Lessons Learned from Execution of Oil Sands' SAGD Projects

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December 4, 2011

Executive Summary

Alberta's oil reserves, the majority of them from the oil sands, are currently the third largest in the world. These significant reserves make the oil sands very important for the future of Alberta's economy. However, there are a number of hurdles such as geology, human and financial resources, project execution, and technology among others, for which creative solutions need to be developed for harnessing the oil cost-effectively. These factors are critical, particularly for *in situ* oil extraction methods, such as Steam Assisted Gravity Drainage (SAGD), which is a relatively recent technology but has gained the confidence of many oil sands' developers.

In order to get a better understanding of hurdles and issues around building SAGD surface facilities, surveys were conducted among professionals working in the EPC industry. The objective was to identify the lessons learned from executing SAGD projects in Alberta, with the intent of improving execution of future projects. Over three hundred lessons learned were collected in round one of the survey. In the second round, ninety summarized lessons learned collected from round one, were presented to the survey participants for rating their importance on successful execution of SAGD projects.

Responses for each of the lessons learned were then averaged out and ranked from the highest to the lowest score. Knowledge/experience of management processes to execute large projects and communication between and within engineering, procurement and construction teams, were among the top ranked lessons learned.

This report, which is based on some data from a recent thesis *"Effective project management of oil & gas projects: A model for oil sands' SAGD plants"* (Halari, 2011), provides the top thirty lessons learned together with a discussion of the rankings. From the survey results, one can conclude that spending more time in the front-end planning can significantly improve project execution. However, this can be challenging at times, due to external and internal forces impacting projects, such as significant change in oil prices, project priorities etc. which lead to a shift in the project execution strategy.

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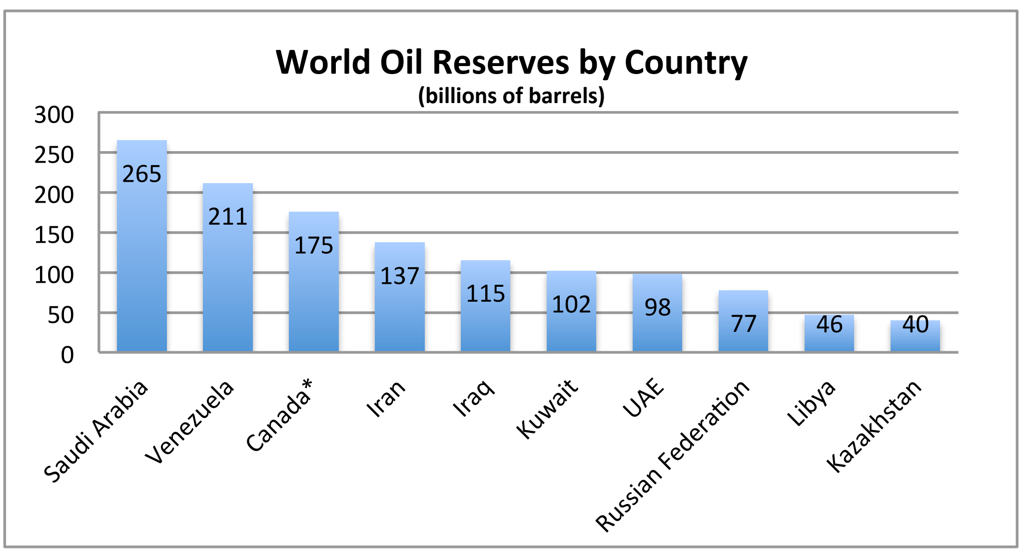
1.1 Alberta's Oil Sands Potential

Alberta's vast oil sands reserves, consisting of nearly 173 billion barrels (AEUB, 2007), gives Canada the third largest oil reserves in the world (McColl, Mei, Millington, & Kumar, 2008). This massive oil supply is a major reason why Canada, and particularly Alberta, has received significant interest in recent years from countries such as the United States, China, Norway and Japan.

A 2006 report of the Joint Economic Study Committee of the United States Congress entitled *Canadian Oil Sands: A New Force in the World Oil Market* predicts that Canada will most likely be among the top five oil producers in the world by the year 2016 (Saxton, 2006). A report by Natural Resources Canada, forecasts that by the year 2030, 90% of the Canadian oil production will come from the oil sands (2010). In addition, Canada's highly stable political and economic climate, relative to other oil producing countries, makes it an attractive place for a secure supply of oil. Thus, Canada's position on the world stage as a major oil supplier is receiving more attention and prominence.

Figure 1. World Oil Reserves

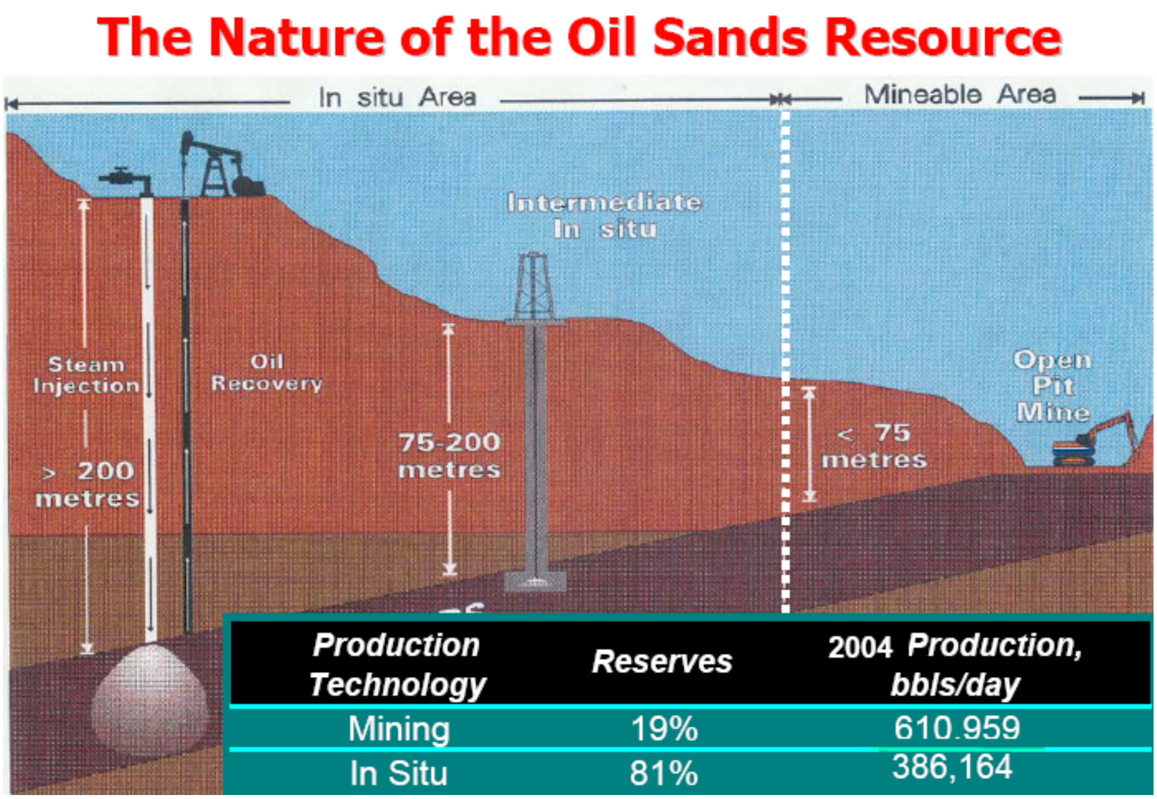


Data source: BP Statistical Review of World Energy (2011)
* Canadian reserves include the oil sands

1.1.1 Background on the Oil Sands

In comparison with countries having oil sands deposits such as Venezuela, Romania, United States, and Russia, Alberta has some of the world's largest deposits (ERCB, 2010). The oil sands are a mixture of sand, water and bitumen, a type of heavy oil that is very thick to flow on its own. Bitumen from the oil sands can be extracted, either by mining the sands or recovered *in situ* or in place. However, 80% of these oil sands deposits in reservoirs contain oil that is deeper than 75 meters below the earth's surface (Dunbar, 2011), making it extremely difficult to mine at such depths.

Figure 2. Nature of the Oil Sands



Source: World Deposits, Heavy Oil and Bitumen Recovery (Weiss, Fall 2011)

Consequently, *in situ* extraction methods have been developed, which, unlike mining, do not disturb the earth as extensively through massive excavations using large trucks and shovels. Thus, *in situ* extraction has become a predominant method in Alberta to recover the oil from the reservoirs (CAPP, 2009). "Since the bitumen is usually too viscous to flow on its own to production wells, either heat or solvent must be injected to reduce the viscosity of the bitumen so that it can be produced to surface" (Weiss, Fall 2011).

Hence, to enable bitumen production to the surface, different *in situ* methods have been developed over the years, such as Cyclical Steam Stimulation (CSS), Vapour Extraction (VAPEX), Toe to Heel Air Injection (THAI), and others. So far, the Steam Assisted Gravity Drainage (SAGD) method has proven to be a reliable technology. An increasing number of oil companies, including Suncor, Cenovus, Husky, and many others, have invested heavily in the utilization of SAGD in their oil sands operations.

Figure 3. Different Types of Crude Oil Found Across the World

Most petroleum comes from the earth as a liquid called *crude oil*. Different types of crude oil vary in color and thickness (viscosity), ranging from clear thin fluids to a dark, tarlike substance. In some parts of the world, petroleum also occurs as a solid in certain sands and rocks. The deeper the reservoir the less viscous petroleum is likely to be. In shallow formations, petroleum becomes much more viscous to, even solid. (Illustration courtesy of World Book)

Source: World Deposits, Heavy Oil and Bitumen Recovery (Weiss, Fall 2011)

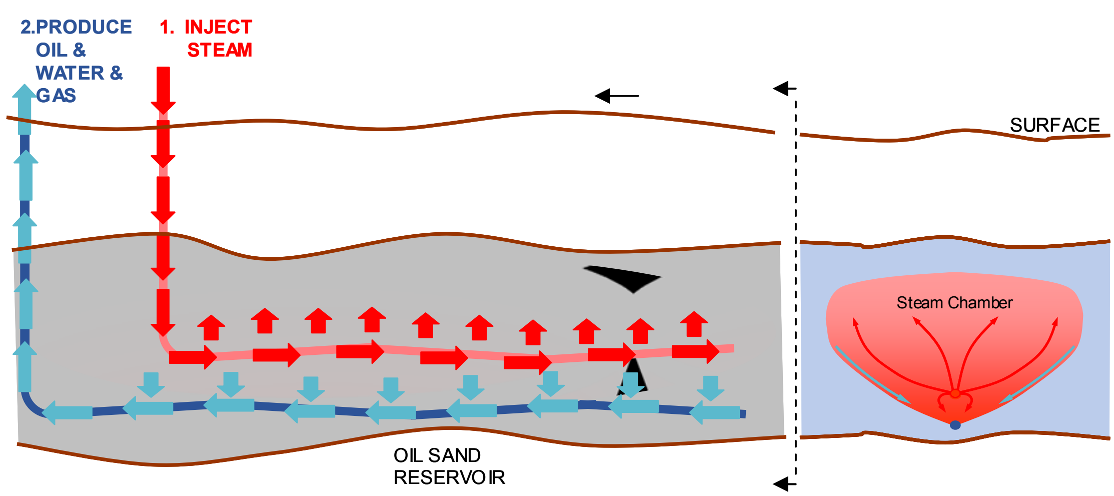
1.1.2 The SAGD Process

The SAGD process was invented by Dr Roger Butler in 1978 (Butler, 2001). This invention, which is still undergoing technological improvements today, has proven to be a great advantage in extracting heavy oil from the reservoirs that are deep (see Figure 2.).

Unlike conventional crude oil, where considerable exploration costs are involved, finding costs for the oil sands are negligible because they are delineated or well defined (F. Gaviria, Santos, & Rivas, 2007); this makes the oil sands very attractive. Rick George, the President and CEO of Suncor Energy, considers Canada's huge oil sands as "extremely long life, low risk, and relatively low-cost commodity" (Moritis, 2004, p. 37).

In the SAGD process, a pair of wellbores or pipes, an injector and a producer, 200 to 475 millimeters in diameter each and 1,000 to 1,600 meters long, is drilled into the oil sands reservoir, 150 to 700 meters deep, depending on the reservoir geology (see Figure 4.) Underground, the two pipes sit horizontally parallel to each other five meters apart. In the pipe sitting above, steam from a surface plant is injected at a high temperature and pressure, which results in a steam chamber forming around it. The steam starts to heat the reservoir, eventually making the bitumen less viscous, which is collected though gravity into the second pipe (producer) and lifted to the surface and collected in huge tanks.

Figure 4. Bitumen Extraction Using the SAGD Process



Source: Institute for Sustainable Energy, Environment and Economy (Patton, Gates, Harding, Lowey, & Schlenker, 2006)

The production from the wells, consists of water, oil, vapour, and gasses, are separated in a pressurized treater, and the bitumen (oil) is cleaned at the above ground facilities

(Edmunds & Suggett, 1995). The surface facilities, constituting the SAGD plant and well pads, is generally divided into the following process areas (see Figure 5.):

i. **Oil Removal**

In the oil removal area, the produced fluids including bitumen and water collected from the reservoir are separated in several steps. Since density of bitumen and water is almost the same, a hydrocarbon such as diluent is added to the bitumen. The mixture of diluent and bitumen, which is called dilbit, is less dense and less viscous than bitumen, and so the separation is done using gravity. Special treating chemicals are added to help the separation of water and dilbit at a reasonable rate.

ii. **Storage Tanks for Dilbit**

The treated bitumen (dilbit) is stored in tanks in this area and sent to a central pipeline terminal in order to be transported to the market.

iii. **Cooling and Separation**

The produced gasses and vapour from the well pads is cooled off in the cooling and separation plant to condense the water, which is sent to the Deoiling area. The remaining methane gas is sent to the steam generators, to be used as fuel gas.

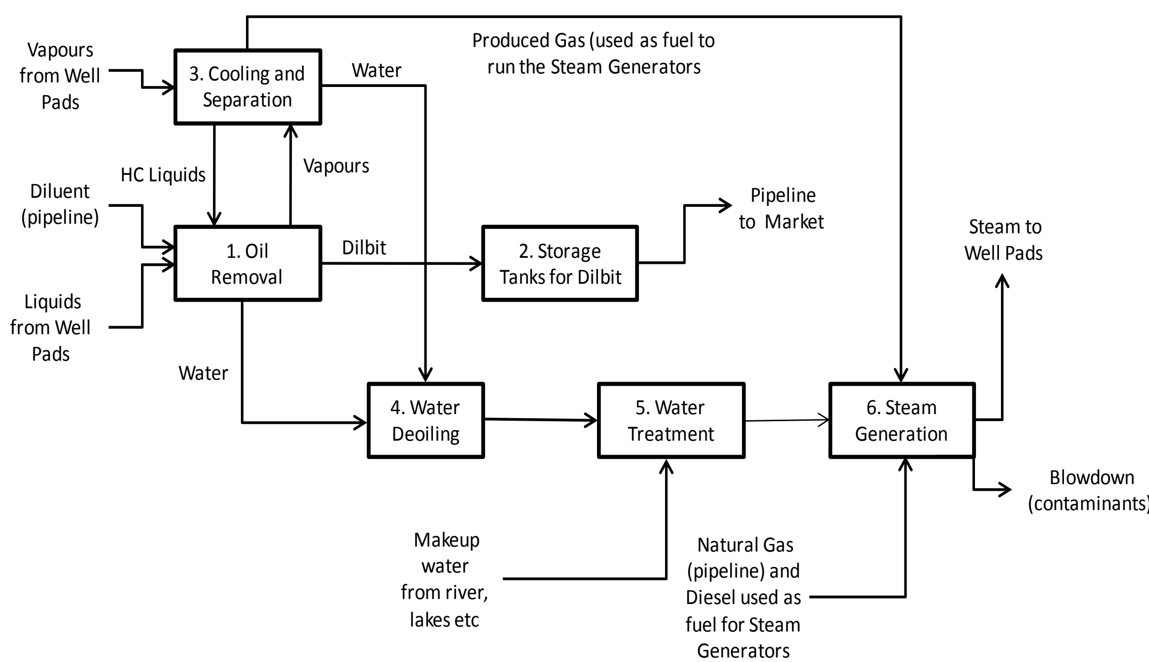
iv. **Water Deoiling**

The produced water from the reservoir, together with the bitumen must have all the contaminants removed before it can be recycled to produce steam. Any free oil that did not separate from the water in the oil removal plant is removed using a process called Microbubble Floatation, and through oil removal filters. This water is then sent to the water treatment area for further elimination of the dissolved solids such as magnesium and carbonates.

v. Water Treatment

In this area, source or raw water from rivers or lakes, also called makeup water, is filtered and treated by removing any solids in order to feed the huge steam generators. In addition, the produced water from the Deoiling plant, which still contains dissolved solids such as calcium, magnesium and silica, must be removed so as to prevent scaling of the pipes and steam generators. Warm Lime Softener, filters, and ion exchange units are used to clear the water from these solids, which is then used as the boiler feed water.

Figure 5. Schematic of the Major Areas of a SAGD Central Processing Plant



vi. Well Pads

This is the base of the steam injection area. Each well pad has several well pairs (injector and producer wells) underneath. Through the wellhead, steam is injected into the wells going into different areas in the reservoir predetermined based on the geological surveys. Bitumen produced as a result, is pumped through the producer well and collected in tanks at the surface.

vii. Flow Lines

These are pipelines running between the SAGD central processing facility (CPF) and the well pads through which the steam generated by the plant is pumped to the pad; In addition, liquids, including bitumen, water, and gases, collected at the pads are sent back to the CPF though these flow lines for further processing.

1.1.3 Why are Lessons Learned from SAGD Execution Required?

Having discussed the importance of the oil sands to Alberta and the SAGD process to extract bitumen, why are lessons learned from execution of SAGD projects important?

With a large part of oil sands production coming from the employment of *in situ* extraction and with SAGD being the most tested and advanced technology currently available, the number of new plants using this technology is likely to increase significantly as the North American economy recovers from the current slow down. The increased demand for oil will subsequently increase the number of SAGD surface facilities, which will require capital investments in the billions of dollars.

Table 1. Cost Overruns on Alberta Oil & Gas Projects (Condon, 2006)

Project	Company	Original Estimate CAD$ billion	Final Cost CAD$ billion	% Cost over run	Original Finish Date	Actual Finish Date
Original GCOS Plant	Suncor	0.25	0.25	0%	1967	1967
Mildred Lake	Syncrude	1.0	2.0	100%	1977	1978
Millennium	Suncor	1.9	3.4	94%	2000	2001
AOSD – Phase 1	Shell	3.5	5.7	63%	2002	2003
UE-1	Syncrude	3.5	7.5	114%	2004	2006

Due to the large amount of capital required, owners and shareholders of such projects will therefore expect greater efficiencies from the engineering, procurement, and construction of the projects than current practices provide. In addition, considering that many large oil & gas projects in Alberta have had significant cost overruns (Condon, 2006; Jergeas & Ruwanpura, 2009), a great deal of attention is being focussed by project owners, contractors, suppliers, and academia on how to make the project management of SAGD projects more effective.

1.2 Survey Objectives

The intent of this survey was to review at a high level the entire engineering, procurement, and construction process for executing SAGD projects. This in turn, would provide an understanding of how the EPC processes function, which can help identify current issues in executing SAGD projects. The approach taken to identify the issues was to collect and rank lessons learned from executing SAGD projects with the objective of identifying ones that have the most impact on executing SAGD projects. These ranked lessons learned are discussed in this report.

1.3 Survey Approach

1.3.1 The Delphi Method

Due to the similar elements involved in project execution, such as cost, schedule, technology, execution strategy, and stakeholders, the case study method was deemed the most suitable, given that it would help in collecting similar but different information about projects that the participants have worked on. Within the case study, the Delphi Method was used to collect data from the survey participants. This surveying method was preferred because of its versatility in providing the participants' voices in a free, discreet, and democratic manner, which in turn helps reduce lopsided or biased research results. The Delphi Method is known to be an efficient survey method, especially where the problem being investigated is new or complex (Turoff & Linstone, 2002).

1.3.2 Round 1 Delphi Survey

Two rounds of surveying using the Delphi Method were conducted. In the first round, lessons learned were collected through one-on-one interviews with 37 participants almost equally divided between the owner and EPC organizations; from those groups, close to 50% of the participants were from the engineering area, 25% of the participants were from the project management area, and the rest were from the procurement, construction, and project support. The high number of engineering participants in the survey is reflective of their actual proportion on oil & gas projects. A total of 339 lessons learned were collected from the one-on-one interviews with participants who had worked on, or were currently working on, SAGD projects.

1.3.3 Round 2 Delphi Survey

After collecting the lessons learned from Round 1 of the Delphi survey, they were sorted and codified from which 91 summarized lesson learned statements were prepared; these statements were later provided to the same participants for rating in Round 2. Using a Likert scale of 1 to 10, where 1 represents *least impact* and 10 represents *high impact*, the participants were asked to rate the impact of each of the lessons learned on the successful execution of SAGD projects. The individual scores of all the participants were tabulated on a spreadsheet and the mean of each of the 91 lessons learned was calculated. The lessons learned were then sorted based on the value of the mean and ranked from highest to lowest in descending order. The top thirty lessons learned together with their rank and average score are listed in Table 2. (Halari, 2011).

The top thirty lessons learned were then grouped together by thematic areas (see Table 3). The objective of grouping was to determine the intensity of the lessons learned, which was indicated by their score in each area. The results of the lessons learned, organized sequentially from reservoir (project inception) to construction (project completion) are discussed in greater detail in subsequent sections of this paper.

Table 2. Top Thirty Lessons Learned

Rank	Lesson Learned	Score
1	Communication between and within engineering/procurement/construction teams	8.6
2	Knowledge/experience of management processes to execute large projects	8.6
3	Define/clarify vendor data requirements early	8.5
4	Have clearly defined scope by EDS phase	8.5
5	Timely receipt of vendor data	8.4
6	Effective change management process	8.4
7	Fully developed and completed P&IDs (IFC)	8.4
8	Identify and order long lead items early	8.4
9	Communication of scope/design changes/technical decisions	8.4
10	Set realistic key schedule milestone dates	8.4
11	Clear definition of roles/responsibilities/accountabilities of Workshare office	8.4
12	Fix basic process design early	8.4
13	Early stakeholder (owner/construction/operations) involvement for design buy-in	8.3
14	After EDS freeze scope in order to start detailed engineering	8.3
15	Communication between stakeholders	8.3
16	Ensure owner quality requirements are met	8.3
17	After EDS, design changes to P&IDs should be limited to minor items	8.3
18	Vendor quality management for larger packages	8.3
19	Well defined reservoir data for engineering SAGD facility	8.2
20	Build in the design, regulatory requirements to meet project approval	8.2
21	Interface between engineering, construction and operations	8.1
22	Assess operability/maintainability/constructability when engineering modules	8.0
23	Place senior/knowledgeable staff in Workshare office	8.0
24	Tie-in payments to vendors based on timely submittal of vendor drawings/data	8.0
25	Multi-discipline input into project planning	7.9
26	Define design philosophy and technology early	7.9
27	Simple, well defined and updated work processes & procedures	7.9
28	Early involvement of and regular feedback from construction during engineering	7.9
29	Early environmental assessment	7.9
30	Plan ahead to take advantage of weather windows (Northern Alberta)	7.9

1.3.4 Top Thirty Lessons Learned Grouped by Execution Area

Table 3. Lessons Learned Grouped by Thematic Areas

Area	Lesson Learned	Score
Reservoir	Well defined reservoir data for engineering SAGD facility	8.2
Front-end Planning	Have clearly defined scope by EDS phase Effective change management process After EDS freeze scope in order to start detailed engineering After EDS design changes to P&IDs limited to minor items Multi-discipline input into project planning Define design philosophy and technology early	8.5 8.4 8.3 8.3 8.3 7.9
Regulatory	Build in the design, regulatory requirements to meet project approval Early environmental assessment	8.2 7.9
Project Execution	Clear definition of roles/responsibilities/accountabilities of Workshare office Assess operability/maintainability/constructability when engineering modules Place senior/knowledgeable staff in Workshare office Simple well defined, updated work processes & procedures	8.4 8.0 8.0 7.9
Engineering	Fully developed and completed P&IDs (IFC) Fix basic process design early Early stakeholder (owner/construction/operation) involvement for design buy-in	8.4 8.4 8.3
Vendor Data	Define/clarify vendor data requirements early Timely receipt of vendor data Vendor quality management for larger packages Tie-in payments to vendors based on timely submittal of vendor drawings/data	8.5 8.4 8.3 8.0
Quality	Ensure owner quality requirements are met	8.3
Procurement	Identify and order long lead items early	8.4
Construction	Early involvement of and regular feedback from construction during engineering	7.9
Management	Knowledge/experience of management processes to execute large projects	8.6
Schedule	Set realistic key schedule milestone dates Plan ahead to take advantage of weather windows – (Northern Alberta)	8.4 7.9
Communication	Communication between and within engineering/procurement/construction teams Communication of scope/design changes/technical decisions Communication between stakeholders (owner/engineering/construction/operations) Interface between engineering, construction, and operations	8.6 8.4 8.3 8.1

1.4 Reservoir

Table 4. Reservoir

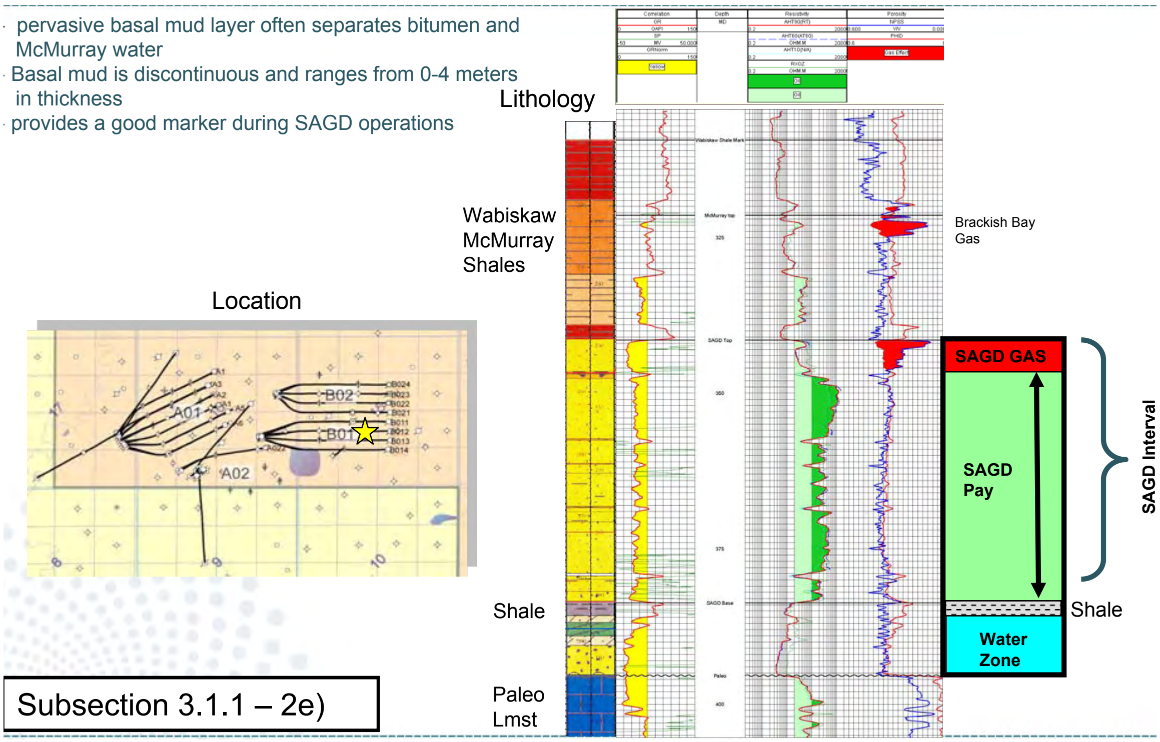
Area	Lesson Learned	Score
Reservoir	Well defined reservoir data for engineering SAGD facility	8.2

As the survey score identifies, well-defined reservoir data is critical for building a sub-surface SAGD facility. This is because many assumptions for building surface facilities are made on basis of the reservoir data. There are, however, many problems in obtaining accurate reservoir data. One of the problems, for example, is the inability to gather a comprehensive set of data using the current methods and processes; this is compounded by the fact that oil sands reservoirs evolve with the changing underground deposits (Selby, personal communication, June 11, 2010) making it difficult to obtain accurate data.

Another problem is the evolution of this reservoir data in terms of stability, reliability, and sustainability, from which production flows can be determined (Fernando Gaviria, 2010). When there are changes to the reservoir data, appropriate changes to the process design have to be reconfigured in order to optimize production. Incorporating such changes create *tremors* to the execution strategy consequently impacting all the respective disciplines' design and engineering work. These changes impact the design of the surface facilities, which can sometimes be significant, depending on how much the reservoir data has changed. Surface design changes can impact the equipment sizes, pipe sizes, pumps, tanks, etc. Needless to say that the changes include the potential of rework on the PFDs, P&IDs and other discipline associated drawings.

Due to the unstable reservoir data, the wells drilled may not reach the optimum pay zone of the oil sands deposits; however, in other cases, there may be an excess of water in the producer wells. As a result, it is quite possible that even a year or two after commissioning the surface facilities, a SAGD reservoir may not yield the production expected during the study phase. This can result in the SAGD plant not being able to produce bitumen at full nameplate capacity, as experienced in a few projects in Alberta. Therefore, it is important to look at the potential range of operations, from the worst case to the best-case scenario of the reservoir performance, and to be able to provide flexibility in the design to meet the variability in the reservoir operating conditions and minimize significant changes to the surface facilities.

Figure 6. Sample Reservoir Data (composite log) of a SAGD Project



Source: In situ Progress Reports (Cenovus Energy, 2010)

Changing reservoir conditions and the additional time required to collect more data do not always impact the project negatively. Additional data could also provide favourable information, resulting in the possibility of higher production scenarios than indicated on previously simulated models. However, significant changes to surface facilities involve long cycles of approval from the government regulatory bodies, which can potentially delay the project. It is therefore important to select an optimum scenario during the study phase and provide flexibility in the design of the surface facilities to prevent such delays. While such overdesign can subsequently increase the project's cost and limit innovation

(Priemus, Flyvbjerg, & van Wee, 2008), there is a trade-off between this option and having delayed bitumen production, which can impact the project's cash-flow.

1.5 Front-end Planning

Table 5. Front-end Planning

Area	Lesson Learned	Score
Front-end Planning	Have clearly defined scope by EDS phase	8.5
	Effective change management process	8.4
	After EDS freeze scope in order to start detailed engineering	8.3
	After EDS, design changes to P&IDs should be limited to minor items	8.3
	Multi-discipline input into project planning	8.3
	Define design philosophy and technology early	7.9

Lack of complete scope definition was one of the biggest burning issues identified during the Round 1 interviews. In Round 2, this was one of the highly rated lessons learned in the survey, thus corroborating the Round 1finding. Other highly rated lessons in the area of front-end planning included early definition of design philosophy, freezing scope after EDS and minimizing changes, and an effective change management process. These lessons learned are discussed in the sections below.

1.5.1 Clear Scope Definition

The survey participants felt strongly that the complete scope of the project should be defined up front in the engineering phase. Failure to do this can result in time being wasted on the project due to rework. Also, at times, staff members are idle with no work fronts because the scope is being defined. There are a couple of aspects to this finding. The first one is that the owners, as one participant stated, "Don't always know what they want". This is because there are numerous decisions project owners need to make in order to finalize the scope; this is compounded by the fact that they do not always have the complete information readily available.

In addition, many other factors can impact the decision making of the scope such as the type of project (e.g. greenfield or brownfield), capital expenditure required versus available cash flow, future expansion plans, equipment & material specifications and standards, project schedule, etc. All of these factors are significant in establishing the project's economics, which in turn determines the scope that can be executed at a given time. On the other hand, the project team do not always appreciate the fact that the ultimate goal of the project owners is to provide a good return on investment and value to its shareholders. Therefore, it is essentially becomes a balancing act between the needs of the project team and the allocation of appropriate financial and human resources to optimize the return on the capital expenditure.

The second aspect emerging from the findings is that not enough time is spent in defining the scope. This is because the project schedules have artificial deadlines (Condon, 2006) established by the project owners depending on market forces and other factors; these deadlines can make it extremely difficult to commit enough time and thought to accurately defining the scope. A well thought out scope helps in minimizing changes, especially when the project's design is in the advanced stages. Rework and redesign, which are by-products of poor scope definition tend to create disorder in the engineering execution sequence.

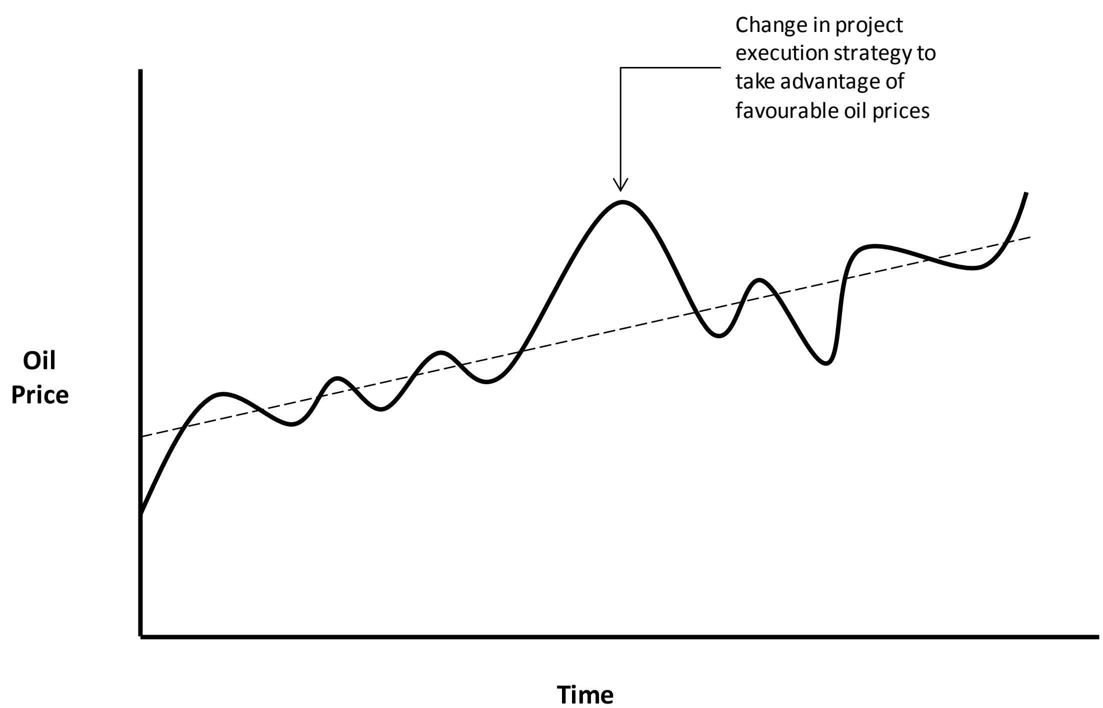
1.5.1.1 Fast Tracking

A major cause of poor scope definition, as demonstrated during the recent boom (2006-2008), is the external market forces hovering over current and future projects, such as the rising price of natural resources. In order to react and capitalize on the opportunities created by market conditions, especially when prices are on the upswing, changing project execution strategies such as fast tracking is a natural reaction (see Figure 7.).

Such a change in execution strategy results in the shrinking of schedules to accommodate and capitalize on the opportunity, which requires people to work at a much more rapid pace than before. In addition, such a strategy requires the overlapping of phases (see

Figure 3), which creates a perception of a poorly defined scope. This fast paced execution was very evident in the oil & gas sector during the recent boom (2006-2008), and much of it was due to the economics of oil prices, which rose to a peak of US$147 a barrel. It should be mentioned that with the drop in oil prices from its peak, oil & gas projects are now executed at a much more normal pace.

Figure 7. Impact of Oil Prices on Execution Strategy

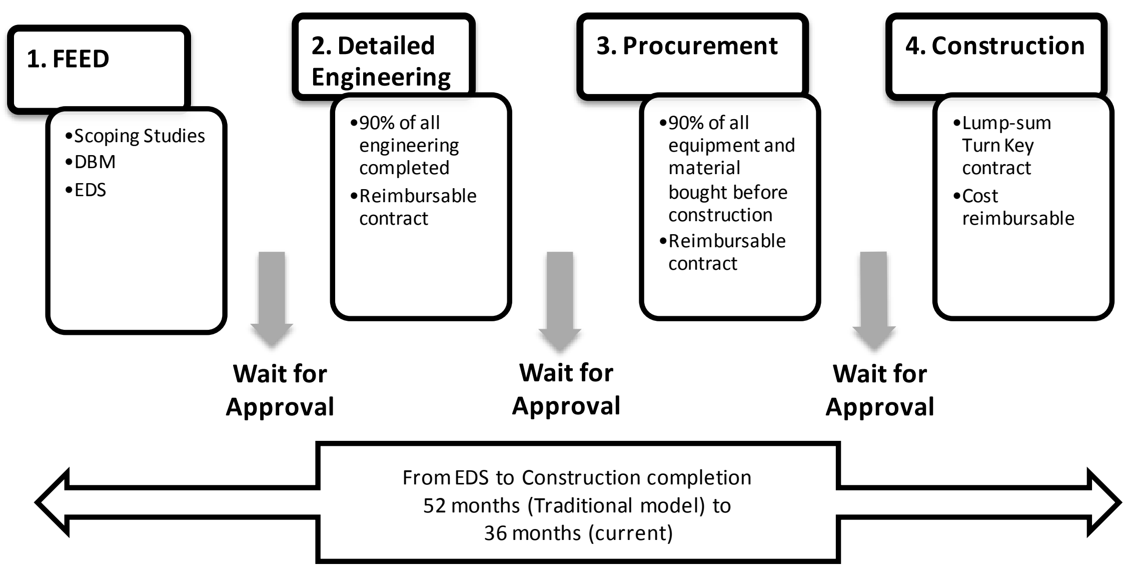


Nonetheless, with the numerous books and articles written by various authors about the "peak oil theory", where there is a theoretical maximum world oil production reached after which it starts to decline (Editorial Dept., 2009), coupled with increased oil consumption from the emerging markets of China, India, and Brazil, it is probable that oil prices will rise again in the future. This will likely bring another round of fast-tracked projects, resulting in issues in and around the front-end planning, unless some learning's have taken place.

1.5.1.2 Traditional versus Current Project Duration

Figure 8. (Harris, personal communication, 2009) shows the traditional model of execution, which has a moderate pace of execution. In this model, which is still practiced on government infrastructure projects, it takes almost 52 months to complete a project from the beginning of the FEED phase to the end of the construction phase. The significant aspect of this model is the completeness of each phase and the time spent, usually 2 to 3 months, between each one of them for deliberations and decision-making before embarking on to the next phase.

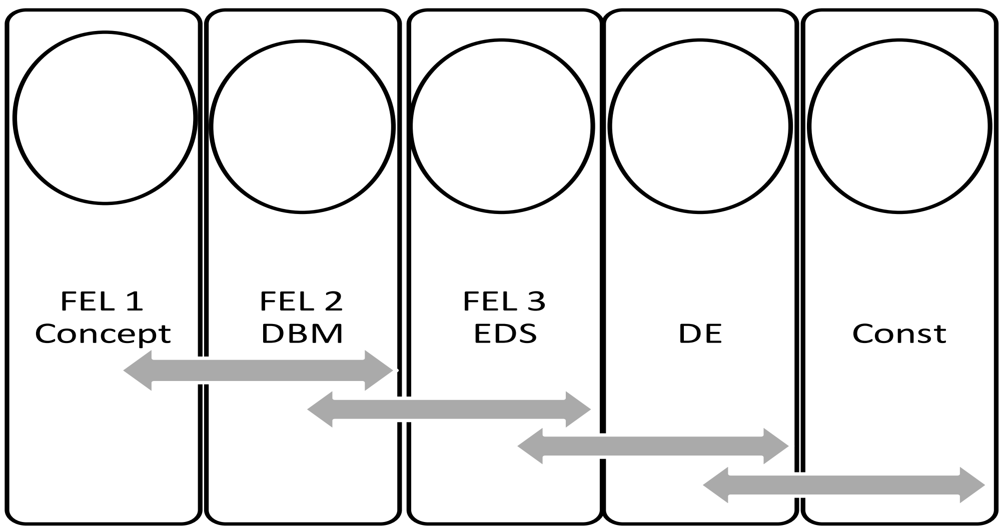
Figure 8. Traditional Durations of EPC Phases



In a project development model, where there is flexibility to spend significant amount of time between each of the phases, a well-defined scope and engineering design can certainly be achieved. It should be noted that the traditional model does not take into consideration the opportunity cost of missed cash flow brought on with extended project duration. In the new paradigm, a couple of execution strategies are used in an attempt to accelerate the product to the market, which in turn brings quicker cash flow to the owner.

The first one is to compress the project phases into shorter durations, which results in reduced schedule. However, such a strategy can result in a loss of discipline in the execution process, which can negatively impact the quality (Harris, personal communication, 2009). The second strategy is to have overlapping project phases, as illustrated in Figure 9. In such a strategy, there is an overlap between the Conceptual and DBM phases by initiating DBM just before the conceptual phase is completed; EDS is started before DBM is completed and so on.

Figure 9. Overlapping EPC Phases



1.5.2 Change Management

On SAGD projects, the construction of the surface facilities are established on the reservoir data, which is known to change over a period of time, even after the wells have started producing bitumen. Although reservoir data, which is collected over a period of time from core logs and pilot plant set up during the project's study phase, is available, this data too is subject to change. The accuracy of this data is also predicated on the length of time upon which the data has been collected; this results in a better understanding of the reservoir. Therefore, the changing reservoir conditions coupled with simulations to achieve optimum bitumen production and to minimize SOR create a significant impact on the size and capacity of the surface plant design (Edmunds &

Suggett, 1995). This in turn, impacts the key initial deliverables such as PFDs and P&IDs (see Figure 10.). SAGD projects have constant changes, which need to be captured in an effective way so that they are communicated to all the project disciplines and stakeholders. It therefore, becomes imperative that the scope is comprehensively and well defined in order to develop a baseline, which can be used for managing changes to the project.

1.5.3 Changes to PFDs and P&IDs

Due to the changing nature of the process design on SAGD projects and resulting changes to the project, other engineering disciplines sometimes mention in jest “the process guys don’t know what they are doing!” While this is *not* an accurate assessment of the process discipline, it shows the difficult nature of process design, especially on SAGD projects, from which PFDs and P&IDs are developed; other engineering disciplines, such as the mechanical, piping, civil, electrical, and instrument and control (I&C) disciplines, depend on these drawings to complete the engineering and design for their respective disciplines. Therefore, changes made to the process design result in changes to the PFDs and P&IDs, which subsequently impact the other disciplines. As illustrated in Figure 10., the process engineering group is dependent on the reservoir and pilot plant data, since this data influences decisions on things such as the steam to oil ratio (SOR). For that reason, it is the changes from the pilot plant data incorporated into the process design, which is the major cause of incomplete or changing P&IDs (not the process guys!).

As pointed out in the survey, this changing nature of P&IDs has a huge impact on the execution of a SAGD project, particularly on the engineering and design disciplines, which ultimately impact the schedule because of the time spent on achieving optimal conditions for the process design. While it is impossible not to have changes at all to the design, and therefore, to the P&IDs, changes up to the end of the Engineering Design Specifications (EDS) phase can be acceptable but they should be controlled and kept to a minimum. Although, changing P&IDs is also a problem on other oil & gas projects, the authors think that the reservoir conditions, which some people call the “black box”, creates a greater impact on SAGD projects in comparison with other oil & gas projects.

1.5.4 Design Changes and 3D-Modelling

Another reason for the design changes is the versatility of the design tools used in the process of designing the oil & gas plants. Over the last two decades or so, with powerful computer aided drawing tools, such as AutoCAD, Smartplant etc., the ability to design a three dimensional model of the entire plant and making design changes has become much easier compared to the days when such tools were not available. During the days when drawings were done manually using a pencil, ruler, paper, and an eraser, making design changes required painstaking work requiring a great deal of time. Although studies are not available, one can see that while improved technology and software tools have provided greater efficiencies in plant design, it has also resulted in the unintended consequence of making frequent design changes than before to the detriment of the entire design process.

1.5.5 Design Philosophy & Technology

The survey highlights the fact that the design philosophy and process technology should be defined early; however, these aspects are also dependent on the reservoir definition and its corresponding data. Edmunds & Sugget mention in their paper, *Design of a commercial SAGD heavy oil project* that SAGD projects have unique technical challenges due to

> economical and timely reservoir delineation, required to support accurate production forecasting; optimization of well pattern dimensions; design of a reliable artificial lift system, capable of high volumes and temperature and management and/or recovery of the large amount of heat contained in the production stream (1995, p. 4).

These challenges impact the design philosophy and selection of appropriate technology for extracting bitumen using SAGD technology. Therefore, an iterative process using simulation is required to confirm the appropriate philosophy, and the technology that flows from it takes time to develop. This creates an impact on the other engineering disciplines, consequently impacting the project schedule.

1.6 Regulatory

Table 6. Regulatory

Area	Lesson Learned	Score
Regulatory	Build in the design, regulatory requirements to meet project approval	8.2
	Early environmental assessment	7.9

1.6.1 Meeting Regulatory Requirements

The regulatory regime for building oil & gas facilities in Alberta is very strict and for good reason - to protect its citizens and the environment from catastrophe and damage. Therefore, in building SAGD and other oil & gas facilities, it is critical to be familiar with the regulatory bodies and agencies that have jurisdiction over the project. Secondly, in order to understand the regulatory issues and compliance required, it is necessary to understand the reasoning and the basis of these regulations and incorporate them into the design in order to meet the requirements. This understanding should permeate not only within the Regulatory Approvals team (usually based in the Project Owner's group), but also within the engineering management and design teams.

It is also critical to keep up with any changes that the regulatory bodies bring that could have an impact on the project. The reason for this caution and alertness is that obtaining regulatory approvals generally take a very long time, and having to revise and or resubmit applications for approval and implement any recommended changes by the regulatory bodies can setback the project significantly in terms of schedule and opportunity cost. Failing to meet all the regulatory requirements can result in, for example, the project not receiving building permits required to start construction, thereby preventing the project from moving ahead.

1.6.2 Early Environmental Assessment

Similar to regulatory requirements, environmental assessments are a key component to receiving project approval for oil & gas projects. It is important to involve environmental agencies early on so as to identify the guidelines and requirements such as baseline disturbance assessments of the natural habitat surrounding the proposed plant's vicinity.

1.7 Project Execution

Table 7. Project Execution

Area	Lesson Learned	Score
Project Execution	Clear definition of roles/responsibilities/accountabilities of Workshare office	8.4
	Place senior/knowledgeable staff in Workshare office	8.0
	Assess operability/maintainability/constructability when engineering modules	8.0
	Simple well defined and updated work processes & procedure	7.9

1.7.1 Executing Project in Countries with a Lower Cost Advantage

To get a cost advantage over competitors, North American manufacturers have been moving the labour component in the production of goods to lower cost countries. This move has not only impacted the North American manufacturing sector, but it is also starting to impact the service industries, given that more and more companies are opting to move to lower cost centers to take advantage of this opportunity. Shifting of services started with the telephone call centers by moving operations from North America to lower cost countries like India and Mexico.

More recently, although at a slower pace, other service providers, such as engineering companies, have followed suit. Several large engineering companies have had their offices worldwide in order to facilitate the execution of local projects in the countries in which they operated. However, over the last decade, such companies are shifting the engineering work from their North American offices to offices in countries where there is a significant cost advantage to the client. Some engineering companies call this concept 'Workshare', which refers to a situation where two or more offices worldwide would be involved in executing a single client's project.

1.7.2 Workshare as an Executing Strategy

Workshare has its benefits and weaknesses; therefore, prior to embarking on a program, the Workshare offices' capabilities have to be assessed in order to assure the client that the work can be executed. Prior to using Workshare as an execution strategy, owners and EPC contractor should raise certain questions; such questions include: how and who will supervise the Workshare team? How will the trust between the parent office and Workshare be developed in ensuring that the correct project standards and procedures have been applied? Will the Workshare be cost effective when applying measures such as productivity and the additional time that has to be spent by the parent office to check and verify the drawings produced by the Workshare office? Would the travel by project leads and managers between the Workshare and parent office be too onerous, and would this pose any risks to the project execution? Would there be engineers available in the Workshare office that possesses the authority from the parent office's country/province to stamp the drawings?

In addition, are there a clear definition of roles, responsibilities, and accountabilities of the Workshare office? Having worked on a Workshare project, the authors can confirm the criticality of having roles and responsibilities clearly identified to ensure that there is no ambiguity as to which office is supposed to be working on what scope; how will the scope be executed? What tools will be used? What deliverables are to be produced by each office? Who will prepare the schedules? What reports need to be submitted to the parent project office? These are some of the questions that need to be considered. Indeed, given all the parameters that need to be identified in order to achieve a successful execution, initiating a Workshare is almost like starting a new project.

Another idea related to the Workshare concept is having a senior knowledgeable project staff member posted to the Workshare office to provide coordination and supervision. This person could also provide technical and project management support to the Workshare office. In addition, a technical person having a good knowledge and understanding of the owner/client's standards and procedures could clarify uncertainties relating to execution, project procedures, standards, quality control, and other operational aspects. Moreover, by having a presence in the Workshare office, a fair assessment of the project's progress and performance, issues, and opportunities can be reported to the parent office.

Workshare, however, is not an easy strategy to implement; it requires educating the Workshare office on the standards and codes of the province or country in which the project is being executed. This sometimes involves rechecking the drawings at the project's home-office to ensure that the standards are being followed and incorporated into the design. Rework of the design is also required in instances of deficiencies. After all, it is the parent office which is legally responsible for all engineering aspects relating to the project; therefore, a high degree of diligence is required to ensure local standards and codes are being applied and adhered to.

1.7.3 Operability, Maintainability and Constructability

When designing a facility during the engineering phase, the owners, project team, construction, and operations and maintenance groups need to provide their feedback as key stakeholders of the project. As far as the technical aspects of the project are concerned, the plant operations group needs to be involved to ensure that what is being built will be operable and will meet the standards and specifications set out by the owners. The plant maintenance group is involved to ensure that access and safety provisions have been incorporated into the design of the facility. The construction team needs to provide feedback that what is being designed is constructible. Considerations, such as moving cranes, rigging equipment and, vehicles, manpower density, and safety in execution, are very important for them. From an execution perspective, the survey shows that the above factors are particularly important during engineering of modules and all the respective groups, namely, operations, maintenance, and construction; therefore, they should provide their feedback so that it can be incorporated into the engineering design.

1.7.4 Simple Well Defined Project Procedures

Every project has procedures that need to be followed in order to have a consistent engineering design and to be able to produce it efficiently. All project activities, from preparing a schedule using Inter Active Planning (IAP) sessions to designing P&IDs to archiving documents, have written procedures. The project owner and the EPC contractor provide these procedures, which are written by experienced people who are subject matter experts and have worked on similar projects before. However, the challenge arises when the procedures are either not comprehensive enough or have too much detail that makes it difficult to follow them.

In addition, a major question arises whether the procedures are well communicated. This is important, considering the fact that the people working on projects come from different backgrounds and may speak different languages, and therefore, may have different understanding and interpretations of the procedures. Moreover, written procedures can sometimes be overwhelming to understand and apply, and not having updated procedures only adds to this challenge. It is from this perspective that the survey participants felt that procedures should be simple and well defined so that the engineering can be executed effectively, efficiently, and therefore, with high productivity.

1.7.4.1 Cause & Effect

It should however be mentioned that if deviation of procedures are not identified and corrected at the beginning or early part of the project, they can result in a significant amount of rework later on in the project. This subsequently creates a cascading impact on the entire project. Often times, issues on projects are a result of not following project procedures; in other words, there is a "cause & effect" relationship. While there can be many reasons for deviation of procedures, a common cause is project team members following the procedures from the previous project worked on. Many people assume that the procedure is, for example, the same or not available, and therefore, do not always validate their assumptions when working on a new project. Such assumptions often lead to not following through the proper established procedures, which creates deviations, delays, and rework.

1.8 Engineering

Table 8. Engineering

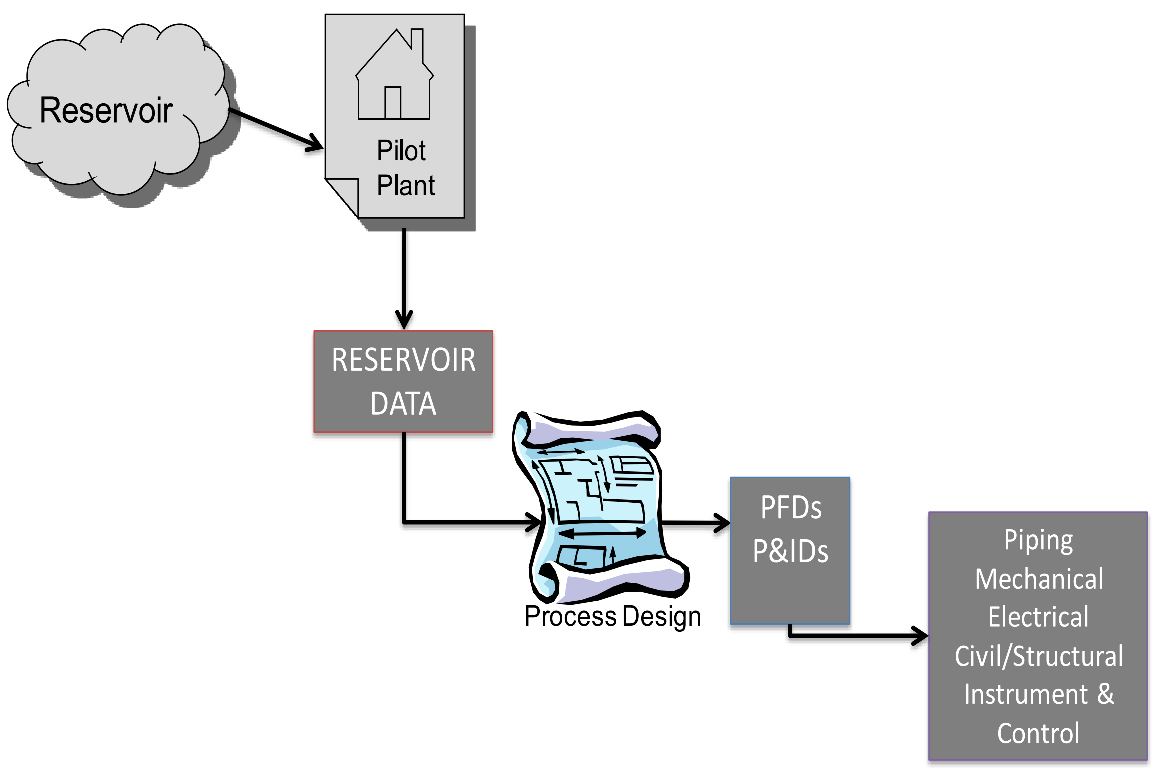
Area	Lesson Learned	Score
Engineering	Fully developed and completed P&IDs (IFC)	8.4
	Fix basic process design early	8.4
	Early stakeholder (owner/construction/operation) involvement for design buy-in	8.3

1.8.1 Developing P&IDs

Piping and Instrument Diagrams (P&ID) show all the equipment, instruments, and process and utility lines running through the oil & gas plant. The starting point to developing P&IDs on a SAGD facility is the oil sands reservoir. To determine the reservoir conditions and properties, a small pilot plant is built. Its purpose is to simulate the functions of a large facility based on the available geological information so that it can provide data in order to make decisions on the type of surface facilities that can be built. This data may include a demonstration of the bitumen chemistry, steam oil ratio (SOR), approximate reservoir yields etc. (Navarrette & Cole, 2001). Other data is also obtained from geological core sample, which are analyzed in laboratories for correct interpretation.

The SOR is one of the fundamental measures that is used to establish the qualities of the reservoir (Fernando Gaviria, 2010). For example, a SOR of 3.0 indicates that three barrels of cold water equivalent in the form of steam are required to produce one barrel of bitumen. A high SOR indicates that more steam, and therefore, more natural gas, which is needed to produce the steam, is required to lift the bitumen, while a low SOR indicates the opposite. A low SOR is preferable in order to lower the project's operating costs. Figure 10. shows the data collection process from an oil sands reservoir and how it is translates into the SAGD plant design.

Figure 10. Process of Designing a Plant – From Reservoir to Engineering



On the basis of the reservoir data and the results from the pilot plant, the design criteria for the surface facilities is established (Fernando Gaviria, 2010). Using the design criteria, various scoping studies are performed and options for plant design are developed during the Study phase. The plant design is selected from the options developed. The project then proceeds into the DBM phase, where the process engineers prepare the process flow diagrams (PFD) and the piping and instrument diagrams (P&IDs)

These drawings illustrate the general design and size of all the pieces of equipment, such as steam generators, heat exchangers, pumps, and tanks, based on the flow pressure and initial flow rates from the reservoir. The PFDs also show the heat and material balances and the appropriate process equipment, major instrument, and control systems required.

The process engineers develop the PFDs into more detailed P&IDs, from which the piping design and engineering, mechanical, electrical, civil/structural, and instrument & control (I&C) disciplines can enhance the design of the SAGD plant. As the survey results indicated, having fully developed and completed P&IDs issued for design (IFD) during early detailed engineering is critical. The IFD P&IDs assure the other engineering disciplines that there will be no major changes to the process design and that they can proceed with the detailed design of the plant and expect minimal changes. It should be clarified that the engineering disciplines are able to work with P&IDs IFD, as long as they are issued by the EDS phase. P&IDs IFC are important, particularly from a construction perspective. This is because IFC drawings include the vendor data and are issued to construction once all the engineering disciplines provide their input into the P&IDs, which happens late in the detailed engineering phase.

1.8.2 Fix Basic Process Design Early

A solution to the late issuing of P&IDs IFC is to issue IFD drawings so that the engineering disciplines can get started. However, the basic design needs to be completed as early as possible so that any changes to design and rework can be minimized. On the other hand, achieving the design early is not a simple issue. There are several contributing factors to the lateness; the most fundamental of these factors is the ever changing oil sands reservoir data,. This incomplete or changing reservoir data impacts the process design, which leads to changes to the PFDs and P&IDs (Fernando Gaviria, 2010). Secondly, SAGD is a fairly new technology, and therefore, in seeking solutions to meeting the design conditions, changes to the technology can sometimes impact the design. Technology selection is usually done during the Study phase. The resulting design options and the development of PFDs and subsequent P&IDs have to be reviewed and approved by the project's owner before they can be IFD prior to completion of the EDS phase. The selection of the options is predicated on the economics of the project together with other decisions impacting the project, which the owner has to firm up. Meanwhile, the engineering disciplines are waiting for confirmation of the design options; however; the project schedule is generally fixed and does not change. This is the reason why there is impatience on the disciplines' part to fix the basic process design early in order to have sufficient time to work on the detailed engineering and design.

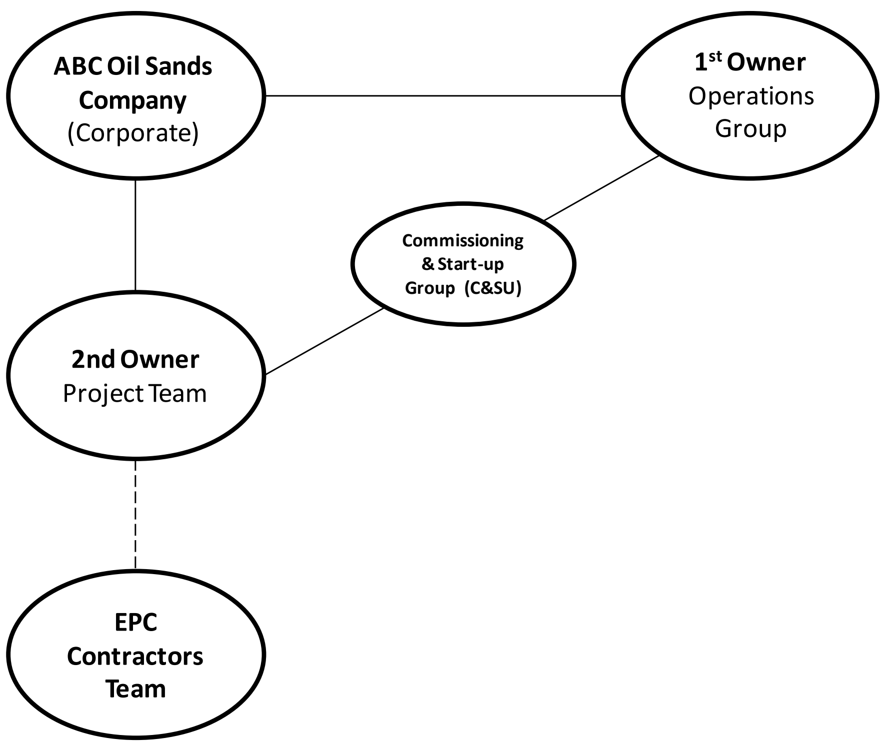
1.8.3 Stakeholder Approval for Design

When building SAGD projects, there are generally two different owners who can be considered the major stakeholders of the project (see Figure 11.). The first owner is the operations group, which owns and operates the facility; the second owner is the project team, which undertakes the execution of the project. The contractors support the project team in areas of engineering, procurement, and construction. Approval of the design, involves these and other stakeholders who provide feedback due to their interests in the project.

The first owner, the operations group, is concerned with the plant's reliability, optimum production and long term safety while operating the facility. The second owner, the project team, is given the task of building the facility by the first owner and is interested in how the facility will be built and whether the design is feasible from the perspective of cost, schedule, quality, and logistics. Within this arrangement, the corporate group is responsible for raising capital and provide financing for the project. It, therefore, undertakes a thorough review of the project from an economics perspective to determine whether it will be able to generate the appropriate cash flow and to provide shareholders a good return on the capital investment. While such criteria can result in conflict of goals and interests between the various owners' financial and operational objectives, it requires the need for providing balance to all the sides through dialogue and compromises.

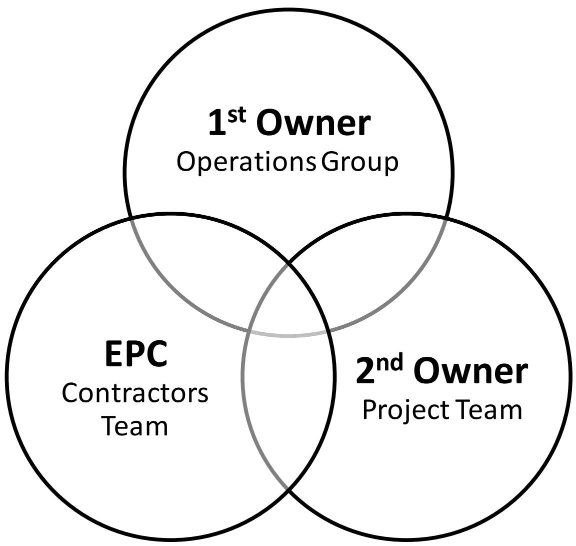
The project's design cannot be done in isolation from the stakeholders; therefore, it is critical to have early involvement from both of the owners to validate it, ensure that design basis is still correct, and determine whether what the owners actually envisioned is being designed and built. Having buy-in from the stakeholders is, therefore, necessary to ensure that all their questions have been answered and requirements have been met.

Figure 11. Various Owners of a Project and Their Relationships



Although this process of validation with the various owners and the EPC contractors takes considerable time, it is nonetheless important to the project's success. The survey shows that it is critical for stakeholders be involved early on in the project to receive quick approval for completing the project's engineering and design. Figure 12., shows the interrelated working relationship between the major stakeholders of the project including the EPC contractors.

Figure 12. Working Relationship of Major Stakeholders of a Project



1.9 Vendor Data

Table 9. Vendor Data

Area	Lesson Learned	Score
Vendor Data	Define/clarify vendor data requirements early	8.5
	Timely receipt of vendor data	8.4
	Tie-in payments to vendors based on timely submittal of vendor drawings/data	8.0

In addition to having a firm scope and stable reservoir information, vendor data, which mostly pertains to the equipment purchased for the project, is among the most important and highly rated factors impacting the successful execution of a SAGD project. Obtaining mechanical equipment and instrument data on time from the vendor is critical because engineering disciplines, such as mechanical, civil and structural, piping, electrical, and instrument & control systems, depend on this information to further develop the engineering design.

For example, the mechanical engineers need the detailed specifications of the equipment to verify whether it will meet the design criteria established by the process engineering group; the piping engineers want to know the nozzle orientation of the equipment so that the piping routing can be designed accordingly; the civil and structural engineers want to identify the weights of the various equipment so that appropriate piling, foundations and steel modules can be designed; the electrical engineering group needs to know the various equipment's power requirements so that the plant power loads can be determined; finally, the instrument and control engineers need to purchase the instruments and write software programs that will automate the plant. Therefore, delays in receiving vendor data create a cascading effect of delaying all the engineering disciplines, and consequently, impacting the construction of the facility and possibly putting the project behind schedule.

There are numerous factors for delays in receiving vendor data. Generally speaking, they can be classified into two categories; internal factors, which refer to issues from within the project, and external, referring to issues brought on by the vendor.

1.9.1 Internal Factors

1.9.1.1 Well Defined Project Scope

The project scope is perhaps the biggest factor that can impact vendor data. When the scope is not fully defined and changes are made to it due to technological or financial considerations, the design of the equipment to be purchased likewise changes. This not only results in changes to the design of the equipment, but also the data relating to the equipment. Almost 90% of the electrical, instrument and control, and mechanical equipment are custom made for a specific plant design (Corner, personal communication, May 5, 2010); equipment such as pumps, vessels, heaters, and exchangers are not always available off the shelf from the vendor's shop and therefore have to be fabricated from scratch. This is a major reason why it is critical to have a well defined scope so that frequent changes to the vendor data are eliminated, and thus being available on a timely basis.

1.9.1.2 Design Changes

When the scope is not well defined, there is a significant potential of having design changes, which impact the engineering disciplines including equipment and its vendors. It should be noted that some of the long lead items, such as equipment are ordered on the basis of engineering design that is only 30% complete. Thus, with changes to the plant capacity, due to changes in reservoir data, plant optimization, and so on, the equipment sizes and capacities also change accordingly. These changes require the engineering design group to revise the previously issued drawings and re-issue a new set of drawings to incorporate the revised equipment capacities, which consequently impact the vendors.

Typically, there are three major releases of the engineering design drawings, namely, issued for (owner's) review (IFR), issued for design (IFD), and issued for construction (IFC). With the increasing number revisions to the drawings, there is an equally corresponding impact on the vendor because they now have to review the re-issued engineering drawings, revise the vendor prints, and issue it back to the engineering contractor. Thus, design changes create a cascading impact on other project stakeholders such as vendors.

1.9.1.3 Schedule

Design changes described earlier not only create an impact to the engineering, but also the construction schedule. Sometimes, the turn-around time in the schedule for providing the vendor data to the mechanical engineering group is too tight. Also, it does not take into account, for example, the fact that vendors have sub-vendors to whom they subcontract some of the work. Therefore, a delay at the sub-vendors shop can impact the prime vendor, which in turn has the potential to impact the overall project schedule.

1.9.1.4 Contractual Relationship with Vendor

To minimize risk, many large oil & gas companies build relationships with the vendors in order to get preferential treatment for pricing and a long-term supply of goods and services including vendor data. Such relationships are formalized into contracts, such as sole source, supplier of choice, strategic partner, etc. In theory, these relationships help reduce the project owner's risk. While such contracts and relationships are supposed to be beneficial to both parties, during heated market conditions, there can be complacency on the part of the vendors to fulfill their obligations to the owners, as was the case during the recent economic boom (2006-2008). During this period, despite having a supplier of choice agreement or sole source contracts, the motivation to provide timely vendor information was not as rigorous as one would have expected. With such a predicament, a question arises that, would there be better service provided if the owner companies moved away from sole source contracts and put out to bid on every contract? Would this strategy translate into a greater incentive to provide vendor data on time?

From the procurement department's perspective, sole source and supplier of choice relationships have their advantages such as being familiar with the vendor and their technical skills & capabilities, safety standards, quality, dependability (or the lack of) service, price, etc. Therefore, there is a certain amount of comfort due to lower risks in such arrangements. Consequently, there is reluctance to change this relationship and move to another vendor.

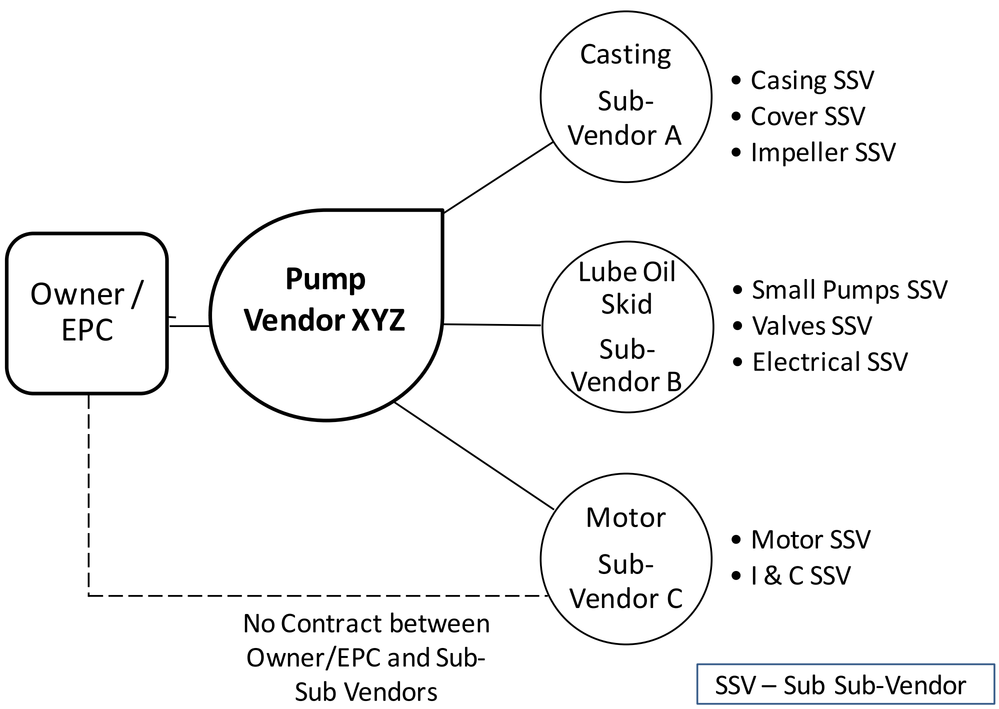
In addition, moving to other suppliers requires time from the procurement and corporate groups to evaluate the vendors, among other things, which is difficult to find during a fast paced project execution.

1.9.2 External Factors

1.9.2.1 Impact of Sub-Vendors

In order to manufacture a piece of equipment, especially large complex ones, the vendor typically sub-contracts parts of the scope to other sub-vendors. As illustrated in the example in Figure 13., in order to manufacture a pump, a Vendor XYZ has three separate sub-vendors. Sub-vendor A fabricating the casting, sub-vendor B making the lube oil skid, and sub-vendor C manufacturing the motor. Vendor XYZ is now dependant on all the three sub-vendors in order to get all the data for finalizing the engineering drawings for the owner/EPC. The prime-vendor cannot integrate, consolidate, and complete the vendor package unless information from all the other sub-vendors is received.

Figure 13. Structure Between Owner/EPC, Vendor, and Sub-Vendors



Moreover, in some cases, the sub-vendors themselves have other vendors, whom they subcontract, thus creating a sequence of vendors. Thus, a delay on the part of any single sub-vendor or sub-sub-vendor has the potential of creating a delay for the entire piece of equipment. This in turn impacts the project in terms of the engineering sequence resulting in rework. Managing all these vendors and their activities can prove to be a complex and difficult task for the prime vendor, and if not well managed, it can potentially become a bottleneck for the entire project.

1.9.2.2 Sub-Vendors' Resources

In some cases, with the increase in the numbers of sub-vendors and their vendors, the size of companies the prime-vendor has to do business with gets much smaller. In smaller companies, the level of organizational sophistication, staffing, and financial wherewithal is somewhat limited. Moreover, in order to economically survive in the market place, these companies constantly juggle their technical, financial, and human resources by in order to fulfill their clients' requirements. In doing so, some clients are given greater or less attention, thus creating an equivalent impact upwards to the prime-vendor.

In some instances, when the vendor is late and additional time is required, a set of a standard off the shelf equipment drawings would be sent when the EPC/owner has clearly stated that the order is for custom equipment. In other cases, vendors would provide the engineering company Code 2 drawings (where comments from the owner/EPC are to be incorporated in the drawings to proceed with engineering) when Code 1 drawings (clean documents where the EPC have no comments resulting from review of vendor data to go ahead with fabrication) are required. Such anomalies naturally result in back and forth inquiries between owner/EPC and the vendor, which gets the sub-vendors additional time until the appropriate personnel, are available to work on the customer's order.

1.9.2.3 Schedule

The other issue is the inability of the vendor to receive schedules from the sub-vendors and be able to track them. Referring to the example in Figure 13, since Vendor XYZ would not have the schedules of the Sub-vendors A, B & C, it becomes difficult to provide an accurate assessment and inform the owner/EPC when to expect vendor data and drawings for the equipment. Thus, receiving the vendor and sub-vendor schedules is critical.

1.9.2.4 Contractual Relationship between Owner/EPC and Vendors/Sub-Vendors

Another aspect creating difficulty in managing the vendors' schedules is the absence of direct contractual relationship between the owner/EPC and the sub-vendors; the purchase contract is generally between the owner/EPC and the vendor. The vendor has a contractual relationship with the sub-vendors but not with the owner/EPC. Such a contractual relationship puts the owner/EPC at a disadvantage; they cannot go directly to the sub-vendors and influence them to expedite the vendor data, even in situations when the information is critical for issuing engineering work packages (EWP).

1.9.2.5 Vendors' Technical Capabilities

Within North America, there are specialized vendors who have high technical expertise in the manufacture and supply of certain types of parts and equipment, for example, pumps, valves, compressors etc. Due to their expertise, these manufacturers receive bulk of the purchase orders from industry. Consequently, when these vendors are over booked with orders, drawings are delayed and subsequently delivery is also delayed. One can argue that with globalization, there are potentially other countries in the world where such equipment could be purchased. A strategy of sourcing internationally definitely helps in cases where the manufacturers do not have sufficient resources locally to execute the work to meet the schedule (Corner, personal communication, May 5, 2010). However, due to the close proximity of North American manufacturers and not having to deal with language and cultural issues, there exists a comfort factor among buyers and management, which results in reluctance to procure supplies from outside the North American continent.

In concluding this section, the above-mentioned reasons, among others, is why the survey participants rated timely receipt of vendor data as very critical to successful execution of SAGD projects. This area is also a prime concern on most oil & gas projects despite the best intentions and commitments from the vendors.

1.10 Quality

Table 10. Quality

Area	Lesson Learned	Score
Quality	Ensure owner quality requirements are met	8.3
	Vendor quality management for larger packages	8.3

1.10.1 Meet Owner Quality Requirements

Over the years, oil & gas companies have executed numerous projects, and as a result of the experience gained, have established their own quality standards and requirements. While some of these requirements also originate from regulatory bodies, such as the Energy Resources and Conservation Board (ERCB), Alberta Boiler Safety Association (ABSA), Petroleum Institute (API) etc., they are integrated into the owner's quality requirements so that both regulatory and company requirements can be met simultaneously.

These quality requirements can be as simple as a pipe's metallurgy to carry certain petroleum products to the more complex such as standards for electrical or compressor packages. The quality requirements are checked and verified by either a third party or the owner's own quality assurance and control (QA/QC) inspection group. Inspection for larger and costly equipment is periodically done at the vendor's shop during the manufacturing process; for critical equipment, the owner's representative is permanently stationed in the vendor's shop to monitor the quality requirements. Not meeting the owner's or the regulatory bodies' quality requirements can result in rework, thereby increasing the cost of the project and causing delay to the schedule. According to the survey participants, meeting the owner's quality requirements, is a significant aspect of the successful execution of SAGD projects, and as a result, has been a highly rated lesson learned.

1.10.2 Vendor Quality Management

Another highly rated lesson learned is vendor quality management.. It seems that there are issues in communicating the exact equipment specifications to the vendors and sub-vendors, which results in quality issues that are sometimes discovered after the equipment has already been fabricated. Despite the owners' quality control inspectors visiting the vendor shops and performing audits, the fabricated equipment sometimes has deficiencies due to not meeting the standards set out in the drawings. Examples of such deficiencies could be, equipment not sitting exactly on the foundations constructed or equipment not starting-up as anticipated. Such issues are identified at the time of installing the equipment and can create frustration or panic for the construction group.

1.11 Procurement

Table 11. Procurement

Area	Lesson Learned	Score
Procurement	Identify and order long lead items early	8.4

From the high score on the survey results, there seems to be unanimous agreement about the importance of long lead items and ordering them early on to meet the construction schedule. Long lead items, such as large diameter pipe for high pressure steam distribution and some pipes made with exotic metallurgy or stainless steel, large vessels, valves, steam generators, and pumps that go with it, have to be ordered early because they take a longer time to manufacture, fabricate and assemble. Ordering early also provides additional buffer to the schedule as well as the potential of cost savings. However, in order to identify and quantify the long lead items a good execution of the DBM phase is required. This is predicated on the reservoir data. Failure to order the long lead items early on in the project results in materials and equipment not being available at the construction site when required. This can result in no work fronts available for the tradesmen, consequently delays to the project and possible cost overruns.

1.12 Construction

Table 12. Construction

Area	Lesson Learned	Score
Construction	Early involvement of and regular feedback from construction during engineering	7.9

1.12.1 Why is Construction Involvement Important?

It is common knowledge that early involvement and regular feedback from the construction group during engineering is an essential aspect of project execution. Constructability reviews provide the construction strategy and the sequencing of activities, which helps in planning and building the schedule. Good sequencing of the construction activities and a well thought out construction strategy can result in the reduction of crane rentals costs, scaffolding, and supervision etc., which are huge on large projects.. Involving construction specialists right from inception provides the project with not only the construction expertise, but also it orients the field staff early with the engineering designs for constructing the facility. Through constructability reviews, the construction team can become knowledgeable of the rationale why certain engineering decisions or design options were considered. This knowledge helps when issues arise in the field or clarification is required during the project's construction phase.

One issue, common on many large projects is that, there are not enough construction representatives or experts available to conduct engineering design reviews. In the survey, a rating of 7.9 for this lesson learned is relatively low in the top thirty lessons learned. This could be because engineers and designers working on the projects have gotten used to working without the construction group's complete input, or they have alternative strategies to get the construction feedback. Therefore, they perhaps do not see construction feedback as critical any longer.

1.12.2 Degree of Construction Involvement

Several questions should be asked on projects regarding the involvement of the construction team: to what degree are construction people really involved in the whole planning process? Do the project teams receive construction's undivided attention? Are construction reviews enough to understand the design, or should the construction representatives be intimately involved in the design on a daily basis? Will the construction representatives working during the planning and engineering phase also be available when the construction actually starts, or will there be another group having little firsthand knowledge of the conditions and assumptions leading to the decisions made during the engineering phase? The project management team may not have thought out complete implications of these and other questions, as simple as they may be. One of the project managers in the survey concurred that the lack of construction people during the design phase is an issue. However, one needs to assess the risks and proceed with the design fully aware that it could possibly create an impact during the construction phase.

1.12.3 Construction Scope

Another aspect that needs to be considered is the construction scope execution. As mentioned in the preceding discussion, an important factor to consider is whether the engineers have a clear understanding of the scope and how the construction group will execute it. For example, in what sequence will the Construction Work Packages (CWP) be required so that the Engineering Work Packages (EWP) can be prepared in that order to meet the construction execution strategy? What is the optimum number of packages that can be accommodated in a CWP for efficient construction execution? All such information pertaining to the scope needs to be thought out during the front-end planning and worked backwards to determine the execution sequence.

1.13 Management

Table 13. Management

Area	Lesson Learned	Score
Management	Knowledge/experience of management processes to execute large projects	8.6

In Round 2 of the survey, apart from communications, knowledge and experience of management processes to execute large projects was the highest ranked lesson learned. This was a surprise to the authors because on large projects such as a SAGD, the technical and engineering aspect underpins everything that happens in designing and building the project. In addition, decisions taken during engineering have far reaching consequences, and therefore, its potential to have a higher impact on a project could be much greater. Therefore, one would be inclined to think that some technical aspect of engineering a SAGD project would be a higher ranked lesson learned, and as a result, have a greater impact on the successful execution. To the contrary, the survey participants suggested that management knowledge and experience in executing projects is more important and has a greater impact on project execution.

1.13.1 Roles & Responsibilities

A dominant theme in the area of management was the roles and responsibilities of the team members of the project organization. In developing an organization chart, certain questions need to be answered, such as, are the job description for the various positions clear, and are the roles, responsibilities, and the accountability that goes with it clearly defined? Is this communicated to the project team members? Do the team members know how to interface with each other? Are the lines of authority for all practical purposes followed the way they are, say, in a military organization? The reason why these questions are important in a project organization is because with clear lines of authority, overlapping of roles and duplication of effort can be avoided. More importantly, the project can be controlled and directed by the responsible team member with appropriate decision-making authority in order to achieve the objectives set out for the respective areas and the project as a whole.

1.13.2 Decision Making

Decision-making is another area suggested in the survey, which is critical to effective project management. One of the survey participants stated, "Due to risk avoidance in decision making, people don't want to own the mistake (if there is one) resulting in more people being involved in decision making." This results, he continued in "decision by committee resulting in sub-optimal decisions". Needless to say, the voices of the people who will do the actual implementation are not heard. Such decisions are not only sub-optimal, but also time-consuming, and in reality impact the project schedule.

1.14 Schedule

Table 14. Schedule

Area	Lesson Learned	Score
Schedule	Set realistic key schedule milestone dates	8.4
	Plan ahead to take advantage of weather windows – (Northern Alberta)	7.9

1.14.1 Realistic Schedule

This area of lessons learned is one of the highly rated areas in the survey, suggesting its significant impact on successful execution of SAGD projects. Schedule impacts everyone on the project, regardless whether it is the engineering, procurement, or construction group. The perception among the project team is that the schedules for project completion are often prepared by the project owner's corporate departments and handed over to the project team to execute based on some predetermined time frames. In some cases, due to various reasons, the project teams find it difficult to meet these project completion dates. Therefore, the survey participants suggested that there is a need to have schedules that meet the needs of the owner as a whole and the project team's ability to execute it.

Some survey participants also argued that the project team, not finance or business development teams, should prepare the initial schedule. This is because, it is the project team that better understands the activities and deliverables required to carry out the scope and is therefore in a better position to prepare the schedule which can result in timely project execution and completion.

1.14.2 Gestation Period

The participants suggested that the schedule should have realistic dates based on standard deliverable durations (from historical projects), instead of working on a compressed schedule driven by current business and market conditions. Compressing the schedule with shorter durations can result in execution problems arising later on in the project. In order to execute the deliverables effectively "do not bypass time proven schedules by reducing engineering durations," suggested one seasoned survey participant. He continued saying "one cannot have a gestation period which is inadequate...one has to go through the proper *thinking process* and have proper information to complete the job". What he was implying is that in order to complete certain deliverables, the schedule cannot be shortened by increasing the number of engineers on the project. Each job is unique, and therefore, a period of thinking, strategizing, and deliberation is required to ensure that a good plant design is achieved. This not only benefits the project owner but the engineering team as well, given that there is a degree of satisfaction derived from a job well done!

1.14.3 Procurement

In developing the schedule, it is essential to have effective input from the procurement or supply chain group, which is a major stakeholder on most oil & gas projects. Approximately 35% of the project's budget is spent on procuring equipment and bulk materials; therefore, involving the procurement group and tapping into their experience early in the project is essential for planning and having a realistic schedule. This results in timely material & equipment deliveries.

1.14.4 Modularization

Modularization is another important area that needs to be well thought out and planned in the schedule. This is because, in building SAGD facilities in Northern Alberta, modularization has now become a key construction strategy. It has become an effective way to get partial construction done in places where there is abundant labour. When modules can be assembled in a controlled environment, it can result in a good quality product with lower costs. In addition, the engineering and procurement activities including fabrication, and module assembly time frames have to be precisely integrated in the overall schedule to achieve the desired benefits to cost and schedule. If modularization is to be used as a construction strategy, its planning has to start at the feasibility stage (Harji, personal communication, September 20, 2009).

Planning for transportation of modules from the module yard to the construction site is critical, especially when transporting along the Northern Alberta highways. There are road bans and seasonal weight limitations to transporting heavy loads. Therefore, opportunities around the weather windows need to be maximized and included in the schedule in order to prevent slippage in the construction activities. Failure to include these factors in the schedule can result in higher costs from using alternative methods.

Figure 14. Truck Carrying a Long Module to Northern Alberta

1.14.5 Third Party Issues

1.14.5.1 Involvement at Project Meetings

Although third party contractors are major contributors and important stakeholders to a project, they are not involved as much during the project meetings held with the project owner and the EPC contractor. As a result, they miss out on the communications, and therefore, do not fully appreciate the project's urgency for certain deliverables. On the other hand, third party contractors are sometimes short on human resources to represent at all the project meetings, thus complicating the situation.

1.14.5.2 Third Party Deliverables in Master Schedule

Another reason for the difficulty in meeting the schedule is due to third party deliverables not being included in the overall master schedule in as much detail as required. The root cause of this omission is the failure to include in the contract with vendors a requirement to submit a Level 2/3 schedule. As a result, the project controls team is unable to monitor and track the delivery of the vendor's promised deliverables so as to bring it to the project manager's attention.

1.14.6 Is the Project Cost or Schedule Driven?

A final point on the topic of schedule, which was not a concern for the project managers but a concern for the engineers, was to define for the project team whether the project is cost or schedule driven. This is due to the fact that the engineering team has to provide the project design consisting of various engineering deliverables. Knowing where the project owner's emphasis is in terms of cost or schedule helps the engineers plan their work. If it is a cost driven project, one needs to ensure that appropriate resources are used with normal engineering durations. On the other hand, if it is a schedule driven project, manpower loading can help identify if additional human resources are required to ensure timely production of deliverables within the timeframes required by the owner.

Additional manpower on the project may require increased coordination and effort, which in turn may drive up the project costs.

1.15 Communication

Table 15. Communication

Area	Lesson Learned	Score
Communication	Communication between and within engineering/procurement/construction teams	8.6
	Communication of scope/design changes/technical decisions	8.4
	Communication between stakeholders (owner/engineering/construction/operations)	8.3
	Interface between engineering, construction and operations	8.1

Table 15. shows that communication between and within engineering, procurement, and construction teams as the highest rated lesson learned in the survey. A similar lesson learned, which is communication between the stakeholders, is equally highly rated. The challenge with communication is that it not only involves communicating with the respective parties involved in the project but also the objects of communication such as scope, design, and schedule, which are part of the process. The combination of people to communicate with and the objects of communication in a project create a number of complex networks or permutations of communication (See Table 16.). Thus, one can appreciate the difficulty in achieving efficient communication on projects.

Communication generally, is a misunderstood word, particularly in execution of oil and gas projects. George Bernard Shaw is quoted saying “The greatest problem with communication is the illusion that it is accomplished” (Thinkexist.com, 2010). This is exactly what happens on projects, that is, the assumption that the other person or party has received the communication and has understood what is being communicated. This ‘illusion of communication being accomplished’ does not absolve the communicating party from responsibility. Unfortunately, this is what generally happens on many projects.

According to Hartman, “Communication is at the heart of effective project management. It needs to be timely, complete, accurate, and verified” (2000, p. 29).

1.15.1 Communication Among Whom and Communication About What?

Communication on projects happens in different modes, which have many aspects to it, especially when dealing with numerous groups, levels, and areas of people. The form and type of communication is varied, from the written and verbal to communication of drawings, schedules, and 3D-models. Table 16. shows a sample of the various groups of stakeholders in a project among whom the communication takes place and the objects of communication, as emerging from this research study.

Table 16. Characteristics of Communication on SAGD Projects

Communication Among (parties)	Communication About (objects)
Reservoir Engineers	The Project
Drilling Engineers	Scope Definition
Geology Group	Schedule
Regulatory Group	Cost
Environmental Groups	Site Infrastructure
Finance	Material Deliveries
Construction	Equipment Packages
Engineering	Client Needs
Procurement	Procurement Plan
Construction	Material Requisitions
Vendors	Purchase Orders
Project Management	Project Charter
Project Controls	Project Goals
Ready for Operations (RFO) Group	Deliverables
Commissioning & Start-up (C&SU)	
Operations Group	

It should be noted that in Table 16., the parties or stakeholders among whom communication takes place are summarized at a high level; when they are drilled down or broken down into sub-categories, a large number of stakeholders can emanate from them; and like wise for the topics or object of communication. The table highlights the complexity of the communication process on a project. While tools, such as a RASCI chart, a matrix identifying roles and responsibilities of stakeholders, are used at the beginning of every project, they do not seem to help much. This survey's finding on communication breakdown is consistent with results of research done on other projects.

1.15.2 Why is Communication Important?

Communication, from a project perspective, is important because it helps the project's team members understand what needs to be done, how it will be done, who will do it, and the timeframe in which it needs to be completed. A large number of survey participants indicated that communication of the project scope is the most important area. The scope of a project defines what needs to be done on a project; it forms the basis of the work from which the goals, objectives, and deliverables are defined. With a well-communicated scope, all the project team members have the same view of the work to be done and the deliverables that need to be produced by the engineering, procurement, and construction groups.

At the same time, the engineering deliverables such as design and drawings from the scope cannot be produced in isolation from the stakeholders. For example, to determine the amount of steam production required to lift bitumen from the oil sands reservoirs, the reservoir engineering group needs to communicate the results of the reservoir studies to the process group so that the process engineers can design the surface facilities for steam production.

As well, the design produced by the process-engineering group has to be communicated back to the reservoir engineers so that they can confirm whether or not it meets the requirements of the reservoir conditions. Upon confirmation, the same information in the form of PFDs and P&IDs needs to be communicated by the process group to the mechanical engineering group to purchase the equipment; to the piping group to determine the liquid and gas inflows and outflows, pressure and temperature to design the piping layout of the surface facilities; the civil engineering group to design the piling and foundation required to set the vessels; to the instrument and controls group to design the controls systems to automate and operate the plant; and finally, the electrical group to determine the power requirements for the plant and to determine the design the routes for the power cables.

In parallel, information from the engineering disciplines has to be communicated to the procurement group so that they can start purchasing the equipment and materials, and to the construction group for planning to build the facility. This simple example of communication in a SAGD project highlights the number of players and specific details that have to be communicated. In addition any change to the design, data, or parameters has to be re-communicated to all the respective parties involved. Therefore, omitting any details or changes in the communication process to any of the players can create a snowball effect, potentially resulting in costly delays impacting the project.

1.15.3 Missed Communication

This can include a multitude of items including missed communications on drawings, such as P&IDs, plot plans, general arrangements, sketches, and other objects, such as project charters, schedules, purchase orders, cost estimates, etc. - all of which have significant information but are not explicitly communicated to the reader. For example, the fact that a Primavera schedule has been issued to an engineer or a project manager, does it necessarily mean that the receiver has understood which deliverables are critical and when do they have to be issued? Was the receiver apprised of its impact on other deliverables and on the engineering disciplines if they are not issued on time? It is therefore scheduler's role to communicate such issues impacting the project including the assumptions upon which the project completion dates have been derived. With complete communication, the receiver has a better understanding of the overall schedule, which can help the receiver in making better decisions.

In the same manner, many other documents are created on projects, which have similar nuances and implications to the above example but are not well communicated. It is assumed that the other person will understand what has been described or identified on paper. This is the crux of the communications conundrum, and which requires multiple solutions and strategies to resolve.

1.15.4 Root of the Communications Conundrum

There are multiple reasons for ineffective communications on projects, which can be explained based on anecdotal information and the authors' observations.

1.15.4.1 Large Volumes of Data from Software Tools

With the explosion of information on projects from using software tools such as AutoCAD for 3D-modelling, automated schedules on Primavera and enterprise systems such as SAP, an incredible volume of data is generated on projects. This information, together with the large number of drawings generated on projects, makes it difficult for the team members to keep up, which results in missed communication.

1.15.4.2 Cosmopolitan Societies

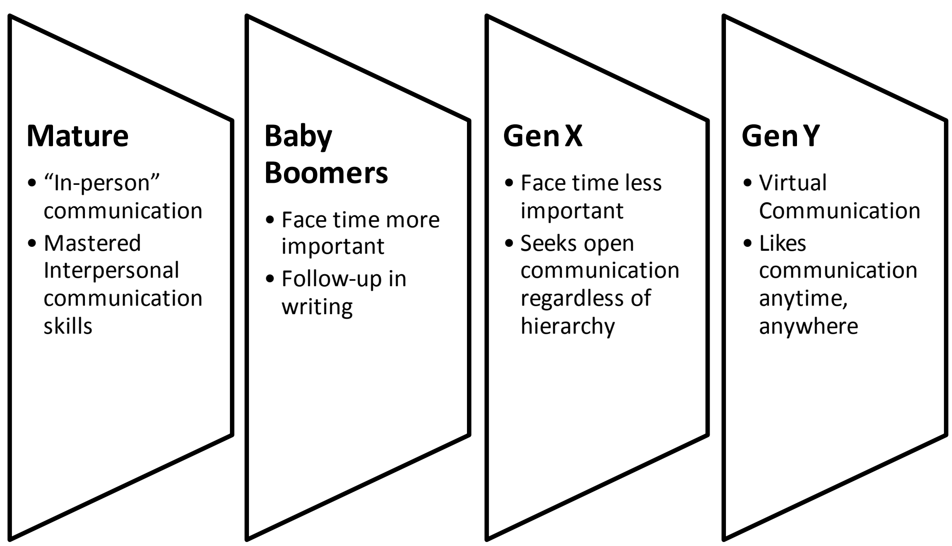
Communication on projects is affected due to people having different languages, cultural backgrounds, and experiences. Moreover, written or spoken words can have different meanings and connotations for various individuals, creating situations of miscommunication. This is a reality given the cosmopolitan societies in which we live.

1.15.4.3 Multigenerational Teams

The two factors mentioned earlier are compounded by the fact that projects have multi-generational team members, who have different styles of communication and prefer different tools to communicate with (Morlan & Gelbtuch, 2010). In an article entitled *Multigenerational teams and their impact in project management*, Morlan & Gelbtuch segment project teams into four different groups: *Mature*, referring to those born before the second World War; *Baby Boomers*, referring to those born after the war, from 1945 to 1964; *Gen X*, referring to those born between the mid-1960s to early 1980; and finally, *Gen Y*, referring to graduates of the new millennium.

According to the authors, these segments of generations have different styles of communication: the Mature segment at one end preferring "in-person" communication, while the Gen Y at the other end preferring virtual communication. Figure 15. adopted from Morlan & Gelbtuch (2010), illustrates the preferred communication styles among the different generations.

Figure 15. Preferred Communication Styles Among Generations



1.16 Conclusion

The results of the survey suggest that spending more time in front-end planning can significantly improve the project execution. This has been difficult bring about at times because of the external forces impacting projects, such as higher oil prices, which encourage changing the project's execution strategy. Getting vendor data on time is another major cause for concern in effective project execution. Delays in obtaining data are often due to the numerous sub-vendors and their vendors involved, over whom the owner exercises little control.

Other areas that lead to a high impact on effective execution of SAGD projects include the softer, but significantly important, areas of knowledge and experience of project management processes as well as communications between the various stakeholders on a project. Communication, which creates a major impact on projects, has been difficult to implement efficiently due to its various attributes, among which it is difficult to achieve a balance. One such attribute that creates imbalance is the preferred styles of communications among project team members, from the face-to face communication with the Mature segment to virtual communication between the Gen Y segment.

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