants are displaced. To simplify the study, the rented properties are estimated using the same method of computing displacement losses for the number of tenants, assumed to be the same as the number of persons per household shown in Table G-6.

G.3.1.3 LOSS OF BUSINESS INCOME

Loss of function is a loss category that is also associated with the loss of business income for commercial structures. The value of the net business income per day is multiplied by the loss of function DDF number of days. There are no commercial structures impacted in the study area. The formula for loss of business income is:

$$\text{Loss of Business Income} = fDDF_d \times \text{Daily Business Income}$$

Where:

$fDDF_d$ = The loss of function DDF damage percentage associated with the flood depth, d_A, of the MP_A scenario
Daily Business Income = Net business income (per square foot per day) times the square footage of the commercial structure

G.3.1.4 MENTAL STRESS AND ANXIETY

The avoidance of mental stress and anxiety is applied to all of the full time occupants of a residential structure. The mental stress and anxiety cost (MSA Cost) is the same as the value used in the BCA Toolkit (Version 5.1). The MSA Cost is $2,443 per person. The number of persons per household is given below. This benefit is computed the same way for the MP_A and MP_C scenario as follows:

Mental Stress and Anxiety Loss = MSA Cost x Number of persons per household

Where:

MSA Cost = $2,443 per person

G.3.1.5 LOSS OF PRODUCTIVITY

The loss of productivity applies to all full-time wage earners living in the home. The assumption is that there is one wage earner per household. The loss of productivity (LP) cost matches the value used in the BCA Toolkit (Version 5.1). The LP cost is $8,736 per person. This benefit is computed the same way for the MP_A and MP_C scenario as follows:

Loss of Productivity = LA cost x Number of persons per household

Where:

LA cost = $8,736 per person

G.3.1.6 ENVIRONMENTAL BENEFIT

Environmental benefits apply to acquisition mitigation projects and take into account the restoration of a parcel of land to a natural condition. There is an annual per-acre benefit that can be considered if the benefits of the hazard mitigation project yield a Benefit Cost Ratio (BCR) of 0.75-1.0. In this project there were no acquired structures, so the benefit does not apply in either the MP_A or MP_C scenario.

G.4 RESULTS OF THE LOSS ESTIMATION ANALYSIS

This section will summarize the loss estimation analysis results for the MP_A and MP_C scenarios. The benefit categories and methodologies for computing losses are described in Section G.3. The results section presents the loss estimation analysis results tables and highlights trends found in the distribution of losses in the study.

G.4.1 MITIGATION PROJECT ABSENT (MP_A) SCENARIO

The MP_A scenario analyzes the total losses to structures in the study area if the Left Hand Creek Flood Project was never completed. The following question was addressed:

If no mitigation projects were performed in the study area, what would the damages be in the 100-year base flood event?

In a 100-year flood, the community of 204 structures in the LAS study area would have an estimated $23.4 million of damages, as shown in Figure G-6.

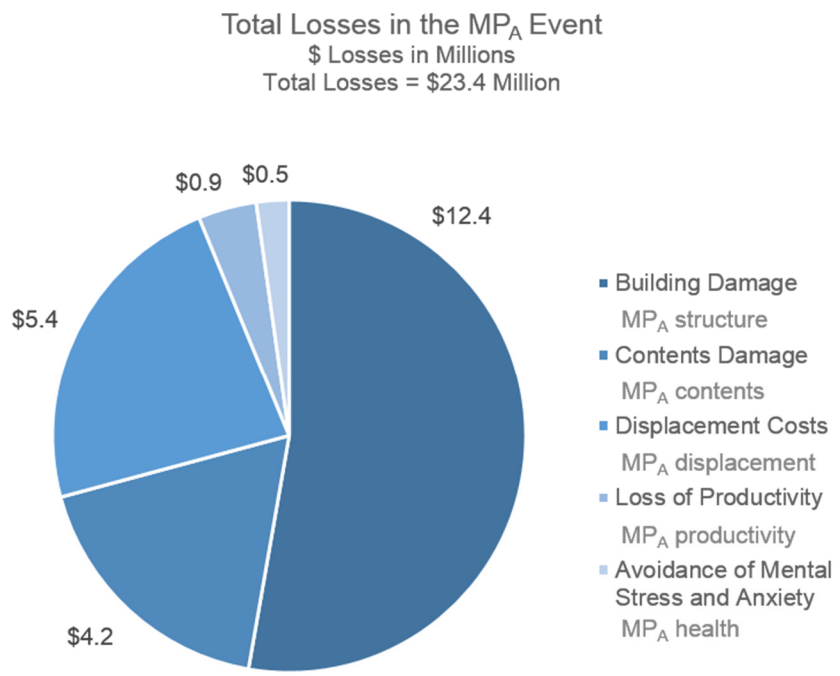

Figure G-6: Total MP_A Losses by Benefit Category

The highest percentage of losses is building losses at 53 percent. The social benefits, loss of productivity and the avoidance of mental stress and anxiety, account for six percent of the total.

The total losses are calculated from the formula:

$$LMP_A = MP_A\ structure + MP_A\ contents + MP_A\ displacement + MP_A\ business + MP_A\ productivity + MP_A\ health + MP_A\ environment$$

$$LMP_A = \$23{,}449{,}720$$

Figure G-7 provides a summary overview of the 100-year event results from the MP_A scenario. The event impacts include the number and characteristics of the impacted structures. A total of 107 structures in the study area were impacted, as identified by the flood inundation analysis (Section G.2.3). Structures built before the jurisdiction NFIP emergency entry date are known as pre-regulatory structures, and after, are known as post-regulatory.

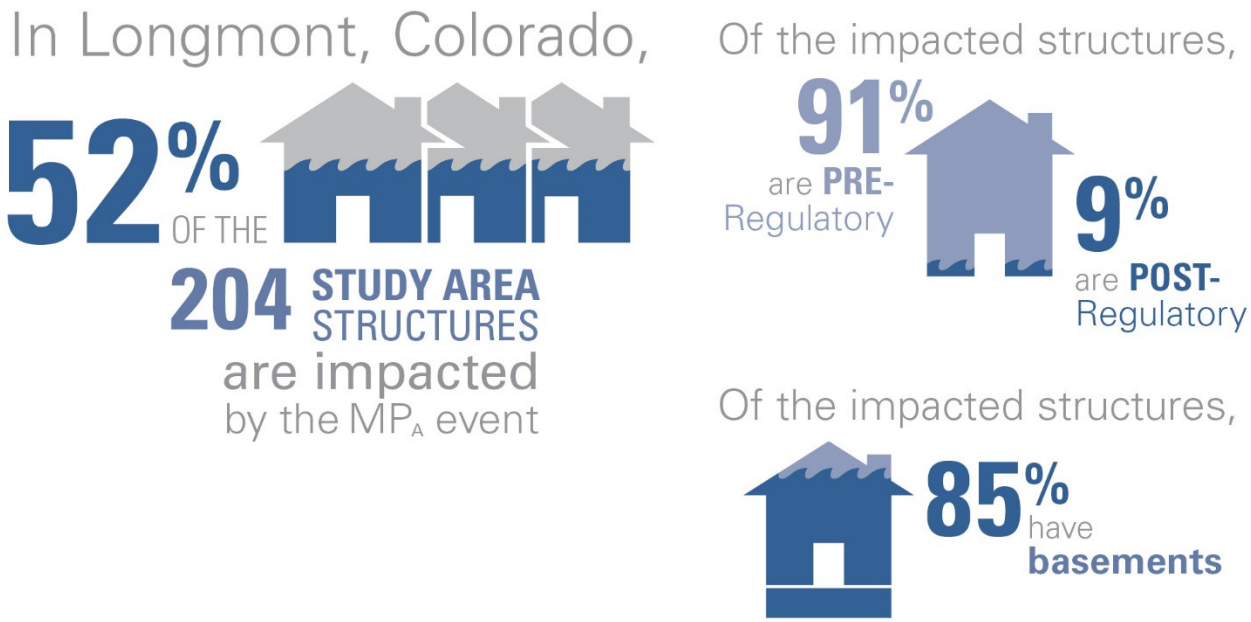

Figure G-7: Impact of Structures in MP_A Loss Estimation Analysis

Of the structures in the study area, 96 percent are residential. All impacted structures are residential and 91 percent of those impacted were built before the jurisdiction entered the NFIP.

There are 106 split-level homes in the study area, which accounts for more than half of the structures. Split-level homes, however, were also impacted the most and had the highest total loss estimation of $17 million. Losses occurred in 52 percent of the single-family residential structures and in 72 percent of the multi-family residential structures in the study area.

Of the residential structures, 79 percent have basements. In the 100-year MP_A event, structures with basements were impacted more than structures without basements. A total of 85 percent of structures with losses in MP_A scenario have basements.

Finished basements account for 72 percent of the basement types in the study area. More structures with finished basements were impacted than any other foundation type. Of the impacted structures, 80 percent have a finished basement, five percent have an unfinished basement and 15 percent have no basement.

G.4.2 MITIGATION PROJECT COMPLETE (MP_C)

The MP_C scenario analyzes the total losses to structures in the study area that occurred as a result of the 2013 event, a 100-year flood event in Left Hand Creek that occurred after the mitigation project was completed. The following question was addressed:

> *After the mitigation project was completed in the study area, what were the damages in the 2013 100-year flood event that impacted the Left Hand Creek?*

After mitigation, the 204 structures in the LAS study area would have an estimated $997,000 of losses, as shown in Figure G-8. There are no flood depth grids for the 2013 event, so the damages were taken from the verified losses of the IA, NFIP, and SBA damage reports.

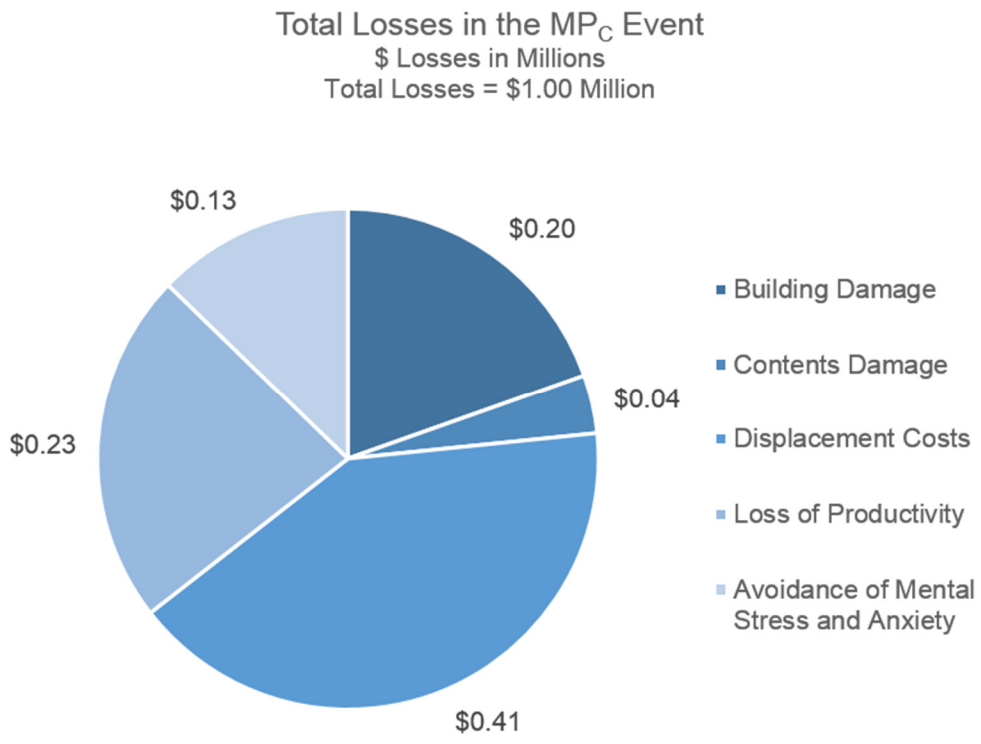

Figure G-8: Total MP_C Losses by Benefit Category

The highest percentage of losses are displacement costs at 41 percent. The social benefits, loss of productivity, and the avoidance of mental stress and anxiety, account for 36 percent of the total.

There were reports of 26 structures with IA, NFIP, or SBA damages in the study area. Losses occurred both in and outside of the 100-year and the 500-year floodplains as shown in Table G-7. The building and contents damages that were reported under one program were compared with another program so that no double counting of benefits would occur; however, some structures were eligible for multiple forms of assistance. The total verified losses are the program totals, but these losses are not the total MP_C scenario losses.

Table G-7: Reports of Damage and Verified Losses by Disaster Assistance Type

Flood zone	Total number of structures in study area	Number of structures with reports of damage			
		Total	IA report	NFIP report	SBA report
In 100 year floodplain	151	9	6	5	1
In 500 year floodplain	50	14	14	2	0
Outside of 500 year floodplain	3	3	3	0	0
Impact total	204	26	23	7	1
MP_C physical damage verified losses		**$232,957**	**$107,115**	**$97,557**	**$28,285**

The benefit categories that are not documented in the disaster assistance reports, such as displacement and social benefits, are estimated for the MP_C results based on the methodology

presented in Section G.3. The structure damage losses and the contents damage losses are actual, verified losses. The results of the loss estimation analysis are shown in Table G-8.

Table G-8: Loss Estimation Analysis Results- MP_C

Benefits evaluated	MP_C loss categories	Losses in the 100-year floodplain	Losses in the 500-year floodplain	Losses outside of the 500-year floodplain	Total Losses
General	Building Damage	$142,937	$43,621	$8,618	$195,175
	Contents Damage	$18,148	$19,420	$214	$37,782
	Displacement Costs	$141,750	$220,500	$47,250	$409,500
	Loss of Business Income	$0	$0	$0	$0
Social	Loss of Productivity	$78,624	$122,304	$26,208	$227,136
	Avoidance of Mental Stress and Anxiety	$43,974	$68,404	$14,658	$127,036
Environmental	Restoration of Floodplain	$0	$0	$0	$0
Total	**Total Losses**	**$425,433**	**$474,249**	**$96,948**	**$996,629**

The physical losses account for 33 percent of the total LMP_C. Not all losses are captured in physical damages, which is why other benefit categories are considered in this analysis. A total of $763,672 in additional losses above the verified losses in the IA, NFIP, and SBA reports, is found by evaluating all of the selected benefit categories.

The total losses are calculated from the formula:

$$LMP_C = MP_C\ structure + MP_C\ contents + MP_C\ displacement + MP_C\ business + MP_C\ productivity + MP_C\ health + MP_C\ environment$$

Where LMP_C = $996,629

Figure G-9 provides a summary of the 100-year event results from the MP_C scenario. The event impacts include the number and characteristics of the impacted structures.

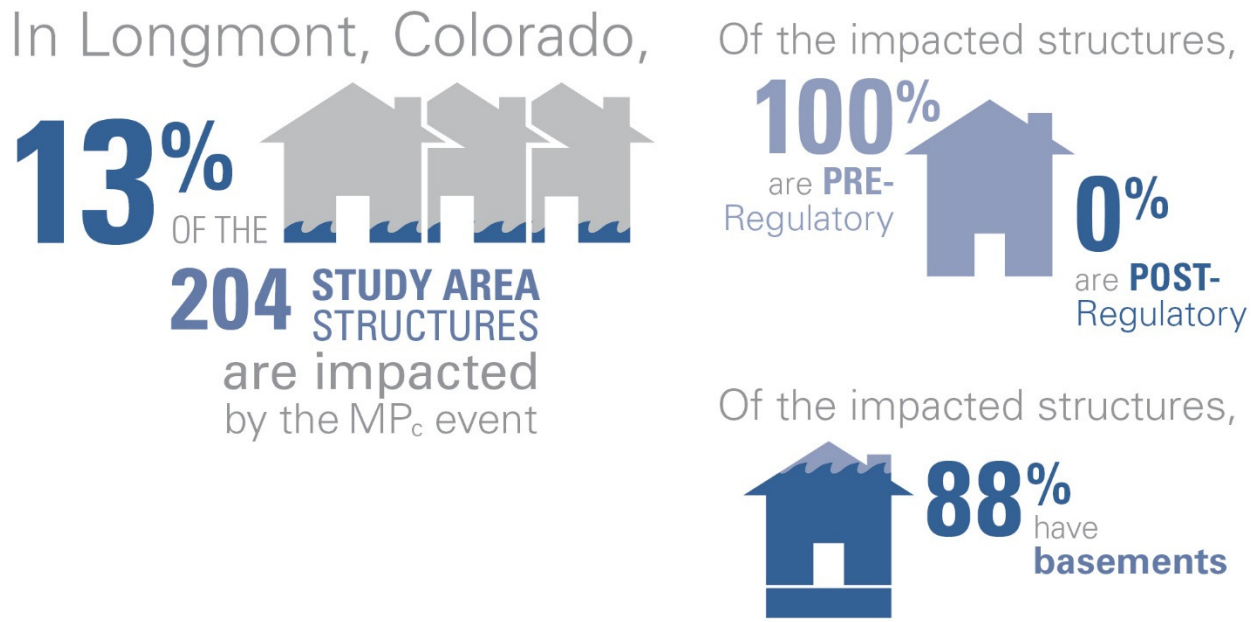

Figure G-9: Impact of Structures in MP_C Loss Estimation Analysis

As in the MP_A scenario, in the MP_C scenario, all of the impacted structures are residential. All 26 impacted structures are pre-regulatory structures. No post-regulatory structures had losses in the MP_C scenario, even though ten post-regulatory structures have losses in the MP_A scenario.

Losses occurred in split level structures more than any other type of residential building. The foundation type with the highest number of impacted structures is a finished walkout basement. Of the impacted structures, 65 percent have a finished basement, 23 percent have an unfinished basement, and 12 percent have no basement.

G.4.3 LOSSES AVOIDED AND RETURN ON INVESTMENT

The losses avoided are calculated by comparing the LMP_A to the LMP_C. The formula is:

$$LA = LMP_A - LMP_C$$

The LMP_C are the actual structural and contents damage losses that were recorded as a result of the 2013 flood. In addition, the estimate includes the losses related to displacement, loss of function, and social benefits, which were not directly reported. The LMP_A are the losses estimated in the study area before the mitigation project was completed. The results are shown in .

Table G-9: Losses Avoided Results

Total Losses		Losses Avoided
LMP_A	LMP_C	LA
$23,449,720	$996,629	$22,453,091

The losses avoided are $22.5 million. The BCR was computed to be 1.942. While the Benefit Cost Analysis (BCA) analyzed the road blocks and hardship to residents as additional benefits, it

also predicted that the channel maintenance project would reduce future maintenance costs following flooding events. It also summarized the hardship to residents if they were displaced.

The ROI compares the losses avoided with the actual mitigation project costs. The Project Investment, PI, is the mitigation project cost plus the present value of the annual maintenance cost. The cost estimate of the construction of the mitigation project is $5,689,013.

The present value of the annual maintenance costs adjusts the annual maintenance over the project useful life to present day values. The annual maintenance cost for mowing and clearing the culverts of debris, provided in the mitigation project application, is $4,500 per year. The useful life for a culvert is 30 years. The Left Hand Creek Flood Project uses more than one mitigation measure; however, the culvert useful life is the shortest and therefore will be used. The present value coefficient (PVC) is determined in accordance with the BCA Toolkit Version 5.1 methodology. The PVC was calculated to be 12.41.

The present worth of the annual maintenance cost is:

Present Worth of Annual Maintenance Cost = Annual Maintenance Cost x PVC

Present Worth of Annual Maintenance Cost = $4,500 x 12.41 = $55,845

The PI is:

PI = Total Project Cost + Present Worth of Annual Maintenance Cost

PI = $5,689,013 + $55,845 = $5,744,858

The ROI is:

ROI = LA / PI

ROI = $22,453,091 / $5,744,858 = 3.91

The present worth of the project cost is $5.7 million. The losses avoided are $22.4 million. ROI estimates the value of the mitigation investment. A ROI equal to one indicates that the losses avoided are equal to the project costs. An ROI greater than one indicates that the investment costs have return, in avoided costs, greater than the amount invested.

The ROI of 3.91 is for one flood event that occurred within one year of the project completion date. The ROI for the mitigation project may be higher over the project useful life of 30 years.

G.5 SUMMARY

The LAS compares the total losses of the MP_A and the MP_C 100-year flood events. Figure G-10 shows the total MP_A losses and the losses avoided. The mitigation project resulted in a 96 percent reduction in losses.

Figure G-10: Left Hand Creek Flood Project LAS Summary (MP_A losses and LA)

The mitigation project achieved $22.5 million in losses avoided because of the number of structures with reduced and/or no damages in the 100-year event. A net total of 81 structures had a reduction in damages between the MP_A and MP_C events. There were 17 structures outside of the SFHA that had damages in the MP_C scenario but not in the MP_A scenario; however, these structures do not show any damages in a modeled scenario due to their locations outside of the regulatory floodplain. The actual event damages are not restricted to the SFHA; however, 98 fewer structures in the SFHA were impacted.

A summary of the LAS results is shown in Figure G-11. Removing structures from the floodplain directly reduces building and contents losses. If the building and contents are not damaged, there is a greater likelihood that the loss of function and social losses will be eliminated or reduced as well.

Figure G-11. Project LAS Results

The losses due to building and contents damages account for 71 percent of the MP_A total losses, as shown in Table G-10. The results from the MP_C analysis, the actual verified building and contents losses, account for only 23 percent of the total losses, which demonstrates that event losses may not be quantified by physical damages alone. The displacement and social benefits are 77 percent of the estimated MP_C losses.

Table G-10: Losses Avoided by Category

Loss Category	Total MP_A Losses	Total MP_C Losses	Losses Avoided
Building Losses	$12,371,223	$195,175	$12,176,048
Contents Losses	$4,235,470	$37,782	$4,197,688
Displacement	$5,385,564	$409,500	$4,976,064
Loss of Business Income	$0	$0	$0
Lost Productivity	$934,661	$227,136	$707,525
Mental Stress and Anxiety	$522,802	$127,036	$395,766
Environmental Losses	$0	$0	$0
Total	$23,449,720	$996,629	$22,453,091

The age of the building is an important consideration when comparing regulatory standards. The total number of pre-regulatory structures in the study area is 78 percent. The percent of pre-regulatory structures impacted for both the MP_A and MP_C scenarios is greater, at 91 percent and 100 percent respectively. The increase in percentage indicates that the pre-regulatory structures have a greater risk, due to unregulated foundation types, building occupancy types, local drainage, or location in the floodplain.

The impacts to structures with different foundation types are shown in Figure G-12.

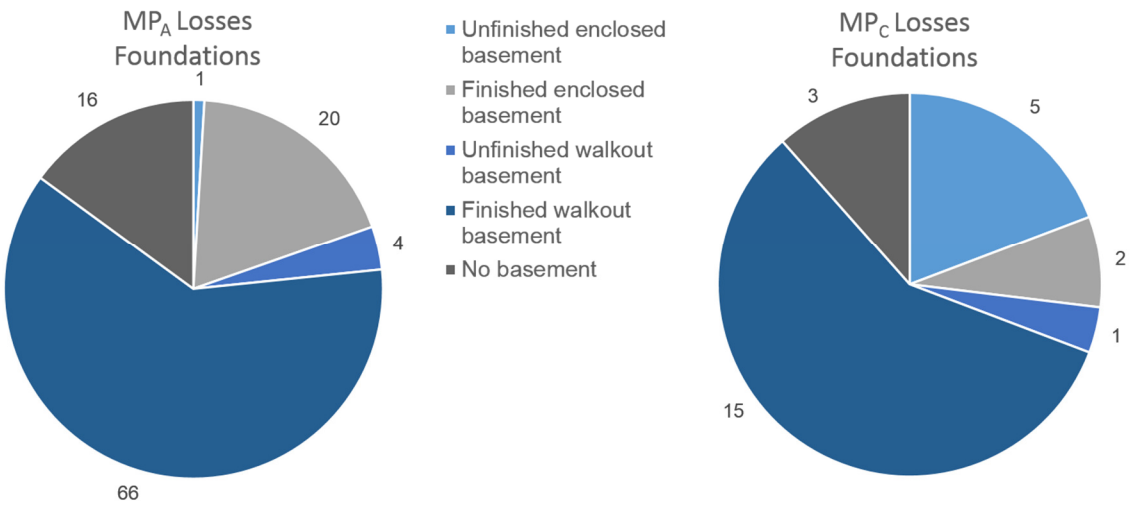

Figure G-12: Impacted Structures by Foundation Types

The MP_A and MP_C results show that the structures with finished walkout basements were impacted the most. The losses in these structures totaled $16.9 million in the MP_A event and $559,000 in the MP_C event. Of the structures in the study area, almost three quarters (72 percent) of the basement foundation structures are finished basements. Losses in structures with finished basements totaled $20.8 million in the MP_A event and $618,000 in the MP_C event. Overall the reduction to losses in basement structures is 96 percent.

Structures that did not have basements had losses in both scenarios as well. The MP_A losses and MP_C losses that occurred in structures without a basement are 15 percent and 11 percent of the total structures impacted, respectively. The total losses in structures without basements were $1.5 million in the MP_A event and $144,000 in the MP_C event.

All of the structures with losses in the LAS were residential structures. In both the MP_A and MP_C scenario almost two thirds (62 percent in each) of the impacted structures were split level single-family homes. Split level homes with and without basements have a lower FFE in one portion of the home, which increases the risk for flood damages. Multi-family structures were damaged in both scenarios as well. Eighteen multi-family structures were impacted in the MP_A scenario and three were impacted in the MP_C scenario. Losses to multi-family structures may increase the social category of losses as well as the potential for a loss of rental income to the property owner.

Conclusions

The study found that:

- The overall losses avoided during the 2013 event were $22 million, with an ROI of $3.9 for every mitigation dollar spent from just this one event.
- Basement losses were reduced by 96 percent.
- Post-regulatory structure losses were reduced by 100 percent.

- Almost all (91 percent) of the impacted structures in the 100-year flood event were pre-regulatory. Of the impacted structures in the 2013 event, 100 percent were pre-regulatory.
- Physical building and contents losses account for 73 percent of the total losses avoided.

The benefits of the Left Hand Creek Flood Project extend beyond the individual homeowner impacts summarized in the loss categories of the LAS. In order to remove structures from the SFHA around Left Hand Creek, improvements to the channel had to be made. These channel maintenance improvements reduce the frequency of flood events by increasing the flow capacity of the channel and of two culverts at road crossings. The structural losses to the roadways and bridges that experienced flooding and overtopping in past events are additional benefits of the project. As indicated in the PDM, the improved channel design decreases flood recovery costs and maintenance efforts following flood events. Not all benefits are captured in the LAS; however, the mitigation measure of removing pre-regulatory structures with finished basements from the SFHA has been shown through this LAS to be effective and to have a high ROI.

APPENDIX H: SCENARIO METHODOLOGY

The individual scenarios studied for the floodplain, floodway, freeboard, critical facility, and erosion regulatory scenarios are described in detail in this appendix. The methodology for these scenarios are presented in the following order:

- Criteria: Description of how structures to be included in the scenario were selected.
- Baseline: Calculation of the baseline scenario (without regulatory change) losses. This is the MP_A scenario.
- Regulatory Change: Description of the "what if" regulatory change to be analyzed. This is the MP_C scenario.
- Procedure: Methodology to determine regulatory losses avoided for the scenario, applying the regulatory change.

In addition to jurisdiction regulations, this appendix describes the methodology for evaluating how the adoption of jurisdiction regulations over time affects losses, and how adoption of jurisdiction regulations as reflected in CRS scores affects NFIP claims and policies. This appendix includes the following subsections:

Section H.1: Floodplain Development Regulations Adopted Earlier

Section H.2: Floodway Development Regulations Adopted Earlier

Section H.3: Freeboard Adopted Earlier

Section H.4: Freeboard Never Adopted

Section H.5: Freeboard Regulated to a Higher or Lesser Standard

Section H.6: Critical Facilities Regulated Earlier

Section H.7: Erosion Setback Assessment

Section H.8: Benchmark Years

Section H.9: NFIP Claims

H.1 FLOODPLAIN DEVELOPMENT REGULATIONS ADOPTED EARLIER

Restrictions on development in the 100-year floodplain are analyzed in this scenario. The following question is addressed:

> *If no development in the 100-year floodplain was allowed when the jurisdiction first entered the NFIP, what losses would this regulation have avoided in the 100-year flood event and in the September 2013 Colorado flood event?*

This scenario analyzes what the impact would be in a 100-year flood event and in the 2013 flood event if jurisdiction regulations did not allow for any development at all in the floodplain. The baseline floodplain boundary used for this scenario was the effective FIRMs for the study area. The NFIP emergency entry date is taken to be the jurisdiction entry date for this scenario. The

date assigned to the structure for year built is assumed to be the year new construction or substantially improved construction was completed. The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- Structures located in the 100-year floodplain, and
- Structures built after the jurisdiction's NFIP emergency entry date.

Baseline:

- Determine the flood depth, *d*, at a structure, for the 100-year flood event from the regulatory depth grid.
- Calculate the losses for the 100-year flood event, $MP_{A\ 100}$, using *d*.
- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the FEMA verified values.

Regulatory Change:

- Remove post-NFIP structure points in the 100-year floodplain from this scenario.

Assumptions:

- No post-regulatory losses would occur in the floodplain if there were no post-regulatory structures in the floodplain.
- The losses for the 100-year flood event, $MP_{C\ 100}$, are equal to the pre-regulatory structure losses.
- The losses for the 2013 event scenario, $MP_{C\ 2013}$, are equal to the pre-regulatory structure losses.
- Calculate losses avoided.

H.2 FLOODWAY DEVELOPMENT REGULATIONS ADOPTED EARLIER

Restrictions on development in the floodway are analyzed in this scenario. The following question is addressed:

> *If no development in the floodway was allowed when the jurisdiction first entered the NFIP, what losses would this regulation have avoided in the 100-year base flood event and in the September 2013 Colorado flood event?*

The NFIP emergency entry date is taken to be the jurisdiction's NFIP entry date for this scenario. The date assigned to the structure for year built is assumed to be the year new construction or substantially improved construction was completed. If all development had been prohibited in the floodway, the losses from structures built after the emergency entry date in the floodway are the losses avoided. The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- Structures located in the floodway, and
- Structures built after the jurisdiction's NFIP emergency entry date.

Baseline:

- Determine the flood depth, *d*, at the structure, for the 100-year flood event from the regulatory depth grid.
- Calculate the losses for the 100-year flood event, $MP_{A\ 100}$, using *d*.
- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the FEMA verified values.

Regulatory Change:

- Remove all structure points in the floodway from this scenario.

Assumptions:

- No post-regulatory losses would occur in the floodway if there were no post-regulatory structures in the floodway.
- The losses for the 100-year flood event, $MP_{C\ 100}$, are equal to the pre-regulatory structure losses.
- The losses for the 2013 event scenario, $MP_{C\ 2013}$, are equal to the pre-regulatory structure losses.
- Calculate losses avoided.

H.3 FREEBOARD ADOPTED EARLIER

The period of freeboard regulation is analyzed in this scenario. The following question is addressed:

> *If freeboard regulation had been adopted starting the year of the jurisdiction's NFIP entry date, what would the losses be in a 100-year base flood event and what would the losses have been in the September 2013 Colorado flood event?*

It is assumed that the current freeboard regulation was not adopted when the jurisdiction entered the NFIP. In this scenario, the current freeboard is added to structures in the SFHA built after the jurisdiction's NFIP emergency entry date. The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- Structures located in the 100-year floodplain, and
- Structures built after the emergency entry date.

Baseline:

- Determine the flood depth, *d*, at the structure, for the 100-year flood event from the regulatory depth grid.
- Calculate the losses for the 100-year flood event, $MP_{A\ 100}$, using *d*.
- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the FEMA verified values.

Regulatory Change:

- Add the current freeboard regulation to the FFE.

Assumptions:

- Adjust the structure's FFE to *FFE adjusted*.
- Calculate the adjusted flood depth, *d adjusted*, at the structure, for the 100-year flood event using the *FFE adjusted*.
- Calculate losses for the 100-year flood event, $MP_{C\ 100}$, using *d adjusted*.
- Calculate a damage percentage, *Z*, of the actual IA event losses divided by the replacement cost.
- Calibrate *Z* with the applicable DDF curves to determine a flood depth, *dZ*.
- Adjust the flood depth for the regulatory change and obtain the adjusted damage percent, *Z adjusted*.
- Calculate the adjusted event losses, $MP_{C\ 2013}$, by multiplying the replacement cost by *Z adjusted*.

H.4 FREEBOARD NEVER ADOPTED

The use of freeboard regulation is analyzed in this scenario. The following question is addressed:

> *If freeboard regulation was never adopted, what would the losses be in a 100-year flood event and what would the losses have been in the September 2013 Colorado flood event?*

This scenario assumes that all structures in the SFHA were built to current freeboard regulatory standards. The current freeboard regulation is removed from all structures in the SFHA. Structures outside of the SFHA are assumed not to have freeboard requirements and are not included in the analysis. The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- Structures located in the 100-year floodplain

Baseline:

- Determine the flood depth, *d*, at the structure, for the 100-year flood event from the regulatory depth grid.

- Calculate the losses for the 100-year flood event, $MP_{A\ 100}$, using *d*.
- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the IA FEMA-verified values.

Regulatory Change:

- Subtract the current freeboard regulation from the FFE.

Assumptions:

- Adjust the structure's FFE to *FFE adjusted*.
- Calculate the adjusted flood depth, *d adjusted*, at the structure, for the 100-year flood event by using *FFE adjusted*.
- Calculate losses for the 100-year flood event, $MP_{C\ 100}$, using *d adjusted*.
- Calculate a damage percentage, *Z*, of the actual IA event losses divided by the replacement cost.
- Calibrate *Z* with the applicable DDF curves to determine a flood depth, *dZ* of the flood event.
- Adjust the flood depth for the regulatory change and obtain the adjusted damage percent, *Z adjusted*.
- Calculate the adjusted event losses, $MP_{C\ 2013}$, by multiplying the replacement cost by *Z adjusted*.

H.5 FREEBOARD REGULATED TO A HIGHER OR LESSER STANDARD

The freeboard regulated to a higher or lesser standard methodology is analyzed in this scenario and addresses the following question:

> *If freeboard was regulated to a higher or lesser standard for structures in the SFHA, what would the losses be in a 100-year flood event and what would the losses have been in the September 2013 Colorado flood event?*

The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- Structures located in the 100-year floodplain

Baseline:

- Determine the flood depth, *d*, at the structure, for the 100-year flood event from the regulatory depth grid.
- Calculate the losses for the 100-year flood event, $MP_{A\ 100}$, using *d*.
- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the FEMA verified values.
- Calculate Losses Avoided (LA) for the baseline scenario.

Regulatory Change:

- Add 1 or 2 feet or subtract 1 or 2 feet from the FFE to change the freeboard regulation

Assumptions:

- Adjust the structure's FFE to *FFE adjusted*.
- Calculate the adjusted flood depth, *d adjusted*, at the structure, for the 100-year flood event by using the *FFE adjusted*.
- Calculate losses for the 100-year flood event, $MP_{C\ 100}$, using *d adjusted*.
- Calculate a damage percentage, *Z*, of the actual IA event losses divided by the replacement cost.
- Calibrate *Z* with the applicable DDF curves to determine a flood depth, *dZ* of the flood event.
- Adjust the flood depth for the regulatory change and obtain the adjusted damage percent, *Z adjusted*.
- Calculate the adjusted regulation scenario event losses, $MP_{C\ 2013}$, by multiplying the replacement cost by *Z adjusted*.

H.6 CRITICAL FACILITIES REGULATED IN SFHA

The critical facilities scenario methodology is analyzed in this scenario and addresses the following question:

> *If the development of critical facilities in the SFHA was restricted and no critical facilities were ever built in the 100-year floodplain, what losses would have been avoided in the 100-year base flood event and in the September 2013 Colorado flood event?*

The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- Structures identified by their description as critical facilities, and
- Structures located in the 100-year floodplain.

Baseline:

- Determine the flood depth, *d*, for the 100-year flood event from the regulatory depth grid.
- Calculate the losses for the 100-year flood event, $MP_{A\ 100}$, using *d*.
- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the FEMA verified values.

Regulatory Change:

- Remove all critical facilities in the 100-year floodplain from this scenario.

Assumptions:

- No post-regulatory losses would occur in the floodplain if there were no post-regulatory critical facilities in the floodplain.
- The losses for the 100-year flood event, $MP_{C\ 100}$, are equal to the pre-NFIP critical facility losses.
- The losses for the 2013 event scenario, $MP_{C\ 2013}$, are equal to the pre-NFIP critical facility losses.

H.7 EROSION SETBACK ASSESSMENT

The erosion setback assessment scenario addresses the following question:

> *What would the losses and losses avoided from the 2013 Colorado floods have been if development in the St. Vrain Creek erosion zone had been prohibited?*

The methodology to set up and run the analysis for this scenario is as follows:

Criteria:

- The structures located in the St. Vrain Creek erosion zone.

Baseline:

- Calculate the 2013 flood event losses, $MP_{A\ 2013}$, from the FEMA verified values.

Regulatory Change:

- Remove all structures in the St. Vrain Creek erosion zone from this scenario.

Assumptions:

- No losses would occur in the St. Vrain Creek erosion zone if there were no structures in the erosion zone.
- The losses for the 2013 event scenario, $MP_{C\ 2013}$, are 0.

H.8 BENCHMARK YEARS

The benchmark years scenario methodology analyzes the question:

> *Do increased regulations, over time, result in fewer damages?*

The methodology to analyze this scenario is different than the previous scenarios since this scenario is analyzing regulatory change over time. There is not a baseline or specific regulatory change for this scenario; however, the criteria and procedure are provided below.

Criteria:

To assess the relationship between regulatory standards and damage costs incurred across jurisdictions, first a database of summary statistics for each jurisdiction's structures based on occupancy type, floodplain status, year built, and extent of damage from the 2013 floods was

developed. The six jurisdictions included in the analysis are the City of Boulder, Unincorporated Boulder County, Fort Collins, Longmont, and Louisville.[5] Summary statistics include the number of structures built, the number of structures damaged, the cumulative structure and contents replacement cost (for both damaged and undamaged structures), and the cumulative cost of damages.

Assumptions:

The procedure for this analysis included identifying the changes in regulatory standards and determining the losses as a result of the changes to the regulatory standards.

- Identify changes in regulatory standards for each jurisdiction based on annual scores for CRS activity 430 (c430): "Higher Regulatory Standards." Specifically, a database was constructed of historical regulatory standards scores for c430 scores from 1998 to 2013. From this database, a "breakpoint analysis" was conducted to identify when changes to each jurisdiction's regulatory standards were significant enough to warrant a change in the jurisdiction's c430 score. In most cases (but not all), regulatory standards become more stringent over time.

- Merge the structure database with the CRS breakpoints across jurisdictions. The summary statistics were calculated for each time period defined by the CRS breakpoint analysis in each jurisdiction. Assuming c430 scores accurately reflect each jurisdiction's enforced regulatory standards for each period—and assuming these standards reduce the vulnerability to flooding of structures built after they have been implemented—the damage suffered by structures as a percentage of total replacement cost should generally be lower for jurisdictions with higher c430 scores.

H.9 NFIP CLAIMS

The NFIP claims scenario methodology is described in this section. This scenario analyzed the question:

> *Is there a correlation between the NFIP policies, claims, and the CRS outreach score for CRS jurisdictions?*

The methodology to analyze this scenario is similar to Section H.8, since this scenario analyzes the relationship between NFIP policies, claims, and the CRS outreach score. There is not a baseline or specific regulatory change for this scenario; however, the criteria and procedure are provided below.

The methodology to set up and run the analysis for this scenario is as follows:

[5] Based on its CRS score for c430, Loveland didn't join the CRS system until recently, and there is no variance in the regulatory scores for the years available. As such, Loveland was excluded from the analysis.

Criteria and Assumptions:

After identifying the relevant structures with NFIP coverage, it was determined whether each structure was inside or outside the SFHA using the FIRM flood zone. The year built was acquired from parcel data and used to determine if the structure was pre- or post-FIRM. The insurance payout was calculated for each damaged structure using the sum of the "T_DMG_BLDG" and "T_DMG_CONT" fields in the Claims database. The total number of policies and claims in each jurisdiction was compared with the total number of structures in these jurisdictions in order to determine whether structures in jurisdictions with strong outreach scores were more likely to be insured through the NFIP than structures in lower scoring-outreach jurisdictions. Finally, the NFIP data were merged with the relevant CRS scores for "Outreach Projects" (c330) using jurisdiction identifiers.

APPENDIX I: LOSS OF FUNCTION VALUES

Loss of function (loss of business income) is a benefit category that is associated with the loss of income for non-residential structures. The value of the net business income per day is multiplied by the loss of function DDF, identified in FEMA's BCA Toolkit (Version 5.1) and the number of days the loss of function is experienced. The net business income per square foot is obtained from Table 15.15 of the Hazus-MH MR4 Technical Manual and is listed in the Table I-1.

Table I-1: Net Business Income Guide (Hazus Table 15.15)

Label	Occupancy Class	Per square foot per year	Per square foot per day
RES1	Single Family Dwelling	0	0
RES2	Mobile Home	0	0
RES3	Multifamily Dwelling	0	0
RES4	Temporary Lodging	32.065	0.088
RES5	Institutional Dormitory	0	0
RES6	Nursing Home	53.442	0.146
COM1	Retail Trade	19.785	0.054
COM2	Wholesale Trade	32.449	0.089
COM3	Personal and Repair Services	42.754	0.117
COM4	Professional/Technical/ Business Services	336.882	0.923
COM5	Banks	384.421	1.053
COM6	Hospital	53.442	0.146
COM7	Medical Office/Clinic	106.884	0.293
COM8	Entertainment/ Recreation	196.013	0.537
COM9	Theaters	64.13	0.176
COM10	Parking	0	0
IND1	Heavy	81.098	0.222
IND2	Light	81.098	0.222

Label	Occupancy Class	Per square foot per year	Per square foot per day
IND3	Food/Drugs/Chemicals	108.131	0.296
IND4	Metals/Minerals Processing	245.687	0.673
IND5	High Technology	162.196	0.444
IND6	Construction Agriculture	79.065	0.217
AGR1	Agriculture	75.031	0.206
REL1	Church/Membership Organization	42.754	0.117
GOV1	General Services	35.112	0.096
GOV2	Emergency Response	0	0
EDU1	Schools/Libraries	53.442	0.146
EDU2	Colleges/Universities	106.884	0.293