Attachment 16

Monte Carlo Simulation Strategic and Tactical Risk Documents

Document Front Sheet

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- ☐ **01 – REVIEWED AND ACCEPTED – NO COMMENTS**
- ☐ **02 – REVIEWED – INCORPORATE COMMENTS, REVISE AND RESUBMIT**
- ☐ **03 – REVIEWED - NOT ACCEPTED**
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Monte Carlo Simulation (MCS) Report

Newfoundland and Labrador Hydro

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BAY D'ESPOIR UNIT 8 FEED

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1. INTRODUCTION AND BACKGROUND

1.1 PURPOSE OF THIS DOCUMENT

This document presents the results of the Monte Carlo Simulation (MCS) performed on the Class 3 Cost Estimate ("Cost Estimate") for the Newfoundland Labrador Hydro (NLH) Project **Bay d'Espoir Unit 8 FEED** ("the Project").

Full details on the Cost Estimate itself and its Cost Estimate Basis are presented in AtkinsRéalis Report *"Final Cost Estimate and Basis"* (Document Reference BDE-AKR-00000-EP-EST-0002-01 / 699257-5200-33ER-0001).

1.2 OBJECTIVE AND BACKGROUND

The main objective of the MCS is to provide Newfoundland Labrador Hydro (NLH) with guidance on the appropriate level of Management Reserve for the Project, a key part of the Project Budget. Determining the Management Reserve is an important undertaking since a Class 3 estimate is usually used for Project Sanction.

1.2.1 What is a Project Budget?

A Project Budget is comprised of two (2) items, as follows.

Project Budget = (Cost Estimate) + (Management Reserve)

Cost Estimate refers to the Capital Cost Estimate developed for the scope of work of a Project. For the current project, this is detailed in the document AtkinsRéalis Group Inc. "Final Cost Estimate and Basis." Bay D'Espoir Unit 8 FEED, Newfoundland Labrador Hydro Doc. BDE-AKR-00000-EP-EST-0002-01, November 2024.

Management Reserve is "*an amount added to the Cost Estimate to allow for discretionary management purposes outside of the defined scope of the project*." Simply put, it is an amount of money that reflects the funding organization's level of risk acceptance or risk aversion. Management Reserve has two (2) components, as follows.

Management Reserve = (Cost Estimate Risk) + (Strategic Risk)

Cost Estimate Risk is the estimated cost of risks directly associated with factors specific to the scope of work of the Project, such as uncertainty in quantities, unit prices, and allowances. For this Project, identification and quantification of Cost Estimate Risk was undertaken by Subject Matter Experts (SMEs) and facilitated by the Project Team. This document deals with Cost Estimate Risk.

Strategic Risk is the estimated cost of other risks, such as extraordinary events that cause costly delays to the project or require extra spending to mitigate; inflation; currency exchange exposure; and others, as necessary.

For this Project, identification and quantification of Strategic Risks were undertaken by NLH SMEs and facilitated by the Project Team. Strategic Risk will be dealt with in a separate document.

1.2.2 Using MCS to Guide Management Reserve

It is important to recognize that every number in the Cost Estimate – a quantity, price, allowance, etc. – has come from somewhere, whether engineering drawings, Material Takeoffs (MTOs), historical information, quotations from vendors, best guesses, and so on.

Cost estimates are put together with input from a large number of people, including many from outside sources like vendors and Subject Matter Experts. It's logical, therefore, to expect that this information has been shaped by the personal experiences of the contributors. It is important to understand the level of comfort in a particular quantity or unit price and, from the SME's perspective, understand the reasons why the number could be lower or higher, and possibly how much lower or higher. It is better to think of numbers in the Cost Estimate as "ranges" rather than absolute numbers.

Once these "low and highs" are better understood, the Monte Carlo Simulation (MCS) can be used by Senior Management to decide on the amount of Management Reserve that is appropriate for the Project. MCS is a numerical method used to conduct a quantitative analysis of risks; in this case, the risks of the inputs in the Cost Estimate being higher or lower than the expected value. In other words, if a particular event occurs, how will it affect the cost of the project? MCS provides a range of possible outcomes and probabilities that help guide the establishment of Management Reserve.

1.3 KEY ASSUMPTIONS AND CONDITIONS

1. The Cost Estimate is a "snapshot in time" of the FEEP-stage Scope of Work at the time of the estimate (Q3-Q4 2024). The Risk Model results therefore also reflect the Scope of Work at the time of the Cost Estimate. While scope growth in the next stage of the Project (Detailed Execution Planning, or DEP) was addressed through Design Development Allowances (DDAs), major scope changes such as an increase in the size of the Turbine/ Generator are not covered in these results.

2. Pricing in the Cost Estimate is also based on Q3-Q4 2024 information. Therefore, the ranges for pricing in the Risk Model reflect uncertainty in pricing for that time and are not adjusted for escalation. Escalation (including inflation) and other macroeconomic risks are addressed separately in Strategic Risks.

3. As detailed in the Cost Estimate Basis document, the Cost Estimate is structured according to Advanced Work Packaging (AWP) principles, the optimum construction sequencing (the Path of Construction), and the Work Packaging Plan (WPP) that supports it. Major changes in the DEP stage to the Path of Construction or the Project Delivery Model (assumed EPCM) are not covered in these results.

4. During the MCS Interactive Planning Sessions, the Project Team often discussed the potential cost impact of events that would have an outsized impact on cost, such as delays in the Project Schedule and Contractor Availability/Capability. At the FEEP-stage, some of these reasons could be related to Procurement and Construction, e.g., delays in Turbine/Generator manufacturing or delivery; failure to

enclose the Powerhouse before the winter season; poor labour productivity for the main construction contractor, etc. Other reasons could be corporate level, e.g., sanctioning delays; significant scope changes in the Detailed Execution Planning (DEP) Stage; labour disputes or protests during construction, etc.

5. NLH decided to treat the cost impact of Schedule Delays (or the cost impact to avoid them) as a Strategic Risk. Strategic Risks were assessed in separate confidential MCS sessions with NLH senior management. Other Strategic Risks include macroeconomic factors such as foreign currency exposure, financing charges, escalation (including inflation), and so on.

6. The accuracy of the Cost Estimate affects the level of confidence in the Risk Model results. Cost Estimate Class (e.g., Class 3, Class 4) and Accuracy Index (e.g., Index 2, 3, 4) is based on the Association for Advancement of Cost Engineering's (AACE) Cost Estimate Classification System (see Estimate Basis document). Both the Class and Accuracy Index depends on an assessment of the "maturity level of Project Definition deliverables". The Cost Estimate can be considered as Class 3 with an Accuracy Index of 3. This equates to an accuracy range of -15% to +30%.

7. Note that a Class 3 estimate has an End Usage of "Budget authorization or control", and is the minimum class required for Project Sanction (Gate 3) in the Decision Gate process.

1.4 REFERENCE DOCUMENTATION

- Association for the Advancement of Cost Engineering (AACE). "Documenting the Schedule Basis." Recommended Practice 38R-06, 2009.
- Association for the Advancement of Cost Engineering (AACE). "Cost Estimate Classification System." Recommended Practice 18R-97, 2020.
- AtkinsRéalis Group Inc. "Path of Construction Plan." Bay D'Espoir Unit 8 FEED, Newfoundland Labrador Hydro Doc. BDE-AKR-00000-CS-PLN-0001, October 2024.
- AtkinsRéalis Group Inc. "Final Cost Estimate and Basis." Bay D'Espoir Unit 8 FEED, Newfoundland Labrador Hydro Doc. BDE-AKR-00000-EP-EST-0002-01, November 2024.
- Construction Industry Institute (CII). "Advanced Work Packaging: Design Through Workface Execution." Implementation Resource 272-2, Version 3.0, 2013.
- Construction Owners Association of Alberta (COAA). "Advanced Work Packaging / WorkFace Planning." COP-AWP-PBP-01-2016-v1, July 2016.
- Project Management Institute (PMI). "Project Management Book of Knowledge (PMBOK)." ANSI/PMI 99-001-2004.
- SNC-Lavalin Inc. "Proposed Bay d'Espoir Hydro Generating Unit 8 CLASS 3 COST ESTIMATE AND PROJECT EXECUTION SCHEDULE." SLI Document No. 647756-0000-40ER-I-0002-00, March 22, 2018.

1.5 DEFINITIONS

AACE Association for Advancement of Cost Engineering.

AWP Advanced Work Packaging, a COAA / CII Best Practice.

CDF Cumulative Density Function. A function that gives the probability that a variable is less than or equal to a certain value. For example, the TOTAL COST CDF is a curve developed by the Monte Carlo Simulation that can be used to determine P10, P50, P90, etc., and help guide Management Reserve.

CID Contractor Indirects. Indirect Costs incurred by the construction contractor(s) during the Execution stage of a project (see Indirect Costs).

COAA / CII Construction Owners Association of Alberta / Construction Industry Institute.

Contingency Contingency (or Contingency Allowance) is defined as “funds allocated to address foreseeable but uncontrollable events related to a Work Item.” It does not include “controllable events”, like improved project definition or natural scope growth as the project advances (see DDA). Since it is an allowance, Contingency can generally be expected to be spent.

CWA Construction Work Area. A CWA is a portion of the plot plan that has, during Front-End Execution Planning (FEEP), been defined as a logical area of work. The CWA includes all the relevant technical disciplines required to complete the WORKS. CWAs reside at Level 2 of the Cost Estimate (Level 1 is the total project cost)

CWP Construction Work Package. A CWP is a unit of the project's scope breakdown and defines a logical and manageable division of work within the construction scope. The scope of work is such that it does not overlap another CWP and can be used as a scoping document for Requests for Proposal and Contracts. CWPs reside at Level 3 of the Cost Estimate (see Basis of Estimate document for details on Cost Estimate Levels).

Direct Costs (“Directs”). These are “costs of completing work directly attributable to the performance of the asset” and are necessary for the asset’s completion. Direct Costs are the sum of the CWAs.

DDA Design Development Allowance. An amount (typically a percentage) applied to account for an anticipated growth in Scope of Work in a particular Work Item as engineering advances, e.g., from front-end engineering to detailed engineering stage. Scope of Work growth is foreseeable and controllable when a project advances to the next stage. Since it is an allowance, DDA can generally be expected to be spent. (See also IDA.)

DEP Detailed Execution Planning. The second stage of a project that follows the Front-End Execution Planning (FEEP) stage and is followed by the Execution (Construction) stage.

FEED Front-End Engineering Design.

FEEP Front-End Execution Planning.

IDA Indirect Development Allowance. Like DDA, an amount (typically a percentage) applied to account for an anticipated growth in Contractor Indirects as the project advances. Since it is an allowance, IDA can generally be expected to be spent.

Indirect Costs ("Indirects") These are "costs not directly attributable to the completion of an activity or an asset." Indirects are costs which do not become a final part of the installation, but which are required for the orderly completion of the installation. Indirect Costs are the sum of Contractor Indirects (CID) and Owner's Costs.

Management Reserve "An amount added to the Cost Estimate to allow for discretionary management purposes outside of the defined scope of the project," i.e., an amount of money that reflects the funding organization's level of risk acceptance or risk aversion.

MCS Monte Carlo Simulation. A numerical algorithm that uses repeated random sampling to simulate approximate solutions to calculations that are too complex to analyze in conventional ways.

MTO Material Take-Off.

NLH Newfoundland and Labrador Hydro.

Owner's Costs Owner's Costs include Engineering, Procurement, and Construction Management (EPCM) Costs and Owner's Internal Costs (personnel, overhead, etc.).

Pn nth Percentile. The percentile on a CDF curve of interest to the user, e.g., a "P90 cost" is the cost on CDF cost curve at the ninetieth percentile. This means that ninety percent of the time, the cost will be less than the P90 value. Conversely, the cost will be greater than P90 ten percent of the time.

Pay Item Pay Items reside at Level 5 of the Cost Estimate and are usually where Quantities and Unit Prices are entered.

PVP Procurement Vendor Package. A comprehensive set of documents, drawings, and information is issued to potential suppliers or vendors to solicit bids or proposals for specific goods or scopes of work required for a project.

SME Subject Matter Expert.

WBS Work Breakdown Structure. The WBS is a hierarchical representation of a complete project or program, used primarily to develop the Cost Estimate and later in project controls and accounting.

Work Item (WI) Work Item. Work Items reside at Level 4 of the Cost Estimate (see Basis of Estimate document) and are specific scopes of work within a CWP.

2. MONTE CARLO SIMULATION (MCS)

2.1 SENSITIVITY ANALYSIS vs. MCS

A *Sensitivity Analysis* shows how different values of an independent variable will affect a dependent variable. For example, in the transportation business, the cost per liter of gasoline has a big impact on business profitability, so it is important to examine how variations in the cost of gasoline would affect the profitability forecast. A Sensitivity Analysis – often called a "what-if" analysis – on gas cost would look at how a +/- change would affect, for example, Revenue, Gross Profit, and Net Earnings. The only variable modified in the Sensitivity Analysis is the gas cost (the independent variable). The other variables (Revenue, Gross Profit, and Net Earnings) are dependent and will change as the gas price goes up and down. Similarly, another variable affecting profitability in the transportation business would be the pricing of your services. A Sensitivity Analysis on price of services would look at a +/- change in sale price (the independent variable) and how it would affect Revenue, Gross Profit, and Net Earnings (the dependent variables).

But what if you have dozens or, in the case of a Capital Cost Estimate, hundreds of independent variables? (There are over 300 inputs in the Cost Estimate for CWA 1 alone, plus over 25 additional tabs of detailed information). Trying to do Sensitivity Analyses on certain inputs would be extremely time consuming and complex. A Monte Carlo Simulation (MCS) is an effective tool in this situation.

Monte Carlo methods are a broad class of numerical algorithms that rely on repeated random sampling to approximate solutions to problems that are too complex to analyze conventionally. For Cost Estimates, a Monte Carlo Simulation (MCS) facilitates the analysis of a very large number of possible combinations of Cost Estimate inputs like quantities, unit prices, allowances, etc.

2.2 RISK RANGES IN THE MCS MODEL

To develop the MCS Model, the potential variability in the Cost Estimate inputs was assessed by developing ranges for the following inputs.

1. Quantities
2. Unit Prices
3. Design Development Allowance (DDA)
4. Contingency

Ranges were developed during a series of Interactive Planning Sessions with SMEs from the Engineering and Construction Teams. The Estimate Basis Tables for each Construction Work Package (CWP) and Procurement Vendor Package (PVP) were then updated to document the SME's agreed "Low, Expected, and High" values for Quantity, Unit Price, DDA and/or Contingency. The complete Estimate Basis Tables are included in the Appendices of the Final Cost Estimate and Basis (refer to BDE-AKR-00000-EP-EST-0002-01) and an example is shown in Figure 1 below. These tables were reviewed, discussed, and updated in a second series of Interactive Planning Sessions, focused as Risk Sessions, held with NLH from October 23rd-29th, 2024.

Figure 1: Example of Cost Estimate Basis Tables Incl. MCS Basis

2.2.1 Quantity and Unit Price Ranges

There are hundreds of individual Quantities for Direct Costs in the Cost Estimate spreadsheet (CWAs 1, 2, 3, and 4), plus thousands of others in the 28 tabs of the spreadsheet that support the buildup of both Direct Costs and Indirect Costs. The sources of Quantities are varied, as documented in the Cost Estimate Basis Tables. Risking each of the many thousands of Quantities is not only impractical, but it adds little value to the MCS. This is because, at the FEEP stage, the uncertainty in Quantities is directly related to the level of scope definition and the uncertainty is better assessed through the Design Development Allowance (DDA), i.e., how the SMEs believed that quantities would change in the next stage of the Project (the Detailed Execution Planning Stage). That assessment was based on the maturity of deliverables and the personal judgement and experience of the SMEs. Therefore, most of the uncertainty in Quantities in this Risk Model was considered in the ranges for DDA.

Similarly, there are also thousands of individual supporting Unit Prices in the spreadsheet. The sources of Unit Price information are similarly varied and include informal quotations, historical information, vendor pricing sheets, provincial labour and equipment rates, etc. These sources are also documented in the Cost Estimate

Basis Tables. Risking each of the many thousands of Unit Prices is impractical and adds little value. For this Risk Model, uncertainty in Unit Prices was considered in the following ways.

1. Unit Price Risk Ranges were applied directly to “discrete” items, i.e., Procurement Vendor Packages (PVPs) for Hydromechanical Equipment, Draft Tube Gates, Turbine/Generator, GSU Transformer, etc. Ranges were based on the SMEs assessment of the quality of the vendor quotation and the personal judgement and experience of the SMEs.

2. For other items, uncertainty in Unit Prices was considered in Contingency ranges for Work Item subtotals. As explained in the Cost Estimate Basis document, Contingency was defined as an allowance for “foreseeable but uncontrollable” events (see below) and this definition was applied consistently across the estimate. Therefore, it was reasonable (and efficient) to address Unit Price uncertainty for items such as Auxiliary Mechanical and Electrical Equipment, TS2 Control Building, etc., at the subtotal level through a Contingency range.

3. Most of the Cost Estimate for Civil Works and Contractor Indirects was based on a buildup of Crews (equipment, labour, productivity) for scopes of work including clearing & grubbing, excavation, backfill, concrete placing, and so on. For these items, Crews were assigned a price range of [redacted] and were assumed to be independent inputs. For items with a very specific scope of work, such as Intake Concrete and Powerhouse Concrete, Unit Prices for those scopes were built up from quantities, manhours and Crews. Those Unit Prices were then assigned a range of [redacted] but were assumed to be dependent (meaning that if one of the Unit Prices in the specific scope of work was low or high, all the Unit Prices for that scope of work would also be correspondingly low or high).

4. Some line items in the Direct Costs, e.g., sediment controls, site drainage, pressure testing, etc., were priced as an Allowance based on SME expert judgement and experience. As shown in the spreadsheet, these Allowances were assumed to be at [redacted] and assumed to be independent from all other inputs.

2.2.2 DDA and Contingency Ranges

As defined in the Cost Estimate Basis document, DDA is an amount (typically a percentage) applied to account for an anticipated growth in Scope of Work in a particular Work Item as engineering advances, e.g., from front-end engineering to detailed engineering stage. Scope of Work growth is “foreseeable and controllable” when a project advances to the next stage. SMEs reviewed the Scope of Work with estimators for each Work Item in the WBS and based on their judgement and experience, agreed on an expected DDA amount for that Work Item. Similarly, the SMEs discussed and agreed on a DDA range based on a number of factors, including current scope definition, historical growth data, and personal judgement and experience. As mentioned above, uncertainty in Quantities at the FEEP stage was a major factor in setting the DDA range for each Work Item.

As defined in the Cost Estimate Basis document, Contingency is defined as “funds allocated to address foreseeable but uncontrollable events related to a Work Item.” (This does not mean trying to offset poor project definition or to make a Cost Estimate “more accurate”.) In the MCS Interactive Planning Sessions, SMEs were tasked with identifying possible Contingency events and estimating the possible cost impact if those events occurred. The Estimate Basis Tables document these discussions, and all Contingency ranges used in the

MCS have a basis to support them. As mentioned above, uncertainty in Unit Prices was also considered in establishing the MCS range for Contingency for some Work Items.

2.3 PROBABILITY DISTRIBUTIONS

The next step in the development of the Risk Model was to translate the MCS Basis (the Risk Range information) into probability distributions in the Cost Estimate spreadsheet. For this, the software add-in for Excel known as @*Risk* ("At Risk") was used. (Note that @*Risk* is just one of several software packages, e.g., *Crystal* Ball by Oracle, that can be used to manage an MCS within a spreadsheet environment.)

The Risk Model for the Unit 8 Cost Estimate used over 200 probability distributions that were developed in the following manner (examples are shown in Figure 2 below).

2.3.1 Trigen Function

For each Risk Range in the MCS Basis column of the Estimate Basis Tables, the Low, Expected, and High values were used to specify a triangular probability distribution (a "Trigen function") with three (3) points: a most likely value (the Expected) and two others at the specified bottom percentile (the Low) and the specified top percentile (the High).

The syntax of the Trigen function is as follows.

$$\text{RiskTrigen}(\textit{Low}, \textit{Expected}, \textit{High}, P_{Low}, P_{high})$$

For example, in the @Risk Excel file, the function

$$\text{RiskTrigen}(A1, B1, C1, 10, 90)$$

represents a triangular distribution with 10th percentile (P_{Low}) equal to the *Low* value in cell A1, the most likely value taken from the *Expected* value in cell B1, and the 90th percentile (P_{high}) equal to the *High* value in cell C1.

The majority of the distributions in the Risk Model assumed that the *Low* value was at the 10^{th} percentile (P_{Low} = 10) and that the *High* value was at the 90^{th} percentile (P_{High} = 90). However, where appropriate, the P_{Low} and P_{High} values were adjusted to meet the MCS Basis criteria agreed upon by the SMEs. For example, if the *Low* value could not possibly be less than the *Low* value (like a quantity), then it was assigned at the zero percentile (P_{Low} = 0). Similarly, if a *High* was the absolute maximum that a value could be, then that *High* was assigned at the 100^{th} percentile (P_{High} = 100). These details are shown in the Risk Model in Excel.

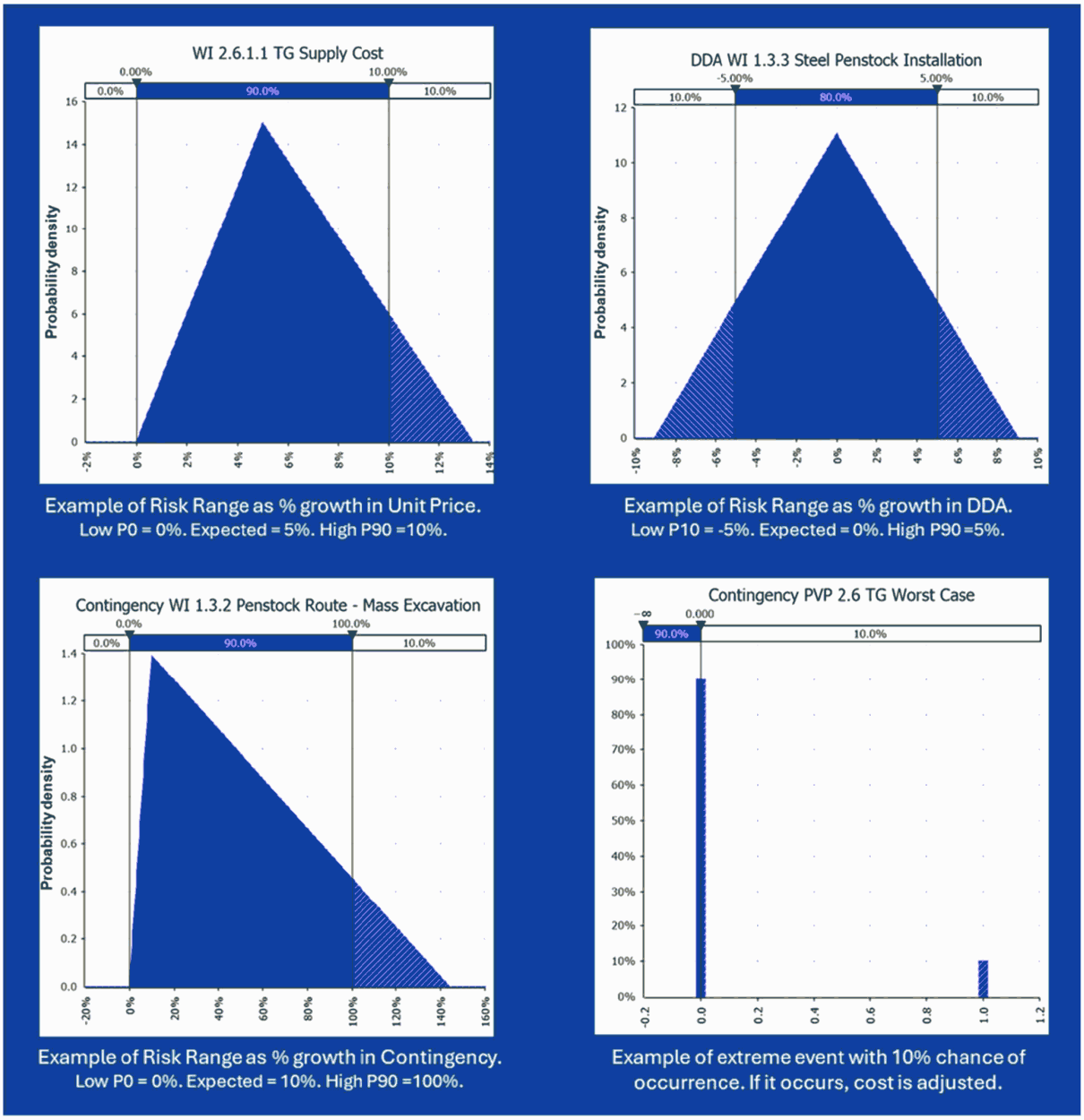


Figure 2: Examples of Probability Distributions in the Cost Estimate Risk Model

2.3.2 Bernoulli Function

In several instances, a specialized probability distribution was used to assess events that the SMEs considered as Extreme but discrete, e.g., an event with a probability of occurring that has a large cost impact but, if the event doesn't happen, has no cost impact. In these instances, the Bernoulli function was used instead of the Trigen. The syntax of the Bernoulli function is as follows.

RiskBernoulli(*p*)

For example, the function

RiskBernoulli(0.10)

has a 10% chance of returning the value of "1" and a 90% chance of returning the value of "0" (see bottom right of Figure 2 above). If the value of "1" is returned, the extreme event has occurred, and the specific cost impact is applied in the Risk Model.

3. RISK MODEL RESULTS

The MCS results presented in this section included the revisions to the Cost Estimate provided by NLH on November 22, 2024, specifically revised costs for CWA 3 and for Owner's Management & Overhead.

3.1 RESULTS FOR "TOTAL COST" OUTPUT

3.1.1 Revised "Expected Cost"

The Total Cost of the Project in the un-risked Cost Estimate, i.e., the "un-risked Total Cost", was $707 MM (rounded to nearest million), which was based on calculations using the Expected value of each Quantity, Unit Price, DDA and Contingency, as documented in the Estimate Basis Tables.

However, one of the benefits of @*Risk* is that it automatically calculates a "new" Expected value for every Risk Input based on the shape of its probability distribution. (In statistical terminology, this Expected value is called the Mode.) Unsurprisingly, most probability distributions for the Inputs are "skewed to the right" because SME judgement was that the chance of an Input increasing was greater than it decreasing.

As a result, most Outputs in the Risk Model return a "new" Expected value that is higher than the value in the un-risked Cost Estimate. For this Project, the "new" Expected TOTAL COST in the Risk Model was calculated by @*Risk* as [redacted] (rounded to nearest million). This equates to lower confidence in the un-risked Cost Estimate total of [redacted]

3.1.2 Risk Model Parameters

The MCS was run in the @*Risk* environment in Excel with the following parameters.

- Number of Input Distributions: 194
- Number of Output Cells Monitored: 85
- Number of Simulations: 10,000

The run-time for the Risk Model was 3 minutes and 4 seconds and the Excel file size, including the saved @*Risk* results, is approximately 41 MB.

NOTE: Since the MCS is an algorithm that samples randomly from probability distributions, the Risk Model results will vary slightly each time the model is run. However, the percentiles of interest (e.g., P50, P90) and the Tornado Chart data will be essentially the same each time.

3.1.3 Cumulative Distribution Function (CDF) Curve for "TOTAL COST"

The results of the MCS are summarized in the cumulative distribution function (CDF) curve for the Output "TOTAL COST" in Figure 3 below. Three (3) important percentiles are shown.

1. The Total Cost before the simulation was run, i.e., the "un-risked Total Cost", was [redacted]. Entering the graph on the x-axis at that value corresponds to a P value of [redacted]. This means that [redacted] of the time, the Capital Cost of this Project would be greater than [redacted].

2. Entering the graph on the y-axis at P50 corresponds to a Total Cost of [redacted]. This means that 50% of the time, the Capital Cost would be greater than [redacted] or less than [redacted]. (In statistical terminology, the P50 value is called the Median.)

3. Entering the graph on the y-axis at P90 corresponds to a Total Cost of [redacted]. This means that 90% of the time, the Capital Cost would be less than [redacted]. Conversely, 10% of the time, the Capital Cost would be greater than [redacted].

3.2 TORNADO CHART FOR "TOTAL COST" OUTPUT

Tornado Charts generated by @*Risk* show how the inputs in the Risk Model drive the behavior of the Outputs. Inputs with the largest impact on the distribution of the Outputs have the longest (and topmost) bars in the Tornado Chart. The way @RISK develops Tornado Charts is complex and is outside the scope of this MCS Report. However, more information is available at the @RISK software's Knowledge Base at the following link. https://kb.palisade.com/index.php?pg=kb.page&id=248

The Tornado Chart also shows the end of each bar that represents high Input values (the blue bar called Input High in the legend) and the end of each bar that represents low Input values (the red bar called Input Low in the legend). The "Baseline", or the centerline of the Tornado Chart, is the overall Mean (or Average) of the Output from the MCS.

Figure 4 below is the Tornado Chart for the Output called "TOTAL COST" and ranks the Inputs from top-to-bottom according to their uncertainty's relative impact on the TOTAL COST Output. For this Risk Model, two (2) Inputs stand out in importance.

1. [redacted] As documented in Estimate Basis Table [redacted] this is an extreme case where, [redacted] of the time, SMEs anticipated that the TG Supply Cost could be [redacted] higher.

   Because it is the top bar of the Tornado Chart, it means that the Input [redacted] has the greatest impact on the shape of the CDF for TOTAL COST compared to all of the other Inputs. In this case, the uncertainty in [redacted] makes TOTAL COST range from between [redacted]. Finalizing the cost for [redacted] will remove this uncertainty.

2. [redacted] Like Item 1 above, uncertainty in [redacted] has a big impact on the CDF for TOTAL COST. However, this is a typical finding for FEEP-stage Cost Estimates and is not unexpected. Since [redacted] for this Project was estimated as a percentage of [redacted], as [redacted] goes up-or-down, so will [redacted].

It is also important to note that some of the bars in the Tornado Chart are more heavily weighted to an increase in TOTAL COST. This means that the impact of uncertainty in those inputs on TOTAL COST is almost always to add more cost, rather than reduce cost. This is also a typical finding and is not unexpected.

Figure 3: Risk Results Summary for TOTAL COST

Figure 4: Tornado Chart for TOTAL COST (Top 10 described below)

1. [redacted] — [redacted] chance that [redacted] could be [redacted] than informal vendor quote.
2. [redacted] — [redacted] was estimated as a percentage of [redacted] at [redacted]
3. [redacted] — [redacted] range of [redacted] for [redacted]
4. [redacted] — Range of [redacted] for the [redacted], which was extracted by SMEs [redacted].
5. [redacted] — Supply Cost [redacted] assumed to vary by the range [redacted]
6. [redacted] — [redacted] for Contractor Legal, Insurance, Financial, and Warranty.
7. [redacted] — NLH specified a range for this Work Item to be [redacted]
8. [redacted] — [redacted] range for installation assumed the same as [redacted].
9. [redacted] — Range of [redacted] for Contingency was applied to the large subtotal [redacted].
10. [redacted] — Range of [redacted], as above.

3.3 RESULTS FOR OTHER OUTPUTS

CDFs and Tornado Charts for the following summary Outputs are included in the Appendix.

1. “CWA 1 TOTAL” (Construction Work Area 1 – Water Conveyance System)
2. “CWA 2 TOTAL” (Construction Work Area 2 – Power Generation)
3. “CWA 3 TOTAL” (Construction Work Area 3 – Transmission)
4. “CWA 4 TOTAL” (Construction Work Area 4 – Terminal Expansion)
5. “CID TOTAL” (Contractor Indirects)
6. “OWNERS COST”

Data for all of the other Outputs is saved in the Risk Model Excel file and can be analyzed with the @*Risk* software installed.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CALCULATING MANAGEMENT RESERVE

The P90 value for TOTAL COST from the MCS was [redacted], including the expected values of Contingency and Design Development Allowance). This value is exclusive of Strategic Risk items like escalation, interest during construction, etc., which were considered by NLH separately.

Should NLH adopt this P90 value as its level of risk acceptance, then…

Management Reserve: Capital Cost = (*P90 value*) – (“*un-risked Total Cost*”)

= [redacted]

= [redacted]

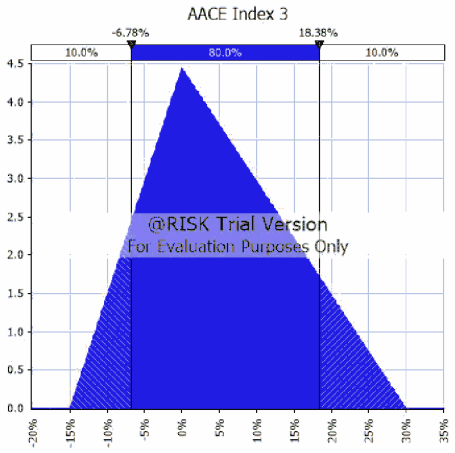
or an additional [redacted] over the “un-risked Total Cost” of [redacted].

4.2 ESTIMATE ACCURACY DISCUSSION

The Cost Estimate can be considered as Class 3 with an Accuracy Index of 3. This equates to an accuracy range of -15% /+30%. Applying this -15% / +30% range to the “un-risked Total Cost” of [redacted] yields a range of [redacted]. The P90 value of [redacted] is within this range, which is the first logical check to support that the Cost Estimate is Class 3. (If the P90 had been outside the -15% / 30% range, it would suggest that the Cost Estimate has a higher Accuracy Index, such as 4 or 5.)

As another check, assume that the -15% / +30% range for AACE Accuracy Index 3 also forms a Trigen distribution bounded at the low end at -15% and at the high end at +30%, as follows.

RiskTrigen(-15%, 0%, +30%, 0, 100)



Applying this Trigen distribution to the "un-risked Total Cost" of [redacted] yields a CDF curve for "AACE Accuracy Index 3". The P90 value of [redacted] from the MCS CDF curve for TOTAL COST is at the P75 on that CDF, which gives further confidence in the Risk Model.

As mentioned earlier, one of the benefits of *@Risk* is that it automatically calculates a "new" Expected value for every Input based on the shape of its probability distribution. As a result, each Output will also have a "new" Expected value. The "new" Expected TOTAL COST in the Risk Model was calculated by *@Risk* as [redacted], which is just below the P50 in Figure 3 above. Applying the Trigen distribution to the "new" Expected TOTAL COST of [redacted] yields an "AACE Accuracy Index 3" Expected value of [redacted], essentially identical to the P90 value for TOTAL COST of [redacted].

While these checks could be argued to be "mixing apples and oranges", i.e., comparing risked-based analyses to a deterministic accuracy range, the similarity in the results lends confidence in adopting the P90 value of [redacted] for the Management Reserve calculation.

4.3 REDUCING ESTIMATE UNCERTAINTIES

NOTE: Reducing uncertainty on inputs (quantities, unit prices, and allowances) in the Risk Model does not automatically mean that the cost of that item also reduces. A "firm quotation" on the [redacted], for example, could be higher than the expected value in this estimate, but there will no longer be uncertainty in that value. However, barring any Strategic Risks affecting the firm quotation, the true cost of [redacted] should fall somewhere on the curve for [redacted] in this Risk Model.

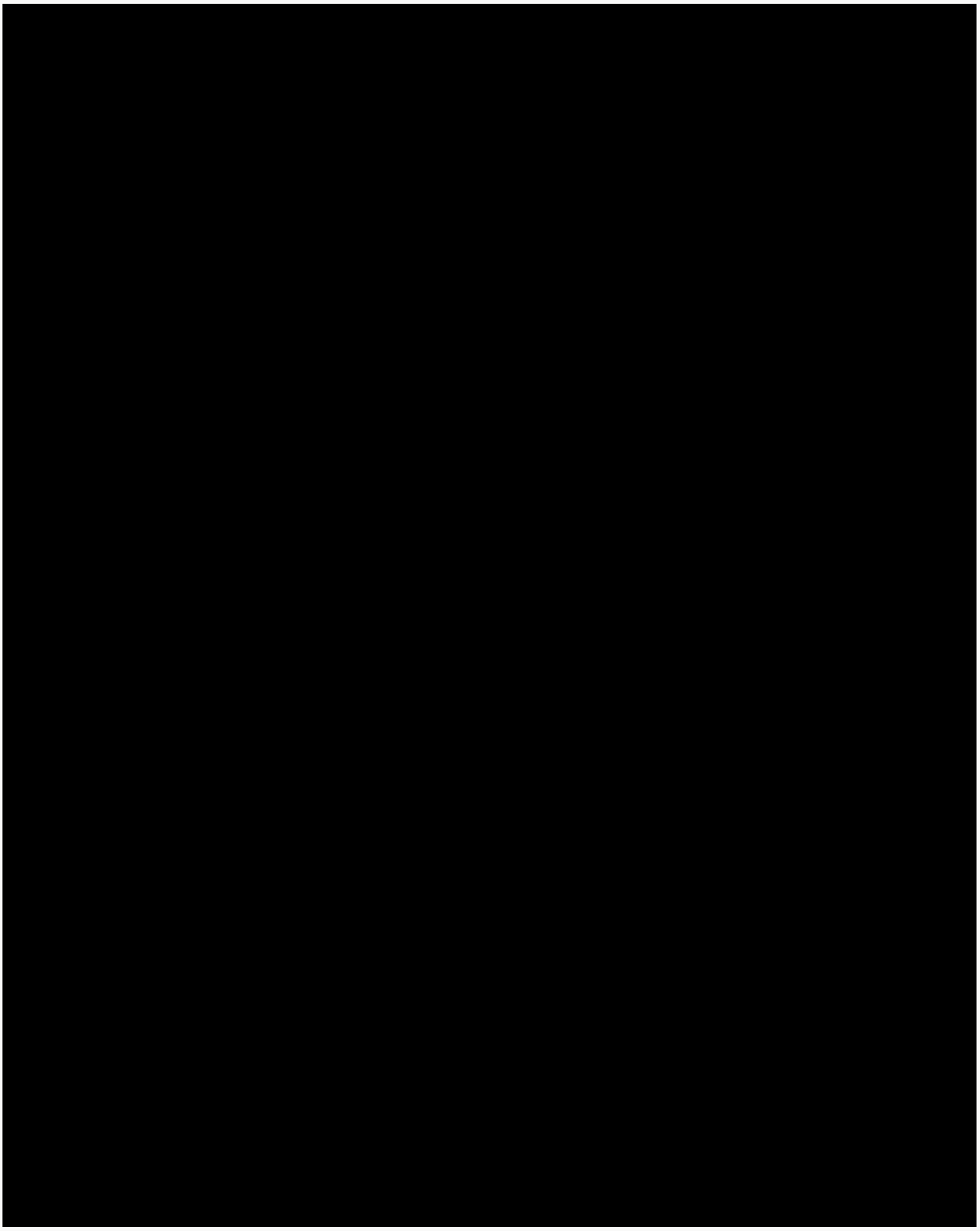
A number of items on the Tornado Chart in Figure 4 can be considered as within NLH's control, i.e., actions can be taken to reduce uncertainty in those Inputs sooner-than-later. These include the following.

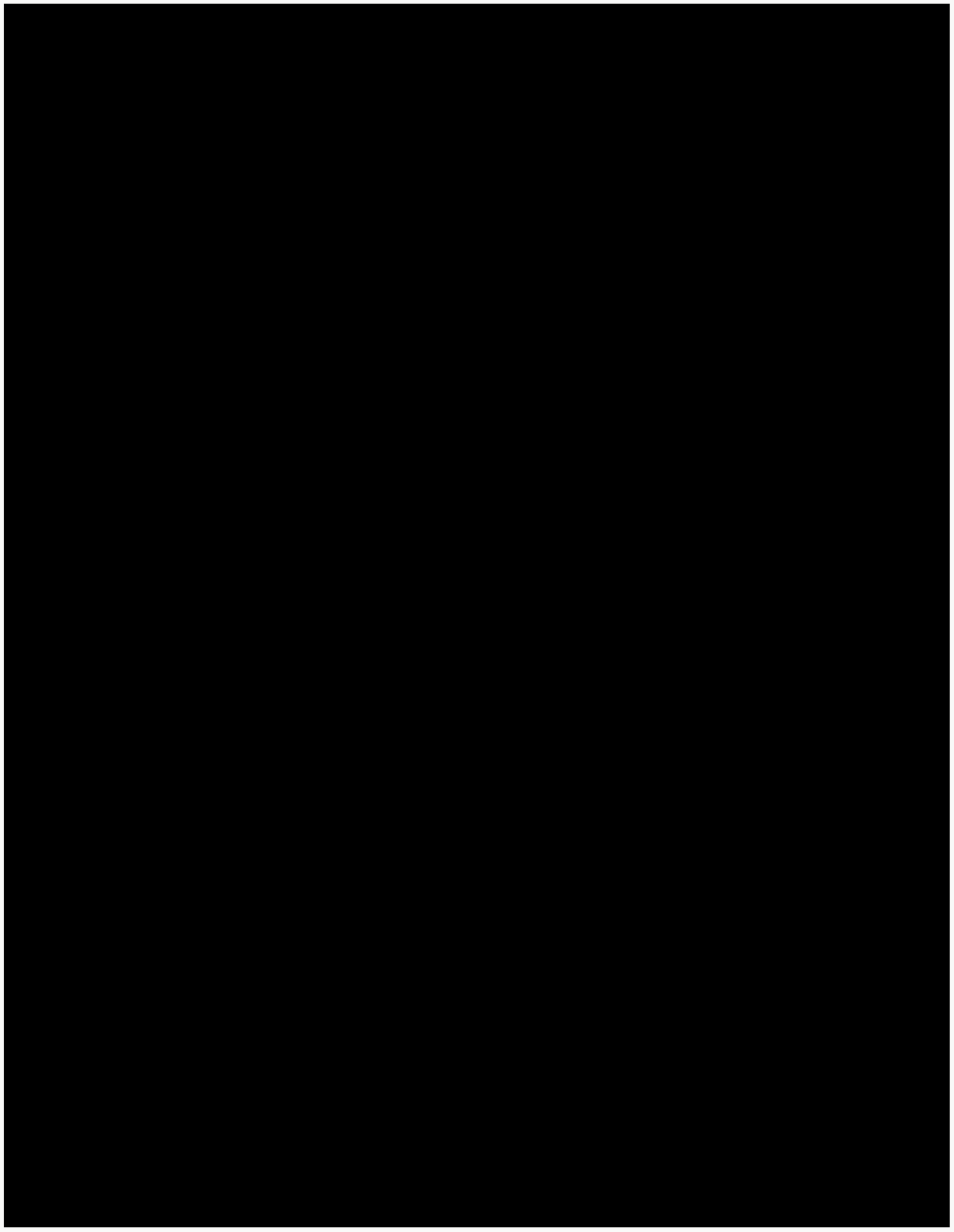
1. Securing firm quotes for the Procurement Vendor Packages (PVPs) that are on the Tornado Chart will mitigate uncertainty in the costs of these Inputs. Getting clarity on these costs will lead directly to less uncertainty in the overall Cost Estimate and a lower amount for Management Reserve. [redacted]
    1. [redacted]
    3. [redacted]
    5. [redacted]
    8. [redacted]
2. [redacted]
3. [redacted]

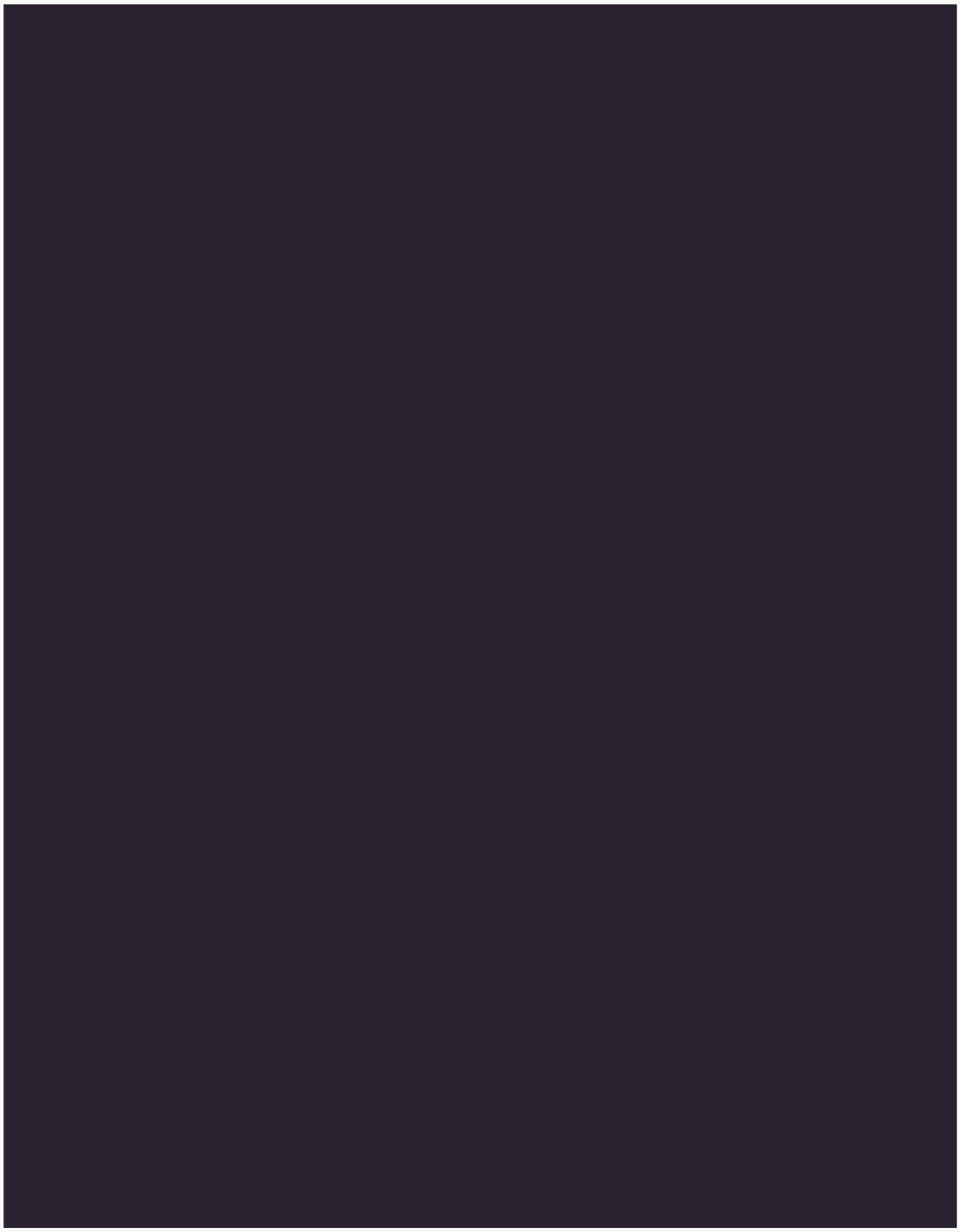
All of the other inputs on the Tornado Chart are "not within NLH's control" at this time. Uncertainties in these inputs will reduce as the Project proceeds into the Detailed Execution Planning (DEP) Stage.

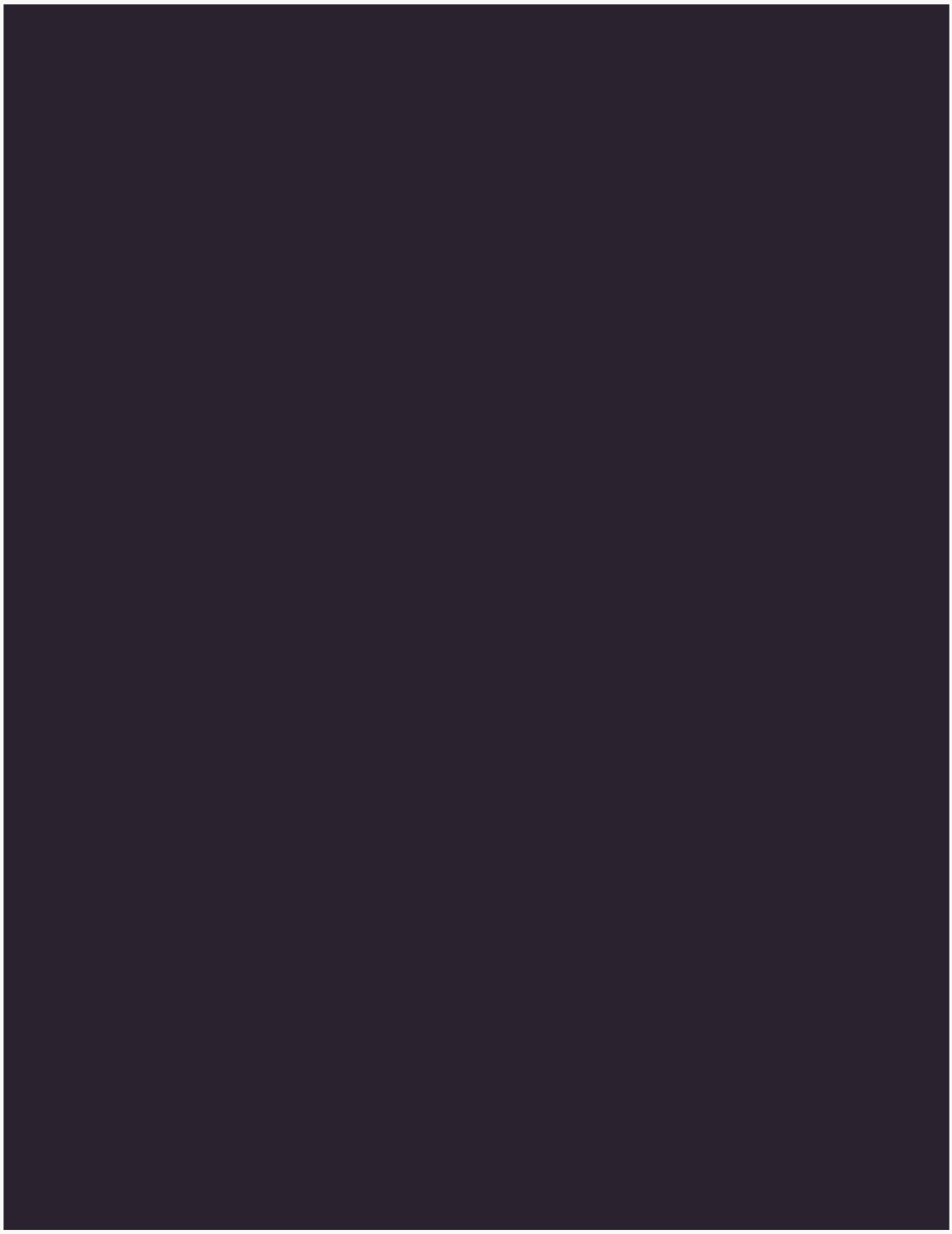
A.1 Appendix

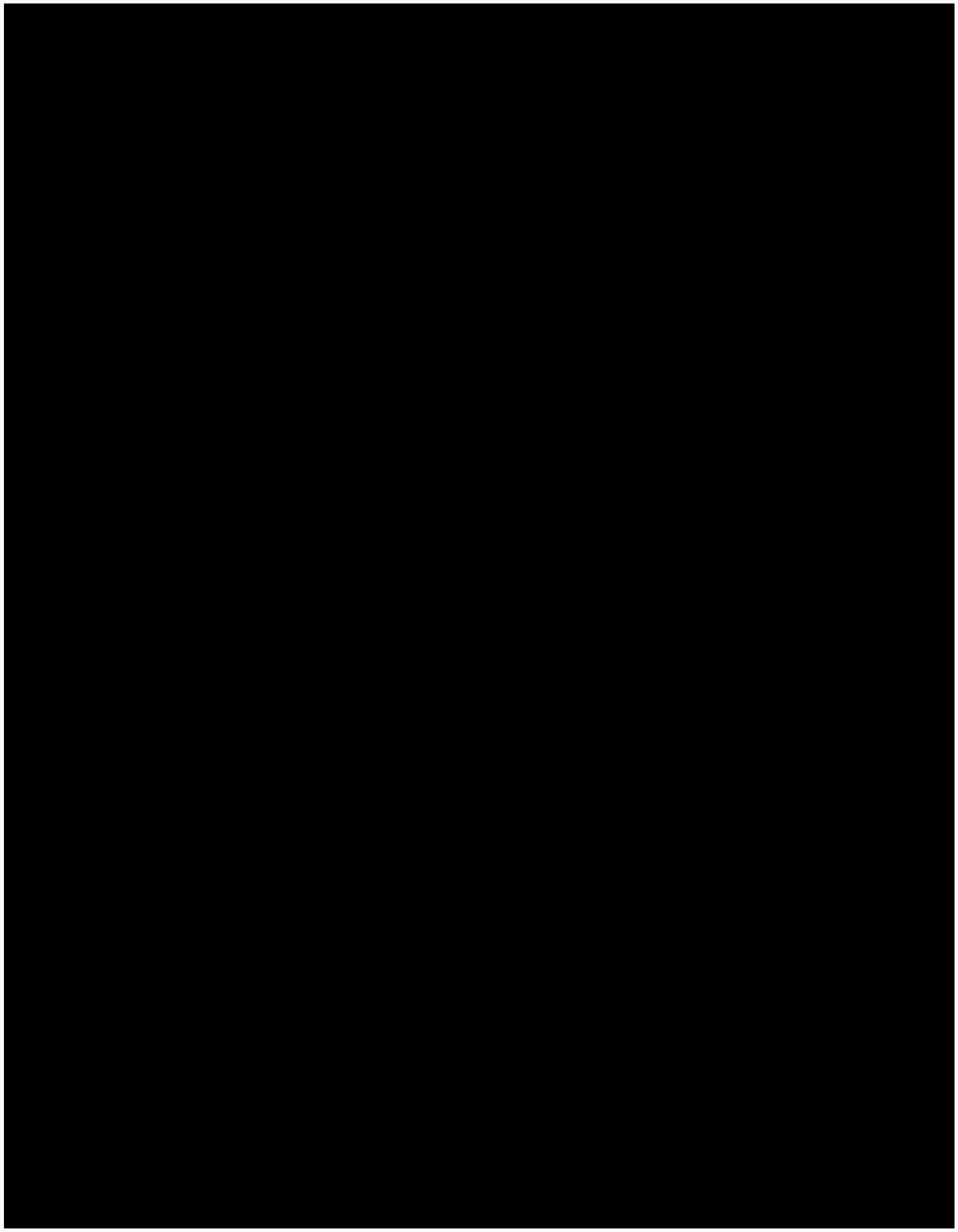
1. Results for @Risk Output “CWA 1 TOTAL” (2 pp.)
2. Results for @Risk Output “CWA 2 TOTAL” (2 pp.)
3. Results for @Risk Output “CWA 3 TOTAL” (2 pp.)
4. Results for @Risk Output “CWA 4 TOTAL” (2 pp.)
5. Results for @Risk Output “CID TOTAL” (Contractor Indirects) (2 pp.)
6. Results for @”OWNERS COST” (2 pp.)

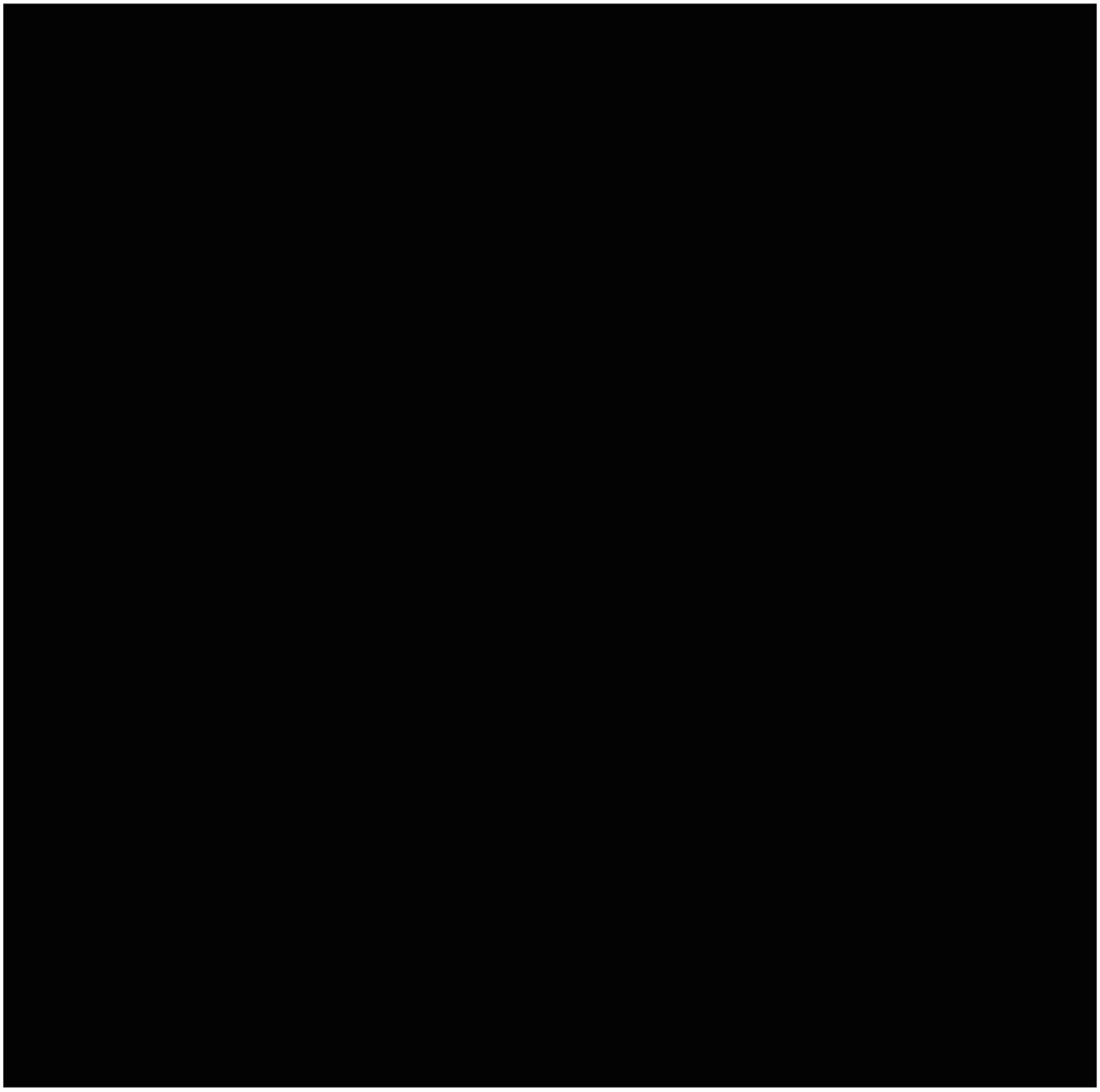


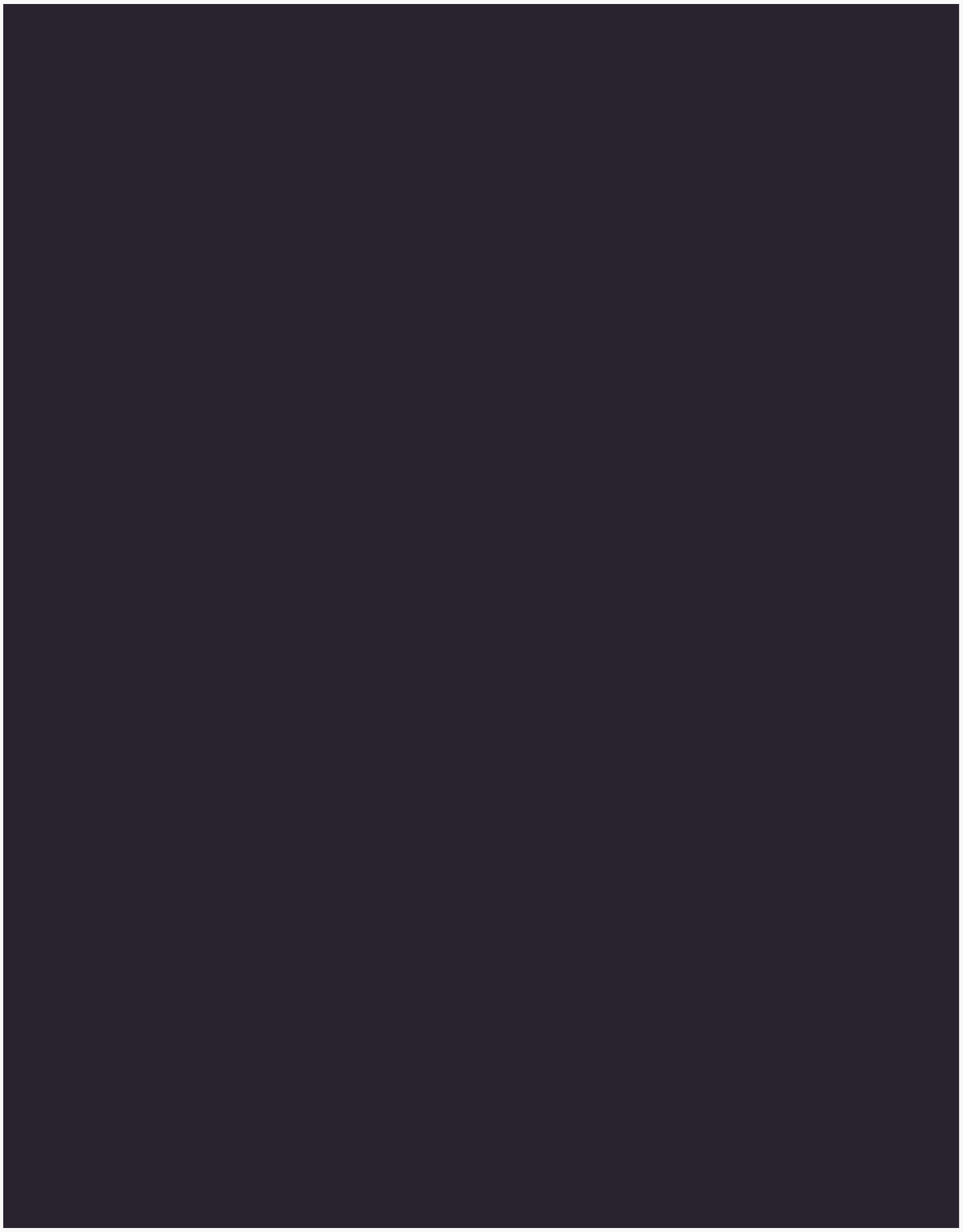












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1 INTRODUCTION AND BACKGROUND

1.1 PURPOSE AND OBJECTIVE

This Brief summarizes results of updates to the Monte Carlo Simulation (MCS) performed on the FEEP-Stage Capital Cost Estimate ("Cost Estimate") for the Newfoundland Labrador Hydro ("NLH") Project **BDE Generation Facility – Unit 8 Addition** ("the Project").

The main objective of the MCS is to provide Newfoundland Labrador Hydro ("NLH") with guidance on the appropriate level of Management Reserve for the Project. Details on the MCS were presented in AtkinsRéalis document "*Monte Carlo Simulation (MCS) Report, BDE-AKR-40000-EP-EST-0001-01, 699257-5200-3JER-0001, November 14, 2024*".

1.2 ABOUT MANAGEMENT RESERVE

A Project Budget is comprised of two (2) items: Capital Cost Estimate + Management Reserve.

Management Reserve is "an amount added to the Capital Cost Estimate to allow for discretionary management purposes outside of the defined scope of the project." Management Reserve has two (2) components: Cost Estimate Risk + Strategic Risk.

Cost Estimate Risk is the estimated cost of risks directly associated with the scope of work of the Project, such as uncertainty in quantities, unit prices, and allowances. Identification and quantification of Cost Estimate Risk was undertaken by Subject Matter Experts (SMEs) and facilitated by the Project Team.

Strategic Risk is the estimated cost of "higher-level" risks, such as extraordinary events that cause costly delays to the project or require extra spending to mitigate; inflation; currency exchange exposure; and others, as necessary. Identification and quantification of Strategic Risks was undertaken by NLH SMEs and supported by the Project Team, as necessary.

1.3 REQUESTED UPDATES TO THE MCS

Updates to the MCS were required based on the following additional information provided by NLH on November 22, 2024, via the *Kiteworks* secure file sharing service.

- Revised costs for CWA 3 and for Owner's Management & Overhead. This information was imported into the Risk Model as spreadsheet tab CWA 3 NLH Nov 8 DJM Rev Nov 23.
- Strategic Risks (SR) developed by NLH. This information was imported into the Risk Model as spreadsheet tab STRATEGIC MCS INPUTS.

The following three (3) specific updates to the MCS were requested by NLH.

1. UPDATE #1: "Re-run cost estimate MCS with revised owner's costs."
2. UPDATE #2: "Run MCS with cost estimate and strategic risk estimate together."
3. UPDATE #3: "Run MCS for strategic risk estimate alone."

1.4 KEY ASSUMPTIONS

Risk Ranges (the *Low*, *Expected*, and *High*) for CWA 3, Owner's Management & Overhead, and Strategic Risks were used to specify triangular probability distributions ("Trigen functions") with three (3) points: a most likely value (the *Expected*) and two others at the specified bottom percentile (the *Low*) and the specified top percentile (the *High*). These distributions were added to the Risk Model spreadsheet and the @RISK software used to manage the MCS updates.

The information provided by NLH on November 22, 2024, was checked only for typos and formula errors. Assessment of the validity of this information was outside the scope of this effort. It was assumed that the Risk Ranges provided by NLH for Strategic Risks were developed and reviewed by relevant SMEs at NLH or under the direction of NLH.

Risk Ranges for Strategic Risks were provided by NLH as a "high level summary," e.g., the cost impact of possible Schedule Delays was consolidated to one line item and a broad Risk Range for the cost impact of "overall schedule delays" provided. Similarly, Risk Ranges for macroeconomic items such as Interest During Construction (IDC), Escalation/ Inflation, etc., were provided as broad ranges applied to the overall project duration rather than at a more granular level (annually or monthly). While this is an acceptable approach, it will arguably lead to more conservative results.

It should be noted that all of the assumptions listed in AtkinsRéalis document "*Monte Carlo Simulation (MCS) Report, BDE-AKR-40000-EP-EST-0001-01, 699257-5200-3JER-0001, November 14, 2024*" also apply to the updates summarized in this Brief.

1.5 DEFINITIONS

CDF Cumulative Density Function. A function that gives the probability that a variable is less than or equal to a certain value. For example, the TOTAL COST CDF is a curve developed by the Monte Carlo Simulation that can be used to determine P10, P50, P90, etc., and help guide Management Reserve.

Management Reserve "An amount added to the Cost Estimate to allow for discretionary management purposes outside of the defined scope of the project," i.e., an amount of money that reflects the funding organization's level of risk acceptance or risk aversion.

MCS Monte Carlo Simulation. A numerical algorithm that uses repeated random sampling to simulate approximate solutions to calculations that are too complex to analyze in conventional ways.

Owner's Costs Owner's Costs include Engineering, Procurement, and Construction Management (EPCM) Costs and Owner's Internal Costs (personnel, overhead, etc.).

Pn n^{th} Percentile. The percentile on a CDF curve of interest to the user, e.g., a "P90 cost" is the cost on CDF cost curve at the ninetieth percentile. This means that ninety percent of the time, the cost will be less than the P90 value. Conversely, the cost will be greater than P90 ten percent of the time.

2 UPDATE #1: MCS ON COST ESTIMATE WITH REVISED OWNER'S COSTS

2.1 UPDATE #1: REVISED "EXPECTED COST"

After the revisions from NLH to CWA 3 and Owner's Management & Overhead, the Total Capital Cost of the Project in the un-risked estimate was [redacted] (rounded to nearest million).

The "new" Expected TOTAL COST in the Risk Model was calculated by *@RISK* as [redacted] (rounded to nearest million). This implies a lower confidence in the un-risked total of [redacted].

2.2 UPDATE #1: CDF CURVE FOR "TOTAL COST"

The cumulative distribution curve (CDF) for the Output "TOTAL COST" is shown in the graph in **Figure 1.1** below. Three (3) important percentiles are shown.

1. The Total Cost before the simulation was run, i.e., the "un-risked Total Cost", was [redacted]. Entering the graph on the x-axis at that value corresponds to a P value of [redacted]. This means that [redacted] of the time, the Capital Cost of this Project would be > [redacted].
2. Entering the graph on the y-axis at P50 corresponds to a Total Cost of [redacted]. This means that 50% of the time, the Capital Cost would be greater than [redacted] or less than [redacted].
3. Entering the graph on the y-axis at P90 corresponds to a Total Cost of [redacted]. This means that 90% of the time, the Capital Cost would be less than [redacted]. Conversely, 10% of the time, the Capital Cost would be greater than [redacted].

2.3 UPDATE #1: TORNADO CHART "TOTAL COST"

Tornado Charts generated by @RISK show how the inputs in the Risk Model drive the behavior of the Outputs. **Figure 1.2** below is the Tornado Chart for TOTAL COST and ranks inputs from top-to-bottom according to their uncertainty's relative impact on the TOTAL COST output. For this Risk Model, two (2) inputs stand out in importance **with no change from the previous MCS**.

1. [redacted]
2. [redacted]

2.4 UPDATE #1: ESTIMATE ACCURACY DISCUSSION

NLH has determined that the Cost Estimate can be considered as Class 3 with an Accuracy Index of 3. This equates to an accuracy range of -15% /+30%. Applying this -15% / +30% range to the "un-risked Total Cost" of [redacted] yields a range of [redacted]. The P90 value of [redacted] is solidly within this range, which is the first logical check to support that the Cost Estimate is Class 3. Similar checks (see AtkinsRéalis document November 14, 2024) lend confidence to support the adoption of a P90 value of [redacted].

Figure 1.1 Risk Results Summary for TOTAL COST: UPDATE #1

Figure 1.2 Tornado Chart for TOTAL COST: UPDATE #1

3 UPDATE #2: MCS ON COST ESTIMATE + STRATEGIC RISK

3.1 UPDATE #2: REVISED "EXPECTED COMBINED TOTAL COST"

Update #2 included the Update #1 revisions (CWA 3 and Owner's Management & Overhead) plus the addition of the Strategic Risks summary. The COMBINED TOTAL COST (total Capital Cost plus Strategic Risks) in the un-risked estimate was [redacted] (rounded to nearest million).

The "new" Expected COMBINED TOTAL COST in the Risk Model was calculated by *@RISK* as [redacted] (rounded to nearest million). This implies lower confidence in the un-risked total of [redacted].

3.2 UPDATE #2: CDF CURVE "COMBINED TOTAL COST"

The CDF for the Output "COMBINED TOTAL COST" is shown in the graph in **Figure 2.1** below.

1. The Combined Total Cost before the simulation was run, i.e., the "un-risked Combined Total Cost", was [redacted]. Entering the graph on the x-axis at that value corresponds to a P value of [redacted]
2. Entering the graph on the y-axis at P50 corresponds to a Combined Total Cost of [redacted] (rounded to [redacted]). This means that 50% of the time, the Combined Total Cost would be greater than [redacted] or less than [redacted].
3. Entering the graph on the y-axis at P90 corresponds to a Combined Total Cost of [redacted] (rounded to [redacted]). This means that 90% of the time, the Combined Total Cost would be less than [redacted]. Conversely, 10% of the time, it would be greater than [redacted].

3.3 UPDATE #2: TORNADO CHART "COMBINED TOTAL COST"

Figure 2.2 below is the Tornado Chart for COMBINED TOTAL COST and ranks inputs from top-to-bottom according to their uncertainty's relative impact on the TOTAL COST output. As expected, two (2) of the Strategic Risks now figure prominently at the top of the Tornado Chart.

1. [redacted]
2. [redacted]
3. [redacted]
4. [redacted]

3.4 COMMENTARY ON UPDATE #2

At [redacted], the "un-risked" cost impact of the Strategic Risks identified by NLH is significant, with the largest contributors being [redacted]. The only significant Strategic Risk potentially under NLH's control is [redacted], which suggests that [redacted] warrant further investigation.

Figure 2.1 Risk Results Summary for COMBINED TOTAL COST: UPDATE #2

Figure 2.2 Tornado Chart for COMBINED TOTAL COST: UPDATE #2

4 UPDATE #3: MCS ON STRATEGIC RISK ONLY

4.1 UPDATE #3: "EXPECTED SR COST"

This update included only the MCS results for the Strategic Risk Inputs provided by NLH. The SR COST in the un-risked estimate was [redacted] (rounded to nearest million).

The "new" Expected SR COST in the Risk Model was calculated by *@RISK* as [redacted] (rounded to the nearest million). This is only around [redacted] higher than the un-risked figure of [redacted].

4.2 UPDATE #3: CDF CURVE FOR "SR Cost"

The CDF for the Output "SR COST" is shown in the graph in **Figure 3.1** below.

1. The SR Cost before the simulation was run, i.e., the "un-risked SR Cost", was [redacted]. Entering the graph on the x-axis at that value corresponds to [redacted].
2. Entering the graph on the y-axis at P50 corresponds to an SR Cost of [redacted]. This means that 50% of the time, the SR Cost would be greater than [redacted] or less than [redacted].
3. Entering the graph on the y-axis at P90 corresponds to an SR Cost of [redacted]. This means that 90% of the time, the SR Cost would be less than [redacted]. Conversely, 10% of the time, the SR Cost would be greater than [redacted].

4.3 UPDATE #3: TORNADO CHART FOR "SR COST"

Figure 3.2 below is the Tornado Chart for COMBINED TOTAL COST and ranks inputs from top-to-bottom according to their uncertainty's relative impact on the TOTAL COST output. Two (2) inputs stand out at the top of the Tornado Chart.

1. [redacted]
2. [redacted]

4.4 COMMENTARY ON UPDATE #3

The Tornado Chart confirms that the Risk Ranges for SR inputs seem to be balanced evenly around the Expected value for each input. While this is not necessarily an issue, it might suggest that the Expected values adopted for the SR Risk Ranges could be conservative (i.e., erring too much on the high side). For example, the un-risked SR Cost of [redacted] adds [redacted] to the un-risked Capital Cost Estimate, which (qualitatively) seems excessive. This figure should be compared against other recent NLH projects to determine if revisiting the SR Risk Ranges is warranted.

Figure 3.1 Risk Results Summary for SR COST: UPDATE #3

Figure 3.2 Tornado Chart for SR COST: UPDATE #3

1 UPDATE #3: MCS ON STRATEGIC RISK ONLY REV. NOV 29

1.1 UPDATE #3: "EXPECTED SR COST" REV NOV 29

This update included only the MCS results for the Strategic Risk Inputs provided by NLH. The SR COST in the un-risked estimate (without Escalation and IDC) was [redacted].

The "new" Expected SR COST in the Risk Model was calculated by *@RISK* as [redacted].

1.2 UPDATE #3: CDF CURVE FOR "SR Cost" REV NOV 29

The CDF for the Output "SR COST" is shown in the graph in **Figure 1.1** below.

1. The SR Cost before the simulation was run, i.e., the "un-risked SR Cost", was [redacted]. Entering the graph on the x-axis at that value corresponds to a P value of [redacted]. This means that [redacted] of the time, the SR Cost would be greater than [redacted].
2. Entering the graph on the y-axis at P50 corresponds to an SR Cost of [redacted]. This means that 50% of the time, the SR Cost would be greater than [redacted] or less than [redacted].
3. Entering the graph on the y-axis at P90 corresponds to an SR Cost of [redacted]. This means that 90% of the time, the SR Cost would be less than [redacted]. Conversely, 10% of the time, the SR Cost would be greater than [redacted].

1.3 UPDATE #3: TORNADO CHART FOR "SR COST" REV NOV 29

Figure 1.2 below is the Tornado Chart for COMBINED TOTAL COST and ranks inputs from top-to-bottom according to their uncertainty's relative impact on the TOTAL COST output.

Figure 1.1 Risk Results Summary for SR COST: UPDATE #3 REV NOV 29

Figure 1.2 Tornado Chart for SR COST: UPDATE #3 REV NOV 29