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Heavy Oil
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Quest CCS Project

QUEST CLOSEOUT REPORT

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Jan 26, 2016	Originator	Paul Tawiah	
Jan 26, 2016	Reviewer	Anita Spence	

Summary

The Project Close Out and Lessons Learned Report documents the major outcomes of the Quest project execution activities completed by the project team during the EXECUTE phase up to Ready for Start up (RFSU) together with the high-impact lessons.

Keywords

Quest, Project Execution, Close Out, Lessons Learned, CCS, CO_2 capture, pipelines

DCAF Authorities

Date	Role	Name	Signature or electronic reference (email)

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1. OBJECTIVES AND SUMMARY OF THE HARDWARE EXECUTION REPORT

The objective of the Quest Project Close Out and Lessons Learned Report is to communicate key outcomes of the project execution activities completed by the project team on how the Quest Project was implemented. As the as-built of the Project Execution Plan (PEP), this hardware execution report (HER) outlines the detailed engineering, procurement, module fabrication, construction, and commissioning and start-up activities of the Quest facilities and processes completed in the Execute phase of the project together with the major project outcomes and high-impact lessons.

The Quest Carbon Capture and Storage (CCS) project is the first fully integrated carbon dioxide capture, pipeline transport and geological storage project in Alberta, Canada. The project captures 1M tonnes of CO_2 per year and thus reduces the GHG emissions from the Shell Scotford Upgrader Complex by up to 1/3 of direct emissions of the Upgrader. The Quest project had significant non-technical risks around the regulatory and stakeholder engagements. Regulatory approval was received at the end of August 2012 after a successful regulatory hearing.

The Governments of Canada and Alberta provided significant funding ($865m total) for the project after successful funding and CO_2 multi-credits negotiations with the governments which included a significant requirement for knowledge-sharing of CCS technology with the Government of Alberta.

The project drivers were cost (NPV-zero target), quality and schedule in order of priority for decision-making. Hence the project was cost-driven and had to be executed within the government-provided funding with any cost overruns being absorbed by the project proponent and any cost under-runs returned to the government. The Project Final Investment Decision (FID) was taken in late August 2012 which allowed the project to formally proceed into the execution phase. The project was executed at a total CAPEX cost of $790.6M, which was $83.1M below its P50 approved budget. Mechanical completion for construction was achieved in early February 2015 (3 months ahead of its P50 mechanical completion date) with a strong execution HSSE performance (TRIF 1.487).

The Quest facilities were successfully started up on August 19, 2015 and passed all three Government of Alberta (GoA) performance tests requirements concurrently in about 35 days on September 28, 2015 to demonstrate Capacity (24 hrs), Efficiency (20 days) and Reliability (30 days).

2. PROJECT DESCRIPTION

2.1. Background and Objectives

To continue meeting the world's growing energy demand, while reducing greenhouse gas (GHG) emissions, Carbon Capture and Storage (CCS) is one of several pathways that Shell is pursuing along with increasing energy efficiency, low CO_2 fuel options, and advocating more effective CO_2 regulations, to reduce GHG emissions. The Quest CCS project is a fully integrated carbon dioxide capture, pipeline transport and storage project, proposed by the Athabasca Oil Sands Project Joint Venture (AOSP JV) owners – Shell Canada Energy (Shell), Chevron Canada Limited (Chevron) and Marathon Oil Sands L.P. (Marathon). The goal of the Quest CCS Project is to reduce greenhouse gas (GHG) emissions from the Scotford Upgrader complex through an integrated CCS project to enhance the environmental competitiveness of the existing Oil Sands facilities.

As a world-scale CCS demonstration project for the AOSP, Shell and Alberta, the Quest CCS Project is designed and built to capture, transport, and store up to 1.08Mt/pa of CO_2 from the Scotford Upgrader. The project execution objectives were:

- Develop world class CCS demonstration facility
- Achieve start up by Dec 31, 2015
- Achieve 1.08Mt/pa of CO_2 capture
- Obtain an NPV of 0 by delivering the project including 10 years of operation for less than the amount of governmental funding
- Execute the work safely
- Avoid a negative impact on the community

2.2. Project Location, Scope and Components

Quest is a fully integrated CCS project in the oil sands sector involving CO_2 capture at the Scotford Upgrader located within Strathcona County (approximately 5 km northeast of Fort Saskatchewan, Alberta, and within Alberta's Industrial Heartland -AIH), pipeline transportation northeast from the Scotford site and CO_2 storage in a deep saline formation zone. The project's major components comprise:

- A Capture and Compression facility where CO_2 from the steam methane reformer (SMR) units process streams at the existing Scotford Upgrader Base Plant and Expansion Hydrogen Manufacturing Units(HMUs) is captured and compressed. The method of CO_2 capture is based on a commercially proven activated amine technology called Shell ADIP-X
- Transport of the compressed CO_2 via a 65-km 12-inch pipeline to an approved Exploration Tenure Area of Interest (AOI) location northeast of the Scotford site

• Injection and storage of the CO_2 underground (2,000 to 2,100 m) in a deep, highly saline aquifer formation (Basal Cambrian Sands) using 3 injection wells and the deployment of a subsurface CO_2 Measurement, Monitoring, and Verification (MMV) technology infrastructure.

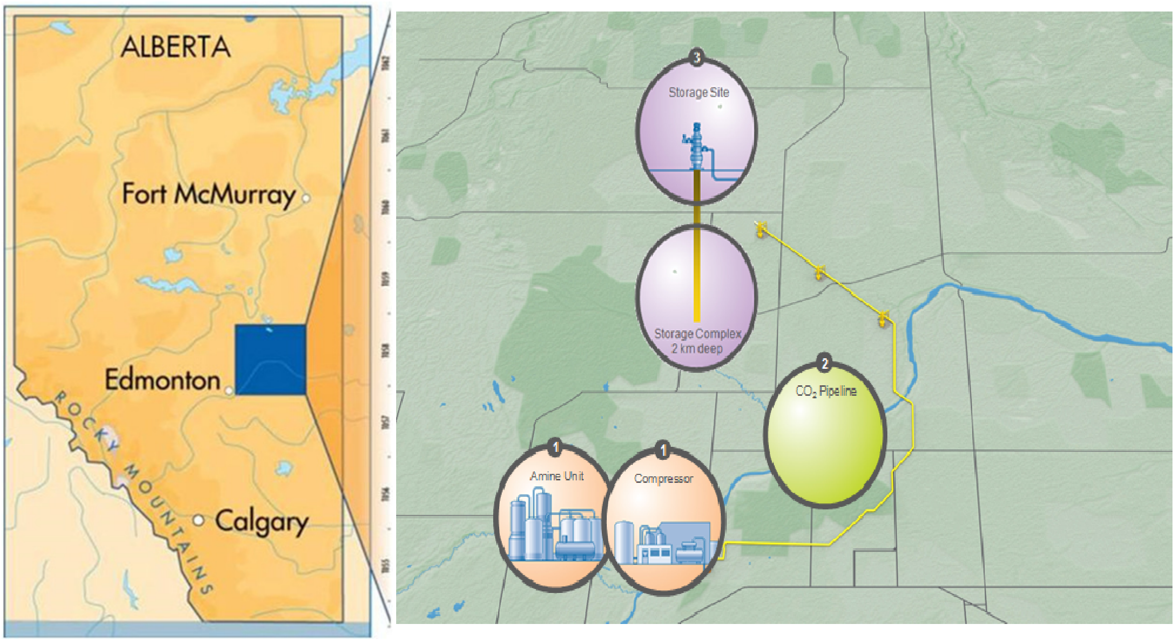


Figure 2-1: Schematic view of the Quest CCS Project in Alberta, Canada

3. PROJECT EXECUTION SUMMARY

3.1. Introduction

The CO_2 capture facilities were executed under an Engineering, Procurement, Construction and Construction Management (EPCCm) agreement with Fluor. Toyo engineered and procured the equipment and materials for the pipeline facilities including wellsite skids; the pipeline was constructed by URS Flint under a Shell construction management organisation. Fluor and Toyo developed the FEED packages for the CO_2 capture and pipeline facilities respectively. The wells were designed, drilled and completed by the Shell P&T wells group. The well location was by the Quest Shell subsurface team. The overall project execution was the responsibility of the Shell Projects & Technology (P&T) team.

3.2. Project Execution HSSE Statistics and Performance (February 2015)

	Quest – Feb 2015	Quest - YTD 2015	Quest Project Targets	Project to Date
Fatalities	0	0	0	0
LWC- Lost Workday Case	0	0	0	0
LTIF- Lost Time Incident Frequency	0.00	0.00	0.00	0
TRC- Total Recordable Cases	0	0	0	4
TRCF- Total Recordable Cases Frequency	0	0	0.00	1.44
First Aids	2	4	0	79
TROI- Total Recordable Occupational Illnesses	0	0	0	0
TROIF- TROI Frequency	0.00	0.00	0.00	0
Exposure Hours	24,305	73,364	N/A	2,761,727
Ram3+ LOPC Incidents	0	0	N/A	0
RAM 3+ (Potential or Actual)	0	0	N/A	5
Environmental Non-Compliances	0	0	=< 5	0
LSR Violations	0	0	0	19
Motor Vehicle Incidents (MVI)	0	0	0	4
Proactive Intervention Ratio (per 1000 exp. hours)	140	142	140	-
Incidents & Exposure Hours (Not P&T Accountability)	20,000 hrs & 3 incidents	43,796 hrs & 3 incidents	N/A	103,724 hrs & 16 incidents

G At or better than Target — Y 10% off Target — R More than 10% off Target

Table 3-1: Project HSSE Statistics at construction Mechanical Completion in Feb 2015

The HSSE targets for the project were set at zero (Goal Zero) for the Execution phase. The four Total Recordable Cases (TRC) were: Fluor MTC: 2 fingers (one on dyke, the other on blind flange), KBR MTC: pinched finger from structural steel; URS MTC: contusion from pipe impact.

3.3. Project Define and Execute Phases Key Activities

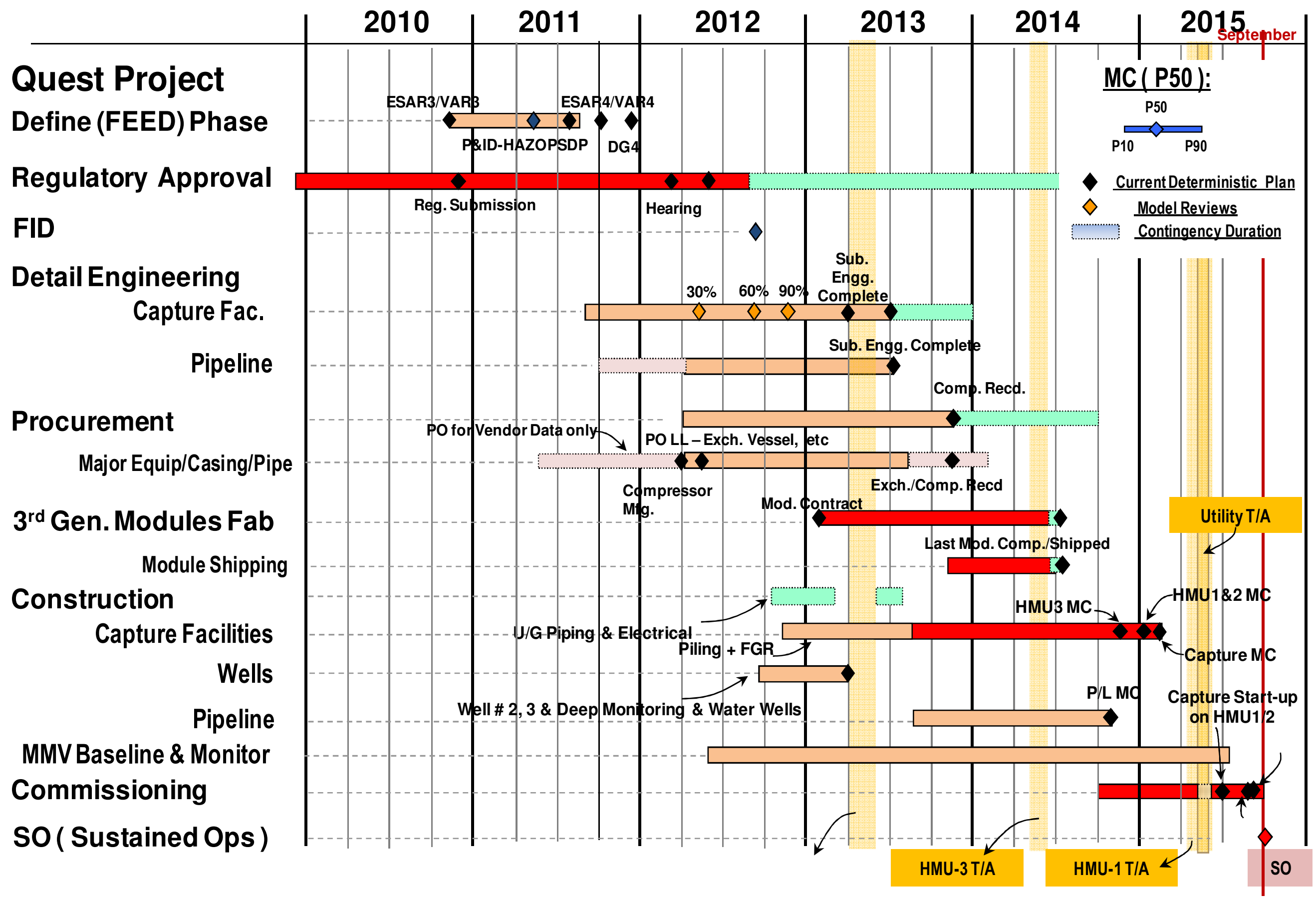


Figure 3-1:High Level-0 Post-DG3 Summary P50 Schedule (including contingency)

3.4. Schedule Performance

CO_2 Capture Facility

The Capture Facility had a deterministic mechanical completion (MC) date of Sept 30, 2014 and a P50 MC date of May 2015. The actual MC date was early Feb 2015. By mid-Feb 2015 all Final Completion Notices (FCNs) on all of the 134 systems were also completed. Late regulatory approval forced much of the early works activities into the winter months. In spite of those challenges (early works, winter impacts, etc.), the schedule performance was excellent when compared to the P50 date. Some key activities and outcomes regarding the execution schedule included the following:

- Module delivery delays: In Q4 2013 when the module delivery was forecasted to slip behind planned progress, the project team held multiple structured schedule recovery sessions ("Schedule & Progress Away Days"), that allowed the project team to fully understand the issues and align on the path forward in the most efficient manner. Cost-driven decisions were made with the appreciation that schedule extension had a cost impact as well. Managed overtime was used effectively with the addition of a small nightshift crew (50 people) for 4 months, peak manpower was delayed and then subsequently extended longer with a steeper ramp down.
- Although the module deliveries did slip from the original plan, once the modules started to arrive the main Capture facilities plot modules were set from April 2015 to August 2015. Having all the modules set in such a short period was a key objective towards realizing the 3rd Generation Modularization opportunity and also key in recovering progress.
- Capturing lessons learned from the early works construction programme and incorporated those lessons into the construction plans and processes for main construction activities for the CO_2 capture facilities.
- Due to the schedule challenges encountered, the deterministic MC date for the Capture Facility moved into Jan 2015. The recovery plans managed to pull the MC date back to Dec 2014. The project team held firm on the Dec 2014 deterministic date until the last possible moment, even though towards the end it appeared highly unlikely. The objective in that approach was to maintain the great momentum that had been building with the "strong finish" approach to the end.
- Construction could have enabled CSU to be more successful if the construction and CSU schedule integration had happened earlier. Some of the CSU key requirements (wants and needs) were not fully identified in time for construction to accommodate in an efficient manner, recognising that there was going to be a trade-off by staying in bulk construction longer.
- Piping tie-ins and turnaround scopes were executed on time; with the exception of the piping hot taps (although not on the construction critical path) were completed 1 year later than the original plan.
- During the initial start up and run of the CO_2 compression system in late May 2015, the CO_2 compressor experienced reverse rotation on shutdown. This delayed the compressor testing and start of CO_2 injection activities by about 11 weeks. (See Appendix 21 for detailed report on the after action review (AAR) on the solution and lessons learned.

Pipeline

Mechanical Completion (MC) for the Pipeline was achieved in Oct 2014 compared to a deterministic FID date of Sept 2014. Considering the increased scope and pipeline construction cost increases, the outcome of the pipeline delivery schedule was still acceptable since it was not on the critical path of the overall project.

3.5. Cost Summary

The Quest CCS project is not expected to generate direct revenues other than via Carbon Credits over its life-cycle i.e. it is NPV-neutral. The project assumed a price of $40 per ton of CO_2 for its economic calculations. However, without considerable funding by the federal and provincial governments, the project could not break even. Hence the project was developed and executed with an optimum combination of CAPEX, OPEX, and GHG efficiency, resulting in the greatest possible value for the AOSP. The project received funding of $120M CDN and $745M CDN from the Government of Canada (GoC) Clean Air Fund and Government of Alberta (GoA) respectively. Table 2-1 below shows the CAPEX breakdown of the project.

Item	GIP Budget ($M)	Approved Budget ($M)	Cost at Completion ($M)
Capture Facilities	453.9	467.3	465.4
Pipeline	52.2	125.0	124.7
Storage/Wells	44.2	45.5	42.9
Owner's Cost	149.3	149.8	157.6
Escalation/Inflation	42.1	1.2	0
Contingency	132.0	85.0	0
TOTAL COST	**873.7**	**873.7**	**790.6**

Table 3-2: Quest Project CAPEX Budget Table and Cost-at-Completion

3.6. Cost Performance

Quest was a cost-driven project and this was continuously reinforced by the project leadership team (PLT) in all project decision-making. The constant reinforcement and messaging of a cost-driven project proved to be very effective for construction decision making, especially when progress and schedule began to slip from their deterministic targets. While it was recognized that schedule extension did affect cost, good cost-driven decisions were made throughout the project while keeping the cost of schedule extension as a key parameter. The total project actual CAPEX cost was $83.4M under the approved Group Investment Proposal (GIP) at Final Investment Decision (FID). Construction cost made up slightly over 50% of the project costs.

Some major cost outcomes included the following:

- Scope reduction from the realisation of an opportunity (which was carried from the Define phase) after subsurface appraisal was completed that reduced the cost with the 3-injection well case from the original FID plan of 5 injection wells leading to a $28M savings in CAPEX cost
- The overall cost management of the EPCM scope (Capture facility engineering & procurement, construction, module & pipe fabrication/transportation and infrastructure) was outstanding. The Type 3 estimate was $430.6M. Shell had stretched Fluor's typical contingency by -$18M from their original estimate $448.6M. The Type 4 estimate was agreed at $437.3M. Final costs (including scope changes and trends) was $438.7M. The key driver for this outcome was the great relationships that were established between Shell and Fluor that enabled transparency and very active management of trends and scope changes. There was effective control and predictability of cost. Very effective project reporting and meetings were key enablers. A discretionary fee, which was behaviour-based, also aided in establishing the great relationships and transparency. The Fluor-executed scope was not without significant challenges i.e. early works schedule slippages, weather impacts, slower earlier DFL progress than planned, late delivery of modules, 12% increase in the direct manhour base budget for progress measurement, craft IFL/DFL ratio increase from 24% at FID to 45% at completion, turnover process and paperwork taking longer than planned, and many trends and scope changes. However, these challenges were effectively managed by having a good handle on the cost and associated trade-offs to enable good decision making.

- Cost increases of over $15M were encountered during Quest construction early works. Late regulatory approval forced much of the early works activities into the winter months. Although that was acknowledged and trended at the time, the full impact of executing these activities in winter months was underestimated. Instead of the predicted 20% - 30% increases due to winter impacts, the actual costs in some instances were up to 100%. Also, since much of the early works was sub-contracted by the EPCCm contractor, many of the budgets were established in the Define phase through budgetary quotes from sub-contractors, instead of using established estimates. Hence many early works budgets were low from the outset and did not take into account the full indirect costs. Piling was an exception and had a good cost performance. The lessons learned from the early works programme were applied to the foundation scope executed by a unit rate sub-contractor resulting in excellent performance outcomes in terms of cost, HSSE, schedule, and quality.

- The Quest Pipeline costs increased very significantly. The FID budget for pipeline construction was $28M and final total installed cost (TIC) was $88M. The major contributors to the cost increase were a much lower level of front end loading (FEL) compared to the level of FEL applied to the capture facility and module fabrication. Better front end loading would have had the pipeline ROW walked which would have helped identify the terrain challenges (topographical and geotechnical) and other construction related issues. Activity in the pipeline corridor was very high. Hence pipeline crossings increased by over100 (initially 228 to 336). Also, the pipe metallurgy required a weld procedure that was very difficult to execute resulting in high rework rate. Better front end loading and effective integrated assessment of that metallurgy change would have exploited this issue in more detailed. Also, early contractor engagement in both the front end and before construction mobilization would have been beneficial. There was limited time after contract execution with the contractor to establish alignment and build relationships. A kick off meeting and mobilization ensued shortly after contract execution. A fulltime Shell construction specialist during the Define phase and early execute would have aided in cost escalation mitigation and predictability. The original strategy was for a lump sum/unit rate contract and it ended up as a reimbursable target price contract. The target price proved to be difficult to manage because of many disputable changes (target price adjustment versus non-target price adjustment). The target price incentive was amended towards the end of the work and a negotiated fixed fee was eventually applied. See Appendix 19 Pipeline Construction Lessons Learned Report for more details.
- Module and pipe fabrication was executed significantly below the Type 3 estimate. The Type 3 estimate was $81.7M. After contract award, this budget was trended down by $18.7M to $63M. The final cost was $65.5M. Some key positive lessons were the robust front end work in engineering, constructability and estimating, resulting in a good commercial deal through robust contract formation and evaluation, as well as having a strong EPCCm and Owner's team in the module yard (see Modules Programme Lessons Learned in Appendices 11, 12 and 13).
- Piping tie-ins and scopes executed during the 2013, 2014 & 2015 Plant Turnarounds were over-budget compared to the FID estimate mainly due to underestimation of the PSA catalyst replacement cost and turnaround indirect allocations.
- The compressor reverse rotation issues experienced during the initial compressor start up resulted in $3.3M of additional CAPEX to fix (See Appendix 21)

4. PROJECT GOVERNANCE AND ASSURANCE

4.1. Project Governance and Assurance Structure

The Quest CCS Project followed the established governance structure for the AOSP JV:

- Executive Committee (Excom: Budgets > $15 million)
- Operating Committee (Opscom: AFE's and contracts < $15 million)

As prescribed in the ORM, the project's Decision Executive (DE), supported by a Decision Review Board (DRB), took all key decisions to progress the Quest CCS opportunity. In the Execution phase, the DE and DRB membership changed to reflect the project's focus on site and module yard execution activities i.e. CO_2 capture facility and pipeline execution, module fabrication & assembly, wells, ready for start up (RFSU) and operation.

4.2. Financial Authorities

Financial authorities were specified by the Executive Committee for managing the EPC contracts for the duration of the project. The Quest CCS Project was managed based on a no-change policy. However, if a change order became necessary, its monetary value and schedule consequences required approval by the Project Manager, Vice President – Projects & Technology, and the Executive Vice President – Heavy Oil, depending on their financial authority limits. Financial authority levels for the EPCM contractor for a reimbursable-type EPC contract was defined within the contract.

4.3. Project Development and Implementation Process

The AOSP JV is operated by Shell, hence the Shell Opportunity Realization Manual (ORM) was followed for the development, planning and execution of the Quest CCS project opportunity.

4.4. ORM Deliverables by Project Phase

The ORM deliverables were through the Project Controls and Assurance Plan (PCAP) list which was developed for each phase of the project in alignment with the approved Opportunity Assurance Plan (OAP), DCAF framework and Decision Road Map.

4.5. Discipline Control and Assurance Framework (DCAF)

During the SELECT phase, the Quest CCS Project began applying DCAF to manage quality. This resulted in the development of a project-specific Project Controls and Assurance Plan (PCAP) for the period until DG3. The PCAP was subsequently defined for the DEFINE phase, for the period until DG4. The PCAP listed critical project deliverables, accountable or responsible parties, and identified those people authorized to sign-off on these deliverables.

Fluor (EPCCm contractor) developed their own quality plans for the DEFINE phase deliverables and activities. The project team checked for contractor's and for Shell's compliance with the DCAF management system.

The contractor Quality Assurance (QA) plan covered technical quality, procurement quality and construction quality. Commissioning and start-up quality was included in the Operations Readiness Plan. Shop inspection and equipment commissioning requirements by both the owner's team and by contractors was specified in the project QA plan and purchase orders (PO) prior to execution of a PO.

4.6. Value Improvement

During the SELECT phase, the project plan for application of VIPs was developed in conjunction with the EPCM contractor. By involving multi-disciplinary teams and external third-party participants, value improvement ideas were identified, developed and implemented; the effect was a >15% reduction in CAPEX prior to completion of the VAR3 estimate.

In addition, the EPCM contractor established a Value Awareness program to facilitate the continuous collection of ideas to reduce costs from the integrated team. A Value Awareness committee was established comprising Shell and EPCM personnel to review and approve ideas as appropriate.

4.7. Lessons Learned Process

The project developed and implemented a robust lessons learned plan and programme from late SELECT, through DEFINE to the end of the EXECUTE phases with a designated Lessons Learned coordinator. During the FEED phase, the lessons learned activities involved the retrieval, assessment and application of lessons from past Shell projects from the Shell global lessons learned database. The applicable lessons were rolled out to the EPC contractors for implementation in the project design development and execution planning. Project execution lessons from other Shell-executed mega projects e.g. the Athabasca Oilsands Expansion 1 project (AOSP1), the Port Arthur Crude Expansion project were retrieved and the responsibility for application of the relevant lessons resided at the Quest project leadership level. Progress of implementation and closure of all applicable lessons were tracked and reported in the monthly project management report for visibility.

During the Execute phase, the lessons learned effort was focused primarily on capturing the Quest project lessons through look-back sessions and After Action Reviews after each major project activity or milestone was reached. Some of the recommendations and lessons from the early execute phase look-back sessions were re-applied and incorporated into the project execution planning and work processes.

4.8. Top Quartile Project Delivery and Benchmarking

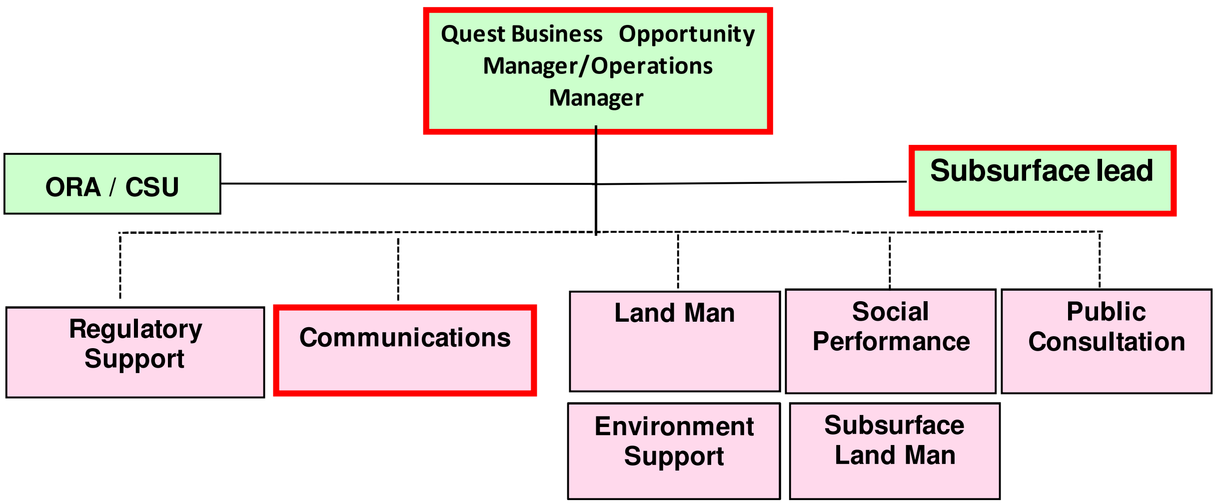
Cost was the primary value driver for the Quest CCS project. Therefore, cost metrics were selected for benchmarking, and Top Quartile targets were identified for those metrics. In general, 2nd- 4th quintile targets were selected for schedule. However, there was no target for the overall Execution Schedule, because the lack of overlap between detailed engineering and site construction made the overall schedule very long compared to most projects. The Project Team believed that one of the key strategies to achieve cost excellence, a super critical project driver, was to have no holds remaining on Issued For Construction (IFC) drawings during construction, and was therefore not interested in overlapping the engineering and construction schedules. IPA Prospective benchmarking was carried out prior to VAR4, and the findings were incorporated into the Top Quartile Plan for the project.

The IPA benchmarking for the project's actual performance was completed in late September 2015 (a month after start up).

5. PROJECT ORGANIZATION

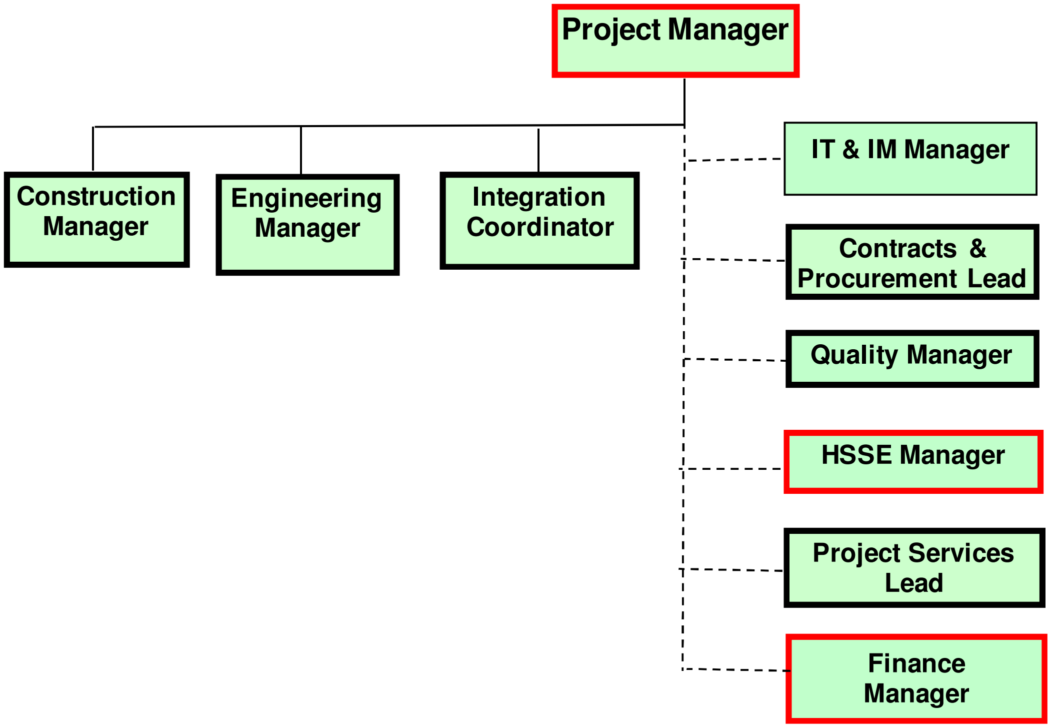
Management of the Quest CCS Project was the responsibility of Shell Canada Limited-Oil Sands (AOSP) on behalf of the Joint Venture partners. The Business Opportunity Manager (BOM), supported by the venture team and Heavy Oil Operations, had the single point accountability for maturing the Quest CCS opportunity from pre-scouting through to completion of the DEFINE phase. Thereafter, the BOM remained responsible for managing the opportunity until Handover. From Decision Gate 4 (DG4) onwards, the Projects and Technology (P&T) division assumed the single point responsibility for delivering the project on behalf of the business (in this case Heavy Oil).

5.1. Venture Organization

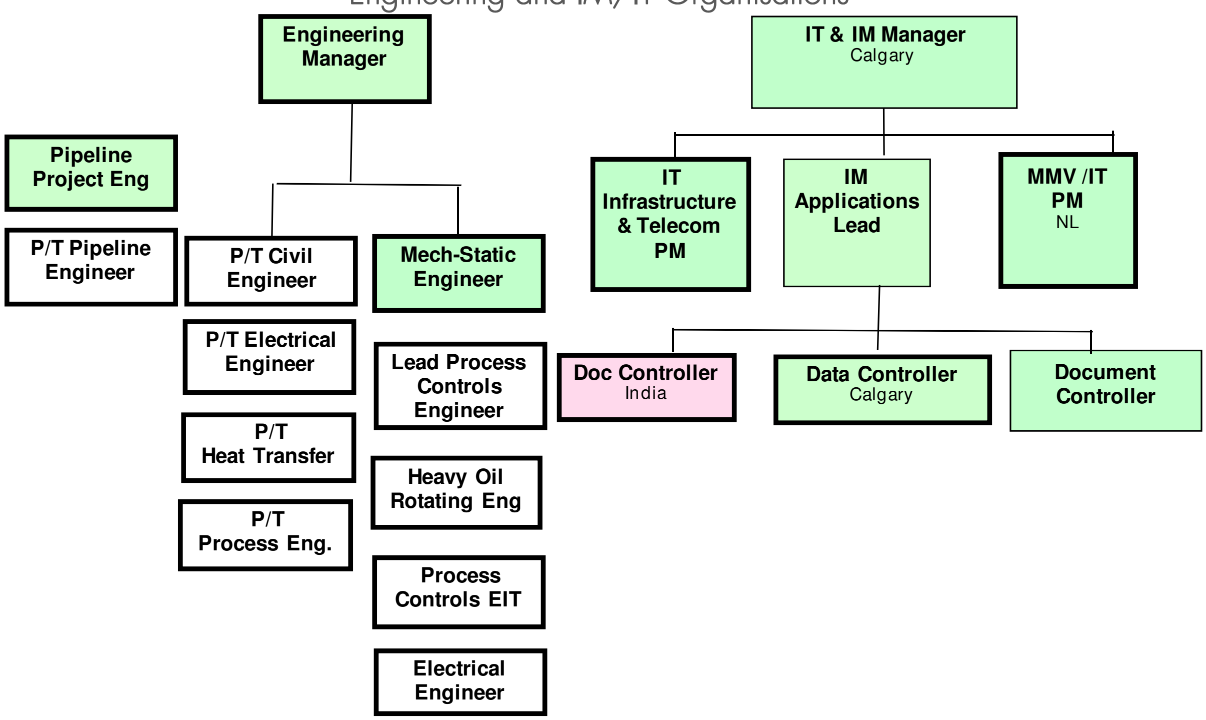


5.2. Project Organization

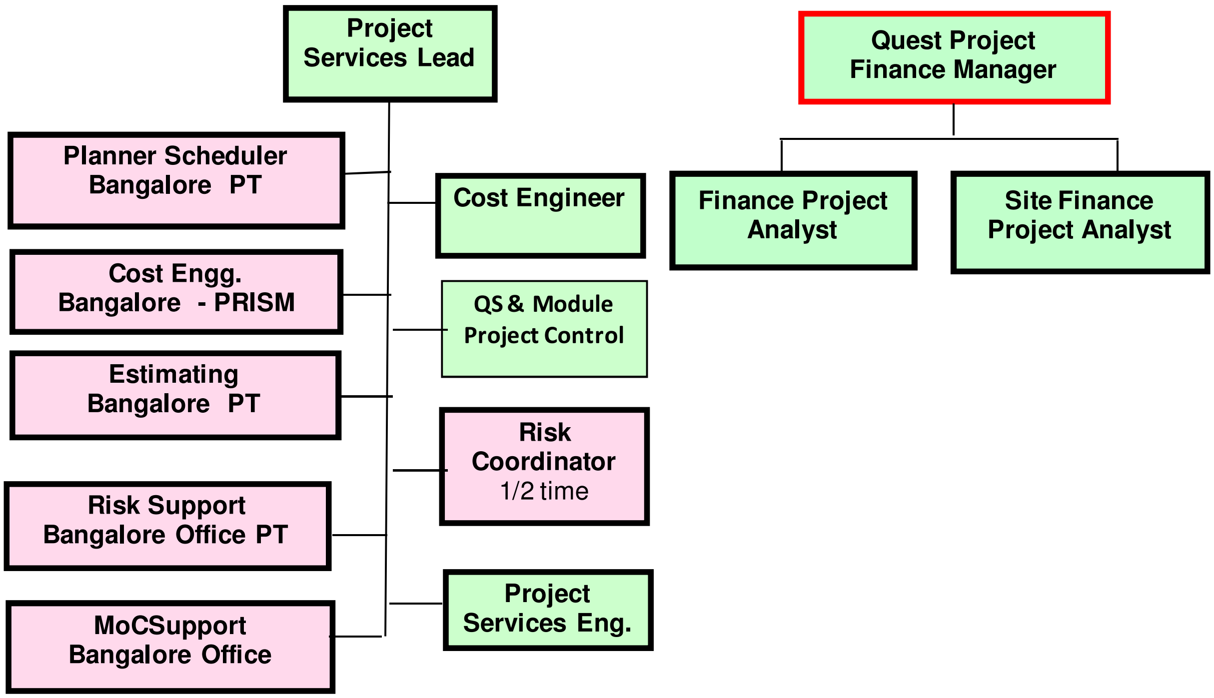
Project organizational chart showing the various Shell functional leads



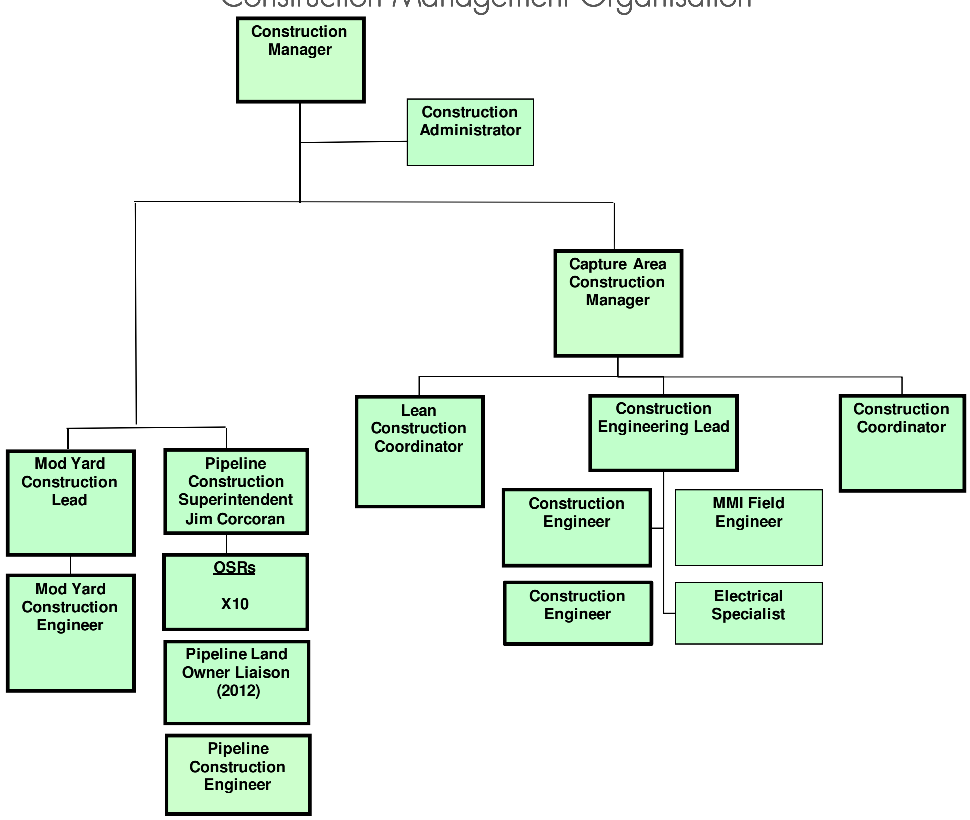
Engineering and IM/IT Organisations



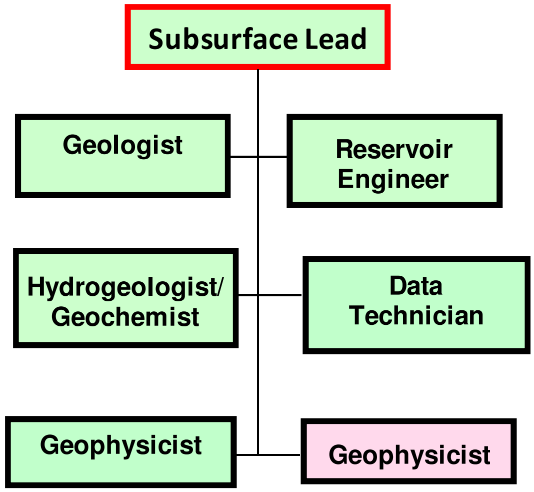
Project Services and Finance Organisations



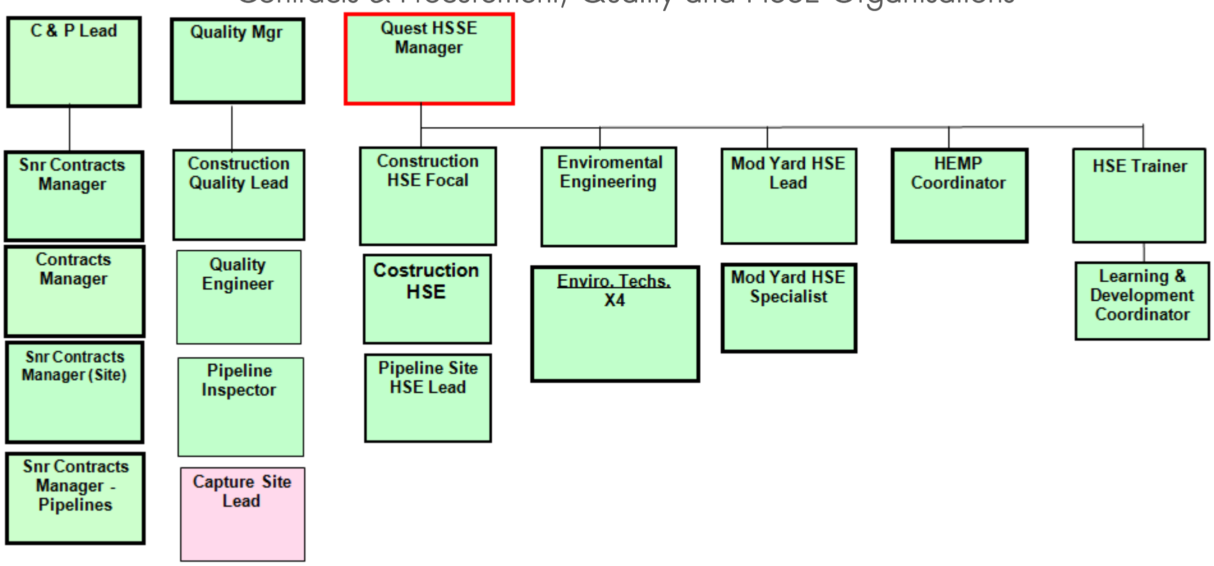
Construction Management Organisation



Subsurface Organisation



Contracts & Procurement, Quality and HSSE Organisations



LEGEND

- Staffed Position
- Shared Resource
- P&ES Resource
- Bold outline indicates Shell Staff
- RED outline indicates Quest Leaadership Team

6. FORMS OF AGREEMENT

6.1. Background

Commercial elements for the Quest CCS Project included agreements negotiated with the Provincial and Federal governments to provide partial funding for Quest. Additionally, there existed the likelihood that a third party agreement would be reached to sell some of the Project's CO_2 for that party's use in Enhanced Oil Recovery (EOR) operations. This was not pursued due to liability clauses in the legislation.

As part of the plan for greenhouse gas management and to reach desired CO_2 reduction targets, the governments of Alberta (GoA) and Canada (GoC) initiated programs to incent early carbon capture and storage projects. The Quest project applied to these programs in a competitive bidding process with the submission of a Full Project Proposal (FPP) in March 2009. After evaluations of the bids submitted and subsequent discussions and negotiations, Quest was notionally awarded funding in both programs, conditional upon having completed and signed funding agreements with federal and provincial governments. The broad terms of the agreements were outlined with the signing of Letters of Intent with the GoA and GoC in September 2009. Amongst other terms, the funding levels are Cdn$745 million from the GoA and Cdn$120 million from the GoC for a total funding level of Cdn$865 million covering project front-end definition through to 10 years of operation.

Negotiations on the terms of the agreements were completed and agreed to by all parties in the government and the AOSP JV. On 24-June-2011, the agreements were signed and announced to the public.

In parallel to the funding agreements, negotiations were conducted and concluded on a related agreement between Quest and the Provincial Government for multi credits applicable to the project. The agreement called for an additional carbon credit to be awarded to Quest for each tonne of CO_2 captured during the first ten years of the project's operating life, subject to CO_2 market prices. These credits will be usable for meeting greenhouse gas reduction commitments by the AOSP JV partners within the province of Alberta firstly, and any additional amounts are tradable.

The key terms for each of these agreements are outlined in the following sections.

6.2. GoA Agreement – Key Terms, Negotiations and Relationship Management

(a) Funding amount – Cdn$745 million
(b) Administered by the Department of Energy (ADOE)

(c) Payment of funding is phased as 40% during the post-FID and construction period, 20% upon successful startup and the final 40% over the first 10 years of operating life
(d) Agreement by Shell to a broad knowledge sharing framework, whereby key CCS knowledge is granted to the government for use in sharing with future CCS developers
(e) Project startup by end of year 2015 with penalties if late and full repayment of funding if beyond end of year 2017, subject to certain force majeure clauses
(f) Total government funding is not to exceed 75% of total project costs, including operating costs over the 10 year project operating window
(g) Money from the operating phase will be withheld if the project is deemed to be profitable. The amount of money withheld will be that amount that brings the project back to a neutral profitability position

The agreement contains clauses regarding eligible costs and revenue definition, Force Majeure, assign ability rights, audit provisions, reporting requirements, etc that protect the interests of all parties.

6.3. GoC Agreement – Key Terms, Negotiations and Relationship Management

(a) Funding amount – Cdn$120 million
(b) Administered by Natural Resources Canada (NRCan)
(c) Payment of funding is immediate upon receipt of information verifying completion of valid work
(d) Agreement by Shell to a broad knowledge sharing framework, whereby key CCS knowledge is granted to the government for use in sharing with future CCS developers
(e) Funding to be released after the project has complied with an environmental assessment as per the Canadian Environmental Assessment Act (CEAA)
(f) Project startup by end of year 2017, otherwise full repayment of funding, subject to force majeure
(g) Total GoC funding is not to exceed 50% of total project costs
(h) Money will be returned to the government if the project is deemed to be profitable. The amount of money returned will be that amount that brings the project back to a neutral profitability position
(i) The agreement contains clauses regarding eligible costs and revenue definition, Force Majeure, assign ability rights, audit provisions, reporting requirements, etc that protect the interests of all parties.

6.4. Multi Credit Agreement (e.g. on GHG) – Key Terms and Credit Discussions

(a) The agreement allows for the granting of additional credits to Quest under the conditions of the agreement and the amendments to the Specified Gas Emitters Regulation of the Province.
(b) Additional credits are to be used for compliance purposes by Shell facilities in Alberta.

(c) The credits expire 3 years after their creation.
(d) Additional credits not required for compliance are tradable.
(e) The maximum amount of additional credits is 10.8 million.
(f) If the project is in a net positive revenue position, then additional credits in that year will not be granted.
(g) The quantity of additional credits will determined by the market price of CO_2. For prices at or under 40 CAD/tone, one additional credit will be granted per tonne of CO_2 captured and stored. For prices at or over 80 CAD/tonne, no additional credits will be granted. For prices between 40 CAD and 80 CAD, the amount granted will be a linear ratio between one credit at 40 CAD and zero credits at 80 CAD. For clarity, in an example of CO_2 market price of 50 CAD/tonne, the amount granted would be .75 credits per tonne of CO_2 captured and stored.

6.5. Third Party CO_2 Sales Agreement – Potential Key Terms

Commercial negotiations with a third party for CO_2 sales had the following considerations under discussion:

(a) Sale of up to 49% of Quest's volumes to a third party for their use in EOR operations in the southern half of the province.
(b) Delivery will be through a take-off point from the Quest pipeline, at a point just outside of the Scotford Upgrader, to the third party's pipeline that runs close by at that point.
(c) Selling price of the CO_2 is tied to the price of crude since crude sales are the revenue generator for the third party.
(d) Deal duration is 10 years after startup, which is the length of time Shell has for the Funding Agreements
(e) The third party has the right to nominate any volumes up to the 50%, including nominating zero. With this option, Shell may still have to inject full rates into the Quest saline aquifer at times; therefore there will be no scaling back of the subsurface design.
(f) Shell is kept whole on any GHG credit losses that are incurred due to the deal. The EOR operation has some inherent losses and might result in some of Quest's credits (and double credits) being reduced. The third party will keep Shell whole on these lost credits with a cash or GHG credit payment.
(g) Some additional facilities have to be built for the commercial agreement (metering and proving facilities, control valves, etc). The third party will pay Shell for the costs of this capital.
(h) No guaranteed volumes from Shell other than up to 49% of what Quest produces. Therefore, if there is an interruption in the Quest feedstock due to mine/upgrader upset or turnaround, the third party will get the correspondingly reduced volumes.

The deal didn't go through due to liability clauses in the waste regulations that kept Shell accountable for the CO_2 for all times.

6.6. *Funding Agreement Closeout Activities*

The two Funding Agreements carry commitments throughout the project's life.

Within the NRCan Agreement, there are reporting requirements that include the Final Report, the Outcome Reports as well as the Revenue & Profitability Reports, which are due every year for 5 years following the date of Final Report submission. Details of report timing and required contents are specified in the Agreement within Schedule C.

For the GoA Agreement, the final 40% of the funding is to be paid over the 10 years of operational performance for Quest. During this time, annual reports outlining project updates, quantities of CO_2 stored, financial performance and detailed knowledge sharing are required. The specific requirements for these commitments are in the Agreement under Schedule D.

The Agreement commitments was managed by the Quest Venture organization until it was demobilized after which time the Scotford organization took over its management.

7. FINANCE & INSURANCE

7.1. Financing

The AOSP JV Owners funded the Quest CCS Project proportionally. Shell Canada's expenditures were financed via an intra-Group loan from Shell Finance Switzerland A.G.

The funding agreements security, which will be provided as a Letter of Credit or as a Guarantee will be revoked at the time of Commercial Operation.

7.2. Insurance

A Capital Project Risk & Insurance Strategy was developed for the Quest CCS Project. It set out strategies and plans for ensuring that all stakeholders in the Project, including insurers, saw their interests addressed in a mutually beneficial way. Topics addressed include, but are not limited to, the following: Role of Risk & Insurance – Modus Operandi, proposed risk management approach, risk allocation principles in contracts (i.e., CARM), insurance clause structure required from contractor to support risk allocation, capital projects risk engineering, marine warranty survey, insurance principles – recommended best practice, proposed insurance procurement strategy, competitive tender exercise, underwriting information, participation of captive companies of the stakeholders, risk retention levels, statutorily and contractually required insurances, insurance in construction phase, early works insurance, general third party liabilities, marine cargo, Construction All Risks (CAR) – Onshore, and claims management.

An insurance risk review was performed utilizing results of the independent risk assessment carried out by DNV. This review combined the key elements of the Design Phase Risk & Insurance Review (DPRIR) and Underwriting Survey to assist with risk reduction measures and cost effective placement of the insurance policies. The scope of Loss Control Surveys depended on the requirements of the lead insurer.

During construction, an Owner controlled insurance program placed by Shell contained the following coverage for the benefit of all Owners, Project Management Consultants and/or Engineering Contractors and/or Construction Contractors and/or Subcontractors:

- First party property damage coverage for the project works could be insured through Construction All Risks (CAR) insurance, including testing, commissioning, and start-up. Existing property was insured under operational insurance policies. This would be revoked and the Quest project would move to be covered under the Scotford Upgrader Operating insurance.

- Coverage for third party liability in the form of a Wrap-Up Liability policy for liability at law to pay any sum as compensation or damages in respect of injury to any person or damage to any property, arising out of, incidental to or in connection with the project. This will end with the closure of the Fluor EPCCm contract.

During construction, each contractor and subcontractor carried specified types and amounts of insurance to include Workers' Compensation, Employer's Liability, Commercial General Liability, and Automobile Public Liability, and other insurance that may be required to reflect risk exposures of specific scopes (Professional Indemnity, Aviation Liability, etc).

Post construction operational risks were absorbed into each JV partners' operational insurance programs or, to the extent that was not possible, insured in the commercial market.

7.3. Government Auditing and Reporting

Audits on the financials of both funding agreements were carried out throughout the FEED and Execute phases of the project.

The final NRCan audit was completed with the final audit report issued in early 2015. A total of three audits were completed and all had a qualified opinion. This was in regards to the related party transaction internal charge-out rates. Subject to this adjustment, project costs exceeded funding by the minimal percentage to ensure receipt of full funding.

The first GoA audit was also completed with the final audit report issued in early 2015. Related party transactions were not a finding under the GoA agreement, and a clean audit opinion was received. Audits will continue into the operating phase as the funding agreement continues for 10 years after construction.

8. RISK MANAGEMENT

8.1. Risk Management Process and Tools

The Quest owner's team identified and evaluated downside risks ("threats") as well as upside risks ("opportunities") to the achievement of the Quest objectives. Each risk was discussed with the Project Leadership Team (PLT) to put in place measures to maximize the likelihood of achieving the project objectives while maintaining risk exposure at an acceptable level. Boundaries for risk acceptance were set and fit-for-purpose responses were agreed. Each risk had an owner in charge of ensuring the implementation of the responses & actions. Risks with the highest impact were reviewed monthly by the project leadership. The Project Team used "EasyRisk" to store, coordinate and report on the risk management activities. The Risk Coordination services were provided to the project by a risk coordinator specialist shared with other projects under the umbrella of Project Services. Quest used the TECOP approach outlined in PS20 (that became PG20 on Risk Management) depicted in the figure below.

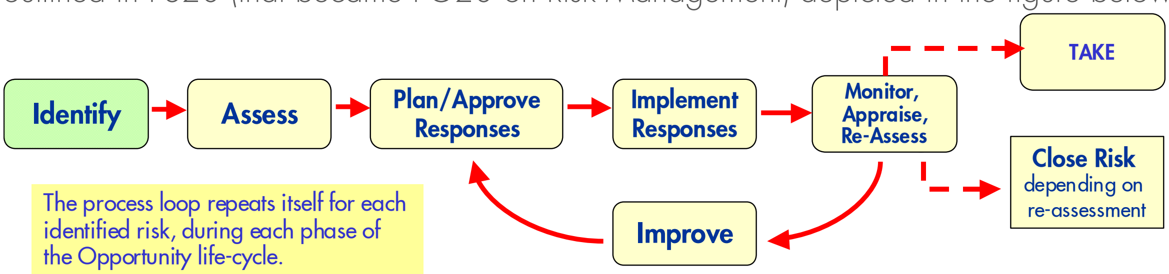


Figure 8-1: Risk Management Process followed on Quest Project

A high focus was placed on key venture non-technical risks due to substantial public interest, novelty of the technology, immature legislative and regulatory regime for Carbon Sequestration, and the potential for Non-Government Organizations (NGO's) to oppose the project. The mitigation actions included a special attention to regulatory approvals and stakeholder engagement.

The project team also conducted Cost and Schedule Risks Analysis (CSRA) every 6 months throughout Detail Engineering and Construction. The results of the CSRA were used to confirm the project outcomes (i.e. P50/P90 figures), validate the adequacy of forecasted contingencies as well as identifying activities more sensitive to the project delivery so they could get more focus, attention and specific mitigation actions.

Throughout the Execute phase up to Mechanical Completion there were a total of 229 risks of which 194 were Threats and 35 were Opportunities. There were 623 actions associated with those risks with the vast majority related to the threats.

8.2. Risk Management Outcomes

Of all the threats identified at DG4 and during Execute none led to a major scope change. Only one materialized into a risk event greater than $25M (Non-Scope Change).

- Construction Productivity
  The Pipeline Construction originally estimated at $25M increased to $88M mostly due to slower than expected field installation and a need for more resourced than anticipated.

Of all the opportunities identified at Decision Gate 4 (DG4) and during Execute, only one resulted in significant improvement on cost. Prior to signing of the Group Investment Proposal (GIP), the Project Team decided to reduce the base case from 5 to 3 injection wells, saving $37M. Another opportunity of potentially selling CO_2 to a third party caused the project team to install a "T" connection on the pipeline but no final agreement was negotiated and the opportunity was dropped.

Overall the Risk Management effort on Quest was considered very successful by the project team and by the various audit and peer reviews conducted every year.

9. REGULATORY PERMITS & APPROVALS AND STAKEHOLDER ENGAGEMENT

9.1. Strategy for Non-Technical Regulatory and Stakeholder Risks

Shell Canada adapted and applied the CCS lessons from the cancelled Barendrecht CCS project[i] in formulating and developing a regulatory and stakeholder engagement strategy for the Quest CCS project. The Quest project team envisaged that:

- There would be a lot of public interest- in the technology and in the project
- There would be concerns because of the 'newness' of the technology
- Some stakeholders would be against the project- due to it being an enabler for oilsands
- The low levels of public knowledge on CCS required that the project engage in a broader outreach program

The Quest project set some consultation principles that guided all non-technical risks (NTR) strategy and interaction with stakeholders. These included:

- Comprehensive and thorough consultation
- Early start of consultation
- Inclusion of potentially affected parties outside the minimum required notification areas
- Engagement with the general public, academics, community, community leaders, etc
- Recognition of the legitimacy of stakeholder concerns and the valuable input they could provide
- Provision of the information needed so that stakeholders could fully participate in the process
- Adaption of plans based on stakeholder input, and feedback provision on how input had affected plans
- Transparency- in technical conclusions
- Adherence to the full regulatory process

9.2. Regulatory Framework, Applications and Approvals

The Quest Project was the first proposed CCS project in the province of Alberta when Shell first began engagement with the regulators in 2009. Large-scale CCS projects utilize existing technologies, but in a novel configuration, and at a scale not seen for other uses. At the time the project was proposed, there was no regulatory framework specifically for CCS in Alberta. As CCS projects include wells, pipelines, and large industrial facilities, much of the existing regulatory framework for the oil and gas sector in Alberta was applicable to CCS, or could

[i] The proposed and then cancelled Royal Dutch Shell CCS project in Barendrecht, The Netherlands, received some very negative stakeholder responses during the project development and planning phase that ultimately led to Shell retracting the proposal in 2009.

be modified slightly to better suit CCS, but other sections of the required regulatory framework needed to be modified significantly or drafted in whole in order to enable CCS.

As CCS proponents were beginning to develop proposals, the Alberta Energy Regulator (AER), the provincial energy regulator, published notice that the existing regulatory framework for petroleum was also suitable, in whole, for CCS. This was not a good start for engagement, and showed that the Quest project team would have to work with the regulators as much as with typical stakeholders in developing a regulatory pathway for the project, and secure all regulatory approvals needed to develop the project. Some of the novel approaches taken for some key aspects of the regulatory process are described below:

Directive 65- Scheme Application

To prove the geology as part of the proposed injection site subsurface characterisation, the ERCB directed Shell to utilize the typical Oil &Gas approach i.e. drill numerous wells in the project area, prove the geology, and then convert some wells to disposal wells. Following this requirement would have introduced additional containment risk for the stored CO_2, so the Quest project team couldn't support this approach.

Due to the initial uncertainties about the subsurface, the Quest project team proposed 3 to 8 injection wells scenario to inject full volume CO_2. The AER directed Shell to apply for wells and pipeline lengths on an as-needed basis. This approach would have exposed the project to the risks/uncertainties of having to secure approvals for needed wells and additional pipeline after injection had started, and this would not have allowed the project team enough time to consult on the broader aspects of this piece-meal approach with key stakeholders.

The project instead proposed a "scheme" approach i.e. utilized a non-invasive technique to prove the geology, applied for all wells and facilities that the project anticipated may be needed for the ultimate project description, conducted all stakeholder consultation based on greatest potential project impact, and then developed injection wells only as needed after approvals. Considerable interaction with the AER was required to table and discuss this novel approach. The AER ultimately supported the proposal.

Directive 71- Emergency Response Plan (ERP)

Alberta regulation does not require CO_2 projects to have Emergency Response Plans (ERPs) to ensure safety of landowner/land occupants in emergency non-containment situations. The project had the view that an ERP was important, and would be important to local stakeholders, and hence discussed this gap with the AER who maintained their non-requirement. The Quest project nonetheless prepared a full Directive 71 compliant ERP to address CO_2 release from wells, pipelines, and leaks to surface within the tenure area. This was then shown to be a very good decision and proactive action as emergency response was a key topic for landowners, and a focus in the regulatory hearing for the Quest Project.

Pore Space Tenure

Early in the discussion with the Government of Alberta on the proposed Quest CCS project, it was shown that the province of Alberta did not have the ability to grant tenure for pore space to CCS proponents. The legislation was geared towards resource rights. Rights over geologic voids had never been an issue. The Government of Alberta (GoA) introduced new legislation to clarify that the Crown had ownership over pore space. Subsequent regulation then also enabled the GoA to grant evaluation permits and sequestration leases. The Quest project had very detailed discussions with the GoA over the project's proposed injection area geology. The initial view from the GoA was that tenure should be for the injection zone only, and only to include the CO_2 plume. The Quest project advocated that tenure should include the full storage containment system i.e. both reservoir and caprock—and that it be extended laterally to include the modeled maximum extent of CO_2 plume after full life of project, and the associated pressure front. If the pressure front were not included, and a future CCS project were to be located too close, the two pressure fronts would affect each other. Alberta's first Carbon Sequestration Leases were granted to Shell in May 2011.

Consultation and Notification

The Oil & Gas requirements for well application stipulates that the proponent consults landowners and subsurface rights holders in a fairly limited radius around the proposed well. The ERCB encouraged the Quest project to follow these practices for CO_2 injection wells. However the Quest project had the view that the CO_2 plume could extend beyond the arbitrary radius, and could impact stakeholders that would not have been notified under the existing O&G consult/notify requirements. The project team therefore considered it critical to include potentially affected parties in the consultations and hence decided to notify all surface occupants and mineral rights holders in relation to the proposed subsurface activity.

Directive 56- Pipeline

The project description utilized as a basis for the major regulatory applications, included as many as eight injection wells, and pipeline length and routing to support all 8 proposed wells. In alignment with the "scheme" approach described above, the Quest project submitted an application for the full potential length of the main pipeline, and consulted with all stakeholders based on the potential length and route. Further subsurface appraisals ultimately showed that only 3 wells would be needed, and hence the pipeline constructed did not extend to the full length approved. An amendment was submitted and approved in 2014 for the actual length of pipeline and all laterals.

Measurement Monitoring and Verification (MMV) Plan

O&G production does not require subsurface monitoring. Following discussion with the GoA and the AER, the Quest project developed and submitted a comprehensive MMV Plan as part of the Tenure Application and the D65 "Scheme" Injection Application. The Alberta regulatory changes ultimately embedded the requirement for MMV plans. The MMV plan is required to be updated every 3 years for the life of injection.

Closure Plan

Following discussion with the GoA and the AER, the project also developed and submitted a Closure Plan as part of the Tenure Application. The Closure Plan set out a description of the activities that Shell will undertake to close down sequestration operations and facilities. The Alberta regulatory changes ultimately embedded requirement for Closure Plans. The Closure Plan also required updates every 3 years after approval of the pore space; timing has been aligned with MMV plan update

Long-Term Liability

A key early point of discussion with the GoA was on the long-term liability for the stored CO_2. The GoA desired a framework that incentivised CCS projects, and so decided the province would take some forms of liability for stored CO_2 if the proponent could show the CO_2 plume was behaving as per model, and that risk was low. Alberta legislation was adjusted so the GoA could assume long-term liability for CCS sites. Recommendations from the Regulatory Framework Assessment process included a 10 year minimum post-injection period until liability can be assumed. This is a strong point of support for subsequent CCS investment in the province.

9.3. Stakeholder Engagement – Public Consultations & External Communication

The Quest CCS project external stakeholder consultation began in 2008 and included face-to-face meetings with landowners along the pipeline right of way (ROW) and wells, open houses which were publicly advertised, Quest café meetings with a cross section of community leaders - business and landowners (both directly and indirectly affected), county representatives (mayor, councilors, fire/EMS) to discuss issues and concerns. Other consultations included Shell presence at local community events to provide an opportunity for dialogue about the project to stakeholders who may not have been able to attend open houses, updates to town and county councils, and project updates via letter and newsletter.

In Q4 2012 a Community Advisory Panel (CAP) was established to help communicate updates about the Quest project, including reporting on the Measurement, Monitoring and Verification (MMV) program. A cross-section of community members (local community, land and business owners, academics, representation from Alberta Energy Regulator, Thorhild

County Councilors and Emergency Services) was invited to participate and advertisements were run in the local paper to attract others from the area.

During construction a tour of the pipeline and storage facility and emergency response facilities at Scotford was offered to CAP members. The tour was very well received and much appreciated by the CAP members who attended. During pipeline construction a number of landowners came forward with concerns about notification prior to accessing their land, water well testing processes by 3rd parties on behalf of Shell and concerns around water well contamination as a result of Quest project activities. All concerns were responded to and tracked in our community feedback reporting mechanism.

Quest Community Surveys were conducted in 2012 and again in 2014. The top 3 themes the survey responders highlighted that Shell should pay attention to were: protecting the environment, communicating openly with the community and providing jobs for local residents. An action plan based on survey results where improvement could be made was developed for continuous improvement in stakeholder management. Shell conducted pre and post drilling and seismic water well tests to provide assurance to local landowners that Shell's activities did not impact water well quality. In some cases baseline sampling revealed that water quality did not meet drinking water quality standards but the technical reports were not written with the layperson in mind which created some frustration. Hence from initial feedback, the messaging/reporting of water well test results was prepared in plain language; and in partnership with the county, the project brought water well experts (from Golder Associates) to the community to explain and create an understanding around some landowners' water quality issues.

Open Houses

The latter part of the project Execution phase saw decreasing attendance at open houses. This was expected as people became more familiar with the project. A more inter-active format with neighbours was developed for 2014 to build trust with Shell and Shell's environmental contractors and to reach new groups of people in the community. Shell's environmental contractors attended and were presented as specialists in their field allowing neighbours to interact with them in a neutral environment. For example Golder Associates (one of the project's environmental consultants) showcased their water and soil sampling equipment and processes. Samples of the core and injection well monitoring equipment were made available. An animated video was used to explain the CCS process. A funding partnership with the Edmonton Telus World of Science Centre was developed where a Quest simulation elevator would remain for 2 years as a CCS education showpiece for school children and others visiting the centre.

Coffee Sessions

The "Coffee on Shell" informal events were held quarterly in the communities of Thorhild and Radway. The event was advertised through a local newspaper, The Review, and by direct mail out to targeted groups (residents in the HBMP or ROW). The Coffee sessions provided an opportunity for community members to meet with Shell representatives and ask questions. This event was developed from feedback that Shell was not present in the communities and instead sends contractors to do the work. The "coffee sessions" thus allowed Shell to continue to build relations and a presence in the community. Coffee sessions were usually attended by the Community Liaison Officer and a member of the MMV team or another local Shell representative from Emergency Response or Operations.

Tours

During July and August 2014, community members surrounding the Scotford site and the Quest project injection area were invited to tour the operations. This provided an opportunity to meet with the neighbours, address any questions or concerns they had, while also being transparent and open. Municipal government representatives and school groups were also invited to tour the site.

Council Updates

Bi-annually the Quest team provided the Thorhild County and Redwater councils near the Quest injection area with project updates. Council updates were key to ensuring community representatives were well informed and no surprises were coming their way and were very well received as a proactive approach to community engagement with community leaders.

Ground-truthing

Groundtruthing (per AER D-71) of all landowners/residents within the pipeline EPZ and Scotford/Quest site was completed in Dec 2013/Jan 2014. Personal visits to each landowner/resident were made by a 3rd party representing Shell. Contact information for each resident/landowner was collected and a public information package was provided outlining emergency response procedures and Shell contacts.

Mail outs

The "Quest for Less CO2" newsletter was published bi-annually and distributed to the communities surrounding the injection zone, including Thorhild, Redwater, Radway and Abee. (Postal drop to T0A 3J0, T0A 2W0, T0A 2V0 and T0A 0A0 respectively)

Quest "Thank You" cards were developed for use with the Quest MMV program, whereby the contracting company would leave thank you cards with residents visited directing them to follow up with the Community Liaison Office (CLO) should they have any concerns.

9.4. Lessons Learned – Regulatory Framework, Applications & Approvals

- Adhere to the full regulatory process—and then some. Do not look to cut any corners or find 'efficiencies' in any stakeholder engagement or regulatory process. A new and novel technology will be under the microscope, and regulators will afford it additional challenge because of this. Cutting a corner may result in additional delay down the road.
- Close engagement/partnership with all regulatory bodies. Setting a precedence in a regulatory process is a challenge. Proponent and regulator need to work in partnership to determine the regulatory pathway best-advised for the project and the technology. The typical proponent vs. regulator relationship with little collaborative interaction may lead to the two parties not having common understanding, and result in additional delay down the road, or stakeholder challenge of the process. Better to act as a partner with the regulator, who may be trying to figure out the new regulatory process themselves. Close collaboration with the regulators for the Quest project likely saved many months of additional time.
- Be an advocate for what is "right" for the technology and for stakeholders. Even if regulators are providing an easier pathway, it may lead to challenge/question later, and expose approvals to challenge(s). As well, the "easy" path may set regulatory precedent that is not well advised for the technology as a whole, and lead to challenge for subsequent projects.
- Include potentially affected parties outside the minimums provided by the regulator. A new and novel technology will be under the microscope, and regulators may afford it additional challenge from stakeholders. Better to have included all reasonable stakeholder challenge within the process from the beginning rather than risk a challenge at a later stage.
- A CCS project will be open to stakeholders beyond local landowners. It will be "tried" in the court of public opinion as well. Best to engage all classes of stakeholders– general public, academics, community, community leaders, others.

9.5. Key Lessons Learned – Stakeholder Engagement and Communication

- The upfront work/effort in engaging with the community leaders in getting them on board, being open and transparent throughout the early regulatory process and the project execute phase (in other words we didn't just get our approval and take our leave) were critical. Continue throughout the project execution phase to engage with the county leaders regularly and keep them apprised of project activities and plans in the area so there are no surprises.
- The Quest Café event was an eye-opening event where we learned that those attending and representing a cross section of community members were more concerned with pipelines and safety than the CO_2 escaping from the Basal Cambrian Sands and contaminating their water. Invest in the community with the project's social

investment funds to elevate the community's view of Shell. The business/employment opportunities from the Quest project were very few and we did get some feedback on this and knew we had to find a way to mitigate the impacts the project was having (traffic, dust etc.), yet managing community expectations of Shell (by not over-spending).

- Importance of ensuring aligned key messages/Q&As – to ensure consistency in messages/information that is being used with the public; especially when there are a number interfaces with the community
- Ensure that communication materials consider the audience i.e. use lay person language vs technical terms
- Language/terminology is very important (know which terms are inflammatory and what language is reassuring)
- Hands on displays and visuals can be very effective in helping to communicate key messages
- Consider principles of risk communications in developing materials (i.e. peoples' perception of risk not just based on scientific formula and that perceptions can be as important as reality)
- Make sure everyone is aligned internally on external communication approach and that stakeholder/community concerns are identified and dealt with promptly; if issues need to be escalated make sure the right people internally are involved.
- Risk communication training given to all individuals representing Shell at the Open Houses for first 2 years was beneficial. Possibly could have avoided some of the issues if we had done same for the later open houses and the Shell field support that had contact with the public.

10. PROJECT INTERGRATION AND INTERFACE MANAGEMENT

An interface management plan and process were established that facilitated the timely identification and resolution of project interfaces during the Execute phase. The aim of the interface management process was to provide a consistent cross-project approach by which interfaces could be identified, developed, mutually agreed to, managed, tracked, controlled and closed out. Key components of the interface management plan included the use of interface data sheets (IDS), interface registry and interface matrix with a designated interface coordinator who managed the interfaces/communication across the different project sub-components i.e. capture facilities, pipelines, wells/subsurface and MMV programme.

10.1. Use of Interface Date Sheets (IDS) in Execution

The IDS system was established during FEED and maintained during the Execute phase. The IDS process worked well between the EPC contractors and Shell; but not so well between the Shell departments. During the project Execute phase, the use of the IDS form seemed complicated and ineffective for the remainder of the Execute phase interface activities for the capture facilities; hence the IDS form was discontinued. Weekly and then biweekly meetings with actions, owners and due dates tracking were used instead to manage the Execute phase interface activities.

10.2. Use of the Interface Matrix

The Quest project used a qualitative tool to evaluate the health of the project-wide interfaces. The matrix was established in the early Execute phase with the goal to identify the main project interfaces and assess their effectiveness. The evaluation process was completed routinely with the project leads and reported out to the PLT. This was a useful tool that allowed the interface coordinator and the PLT to understand where the team thought the interface "hotspots"/issues were, to obtain feedback from interfacing parties on working relationships and the status of the issues that were jointly being managed.

10.3. Interface with Existing Scotford Plant Organisation

10.3.1. 35KV Switchgear Installation by Shell Scotford Turnaround Organisation

New breakers and switchgear were installed in the 35kV substation during Turnaround 2013. However, detailed pre-energization checks on this equipment were not carried out as planned (while the substation was offline). These checks required the assistance of electrical specialists in high-voltage equipment. This was recognized by Fluor (EPC) in their scope of work when they requested Eaton (switchgear vendor) to be present during TA2013. However, Eaton was never contracted by site execution team (i.e. TA 2013 team) to participate. Though electrical contractor Chemco (Construction Division) was onsite to help with installation, Chemco (High-Voltage Division) was not asked to assist. The TA electrical lead was not well-versed in high-voltage equipment, nor was the Quest electrical focal for TA2013.

It was thought that "mechanical completion" was sufficient without considering the pre-energization checks needed to actually operate the breakers at a later date, and that $40k for Eaton participation was not required for a "simple bus extension". The criticality of having the breakers ready to operate after TA2013 was not communicated from the Home Office to the people "on the ground". TA electrical team was also experiencing considerable time pressure, and the Quest scope could have been better-defined (instead of being simply "testing as required" in the Engineering Work Package (EWP) and leaving it to the field team to determine what that is, precisely).

In the end, the turnaround team did not recognize that pre-energization checks were missed. Quest electrical focal for TA2013 did recognize that something was missed, but nobody on Quest fully appreciated its importance. It was only 18 months later after Quest hired a high-voltage specialist and was planning to operate the new breakers, that the significance of the missed pre-energization checks was realized. At that point a new plan was devised to carry out the checks while the 35kV substation was still online, which was a delicate and costly piece of work.

By not contracting initially with Eaton for field support, the project saved $40k but lost many times more than that 18 months later when Eaton was contracted to devise a plan to commission the breakers while the substation was online. Construction energization dates slipped by a month, and many temporary power cables were used in the interim. The primary cause was a failure by too many key personnel to recognize the need for high-voltage skillset when commissioning this type of equipment.

10.3.2. Brownfield 3rd Party Interface

Quest is located at the Scotford Complex, an integrated Refinery/Upgrader/Chemicals facility. At the heart of the facility is located a CoGen/STG, owned and operated by a 3rd party. The STG is used to control LP steam header pressure. Many key utilities (esp. HP steam, LP steam, and cooling water) are intimately bound with the operation of the CoGen/STG.

Because the CoGen/STG is operated by a 3rd party, they were resistant to anything that would impact their power production. Whereas if the facility was owned by Shell, it would have been easier to make Enterprise First decisions to run the CoGen/STG sub-optimally (from a power production point of view) if it will benefit another unit in the complex. This arrangement had ramifications for every phase of the project: Design, Construction, and CSU. During Design it was problematic to secure agreement with the 3rd Party to change the site-wide utility balances to accommodate Quest; this was so from a technical perspective, but even more so from a commercial perspective (which took years to finalize). During Construction, communication was made more arduous when working in close proximity to the

CoGen/STG, because two orders of management (Shell's and the 3rd Party's) needed to be kept informed of progress and incidents. Also during Construction, some activities were difficult to get permits for, e.g. a hot tap of the HP steam line which feeds the CoGen/STG took 6 months longer than planned to execute, due to a changing work procedure in response to the 3rd party CoGen/STG operator's concerns about how hot tap shavings might affect the STG. Finally during CSU, Quest operations (especially start-ups) needed extra coordination with the 3rd party due to the Quest compressor's significant electrical usage.

Future projects need to be aware of how this type of arrangement can affect every phase of the project. Future business development teams should compare the benefits of having a 3rd party own/operate such a unit in the midst of a Shell facility, with the long-term impacts to all Projects and Operations teams at that facility (measured over decades).

10.3.3. Scotford Projects Group (SPG) Interface

The Scotford Projects Group (SPG) completed detailed engineering, procurement, field execution and handover of 47 brownfield piping utilities and process tie-ins including control systems modifications in the HMUs and Cogen area using third party companies on behalf of Quest. Interface with SPG was through weekly project planning, coordination and progress meetings between the SPG execution team and the designated field construction engineer from Quest where engineering, procurement, and field construction interface issues were discussed. SPG prepared and submitted weekly schedule/progress reports and monthly cost reports to the Quest team for review and integration into the overall Quest project reports.

10.4. Lessons Learned - Project Integration and Interface Management

For lessons learned on project integration and interface management refer to Appendix 7.

11. QUALITY ASSURANCE

In accordance with the Project Quality Plan, Quest was implemented using three key quality programs:

1. Discipline Control and Assurance Framework (DCAF)
2. Technical Integrity Verification (TIV)
3. Flawless Project Delivery (FPD)

The Quality Management System also contained Equipment Criticality Assessments that were done for Static Equipment and the pipeline scope from which valuable notes were captured in the criticality analysis. The mitigation actions were addressed in the fabrication and testing of the equipment. For rotating equipment, this was achieved through TA involvement in pumps selections, sparing and vendor PO preparation.

Project-specified quality requirements were communicated to vendors and suppliers within Quality sections of contract documents e.g. the inclusion of specific requirement for Shell-approved Inspection and Test Plans (ITPs) that defined critical fabrication steps and the specific methods and procedures prior to start of fabrication.

QIRMS was not implemented on Quest primarily due to inspection reports and non-conformance reporting (NCR) and tracking systems which were in place from the EPC contractors, as well as the technical limitation of the inability to enter anything into QIRMS without a Shell e-mail address. The NCR's were input into QIRMS at the end of the project.

11.1. Discipline Control and Assurance Framework

The Discipline Controls and Assurance Framework (DCAF) was followed with the Quest Project Controls and Assurance Plans (PCAP). Often, the Quest Execute PCAP was updated due to TA/Owner/due date changes, deliverables being deviated or identified as NA. Quest Project Management applied operational discipline in implementing DCAF and as a result there were limited issues with this process and it delivered clarity and business value.

A self-performed audit in Execute revealed that some deliverables had gaps with reviews and approval. Quest document control helped ensured the deliverables were submitted, reviewed and approved in ASSAI when possible.

The subsurface team followed the standard subsurface process with physical signatures and review meetings on key deliverables with multi-discipline team.

11.2. Technical Integrity Verification (TIV)

TIV was implemented for Safety Critical Elements (SCEs) which have been identified through HSSE Bow-Tie workshops. TIV consisted of the following actions:

- Development of Performance Standards (PSs) and quality management of activities and deliverables critical for verification that the performance standards have been met.
- An audit and review schedule of the project processes and procedures for engineering, procurement and construction activities with follow up action to verify closure of any corrective action requests.
- Development of a TIV Report, DCAF control no. 626, to support the Statement of Fitness.

11.3. Flawless Project Delivery

Flawless Project Delivery (FPD) was implemented on Quest in a fit-for-purpose manner. This included mitigation of Flaws and development of assurance plans for selected Q-areas. A Flawless Project Delivery Implementation Plan was developed in Define and was updated in Execute. The design team participated in the Shell flawless start up initiative (FSI) program, and key engineering staff were assigned to each Q team. The initiative began slowly and had to be re-energized a few times because neither Shell nor Fluor considered it a priority. The Q team flaws lists were reviewed and classified as either high priority items to be incorporated into the design. A register was established to record the results and monitor KPIs. The FSI process continued throughout implementation. Responsibility for the program switched between Engineering for the Select & Define phases to Quality and Operations in the Execute phase.

The Quest FPD program had a Steering Committee consisting of key Project Leadership. With the status of the Flawless program reported, they helped steer the Flawless program and ensured that the FPD organization was committed to executing it. A point of improvement is to ensure the steering committee is working at the right level of detail as it tended to get into too much detail versus steering the program; meetings could also be on a bi-monthly basis. Start the steering earlier as the steering committee wasn't set up till after of main construction.

11.4. QA Organisation and Resources

The philosophy for the QA team was to have a small Owners Team providing oversight to the larger EPC QA organization. In the Engineering phase Shell provided oversight of the 2 engineering contractors Fluor and Toyo. The team was pulled together early and was seen by team members as a key contributor to the project success. The Pipeline Quality Lead indicated she was pulled in a year earlier than is typical for pipeline projects.

For the procurement phase the Fluor Supplier Quality Surveillance (SQS) organization conducted inspections on behalf of Shell for the capture unit scope. In addition Project Management took a strategic decision that for high criticality items, Shell Quality and Discipline Engineering also would attend select Kickoff/pre-inspection meetings to ensure quality requirements were clear. Periodic sponsorship meetings were held for the critical equipment packages (e.g. compressor, heat exchangers, etc.) with assigned representation and active participation from both the Shell and EPCM contractor project leadership team members. For pipeline scope, Toyo Engineering managed third party inspections. Pre-shipment meetings were held either at the vendor shop or through teleconferences for all packages.

During the construction phase the QA organization pulled from CSU and the TA community to assure the construction activities as well as tending to ITP and Witness and Hold points. An ITP matrix was developed to facilitate the notification of Shell personnel for Witness and Hold points. The team was able to assure and deliver quality, but it would have been easier and less issue management if the project had a focused Mechanical QA role to act as Owners Inspector. The Quality Manager was a member of the project leadership team (PLT) and the Pipeline Quality Lead was a member of the Pipeline Construction Management Team, this enabled communication of current status as well as escalation of issues.

The QA team was supplemented with a part time QA Engineer to conduct process audits and manage the generation of the TIV report, as well the Construction department hired an Electrical Lead that greatly supported the QA activities.

The Project Quality Manager was replaced in the middle of Execute; this created some risk of continuity and management of issues. While this is not a recommended practice for leadership positions it did not impact overall project Quality.

11.5. Reviews and Audits

The Project Quality Manager developed a program of reviews and audits necessary to provide quality assurance throughout design, procurement, fabrication, integration, installation and commissioning/start-up. Audit Plans for the Execute phase were prepared.

The program of reviews and audits were included in the Project Quality Plan (PQP). The PQP outlines the roles and responsibilities for execution of assurance. The Lead Discipline Engineers were responsible to ensure proper design control was used in the production of project deliverables. Design control was facilitated by using Fluor Discipline Activity Plans which specified the appropriate procedures, work instructions, and requirements for checking, review, and approval.

Design reviews were performed at appropriate stages in the design. All design review comments were resolved prior to final approval. The PQP specified what reviews were needed during Execute phase to address project risks.

The following areas were audited by the Quality team:

- Discipline Control & Assurance Framework (DCAF) setup and compliance
- Technical Integrity Performance Standards and Verification of Assurance Activities, and Flawless Project Delivery Key Performance Indicators

- Contractor discipline audits (in the case of Fluor, this applied to both Calgary and New Delhi offices). Execute phase audit plans were included in the Fluor and Toyo PEPs respectively. One area that presented challenges was in getting the construction contractors (Capture and Pipeline) to perform their agreed internal audits as per the schedule. This required management attention and intervention.
- Shell and contractor process audits

Wells adhered to the Shell-mandated GWDP (Global Well Delivery Process)

11.6. Cost of Quality Calculation

The cost of Quality for a project is calculated as:

Cost of Prevention + Cost of Appraisal + Cost of Failure = Cost of Quality

For Quest this is $18.6M and details can be found in Appendix 15

11.7. Lessons Learned – Quality Assurance

See Appendix 14 for the list of lessons learned associated with QA

12. PROJECT CONTROLS/SERVICES

12.1. Project Controls Organisation

The Project Controls team customized and implemented the procedures contained in the Project Controls Standardization Program (PCSP).

The Shell Project Services (PS) organization deployed during Execute phase was aligned with the Project Control Plan (PCP). It comprised full time:

- Project Services (PS) Manager
- Scheduling Lead,
- Cost Engineering Lead (focused on Site Capture Unit, SAP/PRISM interface and overall OC1 reporting),
- Quantity Surveyor (focused on Modules fabrication / quantities – unit rate contract, site),
- PS Engineer (focused on Pipeline and Project Management Reporting), and
- MOC Coordinator and cost engineering support.
- Risk Coordinator was 50% part-time at the beginnings then backed off to monthly and cost & schedule risks analysis (CSRAs).

Additional support was provided from the core group for specific tasks (e.g. Estimation for the Shell Type 4 estimate and Cost & Schedule Risks Analysis - CSRA). The project truly benefitted from the continuity of an experienced Project Services Manager between early Select phase up to 85% of field Construction. This continuity allowed setting the work control processes leading to success. The biggest organizational challenge was the resignation of the cost engineering lead before mobilizing for Construction. It was difficult to find a replacement with the right competencies available in the timely manner (prioritization of personnel allocation in the group, change in labour market opinion (LMO) for foreign worker, etc.). During this period the role was split between the other team members and Finance personnel (focused on SAP VOWD and Shell's execution work on Storage Unit and CSU). Shell's Project Control team had full presence in the contractors' offices, at the module yard, and the construction sites to closely monitor the contractors' performances, provided immediate support and directions as well as guidance on contractors' cost and schedule control. PS / Finance integration contributed significantly to the project success.

12.1.1. Collaborating with Bangalore PS Team

The Quest PS Team pioneered the collaboration with Calgary-Bangalore. Team members travelled both sides for visits ranging in duration from a few days to a few months. In 2012 the MOC Coordination function was successfully delivered from the Bangalore office. The role included maintaining the change log, receiving and validating change form, distributing the change for discipline impact assessment and collecting responses, circulating for management reviews and approval as well as collecting evidence of closure. All the activities were completed in Bangalore except face-to-face engagement. Those included change panel review with the project leadership team (PLT), delivery of "lunch & learn" on the process and baseline documents as well as troubleshooting unresolved issues. Other cost support activities that were executed from Bangalore included preparing change load file for PRISM, preparing various cost reports (SERP Time Writer and some Owner's Cost VOWD). On certain occasions estimating and scheduling activities as well as project review preparation were performed by the Bangalore team. A portion of the activities to collect and analyze data for benchmarking was moved to Bangalore Quest team. Calgary-Bangalore work sharing was not very successful with the overall Quest Monthly Project Management Reporting and Risk Coordination. More effort could have led to more positive outcomes.

12.2. Cost Control Framework (WBS, CBS, CTR)

The WBS was ready before entering into Execute with no modification done since. For the CBS, the Project Control Plan called for the implementation of Norsok coding, which was not implemented, but rather the EPCM & EP contractors were allowed to use their own cost structures. The CTR structure was used in Shell to set accountabilities. CTR sheets broke down the project scope into manageable pieces of work grouped by Control Account. Each sheet had a responsible Shell Project Engineer and a responsible Shell PS Engineer in charge of calculating/reviewing VOWD, raising MOC and providing schedule and cost forecasts for their control accounts. CTR sheets did not include hours and quantities.

12.3. Cost Estimation, Control and Forecasting tools and systems

Fluor and Toyo/Flint completed the Type 3 estimate for Capture and Pipeline respectively. Shell estimation covered the owners cost as well as the overall escalation/inflation and contingency. To transform the estimate into the budget, the total P50 GIP figure was broken down into 425 Control Accounts (Fluor had~325, Toyo~50 and Shell~50); each located in "FD Cost", "Trifinity" and PRISM systems. Those tools were utilized by Fluor, Toyo and Shell respectively to manage the costs. The original budget in Fluor and Toyo systems were duplicated in PRISM for Shell to maintain the ability to report the overall Quest cost in OC-1 report from one source database. Challenges arose as the lower level breakdown structure did not align appropriately among the various systems; creating many alignment issues some of which were still outstanding at project closeout. Examples of such system alignment issues included:

- In PRISM the Module contract was split between 26 Control Accounts for module erection, pipe fabrication, etc. In "FD Cost" there was only one Control Account for all the module costs. As a result PRISM carried no details on Modules Budget, VOWD and Forecast.

- In PRISM the Capture Unit Direct Field Labor was split based on geographical area divisions. In "FD Cost" the split was by trades (Concrete, Piping, etc.) causing numbers not to match.
- The "itemization" of POs into many Control Accounts caused complexity Shell was not ready to handle. For example, Toyo purchased valves for many areas under a single PO. Toyo was therefore forced to breakdown the PO amongst many Control Accounts for budget, VOWD, forecast. Keeping track of which portion belonged to which Control Account was a substantial effort.

12.3.1. Value of Work Done (VOWD) Reporting

The PS team, in conjunction with Finance, prepared the VOWD report by verifying contractor data and adding owner's cost components. Around project FID, Heavy Oil changed its existing Enterprise Resource Planning (ERP) solution from JDE to SAP Blueprint. The novelty aspect of SAP, combined with the team's lack of experience with the tool, contributed to early misalignments between the low-level work breakdown structure in SAP and the low-level work breakdown structure in PRISM. As a result, mapping of SAP WBS and Network Activities to PRISM Control Account led to many manual operations. The VOWD data for the capture unit flowed directly from the EPCM's cost system (FD Cost) to SAP and then to PRISM (i.e. the VOWD did not go from the EPCM cost management tools directly to PRISM). The SAP-WBS and Network Activities were mapped to PRISM Control Account. This mapping did not cascade down to the SAP "Element" level. Also the accrual and exchange rates on foreign purchases were not calculated with the same rate in SAP and "FD Cost" (Fluor's cost data system), hence there was a VOWD discrepancy between "FD Cost" and SAP/PRISM.

12.3.2. Cost Forecasting

The Estimate at Completion (EAC) and Latest Estimates (LE) for the year were provided monthly. Five methods were used throughout Execute to provide forecast on the EAC:

- By conducting the Shell Type 4 Estimate (once in Construction).
- By assessing the Cost of the work-to-go in each account (monthly).
- By updating the Base Cost Forecast with the changes and reviewing the Contingency Forecast (monthly).
- By updating the Earned Value projections (monthly).
- By conduction Cost & Schedule Risks Analysis - CSRA (every 6 months)

12.4. Integrated Planning and Scheduling

An Integrated Master Schedule (Level 2) supported by a Detailed Execute Phase Schedule (Level 3) was developed in Primavera (P6 planning software) including the schedule basis prior to DG4. It covered the entire Quest scope with sufficient details that encapsulated the activities associated with regulatory, assurance, HSSE, C&P, and OR&A across Detailed Design Engineering, Procurement, Construction, and Commissioning. Key milestones and interfaces between the sub-components were also included. The schedule was logically linked. As such the critical path and near-critical paths were visible and understood. The level 3 schedule was used for schedule risks analysis (SRA).

Each Quest component had an Execute phase schedule (Level 3).

- Fluor and Toyo developed and updated their respective Capture and Pipeline EPCM schedules in the Shell Primavera Database (Third Party access was provided). URS-Flint developed the Pipeline Construction schedule. Interfaces between sub-projects were updated by the Shell Scheduling lead.
- The Shell Planning/Scheduling Lead, in discussions with the Storage team, developed the storage execute phase Level-3 schedule. To a certain degree, it remained at a high level.
- The schedule for Shell work (HMU, T/A, etc.) was developed and maintained in the Scotford database with interface in Quest EPCM and CSU schedules.
- The Detailed CSU schedule and system-based schedule were developed and maintained by the Quest CSU Planning/Scheduling Lead.

The Shell planning/scheduling lead reviewed, discussed and analyzed contactors schedule and updated monthly the Quest Venture and Storage schedule. The Schedule maintained in P6 by Shell and the contractors served as the control schedule for Execute phase.

Throughout the Execute Phase, Quest experienced many scheduling challenges.

- Issues emerged from the lack of scheduling skills and/or senior project planning experience. It led to quality problems with the schedules (some of which were identified during audit and peer reviews).
- Turnover of Planner/Scheduler role during Define and Execute phases.
- Cultural attitudes around planning with the Pipeline Construction Contractor field personnel who never used the schedule to plan the work. Even after much iteration, the Pipeline Construction schedule still contained uncertain activity durations, unrealistic hours, no linkages and no resource loading; thus preventing proper forecasting and incorporation of schedule information into the cost analysis.
- Alignment between the Capture Construction schedule organized by geographical area and the CSU schedule organized by Turnover Systems. The linkage was difficult to establish in a timely manner to truly benefit CSU in the organization of the CSU activities and as input to the last CSRA.

- Development and update of the CSU resource-loaded schedule to help with forecasting of schedule and cost was challenging due to lack of senior CSU planning experience.
- A better alignment at the lower level between the work breakdown of the full EPC scope for Schedule, Progress and Cost would have been beneficial to facilitate project analysis.

Although there were challenges with regards to development and control at the lower levels 3 and 4 schedules (with the exception of the capture unit), the Project Team had Control of the schedule by maintaining a Level 2 schedule in relatively acceptable condition and reporting with a Level 0/1 to management, enabling key decision to be made. The critical path rested with the Capture EPC where Fluor kept a Level 3 Schedule in good order. Schedule outcomes were excellent. The project finished ahead of the P50 GIP date.

12.5. Progress Measurement and Management

To calculate the overall Quest project progress, the full project scope was broken down into five progress earning components which were weighted based on the original GIP budget: Capture (72%), Pipeline (8%), Storage (8%), Shell Scope (5%) and CSU (7%). Each component was broken down into a lower level and weighted to the others. For example, Capture was broken down by Engineering, Procurement, Module Fabrication and Site Construction. Detailed rules of credits were established based on completion of physical deliverables such as issuance of drawings for Engineering, milestone achievements for Procurement and installation of quantities for Module and Construction.

The PS team decided not to recalibrate the weightings between the components (as changes were approved) to avoid increasing the complexity of the progress measurement system, although this decision slightly distorted the progress numbers. For example, the final Pipeline weight to the overall scope increased to 18% but only accounted for 8% throughout the project.

Fluor utilized a progress database. Per the plan Shell implemented a roll-up of progress in Excel. The PS team intended to have the overall progress calculation done in PRISM but it would have required an additional resource to manage that due to effort already dedicated to the high learning curve on PRISM as well as fixing of mapping issues.

The Project Control Plan called for progress definition and measurements to be carried out such that physical progress of the work could be related and traceable to the WBS and Level 2 Integrated Master Schedule. The intent was to code each level of progress data consistently with the schedule structure to enable a roll-up and summary to higher levels for S-Curve generation and reporting. However, this consistency was not fully achieved.

12.6. Change Management

Fluor, Toyo and Shell each implemented their change management processes moving funds between control accounts within their systems. Once a month, Fluor and Toyo provided Shell with a change upload file containing the list of changes with the budget amount to move between accounts. These files were combined and imported into PRISM to produce the Quest overall OC1 report. Due to the historical discrepancies on the original budget, changes uploaded in PRISM did not align initially with the EPCM systems without many adjustments being made. Only the totals matched.

12.6.1. Engineering Change Management and Change Orders

Change order logs were maintained by Shell, Toyo and Fluor. The Shell project services ensured all three logs were up to date and that changes were being appropriately reviewed and closed-off in a timely manner.

Most of the Execute phase changes were generated from Fluor via the Project Deviation Note (PDN) process and were "trends " as opposed to scope changes reflecting changes in equipment or schedule to execution plans. Overall the execute phase saw few major changes which had material impact on engineering. Detailed HAZOPs were performed prior to FID, with the compressor HAZOP being re-performed in Execute phase to include rotating equipment personnel.

12.7. Monthly Project Management Reporting and Leading Indicators

Throughout Execute phase the project services team issued a monthly Project Management Report analyzing Cost, Progress, Schedule, Contingency, Change Management, Earned Value, Variance Analysis and Leading Indicators. The issuance of the report was preceded by a PLT Accountability meeting to discuss the status of the project while reviewing the report. The report enhanced the quality of conversations and intervention at all levels on the project, initiating corrective actions where necessary. The document included a status update listing the achievements as well as challenges and actions for all departments (HSE, Capture, Pipeline, Storage, PS, C&P, Finance, IM/IT, Risk, Project Assurance, Organization, Lessons Learned, Quality, CSU, Social Performance and Communication). It started with a two-page executive summary and was completed by many appendices (OC1, Schedules, EPCM Monthly reports, MOC log, detailed risk status, NCR log, etc.). A key factor to successfully generating accurate monthly reports on time was the ability to locate the report document in Livelink and a requirement for all contributors to input their sections directly into the document with the use of the Livelink "edit" function instead of using the traditional approach to assemble the report, which would have required all contributors e-mailing their respective sections to the report coordinator who would then have had to assemble the report on his/her local drive. This new approach helped to gain speed and was not fully dependent on the

Report Coordinator. His role was focused on verifying robustness of data, controlling quality of information, ensuring consistency across the sections and providing project controls analysis.

In addition to the multipage report, the PS team also issued a "One Pager" PDF from "Business One" for higher level project reporting to P&T Senior management and JV Partners. The Quest Project Reporting was considered "best-in-class".

12.8. Data Capture and Benchmarking

The Data Capture template provided by the Data Capture and Metrics Tool (DCMT) organization before FID was replaced a few weeks before Mechanical Completion by a new template. The first template was already issued to the contractor who had to redo the exercise of gathering data. Apart from the Capture unit, hours and quantities were not robustly captured through the project as anticipated, filling the new template proved to be a real challenge for the PS Team, especially for the owners' costs.

12.9. Lessons Learned – Project Controls

Although Quest is considered a very successful project, the misalignments between the various project controls tools and systems led to unnecessary mapping exercises of the project controls effort at the lower levels of each system. It prevented leveraging the full capabilities of PRISM/Primavera and left Shell dependent on the EPCMs for the "Data Capture" for Benchmarking activities.

The recommendation would be that enough resources and alignment time be allocated to align the different tools, processes and systems within Project Controls. Excel, Primavera, PRISM and SAP should align appropriately. The objective will be to ensure full alignment at the lower levels of the WBS so the scope of work is reported and reflected in the same order in the breakdown for Schedule, Progress and Cost.

Aspiration would be to eventually complete the Progress calculation in Primavera and/or PRISM to enable automation to recalibrate progress automatically after changes and allow earned value to be done in PRISM. This should also lead to better linkage between the Schedule and the Progress for owner's activities.

Hours and Quantities should be managed and replicated within the Shell tools and systems (along with the control by the EPCM) to enhance Shell forecasting capabilities.

For the full list of lessons learned associated with Project Controls refer to Appendix 22.

13. CONTRACTING & PROCUREMENT

13.1. Introduction

The Quest Project Contracting and Procurement (CP) third party spend post FID was ~$680 million which was spent largely in line with the CP and Category Strategy for the project which was approved in Q4 2010. The project was the first in Shell Canada to have in place and fully comply with the Shell Contracting and Procurement Procedure Manual (CPPM) for projects and was managed in accordance with the approved procedures.

The project achieved a total of ~$9mln (1.3%) in Third Party Spend Savings post FID. It utilized a total of 27 Enterprise Frame Agreements (EFAs) during the execution phase of the project with good interface with the Category Management team though with some challenges at the beginning (see CP Lessons Learned Report Appendices 9 and10). The team implemented the first successful ESPIR program in Shell Canada and was able to get vendor buy-in and EPC house support for the programme.

A CP Transition plan was created and approved during the execution phase with early involvement of the Operations CP team to ensure that the requirements and responsibilities of transition of CP activities were understood and agreed. This led to a smooth transition of CP activities form project to operations. The C&P success of the project was as a result of the combination of the calibre of the C&P personnel on the Shell side as well as those on the EPC side with good collaborative working relationships under a one-team approach.

All contracts and purchase orders that were billed for closure in the plan have been closed with the respective contractors and in the Shell ERP systems.

13.2. Contracting & Procurement Process and Principles

The Quest CCS Project utilized the Shell Contracting and Procurement Procedure Manual (CPPM) and Category Management and Contracting Process (CMCP) for all sourcing activities. Authorizations were obtained in accordance with Shell Manual of Authorities (MOA) and in compliance with Shell Contracts Board and Joint Venture requirements with Chevron and Marathon. All purchases of goods and services were done under a competitive bidding methodology where several contractors with similar capabilities competed against each other on pricing and project execution, while utilizing Shell's TAMAP- (Technically Approved Manufacturers and Producers) qualified suppliers and Enterprise Frame agreements (EFA). The purchase orders (POs) were split into two components (a first component for engineering and a second component for fabrication/manufacturing) to support early vendor data requirements for the 3rd Generation Module programme. (See lessons learned on procurement Appendix 9 for the pros and cons of this two-part PO strategy).

Market Intelligence played a role in determining or changing some contract types for the execution of certain scopes e.g. the pipeline construction contract and the fabrication contract.

Full compliance with Shell Group Business principles was mandated from all contractors, vendors and staff.

13.3. Contracting and Procurement Strategy

The project Contracting & Procurement (CP) and Category strategy as approved in Q4 2010 for the Capture and pipeline facilities (Figs 14.1 and 14.2 below) was implemented. Sponsors (assigned representatives from both the Shell and EPCM contractor project leadership teams) for all major equipment POs were put in place and quarterly visits to the vendor shops to ensure vendor manufacturing/fabrication activities were progressing smoothly.

	Detailed Engineering & Procurement	Construction services				Construction Management	Commissioning & Start Up
		Amine Regeneration Compression	HMU 1&2	HMU 3, Piperack, Utilities and U/G pipeline	SPG Tie-ins		
Percent of Budget		50%	15%	30%	5%		
	FLUOR	Site Preparation and U/G - Unit Rate-Bid			n/a	FLUOR	SITE OPERATIONS
		Piling - Unit Rate-Bid			n/a		
		Civil/Concrete Foundations - Unit Rate-Bid			n/a		
		Module Fabrication - Lumpsum & Unit rate& T&M-Bid			n/a		
		Heavy Haul and Lifting - T&M- Shell existing agreement			n/a		
		Module Installation- T&M			n/a		
		Structural Steel-T&M			SCOTFORD PROJECT GROUP		
		Piping & Mechanical Equipment Installation-T&M					
		Electrical & Instrumentation-T&M					
		Insulation - Unit Rate-Shell existing agreement or bid					
		Services and Indirects - Shell Existing agreements or bid					

Denotes single discipline contract across all areas (yellow)
Multi-discipline contract: Fluor DFL (red)
Green Field
Brown Field

Figure 13-1: Contracting quilt for the capture facilities

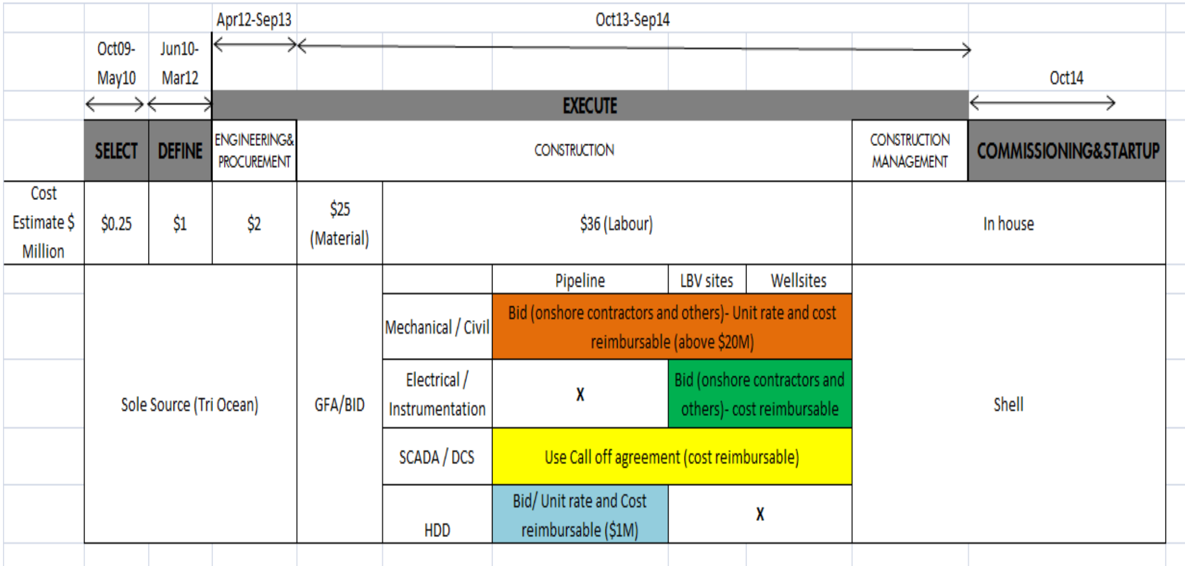


Figure 13-2: Contracting quilt for the pipeline execution

The following deviations to the strategy were made during the late Define and Execute phases of the project in response to market conditions.

- Module fabrication contract could not be placed as lumpsum as the market would not accept any contract in that mode. A change was approved by the HOCB to a full unit rate contract.
- The Pipeline construction was also changed to a fully reimbursable contract as the market would not accept a unit rate contract.

The Engineering, Procurement, Construction and Construction Management (EPCCm) contract of the capture facilities was awarded to Fluor Canada in March 2010 under an EPCM contracting structure with Fluor acting as agent for Shell for all capture site execution contracts. Fluor executed and managed a total of 163 material Purchase Orders and 95 Contracts using Shell contract templates and all have been successfully closed or transitioned to Shell CP Operations for use.

The Engineering and Procurement contract for the Quest pipeline was awarded to Toyo Engineering Limited (formerly TriOcean Engineering) in 2010.

The Quest Project procurement activities covered three (3) main components: the Capture Facility, the Pipeline and the Subsurface (wells and MMV). Procurement activities for the Capture Facility and the Pipeline were managed via two (2) EPC Houses who were awarded the respective procurement scope of work. Fluor procured for the Capture Facility and Toyo (Tri Ocean) procured for the Pipeline both with defined procurement plans pre-agreed and endorsed by Shell. The Shell UA Wells CP team managed the majority of Subsurface CP activities.

13.3.1. EPCCm Contractor and Contracting (Capture Facilities)

The contract was competitively bid among 5 contractors in 2008 with a planned 2-phase approach to the scope i.e. an EP phase concluding at FEED and an Execution phase up to facilities pre-startup. The EPCM Contract was signed in 2010 with Fluor Canada Limited acting as agent on behalf of Shell for all other orders and contracts in support of execution for an ACV of $225mln (excluding cash call cost).

Work execution was issued to contractor via discrete Work Authorization packages under the contract as follows:

Work Authorisation	Activity	Amount
WA1	Pre-FEED	$4,952,945
WA2	Early FEED Activity	$1,006,239
WA3	FEED Phase	$13,990,764
WA4	Pre-FID Execute Phase (16-Aug to 9-Sep 2011)	$713,864
WA5	Deleted	$0
WA6	Deleted	$0
WA7	Pre-FID Execute Phase (10-Sep 2011 to Jun-2012)	$23,067,648
WA8	Home Office Completion	CAD $47,342,110 and US $761,315
WA9	Early Works & Construction	$2,503,789
WA10	Construction & DFL Labour	$112,763,708

Table 13-1: Contract Authorisations issued under the EPCCm contract

Following the successful completion of the FEED and Define Phases, Board approval was received to award site construction management to Fluor Constructors on behalf of Shell. Fluor managed a total of 163 Purchase Orders and 95 Contracts as agents on behalf of Shell during the execute phase, with materials and equipment deliveries coming from various countries around the world (see procurement plan).

Fluor's contract was managed under SAP and a Cash Call program put in place for the payment of vendors, contractors and Direct Field labor and all contracts were on Shell paper with Fluor acting as agent.

4 disciplines were covered in the Fluor organizational structure; contracting, procurement (including expediting), materials management (MM) and logistics. All disciplines performed above average, except for MM which was mainly due to the competency level of the staff in the team.

Systems and processes were in place to execute the C&P aspects but there were gaps in communication between the disciplines that could have avoided certain cost e.g. interface between CP and finance within Fluor was not smooth.

The contract closeout process for all contracts for which Fluor acted as an agent was handled efficiently with little or no issues and no outstanding problems were passed on to Shell except the KBR contract for module fabrication and assembly.

13.3.2. Engineering and Procurement Contracting (Pipelines)

The pipeline Engineering and Procurement (EP) contract was a single source to Tri Ocean Engineering Limited (later changed name due to new ownership to Toyo Engineering) for the following supporting reasons:

- Ensure continuity with Tri Ocean and build on relationships already established with other CCS projects
- Enhance bridging work from Select phase to Define and Execution
- Experience with Shell designing pre-fabricated and assembled skids
- Leverage Shell's experience with pipeline design and construction

Contract was awarded at an ACV of $5.5mln, pre-FID. It was later varied post-FID to incorporate scope and design changes and extended duration for procurement support and "As-Built" documentation to $11mln. Change in company ownership did affect the delivery/performance of the contractor negatively. Contractor had a high turnover of personnel. Contractor performance is as defined in the section 13.3.6 below.

13.3.3. Module Contracting

KBR Industrial Canada Limited was awarded the Quest modules contract (69 modules in total) at an original ACV of $55mln with duration of 15 months following a competitive bidding exercise. The negotiation of the terms and conditions did prove to be a challenge. Contract was administered as a joint effort between Fluor and Shell contracting, recognising that the integrated 3rd Generation Modules had not been built before by the contractor. A total of 36 change orders resulting from scope changes and site instructions were approved on the contract bringing the contract to $65mln and 18 months duration at completion.

Lessons from the bidding phase and those from the execute phase are documented in the project lessons learned Appendix 11. The contractor's performance is as described section 13.3.6 below.

13.3.4. Construction Contract (Pipelines)

The pipeline construction contract Request for Proposals (RFP) was issued to the market in January 2013 and the bids were received in March 2013 from 3 of 7 vendors (Ledcor, URSFlint & Michels). Following the technical and commercial evaluation with subsequent negotiations, the construction contract was awarded to URSFlint at a target sum of $52.7mln under a reimbursable type contract (ACV of $65mln). Due to scope growth and welding productivity issues (mainly attributable to the high strength pipeline material type Grade 386 selected), various variations were approved and the contract price increased to $88.1mln at the completion of the project. URSFlint had project management challenges and were not efficient at managing cost on the project, realizing that some of the risks that materialized during construction were outside the control of the construction contractor e.g. increase in number of pipeline crossings, 3rd party interference, etc. See performance table below.

13.3.5. Drilling Contracting

Please referee to subsurface closeout report.

13.3.6. Contractor Performance

Scope	Safety	Cost	Schedule	Quality	Responsiveness	Innovation	Comments
Capture, EPCM	Green	green	Green	Green	Green	Green	Overall excellent performance. Developed a solid safety culture on site with good leadership visibility. Cost and change management excellent throughout the project. Overall good balance between cost and schedule - understood it was second and remained focused to keep cost in check. See the timing of ordering the valves a big miss in this areas. Quality - reowrk level very low showing good quality of workman ship and control, on assurance did not meet their plan of audits . Very responsive . 3rd Gen their big innovation.
Pipeline, Eng & Proc.	Green	Amber	Amber	Green	Amber	Amber	Partly responsible for the huge overrun on the pipeline both in material costs, and construction - significantly over on manhours and change control was reactive versus proactive. Missed most deliveables dates and delivery of equipment skids. Huge people change issues throughout that resulted in lots of delays. Not very responsive but relationship was reasonable. No real innovation , just followed Shell guidiance .
Pipeline, Construction	Green	Red	Amber	Green	Green	Amber	Safety was reasonable - not in the same league as Fluor - little too much of we always do it that way. Cost prediction was dismal and change mangement was more contractual change management. Schedule only worked because was on the drivers seat- they started too slow and then couldn't staff up fast enough to get back the time, only innovation was in their welding lab to get the welding procedures set up.
Module Fabrication	Green	Red	Amber	Green	Green	Amber	Disappointing as shown on cost but also schedule - especially on the fabrication of the pipe - several months behind . They really didn't make much of an attempt to deliver the fabricated pipe in the order Shell requested. Material management was very disapointing. A few quality issues but mostly with their subs versus them directly. No innovation. Not much by way of responsiveness.
Compressor Manufacturing	Green	Green	Green	Green	Amber	Amber	Met expectations on cost and schedule. Quality was good . Responsiveness - they responded when they felt like it or when we pulled a sponsor in to ask what was up. Innovative - very set in their ways. .

Table 13-2: CO_2 Capture and Pipeline Facilities contractors performance descriptions

13.4. Lessons Learned - Contracting and Procurement

For the C&P lessons and recommendations please see the collated project lessons learned on the Quest project (Appendices 9 and 10)

13.5. Other References

Other reference for the CP aspects of the project can be found in the following documents:

- Quest Project CP Strategy - Document No 07-0-AA-5880-0011
- Quest Project CP Plan – Document No 07-0-VA-5756-0010
- Quest CP transition Plan – Document No 07-0-VA-5756-0017

14. ENGINEERING – CAPTURE FACILITIES

14.1. Project Definition

The Define phase began in the fall of 2010 and the Capture Unit engineering had the following three focus areas:

- Maturation of the process design through P&ID development and detailed HAZOPs

  Significant effort was expended to ensure operations, process, mechanical and instrumentation reviews of the Quest P&IDs were thoroughly completed prior to HAZOP. As well during this phase detailed reviews on tie-in locations with existing Scotford facilities were reviewed with Operations. Lasergrammetry was undertaken to verify the feasibility of those tie in locations.

  Detailed Hazops were undertaken towards the end of the Define phase with the goal of having Hazop actions identified prior to finalizing the FID estimate. Significant effort was expended to ensure the Hazop teams were staffed with the correct individuals and that the P&IDs were adequately matured so that redesign would not occur during the Hazops themselves. If serious process safety concerns were found during the Hazops, the project planned on adding contingency or "below the line" capex to produce the best possible effort; but this was considered to be not needed at the end of Define.

  Overall the P&ID development and Hazops were successful with only the compressor Hazop being re-performed in Execute phase due to changes in the recycle loop and missing rotating equipment TA input during the first Hazop in Define phase. See Appendix 1 for a detailed description and objectives of all the reviews completed in the Define Phase.

- De-risking of the 3rd Generation Module concept

  The Shell and Fluor team developed a list of potential 3rd Generation Module-related concerns by discipline and actively worked to mitigate those concerns throughout the Define phase. Many mechanical, structural and electrical issues were resolved by the joint effort of the Shell & Fluor discipline leads with some input from construction or the Shell Offshore Design group in New Orleans. Decisions and module design approaches were documented in the Fluor 3rd Generation Modular Execution^{SM} Design Guide. Module weight guidelines were developed and initial module concepts including use of vertical modules were reviewed with a potential fabricator.

- Advance procurement of major equipment to secure vendor data and support project schedule

  The schedule critical path was always through fabrication, delivery and installation of the CO_2 compressor. The compressor purchase order required input from multiple engineering disciplines and was placed in Define to confirm key process and layout information.

Other long lead and vendor data critical pieces of equipment included air cooler, large pumps, major vessels, heat exchangers and welded plate and frame exchangers. These items were bid in FEED using a two-purchase order system, where PO #1 covered the vendor design work and PO#2 released the equipment for full fabrication. Vendor qualification, technical and commercial qualification were completed during the PO#1 stage; PO#2 was released to the same vendor once FID was granted in the fall of 2012, with key critical packages being released in March 2012 and the rest in Sept 2012 after FID.

14.2. Facilities Design Lessons Learned in the DEFINE Phase

Lessons learned sessions focused on the Define phase were held with Shell, Fluor and Toyo. FEED phase lessons learned can be found in Appendix 25.

14.3. Detailed Engineering

14.3.1. Introduction

The detailed engineering on Quest commenced immediately upon completion of Define phase deliverables in August 2011. The Shell and contractor teams from Fluor and Toyo were retained and carried from Define into the Execute phase as per the project execution plan.

Execute phase engineering scope was split as follows:

Fluor scopes

- HMU Amine Absorbers
- Main amine stripper area
- Amine filtration
- CO_2 Compression & Dehydration
- Utility piperacks
- FGR revamps within the existing HMUs

Toyo scope

- ISBL pig launcher & pipeline,
- CO_2 pipeline including laterals, LBVs and wellsite surface facilities

Scotford Projects Group (SPG) scope

- Piping tie-ins to first double block and bleed valves for the brownfield tie-ins

Shell P&T (under Technical Authority direction)

- HMU burner replacement, PSA adsorbent replacement

Shell Well Delivery Group

- Subsurface modelling and well designs

Refer to Appendix 2 for a detailed description of the engineering activities by discipline together with the project reviews and work processes that were conducted in the Detailed Engineering phase for the capture and pipeline facilities.

14.3.2. Contractor Organization, Procedures and Standards, Customer's Resident Team or Engineer

14.3.2.1. Shell's Engineering Organization

The Shell engineering organization was staffed with P&T resources with a mixture of fulltime and part time personnel. Rotating, heat transfer, U&O part time personnel were P&T PTE specialists based at Calgary Research Centre; while others (static equipment, electrical, PACO) were full-time resources embedded in the project team. Flow assurance, corrosion, and fired equipment resources were consulted on a part-time basis. See Section 5.2 for the Shell Engineering Team Organisational chart within the project organizational chart.

The part time staffing approach seemed appropriate for the scale of the Quest scope when planning the workforce. For the PACO, rotating, U&O and heat transfer disciplines the allocated was adequate. The static equipment engineer was a TA3 (not TA2 as desired) and coupled with high periods of activity during vendor kick-offs he was frequently overloaded. The electrical lead experienced the same issue since peak workloads for two projects occurred simultaneously.

14.3.2.2. Fluor's Engineering Organization

The Shell and Fluor organizations were reasonably well aligned. Having the Fluor process lead report directly into the Fluor PM created no issues during implementation. Within Fluor the mechanical group was responsible for static equipment, heat transfer and rotating equipment and had specialist engineers available for each discipline. These forced the Fluor mechanical lead to interface with multiple Shell TA's to complete his work scope.

14.3.2.3. Engineering Standards

The Quest engineering standards were selected and finalized at the DG3 gate in Technical Specifications Catalogue.

The standards were mixtures of DEP-Gen and older Shell Canada Standards depending on the discipline. The following disciplines were able to migrate to mostly DEP-GEN standards when the list was frozen: PACO, Rotating Equipment and Heat Transfer.

The Static equipment discipline stayed with existing Shell Canada standards for piping and pressure vessels since they reflected ABSA requirements. Otherwise there would have been significant effort to adopt DEP-Gens and having the Quest scope to be backwards compatible with existing Scotford Upgrader facilities (piping line classes for example) was beneficial to the operations group. Electrical discipline used existing Shell Canada electrical standards to be compliant with Canadian Electrical codes. The pipeline discipline also prepared derogations to allow use of existing Shell Canada pipeline standards which reflected requirements of Z662. For these disciplines DEM1 derogations were prepared to identify gaps between the Quest standards and the June 2010 DEM1 applicable DEPs.

During the Execute phase a few potential derogations were needed, for example low temperature requirements for structural steel, but it was found that later version of the DEP-Gens issued in 2011 or 2012 had fewer SHALL [PS] statements. This allowed the team to write technical deviation notices (TDNs) versus full derogations requiring TA1 approval.

Technical deviation notices were prepared as required throughout the FEED and Execute phases with the master index of those TDNs being maintained by Fluor document control and issued for information every two weeks.

14.3.2.4. Team Location

The Shell resident engineering team lead, civil engineer and process engineer were based at the Fluor Sundance office. The remainder of the Shell engineering team was based at the Shell Center in Calgary but spent 2 days a week or more at Fluor's office.

Fluor had the bulk of their team located at the 55 Sunpark Plaza office in Calgary including all their discipline leads. The Fluor New Delhi office remained in New Delhi without a full time resident Shell presence but numerous alignment meetings were held between discipline leads. The Shell team travelled to New Delhi for the 30% model reviews of their areas in (HMU 1, 2 &3 and Amine Stripper areas) which was found to be beneficial and allowed for model reviews to proceed smoothly.

14.3.3. Summary of Key Define and Detailed Engineering Phases Outcomes and Recommendations

The define phase on Quest did achieve the desired FID quality deliverables and was sustained in Execute. In particular, P&IDs was adequately advanced at detailed design work commencement and already had adequate operations review and input that few significant issues or surprises were found even during the HAZOP process.

The two PO concept which was adopted to allow for de-risking of the 3rd Generation Module design required substantial effort of the mechanical and procurement groups to support. The benefits of this effort are now apparent in as few changes to plots plan, module plans or P&IDs came about due to late vendor data.

Organizationally, the Shell and Fluor organizations were well aligned and staffed on both sides. For the pipeline scope, a Shell Pipeline TA2 dedicated to the project and resident in the Toyo office would have improved the timeliness and quality of the Toyo engineering deliverables. It was a great benefit to the project that as a result of Shell Transition 2009 reorganization, the Shell owners team assembled in 2010 was well staffed with experienced personnel in almost every role and that this staff largely stayed engaged through to the end of the Execute phase by moving project engineers into construction engineering roles. This continuity paid off with very low rework rate and few decisions being revisited (with quality decision notes playing a part too).

It is also worth mentioning, that the EPC and oil industry market slowdown in 2008 and 2009 resulted in Fluor staffing the project with very senior resources considering the relatively small size of the project. Many of the Fluor team had experience working with Shell on either the ULSD project in 2005 or the Scotford baseplant in 1999-2002. This provided early alignment and buy-in on many Shell initiatives like Flawless, HFE etc.

Effective communication can be challenging when project teams are split between office locations, and when different parts of the overall project team are geographically separated (home office and construction site). Project leadership spent effort in forcing use of cost effective electronic tools/technologies that were available to foster online collaboration/meetings even to stipulate that all meetings needed telecom dial in details to allow remote participation. Planning effective face-to-face meetings with Toyo and New Delhi took effort but improved relationships over time.

14.3.4. Lessons Learned – Capture Facilities Detailed Engineering

A Lessons Learned capture sessions were held in May/June 2013. The collection of individual lessons and recommendations from participants have been condensed into the overall Quest lessons learned report. See Appendix 3 for Detailed Engineering Lessons Learned Reports

15. ENGINEERING – PIPELINE FACILITIES

15.1. Responsibility for Project Definition

The Define phase of Quest Pipelines began in the fall of 2010 with the manager of the engineering contractor seconded to the Shell Quest Team. The focus was:

- To develop the integrated P&IDs of the pipeline and the interfaces with the Capture plant and the injection wells.
- To perform safety reviews of the integrated design.
- To perform flow assurance analysis of the pipeline to understand hydrate formation and operation of the injection well.
- To perform coarse HAZOP to identify items that could have a high impact on cost estimate

The pipeline scope was refined in the Define phase in conjunction with the definition of the number of wells to be drilled and the laterals to feed them. As well pipeline procurement was advanced for the line pipe as a long lead item.

To support the cost estimate, only the line pipe material and coating was selected to obtain firm quotes by using EFA for Line pipe. It was decided not to perform materials market survey for the rest of the items of the pipeline.

Although a major project focus during this time was the Alberta Energy Regulator (AER) public hearing on the project, this had very little impact on the progress of engineering. The application was developed during the Select phase. The Define phase main regulatory activity for the pipeline was to answer queries from AER regarding the application submitted and preparation of key personnel for the public hearing.

15.2. Define Phase Reviews

Review Activity	Description
Pipeline P&ID Reviews	Reviewed with operations to understand process control required to interface with the Capture plant and the injection wells.
Coarse HAZOP	A "what if" review of the P&IDs was performed to identify show stoppers and items that could have a high impact on the pipeline cost estimate. At detailed integrated Hazop of Compressor, Pipeline and Wells was performed after feedback from ITR4 indicated that integration of design needed improvement and before VAR-4.
Rangeley EOR Information Sharing	The Shell Quest team visited the Chevron Rangeley Colorado Enhance Oil Recovery (EOR) facility to understand

	Operations, safety and technical issues related to dense phase (supercritical) CO_2 operations.
Constructability review	A constructability review was performed to understand the challenges of building a pipeline on private lands and logistics to perform horizontal directional drilled to cross the North Saskatchewan river.

Table 15-1:Pipeline Engineering Define Phase Review

15.3. Detailed Engineering – Pipeline Facilities

15.3.1. Introduction

Due to delays in the FID date, it was decided to reduce Pre-FID spend. Hence limited detailed engineering activities of the pipeline inside the battery limit was started support the early underground works of the Capture plant. Before mentioned activity was initiated in October 2011.

The topographic survey of the pipeline right of way (ROW) was initiated after completion of Define phase and before the winter of 2011/2012 but it was a conscious decision not to develop survey drawings until Execute funding was released in July 2012.

As part of the approval of the pipeline licence by the regulator, there was the requirement to assess if the use of odorants was necessary for a safe operation of the pipeline in case of leaks. This requirement caused disruptions in detailed engineering activities and additional engineering hours to perform a study about the use of odorants compared to other alternatives for leaks monitoring.

15.3.2. Shell's Engineering Organization

The Shell engineering organization was staffed with P&T resources with a mixture of fulltime and part time personnel. Part time disciplines were: flow assurance, corrosion, and pipeline design.

15.3.3. Toyo Engineering Organization

Toyo Engineering Canada (formerly Triocean) was the detailed engineering contractor for the Quest Pipeline. Kickoff meeting and alignment sessions were held to ensure Shell and Toyo team were properly aligned. In some instances, Toyo designers were invited to participate in design reviews of the Capture plant related to location of the pipeline pig launcher and routing of the pipeline inside the battery limits.

15.3.4. Team Location

The Toyo Engineering Canada team was based at their office in downtown Calgary, within walking distance from Shell Center. The pipeline scope was relatively small so Toyo did not have full time Shell discipline engineers presence in their office. This probably contributed to their poor productivity and quality issues with the Toyo scopes. The Shell team were then directed to spend time at Toyo's offices to allow greater interactions /discussions with the Toyo designers. Once this started to happen, the situation improved slightly. In hindsight should have had a regular schedule of discipline engineers at the Toyo office as well as senior leadership for weekly meetings.

15.4. Pipeline Original Scope vs. Final Scope

Toyo Engineering kept a log with trends and scope changes to document scope changes/growth of several scope items. The project team made a visit in late May 2011 to an EOR-CO_2 facility in Rangely, Colorado, operated by Chevron (one of the Quest project's JV partners) to gain first-hand knowledge of CO_2 pipeline operating experience. The application of the learnings from the Rangely visit (which was undertaken "late" in mid-Define phase) introduced considerable novelty and caused considerable changes to the pipeline design. Such late changes included LBV valve-type and the associated automation & controls engineering required, wellsite skids, double block and bleed (DBB) philosophy introduction, and poorly-defined SCADA radio system and cathodic protection.

Scope changes were generated for new items such as AC mitigation protection, leak detection system software, study of leak detection by means of fiber optic, study to use odorants in dense phase CO_2 and additional pressure transmitters and MMV scope maturity that impacted the pipeline.

Most of the trends were related to under-estimation of cost for several components as there was a decision to not obtain firmed quotes during DEFINE because some were not deemed to be major equipment e.g. bore valves for LBV.

15.5. Detailed Engineering Activities – Pipeline Facilities

Discipline	Activity	Outcomes
Process Engineering	Toyo produced P&IDs using Microstation as they were not SPP&ID-capable during the FEED and Execute Phases. Hours were allocated to Fluor to convert the Toyo P&IDs to SPP&ID at the end of the project once as-builts have	Required extra support with the Shell process lead providing detailed guidance on P&ID development, control narrative preparation, safeguarding and closure of HAZOP items. Pipeline flow assurance report

	been produced by Toyo. There was a high rate of rotation of personnel at Toyo Engineering (e.g. Define Phase process engineer changed in Execute)	was developed by Shell out of Houston; this report was delivered in parts based in several simulations, this situation contributed to some of the delays of Toyo process engineering deliverables.
Civil and Structural (CS)	Pipeline CS scope was minimum, mainly related to earthworks for pipeline ROW, LBV's pads, structural design of skids and MMV building at the well sites. Survey of the pipeline ROW was not performed from earth's work stand point.	Dewatering and rocks management scope was grossly under estimated.
Static Equipment and Materials, Metallurgy and Integrity	There was good alignment between the Shell pipeline TA2 and Toyo pipeline engineer regarding the line pipe PO, bending requirements and valve selections. However development of a cost-effective welding procedure of the linepipe took a significant amount of time; The challenges of producing acceptable high ductile/tough welds in high strength steel material was not flagged early on in the project	Cost and schedule overruns in the pipeline installation and impacted the pipeline costs significantly.
Piping and Pipelines	Toyo used an Autoplant software while Fluor piping designers used Smart Plant 3D to produce the 3D model. The Toyo piping and pipeline scope was relatively smaller but took significant Shell input and guidance to ensure that basics such as valve arrangements around pig launchers were correct due to rapid turnover of Toyo staff.	Many of the deliverables were produced twice, one for ISBL scope and one for OSBL scope, therefore increasing the amount of manhours expended by Toyo. A major oversight in the pipeline design was found early in Execute when the maximum pressure of CO_2 at the lowest point of the pipeline was found to exceed the pipeline design pressure. This was due to the

	Another issue that had a negative effect on the pipeline alignment sheets development was the earlier decision to perform ROW survey in Fall 2011 but to wait to develop drawings only after Execute funding was released. This decision meant that Toyo designers were commissioned to start only ISBL pipeline design work which caused inefficiencies as they were demobilized when project FID was delayed due to the regulatory hearing delays, and re-mobilised a few months later to continue with the rest of the pipeline design.	fact that the static head of CO_2 in the line was not considered in the original design pressure calculations by Toyo. The CO_2 compressor design pressure was reduced from 14,790 kPag to 14,000 kPag to avoid overpressure at the low point under the North Saskatchewan River.
Electrical	The electrical discipline scope for pipeline was really small, as solar power supply was originally selected for LBV sites and well sites. Later it was decided to get power from the grid to the injection well pads to feed the PLCs of the monitoring systems.	
Process Automation and Control (PACO)	The Scotford INTools database was used for Quest; and Toyo was provided direct access to create their tags in the database using remote access controlled with monitoring by Shell. Toyo was supported to complete I&C deliverables throughout the Execute phase due to turnover of personnel and unfamiliarity of working with Shell Scotford Upgrader's requirements. Toyo did not produce detailed Data Sheet of line break valves and ESD valves during Define phase.	The Quest deliverables met Scotford standards without requiring a database "merge" at the end of the project. Tagging of equipment and instruments had rework, Control narrative and Cause & Effect diagrams went through numerous revisions and extensive guidance from Shell TAs. Cost of the LBVs and ESD valves was grossly under estimated because of the change to orbit valves after the Chevron Rangely EOR-CO_2 facility visit. Estimates were based on "sour"

	During detail design and procurement activities it was evident that SCADA system specifications developed during Define phase were not detailed enough to support the cost estimate at FID stage. The strategy to split the scope of supply of the SCADA system into several vendors (radios, PLC/RTU, Cabinets/Solar panels, programming) did not work well. The strategy required Toyo to coordinate the vendors and have a seamless interface among them. The late introduction of a single building (MMV building) at the well site to house the I&C equipment of the pipeline and the MMV equipment meant another interface in the middle of the detailed engineering phase that caused inefficiencies in the development of the I&C work.	service database. This set up produced an increase of engineering man-hours for Toyo to manage the numerous interfaces for the SCADA design and added complexity to the design. For future projects it is recommended to have a one single supplier, in the role of system integrator to have a more effective set up.
Technical Document Management	Toyo did not have a system equivalent to Fluor's POL, therefore Shell's Assai was implemented to allow squad check of Toyo drawings by Shell engineers. The implementation of Assai was new to Shell staff.	This set up in general did not work well as Shell engineers submitted comments manually or via email to Toyo instead of using the Assai tool.

Table 15-2: Pipeline Detailed Engineering Activities

15.6. Key Lessons and Recommendations – Pipeline Detailed Engineering

The define phase for the Quest pipeline scope did not achieve the desired FID quality mainly in the PACO discipline, and hence significant design developments during detailed engineering were required for the line break valves (LBVs) selection and the SCADA system (mainly due to the poor definition of the MMV scope). The visit to the Chevron EOR-CO_2 facility in Rangely, Colorado was taken late.

A Shell Pipeline TA2 designated to the project and resident in the Toyo office would have improved the timeliness and quality of the Toyo engineering deliverables.

The strategy to reduce pre-FID expenditure and only perform detailed design for early works scope (ISBL pipeline scope) and later start design of the rest of the pipeline meant inefficient resources utilization and at the end more engineering hours not previously estimated for.

A "boots on the ground" walk of the right of way by Shell CM and contractor could have helped the project team to assess constructability. Topographic survey is not enough to quantify construction logistics.

When using line pipe material with enhanced mechanical properties above and beyond industry standards, "Weldability test" must be done at an early stage to support cost estimate assumptions. Need to do a comparison between high strength steel and "crack arrestors".

Effective communication can be challenging when project teams are split between different office locations, and when different parts of the overall project team are geographically separated (i.e. home office and construction site). Project leadership enforced the use of cost effective electronic tools that were available to foster online collaboration and meetings (even stipulated that all meetings needed telecom dial in details to allow remote participation). Planning effective face-to-face meetings with Toyo took effort but improved relationships over time.

Turnover of resources in Toyo significantly impacted their ability to deliver, coupled with the dramatic changes in company systems and processes with the buyout of Tri-Ocean (original pipeline Engineering and Procurement contractor) by Toyo.

See Appendices 4 and5 for the detailed lessons learned on the pipeline engineering and procurement activities.

16. SUBSURFACE ENGINEERING

16.1. Geology

16.1.1. Stratigraphic Framework of the BCS storage complex

The well results from the 2012-2013 drilling campaign confirmed that the stratigraphic framework within the QUEST project area was as expected. Table 16-1 provides a summary of the formation thicknesses within the Basal Cambrian Sands (BCS) storage complex and selected overlying formations up to the top of the Quest Sequestration Lease (QSL) rights for injection wells IW 8-19, IW 5-35 and IW 7-11. The differences between actual depth and prognosed formation thickness are also shown for IW 5-35 and 7-11. The formation thicknesses were similar between adjacent deep monitoring wells (DMWs) and injection wells (IWs).

Injection Wells — thickness (m) & actual vs prog (m)

			8-19	5-35		7-11	
	Seal	Prairie Evap./ Lo Prairie Evap.	126	122	+5	127	-4
		Winnipegosis/ Contact Rapids	75	72	-7	70	-4
BCS Storage Complex	Seal	Upper Lotsberg	84	83	0	89	+3
BCS Storage Complex	Seal	Lower Lotsberg	35	36	+2	36	+1
BCS Storage Complex	Seal	MCS	52	51	+1	50	-4
BCS Storage Complex		LMS					
BCS Storage Complex	Injection Target	BCS	47	43	-4	42	-6
		PreCam					

Table 16-1: Summary of zone thicknesses for Quest Sequestration Lease rights interval

Depositional Paleo-Environment	IW 8-19 thickness (m)	IW 5-35 thickness (m)	IW 7-11 thickness (m)
Distal Bay	11*	5*	8*
Proximal Bay	10	12	11
Tide Dominated Bay Margin (TDBM)	25	30	17
TDBM (Fluvial Influenced)	4.5	2.4	13

* Based on core data only – log data indicates that that Distal Bay is significantly thicker.

Table 16-2: Depositional Environment in LMS-BCS for the injection wells from core data.

16.1.2. Basal Cambrian Sands (BCS) – CO_2 injection zone

Based on the IW 5-35 and IW 7-11 BCS cores, the depositional environment was interpreted to be consistent with IW 8-19 (Table 16-2). Consistency was also observed with regards to the geochemical composition of the BCS formation brine from IW 5-35 and IW 7-11 compared to IW 8-19, as illustrated in Figure 16-1.

16.1.3. Bounding Formation Geology - Seals

No fracturing within the BCS Storage Complex top seals (MCS and Lotsberg formations) was evident from drilling, log or core data.

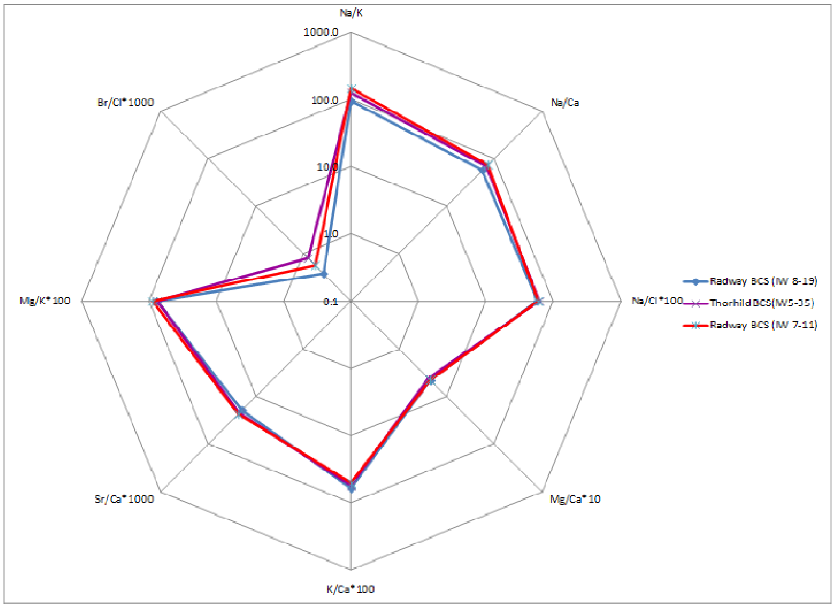


Figure 16-1: Ion Ratio plot of BCS Formation brine waters from IW 8-19 (sampled in 2010), IW 5-35 (sampled in 2012) and IW 7-11 (sampled in 2013).

16.1.4. Basal Seal: Precambrian Basement

The basal seal for the CO_2 injection zone (BCS) in the Cambrian sequence is the granitic Precambrian basement. Both IW 5-35 and IW 7-11 drilled into the Precambrian and a portion of core at the transition from the BCS to the Precambrian basement was obtained. The Precambrian was identified as a coarse, crystalline granite in both wells, in accordance with expectations.

In general, seismic surveys, well core data and FMI logs indicated the existence of fractures on the Precambrian basement surface. Despite the presence of fractures in the basement, no substantial porosity or permeability were identified via core and logs in the Precambrian interval. The seismically visible linear trends/features, which are interpreted as faults, are fairly small and are very old features and likely to be closed and well cemented. There is no evidence of propagation above the basement into the overlying Cambrian sediments.

16.1.5. First Seal: Middle Cambrian Shales of the Deadwood Formation

The IW 5-35 and IW 7-11 confirmed the presence and thickness of the Middle Cambrian Shales (MCS) in the Quest SLA (Table 16-1). To address caprock integrity and seal capacity, a core study was completed on Middle Cambrian Shale (MCS) core from the IW 8-19, focusing on the capillary sealing capacity and addressing the impact of pressure build-up due to CO_2 injection into the underlying BCS. The results from the MCS core experiments indicated that the MCS has very good sealing capacity.

16.1.6. Second Seal and Third (Ultimate) Seal: Lotsberg Formation

The IW 5-35 and IW 7-11 confirmed the presence and thickness of the Lotsberg Salt Formation in the Quest SLA (Table 16-1).

16.1.7. Formation Selection for Deep Pressure Monitoring

The Storage Development Plan (SDP) identified two aquifers in the overburden above the BCS storage complex as formations suitable for pressure monitoring, the Winnipegosis and the Cooking Lake. The primary target formation was the Winnipegosis, with the secondary target being the Cooking Lake. Based on the 2012-2013 drilling campaign, the Cooking Lake was chosen as the target formation for deep pressure monitoring.

16.2. Geomechanics

16.2.1. Surface Heave Deformation

InSAR is a satellite remote sensing method designed to map even the smallest displacements of the Earth's surface. Demonstration of conformance within the BCS storage complex (through observing surface deformation related to pressure changes) will be provided by InSAR from baseline through to post-injection closure of the project.

Radar imagery was collected for over three years across the Quest AOR with the Radarsat-2 satellite on a monthly basis, completing the baseline data acqusition. Two sets of 45 images acquired between June 3, 2011 and July 5, 2014 were processed with TRE's proprietary SqueeSAR™ algorithm. The results of this processing indicated that InSAR will measure surface displacements with a precision of +/ 0.87 mm/year. The InSAR coverage and the density of natural reflectors is shown in Figure 16-2 with an increase of 14,369 reflectors compared to the processing carried out in 2012. The baseline dataset indicates minimal ground movement has occurred within the Quest SLA.

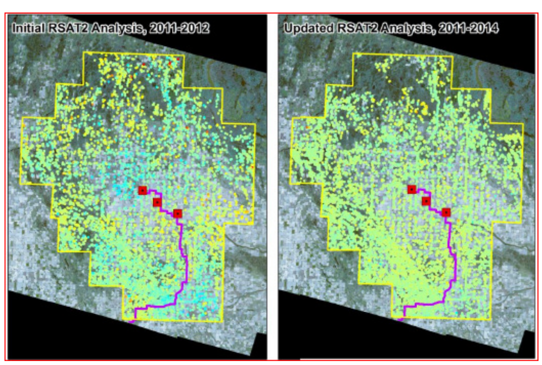


Figure 16-2: InSAR analysis of baseline period data collection from 2012 – 2014

Surface deformation modelling was updated based on the Gen-5 BCS pressure predictions. This modelling was based on the expected pressure increases over the life of the project, but with the high case of geomechanical properties of the reservoir. The maximum surface heave is shown in Figure 16-3 over the project life along with a map of the deformation expected after the first year of injection. These updated results indicated that in the best case (high case geomechanical properties), InSAR can detect surface deformation within the first year of injection. However, as this modelling represents the maximum displacements based on geomechanical properties with an uncertainty of one order of magnitude, the deformation may be too small to be captured within the first number of years of injection.

The moment CO_2 injection stops, pressures inside the BCS will begin to relax and surface displacements will begin to reverse.

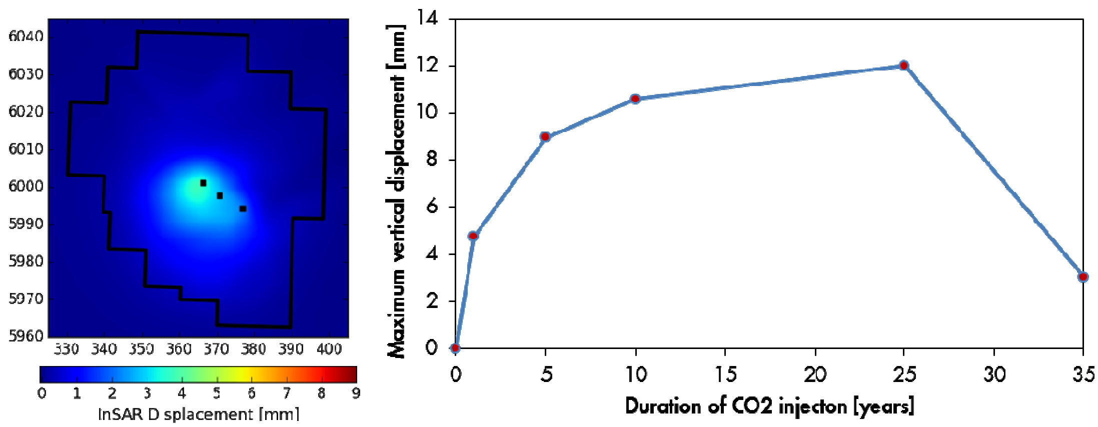


Figure 16-3: Surface heave after one year of injection (left) and maximum surface heave over the life of the project (right)

InSAR capability and efficacy will be reviewed on an annual basis once injection commences, to validate the geomechanical assumptions, pressure and reservoir responses of the BCS and resulting surface heave observations.

16.3. Geophysics/Seismic Studies & Interpretation

Two major geophysical activities were completed in the Execute phase of the project in accordance with the MMV plan; and included:

1. Time-lapse 3D vertical seismic profiling (VSP) baseline survey

   To act as a safeguard to ensure conformance, time-lapse seismic is used to monitor the CO_2 plume with a lateral resolution of 25-50m and a sensitivity of 5-10% of continuous CO_2 saturation within a zone at least 5-10m thick. The expected performance of this monitoring technology will be assessed during the baseline monitoring period and early injection periods. If this technology does not perform as expected, then it will be discontinued as a monitoring technology. The Baseline Walkaway VSP Surveys were designed through an integrated effort between the Geophysical acquisition and processing teams and the Quest Project. This baseline survey is intended to have highly repeatable shot point locations, monitor the CO_2 plume extent over time, and be cost effective. The VSP was successfully acquired in February 2015.

2. Installation of Down-hole microseismic monitoring array (DMW8-19 pad only)
   To aid in containment risk mitigation, the downhole microseismic array will monitor for faults reactivated by induced stress by detecting any fault reactivation within 600m of the injector. Any detection of faults will motivate a reduction in injection pressure. The downhole microseismic array was installed in DMW 8-19 in November 2014 and began recording background microseismicity at the site at this time. The November 2014 install was pulled from the well in April 2015 to install a similar array that met pressure requirements for the long term.

16.4. Reservoir Engineering

16.4.1. BCS Dynamic Model predictions

Refined the Generation 3 dynamic reservoir model into a Generation-4 and then Gen-5 reservoir model using CMG's compositional reservoir modeling software (GEMS) and incorporated reservoir appraisal data from each of the injection locations for pressure and CO_2 plume/saturation prediction.

Pressure Prediction

The expected pressure build-up is illustrated in Figure 17-4 showing the pressure build-up at each of the specific well locations. Figure 17-5 shows an aerial cross-section of expected pressure in year 2040.

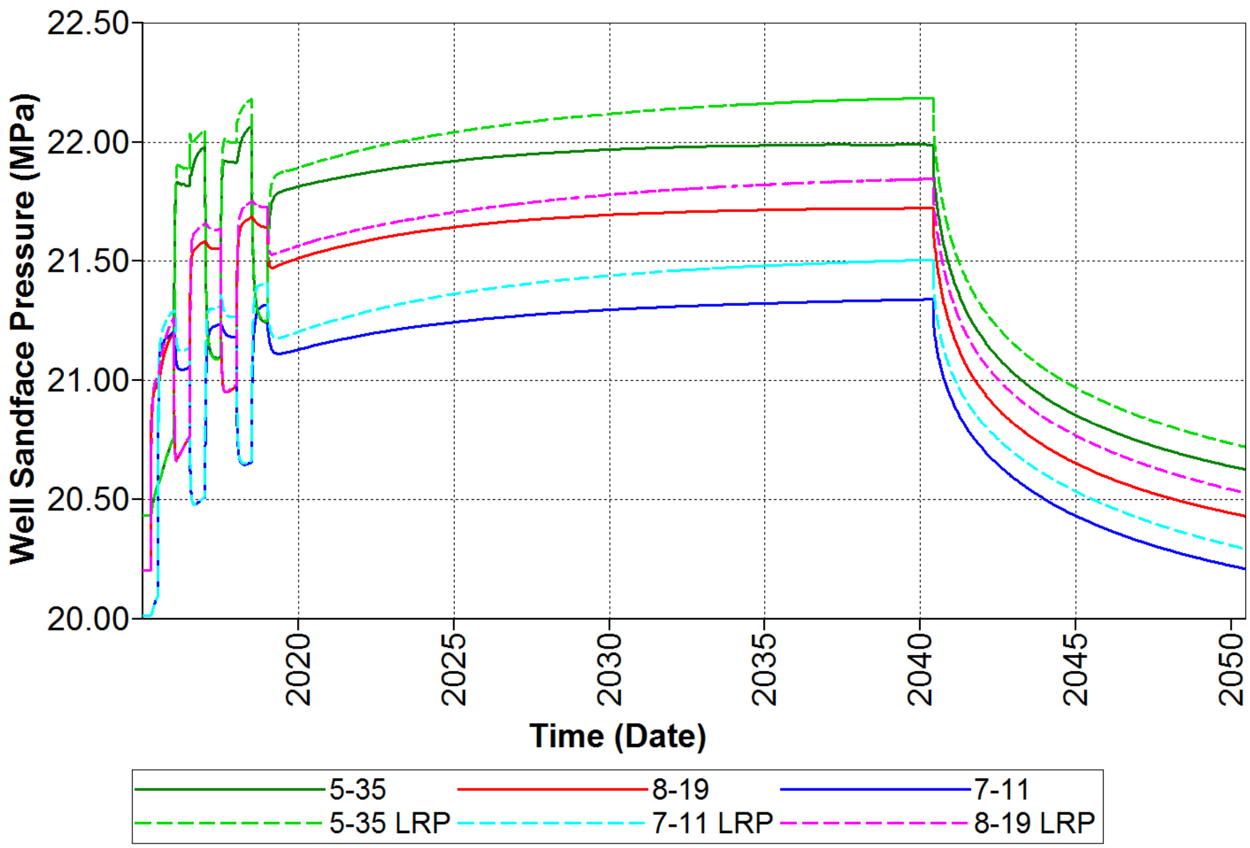


Figure 16-4: Well by well expected pressure build forecast for base and low relative permeability scenarios

Plume Prediction

The model incorporated new well control and estimates well specific CO_2 plume migration, as illustrated in Figure 17-6. Plume dimension per well can be manipulated in time by adjusting the per well injection rates if there is a reason to do so. As the relative permeability remains the largest uncertainty on plume length, the plot included the IW 8-19 high relative permeability scenario.

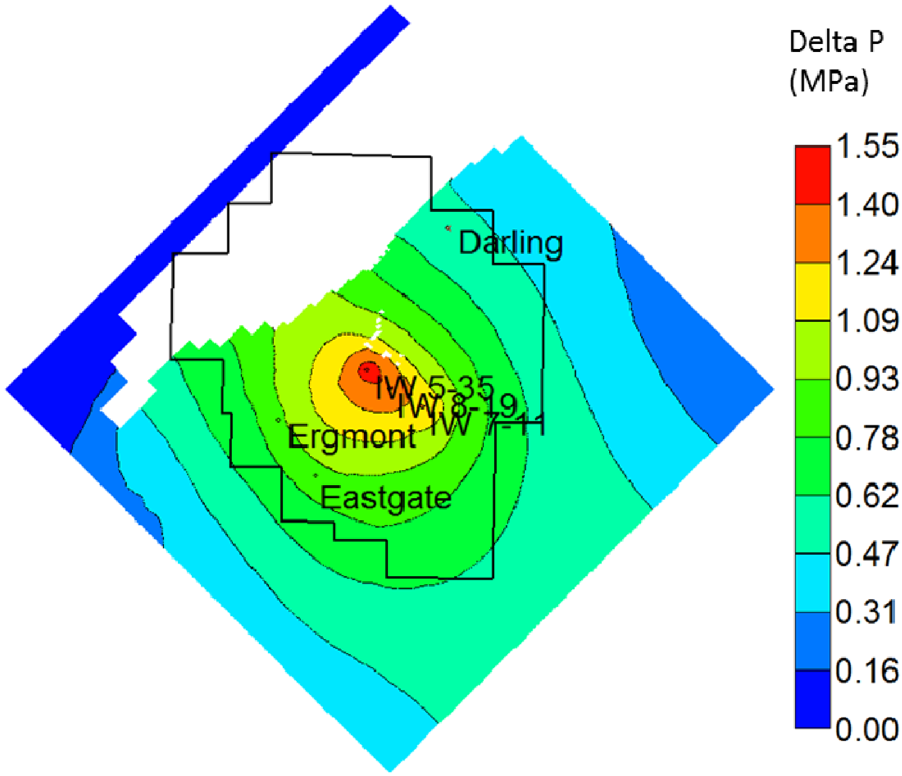


Figure 16-5: Aerial cross-section of pressure in 2040

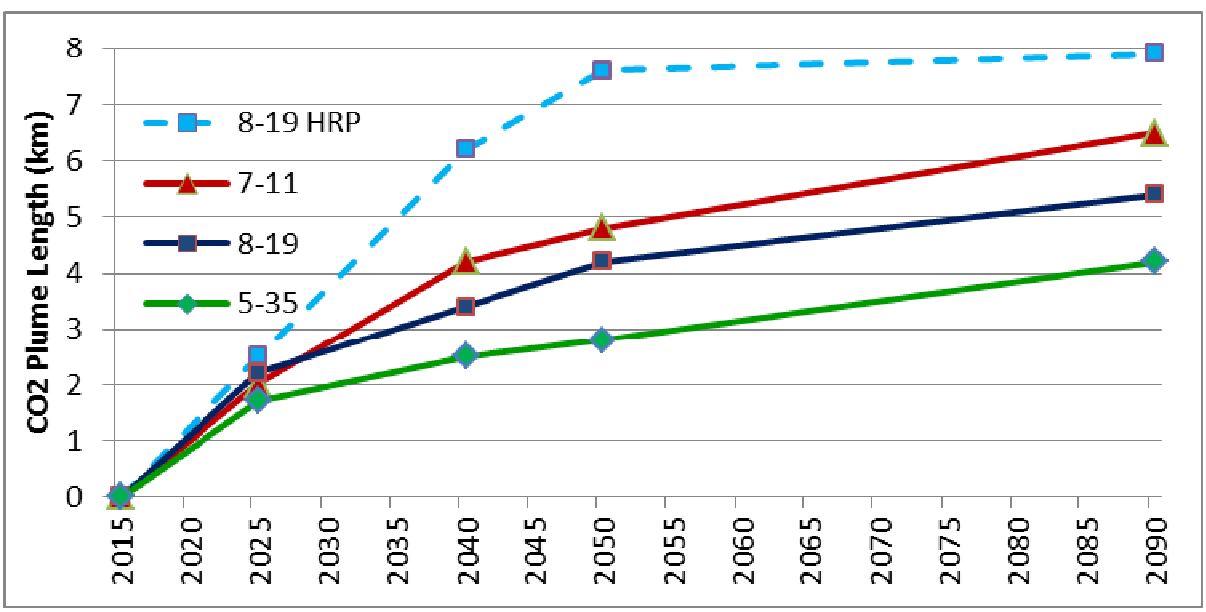


Figure 16-6: Maximum CO_2 plume length per well over time

16.5. Wells and Production Technology

16.5.1. Well Types

The Quest CCS project has three well types: the CO_2 injection wells (IW), the deep MMV wells (DW) and the shallow groundwater MMV wells (GW). See Figure17-7 below.

Injection Wells

The injection wells will be used to inject the CO_2 coming from the Scotford Upgrader into the Basal Cambrian Sands (BCS) storage complex.

BCS Monitoring Wells

There is one BCS monitoring well for monitoring the far-field pressure in the storage formation.

Deep Monitoring Wells

There are three deep monitoring wells, located next to each injection well for monitoring the pressure above the storage complex.

Groundwater monitoring wells

There are a total of 9 groundwater (GW) monitoring wells. These groundwater monitoring wells will be used to monitor the characteristics of the freshwater zone on each injection wellpad using permanent downhole sensors.

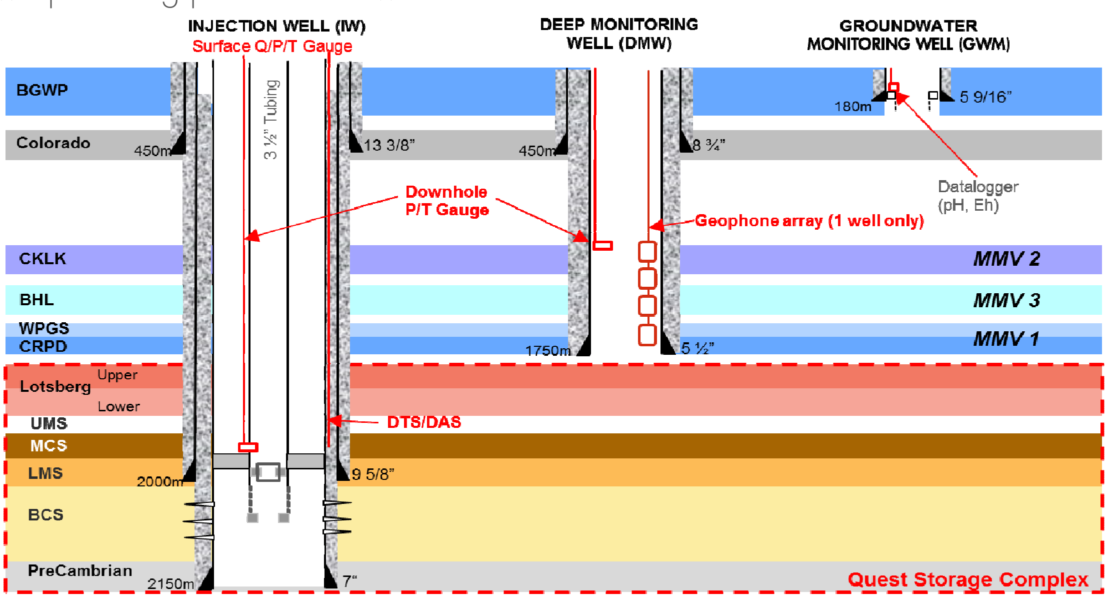


Figure 16-7: Quest project well types

16.5.2. Well Integrity

The Quest CCS project well design followed a risk-based approach. A specific well bowtie (see figure 17-8) was built to ensure the well design would lower the risk of loss of containment from the BCS storage complex to as low as reasonably practical (ALARP) levels. Each barrier and mitigation of the bowtie was incorporated into the well and well operations design.

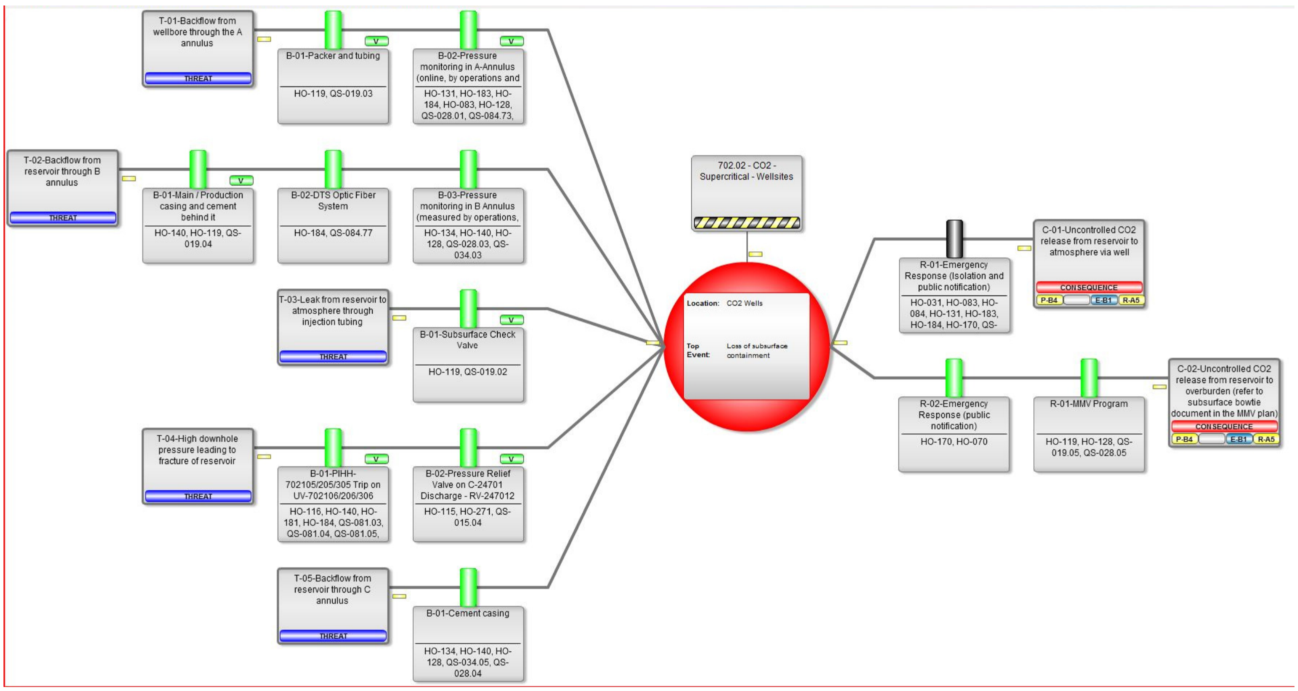


Figure 16-8: Bow-tie used to assess well integrity design

16.5.3. Road and Pad Designs

The Quest CCS project has 4 wellpads with the different types of well. Each pad was designed to limit land disturbance by using pre-existing access or clearings whenever possible. The locations of these are primarily based on reservoir conformance issues, distance to towns, houses and sensitive areas, reservoir quality of vertical target, distance from the edge of the 3D seismic survey and distance to the pipeline.

16.6. Measuring, Monitoring & Verification (MMV) Programme

The storage component the project was accompanied by a detailed Measurement, Monitoring and Verification program designed to prove containment and conformance both of which are key criteria to support the final site closure and hand-over of liability to the Crown at the end of project life.The MMV Plan describes the type, frequency and coverage of monitoring activities included in the four domains, namely the Atmosphere, Biosphere, Hydrosphere, and Geosphere. The diversity of monitoring technologies mitigates the risk of a particular technology failing to work at optimal levels for the project. See Appendix 24 for a comparison of the monitoring activities from the 2011 MMV Plan to the executed 2015 MMV Plan through the pre-injection, injection, and closure phases of the project.

16.7. Key Lessons Learned – Subsurface Development and Execution Planning

See the document titled "Quest Subsurface Learning Summary – Execute" Doc # 07-3-ZG-7180-0042 for a detailed list of the Subsurface lessons and learnings.

Some key Execute phase recommendations and lessons from the subsurface geophysical work include:

1. To successfully implement two different MMV technologies into DMW 8-19, a Project Execution Manager (PEM) is required. This person should be accountable for all the equipment being installed and the work related to the install. The PEM role requires strong communication skills, technical expertise in completions and diagnostic instrumentation systems, and strong field experience with a wells back ground. There are PEMs at Shell who are specifically trained for this type of work but there are few. Quest subsurface found a PEM through an integrated meeting related to the DTS/DAS technologies with the TED (Technical Excellence Deployment) team. Design issues like pressure control and well head design were identified which were caused by a lack of integration that an experienced PEM is likely to pick up when involved at the early stage of well development.
2. Technologies that could impact each other during implementation need to involve a PEM during their initial design and assessment. The PEM should be included in vendor screening and selection to ensure adequate vendor experience with the design/requirements of an integrated but different technologies.
3. VSP modeling prior to acquisition proved to be very effective in designing the survey. This is common practice within the Shell Geophysics community that proved to be successful.
4. DAS fiber technology is getting better every year and should be assessed as a recording technology for all VSPs.
5. Reducing the VSP survey from 3D to 4 walk-away lines centered at each well proved to be very effective from an acquisition stand point with a good chance of repeatability. The shorter time in acquisition allowed for less variability in surface conditions than a 3D would have and required less land permitting.

17. HEALTH, SAFETY, SECURITY AND ENVIRONMENT (HSSE) & SOCIAL PERFORMANCE

17.1. Environmental

17.1.1. Pipeline

Pre-construction

Stantec was contracted to perform environmental baseline monitoring and write the EIA (Environmental Impact Assessment). They also assisted with the regulatory requirements for the project.

Construction

During construction, Environmental Inspectors were hired on contract through Stantec. The inspectors attended morning meetings with the pipeline crews, where they were given the high priorities and activities for the day. The inspectors reported in daily to a site Shell Environmental Engineer. The reports were also provided to the pipeline construction superintendant and the lead Onsite Shell Representative (OSR). The main task of the inspectors was to maintain and document compliance to the project Environmental Protection Plan, which was written to incorporate all requirements.

The turnover from the inspectors included the "Environmental As-builds", a spreadsheet summarizing all key aspects, as well as a set of marked up environmental alignment sheets.

Landowner interface

All landowner issues were dealt with via the land man, contracted through Integrity Lands.

Stakeholder commitments:

All landowner commitments were tracked in the CTSE (Commitment Tracking and Stakeholder Engagement) database.

17.1.2. Capture

Licensing/ Approvals

The Quest Project operated under the existing Scotford APEA (later AER) approval, which was amended to include the construction and operation of the Quest Capture facility.

Compliance:

In order to maintain compliance with the approval, the project functioned under the Upgrader environmental management system (EMS), which is an ISO 14001 certified system. Environmental compliance was monitored by the P&T environmental engineer, who coordinated with the Scotford environmental group as required. All commitments were tracked in the CTSE database, which was included in the project handover process, P2A.

Tracking and Reporting

All incidents were reported and tracked in SIRS, under the Quest project. All waste streams were tracked under the Scotford waste department, using Quest project POs. Water was sourced from the Scotford Upgrader wherever possible. Water was also trucked in from municipal sources. Approval of new products also followed the Scotford protocol.

17.2. Technical HSSE

Technical Process Safety control points were identified in each project's PCAP phase and their deliverables reviewed and signed off using company's approved and authorized Technical Authorities (TAs). In case of PCAP-selected Technical Safety Process control points, they were reviewed and signed off by the project appointed HSSE & SP accountable discipline TAs. The most relevant control points related to Technical Process Safety can be grouped within the following:

- HSSE & SP Premises
- Hazard and Effects Register (risk yellow 5A and 5B and red risk)
- Process Safety Reviews (e.g. HAZOPs, PHAs, Desktop Safety Reviews)
- Safety Risk Studies (e.g. Physical Effects Modelling (PEM), Quantitative Risk Assessment (QRA))
- Design HSE Case

17.3. Construction HSSE Execution

Quest CCS Front end planning began long before field execution with a team of front end HSE planners and technical safety engineers responsible for CHAZID's, HAZOP and CWPP activities related to the scope. This scope were developed out of the engineering home office (in Calgary) and were mostly complete prior to field execution activities.

At the mod yard, having HSSE representation helped build the HSSE culture of the mod yard team. However, the contracting strategy and the mode of module fabrication and assembly contract will determine the amount of HSSE support that would be needed.

Leading up to field execution there was a strong Contractor Safety Management (CSM) focus with the evaluation and selection of contractors for the capture facilities site scope of work. This activity consisted of pre-qualification review, ISN requirements, Green Banding assessments and Green Banding+ assessments on the narrowed down list of contractors. From this, project action plans were developed for specific contractors chosen to work on the project scopes. Mobilization plans helped organized contactors to site ensuring they have first vetted their equipment and personnel to meet the project's expectations.

As part of the construction execution, Fluor Constructors had a strong team of HSE professionals assigned to the project, ranging from an HSE Manager, field level HSE technicians, to HSE leads and an Occupational Nurse. The Fluor team handled the day to day HSE activities on the construction site with Shell HSE providing oversight and assurance activities and supporting the Fluor team.
Shell HSE also kept the training scope of the project, orientating over 3000 personnel and providing a broad range of other training service and outside training coordination.

17.4. Key Lessons Learned – HSSE

The HSSE & SP Best Practices included:

- Best in class "commitments" database (CTSE) to track and monitor till completions; hundreds of commitments and actions tracked.
- Senior leadership engagements; attended toolbox talks every morning with craft and kept up this level of engagement day in and day out; participated in every Quest orientation & HSSE Leadership course.
- 40% of construction management team time was DIRECTLY involved in Visible and Felt Safety Leadership. Over 1600 management safety actions items were tracked to completion over 2013/2014.
- All supervisors (including Shell) had to take HSE Leadership once assigned to Quest
- Use of HSE Tracker for HAZOP actions closeout
- Adoption of new technologies to improve process safety and personnel safety. This included new styles of construction lighting (Airstar), fall protection systems (both fixed and portable) and use of deckhand grapples for handling pipe and removing people from line of fire situations.
- Frequent and effective project communication strategies. This ran a gamut of different channels of communication which included:
    - 7:30 am HSSE meetings with Quest leadership (including Fluor)
    - Bistro – lunch and learn events on a variety of Quest related topics.
    - Job bulletins
    - Lessons Learnt from incidents
    - Weekly toolbox topics
    - Lunch and learn for all levels of project staff including field craft
    - Engagement lunches with craft and field supervision
- Very successful Heavy Lift program. Project identified one Lifting focal point for all lifts. Additional Rigging training over and above whatever the crews came with was mandatory for the riggers

Due to project and company dynamics, it is important that future projects pay attention to planning and managing the following areas:

1. Early in the project, the project execution team must understand and agree with final customer on technical HSSE requirements and expectations. During the development of the Design HSE Case, ensure early engagement with the "Client", in this case Scotford, to ensure that the project Design Case will be consistent with the asset's Case. To avoid any confusion and to maintain an efficient hand over, these discussions should take place early in the project. Align on ALARP demonstrations, HSE Register, etc. and ensure that there is an agreement that all hazards have been identified and will be appropriately managed to Tolerable and ALARP. Design Phase Performance Standards must reflect the identified Major Hazards and should be incorporated into the design and associated equipment specifications before procurement occurs. This needs to be done in conjunction with engineering and procurement.
2. Organization Management of Change: ensure minimum impact on project and people due to flaw handovers, onboarding, staff turnover, competency issues, departing windows, smooth transitions.

See Appendix 23 for the detailed list of HSSE lessons.

18. CONSTRUCTION HIGHLIGHTS – CAPTURE & PIPELINE FACILITIES

18.1. Construction Management Team

18.1.1. Shell Construction Management Team

The Shell Construction Management team for Execute phase was set up as planned, with one change:

An Area Construction Manager for the Capture Facility was added to the Shell Construction Management Team in late 2013. The large scope of the Capture Facility and the under estimation of the time commitment required in making a step change in HSSE required this additional resource to allow the Shell Construction Manager to focus more attention on the CO_2 pipeline construction and module/spools fabrication & assembly scopes. This also reduced the Shell Construction Manager's number of direct reports. See the as-built Shell construction organisation chart (Section 5.2).

18.1.2. EPCM Contractor Construction Team

Fluor, acting as EPCCm, executed the CO_2 capture facility and offsite module fabrication and assembly. The key learning on team integration was the ability for the Fluor and Shell construction management teams (CMTs) to effectively and efficiently act as a fully integrated team – "one team" approach. This was the major contributory factor for the overall success of the Quest project, as the relationships developed and built between Shell and Fluor teams were outstanding.

18.1.3. Pipeline Construction Team

Shell construction self-managed the Pipeline construction scope. The Pipeline Construction Superintendent assembled a competent Pipeline Construction Management Team (CMT) to manage the subcontractors for the pipeline, electrical & instrumentation construction scopes.

18.1.4. Wells Construction Team

The wellhead facilities were installed by the Pipeline CMT. The only significant change in the original plan was that the Pipeline CMT took Care, Custody, and Control from Quest Operations, after the Shell Wells Completions Team turned over the well sites to Quest Operations. This facilitated a more efficient permitting process for the Pipeline CMT to execute their scope; however, it also did burden the Pipeline CMT with issuing permits for scopes they were not directly executing.

18.2. Construction Quality

Although the Construction Quality Plan and the Flawless Delivery Plans were issued later than desired, the Quality of the Capture Facility and Pipeline were good. Flawless was implemented too late on the Pipeline work, although it did get implemented, it was near the tail end of pipeline construction.

Weld Reject Rate

The Pipeline weld reject rate was 9.2%. While the rate may seem high, the weld procedure was very difficult to execute and the requirements were stringent. It was difficult to qualify welders to execute this weld procedure.

The weld reject rate at the Capture Facility for the Closure Welds was 14.7%. Initially the early reject rate on Closure Weld was over 25% and through corrective actions this was substantially improve to finish at the 14.7%. There were stringent requirements on the Closure Welds. There were 23 repairs required on 156 Closure Welds. While the repair rate was high, the Closure Weld program was successful in eliminating the significant cost and schedule associated with hydro-tests. The overall weld reject rate for all capture facility welding was 4.3% for butt welds.

Rework Rate

Total Rework at the Capture Facility was 3.9% of total direct field hours. The target was 3.0%; however, the actual rework is acceptable and much better than the performance of some past projects executed in Alberta. The rework rate is broken down as follows:

- Engineering 0.8%
- Vendor/Sub-contractors 2.4%
- Construction 0.6
- Other 0.1%

The tracking of rework, for the Capture Facility, was well executed and allowed for a very effective back charge program. Of $1.6M identified in actual back chargeable work, over $600K was recovered.

Some rework was experienced on the piping tie-ins by SPG and Turnaround work. With the piping tie-ins, there were 3 instances where there was misalignment at the piping interface between SPG's spool and Fluor's spool and had to be reworked. Shell Scotford turnaround team installed a guillotine in the backward way at the HMU3 stack.

18.3. Construction Scope and Module Management

The major scopes of work were managed by the Construction Management Team(s) according to the construction management and execution plan. An area of improvement is:

- "Oversight and steering for the SPG Tie-in and Turnaround scope" which was a major scope of work that could have been more effectively managed by having a more direct Quest CMT management and supervision. While the Quest CMT eventually did actively manage and continuously applied a more direct oversight approach, initial planning on having more direct control from the outset as well as incorporating and mandating more of Quest's systems and processes to control this work would have resulted in better performance.

18.4. Module Fabrication and Assembly Programme

The module program of the Quest Project successfully removed from site a significant amount of man-hours and also allowed for the early detection of many issues that would have had significant schedule and cost impacts if construction execution were predominantly "stick-build". Some of the key factors for that success included:

- The early buy-in of the engineering team into the 3rd Generation Modules concept.
- The level of involvement and preparedness of the construction team's input into the design of all the facilities and modules.
- From the Construction Management Plan, the module yard team developed a list of actions and checkpoint-items as part of the module yard mobilization readiness checks. This process took 3 months of periodic review meetings and a final Assurance Readiness Review conducted with a panel of independent subject matter experts.
- A robust module contracting strategy and plan which included market conditions research and scouting visits to several module yards with shop facilities along the Alberta High Load Corridor. Five fabricators were invited to bid due to their market availability, strong HSSE performance and previous technical experience. Parallel to the bidding process the construction team led a HSSE Green Banding plus assessment to the five contractors invited to bid (see Appendix 11 for the lessons and outcomes for the module contracting process).
- The module contract signed with KBR was kicked off over two days with first day dedicated solely to HSSE; the second day involved breakout sessions amongst each group to align on requirements, expectations, and deliverables. For the most part this was a success, other than the Quality group which delayed their session causing deliverables to be late. Another beneficial breakout session that should be conducted is Engineering and Turnover expectations.

The final list of modules consisted of 69 modules: 33 equipment modules, 35 pipe-rack modules, and 1 stand alone electrical substation. In terms of configuration or geometry 5 were vertical modules and 5 had buildings within the module boundaries. The vertical modules had the technical challenge of being built in the vertical position and then laid down horizontally for transportation. For the modules with integrated buildings (i.e. those with e-houses) and rotating equipment were the best test case for the 3rd Generation concept with the completing of a significant number of pre-commissioning tests prior to shipment from the yard.

Module Programme HSSE

The module contract was set up as Mode 2 and managed by Fluor, with Shell still accountable for HSSE incidents of KBR while utilizing their own HSSE management system. This involved leveraging Shell/Fluor Construction and HSSE resources to assess KBR's system and the issue of a bridging document with recommendations to close some of the gaps identified. The Mode 2 relationship was an excellent opportunity for continuous team alignment that included opportunities for the Shell/Fluor Team to learn how to intervene by convincing rather than imposing rules and for the KBR team to accept the intervention with "Goal Zero" as the common target. Overall the HSSE program was a success with one unfortunate medical treatment case of a worker receiving stitches in a finger trapped between two pieces of steel while sorting them out.

Module Programme Schedule/Cost

The module program was completed approximately two months behind schedule; with a 2-month delay in mechanical completion impact to site construction. The module program delay was mainly due to:

- Material delays, on the stainless steel piping and weld-in valves supplied by the EFA supplier caused by some pricing issues. This caused delays in pipe fabrication and ultimately decision was made to pipe through (for welded vales) and cut in the valves afterwards for the H_2 and CO_2 valves. The rest was managed at site by putting in flanged spools.
- KBR's poor interface management among the different KBR departments (Shop-Yard-Warehouse, Etc). This lack of effective interface management was particularly prominent with their subcontractors especially for Ideal Welders (IWL). IWL was located in British Columbia and was subcontracted by KBR for piping fabrication to mitigate the impact of KBR's own limitations in fabrication. Lack of planning for material management and shipping restraints through BC to Alberta caused additional field welds, re-work, and schedule delays in the yard.

The module delivery sequence was developed early in the design phase. This sequence was included in KBR's contract and several engagement sessions with the mid-level management helped to maintain the sequence for most of the cases. Assessment of full impact of some of the deviations to the delivery sequence were discussed at weekly meetings with site personnel.

The spool fabrication and module assembly program came in on budget. This includes late requests from KBR of adjustments due to changes and delay impacts.

Module Programme Engineering & Quality

As part of the execution strategies of 3rd Generation Modularization, a strong Field Engineering team mobilised prior to start of yard activities and was part of the team residing in the module yard. This allowed for quick resolution of discrepancies between equipment and structural steel, lack of details for electrical and control connections, or installation details. The Field engineering team at the yard also played an important role in the quality surveillance program and witnessing of tests. The field engineering team resolved many issues that would normally have been identified in the final stages of the project. In addition the field engineering team moved to the construction/module installation site after completion of the module assembly to maintain continuity and to apply the lessons learned from the yard in resolving any field installation issues.

Following a cold eyes review recommendation, KBR was requested to subcontract a 3D laser scanning program. Reality Measurements, a local company, performed the 3D scanning of the modules, comparing against 3D model. KBR corrected any deficiencies prior to the modules being shipped to site.

18.5. Pipeline Construction

The Quest pipeline is roughly 65km in length with 3 laterals and transports supercritical CO_2 from the CO_2 Capture facility (at the Scotford Upgrader) to three wells located in the Thorhild County area. The pipeline consist of:

- 6 line block valves located a maximum of 15km apart
- 3 well site skids
- 2 pig launchers and two pig receivers.

18.5.1. *Pipeline Construction Schedule Performance*

URS Flint supported The Crossing Company (TCC) with the Horizontal Directional Drill (HDD) beneath the North Saskatchewan River (NSR). TCC mobilized in early Sept 2013 and completed the HDD of the NSR in 31 days.

A Construction Readiness Review was completed in July 2013 prior to the start of the main pipeline construction by Flint URS. Construction initially progressed slowly primarily due to welding productivity challenges (see Pipeline Lessons Learned Appendix 19)and by November it was apparent that the pipeline construction schedule would slip significantly if immediate remedial actions were not taken by the project. The biggest risk was that construction would not be completed before the next spring breakup in 2014 which would affect accessibility due to road bans and wet conditions. The schedule recovery measures required URS Flint ramping up manpower to 300 by early January 2014. The ramp up increased productivity and by late March 2014 the main line and laterals (for well sites 7-11 and 8-19) were welded up. Welding of the 5-35 well site lateral was delayed due to the spring breakup and was completed at the end of May 2014. Ditching of the mainline and 8-19 lateral were completed prior to breakup while ditching of 7-11 and 5-35 laterals were delayed until after the spring breakup.

Hydrotesting of the mainline began in early July 2014 with LBV-3 being used as the fill point for both the south and north sections. The project obtained regulatory approval to withdraw and return Hydrotest water to the NSR which made the process a lot faster. The laterals were hydro tested individually with county-supplied potable water.

Hydro testing was followed by cleaning which was performed till the dirt penetration in the foam pigs was below ¼ of an inch. Dry air was then blown through the pipeline to a dew point of -45°c. Once all LBV valves and well site skids were installed, the pipeline and skids were dried again to -45°c dew point and pipeline and skids preserved with Nitrogen. Final clean up and reclamation of the pipeline started in early July 2014. Water pumping, rock picking, and fence replacement were all activities that were more extensive than originally anticipated. Final clean up was completed on Oct 18, 2014.

In early stages of the construction, URSFlint was unable to provide reliable cost and schedule forecasts, causing considerable strain on the project team relationships. The URS Flint project management team was changed and this resulted in considerable improvement in schedule and cost forecasting and reporting.

Approximately 25% of the work was subcontracted by URS Flint who performed the subcontract administration well. With the exception of rig mats, field purchasing was efficient and well documented. Flint Pipeline Services subcontracted the work at wellsites and the LBV sites to its subsidiary Flint Mechanical. Flint Mechanical executed this work well and was very well integrated with the project team.

18.5.2. Pipeline Construction Cost Performance

The pipeline construction experienced significant growth in cost of about 300%. The major contributors to this growth were that:

- Contractor experienced difficulty due to unique pipe metallurgy; this resulted in much lower productivity than planned.
- Subsistence allowances (for extended time and higher workforce) were not adequately covered in the original estimate (CLAC agreement).
- Contractor did not walk the complete Right of Way when preparing the final estimate.
- Contractor underestimated the number of bored crossings due to soil conditions and depth of crossings (17km of HDD)
- Contractor underestimated the impact of land owner issues

See details and lessons learned on the pipeline construction in Appendix 19

18.5.3. Pipeline Construction Quality

During the early works of the Inside Battery Limit (ISBL) pipeline it was recognized that the Quest pipeline requirements and the pipe alloys in the Quest Pipe demanded a welding procedure that was not previously known to the contractor companies. A decision was made to hire Flint independently to find a WPS that met the criteria and provided a mechanically sound weld. Flint provided 4 weld procedures, which were approved by the Shell Technical Authorities for use on the Quest Pipeline Project (see details of weld challenges in Pipeline Lessons Learned Appendix 19) .

Crimtech Services Ltd. was awarded the contract for the fabrication of the 6 line block valve (LBV) skids, 4 pigging skids and 3 well site skids. The Shell approved material vendor list was not released to Crimtech. Therefore Crimtech procured all pressure boundary fittings through Comco, with Toyo approving the MTR's, this led to delays in material delivery, and ultimately the delivery of the skid packages to the field.

The lead URS Flint QC person was not very knowledgeable in the multi-faceted aspects of a pipeline project; hence there was a lack of effective leadership for the pipeline construction QC. Extra support was provided by the Shell Construction Management Team to ensure code requirements and project specifications were met.

18.6. Work Optimisation and Productivity Management

18.6.1. Minimizing Onsite Construction Work

The 3rd Gen Modularization strategy selected for the Capture Facility greatly reduced the site hours and moved them into a more controlled environment, as per plan (see Modules Lessons Learned Report Appendix 11, 12 and 13). Also, the well site and pipeline skids reduced site hours for the Pipeline scope, as per plan.

18.6.2. Integrated Turnaround Schedule

Quest avoided any significant workforce during Scotford Turnarounds throughout the project and did not impact turnaround manpower or site infrastructure. Scotford deferred the full HMU3 outage from the spring of 2014 to spring 2016. However, they did have a Pit Stop in the spring of 2014 to allow the Quest tie-in work in HMU3 which was part of the original Turnaround work, to be executed within this Pit Stop window. This change in HMU3 TA execution plan for Quest tie-ins did increase the Quest turnaround cost since it had to pick up the majority of planning and execution cost.

Fluor executed some of the electrical MCCs tie-in work during the HMU2 2012 TA and during the HMU3 Pit Stop. It was planned for the Scotford TA group to execute this work, but upon closer evaluation of the TA team's capacity and organizational effectives to execute E&I scope, the project decided to award the execution of the MCCs tie-ins to Fluor during the TA.

A more robust schedule integration could have been performed between the construction and turnaround schedules, especially with regards to the E&I scopes & activities.

18.6.3. Managing Construction Site Interfaces

The Interface Management Plan and the Quest/Scotford Engagement Plan were robust plans that served the project well and were mainly led through the Quest Operations team. However, on managing day to day interfaces between Scotford and Quest construction, the Construction Engineering team and the Construction supervision team played a key role in establishing the necessary interfaces to manage the detailed activities to execute the Quest scope.

18.6.4. Construction Indirects Management

There was a lot of attention and focus on the Capture Facility indirect costs and man hours during Define and also throughout the Execute phase. The tracking and monitoring by Fluor throughout the Execute phase was excellent with active management by Fluor and Shell throughout construction. The Fluor craft IFL/DFL ratio was estimated at 24% at FID. The final ratio ended at 45%. The overall (including subcontractor progressable hours) craft IFL/DFL ratio ended at 31%. While the Fluor IFL/DFL ratio increase was significant, Fluor managed to stay within their allocated budget. There was some uncertainty in estimating the craft indirect support required for the Capture Facility as a significant amount of on-site man hours were reduced from the use of 3rd Gen Modularization, and hence a core craft indirect support was required to maintain the site in a safe and productive manner, despite a lower than normal direct man hour base. There were instances where indirect support was increased intentionally to raise the bar in terms of site cleanliness, housekeeping, and winter preparedness. Also, to enable Safe Production, there were instances identified through the Delay Tracker, where an increase in indirect support would enable safer and more productive work fronts. However, the tracking and monitoring enable informed decisions to be made that provided the right balance of indirect support to best enable safe production. Management of indirects is more of an art to strike the proper balance and requires continuous active management.

The tracking and monitoring, as well as active management, of Fluor CM staff indirects were also excellent. The Type 4 estimate for Site and Modyard Fluor staff was estimated at 265K hours and finished at 275K hours. This is considered good performance considering the deterministic MC date slipped 2 months and the Modyard staff was significantly extended by approximately 3 months. Turnover of Fluor staff was very low.

18.6.5. Lean Construction Initiatives

The Quest project deployed a Lean Construction Program from the mid-Define phase, and continued it throughout the Execute phase. Lean Construction, as a methodology was new to the project team and hence a certified Lean practitioner/Instructor was hired as Lean Construction Coordinator embedded in the Shell construction management team, to develop and deploy tools, tactics and techniques that would support the delivery of the Quest CCS project.

During Execute phase, Lean construction was operationalized in the field work processes. This included an introduction to Lean and the seven categories of waste for all of the owner, contractor and subcontractor teams. This was achieved through including Lean awareness slides in the project orientation. All team members were given the opportunity to make suggestions both on issues they encountered and potential remediation(s) through "craft innovation forms", which provided a standard structure for the communication from field to management. Suggestions came from anyone on the project and were used for just identifying the focus area and populating the Opportunity log for making strategic decisions to manage and improve productivity.

Lean construction focused on balancing the flow of material, manpower, communication and approvals; resulting in reduced rework and frustration, improved productivity and reduced risk by empowering the workforce through the Lean Culture.

18.6.6. Work Face Planning (WFP)

Work Face Planning (WFP) was deployed on the Capture Facility by Fluor with development and rollout of a WFP procedure in Define. Various audits were performed on WFP and continuous improvement was employed throughout the execute phase. Approximately 80 Lesson Learned were capture on WFP on the Quest project (see Appendix 17 for the WFP lessons). Good tracking on Field Installation Work Packages (FIWPs) was employed which tracked the FIWP throughout various phases and right through to Close Out of the FIWP, and the tracking was a part of the Weekly Construction Report that served as input to good discussions at the weekly meetings with the senior Shell and Fluor project staff. Some key activities and outcomes of WFP include:

- FIWP man hour tracking was not integrated into the overall progress measurement system. Tracking of FIWPs by man hours was informal or non-existent. FIWPs integration into the progressing system and tracking FIWPs should be implemented on subsequent projects.
- There was a struggle to Close Out FIWPs as the close out process was not integrated into the MC+ system (the MC+ system was the designated EPCCm contractor's system for completion).
- A 12% reduction in the Fluor site location factor was incorporated into the Type 4 estimate to account for the benefits of WFP. Therefore, theoretically a 1.0 PF would have represented a 12% reduction in direct man hours. The overall PF ended at 0.95. It is difficult to determine the exact benefit that WFP had, given the Lean Construction initiatives as well. It was probable that the piping direct hours were under estimated, however, the Shell project team decided to stretch Fluor in that regard. The project believes that WFP did provide a significant benefit to the project.
- Fluor performed two cycles of Performance Engineering (Direct Activity Analysis). The Fluor target was set at 49% on direct activity. The first cycle was performed in May/14 and revealed 44.7% on direct activity. Recommendations were provided and the second cycle was performed in Aug/14 showing 43.4%; however, the analysis revealed that for a few days there was extreme heat. Site directives were sent out during the extreme heat for workers to take micro breaks as required during this period. The second cycle results with the extreme heat days excluded show 50.1% on direct activity.
- Fluor Home Office performed three SCRUBS (Fluor internal construction review). Minor actions were generated for slight improvements.
- The orbital welding program planned for the Capture Facility did not prove as efficient as planned. The project aborted this program.

- The Fluor Weekly Progress Report was very good. It served as a very effective tool for management discussions during the weekly progress meeting. The weekly meeting was very effective for managing the work and also in establishing alignment and trust between Fluor and Shell.

18.6.7. Maximizing Constructability

Constructability was a focus throughout all phases of the project. A key learning is that a more robust constructability program and construction resources, including contractor resources, could have been applied to the Pipeline scope.

The Capture scope, executed by Fluor, had good constructability throughout the project. The Fluor Construction Manager was the longest serving member on Quest project - was involved in the SELECT phase through to Mechanical Completion. While there was constructability processes and logs, the largest benefit was derived by having Fluor construction resources available in the Define and early Execute for the day to day interfacing with engineers and designers. Also, the Path of Construction was developed very early and a Construction Driven approach was implemented throughout the project.

The Shell Construction Manager started in early Define. There may have been additional benefits if a few of the other Shell Construction Leads had been involved in Define as well.

18.6.8. Construction Readiness

Construction Readiness (CR) was a major focus on Quest. A Construction Readiness plan was developed that included a very detailed CR checklist which was set up 6 months prior to planned date for site mobilization, and was initially reviewed monthly (later on a weekly basis) with the owners of each deliverable and due dates. Driving the CR as an on-going work planning process rather than just a review or an event was beneficial. Early Works at the Capture Facility was executed by sub-contractors, a learning from the Early Works CR process was that most of the sub-contracts were not executed at the time of CR approval; therefore, integrating the readiness of sub-contractors needs to be a part of the CR check/process.

18.7. Construction Completions and Pre-Commissioning

The CO_2 capture facility completions activities for a progressive turnover of the project systems maintained the same level of integration among the project groups i.e. Shell CSU, Shell P&T, and Fluor. Hence the database selected to manage the tracking of outstanding construction items/punches, quality records, and milestone activities per system was Fluor's proprietary MC+ system instead of Shell's Go-Completions system as required by Shell PS14. The selection of Fluor's system was driven by the need to maintain the smooth continuity/interfaces with other Fluor management processes. Also MC+ provided easier access to the Fluor team who were the main users of it. The completions team strictly followed the Mechanical

Completion and Turnover Procedure which was prepared during the Define phase using Fluor's know-how and experience from previous projects and with considerable input from the Shell team. See Appendix 18 for Construction Completions Lessons Learned.

The major contributing factors to the success of construction completions and pre-commission were:

- The adoption of Fluor's MC+ completions system and the implementation of a similar version of the Turnover Procedure for the handover of the modules.
- The early population of the completions database with all the tag items, ISO numbers, etc.
- The inclusion of system numbers and module numbers in the applicable engineering documents i.e. isometrics, instrumentation tag items, EHT circuit, etc.
- Continuous engagement and communication with the CSU team (who were co-located with the construction team in the same trailer) on their priorities, alignment, and strategies e.g. Operations team involvement in the preliminary walkdowns/pre-walkdown meetings and post-walkdown meetings/look back sessions.
- Early identification of roles and responsibilities of all the stakeholders.
- The Shell (P&T/CSU) and Fluor completions team members met twice a week to discuss challenges and improvements to the system turnover process

18.8. Industrial Relations and Labour Management

Capture Facilities

Labour from the Alberta Building Trades (ABT) was utilized for the Capture Facility and Module/Pipe Fabrication. There were very minimal labour relation issues for this scope. The ABT supplied skilled labour in a timely manner throughout the project. The Labour contractual requirements, Labour Risks Assessments, labour engagements, Market Analysis, a fulltime Fluor Labour Relations representative, and the development of a Labour Relations Plan (Toolkit) were key factors in making the overall Labour Relations (LR) a huge success for this scope. The project had budgeted $5M for the Capture Facility for subsistence, Attraction/Retention, and Temporary Foreign Workers. Zero dollars were expended from that budget. Fluor's weekly report had several key metrics on LR. Apprentices' ratios averaged between 20 to 25% throughout the project. Craft turnover was 4.9% on a monthly rolling average (however, that included apprentices going back to school). Women typically ranged from 6% - 8% of the weekly manpower. All foreman and above were enrolled in the Industrial Construction Crew Supervision (ICCS). Six people received their certification throughout the Quest project. There were many that had met the requirements to write the exam for certification, but chose not to or had completed their role on the project. Safety Engagement, respect in the work place, and rewards/recognitions played a significant role in the designation of the Capture facility site as a "Site of Choice". Overall the Labour Relation performance at the Capture

Facility was outstanding and that played a key factor in Fluor's performance and Quest's overall performance.

Pipelines

The pipeline was executed by URS who had signed a labour agreement with the Christian Labour Association of Canada (CLAC). CLAC did provide skilled labour. Subsistence allowances were not adequately covered in the original estimate. The daily subsistence rate was estimated lower than the actual. The growth in scope and hence man hours, compounded this under estimation.

18.9. Logistics & Infrastructure

More laydown space, as well as an existing tented structure, in the North Hub at Scotford, was added to the logistics plan. The tented structure at the Main Capture plot was eliminated. The tented structure in the North Hub served as a shelter for the Compressor until it was set in the Compressor Building.

A module staging area was added near the Scotford Fire hall, for an additional cost of $300K.

The lowering of the road under the high voltage power line near the Scotford Main gate was eliminated from the project scope. The power line was permanently raised. This saved $1M in cost.

18.10. Key Lessons Learned – Capture Facilities and Pipeline Construction

The strategy of requesting the module fabricator to design, supply, and install buildings on the modules resulted in schedule pressures and a considerable amount of interfacing with the supplier and the engineering office. Consider preparing a complete "Basis of Design" for buildings or direct engagement of the EPCM home office engineering with building suppliers so the buildings can be included in the free-issued components to the module yard fabricator (see details in Appendices 11, 12 and 13 – 3rd Gen Module Programme Lessons) .

See Appendix 16 for the full list of the construction lessons learned for the capture facilities and Appendix 19 for pipeline construction lessons learned. Appendix 18 shows the lessons learned for the capture facility construction completions

19. CONSTRUCTION HIGHLIGHTS – WELLS DRILLING

19.1. Pre-drilling

The first proposed CO_2 injection well, Radway 8-19, was drilled as an appraisal well in 2010. Locations for four additional wells were identified in 2010 although at that time the 3D seismic was only available over the southeastern part of the development area (covering wells 8-19 and 7-1. Landowners were contacted, well sites were surveyed and well licenses were applied for (and later withdrawn at the regulators request) for these four additional injection wells before the submission of the D65 in November 2010. The locations of the first licensed well and the four additional locations identified in the original November 2010 D65 submission are provided in Table 19-1 below.

Well UWI	Potential Injection well	NAD 27 UTM Zone 12 North	NAD 27 UTM Zone 12 East
08-19-059-20W4	1	5,997,747	370,705
07-11-059-20W4	2	5,994,417	376,674
10-06-060-20W4	3	6,002,874	370,401
12-14-060-21W4	4	6,006,367	366,539
15-29-060-21W4	5	6,010,249	362,409

Table 19-1 Well Locations included in the CO_2 Storage Scheme Application

In May 2011 the additional 3D seismic, acquired at the end of 2010 was processed, allowing for seismic interpretation in support of well site selection. It also allowed a more thorough review of the subsurface reservoir characterization on the sites previously selected based primarily on surface constraints. The total 3D seismic data then covered approximately 415 km^2 or about 11% of the AOI. The latest processed data, indicated increased frequency content of up to 100Hz, which for the first time allowed for an interpretation of an event near the top BCS. Although the presence of strong multiples, the thickness of the BCS and the amplitude of the basement reflector presented challenges for a reliable pick of the BCS top, a BCS thickness map based on an isochron between the top basement and top BCS events were able to be constructed from the 3D surface seismic. This map indicated BCS thickness and suggested the BCS to be thinning towards the north of the survey area as the Precambrian rises towards the “bald highs” interpreted from 2D seismic lines north of the Quest development area. Locations 12-14 and 15-29 in Table 19-1 above appeared less attractive on the basis of the new 3D seismic data. See Figure 19-1 below

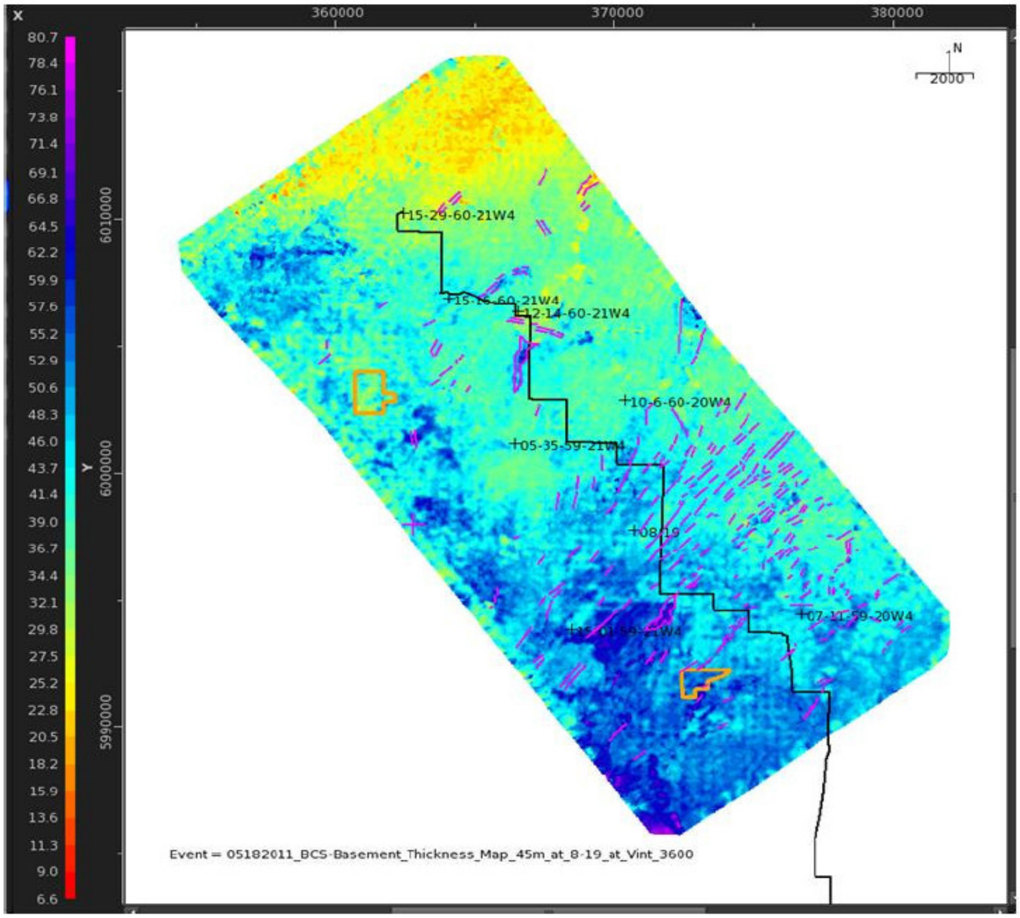


Figure 19-1: BCS Thickness Map Annotated with Faults Interpreted at the Top Precambrian Basement, the Pipeline Route and the Eight Notional Proposed Well Locations

The BCS thickness was thoguht to be much reduced on the 15-29 location. In addition the the 12-14 well appeared to be located right on some NNW-SSE trending seismic features that could represent a ridge of Precambrian highs, likely associated with reduced BCS reservoir quality. Therefore three additional infill locations were identified within the 3D seismic coverage area to complement the five existing locations that could no longer be moved due to regulatory and stakeholder constraints.

The exact locations of all eight injection wells submitted in the June 2011 update to the D65 submission and their notional drilling sequence are provided in Table 19-2 below

Drill order	Timing	Well UWI	NAD 27 UTM Zone 12 North	NAD 27 UTM Zone 12 East
1	2010	8-19-59-20W4	5,997,747	370,705
2	2012	7-11-59-20W4	5,994,417	376,674
3	2012	5-35-59-21W4	6,001,157	366,423
4	2013 Contingency	15-16-60-21W4	6,006,879	364,049
5	2013 Contingency	10-6-60-20W4	6,002,874	370,401
6	>2015 Contingency	15-1-59-21W4	5,993,780	368,543
7	>2015 Contingency	15-29-60-21W4	6,010,249	362,409
8	>2015 Contingency	12-14-60-21W4	6,006,367	366,539

Table 19-2: **Final Well Locations Included in the Updated D65 Scheme Application**

- The wells in the green rows in Table 19-2 represented the expectation case that comprised only three injection wells for Phase 1 development of the pipeline.
- The base case five injection well development case was represented by the Phase 1 wells (in green) plus the next two rows (in yellow) that would have been drilled in 2013 along with the construction of Phase 2 of the pipeline.
- If injectivity couldn't be sustained at sufficiently high levels, Phase 3 development would have been needed. Phase 3 would have comprised three infill wells (orange rows) and the final 6" pipeline extension to the pipeline endpoint from the Regulatory Application. It was expected that these additional injection wells would not be drilled until after start-up with sufficient lead time to be provided by the early field performance data of the development.

The expected 3-injection well case was predicted prior to raising the GIP (and was covered in the GIP).

19.2. Drilling Programme

The 2012-2013 drilling campaign consisted of drilling the wells required for the minimum development case (3-well scenario in the Storage Development Plan -SDP):

- The second and third injection wells (102/05-35-059-21W4 and 103/07-11-059-20W4)
- The three deep monitoring wells associated with the three injection wells (102/08-19-059-20W4, 100/05-35-059-21W and 102/07-11-059-20W4)
- The four remaining groundwater wells required to comply with the commitment made to the authorities (1F1/05-35-059-21W4, UL1/05-35-059-21W4, 1F1/07-11-059-20W4 and UL1/07-11-059-20W4)

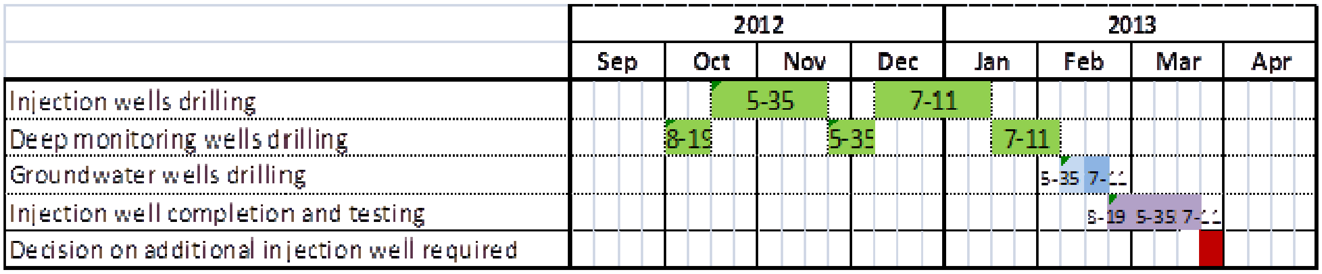


Figure 19-2: 2012/2013 Drilling Campaign Schedule

It also included an extensive data acquisition programme i.e. logging, coring, and pressure. and fluid sampling. This campaign was executed as per the schedule above Figure 19-2

Table 19-3 below shows the objectives of the drilling campaign and the key outcomes

Well Type	Objective	Outcome
Injection wells	Demonstrate well mechanical integrity	**Achieved:** every well was constructed with mechanical integrity. Although not compromising the integrity of the BCS storage complex, surface casing vents and gas migrations were observed on the wells drilled in this campaign
	Appraise BCS to inform the total well count	**Achieved:** - Demonstration of sufficient injectivity for the first years of injection (and probably for the project life time) - Measurements of the BCS fracture pressure - Acquisition of quality logs over the BCS as per plan This confirmed the 3-injection well development case.
	Demonstrate initial injectivity	**Achieved:** 12-24hr production tests were performed on the two new injection wells, confirming sufficient initial injectivity for a 3-well development (900 to 1800% of project requirement)
	De-risk connectivity in the reservoir	**Not achieved:** there was no pressure response seen in 100/08-19-059-20W4 due to the production test in 102/05-35-059-21W4. The absence of response does not allow concluding on the connectivity of the reservoir. This was planned to be addressed during the start-up of CO_2 injection
	Confirm containment	**Achieved:** the BCS storage complex seals were consistent with prognosis
	Project	**Achieved:** overall, the wells were drilled within contingency

	Delivery on time and on budget	of the approved budget (drilling costs were lower than planned, the completion costs were higher than planned due to increase of scope)
Deep Monitoring Wells and Groundwater Wells	Demonstrate well integrity	Achieved: every well was constructed with mechanical integrity. Although not compromising the integrity of the BCS storage complex, surface casing vents and gas migrations were observed on the wells drilled in this campaign
	Inform MMV formation selection	Achieved: Three formation groups were assessed with coring, MDT and logging and the Cooking Lake was selected as the preferred monitoring formation
	Inform MMV water samples baseline	Achieved: Quality water samples were taken from the BCS and the overlaying formations to inform the MMV baseline
	Project delivery on time and on budget	Achieved: overall, the wells were drilled within contingency of the approved budget (drilling costs were lower than planned, the completion costs were higher than planned due to increase of scope, and the groundwater wells costs were much higher than planned due to several factors)

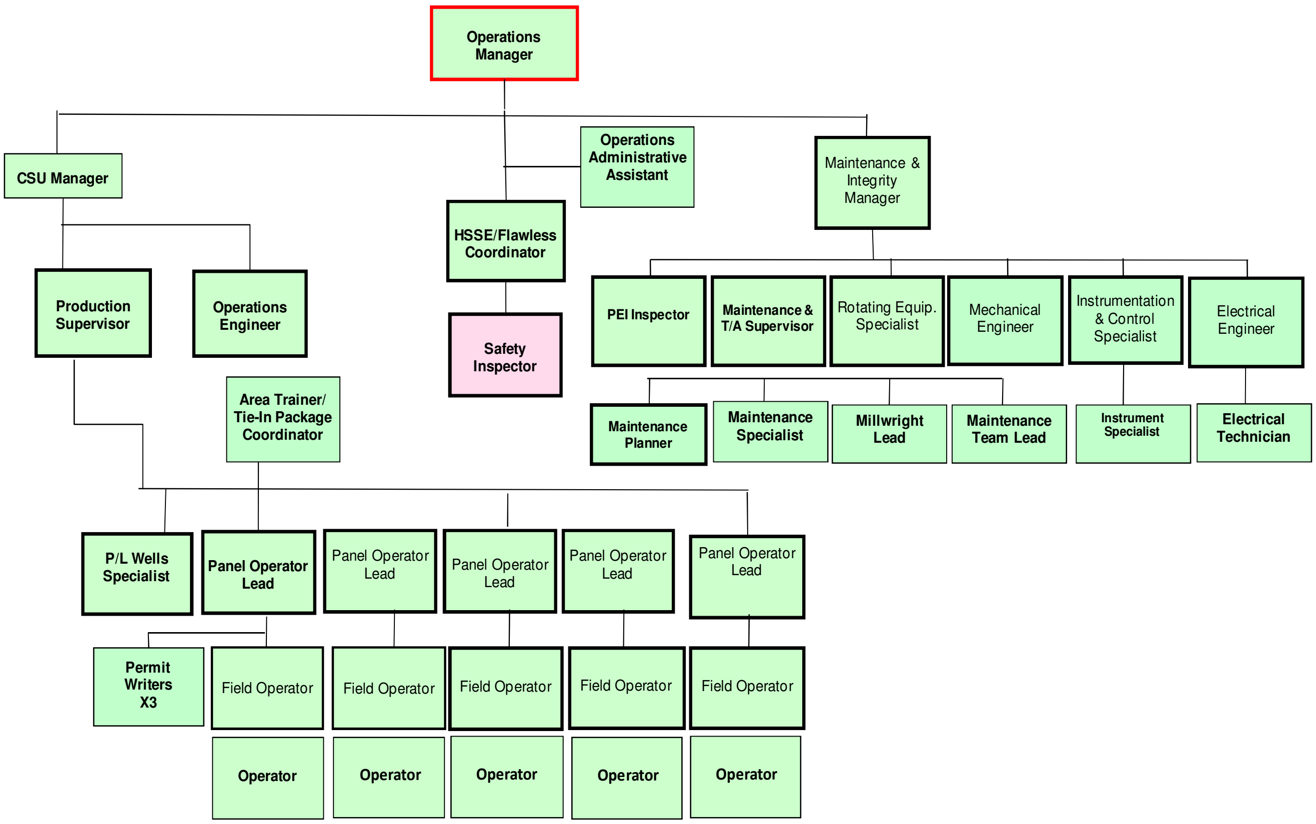
Following the successful drilling campaign, a decision note was issued to confirm the 3-well development case, and the purchase order for the second section of the pipeline, required for the 5-well scenario, was abandoned. In addition, the deep monitoring wells 100/05-35-059-21W4 and 102/07-11-059-20W4 were completed in the Cooking Lake to acquire baseline pressure data to further inform the MMV plan. The injection wells were suspended after installation of their final completion and the groundwater wells were included in the HBMP baseline activities.

19.3. Some Key Lessons Learned – Wells Drilling

1. Wireline Logging: Verify that depth correlations are made and noted on log prints as we had off depth perforations in one well and performed a mini-frac in a cap rock.
2. Optic fiber system installation: the optic fiber systems were installed above the top of the MCS. This doesn't enable the optic fiber system to be used to monitor the integrity of the first seal of the BCS storage complex, which was one of the objectives of this piece of equipment.
3. After action reviews should be conducted after drilling each well (or pad) rather than after the campaign to avoid similar systematic mistakes. Although this sounds like general best practice it is especially applicable in CCS wells where you are implementing never before seen well designs.

20. *OPERATIONS READINESS & ASSURANCE (ORA)*

20.1. ORA Organisation



20.2. ORA Activities and Philosophies

The ORA team had experienced operation and maintenance personnel (with the requisite site experience and knowledge of the existing Scotford Upgrader plant) who joined the project at the early stages (at late SELECT and early DEFINE) and were co-located at the EPCM engineering office. The input from the multidisciplinary ORA team (Operations, Instrumentation & Control, Electrical, Rotating Equipment, Static Equipment & Maintenance Integrity specialists) during design allowed the engineering team to incorporate the appropriate facilities Operability and Maintainability requirements aligned with the existing site standards. The ORA team participated in HAZOPs, 3D model reviews, P&ID reviews, etc. and provided input and produced PCAP deliverables e.g. SIMOP document, Operability Review Report, Asset Reference Plan, RAM report, master start up and operating/emergency procedures. During the Detailed Engineering phase, the ORA specialists also participated in vendor/fabrication shop visits for major critical equipment pre-shipment inspections.

The ORA team really drove the key message on the potential HSE benefits of Flawless Project Delivery (FPD) linked to personal & process safety; as for example, inadequate cleanliness issues during a start-up increase the risk to people completing routine start-up tasks e.g. opening and closing piping/filters/strainers etc. The operators engaged field craft in discussing flawless and held some lunch and learn sessions with the craft on flawless. Flawless was given more focus among the field craft whereby Flawless ideas/concerns were brought up by the field craft for management consideration, by adapting the same approach as safety with the use of reporting cards and drop boxes. This was late in the process but was tried with only a few coming in with ideas that were addressed. If this approach of flawless ideas collection from the field craft had started at the beginning of construction and rolled out with the FPD program, it would have had a bigger impact on making the craft feel they had a role to play in achieving the Flawless project objectives.

With the 3rd Gen Module programme, most work was done in the module yard so there were Operations personnel in the mod yard also driving flawless to ensure the modules coming to site met the ORA standards and requirements by participating in module walkdowns prior to shipment to the construction site.

ORA team also drove Flawless on the pipeline; however this was not implemented as part of the on-boarding of craft and management from the beginning so there was some push back due to lack of understanding.

Overall the flawless program was fully implemented in construction (module yard, site and pipeline) later than optimum due to changes in resourcing.

20.3. Commissioning & Start-Up

The objective of commissioning was to prepare the plant for a smooth start-up and operations. Performance testing was completed to prove that the plant met the guaranteed performance by the various licensors and the government of Alberta's funding agreement requirements.

20.3.1. Commissioning and Start up Philosophy

The philosophy of dividing commissioning into system blocks was applied to the Quest project. The unit blocks contained operational systems and were separated by battery limit valves and spades from live systems and other operating units.

The commissioning & handover of the different system blocks (Pipeline & Wells, Utilities, Compressor & Triethylene Glycol systems, CO_2 absorption systems in the Hydrogen Manufacturing Units, and the Amine system) was phased. This phased approach was dictated primarily by the overall product-in-tank dates and the construction handover of the systems rather than the respective durations of the start-up of individual system blocks. This stretched out the duration of CSU activities as systems were not handed over as per the deterministic schedule. This approach made construction more efficient, and since the project was cost driven, this approach was agreed to during the DEFINE phase of the project. The CSU team worked closely with the EPCM contractor to have the systems turned over in an order that could support cleaning activities.

In addition to the unit blocks, a number of large operational systems were common to more than one of the system blocks, such as cooling water and fuel gas. A systems completion approach for the large operational systems was planned to be used for the commissioning and start-up activities. Due to schedule delays and availability of systems in the existing operating units this approach was found to be impractical, and hence system segments were cleaned and commissioned as they became available. The CSU team identified priority systems and this was given to the construction team, including preliminary system definition and system block priority. In order for construction to be most capital efficient (i.e. remain in "bulk" mode), the construction completions sequence only loosely followed the priorities CSU proposed, which led to delayed and rescheduled CSU activities.

The EPCM contractor (Fluor) was responsible for the mechanical completion activities, with assistance from the Shell project team and the CSU team. The CSU Production Supervisor led the coarse cleaning activities required before mechanical completion. This included air blows, nitrogen blows, and line drying when required. Further cleaning was carried out by the CSU team after care, custody & control by CSU was achieved. This included hot condensate flushes, steam blows, nitrogen blows, and air blows. Inspection with a boroscope was used extensively to confirm cleanliness, particularly around the inlets to the compressor stages.

Flawless Project Delivery practices led by the CSU team and followed by construction contributed significantly to the low number of cleanliness issues and the speed with which CSU cleanliness standards were achieved. After a careful review and discussion with Shell CSU experts in New Orleans and Europe, a decision was made not to chemical clean, which resulted in significant savings and eliminated the need for disposal of cleaning chemicals. There were no cleanliness issues in any system even without the use of chemical cleaning agent.

The pipeline cleaning was managed by the P&T construction group (with extensive pigging of the line) and there were no cleanliness issues on start-up of the pipeline. It was imperative to remove any solid or small particles from the construction activities that could lead to plugging of the subsurface reservoir. The pipeline was cleaned with cleaning pigs (~1100 pigs were used) to clean small particles left in the pipeline. It was dried to a dew point of between -40°C and -45°C, and preserved under approximately 100 kPag of Nitrogen. This cleaning proved to be extremely effective, as the 5 micron filters at each well showed no signs of plugging, after approximately 100,000 tonnes of CO_2 injection to each well to the end of October, 2015. A specialized contractor performed the dry out with 40 °C dry air. Once the pipeline was dried out, it was filled with nitrogen to exclude oxygen until CO_2 was available from the capture facility. The preservation period lasted for approximately 7 months, and helped to identify integrity issues prior to introduction of CO_2.

The following split of responsibilities was agreed for the pipeline, and proved to be an effective strategy:

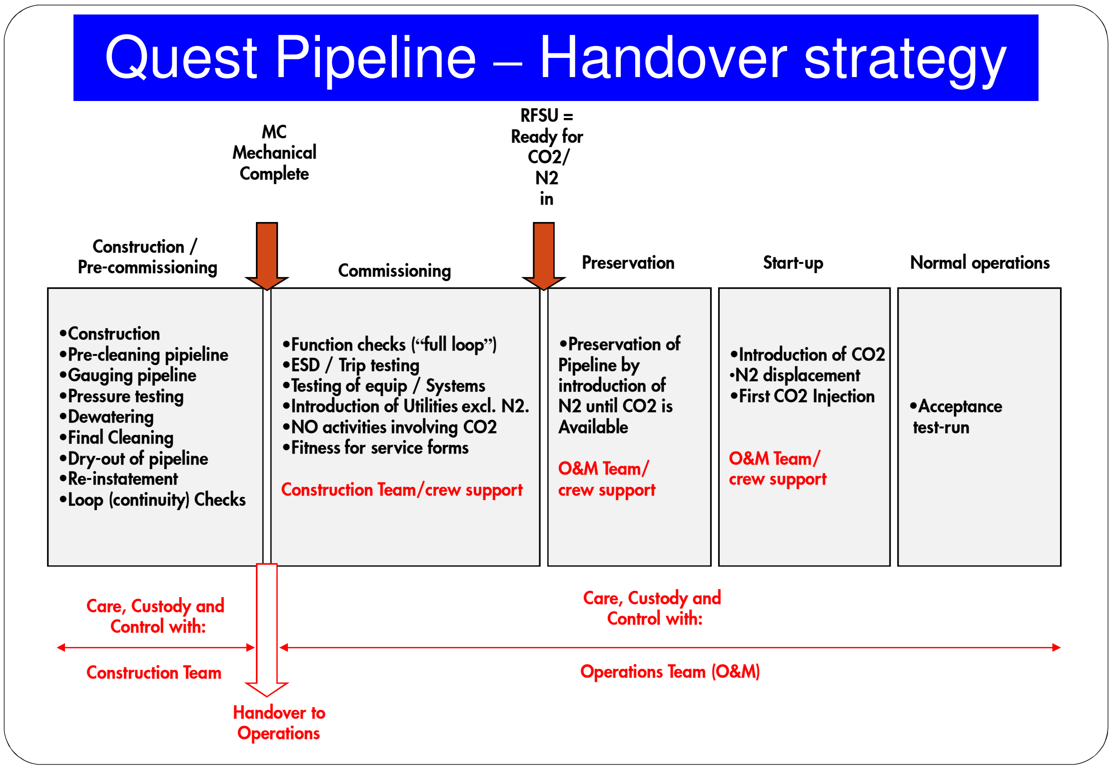


Figure 20-1: Pipeline completions responsibility and handover strategy

Following handover, the Shell CSU team was responsible for commissioning the new facilities. Due to the EPCM (Fluor) general lack of knowledge of the details of operating facilities, the CSU team chose to leverage existing site resources to provide maintenance assistance, rather than the EPCM contractor providing maintenance assistance. As entire (commissionable) systems were turned over to CSU, care, custody & control of the area shifted to Operations (CSU team), and this was made visible by following the "purpling " process of using purple ribbon and tags to clearly identify which areas were under CSU control. This permitted construction and CSU activities to continue progressing while in the same geographical area by maintaining clear physical boundaries.

20.3.2. Vendor and Specialist Support

The EPCM contractor did organize vendor and specialist assistance during construction and before mechanical completion. The Shell CSU team organised vendor and specialist assistance during commissioning, start-up and performance testing. Utilisation of vendors to assist with cleaning and drying of the compressor piping enabled the CSU team to shave significant time off the CSU schedule.

20.3.3. CSU Schedule Performance

The CSU team established the start-up sequence as a schedule input. Individual engineering, procurement and construction (EPC), and commissioning and start-up schedules were integrated into an overall master schedule in Primavera which included the pipeline and well sites CSU activities. The construction schedule became the driving schedule, and so the commissioning schedule changed substantially in reaction to the deterministic construction schedule changes. The key learning is here is to get the CSU planner earlier and get the cleaning strategy to the planner to refine the construction completions earlier. The Define phase original skyline were being used up to November 2014 and so construction really couldn't react to give the utility system first which wasn't in the original sky line.

The Shell project team, along with the Shell CSU team, did define the target completion dates for utilities and process facilities. Handover was phased, but did not follow the schedule originally developed, either in sequence or timing. The CSU team was able to adjust activities in order to progress in a timely manner. The CSU team did work with the EPCM contractor to develop schedule milestones to drive the detailed CSU schedule which was stand alone. Some changes were made in order to accommodate access to existing facilities for tie-ins and project work. The Primavera schedule did not contain enough detail to provide the planning guidance the CSU team required. Hence the CSU team worked together and utilised a common "war" room to visibly show field activities in a detailed level 6/7 using wall charts for daily CSU planning. This mitigation was very successful and enabled the team to deliver ahead of schedule.

Due to operational difficulties in the Hydrogen Manufacturing Units (HMUs) at the time of ready for-start-up, the sequence of start up for the CO_2 absorber units was changed from the original HMU3, followed by HMUs1 & 2 to a revised start up sequence starting from HMUs 1&2, followed by HMU 3 later. This change did not materially change the start-up activities for the amine regeneration and compression units; however did use up approximately 8 weeks of float in the start-up schedule.

20.3.4. Commissioning

For commissioning, individual systems were freed of oxygen using nitrogen where required. Utility systems were put into service first. Commissioning did include final punching by the Shell Project and Operations and concluded with ready-for-start-up for each specific block. RFSU for the facility was achieved on April 3rd, 2015.

20.3.5. Start Up and Performance Testing

For start-up, systems were filled with nitrogen. The nitrogen was purged from the systems as they were brought on-line with CO_2 from the process. Chemical systems got their "first fills" (amine and TEG) and were brought into circulation, then the process gas from the HMUs introduced to the Absorbers & CO_2-rich amine fed to the Stripper. The CO_2 was vented beyond the CO_2-stripping/amine regeneration unit, until the compressor was ready to be brought on line. Start-up of the systems took approximately 5 days.

During the first compressor start up, there were some electrical issues revolving around the C.T. configuration (which was later changed). Upon the first successful run of the compressor, the compressor performance test was stopped as the compressor was observed to experience reverse rotation during shutdown. The cause of the reverse rotation was determined to be inadequate depressurisation through the stages 6 and 8 blow-off valves to release the mass of CO_2 gas in a timely manner during a shutdown. Additional blow off valves and piping with controls modification were added to resolve the issue. (See Appendix 21 for the detailed lessons learned report).

Immediately after the successful re-start-up, 3 government mandated performance tests were completed concurrently, to demonstrate A) Capacity (24 hrs), B) Efficiency (20 days) and C) Reliability (30 days). All 3 tests were completed 35 days after first injection.

20.4. ORA lessons learned

See Appendix 20 for the full list of ORA lessons.

21. INFORMATION MANAGEMENT AND TECHNOLOGY

21.1. Information Management

EPCM's technical documents and deliverables were 100% visually quality-checked before handover to site Operations technical library. The plan of progressive handover of documents was implemented in order to meet the Scotford Technical library requirements with the following outcomes and observations:

- Quality checks were able to detect errors early
- Easier to work with smaller batches of documentation for the project and asset
- Utilized smaller asset resource teams

ASSAI for PCAP was not able to be fully implemented because of the difference in the subsurface and Ops teams and also differences in the tool itself (see IM/IT lessons Appendix 8)

Project-to-Asset (P2A) Handover

IM worked closely with the P2A team by providing definition of IM deliverables, schedule and progress.

Government of Alberta (GoA) Report Documents

The IM team coordinated the issuance of the GoA reporting documents that had to be resized and confidential references removed before IM uploaded documents to GOA.

Group Records Management (GRM)

Quest project was the first project in Canada to coordinate with the GRM Business Leads to develop final record declaration codes and process for Q4 GRM to run the declaration copy for TRIM database.

21.2. Information Technology

There was a dedicated onsite IT representative who was stationed at the Quest construction site throughout the execute phase of the project. Shell GID network was implemented at the following locations - Fluor Sundance, Toyo home office, Quest construction trailer at the Scotford site, Bruderheim Pipeline office, KBR module yard in Edmonton. Other information technology infrastructure that were installed during the execute phase included:

MMV IT Applications (Sample Manager, WRFM IT toolkit and ArcGIS)

A host of tools and applications were implemented to meet the Measurement Monitoring and Verification (MMV) requirements of the project. A special program was executed for a solution architecture and model to these requirements. Special global teams and groups were involved to implement and interconnect several critical applications in a tight schedule and were delivered to the business on time and on budget.

IT Shelter and MMV Radio network

IT was instrumental in coordinating technology activities at the wells. IT started the coordination work with Wells, PACO, subsurface, construction and operations teams to set up the MMV IT shelters at all three well sites. MMV IT shelters included HVAC, electrical, telecommunications, MMV technologies (such as Line of site, DAS, DTS, microseismic) and SCADA system.

IT also implemented a point-to-point radio system to transfer data from the wells to Shell network and its vendors. A dedicated private network was tested and implemented which provided automatic and secure MMV data transfer to the PI data system and third party vendors.

IPAD Mobility Solution for Quest Operations

An innovative solution proof of concept was implemented for Quest operations. A Quest proof-of-concept Bentley mobility application was installed on 6 iPads for use during construction & commissioning and was very well recognized. Within the first hour of the initial Bentley Navigator tool load/configuration, a CSU planner performed a virtual walk-down and identified planned work that would not have been executable and would have resulted in significant re-work/reschedule. Also it avoided a non-productive in-field visit under -18 °C frigid weather condition.

21.3. Lessons Learned – IM/IT

See Appendix 8 for the list of IT and IM lessons

APPENDICES

APPENDIX 1: SELECT AND DEFINE PHASES ENGINEERING REVIEWS

SELECT PHASE ENGINEERING REVIEWS

- *Design Class Review*

A couple of hours workshop with Operations that defined what was going to be done or not done with the objectives of sustainable development, expandability, sparing and what part of the project needed to be highly reliable, which then allowed the project team to define where reliability and sparing should be backed up.

- *Value Engineering*

Led to 3 major ideas i.e. process simplification, integration, and 3rd Gen Module concept, together with another 27 minor ideas that were implemented in the Design phase.

- *Project Execution Planning Project Execution Risk (PEPPER)*

Project execution bow-tie risk analysis the outcome of which were incorporated as mitigations in the project risk register.

DEFINE PHASE ENGINEERING REVIEWS

- *Project Standards Review Workshop*

A two day workshop focused on optimizing standards selected for the Quest project. It also confirmed how standards would be included in key purchase orders to simplify the orders for vendors while still ensuring key HSE and quality needs were maintained.

- *P&ID Reviews*

Detailed reviews by area with required engineering disciplines, operations and the process licensor (or compressor vendor)

- *Modularization Knowledge Sharing*

Two days of shared sessions with New Orleans teams on module design, maintenance of equipment in congested modules and contracting approaches

- *PHAII Reviews (Hazop)*

Detailed Hazops were facilitated by a Fluor facilitator source from their Haarlem office and lasted roughly 20 working days.

- *Criticality Rating Workshops*

A series of meetings were held to establish equipment criticalities, initially for static mechanical equipment but later for piping line classes and instruments as well. This information was used in pre qualifying bidders and including key technical or quality requirements in purchase orders or ITPs.

- *Rangeley EOR Information Sharing*

The Shell Quest team was hosted at the Chevron Rangeley Colorado Enhance Oil Recovery facility to understand Operations, safety and technical issues related to high pressure CO_2

- *Layout Model Reviews with Ops & Construction (pre 30% model reviews)*

Initial layout reviews based on in house and limited vendor data confirmed key aspects of the plot plan, locations of equipment, MCCs and maintenance access routes. These reviews established the module index for the project and path of construction

- *Plot plan and modularization Cold Eyes reviews*

A group of Shell New Orleans designers spend a few days in summer 2011 reviewing the Quest layout, progress in the 3D model and the modularization plans to ensure the 3rd Gen concept was mature enough to successfully proceed with detailed design.

- *SAFEOP*

The initial electrical SAFEOP was facilitated by the Calgary TA1 with input from the Scotford Electrical Lead. This flagged any key electrical design issues which required focus before releasing purchase orders or finalizing single line diagrams

- *LOPA Study*

The initial layers of protection study was completed in the Define phase

APPENDIX 2: DETAILED ENGINEERING PHASE ACTIVITIES BY DISCIPLINE, WORK FLOW & TECHNICAL REVIEWS

1. Process Engineering

Capture Unit piping and instrumentation drawings (P&IDs) were developed and managed using Intergraph® SmartPlant® P&ID software, which incorporates ANSI standards. During FEED phase the Shell IM group aligned on SPP&ID standards and conventions in conjunction with the Scotford Document Management Group.

Toyo produced their P&IDs using Microstation as they were not SPP&ID capable during the FEED and Execute Phases.

Process engineering for the Capture unit proceeded with few significant issues even though the Shell Process lead was replaced just after the FID decision was taken. Fluor had strong continuity of personnel and quickly followed up on HAZOP actions from FEED phase Hazops to finalize P&IDS for the other design disciplines. Toyo required extra support with the Shell lead providing detailed guidance on P&ID development, control narrative preparation, safeguarding and closure of HAZOP items.

2. Civil, Structural and Architectural

The project elements covered by civil, structural & architectural included:

- site preparation, earthwork and site drainage
- roads, pads and fences
- underground piping and sleeves
- above ground structural steel
- initial design of buildings

The lead on the core engineering team was responsible for preparing structural design criteria, specifications and standards, and ensuring compliance across the silos.

Structural steel was detailed by Central Texas Iron Works (CTIW) for the Capture unit structural steel. Early in the execute phase Fluor spent significant effort aligning with CTIW on standard connection designs which saved effort checking the shop drawings and avoided design recycle later in the project. A shop coordinator was assigned from Fluor to manage the drawing review, prioritization and expediting of steel, which was successful.

Midway through Execute a significant change was made to the capacity of the compressor building bridge crane capacity. Initially this crane was sized with a 15 ton capacity to lift the single largest maintainable item on the compressor, the first stage volute. Later it was found that Scotford safe lifting standards required a crane with capacity 25% above that of the heaviest item. Not having this capacity would require an engineering lift be prepared.

Reworking the building steel to accommodate the larger crane capacity delayed completion of IFC steel for the compressor building which was already on the project critical path.

Final detailed architectural design for MCC buildings was subcontracted out to the module yard that would incorporate the buildings into the completed modules. It was felt this would allow the module yard to best manage the interface between the building and the rest of the module construction. However the module yard initially struggled with managing the subcontractors for the building and HVAC and completing the detailed design. Fluor had to rework some building and provide extra assistance to KBR in planning and completing this scope of work.

3. *Static Equipment and Materials, Metallurgy and Integrity*

Pressure vessel orders were placed in the Define phase with actual fabrication being released once the regulatory hearing was completed at the end of March 2012.

The largest single pressure vessel orders were placed with Il Sung in Korea. Although they had a history of quality supply with Shell on the Expansion 1 project, recent financial difficulties resulted in a loss of some of their personnel. This fact coupled with the size of the Quest order was missed in planning of their shop support. Initially only occasional visits of Fluor and Shell responsible engineers was planned, however numerous technical issues related to dimensions and fabrication errors arose early in fabrication. Fluor responded by placing a vessel SME in the Il Sung shop to resolve the found issues and improve communications with the Calgary office. Overall the vessel program has proceeded on budget and generally on schedule.

During material selection completed in Select phase a number of exchangers were specified with duplex tubes. The purchase order with Mangiarotti required that the specific tubes to be used in the exchangers be tested after the U-bends were formed both with and without post bend heat treatment. The desire was to determine if "un" heat treated or heat treated tubes were best to avoid future cracking issues in Scotford CW service. This required a lot of coordination between Fluor, Mangiarotti and their sub vendors of tubes (Salizgitter and Sandvik) and placed fabrication of the exchangers onto the project critical path.

In the future selecting a higher grade of material may increase equipment cost but the cost of EPCM man-hours to coordinate and expedite these specific requirements would have resulted in overall cost savings and simplified execution.

A key issue in progressing in this discipline was the availability of TA2 support in the Execute phase. The assigned Shell technical resource was a TA3, so many project approvals on PCAP items, TDNs & technical decisions required review & approval from the TA1. This slowed the project's ability to make timely decisions and resulted in delays and frustration from Fluor and vendors.

For the Toyo pipeline scope, there was good alignment between the Shell pipeline TA2 and Toyo pipeline engineer regarding the line pipe PO (which didn't consider evaluation of crack arrestors), bending requirements and valve selections. However development of a cost effective welding procedure of the linepipe has taken a significant amount of time and appears to be driving the pipeline construction cost over budget. The challenges of producing acceptable high ductile welds in high strength steel material was not flagged early on the project and has results in cost and schedule overruns in the initial ISBL pipeline installation and is impacting the overall project costs significantly.

4. Rotating Equipment

Shell Rotating equipment support for Quest was well aligned and provided effective support to Fluor in dealing with ongoing vendor issues.

Quest engaged BETA machinery to complete specialized vibration analysis of the reciprocating TEG pumps which are mounted within a steel framed module rather than on a traditional concrete foundation. This work was subcontracted by Fluor due to the specialized knowledge required and the BETA recommendations with respect to pipe supports were adopted by the project. This activity was done to eliminate technical novelty risks and possible issues of reciprocating machinery vibration which had been experienced on Expansion 1.

The single most critical piece of equipment for Quest is the CO_2 compressor and the Shell rotating engineer was essential in challenging the Mann Diesel Turbo instrumented safeguards. Support from the Shell TA1 for rotating safeguarding was required to convince MDT to eliminate some instrumented trips which were felt to be superfluous and which would have reduced the operability of the machine. MDT has been a challenging and difficult vendor as they do not readily share data and how they resolve quality or design issues. They have often threatened to void warranties when Shell asks for design changes to mitigate concerns found during fabrication.

The flawless rotating program was well aligned between Shell & Fluor and well received by vendors who we briefed during initial kick-off meetings. However in a few cases flawless initiatives such as bearing & seal replacement onsite were initiated and change notices not generated to inform construction of the new requirement. For Flowserve, 100% of pumps had to go in for rework despite the shop visits by the SMEs.

The value of shop visits by Shell personnel has been evident in catching issues like missing carbon seals during the FGR fan performance test. As well having a dedicated operations and maintenance representative support the assigned TA2 was very valuable to the project.

5. Heat Transfer Equipment

Early in the execute phase the project was facing poor performance from the supplier of large welded plate and frame exchangers (lean/rich amine service) which were on the project critical path for engineering design of area 4610. The Shell heat transfer specialist was able to coordinate a shop audit of an alternative vendor very quickly which allowed the project to move the order to another vendor and maintain the project schedule without impacting quality.

GEA Rainey is being used as the new air cooler EFA for the Quest project. This order required extra attention in detailed design to align with on vendor data details such as ladders, platforms, piping and instrumentation details. The air coolers purchased for the 6th and 8th stage intercooling service on the compressor are somewhat novel in that they have 3 fans rather than the typical 2, which required modifications to the usual operating and control philosophies used at the Scotford site.

6. Piping and Pipelines

The Fluor piping designers used Smart Plant 3D to produce the 3D model while Toyo used an Autoplant Software.

On the whole, piping was a well run discipline that understood what was required to deliver a successful project and managed well given the challenges of late mechanical and instrument vendor IFC data and dimensions. This discipline was well prepared for various 30, 60 and 90% model reviews and took on the challenge of adhering to the 3rd Gen modular design well. The Fluor design team was familiar with Shell HFE requirements and built them into their layouts in the FEED phase so that few major issues were found during model reviews with operations.

As an indication of the well planned piping design effort, at the time of writing piping quantities in the final control estimate are under the FID budgeted amounts for both linear pipe and bulk valve purchases.

A major challenge created by 3rd gen module design layout was the piping stress analysis. The constrained space limited the options available for moving supports and structural steel to produce allowable piping stress values. This is most apparent in the compressor area. Initially Fluor believed that the requirement to have compressor suction lines sloping away from the compressor was an optional requirement. However given that the CO_2 process stream does contain water which will condense upon shutdown, this is sloping requirement is mandatory.

The Toyo piping and pipeline scope was relatively smaller but took significant Shell input and guidance to ensure that basics such as valve arrangements around pig launchers were correct.

A major oversight in the pipeline design was found early in Execute when the maximum pressure of CO_2 at the lowest point of the pipeline was found to exceed the pipeline design pressure. This was due to the fact that the static head of CO_2 in the line was not considered in the original design pressure calculations by Toyo. The CO_2 compressor design pressure was reduced from 14,790 kPag to 14,000 kPag to avoid overpressure at the low point under the North Saskatchewan River.

7. Electrical

The electrical discipline benefitted from a well planned scope and effective decision making in the Select and Define phases. Major design decisions were settled before the commencement of the Execute Phase:

- location of 35 kV tie ins for the main Quest power supply
- adoption of high voltage underground cabling for feeding numerous smaller MCCs within the Capture unit
- selection of EHT vendor
- numbers, size and locations of MCCs
- hazardous Area classifications
- determination on use of EFA vendors for major electrical equipment

A lot of effort was expended planning and estimating the EHT execution on Quest based upon incorporating lessons learned from past projects. Fluor completed the EHT detailed design using a combination of Calgary and New Delhi based resources and undertook cold eyes reviews with Tracer reps to check the first designs to ensure they were correct and complete. Tracer was also subcontracted to provide skin effect heat tracing

The use of SAFEOPs in the FEED and Execute phases were very valuable in assuring the quality of the electrical engineering design and identifying risks or potential issues with the design well in advance of final IFC deliverables being issued.

The use of multiple MCCs within the relatively small Quest plot was felt to be novel and potentially controversial decision. In the end this design seems to be liked by Operations and maintenance personnel and has reduced cable quantities, so future projects should look at implementing this approach. Also moved a lot of electrical equipment into the modules.

8. Process Automation and Control (PACO)

The PACO discipline was impacted by the Brownfield nature of the Quest project in that Quest required no new DCS system but needed to work within the existing control systems of both the Scotford baseplant and Expansion 1 areas.

The Scotford INTools database was used for Quest and Fluor was provided direct access to create their tags in the database using remote access controlled and monitored by Trish Price. This was quite effective in ensuring the Quest deliverables met Scotford standards without requiring a database "merge" at the end of the project.

In the Define phase a project strategy was adopted to utilize the Scotford onsite contractor Cybertech to complete the detailed DCS and SIS programming activities. The automation work also involved coordination of automation vendors (e.g. Honeywell, Invensys, Bentley Nevada) for technical services, including site support for construction

SIL, LOPA and CHAZOP were performed in the Execute phase. Since Quest is an NPV=0 project, adjustments were required to be made to a few SIL levels to ensure the HSE robustness of controls. The CHAZOP was not effective as it could be since the group tended to raise design optimization issues rather than true control systems hazards. Better terms of reference along with a more focused facilitator could avoid this of future projects.

Finalization of control narratives for the FGR scope took numerous reviews and had significant input from site. The Quest project team maintained poor control over the site input which was significant, late and created rework for Fluor. In the future more effective use of the PACO TA to manage the site input and to filter "nice to have" from "must have" input is required.

Finalization of the compressor control narratives faced some delays as well due to difficulties in aligning with MDT. Numerous scenarios are required to be in the narrative beyond just the normal operating case such as recycles mode, maintenance modes etc. The FAT procedure on the compressor PLC programming needed to be written by the Shell TA to ensure the completeness of the test.

Toyo required more support to complete I&C deliverables throughout the Execute phase due to turnover of personnel and unfamiliarity of working with Shell's Scotford requirements. Control narrative and cause and effect production required numerous revisions and extensive guidance from Shell TA's.

9. Fire and Gas Systems

The gas detection system for Quest required a test program to determine acceptable CO_2 gas detectors. At the beginning of Execute it was expected that a Joint Industry Project involving testing of CO_2 gas detector brands and types using CO_2 releases would provide a recommendation for Quest. The testing was completed in late 2011, however the results were inconclusive and no recommendation was issued. For Quest we arranged to test Senscient CO_2 detectors at the Shell froth treatment pilot plant located near Edmonton. A successful test program was carried out which resulted in these open path laser based detectors being adopted for use on Quest.

Due to congestion of piping and equipment within the CO_2 compression area of Quest, a mix of open path laser detectors as well infrared point detectors were used. Smoke detectors were installed in MCC & I/O buildings are required.

10. I&C Detailed Engineering

The Instrument designers and engineers coordinated instrument purchasing to ensure that accurate vendor data was available early to support the 3rd gen module layouts. The control valve EFA with Flowserve was useful in this regard as actuator sizes were determined in Define phase and few significant changes became apparent in the Execute phase.

Extensive 3D modeling of PACO scope was completed to avoid field construction issues with the 3rd gen design such as modelling of instrument tubing. Overall the modeling and model reviews of PACO scope went smoothly with little rework required by other disciplines due to late PACO design changes.

An open issue from the PACO design remains the finer details and planning of mod yard PACO testing, particularly scope of I&C testing to be completed in the module yard. This testing scope was within the module yard contract, yet detailed planning of the activities experienced some delays.

11. Planning, Coordination and Project Controls

In Capture, an engineering work breakdown (EWB) structure was established to account for all engineering deliverables and project support activities Engineering work packages (EWPs) were used to break the EWBs into detailed, controllable packages of engineering work; largely for individual modules and broken for mod yard or for field installation/ All project drawings and documents were assigned to an EWP and milestone dates were applied to each document.

Engineering work progress was and the work hours were assigned in the Fluor engineering design progress tool called EzTrac. Hours were assigned by each Fluor discipline lead to distinct activities but were not assigned to individual drawings or design deliverables. Piping, electrical and CSA disciplines assigned hours to design areas while PACO and mechanical focused more of their progressing around procurement packages.

Ensuring that the engineering progress was accurately being reported (not accepting a “burned = earned” approach) was achieved by having monthly in depth reviews of individual disciplines EzTrac progress between the Shell & Fluor engineering managers coupled with project services people. Usually 1-2 disciplines were reviewed each month and progress was “sanity” checked line by line against what the Shell TA’s were seeing, known project issues and status of 3D models. This approach worked reasonably well and although three engineering reforecasts were completed in Execute the impacts were not that significant.

The detailed engineering schedule was structured around two milestones – having 90% model reviews completed prior to bidding the module contract and having engineering completed prior to commencement of module fabrication. The design team was well focused on achieving the final 90% model review in Dec 2012 and the review was well done with a mature design supported by accurate vendor data. The piping and structural steel design was generally 100% completed prior to commencement of module fabrication. Instrumentation and electrical activities have slipped about 2 months past the intended EWP IFC dates but at this time that is not expected to have an impact module delivery dates or their completeness.

All technical documents were managed using Fluor’s Projects Online system. This was used for Shell and vendor squad checks as well as issuing of IFC documents. Fluor’s squad checking was completed in POL with Shell personnel having access but the IT setup for this was difficult due to Shell's IT restrictions. Some Shell people lost POL access and upgrades to the POL system eliminated Shell access early in 2013. Squadcheck comments from Shell were submitted manually or via email which was inefficient.

Shell's livelink system is now being populated with IFC deliverables after the data quality is confirmed by Shell's IM group.

12. Technical Reviews

Ongoing technical reviews were held at appropriate points during design and continued during implementation to promote a smooth progression of engineering work with minimum rework. Various Shell discipline experts in fields such as analyser selection, heat exchanger design, and electrical design were included in project review groups to validate designs. Reviews used the following tools and techniques:

Cold Eyes and Peer Reviews

Cold eyes and peer reviews were carried out in selected areas (FGR process design and controls, piping stress analysis compressor dynamic foundation design) and industry experts and senior engineers were brought in to review and critique the design. Concerns and suggestions for improvement were documented, evaluated and adopted, when appropriate. These reviews were productive.

Lessons Learned

Shell adopted a lessons learned register populated with LL from the baseplant, ULSD and expansion 1 projects which was monitored on a discipline basis throughout the life of the project. Fluor did not have a separate lessons learned register but we assigned some of the Shell LL actions as appropriate.

Flawless Startup Initiative (FSI)

The design team participated in the Shell FSI program, and key engineering staff was assigned to each Q team. The Q team flaws lists were reviewed and classified as either high priority items to be incorporated into the design. A register was established to record the results and monitor KPIs. The FSI process continued throughout implementation. The initiative began slowly and had to be re-energized a few times because neither Shell nor Fluor considered it a priority. Responsibility for the program switched between Engineering for the Select & Define phases to Quality and Operations in the Execute phase.

Design Class Reviews

Design Class Review established that the class of design being produced was in line with the plant reliability and availability model, sparing of equipment was appropriate to its service and equipment selection was optimized to meet production targets. This was completed in Define phase and was useful tool when reviewing changes in the Execute phase.

Safety and Operability (SAFOP) Reviews

SAFOP reviews were conducted for the electrical power distribution and protection logic to ensure reliability of supply.

Hazard and Operability (HAZOP) Reviews

All P&IDs were subjected to a HAZOP review to ensure design cases and upset conditions were considered in the safe design and operability of the plant. The HAZOP action list generated by the exercise was addressed by each area engineering team and the resolution documented against action items in the HSE Action Item database held within the Fluor Lotus Notes system (but accessible to third parties like Shell & Toyo). These action items were tracked for timely and robust closure and the online database was very valuable in monitoring and recording closure. This same database was used to track closure of HSE items from other reviews related to health or construction HSE and has proven to be very valuable. In hindsight missed the criticality of the blowdown valves on the compressor.

3D Model Reviews

Many 3D informal model reviews were held by all areas to confirm equipment spacing and plant layout were optimized in the Define phase. Formal reviews were conducted at 30%, 60% and 90% completion with pre agreed prerequisites and focus areas for each review. Operations, HFE and maintenance personnel had the opportunity to confirm the design met their needs during each review. These reviews operated extremely well, and gave the construction team the opportunity to provide valuable constructability input to help ensure the lowest cost and safest construction procedures could be accommodated by the design. The 30% model review for the New Delhi design areas was held face to face in their offices with a significant Shell and Fluor Calgary team in attendance. This worked well and the following 60% & 90% reviews of those areas were held in Calgary with a small Delhi team which went smoothly.

Construction input with respect to modularization was fed into the designed in construction reviews held just in advance of the formal model reviews. This worked well and helped with time management of the formal model reviews.

The procedures for holding model reviews were first rate and the mechanism for recording and closing actions worked well. The major failing was lack of project engineering presence in each model review to develop any required Management of Change documents if required. This resulted in some change notices begin generated months after an initial informal request was made from Shell to Fluor in a model review

Material Selection Diagrams

Material selection diagrams were developed for all areas and reviewed with the CRC specialist to ensure the latest developments and corrosion issues from site were known and addressed.

HFE Analysis

Human factors engineering reps were involved in model reviews and the only specific HFE review completed was for the new operator control station in the existing baseplant control room.

Physical Effect Assessments

Physical effect assessments were completed to assess high-risk hazards; they are also documented in the Design HSE Case.

Escape, Evacuation and Rescue (EER) Analysis

An EER analysis was initiated during the 3D Model Reviews and completed during implementation. It should have been completed sooner, but fortunately, there was no major effect.

Bow Tie Assessments

Bow tie assessments (qualitative risk analysis) were completed for the major hazards of the design, and as-low-as-reasonably-practical (ALARP)) assessments were prepared to demonstrate that the residual risks had been reduced to as low as reasonably practicable.

Preliminary Instrumented Protective Function (IPF) Reviews

Preliminary IPF reviews were performed using SIFPro I™ to confirm that the safety and integrity level of the control systems met operating requirements.

Safeguarding Reports

Safeguarding Reports summarizing all safety-in-design reviews were developed through the detailed engineering phase and completed during implementation. Fluor focused early on this area as the CO_2 compressor was being protected by Over Pressure Protection by System Design (OPPSD). This system included the compressor, intercoolers and knock out drums and TEG system. Fluor had early focus on this scope to ensure a successful ABSA registration and the ABSA response was positive.

Valve Criticality

Valve criticality was provided directly by Shell operations and was marked directly onto P&IDs. These were confirmed and occasionally challenged during model reviews but with the early ops input few issues were found. However missed the criticality on the compressor blowdown valves. And so had to add blowdown valves post start up due to compressor reverse rotation.

Operating Modes Review

Operating modes reviews were held to verify all startup and shutdown cases had been considered and incorporated into the design.

Venting Study

A vent study was completed to ensure that the main CO_2 vent stack and smaller vents were safely routed or combined wherever feasible.

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	Removal of compressor Factory Acceptance Test (FAT) to improve cost and schedule	During the FEED phase a decision was taken to waive the requirement for a Factory Acceptance Test of the only centrifugal compressor on the project in an effort to improve cost and schedule. Further investigation revealed that the test was the only way to verify certain aspects of the design that will now need to be checked on site.	Factory Acceptance Testing should be considered a mandatory requirement for large integrally geared compressors. Certain mechanical running characteristics such as gear mesh contact and pinion stability can only be assessed during a performance test complete with adequate gas loads. Gearbox speed and leakage tests do not represent true running conditions. Should any shortcomings be discovered during the testing it is much easier to have them rectified while the machine is still in the factory.
2	The use of lubrication skids in lieu of running small cooling water lines should be avoided.	A decision was taken to use a lubrication skid in lieu of running a small cooling water line to supply a few GPM to a bearing housing. This lubrication skid added several hundred thousand dollars in direct cost, and likely that again in commissioning, start-up, and fabrication re-work. Decision was also driven by the long time that would be required to achieve an approval for the tie in via the Scotford Management of Change (MOC) process.	Practicality and field experience needs to be considered versus the input of those involved early on a project with no field experience. A lubrication skid that's being used only as a means to provide cooling is overly complicated and expensive, and will likely reduce the overall system reliability due to the addition of many IPF devices. IPF = Instrumented Protective Function
3	DEP for compressor inlet piping slope design	The piping slope requirement for the compressor inlet piping was waived to fit within the modularized design. Subsequently the Rotating TA could not accept this deviation due to past operational experience with existing compressors at the Scotford facility. This resulted in costly re-design.	Compressor suction piping should be rated a Criticality 1 for Shell TA review (either Piping or Rotating TAs)
4	Use of a "stand alone mechanical specification" resulted in nearly missing a DEM1 requirement.	A decision was taken to write a stand-alone mechanical specification for the purchase of the compressor. Several of the DEM1 requirements were transferred over, however, they were not immediately obvious to the EPC. As such, a requirement for "no threaded connections" was missed on the compressor order resulting in a 6 week delay to the project and a several hundred thousand dollar adder.	DEM1 requirements need to be explicitly spelled out in any mechanical specification. We should also consider reinforcing the concept of DEM1 requirements, as well as our Technical Authority arrangement and TDN requirements with the EPC. There are many people in Shell who are not familiar with this concept, let alone the EPC.

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
5	Quality Assurance processes need to be built-in to the purchase orders of equipment.	The notion that quality is some stand-alone discipline is outdated and ineffective, each discipline engineer must take an active role in quality assurance. During the project the Rotating Equipment group ensured that each individual ITP was reviewed, even those of Shell Pre-Engineered Catalogue (SPEC) pumps. Quality steps arising from other projects were then purchased as adders, and a pre-fabrication meeting was held at the vendor's fabrication facility to reinforce these quality requirements.	Continue with the approach that was taken on this project and ensure that the quality requirements needed to ensure success for the equipment are built into the PO, and follow-up with a pre-fabrication meeting at the site of production (not just with the salesman). NB: Written for Quality but applies to all disciplines
6	FEED decision to not have a Dirty Oil (DO) sump in the capture unit.	Additional cost and risk of environmental incident could occur as leakage streams for lube oil, pump mechanical seals and pump plunger packings were not considered for the decision resulting in additional design and fabrication of drain piping to amine sump, as well as addition of TEG pump plunger leakage collection system which all could have been better served with a DO in the unit. We still have pumps (specifically those not in amine service) where the mechanical seal will leak to grade when the seal fails which will result in an environmental incident at site and count as a spill even if it is water. Equipment was added within this unit subsequent to the DO sump decision that had more leak potential than was originally considered when the decision was made.	Unit design class consideration should not trump the ability to operate the facility within the existing site's environmental requirements to meet the license to operate.
7	FEED decision to go with 2 X 50% Cooling Water pumps result in higher reliability risk.	The decision to go with 2 X 50% Cooling Water pumps against the advise of the Rotating Discipline TA and Ops team based on a "no change" philosophy from an ill informed FEED decision adds higher unit reliability risk with very little cost savings as the actual pump casing size is the same as 2 X 100% pumps so for very little extra cost we could have a fully spared service.	Do not break from the Pump Selection DEP convention where Cooling Water is considered a Spared Essential service that recommends either 3 X 50% or 2 X 100% pumps. Taking a reliability risk hit to move to 2 X 50% does not result in any significant cost savings to warrant considering this as an option.

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
8	Use of Shell Pre-Engineered Pumps (SPEPs) on major project	Pump SPEP's were relatively new and EPC, Vendor, and Shell could all stand to brush up on their application. The use of the SPEP's was highly beneficial and of good value to all parties involved, we just need to ensure that Shell is aware of how they are to be executed and that this message can be passed on to the vendor and the original equipment manufacturer (OEM). The SPEP's proved to be highly valuable and fairly easy to execute after a bit of research, there is significant value to be realized by Shell with future execution of this initiative.	Ensure that the Shell personnel have access to and have read the appropriate SPEP. This in turn will get passed on to the EPC, and the vendor during the bid process and reinforced at the pre-fabrication meeting. SPEPs should be made easily accessible for the project users.
9	CO_2 pipeline weld procedure	In order to meet desired weld toughness for dense phase CO_2 service, a manual weld procedure with multiple passes was specified for the high ductile strength Grade 386 pipeline material selected. This turned out to be very inefficient, and was not optimized prior to early works mobilization and pipeline RFP issuance	Scour globe for best practice on CO_2 dense phase welding practice early in FEED, test and optimize weld procedure before bidding and mobilization, consider automated process. Pick a different pipe material and evaluate high strength steel against using crack arrestors (thicker weld pipe on every thread or sour joints)
10	Rolling technical requirements from all DEPs into engineering notes (BEST PRACTICE)	Various technical requirements (including DEM1) are in multiple DEPs. Rolling them into the engineering notes of the PO helped in early clarification of the technical requirements leaving very little for vendor interpretation	Follow this method of rolling all technical requirements into the engineering notes of the PO particularly for multi-discipline Pos.
11	TA2 assignment on the Project	TA2 was not assigned specific to Quest leading to delayed resolution of issues as well as proposed deviations as well as delay in decision making as some of such decisions were interpretations of Shell specs and/or PCAP	Imperative that TA2 be assigned to specific project to avoid delay in project delivery
12	Key HFE requirements for project	Using the existing HFE green book set a common understanding on HFE requirements between designers and Ops during model reviews. This avoid arguments & rework during model reviews	Prepare summary of HFE requirements (key points for the project from Green Book) and issue this to designers & operations early in FEED to avoid rework during model reviews

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
13	Material Testing	Avoid material testing in POs' - Having suppliers wait for testing on duplex tubes on shell & tube exchanges before starting fabrication took a lot of project team focus and effort to coordinate as the Shell TA and test facility is always in high demand.	Consider upgraded materials to avoid significant effort, delays and hidden costs associated with materials testing - cost for upgraded materials would have been cheaper than the testing and disruption to the project team.
14	Vendor shop presence for significant orders with single vendor	Multiple orders of pressure vessels and exchangers (e.g. 20 equipment tags involving significant value at IL Sung) should have justified a full time engineering presence from the Project team from the beginning to expedite responses and facilitate communication with the shop. It is easier to plan for a full time shop presence in a supplier's shop then back down, than to scramble to find people to spend time at the shop	Consider planning for a full time shop presence in a supplier's shop as soon as the order is placed, rather than scramble to find people to spend time there. Consider value of contracts and risk. Assign full time project engineering presence when warranted.
15	Model review attendees	Project engineers should be a mandatory presence in Model reviews to ensure that MOC's are generated as required for model review action items	Add project engineers to model review sessions
16	Pipe stress	DEPs only describe required stress cases, not acceptance criteria for complicated cases (for example what amount of nozzle overloading is acceptable between pump and thin walled vessel). This led to very conservative stress designs with a lot of contractor stress hours	Have Shell SME with pipe stress expertise meeting with contractor stress engineers to provide guidance on what "out of spec" pipe stress situations would be acceptable to shell
17	Flow assurance	Shell's in house flow assurance group is very skilled and can provide quick guidance to aid project team with unusual design problems (amine stripper inlet valves, amine pump flow straightener, pipeline letdown valves)	Continue to engage Shell flow assurance on future projects, not just pipelines
18	CO_2 compressor - Water draw offs on interstage coolers	If compressor vendor had provided interstage heat exchangers with integral water draw off, the equipment and piping savings on Quest would have been huge ($10-50 million). These were not used on the project due to the novel design, unproven experience within Shell and Alberta and the relatively late knowledge of the opportunity (FEED phase)	Have Shell do design release on proposed intercoolers with integral water draw off for next project

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
19	Equipment criticality assessment (BEST PRACTICE)	An equipment criticality list was developed. This added value to the project by aligning all parties on relative process safety importance of various pieces of equipment which helps guide the quality process during fabrication.	**Best Practice:** Continue to have equipment criticality performed on all projects early in FEED (perhaps add to PCAP)
20	Structural steel connection design (BEST PRACTICE)	Selecting the structural steel vendor early in Execute and beginning the process of designing "common" connection designs with the vendor and EPC contractor allowed a very smooth commencement to steel fabrication with no recycle between EPC and vendor. Vendor added value by guiding EPC towards connection types with lower fabrication costs.	**Best Practice:** Select structural steel fabrication contractor ~ 6 months prior to commencement of SS fabrication
21	Material handling matrix (BEST PRACTICE)	The Material Handling Matrix was a list of all equipment and materials that would be lifted/moved for maintenance and operations together with the associated lifting frequency to establish maintenance access and lifting equipment to be provided. For each item an assessment was made of how the item would be accessed and moved for periodic maintenance. Weight, dimensions, lifting gear etc. were listed and agreed with Ops/Maintenance teams. The matrix was initiated during FEED and thoroughly reviewed at 30% and updated at 60% model reviews. This added value since establishing it early documented decisions between designers and maintenance/ops. This led to smoother model reviews at the 60% and 90% stages with less recycle.	**Best Practice:** Begin material handling matrix at very beginning of Execute and refer to it often in model reviews Early engagement with Maintenance to establish weight/ lifting frequency criteria is a critical success factor in this process. Criteria was developed for the project as standards weren't readily available.
22	Performance Standards for Safety Critical Elements	These are poorly understood by the P&T team and at the moment they will not be used by Operations. When considered on top of vendor, EPC and ABSA quality and legal requirements they added no value to the process safety aspect of the project as they repeat information & processes completed elsewhere . Few relevant go-bys are available. ABSA = Alberta Boilers Safety Association (provincial pressure equipment safety authority)	Either provide training or proven in use go-bys on the preparation or use of these documents (especially for static & rotating equipment) or challenge their use during the design/procurement portion of the project
23	Organizational Alignment between Operations and P&T project execution teams(BEST PRACTICE)	Having a corresponding Operations rep for each Shell discipline TA (Electrical, PACO, Rotating, Process) to provide detailed Operations input and challenge the project design worked well. An improvement was noticeable when the corresponding rep for mechanical joined the	**Best Practice:** Bring Operations representatives on by the end of FEED for each key discipline.

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
		project later than the rest.	
24	Metallurgy & other technical requirements alignment with Shell EFA & Approved Instrumentation vendors	Instrument vendors follow industrial standards (e.g. ASME, ASTM) for the manufacture of their equipment (welding & metallurgy). This mainly concerns inline equipment (e.g. valves and inline flow meters). Shell requirements are in the main more strict than industry standards. The enforcement of the Shell requirements causes a number of problems with standard production instrumentation. 1) Instrumentation is not bespoke design and the QA procedures (e.g. WPS) are established for their product line which is not specific to Shell. Many of the Shell DEP are more for custom built mechanical designs (e.g. pressure vessels) 2) The implication of engineering note requirements are not always/completely understood by the vendor and this is not picked up until the vendor welding procedures are squad checked 3) Shell specifications tend be written for worse case process conditions (e.g. sour service) and do not take into account project specific realities. 4) Some requirements are very different to normal industry practice (e.g. charpy testing of WCB valves) 5) This level of materials QA/QC is not undertaken by the Site with respect to the same vendors as the project. Hence the end result is a mis-alignment between project expectations and what the vendor is accustomed to provide for the Site. This is still causing delays in progressing PO packages and approval of vendor drawings/documentation 6) There is a lack of understanding that vendor procedures (e.g. WPS) are not something that can be easily changed as part of their ISO accreditation. 7) Considerable more engineering time spent resolving these issues result in delays to finalizing deliveries. This also distracts from other necessary work	It would be better to have a materials/welding alignment done for Shell EFAs and approved vendors done by a central engineering group (i.e. Shell PTE) rather than at a project level. This would avoid unnecessary delays for Control Systems (or other disciplines) to go through this on every project. There also needs to be a corporate assessment about the level of metallurgy requirements being relevant or not to standard instrumentation (i.e. devices that have been used before) rather than custom built pressure vessels, etc. This would then avoid the persistent surprises from vendors and resistance to changing their QA/QC procedures

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
25	Control Narrative design review process alignment	Procedure for Control Narrative (CN) design review was issued for the project. The more complex narratives were subject of a CHAZOP in addition to the standard design reviews. The basis was to establish a Gate process in order to have an orderly implementation. However the alignment with Site was not completed with everyone. Furthermore the Shell rotating equipment specialists were not engaged in the CN design reviews as much as was needed. This has lead to re-work and delays in the CN implementation.	Establish a more complete alignment process with all required Shell specialists (site Operations and Engineering) for Control Narrative reviews and approvals. This would establish criteria for when changes are to be implemented (i.e. design freeze).
26	Preferred Automation Contractor	The execution approach of utilizing a site specific preferred Automation Contractor to work closely with the EPC for system configuration, integration and systems support during detailed engineering has proven to be far superior to using the project EPC contractor	This approach should be adopted for brownfield sites where site's automation contractors are available and can offer the required resources, and are willing to establish a cooperative and mutually beneficial working relationship.
27	Revamp Scope Execution (Automation)	Revamp automation work has inherent inefficiencies that are only made worse by executing the work from a location hundreds of kilometers away.	Assemble a team of experienced I&C Engineers and Designers to execute and coordinate this type of work on-site. Alternatively, this work could be included in the preferred Automation Contractor's scope.
28	Mechanical package inspections by Control Systems (CS) discipline	CS section in the engineering notes for mechanical packaged equipment included requirements based on client specifications. However it is difficult for mechanical vendors to fully appreciate CS requirements	Include a higher level of CS engagement prior to fabrication (award and kick-off) and inspection at the mechanical vendors. This means more initial manhours in order to save on field hours and rework
29	EHT and Insulation specified for new EFA control valves.	There was concern from prior Site experience with actuator failures. The cost of the EHT and insulation is a significant cost adder to the valve PO. This included the extra EHT controller points and additional engineering	Cost justification for EFA should include risk mitigation costs for known deficiencies. E.g. FlowServe valves slow below -20C
30	Detailed Design HAZOP (BEST PRACTICE)	TOR for HAZOP/PHA and check list to determine the necessity of HAZOP for P&ID changes was very effective	**Best Practice:** Develop a project specific TOR and check list for HAZOP/PHA. Quest document available as a go-by.

APPENDIX 3: CO_2 CAPTURE FACILITIES DETAILED ENGINEERING LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
31	Integration of Operations, Controls and Safeguarding Philosophies at end of Select	More clearly documented Operating, Control and Safeguarding Philosophy before FEED is required and will reduce efforts to prepare control narrative	Philosophies must be detailed enough and integrated at end of Define phase to support the development of the Control Narratives. Operations, Rotating and Process inputs required.
32	Gasket, bolt and flange calculation requirements for shell and tube exchangers	There are differences between Shell gasket, bolt and flange calculation requirements and ASME values.	DEP revision has been recommended by project team. Engage SME support to proactively emphasize requirements that exceed code requirements in engineering notes.
33	Compressor building bridge crane design criteria was adjusted late resulting in late changes	Scotford site requirement of 133% of max lift was not understood early. Crane lifting criteria was not well documented and was hard to find.	Establish a clearly documented crane design basis including lifting criteria. Distribute to Construction, Mechanical and Structural.
34	Design of Heat Exchangers (E-24601A/B)	As per the EPC's piping recommendation heat exchanger E-24601 A/B was originally designed with one saddle as sliding. No good reference could be found to support the proposed novel design of making both saddles sliding. Later E24601A/B design was changed to conventional design. There was much time and effort (hours) put into to resolve this issue which finally reverted to the original design.	Go for a conventional design for heat exchangers - i.e. one saddle is fixed and the other saddle is sliding for thermal expansion.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	No information on Monitoring Measurement and Verification (MMV) system panels for the CO_2 storage reservoir	Toyo did not receive detailed information on the MMV panels and how these panels will be wired. Therefore drawings were issued for construction (IFC) with a lot of holds. Shell MMV design wasn't ready at the time of panel design. Hence the MMV design was very late and is still an on-going issue (as some issues are still unresolved). Little to no information was provided to Toyo. One of the comments made by Shell IT was to Google for the information. MMV program was very novel. The integrated planning between the subsurface and the pipeline/wellsite, did not flag the timing difference between the maturation of the MMV technologies versus the wellsite design – this impacted both electrical requirements and PACO/IT requirements. IMPACT: Re-design of certain engineering deliverables (for buildings, cabinets, P&ID, Instrument Index, programming/configuration, drawings, etc.). Well site building for the MMV has already been designed and constructed and yet the MMV panels are not ready. Potential issues with sizing.	In future where this level of novelty is present ensure all aspects of the project are aware of the maturation timing of the novel technology and ensure the appropriate discussions happen around how to make allowance for the late information. This also required very late involvement of a wells type execution engineer (production engineer normally) which was also no longer on the project at the time.
2	Uninterrupted Power Supply (UPS) panel back up time specification	A decision note was approved by Shell in 2011 specifying a half hour back up time for the project (which was a deviation from the Shell specification of 2 hours). That decision was never communicated on schedule to Toyo Electrical and so the 2-hr specification was used. Toyo electrical received the Decision Note during late detail design in 2013. Battery backup time changed from 2 hours to half an hour in 2013 and Toyo had to ask Hayley (UPS supplier) to re-quote for half hour back up time. Late MMV design/scope maturity and high staff turnover at Toyo were also contributory factors as the Toyo staff who were there at the time of decision changed out at least once. Shell IT provided a specification for serial communication (in May/June 2013 during late stages of detailed engineering) from the UPS to the MMV panels. However the already specified Hayley UPS panel (which is a Scotford standard) didn't that have this serial communication capability. IMPACT: Hayley (UPS supplier) had to re-quote and layout drawings had to be revised. A new 7.5kVA (Hayley) UPS was required to feed another 5kVA smart UPS for the MMV panel. 2 UPS panels instead of one.	Align the project schedules so all major components of the project are at the same level of maturity at any given time (should be using only one UPS instead of two). Communicate Project Decision Notes early and timely to the design team at early stages of the project.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
3	HVAC backup heater design for the Measuring Monitoring & Verification (MMV) building	The original HVAC design for the MMV building had a redundant backup heater which was not aligned with the project's Design Class 1 philosophy of no redundancy. Late MMV design/scope maturity was a major contributory factor Impact: Rework and recycling of drawings and documents (building layouts, cable schedule, load list, all key electrical documents) to meet the design class intent.	Ensure the Design Class specification selected for the project during the SELECT phase is kept alive and constantly communicated to the engineering team. The decision of HVAC backup heater should have been made during IFR (issued for review) stage of the drawings.
4	Sizing of Monitoring, Measurement & Verification (MMV) Building Dimensions	A decision was made in the Basis of Design (BoD) to keep the building size as 3x4 even before the key equipment going into the building were even sized and selected. There was misunderstanding between Civil and Electrical on what inside dimensions were against outside dimensions especially when equipment were being forced and cramped into the building. Late MMV design/scope maturity was a major contributory factor IMPACT: A lot of time was spent discussing building size (3x4 vs 3.6x4 and outside dimensions vs inside dimensions). Final building was 3.6X4 (inside dimensions)	Building size should be decided after the dimensions of all the equipment that's going into the building are known. And then for this type of a small size building, choose standard building size from the vendors and avoid using a custom size.
5	Equipment Tagging requirements to meet Information Management (IM) specifications	Toyo was told to submit tags for all electrical equipment including cables to Shell for approval. A lot of time was spent to compile tags and description of each cable and equipment. Once the tags were submitted, a reply was received from Shell saying that cables tags don't need to be submitted. The approved list of tags for electrical equipment was issued by Shell on May 22, 2013. However, Toyo Electrical team still kept receiving emails (in November 2013) from both Shell and Toyo document control asking specific questions on tags (e.g. provide tags for electrical equipment, provide voltage levels)	Data and document turnover specifications and standards should be rolled out early to the contractor team and refreshed on a periodic basis especially when the project team members change. Ensure IM specs and standards are aligned with the existing facility's document/data requirements.
6	IFC drawings were issued too early	Toyo Electrical drawings were issued IFC in August 2013 without key information/specs on the MMV (i.e. ups battery size, MMV panels information, removal of HVAC heater etc.). The MMV was part of a scope change that was initiated late. Late MMV design/scope maturity was a major contributory factor. RESULT: Electrical drawings were issued IFC with numerous holds (related to the MMV scope) which had to be re-issued as-builts after the work is complete.	Maintain a strict Management of Change (MOC) process with regards to future scope additions; rigorously assess the impact of such late additions on the project.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
7	Two HAZOPs vs one HAZOP approach	Project conducted a so called pre-hazop in early DEFINE phase to understand cost implications. This approach was confusing for the engineering team as P&IDs were not fully developed, and closing actions from first HAZOP created re-work. Closing pre-hazop actions (used a 3rd party contractor's system) which took longer and was considered a distraction to the design team because they had to focus on the design work and at the same time close pre-HAZOP actions. Pre-hazop didn't add any value	Only perform HAZOP when P&IDs are in a reasonable level of completion
8	Ineffective on-boarding of new resources at Toyo/Shell	New project team members were not quickly brought up to speed of prior decisions and actions already completed by other disciplines leads. This led to revisiting and re-cycling of design decisions and actions already completed.	On boarding of new project team members has to be planned and have a proper follow up to avoid re-work and information gaps. Conduct multi-disciplinary team (from Shell and 3rd party contractor) scope refresh meeting periodically. Ensure effective handover of roles for key disciplines of piping and process engineering.
9	Interaction between Shell Technical Authorities (TAs) and Toyo engineering discipline leads	Shell TAs were allowed to interact with Toyo discipline leads and provide input and design advise/suggestions without any control from project management. Hence design decisions made were not fully accessed for their impact on the project . example the material selection for the pipeline, use of Orbit valves for all valving on the pipeline	Interaction between Shell TAs and Toyo discipline leads have to be controlled through established project communication protocols to keep control of information and ensure impact of decisions are understood by everybody and are communicated to all key stakeholders (including CP) Keep decision register and perform multidiscipline approach for decision similar to Management of Change (MOC) approval process
10	Avoid gaps in design phase between different components of project	Project areas in different stages of design. Capture plant was ahead of pipeline but pipeline inside battery limit (ISBL) line needed to be at the same stage of design maturity as the CO_2 Capture facilities (which were designed and constructed by - Fluor). IMPACT: rework of documents. ISBL pipeline engineering was accelerated to meet Fluor's field undergrounds schedule. This split of engineering into two portions created engineering re-work with completing full pipeline engineering.	Progress all areas of project in to be in sync in terms of level of design maturity or flag in advance where areas may get out of sync and prepare a mitigation plan.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
11	Composition of Right of Way (ROW) survey team	ROW survey was conducted with the surveyors and with heavy reliance on the surveyors' expertise (which was heavy in pipeline construction) and therefore surveyors were focused on and were interested in capturing information related to their discipline. IMPACT/OUTCOME: The outcome was that the ROW soil conditions and pipeline design information were missed. This resulted in limited information captured during the survey required to complete the pipeline engineering (especially civil and pipeline). Several ROW conditions were found out later which were not identified earlier during design as the discipline designers did not visit the ROW. ROW construction input and constructability reviews were missed.	All engineering disciplines (especially civil, pipeline design and construction) should be involved in the ROW survey and prepare formal report of their findings
12	Material Traceability Reports (MTR's) Review	Client asked Toyo to review the MTRs in detail to make sure additional spec requirements are met because client had specific material requirements above and beyond that required for standard materials. IMPACT: The MTR's were not reviewed ahead of time which caused significant impact (about 2 months of delay) to the construction schedule and cost (manhours). No significant value was added with Toyo reviewing the MTRs since the norm is that vendors always submit a letter of compliance to the MTR requirements based on standard codes	Request MTRs in the vendor document requirement list (VDRL) two weeks prior to material shipment or as soon as test reports are ready for all materials. Audit the MTR's by vendor to assure compliance versus do a full review of all MTRs; balance the value versus effort of the review.
13	Timing of radio path study	Two radio path studies were conducted. A preliminary study early in the project the results of which were used to pick the original communication tower location i.e. LB5 (line break 5).. A second radio path study was later conducted during detailed engineering which resulted in the relocation of the communication tower to Well site 1 because the new location had permanent power. IMPACT: Radio path study was redone, piling drawings for the tower was revised, height of tower changed, more towers were added to the LBVs which were not originally designed for. Radio path study was done too early.	Conduct the radio path study when LBV module locations are fixed and frozen.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
14	Thru-Bore Fittings on launcher/receiver lines specification (BEST PRACTICE)	On the pigging and receiving lines ……Ensure "thru bore" is specified for the applicable piping components on pig traps. This will ensure that there will be no issues with pigging through the applicable components. As this was specified during the procurement of the items, vendors had clear direction. This entail may have alleviated any connecting issues with pigging through barred tee's etc.	The descriptions (or Thru conduit) should be included on all fittings, valve, flanges that will be pigged through. Vendors will sometimes offer thicker wall fittings and taper bore the ID to match at the weld only. By specifying this from the early stages with a "NOTE" in the applicable piping line class, the requirement shall be clear from the beginning.
15	Selection of proven technology for RTUs / PLCs which are not in Shell's EFAs	Shell has a Global Enterprise Frame Agreement (EFA) in place with Allen-Bradley and so the pipeline engineering team was limited to selecting only the Data Site RTU. - The selected RTU (under the EFA) has no proven history in Alberta Oil & Gas - Scotford (existing asset owner) uses only Modicon which implies additional training, software and spare parts are required for the new Allen Bradley RTU. - All Stakeholders have never worked with this device in terms of design, configuration, etc. RESULT: Much time and effort were spent to justify the Allen-Bradley technical feasibility (e.g. low temperature requirements) and its acceptability to Scotford. The site IT team has to be consulted on the configuration (software programming) as Allen-Bradley uses Microsoft Windows XP which doesn't meet the Scotford site's IT security requirements	Under certain circumstances, the project should be allowed to go outside of the Global Agreement (EFAs) to allow for use of proven technology not covered by the EFA. Design the RTU selection around the process / application and not the other way around.
16	Line Block Valves (LBVs) - Manual Hand Jack vs Automated Pump	Toyo I&C (Pipeline Engineering and Procurement contractor) recommended early in the project that an electro-hydraulic pump would be a preferred method of opening the LBVs. Scotford Operations rejected the electric approach because that would have required them to carry a genset around for routine maintenance. A decision was then made to install a self-enclosed hydraulic option. During the 90% model review the HFE requirements identified about 500 pumps per opening for this hydraulic option. Shell made the decision to go down this road. Late in detailed engineering of the project, Operations voiced their concern regarding the ~500 pumps per opening requirement. RESULT: Additional cost/hours (in terms of meetings, discussions, material) to re-design the system to integrate what was previously purchased.	-Stick to industry standard & proven technology. - Operator feedback at the beginning of discussions is required - Exhaust the option of accessing power from the grid to power large actuator valves

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
17	Inside Scotford Battery Limit (ISBL) SCADA Cabinet construction	Toyo was pushed into providing IFC drawings to Fluor prior to selection of equipment that was going into the SCADA cabinet. - Design of cabinet (IFC) was completed before selection of components going inside the cabinet because of the different phases of design maturity between Fluor (ISBL line contractor) and Toyo (the OSBL). Toyo asked for specific amount of space to be reserved by Fluor, but Fluor would only accept and work with IFC drawings. RESULT: Multiple revisions of the document was required. Much effort spent way too early in the project to issue IFC drawings that had to be revised later	Ensure the different components of the project that physically interface are at the same level of design maturity and delivery schedule or flag early where there will be a disparity and agree to a mitigation plan.
18	Client Review / Approval of Documents	The project didn't have one centralised system for document squad checking between the client and the pipeline design contractor personnel. So when documents were issued for Client Review / Approval, the documents were returned to Toyo by multiple people at Shell. Root cause of this issue was Toyo did not have a system that Shell could participate in (like Fluor did). So we tried to use ASSAI which doesn't allow multiple people to comment on the same document. RESULT/OUTCOME: Toyo had to review more than 1 document from the Client which resulted in additional time required for clarifications. Documents from the client arrived at different times, past deadlines, etc.	Client should assign one owner of the document to compile all comments by Shell (single point accountability for collating Shell review comments on drawings). - Only (1) document should be returned to Toyo as per schedule. - Implement one common system for document squad check for the project (between the contractor and client personnel)
19	Interface Schedule management (non-critical deliverables)	Fluor's schedule / milestones (for the inside battery limit ISBL pipeline) did not line up with Toyo's schedule (for outside battery limit OSBL pipeline). There were times that Fluor requested information that was not required or ready until a later stage in the project. In some cases, preliminary information would have been sufficient but IFC documents were requested. RESULT: Rework, manpower, additional cost (examples: ISBL Cabinet, SCADA Dish, Coaxial Cable, etc.)	- More effort should be put into the Interface Log (by others) prior to issue. Is the item a nice to have or a show stopper. An email (For Information Only) should suffice in many cases until Toyo was ready to issue IFC documentation. Be clear on the protocols and accuracy levels of information/data exchange e.g. around the criticality and accuracy level of information/data required by the interface parties e.g. issued for design (IFD) information vs issued for construction (IFC) information Integrate the schedules to flag any discrepancies and discuss means to mitigate.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
20	Documentation Numbering (Data Sheets)	Toyo document number format was not compatible with Shell Smart Plant Instrumentation (SPI). IMPACT: Resulted in manual entry of document number (by pen) of master document. The issued document did not match the document stored in SPI database.	- Shell should modify Shell's SPI to accommodate 3rd party document format. - Toyo to modify format to accommodate Shell SPI requirements - This issue should be resolved / approved early in the project.
21	Documentation Logo (Loop Drawings)	Shell SPI format for Loop Drawings was not aligned with Toyo requirements/format for Drawing Title Block. SPI was missing Logo / Signature (Done By, Checked By, Approved By) format. - Resulted in manual entry of Logo / Signature section. - Meetings, discussions and cost to accommodate this need within the CITRIX environment maintained by Shell Scotford document control department.	- Shell to modify Shell SPI to accommodate Toyo format. - Toyo to modify format to accommodate Shell SPI. - IM requirement should be resolved / approved early in the project between client and contractor.
22	Temperature Rating of Instruments	Shell specification called for -43degC on all instrumentation. - Very few vendors (Shell EFA vendors) provide instruments that are rated below -40oC. - Very few vendors (Shell EFA vendors) will provide a letter of declaration that states that the instrument will function below -40oC. - A spec deviation issued by Toyo was declined by Shell. Impact: Resulted in numerous discussions and meetings with each and every Shell EFA vendor regarding this topic. Then had to pass information back and forth to Shell. Time, Cost and Schedule impact. Vendors had to physically test every device to meet -43deg if the vendor couldn't provide a letter of declaration.	The Global Enterprise Frame Agreement (EFA) between Shell and vendors regarding this -43o C spec should be fixed prior to the project commencing.
23	Main Automation Contractor Estimated Budget Manhours	During the early stages of the project, the EPC contractor was asked to estimate the required manhours for a MAC (Main Automation Contractor) to program / configure the Pipeline scope. However, the estimated budget hours for the MAC was much much less than (~1/6th) the actual estimates received during the execute phase. The estimates on each line activity was not realistic and the basis for the estimate was not available. Outcome: The new estimate was scrutinized in detail and too many hours were spent reviewing /vetting the quote leading to a delay of about 4 months in the award of the contract (i.e. delay in the completion of the work).	The Shell Global PACO standard manhour estimates per I/O for a MAC should be used as a reference for budgetary purposes (or validate EPC contractor's with Shell internal reference estimate and have the dialogue up front on any differences. And if available, specific site MAC standard manhour estimates be used as a reference and checked for comparison with actual quotations.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
24	Hardware for dense Phase CO_2 depressurization	Pipeline depressurisation design started off with restriction orifices for dense phase CO_2 depressurization. It was found that restriction orifices were not the best fit for this application. The reasons included high pressure drop and high likelihood of ice formation which will choke the restriction offices. OUTCOME: The final depressurisation design settled on choke valve to meet cryogenic conditions due to Joule Thompson (JT) cooling effect.	Depressurization of dense phase CO_2 requires rugged pressure dissipation valve and installing restriction orifice is not a feasible option. Material selection of the valves and downstream piping should also meet cryogenic conditions.
25	Venting/Draining of dense phase CO_2 equipment	Metal temperature can get to extremely low levels if the ambient temperature is low (lower than 0 C) during CO_2 line venting. There is a likelihood of solid formation whilst venting. General venting and drain design philosophy used in industry is not applicable to CO_2 service. RESULT/IMPACT: Significant engineering effort and hours were spent to arrive at a suitable design solution.	Provide N2 connection to drive liquid CO_2 through drain system into vent using an integrated drain-vent system.
26	Depressurization of buried dense phase CO_2 pipelines	Low temperature occurs at pipeline low points and is dependent on the heat gained from the soil. From engineering practice the design team thought low temperature occurrence can be mitigated by controlling the depressurisation rate. But that was later found out to be not the case. Flow assurance study demonstrated that venting from one end or from both ends and pause & vent strategy are more effective than the changing rate of depressurisation approach in controlling the temperature during depressurisation. Also from engineering practice the design team thought low temperature occurrence can be mitigated by purging the line with N2. Subsequent flow assurance study demonstrated that venting from one end or from both ends and pause & vent strategy is adequate without any N2 purging.	Stepwise depressurization procedure based on dynamic simulation is recommended.
27	CO_2 Leak detection: small leaks cannot be detected with rate of change of pressure	Rate of change of pressure detection and ATMOS system where proposed for CO_2 leak detection. However, unlike gas or liquid phase pipelines the rate of change of pressure is significantly low for a dense phase CO_2 system. For this pipeline configuration a leak from an aperture of the order of 40-60 mm can be detected by measuring the rate of change of pressure (that is >20 kPa/s, which is outside operational disturbances). Leaks of smaller size cannot be detected by rate of change of pressure.	Leak from aperture of the order of 5-10 mm cannot be detected by measuring the rate of change of pressure. Alternate methods like ATMOS system is required for small leak detection.

APPENDIX 4: CO_2 PIPELINE DETAILED ENGINEERING LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
28	Thermal expansion of dense phase CO_2 is significant	Dense phase CO_2 unlike other conventional fluids has a higher thermal expansion coefficient and hence small temp changes in the order of 5 deg C can significantly increase the pressure due to thermal expansion. DBB created a safety hazard and should only be used where absolutely required. RESULT: All double block & bleed (DBB) isolation design included measures to mitigate thermal expansion	Thermal Expansion Relief valve (TERV) is required for above ground dense phase piping. Double block and bleed arrangement needs measures to mitigate thermal expansion
29	Use of Mercaptan for CO2 leak detection	Project investigated whether mercaptan can be used for leak detection. The result was that it is technically feasible to inject mercaptan. However there was no evidence of any use of mercaptans in large scale commercial CO2 application worldwide. Therefore lab testing would have been required to select and apply the concept. RESULT: Project decided not to implement leak detection using mercaptan as there was no significant risk reduction identified to justify the additional risk and cost associated with mercaptan injection.	Injecting mercaptan is technically feasible, but, requires lab testing to determine the chemical and rates. No significant risk reduction is identified to justify the additional risk and cost associated with mercaptan injection. Early in the project (SELECT phase), investigate the benefits of fiber optic for communication and leak detection instead of a combined SCADA+Mercaptan+depressurisation rate leak detection solution.
30	Operating Control and Safeguarding Philosophy (OCSP) for CO2 pipeline	The pipeline Basis of Design (BoD) had very little information on OCSP. Having an Operating Control and Safeguarding Philosophy for dense phase CO2 would have enhanced the detailed engineering effort. RESULT: A lot of engineering re-work and meetings to streamline the control narrative.	Develop a clear Operating Control and Safeguarding Philosophy during the FEED phase of the project.

APPENDIX 5: PIPELINE DETAILED ENGINEERING HOURS GROWTH LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	Design changes e.g. Skid design changes and complexity	The LBV original skid design /execution plan was for the manufacturer to design, procure and fabricate the pipeline skids. The delivery time of key components of the skid (e.g. Orbit valves) quoted by the manufacturers was too long to support the schedule and so Toyo (the pipeline Engineering and Procurement contractor) was directed to do the design and procure the skids instead. For the level of pipeline pressure the FEED design basis had a single isolation, using the Shell Canada Onshore Gas experience. However the Scotford Operations (the asset operator) standards required a double block & bleed (DBB) philosophy for the pipeline and was found out after the FEED design was frozen Impact: Increase in Toyo's engineering and procurement hours ; and the level of detail for the skid in the original cost estimate didn't allow for a simple budget transfer for this change The complexity of the skids increased due to the double block & bleed (DBB) valve philosophy requirement from Scotford Operations	Shell Type 3 estimate requirements must be adhered to for all Eng & Proc scopes and not just for some project sub scopes (i.e. Capture facilities). Ensure during the FEED design, the technical requirements of the Operating organisation are fully known and incorporated into the design
2	Quality of FEED package	Coarse HAZOPs were performed during the FEED phase, instead of detailed HAZOPs. Only one detailed HAZOP was conducted at the start of Detailed Engineering (in Nov 2011). Then design changes (e.g. DBB philosophy, venting philosophy) that were made during detailed engineering were re-HAZOPed (in August 2012) Impact: Impact on process engineering design, piping layout, HSE, stress analysis, structural/piling (increase in the number of piles, structural steel), HFE impact (Green book).	Align with the asset operator on the technical specifications of the facilities to be tied into during the FEED phase. Complete the detailed HAZOPs during the FEED phase prior to preparing the Shell Type 3 estimate for Detailed Engineering and Execution

APPENDIX 5: PIPELINE DETAILED ENGINEERING HOURS GROWTH LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
3	High Staff Turnover with EP contractor team	Toyo's turnovoer rate in 2011 (25%), first half of 2012 (~25%), and 2013 (very low 2 - 3%) Change of ownership of Toyo (October 2011; Oct 2012 name changed from Tri-Ocean to Toyo) Project type (pipeline) was perceived as not complex and technically challenging enough for the designers coupled with other more attractive market opportunities elsewhere in the industry at the time of detailed engineering (competitive market conditions to attract and retain staff) Perceived lack of longer tenure opportunity on the project (possibly due to the expiration of the Shell/Tri-Alliance agreement) from the staff of the old "Tri-Ocean" organisation who stayed on in the new Toyo organisation. Toyo brought in their own systems which meant the whole office was new to the systems and procedures while we were in execute. Impact: 60 - 70% of the Toyo staff on the Quest project were new to both Toyo and Shell work processes/procedures/systems leading to productivity losses, and inefficiencies due to new learning curve effects Impact on continuity and loss of organisational knowledge and experience	None
4	Poor Estimate Quality (partially based on engineering deliverables)	The original estimate of 3000hrs for project controls was based on Quest project requirements (which fell under the umbrella of a major P&T project) - e.g. monthly reporting, primavera schedule reporting, requirement for a Project Controls lead, etc. These requirements were more than the usual requirements Toyo was used to under the previous Tri-Alliance agreement with Shell. The estimate assumed that a project engineer working on a particular package had the hours assigned to the discipline budget for that package (e.g. drafting a scope for a package), recycling/re-work (e.g. alignment surveys tied to it). Original project manager's assumptions and basis for preparing engineering packages were different from the basis of the subsequent project managers who took over (staff turnover) and Scotford requirements were all contributory factors The basis for the engineering hours to produce engineering deliverables were not fully cascaded down to the discipline level and not well understood. The official schedule estimates were not aligned with what the discipline engineers had The requirements for Procurement/Materials Management support were not fully explained at the time of estimate preparation (e.g. number of packages, the contracting plan for each package - competitive bid vs sole source vs EFA); poor budget definition for each package (e.g. issue a PO without including all the other activities for bid evaluation, expediting, etc). Lack of experienced procurement resources / personnel assigned to the project. Shell Technical Authority (TA) input and requirements in defining the scope of (e.g. QA/QC, HSE) drove changes	Engage more with the contractor's project controls Lead on the project controls requirements for Detailed Engineering early in Define phase Develop and maintain a good succession plan (with emphasis on hiring or replacing discipline leads from within the contractor organisational than hiring externally.

APPENDIX 5: PIPELINE DETAILED ENGINEERING HOURS GROWTH LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
		Impact: Growth of over 250% in hours for some engineering disciplines (Process, Civil, Mechanical, Piping, Instrumentation & Controls), Project Controls (185%), Procurement/Materials Management (230%)	
5	Project Execution Changes	There was an initial strategy to focus on completing the “Inside Battery Limit” (ISBL) CO2 pipeline engineering scope to support the Early Works schedule of the CO2 Capture facilities plant. Hence many documents were split between ISBL/OSBL when one single document set would have been required. The documents for the ISBL had to be revised later on to include the rest of the pipeline. The amount of Toyo effort expended to support the interface with Fluor EPC for the ISBL was underestimated (i.e. weekly interface meetings, and the general level of effort to maintain a smooth interface); Misalignment of the schedules between Fluor and Toyo regarding timing of key deliverables and differences in the level of engineering maturity of their respective scopes between the two contractors (ISBL pipeline – Fluor whilst OSBL pipeline – Toyo) Impact: Growth (over 200%) in overall engineering hours	Keep a separate budget for the ISBL work Ensure the level of engineering maturity among the different engineering contractors are comparable and develop a detailed interface plan
6	Procurement Execution Changes	Sourcing of line pipe, coating and bending: the original plan called for 3 separate POs A decision was made (in Jan 2012) to change to a single source strategy for all 3 components with one supplier whilst the RFQ processes were already underway Outcome: Increased effort and paper work (re-work) in procurement support hours	Have a clear execution strategy/plan on how procurement will be managed by the beginning of detailed engineering and stick to it. Recognize the cost of the change
7	Uncertainty on the regulatory requirements/approvals for leak detection system	Definition of the pipeline leak detection system (LDS) was based on a set of uncertain regulatory requirements and standards Initial FEED design for the leak detection system was for SCADA and to mature the SCADA design through detailed engineering Options to look at fiber optic leak detection system in parallel with the SCADA-based LDS caused delays in final design. Final design is a SCADA-based LDS. Outcome: Delays in making the decision for the LDS requirements caused delays in final design of SCADA system and its components.	Best practice is to have the main systems definition must be completed in FEED stage. Recognize that regulatory process uncertainty can cause potential rework and schedule extension.

APPENDIX 5: PIPELINE DETAILED ENGINEERING HOURS GROWTH LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
8	Budget constrains to execute field surveys vs FID decision timing	Topographic field survey of pipeline right-of-way (ROW) was scheduled before FID due to seasonal constraints (Q3-2011), but production of drawings was delayed till after FID (Q2-2012) to reduce pre-FID spend . FID was delayed due to regulatory approval delays from March 2012 to mid-summer 2012 ISBL Early work design team was scheduled to rollover seamlessly to OSBL scope once survey drawings were available. FID was delayed causing inefficient rollover of the design team Outcome: A 3-month delay (March to June 2012) on the survey drawings due to the regulatory approval delays for the alignment sheets. The design team waited for 3 months without producing any deliverables (implying hours were spent)	Avoid mobilization of pipeline designers if surveys are not available

APPENDIX 6: PROJECT EXECUTION MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	Hold readiness reviews in advance of key bid packages and construction milestones (Best Practice)	Readiness reviews were held in advance of issuing the module RFP package, early works mobilization etc. These drove discipline in completing deliverables, and gave decision makers assurance by "cold eye" reviewers.	Hold readiness reviews by "cold eye" team, typically 1 day duration, in advance of key bid package and construction milestones.
2	Flawless implementation	Have costs estimated for implementing flawless recommendations. Currently there is little/no link between flawless and MOCs as they are difficult to estimate	Flawless recommendations should trigger MOC when appropriate.
3	Organizational Alignment between Operations and P&T (Best Practice)	Having a corresponding Operations rep for each Shell TA (Elect, PACO, rotating, process) worked well. It was noticeable when the corresponding rep for static equipment joined the project later than the rest	Bring Operations reps for each engineering discipline on by end of FEED.
4	Quality issue with sub-vendors on the project POs	More direct communication is required to ensure the EPC and owner are aware of issues and how help can be provided. More engagement with sub-vendors on ITPs and approval of drawings.	1) EPC and owner need to work off the same, approved ITPs 2) EPC and owner need to approve fabricators detailed drawings where applicable 3) More attention is required when equipment includes multiple disciplines i.e. FGR duct which are both a pressure vessel and have a structural steel component
5	Shell should allow the EPC to execute low value POs without going through the complete Shell approval process.	The approval of a process to allow the EPC to execute low value POs would really have benefited the team.	1) Set up a process early to allow low value POs to be purchased 2) Obtain sign-off on this process early in the project
6	Certain EFA vendors have not responded appropriately, or have any sense of urgency.	Certain EFA vendors have not responded appropriately, or have any sense of urgency, with regards to resolving technical issues (eg. valve suppliers, electrical, etc.) as one would expect with a "frame agreement"	1) Ensure relationships are set up 2) Create a list of expectations from EFAs during execution and hold them accountable

APPENDIX 6: PROJECT EXECUTION MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
7	Communication between O&M, HFE and the design team has been very direct with Shell team members making requests directly to designers	Communication between O&M, HFE and the design team has been very direct with Shell team members making requests directly to designers (in many cases not copying any of the Shell Project Engineers or Engineering Manager).	1) Establish a formal communication protocol that includes the project engineers on all directions given to Fluor to help control changes
8	Role and authority of the Shell Engineering Team Leader.	There has been feedback from several people on the project who worked on Shell ULSD regarding the role and authority of the Shell Engineering Team Leader. Previously the Engineering Team Leader had technical authority (was a multidiscipline TA1 or TA2) to make decisions and sign off documents in consultation with the Shell TA's. On Quest, under new PCAP process, the Engineering Team Leader has no specific technical authority. In general feedback has been that this has been less effective for the following reasons: a. In several cases multi disciplines have been involved in decisions. As a contractor, if a decision needs to be made there used to be a single point of contact that had clear authority to reconcile opinions from other TAs. In the current set up there are multiple TA's who have input and who have equal technical authority. The Engineering Team Lead can encourage and facilitate but cannot actually make the final decision b. In some cases TA's look at decisions from a narrow perspective, are risk adverse or are more closely aligned with Scotford preferences than project goals. On ULSD (in some cases) the Engineering Team Leader overrode TA's and approved / signed off based on what was best for the project. This was viewed by the engineering team as a good thing (although operations may not agree in all cases!)	1) Allow the Shell Engineering Team Leader to make decisions when required if multi discipline issue2) Revisit project DAM to add TA roles and responsibilities to Project Engineering Manager

APPENDIX 6: PROJECT EXECUTION MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
9	Establish clear accountability and authority for managing costs.	When closing model review action items and making decisions on vendor drawings we had numerous requests from the TA's and the Quality group, however, it was not always apparent who in the Shell Organization had cost responsibility. From an organizational point of view the Project Engineers have this responsibility in the matrix format and have done a great job with POs, deviations etc. However, for on-going design and closure of actions, it was not apparent that the Shell TA's knew who they had to review their instructions / requests with related to project cost. The communication tended to be directly from TA's to Fluor with no Shell project people copied. It was not clear / demonstrated that the Shell TA's felt they had to be accountable to the project engineers for cost. Based on this, as the project got more into the details it became harder to prevent scope creep	1) Have clear communication of who has cost responsibility and what communication is required to project engineers 2) Enforce protocol on communication between the project and vendors 3) Consider giving authority to discipline engineers for limited contract changes, as a way of enhancing cost accountability
10	Early works readiness	Early works construction was supposed to start in June of 2012, late regulatory hearing pushed the start date out (combined with availability of new templates) resulted in contracts going out to bid late and getting awarded even later. Early works construction started in November 2012	Construction readiness should not be approved when contracts are not in place. Would keep the original schedule for other activities when one changes since there are other risks that could still effect the outcome of those activities. Basically use the earliest start times instead of latest start times to allow for some of the unexpected.
11	Last minute changes to turnaround welding.	Despite issuing scope narratives to the turnaround group well in advance, constructability review with contractors did not occur until just prior to the turnaround outage.	Formal constructability review be held with turnaround group to go through scopes at a detailed level. Allow ~ 1 month prior to the turnaround to provide adequate time to address issues
12	Last minute redesign of ducting	Actual dimensions of existing ducting unknown due to insulation. Operations rejected removing the insulation prior to the turnaround.	Decision to not remove the insulation should have been challenged. Remove insulation early to survey tie-in points, OR design ducting to allow for flexible tie-in location (e.g. field fit up weld on post turnaround side of guillotine to avoid risk of surprise during the turnaround
13	Repeat of Hardware Acceptance Testing	Hardware Acceptance Test was repeated to (1) include the site personnel that would own the system and (2) have the complete set-up of equipment that would be used in the final installation.	Site QA requirements should drive HAT procedure.
14	Sub-Contract Drawing coordination	Due to accelerated nature of scope the contracts for FGR needed to be awarded prior to drawings being finalized. When awarded and work packages released a drawing audit was required to reconcile drawings. This caused some confusion with contractor.	Document system can automatically send contractor updated drawings; however, better practice is to have equivalent of a "contract holder" at site who screens document changes and determines if there is an impact to contractor.

APPENDIX 6: PROJECT EXECUTION MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
15	EFA Category Manager involvement in projects	Changes to EFA representatives (Shell) and difficulty getting details on EFA scope, T&Cs and work processes slowed down the Quest procurement process and created re-work. Information on EFAs is not centralized or readily available.	EFA Category Managers must be accessible and involved in supporting projects
16	Vendor data from sub-vendors difficult to get	It proved to be difficult to access sub-vendor data on Quest especially due to the split strategy (PO#1 issued for vendor data; PO#2 covered balance of scope)	Ensure sub-vendor deliverables are identified and included in POs
17	As-built drawings unreliable for underground services	Despite forewarning and a relatively young site (~ 12y), when project hydrovaced to locate cables multiple issues occurred, e.g. if one cable was shown on the drawing we would find six or eight, if four cables identified on drawing we would find two.	Incentivise production of accurate as-builts for undergrounds. Schedule the hydrovac early to advance planning. Anticipate as-built drawings will be inaccurate and allow time for addressing issues as they arise.
18	Time estimated for support safety programs	Project accounted for about one hour per day to support safety programs, actual was closer to two hours per day	Do a Lean project on improving HSSE to be more effective and efficient. Be realistic in the estimate of time required for safety support.
19	Impact of schedule change due to winter construction not fully understood	With the delays to the early works schedule the entire scope of work shifted to the right and into mid winter. This caused other impacts as contractors are now overlapping with each other, and with our restricted plot space it is causing knock-on productivity issues	Have a robust planning and estimating review of the winter impacts prior to making a decision. Have a cold eyes review to support the project team's evaluation.
20	EPC estimates for sub-contractor scopes were systematically low	EPC estimates for sub-contractor scopes of work have proved to be low (approx. 20%) from the actual bids/pricing we have received in bids and final awards. This also impacted planning for site manpower, indirects and durations especially on a compact site. Where more effort was invested in working with key module contractors estimate quality was improved.	Cost estimators should develop an experience based adjustment factor to improve predictability of actuals vs. budget quotes. Apply the fact based adjustment factor to budget quotes. Apply more comprehensive estimating approach more broadly for the subcontracts Allow for more Construction review and input into subcontract estimates Provide more owner estimating expertise in preparation of subcontract estimates
21	Resourcing site team for early works	Early works effort underestimated. Project team relied too heavily on the subcontractors to provide good supervision and for planning and scheduling. The project could have done a better job at progressively assessing the impacts of setbacks and changes. Experience of the site team and resources were underestimated.	Early works team needs to be resourced to establish project processes as well as completing the scope. This requires additional resources (numbers and experience). Be realistic about subcontractor capability. Monitor and respond early if subcontractors are not performing as anticipated.

APPENDIX 6: PROJECT EXECUTION MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
22	Breaking PO into 2 parts - engineering and fabrication	Getting engineering done early helped in early clarification of technical requirements. Deliverables of PO#1 included procedures (including NDE), WPS/PQR. Most of vendor information required for 90% model reviews were received early. However where sub-vendors were involved in detailed engineering the advantages were not fully realized due to late selection of sub-vendors.	Breaking up of PO into 2 parts as followed for Quest provides advantages when capital is constrained, however it also results in significant administrative burdens as the project progresses. Consider other options such as: Single PO with phased releases Single PO with cancellation clause
23	Underestimated Accelerated Scope Execution for HMU2 Flue Gas Recirculation (FGR)	The HMU2 FGR scope was put on an accelerated schedule to prove the novelty design and system controls associated with FGR before completing the FGR design for the other 2 HMUs. The impact of accelerating a portion of the total project work scope was typically under-estimated in terms of effort-hours and the disruptive impact to the remainder of the project work scope.	Assemble a dedicated engineering team to execute and coordinate accelerated work scope.
24	Use RETAIN tool for resource planning for owner's team support functions	Shell RETAIN tool provides guidelines for project staffing, but these guidelines are not reflective of current day projects. Resource constraints and cost pressures result in smaller teams which may be under resourced. EPC support services (e.g. PS) planned their resources based on TIC value of the project instead of effort and requirements of client. Resource planning tends to be optimistic.	Consult the RETAIN tool and consider deliverable based resource planning for owner's project support functions.

APPENDIX 7: INTERFACE AND INTEGRATION MANAGEMENT LESSONS

ID	LESSON TITLE	LESSON DESCRIPTION (CAUSES/CONTEXT)	RECOMMENDATIONS
1	Use of Interface Data Sheets (IDS) in Execute Phase	The IDS form was initiated in the FEED phase and continued into the Execute phase for the capture facilities. IDS form was not used for the MMV scope implementation and interface management. Impact/Outcome: The IDS process proved ineffective for managing the capture facilities interfaces during module assembly and site construction phases. The specific scope and interfaces around the MMV caused the most confusion and touched the most aspects of the project in the execution phase. Examples of scopes that could have benefitted from a written scope and sign off by involved parties (as required by the IDS system) or through some form of a decision note: type of IT infrastructure (cell phone to current system) for MMV data transmission; storage and power needs on the well site for MMV equipment (which later drove the need for an MMV building as part of the pipeline scope); type of interface cards and connectors between the MMV IT panel and the SCADA panel; timing and needed infrastructure for FAT testing; narrative testing. All of these decisions and scopes required technical data and design to be confirmed and shared with other parties and most importantly- for changes to be communicated in a timely manner and to the right stakeholders.	The use of the IDS form would be useful for the scope definition and implementation of the MMV plan and associated IT infrastructure, their interfaces with the pipeline scope, scheduling and requirements of FAT and SAT testing for MMV equipment and data transfer over to SCADA system, narrative testing.
2	Commitment to Interface Coordination	The work scope of each team member inevitably involves interface management; the management of these lies within the interfacing parties. It can be difficult to understand just how broad reaching those interfaces can extend and what to bring to the forum that includes the interface coordinator. Suggest that the entire Project Team and Operations Team (including subsurface and MMV Coordinator) need to be committed to highlighting those interface items that impact one or more groups; if nothing else for awareness Interface management is only as successful as the effort and information sharing that comes from the participants. Suggest that this requirement is in the roles and responsibilities of the main team leads. Interfaces were progressed and resolved most efficiently and effectively when the involved parties were committed to the established interface management process. For example, commitment to the established process, was not consistent from the Subsurface Execution manager and thus more rework and churn within the team was experienced to reach resolution on MMV related scopes.	Add participation in “interface coordination “ to the roles and responsibilities of discipline leads.
3	Scope Freeze for IM and MMV Programme Requirements	For the most part the IM component was managed by the IM lead and Subsurface lead. Given there were two main interface points that worked well and the work could progress. To note is that the need for this interface and the scope of the IM component resulting from the MMV program and external commitments was under estimated in FEED but once the correct people and a consistent team was in place the scope could be defined. The data type, frequency of collection, the storage requirements and need for report out was highly dependent on the final regulatory approvals (received in Fall of 2012), the CO2 Protocol (finalized in 2015) and stakeholder commitments throughout the development of	Ensure that the subsurface lead, MMV coordinator, environmental lead and IM/IT Manager align on the possible data requirements and IT infrastructure requirements in the DEFINE phase to get a more realistic idea of scope and cost.

APPENDIX 7: INTERFACE AND INTEGRATION MANAGEMENT LESSONS

ID	LESSON TITLE	LESSON DESCRIPTION (CAUSES/CONTEXT)	RECOMMENDATIONS
		the project (2011-2015) and thus was difficult to predict the scale. Impact/Outcome: MMV scope had R& D component that made it difficult for others to determine its needs resulting in late changes to IT plans.	Dedicate Project delivery engineering resources to work on the execution of the MMV plan. Consider having that resource report into the Project Manager in an effort to gain alignment with the execution of the larger CCS project
4	Interface of Pipelines and Capture facilities for SCADA system installation	Another main interface point for Quest was between the pipeline EPC (Toyo) and the main plant EPCM (Fluor). Toyo designed and procured the antennae for SCADA system from well sites to plant site, and the antennae was mounted on the amine stripped column being designed and installed by Fluor. This interface started in FEED and continued into Execute phase. The main challenge with this interface was the schedule differences between the capture plant and the pipeline: the engineering of the pipeline lagging the capture plant. Once the design was completed and installation was scheduled, this interface came off the interface registry. Retrospectively, it should've remained on the registry until installation was complete. Site orientation requirements, schedule changes for the amine stripper tower installation and material delivery timing all created some churn that may have been minimized if it had been followed until completion. Decision in the FEED phase to delay pipeline design till later to reduce the FEASEX spend did not consider the impact to progressing design components that overlapped between Pipeline and capture.	Interface items must remain visible and tracked on the interface registry until activity is closed. Ensure interface areas are explored when decisions are made to slow down a portion of the project.
5	Narrative Testing Responsibility between Construction and CSU teams	There was no clear accountability regarding which function (Construction or CSU) was responsible for Narrative Testing. The details of this interface was not well understood by all responsible parties until near the end of the execute phase when the work had to be completed. Impact/Outcome: A plan was developed late in the project. CSU became accountable for Narrative testing, however, EPCCM contractor was used under a separate contract to help deliver this scope and the main coordination of the work was directed by a Shell construction resource.	Identify and clearly specify during the Define phase with the development and sign off of the mechanical completions matrix, where the accountability and responsibility lies (either with construction or CSU) for the testing of narratives and integrated/complex loops
6	NTR Functional Support and Project Team interfaces (Best Practice)	Once a project completes the bulk of the regulatory process including stakeholder consultation, the interface between the main Project team and NTR functional support team members often diminishes. Many of the activities are completed and it's up to the project team to execute as per the approvals, agreements and commitments that were made. The main approvals for Quest were acquired in 2012 BUT there were many additional approvals, permits, landowner agreements left to acquire before injection scheduled for 2015. The details of the permitting is outlined in the Quest Permits and Consent plan. These activities were advanced and coordinated by the BOM with the project Integration Coordinator in attendance.	Continuing this practice for future CCS or similar projects. By the very nature of the position, the integration coordinator is in a good position to provide updates on the execution of the project and the contact people of who has information that may be needed by the functional team members. A common challenge for those who support more than one project, is understanding the timeline of each project, who is involved and who has what information. The integration coordinator can fill this gap.

APPENDIX 7: INTERFACE AND INTEGRATION MANAGEMENT LESSONS

ID	LESSON TITLE	LESSON DESCRIPTION (CAUSES/CONTEXT)	RECOMMENDATIONS
			Provide a project interface to the NTR team members Use interface matrix as a tool to qualitatively check on the health and effectiveness of the project interfaces. For maximum results include all the project interfaces Venture to technical support departments (e.g. wells)
7	Quarterly Quest Project Gatherings (Best Practice)	Quest was progressed in 4 main categories: Project (pipeline, capture plant) Subsurface, Operations, Venture (Regulatory, Economics, NTR, etc). For most of the project timeline, these components were all at different phases of project development. This combined with changes in personnel as the project advances, are key reasons to allot time for the entire project to connect, understand and debrief on what is occurring in their specific scope. The Quest gatherings were the venue for such alignment. In addition to understanding the full scope of the project, they were a means of communicating project plans that are written to communicate strategy but not always distributed as broadly as they could be, to be most effective. In addition to communicating information, they were an effective means to build the team and to also understand if there is misalignment within.	Continue quarterly gatherings as project progresses, where topics vary based on project phase, people changes and upcoming events.

APPENDIX 8: IM / IT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
1	Embedding IT infrastructure scope in overall contractor EPC RFP document	Having IT infrastructure scope (e.g. Shared facilities, network requirements, wireless, printing etc.) embedded into EPC contractors' scope prevents rework and change requests	Interface with business at the RFP scoping level to make sure that Shell IT requirements are well defined, documented and covered in RFP deliverables	Detailed Engineering
2	Site specific HSSE requirement IT contractors	IT contractors not having site specific HSSE knowledge / planning can lead to delay of implementation and/or violation of safety	Include site specific HSSE requirement in scope document for IT contractors. Make sure that scope descriptions include time for HSE orientation and requirements at the worksite.	Detailed Engineering
3	Document quality requirements for turnover	Scotford final handover specific requirements that were identified in Define phase were almost forgotten by the FGR turnover. Unless the quality related requirements are spot checked occasionally, there is additional work/potential rework required at the time of the handover.	Identify document quality requirements (metadata, drafting standards) at Select phase (and update after each gate) of the project, and follow through with occasional reminders and spot checking. Discipline Leads should monitor and correct on an ongoing basis. Agreed quality requirements should be documented in the EPC drawing issuing process.	Detailed Engineering
4	People turnover at EPCs	In some cases, EPCs may or may not keep track of documents/data/standards/transmittals after responsible person leaves the company; people don't hand over their work. Shell has to put more effort in keeping track of transmittals and information and explaining the process over and again every time.	Early knowledge of people leaving and ensuring proper knowledge transfer should be part of on-boarding/off-boarding process.	Detailed Engineering
5	New Equipment Tagging Philosophy	Incorrect tagging format of the new electrical equipments of the Quest project were rejected by Scotford database & all issued related drawings and vendor documents were re-issued with cost impact of engineering manhours	Develop equipment tag numbering & line numbering philosophy in early Define phase of the project and to be approved by assigned database to avoid any engineering manhours to redo the work.	Detailed Engineering

APPENDIX 8: IM / IT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
6	Document Squadcheck software (ASSAI)	Shell IT needs to have better flexibility and tools in hand for squadcheck reviews. ASSAI does not allow multiple mark-ups directly on PDFs which makes it cumbersome and Shell's strict IT set up on PC's makes it difficult to install & test contractor tools. ASSAI only tracks signatures; causes nothing but re-work on actual comments	Flag setup of squad checking software in pre-feed and improve ASSAI to allow direct commenting on drawings. Provide part time Shell IT on-site support, especially during early days of the project set up. Need the same for PCAP.	Detailed Engineering
7	Document quality requirements not included in POs	EPC contractor did not issue the standards and specs to their vendors for title and drawing name formatting. Site issued document numbers to vendor drawings that did not conform to specs. This created rework to be done to comply with site requirements at the time of turnover.	Centralize and control project drawing and tag number administration. Ensure proper QA/QC checks and balances are in place up front (as tags and drawings are created). Ensure vendors of EPCs are provided with drawings standards. Require vendors to request tag and drawing numbers from centralized admin process to ensure consistency. Implement document control checklist process.	Detailed Engineering
8	Selection of new Shell IM tools	New tools such as EDW and LiveLink bulk loader were implemented for Quest instead of standard AHA (AHA = data validation tool). New tools always pose risk of inaccuracies and bug fixes that project needs to go through causing rework in some cases.	At early FEED phase, challenge selection of IM tools and make a fit for purpose selection. Fully implement selected tools.	Detailed Engineering
9	Site and Project IM integration	Although project Information Handover guide (IHOG) and validation tools EDW/VTL are based on one specific version of site standard, site always has changes to its own standards and there are variances in different areas (base v/s expansion v/s Quest). This caused confusion as EPCs always work on the specific standard that was issued to them at the beginning and after a certain time they are not valid (obsolete) to current site standards.	Consider using or embedding a site resource for IM on brownfield projects. Consider freezing the site standards for the project	Detailed Engineering

APPENDIX 8: IM / IT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
10	Scotford Asset Team Standards	The standards provided by the Scotford IM team for Manufacturer's Record Books (MRBs) and As-builts did not align with Shell global standards for projects or with EPCM scope. Additional effort was required to get the alignment and at additional cost	Asset IM standards for IM Projects Handover to Shell Assets needs to be standardized much earlier in the project in Define phase. Shell application support should never deactivate the records unique record ID. When this is done the repositories will load and create duplicates in Shell's Engineering Document Management System (EDMS). Mostly happens when EPCMs modify title/descriptions.	Construction
11	Document As-Build Process and Scope	The as-building scope for critical documents were not defined early on in the project. IM took the initiative to interface with Scotford IM and Fluor to come up with defined as-built scope for critical drawings. A decision note was prepared to set alignment between project and site.	The as-built scope of critical drawings should be defined pre-FID as part of the Define phase deliverables and rolled out to the EPCM contractor. Standardize Information Management As-Built workflow for EPCM's. Shell should review Critical Documents list, and instruct only redlined EPCM documents to be handed over to Assets for future closeout and handovers. Stable IM tools sets and review of final system configurations to ensure Document and Data requirement are met.	Construction
13	SP3D Implementation	Scotford IM asset team did not have the capability to view SP3D model delivered by Fluor. Thus project implemented SP3D software for Scotford IM so that the model could be viewed and maintained by operations.	Have the tools and systems to maintain and utilize the IM systems deliverables provided by the EPCM contractors.	Construction
14	EPCM IM Resource Capability/Experience	Not only were EPCM's challenged to understand Shells' standards, but also lacked any IM experience. Specifically either they had no counter parts to project IM staff to interface with or if they did they could not add clarity or value on how to deliver Shell IM scope requirements. EPCM's were simply filling the IM Lead role with IT people who had no previous systems or procedural IM experience. Additional Shell IM effort was required to get alignment on project deliverables to Asset.	Any new Shell IM Lead needs to be provided "read-access" to the Projects' EPC contracts so they can understand the EPC scopes and requirements as part of the on-boarding process and handover process between IM leads. Clear instructions should be provided to EPCs on data validation reporting template and instructions, as this is necessary for EPCMs to demonstrate compliance to DQMF. Important for IM Data Lead to establish relations with EPCM resource that manages their design tool and document	Construction

APPENDIX 8: IM / IT LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
		Shell changed Lead IM resource four times on the project. Original IM was involved in the EPCM contract and scope of services.	control data Shell should review all EPCM project issued instructions that are issued on project, that demonstrate to Shell IM how EPCM's deliver IM scope. IM team personnel should be incorporated into project DDM for issuance of such instructions. Ensure EPCM project personnel are qualified and experienced to deliver Shell project IM scope.	
15	Issuance of Shell Standards to Suppliers by EPCM	Initial vendor error was a result from Shell standards never being issued to Suppliers. EPCM did not issue standards to vendors even though they were issued by Shell to EPCM. This resulted in an ~50% vendor data error which had to be corrected by EPCM. Project had to fix 4200 drawings at an additional cost of $100K	Develop a set of performance metrics to check that EPCMs are rolling out the required Shell IM specs to the vendors as part of IM section of vendor POs.	Construction

APPENDIX 9: CONTRACTS & PROCUREMENT LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
1	Contract Templates	Portion of the contract template - terms and conditions, HSE and Quality requirements were not established in advance of the contract formation process and resulted in slippage of schedule dates for contract award.	Establish and agree the components and develop content of the project contracts templates 2-3 months in advance of commencement on the first contract packages. Freeze project contract templates at DG3 with other standards and stick with them or recognize the impact of global revisions on project schedule and resourcing requirements. Consider establishing a corporate team dedicated to updating contract templates for Operations and Projects. Team would update templates for all groups in the company. Shell projects are typically not resourced to do this.	Execute (Detailed Eng & Procurement)
2	Contracting Plan for capture facilities	The project contracting plan included too many contracts and too much segregation of work for the relatively small value of the project. Taxes resources as too many interfaces and contractors to manage for the value they bring to the project	Look at combining scopes or using general contractor for indirect work when value of contracts is relatively low. Don't underestimate the impact of administering multiple small contracts. Consider impact of engineering sequence on bundling. Consider a general site contractor or using EPC house to execute the small packages.	Execute (Detailed Eng & Procurement)
3	Contract Formation Schedule Too Aggressive	Contract formation schedule did not include enough contingency to account for non-responsive bidder, multiple time pressures for the participants etc. Problems on one contract result in impacts on other contracts because resources are working on multiple contracts.	Ensure the contract formation plan is not based on the schedule the project wants, but on what can be achieved taking into account the completeness and approval of the content and components of project contract templates to be used. Refer to schedule benchmarks from other projects to establish realistic schedule durations.	Execute (Detailed Eng & Procurement)
4	Use of Existing Contracts	The project plan was to make use of existing contract on the site. However all work needed to be rebid under a sole source project contract. The expected time saving were not realized and in some cases the process took longer than a full bid cycle	Do not assume time saving for the use of existing "on-Site contracts" will be realized when the actual contract document cannot be used.	Execute (Detailed Eng & Procurement)

APPENDIX 9: CONTRACTS & PROCUREMENT LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
5	Ability to attract contractors	The small size of the project, the location and timing of other work made it difficult to get interested bidders for work. For the largest contract (mod Yard) - there was considerable effort put into selling the project - (presentations and visits in the pre-qualification stage, and during the bid stage) and its profile within the industry. This was successful. This did not translate down the remainder of the smaller contracts.	When your project is small, look at information sessions to sell the project prior to the start of bidding work. Strategies for making contracts more attractive: - bundle contracts to make them larger, especially indirects and site services - sell the project to potential bidders - monitor business environment and adjust appropriately - piggybacking on existing contracts is challenging	Execute (Detailed Eng & Procurement)
6	Vendor Representative agreements (BEST PRACTICE)	Included the Field Service terms and pricing with the purchase order for equipment so that vendor rep agreements did not need to be renegotiated.	This worked well in preventing renegotiation of vendor rep agreements. Expand this to include schedule and dollars for the vendor rep visits when there is confidence the support will be required.	Execute (Detailed Eng & Procurement)
7	CP Support for accelerated FGR 2 construction execution in HMU2	The final requirements for procurement support for the construction work of the accelerated flue gas recirculation (FGR) scope in HMU2 was significantly more than originally planned which caused a huge drain on the procurement resources. Some of the procurement support requirements for equipment and materials expediting were last minute panics, and had to be balanced from a resource perspective against other capture facility procurement efforts.	Treat any accelerated project scope requirements as a mini project. Establish dedicated resources and manage as a project.	Execute (Detailed Eng & Procurement)
8	Enterprise Framework Agreements (EFA), National Blanket Orders (NBO) Call Offs and Quest Terms	With the new introduction of EFAs in Canada, many of the Canadian Call Offs were not executed. In addition, this project required Quest clauses to be added to the Call Offs. This work was largely completed by the CP Quest project team since we could not wait for the Shell Category Managers to complete the work. This effort kept 1 Shell Quest CP person busy for 2-3 months.	Projects should keep in mind any anticipated changes to Shell's procedures and staff accordingly. New processes such as EFAs, model contract library revisions take significant effort until they are established. Need to review EFA implementation versus resource plan	Execute (Detailed Eng & Procurement)

APPENDIX 9: CONTRACTS & PROCUREMENT LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
9	Shell//Fluor Procurement Teamwork	The teams built a strong working relationship which contributed to a superior delivery of the CP work.	Building strong working relationships between Shell and EPC teams early in the project definitely contributes to improved efficiency and less re-work.	Execute (Detailed Eng & Procurement)
10	Terms and Conditions (T&C) Exceptions	Many of the smaller PO packages had bidders submitting long list of T&C's exceptions. Many of the EPC Buyers struggled to deal with T&C's exceptions and they turned to Shell CP to handle the issues. Tiered templates were available but had not been rolled out in Canada at the time.	There should be at least 1 or 2 dedicated resources in the team that can handle T&C's exceptions. Tiered templates should be used to manage Ts&Cs exceptions	Execute (Detailed Eng & Procurement)
11	Multi-Office Execution (Calgary/India)	The Quest project utilised the Fluor New Delhi office for engineering, procurement and expediting. A visit by the Shell Procurement Manager early in the project gained an understanding of the skill sets of the Procurement and Expediting teams.	Early in a multi-office execution project, the Procurement Manager should take the time to visit the other office(s) to gain an understanding the skill sets of those people and to discuss how to work efficiently when working in different time zones. It also allows for common processes to be discussed and implemented.	Execute (Detailed Eng & Procurement)
12	E-SPIR (electronic spare parts system)	Lack of scope definition has brought challenges trying to get the information required by EPC and Shell (eg. spare parts by tag number). The E-SPIR process and its requirements was not well understood by the Project.	E-SPIR scope should be written into the EPC contract . Identify a Shell focal point to take responsibility for managing E-SPIR related issues.	Execute (Detailed Eng & Procurement)
13	Procurement Strategy (2-PO approach)	The advanced engineering required to meet the 30 - 60 and 90 percent 3rd Generation Modules model reviews required substantial vendor data. We had to push vendors hard to get data on time and in some cases had to go into the model reviews with best information available. In addition the two part POs for procurement did result in some delivery delays since we could not book the shop space with the engineering only purchase orders	Would broaden the list of equipment and material that data was required for and bring the procurement activities forward in the process to ensure appropriate information to support the model review. Splitting the POs would not be recommended if you can get the funding to go with the full award upfront. Consider a single PO with cancellation clause (could raise finance issues) Consider a single PO with 'releases' (will need full authority to award)	Execute (Detailed Eng & Procurement)

APPENDIX 9: CONTRACTS & PROCUREMENT LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
14	New Shell contract template	Shell did a major overhaul on its services contracts. With the new look all service providers went through the contracts with their legal counsel resulting in six to eight month times for bid clarification to contract signing.	Similar to DEPs and other procedures, should have a cut off after which a project freezes the templates and contracts they use. If new contracts, then add in 6 to 8 months into the cycle time for impact, plus extra resources.	Execute (Detailed Eng & Procurement)
15	Consideration of vendor location during equipment selection.	One of the vendors selected during the project was located in Mexico City. This made quality surveillance by Shell difficult as travel to Mexico City was restricted, and also presented unnecessary personnel risks. Use of EFA drives location of fabrication. Equipment is awarded by project without full information to evaluate costs. Project did not access local Shell resources in Mexico City.	For equipment that can be easily procured at various locations (such as OH3 pumps) consideration of the fabrication location should be assessed with respect to the impact it will have on quality surveillance.	Execute (Detailed Eng & Procurement)
16	C&P involvement in purchase order progression.	There were many times during bi-weekly teleconference technical meetings with vendors where items of commercial impact would come up. The vast majority of the time there was no C&P support from the project on the phone, and it created compromising situations for the technical staff and resulted in unnecessary delays due to slow progression of CO's.	C&P representation should be part of all periodic technical meetings with vendors	Execute (Detailed Eng & Procurement)
17	Contract Management (Best Practice)	The Fluor EPCCM contract was a behavioral incentivized contract. To maximize the value of the incentive, the contract management process was revised to include monthly collection and review of feedback from all members of the project leadership team on the key areas of the incentive – safety, cost and schedule management, change management, deliverables quality, quality of people, retention of people, governance and responsiveness. To ensure transparency, the weekly coordination meetings included section on expectations that were met and expectations that were not met. On a quarterly basis, the key leadership members (PD/PM, EM, and CM) of both Shell and the EPCCM got together, pre-read was the summarized Shell monthly feedback and EPCCM feedback on Shell's team performance that quarter. Action plans were agreed to and presented at the Quarterly BPR meetings jointly. BPR meeting pre-read included highlights from the quarter including positive feedback, areas for improvement along with agreed actions plans and key risks in the upcoming quarter.	Would replicate even if there is not an incentivized contract to increase collaboration, alignment of the team and foster continuous improvement in the joint team.	Execute (Detailed Eng & Procurement)

APPENDIX 9: CONTRACTS & PROCUREMENT LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
		Impact/Outcome: IMPACT – There were very few surprises in either direction on where the issues were, issues were worked as soon as they were identified and often resolved prior to the BPR meetings, team alignment and communications were strong (VAR and PER teams had trouble distinguishing members from the contractors team from Shell project team members). Most of the incentives were paid in full with the contractor exceeding expectations by the time of scoring the incentive.		

APPENDIX 10: PIPELINE PROCUREMENT LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	Pipe, Valves and Fittings specs to be communicated to the supplier/manufacturer during kick-off meeting	Cause: Line pipe material was of a custom thickness. No kickoff meeting was scheduled with Comco (bulks material supplier). Comco placed order with manufacturers without highlighting instructions to mark pipe and fittings as Grade 386 which led to material landing in skid manufacturer's yard without the required marking. Impact: The material was placed in quarantine for weeks before a letter of compliance was issued by manufacturer to Comco authorising them to certify the material for Gr 386.	Technical team during kick-off should set time aside in the agenda to go over any extraordinary material specifications (if any). Fittings and flanges should be designed with standard specifications to minimise cost. Schedule kick off meetings with suppliers of specialised materials to highlight any custom specifications from standard specs
2	Shipping weights of heavy modules	Cause: Skid weight was manually calculated. The skid weight was calculated incorrectly and provided to skid fabricator Crimtech (original weight was 31,000 lbs which ended up being 41,000 lbs). Impact: The carrier at the time of pick up established that the weight of the skid was more than 30% over the estimated skid weight provided by the designers which resulted in delayed shipment to site.	Develop mechanism to cross check critical weights and measurements of large modules. Include in the fabricator's scope of work to determine the shipping weight (with final confirmation of the weights by the shipper)
3	Pipeline alignment drawings	Alignment sheets/drawings did have instructions for contractor to perform field adjustment of pipeline center line at interfaces with line break valves (LBVs) plot plans. Contractor staked the right-of-way (ROW) as per alignment sheet without paying attention to changes or center line required to match LBV piping layout. Field adjustment of pipeline alignment was a general note in the contract only. Impact: The pipeline contractor charged Shell over $350K for realignment. A claim was submitted by Shell to Toyo (Pipeline EP contractor) for this amount	Make sure that required field adjustments expected to be done by Contractor are noted in the drawings and not in small print in the contract.
4	Changes in Invoicing Instructions during project execution	Cause: Decision was made half way through the project execution phase to have all 3rd party vendors/suppliers to submit their invoices simultaneously to Shell and Toyo (Pipeline Eng & Procurement contractor) as there was no cash call set up between Shell and Toyo; and Shell decided to pay the vendors directly. Toyo was to approve the invoices and direct Shell to pay Impact: The email instructions were not followed by some of the vendors which resulted in delayed payment up to months and in some cases payment of invoice by Shell even before invoice approval by Toyo.	Any changes in invoicing instruction should be formally communicated to the vendor in the form of Notice letter that requires signatures from vendor as well. Instructions for pre-approval of 3rd party invoices should require approval from the main contractor before payment is made by Shell.

APPENDIX 10: PIPELINE PROCUREMENT LESSONS LEARNED

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
5	Linepipe length calculation and re-order	Background: : MITC (the line pipe supplier) had asked for permission to ship overages from original millrun for the 12" pipe which was turned down based on the assumption that the quantity shipped/ordered was sufficient for Quest pipeline scope Cause: Original calculation of line pipe was not sufficient and fell short of required amount. A major contributory factor was not walking the entire pipeline ROW to establish a more accurate pipeline length and the construction challenges i.e. identifying additional 100 crossings that occurred between DG4 and construction start. Impact. It turned out that we needed close to over 5% of extra line pipe (about 3.5km) which was eventually shipped as a separate consignment from Japan to Canada. This resulted in additional cost burden to the project which could have been averted.	Contingency used in line pipe length calculation, material type, and fabrication location should take into account the unknowns/uncertainties with the right of way (ROW) conditions, number of crossings, type of crossings and if there are a fair degree of unknowns then the contingency values should be higher than norm especially when ordering special grade of material as dedicated millrun from halfway across the globe(Japan in this case).
6	Strategy for design and procurement of the line block valves (LBV) skids	Original procurement strategy was to get Toyo to design and supply the LBV skid materials (manual & control valves, PSVs) because they were considered long lead items; whilst the fabricator was supplying structural steel and fittings. Outcome: With this procurement strategy, the fabricators perceived their scope of services to be limited (as they were used to a market place where the fabricators are responsible for all materials supplies). This led to lack of interest by the more established qualified fabricators to bid for this limited scope of services. Resulted in working with small fabricators who lack the requisite quality controls or materials management systems.	In a matured fabricators' market like in Alberta, instead of spending significant hours developing and completing all the LBV skid designs with the EP contractor resulting in limited scope for the fabricator, consider developing a set of P&IDs and let the fabricators bid on the full scope of the LBV skid to attract more qualified fabricators.
7	Pipeline bid packaging	Cause: The RFP package was compiled literally from scratch as standard terms and RFP template for Canada was not available on Model Contracts Library (MCL) in Q4 2012. Impact: It took around 2-3 weeks longer than it should have taken to compile the entire package.	Have a standardised pipeline bid package - i.e. finalise terms and conditions by Shell legal before engaging EPCMs to start working on bid package(s). In essence this can lead to potential savings in hours spent by EP house and shorten the entire RFQ/RFP cycle.

APPENDIX 11: 3RD GENERATION MODULE PROGRAMME LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	Pre-Qualification process	The prequalification process was planned for 2 stages, including an HSE submission, and a lengthy technical/commercial submission. The submission provided so little differentiation that a visit to the passing bidders was required to establish the final bidders list.	A site visit during the pre-qual stage is an excellent tool is selecting the bidders list. The pre-qualification questionnaire, when dealing with a large number of known bidders with established track records should focus on 2-3 pages of key questions.
2	Drawing / Material Sequencing (BEST PRACTICE)	The sequence of the modules was established early and flowed down to drawing and material issue. Sequence was established based on Engineering, Construction and Operations.	Would repeat. Sequence of module erection be established and frozen early and maintained throughout the project.
3	Constructability session with bidders (BEST PRACTICE)	During the design phase and prior to the RFP issuance the planned bidders were hired to provide constructability input into the design. Positive impact - several good suggestions were incorporated. Negative impact - often the suggestions were conflicting between the bidders and they executed in different manner	Construct module review session with bidder(s) for early constructability input. Set up a contract for this purpose to avoid claims for IP later in the job. Consider additional focused constructability workshops as engineering progresses.
4	Establish Unit Price Structure as Early as Possible (i.e. early Detailed Eng) (BEST PRACTICE)	The unit price methods of measurements and philosophy were established with engineering early in the RFP development. This allowed the scope / design documents to mirror the unit prices tables and avoid rework	Establish unit price methods of measurement philosophy early.
5	Mobilization lead time for mod yard (BEST PRACTICE)	There was a 2 month window between award of contract and start of work. This allowed processes / procedures / interfaces between project and contractor to be tested , and adjusted in advance of work commencing.	Repeat that. Allow time (~ 6 wks - 12 wks) for the planning and testing of systems between owner and mod yard in before work starts and can be impacted.
6	Module Contract Templates	Contract template was only completed just prior to RFP issue, and required extensive effort to close out. There was some disconnect over whose template should be used as the basis for individual sections. The RFP issue had to be delayed to accommodate, which used up valuable float time.	Contract template, including agreement on content of all sections (including whether Shell basis or EPC contractor basis) should be in place 2-3 months before RFP target issue.

APPENDIX 11: 3RD GENERATION MODULE PROGRAMME LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
7	Module Contracting Strategy	For a considerable time (pre-May 2011), due to Shell global influence and Shell Heavy Oil contracts board preference, the strategy of Lump Sum (LS), with use of variations for changes, had been in place. This remained the case, due to Project management directive, despite clear feedback from prospective bidders that unit rates (UR) would be preferred. It was only following an internal Shell PER review, where a HIGH/HIGH finding recommended a switch to unit rates (UR) for various reasons, that action was taken to change the strategy.	The contract strategy for key packages (e.g. where full Heavy Oils Contracts Board (HOCB) approvals would be required) should be reviewed every 6-12 months, to ensure that it is still fit for purpose, in light of changing market conditions.
8	Use of Steering Committee (BEST PRACTICE)	This was a group of senior Project Members, who were used as a sounding board for key decisions during the RFP evaluation, prior to any submittals to Heavy Oils Contract Board (HOCB) / JV partners etc. This process worked well by allowing open discussion, and clear agreement as to an agreed way forward.	Use a Steering Committee approach for all big contract RFP evaluations.
9	Module Contract EFA vs Project RFP	There was concurrent activity surrounding a proposed module EFA for North America. The eventual agreed outcome was a parallel approach whereby the EFA would be bid separately, but using the same terms & conditions as Quest. However this exercise took up valuable RFP time, and ate into the buffer for the RFP issue. Also, the Quest Project Strategy driver was cost-driven, whereas in reality, due to government milestones (linked to $ payments), a substantial amount of effort was required in order to place the contract on time (which thankfully did occur, but could have become derailed). Contract award was 3 months late.	Separate out project requirements from EFA requirements. If an EFA is already in place, the project should be mandated to use it. However, using a project to drive EFA requirements runs the risk of a disconnect in strategy, whereby the project may have schedule constraints (as in the case of Quest), that may not exist or allowed for in the EFA enquiry. Where government milestones are a factor (which was a unique case for Quest), this should be clearly understood by all, and decisions made should be on the basis of maximizing the ability to meet those milestones (credibility perspective).
10	Pricing Basis	Quest was planning and had developed a unit rate based pricing structure. EFA's started to be developed when Quest was nearly ready to issue the RFP. EFAs were on a weight based pricing structure. Pressure was applied to Quest to use weight based and this caused some churn and confusion. Required a recommendation from a Readiness review panel and Project VP support to use unit rate as originally planned. The contract award was 35% less than the budget.	Establish freeze dates or stages during contract formation i.e. do not alter contract plan after the set freeze points due to EFA developments.

APPENDIX 11: 3RD GENERATION MODULE PROGRAMME LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
11	RFP Evaluation process	The procedure was written as a 1) Technical + Unpriced and 2) Priced Commercial staged bid approach, with use of bid conditioning for unresolved items with a potentially "major" price impact prior to opening of priced bids. However, due partly to time factors, with a high number of exceptions taken and theoretically requiring bid conditioning, a decision was taken to open the priced commercials of those bidders who had passed the technical evaluation, without having bid conditioning values previously agreed. The impact of this was that the relative (unconditioned) prices of the bidders became known prior to any agreed bid conditioning. Due to the wide disparity found between 1st and 2nd placed bidders, it was not a major concern, but had all of the bids been close in value, the process may have become very subjective.	The evaluation approach of Unpriced + Priced Bidding evaluation with use of bid conditioning, should be considered carefully for each bid and the time taken to bid condition remaining items should not be underestimated. Use of a UPC + PC approach where schedule appears the key driver, may not be the optimal way to manage, especially if to be used by an EPC house who may not be used to working with an Unpriced bid evaluation/bid conditioning approach.
12	Pumps shipment requirements on modules	The pumps installed in the modules could not be transported. Rework was needed to assemble and disassemble	Include specific instructions in the engineering specification covering the shipment requirements. Pick pumps that can be left in the modules
13	Engagements with module fabricator (sound start)	After a lot of good focus and commitment during the bidding process, the team lost steam and weeks were lost without further contact with the contractor. Team deployment at the location must be early as warranty of a sound start. Lack of alignment in the expectation of the planning phase deliverables was the result of this	Align and schedule early all the consequent engagements of the team/subteams after the Kick-off session with the module fabrication contractor. Monitor and report on progress.
14	Material in PO was confused as material available	The availability of the piping material in POs placed to EFA was not confirmed until the releases were given to the suppliers. Resulting in discovering that some material was not available. Project management assumed with PO placed that delivery date was known; that wasn't the case the project still hadn't issued the specs yet to the suppliers.	Order the material with additional float to the historic delivery time. Request/release three months in advance of material. Don't assume materials will be available without checking with EFA. Ensure full issue of technical specs with PO in order to get the delivery dates.
15	Buildings and stand alone electrical substations in module contract	The strategy of requesting the module fabricator to design, supply, and install buildings on the modules resulted in schedule pressures and a considerable amount of interfacing with the supplier and the engineering office. Detail of the buildings was left to the module contractor without providing	Consider preparing a complete "Basis of Design" for the buildings or direct engagement of the EPCM home office engineering with building suppliers so the buildings can be included in the free-issued components to the Module Yard fabricator

APPENDIX 11: 3RD GENERATION MODULE PROGRAMME LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
		a complete design package, basis of design, interfaces, etc. This resulted in delay and excessive quantity of hours spent on interfacing KBR demonstrated a lack of the requisite technical skills to design and build a stand-alone electrical substation building. The project management team therefore approved a change order for KBR to subcontract Pyramid on a cost reimbursable basis. This change and an active involvement with Pyramid from the Module Yard team prevented this scope item from further schedule slippages and becoming a critical path item. Module Construction contractor was not specialized in Electrical substations. This resulted in delays and risk to quality and schedule.	Complete the detailed building design before awarding module contract. Building and enclosures in the modules should be detailed by the EPCM contractor Test module contractor has the capacity to complete buildings design. Use specialized suppliers.
16	Strategy of bundling pipe fabrication with module assembly	Piping/spool fabrication and module erection were combined with an objective to eliminate an interface. But actual interface in KBR (module fabricator) yard was not optimal and that combination limited the project team's influence.	Test assumptions of any bundling of activities in module contracting strategy during bidding process
17	Push pull philosophy for material delivery	Push pull philosophy established in the bid-package brought initial confusion of who would trigger the request of material. Order the material early. Use EPCM schedule to order the material and establish priorities.	Establish clear responsibilities. Don't expect that the module yard contractor will alter their normal processes without clear instructions.
18	Good team alignment for the evaluation process (BEST PRACTICE)	Plan for the evaluation of the contractors proposals was discussed and aligned with all the team. A second level of decision (steering committee) was designed to avoid dispersion and maintain the alignment. The team achieved all the schedule challenges.	Use a similar approach. Prepare a plan with not only target dates but also team functioning procedure.
19	Pricing Basis	Quest was planning and had developed a unit rate based pricing structure. EFA's started to be developed when Quest was nearly ready to issue the RFP. EFAs were on a weight based pricing structure. Pressure was applied to Quest to use weight based and this caused some churn and confusion. Required a recommendation from a Readiness review panel and Project VP support to use unit rate as originally planned. The contract award was 35% less than the budget.	Establish freeze dates or stages during contract formation i.e. do not alter contract plan after the set freeze points due to EFA developments.

APPENDIX 11: 3RD GENERATION MODULE PROGRAMME LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
20	Construction Readiness Process	There was a process culminating with Readiness Reviews with Cold Eyes participants to issue the RFP then start Module Construction . Recommendations from the review panels were generated. After closing actions a recommendation for the Module Construction Readiness was presented to the DRB for approval to proceed. This process provided more assurance than normal, and identified and drove the completion of deliverables.	Consider standardizing this process
21	Transport beam planning	It was unclear who would be supplying the transport beams. The criteria for use of transport beams was not well established during the design process. Transport beams were assumed to be low cost, but they are not.	Transport beams requirements need to be an integral part of the design.
22	Temporary supports for shipment	Transport stress analysis was done as a separate exercise causing engineering re-work and delay in isometric issue.	Temporary supports for shipment should be addressed in the Design Guideline.
23	Rotating Equipment on Modules	Conflicting priorities (Operations, Maintenance, Construction, Logistics, etc.) must be balanced to establish philosophies / approaches for placing RE on modules.	Establish the criteria for putting rotating equipment on modules during pre-FEED.
24	Vertical Modules	Vertical modules were used to minimize on-site hours. Approach to building vertical modules was established through constructability workshops and discussions with fabricators.	Establish criteria during pre-FEED to decide where to use vertical modules. During Detailed Design establish a structured constructability and design process.

APPENDIX 12: MODULE FABRICATION LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
1	Duration for the Requests For Information (RFIs) process was too long	Background: RFI responses took longer - from about 5 days to sometimes about a month for the extreme cases; about 50% of RFIs were turned around in 1 day Causes: Module fabricator did not use the EPCM contractor's RFI system/process; some RFIs had to be taken back to the EPCM's Home Office Engineering for their input and approval; some initiated RFIs lack already proposed answers Impact: Too much shop space was taken for spool components already in fabrication waiting for disposition on RFIs; delays in releasing ISO drawing (ISOs were not released to the shop on time and not knowing if they were missing materials or not); and additional effort by field engineering to close RFIs	Schedule regular (weekly) engineering alignment/interface meetings between the fabricator and EPCM contractor's field engineering team to discuss and close off RFIs quickly Conduct an early review of the fabricator's RFI process/system with the EPCM contractor's processes/systems for RFIs to identify and close any gaps in order to achieve full alignment and process simplification between the different RFI systems to be used for the project
2	Misuse of RFIs to seek technical deviations and NCRs acceptances	Background: RFIs were used in some instances to propose changes, and also to seek deviations to project specifications and acceptance of non-conformances (NCRs) Causes: Project processes and procedures were not clearly detailed at project kick-off. Impact: Time and effort spent to initiate and route an RFI through the process to seek technical deviations only for it to be rejected at the end of the cycle; created re-work.	Ensure RFI process and objectives are clear to the fabricator; and that RFIs should not be used to seek technical deviation and acceptance of non-conformances
3	Ownership of Non-Conformances	Background: Fabricatioon shop were involved in NCRs generated at the mod yard sometimes lacked clarity as to who was responsible for the NCR; sometimes NCRs got piece-mealed to different individuals Causes: Due to high turnover of staff at the mod yard Impact: Longer time and more effort spent to seek dispositions to NCRs	Ensure ownership (including generation and closure) of each NCR stays with the team (either from the fabrication shop or module yard) that generates it

APPENDIX 12: MODULE FABRICATION LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
5	Hydrogen service flange-face finish not to specification	Background: Out-of-spec H2 service flange finishes were identified after some flanges had already been welded in. Causes: H2 service flange-face smooth finish specification and requirements (e.g. of smooth finish specs of 125 - 175 microns) were clearly stated in the PO to the suppliers but was not included in the technical notes to the fabricator who received the material. Impact: Stalled fabrication of spools; already fabricated spools took up extra shop space pending a resolution; time and effort taken to resolve this issue.	Clearly communicate special requirements (e.g. of smooth finish specs of 125 - 175 microns) of flange faces and other specialty requirements for non-standard items/materials to be received by the fabricator through for example the engineering and technical notes issued to the fabricator
6	J Bevel finish (SAME AS H2 SERVICE FLANGE-FACE FINISH)	Background: J Bevel pipe end preparation for orbital welding was not as per the site contractors requirement. Causes: The site contractor was not consulted on specific dimensional requirements for their J Bevel equipment. Impact: Rework; spools took up extra shop space as fabricator assumed a typical profile per B31.3 was acceptable.	SAME RECOMMENDATION as H2 service
7	Cleanliness requirements for the Flawless Programme was a success (BEST PRACTICE)	Background: Cleanliness requirements for the Flawless Programme was a success. Causes: Persistent enforcement of the cleanliness requirements from the Flawless programme. Impact: Forced the fabricator to be better organised to meet the requirements of the programme and improve fabricator's performance. Fabricator instituted several best practices shop wide (e.g. marking 'cookie' or 'coupon' removed on spool).	Repeat Flawless Programme on Cleanliness requirements for future projects.

APPENDIX 12: MODULE FABRICATION LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
8	Level 5 Fabrication Schedule lacked target delivery dates for spools	Background: Fabricator's schedule didn't have the target delivery dates for spools. Fabricator's summary list was developed by packages. Schedule had production dates. Causes: Impact: Inability to effectively plan module erection/assembly activities; impact of materials delays could not be properly assessed	Fabricator should include delivery dates for the spools in their level 5 schedule
9	Delays in expediting and delivery of ship-loose piping	Background: Expediting the release-for-shipment of ship-loose piping was too long (it took about 10 - 14 days); Causes: Multiple sign-offs required and no one specific person accountable for the process. As such, left to the way side until someone came looking for specific spools. Impact: Delays in spool installation/assembly at the main construction site.	Set a target date for each load of spools being shipped and project team members (shipping and receiving teams with the rigging crew) work towards that target date, including the generation and monitoring of the paperwork by the Ship-Loose Materials Coordinator
10	Drafting process and quality of cut sheets was good (BEST PRACTICE)	Background: Cut sheet drafting process and match up with the ISOs (which used an electronic system) were good. The transfer of information from EPCM design system (SP3D) to Fabricators drafting system (SpoolGen) was seamless and created minimal errors. Causes: Impact: Less rework in both the fab shop and module yard due to limited drafting errors and hence better efficiencies through the fab shop and mod yard.	Follow the same process and standards for cut sheets Institute proper QC checks when CAD sheets are generated. Ensure fabricators cut sheet system is compatible with design software.

APPENDIX 12: MODULE FABRICATION LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation
11	Loss of control on quality and schedule on a portion of the spools fabrication scope which was sub-contracted	Background: Due to constraints and concerns of shop space availability, project made the decision to sub-contract a portion of the spool fabrication to a different 3rd party fabricator (a sub-contractor of the main fabricator) in another province. Spools couldn't be shipped from the sub-contractor's shop as per cut sheets due to transportation constraints. 2000 MTIs were originally planned to be moved to the subcontractor, but only 1000 were completed by the subcontractor due to transportation challenges with the other 1000 being completed by the main fabricator Causes: Due to poor planning (this execution idea was done on the-go) Impact: Rework, additional welding and additional handling of spools resulting in additional project cost.	Have a representative with the requisite technical and QA skills in the 3rd party fabrication sub-contractor's shop to own and manage project and quality. Develop better execution planning for 3rd party fabrication subcontract work ensuring spools that can be transported by trucks are given to the 3rd party fabrication sub-contractor
12	Delays in approval of fabricator's weld procedures (e.g. Flux core) and ITPs	Background: Flux core weld procedures took a long time to get Shell's approval. Given the amount of stainless steel (SS) on the job that could have improved fabrication production. Flux core weld procedure was approved for carbon steel (CS) but not for stainless steel (SS). ITP's took a long time to approve. Causes: Flux core is not an accepted practice within Shell and the Quality breakout session after the Project kick-off took too long to initiate. Impact: Fabricator's weld procedures were late in getting project approvals; extra effort spent in getting fabricator's ITPs approved.	Shell TAs should have a list of pre-approved local fabricators weld procedures before the start of fabrication. For the same fabricator, the owner should investigate the use of derogation approvals and deviations already obtained by the fabricator from the owner from past projects executed for the owner by the same fabricator to minimise effort Fabricator should submit ITPs early to the EPCM contractor for review and approval prior to the start of fabrication (possibly immediately after fabrication contract award)

APPENDIX 13: MODULE ASSEMBLY AND MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Background, Cause, and Impact)	Proposed Recommendation
1	Implementation of Cube Fall Arrest System	Background: Quest noted that KBR workers were in violation of Occupational Health and Safety (OH&S) for working on trailer decks and brought to KBR's attention. Causes: OH&S does not allow workers to work on decks (e.g. trailers) over 42" if it is an everyday activity without an appropriate means of tying off (i.e. allows for occasional instances). Impact: Effective Mode 2 relationship building as KBR and Quest worked together to find a solution to the situation. The result was KBR implemented movable weighted cubes with tie-off capability for working on trailer decks.	Ensure that there is a fall arrest system available for all types of work at heights at the beginning of construction execution.
2	Coordination of Building Testing & Precommissioning	Background: Coordinating of resources (Contractor, EPCM, Client, and Vendors) was a time consuming effort by the EPCM Instrumentation Field Engineer. The preliminary electrical testing and precommissioning original plan was generic and allotted one month, when in actuality it was anywhere from one to six weeks. Causes: Lack of clarity from the EPCM Contractor on the scope definition to maximize the testing at the mod yard. Coordination of up to six different contractors to ensure they were available at the appropriate times during the testing period. Impact: A large portion of the EPCM Field Engineers time was required to manage this scope of work due to the lack of clarity, as such, taking away time from other areas of their responsibilities. A vendor in the modyard started electrical testing before the Inspection & Test Plans (ITPs) were approved by Shell	Have a definitive scope for the testing plans (e.g. a spreadsheet to define what tests required, equipment by equipment). Ensure continuity of testing contractor from the mod yard to the main construction site to minimize retesting. Have a construction coordinator with identified responsibility for testing. Have ITPs reviewed and approved by the client CSU/ORA team prior to start of testing
3	Flawless Project Delivery Implementation	Background: The Quest Project instituted the Flawless Project Delivery (FPD) Program into the module yard contract to minimize issues during start-up of the facility. Causes: Good FPD implementation. Needed some minor tweaks to some of the check sheets (instrumentation) Due to up and down start-up issues globally within Shell the Quest Project implemented the FPD Program to ensure a smooth steady ramp up to capacity of the facility. Impact: The program was well embraced by the Contractor, flaws/actions were caught and rectified progressively prior to final module walk downs. The Contractor implemented some of the learnings as best practices (e.g. writing coupon removed on pipe for branch cut outs). This holds especially true for the EPCM 3rd Generation Modularization Philosophy, which puts a large portion of electrical work into the mod yard facility.	Continue to implement FPD in the mod yard. Review and tailor FPD checksheets for modularization instead of generic template. Provide clear descriptions of issues identified (e.g. location and tag number). Involve crafts person in the walkdown so small items can be addressed on the spot.
4	Timing of receipt of module yard generated hydrotest packs	Background: Module yard generated hydrotest packs were reviewed and signed off late; hydrotest packs were to be issued and used for the pre-module walkdowns/sign offs, and therefore had to be signed off and issued before insulation were installed; but got generated late from the mod yard QC department. There was a contractual requirement to submit test packs 30 days before start of the hydrotest Causes: Resource constraint on timely test packs coordination and releases Impact: Time delay and effort to strip off the insulation; and possible rework (e.g. in correctly installed valves, higher lugs or shimming of lugs not sitting on steel, etc)	Provide a designated resource to clear hydrotest packs on both project and contractor sides. Adapt electronic approval and releases for test packs (confirm the overall process with key stakeholders prior to contract award (e.g. RFP)). Implement an electronic tracking sheet for travel sheets.
5	Cable Schedule Deliverable	Background: Cable schedules were not provided by module and several schedules would cover multiple modules. Causes: For ease of issuance by EPCM the cable schedules were issued by design index (e.g. each electrical building constitutes a design area for electrical supply). Impact: Extra effort was required by the Contractor to sort cables by module, which caused duplication and missed scope. This resulted in a lot of Requests for Information regarding coil lengths, location, coordinates, etc.	Provide a common database for cable schedule and tray with read access given to fabrication contractor. Ensure each module has a complete bill of materials including the cables and tray. Add x, y, z coordinates to coil location including on cable schedules. Review RFI's that have been submitted to identify common trends and take proactive measures to rectify common issues.
6	Vertical Module Laydown	Background: Due to the tailing lug location when lowering the vertical modules the sheaves used in the rigging would flip and became zero gravity which allowed them to move freely. Causes: The tailing lugs were too far up the columns. Impact: This could have caused damage to equipment.	Tailing lugs should be installed as close to bottom of towers as possible. Make one set of lifting lugs higher on the top of the tower.
7	Final Inspection and Vessel Closure (Best Practice)	Background: The mod yard team developed a plan that required coordination of several stakeholders (ABSA, KBR, Operations, etc.) to ensure regulatory body certification of pressure equipment and final closure of vessels. Module Yard Contractor had a dedicated/consistent focal point to coordinate preparing this equipment for inspections. Causes: Past experiences from team members resulted in turnover delays due to pressure equipment inspections and certifications. Impact: This could have caused delays in turning over systems to operations due to coordinating efforts during critical time of project construction.	Replicate best practice and set up vessel final inspections in the mod yard plan/contract and are clearly defined.
8	Material Receiving Inspection	Background: Tardiness in material receipt of equipment by fabricator. Some vessels were received in summer months, however, were not inspected until winter months. This Includes two exchangers that had residual water, which formed ice blocks by time of inspection. Causes: Fabricator had several clients receiving material at the Contractors facility with no clear expectations of inspection criteria. Impact: Material and equipment were being received damaged and not realized until quite some time after receipt and as per the background statement some equipment was damaged after receipt due to residual water in the equipment. This could result in losing opportunities for recourse against supplier as well as delays in construction to resolve issues.	Inspect materials receipt in timely manner (set the timing). Define inspection expectations in contract (including, inspection criteria, competent receivers). Define material that is assembled vs. ship loose (e.g. shipping documents should include every item assembled in a cabinet). Vendor documentation should come with equipment to fabricator.

APPENDIX 13: MODULE ASSEMBLY AND MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Background, Cause, and Impact)	Proposed Recommendation
9	Requirements for Preservation of Equipment (Best Practice)	Background: Contractor had requirements to provide preservation services for all the equipment received for the project. Causes: Due to the duration of the project and receipt of equipment the Suppliers/Vendors had preservation requirements for their equipment to ensure proper operation once in service. Impact: EPCM's proprietary mechanical completion tracking program was very useful in providing fabricator with their weekly tasks for preservation. All the suppliers preservation requirements were loaded into the program and a weekly check sheet was provided to the Contractor with all the weeks activities.	Utilize a system that automatically populates preservation travel sheets.
10	Equipment Bolt Allocation	Background: Equipment bolts were shown on structural drawings, as such the steel fabricator supplied both the structural and equipment bolts for the project. Causes: For ease of supply and design the EPCM had the steel fabricator supply both types of bolts. Impact: Steel fabricator did not differentiate or tag the different types of bolts, as such the equipment bolts were difficult to locate and had to be reordered in some instances.	Equipment bolts should be tagged and shipped separately.
11	Module Walkdown	Background: Although the coordination of resources was well established, the walk downs were occurring while module assembly was on going. The time allotted for module walk downs and clearing punches was reduced as the project progressed. Causes: Due to module assembly delays. Impact: As a result the punch lists were very long and in some cases resulted in the need for a final walkdown. In some cases modules were consciously delayed or scope transferred to site. In some cases, to maintain shipping dates, the puncDue to excessive items because of the early walks sometimes modules were consciously delayed or scope transferred to site. To maintain shipping dates punches cleared and accessibility to module removed prior to sign-off.	Build and allow more float in the module assembly schedule to allow for RFIs and material issues
12	Building Design	Background: The building design scope (which included 5 buildings integrated into the modules and 1 stand alone) was included in the fabricator contract, including HVAC equipment. The Contractor did not have the design or construction expertise to self perform therefore subcontracted the scope to a specialized contractor for the design and build. Causes: Lack of clarity around the scope of work for the buildings. Impact: Due to the lack of clarity around the scope there was a lot of design iterations, tray routing rework, water ingress (improper design of self framing building interface with the checker plate floor), equipment spacing restrictions, equipment mounting issues (e.g. lack of support steel).	Consider having the EPCM do the full design of the buildings or significantly improve the clarity on the scope of work. Ensure flooring system is compatible with building style. Consider stand alone buildings to slide into module supplied by building manufacturer. Consider equipment and cable tray layout in the design
13	Instrumentation Unit Rates	Background: During the execution of the module contract it was realized that there were some unit rates that did not exist for some of the activities required for the scope of work. Causes: Some instrumentation installation details were not finalized prior to the module contract being awarded. Impact: Extra effort was required to agree to new unit rates in order to properly invoice.	Review of Unit Rates once installation details have been IFC'd to ensure they are all covered. Recognize this as work that will need to be done.
14	Building Testing	Background: With the 3rd Generation module philosophy four modules had buildings which were integrated within that required extensive electrical testing. With the buildings spread throughout the yard utilities had to be arranged for supporting the testing requirements at each location. Causes: Due to available yard space and construction sequence of modules. Impact: Extra effort and utilities were required to support the testing at the various locations.	If possible designate an area of the yard for modules that require electrical testing and ensure all utilities are available in that location.
15	Weld Seam Management	Background: When module interconnect piping was being welded at site the pipe seams lined up with one another which is against the Shell specification. Causes: The Contractor did not managing the piping weld seams between cut sheets. Impact: Extra effort was required to prepare a TDN to accept the piping as is, however, the possibility existed of having to cut spools and insert pup pieces to offset the seams.	Have the Contractor utilize a tracking mechanism to ensure module interconnecting pipe seams do not align.
16	Documentation Submission	Background: Project required Quality documentation (e.g. ITP's, Weld Matrix, Procedures) was not submitted within contractual timelines. Causes: The first Quality meeting did not occur until approximately one month after contract award. Impact: Documentation had to be expedited outside of proper document control channels and reviews/approvals were rushed to accommodate construction schedule.	Within a week after contract kickoff have breakout sessions with each group to ensure timely submission of contractual documents or as part of the kickoff meeting set up, also set up all the follow up break out sessions.
17	Completion of Equipment Inspection Reports (EIRs)	Background: The Project was required to complete detailed EIR's upon receipt of equipment (e.g. beyond a typical warehouse receiving report). It was determined through a Continuous Improvement Workshop that a competent tradesperson was capable of completing, however, in actuality the Project insisted on a Quest resource. Causes: Lack of clarity around the requirements of EIR's. Impact: Wasted time and undermanned resources completed these tasks, as such defects (e.g. ice in exchangers and flange face issues) were found much later with less time to resolve said defects.	Provide additional clarity in the module contract as to the requirements of the EIR's. Have a qualified tradesperson carry out the equipment inspection reporting. As well, when a methodology is decided upon to complete the activity stick with it.
18	Handover Binder Review and Turnover	Background: Handover documentation from the Contractor was received with incomplete and missing documentation. Also the EPCM Turnover Software required a lot of QC documentation in comparison to similar projects. Causes: The 3rd Generation concept, whereby, a lot of electrical work and testing was completed by the Module Yard Contractor. Due to the module contractor's lack of resources within the Turnover Department for assembling Handover Binders. Impact: Extra effort was required on the EPCM Quality and Field Engineering groups by taking on more of a	At the Module Yard Kick-off Meeting ensure there is a discussion specifically around Turnover. Ensure the Contractor is properly staffed to complete Handover

APPENDIX 13: MODULE ASSEMBLY AND MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Background, Cause, and Impact)	Proposed Recommendation
		Quality Control as opposed to Quality Assurance role. This also resulted in multiple iterations of the binders back and forth with between the Contractors. The assembly and review of the turnover documentation required a lot more resources from the Contractor then a typical modular program.	documentation including a designated person for final review prior to submission. Review requirements in detail as part of the Quality breakout session after the contract kickoff to ensure understanding of requirements and can influence the capture of documentation as fabrication as assembly progresses.
19	Scan Structural Steel	Background: Although assembly measurements are within tolerance some connections and nozzles in the field needed rework. Causes: Errors in structural steel are often the main cause for incorrectly set connections and nozzles. It causes discrepancies between the as-built module and CAD even if piping connections are measured properly from center of steel. Impact: Extra effort in the field was required to rework some of the module to module connection piping.	Scan structural steel prior to setting any pipes or vessels to avoid errors in critical fit-ups. This allows for mistakes in the structural steel to be eliminated prior to pipe fitting.
20	Strong Communication with Laser Scanning Contractor	Background: Delays in Scanning Contractor completing scanning field work. Causes: Occasionally called to laser scan modules that did not have their piping connections finalized. Impact: This can introduce errors into laser scanning data when connections are adjusted during scanning process, or delay laser scanning.	Prior to laser scanning of module, have all critical connections set and ready for scanning. Communicate any unfinished sections on module to laser scanning provider.
21	Laser Scanning Reports	Background: The writing of professional engineering reports were very detailed and the construction team is only interested in the piping connection fit-up data. Causes: Requirement of reporting was not agreed upon prior to execution of contract. Impact: The writing of professional engineering reports for each module analysis takes up a lot of time and does not allow much time for corrections if required.	Include the level of detailed required in the engineering report in the scope of work package to the laser scanning company. Then ensure to compile the report in such a manner that it only incorporates content limited to the relevant information needed to check the connections.
22	Focus laser scanning on critical components and beams	Background: Modules often have many small piping components and only a few larger critical piping components. While interest is mainly in the larger critical piping components it was later decided to only scan 4" and larger connections. Causes: Treating all piping components with equal importance. Impact: Slows down the field work and analysis of module.	Doing analysis only on pipes four inches and above greatly reduces the time spent completing module analysis which in turn provides faster feedback to the construction team. Only laser scan the critical connections and sections needed for the fit-up 4" and larger. This not only cuts down on time spent in the field but also makes the data files smaller, speeding up the analysis process.
24	EHT Design	Background: There were many EHT modifications required due to missed low point drains, vents, removable spools, and pipe shoes not accounted for in design. Causes: EHT designers using previous revisions of piping isometrics to complete design. Impact: Many RFIs and FCNs required by the field engineering team to rectify the issues.	Prior to finalizing EHT EWP's ensure drawings were designed to the latest revision of piping isometric. This is more prevalent in module programs that incorporate a lot of electrical work within the assembly process (e.g. 3rd Generation).
25	Vendor Equipment Inspections	Background: There were many pieces of vendor supplied equipment (e.g. pumps, vessels, exchangers) that required rework due to deficiencies. This included, mechanical seal failures, soft foot issues, misalignments, flange face damage, hydotest fluid remaining. Causes: Poor workmanship by vendors and missed deficiencies by shop inspectors. Impact: Rework and even shipment of equipment back to shops for repair were required. This caused resources to be allocated to address this rework as opposed to completing the scope of work in the module program.	Include these issues of mechanical failures, misalignment, flange face damage, etc. on the flawless list and ensure the typical flaws encountered are reviewed with the vendors and inspectors during the kick off the purchase order as well as for any discipline or operations shop visits. Definitely should be on the ready to ship check list as well. Ensure equipment is inspected by discipline specific qualified personnel immediately upon receipt to identify issues early and implement a remediation plan.
26	RFI Trends	Background: There were many similar electrical issues that were raised through the RFI process multiple times (e.g. supports, cable coiling, breaker, and tray clearance issues). Causes: Engineering was rushed just to meet EWP issuance deadlines without designs being complete and reviewed. Impact: Many of these issues had to be dealt with in the field many times over which resulted in poor work fronts and productivity.	RFI trends should be identified after the project is 1/3 complete and be addressed with a proactive mitigation plan in order to stay ahead of construction.
27	Mode 2 HSSE Contract (Best Practice)	Background: The module contract was executed utilizing a Mode 2 concept, whereby the contractors HSSE statistics are reported and combined with Shell's. As such, Shell's safety culture is influenced onto the contractors. Causes: This was a project decision to align with other module programs within Shell to be more accountable with large project scopes being executed on contractor's property. Impact: There were difficulties on the contractors side in understanding the concept and intent, as such there was a steep learning curve. However, as time went on everyone bought into the program and it improved the yard for the better (no lost time incidents).	Repeat the Mode 2 in module yard activities, ensure a thorough gap analysis is conducted with the contractor and utilize a single reporting structure.

APPENDIX 13: MODULE ASSEMBLY AND MANAGEMENT LESSONS

ID	Lesson Title	Lesson Description (Background, Cause, and Impact)	Proposed Recommendation
28	Module Yard Orientation for visitors	Background: Contractor orientation was lengthy, craft based, and not conducive to short term visitors. For example Vendors supporting equipment testing for one or two days were required to sit through the nearly full day orientation to provide support for their equipment. Causes: This was the Contractors requirements with no exceptions to differing situations. Impact: This resulted in vendors requiring to travel a day or two earlier to attend orientation complete with D&A results only to witness testing being conducted on their equipment.	During contract negotiations, request the acceptance of a short visitor orientation video for vendors that will visit the yard to witness testing. Other possibility is to use a video or presentation could be given on a CD prior and have a quiz upon arrival at the yard.
29	Rules of Credit (Basis of Reporting)	Background: The Rules of Credit for the module yard contractor to report progress were written into the contract. Contractor was awarded certain percentages for completing certain activities (e.g. drafting cut sheets) as opposed to simple units complete divided by total units. Causes: This is a standard Shell practice of reporting progress, it was written into the contract and enforced. Impact: Difficult to know exactly where the project is in terms of progress especially in a unit rate project.	Develop a fit for purpose progress reporting process that is tailored to the contracts needs.
30	Material Take-offs by Module	Background: The project never had material quantities broken down by module, which would allow alignment with material management. Additionally, during contract development this would provide assurance that all unit rates have been captured. Causes: Engineering was incomplete and the EPCM required the Contractor to provide the material take-offs as the EWP's were issued. Impact: This resulted in difficulties planning and controlling the project.	When Home Office Engineering is complete provide IFC quantities and include with each EWP
31	Schedule Certainty	Background: The module yard program had fluent delivery dates (e.g. ship loose spools). Schedule risks analysis was done with the EPCM contractor at the beginning of the project where 3rd Generation modules featured very prominently Causes: The ship loose spools were not on the risk matrix and hence there were no mitigation strategies for the ship loose spools. The module yard was not treated as an assembly line, which would have ensured all materials were on site ahead of requirement. Impact: This resulted in extra work through PDN's, CSI's, RFI's, and DCN's	Consider the ship loose spools in the schedule risk analysis and include critical spools in the integrated schedule. Define the project priorities and do not change. Have a dedicated weekly fit for purpose schedule meeting. Ensure schedule for module yard is not too detailed (Level 3 will suffice).
32	Invoicing	Background: The Contractors submission of invoices were delayed and not received until well after modules were shipped. Causes: There were difficulties in invoicing when parts of the contract were unit rate and others reimbursable. Impact: Contractor was not paid timely after completion of work.	At the onset of the project ensure there is clear communication on invoice requirements and validation process by understanding the needs of each side. Consider getting agreement on the MTO by module in advance. Be upfront and make it clear in the contract that rework is done at unit rates. Have the Contractor provide a breakdown of the quantities installed each week.
33	Management of Change	Background: When RFI's were submitted that required changes (e.g. not specification interpretations) the change process was lengthy and cumbersome (e.g. RFI issued by Contractor, then FCN raised by EPCM, then PDN raised by Contractor, then CSI raised by EPCM, finally the work could be executed). Causes: Due to the compressed schedule, equipment availability, and lagging of approval of PDN's the work tended to be executed/completed prior to waiting for the CSI to be issued to Contractor. Impact: The project did a poor job of assessing the impact due to the changes since PDN's from Contractor complete with costs lagged timely submission.	Streamline approvals through electronic systems. Update the RFI and PDN process by having an order of magnitude estimate with the RFI and schedule impact on the PDN.
34	Teamwork (Best Practice)	Background: The module yard team gelled quickly and worked collaboratively from the onset of the project. Causes: There were a lot of good, experienced, approachable personnel with a one team (Quest) mentality. – Project team carried out focused alignment sessions with the whole team to drive a one-team concept including, team building with leadership team, use of communication tools like IOPT and Kantor. Project town halls were held every two weeks. Reward and recognition schemes were put in place as well as weekly and monthly 2-way feedbacks on expectations met or not met. Impact: There was excellent, open, and transparent communication throughout the project with everyone having the same goal.	Replicate this team work mindset and approach into projects.

APPENDIX 14: QA/QC LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
1	E-SPIR data requirements	Because the E-SPIR was not setup early during the Execute phase, some suppliers submitted the spare parts information in their own formats and then EPC needed to go back to the suppliers to load the information in the E-SPIR database	Setup the E-SPIR database early during detail design (Execute) phase, in order to ask the supplier to provide the proper format (ASC) and avoid supplier submitting spare parts in their templates (excel, word) PO must explicitly describe E-SPIR information requirements (content and format)	Execute (Detailed Eng)
2	Quality Plan (BEST PRACTICE)	1. Shell word document was exported to an spreadsheet identifying the activities/deliverables to be addressed during the Execute phase, this made it easier for follow up. 2. Periodic review meetings were conducted to review status of these activities Resulting in a smooth implementation of the Quality Plan	Replicate this practice.	Execute (Detailed Eng)
3	Lessons Learned from previous projects (BEST PRACTICE)	1. Good practice implemented during the FEED and Execute phases, having EPC and Shell team members reviewing applicable LL from previous projects, and indicating responsible and target dates to implement them on the project 2. Periodic meetings were conducted per discipline to review status of LL implementation using the project action tracking system This enabled more thorough follow through on the LL.	Replicate this practice.	Execute (Detailed Eng)
4	Team engagement on HSSE in design (BEST PRACTICE)	Good practice to have interview/engagement sessions with project team members in regards to safety and how HSE had been incorporated into the design. Bi weekly meetings were conducted during FEED and Execute Phases to review HSE suggestions, issues and risks (mtg's started in FEED phase and were ended at 60% detail engineering). This team engagement resulted in adopting many good suggestions to improve HSSE on the project.	Replicate this practice.	Execute (Detailed Eng)
5	Vendor Visits Matrix (BEST PRACTICE)	1. Good practice implemented on the project, identifying key Purchase Orders and potential visits to be conducted at suppliers facilities by EPC and Shell engineering, construction and O&M members (Pre fab meetings, fabrication meetings, inspection, testing and pre shipping activities)2. Bi-weekly meetings with leadership team members to review upcoming visitsThis resulted in a focused effort based on equipment criticality to provide enhanced inspection by the project team prior to equipment being shipped.	Replicate this practice.	Execute (Detailed Eng)
6	Ready to Ship Meetings (BEST PRACTICE)	Once a particular equipment was ready to be shipped, a ready-to-ship meeting was scheduled in order to review with EPC and Shell engineering if the equipment was ready to be shipped (review of outstanding activities from suppliers, SOR/NCRs, documentation, testing). SOR = Supplier Observation Report; NCR = Non Conformance Report.	Replicate this practice.	Execute (Detailed Eng)
7	Delinquent suppliers to be escalated to Shell procurement (BEST PRACTICE)	EPC document control chased suppliers to get the information required for our design, but in some POs, suppliers were not very responsive, then the process implemented was: 1) Escalate to EPC Procurement and if a response was not obtained, then the PO was escalated to Shell Procurement	Replicate this practice.	Execute (Detailed Eng)
8	Issue Shell standards and specifications to vendor and skid manufactures	Packaged skids (e.g. Flue Gas Recirculation Fan) have been received which did not meet Shell's standards and specifications. There were issues with the orientation of control switches at a 45 degree angle, top entry of cables into lube oil heater JB, protective covers required for HOA switches, color of SIS operated devices.	Make sure specs and standards are included in POs and at the pre-fabrication meeting verify that fabrication contractors understand Shell standards and specifications for skid manufacturing.	Execute (Detailed Eng)
9	Commissioning and testing requirements for electrical equipment	Duplication of testing occurred for switchgear, transformers and other electrical equipment which increases project costs.	Develop a testing and commissioning matrix which details what testing will be done at the factory, E-house builder and at site.	Execute (Detailed Eng)
10	Equipment Inspection Reports (EIR)	At the beginning of Execute phase, the contracts only had provision for receipt and preservation of materials checked against the bill of materials . There was no provision for equipment inspection reports to be done. There was no provision in the Quest contract for equipment inspection reports (EIRs) to be done on received equipment. If there are internal issues on pumps, switchgear, transformers, motors, generators, etc. this will only be discovered during testing and commissioning phases and could cause start-up delays. Equipment Inspection Reports (EIRs) were subsequently developed for all the major discipline equipment supplied to the project and issues with some equipment were caught early. In general the EIR process was value added and caught many issues. The challenges were in finding resources to actually conduct the inspections, active management and progress reporting which were required to get the work done. To eliminate flaws, discipline EIRs are recommended for other Shell projects.	Recommend that EIRs be put in the scope of work. Scope of work for equipment receiving contractor must include labour to support the inspection tasks and project needs to provide inspection resources for module fabrication shops or wherever equipment is being received.	Execute (Fabrication)
11	Have rules in place for what constitutes an NCR or damaged equipment reports	There have been and will be several damaged cable reports for the project. There needs to be criteria established for what constitutes an NCR verses a damaged cable report. If the damaged cable is a manufacturer's defect and monies can be clawed back, write an NCR. If it is damaged by the installation contractor or other undetermined causes, write a damaged cable report. We are currently discussing this with EPC to come to a mutual understanding of the process.	Establish a Damaged Cable Reporting process including criteria for using either an NCR or Damaged Cable Report.	Execute (Detailed Eng)
12	Standardize Flawless for universal applications	All of the Flawless materials were in the format of a previous project's EPCM contractor's drawings and specifications, and required reformatting for use on other projects.	Establish Shell based standards and specifications for Flawless PowerPoint presentations, handbooks, Hot-topics, etc.	Execute (Detailed Eng)

APPENDIX 14: QA/QC LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
13	Flawless Project Delivery (FPD) linkage to Manage of Change (MOC)	Have costs estimated for implementing flawless recommendations. Currently there is little/no link between flawless and Management of Change (MOCs) as they are difficult to estimate	Have construction look at flawless mitigation earlier	Execute (Detailed Eng)
14	QA Team presence at work fronts	The priority of having early presence of Quality personnel at the engineering offices and continuing presence at key vendor and supplier shops, and at module and construction sites contributed to effective resolution/ management of issues and project success. Presence of key personnel at work fronts was a priority across all disciplines and it made a difference in the quality results and outcomes	Have the owner's key QA/QC team personnel by discipline located at the work fronts (i.e. home office engineering, fabrication yard, construction site) before the start of any activity	Execute
15	Flawless Programme Delivery (FPD) Implementation	Each FPD Q-area was assigned a Q-Captain to lead the effort in ensuring implementation of the assurance plan and mitigation of Flaws for their Q-area. The Q-Captains took a bit of time to start 'owning' their Q and to start reporting on Leading Indicators and driving the activities. In the end the Quality Team did most of the tracking, and the chasing for monthly statistics. Although the Leading Indicators were reported weekly, it was not very effective as the trending did not inform decisions. The Flawless piping and cleanliness craft training program produced good results in ensuring modules and ship-loose pipes delivered to site were clean and free of debris. Flawless training on EHT installations and Electrical installations best practices helped provide a flaw-free product delivered to site with minimal rework required. The craft specific Flawless Training booklets provided valuable installation details. However, the readability (book and font size) was a source of feedback and could be improved. Flawless hot topic (20) posters were created and distributed to bring awareness of issues to the crafts.	Implement the full FPD programme at the beginning of Execute phase and drive early ownership/ accountability of Q areas through the Q-captains with visibility to project leadership team Ensure adequate review of the additional Flawless hot topic posters by construction and project management as there was at least one instance where a Quality Hot Topic was issued that had a (minor) cost impact on the project as it was a change in a process.	Execute
16	Discipline Based Flawless Walkdowns and Actions Closure	Discipline based Flawless walkdowns were scheduled in advance and Project Management had discipline in adhering to it. This identified issues and corrective actions which were tracked and addressed by contractors on a timely basis and helped assure the delivery of a flaw-free product. Based on feedback from these walkdowns, KBR (module fabrication & assembly contractor) designated a "Cleaning Captain" to ensure that the preservation and cleanliness issues found during the fabrication process were mitigated. This resulted in protection of materials as required along with clean and capped pipes. Cleanliness was one of the focus areas, with a great emphasis placed on it for both module construction as well as for the pipeline. Some of the lessons learned included the value added of the use of boroscopes and early checking. There were a number of cleaning activities that were left late in the construction process which would have been better if they were done earlier in Execute. Quest achieved a high level of cleanliness but still had opportunity to be better; cleanliness is difficult to manage and requires focused attention. Action items from the walkdowns were tracked in an independent spreadsheet; later in the project these actions were tracked in the Q5PROS program which was utilized for construction deficiencies. The use of Q5PROS proved to be invaluable for tracking of issues and driving completion of actions,	Implement discipline-based flawless walkdowns and give visibility to the tracking for timely closure of walkdown actions Implement Q5PROS during the construction phase of major projects.	Execute (Fabrication/ Construction/CSU)
17	Technical Integrity Verification (TIV) implementation	The TIV process delivered the intended assurance of Safety Critical Elements (SCEs) and collation of the information in one place. There were challenges in implementation due to the relative novelty of the process and the lack of experience of the contributors in the process. In the procurement phase the TIV performance standards (PS) were not specified to the Vendors and Suppliers and as such the TIV report was much more a report of 'what we did' vs. an output of the TIV Plan. There was no 'special' assurance or verification activities conducted on SCEs and it is best characterized as 'business as usual'. The use of an established EPC company such as Fluor, with their detailed and meticulous engineering, procurement, construction and data management processes enabled the collection of the assurance and verification. Less mature EPC's could present more problems in executing and producing the records.	Key improvements for planning and execution of TIV are: 1) Performance standards assurance and verification activities could / should be limited to the exceptional activities only . 2) All verification activities should be measureable or able to be qualified by way of some kind of a record.	Execute

APPENDIX 15: COST OF QUALITY CALCULATION

COST OF QUALITY QUEST CCS PROJECT					
	PREVENTION	APPRAISAL			FAILURE
	QA/QC Personnel	Equipment Shop Inspection	Construction Inspection	NDE + Testing	Rework
Capture Site / Mod Yard	Fluor HO QA: 546,000	1,841,000	2,818,000	RT: 700,000	Eng. & Design Errors: 1,652,855
	Fluor Modyard QA: 836,000			HydroTest: 150,000	Const Errors: 124,100
	Shell QA HO, Modyard & Site: 2,800,000				Vendor/Subcontractor Errors: 1,867,371
	Shell Equipment Assurance - FAT Witness, In Process reviews at Vendor facility - 350,000				
Total	$ 4, 532,000	$1,841,000	$2,818,000	$850,000	$3,644,326
Pipeline	Toyo QA: 59,375	289,790	1,617,295	RT: 1,480,190	Eng& Design Errors: 176,000
	Shell QA: 782,340			Hydrotest: 200,000	Vendor / Subcontractor Errors: 33,500
					Construction Errors, Weld/RT Rework: 262,025
Total	$841,715	$289,790	$1,617,295	$1,680,190	$471,525
Grand Total	**$5,373,715**	**$2,130,790**	**$4,435,295**	**2,530,190**	**$4,115,851**
	Prevention: $ 5,373,715	**Appraisal: $ 9,096,275**			**Failure: $ 4,115,851**
	Total: $ 18 600 000				
	QA during eng, proc and const. Includes HO QA, Mod Yard QA, Capture Site / Const QA, Shell Equipment Assurance - travel expenses for Shell personnel. Does not include KBR QA.	Includes Shop Inspectors time and travel.	Does not include KBR QC.	RT and Hydrotesting. Does not include KBR RT / hydrotesting	Capture Site / Mod Yard Rework according to Fluor FCNs. Pipeline Rework as reported by Flint only.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
1	Closure Welds and selective use of pup pieces for module interconnects	Closure welds on stainless steel required dams to be installed. The modules fitted very well, however, because of the closure weld program, spools needed to be shifted around to allow the dams to be installed for the argon purge. Impact: At certain locations, this exercise proved to be very difficult. Cost impact $0.5M - $1M	In locations at module-to module-interface points look at installing pup spools to allow for easy installation of dams Continue to use constructability reviews to identify and review with engineering to mitigate issues; possibly use of flanges depending on the type of service During the constructability reviews, take this into consideration and consider designing in using pup pieces at locations that are identified as presented issues during fit up.
2	Maximize use of flanges (BEST PRACTICE)	Project utilised flanges for 4" diameter lines and below. Impact: Cost and schedule savings with welding activities. Avoided welding and cable pulls, etc. Reduced the amount of closure welds	Utilize more flanges where line classes allows; look at utilising flanges on larger line diameter
3	Pre-insulated piping (BEST PRACTICE)	Installed EHT and insulation on spools before setting them on the t posts;; as opposed to having to insulate them up on the t-post Impact: Cost savings ($5M) with scaffold avoidance	Utilise this process and consider utilising this for longer lines.
4	Tie-point misalignment	Tie-point misalignment was observed on flare lines and on 2 cooling water lines in HMU3. Piping scope in the brownfield was split between the site project group and the EPC contractor Impact: Piping misalignment on a few tie-points; rework and schedule impact to the project	Consider giving all scopes including brown field tie-ins to the EPCM contractor with the appropriate construction engineering support from the owner for the interface management or Make our accuracy requirement clear so that the other contractor can meet our expectations.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
5	Construction labour absenteeism	Craft labour attendance was somewhat problematic; there were numerous weeks where 10% or more of the workforce was absent. With Scotford close to Edmonton and other municipalities, this might have been a norm for the region; which the manpower planning didn't account for. Impact: Crews were constantly being juggled to get the right experience and numbers. Overall craft turnover was 4.9% on a monthly rolling average (however, that included apprentices going back to school).	Account for labour absenteeism during the planning of the manpower when you are close to a major center that is required to achieve the planned progress.
6	Electrical - cable length shorts	Cables coiled didn't meet the locations and had to put in RFIs Impact: About 35 out of about 750 cables had to be repulled; some cables were short on one end; and others were reversed.	Verify in the mod yard that coiled cables to be rolled out at site are the correct lengths.
7	Dressing vessels in the horizontal (BEST PRACTICE)	Dressing vessels in the horizontal position was good with regards to insulation and instruments. We missed opportunity to do electrical (lighting) work on the CO_2 vent stack before it was erected. Impact: Cost and time savings with less scaffolding and manlift requirements, less work at heights	Explore all opportunities to dress vessels and stacks in the horizontal position.
8	Installation of vessel internals in the horizontal position (BEST PRACTICE)	Project installed all the vessel internals (in the horizontal position) prior to site arrival. Vessel was fabricated in South Korea and Edmonton and internals in Italy. Impact: Huge cost and schedule savings (internals were installed in Korea or yard in Edmonton - low cost centre vs more expensive labour cost at site). Very minimal quality issues	Continue this process on future projects. Ensure final inspections of vessels at the shop are done with the design drawings and not just the vendor shop drawings. Also inspect again when they get to site versus waiting till fully erected to correct any transportation caused issues early.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
9	Construction involvement in fabrication inspections (BEST PRACTICE)	Sent construction personnel on vendor shop visits/inspection to some equipment vendors. However, Construction personnel did not go to every shop Impact: Where construction personnel were sent observed few quality impacts/issues or rework compared to other shops where construction personnel were not sent.	Ensure construction personnel visit every vendor shop prior to shipment
10	Module setting	Setting of modules had tight tolerances around module locations. Impact: Setting of modules led to some flange faces being scarred or pipes bent. Rework.	Allow less fixed points on module anchor bolts (use larger holes to allow for movement and weld washers over the holes); allow for higher tolerances/movements in setting the modules
11	Pump alignments	With the movement of modules from Mod Yard to site, there was misalignment Impact: Spent manhours at site to reset those pumps. Had to align pumps twice. Didn't have estimates in the site hours to complete alignments	Do alignment in the Mod yard, and repeat at site; clearly define/specify what final alignment is and include the manhours for this task in the estimate. Allow for duplication of hours for this task between Mod Yard and Site
12	EHT- Proximity of EHT cables to the flange	EHT tracing near flanges wasn't properly identified on detailed drawings for those cases where one EHT zone ended and another began. A requirement for maximum distance between EHT and flange (from DEP) was not included in EHT Flawless Handbooks given to craft. Impact: Without detailed instruction from either the detailed drawings or from the EHT flawless handbook, the distance between EHT and flange became a matter of judgement. In the end, insulation was added to 26 locations where calculations showed cold temperatures were a risk to the system.	EHT at flange faces (at EHT transition zones) must be detailed on IFC drawings. Site maintenance must be involved in this detailing in the home office to ensure client requirements are met. If an EHT handbook is issued to craft, this DEP requirement should be included in it.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
13	Construction disciplines input during design	Didn't have electrical and instrumentation, structural and scaffold disciplines with field construction background in the home office during initial and detailed design. Had only piping disciplines, Impact: Didn't have enough E&I input; had some design issues on electrical and instrumentation during construction (e.g. testing, lack of details for some of the supports for instrumentation, misinterpretation of the information provided; possibly better design ideas could have been generated)	Have E&I input during design; engage scaffolding and structural for about a couple of months during design
14	Flowserve pumps (EFA)	Many issues with Flowserve pumps (especially vertical inline pumps). Seals, bearings, shafts, alignments. Every Flowserve pump was sent back to the shop at least once for rework. Impact: Any cost savings realized by using this EFA were more than lost in the field due to the schedule impacts of having to send pumps back to shop (sometimes more than once).	The Flowserve EFA needs re-evaluation or stronger quality language and penalties.
15	Brownfield Safety Processes and Requirements	Use of Scotford Critical Task Analysis CTAs were only identified and done at the middle of construction. Also did more CTAs in HMU1/2 compared to HMU3. Impact: disruption to construction as late CTAs were a surprise and work had to be on hold until CTAs were completed	Identify (and conduct, if possible) the Critical Task Analysis (CTAs) early in the design and pre-work/preplanning phase with Engineering input for better understanding of the existing site's brownfield requirements
16	Orbital welding	Project planned to use Orbital welding with fluxcore welding on all pipes including SS; Didn't have the right welding procedures with the welders to run the orbital welding efficiently. Impact: Procedure didn't provide the expected improved productivity. $2M additional cost for j-preps, re-work, testing and registering of procedures.	Ensure welding procedures appropriate to automatic procedures are in place, and verify that the vendor pre-approves it for efficiency.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
17	Instrument JB set up was good on HMU1/2 Modules (BEST PRACTICE)	With the whole module design and set up, had all junction boxes grouped on one end of the modules . Impact: Had more room to get everything in one area; compared to another areas	Enhance this design idea of grouping junction boxes on other projects
18	Construction driven approach to all phases and areas of the Project (BEST PRACTICE)	Construction was present in the design phase, resulted in moving equipment around to make construction easier. Construction was involved in the detailed design of the modules. Modules were also a Construction deliverable, not a Procurement deliverable. Impact: Mechanical completion was exactly 5 months after the last module was set as per the 3rd Gen Modularistion plan	Replicate including construction in design phase and have the modules assembly part of constructions responsibility. An improvement would have been to have some construction involvement during the Select phase as well and ensure Construction leadership is on seat at the beginning of the Define phase.
19	Project Team Continuity (BEST PRACTICE)	Many people (owner and contractor, engineering, management, project services, C&P) moved with the project from Home Office to Mod Yard to Site. Retention of craft was also excellent. Impact: Impact: Mechanical completion was exactly 5 months after the last module was set as per the 3rd Gen Modularistion plan	Strive for consistency at all levels of the team. Take a single team approach and effective integration between the EPC contractor and Owner's teams. Make regular safety engagements, foster respect in the workplace, and encourage recognitions/rewards for the right behaviours and for notable achievements.
20	Project Team Integration (BEST PRACTICE)	Working relationship between Owner and EPC was outstanding (good trust, respect, transparency, communication, fun). Quarterly feedback sessions were established around the Discretionary Fee from Owner to Contractor. Impact: Mechanical completion was exactly 5 months after the last module was set as per the 3rd Gen Modularistion plan	Trust must be established early (via alignment sessions, transparency both ways and communication, even over-communication). Replicate this practice.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
21	Underground pipe risers structural support	Underground pipe risers need to be secured in place Impact: Underground pipe risers moved around due to ground soils conditions (sandy and wet). More room for errors	Ensure risers have structural support with concrete or piles to avoid elevation movements
22	Effective HSSE Engagement (BEST PRACTICE)	Daily morning HSSE meeting with senior Construction and HSSE staff (immediately after craft toolbox talks) Impact: was very effective in improving and sustaining safety culture, enabling the team to address concerns and issues from craft toolbox talks immediately, mitigating HSSE risks	Replicate this practice
23	Labour Relations/Engagement (BEST PRACTICE)	Labour relations were minimal. Labour risk assessment, labour engagements, and the Labour Relations Plan (Toolkit) all helped in this regard Impact: $5M was budgeted for LOA, Attraction/Retention and TFW, but was not needed	Replicate this practice
24	Change Management (BEST PRACTICE)	Project developed a change management process using the Shell guide Impact: Change management process was very good.	Key to this success was implementation of the process at all levels of both Shell and EPC team. Simple signup sheet outside the project manager or construction manager's office made it easy to "identify" possible changes. Recognition was given to those that identified changes early.
25	Progress Reporting (BEST PRACTICE)	Project developed a construction progress measurement and reporting process that followed a detailed rules of credit for every discipline scope using the FIWPs. Weekly construction progress meetings with the EPCM construction leadership team and Shell CMT to review progress and productivity. Impact: very effective tool and meeting for managing and gaining alignment	Replicate this practice

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
26	Power Distribution (BEST PRACTICE)	All power distribution was completed in undergrounds before modules were set, instead of pulling cables through the modules after module setting. Impact: This was very efficient, much easier than pulling cable through modules would have been.	Replicate this practice
27	Transformers on Modules (BEST PRACTICE)	attempt was made to maximize the number of transformers incorporated in modules (rather than having them installed individually at site) Impact: maximized off-site work, with benefits to cost and schedule	Replicate this practice A key in Fluor's 3rd Gen module design is distributed motor control centers allowing the wiring of the majority of the equipment on the module and just the main feed to the module being underground and to be tied in at site.
28	Electrical Equipment Testing	Different electrical subcontractors were used for the Mod Yard and for Site. Didn't have sufficient electrical expertise in the Mod Yard to provide input to testing results (esp. High Voltage testing). Impact: Values of test results from Mod Yard were not clear (properly recorded); led to re-testing of switchgear, relays, breakers at the site. There was also some confusion about what tests should be Mod Yard only, or Site only, or both.	1. Electrical testing requirements for mod yard and for site must be explicit (not just "testing as required"). Should be understood that some tests must be done at both locations so allocate hours for this. Also ensure sufficient electrical expertise is on hand both for developing the requirements and for vetting test results. 2. Consider using the same electrical testing subcontractor for both the mod yard and site 3. Drive engineering to provide IFC relay settings prior to the start of Mod yard activities and make sure there is clients/owner's input and buy-in to those settings. It is possible to replicate relay setting from other operating equipment from the site – this should be considered during the Define phase.
29	Satellite buildings for loop checking	All loops checks were carried out from one central "hub" building Impact: Too much work needed to take place from out of this one building, and schedule suffered as a result.	Consider a design that enables loop checking back to multiple "satellite" buildings, with only single fiber connections from the satellites to the central hub. Operationally it makes no difference, but for constructability (loop checking) this would be easier.
30	Mapping of FIWPs to Systems turnover packages	Mapping of FIWPs into Systems was not available. Had different systems for different functions that weren't integrated. Impact: Missed a lot of stuff with the 3rd Gen Modules set up.	Have one source of data that feeds materials management, project controls, IWPs development, systems completion, etc.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
		Had to make bolt up packages and mod packages (could have been a big effort on a large project)	
31	3rd Party Interface in Brownfield	At the site there is a 3rd party who operates a CoGen and Steam Turbine Generator; all major site utilities (steam, cooling water, electricity) are bound up with this 3rd party facility. New piperacks for the project also crossed this 3rd party's land. Impact: This interface had design, construction, and operational aspects, and was difficult to manage. Design choices needed additional input, construction in the area needed additional communication, operational impacts needed additional approval. The amount of interfacing required was repeatedly underestimated	Be aware of who owns the brownfield. If there is a 3rd party in the middle of a Shell facility, then this requires additional interfacing and needs to be considered in resourcing requirements as well as planning and scheduling of activities.
32	QC/QA quality inspection at manufacturer facilities (prior to shipping) for equipment.	The Project, owner/EPCM hired the third party inspectors to conduct the FAT(Factory Acceptance Test) for vendor made equipment. Impact: The hired third party inspectors functioned not as expected. The following equipment were shipped to site with deficiencies: 1. the heat exchangers (E24806 & E24802) deficiencies at nozzle overlay; 2. few exchangers' nozzle flanges faces not made up to drawings/code requirement;	As traditionally, FAT should be inspected by engineers/owner/operators. It may cost more travel fee but it will be more achievable in quality and in the end reduces rework costs at site as well as delays in schedule at critical times.
33	Location of Module laydown area (BEST PRACTICE)	Initially the plan was to "bring every module directly to the crane hook", and that laydown would not be needed in abundance. (Some laydown was secured, but at some distance from the site.) An experienced heavy-lift construction manager insisted that we have a laydown closer to the site, which we did. Impact: This was an excellent change to the plan. Having laydown close the site was convenient, and enabled the project to stockpile 5-10 modules. On a good day, this would allow the	Look for laydown as close to the site as possible, enabling a small "backlog" of modules to be accumulated. This gives some flexibility to the team and enables the team to take advantage of good weather to set multiple modules in a day. Realize that "direct to hook" is not realistic due to weather as well as module delivery.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
		team to set 2-3 modules. Getting 2-3 modules "direct to hook" in one day would not be realistic.	
34	Vendor Fabrication Drawings/Documents Review	For vessels/exchanger/equipment skids: after contracts are awarded to the vendor. Vendor proceeded to the fabrication design per contracted data/requirement Impact: Some equipment had some fabrication errors which were not caught during vender drawings/documents review: 1. V-24601(the Stripper), missed the half-pipe, both design review and inspection failed to catch this error; 2. E-24804A/B/C/D/E: the requirement document in the Contract had errors: sands blasting without painting, so that we received a rusty exchanger; 3. two Amine Tanks: the manways blind were too thin that caused the deformed blinds-- not rigidly hold the gasket: field buy and change it to per code thickness ones; 4. P-246001A/B/C: updated vendor data was not incorporated into Fluor layout/piping design (Vendor data updated, but Fluor piping design did not reflect the changes)	Enhance the vendor fabrication design review (in a timely manner and carefully to find the mistakes) and correct the mistakes at the design stage. This may require higher peak loading of discipline engineers during detailed design because of concurrent activities.
35	Shell Global DEP/Specifications need to be trimmed some to suit for the local conditions and local engineering practices.	Shell Global DEP asks for 1: hydrotest min metal temperature -14 deg C, in Alberta we have cold weather, usually people test at > -22 deg C; 2. Spec asked torque wrenches to be calibrated weekly. That is too frequent and costly. Usually, 3months Impact: Impact to cost and project schedule that is over requirements.	specific TDN to trim the global DEP to fit local conditions at early stage so that reduce the impact to construction
36	Numbers of field welds for piping installation	the idea of 3rd Gen module required much pre fabrication leaving very few field welds that resulted in cutting for piping for pump alignments	leave more field welds for pumps that may have alignment problems

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
		Impact: the pre-fabricated piping did not leave enough field welds for pump alignment achievement so we had to cut or heat for alignment. this which cost more than to leave more field welds	
37	Manufacturers selection for Vessels and Exchangers fabrication	Quest selected two good manufacturers that made good quality vessels and exchanger for us: they were Ilsung (Korea) and Mangerotti((Italy) for exchangers Impact: good reputable vendor can make good quality equipments	Evaluate the bidding packages carefully, clearly, and timely to find a best balance point between the cost/schedule and the technical excellence to select the potential best vendors.
38	Flawless Tightness Requirements	If the bolt holes on flanges for PSVs did not line up perfectly, then the flange was cut, the alignment was made perfect, the flange was re-welded and rehydrotested. Outcome: Perfect alignment is needed for a pump, but does it matter for a PSV? The cost of having to cut/align/reweld/rehydro PSV flanges when they are not perfect is considerable, for questionable benefit.	Be more selective about which equipments require perfect alignment.
39	Moving Equipment under Transmission Lines	There is a 138kV transmission line crossing the main road into site. Initial plan was to build a temporary lower road beside the main road to bring large equipment or modules to site, which would cost over $1M. Instead, we contacted the owner of the line and had it raised twice (once temporarily, and once permanently) at a small fraction of that cost. Impact: Cost savings of at least $1M	In similar situations avoid earthworks if possible. May be easier and cheaper to contact the owner of the transmission line and get it raised (either temporary or permanent).
40	Lean Construction - Use of the Delay	To enhance the communication between field and management and ensure budget holders were focused on top impacts to productivity, a Delay Tracker tool and process were implemented. Delays were tracked and documented by all team members, and reviewed in weekly CMT meetings. All	Adapt and implement the use of a delay tracker during construction as one of several tools to manage craft productivity in the field

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ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
	Tracker (BEST PRACTICE)	occurrences were documented for monthly trending. Top delays (by number of occurrence) became the topic of discussion at the management meeting. Issues and appropriate countermeasures were discussed in weekly management meetings. The proposed measures were further explored and implemented with the craft leaders in the Supervisors Luncheon. The bi-weekly luncheon had all craft leaders present which allowed for a collaborative approach and a problem-solving culture that addressed project wide impact to each discipline and overall project about productivity improvement decisions. Impact: This proved to be a great way to get wide communication and fast uptake, as everyone felt they were both involved and considered and therefore understood why changes were occurring.	
41	Motor Shaft Parallelism	Compressor motor from GE did not have motor shaft parallel to feet within 0.002"/ft as recommended by API 546. We learned GE does not check this parallelism in the factory, and we found the flaw in the field when trying to align the motor on its foundation. In the end, GE corrected the shaft alignment in situ, but only after months of deliberation, field measurements, exploring alternative options, etc. Impact: schedule for compressor-related activities was affected, though impact to MC date is unknown	Have motor shaft parallelism checked as part of the FAT.

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ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
42	Compressor Flange Faces	Compressor flange faces from MDT were to comply with ASME B16.5 (roughness of 125 micro in to 250 micro in). However, the flanges were also listed by MDT as being "smooth finish" -- though this was not defined. It was found in the field that "smooth finish" means smoother than ASME B16.5 allows (roughness of 16 micro in to 125 micro in). Shell TAs were not convinced a good seal could be made with flanges this smooth. MDT was asked to supply flanges compliant with ASME, and the flanges were re-machined to the required finish in the field under MDT's supervision. Impact: schedule for compressor-related activities was affected, though impact to MC date is unknown	For flange faces on rotating equipment, be wary of anything with a "smooth finish" if we are also requesting the flange to be compliant with ASME B16.5. "Smooth finish" should be defined by the vendor, and the flange roughness should be checked with a comparator during the FAT.
43	Third party spot inspection requirement during fabrication of vessels and exchangers	The contract with the third party inspector asked for spot inspection during fabrication. We assumed the third party inspector would go to the shop on his own accord and will not need work authorization from us since the contract asked for spot inspection. The third party inspector assumed he would get a work authorization for each time he went to the fabrication shop. Impact: The impact was that fabrication finished without any third party spot inspection. The first time our inspector visited the shop was to witness the hydrotest.	Clarify spot inspection requirements with the inspector during the kick off meeting. A way to track inspection visits is to request inspection reports from the third party contractor.

APPENDIX 16: CAPTURE FACILITIES CONSTRUCTION LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Context/ Cause/Impact)	Proposed Recommendation
44	Final inspection of vessels and duct internals post transportation and erection at main construction site (Best Practice)	Planning and “extra” resources were allocated during detailed design and equipment fabrication/manufacturing stages for visits to vendor shops to emphasise the role of the vendors in meeting the project's Quality and Flawless programme objective and for pre-shipment inspections. Project had to carry out final inspection of vessels/ducts internals prior to their closure to provide the assurance that the integrity of the design and construction has not been compromised by transportation or erection of the column. Without this final inspection, the start-up condition of the column internals would have been unknown and performance of the vessel up to design conditions couldn't have been guaranteed. During one such final post-erection inspections, the internals of one major vessel was found to be damaged. Impact: $186K additional CAPEX cost	In addition to the usual vendor shop QA/QC visits and pre-shipment inspections during detailed engineering and fabrication, plan for final inspection of vessels/ducts internals upon delivery and erection at site; ensure there is budget allocated for the final inspection of vessel internals post transportation and erection at the main construction site before closure to ensure the integrity of the design and construction has not been compromised prior to start up.

APPENDIX 17: CAPTURE FACILITIES WORKFACE PLANNING LESSONS

ID	Lesson Title	Lesson Description (Causes/Context/Background/Impact)	Proposed Recommendation
1	Quality of Work Face Planning (WFP) packages (BEST PRACTICE)	Quality of the Field Installation Work Packages (FIWPs) were good overall. Content of electrical packages included transmitter drawings with the information required highlighted, peripheral stuff, tag numbers etc. for a fully defined scope; Piping packages included QA/QC documentation, bolt up sheets; structural packages included prints for the 3D model and highlighted the areas of information (e.g. erection drawings, point-to-point bolt lists etc.) required, but no CAD sheets. But packages lacked some other details like electrical QA/QC sheets, piping support details, etc. No WFP packages were developed for initial civil/underground work scopes or the EHT/Insulation scopes of work as unit rate contract were used to execute those scopes. Later stage packages lacked the details of the job scope description Safety documents such as Job Hazard Analysis (JHAs) and Construction Work Practices & Procedures (CWPPs) were included in the FIWP packages. Impact: Including the CWPPs in the FIWPs was good.	1. In building the WFP packages, avoid including too much information in the package; include exactly what is required to complete the job. Example don't include specific Job Hazard Analysis (JHA) documents; JHAs in the packages should be included as generic forms/templates (as placeholders) that should guide the crew/team installing the package to develop a job-specific JHA for. No fabrication drawings should be included, highlight only applicable drawings. For piping packages, include 3D shots and a line list at the back of the work package. 2. Have a supplementary package separate from the FIWP that contains all additional information (e.g. CAD sheets, fabrication drawings, etc.) for the area that may be required by the crew; intent is to keep the FIWPs streamlined and small containing only the relevant information. 3. Develop installation packages for EHT and Insulation packages (e.g. by systems) with work completion by discipline verified and checked using the travel sheets to make the planning and interdisciplinary hand-off more efficient to minimise cost 4. Have the detailed /package available in a binder at the point of use in the field. Include MSDS requirements as required depending on the nature of scope and materials being handled for installation of an FIWP.
2	Project team support and buy-in process for the WFP programme roll-out	A top-down management approach was adopted to implement the WFP programme and get the buy-in/support. Training on the WFP was provided for the young crew/team members to provide them with the WFP implementation tools they needed; training for some of the supervisors was however adhoc. Initially when the first work packages were rolled out, team asked for critique of the package (its size, usefulness of content, etc.) Impact: Initial feedback and buy-in on the structural discipline scope packages were positive, some challenges were experienced with the acceptance of the initial piping and electrical work packages	1. When rolling out the WFP programme, encourage initial critique of the packages that are first rolled out as part of the continuous improvement process to get to a stage where packages are accepted by the field crew. Feedback is important (use a feedback form/questionnaires that avoided simple YES or NO answers). 2. Consider developing standard packages for each sub discipline (structural, electrical, piping, etc). Conduct quarterly reviews and surveys of the WFP programme and looking for common trends/patterns in the feedback/survey reports for continuous improvement 3. Build relationships early with the teams/supervision who will be utilising and installing the work packages in the field e.g. review each package with the supervisors or general foreman (this can take up to 2 - 3 hours for each package)

APPENDIX 17: CAPTURE FACILITIES WORKFACE PLANNING LESSONS

ID	Lesson Title	Lesson Description (Causes/Context/Background/Impact)	Proposed Recommendation
3	WFP package development and approval process	Work packages development started in the early phase of the project planning and continued in the Execute phase. The order and steps of the work package development & approval process: started with the Eng Work Packages (EWPs) developed by area, then breaking the EWPs into smaller Field Installation Work Packages (for smaller work areas about 1500 manhours each), Scope for each work package was defined using the engineering information from the EWP, Built/developed Work Packages with all the information and locations required by the crew, then included safety requirements/eng drawings for an initial internal squadcheck, QA/QC documentation was then included, index with check sheets required from the Mechanical Completions System are then included, Superintendents review and approval/signoff ready to be issued to the Foremen. The Construction Work Packages (CWPs) were not used in the development of the WFP packages; skipped the CWP step from EWPs to WFP Work Package development Impact: 1. Safety reviews didn't add much value to the process and delayed sign-off of work packages 2. Experienced delays between the placement of request and receipt of the Mechanical completions system bolt up sheets which were included in the FIWP packages 3. Additional cost was incurred around scaffold requirements for EHT and Insulation installation in the field	1. Don't include Safety discipline review and approval in the WFP packages review/approval /sign-off process. 2. Include scaffolding, electrical, EHT, and insulation disciplines in the pre-design reviews, the initial package development and planning in the early planning phase of the project in the home office engineering team. 3. Conduct a multi-discipline scaffold review of the packages in the home office during package development (will save significant cost during field installation of packages) from a life-cycle perspective 4. Review the model details and materials parts required for the job to ensure they are ideal to the package and will actually work in the field.
4	3D Model usage and quality/accessibility of information in the 3D model	Developed a 3D model using SMART Plant; information from the model was used to build the FIWPs packages. Training on the use of the 3D model was limited due to cost constraints. Computing capability and processing speed were not sufficient to support and run the complex 3D model software. There were limited screens available (1 screen per user). Electrical cable trays shown in the 3D Model were not connected to other trays (couldn't get a flow of the model from one tray to the other), hence cable schedule information couldn't not be uploaded into the 3D Model.	1. Develop a 3D model to be used also as input to developing and building the FIWP package 2. Plan to install 3 to 4 screens per user of the 3D model and with the required computer processing capacity/hardware to make the 3D model information bundling and retrieval quicker and more efficient for building a work package. 3. Populate and upload the 3D model with the maximum information e.g. prints, vendor information, sizing, material, etc. which should then be automated so all information on for a example a piece of structural member or piping can be seen on one screen shot to avoid having to cross reference between a model and an engineering drawing in another system.

APPENDIX 17: CAPTURE FACILITIES WORKFACE PLANNING LESSONS

ID	Lesson Title	Lesson Description (Causes/Context/Background/Impact)	Proposed Recommendation
		Impact: 3D Model users had to spend weeks (sometimes up to 3 months) figuring out how to use the 3D model because of lack of adequate training. A group of people had to use one computer screen to review a 3D model and retrieve information, and this was inefficient e.g. it took 2 hours and sometimes up to 1 day to search for and locate all the information on one transmitter in the 3D model Retrieving reference drawings in the model was a challenge because half way through the project drawing numbering were changed without revising the reference numbers in the 3D Model. Vessels installation after it is insulated; and for deck planning was enhanced	
5	Constraints Removal	Permitting requirements: brown field permitting issuance and approval process was excellent with the dedicated brown field permit issuers Equipment availability: equipment allocation (e.g. JLGs) was managed by the foremen. Vehicle availability for HMU3 work area Tool crib location: tool crib was located about 0.5km to 1km (for the HMU3 area) from the work location Impact: Additional time spent by crew between the tool crib location and work locations leading to delays and productivity impact.	1. Release FIWP package at 80% material availability (100% material availability before starting field installation work on each package is impractical and will lead to unnecessary work start delays) and 100% engineering complete IFC for each package 2. Make electronic records/storage of drawings read-only and readily available to work face planners who should have computers and access. 3. Have a satellite tool crib located and in close proximity to the work location
6	Path of Construction	FIWP release plan was driven by the path of construction and the construction schedule. There was a good link/interface between the project schedule and the FIWP release plan.	Let the FIWP release plan to be strictly driven by the path of construction and the construction schedule

APPENDIX 17: CAPTURE FACILITIES WORKFACE PLANNING LESSONS

ID	Lesson Title	Lesson Description (Causes/Context/Background/Impact)	Proposed Recommendation
7	Materials Management	Different approaches for material management were used for the sub disciplines Electrical - Electrical materials were procured in bulk, didn't itemise each material for each module or Work package as developing a BOM for each module was considered to be time-consuming; once work area and scope were identified, then the materials/electrical pieces required to complete the work were pulled out of the bulk list. Piping: Work face planner wasn't involved in material ordering Structural: Work face planner ordered all the structural materials for each Field Installation Work Package (FIWP) There was no materials warehouse at the construction site. Had to fill out pick order for u-bolt, gaskets and general small consumables Impact: Materials Management: Bill of Materials (BOM) development and materials ordering was good for structural, but experienced challenges with electrical and piping disciplines with delays in receiving the general consumables on time to start field work.	1. Develop the complete Bill of Materials (BOM) for each work package; consider using bulk ordering for electrical & instrumentation components to minimise the time spent in itemising electrical components (e.g. cable connectors) for each electrical package. 2. Bolt-up sheets should be generated by engineering and release every bolt up sheet by ISOs to the WFP planner and to each field foreman before the WFP work packages are released for field installation. 3. Free issue some consumables (e.g. U-bolts, gaskets, etc.), 2" stainless steel pipe, electrical connectors, screws, washers, etc.
8	Punchlist clearance and management	Some of the punchlist items were packaged. Individual deficiency/punch lists were maintained by different disciplines. Initially there was no one master list that captured all the punches and most particularly the inter relationships between different discipline punches e.g. hydrotest reinstatement to EHT to insulation Impact: Instances of where electrical EHT and insulation installed on a line had to be removed so the piping hydrotest punches can be cleared/signed off before the EHT and insulation could be re-installed	Develop one master list that captures all punches by systems and by discipline, so the inter-discipline relationship for punchlist clearance can be managed to eliminate rework of EHT/insulation

APPENDIX 17: CAPTURE FACILITIES WORKFACE PLANNING LESSONS

ID	Lesson Title	Lesson Description (Causes/Context/Background/Impact)	Proposed Recommendation
9	Audits (spot audits)	Used the delay tracker (forms) to identify bottlenecks and causes/conditions impeding work progress in the field. Data from the delay tracking was fed to construction management for decision making to eliminate such bottlenecks/causes.	The output /data from the delay tracker is useful to Construction Management for making decisions to eliminate bottlenecks/constraints to work progress in the field e.g. construction equipment availability, material availability etc. The Work Face Planners have very minimal usage of the data from the delay tracker for building the FIWPs; the planners need not be fed with every data from the delay tracker, only on specific instances where some decisions to eliminate causes of delay that have impact on the content of work packages should the planners be made aware of.

APPENDIX 18: CAPTURE FACILITIES CONSTRUCTION COMPLETIONS LESSONS

ID	Lesson Title	Lesson Description (Background/Context/ Cause, Impact)	Proposed Recommendation
1	Owner's ORA team presence at Mod Yard (Best Practice)	Full time client representation at the Mod/Fab facilities ; had early involvement of Shell Ops on-site and at the yard involved in cleanliness checks and walkdowns Impact/Outcome: Minimal changes that could have impacted site construction and documentation; even though owner's team were a bit stretched between mod yard and site walkdowns	Have full time client rep at Mod and fab shop facilities for all disciplines
2	Walkdowns at Modyard (Best Practice)	Walkdown focal point for each discipline field engineer from the EPCCm contractor who had a good understanding of the issues and the scope; Walkdown had a good composition of Fluor and Shell reps; staffing of field engineers, Ops, to meet the requirements of 3rd Gen Mods; use of MC + provided the tags systems and scope cross reference; performed detailed multi-discipline walkdowns in Mod yard with the intent of not doing detailed walks again at site Impact/Outcome: No module left the yard without following and completing the turnover process. Even though there significant schedule challenges; less turnover activities at site and less site scope to complete	include Owner ORA rep in module yard staffing
3	Preliminary and final system walkdowns and timing of walkdowns	Preliminary and final system walkdowns were redundant. Originally when the procedures were written, Ops were going to do their own Walk down of systems were too early before the systems were substantially complete to meet the schedule Impact/Outcome: Inefficiency and potential additional manhours Punch list became a work to go list and grew larger. Walkdowns became schedule-driven and not progress-driven; took too long to close punches and sign off binders (created about 6,000 pieces of paper)	Have Ops and Constructors attend one single walkdown Don't walk the system if it is not complete; walking the systems doesn't make the work completed faster Include in the schedule the timing between having the system construction ready and the actual ICN. The actual timing was very similar to the already established in the procedure.
4	Progress and Submission of quality records by construction	Difficulty in getting quality records submitted by construction on an ongoing basis as the work was completed (mainly E&I). Construction wanted to keep track of their progress using their own construction system outside MC+ (the completions database system)	Consider the individual status per discipline of construction quality records distributed to each discipline so the individual disciplines within each team (construction and completions) have a clear understanding/knowledge of the status of each

APPENDIX 18: CAPTURE FACILITIES CONSTRUCTION COMPLETIONS LESSONS

ID	Lesson Title	Lesson Description (Background/Context/ Cause, Impact)	Proposed Recommendation
		Impact/Outcome: Confusion on status of work completion, rework and retesting	quality record.
5	Production and Turnover of construction Quality Records	The appropriate follow-up on the production of Quality Records during bulk construction was very challenging initially. Impact/Outcome: Longer durations for putting together the turnover packages (averaged about 5 weeks instead of the 3-4 weeks originally planned for and established in the turnover procedure). Additional resources had to be deployed to track construction quality records in order to improve the duration of turnover packages preparation.	Have designated resources to follow up on the production of construction quality records and their completeness immediately after completion and turnover of construction packages
6	Instrument system definition clarity	Instrument systems definition - clarity of limits and scope that functionally makes sense. Didn't have clear drawings, used sketches that had little detail, had to rely on list in MC+ (the construction completions database) for the DCS systems Impact/Outcome: Test records for DCS systems couldn't be found at one location. As design evolved couldn't go back to verify the details	Engage controls systems in defining controls systems by tags and have the network component tags defined in MC+
7	Use of MC+ completions database (Best Practice)	Use of MC+ (the construction completions database) pulled together the numerous separate cable schedules and indexes into one place using the tag numbers Impact/Outcome: Efficiency increases e.g. EHT cable identification including the cable	In engineering phase use one database
8	System Walkdown process (Best Practice)	Good organised leadership on the walkdowns with prior notifications and the process for clearing punch items (having punch items reviewed between Shell and Fluor at same time); Excellent level of team integration. Turnover Procedure was discussed and agreed before starting construction Impact/Outcome: A more efficient process and issues were resolved quickly; Quick alignment of discrepancies through the Completion Team Meetings.	Repeat practice

APPENDIX 18: CAPTURE FACILITIES CONSTRUCTION COMPLETIONS LESSONS

ID	Lesson Title	Lesson Description (Background/Context/ Cause, Impact)	Proposed Recommendation
9	Lift lugs on large spools (Best Practice)	Provision of lift lugs and temporary transportation shoes on large spools Impact/Outcome: Minimised damage to insulation and EHT	Repeat practice
10	Fabrication of smaller piping spools (Best Practice)	Fabricated 2" and smaller piping Impact/Outcome: Minimal site cost	Repeat practice
11	Module interconnects flanges and closure welds	Provision of flanges and closure welds (Modularisation) for module interconnects Impact/Outcome: Minimised site tests, minimal insulation and EHT work at site.	Repeat practice
12	Turnover binder review process	Cumbersome binder review process (about 15 people in total would review in a typical system) all looking at similar things in some instances. Had in the procedure for on-going reviews but was not enforced. Impact/Outcome: Some binders were done 3 months after the work is done leading to schedule delays	Client reps looking at the quality records should review them at the time when the work is completed and not later. Some forward planning of how the quality records can be reviewed in advance of the final turnover may reduce the peak loading
13	EHT Drawings Revisions availability	Discrepancies between EHT IFC drawing and what construction had installed; due to not having an up to date prints or working off the wrong revisions, or didn't have the correct interconnect RFI from the mod yard Impact/Outcome: Delays and confusion on how to incorporate old drawings into new drawings, piping EHT not done; spools changes not having the new revisions of EHT	Having a readily available EHT drawings when the piping mechanical is complete and ready for EHT installation
14	EHT Focal Person for construction	Site should have had full time EHT rep to support Fluor constructors to facilitate progress on site and give direction on what should (merge with item 16)	Fluor EHT to support Fluor constructors

APPENDIX 18: CAPTURE FACILITIES CONSTRUCTION COMPLETIONS LESSONS

ID	Lesson Title	Lesson Description (Background/Context/ Cause, Impact)	Proposed Recommendation
		Impact/Outcome: Duplication of RFIs	
15	EHT Execution	Mod yard followed the Fluor standards, and RFIs were raised if there were deviations. Where as at site EHT was completed before RFIs were responded to. Impact/Outcome: Quality of EHT installation was much better in the mod yard than at the construction site; more paper work on NCRs and client proof that it was done.	EHT work should only be started after RFIs are completed or seek approval from the site engineer prior to proceeding with EHT work.
16	Quality of Turnover binder package: P&ID version in turnover binders	Outdated scoped P&IDs mostly on instrumentation in turnover binders. Had an electronic method of updating P&IDs but wasn't used there was no system description included in the walkdown package to include an equipment list of what we were looking at. Impact/Outcome: For example some binders had outdated P&IDs and had to insert changes	Incorporate ERB (electronic roller board) in scoped P&IDs drawings Include the system description and equipment list in the binder
17	Use of MC+ (construction completions system/database) for Workface Planning	Use of MC+ : Work face planners didn't use MC+ and built their own lists of the master cable schedule; - Population of MC+ started in the Define phase was good Impact/Outcome: Multiple reports showed the same status leading to too many list being used with different information and caused confusion	Have more people access to MC+ to track completion quality records; ensure the Work Face Planners use MC+ (the construction completions database/system)

APPENDIX 19: PIPELINE CONSTRUCTION LESSONS LEARNED

ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
1	***Pipeline Constructability***	Width of Pipeline Right-of-Way (ROW) Misalignment between ROW and Line Block Valves (LBVs)	ROW width was a lot smaller than was required. Total ROW width (25m), i.e. 18m (ROW) + 7m temporary work space (TWS). 12” line with a 1.5m minimum depth of cover. The project owner (Shell) only registered the ROW and didn’t do the same for TWS. Shell prevented third parties from overlapping their TWS with the project’s TWS There was misalignment of the pipeline going to the LBVs from the alignment sheet that required an expansion loop. This was considered an oversight by Engineering. Impact/Outcome: • Tightness of the ROW was identified as an HSSE hazard during some of the HSE incident investigations; ROW tightness was also perceived (from the Shell perception surveys where it was listed several times – about 6 times) as a concern • From an environmental perspective, some of the pinch points for tie-ins were so tight that it became difficult to separate subsoil and topsoil. Subsoil had to be put on topsoil due to the space restrictions. The space required for club root management (which required full ROW strip) also compounded this issue by reducing the space for construction. • Productivity Impacts: o Multiple handling of the pipe because of the thin ROW (e.g. had to move pipe over for welding of ditch line, moved it back and then over the ditch) o Constantly had to go back to landowners at different locations to ask for extra work space due to inadequate work space during construction o Restricted ROW width for automatic welding shacks and had to drive on ditch line, (especially in winter construction which affected the backend construction activities when going back to the ditch). The driving on the ditch line drove the frost down and had to work with hard soil • Simultaneous use of the ROW by other contractors took a lot of additional workspace in two separate locations (with loss of the 7m TWS in those locations)	• Register the TWS (in addition to the ROW). This is especially necessary if there will be a long time gap between when the land is purchased and when construction is expected to start. Roll the TWS into the ROW and register TWS with ROW. • Identify and define the HDD locations early in the project definition and engineering phase in order to determine the TWS requirements • Walk the entire ROW during early project design and engineering phase to identify where additional space will be needed during construction • Increase the constructability effort in the front-end planning. Include contractors in the front end planning. • Ensure ROW boundary is offset from fenceline and landowner property lines. Do not let the fenceline be a boundary of the ROW or TWS (Construction team had to fix a lot of fencing and dispose off rocks and bushes because of this). Stay 10m away from boundaries of landowners’ property to create a buffer space. Avoid following land owner boundaries for the ROW where possible; if it can’t be avoided then allow for an extra space • Engineering should provide alignment sheets for LBVs (tagging the LBV sites drawings to the ROW drawings) and verified for survey early so that such potential misalignments can be proactively identified early.

APPENDIX 19: PIPELINE CONSTRUCTION LESSONS LEARNED

ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
2	***Pipeline Constructability***	Timing and Ownership of ROW surveying	Construction was right behind the survey team leading to construction delays. Surveying was done by the pipeline contractor. Hence mistakes made from surveying had no lag time for correction. Every survey corrective action led to a construction delay. Survey is typically complete before the construction starts. Equipment was mobilised to the field with no stakes and no survey; and so within 100m of initial clearing of the ROW, the clearance activity was stopped because of boundary discrepancies from the perspectives of the landowners and survey team. Impact/Outcome: • ROW clearance was compounded as in initial stages of clearance it was determined within 1km of the ROW, just from survey, that there was a lake in the middle of the ROW. • Environmental Alignment sheet inaccuracy: Some significant wet areas (e.g. wet area west of Road 5) were missed on the alignment sheets and had to put in dewatering at an additional cost.	• Survey the ROW before the start of construction to allow the contractor enough time to plan the work. Consider the use of drone reconnaissance of pipeline ROW. This can be used to develop a video of the ROW and can be watched by everyone to view the entire landscape (this technology could have been used for Namepi creek HDD with steep banks where the original plan was to do open-cut). This can also minimise the HSE exposure. This may less effective compared to physical boots-on-the-ground surveys of ROW. • Thoroughly review the first initial route selection with different groups of people on the project who have different stakes e.g. Environment, Contractor, etc. to get different opinions to avoid major interferences e.g. wet lands and crossings of existing lines, etc. to minimise the number of crossings. • Develop a Grade plan which should be submitted upon award of construction contract and prior to start of construction. And have an accurate environmental alignment sheet. • Increase the constructability effort in the front-end planning. Include contractors in the front end planning. • Surveying should be in the hands of the owner and not the contractor. Contractors don't have the experience to carry out survey. Don't wait for contract to be awarded before start of survey of the ROW.
3	***Pipeline Constructability***	Public Consultation	Shell took on the landowner engagement (with land man) during construction. Impact/Outcome: This led to unnecessary demands by landowners	Ensure there are allowances for the landowner concerns rather than assume it is not going to add any costs.
4	***Pipeline Constructability***	Timing of stakeholder commitments	Some landowner commitments were made very early during the project regulatory hearing stages. The change in people during project execution led to differences on the perspectives of some of these early promises.	• Get construction input and feedback around stakeholder engagements during the early project phase and regulatory hearings when making stakeholder & regulatory commitments (was done during early project phase of Quest). • Once the route is selected consider paying for crop

APPENDIX 19: PIPELINE CONSTRUCTION LESSONS LEARNED

ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
			Impact/Outcome: Compliance to some of the regulatory hearing commitments resulted in many challenges during construction. Examples include: Landowners were promised that construction would start after farmers had harvested their crops (either don't promise this or don't start construction when farmers have crops in the field) ; the commitment to the North Saskatchewan River (NSR) crossing timing which reduced the amount of time contractor had to do any pre-work (pipeline construction contract was awarded in August 2013 and then had to mobilize to support NSR crossing in early September); Commitment to open-cut for majority of the crossings which posed constructability challenges during construction although open-cut is usually cheaper and hence the crossing method of choice. Government bodies have no issue with converting to HDD.	damage with an understanding on the implications of that on the other project drivers (e.g. cost). It is better to pay crop owners early before construction even starts.
5	***Construction Planning***	Government Milestone	Project had 2 government millstones per year for a total of about 7. Specifically for the pipeline, the North Saskatchewan River (NSR) crossing was one of the key government milestones. And it had been placed as part of the first half of the government's yearly milestones. The award of the contract (which took 6 months to put in place) made the delivery of that milestone extremely tight. Impact/Outcome: Tight planning and mobilization timelines for the pipeline contractor, who had to be in the field within 2 weeks of contract award.	When setting such milestone ensure you have the schedule contingency distributed within the deterministic schedule.
6	***Pipeline Constructability***	Design and Use of Cased Crossings and alternatives	Shell Technical Authorities (TAs) don't like cased crossings. Construction encountered a number of road crossings where HDD could have been used with the impact of damaging the coatings/parent pipe material due to rocks. Cased crossings were used to cross the roads. Alternative designs were available but when it came time to execute the alternatives there was misalignment between Construction and the Shell TAs. e.g. Cased crossing with vents vs Cased crossing without vents. The Shell standards don't have any alternative to using casing if construction encounters rocks during a bore. The effects of casing include impact on t the cathodic protection of the pipe and pressure if there are large temperature variations in the ground.	• Develop an alternative design should an HDD bore not work for any crossing in the field e.g. would cased crossings be acceptable • Get the cased crossings approvals or any other alternative design included in the Engineering package with the Shell Technical Authorities approval/sign off ahead of time so construction can use the alternative design should challenges be encountered during construction with the primary design without having to go back to the technical team for approval of an alternative design in the middle of construction. • Consider alternatives to casings when pipe is crossing through rocky/ hard material e.g. use of Gunite which is a

APPENDIX 19: PIPELINE CONSTRUCTION LESSONS LEARNED

ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
				cement jacketing (a mixture of cement, sand and water that can be sprayed on to the pipe as an exterior protective layer for a pipeline). Pipe is usually ordered with the gunite coating already applied but there are specialist contractors that can do this at site.
7	***Pipeline Constructability***	Mud Handling with D50 regulatory requirements for increased HDD	The new D50 requirements didn't allow the traditional "mix and bury". Project scrambled to investigate spraying, mud mixing pit, mix-and-bury etc. This was also driven by the increased number of HDDs that were required on the project and the fact that the schedule extended into winter which made mud management more complicated. Original plan was only a few HDDs. Contractor didn't have a clear understanding of the D50 requirements. This amplified the scope. Impact/Outcome: The project spent a significant amount of money on mud disposal	Thoroughly review and understand the D50 requirements on mud handling and develop a strategy for managing the D50 requirements of mud disposal during construction, particularly when there is a change in the regulatory requirements. Scout or walk the entire pipeline ROW to understand the full HDD scope and associated mud handling requirements.

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ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
8	***Pipeline Constructability***	HDD Programme (BEST PRACTICE)	HDD crossings on major watercourses worked very well. It forced the team to thoroughly review the mud pit design and location. Project didn't assess thoroughly enough the benefits of maximising the use of HDDs during the pipeline design phase. The project originally proposed to go with open-cut for all water crossings and only 1 HDD for the North Saskatchewan River (NSR) crossing. The primary driver for initially selecting open-cut was that it was easier to get regulatory approval for open-cut; however open-cut posed construction challenges due to congestion issues. Impact/Outcome: Ended up doing more HDDs in wetland areas and water courses. Original 2.5KM of HDD increased to 9KM of HDD to mitigate congestion issues and constructability challenges.	• Thoroughly assess open-cut vs HDD benefits as part of the early project construction strategy development/planning and constructability reviews. Check implications of open cut on major water courses. In wetland areas more horizontal drills should be considered recognising that will require more Front-End understanding of the design and its impacts for early planning since geotechnical/soil information required for a full HDD design may not be readily available at the early stages of the project. Collect geotechnical data/information early in areas where the soil conditions are expected to be complicated for open-cut as input to the assessment and decision between the choice of open-cut and HDD for crossing locations. This requires a complete "walk" of the pipeline right of way by construction.• Design and execution of HDD bores: Except in the case of complicated high-risk specialty bores (greater than 20m deep) there is no need in getting a separate contractor to design low-risk HDD bores (e.g. road crossings). It is better to get the HDD boring contractor to do design and execution of low-risk bores. Spend the extra effort and resources on geotechnical boreholes to collect data early which can be shared with the low-risk HDD boring contractor as input to their design and execution of non-specialty low-risk HDDs. • Read and understand the different land owners crossing agreements very early as input to the estimate preparation. Some are more rigid than others on the agreements and may require different levels of effort to comply with e.g. cathodic protection, ramp design (as crossing ramp design varied from owner to owner), clearance of mechanical excavation. Get the pipeline construction contractor involved early since contractors have good ideas of what companies require. This will be a balance given that the actual crossing agreements are negotiated between FID and start of construction. • Understand Cathodic protection requirements from foreign pipeline owner

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ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
9	***Pipeline Constructability***	Weld Procedure/method (Automatic weld):	Project chose automatic welds, which yielded good weld quality results (good Charpy impacts for the pipeline Grade 386 material selected); but weld productivity was very low (about 7 welds/day/shack X3 shacks against an original estimate of 45 total welds/day). With regards to welding procedures the semi-automatic would have been more practical with higher productivity/production but would not have produced as high a weld quality compared to the automatic for the pipe material grade selected. Impact/Outcome: The low initial productivity with the weld procedure impacted the early works (ISBL pipeline construction) progress, cost and schedule. The project lost a lot of good welders because the project team/weld qualification process didn't give enough time to welders to practice the procedure and so they failed welder testing. This also increased the time to qualify welders. The pipe metal information was marked on the outside but not on the inside and this created a lot of confusion and resulted in the missing of about 41 joints a pipe.	• For CO2 dense phase pipelines ensure an informed decision is made between best quality steel that inherently reduces the risk of long ductile fractures to crack arrestors which are typically thicker wall joints inserted every four joints or so. • For high strength steel material selected for onshore pipelines, perform "weldability" test offsite at the manufacturer's shop (and definitely prior to shipping materials to site) with a recommendation on the welding consumables required. This would provide the pipeline construction contractor with a better understanding of the weld requirements and lead to a more realistic productivity/production estimates. Consider paying for a "weldability" test. • Put essential pipe properties/information (e.g. pipe #, heat #, etc.) on the inside of the pipe, and not just on the outside. • Welders require lead test time (i.e. more time to practice). Give the welders more time to practice the weld procedure.
10	***Pipeline Construction Work Planning***	Material management and delivery	Equipment and Materials purchases/management/expediting responsibility was by a separate entity (i.e. the pipeline engineering and procurement contractor) and therefore was outside the pipeline contractor's scope of services. Impact/Outcome: Materials showed up at site with no prior notification to the contractor and who should be receiving the materials. This was a challenge during the initial construction stages, but improved with time.	During construction contract alignment and kick off meeting, seek alignment with the contractor on the material delivery process, systems and interfaces to be used e.g. timing and issuance of notifications, expediting with the contractor, etc.

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ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
11	***Construction HSSE***	Club root management (Best Practice)	The procedure adapted from the Canadian Association of Petroleum Producers (CAPP) for dealing with club root disease was poorly understood and inadequate. The owner didn't explain the importance of club root management early enough to the contractor even though it was in the contract scope and was known to be bad in that pipeline area; it was only at the construction kickoff meeting that the construction contractor got a full understanding of the club root disease and its potential impact on construction. Impact/Outcome: Resulted in an increase in the number of wash stations from an initial 9 to 59 wash stations; the club root management procedure had to be revised several times to manage it (with bleach blowing) which resulted in additional cost due to the extra time required for cleaning. The club root documentation was properly developed (included details for every unit) and was thorough; a good job was done managing the documentation of club root e.g. taking pictures. (BEST PRACTICE)	Have club root requirements properly understood by the contractor and develop better methods/plans for clean up (bleach, chemical spray, pressure washing, blowing, etc.) Develop very efficient methods up front including a decision basis as to whether stripping the right of way versus just the ditch line is the right approach. (Note – contract negotiating team left the company shortly after contract award so this may be an issue of transfer of information between the contractors bid preparation team and the execution team.)
12	***Construction HSSE***	Communication Protocol for Spills/Incidents (Best Practice)	There were 2 (perhaps 3) different methods for communicating spills. One protocol involved the contractor's foreman reporting to the contractor HSE Dept and the Shell OSR, the Shell OSR then reported the spill/incident to the EI on shift; or sometimes a spill was reported directly to the contactor HSE department and the HSE staff managed the clean-up and completed the spill report. There was lack of consistency on the protocols for communicating spills/incidents. Impact/Outcome: The contractor did a good job on cleaning every spill and reporting. The contractor had an excellent reporting process for spills reporting into the FIMs systems within a contractor culture that facilitated this (e.g. even for the smallest spill of 20ml spill). BEST PRACTICE	Have consistency in the communication method/protocols for handling and reporting spills. Have clear expectation and process on who should be receiving the reports (e.g. use of a flow chart) in a timely manner. Notification of spills/incidents to the EIs on shift needs to be consistent and immediate when a spill occurs in order to ensure the remedial efforts are adequate.

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ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
13	***Construction HSSE***	Life Saving Rule (LSR) on Designated Smoking Area	There was lack of clarity on demarcation between work area and non-work area (for smoking) on the pipeline construction site; designated smoking area on a pipeline was loosely defined and the LSR on smoking was poorly enforced. Impact/Outcome: This led to instances of smoking in work areas on the ROW. Application of some of the LSRs e.g. confined space rules in trenches, working at heights (or trenches for the pipeline case where wearing of harnesses and tying up on the road sides were required), coveralls (PPEs) for people working in trenches where there are no flammable gases, etc. were perceived to be impractical for the pipeline construction setting. Some of the HSE rules were adopted from the Scotford plant which wasn't a good fit for the pipeline construction work set up.	• Clearly define work vs non-work areas in the pipeline construction area. Shell needs to clarify what the "no smoking except in designated area" means on a greenfield pipeline construction site. On a pipeline, a "work area" can be opened to different interpretations compared to a plant set up. • Carefully consider how all the LSRs should be applied on a pipeline green field area. Ensure the intent of the rules are abided by versus the possible process by which they are followed in a plant setting to suit the pipeline construction greenfield setting
14	***Construction HSSE***	Use of Project CWPPs	Originally the CWPPs were supposed to have been taken from Scotford capture "greenfield" execution site and customized for the pipeline with the contractor's input before start of construction. Impact/Outcome:The project ended up with some CWPPs that weren't customized for pipelines which led to conflicts and confusion when work was about to start with disagreements about their use. It was difficult to manage all the HSSE expectations logistically. CWPPs were still being approved and issued several months into construction	• Allow for early planning and use/adaption of CWPPs with the pipeline contractor and not request for their application just in-time when construction is about to start. Allow enough time for adaption before mobilisation of contractor. Allow for more preparation time by the contractor between contract award and boots-on-the-ground. • Develop and customise the CWPP with the contractor's input and what parameters are to be used.

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ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
15	***Construction HSSE***	HSSE Training Requirements	The project required every foreman and supervisor to go on a 2-day HSSE Leadership training and Permit-to-Work training provided by Shell trainers before starting work in the field. Timing of when the training was required (i.e. 1 month before the start of work by each new hire) resulted in logistics and compliance challenges to meeting the training requirements given the training was infrequent (sporadic). Impact/Outcome: This impacted productivity and schedule (in terms of additional time to meet the training requirements).	• Have a requirement for new hires (for foremen and up) to take the HSSE training soon after hiring and before they start work; set realistic expectations on the timing of the HSSE training and communicate the training requirements clearly to the contractor very early. • Plan the training programme as part of the overall project ramp up plan so that the training can be arranged at the right times to meet those ramp ups. • Offer training more frequently to avoid having to always schedule work around the training availabilities. Recognise that supervision training is different – not part of the orientation because not everyone will need the HSE leadership training • Consider the option of the contractor arranging for owner-trained dedicated trainer(s) in the contractor organisation just for HSSE orientation and training
16	***Construction HSSE***	Culture and Behaviours – OSR team execution	Clearer communication and up front work was needed with the OSR's on understanding of the CWPP's and the intent of the CWPP's. It would have been beneficial to have more time onboarding and focusing on the "shell" philosophy. We did not recognize early enough the opportunity to influence the OSR and subsequently concentrated on URS early on when we could have achieved better results by influencing our own Construction team and then having them influence the frontline URS team (success through others) Impact/Outcome: OSRs came from the contracting community so behaviors were more in line with the contractors than with Shell. This meant the "start up" focus of the Shell construction staff was directed at our OSRs versus the contractor.	Make the onboarding process for OSR's more robust and stress the "visible leadership" aspects.

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ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
17	***Construction HSSE***	Work Practices and Safeguards – Material Handling	Successes with URS, we challenged them and had them change some of their practices to meet our client requirements. One particular challenge we faced was using the CWPP's which were designed for a fixed facility construction and adapting them to a constantly moving work front, often remote, separated and spread out over long distances. We relied on URS (as the specialist contractor) policies and procedures and collective experience for a lot of the work. We reviewed their practices and procedures and where we found significant gaps we created additional robust JHA's in conjunction with the field teams to manage the work and gaps between URS and Shell expectations. Impact/Outcome: Material/pipe handling: We were really uncomfortable with the idea of the practice of using pipe sorting hooks for the entire project. Our CWPP's limited their use to highly controlled situations and by exception rather than the norm. The pipeline crews were extensively familiar with the use of pipe sorting hooks and it was the preferred method for them. Lots of discussion, arguments and back and forth went on with this prior to construction. We asked URS to look at using a vacuum system for this task, they countered with a general unease as to the reliability of the vacuum systems. Eventually settled on a deckhand system and the compromise to use it as much as possible for the 12" line and use the sorting hooks for the 6" line. Sorting hooks would used by exception still n the 12" line. In execution of the work we used the Deckhand almost exclusively and even after seeing how much safer and faster it was in operation we got in the 6" attachments for the deckhand system and used it on smaller pipe as well. It completely took the people out of the line of fire and from handling the material while suspended (no tag lines used) as the deckhand grapples are fully articulated and able to precisely place pipe.	Consider having the dialogue on Deckhand and/or Vacuum pipe handling systems as part of the contract negotiation taking the discussion/discretion away from the field level people.
18	***Construction HSSE***	Work Practices and Safeguards - Excavation	Managing excavations on a rapidly moving work front of a pipeline was interesting. The contractors had one way of doing it there Safe Work practices; our CWPP's were a lot more restrictive and originally set up for a fixed facility. We again relied on a robust JHA process to bridge the gaps and work to a method that could be executed in the field and reduce the risk to ALARP. We extensively used Permits, ground disturbance checklist and job and site	Expanded ROW as noted earlier in the lessons learned would be one recommendation that would alleviate some access issues Investigate using the Tuff step system for access/egress of excavations.

APPENDIX 19: PIPELINE CONSTRUCTION LESSONS LEARNED

ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
			specific excavations checklist from our CWPP's to control access/egress from the excavations for tie-ins etc. We compromised with URS north of the river where soil conditions favored using benched steps into the excavations and did not do this (instead used ladders) south of the river where sandy soil did not allow for benched steps. Impact/Outcome: Use of ladders and benched steps combined with tight workspaces and a narrow ROW led to sub-optimal and field based solutions that kept us busy in finding the right solutions.	
19	***Construction HSSE***	Work Practices and Safeguards - Trenching (Excavators & Side booms)	Equipment operation was a key part of the work scope and some of more notable incidents we had on the project. Quality of equipment, Equipment standards, and training and competency of operators were at one time or another questions in our minds. Third party rentals of equipment and sub contractor supplied equipment accounted for a sizable percentage of incidents. URS initially did not have clear expectations laid out to their suppliers and subs in terms of equipment. In the front end planning we reviewed the ASME B30 standards for side booms and asked our contractors and construction team if the equipment met those standards. The answer came back as less than clear, in fact it was realized there was an industry issue of widespread non-compliance to the ASME standard. This also meant technically we did not fully comply with Alberta OHS which cites the ASME standard for this type of equipment. We elevated the issue and Corporate URS leadership is investigating further into the issue. Impact/Outcome: Operator training & competency was the final factor in our incidents. The skill set was variable, the competency and training checks were in some cases when audited found to be paper "check the box" exercises. We asked our contractor to provide feedback to the groups check on practices, in this case excavations. After a subsequent incident on the pipeline several months later we found that answers provided by the contractor did not align with the assurances given in the group check, particularly in the area of ground disturbance and soil condition checks.	Ensure the contractor has a robust equipment acquisition procedure, including specifications provided to third party suppliers, pre-use inspections as part of site mobilization, and a good grasp of the resourcing for a preventive maintenance program. Work with the contractor and specify in the T&C of the contract full compliance to relevant standards prior to the execution of the work Ensure the contractor has robust training and competency programs for heavy equipment operators and audit the program frequently.

APPENDIX 19: PIPELINE CONSTRUCTION LESSONS LEARNED

ID	Sub Discipline	Lesson Title	Lesson Description	Proposed Recommendation
20	***Construction Quality***	Definition of “zero root defect”	At the time of pipeline engineering in 2011, the Z662-2007 specification didn’t cover CO2 dense phase pipeline service and so the owner developed a hybrid specification – i.e. Shell sour gas welding specs was adopted on top of the sweet gas weld specs (since the pipeline was licensed under the B120 licence for sweet gas); a combination of two standards/codes. The NDE subcontractor was therefore not familiar with the hybrid Shell specification on “zero root defect” as it was easier for them to test to an existing code that they were familiar with e.g. ASME/Z662. NDE contractor’s understanding of zero root defect was different from that of Shell’s, leading to a different interpretation of the requirement by the contractor. NDE sub-contractor was changed half way through construction. Impact/Outcome: The result was that instances of differences/misalignment on code interpretation issues spiked due to confusion with the “zero root defect” requirements especially when weld repair rates went up.	• Outline and define the “zero root defect” requirement to a specific code if possible versus just merely stating “no root defects” in the NDE requirements or adapt a single NDE standard/specification (clearly defined in a single document) on zero root defect for the project that the NDE contractor can use (e.g. using an existing code as a guide). Do not reference multiple documents/standards/codes for the NDE requirements for the subcontractor to interpret. Pick a code and include it in the specifications.. • Ensure there is a clear understanding of the interpretation of the NDE requirements among all key parties (pipeline contractor, NDE contractor and owner) to minimise the layers of communication and potential misinterpretation of requirements between the owner, the pipeline contractor and NDE subcontractor.
21	***Construction Quality***	Timing of issuance of documentation on quality and their sign off	Quality documentation on specific work scopes/packages was issued long after the work was completed. Impact/Outcome: Took more than 48 hours (sometimes weeks) after work was completed for the documentation to be submitted for review and sign-off.	Identify and include in the construction contract clear language on the timing requirements of when quality documentation should be received and signed off by the owner.
22	***Construction Quality***	QA/QC Resource team	Contractor had challenges resourcing the Quality Lead role earlier in the project. Ended up with having to resource the contractor Quality lead role about 3 times. The role and expectations of the contractor Quality team was not properly and effectively cascaded to the construction team and execution planning in the field. This was also partly driven by the construction schedule and the requirement to start the NSR HDD work (pipeline construction contract was awarded in August 2013 and contractor was expected to mobilise to site to support the HDD work in mid August. Impact/Outcome: Quality plans were not rolled out early and quickly enough e.g. timing of issuance of ITPs for reviews. Shell brought on Quality support early (before completion of the RFP bid packages) which really helped the project. The Shell Onsite representatives - OSRs (x10) covered much of the contractor’s lack of early resources to perform the Quality functions. The OSRs helped keep the quality high.	• Cascade to the pipeline construction contractor the importance of having a strong and qualified Quality team early on the project. Work with the contractor on strategies to source, attract and retain qualified QA/QC staff to the project. • Need alignment within Shell on the expectation of staffing levels if the owner (Shell) retains Prime Contractor responsibility as well as overall construction management without removing accountability from the contractors for their work

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
1	Walkdowns in the Modyard (BEST PRACTICE)	Shell ORA reps were embedded in multidisciplinary teams that were involved in the Modyard walkdowns for all disciplines. Modyard walkdowns were very specific and had details of what should be inspected. There were ample time for repair of deficiencies (nothing was shipped to site unless all deficiencies were fixed). EPCM field reps who led the walkdowns had a clear understanding of what was expected e.g. getting the base line thickness readings from the Mod yard, opening equipment for preliminary inspections, etc. Impact/Outcome: Minimal rework at site. And less scaffold for elevated access at site (hence cost avoidance). Weld quality issues and flange face serrations were identified and fixed before shipment to site	Explore use of ipads with the facility 3D model shots installed on them for walkdowns in the modyard and construction site Have a multidisciplinary team with the Shell ORA/CSU reps involved in the walkdowns in the modyard .
2	Cladding Damage Acceptance Criteria	Client didn't have clear expectations in the mod yard with regards to acceptance of cladding damage. The Module Fabricator had to meet client's initial stringent requirements (e.g. no damaged insulation be accepted prior to equipment/modules shipment) but had to relax those requirements over time. Impact/Outcome: Cost impact as a result of inconsistencies in meeting the client's own high standards on cladding acceptance	Have clearer expectations on the cladding conditions prior to the walkdowns in the Modyard
3	Electrical Testing at Modyard	A vendor in the modyard started electrical testing before the Inspection & Test Plans (ITPs) were approved by Shell. Lack of clarity from the EPCM contractor on the scope definition of electrical testing to maximize the testing at the mod yard. Coordination of up to six different contractors to ensure they were available at the appropriate times during the testing period The ITRs were not up to Shell's expectation. Impact/Outcome: Rework with retesting of all electrical equipment when they arrived at site	Have a qualified testing agency to be responsible for testing between the Modyard and site to maintain testing and results consistency Have ITPs reviewed and approved by the client CSU/ORA team prior to start of testing

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
4	35KV switchgear electrical tie-in testing requirements	Testing requirements were not very well outlined in the 35KV high voltage tie-in construction work package (CWP) developed by the EPCM contractor. Testing requirements were left for interpretation by the individuals executing the work in the field. Different groups were involved at different stages of the work; the design was by the EPCM contractor whilst execution was by the Shell turnaround team. Impact/Outcome: Work was not completed and there were no records of any testing completed. Schedule delays due to rework. Had to go back in the subsequent turnaround to complete the remaining outstanding work	CWP package should be a bit more detailed around the testing plans (e.g. use of Shell DEP requirements) Have the high voltage switchgear manufacturer's representative at site during the field execution of the work to validate the tie-in work is complete. Have a wider stakeholder review of the CWP package e.g. a more thorough review of the package from a field execution and start up readiness perspective using a project ORA/CSU personnel with strong competencies and background in high voltage electrical tie-in design, execution and testing
5	Casing installation on pipeline (mainline)	Seven 16" casings for a total of 1500ft were installed for sections of the pipeline route that were considered rocky to minimise any damage to coating on the 12" line. A related contributory factor was the poor field reconnaissance on the pipeline ROW resulting in changes made in the field to the execution strategy – change from open cut to horizontal drill and hence no plan for the rock sections Impact/Outcome: Casing reduced the effectiveness of the cathodic protection on the 12" mainline; cost and schedule impact due to installation of casing	Have a better planning for HDD drilling bit (with larger diameter drill bit) to account for rocky sections of the pipeline ROW; consider use of abrasive resistant coating. Get proper discipline review input to proposed changes

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
6	Management of Change (MOC) process	The project MOC process was cumbersome. It was designed more for cost and schedule impact assessment, instead of technical changes. The review process was too long (took 2 - 3 weeks in some cases). MOC processing was outsourced offshore to India and hence lack of local ownership for the MOC approval process made it long. Shell Technical Authorities (TAs) who resided in Calgary were required to review MOCs that prolonged the review and approval process Impact/Outcome: Responsibility for driving approvals of MOC resided offshore.	Have an MOC coordinator who sits with the project team locally to get quick turnarounds on MOC processing. Have a dedicated meeting to review MOCs thereby providing more visibility on the MOCs
7	CSU team resourcing timing and team size	Late on-boarding of ORA personnel (even into the Fall of 2013 when major construction and mod yard activities were on going). The initial premise/assumption was to leverage off existing plant operations & maintenance personnel to develop OR deliverables. A lot of OR deliverables didn't have resources allocated to them (E-Spirs, CMMS, PMs, procedures, practices). CSU team was stretched as the expected resources from the site Ops and Maintenance dept didn't get released to the project on time. Scope was not clearly defined to the Scotford team and with a lack of appreciation of the level of effort required to complete the deliverables. This project was the first to implement ORSAT and the complete list of ORA deliverables at Scotford. Impact/Outcome: Individuals on the ORA team had to wear multiple hats with increased workload for personnel. Additional cost for overtime work; and OR deliverables were not completed in time to support the start up date (e.g. Statement of Fitness); hence mitigations were put in place for the PMs	Have a detailed scope defined with time commitments for the OR deliverables (e.g. RCM studies, PMs) in a timely manner with resources appropriately allocated. Develop a general PMs estimate; and an OR deliverables schedule similar to a maintenance schedule.
8	ACM Development to support GAME ESP (BEST PRACTICE)	Process design/engineering reasons for alarm management were identified with input from Process Engineering as a deliverable at the early detailed design & engineering phase. Impact/Outcome: Simplified the ISU process for developing alarm catalogue, Used for operational procedures development.	Provide ACM table to EPCM contractor at the end of the DEFINE phase and seek buy-in from the contractor's design team. With discussions initiated at the beginning of DEFINE

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
9	Final Process Equipment Internal Inspection	Pre-shipment inspection of major equipment by the ORA team were scheduled and completed at the vendor shops. Final equipment inspection at site was not built into the construction schedule and budget. The CSU/ORA team presented a case for justification to complete internal inspection of equipment when they arrived at site. Impact/Outcome: Observed lots of loose vessel tray components, debris and foreign items found in vessels, major vessel internal components were missing (e.g. distributor for the stripper vessel).	Include final site inspection of major equipment internal into the construction schedule after pre-shipment inspection at the vendor shops.
10	Process Pipe Cleaning/Cleanliness	The CSU team observed more debris in the process piping that were turned over from construction to CSU (with sludge, water, dirt , debris, welding disks, fire blankets) than expected. CSU team assessed each pipe and decided which cleaning method would be the best to clean the line (air blows, N2 Blows, high pressure washing, robotic retrieval of debris, vacuuming high velocity flushing steam blows) The shell standard varies in certain systems; for compressor process piping for instance the cleanliness specification is very tight. For lube oil it is an M1 spec which is no particles on a milk pad. The cleanliness spec was given to construction through the flawless program. There were many inspections at the mod yard for cleanliness of modules prior to shipment to the site that were a great success. The onsite inspection for both off-module spools and stick built spools seemed to have been more of a challenge as much more debris was found Impact/Outcome: The impact to the schedule was cost as well as schedule. Due to the fact that the cleaning took much longer, and was more involved than we had planned for.	Hold the construction contractor accountable to develop a pipe cleaning program where there is a witness point for a Shell rep. With a simple inspection program the cleanliness of the pipes can be kept in check during construction. This could be added as a witness point to the ITP. The definition of "construction clean" needs to be agreed to in the early DEFINE phase so that the schedule for CSU can match that understanding. Then turn over from construction to CSU of the process piping as "construction clean" needs to be checked. Before walk downs are completed, or at least before piping systems are signed off from construction; key lines should be identified and borescoped. Have a designated representative from the CSU/ORA team to monitor cleanliness by working and engaging with the construction team at the craft level on the importance of cleanliness.

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
			Ultimately drive the cleanliness requirements to the craft supervision level.
11	Major Equipment Shop Inspection	The project developed and implemented a shop inspection programme that included pre-fabrication kick off meetings with the vendors and 3rd party inspectors at fab shop for critical equipment, in addition to other fabrication inspections, pre-shipment inspections using a multi-discipline team that included ORA and construction reps. Quality defects and non-conformances were still identified when equipment were received at site. Weld overlays: cracking and porosity indications on 10 small bore nozzles that were manually welded to two pieces of equipment; flange face smoothness issues were found on multiple heat exchangers that didn't meet the specifications (e.g. liners for corrosion resistance were not machined at all), and CO2 compressor flange faces. Impact/Outcome: Re-machining cost and schedule for the heat exchangers and compressor and weld overlay deficiency. Took deviations for equipment in H2 service that had flange smoothness between 175 and 250 AARH.	Share 3rd party inspection reports with the CSU/ORA team Share the equipment criticality rating information with the ORA team for the resourcing of ORA reps to support the shop inspection programme.
12	Critical Documents List as-builts	As-built critical document types were not clearly defined until the end of construction phase. It took three years to get this agreed to by site – site required additional drawings that were not on Shell's as-built critical list as per the DEP. Impact/Outcome: Redlining of critical documents could be missed; as-building cost greater than what was budgeted	When issuing design contract, have specific list of as-built document types and agreement with customer
13	Additional Steam traps (X2) on high pressure (HP) steam line	The overall distance of the high pressure steam line and low points with risers on the HP steam line required traps as per the Shell DEP to have steam traps at every 90m.	Incorporate the steam trap requirements in the design phase

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
		Impact/Outcome: Cost to install additional steam traps	
14	Spill containment plan beneath anti foam injection skid	Had to install spill containment pan beneath the anti foam injection skid and tote tank because they were missed . This was identified during the system walkdown for turnover. Impact: Cost to install	During 3D module reviews – check on spill containment.
15	Vendors not building equipment to Shell DEPs or API specifications	1.Flowserve pumps built in Mexico were not built to API 610 specs, there were many leveling issues, alignment issues, mechanical fit issues. 2. The Compressor motor built at GE's facility wasn't built as per the specified API 546. The feet on the motor were not parallel to the shaft centerline within 0.002"/ft as recommended by API 546 Impact/Outcome: 1. There was a cost impact to the project as 100% of all the Flowserve pumps had to be sent to Flowserve's Leduc (local Edmonton area) facility for re-work and trips had to be made to the facility to inspect and approve the work. 2. This caused a delay in schedule and cost to the project. There was rework that had to be performed at site with the vendor. Note: An additional step to verify that the motor feet are parallel to the shaft during factory acceptance test has been added to the large motor DEP 33.65.11.96-gen Synchronous motors (500KV and Larger) Based on API 546 3rd edition	Have a motor shaft parallelism checked as part of FAT
16	Modular Design for Rotating Equipment proved to be a challenge	The installation of the equipment on structural steel vs concrete pedestals has been challenging. The steel tends to bend and move and is very flexible. This makes installing a pump to API 686 specifications hard. Even with people walking around on the steel we saw deflection in the bases. We are also seeing that the structure can magnify the natural frequency of the running equipment. Impact/Outcome: This was an impact to cost, a few of the bases had to be stiffened up with welding and additional supports having to be added.	A recommendation would be to have more structural steel in place around where the pumps are being set, or a hole in the mod. Rotating Equipment is designed to be installed on concrete bases as per API 686

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
17	Loose vibration probes and wires left from construction	There have been quite a few issues with the Bentley vibration monitoring probes on pumps, mostly due to improper set up and also loose wires in control panels. Impact/Outcome: There is ongoing cost and delays for the probes that have to be checked and fixed as issues pop up from loose wires and wrong gap voltages set from construction.	Have people knowledgeable with the Bentley vibration systems installing and inspecting the probes;.
18	Fin Fan Actuators and Linkages not installed correctly.	The linkages on the louvers for the fin fans were never designed or installed correctly. The louvers had a specific range that they were supposed to able to open, but when they were tested before turn over it was found that they didn't open properly due to binding and had incorrect linkage settings. Impact/Outcome: There was an impact to schedule and cost due to the repair and rework that had to be performed at site on the actuator linkages.	Make sure that all the actuators and linkages are tested at the manufacturer's facility prior to shipping to the site.
19	Communication between construction and maintenance and engineering rotating groups. (Best Practice)	Having weekly scheduled meetings between all groups involved to discuss issues, progress and future work was a great way to keep all parties involved and engaged. Also having all parties in close proximity to each other helped keep open communication Impact/Outcome: The impact to the project positive on all accounts, schedule, cost, quality. Very low punch items in the rotating area on final walk downs and turn overs.	Recommendation would be to hold a meeting once a week between the construction, engineering, and maintenance groups to discuss any issues.

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
20	Compressor suction/discharge spools cleaning plan	In the detailed engineering phase the project team debated the merits of removable spools for cleaning and maintenance requirements for the compressor. Decision was made to go with non-removable spools. Impact/Outcome: Increased the amount of rework/double handling of spools with regards to piping being removed by CSU for cleaning (soon after installation and handover from construction) and then re-installation after cleaning.	For high cleanliness items, for example the compressor spools, develop cleaning strategy/procedures at the Define phase (air blows, or N2 blows, etc.) It is important to understand and develop a cleaning plan early in the project so that equipment can be laid out and designed with removable spools to reduce the amount of large piping that needs to be removed. Determine what the cleaning strategy is early in project DEFINE phase, such as air blows or chemical cleaning so that the proper breakout points (spools etc) can be determined.
21	Draining of hydrotest fluids from lines	After hydrotest the construction team was responsible for getting rid of hydrotest fluids in the lines i.e. draining of lines. Impact/Outcome: Almost a foot of water (water/sludge) was found in the 36" underground cooling water lines; hydrogen lines in HMU3 contained debris, sludge, etc.	Boroscoping of lines immediately after hydrotest by construction team to verify cleanliness of line.
22	Resources and Planning for Process Pipe Cleaning	CSU was responsible for cleaning; but didn't have the exact details and plans of how the cleaning was going to be done. Cleaning activities and development of commissioning procedures happened at the same time. Impact/Outcome: Commissioning and start up procedures were completed in a compressed time frame while cleaning preparation was on going. Quality of procedures (EOPs, NOPs, etc.) were ok; but the CSU personnel worked overtime to complete other procedures but were about 6 months late in completing the operating procedures compared to the originally planned date.	Double up on PS and OE; start early on EOPs and NOPs and prioritize them; then the cleaning procedures later. At the end of DEFINE phase, develop a cleaning strategy or guidance document that identifies at a high level the cleaning methods for each class of line (process vs utilities, line sizes, etc.) to standardize the

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
			cleaning procedures.
23	3rd Gen Modularisation Handover	With 3rd Gen Modularisation, construction had to hand over the process piping complete to CSU who then disassembled the lines/systems for cleaning. The construction component of the EPCM contract required the installation of the full process system for sign off on completion to CSU. Impact/Outcome: Rework with removal of control valves and installing temporary spools by CSU to complete their cleaning.	.Revisit the construction contract with the intent of making provisions to allow temporary spools to be installed instead of instruments (flow meters, valves, etc.) This should be considered before drafting of the construction service contract. Consider having CSU activities as part of the construction phase to allow CSU work before the final installation of instruments, etc.
24	Narrative testing responsibility	Narrative testing (full functionality interlocks logic testing) wasn't clearly defined in the mechanical completions matrix developed with the EPCM contractor; the differentiation between loop function testing and narrative testing was vague in the completions matrix. Impact/Outcome: A separate budget and agreement had to be put in place by CSU to execute the narrative testing (logic tests) by retaining the EPCM contractor design automation controls team to complete the test.	Be clear on field activity and budget responsibility for narrative testing in the mechanical completions matrix developed in the DEFINE phase between the owner (CSU) and contractor.

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
25	Timing of completion of control narratives	The level of effort required to complete the development of the control narratives was underestimated by the EPCM contractor. The site standards for control narrative development were not followed in detail. Only one dedicated EPCM contractor automation engineer was assigned to the narrative control development. The automation engineer didn't have all the details of what were required to develop the controls since the process systems requirements were designed and developed by Process Engineering team, and then was given to the Automation engineer to develop the controls philosophy; with no support from process engineering (who had by then moved on), particularly for integrated loops that interfaced with the existing plant systems. Impact/Outcome: Novelty loops didn't have control narratives developed for them (e.g. Cooling Water loop). Simple control loops which didn't have control narratives didn't have narrative test procedures developed for them. Control narratives were completed 6 months later than the original date (Nov 2013 vs March 2014).	Have agreed detailed scope of what a control narrative should be. Example a process control premise document be created for all areas by Design contractor's Process Engineering team. Design contractor's Process Engineering team should work closely with their automation engineering discipline counterparts to develop the controls strategy for the entire plant including start up and shutdown controls of the facility. Do this work earlier in Detailed Design so that process support is still available to the automation engineer.
26	Permit Issuance	Initial permit resource plan was for 1 permit issuer for an estimated 1000 permits for the entire project. Project didn't take into account the level of effort required to meet the brown field areas permitting requirements (HMU3, Interconnection utilities piperack areas, HMUs 1 & 2), RCDU plot brownfield / greenfield) Impact/Outcome: Additional cost associated with having 5 permit issuers with 15000 permits to write.	Properly account for brownfield areas permitting requirements into the resource plan and budgeting for brownfield projects.
27	ORA support for PCAP deliverables	ORA team spent significant number of hours and resources to develop and issue various deliverables to meet the project PCAP deliverables requirements and Project Guide 14B (for CSU) e.g. SIMOP document, Operability Review Report, Asset Reference Plan. This was the first project at Scotford that used both the PCAP and CSU project guide. (Previous projects were under Downstream and followed different process) Impact/Outcome: Resources allocated to developing some project PCAP deliverables that didn't add value to the project during the Execute phase. E.g. O&M philosophy contained too many details which were unnecessary, SIMOP document, Operability Review Report were not even looked at during the Execute phase	Critically review the set of PCAP deliverables for each phase and get agreement to a derogation where there is overlap .

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
28	Master Start up and Operating Procedures	CSU team struggled with correctly sequencing procedures for commissioning and start up. EPCM contractor provided an Ops manual late in the project (at the end of detailed engineering) but the manual didn't have enough details and there was no opportunity to request for revisions due to cost constraint. Control narratives were not completed at the time of issuance of the Ops Manual Impact/Outcome: Start up procedures were slowly written and had to go through a number of revisions to finalise them.	Engineering contractor should provide the Master Start up plan together with the Process control philosophy right after process design in the DEFINE phase is complete for CSU to develop the detailed procedures.
29	ORA input to design engineering (BEST PRACTICE)	Project team had experienced Operations and Maintenance personnel from the existing Scotford Upgrader plant (with the requisite site experience and knowledge) early in the project (at late SELECT and early DEFINE phases) to be co-located at the EPCM engineering office. The input from the multidisciplinary O&M team (Operations, Instrumentation & Control, Electrical, Rotating Equipment, Static Equipment & Maintenance Integrity specialists) allowed the engineering design team to incorporate into the design the appropriate requirements for Operability and Maintainability of the unit to align with the existing site standards. The input from the Ops and Maintenance specialists helped to explain why some of the design changes needed to be implemented during model reviews, P&ID reviews, HAZOPs, etc. either to comply with site requirements or address Operability. During the Detailed Engineering phase, the O & M specialists also participated in vendor/fabrication shop visits for major critical equipment pre-shipment inspections Impact/Outcome: Reduced the amount of changes in detailed design and construction on the project (NFDC's PDN's etc) and addressed a lot of the HFE requirements upfront during the design	For future projects it is a good practice and probably a cost saving to make the changes while still in engineering rather than later once in the field. Recommended for future projects to have experienced maintenance and Ops representation in post concept selection in the SELECT phase or the early Define phase (at the latest); and particularly for brownfield projects, get the O&M team with the requisite experience, standards and knowledge of the existing plant processes
30	CSU duration and integration into existing plant (BEST PRACTICE)	The project had resources from the existing Scotford Ops and Maintenance organisation who were embedded in the project team to support CSU activities and integration of the new facility systems to the existing plant operations & maintenance. Impact/Outcome: Project was able to leverage off the knowledge and experience of existing plant processes and systems to complete the project activities efficiently. CSU activities were actually completed in 2 months vs an original planned duration of 6 months on the FID baseline schedule which got reduced to 3 months after construction handover schedule was completed.	Where possible leverage existing site ops and maintenance personnel by having them as part of the project CSU team to complete the CSU activities.

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
31	Timing of Integrated CSU Schedule Development & Control	The CSU team established the start-up sequence as a schedule input. Individual engineering, procurement and construction (EPC), and commissioning and start-up schedules were integrated into an overall master schedule in Primavera which included the pipeline and well sites CSU activities. Cause: The original skyline for systems turnover from construction to CSU which was developed in the DEFINE phase of the project was still being used up to November 2014 (i.e. up till 2 months before mechanical completion) Impact/Outcome: Construction really couldn't react to give the utility system first which wasn't in the original sky line. This didn't allow any movement on what construction could deliver. The construction schedule became the driving schedule, and so the commissioning schedule changed substantially in reaction to the deterministic construction schedule changes.	Get the CSU planner / scheduler before start of construction and get the cleaning strategy to the planner to refine the construction completions in early construction. Finalize the commissioning and start up sequencing plan in early construction, so that construction can refine the back end of construction schedule to match commissioning priorities
32	Timing of Flawless Project Delivery (FPD) implementation for construction	Project team didn't have an implementation plan for flawless in construction until after construction started. Flawless booklets for the craft, flawless walks and FPD messaging tied to start up safety etc. were implemented several months into main construction. The pipeline construction flawless implementation was late as well. Cause: Changes in resources Impact/Outcome: The flawless program for construction was fully implemented but later than optimum. There were resistances initially from the pipeline crafts due to a lack of understanding.	Have a designated resource with responsibility for implementing the FPD programme at construction start. Roll out the flawless programme for construction at the beginning of construction as part of the full FPD program with the field craft and supervision.
33	Pipeline: Module flange torques for wellsite skids	Flanges for the wellsite skids were under-torqued. This led to loss of preservation pressure at 150kPa on the wellsite skids (even though tightness was part of the Flawless Programme). Due to the low pressure, it was difficult to pinpoint the exact location of leakage. Had to pressure up the skids with N2 (up to 1000kpa) to locate leaks using ultrasonic. After multiple issues were found, flange torques were checked and majority were found to be under-torqued. Generally there appeared to be a discrepancy between the torque value specified by the Shell DEP and the manufacturer's for gaskets	Re torque module /skids flanges transported long distances over the highway when they arrive at site.

APPENDIX 20: ORA/CSU LESSONS LEARNED

ID	Lesson Title	Lesson Description (Background/Causes/Context + Impact)	Proposed Recommendation
		Impact/Outcome: Multiple pressure tests with N2 packs (additional cost); 2 trips with Integra leak detection personnel (additional cost); Re-tightening of flanges	
34	Pipeline Cleanliness Spec (Best Practice)	The cleanliness specifications were kept and retained throughout the construction and CSU phases through the Flawless Programme. Cleanliness spec for the line was based on repeated pigging (¼" cleanliness i.e. ¼" penetration of dirt into the pig) **Impact/Outcome**: No filters were replaced even over a month of continuous operation	Replicate this cleanliness requirement
35	Use of Orbit Valves (Best Practice)	Early research on the use of orbit valves during the early design phase of the project resulted in the use of orbit valves Impact/Outcome: Zero failures , valves have good control, good quality	For similar CO_2 pipeline service, consider use of orbit valves. Ensure estimate recognizes the cost of orbit valves which can be significant compared to other valves.
36	Initial pipeline fill with CO_2 displacing Nitrogen (N2) (Best Practice)	During line commissioning, started with Nitrogen (N2) blanket. Initial fill with displacement of N2 with CO_2. Interface/interaction between N_2 and CO_2 was expected to be distinct based on information received from other facilities but this was not seen; possibly because the pipeline filling was at a lower pressure. Impact/Outcome: Initially assumed 4 days to fill the line with N2 displacement. But took about 8 hours to fill the line. Noise associated with the venting (at a pressure of about 500kpa) was not an issue (i.e. noise levels were not excessive to the point of reaching the neighbours and upsetting them)	Replicate this practice for initial CO_2 pipeline filling

Quest Project Close-Out and Lessons Learned Report		0
Heavy Oil		

APPENDIX 21: CO_2 COMPRESSOR REVERSE ROTATION ISSUE

BACKGROUND INFORMATION

Scope/Design

- Designed and installed an 8-stage integrally-geared centrifugal compressor with inter-stage coolers and knockout (KO) drums
- Compressor originally had two 6-inch blow-off valves (BOVs) at the 6th stage (UV004) and 8th stage (UV003) discharges for start up; a spill-back & anti-surge control valve (UV001) connected to the 8th stage discharge.
- Compressor piping, heat exchangers and KO drums layout followed the Shell DEPs and Quest project O&M philosophy

Interface and Executing Parties

- Compressor was designed and manufactured by ManTurbo
- Fluor as the EPCM contractor acted as agent of Shell (the owner) to design the inter-stage piping (normally provided by MDT)

WHAT HAPPENED, IMPACT AND SOLUTION

Compressor reverse rotation during initial shutdown

- During shutdown at about *4.8MPag* discharge pressure, the compressor slowed to ***0 RPM in about 30 seconds before accelerating to 514 RPM in reverse***.
- Made another shutdown attempt at minimum discharge pressure of *3.7MPag*, with PLC logic changed to open the blow-off valves 2 seconds before motor stop ***Shutdown resulted in reverse rotation again, this time at 371 RPM***.

Implemented Solution

- Designed and installed additional blow-off capacities at the 4th, 5th and 6th stages using 8” blow off valves (BOV)

Impact to the Quest project

- Surge test and 1st injection milestones were delayed by 11 weeks
- Additional cost of $3.3M to install the additional blow offs design

KEY LESSONS LEARNED – COMPRESSOR REVERSE ROTATION

#	LESSON TITLE	LESSON DESCRIPTION/CAUSES/CONTEXT/IMPACT	RECOMMENDATIONS
1	Novelty around mass/volume of CO_2 to depressurise	1. The volume/mass of higher pressure (both gas phase and super critical) inter-stage CO_2 was not well enough understood by the technical teams. • The mass of material in the system was a *novelty* that was not appreciated by the design team • compressor was 15% by volume larger than any other CO_2 compressor MDT had built at the time 2. The dynamic nature of the compressor shutdown was not communicated as a concern to the project team and/or not well understood. • Backflow leading to reverse spin was not covered in the original HAZOP. From a pressure protection standpoint, backflow was part of the Over Pressure Protection by System Design (OPPSD). • Reverse rotation was not considered because MDT had not experienced this phenomenon in previous installations; nobody on the combined Shell/Fluor/MDT team had seen reverse rotation before (though MDT had seen it on a test stand) 3. The project execution decision with offsite modularisation of the inter-stage coolers/knockout (KO) drums (i.e. design of layout and separation) pushed the volume of the inter-stage piping to be larger than previous experience with supercritical CO_2 compression by MDT who were always responsible for the inter-stage piping design as part of MDT’s proven industry compressor skid package. • The Shell DEP for liquid separation dictated the size of the KO drums. • 5 water-cooled intercoolers were located on a “remote” module; these coolers are traditionally located below the compressor from MDT’s proven design • The dehydration unit (TEG system), located after the 6th stage discharge, contained a large volume. (MDT’s proven design had the dehydration unit traditionally located after	• Fully understand where all the novelty is in the design from a system’s perspective; as the Quest team’s novelty focus was on the machine itself (because it was considered to be the largest of its kind) without assessing the novelty of the full process engineering design around it • Calculate the preliminary stage volumes and venting rates based on a selected time to depressure the compression system (compressor and inter-stage piping/ KO drums/coolers) during the early design phase to determine if reverse rotation is possible • Develop a dynamic model for the compressor system. Note that during FEED, without plant data, the dynamic model would be more “directional” than “prescriptive”. Would be prescriptive after operational data is available to validate the model. • Backflow leading to reverse spin scenario should be considered with any shaft-driven lube oil pumps • Consider minimising the size of the KO drums. Note: This may require a deviation from the Shell DEPs.

KEY LESSONS LEARNED – COMPRESSOR REVERSE ROTATION

#	LESSON TITLE	LESSON DESCRIPTION/CAUSES/CONTEXT/IMPACT	RECOMMENDATIONS
		stage 4 discharge) 4. Use of Shell DEPs for inter-stage piping, KO drums and Heat Exchangers design • Shell insisted on designing the inter-stage piping, KO drums and coolers to Shell's internal DEPs. MDT design was significantly different, with smaller inter-stage volumes (all packaged in a skid). This resulted in a design that was outside of the familiarity range and experience of both companies. Inter-stage volumes could therefore not be vented quickly enough **RESULT**: These factors pushed the design into a PROTOTYPE which the design teams were not fully aware of.	• If the Shell DEPs must be followed, then the gas/liquid separation DEP 31.22.05.11 must be revised to account for the number of stages and inter-stage volumes. DEP should lead design team to look at "reverse spin due to backflow" prevention option and depressurization options (i.e. additional blowoff valves, anti-surge control loops, non-return/check valves)
2	Lack of parallel design examples during FEED	During FEED, the concept of backflow through the compressor was thought of in terms of a single stage compressor or pump. • The only Shell experience on integrally geared compressors that was found during FEED was an air compressor at the Qatar Pearl GTL plant. Relief of air versus CO_2 are different (air has less HSSE concerns compared to CO_2; CO_2 goes cryogenic on depressuring). • The only other example during FEED was in North Dakota (this is a dry CO_2 facility without a dehydration unit) but design team had limited data on that design (had access to the PFDs and conducted a site visit). The limited number of available design and operating examples during FEED (i.e. limited data/information) of MDT's standard design, coupled with the objective to meet certain project decision milestones/schedule made it difficult to justify deviating from the Shell DEPs particularly on the integrated liquid knockouts and coolers design and their HFE aspects for MDT's proven skid package.	• Obtain knowledge on operating experience/data together with site visits to "standard MDT/vendor" facilities (on inter-stage piping and coolers) within a sufficient time frame in order to justify deviating from the Shell DEPs. • Drive for full system integration from a system point of view during the design analysis (especially on novelty identification) that includes Process Engineering in addition to the Rotating and Electrical aspects of the equipment design and performance to meet the different design requirements.
3	Initial Blow off Design Philosophy and valve sizing	1. 6^{th} stage BOV was not sized for depressuring the compressor (or rather, the rate of depressuring was inadequate to prevent reverse flow and rotation on shutdown, and it was not possible for one valve to achieve this). • Datasheet for BOV indicates 6^{th} stage BOV was designed and added to release excess gas from stages 1 – 5 during a start up. This mismatch of excess gas between stages is common in multistage machines running below design speed 2. Final valve sizing for BOVs and anti-surge valve was reviewed by MDT, but the time required to depressure the machine did not come up in the design discussions. • Design team focused on the static conditions for pressure equalization (i.e. the settle out calculations); no dynamic analysis was done on how long it would take to equalize the	• Reduce the overall volumes between compressor stages. (Dynamic simulation for design is out of MDT's experience). E.g. locate coolers and KO drums as close as possible to the compressor i.e. have KO drums integrated with coolers to minimize volumes. (Note: MDT's standard design does these things) • Check the venting capacity to ensure a pressure ratio <1 over the compressor to prevent backflow (i.e. ensure flow will always be in the forward direction) • Consider and assess the possible use of check valves between stages (e.g. between stages 4 and 5); consider more check valves on an 8-stage compressor. System design should be

KEY LESSONS LEARNED – COMPRESSOR REVERSE ROTATION

#	LESSON TITLE	LESSON DESCRIPTION/CAUSES/CONTEXT/IMPACT	RECOMMENDATIONS
		pressure. 3. 8th stage BOV was designed for the full compressor flow to avoid disruptions during the case where the main CO2 pipeline is offline (to allow continuous operation of compressor without having to recycle) *4.* 8th stage discharge check valve was located too far from machine nozzle. This piping contains a large mass of CO2 and has the most energy which then must be blown off. *This is however not a significant contributor to backflow leading to reverse spin (based on the plant data that was gathered)* RESULT: Considering the above factors, the pre-existing BOVs (UV 003 and UV004) were therefore not designed to accommodate depressurization during compressor shutdown	reviewed based on number of stages, type of compressor, inter-stage mass of process gas, and process pressures. Note: check valves aren't the most reliable valves. Also, settle out pressures will be higher in the machine when additional check valves are incorporated, increasing system cost. • Assess all modes of operation i.e. startup, normal, controlled shutdown, emergency shutdown in all design aspects e.g. HAZOP, SIL analysis • Consider backflow leading to reverse spin scenario. Establish "controlling" scenario for valve sizing • Vent valve on dehydration unit: Consider locating the dehydration unit at lower pressure levels (around stage 4 instead of stage 6).Note: at stage 4, dehydration unit would be larger and more expensive due to lower pressures. Could also consider alternate dehydration technologies, *or* consider dehydrating to a less stringent specification. This can be a design consideration for future design teams.
4	Organisational team/design interface coordination	1. It wasn't clear within the design team which party was responsible for determining if depressurization was adequate (including rates i.e. checking the volumes/mass and time required) as it was never understood by the design team that the blowoff valves needed to be sized for depressurization during shutdown. • Fluor looked at MDT as being the expert on depressurization requirements (rates). • Fluor received BOV datasheets with five cases, which were communicated to the control valve vendor, and then the detailed datasheets went back to MDT for review and approval. 2. MDT conducted an internal dynamic study which did not show any risks with the proposed design. MDT's model had a limitation in calculating backflow through the stages, or modeling stages for equipment stop or in reverse spin mode. • MDT's model was focused on analyzing surge phenomenon.	Get early input from rotating engineers and specialists with plant operations experience during the SELECT and DEFINE phases.

KEY LESSONS LEARNED – COMPRESSOR REVERSE ROTATION

#	LESSON TITLE	LESSON DESCRIPTION/CAUSES/CONTEXT/IMPACT	RECOMMENDATIONS
		• MDT assumed that some of the mass will flow back to the suction (backflow); it was considered a normal assumption, that not all the material would be evacuated via BOVs. • MDT looked at Fluor as being responsible for overall system design including inter-stages and connections. *This is where the novelty of having larger mass/volumes tripped up the team* There was a fundamental assumption by all parties that pressure would settle out in the system before reverse spin occurred (some backflow was presumed, as either normal consequence of shutdown or as part of OPPSD, but not reverse spin).	
5	Requirements for equipment performance testing offsite	No Factory Acceptance Test (FAT) was done on the compressor prior to shipment from the manufacturer's shop. • Some discussions were held prior to PO order, on a Performance Test which only considered the compressor design parameters. Simulation of the system was not considered for this test. • The equipment PO was set without any FAT requirements included. 7 months after PO award, the project team discussed adding FAT requirements • This additional FAT requirement would have created considerable impact to the project i.e. additional cost ($1.5M), schedule (3 months) and logistics (possibly needed to have inter-stage/cooling kit shipped to MDT to enable FAT). Hence project team decided to waive FAT (would have been easier to include FAT in the PO before it was issued)	• Consider conducting some kind of FAT with a full test simulation of the inter-stage KO/cooling kit and volumes at the test location. • Strive for a balance between the FAT performance specifications/ requirements against the assurance/output results from a dynamic model which may be directional at the FEED phase • A factory test which would reveal unknowns, such as reverse rotation, would have to include all site conditions including the simulation of volumes and losses between stages for the knock out drums, coolers, dehydration unit, BOV, ASV…etc.. • Any dynamic model being studied for the purposes of compressor/system performance & operation must include the simulation of all site conditions

APPENDIX 22: PROJECT SERVICES LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
1	Management of Change (MOC) Process with EPC contractor	EPC change management process had a log sheet that was available for anyone on the team to enter any change. This was reviewed bi-weekly and suggested opportunities, changes or trends were discussed and accepted or rejected before any effort was spent. This resulted in rigorous change management and less scope deviation. The regular MOC meeting was rigorously managed by key stakeholders.	Implement a change log sheet that is readily available to all members of the project team. This should also be implemented at the construction site	Execute
2	High staff turnover within pipeline EP contractor team	Because of high staff turnover at Toyo EP there was lack of familiarity and confusion on key processes . This resulted in inefficiencies until team members were trained and became familiar with these processes. There were examples of significant loss of capability due to loss of staff at the EPC. Differences in terminology and approach between Shell and the EPC also contributed to confusion.	On-boarding new team members at EPs should include orientation to key project processes and ensure they have an understanding. This may require frequent training and alignment sessions.	Execute
3	Primavera 3rd party access	A new process for providing system access was implemented at Shell as the project was progressing. This resulted in delays in giving 3rd party (EPC planners and schedulers) account ID and system access. Delays impacted productivity and cost the project money.	Streamline registration and issuing accounts to avoid delays for 3rd party access.	Execute
4	On-boarding package for key stakeholders	The project developed an excellent package for new hires joining the project, vendors and other contractors. It covers project scope and objectives, and key drivers. This resulted in quick alignment with project drivers and project objectives.	Projects should adopt an on-boarding process for new team members and other key stakeholders	Execute
5	Early construction works project controls set up	Effort required for early works was underestimated resulting in establishing an under-resourced, inexperienced team which was unable to manage the work effectively.	Establish teams that are adequate to manage fundamental project control processes. Site staffing costs are low compared with loss of site control.	Execute
6	Risk alignment session with EPCs	A joint Alignment and Risk Workshop was held with Shell and EPC to establish a common Risk Register. This process also developed awareness and familiarity with the project's key drivers and risks. The workshop focused on	Hold Alignment and Risk workshops with EPCs covering their scope.	Execute

APPENDIX 22: PROJECT SERVICES LESSONS

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
		project risks that were within the EPC's scope.		
7	Resourcing to establish new processes	Effort required for managing VOWD, MOC, reporting, weekly cash calls, etc. as per Shell's requirements was underestimated. E.g. A new process had to be developed by EPC to meet the VOWD and cash call requirements. Staffing was added late to support the effort. Team was overburdened until additional staff was added. This impacted the team's ability to support forward planning and future readiness.	Don't underestimate the effort required to establish new processes. Ensure Shell requirements are understood and adequate resources are planned (numbers and experience level) from the outset of the project.	Execute
8	Include VOWD process education in kick off meetings	Shell familiarized the main contractors, and their subcontractors with Shell's VOWD process to ensure these would be followed. These are included in the contracts, but are not widely understood by the teams doing the work. By providing the roll out improved compliance with the process was achieved.	Provide VOWD process education for each contractor and subcontractor in the project kick off meetings.	Execute
9	Contract Governance (VOWD, ACV, Contract budget and forecasting)	Process complexity and lack of understanding (within Shell and EPC) made it challenging to implement the contract governance process e.g. Shell terminology, interfaces between different groups, JV approval requirements, authority levels, etc.	Roll out and refresh contract governance communication package regularly to ensure broad understanding is maintained for all key players. Review Contract Register weekly or bi-weekly (including all governance parameters).	Execute
10	Detailed engineering physical progress review by discipline	A monthly detailed deliverable based engineering physical progress review process was implemented with the correct stakeholders (Owner's Project Controls and Engineering staff) to verify the EPC's progress report into the progress management tool. On a monthly basis a detailed audit was conducted to verify inputs from a selected discipline. This resulted in improved confidence in status reporting of engineering progress across all disciplines.	Implement a similar process on other projects.	Execute

APPENDIX 23: HSSE LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
1	Human Factors Engineering (HFE)	Using the existing HFE green book set a common understanding on HFE requirements between designers and Ops during model reviews. This avoid arguments & rework during model reviews	Prepare summary of HFE requirements and issue this to designers & operations early in FEED to avoid rework during model reviews	Execute (Detailed Engineering)
2	Performance Standards	These are poorly understood by the P&T team and at the moment they will not be used by Operations. When considered on top of vendor, EPC and ABSA quality and legal requirements they added no value to the process safety aspect of the project as they repeat information & processes completed elsewhere . Few relevant go-bys are available.	Either provide training or proven in use go-bys on the preparation or use of these documents (especially for static & rotating equipment) or do not enforce their use during the design/procurement portion of the project	Execute (Detailed Engineering)
3	HAZOP linkage with CHAZOP	CHAZOP (Controls HAZOP) review did not seem to add full value. The CHAZOP became a design review which was not the original intent.	Establish the TORs for the entire program of HSSE reviews to make the purpose of each review and the linkages between reviews more transparent to project.	Execute (Detailed Engineering)
4	Safety & Operability (SAFOP) requirements	SAFEOP scope overlapped with HAZOP review scope resulting in duplication of effort.	Establish the TORs for the entire program of HSSE reviews to make the purpose of each review and the linkages between reviews more transparent to project.	Execute (Detailed Engineering)
5	Too many people attended HAZOP review meetings	Recommended HAZOP attendance levels (8-10) were routinely exceeded resulting in poor meeting dynamics. This was mitigated to some extent by use of good facilitators.	Follow Shell guidelines for HAZOP review meeting size. Use qualified facilitators. Challenge unnecessary attendees.	Execute (Detailed Engineering)
6	ALARP demonstration poorly understood	The process for demonstrating a project is ALARP is not well understood or consistently applied. The Decision Log provided valuable reference for the ALARP demonstration.	Provide Shell ALARP guidance (i.e. in early Select phase) for the project so that the approach can be agreed and understood. Generate appropriate documentation as the project decisions are made to support ALARP demonstration.	Execute (Detailed Engineering)
7	Provide easy access to project specs and standards	All project specs were listed in EPC contractor's document management system. Shell's list of applicable project spec's and standards were not easy for the project team to find in the LiveLink system.	Consider producing a list of key documents to make it easy (with hyperlinks).	Execute (Detailed Engineering)

APPENDIX 23: HSSE LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
8	User of commitment database tracker (Best Practice)	Best in class "commitments" database (CTSE) to track and monitor till completions; hundreds of commitments and actions tracked.	Replicate this practice.	Execute (Construction)
9	Visible HSSE Leadership engagement (Best Practice)	Senior leadership engagements; attended toolbox talks every morning with craft and kept up this level of engagement day in and day out; participated in every Quest orientation & HSSE Leadership course. 40% of construction management team time was DIRECTLY involved in Visible and Felt Safety Leadership. Over 1600 management safety actions items were tracked to completion over 2013/2014. All supervisors (including Shell) had to take HSE Leadership once assigned to Quest	Replicate this practice.	Execute (Construction)
10	HSE Tracker (Best Practice)	Use of HSE Tracker for HAZOP actions closeout	Replicate this practice.	Execute (Construction)
11	Adoption of technology to improve process safety (Best Practice)	Adoption of new technologies to improve process safety and personnel safety. This included new styles of construction lighting (Airstar), fall protection systems (both fixed and portable) and use of deckhand grapples for handling pipe and removing people from line of fire situations.	Replicate this practice.	Execute (Construction)
12	Effective Project Communication Strategies (Best Practice)	Frequent and effective project communication strategies. This ran a gamut of different channels of communication which included: ○ 7:30 am HSSE meetings with Quest leadership (including Fluor) ○ Bistro – lunch and learn events on a variety of Quest related topics. ○ Job bulletins	Replicate this practice.	Execute (Construction)

APPENDIX 23: HSSE LESSONS – CAPTURE FACILITIES

ID	Lesson Title	Lesson Description (Cause + Impact)	Proposed Recommendation	Project Phase Identified
		○ Lessons Learnt from incidents ○ Weekly toolbox topics ○ Lunch and learn for all levels of project staff including field craft ○ Engagement lunches with craft and field supervision		
13	Heavy Lift Program focal point (Best Practice)	Very successful Heavy Lift program. Project identified one Lifting focal point for all lifts. Additional Rigging training over and above whatever the crews came with was mandatory for the riggers	Replicate this practice.	Execute (Construction)

APPENDIX 24: MMV PLAN

Table 1: Summary of the 2011 Planned MMV Technologies vs. the 2015 Executed MMV Technologies for the atmosphere, biosphere, hydrosphere, and geosphere

Monitoring Technology	2011 Planned			2015 Executed		
	Pre-injection	Injection	Closure	Pre-injection	Injection	Closure
Atmosphere						
LightSource	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Biosphere						
Remote Sensing:	Twice/ year	Twice/ year	Twice/ year			
RIA[a]				3 times/ year	Discontinued	Discontinued
MIA[b]				Monthly	Discontinued	Discontinued
Soil Monitoring	Every year	Every year	Every 2 years	Quarterly	Semi-annually/ TBD	TBD
Natural Tracers	Every year	Every year	Every 2 years	Every year	Quarterly/ TBD	TBD
Artificial Tracers	Every year	Every year	Every 2 years	Discontinued	Discontinued	Discontinued
Hydrosphere						
Downhole pH	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Downhole WEC[c]	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Natural Tracers	At least every year	Every year	Every 2 years	Every year	Quarterly/ TBD	TBD
Artificial Tracers	At least every year	Every year	Every 2 years	Discontinued	Discontinued	Discontinued
SCVF/ GM[d] water				Annually by	Annually by	Annually if required

and gas sampling with isotopic analyses				April 1, 2014	June 30	
Geosphere						
Time-lapse 3D VSP/ walkaway VSP Surveys[e]	2013	2016, 2018	None	February 2015	December 2015/ January 2016 TBD	None
Time-lapse 3D Surface Seismic Surveys	2010	2022, 2029, 2039	2048	2010	2022, 2029, 2039	2048
Monitoring Technology		**2011 Planned**			**2015 Executed**	
	Pre-injection	**Injection**	**Closure**	**Pre-injection**	**Injection**	**Closure**
Geosphere						
InSAR[f]	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly

Notes:

[a] Radar Image Analysis from RadarSat2. Discontinued post baseline as the risk of brine leakage has significantly reduced and the feasibility of the methodology yielded poor calibration.

[b] Multispectral Image Analysis. Discontinued post baseline as it is inadequate for real-time monitoring and CO_2 leak detection.

[c] Water Electrical Conductivity

[d] Surface Casing Vent Flow and Gas Migration. This monitoring activity falls within Natural Tracer Monitoring activities, but was highlighted as a separate item, as it's a specific AER requirement related to the SCVF and GM issue. Annual reporting to AER is required. This activity was not anticipated as part of the 2011 MMV Plan.

[e] Vertical Seismic Profile. The 2011 MMV Plan recommended the use of 3D VSP surveys. The 2015 MMV Plan used a series of walkaway (2D) VSP surveys at each well. The second VSP survey timing will be based on the observed CO_2 plume growth rate rather than a preset date

[f] Interferometric Synthetic Aperture Radar

Table 2: Summary of the 2011 Planned MMV Technologies vs. the 2015 Executed MMV Technologies for the Deep Monitoring Wells (DMW) and Injection Wells (IW).

Monitoring Technology	2011 Planned			2015 Executed		
	Pre-injection	Injection	Closure	Pre-injection	Injection	Closure
Deep Monitor Wells[a] (Winnipegosis/ Cooking Lake Fms)						
Downhole Pressure – Temperature	None	Continuous	Continuous	12 months	Continuous	Continuous
Microseismic Monitoring[b]	None	Continuous	None	4.5 – 6 months	Continuous	None
Cement Bond Log	Once	None	None	Once	None	None
SCVF Testing as per AER ID 2003-01[c]				Annually by April 1, 2014	Annually by June 30	Annually if required
Gas Migration Testing as per AER Directive 020[d]				Annually by April 1, 2014	Annually by June 30	Annually if required
Observation Well (BCS/ Cooking Lake Fm)[e]						
Downhole Pressure – Temperature	None	Continuous	Continuous	None	Continuous	Continuous
Cement Bond Log	Once	None	None	Once	None	None
Injection Wells						
Wellhead Pressure –	None	Continuous	Continuous	None	Continuous	Continuous

Temperature						
Time-lapse Ultrasonic Casing Imaging	Once	Every 5 Years	Every 10 Years	Once	Every 5 Years	Every 10 Years
Time-lapse Caliper Logs	Once	Every 5 Years	Every 10 Years	Once	Every 5 Years	Every 10 Years
Monitoring Technology		**2011 Planned**			**2015 Executed**	
	Pre-injection	**Injection**	**Closure**	**Pre-injection**	**Injection**	**Closure**
Injection Wells						
Mechanical Well Integrity Testing	Once	Every Year	Every 3 Years	Once	Every Year	Every 3 Years
Injection Rate	None	Continuous	None	None	Continuous	None
Distributed Temperature Sensing	None	Continuous	Continuous	None	Continuous	Continuous
Distributed Acoustic Sensing	None	Continuous	Continuous	None	Continuous	Continuous
Downhole Pressure – Temperature	None	Continuous	Continuous	As Available	Continuous	Continuous
Cement Bond Log	Once	Every 5 Years	Every 5 Years			
Temperature and RST[f] Logs				Once	IW 7-11 and 8-19: 6 months, IW5-35: 3 months, Annually for 2 years	None
Annulus Pressure Monitoring	None	Continuous	Continuous	None	Continuous	Continuous

Artificial Tracer Injection	None	Quarterly	None	Discontinued	Discontinued	Discontinue d
Routine Well Maintenance	Every 6 Months	Every 6 Months	Every 6 Months	Every year	Every year	Every year
SCVF Testing as per AER ID 2003-01[c]				Annually by April 1, 2014	Annually by June 30	Annually if required
Gas Migration Testing as per AER Directive 020[d]				Annually by April 1, 2014	Annually by June 30	Annually if required

Notes:

[a] In the 2011 MMV Plan, the pressure monitoring was to take place in the Winnipegosis Formation. However, site characterization demonstrated that the Winnipegosis had very low permeability near the injection wells and would not be an adequate monitoring interval. The Cooking Lake Formation has since been selected as the first monitoring interval above the storage complex. All of the deep monitor wells have been completed with gauges to monitor continuous pressure and temperature in the Cooking Lake Formation.

[b] The only microseismic monitoring geophone array is located in DMW 8-19. Contingency plans include the potential to deploy microseismic monitoring arrays in DMW 7-11 and 5-35.

[c] Annual SCVF testing as per AER ID 2003-01 for non-serious SCVF, until time of well abandonment or until SCVF dies out. Annual reporting to AER is required. See AER letter from December 3rd 2013 regarding approval of the MMV plan for full details. This activity was not anticipated as part of the 2011 MMV Plan.

[d] Annual Gas Migration testing as per procedure given in AER Directive 020 until time of well abandonment or until the GM disappears. Annual reporting to AER is required. See AER letter from December 3rd 2013 regarding approval of the MMV plan for full details. This activity was not anticipated as part of the 2011 MMV Plan.

[e] The original 2011 MMV Plan included far field pressure monitoring of the BCS in the Redwater 3 – 4 appraisal well. In the 2015 MMV Plan, Redwater 3 – 4 is being used to monitor pressure within the Cooking Lake Formation in order to better understand pressure changes in the Cooking Lake Formation related to Leduc Reef production.

[f] Reservoir Saturation Tool. This tool enables CO_2 saturations to be measured in the formation beyond the casing strings and cement. This activity was not anticipated as part of the 2011 MMV Plan.

APPENDIX 25: FEED PHASE LESSONS LEARNED

Capture Facilities Design FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	Civil: Site physical features in civil scope	Often physical site features are not included in the scope or are buried in the turnover documents, especially when modifications were made on site and subsequent to the original scope. We should also require that contractors note changes to the civil scope, include those in the turnover documents, and post them on LiveLink.	Develop a robust turnover strategy for civil scope with the Engineer Procurement Construction (EPC) company or acquire additional topo surveys of the site during the define phase.
2	Civil: Geotechnical report scope	To avoid the need for a completely new geotechnical report and to avoid conflicts between multiple geotechnical reports, the geotechnical report for Quest addressed new design parameters (Limit States Design and dynamic soil properties local to the new project area) but referenced existing geotechnical reports for other design and construction parameters that did not change and were addressed in the existing reports.	Consider using the same geotechnical contractor for site investigations as was used to prepare any existing reports. Request that they only address new design criteria requirements instead of creating completely new geotechnical reports. This avoids conflicts between multiple reports.
3	Electrical: Coiled cable requirements	Cables damaged while on the ground prior to installation.	Include coiled cables requirement as part of Third Generation Design to reduce damage during construction. Requirements should include a description of the means to protect coiled cables (temporary barriers for example) and cable termination procedures following installation.
4	Electrical: EHT Inspectors	Only one yard had a full-time committed Electrical Heat Tracing (EHT) inspector. The other module yards got random inspections. The quality team raised this as an issue, but this was not considered a priority. Numerous installation issues were encountered.	Ensure full-time electrical heat tracing (EHT) inspectors are available in module yard. Include this requirement in the contract.
5	Controls: Instrument Alignment Workshops	A Review & Alignment meeting was held on CS implementation, technology selection, installation practices, documentation requirements, etc. The initial meeting was held in the Define phase; subsequent meetings were held in the Execute phase. Attendees included Shell Project and CS SMEs.	Continue to have Instrument Alignment Workshops in the Define phase but include Site CS personnel (Site personnel were involved in Execute Phase workshop). Extend instrument alignment workshops into the Define phase.
6	DCAF for brownfield projects	DCAF deliverables are mainly listed for large greenfield projects. Brownfield projects require more clean up, and DCAF deliverables for the Define and Execution phases are not aligned with project execution style.	Adjust FEED for Brownfield projects. Align Discipline Controls and Assurance Framework (DCAF) deliverables for Brownfield projects with project execution style. Bring in heavy front-end loading from EPCM and Project Engineers and agree on what is required.
7	Specification List	The Specification List was a constantly evolving process. It was difficult to keep track of revisions. Furthermore, the alignment between the different discipline DEPs was not 100% due to the out-of-sync updates. This may be a one-off problem due to major changes to the DEPs in recent times.	Review changes to the Project Specifications List before releasing to the EPC. Consider limiting project specification list changes to one per project lifecycle.
8	Shell DEPs/Standards: GEN/SCAN	There were conflicts between DEP-GENs, DEP-SCANs and standards approved to be used on the project. A path forward and clear direction on how to resolve the contradictory requirements has not been established	Allocate adequate time and resources in FEED to sort out these conflicts. Resolve DEP Group Employee Number (GEN) and Shell Canada (SCAN) conflicts in FEED.

Capture Facilities Design FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
		In FEED.	
9	Mechanical: Construction Classes	Construction classes for vessels had been driven late in the Final Investment Decision (FID). Fluor used the criticality ratings to issue drawings. Later they had to be matched with Shell construction classes, but some did not match. The link between the two was not communicated properly, though there had been statements put forward about how the two might link.	Establish construction classes for static equipment earlier in FEED. Extra workshops to align critical aspects, such as construction classes, might be beneficial as they are tied to requirements for fabrication and Non-Destructive Evaluation (NDE).
10	Preservation requirements	Long lead equipment RFQs went out without specific preservation requirements.	Define preservation requirements early in the project.
11	Pumps in modules	Mounting rotating equipment in the modules is not covered well in DEPs.	Use Shell third-party vibration analysis group for pumps 75 horsepower or more, or for PD pumps with known vibration issues on steel modules.
11	Shell and Tube (S&T) Exchangers	Design of S&T exchangers to be mounted on the modules required input from Piping, which came in waves and generated mechanical rework. It is costly to perform mechanical adjustments on site.	Ensure that the size and weight limitations for S&T Exchangers are defined early in the project. Knowing limitations early would help to define requirements. Limitations should include duty and check-rate conditions.
12	Engineering Standards and Technical Guide (ESTG)	Although DEPs provide general guidance for design, they do not have sufficient detail to be used as construction specifications, nor do they contain site specific information required for design (e.g. rainfall intensity values, etc.). This resulted in a number of ESTG/STD specifications needing to be added to the project specification list (e.g. STD 14-3.31, STD 23-4.01) for construction and design to be completed.	Update ESTG/STD specifications to meet the requirements of the Design Engineering Processes (DEPs) and provide sufficient detail for the specifications to be used for construction. Incorporate all related amendments and supplements and TDNs. Use only ESTG/STD specifications for projects to reduce conflicts with local standards.
13	Basic Design and Engineering Packages (BDEPs)	In preparing the write-up for the BDEP package, CSA was unclear on exactly what needed to be included. Therefore, a basic write-up similar to what has been produced for other clients was produced with the hopes that it met Shell's requirements.	Provide clear direction to Engineering Contractors as to the requirements and level of detail for documents such as BDEPs related to Discipline Controls and Assurance Framework (DCAF) and Project Controls Assurance Plan (PCAP) requirements. A sample BDEP from would be useful.
14	Access to LiveLink	Providing the Engineering Contractor with access to LiveLink greatly enhanced the project. Specifically, the Engineering Contractor could locate documentation (drawings, etc.) and proceed with designs without having to wait for drawing requests to be filled. This would help ensure that the right drawings were received. In addition, drawings that need to be revised can be easily identified to better define the Engineering Contractor's Scope of Services.	Recommend that Shell continue to provide access to LiveLink for Engineering Contractors.

Capture Facilities Design FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
15	Piping stress analysis	We have experienced challenges with pipe routing due to stress analysis caused by large-diameter stainless steel pipe and/or two-phase flow. In some cases this has had an impact on pump Net Positive Head Suction (NPHSa).	Perform piping stress analysis earlier in the project execution (FEED phase) to define critical lines and required pipe routing. This is particularly important for stainless steel lines, pump suction lines, and two-phase flow lines where slug flow is a concern.
16	Drainage requirements	We had an inadequate definition of what could be sent to the potentially contaminated storm water sewer and how pump base plate drains would be handled. This resulted in late changes to the drainage philosophy.	A thorough definition of the drainage requirements, considering all commodities, should be done in the FEED phase.
17	Compressor Interfaces and Vessel Packages [Best Practice]	Quest has a compressor at its critical path. Both from a Shell and vendor perspective, there are many specifications around it. These many specifications present a very complicated package. Distilling the full package would be helpful to both the design house (EPC company) and the vendors. The package that went out had some very specific engineering notes on it regarding the Quest project (especially on the control system side). It required a lot of assistance from numerous disciplines in addition to mechanical, however, it benefits bidder proposals and should be adopted for future projects. Engineering notes were site specific and thus could be used in further projects on the site. Technical drawings became standard when they adhered to the DEPs. We could then apply them in each package without further consultation, thus cutting time	Distil Shell specifications for compressor package interfaces and vessel package into the engineering notes.
18	Material Take Off (MTO)	The Material Take-off (MTO) quantities drive an estimate. Allowing three months from MTOs to estimate completion ensures good estimate quality. Rushing estimates often causes problems further down the line in a project.	Ensure early Material Take Off (MTO) quantities to support estimates. Balance timing of MTOs as some projects do not allow sufficient time to prepare a quality MTOs due to the length of time required to prepare an estimate. Adequate review time for an estimate is lost if the base supporting information (such as MTOs) are not of sufficient quality to support an estimate.
19	PCAP – Deliverables duplication	The deliverables in the Project Controls Assurance Plan (PCAP) proved difficult to interpret from a Fluor perspective. Without added help from Shell staff there is a chance of duplication of deliverables.	At the start of a project, create a list of deliverables from each party, compare them and agree on which deliverables will need to be met. Align the PCAP with the EPC deliverables. A workshop driven by Shell is the best way to do this. This will avoid duplication of overlapping Shell PCAP and Engineer, Procure, Construct (EPC) deliverables.
20	Incorporation of PHA III actions prior to AFD P&ID [BEST		Ensure adequate time (approximately two months) to incorporate PHA III actions prior to AFD P&ID

Capture Facilities Design FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
	PRACTICE]		
21	3rd Generation Modularization	Third Generation Modularisation means that the module contains as much built equipment as possible in order to minimize work in the field. The Quest project was approached as an offshore plant. Shell's offshore Design Engineering and Procurement (DEP) packages are not translated to onshore work. Some of the DEP requirements from Version 32 have been applied, but the DEPs have mostly been from Version 31. Special trips were made to learn from offshore and how to apply their methods onshore.	Identify Design Engineering and Procurement (DEP) requirements in FEED so that modularisation reviews can proceed. On Quest, module strategy (third generation) and module envelope size were agreed in pre-FEED, which should be counted as a success for Shell and Flour.

3rd Generation Modularization FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	On-Shore Module Weight Management	There are two classes of modules: onshore and offshore. Each has expectations with regard to weight management. Staff may have assumptions based on a history with one of the two. Third Generation Modularization borrows from offshore ideas but is still mainly based on onshore themes, e.g. all weight data is required in FEED for offshore, whereas onshore modules are smaller, and we focus on other details first. Most weight management practices originated in the off-shore environment to support design and operation after construction. These tend to be rigorous and are required earlier in the design phase. On-shore weight management primarily addresses transportation constraints and does not have post-construction implications.	On-shore weight management should be appropriate to manage the transportation constraint and utilize historical density data. The opportunity to load shed for transportation is also a consideration. Sometimes the comparison with the offshore world is moot for onshore modules. On-shore modules need to be fit-for-purpose and thus may not need to adhere to certain off-shore themes. On-shore really needs to focus on being within the transportation weight limits and not so much on ballast etc.
2	Maximize E&I module scope	The benefits of Third Generation Modularisation are greatest when 100% is modularised (excepting tanks and non-fitting equipment). However, on Quest individual constraints were considered in isolation regarding whether or not to modularize selected Electrical and Instrumentation (E&I) components. E&I requires a lot of fine-tuning in this respect. Capital cost evaluations were performed to understand the trade-offs. These evaluations under represented the construction impact and collectively eroded this opportunity.	We should fully commit to the philosophy and implementation of maximizing module scope for Electrical and Instrumentation installation. Commit to placing the entire E&I kit on a module and engineer a solution for all those considerations. Care must also be taken when trying to be cost neutral. Other aspects could surface, such as increasing HSE risks.

3rd Generation Modularization FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
3	Construction - Optimize pipe guide fabrication [Best Practice].	We normally rely on contractors in the Edmonton area to fabricate guides and supports. However, these contractors were at capacity. This meant that the structural steel fabricator for the project would fabricate them. This could be beneficial as they do similar work already.	Consider shift to Structure Steel fabrication to reduce yard welds and improve scrap management, utilizing cut-off "H" sections. Include pipe guide fabrication and installation in the Structure Steel fabrication scope. If there is high confidence in the pipe routing, guides could be attached reliably, which could offer beneficial fabrication methods. The key is to recognise similar opportunities in fabrication.
4	Construction - Vendor packages.	With a modularisation philosophy in place it is natural to move it to the vendors too. Some are more cooperative than others. Not all packages are suitable for modularisation but some are. Modularisation of vendor packages will help take work off-site.	It is worth investigating the possibilities of modularising certain key vendor packages.
5	Construction – EPC Integration	It is normal practice to have construction come in and look at the design. However, in Quest the team was in with the EPC contractor early and was able to work with them before the design needed to be reviewed. Furthermore, the team was set and well staffed. This will cost more at the start but will pay itself back later on in the project.	Bring Shell construction in a bit earlier. Integrate the construction group within the EPC early on.
6	Construction - HSE team	On the construction side the HSE team was not made up of full-time staff. This was okay in Define, but was felt later during Detailed Design.	The HSE staff should have been full-time to get the end plans needed.
7	Construction - Site integration. [Best Practice]	There was an Integration Manager set up who organised temporary facilities on site for construction. They also worked well in integrating the site needs with those of construction etc. This was crucial to integrate the process into an existing facility.	The whole integration process throughout has been key with regard to site and construction.
8	Construction - Equipment Ownership	At the end of FEED we realized that preservation of equipment was not assigned. It was not clear who had ownership of this issue. If equipment is brought on site without clear ownership it could be ruined due to exposure to the elements.	Preservation requirements should be defined early in the project. This should be a combined effort between Shell and the Engineer Procurement Construction (EPC) company and between the disciplines. Turnover documentation should also include an operation manual for equipment, just like any other mechanical or process package. Update internal requirements (probably this would fall to Mechanical).

3rd Generation Modularization FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
9	Standardize module attachment points.	In Quest there are 2 to 5 bay modules that require reconfiguration of the spreader bars. There is a lot of lifting in the field, so the idea is to reduce the effort that goes into lifting a certain module. This means thinking about cladding etc. around attachment points and trying to standardise those points as much as possible. Non-standard loads and tie downs can also create an unintended HSE exposure.	Standardize module lifting and tie-down attachment points. Develop predictability in attachment methods. This means that the lifters will not have to think of a unique solution for each attachment point when lifting the modules into place. Proactively provide tie-down sketches etc. with the modules for transportation, lifting and rigging.
10	Early access to design benefits	Recognize the accelerated design availability created by the 3rd Gen Modularization work process and utilize it to enhance constructability. 3rd Gen requires more E&I and upfront engineering, so there is more information in the module to review. A constructability review thus has more content than normal. The various disciplines (including construction) must have regular conversations about how the module is progressing. The key is to eliminate the amount of RFIs produced.	Recognize the accelerated design availability created by the 3rd Gen Modularization work process and utilize it to enhance constructability. Seeing the content earlier will allow RFIs to be answered before they are even asked.
11	Module Fabrication contractor selection	Project sanction limited constraints on award and thus opportunities to fully engage the module contractor in design orientation, constructability specific to their infrastructure, and early planning. Contractor availability was also reduced due to an increase in market activity.	Create engagement opportunities with multiple contractors for constructability reviews and ongoing communication releases. Develop a selection strategy that can respond to changing market conditions.
12	Optimize electrical component attachments	Opportunity to improve field installation. Include uni-strut installation in the Structural Steel, Walkway and Platform fabrication scopes.	Optimize early scaffold installation. Opportunity to install scaffold at various weld locations while the module is still in the yard and at ground level vs. in the field and elevated 18-24 meters. Test the method with Contractors during their individual model review sessions and engage Structural Engineer to approve scaffold design for transport.
13	Optimize structural steel assembly	Opportunity to minimize the amount of stick-built steel.	Pre-assemble and ship to site individual bends and corner sections that constitute the base of elevated pipe rack modules.
14	Streamline temporary supports	Reduces the amount of temporary support steel, ready rod, double nut and angle iron. Also reduces prolonged exposure to elevated work and double handling of multiple field designed tie-down methods during the installation and removal process.	Design 3/4" structural bolt tie-down into the structural and pipe shoe detail.

3rd Generation Modularization FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
15	Design guide [Best Practice]	The work Flour required from front-end engineering to provide possibilities for 3rd gen modularisation is written up in the design guide. It covers the 3rd gen philosophy and what needs to be considered. For Quest, a job bulletin was attached detailing how the model would be developed during FEED. For Quest, the execution plan for FEED was to model more than traditionally done and thus remove “Field Run” stamps. The idea is that construction will be more efficient if they know exactly where to place items, rather than doing design in the field. This is due to the criticality of space allocation.	Any stamping on a drawing labelling it “Field Run” in E&I has been removed, this has provided huge benefits regarding schedule. Doing this makes sense in an environment where engineering costs are equal to or cheaper than construction costs (e.g. Alberta).
16	Fluor process	3rd Gen is a service smart work practice developed by Fluor and is their IP. It is on how to approach and implement the design in a step-wise manner and recognises the precedent of information.	Approach Fluor if something similar is to be attempted in the future.
17	Replication contractor selection	The constructability reviews have provided great value for the site team, but the fabrication team has not been present (none has been appointed yet.) The construction team has provided many design enhancements and cost avoidances due to those reviews.	In Quest it was not possible to include the fabrication team, but on certain projects it could be. Therefore, they should be included in the constructability reviews to provide design enhancements etc.
18	Field well locations	In some cases the field well locations have been brought inboard with the modules. Optimising them and grouping them have been good ideas. Just how far the benefits to scaffolding etc. will go is unsure.	Optimising and grouping field well locations provides a great benefit. The places where inter-module connections occur have to be thought about to intelligently locate them. This could be done in the FEED phase, but the detailed design phase may be better.
19	Fluor / Shell relationship	The Fluor / Shell team has worked exceptionally well together. The incentives were around behaviour-based contracts rather than outcome. This meant that safety, service, and honesty were highly valued. This enabled a strong establishment of trust.	The set-up of behaviour-based incentives created a very pleasant atmosphere for cooperation.

Capture Facilities Contract and Procurement (C&P) FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**

Capture Facilities Contract and Procurement (C&P) FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	EFA - Implementation	Quest was the first project in Canada to use Enterprise Framework Agreements (EFAs) and there was a misunderstanding on how they worked and who was supposed to do what (especially around call-offs).	Shell should consider a Best Practice on how to implement an EFA. It should contain an executive summary and a guide on how EPC houses fit into the process. The key is identifying who does what.
2	EFA - Call Offs for Procurement	Quest was requested to use Enterprise Framework Agreements (EFAs) and NBOs for purchase of equipment and materials, but no process was in place for call-offs. In addition, some old agreements were not renewed by Shell (e.g. Hudson air coolers, Spartan for control valves), so changes in the original procurement plan affected the project. Not all EFAs are created with the same content (i.e. Specs and Standards, QA/QCs requirements, pricing, and T&C's), so implementing requirements on the project was difficult without knowing what the agreements contained. Lack of understanding of how Call Offs were to be implemented with Engineer Procure Construct (EPC) houses resulted in over 3 months of work by an EPC house with no resolution. Logic was to have the EPC Houses do the Contract & Procurement (C&P) work; however, the Call Offs should have been handled by Shell's Category Management team (CM). However, due to urgency, the Quest C&P team ended up doing them despite insufficient staffing. Clarity finally arrived from Shell's lawyers on how to handle this work.	Clarify the Call-Off process early in the project in Contract & Procurement Process Manual (CPPM) strategy stage and staff accordingly. EPC houses should not negotiate on behalf of Shell with an EFA partner. Recommend all Call-Offs be completed and executed by Shell's Category Management. Roll-out procedures and work processes for EFAs should be developed and made available to project teams. They should clearly spell out the role of the CM in assisting the Project team (C&P or PE) to handle the EFAs issues. Fully engage and leverage the CMs to understand the terms and conditions of any Enterprise Frame Agreements (EFAs); what parts are global and therefore will be dealt with by the CM, and what parts need to be negotiated locally by the project. (Recommendation relates to materials and equipment only. On services, some discussion between the contractor with an EFA and the EPC house is usually required to agree mob dates etc., and any other peculiarities not addressed in the EFA. But such discussions should only be made with Shell's express prior consent and managed carefully.)
3	EFA - Waiting on POs	An EFA should allow early engagement with a vendor and maybe some preferential treatment. This will result in getting information in early. However, vendors still insist on waiting for the PO before releasing documentation.	Make sure the vendors understand that if they are in an EFA agreement they should be releasing documents and not waiting for POs.
4	EFA - Individual Details	Each EFA comes with small individual details, e.g. from which plant to buy items. This means that they have to be known in order to take correct measures when buying material etc. Furthermore, details are needed on what is covered by the EFA because not knowing makes it difficult to deal with the vendor.	Documentation from Category Management should contain all this information, as it could be crucial in purchasing material.
5	EFA - Vendor Affiliate Notification	Shell has internationally negotiated deals. This means that with the EFA, one deals with an affiliate in a country that represents the vendor. Sometimes, those affiliates are clueless with regard to the EFA.	Suppliers should ensure that their affiliates understand the EFAs. Assigning an EFA or affiliate-designated person to contact for issues is very helpful.

Capture Facilities Contract and Procurement (C&P) FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
6	EFA - Getting a Team Together	When the EFA has been put in place there is a focus on costs and relationship. However, quality execution of the contract and PO are often missing later.	A team should contain members who have worked with EFAs before and are focused on adding quality to the contract. If there are a number of EFAs that have not been called-off, an appropriate staffing plan needs to be set up, especially if Category Management does not have the resources available.
7	EFA - Non-Disclosure Pricing	Non disclosure of EFA pricing, particularly around instrumentation, made estimating difficult. When tagging items with regard to changes it is helpful to know what those are worth. This would be helpful in giving better change estimates. The EFA does not provide a price indication.	Look for opportunities to share detailed pricing when estimating tagged items.
8	Quest Project CPPM	There was no pre-existing Contract & Procurement Process Manual (CPPM) which led to uncertainty on requirements for project-specific Contract & Procurement activities. It is normally used to link the various processes regarding contracting. When one is lacking, all tasks and directives are relayed verbally. With a manual it is written down and thus clear what has to be done. The Contract & Procurement processes on project were driven by experienced C&P staff based on previous projects.	CPPM should be in place at the outset of a project. Ideally, a Quest CPPM would be derived from a C&P Canada CPPM. It would be generic enough to use in any project in Canada.
9	C&P On-Boarding	There is a lack of on-boarding in Canada, especially in C&P. This is being seen to at the moment, but new staff struggled to find procedures.	Formal C&P On-Boarding process should be in place at outset of project, along with a project-specific angle.
10	C&P Lead	Delayed arrival of Contract and Procurement Lead drove the new staff to handle issues with only remote support, which resulted in a prolonged decision-making process. Guidelines state that there should be a project specific team lead in seat. This was not the case on Quest C&P, and it caused a lack of clarity in roles etc. Having someone in seat may have been beneficial on the EFA problem.	C&P Lead should be in seat early (commencement of FEED stage) and replaced with full hand over. A C&P lead in seat would be able to assign staff to their tasks and sign off on documents.
11	C&P Staff Experience	Staff changes resulted in 4 people having either no Canadian or no Shell experience, i.e. no one had both. This was exacerbated by a lack of hand over.	Ensure small C&P project teams (especially less than 5 people) are staffed with adequately experienced people. Ideally at least one person on the team would have both Shell and Canadian experience.
12	Procurement and Contract Plan/Report (BEST PRACTICE).	The overall reporting perspective was lacking in the Engineer Procure Construct (EPC) Houses. Shell Contract & Procurement established a C&P Report that tracked the acquisition cycle and listed all RFQs and RFPs for the EPC House to populate. This report established a road map to monitor the overall acquisition activity. However, the C&P process was not aligned before this report was established, which generated many hours to clarify the bidding process.	Ensure a C&P Report is agreed to at the start of the project for managing the C&P acquisition process.

Capture Facilities Contract and Procurement (C&P) FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
13	Internal Access to Shell Resources	Lack of timely (or any) response to requests for information and existing contracts at the Site led to delays in the Engineer Procure Construct (EPC) contractor sourcing decisions of contract packages.	Recommend single point of contact at Site and agreed-upon turnover time for the provision of information. Also access to contracts in Livelink at the Site would be beneficial.
14	Pre-Qualification Template for Mod Fab	The template provided by the Enterprise Category Supply (ECS) group was not based on the latest C&P group best practices. This led to excessive editing time and delays in issuing the Pre-Qual.	Be prepared to challenge use of ECS templates if not seen to be optimal.
15	Shell contract templates	Lack of Shell contract templates to be used for FEED contract and service agreements hindered a more expeditious RFP and award process. There were various templates sent to the Quest team to use on contracts, ABC, etc. These proved difficult to work with because, although generic, they had to be adjusted quite a bit to fit the project. It was very difficult to establish which templates were to be used at the start of FEED and stick with them, as there are always changes imposed by Shell. Furthermore, they were not in a standard format and thus did not look professional. Some of the templates (for contracts) also changed during the process, which caused confusion with vendors.	Establish templates at the beginning of FEED, and try to minimise change where ever possible. Agree to a suite of Contracts and Procurement templates suitable for the various degrees of complexity and HSSE risk at the start of the FEED phase, then customize the templates with project-specific government funding wording (in case of Quest) and ring-fence them through the project, if at all possible. Build templates in the appropriate software program (in the case of current pre-qual templates, MS Excel).
16	Contracts - Tracker [Best Practice]	There were many bids going on at the same time over numerous vendors, but there was no overview of where each bid was. A template was built, which the EPC houses populated with required information about each bid.	A spreadsheet with an overview of all the bids gives a good picture of where the bids are without having to do an extensive search. It is especially useful when going though the various phases. The EPC house should fill out various details of each bid. One thing to look out for is double entries, but this can be worked around in various ways (not including every schedule date, input using one programme, etc.).
17	Shell Terms and Conditions and RFQ/PO templates	Late development of Shell RFQ instructions, Purchase Order template, and Quest project terms delayed issuance of early RFQs. Subsequently, the new Shell global templates for POs and Terms and Conditions were issued for project use in August. This created some confusion with suppliers who had previously negotiated terms on the "old set".	
18	Integration Management	The overall integration (sub-surface, pipeline and capture) could have been managed better. Through the feedback process Fluor was told that they should have done more to help with the interface between Toyo and their work. It was thought by Fluor that Shell was managing the venture. This came as a surprise because indications on actions had been very different.	Clearly communicate expectations on who has overall responsibility. Develop KPIs on how to manage the interfaces. Do not make assumptions if roles are not clearly stated.
19	Communication – Interface with site	It has been difficult to get information out of Scotford. The relationship and communication with the site has been laboured. It was also not known whom to approach for specific information.	Place an exact date in the communication (email, letter etc.) instead of saying “asap”. Develop site relationships by visiting early in a project. The team lead should initiate this. An Interface Manager/Coordinator would be useful to help approach the right person for information.

HSSE FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	HSE Awareness and requirements	Canada has no legislative framework covering HSE, and thus some of the contractors are not familiar with what HSE is asking for. This means a lot of coaching and tutoring.	A series of engagements (workshops) should be held at the beginning of the project. They should bring across HSE philosophy, design case, premise, key deliverables, and expectations from each of the disciplines. This will enable questions to be answered and avoid confusion. Criteria to develop workshops should be flexible to respond to decisions being made.
2	ALARP Workshops	We tend to develop the requirement for As Low As Reasonably Practicable (ALARP) workshops as the project progresses. The first was around the compressor building. However, they were all rather last-minute affairs and organised as the need was identified.	The requirement for the number and type of ALARP workshops could be determined fairly early in the project, and schedule, where necessary, to ensure information is available for HAZOPs.
3	Design Engineering Practices (DEP) [Best Practice]	A huge amount of time is spent searching for relevant design documents to ensure HSE elements are properly followed and implemented. This applies equally to the EPC and Shell disciplines.	A project would benefit from a project-specific list of DEP's, cross referenced by discipline, and made easily accessible to all project personnel. This approach would enable all personnel to use a single database – providing easy access and preventing confusion.
4	Design Engineering Practices (DEP) Interpretation of Specs.	DEPs are often followed to the letter without considering if they are actually of value. This is a risk-free activity, but the work could be counter-productive. DEP documentation can be excessive and difficult to interpret by an EPC vendor. Having them trimmed down to the essentials would be beneficial.	It can be beneficial to critically review the DEPs and challenge them when creating the design. Conduct a DEP analysis for every discipline at the start of the project in a workshop format.
5	Process Hazard Analysis (PHA) and HAZOP Execution	PHAs are often not fully executed in time to support the cost estimate - resulting in capital cost overruns, engineering rework, and/or technically unsatisfactory remedies. PHA Action Items are often unclear to the assigned person, making resolution difficult. Poorly defined closure criteria and progress tracking can further exacerbate this problem.	Conduct a project schedule and budget-focused PHA review in sufficient time to ensure all major cost and schedule items are included in the cost estimate. The review should look for "showstoppers" that will add cost or disrupt the schedule. Clean drawings are essential. The HAZOP should not be used as a Design Review. The Design Review should be done before the HAZOP, early in FEED. Only assign Action Items to persons present in the review, with their acceptance of the item as worded. Action items need to be issued speedily, while memories are fresh, with realistic closure dates, criteria, and progress tracking.

HSSE FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
6	HSE Deliverables	Shell is not strong at following up on how key HSE deliverables are used. This is a mixture of lack of resources and not having a process in place. For Quest, an HSE summary document was made of the HSE premises and given to engineers. However, the follow-up was not so strong with audits.	Front-end resourcing should be done properly and sufficiently. Internal reviews, Desktop ASAs (Advanced Safety Audit) can be applied but people within the project should also review the HSE premises and philosophies to make sure they are applied.
7	CO_2 dispersion modelling	Quest is pushing all of Shell's technology to the limit on this new and unique project. One area of concern is the lack of criteria for dangerous doses of CO_2 for humans. The level of information available on such things is relatively small when compared to sour gas, for example. All the data we have was generated by this project. This is not a solid base for HSE. Shell Global Services was reluctant to do CO_2 modelling, so a third party (Stantec) was asked to do it. This has been successful, and hopefully the results will be useful for future CCS projects. Also an Integrated Technical Review (ITR) was done by someone from the Goldeneye project with peer review. Some key issues were put down in the Assess phase but they were not good enough. Also, no one addressed a worst-case scenario. When it was done, interesting results came up. There were standards for CO_2 venting that caused problems with regard to material choice and what an acceptable criterion was for ppm of CO_2 at manned stations. The industrial neighbours were not contacted about consequences for them. The industrial neighbours should have been contacted sooner as our operations could have had consequences for site selection (how Quest could impact their operations). Even without a dispersion model, contact should have been made. Emergency response planning was made difficult due to a lack of criteria around CO_2. The statutory figure was not deemed relevant for Quest. This affects CO_2 dispersion modelling and toxicology. A common value has to be reached, which can be applied. One problem is that CO_2 reacts in such a way that many traditional dispersion models do not work. The CO_2 seems to form crystals, but they could be water crystals.	The process should have been started earlier (Select phase) to allow more time to do modelling on this specific site. Hopefully Quest will provide a set of CO_2 standards upon completion. Stantec has valuable information with regard to CO_2 dispersion modelling. It would be helpful if they shared that information so Shell can apply it to future CCS projects. When deciding on modelling, consider not only Shell's preference but also what others (including the public) want to see and be assured of. The Spadeadam results should not be shared before they are further investigated. The subsurface method of working was very good and could be a way to work in the future (just a good estimate that we can adjust over time, rather than getting it right from the start.)
8	CO_2 Thresholds	There are a lot of ideas about good CO_2 thresholds documented in the public domain. SGSi was approached to advise us on usable threshold levels.	SGSi should have been approached earlier. Whatever substances are being dealt with, we should have a statement on the standards to be applied early on in the project.

HSSE FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
9	CO2 Threshold Approach	Shell has to make a decision on which kind of approach should be taken regarding thresholds. Either more dosimetric (time/dose relationship) or an approach based on numbers. The first is a more sophisticated approach to toxic risks, but more difficult to monitor and figure out.	Shell would be well served to choose the dosimetric method. Then population risks can be applied to the workforce as a whole. The approach should be generic but changeable due to regulatory reasons.
10	Staff - HSE Team	The current Quest team is not fully staffed, and some of the work is contracted out.	For each of the three major projects in Canada, the HSE team should consist of an HSE Manager overseeing technical, construction, and environmental leads. Shell should take ownership of each HSE aspect, especially technical, and not contract too much out.
11	Staff - HSE Skill Pool	There is a shortage within the HSE skill-pool, not only within Shell but also on a worldwide level. This is especially true with regard to technical safety.	When resourcing, take the HSE skill pool shortage into account because it could take some time to fill positions.
12	Communication - Project/Site Relationship	There has been a strained relationship with the Scotford site. There are disconnects with staff on site with regard to Quest's goals and work. Scotford is a big site with three different businesses (UA, Chemicals, and Downstream Manufacturing and Refining) and they have not been fully integrated with respect to HSE. If something went wrong, it was not clear how the 400 people working there would get off site. Also there was no place for the visiting HSE team to work. This was resolved later in the project.	An alignment session should have been scheduled for each of the disciplines at the start of the project. It would be good to visit the site as much as possible to keep relationships up. A dedicated space to work for the HSE team would be beneficial too.
13	Communication - Clear Responsibilities	On a Brownfield site it is at times unclear who has the final responsibility over certain aspects and how decisions are made. This makes it difficult to know whom to approach.	Clarity needs to be available on who has control of scope and makes final decisions.
14	HSE Training	Safety critical positions were not identified correctly and thus people were not given the proper training and coaching. The Business Development Team also had no technical safety resources, which needs to change.	The identification and training needs to be done before P&T become involved in the project. On major projects, the Business Development Team must have technical safety experience. They need to understand the Opportunity Realization Manual (ORM) system needs.
15	HAZOP	Hazard and Operability (HAZOP). The action tracking of the HAZOP went slightly off course. The tools Flour and Shell used were different, but that was handled well. The action closure procedure was well written too. The process was good but the actions were not closed out well. We rely on HAZOP as the safety indicator. However, a HAZOP is only as good as the person who writes them and whether they have time to make quality documents. The DEP on writing a HAZOP is not easy to follow. This means that HAZOPs are often not up to standard.	Better leadership should have been given and also targets should have been clearly stated. Shell needs to write a procedure that dictates the way a HAZOP is documented. It should also include the name and email of the writer when actions are being documented. The “parking lot” should be used sensibly and the action items should be as few as possible. Shell retirees could be considered to chair HAZOP meetings.

HSSE FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
16	HSE Activity Plan	The HSE Activity Plan documents what has to be produced and when. The deliverables demonstrate ALARP (as low as reasonably practicable) and every discipline has to contribute. This plan is generic. The requirements cause confusion, and a lot of effort needs to be placed on instructing the disciplines on what is expected. Furthermore, changes in design can have large HSE implications. It is impossible to review all changes, as it is too much work.	It would be helpful if disciplines came to HSE when changes were made to selected parts of the design. A meeting should have been planned at the start around expected HSE deliverables, what they had to contain, and when. A standard list should be developed that details when HSE have to be informed about a change in design.
17	Design Team	On some projects the design goes from group to group before it is implemented. The problem is that each subsequent group may not understand the reasoning of the previous group. This can cause design problems.	The Design team should follow the project through to commissioning.
18	Quantitative Risk Analysis (QRA)	A third-party contractor conducted a QRA for the pipeline that included conclusions and recommendations. However, such reports are often paid by the amount of work done, so if there is no clear scope, we receive a huge report.	The QRA should be fit-for-purpose. Give the company doing a QRA a defined scope for the work. This document should be fairly generic (made by SGSi), with slight adjustments for each project.
19	Shell Special Services - Verification	Any study produced by the main contractor or third parties can be verified by Shell Special Services. They can then say what is needed when from the contractors. One of the problems was that some of the information supplied in the studies was not to Shell standards. If those had been known, the process would have gone smoother.	Within HSE there is a process to verify documents internally. This is a good process. Shell Special Services can also advise on what information is needed from the studies.
20	Inter-Project Alignment	The Quest CCS project was split in to three parts: Capture (Flour), Pipeline (Toyo), and Wells/Subsurface (Shell). It took a while to organise a proper interface between the three groups. One of the reasons of misalignment was the schedule for each group, necessary construction time for example. Each group had a big influence on the others, and this was not fully appreciated at first.	Approved for Design (AFD) should be done on the same day and there should have been more intergroup alignment sessions.
21	Stakeholder Alignment (Best Practice)	A lot of effort was spent on alignment, especially with Scotford. The interface management plan was set up very early. It was also constantly pushed with the use of single contact points, putting responsibility on one person per topic. One problem was that there was only one Interface Manager, and he was relied on too much. There should have been other stakeholders to assist.	The early set-up of the interface management plan was a very good idea. There should be Interface Managers within each stakeholder group to improve communication. They should be quality people, not just the first person available.

HSSE FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
22	Working Relationship with Partners (Best Practice)	Some partners have different business drivers than Shell. For Quest, Fluor had the same drivers, and it made the relationships between the two companies very good. Operations had a big presence for Shell, and the overall relationship with them was also fairly good.	An "open book" approach was used which stimulated feedback. Not all feedback may have been positive, but it made action possible and both companies could see the other was doing its best.

Pipelines FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	Project Timing	The three parts of the Quest project (subsurface, capture, pipelines) did not move forward at the same pace, and thus information was lacking. This resulted in high design uncertainty (data over a fairly broad range) and led to overdesign of the compressor unit.	In a project that contains three separate elements (subsurface, capture, pipelines) the one that is crucial should be planned to maturity first so that information coming from it will be adequate to develop the other elements. As subsurface was the crucial element, we should have had more concrete information on it earlier.
2	CO_2 Pipeline Filling operation	Due to the compressibility of liquid CO_2 and its behaviour during the transition from gas to liquid, pressurizing a CO_2 pipeline for the first time can be inconsistent. This can result in incomplete filling of the pipeline or increased pressurization time if the operator is unaware of this potential behaviour.	The pressure inconsistency is a function of temperature and the CO_2 injection rate. Therefore, the pipeline should be modelled prior to pressurization. We should establish a detailed set of parameters to aid operations during this stage.
3	Pipeline standards for CO_2	There are international standards for pipelines regarding oil and gas, but not for CO_2. Currently the guidelines developed by Det Norske Veritas (DNV) J-202 for CO_2 Pipelines are being used. We also lack standards for elastomers (materials), leak detection systems, valves, pipeline routing, etc. In addition, pipeline standards are highly regulated at the local level. This means that standards vary around the globe.	Pipeline standards should be developed for CO_2. Quest pipeline team member is part of a task force to update Canadian standard CSA 662 for Oil and Gas Pipelines to include requirements for CO_2 pipelines. If CO_2 pipelines are built elsewhere, we recommend that they use the DNV guidelines, in addition to input from local teams, to help standardise the industry.
4	Flow assurance and thermodynamic modelling	CCS is not the kind of project that generates revenue. It is therefore difficult to fund certain activities that are necessary. One of those activities is developing software around flow assurance and thermodynamic modelling.	R&D should request funding from Shell to do more software development, especially when it comes to projects where the software is crucial.

Pipelines FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
5	Blowdown Operation	Due to the Jule-Thomson effect, it is possible to create localized cold spots during pipeline blowdown at the vent location. These cold spots can cause material integrity issues.	Establish a clear set of operating procedures for each blowdown scenario. The procedures should be based on modelling that includes a detailed profile of the pipeline, covering the vents location and the amount of gas/time required to vent. Conservative material selection for the section affected by the blowdown temperatures is recommended.
6	Enterprise Framework Agreement (EFA)	Adherence to project-specific standards resulted in a fair amount of work to ensure that we could take advantage of EFA agreements with the vendor, based on Shell global Design Engineer Procure (DEP) guidelines. Canada had not implemented all the latest DEPs at the time, so the project-specific standards for Quest were difficult to place in the EFAs. This was because the standards used in Canada were not harmonised with the latest DEPs. The basis for cost estimates only came in toward the end of the project. Each element of Quest had a different basis.	We should prioritize specification development by early identification of the project-specific needs and set the common basis for estimates at the beginning of the project rather than the end. From the technical side there were no problems with EFAs. But from a commercial side they were a "black box." In setting up the scope of work, knowing what is in the Terms and Conditions would be beneficial.
7	Pipe requirements	Procurement made a tremendous effort to help Pipelines meet the EFA needs. They would have done an even better job if they had known the amount of pipeline that the job would require. Many of the agreements that Shell has with the Engineer Procure Construct (EPC) company are beneficial because of the forecasts in them. If those are not present, the EFAs become less useful. In addition, project procurement works on different incentives than global procurement, and this can also affect the EFAs.	Forecast pipe requirements to procurement the moment the project is in design phase. Use the Enterprise Framework Agreement (EFA) because it guarantees a low price based on predicted tonnage of piping. If we don't use the EFA, we lose our advantage.
8	Pipeline thickness	The main risk to the pipeline is low temperatures reached due to the Joules-Thompson effect associated with decompression. This effect demands a pipe with a very strong tension, not only with regard to the material, but also in the welds at the seams. Through calculations it was found that the pipe needed 60 Joules of absorbed energy capacity at 45 degrees Celsius. CCS CO_2 literature is very broad and many figures are mentioned around the water content. This affects the corrosion rates. Due to the broad range, the most conservative number is always taken, which has financial implications. However, technology has improved to meet mechanical design conditions and more testing can bring costs down.	We should do more testing and review Shell's toughness models to understand the minimum needs for fracture toughness. More research should be done to understand the corrosion rate of dense phase CO_2 to allow for the calculation of minimum thickness of the pipeline. This might be a possibility for the Materials team working on the development of Hydrocor.

Pipelines FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
9	Pipeline Coating	Due to the high toughness of the pipe, it needs a coating that will adhere and stay on in extreme conditions.	It was found that for these circumstances, fusion bond epoxy coating was sufficient. However for those applications where fusion bond cannot be used, alternate coatings are required, such as liquid epoxy-based, with proven resistance to the thermal cycle.
10	Pipeline bends	The use of 90 degree bends in pipeline arrangement will result in issues with induction bending. Pipeline bends designed in 20D radius require longer lengths of pipe. When the angle is also large (90 degrees) induction bending requires start/stops. The start/stops in the bending process pose metallurgical and integrity concerns.	We should avoid the use of large angle pipeline bends, especially when pipeline materials have additional metallurgical requirements that may be detrimentally affected by the start/stop process. We should also ensure that bend qualification testing includes the start/stop and avoid bending pipe in two or more passes through the induction process.
11	Imported pipe	Coated pipe and coated bends do not fare well during overseas travel. When using manufacturers from abroad, there is nowhere to store or handle the pipe for coating and bending. Use of a local third-party warehouse facility would prevent pipe damage and disruption to pipe routing. Also, certain sections of pipe had to be shipped to a bending company and then to a coating company, while others were just sent to the coating company. The pipe was then stored until use. This involved a lot of logistics that could have become overwhelming. The problem was compounded in Quest because the pipeline manufacturer did not interact with the pipeline layer. Fortunately, Quest had a competent company to oversee logistics.	Employ a dedicated third-party warehouse to handle pipe routing from overseas manufacturers and foreign mills. A third-party should also be used to deal with the logistics, and it should be a company that is dedicated to handling materials.
12	Valve selection	We are not prepared to specify valves for the dense-phase venting. Current piping classes for Onshore Gas Canada were not developed to cover the dense-phase CO_2. Quest is a unique project, and it is important to select the correct valve for the correct application. However, the current piping classes are not set up to cover dense CO_2. It was thought that high-vapour pressure (HVP) class valves would be sufficient. This was not the case when venting, due to the Joule-Thompson effect. Due to the potential damage and danger of leaks, we need to develop dedicated piping classes for CO_2, and then select valves according to an expanded criticality assessment that also covers services.	We should develop dedicated piping classes and expand the criticality assessment to cover CO_2 dense service as well.

Pipelines FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
13	Engineer Procure Construct (EPC) Engagements.	Due to uncertainties around government and financial approvals, the project got off to a slow start. Therefore EPC did not have its best or most stable resources assigned to the project. This resulted in too many staff changes and slow progress. The Quest project ran a long time before the pipeline EPC contractor, Toyo, was chosen. Even after selection, it was not clear that the Quest project would continue. Therefore, Toyo put the lowest number of resources possible on the project. The resources became unstable as many left during the project. These staff changes made pipeline project management difficult. The Pipeline Project Manager was a secondee from Toyo (Tri Ocean) who left the project, which created a chaotic situation.	We should draw up a proposed way of working that contemplates delays and the negative impact of changing resources. The recommendation is to provide the EPC with assurance or a better engagement and manage expectations. Furthermore, the Project Manager should be a Shell employee in order to prevent a potential knowledge gap if they leave. On these kinds of projects (unsure, slow, start/stop) in-house staff is better.
14	Ductile running fractures	Ductile running fractures in long pipe sections are a high risk in CO2 pipelines due to the decompression characteristics of the pipeline. When the decompression velocity is slower than the crack propagation, a crack will run through the pipe material until it meets a physical arrest obstacle (line block valve, thicker wall, crack arrestor). Girth welds provide little arrest to a running ductile fracture.	We should select pipeline materials with improved Charpy impact toughness for good resistance to crack initiation (high absorbed energy) and good ductility (high shear area ratio) in both base metals and seam welds. Consider crack arrestors or include different pipe thicknesses in long lines. Use modelling and/or testing to determine the minimum required material strength for line pipe, well tubing, and well casing.
15	Elastomers	Elastomers were used in valves to provide zero leaks. It is not possible to have elastomers in the valves and pipeline that are sensitive to dense phase CO2. It was found that CO2 had both a mechanical and chemical effect on elastomers that causes ruptures and failure. Tests were done and some were sufficient, but the tests were not fully conclusive.	Do not use elastomers in dense phase CO2 pipelines and valves.
16	Carbonic acid corrosion	The presence of free water in CO2, even in small amounts, can result in aggressive corrosion. When CO2 meets water it makes an acid, which deteriorates the pipe very fast. Water can appear from hydrostatic pressure or as a result of an insufficiently dried CO2 stream (dehydration unit upset) or due to water encountered during CO2 injection (well aquifer). Corrosion due to carbonic acid occurs at a constant rate and does not benefit from passivation with protective oxides.	Where water cannot be eliminated through a dehydration unit and compression trap designs, additional line de-watering activities are required. These may include pigging and batch treating with water-removing agents such as methanol. Where water cannot be managed (well aquifers), we must use corrosion resistant alloys with proven resistance to pH and secondary contaminants such as Cl-H2S and organic acids.

Pipelines FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
17	Casing	Tests were done and a specific mill of super duplex stainless steel passed the test. Super duplex stainless steel will be used for the bottom of the well and carbon steel for the rest.	Super duplex has both high nickel and chromium content and is still an iron-based alloy.
18	Minimum Design Metal Temperatures (MDMT)	MDMT in CO_2 pipelines is much lower than other HVP gases. This is due to the Jules Thomson effect encountered during line depressurization.	The MDMT must be selected based on the highest depressurization rate of the stream encountered during normal and upset operation.
19	Brittle fracture prevention	As a result of chilling during a decompression event, the pipeline components are susceptible to brittle fracture. This is due to the material's Glass Transition Temperature (Tg) becoming higher than the service temperature. Brittle fracture cannot be arrested by mechanical means and will result in loss of containment.	Materials with proven resistance to brittle fracture must be used for pipeline components such as isolation valves, pipelines, fittings, wellheads, well fillings, etc.
20	Leak detection	There are no standards for leak detection. This seems fairly crucial in populated areas. The solution used was a mass-balance leak detection system due to the low population of the area.	Standards need to be made.
21	Modelling software	The software used in modelling pipeline designs is not ready to be used for CO_2. There is a software programme for hydrate formation and one for modelling the solubility of water in CO_2. Most of the models are for pure CO_2, but different purities are possible.	The software needs to be calibrated with lab tests or facilities testing.

Information Management FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**

Information Management FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	PCAP – Changes around sign-off	The Project Controls Assurance Plan (PCAP) process should be controlled by Quality. However, the PCAP was changing after the sign-off in the first phase. Technical Authorities (TAs) were not notified of their responsibility and required approval, so they were making changes around review time. Changes to document control caused rework, and changing TAs caused late approvals and missed review deadlines. These problems arose because the PCAP process is new in Canada. This showed around the Value Assurance Reviews (VARs) as many were not approved.	No changes should be made to the PCAP around the review points, especially after sign-off. The PCAP process should be driven by Quality. The PCAP Owner should inform discipline leads of required PCAP deliverables and deadlines for review and approval.
2	ASSAI	ASSAI is a document control and management system that captures comments. It is used for PCAP deliverables (Fluor's system handled the big drawings). ASSAI has historically been a good tool. In Canada, however, there were performance issues, which made it nearly unusable. The ASSAI Global setup does not provide full functionality. The cause was that the local LiveLink configuration was not standard. Thus setting up, maintaining, and using the tool took up a lot of time. Manual steps were required to perform day-to-day ASSAI activities. The IM Team had to reinvent and create working and training materials.	Configure and install ASSAI tool to the local environment. Formalize ASSAI rollout. Standardize and adjust global rollout to allow for non-standard configurations.
3	Specs and Requirements	Specs and requirements were not clearly defined around Information Management (IM), which caused confusion for the Engineer Procure Construct (EPC) company. Discrepancies between what was happening at the Site and what was being asked of the EPC from Global IM standards created a conflict and confusion.	Clear alignment is required between Shell on a Global IM basis and what is happening at the Site. Have all specs and requirements clearly defined either to the global standard or to the Site requirements. Decide at the beginning of the project which standard to use and stick with it.
4	Tagging Issues	[If adopted a Best Practice] At times there are issues with new (equipment) tags from engineering contractors. There is a process around tagging but it could be improved. Sometimes a new tag requested by EPC may be incorrect or unnecessary. This causes additional work for the DC and Site IM and may cause invalid handover of tags to Site Operations applications.	Ensure Shell Discipline leads verify and confirm new tags. The Shell discipline lead needs to verify the information prior to the IM team implementing a tag request. This will remove ambiguity between what the contractor and Shell mean with a tag.

Information Management FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
5	Interface - Focal Point	We have a weekly interface meeting with input from multiple sources. At times it is unclear who is directing. When a Fluor employee entered the project, it was unclear at the beginning who was driving the project from the Shell side. This is also the case at times when entering a new group internally in Shell. There is no on-boarding procedure between Shell and Fluor (internally yes).	Define a single point of contact and run communications through that person. If alignment or clarification is required within Shell, provide that as a follow up.
6	On / Off Boarding	IM missed on- and off-boarding, so users were not aware of the Quest project layout of LiveLink and document processes. New project personnel were not familiar with LiveLink and project structure which can lead to incorrect handling of project information, including templates. The process needs to be more refined. If off-boarding does not go well, it presents security issues, especially with respect to LiveLink.	IM should become a more structured piece of on-boarding. Provide a half-hour overview of IM to all new employees.
7	Management of Change (MOC)	Engineering process updates from site. When there is a Management of Change (MOC) on a piece of engineering, it will be marked with a number by the contractor. While the contractor holds that drawing, the changes are not passed on through the site. There could also be updates on site that the IM team is not aware of, which means that the contractor is also possibly not aware of them. This leads to modifications of the wrong version of drawing and incorrect engineering. The check-in/check-out system does not cover all possible changes.	Reports from the site and contractors need to be more fine-tuned. One way to do this is with monthly meetings. Assign a Project Engineer who represents the project on site to deal with engineering MOC.
8	IM – Data validation	The specs and requirements that Shell has around data validation toward Fluor have not been very clear or defined. There have been a lot of meetings and discussions to try to get it right. This has taken a lot of effort. SAP has been used, and it has been difficult.	Have clear definitions with reference documentation around data validation.

Information Management FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
9	Brownfield global tools alignment	Trying to implement global tools in a non-standard environment is extremely difficult. Configuring and setting up systems took a lot more time than expected. It also created confusion around data validation. For Quest this relates to the Engineering Data Warehouse (EDW) system. The site requirements were not clearly defined. Thus Fluor was asked to provide information, but site data was not available to provide them with what they needed. The global tools being imposed do not fit well with how the base plant has been run or with the integration of the expansion. The contractor is confused by the various IM data styles required. The IM handover guide does not work well with the site.	Clear requirements need to be given around IM. Insist on proper analysis to ensure feasibility of tool deployment. There will be a Lessons Learned session and after-action review in the near future, possibly also with Ormen Lange and project representatives present. This will be hosted by Peter van Brussel's group in Rijswijk.

Project Services/Controls FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
1	Project Services and Control Procedures	There were certain expectations from both sides (Shell and EPC) around procedures. It took a long time to align, which impacted project activities. If an Engineer Procure Construct (EPC) company is not allowed to use its own practices, it may be confused as to the correct procedures. Also there can be gaps when combining procedures, and those gaps need to be worked out. Specifically, procedures such as Earned Value, CAPEX Phasing Accuracy, and the Requirements Process were not fully aligned. Buy-in from the EPC caused rework and delays in setting up the project at the Estimate and Schedule Assurance Review (ESAR) 4. Further delay could have impacted Shell's procedure compliance and forecasting. Quest Project Services conducted a GAP analysis with the contractor's process and procedures, however, the project was not sufficiently staffed to realise this expectation, and we did not roll out all 27 Shell procedures due to work and schedule pressures at ESAR4 and implemented before DG4. This is an issue during the transition from FEED to the Execute phase.	Project services and controls procedures need to be aligned early in Front End Engineering Design (FEED). It is important to find out how the procedures of both Shell and the EPC can fit together and define the practices to be used. Define and solve gaps in terms of expectation by rolling them out early in FEED. Ensure appropriate staff is available to complete the 27 Shell procedures and customization fit-for-purpose for the project. The 27 procedures need to be provided to the EPC during Select so that they can get an idea of the scope. They have to be rolled out and not just sent out. Conduct the GAP analysis with contractors and then roll out requirements and expectations for each procedure for alignment and upfront buy-in.

Project Services/Controls FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
2	Procedures – Close Out and Risk.	It was apparent during our audit that documented proof to close a risk or action was handled differently by each group on the Quest Project. Some of the procedures were different for each phase and had to be completed and updated depending on phase. Risk is often misunderstood in what it actually affects. For Quest, risk was given high importance, and leadership took ownership of it. However, not all the risk registers were maintained in the designated programme, EasyRisk. Project Guide 20 details how closeouts should be done. Lack of familiarity with what's done behind the scenes in Project Controls may inhibit meaningful flow of information and productive discussion.	Ensure that the team has a consistent method to provide and store documented proof that risks and actions are complete. Ensure that the risk owner is in agreement with the proof and that the information is noted in Easy Risk. Ensure that risk and actions are described using the Cause/Event/Consequence protocol and that all key fields have information (dates, names, proper risk and actions descriptions). Provide a monthly report that highlights lacking information and require owners to update it. Make sure that Project Guide 20 is followed and all the data fields are correctly filled out. Provide Lunch-and-Learn or Awareness sessions to familiarize the team with the inner workings of Project Control. Best Practice is for leadership to have access to the risk register and steer everyone with regard to risk.
3	Procedures - Templates	Quest wanted to maintain a global standard with regard to the procedures. However, by the end of the Define phase not all the templates had been received due to manpower issues in the organisation.	This should be started much earlier in the phase.
4	Transition to Design Detail	The EPC (Fluor) had to get a lot of information ready to support the Shell reviews. Shell transitioned to Detail Design two months after Fluor finished all FEED deliverables due to Shell having to review its deliverables. This meant that the EPC had to wait before passing into the next phase, even though they were ready. Such waiting could cause them to move resources to other projects and lose continuity.	Transition to Detail Design should align with Shell gate reviews and not with the FEED deliverables. Money should be available upfront for the EPC to transition into Detailed Design. This will add a little risk, but may keep the EPC team together. The transition period should be recognised more explicitly by Shell. Then various options (from a planning and monetary perspective) can be applied to that period that fit the project. Complete removal of the bridging period is impossible and should not be attempted.
5	Transition - Planning	There are standard schedules based on project size. Quest is a small project but highly visible, thus some of the procedures that were scheduled needed to be treated at a higher level, which required more time. This put a lot of pressure on the project. This was especially the case for DG4. The timing of reviews and assurances is also important, especially when they fall after a prominent vacation period (e.g. summer).	Plan appropriately to the project need and not only to the standard schedule. The plan should be resource loaded on the soft-skill aspects.

Project Services/Controls FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
6	Planning - Assurance Events and Deliverables Schedules	Deliverables and assurance events are planned in the schedule with a regular review six months before ESAR4/VAR4 is required. These include economics assurance events, external reviews such as Independent Project Analysis (IPA) benchmarking, and others. However, some external reviews can't happen until major deliverables from the contractor's team are completed. IPA benchmarking, for example, without a completed probabilistic analysis contingency on cost and schedule, can cause rework and unrealistic outcomes during ESAR4/VAR4 reviews. This impacts the non-value added work and actions from assurance reviews.	Schedules should be driven logically considering vacation seasons and based on project scope, joint-venture governance structure, internal and external assurance reviews, PCAP assurances, and similar factors. Include schedules in Define Phase 3 with all appropriate stakeholders, and then pursue buy-in from everyone with a timeline and dates of vacations, etc. (Cost and Schedule probabilistic workshops, one-to-one interviews, IPA interviews, data books filling etc.).
7	Contractor's Schedule Integration	Changes in Contractor's schedule (change in relationships, removal of activities, and change in activity ID) caused problems in integration and produced incorrect results.	Avoid changes in schedule once it is baselined as per practice. Minor necessary changes should be communicated by the contractor so that they can be accounted for while integrating with Master Schedule.
8	Project Schedule	Sometimes, various teams did not understand the project schedule. They are not in tune with what Project management expects and thus do not provide a sufficiently usable schedule. They do not think of how their deliverables impact other aspects of the project.	There should be a better awareness to provide a more realistic schedule. This could be done in Lunch and Learn sessions for overall project deliverables.
9	Project Management of Change and Capex Monitoring	Generally the focus in the FEED Define phase is to manage the project control perspective, the Define phase cost, and to implement the change management within the FEED budget, scope, and schedule. This was not the case in Quest, where Fluor went through all the phases. However, if the Engineer Procure Construct Management (EPCM) plan changes at the end of a phase (such as the transition from Define to Execute) then the CAPEX needs to be monitored in order to make justified changes or not.	Continue to apply the CAPEX management and visibility via Change Management process for the overall project. At the end of the Select phase or beginning of the Define phase, the EPCM contractor should make a CAPEX Cost and Schedule and update it through the Design Phase, so that the potential cost and schedule impacts of changes made during Design are visible and subject to review. The EPCM should also have a baseline at the beginning of the Define phase; this can be a quick estimate. Managing change in early work needs special attention and allocation of budget to account for revisions. Align Shell and EPCM change management procedures and terminology.
10	MOC – Project scope, cost and schedule [Best Practice]	In the FEED Define phase, the general CAPEX impact is always looked at, but not always the detailed, bottom-line impact. Shell's project procedures do not deal with this.	Recognize that each change has a potential impact on the Execute schedule. Continuously monitor the FEED budget, schedule, Total Installed Cost budget, and schedule in the Define phase. This should be done at the senior level on a regular (monthly) basis.
11	Project Service Organizational and Staffing	A heated Alberta market, the staffing, attrition, and retention were major risks to the project. Despite frequent changes in owner staffing, deliverables and time frames still need to be managed. The project lost a planner and an estimator during the Define phase. This reduced the import quality of deliverables in the Define phase and the team's ability	Recommend we have "Plan B" for Project Service resourcing using the Global execution model of P&T - PS group to engage available staff.

Project Services/Controls FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
		to set up a project service process and system for the Execute phase. Quest implemented a global office execution model through continuous engagement with Bangalore. Tasks included Estimating, Planning, Risk, Cost, and Management of Change. Thus, Quest completed quality deliverables in a timely fashion with PS support from Bangalore.	
12	Dedicated Project Controls Support for Contractor Organizations	Staff movements were high in one of the contractor organizations, and Shell had to take over a large part of their work. It caused rework and extra effort from Shell Project Service to have deliverables in place on time. There should have been a full-time Cost Engineer to support this project. The existing Cost Engineer was supporting multiple projects until nearly the close of the Define phase. That impacts the readiness and set up process for the Execute phase.	Recommend that contractor organizations have dedicated PS support in place for each phase of the project.
13	Integrated Planning - Primavera	The Primavera software had to be integrated into the Quest project. This meant that first the Shell team and then the EPC team had to integrate it into their planning schedule. This was a lot of work and caused problems, especially around the change of activity IDs. Such integration holds for InTools and SAP as well.	This type of integration with an EPC needs to be planned well in advance with specific procedures. If schedule integration into Shell's database is proposed, then it first has to be placed in the contract with the contractor (as the ITSA – IT Service Agreement). If this is not possible, then apply adequate time to implement it. Setup Integrated Planning well in advance by providing contractors with third-party access (TPA) to Shell Standard Primavera. Setting up TPA requires an IT Security Agreement between the client and contractor. The signing of the agreement generally takes a long time. Do this along with the signing of the main contract so that as soon the successful contractor comes on board, the process for setting up TPA can be initiated.
14	Owner's Cost Development Plan.	The Quest project initiated the Owner's Cost Development Plan and division of responsibilities 6 months earlier than the estimate completion date. However, during the owner's cost estimate development and compilation, there were a lot of double dips, omissions, and iterations to the Owner's cost due to clarity around division and responsibilities and staff/team turnovers impacting rework and iterations for finalizing the Owner's cost.	Continue to prepare the Owner's cost development plan and division of responsibilities of Owner's cost within Shell team, however, clarify the scope on division of responsibilities and communicate to new staff regarding responsibilities. It would have been good to have an estimator or cost engineer check it all and a handy resource in the Define phase.
15	Quest Work Breakdown Structure (WBS)	For Quest Shell established a high (Level - 5) WBS early on with all the key stakeholders involved and frozen. This assisted the project during the Define phase on setting all the EPC contractors, their estimates, data flow, and progress management.	Continue to follow WBS development practice, and make sure all the stakeholders are involved, including EPC contractors. This provides synergies and the Eliminate Simplify Standardize Automate (ESSA) perspective for setting up the project correctly during the Execute phase.

Project Services/Controls FEED Phase Lessons			
ID	**Lesson Title**	**Lesson Description (Cause + Impact)**	**Proposed Recommendation**
16	Quest Cost Management tool	On Quest the Cost Management tool was not up and ready at the end of the Define phase (ESAR4/VAR4), meaning that the Control Budget (final draft) was not in Shell system. This caused delays in preparing the overall OC-1 report for the project. The impact was low for Quest as the project had never planned to go full throttle after DG4 in terms of spending. Due to regulatory approval and the formal Final Investment Decision (FID) not being aligned with DG4, the impact was insignificant. However, for other capital projects with significant pre-FID and post DG4 spending, this might have an impact on reporting, analysis, and true cost status.	Ensure appropriate staffing is in place to implement the full Cost Management tool and coding so that before DG4 or FID, the baseline cost is uploaded and ready for control in the Cost Management tool.
17	Risk Management: Risk to Owner Ratio	The number of risks owned by one single person should be limited. Having an owner manage too many at any given time could cause the owner to focus on the wrong risk. If one person owns all the risks, it can become very confusing and difficult to manage.	Identify a reasonable risk to owner ratio. This will help prioritize risk in accordance with the schedule and ensure that the owner is focused on the right risk. No one person should have more than 5 risks, depending on the phase and size of the project. Adding resources at the right time will help.
18	Prism CMT	There was confusion regarding which Cost Management Tool (CMT) would be used. A decision was made to use Prism. In the past Prism was used only as an interface between contractors. No analysis was performed.	Prism CMT should be implemented earlier in the project for better cost support.
19	CBS - Norsok	The project should have initiated Cost Breakdown Structure (CBS) alignment much earlier in Define phase. Discussions started, but were still not finalized after the estimate was converted to manageable budgets because of challenges with SAP.	We should have had a simpler solution of interface with SAP and more details to be managed in Prism CMT.
20	Cost Estimates [Best Practice]	Alignment on the Type-3 estimate is critical. The project team aligned early regarding Shell's expectations for the Type-3 estimate. This took considerable time and effort but was well worth it as all expectations could be built into the estimate plan. In Quest it was done early, and the EPC was matched up, which worked very well. Key issues were identified early, and the owner costs were identified.	Alignment on Type-3 estimates needs to be done early in the Define phase. To have this lesson as a best practice, the estimate plan must be worked out further than just a couple of pages; it needs to be done well.

APPENDIX 26: LIST OF ACRONYMS

AAR	After Action Review
ABSA	Alberta Boilers Safety Association
ABT	Alberta Buildings Trades
ACV	Authorised Contract Value
AER	Alberta Energy Regulator
ALARP	As Low As Reasonably Practicable
AOI	Area of Interest
AOSP	Athabasca Oil Sands Project
BCS	Basal Cambrian Sands
BOM	Business Opportunity Manager
CAP	Community Advisory Panel
CAPEX	Capital Expenditure
CAR	Construction All Risk
CARM	Contractual Allocation of Risk Manual
CBS	Cost Breakdown Structure
CCS	Carbon Capture and Storage/Sequestration
CEAA	Canadian Environmental Assessment Act
CHAZOP	Control HAZOP
CLAC	Christian Labour Association of Canada
CLO	Community Liaison Officer
CM	Construction Management
CMCP	Category Management and Contracting Process
CMG	Computer Modelling Group
CMT	Construction Management Team
CO_2	Carbon Dioxide
CP	Contracts and Procurement
CPPM	Contracting and Procurement Procedure Manual
CR	Construction Readiness
CRA	Cost Risk Analysis
CSRA	Cost & Schedule Risk Analysis
CSU	Commissioning & Start Up
CTR	Cost, Time & Resources
CTSE	Commitment Tracker and Stakeholder Engagement
CWP	Construction Work Package
CWPP	Construction Work Practices and Procedures
DAS	Distributed Acoustic Sensing
DCAF	Discipline Control and Assurance Plan
DCS	Distributed Control System
DEM	Design and Engineering Manual

DFL	Direct Field Labour
DG	Decision Gate
DMW	Deep Monitoring Well
DTS	Distributed Temperature Sensing
EFA	Enterprise Frame Agreement
EMS	Emergency Management System
EOR	Enhanced Oil Recovery
EP	Engineering and Procurement
EPCCm	Engineering, Procurement, Construction and Construction Management
EPCM	Engineering, Procurement and Construction Management
ERP	Emergency Response Plan
ESD	Emergency Shutdown
EWBS	Engineering Work Breakdown Structure
EWP	Engineering Work Package
FCN	Field Change Notice
FEED	Front-End Engineering & Design
FEL	Front End Loading
FGR	Flue Gas Recirculation
FID	Final Investment Decision
FIWP	Field Installation Work Package
GHG	Greenhouse Gas
GIP	Group Investment Proposal
GoA	Government of Alberta
GoC	Government of Canada
GW	Groundwater
GWDP	Global Wells Delivery Process
HAZOP	Hazards & Operability
HDD	Horizontal Directional Drilling
HMU	Hydrogen Manufacturing Unit
HOCB	Heavy Oils Contracts Board
I&C	Instrumentation & Control
IDS	Interface Data Sheet
IFC	Issued For Construction
IFL	Indirect Field Labour
IM	Information Management
ISBL	Inside Battery Limit
ITP	Inspection Test Plan
IW	Injection Well
JV	Joint Venture
LBV	Line Break Valve
LOPA	Layers of Protection Analysis

MC	Mechanical Completion
MCC	Motor Control Centre
MM	Materials Management
MMV	Measurement, Monitoring and Verification
MOC	Management of Change
NCR	Non Conformance Report
NPV	Net Present Value
NRCan	Natural Resources Canada
NSR	North Saskatchewan River
NTR	Non-Technical Risk
OAP	Opportunity Assurance Plan
OPEX	Operating Expenditure
ORM	Opportunity Realisation Manual
OSBL	Outside Battery Limit
OSR	Onsite Shell Representative
P&ID	Piping & Instrumentation Diagram
P&T	Projects & Technology
P2A	Project to Asset
PACO	Process Automation & Control
PCAP	Project Controls & Assurance Plan
PCP	Project Controls Plan
PCSP	Project Controls Standardisation Programme
PEP	Project Execution Plan
PG	Project Guide
PLC	Programmable Logic Control
PLT	Project Leadership Team
PO	Purchase Order
POL	Projects on Line
PQP	Project Quality Plan
PQR	Procedure Qualification Record
PS	Project Specifications, Performance Specification, Project Standard
PSA	Pressure Swing Adsorber
QC/QA	Quality Control/Quality Assurance
QIRMS	Quality Information Reporting Management System
RFP	Request For Proposal
RFSU	Ready For Start Up
ROW	Right of Way
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCEs	Safety Critical Elements
SDP	Storage Development Plan

SIS	Safety Instrumented System
SLA	Sequestration Lease Area
SMW	Shallow Monitoring Well
STG	Steam Turbine Generator
TA	Technical Authority; Turnaround
TAMAP	Technically Accepted Manufacturers and Products
TDN	Technical Deviation Notice
TECOP	Technical, Economic, Commercial, Organisational & Political
TIC	Total Installed Cost
TRIF	Total Recordable Incident Frequency
U&O	Utilities & Offsites
VLT	Venture Leadership Team
VOWD	Value of Work Done
VSP	Vertical Seismic Profile
WBS	Work Breakdown Structure
WFP	Workface Planning
WPS	Welding Procedure Specification