UH-Fluor Industrial Conference, 2019

Construction-Driven Execution Design Challenge:

“Pump It Up”

Revision 1
## Contents

I. Pump It Up (Background) ........................................................................................................................................ 4  
II. Requirements of the Challenge ............................................................................................................................... 8  
III. Pipeline Hydraulics Design ...................................................................................................................................... 9  
  a. Pump Selection ........................................................................................................................................... 10  
  b. Pipeline Mechanical Design ......................................................................................................................... 10  
IV. Civil Design ............................................................................................................................................................ 12  
  a. Excavation ................................................................................................................................................... 12  
  c. Foundation .................................................................................................................................................. 13  
  d. Foundation Design Philosophy .................................................................................................................... 14  
V. Constructability ..................................................................................................................................................... 16  
VI. Cost Estimating .................................................................................................................................................... 17  
VII. Zero Based Execution (ZBE) and Modularization .................................................................................................. 17  
VIII. Submission of Your Teams Proposal – Phase 1 ..................................................................................................... 18  
IX. Evaluations – Analysis and Narrative Components ............................................................................................... 19  
X. Presentation .......................................................................................................................................................... 19  
XI. Team Size and Your Deliverables .......................................................................................................................... 19  
XII. File Naming Convention and Size Limit ................................................................................................................. 20  
XIII. Evaluation Process ................................................................................................................................................ 20  
XIV. Tips for Success ..................................................................................................................................................... 21  
XV. Rewards ................................................................................................................................................................ 22  
XVI. Design Challenge FAQ ........................................................................................................................................... 22  
XVII. Appendix – Hydraulic and Pump Selection Instructions ........................................................................................ 24  
  a. Input Parameters .................................................................................................................................................. 27  
  b. Pipe Input Parameters .......................................................................................................................................... 28  
  c. Flow Rate Input Parameters per Pipe Segment .................................................................................................... 29  
  d. Assigned Pressure Input Parameters .................................................................................................................... 30  
  e. Branch Properties ................................................................................................................................................. 31  
  f. Hydraulics and Pump Selection ............................................................................................................................. 32  
  g. Model Results and Table Results .......................................................................................................................... 33  
  h. Requirements of the Outputs: .............................................................................................................................. 34  
  i. Pump Selection Criteria ......................................................................................................................................... 34  
  j. Pump Assembly Weight and Dimensions ............................................................................................................ 34  
XVIII. Engineering Quick Reference Guide ...................................................................................................................... 35
Revisions

This Section covers the modifications to the Design Challenge from its Original Version with Revision 1 that provides a quick reference with the Table below detailing the modifications that were made in the Design Challenge Document.

The amendment that was planned to detail the pump selection will NOT be a separate document, but all contained within this Revision 1 of the Design Challenge along with modifications necessary.

Due to limitations of Versions of AFT – FATHOM Student version, this document is updated to reflect changes necessary. The two primary differences are how elevations are built into the hydraulics model along with limitations to only 12 segments of pipe. Note that the modeling of variations to your design becomes easier to complete.

<table>
<thead>
<tr>
<th>Revision</th>
<th>Section</th>
<th>Page</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All</td>
<td>All</td>
<td>Added Table Reference Numbers and Titles</td>
</tr>
<tr>
<td>1</td>
<td>All</td>
<td>All</td>
<td>Updated Section References and Table References</td>
</tr>
<tr>
<td>1</td>
<td>IV (a)</td>
<td>12</td>
<td>Clarification added for “cut” calculations and ZBE approach</td>
</tr>
<tr>
<td>1</td>
<td>IV (d)</td>
<td>15</td>
<td>Added additional requirement for sizing concrete foundation</td>
</tr>
<tr>
<td>1</td>
<td>Table 3</td>
<td>16</td>
<td>Sections of Soils Reduced to 12 Segments</td>
</tr>
<tr>
<td>1</td>
<td>VII</td>
<td>17-18</td>
<td>Added Section Describing ZBE Requirements and Modularize</td>
</tr>
<tr>
<td>1</td>
<td>XVII</td>
<td>25</td>
<td>Added Initial Interface Window in Fathom and Instructions</td>
</tr>
<tr>
<td>1</td>
<td>XVII</td>
<td>25</td>
<td>Updated AFT – Fathom Hydraulics Diagram Goal</td>
</tr>
<tr>
<td>1</td>
<td>XVII</td>
<td>26</td>
<td>Icon Diagram Notes updated</td>
</tr>
<tr>
<td>1</td>
<td>Table 6</td>
<td>27</td>
<td>Changed Units for Flow to gal/min</td>
</tr>
<tr>
<td>1</td>
<td>Table 6</td>
<td>27</td>
<td>Removed Design Criteria for Max Shutoff Pressure Margin</td>
</tr>
<tr>
<td>1</td>
<td>Table 6</td>
<td>27</td>
<td>Added Minimum Flow Velocity Requirement 2 ft/sec</td>
</tr>
<tr>
<td>1</td>
<td>Table 7</td>
<td>27</td>
<td>Elevation Profile Update to reduce for 12 Segments of pipe</td>
</tr>
<tr>
<td>1</td>
<td>XVII (b)</td>
<td>28</td>
<td>Updated Model Window Shot and Notes</td>
</tr>
<tr>
<td>1</td>
<td>XVII (c)</td>
<td>29</td>
<td>Updated Model Window Shot and Notes</td>
</tr>
<tr>
<td>1</td>
<td>XVII (d)</td>
<td>30</td>
<td>Updated Model Window Shot and Notes</td>
</tr>
<tr>
<td>1</td>
<td>XVII (e)</td>
<td>31</td>
<td>Added Model Window Shot and Notes</td>
</tr>
<tr>
<td>1</td>
<td>XVII (f-j)</td>
<td>32-34</td>
<td>Added Sections on Pump Selection Criteria</td>
</tr>
</tbody>
</table>
Construction Driven Execution Design Challenge

I. Pump It Up (Background)

Due to climate change and the use of water for agriculture and population consumption, many locations around the globe have significant increase in demand for fresh water. This has caused depletion of natural resources such as lakes and rivers due to this increased demand. The needs are often significant enough that the replenishment of the water is not sufficient to meet the demand. Therefore, the growing need to move water from the plentiful sources to the areas without will increase over time. To ensure the supply of water for maintenance of natural lakes and prevent the depletion due to use by population, water pipelines have been built to provide that replenishment. However, the source of the water and the final destinations can be challenging to move the water. This design challenge is built to simulate the design concepts around designing a water pipeline to overcome the obstacles in the terrain taking into consideration the constructability challenges in each of the design decisions.

Last year’s design challenge consisted of routing a pipeline through the Island of Puerto Rico considering construction driven execution in the process of your team’s efforts and how it impacts the overall cost of a project. Since completion of the design challenge of last year, the industry has made significant leaps in technology that routing of a pipeline has been automated. Therefore, the next step in progression of automation is associated with identifying and
optimizing the locations of the associated facilities for the pipeline. This year’s design challenge will be a pipeline project that your team will conduct a hydraulic analysis for the flow of water through the pipeline for an elevation change that will require locating a pump station along the route. The pump station location and the pumps utilized in the pump station will need to be determined by your engineering team taking into consideration several concepts. The challenge is designed to develop the most optimized materials costs and construction costs with the final selection of the location of the pump station. The challenge will also demonstrate value of Modularization, Zero Based Execution™, and Risk Assessments.

This design challenge has been created to replicate the efforts that Fluor is tasked with for each of the pipeline projects. This design challenge has been built so that any level of education or knowledge base can participate since it intuitively ties into teamwork and how each decision specifically influences the resulting execution of the work. As you pursue an efficient design, you will see that the decisions that you make during engineering design directly affect the overall cost of the project during construction. Therefore, it is extremely important to take into consideration the challenges of construction. At Fluor, we refer to this as “Construction-Driven Execution”.

The goal will be to find the most economical solution that has the following criteria that influences the outcome of the project cost:

- Pipeline Hydraulics and Pump Selection (software simulation)
- Pipeline Mechanical Design (calculation)
- Civil and Geotechnical Design (calculation)
- Constructability (optimization)
- Supply Chain and Material Management (cost optimization)
- Modularization (narrative)
- Zero Based Execution (narrative, minimal calculations)
- Risk Assessments (narrative)

These design and planning aspects all result in construction and fabrication costs to the project and require planning to meet the most effective and efficient design. The major components of the cost are:

- Materials – Pumps, Pipe, and Concrete
- Construction – Excavation and Equipment for Construction

You will utilize hydraulic design software and the features within the program to conduct hydraulic analysis on the pipeline and keep models of the simulation for your proposal.
To understand the complexity of the work, diagrams of typical pipeline construction is shown below. This diagram of a typical pipeline spread for construction is shown to be on level ground. However, with significant elevation changes through mountainous terrain, the construction techniques change considerably and the safety of personnel becomes extremely important.

Cross Country Pipeline Construction

On the following page, pictures of mountainous pipeline construction are shown to give your team an idea on the differences between the two.
Mountain Pipeline Construction
II. Requirements of the Challenge

Your team will complete the challenge in two components (analysis and narrative). The analysis component will be to complete a design based on the given parameters that will have design and constructability activities that include:

- Mechanical and Hydraulic Design of the Pipeline and Pump Stations
- Location of Pump Stations based on Hydraulic Performance
- Constructability of the selected pump station site
  a. Excavation Requirements
  b. Foundation Design Requirements
- Estimating of Material and Construction Costs

The mechanical design and hydraulics have to be done in accordance with the process conditions and elevation profile of the pipeline route as the elevation changes have direct impact on the hydraulics of the system. The pipeline route has already been selected and will not change for this challenge or as any recommendation for improvement of the challenge. The results of the mechanical design based on the hydraulic analysis and location of the pump stations will be applied to each of these requirements and therefore it is important that it is done correctly, as rework can be very expensive and the design team will be heavily penalized if rework is necessary for construction rework. Each design component has the potential for your Team to be penalized. This drives the concept that constructability and material supply chain have an important role in the engineering process so that surprises and discoveries not caught during the engineering design process do not lead to expensive costs during construction.

The pump station location selection, civil design, constructability, pump selection, and construction equipment allocation are all interdependent. Teamwork will be required to take each of these into consideration, as one decision will impact the other.

The following pages describe each of the parameters of these design requirements.

The Second Component of the Challenge (narrative) will introduce changes to the project, similar to how projects are typically challenged with as an initial design is being developed. Your team will have to understand how the changes impact your initial design and make adjustments to the design to reflect these three primary concepts:

1. Zero Based Execution – This is your team’s primary opportunity to provide design innovation to the overall concept. This is Fluor’s term for revisiting the early decisions that were made on a project that may have inadvertently driven cost and schedule high. For example, in this case if the pipeline is operating 24 hours, thereby reducing the flow rate condition. It was also decided that the pump cannot be placed within the first 30,000 feet of the start of the pipeline; if that decision was revisited, how could it positively impact the
overall cost of the project. Show calculations for how it impacts the design (wall thickness, pipe diameter, pump size, etc) and how it leads to lower costs.

2. Modularization – This is the process in which we utilize a compact design of process equipment and condense the pipe, steel, and instruments so that it can be fabricated safely and with high quality control. The entire module is then moved to site and set in place with minimal efforts in the field. Show in your narrative what aspects of the design have the potential for modularization and list the pro-cons of modularizing the design.

3. Risk Assessment – Your team will be tasked with determining the risks of the project and quantifying them in terms of costs. After completing the first component (analysis), your team is familiar with aspects of the analysis that entail design, costs of procuring and installation. Your team will identify five risk areas and your plan to mitigate them.

The following sections describe the first component (analysis) of the design challenge and the criteria to be considered in the design. The last page of this challenge provides a flow chart to assist the teams in completion of the activities.

III. Pipeline Hydraulics Design

Your team will analyze the pipeline for delivery of water from the source to the end destination. The pipeline elevation changes will require a pump station along the pipeline route to achieve the targeted delivery pressure. AFT (software developer) has provided software for the University of Houston students to utilize specifically for this Design Challenge at no cost to model the pipeline segments and the pumps in this system to determine the pump requirements and the location of the pump station along the pipeline route. The instructions on use of the software are included in the Appendix of this Challenge. The decisions that your team will have to make are in the selection of the pumps to achieve the required delivery pressure and meet the flow rates as required. The modelling of the hydraulics of the system will have the initial given design parameters:

- Inlet Pressure
- Outlet Pressure
- Elevation Profile of Pipeline
- Diameter of Pipeline
- Flow Rate
- Pump Station Location cannot be located at the beginning of the line from station 0 through 30,000 due to permitting restrictions.

What you will have to determine is the following:

- Associated Wall Thickness of the Pipeline (Section III (b) – Pipeline Mechanical Design)
- Pump Selection (XVII - Appendix)
- Pump Site Selection (Consider Constructability)
The elevation profile of the selected pipeline route has already been determined by the routing of the pipeline. The stationing of the pipeline and the associated elevations are included in the XVII - Appendix of this challenge. This elevation profile for the hydraulics simulation cannot be adjusted, as this profile is associated with the pipeline route.

The hydraulics that your team will have to perform shall be done with the utilization of AFT Fathom software that can be downloaded per the instructions provided in the XVII - Appendix of this document. All of the instructions for utilizing the software on a step by step basis are included in the XVII - Appendix.

a. Pump Selection

The pump equipment that are provided by available vendors will have a big impact on the project, as each of the pumps have a specific performance that they will be able to meet, but they also have varying costs depending on the availability of the pump and the source location of where the pumps will come from. The pumps to be selected from are identified in the XVII - Appendix of this document. Additional data on pump performance will be included as part of the XVII - Appendix of this Design Challenge to utilize in the selection of pumps.

Once the results of the hydraulic analysis are complete, the team will need to review the rest of the design criteria for the pipeline to determine if there are opportunities for improvement of the location of the pump station. Each of the criteria from the Construction, Civil, and material supply has an influence on the cost of the project. Therefore, the hydraulic simulation may need to be done more than one time, or multiple times to find an optimized solution. While the initial answer can be sufficient to complete the design, the resulting cost for the overall project may not be optimized. There are other solutions that could reduce the cost of the project that will need to be taken into consideration. The following sections identify the criteria for these considerations.

b. Pipeline Mechanical Design

Your team will be responsible for using the provided data to carry out the mechanical design of the pipeline. It is imperative that the calculations be done correctly to meet code requirements and avoid rework in the future. The goal will be to keep material costs low. During the mechanical design phase, the primary goal will be to ensure that the pipeline is capable of resisting the stresses that it will experience during its service life. These stresses will include resisting the internal pressure to contain the water flowing through the line (hoop stress) taking into account the differences in elevation head.

For this challenge, the pipe can be ordered in three different wall thicknesses based on varying pressures along the pipeline route. Typically, the pipe will be done in a single mill run with all the same wall thickness, but there will be availability of the pipe mills to provide three separate runs.
The design data on the water system and the following requirements for the design of the Pipeline were determined:

Table 1 – Pipeline Mechanical Design Inputs

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S - Specified Minimum Yield Strength (psi)</td>
<td>52,000</td>
</tr>
<tr>
<td>( P_{\text{in}} ) – Pipeline Design Pressure at Inlet (psig)</td>
<td>100</td>
</tr>
<tr>
<td>( P_{\text{out}} ) – Pipeline Design Pressure at Outlet (psig)</td>
<td>50</td>
</tr>
<tr>
<td>( P_{\text{design-Segment-1}} ) – Maximum pressure for pipeline design for upstream segment (psig)</td>
<td>To be determined by team</td>
</tr>
<tr>
<td>( P_{\text{design-Segment-2}} ) – Maximum pressure for pipeline design for downstream segment (psig)</td>
<td>To be determined by team</td>
</tr>
<tr>
<td>D - Pipeline Nominal Outside Diameter (inch)</td>
<td>30</td>
</tr>
<tr>
<td>E – Longitudinal Joint Factor</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The design formulas for the calculations can be found in ASME B31.4 in accordance with the following:

- Wall Thickness Calculation
  \[
  t = \frac{PD}{2 \times Sh}
  \]
  \( t \) = wall thickness, inch
  \( Sh \) = circumferential (hoop) stress due to internal pressure, psi
  \( P \) = design pressure, psig (*see note below)
  \( D \) = nominal outside diameter of pipe, inch

  * Each segment of pipe or mill run of pipe can have a different maximum design pressure. The team can utilize three different wall thicknesses as the result of this evaluation.

\[
Sh = Sy \times F \times E
\]
  \( E \) = longitudinal joint factor (1.0)
  \( Sy \) = specified minimum yield strength, psi
  \( F \) = 0.72 (Design Safety Factor)

The calculations of your design will need to be shown and submitted with native excel file, MathCAD, or hand written calculations.
IV. Civil Design

The civil design will be critical to work with construction as the work to be considered for civil design includes consideration for excavation for the pump station site as well as determining the size and type of foundation that would be required to set the pump.

a. Excavation

Your team will determine the excavation required to build a 500’ x 500’ level plot of space for the pump station for all permanent facilities and access to the facilities by vehicles and personnel. The side slopes of the cut area along the side of the hill will require certain safety factors based on the soil types in that area. The following are the criteria:

<table>
<thead>
<tr>
<th>Soil Types</th>
<th>Allowable Net Soil Bearing Capacity (lbs/ft$^2$)</th>
<th>Maximum Allowable Slope</th>
<th>Excavation Cost</th>
<th>Foundation Depth Below Grade (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable Rock</td>
<td>6,000</td>
<td>0.1H : 1.0V</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>Firm Clay</td>
<td>1,500</td>
<td>0.75H : 1.0V</td>
<td>1.0</td>
<td>3</td>
</tr>
<tr>
<td>Silty Sand</td>
<td>2,000</td>
<td>1.0H to 1.0V</td>
<td>1.0</td>
<td>4</td>
</tr>
<tr>
<td>Medium Dense Sand</td>
<td>2,500</td>
<td>1.5H to 1.0V</td>
<td>1.0</td>
<td>3</td>
</tr>
</tbody>
</table>

H = Horizontal; V = Vertical

For this challenge, the assumption to be made is that the slope is uniform in depth (into the page). For your initial design to be submitted, cut material will all have to be removed from the Pump Station Site per equipment specifications in Table 4 and no cut material should be used as fill material to level the site. For your Zero Based Execution solution, the “Cut” material should be used as fill material to provide a level site and the cut and fill quantities should be balanced to eliminate or minimize disposal of cut material, if possible.
The concern around maximum allowable slope, is to avoid the potential for slope failures. When the slope of the different types of soil exceed the specified slopes, the risk for failure of the ground increases significantly. Soil failures can be caused by large slopes created during construction in soils that are prone to failure. The parameters above for the maximum allowable slopes provide the guidelines to prevent this from occurring.

![Slope Failure Image]

**c. Foundation**

Foundations will need to be designed and concrete is not readily available, so the cost of concrete is expensive for this location. Therefore, minimizing the amount of concrete to be used on the project is critical. Your team will need to design the foundations based on the loads of the pump equipment that is selected as well as take into consideration the strength of soil that the site is selected.

Your team will provide a foundation design so that the pumps that are placed on the foundation will not be compromised by failure of the soil or the concrete foundation. The loads “P” will be provided along with the pump dimensions that are associated with the pumps selected. The pumps themselves will weigh a specific amount, but the associated structural steel and connections will add to the overall weight that needs to be supported by the foundation. For this exercise, the loads “P” and dimensions of the pumps will be all inclusive of the pump, structural steel skid, and all related connections.

Inappropriately designed foundations can have significant impact on the long term stability of the equipment that is placed on the foundation. It is critical that the foundations are sized appropriately with the safety factors applied.
d. Foundation Design Philosophy

Pedestals for equipment should have plan dimensions based on equipment baseplate dimensions + 1'-0” in each direction rounded up to a 2” increment to accommodate the use of standard concrete forms.

Pedestal should extend 1’-0” vertically above grade.

Footing should be sized in plan dimensions based on qnet ≤ allowable net soil bearing pressure for the soil type at the pump station site, but should not be less than the plan dimensions of the pedestal.

If the calculated plan dimensions of the footing are > plan dimensions of the pedestal but ≤ plan dimensions of the pedestal + 1'-0” in each direction, then increase the size of the pedestal to the calculated size of the footing, eliminate the footing and extend the pedestal to the required depth of foundation based on the soil type at the pump station site.

If the calculated plan dimensions of the footing are > plan dimensions of the pedestal + 1’-0” in each direction, then use the calculated plan dimensions of the footing with a thickness of the footing = 1’-6” and the bottom of the footing at the required depth of foundation based on the soil type at the pump station site.

Excavations for foundations will be after cut and fill work has been completed. Excavations for foundations should have a base dimension = footing plan dimensions + 2’-0” in each direction.
Excavation slopes should be maximum allowable slope based on the soil type at the pump station site.

Between the excavation (cut) requirements and the foundation design requirements, your team will need to determine if the location of the pump station is the most economical solution and meets the schedule requirements.

Foundation should also be sized to provide a minimum 1:3 mass ratio, which is the ratio of the mass of pump, structural steel skid, and all related connections to mass of concrete foundation (not including mass of soil). This requirement can be satisfied by the following equation:

\[ W_f > 3 \times P \]
The calculations of your design will need to be shown and submitted with native excel file, MathCAD, or hand written calculations.

The types of soils along the length of the pipeline route have been collected through geotechnical investigations and were determined to be a mixture of 4 different types. The following are the types of soil along the length of the pipeline. For this design challenge, the soils are assumed to be clear division at the beginning and end of the stationing.

Table 3 – Geotechnical (Soil) Types Along Route

<table>
<thead>
<tr>
<th>Section</th>
<th>Starting Stationing (ft)</th>
<th>Ending Stationing (ft)</th>
<th>Soil Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>10000</td>
<td>Silty Sand</td>
</tr>
<tr>
<td>2</td>
<td>10000</td>
<td>20000</td>
<td>Silty Sand</td>
</tr>
<tr>
<td>3</td>
<td>20000</td>
<td>30000</td>
<td>Stable Rock</td>
</tr>
<tr>
<td>4</td>
<td>30000</td>
<td>50000</td>
<td>Stable Rock</td>
</tr>
<tr>
<td>5</td>
<td>50000</td>
<td>80000</td>
<td>Stable Rock</td>
</tr>
<tr>
<td>6</td>
<td>80000</td>
<td>100000</td>
<td>Medium Dense Sand</td>
</tr>
<tr>
<td>7</td>
<td>100000</td>
<td>110000</td>
<td>Medium Dense Sand</td>
</tr>
<tr>
<td>8</td>
<td>110000</td>
<td>120000</td>
<td>Medium Dense Sand</td>
</tr>
<tr>
<td>9</td>
<td>120000</td>
<td>150000</td>
<td>Silty Sand</td>
</tr>
<tr>
<td>10</td>
<td>150000</td>
<td>160000</td>
<td>Firm Clay</td>
</tr>
<tr>
<td>11</td>
<td>160000</td>
<td>180000</td>
<td>Firm Clay</td>
</tr>
<tr>
<td>12</td>
<td>180000</td>
<td>200000</td>
<td>Stable Rock</td>
</tr>
</tbody>
</table>

Distances are per coordinates along the route and not 3D lengths.

V. Constructability

Your team has been keeping construction and constructability in mind, right?!?! After all, this is Construction-Driven Execution.

There are several aspects that have been evaluated from an engineering perspective, but the construction costs related to the location of the facilities haven’t been entirely taken into account. While the total amount of excavated material, the sizing of foundations, and selections of pumps have been done to determine a working solution of the system, the cost for the construction work has not been fully appreciated. The considerations in the evaluation would be to determine the appropriate equipment needed to conduct the work. Each piece of equipment will be able to handle a certain amount of soil excavated or concrete that is needed for completing the foundations. Therefore, an evaluation of the cost per piece of equipment and the effective time that each piece of equipment can complete its task needs to be...
considered. The following tables provide a breakdown in the capacity of each of the pieces of equipment along with the cost component to be considered.

**Table 4 - Equipment Requirements for Excavation**

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Work Description</th>
<th>Time Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track Hoe</td>
<td>10 cubic yards /hr</td>
<td></td>
</tr>
<tr>
<td>Dump Truck</td>
<td>12 cubic yards / truck</td>
<td>4 hour round trip</td>
</tr>
<tr>
<td>Crane</td>
<td>12 tons lift capacity</td>
<td></td>
</tr>
<tr>
<td>Concrete Truck</td>
<td>9 cubic yards / truck</td>
<td>8 hour round trip</td>
</tr>
</tbody>
</table>

*cubic yards is of rock or soil, but rock will be 3 times the cost for excavation

The work day is 10 hours and 7 days per week. The cost per unit of equipment is included in the cost estimating spreadsheet. The challenge will be selecting the quantity of equipment necessary to meet the schedule demands for construction of 50 days of site preparation with a following construction schedule of 10 days to complete the foundations and building of the pump station.

The pipeline will be built by a separate contractor with equipment supplied separately, but the cost of the construction for the pipeline will be factored into the overall cost according to the total tonnage of steel. Therefore, it is critical that the mill runs for the pipe (no more than 3) optimize the use of the pipe along the pipeline route.

VI. Cost Estimating

Your team will have to prepare a cost estimate of the final proposal. An excel sheet is provided to assist you with the cost estimating and the format needs to remain the same.

The goal of the final cost estimate that your team submits will be to accurately account for all materials and construction costs to minimize the overall project expenditure.

VII. Zero Based Execution (ZBE) and Modularization

This is your team’s primary opportunity to provide design innovation to the original concept. This is Fluor’s term for revisiting the early decisions that were made on a project that may have inadvertently driven cost and schedule high. Show calculations for how it impacts the design (wall thickness, pipe diameter, pump size, etc) and how it leads to lower costs.

The following table describes the Project’s Initial Decision to proceed into design. However, once you have determined the solution that is included as your team’s Proposal, a narrative and supporting calculations / simulations for the Zero Based Execution changes “Change to be evaluated” will need to be included.
Table 5 – ZBE and Modularization Approach Differences

<table>
<thead>
<tr>
<th>Topic</th>
<th>Initial Decision</th>
<th>Change to be evaluated</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Hours of Operation</td>
<td>8 hours per day</td>
<td>24 hours a day</td>
<td>Pipe Diameter due to modified Flow Rate for same volume per day</td>
</tr>
<tr>
<td>Excavated Soil</td>
<td>Remove from site with dump trucks</td>
<td>Use cut as fill material</td>
<td>Dump Truck QTY</td>
</tr>
<tr>
<td>Fabrication</td>
<td>Stick Build Assembly</td>
<td>Modularization</td>
<td>Weight and Dimension Change for Foundation</td>
</tr>
<tr>
<td>Pump Station Location (Note 1)</td>
<td>One pump station and No closer than 30,000 feet from Inlet (source)</td>
<td>Multiple pump stations and anywhere along route</td>
<td>Quantity of pump stations and wall thickness of pipeline (Note 2)</td>
</tr>
<tr>
<td>Pump Station Site Space</td>
<td>500’ x 500’</td>
<td>200’ x 200’</td>
<td>Cut quantities</td>
</tr>
</tbody>
</table>

Notes:
(1) For this Design Challenge’s Cost Estimating Spreadsheet, you will utilize a quantity of 1 for every pump station for the original design. For ZBE evaluation, you could increase pump station quantities.
(2) The minimum wall thickness allowed is 0.250 inches

VIII. Submission of Your Teams Proposal – Phase 1

Once your team has completed the requirements, you will submit your proposal through the University of Houston web site that will contain the following information:

1. Hydraulics Model – File (.fth)
2. Design Calculations – Pipeline Mechanical Design, Foundation Design, and Excavation Quantities
3. Cost Estimating Spreadsheet that is populated with your data
4. Design Narrative that describes your design process – Written account of your design and the process that your team followed to come to a final solution. (template provided)
5. Zero Based Execution Narrative and Calculations: Your team will be evaluated based on the adjustments that were made with the changes in the project design criteria. (part of the narrative)
6. Narrative around Modularization Pros and Cons: Your team will submit ideas on how the modularization has improved the overall cost of the project, and identify any downsides related to modularization strategy. (part of the narrative)
7. **Risk Assessment**: Your team will need to review the risks on the project that could occur during the engineering process, procurement of materials, logistics of construction, and the actual construction. Your team will do this by identifying 5 risk areas and then evaluating each of the risk criteria and assigning a ranking of the risk profile of that activity (part of the narrative).

**IX. Evaluations – Analysis and Narrative Components**

Your Team’s proposal will be evaluated with the following process:

1. The Design Challenge Committee will rank the Teams Based on the Overall Cost in the Cost Estimating Spreadsheet
2. The Design Challenge Team will evaluate the Technical contents of the Design Narrative that describes your design process, the calculations, and the model files and validate it with the cost estimating spreadsheet.
3. The Design Challenge Committee will administer any penalties and provide final tally of Cost and notify the top Teams of their success with further instructions.
4. The Design Challenge Committee will review your narrative and reasoning on Zero Base Execution.
5. The Design Challenge Committee will review your Modularization Strategy
6. The Design Challenge Committee will review your risk assessment.

**X. Presentation**

Presentation forms the Phase 2 of the evaluation. Only those who are shortlisted will be required to make the presentation. (Refer FAQ 6 on critical dates). The presentation duration should not be more than 10 minutes (roughly 6-8 slides), with 10 minutes of Q&A session.

The presentation at a minimum should address:

1. An introduction slide about the team and individual contributions made to solve the design challenge.
2. Time Management; how long did it take (time spent on each section) and your steps to solve the problem
3. Summarize results of calculation
4. Summary of your constructability process
5. Summarize narrative on Modularization, ZBE and Risk Assessment
6. Proposed Innovation idea (safety, cost improvement, ease of construction or some improved/emerging technologies that do not exist in the market currently)

**XI. Team Size and Your Deliverables**

*It MUST be a three member team. The team size cannot exceed more than three members.*

You will have to submit three files as part of the Design Challenge Deliverable:
1. A word document or a pdf file which will contain your mechanical calculations, proposal narrative and innovation proposition.
2. A cost estimating spreadsheet in an excel format as provided.
3. A .fth file to show the hydraulic model.

In addition, it is recommended that you are ready with your 10 minute power point presentation and are ready to present your proposal should you be in the top finalists. Please note the following:

- There is not much time between announcement of top finalist and the “in person” presentation date.
- Power-point is not one of the three deliverables for the initial evaluation, however, you are required to be ready to present, when selected in the top finalists.

XII. **File Naming Convention and Size Limit**

All submissions MUST follow the below naming convention:

3. Pipeline **Hydraulics**: `<teamname>_Pipeline_Hydraulics.fth`
4. Make sure to keep your file limit to less than 50MB.

**Things to keep in mind when submitting:**

- Team name should be the same for all the three files. Any inconsistency and you will be disqualified.
- Watch out for typos in the file name that may lead to inconsistent team name.
- As you can see, it is very important that you pick a good team name, as that will be used to identify the files, publish the results, and will even go on the certificates should you be the winners!

XIII. **Evaluation Process**

The bottom line (cost) is the primary driver for successful award of projects. Your design proposal will be evaluated based on lowest commercial offering and technically acceptable design content. The top teams with the lowest cost and technically sufficient in meeting the requirements as outlined in the instructions will be considered for final evaluation and presentation.

The Conference Design Team will initially review the cost estimating spreadsheet for completeness and lowest cost. If there are any teams that did not meet the input requirements,
they will be disqualified and the next lowest cost team will be considered. The Conference Design Team will review the following Technical content for validation of the Design Proposal:

1. Mechanical Design Calculations (part of the narrative. A word document or a pdf)
2. Cost estimating spreadsheet (Excel file)
3. Hydraulics, Constructability, and Equipment Selected – Review calculation files and compare data to cost estimating input spreadsheet data
4. Proposal Narrative and Innovation Proposition – Your design team will describe the process you executed your work and addressing Zero Based Execution, Modularization, and Risk Analysis on what your team can do that would improve efficiency, safety, and/or constructability for this type of project (part of the narrative. A word document or a .pdf)

Note that if there are a few errors in your data or your design, you will not be entirely disqualified, but it will be part of the Conference Design Team’s evaluation to penalize your proposal based on the severity of the error.

The teams that have been selected for further evaluation will be evaluated and scored by the Conference Design Team based on their presentation of the proposal that will include the proposal narrative and the concepts around ZBE, Modularization and Risk. The Conference Design Team will work with the final Teams to prepare their presentation. The top finalists will be invited to Fluor Sugarland campus to make presentations to Fluor leadership. The format of the presentation will be similar to a Thesis defense.

XIV. **Tips for Success**

The portal for submission opens on Sep 3rd, 2019 and will stay open till Oct 18th, 2019 midnight. After that the portal will close (refer to critical dates in FAQ section). Things to keep in mind:

1. Time management is critical to your success. We know the FALL semester just started and you are swamped with classes and have loads of critical decisions to make. The challenge is designed to be finished in six weeks for you to plan and manage your time, and execute to the plan!
2. Diversity of majors and team is critical to your success. Start reaching out to other majors and have your team ready before the Design Challenge is published.
3. Please do not wait till the last minute to submit your solution. There is always the risk of a site shut down or slow down or issues with internet access. We will not be able extend the time line for submission.
4. Once your solution is submitted, it is recommended that you do not resubmit again. We will have a time stamp against your submission and will not consider another revision of your work.
5. When in doubt ask questions and we are here to help you out.
6. Please make sure to properly name your files, and upload them through the right channels.

XV. Rewards
- Cash awards up to $3000 for Top 3 Finalists
- Certificates that can go into your résumé builder for Top 3 Finalists

XVI. Design Challenge FAQ

1. Does this pipeline challenge require pipeline knowledge?

No. The instructions and requirements of the challenge is focused on demonstrating the importance of early engagement of construction input to office engineering effort and how it impacts constructability and the resulting cost. The biggest challenge is determining an efficient iterative process to refine your results.

2. How do I get AFT Fathom?

http://flow.aft.com/UH

3. What software can I make my mechanical calculations in?

MS Excel, MathCAD, or by Hand. If it is Excel or Mathcad, embed the excel/mathcad file into the word doc to show all your work. If it is hand calculation, scan the page and attach it to the narrative.

4. In the cost estimating spreadsheet, can we make modifications?

The cost estimating spreadsheet will have color coded cells that will identify your inputs and the cells that need to remain unchanged so that the calculations can be processed correctly. Do not modify the spreadsheet beyond the inputs that your team develops.

5. How long does my Proposal Narrative and Phase 2 design concept that addresses ZBE, Modularization and Risk need to be?

No more than 5 pages for both combined.

6. What are critical dates for Design Challenge?

- **September 3rd**: The actual challenge will be published.
- **Sept 3rd – Oct 18th**: Teams work on “Pump it Up!”
- **Oct 14th**: Portal for submissions opens. You can submit your solution here if you are ready. Keep in mind, once submitted, you cannot resubmit your solution.
Oct 18th: Portal for submissions closes. But we know you are always ahead of time and you will beat the deadline! (Not responsible if the website is slow or shuts down due to internet traffic).


Oct 22nd: Results published on the conference website and Top 5 teams will be notified via email. Be ready with your 10 minute presentations ahead of time in case you are in the top! Design team will work with Top teams to help prepare for the presentations.

Oct 28th – Nov 1st: Top teams will be invited to Fluor Campus to make presentations, interviews by the Design challenge panel and top 3 will be picked. Results will be published on the conference website and notifications of which the top 3 teams are will be sent via email.

Nov 5th (Day of the Conference): Student presentations of top-three teams and announcement of the winners by Nagu Vangury, UH Fluor Executive Sponsor.

7. Can I contact the Conference Design Team for questions and clarifications on the Design Challenge?

Yes, all the questions will be communicated back to all teams along with the answers. The questions can be emailed to: david.vogel@fluor.com.

8. I participated last year in the design challenge. Does that disqualify me from participating this year?

No, it does not. This is a different problem set; therefore we highly encourage everyone to participate. As long as your team comprises of students who are currently enrolled at University of Houston (College of Engineering and College of Technology).

9. Will there be any information sessions to help us with the design challenge?

Yes, Fluor team will be there once a week to conduct group information sessions to assist you in the design challenge. Please get with Jennifer Knobloch at jaknoblo@Central.UH.EDU for further information on time and date and venue of the information sessions.
XVII. Appendix – Hydraulic and Pump Selection Instructions

The hydraulics that will be conducted for this design challenge is key to evaluating the decisions that will impact the overall cost of the project. Initially, the hydraulics will determine the pressures that the pipeline will have to contain and the pump requirements for the pump equipment and the location of the pump station. Your team will need to perform the hydraulic analysis to determine each of these parameters so that the engineering design can be completed and the construction evaluated for the location of the pump station. The software that will be utilized is AFT Fathom. The software can be downloaded from:

http://flow.aft.com/UH

The instructions for installing the software are as follows:

1. Go to the website listed above and fill in the information requested using your University of Houston email address.
2. You will receive your license for use to your email address.
3. Once received, identify the location where the AFT Fathom file is downloaded and execute the installation file.
4. Open AFT Fathom

The following categories for the instructions for setting up your model are as follows:

1. Model components
2. Input parameters
3. Running the model
4. Output Results

The model will be fairly simple and will effectively be as shown with an upstream segment of pipeline and a downstream segment of pipeline with the pump in a location between the segments.
**AFT – Fathom Hydraulics Diagram to be Achieved**

- **Source Inlet** (100 psig)
- **Destination Outlet** (50 psig)
- **Pump Location** to be placed at the Junctions (J#)

200,000 feet total length with varying distances between Junctions

- Select “US Only”;
- Set Temp to 72 deg F
- Select “Start Building Model”
There will be multiple (12 total) segments to the pipeline that will be built in the model. The segments of the pipeline have to match the elevation profile provided in Table 7. Therefore, it is important to ensure that the lengths of the segments and the elevations that correspond to the lengths are inputted correctly, otherwise the model will not replicate the actual conditions in the field.

The pipe icon shown on the left will be used to build the segments of pipe.

The Branch icon shown on the left as grey circle will be used to connect the segments of pipe and provide inputs to elevations.

The Assigned Pressure icon shown on the left in blue with a “P” will be used at the beginning of the route and at the end of the route to be able to build the Inlet and Outlet parameters.

The pump icon shown on the left in yellow will be dragged and placed at the junction between two pipe segments. Ensure that the pump is connected to the two pipe segments when placed in the model.
a. Input Parameters

The process data that will be utilized to conduct the hydraulics simulation is identified in the table below:

**Table 6 – Process Conditions for Hydraulic Analysis**

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate (gallons/min)</td>
<td>11,111</td>
</tr>
<tr>
<td>Pipeline Inlet Pressure (psig)</td>
<td>100</td>
</tr>
<tr>
<td>Min. Pipeline Outlet Pressure (psig)</td>
<td>50</td>
</tr>
<tr>
<td>Maximum Flow Velocity (ft/s)</td>
<td>8</td>
</tr>
<tr>
<td><strong>Minimum Flow Velocity (ft/s)</strong></td>
<td>2</td>
</tr>
<tr>
<td>Temperature of Water (F)</td>
<td>72</td>
</tr>
<tr>
<td>Specific Gravity of Water</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The results that you will need to determine are as follows:

- Design Pressure – Upstream Segment
- Design Pressure – Downstream Segment
- Location of Pump Station along Route

The stationing and associated elevations of the pipeline route that will need to be considered in the model are as follows:

**Table 7 – Pipeline Elevation Profile**

<table>
<thead>
<tr>
<th>Junction</th>
<th>Length along line (feet)</th>
<th>Elevation (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>10000</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>20000</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>30000</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>50000</td>
<td>500</td>
</tr>
<tr>
<td>6</td>
<td>80000</td>
<td>800</td>
</tr>
<tr>
<td>7</td>
<td>100000</td>
<td>1200</td>
</tr>
<tr>
<td>8</td>
<td>110000</td>
<td>1300</td>
</tr>
<tr>
<td>9</td>
<td>120000</td>
<td>1350</td>
</tr>
<tr>
<td>10</td>
<td>150000</td>
<td>1800</td>
</tr>
<tr>
<td>11</td>
<td>160000</td>
<td>2000</td>
</tr>
<tr>
<td>12</td>
<td>180000</td>
<td>3250</td>
</tr>
<tr>
<td>13</td>
<td>200000</td>
<td>4000</td>
</tr>
</tbody>
</table>
b. Pipe Input Parameters

Use Standard (STD) Wall Thickness for ALL Evaluations

Input Length of Pipe Segment Based on Table 6
c. Flow Rate Input Parameters per Pipe Segment

Select “Optional” Tab to input Flow Rate

Input 11,111 gal/min for Flow Rate
d. Assigned Pressure Input Parameters

**Assigned Pressure for Pipeline Inlet (Source)**

- **Input 100 psig Inlet Assigned Pressure**
- **Input 2000 feet for Inlet Elevation**

**Assigned Pressure for Pipeline Outlet (Destination)**

- **Input 4000 feet for Outlet Elevation**
- **Input 50 psig Outlet Assigned Pressure**
e. Branch Properties

Input the elevation for each “Branch” connection based on Table 6.
f. Hydraulics and Pump Selection

There is a lot that can go into selection of a pump that would include creating pump curves and performance of the pump in the flow conditions. Often we would be selecting multiple pumps for performance and redundancy. For this exercise, we will focus on identifying the pump location that best fits the Construction-Driven Execution approach while meeting hydraulics requirements that drives the overall pressure in the system that influence the wall thickness requirements for the pipeline.

To build a pump into the hydraulic model you will select the Pump Icon and locate it between the two pipe segments. Then double left clicking on the pump icon, it will pull up the pump input window as shown below.

[Diagram of pump input window with annotations:]
- Select Volumetric Flow Rate
- Input Elevation of Pump Based on YOUR TEAM’S selected location from Table 7 (Example only)
- Input Flow Rate of 11,111 gal/min
g. Model Results and Table Results

To be able to see the results of the analysis from a pressure profile standpoint, the results can be found to the “Graph Results Tab” which will show a window on the right where you can select “Profile” Tab. Follow the instructions to plot the pressure curve.

Checks to be conducted for selection of the pump

- Choose Pump so that hp requirement < Pump Performance hp
- Choose Pump so that NPSHA > Pump Performance NPSHA
h. Requirements of the Outputs:
- Net Positive Suction Head Available > Minimum Requirement to prevent Cavitation per Pump Table
- Horsepower of Pump > Horsepower Requirements from Analysis
- Maximum Flow Velocity = 8 ft/s (check in Output Tab under Pipe for Flow Velocity)
- Minimum Flow Velocity = 2 ft/s (check in Output Tab under Pipe for Flow Velocity)

i. Pump Selection Criteria
The information in the table below will be the criteria in which you will select your pump along with the cost associated in Table 9 with each of the pumps assemblies. The respective cost of the pump station will be entered into the cost estimating spreadsheet.

Table 8 – Pump Selection

<table>
<thead>
<tr>
<th>Pump</th>
<th>Performance NPSHA (ft)</th>
<th>Horsepower</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>400</td>
<td>7,000</td>
</tr>
<tr>
<td>B</td>
<td>200</td>
<td>8,000</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>4,000</td>
</tr>
<tr>
<td>D</td>
<td>100</td>
<td>6,500</td>
</tr>
<tr>
<td>E</td>
<td>100</td>
<td>7,500</td>
</tr>
<tr>
<td>F</td>
<td>50</td>
<td>3,500</td>
</tr>
</tbody>
</table>

j. Pump Assembly Weight and Dimensions
The information in the table below will be the weight, dimensions, and costs for the pump that you select from the table above. The table identifies the difference between a stick build assembly and a modularized assembly. The narrative that your team will draft will need to include a description of the benefits between stick build and modularization.

Table 9 – Pump Assembly Weights, Dimensions and Costs

<table>
<thead>
<tr>
<th>Pump</th>
<th>Weight – “P” (lbs)</th>
<th>Dimensions of Pump</th>
<th>Pump, Installation, and Site Labor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stick Build</td>
<td>Modularization</td>
<td>Stick Build</td>
</tr>
<tr>
<td>A</td>
<td>4,500</td>
<td>5,000</td>
<td>7’ x 9’</td>
</tr>
<tr>
<td>B</td>
<td>7,000</td>
<td>7,500</td>
<td>10’ x 12’</td>
</tr>
<tr>
<td>C</td>
<td>8,500</td>
<td>10,000</td>
<td>12’ x 14’</td>
</tr>
<tr>
<td>D</td>
<td>7,500</td>
<td>9,000</td>
<td>10’ x 10’</td>
</tr>
<tr>
<td>E</td>
<td>10,000</td>
<td>12,000</td>
<td>15’ x 15’</td>
</tr>
<tr>
<td>F</td>
<td>4,000</td>
<td>4,000</td>
<td>6’ x 8’</td>
</tr>
</tbody>
</table>

For this challenge, the weights, dimensions, and costs that are identified above are arbitrary to create a differentiation in the design of foundations and to distinguish between pump selection costs.
XVIII. Engineering Quick Reference Guide

Start

Input from Floor:
- Pipeline Size, Elevation Profile, Pipeline length, Inlet and outlet pressures, Flow rate
- UH to Conduct Preliminary Hydraulics Analysis in APT Fathom to determine:
  - Pump Location and Site (hydraulic requirements)
  - Wall thickness of Pipeline

Input from Floor:
- Soil Conditions
- Excavation and Foundation Calculations

Civil Design. Determine:
- Excavation Requirements for Selected Location of the Pump Station
- Foundation requirements based on the Pump Selected.

Constructability Review
Check to determine if excavation can be reduced
Check to determine if foundations design can be improved

No

Input from Floor:
Spreadsheet containing calculations for estimates

Equipment Quantities for Construction – UH to Determine quantity of equipment to be utilized for construction of:
- Pipeline
- Excavated Material
- Foundations

Is the COST optimal for the design? Can it be improved?

No

Yes

Submit Design Challenge to U of H Portal That includes:
- APT Fathom (.fth) file
- Written Narrative that includes Calculations, written portion describing how your team completed the Design Challenge, and innovation ideas
- Cost Estimating Spreadsheet with all data filled out
- Narrative on Zero Base Execution (show calculations)
- Narrative on Modularization (Pros/cons)
- Narrative on Risk Assessment

End

Output is a spreadsheet containing estimates and equipment information

Outputs are excavation and foundation design calculation (shown in the narrative)

Output is a .fth file (part of design submission)

Outputs are .fth file, cost estimating spreadsheet, Narrative with calculations and write ups on ZBE, Modularization and Risk assessment

LEGEND
- Floor input
- UH Action