RegionalWaterAuthority

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March 31, 2022

Members of the Representative Policy Board
South Central Connecticut Regional Water District
90 Sargent Drive
New Haven, CT 06511-5966

Subject: Application to the Representative Policy Board for Approval of the Water Treatment Plants Valve Replacement Program – Lake Gaillard Water Treatment Plant Filter Influent Valve Replacement Project Located in North Branford, CT

Ladies and Gentlemen:

The South Central Connecticut Regional Water Authority requests that the Representative Policy Board (RPB) accept the following enclosed document as complete:

> Application for Approval to the Representative Policy Board of the Water Treatment Plants Valve Replacement Program - Lake Gaillard Water Treatment Plant Filter Influent Valve Replacement Project Located in North Branford, CT

Based on our conclusion that the proposed actions are consistent with the policies and advance the goals of the South Central Connecticut Regional Water Authority, are in the best interests of our customers, and will have no significant adverse impact on the environment, we are further requesting that the RPB approve this action following a public hearing.

Section 1-210(b)(19) of the Connecticut General Statues provides that documents describing critical infrastructure and related operational details of water supply and distribution systems are exempt from public disclosure. This application contains materials that fall within the category of confidential protected information. This material is contained in Appendices A and B of the Application, and is attached separately herein.

To protect this material from public disclosure during Application processing, including public hearings, contemplated by Sections 10 and 19 of the Authority's enabling legislation we are requesting that the RPB take the following protective measures:

- Grant the protective order that accompanies the application.
- Conduct any part of the public hearing on this application that includes detailed discussion of the protected material in a special session closed to the public, including keeping the recording of that session confidential.

Counsel to the Authority and RPB recommends that the procedures put in place for the closed public hearing follow closely the procedures followed by the Public Utilities Regulatory Authority in similar circumstances. You should feel free to follow up regarding details of these procedures directly with counsel.

Any questions regarding this Application may be directed to Sunny Lakshminarayanan, Vice President Engineering and Environmental Services.

Sincerely,

SOUTH CENTRAL CONNECTICUT REGIONAL WATER AUTHORITY

____

David Borowy, Chair
Kevin Curseaden
Anthony DiSalvo
Catherine LaMarr
Suzanne Sack

Enclosures

SL/lm

Application to the Representative Policy Board for Approval of the Water Treatment Plants Valve Replacement Program - Lake Gaillard Water Treatment Plant Filter Influent Valve Replacement Project

South Central Connecticut Regional Water Authority
March 31, 2022

Application for Approval to the Representative Policy Board: Water Treatment Plants Valve Replacement Program - Lake Gaillard Water Treatment Plant Filter Influent Valve Replacement Project

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1. Statement of Application

This application is presented by the South Central Connecticut Regional Water Authority (RWA) to the Representative Policy Board (RPB) of the South Central Connecticut Regional Water District for approval of the Water Treatment Valve Replacement Program - Lake Gaillard Water Treatment Plant (LGWTP) Influent Filter Valve Replacement Project. Section 19 of Special Act 77-98, as amended, requires the RPB's approval before the RWA commences any capital project that will cost more than $2 million. The proposed project will cost approximately $2.69 million.

This project is part of a multi-year program that has been created to ensure that valves at RWA treatment plants are in good working order, providing the ability to operate plants in the most efficient manner, and to allow plant staff to perform preventive maintenance in a safe manner. Valve failures can severely disrupt and shutdown water treatment plants and lead to regulatory violations and public health concerns. Typical valve failures include mechanical breakdown of the gearing, faulty electrical valve actuators, and gasket seating malfunctions. The filter influent valves at the LGWTP have been prioritized in this program, and have been determined to need replacement. The average annual spend for the Water Treatment Plant Valve Replacement program is anticipated to range from $100,000 to $700,000 per year, typically alternating planning and construction years.

As way of background, the LGWTP, located in North Branford, Connecticut, went online in 1986. It is a direct filtration plant that treats water from the Lake Gaillard surface supply. The Lake Gaillard Pump Station, located at the LGWTP, provides treated water directly to the New Haven and Branford service areas, and provides water indirectly to additional service areas through other pump stations and pressure-reducing stations. With a rated capacity of 80 million gallons per day (MGD), the LGWTP is the RWA's largest water treatment facility. The plant was originally designed with a capacity of 60 MGD, and in 1991, the plant's design flow was expanded from 60 MGD to 80 MGD with an additional set of flocculation basins and four filters.

A Capital Improvements Plan (CIP) was completed for the LGWTP in 2004, which evaluated the civil, architectural/structural, process, instrumentation, electrical, and HVAC components of the water treatment plant. Since that time, the RWA has completed various improvements projects throughout the treatment plant. Despite the significant upgrades completed over the last 15 years, many components of the water treatment plant are original and approaching the end of their service life. Another Capital Improvements Plan was completed in 2015, which expanded upon the 2004 CIP, and identified systems and infrastructure that are high priority to be upgraded or replaced due to condition or to improve reliability. The same components evaluated in 2004 were also evaluated in 2015 with the addition of security and safety concerns. The results from the 2015 CIP are included as Appendix B, which were used to develop the LGWTP Filter Influent Valve Replacement Project presented in this application.

Filter operations at the LGWTP are controlled by a series of actuated butterfly valves located in the Filter Building. There are a total of 16 actuated 30-inch filter influent valves which control flow to the filters from the flocculation basin effluent channel. In between these control valves and the flocculation basin are three large feed pipes. The butterfly valves are original to the water treatment facility. They do not seal completely and are leaking. As detailed in the 2015 CIP, the typical design life for automated valves is 25 to 30 years. As valves reach the end of their useful life, they often become obsolete and repair parts are difficult to obtain. Replacement of the 16 critical 30-inch filter influent valves is recommended to maintain the reliability of the LGWTP and prevent unexpected shutdowns from occurring in the future.

The Water Treatment Plant Valve Replacement program will continue work like that specific to this Application. Valves and actuators that are included in the program are located at Water Treatment Plant facilities and are critical to the operation and control of the plants. The valves perform a variety of functions and are both buried or within the WTP. Due to the age and condition of the RWA's treatment facilities, there are many years of work that need to be completed, leading to the need for this program. In the future, periodic replacement of valves through this program will ensure their continued functionality and performance.

2. Description of the Proposed Action

Tighe & Bond, an engineering and environmental services consulting firm, is providing design services for the LGWTP Filter Influent Valve Replacement Project.

The LGWTP Filter Influent Valve Replacement Project will include sequenced isolation of the filter influent trains and subsequent replacement of 16 critical 30-inch filter influent valves with motorized open and close actuators.

The primary challenge with the current conditions at the treatment plant is the inability to isolate the filter influent pipes in order to perform inspection or repair/replacement activities since there are no other isolation valves in the present filter influent system. While a series of stop plank grooves exist in the flocculation basin effluent channel, they do not provide effective means of stopping downstream flow to the filters in order for them to be taken out of service while keeping the remaining filters online. Due to the criticality of the LGWTP, only very brief shutdowns of the treatment plant can be permitted during construction activity.

There is no efficient or effective way to isolate either of the header pipes that feed the majority of the plant filters. Instead, temporary isolation is needed during construction by using 78-inch mechanical plugs at the inlet to each filter influent pipe. The plugs will be installed in one pipe at a time, immediately downstream of where the pipe commences in the flocculation effluent channel distribution chamber. Additionally, drain taps will be installed in the pipe to monitor the plug seal and prevent any leakage from reaching the work area. During final design, the temporary isolation system will be carefully vetted to confirm the proposed approach and minimize cost and risk.

Specifically, the work consists of:

- Demolition/Temporary Provisions
  - Install temporary scaffolding towers for each 30-inch valve replacement
  - Temporarily install stop planks in the flocculation basin effluent channel to stop flow to the filter trains
  - Install mechanical pipe plug in the 78-inch steel header pipes
  - Install three-inch drain taps into filter influent header pipes downstream of mechanical plugs/stop planks to confirm the temporary seals are adequately tight and to drain any flow that seeps past the temporary plugs
  - Sequentially demolish the existing 30-inch filter influent butterfly valves and motorized actuators for Filters 1-16
- Mechanical
  - Sequentially install 30-inch filter influent butterfly valves with motorized open and close actuators for Filters 1-16
  - Insulate associated filter influent train and repair paint to match existing conditions
- Electrical
  - Work for associated wiring and conduit for proposed actuators

This work will result in the replacement of the 16 existing 30-inch filter influent control valves and actuators. This will prevent ongoing leakage which negatively effects plant operations and limits controls. The procurement of the mechanical pipe plug will allow for future inspection and maintenance work (including emergency work) on the piping, valves, and associated equipment as well as increase the safety of future projects which may require complete removal and lockout of plant filters.

3. Need for the Proposed Action

Replacing the filter influent valves will improve the control and reliability of the LGWTP and reduce the risk of unexpected shutdowns. Specifically, it has been determined that this project is necessary based on the following reasons:

- The existing valves do not seal completely and are leaking
    - Leakage results in decreased plant performance during filter maintenance activities
    - Leakage limits the ability to control filter operations
- The existing valves are original to the facility and have exceeded their design life of 25-30 years
- New filter influent valves will increase the reliability of the LGWTP, the RWA's largest water treatment facility
- There is currently no means of isolating the filter influent piping for Filters 1-12. Purchase of a 78-inch temporary mechanical plug would provide the RWA with the ability to provide provisional isolation to these pipes for future maintenance

4. Analysis of the Alternatives to the Proposed Action

In determining the best course of action to address the filter influent valves at the LGWTP, Tighe & Bond evaluated several different alternatives. The alternatives, listed below, included 1) a no-action approach, 2) connecting a permanent isolation system and 3) installing a temporary isolation system – the recommended action.

Alternative 1 – No Action: Not replacing the existing filter influent valves poses operational and reputational risk. If the valves are left online, they will continue to leak and eventually require replacement in the future. Replacement parts for outdated valves are more expensive and difficult to obtain. This alternative may result in an unplanned shutdown of the LGWTP, costing the RWA time and money as well as reputational risk, limiting the RWA's ability to supply reliable, high-quality drinking water to customers. Leakage in the valves is likely to worsen over time and already limits the ability to perform effective filter maintenance activities in the filters and hampers operational flexibility by restricting filter operational flow rates.

Alternative 2 – Permanent Isolation System: Installing a 54-inch butterfly valve on each filter train inside the pipe gallery would provide an improved permanent solution for isolating flow to the filter influent pipes and valves. However, 54-inch butterfly valves are expensive, large, and heavy. Installing four valves 11-feet off the ground would complicate construction and likely extend the length of the project. It would also be difficult to fit and operate these valves in the existing pipe gallery due to their size. This alternative would still require the labor and material cost of using stop planks, draining the pipes, and temporarily plugging the 78-inch headers with a pipe plug. While this alternative would provide the RWA with the convenience of being able to easily isolate flow in the future, it is a costly alternative with high construction risk and is not recommended.

Alternative 3 – Temporary Isolation System: Installing a temporary mechanical plug in the header pipes would effectively isolate flow to the filter influent pipes and allow for the valves to be replaced. One mechanical plug costs less than four 54-inch butterfly valves and requires less invasive and risky construction to the existing system. Additionally, the mechanical plug can be reused by the RWA, providing a solution to the inability to isolate flow in the future. This recommended alternative addresses the aging filter influent valves in a cost-effective and operationally-efficient manner.

The alternatives analysis concluded that Alternative 3 – Temporary Isolation System is most favorable in terms of cost and ease of construction. The temporary isolation system replacement alternative was selected for the following major reasons:

- This is a more cost-effective and operationally-efficient approach to provide a means of isolating flow.
- A temporary plug involves less cutting of existing pipe, repair to insulation and repainting, as compared to the installation of permanent 54-inch butterfly valves for isolation purposes.
- The mechanical plug can be reused for future isolation needs.
- The length of construction will be optimized since mechanical plugs are quicker to install than elevated valves.

5. Statement of the Cost to Be Incurred and/or Saved

5.1 Capital Cost

This project will result in a capital expenditure of $2.69 million including a 15% contingency. A breakdown of the capital cost for this project is presented in Table 1 below, and a detailed breakdown of this cost estimate is contained in Appendix C of this application. The project costs presented are based on a conceptual design prepared in February 2022. In accordance with cost-estimating principles, the project costs have been adjusted for inflation.

For the construction cost estimate, a 15% contingency is included. This is consistent with the American Association of Cost Engineers (AACE) International Recommended Practices and Standards for a Class 3 estimate, which is included in Appendix D. In a Class 3 estimate, the design of the project is expected to be 10% to 40% complete and accurate within -20% to +30%. The AACE defines contingency as a specific provision for unforeseeable elements of cost within the defined project scope, particularly where experience has shown that unforeseeable costs are likely to occur. The 15% contingency allowance is included at this design stage in anticipation of items that will be further defined in subsequent phases of the design process, as well as for uncertainty in future bid prices and as a means to reduce the risk of possible cost overruns.

Due to the escalation of prices, parts and equipment shortages, and supply chain disruptions that have occurred as a result of the COVID-19 pandemic, additional material and bidding contingencies have been factored into the below estimated cost.

TABLE 1
Estimated Project Capital Cost

Cost Description	Estimated Cost
Demolition/Temporary Provisions	$368,500
Mechanical	$809,500
Electrical	$144,000
Construction Subtotal in 2022 dollars:	**$1,322,000**
General Conditions, Overhead, and Profit (20%)	$264,400
Escalation to Mid-Point of Construction – 10% per year	$333,600
Construction Total With Inflation	**$1,920,000**
Contingency (15%)	$288,000
Construction Phase Engineering Services	$280,000
RWA Cost during Construction	$198,720
PROJECT TOTAL:	**$2,686,720**
ROUNDED TOTAL:	**$2,690,000**

5.2 Operation and Maintenance (O&M) Costs

The new filter influent valves will require periodic maintenance to the valve and actuator, but valve maintenance activities tend to be minor. In addition, the limited O&M activities for the new valves will be similar to the existing valves, except that repair parts will be more readily available with the new valves along with the spare parts that are included in the project scope. The replacement of leaking valves will assist with plant operations, allowing for increased flexibility of controls and reduction in wasted water of over 50,000 gallons per day when filters are taken out of service. However, we do not anticipate a significant change in overall O&M costs associated with this project.

5.3 Bonds or Other Obligations the RWA Intends to Issue

"As a result, the annual cost of this project to an average residential customer, assuming a conservative financing assumption of RWA Bonds, would be approximately $0.89, based on the project cost of $2.69 million and existing rates.

For this project we expect to use RWA Bonds as well as internally generated funds."

6. Preliminary Project Schedule and Permitting

6.1 Schedule

The project schedule is presented below.

1.	Preliminary Design:	February 2022
2.	RPB Application	Submitted March 2022
3.	Assuming RPB Approval & Final Design	June to August 2022
4.	Permitting & Bidding	September to October 2022
5.	Award	November 2022
6.	Construction	December 2022 to April 2024
7.	Start-up, Optimization and Punch List	May 2024

Based on the requirement to perform this work during the low-demand season (November to March), we anticipate that active construction on this project will occur from November 2023 until April 2024. With bidding requirements and predicted valve supply lead times, we don't anticipate that active construction will occur during the 2022-2023 winter season.

6.2 Permitting

This project involves replacement of valves inside of the LGWTP Filter Building and will not result in any process changes to the water treatment plant. For these reasons, we do not expect this project will require any special permit approvals from either local North Branford authorities or the Connecticut Department of Public Health.

6.3 Statement of the Facts on Which the RPB Is Expected to Rely on in Granting the Authorization Sought

- Assessing the condition of, and replacing as needed, valves that are critical to water treatment plant operations has been identified as a multi-year capital program that is key to the success of the RWA's company-wide asset management program and its ability to deliver reliable, high-quality drinking water to customers.
- As an 80 MGD capacity facility, the LGWTP is the RWA's largest and most critical water asset. If the facility went offline due to unexpected damage or failure, the impact to the water system and consumers could be significant.
- Temporary provisions to isolate the filter influent flow is the most cost-effective solution to provide flow isolation required to install new valves.
- Mechanical plugs can be reused. This will provide the RWA with the ability to temporarily isolate the filter influent flow in the future to perform repairs or inspections on the filter feed pipelines.

7. Explanation of Unusual Circumstances Involved in the Application

There were no unusual circumstances involved in this Project application. This project is part of a new program to replace aging and underperforming valves at water treatment facilities. The average annual spend for the Water Treatment Plant Valve Replacement Program is anticipated to range from $100,000 to $700,000 per year, typically alternating planning and construction years.

8. Conclusion

The LGWTP is the RWA's largest water treatment plant. It provides water directly to the New Haven and Branford service areas and indirectly to additional service areas through pump stations and pressure-reducing stations. The proposed valve replacement will optimize construction and cost, while improving the overall reliability of the LGWTP.

At $2.69 million, the LGWTP Filter Influent Valve Replacement Project maximizes the cost and non-cost benefits for the RWA.

As such, the RWA has concluded that the proposed recommended action is consistent with and advances the policies and goals of the organization and provides public health benefits to our consumers.

Appendix C

Engineer's Opinion of Probable Cost for Lake Gaillard Water Treatment Plant Filter Influent Valve Replacement Project

Lake Gaillard Water Treatment Plant Filter Influent Valve Replacement

Opinion of Probable Construction Cost

South Central Connecticut Regional Water Authority

February 2022

ITEM	DESCRIPTION	UNITS	QTY	UNIT PRICE	SUB TOTAL	INSTALLATION	TOTAL
1.	**Demolition/Temporary Provisions**						**$368,500**
	30" Filter Influent Valves	EA	16	$2,500	$40,000	N/A	$40,000
	Electrical Demolition	EA	16	$1,000	$16,000	N/A	$16,000
	Scaffolding Towers - Each 30" valve	EA	16	$5,000	$80,000	N/A	$80,000
	Stop Logs in Floc Basin Effluent Channel	EA	3	$5,000	$15,000	N/A	$15,000
	78-inch Mechanical Plug	EA	2	$25,000	$50,000	$50,000	$100,000
	3" Drain Taps on 78-inch pipe	EA	4	$2,500	$10,000	N/A	$10,000
	Shutdown/Coordination Meetings	LS	1	$5,000	$5,000	N/A	$5,000
	Hazardous Materials Allowance	LS	1	$2,500	$2,500	N/A	$2,500
	Miscellaneous Temporary Mechanical Allowance	LS	1	$100,000	$100,000	N/A	$100,000
2.	**Mechanical**						**$809,500**
	30" Filter Influent Butterfly Valve with Actuator, Install, Insulation	EA	16	$25,000	$400,000	$320,000	$720,000
	Allowance - Supports	LS	1	$57,500	$57,500	N/A	$57,500
	Painting	EA	16	$2,000	$32,000	NA	$32,000
3.	**Electrical**						**$144,000**
	Wiring and Conduit	EA	16	$5,000	$80,000	NA	$80,000
	Controls Modifications	EA	16	$4,000	$64,000	NA	$64,000
					SUBTOTAL		**$1,322,000**
4.	**General Conditions - 20%**						**$264,400**
5.	**Escalation To Mid Point of Construction (Anticipated January 2024) 2 years at 10% per year**						**$1,920,000**
6.	**Contingency - 15%**						**$288,000**
					CONSTRUCTION TOTAL		**$2,208,000**
					ENGINEERING		**$280,000**
					Design		$71,000
					Bidding		$6,000
					Construction Administration		$59,000
					Full Time Construction Observation		$144,000
					PROJECT TOTAL		**$2,488,000**
					SAY		**$2,490,000**

Appendix D

American Association of Cost Engineers (AACE) standards

AACE INTERNATIONAL RECOMMENDED PRACTICE

18R-97

COST ESTIMATE CLASSIFICATION SYSTEM - AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

AACE

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AACE International Recommended Practice No. 18R-97

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. August 7, 2020

Note: As AACE International Recommended Practices evolve over time, please refer to web.aacei.org for the latest revisions.

Any terms found in AACE Recommended Practice 10S-90, *Cost Engineering Terminology*, supersede terms defined in other AACE work products, including but not limited to, other recommended practices, the *Total Cost Management Framework*, and *Skills & Knowledge of Cost Engineering*.

Contributors:

Disclaimer: The content provided by the contributors to this recommended practice is their own and does not necessarily reflect that of their employers, unless otherwise stated.

August 7, 2020 Revision:

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AACE® International Recommended Practice No. 18R-97

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

TCM Framework: 7.3 – Cost Estimating and Budgeting

August 7, 2020

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1. PURPOSE

As a recommended practice (RP) of AACE International, the *Cost Estimate Classification System* provides guidelines for applying the general principles of estimate classification to project cost estimates (i.e., cost estimates that are used to evaluate, approve, and/or fund projects). The *Cost Estimate Classification System* maps the phases and stages of project cost estimating together with a generic project scope definition maturity and quality matrix, which can be applied across a wide variety of industries and scope content.

This recommended practice provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for the process industries. It supplements the generic cost estimate classification RP 17R-97[1] by providing:

- A section that further defines classification concepts as they apply to the process industries.
- A chart that maps the extent and maturity of estimate input information (project definition deliverables) against the class of estimate.

As with the generic RP, the intent of this document is to improve communications among all the stakeholders involved with preparing, evaluating, and using project cost estimates specifically for the process industries.

The overall purpose of this recommended practice is to provide the process industry with a project definition deliverable maturity matrix that is not provided in 17R-97. It also provides an approximate representation of the relationship of specific design input data and design deliverable maturity to the estimate accuracy and methodology used to produce the cost estimate. The estimate accuracy range is driven by many other variables and risks, so the maturity and quality of the scope definition available at the time of the estimate is not the sole determinate of accuracy; risk analysis is required for that purpose.

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating processes, terminology, and may classify estimates in other ways. This guideline provides a generic and generally acceptable classification system for the process industries that can be used as a basis to compare against. This recommended practice should allow each user to better assess, define, and communicate their own processes and standards in the light of generally-accepted cost engineering practice.

2. INTRODUCTION

For the purposes of this document, the term *process industries* is assumed to include firms involved with the manufacturing and production of chemicals, petrochemicals, and hydrocarbon processing. The common thread among these industries (for the purpose of estimate classification) is their reliance on process flow diagrams (PFDs), piping and instrument diagrams (P&IDs), and electrical one-line drawings as primary scope defining documents. These documents are key deliverables in determining the degree of project definition, and thus the extent and maturity of estimate input information. This RP applies to a variety of project delivery methods such as traditional design-bid-build (DBB), design-build (DB), construction management for fee (CM-fee), construction management at risk (CM-at risk), and private-public partnerships (PPP) contracting methods.

Estimates for process facilities center on mechanical and chemical process equipment, and they have significant amounts of piping, instrumentation, and process controls involved. As such, this recommended practice may apply to portions of other industries, such as pharmaceutical, utility, water treatment, metallurgical, converting, and similar industries.

Most plants also have significant electrical power equipment (e.g., transformers, switchgear, etc.) associated with them. As such, this RP also applies to electrical substation projects, either associated with the process plant, as part of power transmission or distribution infrastructure, or supporting the power needs of other facilities. This RP excludes power generating facilities and high-voltage transmission.

This RP specifically does not address cost estimate classification in non-process industries such as commercial building construction, environmental remediation, transportation infrastructure, hydropower, "dry" processes such as assembly and manufacturing, "soft asset" production such as software development, and similar industries. It also does not specifically address estimates for the exploration, production, or transportation of mining or hydrocarbon materials, although it may apply to some of the intermediate processing steps in these systems.

The cost estimates covered by this RP are for engineering, procurement, and construction (EPC) work only. It does not cover estimates for the products manufactured by the process facilities, or for research and development work in support of the process industries. This guideline does not cover the significant building construction that may be a part of process plants.

This guideline reflects generally-accepted cost engineering practices. This recommended practice was based upon the practices of a wide range of companies in the process industries from around the world, as well as published references and standards. Company and public standards were solicited and reviewed, and the practices were found to have significant commonalities. [4,5,6,7] These classifications are also supported by empirical process industry research of systemic risks and their correlation with cost growth and schedule slip [8].

3. COST ESTIMATE CLASSIFICATION MATRIX FOR THE PROCESS INDUSTRIES

A purpose of cost estimate classification is to align the estimating process with project stage-gate scope development and decision-making processes.

Table 1 provides a summary of the characteristics of the five estimate classes. The maturity level of project definition is the sole determining (i.e., primary) characteristic of class. In Table 1, the maturity is roughly indicated by a percentage of complete definition; however, it is the maturity of the defining deliverables that is the determinant, not the percent. The other characteristics are secondary and are generally correlated with the maturity level of project definition deliverables, as discussed in the generic RP [1]. The specific deliverables, and their maturity or status are provided in Table 3. The post sanction (post funding authorization) classes (Class 1 and 2) are only indirectly covered where new funding is indicated. Again, the characteristics are typical but may vary depending on the circumstances.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges at an 80% confidence interval
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1 – Cost Estimate Classification Matrix for Process Industries

This matrix and guideline outline an estimate classification system that is specific to the process industries. Refer to Recommended Practice 17R-97 [1] for a general matrix that is non-industry specific, or to other cost estimate classification RPs for guidelines that will provide more detailed information for application in other specific industries. These will provide additional information, particularly the *Estimate Input Checklist and Maturity Matrix* which determines the class in those industries. See Professional Guidance Document 01, *Guide to Cost Estimate Classification*. [16]

Table 1 illustrates typical ranges of accuracy ranges that are associated with the process industries. The +/- value represents typical percentage variation at an 80% confidence interval of actual costs from the cost estimate after application of appropriate contingency (typically to achieve a 50% probability of project cost overrun versus underrun) for given scope. Depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall into the ranges identified. However, this does not preclude a specific actual project result from falling outside of the indicated range of ranges identified in Table 1. In fact, research indicates that for weak project systems and complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 1. [17]

In addition to the degree of project definition, estimate accuracy is also driven by other systemic risks such as:

- Level of familiarity with technology.
- Unique/remote nature of project locations and conditions and the availability of reference data for those.
- Complexity of the project and its execution.
- Quality of reference cost estimating data.
- Quality of assumptions used in preparing the estimate.
- Experience and skill level of the estimator.
- Estimating techniques employed.
- Time and level of effort budgeted to prepare the estimate.
- Market and pricing conditions.
- Currency exchange.
- The accuracy of the composition of the input and output process streams.

Systemic risks such as these are often the primary driver of accuracy, especially during the early stages of project definition. As project definition progresses, project-specific risks (e.g. risk events and conditions) become more prevalent and also drive the accuracy range. Another concern in estimates is potential organizational pressure for a predetermined value that may result in a biased estimate. The goal should be to have an unbiased and objective estimate both for the base cost and for contingency. The stated estimate ranges are dependent on this premise and a realistic view of the project. Failure to appropriately address systemic risks (e.g. technical complexity) during the risk analysis process, impacts the resulting probability distribution of the estimated costs, and therefore the interpretation of estimate accuracy.

Figure 1 illustrates the general relationship trend between estimate accuracy and the estimate classes (corresponding with the maturity level of project definition). Depending upon the technical complexity of the project, the availability of appropriate cost reference information, the degree of project definition, and the inclusion of appropriate contingency determination, a typical Class 5 estimate for a process industry project may have an accuracy range as broad as -50% to +100%, or as narrow as -20% to +30%. However, note that this is dependent upon the contingency included in the estimate appropriately quantifying the uncertainty and risks associated with the cost estimate. Refer to Table 1 for the accuracy ranges conceptually illustrated in Figure 1. [18]

Figure 1 also illustrates that the estimating accuracy ranges overlap the estimate classes. There are cases where a Class 5 estimate for a particular project may be as accurate as a Class 3 estimate for a different project. For example, similar accuracy ranges may occur if the Class 5 estimate of one project that is based on a repeat project with good cost history and data and, whereas the Class 3 estimate for another is for a project involving new technology. It is for this reason that Table 1 provides ranges of accuracy values. This allows consideration of the specific circumstances inherent in a project and an industry sector to provide realistic estimate class accuracy range percentages. While a target range may be expected for a particular estimate, the accuracy range should always be determined through risk analysis of the specific project and should never be pre-determined. AACE has recommended practices that address contingency determination and risk analysis methods. [19]

If contingency has been addressed appropriately approximately 80% of projects should fall within the ranges shown in Figure 1. However, this does not preclude a specific actual project result from falling inside or outside of the indicated range of ranges identified in Table 1. As previously mentioned, research indicates that for weak project systems, and/or complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 1.

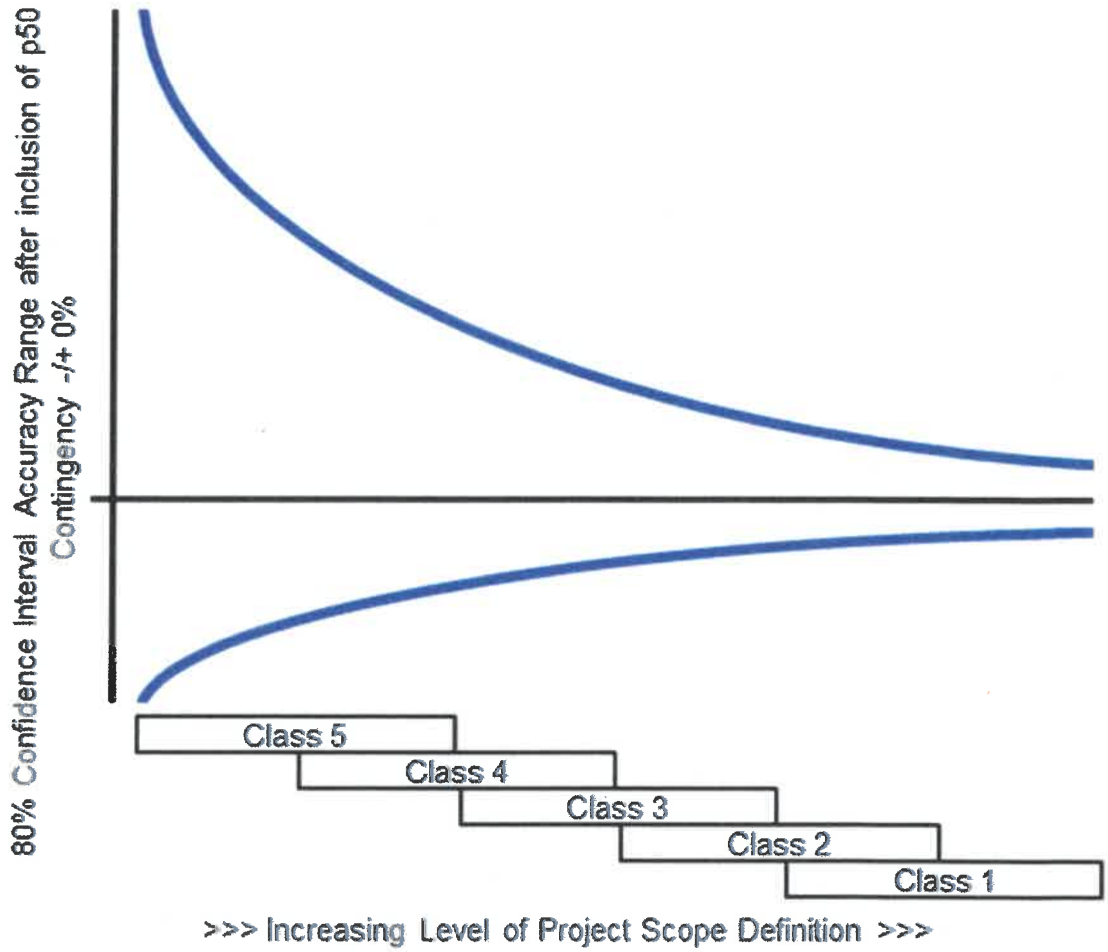

Figure 1 – Illustration of the Variability in Accuracy Ranges for Process Industry Estimates

4. DETERMINATION OF THE COST ESTIMATE CLASS

For a given project, the determination of the estimate class is based upon the maturity level of project definition based on the status of specific key planning and design deliverables. The percent design completion may be correlated with the status, but the percentage should not be used as the class determinate. While the determination of the status (and hence the estimate class) is somewhat subjective, having standards for the design input data, completeness and quality of the design deliverables will serve to make the determination more objective.

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5. CHARACTERISTICS OF THE ESTIMATE CLASSES

The following tables (2a through 2e) provide detailed descriptions of the five estimate classifications as applied in the process industries. They are presented in the order of least-defined estimates to the most-defined estimates. These descriptions include brief discussions of each of the estimate characteristics that define an estimate class.

For each table, the following information is provided:

- **Description:** A short description of the class of estimate, including a brief listing of the expected estimate inputs based on the maturity level of project definition deliverables.
- **Maturity Level of Project Definition Deliverables (Primary Characteristic):** Describes a particularly key deliverable and a typical target status in stage-gate decision processes, plus an indication of approximate percent of full definition of project and technical deliverables. Typically, but not always, maturity level correlates with the percent of engineering and design complete.
- **End Usage (Secondary Characteristic):** A short discussion of the possible end usage of this class of estimate.
- **Estimating Methodology (Secondary Characteristic):** A listing of the possible estimating methods that may be employed to develop an estimate of this class.
- **Expected Accuracy Range (Secondary Characteristic):** Typical variation in low and high ranges after the application of contingency (determined at a 50% level of confidence). Typically, this represents about 80% confidence that the actual cost will fall within the bounds of the low and high ranges if contingency appropriately forecasts uncertainty and risks.
- **Alternate Estimate Names, Terms, Expressions, Synonyms:** This section provides other commonly used names that an estimate of this class might be known by. These alternate names are not endorsed by this recommended practice. The user is cautioned that an alternative name may not always be correlated with the class of estimate as identified in Tables 2a-2e.

CLASS 5 ESTIMATE	
Description: Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Block flow diagram agreed by key stakeholders. List of key design basis assumptions. 0% to 2% of full project definition. **End Usage:** Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	**Estimating Methodology:** Class 5 estimates generally use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

Table 2a – Class 5 Estimate

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CLASS 4 ESTIMATE	
Description: Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Process flow diagrams (PFDs) issued for design. 1% to 15% of full project definition. **End Usage:** Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	**Estimating Methodology:** Class 4 estimates generally use factored estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Screening, top-down, feasibility (pre-feasibility for metals processes), authorization, factored, pre-design, pre-study.

Table 2b – Class 4 Estimate

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CLASS 3 ESTIMATE	
Description: Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineered process and utility equipment lists. Remedial action plan resulting from HAZOPs is identified. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Piping and instrumentation diagrams (P&IDs) issued for design. 10% to 40% of full project definition. **End Usage:** Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase control estimates against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate is often the last estimate required and could very well form the only basis for cost/schedule control.	**Estimating Methodology:** Class 3 estimates generally involve more deterministic estimating methods than conceptual methods. They usually involve predominant use of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring methods may be used to estimate less-significant areas of the project. **Expected Accuracy Range:** Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, feasibility (for metals processes) development, basic engineering phase estimate, target estimate.

Table 2c – Class 3 Estimate

CLASS 2 ESTIMATE	
Description: Class 2 estimates are generally prepared to form a detailed contractor control baseline (and update the owner control baseline) against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the bid estimate to establish contract value. Typically, engineering is from 30% to 75% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, piping and instrument diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: All specifications and datasheets complete including for instrumentation. 30% to 75% of full project definition. **End Usage:** Class 2 estimates are typically prepared as the detailed contractor control baseline (and update to the owner control baseline) against which all actual costs and resources will now be monitored for variations to the budget, and form a part of the change management program. Some organizations may choose to make funding decisions based on a Class 2 estimate.	**Estimating Methodology:** Class 2 estimates generally involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detail takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods. **Expected Accuracy Range:** Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Detailed control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.

Table 2d – Class 2 Estimate

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CLASS 1 ESTIMATE	
Description: Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, overall engineering is from 65% to 100% complete (some parts or packages may be complete and others not), and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: All deliverables in the maturity matrix complete. 65% to 100% of full project definition. **End Usage:** Generally, owners and EPC contractors use Class 1 estimates to support their change management process. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution. Construction contractors may prepare Class 1 estimates to support their bidding and to act as their final control baseline against which all actual costs and resources will now be monitored for variations to their bid. During construction, Class 1 estimates may be prepared to support change management.	**Estimating Methodology:** Class 1 estimates generally involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities. **Expected Accuracy Range:** Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Table 2e – Class 1 Estimate

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6. ESTIMATE INPUT CHECKLIST AND MATURITY MATRIX

Table 3 maps the extent and maturity of estimate input information (deliverables) against the five estimate classification levels. This is a checklist of basic deliverables found in common practice in the process industries. The maturity level is an approximation of the completion status of the deliverable. The completion is indicated by the following descriptors:

General Project Data:

- **Not Required (NR):** May not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.
- **Preliminary (P):** Project definition has begun and progressed to at least an intermediate level of completion. Review and approvals for its current status has occurred.
- **Defined (D):** Project definition is advanced, and reviews have been conducted. Development may be near completion with the exception of final approvals.

Technical Deliverables:

- **Not Required (NR):** Deliverable may not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.
- **Started (S):** Work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion.
- **Preliminary (P):** Work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals.
- **Complete (C):** The deliverable has been reviewed and approved as appropriate.

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
GENERAL PROJECT DATA:					
A. SCOPE:					
Non-Process Facilities (Infrastructure, Ports, Pipeline, Power Transmission, etc.)	P	P	D	D	D
Project Scope of Work Description	P	P	D	D	D
Byproduct and Waste Disposal	NR	P	D	D	D
Site Infrastructure (Access, Construction Power, Camp etc.)	NR	P	D	D	D
B. CAPACITY:					
Plant Production / Facility (includes power facilities)	P	P	D	D	D
Electrical Power Requirements (when not the primary capacity driver)	NR	P	D	D	D

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MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
C. PROJECT LOCATION:					
Plant and Associated Facilities	P	P	D	D	D
D. REQUIREMENTS:					
Codes and/or Standards	NR	P	D	D	D
Communication Systems	NR	P	D	D	D
Fire Protection and Life Safety	NR	P	D	D	D
Environmental Monitoring	NR	NR	P	P	D
E. TECHNOLOGY SELECTION:					
Process Technology	P	P	D	D	D
F. STRATEGY:					
Contracting / Sourcing	NR	P	D	D	D
Escalation	NR	P	D	D	D
G. PLANNING:					
Logistics Plan	P	P	P	D	D
Integrated Project Plan[1]	NR	P	D	D	D
Project Code of Accounts	NR	P	D	D	D
Project Master Schedule	NR	P	D	D	D
Regulatory Approval & Permitting	NR	P	D	D	D
Risk Register	NR	P	D	D	D
Stakeholder Consultation / Engagement / Management Plan	NR	P	D	D	D
Work Breakdown Structure	NR	P	D	D	D
Startup and Commissioning Plan	NR	P	P/D	D	D
H. STUDIES:					
Environmental Impact / Sustainability Assessment	NR	P	D	D	D
Environmental / Existing Conditions	NR	P	D	D	D
Soils and Hydrology	NR	P	D	D	D
TECHNICAL DELIVERABLES:					
Block Flow Diagrams	S/P	C	C	C	C
Equipment Datasheets	NR/S	P	C	C	C
Equipment Lists: Electrical	NR/S	P	C	C	C

[1] The integrated project plan (IPP), project execution plan (PEP), project management plan (PMP), or more broadly the project plan, is a high-level management guide to the means, methods and tools that will be used by the team to manage the project. The term integration emphasizes a project life cycle view (the term execution implying post-sanction) and the need for alignment. The IPP covers all functions (or phases) including engineering, procurement, contracting strategy, fabrication, construction, commissioning and startup within the scope of work. However, it also includes stakeholder management, safety, quality, project controls, risk, information, communication and other supporting functions. In respect to estimate classification, to be rated as *defined*, the IPP must cover all the relevant phases/functions in an integrated manner aligned with the project charter (i.e., objectives and strategies); anything less is *preliminary*. The overall IPP cannot be rated as *defined* unless all individual elements are defined and integrated.

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Equipment Lists: Process / Utility / Mechanical	NR/S	P	C	C	C
Heat & Material Balances	NR	C	C	C	C
Process Flow Diagrams (PFDs)	NR	C	C	C	C
Utility Flow Diagrams (UFDs)	NR	C	C	C	C
Design Specifications	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S/P	C	C	C
Instrument List	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Plot Plans / Facility Layouts	NR	S/P	C	C	C
Construction Permits	NR	S/P	P/C	C	C
Civil / Site / Structural / Architectural Discipline Drawings	NR	S/P	P	C	C
Demolition Plan and Drawings	NR	S/P	P	C	C
Erosion Control Plan and Drawings	NR	S/P	P	C	C
Fire Protection and Life Safety Drawings and Details	NR	S/P	P	C	C
Electrical Schedules	NR	NR/S	P	P/C	C
Instrument and Control Schedules	NR	NR/S	P	P/C	C
Instrument Datasheets	NR	NR/S	P	P/C	C
Piping Schedules	NR	NR/S	P	P/C	C
Piping Discipline Drawings	NR	NR/S	S/P	C	C
Spare Parts Listings	NR	NR	P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Facility Emergency Communication Plan and Drawings	NR	NR	S/P	P/C	C
Information Systems / Telecommunication Drawings	NR	NR	S/P	P/C	C
Instrumentation / Control System Discipline Drawings	NR	NR	S/P	P/C	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C

Table 3 – Estimate Input Checklist and Maturity Matrix (Primary Classification Determinate)

7. BASIS OF ESTIMATE DOCUMENTATION

The basis of estimate (BOE) typically accompanies the cost estimate. The basis of estimate is a document that describes how an estimate is prepared and defines the information used in support of development. A basis document commonly includes, but is not limited to, a description of the scope included, methodologies used, references and defining deliverables used, assumptions and exclusions made, clarifications, adjustments, and some indication of the level of uncertainty.

The BOE is, in some ways, just as important as the estimate since it documents the scope and assumptions; and provides a level of confidence to the estimate. The estimate is incomplete without a well-documented basis of estimate. See AACE Recommended Practice 34R-05 *Basis of Estimate* for more information [12].

8. PROJECT DEFINITION RATING SYSTEM

An additional step in documenting the maturity level of project definition is to develop a project definition rating system. This is another tool for measuring the completeness of project scope definition. Such a system typically provides a checklist of scope definition elements and a scoring rubric to measure maturity or completeness for each element. A better project definition rating score is typically associated with a better probability of achieving project success.

Such a tool should be used in conjunction with the AACE estimate classification system; it does not replace estimate classification. A key difference is that a project definition rating measures overall maturity across a broad set of project definition elements, but it usually does not ensure completeness of the key project definition deliverables required to meet a specific class of estimate. For example, a good project definition rating may sometimes be achieved by progressing on additional project definition deliverables, but without achieving signoff or completion of a key deliverable.

AACE estimate classification is based on ensuring that key project deliverables have been completed or met the required level of maturity. If a key deliverable that is indicated as needing to be complete for Class 3 (as an example) has not actually been completed, then the estimate cannot be regarded as Class 3 regardless of the maturity or progress on other project definition elements.

An example of a project definition rating system is the *Project Definition Rating Index* developed by the Construction Industry Institute. It has developed several indices for specific industries, such as IR113-2 [13] for the process industry and IR115-2 [14] for the building industry. Similar systems have been developed by the US Department of Energy [15].

9. CLASSIFICATION FOR LONG-TERM PLANNING AND ASSET LIFE CYCLE COST ESTIMATES

As stated in the Purpose section, classification maps the phases and stages of project cost estimating. Typically, in a phase-gate project system, scope definition and capital cost estimating activities flow from framing a business opportunity through to a capital investment decision and eventual project completion in a more-or-less steady, short-term (e.g., several years) project life-cycle process.

Cost estimates are also prepared to support long-range (e.g., perhaps several decades) capital budgeting and/or asset life cycle planning. Asset life cycle estimates are also prepared to support net present value (e.g., estimates for initial capital project, sustaining capital, and decommissioning projects), value engineering and other cost or economic studies. These estimates are necessary to address sustainability as well. Typically, these long-range estimates are based on minimal scope definition as defined for *Class 5*. However, these asset life cycle "conceptual" estimates are prepared so far in advance that it is virtually assured that the scope will change from even the minimal level of definition assumed at the time of the estimate. Therefore, the expected estimate accuracy values reported in Table 1 (percent that actual cost will be over or under the estimate including contingency) are not meaningful because the Table 1 accuracy values explicitly *exclude scope change*. For long-term estimates, one of the following two classification approaches is recommended:

- If the long-range estimate is to be updated or maintained periodically in a controlled, documented life cycle process that addresses scope and technology changes in estimates over time (e.g., nuclear or other licensing may require that future decommissioning estimates be periodically updated), the estimate is rated as *Class 5* and the Table 1 accuracy ranges are assumed to apply for the specific scope included in the estimate at the time of estimate preparation. Scope changes are explicitly excluded from the accuracy range.

- If the long-range estimate is performed as part of a process or analysis where scope and technology change is not expected to be addressed in routine estimate updates over time, the estimate is rated as *Unclassified* or as *Class 10* (if a class designation is required to meet organizational procedures), and the Table 1 accuracy ranges cannot be assumed to apply. The term *Class 10* is specifically used to distinguish these long-range estimates from the relatively short time-frame *Class 5* through *Class 1* capital cost estimates identified in Table 1 and this RP; and to indicate the order-of-magnitude difference in potential expected estimate accuracy due to the infrequent updates for scope and technology. Unclassified (or Class 10) estimates are not associated with indicated expected accuracy ranges.

In all cases, a *Basis of Estimate* should be documented so that the estimate is clearly understood by those reviewing and/or relying on them later. Also, the estimating methods and other characteristics of Class 5 estimates generally apply. In other words, an *Unclassified* or *Class 10* designation must not be used as an excuse for unprofessional estimating practice.

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APPENDIX: UNDERSTANDING ESTIMATE CLASS AND COST ESTIMATE ACCURACY

Despite the verbiage included in the RP, often, there are still misunderstandings that the class of estimate, as defined in the RP above, defines an expected accuracy range for each estimate class. This is incorrect. The RP clearly states that "while a target range may be expected for a particular estimate, the accuracy range should always be determined through risk analysis of the specific project and should never be predetermined." Table 1 and Figure 1 in the RP are intended to illustrate only the general relationship between estimate accuracy and the level of project definition. For the process industries, typical estimate ranges described in RP 18R-97 above are shown as a range of ranges:

- Class 5 Estimate:
  - High range typically ranges from +30% to +100%
  - Low range typically ranges from -20% to -50%
- Class 4 Estimate:
  - High range typically ranges from +20% to +50%
  - Low range typically ranges from -15% to -30%
- Class 3 Estimate:
  - High range typically ranges from +10% to +30%
  - Low range typically ranges from -10% to -20%
- Class 2 Estimate:
  - High range typically ranges from +5% to +20%
  - Low range typically ranges from -5% to -15%
- Class 1 Estimate:
  - High range typically ranges from +3% to +15%
  - Low range typically ranges from -3% to -10%

As indicated in the RP, these +/- percentage members associated with an estimate class are intended as rough indicators of the accuracy relationship. They are merely a useful simplification given the reality that every individual estimate will be associated with a unique probability distribution correlated with its specific level of uncertainty. As indicated in the RP, estimate accuracy should be determined through a risk analysis for each estimate.

It should also be noted that there is no indication in the RP of contingency determination being based on the class of estimate. AACE has recommended practices that address contingency determination and risk analysis methods (for example RP 40R-08, *Contingency Estimating – General Principles* [9]). Furthermore, the level of contingency required for an estimate is not the same as the upper limits of estimate accuracy (as determined by a risk analysis).

The results of the estimating process are often conveyed as a single value of cost or time. However, since estimates are predications of an uncertain future, it is recommended that all estimate results should be presented as a probabilistic distribution of possible outcomes in consideration of risk.

Every estimate is a prediction of the expected final cost or duration of a proposed project or effort (for a given scope of work). By its nature, an estimate involves assumptions and uncertainties. Performing the work is also subject to risk conditions and events that are often difficult to identify and quantify. Therefore, every estimate presented as a single value of cost or duration will likely deviate from the final outcome (i.e., statistical error). In simple terms, this means that every point estimate value will likely prove to be wrong. Optimally, the estimator will analyze the uncertainty and risks and produce a probabilistic estimate that provides decision makers with the probabilities of over-running or under-running any particular cost or duration value. Given this probabilistic nature of an estimate, an estimate should not be regarded as a single point cost or duration. Instead, an estimate actually reflects a range of potential outcomes, with each value within this range associated with a probability of occurrence.

Individual estimates should always have their accuracy ranges determined by a quantitative risk analysis study that results in an estimate probability distribution. The estimate probability distribution is typically skewed. Research shows the skew is typically to the right (positive skewness with a longer tail to the right side of the distribution) for large and complex projects. In part, this is because the impact of risk is often unbounded on the high side.

High side skewness implies that there is potential for the high range of the estimate to exceed the median value of the probability distribution by a higher absolute value than the difference between the low range of the estimate and the median value of the distribution.

Figure A1 shows a positively skewed distribution for a sample cost estimate risk analysis that has a point base estimate (the value before adding contingency) of $89.5. In this example, a contingency of $4.5 (approximately 5%) is required to achieve a 50% probability of underrun, which increases the final estimate value after consideration of risk to $93. Note that this example is intended to describe the concepts but not to recommend specific confidence levels for funding contingency or management reserves of particular projects; that depends on the stakeholder risk attitude and tolerance.

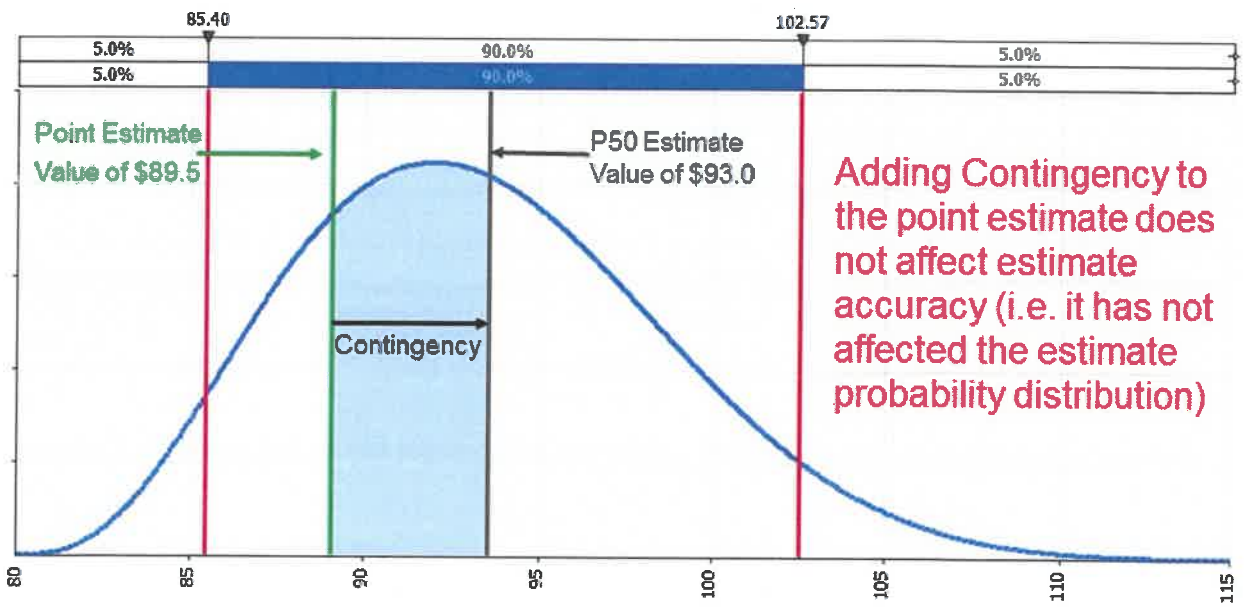

Figure – A1: Example of an Estimate Probability Distribution at a 90% Confidence Interval

Note that adding contingency to the base point estimate does not affect estimate accuracy in absolute terms as it has not affected the estimate probability distribution (i.e., high and low values are the same). Adding contingency simply increases the probability of underrunning the final estimate value and decreases the probability of overrunning the final estimate value. In this example, the estimate range with a 90% confidence interval remains between approximately $85 and $103 regardless of the contingency value.

As indicated in the RP, expected estimate accuracy tends to improve (i.e., the range of probable values narrows) as the level of project scope definition improves. In terms of the AACE International estimate classifications, increasing levels of project definition are associated with moving from Class 5 estimates (lowest level of scope definition) to Class 1 estimates (highest level of scope definition), as shown in Figure 1 of the RP. Keeping in mind that accuracy is an expression of an estimate's predicted closeness to the final actual value; anything included in that final actual cost, be it the result of general uncertainty, risk conditions and events, price escalation, currency or anything else within the project scope, is something that estimate accuracy measures must communicate in some manner. With that in mind, it should be clear why standard accuracy range values are not applicable to individual estimates.

The level of project definition reflected in the estimate is a key risk driver and hence is at the heart of estimate classification, but it is not the only driver of estimate risk and uncertainty. Given all the potential sources of risk and uncertainty that will vary for each specific estimate, it is simply not possible to define a range of estimate accuracy solely based on the level of project definition or class of estimate.

