

Quantitative Cost and Schedule Risk Analyses

RISK MANAGEMENT
in Underground Construction

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Schnabel ENGINEERING
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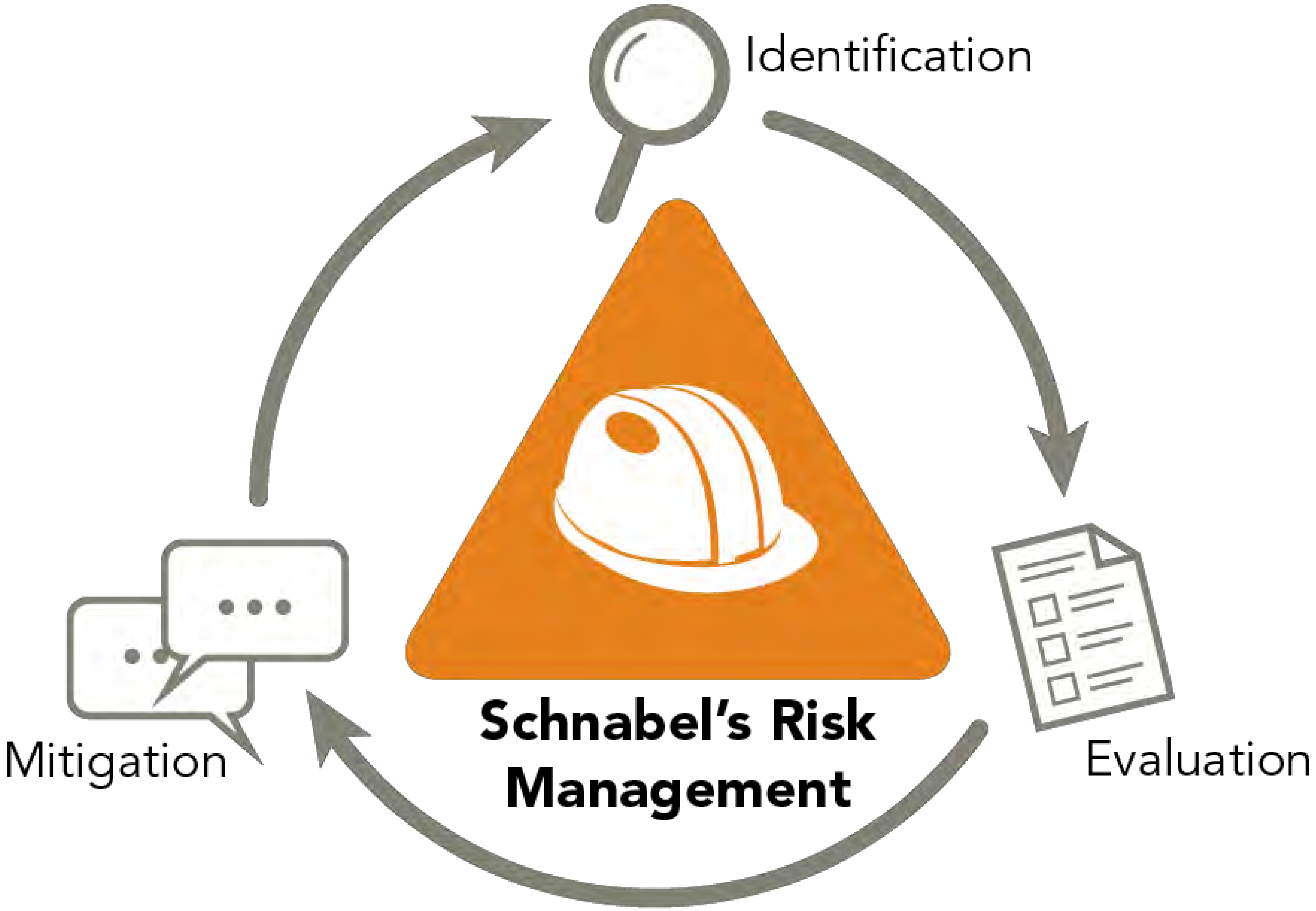
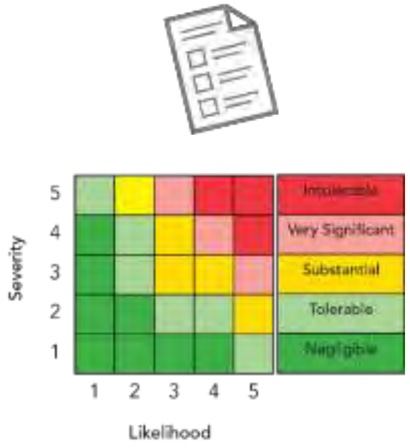
Outline

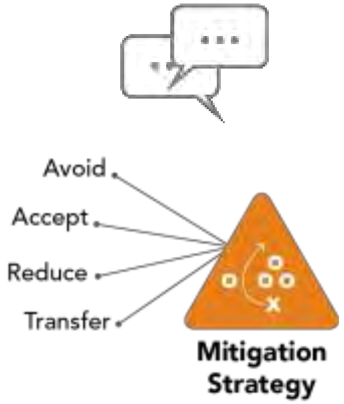
- Qualitative risk analysis recap
- Quantitative cost analysis
  - Workshop and input values
  - Probabilistic distributions
  - Results
  - Applications
- Quantitative schedule analysis
  - Scheduling basics
  - Probabilistic distributions
  - Results
- Brainstorm / Discussions / Questions

Qualitative Risk Analysis Summary



Qualitative Risk Analysis Summary

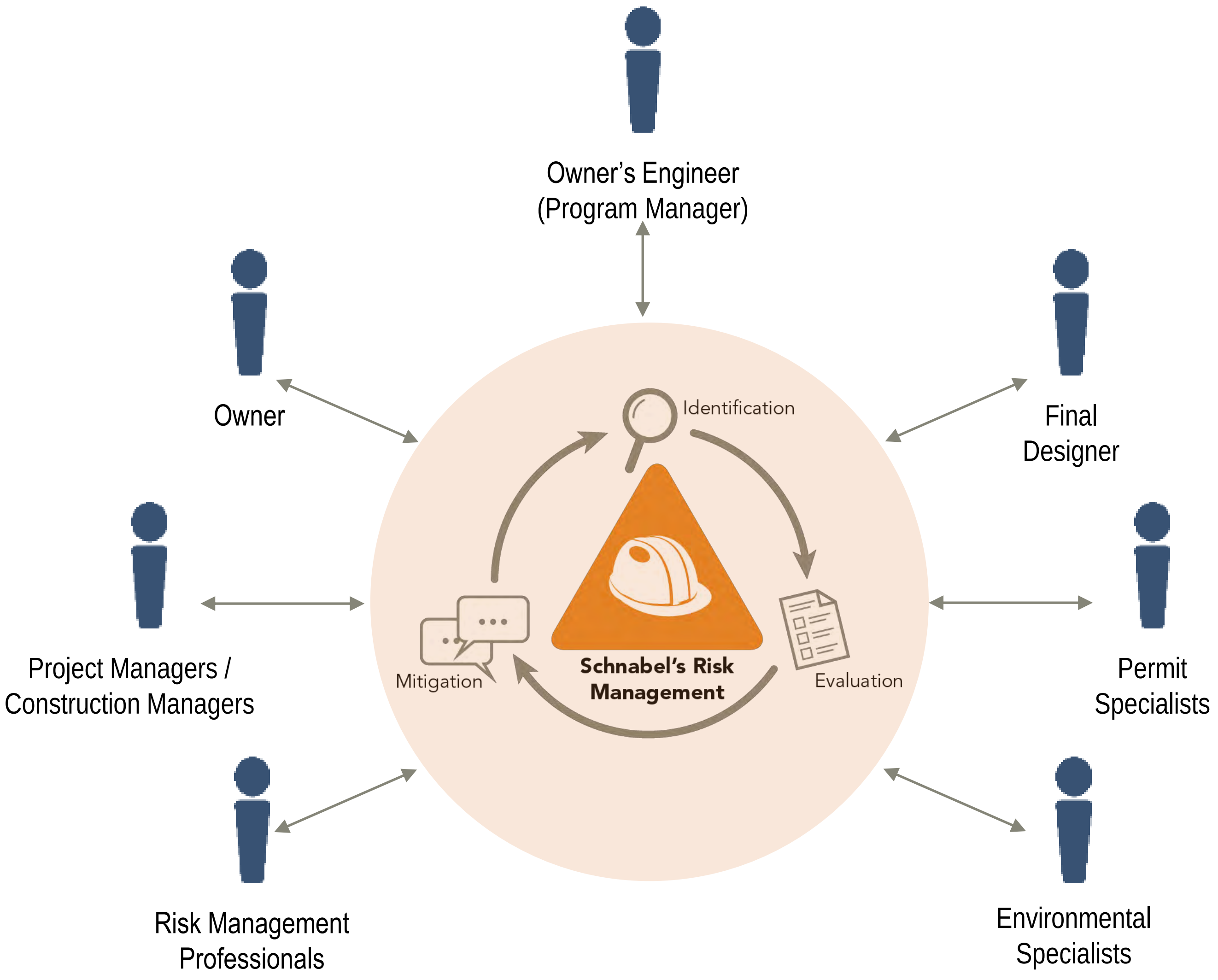




Risk ID	Risk Description	Areas Impacted	Pre-Mitigation Risk Rating			Mitigation Actions	Mitigation Actions Responsibility	Mitigation Actions Status
			Likelihood of Occurrence (L)	Severity (S)	Risk Rating (L x S)			
		S - Schedule C - Cost H - Safety/Health O - Other	1. Very Unlikely 2. Unlikely 3. Possible 4. Likely 5. Very Likely	1. Insignificant 2. Minor 3. Moderate 4. Significant 5. Severe	Intolerable Very Significant Substantial Tolerable Negligible		Owner Designer Contractor Const. Mgr.	Future Ongoing Complete Did not do If necessary
100	**PROJECT PLANNING & DEVELOPMENT - General Planning**							
101	Failure to adequately identify/secure sufficient size staging area(s) for construction.	S - Schedule C - Cost	2	3	6	1. Research necessary size. 2. Sequencing of construction. 3. Identify alternative storage areas.	1. Designer 2. Owner/Designer 3. Owner/Designer	1. Ongoing 2. Future 3. Ongoing
200	**PROJECT PLANNING & DEVELOPMENT - ROW & Easements**							
201	Unable to obtain ROW from local DOT.	S - Schedule C - Cost	2	4	8	1. Submit MOT plans to DOT early. 2. 3.	1. Designer 2. 3.	1. Future 2. 3.
300	**PROJECT PLANNING & DEVELOPMENT - Permits**							
301	Difficulty in obtaining or maintaining permit for dewatering.	S - Schedule	4	3	12	1. Research State requirements. 2. Determine theoretical drawn-down levels. 3.	1. Designer 2. Designer 3.	1. Ongoing 2. Ongoing 3.
302	An unknown permit is required (e.g. air quality).	S - Schedule	4	2	8	1. Research power needs and availability. 2. Develop list of permits. 3. Conduct a permit preapplication meeting.	1. Owner/Designer 2. Designer 3. Designer	1. Ongoing 2. Ongoing 3. Complete
400	**PROJECT PLANNING & DEVELOPMENT - Public Relations/Acceptance**							
401	Local public opposition to road closures/traffic issues associated with construction.	C - Cost O - Other	5	3	15	1. Educate community about project. 2. Identify construction haul and access routes. 3. Identify alternate routes and detours.	1. Owner 2. Owner/Designer 3. Designer	1. Ongoing 2. Ongoing 3. Future

Qualitative Risk Analysis Summary

The risk management process utilizes the input and perspectives from all project stakeholders.



Quantitative Cost Analysis – Workshop and Input Values

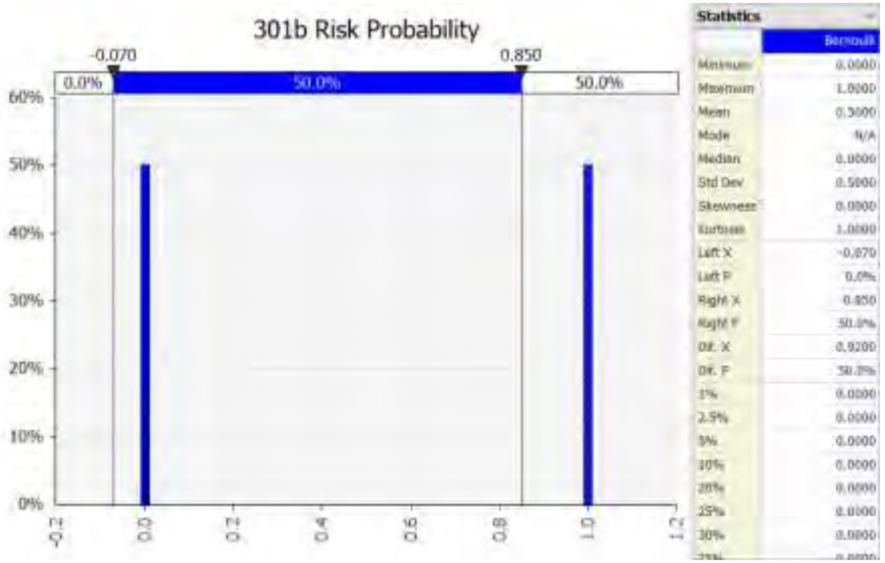
In a collaborative workshop we quantify each cost impact risk by assigning a probability of occurrence and a range of cost consequences in dollars.

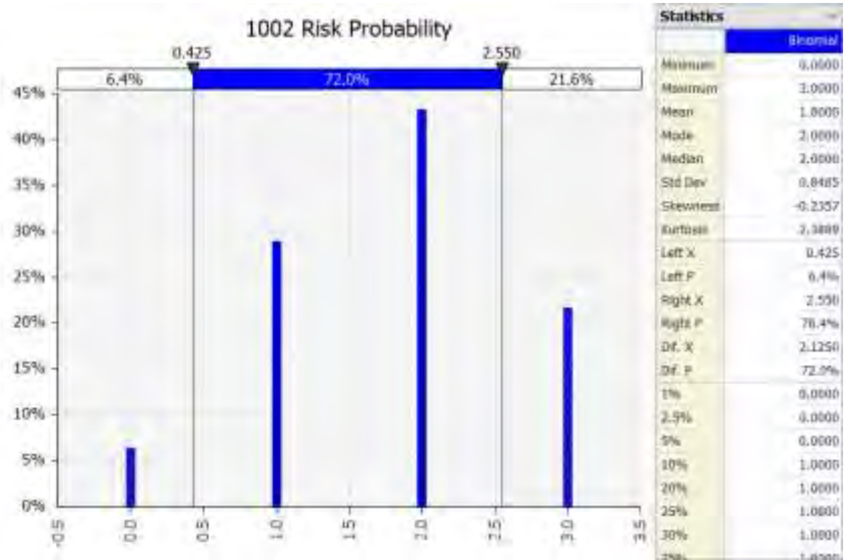
Risk ID	Risk Description	Probability of Occurrence %	Owners Share of Risk %	Multiple Occurrence Possible?	Consequence in $ C				
		P	O	Y/N	Min	10%	50%	90%	Max
900	**CONSTRUCTION - Environmental/Public Impacts (permit non-compliance)**								
903	Contaminated groundwater drawn into excavations resulting in extra cost, time and 3rd party claims	5%	100%	Y	$250k	$300k	$500k	$700k	$750k
904	Contractor encounters cultural or archaeological resources (or potentially cultural or archaeological resources) during construction	90%	100%	Y	$25K	$100K	$250K	$300K	$750K
908	Contractor unable to cut off water from excavations due to multiple SOE systems is used	50%	100%	Y	$0k	$50k	$500k	$700k	$2500k
1000	**CONSTRUCTION - General Site Conditions**								
1001b	Construction fails to complete TBM removal in their 90-day window	50%	100%	N	$100k	$200k	$400k	$750k	$1000k

Cost Impacts = P x C x O

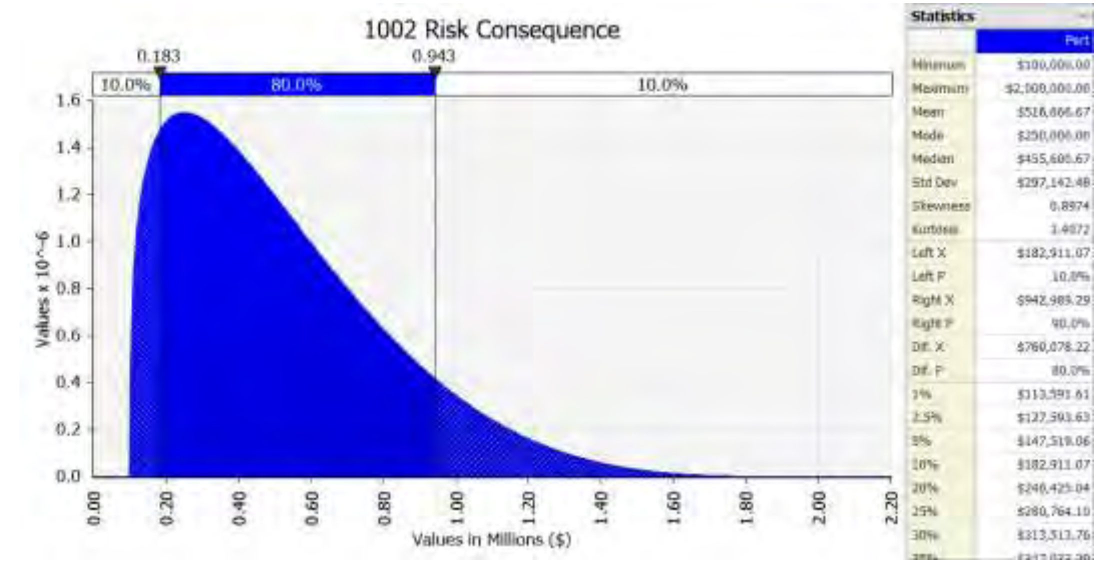
Quantitative Cost Analysis – Probabilistic Distributions

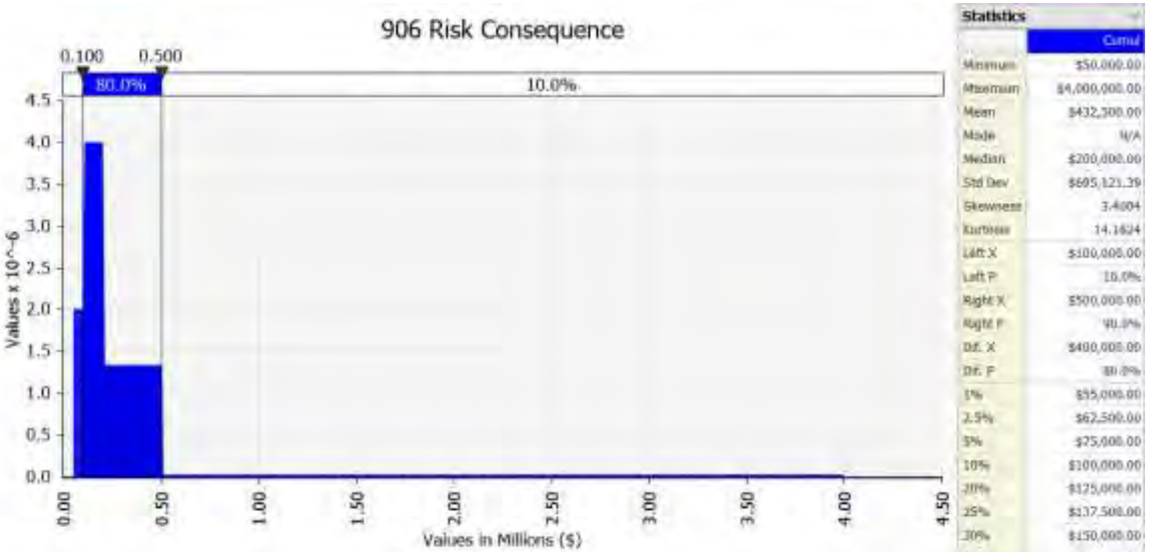
Probability of Occurrence



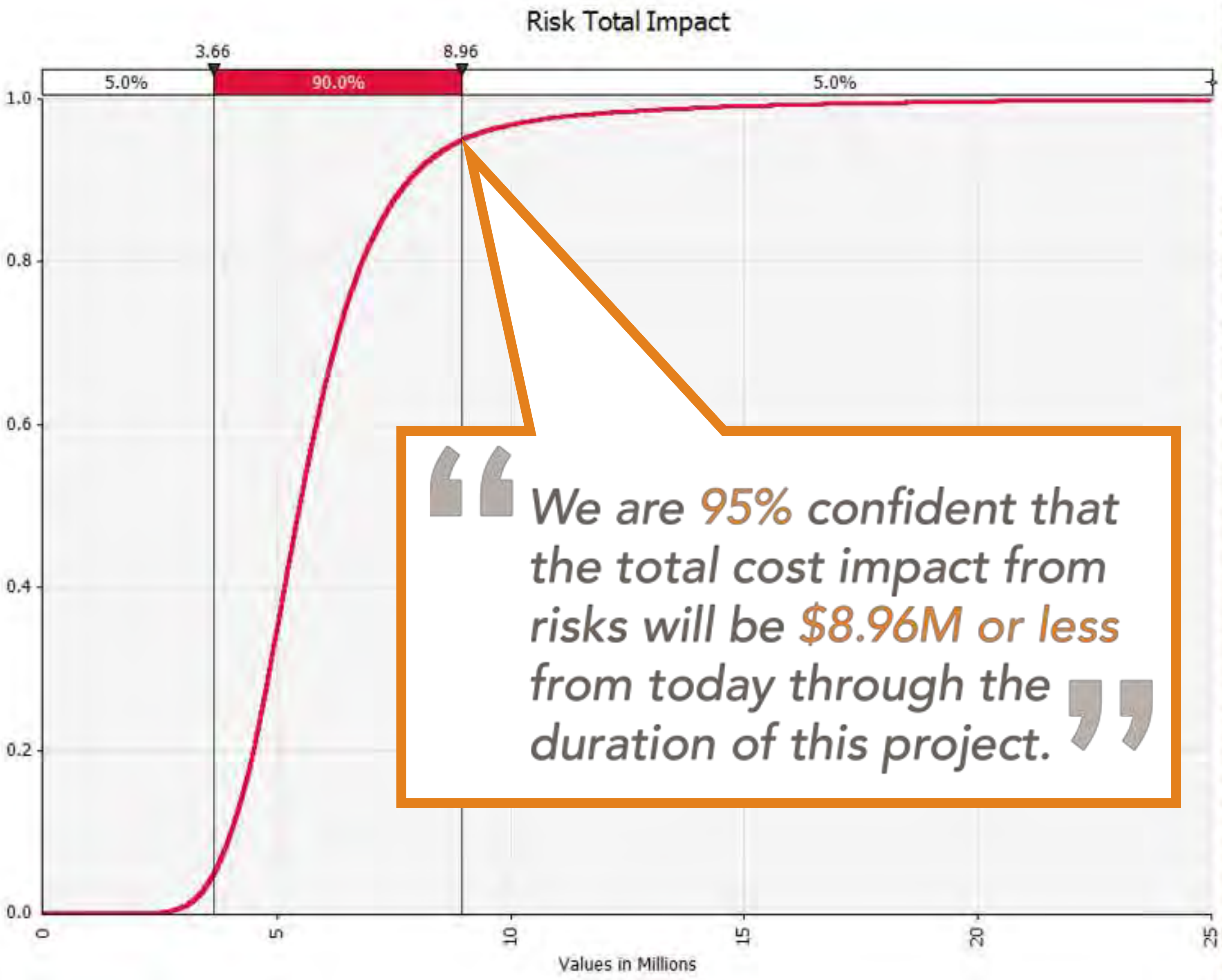


Cost Impact





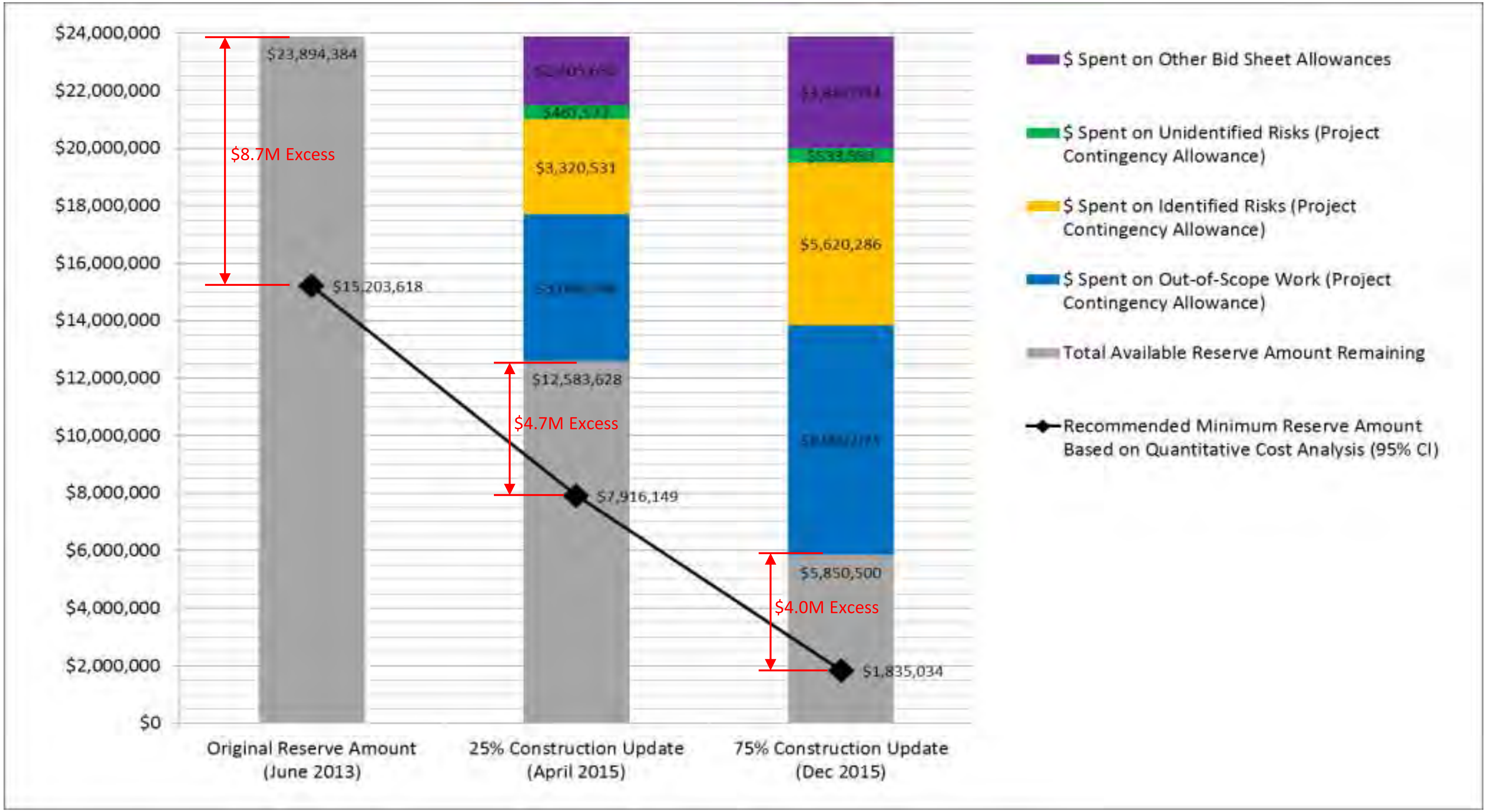
Quantitative Cost Analysis – Results



"We are 95% confident that the total cost impact from risks will be $8.96M or less from today through the duration of this project."

Statistics	Risk Total Impact
Cell	Model Input!N40
Minimum	2,068,530.85
Maximum	44,731,537.01
Mean	5,847,790.91
Mode	5,363,318.61
Median	5,480,507.84
Std Dev	2,047,429.24
Skewness	3.2810
Kurtosis	23.3622
Values	100000
Errors	0
Filtered	0
Left X	3,655,268.23
Left P	5.0%
Right X	8,958,395.72
Right P	95.0%
Dif. X	5,303,127.49
Dif. P	90.0%
1%	3,067,545.79
5%	3,655,268.23
10%	4,016,503.33
15%	4,281,177.80
20%	4,495,389.03
25%	4,674,587.00
30%	4,837,914.75
35%	4,999,721.91
40%	5,156,557.49
45%	5,316,837.94
50%	5,480,507.84
55%	5,648,957.04
60%	5,833,421.40
65%	6,034,870.88
70%	6,253,002.06
75%	6,506,258.14
80%	6,817,282.03
85%	7,222,740.59
90%	7,813,850.38
95%	8,958,395.72
99%	14,243,416.86

Quantitative Cost Analysis - Applications



Step 1: Identify Activities

Step 2: Determine estimated (most likely) Durations.

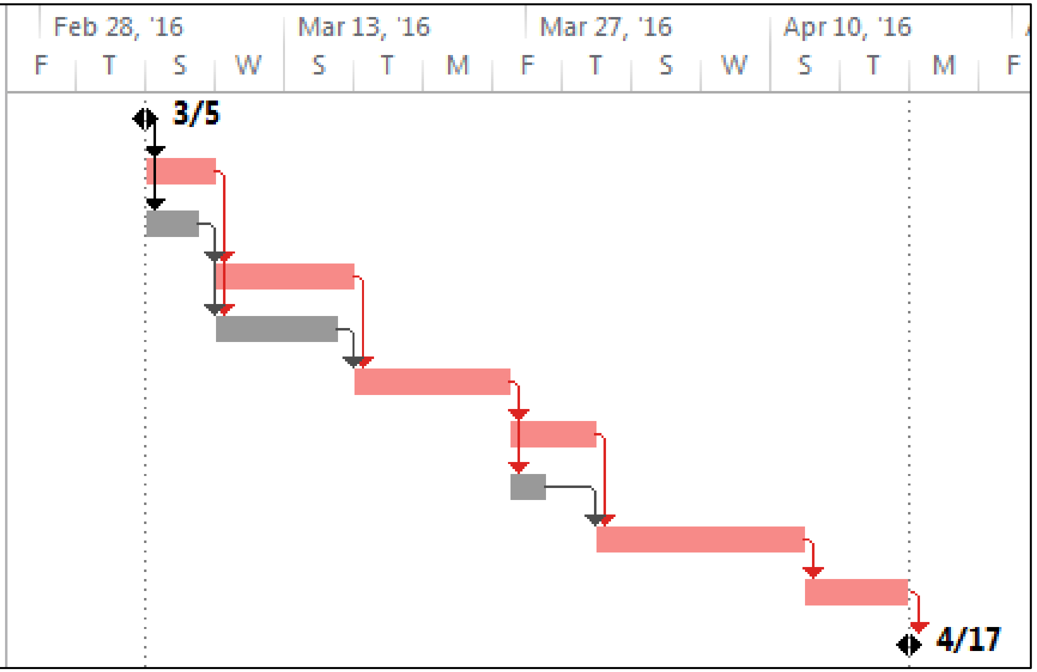
		Task Name	Duration
1		NTP	0 days
2		Site Clearing	4 days
3		Removal of Trees	3 days
4		General Excavation	8 days
5		Grading General Area	7 days
6		Excavation for Trenches	9 days
7		Install Other Utilities	5 days
8		Install Sewer Lines	2 days
9		Concrete Formwork and Rebar	12 days
10		Pouring Concrete	6 days
11		Finish	0 days

Quantitative Schedule Analysis – Scheduling Basics

Step 3: Assign Dependencies. Relationship between two project activities in which the start or end date of one activity depends on the start or end date of another activity.

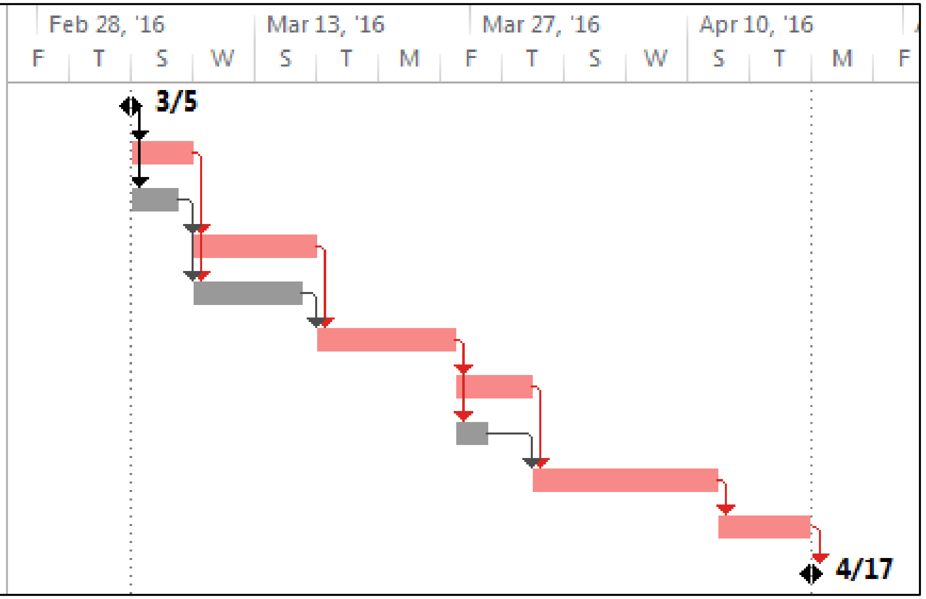
Step 4: The project schedule software calculates each activity's start date, end date, float, and the Critical Path.

		Task Name	Duration	Start	Finish	Prede
1		NTP	0 days	3/5/16	3/5/16	
2		Site Clearing	4 days	3/5/16	3/8/16	1
3		Removal of Trees	3 days	3/5/16	3/7/16	1
4		General Excavation	8 days	3/9/16	3/16/16	2,3
5		Grading General Area	7 days	3/9/16	3/15/16	2,3
6		Excavation for Trenches	9 days	3/17/16	3/25/16	5,4
7		Install Other Utilities	5 days	3/26/16	3/30/16	6
8		Install Sewer Lines	2 days	3/26/16	3/27/16	6
9		Concrete Formwork and Rebar	12 days	3/31/16	4/11/16	8,7
10		Pouring Concrete	6 days	4/12/16	4/17/16	9
11		Finish	0 days	4/17/16	4/17/16	10



Quantitative Schedule Analysis – Scheduling Basics

	Task Name	Duration	Start	Finish	Prede
1	NTP	0 days	3/5/16	3/5/16	
2	Site Clearing	4 days	3/5/16	3/8/16	1
3	Removal of Trees	3 days	3/5/16	3/7/16	1
4	General Excavation	8 days	3/9/16	3/16/16	2,3
5	Grading General Area	7 days	3/9/16	3/15/16	2,3
6	Excavation for Trenches	9 days	3/17/16	3/25/16	5,4
7	Install Other Utilities	5 days	3/26/16	3/30/16	6
8	Install Sewer Lines	2 days	3/26/16	3/27/16	6
9	Concrete Formwork and Rebar	12 days	3/31/16	4/11/16	8,7
10	Pouring Concrete	6 days	4/12/16	4/17/16	9
11	Finish	0 days	4/17/16	4/17/16	10



The critical path can be defined as the longest possible path through the "network" of project activities. Or, the path of activities with zero float.

If activities on this path are delayed then the overall project is guaranteed to be delayed.

There may be “near” critical paths among all the project activities, so the overall project could be delayed by delaying activities along the “near” critical paths.

Quantitative Schedule Analysis – Workshop and Input Values

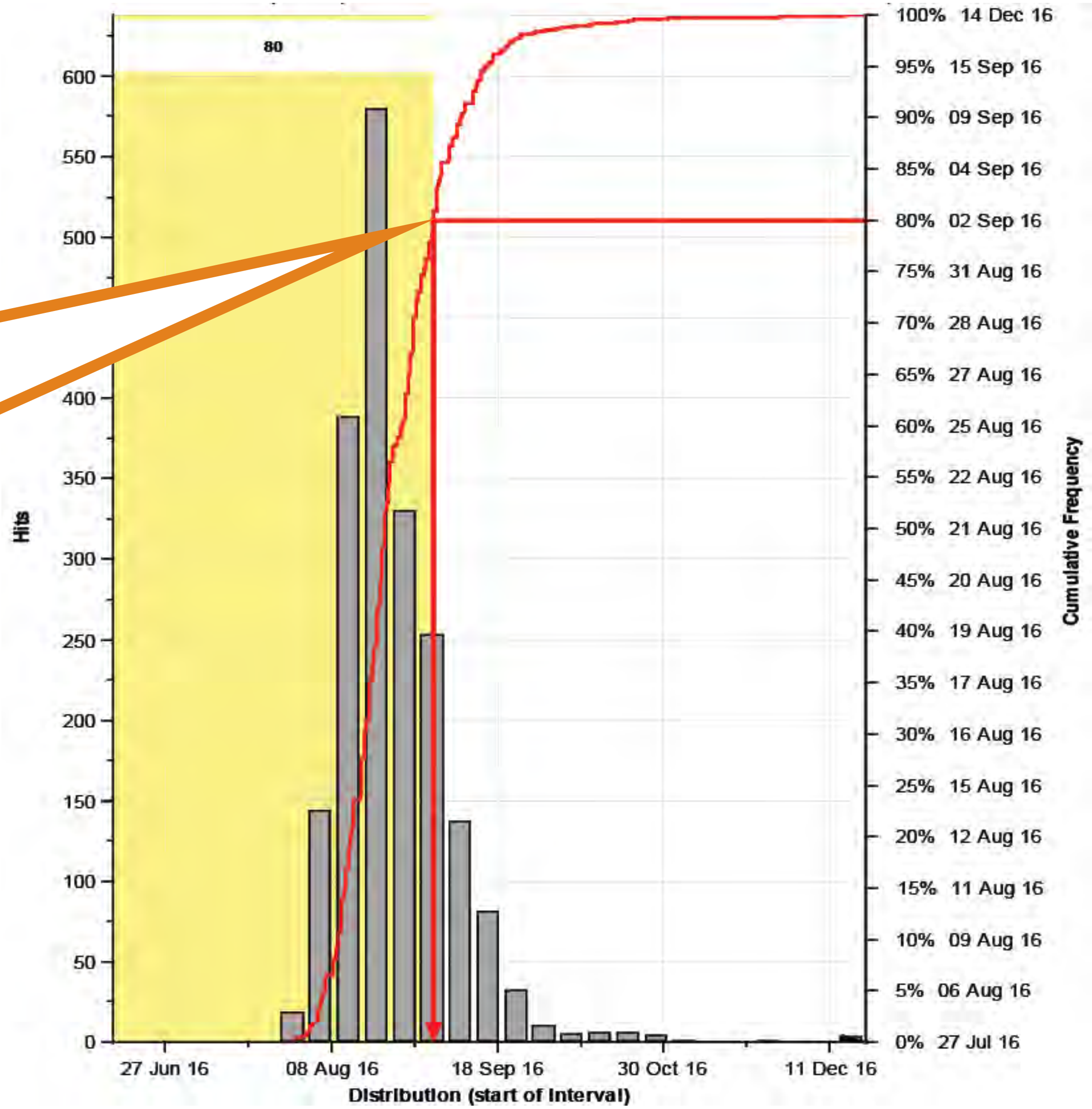
Risk ID	Risk Description	Schedule Activity	Probability of Occurrence %	Consequence in Days		
				Minimum	Most Likely	Maximum
1100						
1103	Tunneling induced settlement of CSX railroad, exceeds allowable limits	**TBM-CON-1120**	**2%**	5	10	20
1107	Existing sewers or utilities are damaged due to age or condition	**CON-VS-1570** **CON-VS-1240**	**20%**	3	5	10

The variability of schedule activities are also assigned >

Activity ID	Activity	Activity Duration		
		Minimum	Most Likely	Maximum
TBM-CON-1120	**TBM mine from Station 0+00 to 12+43**	20	25	35
CON-VS-1570	**Tie-in to existing 36" RCCP water main**	3	5	10

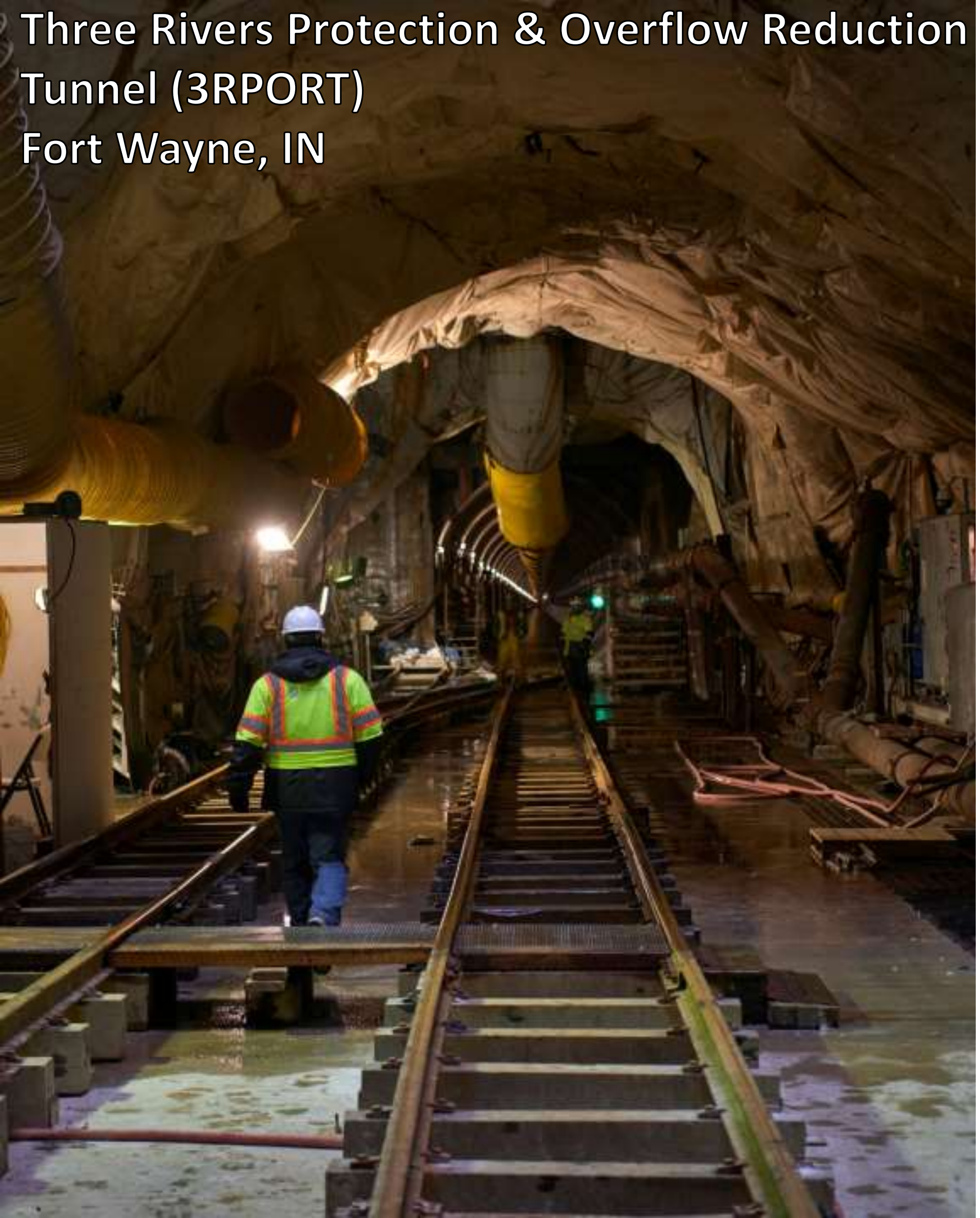
Quantitative Schedule Analysis – Results

"We are 80% confident that, considering the impacts of risks and the estimated variability in selected activity durations, the project will finish on 09-02-16 or earlier."



Quantitative Schedule Analysis – Results

Rank	Description	Deterministic Remaining Duration	Probabilistic P80 Duration	Duration Sensitivity	Criticality Index	Duration Cruciality
1	C-T-23500C-3 - Excavate 659' past the WMATA and 18" Water Sta. 120+95 to Sta. 127+54	10	17	87.97%	53.65%	**47.20%**
2	C-T-23500C-14 - Excavate 100' prior to the WMATA and 18" Water Sta. 111+55 to Sta. 112+55	2	9	91.19%	36.60%	**33.37%**
3	C-T-23500C-4 - Excavate 707.04' to Poplar Point Sta, 127+54 to Sta. 134+61.04	10	14	60.40%	53.65%	**32.40%**
4	C-T-23500C-24 - Excavate 840' under WMATA and 18" Water Sta. 112+55 to Sta. 120+95	12	19	87.89%	36.45%	**32.04%**
5	C-T-23500C-2 - Excavate 1,425' to WMATA Greenline from Sta. 97+30 to Sta. 111+55	20	27	83.93%	36.60%	**30.72%**
6	C-T-23500C-1 - Excavate 3,648.83' from Sta. 60+81.17 under River, 30" and 42" Water to Sta. 97+30	50	59	73.90%	36.60%	**27.05%**
7	C-19-80120-3 - CSO 019 - Excavate NEBTS & Install Struts from (el 15 to el 5)	16	18	11.63%	30.70%	**3.57%**
8	C-19-80125-2 - CSO 019 - Excavate NEBTS & Install Struts from (el 5 to el -5)	14	17	9.05%	30.70%	**2.78%**
9	C-PP-22110-22 - Poplar Point: Backfill and restore around shaft and structure	5	5	6.13%	42.95%	**2.63%**



Brainstorm / Discussions / Questions

Thank You!

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