Controlling Sand Production Problem in Open-Hole Completion; a Case Study

by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

____
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UNIVERSITI TEKNOLOGI PETRONAS
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September 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

Sand Control is an activity that is very vital to when the well is in completion phase of an oil and gas field. This case study is going to quantify sand production risk and determine on how and when to implement control or prevention technique to optimize production and maximize return on investment by preventing or delaying sand production throughout the life of a well or field. This paper summarize the finding of information regarding factors, reasons, causes and methods related to sand production problems in open-hole completions will be explained in details later in the report. This case study may apply to the well or field with sanding problems, fields undergoing depletion and wells in unconsolidated formations. The achievement for this case study is to develop the Knowledge Based Systems (KBS) application to provide the most suitable sand control methods based on current technologies in Oil and Gas industries.

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LIST OF ABREVIATIONS

UTP	University Teknologi PETRONAS
DIF	Drill in Fluid
KBS	Knowledge Based System
PPG	Pound per Gallon
bbl/d	Barrels per Day
md	milliDarcy
mmcf/d	million cubic feet per day
ID	Inner Diameter

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Sand control define by (Halliburton, n.d.) is essential to the reliable production in many sandstone reservoirs where sand can exist and create a major obstacle to well production. The oil and gas industry have spends billions of dollars to prevent and repair sand related problems since this could cause an issue in reduced production rates, sand bridging, erosion of equipment, and sand disposal and removal.

Referring to (Perrin, 1999) the word “completion” itself means conclusion in the case that the well has just completed drilled. Another study stated that there are two classification type of well during production which are Open-Hole Completion and Cased Hole Completion (The Lease's Pumper Handbook, n.d.). This case study will focus on controlling sand production problem in open-hole completion. An open-hole completion refers to (Rigzone, 2013) is a well that is drilled to the top of the hydrocarbon reservoir. The well is then cased at this level, and left open at the bottom. It is also known as top sets and barefoot completions, open-hole completions are used to reduce the cost of casing where the reservoir is solid and well-known. Figure 1 (Wikipedia, 2013) demonstrate the proper location and labeling illustrations of Open Hole Completion Well.

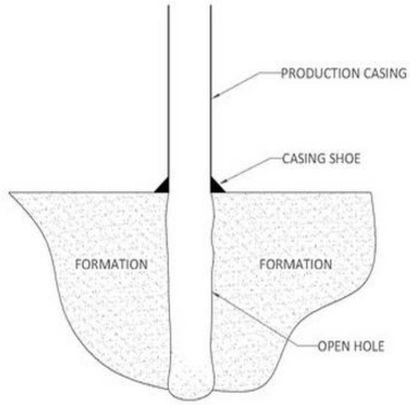

Figure 1.1: Open-Hole Completion Well
(Courtesy of Wikipedia)

This case study will analyze all the related problem according to sand production and the methods to solve it and translate all the information regarding sand control based on current technologies to Knowledge Based System application. Knowledge Based System that will help and ease the user or engineer to recognize the problems relates to sand production and how to solve it.

1.2 Problem Statement

Sand production associated with oil and gas wells is one of the oldest problems facing the petroleum industry. Operational problems related to sand production vary from expensive sand-handling problems to the complete loss of a production zone. In order to optimize the production of the oil and gas well, the operational problems and factors affecting sand production needs to identify. The challenge is to choose the suitable method to controlling the formation of the sand.

1.3 Objectives of the Study

The main objective of this project is to develop a Knowledge Based System regarding sand control and to propose the suitable method that are currently being use by Petroleum industry. Finding this relationship will help petroleum engineers to provide a better view and understanding of the related problem on sand production in open-hole completion well.

Apart from the specific objective, there are also some side objectives of this study which are:

1) To identify the operational problems related to and factors affecting sand production.
2) To identify and compare various methods of sand control.
3) To propose the most suitable methods for controlling sand related problem for the case study.

1.4 Scope of the Study

There are two type of completion methods that used on well which are Open-Hole Completion and Cased-Hole Completions. The scope of the study in this final year project is to focus on the sand control problem and their method in Open-Hole Completion well.

CHAPTER 2
LITERATURE REVIEW

2.1 Factors of Sand Control

Research shows that sand (or “fines”) production is always a problem in many oil and gas wells throughout the world. This problem can be encounter mechanically by a number of ways including the use of screens, gravel packing, frac-packing and modification to the perforation technique during completion stage (A.Kelland, 2009). According to Schlumberger personnel (Gomez, Introduction to Sand Control, 2006) stated that these are the mainly factors affect sand production from a producing formation which are:

1. Overburden, friction, and differential stresses in the formation
2. The amount of cementitious material in the formation plus the degree of consolidation of the rock
3. Fluid velocity, production velocity, and drag forces caused by the moving fluid in the well
4. Capillary forces and wettability in the formation.

While based on the research by (William K. Ott & Woods, 2003) state that the solid material produced from a well can consist of both formation fines and load bearing solids and the factors that influence the tendency of a well to produce sand are as per below:

1. Degree of formation consolidation
2. Reduction in pore pressure through-out the life of the well
3. Production rate
4. Reservoir fluid viscosity - Increase of water production

So basically, if the formations where the sand is porous, permeable and well cemented together, large volumes of oil and gas can flow easily through the sand and into production wells, and that is good news as shown in Figure 2.1. But if the sand formations are so poorly cemented that the sand flows into the wells too, there could be trouble ahead. When it reaches the surface, sand can damage equipment such as valves, pipelines, pumps and separators. It can also lead to poor performance in wells and, ultimately lost the production (BP, 2008).

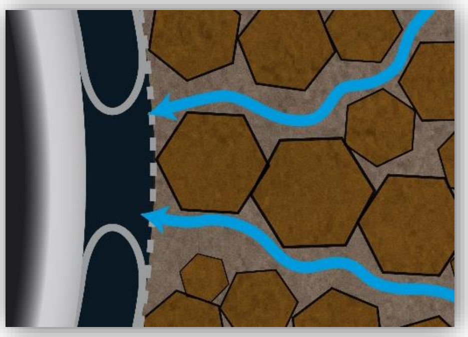

Figure 2.1: Illustration Permeability of Sand
(Courtesy of Schlumberger)

2.2 Reasons for Sand Control

According to Schlumberger (Gomez, Introduction To Sand Control, 2006) research, the reasons for sand control is required are to prevent the operational problems associated with sand production, including;

- Sand bridges
- Sand erosion
- Casing or liner failure
- Sand disposal.

2.3 Consequences of Sand Production

The consequences of sand production are always detrimental to the short-long-term productivity of the well. Although some wells routinely experience manageable sand production, these are the exception rather than the rule. In most cases, attempting to manage sand production over the life of the well is not an attractive or prudent operating alternative.

2.3.1 Accumulation Downhole

If the production velocity in well tubulars is insufficient to transport sand to the surface, it will begin to fill the inside of the casing. Eventually, the producing interval may be completely covered with sand. In this case, the production rate will decline until the well becomes "sanded up" and production ceases. In situations like this, remedial operations are required to clean out the well and restore productivity. One cleanout technique is to run a "bailer" on a wireline to remove the sand from the production tubing or casing. Because the bailer removes only a small volume of sand at a time, multiple wireline runs are necessary to clean out the well. Another cleanout operation involves running a smaller diameter tubing string or coiled tubing down into the production tubing to agitate the sand and lift it out of the well by circulating fluid. The inner string is progressively lowered while circulating the sand out of the well. This operation must be performed cautiously to avoid the possibility of sticking the inner string inside the production tubing. If the production of sand is continuous, the cleanout operations may be required periodically, as often as monthly or even weekly, resulting in lost production and increased well maintenance costs.

2.3.2 Accumulation in Surface Equipment

If the production velocity is sufficient to transport sand to the surface, the sand may still become trapped in the separator, heater treater, or production flowline. If enough sand becomes trapped in one of these areas, cleaning will be required to allow for efficient production of the well. To restore production, the well must be shut in, the surface equipment opened, and the sand manually removed. In addition to the cleanout cost, the cost of the deferred production must be considered.

2.3.3 Erosion of downhole and surface equipment

If fluids are in turbulent flow, such sand-laden fluids are highly erosive. Figure 2.2 is a photograph of a section of eroded well screen exposed to a perforation that was producing sand. Figure 2.3 shows a surface choke that failed because of erosion. If the erosion is severe or occurs long enough, complete failure of surface and/or downhole equipment may occur, resulting in critical safety and environmental problems as well as deferred production.

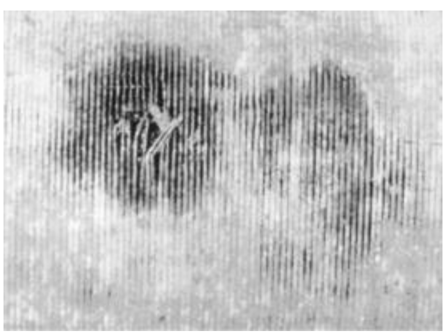

Figure 2.2: Wire-wrapped screen failure (Courtesy of Baker Oil Tools)

Figure 2.3: Surface choke failure (Courtesy of Baker Oil Tools)

2.3.4 Collapse of the formation

Collapse of the formation around the well occurs when large volumes of sand are produced. Apparently, when a void is formed and becomes large enough to inadequately support overlying formations, collapse occurs because of a lack of material to provide support. When the collapse occurs, the sand grains rearrange themselves to create a lower permeability than originally existed. This is especially true for formation sand that has a high clay content or wide range of grain sizes. For a formation with a narrow grain-size distribution (well sorted) and/or very little clay, the rearrangement of formation sand causes a decrease in permeability that is not as severe.

In the case of the overlying shale collapsing, complete loss of productivity is probable. In most cases, continued long-term production of formation sand usually decreases the well's productivity and ultimate recovery. The collapse of the formation particularly becomes critical to well productivity if the formation material fills the perforation tunnels. Even a small amount of formation material filling the perforation tunnels will lead to a significant increase in pressure drop across the formation near the wellbore for a given flow rate. Considering these consequences of sand production, the desired solution to sand production is to control it downhole. Compaction of the reservoir rock may occur as a result of reduced pore pressure leading to surface subsidence.
Examples of subsidence, caused by withdrawals of fluids and reduced pore pressure, are found in:

- Venezuela
- Long Beach, California
- Gulf Coast of Texas
- Ekofisk Field in the central North Sea, where the platforms sank about 10 ft.

2.4 Methods of Sand Control

One study found that the most popular options for completing sand production or sand prone physically restrain the sand movement (Carlson, Gurley, King, Price-Smith, & Waters, 1992). Gomez, Bernadette (2006) stated that several methods are currently available to control the production of sand. The most common methods currently in use include:

1. Production rate restriction
2. In-situ consolidation
3. Resin-coated gravel packing
4. Gravel packing
5. Natural sand packing (Using Screens)
6. Fracturing the formation

Figure 2.4 demonstrate the illustration of an anatomy of cased-hole gravel pack (Carlson et al., 1992).

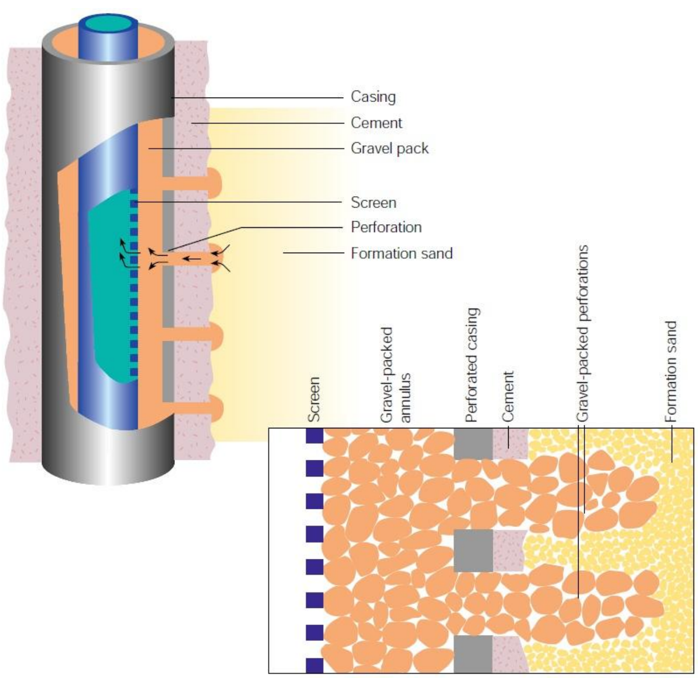

Figure 2.4: Anatomy of Cased-Hole Gravel Pack
(Courtesy of Schlumberger)

2.4.1 Production Rate Restriction

Some weak formations have enough strength to produce sand-free at low production rates. However, as production rates increase, drag forces increases and the formation could start producing sand. Sand production is frequently preceded by water production, which significantly alters the formation properties. If production must be constrained to avoid sanding, the completion is generally considered a failure.

2.4.2 In-Situ Consolidation

According to (Gomez, Introduction To Sand Control, 2006) In-situ consolidation involves the use of pressure and/or chemicals (e.g., resins) to improve the consolidation of the formation without reducing the permeability of the formation. In other word In-Situ Consolidation involves the use of resins as bonding material to cement the grains of formation sand several feet around the wellbore, so that formation fluids can be produced sand-free. Figure 2.5 below shows In-Situ consolidation.

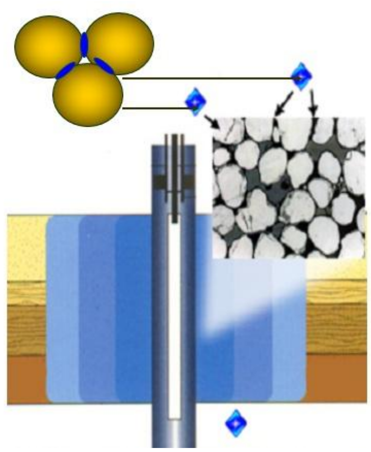

Figure 2.5: In-Situ Consolidation
(Courtesy of Schlumberger)

2.4.3 Resin Coated Gravel Packing

Gravel coated with resin is another sand-control/proppant flowback technique used as a screenless completion alternative. Figure 2.6 shows the method of resin coated gravel packing. Gravel and resin or resin-coated particles are injected and left in the perforations and wellbore. So basically, Resin Coated Gravel Packing according to (Gomez, Introduction To Sand Control, 2006) are;

- Proppant (Gravel) is precoated with resin material.
- Particles are mixed with viscous gel and pumped into the formation.
- Particles are contacted grain-to-grain.
- Temperature + H2O fuses the particles together into a consolidated permeable, drillable network

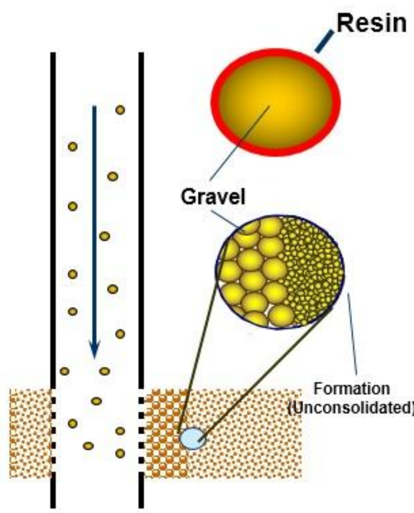

Figure 2.6: Resin Coated Gravel Packing
(Courtesy of Schlumberger)

2.4.4 Gravel Packing

Gravel Pack is the most popular technique used in sand control. It was used for water wells before it was used in the oil and gas industry. It involves running downhole a mechanical device, such as screens or slotted liners and place an accurately sized gravel around the screen or slotted liner. This placement allows the entry of fluids through the gravel but filters the formation sand from the flow stream so that sand-free production is possible. However, in all gravel packs a small amount of solids is produced, but it consists in very fine particles that can move through the gravel throats. When performed properly, the gravel pack yields long-life, high productivity completions. Figure 2.7 below illustrated the gravel pack completion (Woods & K.Ott, 2003).

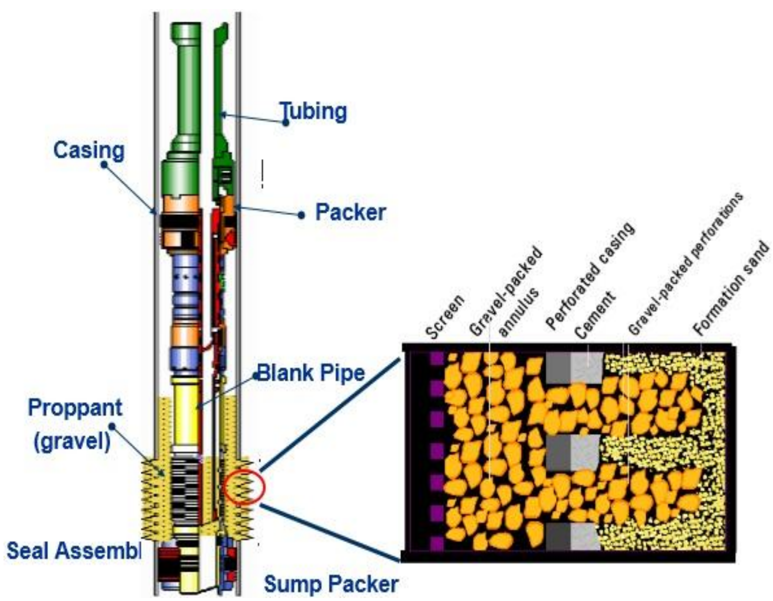

Figure 2.7: Gravel Pack Completion
(Courtesy of Schlumberger)

Open-hole gravel packing is a common completion technique in many areas of the world, such as California, Canada, Bolivia, Venezuela, Brunei, China, Indonesia, Malaysia, and Nigeria; and in some wells in the Gulf of Mexico and the North Sea. However, there are advantages and disadvantages of open-hole gravel packing, and an understanding of these factors will assist in selecting the completion technique to use where a choice is possible.

Advantages of open-hole gravel packing include:

- Easiest type of gravel pack to place because of the large annular space between the screen and the formation. Since gravel does not have to be carried through perforations, this technique presents minimal gravel transport problems.
- Highest theoretical productivity because there are no perforation tunnels filled with gravel, sand or dirt to restrict flow.
- Lowest possible velocity for produced fluids flowing through the gravel pack. Usually less expensive because it eliminates some casing and cementing costs.

Disadvantages of open-hole gravel packing include:

- More difficult to control unwanted water or gas production, or injection into thief zones, within the completion interval.
- Hole stability during placement of the gravel is often a problem, which may result in sand filling the annulus around the screen before the gravel is placed.
- Screen is more easily plugged with formation sand during gravel placement than in cased-hole completions.
- The underreaming process may cause additional formation damage.
- Generally limited to a bottom interval in multiple zone completions.
- Sloughing problems may occur at the casing to open-hole interface.

Most open-hole completions are underreamed before they are gravel packed. The underreaming usually increases the diameter of the borehole to approximately twice the casing inside diameter (ID). Usually casing is set above the productive zone, but sometimes casing is set through all productive intervals. Then, a window or windows are milled out through the zones to be gravel packed. Underreaming (Figure 2.8) is defined as enlarging a wellbore past its original drilled size.

It serves two purposes:

1. Provides a larger wellbore diameter for slightly increased theoretical productivity and
2. Removes mud cake and mud invasion damage. Unfortunately, the underreaming process, as it is commonly practiced, may cause as much formation damage as it removes due to the combination of fluid loss additives, dirt in the fluid and formation fines that are recirculated with the underreaming fluid.

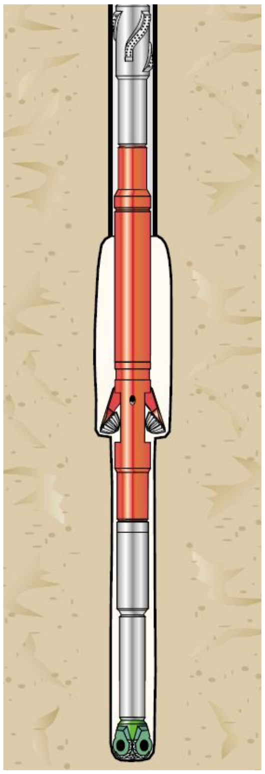

Figure 2.8: Underreaming Operation
(Courtesy of Schlumberger)

2.4.5 Natural Sand Packing (Using Screens)

Natural sand packing is also known as Stand Alone Screens. Installation of a screen system (without the use of particles) can be done in either cased or open holes. Screens have been the main option for sand control in horizontal or highly deviated wells. The screen system may be;

- a slotted liner
- a prepack screen
- a wire-wrapped screen
- premium screen

Since the screen prevents the passage of sand into the production tubing, the annular space is eventually filled with the blocked formation sand. On the other hand, if sand is allowed to flow through the screen, screen erosion may occur, leading to a higher sand-production rate and, consequently, to failure of the completion according to (Woods & K.Ott, 2003). Figure 2.9 illustrates a typical installation of screens in horizontal open-hole completion (Woods & K.Ott, 2003).

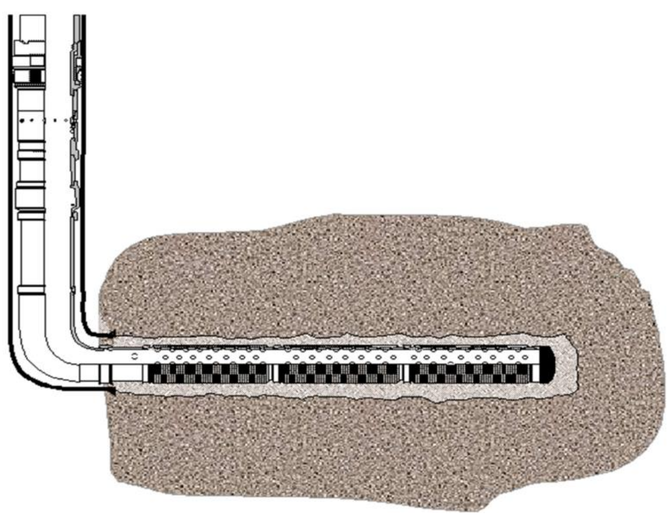

Figure 2.9: Installation of Screens in open-hole
(Courtesy of Schlumberger)

2.4.6 Fracturing the formation

Fracturing is performed to bypass formation damage so that the well produces from an undamaged area. Figure 2.10 illustrate the how fracturing works. By using this methods it can;

- bypasses formation damage
- restores formation stress
- reduces matrix flow velocity
- connects reservoir layers
- Stimulates the well.

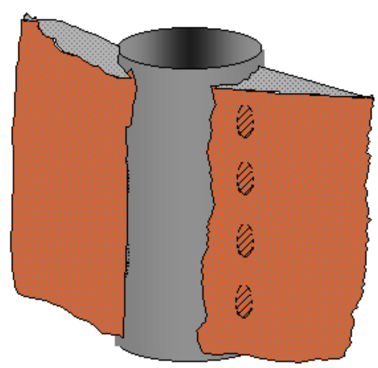

Figure 2.10: Fracturing the formation
(Courtesy of Schlumberger)

2.5 Types of Well Conditions for Open-Hole Completion

Well are divided into two categories which are Vertical Well and Horizontal or Deviated Well. In this case studies, both of the categories will be explain in brief regarding the technique for sand control.

2.5.1 Vertical Wells

Reverse circulation gravel packing (Figure 2.11) was one of the early technique used before the development of the crossover tool. It was frequently used in relatively short, open-hole intervals where there was minimum deviation and separation of zones was not necessary. It is not as popular today because of the following problems:

- Requires large volumes of fluid
- Potential pack damage due casing debris during annular gravel placement
- Potential pack damage due to mixing gravel with filter cake and formation sand.

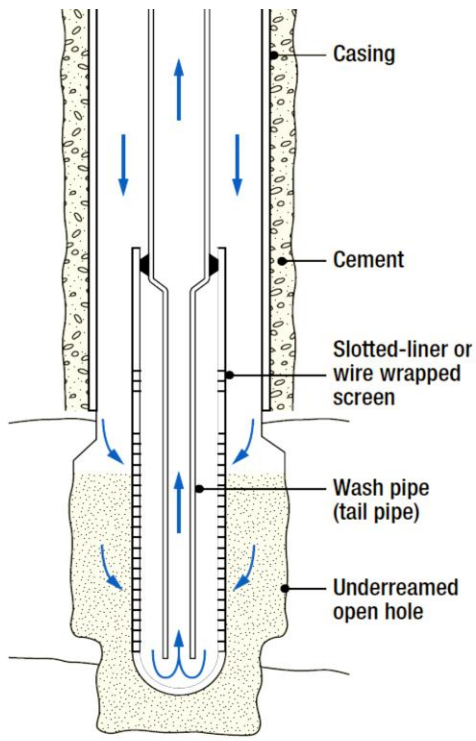

Figure 2.11: Reverse circulation, open-hole
(Courtesy of Schlumberger)

a) Low-Pressure and Shallow Wells

For low-pressure, shallow wells, one popular version of the crossover method, which has been around for decades, is the “over-the-top” system. It uses a downward cup-type pack above the crossover tool.

- Over the Top Gravel Pack Tool

The Over the Top gravel pack tool is designed to place gravel by a crossover circulating method when running screen or liner on a landing nipple. The lefthand square thread on the release nut attaches to the landing nipple while the two down-facing packer cups direct flow down the screen/casing annulus. During gravel packing, the slurry flows out the crossover port below the packer cups, and over the landing nipple to the screen casing annulus. Returns are taken through the screen or slotted liner, into the tailpipe, through the bypass ports above the cups, and up the annulus. Upon completing the gravel packing process, excess slurry is reversed from the workstring by pumping down the annulus over the packer cups and into the gravel pack port. A check valve prevents fluid from flowing into the ID of the slotted liner or screen. Figure 2.12 shows the Over the Top Gravel Pack Tool.

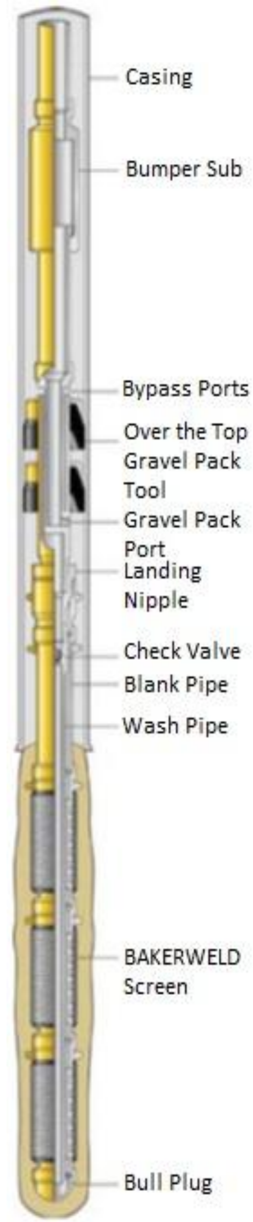

Figure 2.12: Over the Top Gravel Pack Tool
(Courtesy of Baker Hughes)

Gravel is placed below a cup-type service packer (Figure 2.13). For reversing, clean fluids are pumped past the cup packer and back up the tubing. The cup packer is then pulled, and an inexpensive 0-ring or Chevron seal overshot is landed into the top of the screen (Figure 2.14).

Figure 2.13: Mechanical set cup-type packer (Courtesy of Schlumberger)

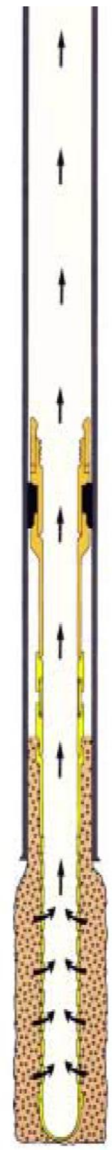

Figure 2.14: Liner sealed to casing with O-ring (Courtesy of Schlumberger)

b) High-Pressure Well

In many cases the production packer is required as an integral part of a high-pressure well completion. (Figure 2.15) illustrates a modern gravel-pack tool being used to circulate a pack into place in an underreamed hole, with fill-up to be indicated with an upper, tell-tale screen. Special equipment that may be used in open-hole gravel packing includes port collars, inflatable packers and combination tools.

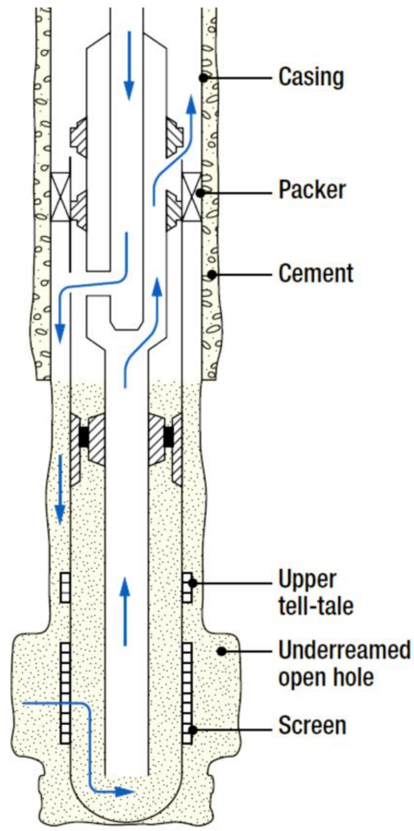

Figure 2.15: Open-hole, low-viscosity, low density,
(Courtesy of Schlumberger)

In a vertical open-hole well, the gravel-packing screen and tool hookup should typically be as follows (starting on the bull plug on the bottom):

1. Approximately 5 to 10 ft. (1.52 to 3.05 m) of blank liner will allow for some sloughing of formation sand between the times the screen is on bottom and the time the gravel is placed. A 5 ft. (1.52 m) blank is probably enough for relatively strong (friable) formations and 10 ft. (3.05 m) should be used for weaker formations.
2. Approximately 5 ft. (1.52 m) lower tell-tale screen and seal bore above it will indicate sand fill, screen plugging and when gravel reaches the bottom of the well.
3. Slotted liner or screen from the lower blank liner to within 10 ft. (3.05 m) below the top of the underreamed hole section.
4. At least 10 ft. (3.05 m) of blank liner, or 10% of the total open-hole length if the total open-hole length is more than 100 ft. (30.48 m). This allows reserve gravel to be placed inside the underreamed hole so that the gravel may settle without exposing the screen or slotted liner to direct contact with the formation.
5. About 20 to 30 ft. (6.10 to 9.14 m) of blank liner up in the casing.
6. Approximately 5 ft. (1.52 m) upper tell-tale screen, only if conventional gravel packing placement technique is used.
7. Approximately 5 to 10 ft. (1.52 to 3.05 m) of blank liner.
8. Crossover tool assembly and packer.
9. Washpipe or stinger hanging from the crossover tool with its bottom in the seal assembly, if a lower tell-tale screen is used (otherwise hanging just to near the bottom of the main screen).
10. Bow-spring centralizers spaced out every 15 ft. (4.57 m) in the open hole, starting with one on the lower blank liner.
11. Steel-wing centralizers should be used on the upper blank liner in the casing.

A simplified illustration of this assembly, but without the lower tell-tale screen, is illustrated in (Figure 2.16).

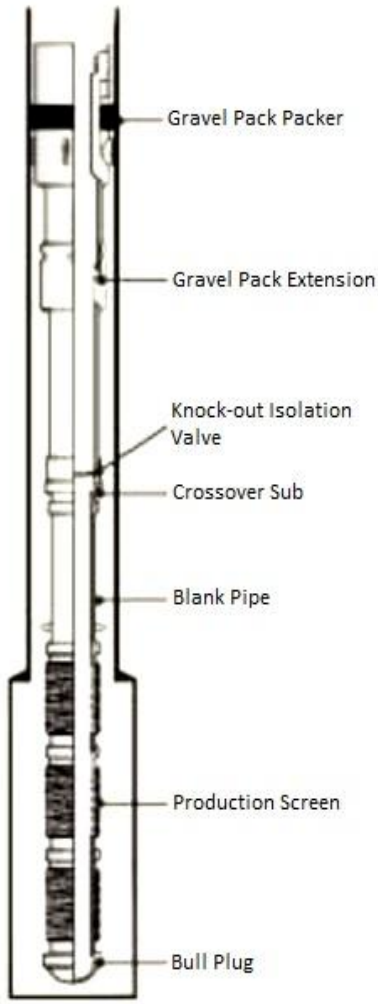

Figure 2.16: Typical vertical open-hole
(Courtesy of Schlumberger)

2.5.2 Horizontal or Deviated Wells

An exact definition of a horizontal well is a drilled hole achieving a deviation angle of 90° from vertical. In application, the technology is much broader than this, and well profiles with deviation angles exceeding ±70° (highly deviated) are often referred to as "horizontal" if the length of the wellbore within the producing formation is many times greater than the thickness of the producing formation.

Gravel packing is the option to standalone screens, for completing horizontal wells in unconsolidated formations. While this technology is more complicated and sophisticated than slotted liners, wire-wrapped screens, prepacked screens or premium screens, it is a more general-purpose completion for horizontal wells where sand control presents a problem. While using slotted liners, wire-wrapped screens, prepacked screens or premium screens may be applicable only for certain wells; a gravel pack can be used on almost any horizontal completion provided that sound gravel placement guidelines are followed.

Additionally, this technique is believed to meet the challenge of completing high volume producers (>15,000 bbl/d in oil wells or >70 mmcf/d in gas wells) in high permeability formations with well lives of up to 15 years.

Some studies believe that gravel packing long, horizontal wellbores should only be considered if it will improve well productivity or stability. The combination of high angle and long interval is very difficult to gravel pack successfully without trapping a lot of formation damage in place. If gravel packing is not done, the formation sand may eventually fill the screen/hole annulus when the well is on production. This will not significantly reduce the well productivity, if the permeability of the sand remains nearly equal to that of the undamaged formation sand.

However, if mud cake and formation mix reduces the permeability of the sand in the annulus from 1,000 to 100 md, the well productivity may be reduced by approximately 24%. Because it is highly unlikely that it will occur in a horizontal wellbore, sand and shale mixing will not reduce gravel permeability. Theoretically, the impairment of well productivity will be less if gravel prevents the screen/casing annulus from filling with low permeability. However, more damage to the formation may be done by fluid-loss-control solids and polymer during the gravel pack, which will result in severe impairment.

Gravel packing has not been widely used in horizontal wells until the last decade or so, but results since then have been promising. The reason for the initial lack of use appears to have been reluctance on the part of operating companies to try a long, horizontal gravel pack because of the perception that the technology is not available to place gravel over an interval of several thousand feet with success.

The industry has long recognized the difficulties of successfully gravel packing long, highly deviated conventional wells using viscous gravel carrier fluids. Since horizontal wells represent the ultimate long, highly deviated well, a reluctance to gravel pack is well founded.

At the time horizontal wells were beginning to be drilled in unconsolidated formations, viscous gel carrier fluids represented the state-of-the-art in gravel-packing technology. Research and studies in physical models confirm that performing a successful gravel pack in a horizontal well using viscous gravel carrier fluids is extremely difficult.

Research and studies in physical models confirm that performing a successful gravel pack in a horizontal well using brine is possible. It is widely believed that by stabilizing the formation sand, gravel packing increases the reliability and longevity of sand control completions in highly deviated and horizontal wells.

An additional driver for open-hole gravel packing is the productivity limitations of the cased-hole frac-packing technique in high transmissibility formations. Although open-hole gravel packing of horizontal wells extends well life, achieving a high-productivity, sand-free completion involves a number of considerations in the design and execution stages.

CHAPTER 3

METHODOLOGY

3.1 Project Flow

This chapter will cover the details explanation of methodology that is being used to make this project achieve the objective. Figure 3.1 shows the project flowchart.

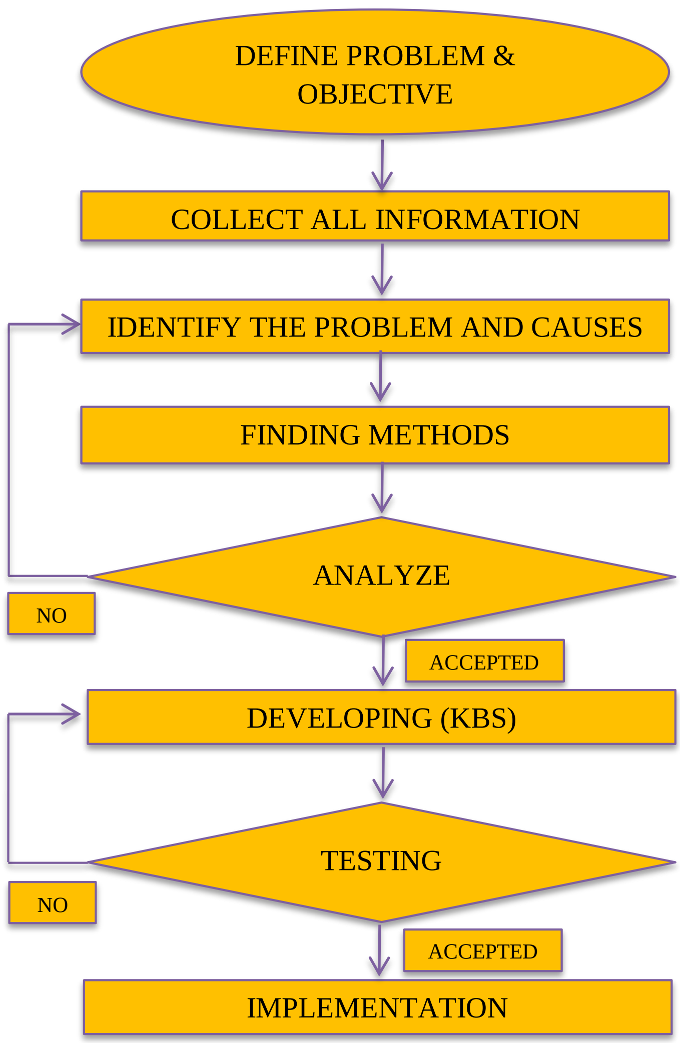

Figure 3.1: Project Flow Chart

3.2 Gantt Chart FYP I and FYP II

The following week will be on the development of the KBS. The data then will be analyzed to choose the best method and suggestion for the related problem regarding sand control. All the information regarding factors and methods will then be recorded in the Macromedia Authorware to implement the Knowledge Based System. Mentioned above are the planned activities for the FYP II durations. The work breakdown structure for this final year project are illustrated in Appendix 1-1 for FYP I Gantt Chart and Appendix 1-2 for FYP II Gantt Chart.

3.3 Project Activities

This final year project is divided into three categories in order to implement the project starting from identify, finding and develop.

3.4 Identify Problems and Causes

To identify all the operational problems related to and factors affecting sand production. The Identify phase have two main elements namely causes and effects of the sand production. This research is based on through several sources such as text books, journal, paper references, the Internet and from various company information due to get the information about the project related.

3.4.1 Fishbone or Ishikawa Diagram

To identify the causes and effects, the fishbone diagram also known as the Ishikawa diagram is used to provide a better visual representation of the analysis and helps to focus on specific cause categories. Figure 3.2 shows Fishbone or Ishikawa diagram example.

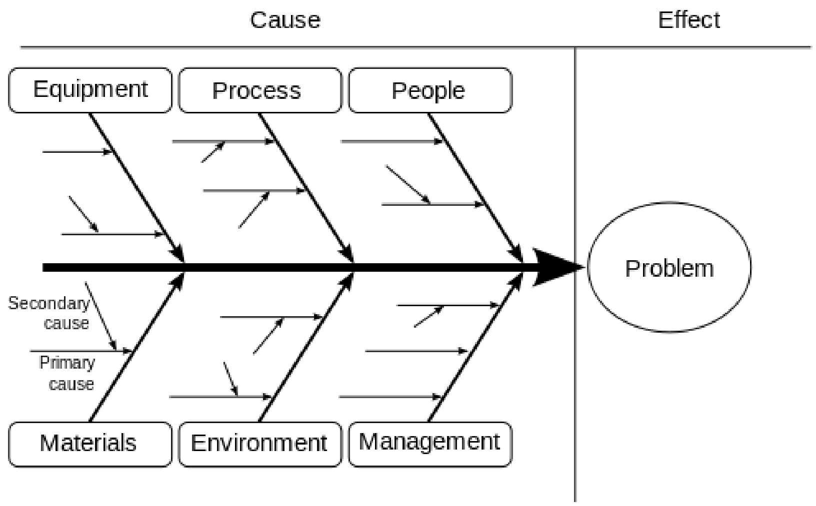

Figure 3.2: Fishbone or Ishikawa Diagram Example
(Courtesy of Wikipedia)

3.4.2 Flow Chart Diagram

Flowchart is used to represents the process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. This diagrammatic representation illustrates a solution to the open-hole completion steps. Process operations are represented in these boxes, and arrows; rather, they are implied by the sequencing of operations. Figure 3.3 below shows flow chart diagram example.

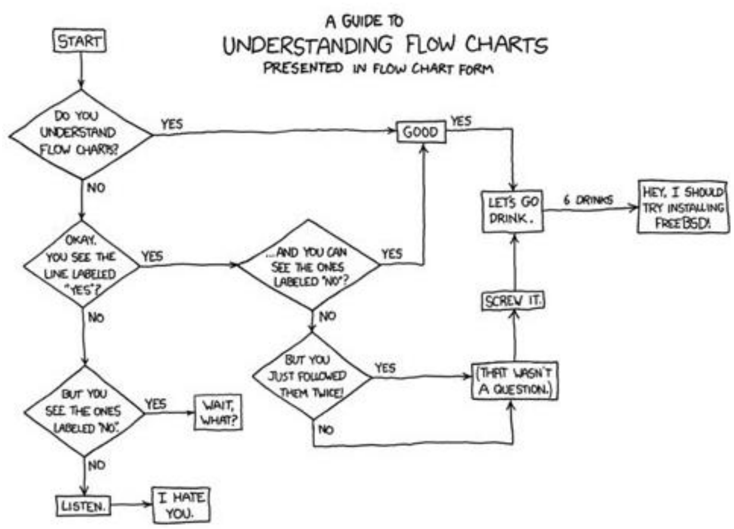

Figure 3.3: Flow Chart Diagram Example
(Courtesy of Wikipedia)

3.5 Finding Methods

Several methods for controlling sand production were compare after all the related problems have been identify. This methods consists of current technologies of different Oil and Gas Company.

3.5.1 Interview

Interview with the Sand Controls Engineer's or Specialists on how they prevented the sand production and what are the sand controls tools or equipment's that they are using and planning to have an interview sessions with Schlumberger personnel for this case study.

3.6 Develop

The final stage is to develop Knowledge Based Systems (KBS) application after all the data and analysis have been collected to make ease for future references regarding sand controls in Open-Hole Completions. This KBS will provide the user to click and choose their preferences of the suitable methods regarding sand production. These are the components of platform software to develop the KBS which are:

1. Macromedia Authorware 7
2. Microsoft Excel
3. Microsoft Access
4. Visual Basic Application

CHAPTER 4
RESULT AND DISCUSSION

4.1 Discussion

The following chapter will discuss the finding of operational problems and condition of the vertical and horizontal open-hole completion well. The method for sand control in different operating well condition have been extracted thru the thorough feasibilities studies from various references and company is conclude in this chapter.

4.2 Fishbone or Ishikawa Diagram

To provide a better visual representation of the cause and effects of the sanding formation in the well and helps to focus on specific cause categories, fishbone or Ishikawa diagram were use in this finding. Figure 4.1 shows the causes that influences the tendency of well to produce sand.

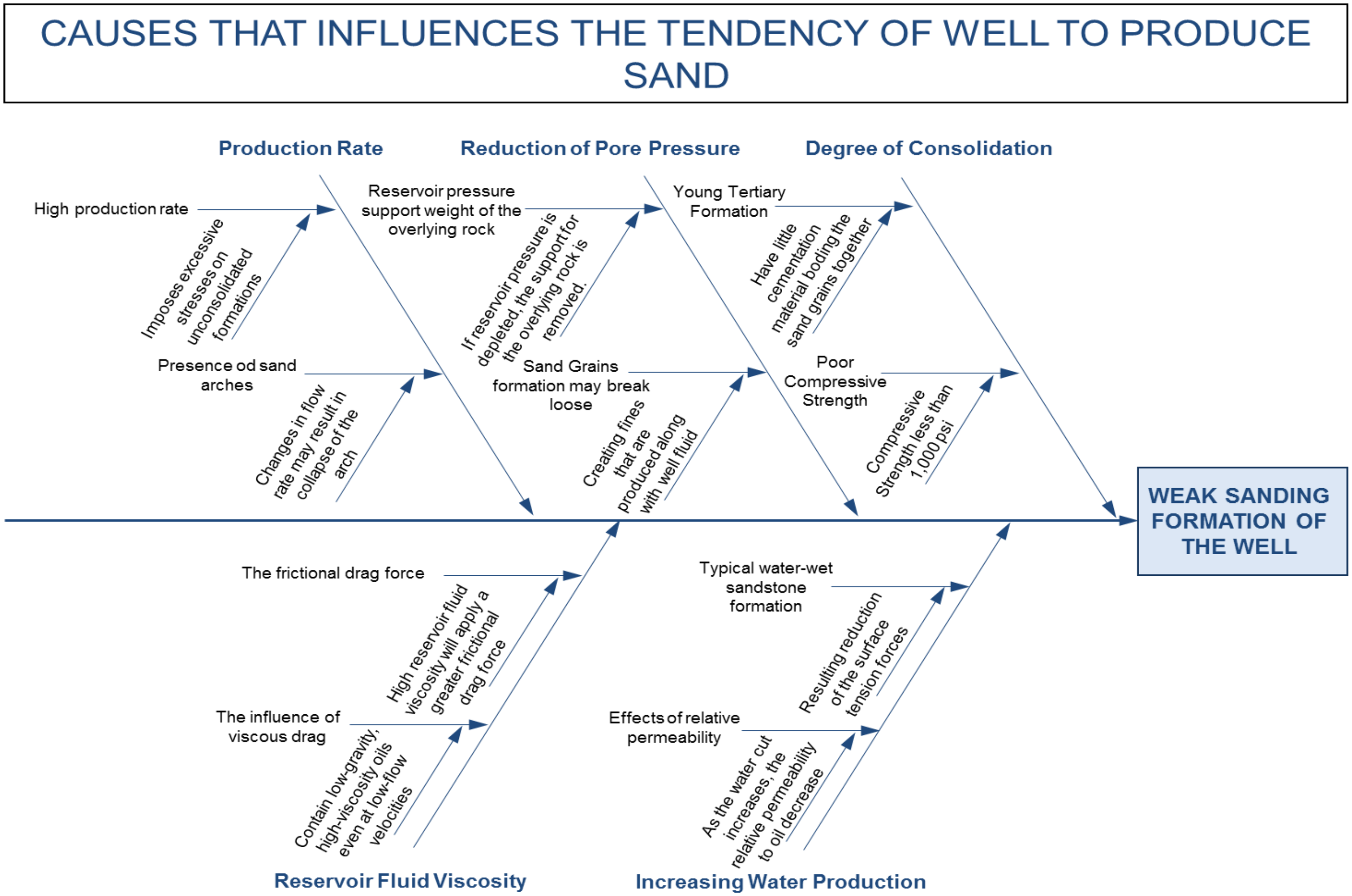

Figure 4.1: Causes that influences the tendency of well to produce sand

4.3 Sand Control Method Selection Flow Chart

To provide a better view interaction of the decision process to select the optimum completion a flow chart were use in this finding. Often a good sand prediction model analysis is essential for the optimal selection of the completion program. Figure 4.2 shows a flow chart to find sand production problems and methods.

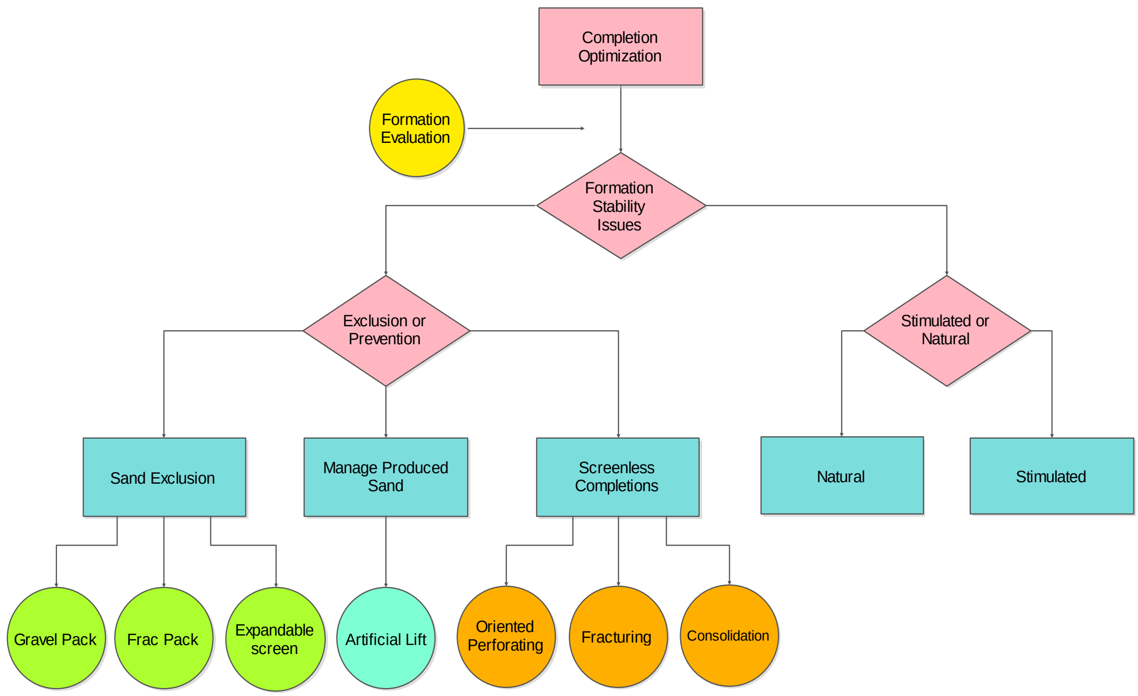

Figure 4.2: Sand Control Methods Selection Flow Chart

4.4 Open-Hole Completion Guide Flow Chart

Flow chart in Figure 4.3 shows the selection of the methods to use in open-hole completion. The selection is consist of set of question and the method to solve the problem depend on the well and sand characteristic. The finding of this steps is gather from Schlumberger Field Specialist Sand Control.

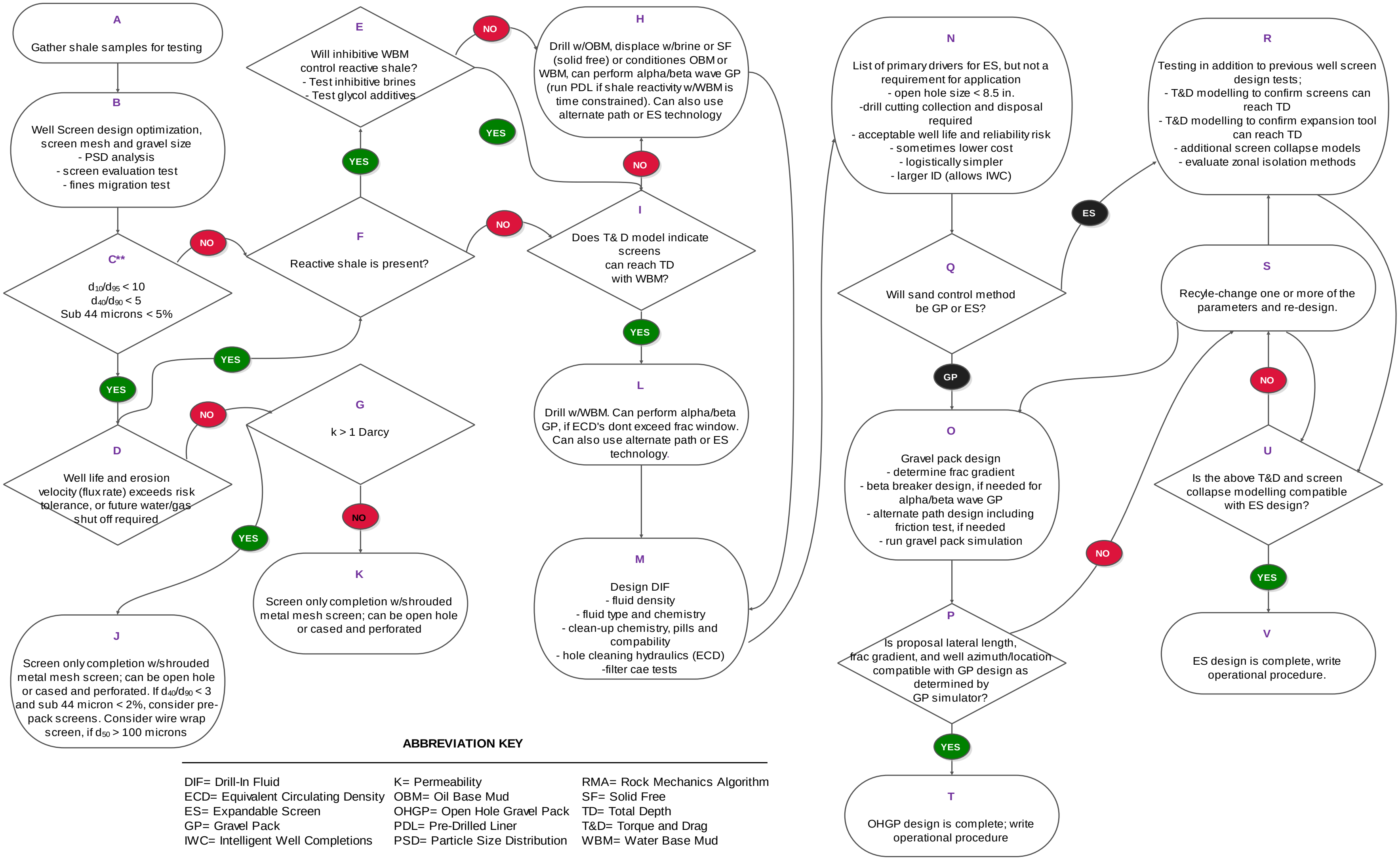

Figure 4.3: Open-Hole Completion Guide Flow Chart

4.5 Interview Result

For a better understanding and analysis for this final year project, the interview session have been conducted to gain some knowledge and useful information regarding sand control in open-hole completion. The interview session was done via phone due to the respondent is located in Labuan, Sabah.

The name of the interviewee is Mohd Jamal Ataillah bin Azman currently a Field Specialist Supervisor Sand Control Tools, Schlumberger. Below are the result from the interview session that been recorded.

Question 1

Author: What is the methods for sand control used in Schlumberger?

Mr. Jamal: There 6 types of methods that been apply in Schlumberger which are;

1. Production rate restriction
2. In-situ consolidation
3. Resin-coated gravel packing
4. Gravel packing
5. Natural sand packing (screens)
6. Fracturing.

Question 2

Author: How long is normally the duration of the tools or methods that been used to hold the formation can avoid the sand from entering the tubing again?

Mr. Jamal: Normally if there is no problem during running the tools in the well the duration that the method used can hold up to 20 year of production.

Question 3

Author: What is the best method in sand control?

Mr. Jamal: The best method in sand control is gravel pack. Actually all the methods depends on well condition and client needs.

Question 4

Author: Which method is the cheapest and expensive in term of cost?

Mr. Jamal: The cheapest method is restricting the production rate which is limiting production flow rate at the rig platform. This method is actually not preferable because let say if the production rate can produce 1000 Barrel per day by restricting the production rate it may produce only 600 Barrel per day. The most expensive method are Fracturing and In-Situ Consolidation method. This method are expensive since it involve with mixing complex chemical into the well.

Question 5

Author: What are the installation method in open-hole sand control?

Mr. Jamal: The typical installation method for open-hole, horizontal gravel pack are:

1) Drill open-hole with formation compatible fluid designed to be non-damaging to the payzone and establish a nearly impermeable filter cake that allows fluid return to almost equal the pumping rate.
2) Circulate the hole clean and displace open hole with solids-free DIF (Drill in Fluid).
3) Run in hole with bottom gravel pack assembly. Figure 4.4 illustrates a simplified assembly (Woods & K.Ott, 2003).

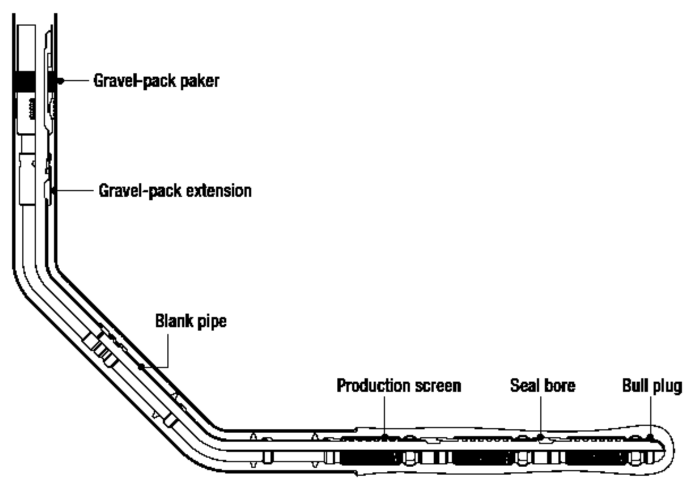

Figure 4.4: Horizontal Open-Hole

4) Flush-joint wash pipe is run in the screen assembly till it engages to the receptacle of the isolation plug.
5) The retrievable packer, closing sleeve with upper and lower extensions threaded to the gravel pack service tool is picked up and made up to the wash pipe as well as screens.
6) The entire packer assembly is run in the well on drill pipe until the packer reaches setting depth inside the liner and screens are in open hole.
7) After reaching the target depth the circulation test is perform to make sure the open hole is in stable condition.
8) Set the gravel-pack packer.
9) Test the packer by pressuring the annulus, then apply an upward pull and slack off.
10) Mark positions and pump the gravel slurry at a concentration of no more than 1.5 ppg.

Question 6

Author: What are the calculation involved to control the formation of sand?

Mr. Jamal: There are two type of calculation actually involved in sand control;

a) Hydrostatic Pressure

Hydrostatic pressure is defined as the pressure exerted by a column of fluid. The pressure is a function of the average fluid density and the vertical height or depth of the fluid column.

$$HP = g \times \rho_f \times D$$

Where:

HP = hydrostatic pressure
g = gravitational acceleration
ρ_f = average fluid density
D = true vertical depth or height of the column

b) Gravel pack sand size

In practice, the proper gravel pack sand size is selected by multiplying the median grain size of the formation sand by four and eight to achieve a gravel pack sand size range whose average is six times larger than the median grain size of the formation sand. This calculated gravel pack sand size range is compared to the available commercial grades of gravel pack sand. The available gravel pack sand that matches the calculated gravel pack size range is than selected.

Question 7

Author: If knowledge Based Systems (KBS) is being develop is it useful for the completion engineer?

Mr. Jamal: Yes. As far as I know that kind of software doesn't been develop yet and it will be very useful to us that involve in this kind of field. It will also help us and new recruit to have a better understanding and overview of sand control since all the learning is done manually from reading the operating manual.

4.6 Developing Knowledge Based System (KBS)

A research and practice have been done from the list of software application platform option to build this KBS. From the practice that have been done, the most suitable platform to build this Knowledge Based System is Macromedia Authorware 7. All the finding from the studies have been translate in the KBS with an interactive user interface. Four main button are created (Content, Objective, Find and Quit Button) for the Engineers/Users to click and providing all the information needed for the sand control in open-hole completion including all the methods that need to be used for a certain well condition. The content of this KBS are divided into three main categories which are; Introduction, Sand Controls and Guide for Open-Hole Completion. This KBS can be edited for further new information that need to be put inside the software. Figure 4.5 below shows the Macromedia Authorware.

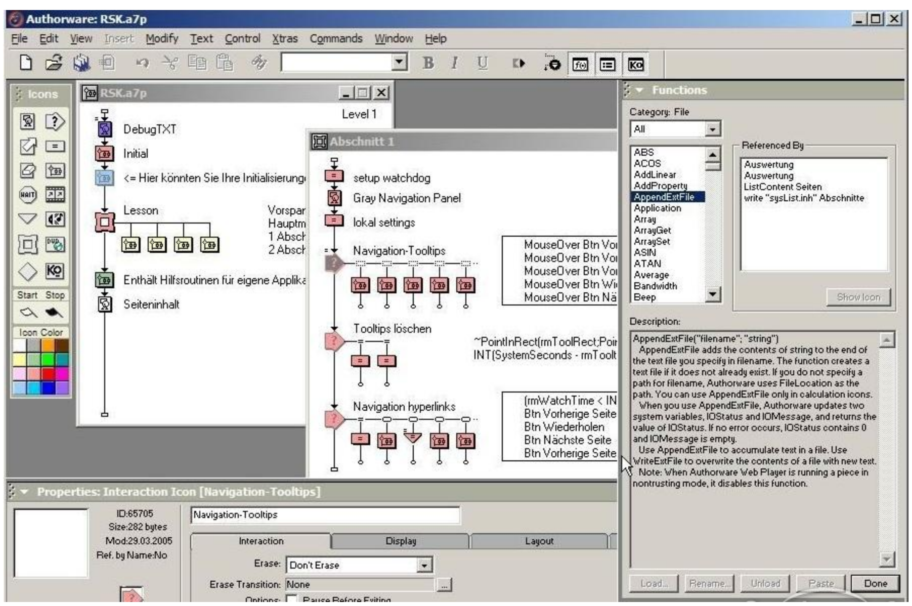

Figure 4.5: Macromedia Authorware

Figures 4.6 until 4.16 shows some of the screen capture from the KBS application.

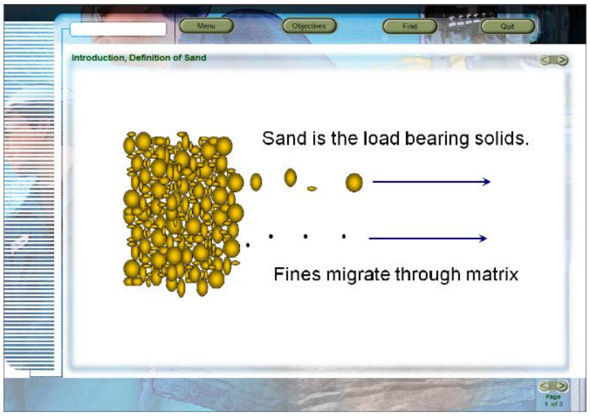

Figure 4.6: KBS Interface

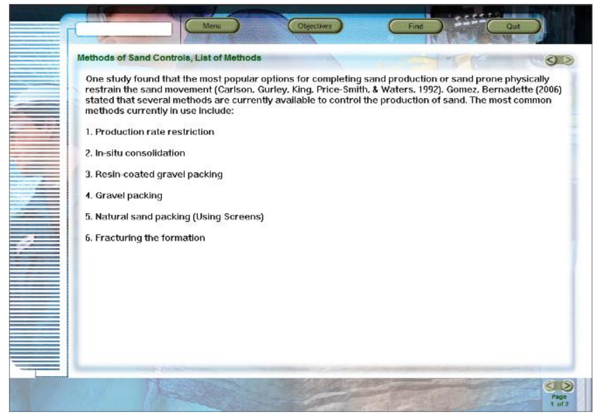

Figure 4.7: KBS for Methods for Sand Control

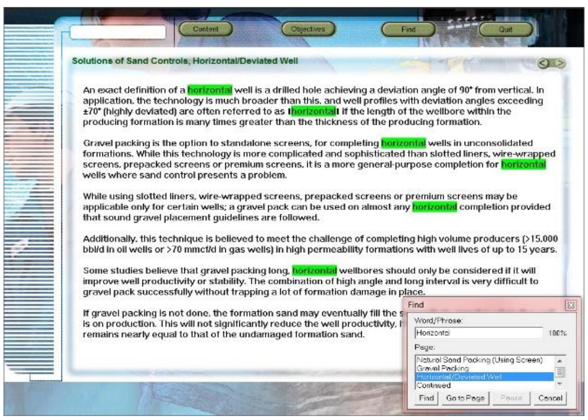

Figure 4.8: KBS Find Button

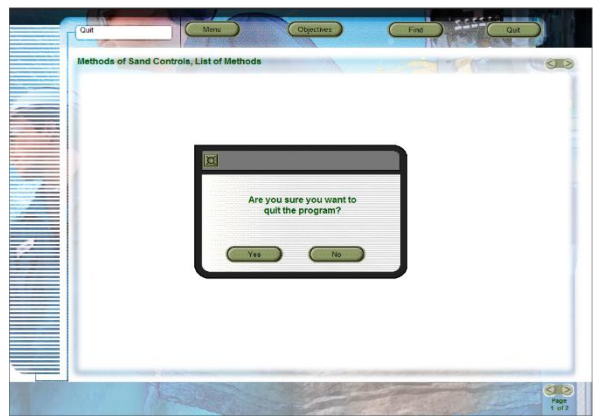

Figure 4.9: KBS Quit Button

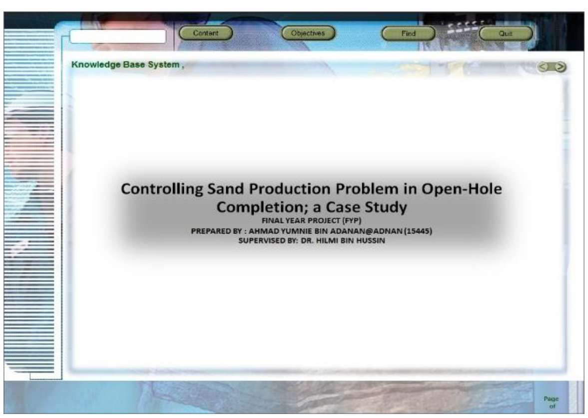

Figure 4.10: KBS Front Interface

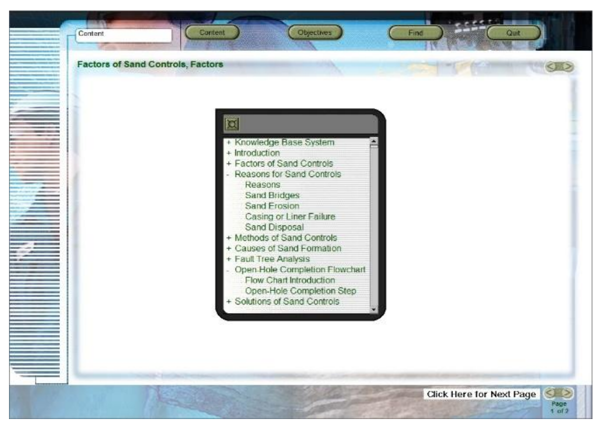

Figure 4.11: KBS Content

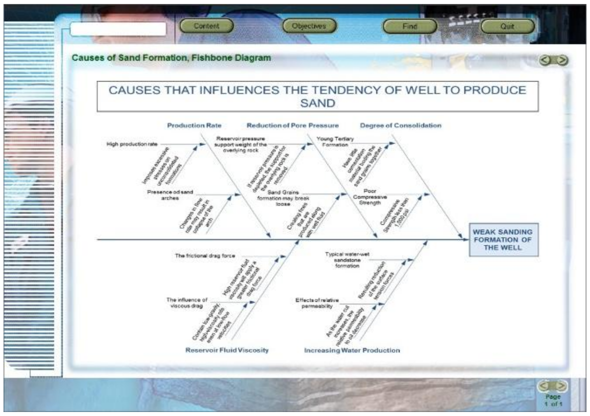

Figure 4.12: KBS Fishbone Diagram

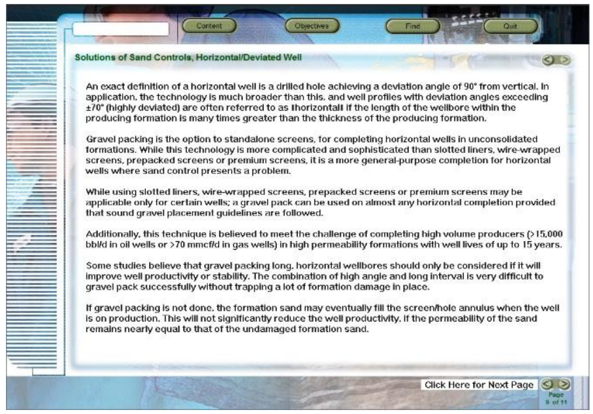

Figure 4.13: KBS Explanation on Horizontal Well

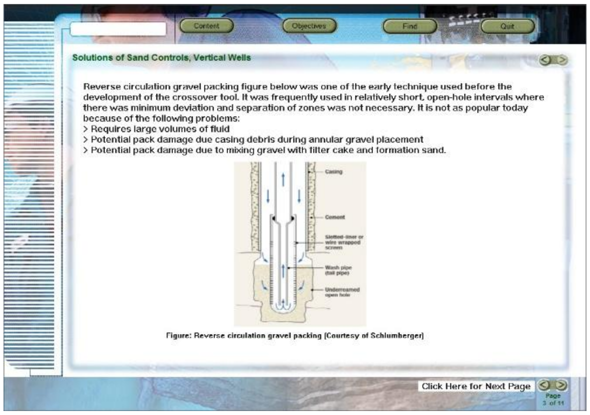

Figure 4.14: KBS Explanation on Vertical Well

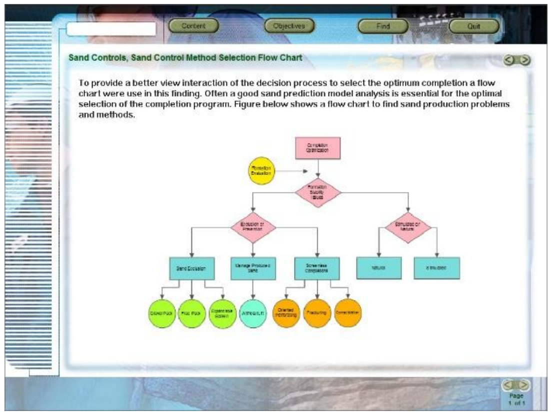

Figure 4.15: KBS Selection Flow Chart

Figure 4.16: KBS Button Click Open-Hole Completion Steps

4.6.1 Programming the Knowledge Based System

Figure 4.17 shows the programming function that been apply to develop the application. Each of the interaction icon in the left side of the program (Macromedia Authorware) have different set of interaction. This is all the interaction function that been used to build the KBS; Display, Erase, Framework, Interaction, Decision and Calculation. Figure 4.18 shows the KBS Coding for Main Interface and Title. All the coding that been used to translate it into a program are shows in Appendix 1-3 (Coding for Main Interface and Title) and Appendix 1-4 (Coding for Page Section in KBS).

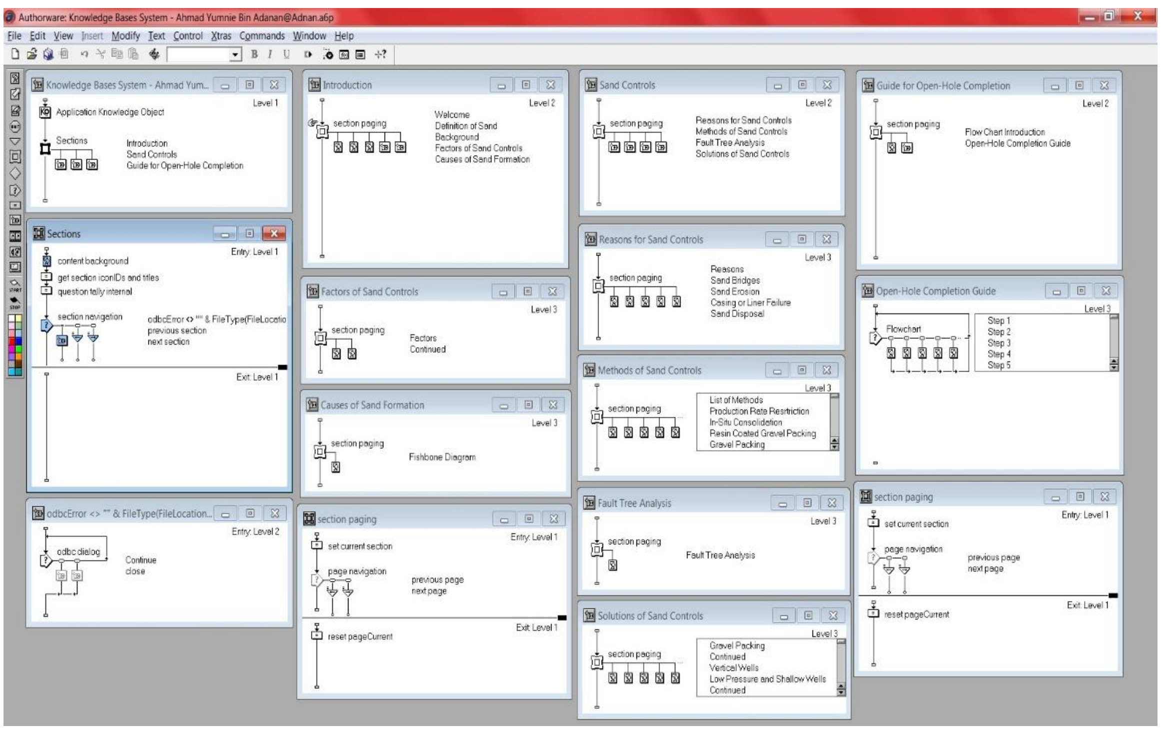

Figure 4.17: KBS Programming Function

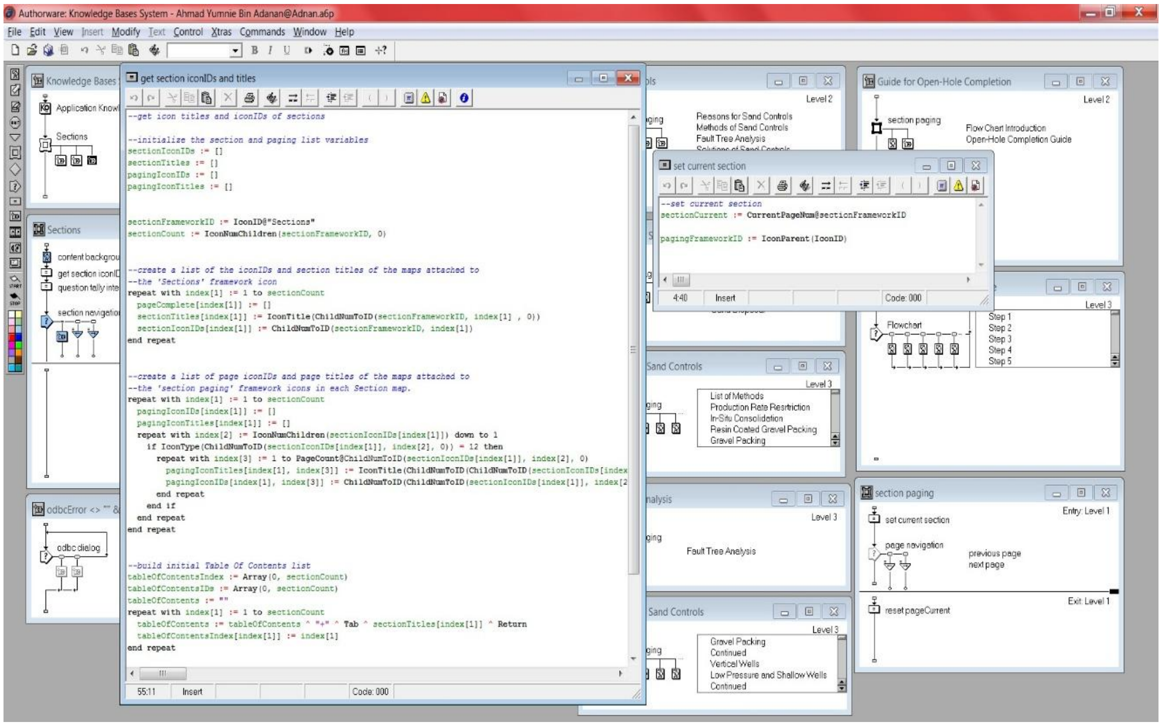

Figure 4.18: KBS Coding for Main Interface and Title

4.7 Benefits of Using Knowledge Based System

According to (Akerkar, 2014) A Knowledge-based system (KBS) is a computer program that reasons and uses a knowledge base to solve complex problems. The term is broad and is used to refer to many different kinds of systems. The one common theme that unites all knowledge based systems is an attempt to represent knowledge explicitly via tools such as ontologies and rules rather than implicitly via code the way a conventional computer program does.

Knowledge-Based Systems focuses on systems that use knowledge-based techniques to support human decision-making, learning and action. Such systems are capable of cooperating with human users and so the quality of support given and the manner of its presentation are important issues. Finding all information will be ease if all the information needs is in one application or just a click.

4.7 Conclusion

As a conclusion, Knowledge-based systems (KBS) provide a way of formalizing and automating knowledge of Sand Control management. By managing and gather all the information on literature review, journal and research this KBS are the outcome of a knowledge engineering process that may be seen as providing some of the building blocks of knowledge management.

Most of the companies nowadays are using KBS for training purposes because it is easy to use by just one click, have a user friendly interface to avoid boring reading in the books or manual, save a lot of time in the matter of learning, easy to monitor the progress or any update on the learning, save a lot of printing paper and can reduce some of the company cost to hire some instructor to teach the trainee since they can learn it by themselves. Some of the company, also uses KBS as a tools to track their employees learning progress thus providing information of their knowledge level.

Finally, in developing phase, the project was come out with the Knowledge Based Systems (KBS) application to provide the suitable methods of sand-related problem just by choosing the preferences of the operational problems. Users can view all the information regarding sand control in open-hole completion in this KBS. The main objective of this final year project to build KBS that will help and ease the users or engineer to recognize the problems relates to sand production and how to solve it was achieved.

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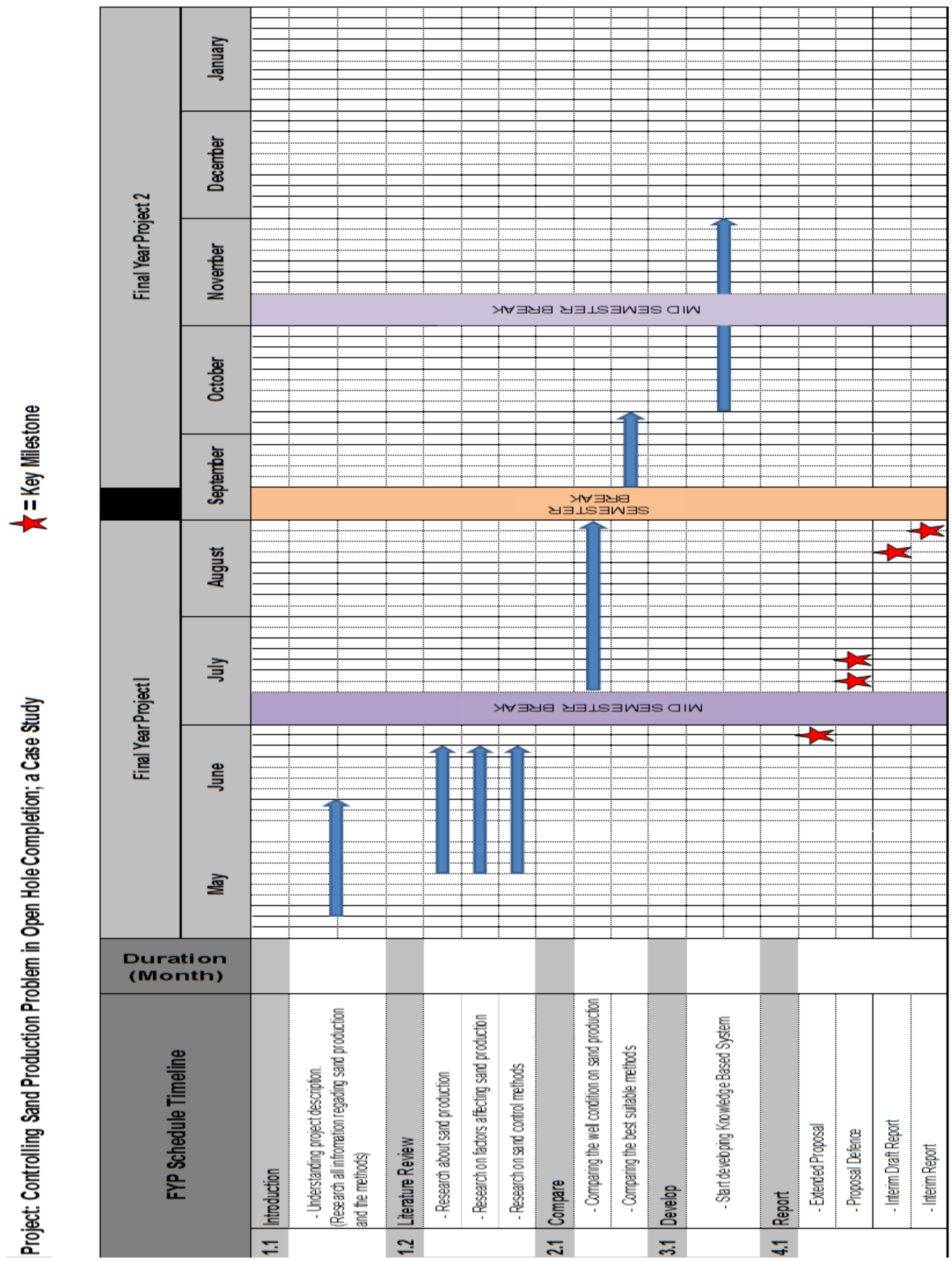
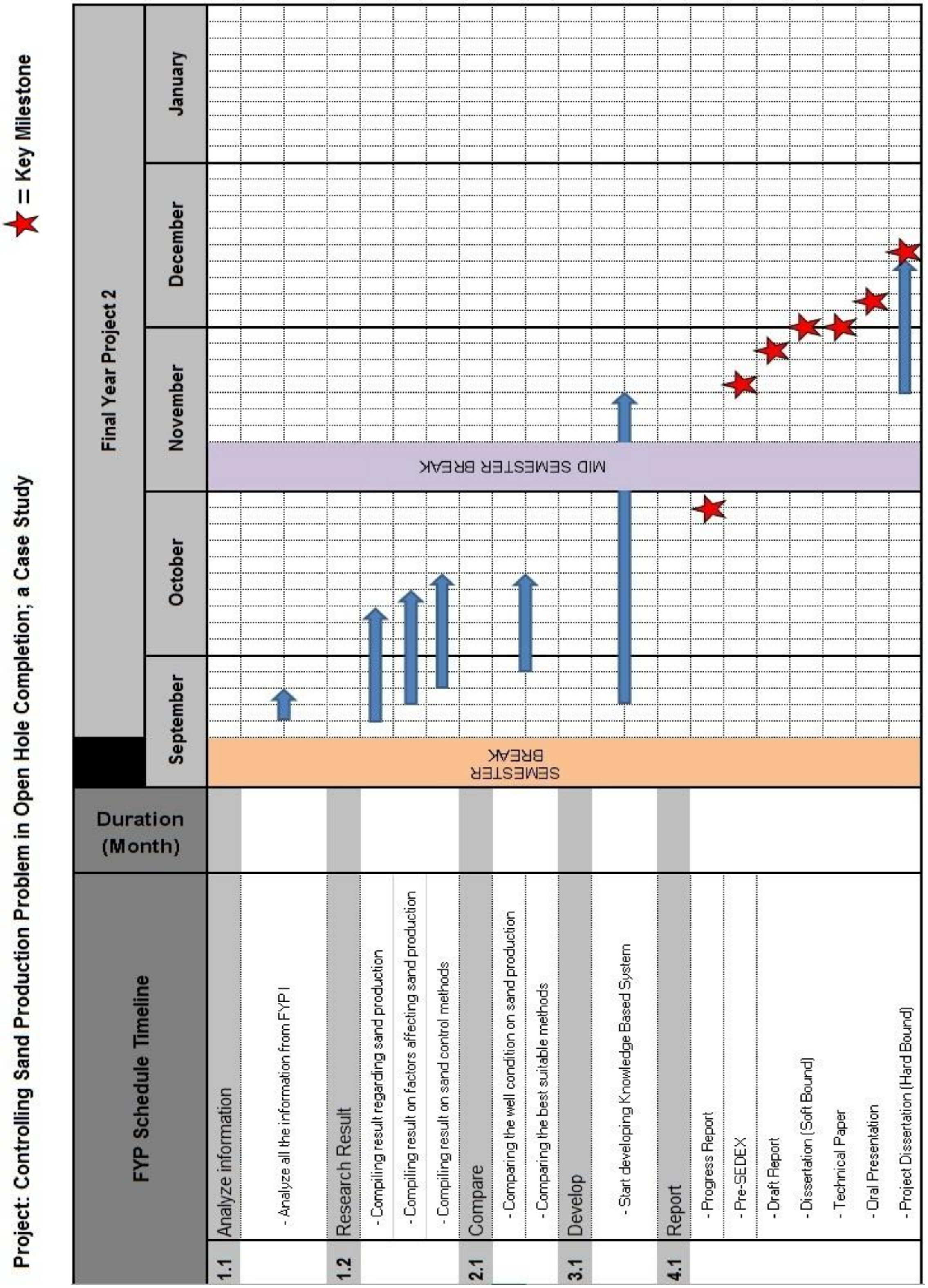
APPENDICES

APPENDIX 1-1: Gantt chart FYP I



APPENDIX 1-2: Gantt chart FYP II



APPENDIX 2-1: Coding for Main Interface and Titles in KBS

```
--get icon titles and iconIDs of sections
--initialize the section and paging list variables
sectionIconIDs := []
sectionTitles := []
pagingIconIDs := []
pagingIconTitles := []
sectionFrameworkID := IconID@"Sections"
sectionCount := IconNumChildren(sectionFrameworkID, 0)
--create a list of the iconIDs and section titles of the maps attached to
--the 'Sections' framework icon
repeat with index[1] := 1 to sectionCount
  pageComplete[index[1]] := []
  sectionTitles[index[1]] := IconTitle(ChildNumToID(sectionFrameworkID, index[1] , 0))
  sectionIconIDs[index[1]] := ChildNumToID(sectionFrameworkID, index[1])
end repeat
--create a list of page iconIDs and page titles of the maps attached to the 'section paging' framework icons in each Section map.
repeat with index[1] := 1 to sectionCount
  pagingIconIDs[index[1]] := []
  pagingIconTitles[index[1]] := []
  repeat with index[2] := IconNumChildren(sectionIconIDs[index[1]]) down to 1
    if IconType(ChildNumToID(sectionIconIDs[index[1]], index[2], 0)) = 12 then
      repeat with index[3] := 1 to PageCount@ChildNumToID(sectionIconIDs[index[1]], index[2], 0)
        pagingIconTitles[index[1], index[3]] := IconTitle(ChildNumToID(ChildNumToID(sectionIconIDs[index[1]], index[2], 0),
index[3], 0))
        pagingIconIDs[index[1], index[3]] := ChildNumToID(ChildNumToID(sectionIconIDs[index[1]], index[2], 0), index[3], 0)
      end repeat
    end if
  end repeat
end repeat
--build initial Table Of Contents list
tableOfContentsIndex := Array(0, sectionCount)
tableOfContentsIDs := Array(0, sectionCount)
tableOfContents := ""
repeat with index[1] := 1 to sectionCount
  tableOfContents := tableOfContents ^ "+" ^ Tab ^ sectionTitles[index[1]] ^ Return
  tableOfContentsIndex[index[1]] := index[1]
end repeat
--initialize Bookmark List
bookMarkList := ""
bookMarkIDs := ""
bookMarkIndex := []
repeat with index[1] := 1 to sectionCount
  bookMarkIndex[index[1]] := Array(0, ListCount(pagingIconIDs[index[1]]))
end repeat
```

APPENDIX 2-2: Coding for Page Section in KBS

```
--set current section
sectionCurrent := CurrentPageNum@sectionFrameworkID

pagingFrameworkID := IconParent(IconID)
```