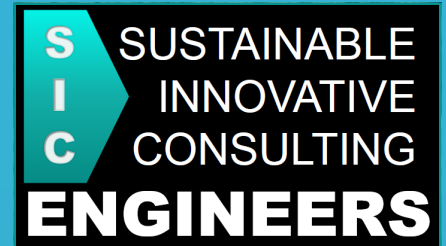


ENGI 8700

Design Project Plan

Submitted to: Dr. Steve Bruneau
February 4, 2013



Terra Nova FPSO WHRU Remediation Design



Prepared for: Mr. Dan Whiffen



Joanne Dodd
Heather Kelly
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February 4, 2013

D. Whiffen
Wood Group PSN
277-281 Water Street, St. John's, NL
A1C 6L3

Subject: Terra Nova FPSO - WHRU Remediation Design Project Plan

Dear Mr. Whiffen,

SIC Engineers are pleased to provide the attached project plan for the Terra Nova FPSO WHRU Remediation Design. This project plan outlines how The SIC Engineers Team plans to complete the required work for Wood Group PSN as well as meet the requirements for ENGI 8700.

The project plan outlines the tasks to be completed and methodology that will be used to approach them. An initial schedule is also included in the form of a gantt chart and will outline the tasks and milestones throughout the life of this project. This schedule will be updated throughout the term.

If there are any questions concerning this project plan, please feel free to contact us.

Sincerely,

SIC Engineers

cc. Dr. S. Bruneau

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1.0 Project Description

The Terra Nova Floating Production Storage and Offloading (FPSO) Unit is an oil production vessel located on the Grand Banks, approximately 350 kilometres southeast of Newfoundland and Labrador. As one can see in the figure below, there are a number of complicated structures that are on or surrounding this FPSO Unit.



Figure 1 - Terra Nova FPSO (Suncor Energy)

In addition to this, the Grand Banks are a fairly shallow body of water making it susceptible to the brunt of nature's forces; namely wind and waves. These forces can, over time, damage a structure quite significantly, making repair necessary. Also, the salt water and waste materials onboard have a tendency to corrode any steel or metal with which it comes into contact.

This was exactly the case when a client, Wood Group PSN, brought The SIC Engineers Team a work scope of repairing the Waste Heat Recovery Unit (WHRU) on the Terra Nova FPSO Unit. This unit has been severely corroded over the past few years and is in need of some structural upgrades. Two possible solutions for the structural repairs will need to be explored: A conventional repair such as bolting and clamping and a more modern option consisting of a Fibre Reinforced Polymer (FRP) repair.

2.0 Project Requirements

The SIC Engineers Team will work for Wood Group PSN in the remediation design of the support structure for a WHRU on the Terra Nova FPSO Unit. The structure, as can be seen in the figure below, will have to be repaired during normal operations, meaning that no hot-work may be done.

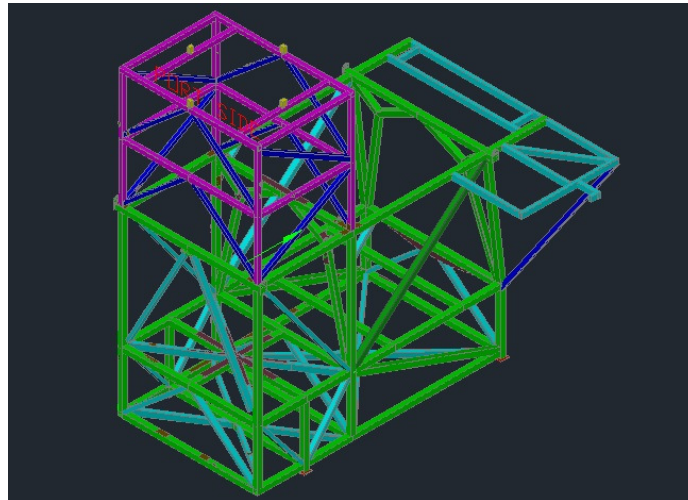


Figure 2 - WHRU Support Structure

This led to the requirement of two options needing to be developed for the design: A conventional repair such as bolting and clamping and a more modern option consisting of a FRP repair.

In order to begin these designs, an engineering assessment of the existing structure must be completed. This includes calculation of all existing loads as well as the consideration of all design conditions (i.e. 10 year bow wave vs. 1 year beam wave). Once all loads are calculated, a model must be developed in S-Frame to analyze the stress in the structure. The design options can then be developed for a 20-year life expectancy. The conventional design will be completed using CAN/CSA S16-01 and CSA Z19902 codes while the FRP design will be completed using its applicable codes.

An estimate is required for each final design solution as well as a detailed plan and schedule for construction of these options.

3.0 Methodology

3.1 Approach

The SIC Engineers team will approach this project by developing a deep understanding of the various components to ensure no aspects are overlooked. Also, every resource at their disposal will be assessed to ensure all design aspects are to code and to determine the optimal materials and procedures to utilize.

The first step of the design process will be to examine the existing structure and create a replica within a structural analysis program. Applicable loads will then be calculated and various load combinations will be created. These load combinations will then be applied to the various members and joints of the electronic support structure. Damaged areas on the support structure that are prominent within the supplied electronic drawing will be analyzed to determine which members should be considered for repair in the scope of this project. All the while, FRPs will be researched to determine how they can be applied to the structure to repair the damaged areas. Also, conventional methods, such as bolting and clamping, will be researched and compared to FRPs to determine the preferred method of choice. This comparison will evaluate the cost, difficulty, and length of installation, as well as the strength and lifespan of each material.

3.2 Group Organization and Roles

Each member within the SIC Engineers team has gained a specific set of skills developed from personal interest and work experience. Although major tasks within this project will be shared amongst various team members, specific roles have been appropriately assigned to ensure the finest quality of work is obtained with maximum productivity. The roles of the individual members are as follows:

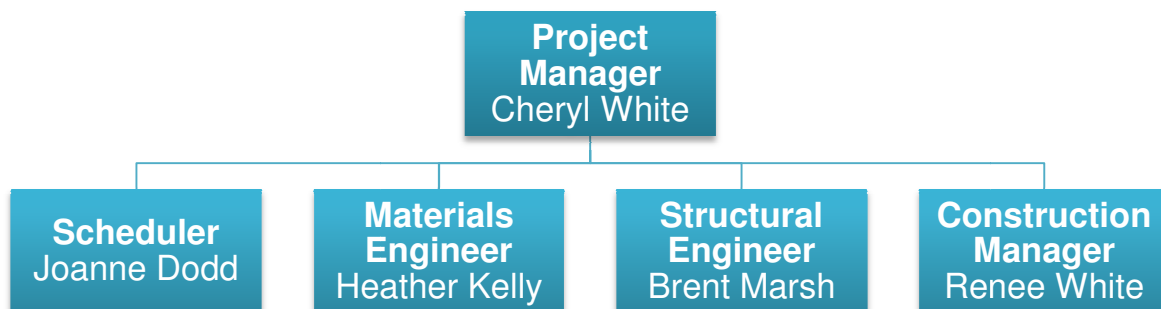


Figure 3 - Organizational Chart

Cheryl White: Project Manager

Cheryl has been assigned the role of Project Manager due to her consecutive workterms within a Project Management Group. Her responsibilities include liaising between the client and the project team, coordinating and chairing team meetings, as well as ensuring all project requirements are met. Cheryl will also be in charge of creating the electronic model using structural analysis software, determining the various load combinations to be applied, and generating the resultant reactions.

Brent Marsh: Structural Engineer

Brent's previous experience in the Oil and Gas Industry has made him familiar with the offshore design codes and standards, and thus has been assigned the lead structural engineer. He will be responsible for ensuring all code requirements are met, as well as making all design requirements clear to the team members. Brent will lead the team in calculating all the applied loads upon the support structure and assist Cheryl in creating the load combinations.

Joanne Dodd: Scheduler

Joanne will be in charge of completing and updating the project team's schedule for the entire term project. This skill set will then be carried forward to lead the team in developing the remediation construction schedules for the two final repair methods to be purposed to the client. Joanne will also be the lead researcher for conventional repair methods and will lead the team to determine which conventional repair method should be further analysed and purposed to the client.

Heather Kelly: Materials Engineer

The client has requested that one option for repair is to utilize FRPs. Heather has undertaken the task of researching this new technology and investigating the costs, strengths, availability and its functionality. She will also be assisting Brent with the determination of the applied loads to the structure and leading the comparison between FRP and conventional repair methods.

Renee White: Drafter and Construction Manager

Renee's extensive experience in the construction industry gives her a keen interest in worker productivity and thus will be the lead in determining how the two remediation techniques will be implemented. She will work closely with Joanne to create reasonable schedules and will be the principal selector and presenter of the optimal repair method. Also, Renee will be analyzing the existing electronic model of the structure to attain all the sizes of the existing members and to determine which members have the greatest amount of damage.

3.3 Meetings and Client Interaction

3.3.1 Internal Meetings

The SIC Engineers team will conduct internal meetings to obtain progress updates from each member and to address any issues members are facing with their assigned tasks. A path forward will be established at the end of each meeting and specific tasks will be assigned to individual members. These meetings will occur during scheduled time slots, Monday and Thursday at 3:30PM weekly, as well as whenever necessary.

3.3.2 Class Meetings

The second section of the Engineering 8700 class will meet weekly on Mondays at 2:30 PM. It is in this meeting where a safety issue will be addressed and each individual group will discuss their progress, paths forward and current issues.

3.3.3 Client Interaction

Dan Whiffen is a Structural Lead with Wood Group PSN. The SIC Engineers team will be meeting their client, Dan Whiffen, every Wednesday from 3:30 to 4:30 pm at the Wood Group PSN office on Water Street in St. John's. It is during these meetings that the team will discuss their progress, describe their path forward, and inquire about any issues the team may be facing. Mr. Whiffen is expected to provide standards, drawings, and specifications regarding the current support structure, as well as to provide insight, concerns and recommendations concerning the issues facing the SIC Engineers team.

3.4 Design Principals to be Applied

All design work will comply with the following codes and standards:

- ASME PCC-2-2011
- BS EN 1465:2009
- BS EN 14692-3,4:2002
- CAN/CSA S16-01
- CAN/CSA-S471-92
- CAN/CSA-S473-92
- CSA Z19902
- DD CEN ISO/TS 24817:2011

The client has also instructed that the proposal must include both a conventional and an advanced material (FRP) repair design with no hotwork allowed (ie: welding).

3.5 Proposed Cost Estimating Strategy and Level of Accuracy

The SIC Engineers team will provide a “Class D” Estimate which will indicate the relative costs for each potential solution. The proposal from the team will only include the remediation of one specific joint and thus the estimate will not reflect the cost to repair the entire structure. The purpose of this estimate is help rank the repair options being considered. External companies will be contacted to determine specific material costs, and the RS Means Cost Data will be utilized to determine labour costs.

3.6 Desired Outcomes

The desired outcome of this project is to deliver two complete remediation designs for a corroded joint on the Terra Nova FPSO's WHRU Structure. From these design comparisons, it is expected that an educated and assertive decision can be made as to what is the optimal method of repair. To ensure that the SIC Engineers team meets all project requirements set forth by the Engineering 8700 Instructor, as well as the client, the team will discuss their progress and path forward with each party on a weekly basis.

3.7 Reporting and Deliverables

Each individual member of the SIC Engineers team will record their daily activities regarding their project work within their own personal logbook. Minutes of weekly meetings with the client will be recorded and posted on the SIC Engineers Google Drive (the G-Drive) within one week of the meeting in question for all members to review and consult. Weekly progress reports will also be composed, posted to the G-Drive, and presented to the class during class meetings. The deliverables for this report, as stated in Section 8.0 of this report will be worked on throughout the course of this project, and all preliminary works will be posted on the G-Drive for constant peer review.

3.8 Troubleshooting

In the case of any problems during the course of this project, the SIC Engineers team will first discuss, document and solve issues internally. If the issue cannot be solved internally, the matter will be brought forth by the project manager during a weekly meeting to the Engineering 8700 Instructor and/or the client (whichever is most applicable to the situation). These problems (outstanding and resolved) will be addressed on a weekly basis during class meetings.

4.0 Tasks

The SIC Engineers team must design and recommend the best option to remediate severely corroded members on the support structure for a WHRU on the Terra Nova FPSO. To complete this project the team has divided the project into 9 tasks each with its corresponding subtasks. In this section you will find a description of each task and subtask. Following the descriptions is a table which details the tasks, their associated subtasks, time allocated for each subtask, team members assigned to work on each subtask and the resources that will be utilized to complete each subtask.

4.1 Analyze Existing AutoCAD Model

The team was provided with an AutoCAD model of the existing WHRU Support Structure. The model illustrates all aspects of the structure including: corrosion of each individual member and member properties.

4.1.1 Determine Existing Structure Member Dimensions

Dimensions and properties of each member of the support structure must be found and recorded. These dimensions and properties will be used later when modelling the structure in S-Frame.

4.1.2 Analyze Damaged Members

The corrosion of the structure is quite extensive. To determine the damage to the overall structure each member will be analyzed separately to determine the severity of corrosion on each member.

4.1.3 Initial Selection of Members to Repair

The team has been instructed to choose one joint of the structure to focus on repairing for the project. This joint should be one of the more severely corroded joints and should also carry a high percentage of the load. The initial selection of the joint to be repaired can only be based on the analysis of the damage. From this analysis three joints and their adjacent members will be identified as having the greatest amount of damage due to corrosion.

4.1.4 Present Preliminary Members to PSN

The three joints that were chosen in 4.1.3 as having the greatest amount of damage will be presented to the client at weekly meeting. Images of each joint as well as an image that illustrates where each joint is located in terms of the entire structure will be presented to the client. Emphasis will be placed on the joint with the greatest amount of corrosion as that will likely be the joint that will be the focus of the repair for the remainder of the project. A final decision on the joint will be made following the completion of 4.3 Model and Analyze phase.

4.2 Research

Due to the fact that this project is quite complicated the team will need to complete a large amount of research to ensure that the problem can be solved in the most realistic and economical fashion.

4.2.1 Initial Research of FRP and Applicable Applications

One of the remediation methods for this project must be FRP. Due to the fact that the team has very little knowledge in this subject a great deal of research must be completed in this area.

4.2.2 Initial Research of Conventional Repair Methods

Research must be completed to become familiar with structural steel reinforcement used in harsh environments such as offshore Newfoundland. Since no hot work can be used during installation research must be geared toward clamp and bolt reinforcement methods.

4.2.3 Initial Research of Corrosion

The team must determine what may have caused the severe corrosion of the existing structure and use this knowledge to improve the remediation methods that will be proposed.

4.2.4 Review Terra Nova Design Basis

The Terra Nova Design Basis was provided to us by the client. The design basis

includes a great deal of information such as accelerations, which will be important for the analysis and design stages. The design basis will be reviewed by a team member and sections of interest to the team will be highlighted.

4.3 Model and Analyze

The AutoCAD model of the structural support system must be replicated and analyzed in S-Frame.

4.3.1 Model in S-Frame

Using the dimensions and properties recorded in task 4.1.1 a model will be created in S-Frame.

4.3.2 Determine Applied Loads on the Structure

Using information found in the design basis accompanied with engineering judgment the loads that could be applied to the structure will be identified and quantified.

4.3.3 Create Load Combinations

Using the applied loads found in the previous step and information from the design basis, a series of load combinations will be created and applied to the model in S-Frame.

4.3.4 Model Internal Reactions for Selected Members

The moments and forces within the members adjacent to the two most severely corroded joints will be evaluated in S-Frame. This will determine the joint which is under the most stress and will allow a final decision to be made on the joint that will be studied for the remainder of the project. This information will also be needed to complete the detailed designs.

4.4 Repair Methods

The team must decide on two separate methods for the remediation design process.

One option must use FRP while the other should use conventional steel.

4.4.1 Decide on Most Appropriate FRP Option

Based on the research that has been conducted about FRP, the team must decide which of the different forms and methods of using FPR will be the most suitable for the remediation of the specific joint of the structure.

4.4.2 Decide on Most Appropriate Conventional Option

To continue with detailed design a method which will most likely include bolts or clamps will need to be decided. The best method will be a result of the research on conventional steel that was completed earlier.

4.5 Detailed Design

4.5.1 Design Conventional Method

Based on the conventional steel remediation method that will be chosen in the previous step, a detailed design will begin. The design will need to reinforce the joint and its adjacent members so that it can withstand the loads that are placed on the joint. The detailed design will include number and spacing of clamps and/or bolts along with other design details.

4.5.2 Design FRP method

Based on the FRP remediation method that will be chosen in the previous step, the team must use the loading cases to complete the detailed design for the FRP method. This will include sizing, amount of FRP needed and an adhering method.

4.6 Construction Schedules

Detailed construction schedules for both methods will be completed.

4.6.1 Detailed Construction Schedule Using FRP

A construction schedule will be completed to help determine labour costs for construction and to determine the overall timeline for the remediation. RS Means and consultations with personnel in the industry will help to make the schedule as accurate as possible.

4.6.2 Detailed Construction Schedule Using Conventional Method

A construction schedule which focuses on the previous, detailed, conventional steel design will be completed to help determine labour costs for construction and to determine the overall timeline for the remediation.

4.7 Cost Breakdown

The cost breakdown will be used later to decide which remediation method is most economical.

4.7.1 Detailed Cost Breakdown Using FRP

Based on the detailed design of the FRP option, the team must perform a cost estimate that will determine the expense of this option from acquiring the needed materials to completion of installation.

4.7.2 Detailed Cost Breakdown Using Conventional Method

A cost estimate of the conventional steel remediation method will be completed. It will be used later when the team must decide between the FRP and conventional methods.

4.8 Compare Remediation Methods

4.8.1 Decide on Most Appropriate Method

Based on the cost breakdown, construction timeline and lifespan of the project for both the FRP option and the conventional steel option the team must choose the best solution to remediate the joint of the structural support.

4.9 Project Deliverables

Once all previous tasks are completed, the project report and project presentation must be compiled.

4.9.1 Project Report

The entire group will use the time that remains to prepare the project report. The report will include all workings, and data collected throughout the project. It will also include a recommendation which will state, based on the work completed, the best method to use to remediate the support structure.

4.9.2 Final Presentation

Key aspects of the project will be presented to the class and the group of clients through a formal presentation. The presentation will be prepared by all group members.

Task	Subtask	Time Allotted (Days)	Team Members					Resource Utilization
			Brent	Cheryl	Heather	Joanne	Renee	
Analyze Existing AutoCAD Model	Determine existing structure member dimensions	9					X	AutoCAD
	Analyze damaged members	6					X	AutoCAD
	Initial selection of members to repair	1	X	X	X	X	X	AutoCAD
	Present preliminary members to PSN	1					X	Client Feedback
Research	Initial research of FRP and applicable applications	15			X			Internet, Scholarly Articles, Dr. Hussein
	Initial research of conventional repair methods	7				X		Internet, Dr. Adluri, Steel Handbook
	Initial research of corrosion	7					X	Dr. Kenny, Internet, Scholarly Articles
	Review Terra Nova Design Basis	8	X					Provided by Client
Model and Analyze	Model in S-Frame	6		X				S-Frame
	Determine applied loads on the structure	7	X		X			Terra Nova Design Basis, Various Codes, Client Suggestions
	Create load combinations	3	X	X	X			Terra Nova Design Basis, Various Codes, S-Frame
	Model internal reactions for selected members	1		X				S-Frame
Repair Methods	Decide on most appropriate FRP option	9	X	X	X	X	X	Previous Research
	Decide on most appropriate conventional option	9	X	X	X	X	X	Previous Research
Detailed Design	Design conventional method	14		X		X	X	Internal Reactions, Various Codes
	Design FRP method	14	X		X			Internal Reactions, Various Codes
Construction Schedules	Detailed construction schedule using FRP	7				X	X	RS Means, Various Codes
	Detailed construction schedule using conventional method	7	X			X		RS Means, Various Codes
Cost Breakdown	Detailed cost breakdown using FRP	5		X			X	RS Means, Various Codes
	Detailed cost breakdown using conventional method	5	X		X			RS Means, Various Codes
Compare Remediation Methods	Decide on most appropriate method	1	X	X	X	X	X	Preliminary Work
Project Deliverables	Project Report	7	X	X	X	X	X	AutoCAD, MS Word
	Final Presentation	5	X	X	X	X	X	PowerPoint

Figure 4 - Task and Resource Breakdown

5.0 Schedule

To help organize, assign and oversee project tasks to ensure all proper deadlines and work are completed, a Gantt chart was developed. The Gantt chart is broken into several main jobs to make certain that all required components of the project are completed to the client needs and requests. The project is to take place from January 23, 2013 to April 1, 2013 with weekends scheduled as working days, however team members will work weekends on a rotational basis.

To start, the existing structure was analyzed using AutoCAD software to which the dimensions of the structure were determine and preliminary joints/members to be repaired were selected. Going forward, ongoing research of fiber reinforced polymers (FRP) will be completed, as a required repair option, along with more conventional repair method likely to be steel. In conjunction with the research components, the existing structure is to be modeled using s-frame along with calculated applied loads and load combinations. Once all required input parameters are determined, a run of the model will be completed to illustrate all internal forces. Following these results, a member will be selected on several factors including the severity of the corrosion, importance of the member, and forces excreted on the member. It is at this point in the project schedule that will mark the first milestone, Existing Structural Analysis Complete.

To reach the next milestone, all research will be compiled and review by the project team. Once two repair options are determined the next milestone will have been completed, Repair Methods Chosen for Design.

The completion of the above will allow the detail design process to commence in conjunction with a construction schedule marking the third milestone, Detailed Designs Complete.

To complete the design information, cost breakdowns will also be developed for both repair options. The option to be recommended to the client will be chosen once this task is complete and will be based on several factors such as cost, design life, construction schedule and efficiency. This will mark the fourth milestone, Final Design for Project Complete.

In closing, a report and presentation containing the project deliverables will be completed marking the fifth milestone, Project Deliverables Complete, then the client will be presented with the overall project findings. This task will mark the end of the project and final milestone, Project Complete.

Throughout the duration of the project, the schedule will be used as a working reference and presented to the client when requested.

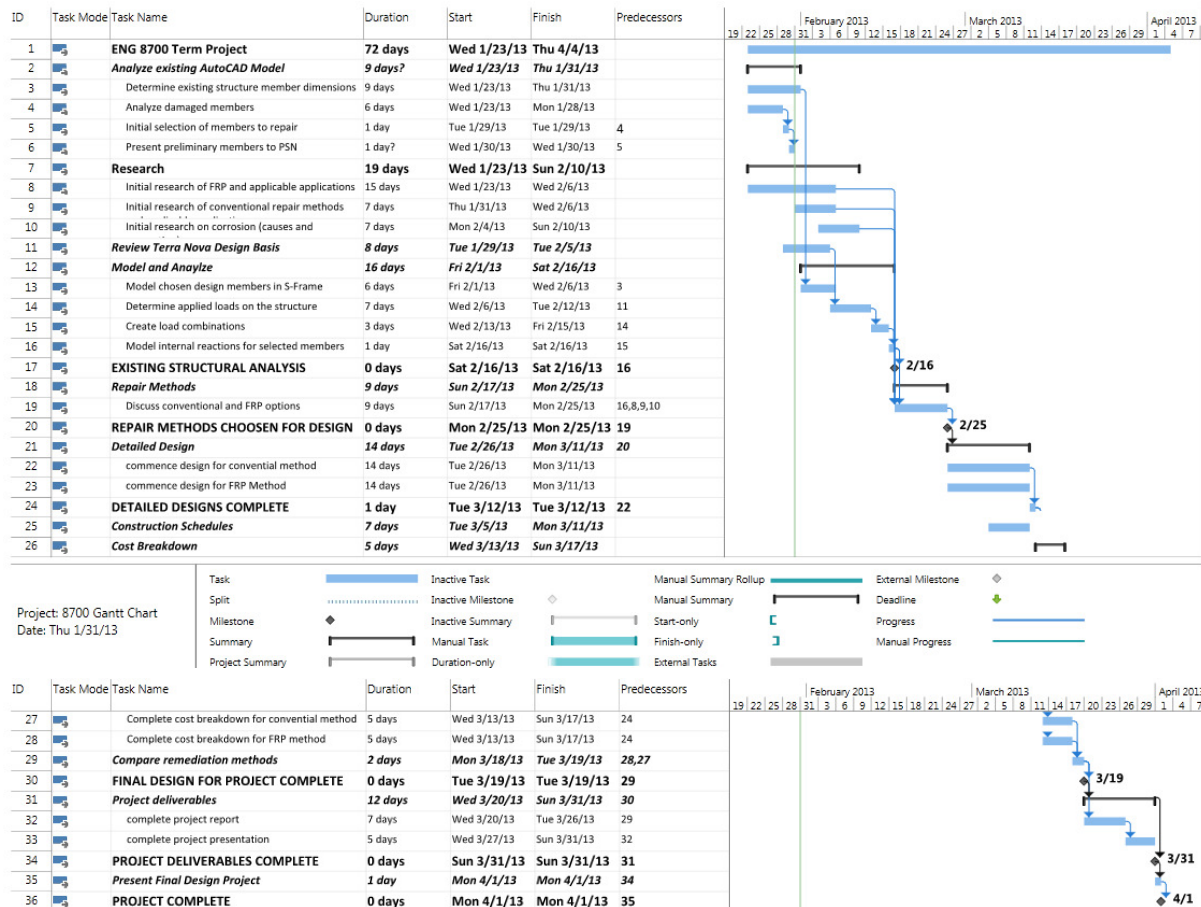


Figure 5 – Gantt Chart

6.0 Environmental Sustainability

On today's global scale, it is important to consider the environmental sustainability of even the smallest of projects. The SIC Engineers Team has taken into consideration several key environmental factors that will be carefully monitored and planned for throughout this project. These include; potential air and ocean pollution from the

required work, safe disposal of any excess material (utilizing re-use and recycling where possible), efficient use of any required energy and selection of more environmentally friendly materials when functionality is not affected. The team intends to follow the Newfoundland Environmental Protection Act as well as The Canadian Environmental Protection Act to ensure that all regulations are followed.

7.0 Costs

The expected costs to be incurred for this project are relatively minimal. They will consist of expenses generated from gas and parking required for client meetings, as well as the cost of printing and binding the final design report. No costs will be incurred from site visits as the area is inaccessible to untrained personnel. Below is a compilation of the total expenses.

ITEM	COSTS
Gas Expenses	\$30.00
Parking Expenses	\$20.00
Printing Expenses	\$20.00
Binding Expenses	\$8.00
Total Expenses	\$78.00

Figure 6 - Cost Chart

8.0 Deliverables

The client has requested softcopy pdf deliverables instead of hard copies. These deliverables include the project plan and the final project report. The final project report includes design of conventional remediation & advanced material remediation, cost estimates of each, planning and scheduling for construction of each, and drafted drawings of each. The softcopy pdf as well as a hard copy will be delivered to the class instructor. The soft copies will be provided through email, while any hard copies will be delivered in person by a member of the group.

9.0 Risks

Completion of this project contains certain inherent risks that must be carefully planned for and mitigated as best possible. Some of the major risks include:

- Lack of data on the structure in need of repair. There is no analysis report from the original design, and only the only available drawings are of both the structural support and surrounding equipment.
- Access to all relevant codes needed for design. Certain codes may not be available through the university or client's resources,
- Restrictions on required software availability. This may slow progression of several key tasks.
- Delays due to weather and other unforeseen events. This may potentially throw the schedule off track.
- Assumptions made in design. If not carefully considered these assumptions may greatly affect final results in a negative way.

10.0 References

Bruneau, S. (2013). *Term 8 Design Project ENGR - 8700*. Retrieved from
<http://www.engr.mun.ca/~sbruneau/teaching/8700project/classof2013/>

Suncor Energy. (n.d.). *Terra Nova*. Retrieved from
<http://www.suncor.com/en/about/4001.aspx>

Appendix - Statement of Qualification (SOQ)

**S
I
C** SUSTAINABLE
INNOVATIVE
CONSULTING
ENGINEERS



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Mission Statement

- SIC Engineers focus on safety, professionalism and innovation and are committed to ensuring client satisfaction by producing the best solution to every problem

Engineering Specialties

- Environmental Engineering
- Estimating
- Field Engineering
- Geotechnical Engineering
- Oil and Gas
- Project Management
- Structural Engineering
- Water Resources

Previous Employers

- Allied Constructor's
- AMEC Earth and Environment
- BAE Newplan Group Ltd.
- BC Hydro
- Canadian Coast Guard
- City of St. John's
- C-NLOPB
- Dept. of Transportation and Works
- ExxonMobil Canada Ltd.
- Nalcor Energy
- North American Construction Group
- North Atlantic Refining Ltd.
- Public Works & Government Services Canada
- Shell Canada Ltd.
- Syncrude Canada Ltd.
- Technip USA Ltd.
- WorleyParsons Canada Ltd.

Software Capabilities

- ArcGIS
- AutoCAD
- Eclipse
- Heavy Bid
- HEC-HMS
- HEC-RAS
- InfoSewer
- InfoSWMM
- MathCAD
- Matlab
- Microsoft Access
- Microsoft Excel
- Microsoft Power Point
- Microsoft Project
- Microsoft Word
- Microstation
- PDMS
- SACS
- SAP 2000
- SEEP-W
- S-Frame
- SLOPE-W
- SolidWorks
- Vulcan
- XP SWMM

The SIC Engineers



JoAnne Dodd

JoAnne is a Term 8 Civil Engineering Student currently attending Memorial University. She will be graduating in April 2013 with engineering experience in municipal, consulting, construction, geotechnical, oil and gas, environment, project management, health and safety.



Heather Kelly

Heather is a senior Civil Engineering student at Memorial University of Newfoundland. Working with ExxonMobil and Technip has familiarized her with many processes involved in the oil and gas industry. Through her work terms she has also gained valuable experience in data analysis, project management, and structural design.



Renee White

Renee will complete the civil engineering program at Memorial University in April. Renee has completed the majority of her work terms in the fast paced environment of the Alberta Oil Sands. From this experience she has developed a strong set of skills in the field of project management which include: attention to detail, critical thinking, and hazard mitigation.



Brent Marsh

Brent is currently in his last term of the Civil Engineering program at Memorial University and is specializing in the OOG (Offshore Oil and Gas Engineering) option. He has gained the vast majority of his experience in the oil and gas field working in several project management positions as well as in an offshore structural design position.



Cheryl White

Cheryl is completing her senior year of the Civil Engineering program at Memorial University of Newfoundland. Through working with hydroelectric companies on both sides of the country, and the oil industry in Alberta, Cheryl has gained a great appreciation and vast knowledge in the energy sector.

CONTACT INFORMATION

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CLIENT

Wood Group PSN
Dan Whiffen

INSTRUCTOR

Dr. Steve Bruneau