THE UNIVERSITY OF TENNESSEE KNOXVILLE

May 13, 2022

Chancellor's Honors Program
Howard Baker Center
1640 Cumberland Ave. Knoxville, TN 37996

To whom it may concern,

My senior design project aimed to provide a hydroelectric source of power to the remote community of Nazarét, Panama using the nearby Rio Chico. The community currently uses diesel generators as their power source and is not connected to the national electrical grid. Residents primarily have access to power at one building in the community. Solea Water reached out to the University of Tennessee Civil & Environmental Engineering Department to provide the community with a more sustainable and accessible power source. Since we could not travel to the site or communicate with those living in Nazaét, we coordinated with our client to gather data and understand the project site. Our team was able to develop a design that consists of (2) turbine unit options and (3) structural stabilization options which allows the contractor to have the flexibility of selecting any point on the Rio Chico to install the turbine system.

To achieve this goal, my senior design team needed to select a turbine, design a structural support system, and create a construction management plan. I was responsible for selecting the turbine, evaluating the turbine's power storage capabilities, and analyzing the turbine's performance over the next 20 years. To select a turbine, I researched commercially available turbines and evaluated the feasibility of each option based on expected shipping costs, size, and possible power production. I selected (2) options from the company New Energy Corporation to use in our designs, the options include (1) 10 kW unit or (2) 5 kW units from their EVG series turbines. I then used velocity-power curves provided by the company and expected power demands to generate power storage and river velocity requirement curves. These curves showed that both turbine options could supply the required amount of power in a typical day to the community at river velocities measured by Solea Water. Additionally, the curves indicated that an additional turbine unit would be required between the years 2036 to 2038 to accommodate expected increases in demand.

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Additionally, I calculated the drag force the turbine system would exert on the structural system using the measured river velocity and the drag equation. The drag used in the structural design was 24 kN, which encompasses the turbine option with the greatest drag force and a safety factor. I also determined possible impact forces that could occur due to debris colliding with the system while in the river. Using the impact force equation, calculated masses of saturated wooden logs, and the measured river velocity, the impact force was determined to be 100 kN. In my team's design, at this force only one turbine connection would break, allowing the turbine system to drift to the bank, preventing any further impacts.

The major deliverables for my senior design project include a project report and construction drawings of the design. These documents detail the work that my team has performed throughout the last academic year. Enclosed is my team's complete project report and construction drawings. Appendix A contains all of my work concerning turbine selection and Appendix B contains my work calculating forces. The enclosed drawings show my team's completed design and installation plans.

Thank you,

Claudia Bible

Claudia Bible
Senior, Civil & Environmental Engineering

Enclosed:

Hydroelectric Turbine System Design in Nazarét, Panama Report
Hydrokinetic Turbine System in Nazarét, Panama Construction Drawings

Hydroelectric Turbine System Design
Nazarét, Panama

The University of Tennessee, Knoxville
Civil & Environmental Engineering
Senior Design Project
2022









Claudia Bible, AJ Condra, Drew Houser,
Nathan Smith, Matthew Tolson



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Mark McKinney – First Utility District – Technical Mentor
Dr. Moonkencheril Cherian – DLZ – Technical Mentor
Dr. Jennifer Retherford – University of Tennessee – Senior Design Instructor
Alan Foster – Solea Water – Client
Shane Bear – New Energy Corporation

Disclaimer

The following report was created by un-licensed civil engineering students from the University of Tennessee. This report is part of a senior design project and should not constitute as legal engineering documentation. The University of Tennessee and the individuals involved with this project do not hold liability for any construction done with these designs.



Clean Energy Engineers is a Senior Design team from the University of Tennessee, Knoxville focused on creating renewable power options for those with minimal access to electricity. Our team is committed to working in collaboration with our clients to provide designs that are sustainable for years to come. We ensure every project has a lasting impact on the communities we serve by taking the time to understand our clients' culture and values. We are constantly learning and improving with each project to produce infrastructure that will serve communities for years to come.

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Introduction

The village of Nazarét, Panama is in need of a more reliable and sustainable power source. The Clean Energy Engineers team used civil engineering services to determine a viable solution to establish a power generation system for the village which capitalizes on the potential to draw energy from the Rio Chico. Engineering services include the design of an in-stream turbine with appropriate anchoring and a plan for long-term operations and maintenance was created to establish a hydroelectric source for power generation. It is our goal to create a lasting and reasonably maintainable system for the people of Nazarét that considers their concerns and lifestyle.

Project Background

The village of Nazarét is a small rural community in southern Panama and the inhabitants live a very traditional lifestyle using the Rio Chico for bathing, recreation, and travel. Currently Nazarét uses diesel gas powered generators for electricity and is in need of a more reliable energy source. Using diesel gas generators requires significant operational effort as trips to retrieve fuel require a 4-hour canoe trip to the nearest gas station. The village of Nazarét is a self-sustaining village using generators to power lights and small appliances. Adding a more dependable, less-demanding, and sustainable power source would be beneficial to Nazarét by decreasing the efforts of the villagers to keep the diesel generators operational.

Site Conditions

The community of Nazarét is located in southern Panama along the Rio Chico. The community is accessible only by canoe and no roadway infrastructure leads to the village. The Rio Chico is an 8-meter-wide river which provides sole means of access into the village. The flow and depth of the Rio Chico is dependent on the significant rainy and dry seasons experienced throughout the year, but also because of the terrain and channel characteristics. As described by Alan Foster, the Rio Chico has a variable velocity and flows forcefully during the many significant rain events encountered during the wet season. During wet seasons, flooding is common around the village of Nazarét. In some places, the water surface of the river may rise by 4.5 meters. The increased flow often sends large debris downstream such as large trees from the surrounding forested area.

Project Team

Clean Energy Engineers is comprised of five senior civil and environmental engineering students from the University of Tennessee, Knoxville (Figure 1). Team members will graduate with a Bachelor of Science degree from the university. Each team member has taken on project responsibilities relevant to their experience and interests. The senior civil and environmental team has a wide range of experiences with each individual having participated in senior-level coursework in water resources. Claudia Bible was assigned to select and analyze turbines because of her experience water resources undergraduate research. Matthew Tolson was selected for the geotechnical characterization, soil anchor, and rock anchor of the design based on his experience as a geotechnical engineering intern. AJ Condra was delegated to design and in-river anchor due to his past experience in civil site design. Nathan Smith was assigned to design the stabilization cables and connections because of his interest in structures and the challenge of working in three dimensions. Drew Houser was delegated to lead the construction management of the project due to experience in construction management from a previous internship. Other interests within the team include geotechnical and environmental engineering. Assisting the senior design team, representatives from Solea Water, First Utility District, DLZ Corporation, and faculty from the University of Tennessee (see Table 1) have contributed valuable mentorship for the design project.



Figure 1. Senior Design Team

(Left to Right: Nathan Smith, Drew Houser, AJ Condra, Matthew Tolson, Claudia Bible)

Table 1. Team Members

Team Members	**Affiliation**	**Contact Information**
Claudia Bible	Student at University of Tennessee	cbible6@vols.utk.edu
AJ Condra	Student at University of Tennessee	acondra@vols.utk.edu
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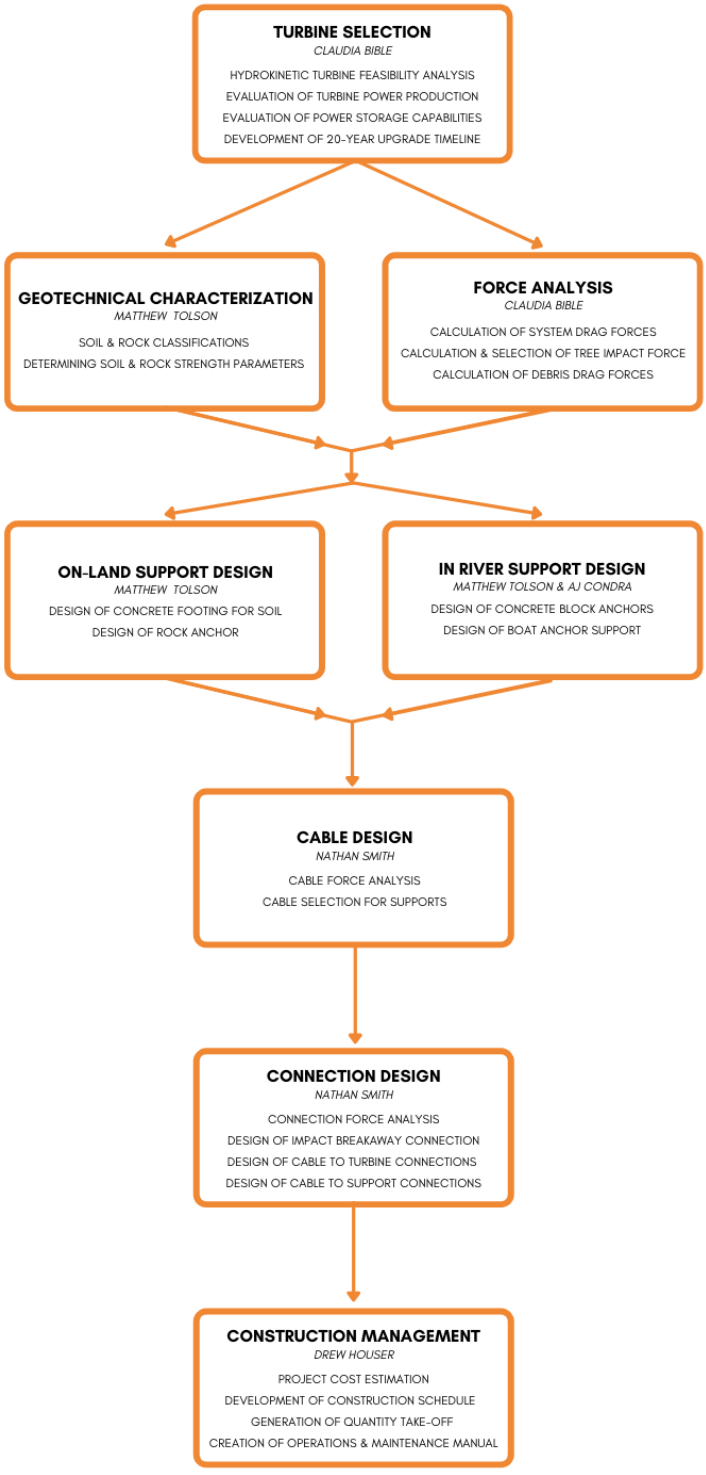

Figure 2. Organizational Chart

Technical Scope of Work

Clean Energy Engineers has been tasked with providing civil engineering services for the design of an in-stream hydroelectric turbine system for the community of Nazaret, Panama. Feasibility, potential power production, and capacity analyses were used to determine a suitable hydroelectric turbine to meet the power demand requested. Geotechnical guidelines were applied to define anticipated soil and rock classifications and strength properties. Two structural design options have been developed to provide anchoring and stability for the turbine platform with flexibility to move the platform off-shore to avoid damage during flood events.. Construction engineering services included developing an estimate of probable cost, quantity take-off, a construction schedule, and a general operations and maintenance manual.

Turbine Selection

Turbine selection services included a feasibility analysis of available hydrokinetic turbines, an examination of the turbine power production capabilities, and twenty-year capacity projections. To select turbine options, hydrokinetic turbines were compared based on size, power production capabilities, and availability. The power production and storage of each turbine option was evaluated based on velocity-power curves provided by the manufacturer, the measured velocity of the Rio Chico, and power requirement data. Future turbine additions to accommodate a twenty-year projection in power demand were analyzed to develop a system upgrade timeline.

Power demand and physical equipment size were used to select turbines suitable for the project needs. Four turbines from three different companies (see Appendix A) were selected and published power-velocity curves were used to confirm the suitability of each option. The minimum number of turbine units for each option was determined based on the maximum possible power production, design velocities, and measured river velocity, shown in Table 2. A power demand was established as 10 kW based on estimated use anticipated for the village. Each turbine option evaluated was confirmed to suit the physical 8-meter width of the river and provide the required power output. The DLZ Corporation turbine was eliminated because the product is not currently commercially available. The SMART Hydropower Monofloat option was eliminated due to significant shipping costs anticipated for the product. The two New Energy Corporation models satisfied demand costs, physical installation needs, were most viable for purchase, and therefore both were selected for the project. In order to meet the power demand, two options were defined: (1) EVG-010 turbine or the use of (2) EVG-005 turbines.

Table 2. Commercially Available Turbine Comparison

Parameters (per unit)	**New Energy Corp. EVG-005**	**New Energy Corp. EVG-010**	**DLZ Corp. Horizontal Axis Darrieus**	**SMART Hydropower Monofloat**
Maximum Power Produced	5 kW	10 kW	30 kW	5 kW
Design Velocity	3 m/s	3 m/s	2.4 m/s	2.8 m/s
Units Required at Design Velocity	2	1	1	2
Unit Size	Width= 3 m Length= 3 m Height= 1.7 m	Width= 3 m Length= 3 m Height= 2.45 m	Physical Dimensions Unknown	Width= 1.6 m Length= 3.13 m Height= 2.01 m

The power production and storage capabilities of one EVG-010 unit and two EVG-005 units were evaluated using the measured velocity of the Rio Chico, the manufacturer velocity-power curve, and the power demand curve. Both turbine options have the same design velocity and total power output, therefore one power production analysis was required. A velocity requirement curve was generated showing the required velocity over a typical 24-hour period to identify the time periods at which battery stored power would be required to meet demands (see Appendix A). The velocity requirement curve was generated by determining the required river velocity for the expected demand at each hour using the power demand curve and manufacturer velocity-power curve. Based on the power demand curve and the possible power produced at measured river velocities, indicated by the manufacturer velocity-power curve, a net cumulative power storage curve was developed, shown in Figure 3. The curve confirmed that both turbine options can meet the community's power demand throughout a typical day at varying river velocities.

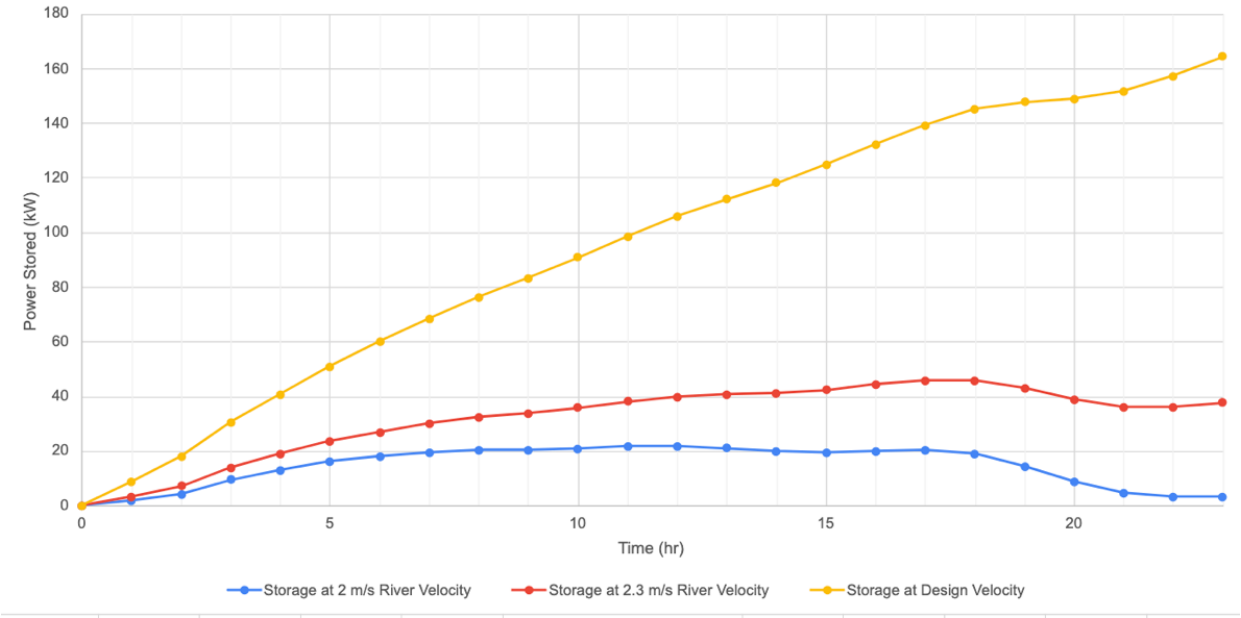

Figure 3. Cumulative Net Power Storage Over 24-Hours

For (1) EVG-010 or (2) EVG-005

A system upgrade timeline was developed by determining the average required river velocity for each year and approximating the cumulative net power storage over the next 20 years. A river velocity requirement curve was developed to evaluate the year at which the community would become reliant on stored power, shown in Figure 4. This curve was generated using yearly power demand estimates and the manufacturer power-velocity curve. The system's power storage capabilities were evaluated to identify the year at which the community will use more power than is produced, requiring an additional turbine. The approximate cumulative net power stored for each year was determined using 20-year power demand projections and the possible power produced at measured river velocities, indicated by the manufacturer velocity-power curve (see Appendix A). The 20-year power storage values indicate that the community will require an additional unit between the years 2036 and 2038 for both options, (1) EVG-010 turbine and (2) EVG-005 turbines.

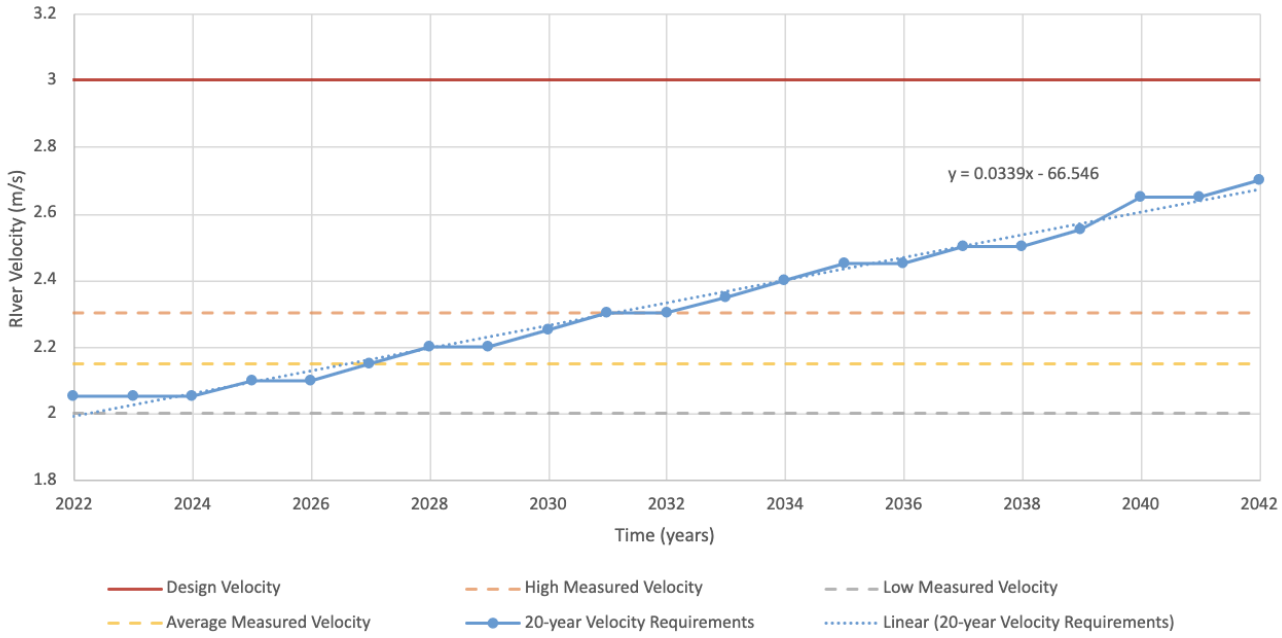

Figure 4. Average River Velocity Requirement by Year

Geotechnical Characterization

Geotechnical characterization services included classifying on-site soil and rock and quantifying associated strength parameters for use in structural stabilization design. Classifications were based on site photographs, applicable on-site testing, and reference materials. Strength parameters were determined based on reference materials in order to select conservative design values for soil and rock conditions anticipated on site.

Soil classification based on a ribbon test performed by a representative from Solea Water) was verified (see Appendix B). The soil sample was taken from the pueblo of Corozal, which is a similar area to Nazarét as it also sits adjacent to the Rio Chico. The ribbon test provided a general classification of the soil as a silty clay loam (see Appendix B). The soil sample tested was photographed in its dry and wet state and provided by Solea Water.



Figure 5. Dry Soil Sample



Figure 6. Wet Soil Sample

Strength parameters for the silty clay loam and rock anticipated at the site were determined. The bearing capacity of silty clay was quantified based on literature from The Council of American Building Officials (CABO) and Engineering Toolbox (see Appendix B). The density, unit weight, cohesion strength, and friction angle of silty clay were also quantified from Engineering Toolbox and Engineers Edge (see Appendix B). Strength parameters found in literature often were provided in ranges, and values used for design in this project were selected by averaging maximum and minimum published values. Rock classification was performed using site photographs which displayed eroded soil banks indicating substantial rock presence (see Figure 7), and *Principles of Foundation Engineering 7th Edition* by Braja Das was used to acquire standard strength parameter values based on this photographic visual observation. Despite the likely presence of viable rock, the on-site rock was conservatively classified as a weak sandstone with poor quality (see Appendix B). Strength parameters including bearing capacity, friction angle, and RQD were used to determine the approximate modified ultimate bearing capacity of weak sandstone (see Appendix B). Soil bearing capacity and modified ultimate bearing capacity for rock anticipated for the site were compiled and are presented in Table 3.



Figure 7. Eroded Soil Banks

Table 3. Strength Parameters of Soil & Rock Conditions

Soil Parameter	**Value/Descr.**	**Rock Parameter**	**Value/Descr.**
Classification	Silty Clay Loam	Classification	Weak Sandtstone
Wet Density	14,900 N/m3	Ultimate Bearing Capacity	25 MN/m2
Cohesion	15 kPa	RQD	0.25
Friction Angle	0-degrees	Friction Angle	30-degrees
Bearing Capacity	100 kPa	Modified Ultimate Bearing Capacity	1.6 MN/m2

Structural Stabilization

Mooring options for the turbine system were designed to resist the flow conditions of the Rio Chico. The forces required to stabilize turbine(s) were determined based on drag and impact forces. Mooring cables were sized and selected to safely resist resultant force caused by the influence of water pressure on the turbine(s). To transfer loading from cables to the site subgrade, supports were designed in the form of a rock anchor, soil footing, and in-river boat anchor. Structural connections from turbine(s) to supports were designed to withstand loading and required breakaway strength due to impact forces while allowing for turbine removal during weather events. Removable connections were developed to include buoys positioned near turbine(s) for cable flotation. The stabilization supports were designed as options that may be installed at various points along the Rio Chico that meet minimum requirements outlined in the provided construction drawings.

The drag force of the turbine system and the impact force of a tree on the system were determined. Drag force was calculated using the standard drag equation based on the turbine design velocity and turbine cross-sectional area perpendicular to the flow of the river. The drag force of the two EVG-005 units was selected as the final drag force for the stabilization design to withstand given that it was larger than the drag force of the single EVG-010 unit. The impact force was quantified for the collision of various sizes of saturated logs with the system using an equation from literature by Haehnel and Daly (see Appendix C).

Based on the forces applied to the turbine, mooring cables were designed for tensile rupture using the AISC Manual. A Max Industrias Steel 6 x 25 Black Cable with a diameter of 22.23mm (or equivalent) was selected for in-river anchors using a colinear impact force analysis (see Appendix C). Based on a non-colinear impact force analysis for on-land anchors, a Max Industrias Fiber Core 6 x 25 Balck Cable with a diameter of 25.40mm (or equivalent) was designed. The design strengths of both cable options were chosen based on the required strength due to impact forces and were included in Table 4.

Table 4. Cable Design Strengths for Impact Forces

Cable	Limit State	Required Strength	Design Strength of Cable
Turbine to In-River Anchor	Tensile Rupture	250 kN	354 kN
Turbine to On-Land Support	Tensile Rupture	300 kN	459 kN

Structural supports were designed in the form of a rock anchor, soil footing, and in-river boat anchor. The rock anchor was designed by sizing an anchor and post-grouted bore-hole to withstand the pressures created by the transfer of loading from the mooring cable to the anchor without exceeding the rock modified ultimate bearing capacity. Safety factors of 2 and 4 were placed on the design loading and allowable bearing capacity of rock, respectively (see Appendix C). The grout mix design used for post-grouting was formulated based on ASTM C476 (see Appendix C-08). The soil footing was designed by sizing an isolated footing with necessary rebar to resist lateral forces generated from the attached mooring cable without failing due to overturning moment, sliding, and soil pressure failure modes. Minimum rebar cover and spacing requirements were included along with factors of safety applied to overturning moment and sliding failure modes equal to 2 and 1.5, respectively (see Appendix C). A rebar connection hook was also designed for the soil footing in terms of development length to resist pullout failure (see Appendix C and drawings). The in-river support was designed by selecting a corrosion-resistant, high-tensile boat anchor to withstand the drag force generated from situating turbine(s) in a steady position without surpassing the resistance provided by the river channel bottom. A factor of safety of 2 was applied to the drag force transferred from the cable to the anchor (see Appendix C). A Guardian G-125 anchor (or equivalent) was selected based on ease of use and working load capacity (see drawings).

Structural connections were designed for loading, breakaway strength, and cable floating. Each component of the connections were designed to withstand the tensile load from the cables as shown in Table 5. The components included two thimbles, two ferrules, two stops, and a varying number of hooks. Breakaway connections were designed to fail under significant impact force by selecting a hook connection rated for 20kN, allowing the turbine(s) to move towards a bank as shown in Table 5. The impact of a 3-meter log was selected to be the breakaway strength at which a breakaway connection would release to prevent system damage. Removable connections in the form of hooks were developed to include buoys positioned near turbine connections for cable flotation in order to prevent

cables from sinking to the channel bottom when disconnected. The Taylor Made 18”D x 24”L buoy was selected based on estimated cable weights (see Appendix C). The floats were designed to slide onto cables and rest near the turbine for ease of use.

Table 5. Cable Design Strengths for Impact Forces

Cable	Limit State	Design Strength of Recommended Thimble	Design Strength of Recommended Hook	Number of Hooks
Turbine to In-River Anchor	Tensile Rupture	313 kN	107.8 kN	2
Turbine to On-Land Support	Tensile Rupture	313 kN	107.8 kN	3
Turbine to Soil/Rock Or Turbine to In-River Anchor (Breakaway)	Tensile Rupture	313 kN	19.6 kN	1

Stabilization supports were designed as options that may be installed at various points along the Rio Chico. Option one was created to utilize two on-land support options with a standard connection and a breakaway connection attached to opposite sides of the turbine(s) to allow for turbine system recovery during an extreme weather event. Similarly, option two was created to utilize an on-land support and an in-river boat anchor with a standard connection on the on-land support side of the turbine system and a breakaway connection on the in-river anchor side of the system to allow for recovery during a weather event. This mixed-support option design was imagined to maintain navigable waters adjacent to the turbine system (see drawings).

Construction Management

Construction management services included developing a project schedule, an estimate of probable cost, and an operations and maintenance manual. Project tasks and durations were determined based on anticipated labor structures. A quantity take-off was created, which includes materials needed for the project, and an estimate of probable cost determined. An operations and maintenance manual were created based on manufacturer product specifications and standards of practice for the specific equipment being installed for the hydroelectric turbine system.

Construction durations were estimated to allow the contractor to select one of five potential anchoring options based on conditions experienced on the site. Shipping duration was determined from New Energy Corporation and will require 14 days for the turbines to get from Canada to the village of Nazarét and this construction-related duration is constant regardless of the anchoring option selected by the contractor. Anchor installation durations were estimated based on anticipated labor and time for concrete curing. Labor time intervals for site preparation, formwork, and pouring the concrete were determined for each of the three anchors, based on a 3-laborer crew working 8-hour day, 6-day per week work weeks. A 28-day concrete curing period was determined by ASTM C39. Installation schedules for the five options were determined using the Critical Path Method and a work breakdown structure established in Microsoft Project (see Appendix D). Anticipated installation durations for the five proposed anchors were compiled, see Table 6

.

Table 6. Anchoring Options with Expected Durations

Anchoring Option	Duration: Days
Soil – Soil Anchors	55
Rock – Rock Anchors	50
Soil – Rock Anchors	53
Rock – River Anchors	46
Soil – River Anchors	46

A quantity take-off and estimate of probable cost was determined from the engineered designs. A quantity take-off was determined from the engineered design for each option of structural anchor, see appendix D. Pricing was determined for the turbine and materials using vendors. To decrease the cost of shipping, pricing of all materials was

determined from local vendors in Panama except for the turbine. The price and shipping cost of both turbine options was estimated to be equal amounts. Anticipated pricing for the different anchoring options are shown in Table 7.

Table 7. Anchoring Options with Estimated Cost

	Soil Anchor (NB)	**Rock Anchor (NB)**
Soil Anchor (B)	$ 49,364.19	$ 47,714.52
Rock Anchor (B)	$ 47,714.52	$ 46,064.85
River Anchor (B)	$ 49,412.46	$ 47,762.79

(B) = Breakaway Connection (NB) = Non-breakaway Connection

An operations and maintenance manual was developed with the intent to provide documentation for the village of Nazarét on turbine(s) selection, replacement parts used for the structural connections, maintenance checks for the turbines, removal of the turbine, and safety protocols for the villagers. Turbine specifications for each option were determined and listed within the operations and maintenance file. From engineering designs, a list of parts used for the structural connection was compiled specifically for future replacement needs. A maintenance plan was determined from New Energy Corporation's recommendations with included information on regular checks of the structural connections. Best practices for when to raise the impellors of the turbine, or when to remove the turbine(s) from the river were determined, and steps of the process were included within the operations and maintenance file. Best practices for the safety of the villagers was determined and included at the end of the operations and maintenance file, see Appendix D.

Conclusion

The village of Nazaret, Panama has the potential to develop a sustainable power source by harnessing the energy from the Rio Chico and a hydroelectric turbine option is viable. The engineering work performed by Clean Energy Engineers determined best fit turbines from New Energy Corportation and developed two turbine options to fit the village's demand. Two structural options were developed to accommodate placement of the turbine along the Rio Chico. Three structural anchoring options were designed to allow for different placement scenarios. The three anchoring options include a soil anchor, a rock anchor, and a river anchor which are also able to be used in tandem with each other. A construction management plan was developed with project schedules, estimate of probable cost, and an operations and maintenance manual were also created based on engineering work and New Energy Corporation standards. Clean Energy Engineers' hydroelectric turbine design is an engineered solution giving the village sustainable power generation.

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Appendix A: Turbine Selection

COLLECTED DATA from "Data Collection Plan", collected by Alan Foster (Solea Water)			
Run 1 (10 m distance)			
Location: Above community in narrows (closer to project site) **Project site is expected to have greater depth and somewhat lower velocities, therefore higher flow*			
Estimated Width (b)	7.61962816	m	
Estimated Depth (y)	1	m	*estimated parameter, will assume this is "normal condition"
Time 1 (t_1)	3.5	s	
Time 2 (t_2)	5	s	
Time 3 (t_3)	4.5	s	
Velocity 1 (V_1)	2.85714286	m/s	
Velocity 2 (V_2)	2	m/s	
Velocity 3 (V_3)	2.22222222	m/s	
Average Velocity (V_{avg})	2.35978836	m/s	*will vary greatly throughout the seasons, assuming "normal condition"
Approx. Area (A)	7.61962816	m^2	*assuming rectangular channel, again this is the assumed "normal condition"
Raw Value Flow (Q)	17.9807098	m^3/s	*will vary greatly, assuming "normal condition"
Modified Flow (Q)	14.3845679	m^3/s	*accounts for variation in velocity on surface vs bottom (value given by Dr. Schwartz)
Run 2 (30 m distance)			
Location: In front of community (downstream of site)			
Estimated Width (b)	7.61962816	m	
Estimated Depth (y)	1	m	*estimated parameter, will assume this is "normal condition"
Time 1 (t_1)	20	s	
Time 2 (t_2)	19	s	
Time 3 (t_3)	17	s	
Time 4 (t_4)	18	s	
Time 5 (t_5)	16	s	
Time 6 (t_6)	17	s	
Velocity 1 (V_1)	1.5	m/s	
Velocity 2 (V_2)	1.57894737	m/s	
Velocity 3 (V_3)	1.76470588	m/s	
Velocity 4 (V_4)	1.66666667	m/s	
Velocity 5 (V_5)	1.875	m/s	
Velocity 6 (V_6)	1.76470588	m/s	
Average Velocity (V_{avg})	1.69167097	m/s	*will vary greatly throughout the seasons, assuming "normal condition"
Approx. Area (A)	7.61962816	m^2	*assuming rectangular channel, again this is the assumed "normal condition"
Raw Value Flow (Q)	12.8899037	m^3/s	*will vary greatly, assuming "normal condition"
Modified Flow (Q)	10.311923	m^3/s	*accounts for variation in velocity on surface vs bottom (value given by Dr. Schwartz)



REQUIRED & KNOWN VALUES

from known standard values and project scope of work

Required			
Power (P)	10	kW	*minimum

Known			
Specific Weight Water (ɣ)	9810	N/m^3	
Density of Water	1000	kg/m^3	
Gravity	9.81	m/s^2	
Average Velocity (V)	2.35978836	m/s	*likely slower
Assumed V Range of Site	2 - 2.3	m/s	
Width (b)	7.619628162	m	*approx
Depth	1	m	*variable & likely deeper
Assumed Depth	1.5 - 2	m	

POWER

initial equations & values

Hydrokinetic Power Equation	$P=0.5*n*\rho*Q*V^2$		
Hydrokinetic Power w/ Betz Law	$P=0.5*0.59*n*\rho*Q*V^2$		
Flow Equation	Q=AV		
Efficiency (n)	30-60 %	*generally low due to water diverting around system (Betz Law)	
Q_1 (m^3/s)	22.85888449	where y=1.5 m & V=2 m/s	
Q_2 (m^3/s)	30.47851265	where y=2 m & V=2 m/s	
Q_3 (m^3/s)	26.28771716	where y=1.5 m & V=2.3 m/s	
Q_4 (m^3/s)	35.05028955	where y=2 m & V=2.3 m/s	
V_1 (m/s)	2		
V_2 (m/s)	2.3		
Velocity Head 1 ($V^2/2g$) (m)	0.203873598		
Velocity Head 2 ($V^2/2g$) (m)	0.269622834		

REQUIRED EFFICIENCIES

based on river conditions

Hydrokinetic Power Equation	$P=0.5*n*\rho*Q*V^2$	$P=0.5*0.59*n*\rho*Q*V^2$
Q_1 & V_1	21.87333333	37.07344633
Q_2 & V_1	16.405	27.80508475
Q_3 & V_1	19.02028986	32.23777942
Q_4 & V_1	14.26521739	24.17833456
Q_1 & V_2	16.53938248	28.03285167
Q_2 & V_2	12.40453686	21.02463875
Q_3 & V_2	14.38207172	24.37639275
Q_4 & V_2	10.78655379	18.28229456
Minimum Efficiency	22%	38%

TURBINE SPECIFICATIONS

comparison of each individual turbine

	New Energy Corp.		*SMART Hydro Power*	*DLZ Corp.*
	"Vertical Axis Darrieus"		*"Axial Propeller"*	*"Horizontal Axis Darrieus"*
	EVG-005H	**EVG-010H**	**Monofloat**	**Hydrokinetic Turbine**
Power Output (kW)	5	10	5	30
Design Velocity (m/s)	3	3	2.8	2.4
Turbine Diameter (m)	0.75	1.5	1.6	2.1336
Turbine In-Water Width (m)	1.5	1.5		
Boat Width (m)	3	3		
Height (m)	1.7	2.45	2.01	
Length (m)			3.13	
Generator Output (Volts)	300	300		
Cost of Energy ($/kWh)	0.2	0.2		
Min. Dist. From Bank (m)			0.2	
Min. Dist. From Bed (m)	0.25	0.25		
Min. Water Depth (m)	1.4	2.15	2	
Weight (kg)			380	
Notes	*also offers a fixed, non-floating option		* located in Germany, possible high shipping costs	*would need to be scaled down *requires more info, not commercially available

50% DESIGN DEVELOPMENT

- TURBINE SELECTION
- DRAG FORCE OF TURBINES
- OBSTRUCTION MAX. DRAG FORCE

CLAUDIA BIBLE

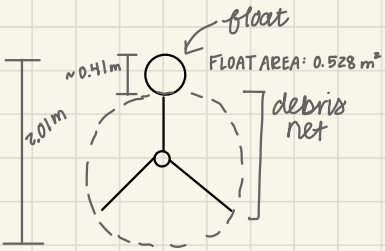
2/24/22

PANAMA RIVER FLOW

1

TURBINE SELECTION

SMART: MONOFLOAT





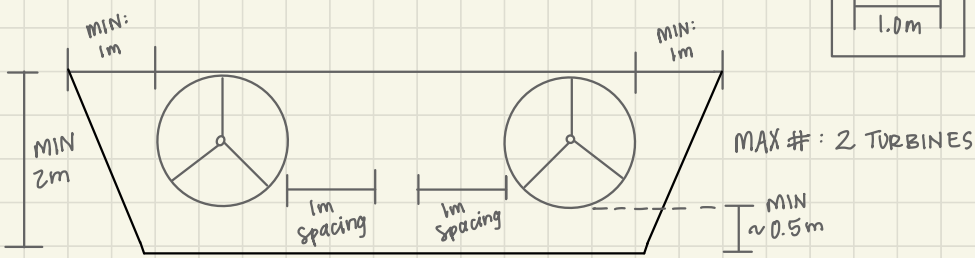
CIRCLE AREA: 2.011 m² ← use this to overcompensate

BLADE AREA:

WEIGHT: 380 kg = 837.76lb

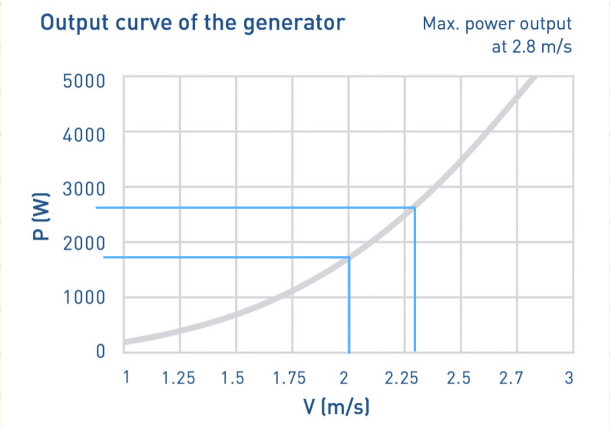
MAX OUTPUT @ 2.8m/s

generalized XS



SCALE
1.0m

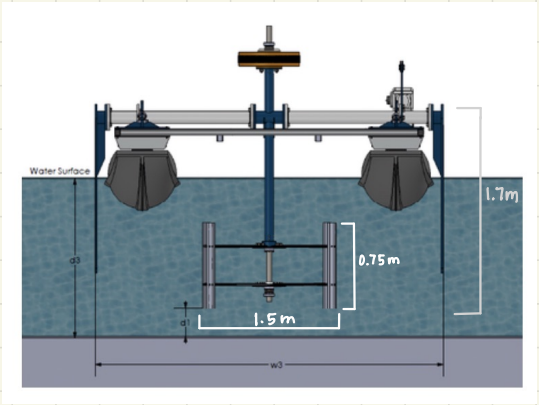
MAX #: 2 TURBINES

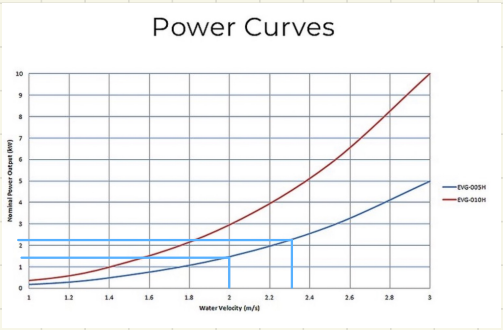


CURRENT CONDITIONS: 1.8 - 2.8 kW per turbine

REQUIRED: 4 - 6 turbines

NEW ENERGY: EVG-005



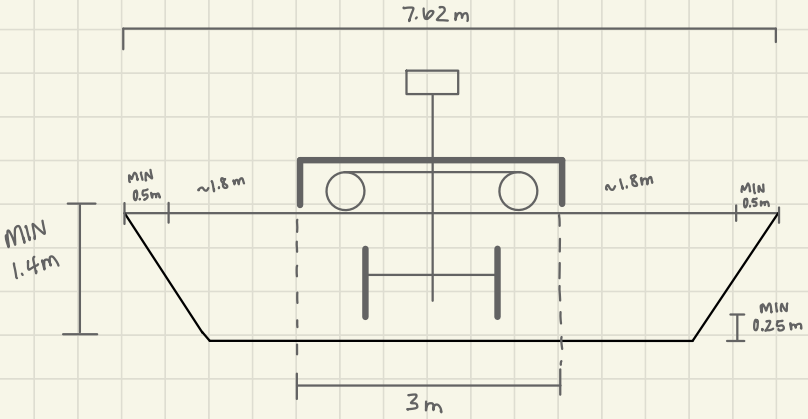


WEIGHT: 250 kg

MAX OUTPUT @ 3 m/s

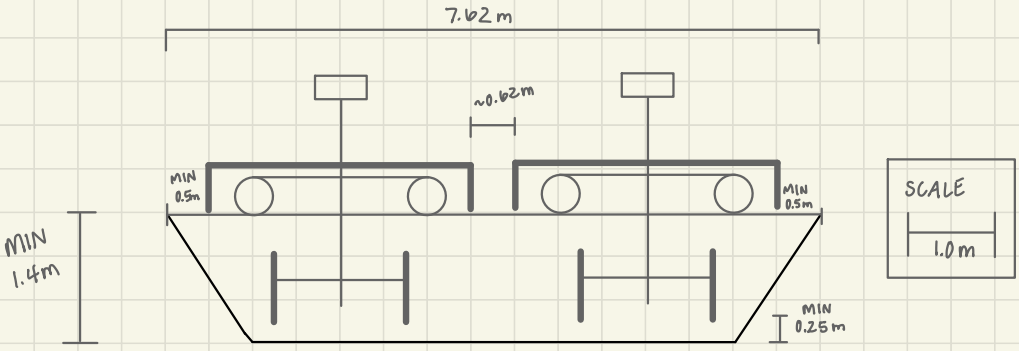
CURRENT CONDITIONS: 1.5-2.3 kW per turbine

REQUIRED: 5-7 turbines



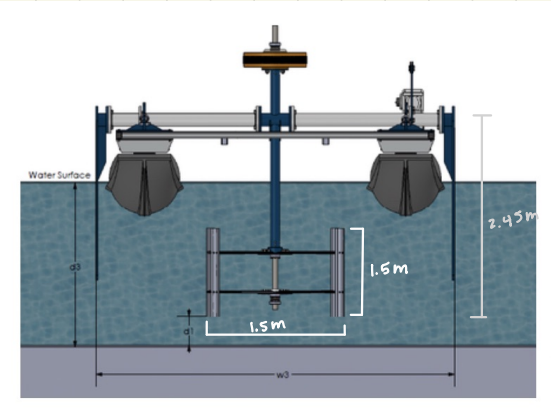
MAX # w/ TRAVEL INTACT: 1

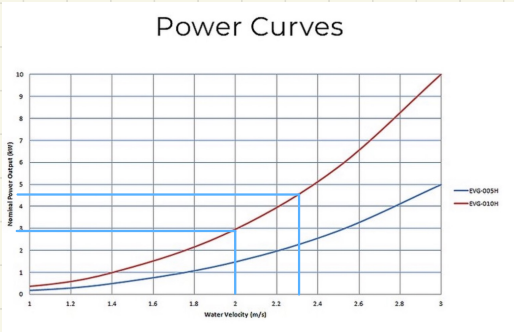
MAX # w/ COMPLETE BLOCKAGE: 2



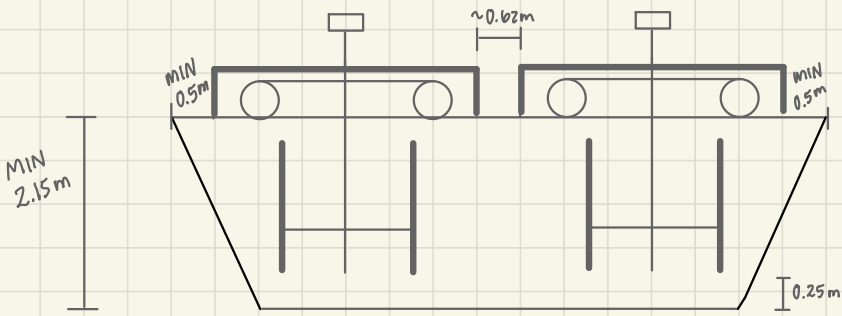
NEW ENERGY EVG-010

MAX OUTPUT @ 3m/s
~5kw @ 2.4 m/s

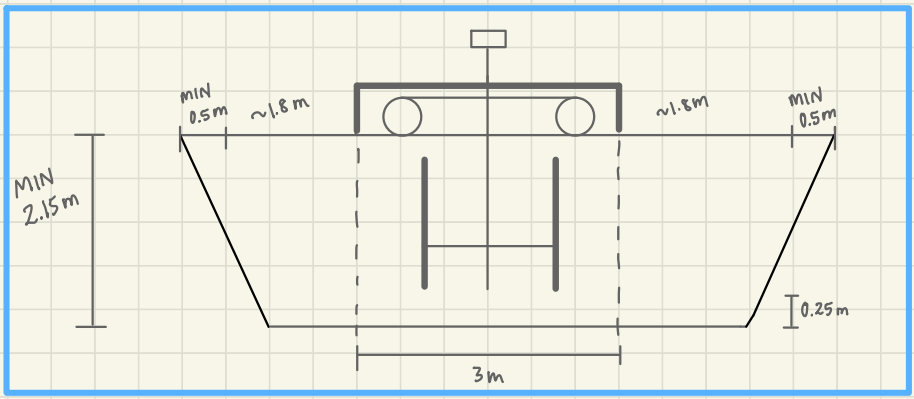




CURRENT CONDITIONS: 3 - 4.5 KW/turbine
REQUIRED: 3 - 4 turbines



MAX # w/ TRAVEL INTACT: 1
MAX # w/ COMPLETE BLOCKAGE: 2



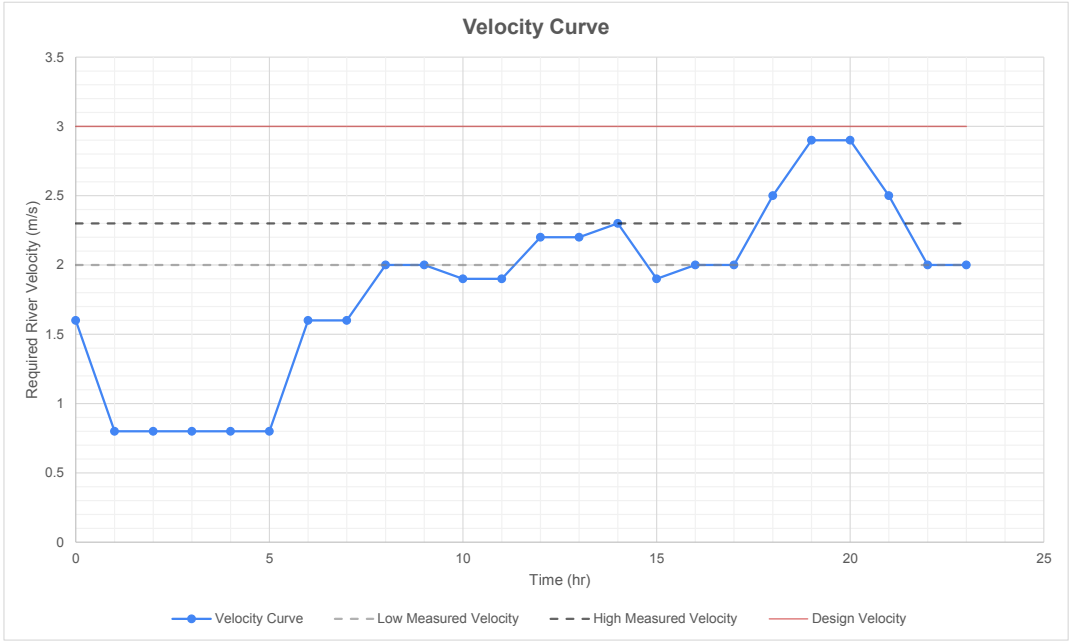
SCALE:
1.0 m

*#1 OPTION
*1 TURBINE, CENTER CHANNEL

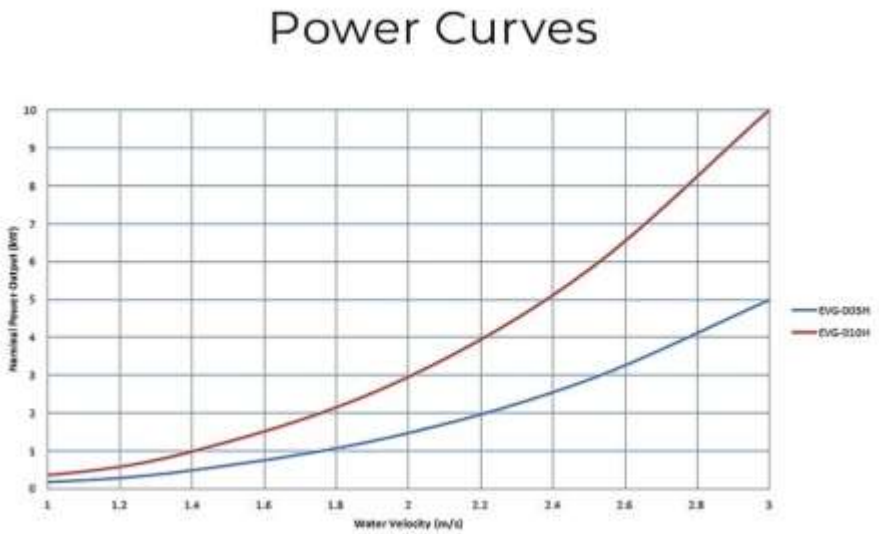
		EVG-010	EVG-005
Time	Consumption (kWh)	Required Velocity (m/s)	Required Velocity (m/s)
0	1.458254286	1.6	1.7
1	0.729127143	0.8	1.4
2	0.729127143	0.8	1.4
3	0.729127143	0.8	1.4
4	0.729127143	0.8	1.4
5	0.729127143	0.8	1.4
6	1.458254286	1.6	1.7
7	1.458254286	1.6	1.7
8	2.916508571	2	2
9	2.916508571	2	2
10	2.187381429	1.9	1.8
11	2.187381429	1.9	1.8
12	3.645635714	2.2	2.2
13	3.645635714	2.2	2.2
14	4.374762857	2.3	2.3
15	2.187381429	1.9	1.8
16	2.916508571	2	2
17	2.916508571	2	2
18	5.833017143	2.5	2.5
19	8.749525714	2.9	2.9
20	8.749525714	2.9	2.9
21	5.833017143	2.5	2.5
22	2.916508571	2	2
23	2.916508571	2	2

Consupmtion from REF 24 hr demand curve

Time	Oct. 2022 Low Range "Base Flow" (m/s)	Oct. 2022 High Range "Base Flow" (m/s)	Design Velocity (m/s)
0	2	2.3	3
1	2	2.3	3
2	2	2.3	3
3	2	2.3	3
4	2	2.3	3
5	2	2.3	3
6	2	2.3	3
7	2	2.3	3
8	2	2.3	3
9	2	2.3	3
10	2	2.3	3
11	2	2.3	3
12	2	2.3	3
13	2	2.3	3
14	2	2.3	3
15	2	2.3	3
16	2	2.3	3
17	2	2.3	3
18	2	2.3	3
19	2	2.3	3
20	2	2.3	3
21	2	2.3	3
22	2	2.3	3
23	2	2.3	3

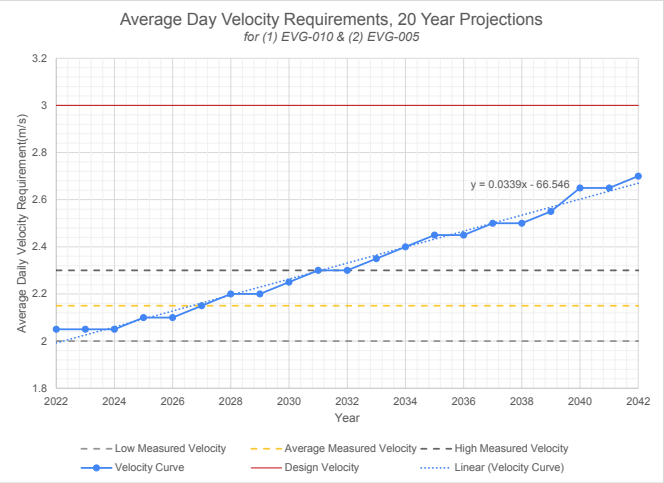


From New Energy Corp.:



Year	Avg. Yearly Energy (kWh)	Max Power for each year (kW)	Avg. Power per Day (kWh)	Avg. Power per Hour (kW)	Avg. Velocity Required (m/s)
2022	26613.14071	45.125	72.91271429	3.038029762	2.05
2023	27753.70389	47.05892857	76.0375449	3.168231037	2.05
2024	28951.29522	49.08955357	79.31861704	3.304942377	2.05
2025	30208.76612	51.22170982	82.76374279	3.448489283	2.1
2026	31529.11056	53.46047388	86.38112483	3.599213535	2.1
2027	32915.47223	55.81117615	90.17937597	3.757473999	2.15
2028	34371.15198	58.27941353	94.16753966	3.923647486	2.2
2029	35899.61571	60.87106278	98.35511155	4.098129648	2.2
2030	37504.50264	63.59229449	102.752062	4.281335918	2.25
2031	39189.63391	66.44958778	107.36886	4.473702501	2.3
2032	40959.02174	69.44974574	112.2164979	4.675687413	2.3
2033	42816.87896	72.5999116	117.3065177	4.887771571	2.35
2034	44767.62905	75.90758575	122.6510385	5.110459937	2.4
2035	46815.91664	79.38064361	128.2627853	5.344282722	2.45
2036	48966.61861	83.02735436	134.1551195	5.589796645	2.45
2037	51224.85568	86.85640065	140.3420704	5.847586265	2.5
2038	53596.0046	90.87689926	146.8383688	6.118265365	2.5
2039	56085.71097	95.09842279	153.6594821	6.402478421	2.55
2040	58699.90266	99.5310225	160.8216511	6.70090213	2.65
2041	61444.80393	104.1852522	168.3419286	7.014247023	2.65
2042	64326.95026	109.0721934	176.2382199	7.343259162	2.7
	**REF: 20 yr - Electrical*	**REF: 20 yr - Electrical*			** Same for EVG-010 & EVG-005*

Year	Oct. 2022 Low Range "Base Flow" (m/s)	Oct. 2022 High Range "Base Flow" (m/s)	Design Velocity (m/s)	Average Measured Velocity (m/s)
2022	2	2.3	3	2.15
2023	2	2.3	3	2.15
2024	2	2.3	3	2.15
2025	2	2.3	3	2.15
2026	2	2.3	3	2.15
2027	2	2.3	3	2.15
2028	2	2.3	3	2.15
2029	2	2.3	3	2.15
2030	2	2.3	3	2.15
2031	2	2.3	3	2.15
2032	2	2.3	3	2.15
2033	2	2.3	3	2.15
2034	2	2.3	3	2.15
2035	2	2.3	3	2.15
2036	2	2.3	3	2.15
2037	2	2.3	3	2.15
2038	2	2.3	3	2.15
2039	2	2.3	3	2.15
2040	2	2.3	3	2.15
2041	2	2.3	3	2.15
2042	2	2.3	3	2.15



Turbine Additions		
	1 Unit	2 Units
EVG-010	2045	2068
EVG-005	2045	2056

***Additions cannot be confirmed without power storage information**

Turbine Addition Calcs		
% Avg Velocity	Velocity (m/s)	Year
10	2.365	2033
15	2.4725	2036
20	2.58	2039
25	2.6875	2042
30	2.795	2045
35	2.9025	2049
40	3.01	2052
45	3.1175	2055
50	3.225	2058
55	3.3325	2061
60	3.44	2064
65	3.5475	2068
70	3.655	2071
75	3.7625	2074
80	3.87	2077
85	3.9775	2080
90	4.085	2084
95	4.1925	2087
100	4.3	2090

From New Energy Corporation:

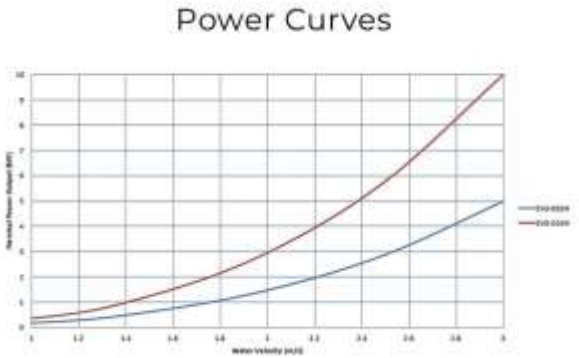


FIGURE 1. NEW ENERGY CORPORATION POWER-VELOCITY CURVE

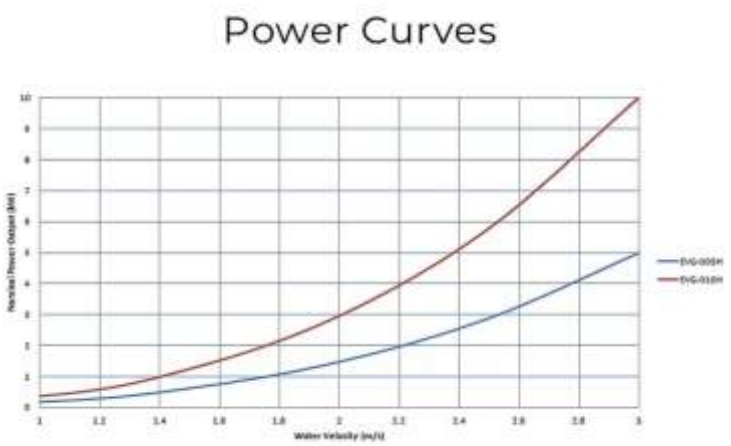


FIGURE 2. ISD POWER CONSUMPTION CURVE, WITH RANGE OF POSSIBLE POWER PRODUCTIONS, *Ref: Tables 2 & 3*

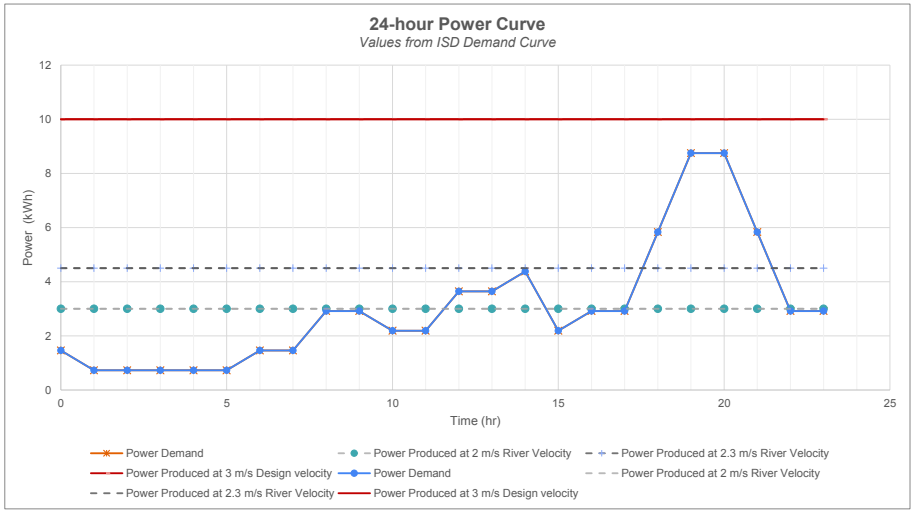


TABLE 1. CONSTANT POSSIBLE VELOCITIES FOR VELOCITY CURVE COMPARISONS

Time	Oct. 2022 Low Range "Base Flow" (m/s)	Oct. 2022 High Range "Base Flow" (m/s)	Design Velocity (m/s)
0	2	2.3	3
1	2	2.3	3
2	2	2.3	3
3	2	2.3	3
4	2	2.3	3
5	2	2.3	3
6	2	2.3	3
7	2	2.3	3
8	2	2.3	3
9	2	2.3	3
10	2	2.3	3
11	2	2.3	3
12	2	2.3	3
13	2	2.3	3
14	2	2.3	3
15	2	2.3	3
16	2	2.3	3
17	2	2.3	3
18	2	2.3	3
19	2	2.3	3
20	2	2.3	3
21	2	2.3	3
22	2	2.3	3
23	2	2.3	3

TABLE 2. REQUIRED VELOCITIES FOR POWER CONSUMPTION

		EVG-010	EVG-005
Time	Consumption (kWh)	Required Velocity (m/s)	Required Velocity (m/s)
0	1.458254286	1.6	1.7
1	0.729127143	0.8	1.4
2	0.729127143	0.8	1.4
3	0.729127143	0.8	1.4
4	0.729127143	0.8	1.4
5	0.729127143	0.8	1.4
6	1.458254286	1.6	1.7
7	1.458254286	1.6	1.7
8	2.916508571	2	2
9	2.916508571	2	2
10	2.187381429	1.9	1.8
11	2.187381429	1.9	1.8
12	3.645635714	2.2	2.2
13	3.645635714	2.2	2.2
14	4.374762857	2.3	2.3
15	2.187381429	1.9	1.8
16	2.916508571	2	2
17	2.916508571	2	2
18	5.833017143	2.5	2.5
19	8.749525714	2.9	2.9
20	8.749525714	2.9	2.9
21	5.833017143	2.5	2.5
22	2.916508571	2	2
23	2.916508571	2	2
	**Consupmtion from REF 24 hr demand curve*	**Corresponding Velocity on Manufacturer Curve for each consumption value*	

TABLE 3. POWER PRODUCTION AT CONSTANT POSSIBLE VELOCITIES

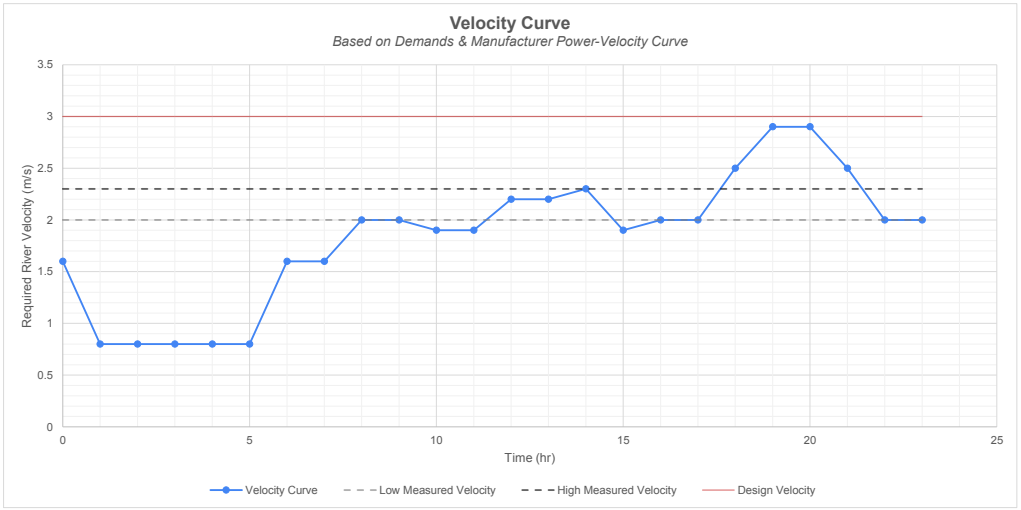
Time	Power at 2 m/s (kW)	Power at 2.3 m/s (kW)	Power at 3 m/s (kW)
0	3	4.5	10
1	3	4.5	10
2	3	4.5	10
3	3	4.5	10
4	3	4.5	10
5	3	4.5	10
6	3	4.5	10
7	3	4.5	10
8	3	4.5	10
9	3	4.5	10
10	3	4.5	10
11	3	4.5	10
12	3	4.5	10
13	3	4.5	10
14	3	4.5	10
15	3	4.5	10
16	3	4.5	10
17	3	4.5	10
18	3	4.5	10
19	3	4.5	10
20	3	4.5	10
21	3	4.5	10
22	3	4.5	10
23	3	4.5	10

TABLE 4. CUMULATIVE POWER STORAGE AT POSSIBLE VELOCITIES

Time (hr)	Cumulative Power Stored @ 2 m/s (kW)	Cumulative Power Stored @ 2.3 m/s (kW)	Cumulative Power Stored @ 3 m/s (kW)
0	0	0	0
1	1.9065	3.4065	8.9065
2	4.1775	7.1775	18.1775
3	9.4871025	13.9871025	30.4871025
4	12.7581025	18.7581025	40.7581025
5	16.0291025	23.5291025	51.0291025
6	17.9356025	26.9356025	59.9356025
7	19.4776025	29.9776025	68.4776025
8	20.2901025	32.2901025	76.2901025
9	20.3731025	33.8731025	83.3731025
10	20.8211025	35.8211025	90.8211025
11	21.6341025	38.1341025	98.6341025
12	21.6758525	39.7176025	105.717603
13	21.0298525	40.5716025	112.071603
14	20.0193525	41.0611025	118.061103
15	19.6053525	42.2801025	124.780103
16	20.0533525	44.2281025	132.228103
17	20.1363525	45.8111025	139.311103
18	18.8028525	45.8736025	144.936103
19	14.5113525	43.0821025	147.644603
20	8.7613525	38.8321025	148.894603
21	4.4698525	36.0406025	151.603103
22	3.1363525	36.1031025	157.228103
23	3.2193525	37.6861025	164.311103
	** Cumulative power storage values are based on intergrals of Figure 2. See "Cumulative Power Storage Process"*		

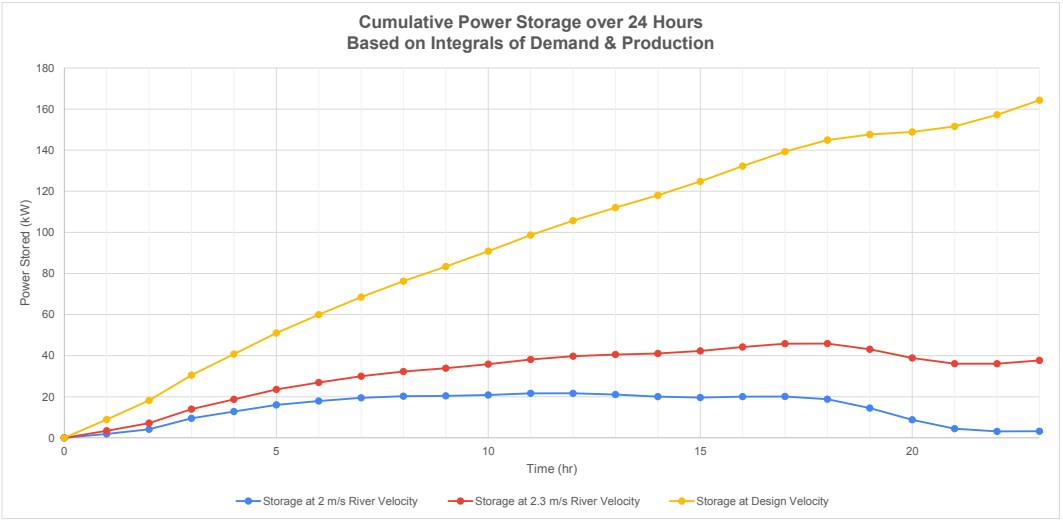
ALL WORK IS FOR (1) EVG-010 UNIT AND (2) EVG-005 UNITS. CALCULATIONS ARE THE SAME GIVEN UNITS HAVE THE SAME DESIGN VELOCITY & HAVING (2) EVG-005S PRODUCES THE SAME POWER AS (1) EVG-010

FIGURE 3. VELOCITY REQUIREMENTS FOR POWER DEMAND OVER 24-HOURS, *Ref: Tables 1 &2*



CONCLUSIONS: For the entire range of potential river velocities, the turbine will produce enough power to meet the demands; The storage curve assumes no power has been stored in previous days;At the end of the day, not all power stored has been consumed, so the battery will gradually build up excess power over several days

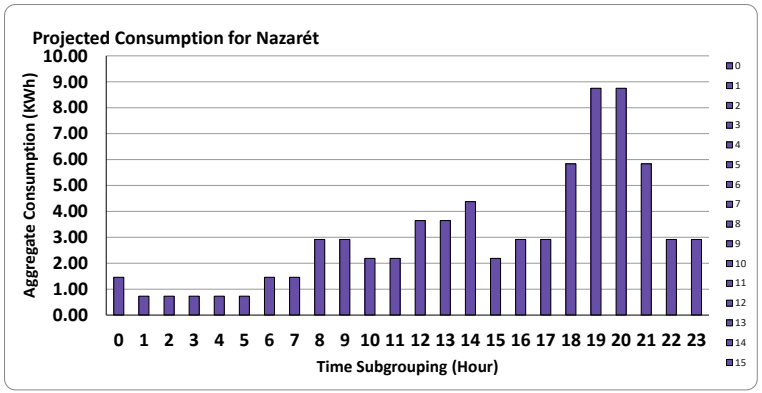
FIGURE 4. CUMULATIVE POWER STORAGE OVER 24 HOURS, *Ref: Figure 2 & Table 4*



Cumulative Power Storage Process:
Total Power Consumed = Integral from 0 to X time of Power Demand
Total Power Produced = Integral from 0 to X time of Power Production Line of Desired Velocity
When power demand curve is BELOW power production line:
Power is stored, area between the two is added
When power demand curve is ABOVE power production line:
Power is used from storage, area between the two is subtracted
So, if the cumulative curve drops below 0, then system cannot accommodate power demand

Time	Wh Consumption	KWh Consumption	Assumed Capacity Utilization
0	1458.254286	**1.46**	2%
1	729.1271429	**0.73**	1%
2	729.1271429	**0.73**	1%
3	729.1271429	**0.73**	1%
4	729.1271429	**0.73**	1%
5	729.1271429	**0.73**	1%
6	1458.254286	**1.46**	2%
7	1458.254286	**1.46**	2%
8	2916.508571	**2.92**	4%
9	2916.508571	**2.92**	4%
10	2187.381429	**2.19**	3%
11	2187.381429	**2.19**	3%
12	3645.635714	**3.65**	5%
13	3645.635714	**3.65**	5%
14	4374.762857	**4.37**	6%
15	2187.381429	**2.19**	3%
16	2916.508571	**2.92**	4%
17	2916.508571	**2.92**	4%
18	5833.017143	**5.83**	8%
19	8749.525714	**8.75**	12%
20	8749.525714	**8.75**	12%
21	5833.017143	**5.83**	8%
22	2916.508571	**2.92**	4%
23	2916.508571	**2.92**	4%
Totals:	72912.71429	**72.91**	100%

**** ALL "REF" SHEETS WERE CREATED BY THE INTERDISCIPLINARY DESIGN TEAM AND WERE USED AS REFERENCES FOR THIS PROJECT. THESE SHEETS WERE NOT CREATED BY THE PANAMA FLOW TEAM**



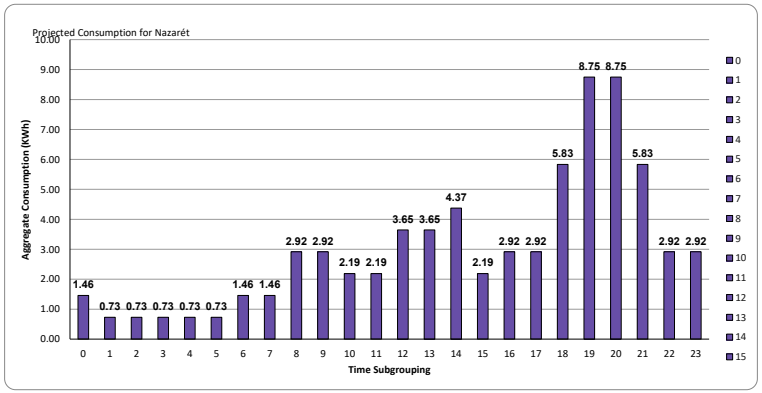


FIGURE 1. NEW ENERGY CORPORATION POWER-VELOCITY CURVE

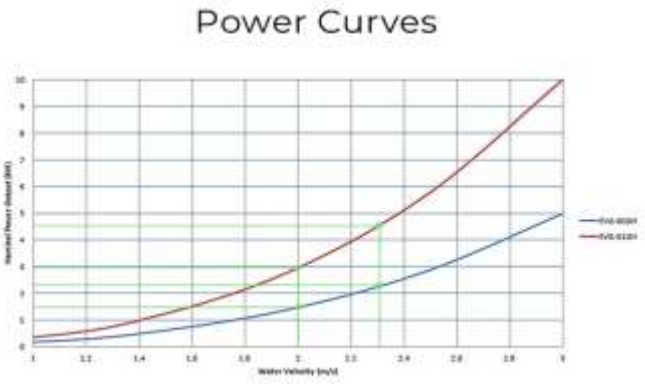


FIGURE 2. VELOCITY REQUIREMENTS OVER 20 YEARS, *Ref: Tables 1 & 2*

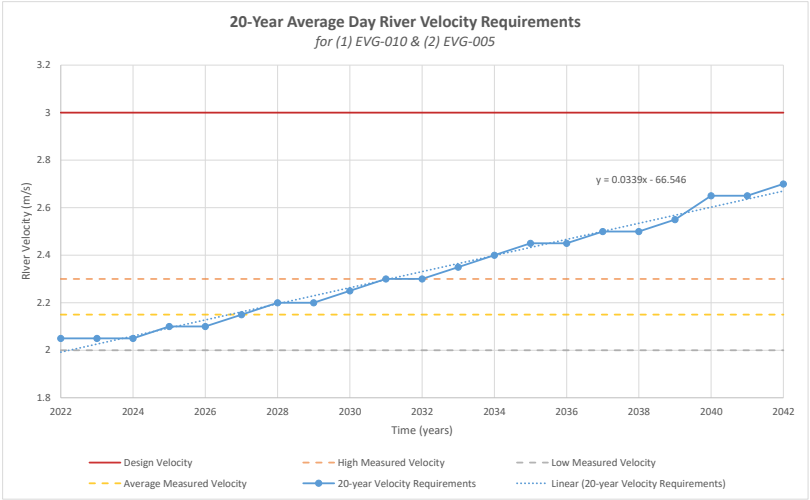


TABLE 1. POSSIBLE RIVER VELOCITIES

Year	Oct. 2022 Low Range "Base Flow" (m/s)	Oct. 2022 High Range "Base Flow" (m/s)	Design Velocity (m/s)	Average Measured Velocity (m/s)
2022	2	2.3	3	2.15
2023	2	2.3	3	2.15
2024	2	2.3	3	2.15
2025	2	2.3	3	2.15
2026	2	2.3	3	2.15
2027	2	2.3	3	2.15
2028	2	2.3	3	2.15
2029	2	2.3	3	2.15
2030	2	2.3	3	2.15
2031	2	2.3	3	2.15
2032	2	2.3	3	2.15
2033	2	2.3	3	2.15
2034	2	2.3	3	2.15
2035	2	2.3	3	2.15
2036	2	2.3	3	2.15
2037	2	2.3	3	2.15
2038	2	2.3	3	2.15
2039	2	2.3	3	2.15
2040	2	2.3	3	2.15
2041	2	2.3	3	2.15
2042	2	2.3	3	2.15

TABLE 2. AVERAGE DEMANDS OVER 20-YEARS WITH REQUIRED VELOCITIES

Year	Avg. Yearly Energy (kWh)	Max Power for each year (kW)	Avg. Power per Day (kW)	Avg. Power per Hour (kWh)	Avg. Velocity Required (m/s)
2022	26613.14071	45.125	72.91271429	3.038029762	2.05
2023	27753.70389	47.0589286	76.0375449	3.168231037	2.05
2024	28951.29522	49.0895536	79.31861704	3.304942377	2.05
2025	30208.76612	51.2217098	82.76374279	3.448489283	2.1
2026	31529.11056	53.4604739	86.38112483	3.599213535	2.1
2027	32915.47223	55.8111762	90.17937597	3.757473999	2.15
2028	34371.15198	58.2794135	94.16753966	3.923647486	2.2
2029	35899.61571	60.8710628	98.35511155	4.098129648	2.2
2030	37504.50264	63.5922945	102.752062	4.281335918	2.25
2031	39189.63391	66.4495878	107.36886	4.473702501	2.3
2032	40959.02174	69.4497457	112.2164979	4.675687413	2.3
2033	42816.87896	72.5999116	117.3065177	4.887771571	2.35
2034	44767.62905	75.9075858	122.6510385	5.110459937	2.4
2035	46815.91664	79.3806436	128.2627853	5.344282722	2.45
2036	48966.61861	83.0273544	134.1551195	5.589796645	2.45
2037	51224.85568	86.8564007	140.3420704	5.847586265	2.5
2038	53596.0046	90.8768993	146.8383688	6.118265365	2.5
2039	56085.71097	95.0984228	153.6594821	6.402478421	2.55
2040	58699.90266	99.5310225	160.8216511	6.70090213	2.65
2041	61444.80393	104.185252	168.3419286	7.014247023	2.65
2042	64326.95026	109.072193	176.2382199	7.343259162	2.7
	**REF: 20 yr - Electrical*	**REF: 20 yr - Electrical*	*Avg. Year / 365 days*	*Avg. Day / 24 hours*	** Same for EVG-010 & EVG-005*

TABLE 3. VELOCITY INCREASES OVER 20 YEARS

% Avg Velocity	Velocity (m/s)	Year
10	2.365	2033
15	2.4725	2036
20	2.58	2039
25	2.6875	2042
30	2.795	2045
35	2.9025	2049
40	3.01	2052
45	3.1175	2055
50	3.225	2058
55	3.3325	2061
60	3.44	2064
65	3.5475	2068
70	3.655	2071
75	3.7625	2074
80	3.87	2077
85	3.9775	2080
90	4.085	2084
95	4.1925	2087
100	4.3	2090
** Corresponding velocity from manufacturer curve for avg. hourly demand per year*		

TABLE 4. POWER PRODUCTION AT CONSTANT POSSIBLE VELOCITIES

Time	Power at 2 m/s (kW)	Power at 2.3 m/s (kW)	Power at 3 m/s (kW)
2022	3	4.5	10
2023	3	4.5	10
2024	3	4.5	10
2025	3	4.5	10
2026	3	4.5	10
2027	3	4.5	10
2028	3	4.5	10
2029	3	4.5	10
2030	3	4.5	10
2031	3	4.5	10
2032	3	4.5	10
2033	3	4.5	10
2034	3	4.5	10
2035	3	4.5	10
2036	3	4.5	10
2037	3	4.5	10
2038	3	4.5	10
2039	3	4.5	10
2040	3	4.5	10
2041	3	4.5	10
2042	3	4.5	10

ALL WORK IS FOR (1) EVG-010 UNIT AND (2) EVG-005 UNITS. CALCULATIONS ARE THE SAME GIVEN UNITS HAVE THE SAME DESIGN VELOCITY & HAVING (2) EVG-005S PRODUCES THE SAME POWER AS (1) EVG-010

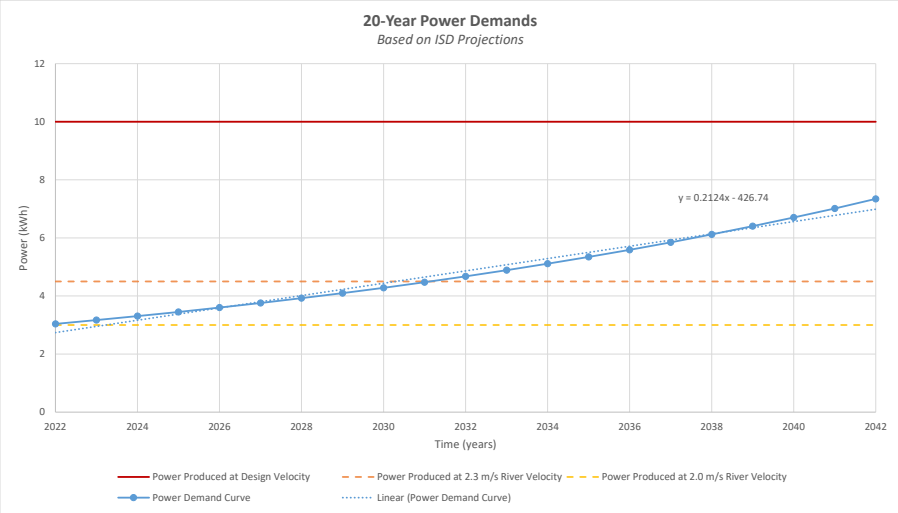


TABLE 6. AVERAGE POWER STORED PER YEAR

Time	Avg. Power per Hour (kW)	Power Storedy at 2 m/s (kW)	Power Stored at 2.3 m/s (kW)	Power Stored at 3 m/s (kW)
2022	3.038029762	-333.14072	12806.8593	60986.8593
2023	3.168231037	-1473.7039	11666.2961	59846.2961
2024	3.304942377	-2671.2952	10468.7048	58648.7048
2025	3.448489283	-3928.7661	9211.23388	57391.2339
2026	3.599213535	-5249.1106	7890.88943	56070.8894
2027	3.757473999	-6635.4722	6504.52777	54684.5278
2028	3.923647486	-8091.152	5048.84802	53228.848
2029	4.098129648	-9619.6157	3520.38428	51700.3843
2030	4.281335918	-11224.503	1915.49736	50095.4974
2031	4.473702501	-12909.634	230.366091	48410.3661
2032	4.675687413	-14679.022	-1539.0217	46640.9783
2033	4.887771571	-16536.879	-3396.879	44783.121
2034	5.110459937	-18487.629	-5347.629	42832.371
2035	5.344282722	-20535.917	-7395.9166	40784.0834
2036	5.589796645	-22686.619	-9546.6186	38633.3814
2037	5.847586265	-24944.856	-11804.856	36375.1443
2038	6.118265365	-27316.005	-14176.005	34003.9954
2039	6.402478421	-29805.711	-16665.711	31514.289
2040	6.70090213	-32419.903	-19279.903	28900.0973
2041	7.014247023	-35164.804	-22024.804	26155.1961
2042	7.343259162	-38046.95	-24906.95	23273.0497
		***Storage values are generalized, not		

TABLE 4. AVERAGE POWER STORED OVER 24-HOURS PER YEAR

Time	Avg. Power per Hour (kW)	Power Stored in 1-day at 2 m/s (kW)	Power Stored in 1-day at 2.3 m/s (kW)	Power Stored in 1-day at 3 m/s (kW)
2022	3.038029762	-0.9127143	35.0872857	167.087286
2023	3.168231037	-4.0375449	31.9624551	163.962455
2024	3.304942377	-7.318617	28.681383	160.681383
2025	3.448489283	-10.763743	25.2362572	157.236257
2026	3.599213535	-14.381125	21.6188752	153.618875
2027	3.757473999	-18.179376	17.820624	149.820624
2028	3.923647486	-22.16754	13.8324603	145.83246
2029	4.098129648	-26.355112	9.64488845	141.644888
2030	4.281335918	-30.752062	5.24793797	137.247938
2031	4.473702501	-35.36886	0.63113998	132.63114
2032	4.675687413	-40.216498	-4.2164979	127.783502
2033	4.887771571	-45.306518	-9.3065177	122.693482
2034	5.110459937	-50.651038	-14.651038	117.348962
2035	5.344282722	-56.262785	-20.262785	111.737215
2036	5.589796645	-62.155119	-26.155119	105.844881
2037	5.847586265	-68.34207	-32.34207	99.6579296
2038	6.118265365	-74.838369	-38.838369	93.1616312
2039	6.402478421	-81.659482	-45.659482	86.3405179
2040	6.70090213	-88.821651	-52.821651	79.1783489
2041	7.014247023	-96.341929	-60.341929	71.6580714
2042	7.343259162	-104.23822	-68.23822	63.7617801
		***Storage values are generalized, not considering changes in demand throughout the day.*		

TABLE 5. ACTUAL POWER STORED IN 24-HOURS FOR CURRENT DEMAND

Time	Power Stored in 1-day at 2 m/s (kW)	Power Stored in 1-day at 2.3 m/s (kW)	Power Stored in 1-day at 3 m/s (kW)
2022	3.2193525	37.6861025	164.311103
% Error	128.350865	6.89595531	1.68958955
	Error is too high for values to be considered	*Acceptable error*	

CONCLUSIONS

Additional turbine unit required between 2036-2038

TABLE 7. CUMULATIVE POWER STORED PER YEAR

Time	Avg. Power per Hour (kW)	Power Storedy at 2 m/s (kW)	Power Stored at 2.3 m/s (kW)	Power Stored at 3 m/s (kW)
2022	3.038029762	-333.14072	12806.8593	60986.8593
2023	3.168231037	-666.28143	24473.1554	120833.155
2024	3.304942377	-2671.2952	34941.8602	179481.86
2025	3.448489283	-5342.5904	44153.0941	236873.094
2026	3.599213535	-5249.1106	52043.9835	292943.983
2027	3.757473999	-10498.221	58548.5113	347628.511
2028	3.923647486	-8091.152	63597.3593	400857.359
2029	4.098129648	-16182.304	67117.7436	452557.744
2030	4.281335918	-11224.503	69033.2409	502653.241
2031	4.473702501	-22449.005	69263.607	551063.607
2032	4.675687413	-14679.022	67724.5853	597704.585
2033	4.887771571	-29358.043	64327.7063	642487.706
2034	5.110459937	-18487.629	58980.0773	685320.077
2035	5.344282722	-36975.258	51584.1606	726104.161
2036	5.589796645	-22686.619	42037.542	764737.542
2037	5.847586265	-45373.237	30232.6863	801112.686
2038	6.118265365	-27316.005	16056.6817	835116.682
2039	6.402478421	-54632.009	-609.02923	866630.971
2040	6.70090213	-32419.903	-19888.932	895531.068
2041	7.014247023	-64839.805	-41913.736	921686.264
2042	7.343259162	-38046.95	-66820.686	944959.314
		***Storage values are generalized, not considering changes in demand throughout the day.*		

Year	Avg. Yearly Energy (kWh)	Max Power for each year (kW)
2022	26613.14071	45.125
2023	27753.70389	47.05892857
2024	28951.29522	49.08955357
2025	30208.76612	51.22170982
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2027	32915.47223	55.81117615
2028	34371.15198	58.27941353
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2030	37504.50264	63.59229449
2031	39189.63391	66.44958778
2032	40959.02174	69.44974574
2033	42816.87896	72.5999116
2034	44767.62905	75.90758575
2035	46815.91664	79.38064361
2036	48966.61861	83.02735436
2037	51224.85568	86.85640065
2038	53596.0046	90.87689926
2039	56085.71097	95.09842279
2040	58699.90266	99.5310225
2041	61444.80393	104.1852522
2042	64326.95026	109.0721934

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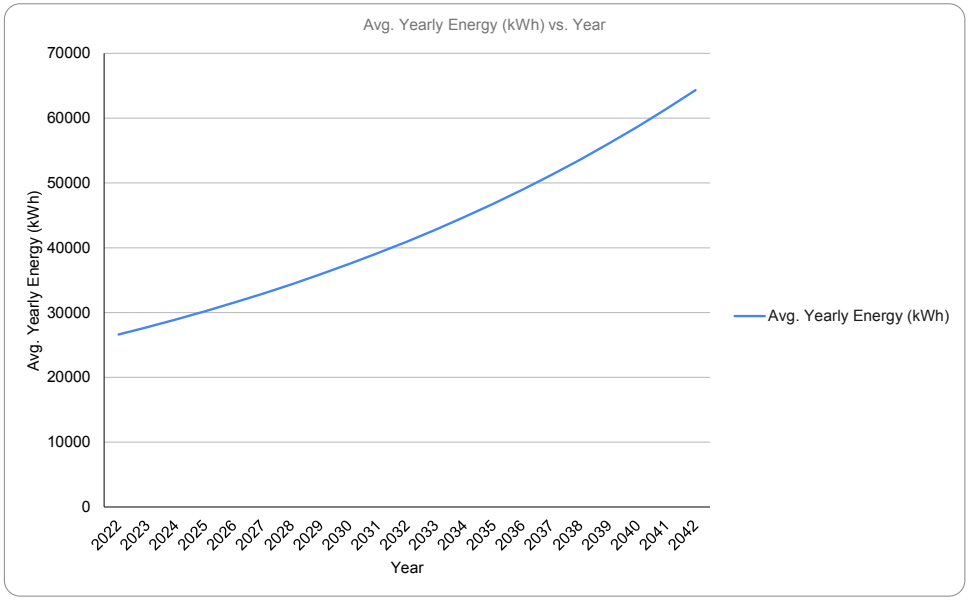

From: **Claudia Bible** cbible6@vols.utk.edu
Subject: Senior Design Work Review
Date: April 25, 2022 at 8:42 AM
To: Mookencheril Cherian mcherian@dlz.com
Cc: Matthew mtolson@vols.utk.edu, Andrew Houser ahouse15@vols.utk.edu, Anthony Condra acondra@vols.utk.edu, Nathan Merion Smith nsmit104@vols.utk.edu

CB

Hi Dr. Cherian,

As a part of our senior design course, it is requested that our technical mentor reviews one engineering task each team member has completed. Our team was wondering if you had availability over the next week to help us complete this task?

Each of our team members will individually send you their work with details about what parts to review and how their work is set up. The review does not have to be extensive, we just need a few comments or corrections. The goal of this task is for us to gain general confirmation that the work is valid or fix any incorrect work before our final deadline.

Thanks so much,

Claudia Bible

Undergraduate Research Assistant
Recording Secretary | Society of Women Engineers
Corresponding Secretary | American Society of Civil Engineers
Civil & Environmental Engineering

THE UNIVERSITY OF TENNESSEE KNOXVILLE

cbible6@vols.utk.edu | cmbible@comcast.net | (865) 314-1173

From: **Mookencheril Cherian** mcherian@dlz.com
Subject: Re: Senior Design Work Review
Date: April 25, 2022 at 8:49 AM
To: Claudia Bible cbible6@vols.utk.edu
Cc: Matthew mtolson@vols.utk.edu, Andrew Houser ahouse15@vols.utk.edu, Anthony Condra acondra@vols.utk.edu, Nathan Merion Smith nsmit104@vols.utk.edu

MC

Claudia

Yes, I can do a quick review if that is OK.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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From: Claudia Bible <cbible6@vols.utk.edu>
Sent: Monday, April 25, 2022 8:42 AM
To: Mookencheril Cherian <mcherian@dlz.com>
Cc: Matthew <mtolson@vols.utk.edu>; Andrew Houser <ahouse15@vols.utk.edu>; Anthony Condra <acondra@vols.utk.edu>; Nathan Merion Smith <nsmit104@vols.utk.edu>
Subject: Senior Design Work Review

EXTERNAL: Message origin is from an external network. Use proper judgment and caution when opening attachments, clicking links, or responding to this email.

Hi Dr. Cherian,

As a part of our senior design course, it is requested that our technical mentor reviews one engineering task each team member has completed. Our team was wondering if you had availability over the next week to help us complete this task?

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Thanks so much,

Claudia Bible
Undergraduate Research Assistant
Recording Secretary | Society of Women Engineers
Corresponding Secretary | American Society of Civil Engineers
Civil & Environmental Engineering

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From: **Claudia Bible** cbible6@vols.utk.edu
Subject: Re: Senior Design Work Review
Date: April 28, 2022 at 6:21 PM
To: Mookencheril Cherian mcherian@dlz.com

CB

Hi Dr. Cherian,

Please find below my drag and impact force calculations for review. Let me know if I can answer any questions or if any changes are needed!

Thanks so much,

Claudia Bible
Undergraduate Research Assistant
Recording Secretary | Society of Women Engineers
Corresponding Secretary | American Society of Civil Engineers
Civil & Environmental Engineering
THE UNIVERSITY OF TENNESSEE KNOXVILLE

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A02_Turbine Drag a...lcs.pdf

A03_Drag Force Calcula...ns.xlsx

> On Apr 25, 2022, at 8:48 AM, Mookencheril Cherian <mcherian@dlz.com> wrote:
>
> Claudia
>
> Yes, I can do a quick review if that is OK.
>
>
> **Mookencheril Cherian** | Senior Project Manager
>
> 614-888-0040 x356 (office)
> mcherian@dlz.com | www.dlz.com
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> ---
>
> **From:** Claudia Bible <cbible6@vols.utk.edu>
> **Sent:** Monday, April 25, 2022 8:42 AM
> **To:** Mookencheril Cherian <mcherian@dlz.com>
> **Cc:** Matthew <mtolson@vols.utk.edu>; Andrew Houser <ahouse15@vols.utk.edu>; Anthony Condra <acondra@vols.utk.edu>; Nathan Merion Smith <nsmit104@vols.utk.edu>
> **Subject:** Senior Design Work Review
>
>
> **EXTERNAL:** Message origin is from an external network. Use proper judgment and caution when opening attachments, clicking links, or responding to this email.
>
>
> Hi Dr. Cherian,
>
> As a part of our senior design course, it is requested that our technical mentor reviews one engineering task each team member has completed. Our team was wondering if you had availability over the next week to help us complete this task?

From: **Mookencheril Cherian** mcherian@dlz.com
Subject: Re: Senior Design Work Review
Date: May 1, 2022 at 10:19 PM
To: Claudia Bible cbible6@vols.utk.edu

MC

Claudia

I am attaching my comments in the attached and they are in red font.
I think it may be good to have a 1- or 2-page narrative that refers to the hand calculations (you could label these in the handwritten notes as Calculation or Sheet 1, and so on) so it is clearer.

There should be a summary section, that indicates the final forces and angles to be considered in the design.

I am not sure of the calculations in the spreadsheets. Shouldn't the drag calculations have velocity squared in them (I didn't see that in the formula)?
Also, the impact force and drag force should not be additive. When the machine is hit by a log that results in an impact force. When it is turned around and rests on the machine, it causes added drag. The larger of the two is what will add to the drag of the machine when it is spinning.

Hope this helps.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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ARCHITECTURE - ENGINEERING - PLANNING
SURVEYING - CONSTRUCTION SERVICES

INNOVATIVE IDEAS
EXCEPTIONAL DESIGN
UNMATCHED CLIENT SERVICE

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From: Claudia Bible <cbible6@vols.utk.edu>
Sent: Thursday, April 28, 2022 6:21 PM
To: Mookencheril Cherian <mcherian@dlz.com>
Subject: Re: Senior Design Work Review

EXTERNAL: Message origin is from an external network. Use proper judgment and caution when opening attachments, clicking links, or responding to this email.

Hi Dr. Cherian,

Please find below my drag and impact force calculations for review. Let me know if I can answer any questions or if any changes are needed!

Thanks so much,

Claudia Bible
Undergraduate Research Assistant
Recording Secretary | Society of Women Engineers
Corresponding Secretary | American Society of Civil Engineers
Civil & Environmental Engineering
THE UNIVERSITY OF TENNESSEE KNOXVILLE

cbible6@vols.utk.edu | cmbible@comcast.net | (865) 314-1173

> On Apr 25, 2022, at 8:48 AM, Mookencheril Cherian <mcherian@dlz.com> wrote:
>
> Claudia
>
> Yes, I can do a quick review if that is OK.

From: **Claudia Bible** cbible6@vols.utk.edu
Subject: Re: Senior Design Work Review
Date: May 3, 2022 at 8:01 PM
To: Mookencheril Cherian mcherian@dlz.com

CB

Dr. Cherian,

Thank you so much for taking the time to review my work, I really appreciate it!

I have corrected the drag force equation in the tree spreadsheet. I also confirmed that the combined drag and impact force was not used in any design work. I also confirmed our structures were designed for the drag force and our breakaway strength is the impact force.

Thank you again,

Claudia Bible
Undergraduate Research Assistant
Recording Secretary | Society of Women Engineers
Corresponding Secretary | American Society of Civil Engineers
Civil & Environmental Engineering
THE UNIVERSITY OF TENNESSEE KNOXVILLE
cbible6@vols.utk.edu | cmbible@comcast.net | (865) 314-1173

> On May 1, 2022, at 10:19 PM, Mookencheril Cherian <mcherian@dlz.com> wrote:
>
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>
> I am attaching my comments in the attached and they are in red font.
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> There should be a summary section, that indicates the final forces and angles to be considered in the design.
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> I am not sure of the calculations in the spreadsheets. Shouldn't the drag calculations have velocity squared in them (I didn't see that in the formula)?
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>
> Hope this helps.
>
>
> **Mookencheril Cherian** | Senior Project Manager
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> DLZ ARCHITECTURE - ENGINEERING - PLANNING SURVEYING - CONSTRUCTION SERVICES
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> **From:** Claudia Bible <cbible6@vols.utk.edu>
> **Sent:** Thursday, April 28, 2022 6:21 PM
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> **Subject:** Re: Senior Design Work Review
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>
>
> Hi Dr. Cherian,
>
> Please find below my drag and impact force calculations for review. Let me know if I can answer any questions or if any changes are needed!

Documentation of Items Addressed:

- Drag force calculation for trees missing squared in velocity term
    - Corrected on spreadsheet
- Drag and impact are not additive
    - Confirmed that additive force was not used in design

Appendix B: Geotechnical Characterization

Included by Matthew Tolson

Included by Matthew Tolson for SD Package

Hey Penstock and River teams,

I did my best with the recon work. Some of my assumptions were a bit off on elevation changes and distances, based on prior interviews in the community. I didn't do the most thorough job with photos, but hopefully what I have will suffice. I didn't get a good drone photo of a potential site on the main river with the cliff due to inclement weather, but there is a video that shows it pretty well.

I understand that this is a feasibility study, so there are broad numbers to crunch to determine the feasibility. It seems that some questions are very specific to things like foundations and floor plan of a powerhouse, for instance. We need to make sure we have the horse before the cart.

My gut feeling is that the most reasonable possibility for (penstock) hydropower involves building the penstock some distance from the community and then using a transmission line. This is for a couple reasons.

1. The elevation gain for the tributary stream is quite steep from where it empties into the main river (You can see on the map that the main river splits not far above the community. The stream empties into the eastern branch at a point I will include). So the penstock wouldn't need to be that long to gain significant head.
2. The topography after that point would be cost-prohibitive to conquer with a penstock (4 or 5 major river crossings) whereas a transmission line could follow a ridgeline or make longer crossing much cheaper.

For the river flow team, there is a large variation in available flow scenarios. I focused on the areas that seemed best based on my limited experience. Some also accounts for interviews regarding debris that could damage any infrastructure.

Preliminary Data Collection Plan

October 2021

PENSTOCK

List of Measurement Parameters:

1. Flow Rate of the tributary stream

So, there were actually 2 significant tributaries where they took me. The smaller one was where they tried to install the old aqueduct. I took points above the old intake, at the old intake, at the V where the 2 tributaries merge, and below where the combined streams enter the main river. I didn't take any points above the V on the larger tributary. Both would have similar elevation gains continuing on up. So you can assume that the larger tributary would follow the elevation pattern of the smaller one, and also that you could gain more elevation if you continued a given distance. I measured for flow rate on the smaller tributary and on the combined tributaries, so you can subtract to estimate the larger one.

Included by Matthew Tolson

I went ahead and did the flow calculations because my stream profile drawings were a little scribbly. I used to do stream flow estimations for the NPS, so they're probably fairly accurate. And I would say that a conservative estimate for the dry season could be half of this flow rate.

1st tributary

5m run

10s, 9s, 9s, 10s = 9.5 s/5m = 1.9 s/m = 0.53 m/s

2.3m wide

10cm, 16, 14, 18, 16 depth = 14.8cm avg

Área = 2.3 x 0.148 = 0.3404 m2

V=0.180412 m3/s = 180 L/s = 48 gal/s = 2,853 gal/min

Lower river

4m run

3.0 m wide

3 sections

1.0m wide, 21cm avg. depth, 9s avg. time, 9s/4m = 2.25 s/m = 0.44 m/s

A = 0.21m2, V = 0.44 x 0.21 = 0.0924 m3/s

1.0m wide, 33cm avg. depth, 5s avg. time, 5s/4m = 1.25 s/m = 0.8 m/s

A = 0.33m2, V = 0.8 x 0.33 = 0.264 m3/s

1.0m wide, 33cm avg. depth, 5s avg. time, 5s/4m = 1.25 s/m = 0.8 m/s

A = 0.33m2, V = 0.8 x 0.33 = 0.264 m3/s

Vt = V1 + V2 + V3 = 0.6204 m3/s = 620 L/s = 164 gal/s = 9,828 gal/min

2nd tributary estimation V = 9828 – 2853 = 6975 gal/min

2. Change of elevation from stream to area potential powerhouse location See GPS points

3. Distance from stream output to potential powerhouse location See GPS points

4. Photos of site We need a desired elevation to hone in on a forebay site. A typical design for one of these intakes (whether an aqueduct or hydro) involves a small (1 or 2ft) dam that may only cover a portion of the stream bed. A covering may be used to minimize the entry of larger debris (wedge wire sometimes)

Measurement Parameters Explanation:

1. Flow Rate of the tributary stream

Included by Matthew Tolson

In order to estimate the flow rate of the stream, a segment of stream will be measured and recorded. A floating object is to be placed into the stream and the time for it to travel the specified distance is to be recorded. In addition, the depth of flow is being requested at three even places along the cross section of the stream.
Smaller tributary:

2. Elevation of Stream, Powerhouse, Proposed Forebay Location

Utilize GPS to specify the elevation at the stream, the powerhouse, and the forebay location. As flow rate has not been determined; the stream elevation required is unknown. Because of this, it is requested that the elevation of two stream diversion locations is provided.

3. Stream to Powerhouse Distance

It is requested that the distance between the prospective stream diversion locations and the powerhouse is measured.

4. Site Photos

Please take as many pictures as possible!! Please provide pictures of potential obstructing vegetation, stream, potential diversion stream location, forebay location, and proposed powerhouse area.

Included by Matthew Tolson

RIVER FLOW

List of Measurement Parameters:

1. Flow Rate of the river
2. Slope of river
3. Approximate river depth and width
4. Soil type of bank and bluff
5. Potential Locations for power house
6. Needs/Concerns of the community

Measurement Parameters Explanation:

1. Flow Rate

Measure velocity of river by measuring the time it takes for an object to travel a certain distance; perform at multiple points on the river and across a profile; record locations. Flow rate can be calculated from this value and the river dimensions. Multiply by a factor of 0.8 to account for difference in surface and bottom flows due to friction

This is the only area where it was practical to get data to estimate a flow rate.
Rio Chico above community in narrows
10m run
3.5s, 5s, 4.5s, avg. velocity = 4.33s for 10m = 2.3 m/s
25' wide
1.5m deep (that was their estimation. 1.0m is probably a more accurate average)
I don't think that total flow rate will be particularly useful as depth and velocity are more important for this type of power exploitation. Unfortunately, I didn't get flow rate measurements for the river portion that would be more practical. It is significantly deeper and somewhat slower. Again, there is a tremendous variation in depths and flow rates available very close by the community.

Here are some measurements for velocity in the section in front of the community.
Rio Chico in front of community
30m
20s, 19s, 17s, 18s, 16s, 17s

2. Slope

Assume the slope of the bank is approximately the slope of the river, measure slopes of left and right banks which can be averaged
The slopes are different everywhere, ranging from cliffs to level

3. River depth and width

Measure width with tape
Approximate depth as best as possible
Again, it varies tremendously. We estimated the width at 25' where flow was estimated. It was too dangerous to measure.

Included by Matthew Tolson

4. Soil type

Option to collect sample or visually classify on site
Again, there is tremendous variation. As stated in one video, the area that seems practical for potential exploitation has a 25' tall sheer cliff of rock that has not changed in recorded memory. It would provide viable anchor points

5. Powerhouse locations

Approximate Locations that a power house could be placed. Ensure area has enough space
Record approximate distance from river
GPS locations or on a map if possible
I don't understand the term "powerhouse" here unless there is a different technology being considered. There is plenty of space for any infrastructure needed.

6. Community

Please record any concerns or requests from the community. We want to ensure our work meets their expectations, despite not being able to directly speak with them.

We held meetings with leaders and meetings with the community. There are not specific concerns or requests per se, and they seem quite clear on the study, its goals, and their potential role in a successful project.

Overall, this is a sort of iterative process. As the team hones in on the most appropriate technology, that tech will have depth and velocity requirements. We will also have to consider the behavior of the rivers in terms of debris and flooding for final site selection.

References for Schematic Design Package – Matthew Tolson

Guiding document:

Weber, R. P. (2010). “Basic Geotechnical Engineering.” Continuing Education and Development, Inc., <https://www.cedengineering.com/userfiles/Basic%20Geotechnical%20Engineering%20R1.pdf> (Dec. 1, 2021).

Cohesion estimate:

Komurlu, E., and Demir, A. D. (2018). “Determination of Cohesion values of Rock Materials using Double Shear Jaws.” Periodica Polytechnical Civil Engineering, <https://www.researchgate.net/publication/325196191_Determination_of_Cohesion_values_of_Rock_Materials_using_Double_Shear_Jaws> (Dec. 1, 2021).

Rock Density estimate:

Sharma, P. V. (1997). “Environmental and engineering geophysics.” *Cambridge Core*, <https://www.cambridge.org/core/books/environmental-and-engineering-geophysics/43698769072DBC9047686044FFA5AE73> (Dec. 1, 2021).

Geology in Darien Province:

Coates, A. G., Collins, L. S., Aubry, M.-P., and Berggren, W. A. (2004). “The geology of the Darien, Panama, and the late Miocene-Pliocene collision of the Panama Arc with Northwestern South America.” *GSA Bulletin*, GeoScienceWorld, <https://pubs.geoscienceworld.org/gsa/gsabulletin/article-abstract/116/11-12/1327/125266/The-Geology-of-the-Darien-Panama-and-the-late> (Dec. 1, 2021).

Friction Angle estimation:

Singh, B., and Goel, R. K. (2011). “Engineering rock mass classification.” *ScienceDirect*, <https://www.sciencedirect.com/book/9780123858788/engineering-rock-mass-classification> (Dec. 1, 2021).

References for 50% DD – Matthew Tolson

Concrete/Footing Design Code:

ACI 318-19: Building Code Requirements for Structural Concrete: Commentary on Building Code Requirements for Structural Concrete (ACI 318R-19). (2019). American Concrete Institute, Farmington Hills, MI.

Soil Hand Test:

"Estimating soil texture by hand." (2021). *Agriculture and Food*, Department of Primary Industries and Regional Development, <https://www.agric.wa.gov.au/soil-constraints/soil-texture-estimating-hand>

Bearing Capacity Table:

"Foundations." (1995). *Cabo one and two family dwelling code: 1995 edition*, essay, Council of American Building Officials, Falls Church, VA, 25–25.

USDA Soil Classification Chart:

Eagle, B. (2020). "Soil Texture: Sand, Silt and Clay." *Thinking Country*, <https://thinkingcountry.com/2016/11/30/soil-texture-sand-silt-and-clay/>

Ultimate Bearing Capacity of Footing on Sheer Cliff (Rock) Matthew Tolson

Basic Eq: q = cNc + yDNq + 0.5yBNy

Input Parameters:

c =	6000000	Pa
D =	0	m
B =	1	m
y =	19620	n/m3
Nc =	32	
Nq =	20	
Ny =	18	

Output: q = 192176580 Pa

Notes:

D = 0 if foundation sits on top of rock
B depends on required capacity
Rock cohesion assumed to be 6 Mpa (subject to change)
Rock density assumed to be 2000 kg/m3 (subject to change)
Friction angle assumed to be 30 degrees (subject to change)
N-factors subject to change as friction angle changes

*Placeholder values based on preliminary research

4.9 Foundations on Rock

On some occasions, shallow foundations may have to be built on rocks, as shown in Figure 4.26. For estimation of the ultimate bearing capacity of shallow foundations on rock, we may use Terzaghi's bearing capacity equations [Eqs. (3.3), (3.7) and (3.8)] with the bearing capacity factors given here (Stagg and Zienkiewicz, 1968; Bowles, 1996):

$$N_c = 5\tan^4\left(45 + \frac{\phi'}{2}\right) \tag{4.47}$$

$$N_q = \tan^6\left(45 + \frac{\phi'}{2}\right) \tag{4.48}$$

$$N_\gamma = N_q + 1 \tag{4.49}$$

For rocks, the magnitude of the cohesion intercept, c', can be expressed as

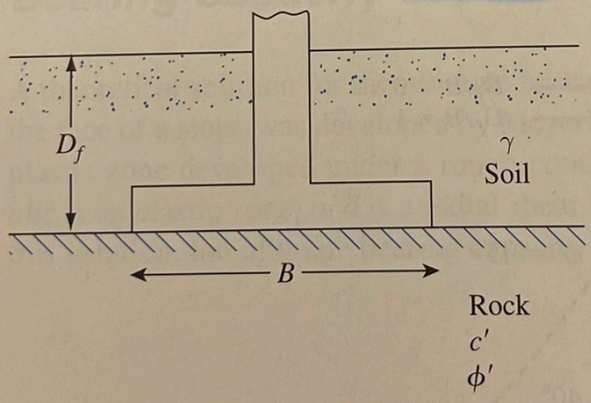
$$q_{uc} = 2c'\tan\left(45 + \frac{\phi'}{2}\right) \tag{4.50}$$

where
q_{uc} = unconfined compression strength of rock
ϕ' = angle of friction

The unconfined compression strength and the friction angle of rocks can vary widely. Table 4.2 gives a general range of q_{uc} for various types of rocks. It is important to keep in mind that the magnitude of q_{uc} and ϕ' (hence c') reported from laboratory tests are for intact rock specimens. It does not account for the effect of discontinuities. To account for discontinuities, Bowles (1996) suggested that the ultimate bearing capacity q_u should be modified as

$$q_{u(\text{modified})} = q_u(\text{RQD})^2 \tag{4.51}$$

where RQD = rock quality designation (see Chapter 2).



from ch. 2, RQD found in table 2.11

RQD = 0.25 for poor rock.

Figure 4.26 Foundation on rock

Table 4.2 Range of the Unconfined Compression Strength of Various Types of Rocks

Rock type	q_{uc} MN/m²	q_{uc} kip/in²	ϕ' (deg)
Granite	65–250	9.5–36	45–55
Limestone	30–150	4–22	35–45
Sandstone	25–130	3.5–19	30–45
Shale	5–40	0.75–6	15–30

recovered from each run, the following quantities may be calculated for a general evaluation of the rock quality encountered:

$$\text{Recovery ratio} = \frac{\text{length of core recovered}}{\text{theoretical length of rock cored}} \tag{2.70}$$

$$\text{Rock quality designation (RQD)} = \frac{\Sigma \text{ length of recovered pieces equal to or larger than 101.6 mm (4 in.)}}{\text{theoretical length of rock cored}} \tag{2.71}$$

A recovery ratio of unity indicates the presence of intact rock; for highly fractured rocks, the recovery ratio may be 0.5 or smaller. Table 2.11 presents the general relationship (Deere, 1963) between the RQD and the *in situ* rock quality.

Table 2.11 Relation between *in situ* Rock Quality and RQD

RQD	Rock quality
0–0.25	Very poor
0.25–0.5	Poor
0.5–0.75	Fair
0.75–0.9	Good
0.9–1	Excellent

Department of
Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

Estimating soil texture by hand



Extruding a soil ribbon to estimate a texture class

Estimating or measuring soil texture provides valuable information about soil properties affecting crop and pasture growth. Soil texture affects the movement and availability of air, nutrients and water in a soil. A simple and quick measure of soil texture is the way a soil feels when manipulated by hand.

The Department of Primary Industries and Regional Development recommends laboratory testing of soil texture (and other factors) for all critical soil uses, including farm dam construction and claying.

Soil texture explained

Soil texture is an estimate of the amount of sand, silt and clay particles present in the soil. It is an inherent property of the soil and cannot be changed by normal agronomic practices.

Many physical characteristics of the soil depend on texture, and the clay content is very important. Soil texture affects drainage and structure, which in turn affect how plants will grow in the soil. The clay and organic matter help to bind soil particles together, forming stable aggregates, which are an indicator of good soil structure: good soil drainage, root and seedling penetration, and aeration.

Before you start

Step 1 Sieve your soil

Use a 2-millimetre (mm) sieve to remove stones and gravel, and break down lumps in the soil, making it easier to work with. If your soil is damp, you will need to dry it before sieving. To dry, place about 1 kilogram of broken-up soil in an oven at 150°C for 2–4 hours.

Step 2 Estimate percentage of stones or gravel in the soil

Make a visual estimate of the percentage of stones and gravel in the soil from step 1. This helps if you plan to estimate the plant available water capacity of the soil.

Hand texturing

Step 3 Take a small handful of soil

To fit comfortably in the palm of your hand.

Step 4 Add water to the sample

Add enough water to make a bolus or ball (Figure 1). Knead the bolus for 1–2 minutes, adding more water or soil until it just stops sticking to your fingers. Note how the soil feels when kneading it: gritty (sandy), silky (silty) or plastic/sticky (clay). If you can't make a bolus, the soil is very sandy.



Figure 1 Making a ball of the soil sample shows that it is not a sand

Step 5 Form a soil ribbon

Gently press out the soil between your thumb and index finger to form a hanging ribbon. The ribbon should only be 2–3mm thick. The more clay you have in your soil, the longer your ribbon will be (Figures 2 and 3).



Figure 2 Moulding a moist soil sample into a ribbon

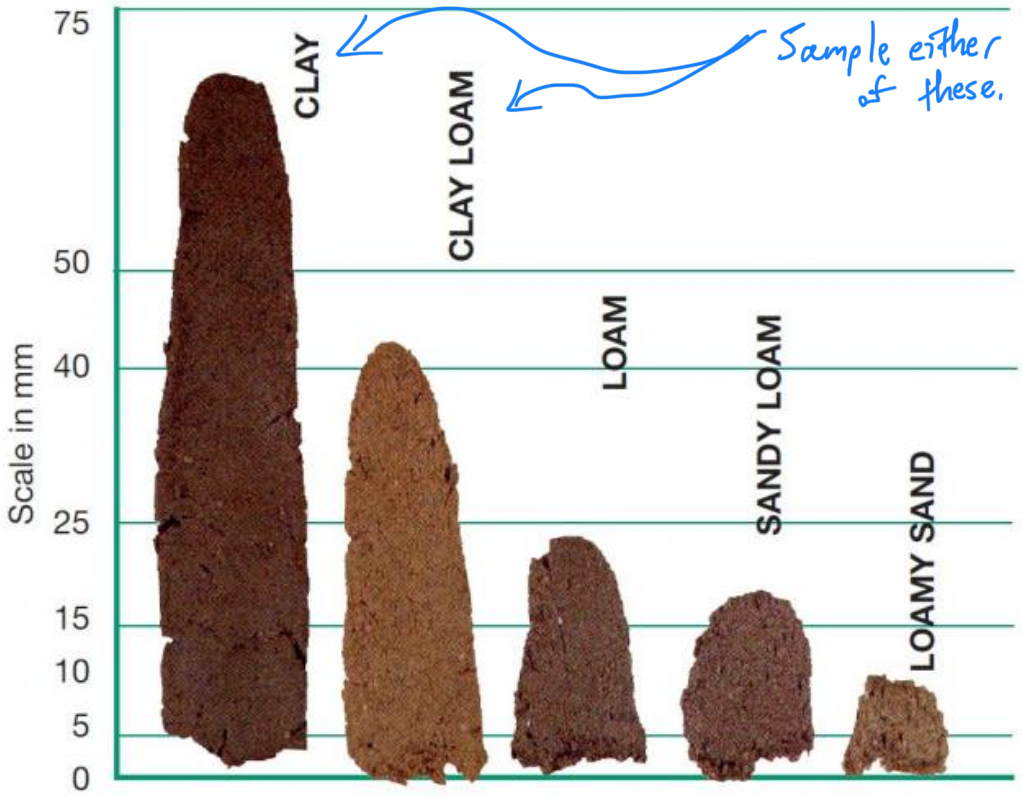


Figure 3 Hand extruded soil ribbons to demonstrate texture
Use information in Table 1 to more accurately identify your soil's texture.

Field texturing is not as accurate as laboratory testing for particle size: field textures are influenced by organic matter, different clay minerals, the sodicity (i.e. the proportion of sodium on the cation exchange sites of the clay) and the amount of calcium carbonate (lime) present.

In general, field texture is a reasonable guide to soil behaviour for crop and pasture agronomy. More information to help you texture a soil sample is given in Tables 1 and 2.

Table 1 Field texture grade and description

Texture grade	Behaviour of moist bolus (the way a soil feels and the ribbon formed when manipulated by hand)	Approximate clay content	Soil code
Sand	Coherence is nil to very slight; cannot be moulded; single sand grains stick to fingers	Less than 5%	S
Loamy sand	Slight coherence; can be sheared between thumb and forefinger to give minimal ribbon of about 5mm	About 5%	LS
Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain; will form minimal ribbon of 5–15mm	5–10%	CS
Sandy loam	Bolus is coherent but very sandy to touch; dominant sand grains are of medium size and are readily visible; ribbon of 15–25mm	10–20%	SL
Loam	Bolus is coherent and rather spongy; no obvious sandiness or silkiness; will form a ribbon of about 25mm	About 25%	L
Sandy clay loam	Strongly coherent bolus; sandy to touch; ribbon of 25–40mm	20–30%	SCL
Clay loam	Coherent plastic bolus; smooth to manipulate; will form ribbon of 40–50mm	30–35%	CL
Clay loam, sandy clay	Coherent plastic bolus; sand grains visible in finer matrix; sandy to touch; ribbon of 40–50mm	30–35%	CLS
Light clay	Plastic bolus; smooth to touch; slight resistance to shearing; ribbon of 50–75mm	35–40%	LC
Light medium clay	Slight to moderate resistance to ribboning shear; ribbon of about 75mm	40–45%	LMC
Medium clay	Smooth plastic bolus; handles like plasticine, and can be moulded into rods without fracture; moderate resistance to ribboning shear; ribbon of 75mm or more	45–55%	MC
Medium heavy clay	Handles like plasticine; moderate to firm resistance to ribboning shear; ribbon of 75mm or more	55% or more	MHC
Heavy clay	Handles like stiff plasticine; firm resistance to ribboning shear; ribbon of 75mm or more	55% or more	HC

Determined to be Silty clay with < 5% gravel/stones

Table 2 Texture qualifiers (as a prefix) can be used to refine a field or hand texture description

Coarse sandy	Coarse sand is obviously coarse to touch. Sand grains are readily seen with the naked eye
Fine sandy	More than 35% very coarse sand and very fine gravel between 1 and 3mm
Gritty	35–70% by volume gravel
Stony	35–70% by volume stones

See Also

Soil classification in Western Australia
MySoil
MyCrop
Claying to ameliorate soil water repellence

Excavated tanks (farm dams)

All Page Links

[1] https://www.agric.wa.gov.au/sites/gateway/files/styles/original/public/Soil%20hand%20texturing%20-%20making%20a%20ball.jpg?itok=a1Ez5uMR
[2] https://www.agric.wa.gov.au/sites/gateway/files/styles/original/public/Soil%20hand%20texturing%20-%20making%20a%20ribbon.jpg?itok=jj1ZfUCd
[3] https://www.agric.wa.gov.au/sites/gateway/files/styles/original/public/Hand%20extruded%20soil%20ribbons%20to%20demonstrate%20texture.jpg?itok=9_drNClt
[4] https://www.agric.wa.gov.au/identifying-wa-soils/soil-classification-western-australia
[5] https://www.agric.wa.gov.au/managing-soils/mysoil
[6] https://www.agric.wa.gov.au/mycrop
[7] https://www.agric.wa.gov.au/water-repellence/claying-ameliorate-soil-water-repellence
[8] https://www.agric.wa.gov.au/water-management/excavated-tanks-farm-dams

Source URL: https://www.agric.wa.gov.au/soil-constraints/soil-texture-estimating-hand
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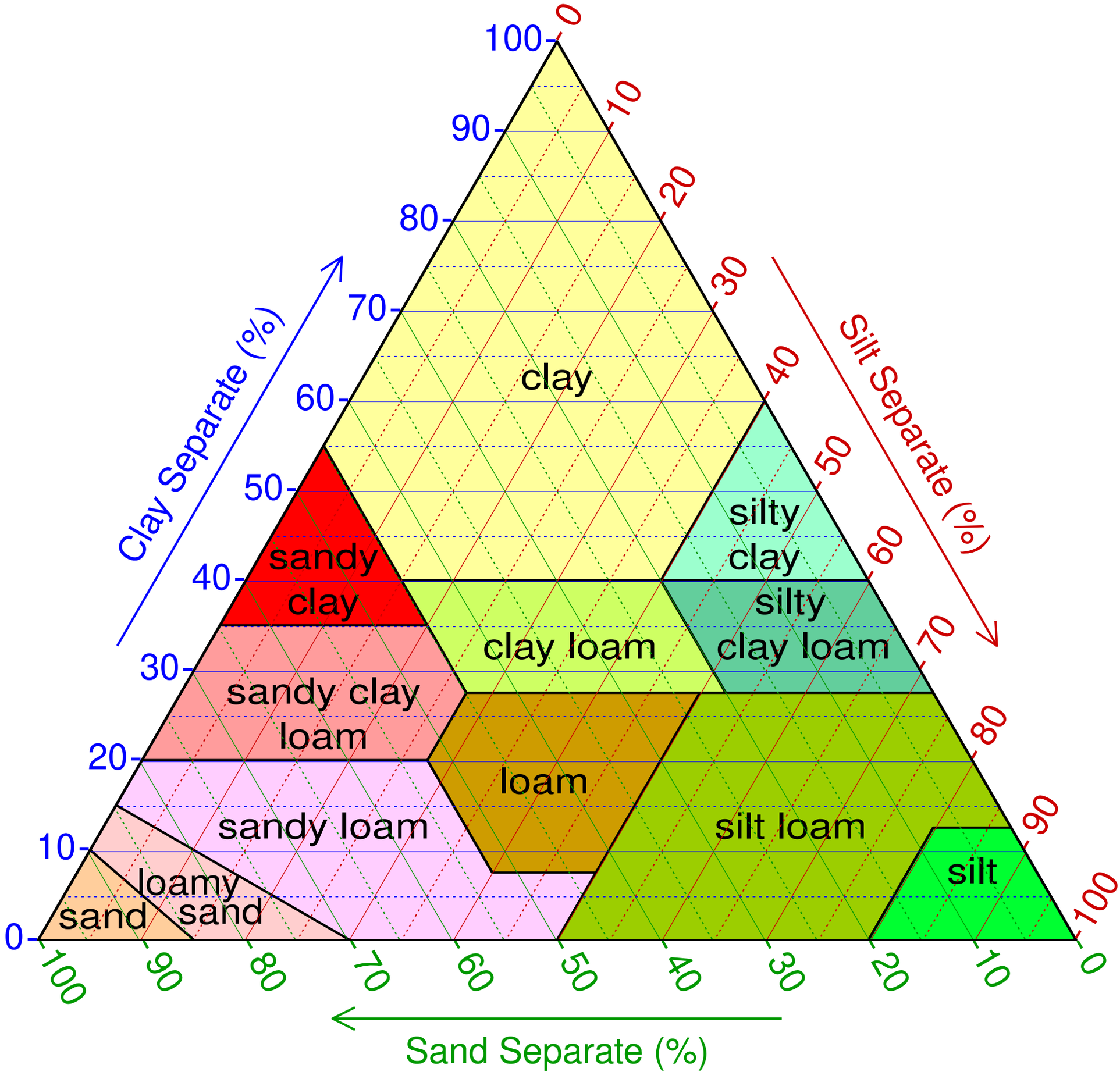
Clay Separate (%)
Silt Separate (%)
Sand Separate (%)
clay
silty clay
sandy clay
clay loam
silty clay loam
sandy clay loam
loam
sandy loam
silt loam
silt
loamy sand
sand

CHAPTER 4
FOUNDATIONS

SECTION 401
GENERAL

401.1 Application. The provisions of this chapter shall control the design and construction of the foundation and foundation spaces for all buildings.

Exception: The provisions of this chapter for wood foundations apply only in the following situations:

1. Buildings supported by wood foundations shall be limited to no more than two floors and a roof.
2. No dimension in a basement room or crawl space area shall exceed the smaller of either the building width or length.

401.2 Requirements. The foundation and its structural elements shall be capable of accommodating all superimposed live, dead and other loads according to Section 301 and all lateral loads in accordance with the provisions of this code. Fills which support footings and foundations shall be designed, installed and tested in accordance with accepted engineering practice. Gravel fill used as footings for wood foundations shall comply with Section 403.

401.3 Drainage. Surface drainage shall be diverted to a storm sewer conveyance or other point of collection so as to not create a hazard. Lots shall be graded so as to drain surface water away from foundation walls. The grade away from foundation walls shall fall a minimum of 6 inches (153 mm) within the first 10 feet (3048 mm).

Exception: Where lot lines, walls, slopes or other physical barriers prohibit 6 inches (153 mm) of fall within 10 feet (3048 mm), drains or swales shall be provided to ensure drainage away from the structure.

401.4 Soil tests. In areas likely to have expansive, compressible, shifting or other unknown soil characteristics, the building official shall require a soil test to determine the soil's characteristics at a particular location. This determination shall be made by an approved agency using an approved method.

401.4.1 Geotechnical evaluation. In lieu of a complete geotechnical evaluation, the load-bearing values in Table 401.4.1 shall be assumed.

401.5 Expansive, compressible or shifting soil. When top or subsoils are expansive, compressible or shifting, such soils shall be removed to a depth and width sufficient to assure stable moisture content in each active zone and shall not be used as fill; or stabilized within each active zone by chemical, dewatering or presaturation.

TABLE 401.4.1
PRESUMPTIVE LOAD-BEARING VALUES OF FOUNDATION MATERIALS

CLASS OF MATERIAL	LOAD-BEARING PRESSURE (pounds per square foot)
Crystalline bedrock	12,000
Sedimentary rock	6,000
Sandy gravel or gravel	5,000
Sand, silty sand, clayey sand, silty gravel and clayey gravel	3,000
Clay, sandy clay, silty clay and clayey silt	2,000

For **SI:** 1 psf = 0.0479 kN/m^2.

SECTION 402
MATERIALS

402.1 Wood foundations. Wood foundation systems shall be designed and installed in accordance with the provisions of this code.

402.1.1 Fasteners. Fasteners used below grade to attach plywood to the exterior side of exterior basement or crawlspace wall studs, or fasteners used in knee wall construction, shall be of Type 304 or 316 stainless steel. Fasteners used above grade to attach plywood, and all lumber-to-lumber fasteners except those used in knee wall construction shall be of Type 304 or 316 stainless steel, silicon bronze, copper, hot-dipped galvanized (zinc coated) steel nails, or hot-tumbled galvanized (zinc coated) steel nails. Electrogalvanized steel nails and galvanized (zinc coated) steel staples shall not be permitted.

402.1.2 Wood treatment. All lumber and plywood shall be treated in accordance with AWPA C22 and shall be identified as in conformance with such standard by an approved inspection agency. Where lumber and plywood is cut or drilled after treatment, the cut surface shall be field treated with Ammoniacal Copper Arsenate (ACA), Chromated Copper Arsenate (CCA), or Copper Napthenate by repeated brushing, dipping or soaking until the wood absorbs no more preservative. Water-borne preservatives ACA and CCA Types A, B and C shall have a minimum concentration of 3 percent in solution. Water-borne preservatives FCAP and ACC shall be permitted for field treatment of material originally treated with CCA and ACA water-borne preservatives, and the concentration of FCAP or ACC shall be a minimum of 5 percent in solution. Copper Napthenate shall be prepared with a solvent conforming to AWPA P5. The preservative concentration shall contain a minimum of 2 percent copper metal.

402.2 Concrete. Concrete shall have a minimum specified compressive strength as shown in Table 402.2. Concrete subject to weathering as indicated in Table 301.2a shall be air entrained as specified in Table 402.2. The minimum cement content of concrete mixtures for exterior porches, carport slabs, and steps that









As of January 2004, this manual is no longer up to date. Please see someone at the desk for the updated version. Thanks.

CABO ONE and TWO FAMILY DWELLING CODE

1995 EDITION

9:55 AM Sat Apr 23 98%
engineeringtoolbox.com

Material	Density - ρ -	
	(lb/ft^3)	*(kg/m^3)*
Dirt, loose dry	76	1220
Dirt, loose moist	78	1250
Clay, dry	100	1600
Clay, wet	110	1760
Gravel, dry	105	1680
Gravel, Wet	125	2000
Limestone	160	2560
Loam	80	1280
Mud, flowing	108	1730
Mud, steady	115	1840
Rock, well blasted	155	2480
Sand, dry	97	1555
Sand, wet	119	1905

avg. = 1520 kg/m^3

= 14,900 N/m^3

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for geotechnical problems, however, specific condition of each engineering problem often needs to be considered for an appropriate choice of geotechnical parameters.

Description	Cohesion [kPa]		
	min	max	Nominal
Well graded gravel, sandy gravel, with little or no fines	-	-	0
Poorly graded gravel, sandy gravel, with little or no fines	-	-	0
Silty gravels, silty sandy gravels	-	-	0
Clayey gravels, clayey sandy gravels	-	-	20
Well graded sands, gravelly sands, with little or no fines	-	-	0
Poorly graded sands, gravelly sands, with little or no fines	-	-	0
Silty sands	-	-	22
Silty sands - Saturated compacted	-	-	50
Silty sands - Compacted	-	-	20
Clayey sands	-	-	5
Clayey sands - Compacted	-	-	74
Clayey sands -Saturated compacted	-	-	11
Loamy sand, sandy clay Loam - compacted	50	75	
Loamy sand, sandy clay Loam - saturated	10	20	
Sand silt clay with slightly plastic fines - compacted	-	-	50
Sand silt clay with slightly plastic fines - saturated compacted	-	-	14
Inorganic silts, silty or clayey fine sands, with slight plasticity	-	-	7
Inorganic silts and clayey silts - compacted	-	-	67
Inorganic silts and clayey silts - saturated compacted	-	-	9
Inorganic clays, silty clays, sandy clays of low plasticity	-	-	4
Inorganic clays, silty clays, sandy clays of low plasticity - compacted	-	-	86
Inorganic clays, silty clays, sandy clays of low plasticity - saturated compacted	-	-	13
Mixture if inorganic silt and clay - compacted	-	-	65
Mixture if inorganic silt and clay - saturated compacted	-	-	22
Organic silts and organic silty clays of low plasticity	-	-	5
Inorganic silts of high plasticity - compactd	-	-	10
Inorganic silts of high plasticity - saturated compacted	-	-	72
Inorganic silts of high plasticity	-	-	20
Inorganic clays of high plasticity	-	-	25
Inorganic clays of high plasticity - compacted	-	-	103
Inorganic clays of high plasticity - satrated compacted	-	-	11
Organic clays of high plasticity	-	-	10
Loam - Compacted	60	90	
Loam - Saturated	10	20	
Silt Loam - Compacted	60	90	
Silt Loam - Saturated	10	20	
Clay Loam, Silty Clay Loam - Compaced	60	105	
Clay Loam, Silty Clay Loam - Saturated	10	20	
Silty clay, clay - compacted	90	105	
Silty clay, clay - saturated	10	20	
Peat and other highly organic soils	-	-	

References

- Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers
- Minnesota Department of Transportation, Pavement Design, 2007
- NAVFAC Design Manual 7.2 - Foundations and Earth Structures,SN 0525-LP-300-7071, REVALIDATED BY CHANGE 1 SEPTEMBER 1986

Rock Characteristics

Assume weak rock to be conservative. (strong shale or weak stone)

From *Principles of Foundation Engineering 7th edition* by Braja Das:				
	Ultimate bearing capacity qu = 25 MN/m2 for shale/weak sandstone (Table 4.2)			
	Friction angle = 30 degrees for shale/weak sandstone (Table 4.2)			
	RQD = 0.25 for poor rock quality (Table 2.11)			
	Equation 4.51 for modified ultimate bearing capacity = qu(RQD)^2			
	qu (modified) =	1.5625	MN/m2	

*Grout mix design not contained in this file

Soil Characteristics

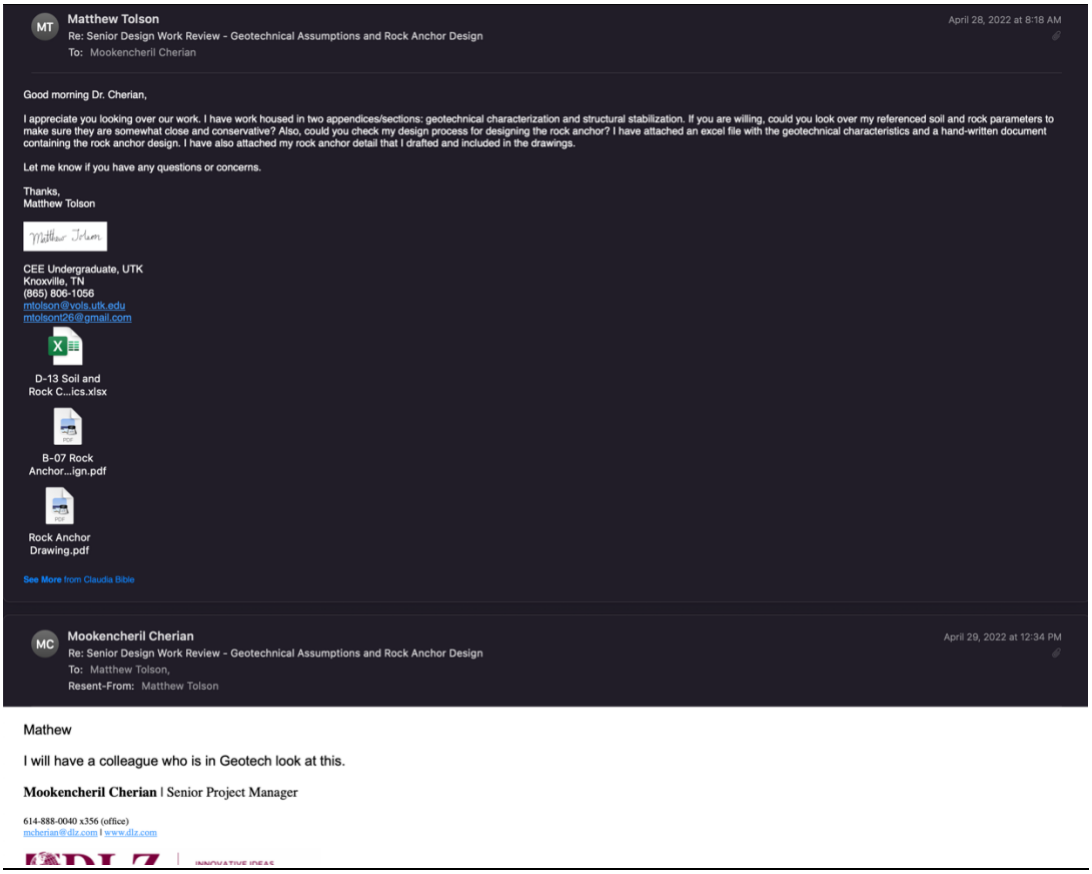
Based on Solea Water ribbon test, assume silty clay
Wet Density assumed to be 14,900 N/m3 from reference
Cohesion strength for silty clay loam ranges from 10-20 kPa (use 15 kPa for design)
Engineering Toolbox & CABO lists bearing load of soft clay as 100 kPa and 96 kPa, respecitvely (assume 100 kPa)
Friction angle = 0 for clay material

Soil Characteristics

Based on Solea Water ribbon test, assume silty clay
Wet Density assumed to be 14,900 N/m3 from reference
Cohesion strength for silty clay loam ranges from 10-20 kPa (use 15 kPa for design)
Engineering Toolbox & CABO lists bearing load of soft clay as 100 kPa and 96 kPa, respecitvely (assume 100 kPa)
Friction angle = 0 for clay material

Geotechnical Mentor Feedback

I went through the process, but the feedback seemed that it would change the design too much given the time constraints. Therefore, the mentor comments were not addressed as they should be according to the rubric.



Matthew Tolson — April 28, 2022 at 8:18 AM
Re: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design
To: Mookencheril Cherian

Good morning Dr. Cherian,

I appreciate you looking over our work. I have work housed in two appendices/sections: geotechnical characterization and structural stabilization. If you are willing, could you look over my referenced soil and rock parameters to make sure they are somewhat close and conservative? Also, could you check my design process for designing the rock anchor? I have attached an excel file with the geotechnical characteristics and a hand-written document containing the rock anchor design. I have also attached my rock anchor detail that I drafted and included in the drawings.

Let me know if you have any questions or concerns.

Thanks,
Matthew Tolson

CEE Undergraduate, UTK
Knoxville, TN
(865) 806-1056
mtolson@vols.utk.edu
mtolson926@gmail.com

D-13 Soil and Rock C...ics.xlsx

B-07 Rock Anchor...ign.pdf

Rock Anchor Drawing.pdf

See More from Claudia Bible

Mookencheril Cherian — April 29, 2022 at 12:34 PM
Re: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design
To: Matthew Tolson,
Resent-From: Matthew Tolson

Mathew

I will have a colleague who is in Geotech look at this.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

MC **Mookencheril Cherian**
Fw: Senior Design Work Review – Geotechnical Assumptions and Rock Anchor Design
To: Tolson, Matthew Joseph,
Resent-From: Matthew Tolson

May 1, 2022 at 11:09 PM

Matthew

I had my colleague review your calculations. Attached are his comments.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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From: Eric Tse <etse@dlz.com>
Sent: Sunday, May 1, 2022 9:44 AM
To: Mookencheril Cherian <mcherian@dlz.com>
Subject: RE: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design

---

From: Mookencheril Cherian <mcherian@dlz.com>
Sent: Friday, April 29, 2022 12:35 PM
To: Eric Tse <etse@dlz.com>
Subject: Fw: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design

Eric

Can you quickly look at this submittal by this student for the senior project? Thanks.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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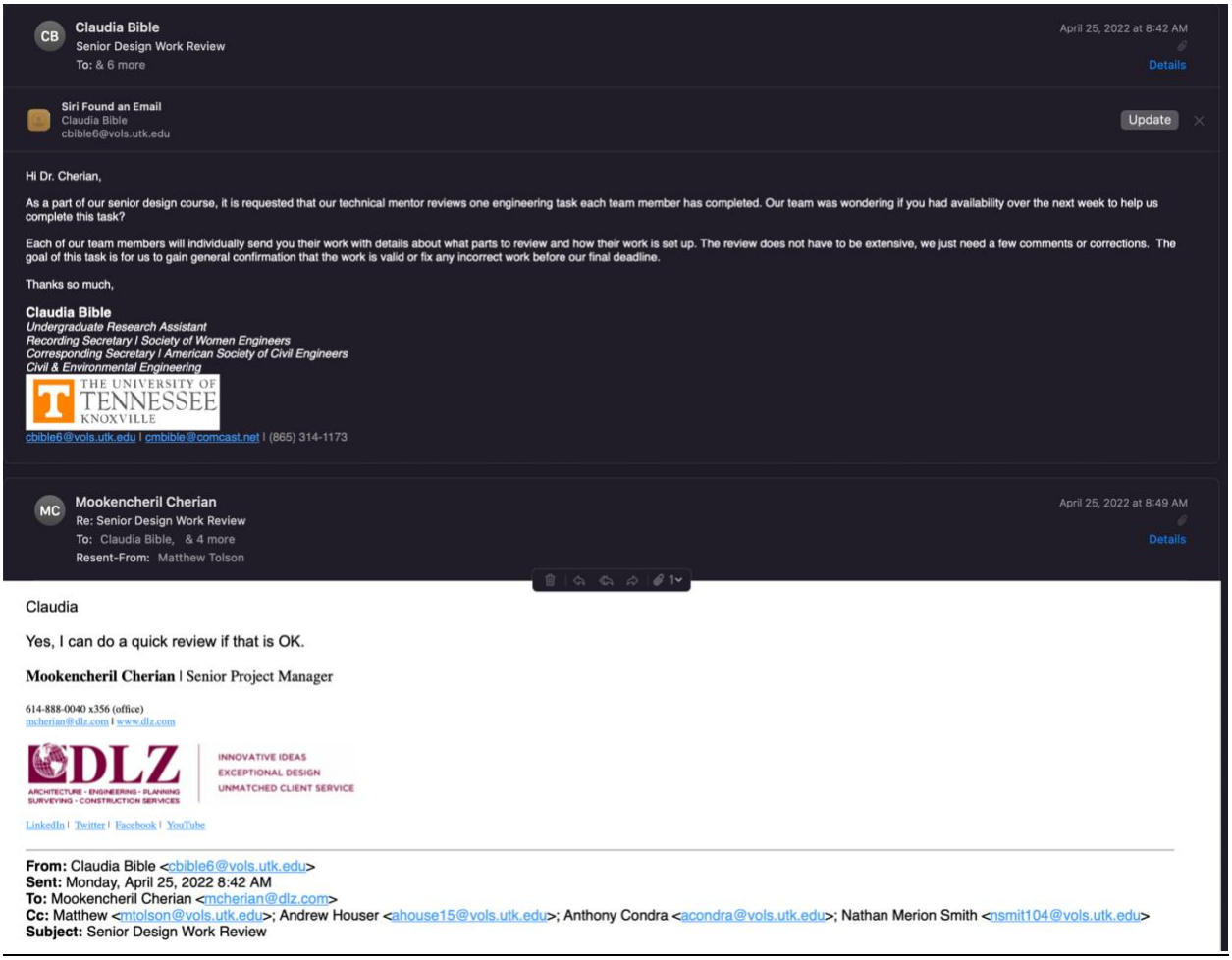

Claudia Bible
Senior Design Work Review
To: & 6 more

April 25, 2022 at 8:42 AM
Details

Siri Found an Email
Claudia Bible
cbible6@vols.utk.edu

Update

Hi Dr. Cherian,

As a part of our senior design course, it is requested that our technical mentor reviews one engineering task each team member has completed. Our team was wondering if you had availability over the next week to help us complete this task?

Each of our team members will individually send you their work with details about what parts to review and how their work is set up. The review does not have to be extensive, we just need a few comments or corrections. The goal of this task is for us to gain general confirmation that the work is valid or fix any incorrect work before our final deadline.

Thanks so much,

Claudia Bible
Undergraduate Research Assistant
Recording Secretary I Society of Women Engineers
Corresponding Secretary I American Society of Civil Engineers
Civil & Environmental Engineering
THE UNIVERSITY OF TENNESSEE KNOXVILLE
cbible6@vols.utk.edu I cmbible@comcast.net I (865) 314-1173

Mookencheril Cherian
Re: Senior Design Work Review
To: Claudia Bible, & 4 more
Resent-From: Matthew Tolson

April 25, 2022 at 8:49 AM
Details

Claudia

Yes, I can do a quick review if that is OK.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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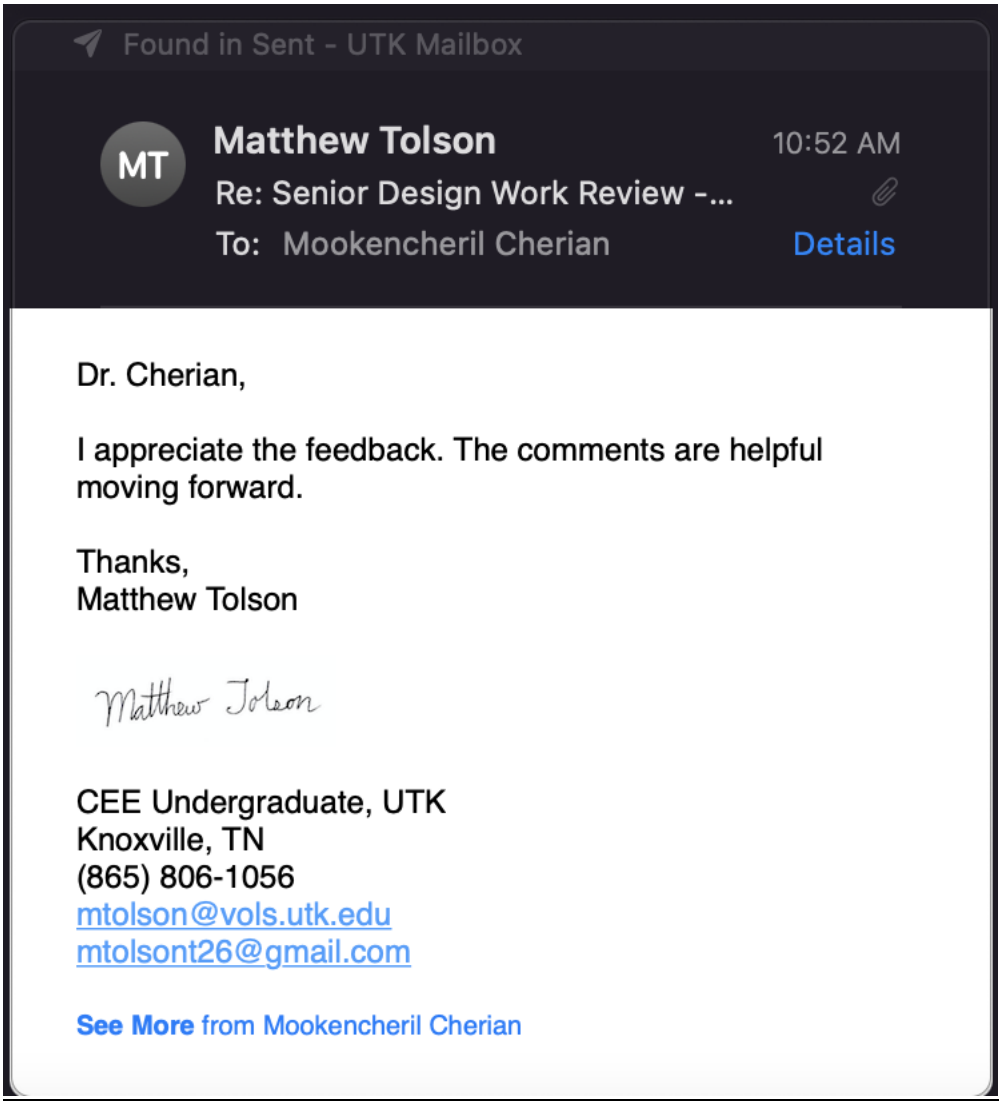
INNOVATIVE IDEAS
EXCEPTIONAL DESIGN
UNMATCHED CLIENT SERVICE

LinkedIn | Twitter | Facebook | YouTube

From: Claudia Bible <cbible6@vols.utk.edu>
Sent: Monday, April 25, 2022 8:42 AM
To: Mookencheril Cherian <mcherian@dlz.com>
Cc: Matthew <mtolson@vols.utk.edu>; Andrew Houser <ahouse15@vols.utk.edu>; Anthony Condra <acondra@vols.utk.edu>; Nathan Merion Smith <nsmit104@vols.utk.edu>
Subject: Senior Design Work Review


Found in Sent - UTK Mailbox
MT
Matthew Tolson
10:52 AM
Re: Senior Design Work Review -...
To: Mookencheril Cherian
Details
Dr. Cherian,
I appreciate the feedback. The comments are helpful moving forward.
Thanks,
Matthew Tolson
Matthew Tolson
CEE Undergraduate, UTK
Knoxville, TN
(865) 806-1056
mtolson@vols.utk.edu
mtolsont26@gmail.com
See More from Mookencheril Cherian

Rock Characteristics

Assume weak rock to be conservative. (strong shale or weak stone)

From *Principles of Foundation Engineering 7th edition* by Braja Das:				
	Ultimate bearing capacity qu = 25 MN/m2 for shale/weak sandstone (Table 4.2)			
	Friction angle = 30 degrees for shale/weak sandstone (Table 4.2)			
	RQD = 0.25 for poor rock quality (Table 2.11)			
	Equation 4.51 for modified ultimate bearing capacity = qu(RQD)^2			
	qu (modified) =	1.5625	MN/m2	

too low for weathered shale/weak sandstone, consider 35 degrees

*Grout mix design not contained in this file

What is the unit weight/density of rock?

Soil Characteristics

Based on Solea Water ribbon test, assume silty clay
Density assumed to be 14,900 N/m3 from reference

Is this a dry density? too low for moist soft clay.

Cohesion strength for silty clay loam ranges from 10-20 kPa (use 15 kPa for design)
Engineering Toolbox & Reference (D-09 and D-10) lists bearing load of soft clay as 100 kPa and 96 kPa, respecitvely (assume 100 kPa)
Friction angle = 0 for clay material

Is this allowable bearing capacity (vertical)? If it is, too high for soft clay.

For is the soil for? It is a rock anchor, correct?

Appendix C: Structural Stabilization

50% DESIGN DEVELOPMENT

- TURBINE SELECTION
- DRAG FORCE OF TURBINES
- OBSTRUCTION MAX. DRAG FORCE

CLAUDIA BIBLE

2/24/22

PANAMA RIVER FLOW

2

TURBINE DRAG FORCE

NTS

DRAG: EVG-010

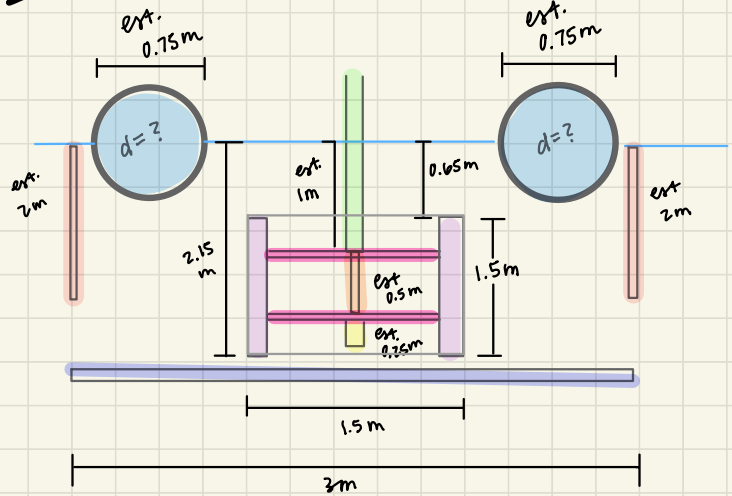


Table 8.1 Drag Coefficients

Shape	Drag coefficient
Sphere	0.47
Half-sphere	0.42
Cone	0.50
Cube	1.05
Angled cube	0.80
Long cylinder	0.82
Short cylinder	1.15
Streamlined body	0.04
Streamlined half-body	0.09

$$C_d = \frac{2F_d}{\rho v^2 A}$$

$$F_d = \tfrac{1}{2}\rho v^2 C_D A$$

floats: (x2)

$\pi r^2 = \pi (0.75/2)^2 = 0.442\ m^2$

total: $0.884\ m^2$

ASSUMPTIONS —

* circular shape
* completely submerged
* $C_D = 0.47$

$F_d = (1/2)(\rho)(v^2)(C_D)(A)$

$= (1/2)(1000\ kg/m^3)(3\ m/s)^2(0.47)(0.442\ m^2)$

$= 311.61\ N$

$F_{d1} = 311.61\ N$ $F_{d2} = 311.61\ N$

turbine "box":

$LW = (1.5)(1.5) = 2.25\ m^2$

ASSUMPTIONS —

* combined turbine-area parts into box
* $C_D = 1.05$

$F_d = (1/2)(\rho)(v^2)(C_D)(A)$

$= (1/2)(1000\ kg/m^3)(3\ m/s)^2(1.05)(2.25 m^2)$

$F_{d3} = 10,631.3\ N$

EVG-010

TOTAL DRAG: 11,254.5 N

~ 11,300 N

* assuming turbine-area box over-compensation accounts for poles that reel turbine in

DRAG: EVG-005

Table 8.1 Drag Coefficients

Shape	Drag coefficient
Sphere	0.47
Half-sphere	0.42
Cone	0.50
Cube	1.05
Angled cube	0.80
Long cylinder	0.82
Short cylinder	1.15
Streamlined body	0.04
Streamlined half-body	0.09

$$C_d = \frac{2F_d}{\rho v^2 A}$$

$$F_d = \frac{1}{2}\rho v^2 C_D A$$

floats: (x2)

$\pi r^2 = \pi (0.75/2)^2 = 0.442\ m^2$

total: $0.884\ m^2$

ASSUMPTIONS —

* circular shape
* completely submerged
* $C_D = 0.47$

$F_d = (1/2)(\rho)(v^2)(C_D)(A)$

$= (1/2)(1000\ kg/m^3)(3\ m/s)^2(0.47)(0.442\ m^2)$

$= 311.61\ N$

$F_{d1} = 311.61\ N$ $F_{d2} = 311.61\ N$

turbine "box":

$LW = (0.75)(1.5) = 1.125\ m^2$

ASSUMPTIONS —

* combined turbine-area parts into box
* $C_D = 1.05$

$F_d = (1/2)(\rho)(v^2)(C_D)(A)$

$= (1/2)(1000\ kg/m^3)(3\ m/s)^2(1.05)(1.125\ m^2)$

$F_{d3} = 5315.63\ N$

EVG-005

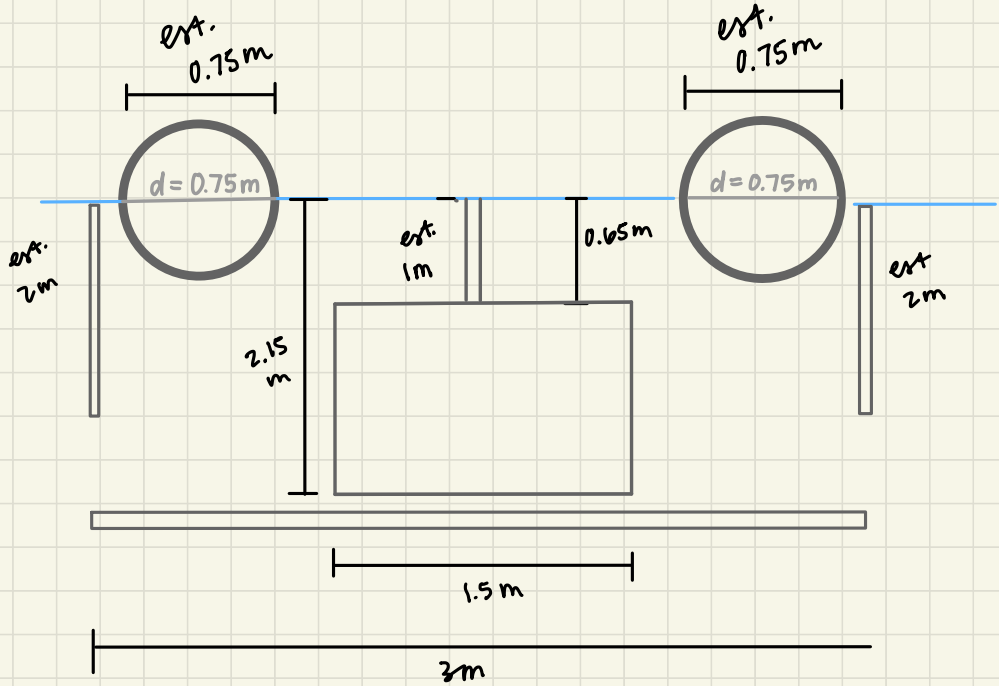
TOTAL DRAG: 5938.85 N

$\sim$ 6000 N PER UNIT

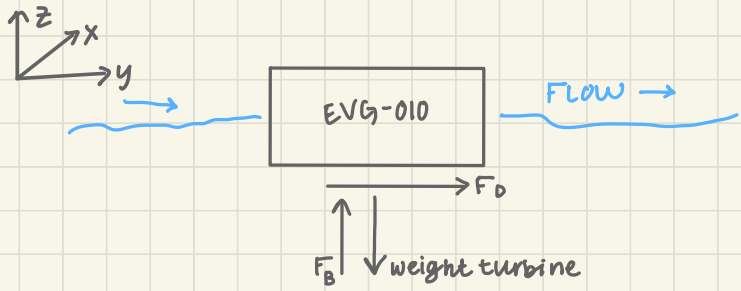
2 UNIT DRAG: 12,000 N

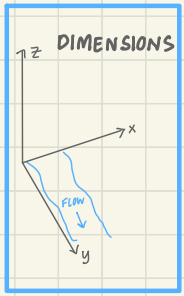
* assuming turbine-area box over-compensation accounts for poles that reel turbine in

GENERALIZED TURBINE XS:



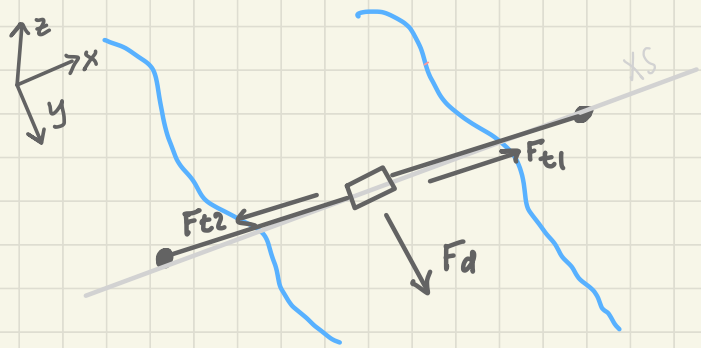
STREAM PROFILE VIEW — Z





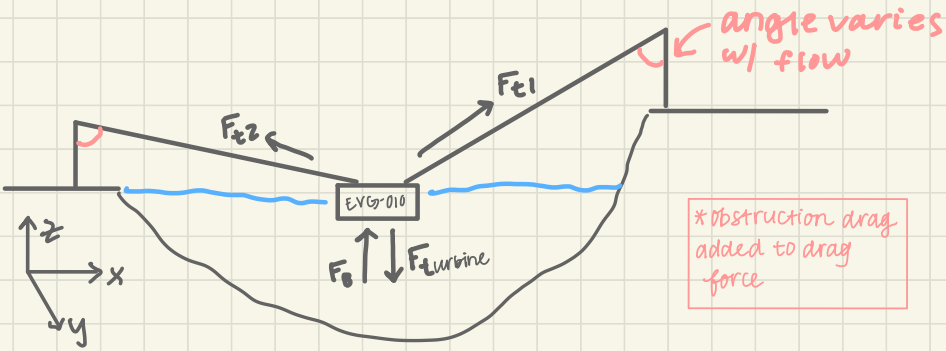
FORCE	X	y	z
F_{t1}			
F_{t2}			
F_D			
F_{turb}			
F_B			

STREAM PLAN VIEW — y

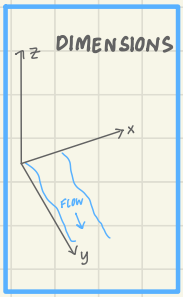


STREAM XS VIEW — X

Same FBD for gravity footings, just different angle



*Obstruction drag added to drag force



FORCE	X	y	z	VALUE (N)
F_{t1}				?
F_{t2}				?
F_D				12,000
F_{turb}				
F_B				
F_{DMAX}				

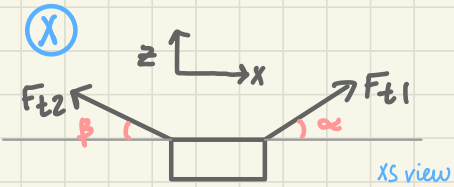
weights

EVG-005 = (2)(250kg) = 500kg

EVG-010 =

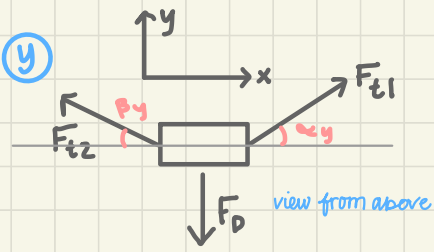
* Purpose of cables. (both structures)
  - ~hold turbine in the y direction
  - ~ design on x-y plane for drag
  - ~ design on z-x for removal

(X)



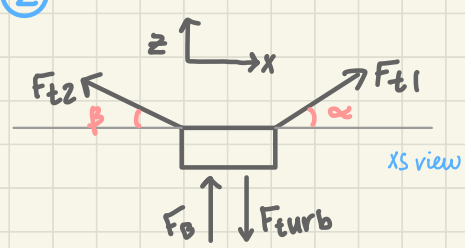
$$F_x = -F_{t2}\cos(\beta) + F_{t1}\cos(\alpha) = 0$$

(y)



$$F_y = F_{t2}\sin(\beta_y) + F_{t2}\sin(\alpha_x) - F_D = 0$$

(z)



$$F_z = F_{t2}\sin(\beta) + F_{t2}\sin(\alpha) + F_B - F_{turb} = 0$$

REFERENCES

Drag coefficient chart:

https://phys.libretexts.org/Bookshelves/Classical_Mechanics/Classical_Mechanics_(Dourmashkin)/08%3A_Applications_of_Newtons_Second_Law/8.06%3A_Drag_Forces_in_Fluids

3

OBSTRUCTION DRAG FORCE

DRAG: OBSTRUCTED

turbine	unobstructed/ obstructed	drag
EVG-005	U	12.0 kN
EVG-010	U	11.3 kN
EVG-005	O	162 kN
EVG-010	O	161.3 kN

MAXIMUM TREE SIZE —

https://forestecosyst.springeropen.com/articles/10.1186/s40663-020-00246-z =

1) Panama has 3043 tree species in 141 families and 752 genera; 57.6% were ≥ 10 m tall and 16.9% were 3-5 m tall.2) The widest ranges were >1.5×107 km2, covering the entire neotropics and reaching >30◦ latitude; 12.4% of the species had ranges exceeding 107 km2. The median range was 6.9×105 km2.3) At the other extreme, 16.2% of the species had a range <20,000 km2, a criterion suggesting endangered status.4) Range size increased with a tree species' height and varied significantly among families.5) Tree census plots, where we mapped and measured all individuals, captured 27.5% of the tree species, but a biased selection relative to range size; only 4.5% of the species in plots had ranges <20,000 km2. I

↳ MAX HEIGHT = 60 m ∴ diameter ≈ 2.34 m

https://assets.press.princeton.edu/chapters/s9289.pdf

Trees are tall; indeed, the biggest trees in the area are characteristic of moist forest (e.g., the kapok [Ceiba pentandra] and the espavé [Anacardium excelsum]).

https://www.sidmartinbio.org/what-is-unique-about-the-kapok-tree/

MAX: 230' tall : 9-10' diameter

H:D ratio = 25.56 − 23

MAX DIMENSIONS:

H = 60 m , D = 2.5 m

approx XS area: (60)(2.5) = 150 m²

*assuming solid cylinder, most conservative given branches are less dense, but accounted for in height

(ρ_w) unit weight water = 1 g/cm³

(ρ_{dry}) unit weight wood = 1500 kg/m³

(V) volume = $\pi r^2 h$ = 295 m³

SG wood = 1.5

wood characteristics

https://extension.psu.edu/calculating-the-green-weight-of-wood-species

$m_{sat} = (m_{dry})(1+MC)(2)$

$= (1500\ kg/m^3)(295\ m^3)(1+1)(2)$

$= 1{,}770{,}000\ kg$ → *very large, a tree this size is unlikely to fall in river

$m_{dry} = (\rho)(V)$

$\rho_{wet} = 1770000\ kg / 295\ m^3 = 6000\ kg/m^3$

REV. TREE DRAG

https://forestecosyst.springeropen.com/articles/10.1186/s40663-020-00246-z =

HEIGHT RANGES. (m)

50-60, 40-50, 30-40, 20-30, 15-20, 10-15

DIAMETER (m):

$d = h / 25.56$

https://extension.psu.edu/calculating-the-green-weight-of-wood-species

(ρ_w) unit weight water = $1\ g/cm^3$

(ρ_{dry}) unit weight wood = $1500\ kg/m^3$

SGwood = 1.5

(v) volume = $\pi r^2 h$

$m_{sat} = (m_{dry})(1 + MC)(2)$

$m_{dry} = (\rho)(V)$

HEIGHT (m)	DIAM (m)	VOL (m^3)	mdry (kg)	msat (kg)	drag (N)	
60	2.347	260	3.9×10^5	1.6×10^6	1.7×10^5	→ too large to wash down river
50	1.956	151	2.3×10^5	9.0×10^5	1.2×10^5	more reasonable range
40	1.565	77	1.2×10^5	4.6×10^5	7.7×10^4	
30	1.174	33	5.0×10^4	1.9×10^5	4.3×10^4	
20	0.782	10	1.5×10^4	5.8×10^4	1.9×10^4	
15	0.587	5	7.5×10^3	2.4×10^4	1.1×10^4	

DRAG & IMPACT FORCES OF TREES

HEIGHT	HEIGHT	DIAMETER	VOLUME	DRY MASS	SAT. MASS	XS AREA	AVG. DRAG FORCE	SF DRAG FORCE	AVG. IMPACT FORCE	SF IMPACT FORCE
ft	m	m	m^3	kg	kg	m^2	N	N	N	N
196.86	60	2.347	259.67	389505	1558021	140.85	519718	1169366	5804162	8706243
164.05	50	1.956	150.27	225408	901632	97.81	360915	812060	4415376	6623064
131.24	40	1.565	76.94	115409	461636	62.60	230986	519718	3159386	4739079
98.43	30	1.174	32.46	48688	194753	35.21	129930	292342	2052081	3078122
65.62	20	0.782	9.62	14426	57704	15.65	57746	129930	1117012	1675517
49.215	15	0.587	4.06	6086	24344	8.80	32482	73085	725520	1088280
32.81	10	0.391	1.20	1803	7213	3.91	14437	32482	394923	592385
25	7.62	0.298	0.53	798	3191	2.27	8382	18859	262672	394008
16.405	5	0.196	0.15	225	902	0.98	3609	8121	139626	209440
9.843	3	0.117	0.03	49	195	0.35	1299	2923	64893	97339
3.281	1	0.039	0.00	2	7	0.04	144	325	12489	18733

* River Width = 25 ft

STANDARD VALUES		
PARAMETER	VALUE	UNITS
UNIT WT. WATER	1	g/cm^3
DRY UNIT WT. WOOD	1500	kg/m^3
MOISTURE CONTENT	1	
SPEC. GRAVITY WOOD	1.5	
LONG CYLINDER C_d	0.82	
AVG. RIVER VELOCITY	3	m/s
RIVER VELOCITY * SF OF 1.5	4.5	m/s

EQUATIONS	
SAT. MASS	$(m_{dry})*(1+MC)(2)$
VOLUME	PI*(r^2)*h
IMPACT	1550*V*SQRT(m)
DRAG	$0.5*\rho*V^2*C_d*A$

DESIGN IMPACT FORCE:
100 kN
* This force should be used as the "breakaway" strength for the connection to release upon impact of a 5m / 15 ft

From C-01 Turbine Drag Hand Calcs

DRAG OF TURBINE:	DRAG W/ SF OF 2:
12 kN	24 KN
*These forces should be used to design the stabilization options	

REFERENCES

https://forestecosyst.springeropen.com/articles/10.1186/s40663-020-00246-z
https://assets.press.princeton.edu/chapters/s9289.pdf
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nd_Law/8.06%3A_Drag_Forces_in_Fluids
bject's%20velocity

DRAG & IMPACT FORCES OF TREES

HEIGHT	HEIGHT	DIAMETER	VOLUME	DRY MASS	SAT. MASS	XS AREA	AVG. DRAG FORCE
ft	m	m	m^3	kg	kg	m^2	N
196.86	60	2.347	259.67	389505	1558021	140.85	173239
164.05	50	1.956	150.27	225408	901632	97.81	120305
131.24	40	1.565	76.94	115409	461636	62.60	76995
98.43	30	1.174	32.46	48688	194753	35.21	43310
65.62	20	0.782	9.62	14426	57704	15.65	19249
49.215	15	0.587	4.06	6086	24344	8.80	10827
32.81	10	0.391	1.20	1803	7213	3.91	4812
25	7.62	0.298	0.53	798	3191	2.27	2794
16.405	5	0.196	0.15	225	902	0.98	1203
9.843	3	0.117	0.03	49	195	0.35	433
3.281	1	0.039	0.00	2	7	0.04	48

STANDARD VALUES		
PARAMETER	VALUE	UNITS
UNIT WT. WATER	1	g/cm^3
DRY UNIT WT. WOOD	1500	kg/m^3
MOISTURE CONTENT	1	
SPEC. GRAVITY WOOD	1.5	
LONG CYLINDER C_d	0.82	
AVG. RIVER VELOCITY	3	m/s
RIVER VELOCITY * SF OF 1.5	4.5	m/s

EQUATIONS	
SAT. MASSS	$(m_{dry})*(1+MC)(2)$
VOLUME	$PI*r^2*h$
IMPACT	$1550*V*SQRT(m)$
DRAG	$0.5*\rho*V^2*C_d*A$

SF DRAG FORCE	AVG. IMPACT FORCE	SF IMPACT FORCE
N	N	N
259859	5804162	8706243
180458	4415376	6623064
115493	3159386	4739079
64965	2052081	3078122
28873	1117012	1675517
16241	725520	1088280
7218	394923	592385
4191	262672	394008
1805	139626	209440
650	64893	97339
72	12489	18733

* River Width = 25 ft

**** INCORRECT IMPACT FORCES, DO NOT USE**

DESIGN IMPACT FORCE:

200 kN

DRAG OF TURBINE:

12 kN

TOTAL DRAG/IMPACT: 212 kN

Steel Cable Design:



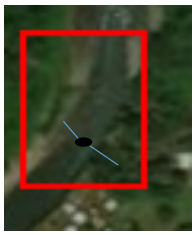


The width of the river is being estimated from the pictures above but is subject to refinement

The turbine would likely be placed and anchored inside the red box (right photo)

Minimum required clearance for a dug out canoue is 6 meters

Blue lines = cables
Black dot = turbine



Parameters: Assumed=

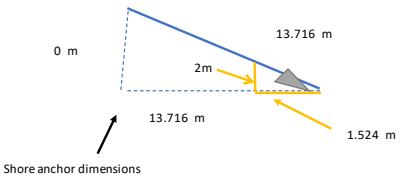
width of the river = 50 ft = 15.24 m

height of the cliff (the river's height is the datum) = m

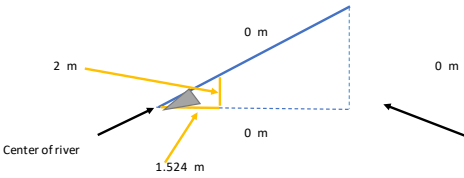
distance from cliff anchor to turbine (lateral) = 0 m

distance from shore anchor to turbine (lateral) = 45 ft = 13.716 m

height of the shore anchor (the river's height is the datum) = m



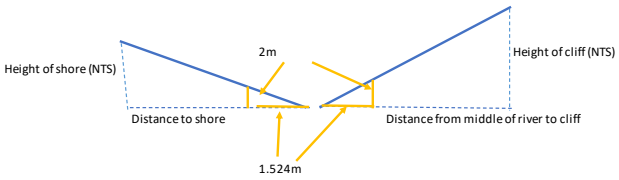
Shore anchor dimensions



Center of river

Cliff anchor dimensions

Angle= 3.782526 deg
tangent= 0.066018 rad



For EVG - 010:

Total Drag = 11.3 kN

Drag from a 40ft tree = 77 kN

According to AISC equation (5-1a),

$$0.90F_yA_g \leq 0.75F_uA_e$$

Ag = gross area

Ae = effective area = net area (An) times shear lag coeffecient (U)

Fy = tensile yield stress

Fu = tensile rupture stress

For a size 008 Pfeifer Structures steel cable (file:///C:/Users/natha/AppData/Local/Temp/Temp1_UMIX-Cable-Stainless-Steel-TDEN.zip/Cable_TDEN.pdf)

Ag = 24 mm^2 = 0.000576 m^2

An= gross area because all of the cable is under tension = 0.000576 m^2

U = 1 (according to AISC Table D3.1 Case 1)

Fy = 19 kN

Fu= 28 kN

0.9FyAg= 17.1

0.75FuAe= 21 **Does satisfy ratio but not strength hold back a tree**

For a size 020 Pfeifer Structures steel cable (file:///C:/Users/natha/AppData/Local/Temp/Temp1_UMIX-Cable-Stainless-Steel-TDEN.zip/Cable_TDEN.pdf)

Ag = 160 mm^2 = 0.0256 m^2

An= gross area because all of the cable is under tension = 0.0256 m^2

U = 1 (according to AISC Table D3.1 Case 1)

Fy = 120 kN

Fu= 188 kN

0.9FyAg= 108

≤

0.75FuAe= 141 **Does satisfy ratio and is strong enough to hold back a tree**

(and it will satisfy the 0.7 kN increase for the EVG-005)

Total Drag = 11.3 kN

Drag from a 15m tree = 11 kN

According to AISC equation (5-1a),

$$0.90F_yA_g \leq 0.75F_uA_e$$

Ag = gross area

Ae = effective area = net area (An) times shear lag coeffecient (U)

Fy = tensile yield stress

Fu = tensile rupture stress

For a Lexco 7x19 Galvanized Nylon Coated Cable (https://catalog.lexcocable.com/viewitems/vinyl-nylon-coated-cable--1063/7-x-19-galvanized-nylon-coated-cable)

Diameter = 5/16in

Ag = 0.307 in^2 = 0.0002 m^2

An= gross area because all of the cable is under tension = 0.0002 m^2

U = 1 (according to AISC Table D3.1 Case 1)

Fy = 8500 psi = 2609.5 lb = 11607.63 N = 12 kN

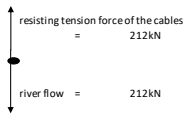
Fu= 7000 lbf = 31,130 N = 31 kN

0.9FyAg= 10.8

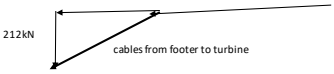
0.75FuAe= 23.25 **Does satisfy ratio and has the necessary strength hold back a tree**

FBD

In-River:
(from above)



Raised Footing:



angle:	cable strength:	
30 deg	424 kN	
45 deg	300 kN	(The force will decrease with an increase in angle)
60 deg	245 kN	

Cables

Ag = gross area

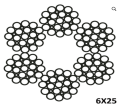
Ae = effective area = net area (An) times shear lag coeffecient (U)

Fy = tensile yield stress

Fu = tensile rupture stress

$$0.90F_yA_g \le 0.75F_uA_e$$

Max Industrias Black Cable - Fiber Core 6 x 25 Diameter = 22.23 mm = 7/8 in
(for In-River use)



Ag = 0.000285 m^2

An= gross area because all of the cable is under tension = 0.000285 m^2

U = 1 (according to AISC Table D3.1 Case 1)

Fy = 250 kN

Fu= 32115 kgf = 314,940 N = 314.94 kN

0.9FyAg= 225

0.75FuAe= 236.205

Ag = 0.000507 m^2

An= gross area because all of the cable is under tension = 0.000507 m^2

Max Industrias Black Cable - Fiber Core 6 x 25 Diameter = 25.40 mm = 1 in
(for footer to turbine use)

U = 1 (according to AISC Table D3.1 Case 1)

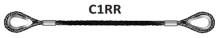
Fy = 300 kN

Fu= 41730 kgf = 409,232 N = 409.232 kN

0.9FyAg= 270

0.75FuAe= 306.924

Connections (thimble, ferrule and stop)





For in river use:
Thimble: 03-03-1 HD 1inch (25.4mm) diameter
10500kgf (individual) = 205kN (using both)



Ferrule and stops, no requirements other than fitting the diameter

For above ground footer use:
Thimble:
03-03-1.125-1.25 HD 1.25 inch (31.75mm) diameter
16000kgf (individual) = 313kN (using both)

For breakaway connection:
Thimble:
03-03-0.312 HD 5/16 inch (7.94mm) diameter
1000 kgf (individual) = 19 kN (using both)

Winch

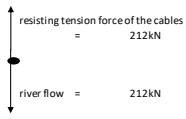
Any winch with the ability to pull 3500lbs or 15kN

Endurance Marine Hand Winch With Auto Brake — 3500-Lb. Capacity, Model# RBW3500

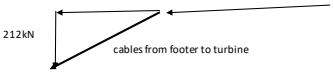


FBD

In-River:
(from above)



Raised Footing:



angle:	cable strength:	
30 deg	424 kN	
45 deg	300 kN	(The force will decrease with an increase in angle)
60 deg	245 kN	

Cables

Ag = gross area

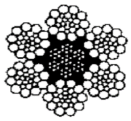
Ae = effective area = net area (An) times shear lag coeffecient (U)

Fy = tensile yield stress

Fu = tensile rupture stress

$$0.90F_yA_g \leq 0.75F_uA_e$$

Max Industrias Black Cable - Steel Core 6 x 25 Diameter = 22.23 mm = 7/8 in
(for In-River use)



Ag = 0.000285 m^2

An= gross area because all of the cable is under tension = 0.000285 m^2

U = 1 (according to AISC Table D3.1 Case 1)

Fy = 250 kN

Fu= 36105 kgf = 354,070 N = 354.07 kN

0.9FyAg= 225

0.75FuAe= 265.5525

Ag = 0.000507 m^2

An= gross area because all of the cable is under tension = 0.000507 m^2

Max Industrias Black Cable - Steel Core 6 x 25 Diameter = 25.40 mm = 1 in
(for footer to turbine use)

U = 1 (according to AISC Table D3.1 Case 1)

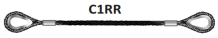
Fy = 300 kN

Fu= 46900 kgf = 459,932 N = 459.932 kN

0.9FyAg= 270

0.75FuAe= 344.949

Connections (thimble, ferrule and stop)









For in river use:

Thimble:	03-03-1 HD	1inch (25.4mm) diameter 10500kgf (individual) = 205kN (using both)
Aluminum Bush/ferrule:	03-06-0.875 ALU	diameter = 22.23mm (7/8 inch diameter)
Stop bushings:	03-06-TOPE 0.875	diameter = 22.23mm (7/8 inch diameter)
Swivel hook:	03-07-322 A 11-Y	2 of them (11,000 kgf strength per hook)

*Ferrule and stops, no requirements other than fitting the diameter

For above ground footer use:

Thimble:	03-03-1.125-1.25 HD	1.25 inch (31.75mm) diameter 16000kgf (individual) = 313kN (using both)
Aluminum Bush/ferrule:	03-06-1 ALU	diameter = 25.40mm (1 inch diameter)
Stop bushings:	03-06-TOPE 1	diameter = 25.40mm (1 inch diameter)
Swivel hook:	03-07-322 A 11-Y	3 of them (11,000 kgf strength per hook)

For break away use:

Swivel hook:	03-07-322 2-Y	1 of them	(2000 kgf strength per block)

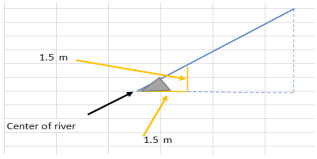
Winch

Any winch with the ability to pull 3500lbs or 15kN

Endurance Marine Hand Winch With Auto Brake — 3500-Lb. Capacity, Model# RBW3500



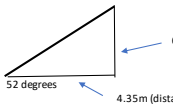
Angle of Cable (to raised footer)



Angle at center of the river = 45 degrees

Length of Cable (estimation)

Turbine to above-water footer:



6.1m (estimated height of cliff)

4.35m (distance to turbine based on 45 degree lateral angle from above)

SQRT((4.35m)^2 + (6.10m)^2) = 7.5m → Length = 10 m (convenience of buying and extra cable length for positioning)

Turbine to in-water footer:

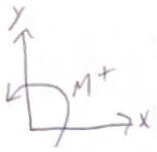
Depth of water = approximately 1.5m - 2.5m

Height of floods = approximately 5m

Depth + Floods = 7.5m → Length = 8 m (for buying convienece)

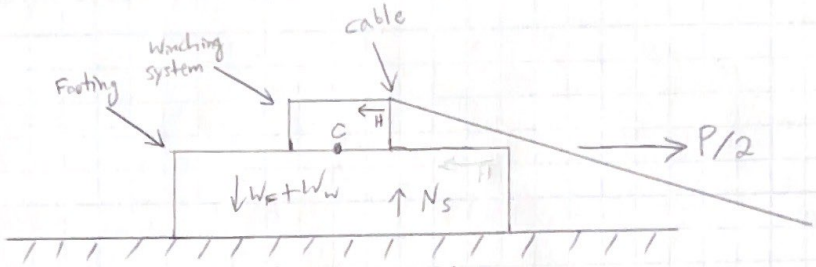
Prelim forces	Panama River Flow	Matthew Tolson

50 % Design Development ⇒ Spread Footing Free-Body Diagrams



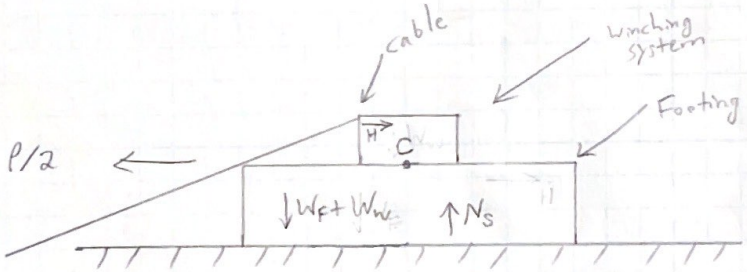
Left-of-bank Footing
(village side)

*Perspective is facing downstream



silty clay or bedrock
(<5% gravel/stones)

Right-of-bank Footing



silty clay or bedrock
(<5% gravel/stones)

- Assume weight of winch is 150 lbs. as a LL.
- P = Drag force of turbine(s)
- W_W = Weight of winching system
- W_F = Weight of footing
- N_S = Normal force exerted by supporting soil.
- H = Opposite horizontal force exerted by footing.
- C = Central Point on footing surface

Prelim forces	Panama River Flow	Matthew Tolson

50 % Design Development ⇒ Spread Footing Force Summations

* Assume drag is a horizontal force, P.

Left-of-bank footing

$\sum F_x = 0 = P/2 - H$

$\sum F_y = 0 = N_S - W_F - W_W$

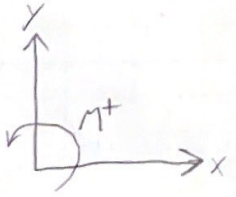
$\circlearrowleft + \sum M_C = 0 = -(P/2)(\text{Height of Winch}) + (H)(\text{Height of Winch})$

Right-of-bank footing

$\sum F_x = 0 = -P/2 + H$

$\sum F_y = 0 = N_S - W_F - W_W$

$\circlearrowleft + \sum M_C = 0 = (P/2)(\text{Height of Winch}) - (H)(\text{Height of Winch})$



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19.3.1 *Exposure categories and classes*

19.3.1.1 The licensed design professional shall assign exposure classes in accordance with the severity of the anticipated exposure of members for each exposure category in Table 19.3.1.1.

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition	
Freezing and thawing (F)	F0	Concrete not exposed to freezing-and-thawing cycles	
	F1	Concrete exposed to freezing-and-thawing cycles with limited exposure to water	
	F2	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water	
	F3	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals	
Sulfate (S)		Water-soluble sulfate (SO_4^{2-}) in soil, percent by mass[1]	Dissolved sulfate (SO_4^{2-}) in water, ppm[2]
	S0	$SO_4^{2-} < 0.10$	$SO_4^{2-} < 150$
	S1	$0.10 \le SO_4^{2-} < 0.20$	$150 \le SO_4^{2-} < 1500$ or seawater
	S2	$0.20 \le SO_4^{2-} \le 2.00$	$1500 \le SO_4^{2-} \le 10{,}000$
	S3	$SO_4^{2-} > 2.00$	$SO_4^{2-} > 10{,}000$
In contact with water (W)	W0	Concrete dry in service	
	W1	Concrete in contact with water where low permeability is not required	
	W2	Concrete in contact with water where low permeability is required	
Corrosion protection of reinforcement (C)	C0	Concrete dry or protected from moisture	
	C1	Concrete exposed to moisture but not to an external source of chlorides	
	C2	Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources	

[1]Percent sulfate by mass in soil shall be determined by ASTM C1580.

[2]Concentration of dissolved sulfates in water, in ppm, shall be determined by ASTM D516 or ASTM D4130.

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concrete properties from Table 19.3.2.1 to include in the construction documents.

The Code does not include provisions for especially severe exposures, such as acids or high temperatures.

R19.3.1 *Exposure categories and classes*

The Code addresses four exposure categories that affect the requirements for concrete to ensure adequate durability:

Exposure Category F applies to concrete exposed to moisture and cycles of freezing and thawing, with or without deicing chemicals.

Exposure Category S applies to concrete in contact with soil or water containing deleterious amounts of water-soluble sulfate ions.

Exposure Category W applies to concrete in contact with water.

Exposure Category C applies to nonprestressed and prestressed concrete exposed to conditions that require additional protection against corrosion of reinforcement.

Severity of exposure within each category is defined by classes with increasing numerical values representing increasingly severe exposure conditions. A classification of 0 is assigned if the exposure severity has negligible effect (is benign) or the exposure category does not apply to the member.

The following discussion provides assistance for selecting the appropriate exposure class for each of the exposure categories. Members are required to be assigned to four exposure classes, one for each exposure category, and are also required to meet the most restrictive requirements of all of these exposures. For example, the slabs of a parking garage in a cold climate might be assigned to Exposure Classes F3, S0, W2, and C2, and a potable water tank inside a heated building might be assigned to Exposure Classes F0, S0, W2, and C1.

Exposure Category F: Whether concrete is damaged by cycles of freezing and thawing depends on the amount of water in the pores of the concrete at the time of freezing (Powers 1975). The amount of water present may be described in terms of the degree of saturation of the concrete. If the degree of saturation is high enough, there will be sufficient water in the concrete pores to produce internal tensile stresses large enough to cause cracking when the water freezes and expands. The entire member need not be saturated to be susceptible to damage. For example, if the top 3/8 in. of a slab or outer 1/4 in. of a wall is saturated, those portions are vulnerable to damage from freezing and thawing, regardless of how dry the interior may be.

For any portion of a member to be resistant to freezing and thawing, that portion of the concrete needs to have sufficient entrained air and adequate strength. Adequate strength is obtained by requiring a low w/cm, which also reduces the pore volume and increases resistance to water penetration. Entrained air makes it more difficult for the

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Table 19.3.2.1—Requirements for concrete by exposure class

Exposure class		Maximum *w/cm*[1,2]	Minimum f_c', psi	Additional requirements			Limits on cementitious materials
				Air content			
F0		N/A	2500	N/A			N/A
F1		0.55	3500	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			N/A
F2		0.45	4500	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			N/A
F3		0.40[3]	5000[3]	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			26.4.2.2(b)
				Cementitious materials[4] — Types			Calcium chloride admixture
				ASTM C150	ASTM C595	ASTM C1157	
S0		N/A	2500	No type restriction	No type restriction	No type restriction	No restriction
S1		0.50	4000	II[5][6]	Types with (MS) designation	MS	No restriction
S2		0.45	4500	V[6]	Types with (HS) designation	HS	Not permitted
S3	Option 1	0.45	4500	V plus pozzolan or slag cement[7]	Types with (HS) designation plus pozzolan or slag cement[7]	HS plus pozzolan or slag cement[7]	Not permitted
	Option 2	0.40	5000	V[8]	Types with (HS) designation	HS	Not permitted
W0		N/A	2500	None			
W1		N/A	2500	26.4.2.2(d)			
W2		0.50	4000	26.4.2.2(d)			
				Maximum water-soluble chloride ion (Cl^-) content in concrete, percent by mass of cementitious materials[9,10]			
				Nonprestressed concrete	Prestressed concrete	Additional provisions	
C0		N/A	2500	1.00	0.06	None	
C1		N/A	2500	0.30	0.06		
C2		0.40	5000	0.15	0.06	Concrete cover[11]	

[1]The *w/cm* is based on all cementitious and supplementary cementitious materials in the concrete mixture.

[2]The maximum *w/cm* limits do not apply to lightweight concrete.

[3]For plain concrete, the maximum *w/cm* shall be 0.45 and the minimum f_c' shall be 4500 psi.

[4]Alternative combinations of cementitious materials to those listed are permitted for all sulfate exposure classes when tested for sulfate resistance and meeting the criteria in 26.4.2.2(c).

[5]For seawater exposure, other types of portland cements with tricalcium aluminate (C_3A) contents up to 10 percent are permitted if the *w/cm* does not exceed 0.40.

[6]Other available types of cement such as Type I or Type III are permitted in Exposure Classes S1 or S2 if the C_3A contents are less than 8 percent for Exposure Class S1 or less than 5 percent for Exposure Class S2.

[7]The amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount that has been determined by service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount tested in accordance with ASTM C1012 and meeting the criteria in 26.4.2.2(c).

[8]If Type V cement is used as the sole cementitious material, the optional sulfate resistance requirement of 0.040 percent maximum expansion in ASTM C150 shall be specified.

[9]The mass of supplementary cementitious materials used in determining the chloride content shall not exceed the mass of the portland cement.

[10]Criteria for determination of chloride content are in 26.4.2.2.

[11]Concrete cover shall be in accordance with 20.5.

19.3.3 *Additional requirements for freezing-and-thawing exposure*

19.3.3.1 Concrete subject to freezing-and-thawing Exposure Classes F1, F2, or F3 shall be air entrained. Except as

R19.3.3 *Additional requirements for freezing-and-thawing exposure*

R19.3.3.1 A table of required air contents for concrete to resist damage from cycles of freezing and thawing is

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permitted in 19.3.3.6, air content shall conform to Table 19.3.3.1.

Table 19.3.3.1—Total air content for concrete exposed to cycles of freezing and thawing

Nominal maximum aggregate size, in.	Target air content, percent	
	F1	F2 and F3
3/8	6.0	7.5
1/2	5.5	7.0
3/4	5.0	6.0
1	4.5	6.0
1-1/2	4.5	5.5
2	4.0	5.0
3	3.5	4.5

Range of 4.5 - 7.5 % selected since concrete bag mix unknown

19.3.3.2 Concrete shall be sampled in accordance with ASTM C172, and air content shall be measured in accordance with ASTM C231 or ASTM C173.

19.3.3.3 Wet-mix shotcrete subject to freezing-and-thawing Exposure Classes F1, F2, or F3 shall be air entrained. Dry-mix shotcrete subject to freezing-and-thawing Exposure Class F3 shall be air entrained. Except as permitted in 19.3.3.6, air content shall conform to Table 19.3.3.3.

Table 19.3.3.3—Total air content for shotcrete exposed to cycles of freezing and thawing

Mixture type	Sampling location	Target air content, percent		
		F1	F2	F3
Wet-mix shotcrete	Before placement	5.0	6.0	6.0
Dry-mix shotcrete	In-place	N/A[1]	N/A[1]	4.5

[1]Entrained air is not required in dry-mix shotcrete for these exposure classes.

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included in the Code, based on guidance provided for proportioning concrete mixtures in ACI 211.1. Entrained air will not protect concrete containing coarse aggregates that undergo disruptive volume changes when frozen in a saturated condition.

R19.3.3.2 The sampling of fresh concrete for acceptance based on air content is usually performed as the concrete is discharged from a mixer or a transportation unit (for example, a ready mixed concrete truck) to the conveying equipment used to transfer the concrete to the forms. ASTM C172 primarily covers sampling of concrete as it is discharged from a mixer or a transportation unit, but recognizes that specifications may require sampling at other points such as discharge from a pump. Table 19.3.3.1 was developed for testing as-delivered concrete. ASTM C231 is applicable to normalweight concrete and ASTM C173 is applicable to normalweight or lightweight concrete.

If the licensed design professional requires measurement of air content of fresh concrete at additional sampling locations, such requirements should be stated in the construction documents, including the sampling protocol, test methods to be used, and the criteria for acceptance.

R19.3.3.3 Adding air-entraining admixtures improves freezing-and-thawing resistance of wet-mix shotcrete (ACI 506R). Having air contents before placement as specified in Table 19.3.3.3 will provide required performance in freezing and thawing. Air contents greater than those specified will not improve shotcrete performance because once adequate air content for durability is achieved, there is no further benefit. As in all concrete, too much in-place air will reduce strength.

Dry-mix shotcrete without air entrainment has performed well in freezing-and-thawing environments with no exposure to saltwater or deicing salts (ACI 506R; Seegebrecht et al. 1989). For exposure to saltwater or deicing salts, air-entraining admixtures, in either a wet or dry form, can be added to dry-mix shotcrete to provide the required air content for durability in these exposures (Bertrand and Vezina 1994). The higher air content of wet-mix shotcrete sampled at the point of delivery accounts for expected air losses during shooting.

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Designation: C476 – 10

Standard Specification for Grout for Masonry[1]

This standard is issued under the fixed designation C476; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers two types of grout, fine and coarse grout, for use in the construction of masonry structures. Each type (fine and coarse) is further classified as conventional grout (requiring mechanical consolidation by puddling or vibration when placed) and self-consolidating grout (not requiring mechanical consolidation when placed). Conventional grout is specified by (*1*) proportions or (*2*) strength requirements. Self-consolidating grout is specified by strength requirements.

1.2 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C5 Specification for Quicklime for Structural Purposes
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150 Specification for Portland Cement
C207 Specification for Hydrated Lime for Masonry Purposes
C260 Specification for Air-Entraining Admixtures for Concrete
C404 Specification for Aggregates for Masonry Grout
C494/C494M Specification for Chemical Admixtures for Concrete
C595 Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C989 Specification for Slag Cement for Use in Concrete and Mortars
C1019 Test Method for Sampling and Testing Grout
C1157 Performance Specification for Hydraulic Cement
C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete

3. Materials

3.1 Materials used as ingredients in grout shall conform to the requirements specified in 3.1.1-3.1.8.

3.1.1 *Cementitious Materials*—Cementitious materials shall conform to one of the following specifications:

3.1.1.1 *Portland Cement*—Type I, IA, II, IIA, III, and IIIA of Specification C150.

3.1.1.2 *Blended Cements*—Type IS, IS(MS), IS-A, IS-A(MS), IP, or IP-A of Specification C595 or types GU, HE, MS, or HS of Specification C1157.

3.1.1.3 *Quicklime*—Specification C5.

3.1.1.4 *Hydrated Lime*—Type S of Specification C207.

3.1.1.5 *Coal Fly Ash or Raw Calcined Natural Pozzolan*—Specification C618. Addition rates shall be in an amount governed by the portland-pozzolan cement category of Specification C595. The grout produced with blends of portland cement and fly ash or raw calcined natural pozzolan shall have the compressive strength specified (4.2.1.2 or 4.2.2.1).

3.1.1.6 *Granulated Blast Furnace Slag*—Specification C989. Addition rates shall be as governed by the portland blast furnace slag cement category of Specification C595. Grouts produced with blends of portland cement and granulated blast furnace slag shall have the compressive strength specified (4.2.1.2 or 4.2.2.1).

3.1.2 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification C260.

3.1.3 *Aggregates*—Aggregates shall conform to Specification C404.

[1] This specification is under the jurisdiction of ASTM Committee C12 on Mortars and Grouts for Unit Masonry and is the direct responsibility of Subcommittee C12.05 on Grout & Grout Admixtures for Masonry.

Current edition approved June 1, 2010. Published June 2010. Originally approved in 1961. Last previous edition approved in 2009 as C476 – 09. DOI: 10.1520/C0476-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Conventional Grout Proportions by Volume

Type	Parts by Volume of Portland Cement or Blended Cement	Parts by Volume of Hydrated Lime or Lime Putty	Aggregate, Measured in a Damp, Loose Condition	
			Fine	Coarse
Fine grout	1	0–1/10	2 1/4 –3 times the sum of the volumes of the cementitious materials	. . .
Coarse grout	1	0–1/10	2 1/4 –3 times the sum of the volumes of the cementitious materials	1–2 times the sum of the volumes of the cementitious materials

3.1.4 *Water*—Water shall be clean and potable.

3.1.5 *Admixtures*—Integral waterproofing compounds, accelerators, or other admixtures not mentioned definitely in the specification shall not be used in grout for use in reinforced masonry without approval from the purchaser.

3.1.5.1 *Admixtures for Self-consolidating Grout*—High-range water-reducing admixtures conforming to Specification C494/C494M, Type F or G, and viscosity-modifying admixtures conforming to Specification C494/C494M, Type S, for producing self-consolidating grout are permitted.

NOTE 1—Polycarboxylate-based high-range water-reducing admixtures are best suited to achieve the water reduction and slump flow values required for self-consolidating grout. While viscosity-modifying admixtures are acceptable for producing self-consolidating grout, there currently are no ASTM specifications specifically for these admixtures. The C494/C494M requirements for Type S (specific performance) admixture provide a means of determining that the viscosity-modifying admixture will not have adverse effects on fresh, hardened and durability properties of the grout. Admixture suppliers should be consulted to ensure that the particular high-range water-reducing admixture and viscosity-modifying admixture being used are suitable for production of self-consolidating grout.

3.1.6 *Pumping Aids*—Pumping aids are permitted to be used in cases where the brand, quality, and quantity are approved in writing by the purchaser or are definitely stipulated in the specification.

3.1.7 *Antifreeze Compounds*—No antifreeze liquids, salts, or other substances shall be used in grout to lower the freezing point.

3.1.8 *Storage of Materials*—Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material or moisture. Any material that has become unsuitable for good construction shall not be used.

NOTE 2—If the grout is to be used to bond masonry units to reinforcing bars, the use of air-entraining materials or air-entraining admixtures is not recommended.

4. Grout Type and Proportions

4.1 *Type*—Grout type shall be specified as fine or coarse.

4.1.1 Fine grout shall be manufactured with fine aggregates.

4.1.2 Coarse grout shall be manufactured with a combination of coarse and fine aggregates.

NOTE 3—Building code provisions and grout space dimensions should be reviewed when selecting grout type or types.

4.2 *Proportions of Ingredients*—Proportions shall be determined as follows:

4.2.1 *Conventional Grout*—Proportions shall be determined by one of the following methods:

4.2.1.1 Requirements of Table 1.

4.2.1.2 *Specified Compressive Strength*—Proportions established by 28-day compressive strength tests in accordance with Test Method C1019 that equal or exceed the specified compressive strength. The grout shall be mixed to a slump of 8 to 11 in. (200 to 280 mm) as determined by Test Method C143/C143M and shall have a minimum compressive strength of 2000 psi (14 MPa) at 28 days.

4.2.2 *Self-consolidating Grout*—Proportions shall be determined by the following method:

4.2.2.1 *Specified Compressive Strength*—Proportions established by 28-day compressive strength tests in accordance with Test Method C1019 that equal or exceed the specified compressive strength. The grout shall be mixed to a slump flow of 24 to 30 in. (610 to 760 mm) as determined by Test Method C1611/C1611M and shall have a Visual Stability Index (VSI) of not greater than 1 as determined by Appendix X1 of Test Method C1611/C1611M. The grout shall have a minimum compressive strength of 2000 psi (14 MPa) at 28 days.

NOTE 4—The value for T_{50} as described in Appendix X1.1 and Note X1.1 of Test Method C1611/C1611M is a property of self-consolidating concrete and can be used as an indicator of batch-to-batch quality, consistency and performance in-situ of self-consolidating grout. While there is no consensus as to the appropriate T_{50} for all self-consolidating grouts, average values from 1.5 to 4 sec, with variations of ±0.5 sec from the average value, determined for the particular self-consolidating grout, typically provide proper viscosity and indicate batch-to-batch consistency.

NOTE 5—Building code provisions should be reviewed when selecting the specified compressive strength of grout.

5. Measurement and Production

5.1 *Measurement of Materials*—Measure materials for grout such that the required proportions of the grout materials are controlled and accurately measured.

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NOTE 6—When converting volume proportions to batch weights, use the following material bulk densities:

Material	Weight, lb/ft^3(kg/m^3)
Portland cement	94 (1505)
Blended cement	Obtain from bag or supplier
Other cementitious materials	Obtain from bag or supplier
Hydrated lime	40 (640)
Lime putty[A]	80 (1280)
Sand, damp and loose	80 (1280) of dry sand
Coarse aggregate	Refer to C404 to determine weight per cubic foot.

[A] All quicklime should be slaked in accordance with the manufacturer's directions. All quicklime putty, except pulverized quicklime putty, should be sieved through a No. 20 (850-µm) sieve and allowed to cool until it has reached a temperature of 80°F (26.7°C). Quicklime putty should weigh at least 80 lb/ft^3 (281 kg/m^3). Putty that weighs less than this may be used in the proportion specifications if the required quantity of extra putty is added to meet the minimum weight requirements.

5.2 *Production Methods*—Grout shall be produced using one of the following procedures:

5.2.1 *Grout Materials Mixed with Water at the Job Site*:

5.2.1.1 *Conventional Grout*:

(1) Individual cementitious materials and aggregates stored at the job site shall be mixed in a mechanical mixer for a minimum of 5 min with sufficient water to achieve the desired consistency.

(2) Individual ingredients transported to the job site in suitable compartments shall be mixed with water at the job site using continuous volumetric proportioning equipment to achieve the desired consistency. Mix with an auger of appropriate length to provide adequate mixing.

(3) Factory pre-blended grout materials delivered to the job site shall be mixed in a mechanical batch mixer for a minimum of 5 min or in a continuous mixer following mixer manufacturer's recommendation with sufficient water to achieve the desired consistency.

NOTE 7—Conventional grout may be hand-mixed on small jobs with written approval of the mixing procedure by the specifier.

5.2.1.2 *Self-consolidating Grout*:

(1) Individual ingredients transported to the job site as part of a self-consolidating grout manufacturer's system, shall be mixed at the job-site with water, per the manufacturer's recommendations, using continuous volumetric proportioning equipment to achieve the desired consistency. Mix with an auger of appropriate length to provide adequate mixing.

(2) Factory preblended grout materials delivered to the job site shall be mixed in a mechanical mixer with sufficient water, per the self-consolidating grout manufacturer's recommendation, to achieve the desired consistency.

(3) Job site proportioning and mixing of individual materials that are not part of a self-consolidating grout manufacturer's system shall not be permitted.

5.2.2 *Ready-Mixed Grout Transported to the Job Site*:

5.2.2.1 *Conventional Grout*—Grout shall arrive at the job site in a ready-mixed condition. Slump shall be adjusted as necessary, and grout shall be re-mixed at mixing speed for at least 1 min before discharging to achieve the desired consistency.

5.2.2.2 *Self-consolidating Grout*—Grout shall arrive at the job-site in a ready-mixed condition. The addition of water at the job site is permitted in accordance with the self-consolidating grout manufacturer's recommendations.

6. Keywords

6.1 aggregates; cement; compressive strength; grout; masonry; portland cement; proportions; self-consolidating grout

SUMMARY OF CHANGES

Committee C12 has identified the location of selected changes to this standard since the last issue (C476 – 09) that may impact the use of this standard. (Approved June 1, 2010.)

(*1*) Subsection 1.1 was revised to clarify types of grout.
(*2*) Conformance to C494/C494M Type S for viscosity-modifying admixtures in self-consolidating grout was added to 3.1.5.1.
(*3*) Additional information on C494/C494M Type S specification was added to Note 1.
(*4*) Subsection 5.2.1.2 was revised to clarify the provisions for job site mixing of self-consolidating grout.
(*5*) Note 4 was added to provide guidance on the use of the T_{50} value for self-consolidating grout. Subsequent notes were renumbered accordingly.

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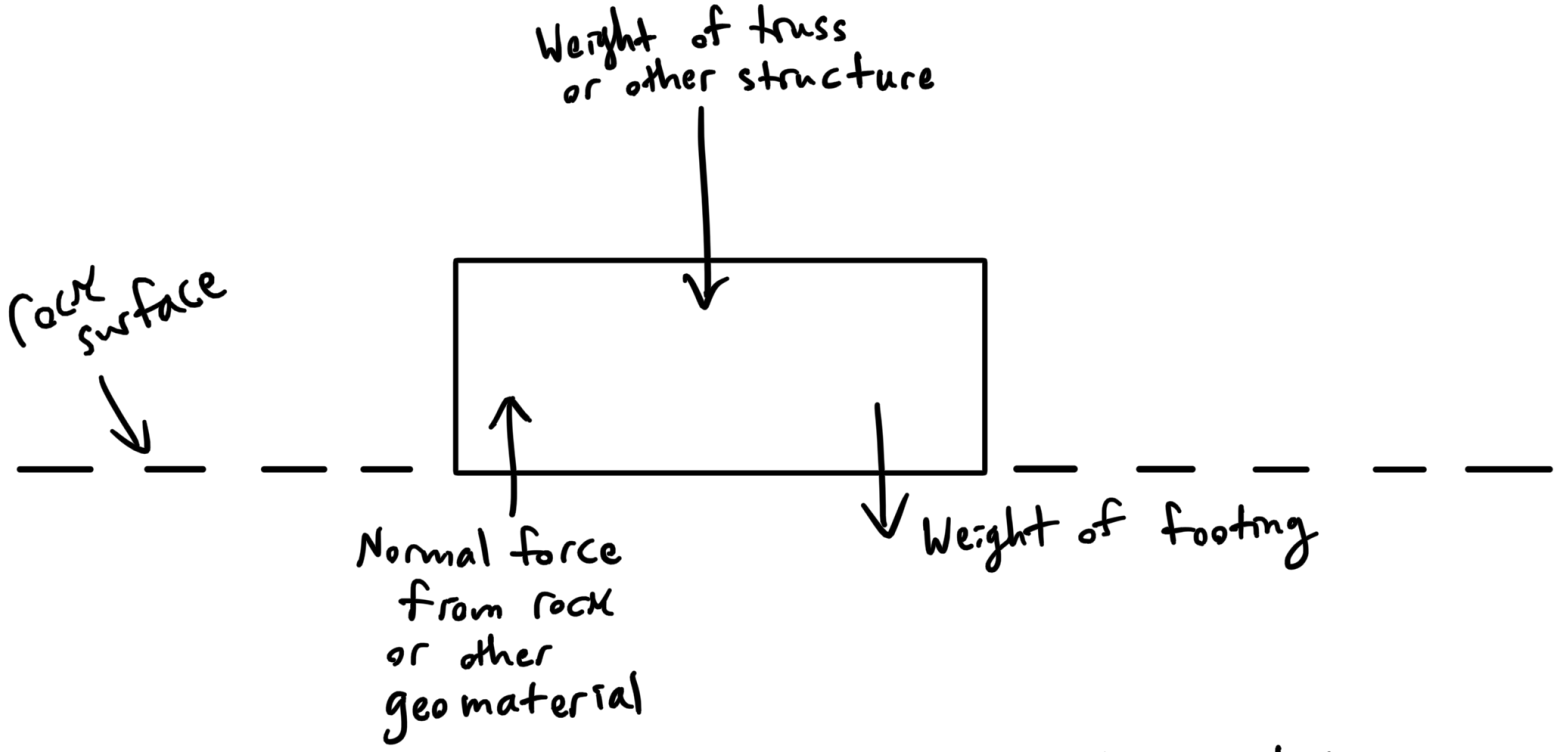
Free Body Diagram of Footing Experiencing Loading from Turbine System

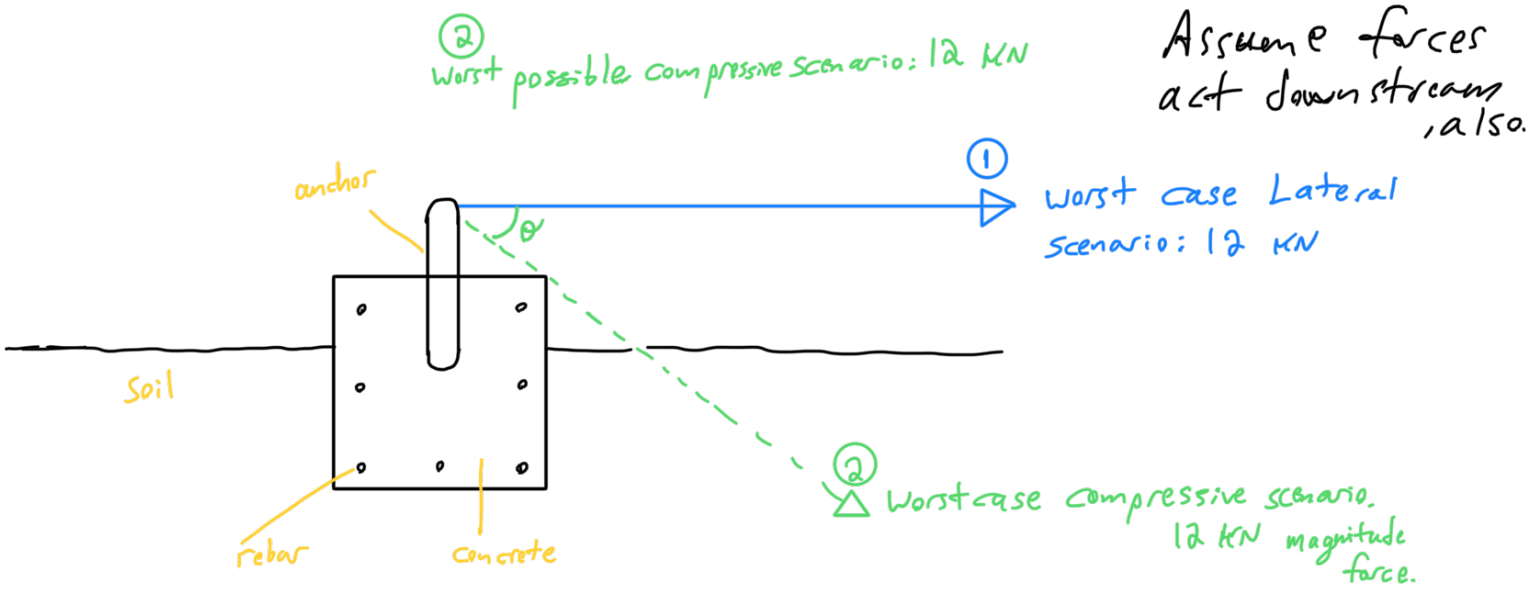
Matthew Tolson

12/1/21



* Horizontal or uplift forces may be experienced by the footing

Footing Free Body Diagram and Design Sheet



Moment arm = 6" of exposed anchor/eye.

Hooked Rebar Design

F_y = 344.7 MPa

Force to withstand = 24 kN (SF = 2)

Bar Size = 20 (19.5 mm diameter)

Min bend diameter = 117 mm

Min straight ext = 78 mm

LDH = 307 mm

Input parameters

Concrete $f'c = 27.6$ MPa (4000 psi), unit weight $= 22$ kN/m^3

Bearing capacity of soft clay = 100 kPa

Cohesive strength for clay loam/silt loam, saturated = 15 kPa

Unit weight of clay loam = 14,900 N/m^3

Friction angle of clay = 0

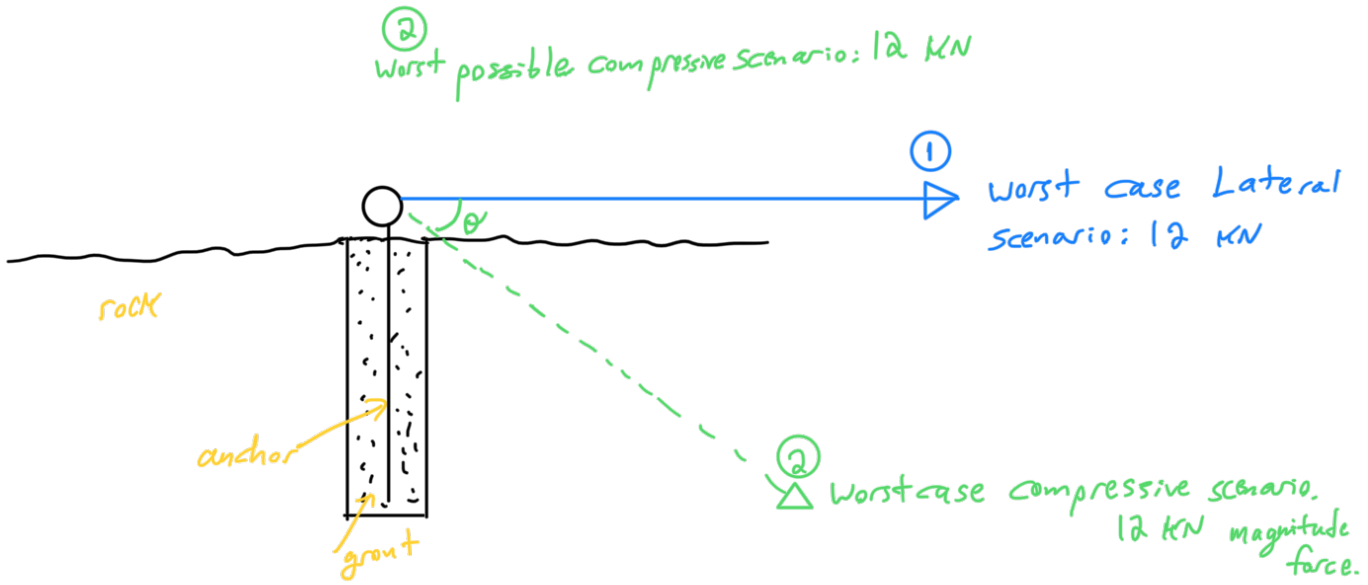
Rock Anchor Design Sheet - Matthew Tolson

Grout $f'_c = 14 \times 10^6$ Pa

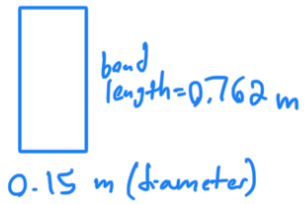
Rock Bearing Capacity $= 1.5625 \times 10^6$ Pa (3.90625×10^5 Pa allowable, SF = 4)

Safety Factors

1.5 SF applied to velocity
4.0 SF applied to rock strength



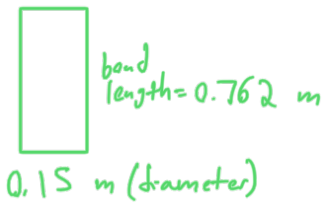
① Assume bore-hole walls are rectangular.



$$\text{Area} = 0.762\ m \times 0.15\ m = 0.1143\ m^2$$

$$P = F/A = \frac{12\ KN}{0.1143\ m^2} = 104{,}987\ Pa \quad \checkmark$$

② Assume bore-hole walls are rectangular.



$$\text{Area} = 0.762\ m \times 0.15\ m = 0.1143\ m^2 \qquad \theta = 35°$$

$$P = F/A = \frac{12\ KN \cos(\theta)}{0.1143\ m^2} = 86{,}000\ Pa \quad \checkmark$$



$$\text{Area} = \frac{\pi (0.15\ m)^2}{4} = 0.17671\ m^2 \qquad \theta = 35°$$

$$P = F/A = \frac{12\ KN \sin(\theta)}{0.17671\ m^2} = 38{,}950\ Pa \quad \checkmark$$

Summary of Design

- Anchor Ultimate Strength must be greater than 24 KN (Force w/ SF = 2)
- Minimum Bore-hole diameter = 0.15 m
- Minimum Anchor Length = 0.762 m
- Grout must be mixed according to ASTM C476
- For expanding anchors with expanded rod diameters < 0.15 m, expanding must occur post grout pouring and curing to ensure anchors generate proper embedment into surrounding grout.
- Range of acceptable cable angles = 0° – 35° from horizontal.

Grout Design

- Follow ASTM C476
- coarse grout (on-site material)
- f'c = 2000 psi at 28 days (14 MPa)
- slump: 8-11 in (follow ASTM C143)
- Mix: 1 part cement, 2.25-3 parts fine aggregate, 1-2 parts coarse aggregate.

Input:

SI Metric Units | US Customary Units

Method of Computation for Tension Development Length

Simplified Method

Select ACI Formula to be used (see explanation in background section)

Bar Diameter (mm)

19.5

f'c (MPa)

27.6

fy (MPa)

344.7

Concrete Type:

(•) Normal Weight ( ) Light weight

Spacing and cover satisfies:

(•) Clear spacing of bars or wires not less than ***db***, clear cover not less than ***db***, and stirrups or ties throughtout *ld* not less than code minimum

( ) Clear spacing of bars or wires not less than **2*db*** and clear cover not less than ***db***

( ) All other cases

Rebar Position:

Horizontal bar with more than 300mm fresh concrete below

All other types of rebar position

Rebar Coating:

Uncoated

Epoxy Coated (cover<3db or s<6db)

Epoxy coated (all other types)

Result:

Tension Anchorage Length:

Ld = 38.60 x ***db***
Ld = 752.61 mm

Tension Lap Splice Length:

L = 50.17 x ***db*** (Class B splice)
L = 978.40mm
For Class A splice, use same as anchorage length.

Compression Development Length:

Ld = 15.75 x ***db***
Ld = 307.07 mm

Compression Lap Splice Length:

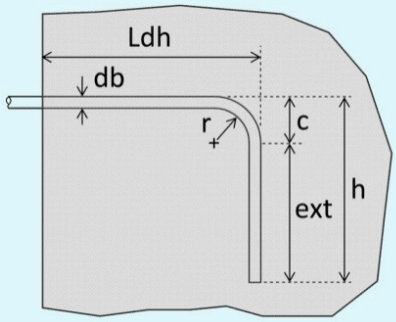
L = 24.47 x ***db***
L = 477.24 mm

Governing factors used:

√(f'c) = 5.25 MPa
λ = 1.00
Ψt = 1.00
Ψe = 1.00
Ψt Ψe = 1.00
Ψs = N.A.
(cb + Ktr)/db = N.A.

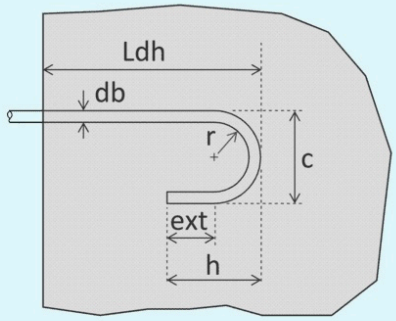
Standard Hook Development Length:

90° Standard Hook



Ldh = 15.75 x ***db***
Ldh = 307.07 mm
r = 3.00 x ***db*** = 58.50 mm
c = 78.00 mm
ext = 234.00 mm
h = 312.00 mm

180° Standard Hook



Ldh = 15.75 x ***db***
Ldh = 307.07 mm
r = 3.00 x ***db*** = 58.50 mm
c = 156.00 mm
ext = 78.00 mm
h = 156.00 mm

Studies on the pull-out strength of ribbed bars in high-strength concrete

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ABSTRACT: The transfer of forces from reinforcing bars to surrounding concrete in reinforced concrete (RC) is influenced by many parameters. Several efforts were made to understand the influence of bond on global behaviour of RC members. However, the information on bond strength of high strength concrete (HSC) is lacking. An attempt was made to study the influence of various parameters on bond such as bar diameter, strength of concrete, lateral confinement and embedment length. The bond lengths were 50mm and 150mm with different bar diameters, strength of concrete and type of confinement. The bar diameters were 16mm and 20mm. The bars were embedded in concrete without confinement and with confinement using spirals and ties. The casting was done keeping the bars in the horizontal position. The anchorage bond specimens were tested using displacement control system and the slip of the bars was controlled at a rate of 1.51mm/minute (0.025mm/second). The bond stress-slip response was studied by varying the variables. As the strength of concrete increases the slip at failure decreases in the descending branch. With smaller bond length, the bond stress was found to be higher. The bond strength was found to decrease as the bar diameter increased. Splitting failure was observed in unconfined specimens, whereas pullout failure in confined specimens. The ultimate bond strength ranges between 10.8 MPa and 19 MPa with spiral confinement, whereas it ranges between 9.2 to 16 MPa with tied reinforcement. The ductility was found to increase with spiral reinforcement.

1 INTRODUCTION

Bond in reinforced concrete (RC) refers to the resistance of surrounding concrete against pulling out of reinforcing bars. Anchorage bond is developed parallel to the direction of force over a contact surface in order to induce stress in rebars at critical sections. The bond resisting mechanisms in RC members are understood well in normal strength concrete (NSC) after the numerous studies performed in the last thirty years. If the bond resistance is inadequate, slipping of reinforcing bar occurs destroying composite action. In RC members sudden loss of bond between rebars and concrete in anchorage zones causes brittle failure. However, the information on bond strength of high strength concrete (HSC) is scanty (FIB 2000).

Bond is necessary not only to ensure adequate level of safety allowing composite action of steel and concrete, but also to control structural behavior along with sufficient ductility. The bond in RC members depends on a number of factors such as reinforcing unit (bar or multi wire) and stress state in both reinforcing unit and surrounding concrete. Other parameters such as concrete cover, space between rebars, number of layers and bundled bars, casting direction and bar position play important role. Several research studies have been reported on the influence of deformation patterns and rib geometry on bond *(Rehm, 1961; Goto, 1971)*. For bars with rib face angles, bond behaviour is influenced by the rib face angle. However, when the rib face angle is less than 30 degrees, the bond behaviour is different. In bars with small rib spacing and small rib height the bond strength is reduced.

Mathey and Watstein (1961) reported that the bond strength decreases as the embedment length increases, and decreases as the bar diameter increases. *Hansen and Liepins (1962)* reported an increase in the bond strength under dynamic loading over static loading. Also progressive bond failure and large slip were expected from large repeated loading. *Ferguson and Thomson (1962)* reported on development length of rebars and effect of confinement. Bond stress varies as a function of development length rather than bar diameter. Ultimate bond stress varies as a function of $\sqrt{f_c'}$, with other factors being constant, since the bond strength is related to concrete tensile strength. The nature of bond failure and factors influencing splitting, importance of bar spacing

and beam width, end anchorage, flexural bond and anchorage bond were reported by *Ferguson et al. (1966)*.

Lutz and Gergely (1967) studied the action of bond forces and the associated slip and cracking using rebars with different surface properties. The slip was found to be due primarily to the relative movement between concrete and steel along the surface of the ribs and also due to crushing of mortar. *Goto (1971)* studied the primary and secondary cracking by injecting ink around the deformed rebars in axially loaded tests. *Nilson (1972)* estimated the bond stress from the slope of the steel strain curve. The strain in concrete and steel was measured internally and the bond slip was calculated from the displacement functions obtained by numerical integration of strains. *Jiang et al. (1984)* developed new test method by cutting the reinforcing bars into two halves and placing in two opposite sides of the cross section to study the local slip, secondary cracking and strain distribution in concrete surrounding the interface. A simple one-dimensional analysis predicts the stresses in steel and concrete, local bond-slip, tensile stiffening and total elongation of the reinforcing bar. *Ueda et al. (1988)* studied the beam bar anchorage in exterior beam-column joints. A model has been proposed to predict the load-lead end deformation and anchorage length of rebars extended from beams into exterior columns and subjected to large inelastic loadings.

Effects of anchored bar diameter, confinement of joint and compressive strength of concrete on the hook behaviour in exterior beam-column joints have been studied (*Soroushian, 1988)*). An analytical model has been developed for predicting the overall pullout behaviour of rebars, which has been recognised by *ACI–318-83* for development of standard hooks in tension. *Soroushian and Choi (1989)* reported on local bond strength of deformed bars with different diameters in confined concrete. The bond strength decreases as the bar diameter increases. *Soroushian et al. (1991)* studied the influence of strength of concrete with different confinements. Confinement influences local bond of deformed bars. The ultimate bond strength increases as square root of concrete compressive strength.

Abrishami and Mitchell (1992) formulated a new testing technique to simulate uniform bond stress distribution along a rebar to determine bond stress-slip response. *Malvar (1992)* tested specimens with varying confining pressure using confining rings with rebar ribs normal and inclined to the surface and obtained consistent bond-slip response over a short embedded length. Mathematical model for bond-slip behaviour of a reinforcing steel bar embedded in concrete subjected to cyclic loading was reported by *Yankelevsky et al. (1992). Bortolotti (2003)* proposed models to predict the tensile strength of concrete from pullout load.

The confinement improved the bond strength slightly but ductility was improved significantly (*Harajli et al. 2004)*. *Somyaji et al. (1981) and Jiang et al. (1984)* conducted several experimental and theoretical studies on bond in NSC. The secondary cracks as well as the distribution of strain in concrete in the vicinity of rebar have been studied. *Darwin et al. (1996)* reported development length criteria for conventional and high relative rib area of reinforcement. On the basis of a statistically based expression, the development length of reinforcement and splice strength in concrete for compressive strength varying between 17 and 110MPa with and without confinement have been investigated. The effects of cover, spacing, development/spliced reinforcement were incorporated in design equation.

The effects of concrete compressive strength, splice length and casting position on the bond strength of rebars have been studied (*Azizinamini et al. 1993; 1999a))*. Increasing the development length in HSC in tension does not seem to increase the bond strength of deformed rebars, when concrete cover is small. Concrete crushing occurred in front of the ribs in NSC, whereas there was no indication of concrete crushing in front of the ribs in HSC with the first few ribs being more active. In HSC with small cover, failure occurred due to splitting of concrete prior to achieving uniform load distribution *Azizinamini et al. (1993)*. *Azizinamini et al. (1999b)* in another study reported that when calculating the development length in HSC for tension splice, a minimum number of stirrups should be provided over the splice region. Statically based on the experimental data an expression has been proposed to calculate the extra number of stirrups required.

Eligehausen et al. (1983) reported comprehensive study on the effect of bar diameter embedded in NSC. The maximum bond capacity decreases slightly with increasing bar diameter. The frictional bond resistance was not influenced by the bar diameter, lug spacing or relative rib area. *Larrard et al. (1993)* investigated the effect of bar diameter on bond strength. The bond strength increases with tensile strength of concrete at a higher rate with smaller bar diameters. A parameter which accounts for the ratios of side cover and bottom faces, and spacing of the spliced bars was introduced. CEB-FIB report *(2000)* presented a general description of the local bond law for tensile forces. Six main stages have been recognized in local bond stress-slip response.

Goto (1971) carried out tests to clarify the propagation of different types of cracks around the tensile reinforcing bars. The internal cracks develop around the reinforcing bars in concrete cylinders as shown in Figure 1. The inclination of internal cracks and the direction of compressive forces on the bar ribs vary between 45 and 80^0.

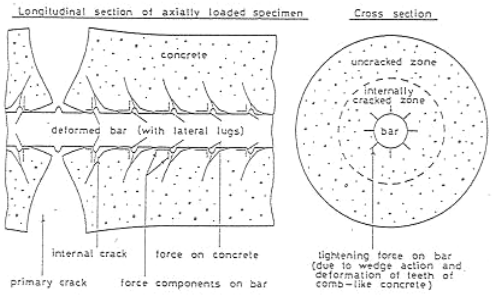

Figure 1. Internal cracks around the reinforcing bar embedded in concrete (Goto, 1971).

Tepfers (1973) showed the radial components of bond forces balanced against tensile rings in concrete in Figure 2, using a two dimensional finite element analysis (FEA). The angle "α" is 45 degrees along a perimeter touching the ribs of reinforcing bars independent of rib face angle.

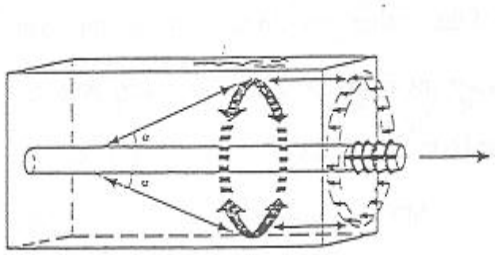

Figure 2. View of tensile ring (Tepfers, 1973).

Three mechanisms for bond resistance i.e. (i) chemical adhesion, (ii) friction, and (iii) mechanical interaction between concrete and deformed bars are responsible (*Lutz and Gergely, 1967)*. According to *Rehm (1961)***,** and *Lutz and Gergely (1967)*, slip of deformed bars occurs due to (i) splitting of concrete by wedging action, and (ii) crushing of concrete in front of the ribs. For the face angles between 40 and 105 degrees, the slip seems to be not influenced. However, the slip is mostly due to crushing of concrete in front of the ribs. This in effect produces a rib with face angles of 30 to 40 degrees *(Lutz and Gergely, 1967)*.

2 EXPERIMENTAL PROGRAMME

2.1 *Materials*

A 43 grade Portland Pozzolanic Cement (PPC) was used. Specific gravity of cement was 3.12. The fineness of cement was 5.6 %. The initial and final setting times were 124 and 300 minutes respectively. Fe 415 grade high strength deformed bars of diameters 16mm and 20mm as main reinforcement and 6mm mild steel (MS) bars for stirrup/spirals as confinement reinforcement were used. Concrete was made from normal weight black granite aggregate. Specific gravity of cement was 3.12. Specific gravity of coarse aggregate was 2.6. Specific gravity of fine aggregate was 2.6. Two concrete mixes were adopted. In 30 MPa concrete; weight of cement was 300 kg/m^3 and water-cement ratio was 0.45. The concrete mix proportions were 1: 2.30: 4.27: 0.45. In 60 MPa concrete; weight of cement was 400 kg/m^3 and water cement ratio was 0.35. Mix proportions were : 1: 1.64: 3.02: 0.35. Three standard cubes of size 150mmx150mmx150mm were used to determine the compressive strength of concrete.

2.2 *Test specimen*

Main bar was embedded in each cube with different confinements such as spirals, ties and without confinement. The test specimen was basically a concrete cube 150mmx150mmx150mm with a bar embedded coaxially (IS: 2770-1997). One end of the rebar was projected about 15mm to measure the free end slip, while the loaded end was jutted out about 750mm in order to grip the rebar for applying the tensile force. The specimens were cast using 16 and 20mm diameter rebars in two different concretes with different embedment lengths. By using PVC tubes the required embedment length was achieved. To achieve 50mm embedment length at the centre of the specimen, PVC tubes were used to unbond the bars from concrete over 100mm length. The PVC tube neither restrains the slip of the bar nor affects the transfer of bar forces to concrete. The slip was recorded at both loaded and unloaded ends of the bar. The bars were placed in the middle of the specimen horizontally.

2.3 *Test programme*

Tests were carried out on pullout specimen with four different parameters. In a set there were three specimens with different confinements. Only two specimens were tested without confinement. In this study, two concretes of strength 40 and 50MPa, embedment lengths of 150 and 50mm, bar diameters 16 and 20 mm and three confinements (spirals, ties and no confinement) were adopted. Typical reinforcements are shown in Figure 3



Figure 3. Confining reinforcement in pull-out specimens.

2.4 *Fabrication of test specimen*

Well seasoned wooden moulds were fabricated to cast 10 specimens in a single batch. Provisions were made at appropriate locations in the moulds to accommodate 3-16mm, 3-20mm and 4-25mm diameter bars. The bars were placed horizontally and concrete was poured vertically. The moulds had provision for fixing the reinforcement cage. Lubricating oil was applied on all sides of the moulds for easy removal of specimens. Concrete was poured carefully from the top and segregation was avoided. Needle vibrator was used to compact the concrete. After twenty four hours the specimens were demolded and cured up to 28 days till testing.

2.5 *Experimental set-up and testing*

The test setup for testing pullout specimens under controlled displacements is shown in Figure 4. A 250 kN capacity actuator was hung from an existing A frame which could transmit 2000kN load. The specimen was kept in a frame which hanged from the actuator. To avoid the influence of lateral strains by friction at the bearing plates Teflon sheets were placed between the specimen and base plate of the frame. A steel plate of size 150 x 150 x 12mm with a central opening of 100 x 100 x 12mm was placed below Teflon sheet to allow free failure of concrete due to pullout.



Figure 4. Experimental Test set-up.

The loaded surface was leveled off using gypsum (POP) and a steel plate was placed on top of POP over which an LVDT was fixed to record displacement at unloaded end of the bar. At loaded end two LVDTs were placed to monitor the end displacement. A locking arrangement by means of steel wedges was used. Load cell, which was placed above the wedge along with LVDTs and strain gauges were connected to the data logger which continuously recorded the respective readings at a frequency of 0.5Hz. Monotonic load was applied by means of the actuator and the rate of stroke control was maintained at 1.51mm/min (i.e.0.025mm/sec). The total displacement of 60mm in the actuator was set as the end value or complete pullout of the bar whichever occurred first to end the test. Three identical tests were carried out to have a minimal statistical basis.

3 RESULTS AND DISCUSSIONS

Forty pull-out specimens were tested for anchorage bond strength and its variation. The bond stress-slip curves were drawn from the experimentally monitored load vs. slip (at the free and loaded ends) data. The actual materials properties and various parameters obtained from the observations were used. The bond stress (τ) was calculated as the stress developed over an equivalent surface area using the formula

$$\tau = \frac{P}{\pi \, d_b \, l_b} \qquad (1)$$

"Where" P = load (N), l_b = embedment length (mm), and d_b = diameter of the rebar (mm)

3.1 *Modes of failure*

The unconfined concrete at the end of rebar in tension offers the least bond resistance because of early formation of radial splitting cracks caused by high tensile hoop stresses. The failure was caused by the formation of a concrete cone from the concrete block due to bond forces acting on the concrete in front of rebar lugs. Better bond performance was observed with confining reinforcement. Splitting cracks in the plane between bars was developed, but its growth was resisted by the confinement. The bond failure was probably due to shear failure in concrete between the lugs.

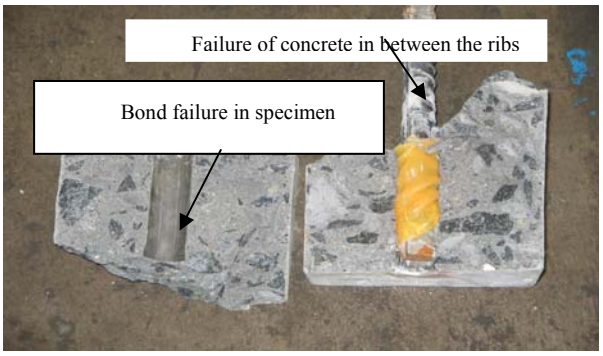

Figure 5. Splitting failure in unconfined specimen.

An ideal pull-out failure was occurred in all the tested specimens with confinement. However, splitting failure was encountered in the specimens without confinement. Wide longitudinal cracks were

formed along the specimen surface. Eventually, the specimen was split into two halves in most of the test specimens as shown in Figure 5. In the tested specimens confined by ties or spirals the splitting cracks were effectively arrested by the confinement, due to which splitting failure was minimized or avoided altogether resulting only in pull-out of rebars from concrete as shown in Figure 6. This was clearly shown by the descending branch of the bond-slip curve which lost its bond stiffness gradually with load. The portion of concrete in between the ribs was sheared off in confined concrete specimens and the bar experienced with stresses much below the yield strength of rebar. The failure of concrete in between the ribs was clearly noticed by observing the tested specimens. The unconfined specimens failed due to splitting and the pulled out bar was intact showing that there was no crushing failure and the bar was pulled out from the concrete.



Figure 6. Pullout failure in confined concrete specimen.

3.2 *Bond strength*

The maximum bond strength of unconfined concrete ranged between 50 and 60 % of that with confinement. The bond stress at the stage of longitudinal splitting was about 8.0 to 11.8 MPa in both 40MPa and 50MPa concretes. After attaining the peak value, a sudden drop in the load was observed. The descending branch did not reveal any resistance due to friction. The maximum bond stress in tested specimens with 16mm diameter bars with different confinements was observed when the slip was between 0.3 and 1.5mm. The slope of the ascending branch of bond stress-slip curve decreased gradually. It was relatively steeper than those with 20mm diameter rebars. A horizontal plateau was observed at a maximum bond stress, τ_{max} at a slip of around 0.3mm and the slip increased further at the same shear stress up to about 1.5 to 4.0mm. Subsequently the bond resistance dropped to τ_f called frictional bond resistance at a slip of about 10mm and then was remained constant thereafter up to failure. Coincidentally this value was equal to the clear spacing between the ribs in the bars. The slip continued to increase when the bond stress reached a constant value in the post-peak region of the bond stress-slip curve.

3.3 *Bond stress-slip response*

Slip is defined as the relative displacement of rebar with reference to the surrounding concrete. The relative displacement of the bar is always measured with reference to the undisturbed concrete and consists of relative slip at the interface and shear deformations in concrete. Therefore, displacement occurred due to localized strains in the interface even if there was no slip. Figure 7 shows a typical bond stress-slip response with 16mm bars at 150mm embedment length in 40 MPa concrete.

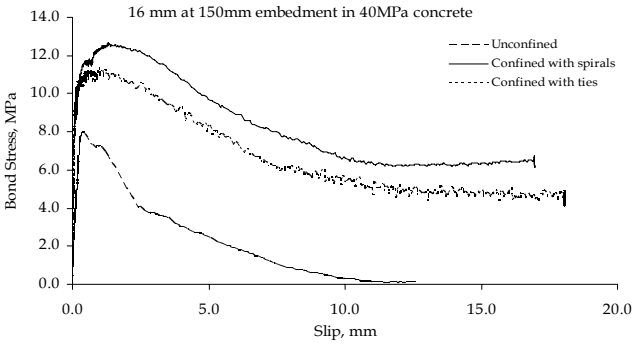

Figure 7. Bond stress vs. Slip with 16mm bars at 150mm embedment in 40 MPa concrete.

3.4 *Effect of various parameters*

The bond strength did not change much with diameter of bars. However, the resistance increased slightly with increase in bar diameter in certain cases. The variation in rebar diameter did not influence much the extent of the plateau. The post peak behaviour was better when large bar diameter was used. The maximum bond stress (τ_{max}) was relatively higher at small embedment length, at 50 mm and it was achieved at a slip varying between 0.3 and 1.5mm. There was no significant change of the slope of the ascending branch as well as the maximum bond stress plateau. But for specimen with 50mm embedment length, the descending branch was more ductile compared to that with 150mm embedment length. As the surface area of embedment increased, the maximum bond stress decreased. It shows, however, that there exists a size effect on bond strength of rebars. It has been proved that a splitting failure can be delayed or avoided altogether by providing confining reinforcement. Though the effects of the confining reinforcement (be it spiral or ties) was rather limited, however by providing spirals the bond strength was slightly increased. Usually, it is assumed that once a pull-out failure is initiated, providing a large concrete cover or a sufficiently strong restraining (confining) reinforcement, the value of τ_{max} can not be increased further. The extent of the

post-peak curve was significantly increased by spirals showing increase of ductility with spiral reinforcement.

4. CONCLUSIONS

From the present study, the following conclusions can be drawn;

1. The maximum bond stress τ_{max} for unconfined specimens was about 50 to 60% of that of those confined with spirals.
2. The lateral confinement increased the bond strength significantly and the extension of the post-peak curve increased showing improved ductility.
3. The maximum bond stress τ_{max} for specimens confined with spirals was higher and showed significant improved ductility.
4. The influence of bar diameter on the local bond stress-slip relationship was rather small in the tested range (d_b = 16mm and 20mm).
5. The bond strength also decreased as the embedment length increased. The bond stress varies along the larger embedment lengths while it is more or less uniform in smaller lengths.

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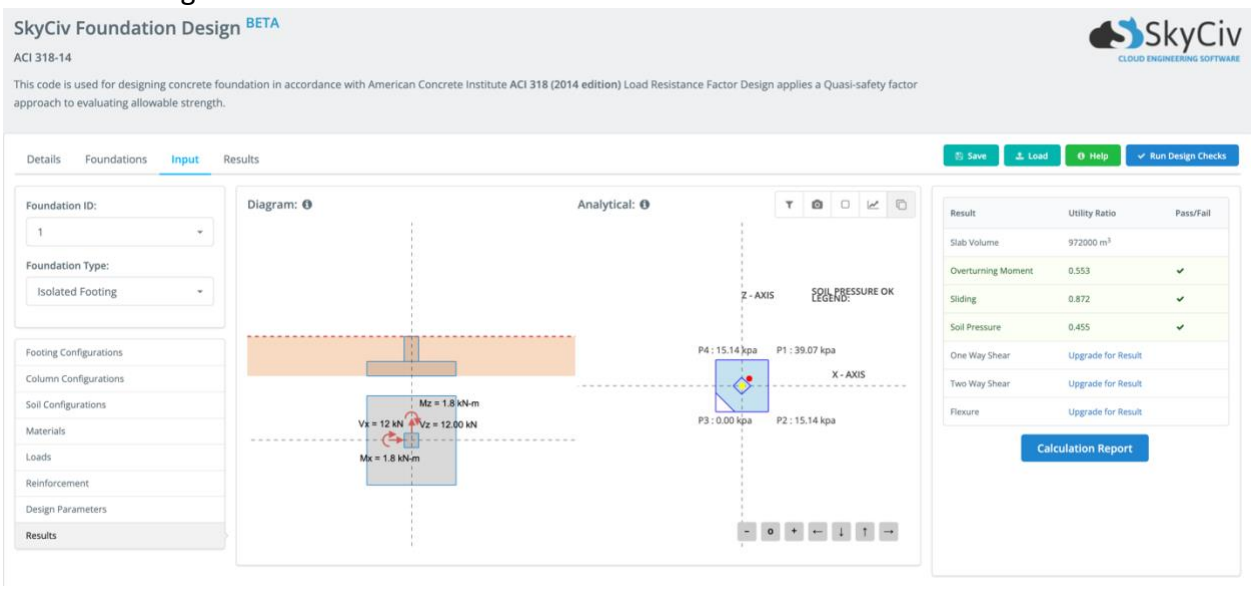
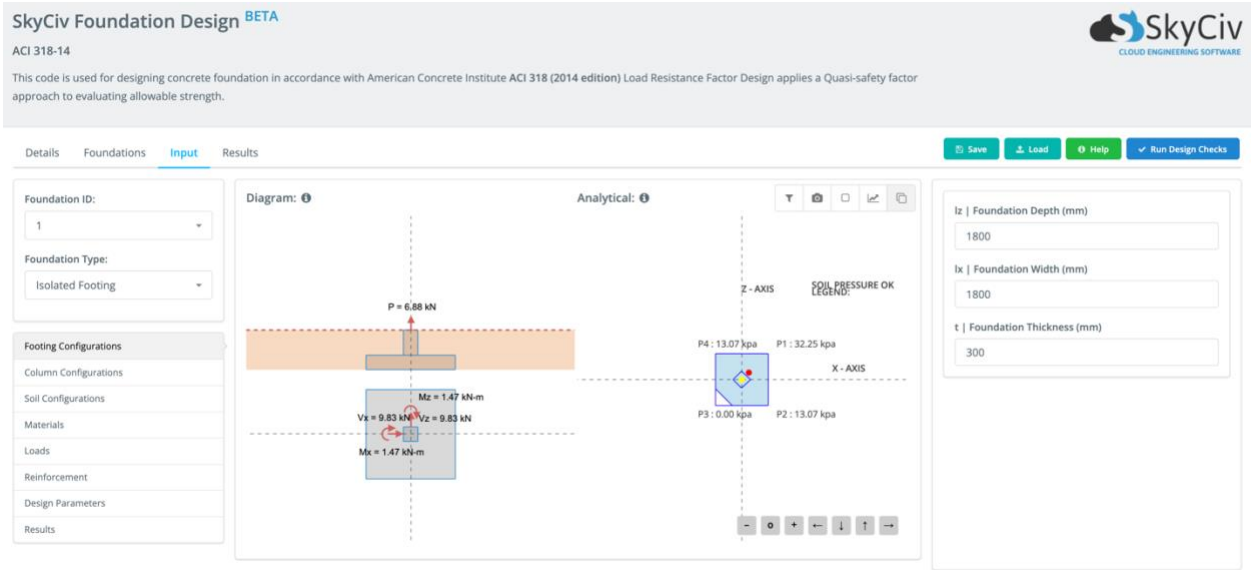
Soil Option Footing Design for Both Turbine Options – Matthew Tolson

Case 1 Loading and Results



Case 2 Loading, Results, and Base Dimensions



Result	Utility Ratio	Pass/Fail
Slab Volume	972000 m^3	
Overturning Moment	0.532	✔
Sliding	0.714	✔
Soil Pressure	0.375	✔

Column Dimensions

Column Section Dimension

(•) Rectangular ( ) Round

cz | Foundation Column Depth (mm)

300

cx | Foundation Column Width (mm)

300

cH | Foundation Column Height (mm)

500

Column Offset Distance

off_x | offset distance (mm)

0

off_z | offset distance (mm)

0

λs | Column position

Interior

Soil Parameters

W_s | Surcharge load (kN / m)

0

sT | Soil Thickness (mm)

500

sbc | Soil Bearing Capacity (KPa)

100

$\Phi_{friction}$ | Angle of Friction

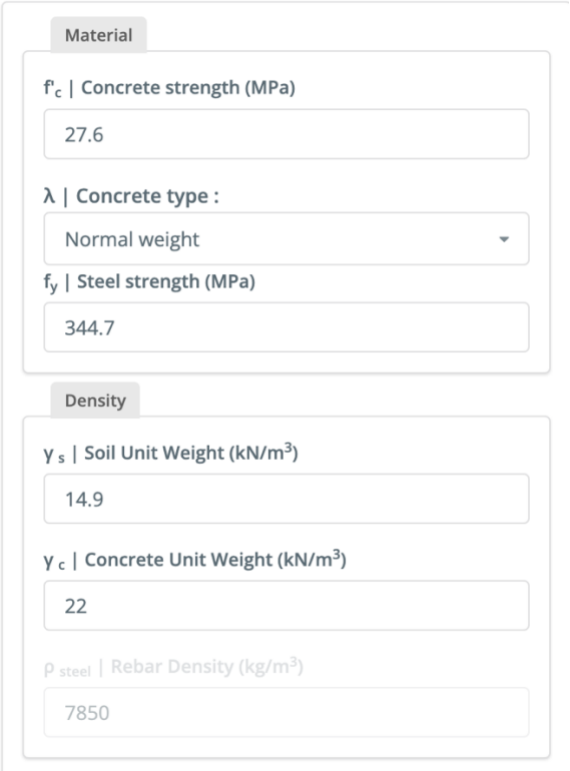
0

$\mu_{friction}$ | Coefficent of Friction

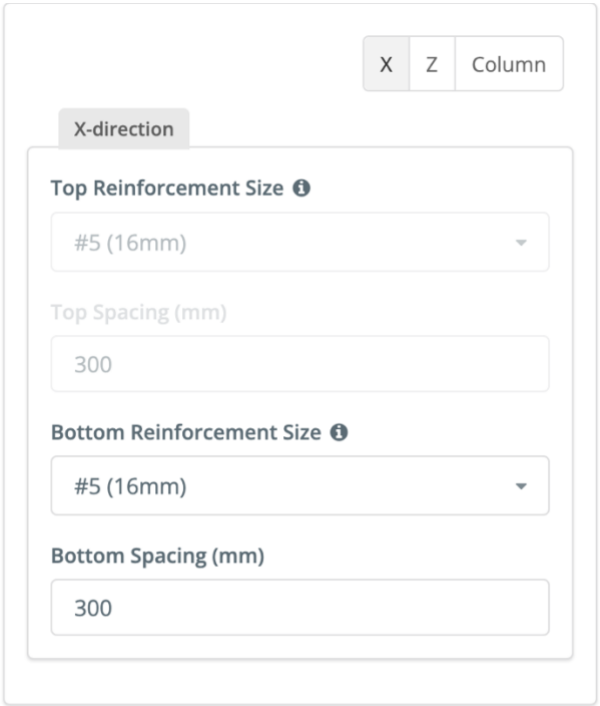
0.45

[ ] Ground Water Table

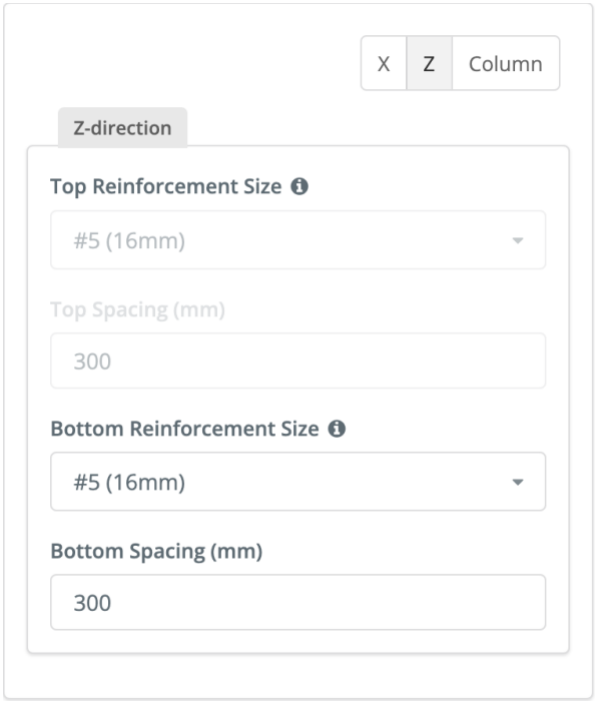
Material Strength and Density



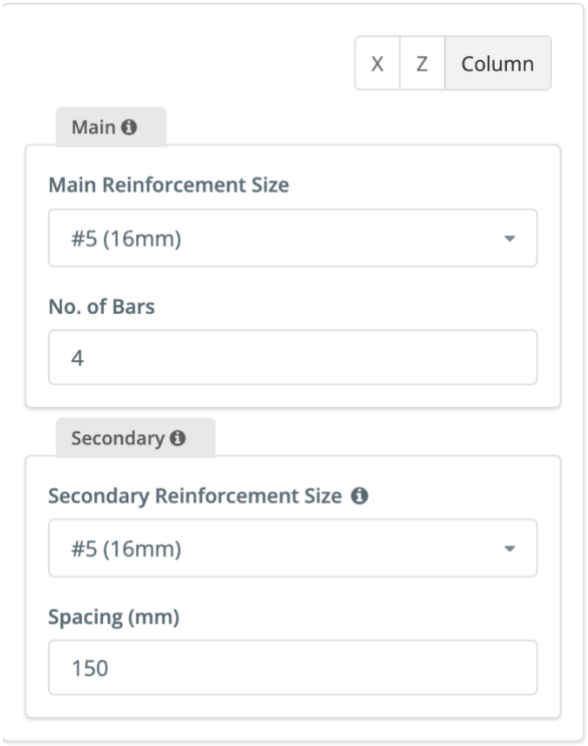
X-Axis Reinforcement



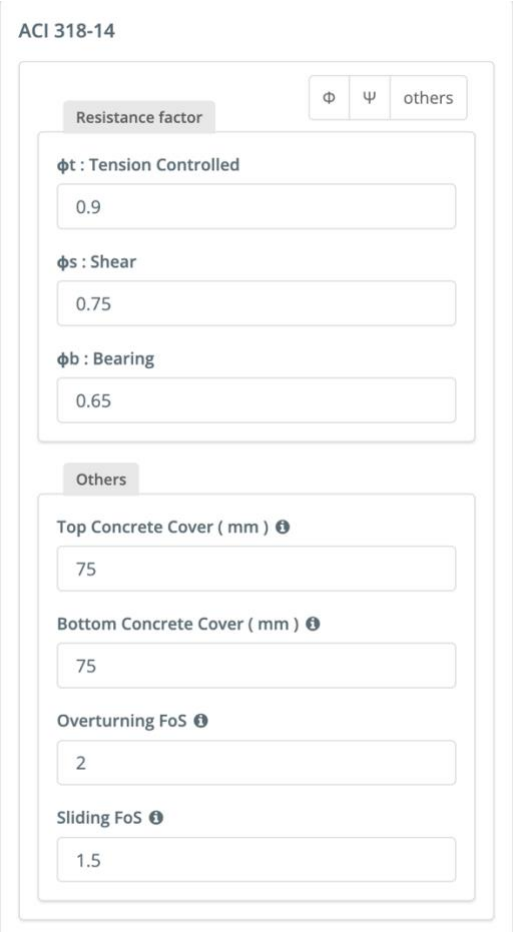
Z-Axis Reinforcement



Column Reinforcement



Concrete Design Parameters and Factors of Safety

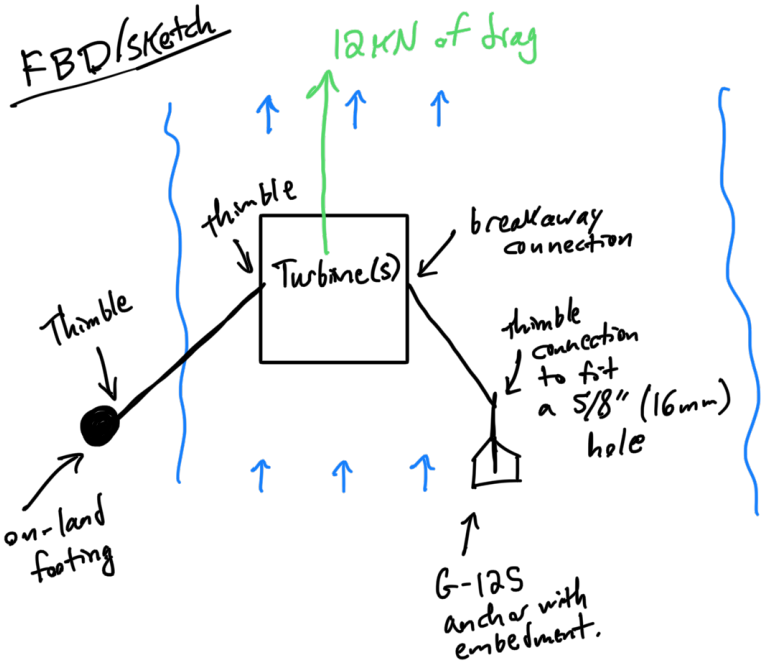


Development Length Parameters



Fortress Marine Anchor ⇒ Guardian Anchor G-125 model

FBD/Sketch



On land support can withstand 24 KN.

Anchor can also withstand 24 KN (6000 lbs ≈ 26.7 KN)

12 kN ≈ 2700 lb

even for worst-case scenario (soft mud), power exceeds drag by factor of 1.33

BOAT LENGTH	ft	12'-16'	17'-22'	23'-27'	28'-33'	34'-41'	42'-47'	48'-53'	54'-62	63'-72'
	m	4-5m	5-7m	7-8m	8-10m	10-12m	12-14m	14-16m	16-19m	19-22m
GUARDIAN MODEL		**G-5**	**G-7**	**G-11**	**G-16**	**G-23**	**G-37**	**G-55**	**G-85**	**G-125**
Weight	lb (kg)	2.5 (1.1)	2.9 (1.3)	5(2.26)	7 (3.2)	13 (5.9)	18 (8.2)	29 (13.1)	42 (19)	65 (29.3)
Replaces Steel Anchors	lb	4-6	6-9	10-13	14-18	19-28	33-50	50-65	70-90	100-170
	kg	2-3	3-4	5-6	6-8	9-13	15-23	23-29	32-41	45-77
HOLDING POWER										
Working Load	lb	350	575	750	1,075	1,625	2,500	3,500	4,625	6,000 ✓
	kg	159	261	340	488	737	1,134	1,588	2,098	2,722
Hard Sanding Holding	lb	1,050	1,725	2,250	3,225	4,875	7,500	10,500	13,875	18,000 ✓
	kg	476	782	1,021	1,463	2,211	3,402	4,763	6,294	8,165
Soft Mud Holding	lb	210	345	450	645	975	1,500	2,100	2,775	3,600 ✓
	kg	95	156	204	293	442	680	953	1,259	1,633

all exceed drag force of 12 kN.

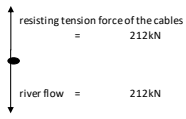
DIMENSIONS										
"A" Shank Length	in (mm)	19" (483)	22" (559)	25" (635)	29" (737)	33" (838)	38" (965)	43" (1.092)	48" (1,219)	53" (1,356)
"B" Fluke Length	in (mm)	11" (279)	13" (330)	15" (381)	17" (432)	19" (483)	22" (559)	25" (635)	28" (711)	31" (787)
"C" Stock Length	in (mm)	16" (406)	18" (457)	20" (508)	23" (584)	27" (686)	31" (787)	35" (889)	39" (991)	43" (1,092)
SUPPORT HARDWARE										
Proof Coil Chain	in (mm)	3/16" (5)	3/16" (5)	3/16" (5)	1/4" (6)	5/16" (8)	3/8" (9)	3/8" (9)	1/2" (13)	1/2" (13)
Nylon Rope **	in (mm)	3/8" (9)	3/8" (9)	3/8" (9)	3/8" (9)	1/2" (13)	5/8" (16)	3/4" (19)	7/8" (22)	1" (25)
Shackle Size	in (mm)	3/16" (5)	3/16" (5)	1/4" (6)	1/4" (6)	5/16" (8)	3/8" (10)	7/16" (12)	1/2" (12)	5/8" (16)

For all tech questions please email techsupport@fortressanchors.com and a Fortress Marine Anchors representative will respond in 24-48 hours.

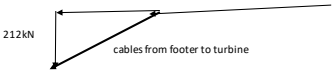
Thimble Jaw must be ≥ 5/8" (16mm)

FBD

In-River:
(from above)



Raised Footing:



angle:	cable strength:	
30 deg	424 kN	
45 deg	300 kN	(The force will decrease with an increase in angle)
60 deg	245 kN	

Cables

Ag = gross area

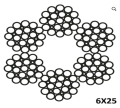
Ae = effective area = net area (An) times shear lag coeffecient (U)

Fy = tensile yield stress

Fu = tensile rupture stress

$$0.90F_yA_g \le 0.75F_uA_e$$

Max Industrias Black Cable - Fiber Core 6 x 25 Diameter = 22.23 mm = 7/8 in
(for In-River use)



Ag = 0.000285 m^2

An= gross area because all of the cable is under tension = 0.000285 m^2

U = 1 (according to AISC Table D3.1 Case 1)

Fy = 250 kN

Fu= 32115 kgf = 314,940 N = 314.94 kN

0.9FyAg= 225

0.75FuAe= 236.205

Ag = 0.000507 m^2

An= gross area because all of the cable is under tension = 0.000507 m^2

Max Industrias Black Cable - Fiber Core 6 x 25 Diameter = 25.40 mm = 1 in
(for footer to turbine use)

U = 1 (according to AISC Table D3.1 Case 1)

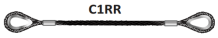
Fy = 300 kN

Fu= 41730 kgf = 409,232 N = 409.232 kN

0.9FyAg= 270

0.75FuAe= 306.924

Connections (thimble, ferrule and stop)





For in river use:
Thimble: 03-03-1 HD 1inch (25.4mm) diameter
10500kgf (individual) = 205kN (using both)



Ferrule and stops, no requirements other than fitting the diameter

For above ground footer use:
Thimble:
03-03-1.125-1.25 HD 1.25 inch (31.75mm) diameter
16000kgf (individual) = 313kN (using both)

For breakaway connection:
Thimble:
03-03-0.312 HD 5/16 inch (7.94mm) diameter
1000 kgf (individual) = 19 kN (using both)

Winch

Any winch with the ability to pull 3500lbs or 15kN

Endurance Marine Hand Winch With Auto Brake — 3500-Lb. Capacity, Model# RBW3500



Float Sizing for Unclipped cables

10m long. based on longest estimated cable.
25.4 mm diam
unit wt steel around $7850\ Kg/m^3$ (from Civil Sir. com)



$$V = \pi(0.0127)^2 10$$
$$V = 0.00506\ m^3$$

$$7850\ Kg/m^3 = \frac{W}{0.00506 m^3} \Rightarrow W = 39.8\ Kg$$
or 390 N
(basically 90 lbs)





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(1)

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Select Product:

Net Buoy, 18"D x 24" L, Rocket Red $69.99

$69.99

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Model # 4252664 | Mfg # 505718

Inflation Instructions

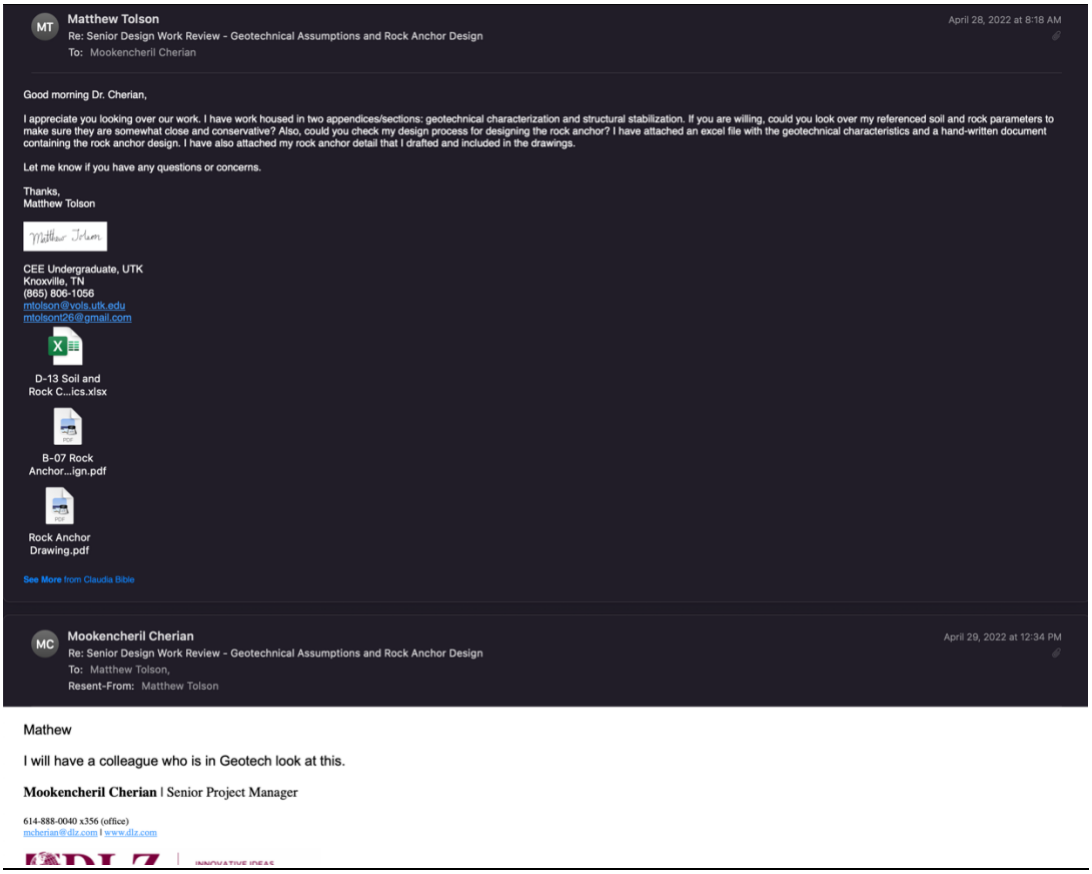
Model	4252631	4252649	4252664	4252672	4252680
Circumference	28"	38"	57"	66"	85"
Diameter x Height	9" x 12"	12" x 16"	18" x 24"	21" x 27"	27" x 33"
Saltwater Buoyancy	16lb.	38lb.	132lb.	200lb.	421lb.
Freshwater Buoyancy	15lb.	36lb.	128lb.	194lb.	408lb.
Rope Eye Diameter	1 1/16"	1 1/16"	1 1/2"	1 1/2"	1 1/2"

meets required cable weight capacity

fits cable diameter

Structural Mentor Feedback

I went through the process, but the feedback seemed that it would change the design too much given the time constraints. Therefore, the mentor comments were not addressed as they should be according to the rubric.



Matthew Tolson — April 28, 2022 at 8:18 AM
Re: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design
To: Mookencheril Cherian

Good morning Dr. Cherian,

I appreciate you looking over our work. I have work housed in two appendices/sections: geotechnical characterization and structural stabilization. If you are willing, could you look over my referenced soil and rock parameters to make sure they are somewhat close and conservative? Also, could you check my design process for designing the rock anchor? I have attached an excel file with the geotechnical characteristics and a hand-written document containing the rock anchor design. I have also attached my rock anchor detail that I drafted and included in the drawings.

Let me know if you have any questions or concerns.

Thanks,
Matthew Tolson

CEE Undergraduate, UTK
Knoxville, TN
(865) 806-1056
mtolson@vols.utk.edu
mtolson926@gmail.com

D-13 Soil and Rock C...ics.xlsx

B-07 Rock Anchor...ign.pdf

Rock Anchor Drawing.pdf

See More from Claudia Bible

Mookencheril Cherian — April 29, 2022 at 12:34 PM
Re: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design
To: Matthew Tolson,
Resent-From: Matthew Tolson

Mathew

I will have a colleague who is in Geotech look at this.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

MC **Mookencheril Cherian**
Fw: Senior Design Work Review – Geotechnical Assumptions and Rock Anchor Design
To: Tolson, Matthew Joseph,
Resent-From: Matthew Tolson

May 1, 2022 at 11:09 PM

Matthew

I had my colleague review your calculations. Attached are his comments.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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From: Eric Tse <etse@dlz.com>
Sent: Sunday, May 1, 2022 9:44 AM
To: Mookencheril Cherian <mcherian@dlz.com>
Subject: RE: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design

---

From: Mookencheril Cherian <mcherian@dlz.com>
Sent: Friday, April 29, 2022 12:35 PM
To: Eric Tse <etse@dlz.com>
Subject: Fw: Senior Design Work Review - Geotechnical Assumptions and Rock Anchor Design

Eric

Can you quickly look at this submittal by this student for the senior project? Thanks.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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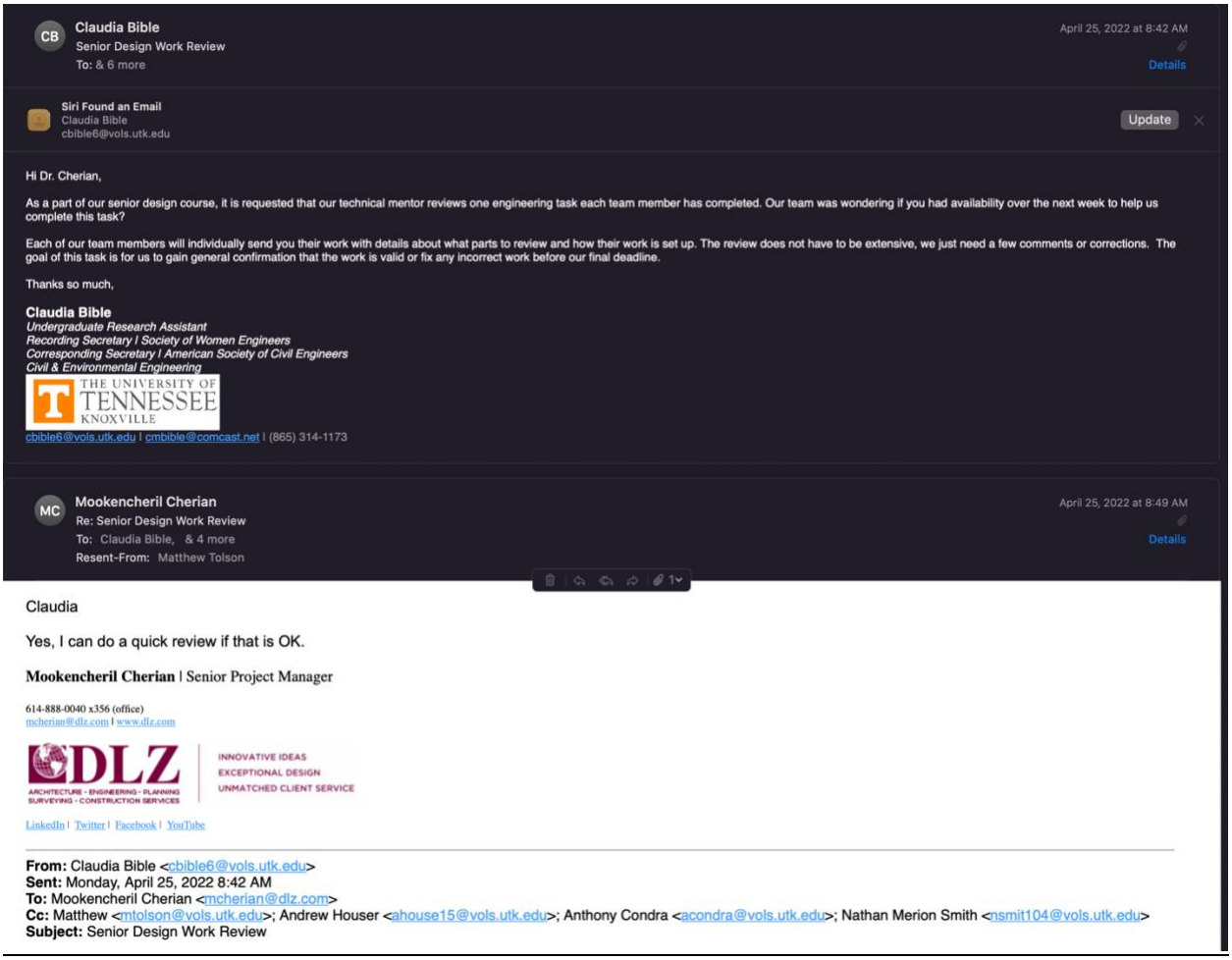

Claudia Bible
Senior Design Work Review
To: & 6 more

April 25, 2022 at 8:42 AM
Details

Siri Found an Email
Claudia Bible
cbible6@vols.utk.edu

Update

Hi Dr. Cherian,

As a part of our senior design course, it is requested that our technical mentor reviews one engineering task each team member has completed. Our team was wondering if you had availability over the next week to help us complete this task?

Each of our team members will individually send you their work with details about what parts to review and how their work is set up. The review does not have to be extensive, we just need a few comments or corrections. The goal of this task is for us to gain general confirmation that the work is valid or fix any incorrect work before our final deadline.

Thanks so much,

Claudia Bible
Undergraduate Research Assistant
Recording Secretary I Society of Women Engineers
Corresponding Secretary I American Society of Civil Engineers
Civil & Environmental Engineering
THE UNIVERSITY OF TENNESSEE KNOXVILLE
cbible6@vols.utk.edu I cmbible@comcast.net I (865) 314-1173

Mookencheril Cherian
Re: Senior Design Work Review
To: Claudia Bible, & 4 more
Resent-From: Matthew Tolson

April 25, 2022 at 8:49 AM
Details

Claudia

Yes, I can do a quick review if that is OK.

Mookencheril Cherian | Senior Project Manager

614-888-0040 x356 (office)
mcherian@dlz.com | www.dlz.com

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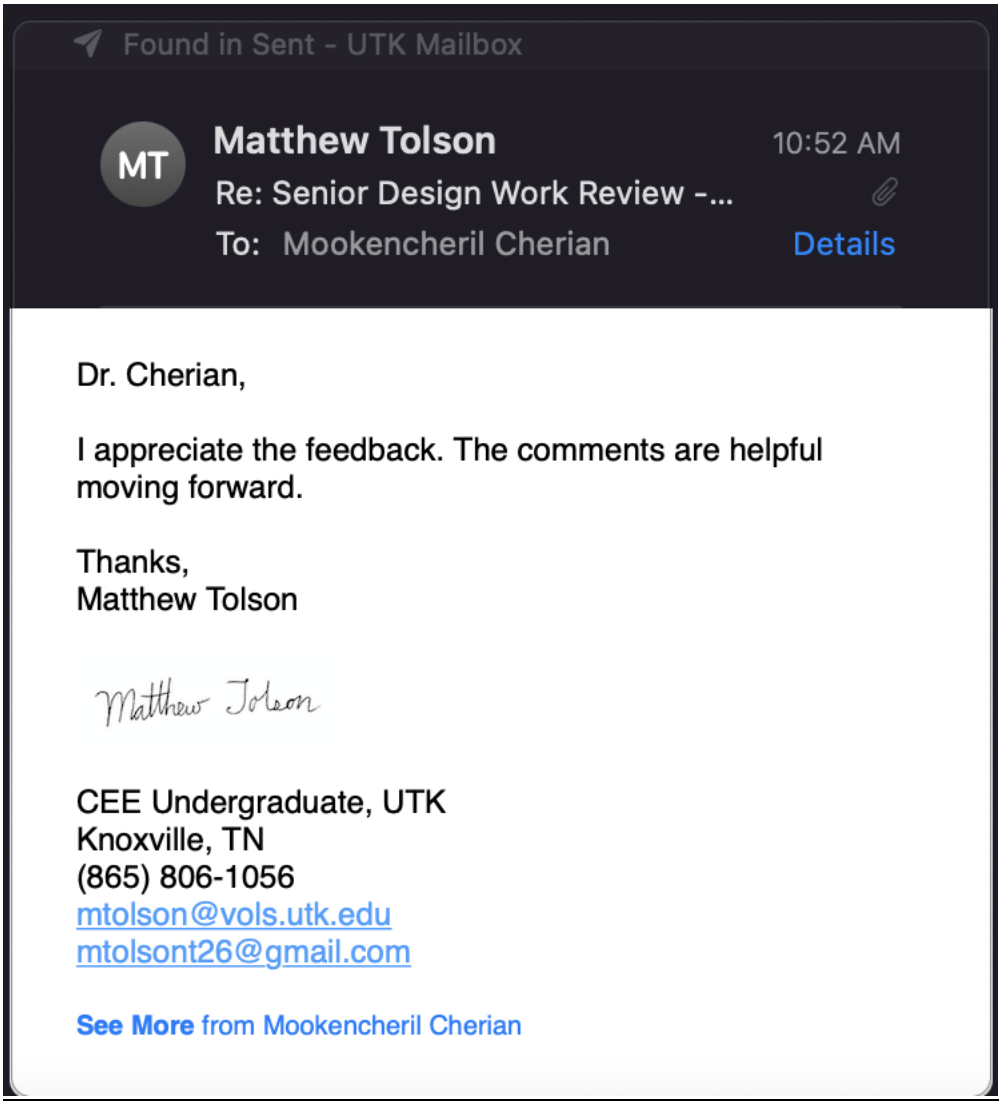
From: Claudia Bible <cbible6@vols.utk.edu>
Sent: Monday, April 25, 2022 8:42 AM
To: Mookencheril Cherian <mcherian@dlz.com>
Cc: Matthew <mtolson@vols.utk.edu>; Andrew Houser <ahouse15@vols.utk.edu>; Anthony Condra <acondra@vols.utk.edu>; Nathan Merion Smith <nsmit104@vols.utk.edu>
Subject: Senior Design Work Review


Found in Sent - UTK Mailbox
MT
Matthew Tolson
10:52 AM
Re: Senior Design Work Review -...
To: Mookencheril Cherian
Details
Dr. Cherian,
I appreciate the feedback. The comments are helpful moving forward.
Thanks,
Matthew Tolson
Matthew Tolson
CEE Undergraduate, UTK
Knoxville, TN
(865) 806-1056
mtolson@vols.utk.edu
mtolsont26@gmail.com
See More from Mookencheril Cherian

Rock Anchor Design Sheet - Matthew Tolson

too low for "vertical" bearing capacity forshale/weak sandstone

Is this velocity? What is it for?

Grout $f'_c = 14 \times 10^6$ Pa

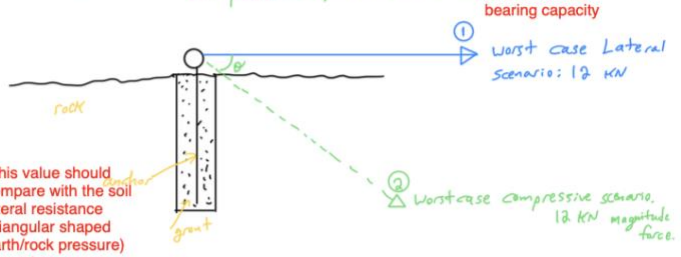
Rock Bearing Capacity $= 1.5625 \times 10^6$ Pa (3.90625×10^5 Pa allowable, SF=4)

Safety Factors
1.5 SF applied to velocity
4.0 SF applied to rock strength

What is the lateral resistance/capacity of rock?

② Worst possible compressive scenario: 12 kN

too high, consider 2 to 3 for vertical bearing capacity



This value should compare with the soil lateral resistance (triangular shaped earth/rock pressure) along the depth/length of the anchor, not vertical bearing capacity of rock

① Assume bore-hole walls are rectangular.



Area $= 0.762\ m \times 0.15\ m = 0.1143\ m^2$

$P = F/A = \frac{12\ KN}{0.1143\ m^2} = 104{,}987\ Pa$ ✓

This value should compare with the soil lateral resistance (triangular shaped earth/rock pressure) along the depth/length of the anchor, not vertical bearing capacity of rock

② Assume bore-hole walls are rectangular.



Area $= 0.762\ m \times 0.15$

$P = F/A = \frac{12\ KN \cos(\theta)}{0.1143\ m^2}$ $\theta = 35°$ Pa ✓

0.017674?



Area $= \frac{\pi (0.15\ m)^2}{4} = 0.17671\ m^2$ $\theta = 35°$

$P = F/A = \frac{12\ KN \sin(\theta)}{0.17671\ m^2} = 38{,}950\ Pa$ ✓

Summary of Design

- Anchor Ultimate Strength must be greater than 24 KN (Force w/ SF=2)
- Minimum Bore-hole diameter = 0.15 m
- Minimum Anchor Length = 0.762 m
- Grout must be mixed according to ASTM C476
- For expanding anchors with expanded rod diameters < 0.15 m, expanding must occur post grout pouring and curing to ensure anchors generate proper embedment into surrounding grout.
- Range of acceptable cable angles = 0° – 35° from horizontal.

Lateral or vertical? Vertical bearing capacity does not control, soil lateral resistance does, not certain the rock capacity you have is vertical or lateral resistance

Grout Design

- Follow ASTM C476
- coarse grout (on-site material)
- f'_c = 2000 psi at 28 days (14 MPa)
- slump: 8-11 in (follow ASTM C143)
- Mix: 1 part cement, 2.25-3 parts fine aggregate, 1-2 parts coarse aggregate.

Too short, consider ground disturbance at the surface, ignore certain depth/length of the embedment for lateral resistance

TABLE 1
Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock	0.70	35
Dressed hard rock on dressed soft rock	0.65	33
Dressed hard rock on dressed hard rock	0.55	29
Masonry on wood (cross grain)	0.50	26
Steel on steel at sheet pile interlocks	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300

Rebar Diameter (mm)	19.05
Bond Strength (MPa)	9.2
Rebar Embedment Length (mm)	50
FS	2

Pu (N)	27529.78
Pn (N)	13000
FS Pn	26000

Block Self Weight	Total Drag Force
13,000 N	6,000 N

Imperial Bar Size	"Soft" Metric Size	Weight per unit length (lb/ft)	Mass per unit length (kg/m)	Nominal Diameter (in)	Nominal Diameter (mm)	Nominal Area(in^2)	Nominal Area (mm^2)
#3	#10	0.376	0.561	0.375	9.525	0.11	71
#4	#13	0.668	0.996	0.500	12.7	0.2	129
#5	#16	1.043	1.556	0.625	15.875	0.31	200
#6	#19	1.502	2.24	0.750	19.05	0.44	284
#7	#22	2.044	3.049	0.875	22.225	0.6	387
#8	#25	2.67	3.982	1.000	25.4	0.79	509
#9	#29	3.4	5.071	1.128	28.65	1	645
#10	#32	4.303	6.418	1.27	32.26	1.27	819
#11	#36	5.313	7.924	1.41	35.81	1.56	1006
#14	#43	7.65	11.41	1.693	43	2.25	1452
#18	#57	13.6	20.284	2.257	57.33	4	2581

$$\tau = \frac{P}{\pi \, d_b \, l_b} \tag{1}$$

"Where" P = load (N), l_b = embedment length (mm), and d_b = diameter of the rebar (mm)

Rebar Diameter (mm)	25.4
Bond Strength (MPa)	9.2
Rebar Embedment Length (mm)	100
FS	2

Pu	73412.74
Pn (N)	24500
FS Pn	49000

Block Self Weight	Total Drag Force
24,500N	12,000N

Imperial Bar Size	"Soft" Metric Size	Weight per unit length (lb/ft)	Mass per unit length (kg/m)	Nominal Diameter (in)	Nominal Diameter (mm)	Nominal Area(in^2)	Nominal Area (mm^2)
#3	#10	0.376	0.561	0.375	9.525	0.11	71
#4	#13	0.668	0.996	0.500	12.7	0.2	129
#5	#16	1.043	1.556	0.625	15.875	0.31	200
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#11	#36	5.313	7.924	1.41	35.81	1.56	1006
#14	#43	7.65	11.41	1.693	43	2.25	1452
#18	#57	13.6	20.284	2.257	57.33	4	2581

$$\tau = \frac{P}{\pi\, d_b\, l_b} \tag{1}$$

"Where" P = load (N), l_b = embedment length (mm), and d_b = diameter of the rebar (mm)

Note: Windloading on the turbine and drag on the self wieght anchors were determined to be negligible

Drag Force (N)	6,000
Cable 1 Horizontal Angle	-20
Cable 2 Horizontal Angle	0
Cable 3 Horizontal Angle	20
Cable 1 Angle Below Water	30
Cable 2 Angle Below Water	30
Cable 3 Angle Below Water	30

	Force on Footings		
	x	y	z
F1 (N)	-1593.51	579.9888	979.0555
F2 (N)	-1804.6	0	1041.889
F3 (N)	-1593.51	-579.989	979.0555

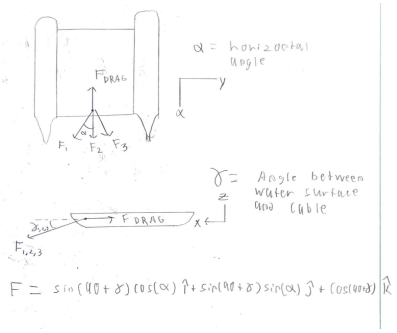
FS	1.5	
Conc. Density kg/m3	2400	
Water Density kg/m3	1000	
Coeff. Static Friction	0.45	
Friction Required (N)	1804.605	
Concrete Required (m^3)	0.551783	
Concrete Required (kg)	1324.278	2913.412

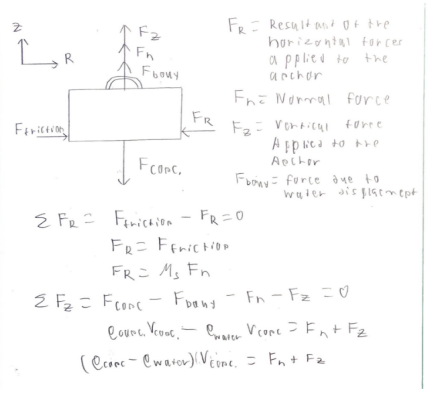
	Cable Unit Vectors		
	F1	F2	F3
x	0.813798	0.866025	0.813798
y	-0.2962	0	0.296198
z	-0.5	-0.5	-0.5

Drag Vector
-6,000
0
0

H (m)	0.5
W (m)	0.5
L Design (m)	2.3

Total Force in Cable 1 (N)	1958.111
Total Force in Cable 2 (N)	2083.778
Total Force in Cable 3 (N)	1958.111





Note: Windloading on the turbine and drag on the self wieght anchors were determined to be negligible

Drag Force (N)	11,300
Cable 1 Horizontal Angle	-20
Cable 2 Horizontal Angle	0
Cable 3 Horizontal Angle	20
Cable 1 Angle Below Water	30
Cable 2 Angle Below Water	30
Cable 3 Angle Below Water	30

	Force on Anchors		
	x	y	z
F1 (N)	-3001.1	1092.312	1843.888
F2 (N)	-3398.67	0	1962.224
F3 (N)	-3001.1	-1092.31	1843.888

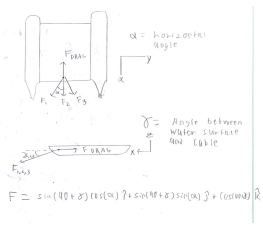
FS	1.5
Conc. Density kg/m3	2400
Water Density kg/m3	1000
Coeff. Static Friction	0.45
Friction Required (N)	3398.672
Concrete Required (m^3)	1.039191
Concrete Required (kg)	2494.058 5486.927

	Cable Unit Vectors		
	F1	F2	F3
x	0.813798	0.866025	0.813798
y	-0.2962	0	0.296198
z	-0.5	-0.5	-0.5

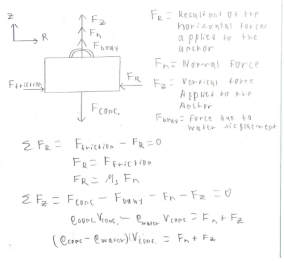
Drag Vector	
	-11,300
	0
	0

H (m)	0.7
W (m)	0.7
L Design (m)	2.2

Total Force in Cable 1 (N)	3687.776
Total Force in Cable 2 (N)	3924.449
Total Force in Cable 3 (N)	3687.776



$$\vec{F} = \sin(180+\beta)\cos(\alpha)\,\hat{i} + \sin(180+\beta)\sin(\alpha)\,\hat{j} + \cos(\beta)\,\hat{k}$$



$$\Sigma F_R = F_{friction} - F_R = 0$$

$$F_R = F_{friction}$$

$$F_R = A_s F_n$$

$$\Sigma F_z = F_{conc} - F_{buoy} - F_n - F_2 = 0$$

$$\rho_{conc} V_{conc} - \rho_{water} V_{conc} = F_n + F_2$$

$$(\rho_{conc} - \rho_{water}) V_{conc} = F_n + F_2$$

ACI 318 for rebar

TABLE 1
Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan (delta)	Friction angle (delta), degrees
Mass concrete on the following foundation materials:		
Clean sound rock	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay (Masonry on foundation materials has same friction factors.)	0.30 to 0.35	17 to 19
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	0.40	22
Clean sandy, silty sand-gravel mixture, single size hard rock fill	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock	0.70	35
Dressed soft rock on dressed hard rock	0.65	33
Dressed hard rock on dressed hard rock	0.55	29
Masonry on wood (cross grain)	0.50	26
Steel on steel at sheet pile interlocks	0.30	17

Interface Materials (Cohesion)	Adhesion c=a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300

Appendix D: Construction Management

Reflection on Contributions

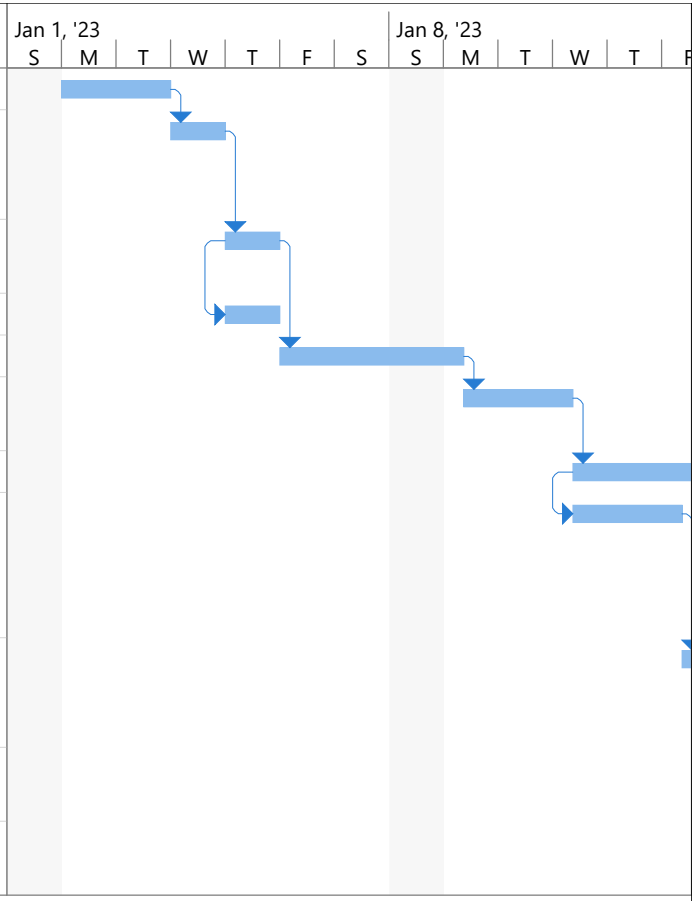
Claudia Bible, Chancellor's Honors Capstone Project

My primary role on my senior design team was to select the proper turbine(s) for the project, analyze the power output of the system, evaluate the system's storage capabilities, and project any system upgrades needed over the next 20 years. Outside of the technical tasks I performed for the project, I also regularly coordinated and attended meetings with our client and mentors, contributed to the team's set of construction drawings, and wrote multiple portions of the project report.

To properly select a turbine and confirm its ability to meet the project needs, I researched options for commercially available hydrokinetic turbines, create river velocity requirement curves for a typical 24-hours and a 20-year period, and create power storage curves for a typical 24-hours and a 20-year period. To select potential turbines for the project, I evaluated the feasibility of commercially available turbines. The client requested that the turbine system be in the river, which requires a hydrokinetic turbine. This type of turbine is a relatively new technology, so a number of options were eliminated from further evaluation due to factors such as expected high intercontinental shipping costs and excessive size or output for the project needs.

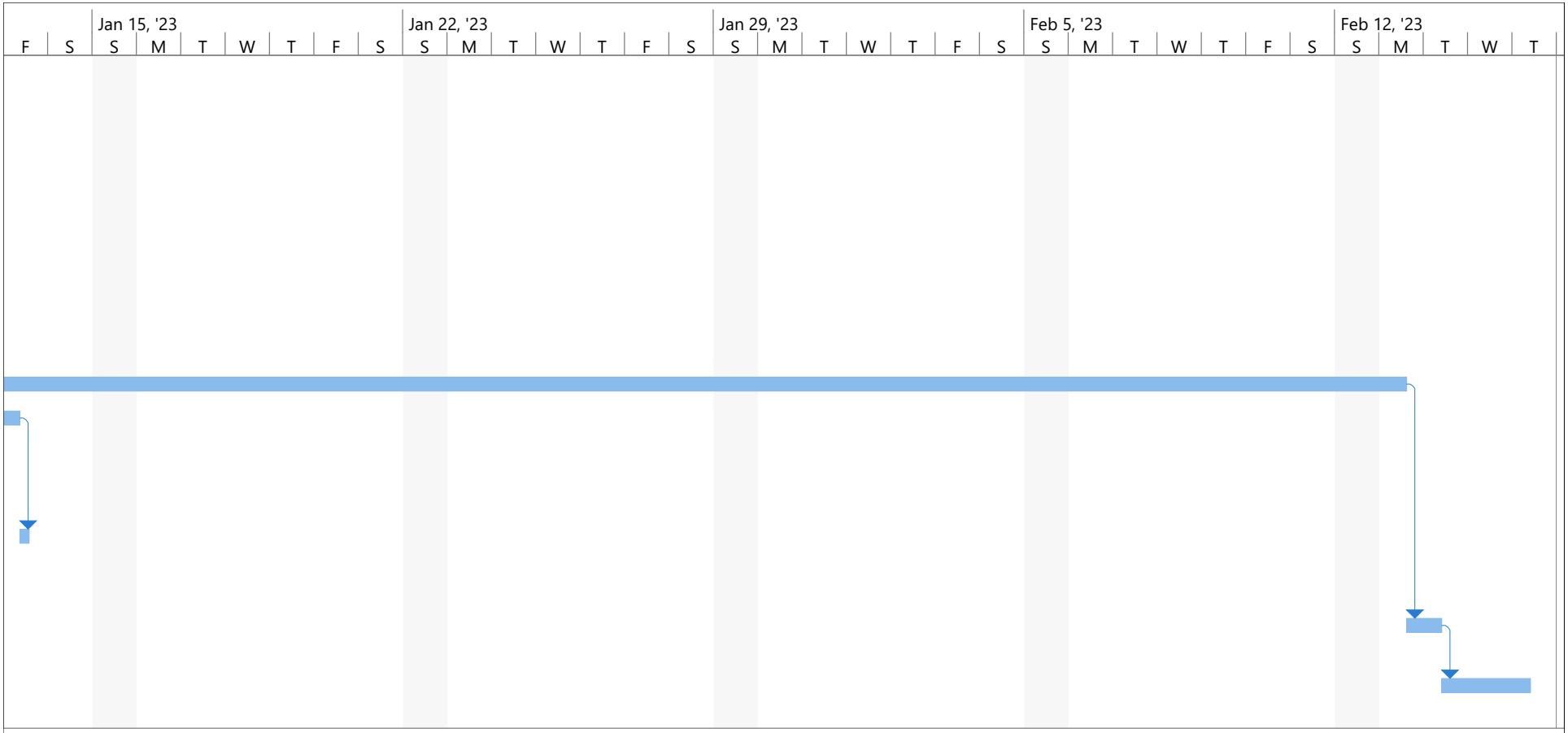
Velocity-power curves were obtained from the selected company and used to create river velocity requirement curves for projected demands in a 24-hour and 20-year period. Additionally, power storage curves were created by integrating portions of the river velocity requirement curves. The power storage curves show the cumulative power stored by the turbine in a 24-hour and 20-year period. The power storage and river velocity requirement curves confirmed that the selected turbines have the capacity to supply Nazarét with the requested amount of power in a typical day. The curves also indicated that an additional turbine unit would be required between the years of 2036-2038 to accommodate an increase in demand that exceeds the system's power storage capabilities.

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation for footings	1 day	Thu 1/5/23	Thu 1/5/23	2
4		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	3SS
5		Rebar placement	2 days	Fri 1/6/23	Mon 1/9/23	3
6		Concrete forms pouring of concrete	2 days	Mon 1/9/23	Wed 1/11/23	5
7		Concrete Curing	28 days	Wed 1/11/23	Mon 2/13/23	6
8		Construction of turbines by manufactures directions	2 days	Wed 1/11/23	Fri 1/13/23	7SS
9		Installation of cable connection to concrete footing	0.5 days	Fri 1/13/23	Fri 1/13/23	8
10		Turbine connection and placement	0.5 days	Mon 2/13/23	Tue 2/14/23	7
11		System inspection and cleanup	2 days	Tue 2/14/23	Thu 2/16/23	10



Project: Project1
Date: Sun 5/1/22

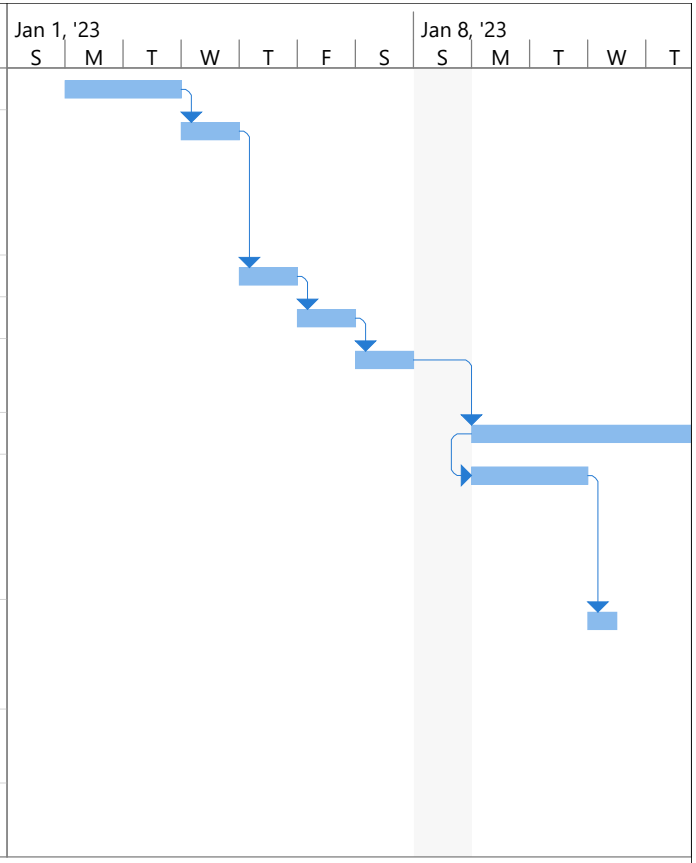
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			



Project: Project1
Date: Sun 5/1/22

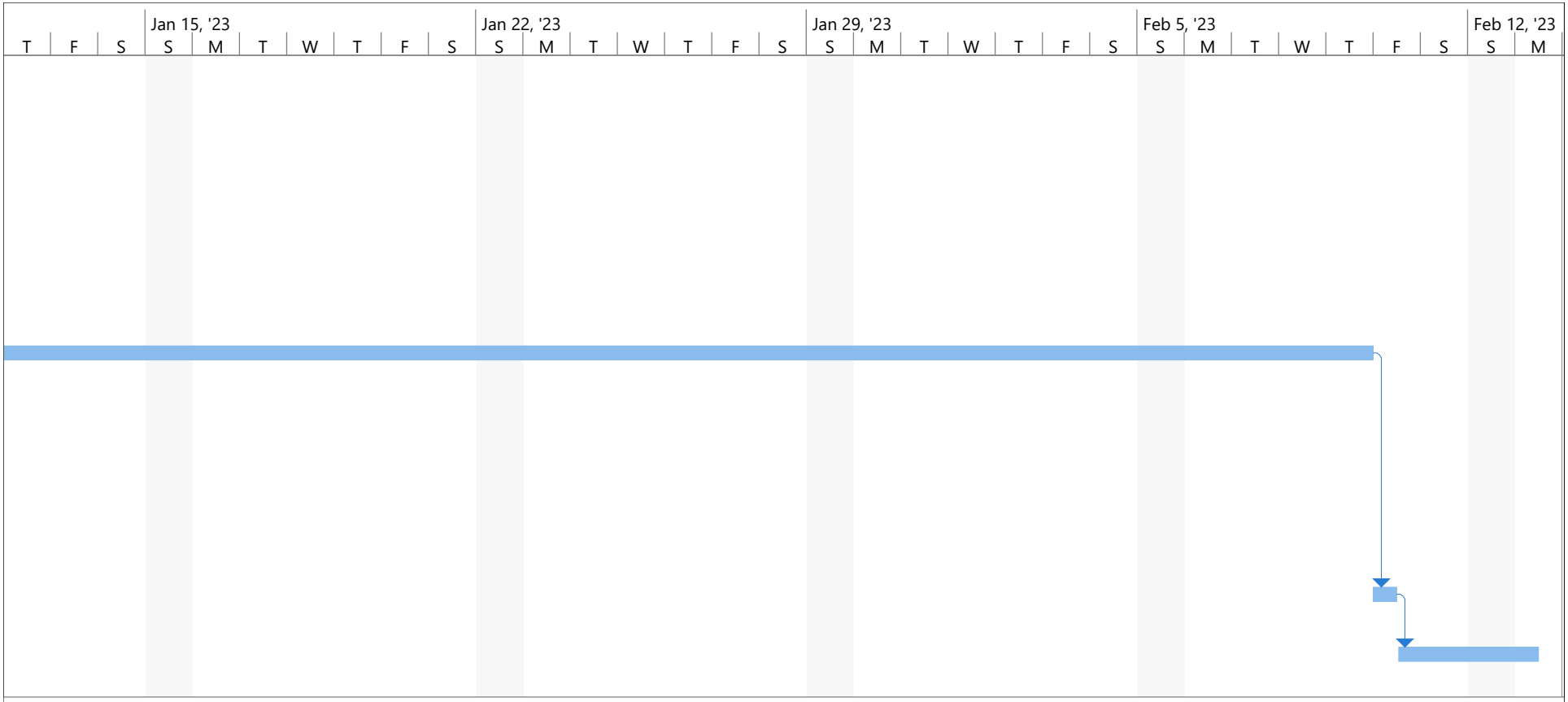
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation of rock	1 day	Thu 1/5/23	Thu 1/5/23	2
4		Placement of anchor	1 day	Fri 1/6/23	Fri 1/6/23	3
5		Pouring of structural grout	1 day	Sat 1/7/23	Sat 1/7/23	4
6		Grout Curing	28 days	Mon 1/9/23	Thu 2/9/23	5
7		Construction of turbines by manufactures directions	2 days	Mon 1/9/23	Tue 1/10/23	6SS
8		Installation of cable connection to rock anchor	0.5 days	Wed 1/11/23	Wed 1/11/23	7
9		Turbine connection and placement	0.5 days	Fri 2/10/23	Fri 2/10/23	6
10		System inspection and cleanup	2 days	Fri 2/10/23	Mon 2/13/23	9



Project: In Rock Anchor
Date: Sun 5/1/22

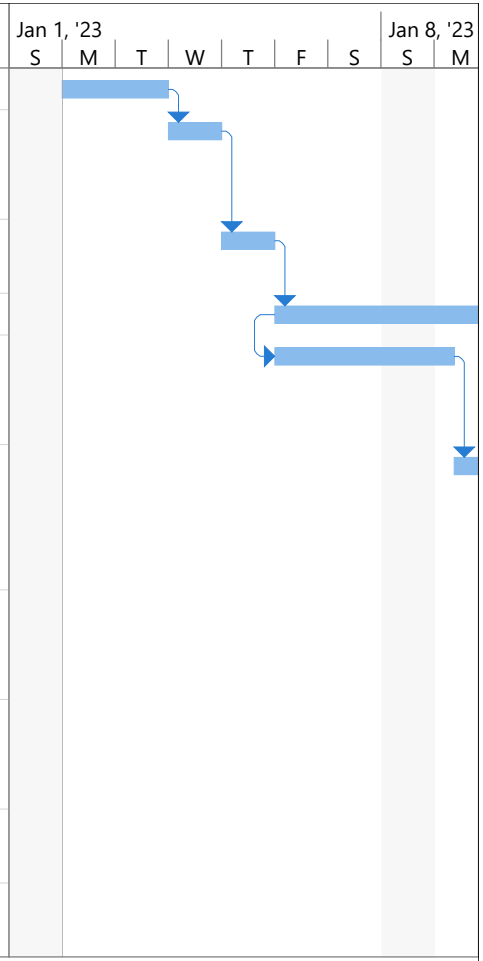
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			



Project: In Rock Anchor
Date: Sun 5/1/22

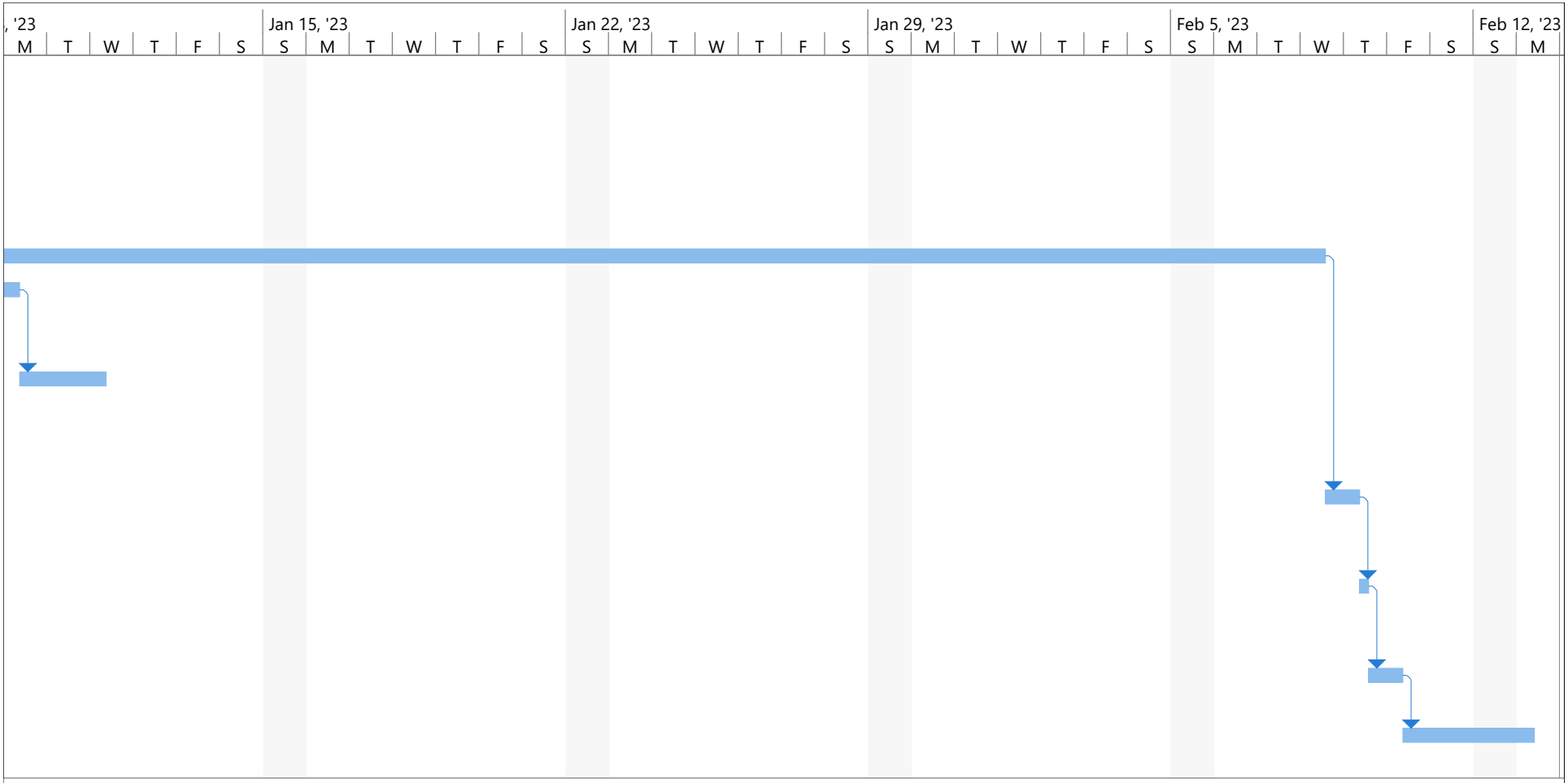
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		Mobilitzation	2 days	Mon 1/2/23	Tue 1/3/23		
2		Determine placement based on parameters	1 day	Wed 1/4/23	Wed 1/4/23	1	
3		Forming and pouring of concrete anchors	1 day	Thu 1/5/23	Thu 1/5/23	2	
4		Concrete Curing	28 days	Fri 1/6/23	Wed 2/8/23	3	
5		Placement of whinching system on bank	2 days	Fri 1/6/23	Mon 1/9/23	4SS	
6		Construction of Turbine by manufactures directions	2 days	Mon 1/9/23	Wed 1/11/23	5	
7		Installation of cable connections to anchor blocks	0.5 days	Wed 2/8/23	Thu 2/9/23	4	
8		Placement of concrete anchors into Rio Chico	0.5 days	Thu 2/9/23	Thu 2/9/23	7	
9		Turbine connection and placement	0.5 days	Thu 2/9/23	Fri 2/10/23	8	
10		System inspection and cleanup	2 days	Fri 2/10/23	Mon 2/13/23	9	



Project: Project1
Date: Sun 5/1/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Sun 5/1/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Priving for New Energy Corporation, Turbine ENV-005

Turbine	Unit	Cost per unit (U.S. Dollar)	Number of units	Material Cost	Shipping cost	Total Cost
New Energy ENV-005	Per Turbine	$ 20,000.00	2	$ 40,000.00	$ 2,000.00	$ 42,000.00
First Year Maintenance Check from New Energy Corporation	Per Technician	$ 1,200.00	2	$ 2,400.00		$ 2,400.00

Soil Anchor	Unit	Cost per unit (U.S. Dollar)	Number of units	Material Cost		Total Cost
22.23 mm diameter cable	per meter	$ 7.07	10	$ 70.70		$ 70.70
Stopper	per stopper	$ 63.15	1	$ 63.15		$ 63.15
Aluminum Ferrule	per ferule	$ 22.80	1	$ 22.80		$ 22.80
Galvanized Thimble	per thimble	$ 5.62	1	$ 5.62		$ 5.62
Crosby Swivel hook (non-breakaway)	per hook	$ 541.00	1	$ 541.00		$ 541.00
Crosby Swivel hook (breakaway)	per hook	$ 75.39	1	$ 75.39		$ 75.39
No. 5 Rebar	per 30ft bar	$ 20.31	6	$ 121.86		$ 121.86
No. 7 Rebar	per 30ft bar	$ 37.88	1	$ 37.88		$ 37.88
Tie Wire	per role	$ 1.26	2	$ 2.52		$ 2.52
Plywood (forms)	per sheet	$ 46.99	3	$ 140.97		$ 140.97
Concrete (Bags)	per bag	$ 8.99	163	$ 1,465.37		$ 1,465.37
Nails	per box	$ 1.09	1	$ 1.09		$ 1.09
Epoxy Coating	per can	$ 4.99	1	$ 4.99		$ 4.99
Buoy Floats for Cables	par float	$ 69.99	1	$ 69.99		$ 69.99

Rock Anchor	Unit	Cost per unit (U.S. Dollar	Number of units	Material Cost		Total Cost
22.23 mm diameter cable	per meter	$ 7.07	10	$ 70.70		$ 70.70
Stopper	per stopper	$ 63.15	1	$ 63.15		$ 63.15
Aluminum Ferrule	per ferule	$ 22.80	1	$ 22.80		$ 22.80
Galvanized Thimble	per thimble	$ 5.62	1	$ 5.62		$ 5.62
Crosby Swivel hook (non-breakaway)	per hook	$ 541.00	1	$ 541.00		$ 541.00
Crosby Swivel hook (breakaway)	per hook	$ 75.39	1	$ 75.39		$ 75.39
Rock Anchor	per anchor	$ 98.04	1	$ 98.04		$ 98.04
Concrete (Bags)	per bag	$ 8.99	3	$ 26.97		$ 26.97
Buoy Floats for Cables	par float	$ 69.99	1	$ 69.99		$ 69.99

River Anchor	Unit	Cost per unit (U.S. Dollar	Number of units	Material Cost		Total Cost
22.23 mm diameter cable	Per meter	$ 7.07	40	$ 282.80		$ 282.80
Stopper	per stopper	$ 63.15	1	$ 63.15		$ 63.15
Aluminum Ferrule	per ferule	$ 22.80	1	$ 22.80		$ 22.80
Galvanized Thimble	per thimble	$ 5.62	1	$ 5.62		$ 5.62
Crosby Swivel hook (breakaway)	per hook	$ 75.39	1	$ 75.39		$ 75.39
River Anchor	per anchor	$ 1,610.85	1	$ 1,610.85		$ 1,610.85
Buoy Floats for Cables	par float	$ 69.99	1	$ 69.99		$ 69.99

Pricing for New Energy Corportation, Turbine ENV-010

Turbine	Unit	Cost per unit (U.S. Dollar)	Number of units	Material Cost	Shipping cost	Total Cost
New Energy ENV-010	Per Turbine	$ 40,000.00	1	$ 40,000.00	$ 2,000.00	$ 42,000.00
First Year Maintenance Check from New Energy Corporation	Per Technician	$ 1,200.00	2	$ 2,400.00		$ 2,400.00

Soil Anchor	Unit	Cost per unit (U.S. Dollar)	Number of units	Material Cost		Total Cost
22.23 mm diameter cable	per meter	$ 7.07	10	$ 70.70		$ 70.70
Stopper	per stopper	$ 63.15	1	$ 63.15		$ 63.15
Aluminum Ferrule	per ferule	$ 22.80	1	$ 22.80		$ 22.80
Galvanized Thimble	per thimble	$ 5.62	1	$ 5.62		$ 5.62
Crosby Swivel hook (non-breakaway)	per hook	$ 541.00	1	$ 541.00		$ 541.00
Crosby Swivel hook (breakaway)	per hook	$ 75.39	1	$ 75.39		$ 75.39
No. 5 Rebar	per 30 ft bar	$ 20.31	6	$ 121.86		$ 121.86
No. 7 Rebar	per 30ft bar	$ 37.88	1	$ 37.88		$ 37.88
Tie Wire	per role	$ 1.26	2	$ 2.52		$ 2.52
Plywood (forms)	per sheet	$ 46.99	3	$ 140.97		$ 140.97
Concrete (Bags)	per bag	$ 8.99	163	$ 1,465.37		$ 1,465.37
Nails	per box	$ 1.09	1	$ 1.09		$ 1.09
Epoxy Coating	per can	$ 4.99	1	$ 4.99		$ 4.99
Buoy Floats for Cables	par float	$ 69.99	1	$ 69.99		$ 69.99

Rock Anchor	Unit	Cost per unit (U.S. Dollar	Number of units	Material Cost		Total Cost
22.23 mm diameter cable	Per meter	$ 7.07	10	$ 70.70		$ 70.70
Stopper	per stopper	$ 63.15	1	$ 63.15		$ 63.15
Aluminum Ferrule	per ferule	$ 22.80	1	$ 22.80		$ 22.80
Galvanized Thimble	per thimble	$ 5.62	1	$ 5.62		$ 5.62
Crosby Swivel hook (non-breakaway)	per hook	$ 541.00	1	$ 541.00		$ 541.00
Crosby Swivel hook (breakaway)	per hook	$ 75.39	1	$ 75.39		$ 75.39
Rock Anchor	per anchor	$ 98.04	1	$ 98.04		$ 98.04
Concrete (Bags)	per bag	$ 8.99	3	$ 26.97		$ 26.97
Buoy Floats for Cables	par float	$ 69.99	1	$ 69.99		$ 69.99

River Anchor	Unit	Cost per unit (U.S. Dollar	Number of units	Material Cost		Total Cost
22.23 mm diameter cable	per meter	$ 7.07	40	$ 282.80		$ 282.80
Stopper	per stopper	$ 63.15	1	$ 63.15		$ 63.15
Aluminum Ferrule	per ferule	$ 22.80	1	$ 22.80		$ 22.80
Galvanized Thimble	per thimble	$ 5.62	1	$ 5.62		$ 5.62
Crosby Swivel hook (breakaway)	per hook	$ 75.39	1	$ 75.39		$ 75.39
River Anchor	per anchor	$ 1,610.85	1	$ 1,610.85		$ 1,610.85
Buoy Floats for Cables	par float	$ 69.99	1	$ 69.99		$ 69.99

Extra Connection parts for replacement added to breakaway costs.

Part	Unit	Cost per unit (U.S. Dollar	Number of units	Material Cost
Stopper	per stopper	$ 63.15	2	$ 126.30
Aluminum Ferrule	per ferule	$ 22.80	2	$ 45.60
Galvanized Thimble	per thimble	$ 5.62	2	$ 11.24
Crosby Swivel hook (breakaway)	per hook	$ 75.39	2	$ 150.78
			Total	$ 333.92

Total for anchoring options	
Total Soil Anchor (Breakaway)	$ 2,416.25
Total Soil Anchor (Non-Breakaway)	$ 2,547.94
Total Rock Anchor (Breakaway)	$ 766.58
Total Rock Anchor (Non-Breakaway)	$ 898.27
Total River Anchor	$ 2,464.52

Final Pricing for Anchoring Options and Turbines	
Soil (B) & Soil (NB)	$ 49,364.19
Soil (B) & Rock (NB)	$ 47,714.52
Rock (B) & Soil (NB)	$ 47,714.52
Rock (B) & Rock (NB)	$ 46,064.85
Rock (NB) & River (B)	$ 47,762.79
Soil (NB) & River (B)	$ 49,412.46

Total for anchoring options	
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Rock (NB) & River (B)	$ 47,762.79
Soil (NB) & River (B)	$ 49,412.46

Operations and Maintenance Manual

Introduction

An operations and maintenance manual has been created to display the turbine(s) selection, extra parts ordered for replacement, a preventative maintenance plan, turbine removal procedure, and safety concerns regarding the turbine. Two turbine options were determined to be the best fit for the village of Nazarét. A list of extra items ordered that may need to be replaced was determined from engineering drawings. A preventative maintenance plan was also created from the manufacturer's recommendations. A first-year maintenance check from a New Energy Corporation technician is recommended for longevity of the turbine(s). Best safety practices for the handling the turbine(s) was determined and safety recommendations were derived . This booklet is to be used as a guide by the village of Nazarét to maximize sustainability of the hydroelectric turbine and for determining the placement of the hydroelectric turbine.

Turbines

Turbine option 1

EVG-005

- 5 kW max power output
- Boat width – 3 m
- Rotor width – 1.5 m
- Rotor height – 0.75 m
- Requires 2 turbine systems to meet power needs
- Can connect 2 boats side by side based on manufacture specs, or place at different areas of the river.
- Minimum river depth – 1.40 m

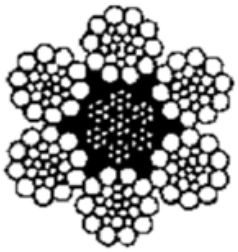
Turbine option 2

ENG-010

- 10 kW max power output
- Boat width – 3 m
- Rotor width – 1.5 m
- Rotor height – 1.5 m
- Requires 1 turbine system to meet power needs
- Minimum river depth – 2.15 m

Extra Connection Parts for Replacement

The following table displays a list of parts that may need to be replaced during normal use of the structural systems.

Part	Description	Image	Specifications
Thimble	Connection piece. Metal loop allowing for cable to be tied around structural connection points.		Provider: Max Industrias 03-03-0.875 HD (for 22.23 mm cable)
Ferrules	Connection piece. Aluminum tie-in that the cable is guided in one way, then cables are put around the thimble and structural connection, and then guided through the ferrule again in the opposite direction. This is then crimped to secure the cable.		Provider: Max Industrias 03-06-0.875 ALU (for 22.23 mm diameter cable)
Stop	Connection piece. Placed at the open end of the cable to stop the ferrule if a slip occurs		Provider: Max Industrias 03-06-TOPE 0.875 (for 22.23 mm diameter cable)
Cables (Soil and Rock Anchor)	Structural steel core cable (25.40 mm diameter)		Provider: Max Industrias Part Number: 01-1 A 6X25DNNDSR
Connections	Connection piece. Allows the ability to disconnect the cable from the pontoon. Two sizes, breakaway and non-breakaway connections.		Provider: Max Industrias Part Number (Non-breakaway): 03-07-322 2-Y Part Number (Breakaway): 03-07-322 A 11-Y

Preventative Maintenance Plan

The following preventative maintenance plan should be used as a guide to schedule regular checks on the turbine system. These regular maintenance checks are taken from New Energy Corporation's recommendations with additional input specifically for the village of Nazarét. It is recommended that two villagers of Nazarét are trained to perform these checks.

Preventative Maintenance and Timelines	Explanation
General Inspection of turbine: Once a week for the first 30 days	- Check for any debris within the impellors. The impellor does not have to be taken out of the water. - Check for any differing noises or vibrations.
General inspection of turbine: Once every 30 days	- Check for any debris within the impellors. The impellor does not have to be taken out of the water. - Check for any differing noises or vibrations.
Visual inspection of structural system: Once every 30 days	- Visual inspection of structural cables and connections for any fraying or tearing - Visual inspection of on land structural footing if applicable.
In-depth turbine inspection: Once every 6 months	- Impellors should be taken out of the water and checked for any bent impellors and loose or turned bolts. - Check torque of bolts compared with manufactures specifications. - Check for any corrosion.

Before any inspection occurs where the impeller needs to be taken out of the water, place the turbine in the off position before the inspection process begins. Each turbine will have a switch to stop the impellers and a switch to raise the impellers out of the water and into the maintenance position.

Further Maintenance

New Energy Corporation recommends that a trained turbine technician comes to the site after the first year of installation to check the power components of the selected turbine(s). After this a scheduled check by a trained technician should occur every other year.

Removal of Turbine

Turbines can be left in the water or taken out of the water during high flood scenarios. If the turbine is left in the water during high floods the following steps should be taken to raise the impellers out of the water. The impellers should also be taken out of the water if there is a drought situation, and the water level may reach the minimum water level

for the selected turbine. Another option is to take the turbine fully out of the water during high flood scenarios.

Raising of Turbine Impellors

1. Approach the turbine pontoon from down river
2. Turn off the turbine based on New Energy Corportation's specifications
3. Raise the turbine into the maintenance position. This raises and holds the impeller perpendicular to the pontoon deck
4. The impellers should stay out of the water until flooding subsides or until water rises back to acceptable levels.

Removing Turbine from Water

1. Approach the turbine pontoon from down river
2. Turn off the turbine based on New Energy Corporation's specifications
3. Raise the turbine into the maintenance position. This raises and holds the impeller perpendicular to the pontoon deck
4. Disconnect breakaway connection from the turbine, and leave the non-breakaway connection still attached.
5. Using an outboard motor attached to the pontoon, motor the pontoon to the bank and take the pontoon out of the water. Non-breakaway connection can still be connected or disconnected while on the bank.

Safety

Safety must be a large priority for villagers of Nazarét. Placement of the turbine needs to follow the specs set forth by the engineered design, but safety should also be considered during the placement of the turbine. Ideally, the turbine system should be placed upriver from the community and away from the areas where the villagers use the river for recreational and living purposes. Villagers need to stay away from the turbine while it is in use and should only approach the turbine by canoe and from downriver of the turbine.





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Características

- Ideal para aplicar con temperaturas bajas.
- Alcanza una fuerza de compresión de 5000 psi después de 28 días.
- Con solo agregar agua, puedes realizar trabajos en: aceras, pisos, escaleras

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CEMENT & CONCRETE PRODUCTS™

CONCRETE MIX

PRODUCT NO. 1101-40, -50, -60, -80, -90

DIVISION **3**

03 31 00 Structural Concrete

PRODUCT DESCRIPTION

QUIKRETE® Concrete Mix is a pre-blended mixture of cement and aggregates for general structural uses, requiring only the addition of water



PRODUCT USE

QUIKRETE® Concrete Mix is designed for pouring concrete 2 in (50 mm) thick or more and building or repairing anything out of concrete, including:

- Foundation walls and footings
- Sidewalks, curbs, steps, ramps and walkways
- Appliance and equipment platforms
- Pipe and post footings
- Floor slabs and patios
- Pools, fish ponds, stepping stones
- Splashblocks and bird baths
- Riprap & slope protection
- Driveway repairs

SIZES

QUIKRETE® Concrete Mix is available in the following bag sizes:

- 40 lb (18.1 kg)
- 50 lb (22.6 kg)
- 60 lb (27.2 kg)
- 80 lb (36.2 kg)
- 90 lb (40.8 kg) (*regional availability*)

YIELD

- A 40 lb (18.1 kg) bag yields approximately 0.30 ft^3 (8.5 L)
- A 50 lb (22.6 kg) bag yields approximately 0.375 ft^3 (10.6 L)
- A 60 lb (27.2 kg) bag yields approximately 0.45 ft^3 (12.7 L)
- An 80 lb (36.2 kg) bag yields approximately 0.60 ft^3 (17 L)
- A 90 lb (40.8 kg) bag yields approximately 0.675 ft^3 (19.1 L)

TECHNICAL DATA

APPLICABLE STANDARDS

- ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
- ASTM C138 Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- ASTM C143 Standard Test Method for Slump of Hydraulic-Cement Concrete
- ASTM C387 Standard Specification for Packaged, Dry, Combined Materials for Concrete and High Strength Mortar

PHYSICAL/CHEMICAL

Typical results obtained for QUIKRETE® Concrete Mix, when tested in accordance with the referenced ASTM test methods, is shown in Table 1.

TABLE 1 TYPICAL PHYSICAL PROPERTIES

Slump, ASTM C143	2 in to 3 in (50 mm to 75 mm)
Unit Weight, ASTM C138	Approximately 140 lb/ft^3 (2242.5 kg/m^3)
Compressive Strength, ASTM C39	
Age	*PSI (MPa)*
7 days	2500 (17.2)
28 days	4000 (27.5)

INSTALLATION

SURFACE PREPARATION

Stake out the planned area and remove sod or soil to the desired depth. Nail and stake forms securely in place. Tamp and compact the sub-base until firm.

MIXING

WEAR IMPERVIOUS GLOVES, such as nitrile when handling product.

QUIKRETE® Concrete Mix can be mechanically mixed in a barrel type concrete mixer or a mortar mixer. Choose the mixer size most appropriate for the size of the job to be done. Allow at least 1 ft^3 (28.3 L) of mixer capacity for each 80 lb (36.2 kg) bag of QUIKRETE® Concrete Mix to be mixed at one time. For each 80 lb (36.2 kg) bag of QUIKRETE® Concrete Mix to be mixed, add approximately 6 pt (2.8 L) of fresh water to the mixer. Turn on the mixer and begin adding the concrete to the mixer. If the material becomes too difficult to mix, add additional water until a workable mix is obtained. If a slump cone is available, adjust water to achieve a 2 in to 3 in (50 mm to 75 mm) slump.

QUIKRETE® Concrete Mix may also be mixed by hand. Empty concrete bags into a suitable mixing container. For each 80 lb (36.2 kg) bag of mix, add approximately 6 pt (2.8 L) of clean water. Work the mix with a shovel, rake or hoe and add water as needed until a stiff, moldable consistency is achieved. Be sure there are no dry pockets of material. Do not leave standing puddles of water.

Final water content should be approximately 6 pt to 9 pt (2.8 L to 4.3 L) of water per 80 lb (36.2 kg) bag of concrete. For other bag sizes, use Table 2 to determine water content.

TABLE 2 MIXING WATER FOR QUIKRETE® CONCRETE MIX

Package Size lb (kg)	Starting Water Content pt (L)	Maximum Expected Water Content pt (L)
40 (18.1)	3 (1.4)	4-1/2 (2.1)
50 (22.6)	3-1/2 (1.7)	5-1/2 (2.6)
60 (27.2)	4 (1.9)	7 (3.3)
80 (36.2)	6 (2.8)	9 (4.3)
90 (40.8)	7 (3.3)	10 (4.7)

APPLICATION

WEAR IMPERVIOUS GLOVES, such as nitrile when handling product.

Method for Pouring a Slab

Start by dampening the sub-grade before concrete is placed. Do not leave standing puddles of water. Shovel or place concrete into the form; fill to the full depth of the form. Fill the repair area completely working continuously from one end to the other. Avoid partial depth fills which could lead to cold joints. After concrete has been compacted and spread to completely fill the forms without air pockets, strike off and float immediately. To strike off, use a straight board (screed), moving the edge back and forth with a saw-like motion to smooth the surface. Use a darby or bull float to float the surface; this will level any ridges and fills voids left by the straight edge. Cut the concrete away from the forms by running an edging tool or trowel along the forms to compact the slab edges. Cut 1 in (25 mm) deep control joints into the slab every 6 ft to 8 ft (1.8 m to 2.4 m) using a grooving tool. Allow concrete to stiffen slightly, waiting until all water has evaporated from the surface before troweling or applying a broom finish.

Note - For best results, do not overwork the material.

Method for Setting Fence Posts

Start by digging the post hole about 3 times the diameter of the post. Hole depth should be 1/3 the overall post height. Place 6 in (150 mm) of dry concrete mix in the bottom of the hole. Position the post, checking that it is level and plumb. Mix QUIKRETE® Concrete Mix with water prior to placement into the hole. When standing water has evaporated from the concrete, smooth the surface. Taper it away from the post so rain will flow in that direction. Wait 24 hours before post is subjected to any strain. For load-bearing applications, follow local building codes for proper footing specifications.

Finishing

Any standard concrete finishing technique is acceptable for use with QUIKRETE® Concrete Mix. Concrete can be hand troweled, power-troweled, broom finished or finished with other specialty finishes.

CURING

General

Curing is one of the most important steps in concrete construction. Proper curing increases the strength and durability of concrete, and a poor curing job can ruin an otherwise well-done project. Proper water content and temperature are essential for good curing. In near freezing temperatures the hydration process slows considerably. When the weather is too hot, dry or windy, water is lost by evaporation from the concrete, which will hinder the hydration reaction, which may result in finishing difficulties and shrinkage cracking. The ideal circumstances for curing are ample moisture and moderate temperature and wind conditions. Curing should be started as soon as possible and should continue for a period of 5 days in warm weather at 70 ºF (21 ºC) or higher or 7 days in colder weather at 50 ºF to 70 ºF (10 ºC to 21 ºC).

Specific Curing Methods

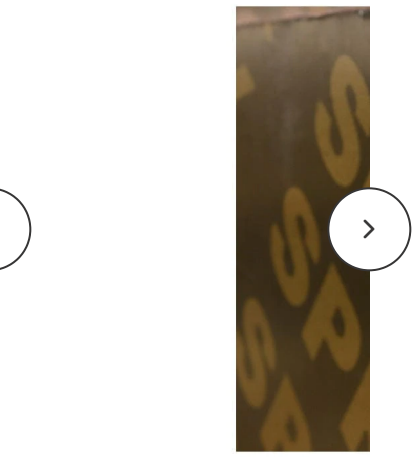
QUIKRETE® Acrylic Concrete Cure & Seal – Satin Finish (No. 8730) provides the easiest and most convenient method of curing. Apply by spray, brush or roller soon after the final finishing operation when the surface is hard. The surface may be damp, but not wet, when applying curing compound. Complete coverage is essential. Other methods of providing proper curing include covering the surface with wet burlap, plastic sheeting, or waterproof paper to prevent moisture loss; keeping the surface wet with a lawn sprinkler is also acceptable. If burlap is used, it should be free of chemicals that could weaken or discolor the concrete. New burlap should be washed before use. Place it when the concrete is hard enough to withstand surface damage and sprinkle it periodically to keep the concrete surface continuously moist. Water curing with lawn sprinklers, nozzles or soaking hoses must be continuous to prevent interruption of the curing process. Curing with plastic sheets is convenient. They must be laid flat, thoroughly sealed at joints and anchored carefully along edges.

PRECAUTIONS

- Curing compounds should not be applied if rain or temperatures below 50 ºF (10 ºC) are expected within 24 hours
- Curing with plastic or burlap can cause patchy discoloration in colored concrete. For colored concrete, wet curing or the use of QUIKRETE® Acrylic Concrete Cure & Seal – Satin Finish (No. 8730) is recommended
- Do not use curing compounds during late fall on surfaces where de-icers will be used to melt ice and snow. Using curing compounds at that time may prevent proper air drying of the concrete, which is necessary to enhance its resistance to damage caused by de-icers
- Protect concrete from freezing during the first 48 hours. Plastic sheeting and insulation blankets should be used if temperatures are expected to fall below 32 ºF (0 ºC)

WARRANTY

NOTICE: Obtain the applicable **LIMITED WARRANTY** at www.quikrete.com/product-warranty or send a written request to The Quikrete Companies, LLC, Five Concourse Parkway, Atlanta, GA 30328, USA. Manufactured by or under the authority of The Quikrete Companies, LLC. © 2020 Quikrete International, Inc.









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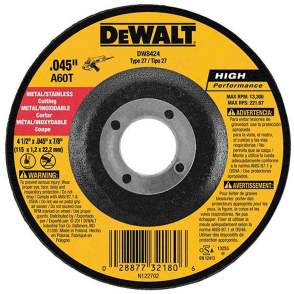

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ESPECIFICACIONES

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Houser, Andrew <ahouse15@vols.utk.edu>

Hydrokinetic Power Generation - Panama

Shane Bear <shane.bear@newenergycorp.ca> Wed, Apr 6, 2022 at 2:10 PM
To: "Houser, Andrew" <ahouse15@vols.utk.edu>

Drew,

See answers to your questions below:

1 - Preventative maintenance: See Attached Document

2 - 2 x EVG-005: ~ USD $40,000
EVG-010: ~ USD $40,000

The difference here is 2 boats are required for the 5 kW mini-array, and only one for the 10 kW system. Typically, the boats cost between USD $15,000-20,000/each (on top of the prices listed for the turbines).

One comment I will make is that for an application like this is we would typically recommend installing 2 x 5 kW systems. The reason being that this de-risks energy production as there are two independent power generation devices. This is ideal for remote locations that are relying on the systems for consistent base load power.

3 - Shipping: This largely depends on the where and what is being shipping. The turbine and generators package up neatly into shipping crates (approx 2 x 3 x 8 ft), and the boats are modular and can be broken up into smaller sections. If you are just shipping the turbines, I would say it would probably cost in the range of $2000 too get each turbine crate to site.

With that being said, one thing that New Energy can offer (and have done in the past) given the size/configuration of our systems is shipping the turbine + boat + power electronics to site in a metal shipping container, and then setting up the shipping container on site to double as the control room with all of the necessary power electronics, batteries, etc. May be something to consider for a project such as this..

Cheers,

Shane

[Quoted text hidden]

Hydrokinetic Power Generation - Panama

Shane Bear <shane.bear@newenergycorp.ca> Wed, Apr 20, 2022 at 12:22 PM
To: "Houser, Andrew" <ahouse15@vols.utk.edu>

Hello Andrew,

Best of luck in this final gauntlet for you and your teammates! Yes, I would be happy to see your work when you are ready to share. See answers to your questions below:

1. Typically, this is the preference. Service contracts can be negotiated at the time of sale for such activities (day rate @ ~ $1200/technician + government recommended daily per dium + travel cost). An inspection at year one is mainly to ensure that no faults or failures have began to develop in the first year of operation (mainly only an issue with improper assembly). After that, maintaining the semi-annual inspections should be sufficient for a fresh water application.
2. This is mainly dependent on the medium of transportation. Shipment by air only takes a couples days, however the turbines may need to be transported to the final destination via truck or boat and this can add a few days. In total, expecting a turbine to arrive within 1 or 2 weeks is not unreasonable.
3. Due to the minimal part count, assembling the turbine itself should only take a day. Additionally infrastructure such as the power electronics (microgrid), deploying anchor blocks, and any other necessary activities will take additional time.

Previously you had asked questions about anchoring/mooring a floating system. One methodology we use frequently is to deploy the anchor blocks first, marked with a heavy duty buoy. When ready to install, the turbines mooring/bridal assembly can simply be attached to the buoy, as opposed to a direct boat to anchor connection (if that makes sense, not sure if I mentioned that to you already).

Cheers and let me know if you need anything else,

Shane

[Quoted text hidden]

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XO RUST

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- 2 in 1: paint and base

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EVG-005 – Maintenance and Inspection

Revision: A1

Document #: EVG005-MAI

1.0 Introduction

This document outlines a recommended maintenance and inspection regime for the 5kW Envirogen turbine. While maintenance is minimal, routine inspection is important, as potential issues can be caught before they develop into a problem.

EVG-005 Maintenance and Inspection Intervals

First 30 Days

Interval + Labor	Activity	Description
Weekly – first 30 days 0.5hr 1 technician per turbine	Inspection of mechanical and electrical components.	A simple inspection during turbine operation. Visually ensure there are no debris, or obvious mechanical faults, listen to the sound of the machine. Is it making any strange sounds or vibrations? Are there any error readouts on the electrical components?

Ongoing

Interval + Labor	Activity	Description
30 days 0.5hr 1 technician per turbine	Inspection of mechanical and electrical components.	A simple inspection during turbine operation. Visually ensure there are no debris, or obvious mechanical faults, listen to the sound of the machine. Is it making any strange sounds or vibrations? Are there any error readouts on the electrical components?
6 months 1hr 2 technicians per turbine	In depth inspection of mechanical and electrical components	Turbine is rotated out of the water and rotor components inspected. Witness marks are checked on bolts to ensure fasteners are not moving, and bolt torque is checked. Electrical components are checked for faults, enclosures are checked for corrosion, water ingression and any other potential risks.
1 Year – after first year, adjust schedule according to measured wear	Disassembly of turbine Drivetrain, inspection and replacement of components as needed.	The turbine is rotated into the maintenance position and the rotor completely disassembled. This allows inspection of the diamond bearing and analysis of key rotor components such as blades, fasteners, and anodes as they reach the end of their useful life due to factors such as corrosion and fatigue.

8hrs 2 technicians per turbine		

2.0 Maintenance and Inspection details

2.1 Monthly Inspection

The purpose of this inspection is to catch issues before they become problems, as such this inspection is performed while the turbine is in operation. A visual inspection of all visible turbine components, mounting gear, and structural equipment is carried out to ensure there are no failures, locations with excess corrosion, or other concerns. This should take no more than 30 minutes per turbine. The power electronics are to be inspected to ensure no error codes are present, and a visual inspection should be made of all exposed power cabling, such that any wear or damage to the cables is found. **If damage to the turbine or other systems is found, immediately cease operation** of the turbine system and consult New Energy.

2.2 Semi-Annual Inspection

The purpose of this inspection is to check the status of several key components of the turbine system and is a more involved inspection than the monthly inspection.

- Rotate turbine into maintenance position
- Inspect the witness marks on the two bolts at each support arm/hydrofoil interface, total of 16 bolts.
- Inspect the witness marks on the two bolts at the support arm/rotor flange interface.
- Using a torque wrench set 10% below assembly torque for each fastener, ensure all fasteners are tight.
- Insect all anodes and replace if less than 50% of the material remains.
- Inspect all electrical components for error codes, corrosion on enclosures and potential water ingress.

MaxIndustrias, S.A.

Ave. Ernesto T. Lefevre
Teléfono Panamá: +507 224-5050 / Fax: 224-0055
Email: ventas@maxindustrias.com
www.maxindustrias.com

FECHA: 29/04/2022

COTIZACION #: PA-242149

Cliente: **ALAN FOSTER**
CC196671

Vendedor: CASA MATRIZ
Condición de Pago: CONTADO

CANTIDAD		DESCRIPCION	CODIGO	PRECIO	MONTO
50.00	MTS	*CABLE IND. 25,4mm (1") AF 6X25 DSR	01-1 F 6X25DNNDSR	7.07	353.50
50.00	MTS	CABLE *IND. 22,23mm (7/8") AA 6X25 DSR	01-0.875 A6X25DNND	8.67	433.50

Total mercadería:	787.00
ITBM:	55.10
Flete:	0.00
Seguro:	0.00
Documentación:	0.00
Total General:	**842.10**

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Vendedor:

CASA MATRIZ

Observaciones: Precios validos por 15 dias a partir de la fecha de emision

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16 Gauge Galvanized Plain Wire - 1lb

BISON

577-16

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Rock Anchor 1"-30" Length JR130L

Our Price: $98.04

Product Code: H-JR130L-ALL55508-ROCK

Qty:

- 1 +

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Description **Extended Information**

1" X 30" Expanding Rock Anchor 36,000 lbs. Unlimited strength

Rock Anchors are installed into core holes bored into rock. The Rock Anchor is tightened along the anchor shaft to expand the resistance wedges into the rock.

To install anchor, drill a 12" deep hole in solid rock, put anchor in hole, turn rod until anchor expands and wedges in the hole.

- Anchor consists of two Malleable castings and a Triple Eye Anchor Rod.
- Anchor diameter is 2-1/4".
- Anchor size expanded is 3-1/8".
- Hole diameter is 2-3/8".
- The harder the pull on the rod, the tighter it wedges into the rock.

CROSBY

Swivel Hook, Alloy Steel, 3000 lb., Gold

Zoro #: G7095724 **Mfr #:** 1048816

0.0 No Reviews Write the First Review

Rated 0.0 out of 5 stars







$75.39

- **Item:** Slip Hook
- **Material:** Alloy steel
- **Hook Attachment Type:** Swivel Eye

See full product details

0

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SKU: L322AN-11T

$541.00

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DESCRIPTION

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Fishing / Fishing Gear / Fishing Buoys





TAYLOR MADE – Net Buoys

(1)

Prices from **$37.99 - $144.99**

Select Product:

Net Buoy, 18"D x 24" L, Rocket Red $69.99

$69.99

In stock online.

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Model # 4252664 | Mfg # 505718

SPECS PRODUCT OVERVIEW ADVICE REVIEWS PRODUCT Q & A

Specs

Net Buoy, 18"D x 24" L, Rocket Red

Type	Buoy

Product Overview

Taylor Made Products® Net Buoys feature heavy duty seamless construction to meet the demands of the commercial fishing industry.

The ends of these Net Buoys are made from injection molded vinyl tested to 2,000psi tensile strength—the strongest in the industry. The versatile design features large line holes, which in addition to rope will accept standard shackles. The curved design hole prevents chafing. "Rocket Red" color makes these buoys easy to spot.

Key Features

- Rugged, seamless construction
- Valve located on side of buoy for easy inflation
- Patented Trivalve™ does not require removal to inflate, and allows inflation with a football needle or compressor
- apered eyelet shape allows the attachment of a standard shackle
- One year warranty

Inflation Instructions

Model	4252631	4252649	4252664	4252672	4252680
Circumference	28"	38"	57"	66"	85"
Diameter x Height	9" x 12"	12" x 16"	18" x 24"	21" x 27"	27" x 33"
Saltwater Buoyancy	16lb.	38lb.	132lb.	200lb.	421lb.
Freshwater Buoyancy	15lb.	36lb.	128lb.	194lb.	408lb.
Rope Eye Diameter	1 1/16"	1 1/16"	1 1/2"	1 1/2"	1 1/2"

⚠ **WARNING**: This product can expose you to chemicals including di-isononyl phthalate which are known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Advice

The West Advisor articles have answered boaters' questions and provided solutions to boating problems for more than 20 years. West Marine has compiled one of the Web's most comprehensive collections of technical boating information articles.

Related West Advisor Articles

- Kite Fishing

Reviews

Review Snapshot by PowerReviews

4.0 1 Review Write a Review

100% of respondents would recommend this to a friend

Ratings Distribution

5 Stars	0
4 Stars	1
3 Stars	0
2 Stars	0
1 Star	0

Pros

1 Functional

Cons

1 Difficult To Use



GUARDIAN ANCHOR

$75.98 – $1,610.85

Guardian anchors benefit from years of Fortress research and development, offering excellent quality, performance, and economy. These anchors are manufactured from the same corrosion-resistant, high-tensile aluminum magnesium alloy as Fortress, which makes them stronger and lighter than competitive steel anchors.

With Guardian anchors, several Fortress machining steps and extra features, such as anodizing and adjustable fluke angles, are eliminated. The Guardian Anchor is limited to one, single, 32-degree angle, which will work for most common sea bottoms. The result is a high-performance anchor that is engineered for fast setting and strong holding power, and a very affordable alternative to those heavy, rust-prone steel anchors.

As strong as steel, but only half the weight, Guardian anchors are second only to Fortress FX model in holding power tests. They make an excellent spare or storm anchor for your boat or yacht.

ANCHOR SELECTION

G-125

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SKU: 647124341253 Category: Guardian Marine Anchors



MaxIndustrias, S.A.

Ave. Ernesto T. Lefevre
Teléfono Panamá: +507 224-5050 / Fax: 224-0055
Email: ventas@maxindustrias.com
www.maxindustrias.com

FECHA: 03/05/2022

COTIZACION #: PA-242270

Cliente: **ALAN FOSTER**
CC196671

Vendedor: CASA MATRIZ
Condición de Pago: CONTADO

CANTIDAD		DESCRIPCION	CODIGO	PRECIO	MONTO
1.00	UNO	GUARDACABOS GALV.7/8" H.D	03-03-0.875HD	5.62	5.62
1.00	PCS	TOPE P/CABLE 7/8"	03-06-TOPE 0.875	63.15	63.15
1.00	PCS	CASQUILLO 7/8" ALUM T-24	03-06-0.875 ALU	22.80	22.80
1.00	PCS	CASQUILLO 1" ALUM T-26	03-06-1 ALU	26.55	26.55
1.00	UNO	GUARDACABO GALV. 1" H.D.	03-03-1" HD	6.70	6.70
1.00	PCS	TOPE P/CABLE 1"	03-06-TOPE 1	72.70	72.70

Total mercadería:	197.52
ITBM:	13.83
Flete:	0.00
Seguro:	0.00
Documentación:	0.00
Total General:	**211.35**

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Vendedor:

CASA MATRIZ

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*Precios validos por 15 días a partir de la fecha de emisión

Fecha de Impresión: 03/05/2022 04:41:18PM

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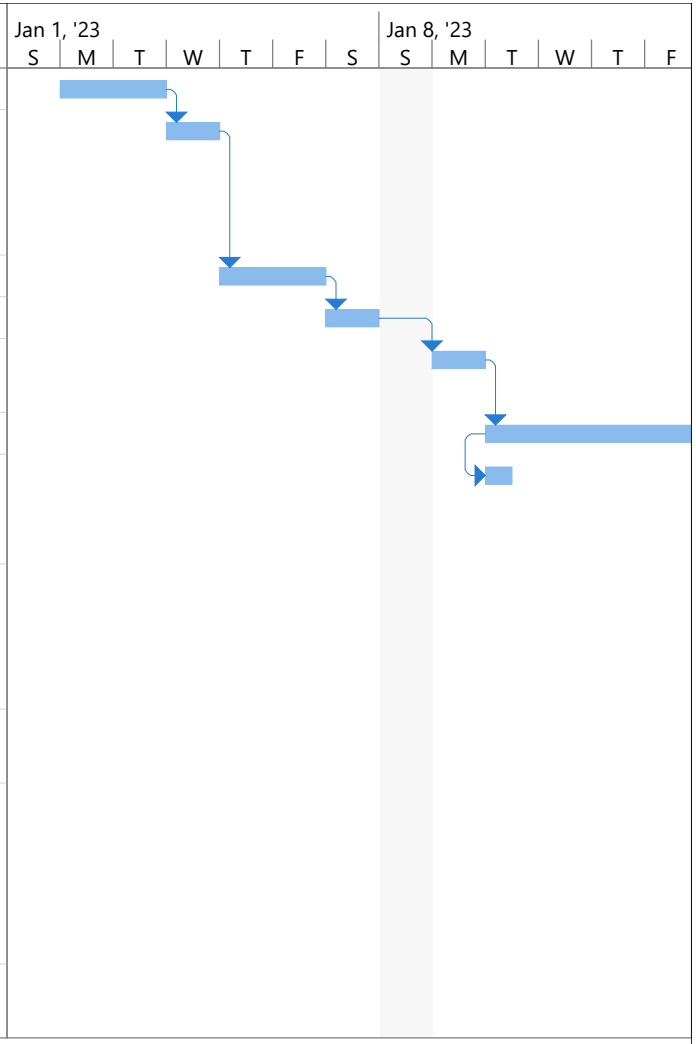
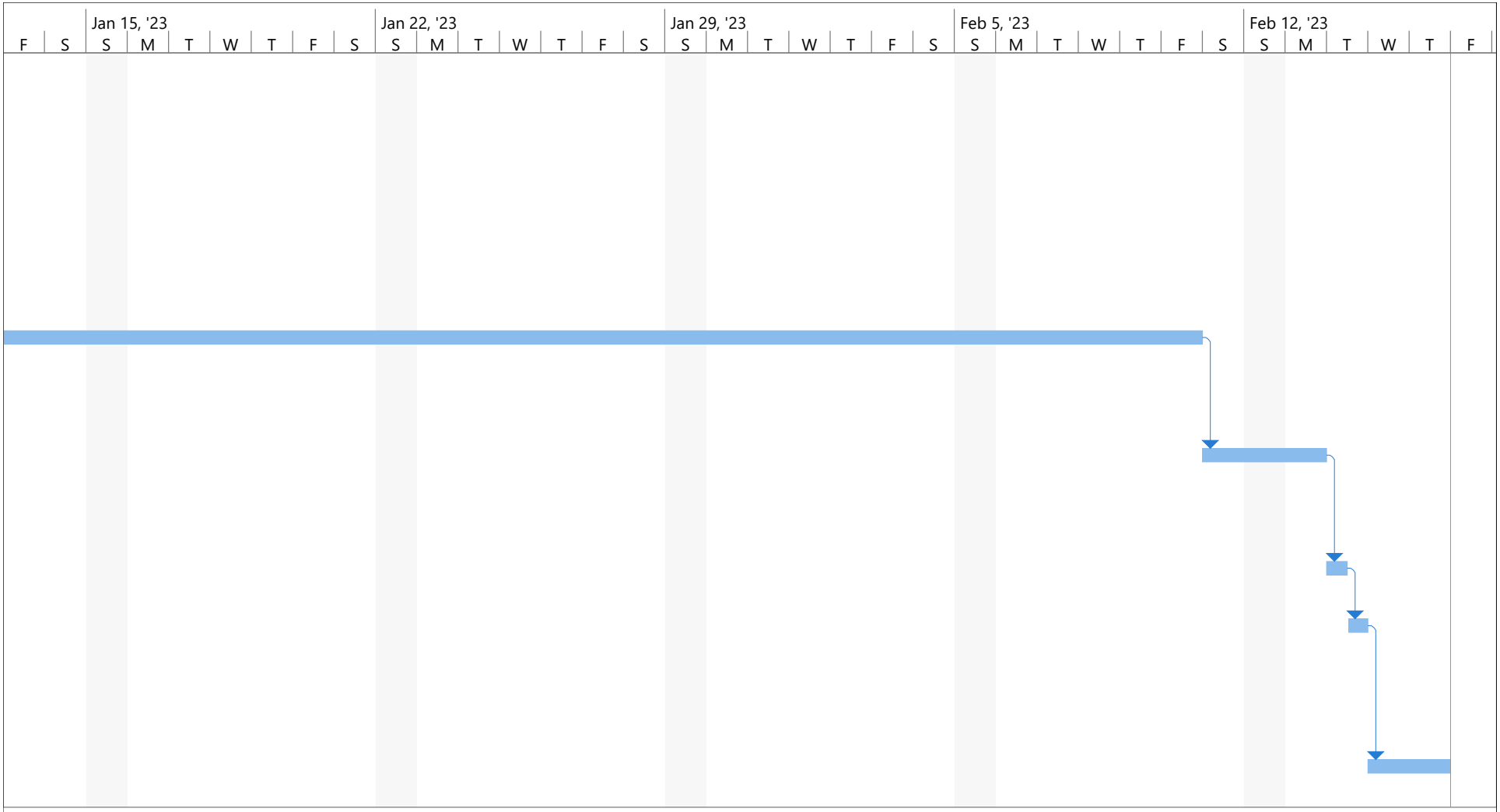
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation of rock	2 days	Thu 1/5/23	Fri 1/6/23	2
4		Placement of anchor	1 day	Sat 1/7/23	Sat 1/7/23	3
5		Pouring of structural grout	1 day	Mon 1/9/23	Mon 1/9/23	4
6		Grout Curing	28 days	Tue 1/10/23	Fri 2/10/23	5
7		Installation of cable connection to rock anchor	0.5 days	Tue 1/10/23	Tue 1/10/23	6SS
8		Installation of turbine(s) by manufactures directions	2 days	Sat 2/11/23	Mon 2/13/23	6
9		Turbine connection to rock anchor	0.5 days	Tue 2/14/23	Tue 2/14/23	8
10		Turbine Connection to river anchor and placement based on manufactures directions	0.5 days	Tue 2/14/23	Tue 2/14/23	9
11		System inspection and cleanup	2 days	Wed 2/15/23	Thu 2/16/23	10



Project: In Rock Anchor
Date: Wed 5/4/22

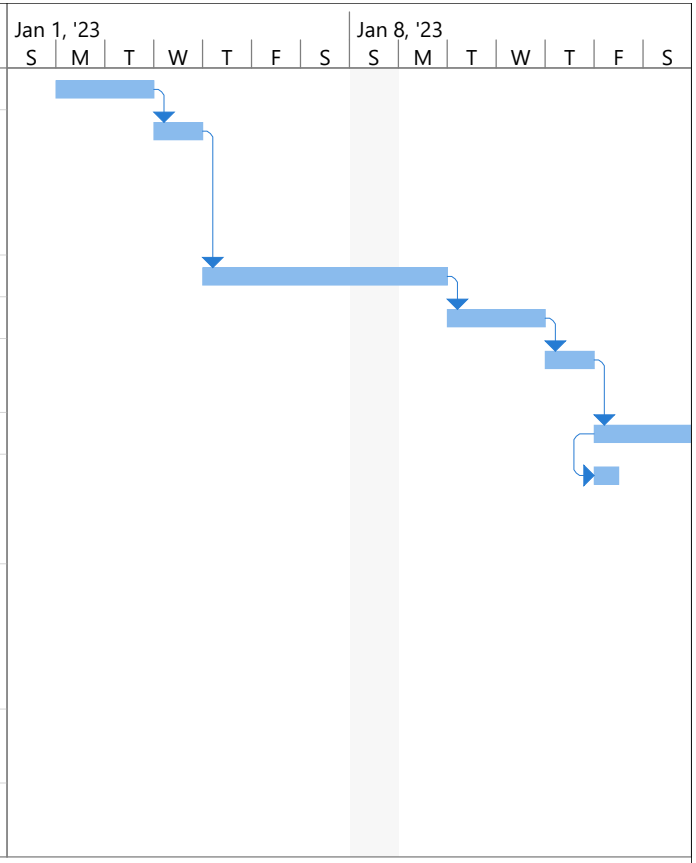
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: In Rock Anchor
Date: Wed 5/4/22

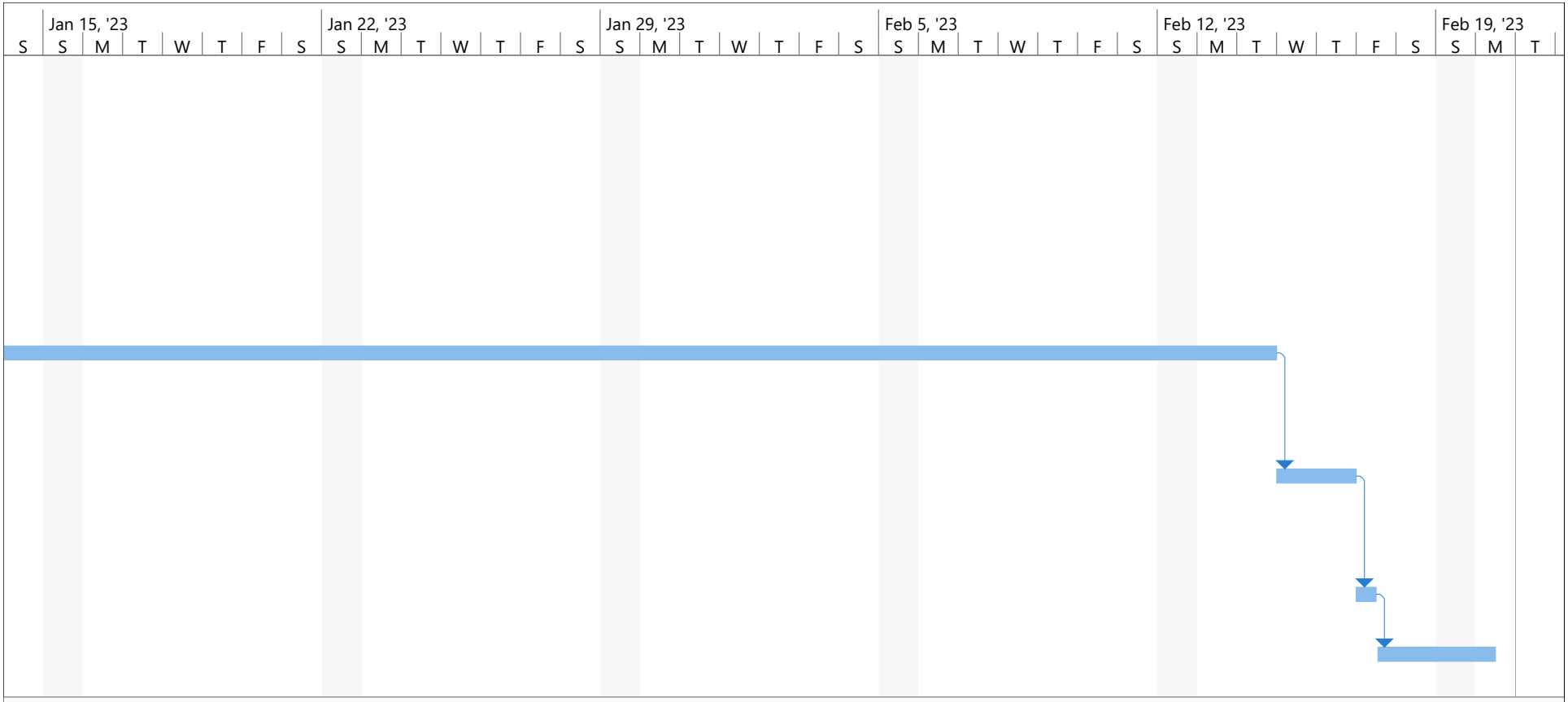
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation of rock	4 days	Thu 1/5/23	Mon 1/9/23	2
4		Placement of anchor	2 days	Tue 1/10/23	Wed 1/11/23	3
5		Pouring of structural grout	1 day	Thu 1/12/23	Thu 1/12/23	4
6		Grout Curing	28 days	Fri 1/13/23	Tue 2/14/23	5
7		Installation of cable connection to rock anchor	0.5 days	Fri 1/13/23	Fri 1/13/23	6SS
8		Installation of turbine(s) by manufactures directions	2 days	Wed 2/15/23	Thu 2/16/23	6
9		Turbine connection and placement	0.5 days	Fri 2/17/23	Fri 2/17/23	8
10		System inspection and cleanup	2 days	Fri 2/17/23	Mon 2/20/23	9



Project: In Rock Anchor
Date: Wed 5/4/22

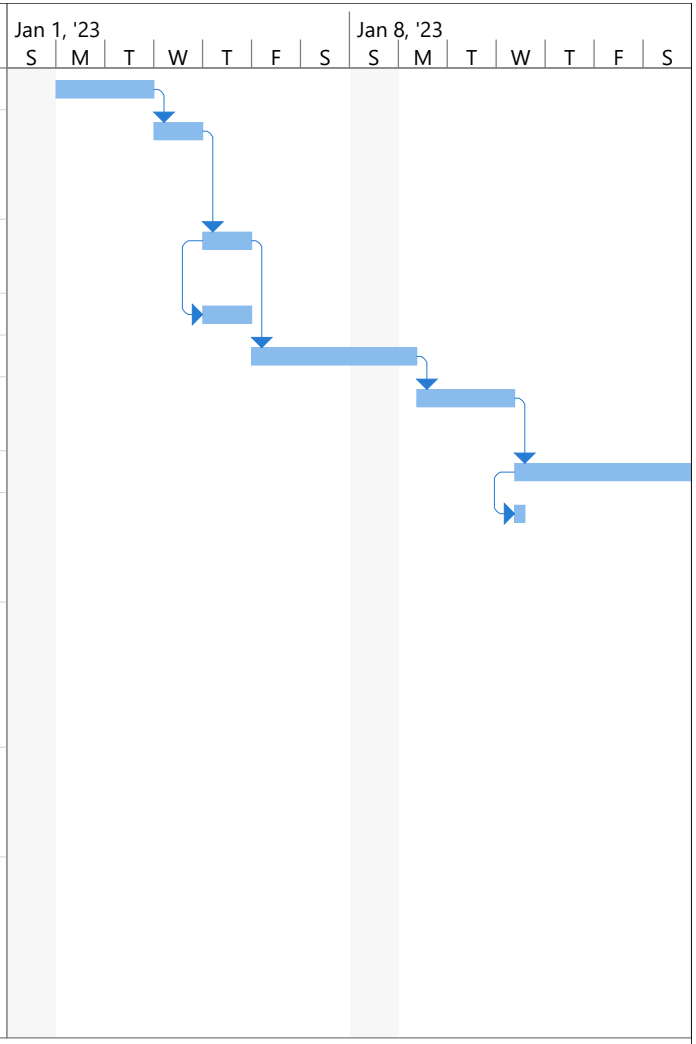
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: In Rock Anchor
Date: Wed 5/4/22

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation for footings	1 day	Thu 1/5/23	Thu 1/5/23	2
4		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	3SS
5		Rebar placement	2 days	Fri 1/6/23	Mon 1/9/23	3
6		Concrete forms pouring of concrete	2 days	Mon 1/9/23	Wed 1/11/23	5
7		Concrete Curing	28 days	Wed 1/11/23	Mon 2/13/23	6
8		Installation of cable connection to concrete footing	0.5 days	Wed 1/11/23	Wed 1/11/23	7SS
9		Construction of turbines by manufactures directions	2 days	Mon 2/13/23	Wed 2/15/23	7
10		Turbine connection and placement to soil anchor	0.5 days	Mon 2/13/23	Tue 2/14/23	7
11		Turbine Connection to river anchor and placement based on manufactures directions	0.5 days	Tue 2/14/23	Tue 2/14/23	10

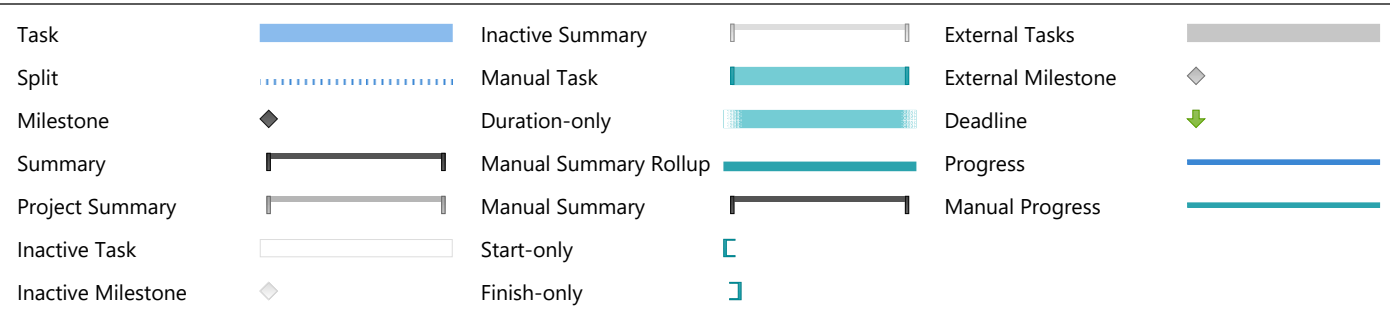


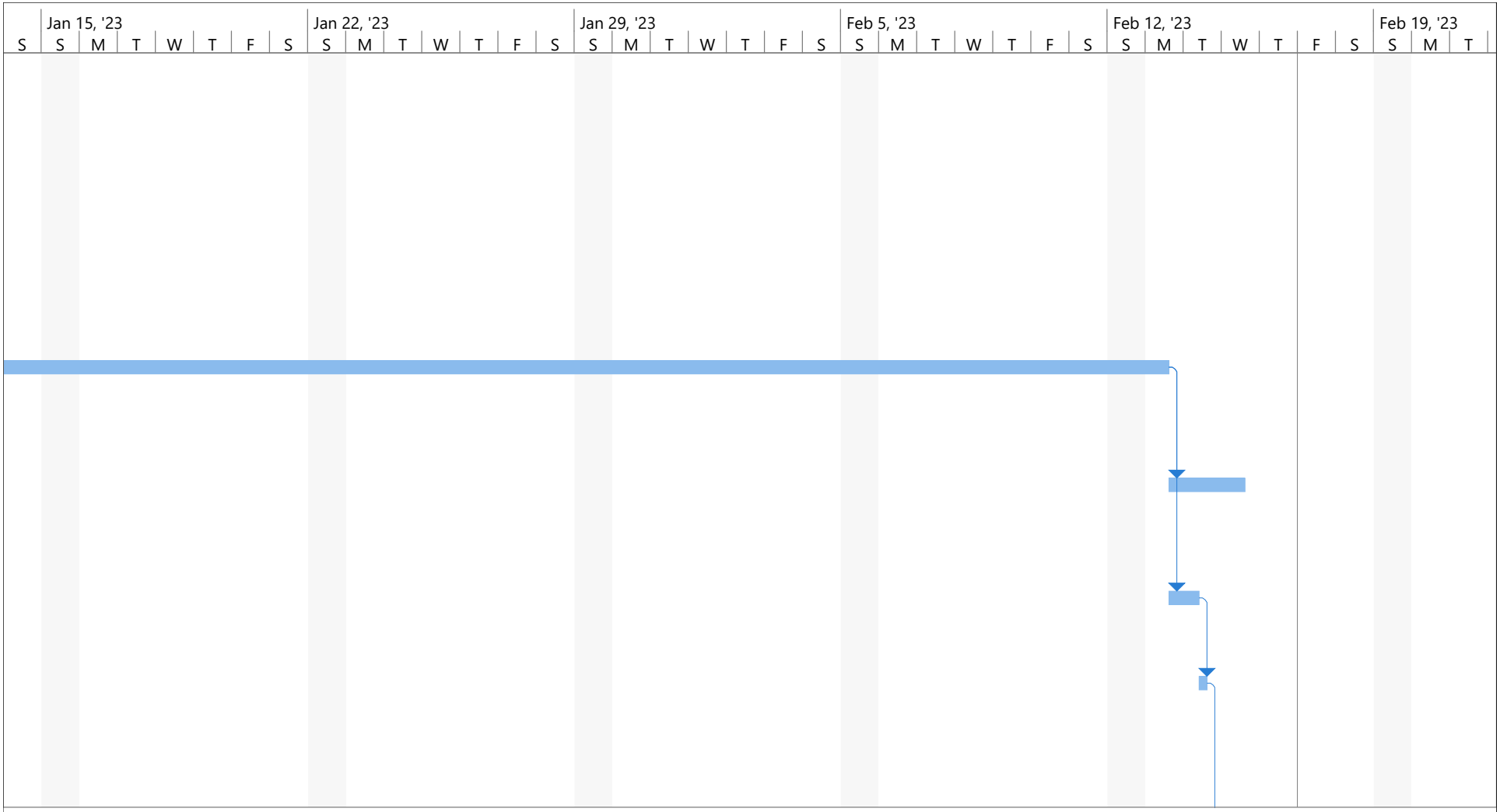
Project: Project1
Date: Wed 5/4/22

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Jan 1, '23 S M T W T F S	Jan 8, '23 S M T W T F S
12		System inspection and cleanup	2 days	Tue 2/14/23	Thu 2/16/23	11		

Project: Project1
Date: Wed 5/4/22

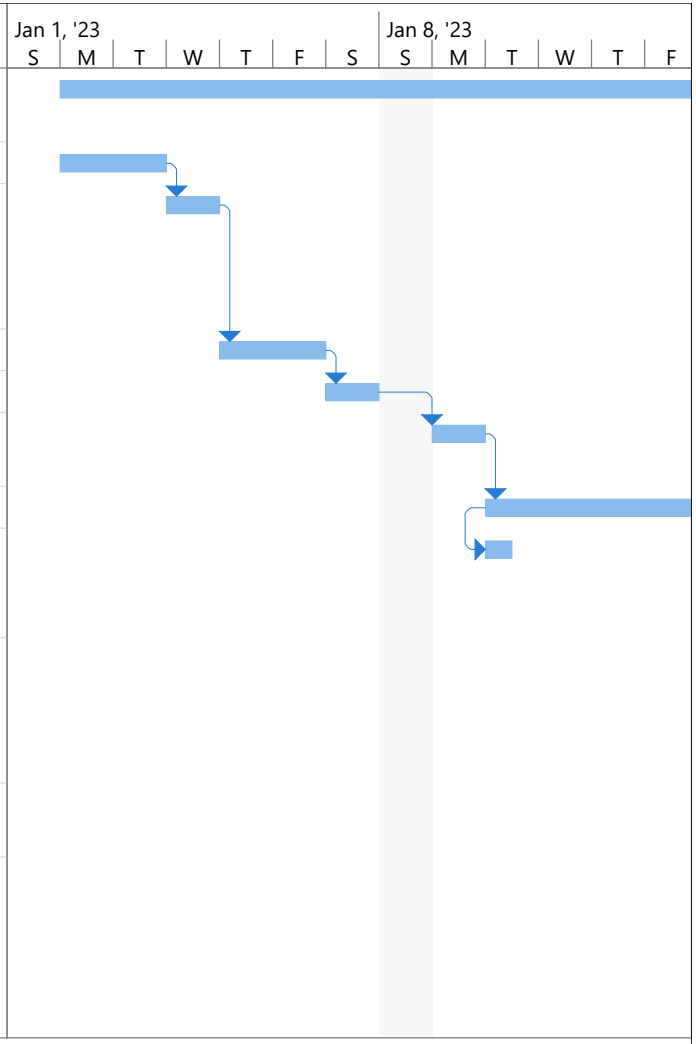




Project: Project1
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

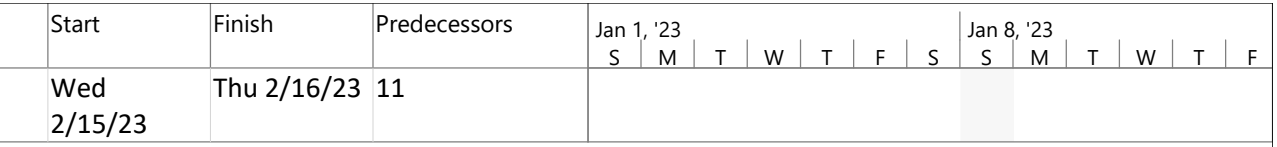
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Shipping of Turbine(s)	14 days	Mon 1/2/23	Tue 1/17/23	
2		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
3		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	2
4		Excavation of rock	2 days	Thu 1/5/23	Fri 1/6/23	3
5		Placement of anchor	1 day	Sat 1/7/23	Sat 1/7/23	4
6		Pouring of structural grout	1 day	Mon 1/9/23	Mon 1/9/23	5
7		Grout Curing	28 days	Tue 1/10/23	Fri 2/10/23	6
8		Installation of cable connection to rock anchor	0.5 days	Tue 1/10/23	Tue 1/10/23	7SS
9		Installation of turbine(s) by manufactures directions	2 days	Sat 2/11/23	Mon 2/13/23	7,1
10		Turbine connection to rock anchor	0.5 days	Tue 2/14/23	Tue 2/14/23	9
11		Turbine Connection to river anchor and placement based on manufactures directions	0.5 days	Tue 2/14/23	Tue 2/14/23	10



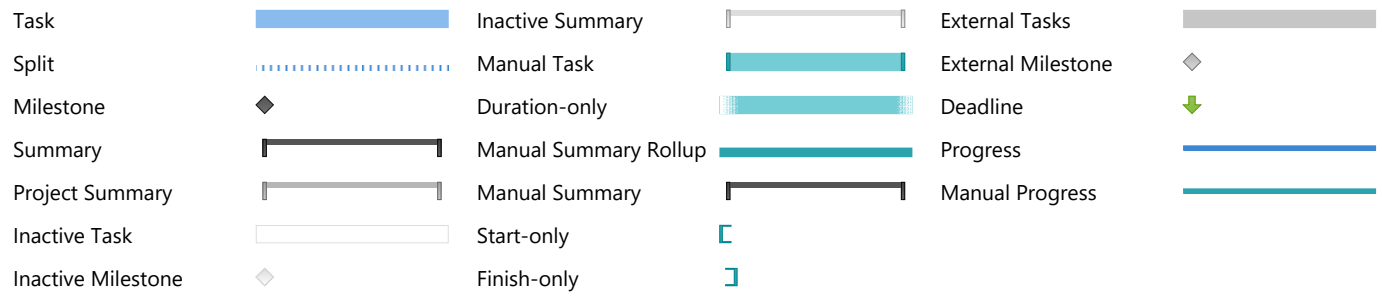
Project: In Rock Anchor
Date: Wed 5/4/22

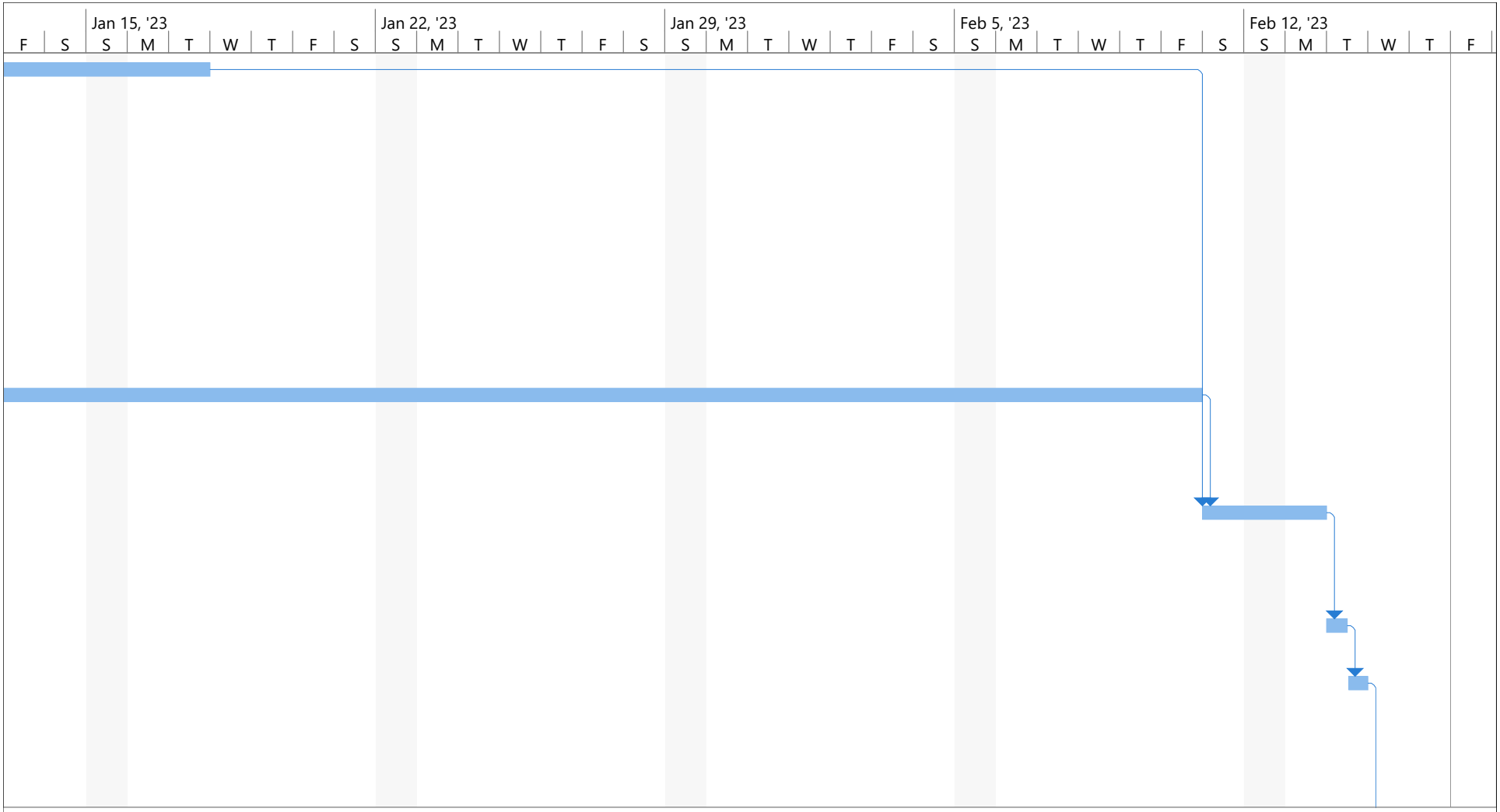
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
12		System inspection and cleanup	2 days	Wed 2/15/23	Thu 2/16/23	11



Project: In Rock Anchor
Date: Wed 5/4/22





Project: In Rock Anchor
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
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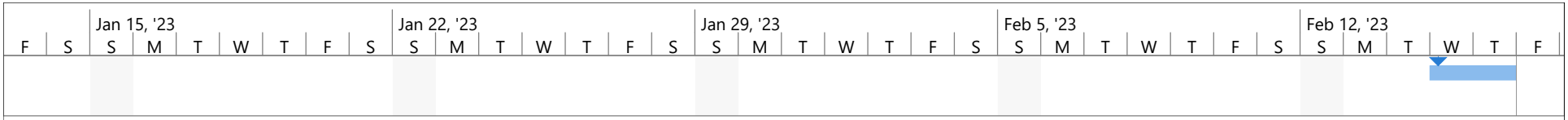
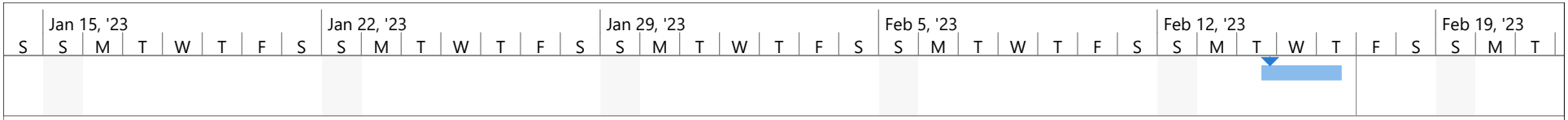


Project: In Rock Anchor
Date: Wed 5/4/22

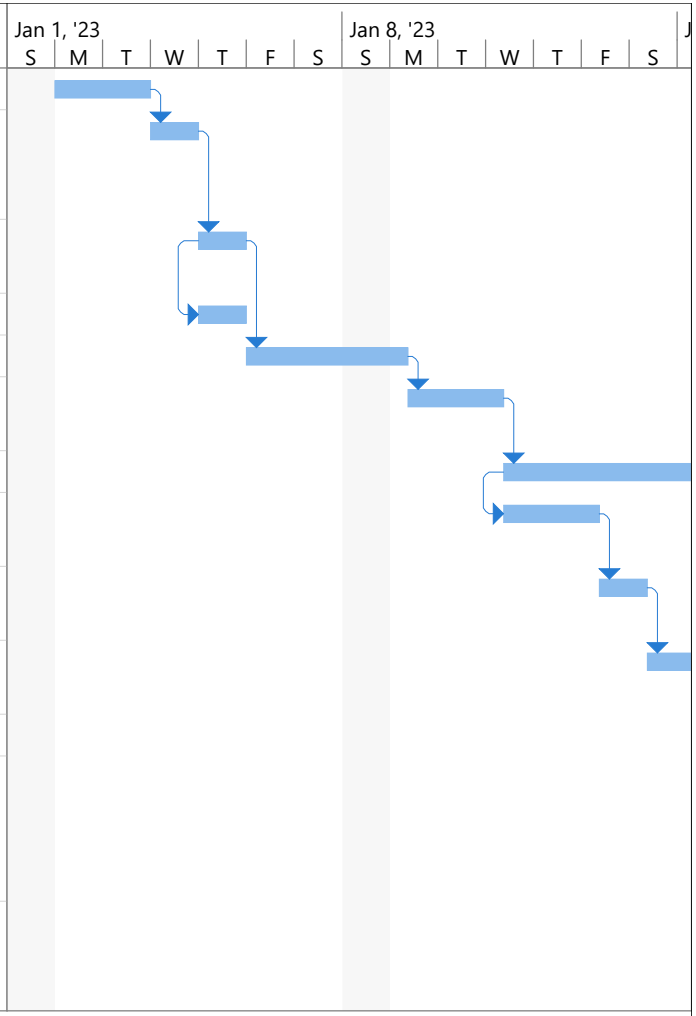
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			



Project: Project1
Date: Wed 5/4/22

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

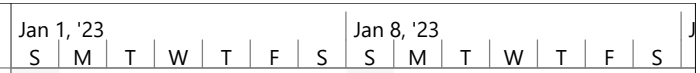
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation for soil footings	1 day	Thu 1/5/23	Thu 1/5/23	2
4		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	3SS
5		Rebar placement	2 days	Fri 1/6/23	Mon 1/9/23	3
6		Concrete forms pouring of concrete	2 days	Mon 1/9/23	Wed 1/11/23	5
7		Concrete Curing	28 days	Wed 1/11/23	Mon 2/13/23	6
8		Excavation for rock anchor	2 days	Wed 1/11/23	Fri 1/13/23	7SS
9		Placement of rock anchor	1 day	Fri 1/13/23	Sat 1/14/23	8
10		Pouring of structural grout	1 day	Sat 1/14/23	Mon 1/16/23	9
11		Grout cruing	28 days	Mon 1/16/23	Fri 2/17/23	10
12		Installation of turbine(s) by manufactures directions	2 days	Fri 2/17/23	Mon 2/20/23	11
13		Installation of cable connection to concrete footing	0.5 days	Mon 1/16/23	Mon 1/16/23	11SS



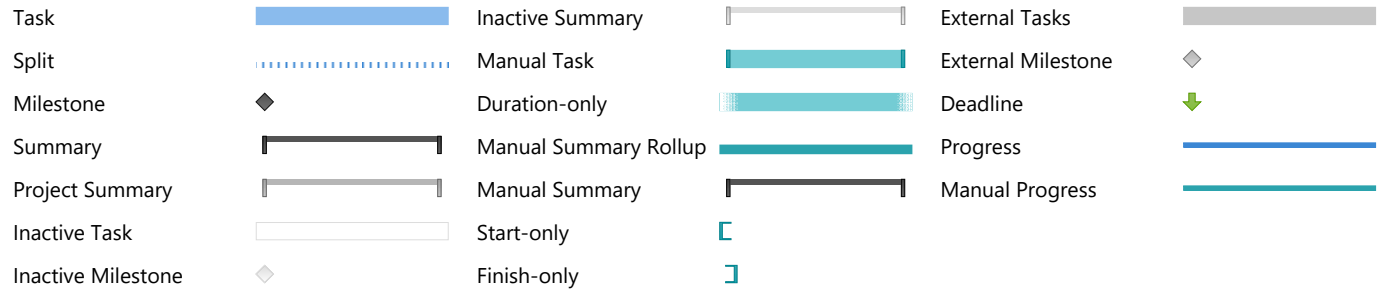
Project: Project1
Date: Wed 5/4/22

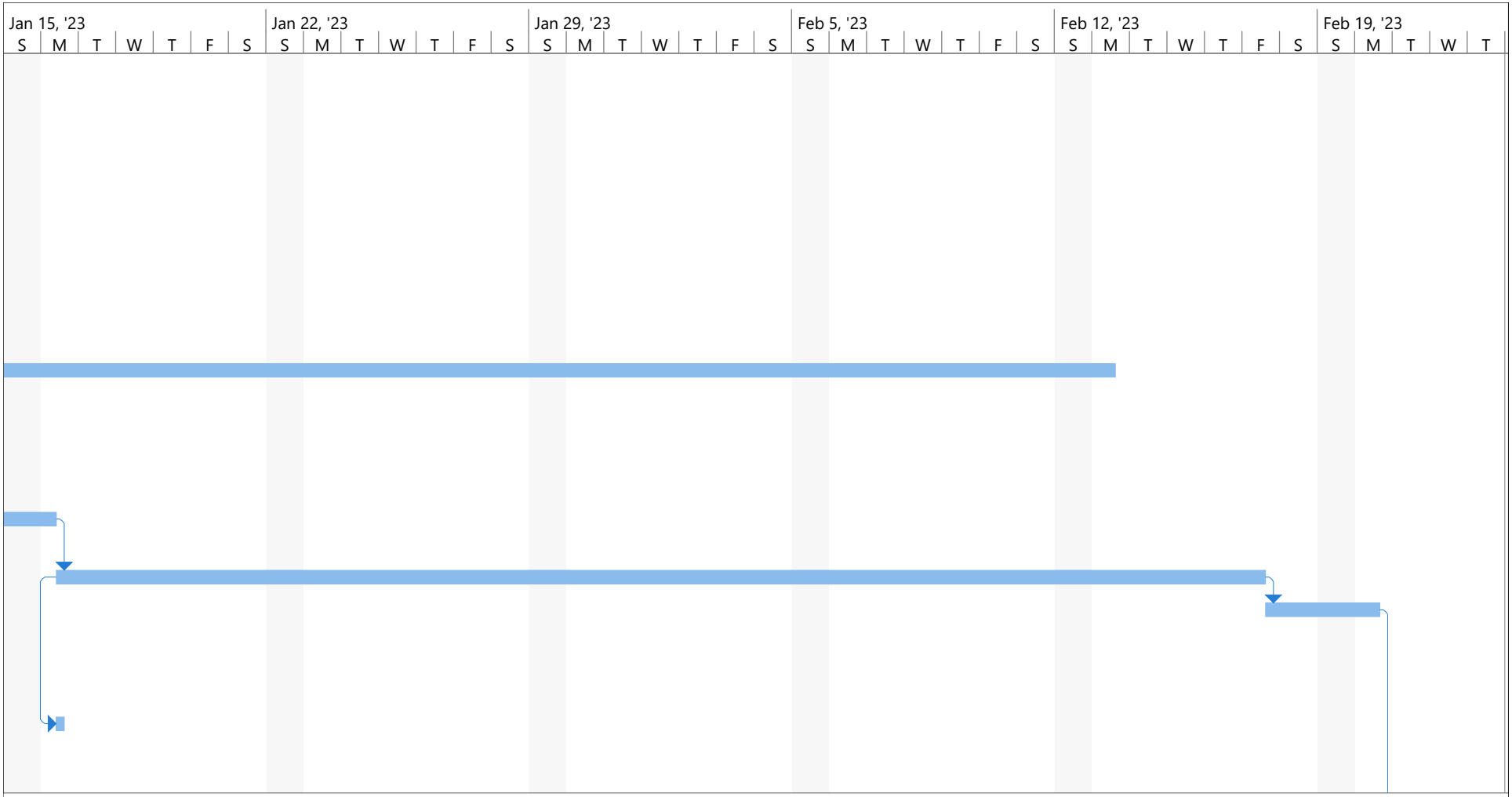
Task	Inactive Summary	External Tasks			
Split	Manual Task	External Milestone			
Milestone	Duration-only	Deadline			
Summary	Manual Summary Rollup	Progress			
Project Summary	Manual Summary	Manual Progress			
Inactive Task	Start-only				
Inactive Milestone	Finish-only				

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
14		Turbine connection and placement	0.5 days	Mon 2/20/23	Tue 2/21/23	12
15		System inspection and cleanup	2 days	Tue 2/21/23	Thu 2/23/23	14



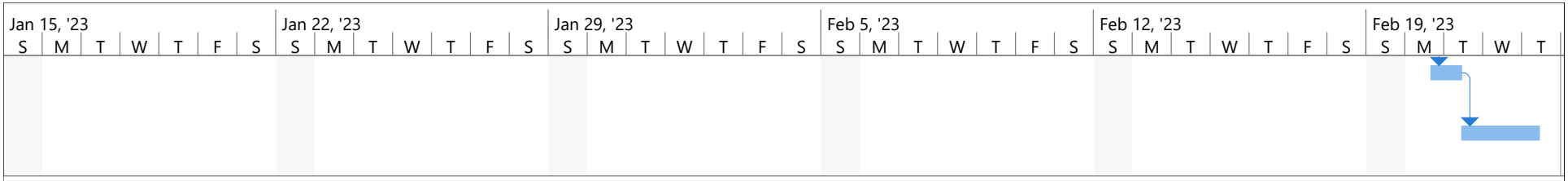
Project: Project1
Date: Wed 5/4/22





Project: Project1
Date: Wed 5/4/22

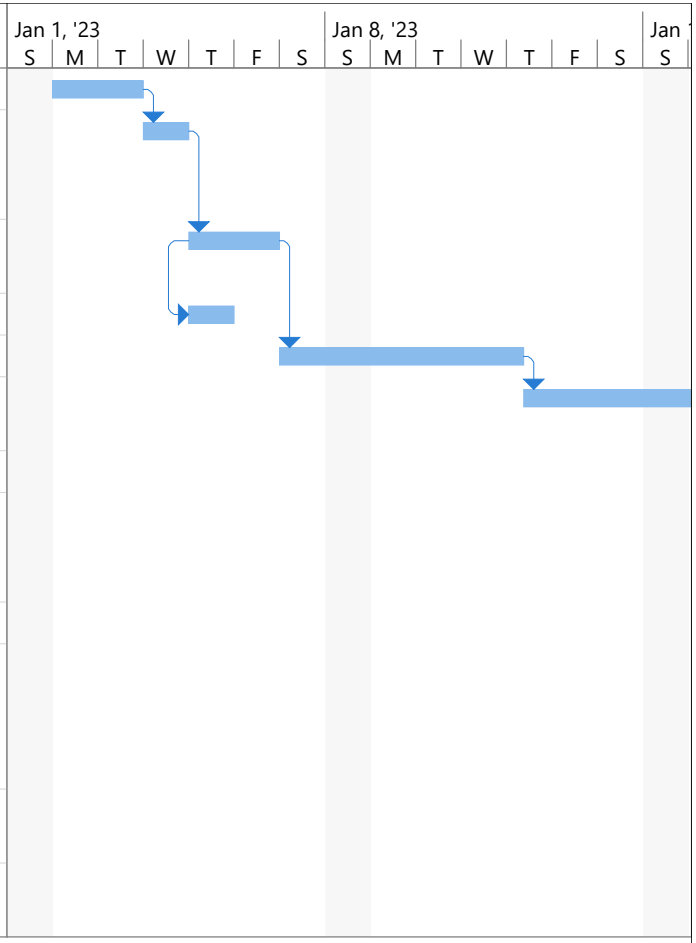
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Wed 5/4/22

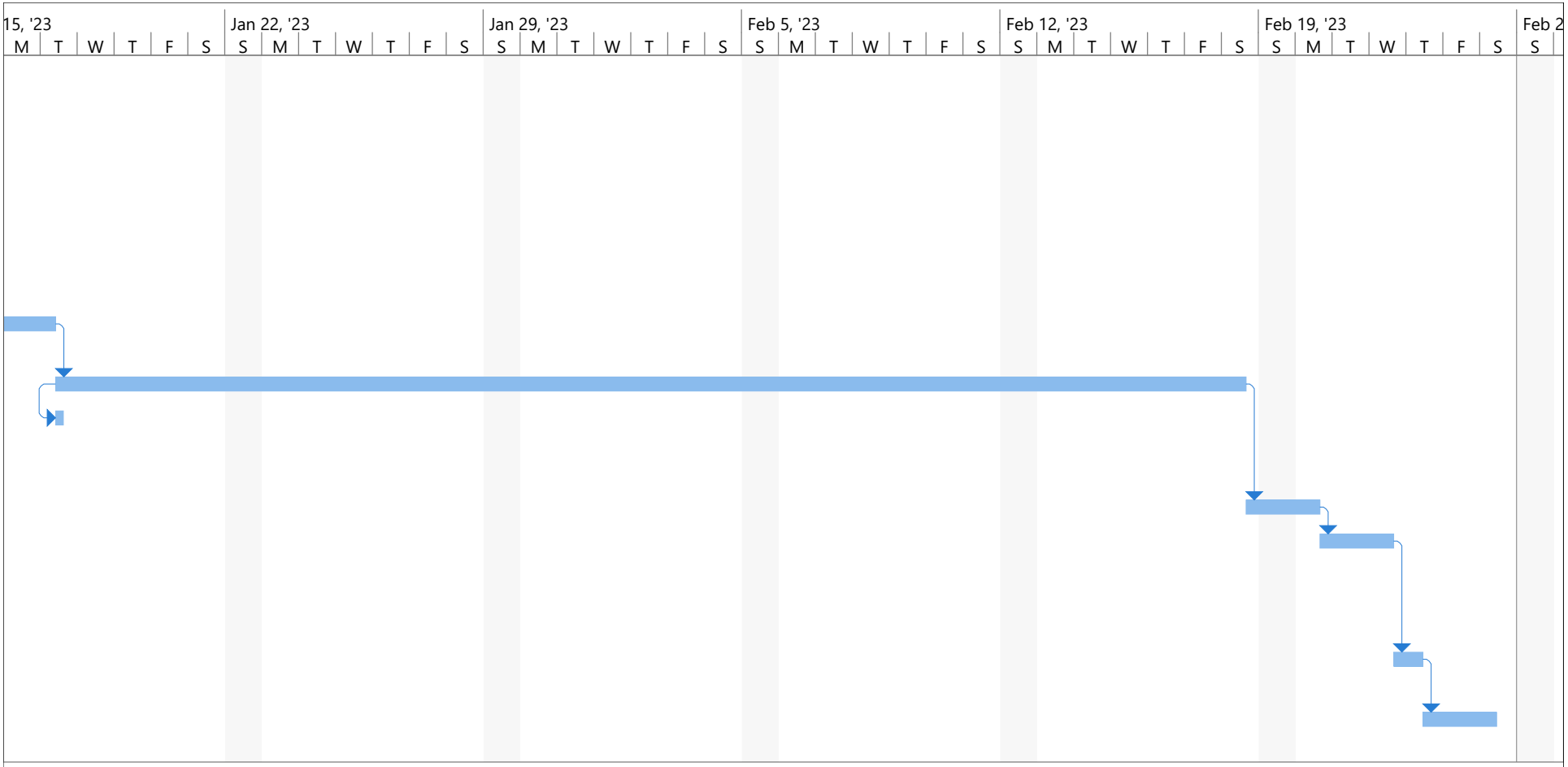
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation for footings	2 days	Thu 1/5/23	Fri 1/6/23	2
4		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	3SS
5		Rebar placement	4 days	Sat 1/7/23	Thu 1/12/23	3
6		Concrete forms pouring of concrete	4 days	Thu 1/12/23	Tue 1/17/23	5
7		Concrete Curing	28 days	Tue 1/17/23	Sat 2/18/23	6
8		Installation of cable connection to concrete footing	0.5 days	Tue 1/17/23	Tue 1/17/23	7SS
9		Backfill footers	1 day	Sat 2/18/23	Mon 2/20/23	7
10		Installation of turbine(s) by manufactures directions	2 days	Mon 2/20/23	Wed 2/22/23	9
11		Turbine connection and placement	0.5 days	Wed 2/22/23	Thu 2/23/23	10
12		System inspection and cleanup	2 days	Thu 2/23/23	Sat 2/25/23	11



Project: Project1
Date: Wed 5/4/22

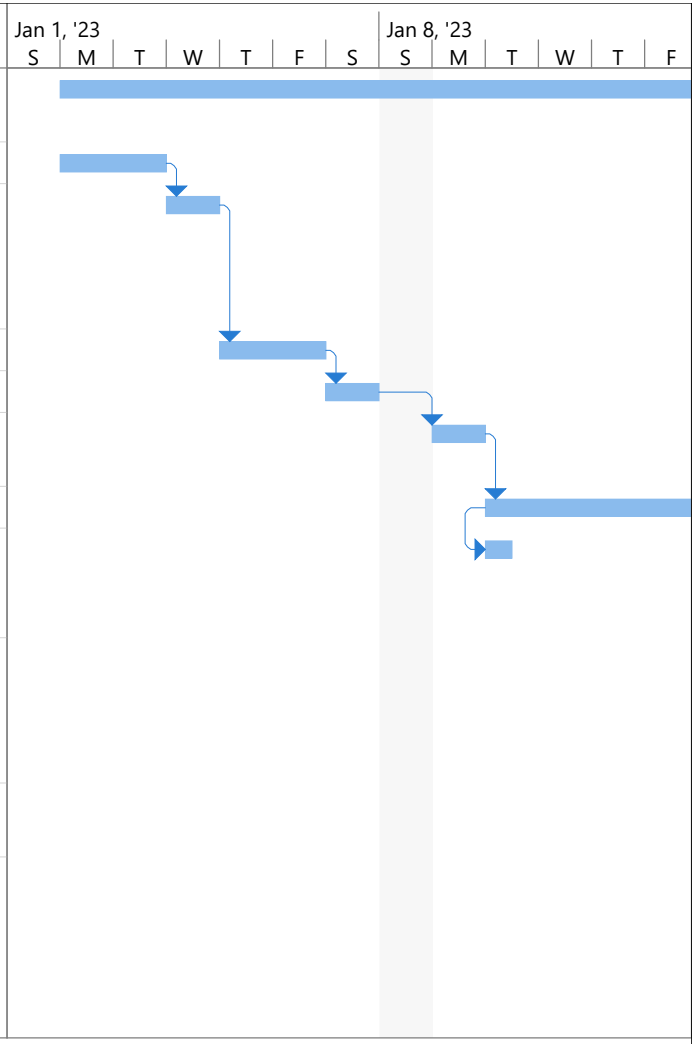
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

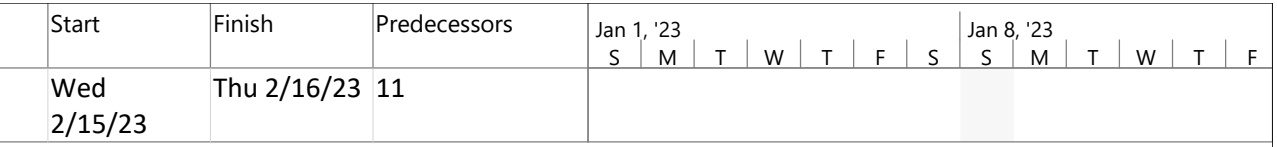
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Shipping of Turbine(s)	14 days	Mon 1/2/23	Tue 1/17/23	
2		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
3		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	2
4		Excavation of rock	2 days	Thu 1/5/23	Fri 1/6/23	3
5		Placement of anchor	1 day	Sat 1/7/23	Sat 1/7/23	4
6		Pouring of structural grout	1 day	Mon 1/9/23	Mon 1/9/23	5
7		Grout Curing	28 days	Tue 1/10/23	Fri 2/10/23	6
8		Installation of cable connection to rock anchor	0.5 days	Tue 1/10/23	Tue 1/10/23	7SS
9		Installation of turbine(s) by manufactures directions	2 days	Sat 2/11/23	Mon 2/13/23	7,1
10		Turbine connection to rock anchor	0.5 days	Tue 2/14/23	Tue 2/14/23	9
11		Turbine Connection to river anchor and placement based on manufactures directions	0.5 days	Tue 2/14/23	Tue 2/14/23	10



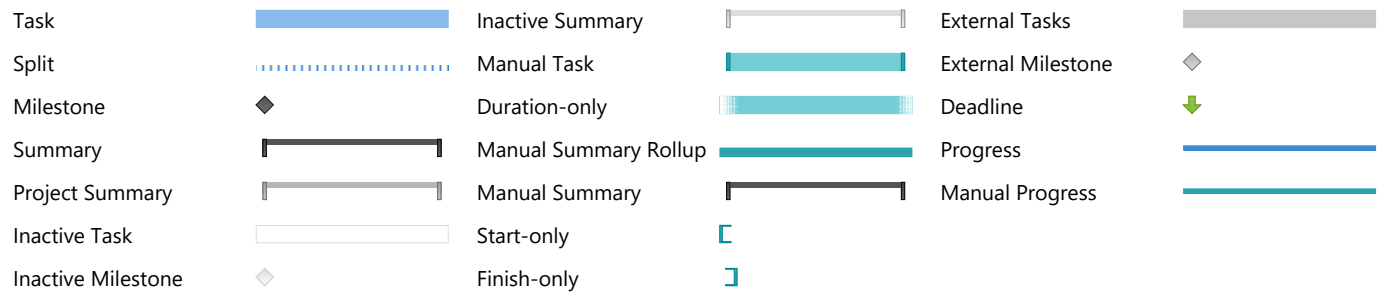
Project: In Rock Anchor
Date: Wed 5/4/22

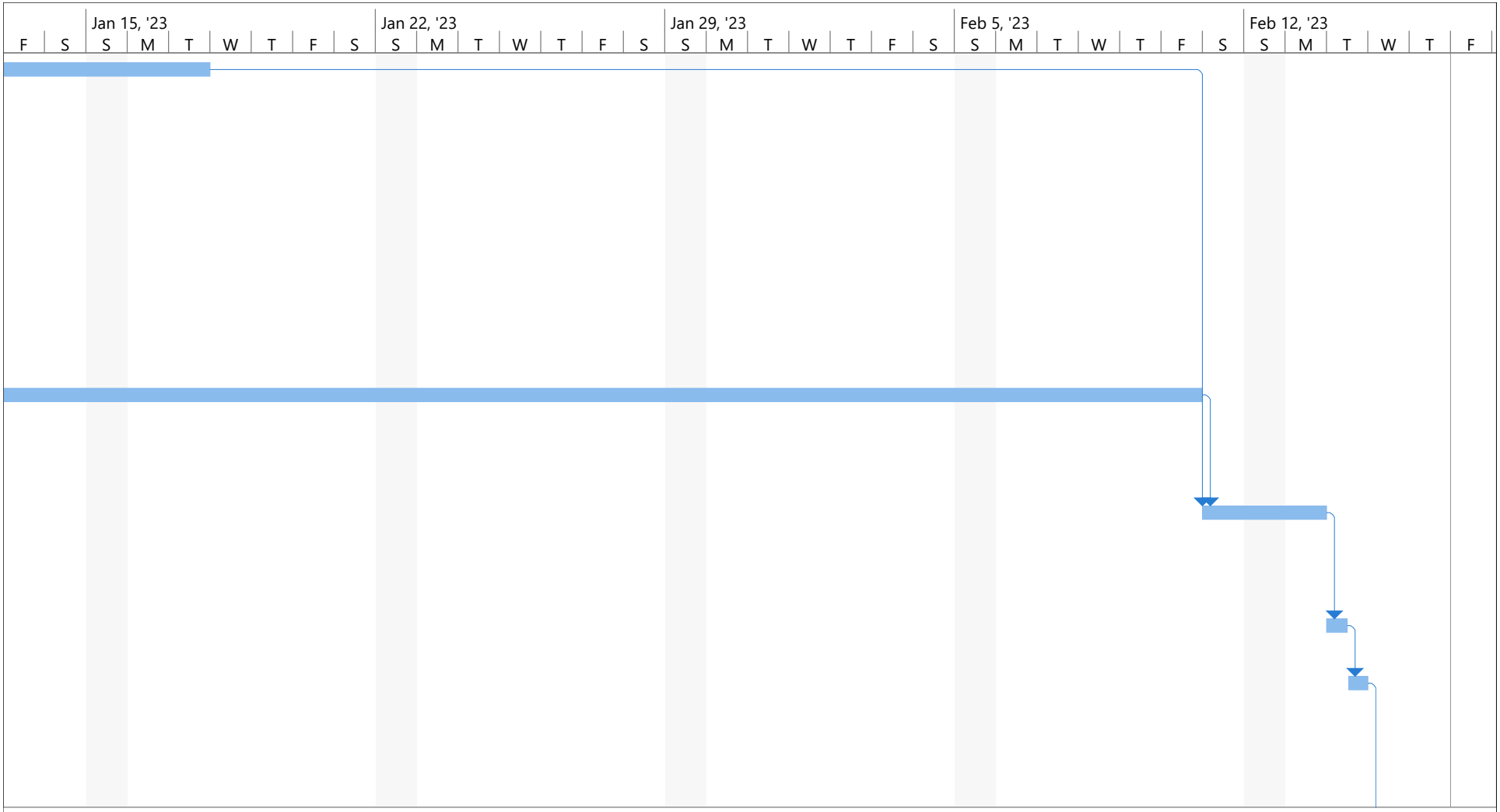
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
12		System inspection and cleanup	2 days	Wed 2/15/23	Thu 2/16/23	11



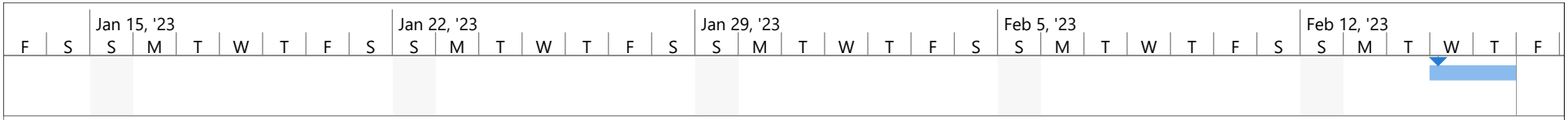
Project: In Rock Anchor
Date: Wed 5/4/22





Project: In Rock Anchor
Date: Wed 5/4/22

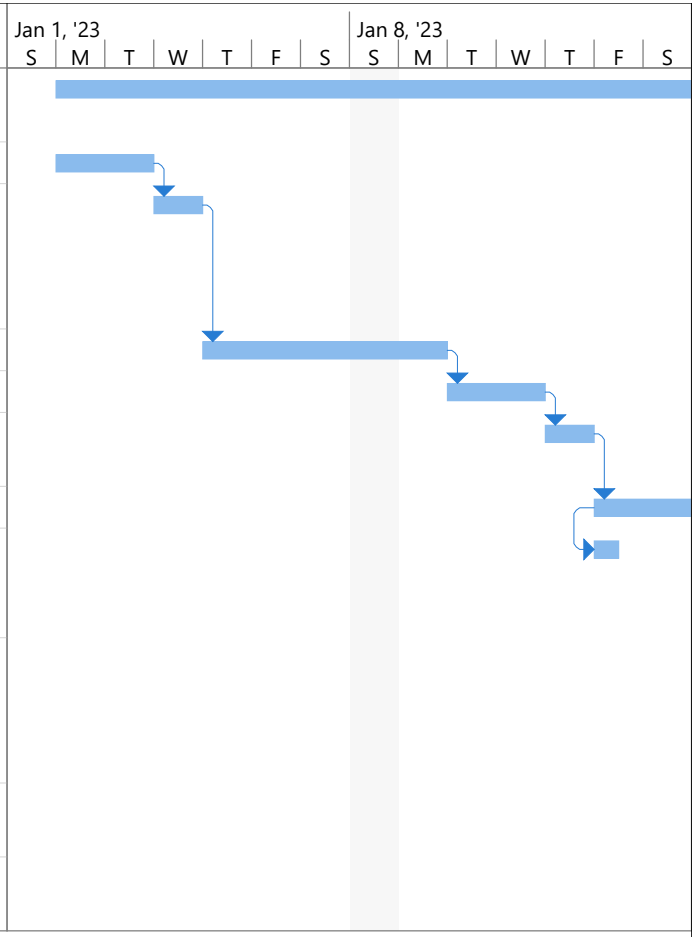
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: In Rock Anchor
Date: Wed 5/4/22

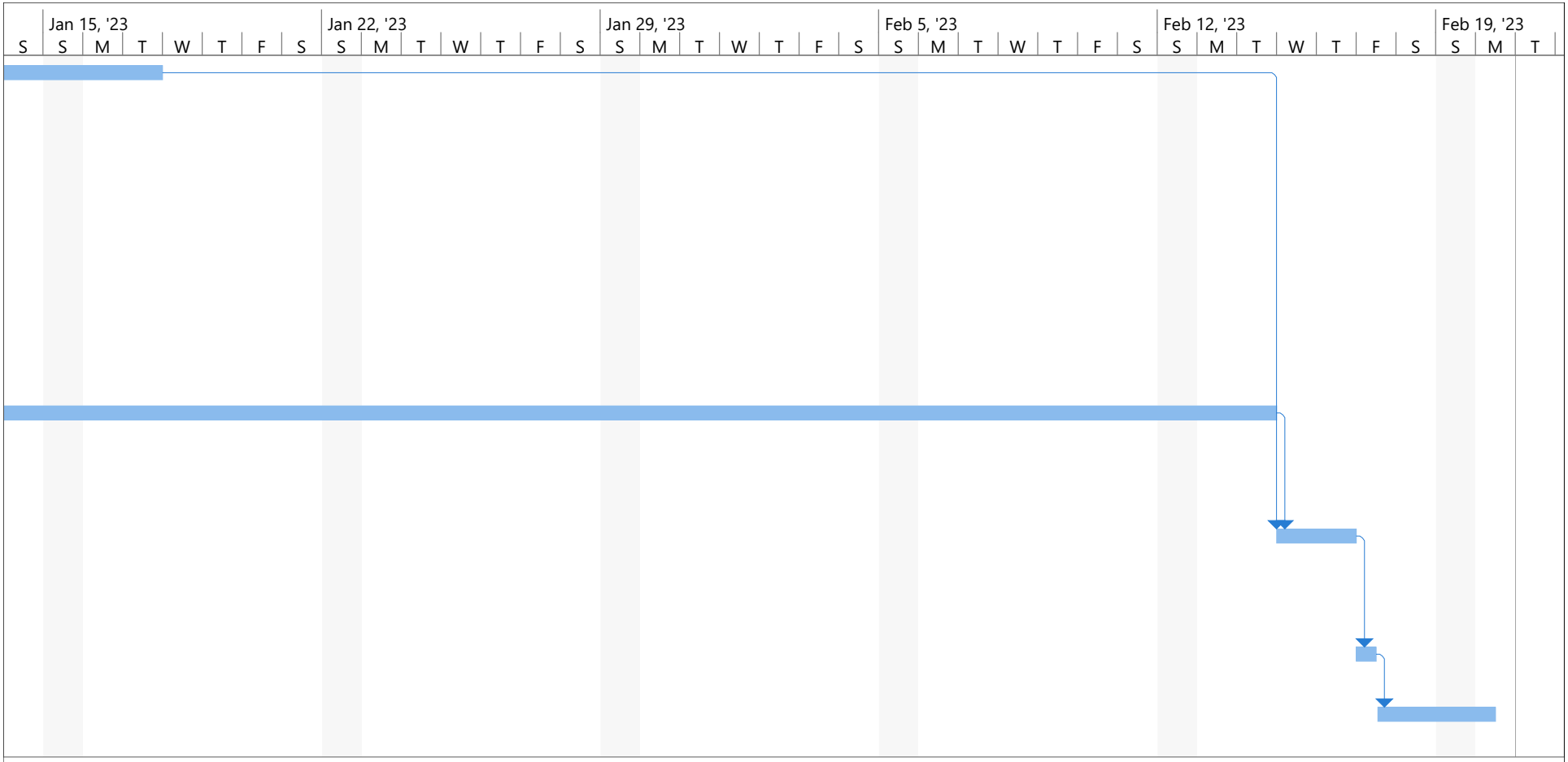
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Shipping of Turbine(s)	14 days	Mon 1/2/23	Tue 1/17/23	
2		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
3		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	2
4		Excavation of rock	4 days	Thu 1/5/23	Mon 1/9/23	3
5		Placement of anchor	2 days	Tue 1/10/23	Wed 1/11/23	4
6		Pouring of structural grout	1 day	Thu 1/12/23	Thu 1/12/23	5
7		Grout Curing	28 days	Fri 1/13/23	Tue 2/14/23	6
8		Installation of cable connection to rock anchor	0.5 days	Fri 1/13/23	Fri 1/13/23	7SS
9		Installation of turbine(s) by manufactures directions	2 days	Wed 2/15/23	Thu 2/16/23	7,1
10		Turbine connection and placement	0.5 days	Fri 2/17/23	Fri 2/17/23	9
11		System inspection and cleanup	2 days	Fri 2/17/23	Mon 2/20/23	10



Project: In Rock Anchor
Date: Wed 5/4/22

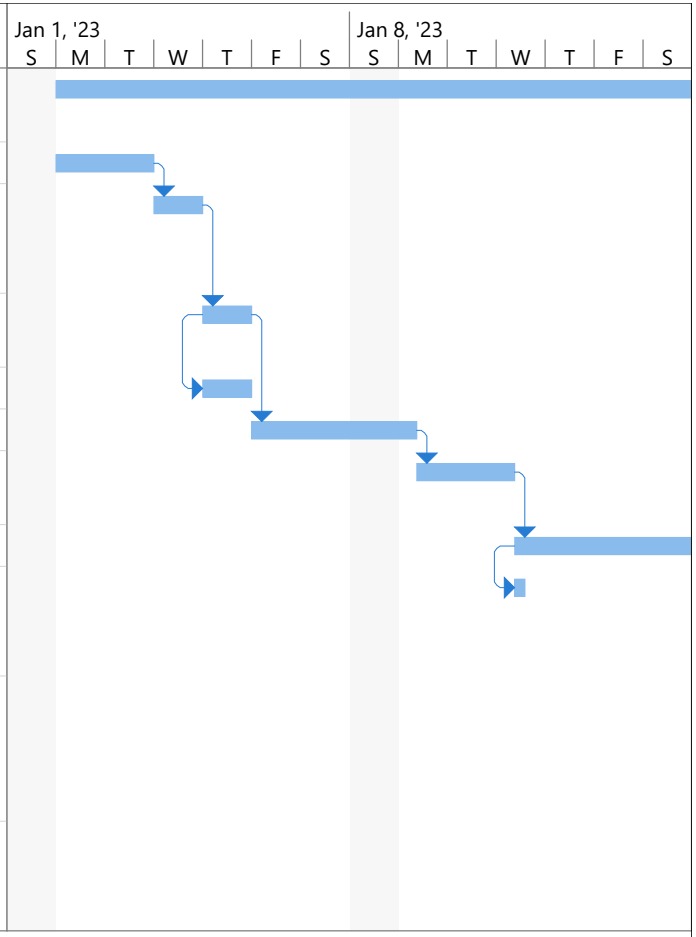
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: In Rock Anchor
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

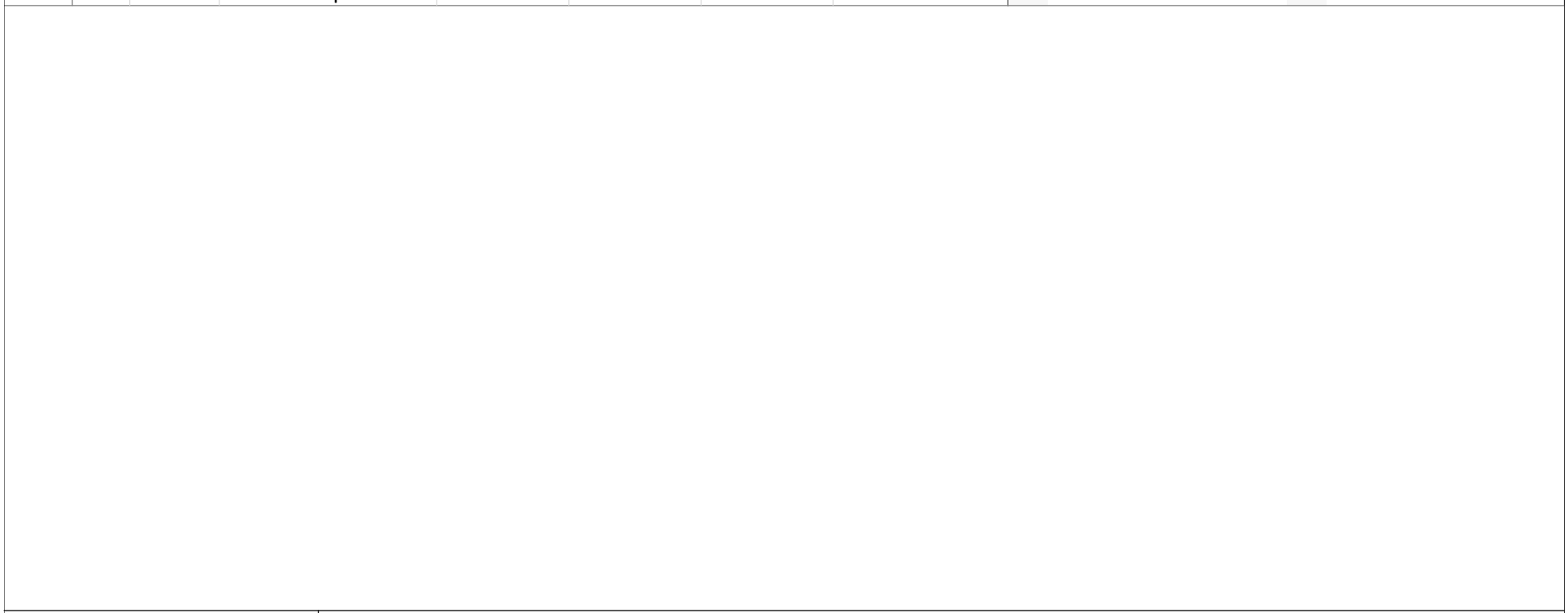
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Shipping of Turbine(s)	14 days	Mon 1/2/23	Wed 1/18/23	
2		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
3		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	2
4		Excavation for footings	1 day	Thu 1/5/23	Thu 1/5/23	3
5		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	4SS
6		Rebar placement	2 days	Fri 1/6/23	Mon 1/9/23	4
7		Concrete forms pouring of concrete	2 days	Mon 1/9/23	Wed 1/11/23	6
8		Concrete Curing	28 days	Wed 1/11/23	Mon 2/13/23	7
9		Installation of cable connection to concrete footing	0.5 days	Wed 1/11/23	Wed 1/11/23	8SS
10		Construction of turbines by manufactures directions	2 days	Mon 2/13/23	Wed 2/15/23	8,1
11		Turbine connection and placement to soil anchor	0.5 days	Mon 2/13/23	Tue 2/14/23	8



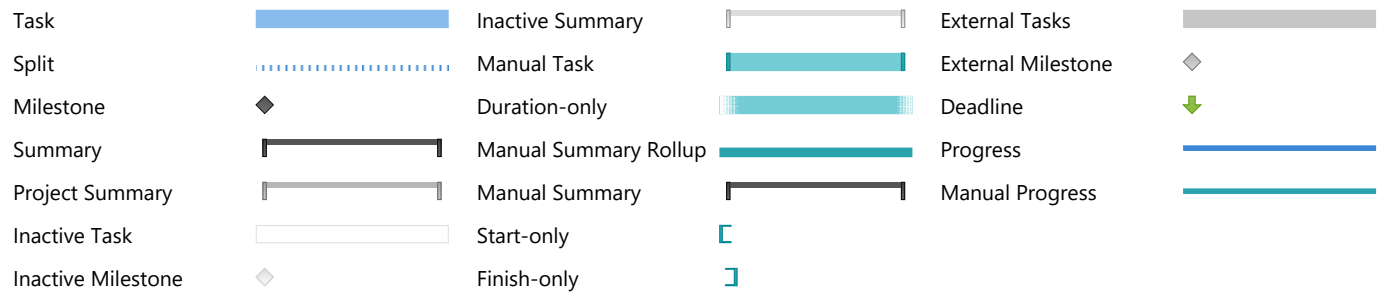
Project: Project1
Date: Wed 5/4/22

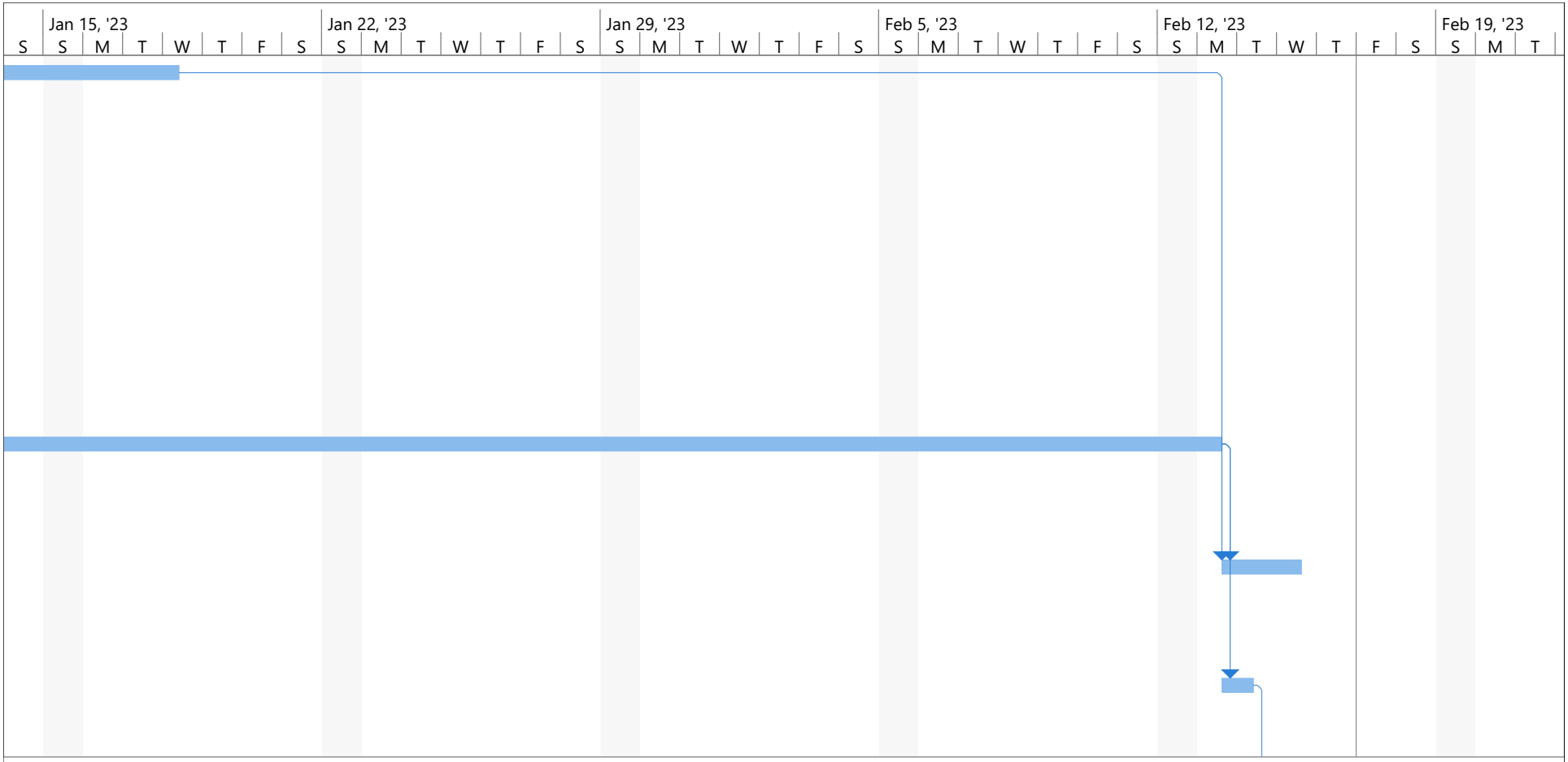
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
12		Turbine Connection to river anchor and placement based on manufactures directions	0.5 days	Tue 2/14/23	Tue 2/14/23	11
13		System inspection and cleanup	2 days	Tue 2/14/23	Thu 2/16/23	12



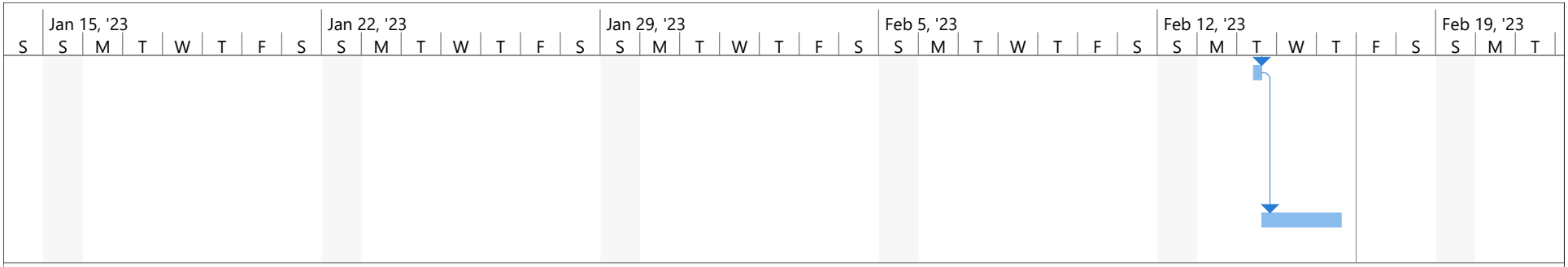
Project: Project1
Date: Wed 5/4/22





Project: Project1
Date: Wed 5/4/22

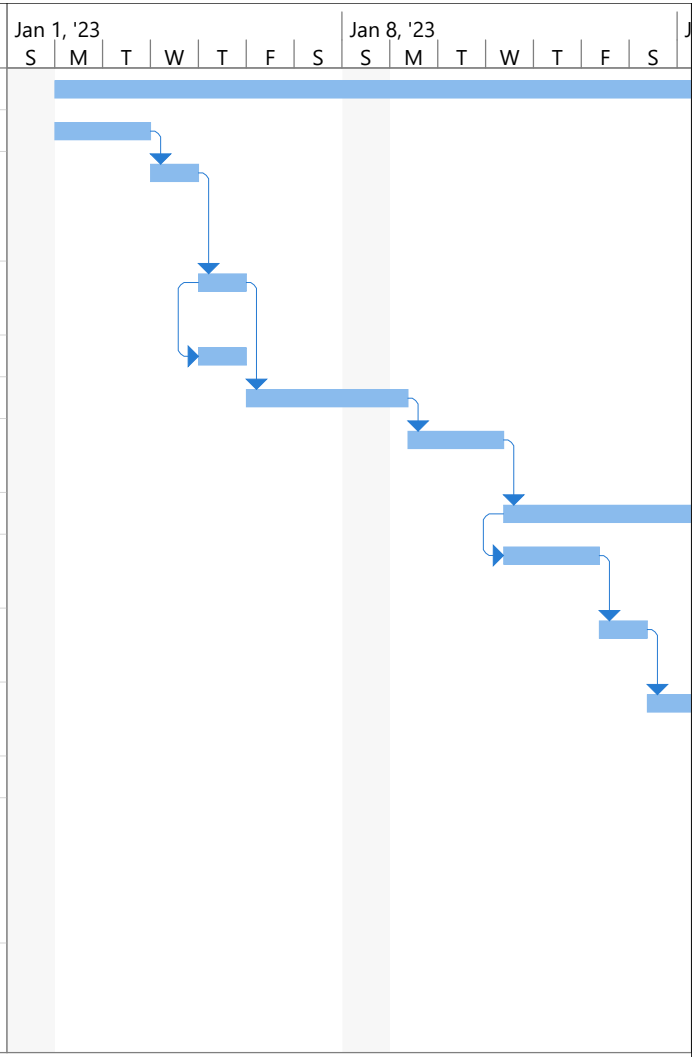
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Wed 5/4/22

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

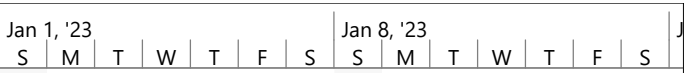
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Shipping of Turbines	14 days	Mon 1/2/23	Wed 1/18/23	
2		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
3		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	2
4		Excavation for soil footings	1 day	Thu 1/5/23	Thu 1/5/23	3
5		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	4SS
6		Rebar placement	2 days	Fri 1/6/23	Mon 1/9/23	4
7		Concrete forms pouring of concrete	2 days	Mon 1/9/23	Wed 1/11/23	6
8		Concrete Curing	28 days	Wed 1/11/23	Mon 2/13/23	7
9		Excavation for rock anchor	2 days	Wed 1/11/23	Fri 1/13/23	8SS
10		Placement of rock anchor	1 day	Fri 1/13/23	Sat 1/14/23	9
11		Pouring of structural grout	1 day	Sat 1/14/23	Mon 1/16/23	10
12		Grout cruing	28 days	Mon 1/16/23	Fri 2/17/23	11
13		Installation of turbine(s) by manufactures directions	2 days	Fri 2/17/23	Mon 2/20/23	12,1
14		Installation of cable connection to concrete footing	0.5 days	Mon 1/16/23	Mon 1/16/23	12SS



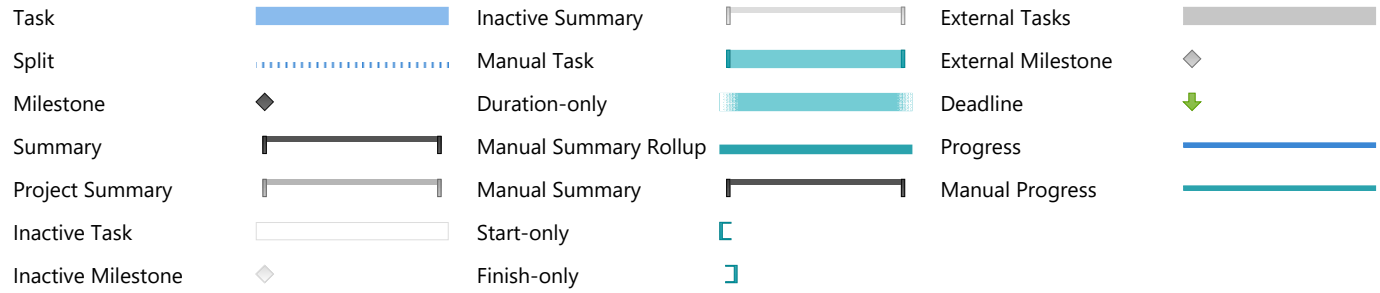
Project: Project1
Date: Wed 5/4/22

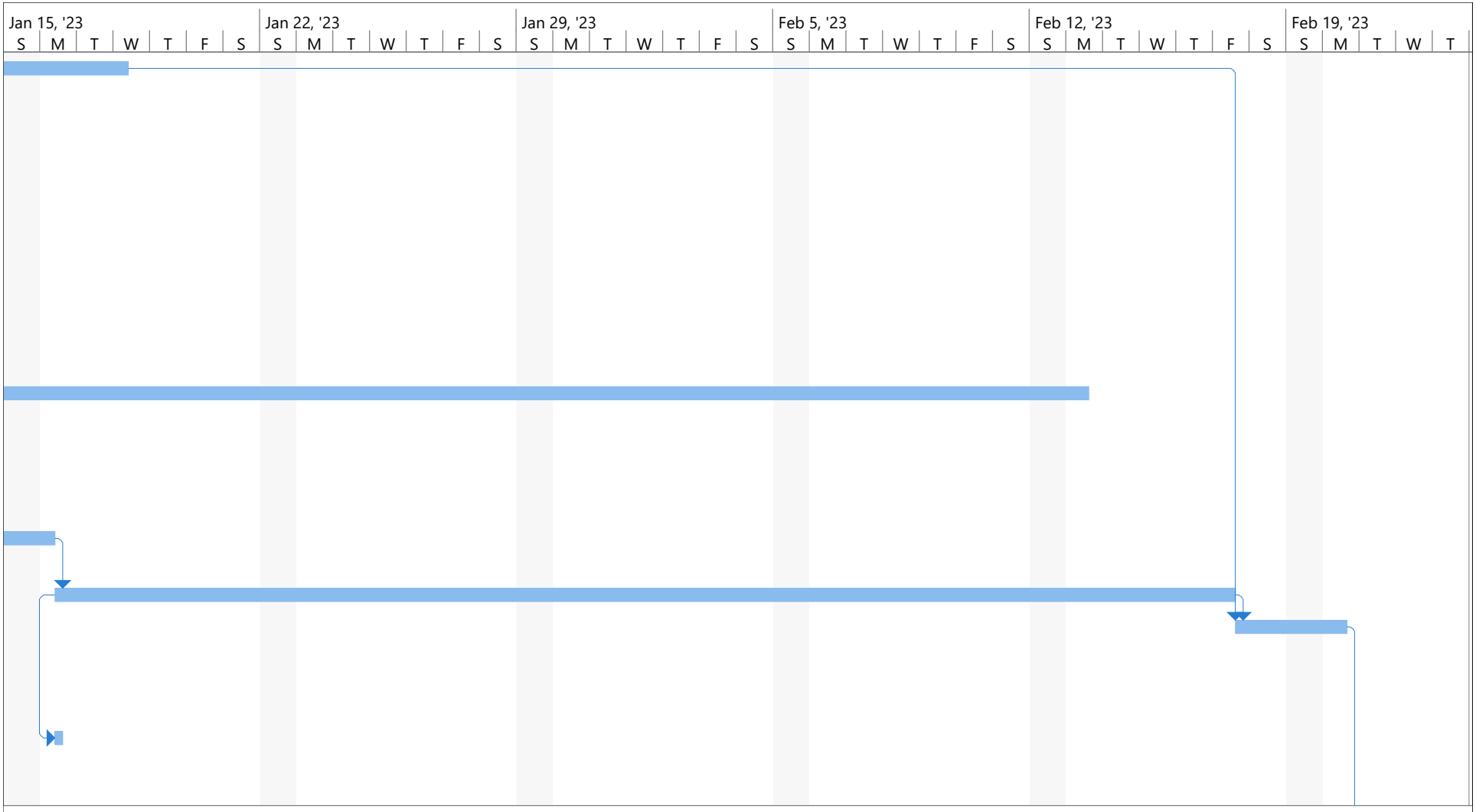
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
15		Turbine connection and placement	0.5 days	Mon 2/20/23	Tue 2/21/23	13
16		System inspection and cleanup	2 days	Tue 2/21/23	Thu 2/23/23	15



Project: Project1
Date: Wed 5/4/22





Project: Project1
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
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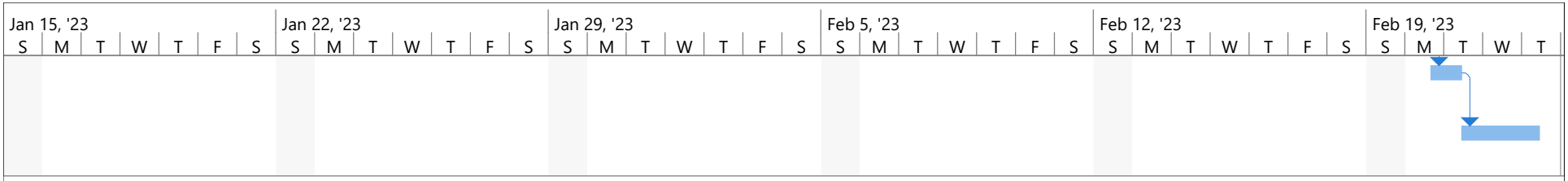
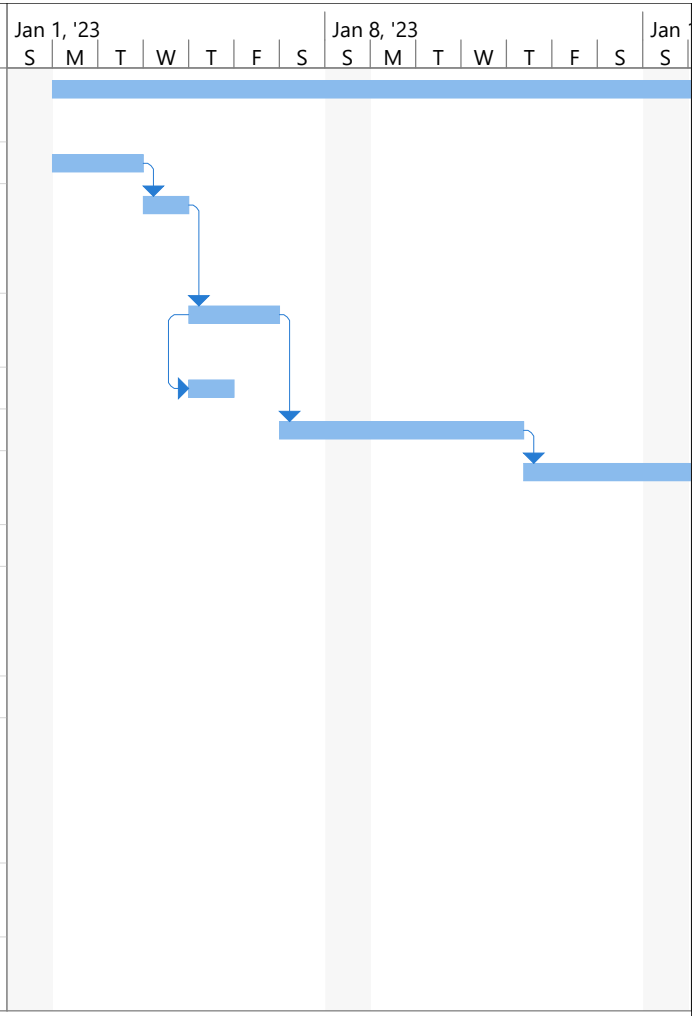
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Shipping of turbine(s)	14 days	Mon 1/2/23	Wed 1/18/23	
2		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
3		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	2
4		Excavation for footings	2 days	Thu 1/5/23	Fri 1/6/23	3
5		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	4SS
6		Rebar placement	4 days	Sat 1/7/23	Thu 1/12/23	4
7		Concrete forms pouring of concrete	4 days	Thu 1/12/23	Tue 1/17/23	6
8		Concrete Curing	28 days	Tue 1/17/23	Sat 2/18/23	7
9		Installation of cable connection to concrete footing	0.5 days	Tue 1/17/23	Tue 1/17/23	8SS
10		Backfill footers	1 day	Sat 2/18/23	Mon 2/20/23	8
11		Installation of turbine(s) by manufactures directions	2 days	Mon 2/20/23	Wed 2/22/23	1,10
12		Turbine connection and placement	0.5 days	Wed 2/22/23	Thu 2/23/23	11
13		System inspection and cleanup	2 days	Thu 2/23/23	Sat 2/25/23	12



Project: Project1
Date: Wed 5/4/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
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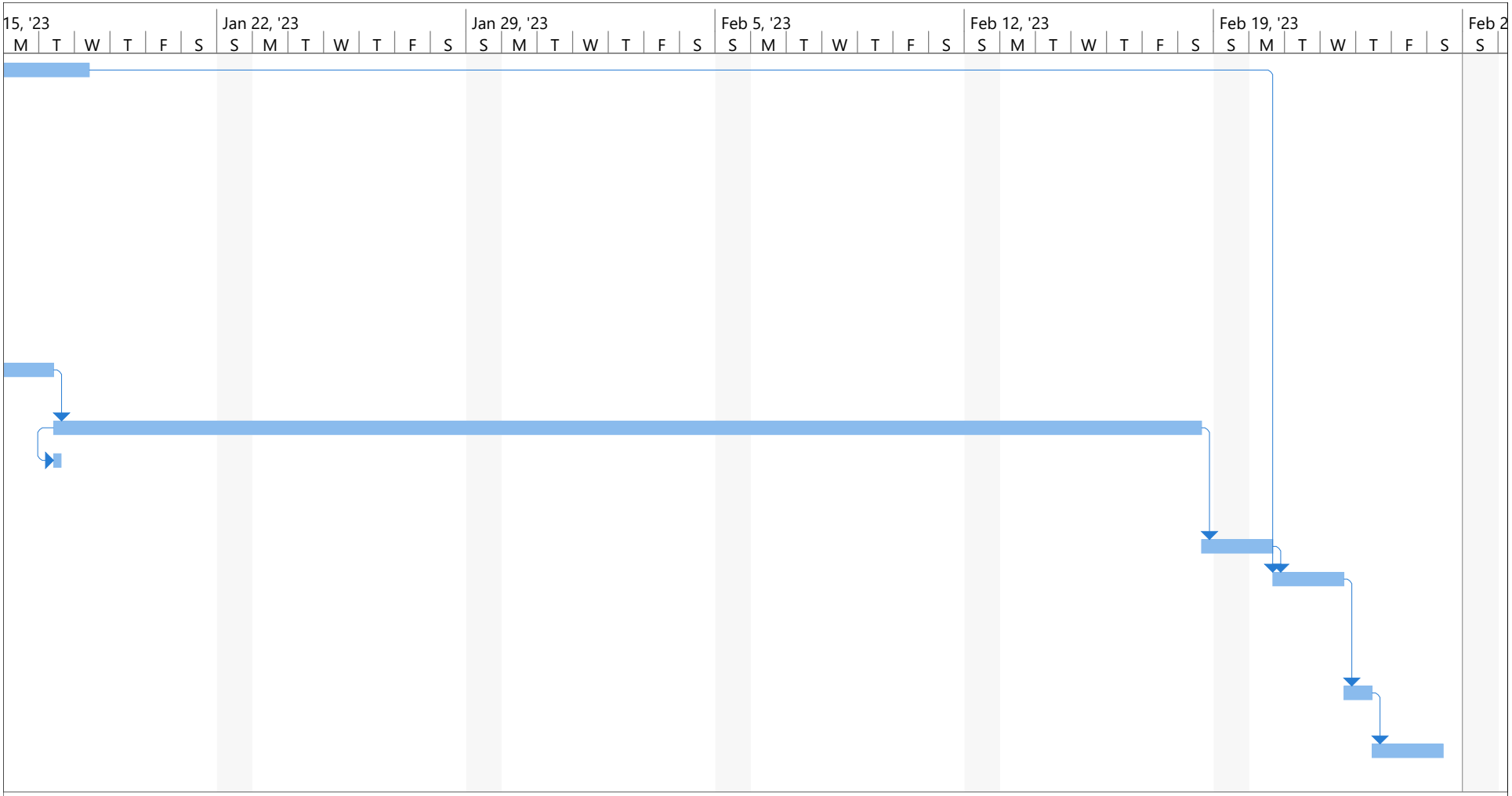
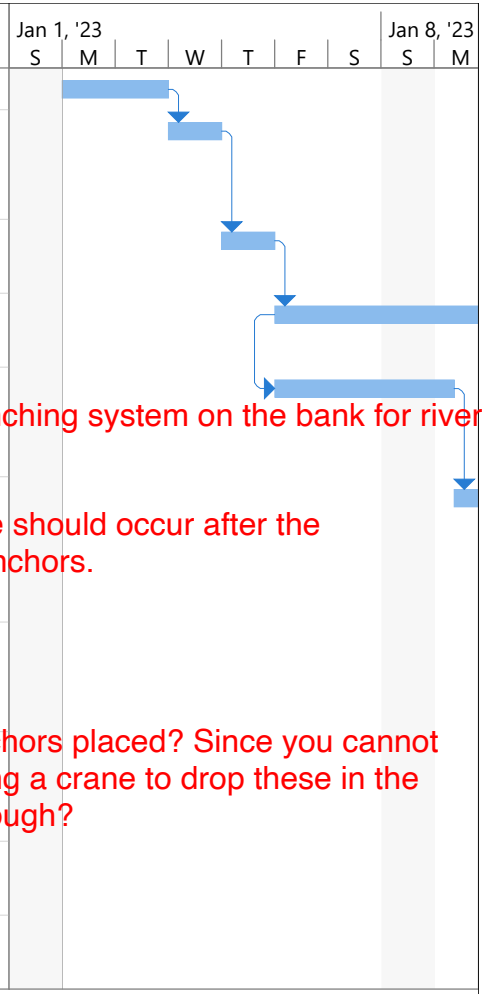
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Wed 5/4/22

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		Mobilitzation	2 days	Mon 1/2/23	Tue 1/3/23		
2		Determine placement based on parameters	1 day	Wed 1/4/23	Wed 1/4/23	1	
3		Forming and pouring of concrete anchors	1 day	Thu 1/5/23	Thu 1/5/23	2	
4		Concrete ~~Procurement~~ Curing	28 days	Fri 1/6/23	Wed 2/8/23	3	
5		Placement of ~~whinching~~ system on bank	2 days	Fri 1/6/23	Mon 1/9/23	4SS	
6		~~Construction~~ Installation of Turbine by manufactures directions	2 days	Mon 1/9/23	Wed 1/11/23	5	
7		Installation of cable connections to anchor blocks	0.5 days	Wed 2/8/23	Thu 2/9/23	4	
8		Placement of concrete anchors into Rio Chico	0.5 days	Thu 2/9/23	Thu 2/9/23	7	
9		Turbine connection and placement	0.5 days	Thu 2/9/23	Fri 2/10/23	8	
10		System inspection and cleanup	2 days	Fri 2/10/23	Mon 2/13/23	9	



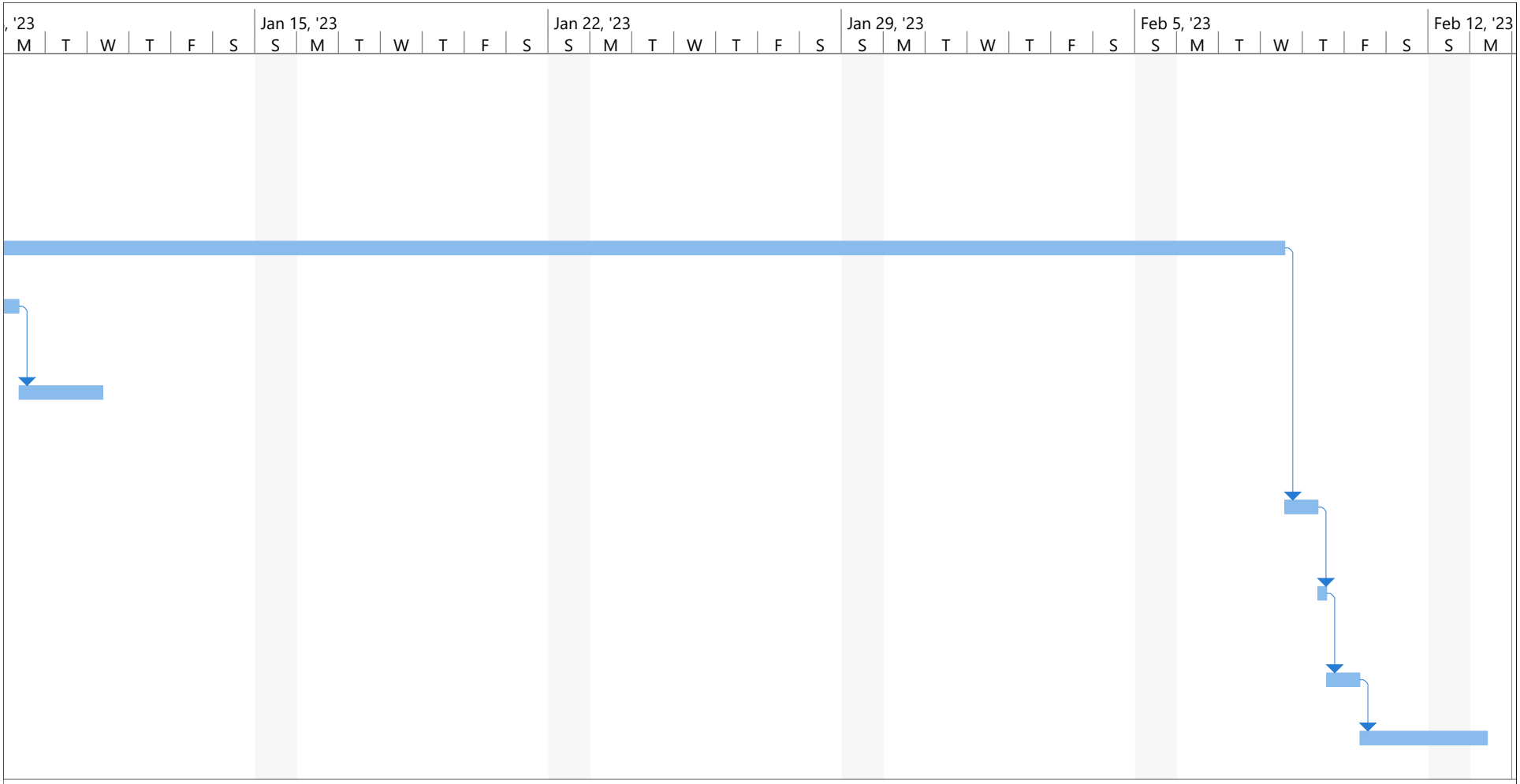
Do you need a winching system on the bank for river anchors?

Installation of the turbine should occur after the placement of the river anchors.

How are the river anchors placed? Since you cannot dewater, are you using a crane to drop these in the river? Is 0.5 days enough?

Project: Project1
Date: Wed 4/27/22

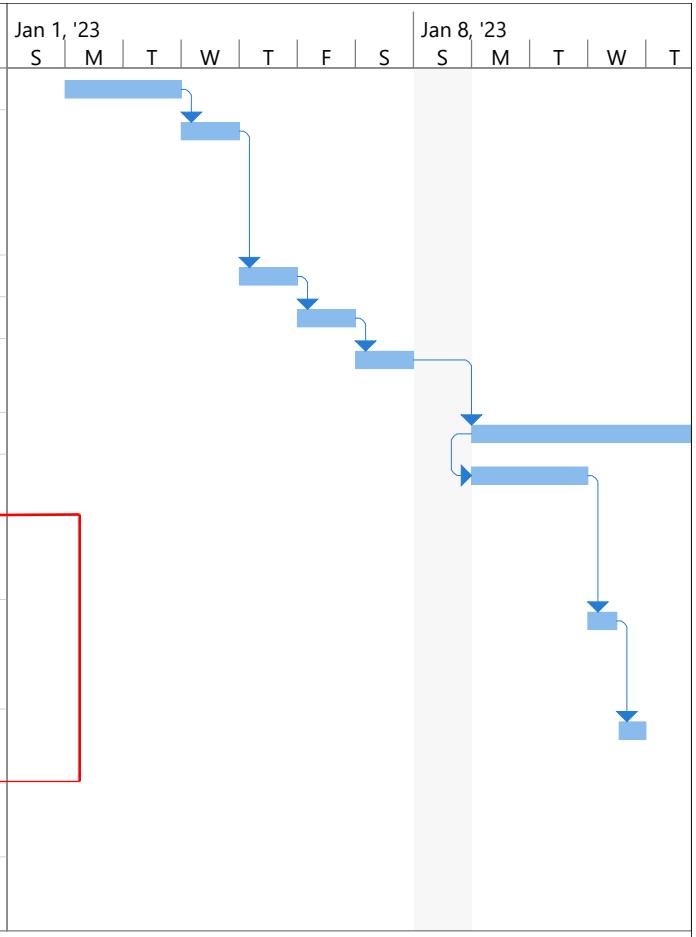
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			



Project: Project1
Date: Wed 4/27/22

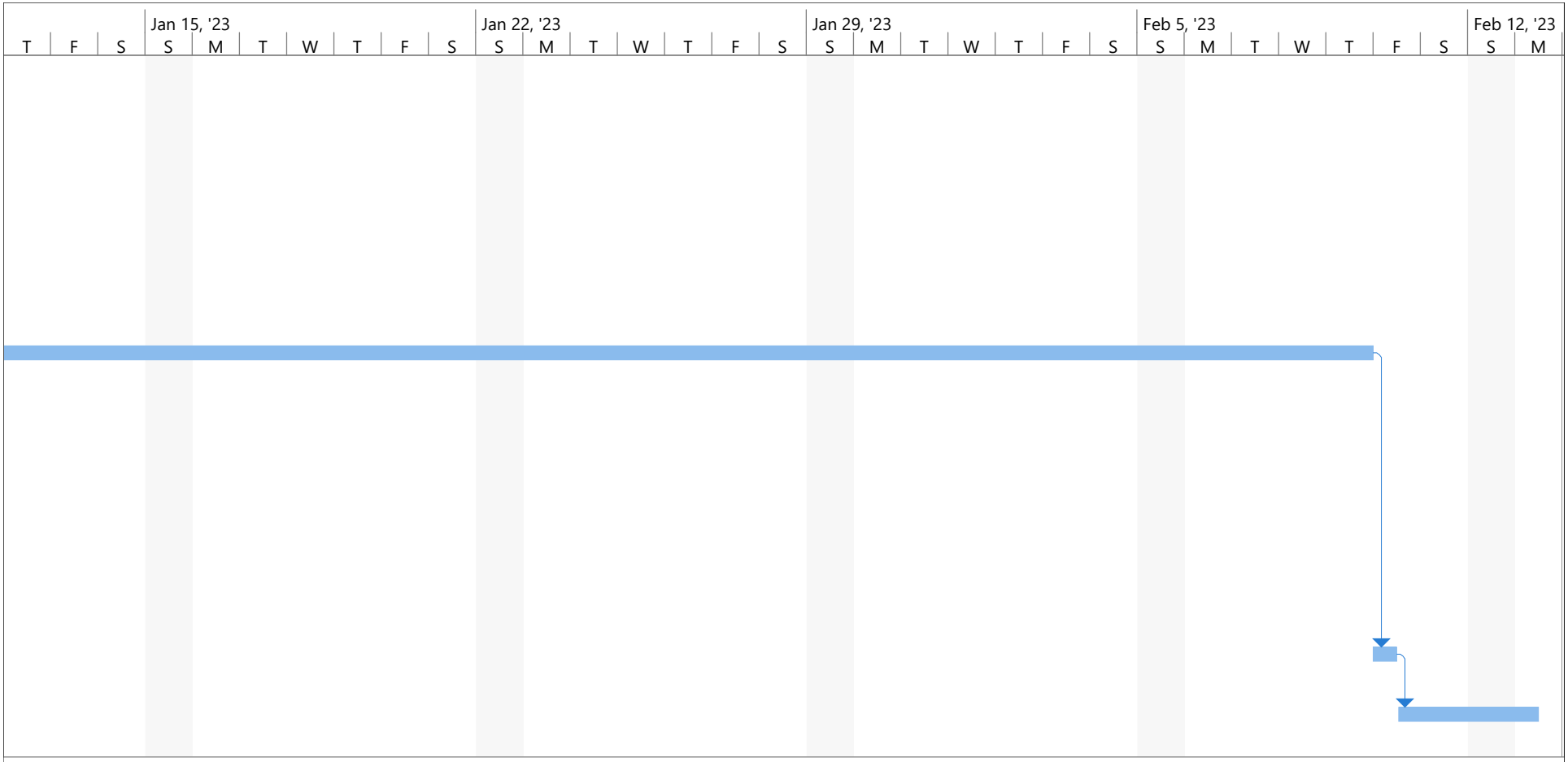
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement of turbine(s) based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation of rock	1 day	Thu 1/5/23	Thu 1/5/23	2
4		Placement of anchor	1 day	Fri 1/6/23	Fri 1/6/23	3
5		Pouring of structural grout	1 day	Sat 1/7/23	Sat 1/7/23	4
6		Grout ~~procurement~~ Curing	28 days	Mon 1/9/23	Thu 2/9/23	5
7		~~Construction~~ Installation of turbines by ~~manufactures~~ directions	2 days	Mon 1/9/23	Tue 1/10/23	6SS
8		Installation of cable connection to rock anchor	0.5 days	Wed 1/11/23	Wed 1/11/23	7
9		Installation of Winching system	0.5 days	Wed 1/11/23	Wed 1/11/23	8
10		Turbine connection and placement	0.5 days	Fri 2/10/23	Fri 2/10/23	6
11		System inspection and cleanup	2 days	Fri 2/10/23	Mon 2/13/23	10



Project: In Rock Anchor
Date: Wed 4/27/22

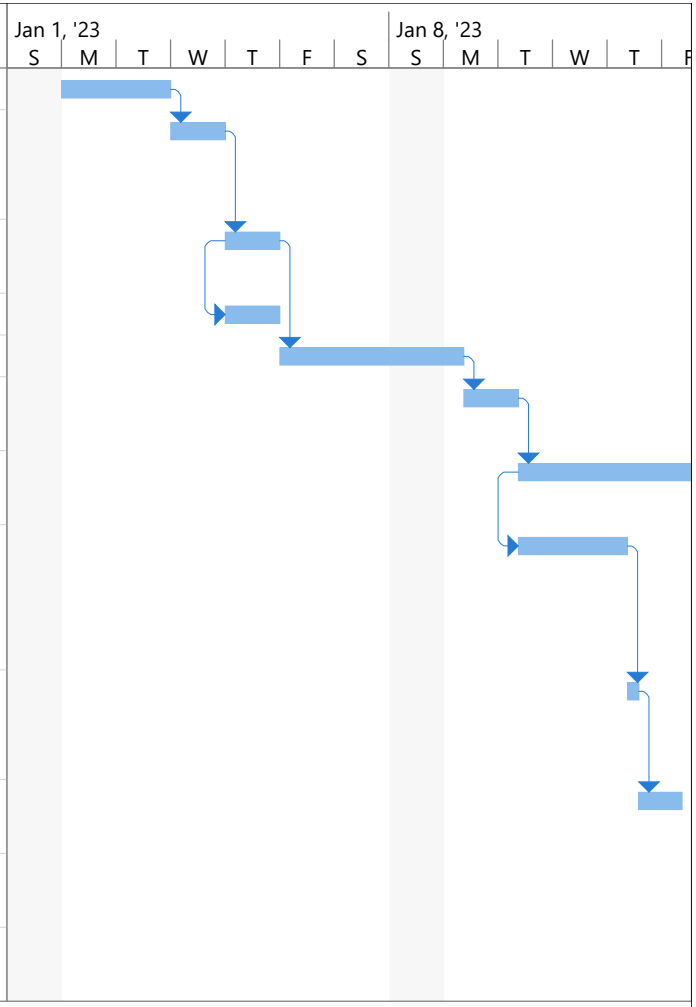
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: In Rock Anchor
Date: Wed 4/27/22

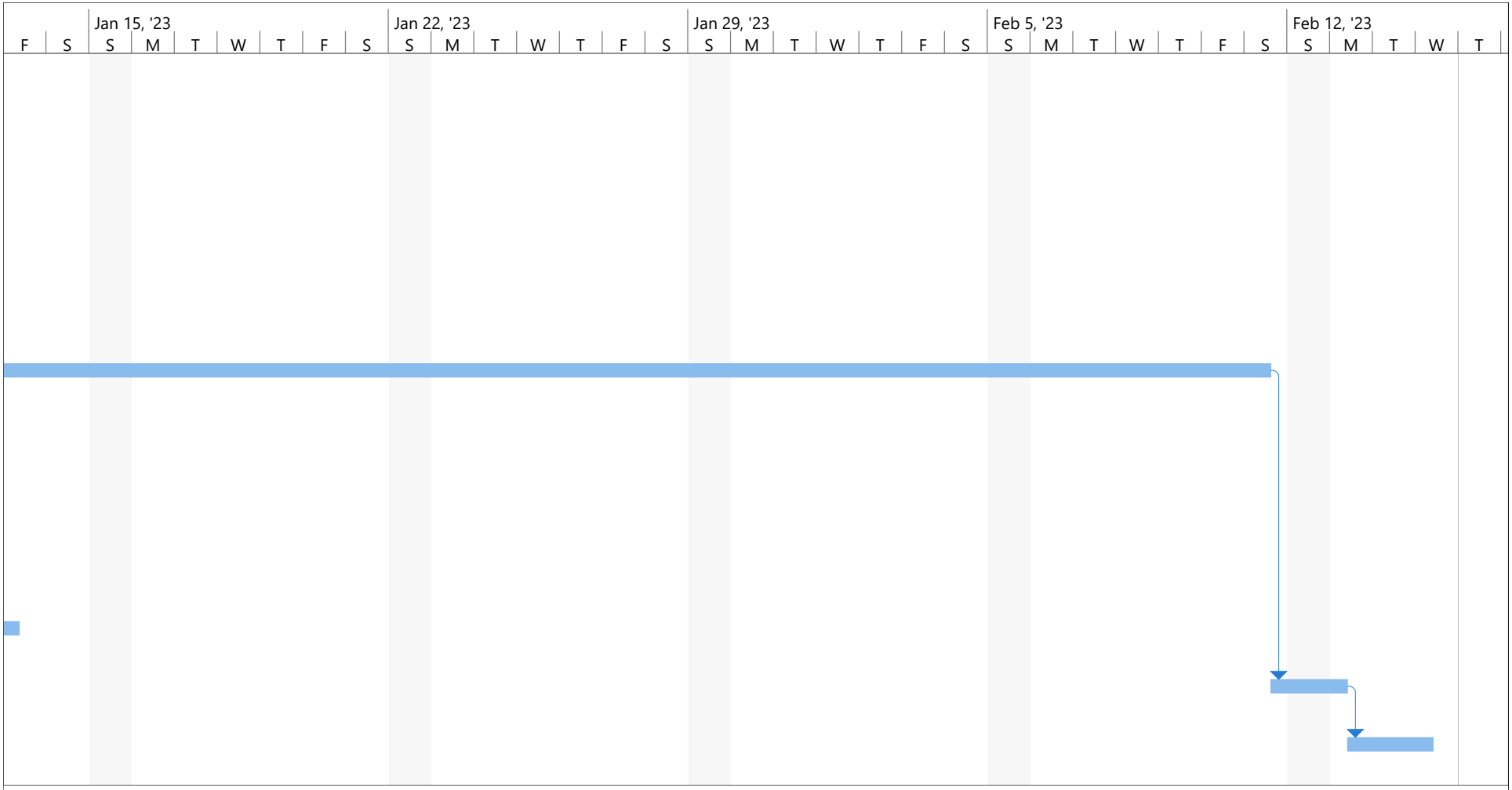
Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	2 days	Mon 1/2/23	Tue 1/3/23	
2		Determine placement based on engineered specs	1 day	Wed 1/4/23	Wed 1/4/23	1
3		Excavation for footings	1 day	Thu 1/5/23	Thu 1/5/23	2
4		Tamping of soil	1 day	Thu 1/5/23	Thu 1/5/23	3SS
5		Rebar placement	2 days	Fri 1/6/23	Mon 1/9/23	3
6		Concrete forms pouring of concrete	1 day	Mon 1/9/23	Tue 1/10/23	5
7		Concrete ~~procurement~~ Curing	28 days	Tue 1/10/23	Sat 2/11/23	6
8		Installation ~~Construction~~ of turbines by manufactures directions	2 days	Tue 1/10/23	Thu 1/12/23	7SS
9		Installation of cable connection to concrete footing	0.5 days	Thu 1/12/23	Thu 1/12/23	8
10		Installation of whinching system	0.5 days	Thu 1/12/23	Fri 1/13/23	9
11		Turbine connection and placement	0.5 days	Sat 2/11/23	Mon 2/13/23	7
12		System inspection and cleanup	2 days	Mon 2/13/23	Wed 2/15/23	11



Project: Project1
Date: Wed 4/27/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Project: Project1
Date: Wed 4/27/22

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

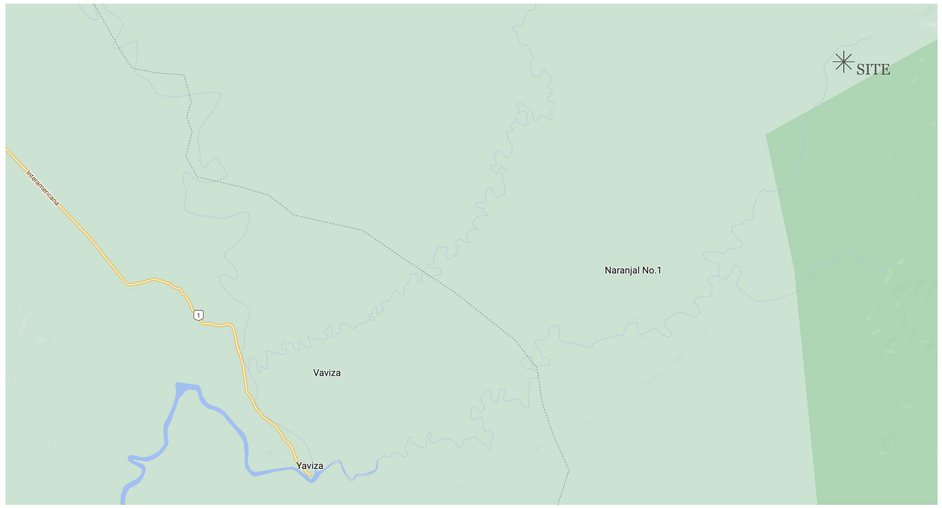
RIVER FLOW TEAM PRELIMINARY DRAWINGS

HYDROKINETIC TURBINE SYSTEM

NAZARÉT, PANAMA

SEMESTER - SPRING 2022

SITE VICINITY



SITE LOCATION: 8°16'34.4"N 77°31'23.6"W

PARTNERS

First UTILITY DISTRICT OF KNOX COUNTY

DLZ

TICKLE COLLEGE OF ENGINEERING
THE UNIVERSITY OF TENNESSEE, KNOXVILLE

solea water

811 Know what's below. Call before you dig.

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CE 399S & CE 400
FALL 2021 - SPRING 2022

RIVER FLOW TEAM

Team Members: Claudia Bible, AJ Condra,
Drew Houser, Nathan Smith, and Matthew Tolson

COVER SHEET

DATE
5/5/22

SCALE
NTS

DRAWN BY
MT

SHEET
C o

SHEET INDEX

SHEET	DESCRIPTION
C 0	COVER SHEET
C 1	SHEET INDEX & GENERAL NOTES
C 2a	ONE UNIT TURBINE OPTION, ON-LAND SUPPORTS
C 2b	ONE UNIT TURBINE OPTION, MIXED SUPPORTS
C 3a	TWO UNIT TURBINE OPTION, ON-LAND SUPPORTS
C 3b	TWO UNIT TURBINE OPTION, MIXED SUPPORTS
C 4a	CABLE, CONNECTION, AND IN-RIVER SUPPORT DETAILS
C 4b	BANK MOORING DETAILS

GENERAL NOTES

SITE:

1 - Measure channel dimensions at location prior to installation to confirm minimums are met.
2 - Confirm site river velocity to be at least 2.0m/s prior to installation.
3 - Given a one-support system is selected, ensure that river currents situate the turbine(s) in a suitable position according to the minimum clearances shown on sheets C2a, C2b, C3a, and C3b.

CONCRETE & REBAR:
1 - Concrete shall have a minimum 28-day compressive strength of 27.5MP
2 - Unit weight shall be approximately 2242.5kg/m3
3 - Slump shall be tested in the field to be 50-75mm
4 - All exposed rebar shall be epoxy-coated with Exorust spray or equivalent

TURBINE:
1 - New Energy Corporation EVG-010 produces a maximum of 10kW of power at a velocity of 3m/s. One unit is required for adequate power production.
2 - New Energy Corporation EVG-005 produces a maximum of 5kW of power at a velocity of 3m/s. Two units are required for adequate power production.
3 - Connection between EVG-005 turbine units is provided by New Energy Corporation.

MOORING:
1 - Options include two on-land supports (rock anchor or soil footing depending on site conditions) or one on-land support paired with an in-river anchor (Guardian G-125 or equivalent).
2 - Specific details and requirements regarding cables, connections, and supports are shown on sheets C4a and C4b.
3 - Attach Taylor Made net buoys 18"D x 24"L to cables near connection to turbine prior to fastening connection to turbine.

CHANNEL NAVIGATION:
1 - Minimum clearance of 3.0m required on one side of the river from the bank to the turbine.
2 - Given a two-support system is selected, ensure that adequate vertical clearance under at least one support cable allows for navigation.

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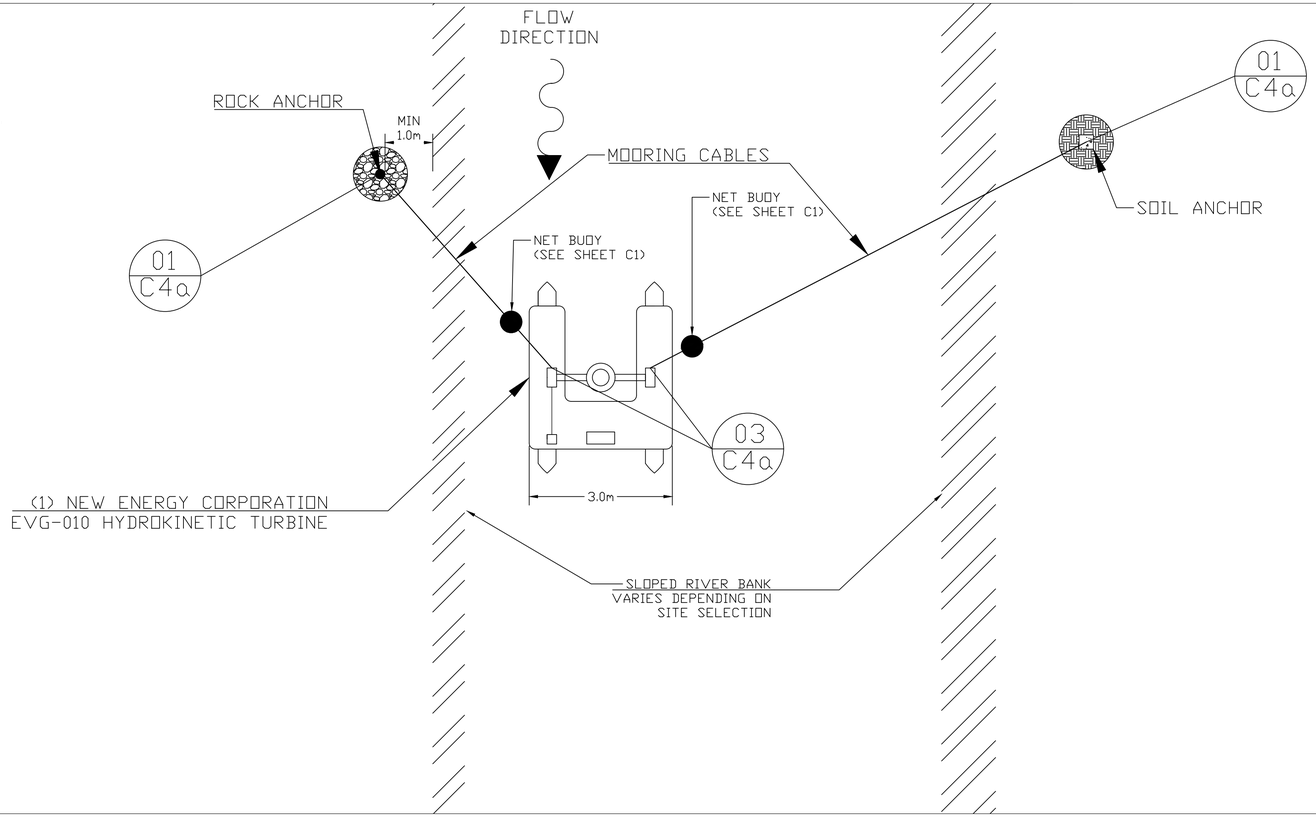
SHEET INDEX & GENERAL NOTES

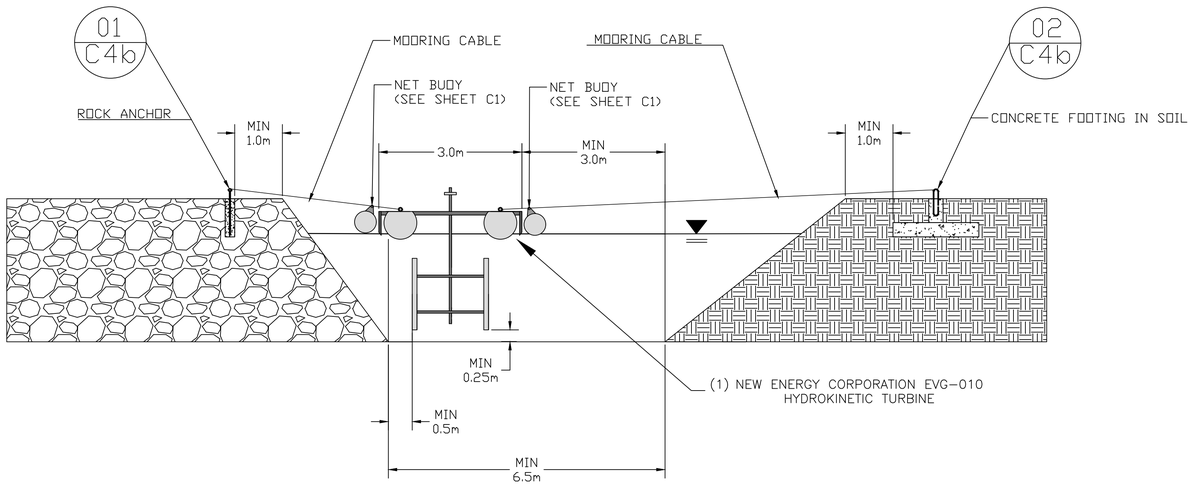
DATE
5/5/22

SCALE
NTS

DRAWN BY
MT

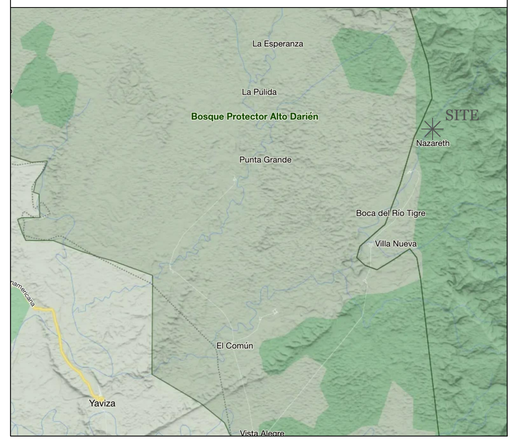
SHEET
C 1





0 1in 1.5m

SITE VICINITY



GENERAL NOTES

INSTALLATION:
1.0 - Assemble turbine unit on bank per New Energy Corporation instructions.
1.1 - Use boat to tow assembled turbine into the river at desired location.
1.2 - Attach one Taylor Made Net Buoy, 18" D x 24" L, or equivalent, to each cable prior to installing connections.

SITE:
2.0 - Confirm water level at desired turbine location is 2.15 m at minimum during low flow conditions.
2.1 - Measure channel dimensions prior to installation to confirm minimum conditions shown are met.

CONNECTIONS:
3.0 - See sheet XX for turbine to cable, anchor to cable connections, and cable specifications.
3.1 - Ensure one connection is a breakaway connection (CXX Detail XX) and second connection is a standard connection (CXX Detail XX).

ANCHORING COMBINATIONS:
4.0 - Select anchor for each bank based on geotechnical conditions. If rock bank, install rock anchor (CXX Detail XX). If soil bank, install concrete footing in soil (CXX Detail XX).

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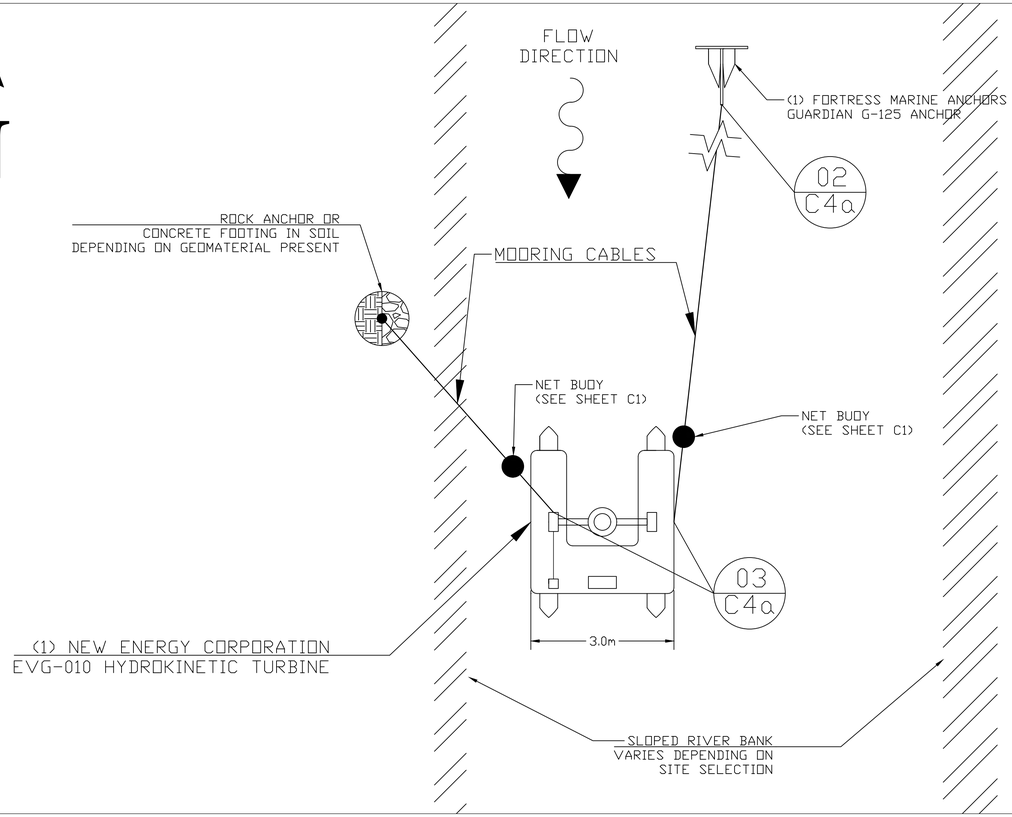
ONE-UNIT TURBINE OPTION, ON-LAND SUPPORTS

DATE
5/5/22

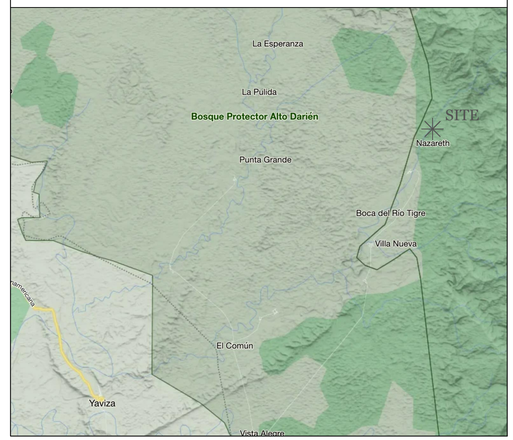
SCALE
1:1.5

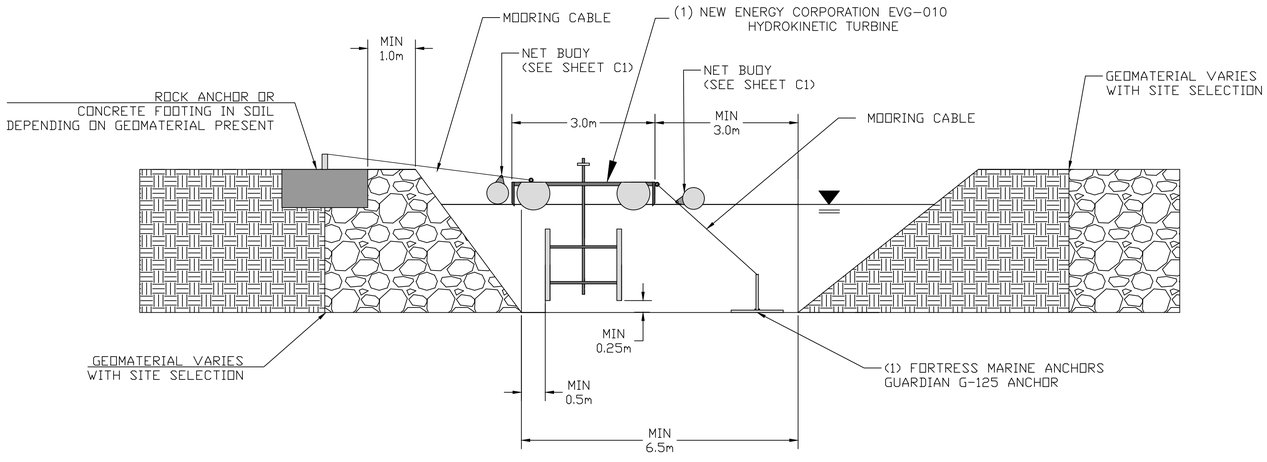
DRAWN BY
CB & AH

SHEET
C2a



SITE VICINITY





0 1in 1.5m

GENERAL NOTES

INSTALLATION:

1.0 - Assemble turbine unit on bank per New Energy Corporation instructions.
1.1 - Use boat to tow assembled turbine into the river at desired location.
1.2 - Attach one Taylor Made Net Buoy, 18" D x 24" L, or equivalent, to each cable prior to installing connections.
1.3 - Lower Guardian G-125 anchor into water approximately 5.0 m upstream from desired location.
1.4 - Anchor must be placed at minimum 30 m directly away from turbine.

SITE:

2.0 - Confirm water level at desired turbine location is 2.15 m at minimum during low flow conditions.
2.1 - Measure channel dimensions prior to installation to confirm minimum conditions shown are met.

CONNECTIONS:

3.0 - See sheet XX for turbine to cable, anchor to cable connections, and cable specifications.
3.1 - Ensure turbine to cable connection on in-river anchor side is a breakaway connection (CXX Detail XX) and turbine to cable connection on land anchor side is a standard connection (CXX Detail XX).

ANCHORING COMBINATIONS:

4.0 - Select anchor for each bank based on geotechnical conditions. If rock bank, install rock anchor (CXX Detail XX). If soil bank, install concrete footing in soil (CXX Detail XX).

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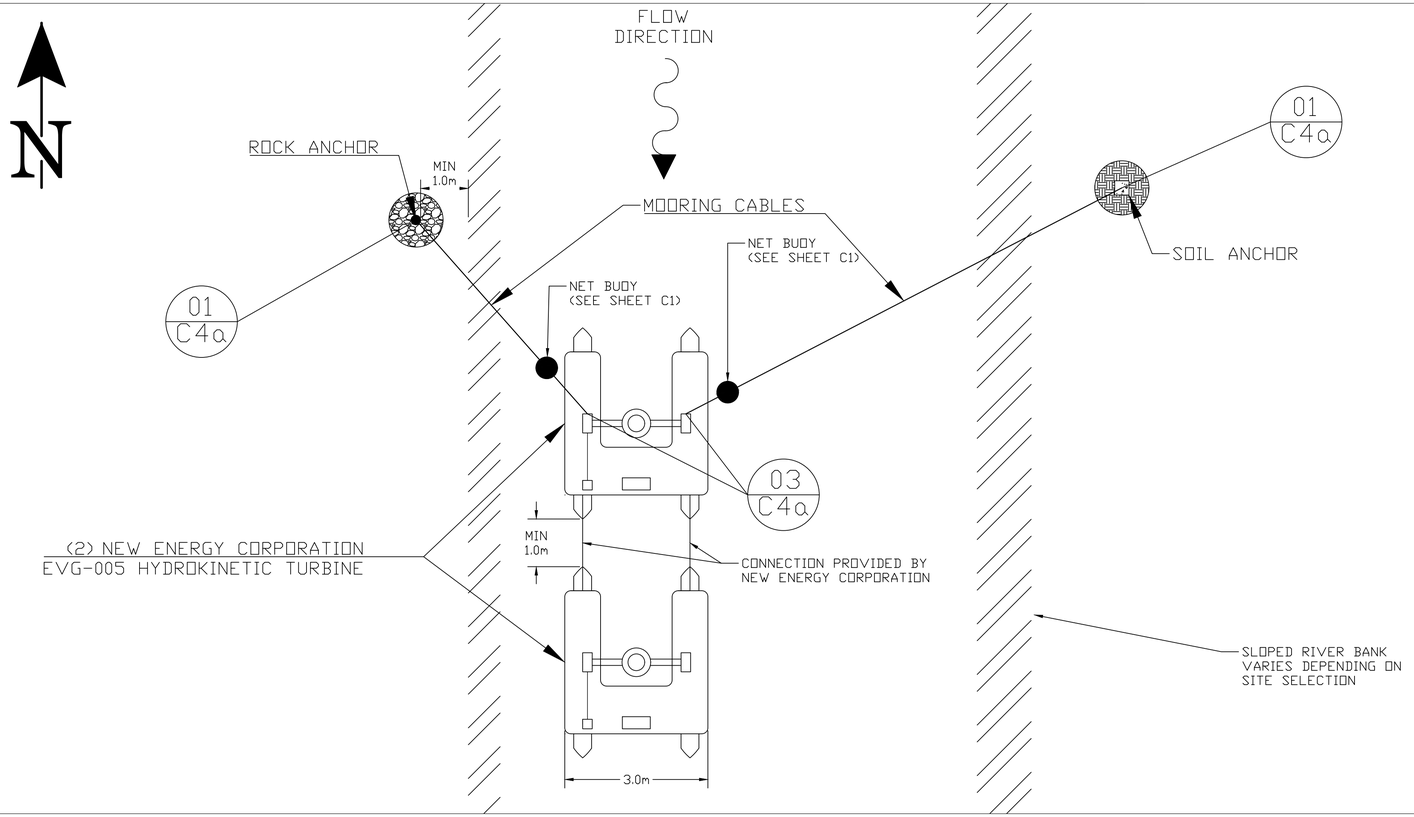
ONE-UNIT TURBINE OPTION, MIXED SUPPORTS

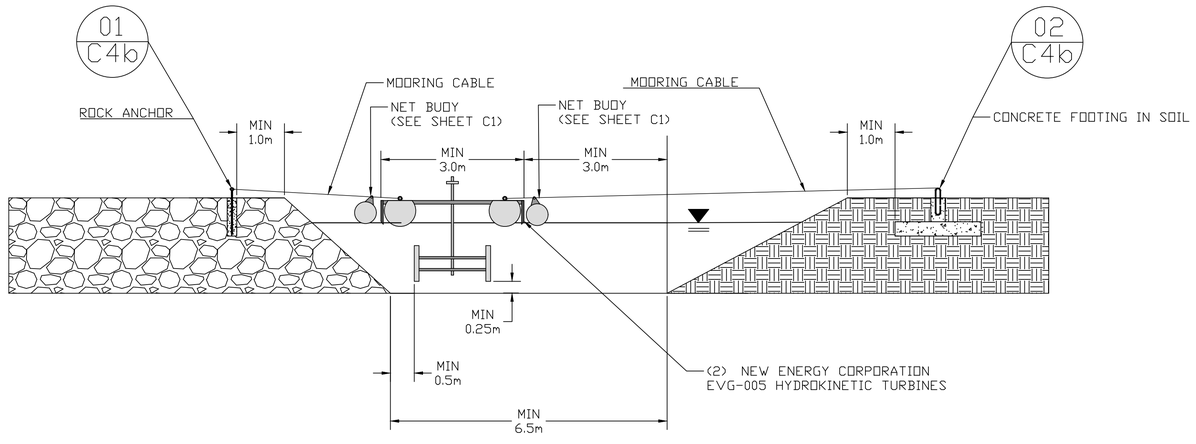
DATE
5/5/22

SCALE
1:1.5

DRAWN BY
CB & AH

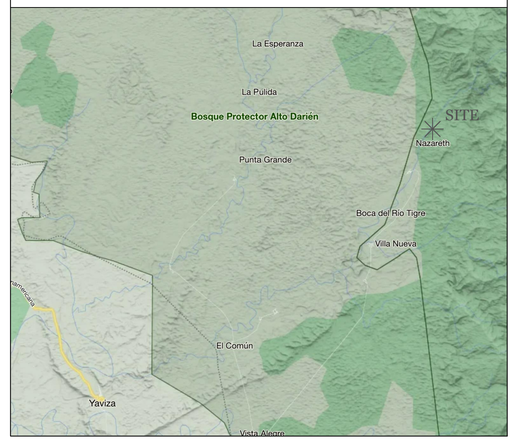
SHEET
C2b





0 1in 1.5m

SITE VICINITY



GENERAL NOTES

INSTALLATION:

1.0 - Assemble turbine units on bank per New Energy Corporation instructions.
1.1 - Use boat to tow assembled turbine into the river at desired location.
1.2 - Attach one Taylor Made Net Buoy, 18" D x 24" L, or equivalent, to each cable prior to installing connections.

SITE:

2.0 - Confirm water level at desired turbine location is 1.40 m at minimum during low flow conditions.
2.1 - Measure channel dimensions prior to installation to confirm minimum conditions shown are met.

CONNECTIONS:

3.0 - See sheet XX for turbine to cable, anchor to cable connections, and cable specifications.
3.1 - Ensure one connection is a breakaway connection (CXX Detail XX) and second connection is a standard connection (CXX Detail XX).

ANCHORING COMBINATIONS:

4.0 - Select anchor for each bank based on geotechnical conditions. If rock bank, install rock anchor (CXX Detail XX). If soil bank, install concrete footing in soil (CXX Detail XX).

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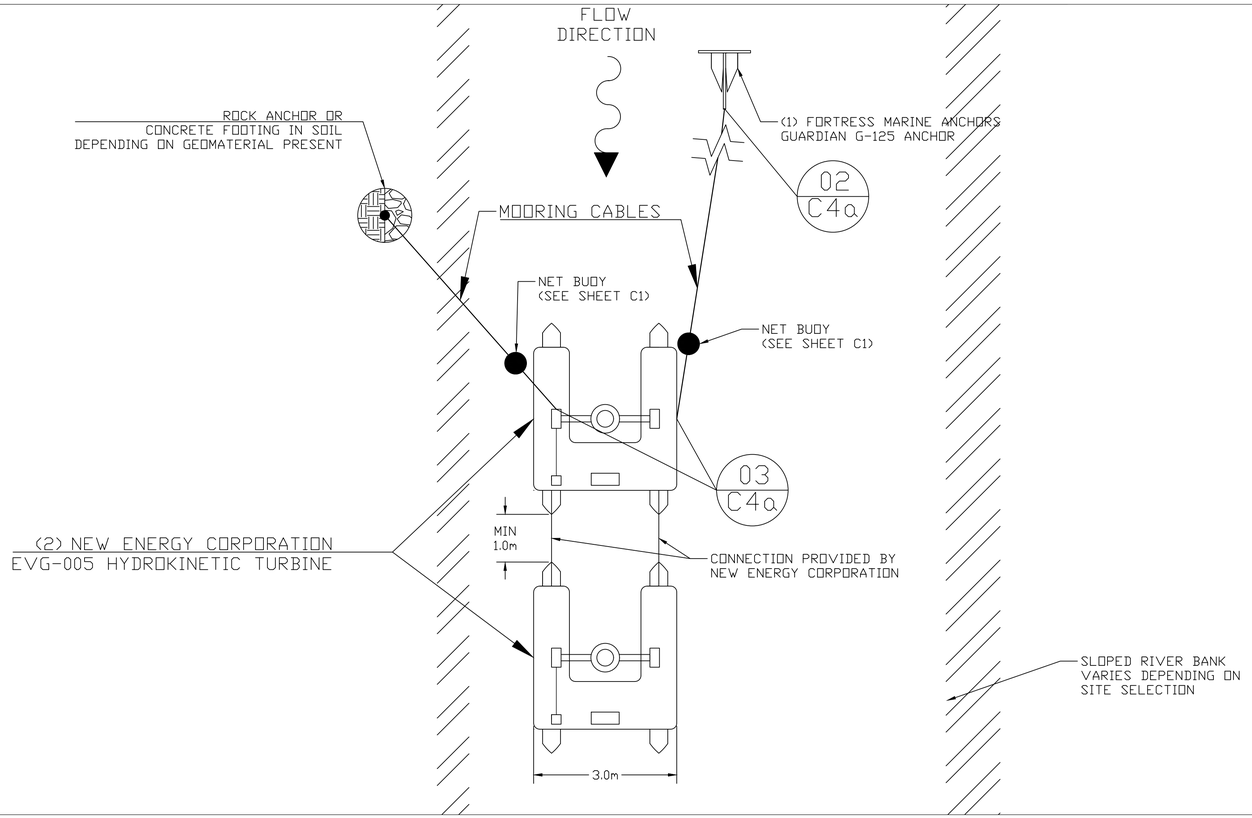
TWO UNIT TURBINE OPTION, ON-LAND SUPPORTS

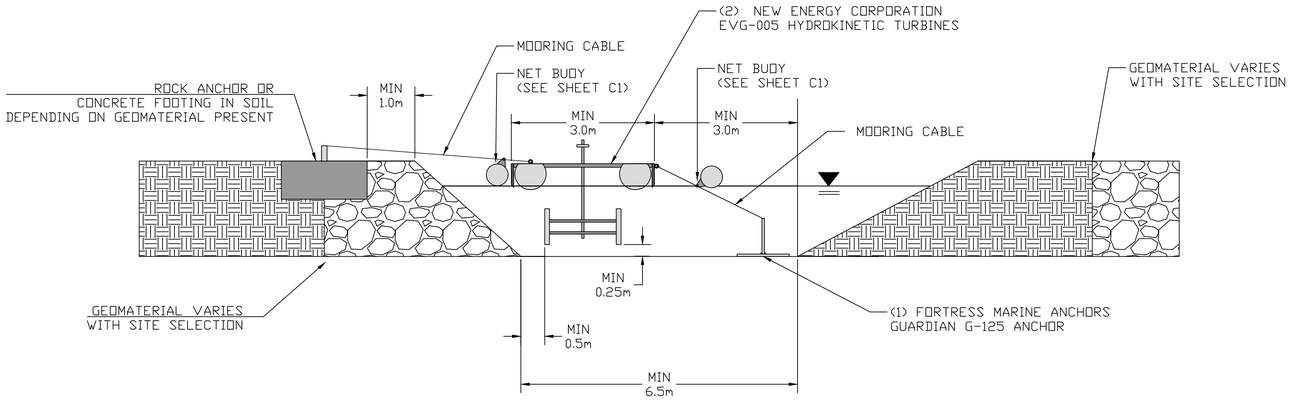
DATE
5/5/22

SCALE
1:1.5

DRAWN BY
CB & AH

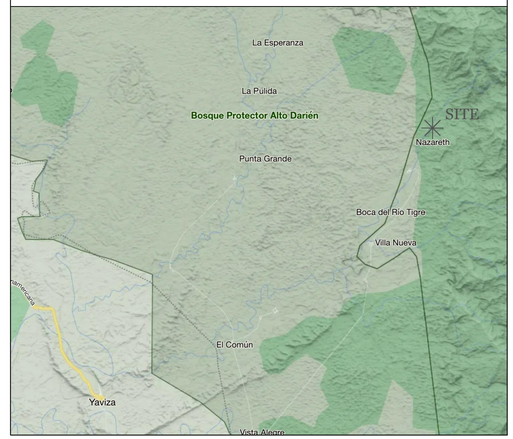
SHEET
C3a





0 1in 1.5m

SITE VICINITY



GENERAL NOTES

INSTALLATION:
1.0 - Assemble turbine units on bank per New Energy Corporation instructions.
1.1 - Use boat to tow assembled turbine into the river at desired location.
1.2 - Attach one Taylor Made Net Buoy, 18" D x 24" L, or equivalent, to each cable prior to installing connections.
1.3 - Lower anchor into water approximately 5.0 m upstream from desired location.
1.4 - Anchor must be placed at minimum 30 m directly away from turbine.

SITE:
2.0 - Confirm water level at desired turbine location is 1.40 m at minimum during low flow conditions.
2.1 - Measure channel dimensions prior to installation to confirm minimum conditions shown are met.

CONNECTIONS:
3.0 - See sheet XX for turbine to cable, anchor to cable connections, and cable specifications.
3.1 - Ensure one connection is a breakaway connection (CXX Detail XX) and second connection is a standard connection (CXX Detail XX).

ANCHORING COMBINATIONS:
4.0 - Select anchor for each bank based on geotechnical conditions. If rock bank, install rock anchor (CXX Detail XX). If soil bank, install concrete footing in soil (CXX Detail XX).

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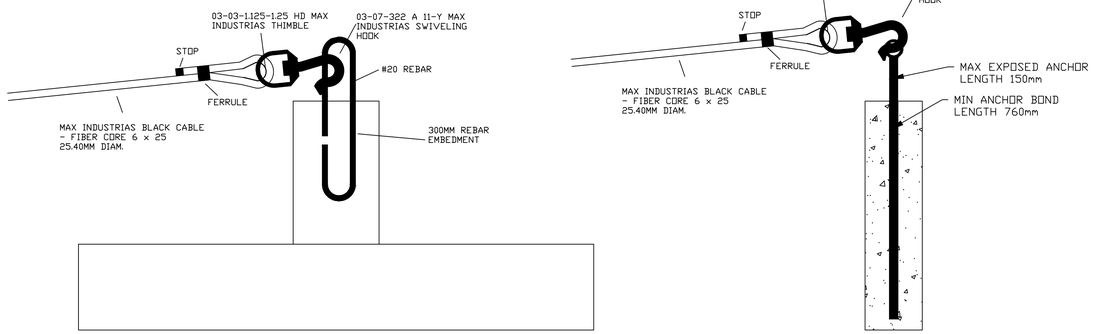
TWO UNIT TURBINE OPTION, MIXED SUPPORTS

DATE
5/5/22

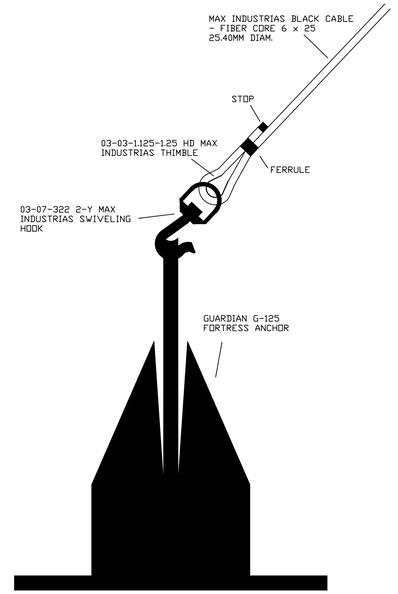
SCALE
1:1.5

DRAWN BY
CB & AH

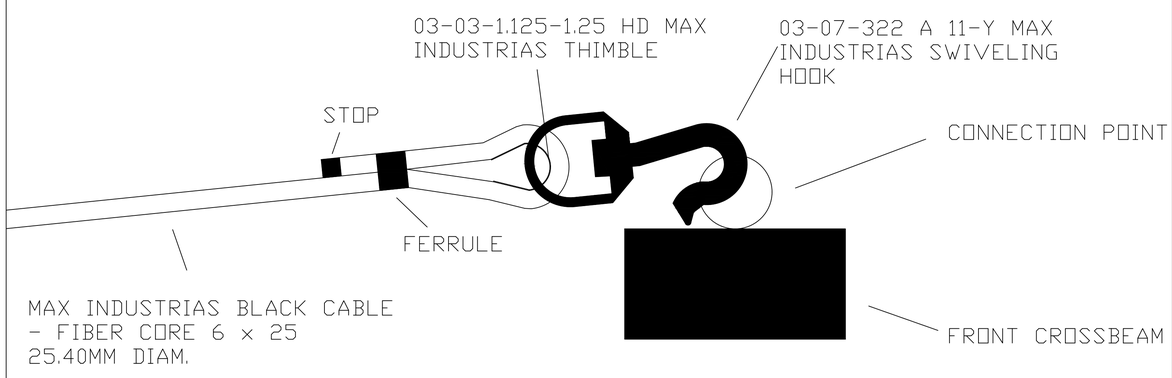
SHEET
C3b



01 / C4a — CONNECTIONS TO ROCK AND SOIL SUPPORTS DETAIL
SCALE = 4:1



02 / C4a — CONNECTION TO IN-RIVER ANCHOR DETAIL
SCALE = 4:1



NOTE: FOR STRUCTURAL COMBINATIONS IMPLEMENTING TWO SUPPORTS OUTLINED ON SHEET C1.1A & C1.1B, ALTERNATE THIMBLE CONNECTION MUST BE USED FOR ONE CABLE CONNECTION TO ALLOW FOR BREAKAWAY WHEN IMPACTED BY LARGE DEBRIS. USE 03-03-0.312 HD INDUSTRIAS THIMBLE OR EQUIVALENT.

03 / C4a — CABLE AND CONNECTION TO TURBINE FROM ON-LAND SUPPORT DETAIL
SCALE = 10:1

GENERAL NOTES

ON-LAND SUPPORTS:
1.0 - The angle of the cable from the footer to the turbine cannot be less than 45 degrees (plan view).
1.1 - The ferrule and stopper can be placed at any distance from the rebar.
1.2 - The exposed rebar is coated with epoxy.
1.3 - One hook is shown in the drawings for understanding, but three hooks will be used.

IN-RIVER SUPPORTS:
2.0 - The ferrule and stopper can be placed at any distance from the rebar.
2.1 - One hook is shown in the drawings for understanding, but two hooks will be used.
2.2 - 5:1 minimum scope required. 10:1 scope recommended for full anchor capacity.
2.3 - To retrieve anchor, position boat directly over anchor, snub the line, and slowly power backwards.

TURBINE CONNECTION:
3.0 - The thimble should be placed on the corner furthest from the footer.
3.1 - Connection point will be installed by the turbine manufacturer at the center of the cross beam
3.2 - The ferrule and stopper can be placed at any distance from the rebar.
3.3 - One hook is shown in the drawings for understanding, but two or three hooks will be used, depending on if it is connected to the anchor or rock/soil supports, respectively.

NOTE: Any connection may be substituted with suitable equivalent.

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SENIOR DESIGN COURSE EXPERIENCE
CE 399S & CE 400
FALL 2021 - SPRING 2022

RIVER FLOW TEAM
Team Members: Claudia Bible, AJ Condra,
Drew Houser, Nathan Smith, and Matthew Tolson

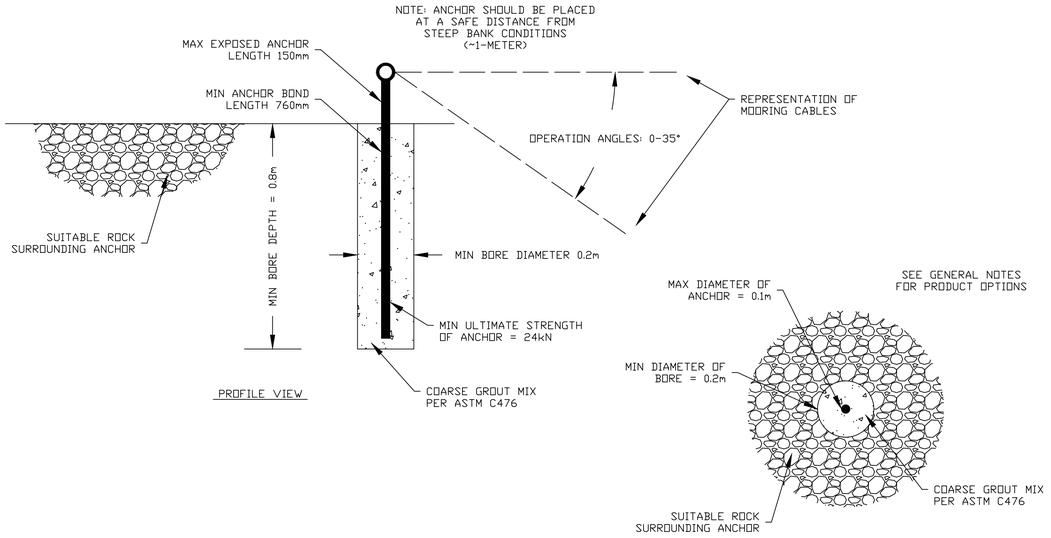
CABLE, CONNECTION, AND IN RIVER SUPPORT DETAILS

DATE
5/5/22

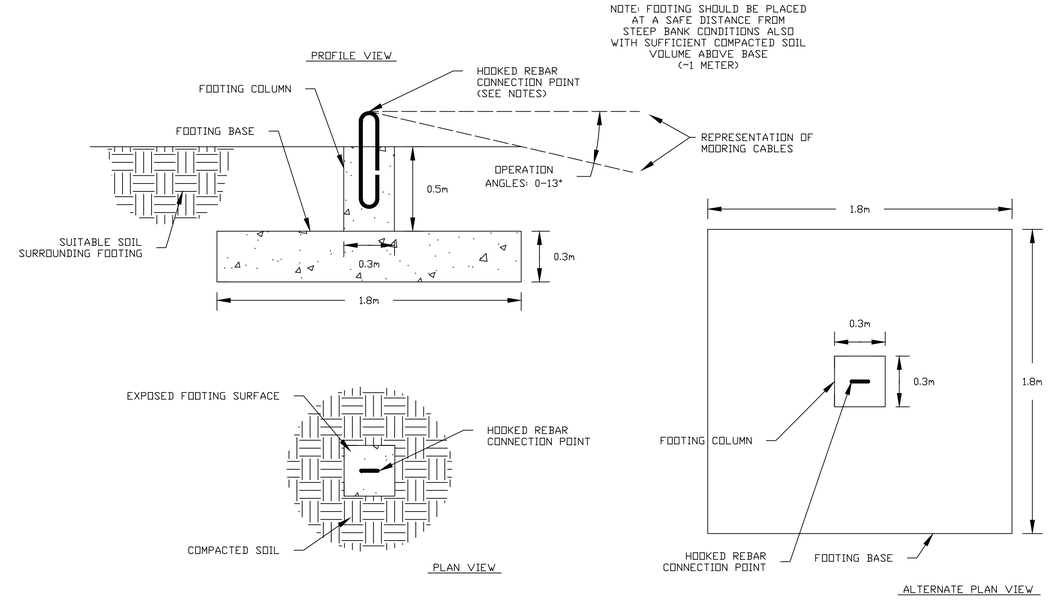
SCALE
VARIES

DRAWN BY
NS

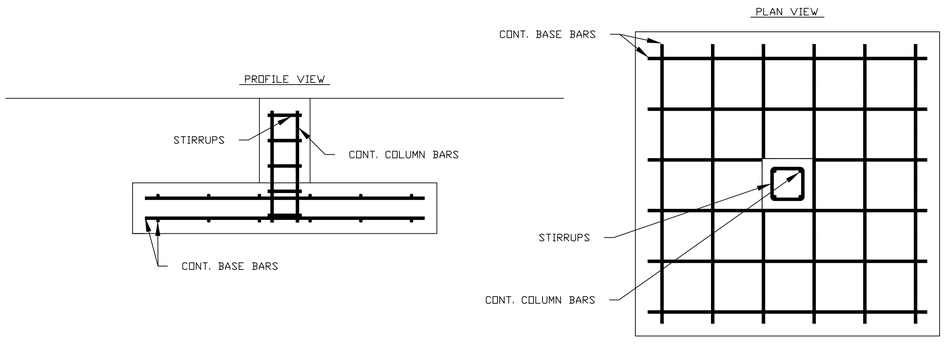
SHEET
C 4a



01 / C4b — ROCK ANCHOR DETAILS
SCALE= 1:100



02 / C4b — FOOTING SIZING DETAIL
SCALE= 1:60



SECTION:	TYPE, SIZE, & SPACING:	QUANTITY:	LENGTH PER BAR:	TOTAL LENGTH:
Column	Continuous Bars & Stirrups: No. 5 (16mm) at 150mm spacing	4 Continuous Bars 5 Stirrups	Cont. Bars = 0.7m Stirrups = 0.8m	Cont. Bars = 2.7m Stirrups = 3.7m
Base	Continuous Bars: No. 5 (16mm) at 300mm spacing	24 Continuous Bars	Cont. Bars = 1.7m	Cont. Bars = 39.6m

03 / C4b — FOOTING REBAR LAYOUT AND SCHEDULE
SCALE= 1:60

GENERAL NOTES

ROCK ANCHOR:
1.0 - Install Altec JR130L anchor or equivalent that exceeds 24kN ultimate strength
1.1 - Allowed cable operation angles range from 0 to 35 degrees from horizontal
1.2 - Rock conditions should be verified to have a bearing capacity of at least 1.6MPa
1.3 - Anchor should be placed away from steep bank conditions to ensure safety of use (approximately 1-meter)
1.4 - Coarse grout mix design should follow ASTM C476 as outlined below:
- 1.4a - 28-day compressive strength = 14MPa
- 1.4b - Slump = 200-280mm
- 1.4c - Mix: 1 part cement, 2.25-3 parts fine aggregate, 1-2 parts coarse aggregate
- 1.4d - On-site material permissible for use

FOOTING:
2.1 - Soil conditions should be verified to have a bearing capacity of at least 100kPa and a unit weight of 14.9kN/m3
2.2 - Allowed cable operation angles range from 0 to 13 degrees from horizontal
2.3 - Footing should be placed away from steep bank conditions to ensure safety of use (approximately 1-meter)
2.4 - Concrete should have a 28-day compressive strength = 27.5MPa and a unit weight of 22kN/m3
2.5 - Reinforcement spacing for base and column bars shall be 300mm and 150mm, respectively
2.6 - Concrete cover shall be maintained as 75mm from any edge of footing
2.7 - Steel reinforcement shall have a yield strength of 344.7MPa
2.8 - Hooked rebar connection point should adhere to the following parameters:
- 2.7a - No. 20 (19.5mm diameter) rebar
- 2.7b - Hook diameter = 120mm
- 2.7c - Minimum embedded length = 300mm, Opposite side minimum extension length = 80mm
- 2.7d - Exposed length = 150mm

Note: During installation, rebar ends should be placed in concrete toward active forces to minimize pullout

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BANK MOORING DETAILS

DATE
5/5/22

SCALE
VARIES

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