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Operation and Deployment Risk Assessment Report for the City of Cedar Rapids, Iowa

Alternative and Sequencing Optimization for Removable Flood Barriers

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Abstract

The City of Cedar Rapids, Iowa, partnered with engineering firms and the US Army Engineer District, Rock Island (MVR), to develop a Flood Control System (FCS). In 2011, the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL), was tasked with completing a risk assessment of removable floodwalls on the eastern side of the Cedar River. In 2016, ERDC-CHL was asked to include the temporary flood closure barriers on both sides of the Cedar River. Phase 1 of the study consisted of seven alternatives to be considered for the final FCS design, with a goal of a 90% confidence of successful deployment. Phase 2, initiated by MVR, targeted a 95% confidence level. The method used for evaluation was RiskyProject® software. The software used a Monte Carlo method of analysis to determine a range of durations, manpower, and labor costs based on logical sequencing. The results showed that the "Master Plan Minus 400 ft" alternative to be the most efficient for Phase 1. The most efficient alternative for Phase 2 was Task 5.4, which achieved a 95% confidence level of completion within 48 hours. The Phase 1 and the Phase 2 descriptions are detailed within this report.

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Preface

The first phase of this study was conducted for and funded by the City of Cedar Rapids, IA, under the Cedar Rapids Flood Risk Management Project, Project No. 474867, MIPR 96514793119495. The technical monitors were Mr. Robert Davis of the City of Cedar Rapids and Mr. Bill Bogert of Anderson-Bogert Engineers & Surveyors, Inc. Phase 2 was funded by the US Army Engineer District, Rock Island (MVR). The technical monitor for MVR was Mr. Toby Hunemuller. Mr. Jason Smith served as the project manager for MVR.

The work was performed by the Harbors, Entrances, and Structures Branch of the Navigation Division, US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL), and the Structural Mechanics Branch of the Geosciences and Structures Division of the ERDC Geotechnical and Structures Laboratory (ERDC-GSL).

At the time of publication of this report, Mr. James Gutshall was Chief, Harbors, Entrances, and Structures Branch, and Dr. Jackie S. Pettway was Chief, Navigation Division. The Deputy Director of ERDC-CHL was Mr. Jeffrey R. Eckstein, and the Director was Dr. Ty V. Wamsley. Mr. Bradford A. Steed was Chief, Structural Mechanics Branch, and Mr. James L. Davis was Chief, Geosciences and Structures Division. The Deputy Director of ERDC-GSL was Mr. Charles W. Ertle II, and the Director was Mr. Bartley Durst.

Appreciation is expressed to Mr. Matthew Hossley, Structural Mechanics Branch (ERDC-GSL), for his contribution to this effort.

COL Teresa A. Schlosser was the Commander of ERDC, and the Director was Dr. David Pittman.

1 Introduction

1.1 Background

1.1.1 Site Description

Cedar Rapids, IA, is located in Linn County, IA (Figure 1). The Cedar River Watershed (Figure 2) is approximately 30 miles north of Iowa City, IA; 70 miles southwest of Dubuque, IA; and 130 miles northeast of Des Moines, the state capital of Iowa. The drainage area of the Cedar River at Cedar Rapids is 6,510 square miles. Cedar Rapids lies on both banks of the Cedar River, and much of its downtown sits within the 100-year floodplain. Major floods have historically been caused by heavy rainfall.

Figure 1. Vicinity map.

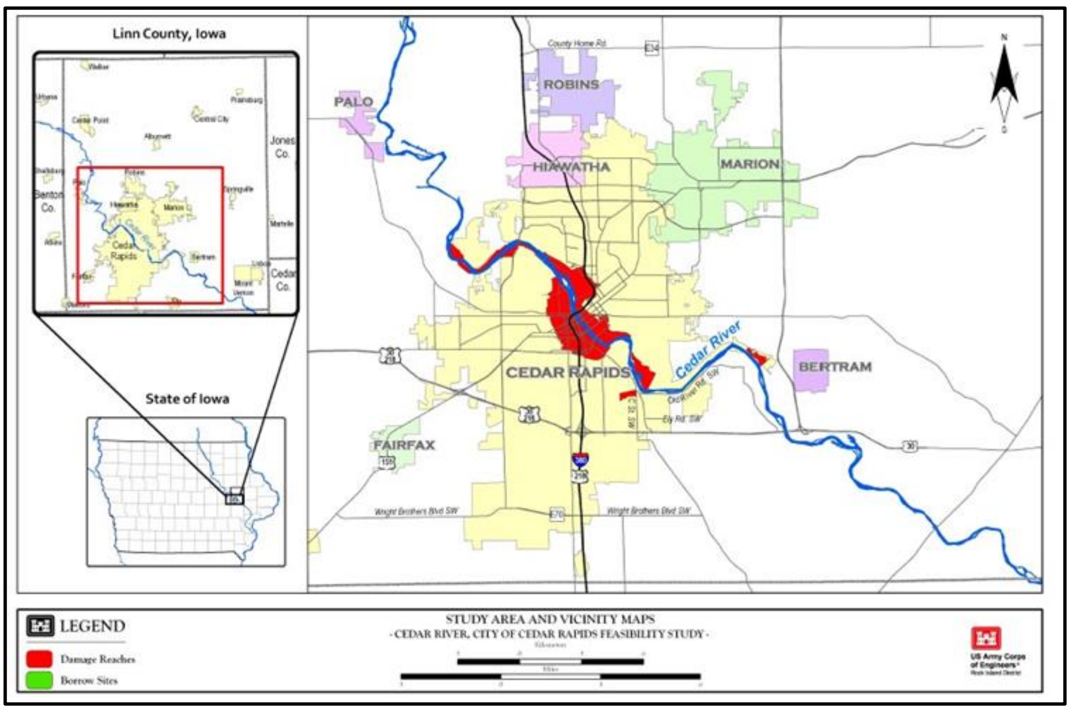
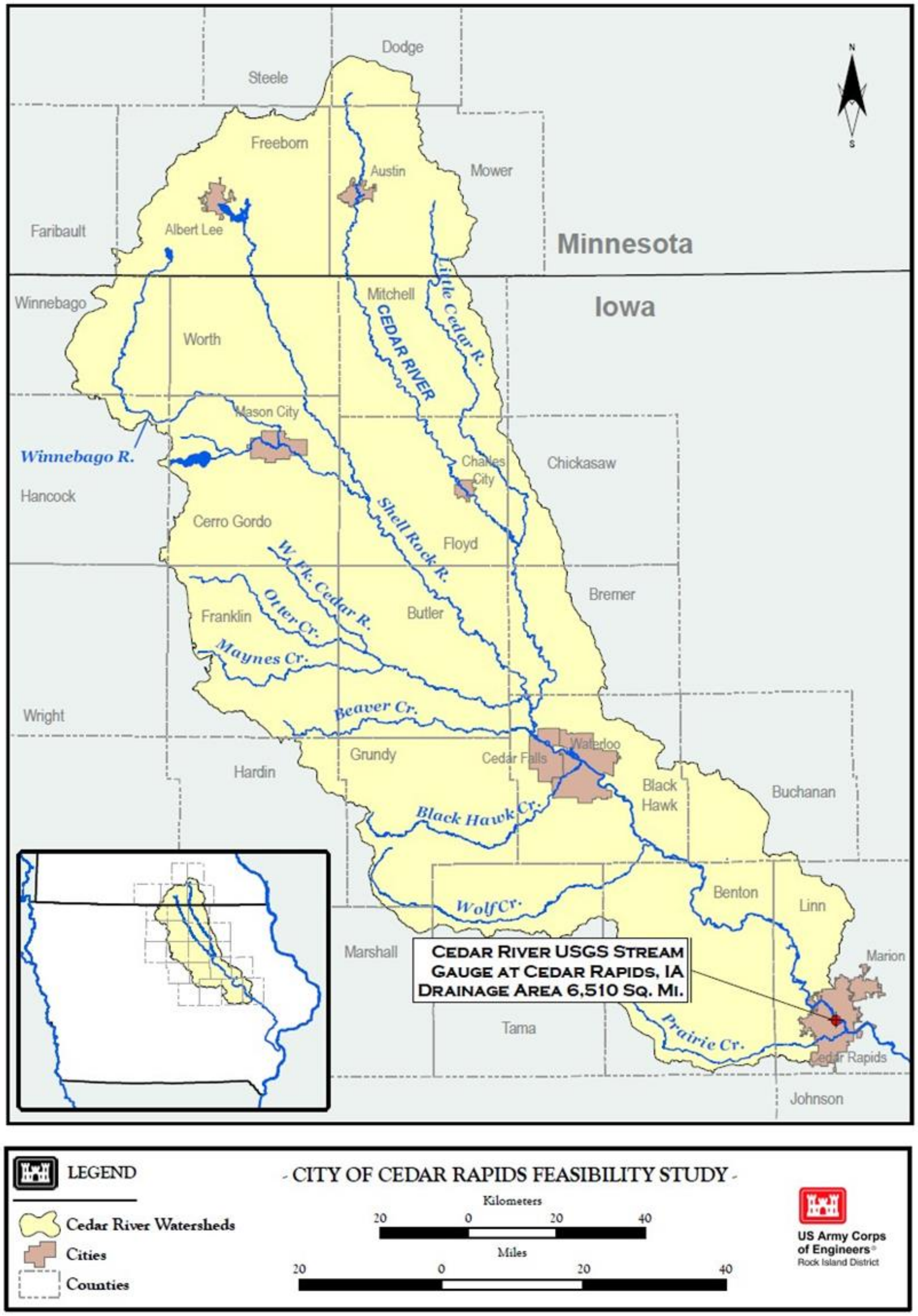


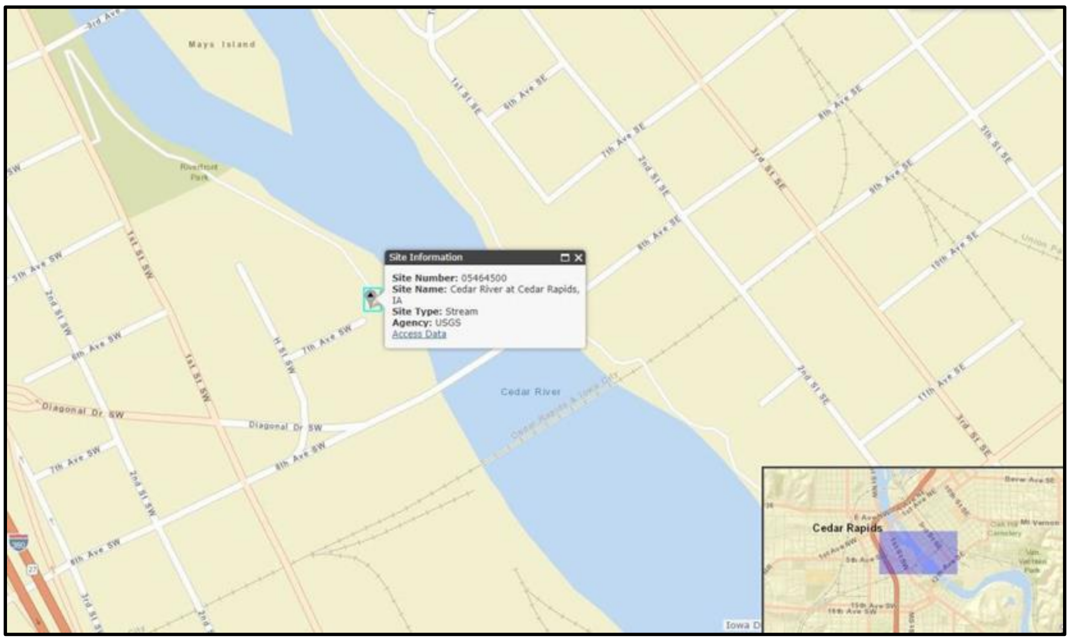
Figure 2. Watershed map of the Cedar River upstream of Cedar Rapids, IA.



1.1.2 History of Cedar Rapids, IA, flooding and need for flood plan

On June 13, 2008, the Cedar River crested at the highest level in Cedar Rapids history. During this historical event, the flood elevation reached approximately 31.1 ft on the US Geological Survey (USGS) stream gage number 05454500 (Figure 3), located near the 8th Street bridge in downtown Cedar Rapids (gage location Latitude 41.971945 north, Longitude 91.667124 west). The previous record was 20 ft. The river rose from 12 ft to 20 ft in 2 days and rose an additional 11 ft over the following 2 days. Flood waters penetrated 10 square miles and impacted 7,198 parcels, including 5,390 houses, dislocated more than 18,000 residents, and damaged 310 facilities owned by the City of Cedar Rapids.

Figure 3. USGS Gate 05464500 location.



In reviewing hydrographs for previous floods, it can be inferred that the City of Cedar Rapids has only 1 day of advanced warning time prior to the 48 hr trigger for closure and removable floodwall deployment if the sill elevations are 25 ft relative to the Cedar River stream gage (MVR 2011).

In 2011, the US Army Engineer District Rock Island (MVR) recommended construction of a floodwall on the east bank of the Cedar River at Cedar Rapids to protect downtown area properties. The US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), was tasked with providing flood risk analysis for this area. RiskyProject® software was used in the analysis for this effort. The software used a Monte Carlo method of analysis to determine risk outcomes. This software and analysis method is discussed in later sections of this report.

In 2012, three alternative configurations of removable floodwalls for the east side of the river were preliminarily defined by MVR. CHL developed 24 alternatives, of which 3 alternatives were used for their initial risk study[1]. These schedules were created using installation estimates from vendors, site assessments and lists of available city resources, and removable floodwalls in use by other cities.

The 2012 Alternative 1 would consist of removable aluminum panel floodwalls and bulkhead panels, both of which include closures and permanent floodwalls. This alternative was given a deployment time of 24 hr. The median deployment duration with the MVR risks applied was 37.3 hr, and the median deployment duration using the Cedar Rapids estimated risks was 36.6 hr.

The 2012 Alternative 2 would consist of aluminum panel floodwalls that include closures, concrete folding walls, bulkhead panel closures, and permanent floodwalls. Alternative 2 was given a deployment time of 25 hr. The median duration for deployment with risks applied using the MVR estimates was 38.7 hr and 39.1 hr with the Cedar Rapids estimated risks.

The 2012 Alternative 3 would consist of all permanent walls except for the aluminum panel closures and bulkhead closures. This alternative was given a deployment time of 11 hr. This time was to deploy the demountable and bulkhead panel closures and swing gate closures. With risks applied, the median deployment duration was 22.1 hr given the MVR risk estimates and 21 hr given the Cedar Rapids estimates.

1.1.3 Cedar Rapids Flood Risk Management (FRM) Project

The Cedar Rapids FRM Project provides risk reduction to properties located along the Cedar River in the downtown reach of the City of Cedar Rapids, IA (the City). The project's feasibility study was finalized in November 2010, and the Chief of Engineers Report was signed in January 2011. In September 2011, MVR tasked CHL to "evaluate risks associated with the operation and deployment of a removable floodwall system in the downtown area of Cedar Rapids, Iowa." Through the General Investigation

[1] Cohen, Julie, and Donald L. Ward. Unpublished. Draft Report to Sponsor. *Risk Assessment of Deployment for the Proposed Removable Floodwall System, Cedar Rapids, Iowa*. US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.

Research and Development Program, CHL conducted research and provided a composite risk analysis of the proposed removable floodwall system being designed for Reach II[1]. CHL conducted a project feasibility study in 2011–2012 for the Cedar Rapids FRM project. This project included 3.1 miles of earthen levees, floodwalls, and roadway/railroad closure structures along the eastern bank of the Cedar River.

In early February 2016, it was determined that a continuation of the previous evaluation was needed. This study would include all areas (formerly referred to as "reaches") identified in the June 23, 2015, City Of Cedar Rapids, Iowa Cedar River Flood Control System (FCS) Master Plan, revised on August 9, 2016.

Phase 1 of this study was initiated to evaluate seven alternatives that would provide the City with options to consider for the final FCS design, with a goal of a 90% confidence of successful deployment within 48 hr of the notice to proceed.

In March 2019, Phase 2 was initiated to enhance the results of Phase 1 by optimizing crews, changing and removing closures, and revisiting risk parameter assumptions. This was done to increase the probability of reaching a 95% confidence level. This phase consisted of four alternatives, identified in this report as "Tasks 1–4" to avoid confusion with the nomenclature of the Phase 1 alternatives.

1.1.4 Temporary closure type descriptions

In an effort to explore potential alternative solutions for temporary flood closures, extensive literature and internet searches were conducted. Focus was placed on products with proven reliability and recommendations from contacts within the flood-fight community. The following paragraphs describe closure types used in the alternatives reported herein.

1.1.4.1 Monroe Solution

Site visits to Monroe, LA, were conducted by CHL personnel in July 2018 and again by members of the City and MVR in August 2018. The floodwall

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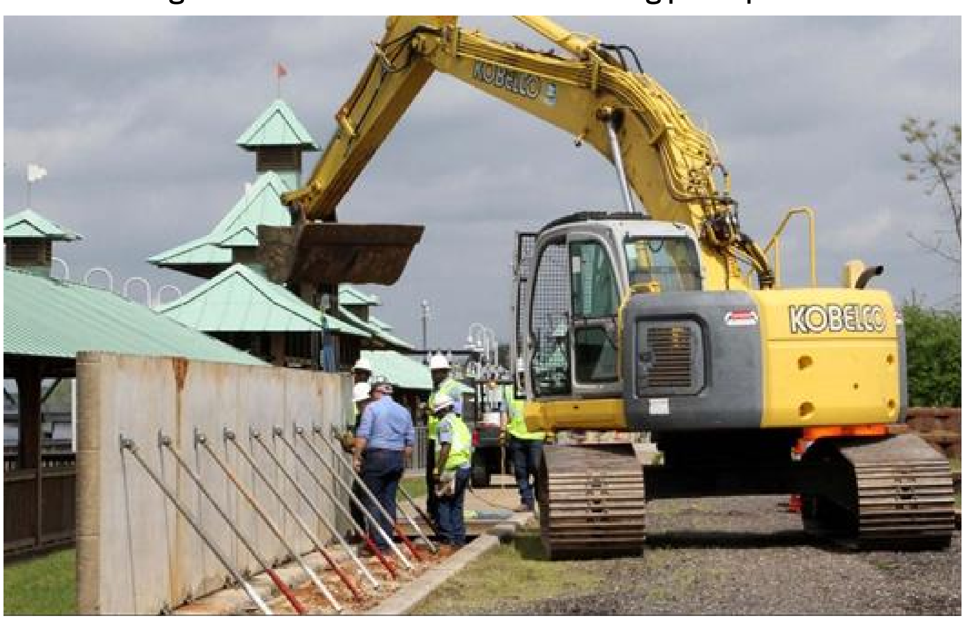
[1] Cohen, Julie, and Donald L. Ward. Unpublished. Draft Report to Sponsor. *Risk Assessment of Deployment for the Proposed Removable Floodwall System, Cedar Rapids, Iowa*. US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.

system there consists of a permanent sidewalk that will fold up to create a floodwall. Bracing components were stored under the sidewalk to make for easy access during deployment. This type system is included in one alternative along a 950 ft section along the west bank of the Cedar River, southeast of the amphitheater. This type area was referred to as the "Monroe Solution" and can be seen in Figures 4 and 5 below.

Figure 4. Monroe Solution floodwall in sidewalk position.

Figure 5. Monroe Solution floodwall being put in place.



1.1.4.2 Combination walls

Combination walls for this study are comprised of a base and permanently mounted support columns to accommodate aluminum stop-logs deployed just prior to anticipated flood events. A section of combination wall has been constructed near the amphitheater in Cedar Rapids and can be seen in Figure 6.

Figure 6. Combination wall near the Cedar Rapids amphitheater.

During the ERDC 2011–2012 study, the City of Davenport, IA, was visited to observe its combination and demountable wall systems. Cohen and Ward[1] noted that according to the City of Davenport, IA, and Woodman Park stadium representatives, a trained eight-person crew at Davenport, IA, erected 4,450 ft^2 of demountable combination walls in 12 hr, or 370 ft^2/hr per eight-person crew.

Figures 7 and 8 below show combination walls before and after deployment at Davenport, IA.

[1] Cohen, Julie, and Donald L. Ward. Unpublished. Draft Report to Sponsor. *Risk Assessment of Deployment for the Proposed Removable Floodwall System, Cedar Rapids, Iowa*. US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.

Figure 7. Combination wall in Davenport, IA, before deployment.

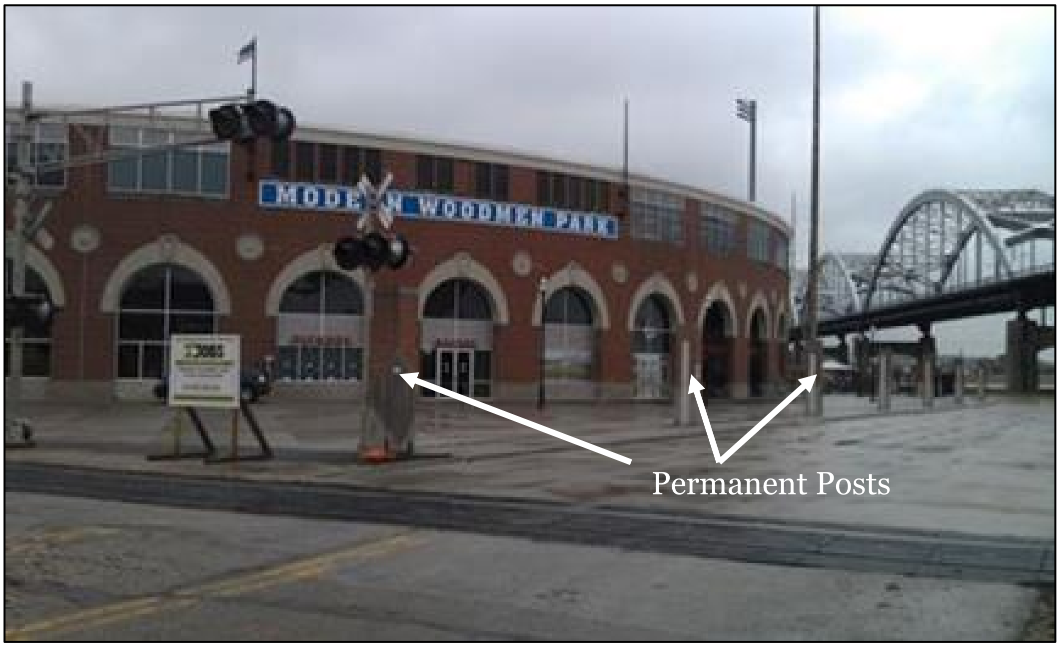
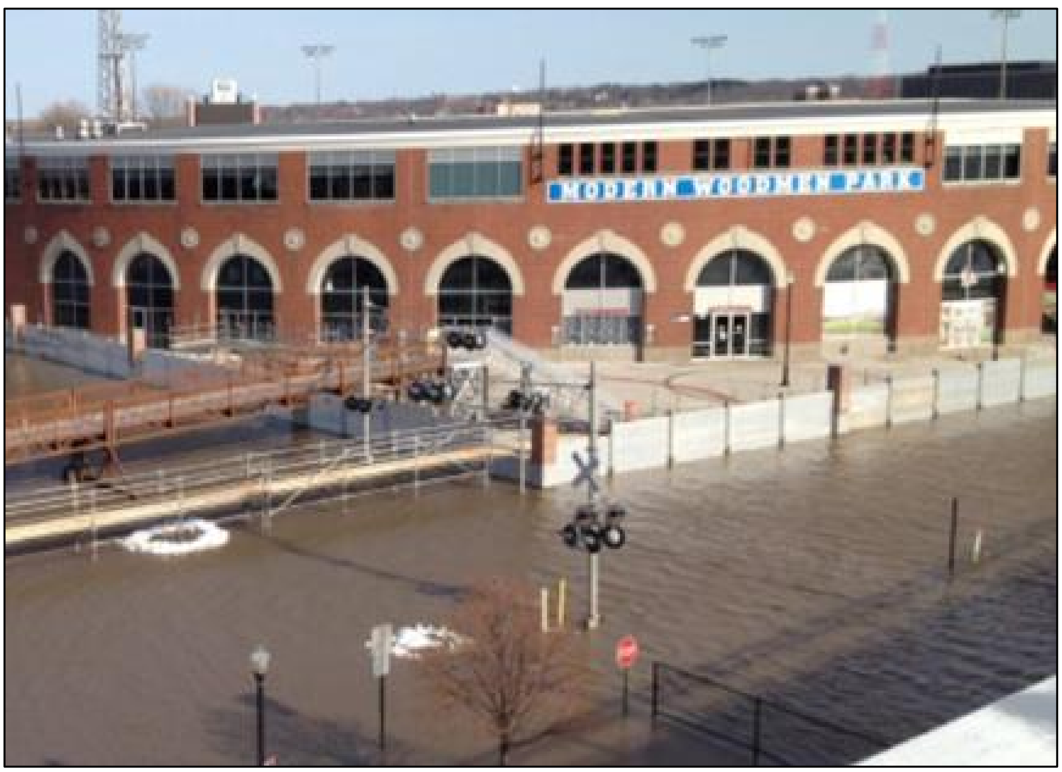


Figure 8. Combination wall in Davenport, IA, after deployment.



Combination walls provide the advantage of containing a permanent structural base system only used in the event of a flood event. The walls allow an aesthetically pleasing view while allowing for the deployment of a relatively quick flood protection system. However, a potential disadvantage of combination walls is the possibility of structural damage to the permanent columns and base, which could result in significantly increased deployment durations.

1.1.4.3 Fully demountable walls

Demountable wall barriers, while similar in functionality to combination walls, are completely removable systems. The units consist of a pre-installed base anchor system mounted at the ground level that is used as support for removable vertical columns and horizontal stop-logs. The system used for this study is comprised of aluminum stop-logs, following the example of other municipalities researched and for consistency with the preferred combination-wall type within Cedar Rapids. An example is shown in Figure 9. A trained eight-person crew could deploy this system at a rate of approximately 567 ft^2/hr per manufacturer’s specifications.

Figure 9. Demountable floodwall system.

1.1.4.4 Miter gates

Miter gates are a two-piece gate with a mitered connection that when closed, water pressure pushes the two gates together to form a seal (Figure 10).

Figure 10. Miter gate.

1.1.4.5 Swing gates

A single swing gate is normally a heavy duty single-hinged gate that swings closed and is secured with sliding, locking bolts (Figure 11). Double-swing gates include the use of two single-swing gates working together for one closure. They may be sealed with industrial rubber gaskets or inflatable bladders.

Figure 11. Single-swing gate.

1.1.4.6 Rolling gates

Rolling gates, as seen in Figure 12, rest and roll on a ground wheel carrier. It is always the size of the opening of the gate closure. Rolling gates can be operated either manually or mechanically. For the purposes of this study, rolling gates are assumed to be manually operated.

Figure 12. Rolling gate (photo: MVR).

1.1.4.7 Other examined closure types

Other alternative closures types were researched but not included in the analysis described in this report. Some of these are the following:

1. Pop-Up Gates. Pop-up gates are a potential alternative to swing and roller gates. They are either manually or self-deploying systems primarily used within road beds. They will rise or unfold automatically with the rising water. An example is shown in Figure 13.

Figure 13. Pop-up gate (photo: FloodBreak®).

2. Expedient Flood Barriers. Expedient flood barriers are temporary structures intended for rapid deployment during a flood event. The City ultimately decided that this was not a viable solution for closures, opting for more consistent, semi-permanent solutions. However, numerous expedient flood barriers were examined prior to this final decision.
   a. Aquafence offers reusable, foldable panels from 4 to 8 ft in height (Figure 14). The manufacturer does not specify the need for anchoring but includes the option for high-wind conditions. During a product test evaluation of Aquafence at ERDC in 2012, it was found that for installation, an eight-person crew could erect 100 ft of unanchored Aquafence in 1.9 hr. The perceived disadvantage to this product is the bracing, which was on the flood side of the fence.

Figure 14. Aquafence installation.

b. Hesco Barriers (Figure 15). When assembled, Hesco barriers connect 3 × 3 × 3 ft gabion style containers partially lined with a geotextile material. They can be filled with sand and are stackable. They are reusable when disassembled carefully. The City currently possesses approximately 10 miles of 3 ft high Hesco barriers. These were used extensively during the 2016 flood. While providing the city with a mitigation against minor FCS failure, they are not intended to serve as part of the planned system.

Figure 15. Hesco barrier system deployed at Cedar Rapids, IA (photo: Stephan Mally/*The Gazette*).

The City was also provided with an extensive list of expedient flood-fight product websites (see Appendix A). This list was compiled for a US Department of Energy data collection effort (Madison and Myrick 2016).

1.2 Objectives

The purpose of this project is to define and assess the risks and resources associated with the removable floodwall systems proposed by the City. The objective is to evaluate the risks associated with the operation and deployment of composite systems of flood prevention measures. The Phase 1 analysis explored alternatives toward achieving a 90% confidence level of successful operation along both the east and west banks of the Cedar River within the FCS of Cedar Rapids, IA, while Phase 2 focused on increasing the confidence level to 95%.

The removable sections considered within the Risk Assessment Report (RAR) included combination (combo) walls, demountable walls, miter gates, swing gates (single and double), rolling gates, and sidewalk-wall conversions referred to as the Monroe Solution. Given that various brands performed similarly with regard to installation and function, a generalized version of each was used for the identification of risks, installation time, and function. Additionally, for the purposes of the RAR, miter gates and double-swing gates were assigned the same time and effort values. Rolling gates and single-swing gates, taking slightly less effort and time, were also categorized as one.

The FCS, when complete, will provide flood protection for the City of Cedar Rapids for up to an annual chance exceedance of 0.115% (~870-year flood).

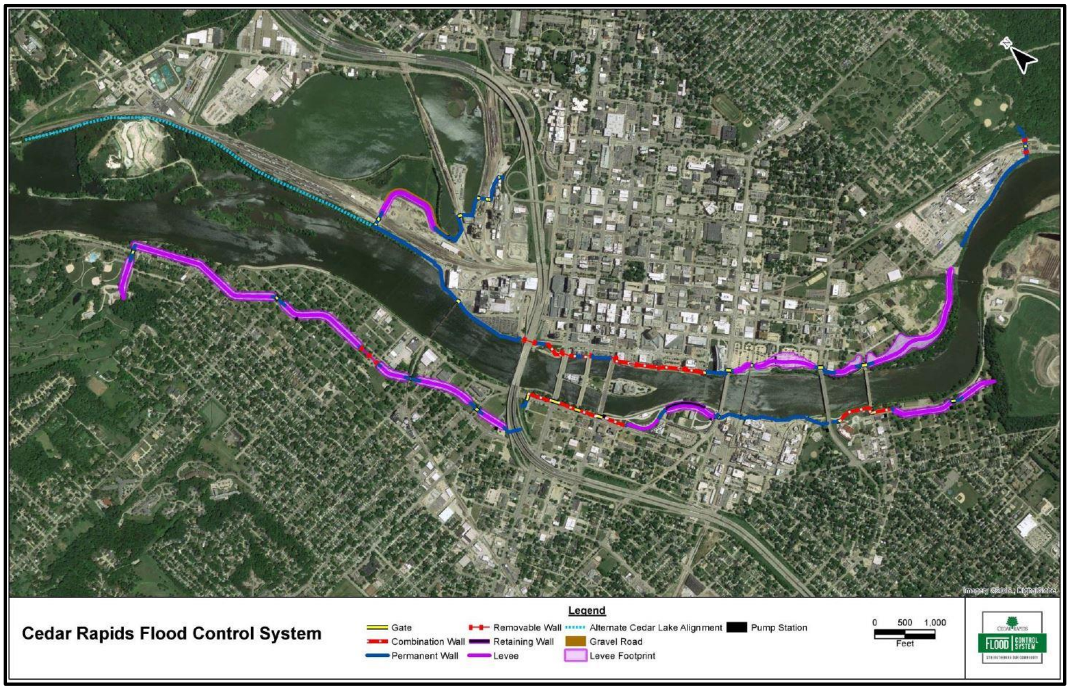
1.3 Approach

1.3.1 Data collection and information

In November 2016, ERDC conducted a site visit to Cedar Rapids, IA. Team members from ERDC and MVR met with representatives of the City, Stanley Consultants, and Anderson-Bogert Engineers and Surveyors, Inc. to discuss the Risk Assessment Plan described herein. ERDC was provided with city department contact information and a detailed map of the Cedar Rapids FCS (Figure 16). ERDC personnel were escorted through a generalized tour of the east and west flood control areas. ERDC later conducted a more in-depth assessment of the areas that included documentation through observational notes, photographs, and Global Positioning System coordinates. Data were taken back to ERDC and loaded into a KML[1] file for quick reference.

[1] Key-hole Markup Language

Figure 16. Cedar Rapids FCS.



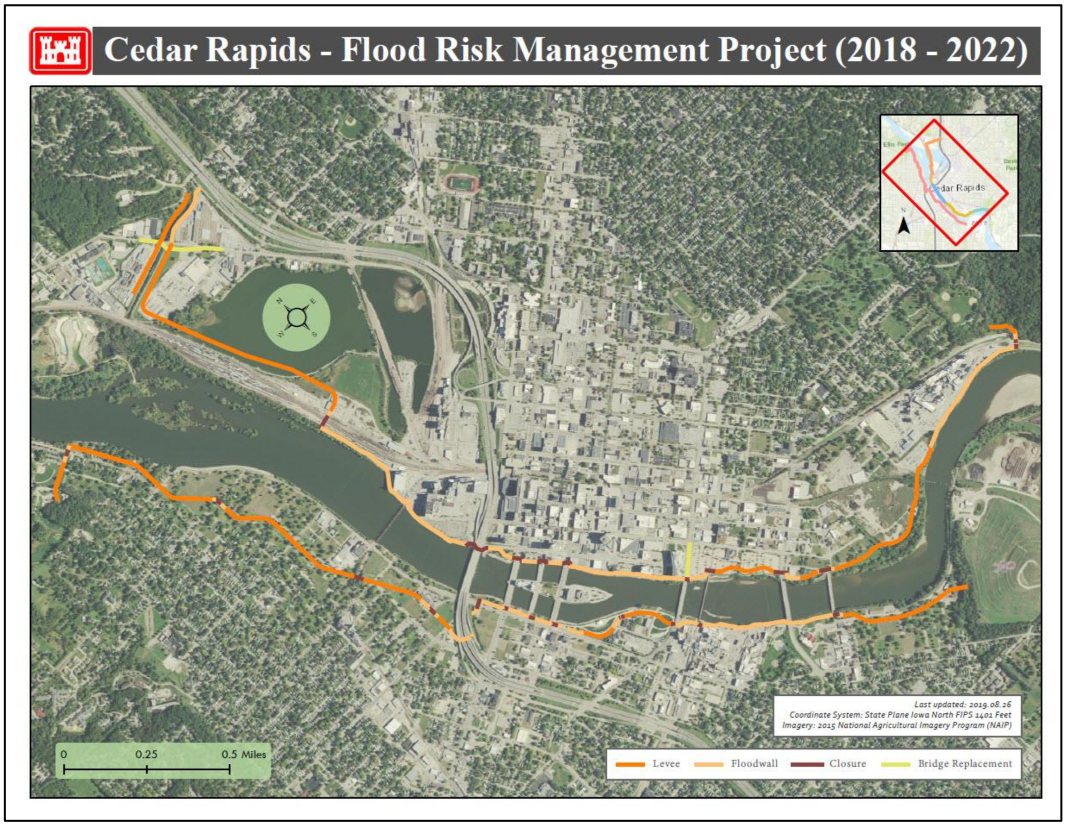
ERDC conducted another site visit in September 2017 to introduce a new team member and view the FCS progress. In June 2018, ERDC conducted a facilities, equipment, and storage site visit with the City of Cedar Rapids and again toured the FCS area to view progress. In August 2018, representatives from the City, MVR, and CHL met at ERDC to discuss progress and receive further clarity on alternative options. City and MVR personnel also conducted a site visit to Monroe, LA, to view the Monroe Solution, which is in place along its city front to prevent flooding from the Ouachita River.

Communications continued with weekly meetings throughout much of 2018–2019. During these meetings, progress reports were provided along with FCS updates used to develop and adjust alternatives.

In November 2018, ERDC personnel traveled to Cedar Rapids, IA, to present initial Phase 1 results to leaders of the City of Cedar Rapids and MVR.

Following the presentation of data and conclusion of the City of Cedar Rapids sponsored work, MVR sponsored a new set of alternatives (Phase 2). This improved efficiencies within scheduling, personnel usage, and risk evaluations, which increased the confidence of success within 48 hr of the trigger warning. An updated map containing revised alignments and closures is shown in Figure 17.

Figure 17. Phase 2 alignment and closure map.



1.3.2 Area descriptions

The FCS and Phase 2 alignment plans divide the project into eight areas on the east and west sides of the Cedar River with four on each side. Below are the original area descriptions for the FCS. Closure types and lengths for both FCS and Phase 2 are identified in Appendix B.

1.3.2.1 East-1: north industrial area

This area extends from the north tie-in point to Interstate 380 (I-380) (Figure 18). The original plans included the 275 ft area under I-380, but this was moved to the East-2 area during analysis. The narrow line shows the alignment for Phase 1 of this study. The wide line shows the alignment for Phase 2, which was extended north to McLoud Run.

Figure 18. East-1, north industrial area.

1.3.2.2 East-2: downtown area

This area is from Interstate I-380 to the 8th Avenue bridge (Figure 19).

Figure 19. East-2, downtown area.

1.3.2.3 East-3: New Bohemia area

The New Bohemia area continues to extend southward from the 8th Avenue bridge to the new Alliant Substation (Figure 20).

Figure 20. East-3, New Bohemia area.

1.3.2.4 East-4: Cargill south area

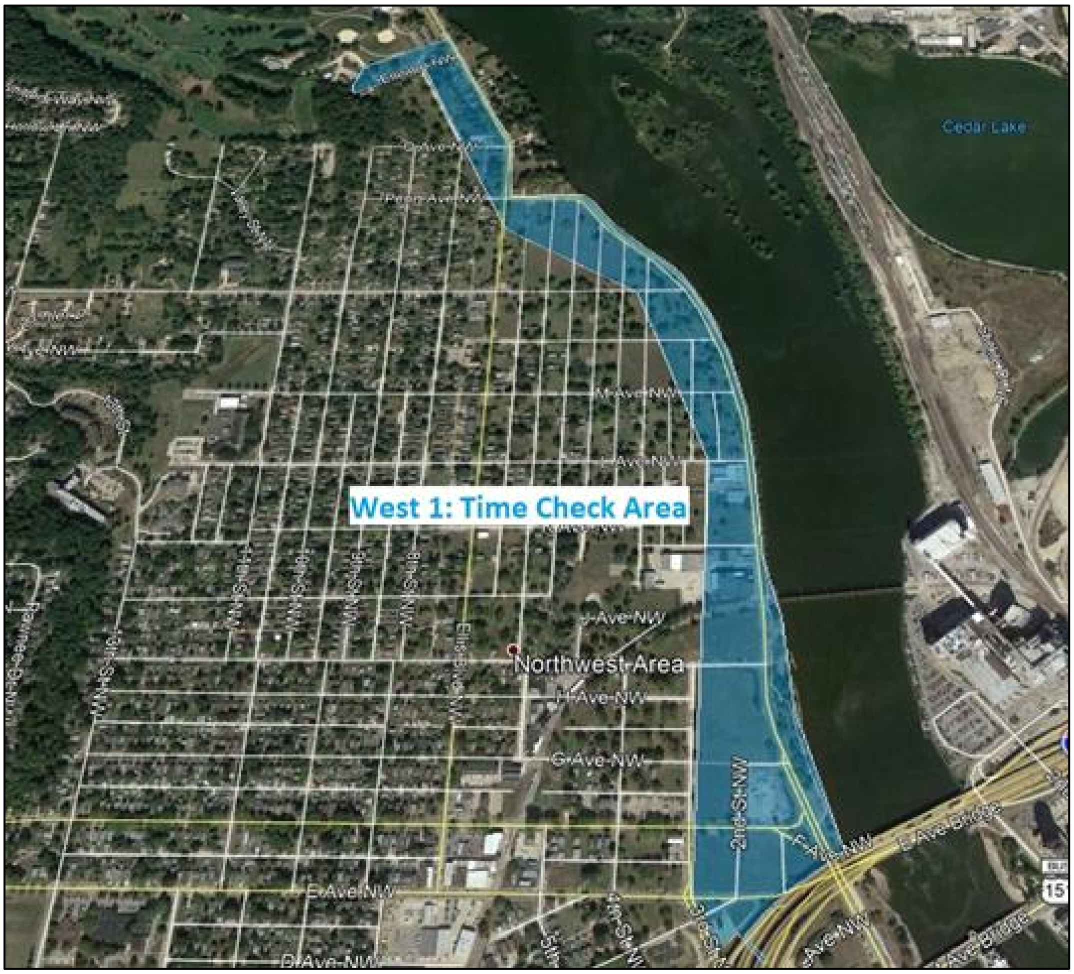
The Cargill south area extends from the Alliant Substation to the southernmost tie-in point south of the Cargill Plant (Figure 21), as shown with the narrow line. The wide line shows the alignment for Phase 2 extending across Otis Road and Union Pacific Railroad (UPRR).

Figure 21. East-4, Cargill south.

1.3.2.5 West-1: time check area

The time check area begins at the north tie-in point at the end of Ellis Lane and extends to the tie-in of I-380 (Figure 22).

Figure 22. West-1, time check area.



1.3.2.6 West-2: Kingston Village area

The Kingston Village area extends from I-380 to the 8th Avenue bridge (Figure 23).

Figure 23. West-2, Kingston area.

1.3.2.7 West-3: Penford area

The Penford area begins at the 8th Avenue bridge and ends at the 12th Avenue bridge (Figure 24).

Figure 24. West-3, Penford area.

1.3.2.8 West-4: Czech Village area

The Czech Village area begins at the 12th Avenue bridge and ends at the south tie-in area of the former landfill site (Figure 25).

Figure 25. West-4, Czech Village area.

2 Methodology for Risk Analysis

A software package called RiskyProject was used during the ERDC 2012 analysis. RiskyProject is an advanced project management software used for planning, scheduling, and determining how risks and uncertainties can affect project schedules or milestones. For continuity and because of the capabilities of the program, RiskyProject was again used for the current study. The most recent version used was RiskyProject Professional 7.

The risk analysis for this study was performed through a series of seven steps:

1. Identification of types, location, elevations, and lengths of temporary closures within the City of Cedar Rapids FCS.
2. Identification of tasks necessary for deployment of each closure type.
3. Identification and assignment of risks and their probability of occurrence and possible delay(s) for each task.
4. Identification and assignment of workforce needed to accomplish tasks in a logical and efficient order.
5. Identification of alternative plans.
6. Monte Carlo analysis by the software on selected alternatives.
7. Identification of possible efforts, products, and systems that can be implemented when needed to mitigate risks in the proposed FCS plan.

The identification of alternatives for this study was done in cooperation with the City of Cedar Rapids Department of Public Works (DPW) and representatives from MVR.

The 2012 study provides a detailed analysis of how the Monte Carlo method of analyzation is employed within the RiskyProject Software.

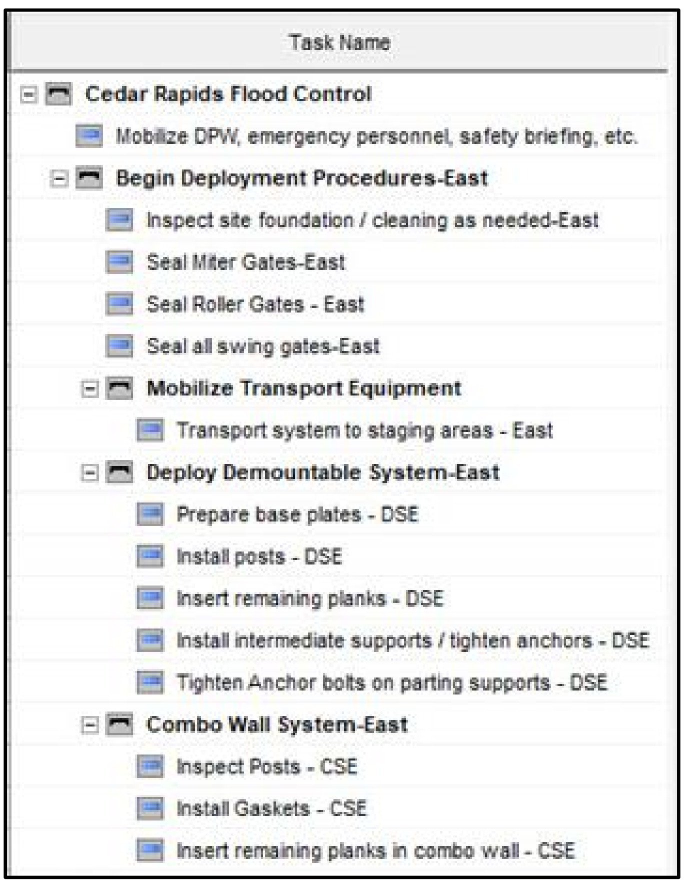
2.1 Temporary closures

The baseline for this RAR was collected from the 2016 revision of the FCS and ongoing discussions with the City and MVR that identified revisions that excluded some of the temporary closures found in the 2016 FCS and added some revisions based on alternative closure types and an evolving FCS. Closure area details are found in Appendix B.

2.2 Schedule activities

Each scheduled activity was identified and assigned a “low,” “base,” and “high” duration based on potential deployment estimates for the various type systems. The base duration is the time required for the deployment of the alternative under realistic environmental, manpower, and equipment conditions, considering reasonable risks. It is considered the most likely scenario. The low duration accounts for perfect conditions, and the high estimate is given for extenuating deployment circumstances, such as working during nighttime conditions, extreme cold, or other factors not accounted for in the risk registry. Both low and high durations are provided as an attempt to give a more robust estimate for the base duration. The current RAR used these conditional factors, developed by a 2012 study team. The estimates were reviewed and revised as needed during the current efforts, using installation estimates from vendors, experience from other cities, removable floodwalls in use by other cities, and site assessments. An example of this is shown in Figure 26.

Figure 26. Sample task sheet.



2.3 Risk assignment

For each scheduled activity, associated risks were input into a Risk Register in the RiskyProject software. The risks were then applied to multiple activities within the deployment schedule. Cohen and Ward[1] describe a risk for the purposes of this type analysis as "any event that may cause a delay in construction of the floodwall." Phase 1 risks are presented in Table 1.

Table 1. Risk Register for Phase 1 alternatives.

Risks	Description	Specific to Alternative
Not enough employees for given time	Not enough employees available for the amount of time (notice) of a flood, either from absenteeism or insufficient warning time	All
Rain	Rain associated with a storm front moving through	All
City employees not trained or insufficient training	City employees not trained	All
Contractors/contracted/rental equipment not available	City not able to contact the companies that have contracted to provide equipment during a flood	All
One or more gate(s) gaskets damaged/missing during event	Gates become damaged beyond repair during deployment	All
Wind	Wind in excess of allowable limits associated with a passing storm front	All
One or more gate(s) unable to seal during event	Gasket damaged, missing, or leaking during an event	All
Damaged foundation	Foundation has been damaged	All
Components missing from demountable system	Components for the demountable system are missing (e.g., beams, braces, hold down clamps)	All
Damaged roller track	Rolling Gates	All
Damaged wheel(s)	Rolling Gates	All

[1] Cohen, Julie, and Donald L. Ward. Unpublished. Draft Report to Sponsor. *Risk Assessment of Deployment for the Proposed Removable Floodwall System, Cedar Rapids, Iowa*. US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.

Risks	Description	Specific to Alternative
Damaged aluminum panels/posts	Removable aluminum panels or posts have been damaged	All
Debris not removed from foundation	Minor debris on the floodwall foundation	All
Installation equipment (heavy equipment) not available	Equipment owned by DPW is unavailable due to other flood fighting efforts or inoperable	All
Insufficient access space for equipment, vehicle, etc., to maneuver	The equipment needed to install the removable floodwall does not have sufficient space to maneuver in the downtown area	All
Late delivery from rental company	Due to traffic, miscommunication, weather conditions, etc.	All
Lightning	Storm front with associated lightning happening during an event	All
Limited hand tools necessary for installation	Hand tools, such as drills, wrenches, etc., are limited in quantity and must be shared throughout the downtown deployment area	All
Mechanical problems	Dead battery, broken components	All
Misplaced equipment (ladders, scaffolding, etc.)	Rented or owned	All
Storage distance of demountable system components too far	The storage distance of the floodwalls components from the deployment site is distant enough to cause a delay. Demountable system.	All
Storage distance of installation equipment too far	The storage distance of the installation equipment from the deployment site is distant enough to cause a delay. Includes ladders, tractor-trailers, forklifts, machinery, etc.	All
Uneven surfaces or terrain	Slopes, steps	All
Damaged permanent combo wall posts	Damage to currently installed posts downtown	All except roads and railroad alternatives

Risks	Description	Specific to Alternative
Components missing from combo wall system	Seals, bracing, beams, etc.	All except roads and railroad alternatives
Damage to strut braces (Monroe Wall)	Struts frozen, corroded, etc.	Alt 2 only
Hinge Damaged (Monroe Wall)	Hinge damaged or frozen; weight of panel should mitigate placement.	Alt 2 only
Lifting hook damaged (Monroe Wall)	Hook or hook wall attachment	Alt 2 only
Sealing compound unavailable or insufficient (Monroe Wall)	Bottom and between panels	Alt 2 only
Structural Damage to Wall (Monroe Wall)	Can be caused prior or during installation	Alt 2 only

Most risks assigned within the 2018–2019 RAR study were identified during the 2012 study and applied for this study. A description of how risks were assigned and the impacts of risks can be referenced to Cohen and Ward for previously identified risks.

For Phase 1 and Phase 2, new risks were collected from product operation and maintenance manuals, site-specific observations, and vendor and user contacts for systems not included in the previous study. Below is an explanation of newly identified risks for this study and how they might affect the evaluated Phase 1 alternatives and Phase 2 tasks.

System Risk: Components Missing from Combination Walls

Much like a fully demountable aluminum panel floodwall system, a combination floodwall system may have many components to install. However, they will not have intermediate posts to install as these will already be in place in a specific area. A more detailed explanation of aluminum panel system components is described in the 2012 report.

System Risk: Damaged Gate Wheels

Gate wheels are found on roller gates and on some swing gates. Damage to gate wheels could include such items as faulty bearings, bent wheel assembly, torn or punctured wheels (if inflatable), or missing or vandalized wheels. This type of damage could lead to delays in the closure of these type systems.

System Risk: Damaged Roller Track

The roller track is designed to work with roller gates. The wheel components follow the horizontal tracks to open and close the gate. Damage to the tracks could come in the form of bent tracks or deterioration from environmental elements. Each would prohibit the travel of wheels, thereby delaying closure.

Equipment Risk: Late Delivery from Rental Companies

Similar to the “contracted equipment” risk noted in 2012, the possibility exists for late delivery of rental equipment, such as vertical scissor lifts or forklifts. There is the potential for rental companies to be out of stock or unable to navigate traffic to provide timely delivery.

Equipment Risk: Mechanical Problems

There are an unlimited number of mechanical problems that could occur when working with any type of machinery. This can be mitigated by regular maintenance, but the risk still exists. Examples include dead batteries, broken parts, tire issues, motor failure, etc.

Equipment Risk: Installation Equipment (heavy equipment) Not Available

This refers to the type of equipment needed to install or deploy the closure systems. It is recommended that all necessary installation components and equipment have a designated storage area and purpose. If equipment is in use elsewhere, locating or procuring the items will cause a delay in the deployment of the flood control system.

Equipment Risk: Uneven Surface or Terrain

Uneven surfaces or terrain creates difficulties in the placement of lifting equipment to raise the wall sections along the entirety, especially during substantial weather events.

The following risks are inherent to the Monroe Solution in Phase 1 Alternative 2. They are only applied to the applicable scheduled events in that alternative.

System Risk: Hinge Damage

This hinge damage is specific to the Monroe Solution, differentiated from the hinge damage to gates. The hinges are on the bottom of the raised wall, and each hinged section requires heavy equipment to raise. The hinges are therefore more likely to become damaged from deployment activities. They can also be damaged due to environmental exposure. These risks could cause a small delay in the deployment of individual sections of the wall.

System Risk: Lifting Hook Damaged

Each section of the Monroe Solution is constructed with a preinstalled lifting hook located on the top of each wall section. A delay will be caused if these become damaged, dislodged, or are missing.

System Risk: Sealing Compound Unavailable or Insufficient

Sealing compound is necessary at the base and at the intersection of each vertical section. Significant leaks occur at any junction not adequately sealed. The compound should be regularly inspected to ensure it has not exceeded its expiration period and become unusable. An adequate supply should always be available and easily located. Procurement of needed compound could cause a delay in full deployment.

System Risk: Structural Damage to Wall

Similar to combination wall damage, the Monroe Solution presents a possibility for cracked or broken masonry. This presents the possibility for a significant delay if one or more sections cannot be deployed.

System Risk: Damage to Strut Braces

The Monroe Solution is designed to have bracing stored in place, beneath the non-deployed wall sections. Environmental exposure could cause seizure of movable bracing sections and not allow the section to be lifted or properly installed. Damage could also occur from heavy equipment used for deployment or could have occurred during lowering of walls due to previous flood events, training, or inspections.

Additionally, for Phase 2 Tasks 5.2, 5.3, and 5.4, risk percent probabilities and outcomes were reevaluated and adjusted by members of ERDC, the City of Cedar Rapids, and MVR. This reevaluation was an effort to further refine risk probabilities and outcomes based on new information about the deployment zone in the downtown area and the City's current proposed flood response plan. These numbers can be seen in Appendix C.

2.3.1 Workforce

ERDC CHL was tasked with recommending the number of personnel needed to accomplish a 90% confidence level of success within 48 hr, based on the closure recommendations provided by the City for Phase 1 of this study. For Phase 2, the preferred confidence level was increased to 95% within 48 hr.

These analyses were accomplished by applying a logical scheduling order within RiskyProject software to the identified deployment tasks. Then, crews were assigned to each task. Crew assignments were based on having no installation crews cross the river from one side to the other during any of the deployment tasks. The schedule for each alternative was developed with the assumption that deployment of the FCS on both sides of the river would begin simultaneously and continue until the full system on each side is in place.

Note that the number of crews, and associated personnel within the crews, assigned to tasks, are not based on current City resources but rather the amount of resources needed to complete the scheduled tasks with sufficient labor necessary for specific system deployment.

Tables 2 and 3 show the crews and number of personnel assigned to them that were used throughout each evaluated alternatives for Phases 1 and 2. Each alternative required a different number of personnel based on the amount and type of system being deployed.

Table 2. Identification and number and size of crews for Phase 1.

Alternative	Crew Identification	Number of Crewmembers (per crew)	Total Number of Workers per Alternative
Baseline	1 and 2	4	136
	3, 8 and 10	6	
	4, 5, 6, 7, 9, 11-16	10	
Alternative 1	1 and 2	4	140
	3 and 10	6	
	4- 9, 11-16	10	
Alternative 2	1 and 2	4	156
	3, 8 and 10	6	
	4-7, 9 and 11-18	10	
Master Plan	1 and 2	4	136
	3, 8, and 10	6	
	4-7, 9, 11-16	10	
Master Plan-400 ft	2	4	142
	1, 3, 10	6	
	4-9, 11-16	10	
Roads and Railroads Only	1, 2, and 10	4	138
	3	6	
	4-9, 11-16	10	
Roads and Railroads Only Optimized	1 , 2, and 10	4	134
	3 and 8	6	
	4-7, 9, 11-16	10	

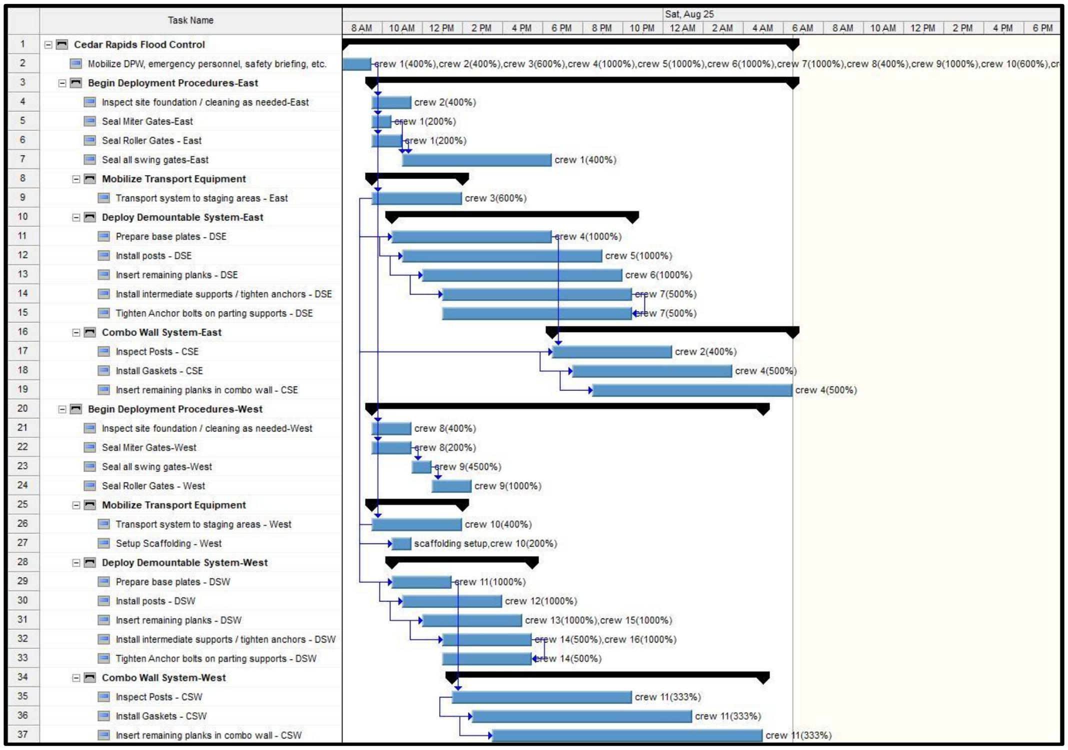
Table 3. Identification and number and size of crews for Phase 2.

Alternative		Crew Identification	Number of Crew Members (per crew)	Total Number of Workers per Alternative
Task 5.1	Deployment	1 and 2	4	136
		3, 8 and 10	6	
		4-7, 9, 11-16	10	
Task 5.2	Pre-Deployment	1 and 2	4	56
		3, 8 and 10	6	
		4, 7, 9, 11	10	
	Deployment	1	4	116
		8 and 10	6	
		4-7, 9, 11-15	10	
Task 5.3	Pre-Deployment A	1 and 2	4	66
		3, 8 and 10	6	
		4, 7, 9, 11	10	
	Pre-Deployment B	1, 2, 6, and 16	4	110
		3, 8, 10, 14	6	
		4, 7, 9, 11-13, 15	10	
	Deployment	1 and 2	4	136
		3, 8, and 10	6	
		4-7, 9, 11-16	10	
Task 5.4	Deployment	1 and 2	4	136
		3, 8, and 10	6	
		4-7, 9, 11-16	10	

Figure 27 is an example of a Gantt chart created in RiskyProject to help depict the sequencing of scheduled tasks and the corresponding crews assigned to each. The Gantt chart crew percentages noted beside each activity represent the level of effort per person at 100%. Therefore, 1000%

is representative of a 10-person crew. A Gantt chart for each alternative is provided in Appendix D of this report.

Figure 27. Gantt chart from RiskyProject showing project schedule.

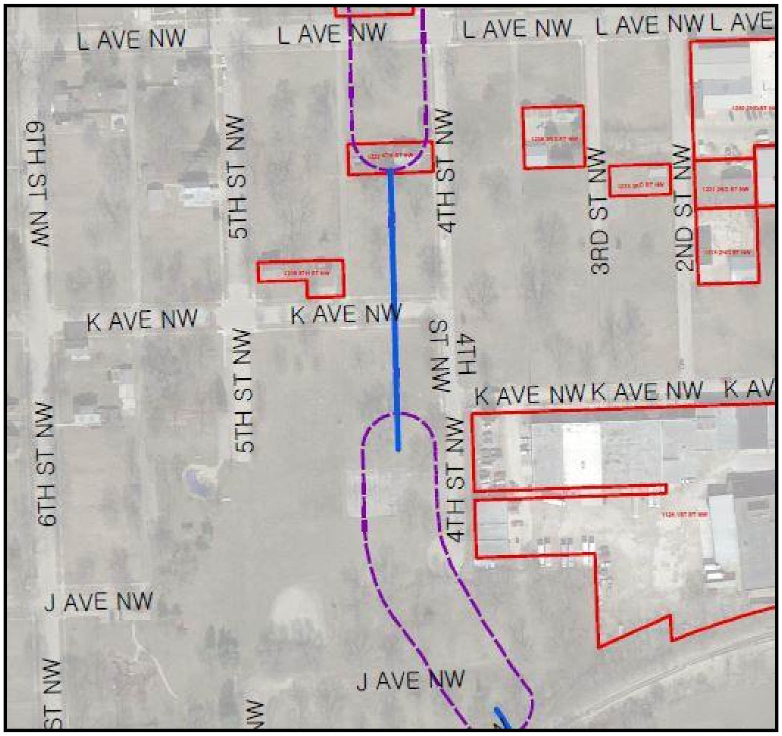


2.3.2 Alternatives

There were seven complete analysis sets included for Phase 1.

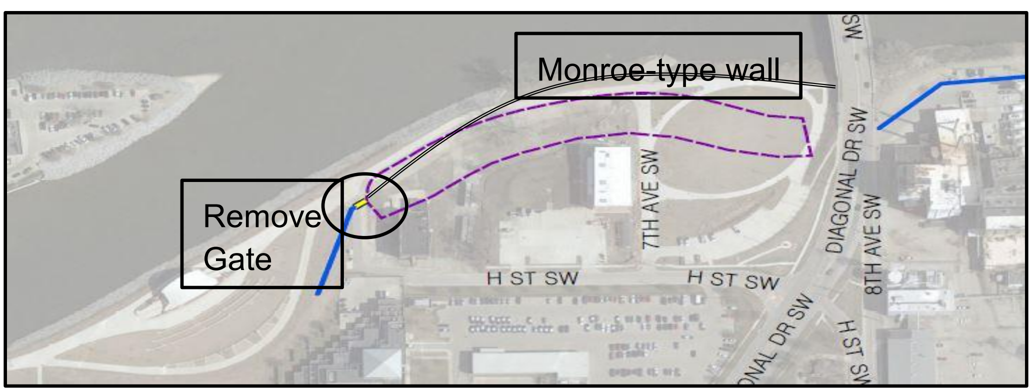
1. Baseline: The baseline was the first risk analysis performed. It followed the 2016 version of the FCS as closely as possible with modifications from the City in the form of an Excel spreadsheet containing details of closures. Correspondence with the City also indicated that the 21st Avenue gate closure would no longer be needed. They also indicated that the demountable section between the 12th and 16th Avenue bridges was no longer in the FCS as an earthen berm had already been constructed to raise the sill elevation.
2. Alternative 1: This is the baseline with the 8th Avenue bridge closures removed for both the east and west sides. This alternative also called for the removal of a 400 ft section of planned demountable wall closures at the eastern end of K Ave NW in the Kingston Village area (Figure 28).

Figure 28. Alternative 1.



3. Alternative 2: This includes everything in the Baseline and Alternative 1, along with the addition of a 950 ft section of the Monroe Solution and the removal of a pedestrian gate near the amphitheater (Figure 29).

Figure 29. Alternative 2.



4. Master Plan: The FCS has evolved since the 2016 version to include fewer temporary closures and an additional 400 ft demountable between the amphitheater and 7th Avenue. This alternative contains the known differences from the original baseline. This guidance was obtained through a series of correspondence between the City and CHL. The Monroe Solution was not included in the Master Plan

alternative. The 400 ft section of demountable wall closures at the eastern end of K Ave NW was added back.

5. Master Plan Minus 400 ft: This alternative includes the Master Plan, minus a 400 ft section of planned demountable wall closures at the eastern end of K Ave NW in the Kingston Village area.
6. Roads and Railroads Only: Only road and railroad closures were included as removable structures. All other closures were considered permanent. Crews remained the same to allow for comparisons with the previous five alternatives. This alternative was conducted for comparison purposes only and not considered a viable alternative by the City of Cedar Rapids.
7. Roads and Railroads Only, Optimized: This alternative is the same as the Roads and Railroads Only with rearranged and reassigned crews to maximize efficiency. This alternative was conducted for comparison purposes only and not considered a viable alternative by the City of Cedar Rapids.

There were four complete analysis sets included for Phase 2.

1. Task 5.1: Based off of the Phase 1, Master Plan alternative. This was modified to add back the railroad bridge closure at Quaker Oats and the demountable closures under I-380.
2. Task 5.2: This alternative was developed from the results of Task 5.1 to include the following:
   a. Three closures on the West side were changed to levees.
      (1) Park access opening of 400 ft at L Avenue
      (2) 1st St SW, north of A Ave NW
      (3) A Ave NW to 1st Ave W
   b. A decrease in length of the 16th Ave bridge on the East side.
   c. Changed the 1st Ave bridge from demountable to a roller gate and decreased the length on the East side.
   d. Changed the Five Seasons Plaza closures from demountable to levee structures.
   e. Changed Otis Road closure from demountable to swing gate and decreased the length.
   f. Increased the length of railroad closure parallel to Otis Road at the Cargill plant
   g. Changed the closure at I-380 from demountable to roller gates and decreased the length.

Task 5.2 has a total reduction of 1,623 linear ft and 19,523 ft^2 of deployable systems from Task 5.1.

Additionally, this task experimented with pre-deployment activities in an effort to increase the probability of successful deployment after the trigger event. Pre-deployment activities included such things as staging supplies and equipment, checking and cleaning sill areas, combo walls, gate hinges, gate wheels, and gate tracks,

Deployment activities can be defined as only those things done after the event trigger occurred. Deployment activities included but are not limited to the actual installation of demountable posts and panels, gate closures, and combo wall panel installation.

3. Task 5.3: This task included pre-deployment activities, but this time the task was evaluated before and after crew optimization through Task 5.3A (before) and 5.3B (after). Deployment procedures remained the same as Task 5.2, however crew usage was optimized.
4. Task 5.4: This task did not include pre-deployment activities. Modifications to the deployment utilized Task 5.2 as a baseline. These modifications included the following:
   a. Two East-side closures were changed to permanent walls
      (1) 3rd Avenue SE to 4th Avenue SE
      (2) 5th Avenue to 6th Avenue
   b. Three West-side closures sill elevations increased by 1–1.5 ft each.

Task 5.4 has a total reduction of 515 linear ft and 6,305 ft^2 of deployable systems from Tasks 5.2 and 5.3.

Detailed information for all of the Phase 1 alternatives and Phase 2 tasks can be found in Appendix B.

2.4 Cost analysis

2.4.1 Labor hours

Labor hours were provided by the City of Cedar Rapids at a rate $63/hr via email on June 8, 2018. This rate was applied as an average for each employee entered into the RiskyProject software to account for portions of the differences in costs when comparing the various alternative plans.

Variations in the crew sizes and numbers, sequences, and types of closures and associated activities accounted for cost differences.

Table 4 and Table 5 show each of the Phase 1 and Phase 2 alternatives, respectively, and their base estimated duration, labor hours, and labor costs. The base numbers are the estimates applied before the schedule risk analysis was performed. This accounts for labor only, not equipment purchase or rental costs.

Table 4. Estimated base labor hours, total costs, and deployment duration for the Phase 1 alternatives before the risks are applied to the schedule.

Description	Labor Hours	Total Costs	Deployment Duration (hours)
Baseline	1,176	$95,741	22.5
Alternative 1	1,222	$98,611.	22.5
Alternative 2	1,362	$121,329	22.5
Master Plan	1,498	$115,996	21
Master Plan Minus 400 ft	1,214.5	$98,167	19.5
Roads and Railroads Only	682.5	$56,898	10
Roads and Railroads Only, Optimized by Crew Location	564.5	$57,264	7.5

Table 5. Estimated base labor hours, total costs, and deployment duration for the Phase 2 tasks before the risks are applied to the schedule.

Description		Labor Hours	Total Costs	Deployment Duration (hours)
Task 5.1	Deployment	1,407	$110,280	21
	Pre-Deployment	349	$43,687	10.5
Task 5.2	Deployment	714.5	$44,967	8.5
	Total Pre-Deployment and Deployment	1,063.5	$88,654	19

Description		Labor Hours	Total Costs	Deployment Duration (hours)
	Pre-Deployment A	365	$44695	8
	Pre-Deployment B	425	$48,475	4.5
Task 5.3	Deployment	717.5	$45,156	8.5
	Total Pre-Deployment A and Deployment	1169.5	$117,095	16.5
	Total Pre-Deployment B and Deployment	1168.5	$117,032	13
Task 5.4	Deployment	712	$66,510	12

Tables 6 and 7 show a further breakdown of costs and labor hours on the east and west sides of the river, before risks are applied, for each Phase 1 alternative and Phase 2 task. This accounts for labor only, not equipment purchase or rental costs.

Table 6. Phase 1 labor hours and labor costs for deployment (excluding equipment costs).

Alternative	East			West		
	Cost	Labor Hours	# of Workers	Cost	Labor Hours	# of Workers
Baseline	$40,320	613	54	$34,099	499	86
Alternative 1	$40,320	613	54	$36,591	539	86
Alternative 2	$52,197	592	54	$46,865	686	96
Master Plan	$37,139	590	54	$57,158	908	82
Master Plan Minus 400 ft	$37,580	595	56	$36,620	618	86
Roads and Railroads Only	$22,019	488	54	$21,105	249	84
Roads and Railroads Only Optimized by Crew	$23,436	510	74	$11,245	179	50

Table 7. Phase 2 labor hours and labor costs for deployment (excluding equipment costs).

	East			West		
Alternative	Cost	Labor Hours	# of Workers	Cost	Labor Hours	# of Workers
Task 5.1	$31,406	445	54	$57,158	1,240	82
Task 5.2						
Pre-Deployment	$9,639	129	24	$12,348	164	32
Deployment	$16,979	226	44	$27,989	373	72
Task 5.3						
Pre-Deployment A	$11,025	135	40	$11,970	164	26
Pre-Deployment B	$12,411	143	54	$14,364	172	56
Deployment	$16,978	220	50	$28,178	362	86
Task 5.4	$14,490	230	54	$25,532	406	82

2.4.2 Equipment

Ladders, scaffolding, and vertical lifts were the only equipment broken out into individual cost units within Risky Project. Trucks and trailers for transporting supplies to the staging areas and forklifts for loading and removal of supplies were included within the tasks and thus already accounted for within the program.

Ladders and scaffolding were considered a one-time cost. An estimate of 10 extension ladders will be needed at a cost of approximately $3,000.00. An estimate of six 12 ft sections of scaffolding will be required at a cost of $7,800.00. The source for each of these estimates comes from a national industrial equipment supplier.

Vertical lifts costs were based on 1-month rentals at a rate of $1,350 per month for four lifts, for a total of $7,800.00. Costs were sourced from a local rental company in Cedar Rapids, IA.

Most rental equipment costs were assigned to the beginning activity of Deployment so as to capture the one-time cost for rental during the life of the deployment. The crane operation cost was captured during the corresponding task using it for the Monroe Solution in Alternative 2. The estimated cost of the crane is based on estimates available at the time in RSMeans Building Construction Cost Data Book©. For this study, an operating cost of $166.88/hr was used.

These costs are strictly for rental and machinery operation cost. Labor to operate this equipment is assumed to be captured in crew labor charges.

2.4.3 Yearly inspection and maintenance

Yearly maintenance can be achieved concurrently with yearly testing. It is recommended that one-third of the removable system be deployed each year on a rotating 3-year cycle. This ensures the entire system is completely tested every 3 years. A complete inventory inspection and maintenance of system components should be conducted annually.

Costs associated with the one-third testing would include both deployment and system removal. For the purposes of this cost estimate, the deployment of the system includes risks, with the assumption that deployment would be treated as an actual flood event for training purposes. Since the removal cost estimate does not include risks, the base cost component of each alternative is used instead. The rationale being that removal is considered a non-emergency and thus could be achieved under optimal conditions, at a slower pace over a longer period of time.

Accurate estimates of the costs for replacing components and materials are not achievable and as such, not factored into this estimate. These items would need to be identified during inventory and inspection periods and replaced based on manufacturer’s recommendations.

Tables 8 and 9 show the estimated costs for deployment, disassembly, and annual training and maintenance for Phases 1 and 2, respectively.

Table 8. Estimated annual training and maintenance costs for Phase 1.

Alternative Name	Cost to Deploy and Disassemble	One-Third Cost of Total
Baseline	$299,531	$99,844
Alternative 1	$283,667	$94,556
Alternative 2	$341,449	$113,816
Master Plan	$324,5322	$108,177
Master Plan Minus 400 ft	$275,807	$91,936
Roads and Railroads Only	$193,021	$64,340
Roads and Railroads Only Optimized by Crew	$190,527	$63,509

Table 9. Estimated annual training and maintenance costs for Phase 2.

Task Name		Cost to Deploy and Disassemble	One-Third Cost of Total
Task 5.1		$313,124	$104,375
Task 5.2			
	Pre-Deployment	$131,275	$43,758
	Deployment	$157,066	$52,355
Task 5.3			
	Pre-Deployment A	$139,222	$46,407
	Pre-Deployment B	$167,924	$55,975
	Deployment	$166,252	$55,417
Task 5.4		$216,074	$72,025

3 Results

Results of the risk analyses for Phases 1 and 2 are shown in Tables 10 and 11. The top of each table gives the minimum, mean, and maximum deployment durations from the Monte Carlo analysis for each alternative. The center of the table shows the cumulative probabilities of deployment duration times. The percent chance of deployment means that the deployment duration is expected to be at or less than the resulting number of hours. Conversely, it also means that there is a probability of *not* completing the deployment in the resulting number of hours. This probability is interpolated by subtracting the percent chance of deployment from 100%. For example, a 90% chance of a resulting duration of 48 hr means that there is also a 10% chance that the duration will be more than 48 hr. The bottom rows of the table show the size and number of closures for each alternative.

Table 10. Duration to complete FCS by alternatives for Phase 1.

	Baseline	Alternative 1	Alternative 2	Master Plan	Master Plan – 400 ft	Roads and Railroads Only	Roads and Railroads Only, Optimized by Crew Locations
Minimum (Hours)	22.02	25.37	24.03	22.15	19.63	12.55	11.58
Mean (Hours)	42.60	38.33	40.36	36.32	33.13	23.55	22.21
Maximum (Hours)	89.70	64.13	86.23	69.30	70.00	63.55	63.75
% Probability (Hours)							
1% Chance	24.77	27.17	27.07	24.00	21.03	14.12	12.33
5% Chance	28.12	29.40	29.70	26.00	23.05	15.43	14.53
10% Chance	31.05	30.68	30.98	28.25	24.33	16.80	15.33
20% Chance	34.12	32.62	32.92	30.33	26.23	18.22	16.85
50% Chance	41.98	37.52	38.97	35.20	31.67	21.83	20.47
80% Chance	49.58	43.75	45.18	41.75	39.10	28.35	26.85
90% Chance	55.40	47.57	50.52	45.87	44.60	33.43	31.8
95% Chance	61.07	50.65	59.05	50.67	49.53	36.75	35.78
99% Chance	70.45	58.88	75.02	59.33	56.27	46.38	43.97
Length of Closures (ft)	6,188	5,859	6,777	6,125	5,725	2,005	2,005
Sq ft of Closures (ft^2)	65,001	50,134	55,776	63,773	62,844	22,694	22,694
Number of Closures	38	50	50	37	36	22	22

Table 11. Duration to complete FCS by alternatives for Phase 2.

	Task 5.1	Task 5.2		Task 5.3			Task 5.4
		Pre-Deployment	Deployment	Pre-Deployment A	Pre-Deployment B	Deployment	Deployment
Minimum (hours)	20.93	12.3	11	11.63	8.1	10.15	12.32
Mean (hours)	35.85	27.95	23.48	25.66	19.63	23.00	24.92
Maximum (hours)	67.6	56.67	51.02	51.73	38.2	61.97	56.15
Standard Deviation	7.40	7.59	7.25	7.11	5.51	7.31	7.06
% Probability (hours)							
1% Chance	23.77	14.27	12.2	13.63	9.80	11.80	13.88
5% Chance	25.67	17.50	14.22	15.83	12.00	13.87	16.13
10% Chance	27.20	19.32	15.78	17.56	13.10	15.23	17.33
20% Chance	29.75	21.45	17.75	19.68	14.92	17.32	19.13
50% Chance	34.82	26.88	21.95	24.6	18.87	21.32	23.60
80% Chance	41.38	34.05	28.5	31.08	23.87	27.62	29.78
90% Chance	45.68	38.28	33.93	35.36	27.28	33.22	34.48
95% Chance	50.03	42.30	39.52	38.83	30.03	38.90	39.00
99% Chance	57.88	49.63	44.93	48.57	36.15	45.50	48.60
Length of Closures (feet)	6,188	4,565		4,565			4,050
Sq ft of Closures (ft^2)	65,796	46,272		46,272			39,967
Number of Closures	39	35		35			35

Figures 30 and 31 show a graphical view of the cumulative probabilities of deployment duration times for Phases 1 and 2.

Figure 30. Cumulative probability percent chance of deployment for the Phase 1 alternatives.

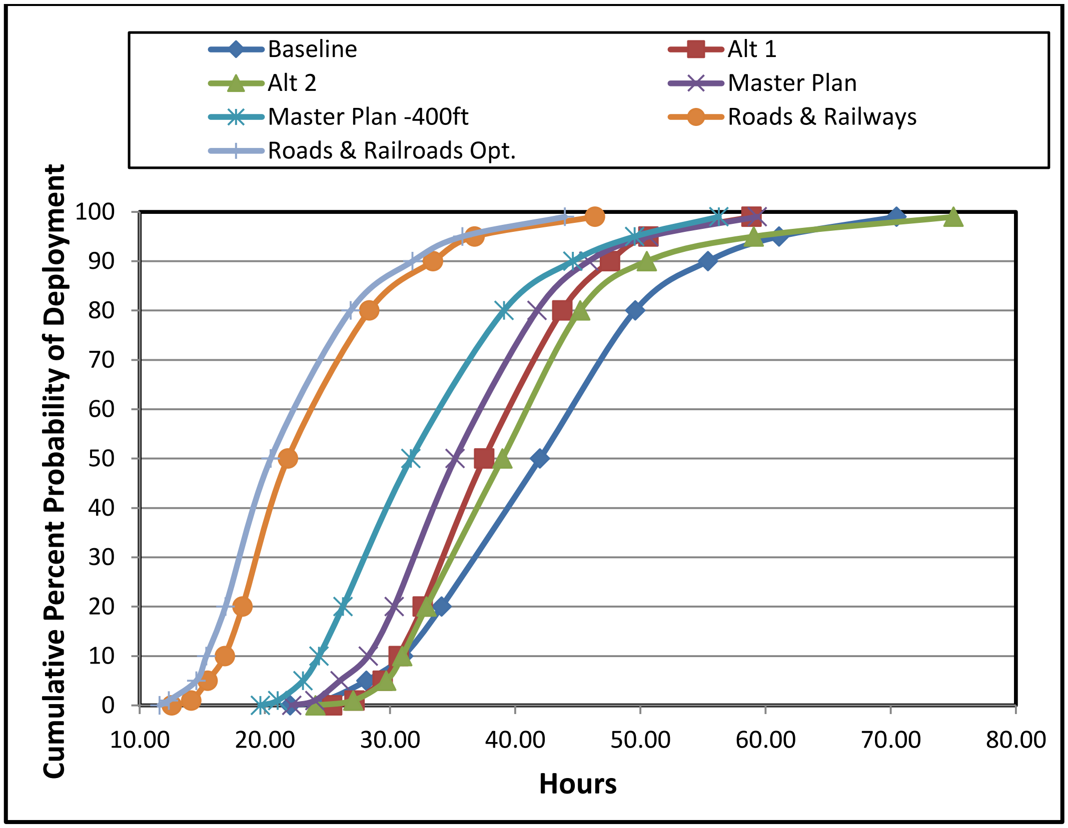
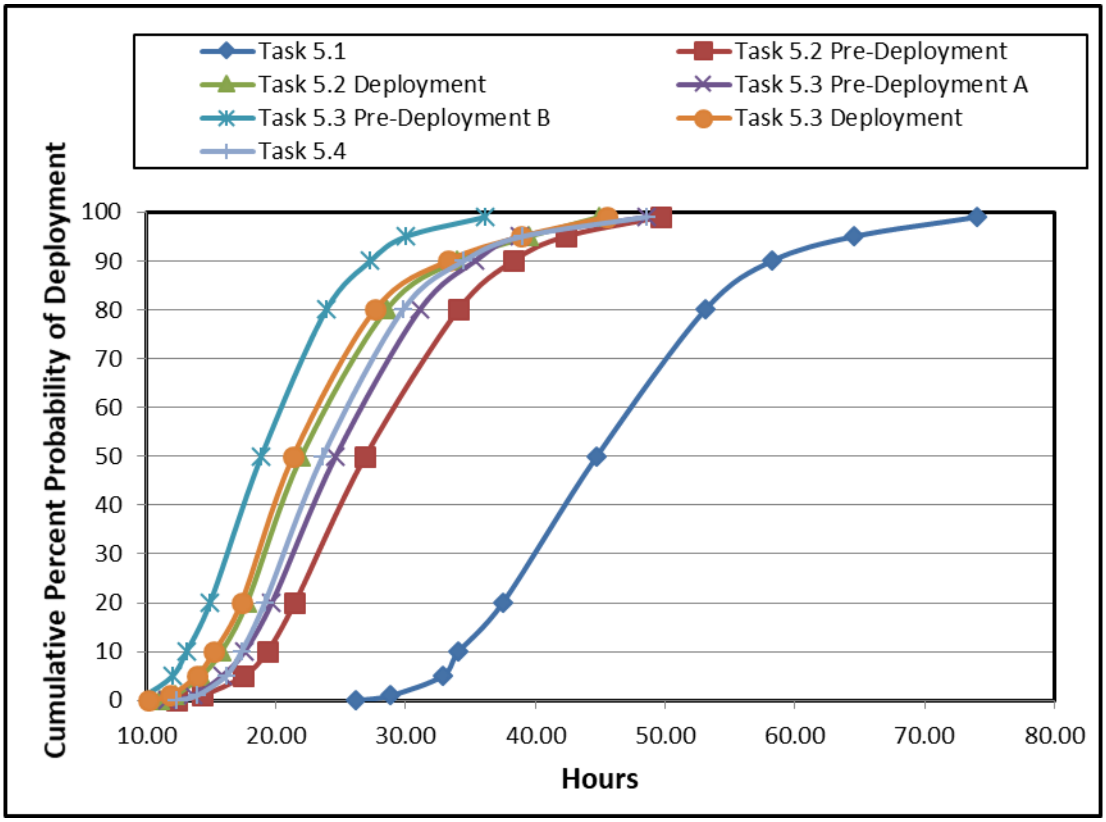


Figure 31. Cumulative probability percent chance of deployment for the Phase 2 tasks.



The range of times of completion for Phases 1 and 2 are also shown in Figures 32 and 33, respectively, as a high-low chart. The vertical line depicts the highest-to-lowest duration for each alternative. The horizontal line depicts what duration a 90% probability in Phase 1 and 95% probability in Phase 2 may have when the full systems are deployed.

Figure 32. Times to complete installation for Phase 1 alternatives. Horizontal marker shows duration for 90% probability of completion of installation, and the range shows from minimum to maximum times.

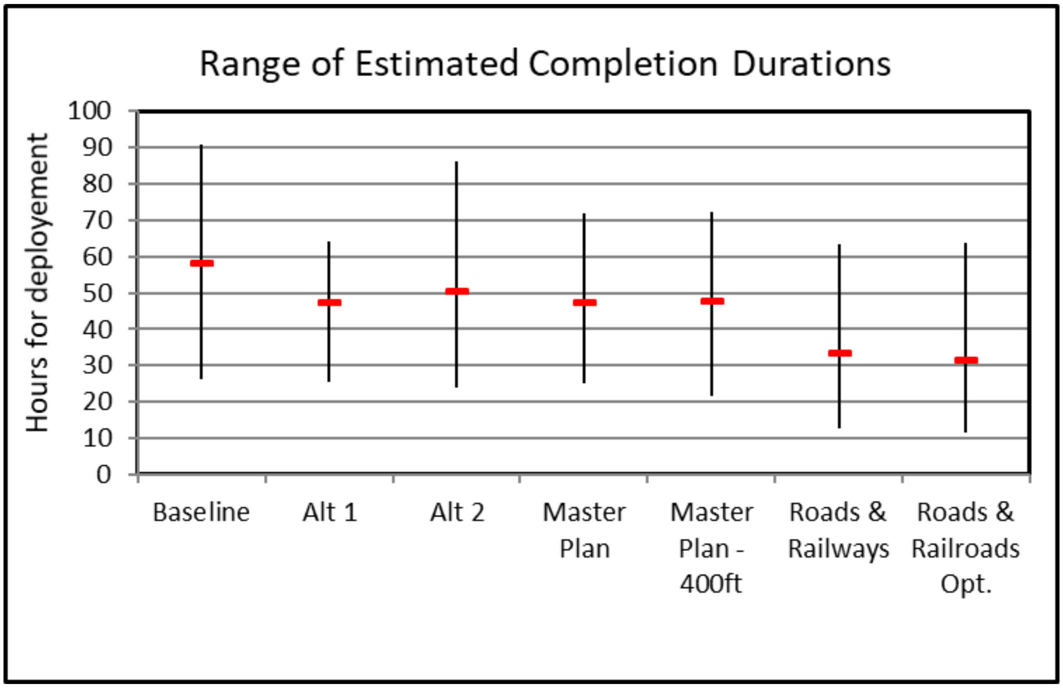
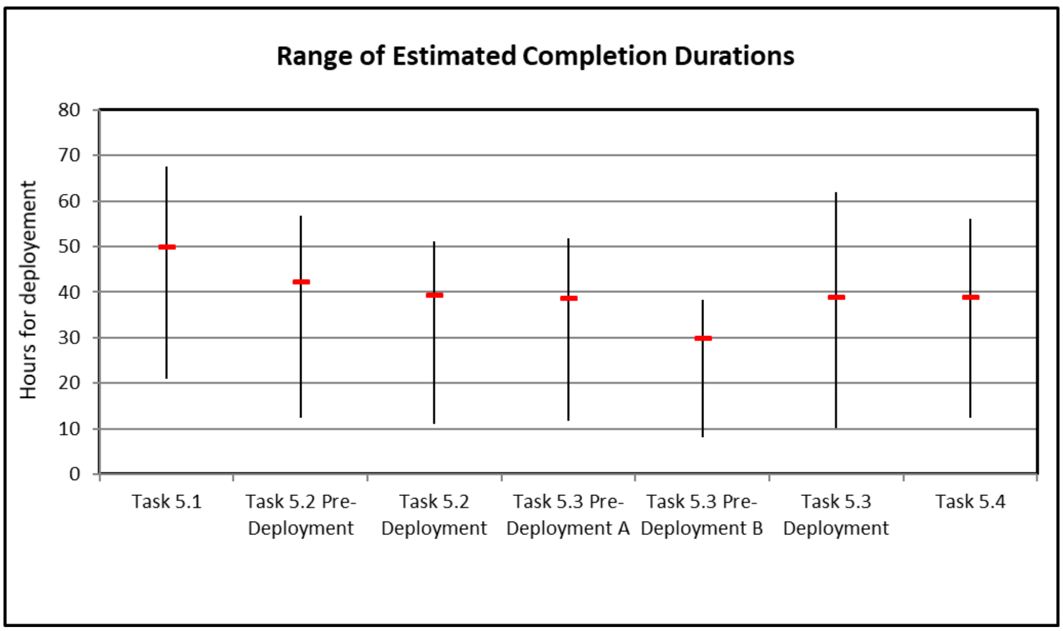


Figure 33. Times to complete installation for Phase 2 tasks. Horizontal marker shows duration for 95% probability of completion of installation, and the range shows from minimum to maximum times.



3.1 Gantt charts

Appendix D graphically portrays Gantt charts showing the schedule of events and the base times of deployment without risks applied for each Phase 1 alternative and Phase 2 task. This baseline was used in a Monte Carlo analysis, run by the RiskyProject software, to analyze the deployment schedule with several possible risk probabilities assigned to activities in the schedules. The results of the Monte Carlo analysis are discussed in the following sections.

3.2 Results of risk analysis

Table 12 and Table 13 show each of the Phase 1 and Phase 2 alternatives, respectively, with the expected mean duration, mean labor hours, and mean labor cost with the risks applied to the schedule. The mean costs/hours were used for analysis because this is the methodology of the RiskyProject Software. It does not calculate these numbers for any other probability.

Table 12. Estimated mean labor hours, labor costs, and deployment duration for Phase 1 with risks applied to the schedule.

Description	Labor Hours (Mean)	Labor and Equipment Costs (Mean)	Deployment Duration (Hours)
Baseline	3,043	$213,110	42.62
Alternative 1	2,597	$185,056	38.32
Alternative 2	2,922	$220,120	40.35
Master Plan	2,969.35	$208,536	36.32
Master Plan Minus 400 ft	2,585	$184,308	33.12
Roads and Railroads Only	1,940	$136,123	23.57
Roads and Railroads Only, Optimized by Crew Location	1,771	$133,263	22.22

Table 13. Estimated mean labor hours, labor costs, and deployment duration for Phase 2 with risks applied to the schedule.

Description		Labor hours	Labor Cost	Deployment Duration (hours)
Task 5.1	Deployment	2,879.3	$202,869	35.85
Task 5.2	Pre-Deployment	1,045.83	$87,588	27.95
	Deployment	1,783.04	$112,099	23.48
	Total Pre-Deployment and Deployment	2828.87	$199,687	51.43
Task 5.3	Pre-Deployment A	1,166.27	$94,527	25.15
	Pre-Deployment B	1,551.57	$119,449	19.62
	Deployment	1,951.25	$121,096	23.00
	Total Pre-Deployment A and Deployment	3,117.52	$215,623	48.15
	Total Pre-Deployment B and Deployment	3,502.82	$240,545	42.62
Task 5.4	Deployment	1,972.54	$145,784	24.92

As documented in the 2012 report, and in discussions with other communities deploying removable systems, the mean labor hours and labor costs should be considered the most likely outcome for deployment. Maximum estimates would occur only during the most extreme outcomes.

For Phase 1, the Master Plan Minus 400 ft alternative results showed the best outcome toward achieving the required 90% confidence level (Table 10) when not considering the “roads and railroads” demonstration alternatives. The Phase 1 Master Plan Minus 400 ft alternative has a calculated minimum duration of 19.63 hr, maximum of 70 hr, and a mean duration of 33.13 hr. The 90 percentile is 44.6 hr, meaning that 90% of the time, the deployment duration will be 44.6 hr or less.

3.3 Monte Carlo Analysis

Phase 2 Task 5.4 results show that this is the most efficient deployment schedule in this Phase. Task 5.4 of Phase 2 has a calculated minimum duration of 12.32 hr, maximum of 56.15 hr, and a mean duration of 24.92 hr. The 95 percentile is 39.00 hr, meaning that 95% of the time the deployment duration will be 39.00 hr or less (Table 11). The mean outcome is the most likely outcome based on discussions with neighboring communities and private entities with removable systems. With regular training, maintenance, and usage, it is highly probable that the deployment durations will be closer to the median (50% chance) duration results estimated in this analysis for the analyzed alternatives and tasks, over the life of the system.

The RiskyProject software was set to perform 600 simulations in the Monte Carlo analysis for Phase 1 to achieve these estimates. Due to the presence of a skewed probability curve and outlier points producing unlikely high durations, a review of the statistical distributions for Phase 1 was conducted. This review concluded that the while the data of Phase 1 are reliable, the probability distribution curve shown in the histogram resulted in a marginally random distribution instead of a perfectly normal distribution. This was evidenced by the large dip(s) between the bins of the histogram. For Phase 2, the Monte Carlo simulations were increased to 1,000 from 600. This increase in simulations led the output from the analysis to have consistent values, without large dips in the probability curve, giving a more normal distribution curve.

Variations in durations for each Phase 1 alternative are attributed to a number of factors. The analysis shows that the most pronounced factors are the increase or decrease of closure areas. As to be expected, the addition of the Monroe Solution increased the closure area by 950 ft but also introduced an entirely new set of tasks and associated risks.

The reduction of the 400 ft of demountable walls at the end of L Avenue in the Master Plan Minus 400 ft alternative reduced the duration and costs of both the alternatives examined versus the most similar alternatives containing the 400 ft section, the Master Plan and the Baseline alternatives.

The results of the Monte Carlo analysis rank the probabilities and lists them in order of severity. Tables 14 and 15 show the three most critical risks affecting each alternative as identified during the Monte Carlo analysis, which is described in Section 3.4. A complete set of risk matrices is found in Appendix E.

The Monte Carlo analysis shows that there are consistently three risks that, when applied to each schedule, become critical issues for completing the full deployment of the RAR in each alternative. These risks impact the overall cost of deployment when risks are applied as well as duration. One risk factor, Damaged Permanent Combo Wall Posts, is also a critical risk in the deployment of the Phase 1 alternatives and Phase 2 tasks that use this method of flood fighting.

The risk that could most hinder the deployment of the evaluated alternatives and tasks in this study is rain, with the exception of the Master Plan Minus 400 ft alternative. The risk of rain is critical because if it were to happen as the trigger is reached to begin the 48 hr deployment, it would delay not just one activity in the schedule(s) but all of them.

Phase 1 alternative and Phase 2 task. While each system could still be deployed with untrained personnel, the delay would come from the lack of knowledge and experience by those employees or volunteers. A delay could also be caused by having trained personnel leading and supervising untrained personnel in multiple locations, thereby splitting the effectiveness of those trained personnel.

The risk of not having enough employees, trained or untrained, to deploy the system can also cause significant delays. If personnel are not available to be mobilized in sufficient time to allow for full installation, the entire schedule could be significantly delayed. Since a major flood event could impact the availability of City personnel, there could be insufficient labor to deploy any and all flood-fighting measures before the first impacts of the impending flood are experienced along the deployment zone.

Table 14. Critical risks that effect each Phase 1 alternative.

Alternative	Risks	Affect on Total Project Cost	Affect on Project Duration	Affect on All Parameters
Baseline (25 Risks Total)	1	Not Enough Employees for Given Time	Rain	Rain
	2	Contractors/Contracted/Rental Equipment not Available	Not Enough Employees for Given Time	Not Enough Employees for Given Time
	3	City Employees Not Trained or Insufficient Training	Damaged Permanent Combo Wall Posts	Contractors/Contracted/Rental Equipment not Available
Alternative 1 (25 Risks Total)	1	Not Enough Employees for Given Time	Rain	Rain
	2	Contractors/Contracted/Rental Equipment not Available	Not Enough Employees for Given Time	Not Enough Employees for Given Time
	3	City Employees Not Trained or Insufficient Training	Damaged Permanent Combo Wall Posts	Contractors/Contracted/Rental Equipment not Available
Alternative 2 (30 Risks Total)	1	City Employees Not Trained or Insufficient Training	Rain	Rain
	2	Not Enough Employees for Given Time	City Employees Not Trained or Insufficient Training	City Employees Not Trained or Insufficient Training
	3	Contractors/Contracted/Rental Equipment not Available	Not Enough Employees for Given Time	Not Enough Employees for Given Time
Masterplan (23 Risks total)	1	Rain	Damaged Permanent Combo Wall Posts	Rain
	2	City Employees Not Trained or Insufficient Training	Rain	City Employees Not Trained or Insufficient Training
	3	Contractors/Contracted/Rental Equipment not Available	City Employees Not Trained or Insufficient Training	Contractors/Contracted/Rental Equipment not Available
Masterplan-400 Ft (24 Risks Total)	1	Contractors/Contracted/Rental Equipment not Available	City Employees Not Trained or Insufficient Training	City Employees Not Trained or Insufficient Training
	2	City Employees Not Trained or Insufficient Training	Damaged Permanent Combo Wall Posts	Contractors/Contracted/Rental Equipment not Available
	3	Not Enough Employees for Given Time	Not Enough Employees for Given Time	Not Enough Employees for Given Time
Roads and Railroads Only (23 Risks Total)	1	City Employees Not Trained or Insufficient Training	Rain	Rain
	2	Not Enough Employees for Given Time	Not Enough Employees for Given Time	Not Enough Employees for Given Time
	3	Contractors/Contracted/Rental Equipment not Available	City Employees Not Trained or Insufficient Training	City Employees Not Trained or Insufficient Training
Roads and Railroads Only Optimized by Crew Location (23 Risks Total)	1	City Employees Not Trained or Insufficient Training	Not Enough Employees for Given Time	Not Enough Employees for Given Time
	2	Contractors/Contracted/Rental Equipment not Available	Rain	Rain
	3	Not Enough Employees for Given Time	City Employees Not Trained or Insufficient Training	City Employees Not Trained or Insufficient Training

Table 15. Critical risks that effect each Phase 2 alternative.

Description			Effect on Total Project Cost	Effect on Project Duration	Effect on All Parameters
Task 5.1	Deployment	1	Rain	Damaged Permanent Combo Wall Posts	Rain
		2	City Employees not Trained or Insufficient Training	Rain	City Employees not Trained or Insufficient Training
		3	Contractors/Contracted Equipment/Rental Equipment not Available	City Employees not trained or insufficient training	Contractors/Contracted Equipment/Rental Equipment not Available
Task 5.2	Pre-Deployment	1	Rain	Damaged Permanent Combo Wall Posts	Damaged Permanent Combo Wall Posts
		2	Contractors/Contracted Equipment/Rental Equipment not Available	Rain	Rain
		3	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training
	Deployment	1	Rain	Rain	Rain
		2	Contractors/Contracted Equipment/Rental Equipment not Available	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training
		3	City Employees not Trained or Insufficient Training	Not Enough Employees for a Given Time	Not Enough Employees for a Given Time
Task 5.3	Pre-Deployment A	1	Rain	Damaged Permanent Combo Wall Posts	Rain
		2	Contractors/Contracted Equipment/Rental Equipment not Available	Rain	Damaged Permanent Combo Wall Posts
		3	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training
	Pre-Deployment B	1	Rain	Not Enough Employees for a Given Time	Not Enough Employees for a Given Time
		2	Contractors/Contracted Equipment/Rental Equipment not Available	Damaged Permanent Combo Wall Posts	Rain
		3	City Employees not Trained or Insufficient Training	Rain	Damaged Permanent Combo Wall Posts
	Deployment	1	Rain	Rain	Rain
		2	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training
		3	Contractors/Contracted Equipment/Rental Equipment not Available	Not Enough Employees for a Given Time	Not Enough Employees for a Given Time
Task 5.4	Deployment	1	Rain	Rain	Rain
		2	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training	City Employees not Trained or Insufficient Training
		3	Not Enough Employees for a Given Time	Damaged Permanent Combo Wall Posts	Damaged Permanent Combo Wall Posts

The risk of City employees not being properly trained, or inadequately experienced in installation procedures, could cause significant delays in each alternative and task.

Additionally, the risk of not having contractors, contracted equipment, and/or rental equipment available could cause significant delays in deployment. Systems such as the demountable walls, combo walls, and the Monroe Solution type sidewalks require equipment to install that must either be owned and available at the time of deployment by the City or contracted or rented from other entities. If the contractors are unavailable, perhaps due to prior commitments or other factors, the full deployment of the system can be delayed. Likewise, contracted or rental equipment being unavailable, due to factors such as distance from Cedar Rapids and the deployment areas, could cause delay to the specific activities in the schedule that rely on these resources, causing delay in the full deployment of the entire system.

There is a potential for critical delay in activity duration to Phase 1 alternatives and Phase 2 tasks that use the combo wall system. While permanent posts that utilize demountable panels in between them can lesson installation durations, the posts themselves carry a significant risk should they be un-usable or damaged before or during installation. A damaged permanent post will impact two sections of the combo wall system, allowing a wider area to be exposed to the oncoming flood. Since the posts cannot be readily replaced, the mitigation measures needed for the area being exposed will be much greater than that of a fully demountable system. With proper inspection, regular annual or quarterly maintenance, and proper installation procedures when using mechanized equipment around the posts, the risk to the combo wall permanent posts can be lessened. However, just by their nature of being permanent, they will always have an inherent risk of possibly being unusable.

These risks do not take into account any mitigation measures that may be applied by the City of Cedar Rapids during a flood event. These risks are evaluated in the deployment schedule to show what could happen if no mitigation measures are used. In this way, a *possible* worst-case scenario can be analyzed to provide information in developing possible mitigation measures.

During Phase 2, Tasks 5.2 and 5.3, risks probabilities and delay durations were reviewed and revised together by members of ERDC, the City of Cedar Rapids, and the Rock Island District. The revisions were necessary due to pre-deployment addition effects on the outcome of post-trigger deployment activities. It is logical to assume that activities such as inspections and cleanings during pre-deployment would reduce the time needed during deployment activities and lesson the probabilities of risks. Together, the team evaluated each risk probability based on its effect on pre-deployment and deployment activities. A consensus was reached on each risk probability and delay duration.

3.4 Probability of deployment within 48 hr

The target deployment completion time for the City is 48 hr from the trigger warning of the upstream gage. The following figures depict the results of the Monte Carlo analysis from Tables 10 and 11 at approximately 48 hr. Figures 34–47 are graphical representations of each Phase 1 alternative's and Phase 2 tasks' frequency and cumulative probability (percentage) that duration of deployment of all systems on the east and west sides will be accomplished within 48 hr given known risks with assigned probabilities.

For each graph, the left vertical range shows the frequency, the right vertical range shows the probability as a percentage, duration is shown on the bottom horizontally, and the cumulative probability is shown as a percentage chance of duration at approximately 48 hr at the top of the graph.

Figure 34. Phase 1 - baseline alternative.

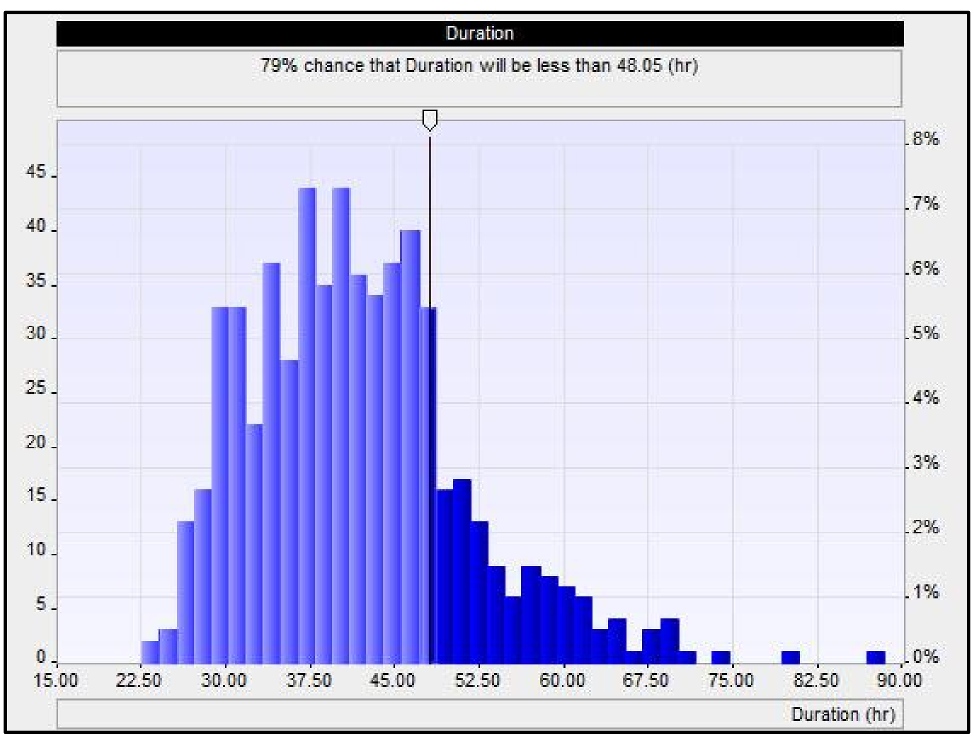


Figure 35. Phase 1 - Alternative 1.

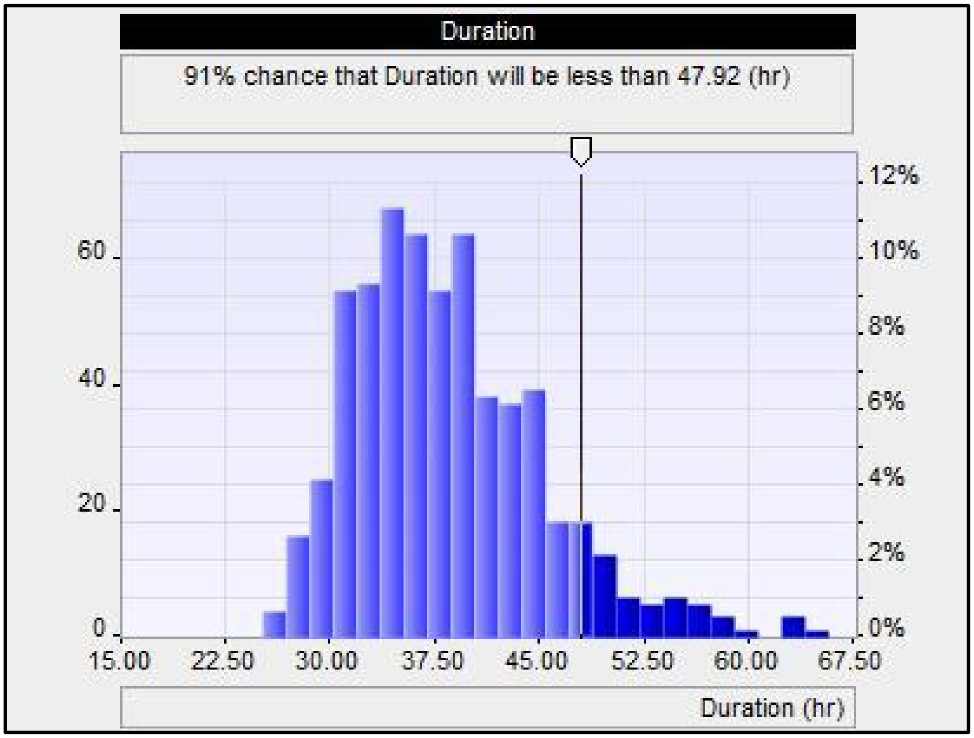


Figure 36. Phase 1 - Alternative 2.

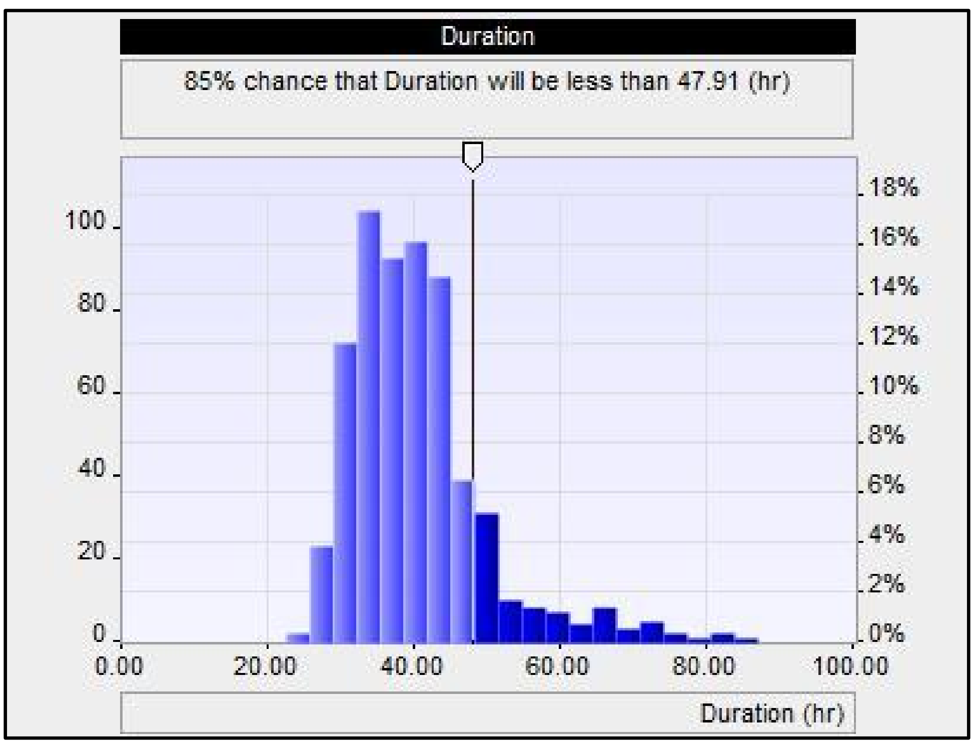


Figure 37. Phase 1 - Master Plan.

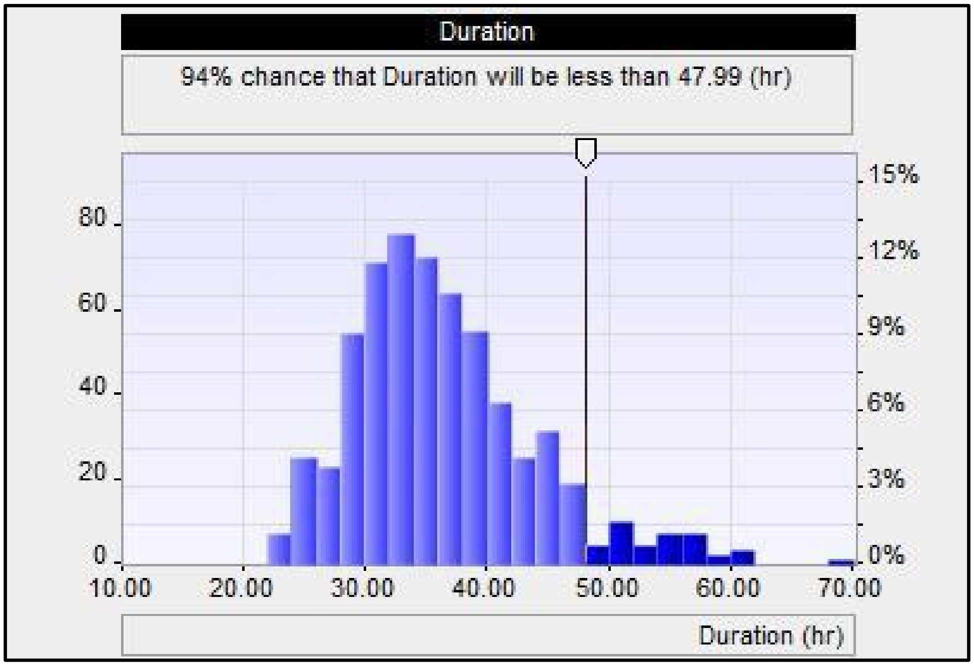


Figure 38. Phase 1 - Master Plan Minus 400 ft.

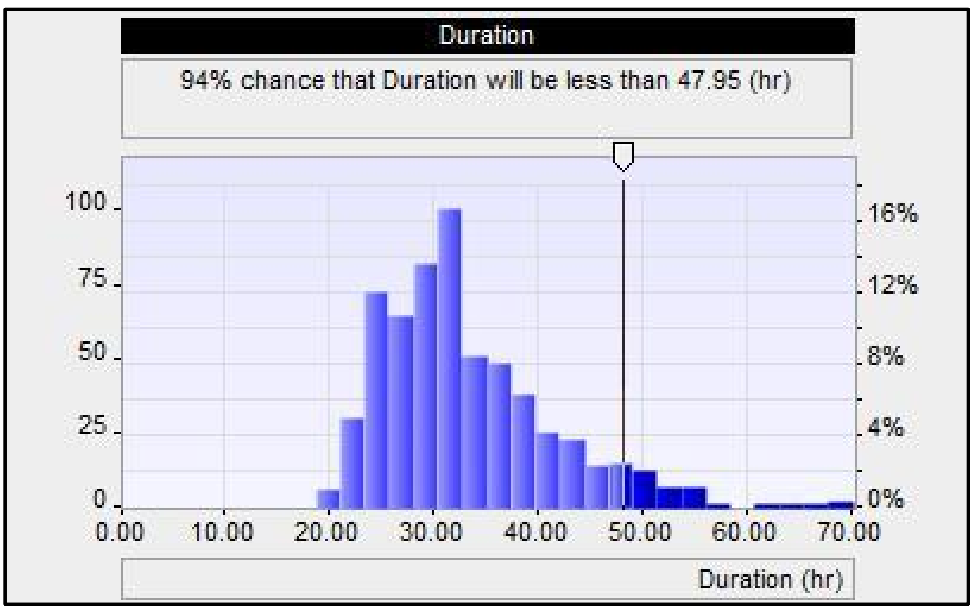


Figure 39. Phase 1 - Roads and Railroads Only.

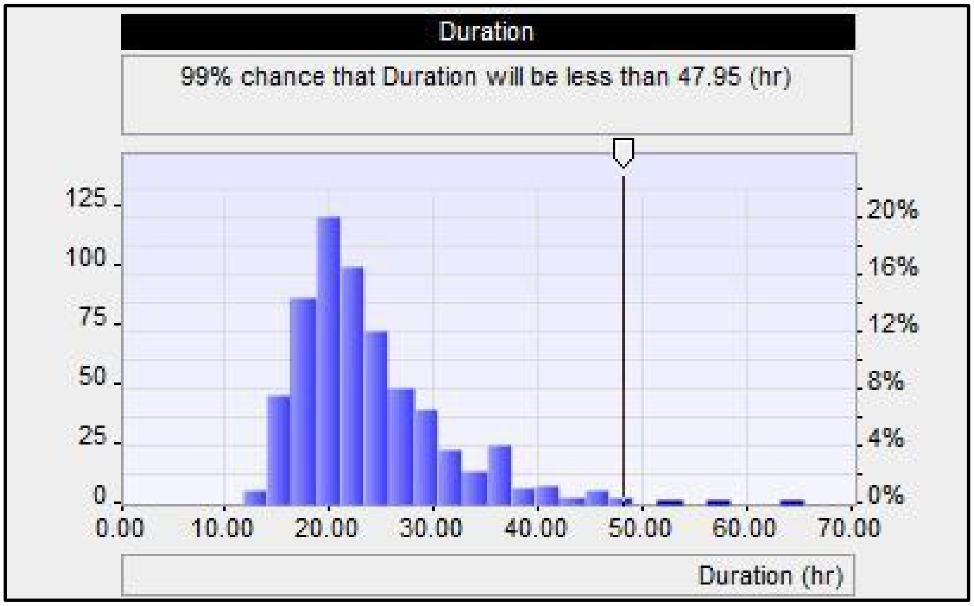


Figure 40. Phase 1 - Roads and Railroads Only Optimized by Crew Locations.

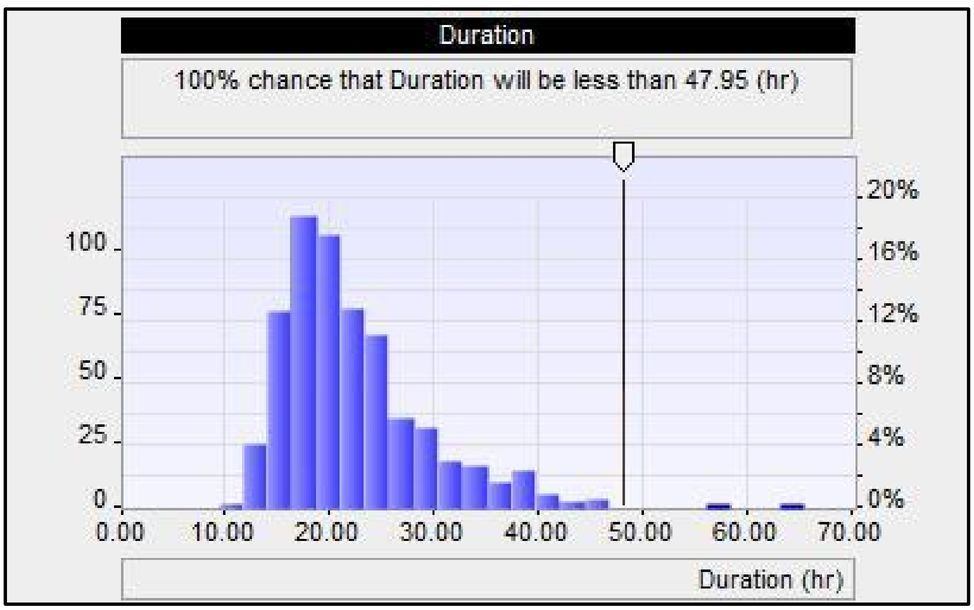


Figure 41. Phase 2 – Task 5.1.

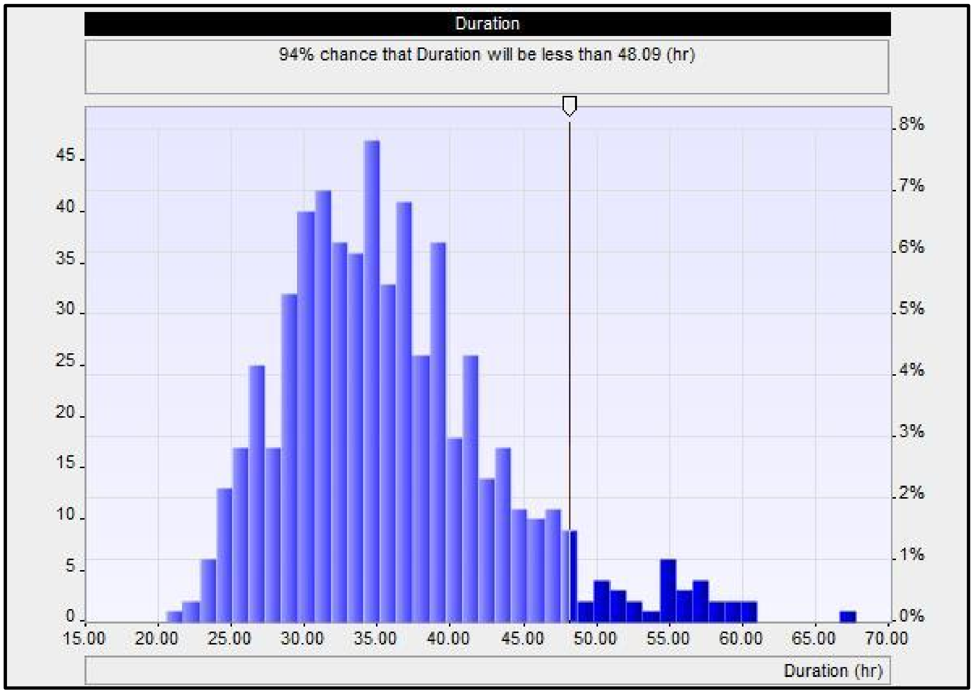


Figure 42. Phase 2 – Task 5.2 Pre-Deployment.

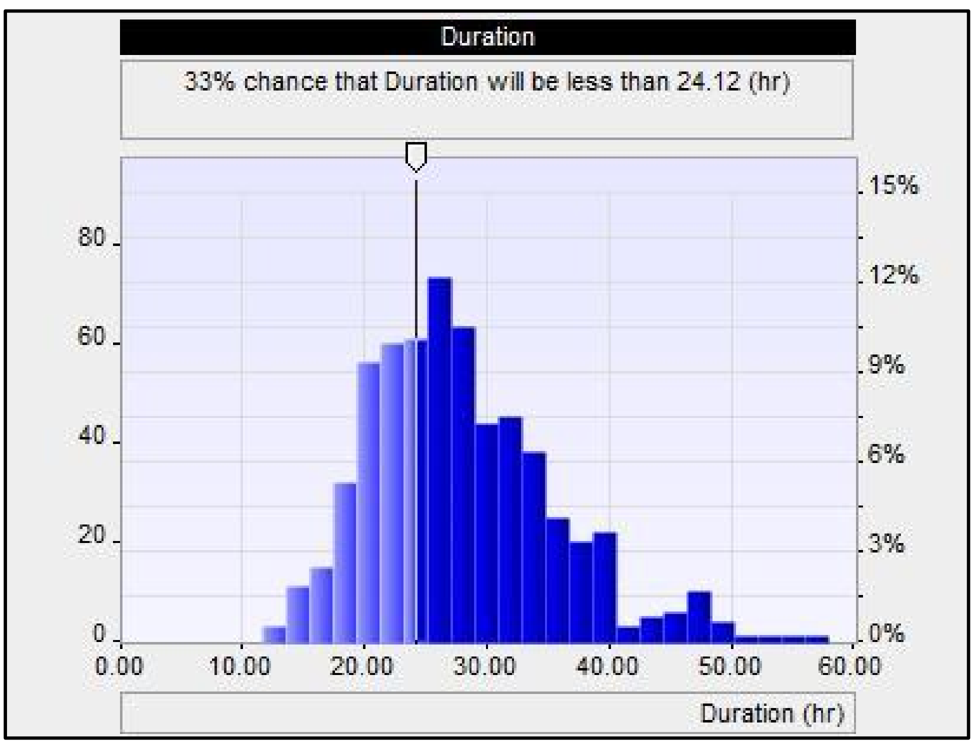


Figure 43. Phase 2 – Task 5.2 Deployment.

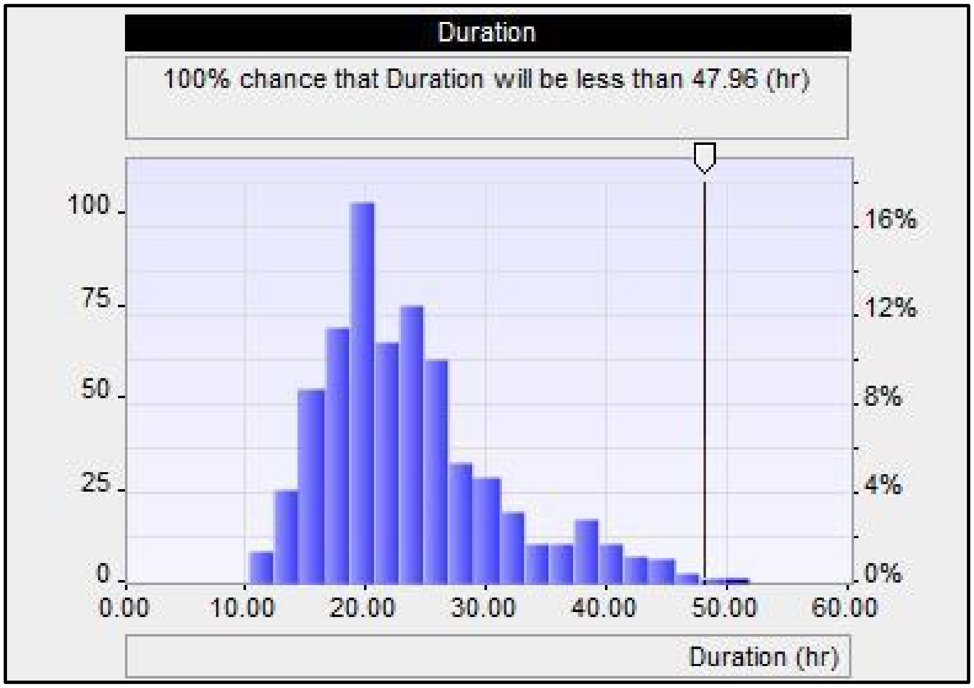


Figure 44. Phase 2 – Task 5.3 Pre-Deployment A.

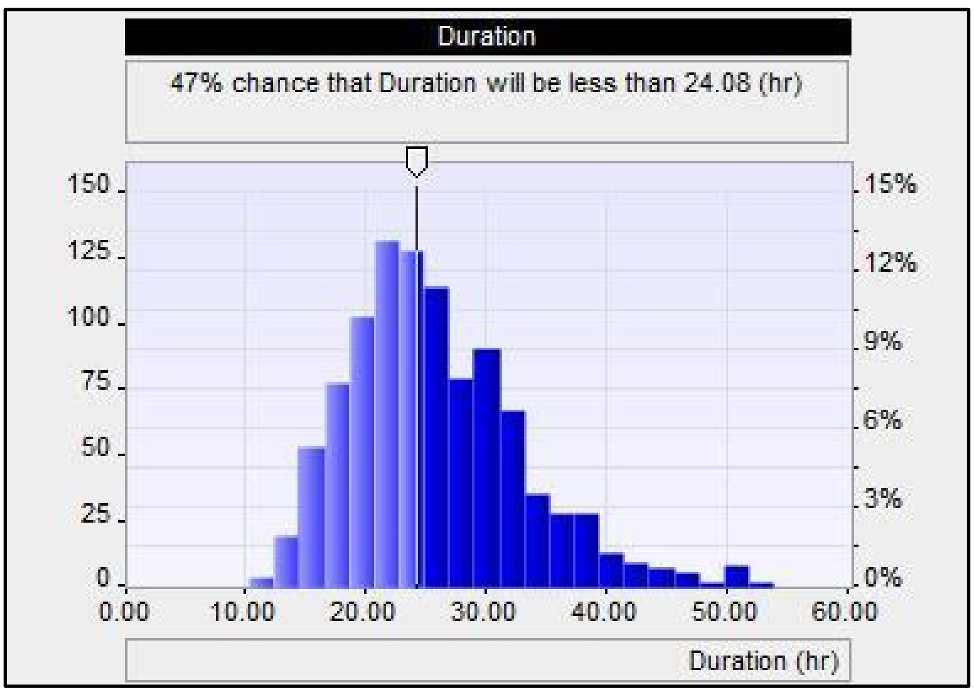


Figure 45. Phase 2 – Task 5.3 Pre-Deployment B.

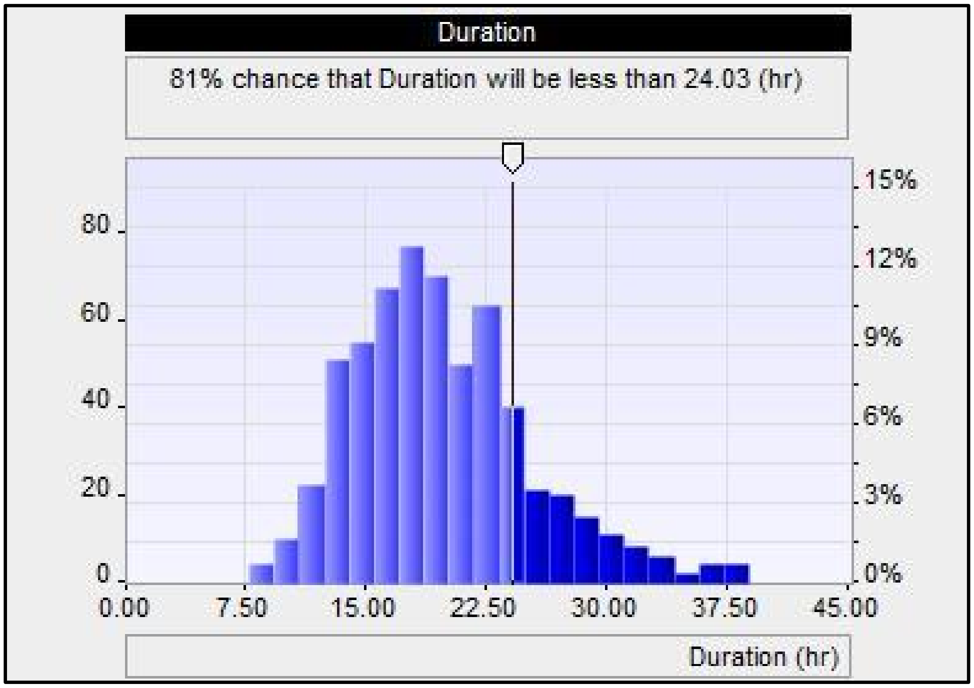


Figure 46. Phase 2 – Task 5.3 Deployment.

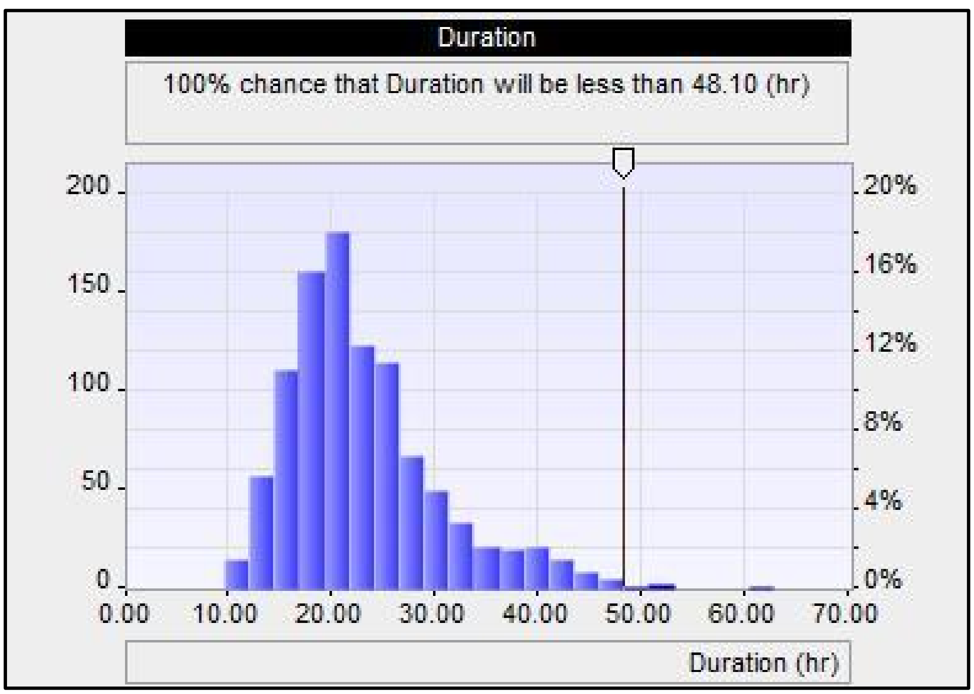
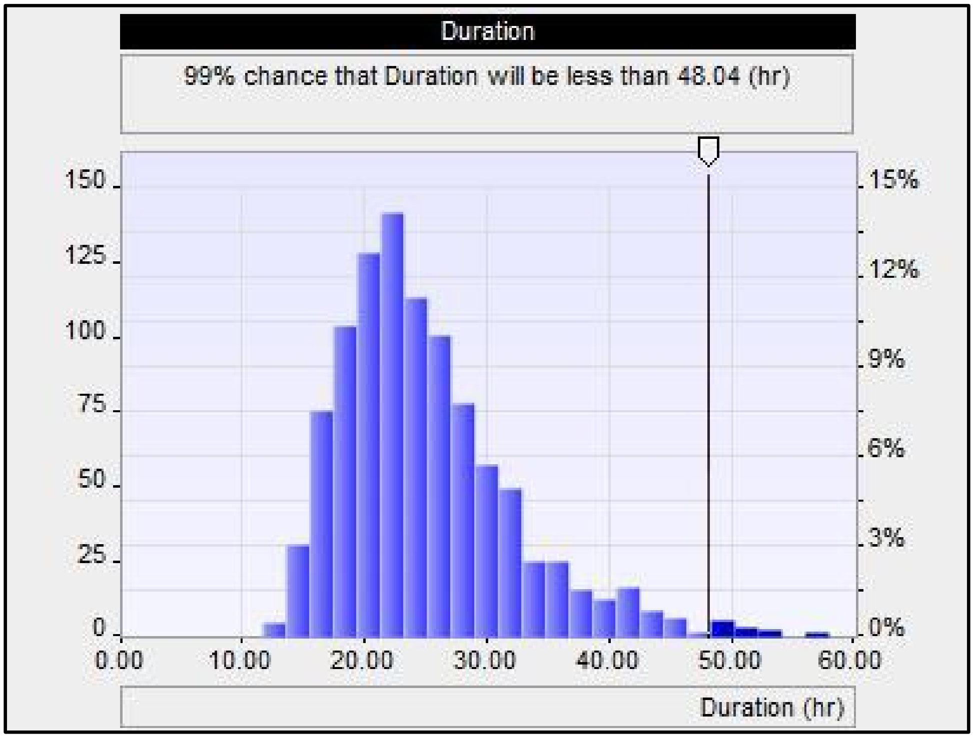


Figure 47. Phase 2 – Task 5.4 Deployment.



3.5 Results for parametric analysis

In addition to the 48 hr, 90% confidence requirements for Phase 1, the City requested CHL to provide estimates for a 30 hr deployment duration for Phase 1 alternatives with the highest likelihood of implementation. The deployment schedule for each alternative is initially set based on the required labor force needed to assemble and install each system component. Risks are then identified and assigned a probability of occurrence and delay duration for each risk probability. The result of the schedule analysis is a potential probability of deployment for each alternative. For this study, all Phase 1 alternatives, and Phase 2 tasks, began with a schedule based on known system requirements for installation. All of the alternatives and tasks began with a duration less than the requested 30 hr evaluation. Therefore, it is the inherent risks to deployment for each type of system that controls the resulting deployment durations in this study analysis. Mitigating known risks, before and during flood events, will increase the likelihood that deployment can be accomplished within a 48 hr, or even 30 hr, timeframe.

There are inherent limitations in the software used for this study. The software does not provide labor hours and costs for estimated probabilities of completion other than the low, mean, and high durations with risks applied to the schedule. To overcome this limitation, a parametric analysis is used to estimate the labor hours and costs at incremental times during an evaluated deployment schedule. This type of parametrical analysis can aid in future evaluations and field deployment planning of proposed flood risk management systems. The Phase 1 Master Plan and Master Plan Minus 400 ft alternatives are used here as an example to demonstrate how labor hours and costs can be inferred for specific hourly points in a proposed deployment schedule. Using the mean labor hour and cost parameters along with the percentage chance of duration at mean duration, an estimate of labor hours and costs, square feet of system, and an expected probability of completion of that amount of system can be derived. This analysis may be helpful in evaluating proposed deployment schedules for incremental hourly costs and expected percentage of system completion at each increment.

Table 16 shows a parametrically derived analysis for deployment estimates of duration, labor hours, labor cost, and percent probability of completion per square foot of the entire FCS for the Phase 1 Master Plan alternative. This estimate is based on the mean resultant from the Monte Carlo analysis run on the alternative.

Table 16. Results of a parametric analysis of deployment duration based on the mean duration of the Phase 1 Master Plan.

	1 hr	5 hr	10 hr	15 hr	20 hr	25 hr	30 hr	35 hr	36.32 hr
Hours	1	5	10	15	20	25	30	35	36.32
Square Feet	1,790	8,948	17,897	26,845	35,794	44,742	53,690	62,639	65,502
Labor Hours	81	406	811	1,217	1,623	2,028	2,434	2,840	2,969
Labor Cost	$5,698	$28,489	$56,977	$85,466	$113,954	$142,443	$170,931	$199,420	$208,536
Probability of Completion (%)	1.5	7.7	15.4	23.1	30.8	38.5	46.3	54.0	56.0

The square foot of system also accounts for any swing gates, roller gates, and miter gates deployed in the system.

Figure 48 is a graphical representation of the parametric analysis of the Phase 1 Master Plan showing the relationship of labor costs and labor hours to installation per square foot of the whole FCS system.

Figure 48. Comparison labor costs for deployment per square foot of system and estimated labor hours per square foot of system. This comparison is based on the mean duration of deployment for the Phase 1 Master Plan

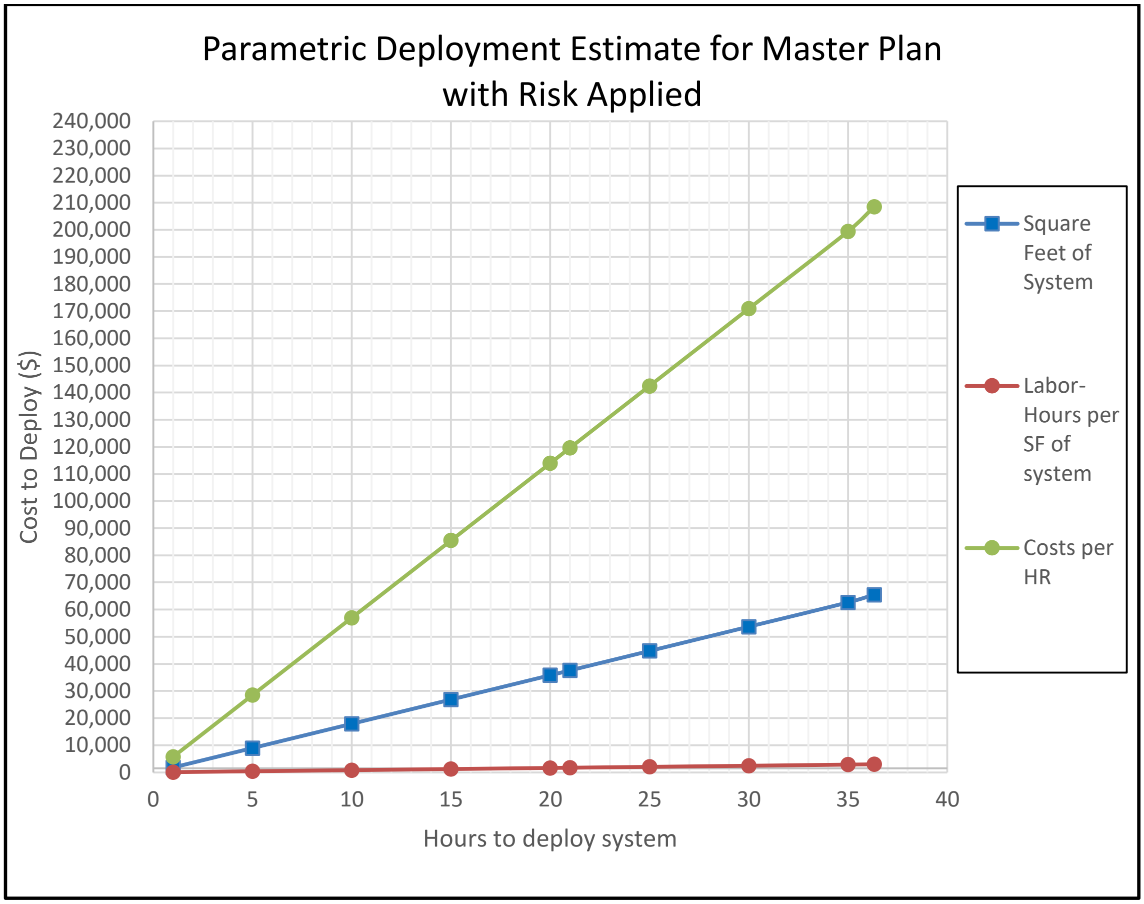


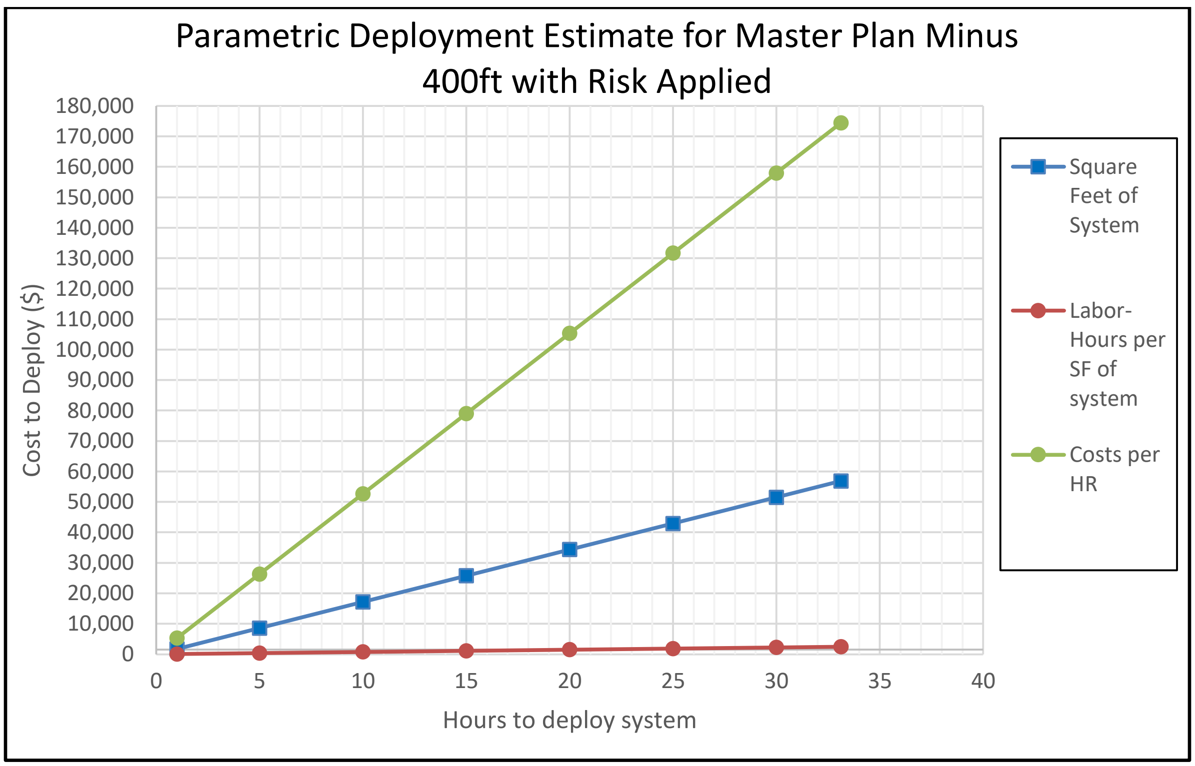
Table 17 shows a parametrically derived analysis for deployment estimates of duration, labor hours, labor cost, and percent probability of completion per square foot of the entire FCS for the Phase 1 Master Plan Minus 400 Ft alternative. This estimate is based on the mean resultant from the Monte Carlo analysis run on the alternative.

Table 17. Results of a paramteric analysis of deployment duration based on the mean duration of the Phase 1 Master Plan Minus 400 ft.

	1 hr	5 hr	10 hr	15 hr	20 hr	25 hr	30 hr	33.12 hr
Hours	1	5	10	15	20	25	30	33.12
Square Feet	1,717	8,585	17,171	25,756	34,342	42,927	51,513	56,870
Labor Hours	74	369	739	1,108	1,477	1,846	2,216	2,446
Cost	$5,266	$26,330	$52,659	$78,989	$105,319	$131,649	$157,978	$174,408
Probability of Completion (%)	1.8	9.2	18.4	27.6	36.8	46.0	55.3	61.0

Figure 49 is a graphical representation of the parametric analysis of the Phase 1 Master Plan Minus 400 ft alternative showing the relationship of labor costs and labor hours to installation per square ft of the whole FCS system.

Figure 49. Comparison labor costs for deployment per square feet of system and estimated labor hours per square feet of system. This comparison is based on the Mean duration of deployment for the Phase 1 Master Plan Minus 400 ft.



4 Conclusions

The City of Cedar Rapids, IA, requested a risk analysis of its proposed FCS on the east and west sides of the Cedar River. The proposed system includes the use of semi-permanent removable systems, including roller gates, miter gates, swing gates, fully demountable walls, combination demountable walls, and the Monroe Solution.

Information for risk analysis was obtained from a variety of sources. Previously identified risks are outlined in the 2012 report, with new risks identified through manufacturer's recommendations and specifications and interviews with experienced personnel.

Five of the alternatives analyzed in Phase 1 of this study were based on the City of Cedar Rapids recommendations, to include the Master Plan and Master Plan Minus 400 ft alternatives. The two Roads and Railroads Only alternatives were proposed by MVR. These alternatives were conducted for comparison purposes only and not considered a viable alternative by the City of Cedar Rapids. The Phase 2 tasks were taken from the most current alignment guidance from the City of Cedar Rapids and MVR.

RiskyProject software was used in this study to analyze each of the identified Phase 1 alternatives and Phase 2 tasks. The software uses a Monte Carlo analysis to determine the probable duration of deployment for of each of the alternatives.

The results show that of the seven alternatives in Phase 1, the Master Plan Minus 400 ft alternative was the most cost effective at the mean probably showing $184,308 and had the shortest mean deployment duration of 33.12 hr when risks were applied. The Roads and Railroads Only and the Roads and Railroads Only Optimized by Crew alternatives were requested by MVR to examine the results when the only closures were roads and railroads.

At the request of the City of Cedar Rapids and MVR, further work was undertaken after the initial results to analyze alignment options currently being vetted in Cedar Rapids. This work was identified as Phase 2 of the study and consisted of four tasks. These tasks evaluated options of different flood-fighting systems in the identified alignments as well as optimizing the number of personnel employed in the deployment.

Some of the tasks associated with mobilization, inspection, and transportation of system components were scheduled to be done prior to the 48 hr flood warning trigger. Tasks 5.2 and 5.3 were split into separate stages. These stages are identified as Pre-Deployment and Deployment. The actual installation of flood-fighting systems is scheduled to happen during Deployment stage, after the 48 hr trigger.

The results of Phase 2 showed that Task 5.4 is the most cost effective at $145,784 and a mean duration of 24.92 hr. Task 5.4 did not include a pre-deployment element. Splitting the deployment into stages as in Tasks 5.2 and 5.3 actually increased the overall cost and duration. This happened because most of the activities with the highest risk probabilities were scheduled to happen before the 48 hr trigger. Adding an additional day to the schedule also increased mobilization costs.

The most efficient way to decrease the duration and costs is to reduce the amount of closures. This was demonstrated with the two Phase 1 Roads and Railroad Only alternatives, which created permanent walls for all closures other than roads and railroads. These alternatives did not take into account any of the aesthetics desired by the City of Cedar Rapids but were used for demonstration purposes. These demonstration alternatives do not meet the City's needs. It was also seen in Phase 2 Task 5.4 where some closures were changed to permanent levee or other types of systems requiring less installation times.

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MVR (US Army Engineer District, Rock Island). 2011. *Cedar Rapids, Iowa Flood Risk Management Project, Removable Panel Floodwall Erection Times, Manpower Requirements and Advance Warning Times Report*. Rock Island, IL: Rock Island District. Expedient Flood Fight Products.

Reed Construction Data. 2012. *RSMeans Building Construction Cost Data*. Normwell, MA: Construction Publishers & Consultants. https://www.rsmeans.com/?utm_source=Google&utm_medium=cpc&utm_campaign=RS-Means-Brand-Exact&utm_content=rs-means-construction-building-cost-data&utm_term=rsmeans%20building%20construction%20cost%20data&gclid=EAIaIQobChMI3eLuhYOJ5wIVQx6tBh3gGAp2EAAYASAAEgK9YfD_BwE

Appendix A: Expedient Flood Fight Products

This list is not an endorsement of any product listed. It is a sampling of available products on the market.

Table A-1. Available products.

Product	Description	Website
Flood Control America	Removable floodwall	www.floodcontrolam.com
Presray	HYFLO self-closing flood barrier, self-rising flood wall (similar to UK Flood Barriers, Ltd. product)	http://www.presray.com/flood-protection/self-closing-flood-barrier-hyflo-scfb/
CMI Sheet Piling	Sheet piling – more permanent – floodwalls, levee, etc.	http://cmisheetpiling.com/applications/flood-protection/
Watershed Innovations	HydraBarrier – water-filled bags – 20inch max	http://hydrabarrier.com/collections/hydrabarrier
Barrier Force	Unique sandbags – various	http://www.barrierforce.com/home
Hydrological Solutions, Inc.	Very large water filled bags (bladders)	http://www.hydrologicalsolutions.com/
Water Damage Defense	Sells Water-Gate and Water-Plug products (distributor)	http://www.waterdamagedefense.com/collections/water-gate-water-barriers-for-flood-protection-for-homes-businesses-municipalities
Barrier Systems, LLC	Sandbag filler for Bobcat	http://www.barriersystemsllc.com/
PS Doors Manufacturing	Doors, planks, walls, gates, rising barriers, sliding barriers,	http://www.psdoors.com/flood-protection/
EkoFloodSystem	Removable floodwall	http://www.ekofloodusa.com/index.php
US Flood Control – Tiger Dams	42 in. bladders	http://usfloodcontrol.com/
Sakenenterprise	Vertical lift barrier, doors, planks, etc.	http://www.sakenterprise.com/Flood-Protection-Products.html
Muscle Wall *Already responded to RFI	Polyethylene wall	http://www.musclewall.com/
Big Bags USA	Stackable XL sandbag system	http://www.bigbagsusa.com/

Product	Description	Website
Hydro Response, Ltd	Inflatable Water-Gate (video shows testing at ERDC), Water-Inflated Property Protector, Floodgate, EKO Barrier, Geodesign	http://www.hydroresponse.com
TrapBag	Large sandbags, used on top of levees by USACE	http://www.trapbag.com/en/
Flood Panel	doors, planks, walls, gates	http://www.floodpanel.com/
Walz & Krenzer, Inc.	Watertight and airtight closures – doors, gates, walls, hatches, pop-up walls,	http://www.floodbarriers.com/
FloodBreak	Vent Shaft System	http://floodbreak.com/
Metalith	Metal sand filled wall (temp or permanent)	www.floodcontrolam.com
Typar	Stackable XL sandbag system	http://www.typargeosynthetics.com/
FEMA Flood Control Barriers	Distributes autowalls, flood panels, flood shields, etc.	http://femafloodbarriers.com/

Appendix B: Closure Descriptions

Table B-1. Baseline alternative east.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
E-1 North Industrial Area	Double Swing Gate	Cargill Plant railroad (RR) crossing	40	727.5	741.1	544.0
E-1 North Industrial Area	Double Swing Gate	Railroad crossing below switchyard/ Cargill	54	723.5	741.1	950.4
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	741.1	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	740.8	426.4
E-1 North Industrial Area	Swing Gate	Silos near 8th St	16	728.0	741.1	209.6
E-1 North Industrial Area	Swing Gate	Pedestrian RR at Cargill Plant	22	727.5	741.1	299.2
E-1 North Industrial Area	Swing Gate	Removed track Cargill	40	726.0	741.1	604.0
E-1 North Industrial Area	Swing Gate	End of Gravel Road/Cedar River Trail	15	724.5	741.1	249.0
E-1 North Industrial Area	Swing Gate	RR crossing, dead end single track Stickler Dr	22	727.0	741.1	310.2
E-2 Downtown	Combo Wall Panels	E & F Ave closure		729.5	736.4	0
E-2 Downtown	Combo Wall Panels	Along 1st St through Five Seasons Plaza	375	731.5	739.0	2812.5
E-2 Downtown	Combo Wall Panels	3rd Ave SE to 4th Ave SE	245	729.0	737.4	2058.0

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
E-2 Downtown	Combo Wall Panels	4th Ave SE to 5th Ave	410	729.0	736.6	3116.0
E-2 Downtown	Combo Wall Panels	5th to 6th Ave	270	729.0	736.6	2052.0
E-2 Downtown	Combo Wall Panels/Demountable	City hall (combine all three)	310	730.0	739.0	2790.0
E-2 Downtown	Combo Wall Panels/Demountable			730.0	737.9	0
E-2 Downtown	Combo Wall Panels/Demountable	2nd Ave bridge	134	726.1	737.9	1581.2
E-2 Downtown	Combo Wall Panels/Demountable	3rd Ave bridge	135	725.3	737.4	1633.5
E-2 Downtown	Combo Wall Panels/Demountable	4th Ave SE river terminus	150	721.5	736.6	2265.0
E-2 Downtown	Combo Wall Panels/Demountable	6th Ave SE to 7th Ave SE	320	729	736.2	2304.0
E-2 Downtown	Demountable Wall Panels	Under 380	275	734.7	740	1457.5
E-2 Downtown	Demountable Wall Panels	1st Ave bridge	120	727.8	739	1344.0
E-2 Downtown	Demountable Wall Panels	6th Ave SE	100	723.5	736.2	1270.0
E-2 Downtown	Swing Gate	Offset at sidewalk behind the Economic Alliance Bldg.	14	724	736.4	173.6
E-2 Downtown	Swing Gate	7th Ave SE walkway	20	726	736.2	204.0
E-3 New Bohemia	Roller Gate	8th Ave bridge	100	727.8	735.9	810.0
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	734.9	615.0
E-3 New Bohemia	Roller Gate	16th Ave bridge	65	722.1	734.12	781.3
E-3 New Bohemia	Swing Gate	9th Ave SE	25	726	735.3	232.5

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
E-4 Cargill South Plant	Combo Wall Panels/Demountable	Otis Rd	72	717.2	728.6	820.8
E-4 Cargill South Plant	Combo Wall Panels/Demountable	Plant entrance	60	717.2	728.6	684.0
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	28	718.4	728.6	285.6

Table B-2. Baseline alternative west.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd road closure, north of Ellis Lane	79	728.00	13.5	1066.50
W-1 Time Check	Demountable Wall Panels	Park access opening near L Ave NW	400	722.00	19.5	7800.00
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727.00	14.0	1694.00
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	109	729.24	11.0	1199.00
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725.00	14.0	1484.00
W-2 Kingston	Combo Wall Panels	A Ave NW to 1st Ave W	385	728.50	10.5	4042.08
W-2 Kingston	Demountable or Rising Gate	1st Ave W road closure	134	726.20	13.0	1742.00
W-2 Kingston	Combo Wall Panels	1st Ave W to 2nd Ave SW	284	729.20	10.0	2843.60
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW road closure	98	725.00	13.0	1274.00
W-2 Kingston	Combo Wall Panels	2nd Ave SW to 3rd Ave SW	290	727.50	10.5	3048.25
W-2 Kingston	Demountable or Rising Gate	3rd Ave SW road closure	96	724.20	13.5	1296.00
W-2 Kingston	Demountable Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.50	10.0	774.40
W-2 Kingston	Demountable Wall Panels	Demountable Wall near Amphitheater	76	725.00	12.5	953.62
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.80	12.0	1869.72

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
W-2 Kingston	Demountable or Rising Wall	Partial height earthen levee with Demountable Wall between Amphitheater and 7th Avenue	400	728.40	8.0	3200.00
Penford	Miter Gate	Cedar Rapids & Iowa City Railway Co. (CRANDIC) RR closure at Ingredion	40	725.00	10.5	420.00
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.00	13.5	1026.00

Table B-3. Alternative 1 east and Alternative 2 east.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
E-1 North Industrial Area	Double Swing Gate	Cargill Plant RR crossing	40	727.5	741.1	544.0
E-1 North Industrial Area	Double Swing Gate	Railroad crossing below switchyard/ Cargill	54	723.5	741.1	950.4
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	741.1	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	740.8	426.4
E-1 North Industrial Area	Swing Gate	Silos near 8th St	16	728.0	741.1	209.6
E-1 North Industrial Area	Swing Gate	Pedestrian RR at Cargill Plant	22	727.5	741.1	299.2
E-1 North Industrial Area	Swing Gate	Removed track Cargill	40	726.0	741.1	604.0
E-1 North Industrial Area	Swing Gate	End of gravel road/Cedar River Trail	15	724.5	741.1	249.0
E-1 North Industrial Area	Swing Gate	RR crossing, dead end single track Stickler Dr	22	727.0	741.1	310.2
E-2 Downtown	Combo Wall Panels	E & F closure	375	729.5	736.4	2587.5
E-2 Downtown	Combo Wall Panels	Along 1st St through Five Seasons Plaza	375	731.5	739.0	2812.5
E-2 Downtown	Combo Wall Panels	3rd Ave SE to 4th Ave Se	275	730.0	737.4	2035.0
E-2 Downtown	Combo Wall Panels	4th Ave SE to 5th Ave	320	729.5	736.6	2272.0

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
E-2 Downtown	Combo Wall Panels/Demountable	1st Ave SE to north third of City Hall	100	730.0	739.0	900.0
E-2 Downtown	Combo Wall Panels/Demountable	South third of City Hall to 2nd St	80	730.0	737.9	632.0
E-2 Downtown	Combo Wall Panels/Demountable	2nd Ave bridge	147.3	726.1	737.9	1738.14
E-2 Downtown	Combo Wall Panels/Demountable	3rd Ave bridge	156.8	725.3	737.4	1897.28
E-2 Downtown	Combo Wall Panels/Demountable	4th Ave SE river terminus	150	721.5	736.6	2265.0
E-2 Downtown	Combo Wall Panels/Demountable	6th Ave SE to 7th Ave SE	320	729.0	736.2	2304.0
E-2 Downtown	Demountable Wall Panels	Under 380	275	734.7	740.0	1457.5
E-2 Downtown	Demountable Wall Panels	1st Ave bridge	126.5	727.8	739.0	1416.8
E-2 Downtown	Demountable Wall Panels	6th Ave SE	100	723.5	736.2	1270
E-2 Downtown	Swing Gate	Offset at sidewalk behind the Economic Alliance Bldg.	14	724.0	736.4	173.6
E-2 Downtown	Swing Gate	7th Ave SE walkway	20	726.0	736.2	204.0
E-3 New Bohemia	Roller Gate	8th Ave bridge	100	727.8	735.9	810.0
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	734.9	615.0
E-3 New Bohemia	Roller Gate	16th Ave bridge	75	722.1	734.12	901.5
E-3 New Bohemia	Swing Gate	9th Ave SE	25	726.0	735.3	232.5
E-4 Cargill South Plant	Combo Wall Panels/Demountable	Otis Rd	72	717.2	728.6	820.8

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
E-4 Cargill South Plant	Combo Wall Panels/Demountable	Plant entrance	60	717.2	728.6	684.0
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	28	718.4	728.6	285.6

Table B-4. Alternative 1 west.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd road closure, north of Ellis Lane	79	728.0	14.0	1106.00
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727.0	14.0	1694.00
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	109	729.1	16.0	1744.00
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725.0	13.0	1378.00
W-2 Kingston	Combo Wall Panels	A Ave NW to 1st Ave W	385	728.5	9.5	3657.12
W-2 Kingston	Demountable or Rising Gate	1st Ave W road closure	134	726.2	13.0	1742.00
W-2 Kingston	Demountable Wall Panels	1st Ave W to 2nd Ave SW	284	729.2	9.5	2701.42
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW road closure	98	725.0	12.0	1176.00
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW to 3rd Ave SW	290	727.5	9.5	2757.94
W-2 Kingston	Demountable or Rising Gate	3rd Ave SW road closure	96	724.2	13.0	1248.00
W-2 Kingston	Combo Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.5	10.5	813.12
W-2 Kingston	Combo Wall Panels	Demountable Wall constructed with Amphitheater	76	725.0	14.0	1068.06
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.8		0.00
W-2 Kingston	Swing Gate	Pedestrian gate south of Amphitheater	31	719.0	17.0	533.12
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40	725.0	10.0	400.00

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
Penford	Miter Gate		35		24.0	840.00
Penford	Miter Gate		35		18.0	630.00
W-4 Czech Village	Swing Gate	Czech museum dock area	55		17.0	935.00
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.0	13.0	988.00

Table B-5. Alternative 2 west.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
W-1 Time Check	Rolling Gate	Ellis Blvd road closure, north of Ellis Lane	79	728.00	14.00	1106.00
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727.00	14.00	1694.00
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	109	729.12	16.00	1744.00
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725.00	13.00	1378.00
W-2 Kingston	Combo Wall Panels	A Ave NW to 1st Ave W	385	728.50	9.50	3657.12
W-2 Kingston	Demountable or Rising Gate	1st Ave W road closure	134	726.20	13.00	1742.00
W-2 Kingston	Demountable Wall Panels	1st Ave W to 2nd Ave SW	284	729.20	9.50	2701.42
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW road closure	98	725.00	12.00	1176.00
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW to 3rd Ave SW	290	727.50	9.50	2757.94
W-2 Kingston	Demountable or Rising Gate	3rd Ave SW road closure	96	724.20	13.00	1248.00
W-2 Kingston	Combo Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.50	10.50	813.12
W-2 Kingston	Combo Wall Panels	Demountable Wall constructed with Amphitheater	76	725.00	14.00	1068.06
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.80		0.00
W-2 Kingston	Folding Sidewalk/wall	Monroe Solution	950		6.50	6175.00
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40	725.00	10.00	400.00

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
Penford	Miter Gate		35		24.00	840.00
Penford	Miter Gate		35		18.00	630.00
W-4 Czech Village	Swing Gate	Czech Museum dock area	55		17.00	935.00
W-4 Czech Village	Rolling Gate	16th Ave SW Road Closure	76	721.00	13.00	988.00

Table B-6. Master Plan East and Master Plan Minus 400 ft East.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	741.1	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	740.8	426.4
E-1 North Industrial Area	Swing Gate	RR crossing dead end single track Stickler Dr	22	727.0	741.1	310.2
E-2 Downtown	Combo Wall Panels	Along 1st St through Five Seasons Plaza	375	731.5	739.0	2812.5
E-2 Downtown	Combo Wall Panels	3rd Ave SE to 4th Ave Se	245	729.0	737.4	2058.0
E-2 Downtown	Combo Wall Panels	4th Ave SE to 5th Ave	410	729.0	736.6	3116.0
E-2 Downtown	Combo Wall Panels	5th to 6th Ave	270	729.0	736.6	2052.0
E-2 Downtown	Combo Wall Panels	City hall (combine all three)	310	730.0	739.0	2790.0
E-2 Downtown	Demountable Wall Panels	2nd Ave bridge	134	726.1	737.9	1581.2
E-2 Downtown	Demountable Wall Panels	3rd Ave bridge	135	725.3	737.4	1633.5
E-2 Downtown	Combo Wall Panels	4th Ave SE river terminus	150	721.5	736.6	2265.0
E-2 Downtown	Combo Wall Panels	6th Ave SE to 7th Ave SE	320	729.0	736.2	2304.0
E-2 Downtown	Demountable Wall Panels	Under 380	275	734.7	740.0	1457.5
E-2 Downtown	Demountable Wall Panels	1st Ave bridge	120	727.8	739.0	1344.0
E-2 Downtown	Demountable Wall Panels	6th Ave SE	100	723.5	736.2	1270.0

E-2 Downtown	Swing Gate	Offset at sidewalk behind the Economic Alliance Bldg.	14	724.0	736.4	173.6
E-2 Downtown	Swing Gate	7th Ave SE walkway	20	726.0	736.2	204.0
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	734.9	615.0
E-3 New Bohemia	Roller Gate	16th Ave bridge	65	722.1	734.12	781.3
E-3 New Bohemia	Swing Gate	9th Ave SE	25	726.0	735.3	232.5
E-4 Cargill South Plant	Combo Wall Panels/Demountable	Otis Rd	72	717.2	728.6	820.8
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	28	718.4	728.6	285.6

Table B-7. Master Plan West.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd Road Closure, north of Ellis Lane	79	728.00	13.5	1066.50
W-1 Time Check	Demountable Wall Panels	Park access opening near L Ave NW	400	722.00	19.5	7800.00
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727.00	14.0	1694.00
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	109	729.24	11.0	1199.00
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725.00	14.0	1484.00
W-2 Kingston	Combo Wall Panels	A Ave NW to 1st Ave W	385	728.50	10.5	4042.08
W-2 Kingston	Demountable or Rising Gate	1st Ave W road closure	134	726.20	13.0	1742.00
W-2 Kingston	Combo Wall Panels	1st Ave W to 2nd Ave SW	284	729.20	10.0	2843.60
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW road closure	98	725.00	13.0	1274.00
W-2 Kingston	Combo Wall Panels	2nd Ave SW to 3rd Ave SW	290	727.50	10.5	3048.25
W-2 Kingston	Demountable or Rising Gate	3rd Ave SW road closure	96	724.20	13.5	1296.00
W-2 Kingston	Demountable Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.50	10.0	774.40
W-2 Kingston	Existing Demountable Wall	Demountable Wall constructed with Amphitheater	76	725.00	12.5	953.62
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.80	12.0	1869.72

W-2 Kingston	Demountable or Rising Wall	Partial height earthen levee with Demountable Wall between Amphitheater and 7th Avenue	400	728.40	8.0	3200.00
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40	725.00	10.5	420.00
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.00	13.5	1026.00

Table B-8. Master Plan Minus 400 ft West.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd Road Closure, north of Ellis Lane	79	728	13.1	1034.9
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727	13.8	1669.8
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	109	729.24	10.86	1183.74
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725	14.0	1484.0
W-2 Kingston	Combo Wall Panels	A Ave NW to 1st Ave W	385	728.5	10.5	4042.08
W-2 Kingston	Demountable or Rising Gate	1st Ave W road closure	134	726.2	12.8	1715.2
W-2 Kingston	Combo Wall Panels	1st Ave W to 2nd Ave SW	284	729.2	9.8	2786.73
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW road closure	98	725.0	12.9	1264.2
W-2 Kingston	Combo Wall Panels	2nd Ave SW to 3rd Ave SW	290	727.5	10.4	3019.22
W-2 Kingston	Demountable or Rising Gate	3rd Ave SW road closure	96	724.2	13.2	1267.2
W-2 Kingston	Demountable Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.5	9.9	766.656
W-2 Kingston	Existing Demountable Wall	Demountable Wall near Amphitheater	76	725.0	12.4	945.996
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.8	11.6	1807.4
W-2 Kingston	Demountable or Rising Wall	Partial height earthen levee with Demountable Wall between Amphitheater and 7th Avenue	400	728.4	8.0	3200.0

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
Penford	Miter Gate	CRANDIC RR closure at Ingredion	40	725.0	10.3	412.0
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.0	13.2	1003.2

Table B-9. Roads and Railroads Only East and Roads and Railroads Only Optimized by Crew Location East.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	741.10	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	740.80	426.4
E-1 North Industrial Area	Swing Gate	RR crossing dead end single track Stickler Dr	22	727.0	741.10	310.2
E-2 Downtown	Demountable Wall Panels	2nd Ave bridge	134	726.1	737.90	1581.2
E-2 Downtown	Demountable Wall Panels	3rd Ave bridge	135	725.3	737.40	1633.5
E-2 Downtown	Demountable Wall Panels	Under 380	275	734.7	740.00	1457.5
E-2 Downtown	Demountable Wall Panels	1st Ave bridge	120	727.8	739.00	1344.0
E-2 Downtown	Demountable Wall Panels	6th Ave SE	100	723.5	736.20	1270.0
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	734.90	615.0
E-3 New Bohemia	Roller Gate	16th Ave bridge	65	722.1	734.12	781.3
E-3 New Bohemia	Swing Gate	9th Ave SE	25	722.1	735.30	232.5
E-4 Cargill South Plant	Combo Wall Panels/Demountable	Otis Rd	72	717.2	728.60	820.8
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	28	718.4	728.60	285.6

Table B-10. Roads and Railroads Only East and Roads and Railroads Only Optimized by Crew Location West.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd road closure, north of Ellis Lane	79	728.0	13.10	1066.5
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727.0	13.80	1694.0
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	109	729.2	10.86	1199.0
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725.0	14.00	1484.0
W-2 Kingston	Demountable wall panels	1st Ave W road closure	134	726.2	12.80	1742.0
W-2 Kingston	Demountable wall panels	2nd Ave SW road closure	98	725.0	12.90	1274.0
W-2 Kingston	Demountable wall panels	3rd Ave SW road closure	96	724.2	13.20	1296.0
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40	725.0	10.30	420.0
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.0	13.20	1026.0

Table B-11. Phase 2 Task 5.1, East Side.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	13.6	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	10.4	426.4
E-1 North Industrial Area	Swing Gate	RR crossing dead end single track Stickler Dr	22	727	14.10	310.2
E-2 Downtown	Combo Wall Panels	Along 1st St through Five Seasons Plaza	375	731.5	7.5	2812.5
E-2 Downtown	Combo Wall Panels	3rd Ave SE to 4th Ave Se	245	728	9.4	2303
E-2 Downtown	Combo Wall Panels	4th Ave SE to 5th Ave	410	728	8.6	3526
E-2 Downtown	Combo Wall Panels	5th to 6th Ave	270	728	8.6	2322
E-2 Downtown	Combo Wall Panels	City hall (combine all three)	310	730	9	2790
E-2 Downtown	Demountable Wall Panels	2nd Ave bridge	134	726.1	11.8	1581.2
E-2 Downtown	Demountable Wall Panels	3rd Ave bridge	135	725.3	12.1	1633.5
E-2 Downtown	Combo Wall Panels	4th Ave SE river terminus	150	721.5	15.1	2265
E-2 Downtown	Combo Wall Panels	6th Ave SE to 7th Ave SE	320	728	8.2	2624
E-2 Downtown	Demountable Wall Panels	Under 380	275	734.7	5.3	1457.5
E-2 Downtown	Demountable Wall Panels	1st Ave bridge	120	727.8	11.2	1344
E-2 Downtown	Demountable Wall Panels	6th Ave SE	100	728	8.2	820

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
E-2 Downtown	Swing Gate	Offset at sidewalk behind the Economic Alliance Bldg	14	724	12.4	173.6
E-2 Downtown	Swing Gate	7th Ave SE walkway	20	726	10.2	204
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	8.2	615
E-3 New Bohemia	Roller Gate	16th Ave bridge	65	722.1	12.02	781.3
E-3 New Bohemia	Swing Gate	9th Ave SE	25	726	9.3	232.5
E-4 Cargill South Plant	Demountable Wall Panels	Otis Rd	72	717.2	11.4	820.8
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	28	718.4	10.2	285.6

Table B-12. Phase 2 Task 5.1, West Side.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd road closure, north of Ellis Lane	79	728.00	13.5	1066.50
W-1 Time Check	Demountable Wall Panels	Park access opening near L Ave NW	400	722.00	19.5	7800.00
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	121	727.00	14.0	1694.00
W-1 Time Check	Rolling Gate	F Ave NW Road closure, east of 3rd St NW	109	729.24	11.0	1199.00
W-2 Kingston	Rolling Gate	1st St SW, north of A Ave NW	106	725.00	14.0	1484.00
W-2 Kingston	Combo Wall Panels	A Ave NW to 1st Ave W	385	728.50	10.5	4042.08
W-2 Kingston	Demountable	1st Ave W road closure	134	726.20	13.0	1742.00
W-2 Kingston	Combo Wall Panels	1st Ave W to 2nd Ave SW	284	729.20	10.0	2843.60
W-2 Kingston	Demountable	2nd Ave SW road closure	98	725.00	13.0	1274.00
W-2 Kingston	Combo Wall Panels	2nd Ave SW to 3rd Ave SW	290	727.50	10.5	3048.25
W-2 Kingston	Demountable	3rd Ave SW road closure	96	724.20	13.5	1296.00
W-2 Kingston	Demountable Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.50	10.0	774.40
W-2 Kingston	Existing Demountable Wall Panels	Demountable Wall constructed with Amphitheater	76	725.00	12.5	953.62
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.80	12.0	1869.72

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
W-2 Kingston	Demountable	Partial height earthen levee with Demountable Wall between Amphitheater and 7th Avenue	400	728.40	8.0	3200.00
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40	725.00	10.5	420.00
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.00	13.5	1026.00

Table B-13. Phase 2 Task 5.2 and 5.3, East Side.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft²
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	13.6	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	10.4	426.4
E-1 North Industrial Area	Swing Gate	RR crossing dead end single track Stickler Dr	22	727	14.10	310.2
E-2 Downtown	Levee	Along 1st St through Five Seasons Plaza	0	731.5	7.5	0
E-2 Downtown	Combo Wall Panels	3rd Ave SE to 4th Ave Se	245	728	9.4	2303
E-2 Downtown	Combo Wall Panels	4th Ave SE to 5th Ave	410	728	8.6	3526
E-2 Downtown	Combo Wall Panels	5th to 6th Ave	270	728	8.6	2322
E-2 Downtown	Combo Wall Panels	City hall (combine all three)	310	730	9	2790
E-2 Downtown	Demountable Wall Panels	2nd Ave bridge	134	726.1	11.8	1581.2
E-2 Downtown	Demountable Wall Panels	3rd Ave bridge	135	725.3	12.1	1633.5
E-2 Downtown	Combo Wall Panels	4th Ave SE river terminus	150	721.5	15.1	2265
E-2 Downtown	Combo Wall Panels	6th Ave SE to 7th Ave SE	320	728	8.2	2624
E-2 Downtown	Dual Roller Gate	Under 380	120	734.7	5.3	636
E-2 Downtown	Roller Gate	1st Ave bridge	80	727.8	11.2	896
E-2 Downtown	Combo Wall Panels	6th Ave SE	100	728	8.2	820

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
E-2 Downtown	Swing Gate	Offset at sidewalk behind the Economic Alliance Bldg.	14	724	12.4	173.6
E-2 Downtown	Swing Gate	7th Ave SE walkway	20	726	10.2	204
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	8.2	615
E-3 New Bohemia	Roller Gate	16th Ave bridge	59	722.1	12.02	709.18
E-3 New Bohemia	Swing Gate	9th Ave SE	25	726	9.3	232.5
E-4 Cargill South Plant	Swing Gate e	Otis Rd	40	717.2	11.4	456
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	45	718.4	10.2	459

Table B-14. Phase 2 Task 5.2 and 5.3, West Side.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft²
W-1 Time Check	Rolling Gate	Ellis Blvd Road closure, north of Ellis Lane	79	728.00	13.5	1067
W-1 Time Check	Levee	Park access opening near L Ave NW		722.00	19.5	0
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	44	727.00	14.0	616
W-1 Time Check	Rolling Gate	F Ave NW Road closure, east of 3rd St NW	80	729.24	11.0	880
W-2 Kingston	Levee	1st St SW, north of A Ave NW		725.00	14.0	0
W-2 Kingston	Levee	A Ave NW to 1st Ave W		728.50	10.5	0
W-2 Kingston	Demountable	1st Ave W Road closure	100	726.20	13.0	1300
W-2 Kingston	Combo Wall Panels	1st Ave W to 2nd Ave SW	284	729.20	10.0	2840
W-2 Kingston	Demountable	2nd Ave SW Road closure	98	725.00	13.0	1274
W-2 Kingston	Combo Wall Panels	2nd Ave SW to 3rd Ave SW	290	727.50	10.5	3045
W-2 Kingston	Demountable	3rd Ave SW Road closure	96	724.20	13.5	1296
W-2 Kingston	Demountable Wall Panels	3rd Ave SW to existing Demountable Wall	77	727.50	10.0	770
W-2 Kingston	Existing Demountable Wall	Demountable Wall constructed with Amphitheater	76	725.00	12.5	950
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156	725.80	12.0	1872
W-2 Kingston	Demountable	Partial height earthen levee with Demountable Wall between	400	728.40	8.0	3200

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure, ft^2
		Amphitheater and 7th Avenue				
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40	725.00	10.5	420
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76	721.00	13.5	1026

Table B-15. Phase 2 Task 5.4, East Side.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
E-1 North Industrial Area	Double Swing Gate	RR crossing below switch yard Stickle Dr	54	727.5	13.6	734.4
E-1 North Industrial Area	Miter Gate	RR bridge at Quaker Oats	41	730.4	10.4	426.4
E-1 North Industrial Area	Swing Gate	RR crossing dead end single track Stickler Dr	22	727	14.1	310.2
E-2 Downtown	Levee	Along 1st St through Five Seasons Plaza	0	731	8	0
E-2 Downtown	Combo Wall Panels	3rd Ave SE to 4th Ave Se	0	728.5	8.9	0
E-2 Downtown	Combo Wall Panels	4th Ave SE to 5th Ave	410	728.5	8.1	3321
E-2 Downtown	Combo Wall Panels	5th to 6th Ave	0	728.5	8.1	0
E-2 Downtown	Combo Wall Panels	City hall (combine all three)	310	730.5	8.5	2635
E-2 Downtown	Demountable Wall Panels	2nd Ave bridge	134	726.1	11.8	1581.2
E-2 Downtown	Demountable Wall Panels	3rd Ave bridge	135	725.3	12.1	1633.5
E-2 Downtown	Combo Wall Panels	4th Ave SE river terminus	150	721.5	15.1	2265
E-2 Downtown	Combo Wall Panels	6th Ave SE to 7th Ave SE	320	728.5	7.7	2464
E-2 Downtown	Dual Roller Gate	Under 380	120	734.7	5.3	636
E-2 Downtown	Roller Gate	1st Ave bridge	80	727.8	11.2	896
E-2 Downtown	Combo Wall Panels	6th Ave SE	100	728.5	7.7	770

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
E-2 Downtown	Swing Gate	Offset at sidewalk behind the Economic Alliance Bldg.	14	724	12.4	173.6
E-2 Downtown	Swing Gate	7th Ave SE walkway	20	726	10.2	204
E-3 New Bohemia	Roller Gate	12th Ave bridge	75	726.7	8.2	615
E-3 New Bohemia	Roller Gate	16th Ave bridge	59	722.1	12.02	709.18
E-3 New Bohemia	Swing Gate	9th Ave SE	25	726	9.3	232.5
E-4 Cargill South Plant	Swing Gate	Otis Rd	40	717.2	11.4	456
E-4 Cargill South Plant	Swing Gate	RR parallel to Otis Road at Cargill Plant	45	718.4	10.2	459

Table B-16. Phase 2 Task 5.4, West Side.

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
W-1 Time Check	Rolling Gate	Ellis Blvd road closure, north of Ellis Lane	79.0	728.00	13.5	1066.50
W-1 Time Check	Levee	Park access opening near L Ave NW	0.0	722.00	19.5	0.00
W-1 Time Check	Miter Gate	UPRR closure, near 4th Street NW	44.0	727.00	14.0	616.00
W-1 Time Check	Rolling Gate	F Ave NW road closure, east of 3rd St NW	80.0	729.24	11.0	880.00
W-2 Kingston	Levee	1st St SW, north of A Ave NW	0.0	725.00	14.0	0.00
W-2 Kingston	Levee	A Ave NW to 1st Ave W	0.0	728.50	10.5	0.00
W-2 Kingston	Demountable or Rising Gate	1st Ave W road closure	100.0	726.20	13.0	1300.00
W-2 Kingston	Combo Wall Panels	1st Ave W to 2nd Ave SW	284.0	730.50	10.0	2417.06
W-2 Kingston	Demountable or Rising Gate	2nd Ave SW road closure	98.0	725.00	13.0	1274.00
W-2 Kingston	Combo Wall Panels	2nd Ave SW to 3rd Ave SW	290.0	729.50	10.5	2438.60
W-2 Kingston	Demountable or Rising Gate	3rd Ave SW road closure	96.0	724.20	13.5	1296.00
W-2 Kingston	Demountable Wall Panels	3rd Ave SW to existing Demountable Wall	77.0	728.50	10.0	689.22
W-2 Kingston	Existing Demountable Wall	Demountable Wall constructed with Amphitheater	76.0	725.00	12.5	950.00
W-2 Kingston	Demountable Wall Panels	Existing Demountable Wall to 4th Ave SW	156.0	725.80	12.0	1872.00

Reach	Anticipated Closure Type	Location Description	Length, ft	Preferred Sill Elevation	Height, ft	Closure ft^2
W-2 Kingston	Demountable or Rising Wall	Partial height earthen levee with Demountable Wall between Amphitheater and 7th Avenue	400.0	728.40	8.0	3200.00
Penford	Miter Gate	CRANDIC RR closure at Ingredion (formerly Penford)	40.0	725.00	10.5	420.00
W-4 Czech Village	Rolling Gate	16th Ave SW road closure	76.0	721.00	13.5	1026.00

Appendix C: Phase 2 Tasks 5.2, 5.3, and 5.4 Risk Probabilities

Table C-1. Phase 2 Tasks 5.2 and 5.3.

Tasks 5.2 and 5.3	Risk Percent Probabilities and Outcomes				Pre-deployment				Deployment		
Risks	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Chance	Low Outcome (time in hours)	High Outcome (time in hours)
Rain	50	0	1		50	0	1		50	0	1
	30	1	3		30	1	3		30	1	3
Not enough employees for given time	75	0	1		75	0	1		50	0	1
	25	1	3		25	1	3		5	1	3
Wind	20	0	1		20	0	1		20	0	1
	5	1	3		5	1	3		5	1	3
City employees not trained or insufficient training	50	0	1		50	0	1				
	10	1	3		10	1	3				
	5	3	6		5	3	6				
	3	6	9		3	6	9		10	1	3
Contractors/contracted equipment/rental equipment not available	50	1	6		50	1	6		10	1	6

Tasks 5.2 and 5.3	Risk Percent Probabilities and Outcomes				Pre-deployment				Deployment		
Risks	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Chance	Low Outcome (time in hours)	High Outcome (time in hours)
	50	0	1		50	0	1		50	0	1
Rain	30	1	3		30	1	3		30	1	3
	40	0	1		40	0	1				
	30	1	3		30	1	3				
	20	3	6		10	3	6				
Damaged Permanent Combo Wall Posts	10	6	12		10	6	12		10	1	3
	5	0	1		5	0	1				
Components missing from Demountable system	2	6	8		2	6	8		2	0	1
	5	0	1		5	0	1		5	0	1
Lightning	3	1	3		3	1	3		3	1	3
	50	0	1		50	0	1				
1 or more gate(s) gaskets damaged/missing during event	10	3	6		10	3	6		5	0	1
	20	0	1		10	0	1				
1 or more gate(s) unable to seal during event	3	6	12		3	1	3		2	0	1

Tasks 5.2 and 5.3	Risk Percent Probabilities and Outcomes			Pre-deployment			Deployment		
Risks	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)	Chance	Low Outcome (time in hours)	High Outcome (time in hours)
	50	0	1	50	0	1	50	0	1
Rain	30	1	3	30	1	3	30	1	3
Components missing from Combo Wall System	10	1	3	10	1	3	No Risk		
Damaged Gate Wheel(s)	10	0	1	10	0	1	2	0	1
Damaged Roller Track	5	1	3	5	1	3	2	0	1
	10	0	1	10	0	1			
	5	1	3	5	1	3			
Damaged aluminum panels/posts	2	3	6	2	3	6	2	0	1
	5	1	3	5	1	3			
Damaged foundation	3	3	6	3	3	6	3	1	3
Debris not removed from foundation	10	0	1	10	0	1			
	3	1	3	3	1	3	3	1	3

Tasks 5.2 and 5.3	Risk Percent Probabilities and Outcomes				Pre-deployment				Deployment		
Risks	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Chance	Low Outcome (time in hours)	High Outcome (time in hours)
	50	0	1		50	0	1		50	0	1
Rain	30	1	3		30	1	3		30	1	3
Installation equipment (heavy equipment) not available	25	0	1		25	0	1				
	10	1	3		10	1	3		5	0	1
Insufficient access space for equip., vehl., etc. to maneuver	20	0	1		10	0	1				
	5	1	3		3	1	3		2	0	1
Late delivery from rental companies	15	1	3		15	1	3				
	5	3	6		5	3	6		No Risk		
Limited hand tools necessary for installation	20	0	1		20	0	1				
	5	1	3		5	1	3		2	0	1
	10	0	1		10	0	1				
Mechanical problems	2	1	3		2	1	3		2	1	3
	20	0	1		20	0	1		No Risk		

Tasks 5.2 and 5.3	Risk Percent Probabilities and Outcomes				Pre-deployment				Deployment		
Risks	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Chance	Low Outcome (time in hours)	High Outcome (time in hours)
	50	0	1		50	0	1		50	0	1
Rain	30	1	3		30	1	3		30	1	3
	10	1	3		10	1	3				
Storage distance of inst. equipment too far	5	3	6		5	3	6				
Uneven surfaces or terrain	50	0	1		10	0	1				
	20	1	3		5	1	3		3	0	1

Table C-2. Phase 2 Task 5.4.

Task 5.4	Risk Percent Probabilities and Outcomes				Re-Evaluated and Adjusted Risk Percent Probabilities and Outcomes		
					Deployment		
Risk	Percent Chance	Low Outcome (time in hours)	High Outcome (time in hours)		Chance	Low Outcome	High Outcome
	50	0	1		50	0	1
Rain	30	1	3		30	1	3
	75	0	1		50	0	1
Not enough employees for given time	25	1	3		**5**	1	3
	20	0	1		20	0	1
Wind	5	1	3		5	1	3
	50	0	1				
	10	1	3				
	5	3	6				
City employees not trained or insufficient training	3	6	9		10	1	3
Contractors/contracted equipment/rental equipment not available	50	1	6		10	1	6

Task 5.4	Risk Percent Probabilities and Outcomes				Re-Evaluated and Adjusted Risk Percent Probabilities and Outcomes		
					Deployment		
	40	0	1				
	30	1	3				
	20	3	6				
Damaged Permanent Combo Wall Posts	10	6	12		10	1	3
Components missing from Demountable system	5	0	1				
	2	6	8		2	0	1
	5	0	1		5	0	1
Lightning	3	1	3		3	1	3
1 or more gate(s) gaskets damaged/missing during event	50	0	1				
	10	3	6		5	0	1
	20	0	1				
1 or more gate(s) unable to seal during event	3	6	12		**2**	**0**	**1**
Components missing from Combo Wall System	10	1	3		No Risk		

	Risk Percent Probabilities and Outcomes				Re-Evaluated and Adjusted Risk Percent Probabilities and Outcomes		
Task 5.4					**Deployment**		
Damaged Gate Wheel(s)	10	0	1		2	0	1
Damaged Roller Track	5	1	3		2	0	1
	10	0	1				
	5	1	3				
Damaged aluminum panels/posts	2	3	6		2	0	1
	5	1	3				
Damaged foundation	3	3	6		3	1	3
	10	0	1				
Debris not removed from foundation	3	1	3		3	1	3
Installation equipment (heavy equipment) not available	25	0	1				
	10	1	3		5	0	1
Insufficient access space for equipment, vehicle., etc., to maneuver	20	0	1				
	5	1	3		2	0	1

Task 5.4	Risk Percent Probabilities and Outcomes				Re-Evaluated and Adjusted Risk Percent Probabilities and Outcomes		
					Deployment		
Late delivery from rental companies	15	1	3		No Risk		
	5	3	6				
Limited hand tools necessary for installation	20	0	1		2	0	1
	5	1	3				
Mechanical problems	10	0	1		2	1	3
	2	1	3				
Storage distance of instruments. equipment too far	20	0	1		No Risk		
	10	1	3				
	5	3	6				
Uneven surfaces or terrain	50	0	1		3	0	1
	20	1	3				

Appendix D: Gantt Charts

The following figures present Gantt charts.

Figure D-1. Phase 1, Baseline alternative schedule of events.

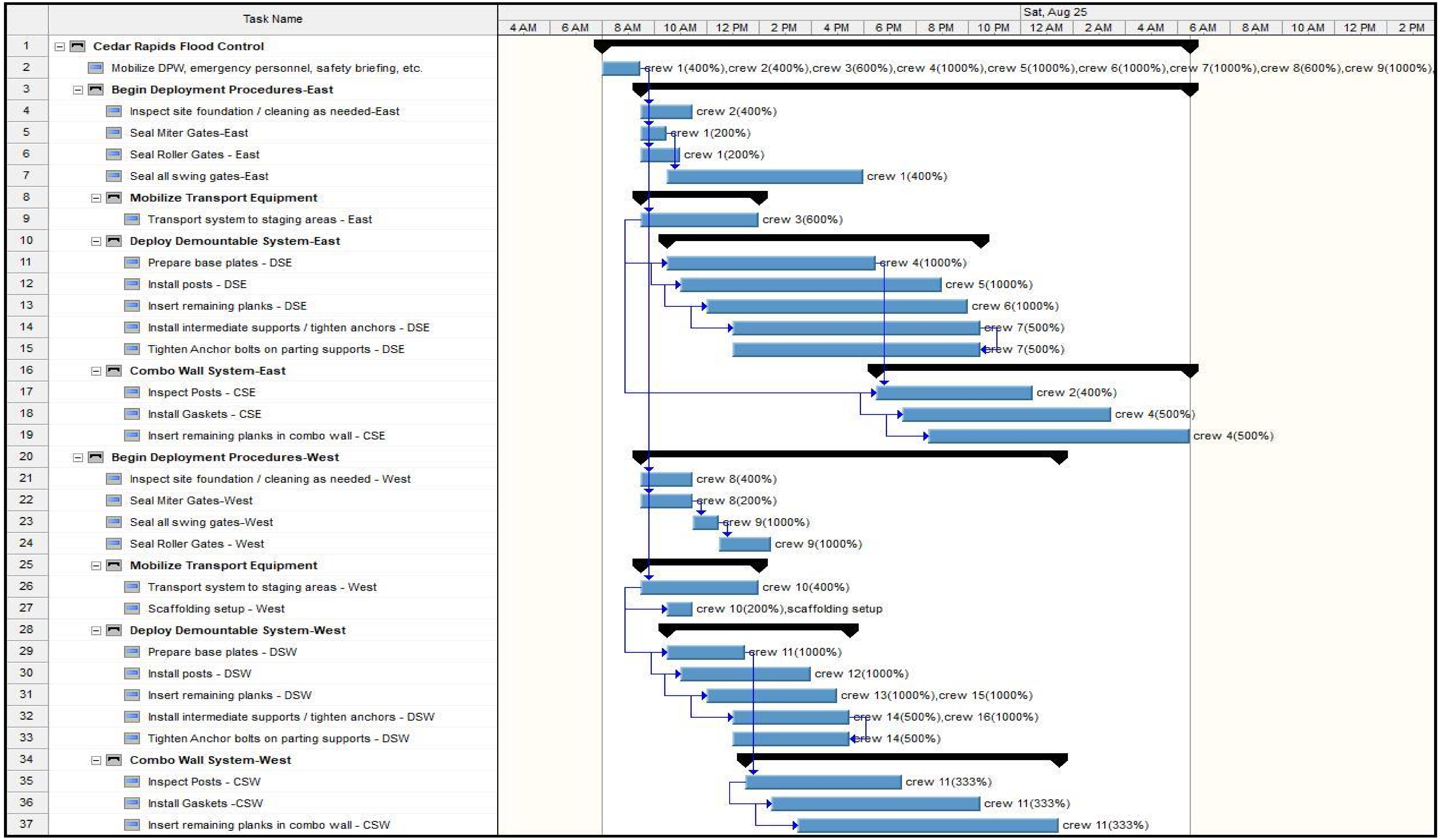


Figure D-2. Phase 1, Alternative 1 schedule of events.

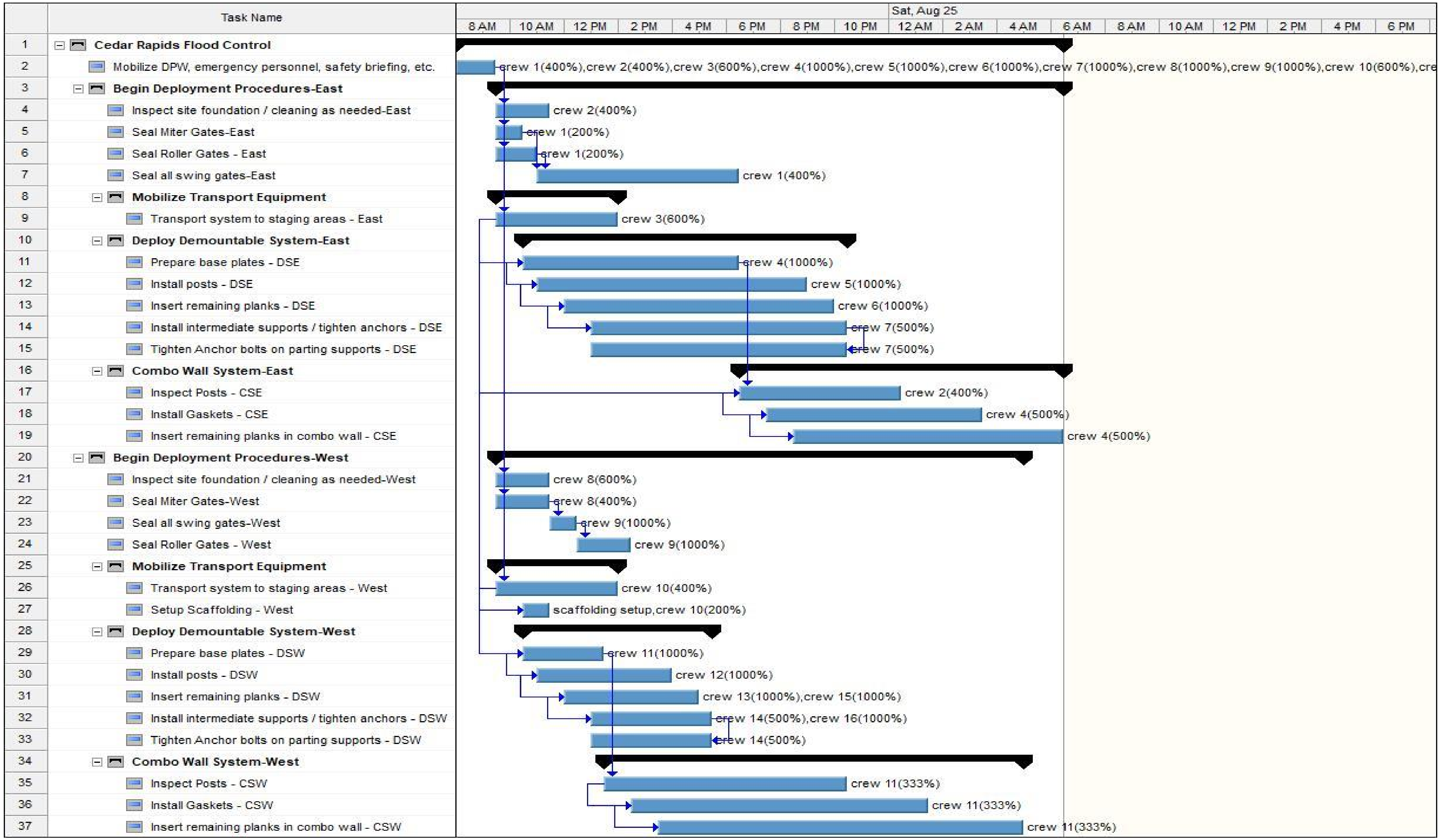


Figure D-3. Phase 1, Alternative 2 schedule of events.

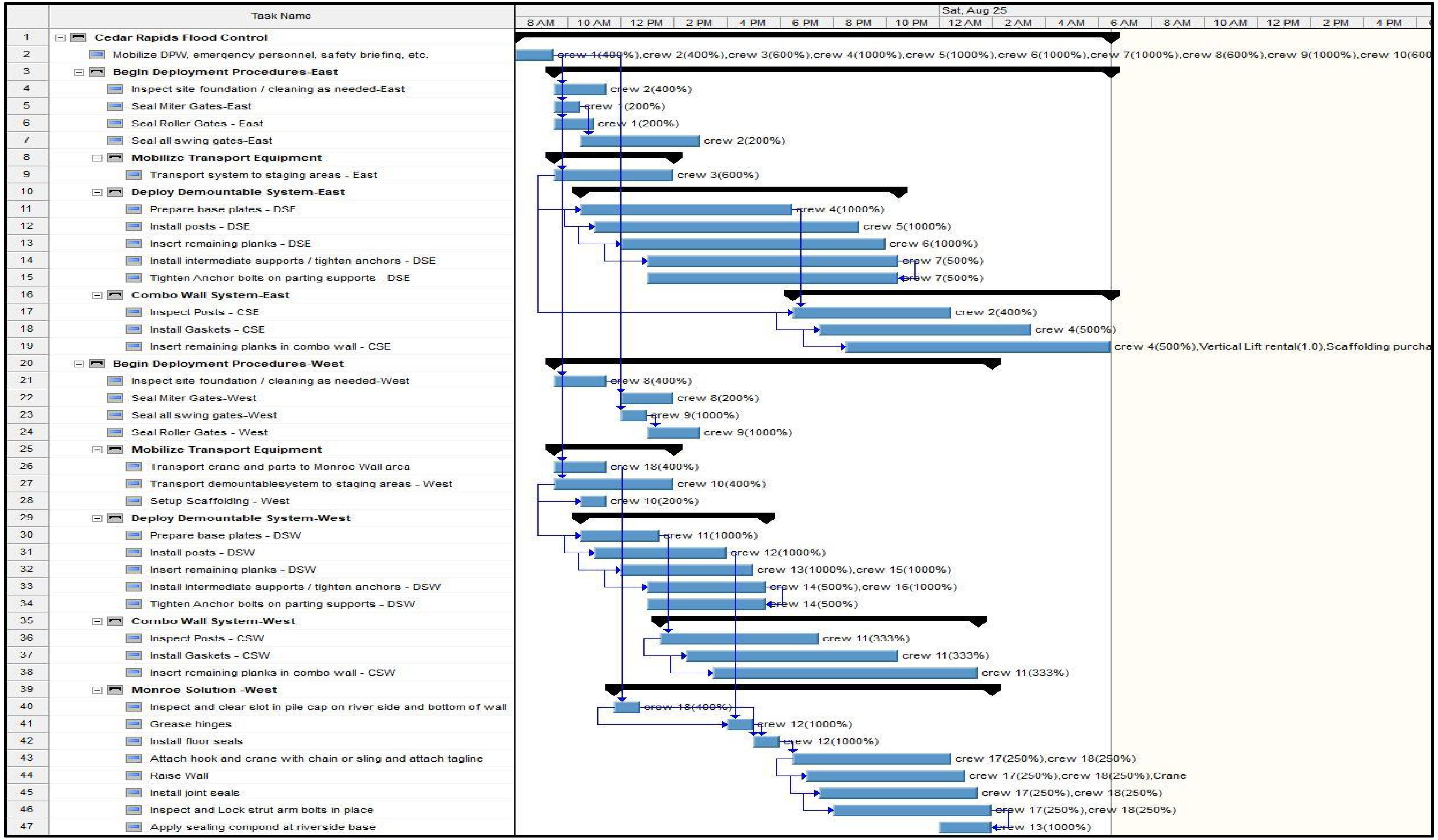


Figure D-4. Phase 1, Master Plan schedule of events.

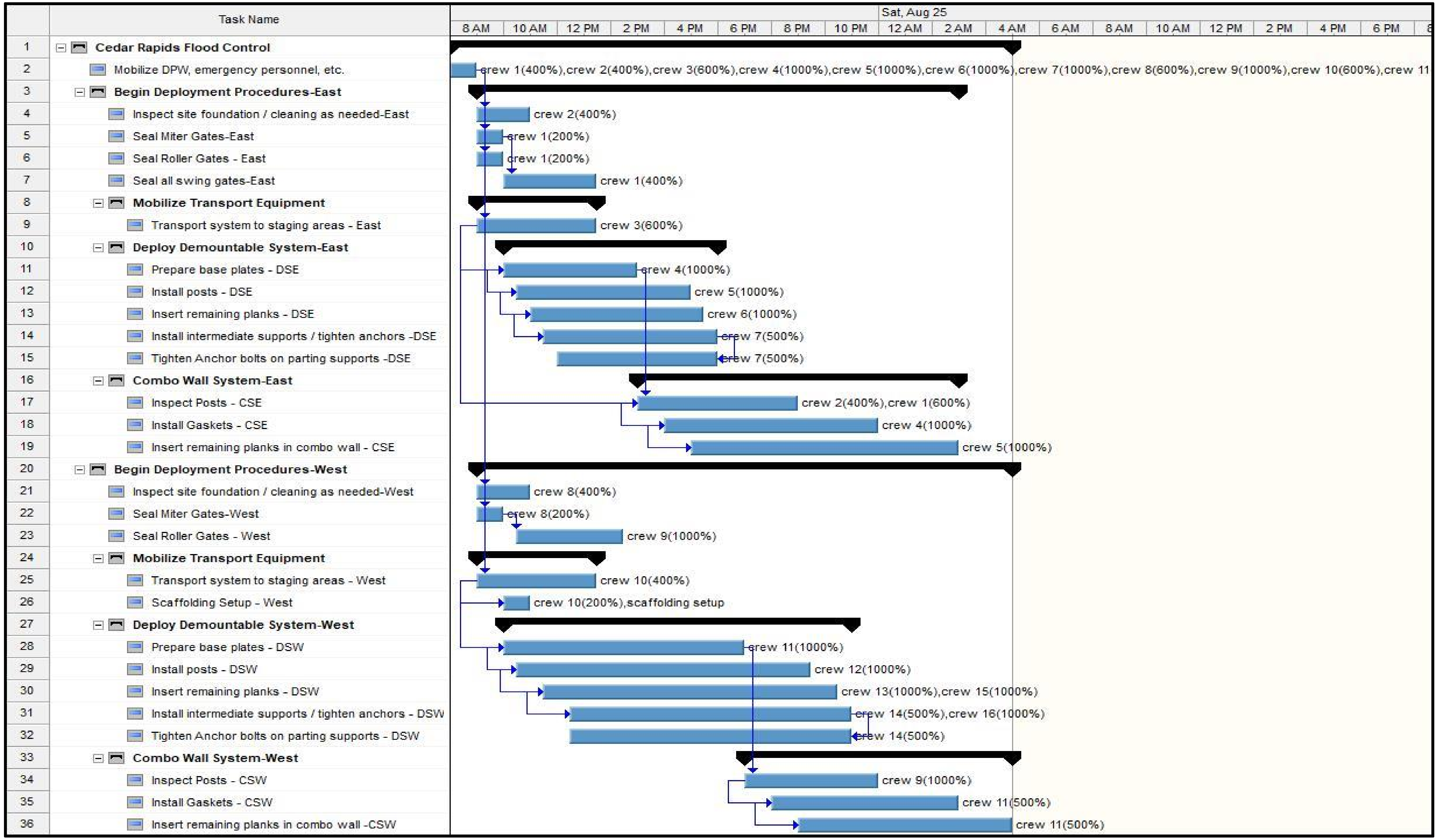


Figure D-5. Phase 1, Master Plan Minus 400 ft schedule of events.

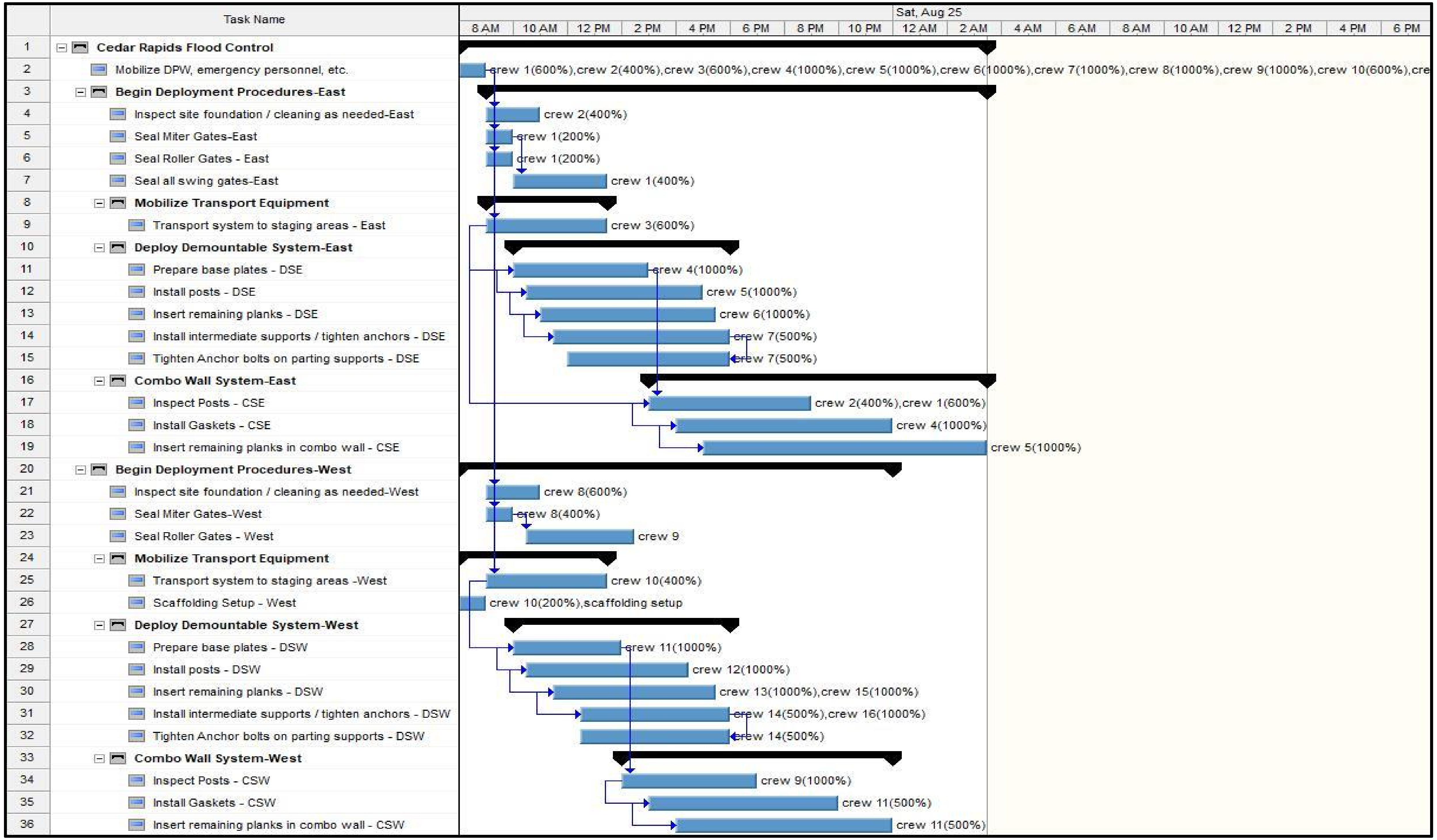


Figure D-6. Phase 1, Roads and Railroads Only schedule of events.

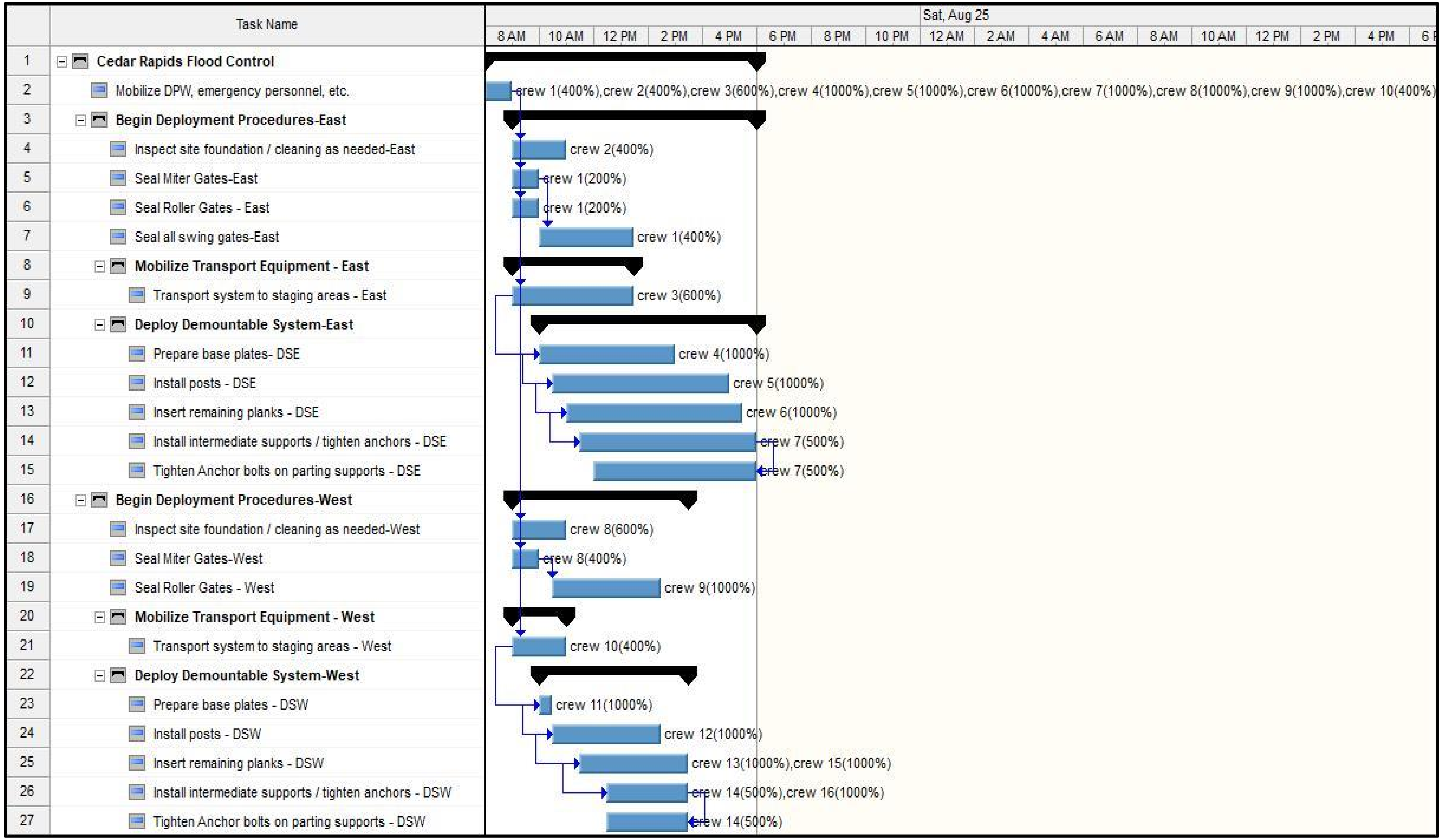


Figure D-7. Phase 1, Roads and Railroads Only Optimized by Crew Location schedule of events.

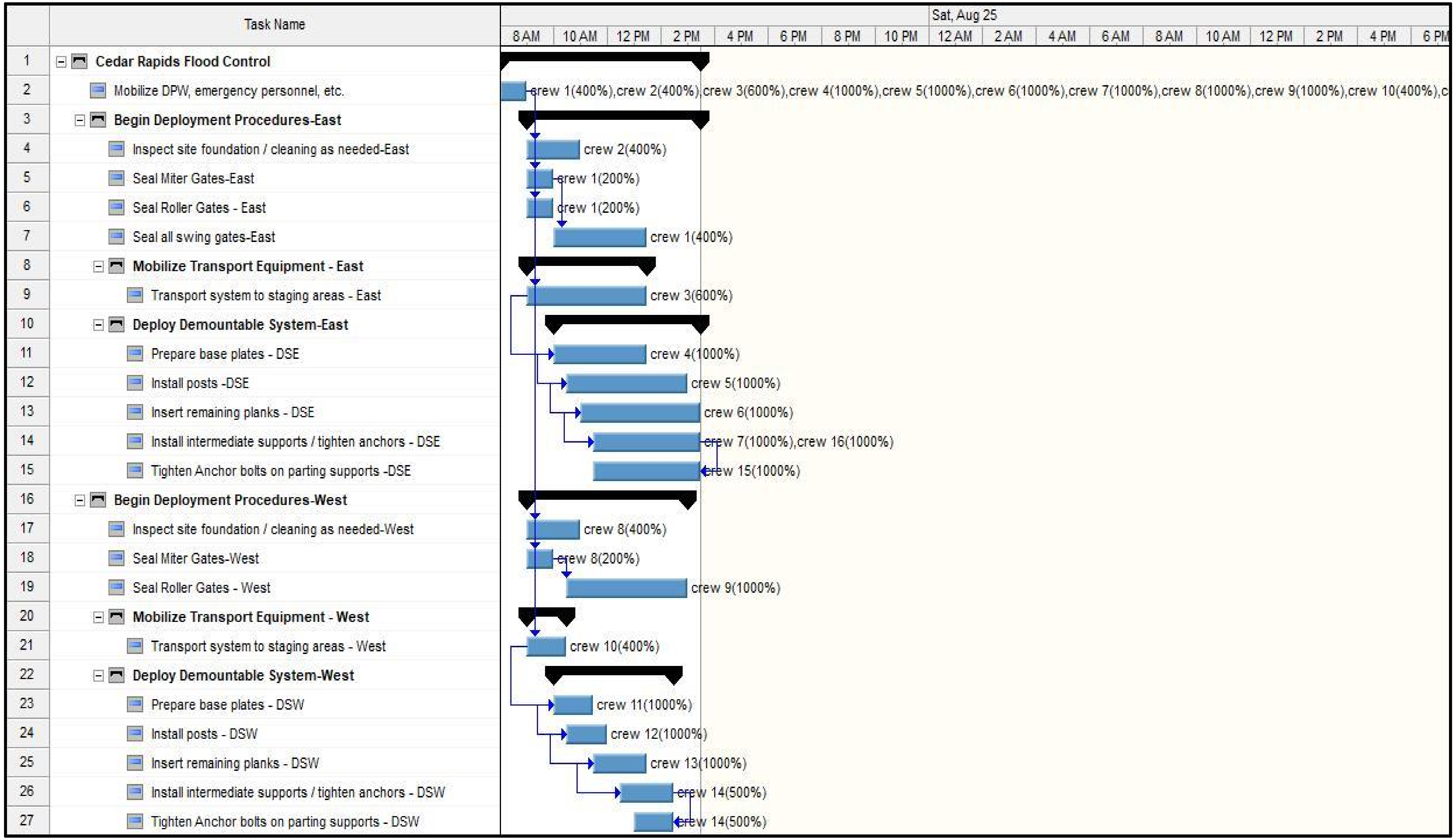


Figure D-8. Phase 2, Task 5.1 schedule of events.

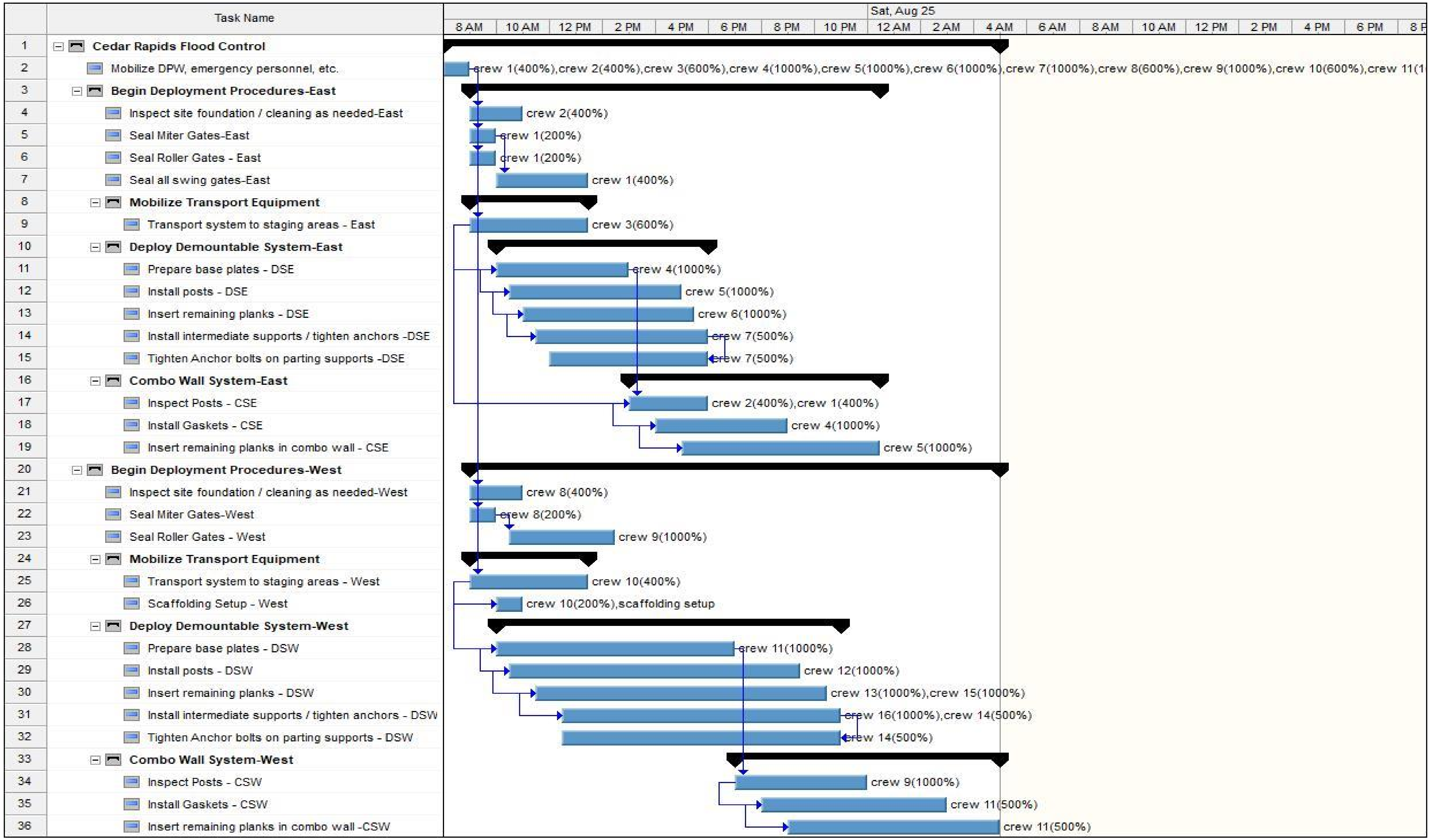


Figure D-9. Phase 2, Task 5.2 Pre-Deployment schedule of events.

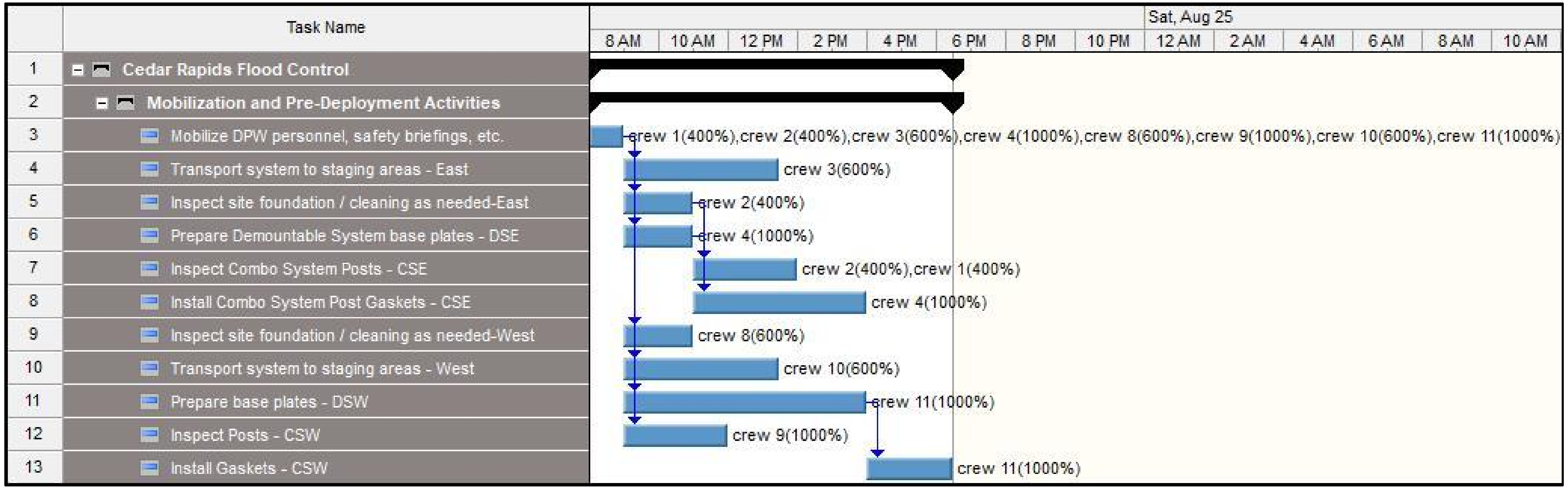


Figure D-10. Phase 2, Task 5.2 Deployment schedule of events.

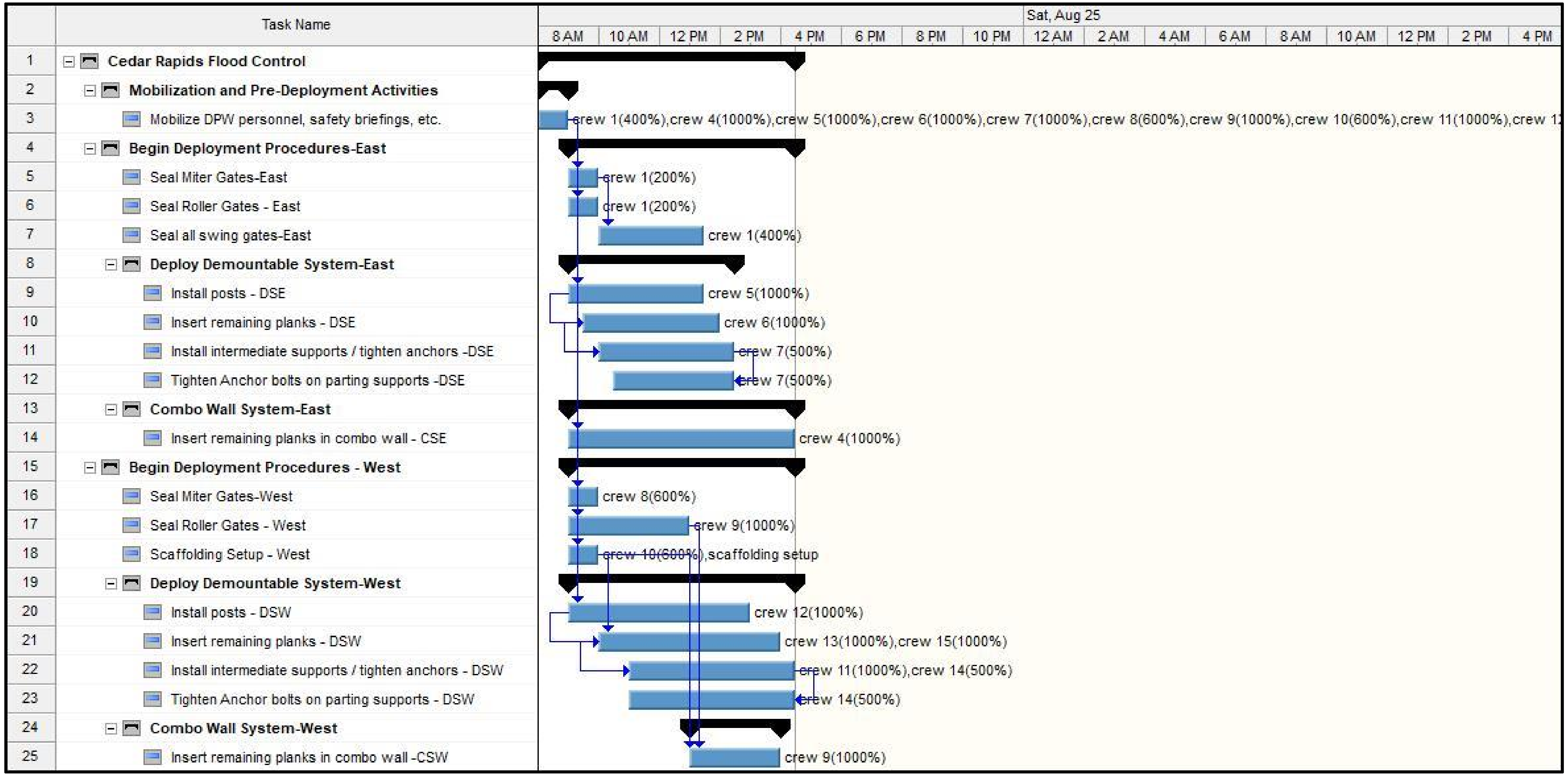


Figure D-11. Phase 2, Task 5.3 Pre-Deployment A schedule of events.

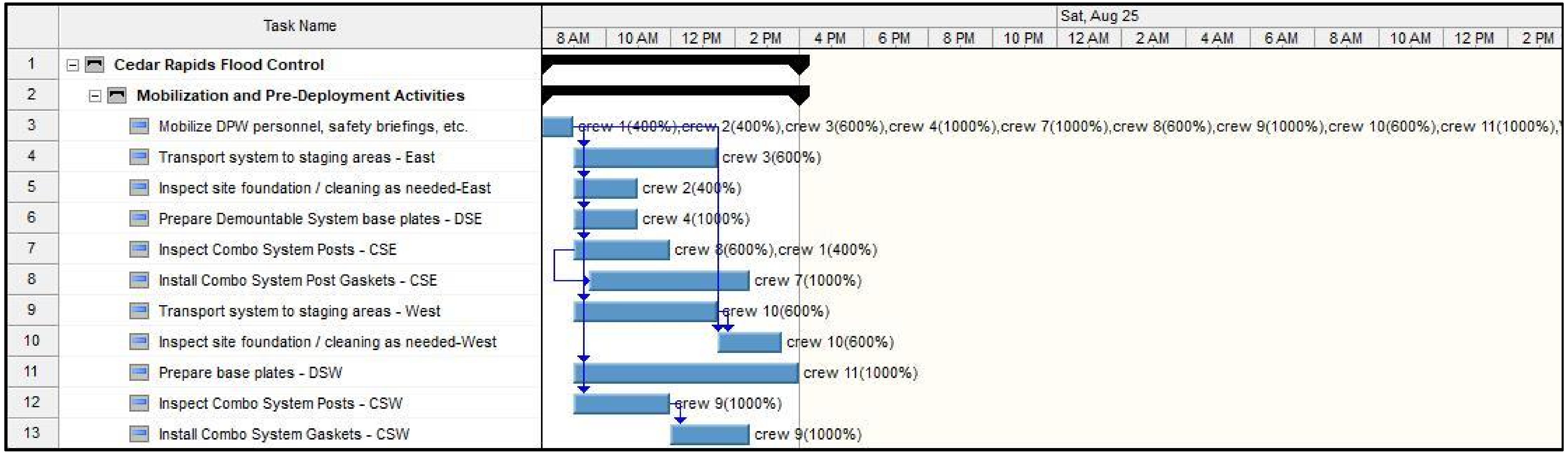


Figure D 12. Phase 2, Task 5.3 Pre-Deployment B schedule of events.

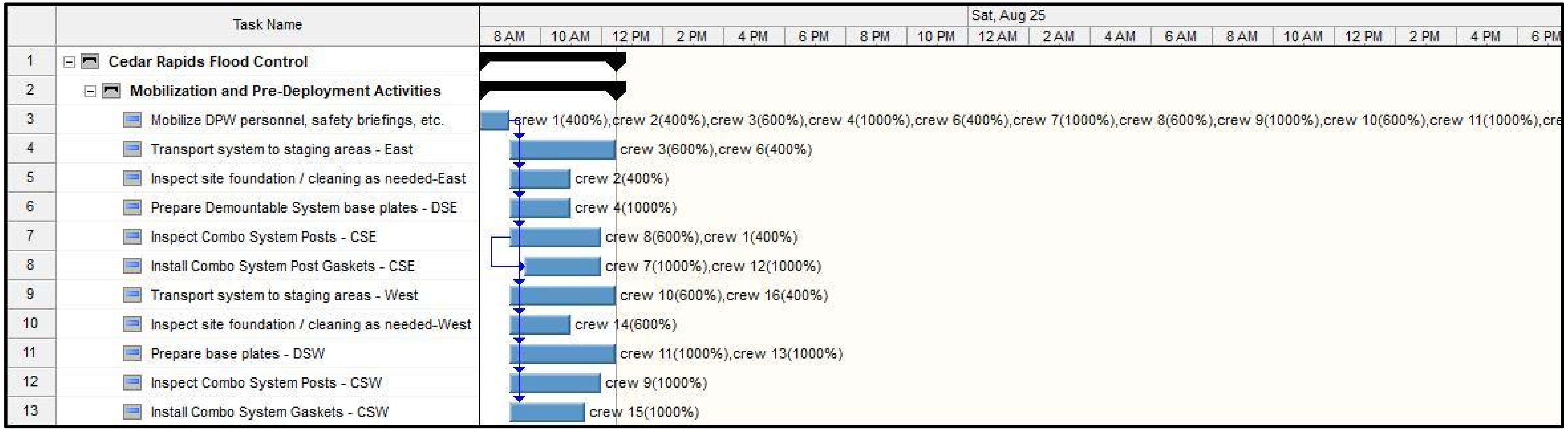


Figure D-13. Phase 2, Task 5.3 Deployment schedule of events.

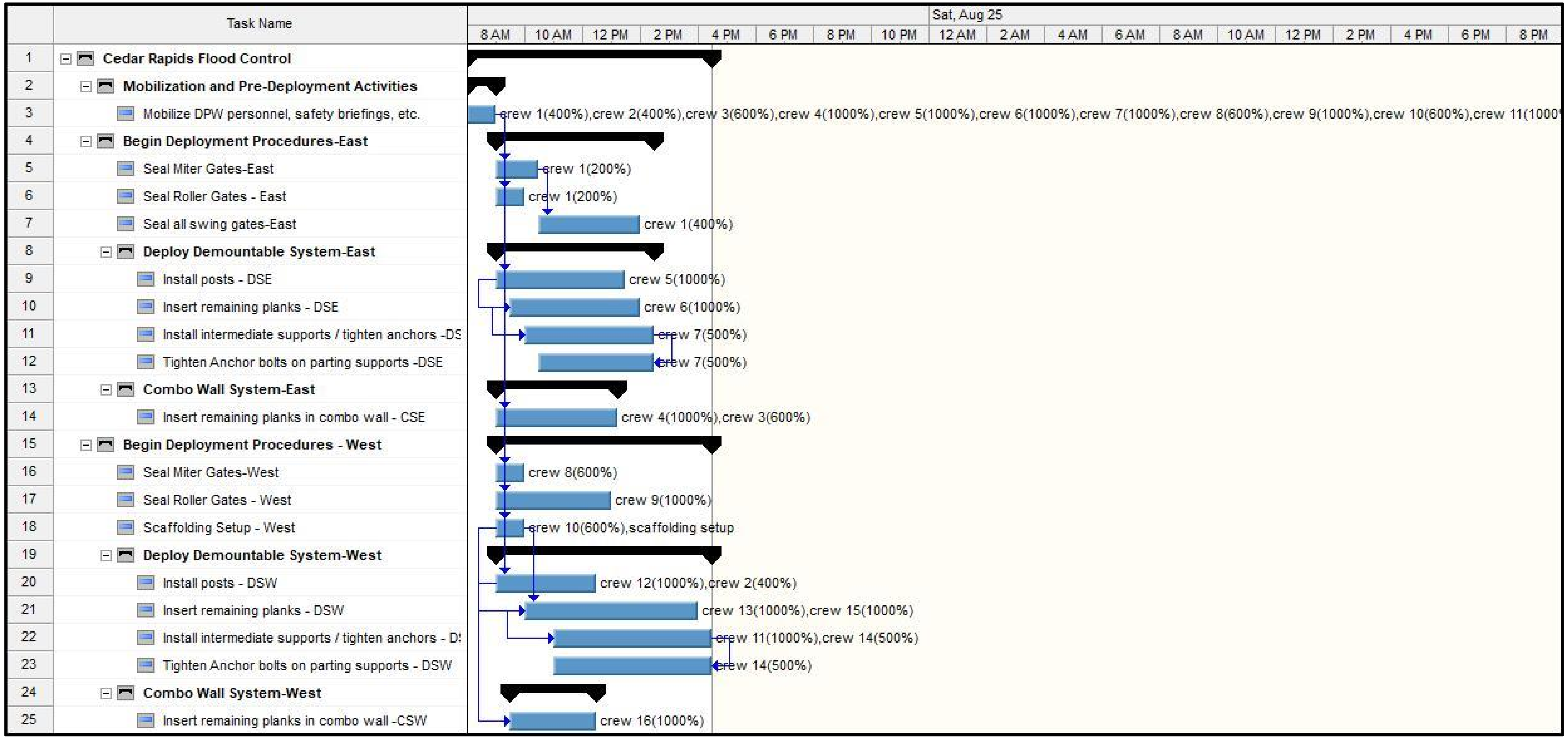
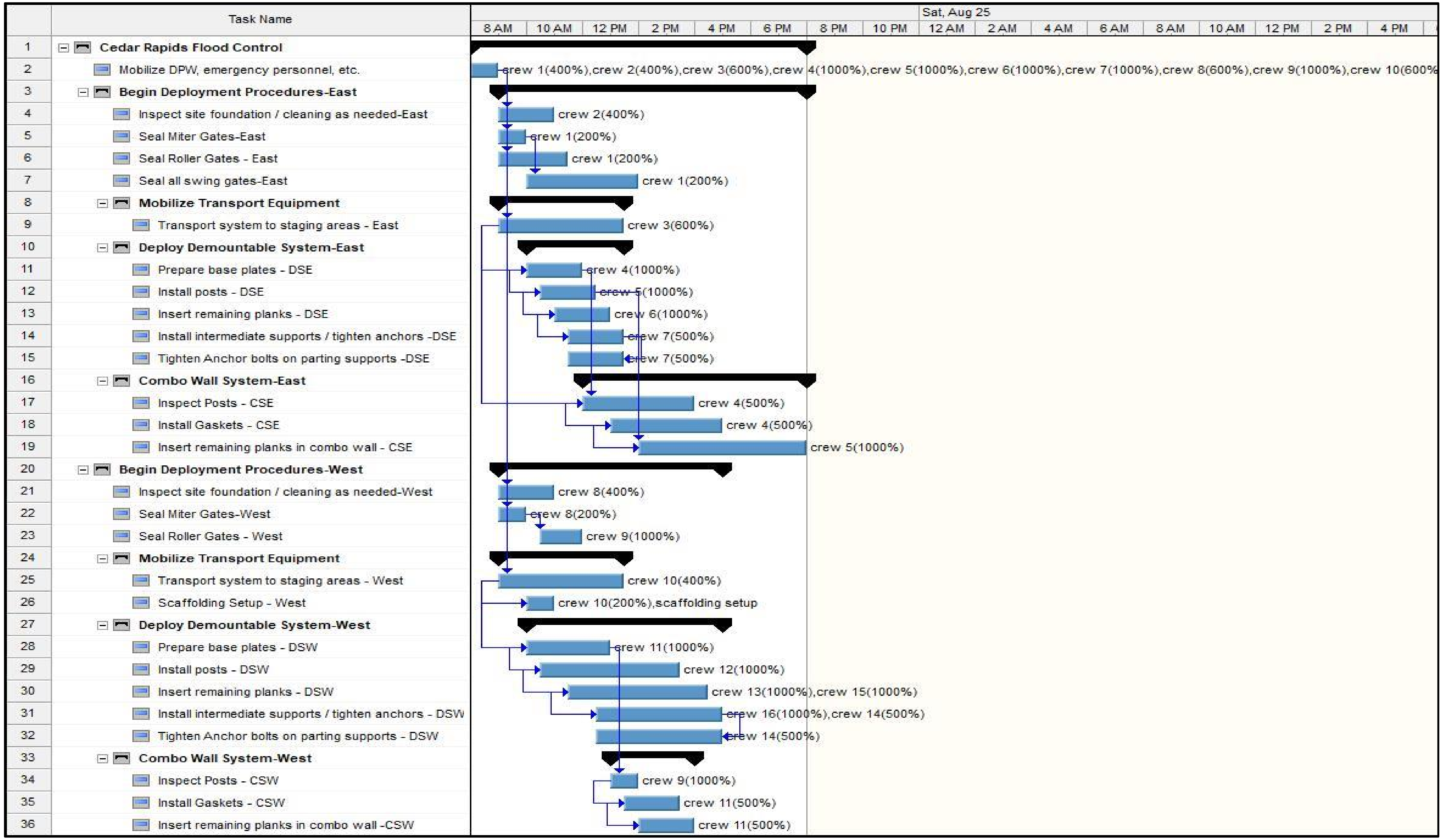


Figure D-14. Phase 2, Task 5.4 Deployment schedule of events.



Appendix E: Risk Matrices

The following figures present the risk matrices.

Figure E-1. Phase 1, Baseline risk matrix.

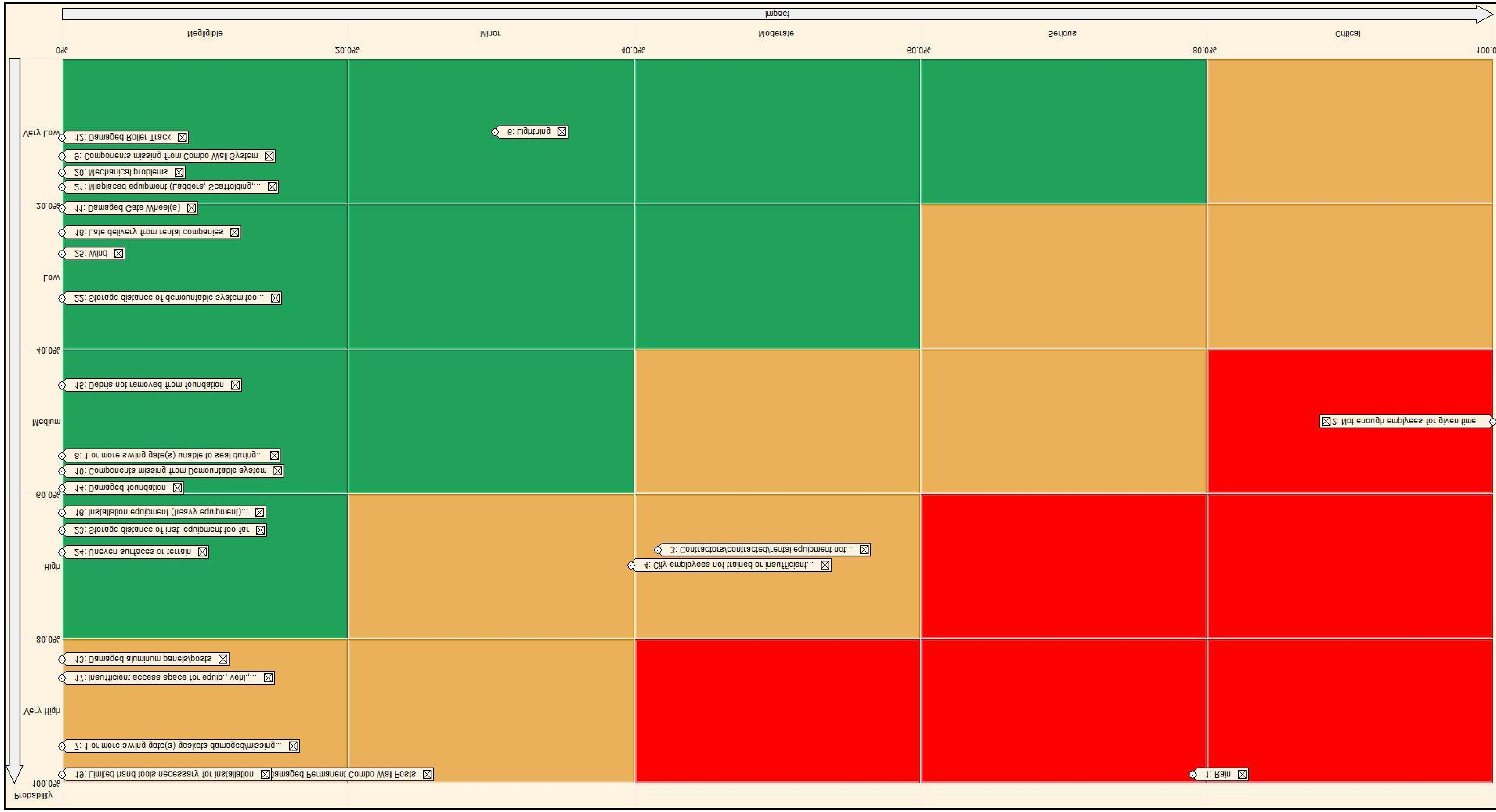


Figure E-2. Phase 1, Alternative 1 risk matrix.

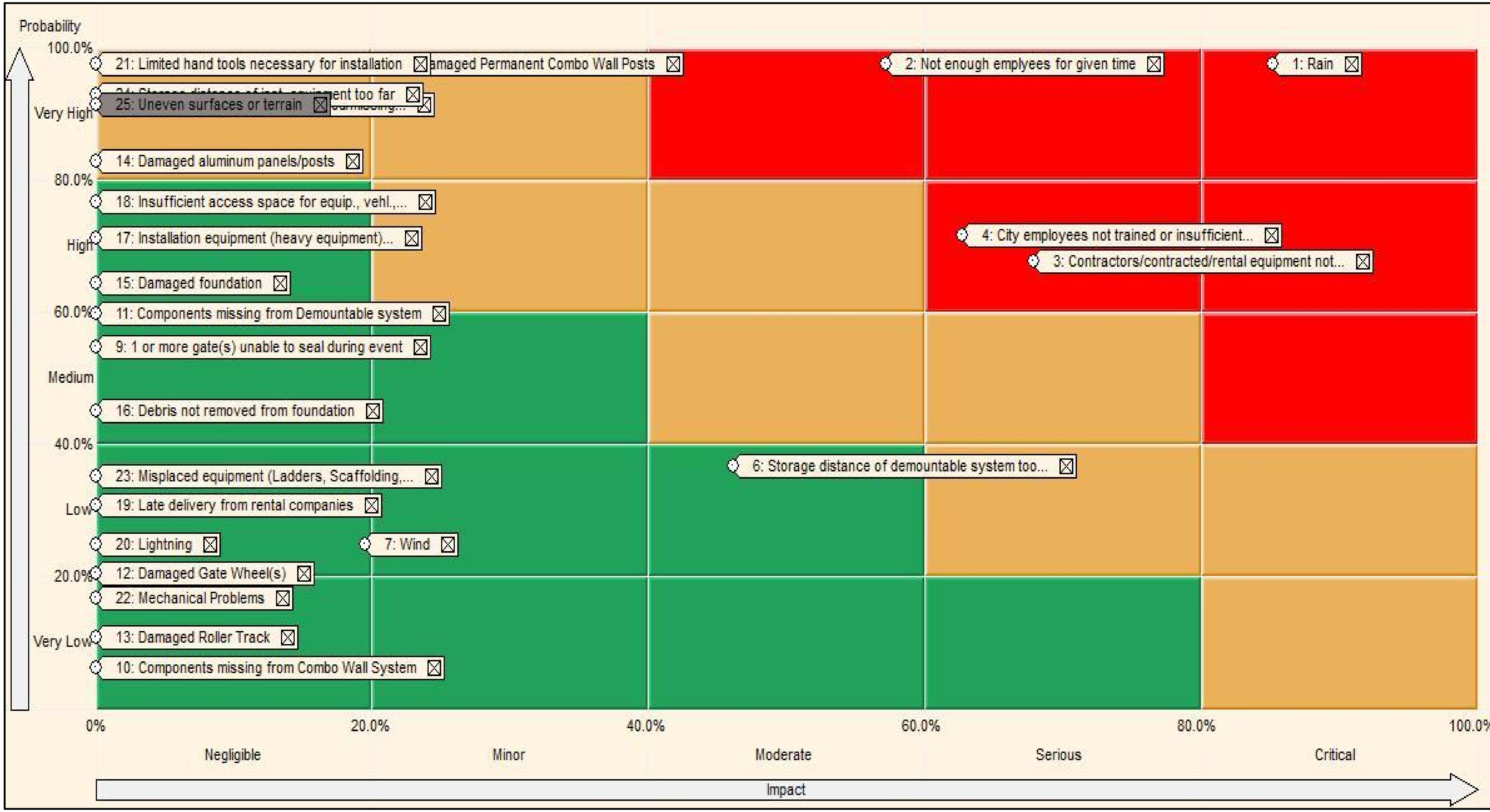


Figure E-3. Phase 1, Alternative 2 risk matrix.

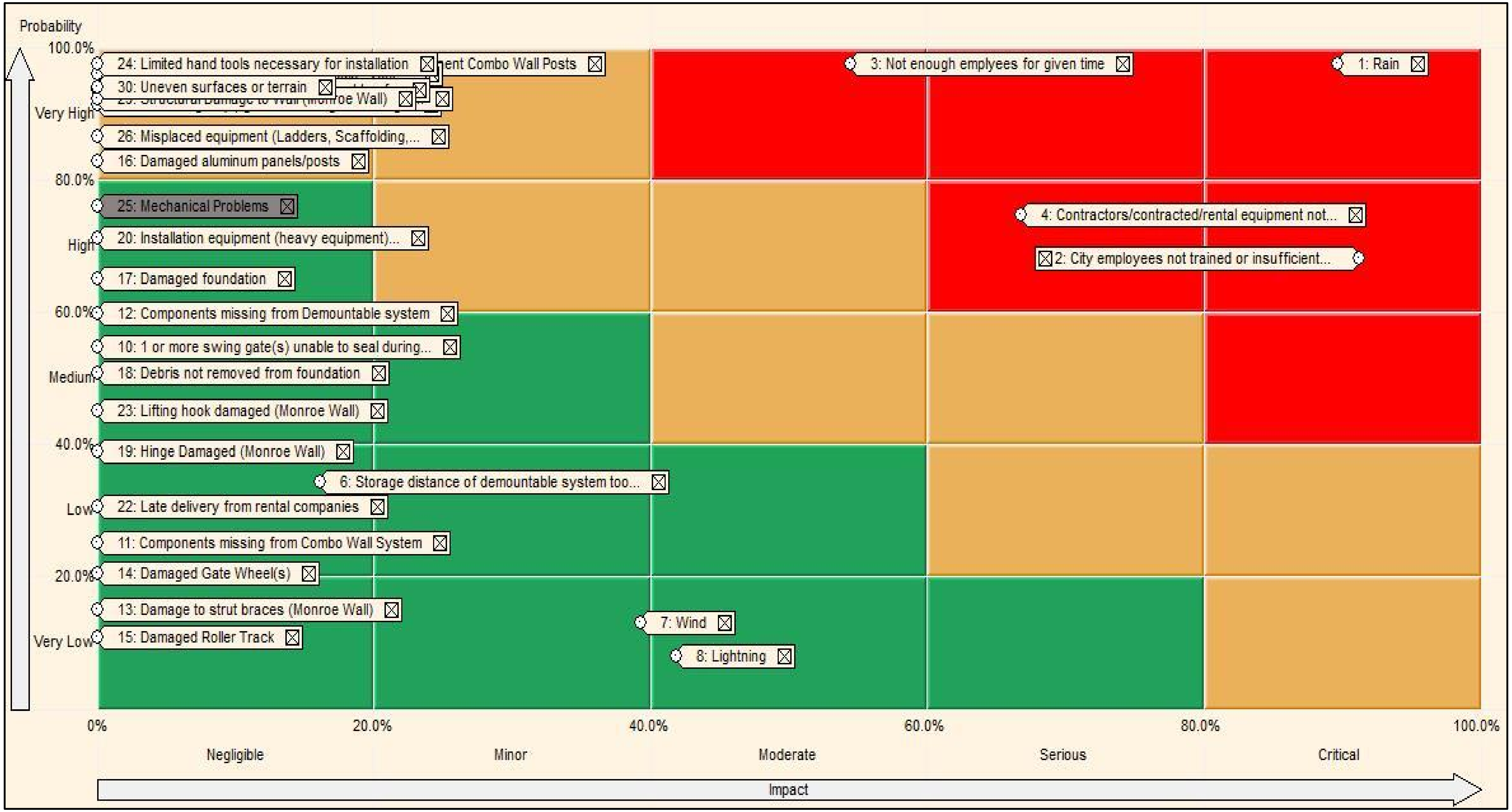


Figure E-4. Phase 1, Master Plan risk matrix.

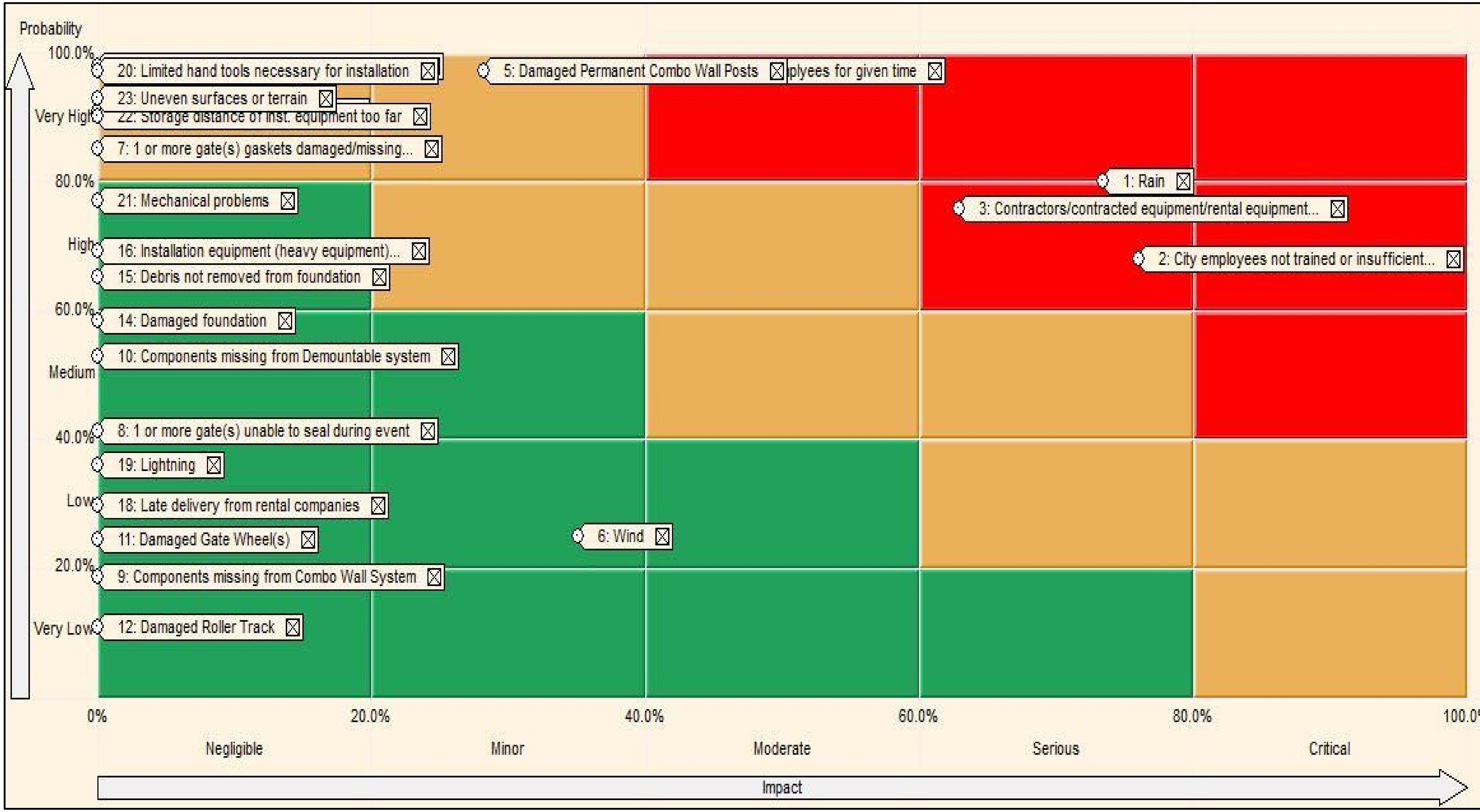


Figure E-5. Phase 1, Master Plan Minus 400 ft risk matrix.

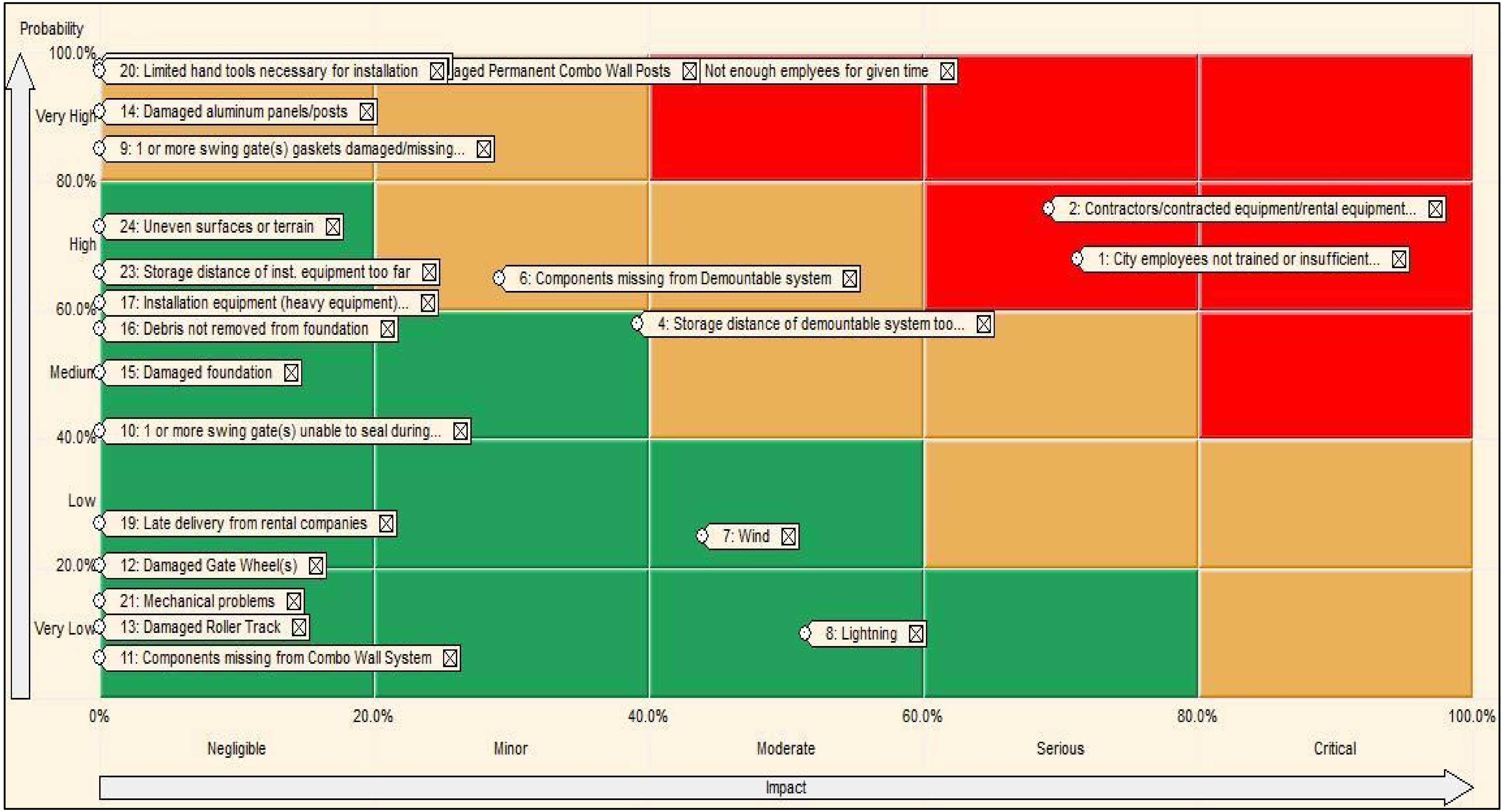


Figure E-6. Phase 1, Roads and Railroads Only risk matrix.

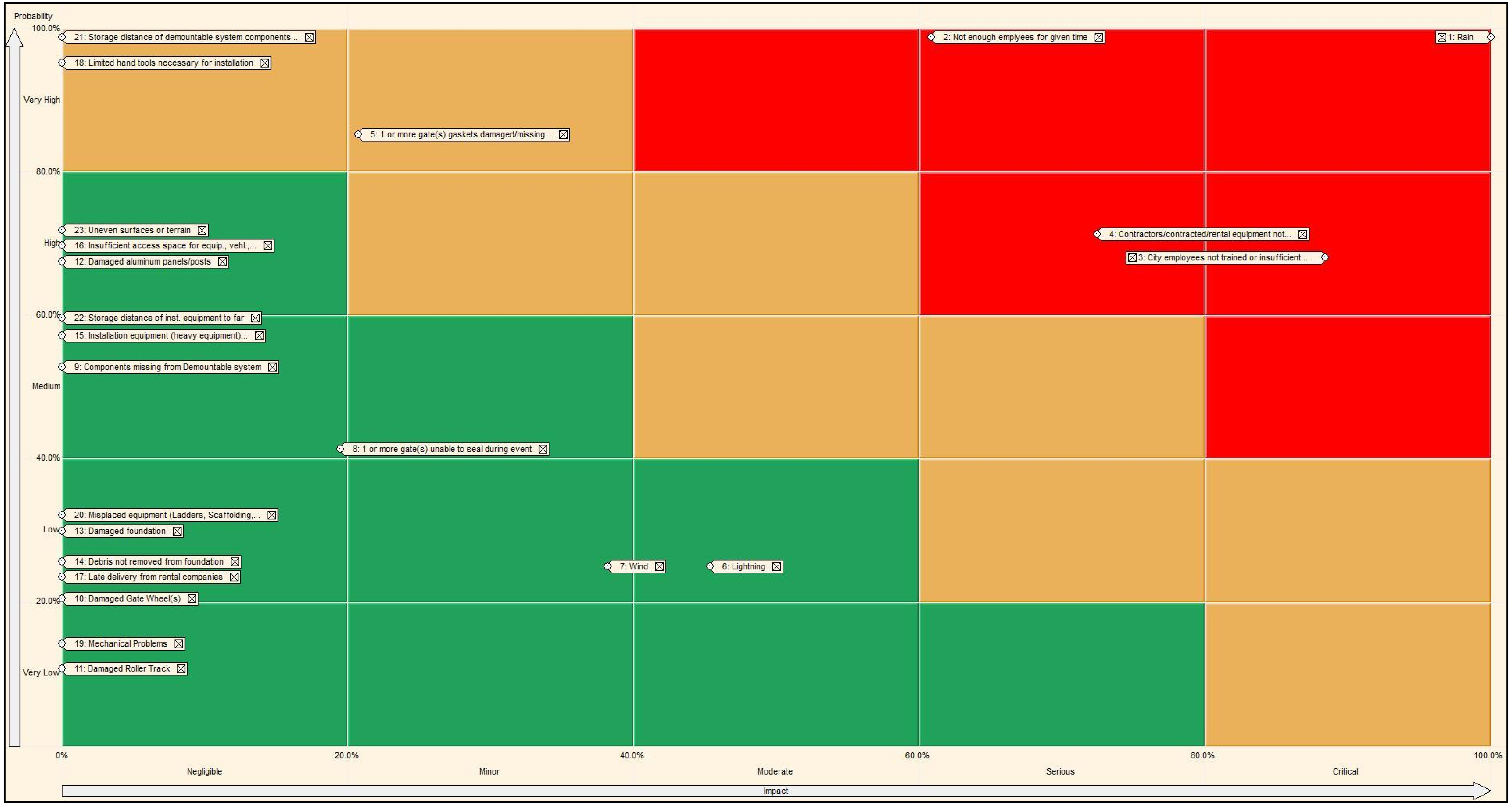


Figure E-7. Phase 1, Roads and Railroads Only, Optimized by Crew Locations risk matrix.

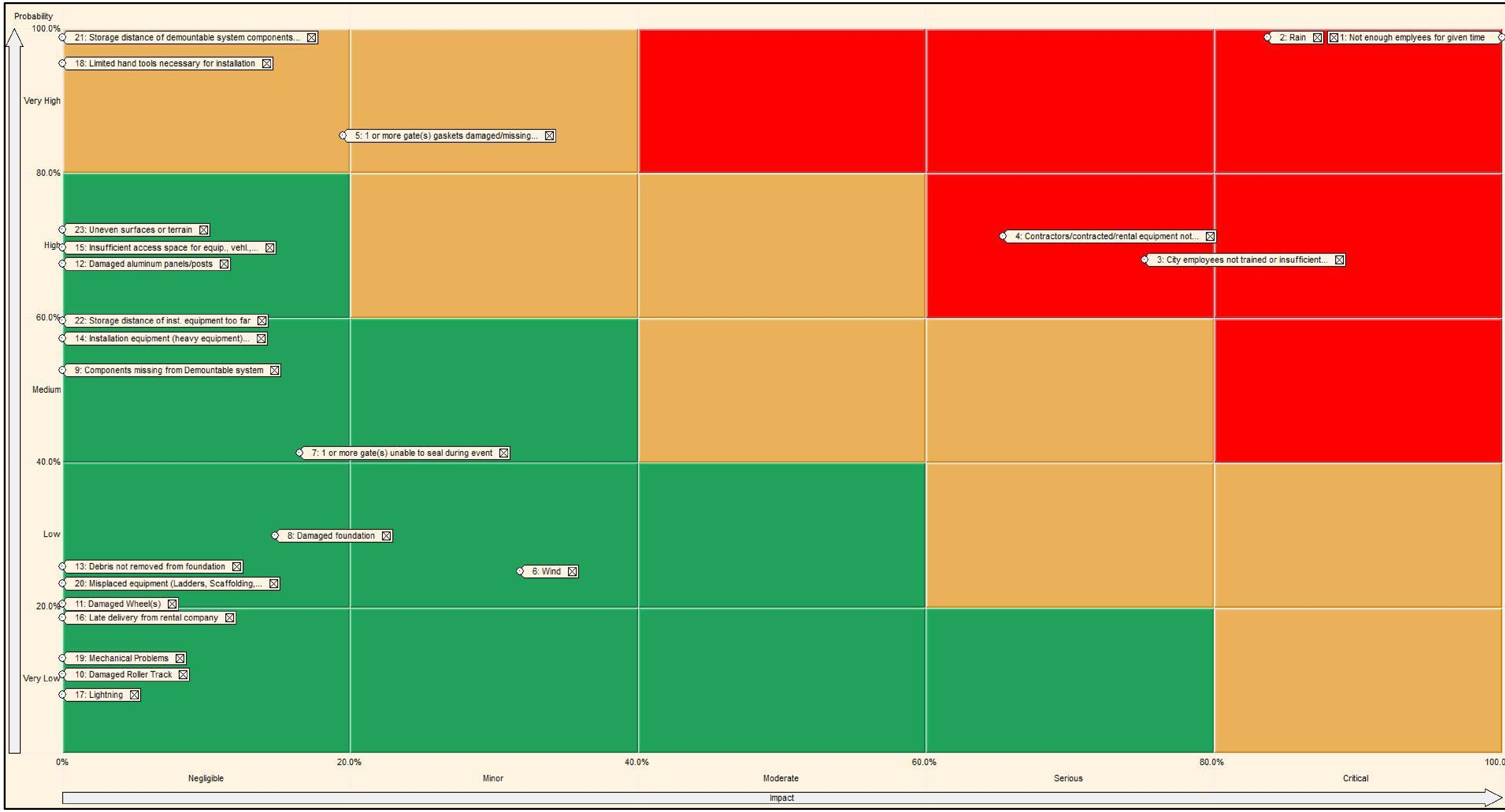


Figure E-8. Phase 2, Task 5.1 risk matrix.

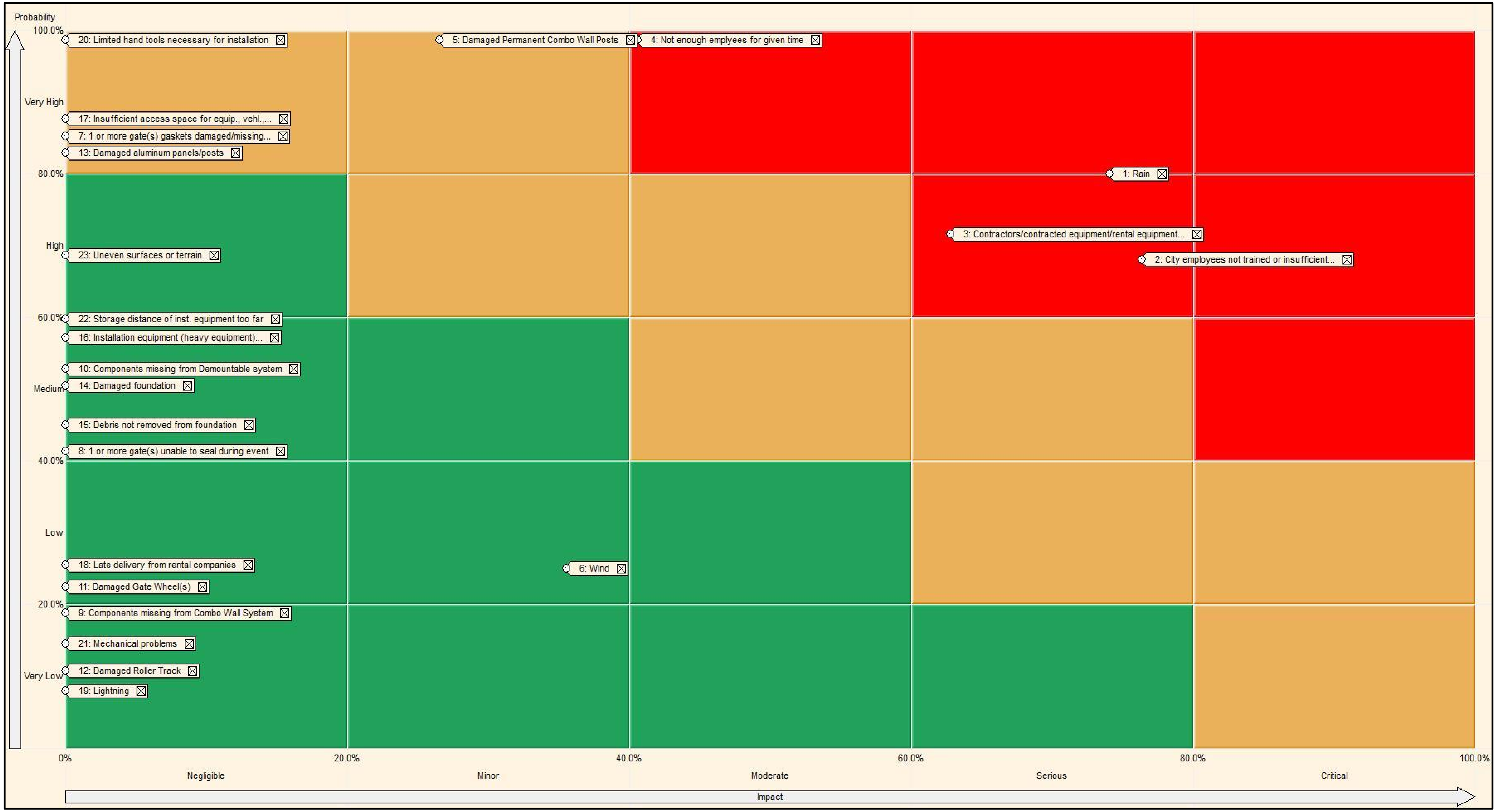


Figure E-9. Phase 2, Task 5.2 Pre-Deployment risk matrix.

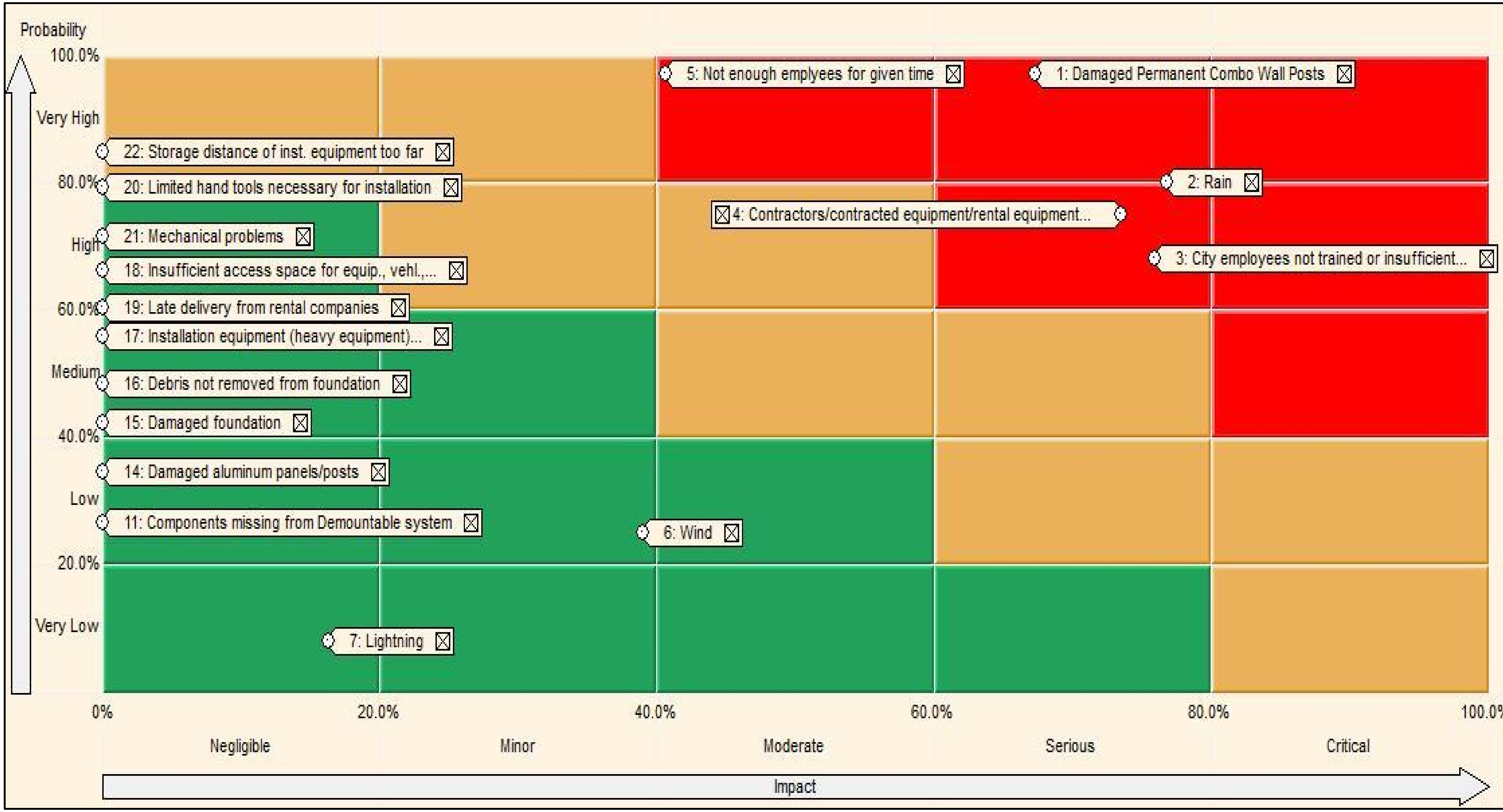


Figure E-10. Phase 2, Task 5.2 Deployment risk matrix.

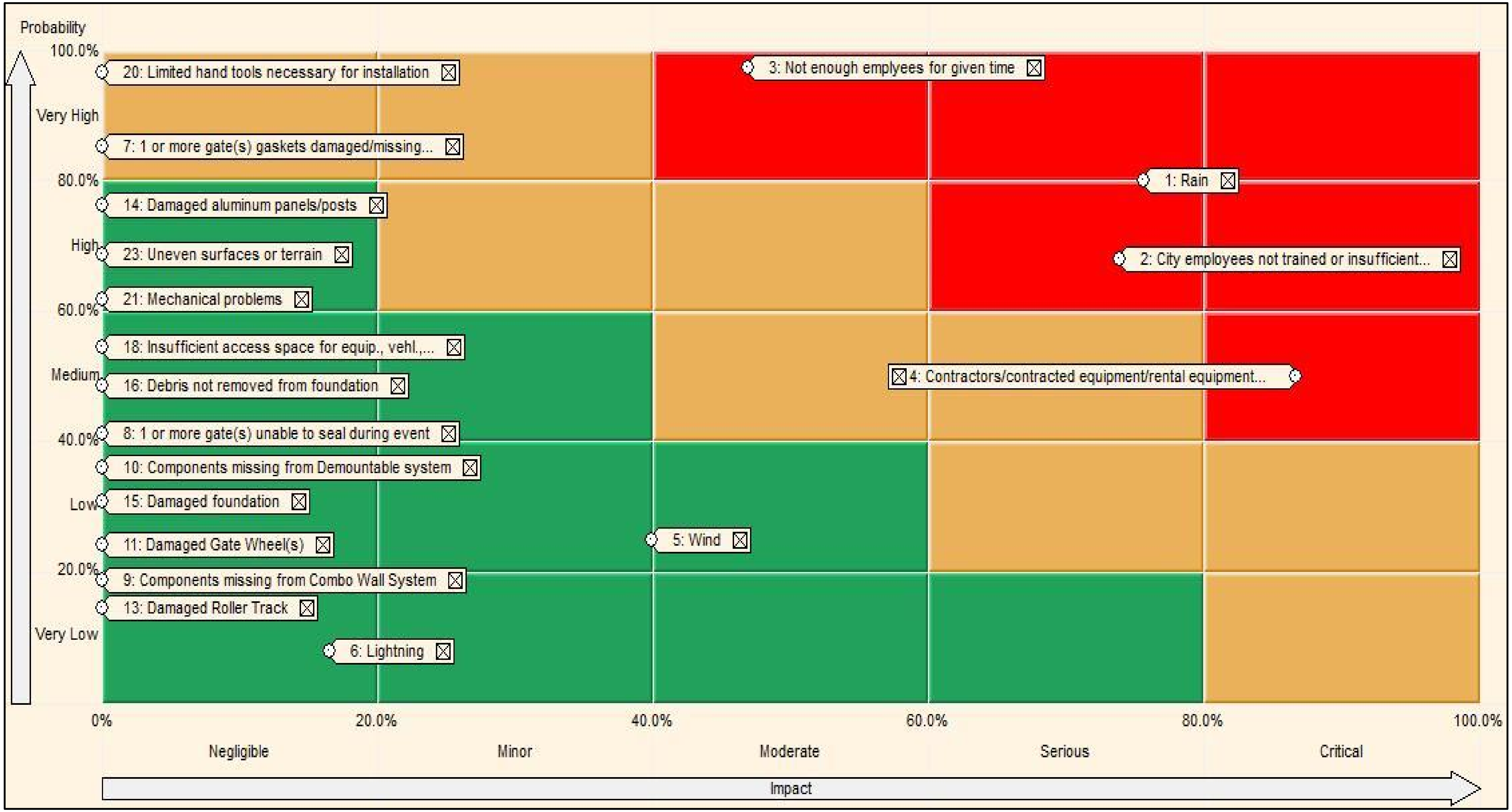


Figure E-11. Phase 2, Task 5.3 Pre-Deployment A risk matrix.

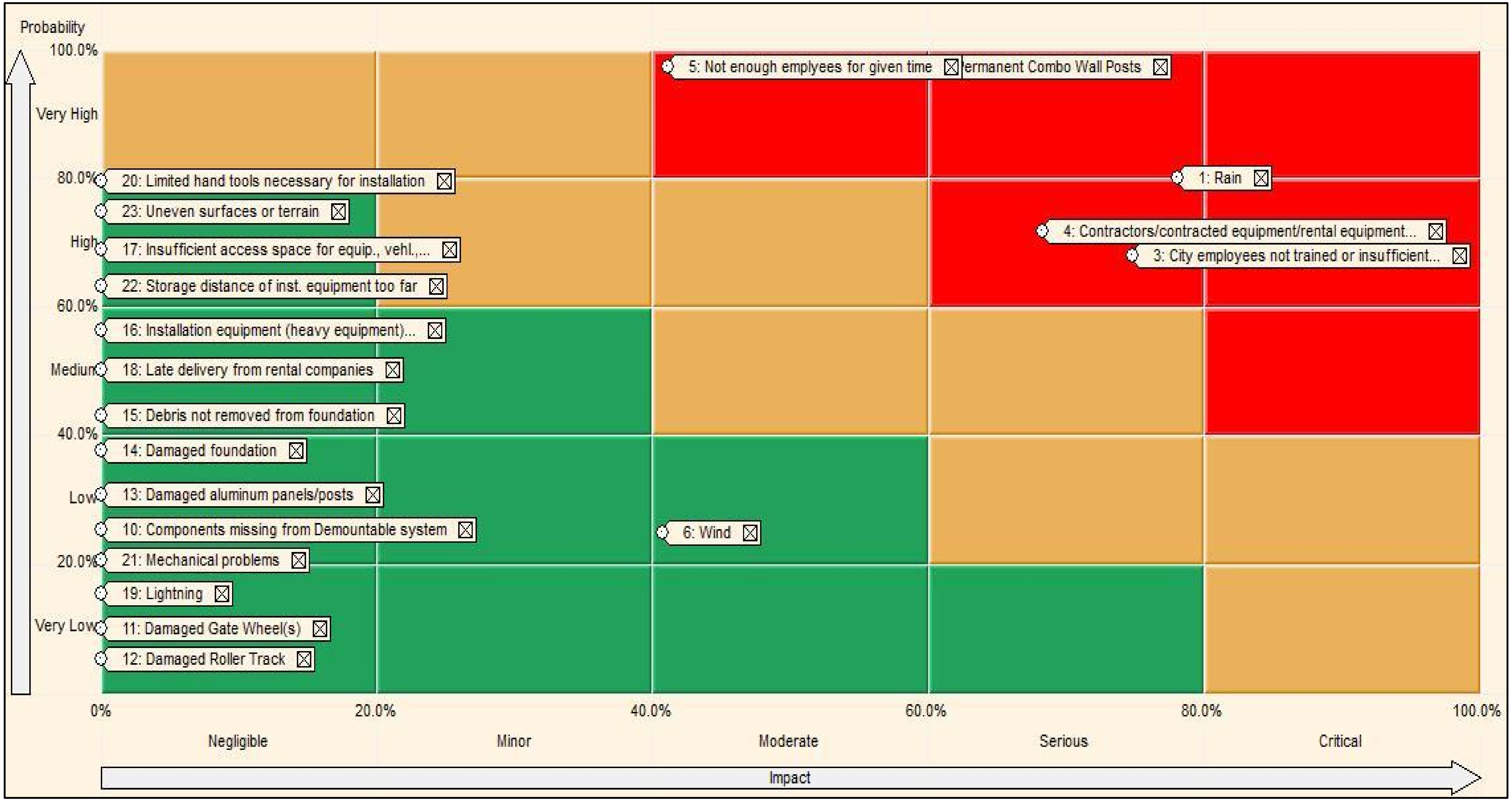


Figure E-12. Phase 2, Task 5.3 Pre-Deployment B risk matrix.

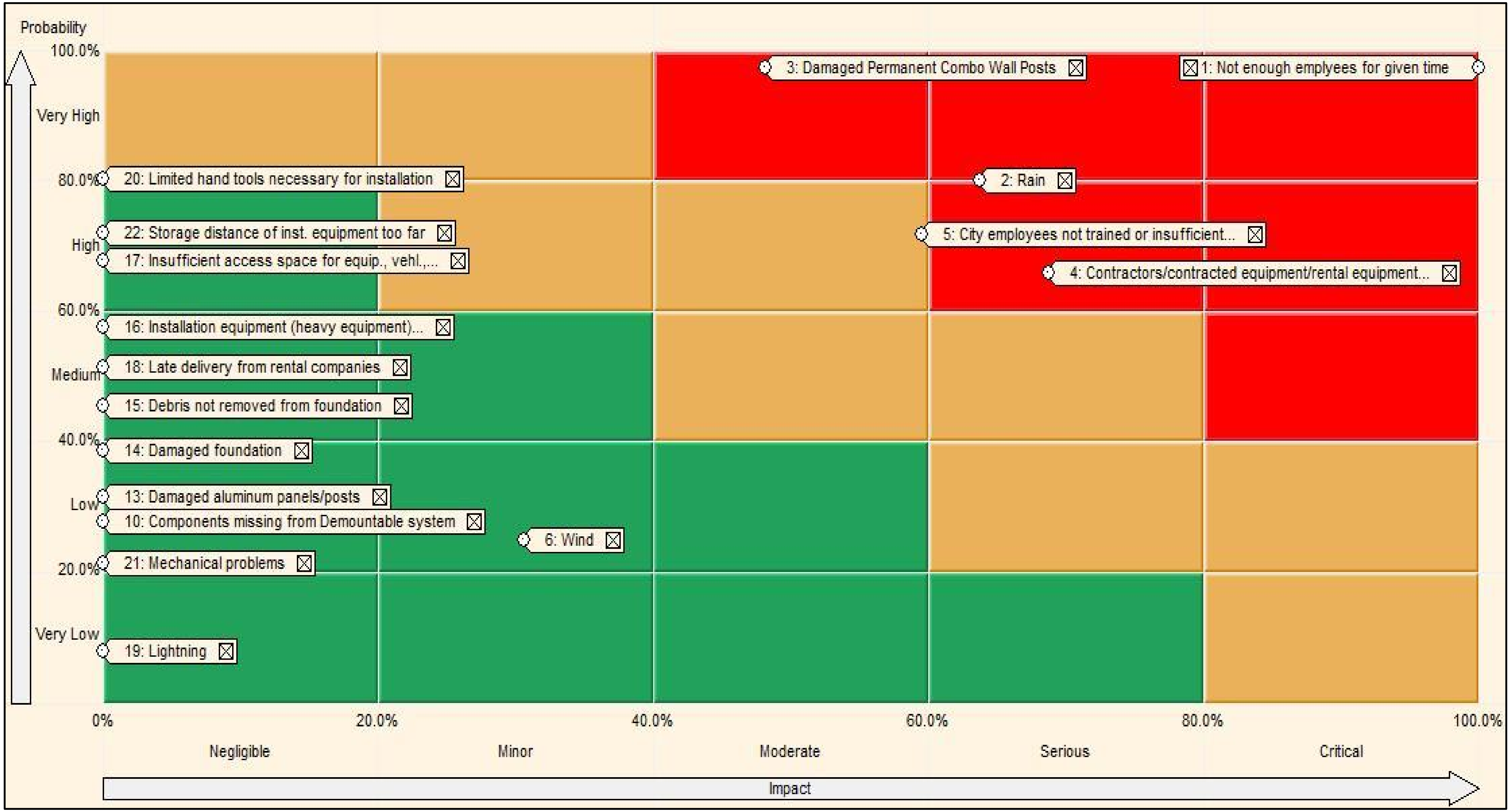


Figure E-13. Phase 2, Task 5.3 Deployment risk matrix.

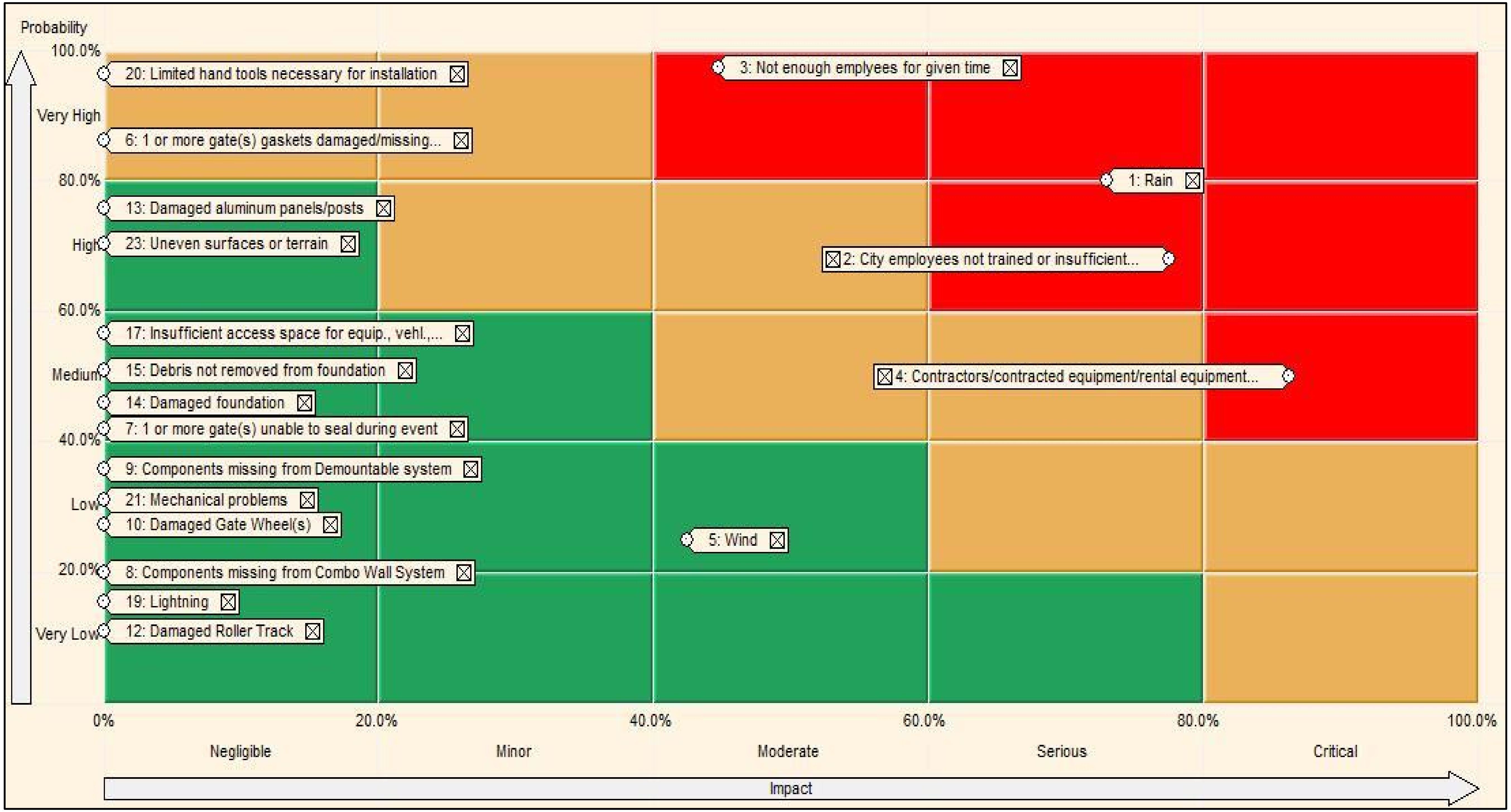
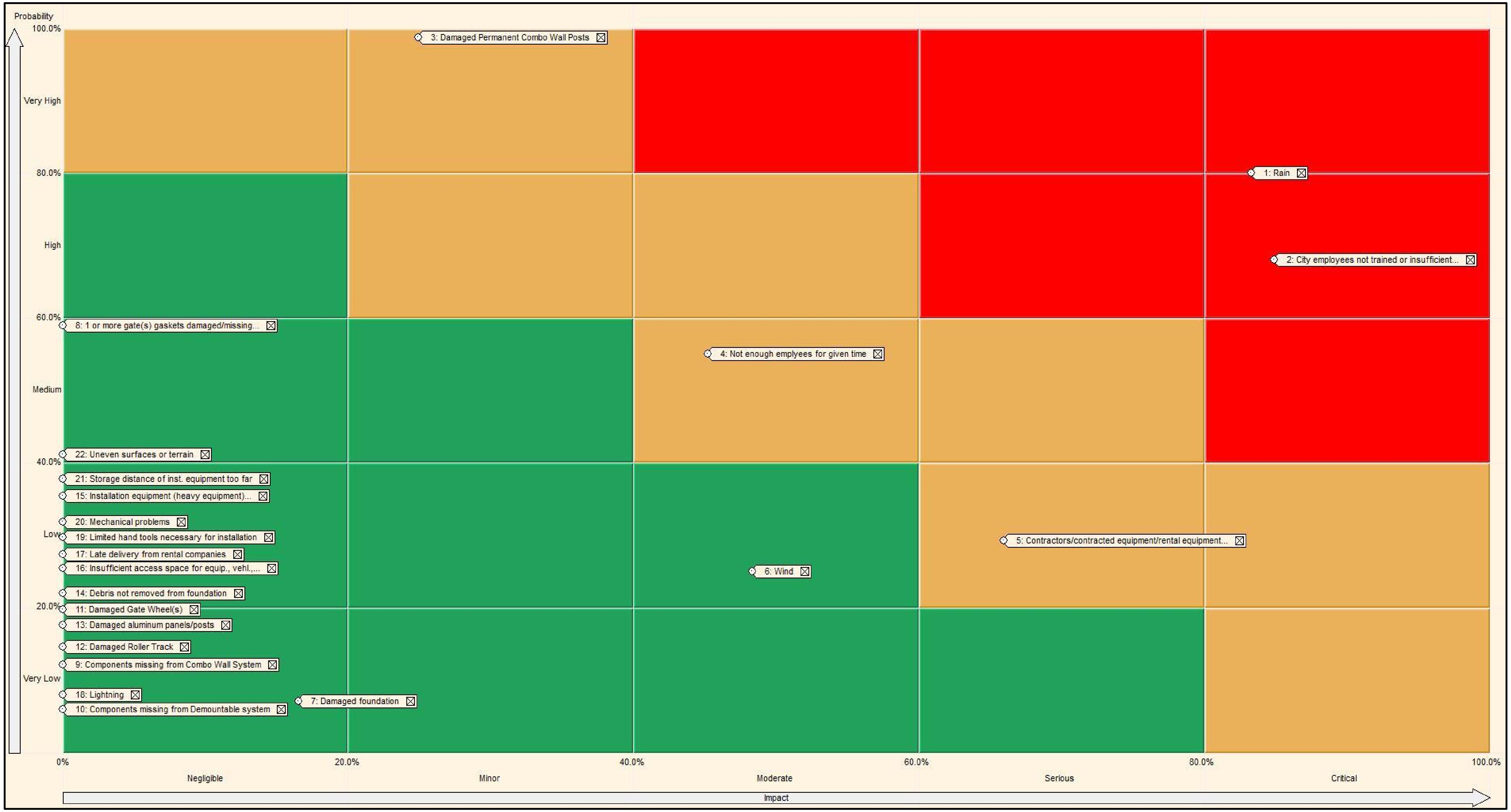


Figure E-14. Phase 2, Task 5.4 Deployment risk matrix.



Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (US statute)	1,609.347	meters
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters

Acronyms and Abbreviations

CHL	Coastal and Hydraulics Laboratory
CRANDIC	Cedar Rapids & Iowa City Railway Co.
DPW	Department of Public Works
ERDC	US Army Engineer Research and Development Center
FCS	Flood Control System
FRM	Flood Risk Management Plan
KML	Key-hole Markup Language
MVR	US Army Engineer District Rock Island
RAR	Risk Assessment Report
RR	railroad
UPRR	Union Pacific Railroad
USGS	US Geological Survey

Glossary

chance: Possibility or probability of a given outcome in a situation that is uncertain. See also *probability*.

closure: The process of installing or shutting the moveable parts of a temporary or demountable flood protection system following the mobilization of resources required to commence the process.

combination walls: A moveable flood protection system that is partially pre-installed and requires operation during a flood event, or one that requires part installation into guides or sockets within a pre-constructed posts. It is made up of demountable sections and permanent columns which act together to form a temporary, removable flood protection system when fully installed.

critical risk: Any risk that may endanger the project from completion.

delay: A duration in time that would be added to a schedule should a risk event occur.

demountable flood protection system: A moveable flood protection system that is not pre-installed and requires operation during a flood event by being installed into a pre-constructed foundation. It is made up of demountable sections that act together to form a temporary, removable flood protection system when fully installed.

demountable section: The section of a demountable flood protection system that can be removed or opened when water levels are not in flood condition.

deployment: The process of mobilization of all required resources and installation or closure of the moveable parts of a temporary or demountable flood protection system. This process is triggered when the water level reaches a pre-determined flood warning trigger (action) level.

duration: The amount of time associated with completing an activity, task, or element of work in a given schedule.

failure: Exceedance of a defined performance threshold or performance indicator.

flood warning trigger (action) level: The flood level normally measured upstream of the deployment area at which the process of mobilization or closure commences.

mean duration: The average of a set of numbers, or the average of the probabilistic outcomes of durations from a Monte Carlo Analysis.

mobilization: The process of communication of the warning trigger (action) level to the deployment team and the transportation of all resources required for the commencement of erection or closure operations.

Monte Carlo Analysis: A simulation-driven, iterative statistical analysis of possible outcomes that generates a curve to reflect the likelihood of given time and cost parameters based on the outcomes of multiple iterations.

probability: A mathematical expression of the possibility or likelihood of occurrence, normally expressed as a percentage.

performance: The creation or achievement of something that can be valued against some stated initial aim or objective.

risk: Any event that may cause a delay in construction. Expressed as a written summary of the event, its implications, and impacts.

trigger: An indicator of the imminent occurrence of a given risk event that serves as an immediate precursor to the occurrence of the risk.

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14. ABSTRACT
The City of Cedar Rapids, Iowa, partnered with engineering firms and the US Army Engineer District, Rock Island (MVR), to develop a Flood Control System (FCS). In 2011, the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL), was tasked with completing a risk assessment of removable floodwalls on the eastern side of the Cedar River. In 2016, ERDC-CHL was asked to include the temporary flood closure barriers on both sides of the Cedar River. Phase 1 of the study consisted of seven alternatives to be considered for the final FCS design, with a goal of a 90% confidence of successful deployment. Phase 2, initiated by MVR, targeted a 95% confidence level. The method used for evaluation was RiskyProject® software. The software used a Monte Carlo method of analysis to determine a range of durations, manpower, and labor costs based on logical sequencing. The results showed that the “Master Plan Minus 400 ft” alternative to be the most efficient for Phase 1. The most efficient alternative for Phase 2 was Task 5.4, which achieved a 95% confidence level of completion within 48 hours. The Phase 1 and the Phase 2 descriptions are detailed within this report.

15. SUBJECT TERMS
Cedar Rapids (Iowa), Cedar River (Minn. And Iowa), Emergency management, Flood control

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