CITY OF BOULDER
CRITICAL FACILITIES AND MOBILE POPULATIONS ORDINANCE
COST ANALYSIS

Prepared
For

CITY OF BOULDER
DEPARTMENT OF PUBLIC WORKS

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March 15, 2011

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PROPOSED FLOODPLAIN ORDINANCE REVISIONS
COST ANALYSIS
Boulder, Colorado

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1.0 INTRODUCTION

The City of "Boulder is the #1 flash flood risk community in Colorado"[1]. Because of this elevated risk the city must diligently evaluate ways to reduce damages to property and injuries resulting from flooding. Flood protection regulations increase public safety and reduce potential damages from flood waters. Under current flood protection regulations, two segments of the community are particularly vulnerable during a flood: Mobile Populations and Critical Facilities. Mobile populations often lack flood risk awareness and warrant additional flood protection regulations to improve public health and safety during a flood. Critical Facilities warrant additional flood protection to ensure essential services for the community remain uninterrupted or, if flooded, a facility does not pose a risk to public health and safety.

In 2002, the City Council supported developing additional flood protection regulations for Critical Facilities. City Staff, with input from the Boulder Chamber of Commerce, the Local Emergency Planning Committee, Colorado Water Conservation Board, City of Boulder first responders, local business owners, and members of the public, drafted additional flood protection regulations for both Mobile Populations and Critical Facilities. Under the proposed flood protection regulations, Mobile Populations facilities within the 100-year or 500-year floodplains will be required to have a Flood Emergency Operations Plan. Critical Facilities within the 500-year floodplain will be required to dry floodproof, elevate, construct floodwalls or construct other equivalent protection measures to the 500-year water surface elevation plus one foot of freeboard. The proposed flood protection regulations will not be enacted retroactively and will apply to future activities requiring a City Floodplain Development Permit.

Purpose

City Staff is currently studying the potential impacts of the proposed flood protection regulations. As part of their due diligence, City Staff engaged The Sanitas Group to quantify potential specific cost impacts to land owners and facility operators directly resulting from the proposed flood protection regulations. For facilities with Mobile Populations, the cost impacts addressed by this report include the cost of preparing a Flood Emergency Operations Plan (shelter-in-place or evacuation options) and any added floodplain development permitting costs. For Critical Facilities, the cost impacts addressed by this report include engineering services needed to design the flood proofing measures, construction costs to build the flood proofing measures, and floodplain development permitting costs.

The following report summarizes the potential specific cost impacts to land owners and facility operators directly resulting from the proposed flood protection regulations. The report includes background data and the assumptions used to develop this cost impact analysis. The cost opinions stated in this report are at a feasibility level study, meaning they are meant to address overall characteristics and patterns of the subject properties, and facilities were not analyzed on a specific case by case basis. Cost data was obtained through previous project experience, discussions with local contractors and design professionals, and RS Means Costworks data. Costs are based on 2010 dollars.

[1] www.BoulderFloodInfo.net

Proposed New Regulations

This analysis will look at two different parts of the proposed regulations. The first part involves mobile populations located within the 100-year and 500-year floodplain areas. Mobile populations consist of facilities such as hotels, motels, dormitories, bed and breakfasts, hostels, and assembly group uses[2] such as restaurants/taverns, theaters/halls and similar spaces where groups of people gather. With the proposed new regulations, facilities meeting the above description located within the 100-year and 500-year floodplain will prepare a Flood Emergency Management Plan. The intent of these plans is to make sure that staff and occupants are aware of the areas flooding potential and have information they need to keep themselves safe. The City has prepared an emergency planning document (see Appendix B) to assist property owners/managers in preparing plans, and this document outlines both "shelter in place" and "evacuation" options. Facilities will prepare plans upon change of use, new use, or expansion/building permit application.

The second part of the new regulations is in regard to Critical Facilities located within the 500-year floodplain. Per the proposed Ordinance, a Critical Facility is defined as:

> *"any facility, including without limitation, a structure, infrastructure, property, equipment or service, that if flooded may result in severe consequences to public health and safety or interrupt essential services and operations for the community at any time before, during, and after a flood. A critical facility is classified by the following categories: (1) Essential Services Facilities, (2) Hazardous Materials Facilities, (3) At-risk Populations Facilities."*

Under the proposed regulation, new or substantially improved/modified at-risk population and essential service facilities will protect buildings through floodproofing, floodwalls, elevation or other equivalent measures to the 500-year water surface elevation plus one foot of freeboard. In instances where the standard 100-year flood protection elevation (100-year water surface elevation plus two feet) is lower than the 500-year water surface elevation plus one foot, the 100-year flood protection elevation may be used. For additions to existing critical facilities that are smaller than these limits, the new construction will be protected to the 500-year water surface elevation plus one foot of freeboard or 100-year flood protection elevation. Hazardous materials facilities will be required to secure their hazardous materials from flooding during a 500-year flood event upon new use or modification requiring a building permit.

Additional discussion of the proposed new regulations is included in the detailed analysis.

2.0 BACKGROUND

Why Higher Regulation Standards?

Historically, the original approach to mitigating the effects of flooding was construction of flood mitigation projects such as channelizing the watercourse and construction of flood levees. However, these projects did nothing to prevent unwise development in floodplains and as a result, flood damage and risk for flood damage actually increased. In response to continually increasing flood recovery costs, regulations have evolved to provide rules on how to develop in the 100-year floodplain. The National Flood Insurance Program (NFIP)

[2] 2009 International Building Code, Chapter 3, Section 303 "Assembly Group A"

was started in 1968. This program provides minimum regulations for communities which promote safer development in the floodplain, and makes available flood insurance for all residential and non-residential buildings.

Even with these efforts to minimize flood impacts, damages due to flooding in the United States, both in terms of human safety and economic recovery costs, continue to rise. Additionally, an increased barrier to local community economic and social recovery from flooding has been noticed in areas where flood damage has occurred to a subset of critical uses in flood prone areas. In response, the National Flood Insurance Program has developed the Community Rating System and the Community Rating System Coordinators Manual which promotes research on additional flood protection measure local governments can adopt including the development of 500-year protection standards for critical land uses.

Nationally, the concept of promoting additional protection to critical facilities beyond the standard 100-year flood event is not a new one. In 1977, through Executive Order 11988 (which is implemented though Title 18, Chapter VI, Part 725 of the Code of Federal Regulations and the U.S. Water Resources Council's Floodplain Management Guidelines for Implementing Executive Order 11988) federal critical facilities are directed to either avoid the 500-year flood plain or protect federal facilities to the 500-year water surface level. This is in order to insure that during a major flood event, critical government operations sustain the least structural and economic damage and inflict the least environmental damage possible.

Nationally, there is a renewed interest in providing a higher level of protection, specifically for critical facilities. In November 2010, the Association of State Floodplain Managers (ASFPM) published a white paper called "Critical Facilities and Flood Risk" (see appendix E). The paper specifically called for states to adopt rules protecting critical facilities from the 500-year flood event. Additionally, FEMA has been encouraging communities to adopt higher standards and is currently working on updating the NFIP to try and strengthen the rules regarding critical facilities.

Because flood risk is very much an economic risk, it is prudent that we take a commonsense approach to examining the rules and regulations that have been followed by floodplain managers for the last 40-years. For the most part, the current approach to floodplain management deals primarily with how to build in a floodplain; not how to minimize future damages and create a sustainable environment. The basis of sustainability mandates that we simply cannot continue to do the same things as we have done in the past.

According to ASFPM publication "Floodplain Management 2003: State and Local Programs", at that time a total of six states required critical facilities to be protected from the 500-year flood event. These states are Alabama, Illinois, Michigan, Mississippi, North Carolina, and Ohio. At the local level, the City of Fort Collins has also adopted critical facilities regulations for their 100 and 500-year floodplains. In 2010, the State of Colorado, through the Colorado Water Conservation Board (CWCB), proposed new "Rules and Regulations for Regulatory Floodplains in Colorado". Rule 6 of this document defined critical facilities and set higher protection standards for those facilities. Although the rules do not require that critical facilities be protected outside of the 100-year floodplain, the document recommends that local communities use the 500-year floodplain in their critical facilities planning.

Why the City of Boulder

As previously stated, the City of Boulder is the #1 flash flood risk community in the Front Range of Colorado, and the City has historically had stricter flood protection regulations than the NFIP and the State of Colorado's Colorado Water Conservation Board. This is due to the fact that the City is located at the base of the foothills, with a number of creek drainages coming directly into the City. Because of this flood risk, the complications to flood recovery that damaged critical facilities present and the current exposure of many critical facilities to flood damage, in 2002 the City Council endorsed the investigation and development of additional protection measures that will help protect critical facilities serving the City. This guidance was later incorporated in the Comprehensive Flood and Stormwater Master Plan in 2004. This master plan directs city staff to review and update the floodplain regulations occasionally in order to reflect the ever changing needs of the community. In 2008, the City of Boulder's Multi-Hazard Mitigation Plan was adopted. This plan calls for the development of an ordinance that will regulate critical facilities located in the 500-year floodplain as a top priority. City Council reiterated their support for such an ordinance in April 2009.

When new flood protection regulations are proposed for Boulder, many people ask "Why?" pointing out that Boulder is not in the southeast where flooding can occur over days or even weeks in the spring or can result from hurricanes like along the gulf coast. They are correct; Boulder is not subject to the long-term flooding that impacts some portions of the country. But Boulder is at risk to flash flooding in many areas, and although the duration of the flooding is shorter, that does not mean the impacts are not significant. In a flash flood, water levels rise very quickly, often with little or no warning giving little time to implement flood protection measures or evacuate. Combine this with the city's step gradient streams which will exhibit high water velocities and the very rapid increases in flow depth associated with flash flooding, and the danger to public safety is significant. Additionally, during a flood, it does not matter if you have water in your living room or mechanical room for 2 days or 2 weeks, the structure and contents will still be significantly damaged. When this damage occurs to critical facilities it will impede flood response and community recovery.

It should be pointed out that loss-of function impacts associated with flooded critical facilities are sometimes as important as or even more important than the direct physical damages. For example, the loss of function of a hospital or fire station or other facility critical to the emergency response and recovery during and immediately after a disaster may have a much greater economic impact on the community than simply the repair costs for the physical damages. Similarly, loss of utility services (water, power and sanitary sewer) has a much larger economic impact on a community than simply the costs to repair damage to the utility system.

The positive side to Boulder's flood situation is that there are many relatively low cost solutions that when properly thought out and implemented, can have significant impacts on minimizing damages during a flood. By requiring operators of mobile population facilities to prepare a Flood Emergency Management Plan, public safety can be significantly increased, for a relatively low cost. By educating the operators of such facilities of the flood risks, having a warning system to notify of a flood warning or watch in place, and having a chain of command and procedures to follow can greatly reduce the risk of injury or death. Additionally, by making sure groups of people are either evacuated from the flood zone; or

in a safe shelter from the flood, emergency services can focus on those less fortunate. This sort of planning can help educate the community of Boulder's flood risk and reduce injuries or even deaths during flooding.

Protecting critical facilities in Boulder from the 500-year flood event can also be a cost effective solution. The majority of areas subject to 500-year flooding in the City are subject to depths 2' or less. Constructing floodwalls, importing fill to raise the building site, or floodproofing to these smaller depth can be done in a cost effective manner in many cases. Due to the flash flooding nature of the creeks in the area, flood levels go down quickly, allowing roads and access to critical facilities to be reopened quickly. Having these facilities operational and ready for service immediately means the downtime of City services is greatly reduced, increasing human safety and minimizing the economic impacts from a flood.

Additional discussion of the benefits and impacts resulting from the proposed regulations is included in the detailed analysis below.

3.0 MOBILE POPULATION ANALYSIS

Methodology and Assumptions

The proposed regulations will require facilities classified as a mobile population by the City to prepare a Flood Emergency Management Plan. The City has prepared a guideline and checklist to assist facility owners/operators as well as engineers and architects in preparing plans. A copy of this document is included in Appendix A for reference. For this analysis, The Sanitas Group was tasked with analyzing the direct costs of preparing the required Flood Emergency Management Plans. This includes the cost to review the City requirements, discuss plan options with pertinent parties, and prepare the final plan for review and approval by City staff. The analysis will analyze direct costs to prepare a plan, and costs associated with community benefits, like reduced deaths and injuries and avoided emergency management costs, were not analyzed, although these impacts are discussed in a qualitative manner.

After review of the City database of mobile populations and their locations throughout the City, it was determined that evacuation based plans would be the most common for existing facilities. This is due to the fact that in order to shelter in place, a structural engineer will need to verify that the existing structure can withstand the hydrodynamic forces generated from flood waters. Additionally, a shelter in place plan requires that any necessary supplies, including water, food, bedding, etc. be stored on site for any potential occupants during a flood. All of these items have costs and coordination/upkeep time associated with them. Therefore, it is reasonable to expect that when possible, facility owners will prefer to utilize an evacuation plan. Shelter in place plans will most likely only be utilized in areas of high hazard flooding, excessive flood depths, large evacuation distance to non-flooded areas, or areas of high velocity flood waters. Based on a review of facility types and locations, it is expected that approximately 10% of existing facilities classified as mobile populations will shelter in place.

For evacuation and shelter in place plans, two scenarios were reviewed, a simple one and a more complex. A summary of plan assumptions is as follows:

Simple Evacuation Plan
Facilities that fall under this designation may consist of:

- Smaller to mid-size facilities with one main gathering area or a limited number of rooms that are in close proximity to each other.
- Facilities that do not provide overnight housing, temporary or permanent.
- Areas of shallow flooding with direct evacuation routes to higher elevations.
- Evacuated persons will not necessarily need housing/long term shelter once evacuated if facility is damaged/inaccessible.
- Will include most gathering spaces such as halls, restaurants, theatres, gymnasiums, etc. (Assembly Group Uses).

Complex Evacuation Plan
Facilities that fall under this designation may consist of:

- More complicated facilities such as hotels, dormitories, etc. that occupants will be spread out in and will take more advanced planning and staff to assure everyone is accounted for and safely evacuated.
- Facilities that have temporary or permanent residents that may require housing/shelter once they have been evacuated.

Simple Shelter in Place Plan
Facilities that fall under this designation may consist of:

- Designations similar to that of the simple evacuation plan facilities.
- New facilities where the structural analysis and necessary components to deal with flood waters have been previously incorporated into the design.
- Existing facilities with flood depths and foundation/structural components that will allow for a structural engineer to do a basic review and analysis of the structure and approve for sheltering in place.
- Facilities without occupants that would require planning for storage for medical supplies beyond that of a basic first aid kit.

Complex Shelter in Place Plan
Facilities that fall under this designation may consist of:

- Facilities with a large number of occupants that require advanced staff planning to track and account for.
- Facilities that will require a high level of structural analysis by a structural engineer to determine if flood waters can be supported.

Analysis Results

In order to review costs of the different levels of Flood Emergency Management Plans, spreadsheets were created for the different scenarios. The spreadsheets broke down basic tasks associated with preparing the plan and an approximate number of hours applied. For this analysis, an average consulting/preparation fee of $100 per hour was used. The spreadsheets are included in Appendix A for reference. A summary of results is below:

	Evacuation Based		Shelter in Place Based		Shelter in Place – New Construction
	Simple	**Complex**	**Simple**	**Complex**	
Approximate Number of Existing Facilities Impacted	95	12	6	5	N/A
Estimated Plan Prep Costs	$2,500	3,600	$5,000	$11,500	$3,500
City Fees	$542	$542	$1,082	$1,082	$1,082
Total Costs	$3,042	$4,142	$6,582	$12,582	$4,582

See Appendix A for detailed calculations.

Mobile Population Regulations Conclusions

Based on the results of the analysis, it is expected that approximately 80% of facilities classified as mobile populations which required a Flood Emergency Management Plan will fall under the simple evacuation plan category. For these facilities the process for completing plans and gaining city approval involves the development of site specific plans and flood education.

For facilities requiring a structure in place plan, the structural evaluation for sheltering in the building during a flood event may call for structural improvements. The costs for the shelter in place plans include an estimated structural engineering analysis fee, but due to the number of different construction types and facility sizes in the City, the associated fee can vary greatly. Due to this, actual construction costs of structural improvements that may be implemented are not included as part of this analysis. It is expected that the number of facilities who chose to shelter in place and require building improvements after structural review will be limited and the improvements will vary on a case by case basis.

Emergency management plans will develop the most practical solution that can be implemented properly and safely. One of the benefits to requiring these plans is the increase in knowledge about flood situations and how they are going to affect certain areas. The plans will promote situational awareness, and monitoring of the weather for flood warnings and watches. The increase in public safety resulting from having a plan before the flood hits can be significant. This analysis does not apply a monetary value to increased public safety, but we do feel its benefit is important to note.

4.0 CRITICAL FACILTIY ANALYSIS

Proposed Rules

The second part of the proposed ordinance involves critical facilities. As stated previously, a Critical Facility is defined as:

> *"any facility, including without limitation, a structure, infrastructure, property, equipment or service, that if flooded may result in severe consequences to public health and safety or interrupt essential services and operations for the community at any time before, during, and after a flood. A critical facility is classified by the following categories: (1) Essential Services Facilities, (2) Hazardous Materials Facilities, (3) At-risk Populations Facilities."*

- "Essential Services" include, without limitation, public safety, emergency response, emergency medical, designated emergency shelters, communications, public plant facilities and equipment, and government operations.

- "At-risk Population Facilities" include, without limitation, pre-schools, public and private primary and secondary schools, before and after school care centers with 12 or more students, daycare centers with 12 or more children, group homes, and assisted living residential or congregate care facilities with 12 or more residents.

- "Hazardous Materials Facilities" include (a)Facilities subject to Section 303 of the Emergency Planning and Community Right to Know Act, 42 USC §11003, because they have an "Extremely Hazardous Substance" in excess of the "Threshold Planning Quantities" established by the United States Environmental Protection Agency and listed at 40 CFR Part 355, Appendix A and Appendix B. (b)Unless covered by subpart (a), facilities storing Hazardous Material as defined by Department of Transportation regulations at 49 CFR Parts 171-180 but only to the extent that the facility is storing the Hazardous Material in the "Bulk Packaging" container in which it was delivered as that term is defined at 49 CFR 171.8. (c)Facilities storing a Hazardous Substance of the type and quantities listed by §29-22-107 C.R.S. (d)Facilities regulated as transfer stations under Colorado hazardous waste regulations at 6 CCR 1007-3, Part 263.

Extent of Impact on Critical Facilities

The City has researched business and government operations that have the potential to be classified as a critical facility under the new ordinance. This list was used as a dataset from which attributes of average facility types, construction methods, flood depths, and locations were developed. The subsequent analysis represents average compliance cost representing the types of facilities and characteristics of flooding expected. Any facilities that are non representative (for either having less than average cost of compliance or more than average cost of compliance) are not explicitly analyzed. For the purpose of this analysis, existing buildings that have the potential to be considered critical were used to develop costs of compliance. Any future critical facilities that chose to construct in the 500-year floodplain can reasonably be expected to be of similar sizes and types.

For operators of critical facilities that wish to make improvements, there are a number of ways they can protect their property from flood waters, including importing fill, elevating the first floor via structural improvements, construction of flood walls, and floodproofing. The two most common and economical forms of flood protection for individual properties in Colorado are importing fill in order to raise the building site, and floodproofing the building. This analysis has been tasked with reviewing these two most common flood protection approaches specific to the City of Boulder. For the purposes of this analysis, new facilities are assumed to utilize a fill based flood protection approach, and be of similar type and size as existing critical facilities within the City of Boulder. Detailed discussion of both approaches and their associated benefits and impacts is presented below.

What about Hazardous Materials Facilities?

The proposed ordinance will require facilities that store hazardous materials to protect those materials from being released during the 100 and 500-year flood events. Many types of hazardous materials are required to be stored in a water tight manner by existing EPA regulations, and most are stored inside an existing structure or with permanently mounted tanks adjacent to the building. Based on these types of best management practices, it is anticipated that the majority of hazardous materials facilities will choose to obtain an engineer's certification that the hazardous materials will be secure during a flood instead of floodproofing or elevating the facility. Protecting materials from release would require confirming that they are stored in watertight containers, which is very common, and cannot float away, which is also common as most hazardous materials are stored inside a building or a secure facility. Other economical solutions may involve certifying that hazardous materials are stored in an elevated location protected from flood waters; this can be accomplished with shelves or similar means. In cases where a facility may have a permanent tank storing hazardous materials, the tank will need to be elevated or evaluated to confirm it cannot float away during a flood. If flooding is a concern, additional mounting supports may be required. All of these solutions would be of significantly lower cost than floodproofing the entire structure. Applying the above techniques to the construction of a new facility would have a negligible impact on the overall construction cost of the project. In the rare case an entire hazardous materials facility needs to be elevated or floodproofed, the results of the cost analysis for at-risk and essential services facilities would apply.

4.1 FILL BASED FLOOD PROTECTION ANALYSIS

Methodology and Assumptions

When importing fill to raise a building site, the key factors are the size of the building footprint and depth of fill required to raise the site to the desired grade. After reviewing City data regarding potential critical facilities, it was determined that two building footprints would provide a representative sample. A 5,400 square foot footprint represents the approximate average building footprint of the smaller facilities, and a 65,000 square foot footprint represents the approximate average of the mid-size to larger facilities. These two footprints were utilized in the fill analysis. A summary the existing structure sizes is included in the appendices.

Based on a review of the City data on potential critical facilities, the approximate depths of flood water during the 500-year event for the impacted 26 facilities were reviewed. It was determined that the average water depth was approximately 2.0 feet. For this analysis, three water depths would provide a representative sample size, with additional water depths of 0.5 foot and 3.5 feet. With the required 1-foot of freeboard included, the final depths of fill used in this analysis were 1.5 feet, 3.0 feet, and 4.5 feet.

For a typical fill section, it was assumed that the area under the building footprint would require structural fill. All other areas of the property would utilize a lower cost standard fill material. For earthwork volume determination, it was assumed than an average tie in slope of 20:1 horizontal to vertical (5%) from the building limits to existing grade would be reasonable. Slopes steeper than this are difficult to provide ADA access and parking on. The unit costs for fill are "in-place", meaning the final cost includes the purchase of the material, delivery, and fill placement in compliance with necessary compaction

requirements. Fine grading costs are excluded, as the developer would be required to do fine grading on the site with or without the fill requirements of the proposed ordinance.

Analysis Results

The results of the fill analysis showed fill costs per square foot of building footprint ranging from $1.13 to $9.68. The resulting percentage increase in building costs per square foot ranges from 1% to 6%, with the majority between 1% and 3%. These results are based on single story construction in order to look at worst case scenarios, and an initial per square foot construction cost of $160 per square foot for smaller facilities and $135 per square foot for larger facilities. See Floodproofing Assumptions in Appendix C for details on base cost determination. In the case of a multi-story facility, the amount of fill required per square foot of building is less than for a single story structure of similar footprint; therefore the percent increase in construction costs per overall building square footage would be lower.

A summary of results is presented below:

	Building Footprint					
	5,400 Square Feet			**65,000 Square Feet**		
Depth of Fill Required (ft)	1.5	3.0	4.5	1.5	3.0	4.5
Fill Quantity (CY)	612	2,015	4,905	4,530	11,155	20,285
Fill Cost per Building SqFt	$1.52	$4.36	$9.68	$1.13	$2.54	$4.31
Orig. Assumed Const. Cost	$160	$160	$160	$135	$135	$135
Adjusted Construction Cost	$161.52	$164.36	$169.68	$136.13	$137.54	$139.31
% Increase	0.94%	2.65%	5.70%	0.83%	1.85%	3.09%

See Appendix C for detailed calculations.

Importing fill as a means of flood protection is an effective solution for protecting critical facilities, especially on new large scale projects. In the 500-year floodplain the water depths and velocities are typically lower than in the 100-year, meaning the average depth of fill required on most sites is less than 100-year areas, Additionally, there are no FEMA flood permitting requirements for 500-year flood areas, reducing the costs and timeframe compared to 100-year flood areas. This method of flood protection is expected to be most commonly used on new construction, and is limited to properties that have adequate space to raise the building and still provide adequate access from adjacent roads, etc. See the Critical Facilities Conclusions section for additional discussion.

4.2 FLOODPROOFING BASED FLOOD PROTECTION ANALYSIS

Methodology and Assumptions

The costs associated with dry floodproofing a structure can vary significantly depending on the building construction type and size, the depth of the floodwaters, and the number of doors, windows, and other openings. Because of this, standardized cost data for floodproofing is limited. The cost data that is available is related to the 100-year floodplain, and includes a wide range of building types including wood frame residential structures, which because of the relatively weak timber structural components typically have a higher floodproofing costs. The proposed critical facilities ordinance will only impact facilities containing critical land uses located in the 500-year floodplain, buildings that typically have commercial grade construction types and have shallow flood depths.

A review of the potential critical facilities identified by the City of Boulder as being essential services or containing at-risk populations showed that the typical construction type for

these facilities involves either brick, masonry, or similar type water resistant construction. Additionally, large storefronts or similar types of construction that include large expanses of windows or similar wall openings that go low to the ground are not common.

The current 500-year flood depths were reviewed at each site, and it was determined that 30% of the potential at-risk population or essential service facilities currently have main level finish floors located greater than 1-foot above the 500-year floodplain, and therefore would not require floodproofing. In order to have an accurate representation of required floodproofing depths, these facilities were excluded from that analysis. The remaining facilities were used as a sample set for the floodproofing analysis.

When floodproofing an existing structure, there are two main types of floodproofing often utilized. The first involves providing a waterproof barrier that uses the existing walls for support. This approach can only be used for lower flood depths, as the existing wall structure can only resist a certain amount of load. Based on a review of FEMA design guidelines, as well discussions with local design professionals, existing structures can typically resist water depths of 1 to 3 feet, depending on the existing structural design. Doors and other openings are typically protected by reinforced floodproof doors, and floodgates. For structures where the existing wall systems cannot resist the forces from the flood waters, it is typically most cost effective to install a ringwall around the structure to provide flood protection. Access openings in the ringwall are typically protected by a floodgate or similar device that remains open until flood waters come up. In some cases, the ringwall is tied into the existing structure at doors, and a floodproof door installed. This analysis included costs for floodgates.

The cost-impact analysis results are broken into two groups, one for facilities with 500-year flood depths of 2 feet or less (flood protection depth of 3 ft), which are assumed to be able to utilize the existing wall structure to resist flood forces, and a second group consisting of flood depths greater than 2 feet where a concrete ringwall is utilized for flood protection.

Flood Depth 0-2 feet Analysis Results

A review of City data finds that 56% of the proposed at-risk population and essential service facilities that will require floodproofing, or 38% to the total number of potential at-risk population and essential service facilities in the 500-year floodplain, will have flood depth in the range of 0-2 feet. The main level building footprints of these sites were reviewed and two representative building sizes were chosen for the analysis, 3,000 square feet and 35,900 square feet. The average 500-year flood depth for these 10 facilities is 0.6 feet.

	Floodproofing – Facilities with Flood Depths to 2 Feet	
	3,000 Square Feet	**35,900 Square Feet**
Floodproofing Depth (FT)	0-3	0-3
Estimated Average Cost	$29,940	$121,340
Contingency (20%)	20%	20%
Total Estimated Average Cost	$35,928	$145,608
Estimated Cost per S.F.	$12	$4

See Appendix C for detailed calculations.

Based on the results presented above, it is estimated that floodproofing existing structures where the existing structure can resist the forces from flood waters will cost between $4 and $12 per square foot. One half of the proposed at-risk population and essential service

facilities located in the 500-year floodplain are anticipated to be able to floodproof in this manner. Existing facility sizes included in this portion of the analysis range in size from under 1,000 square feet to over 65,000 square feet. The results are based on a single story facility. In cases where a multi-level facility is involved, the cost per total square footage would be reduced significantly.

To determine base substantial improvement or modification costs two alternative trigger points were analyzed. The first, substantial improvements, requires the owner to improve the existing structure more than 50% of its current building value. For substantial improvements, the proposed facilities for which Assessor's building value information was available were averaged and multiplied by one-half. A resulting baseline remodel cost per overall building square foot of approximately $38 per square foot to trigger the need for floodproofing was determined. This is an average of varying building types and sizes, therefore actual numbers will vary and this is only the average minimum. A full remodel project will cost significantly more per square foot. The second trigger point, substantial modifications, applies if the existing building square footage is increased more than 50% via an addition. For this, an average of the base construction costs used in the fill analysis ($135/SF and $160/SF) was used, resulting in $148 per square foot as a baseline construction cost that would trigger floodproofing. Under the minimum substantial modification threshold up to three feet of building could be protected for one foot of addition resulting in a worst case base cost per square foot of $49/SF. The average of the substantial improvement or modification costs is $44 per square foot.

Flood Depth 2+ feet Analysis Results

A review of City data estimates that 44% of proposed at-risk population and essential service facilities that require floodproofing will have flood depths greater than 2 feet. The main level building footprints of potential sites were reviewed and two representative building sizes were chosen for the analysis, 3,000 square feet and 69,000 square feet. In order to provide a conservative estimate on cost of compliance existing facilities with flood depths greater than 2 feet are assumed to utilize a ringwall for flood protection. This is a worst-case analysis, as existing structures utilizing masonry block or concrete construction may be able to resist higher flood depths than the three foot design threshold used here.

	Floodproofing – Facilities with Flood Depths Greater than 2 Feet	
	3,000 Square Feet	**69,000 Square Feet**
Average Flood Depth (FT)	3.5	3.5
Flood Protection Depth (FT)	4.5	4.5
Estimated Cost per S.F.	$76	$11

See Appendix C for detailed calculations.

The resulting costs can range from $11/SF or less for large multi-level facilities, to $76/SF plus for small single level facilities. Ringwalls are a cost effective solution for large or multilevel structures in areas of relatively deep flooding. For small existing structures, compliance with the proposed ordinance is required only for additions or remodels exceeding 50% of the value of the structure. For small buildings, such a large improvement will most likely include such a significant change to the structure involving structural improvements. In this situation additional evaluation to include dry floodproofing measures will be more cost effective than installing a ringwall. This approach is site and building specific, therefore the worst case scenario of installing a ringwall was assumed for

this analysis. It should be noted that only 2 facilities impacted by the ordinance have a footprint of less than 5,500 square feet and flood depths greater than 2 feet, and both of those are preschools/day care centers located in single family home structures. The single family structures could still be used as a single family home and therefore another cost effective alternative may be to relocate the facility to another single family home outside of the 500-year floodplain. The anticipated cost impacts for the remaining 6 larger structures in this category ranges from less than $11/SF to roughly $40/SF. This is a conservative analysis assuming none of the structures would be able to utilize the existing structure for flood protection.

Using the same data as discussed previously for the 0 to 2 foot flood depth analysis, the average baseline cost for substantial improvement or modification average costs is $44 per square foot.

4.3 CRITICAL FACILITIES CONCLUSIONS

Of the potential at-risk populations and essential service facilities located in the 500-year floodplain, 30% are potentially located above the 500-year water surface elevation, 38% have flooding depth of zero to two feet and 31% have flooding depths greater than 2 feet. The cost associated with providing flood protection to these facilities is dependent on the depth of flooding and existing structural configuration of the facility.

When the extensive flood risk in the City of Boulder, is coupled with the limited future development space, it is likely that new critical facilities will be constructed in the 500-year floodplain. Importing fill to elevate the building is a cost effective approach to provide flood protection in 500-year flood areas. The flooding depths and velocities are typically lower than in the 100-year floodplain. Additionally, permitting requirements for importing fill in the 500-year floodplain are less than in the 100-year, as there are no FEMA approvals necessary, reducing costs and timeframe impacts.

It should also be noted that Boulder Valley School District (BVSD) facilities, Boulder County Facilities, Federal Facilities, State of Colorado Facilities and facilities operated by the University of Colorado have no requirement to comply with the City of Boulder critical facilities and mobile population ordinance. Critical facilities and mobile population facilities operated by these entities are included in this analysis, as the City will encourage all critical land uses and mobile population facilities to comply with the proposed ordinance.

5.0 FINAL CONCLUSIONS

Protecting critical facilities and mobile population facilities from flooding is important for a number of reasons, whether it be reducing the economic impact of flooding, protecting public health or reducing risk to life and safety. When a critical facility is damaged from flood waters, the damage extends well beyond the limits of the facility itself and includes loss of everyday services that can have severe economic impacts to a community and delays the economic and social recovery of the community. Protecting mobile population facilities through emergency management plans will allow the dispersement of flood protection information to people not familiar with Boulder's flood risk or the area they are located.

Providing 500-year flood protection to critical facilities and mobile population facilities will increase public safety, reduce the impact of flooding, and increase the communities' sustainability and ability to recover and thrive after a major flood.

In summary:

1. Educating the public on the risks associated with flooding is one of the best ways to reduce injuries and loss of human life. Requiring operators of facilities containing mobile populations to have a Flood Emergency Plan in place will increase public knowledge and planning.
2. Providing flood protection to critical facilities protects the overall community population, not just the public within a defined floodplain.
3. Providing flood protection to a critical facility limits the interruption of response and service to the public during a flood event.
4. Providing flood protection to critical facilities helps control costly repairs to public or private infrastructure facilities, which are extended to the overall community.

The intent of this analysis is to provide a feasibility level opinion of probable cost impacts associated with the proposed ordinance. A list of assumptions is included in the appendices for reference. Facility specific costs were not part of this analysis, and actual bid costs for construction will vary depending on actual site conditions, economic conditions, and extent of work proposed on the facility.

6.0 REFERENCES

- "*Critical Facilities and Flood Risk*" prepared by Association of State Floodplain Managers, Inc., November 2010.
- *"Rules and Regulations for Regulatory Floodplains in Colorado"* prepared by the Colorado Water Conservation Board, November 17, 2010.
- "*2010 Proposed Rules and Regulations for Regulatory Floodplains in Colorado – Cost, Benefit, and Regulatory Analysis"* prepared by Icon Engineering and Colorado Water Conservation Boars, October 14, 2010.
- *"Cost, Benefit, and Regulatory Analysis – Addendum 1",* Colorado Water Conservation Board, November 1, 2010.
- *"CDOT Construction Cost Data 2009",* Colorado Department of Transportation.
- *"RS Means CostWorks",* online construction cost database, RS Means.