Construction Cost Estimate for Relocation of Monte Pelao Tank Pump Station, Guanica, Puerto Rico

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Abstract *— On December 28, 2019, the seismic sequence to the South-Southwest of Puerto Rico began with a magnitude 4.7 Mw tremor, and what is considered the main event of this sequence occurred on January 7, 2020, a magnitude 6.4 Mw tremor, with epicenter 12.7 km south of Guayanilla. This strong tremor with a depth of 7 km, had a maximum intensity of VIII in Guánica and caused considerable damage throughout Puerto Rico. Since then, this area has remained active, registering over 16,000 tremors until August 2021. Among the damages caused by said telluric movements is a landslide due to a fault in the slope where the Monte Pelao Tank is, in the community of Alturas de Belgica in Guánica. This project has the objective of establishing a cost estimate for the demolition works of the existing tank and the construction of a new tank and pumping station for the supply of drinking water to the families of the mentioned sector.*

Key terms *— construction estimate, water tank, earthquake, takeoff.*

INTRODUCTION

On January 7, 2020, a strong earthquake was recorded in the south of Puerto Rico that shook the entire Island. The earthquake with a magnitude of 6.4 had an epicenter south of Guayanilla and is the strongest telluric movement since the historic earthquake. of San Fermín in 1918. This tremor is part of a seismic sequence that began on December 28, 2019, with a 4.7 tremor and is still active today, registering over 16,000 events, according to data published by the Puerto Rico Seismic Network (Red Sísmica de Puerto Rico).

Although the earthquake was felt throughout the island, the southern and southwestern areas were the most affected by the tremor. According to data published by the Puerto Rico Fiscal Agency and Financial Advisory Authority, damage losses exceed $782 million. Among the municipalities most affected by the tremors is Guánica. The Monte Pelao pumping station is in this municipality. These facilities consisted of two tanks of 30K and 50K gallons each, respectively. The 2019-2020 seismic events caused a landslide near the tank site, which in turn compromised the stability of the nearby hillside, so the 30,000-gallon elevated tank was demolished as a safety measure. After several studies and evaluations, the construction of a secant pile wall of approximately 230 linear feet was recommended. Due to the high cost of this option, the Aqueduct and Sewer Authority requests the evaluation of additional alternatives. Finally, the option of relocating the tank to a nearby town was chosen.

This project discusses the scope of work included in the project for the Relocation of the Monte Pelao Tank in Guánica. Using the plans and documentation provided by the project managers, a Work Breakdown Structure (WBS) is developed, which will later serve as a guide for the development of a cost estimate for the construction work. All steps are discussed in the theoretical background and methodology sections, where guidelines from professional organizations such as the Project Management Institute are used to explain the step-by-step estimation process for this project. Finally, in the results section, the estimated cost of construction work for the project under study is presented.

LITERATURE REVIEW

As per the Project Management Institute (PMI) "Practice Standard for Project Estimating 2nd Edition, an estimate is an assessment of the likely amount or outcome of a variable, such as project costs, resources, effort, durations, and probability and impacts of risks or potential benefits.

The level of confidence is influenced by information available on, for example: market dynamics, stakeholders, regulations, organizational capabilities, risk exposure, and level of complexity. Unrealistic estimates may compromise the ability of programs and projects to deliver the expected value.

There are three key stages of the project estimating life cycle:

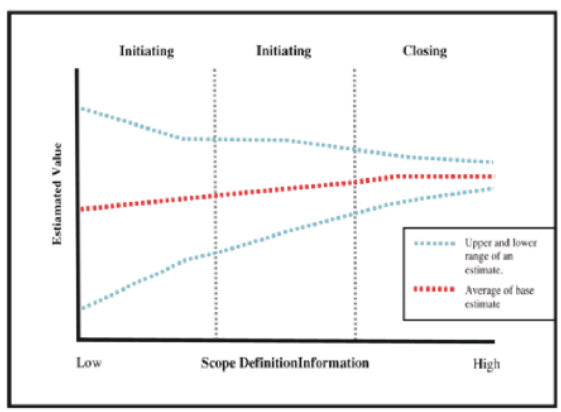
- Prepare to estimate: this stage of the life cycle is the creation of the estimation approach. In this stage the activities of the project are identified, better tools and techniques to be used for estimating are determined, estimating team is identified, preparing estimating inputs, and documenting any constraints and assumptions to the estimate (e.g., funding limits, resource constraints, or required dates.)
- Create estimates: In this stage, estimating effort, activity resources, activity durations, and costs are performed.
- Manage estimate: once the original estimate has been completed, validated, and baselined with the project team members and the project work has started, this stage of project estimating includes many activities that are used to manage the estimate, including change controls, calibrating the forecast, and comparing actuals to the baseline estimate.

Evolving estimates:

It's important to establish that all project estimates involve assumptions, constraints, uncertainty, and risk perceptions. Confidence level for an estimate is directly related to the available information. Project estimates should be redefined as information becomes available; in other words, project estimating is iterative and evolving process, aligned with the concepts of progressive elaboration. Due to the limited scope definition and available information, projects at early stages have reduced estimate confidence and accuracy, thereby requiring a larger confidence range. As the project planning evolves, the scope is refined, and a Work Breakdown Structure is created. As more information about the requirements, desired deliverables, and acceptance criteria becomes available, the estimate can be fine-tuned to higher levels of precision and confidence.

Table 1

Cone of uncertainty (Sourced from PMI "Practice Standard for Project Estimating 2nd Edition)



As per information extracted from the PMI "Practice Standard for Project Estimating 2nd Edition "A project in the star-up phase may have a rough order of magnitude (ROM) estimate in the range of -25% to 75%. Later in the project, as more information is known, work product estimates could narrow to a range of -10% /+15%. Figure 1 depict how the level of uncertainty decreases as the project progresses and more information become available. In some organizations, there are guidelines for these requirements and the degree of accuracy that is expected. Contingency reserves are applied to estimates based upon available information and identified risks.

Type of Estimate

There are several different types of estimates, depending on the project stage and the information available. Some examples of common estimate types or methods used for pricing construction projects are

preliminary estimate, plinth area cost estimate and detailed estimates.

Detailed estimates, also called deterministic estimating or bottom-up estimates, are applied as the estimating tool of choice for estimating costs and resource requirements when detailed project data become available. When using this technique, the expenditure of every resource of every component of the project is estimated as a prelude to rolling up these estimates to the higher levels of the WBS and the total project.

The bottom-up estimating technique is recognized to produce the most accurate and most reliable estimate. Pre-requisites to a bottom-up estimate are detailed WBS, an activity list, and a comprehensive directory of project resources. WBS, an activity list, and a comprehensive directory of project resources.

The project estimate is derived from the summation of detailed estimates for all the individual constituent components of the project. Using the bottom-up estimating method, the cost of each component is estimating, and the results are combined to arrive at an estimated cost of the overall project. This method aims at constructing the estimate of a system from the knowledge accumulated about the small components and their interactions.

The process begins by determining which resources are required to implement a specific lowest level element of the WBS, known as a work package. The list of resources can include all costs, labor; and other assets, including materials, embedded equipment, supplies, facilities, or implementation tools. The estimator uses the list of resources to assign the needed resources to each work package. For each resource the estimator provides the optimum crew size for a function and the amount of time required by the optimum crew to craft the specific activities necessary to finalize the work package. The cost of the work package is then calculated by summing the product of intensity, duration, and unit price of the resource.

METHODOLOGY

Estimating "Monte Pelao Tank Relocation" Project:

As mentioned earlier, the first stage of the project estimating life cycle is prepared to estimate. During this phase, the estimator should verify the available project data. Table 2 summarize project general information and available data.

Table 2

Project General Data

Monte Pelao Tank Relocation Project - General Data	
Project Name:	EB Tanque Monte Pelao
Location:	Calle Los Caobos, Comunidad Alturas de Bélgica, Bo Caño, Guánica, Puerto Rico.
Project ID:	CIP 4-29-6001
Requestor:	Puerto Rico Aqueducts and Sewer Authority (PRASA)
Available Data:	90% Relocation of Monte Pelao Tank Pump Station PDF Plans (90% Deliverable) Pre-construction Summary report Pre-Kickiff-Meeting presentation
Project Management office:	CMA Architects & Engineers LLC
Construction Coordination Office:	Jacobs Engineering Group
Funding Agency:	FEMA (Federal funds)

For construction projects it is always advisable to hold a meeting with the owner or their representatives, project managers or designers, to discuss project details such as: scope of work, restrictions, or special instructions. Likewise, it is highly recommended, whenever possible, to make

visits to the project area to familiarize with the existing conditions, accesses, limitations, etc. For this project, a meeting was held with the Project Manager to discuss these details.

Once the project documents have been studied and the available data verified, the list of activities is established, which will serve as an outline to prepare the project cost estimate. We call this list "Work breakdown structure". The WBS for this project has been organized following the divisions established by the CSI Masterformat (1995 Edition), as shown on Table 3. The MasterFormat is a standard utilized by the architecture, engineering, and construction (AEC) industry for organizing and communicating specifications and work results for construction projects.

Table 3

Monte Pelao Tank Relocation Work Breakdown structure

Monte Pelao Tank Relocation Project - WBS
01 - GENERAL REQUIREMENTS
Supervision (Project manager, project engineer, foreman, safety officer)
Required permits (Incidental Single Permit, SWPPP, etc)
Construction facilities
Mobilization to the project area, applies to both sites
Preparation of staging area, applies to both work sites
Demobilization
02 - SITEWORKS
Implementation of CEST plan, applies to both work sites - Truck entrance
Implementation of CEST plan, applies to both work sites - Inlet protection installation to avoid sedimentation
Implementation of CEST plan, applies to both work sites - silt fence
Demolition of existing tank, pump station & related infrastructure
Removal of pumping and metering equipment to be salvaged and delivered to AAA
Removal of electrical equipment to be salvaged and delivered to AAA
Debris removal and disposal
Backfill void left per tank (A-2-4)
Earthwork new tank site - Cut to waste
Earthwork new tank site - Fill
Soil stabilization
Chainlink fence & gates
03 - CONCRETE WORKS
New concrete tank construction (foundation, walls, columns, roof slab)
Concrete pad for electrical & mechanical equipment
Sidewalks, curbs & retention wall.
05 - METALS
Vertical ladder
07 - THERMAL & MOISTURE PROTECTION
Damp-proofing
Roof hatch
09 - FINISHES
Paint
15 - MECHANICAL WORKS
Installation of pumping equipment
Pipe connection to the existing system
16 - ELECTRICAL WORKS
Electric generator installation
Metering equipment
Electric connections

Once the activities to be carried out as part of the project have been established, it is necessary to identify who will be responsible for each activity. It is normal in construction projects that external labor or other companies must be used to carry out certain project activities. Once these activities have been defined, suitable subcontractors must be identified so that they can prepare a cost and time estimate for these activities.

The next step should be the identification of the materials and equipment necessary to complete the different tasks involved in the project, and which

suppliers and/or distributors of each of these materials and equipment should be contacted to request a quote. An industry standard when preparing an estimate is to request at least three (3) quotes and/or proposals for both materials and subcontracts. This allows us to have enough information to be able to compare and determine if the costs and terms presented are fair and reasonable, and if the scope of work considered by each subcontractor or supplier is correct. When evaluating these quotes or proposals, the one with the lowest cost should not necessarily be chosen. Other factors must be considered such as time to complete the activity or delivery, terms of payment, experience, among others.

Another essential step in preparing a cost estimate is to determine the quantities of materials. This process is known as takeoff. Quantity takeoff requires a highly specialized skill set to perform data management successfully. This crucial step in the initial stage of a project can make or break success. In fact, inadequate quantity takeoffs can underestimate or overestimate construction costs, causing inefficiency throughout the construction chain.

It can be detrimental to any job when required material quantities and realistic price values are overlooked or duplicated. The key to successful construction data collection is thoroughness and accuracy. Technology has changed the method of calculating quantities. Currently there are several computer programs that help estimators to be more efficient and accurate when calculating the quantities of construction materials. For this project OnScreen Takeoff software was used to complete material quantity takeoff. As extracted from OnCenter webpage (On Screen Takeoff software company) *On-Screen Takeoff is a construction estimating and takeoff solutions for contractors and construction professionals. The solution offers tools for estimating, managing bids and having project visibility.*

Once the activities and the quantities of the materials have been determined, the necessary labor and the time required to complete all the tasks must be estimated. The workforce is determined based on various factors such as the number of employees required to carry out the activity, productivity, working conditions, volume of work, equipment, etc. It is important when calculating the cost for labor to consider factors such as:

Minimum wage – may depend on the type of project, the employee's preparation, location, schedule, agreements, and legal provisions such as executive orders.

Fringe benefits, required professional certifications, bonuses, transportation costs, lodging, etc.

Once the time, labor, and materials necessary to complete the work have been established, the indirect costs, supervision and general requirements of the project must be determined. This item includes costs such as:

Temporary facilities (storage for materials and equipment, temporary offices, temporary water, and electricity services),

Mobilization costs,

Project signage,

Supervision

Profit

Payment of patents, taxes, bonds

Insurance

Required permits

As previously mentioned, in all projects there are always assumptions that must be made to complete cost estimates, sometimes because the information is not available at the time the estimate is prepared. The following factors were taken into consideration for this project:

The financing of the project will be with federal funds from FEMA.

Jobs must comply with the provisions established by the Davis-Bacon Act. which in turn means that

project must comply with the provisions of the Executive Orders of the Governor of Puerto Rico and the President of the United States with reference to salary payment minimum to construction workers on projects financed with federal funds.

- It is also presumed that the provisions established in the Buy-American-Act for the purchase of materials to be used in the project must be complied with.
- For purposes of this, it is presumed that the procedures for the acquisition of the land where the works for the construction of the new Monte Pelao tank will be carried out have already been completed, so this estimate does not consider such cost.
- It is also presumed that, as happens in a large part of the construction projects on PR, the municipal taxes will be paid by the owner of the work, so they are not considered in the cost estimate presented.
- It is also presumed that the costs for the preparation and filing of the permits will be the client's responsibility, which is why they are not included in the project, except for the Single Incidental Permit, which is submitted by the general contractor.
- It is presumed that as part of the work carried out by the design team, a certified firm has been contracted to carry out tests to determine the presence of asbestos and lead in the existing facilities to be demolished. It is also presumed that the results of these tests are negative, and that the owner will have the negative certification of the presence of the material. For this reason, costs for removal and mitigation work are NOT included.
- The construction materials market is a volatile market that has been seriously affected by the pandemic and the shipping problem. For this reason, the cost presented will be subject to market variations.
- The cost does not assume delays in the delivery of materials and/or construction work due to pandemics, natural events, strikes or any other situation beyond the control of the general contractor.

It is being assumed that the contractor will be required to obtain Payment and Performance bonds for 100% of the value of the work.

- Since it was not specified, no type of exemption is being considered for the payment of taxes, patents, sales and use tax, business-to-business tax or any other tax required by law. In the case of having any exemption for the payment of taxes, the due certificate from the Treasury or regulatory agency must be submitted.

RESULTS

The results of this work are shown in Table 4. The table summarizes the costs of the estimate made for the demolition of the existing tank and the construction of a new tank with all the infrastructure and its auxiliary equipment. This breakdown is presented using the format of the 16 divisions of the MasterFormat 1995 as discussed in the methodology section of this article. The estimated cost for this project, based on the drawings (deliverable of 90%) and the information available at the time, is one million two thousand sixty-two dollars and sixty cents ($1,002,062.60). As shown in the table, this cost includes the direct costs of the project and the general conditions associated with it. These items total the amount of seven hundred thirty-nine thousand three hundred sixty-one dollars and forty-three cents ($739,361.43). To this amount are added the items of "contractor fees and overhead estimated at one hundred and sixty-six thousand three hundred and fifty-six dollars and thirty-two cents ($166,356.32), which is equivalent to about twenty-two-point five percent (22.5%) of the total direct costs of the project.

For this project it is also considered the payment of the following administrative costs: municipal patent estimated at 0.5% of the total project,

equivalent to four thousand eight hundred and seventy-five thousand dollars ($4,875.00); Insurances (General liability, Builder Risk, CFSE) with estimated cost of twenty-seven thousand four hundred fifty-one thousand dollars and sixty cents ($27,451.60); tax payment estimated at thirteen thousand six hundred and fifty dollars and seventeen cents ($13,650.17) and the payment of the Payment and Performance Bond estimated at thirteen thousand four hundred dollars. ($13,400.00).

Given that the plans are not completed and there is project information that was not available at the time of preparing the estimate (technical specifications, soil survey report, etc.), a contingency of thirty-six thousand ninety-eight dollars and seven cents is being included. This amount is equivalent to five percent (5%) of the total direct costs of the project.

The cost of the project determined during the preparation of this work is greater than the Engineer's estimate by one hundred eighty-four thousand seven hundred thirty-five and sixty cents ($184,735.60), which represents a twenty-two-point six percent (22.6%) difference. To establish a point of comparison, the results of public bids carried out by different government agencies, such as the Infrastructure Financing Authority and the Highway and Transportation Authority, were used as references. In these bids, the difference between the engineer's estimate versus the bidders' proposals ranged from -12% to 20%, eliminating outliers. These values are close to those discussed in the Literature review section where it is indicated that this variation could be between -10%/+15%.

The difference in cost could be due to several factors such as the values assumed for the Contractor's fees, overhead and insurance items; to the costs of the general conditions considered to complete the works. In addition, it must be considered that the construction materials industry is a volatile one and that costs can vary considerably depending on various factors such as supply and demand or the cost of raw materials. Now, the construction industry, like other industries, is affected by shipping problems, this has had an effect on the availability, delivery time and therefore on the cost of materials. Similarly, the effects of the pandemic caused by COVID-19 have had adverse effects on the industry. More recently, the rise in fuel costs has caused a considerable increase in all items.

Table 4

Project cost breakdown

BID FORM					
Item No.	Work Description	Qty	Unit	Unit Cost	TOTAL
1	Insurances	1	lump sum	$ 27,451.60	$ 27,451.60
2	Patents	1	lump sum	$ 4,875.00	$ 4,875.00
3	Taxes	1	lump sum	$ 13,650.17	$ 13,650.17
4	Payment & Permformance Bond	1	lump sum	$ 13,400.00	$ 13,400.00
5	Contingency	1	lump sum	$ 36,968.07	$ 36,968.07
6	Contractor's fees & overhead	1	lump sum	$ 166,356.32	$ 166,356.32
			TOTAL	=	TOTAL
	LUMP SUM TOTAL=				$ 262,701.17
BREAKDOWN (Sixteen divisions [15] listed in the CSI Master					TOTAL
Division 01	General Requirements	1	lump sum	$ 209,976.25	$ 209,976.25
Division 02	Site Construction	1	lump sum	$ 42,942.32	$ 42,942.32
Division 03	Concrete	1	lump sum	$ 145,375.06	$ 145,375.06
Division 04	Masonry	1	lump sum	$ -	$ -
Division 05	Metals	1	lump sum	$ 7,427.70	$ 7,427.70
Division 06	Wood and Plastics	1	lump sum	$ -	$ -
Division 07	Thermal and Moisture Protection	1	lump sum	$ 5,836.10	$ 5,836.10
Division 08	Doors and Windows	1	lump sum	$ -	$ -
Division 09	Finishes	1	lump sum	$ -	$ -
Division 10	Specialties	1	lump sum	$ -	$ -
Division 11	Equipment	1	lump sum	$ -	$ -
Division 12	Furnishings	1	lump sum	$ -	$ -
Division 13	Special Construction	1	lump sum	$ -	$ -
Division 14	Conveying Systems	1	lump sum	$ -	$ -
Division 15	Mechanical	1	lump sum	$ 190,204.00	$ 190,204.00
Division 16	Electrical	1	lump sum	$ 137,600.00	$ 137,600.00
			TOTAL		$ 739,361.43
	TOTAL=				$1,002,062.60

CONCLUSION

In summary, throughout this work, the author tried to explain what a cost estimate consists of, the steps to follow, and the importance of the available information when establishing the budget for a project. Using this as a basis, the cost estimate for the Relocation project of the Monte Pelao Tank in Guánica was generated. The estimated cost for this project, based on the information available and the assumptions made, is $1,002,062.60. This represents 22.6% over engineer's budget stated in the Pre-construction summary report generated by the management office for this project.

As discussed in the results section, this variation may depend on multiple factors such as contractor's fees, performance period, insurance, and general conditions. On the other hand, situations such as

freight problems, availability of raw material, Covid-19 pandemic and now the rise in fuel prices, maintain instability in the market, which in turn results in considerable increases in the cost of the projects.

The Monte Pelao Relocation project will be put up for bid in the coming months. Once the results of the bid are published, the award costs can be compared against the cost established in the article.

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