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THE DEVELOPMENT OF A SCHEDULE REPORTING SYSTEM FOR INDUSTRIAL PROJECTS

Tarcisio Althoff

Master of Engineering in Management

College of Engineering

University of Canterbury

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EXECUTIVE SUMMARY

Background

Beca is an engineering consulting company that provides professional services in the Asia Pacific region. One of the segments that Beca works within is the industrial sector. Within this segment, Beca has a joint-venture with Wood PLC, a global engineering company. This joint-venture, named Wood Beca, is focused on providing solutions for pulp and paper, wood products and bioprocess industries in New Zealand and Australia.

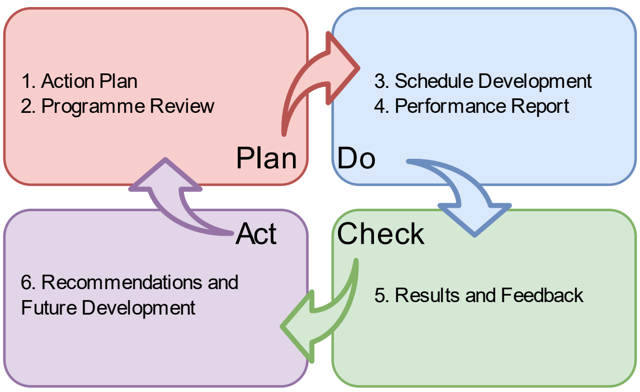
In April of 2019, Wood Beca was commissioned by one of its paper and pulp clients for the management and design engineering of a programme containing nine projects. This programme aims to improve the wastewater treatment system in one of their paper mills.

Project Scope

The scope of this project was to develop the detailed schedules for this programme of projects, including resource allocation if applicable. After the development of the schedules, a routine of update and control was implemented. Then, a reporting system was developed to regularly inform the project team about the programme performance. The system included key performance indicators (KPIs) and visual tools to adequately track and inform the progress of the project.

Action Plan

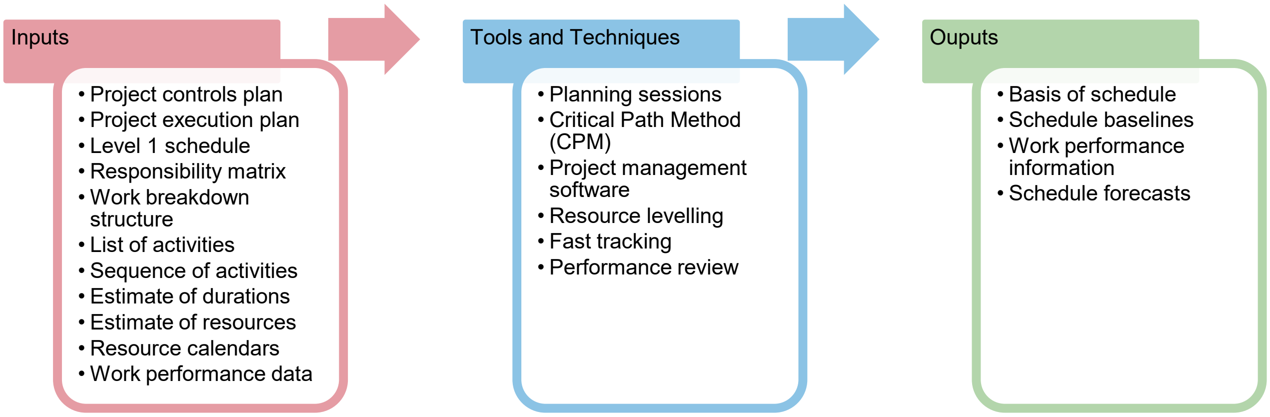
The action plan was developed using a PDCA cycle. An action plan supported by a detailed review of the programme documentation was completed first. Then, the execution phase was split into two main steps: the development of the schedules and the performance report system. After the execution, a check phase was performed in order to collect feedback from the management team and register the results achieved during the execution. The final step was an action stage, containing the compilation of recommendations and potential future development based on the results obtained.



Programme Review

The documentation review revealed the management methodology of the programme based on a stage-gate system named Front-End Loading (FEL). The multiple stages system required a mixed scheduling approach between predictive and incremental. In this approach, the schedules should be developed following a three-level hierarchical system with incremental detailing, in a rolling wave planning strategy. The lack of clear scope definition and the programme execution team being spread across two companies were examples of challenges that would be faced.

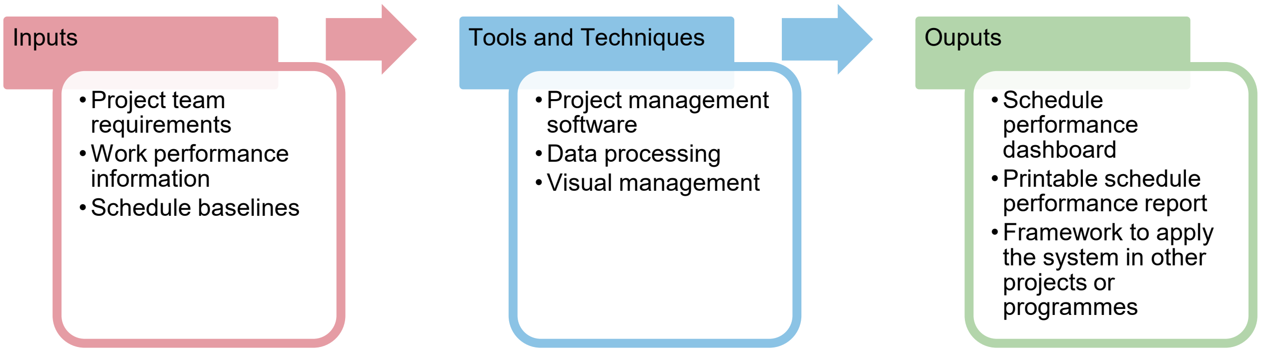
Schedule Development



The schedule development process was done following the requirements and definitions present on the programme documentation. The base of the data collection for the schedule development was a structured meeting called a Planning Session. The main goal of this meeting was to extract from the programme team a list of activities, sequence, durations and resources necessary to perform the scope. Then, the data was inputted in the Project Management Software (PMS), which calculates the activity network and generates a schedule. After a round of adjustments, the schedule was baselined and the main assumptions used during the schedule development were registered in a document named Basis of Schedule.

With schedules developed and baselined, a routine of updates was also implemented. This routine aimed to keep the schedules aligned with the project execution. The outputs of this process were updated forecasts and information about the performance of the execution in comparison to the baseline.

Performance Report



The next step was the development of a reporting system. The collection of management requirements led to the creation of three Key Performance Indicator (KPIs) based on Earned Value Management (EVM) methodology. The first was the Schedule Performance Index (SPI) which indicates how far the current execution is from the baseline plan. The second is the Schedule Variance (SV), aiming to indicate the slippage between the last forecasted finish date and the baseline. The last KPI was the Criticality, and its target was to point to the risk of delay present on the execution strategy, calculating the proportion of activities sitting on the critical path of the project schedule.

In the sequence of the KPIs definition, they were adapted to a visual interface. A dashboard was created using concepts of visual management. It allows quick visualisation of the KPIs using a dynamic interface in which the user can use a series of filters to summarise the information related to their scope of interest. A printable report was also created, following the management requirements. The interface between the Project Management Software (PMS) and the dashboard was designed using automation tools and data processing concepts, to allow a fast and reliable updating process and the use of the system in other projects.

Results

The results of the project were considered positive by the management team, with the deliverables being completed as planned. The major part of the comments received was related to opportunities to improve the dashboard interface.

Some challenges were faced during the execution. In the schedule development, the lack of clearness in the programme Work Breakdown Structure (WBS) can lead to future rework. The approach used to develop the schedule requires a high degree of definition in terms of scope from the early stages, which has not happened. The three-level scheduling system proved hard to follow, with the development of the schedule levels happening out of the right sequence.

During the reporting system development, the lack of integration between cost and schedule was a significant challenge. This required the development of specific KPIs based on duration, which is not usual in the EVM methodology and can be considered confusing. The lack of standardisation about project management practices required some extra time to define templates and layouts.

Recommendations and Future Development

Based on the results, feedback and challenges faced during the execution, a list of recommendations was compiled.

- Potential use of adaptative approaches for some phases of the projects
- Development of a single unique WBS in the very early stages of every new project
- A better definition of the three-level scheduling system
- Integration of cost and schedule to allow the use of EVM
- Implementation of a Project Management Office (PMO) for industrial projects
- Further testing and adaptation of the reporting system dashboard to a web interface

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LIST OF ABBREVIATIONS AND ACRONYMS

CPM – Critical Path Method

EVM – Earned Value Management

FED – Front-End Development

FEL – Front-End Loading

IPO – Input Process Output

KPI – Key Performance Indicator

PDCA – Plan, Do, Check, Act

PEP – Project Execution Plan

PM – Project Management

PMI – Project Management Institute

PMO – Project Management Office

PMS – Project Management Software

REE – Relevance, Efficiency and Effectiveness

SPI – Schedule Performance Index

SV – Schedule Variance

WBS – Work Breakdown Structure

WWTP & SC – Wastewater Treatment Plant and Source Control

List of Appendices

1 INTRODUCTION

1.1 Background

Beca is an engineering consulting company which provides professional services in the Asia-Pacific region, with more than 3,300 employees in 20 offices, delivering projects in 70 countries [1]. The company is structured in business groups divided by market segments, such as Utilities, Transport and Infrastructure, Buildings, Advisory and Industrial [2].

Wood PLC is an engineering company with headquarters in the United Kingdom, providing solutions across a wide range of industrial markets, from project concepts to decommissioning. Wood PLC has more than 60,000 employees in 400 offices around 60 countries [3].

Within the Industrial segment, Beca Ltd and Wood PLC have a joint venture named Wood Beca, focused on developing solutions for pulp and paper, wood products and bioprocess industries in New Zealand and Australia.

The main Wood Beca client in terms of revenue in 2019 is one of the largest global manufacturers of pulp, paper and fibre-based packaging. For confidentiality reasons, the name of this client will be suppressed in this report, and it will be referred to as “the Client”. The Client has several plants in New Zealand, the largest of which produces over 600,000 tonnes of fibre products per annum.

Following Beca revenue forecasts for 2020, the Industrial segment will be responsible for nearly 15% of Beca group revenue. The Client projects managed by Beca represents around 9% of the Industrial revenue. These proportions are depicted in Figure 1. [4]

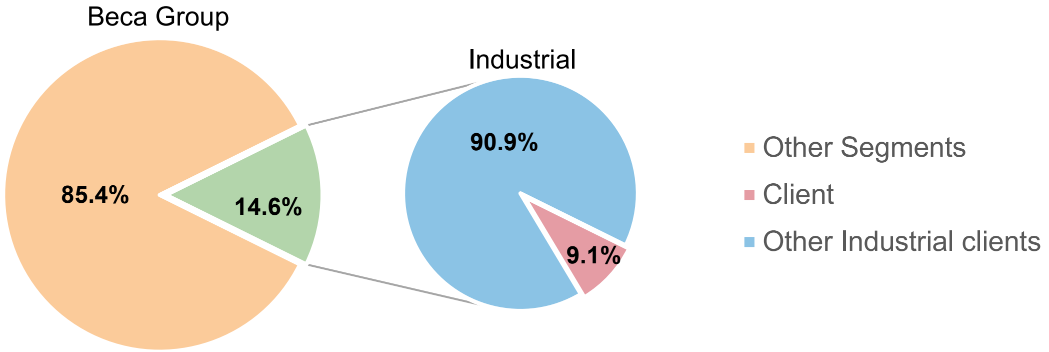

Figure 1 - Beca Group forecast revenue of 2020

1.2 Project Problem

In April of 2019, Wood Beca was commissioned by the Client for the management and design engineering of a programme of projects. The programme aims to improve the wastewater treatment system in one of their mills. Wood Beca had established a general summary timeline for the entire programme. The detailed schedules for the execution stages were still to be developed, including the resource allocation if applicable. After the development of the schedules, a routine of update and control needed to be implemented. This routine should comply with the frequency requirements of the programme documentation and management team.

Moreover, it is also necessary to develop a reporting system to inform the project team about the programme performance regularly. This system must include information about scope completion and scheduling. It should use Key Performance Indicators (KPIs) based on Earned Value Management (EVM) and visual tools to track and inform the progress of the project adequately. Preferably, this system should be standardised to be used in other projects managed by Beca. The system is not required to report information related to cost since Beca has other tools for cost management and control.

2 ACTION PLAN

2.1 Analysis Methodology

Since the beginning of the scientific method created by Galileo in the 1600s, problem-solving methodologies have been based on a sequence that includes at least a plan, action and check stage. From the 1950s, some publications spread a Japanese concept of a cycle for problem-solving and improvements with four stages: Plan, Do, Check and Act (PDCA). Since then, no other problem-solving methodology has become as popular in the corporate world than the PDCA cycle [5]. The proposed solution to achieve Beca needs was based on a PDCA cycle, as Figure 2 illustrates.

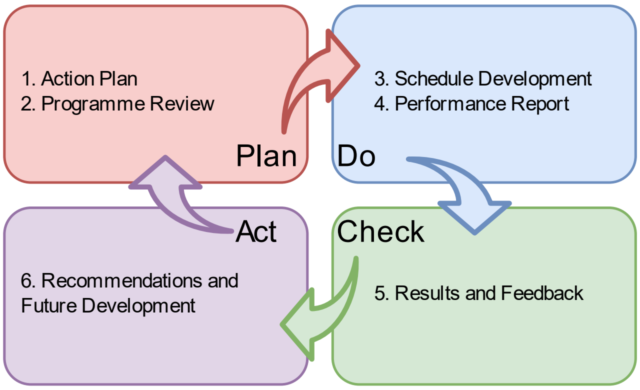

Figure 2 - Proposed project methodology using the PDCA cycle

2.2 Course of Action

During the Plan phase, the action plan summarised in this chapter was developed. Moreover, the documentation already developed by Wood Beca for the programme subject of this project was reviewed. The main goal of this review was to allow a better understanding of the status of the programme and the project team needs.

The Do phase included the development of the two main blocks of deliverables stated in the project problem section. The development of these deliverables was planned using a systems engineering approach known as the IPO model (input-process-output). This model defines boundaries around the tools and techniques used to process the information. Everything coming from outside the boundary is considered an input and the result of the process is an output [6]. The development of each deliverable was considered a process in which inputs, tools and techniques were planned to achieve the desired outputs.

Figure 3 summarises the IPO model for the schedule development and update process. The necessary inputs, tools and techniques were planned based on the Project Management Institute (PMI) methodology for schedule development [7], [8]. After the development of the programme schedules, a routine needed to be implemented to keep the programme schedules up to date. The outputs of this process are the programme schedule baselines, performance information and schedule forecasts.

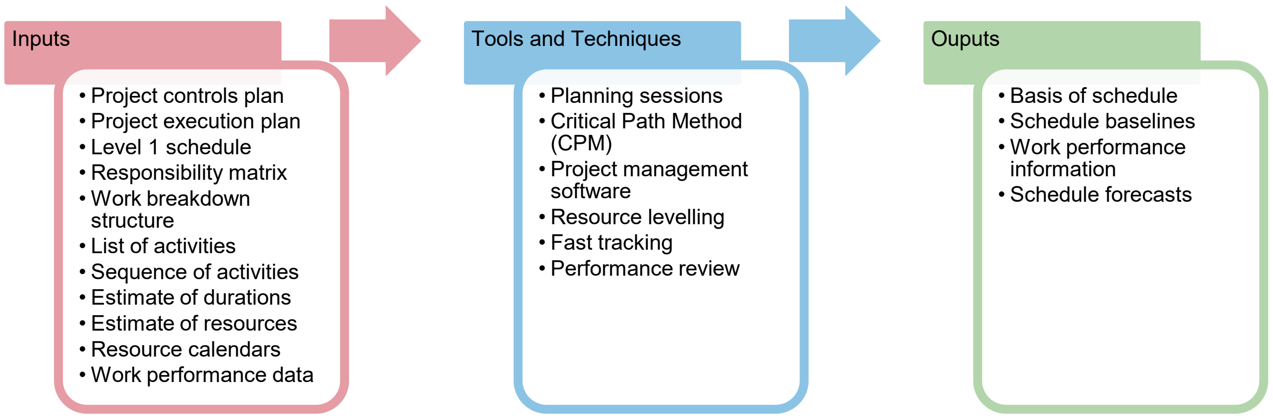

Figure 3 - Schedule development and update process map

The second block of the execution of this project was the development of a reporting system to summarise the performance of the programme in terms of schedule. Figure 4 summarises the IPO to develop the schedule performance reporting system. The outputs of this process were a dashboard summarising the programme schedule performance, a printable version of this dashboard and a guideline which allows the use of the system in other projects.

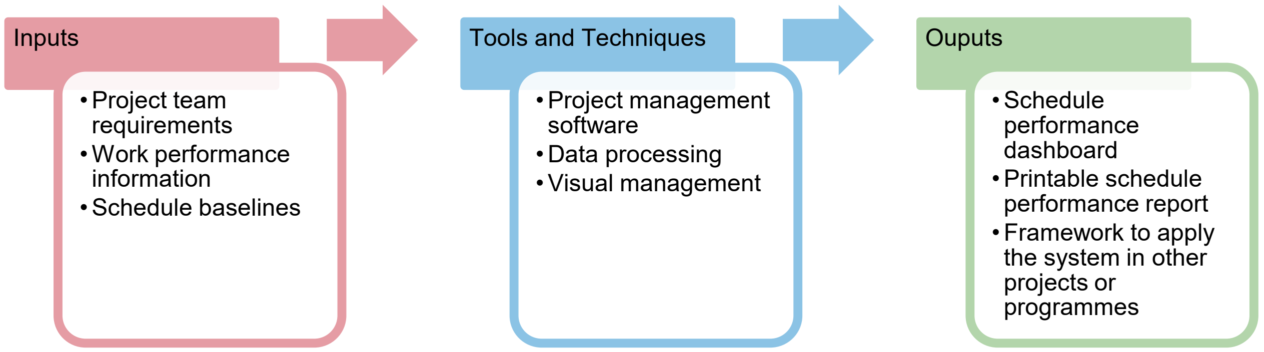

Figure 4 - Reporting system development process map

The Check phase included the compilation of results achieved and the challenges faced during the execution phase. A round of feedback was also proposed to collect the opinion of the management team about the project deliverables.

The Act stage aimed to close the cycle, providing a list of suggestions containing improvement opportunities for further development of the process and deliverables created, based on the feedback received and observations made during the project.

3 PROGRAMME REVIEW

An extensive review of the project documentation was made in order to understand the concepts and basic processes already defined for the programme execution. This chapter is a brief description of the information found in the project documentation, which was used as a base of the execution steps.

3.1 List of Documents Reviewed

Below a list of the main documents consulted and their scope.

- Programme execution plan (PEP) - Describes the management and project control procedures to be adopted during the programme execution. It considers all aspects of the programme, describing the team and methods mobilised to achieve the objectives of the programme. Below, a list of the definitions the PEP is intended to provide
    - Scope of the project
    - Team to manage the project
    - Strategy for executing the project
    - Health, safety and environment requirements
    - Quality assurance requirements
    - Project controls
    - Risk management of the project
    - Engineering and design management
    - Change management of the project
    - Procurement and contracting plan
    - Estimating plan
    - Value management
    - Project reports
    - Project completion

- Project controls plan - Provides a framework by which team members can detail the internal and client-agreed control processes. It defines the control tools and process for schedule, cost and scope management used on the programme execution.
- Project organisation chart - Displays the project team members, their functions and reporting relationships.

3.2 Management Methodology

The Client requires the use of a programme delivery methodology commonly known as Front-End Loading (FEL) or Front-End Development (FED). This methodology is used to minimise the risks associated with the development of a capital expenditure programme. This methodology is based on the investment programme being split into stages in which the level of detail of the information regarding the development is progressively increased. At the end of each stage, the project owner has an opportunity to evaluate the project and decide to proceed or not to the following stage. These go/no-go decisions are named gates. [9], [10]

Figure 5 provides an overview of the programme delivery system. Appendix 1 shows the requirements for each stage, according to the work agreement between the Client and Wood Beca.

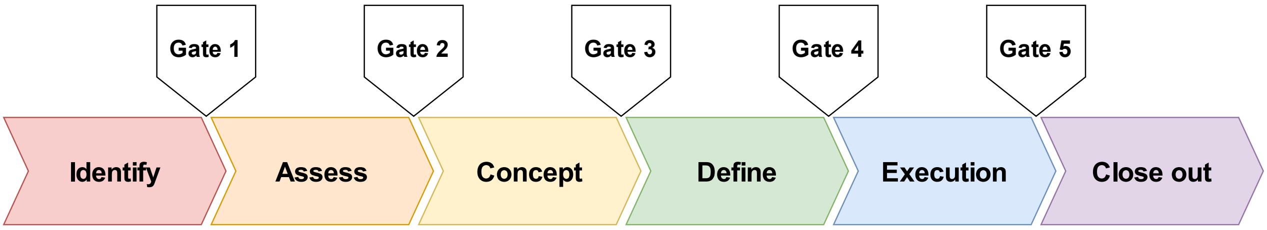

Figure 5 - Programme delivery system

3.3 Programme Scope

The programme comprises two main parts. The first is composed of eight Source Control projects (SC01-08), consisting of changes to the industrial process in order to reduce the total amount or improve the quality of the wastewater generated during paper production. The second is the construction of a new Waste Water Treatment Plant (WWTP), which is targeted at aligning the quality of the industrial plant effluent with international standards.

Each one of the nine WWTP & SC projects is required to pass through the FEL stages and approval gates, meaning each project has an independent approval path and can be cancelled, modified or postponed during each stage gate. For this reason, these projects should be managed independently, minimising their interdependence as much as possible. While the Identify and Assess stages were developed internally by the Client, from Gate 2 onwards, the programme management was handed over to Wood Beca.

Figure 6 illustrates a high-level Work Breakdown Structure (WBS) comprising the programme scope under Wood Beca responsibility. Some of the projects had the Concept and Define stages merged due to specificities in the scope or client strategy.

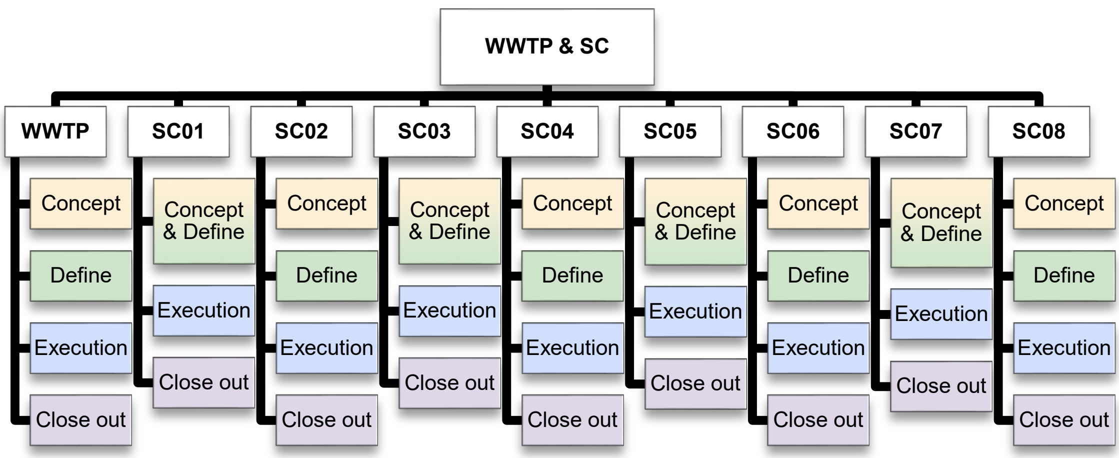

Figure 6 - WWTP & SC programme high level WBS

Figure 7 shows a general timeline of the WWTP & SC programme considering the scope managed by Wood Beca. This illustrates that the status of the programme in September 2019 – the start date of the student project – was a mix of different stages for each project portion.

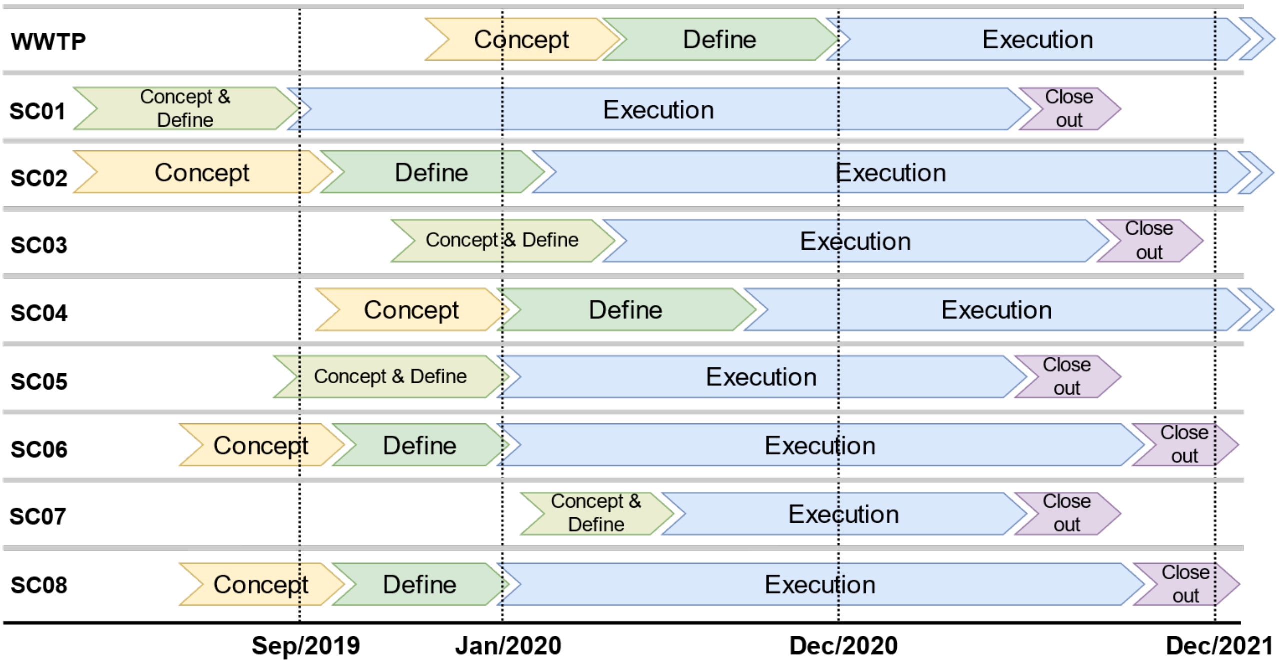

Figure 7 - Overall programme timeline

3.4 Scheduling Approach and Project Management Software

Different approaches can be used to develop a schedule depending on the characteristics of the project that is being planned. The type of life-cycle is an important factor to consider during schedule development. Projects and programmes with linear development sequence and few changes can take advantages of predictive approaches – when all the planning is done before the execution. On the other hand, adaptive approaches are used in projects with constant changes and lack of scope definition in the early stages. Using the wrong approach can lead to several problems, such as waste of resources, rework and inaccurate forecasting. [8]

The approach used for scheduling WWTP & SC programme is considered to be a mix between Predictive and Incremental. Although changes can affect technical details, the desired output of the programme is considered well known. For this kind of project, the predictive approach is generally considered the most appropriate, in a sequence of planning commonly known as waterfall [11]. However, the life-cycle based on multiple stages used in this programme requires an approach also aligned with the concept of rolling wave planning, where the schedule is incrementally developed in consideration of the programme stages as partial deliveries. Figure 8 shows where the WWTP & SC programme is positioned on a diagram which summarises the appropriate scheduling approach based on the characteristics of the project [8].

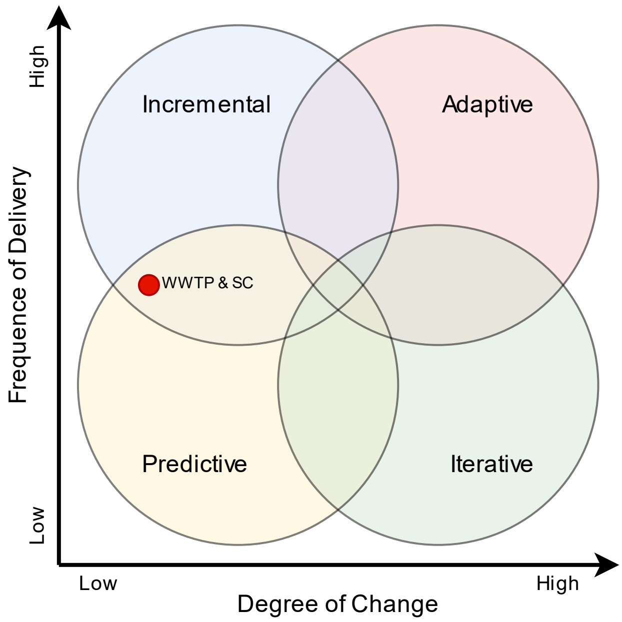

Figure 8 - WWTP & SC Programme scheduling approach diagram

The project management software, which is the main tool used for scheduling, was already defined in the project documentation as the software Primavera P6 Professional. This software mainly uses a Critical Path Method (CPM) for scheduling, in which the dates are calculated through a network of sequenced activities. Moreover, additional information can be loaded in the software to increase the accuracy of the model, such as calendars, resources, constraints, leads and lags.

3.5 Schedule Management

The project controls plan states the level of detail required for the programme schedule development using a system with three different schedules with different levels of detail each. The three-level scheduling system and its requirements are shown in Figure 9. This multilevel approach for scheduling adopted by Wood Beca is relatively common and can be found in several sources of technical literature [8], [12], [13], primarily related to the management of large industrial projects.

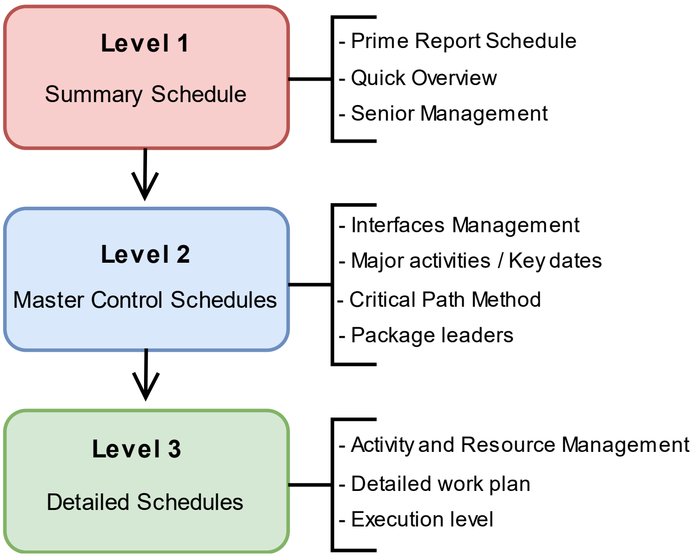

Figure 9 - Three-level scheduling system

Although it is necessary to develop the 3 schedule levels for the entire programme scope, these schedules should not be developed at the same time. The general idea of the FEL methodology is to minimise the sunk costs in case any portion of the programme scope is cancelled during a stage-gate approval. Generally, the Level 1 schedule is developed during the Assess phase, while the Level 2 schedule is developed within the Concept phase. Both schedules are reviewed and potentially rebaselined at each subsequent stage-gate approval, considering the refined information originated of a more detailed schedule. The Level 3 schedules are established only during the definition stage, aiming to control the execution activities. Figure 10 summarises the moment when each schedule level should be developed during the programme life-cycle and how the information flows between the schedules on different stages of the programme.

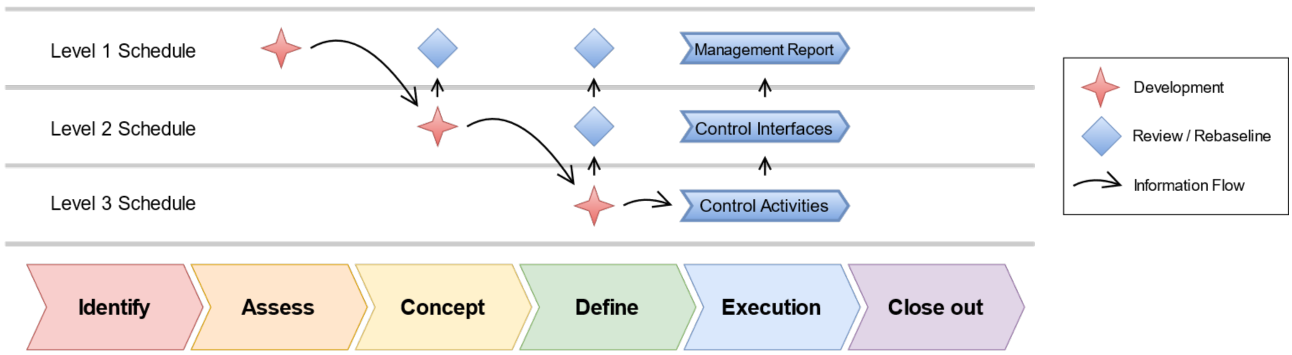

Figure 10 - Schedule development on programme life-cycle

3.6 Organisation Chart

As Wood Beca represents a joint venture between both companies, a portion of the scope of the programme was developed in Beca and another portion in Wood. While the Beca scope was managed and developed in New Zealand offices (mainly Tauranga), the office responsible for the Wood scope is located in Vancouver, Canada. Dealing with global teams geographically dispersed can lead to a variety of problems, such as a distorted perception of power, lack of empathy between members who do not know each other in person and problems with communication due to time zone differences, connection issues and language [14].

In order to minimise these conditions, a detailed responsibility matrix was developed by the project team. Each project of the WWTP & SC programme was delegated to a leader, responsible for managing that work package. Figure 11 shows a simplified version of the programme organisation chart, segregated by location.

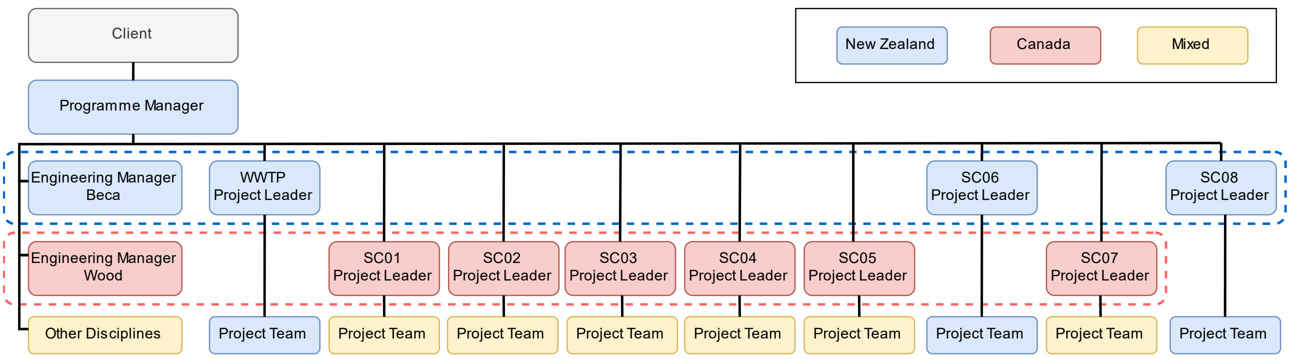

Figure 11 - Simplified Programme Organisation Chart

4 Schedule Development and Update

Scheduling is a process which ensures the development of an effective project model which rationally organises and integrates project components, such as activities, resources and logical relationships. The main objective of this model is to optimise the information available to the management team and facilitate the likelihood of successful completion of the scope within the time available [8]. When the scheduling process is not performed well, it is more difficult to achieve cost and duration goals. Studies reveal that nearly 40% of projects fail because of inefficient planning [15].

The development of a schedule starts with the selection of an adequate scheduling approach and tools to support it. Next, the project WBS should be used as a basic structure into which data from diverse sources is incorporated to achieve a consistent project model. After a series of optimisations on this model, a snapshot of the schedule is stored aiming to be used as a control and monitoring base of comparison between the plan and the future execution. This snapshot is called a baseline. [7]

This chapter describes the process of development of the schedules and baselines for the WWTP & SC programme mapped on the programme review.

4.1 Delimitation

Table 1 shows the programme schedules included as part of the scope of this project, according to the programme documentation review. It includes all Level 2 schedules, except for WWTP and SC07 projects due to their low level of maturity during the execution timeframe of this project. The Level 3 schedules which are the responsibility of the New Zealand team were also included, excluding the WWTP and SC07 due to their early stage of development.

Table 1 - Programme schedules development included in the scope of this project

Project	Level 1	Level 2	Level 3
WWTP	Already developed	Future development	Future development
SC01		Included	Canada Team
SC02		Included	Canada Team
SC03		Included	Canada Team
SC04		Included	Future development
SC05		Included	Canada Team
SC06		Included	Included
SC07		Future development	Future development
SC08		Included	Included

4.2 Data Collection

The major part of the detailed knowledge necessary for the construction of a schedule is tacit. For this reason, the approach used to collect data necessary for the schedule development was a structured meeting called a Planning Session.

A Planning Session is a meeting between the project scheduler and the team responsible for the execution of a work package. During this meeting, the work package scope is reviewed and decomposed as a list of activities. Next, the activities are sequenced and their durations are estimated. If necessary, resources are also estimated and allocated for each activity. Throughout this stage, interfaces with other work packages are inserted as milestones with dates assumed.

All the data is then entered in the PMS, which calculates the activity network. The overall duration is reviewed and adjustments are made if necessary. The output of the Planning Session is a sub-schedule of the work package. Figure 12 summarises the Planning Session process.

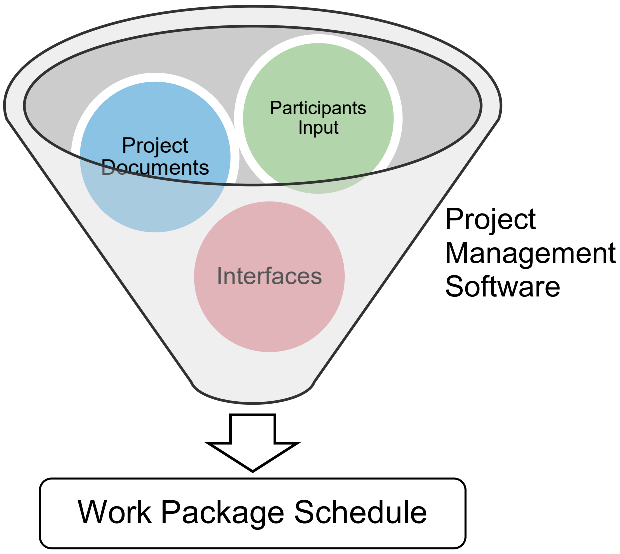

Figure 12 - Planning Session Process

As described in section 3.5, the expected outcome of the level 2 schedule is to manage the interfaces between disciplines. For this reason, the engineering manager was considered the appropriate person to drive the session, with support of the design engineers when required.

In contrast with level 2, the outcome of the level 3 schedule is to manage activities and deliverables, which requires a more detailed analysis. Moreover, it is necessary to list and estimate the resources needed for each activity. The Planning Sessions performed to develop the level 3 schedules had the direct involvement of the project leaders.

4.3 Schedule Integration and Adjust Rounds

After the Planning Sessions covered all the programme scope, the sub-schedules were linked to each other using the interface milestones. Finally, the PMS calculated the entire programme schedule, which could be reviewed by the programme manager and primary stakeholders.

The next step was a round of adjustments aiming to compress the overall programme duration. Some techniques were used to accelerate the project execution without reduction of scope, such as crashing and fast-tracking. These techniques involve changing the duration of individual tasks or the interdependency between them. The result of this process is a tighter and optimised schedule. The trade-offs can be an increased risk of delays, an increase in the project budget, or problems with the quality of the scope developed. [7]

It is crucial to find the right balance between the level of compression desired by the project team and its trade-offs during the round of adjustments, as shown in Figure 13. A poor balance between schedule compression, risk and cost can lead to an unachievable execution plan.

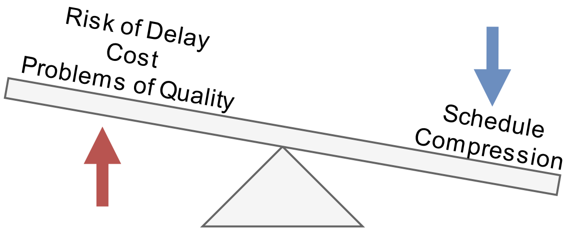

Figure 13 - Trade-offs faced during schedule compression

4.4 Baseline and Basis of Schedule

The main output of the schedule development is the schedule baseline. The baseline is an approved version of the schedule that can be changed only through formal change control procedures and is used as a basis for comparison to actual results [7]. After the management approval, the schedule baselines were issued as formal documents and were made available on the programme documentation management system to be consulted by the project team when required. Appendix 2 shows an example of a schedule baseline document issued. After the baselines were issued, the programme schedules became available in the PMS for future updates.

Another output of the schedule development is a document called basis of schedule. This document is a register of the basis of estimate, assumptions, constraints, range of uncertainty assumed and potential risks taken into consideration during the schedule development [7]. The basis of schedule is an essential appendix to the schedule, especially for external stakeholders who are not directly involved in the programme planning processes. Appendix 3 shows an example of basis of schedule document.

4.5 Schedule Update Process

An essential step for controlling the execution of a project is the schedule update process. This routine should be performed throughout the entire project life-cycle and the main outputs are schedule forecasts and information about the execution performance in comparison to the baseline [8].

The first step for developing this process was to collect the needs of the management in terms of routine, frequency and format of information. The programme has two weekly progress meetings happening at the end of each week, one for the projects managed in New Zealand and the other for the projects managed from Canada. These meetings were initially structured around a log of actions, where the future actions were listed and reviewed by the team. This approach works well when few activities are in execution, but the project team can easily forget future activities if the list grows large.

After the development of the schedule, these meetings were slightly changed. Instead of being based on the log of actions, the meetings were restructured to focus on a 4-week lookahead view of the programme schedule. This provides a more reliable list of activities by avoiding to rely only on attendants' memory. Moreover, the discussion provides the information necessary for the schedule update.

After each schedule update, a series of documents containing different views of the schedule is issued and shared on the project documentation system. These documents are developed targeting different needs of the management team. Figure 14 summarises the routine implemented.

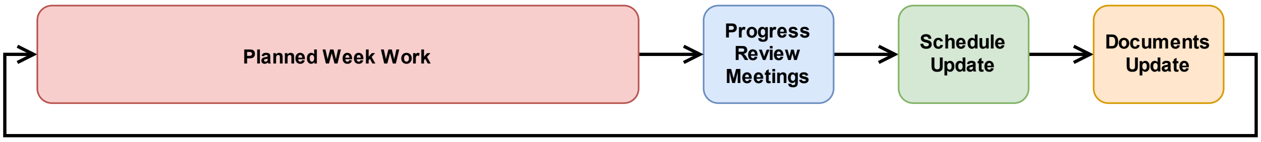

Figure 14 - Schedule Updating Routine

5 PERFORMANCE REPORT

Since the 1980s, measuring performance has been a recurring subject of research among academic and market-oriented professionals. From the 1980s to the beginning of the 2000s, many different performance measurement methodologies and philosophies were developed, most of them focusing on the overall business performance. From the early 2000s, other methodologies focused on specific disciplines started to become more popular, and the first Performance Measurement Systems focused on project management processes appeared. [16]

Performance Management Systems are multi-criteria instruments that summarise information, facilitating and improving decision-making. Their main objective is to save management time. [17] A widely accepted definition of a Performance Management System is “a set of metrics or performance measures, used to quantify both the efficiency and effectiveness of actions” [18]. Some authors add “relevance” as a third dimension, in a model named REE – Relevance, Efficiency and Effectiveness [17].

The characteristics of a project involve many criteria, and this poses a significant challenge when developing a Performance Management System. Since the classical approach of the iron triangle, to more modern methodologies like Agile and Scrum, the definition of project management is always surrounded by processes aiming at managing a limited amount of resources in order to achieve a determined scope [19]. This means that any project manager faces trade-offs in their routine. The goal of a Performance Management System for the project manager is to make these trade-offs clearer and easier to understand.

5.1 Programme Team Requirements

A series of informal interviews were made with the programme management team in order to collect the requirements for the reporting system. The following sequence shows the main requirements.

i. Indicate the performance of the schedule up to the date
ii. Indicate the future performance of the project schedule
iii. Indicate the level of risk present on the project schedule
iv. Measure the performance of the programme schedule without using data related to cost
v. Use Earned Value Management concepts
vi. Use visual management concepts
vii. Shareable using a web interface
viii. Able to be applied in other projects or programmes managed by Beca.
ix. Automated, minimising manual processes

5.2 Performance Indicators

Three KPIs were created to comply with the requirements raised in section 5.1. The details of each KPI are explained in Appendix 4, which is a KPI dictionary submitted to Wood Beca as a framework to allow the system to be applied in future projects. The KPIs are summarised below.

Schedule Performance Indicator (SPI)

SPI aims to indicate the performance of past activities, comparing the progress performed up to the data date with the progress forecasted on the baseline to the same date. The KPI is given as a percentage, where an SPI of 100% means the performance is exactly as it was baselined. Values lower than 100% mean a performance behind the baseline, while values above 100% mean a performance ahead of the baseline.

Schedule Variance (SV)

SV indicates the slippage between the forecasted finish date calculated in the latest schedule update and the baseline finish date. It aims to indicate the impact on the finish date caused by past and/or future activities performed differently than what was baselined. It is given in working days. A negative variance means a finish date behind the baseline, and positive variance means a date ahead of the baseline.

SPI and SV are visually represented in Figure 15, which shows a curve of progress for a hypothetical project as an example. Both indicators were created using the concepts of Earned Value Management theory [20], with some adaptations. The curve of 'value' used as the base of the EVM methodology was substituted by a curve of progress calculated using the activity durations. Another difference from EVM is that the SV was calculated using the forecast finish date given by the schedule, instead of being based on past performance.

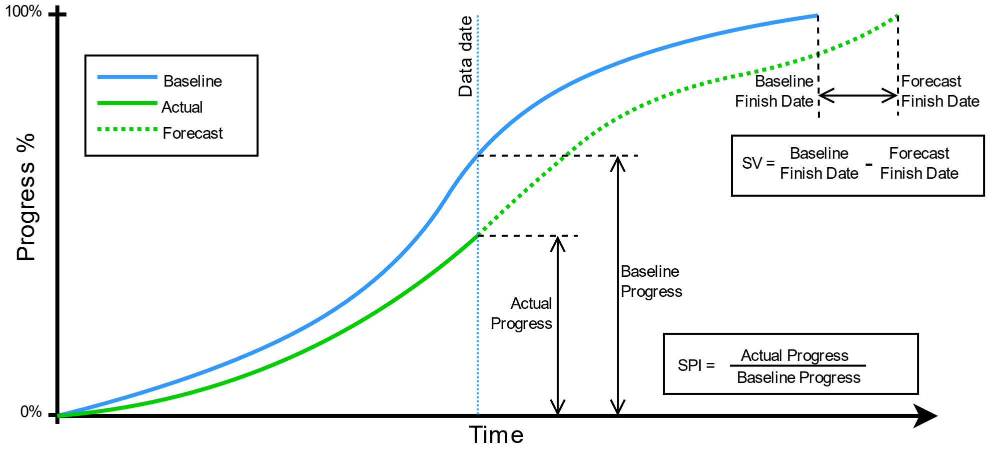

Figure 15 - Visual representation of SPI and SV calculation

Criticality

The criticality calculates the proportion of critical activities on the project schedule. It aims to indicate the risk of delay on the final dates, which is generally proportional to the number of critical activities. The criticality is given as a percentage ranging from 0% to 100%. There is no ideal value for the criticality, but generally, the lower, the better – a lower value indicating a low risk of delay. Moreover, the increase in criticality from one reporting period to the next is of particular interest to the project manager, indicating the need for actions to minimise risks.

5.3 Visual Management

Visualisation in a management context concerns the representation of data, information and knowledge in a graphic format which is favourable to acquiring insights and developing a thorough yet rapid understanding of what is being presented [21]. The literature on visual communication comes from diverse sources, including graphic design, marketing, education and performance measurement.[22].

The use of visual tools is currently one of the most accepted trends in our society. A series of studies have proven that the human brain is faster in processing visual illustrations than text and spoken language [23]. For this reason, Visual Management has emerged in business during the past decades as an effective way to share the status of many different types of process. Visual management tools, such as performance walls or dashboards, can improve communication among team members by displaying indicators of performance containing objectives, results and deviations. By sharing performance results, process gaps can be identified and addressed more quickly and efficiently [24].

In order to take advantage of these characteristics, the KPIs described in the previous section have been adapted to a visual context. Figure 16 shows examples of how SPI and SV were plotted. A simple code of colours was implemented, using green for values on target, red for values off-target and yellow as an intermediate/transition value. The criticality was plotted using a treemap chart, which shows the proportion of activities segregated by their float size, as demonstrated in Figure 17.

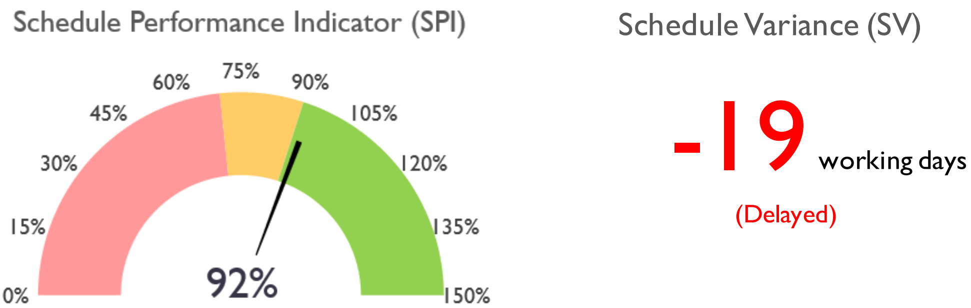

Figure 16 - Visual plot of SPI and SV

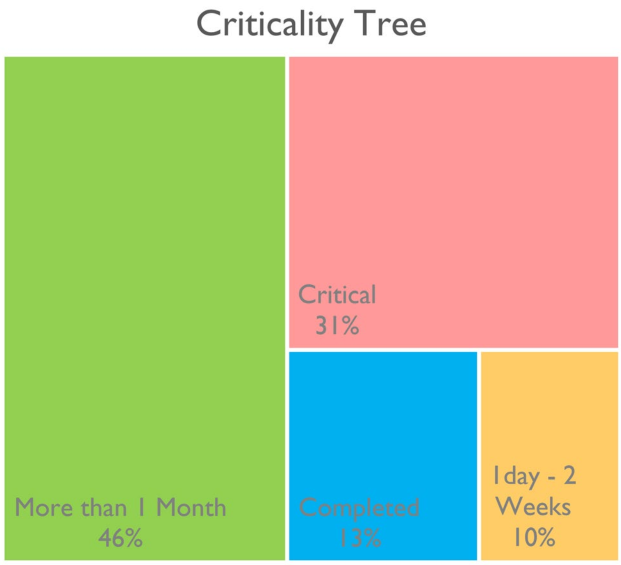

Figure 17 - Criticality shown over a treemap chart

5.4 Tools, updating and interface

The tool chosen to generate the visual reports was Microsoft Excel 365. Currently, this tool meets the requirements of Beca management: It can be automated, has a web interface and contains the visual tools necessary for the development of the reports.

The data related to the schedule was exported from the Project Management Software and imported to a spreadsheet using automation tools like Power Pivot and a routine developed in Visual Basic. These tools allow the data to be imported without any manual manipulation. Moreover, the spreadsheet was structured using concepts of database, such as scalability, standardisation and data independence [25]. As a result, having the database structure accessed only by automated tools allows quick importation of future data, making the update process fast and reliable.

The dashboard which was developed comprising the visual information sketched and fed by the database created is shown in Appendix 5. The graphs and diagrams were built on an interface containing buttons which allow the user to filter the entire programme, or portions of it such as a specific project, phase or discipline. The graphs follow the filters, showing the information for the work package filtered. This dynamic interface allows the team members to have the information related to their own scope of interest. A table containing the main milestones of the programme helps the user to understand the data shown.

A printable report was also made for the management to take to a meeting for a fast consultation, if necessary. It contains the main dates for each project phase and a visual indication of the current SPI for each project. The printable report is shown in Appendix 6.

6 RESULTS

6.1 Project Results Overview

The proposed scope was developed as planned, and the needs described in the project problem section 1.2 were achieved. Figure 18 shows a curve of the progress of the work executed. The deliverables were finished within the proposed timeframe, with slight corrections due to calendars or technical difficulties on the development.

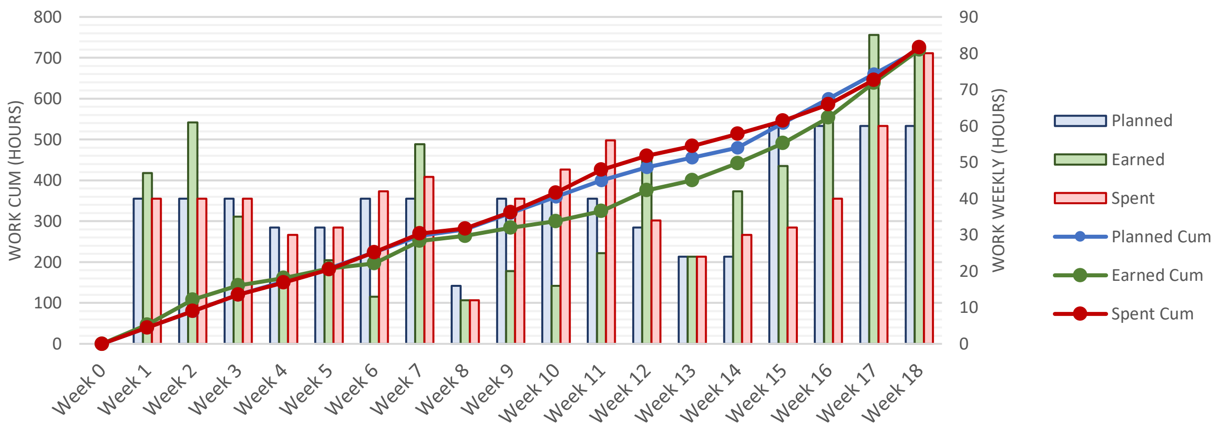

Figure 18 - Project execution progress

6.2 Challenges

Below is a summary of the main challenges encountered during the project.

Changes in the programme scope

The concept of some projects within the WWTP & SC programme faced significant changes due to client requests during the schedule development process. In some cases, the project's scope was not properly defined, with different options still to be assessed and evaluated. This caused a loss of time and rework during the schedule development, once the predictive approach used relies on a high degree of maturity in the scope definition, as described in section 3.4.

Lack of a detailed WBS for the programme

The programme WBS was originally issued breaking the scope into 2 levels only, as explained in section 3.3. A further breakdown was necessary to allow the schedule development. For this reason, the WBS needed to be detailed during the Planning Sessions. This resulted in Planning Sessions taking longer than expected. There is potential for future rework if the detailed WBS becomes inadequate for scope and cost control.

Schedule hierarchy developed out of sequence

The three-level schedule management system was not entirely followed. The system predicts a sequence where the level 3 schedule is developed based on the information of level 2. In practice, this sequence proved very hard to achieve, and both schedule-levels were developed at the same time when managed by different teams. Not only were different assumptions and constraints used, but also the schedules were created using different Project Management Softwares. Additionally, the lack of detail on the programme WBS obligated each team to break the project structure on their own. As a consequence, both schedule levels became incompatible with future updates and need to be reworked.

Lack of standardisation

Schedule report templates, layouts for the project management software or even typical sequences of activities (like a procurement process), were entirely developed during this project, in an effort that could have been minimised if more standardisation was implemented on a group level.

Lack of integration between cost and schedule

Cost and schedule are managed independently, using different systems. The vast majority of the KPIs suggested in specialised literature aiming to measure the performance of project scheduling are somehow related to cost or resources allocation. This type of information was not available on the level 2 schedules. For this reason, the indicators created to report the schedule performance use only activity durations as an indicator of completion. Moreover, accruing the performance information to a project or programme levels was made without any weighting, which means all the activities inherited the same importance. Both characteristics should be highlighted to avoid misinterpretation.

6.3 Programme Team Feedback

In order to allow qualitative measurement of the project execution success, feedback was requested from the management team. Overall, the feedback received was positive about the work implemented with minor technical improvement opportunities identified.

It was reported a noticeable improvement in terms of the maturity of the scheduling process following the start of the project - with updates being obtained from the multiple geographies, updated accurately, and reports generated that were able to be used to drive changes in behaviour and enable more effective meetings.

Regarding the reporting system, it was highlighted the challenge faced in having a schedule reporting system that could exist separate from cost and so be more easily scaled across multiple projects. Given the varied size and scale of projects that are worked on, it is not uncommon for the schedule to not have cost information within it directly. The system that has been developed enables that and could be adjusted to incorporate the cost elements when/if required. This flexibility is essential and has been properly addressed.

Some points of concern raised by management focused on the 3-level system used on schedule development. The interface between level 2 and level 3 schedules did not work properly, with both schedule levels being developed in parallel by different teams. However, the emphasis placed on defining and implementing a consistent WBS across the programme was considered by the management team to have added significant value. A better definition of the WBS could have solved the inconsistencies regarding multi-level scheduling system.

7 RECOMMENDATIONS AND FUTURE DEVELOPMENT

Based on the results of the project and feedback received from the programme team, a list of recommendations and future development is suggested in the following sequence.

Potential use of Adaptative approaches for some phases of the projects

It is a common concept adopted in predictive project management approaches that scope should be defined at the beginning of the project development. If the project scope is changing, developing a schedule and the subsequent planning steps can lead to unnecessary rework. Even the incremental approach used in a stage-gate system requires a specific degree of definition during each phase to allow effective scheduling. Considering the constant changes and fast pace required for studying multiple concept options, Beca should consider the possibility of using adaptive approaches for planning the initial phases of the projects.

Adaptive approaches were created in the software development industry in the early 2000s in order to facilitate flexibility and responsiveness to changes. Some studies suggest there is a “sweet spot” between predictive and adaptative approaches where the effort expended in initial planning pays off in success [26]. If too many resources were spent in a detailed plan without the basic definition, the result is effort wasted and rework, whereas not enough initial planning can result in failure.

Many concepts of adaptive methodology can be incorporated in the traditional engineering project life-cycle, in order to solve some typical problems and disadvantages of the traditional methodology. A complete comparison between traditional/predictive and adaptive approaches can be found in Appendix 7.

Development of a single unique WBS in the very early stages of every new project

The WBS is a hierarchical decomposition of the total scope of the work into smaller and easier manageable parts called work packages. The work package is the level where the work is estimated, scheduled and budgeted during the planning stages, and monitored and controlled during the execution. Building a WBS is one of the first steps of the project planning processes, just after the collection of client requirements and the development of a scope statement [7]. Some authors [27] state that for large projects, the decomposition of the project in small segments is a mandatory step in order to properly plan and execute the scope. Others [28] argue that an efficient WBS can prove pivotal for the success of some project management processes such as scheduling and budgeting.

Beca should consider mapping the WBS development as one of the initial mandatory processes during a new project establishment. Lack of a unique WBS can cause delays and rework on the scope, budget and schedule planning and control. The WBS should be used since the very early stage of a project as a contractual document between client and service provider, which helps to clarify and organise project scope [28]. Although changes in the WBS can be necessary during the project lifecycle, it is generally better to have a WBS and manage future changes than not having one.

A better definition of the three-level scheduling system

One of the major negative points raised by the programme management team about the schedule development process was the lack of clarity about the three-level scheduling system. Although this hierarchical multi-level system is broadly recognised in the specialised literature as a good practice [12], the system must follow a sequence of development and integration between the teams to work correctly.

The boundaries of each schedule level should be better defined in the project documentation, to avoid excess or lack of detail on levels 2 and 3, respectively. The project WBS must be the same for all the schedule levels in order to allow a smooth update process. The level 2 and 3 schedules should be developed preferably in the same Project Management Software to improve compatibility and automation of the information transference process.

Integration of cost and schedule to allow the use of EVM

The Earned Value Management is commonly used to measure the performance of projects integrating scope, schedule and cost. All its methodology is based on the concept of value, defined as “the measurement of work performed expressed in terms of the budget authorised for that work”[20]. The value does not necessarily mean money, but the cost is the unit commonly used in EVM because it can easily integrate the whole project using the same unit of measure.

A necessary step for implementing EVM is the development of a time-phased schedule of the values associated with each work package [29]. In other words, the budget of each package should be spread over time using the project schedule. For this reason, the lack of integration between cost and schedule makes the proper use of EVM unfeasible.

Beca should consider integrating cost and schedule management. This does not necessarily mean to use one unique tool or software for scheduling and controlling cost. However, standardising the processes and tools aiming for some degree of interaction could be beneficial. The use of standard activity codes, cost-accounts and automation can make the Project Management Software compatible with the cost control system. Moreover, the integration between cost and schedule can make cost forecasting easier.

Implementation of a Project Management Office for industrial projects

A Project Management Office (PMO) is a management structure that standardises the processes and facilitates the sharing of resources, methods, tools and techniques related to project management [30]. A PMO can be assigned to a wide range of different responsibilities related to projects under its domain, from support and operational tasks to strategic functions such as prioritisation and strategic alignment [31].

PMOs were created in an effort to target primarily resource optimisation. Projects are unique by definition. However, the methodology management, tools, reports and approach can be easily standardised among an organisation in order to avoid waste of resources and redundancy.

Although Beca has significant initiatives aligned with the concepts of a PMO in a corporative level, the Industrial business group could have its own centralised structure responsible for project management standardisation. The suggestion is a PMO focused on the operational level, providing basic support to project teams, standardisation and a set of templates and tools for scheduling, budgeting and performance reporting. Other potential activities of an Industrial PMO would be providing training about PM practices, the administration of a lessons learned repository, and the management of specialised resources related to non-conventional activities, such as quantitative risk analysis. The potential gains in productivity for individual projects can pay off the costs of the resources allocated to this structure.

Further testing and adaptation of the reporting system dashboard to a web interface

Most of the comments received as feedback about the dashboard developed to report the schedule performance were related to the interface. Some of the planned functions and interactivity were not implemented due to restrictions of the tool used. Further development of the dashboard in a platform more web-friendly and interactive, such as Power BI, is the logical next step for improving this tool.

Considering a potential integration between cost and schedule management, the dashboard can be complemented to show the performance of the programme as a whole, not just scheduling. In this case, the system can evolve to a complete Project/Programme Performance Management System, or be integrated into the existing systems at Beca for cost and deliverables control.

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9 APPENDICES

APPENDIX 1 – DELIVERABLES SCOPE AND RESPONSIBILITY MATRIX

DELIVERABLES SCOPE & RESPONSIBILITY MATRIX

	Deliverables	Client Terminology	Gate 2 Assess	Gate 3 Concept Select	Gate 4 Define	Gate 5 Execute	Principal design Document	Key input to CAPEX	Input to Procurement	Key input to other WP
Question per the client Engineering Procedures Handbook	Selected concept consistent with Project Definition?			Wood Beca	Wood Beca					
	Technical solution valid?				Wood Beca					
	Options considered?			Wood Beca						
	Selection criteria?			Wood Beca						
	If more than one option carried forward, why?			Client	Client					
	Value drivers & environmental factors understood?			Client	Client					
	What are the critical success factors?			Client	Client					
	Main HSE issues and decisions?			Client	Client					
	Is the Scope frozen?				Client					
	What decisions are needed now, and why?			Wood Beca	Wood Beca					
	What decisions can wait?			Wood Beca	Wood Beca					
	Maturity of the design - how many holds?			Wood Beca	Wood Beca					
	What reviews/workshops have been done?			Wood Beca	Wood Beca					
	Status of actions arising from reviews?			Wood Beca	Wood Beca					
	Scope certainty (brownfield and holds)?			Wood Beca	Wood Beca					
	What level of cost estimate and contingency?			Wood Beca	Wood Beca					
	How to handle long lead items.			Wood Beca	Wood Beca					
	What could jeopardise project delivery?			Wood Beca	Wood Beca					
	Stakehold and Technical sign off?			Client	Client					
	Coherence between cost estimate, schedule, basis of design and project specification?			Client	Client					
	Are risks identified and how are they managed?			Client	Client					
	Key risks and uncertainties?			Client	Client					
	Risk prevention and mitigation			Client	Client					
	Is project organisation adequate?			Client	Client					
	Review the Business Case			Client	Client					
	Operations Philosophy?			Client	Client					

DELIVERABLES SCOPE & RESPONSIBILITY MATRIX

	Deliverables	Client Terminology	Gate 2 Assess	Gate 3 Concept Select	Gate 4 Define	Gate 5 Execute	Principal design Document	Key input to CAPEX	Input to Procurement	Key input to other WP
Project Management & General	**Project Execution Plan**	Project Execution Plan		Wood Beca	Wood Beca	Wood Beca				
	Project Controls Plan			*incl.*	*incl.*					
	Project Engineering Plan			*incl.*	*incl.*					
	Project Construction Plan			*incl.*	*incl.*					
	Project Commissioning Plan			*incl.*	*incl.*					
	Project Safety Plan			*incl.*	*incl.*					
	Project Quality Plan	Project Assurance Plan		*incl.*	*incl.*					
	Project Org Chart			*incl.*	*incl.*					
	ClientFS execution plan			Client	Client					
	Procurement Procedure			*incl.*	*incl.*					
	Expediting Plan			*incl.*	*incl.*					
	Change management system			*incl.*	*incl.*					
	PEP Appendices			Wood Beca	Wood Beca					
	Project Scope of Plant (by sub-project and by Discipline)			*incl.*	*incl.*					
	Project Scope of Services (by sub-project and by Discipline)			*incl.*	*incl.*					
	Procurement Strategy (by sub-project)			*incl.*	*incl.*					
	Project Environmental Management Plan			Wood Beca	Wood Beca					
	Deliverables Status Register (DSR)			Wood Beca	Wood Beca	Wood Beca				
	design Basis by Discipline	Basis for design Project Specification		Wood Beca	Wood Beca		x			
	Work Break Down Structure			Wood Beca	Wood Beca					
	Final Project Definition	Final Project Definition		Client	Client					
	Stage Gate Report	Concept Selection Report		Wood Beca	Wood Beca					
	Project Scope of Plant (by sub-project and by Discipline)			*incl.*	*incl.*					
	Project Scope of Services (for next Gate)			*incl.*	*incl.*					
	Risk Register	Risk Register & Management Plan		Client	Client					
	Project Schedule			Wood Beca	Wood Beca	Wood Beca				
	Schedule Basis Memorandum			*incl.*	*incl.*					
	Capital Cost Estimate (CCE)	Budget estimate		Wood Beca	Wood Beca	Wood Beca				
	Estimate Basis Memorandum			*incl.*	*incl.*					
	Materials Costs and Delivery Estimates or Budget Pricing by Discipline			*incl.*	*incl.*					
	Labour rate schedule			*incl.*	*incl.*					
	Freight rate schedule			*incl.*	*incl.*					
	Operations Strategy & Requirements	Operations Strategy & Requirements		Client	Client					
	Updated Framing & Roadmap	Updated Framing & Roadmap		Wood Beca	Wood Beca					
Procurement	Major equipment and long lead items quotations	Long lead items quotations		Wood Beca	Wood Beca			x		
	Bid evaluations for major equipment, long lead items	Bid evaluations for major equipment/labour		Wood Beca	Wood Beca					
	Minor equipment quotations					Wood Beca		x		
	Contract enquiries					Wood Beca				
	Purchase Order Register	Purchase Order Register				Wood Beca				
	Sub-Contractor Register	Sub-Contractor Register				Wood Beca				
Construction	Contract Strategy	Contract Strategy		Wood Beca	Wood Beca			x	x	
	Contractor availability	Contractor availability		Wood Beca	Wood Beca					
	Material availability	Material availability		Wood Beca	Wood Beca					
	Construction management					Wood Beca				
Geotech	General Geotechnical Scope for Report and CCE			Wood Beca	Wood Beca					
	Geotechnical investigation reports (factual & interpretative)				Wood Beca	Wood Beca	x	x		x

DELIVERABLES SCOPE & RESPONSIBILITY MATRIX

	Deliverables	Client Terminology	Gate 2 Assess	Gate 3 Concept Select	Gate 4 Define	Gate 5 Execute	Principal design Document	Key input to CAPEX	Input to Procurement	Key input to other WP
Process design	General scope for reports			Wood Beca	Wood Beca					
	Material & Energy Balances			Wood Beca	Wood Beca		x			
	Block Flow diagram			Wood Beca	Wood Beca					
	Process Flow diagrams			Wood Beca	Wood Beca					
	Process & Control diagrams				Wood Beca	Wood Beca	x	x		x
	Equipment lists			Wood Beca	Wood Beca		x	x		x
	Major equipment technical specifications			Wood Beca	Wood Beca	Wood Beca	x		x	
	Materials selection				Wood Beca			x		
	Vendor document review					Wood Beca				
	Installed online vs. standby equipment requirements				Wood Beca			x		
	Piping list			Wood Beca	Wood Beca	Wood Beca	x	x		x
	HAZOP	Preliminary HAZOP/ design Review/ MOC			Wood Beca	Wood Beca				
	Functional narrative					Wood Beca				x
	Hazardous Zone Spacing			Wood Beca	Wood Beca					
	Equipment datasheets				Wood Beca	Wood Beca				
Instruments & Controls	Instrument & I/O lists			Wood Beca	Wood Beca	Wood Beca	x	x	x	
	General scope for reports			Wood Beca	Wood Beca		x			
	Detailed scope for construction packages			Wood Beca	Wood Beca				x	
	Instrument datasheets				Wood Beca	Wood Beca			x	
	Price enquiry & evaluation					Wood Beca				
	Vendor document review					Wood Beca				
	Control system schematic			Wood Beca	Wood Beca	Wood Beca	x	x	x	
	Control system layout					Wood Beca				
	Cable Schedule				Wood Beca	Wood Beca	x	x		
	Loop drawings					Wood Beca				
	Functional Description					Wood Beca				x
	Control software development					Wood Beca				
	Junction box/rack schedules & rack layouts					Wood Beca				
	Instrument location layout drawings					Wood Beca				
	Construction support/ Site requests					Wood Beca				
Mechanical design	General equipment arrangement drawings			Wood Beca	Wood Beca	Wood Beca				
	General scope for reports			Wood Beca	Wood Beca		x			
	Detailed scope for construction packages			Wood Beca	Wood Beca				x	
	Equipment technical specifications			Wood Beca	Wood Beca	Wood Beca	x		x	
	Price enquiry & evaluation					Wood Beca				
	Vendor document review					Wood Beca				
	Equipment lists			Wood Beca	Wood Beca	Wood Beca	x	x	x	x
	Site layout drawings (Plot Plans, GAs)			Wood Beca	Wood Beca	Wood Beca	x			
	Mechanical loading diagrams					Wood Beca				x
	Equipment/Floor layouts					Wood Beca	x	x		
	Safety in Design Review	Preliminary HAZOP/ design Review/ MOC		Wood Beca		Wood Beca		x		
	Tank/Vessel Dwgs					Wood Beca			x	
	Stairs, access platforms & monorails layouts					Wood Beca				x
	Detail Mechanical design					Wood Beca				
	Demolition Dwgs					Wood Beca				
	Construction support/ Site requests				Wood Beca	Wood Beca				

DELIVERABLES SCOPE & RESPONSIBILITY MATRIX

	Deliverables	Client Terminology	Gate 2 Assess	Gate 3 Concept Select	Gate 4 Define	Gate 5 Execute	Principal design Document	Key input to CAPEX	Input to Procurement	Key input to other WP
Electrical design	Electrical Equipment & Load lists			Wood Beca	Wood Beca	Wood Beca	x	x	x	
	General scope for reports			Wood Beca	Wood Beca		x			
	Detailed scope for construction packages			Wood Beca	Wood Beca				x	
	Power Supply Infrastructure Upgrades			Wood Beca	Wood Beca	Wood Beca				
	Electrical technical specifications					Wood Beca			x	
	Price enquiry & evaluation					Wood Beca				
	Vendor document review			Wood Beca	Wood Beca	Wood Beca				
	Electrical Area Classifications			Wood Beca	Wood Beca					
	Electrical Single Line diagrams					Wood Beca	x	x		
	Motor Starter diagrams					Wood Beca				
	Major Equipment & MCC layouts			Wood Beca	Wood Beca	Wood Beca	x	x		x
	Grounding/Earthing layouts				Wood Beca	Wood Beca				
	Lighting layouts				Wood Beca	Wood Beca				
	Panel layouts					Wood Beca				
	Cable schedule & ladder layouts				Wood Beca	Wood Beca		x		
	Lightning Protection					Wood Beca				
	Source equipment inspection				Wood Beca	Wood Beca				
	Construction support/ Site requests					Wood Beca				
Piping design	Piping Sizing and Major Route layouts			Wood Beca	Wood Beca	Wood Beca				
	Piping layout drawings and Lengths				Wood Beca	Wood Beca		x		
	Pipe/Valve/Tie-In lists				Wood Beca	Wood Beca	x	x	x	
	Tie-in drawings					Wood Beca				
	Pipe & valve specifications				Wood Beca	Wood Beca			x	
	Pipe Stressing, Support design					Wood Beca				x
	Pipe Support Details					Wood Beca				
	Piping Isometrics					Wood Beca				
	Construction support/ Site requests					Wood Beca				
HVAC design	General HVAC Scope for Report and CCE			Wood Beca	Wood Beca					
	Equipment specifications				Wood Beca				x	
Architectural	Architectural Plan drawings				Wood Beca					

Sensitivity: General

DELIVERABLES SCOPE & RESPONSIBILITY MATRIX

	Deliverables	Client Terminology	Gate 2 Assess	Gate 3 Concept Select	Gate 4 Define	Gate 5 Execute	Principal design Document	Key input to CAPEX	Input to Procurement	Key input to other WP
Structural / Buildings design	General scope for reports			Wood Beca	Wood Beca		x			
	Detailed scope for construction packages			Wood Beca	Wood Beca				x	
	Modification to Existing Facilities, Relocation or Demolition			Wood Beca	Wood Beca					
	Building list			Wood Beca	Wood Beca					
	Structural design drawings			Wood Beca	Wood Beca					
	Structural technical specifications									
	Price enquiry & evaluation									
	Foundation drawings				Wood Beca					
	layout and Elevation drawings				Wood Beca					
	Structural Steel design			Wood Beca	Wood Beca		x	x		x
	Fire and Safety Requirements				Wood Beca					
Civil & Infrastructure design	General scope for reports			Wood Beca	Wood Beca		x			
	Detailed scope for construction packages			Wood Beca	Wood Beca				x	
	Modification to Existing Facilities, Relocation or Demolition			Wood Beca	Wood Beca	Wood Beca				
	Civil technical specifications									
	Price enquiry & evaluation									
	Building Permits				Wood Beca	Wood Beca				
	Topographic survey					Wood Beca				
	Drainage plans & sections					Wood Beca				
	Paving, contouring, landscaping plan					Wood Beca				
Site & Facilities	Underground Piping & Facilities Identified			Wood Beca	Wood Beca	Wood Beca				
	Site dewatering, excavations, shoring, special construction methods identified				Wood Beca	Wood Beca				
Planning & Environmental	General Planning/Environmental Scope for Report and CCE			Wood Beca	Wood Beca					
Operations and Maintenance	Capital &/or Commissioning Spares				Wood Beca					
	Vendor Maintenance Manuals									
	Convert vendor P&Cs to ClientFS standard									
	Operational Readiness Asssement				Wood Beca					
	Manning Plans			Client	Client					

APPENDIX 2 – EXAMPLE OF A SCHEDULE DEVELOPED

Client Logo

WWTP & Source Control Projects
SC08 Black Liquor Spill Recovery
Execution Phase Detailed Schedule

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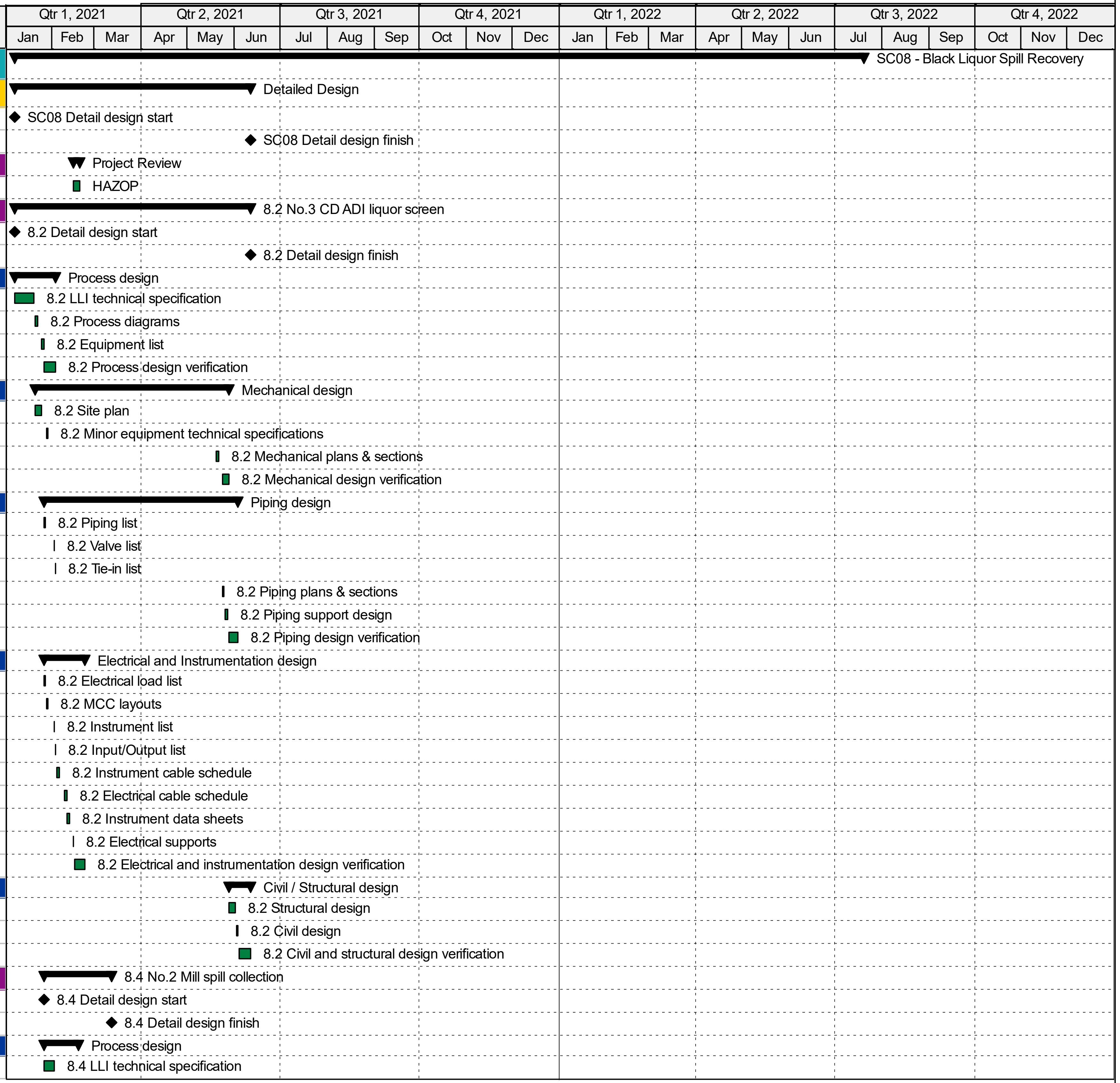
Activity ID	Activity Name	Original Duration	Start	Finish
SC08 - Black Liquor Spill Recovery		560	07-Jan-21	20-Jul-22
Detailed Design		106	07-Jan-21	11-Jun-21
508.1010	SC08 Detail design start	0	07-Jan-21*	
508.1020	SC08 Detail design finish	0		11-Jun-21
Project Review		5	15-Feb-21	19-Feb-21
508.3570	HAZOP	5	15-Feb-21	19-Feb-21
8.2 No.3 CD ADI liquor screen		106	07-Jan-21	11-Jun-21
508.4180	8.2 Detail design start	0	07-Jan-21	
508.4190	8.2 Detail design finish	0		11-Jun-21
Process design		19	07-Jan-21	03-Feb-21
508.4160	8.2 LLI technical specification	10	07-Jan-21	20-Jan-21
508.4090	8.2 Process diagrams	2	21-Jan-21	22-Jan-21
508.3940	8.2 Equipment list	2	25-Jan-21	26-Jan-21
508.4100	8.2 Process design verification	5	27-Jan-21	03-Feb-21
Mechanical design		87	21-Jan-21	28-May-21
508.4070	8.2 Site plan	3	21-Jan-21	25-Jan-21
508.4060	8.2 Minor equipment technical specifications	2	28-Jan-21	29-Jan-21
508.3990	8.2 Mechanical plans & sections	2	20-May-21	21-May-21
508.4150	8.2 Mechanical design verification	5	24-May-21	28-May-21
Piping design		87	27-Jan-21	03-Jun-21
508.3950	8.2 Piping list	1	27-Jan-21	27-Jan-21
508.4080	8.2 Valve list	1	02-Feb-21	02-Feb-21
508.3960	8.2 Tie-in list	1	03-Feb-21	03-Feb-21
508.4040	8.2 Piping plans & sections	2	24-May-21	25-May-21
508.3920	8.2 Piping support design	2	26-May-21	27-May-21
508.4110	8.2 Piping design verification	5	28-May-21	03-Jun-21
Electrical and Instrumentation design		17	27-Jan-21	22-Feb-21
508.3970	8.2 Electrical load list	1	27-Jan-21	27-Jan-21
508.3980	8.2 MCC layouts	2	28-Jan-21	29-Jan-21
508.4000	8.2 Instrument list	1	02-Feb-21	02-Feb-21
508.4010	8.2 Input/Output list	1	03-Feb-21	03-Feb-21
508.4020	8.2 Instrument cable schedule	2	04-Feb-21	05-Feb-21
508.4030	8.2 Electrical cable schedule	2	09-Feb-21	10-Feb-21
508.4050	8.2 Instrument data sheets	2	11-Feb-21	12-Feb-21
508.4170	8.2 Electrical supports	1	15-Feb-21	15-Feb-21
508.4120	8.2 Electrical and instrumentation design verification	5	16-Feb-21	22-Feb-21
Civil / Structural design		10	28-May-21	11-Jun-21
508.3930	8.2 Structural design	3	28-May-21	01-Jun-21
508.4130	8.2 Civil design	2	02-Jun-21	03-Jun-21
508.4140	8.2 Civil and structural design verification	5	04-Jun-21	11-Jun-21
8.4 No.2 Mill spill collection		31	27-Jan-21	12-Mar-21
508.1900	8.4 Detail design start	0	27-Jan-21	
508.1910	8.4 Detail design finish	0		12-Mar-21
Process design		15	27-Jan-21	18-Feb-21
508.1920	8.4 LLI technical specification	4	27-Jan-21	02-Feb-21



🟦 Actual Work	◆ ◆ Milestone
🟩 Remaining Work	Summary
🟥 Critical Remaining Work	

Issued by: Tarcisio Althoff
Issued date: 20-Jan-20
Data date: 20-Jan-20

Client Logo

WWTP & Source Control Projects
SC08 Black Liquor Spill Recovery
Execution Phase Detailed Schedule

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Activity ID	Activity Name	Original Duration	Start	Finish
508.1930	8.4 Process diagrams	2	05-Feb-21	09-Feb-21
508.1940	8.4 Equipment list	2	10-Feb-21	11-Feb-21
508.1950	8.4 Process design verification	5	12-Feb-21	18-Feb-21
Mechanical design		12	05-Feb-21	23-Feb-21
508.1960	8.4 Site plan	2	05-Feb-21	09-Feb-21
508.1970	8.4 Mechanical plans & sections	2	10-Feb-21	11-Feb-21
508.1980	8.4 Minor equipment technical specifications	3	12-Feb-21	16-Feb-21
508.1990	8.4 Mechanical design verification	5	17-Feb-21	23-Feb-21
Piping design		12	17-Feb-21	04-Mar-21
508.2000	8.4 Piping list	1	17-Feb-21	17-Feb-21
508.2010	8.4 Valve list	1	18-Feb-21	18-Feb-21
508.2020	8.4 Tie-in list	1	19-Feb-21	19-Feb-21
508.2030	8.4 Piping plans & sections	2	22-Feb-21	23-Feb-21
508.2040	8.4 Piping support design	2	24-Feb-21	25-Feb-21
508.2050	8.4 Piping design verification	5	26-Feb-21	04-Mar-21
Electrical and Instrumentation design		17	16-Feb-21	10-Mar-21
508.2060	8.4 Electrical load list	1	16-Feb-21	16-Feb-21
508.2070	8.4 MCC layouts	2	17-Feb-21	18-Feb-21
508.2080	8.4 Instrument list	1	19-Feb-21	19-Feb-21
508.2090	8.4 Input/Output list	1	22-Feb-21	22-Feb-21
508.2100	8.4 Instrument data sheets	2	23-Feb-21	24-Feb-21
508.2110	8.4 Instrument cable schedule	2	25-Feb-21	26-Feb-21
508.2120	8.4 Electrical cable schedule	2	01-Mar-21	02-Mar-21
508.2130	8.4 Electrical supports	1	03-Mar-21	03-Mar-21
508.2140	8.4 Electrical and instrumentation design verification	5	04-Mar-21	10-Mar-21
Civil / Structural design		7	04-Mar-21	12-Mar-21
508.2150	8.4 Structural design	2	04-Mar-21	05-Mar-21
508.2170	8.4 Structural design verification	5	08-Mar-21	12-Mar-21
8.6 Junk traps and Knots bunker		45	03-Feb-21	09-Apr-21
508.4460	8.6 Detail design start	0	03-Feb-21	
508.4470	8.6 Detail design finish	0		09-Apr-21
Process design		13	03-Feb-21	22-Feb-21
508.4440	8.6 LLI technical specification	2	03-Feb-21	04-Feb-21
508.4370	8.6 Process diagrams	1	12-Feb-21	12-Feb-21
508.4220	8.6 Equipment list	1	15-Feb-21	15-Feb-21
508.4380	8.6 Process design verification	5	16-Feb-21	22-Feb-21
Mechanical design		11	01-Mar-21	15-Mar-21
508.4340	8.6 Minor equipment technical specifications	2	01-Mar-21	02-Mar-21
508.4350	8.6 Site plan	2	03-Mar-21	04-Mar-21
508.4270	8.6 Mechanical plans & sections	2	05-Mar-21	08-Mar-21
508.4430	8.6 Mechanical design verification	5	09-Mar-21	15-Mar-21
Piping design		18	26-Feb-21	23-Mar-21
508.4230	8.6 Piping list	1	26-Feb-21	26-Feb-21
508.4360	8.6 Valve list	1	09-Mar-21	09-Mar-21
508.4240	8.6 Tie-in list	1	10-Mar-21	10-Mar-21
508.4320	8.6 Piping plans & sections	2	11-Mar-21	12-Mar-21

Timeline: Qtr 1, 2021 – Qtr 4, 2022 (Jan – Dec)

Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

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WWTP & Source Control Projects
SC08 Black Liquor Spill Recovery
Execution Phase Detailed Schedule

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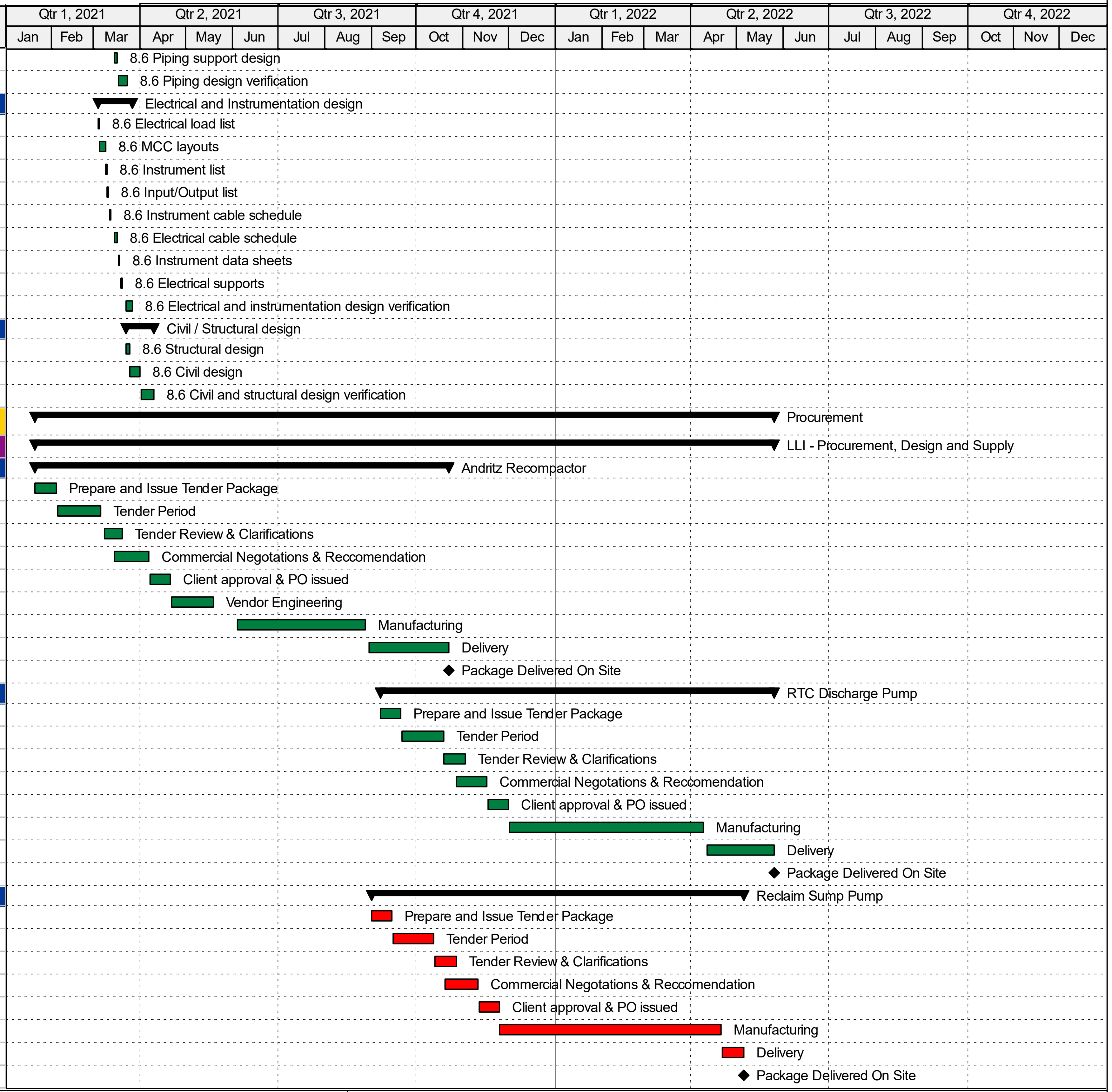
Activity ID	Activity Name	Original Duration	Start	Finish
508.4200	8.6 Piping support design	2	15-Mar-21	16-Mar-21
508.4390	8.6 Piping design verification	5	17-Mar-21	23-Mar-21
Electrical and Instrumentation design		17	04-Mar-21	26-Mar-21
508.4250	8.6 Electrical load list	1	04-Mar-21	04-Mar-21
508.4260	8.6 MCC layouts	2	05-Mar-21	08-Mar-21
508.4280	8.6 Instrument list	1	09-Mar-21	09-Mar-21
508.4290	8.6 Input/Output list	1	10-Mar-21	10-Mar-21
508.4300	8.6 Instrument cable schedule	2	11-Mar-21	12-Mar-21
508.4310	8.6 Electrical cable schedule	2	15-Mar-21	16-Mar-21
508.4330	8.6 Instrument data sheets	2	17-Mar-21	18-Mar-21
508.4450	8.6 Electrical supports	1	19-Mar-21	19-Mar-21
508.4400	8.6 Electrical and instrumentation design verification	5	22-Mar-21	26-Mar-21
Civil / Structural design		13	22-Mar-21	09-Apr-21
508.4210	8.6 Structural design	3	22-Mar-21	24-Mar-21
508.4410	8.6 Civil design	5	25-Mar-21	31-Mar-21
508.4420	8.6 Civil and structural design verification	5	01-Apr-21	09-Apr-21
Procurement		327	21-Jan-21	25-May-22
LLI - Procurement, Design and Supply		327	21-Jan-21	25-May-22
Andritz Recompactor		191	21-Jan-21	22-Oct-21
506.1160	Prepare and Issue Tender Package	10	21-Jan-21	04-Feb-21
506.1170	Tender Period	20	05-Feb-21	05-Mar-21
506.1180	Tender Review & Clarifications	10	08-Mar-21	19-Mar-21
506.1210	Commercial Negotations & Reccomendation	15	15-Mar-21	06-Apr-21
506.1190	Client approval & PO issued	10	07-Apr-21	20-Apr-21
506.1400	Vendor Engineering	20	21-Apr-21	19-May-21
506.1200	Manufacturing	60	04-Jun-21	27-Aug-21
506.1230	Delivery	40	30-Aug-21	22-Oct-21
506.1220	Package Delivered On Site	0		22-Oct-21
RTC Discharge Pump		170	07-Sep-21	25-May-22
506.1000	Prepare and Issue Tender Package	10	07-Sep-21	20-Sep-21
506.1010	Tender Period	20	21-Sep-21	18-Oct-21
506.1020	Tender Review & Clarifications	10	19-Oct-21	02-Nov-21
506.1050	Commercial Negotations & Reccomendation	15	27-Oct-21	16-Nov-21
506.1030	Client approval & PO issued	10	17-Nov-21	30-Nov-21
506.1040	Manufacturing	80	01-Dec-21	08-Apr-22
506.1070	Delivery	30	11-Apr-22	25-May-22
506.1060	Package Delivered On Site	0		25-May-22
Reclaim Sump Pump		160	01-Sep-21	05-May-22
506.1240	Prepare and Issue Tender Package	10	01-Sep-21	14-Sep-21
506.1250	Tender Period	20	15-Sep-21	12-Oct-21
506.1260	Tender Review & Clarifications	10	13-Oct-21	27-Oct-21
506.1290	Commercial Negotations & Reccomendation	15	20-Oct-21	10-Nov-21
506.1270	Client approval & PO issued	10	11-Nov-21	24-Nov-21
506.1280	Manufacturing	90	25-Nov-21	20-Apr-22
506.1310	Delivery	10	21-Apr-22	05-May-22
506.1300	Package Delivered On Site	0		05-May-22



Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

Issued by: Tarcisio Althoff
Issued date: 20-Jan-20
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Client Logo

WWTP & Source Control Projects
SC08 Black Liquor Spill Recovery
Execution Phase Detailed Schedule

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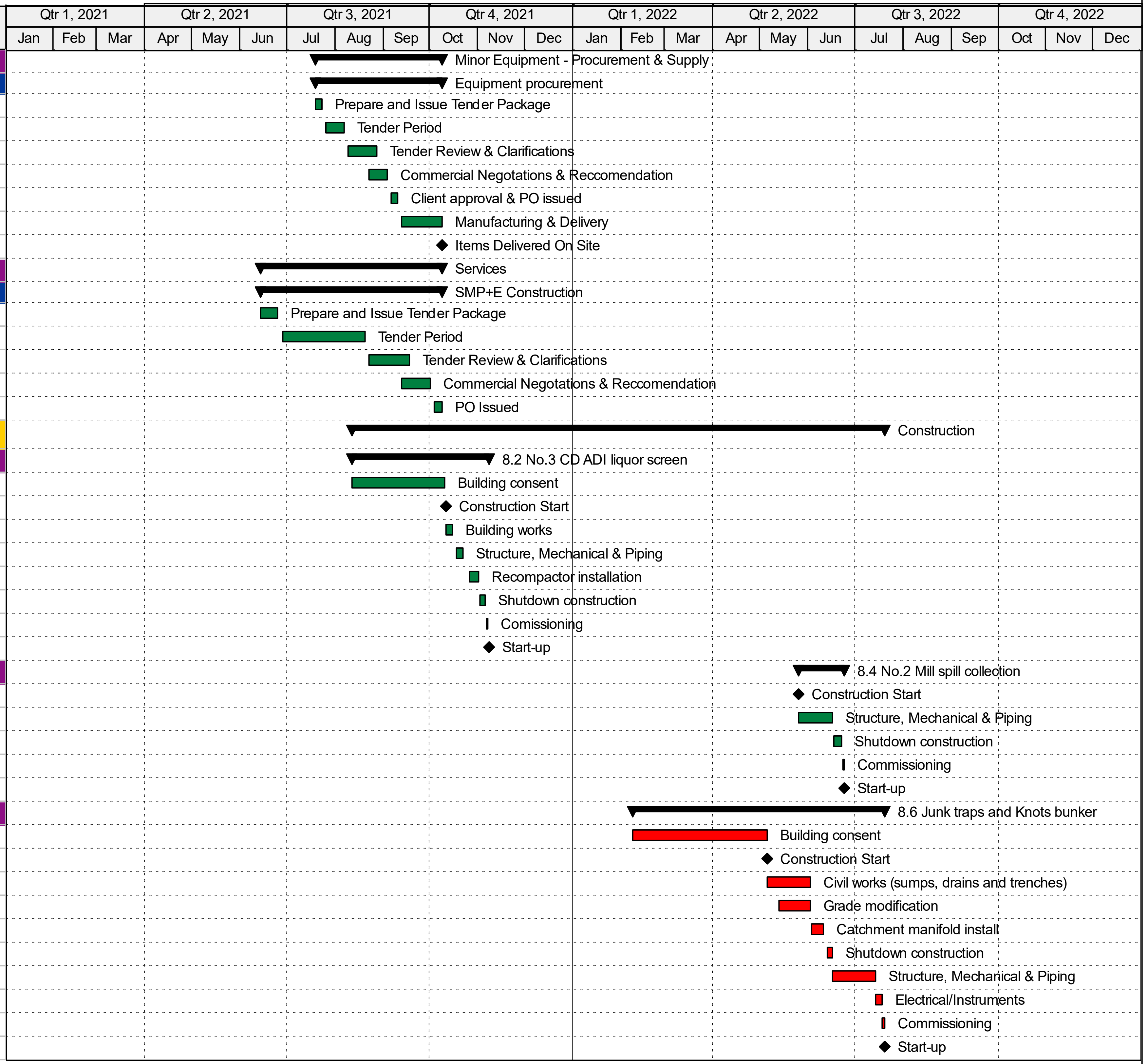
Activity ID	Activity Name	Original Duration	Start	Finish
Minor Equipment - Procurement & Supply		60	19-Jul-21	08-Oct-21
Equipment procurement		60	19-Jul-21	08-Oct-21
508.3430	Prepare and Issue Tender Package	5	19-Jul-21	23-Jul-21
508.3440	Tender Period	10	26-Jul-21	06-Aug-21
508.3450	Tender Review & Clarifications	15	09-Aug-21	27-Aug-21
508.3460	Commercial Negotations & Reccomendation	10	23-Aug-21	03-Sep-21
508.3470	Client approval & PO issued	5	06-Sep-21	10-Sep-21
508.3480	Manufacturing & Delivery	20	13-Sep-21	08-Oct-21
508.3490	Items Delivered On Site	0		08-Oct-21
Services		85	14-Jun-21	08-Oct-21
SMP+E Construction		85	14-Jun-21	08-Oct-21
508.3170	Prepare and Issue Tender Package	10	14-Jun-21	25-Jun-21
508.3180	Tender Period	40	28-Jun-21	20-Aug-21
508.3190	Tender Review & Clarifications	20	23-Aug-21	17-Sep-21
508.3200	Commercial Negotations & Reccomendation	15	13-Sep-21	01-Oct-21
508.3210	PO Issued	5	04-Oct-21	08-Oct-21
Construction		343	12-Aug-21	20-Jul-22
8.2 No.3 CD ADI liquor screen		88	12-Aug-21	08-Nov-21
608.1630	Building consent	60	12-Aug-21	10-Oct-21
608.1490	Construction Start	0	11-Oct-21	
608.1530	Building works	5	11-Oct-21	15-Oct-21
608.1460	Structure, Mechanical & Piping	5	18-Oct-21	22-Oct-21
608.1470	Recompactor installation	5	26-Oct-21	01-Nov-21
608.1510	Shutdown construction	4	02-Nov-21	05-Nov-21
608.1480	Comissioning	2	06-Nov-21	07-Nov-21
608.1500	Start-up	0		08-Nov-21
8.4 No.2 Mill spill collection		30	26-May-22	24-Jun-22
608.1430	Construction Start	0	26-May-22	
608.1600	Structure, Mechanical & Piping	15	26-May-22	16-Jun-22
608.1400	Shutdown construction	6	17-Jun-22	22-Jun-22
608.1450	Commissioning	2	23-Jun-22	24-Jun-22
608.1440	Start-up	0		24-Jun-22
8.6 Junk traps and Knots bunker		163	08-Feb-22	20-Jul-22
608.1640	Building consent	60	08-Feb-22	05-May-22
608.1370	Construction Start	0	06-May-22	
608.1410	Civil works (sumps, drains and trenches)	20	06-May-22	02-Jun-22
608.1420	Grade modification	15	13-May-22	02-Jun-22
608.1550	Catchment manifold install	5	03-Jun-22	10-Jun-22
608.1390	Shutdown construction	4	13-Jun-22	16-Jun-22
608.1340	Structure, Mechanical & Piping	20	16-Jun-22	14-Jul-22
608.1350	Electrical/Instruments	2	14-Jul-22	18-Jul-22
608.1360	Commissioning	2	18-Jul-22	20-Jul-22
608.1380	Start-up	0		20-Jul-22



Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

Issued by: Tarcisio Althoff
Issued date: 20-Jan-20
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APPENDIX 3 – EXAMPLE OF BASIS OF SCHEDULE DOCUMENT

3 Project Schedule

3.1 Basis of Schedule

The execution phase schedule has been developed based upon the following assumptions:

- No detailed engineering or tendering of the equipment packages will take place until after project CAPEX approval. It is expected that CAPEX approval will be granted in 2020 and detailed engineering will begin January 2021.
- One lump sum construction contract will be issued for structural / mechanical / electrical / instrumentation works during each shut. It is expected that much of the construction for Project 8.2 – No.3 Continuous Digester ADI liquor screen will be carried out during the November 2021 shut and the other projects during the June 2022 shut.
- The scope of project work planned during the annual shuts have been minimised to avoid disruption. E.g. Major civil works in Project 8.6 will be completed prior to the June 2021 shut down. Area day shuts may be used to accelerate the schedule and reduce annual shut work.
- Where there are building or significant structural modifications, three months have been allowed for the application of a building consent.

3.2 Long Lead Items

The long lead items that will define the project schedule have been listed in Table 5.

Table 5 - SC08 Long Lead Items

Project	Item	Manufacturing	Delivery
8.2	Andritz Rejects Compactor (ReCo)	12 weeks	8 weeks
8.4	Rejects Transfer Chest Pump	16 weeks	6 weeks
8.6	Reclaim Sump Pump	12 weeks	2 weeks

An procurement period of four months has been allowed for each long lead item.

3.3 SC08 Project Key Milestones

The SC08 project key milestones are listed in Table 6 below:

Table 6 - SC08 Project Key Milestones

Project Phase	Scheduled Construction Date/(s)
Capital Expenditure Request Submission	February 2020
Project HAZOP	February 2021
Detailed Design	January 2021 – May 2021
Procurement of Major Equipment	January 2021 – May 2022

Procurement of Minor Equipment	July 2021 – October 2021
Procurement of Services	June 2021 – October 2021

3.4 Schedule Commentary

The three projects are split across the annual June and November shuts according to their plant area. Project 8.2 is in the No.3 Continuous Digester plant, which shuts down in November. The remaining projects are in the No.2 Pulp Mill, which shuts down in June. This section provides a brief commentary on the expected schedules for each project. For further information refer to the SC08 execution schedule in Appendix D.

3.4.1 Project 8.2 - No.3 Continuous Digester ADI Liquor Screen

Table 7 below details some of the project's key milestones:

Table 7 - Project 8.2 Key Milestones

Project Milestones	8.2 – No.3 Continuous Digester ADI Liquor Screen
Detailed Design	January 2021 – June 2021
Procurement of ReCo	January 2021 – October 2021
Scheduled Construction Dates	October 2021 – November 2021

- A building consent may be required for modifications to the No.3 Continuous Digester building
- Given that Project 8.2 is scheduled to commence in November 2021, the procurement process for the project must begin in early January 2021. This will require the design basis for the ReCo to be finalised by the end of December 2020. This project will be prioritised over the others in order to achieve the scheduled completion date.
- The detailed design duration for this project is significantly longer than the others, due to some time being allowed for vendor engineering / interactions.
- There is an opportunity to begin construction of Project 8.2 earlier by reducing the procurement time for the Structural, Mechanical, Piping and Electrical (SMP+E) packages. This would allow for some buffer time between the completion of the building works and the installation of the ReCo.
- An area day shut in the No.3 Continuous Digester plant would reduce the tie-in work scheduled during the shut.

3.4.2 Project 8.4 - No.2 Mill Spill Collection

Table 8 below details some of the project's key milestones:

Table 8 - Project 8.4 Key Milestones

Project Milestones	8.4 – No.2 Mill Spill Collection
Detailed Design	January 2021 – March 2021
Procurement of Rejects Transfer Chest Pump	September 2021 – May 2022
Scheduled Construction Dates	May 2022 – June 2022

- Most of the pump installation and alignment work will be carried out before the shut. The June shutdown period will be used to commission the pump and construct the stab-in to the Rejects Transfer Chest.
- Given that the commissioning of the pump must take place during a shut, procurement of the pump has been delayed to begin as late as possible.

3.4.3 Project 8.6 - Junk Traps and Knots Bunker

Table 9 below details some of the project's key milestones:

Table 9 - Project 8.6 Key Milestones

Project Milestones	8.2 – No.3 Continuous Digester ADI Liquor Screen
Detailed Design	February 2021 – April 2021
Procurement of Reclaim Sump Pump	September 2021 – May 2022
Scheduled Construction Dates	May 2022 – July 2022

- Building consent may be required for the modification of the grade in the No.2 Pulp Mill area.
- Civil works have been scheduled prior to the June shut to avoid delaying the work due to unfavourable weather conditions. The New Zealand winter season begins in June.
- Given that the commissioning of the pump must take place during a shut, procurement of the pump has been delayed to begin as late as possible.

3.5 Schedule Risks

3.5.1 Project 8.2: No.3 Continuous Digester ADI Liquor Screen

A major risk to the schedule is the procurement of the ReCo, as the tender package must be issued by the end of January 2021 in order to meet the planned construction date prior to the November 2021 shut. In order to achieve this, "*the client*" must confirm the design basis for the project by the end of December 2020.

3.5.2 Project 8.6: Junk Traps and Knots Bunker

Poor weather conditions may affect civil works carried out however there is an opportunity for the civil design to be prioritised and implemented earlier than the rest of the project during the summer months. This would require a separate contract to be procured.

Appendix 4 – KPI Dictionary

Schedule Variance

Definition

The Variance calculates the slippage between the planned or actual finish dates and the baseline finish dates.

What it indicates

It aims to indicate the impact on the finish dates of an activity or work package that is caused by past and/or future activities performed differently than what was baselined.

Can be calculated for activities, work packages or the entire project. For work packages and projects, it is considered the last date of the package, even if this date is not given by the same activity on the baseline and the updated schedule.

Interpretation

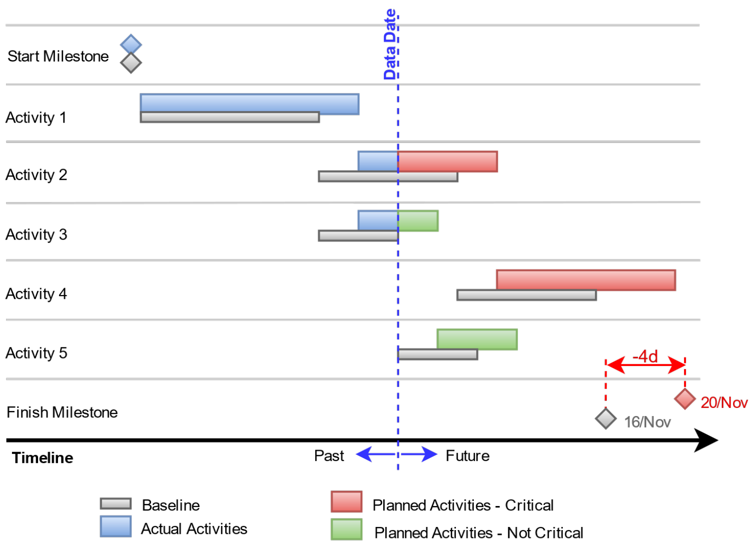
It is given in working days. A negative variance means a finish date behind the baseline, and positive variance means a date ahead of the baseline.

Negative values are highlighted as RED and positive values as GREEN on the project reports.

Formula

$$Variance = Baseline\ Finish\ Date - Planned\ (or\ Actual)\ Finish\ Date$$

Example



$$Variance = 16/Nov - 20/Nov$$

$$Variance = \mathbf{-4\ days}$$

Schedule Performance Indicator (SPI)

Definition

SPI is the proportion of the actual duration percent complete and the baseline duration percent complete forecasted to the data date.

What it indicates

It aims to indicate the performance of past activities, comparing the level of completion performed up to the data date with the level of completion forecasted on the baseline. It does not take in consideration any planned or future activities, once measures only past performance.

Can be calculated for activities, work packages or the entire project. For work packages and projects, the indicator is calculated using the sum of actual and baseline duration percent complete of the activities.

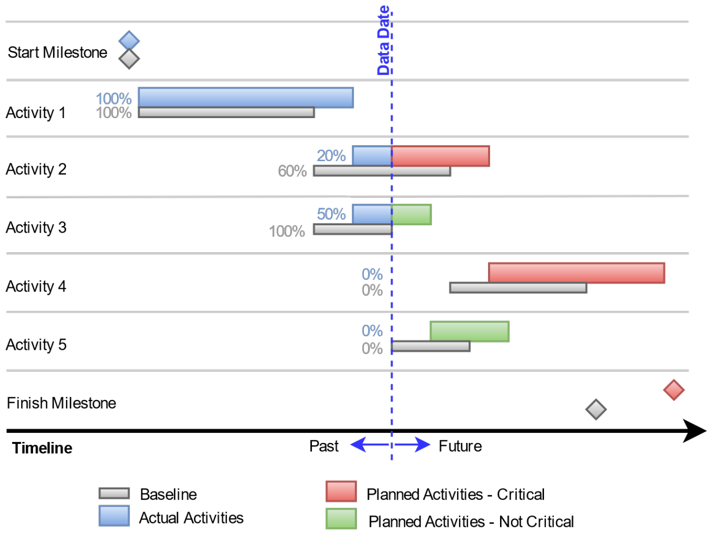
Interpretation

It is given in percent. An SPI of 100% means the performance is exactly as it was baselined. Values lower than 100% mean a performance behind the baseline, while values above 100% mean a performance ahead of the baseline. Values lower than 75% are highlighted as RED, from 75% to 95% as YELLOW and above 95% as GREEN.

Formula

$$SPI = \frac{Actual\ Duration\ \%\ Complete}{Baseline\ Duration\ \%\ Complete}$$

Example



$$SPI = \frac{100\% + 20\% + 50\% + 0\% + 0\%}{100\% + 60\% + 100\% + 0\% + 0\%}$$

$$SPI = \frac{170\%}{260\%}$$

$$SPI = 65\%$$

Criticality Tree

Definition

It is a treemap chart which shows the number of activities on the schedule segregated in categories according to their total float.

What it indicates

The tool allows a fast understanding of the proportion of activities on the critical path (or near-critical paths) in comparison to the total number of activities. It indicates the risk of delay in a project schedule.

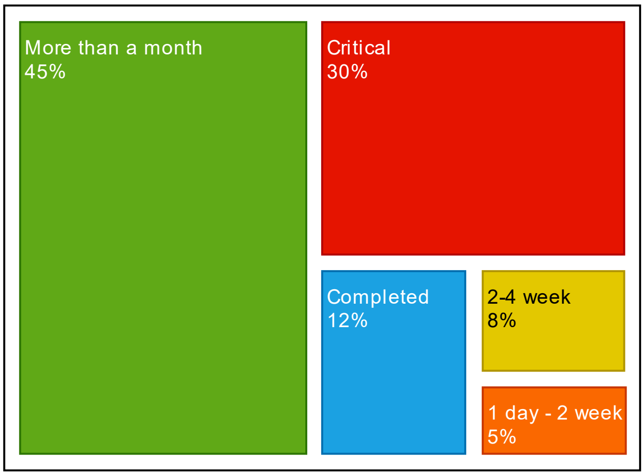
Interpretation

There is no ideal shape for a criticality tree. Depending on the nature of the project, its drivers and management requirements, the proportion of activities on the critical path will change drastically. However, it is a comparative way to understand the risk associated with a project and different management strategies. For instance, a project scheduled using the "as late as possible" methodology will show a criticality tree 100% critical. On the other hand, a project in which the critical path is composed of only one long lead item supply will show a very low proportion of criticality.

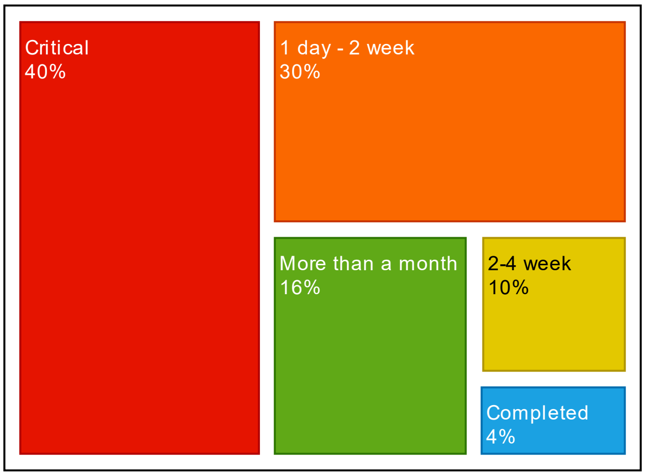
Example

Below are examples of criticality trees for two different projects. Project 2 has a more significant proportion of critical or near-critical activities than Project 1, which indicates a higher risk of delay on the finish date.

Project 1



Project 2



APPENDIX 5 – PROJECT SCHEDULE PERFORMANCE DASHBOARD

1- Header
2- Filters
3- Visual Management / KPIs
4- Milestones table with additional filters

APPENDIX 6 – PROJECT SCHEDULE PERFORMANCE REPORT

WWTP & Source Control Projects

Schedule Performance Report

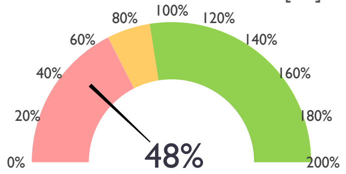
22/Dec/2019

Client Logo

SC01 - No.1 Mill Washing

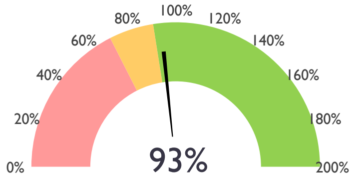
Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	12/Jul/2019		12/Jul/2019	0	✓
Definition / Gate 4					
Execution / Start Up	2/Mar/2021	7/Jul/2021		-127	🔴

Schedule Performance Indicator [SPI]



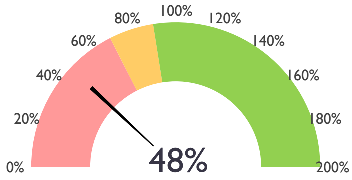
SC02 - CD3 Washing

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	11/Nov/2019	10/Jan/2020		-60	🔴
Definition / Gate 4	24/Apr/2020	1/May/2020		-7	🔴
Execution / Start Up	7/Jul/2021	20/Dec/2021		-166	🔴



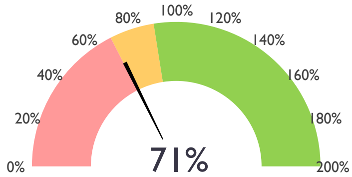
SC03 - Warm Water Recovery

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	18/Feb/2020	30/Mar/2020		-41	🔴
Definition / Gate 4					
Execution / Start Up	21/Jul/2021	5/Oct/2021		-76	🔴



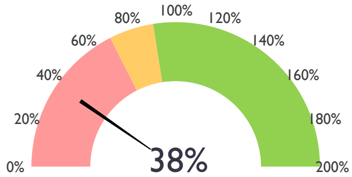
SC04 - Condensate Stripping

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	17/Jan/2020	24/Jan/2020		-7	🔴
Definition / Gate 4	20/Aug/2020	25/Sep/2020		-36	🔴
Execution / Start Up	29/Mar/2022	9/Feb/2022		48	🟢



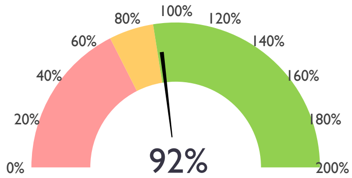
SC05 - PD2 White Water Recovery

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	20/Nov/2019		20/Nov/2019	0	✓
Definition / Gate 4					
Execution / Start Up	11/Jan/2021	26/May/2021		-135	🔴



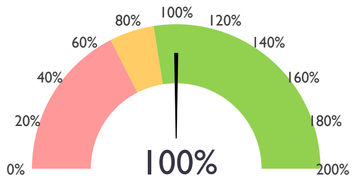
SC06 - Water Recovery Projects

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	22/Jul/2019		22/Jul/2019	0	✓
Definition / Gate 4	21/Apr/2020	8/May/2020		-17	🔴
Execution / Start Up	21/Jun/2021	21/Jun/2021		0	🟢



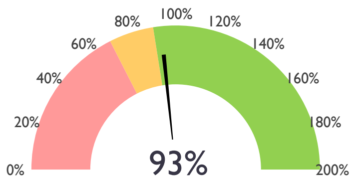
SC07 - Combined Condensate Recovery

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	24/Mar/2020	24/Mar/2020		0	🟢
Definition / Gate 4					
Execution / Start Up	20/May/2021	20/May/2021		0	🟢



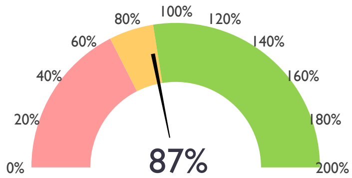
SC08 - Black Liquor Spill Recovery

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	11/Dec/2019		17/Dec/2019	-6	✓
Definition / Gate 4	1/May/2020	1/May/2020		0	🟢
Execution / Start Up	11/May/2021	11/May/2021		0	🟢



WWTP - Waste Water Treatment Plant

Stage / Gate	Baseline	Planned	Actual	Variance	Indicator
Concept / Gate 3	31/Mar/2020	31/Mar/2020		0	🟢
Definition / Gate 4	1/Jun/2021	1/Jun/2021		0	🟢
Execution / Start Up	19/Feb/2024	19/Feb/2024		0	🟢



APPENDIX 7 – ADAPTIVE APPROACHES IN ENGINEERING PROJECTS

The basis of project management traditional methodology was established in the 1950s when the space race started during the cold war. The pack of efforts and resources employed to achieve determined goals were organised in a structured way which later became known as project management. During the 1980s, project management organisations started developing their bodies of knowledge and this traditional methodology was considered the only acceptable and effective project management approach.[1]

The main idea of the traditional approach is that the customer defines what they want the project to achieve at the initiation stage of the project, or sometimes even before this point. However, a situation in which the outcome is clearly and completely defined at the beginning of the project is relatively uncommon. [2]

Currently, this traditional approach is considered by some managers as bureaucratic and outdated. Projects become progressively complex, with a higher number of tasks and interrelations, while traditional project management approach is based on mostly hierarchical and linear task relations. Another disadvantage of the traditional approach is the assumption that projects are isolated from their environment. Change is the reality of today's business environments, and adaptations in the initial plan are inevitable due to adjustments in the project environment or within the project itself. [1]

An emerging trend about project management is the development of adaptive methodologies. The adaptive approach divides the project into smaller segments, named iterations, each of which concludes in a partial result, preferably relevant to the general goal of the project. The idea of this division into iterations is to allow a gradual analysis of smaller and more manageable portions of the scope [2]. The most common name used for this approach is Agile, but other names are common like lean, extreme and adaptive approaches [1], SCRUM and ASD – Adaptive Software Development (the last two mostly used in software development environment) [2].

The adaptive approach was developed in the software industry in the early 2000s by some developers who proposed the Agile Manifesto, which stated the first principles of adaptive methods [3]. This methodology is designed to use a minimum of documentation in order to facilitate flexibility and responsiveness to changing conditions. Also, it claims that early specification of requirements results in gold plating (adding more features than required) because there will be no other opportunities to changes [4]. Other principles include entrust and empowers staff, encouraging ongoing communication between the business areas and project team members, and an increase in the client's involvement [5]. A comparison between adaptive and traditional methodologies is shown in the table below.

	Traditional	Adaptive
Fundamental Assumption	The scope is fully specifiable, predictable and is built through extensive planning	The scope is incrementally developed using principles of continuous design improvement based on rapid feedback of the client
Planning	Linear	Iterative
Management Style	Command and Control	Collaborative
Knowledge management	Explicit	Tacit
Communication	Formal	Informal
Organisational Structure	Hierarchical and bureaucratic with a high degree of formalisation in its processes	Organic and participative
Quality Control / Project acceptance	Client tests and accepts the scope at the project delivery	Continuous control and testing with client participating in each iteration

Is the adaptive approach feasible for engineering environment? Probably not entirely. The reality of developing an engineering project is different from the software development environment where adaptive mythology was first conceived. Both traditional and adaptive approaches have advantages and disadvantages, and it is often necessary to use both approaches. [1]

The traditional approach is appropriate for projects with clear initial user requirements and goals, therefore with a low level of uncertainty. On the other hand, the adaptive approach is more effective in creative, innovative projects, which include the development of new technologies or novelty design. All such projects are characterized by a high level of uncertainty, unclear project goals or incomplete and unpredictable requests, for which it could be assumed that will be significantly changed during the course of the project. [1]

Some studies suggest there is a "sweet spot," which is dependent on project or phase characteristics where the effort expended in initial planning pays off in success [4]. If too many resources were spent in a detailed plan, the result is effort wasted and rework, whereas not enough initial planning can result in failure. For this reason, many concepts of adaptive methodology should be incorporated in the traditional engineering project life-cycle, in order to solve some typical problems and disadvantages of the traditional methodology:

- Bureaucracy, excess documentation and formalisation. The excess of formalisation and time spent in documentation which is used for nobody is a recurrent criticism of project teams, managers and customers. The vision of the adaptive approach is to reduce documentation to improve flexibility.
- Poor interaction with the client. The interaction between client and project manager traditionally occurs through formal reports, letters, contracts and management meetings. The adaptive approach relies on a closer relationship between the project team and customers, with several opportunities for validation and quality check.
- Requests for change are considered a big problem. Generally, it takes several steps and degrees of approval to a change be approved on the traditional methodology. The adaptive approach considers

changes as an opportunity to create a final result with a higher likelihood to generate the benefits to the customer.

- Rework when planning the initial phases of a project. The initial phases of the typical sequence of Front-End Loading projects are non–linear, with frequent modifications and updates and require close and frequent collaboration with the customer. The traditional approach insists on developing extensive planning documentation for these phases, which generally means a waste of resources once the plans change several times. The adaptive approach can address better portions of the scope which require constant changes and adaptations.

Known-unknowns, like punch-lists and pendency-lists, cannot be planned effectively. Common at the end of construction or commissioning phases, these lists of problems need to be addressed by the project team before the end of the project or phase. However, the effort to solve these issues is generally unknown, what makes effective planning using traditional approach impossible. Adaptive methodology deals efficiently with portions of the scope which are not clear.

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[2] M. Wirkus, "Adaptive Management Approach to an Infrastructure Project," *Procedia - Soc. Behav. Sci.*, vol. 226, no. October 2015, pp. 414–422, 2016.

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