UNIVERSIDADE DE SÃO PAULO
ESCOLA POLITÉCNICA

ADEYINKA OLUWAYOMI OMOTEHINSE

Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase.

São Paulo
2020

ADEYINKA OLUWAYOMI OMOTEHINSE

Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase.

São Paulo

2020

ADEYINKA OLUWAYOMI OMOTEHINSE

Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase.

Revised version

(The original version can be found in the unit that hosts the Graduate Program)

Thesis Presented to Escola Politécnica da Universidade de São Paulo to obtain the degree of Doctor of Science

Concentration area: Mineral Engineering

Advisor: Prof. Dr. Giorgio de Tomi

São Paulo

2020

Este exemplar foi revisado e corrigido em relação à versão original, sob responsibilidade única do autor e com a anuência de seu orientador.
São Paulo, ________ de ________________________ de _____________

Assinatura do autor: ____________________________________

Assinatura do orientador: ____________________________________

Catalogação-na-publicação

Adeyinka Oluwayomi Omotehinse
Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase / A.O. Omotehinse – versão corr. – Sao Paulo, 2020.
194p.

Tese (Doutorado) Escola Politécnica da Universidade de São Paulo. Departmento de Engenharia de Minas e Petroleo.

1. Oil sands 2. Pre-mining phase 3. Social license to operate 4. Ecosystem services 5. Preliminary economic assessment 6. Small-scale mining 7. Ondo state, Nigeria I. Universidade de São Paulo. Escola Politécnica. Departmento de Engenharia de Minas e Petroleo II.t.

Name: Adeyinka Oluwayomi Omotehinse

Title: Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase.

Thesis Presented to Escola Politécnica da Universidade de São Paulo to obtain the degree of Doctor of Science.

Aprovado em:

Banca Examinadora

Prof. Dr. Giorgio Francesco Cesare de Tomi
Instituição: Escola Politécnica da Universidade de São Paulo
Julgamento: ____

Prof. Dr. Anna Luiza Marques Ayres da Silva
Instituição: Escola Politécnica da Universidade de São Paulo
Julgamento: ____

Prof. Dr. Vagner Roberto Elis
Instituição: Instituto de Astronomia, Geofisica e Ciencias Atmosféricas
Julgamento ____

Prof. Dr. Edmo da Cunha Rodovalho
Instituição: Universidade Federal de Alfenas
Julgamento ____

Prof. Dr. Ayodele Ebenezer Ajayi
Instituição: Federal University of Technology, Akure Nigeria
Julgamento ____

I dedicate everything I am and have to the one and only Alpha and Omega, the One who was, who is and who is to come. The Almighty God. To Him alone be all the Glory, Honour and Adoration, AMEN.

ACKNOWLEDGMENTS

I want to acknowledge my parents, sisters and brother for their training, care, support and prayers for me. May you all reap the fruits of your labour in Jesus Name. Dad has been a great tutor and support, a medical doctor turned mining engineer. Mum, thanks for your motherly care, supports and prayers, and to the rest of my siblings, I thank you and love you all.

I want to appreciate Prof. E.O. Ajaka for his encouragement, support and making this program a reality. Prof. B. D. Ako for his role as a father, academic mentor, provision of the Ondo State oil sand exploration data, information and all the support he gave me both in Nigeria and in Canada. Prof. Ayo Ajayi and Prof. B. Aborisade for their support, mentorship and making sure this program is a reality. The past and present Vice Chancellors of The Federal University of Technology Akure, Nigeria (Prof Biyi Daramola and Prof Joseph Fuwape) for the opportunity given to me to do my Doctorate program in this University.

I will like to appreciate my friends at home and abroad for their contribution and support in this journey; especially Adedotun Afuye and Oluwatosin Ogunlade who incidentally are mathematicians. I say thanks to you all.

I want to appreciate the Petroleum Technology Development Fund (PTDF) Nigeria and Tertiary Education Trust Fund (TETFund) Nigeria for sponsoring my program. I want to appreciate the efforts of Prof Egberto Pereira, the Coordinator of the Laboratório de Estratigrafia Química e Geoquímica Orgânica (LGQM), Universidade do Estado do Rio de Janeiro (UERJ) and the other members of the laboratory for their help and support in analysing the oil sands samples that was sent to their laboratory. I also want to appreciate the efforts of Pedro Esteves of the BNA Mining Solutions Brazil.

Finally, I want to appreciate my supervisor Prof Giorgio de Tomi for receiving me, his help and guidance in improving the quality of my research and leading me on to achieve my doctorate degree in this University.

I really appreciate you all.

Thanks and God bless you all. Amen.

ABSTRACT

OMOTEHINSE, A.O. **Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase**. 2020. Thesis (Doctor of Science) Escola Politécnica, Universidade de São Paulo, São Paulo, 2020.

The mining industry may have adverse impacts on the environment, ecosystems, ecosystem services and the society, all of which are essential to human well-being. The industry has understood that obtaining a formal license to operate from governments, meeting regulatory requirements is no longer enough, and in order to reduce risks for the stakeholders, a social license to operate needs to be obtained. Although impact of mining activities is experienced throughout the life of mine, pre-mining phase was considered in this research because it determines the relationship of the mining industries with the community. Despite the vast abundance of oil sands resources in Nigeria, an economic analysis is yet to be carried out to evaluate the feasibility of a mining operation at different production scales. Most importantly, this resource is associated with natural contamination referred to as ***bituminous natural effects***. Therefore, mining is not only perceived to be an opportunity for both social-economic improvement by the local communities but also as an efficient approach to reduce exposure to bitumen fumes. To address these issues, this research aimed to carry out a pro-active study on some oil sands deposit communities in Nigeria. The methodology used include appraisal of questionnaire to the communities involved, applying an existing methodology of ecosystem services to the oil sands deposits located in Ondo State, Nigeria, modelling of the oil sands resource considering three mining scenarios taking into account synthetic crude oil, bitumen and tar production. A preliminary economic assessment and a sensitivity analysis was also carried out for three different production scales. The results of the research include an evaluation of the social license to operate locally; assessment of the impacts of pre-mining activities on the ecosystem services; and a preliminary economic assessment of three types of oil sands mining operations. The conclusions indicate that the challenges faced by a mining company can be managed if proper measures are taken and if the mining company communicates transparently with the community; in addition mining is perceived as a practical solution to the ***bituminous natural effects***. Also, the ecosystem service assessment was proven to be an appropriate approach for mitigating impacts of pre-mining activities on ecosystem services. There will be opportunities for a public policy with minimum price guarantee so that small-scale mining of oil sands will be able to operate profitably and will help to solve the regional problem of untarred/unpaved roads. This will bring both economic and environmental benefits to both the local communities and the Nigerian government and it can represent an important driver for transformation to sustainability in the region.

Key words: Oil sands; Pre-mining activities; Social license to operate (SLO); Ecosystem services; Preliminary economic assessment (PEA); Small-scale mining; Ondo state, Nigeria.

RESUMO

OMOTEHINSE, A.O. **Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase**. 2020. Tese (Doutorado em Ciências – Engenharia Mineral) – Escola Politécnica, Universidade de São Paulo, São Paulo, 2020.

O setor de mineração pode ter impactos adversos no meio ambiente, nos ecossistemas, nos serviços ecossistêmicos e na sociedade, todos essenciais para o bem-estar humano. O setor entendeu que a obtenção de uma licença formal para operar junto aos governos, não é mais suficiente, e para reduzir os riscos para as partes interessadas, é necessário obter uma licença social para operar. Embora o impacto das atividades de mineração seja experimentado ao longo da vida de uma mina, a fase de pré-mineração foi considerada nesta pesquisa porque determina o relacionamento das indústrias de mineração com a comunidade. Apesar da grande abundância de recursos de areias petrolíferas na Nigéria, ainda está sendo realizada uma análise econômica para avaliar a viabilidade de uma operação de mineração em diferentes escalas de produção. Mais importante, este recurso está associado à contaminação natural por efeitos naturais betuminosos. Portanto, a mineração não é apenas percebida como uma oportunidade de melhoria socioeconômica pelas comunidades locais, mas também como uma abordagem eficiente para reduzir a exposição aos vapores de betume. Para abordar essas questões, esta pesquisa teve como objetivo realizar um estudo pró-ativo em algumas comunidades de depósitos de areias petrolíferas na Nigéria. A metodologia utilizada inclui a avaliação do questionário para as comunidades envolvidas, aplicando uma metodologia existente de serviços ecossistêmicos aos depósitos de areias petrolíferas localizadas no estado de Ondo, na Nigéria, modelando o recurso de areias petrolíferas considerando três cenários de mineração, considerando petróleo bruto sintético, betume e produção de alcatrão. Também foram realizadas uma avaliação econômica preliminar e uma análise de sensibilidade para três escalas de produção diferentes. Os resultados da pesquisa incluem uma avaliação da licença social para operar localmente; avaliação dos impactos das atividades de pré-mineração nos serviços ecossistêmicos; e uma avaliação econômica preliminar de três tipos de operações de mineração de areias petrolíferas. As conclusões indicam que os desafios enfrentados por uma empresa de mineração podem ser gerenciados se medidas apropriadas forem tomadas e se a empresa de mineração se comunicar de forma transparente com a comunidade; além disso, a mineração é considerada uma solução prática para os efeitos naturais betuminosos. Além disso, a avaliação dos serviços ecossistêmicos demonstrou ser uma abordagem apropriada para mitigar os impactos das atividades de pré-mineração nos serviços ecossistêmicos. Haverá oportunidades para uma política pública com garantia de preço mínimo, para que a mineração em pequena escala de areias petrolíferas possa operar com lucro e ajude a resolver o problema regional de estradas não asfaltadas. Isso trará benefícios econômicos e ambientais para as comunidades locais e para o governo nigeriano e pode representar um importante fator para a transformação da sustentabilidade na região.

Palavras-chave: Areias petrolíferas; Atividades de pré-mineração; Licença social de operação (SLO); Serviços de ecossistemas; Avaliação econômica preliminar (PEA); Mineração em pequena escala; Estado de Ondo, Nigéria.

LIST OF ABBREVATIONS AND ACRONYMS

AER - Alberta Energy Regulator

AOI – Area of Interest

API – American Petroleum Institute

AusIMM - Australasian Institute of Mining and Metallurgy

CAD – Canadian dollar

CAPEX – Capital expenditure

CDA - Community Development Agreement

CIM – Canadian Institute of Mining, Metallurgy and Petroleum

CMMI - Council of Mining and Metallurgical Institutions

COT – Total Organic Carbon

CSR – Corporative Social Responsibility

cP - Centipoises

EIA – Environmental Impact Assessment

E.O – Organic extract

ERDAS - Earth Resource Development Assessment System

ES – Ecosystem services

G&A – General and Administrative

GCU – Geological Consultancy Unit, University of Ile Ife, now (Obafemi Awolowo University), Ile Ife.

GLC - Global Land Cover

IDW - Inverse distance weighting

IGBP - International geosphere–biosphere program

JORC - Joint Ore Reserve Committee

LECO SC 632 (002) – Carbon determining devise

LG – Lerchs-Grossman

LOM – Life of mine

LU/LC – Land use/Land cover

MEA – Millennium ecosystem assessment

MMBPD - million barrels per day

MMSD - Ministry of Mines and Steel Development

MOSOP – Movement for the survival of the Ogoni people

NBC - Nigeria Bitumen Corporation

NDDC - Niger Delta Development Commission

NPV – Net present value

OB - Overburden

OPEX – Operating expenditure

PEA – Preliminary economic assessment

PSV – Primary separation vessel

SAIMM - Southern African Institute of Mining and Metallurgy

SCO – Synthetic crude oil

SLO – Social license to operate

SME - Society for Mining, Metallurgy, and Exploration

USGS - United States Geological Survey

UPL – Ultimate pit limit

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

CHAPTER ONE

1. INTRODUCTION

Nigeria is a country blessed with minerals resources found all over the country. These mineral resources have greatly added to the country's wealth (AJAKAIYE, 1985; ADEKOYA, 2003; AIGBEDION; IYAYI, 2007; CHINDO, 2012). These minerals include solid minerals, natural gas, and oil. Currently, Nigeria wants to diversify her attention to some major minerals, which are oil sands (bitumen), coal, iron ore, and limestone and the focus of this research will be on oil sands.

Oil sand (Figure 1) also known as tar sand and bituminous sand can be described as an unconventional source of petroleum that occurs naturally, it consists of a mixture of clay, sand, water and bitumen also known as heavy oil (ROGERS et al., 2002; SCHRAMM; STASIUK; TURNER, 2003; QUAGRAINE; PETERSON; HEADLEY, 2005; YANG et al., 2011; BRANDT, 2012). It is found in several countries including Canada and Venezuela (CHALATURNYK; SCOTT; ÖZÜM, 2002; MEYER; ATTANASI; FREEMAN, 2007; TENENBAUM, 2009; CHAN et al., 2012).

In Nigeria, oil sand was discovered in the early part of the 19th century, but it has not been exploited until date. The oil sand deposits in Nigeria are estimated to be between 41-43 billion barrels and they occur within the southwestern part of the country (ADEGOKE; AKO; ENU, 1980; AKO et al., 1983; ENU, 1985; MMSD, 2018; CHINDO, 2011).

Figure 1 - Oil sands deposits

Source: TENENBAUM, (2009).

Source: Personal file

Despite the lack of mining activities on oil sands in Ondo State, Nigeria, bitumen seepage from the oil sands deposits occurs during the dry hot season. These occurrences are seen in some hand-dug wells and farmlands within the communities. This effect is referred to as *bituminous natural effects* in this research. There are complaints from the local community about these *bituminous natural effects* affecting the plant and water in this region.

Extraction of minerals, which include oil sands, coal, limestone, quartz, lignite etc., can be referred to as mining activity. This activity is very essential to mans' existence, and has increased because of the increase in demand for minerals and energy (IKEMEFUNA, 2012). One of the very important sector for the development of any nation is the mining sector; because it generates income, provides employment and economic growth, but one of its setback is that it can disrupt the nation's ecosystems.

It is said to be the second immense origin of pollution in Africa. In most developing countries, it is confirmed that opposition arises when mining companies fail to address environmental impacts and the needs of the host communities (KUMAH, 2006). This type of opposition was portrayed in the Niger Delta region of Nigeria made up of nine states, which are Bayelsa, Rivers, Delta, Akwa-Ibom, Cross-Rivers, Ondo, Abia, Imo and Edo states where the domineering activity is the oil and gas exploration. Therefore, mining companies and the Nigerian government must be ready to take a proactive approach to minimize the impacts of oil sands mining activities on the environment.

Mining companies do not only depend on formal license to operate from governments, there are instances of delayed operations in mining due to oppositions from the community (OWEN; KEMP, 2013; HALL et al., 2015), therefore informal agreements are made between the host communities and the mining company on how to obtain a social license to operate (SLO). A SLO is a set of meaningful relationships that exists between operational stakeholders. These relationships depends on the mutual trust that will be built and demands and expectations on how the local stakeholders and the civil society will operate a business (MOFFAT; ZHANG, 2014).

Mining activities have impacts on the ecosystem and its services; it may disrupt a site's ecosystem by altering the natural landscape, its ecological balance, agricultural lands, forests, plantations and vegetation (GUTTI; AJI; MAGAJI, 2012; OLADIPO; OLAYINKA; AWOTOYE, 2014). An ecosystem is an ecological system, which can be illustrated by a natural environment, the creatures that live in it and the relations between the two (NEBEL; WRIGHT, 1996). Ecosystems can also be referred to as complex networks of human, animal, plant, microbial and abiotic interactions (PERSSON et al., 2010).

Land is a significant natural resource, since life and developmental activities are based on it (EZEOMEDO; IGBOKWE, 2013). Modification in land-use and land cover are mostly because of pre-industrial human effects on the environment. This alters both the shape and the working order of ecosystems, and how they interact with the atmosphere, aquatic systems, and with land (VITOUSEK et al., 1997). Land use is the type of usage to which man has put the land (EZEOMEDO; IGBOKWE, 2013); it can also be described as activity of man on land, which is directly related to it (SHARMA et al., 2012).

Land cover is the vegetal attributes of land (SHARMA et al., 2012; EZEOMEDO; IGBOKWE, 2013) and artificial constructions covering the land surface (SHARMA et al., 2012). Software's such as ArcGIS, air-and space-borne remote sensing, Google Earth and others are used in land use and land cover mapping and it possible to obtain pre-and post-project land use and land cover data in consistent manner. Land transformation, which is one of the principal factor of ecosystem loss, influences biota directly by destroying the natural environment and indirectly by disintegrating ecosystems (VITOUSEK et al., 1997).

Large projects such as mining may disrupt and displace people and their livelihoods. Experiences gotten when people are displaced and/or resettled can be disturbing, affecting their livelihoods, their social networks and the relationship between communities. Displacement/resettlement is a major and costly social impact for projects; and should be avoided wherever possible (VANCLAY et al., 2015).

Choice of mining methods include surface mining, in-situ and underground mining methods. The primary mining method in this research is the surface mining method, and it was used because of the depth of the deposits, which are closer to the surface.

Surface mining: Oil sands are mined either using open cast (SHAH et al., 2010) or open pit mining method (MASLIYAH et al., 2004; MECH, 2011), this method is applied to reserves at shallow depths (<75 m) (SHAH et al., 2010; ZHANG, 2014). There is clearing of the area and the oil sands deposits are exposed by removing the overburden (OIL SANDS DISCOVERY CENTRE, 2014[1]; ZHANG, 2014). Oil sand ore is mined with diesel or electric hydraulic shovels (BHATTACHARJEE, 2011; BRANDT, 2012). Surface mining operation is

[1]OIL SANDS DISCOVERY CENTRE. Facts about Alberta's oil sands and its industry. Alberta, 2014. **Unpublished manuscript.**

capital intensive (BHATTACHARJEE, 2011; SHAH et al., 2010) and may be associated to environmental issues (SHAH et al., 2010).

In this research, three alternatives of surface mining of oil sands were evaluated: large scale mining with synthetic crude oil (SCO) production; medium scale mining with bitumen production; and small scale mining with tar production.

1.1 RESEARCH QUESTIONS

1) How can the challenges of securing a social license to operate be managed from the pre-mining phase taking into account the *bituminous natural effects* and the effects of pre-mining activities on local communities[2, 3]?

2) Can the impacts of oil sands pre-mining activities be assessed using an ecosystem services (ES) approach[4]?

3) What is the appropriate scale for a mining operation of oil sands deposits in Ondo State?

1.2 PROBLEM STATEMENT

Oil sands is a strategic source of oil for many countries; however in Ondo state, Nigeria, mining of oil sands may face challenges from the pre-mining phase due to the complexity of this type of operation. In addition, this particular deposit has several outcrops that may represents a natural source of contamination to the local communities, which is known as *bituminous natural effects***.** Therefore, mining is perceived to be a practical option to minimize the natural contamination of bitumen. However, even if mining is welcomed by the communities, the implementation of the mining operations must take into accounts the management of all the economic and environmental impacts from its pre-mining phase. The choice of type and scale

[2] OMOTEHINSE, A. O.; TOMI, G. D. A social license to operate: pre-mining effects and activities perspective. **REM-International Engineering Journal,** v. 72, n. 3, p. 523-527, 2019. https://doi.org/10.1590/0370-44672018720020

[3] OMOTEHINSE, A. O.; DE TOMI, G. Managing the challenges of obtaining a social license to operate in the pre-mining phase: A focus on the oil sands communities in Ondo State, Nigeria. **World Development Perspectives**, 100200, 2020. https://doi.org/10.1016/j.wdp.2020.100200

[4] OMOTEHINSE, A. O.; DE TOMI, G.; BANINLA, Y. Proactive Management of Ecosystem Services in Oil Sands Pre-mining Phase. **Natural Resources Research** 29, 949–965, 2020. https://doi.org/10.1007/s11053-019-09505-5

of the appropriate mining operation to address all these challenges is the objective of this research.

1.3 STRUCTURE OF THESIS

According to the outlined research questions, the thesis were organised following the sequence below:

Chapter 1: This chapter entails general introduction about the thesis and the research questions.

Chapter 2: This chapter contains a detailed literature review on oil sands resources in the world and in Nigeria. An extensive review of the social license to operate (SLO), the importance of securing and maintaining SLO, displacement/resettlement and the history of conflicts in the extractive mineral industries in Nigeria were made. A review of the impacts of oil sands pre-mining processes on the ecosystems and the ecosystem services (ES) was made and the mitigation hierarchy was also reviewed. A detailed review was made extensively on the oil sands mining processes. This includes the description of the phases in the life of a mine (LOM), analysis of a conceptual mine planning and an extensive review of the extraction processes of bitumen from oil sands (surface mining methods and in-situ mining).

Chapter 3: In this chapter, a general introduction was made on the methodology used. This was followed by an extensive description of the fieldwork done and the description of the site. Thereafter, a detailed assessment of the impact of pre-mining activities on the ecosystem and ES was done, and the methodology used was detailed properly. Finally, the methodology used for the development of a conceptual mine planning was described in details.

Chapter 4: This chapter gave the result of each research carried out as stated in chapter three.

Chapter 5: This chapter discussed the results obtained and the relationship with the research objectives.

Chapter 6: This chapter gave the conclusions on the results gotten and the relationship with the research objectives.

The references of all studies are given in the last chapter.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 OVERVIEW OF OIL SANDS

Oil sands are unconsolidated sands that are held together by bitumen and host sediment with minerals and insoluble organic matter (KASHIRTSEV; HEIN, 2013; HEIN et al., 2013). Sometimes, secondary element like clays bind the sands. In history, oil sands are reservoirs with very viscous oil and because of their very high viscosity, they cannot flow in sufficient volumes into a well bore under natural reservoir conditions for economic development of the resource (MASLIYAH et al., 2004; HEIN, 2006; HEIN et al., 2013).

The oil quality is measured by the American Petroleum Institute gravity (or API gravity), which is the oil density–based standard used. It is reported in degrees.

API gravity = $\frac{141.5}{\rho} - 131.5$ (1)

Where ρ is the relative density with respect to water or specific gravity, measured at 60 °F.

Despite having a standard in place, there has been inconsistencies and confusion as regards the terminologies oil sands, heavy oil, and bitumen. Depending on their API gravity reported in degrees, many of the "extra heavy oils" of Venezuela would be considered "oil sands" in Canada or tar sands" in the United States.

Natural bitumen can be described as oil whose API gravity is less than 10° and whose viscosity is commonly higher than 10,000 centipoises (cP) at ambient conditions. Heavy Oil can be described as oil with API gravity between 10°API and 20°API and a viscosity greater than 100 cP. The major difference between these terms is that under in-situ reservoir conditions, natural bitumen because of its high viscosity is unable to flow to a wellbore, but extra heavy and heavy oil will flow to the wellbore under the same condition (MEYER; ATTANASI; FREEMAN, 2007; HEIN et al., 2013; LARTER; HEAD, 2014). Viscosity is a measure of a fluid's resistance to flow and it indicates how a fluid will flow easily to the well for extraction. It varies highly with temperature. Density is a measure of mass per unit volume. The density of oil is expressed in degrees of API gravity (MEYER; ATTANASI, 2003).

According to measured API gravity, crude oil is classified as light, medium, or heavy as shown in Table 1.

Table 1 - Classification of crude oil according to its measured API gravity

Crude oil	API gravity	Viscosity (centipoises (cP))
Light	°API ≥ 31.1 (< 870 kg/m³)	
Medium	22.3 ≤ °API ≤ 31.1 (870 to 920 kg/m³)	
Heavy	10 ≤ °API ≤ 22.3 (920 to 1000 kg/m³)	> 100
Extra heavy	°API ≤ 10 (> 1000 kg/m³)	≤10,000
Bitumen	°API ≤ 10 (> 1000 kg/m³)	>10,000

Source: Personal file

2.1.1 Oil sands resources in the world

The estimate of the bitumen and heavy oil resources in the world is 5.6 trillion barrels, and more than 80 % are found in Venezuela, Canada and the U.S.A. The Orinoco Oil Belt of Venezuela has the single largest heavy-oil field comprising of the 90% of the World extra-heavy and heavy oil in place (HEIN, 2006).

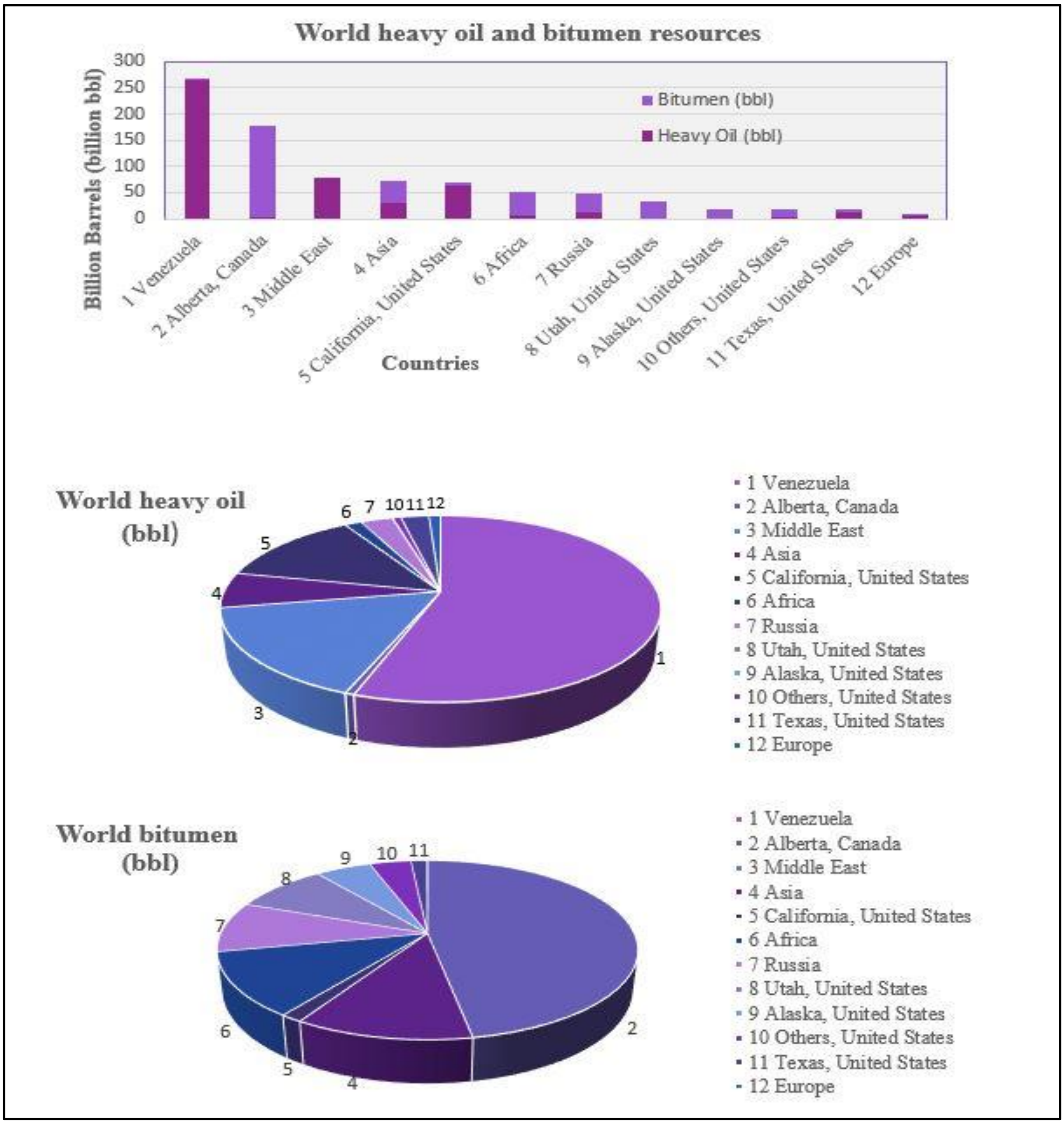
The Alberta, Canada have the largest oil-sand deposits and account for > 70 % of World bitumen in place (MASLIYAH et al., 2004; HEIN, 2006; TENENBAUM, 2009). In the North America, California (77.6 %), Texas (14.6 %) and Alberta (3.3 %) have the largest heavy oil deposits, and the bitumen resources are mostly found in Alberta (69.6 %), Utah (12.9 %) and Alaska (7.58 %) (HEIN, 2006). Figures 2 and 3 show the histogram and pie chart of the major heavy oil and bitumen reserves in the world.

The oil sands in Canada are found in three locations; province of Alberta, Athabasca, Peace River and Cold Lake regions covering about 141,000 square kilometres (MASLIYAH et al., 2004; TENENBAUM, 2009). The world's largest deposit is in the Athabasca area, located in the northeast part of Alberta and the total bitumen in place in Alberta is estimated at 1.7 to 2.5 trillion barrels (MASLIYAH et al., 2004) and about 170-175 billion barrels of oil can be recovered economically from the oil sands (TENENBAUM, 2009; YUAN; XU; YANG, 2011). Using open pit mining and in-situ technologies, the estimate of recoverable barrels of oil is about 300 billion barrels (MASLIYAH et al., 2004; YUAN; XU; YANG, 2011).

8-20 % of Alberta's oil sand deposits are of shallow depth (depending on the estimate) and are mined by surface mining methods, while deposits of deeper deposits more than 75 meters are mined using secondary recovery methods also known as in situ production (TENENBAUM, 2009).

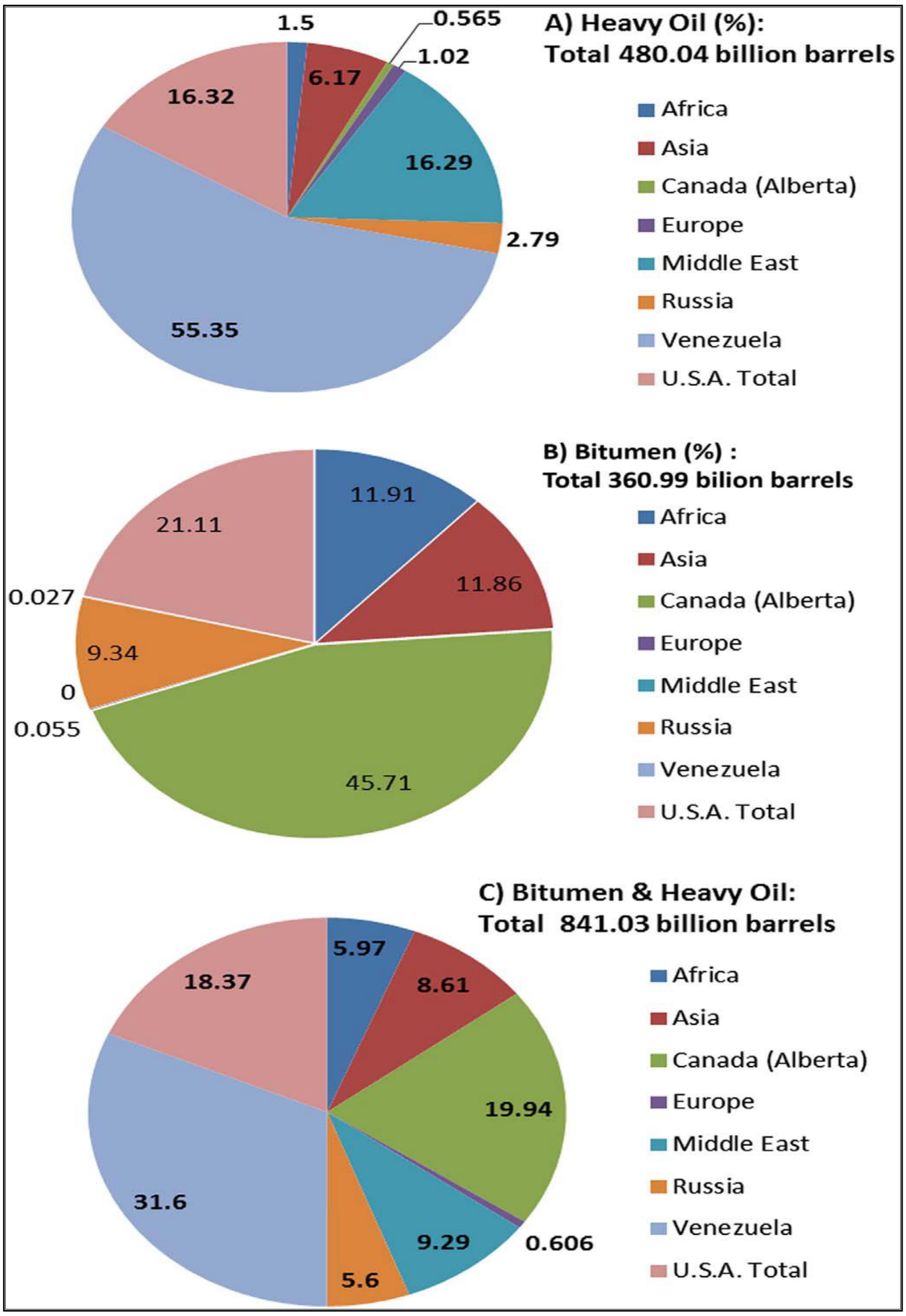
The formation of heavy oil and natural bitumen involve various processes. These includes expulsion of the oil from its source rock as immature oil which can either be as light or medium oil and thereafter migrate to a trap, which is elevated into an oxidizing zone that can convert the oil to heavy oil. The processes of conversion include water washing, bacterial degradation and evaporation. Heavy oil can also be formed as a result of biodegradation at depth in subsurface reservoirs (MEYER; ATTANASI; FREEMAN, 2007).

Figure 2 - Major world heavy-oil and bitumen resources. (A) Histogram showing the main deposits (blue = heavy oil; purple = bitumen). (B) Pie chart of heavy oil deposits. (C) Pie chart of bitumen deposits (Hein, 2006; Meyer and Freeman, 2003; Meyer et al., 2007; Humphries, 2008)



Source: Modified after KASHIRTSEV; HEIN, (2013).

Figure 3 - Pie charts of major world heavy-oil and bitumen estimated remaining technically- recoverable reserves



Source: HEIN, (2017).

2.1.2 Oil sands in Nigeria

The Nigeria Bitumen Corporation (NBC) was founded in November 1905 and operations started in 1906. The original intention of the Corporation was to search for both bitumen and crude oil, but from 1908 onwards, their major focus changed towards searching for crude oil. Between 1908 and 1912, about fifteen wells were drilled by NBC in their Lekki Lagoon concession. They struck oil in November 1908 at well no 5 but that was not the anticipated active oil field and coupled with financial difficulties, the projects were abandoned, as they were uneconomical (ENU, 1985; STEYN, 2009). The Geological Consultancy Unit, Department of Geology, University of Ife (Obafemi Awolowo Universty, Ile-Ife) did a detailed exploration study in 1974. The preliminary survey proved that the sands were continuous and they covered Ondo and Ogun states. The detailed study involved geological field mapping, geophysical work and the drilling of over forty boreholes in an area of about 17 square kilometres in the Odigbo local government area of Ondo state (ADEGOKE et al., 1976[5]; ENU, 1985).

Oil sands reserve in Nigeria is estimated to be between 41-43 billion barrels occurring within a belt that cuts across Edo, Lagos, Ondo and Ogun states (ADEGOKE; AKO; ENU, 1980; ENU, 1985; MMSD, 2018; CHINDO, 2011). The overburden has an average thickness of 24m, the X and Y horizon is separated by an average of 8m thick oil shale. The lower horizon, which is the Y horizon has an average thickness of 13m, while the upper horizon, which is the X horizon has an average thickness of 14m (ENU, 1985; ADEGOKE; AKO; ENU, 1980).

2.2 SOCIAL LICENSE TO OPERATE (SLO)

The concept of a ‘social license’ first emerged at meetings convened by the World Bank about mineral projects in developing countries in the late 1990s (KUCH et al., 2013; HALL et al., 2015; LINCOLN, 2015). SLO is an approval of a company’s ongoing presence or project by the local community, it is usually informal and intangible, and because the SLO is intangible, it can be difficult to know when it has been secured (YATES; HORVATH, 2013).

[5] ADEGOKE, O. S.; AKO, B. D.; OMATSOLA, M. E.; RAHAMAN, M. A. Tar Sand Project Phase II. Estimation of reserves, materials, testing and chemical analyses. **Unpublished Report. Geological Consultancy Unit, Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria**, 155p 1976.

SLO is believed to be both a goal and as a set of rules to be followed. It is a continuous and negotiated process in which a community's disapproval of one element of a project does not mean that the full support is being threatened or withdrawn (SMITH; RICHARDS, 2015).

Some definitions of SLO by different authors are as follows:

- When a mining project is seen as having the broad, ongoing approval and acceptance of society to conduct its activities (PRNO; SLOCOMBE, 2012; PRNO, 2013a; PARSONS; LACEY; MOFFAT, 2014).
- Ongoing acceptance and approval of a mining development by local community members and other stakeholders that can affect its profitability (PRNO, 2013a; MOFFAT; ZHANG, 2014; SMITH; RICHARDS, 2015).
- It is informal and intangible, granted by a community based on the opinions and views of local stakeholders and aboriginal groups (YATES; HORVATH, 2013).
- It is a tool whereby companies manage socio-political risk by following a set of implicit rules imposed by their stakeholders (SMITH; RICHARDS, 2015).
- An informal social contract existing between an industry and the community in which it operates, and the level of acceptance by a community to a company (LACEY; LAMONT, 2014).

In this research, the definition of SLO adopted is the one by PARSONS; LACEY; MOFFAT, (2014), PRNO (2013a) and PRNO; SLOCOMBE (2012). Their definition shows, first, that the approval of an SLO is ongoing and not permanent, which means it can be revoked or put on hold at any moment, and second, that the social license indicates that a society accepts that a company carry out its activities but it can also, at any point, reject the conduct of the company's operations. This definition is similar to those of SMITH; RICHARD (2015), MOFFAT; ZHANG (2014) and PRNO (2013a).

2.2.1 Motivations behind social investment

Almost all mining companies have shown that obtaining a formal license to operate from governments and meeting regulatory requirements is no longer enough. There are instances of delays in mining operations (OWEN; KEMP, 2013; HALL et al., 2015), interrupted, and even shutdown due to public opposition (PRNO, 2013a; MOFFAT; ZHANG, 2014; PRNO; SLOCOMBE, 2014). Project impacts that may contribute to this opposition include relocation of local communities, destruction of farmlands, operational dust and noise, and impacts on or perceived future risks on groundwater quality and quantity. Therefore, many mining companies tend to carry out social investment. The term social investment does not have a standard definition so; different companies define it in different ways. The definition by (AFRICAN DEVELOPMENT BANK GROUP, 2015) which says; any investment that is of benefit to the host community, and may benefit the company, but is not essential for the company's major operations was adopted in this research.

There are various reasons why different companies will tend to carry out social investment. Social investments are required by statute or regulation in some countries like South Africa and Nigeria. In addition to mandatory requirements, voluntary social investments are made by most companies (MCNAB et al., 2012; AFRICAN DEVELOPMENT BANK GROUP, 2015) and a major reason is to secure public support, which is also known as SLO. Decision on social investment depends on the companies, but governments can offer to cooperate with companies to add their local knowledge and access to planning processes, bringing possibilities for shared use infrastructure and joint projects (AFRICAN DEVELOPMENT BANK GROUP, 2015).

One of the qualifier is whether expenditure is to reduce the negative effects of a mining project or to get additional positive benefits for the host community. These two types of expenditure can add to corporate 'social performance', which includes efforts to guarantee that a company's performance in the social sphere does not undermine the objectives of the business. Some companies invest in projects to compensate for their negative impacts on the community, but such as do not qualify as social investments. Positive interventions that are not related to specific compensation but are meant for the positive benefits of the community are the ones that qualify as social investments (AFRICAN DEVELOPMENT BANK GROUP, 2015).

Table 2 shows examples of social investments that exist in Nigeria; these investments are not classified as SLO because the investment schemes are listed as either mandatory or regulated. However, for any social investment to be qualified as SLO, the investment must be voluntary. Moreover, any investments made by companies to compensate for their negative impacts on the community do not qualify as social investment (AFRICAN DEVELOPMENT BANK GROUP, 2015)

Table 2 - Examples of social investment schemes that exist in Nigeria

Scheme	Description	Type	Management responsibility	Mechanism	Focus	Method for determining quantum	Stated objectives
Niger Delta Development Commission Act, 2000 - Niger Delta Development Commission (NDDC)	All oil companies must make payments into a fund administered by the NDDC to support human development, infrastructure, health services and community development in the Niger Delta.	Mandatory contribution	NDDC (governed by a board of one industry member, members from oil- and non-oil-producing states and federal ministries of finance and environment)	Payment to fund/third party	Regional	Formula (3% of profits/total annual budget)	Infrastructure development; Human development; community development
Corporate Social Responsibility Commission Bill, 2009	Proposes an obligatory spend of 3.5% of gross annual profits per annum on CSR.	Regulated social initiative	Company	Social investment budget	National	Formula (3.5% of gross profits)	Human development; Environment protection; Community development
Nigerian Minerals and Mining Act, 2007 - section 116[3].14	A Community Development Agreement must be developed with the local community to ensure the transfer of social and economic benefits.	Regulated social initiative	Company	Binding, negotiated agreement	Local	Negotiated	Community development; Impact management; Environment protection

Source: MCNAB et al., (2012).

2.2.1.1 Overview of policy and legal frameworks on mineral resources in Nigeria.

The major law governing mining and mineral resources in Nigeria is the Minerals and Mining Act of 2007. The aim of the Act is to regulate all aspects of the exploration and exploitation of solid minerals in Nigeria and related purposes. The regulation of the mining sector is vested under the Minister for Solid Minerals Development who the Federal Government of Nigeria gave the authority to issue licenses to mining operators (LADAN, 2014; FEDERAL REPUBLIC OF NIGERIA, 2011). The Ministry of Solid Minerals Development, now Ministry of Mines and Steel Development (MMSD) was established in 1995 with the goal of ensuring full exploration and exploitation of the enormous solid mineral resource in the country. The Ministry is the principal organ for information, policy and regulatory oversight in the solid mineral sector in Nigeria (FEDERAL REPUBLIC OF NIGERIA, 2011).

Ownership of Mineral Resources

The term “Mineral Resources or Minerals” as defined in the Act means any substance whether in solid, liquid or gaseous form occurring in or on the earth, formed by or subjected to geological processes including occurrences or deposits of rocks, coals, cola bed gases, bituminous shales, tar sands, any substances that may be extracted from coal, shale or tar sands, mineral water, and mineral components in railing and waste piles, but with the exclusion of petroleum and waters without mineral content (LADAN, 2014). Countries including Nigeria, South Africa, and India, created legislation, which assigns the ownership of mineral resources to the care of the government. This is to protect and ensure that the development and extraction of the resources are of benefits to the landowners on whose lands the resources are found, and the rest of the citizenship (CHINDO, 2012).

2.2.1.2 The Minerals and Mining Act, 2007

There are about five to six mineral acts and decrees in Nigeria from 1940 to 1999. Presently, the Minerals and Mining Acts, 2007 (“the Act”) governs the mining operations (CHINDO, 2012). In this new Act, issues on mining administration, incentives for investors, mining community development and socio-environmental considerations are addressed. The Act contains provisions that will strengthen private sector investment in the development of the mining industry in the country. The following outlines some aspects of the Mining Act 2007 that are relevant to some of the objectives of this thesis.

All minerals in Nigeria are solely owned by the Federal Government, not the States, Local Governments, Communities or Individuals as written in the Mining Act. The Section 1(1), (2) and (3) of the Mining Act state that the control of all mineral resources in, under or upon any land in Nigeria is vested to the Federal Governments. Therefore, the Federal Government is solely responsible for mineral resources development, its licencing, regulation, supervision, and the collection of mineral royalties (NIGERIAN MINERALS AND MINING ACT, 2007). Although the Federal Government is solely responsible for mineral resources, in order to include the participation of the States Government authorities, especially since mining involves taking over lands in the states, the Section 19(1) of the Act provides for the establishment for each state, to participate as a member of State Mineral Resources and Environmental Management Committee. However, the State Governments have no power to enact, repeal any mining legislation nor establish their own mineral regulatory institutions.

Even though States where the mineral resources are extracted may be allocated a certain proportion of the revenue realised from the mineral products based on a principle known as the 'Derivation Principle'. A revenue allocation formula, in which a certain percentage of mineral revenues is allocated to the mining states but most mining communities barely feel the impact of the wealth (CHINDO, 2012). This derivation principle has been implemented in oil and gas sector of the country, but it is yet to be applied in the solid mineral sector. A number of commissions were set up for the development of the oil producing communities, which include the Niger Delta Development Commission (NDDC) and the Ministry of the Niger Delta. However, the Mining Act 2007 failed to deal with this issue (CHINDO, 2012).

The Local Governments authorities, village head/community leaders play important roles in addressing conflict and ensuring peaceful co-existence between miners and local communities (CHINDO, 2012). Section 100 of the Act requires that mineral title applicants obtain the consent of private landowners and land under the State lease before license can be granted.

To support the mining host communities, a Community Development Agreement (CDA) that will help in the provision of the social and economic benefit to the local community was put in place in the Act; this can be found in Section 116 (1), (2), (3), (4) and (5) (NIGERIAN MINERALS AND MINING ACT, 2007). Therefore, the local communities where mining operation are being conducted can rightfully have a signed agreement that will ensure the socio-economic benefits of the communities are transferred to the community, without it, no license shall be issued to the mining company.

Likewise, submission of both the Environmental Impact Assessment Report and Environmental Protection and Rehabilitation Program in addition to the CDA is required from the Mineral title applicants. This is ensure that the mine site is not left degraded at the end of the mining lease (LADAN, 2014). Section 118 a and b of the Act emphasized that that all mine sites are to be restored, rehabilitated or reclaimed back to its natural or predetermined state or to such state as may be specified in the Act, which is also explained in the Section 115 of the Act (NIGERIAN MINERALS AND MINING ACT, 2007). It is however not stated specifically with who and how the CDA will be negotiated and agreed upon. Without this, some powerful people in the community may hijack the CDA process and thus, preventing it from benefiting the community (LADAN, 2014). Compensations for damages and destructions that may result from any mining titleholder was addressed in the Section 107 (a) and (b) of the Act. This was explained further in Section 113 of the Act.

Two funds were established in order to provide support services. The first one is known as the ‘Solid Minerals Development Fund’ or referred to as "the Fund" as stated in the Section 34(1) and (2) in the Act. These are meant for human and physical capacity development, geo-scientific data gathering, storage and retrieval, equipping the mining institutions, provision of funding for the small-scale and artisanal mining operators; and provision of infrastructure in mines land. The second fund is “the Environmental Protection and Rehabilitation Fund”. This is to be funded yearly by mineral titleholders and it is meant to guarantee the environmental obligations of the Minerals titleholders (NIGERIAN MINERALS AND MINING ACT, 2007).

To attract more investors, it is stated in the Act that the mining companies with mineral title can enjoy a tax relief period of three years at the commencement of mining operations as shown in the Section 28(1), (2) and (3) and may be extended by the Minister for a further period of two years. Royalty payments can be reduced or waived by the minister. The Section 33(1), (2) and (3) of the Act show that the royalty is meant to be paid on mineral obtained during exploration or mining. As the regulation of the mining sector is vested under the MMSD, the Minister have the power to reduce or waive royalty on any mineral, which the Minister is satisfied as being exported mainly for the aim of scientific purposes. Section 25 (1), (2), (3) and (4) exempt all mining operators from payment of customs and import duties on machinery and equipment. Expatriate quota and resident permit for the approved expatriate personnel, which is free from imposed tax on funds transfer outside the country. Section 26 permits the holder of a mineral title to retain and use earned foreign exchange and Section 27 gives free transfer of funds through the Central Bank of Nigeria (NIGERIAN MINERALS AND MINING ACT, 2007).

Mineral licences are issued to ensure that the mining sector generates revenue for the government. Under Section 46(1) of the Mineral Act 2007, the right to search for and exploit minerals in Nigeria can be obtained under one or a combination of the following titles:

(a) Reconnaissance Permit;

(b) Exploration Licence;

(c) Small-scale Mining Lease;

(d) Mining Lease;

(e) Quarry Lease; and

(f) Water Use Permit.

The mining titles in Nigeria can be found in chapter 6 of the Act. Table 3 shows the summary of the mineral titles, their allowable area coverage and the duration of grant.

Table 3 - Mineral titles in Nigeria and their area extent

Type of Licence/Permit	Duration (Year)	Maximum Area (Km2)	Granting/Refusal Period (Days)
Reconnaissance Permit (PR)	1	Non-exclusive	30
Exploration Permit (EP)	3	1000	30
Mining Lease (ML)	25	50	45
Small-Scale Mining Lease (SSML)	5 0r 10	3	45
Quarry lease (QL)	10	3	45
Water use Permit (WP)	-	-	-

Source: CHINDO, (2012)

2.2.2 Importance of securing and maintaining a social license to operate

Acquisition and maintenance of SLO is very relevant to mining companies, and the consent of the stakeholders is greatly important in operating and developing a specific asset. One of the most serious problems faced by mining companies is obtaining and maintaining an SLO. Most of the work done to secure an SLO takes place in the period before a mine begins operations (PIKE, 2012) or pre-mining phase, which is the best moment for obtaining a social license. The negative consequences of investing capital on resources that a mining company will be unable to mine are great if the capital cannot easily be recovered, but are much smaller during the pre-mining phase because there is less capital invested (PIKE, 2012). However, obtaining the license is not enough; the company must make a constant effort to correspond to the community's expectations of how it will be treated, so as to keep the license for the entire life of mine (LOM). The differences between obtaining and maintaining an SLO may seem to be small, but the impacts on business are intense.

2.2.2.1 Securing a social license to operate

Securing SLO is stated as one of the most crucial challenges that will be faced by mining companies (ERNST & YOUNG GLOBAL LIMITED, 2011; PRNO; SLOCOMBE, 2012). Local communities are often major authorities in granting SLOs because they are situated on the mining project's vicinity and have the ability to affect its outcome (PRNO; SLOCOMBE, 2012). If SLO is issued by a society, the closeness of the local communities to the project, understanding the effects and ability to affect the outcome of the project often makes it a key arbiter in the process. An SLO reduces risk and allows operation continuity without conflict.

The granting of a SLO for local communities usually means they have been involved in decision-making and have gotten enough benefit from the project. This has thus granted some mining communities the power to grant or withhold SLO (PRNO; SLOCOMBE, 2012). Mining companies must endeavour to convince the community to accept mining and grant them an SLO, because a social license is essential to guarantee the continuity of the company's activities while minimizing conflicts with the local communities. Communities' and stakeholders' views and concerns are seen as part of the socio-economic factors in developing new resources (OMOTEHINSE; TOMI, 2019; LACEY; LAMONT, 2014), which the Red Dog Company demonstrated in (PRNO, 2013a), ***"**It stated that its SLO is because of the economic benefits provided by the mine to the local community".*

Failure to obtain an SLO may lead to inability to develop economically valuable mineral resources (PRNO; SCOTT SLOCOMBE, 2012). The neglect of the social impacts of mining activities and the absence of mitigating measures may result in social conflicts and prevent the company from obtaining an SLO (RADON et al., 2016). Differences between expected and experienced impacts may affect the level of the community's trust in the mining company. If actual impacts are more severe than expected, the community may reject mining activities altogether, and if they are less severe than expected, this can contribute to the community's acceptance and trust (MOFFAT; ZHANG, 2014). Experience shows that compensation and agreements made at the beginning of an operation cause some tensions and these often continue throughout the LOM (MINING, MINERALS AND SUSTAINABLE DEVELOPMENT, 2002). Therefore, restoration of the community's way of life should include capacity building to help small businesses and a resettlement plan detailing how individuals will be resettled (VANCLAY et al., 2015).

YATES; HORVATH (2013) stated that SLO can be earned by building trust and credibility through: effectively communication of complete information; respecting community engagement and giving them audience; providing support for local communities; carrying out projects in an environmentally and socially responsible manner and; ensuring that communities benefits and that they are not unfairly affected by activities. SLO is highly regarded by companies because it: gives a legitimate presence and actions for SLO holder in a local community; provides regulators with a level of comfort that a supporter is acting responsibly; minimizes and manages the risk of costly delays by opposition; enhances trust; and protects a company's reputation (YATES; HORVATH, 2013).

There are criticism that SLO places too much power in the public because it gives corporations the liability to negotiate directly with community members, which is seen as a "free-market killing concept" (CORCORAN, 2014). CORCORAN, 2014 described the concept of SLO as being a mystery because it cannot be defined and that it is based on the perceptions of the people, it's impermanent, it's unwritten and it's subject to change". Although, this may be debatable in some countries, but it does not refute the fact that mining activities may have direct and indirect impacts on the host communities and these may have environment and social effects on their livelihood. It is therefore important that the host communities be engaged and there should be dialogue on how to resolve the impacts of mining activities. This has led to what is being referred today as SLO.

2.2.2.2 Maintaining a social license to operate

Legitimacy, credibility, and trust were identified as the three components of SLO while withdrawal, acceptance, approval, identification with the project psychologically were said to be the four levels of SLO (BOUTILIER; THOMSON, 2011). It was said that moving from one component to another builds and balances the social capital in the relationships between the company and local stakeholders, which helps the community to issue a meaningful SLO. This capital comes from structural, relational and cognitive sources. BOUTILIER; THOMSON (2011) further note that community partnership participation can earn a SLO if the company can learn it, and the issuance of SLO by communities who want mining depends on their social structure capacity that shows their capability of issuing a legitimate, credible, trustworthy SLO.

There are financial and operational reasons which causes the mining company to ensure that their projects is free of interruptions and SLO can be seen as a type of insurance because lack of SLO can lead to higher project costs which can increase the interest rate for financing these projects. Thus jeopardizing the company's capability to get finances and it decreases shareholders' profits. PRNO (2013a) gave an illustration using a mining company known as Red Dog, which states that:

"*Red Dog employees have generally been inclusive of community perspectives, responsive to conflict, and willing to modify their approach to operating the mine when needed"* (PRNO, 2013a).

The willingness of the Red Dog Company to reason along with the local communities can contribute to the maintenance of their SLO throughout the LOM.

2.2.3 Displacement/Resettlement

Resettlement, which is another major negative social impact, can be defined as a planned process of relocating people and communities from one place to another. It should be avoided when possible because it is very costly for projects. There can be both physical and economical displacement. Physical displacement is the loss of housing as a result of acquisition of land and/or restrictions on land use by mining companies. Economic displacement are situations where there is a loss of other assets or inability to access other assets (e.g. agricultural land) which will result in a disruption of livelihoods and loss of income. Appropriate compensation must be made by companies that cause physical or economic displacement (VANCLAY et al., 2015). In the region under study, displacement/resettlement is unavoidable because the oil sands deposits are scattered within the region. There will be some physical displacement as well as economic displacement because the oil sands deposits are located in places where their major source of living is farming and fishing.

A settled community that is displaced can cause a major resentment and conflict between mines and communities. Loss of land, livelihoods and disrupting community institutions and power relations can cause resentment. Involuntary resettlement can be catastrophic for local communities with strong cultural and spiritual ties to the lands and may find it difficult to survive when these are broken (MINING, MINERALS AND SUSTAINABLE DEVELOPMENT, 2002).

2.2.4 History of conflicts in the extractive mineral industries of Nigeria

The term extractive industries applies to both the mining and the oil and gas sectors, since both of them extract non-renewable mineral resources. Nevertheless, there are some major differences in their mode of industrial operation. The lifespan of a mine is often long and mainly leads to formation of new or extended communities where their employees stay, and the company and its employees have to live with the consequences of the way they run their business. In contrast, the development of an oil and gas company comes with the assumption that the company has a short-term relationship with the community located in the area of its activities. Their employees are often without their families, they come and go and mostly stay in temporary houses (SMITH; RICHARD, 2015). Although the end product of oil sands mining is synthetic crude oil, it uses mining methods and technology and undergoes all five stages of mining, and therefore does not belong in the oil and gas sector.

Most extractive-rich communities across Nigeria are located within rural areas with poor community members, illiterate farmers, fishermen or petty traders (GLOBAL RIGHT, 2016). Nigeria's Niger Delta region has recently been home to a series of conflicts between local communities and multinational oil companies, due to the latter's poor environmental performance and different cases of oil spillage within the communities, which went on for years. OSAGIE et al., (2010) gave some examples, including Obobutu vs Elf (October 1989), Umuechem vs Shell (October 1990), Uzere vs Shell (July 1992) and Ogoni vs Shell (1990 to the present). The Ogoni vs Shell conflict is taken as an example in this research because there were fewer reports on the conflicts involving the communities of Obobutu, Umuechem, and Uzere. The cases of oil spillage and conflicts in these communities followed the same pattern as Ogoni vs Shell and most are unpublished.

Ogoni Land, one of the oil and gas communities in the Niger Delta, enjoyed prosperous farming and fishing before the arrival of Shell in 1958. The start of Shell's oil exploration operations had a serious impact, devastating the farmland and the environment (USANG; IKPEME, 2015). Young Ogoni elites seeking to guarantee autonomy for their region created the Movement for the Survival of the Ogoni People (MOSOP). In December 1992, MOSOP issued a series of ultimatums demanding payment of royalties and damages, and re-negotiations for future oil exploration. Despite some of MOSOP’s success, the power-holders gave little assistance to the movement. Thus, Ken Saro-Wiwa, an Ogoni leader and activist, sought international assistance to fight Shell and the Nigerian government, something which slowly encouraged the spread of activism in the region (GROVES, 2009).

MOSOP’s anti-Shell protest was answered with state violence, which included killings, rapes, and protesters’ arrests, while globally the company faced negative press coverage. Following the growth of the security threat, the company was forced to close down production in Ogoni land entirely by mid-1993. During the continued protests, Ken Saro-Wiwa and eight other MOSOP leaders were arrested and charged with incitation of murder, and hung in November 1995 (USANG; IKPEME, 2015; GROVES, 2009). The death of Ken Saro-Wiwa and the other MOSOP leaders resulted in the disintegration of the movement. This provoked other youths from minor ethnic groups, leading to vandalization of pipelines, kidnapping of expatriates, and emergence of other militant groups (USANG; IKPEME, 2015; ONWUBIKO et al., 2013).

The death of Ken Saro-Wiwa brought about a public relations disaster for Shell. The company was implicated in human rights violation and shown to have tried to suppress a movement for environmental justice (GROVES, 2009). Oil production capacity dropped drastically as the company withdrew its workers from the affected areas. Shell distanced itself from the repressive policies of the Nigerian government in late 1996, embraced the corporate social responsibility (CSR) movement and sought to obtain an SLO in the Delta region (GROVES, 2009). The Nigerian government had to publically seek peaceful negotiations and adjust its policies, and in 2000, a board was set up for the development of the Niger Delta (ONWUBIKO et al., 2013). OSAGIE et al., (2010), however, concluded that the reason for this great conflict was the natives being deprived of their dividends from oil proceeds.

Non-compliance of agreement by the government, bad leadership, political manipulation of youths and violence combined to allow a set of people to take advantage of the situation to become wealthy quickly and gain recognition and status (USANG; IKPEME, 2015). A high level of corruption prevented the Niger Delta people from getting their benefits from the allocated revenue (ONWUBIKO et al., 2013). The crisis at that time (1990) caused the creation of different militant groups in the Niger Delta region, which persist to this day. Although water pollution, gas flaring and environmental degradation are still present in the Niger Delta region, the Nigerian government and the board that was set up to help the people of that region were able to overcome some of the calamities brought about by the crisis in the region.

The Ken Saro-Wiwa family sued Shell, accusing the company of collaboration in the executions. Although the company did not admit to any wrongdoings, in 2009, it paid a sum of $15.5 million to settle the lawsuit, the survivors and Ogoni charities (BUSINESS AND HUMAN RIGHTS RESOURCE CENTRE, 2009; INSTITUTE FOR HUMAN RIGHTS AND BUSINESS, 2015).

As the oil sands deposit is located in the Niger Delta region of Nigeria, it is important to carry out a study on the oil sands communities to identify the challenges that will be faced by a company when it seeks to obtain an SLO to explore these oil sands. It is also important to discuss how to manage these challenges in order to avoid repeating the mistakes made by the oil and gas industries in the Niger Delta region.

2.3 ECOSYSTEMS SERVICES

Ecosystem can be defined as the complex networks of human, animal, plant, microbial and abiotic interactions (Figure 4) (PERSSON et al., 2010; MILLENNIUM ECOSYSTEM ASSESSMENT, 2003), and an integral part of the ecosystems are humans. There are various types of ecosystems (Figure 5) and healthy ecosystems are very important in the provision of various processes that improve human wellbeing (KUNZ et al., 2011; MILLENNIUM ECOSYSTEM ASSESSMENT, 2003), these processes and products are commonly referred to as ecosystem services (ES).

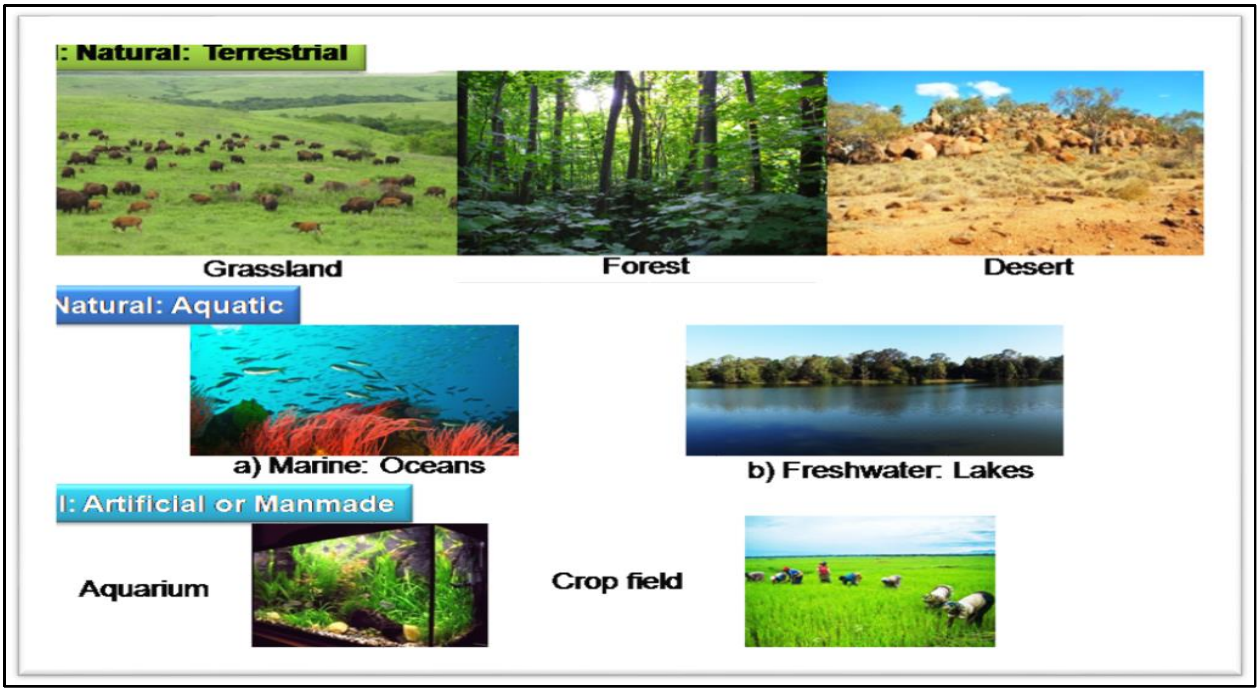
ES can also be defined as the direct (e.g. food supply) or indirect (e.g. climate regulation), both large and small benefits humans gain from ecosystems (EGOH et al., 2011), also as the conditions in which ecosystems sustain and fulfil life (DAILY, 1997). The Millennium Ecosystem Assessment (MILLENNIUM ECOSYSTEM ASSESSMENT, 2003; 2005) defines it as benefits derived by people from ecosystem.

Most ecosystems have been converted to different type of land cover that differs by its management or type of land use and management systems differ in the way people extract and in the level of production. A change in land use or management will thus cause a change in supply of the complete package of services provided by that ecosystem (DE GROOT et al., 2010). ES are important to the existence of human; also, products derived from mining activities are also very important in human daily existence. Mining is said to have impacts on ES and because of different benefit enjoyed or derived from it by humans, this research tends to look for a more practical way of reducing the effects of mining on these services.

Figure 4 - Ecosystems

Source: PLANT SCIENCE 4 U, (2019)

Figure 5 - Types of ecosystem



Source: PLANT SCIENCE 4 U, (2019)

The variation in ES depends on the ecosystems and the organisms they constitute (KUNZ et al., 2011). Degradation of ecosystem harm rural populations more directly than urban populations and has most of its direct and dangerous impact on poor people (MILLENNIUM

ECOSYSTEM ASSESSMENT, 2003; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005). Productive ecosystems, with their variety of services can provide communities with resources and options when faced with natural calamities. Well-managed ecosystems mitigate risks and vulnerability while poorly controlled ecosystems can increase them by intensifying the chances of flood, crop failures and diseases (MILLENNIUM ECOSYSTEM ASSESSMENT, 2003). Poor people are not opportune to the use of alternate services and are powerless when there are changes in the ecosystems that result in famine or floods. They mostly live in areas that are mostly sensitive to environmental threats, and they lack educational and financial cautions against these threats.

For example, degradation of the fishery resources reduces the protein intake by the local community since fishermen may not have access to other sources of fish and the community may not be earning enough money to purchase fish. Therefore, degradation affects their survival (MILLENNIUM ECOSYSTEM ASSESSMENT, 2003; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005).

Some ES have substitute, with often-high cost of technological substitution and not all services lost may be replaced. For example, substitution of the ecosystem in providing clean water-by-water treatment plants, even if this is expensive or not, it sure cannot overcome the impacts of water pollution on the ecosystem and the services they provide. In most case, the individual who benefits from the ES often turns out not to be the one benefitting from the substitution. For example, local fish production can be replaced by shrimp ponds in tropical regions, but the individuals that earns their living from capture fisheries will not be the ones who would benefit from the new shrimp aquaculture business. Therefore, in assessing ecosystems and their services, one consider information and implication on the cost of a substitute i.e. cost of maintaining the service; impacts and cost of cross-service; and the distributional impacts of any substitution (MILLENNIUM ECOSYSTEM ASSESSMENT, 2003; DAILY et al., 2000).

2.3.1 Ecosystem services categories

The MEA categorizes the ES into four: provisioning, regulating, cultural and supporting services (Figure 6) (MILLENNIUM ECOSYSTEM ASSESSMENT, 2003; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005)

- Commodities gotten from ecosystems such as livestock, fishes, and freshwater are referred as provisioning services.

- Rewards gotten from the natural process of ecosystem's control, such as regulation of water timing and flow, and disease regulation are called regulating services.
- The rewards gotten from ecosystems, such as educational, inspirational, and aesthetic enjoyment are referred to as cultural services.
- The inherent procedure that preserve the other ES, such as nutrient cycling and habitat are referred to as supporting services (LANDSBERG et al., 2013; LANDSBERG et al., 2011).

Figure 6 - Ecosystem services

Source: BATH AND NORTH EAST SOMERSET COUNCIL, (2020).

2.3.2 Ecosystem services mitigation hierarchy

- Avoidance measures: These are measures taken in order to avoid impacts of project activities on ecosystems in order to make the benefits associated with these services and capacity of ecosystems to supply services remain unchanged.
- Minimization measures: These are measures taken in order to keep to minimum the duration, intensity, and/or extent of project impacts on ecosystems. This helps to reduce the impacts on ES supply and benefits.
- Restoration measures: These are measures taken to restore impacts on ecosystems that cannot be totally avoided and/or decreased.

- Offset measures: These are measures taken to compensate for loss in ES benefit. They include: using man-made substitutes as compensation; restoration of ecosystems supplying the ES to the same affected stakeholders but are not impacted; and increasing the benefit accrued from one unit of ES supply (MCKENNEY; KIESECKER, 2010; CHAMBER OF MINES OF SOUTH AFRICA, 2013; LANDSBERG et al., 2013).

After the mitigation hierarchy is followed, an assessment of the priority measures is carried out taking into account the specific features of the area under study.

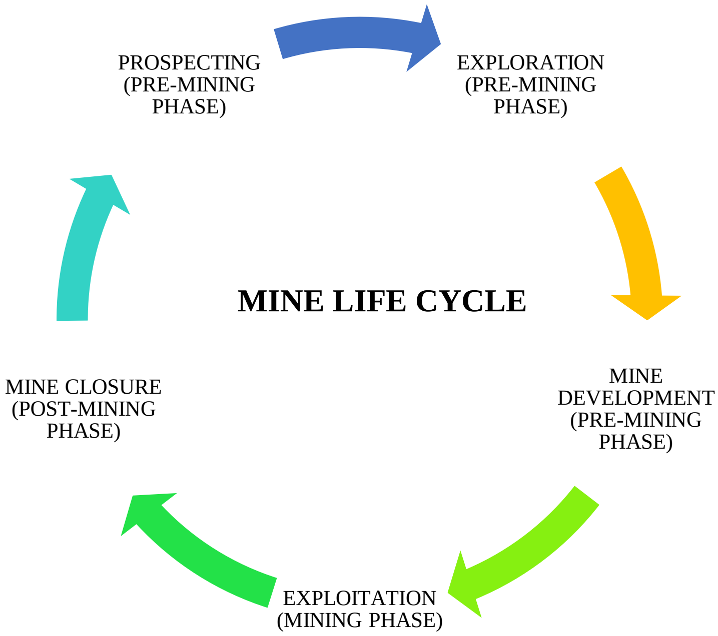
In this research, the concept of LANDSBERG et al., (2013) and associated indicators will be applied to assess the pre-mining effects on the ES. ES are assumed to serve as landscape assessments, evaluating the individual parts and functions by different users (LARONDELLE; HAASE, 2012). Mining operations are usually involve a twofold change: (i) from a pre-mining landscape to a mining landscape and (ii) from a mining landscape to a post-mining landscape. This research considered the first fold i.e. from a pre-mining landscape to a mining landscape, which is usually the fold for preparing the mine before exploitation begins in mines. Due to increase in impacts of mining activities on the environment and ecosystems, a more integrated assessment of mining on ecosystem and services are needed to achieve more sustainable pre-mining development (LARONDELLE; HAASE, 2012).

2.4 OIL SANDS MINING PROCESSES

2.4.1 Phases in the life of a mine

The mine life cycle comprises five stages as shown in Figure 7: (1) prospecting, (2) exploration, (3) mine development, (4) exploitation (extraction) and (5) mine closure (OFORI; OFORI, 2019; HARTMAN; MUTMANSKY, 2002). In this research, these stages were divided into three phases: pre-mining, mining and post-mining.

Figure 7 - Mine life cycle



Source: Personal file

2.4.1.1 Pre-mining

These are the activities carried out before the exploitation of the deposits starts. They include the stages of prospecting, exploration and mine development (OMOTEHINSE; TOMI, 2019; HARTMAN; MUTMANSKY, 2002).

Prospecting: this is the search for new deposits or minerals of significant potential and are discovered using the earth's properties by visual inspection and physical measurements, which suggest that the occurrence of the deposits is worth subsequent testing. Prospecting activities include geophysical / geological / geochemical studies to drill areas in which the ore body are found, and hand sampling of the mineral specimens (NATIONAL RESEARCH COUNCIL, 1999; NEWMAN et al., 2010; AL-USMANI, 2011).

Exploration: this stage is critical because it is mostly the first encounter between the community and mining company. This is when the relationship between the community and mining company is built, and depending on the way it is managed, perceptions of the company will be built for a long period of time, this can either be positive or negative and will affect the other stages of mine operation (MINING, MINERALS AND SUSTAINABLE DEVELOPMENT, 2002). The main objective of exploration is to discover an economic mineral deposit. In the exploration stage, which is the second stage, the value of the deposits are determined by estimating the mineral concentration and how it varies throughout the ore-body (OMOTEHINSE; AKO, 2019; NATIONAL RESEARCH COUNCIL, 1999; NEWMAN et al., 2010; AL-USMANI, 2011). In this stage, the presence of a deposit and its size, shape, and composition are tested and confirmed. Drilling method is mostly used to determine both the lateral and vertical extent of the deposit. Other characteristics, such as continuity of mineralization, grade, rock types, and hydrologic information are also determined (NATIONAL RESEARCH COUNCIL, 1999).

Mine development: this is the third stage of a mining operation. It includes obtaining rights to access the land and preliminarily preparing it to be mined. This stage involves; getting proper access to land, preparing the mine site by constructing the road, putting surface facilities and infrastructures in place, preparing locations for overburden material, stockpiles, and tailings impoundments, creating access to the minerals through vertical shafts or horizontal adits. Underground drifts and ramps are excavated to provide the access needed to mine the ore, transition from mine planning studies into mine design by; determining the method of mining, performing the engineering design, estimating the capacity of production and preparation of the mine for production by pit excavation (NATIONAL RESEARCH COUNCIL, 1999; NEWMAN et al., 2010; AL-USMANI, 2011).

2.4.1.2 Mining

Mining**:** In the mining phase, the ore is removed from the ground via surface and (or) underground mining methods which is transported via haulage ramps, shafts and conveyor belts etc. to the surface where it could be stockpiled or it can be sent directly to a processing plant (NATIONAL RESEARCH COUNCIL, 1999; NEWMAN et al., 2010). Although deposits are different, but most mines, (both surface and underground) use the same basic operations: drilling, blasting, mucking (loading), and transporting (hauling). Placer mining (gold mining) can be different in that it uses gravity separation method, which is quite different from typical hard-rock mining in several respects. Some placer mining in the United States involves mining with suction dredger (NATIONAL RESEARCH COUNCIL, 1999).

The most likely longest phase that needs concentration and decision-making is the mining phase. It has the most intensive environmental and social impact (MINING, MINERALS AND SUSTAINABLE DEVELOPMENT, 2002; PIMENTEL; GONZALEZ; BARBOSA, 2016).

Oil sand surface extraction involves the removal of overburden and the ore, which is usually about 75 meters. During this process, the ore extraction, uses barrels of fresh water (between 7.5 and 12 barrels, to include recycled water) to extract and upgrade the oil sand. The wastewater is usually stored as tailing water in the mine site and cannot function as part of the water cycle because of its high toxicity (SBERT, 2015) except it is processed and recycled.

2.4.1.3 Post-mining

This is majorly the activity carried out after the exploitation of the deposits and can be referred to as mine closure (HARTMAN; MUTMANSKY, 2002).

Mine closure: this is the fifth stage in the LOM. It means restoring the mine site to its natural state to the possible extent or the sites maybe turned to beneficial use. Common reclamation and rehabilitation practices include reducing of slopes to minimize erosion; landfill of open pits; planting grasses that will help in erosion control and benefit. Normally, a mine is not to be closed until reclamation is complete, but in some cases, reclamation may not be fully accomplished therefore monitoring the site for a long time will be necessary (NATIONAL RESEARCH COUNCIL, 1999). All mining phases are connected to SLO; however, the procurement for SLO starts from the pre-mining phase of a mine operation and mostly throughout the LOM.

The pre-mining phase was considered because it encompasses the first set of operations that will be carried out by the mining company and the impression they leave on the community is what the latter will hold on to in the following phases. This phase has three major stages, which will be the focus of this research, the last stage that is mine planning and design encompasses some other studies and the ones related to this research are discussed in details.

2.4.2 Conceptual mine planning

The order of economic and magnitude study of the potential viability of mineral resources can be referred to as the Conceptual or Scoping Study. This study includes proper evaluation of realistically assumed Modifying Factors with other applicable operational factors that are required to demonstrate that progress to a pre-feasibility study can be reasonably justified when making the report. A Conceptual Study cannot be used as a basis for ore reserves estimation (AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, 2012; COMISSÃO BRASILEIRA DE RECURSOS E

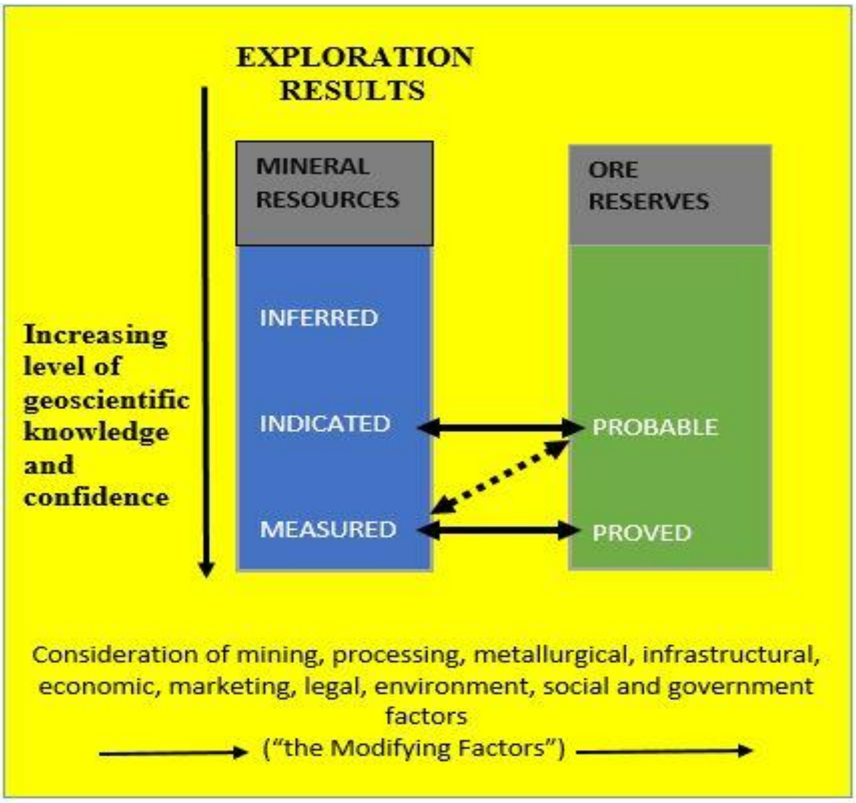
RESERVAS, 2016). Conceptual Studies are preliminary economic assessments (PEA) of a project that can be based on a combination of data that is compiled directly from the project together with assumptions from deposits. They are used by companies for planning and comparative purposes. The process and data input used in estimating a mineral resources should be indicated in a Conceptual Study and the study should state if it is partially or fully supported by Inferred Mineral Resources with a cautionary statement included (AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, 2012; COMISSÃO BRASILEIRA DE RECURSOS E RESERVAS, 2016).

The Joint Ore Reserve Committee (JORC Code) is the *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves*. This committee, which was established in 1971, sets outs recommendations, guidelines and minimum standards for Reporting of Exploration Results, Mineral Resources and Ore Reserves (AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, 2012). They were also the first to define the concept of Competent Person in 1972.

Some countries including Australia and South Africa have their international systems for declaration of mineral resources and reserves. Australia made the first move in 1989 and the Australasian code for reporting of exploration results, mineral resources and ore reserves; the JORC code (AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, 2012) was published.

The South African Code for Reporting of Exploration results, Mineral Resources and Mineral Reserves (Figure 8) (The SAMREC Code) (SOUTH AFRICAN MINERAL RESOURCE COMMITTEE, 2007) was published in 2000. In 1991, the guide for reporting exploration information, resources and reserves was published by the U.S. Society for Mining, Metallurgy, and Exploration (SME). The revisions for both the U.S. guide and United Kingdom were based on the 1989 JORC code. A mineral resources/reserves international definition working group was set up by the Council of Mining and Metallurgical Institutions (CMMI) in 1993 with representatives from Australia (AusIMM), Canada (CIM), South Africa (SAIMM) and the U.S.A. (SME). This brought about the development of an international definition of a Competent Person, reciprocity conditions for the recognition of Competent Persons, Competent Persons professional rules of conduct and an international reporting code and guidelines. As these international guidelines will come into use, the need for modifications will be made by experiences (RENDU; MISKELLY, 2001).

Figure 8 - Relationship between Mineral Resources and Ore Reserves



Source: Modified after, AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, (2012)

A 'Competent Person' is a professional in the minerals industry who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy, or of the Australian Institute of Geoscientists, or of a 'Recognised Professional Organisation' (RPO), as included in a list available on the JORC and ASX websites. A Competent Person must have a minimum of five years relevant experience in the type of deposit under consideration and in the activity, which that person is undertaking (AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, 2012). Modifying Factors are considerations used to convert mineral resource to ore reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors (AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES, 2012).

2.4.2.1 Geological block modelling

Orebody block modelling is a significant step in modern open pit mine planning (THORLEY, 2012). It is made up of the geologic and economic block models which is the backbone of the activities throughout the LOM (HUSTRULID; KUCHTA; MARTIN, 2013; BEN-AWUAH, 2013).

A regular, three-dimensional array of blocks that represent the properties and characteristics of an ore body for the purpose of mathematical modelling can be defined as a block model (THORLEY, 2012; CACCETTA; HILL, 2003; BLEY et al., 2010). The block model is based by dividing the ore body into fixed size blocks. The dimension of the block depends on the physical characteristics of the mine, such as pit slopes, dip of deposit and grade and sometimes by the deposit type (THORLEY, 2012).

Based on drill hole data and a numerical technique, mineral samples are used to interpolate grades and densities of the deposit where the orebody will be divided into a regular three dimensional array of blocks and each will be assigned with an estimated tonnage and mineral grades. At each block location, the properties of the deposit are populated from the geologic model and by geostatistical estimation methods. Examples of the geostatistical or numerical technique used are method such as: geostatistical (e.g. kriging, simulations) or conventional (e.g. inverse distance weighting, polygonal). The net profit of each block is determined and computed using the financial and metallurgical data. Profits calculations are done in present value; not considering the time in which the block is extracted (CACCETTA; HILL, 2003; BLEY et al., 2010; CHICOISNE et al., 2012; THORLEY, 2012).

2.4.2.2 Ultimate pit limit

One of the major problem in mine planning is the determination of the optimum ultimate pit limit (UPL) of a mine. The contour that is generated as a result of the extraction of the volume of material which gives the total maximum profit while satisfying the operational requirement of safe wall slopes is called the UPL of the mine, this is usually smoothened to give the final pit outline. The shape of the mine at the end of its life is given by the UPL. A huge role is played by the optimum pit design in all stages of the life of an open pit. During the different stages of the mine, a continuous monitoring and review of the optimum pit is required to give the best long, medium and short term mine planning and subsequent exploitation of the reserve.

The Lerchs- Grossmann (LG) graph theoretic algorithm has resolved the problem of the UPL such that it maximizes the total profit from the mine. This method is based on the “block model” of an orebody (CACCETTA; GIANNINI, 1988; CACCETTA; HILL, 2003; BLEY et al., 2010).

Pit optimization is used in defining the pit shell. The pit shell was optimized using the LG algorithm (LERCHS; GROSSMAN, 1968) in mining Software. This algorithm helps to produce a pit outline that maximizes the difference between the total value of the ore mined and the total cost of extracting both the ore and waste. It takes in the geologic models and mining parameters and a set of blocks that should be extracted to maximize profit subject to pit slope constraints will be created (BEN-AWUAH, 2013).

Delineation of final pit contour involves defining the areas in which extraction will be carried out in the mine site; this subdivision is called the final pit contour or UPL. Before extraction of any block, all blocks immediately above must be removed and at certain angles known as wall-slope requirement angles. Determination of the UPL requires knowing the slope angle. This depends on the structural composition of the rocks, which varies according to the location, and depth of each block. Once the slope angle requirements are known, the precedence relationships between blocks can be defined (CACCETTA; HILL, 2003; CHICOISNE et al., 2012).

Once the outline of the ultimate pit is done, design engineers will begin the scheduling of the material to be extracted within this excavation limit. This long term, LOM and scheduling is mostly done in a series of detailed stages with the first stage being the development of pushbacks which is the intermediate excavation limits (THOMPSON; BARR, 2014). Extraction of ore and waste are done in the proportions given by the stripping ratio. Classification of the volume of rock within a given phase in its fraction of recoverable metal content, known as the recoverable grade of the rock is done. In histogram, the phase distributions given are direct outputs of standard mine design software (such as Micromine and Surpac) (THOMPSON; BARR, 2014).

Graham Tudor was the founder of Micromine mining software; it was established in the late 1980’s as an exploration data management and modelling system. Subsequently, the technical capabilities covered the areas of geological modelling, mine planning and production management, drilling and geoscientific information management. There are other many

professional mining software, used for economic evaluation of open pit mine, the geology of the ore body, transport communications and other technological processes.
The identification of the optimum pit limit and a series of sub-pits or nested pits within the final pit limit is done using the pit limit analysis. The establishment of the occurrence of the transition from the most profitable material at the pit limit to the least profitable or break-even material are done using the nested pits.

This establishment helps the mine planner to select where to start mining, and the sequence of mining out the pit in order to generate the maximum net present value (NPV) from the material within the final pit limit. It also guide the mine planner in the identification of the highest value per tonne portions of the orebody thereby guiding the mining sequence. Using the same algorithm and methods, the nested pits are generated at the same time as the pit limit; the difference is varying one input (commodity sale price or processing cost) in which the commodity price approach is often used by most software although the specifics of the implementations vary (THORLEY, 2012).

2.4.3 Oil sands mining

Crude bitumen that is semi-solid was discovered first in the Athabasca oil sands in 1719 and commercial production did not start until the 1960s (STEWART; MACCALLUM, 1978). The Great Canadian Oil sands company (now Suncor Energy Corporation) began the first commercially viable production in 1967 (STEWART; MACCALLUM, 1978) and employed large bucket wheel excavators because the truck and shovel equipment were not of sufficient quantity to operate at the production capacities needed in the 1960s and 1970s (CANADA, 2012). Long conveyors were used to transport the mined ores to the extraction plant. Large draglines were used by Syncrude Mildred Lake Mine to excavate the ore and place it in windrows (CANADA, 2012).

Oil sands sometimes referred to as tar sands (MASLIYAH et al., 2004; BRANDT, 2012) and bituminous sands (MASLIYAH et al., 2004), are naturally occurring mixtures of bitumen, sand, water, small amounts of heavy metals and other contaminants. A layer of water and a film of bitumen surround each grain of sand (BRANDT, 2012). The oil in oil sands is called bitumen, which comprises about 10% of the oil sands, and is a hydrocarbon that solidifies at normal temperatures and mixed in with sand, clay and water (MECH, 2011).

Bitumen is usually extracted from oil sands using either surface mining (mining the sands for bitumen separation in mineral processing plants) or in-situ techniques (extracting oil without processing the oil sand itself) (BHATTACHARJEE, 2011; BRANDT, 2012; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014) The in situ mining techniques are discussed in Appendix 1.

The mining methods are selected based on the depth of the oil sands deposit (BHATTACHARJEE, 2011; ZHANG, 2014), or on the overburden ratio. Overburden can be defined as the thickness of non-valuable material above the valuable deposit. The ratio between the thickness of the overburden and the thickness of the bitumen deposit is the overburden ratio. A low overburden ratio i.e. (below 1), means the deposit is close to the surface, therefore, surface mining and bitumen/sand separation technique is the selected mining method. Whereas, if the deposit is deeper below the surface, in situ processing is the preferred mining method (ZHANG, 2014).

Bitumen is extracted by open pit mining techniques when the depth is less than 75m (TOMAN et al., 2008; GOSSELIN et al., 2010; BANERJEE, 2012; MCWHINNEY, 2014) or when the deposit is less than 75m below the surface (MECH, 2011; ZHANG, 2014). The thickness of the oil sands themselves are typically 40 to 60 meters (ENGELHARDT; TODIRESCU, 2005). When it is greater than 75m, the in situ technique is used (MECH, 2011; OIL SANDS DISCOVERY CENTRE, 2014). In situ mining methods are used when the deposits are 350 to 600 metres below the surface (MECH, 2011). Only 20 percent of Alberta's oil sands can be recovered through surface-mining techniques (OIL SANDS DISCOVERY CENTRE, 2014).

2.4.3.1 Surface mining in oil sands

This mining method is used for ore bodies that are close to the surface (POVEDA; LIPSETT, 2011), different methods of surface mining exists and this include strip mining (LATTANZIO, 2014); open cast (SHAH et al., 2010) and open pit mining (MASLIYAH et al., 2004; MECH, 2011; LATTANZIO, 2014). Oil sands deposits that are at shallow depths, less than 75 meters below the surface can be removed using these mining methods (SHAH et al., 2010; LATTANZIO, 2014; ZHANG, 2014).

In a surface mining operation, there is removal of vegetation, and the oil sands deposits are exposed by removing the underlying clay, silt and gravel (overburden) (BRANDT, 2012;

MECH, 2011; OIL SANDS DISCOVERY CENTRE, 2014; LATTANZIO, 2014; ZHANG, 2014). This is done by using immense truck-and-shovel operation with advancement of technologies (BRANDT, 2012; BANERJEE, 2012; CANADA, 2012), and the resource is excavated and transported to a processing facility (LATTANZIO, 2014)**.**

Large-scale oil sands open pit mines operations use the largest available equipment (up to 400 T trucks and 100 T excavators) for overburden removal and ore haulage to the extraction plant. The overburden removal and the mining operation use "benches" that are up to 15 to 17 m high putting into consideration the capability of the mining shovels and waste-ore intervals (CANADA, 2012). A large cable shovel has a higher capacity and can excavate over 100 tonnes of oil sands per pass than the hydraulic shovels.

Mining with a shovel can be selective because it bypasses the "waste islands" and sets bench levels above centre reject zones. However, the ability for large shovels to selectively mine within a bench is restricted, thus including oil sands layers of low bitumen content with ore feed of richer and coarser zones (CANADA, 2012). Shovel technology, a more reliable lesser operational cost (Figure 9) is a mix of large electric cable shovels (Figure 10), and diesel-electric hydraulic shovels. They are easily movable and has the ability to selectively mine and reject mid-bench material (CANADA, 2012).

Soil that is deemed suitable from the overburden is separated and stockpiled for future land reclamation (CLARK et al., 2007; MCWHINNEY, 2014; ZHANG, 2014) or used to build retaining dykes for ponds. Oil sand ore is mined with diesel or electric hydraulic shovels (BHATTACHARJEE, 2011; BRANDT, 2012) or using trucks and shovel technology (MASLIYAH et al., 2004; BHATTACHARJEE, 2011; CANADA, 2012; OIL SANDS DISCOVERY CENTRE, 2014).

Figure 9 - Hydraulic shovel: Syncrude

Source: OIL SANDS MAGAZINE, (2018c)

Figure 10 - Electric shovels: Suncor (Left) and Syncrude (Right)

Source: OIL SANDS MAGAZINE, (2018c)

Traditionally, open-pit mining was carried out using bucket wheels excavators (Figure 11) (BHATTACHARJEE, 2011; MCWHINNEY, 2014) and dragline (MCWHINNEY, 2014). The dragline (Figure 12) excavates (digs out the sands) the ore and places the piles of ore in a row where it will be scooped by bucket wheels and this will be transported in a conveyor belt to the extraction plant (BHATTACHARJEE, 2011; BANERJEE, 2012; MCWHINNEY, 2014). This method has been replaced with the shovel and truck excavation (Figure 13); and hydro transport (MCWHINNEY, 2014).

Figure 11 - Bucket wheels excavator

Source: OIL SANDS MAGAZINE, (2018c)

Figure 12 - Dragline

Source: OIL SANDS MAGAZINE, (2018c).

Figure 13 - Modern oil sands mining by 400 tonne truck and cable shovel.

Source: SOBKOWICZ, (2012).

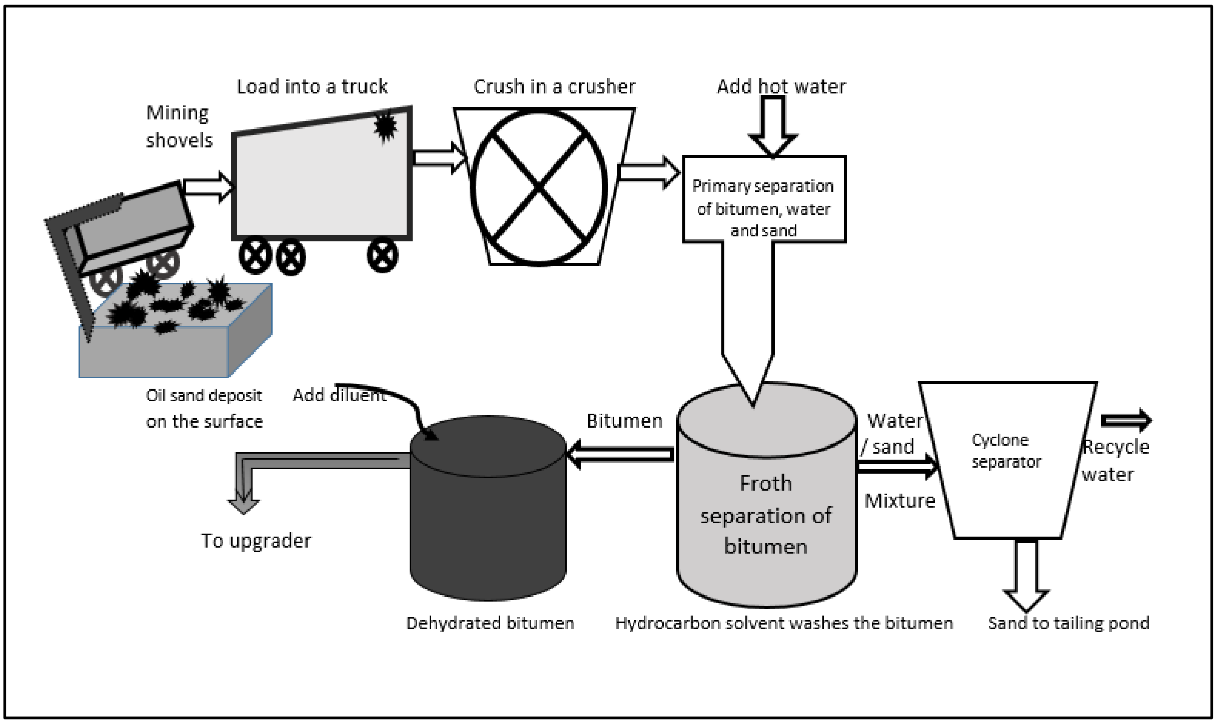
Surface mining operation is limited by the depth of the reservoir and in estimate, approximately 80% of the Alberta oil sands (CANADA, ALBERTA (GOVERNMENT), 2009; SHAH et al., 2010) and nearly all of the Venezuelan sands are too far below the surface to allow open-cast mining (SHAH et al., 2010). However, the operations is very efficient and tend to yield high recoveries (ZHANG, 2014) and around 90% of the bitumen found in the deposit is recovered (SHAH et al., 2010). Approximately two tonnes (CANADA, ALBERTA (GOVERNMENT), 2009) - four tonnes (SHAH et al., 2010; BANERJEE, 2012) of oil sands must be mined to produce one barrel of bitumen.

Surface mining operation is capital intensive (BHATTACHARJEE, 2011; SHAH et al., 2010) and there are severe environmental problems associated with it (SHAH et al., 2010). In Canada, the cost of operation for mining and extracting bitumen are estimated at $16 to $18, and cost of mining, extraction and upgrading are estimated to be $32 to $36.12 per barrel (CLARK et al., 2007).

2.4.3.2 Processing of oil sands

In oil sands operation, maximum recovery always encompass the three basic operations: mining, extraction and upgrading (Figure 14). Therefore, bitumen can be economically recovered efficiently with minimum adverse environmental impact through proper integration of these three operations. The mining operation affects the bitumen extraction processes and the extraction operations affect the upgrading operation. Therefore, these processes may not be considered as independent operations (MASLIYAH et al., 2004).

Figure 14 - Generalized scheme for oil sands mining process



Source: BANERJEE, (2012).

Extraction of bitumen involves froth flotation to strip the bitumen from mined ore (BHATTACHARJEE, 2011). The steps include mining of the oil sand deposits, the ore is crushed to reduce the size, and hot water is added to create an ore slurry. This slurry is transported to be cleaned at the bitumen extraction plant where the bitumen is separated from the water and sand (tailings) in a separation vessel, and it is processed to obtain pure bitumen before it is upgraded to oil (DYER; HUOT, 2010; BHATTACHARJEE, 2011; BUSHEY, 2011) and the tailings are discarded into tailings ponds (BHATTACHARJEE, 2011).

G.C. Hoffman of the Geological Survey of Canada in 1883 made the first attempt to separate bitumen from oil sands using water. Separation techniques of oil sands was done by Sidney Ells of the Federal Mines Branch in 1915, and the resulting bitumen was used in paving 600 feet of road in Edmonton, which lasted for 50 years (OIL SANDS DISCOVERY CENTRE, 2014).

The extraction of bitumen from oil sands was placed on a scientific basis in the 1920's. This was in respect to a work pioneered by Dr. Karl Clark's of the Alberta Research Council and other bench and field-scale bitumen separation tests. This led to the strong foundation of our present oil sands technology (MASLIYAH et al., 2004; OIL SANDS DISCOVERY CENTRE, 2014). He was granted a patent for the hot water extraction process in 1928 (OIL SANDS DISCOVERY CENTRE, 2014). It was discovered that hot water with the addition of alkaline solution (NaOH) (MASLIYAH et al., 2004) and a surface-active agent would enhance the extraction of bitumen. During extraction, the acid functional group of the bitumen is neutralized by the addition of NaOH to produce surface-active surfactants that are generated as naphthenic acids, this break the bitumen/ water interfacial tension, and separate the bitumen from the sand (BANERJEE, 2012).

The liberation and aeration of bitumen occurs in this process in a tumbler where the oil sand is mixed with water, reagents and caustic (NaOH) and the mixture is heated to 85°Celsius (ZHANG, 2014) to form a thick mixture called a slurry (OIL SANDS DISCOVERY CENTRE, 2014). The process of mixing oil sands with water, reagents and caustic in the tumbler is called conditioning (MASLIYAH et al., 2004; ZHANG, 2014) which is the first step in the separation of bitumen from oil sand. During conditioning, large lumps of oil sand are broken up, size reduction takes place, and the oil sand is mixed with water (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). The conditioned mixture is called a slurry (BHATTACHARJEE, 2011). After conditioning, the tumblers introduced air into the slurry and it is screened in order to remove coarse material (OIL SANDS DISCOVERY CENTRE, 2014). As air is introduced in the tumblers, liberation of bitumen from the oil sand grains occurs due to reduction in the viscosity (MASLIYAH et al., 2004; SHAH et al., 2010). The resulting bitumen froth can then be skimmed from the top (SHAH et al., 2010).

Steps involved in extracting bitumen

Step 1: Crushing

Unconsolidated oil sands deposits are loaded and transported from via large shovels and trucks from the mine face to an ore crusher (Figure 15) (CLARK et al., 2007) and the reduction in the size of the material is carried out according to specification by crushing (CANADA, ALBERTA (GOVERNMENT), 2009; BRANDT, 2012; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014). The crushed ores are then transferred to a hot-water rotating slurry tank (BANERJEE, 2012).

Figure 15 - Truck dumping mined oil sands into the top of a crusher installed within a retaining wall. Photo courtesy Shell Canada.

Source: OIL SANDS MAGAZINE, (2018b)

Step 2. Hydrotransport

This involves the transportation of the oil sands to a processing facility where the bitumen is separated from the sands using hot water (CANADA, ALBERTA (GOVERNMENT), 2009; ZHANG, 2014). Transportation of the bitumen was a major problem for the bitumen producer since it is not mobile (BUTLER, 1991). Therefore, modification was made to the Clark Hot Water Process to a process called hydrotransport (Figure 16), which is the use of pipelines to deliver slurry directly from the mining operation (OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014).

The process of hydro transport involves mixing the ore with warm water and sodium hydroxide (MCWHINNEY, 2014) or solvent such as condensate (BUTLER, 1991), generating an ore-and-water slurry that is piped to the extraction plant (BUTLER, 1991; MCWHINNEY, 2014). The process of hydro-transport has an added advantage of pre-conditioning the ore before it goes through froth treatment and it is less energy-intensive than the conveyor method (MCWHINNEY, 2014). The time of transporting bitumen between the mine and milling operations are used as conditioning time (ZHANG, 2014). Conditioning starts the separation of bonds between the sand, water and bitumen, which begins during hydrotransport (CLARK et al., 2007; BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). The conditioned mixture is called a slurry (BHATTACHARJEE, 2011). The water used for hydrotransport is cooler (35°C) than in the tumblers, making the process more energy efficient (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014).

Figure 16 - Hydro pipelines

Source: OIL SANDS MAGAZINE, (2018a)

Step 3: Primary separation (Bitumen, sand and water separation)

The hot mixture (slurry), between 70–80°C (BANERJEE, 2012) is fed into the primary separation vessel (PSV) (Figure 17) and more hot water is added to the slurry to facilitate the separation (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). The machine is supplied with air, establishing bubble dispersions for bitumen-air attachment. The slurry separates into three primary streams in the PSV. The impure bitumen, which rises to the top being the least dense, are recovered as froth. The coarse tailings, which majorly consist of the sand at the bottom of the PSV exits through the bottom of the machines and it is pumped into storage areas called tailings ponds.

The mid layer, consisting of clay, sand, water and some bitumen called middling (BHATTACHARJEE, 2011; BANERJEE, 2012; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014) drop out by gravity (BANERJEE, 2012). The water from the tailings ponds is recycled back into the extraction plant for re-use (OIL SANDS DISCOVERY CENTRE, 2014). The bitumen in the middling is recovered through an additional treatment called secondary separation (BHATTACHARJEE, 2011) or they are sent to flotation cells for further recovery (ZHANG, 2014).

Figure 17 - View of sloped inlet piping feeding into a PSC

Source: OIL SANDS MAGAZINE, (2018d)

Step 4: Froth separation of bitumen

The bitumen froth is treated to remove water and solids, using naphtha or paraffinic solvents after the primary separation (BRANDT, 2012) and a bitumen ready for both dilution and sale or for upgrading to synthetic crude oil is produced (BRANDT, 2012). In secondary separation, (OIL SANDS DISCOVERY CENTRE, 2014), the Bitumen froth from the PSV contains approximately 30% water and 10% solids on a mass basis and 60% bitumen (MASLIYAH et al. 2004; CLARK et al., 2007; BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014).

The bitumen froth recovered is de-aerated (MASLIYAH et al., 2004; OIL SANDS DISCOVERY CENTRE, 2014), the de-aerated bitumen froth is cleaned of solids and water in the froth treatment plant (Figure 18) or counter-current decantation vessels (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). It is diluted with naptha or paraffinic solvents to remove water and fine solids (MASLIYAH et al. 2004; CLARK et al., 2007; OIL SANDS DISCOVERY CENTRE, 2014). This makes it less viscous (MASLIYAH et al., 2004; BHATTACHARJEE, 2011), and enhance easy flow (OIL SANDS DISCOVERY CENTRE, 2014) and is then sent through a combination of Inclined plate settlers, and cyclones and/or Centrifuges (MASLIYAH et al., 2004; BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). Inclined plate settlers allow particles to settle efficiently under gravity for further cleansing of the froth and the centrifuges separate the heavy particles from the froth (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). The flow is directed further into a naphtha recovery unit to recover traces of naphtha that is left in the product (BHATTACHARJEE, 2011). A paraffinic diluent (mainly hexane) is used (MASLIYAH et al., 2004).

Figure 18 - Froth treatment unit

Source: OIL SANDS MAGAZINE, (2018e)

The paraffinic froth treatment process results in bitumen with less than 0.1% water and fines remaining. Clean sand from the PSV is removed and stockpiled and the fine tailings is transported to a pond (CLARK et al., 2007). The product is now called Dilbit and consists of 94.5% bitumen, 5% water and only 0.5% solids. Approximately 91% of the bitumen in the oil sand is recovered (BHATTACHARJEE, 2011).

Step 5: Upgrading

There is need for extensive processing of bitumen before it can be pipelined and used by oil refineries (BHATTACHARJEE, 2011) and because contaminants are concentrated in heavy hydrocarbon fractions, bitumen requires more intensive upgrading and refining than conventional crude oil (BRANDT, 2012). The process of upgrading can be referred to as a preliminary refining process because the bitumen are converted to lighter fractions with fewer contaminants and this can be achieved by reducing the size of the hydrocarbon molecules and increasing the hydrogen-to-carbon ratio of the oil (MCWHINNEY, 2014).

The main characteristic of bitumen are relatively large molecular weight, carbon-rich, hydrogen-deficient (BHATTACHARJEE, 2011; GOSSELIN et al., 2010; BRANDT, 2012), and high sulphur, nitrogen and metal content (GOSSELIN et al., 2010; BRANDT, 2012).

The viscous bitumen with high asphaltene content cannot be directly processed by refineries designed for conventional crude oil (GOSSELIN et al., 2010) therefore, bitumen needs to be diluted (OIL SANDS DISCOVERY CENTRE, 2014) or upgraded to synthetic crude oil (SCO) before it is processed in downstream refineries to produce gasoline and diesel fuels (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; GOSSELIN et al., 2010; OIL SANDS DISCOVERY CENTRE, 2014).

Bitumen is deficient in hydrogen, having an H/C ratio of less than 1.5, in order to increase the H/C ratio to above 1.5 in the final product, the bitumen must be upgraded (BANERJEE, 2012), this is done by either rejecting carbon or adding hydrogen (BANERJEE, 2012; OIL SANDS DISCOVERY CENTRE, 2014).

Upgrading requirements vary depending on the technique used in the froth treatment. If the hydrocarbon solvent used is naptha, which is mostly the general technique used, the requirements of upgrading are more significant. However, the requirements can be reduced or stopped if paraffinic solvent is used instead. As asphaltenes, which is one of the heaviest, lowest-value fractions of the bitumen and do not easily dissolve in paraffinic solvents thereby making them easier to separate (MCWHINNEY, 2014). Further discussing on upgrading processes of bitumen can be found in Appendix 2.

CHAPTER THREE

3. METHODOLOGY

This chapter describes the methodology used in the research. Section 3.1 gave the description of the fieldwork done, which included meetings and interviews with the community leaders, distribution of questionnaires to community members and observations. In addition, the interviews and field observations allowed the identification of the key challenges involved in securing an SLO. Section 3.2 gives a detail description of the ecosystems and ES in the study area. The methodology used in assessing the impacts of oil sands pre-mining activities in the study area is described. The ecosystems in the area were identified through observation and using a land use map. In section 3.3, a detailed description of the conceptual mine plan is given. A mine is planned and designed at a conceptual level using a mining software and a preliminary economic assessment (PEA) is presented to know the appropriate mine product that will be economically viable for the study area.

3.1 FIELD WORK

The three oil sand deposits communities under study are Mulekangbo, Ilubirin and Mile 2. These communities are within the Foriku-Agbabu axis, Odigbo Local Government Area of Ondo State, Nigeria. These three communities were chosen because of the profound *bituminous natural effects*, bitumen outcrops and available exploratory data for mining studies. These are small (with an average of 300 people and 40–50 families) and comprise people whose primary sources of living are farming and fishing. The major sources of water are hand dug wells, streams, and rivers.

The study started with a formal contact with the community leaders of two of the three communities visited, the purpose of the visit was stated and a little discussion on the oil sands in the study areas was done with the community leaders. Permission to distribute questionnaire was requested and it was granted. The distribution of the questionnaire was developed through random selection of people. The target was to interview about 30 people from different families (avoiding people from the same families, i.e., husbands and wives, to avoid repetition of answers) in each community. The community leaders and one elder from both Ilubirin and Mulekangbo communities were given questionnaire to answer.

The concept used was semi-structured (LUOMA; PAASI; VALKOKARI, 2010). This type of concept is partly explorative, and the ideas are usually explained to the people. The questionnaire was distributed to know the demographic information of the communities. Each person used an average of 15 to 20 minutes, and their responses were written down; their responses were both in English (official language) and Yoruba (native language) (Table 4).

The field study was based on a sampling campaign, which was planned and executed with support from The Federal University of Technology Akure, Nigeria. The data collection was carried out within the period of 3 June to 30 July 2016.

The pictures of some sensitive places like the hospital, houses, and roads were taken, physical observations and critical analysis of previous literatures was done. The data used in this section is majorly a primary data, which is the result of the research questionnaire.

Table 4 - Methodology used

Method	Description
Language	English (official language) and Yoruba (native language)
Technique	One-on-one, individual questioning and observations
Location	Community
Duration	15-20 minutes per person
Recording	Verbal and written
Recruitment	Voluntarily (98%), Community leaders (2%)
Structure	Semi- formal structured

Source: Personal file

Ondo State, which is an agrarian state, has over 70 per cent of the population engaged in agriculture. During this study, the oil sands regions were visited and it was observed that the region prosper in rubber, oil palm and cocoa plantation businesses. It was noted that many of the oil sands blocks allocated by the government in these communities are in the region where most of the cash crops are situated.

Although there are ongoing mining activities in Ondo state, which are majorly quarries, the mines do not have major pre-mining impacts on the communities because they are mostly located in the outskirt of the towns, villages and settlements. Since oil sands mining is likely to affect the daily jobs of the people of Odigbo Local Government, whose major occupation is fishing and farming, questionnaire were distributed to know how the people would feel about the commencement of oil sands mining activities in the region.

The term social license to operate (SLO) is not often used in the mining discourse in Nigeria, it was considered important for this study area because of the impacts pre-mining activities may likely have on the communities. This is to avoid the existing conflicts in the oil producing states of Niger Delta, which includes Ondo State. The conflicts result in violence, kidnaping of workers and vandalization of pipelines, and stoppage of oil exploration activities because of the environmental pollution of oil exploration activities on the environment.

In addition, because the communities under study are situated where there are no ongoing mining activities and most of the community members are not familiar with mining activity and its impacts, a study on the area was made.

This study was made to know the likely challenges that would be faced by the mining company when obtaining SLO, how to solve these challenges, the critical elements of SLO and how to obtain an SLO. These were analysed from the data obtained during the fieldwork, observations and detailed analyses of literatures.

3.2 ASSESSMENT OF ECOSYSTEM SERVICES

3.2.1 Data Collection

Research questionnaires with 16 questions was distributed to the selected interviewees. The questionnaire was to confirm the types of ecosystems that exist in the communities, their uses, and the services they render (for comparison with those shown on the land cover map that was generated using Arc-GIS software). The data used were both primary and secondary data. The primary data used are majorly the result of the research questionnaire gotten from the field and through direct observations. The secondary data used is the land use map obtained from the Geological Consultancy Unit (GCU), University of Ile Ife, now (Obafemi Awolowo University), Ile Ife. Pictures were taken to have a general idea of the ecosystems and their services.

3.2.2 Land Use Assessment

3.2.2.1 Image Pre-processing and Classification

In assessing the land use of the area of interest (Foriku-Agbabu area), a pre-processing of data in Earth Resource Development Assessment System (ERDAS) imagine 2015 software for geo-referencing, mosaicking, and sub-setting of the image based on area of interest (AOI) was done. To assign different spectral signatures from the Landsat satellite image data to different land use/land cover (LU/LC), an image classification was carried out (BUTT et al., 2015). Each Landsat image was geo-referenced to the WGS_84 datum and Universal Transverse Mercator Zone 35 North coordinate system. The satellite image of each Landsat band was stacked in ERDAS Hexagon within interpreter main icon utilities with layer stacked function. The map of Nigeria was downloaded and it was digitized using feature class tools in ArcGIS software.

Vegetation dataset of Nigeria was derived using Landsat imagery acquired from the United States Geological Survey (USGS) Earth Explorer, and was overlaid on the digitized Foriku-Agbabu map. The vegetation map of the study area was then clipped out using Nigeria's map as the input feature and the Foriku-Agbabu area as the clip feature. Google imagery for the study area was obtained from Google Earth Pro, which was georeferenced using the Geo-referencing tool in ArcMap. This was done based on reflectance characteristics of the different LU/LC types. Different colour composites were used to improve visualization of different objects on the imagery.

3.2.2.2 Land use/Land cover classification

In this study, supervised classification was applied after defined AOI, which is called training classes. For each of the pre-determined land use/land cover (LU/LC) type, training samples were selected by delineating polygons around representative sites. Spectral signatures for the respective LU/LC types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons (BUTT et al., 2015; RWANGA; NDAMBUKI, 2017). The numbers of training sites vary from one LU/LC class to another depending on ease of identification and the level of variability. The maximum likelihood classification is the most widely used per-pixel method by taking into account spectral information of land cover classes. The delineated LU/LC classes are built up areas, water bodies, croplands, evergreen broad-leaf forests, shrublands, and grasslands as described in Table 5.

Table 5: International geosphere–biosphere program (IGBP) land cover classes, global land cover 2000 (GLC-2000) equivalent classes, and their class description

IGBP class	GLC-2000 equivalent	IGBP class description
Evergreen broadleaf forest	Tree cover, broad-leaved, evergreen or tree cover, regularly flooded, fresh water and saline water.	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 m. Almost all trees and shrubs remain green year round. Canopy is never without green foliage.
Open shrubland	Shrub cover, closed-open, evergreen	Lands with woody vegetation less than 2 m tall and with shrub canopy cover between 10% and 60%. The shrub foliage can be either evergreen or deciduous.
Grasslands	Herbaceous cover, closed-open	Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.
Cropland	Cultivated and managed areas	Lands covered with temporary crops followed by harvest and a bare soil period mosaic lands (e.g., single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.
Cropland/natural vegetation mosaic	Cropland/tree cover/other natural vegetation	Lands with a mosaic of croplands, forests, shrubland, and grasslands in which no one component comprises more than 60% of the landscape.

Source: Modified after GIRI; ZHU; REED, (2005).

3.2.3 Identification and prioritization of the ecosystem services

To identify and prioritize the ES, a Landsberg methodology was applied and the steps taken is clearly shown in Figure 19 (LANDSBERG et al., 2013).
In this section, five different pro-active management approaches were implemented prior to the mining stage to reduce the pre-mining impacts and increase long-term ecosystem and its services sustainability.

The five different options will be examined for mitigation by:

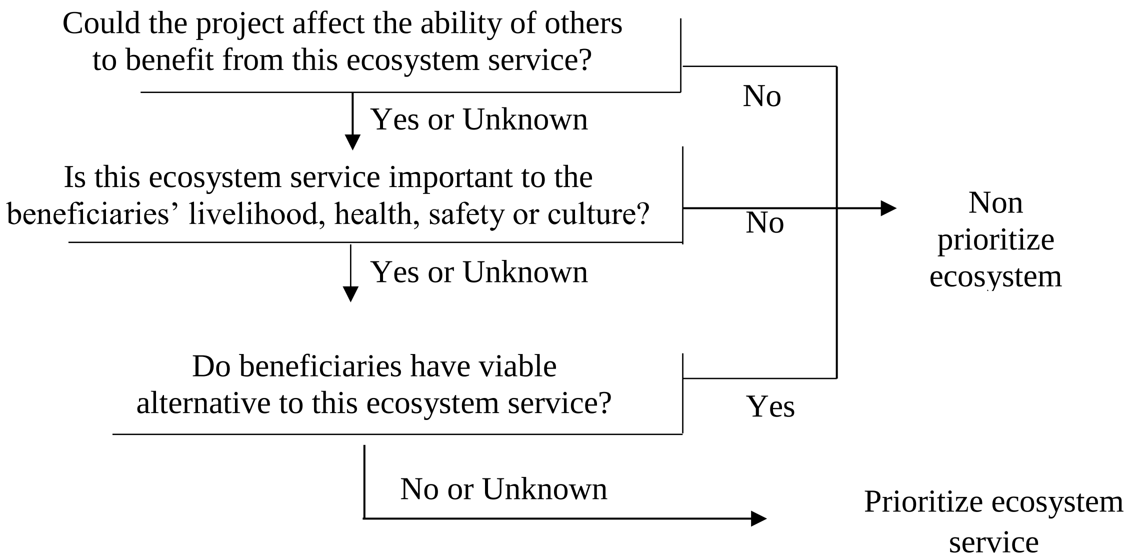
- Identifying probable affected ecosystem: a land cover map of scale 1: 10,000 of the study area was generated. The land use description on the map was used to identify the ecosystems that will probably be affected.
- Identifying the ES and their beneficiaries that will probably be potentially impacted: The ES that were available in the study area were chosen from the list made available by LANDSBERG et al., (2013). The ES that the pre-mining activities could potentially

impact were identified and listed. Different beneficiaries, which include individuals, communities, institutions, and companies that the mining activities will potentially affect as a result of impacts on ES was highlighted.

- Prioritizing ES: The prioritized ES are the ES in which the pre-mining activities will probably affect. To prioritize these services, the processes in the decision tree were followed (Figure 19).
- Assessing probable impacts on ES: The synthesis of standards proposed by (LANDSBERG et al., 2013) were used in the evaluation.
- Analyzing mitigation measures for impacts on ES

The impacts were evaluated using a synthesis of standard proposed by (LANDSBERG et al., 2013).

Figure 19 - Decision tree for prioritizing ecosystem services



Source: LANDSBERG et al. (2013).

3.3 CONCEPTUAL MINE PLANNING

A conceptual mine plan was done for the oil sands deposit.

3.3.1 Methodology for mine planning and optimization

In this study, the exploration data of the Nigerian oil sands belt located in the 17 Km^2 area north of Agbabu, Ondo State was used to build a geological model of the oil sands deposit. The data was obtained from Geological Consultancy Unit (GCU), University of Ife (now Obafemi Awolowo University), Ile-Ife. This data set is a survey report-containing hole positioning (collar), assay and lithological data (geology) which was processed and modelled using a specialized mining software (MICROMINE, 2020). The assay, collar and lithology of each drillhole was determined and were used for the mine design and resource estimation. The mining software was used also for mine optimisation and mine design as described below.

From the analysis of the samples, a geological model was built using sectional interpretations, solid modelling, block modeling and grade estimation using inverse power distance method. This step gave a result of the geological block model of the oil sands deposit under study. The LG algorithm was used for the pit optimization in order to determine the limit that maximizes the mine profit. For this, the algorithm considers the monetary value for each geological block, calculated from the economic parameters and operational premises of the block (sell price, mining recovery, metallurgical recovery, dilution, sell cost, processing cost, waste mining cost, ore mining cost, and rehabilitation cost).

Based on the geological, geometric and spatial characteristics of the mineral deposit, the strip mining method was selected (HARTMAN; MUTMANSKY, 2002). Each strip has width of 10m, length of 10m and depth of 2m. A 30º slope angle was adopted for the final pit (OYEBAMIJI et al., 2019). An annual production scale was defined for strategic mine planning, based on the production capacities of the excavation equipment selected for the operations. Thus, it was possible to carry out production scheduling at a conceptual level, allowing the definition of the potential LOM.

3.3.2 Preliminary economic assessment (PEA)

The PEA was done following the steps in the NI 43-101 preliminary economic assessment (CANADIAN INSTITUTE OF MINING METALLURGY AND PETROLEUM, 2014). The methods involve the following steps:

Input data**:** The data for topography, assay, collar, bitumen saturation and lithology were imputed into the mining software.

Geological setting and mineralization**:** The geological setting and mineralization of the study were carried out. The oil sands regions were visited and four pits were visited for collection of oil sands samples, tar sand sample were collected from Illubirin and Mulekangbo communities, 2 outcrop samples were collected, and bitumen samples were collected from Agbabu, Mile 2 and Mulekangbo communities. Table 6 shows the sample locations and the depth at which each sample was collected.

Table 6 – Samples location (oil sands, tar sands and bitumen) and depth at which they were collected

Pit no	Sample no	Depth	Location
P1	1	800cm	06° 38’31.4’’N 04° 49’46.5’’E
	2	850cm	
P2	3	350cm	06° 38’32.3’’N 04° 49’46.8’’E
	4	400cm	
P3A	5	150cm	06° 38’32.9’’N 04° 49’46.6’’E
	6	200cm	
P3W	7	110cm	06° 38’32.9’’N 04° 49’46.6’’E
	8	160cm	
	9	200cm	
P4A	10	570cm	06° 38’12.9’’N 04° 49’52.8’’E
P4B	11	570cm	
Ilubirin tar sand	12	50cm	06° 38’16.1’’N 04° 49’50.7’’E
Mulekangbo tar sand	13	50cm	06° 39.406’N 04° 50.497’E
Point 5 outcrop 1	14	20cm	
Point 5 outcrop 2	15	20cm	
Agbabu bitumen	16	Borehole	06° 35’24.6’’N 04° 49’56.3’’E
Mile 2 bitumen	17	Water surface	06° 36’47’’N 04° 49’55.1’’E
Mulekangbo bitumen	18	Borehole	

Source: Personal file.

Eighteen samples were collected in all. The samples were taken to the laboratory for analysis. Bitumen, saturate, asphaltene, aromatic and sulphur content analysis were carried out on each sample and the procedure is explained below:

Each sample was weighed directly into the cellulose cartridge. The cartridge was placed in a Soxhlet extraction system using dichloromethane P.A as a solvent. After extraction, the organic extract was concentrated on a rotary evaporator. After the organic extract was completely dry, the previously identified vial was weighed to determine the organic extract in the sample (% organic extract - EO). To specify the saturated and aromatic fraction, column chromatography was used to separate these fractions. The solid phase of the chromatographic column was composed of silica gel and alumina in one third / two third (1:3/2:3) ratio. The column was activated with hexane P.A. Hexane was added to the organic extract by pouring the mixture into the column, collecting the saturated fraction in a previously weighed and identified flask. On the second elution, the aromatics were extracted with a hexane / dichloromethane mixture, which was collected into also weighed weak and identified.

Creation of the preliminary resource model**:** The resource model was created using the data set obtained from GCU and the following steps were followed:

- Creation of new project
- Importation of data: import data from files (assay, lithology, collar, and topography).
- Validation of drill hole
- Creation of database: collar file and interval file
- Visualization in 2D / 3D
- Geological interpretation

Definition of conceptual modifying factors: based on data from literatures, the conceptual modifying factors was gotten and was the major data used in the software as input for the mine algorithm.

Ultimate pit analysis: The ultimate pit limit was designed using the geological (block) model. The geological model data, the mining cost for the ore and waste, mining parameters, processing costs and processing elements were the primary data that was input into the mining software for the pit optimisation.

Conceptual pit design: The pit design was carried out using the following features: geological data, borehole data, geological map, topographic profile, geological interpretation of the site, and the layout of the mine.

Preliminary economic assessment: An economic assessment was carried with assumptions of capital expenditure (CAPEX), operating expenditure (OPEX), recovery, sales based on literatures. The PEA was carried using the mine design factors and four different Scenario were considered to maximise ore recovery at the lowest possible cost.

- Scenario 1: Large-scale SCO producing mine
- Scenario 2: Medium-scale bitumen producing mine
- Scenario 3: Small-scale tar producing mine
- Scenario 4: Small-scale tar producing mine + additional investment for SLO

These four scenarios were considered in order to know the production scale that will be the most suitable and profitable for the Nigerian investors.

Sensitivity analysis: A sensitivity analysis was carried out with changes to two parameters, the discount rate and the tar price.

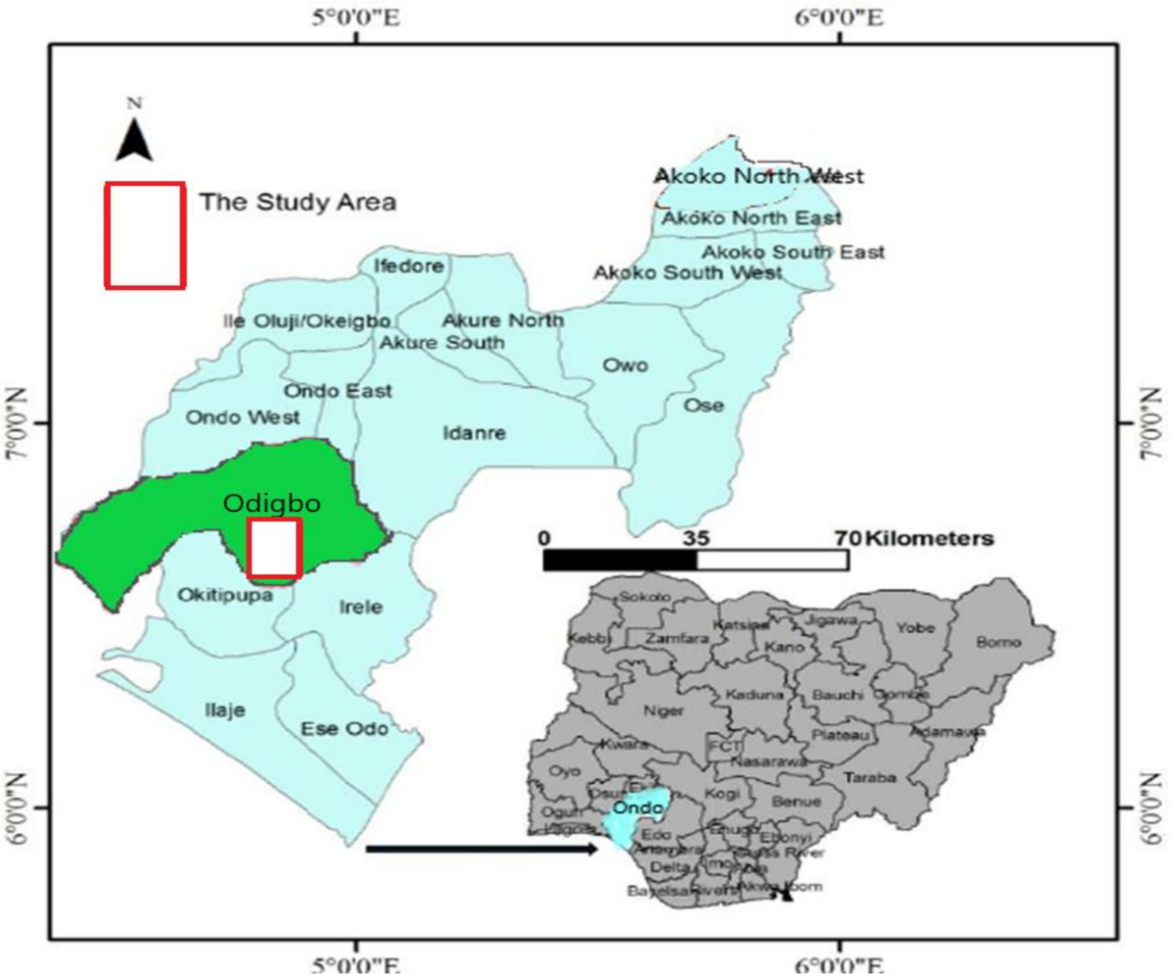
CHAPTER FOUR

4 RESULTS

4.1 FIELD WORK

Recent exploration studies on oil sands deposits were done in Odigbo and Irele Local Government areas of Ondo State, Nigeria thus making it the choice of study. Ondo State is situated in the southwestern area of Nigeria with Akure as its capital city (Figure 20). It is one of the nine oil-producing states of Nigeria. The population as recorded in 2006 census showed 3,441,024 people living in an area of about 14,606 square kilometres.

Figure 20 - Map of Ondo State Showing the study area. Inset: Map of Nigeria showing Ondo State



Source: Personal file

Ondo State is an agrarian state with over 70 per cent of the population engaged in agriculture, the settlements are rural in nature and dispersed thereby creating more land space for farming. The settlement pattern of Ondo is about 40 percent urban, 55 percent rural and 5 percent riverine. There are about 479 settlements in the rural area of the state; 38 per cent of this falls within the mining-licensed areas (CHINDO, 2012). From this proportion, about 80 per cent are located within the oil sands-licensed areas. Examples of cash crops produced in the state include cocoa, rubber, timber, palm kernels, cotton and tobacco. Oil sands deposits are situated across six local government areas: Odigbo, Ode-Irele, Idanre, Okitipupa, Ese-Odo and Ilaje. Presently, there is no on-going mining activity in the oil sands communities in Ondo State. Odigbo local government area of Ondo State, Nigeria has a land area of 1,818 km^2 and a population of 230,351 persons (NIGERIA, ONDO STATE, 1991).

Questionnaires were used to ascertain the feelings of the communities about mining of the oil sands. The *bituminous natural effects* were of major concern to the communities, despite the non-exploitation activity in the Foriku–Agbabu axis; the oil sand has posed several natural threats to the villagers. The community members complained of contamination of farmland because of seepage of bitumen during dry season, which affects their cocoa, vegetables, plantain and rubber plantation. Majority of these community members are farmers and are therefore of the opinion that the *bituminous natural effects* is a threat to their major source of income. This bitumen also seeps inside the hand-dug well, which is a major source of water to the community. Communities in Odigbo local government will be affected by oil sands mining activities because the communities are less than one kilometre distance to the oil sands blocks and the blocks were licensed to cover the land area they occupy. The setting of each community varies; some are located along river channels, while others are located along major roads.

4.1.1 Compilation of the answers to the questionnaire

Three (3) communities, which are Mulekangbo, Ilubirin and Mile 2 are the major oil sands communities within the Foriku-Agbabu axis were selected. The population of each community is about 250-300 persons (and 40-50 families). One hundred (100) respondents were randomly selected, forty (40) respondents from Mulekangbo, thirty (30) respondents were selected from Ilubirin and thirty (30) from Mile 2 putting into consideration that these are small communities; the target was to interview about 30 people from different families. The community leaders of two (Ilubirin and Mulekangbo) of the three communities nominated themselves and two elders of the communities who were accepted and others were done randomly.

Ninety (90) of the respondents from the three villages were farmers, and this was supported by the reports from Government of Nigeria (NIGERIA, ONDO STATE, 1991), which confirm that most of the Ondo State indigenes are farmers. The major source of water available to the community is hand dug well as concluded from this data while the borehole facility is only available to a minority of the respondents. The health centre facility is only available to the community members of Mulekangbo, while Ilubirin and Mile 2 have no such facility. All the participants were aware of oil sands in the communities, eighty-six (86) of the participants complained about the oil sands affecting their social and environmental activities while fourteen (14) had no such experience, and the results are shown in Tables 4-6.

All the respondents from the three communities were aware of the oil sand in their communities; ninety-five (95) of respondents of Mulekangbo, eighty-five (85) of Ilubirin and seventy (70) of Mile 2 complained that the oil sand was affecting their lives negatively. This was because bitumen from the oil sand seeps into the water surface in hand dug wells and their farmlands, especially in the dry hot season. After much deliberation, most of the community members believed that oil sand mining will eventually bring development to the community and if there is a need for relocation because of mining activities, ninety-three (93) of the respondents would be ready if properly compensated. Most of the respondents (85) acknowledged that commencement of mining activities would be an advantage to both the government and the immediate society. The questioning was considered relevant because the living condition of the people should be known and these can bring some ideas on how mining companies can help improve these conditions; also, it helped in knowing the level of knowledge the community had about mining activities and its impacts.

Table 7 summarizes the social characteristics, Table 8 summarizes the basic amenities available to the respondents of the three communities, and Table 9 summarizes the awareness of oil sand in the community.

Table 7 - Social characteristics of the respondents

Questions and categories		Mulekangbo (N = 40)	Ilubirin (N = 30)	Mile 2 (N = 30)
Sex	Male	21	23	21
	Female	19	7	9
Age	18-25	0	0	4
	26-30	2	8	2
	30-40	12	8	10
	40-above	26	14	14
Educational status	Primary	28	24	25
	Secondary	7	4	4
	Grade 2	3	2	0
	No formal education	2	0	1
Religion	Christian	26	20	17
	Muslim	3	2	3
	Local worshippers	11	8	10
Occupation	Farming/fishing	40	24	26
	Students	0	0	2
	Others	0	6	2

Source: Personal file

Table 8 - Basic amenities of the respondents

Questions		Mulekangbo	Ilubirin	Mile 2
	Stream	20	20	0
	Borehole	6	0	0
Source of water	Well	14	10	30
	Available	31	4	8
Health facilities	Not available	9	26	22
	Available	6	0	8
Electricity	Not available	34	30	22
	Available	7	0	8
School	Not available	33	30	22
	Poor	26	4	8
Livelihood	Fair	14	26	22
condition	Good	0	0	0
	Poor	32	28	25
Communication	Fair	0	2	5
infrastructure	Good	8	0	0
	Poor	26	30	30
	Fair	6	0	0
Road condition	Good	8	0	0

Source: Personal file

Table 9 - Awareness of oil sand in the community

		Mulekangbo	Ilubirin	Mile 2
Season for shortage of water	Raining	0	0	0
	Dry	40	30	30
Do the water have negative effect?	Yes	32	21	4
	No	8	9	26
Types of effect	Body	27	24	4
	Environmental	13	6	26
Awareness of oil sands	Yes	40	30	30
	No	0	0	0
Challenges with the oil sands?	Yes	38	25	23
	No	2	5	7
Type of challenge	Environmental (Plant and water)	36	26	27
	Social (Road)	4	4	3
Reaction to impacts of oil sands	Compensation	37	30	28
	Charity	3	0	2
Acceptance of relocation	Yes	40	26	27
	No	0	4	3
Acceptance of mining activities	Yes	40	30	30
	No	0	0	0

Source: Personal file

Figures 21-24 are some pictures taken during the fieldwork to show the living condition of the community, from the pictures, it can be seen that the houses in these communities are rural houses with little or no protection, also, the condition of the road of the three villages is very poor. From these results, interactions and general observations, it was concluded that the people are living below an average standard of living.

Figure 21 - Residential views of Ilubirin community

Source: Personal file

Figure 22 - Health center in Mulekangbo

Source: Personal file

Figure 23 - Road condition from Mulekangbo to Ilubirin community

Source: Personal file

Figure 24 - Bitumen seepage in Ilubirin community

Source: Personal file

4.1.2 Social license to operate (SLO)

In Nigeria, if a mining company follows the formal rules of the Ministry of Mines and Steel Development (MMSD), the company is seen as fulfilling its duties toward the local community. It is important to note that Ondo State where the oil sands deposit is located, is a state in the Niger Delta Region of Nigeria where the people are well acquainted with conflicts resulting from oil and gas exploration activities and their impacts on the environment. Researches have shown that there have been recent violent activities, oil pipelines vandalism by different militants groups arising in the Niger Delta due to pollution from oil exploration and oil spillage which impact the environment. Therefore, the environmental impacts of mining activities must be taken seriously because it affects the major source of living of the communities.

4.1.2.1 Challenges of obtaining an SLO

Based on an analysis of the results of the questionnaires, discussions made with community leaders to assess their acceptance of mining activities in their area and general observation, the following are the various challenges that a mining company could be faced with when seeking to obtain an SLO.

Expected challenges

These are the challenges that will certainly happen, and therefore will have to be addressed.

Negative impact of pre-mining activities on the socio-environmental activities of the community. The impacts of pre-mining activities, like ecological disruption, water pollution and loss of soil fertility (OMOTEHINSE; DE TOMI; BANINLA, 2020) affect the environment on which communities depend for farming and fishing. The farmers in those regions have cocoa, rubber, timber and oil palm plantations. Many lands are privately owned and some are owned by the government. The communities grow crops such as maize, plantains and vegetables and some of them raise animals like ducks, chickens, and goats. The fishermen use river Oluwa, and its main tributaries, the Ofara and Erinodo rivers, for fishing, and the fish are either sold or consumed by them, also many of the farmers are also fishermen. As can be seen in Table 7, 35 out of the 100 respondents are females; this indicates that both fishing and farming are done by both males and females. The results show that 90 out of the 100 respondents of these communities are farmers and fishermen and therefore pre-mining activities, as previously stated, will disrupt their source of livelihood, which may bring about protests from the community. In addition, because the communities sit on oil sands (OMOTEHINSE; DE TOMI; BANINLA, 2020), mining companies will tend to propose that the inhabitants be relocated. However, some community members and leaders will not agree to relocation.

Education of the local population about the negative environmental and social impacts of pre-mining activities. The questionnaires revealed that all 100 respondents were ready for the commencement of mining activities in the region, that 80 of them have little or no schooling, and that none of them has any knowledge of the impacts caused by pre-mining activities. Thus, it is clear that educating the community about the environmental impacts of pre-mining activities, which include water pollution, relocation and deforestation, will pose a challenge. These local communities have a strong attachment to their land, as shown by the results. Twenty-nine out of the 100 respondents are local worshippers and have sacred grounds for worshipping, some have lands for growing native plants used in *ifa* divinations by the priests (*babalawo*), and some worship a river deity (*yemoja*) and trees. This is an essential aspect of their cultural and spiritual life, so that relocating or destroying through deforestation their ancestral lands, which are passed from generation to generation, poses a major problem to the company, as it will affect the communities due to an inevitable loss of traditions, family roots, and cultural elements. Pre-mining activities will disturb places that provide spiritual fulfilment to the local worshippers, thereby affecting their cultural and aesthetic values.

As already noted, the communities studied also depend on these lands' local resources for their daily income, through farming and fishing. In the Niger Delta region, most of the population is likewise composed of fishermen and farmers (ELUM; MOPIPI; HENRI-UKOHA, 2016). Unmitigated land and water pollution from oil exploration has generated much violence and many community protests and has affected the relations between the oil and gas companies and the communities in the region (USANG; IKPEME, 2015). It is therefore important that communities like the ones herein studied be well informed about all the potential consequences of mining activity in terms they can understand, so as not to be caught unaware if and when the unexpected negative impacts suddenly disrupt their lives.

Difficulties in communicating with the community, due to language diversity and/or poor educational background. Ethnically and linguistically, Nigeria is the third most diverse country in the world. Although English is the official language, many communities do not speak or understand it. There are three major native languages, Yoruba, Igbo and Hausa, and at least five hundred languages are spoken in the country, though the exact number remains unknown (BLENCH; DENDO, 2013). Out of the 36 states in the country, there are seven states that speak Yoruba, including Ondo. Ondo State contains eighteen local government areas, including Odigbo, but these local governments speak various languages, and the predominant language in Odigbo is Ikale. During fieldwork, communication with many of the respondents was in their local language, their sole means of communication, as they do not understand English. In addition, as the results from the questionnaires revealed, most people (80 out of 100 respondents) have little or no schooling.

Many challenges have to do with the inability of one party to understand the other, and this is due to a combination of different languages, lack of formal education and lack of information. These complex situations and their implications can be quite challenging for both the mining company and for the rural population. This is surely a recurring problem in mineral extractive areas around the world, especially in developing countries. As RADON et al., (2016) points out, extractive minerals are most often located in remote regions where the local people have little or no education.

Reaching an agreement between the company and the communities, taking into account differences of interest and goals among community leaders. Field research conducted for this study started with a visit to the community leader (*baale*) and the elders, and some visits were quite challenging due to disagreements between them. During the first visit to the Mulekangbo community, some of the elders asked for a huge sum of money in order to take us to locations with bitumen outcrops. During the second visit, one of these elders incited the Mulekangbo *baale* to seize the questionnaires and insisted we pay a given sum before we could be given permission to hand them out to community members.

It was pointed out that, as a student from the region, its development is a goal we all shared, and that some community members would stay at home to manipulate the questions and answers, since, as local literates, they had the necessary knowledge to do it. After much deliberation, I was given permission to continue with my fieldwork. During my visit to Ilubirin, on the other hand, there was no problem because the *baale* understood that the goal was community development. In my visit to Mile 2, although the *baale* was not available, their representatives were quite welcoming and understanding. These leaders (both *baale* and elders) play a huge role in the negotiations for obtaining an SLO and in the outcome, since they choose the community representatives. If most of them have their personal interests at stake and are greedy, there will be continuous disagreements between leaders and elders, which might bring about delays in obtaining the license and non-compliance of the agreements.

Some communities no longer trust the Nigerian government, which could affect the relationship between the mining company and the communities. During our visits to the communities, many members expressed their distrust of the government in terms of the general development of the region and the continuous promises to explore the oil sands deposits. The Nigerian government has been promising to develop these deposits since 1970, but to date has not fulfilled these promises. During the visit made to Ilubirin, the *baale* and elders, based on the history of the country's oil and gas sector, expressed their concern that the government paid little or no attention to the environmental impacts in the Niger Delta region and failed to address their concerns. As mining probably will commence soon in Ondo State, the mining company must take proactive approach to avoid the mistakes made by the oil and gas companies in the Niger Delta region, considering that the mining industry is believed to have a larger negative environmental footprint than conventional oil.

Additional potential challenges

These are challenges that may happen, depending on site-specific circumstances. They are known to be possible because they are mentioned in the literature.

The communities might demand a greater portion of benefits than what is envisaged by the company. Communities in countries like Australia and Canada with large mining companies have increasingly pressed for a more egalitarian sharing of the benefits derived from mining activities (MORITZ et al., 2017; O'FAIRCHEALLAIGH, 2013). O'FAIRCHEALLAIGH (2013) cites the case of a group of mining companies increasing a yearly pay in royalties to communities and landowners from less than USD 100,000 in 1990 to USD 64 million in 2010. For example, Rio Tinto mining company Australia had to increase its spending on communities from USD 107 million in 2007 to USD 294 million in 2011.

In our research area, where most community members are farmers, when offsetting for farmland disruption most of them might thus demand a greater portion of benefits than the ones envisaged by the company. Our fieldwork revealed that community members from the three villages studied have no idea of how many hectares of land they own and that they do not charge similar prices for cocoa, rubber and palm oil. Many of them expect the mining company to compensate them for their farmlands and provide them with a job as well, which they believe to be their right since the oil sands are located in their community.

Communities might demand to be made part of the decision-making process. In South Africa, there are examples of community resistance to mining as a result of local communities being side-lined in the decision-making process concerning environmental and social impacts of mining activities.

A sand-mining and minerals processing company named Richards Bay Minerals began prospecting activities in the sand dunes of St Lucia, South Africa in the late 1980s. In 1989, the company filed a formal application to mine titanium and released an environmental impact assessment (EIA), which led to protests in the community to be affected by the mining operations and elsewhere in the country. Opposition was based on the fact that mining operations would lead to environmental degradation in biodiversity-rich areas which are ideal for ecotourism, and that the community was marginalized in the EIA-making process and was unable to state its views on the matter. Although the government initially argued that mining and ecotourism could coexist, due to continued protests it decided to review the EIA and to compare the costs and benefits that mining would bring against those afforded by ecotourism.

In 1993, based on this EIA, the review board panel advised the government against the mining proposal and, in 1996, the government issued an official statement declaring the end of the mining project in the area (GQADA, 2011). While it is true that some communities have been more successful in preventing concession of mineral rights than others, even in the unsuccessful cases the community's opposition has resulted in protests that highlighted community rights and arguments for sustainable development (GQADA, 2011).

The actual impact of the pre-mining operation on the community might differ from the expected impact, which may lead to protests. While all the respondents favoured the idea of mining activities, they ignored what mining operations entail, and this may lead to protests when they are faced with the actual impact from these operations.

HUMAN RIGHTS WATCH (2018) reported that farmers from 16 villages located near mines and mining roads in the Boké region of northwestern Guinea complained how mining companies took away their ancestral farmlands while giving compensation that did not replace the benefits afforded by the land, their source of subsistence. Land compensations were mostly paid to men in the family or to community leaders, and there were few or no employment opportunities for women. This was aggravated by the damage caused to other sources of livelihood, like fishing, and by pollution of the air by dust in the farmlands. Bauxite mining had significant impacts on community rivers, which threatened the water supply of thousands of people and damaged fisheries. The government agencies in charge of mining have tried to improve the country's capacity for compensation and resources with help from international donors.

Identifying whether the members of the community that grant the SLO are truly representative of all the segments affected. Different communities are present in the mine site vicinity and may experience both positive and negative impacts from mining activities. When discussing the SLO with the mining company, it will be difficult to identify the people who will be negatively affected (LESSER; SUOPAJÄRVI; KOIVUROVA, 2017).

Ensuring an equal distribution of benefits among different communities and groups. The company must be prepared to manage the different expectations of communities and groups potentially affected by the project, some of whom may feel they are entitled to more benefits. If the company is unable to resolve these issues, disagreement between the communities and the company may ensue (LESSER; SUOPAJÄRVI; KOIVUROVA, 2017; RADON et al., 2016).

Contact with different communities that do not have a shared vision of the project. As stated by LESSER; SUOPAJÄRVI; KOIVUROVA, (2017), the mining company must be able to identify who makes up the community. The "community" is fragmented and there are different interests in the same geographic area (QUIGLEY; BAINES, 2014). The company must make the effort to understand the needs and visions of the communities that will be impacted.

4.1.2.2 Benefits that can be derived by the communities by commencing mining operation

In order to obtain an SLO from the communities, there must be the conviction that the extraction of the oil sands deposit will be more advantageous to the communities than leaving the deposit unmined. Below are some benefits the mine areas under consideration could derive from mining of the oil sands deposits. These benefits are stated because in Nigeria, most minerals are being mined by the illegal artisanal mining method.

• Reduction in mining-related natural hazards: most minerals in the developing countries cause natural hazards, which are threats to the communities and the environment. Some of the problems posed by these natural hazards include water, soil, and air pollution. In rural communities where streams and rivers constitute the major sources of water, and farming is one of the major sources of income, natural pollution from minerals can easily spread to streams and rivers, which constitute health and environmental hazards to people. These benefits are stated because in Nigeria, most minerals are being mined by the illegal/artisanal miners who have no regard for impacts caused by their activity (COLLINS; LAWSON, 2014; ASARE; DARKOH, 2001).

• Reduction of conflicts in the community: where informal mining operations hold sway, the miners do not seek the permission of the villages or bother seriously about their corporate needs and interests, thereby causing a lot of conflicts between villages and informal miners, which can result in accidents and loss of lives and properties. But with adoption of the SLO, potential problems can be envisaged and appropriate solutions applied, thus reducing conflicts.

• Local business development: when a mining operation begins, the villagers can engage in small-scale jobs like selling foodstuffs, provisions and drinks. Some of the villagers will be involved in the supply of local materials needed in their operations. New business opportunities related to mining will also spring up in the vicinity.

• General development of the communities: with a mining company in an area, the company will have to relocate the existing communities where necessary, rebuild and improve some of their infrastructure, and put in place some social services as part of its CSR commitment to the communities. All these will bring about an improved tone and development status of the communities.

• New skills will be acquired by the youths in the communities through training that will be done by the mining companies operating in the area. This will raise the standard of living of these youths and bring about improvements in the general standard of living of the communities.

• There will be more comprehensive land planning for towns or regions impacted by mining activities.

4.1.2.3 Recommendations on how to obtain a social license to operate

According to the research done, the following are the recommendations on how to obtain a SLO. If each step is followed accordingly, the stakeholder's willingness is likely to be achieved.

• There should be a local representative who can act as a liaison between the company and the people living in the community.

• Discussion should be held based on each community (if there is more than one) and not all the communities together, because each stakeholder has different views on different aspects.

• In addition to the discussion, which usually starts during the pre-mining activities of a mine, further discussions should be held throughout the LOM, which means that the community must remain involved throughout the LOM.

• Analyze the potential benefits (advantages) of mining an area that has not been mined before, as stated in 4.1.2.2.

• State reasons for choosing the community.

• Analyze the pre-existing social and environmental impacts of the oil sands caused by human activities on the community before the company decides to invest in the community.

• State the precautions the community will need against the environmental (i.e. deforestation) and social (i.e. relocation) effects, if mining activities should commence.

• In an open- ended dialogue, ask for the community's opinions and suggestions, making sure they are carried out.

• Be fair enough and respect their views and community rights.

4.2 ASSESSMENT ON ECOSYSTEM SERVICES

4.2.1 Analysis of data obtained from the questionnaire

The results of the questionnaire and the land use map were used for identifying the ecosystems that exist in the communities, their uses, and the services they render. Forest ecosystems (cocoa and palm tree) are available to the three communities, but rubber is only available in Ilubirin. It was also noted that the fresh water ecosystem is not available to the Mile 2 community. In the field, direct observations were included for observing the ecosystems that will be affected (Table 10).

Table 10 - Result of the interview conducted on ecosystems

Ecosystem availability and usage		Mulekangbo		Ilubirin		Mile 2	
		Yes	No	Yes	No	Yes	No
Forest (Plantations) available	Cocoa	40	0	30	0	30	0
	Rubber	40	0	30	0	30	0
	Palm tree	40	0	30	0	30	0
	Others	0		0		0	
Forest (Cocoa and Rubber) usage	Food	0	40	0	30	0	30
	Sale	40	0	30	0	30	0
	Others	0		0		0	
Forest (Palm tree) usage	Food	40	0	30	0	30	0
	Sale	40	0	30	0	30	0
	Others	10		8		5	
Forest (woodland)	Availability	40	0	30	0	30	0
Forest (woodland) usage	Cooking	20	20	18	12	22	8
	Sale	40	0	30	0	30	0
	Others	0	40	0	30	0	30
Freshwater (River)	Availability	40	0	30	0	0	30
Freshwater (River) usage	Household chores	35		30		0	
	Drinking and Cooking	25		30		0	
Freshwater (River) Usage Frequency	Daily	35		30		0	
	Weekly	5		0		0	
	Monthly	0		0		0	
Artificial (cropland / poultry) available	Cropland	25	15	22	8	18	12
	Poultry	8	32	5	25	2	28
	others	10		5		3	
Artificial (cropland / poultry) usage	Food	40	0	30	0	30	0
	Sales	40	0	30	0	30	0

Source: Personal file

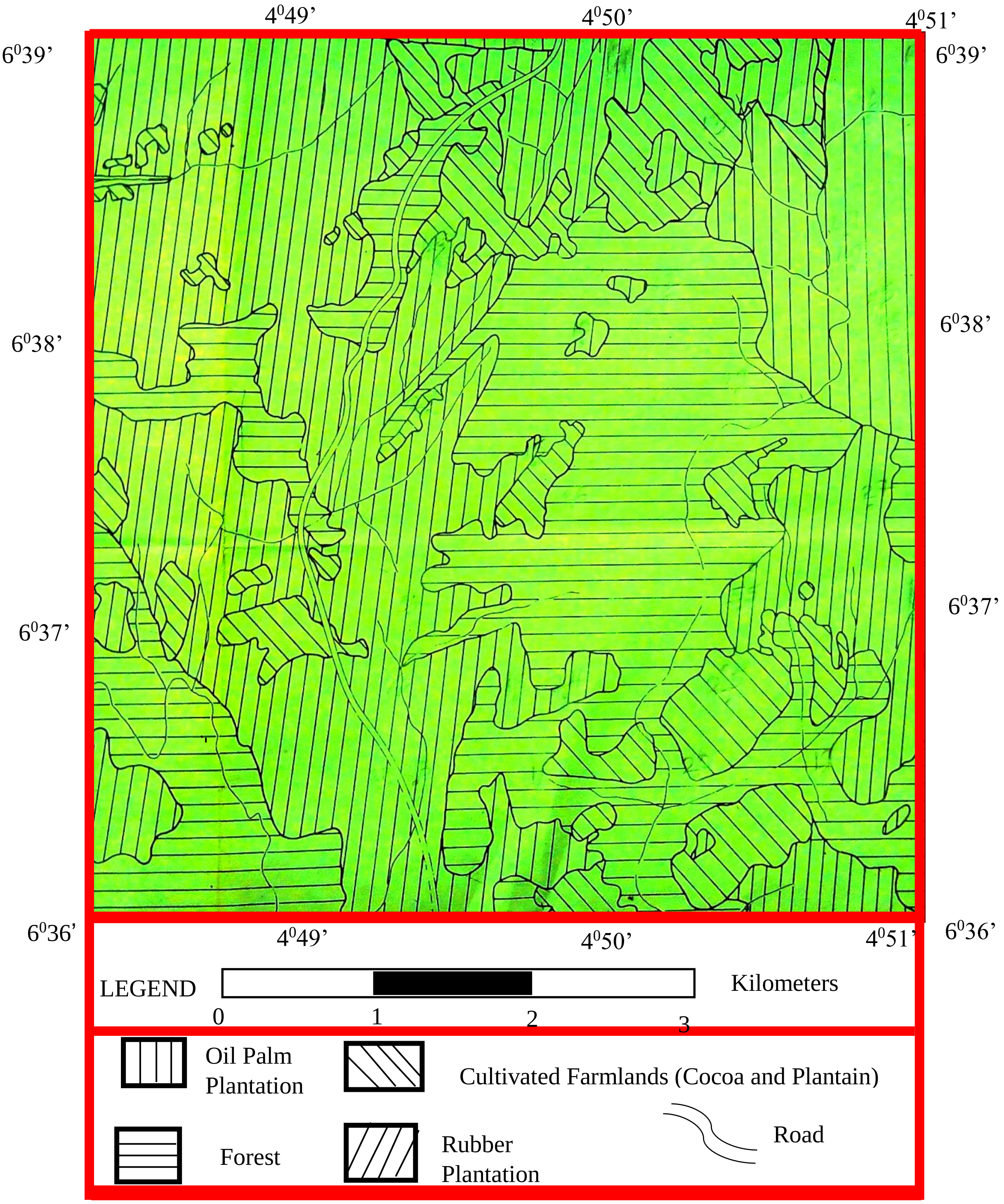
4.2.2 Land use assessment

The figures below show the pre-project land use and land cover data in consistent manner. Figures 25 and 26 show the land use map of the area. Figure 25 is the land use map created by the Geological Consultancy Unit, University of Ife (Now Obafemi Awolowo University, Nigeria) that drilled the oil sands boreholes in 1970's and the scale was not altered while Figure 26 is the land cover map that was generated by the author in this research using Arc GIS. Figure 25 has a larger scale, while Figure 26 has a smaller scale. A large-scale map shows a small area, but it shows more detail. Figure 26 shows that the land use of the area includes cropland, forest/cropland, closed to open broadleaved evergreen, closed broadleaved evergreen, grassland/forest-shrubland and closed grassland. Compounds or clusters of buildings within the communities and river that runs through the communities are also shown on the map. Some features in the land use map generated by ArcGIS (Figure 26) was confirmed through the interviews and Figure 25 gave more explanation on it.

Figure 26 shows that the Foriku-Agbabu area is dominated by closed to open broadleaved evergreen forest, closed broadleaved evergreen forest and croplands**.** GIRI; ZHU; REED, (2005) and DI GREGORIO; JANSEN (2000) explained broadleaved evergreen forest as land dominated by woody vegetation with >60% cover and height exceeding 2 m, and almost all trees and shrubs remain green year round. They described cropland as land covered with temporary crops followed by harvest and a period of bare soil. DI GREGORIO; JANSEN (2000) explained that woody plants can be subdivided into trees and shrubs according to their life form, and to separate trees from shrubs, their heights are considered. Woody plants higher than 5 m are classified as trees while the ones lower than 5 m are shrubs. Plant cover can be closed (>60–70%), open (between 60–70% and 10–20%) and sparse (below 10–20% but >1%). Evergreen plants are perennial plants that are never entirely without green foliage; these include broadleaved. Broadleaved refers to trees and shrubs of the botanical group Angiospermae.

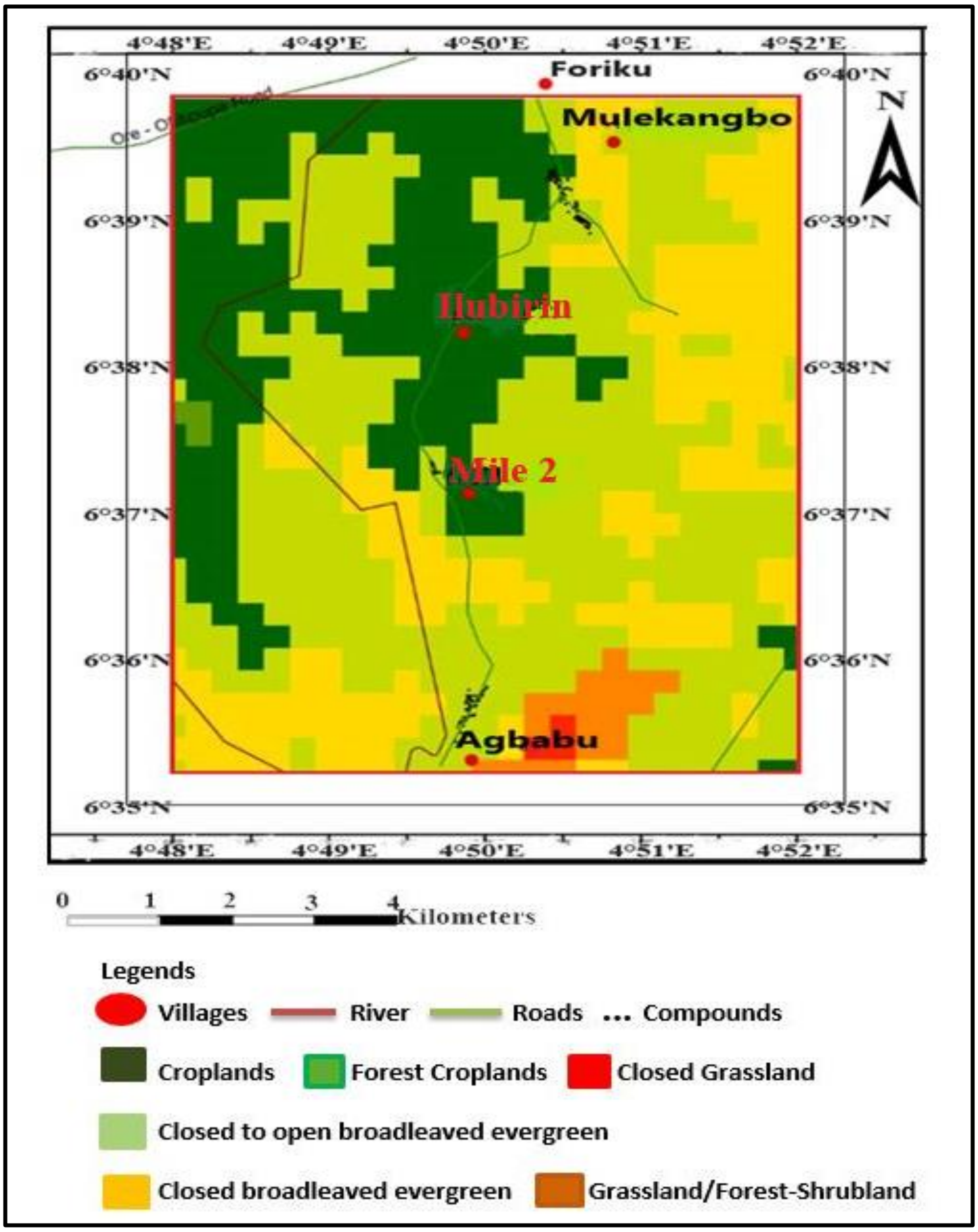
From the land-use maps, the results of questionnaires and as confirmed through observations, it was known that the ecosystems in the area include both acquatic and terrestial ecosystems. The acquatic ecosystem available in the area are both marine and fresh water ecosystem and include rivers, streams, and ponds. The terrestial ecosystem in the area is mostly forest ecosystem (which includes the cocoa, rubber, oil palm and timber plantations), and croplands. More details on the ecosystems available in this area are given in Appendix 3.

Figure 25 - Land use map of Foriku–Agbabu axis, Ondo state Nigeria



Source: Modified after Geological Consultancy Unit (GCU), University of Ile-Ife now Obafemi Awolowo University Ile-Ife (1970).

Figure 26 - GIS map showing the Land use of Foriku-Agbabu area



Source: Personal file

4.2.3 Ecosystem Services

The ES were identified from the lists, definitions, and examples of the ES analysed by the MEA (HANSON et al., 2012; LANDSBERG et al., 2013) which showed that the services rendered by the ecosystems include provisioning, regulating, cultural, and supporting. The results of the interviews show that the ES used daily include forest, livestock, crops and captured fisheries, water purification and waste treatment, freshwater and regulation of water timing, and flows.

The ES used weekly include the biomass fuel and timber. These services (both daily and weekly) were considered of high importance based on the responses provided by the interviewees of the three villages, where the dependency of the communities on local natural resources is very high.

Figures 27 - 29 show examples of ecosystems and their services in the study area. In Figure 27, the ecosystems shown are the rubber and cocoa plantations. Figure 28 shows a river and its services, i.e., the river is used for personal (washing) and household chores (Figure 29). Figures 30 – 32 shows the *bituminous natural effects***.** There were seepages of bitumen from oil sand on flowing river, hand dug well and also on the water fetcher.

Figure 27 - Examples of ecosystems that exist in the study area (Rubber and cocoa plantation)

Source: Personal file

Figure 28 - Ecosystem (River)

Source: Personal file

Figure 29 - Ecosystem service (House hold chores and washing)

Source: Personal file

Figure 30 – Bitumen seepage on flowing river

Source: Personal file

Figure 31 - Bitumen seepage in hand-dug well

Source: Personal file

Figure 32 - Water fetcher stained with bitumen seepage

Source: Personal file

Pre-mining project activities have the potential to affect 18 ES and, from the interviews that were carried out in this research, it was seen that 98% of the beneficiaries from the three villages (Mulekangbo, Ilubirin and Mile 2) are dependent on most of those services. The pre-mining activities include construction of mine site buildings, bringing of equipment and machineries to mine site and road construction. These activities will affect the ecosystem because there will be alteration of the landform, which causes pollution of the river, also deforestation affects the forest as an ecosystem, and siltation will affect both the hand dug well and the aquatic ecosystem. Table 11 shows the significance of the impact of pre-mining activities on the prioritized ES. The impacts on the prioritized ES by pre-mining activities are divided into three categories (WOOD, 2008), namely major (xxx), moderate (xx), and minor (x). The identification and prioritization of the ESs are described in Appendix 4.

From the results, it can be seen that one pre-mining activity can have impacts on all ESs (i.e. provisioning, regulating, cultural and supporting services), but the significance of the impacts varies. This is because the functions of these services to the environment also varies.

A decision tree was applied to prioritize the ES's. Out of the 18 identified ES in the area, 14 were considered to be of high priority, and these included eight provisioning services, three regulating services, two cultural services, and one supporting service. This research shows that there were four major ecosystems rendering different types of services. Out of the 14 prioritized ESs, there are five of major priority, six of moderate and three of minor priority. It was observed that most of the prioritized ESs are the source of income of the community members, therefore if these pre-mining effects can be mitigated; it will reduce the negative impact of mining on the community.

Appendix 5 and 6 gave more details on the project impacts, the use of the ESs by the communities and their prioritization.

Table 11: Potentially impacted prioritized ecosystem services and pre-mining activities

		Provisioning services								**Regulating services**			**Cultural services**		**Supporting service**
Ecosystem Change Driver	**Examples of pre-mining activities associated with project**	Livestock	Crops	Fishes	Aquaculture	Wild foods	Biomass Fuel	Freshwater	Fiber and Resins	Regulation of water timing and flow	Regulation of disease	Water purification and waste treatment	Educational and inspirational values	Ethical and spiritual values	Habitat
Change in Land use and cover	Deforestation		xxx			xxx	xxx		xxx	xx	xx		xxx		
	Road Construction	x	xxx	x	x	xxx	xxx		xxx						
	Site Planning					xxx	xxx		xxx						xx
	Equipment and Machineries Installation	x													xx
	Construction of Mine, Site Buildings and offices					xxx	xxx		xxx						xx
Pollution	Hole drilling and blasting activities	x		x	x			xx				xx		xx	xx

Source: WOOD, (2008).

xxx: impact of major significance. This shows that the extent of the impact is in large scale as a result of high sensitivity to change, and the impact is of regional importance and will be long term in nature, certain or likely to occur.
xx: impact of moderate significance. This is where the extent of the impact is in medium scale as a result of lower sensitivity to change, and the impact is of district or local importance and will be medium or short term in nature and likely to occur.
x: impact of minor significance. This is where the extent of the impact is low or barely noticeable as a result of low sensitivity to change, and the impact is of local importance and will be short term in nature and unlikely to occur.

4.2.4 Impacts Mitigation on Prioritized ES

Mitigation measures are to guarantee that affected stakeholders maintain the benefits obtained from prioritized ES and to protect affected stakeholders from experiencing loss in well-being because of the projects impacts on ecosystems. Impacts mitigation is done by identifying measures to avoid, minimize, restore, offset losses, and enhance gains in ES benefits.

Avoidance measures are crucial measures to consider on ES. Project impacts on ES such as livestock can be avoided because the ES can be removed from the project site. However, activities such as deforestation and construction of roads that impact ecosystems like terrestrial and aquatic habitat can hardly be avoided; these activities can also impact ES such as croplands. Impacts on ES such as fishes and aquaculture can be minimized by using effective erosion control measures for rivers and ponds and avoiding discharge of chemicals and pollutants into aquatic ecosystems. The proposed mitigation measures to be taken are shown in Table 12.

Table 12 – Proposed mitigation measures

Prioritized Ecosystem Services	Avoidance measures	Minimization measures	Restoration measures	Offset measures
Livestock	1st measure	2nd measure		
Crops			1st measure	2nd measure
Fishes		1st measure	2nd measure	
Aquaculture		1st measure	2nd measure	
Wild food			1st measure	2nd measure
Biomass fuel			1st measure	2nd measure
Fresh water		1st measure	2nd measure	
Fiber and resins			1st measure	2nd measure
Regulation of water timing and flow		1st measure	2nd measure	
Regulation of disease		1st measure	2nd measure	
Water purification and waste treatment		1st measure	2nd measure	
Educational and inspirational values			1st measure	2nd measure
Ethical and spiritual values		1st measure	2nd measure	
Habitat		1st measure	2nd measure	

Source: Personal file

4.2.5 Assessment of the outcome of proposed mitigation measures

Table 13 shows the summary of mitigation measures carried out on each ES. The outcome was measured either as significant reduction or no significant reduction in impact occurrences, and it was rated according to how successful the mitigation of the impacts of the pre-mining activities was to achieve no loss of ES benefits.

Considering the proposed mitigation measures in Table 13, the various impacts on the different services (provisioning, regulating, cultural and supporting) can be summarized as follows:

- There can be four major impacts that pre-mining activities can have on provisioning services, and these impacts can be mitigated by restoration measures, the moderate impact can be mitigated by minimization measure, and the three minor impacts can be mitigated by one avoidance and two minimization measures. These mitigation measures greatly reduced the impacts of pre-mining activities on ES.
- Pre-mining activities can have three moderate impacts on regulating services and these impacts can be mitigated by minimization measures, which will lessen the significance of impacts of pre-mining activities on ES.
- Pre-mining activities can have one major and one moderate impact on cultural services. The moderate impact can be minimized while the major impact can only be restored. The mitigation measures cannot reduce the impacts of mining activities on the ES because the ES will be destroyed and restored in the future.
- The moderate impact that pre-mining activities can have on supporting service can be minimized; this will lessen the significance of impact of pre-mining activities on ES.

Table 13 - Summary of mitigation measures

Services	Impacts on ES	Mitigation Measures	Outcome on mitigation measures
Provisioning service	4 major 1 moderate 3 minor	1 avoidance measures 3 minimization measures 4 restoration measures 0 offsetting measures	Significant reduction
Regulating service	3 moderate	3 minimization measures	Significant reduction
Cultural service	1 major 1 minor	1 restoration measure 1 minimization measure	No Significant reduction
Supporting service	1 moderate	1 minimization measures	Significant reduction

Source: Personal file

4.3 CONCEPTUAL MINE PLANNING

In this study, the mining software package for mine planning and design was applied to an oil sands deposit field in Ondo State, Nigeria. The database was generated using twenty-five drill holes. Holes logs are drawn one by one in two dimensions and entirely in three dimensions. Contour maps of topography, thickness and grade are drawn as well as three-dimensional surface generation and cross sectioning. Besides, following the three-dimensional ore body block modelling, open pit was designed.

The results indicate that the oil sands lithology was divided into four categories, which are; overburden, X-horizon, oil shale and the Y-horizon. The results gotten from the surveys and the topographic model constructed (using geo-processing of satellite images) were used to build a geological model of the deposit. The drill-hole data showed that the oil sands deposits can be mined using the surface mining method.

4.3.1 Input data

The input data for the mine design was gotten from GCU and the structure of the datasheet used is shown in Table 14.

The oil sands lithology was divided into overburden, X-horizon, oil shale and the Y-horizon.

Table 14 - Datasheet structure of geologic database

Table name	Field				
Collar	Borehole ID	X coordinate	Y coordinate	Z coordinate	Borehole depth
Lithology	Borehole ID	Sample start point	Sample end point	Rock code	
Assay	Borehole ID	Sample start point	Sample end point	C, S, H grades	Btu/lb, C/Atomic ratio, Kj/Kg
Rock codes	Borehole ID	Description	Colour		

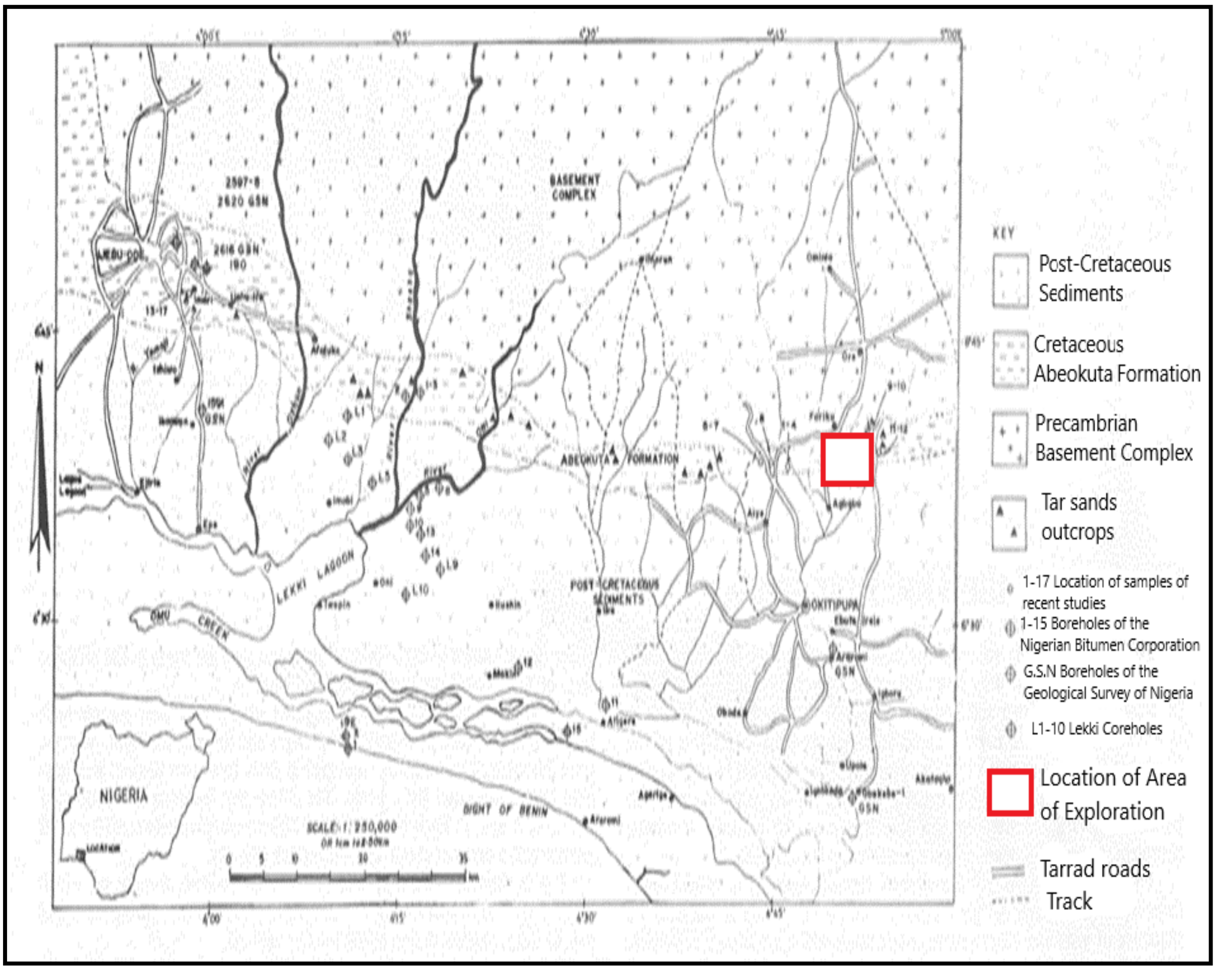
Source: Personal file

4.3.2 Geological setting and mineralization

4.3.2.1 Regional geology

The oil sands occur within the Cretaceous sequence of the Dahomey (Benin) Basin. The basin covers the five West African countries coastline (Ghana, Ivory Coast, Togo, Benin republic and Western Nigeria) (ORIRE, 2009). The outcrop belt is about 6 km wide, stretching over a region of 120 km in length and cut across four different States in Nigeria, which are Ondo, Ogun, Edo, and Lagos States (Figure 33). OMATSOLA; ADEGOKE, 1980 reviewed the stratigraphy of the sequence. They recognized three Formations in the **Abeokuta Group** based on lithologic homogeneity and similarity of origin.

Figure 33 - Geological map of the South-western Nigeria showing oil sand locations



Source: Modified after AKO et al., (1983).

These are the Ise, Afowo and Araromi Formations and they represent the thickest unit as a group within the basin. The Imo (Ewekoro and Akinbo Formations), the Oshosun, Ilaro Formations, Coastal plain sands and the Recent Alluvium (ADEGOKE; AKO; ENU, 1980; ENU, 1985) overlie the Abeokuta group (Table 15).

Table 15 - Age and stratigraphic relationship of the formations of the Dahomey basin

	Jones and Hockey (1964)[6]		Omatsola and Adegoke (1980)		Agagu (1985)[7]	
	Age	Formation	Age	Formation	Age	Formation
Quaternary	Recent	Alluvium			Recent	Alluvium
Tertiary	Pleistocene to oligocene	Coastal plain sands	Pleistocene to oligocene	Coastal plain sands	Pleistocene to oligocene	Coastal plain sands
	Eocene	Ilaro	Eocene	Ilaro Oshoshun	Eocene	Ilaro Oshoshun
	Paleocene	Ewekoro	Paleocene	Akinbo Ewekoro	Paleocene	Akinbo Ewekoro
Late Cretaceous	Late Santonian	Abeokuta	Maastrichtian-Neocomian	Ise-Afowo-Araromi	Maastrichtian-Turonian-Neocomian	Araromi-Afowo-Ise
Precambrian Basement rock						

Source: Personal file (Modified from various authors).

Ise Formation: The Ise Formation, which unconformably overlies the basement complex rock, is the oldest formation in the Abeokuta group. The base is made up of conglomerate, gritty to medium grained loose sand, capped by kaolinite clay (OMATSOLA; ADEGOKE, 1980; ENU, 1985). The maximum thickness encountered in one of the drilled well was about 609m, and similar section were exposed near Ode- Remo on the Lagos-Ibadan expressway. The age is Neocomian and the unit has no bituminous sands both at surface and subsurface section (ORIRE, 2009).

Afowo Formation: Overlying the Ise Formation is the Afowo Formation (ORIRE, 2009), the Afowo Formation is composed of coarse to medium grained sandstone with variable but thick inter-bedded shale, siltstone and claystone. The sandy facies are tar-bearing while the shale are organic-rich (ENU, 1985). Using palynological assemblage, a Turonian age is assigned to the lower part of this Formation, while the upper part ranges into Maastrichian. In the Afowo Formation, shales of the Araromi Formation seal the oil sands. The beds are overlain by two bitumen-impregnated sandy horizons (Horizons X and Y). The horizons of the bitumen are separated by thick greenish to grey shale. Shales, siltstones, interbedded limestone and lateritic

[6] JONES H. A.; HOCKEY R. D. The geology of part of Southwestern Nigeria. **Bulletin of the Geological Survey Nigeria**, 31:101, 1964.
[7] AGAGU O. K. A geological guide to bituminous sediments in Southwestern Nigeria. **Unpublished Report, Department of Geology, University of Ibadan**, 1985.

top soil of variable thickness overlie the oil sands. The thickness of the overburden varies depending on the region (ENU, 1985). The oil sands can be exploited by both surface mining methods and secondary recovery methods, the processes of removing the oil sands deposits from the earth crust follows the same process for most of the other solid mineral deposits.

Araromi Formation: The youngest topmost sedimentary sequence in the Abeokuta group is the sediments of the Araromi Formation. It consists of shales, fine-grained sand, thin inter-beds of limestone clay and lignite bands (OMATSOLA; ADEGOKE, 1980). It is an equal to the Araromi shale unit. The age ranges from Mastrichian to Palaeocene.

Imo group: Overlying the Abeokuta group conformably is the Imo group, the two-lithosratigraphic units under this group are: Ewekoro Formation that consists of thick fossiliferous limestone, and Akinbo Formation lies on the Ewekoro Formation. The age of the formation is Paleocene to Eocene (AKINMOSIN; OSINOWO; OLADUNJOYE, 2009).

Oshoshun Formation: this overlays the Imo group; it is a sequence of pale greenish-grey laminated phosphatic marls, with interbeds of sandstones. It consists of claystone underlain by limestones and shale at the bottom. The formation is Eocene in age (AKINMOSIN; OSINOWO; OLADUNJOYE, 2009).

Ilaro Formation: The sandstone unit of the Ilaro Formation was formed due to regression of the sedimentation of the Oshoshun Formation, which consists of mainly coarse sandy estuarine deltaic and continental beds that show rapid lateral facies change (AKINMOSIN; OSINOWO; OLADUNJOYE, 2009).

C**oastal plain sands:** It consists of soft, poorly sorted clayey and pebbly sands, of Oligocene to Recent age. It probably overlay the Ilaro Formation unconformably, but with no much evidence (AKINMOSIN; OSINOWO; OLADUNJOYE, 2009).

4.3.2.2 Local Geology

The main area of interest which are Mulekangbo, Ilubirin and Mile 2 are located within the geographical grids of latitude 06° 40’ 6.7”N and 06° 36’ 52.0”N and longitudes 04° 50’ 23.5”E and 04° 49’ 51.9”E in Ondo State.

Within the state, there are excellent bitumen outcrops and oil sands with bitumen saturation of average of 15%. The bitumen is found impregnating mostly in sands (Figure 34). There has been frequent occurrence of seepages of oil from the oil sand deposit in some of the hand-dug wells in various locations in the villages.

Figure 34 - Mode of occurrence of oil sand outcrop in Ondo state. (a) River channel; (b) (c) & (f) oil sand outcrop; (d) Shallow borehole at Agbabu and (e) bitumen occurring on surface of water

Source: Personal file

The oil sands occur in two horizons designated as “X” and “Y” horizons, from the borehole studies, the typical sequence shown is as follow:

- Top soil with heavy vegetation: The oil sands area located in fertile agricultural lands with forests. This sequence overlies the oil sands deposits. There are no occurrence of bituminous seepage recorded. The sequence is the overburden unit that must be cleared for mining to proceed and it increases southwards. The top soil, shale, limestone and vegetation will have to be cleared before mining. The thickness varies from 3.1m to about 60 m with an average of 24 m.

- X bitumen-impregnated horizon: this is the horizon with primary bitumen impregnation, it is referred to as X-horizon in this research. The X-horizon is closer to the surface, and this horizon forms most of the outcrops in most areas. The variation in its thickness is between 9m to about 22m with an average of 14m.
- Alternating sands and shale: This unit is referred to as the oil shale unit, it separates the two horizons. The oil shale is the unit below the X-horizon with the thickness varying from 1m to about 16m with an average of 8m.
- Y bitumen-impregnated horizon: this horizon is below the "X" horizon. Its thickness varies widely from 1m to 38m with an average of about 13m.

4.3.2.3 Mineralization

The GCU, Ile-Ife studied the heavy minerals in 21 of the sands suites. The result showed that the sands were dominated with opaque (30-74%) followed by staurolite, tourmaline and zircon. The tourmaline grains were mostly angular, large and prismatic. They were represented in brown, blue and green varieties. Other heavy minerals in order of relative abundance include kyanite, sillimanite, rutile, hornblende, garnet, hypersthene, andalusite, augite and zoisite.

The laboratory analysis carried out on 15 different oil sands samples in this research is shown in Tables 16 and 17. The result shows that sample 14 has the highest bitumen content, which is 67.7% while sample 8 has the lowest with 0.08%. Sample 5 has the highest saturate content with 76.9% and sample 13 has the lowest with 12.7%. Sample 2 has the highest aromatic content with 60.9% while sample 5 has the lowest with 10.1%. Sample 6 has the highest asphaltene content with 72.2% and sample 5 has the lowest with 13%. The sulphur content analysis shows sample 5 has the highest sulphur content with 1.91% sulphur and sample 12 has the lowest with 0.89%.

Table 16 – Saturates, Aromatics and Asphaltenes content analysis in oil sands samples

Sample	E.O (mg)	%	Saturates (mg)	%	Aromatic (mg)	%	Asphaltenes (mg)	%
Sample 1	1727.1	10.4	3.9	20.2	6.4	33.2	9.0	46.6
Sample 2	2533.8	16.5	6.1	24.6	15.1	60.9	3.6	14.5
Sample 3	782.6	5.1	5.3	22.4	5.5	23.2	12.9	54.4
Sample 4	105.3	1.97	4.2	22.6	3.9	21.0	10.5	56.5
Sample 5	23.8	0.55	18.3	76.9	2.4	10.1	3.1	13.0
Sample 6	268.3	1.66	3.8	17.6	2.2	10.2	15.6	72.2
Sample 8	10.2	0.08	3.2	31.4	1.8	17.6	5.2	51.0
Sample 9	273.6	1.73	6.8	34.7	5.9	30.1	6.9	35.2
Sample 11	630.0	6.0	6.5	29.0	6.1	27.2	9.8	43.8
Sample 12	3930.3	20.9	6.6	27.4	7.1	29.5	10.4	43.2
Sample 13	4925.7	34.5	3.2	12.7	6.0	23.9	15.9	63.3
Sample 14	8394.6	67.7	3.5	14.5	5.7	23.6	15.0	62.0
Sample 16	0.0	####	6.0	24.1	5.7	22.9	13.2	53.0
Sample 17	0.0	####	6.1	25.1	14.4	59.3	3.8	15.6
Sample 18	0.0	####	4.7	19.7	6.7	28.2	12.4	52.1

Note: There was no bitumen extraction (sample 16, 17 and 18). They were directly fractionated.
Source: Personal file.

Table 17 – Sulphur content analysis in oil sands samples

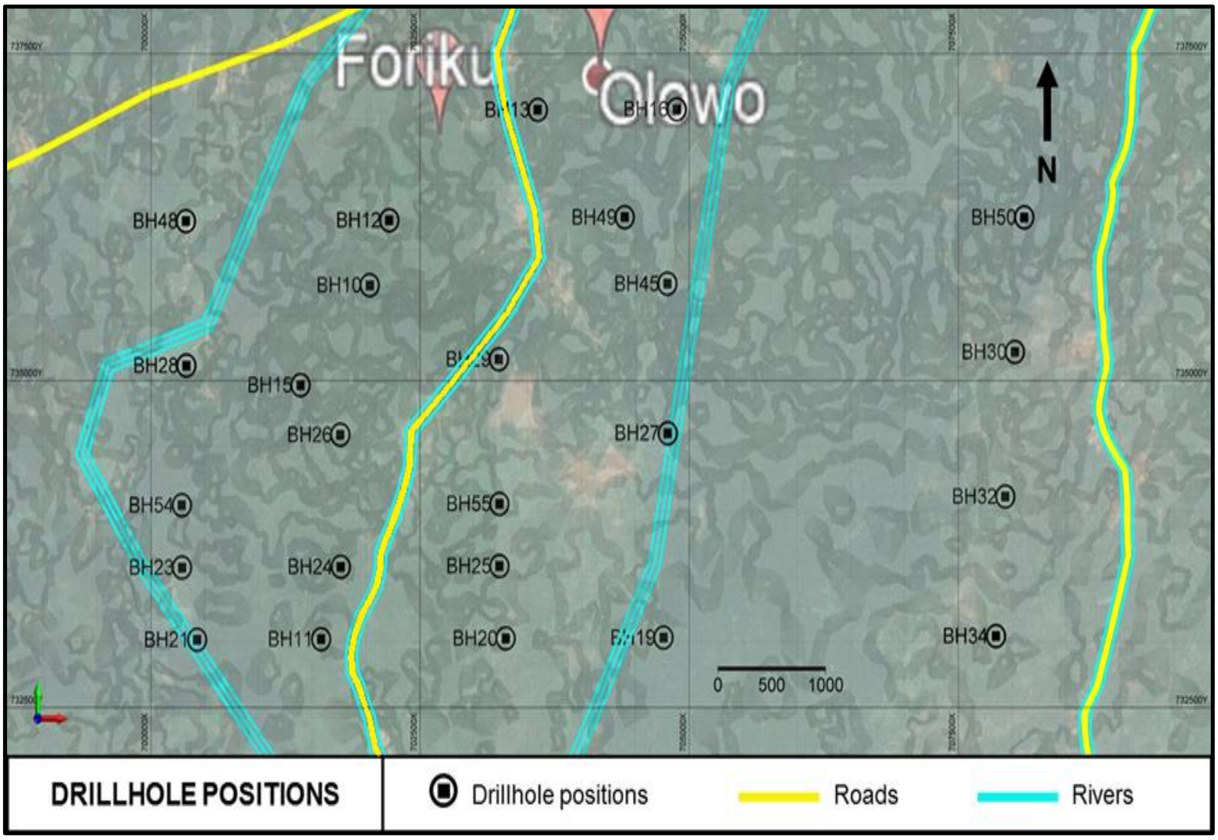
LECO SC 632 (002)		DATE				% COT	% Sulphur (S)
Reference		Standard deviation					
502-026 LOT 1007 OIL	2.10 ± 0.04	2.14	The		2.06	2.10	
Depth	Little boat	Barq. + Amost.	Get off	Weight	R.I	COT%	S %
SAMPLE 1 R1		12/03/19		0.020	0		0.96
REP SAMPLE 1 R1		12/03/19		0.020	0		0.93
SAMPLE 2		12/03/19		0.020	0		0.90
SAMPLE 3		12/03/19		0.020	0		0.95
SAMPLE 4 R1		12/03/19		0.020	0		0.90
REP SAMPLE 4 R2		12/03/19		0.020	0		0.90
SAMPLE 5		28/03/19		0.020	0		1.91
SAMPLE 6		12/03/19		0.020	0		0.96
SAMPLE 8		28/03/19		0.020	0		0.92
SAMPLE 9		12/03/19		0.020	0		1.21
SAMPLE 11		12/03/19		0.020	0		0.92
SAMPLE 12		12/03/19		0.020	0		0.89
SAMPLE 13		12/03/19		0.020	0		0.96
SAMPLE 14		12/03/19		0.020	0		0.96
SAMPLE 16		28/03/19		0.020	0		0.96
SAMPLE 17		28/03/19		0.020	0		0.95
SAMPLE 18		28/03/19		0.020	0		0.94
502-026 LOT 1007 OIL		12/03/19		0.020	0		0.21
502-026 LOT 1007 OIL		28/03/19		0.020	0		2.10

Source: Personal file

4.3.3 Preliminary resource model

The borehole (exploration) data obtained from GCU, Ile-Ife was organised into a Microsoft Excel format and was used as the primary data that was used for geological (block) modelling using mining software (XIANG et al., 2020). Figure 35 shows the drillhole positions, the roads and rivers that cut across the area under study.

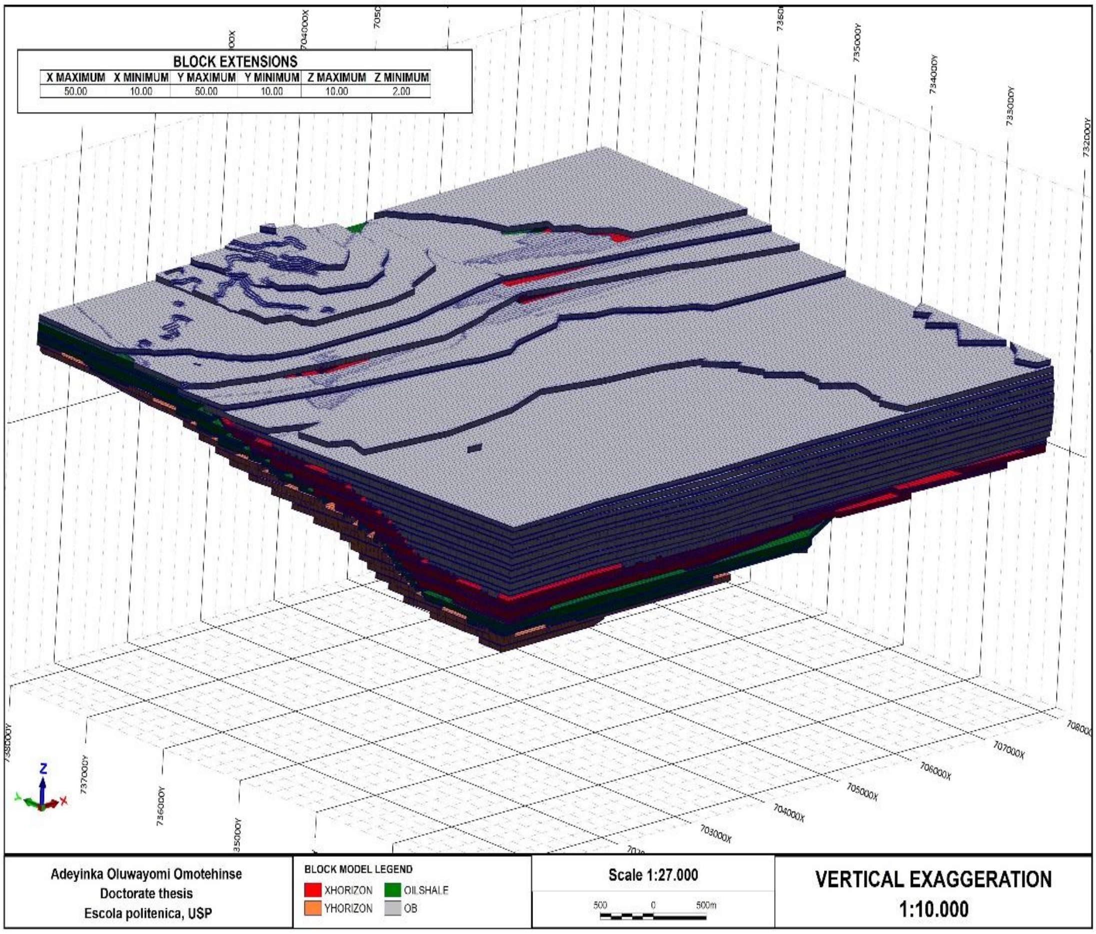
Figure 35 - Drillhole positions



Source: Personal file

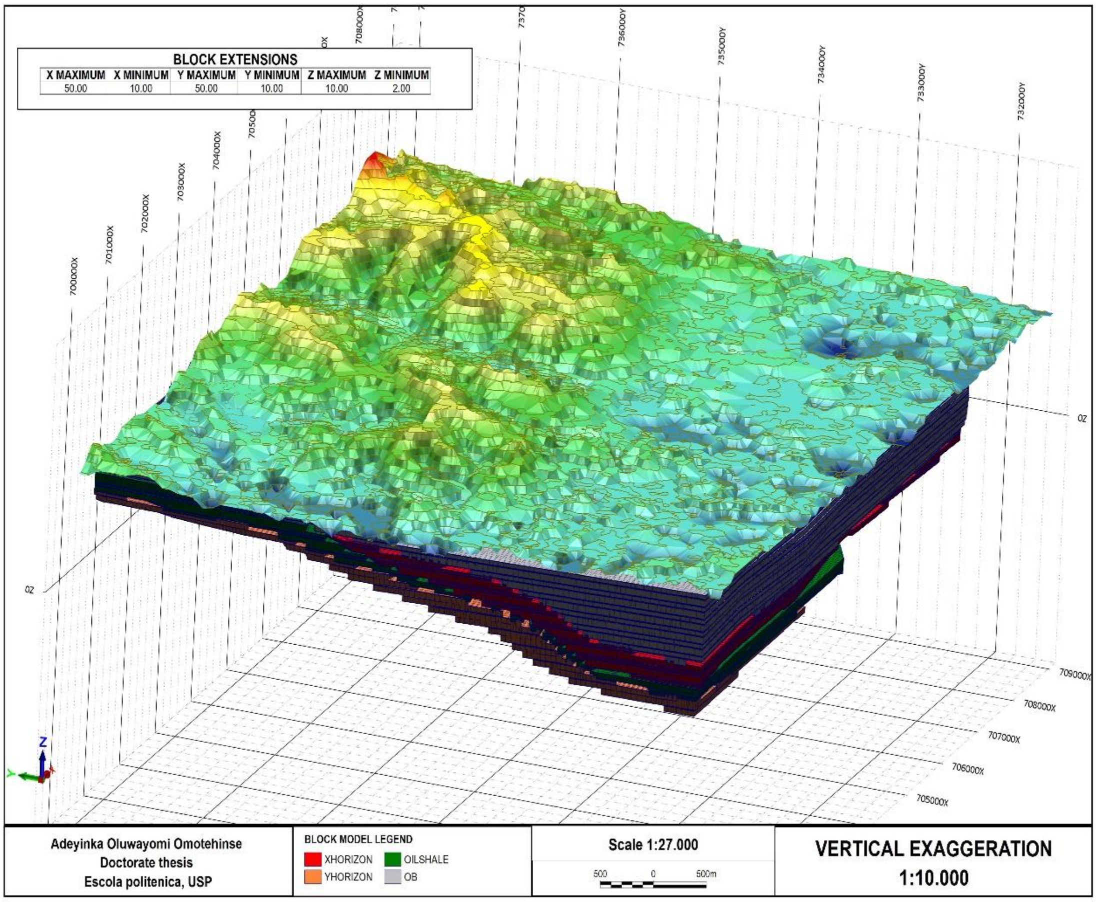
The geological model is shown in Figures 36 (a, b &c). The geologic database used were titled collar, assay and geology. Geologic database is the basis of 3D modelling necessary for the creation of a 3D model of ore body and analysing the borehole data. The block size for the geological model was 50 x 50 x 10 (x, y, z) while the sub block size was 10 x 10 x 2 (x, y, z).

Figure 36a - Geological model 3-Dimensional view



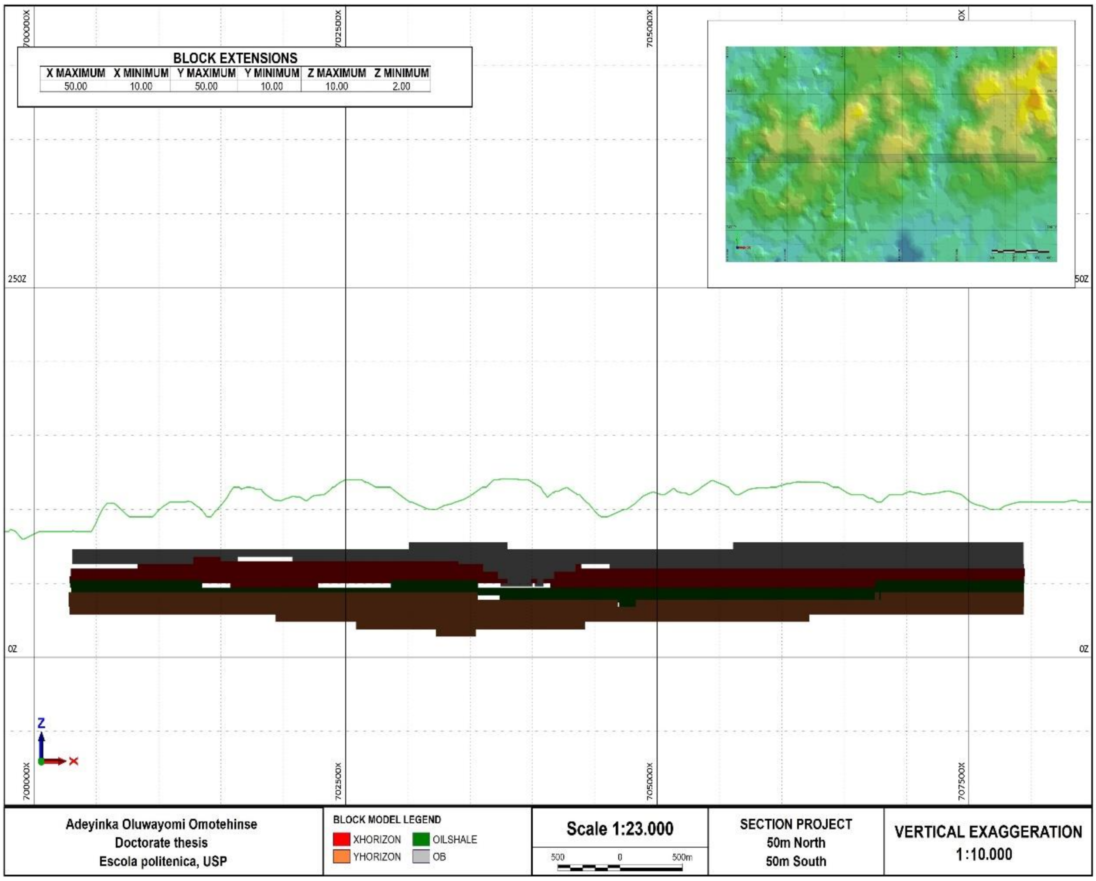
Source: Personal file

Figure 36b - Geological model 3-Dimensional view with topography



Source: Personal file

Figure 36c - Geological model Section view



Source: Personal file

4.3.4 Conceptual modifying factors

Table 18 presents the conceptual modifying factors, which were estimated based on the field observations and from the literature.

Table 18 - Conceptual modifying factors

Parameter	Criteria	Reference
Mining cost (Can$/tonne)	14 (8 for ore, 6 for waste)	CLARK et al., 2007
Sell cost (Can$/tonne)	2	BEN-AWUAH, 2013
Mining recovery fraction (%)	95	BEN-AWUAH, 2013
Processing cost (Can$/tonne)	15	CLARK et al., 2007
Processing recovery fraction (%)	90	BEN-AWUAH, 2013
Selling price (Can$/tonne)	250	MILLINGTON, 2017
Mining / ore dilution (m)	0.3 m	CANADA (GOVERNMENT), 2019

Source: Personal file

4.3.5 Pit Optimisation and design

Three sequential steps were taken using the mining software. The first step was to develop a geological (block) model for the orebody, the block model was used for pit optimisation. The parameters in Table 18 referred to as the conceptual modifying factors were also used for the pit optimization, the data was computed in the mining software and the pit optimization result is shown in Table 19.

Table 19 - Optimization data

Rock type	Ore volume (million)	Waste volume (million)	Ore tonnes (million)	Waste tonnes (million)	Mined ore tonnes (million)	Mined waste tonnes (million)	Strip ratio	Total pit tonnes (million)	Process-ing tonnage (million)	Process-ing cost (million CAD $)	G&A cost (million CAD $)	Ore mining cost (million CAD $)	Waste mining cost (million CAD $)	Rehab cost (million CAD $)	Sell cost (million CAD $)	Total cost (millio n CAD $)	Profit (million CAD$)
Default	0	4.850	0	10.087	0	10.087			0	0	0	0	60.520	0	0		
OB	0	2.414	0	5.022	0	5.022			0	0	0	0	30.135	5.022	0		
X-horizon	0.4332	0	0.899	0	0.831	0.068			0.831	12.459	1.661	7.191	0	0	0.195		
Oil shale	10.786	0	22.435	0	20.730	1.705			20.730	248.760	41.460	179.480	0	0	4.863		
Y-horizon	32.053	0	66,671	0	61.604	5.067			61.604	739.253	123.209	533.372	0	0	15.023		
Total	43.271	7.264	90.005	15.109	83.165	21.949	0.26	105.110	83.165	1,000	166.330	720.043	90.655	5.022	20.081	2,003	507.543

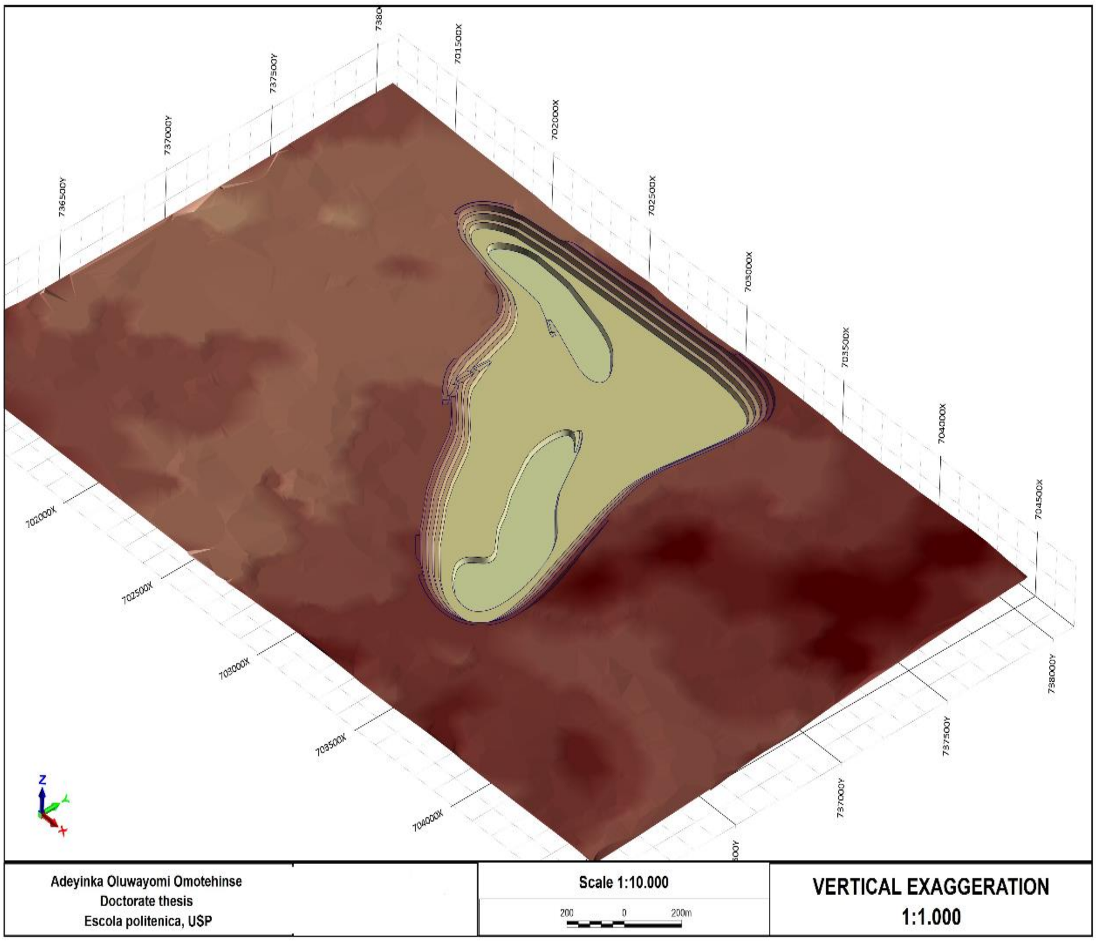
Source: Personal file

Finally, the result from the optimal pit was used for the pit design as shown in Figures 37 (a, b & c).

4.3.6 Conceptual pit design

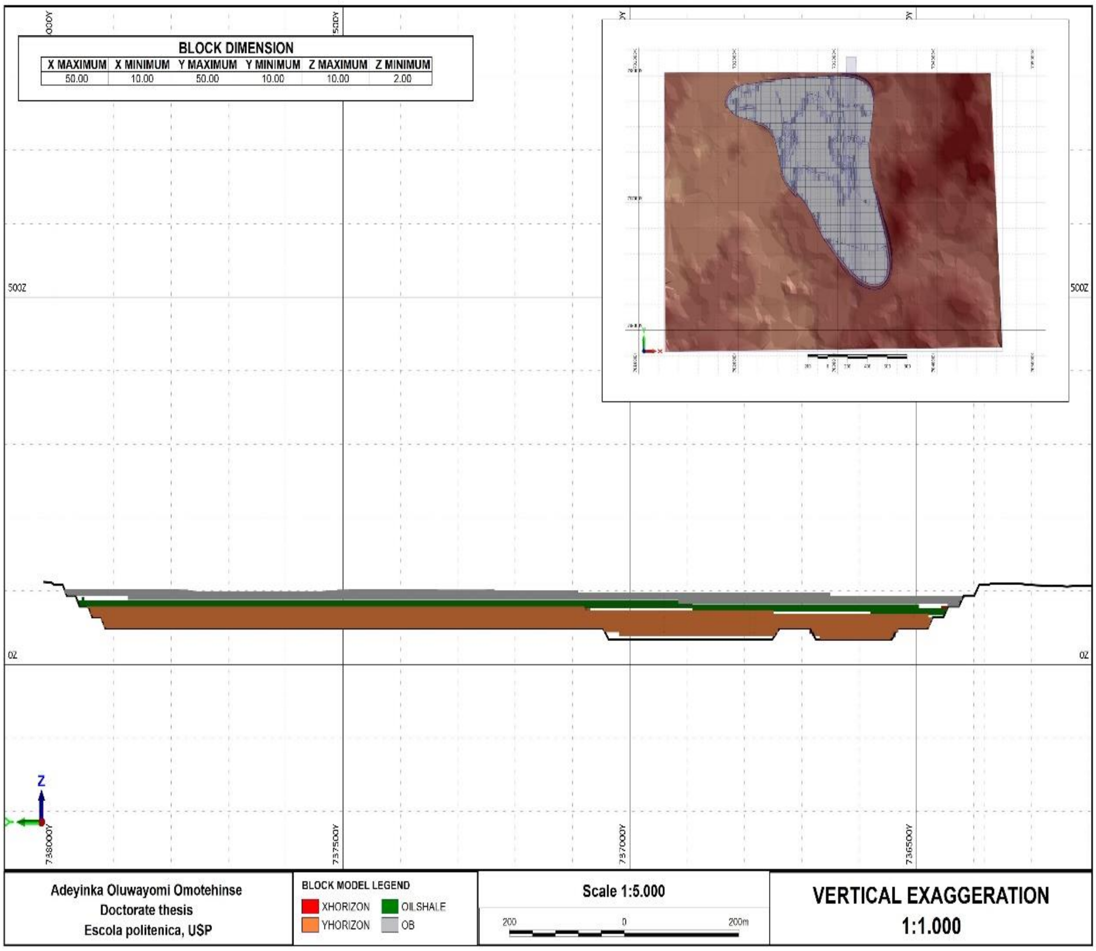
The pit design was carried out using the following features: the final (optimal) pit limit, a bench height of 15m, berm width of 15m and slope angle of 30°.

Figure 37a - Pit design 3-Dimensional view



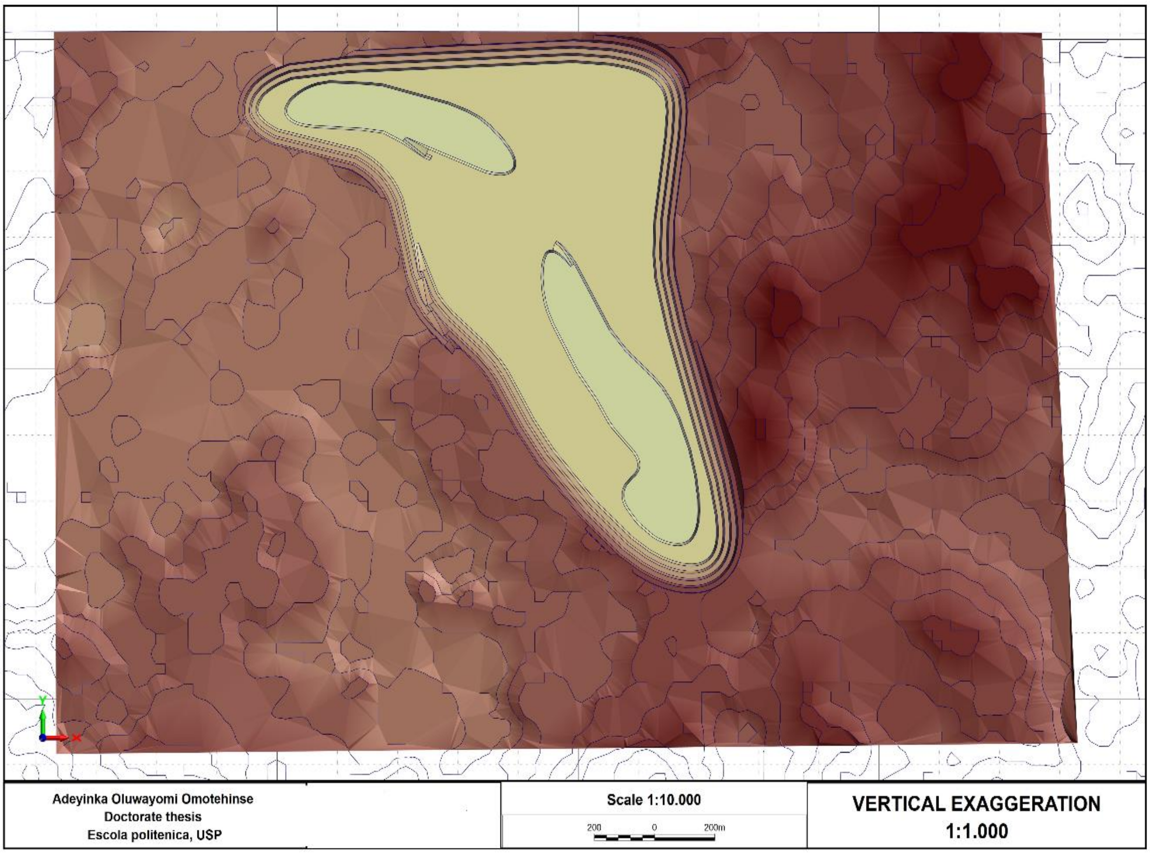
Source: Personal file

Figure 37b - Pit design Section view



Source: Personal file

Figure 37c - Pit design Plan view



Source: Personal file

4.3.7 Preliminary economic assessment

An economic assessment was carried out on three different types of mine to select the best profitable processing technology for the Nigerian oil sands with assumptions of CAPEX, OPEX, recovery, sales based on literatures on which the economic decisions are made. The results for the PEA carried out are shown below.

PEA for large-scale synthetic crude oil (SCO) producing mine

The model used indicates that the SCO producing mine will not be feasible for the oil sands resources in Nigeria. There was negativity in the NPV due to a very high CAPEX that will be required. The literatures online show that Canadian bitumen production, which comprised of in-situ (thermal and cold bitumen) production of 1.6 million barrels per day (MMBPD) and mining production of 1.5 MMBPD reached about 3 MMBPD in 2018 (NATURAL RESOURCES CANADA, 2019; MILLINGTON, 2017). It was projected to rise to 4.25 MMBPD by 2035 (CANADA'S OIL AND NATURAL GAS PRODUCERS, 2019). Alberta Energy Regulator (AER) reported the production of SCO to be 1.25 MMBPD in July 2019 (OIL SANDS MAGAZINE, 2019).

In addition, the minimum CAPEX invested in 2016 for the production was about $20 billion Canadian dollar (CAD) (CANADA'S OIL AND NATURAL GAS PRODUCERS, 2019), which might not be feasible for the Nigerian oil sands mine in terms of capacity (production) and investment.

Moreover, Nigeria is is already a world class exporter of conventional crude oil; therefore, it will be unreasonable to invest a sum of $25 billion on oil sands in order to produce SCO, which is less valuable than the conventional crude oil. It was therefore concluded that the project would not be feasible due to these conditions.

PEA for medium-scale bitumen producing mine

The result in Table 20 indicates that the mine will be able to invest a sum of $2 billion CAD as CAPEX and the bitumen can be sold at $ 284/ ton to break-even. The discount rate used was 12% with 32 % tax.

The LOM was assumed to be 50 years with a production capacity of 24,010 t/day at 90% recovery rate. The NPV that will be achieved at an average grade of 15% bitumen will be $ 33,164,439 CAD.

Table 20 – Assumptions for cash flow of medium-scale bitumen producing mine

Cash flow: Oil sands (Bitumen production) (Medium scale mine) 17 January 2020			
Assumptions		**Assumptions**	
First year	2021	Investment (exploration, pre-mining activities)	$25,000,000
Discount rate (total)	12.0%	CAPEX (mining, processing) no upgrading	$2,000,000,000
Royalties (%)	3.0%	CAPEX (infrastructure)	$500,000,000
Price annual readjustment	6.0%	Sustaining capital	3.0%
Cost annual readjustment	1.0%	Mining cost (CAD$/t)	$8
		Processing cost (no upgrading) (CAD$/t)	$10
Life of mine (years)	50		
Total resources (t)	432,196,000		
Mine production (t/year)	8,643,000	G&A (%)	3.0%
Plant feed (t/year)	8,210,850		
Plant capacity (t/day)	27,370		
Plant capacity (t/hour)	1,368	Annual contingencies	5.0%
Average bitumen content (%)	15%		
Mining recovery	95.0%	Price (CAD/t bitumen)	$284
Processing recovery	90.0%	Taxes and duties	32.0%

Source: Personal file

The implied bitumen is the end-product used in this scenario. This is bitumen extracted from the oil sands before addition of condensate to enable easy flow of the oil through pipelines, it is assumed to have a blend composition of 30% condensate and 70% bitumen (NATURAL RESOURCES CANADA, 2019).

In Table 21, a worksheet showing the analysis of the cash flow for the medium-scale bitumen producing mine for 50 years (2021-2070) was presented.

The result has therefore shown that the mine will operate near breakeven level for the implied bitumen, which will not be competitive for the Nigerian government against the other sources of crude oil in Nigeria, there is little room for reclamation activities and SLO will not be covered.

These two types of products were therefore not considered any further due to reasons stated above.

Table 21 - Worksheet showing the cash flow for the medium-scale bitumen producing mine (Year 2021-2070)

Cash flow: Oil sands (Bitumen production) (Medium-scale mine)

17 January 2020

Cash flow	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAPEX + Sustaining	CAD$ (*1000)	-2,525,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000
Residual (2*net profit)	CAD$ (*1000)										
OPEX	CAD$ (*1000)	0	-175,858	-178,262	-180,735	-183,282	-185,906	-188,612	-191,406	-194,291	-197,273
Revenue	CAD$ (*1000)	0	351,255	372,330	394,670	418,350	443,451	470,058	498,262	528,158	559,847
Gross profit	CAD$ (*1000)	0	175,397	194,068	213,935	235,069	257,545	281,446	306,856	333,867	362,574
Depreciation	CAD$ (*1000)	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000
Tax base	CAD$ (*1000)	0	0	0	0	0	7,545	31,446	56,856	83,867	112,574
Taxes and duties	CAD$ (*1000)	0	0	0	0	0	-2,415	-10,063	-18,194	-26,837	-36,024
Net profit	CAD$ (*1000)	0	175,397	194,068	213,935	235,069	255,131	271,383	288,662	307,029	326,550
Cash flow pre-tax	**CAD$ (*1000)**	**-$2,525,000**	**$100,397**	**$119,068**	**$138,935**	**$160,069**	**$182,545**	**$206,446**	**$231,856**	**$258,867**	**$287,574**
Cash flow after tax	**CAD$ (*1000)**	**-$2,525,000**	**$100,397**	**$119,068**	**$138,935**	**$160,069**	**$180,131**	**$196,383**	**$213,662**	**$232,029**	**$251,550**

Table 21 - Worksheet showing the cash flow for the medium-scale bitumen producing mine (Year 2021-2070) (continuation)

Cash flow: Oil sands (Bitumen production) (Medium-scale mine)

17 January 2020

Cash flow	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CAPEX + Sustaining	CAD$ (*1000)	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000
Residual (2*net profit)	CAD$ (*1000)										
OPEX	CAD$ (*1000)	-200,359	-203,555	-206,866	-210,301	-213,866	-217,570	-221,422	-225,431	-229,607	-233,959
Revenue	CAD$ (*1000)	593,438	629,044	666,787	706,794	749,202	794,154	841,803	892,311	945,850	1,002,601
Gross profit	CAD$ (*1000)	393,079	425,489	459,921	496,493	535,336	576,583	620,381	666,880	716,243	768,641
Depreciation	CAD$ (*1000)	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000
Tax base	CAD$ (*1000)	143,079	175,489	209,921	246,493	285,336	326,583	370,381	416,880	466,243	518,641
Taxes and duties	CAD$ (*1000)	-45,785	-56,157	-67,175	-78,878	-91,307	-104,507	-118,522	-133,402	-149,198	-165,965
Net profit	CAD$ (*1000)	347,293	369,333	392,746	417,615	444,028	472,077	501,859	533,478	567,045	602,676
Cash flow pre-tax	**CAD$ (*1000)**	**$318,079**	**$350,489**	**$384,921**	**$421,493**	**$460,336**	**$501,583**	**$545,381**	**$591,880**	**$641,243**	**$693,641**
Cash flow after tax	**CAD$ (*1000)**	**$277,293**	**$294,333**	**$317,746**	**$342,615**	**$369,028**	**$397,077**	**$462,859**	**$458,478**	**$492,045**	**$527,676**

Table 21 - Worksheet showing the cash flow for the medium-scale bitumen producing mine (Year 2021-2070) (continuation)

	Cash flow: Oil sands (Bitumen production) (Medium-scale mine)										
	17 January 2020										
Cash flow	Unit	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
CAPEX + Sustaining	CAD$ (*1000)	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000
Residual (2*net profit)	CAD$ (*1000)										
OPEX	CAD$ (*1000)	-238,501	-243,244	-248,200	-253,384	-258,811	-264,496	-270,457	-276,712	-283,279	-290,181
Revenue	CAD$ (*1000)	1,062,757	1,126,522	1,194,114	1,265,760	1,341,706	1,422,208	1,507,541	1,597,993	1,693,873	1,795,505
Gross profit	CAD$ (*1000)	824,256	883,279	945,914	1,012,376	1,082,895	1,157,712	1,237,084	1,321,282	1,410,594	1,505,325
Depreciation	CAD$ (*1000)	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	- 25000,000	-250,000	-250,000
Tax base	CAD$ (*1000)	574,256	633,279	695,914	762,376	832,895	907,712	987,084	1,071,282	1,160,594	1,255,325
Taxes and duties	CAD$ (*1000)	-183,762	-202,649	-222,692	-243,960	-266,526	-290,468	-315,867	-342,810	-371,390	-401,704
Net profit	CAD$ (*1000)	640,494	680,629	723,221	768,416	816,369	867,244	921,217	978,472	1,039,204	1,103,621
Cash flow pre-tax	**CAD$ (*1000)**	**$749,256**	**$808,279**	**$870,914**	**$937,376**	**$1,007,895**	**$1,082,712**	**$1,162,084**	**$1,246,282**	**$1,335,594**	**$1,430,325**
Cash flow after tax	**CAD$ (*1000)**	**$565,494**	**$605,629**	**$648,221**	**$693,416**	**$741,369**	**$792,244**	**$846,217**	**$903,472**	**$964,204**	**$1,028,621**

Table 21 - Worksheet showing the cash flow for the medium-scale bitumen producing mine (Year 2021-2070) (continuation)

Cash flow: Oil sands (Bitumen production) (Medium-scale mine)											
17 January 2020											
Cash flow	Unit	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
CAPEX + Sustaining	CAD$ (*1000)	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000
Residual (2*net profit)	CAD$ (*1000)										
OPEX	CAD$ (*1000)	-297,439	-305,077	-313,121	-321,597	-330,536	-339,968	-349,927	-360,449	-371,572	-383,337
Revenue	CAD$ (*1000)	1,903,236	2,017,430	2,138,476	2,266,784	2,402,791	2,546,959	2,699,776	2,861,763	3,033,469	3,215,477
Gross profit	CAD$ (*1000)	1,605,797	1,712,353	1,825,355	1,945,187	2,072,255	2,206,991	2,349,849	2,501,314	2,661,897	2,832,140
Depreciation	CAD$ (*1000)	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000	-250,000
Tax base	CAD$ (*1000)	1,355,797	1,462,353	1,575,355	1,695,187	1,822,255	1,956,991	2,099,849	2,251,314	2,411,897	2,582,140
Taxes and duties	CAD$ (*1000)	-433,855	-467,953	-504,114	-542,460	-583,122	-626,237	-671,952	-720,420	-771,807	-826,258
Net profit	CAD$ (*1000)	1,171,942	1,244,400	1,321,241	1,402,727	1,489,134	1,580,754	1,677,897	1,780,893	1,890,090	2,005,855
Cash flow pre-tax	**CAD$ (*1000)**	**$1,530,797**	**$1,637,353**	**$1,750,355**	**$1,870,187**	**$1,997,255**	**$2,131,991**	**$2,274,849**	$2426,314	**$2,586,897**	**$2,757,140**
Cash flow after tax	**CAD$ (*1000)**	**$1,0965,942**	**$1,169,400**	**$1,246,241**	**$1,327,727**	**$1,414,134**	**$1,505,754**	**$1,602,897**	**$1,705,893**	**$1,815,090**	**$1,930,855**

Table 21 - Worksheet showing the cash flow for the medium-scale bitumen producing mine (Year 2021-2070) (continuation)

Cash flow: Oil sands (Bitumen production) (Medium-scale mine)											
17 January 2020											
Cash flow	Unit	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070
CAPEX + Sustaining	CAD$ (*1000)	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000	-75,000
Residual (2*net profit)	CAD$ (*1000)										6,832,162
OPEX	CAD$ (*1000)	-395,787	-408,971	-422,938	-437,741	-453,440	-470,094	-487,771	-506,541	-526,479	-547,666
Revenue	CAD$ (*1000)	3,408,405	3,612,910	3,829,648	4,059,465	4,303,033	4,561,215	4,834,888	5,124,981	5,432,480	5,758,429
Gross profit	CAD$ (*1000)	3,012,618	3,203,939	3,406,747	3,621,724	3,849,594	4,091,121	4,347,117	4,618,441	4,906,001	5,210,763
Depreciation	CAD$ (*1000)	-250,000	-250,000	-250,000	-250,000	-250,000	-250,100	-250,000	-250,000	-250,000	-250,000
Tax base	CAD$ (*1000)	2,762,618	2,953,939	3,156,747	3,371,724	3,599,594	3,841,121	4,097,117	4,368,441	4,656,001	4,960,763
Taxes and duties	CAD$ (*1000)	-884,038	-945,260	-1,010,159	-1,078,952	-1,151,870	-1,229,159	-1,311,077	-1,397,901	-1,489,920	-1,587,444
Net profit	CAD$ (*1000)	2,128,580	2,258,678	2,396,588	2,542,772	2,697,724	2,861,962	3,036,040	3,220,540	3,416,081	3,623,319
Cash flow pre-tax	**CAD$ (*1000)**	**$2,937,618**	**$3,128,939**	**$3,331,747**	**$3,546,724**	**$3,774,594**	**$4,016,121**	**$4,272,117**	**$4,453,441**	**$4,831,001**	**$5,135,763**
NPV pre-tax @ 12%a.a	**$560,820,136**										
Cash flow after tax	**CAD$ (*1000)**	**$2,053,580**	**$2,183,678**	**$2,321,588**	**$2,467,772**	**$2,622,724**	**$2,786,962**	**$2,961,040**	**$3,145,540**	**$3,341,081**	**$3,548,319**
NPV after-tax @ 12%a.a	**$33,164,439**										
IRR	**-4.55%**										

Source: Personal file.

Small-scale tar mine for asphalt production

The key parameters (input data) for small-scale tar mine for asphalt production are shown in Table 22.

Table 22 - Parameters for small scale tar mine for asphalt production (base-case)

Parameters	Value	Unit
Year of Construction	1	Year
Year of Production	10	Years
Year of Reclamation	2	Years
Total Project Life	13	Years
Maximum production capacity	3,886	Tons per day
Production capacity factor	90	%
Tar price	100	CAD Dollars ($)
Total CAPEX (tar production)	16	Million CAD Dollars ($)

Source: Personal file

The total project life span was assumed to be 13 years. A discounted rate of 12% was assumed and a corporate tax rate of 32% was used in line with what is obtainable in the country. The exchange rate was assumed to be CAD 1.2 to US$1. It was assumed that the mining company will be working for 365 days a year and that 90% of the bitumen content in the Nigeria oil sands is recoverable. The incremental factor in the price of tar were taken to be 6% per annum consistent with inflation rate in the country over and the operating cost increases also at the rate of 1% per annum.

PEA for small-scale tar mine for asphalt production

The result in Table 23 shows that the mine will be able to invest a sum of $16 million CAD as CAPEX and the tar can be sold at $ 100/ ton. The production capacity of the mine will be 3,411 t/day. The NPV at average grade of 15% bitumen will be $ 4,456,136 CAD.

Table 23 – Assumptions for cash flow of small-scale tar mine for asphalt production (Base case, no SLO)

Cash flow: Oil sands (Tar production) (Small-scale mine) (Base case no SLO)			
17 January 2020			
Assumptions		**Assumptions**	
First year	2021	Investment (exploration, pre-mining activities)	$5,000,000
Discount rate (total)	12.0%	CAPEX (mining, tar processing)	$8,000,000
Royalties (%)	3.0%	CAPEX (infrastructure)	$3,000,000
Price annual readjustment	6.0%	Sustaining capital	3.0%
Cost annual readjustment	1.0%	Mining cost (CAD$/t)	$8
		Processing cost (tar processing only) (CAD$/t)	$3
Life of mine (years)	10		
Total resources (t)	12,278,000		
Mine production (t/year)	1,227,000	G&A (%)	3.0%
Plant feed (t/year)	1,165,650		
Plant capacity (t/day)	3,886		
Plant capacity (t/hour)	194	Annual contingencies	5.0%
Average bitumen content (%)	15%		
Mining recovery	95.0%	Price (CAD/t bitumen)	$100
Processing recovery	90.0%	Taxes and duties	32.0%

Source: Personal file

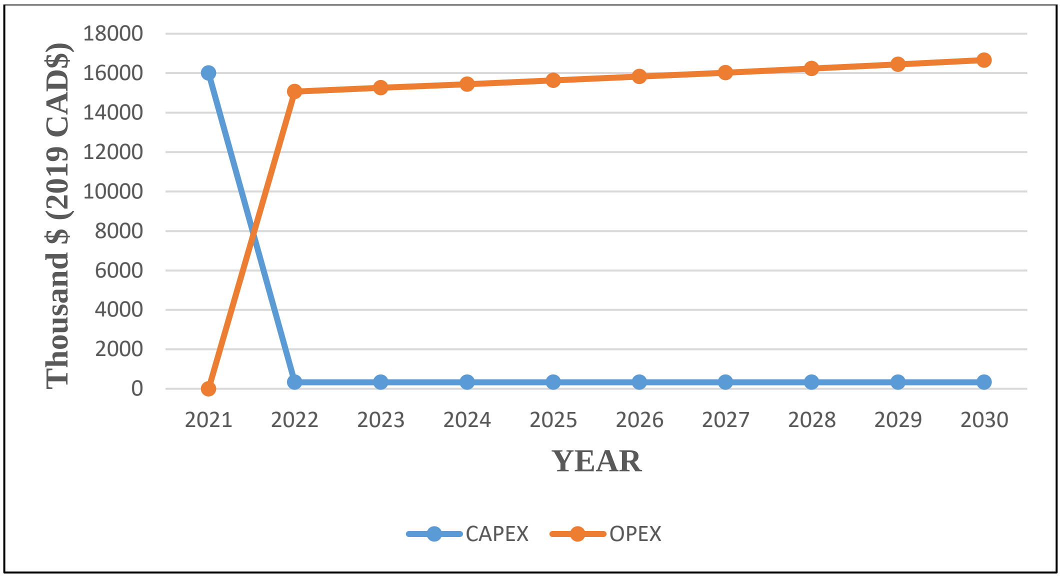
In Table 24, a worksheet showing the analysis of the cash flow for the small-scale tar mine for asphalt production for 10 years (2021-2030) was presented. Figure 38 shows the cost incurred per year for both CAPEX and OPEX.

Table 24 - Worksheet showing the cash flow for the small-scale tar mine for asphalt production (base case, no SLO)

Cash flow: Oil sands (Tar production) (Small-scale mine) (Base case no SLO)											
17 January 2020											
Cash flow	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAPEX + Sustaining	CAD$ (*1000)	-16,000	-330	-330	-330	-330	-330	-330	-330	-330	-330
Residual (2*net profit)	CAD$ (*1000)										
OPEX	CAD$ (*1000)	0	-15,074	-15,257	-15,444	-15,635	-15,831	-16,032	-16,238	-16,449	-16,665
Revenue	CAD$ (*1000)	0	17,558	18,612	19,729	20,912	22,167	23,497	24,907	26,401	27,985
Gross profit	CAD$ (*1000)	0	2,484	3,355	4,285	5,277	6,336	7,465	8,669	9,953	11,320
Depreciation	CAD$ (*1000)	-1,100	-1,100	-1,100	-1,100	-1,100	-1,100	-1,100	-1,100	-1,100	-1,100
Tax base	CAD$ (*1000)	0	1,384	2,255	3,185	4,177	5,236	6,365	7,569	8,853	10,220
Taxes and duties	CAD$ (*1000)	0	-443	-722	-1,019	-1,337	-1,675	-2,037	-2,422	-2,833	-3,271
Net profit	CAD$ (*1000)	0	2,041	2,633	3,266	3,940	4,660	5,428	6,247	7,120	8,050
Cash flow pre-tax	**CAD$ (*1000)**	**-$16,000**	**$2,154**	**$3,025**	**$3,955**	**$4,947**	**$6,006**	**$7,135**	**$8,339**	**$9,623**	**$10,990**
NPV pre-tax @ 12%a.a	**$11,551,985**										
Cash flow after tax	**CAD$ (*1000)**	**-$16,000**	**$1,711**	**$2,303**	**$2,936**	**$3,610**	**$4,330**	**$5,098**	**$5,917**	**$6,790**	**$7,720**
NPV after-tax @ 12%a.a	**$4,456,136**										
IRR	**17.91%**										

Source: Personal file.

Figure 38 - Total costs of production incurred per year.



Source: Personal file

Small-scale tar mine for asphalt production (with SLO)

The parameters in Table 22 indicates that the total CAPEX will be $16 million CAD. However, for the small-scale tar producing mine with SLO, as shown in Table 25, an additional $3 million CAD will be invested on the SLO (19% of the total CAPEX), making a total of $19 million CAD for CAPEX and the tar will be sold at $ 100/ ton. The production capacity of the mine will be 3,411 t/day. The NPV at average grade of 15% bitumen will be $ 4,974,564 CAD. The discount rate was also reduced from 12% to 9% with 32 % tax.

Table 25 – Assumptions for cash flow of small-scale tar mine for asphalt production (with SLO)

Cash flow: Oil sands (Tar production) (Small-scale mine) (with SLO) 17 January 2020			
Assumptions		**Assumptions**	
First year	2021	Investment (exploration, pre-mining activities)	$5,000,000
Discount rate (total)	9.0%	CAPEX (mining, tar processing)	$8,000,000
Royalties (%)	3.0%	CAPEX (infrastructure) + SLO	$6,000,000
Price annual readjustment	6.0%	Sustaining capital	3.0%
Cost annual readjustment	1.0%	Mining cost (CAD$/t)	$8
		Processing cost (tar processing only) (CAD$/t)	$3
Life of mine (years)	10		
Total resources (t)	12,278,000		
Mine production (t/year)	1,227,000	G&A (%)	3.0%
Plant feed (t/year)	1,165,650		
Plant capacity (t/day)	3,886		
Plant capacity (t/hour)	194	Annual contingencies	5.0%
Average bitumen content (%)	15%		
Mining recovery	95.0%	Price (CAD/t bitumen)	$100
Processing recovery	90.0%	Taxes and duties	32.0%

Source: Personal file

Table 26 presents a worksheet showing the analysis of the cash flow for small-scale tar mine for asphalt production. It was considered for a duration of 10 years (2021-2030) with additional investment for SLO.

Table 26 - Worksheet showing the cash flow for the small-scale tar mine for asphalt production (with SLO)

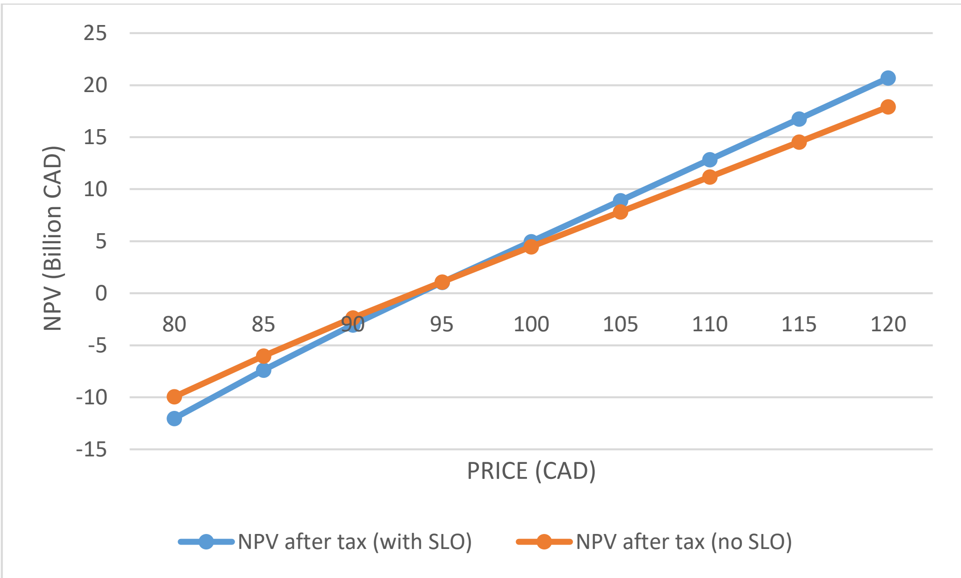
Cash flow: Oil sands (Tar production) (Small-scale mine) (with SLO)											
17 January 2020											
Cash flow	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAPEX + Sustaining	CAD$ (*1000)	-19,000	-420	-420	-420	-420	-420	-420	-420	-420	-420
Residual (2*net profit)	CAD$ (*1000)										
OPEX	CAD$ (*1000)	0	-15,074	-15,257	-15,444	-15,635	-15,831	-16,032	-16,238	-16,449	-16,665
Revenue	CAD$ (*1000)	0	17,558	18,612	19,729	20,912	22,167	23,497	24,907	26,401	27,985
Gross profit	CAD$ (*1000)	0	2,484	3,355	4,285	5,277	6,336	7,465	8,669	9,953	11,320
Depreciation	CAD$ (*1000)	-1400	-1,400	-1,400	-1,400	-1,400	-1,400	-1,400	-1,400	-1,400	-1,400
Tax base	CAD$ (*1000)	0	1,084	1,955	2,885	3,877	4,936	6,065	7,269	8,553	9,920
Taxes and duties	CAD$ (*1000)	0	-347	-626	-923	-1,241	-1,579	-1,941	-2,326	-2,737	-3,175
Net profit	CAD$ (*1000)	0	2,137	2,729	3,362	4,036	4,756	5,524	6,343	7,216	8,146
Cash flow pre-tax	**CAD$ (*1000)**	**-$19,000**	**$2,064**	**$2,935**	**$3,865**	**$4,857**	**$5,916**	**$7,045**	**$8,249**	**$9,533**	**$10,900**
NPV pre-tax @ 9%a.a	**$12,981,874**										
Cash flow after tax	**CAD$(*1000)**	**$19,000**	**$1,717**	**$2,309**	**$2,942**	**$3,616**	**$4,336**	**$5,104**	**$5,923**	**$6,796**	**$7,726**
NPV after-tax @ 9%a.a	**$4,974,564**										
IRR	**14.13%**										

Source: Personal file

4.3.8 Sensitivity analysis

A sensitivity analysis was done with changes to two parameters, the discount rate and the tar price for scenario 3 and 4. The input data for the discount rate was varied between 4% and 12% and the tar price was varied between 80 and 120. Under the low price case ($80) as shown in Figure 39, the project's NPV of the scenario with SLO is CAD$-12.02 billion and CAD$-9.95 billion of the scenario without SLO. In addition, under the high price case ($120), the project's NPV of the scenario with SLO is CAD$20.68 billion and CAD$17.91 billion of the scenario without SLO. The average tar price in which the project's NPV is the same for both cases is around CAD$95.

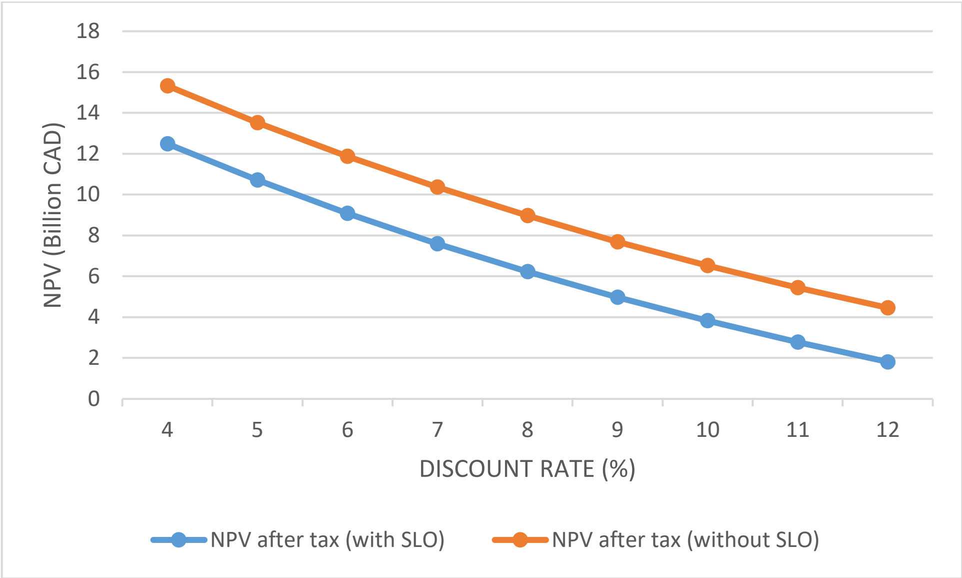
Figure 39 - Sensitivity analysis of price of tar with and without SLO



Source: Personal file

Under the low discount rate as shown in Figure 40 (4%), the project's NPV of the scenario with SLO is CAD$ 12.49 billion and CAD$ 15.33 billion of the scenario without SLO, and under the high discount rate (12%), the project's NPV of the scenario with SLO is CAD$ 1.81billion and CAD$ 4.46 billion of the scenario without SLO.

Figure 40 - Sensitivity analysis of discount rate with and without SLO



Source: Personal file

CHAPTER FIVE

5. DISCUSSION

Discussion on the results of the assessment on the social license to operate

To manage controversies and misunderstandings involving mining companies and communities, the company must have a better understanding of whom they are dealing with it and hire professionals, especially anthropologists and sociologists, trained to understand other people's points of view. This is important because the communities are not homogeneous, and different communities have different views and attitudes towards mining.

The challenges associated with ways to mitigate the negative impact of pre-mining activities on socio-environmental and economic aspects of the community were addressed using the sustainability approach. This approach balances the economic, social and environmental considerations in the pre-mining phase. Table 27 shows the effects of pre-mining and proposed solutions, based on the needs of the communities. These three aspects are interdependent and interrelated, constituting the pillar of the SLO and the balancing sustainability concept.

Table 27 - Sustainability approach in solving the challenges of obtaining a social license to operate (SLO) taking into account the views of the local communities.

	Effects	**Solutions**
Environmental aspects	Ecological disruption	Restoration/offsetting
	Water pollution	Provision of wells / boreholes
	Loss of soil fertility	Provision of crop seedlings
	Land degradation	Management of land and water and protection of the vegetation cover
	Dust generation	Water spraying
	Noise pollution	Lower gradient of haul road
Social aspects	Relocation	Provision of houses
	Loss of jobs	Creation of jobs
	Impact on cultural and aesthetic resources	Early identification of cultural resources so that they can be taken into account
	Impact on quality of life	Improvement in quality of life
	Increased poverty	Poverty alleviation
Economic aspects	Lack of community development	Community development
	Lack of technical know-how	Skill acquisition
	Lack of knowledge about mining activities	Educating and involving stakeholders in decision making

Source: Personal file

The mining company can minimize the disruptive effects of its activities on the environment, the communities' livelihood sources and the socio-cultural aspects through technological solutions.

In the case of the communities studied, this is true because their farmlands will be destroyed and their rivers will be polluted. Pre-mining social effects, which include relocation, loss of jobs, and impacts on cultural and aesthetics resources (KUMAH, 2006) will negatively affect the community**.** Therefore, compensating farmers by offsetting for loss of farmlands and provision of wells or boreholes can help mitigate the environmental effects of pre-mining.

The economic aspects are not a result of pre-mining activities, but refer to those conditions that already exist in the communities before the mining company arrives in the region. The results of this study evidenced a lack of infrastructure, health care, bad roads, and lack of technical knowledge about mining activities in the communities investigated. The economic benefits are considered as a positive contribution given by the mining company to the community (WORRALL et al, 2009).

Nigeria is a country with very diverse languages, and it will be difficult for all the community members, especially the elders, to learn a new language. Therefore, a liaison officer is needed. The officer must be a literate person who understands the region and the language, probably a mining engineer, who will communicate easily, educate the people of the local community about the mining project and adequately provide the information they require. The impacts must be explained to community members, making sure they understand that some negative impacts will be unavoidable.

The oil and gas sector conflicts in Nigeria demonstrated that the conflict between the communities and the company was not resolved until the company took on its social responsibility (GROVES, 2009). The challenge of how to reach an agreement between the company and the community can be solved through the establishment of company-community relations that help the company learn how to contribute to the community in terms of CSR.

Implementation of benefits will depend on the guidance of the community itself, as it must state what it wants. Fulfilment of these promises is also very important. The social demands of the stakeholders must be considered a priority in decision making. The mining company must gain the full trust of the communities and avoid losing credibility, for, once it is lost, the company's reputation will suffer. Any form of distrust would incur in greater expense than what would be spent to gain the community's trust. Trust is a major factor in social acceptance of mining activities (MERCER-MAPSTONE et al., 2018).

To address the hypothetical or possible challenges, a proper economic and environmental assessment must be made to obtain knowledge about the areas that will be affected by mining activities. A technical detail of how many hectares of land are available, the types of plants grown and the landowners should be carried out. The mining company must offer a reasonable price when offsetting. Negotiations should include all the affected members before offsetting. The community must not become greedy and demand more than it has agreed to receive.

The company's representatives must be in constant communication with the community to identify important issues, especially culture-related ones. In addition, mining companies should make the interest of the community a priority. The mining company should be transparent and truthful about the impacts of mining, without withholding any information from community members. The company needs to undertake a social assessment of the communities to understand their social structure. The company must spend money, time, and effort to understand the needs and visions of the communities that will be impacted.

Communities must coordinate themselves to know what to demand from the mining companies during offsetting. Different groups' representatives must be vocal and share the same interests and views. The mining company must have a local representative that will help with interactions with the local communities and bargain with them. More discussion on SLO can be found in Appendix 7.

Discussion on the ecosystem services assessment

The impacts of oil sands pre-mining activities were assessed using the ES approach. Different ESs were assesses and the effects of pre-mining activities on them were analysed. Provisioning services are sources of income, food, and they are used for household chores. The study area is a rural location and most of the community members cook using timbers and wood. Deforestation reduces access of the community to timber and wood thereby rendering many people jobless and increasing their living expenses. Siltation of rivers during blasting activities and road construction will lead to escape of the fishes, thereby causing a lesser yield of fish capture by the villagers. The result from the interviews showed that farming is one of their major daily activities. If loss of biomass fuel would cause reduction of standard of living and inevitably breed poverty, a way to mitigate it should be envisage. Turning a community into an industrial area can result in the escape or death of the animals and plants kept and planted by humans as a source of food or for sale, thereby increasing the living expenses and also destruction of the croplands.

Siltation of the river during the planning stage will bring a lot of difficulty for the people because the river is a major source of water, which is used for different home chores, if not mitigated, malnutrition, water borne diseases, and poverty could become a common problem in the communities. The research has shown an example of an ecosystem (river) and its services (cooking, drinking and washing). Mitigation measures should be embarked upon to prevent widespread poverty, breach of peace and to prevent reduction of income of the people.

Regulating services are services that are meant to keep the people's health in a better condition. Destruction of the ecosystem will therefore expose the people to a more dangerous condition. Cultural services, which includes the forest area, is a place where students in institutions and secondary schools go, to learn more about forest reserves. Rivers are places that provide spiritual fulfilment to the community. Therefore, deforestation will reduce the inspirational and educational values of these places, also siltation and erosion of the rivers will limit the ethical and spiritual values. Supporting services, which include the land and river, serve as reproduction places for animals and plants. Destruction of the ecosystem will reduce the access to these places thereby impacting the plants and animals.

To reduce the impacts of pre-mining activities on these ES, if avoidance measure as the first step of mitigation is insufficient to mitigate for loss in livestock, then a proposition of combination of avoidance and minimization measures can be taken. If minimization measure as a first step is insufficient to mitigate for loss in educational and inspirational values, the mining company can propose to restore the forest area as part of project decommissioning and closure. If there is still any expected residual loss in benefit after proposed mitigation, the affected beneficiaries should determine whether they could accept the residual loss or not. The cost of ES should be put into consideration when taking mitigation measures. In reality, farmers will prefer compensation rather than restoration as measure to mitigate for loss in forest service because this service is their source of daily income and nevertheless, a need to restore the service back to its previous state is inevitable in future. The pre-mining phase (especially prospecting and exploration) is crucial for mining companies as they are only able to determine toward the end of the phase whether the mining project will be feasible or not based on findings. The impacts of mining and post-mining phases are most often of major significance and the effects can be mitigated. Strip mining method is often used in oil sands surface mining. For this mining method, restoration can occur alongside with mining operations, the overburden removed can be used to fill up pit holes created by exploitation. In these phases, measures should be taken to remedy residual impacts through restoration and/or offsets.

Discussion on the conceptual mine planning and economic assessment

The oil sands deposit was considered for surface mining, and this was due to the closeness of the deposit to the surface as seen from the bitumen outcrops in various locations in the communities. The exploration work for this deposit done by the GCU, Ile-Ife, and twenty-five drillholes were considered for this study. Understanding the geology of the orebody in mining operation is important for different stages of a mining operation such as mine design, scheduling, valuation and processing. Geological modelling and /or resource estimation is an important stage in mining operation because it gives different perspectives of the planned mining operation and detailed representation of grade and structure.

The inverse distance weighting (IDW) interpolation scheme was used for estimating grades. The drillholes grades were estimated according to their bitumen saturation and chemical elements present using the IDW method, and from this, a geological block was modelled. The block size used was 50 x 50 x 10 m (x, y, z), the sub block size was 10 x 10 x 2 m (x, y, z) and vertical exaggeration of 20. The block that was modelled was then used for pit optimisation.

A detailed mine design was done using the optimal pit shell, by defining benches, slopes and mine roads.

The economic assessment carried out shows that the small-scale tar mine for asphalt production is the most feasible of all the scenarios observed because it has reasonable profit which is very sensitive to price. In addition, exploiting the oil sands have a potential to solve the impact of the *bituminous natural effects*, which can represent an important driver for transformation to sustainability in the region. The positive impact of implementing this type of operation has been evaluated by examining two small-scale tar mining operation scenarios: the first one without a specific investment for obtaining an SLO and the second one with a specific allocation for seeking a social license to operate with the local community. From the results, the NPV for a small-scale tar sand producing mine without investment for SLO is $ 4,456,136 CAD, while the NPV for a small-scale tar sand producing mine with additional investment for SLO is $ 4,974,564 CAD. The results show that the SLO scenario, even with an additional investment of $ 3M CAD, deliver an NPV 11% higher than the scenario without it. This can be attributed to the fact that with SLO, the mining company is likely to have less delays and risk in operation, which is why most mining companies agree with obtaining SLO during their operation, and with that, they can easily secure a lesser discount rate.

The sensitivity analysis was conducted to examine how the NPV will be affected when alternating the values for these parameters in an excel work sheet (ZAGAYEVSKIY; DEUTSCH, 2015). This could be done in a model analyser using multi scenarios in excel work sheet, what- if - analysis table also known as data table format, or multi-goal seeker (ORIRE, 2009). As stated, the input data for the discount rate was varied between 4% and 12% and the tar price was varied between 80 and 120.

It can be seen that the NPV of the scenario without SLO was higher at the lowest price. However, as the price further increased, the scenario with SLO had a higher NPV. The sell price for both scenario is the same, which will make the NPV with SLO more profitable.

It can be seen that at the lowest and highest discount rate, the NPV of the scenario without SLO was higher, however, it is bound to have risk which will incur additional spending. A lower discount rate (9%), was chosen for the scenario with SLO because the project was assume to have lesser risk. It can be seen that the project will be profitable with or without SLO. It is however advisable to obtain an SLO from the community to reduce risk in operation and to maximize profit.

CHAPTER SIX

6. CONCLUSIONS

Most mining companies have realized that the formal license to operate is no longer enough to carry out their operation; therefore, the companies seek to obtain an SLO from the community. There can be several challenges when a mining company seeks to obtain a social license to operate but these challenges can be managed if proper measures are taken. Most of these challenges are consequences of communication difficulties, due to the high linguistic diversity and the poor formal education of the members of local communities to interact and to understand the technical aspects of mining and its effects on their environmental and social activities. Other important challenges are related to companies' lack of information about local communities, their complexities, needs and wishes, and lack of understanding about the importance and complexities of the process for obtaining and maintaining an SLO.

The mining companies must therefore take action by educating the local communities, provide all the required information on their activities, implement some of the proposed solution to the socio-environmental and economic problems and must be ready to earn the trust of the local communities. As these are measures that can help in establishing the SLO and it needs to be maintained throughout the mine's life; therefore, the company must make a consistent effort to correspond to the community's expectations of how it will be treated. The mining company must communicate transparently with the community about the negative impacts of its activities and be ready to dialogue with the community; this will help avoid conflicts and delays in operations.

The company must establish a relationship with the community, gain its full trust and reach an agreement, which must be totally documented, with outside witnesses (NGOs, civil society, and the press) that attest to its impartiality and fairness. The agreement must be constantly checked (hence the importance of ongoing and honest communication) and any conflict that arises should be addressed as quickly as possible. ***The success of the agreement depends on both parties keeping their word***. ***Not only the company must deliver what was accorded, but the community must not become greedy and make more demands than what was accorded***.

Pre-mining activities have impacts on the ecosystems and ES; the ES assessment was proven to be an appropriate approach for mitigating these impacts if appropriate mitigation measures can be taken. A combination of two mitigation measures can be used if one mitigation measure will be insufficient to mitigate for loss in ES. Regarding the educational and inspirational values ES that will be destroyed, the community will bear the impacts for a long duration until the service can be restored to its previous state since the success of restoration is in long term. The negativity in cultural service can be solved between the mining companies, the government, and the community representatives. To forestall complete loss that can be encountered on cultural service, the mining company must work with the government to ensure acquisition of part of the forest in order to retain the ecosystem for education, research and tourism since the people in the study area are not opposed to pre-mining activities.

The Landsbergs ES assessment was improved in this research because an assessment on the outcome of the mitigation measures on ES for significant reduction in impact occurrences was done and the feedback of mitigation measures would be given to the community. This will assist the residents of the local communities to understand the challenges related to the envisaged pre-mining activities around them and will prepare the government and mining companies on the road map for a successful mining engagement.

The open cast mining method was chosen to be the appropriate mining method for the oil sands. The mining alternative with tar production by small-scale mining has shown significant profits and has shown to be the most effective and economic approach to exploit the oil sands deposits in parts of Ondo State. The results for the sensitivity analysis for the discount rate for scenario 3 and 4 show that both scenario are profitable at the minimum and the maximum discount rates. In addition, it was seen that the scenario with SLO with an additional investment of CAD $3million is highly sensitive to price having NPV of CAD$ 20.68 billion at the maximum price used which was higher than the scenario without SLO by 11%.

There will be opportunity for a public policy with minimum price guarantee so that small-scale mining will have incentives to open up new operations, which is a major contribution for the transformation to sustainability (t2s) in Ondo state. The new operation will have room for proper SLO and reclamation efforts at the pre-mining, mining and post-mining phases. Implementation of this type of operation will help to solve the regional problem of untarred roads and it will bring both economic and environmental benefits to both the local communities and the Nigerian government. ***Exploiting the oil sands in Nigeria have a potential to solve the impact of the bituminous natural effects and it can represent an important driver for transformation to sustainability in the region***. ***In addition, these results can be extended to cover other parts of Ondo State with similar geology, ecology and inhabitants.***

REFERENCES

ADEGOKE, O. S.; AKO, B. D.; ENU, E. I. Geotechnical investigations of the Ondo State bituminous sands. In: NIGERIA. Obafemi Awolowo University. Geology Department. **Report of Geological Consultancy Unit, n. 257.** Ile Ife, 1980. p. 27-36.

ADEKOYA, J. A. Environmental effect of solid minerals mining. **Journal of Physical Sciences,** Kenya, v. 1, p. 625-640, 2003.

AFRICAN DEVELOPMENT BANK GROUP. BILL & MELLINDA GATES FOUNDATION. Flagship Report Paper Series - Paper 8. Extractive Industries and Social Investments: principles for sustainability and option for support. In: ______. **Delivering on the promise: leveraging natural resources to accelerate human development in Africa.** /Challenges/ 43p, 2015. Available from: < www.NaturalResourcesForHumanDev.org>. Access in: 17 December 2016.

AIGBEDION, I.; IYAYI, S. E. Environmental effect of mineral exploitation in Nigeria. **International Journal of Physical Sciences**, v. 2, n. 2, p. 33–38, Feb. 2007. Available from: <https://academicjournals.org/journal/IJPS/article-full-text-pdf/32F72A212872>. Access in: October, 2016.

AJAKAIYE, D. E. **Environmental problems associated with mineral exploitation in Nigeria**. Paper presented at the 21st Annual Conference of the Nigeria Mining and Geosciences Society, 1985, Jos. p. 140–148.

AKINMOSIN, A.; OSINOWO, O. O.; OLADUNJOYE, M. A. Radiogenic components of the Nigerian tar sand deposits. **Earth Sciences Research Journal,** v. 13, n. 1, p. 64-73, 2009.

AKO, B. D.; ALABI, A. O.; ADEGOKE, O. S.; ENU, E. I. Application of resistivity sounding in the exploration for Nigerian tar sand. **Energy Exploration and Exploitation**, v. 2, n. 2, p. 155-164, 1983.

AL-USMANI S. M. P. Impact of mining activities on land and water areas of Goa. **Journal of Coastal Environment**, v. 2, n. 1, p 43-54, 2011.

ASARE, B. K.; DARKOH, M. B. K. Socio-economic and environmental impacts of mining in Botswana: a case study of the Selebi-Phikwe copper-nickel mine. **Eastern Africa Social Science Research Review**, v. 17, p. 1-41, Jan. 2001.

AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES. **The JORC Code:** 2012 edition. Melbourne, AIG/AusIMM/MCA/JORC, 2012. 44p. Available from: < http://www.jorc.org/docs/JORC_code_2012.pdf>. Access in: 15 December 2019.

BANERJEE, D. K. **Oil sands, heavy oil & bitumen:** from recovery to refinery. Tulsa: PennWell Corp., 2012. 265 p.

BATH AND NORTH EAST SOMERSET COUNCIL. **Ecosystem services.** 2020. Available from: https://www.bathnes.gov.uk/services/your-council-and-democracy/local-research-and-statistics/wiki/ecosystem-services. Access in: 09 May 2020.

BEN-AWUAH, E. **Oil sands mine planning and waste management using goal programming** 2013. 149 p. Thesis (Doctor of Philosophy) – Department of Civil and Environmental Engineering, University of Alberta, Edmonton, 2013. DOI: https//doi.org/10.7939/R3MC7W.

BHATTACHARJEE, S. Oil sands; a bridge between conventional oil and a sustainable energy future. In: TOWARDS sustainable clean energy, 2011.

BLENCH, R.; DENDO, M. **Position paper:** the dimensions of ethnicity, language and culture in Nigeria. Cambridge: DFID, 2013.

BLEY, A.; BOLAND, N.; FRICKE, C.; FROYLAND, G. A strengthened formulation and cutting planes for the open pit mine production scheduling problem. **Computers and Operations Research**, v. 37, n. 9, p. 1641-1647, 2010.

BOUTILIER, R. G.; THOMSON, I. **Modelling and measuring the social license to operate fruits of a dialogue between theory and practice.** Queensland, Australia: International Mine Management, 2011.

BRANDT, A. R. **Upstream greenhouse gas (GHG) emissions from Canadian oil sands as a feedstock for European refineries.** Stanford: Stanford University.Department of Energy Resources Engineering, 2001. 51 p.

BRANDT, A. R. Variability and uncertainty in life cycle assessment models for greenhouse gas emissions from Canadian oil sands production. **Environmental Science and Technology**, v.46, n. 2, p. 1253-1261, 2012.

BUSHEY, G. **Athabascan oil sands extraction techniques:** an economic analysis of surface mining versus SAGD. Walla Walla: Whitman College, 2011. **(**Whitman College Economics Working Papers, 27).

BUSINESS AND HUMAN RIGHTS RESOURCE CENTRE. Shell settles Saro-Wiwa lawsuit over 1995 execution of Nigerian activists for $15.5 million. 2009. Available from: https://www.business-humanrights.org/en/shell-settles-saro-wiwa-lawsuit-over-1995-execution-of-nigerian-activists-for-155-million. Access in: 11 May 2020.

BUTLER, R. M. **Thermal recovery of oil and bitumen.** Englewood Cliffs, NJ: Prentice Hall, 1991.

BUTT, A.; SHABBIR, R.; AHMAD, S. S.; AZIZ, N. Land use change mapping and analysis using remote sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan. **The Egyptian Journal of Remote Sensing and Space Science**, v.18, n. 2, p. 251-259, 2015.

CACCETTA, L.; GIANNINI, L. An application of discrete mathematics in the design of an open pit mine. **Discrete Applied Mathematics**, v. 21, p. 1–19, 1988. Available from: <http://www.sciencedirect.com/science/article/pii/0166218X88900303>. Access in 12 February 2018.

CACCETTA, L.; HILL, S. P. An application of branch and cut to open pit mine scheduling. **Journal of Global Optimization,** v. 27, p. 349-365, 2003. Available from: < https://link.springer.com/content/pdf/10.1023/A:1024835022186.pdf>. Access in: 26 January 2018

CANADA. Consortium of Oil Sands Tailings Management Consultants. **Oil sands tailings technology deployment roadmaps:** Project Report, v.2; component 1 results. Calgary: Alberta Innovates, 2012. Report to AE-Energy and Environment Solutions. Available from

<https://www.cosia.ca/uploads/documents/id10/Tailings%20Roadmap%20Volume%202%20June%202012.pdf>. Access in: 20 December 2016

CANADA, ALBERTA (GOVERNMENT). **Environmental management of Alberta's oil sands.** Alberta, 2009. Available from: < https://documents.techno-science.ca/documents/EnvironmentAlbertsoilsandsenvironmentalmanagement.pdf> Access in 10 June 2015.

CANADA (GOVERNMENT). **Frontier Oil Sands Mine Project 2019.** Ottawa, 2020. Available from: <https://iaac-aeic.gc.ca/050/evaluations/proj/65505>. Access in: 11 November 2019.

CANADA'S OIL AND NATURAL GAS PRODUCERS (CAPP). 2019 Crude oil forecast, markets and transportation. Available from: <https://www.capp.ca/wp-content/uploads/2019/11/CAPP-2019-Crude-Oil-Markets-and-Transportation-338794-1.pdf>. Access in: 20 November 2019.

CANADIAN INSTITUTE OF MINING METALLURGY AND PETROLEUM. C**IM definition standards for mineral resources & mineral reserves.** Adopted by CIM Council, in May 19, 2014. Quebec, 2014. Available from: < https://mrmr.cim.org/media/1128/cim-definition-standards_2014.pdf>. Access in: 28 November 2019.

COMISSÃO BRASILEIRA DE RECURSOS E RESERVAS. Guia CBRR para declaração de resultados de exploração, recursos e reservas minerais. Brasília, 2016. Available from: < http://www.cbrr.org.br/docs/guia_declaracao.pdf>. Access in: 07 December 2019.

CHALATURNYK, R. J.; SCOTT, J. D.; ÖZÜM, B. Management of oil sands tailings. **Petroleum Science and Technology**, v. 20, n. 9–10, p. 1025-1046, 2002. DOI: https://doi.org/10.1081/LFT-120003695.

CHAMBER OF MINES OF SOUTH AFRICA. Department of Environmental Affairs. Department of Mineral Resources. **Mining and biodiversity guideline:** mainstreaming biodiversity into the mining sector. Pretoria, 2013. Available from: < https://www.environment.gov.za/sites/default/files/legislations/miningbiodiversity_guidelines2013_0.pdf>. Access in: 30 November 2016.

CHAN, G.; REILLY, J. M.; PALTSEV, S.; CHEN, Y. H. H. The Canadian oil sands industry under carbon constraints. **Energy Policy**, v. 50, p. 540-550, 2012. DOI: http://dx.doi.org/10.1016/j.enpol.2012.07.056.

CHICOISNE, R.; ESPINOZA, D.; GOYCOOLEA, M.; MORENO, E.; RUBIO, E. A new algorithm for the open-pit mine production scheduling problem. **Operations Research**, v. 60, n. 3, p. 517–528, 2012. Available from: http://pubsonline.informs.org/doi/abs/10.1287/opre.1120.1050. Access in: 25 January 2018.

CHINDO, M. I. **An examination of the socio-economic and environmental impact of planned oil sands development in Nigeria** 2012**.** 338p. Thesis (Doctor of Philosophy) - University of Leicester, 2012.

CLARK, B.; GRAVES, W. G.; LOPEZ-DE-CARDENAS, J. E.; GURFINKEL, M. E.; PEATS, A. W. Heavy oil, extra-heavy oil and bitumen unconventional oil. In: THE NATIONAL PETROLEUM COUNCIL. **Facing the hard truths about energy.** Washington, 2007. (Working Document of the NPC Global Oil and Gas Study, Topic Paper, n.22: Heavy oil). Available from: <https://npchardtruthsreport.org/Hard_Truths-Topic_Papers/22-TTG-Heavy-Oil.pdf> Access in: 06 October 2018.

COLLINS, N.; LAWSON, L. Investigating approaches to working with artisanal and small-scale miners: a compendium of strategies and reports from the field. In: INTERNATIONAL MINING FOR DEVELOPMENT CENTRE. **IM4DC Action Research Report.** Brisbane, 2014. 124 p. Available from: < https://www.im4dc.org/wp-content/uploads/2013/09/Collins-FR-1psum-appr.pdf>. Access in: 02 February 2018.

CORCORAN, T. From Northern Gateway to Keystone, the undefinable ‘social licence’ movement is in control of jobs and growth. **Business Financial Post,** Toronto, Apr. 22, 2014. Available from: < https://business.financialpost.com/opinion/terence-corcoran-from-northern-gateway-to-keystone-the-undefinable-social-licence-movement-is-in-control-of-jobs-and-growth>. Access in: 01 March 2020.

DAILY, G. C. **Nature’s services:** societal dependence on natural ecosystems. Washington: Island Press, 1997.

DAILY, G. C.; SÖDERQVIST, T.; ANIYAR, S.; ARROW, K.; DASGUPTA, P.; EHRLICH, P. R.; LEVIN, S. The value of nature and the nature of value. **Sciences** v. 289, n. 5478, p. 395-396, 2000.

DE GROOT, R. S.; ALKEMADE, R.; BRAAT, L.; HEIN, L.; WILLEMEN, L. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. **Ecological Complexity**, v. 7, n. 3, p. 260–272, 2010. DOI: doi:10.1016/j.ecocom.2009.10.006.

DI GREGORIO, A.; JANSEN, L. J. M. **Land cover classification system (LCCS):** Classification concepts and user manual. S.n.: Environment and Natural Resources Service, 2000. 179 p. (GCP/RAF/287/ITA Africover—East Africa Project and Soil Resources, Management and Conservation Service, Food and Agriculture Organization).

DYER, S.; HUOT, M. What is the highest environmental impact oil? **Mining VS In Situ.** Fact Sheet. Alberta: Pembina Institute, 2010.

EGOH, B. N.; REYERS, B.; ROUGET, M.; RICHARDSON, D. M. Identifying priority areas for ecosystem service management in South African grasslands. **Journal of Environmental Management**, v. 92, n. 6, p. 1642–1650, 2011. DOI: doi:10.1016/j.jenvman.2011.01.019.

ELUM, Z. A.; MOPIPI, K.; HENRI-UKOHA, A. Oil exploitation and its socioeconomic effects on the Niger Delta region of Nigeria. **Environmental Science and Pollution Research,** v. 23, n. 13, p. 12880-12889, 2016. DOI: DOI 10.1007/s11356-016-6864-1.

ENGELHARDT, R.; TODIRESCU, M. An introduction to development in Alberta's oil sands. 2005. 17 p.

ENU, E. I. Textural characteristics of the Nigerian tar sands. **Sedimentary Geology, v.** 44, n. 1-2, p. 65-81, 1985.

ERNST & YOUNG GLOBAL LIMITED. **Business risks facing mining and metals 2011–2012.** United Kingdom, 2011. Available from: <http://www.ey.com/GL/en/Industries/Mining---Metals/Business-risks-facing-mining-and-metals-2011-2012>. Access in: 12 February 2018.

EZEOMEDO, I.; IGBOKWE, J. Mapping and analysis of land use and land cover for a sustainable development using high resolution satellite images and GIS. **TS03B - Remote**

Sensing for Landuse and Planning 6421.:S.L.: Environment for Sustainability, 2013. (FIG Working Week)**.**

FEDERAL REPUBLIC OF NIGERIA. Scoping Study on the Nigerian Mining Sector. **Nigeria extractive industries transparency initiative (NEITI) NEITI secretariat.** Trust Fund No. 95381; Project No P114267. 2011, 90p. Available from: https://richfloodinternational.files.wordpress.com/2015/12/neiti-mining-scoping-study-report.pdf. Access in 8 May 2020.

GIRI, C.; ZHU, Z.; REED, B. A comparative analysis of the Global Land Cover 2000 and MODIS land cover data sets. **Remote Sensing of Environment,** v. 94, n. 1, p. 123-132, 2005.

GLOBAL RIGHTS. Advocate for Sustainable Justice. Protecting Host Community Rights. **An assessment report on extractive host community in Nigeria**. 2016. Available from: <www.globalrights.org/ngn/wp-content/.../Assessing_Community_Rights_Report.pdf.> Access in 11 October 2019.

GOSSELIN, P.; HRUDEY, S. E.; NAETH, M. A.; PLOURDE, A.; THERRIEN, R.; VAN DER KRAAK, G.; XU, Z. **Environmental and health impacts of Canada's oil sands industry**. Ontario, Canada: Royal Society of Canada Ottawa, 2010.

GQADA, I. **Setting the boundaries of a social licence for mining in South Africa**: the Xolobeni Mineral Sands Project. Johannesburg: South African Institute of International Affairs, 2011.

GROVES, A. Shell and society: securing the Niger Delta. **E-International Relations Students**, June 10, p. 1-24, 2009.

GUNNINGHAM, N.; KAGAN, R. A.; THORNTON, D. Social license and environmental protection: why businesses go beyond compliance. **Law and Social Inquiry,** v. 29, n. 2, p. 307-341, 2004.

GUTTI, B.; AJI, M. M.; MAGAJI, G. Environmental impact of natural resources exploitation in Nigeria and the way forward. **Journal of Applied Technology in Environmental Sanitation**, v. 2, n. 2, p. 95-102, 2012.

HALL, N.; LACEY, J.; CARR-CORNISH, S.; DOWD, A. M. Social license to operate: understanding how a concept has been translated into practice in energy industries. **Journal of Cleaner Production**, v. 86, p. 301–310, 2015. DOI: http://dx.doi.org/10.1016/j.jclepro.2014.08.020. Access in: February 2017.

HANSON, C.; RANGANATHAN, J.; ICELAND, C.; FINISDORE. J. **Guidelines for identifying business risks and opportunities arising from ecosystem change.** Version 2.0. Washington, DC: World Resources Institute, 2012. (The Corporate Ecosystem Services Review). Available from: < https://wriorg.s3.amazonaws.com/s3fs-public/corporate_ecosystem_services_review_1.pdf>. Access in: 27 August 2018.

HARTMAN. J.; MUTMANSKY, J. M. **Introductory mining engineering.** 2nd. ed. Hoboken, NJ: John Wiley & Sons, 2002.

HEIN, F. J. Heavy oil and oil (tar) sands in North America: an overview & summary of contributions. **Natural Resources Research,** v. 15, n. 2, p. 67-84, 2006.

HEIN, F. J.; LECKIE, D.; LARTER, S.; SUTER, J. R. Heavy oil and bitumen petroleum systems in Alberta and beyond; the future is nonconventional and the future is now. In: Hein, F.J. et al (Ed.) **Heavy-oil and oil-sand petroleum systems in Alberta and beyond.** Tulsa: AAPG, 2013. p. 1-21. AAPG Studies in Geology, n. 64.

HEIN, F. J. Geology of bitumen and heavy oil: an overview. **Journal of Petroleum Science and Engineering**, v. 154, p. 551-563, 2017.

HOWITT, R. Theoretical foundations. In: Vanclay, F.; Esteves, A. M. (Ed). **New directions in social impact assessment:** conceptual and methodological advances. Cheltenham: Edward Elgar, 2011. p. 78–95.

HUMAN RIGHTS WATCH. **What do we get out of it?:** the human rights impact of bauxite mining in Guinea. 2018. Available from: <https://www.hrw.org/sites/default/files/report_pdf/guinea1018_web2.pdf> Access in: 10 October 2019.

HUSTRULID, W.; KUCHTA, M.; MARTIN, R. **Open pit mine planning and design.** 3rd. ed. Boca Raton: CRC Press. 2013. 2 v.

IKEMEFUNA, P. Evaluating the influence of open cast mining of solid minerals on soil, land use and livelihood systems in selected areas of Nasarawa State, North-Central Nigeria. **Journal of Ecology and the Natural Environment**, v. 4, n. 3, p. 62-70, 2012.

IMPERIAL OIL. Imperial's Cold Lake. Cyclic Steam Stimulation (CSS). Alberta, 2018. Available from: <https://www.imperialoil.ca/en-CA/Company/Operations/Cold-Lake#coldLakeExpansionProject> Access in: 20 September 2018

INSTITUTE FOR HUMAN RIGHTS AND BUSINESS: Human rights defenders: Why Ken Saro-Wiwa Matters. Commentary. 2015. Available from: **https://www.ihrb.org/other/human-rights-defenders/why-ken-saro-wiwa-matters**. Access in: 11 May 2020

KASHIRTSEV, V. A.; HEIN, F. J. **Overview of natural bitumen fields of the Siberian platform.** Olenek uplift, Eastern Siberia**,** Russia, 2013. DOI: 10.1306/13371591St643560.

KUCH, D.; ELLEM, G.; BAHNISCH, M.; WEBB, S. **Social license and communications report.** Melbourne: Australian Council of Learned Academies, January 2013. 32 p. (ACOLA ARC LASP Program Securing Australia's Future Project, 6. Engineering Energy: Unconventional Gas Production). Available from: <https://acola.org/wp-content/uploads/2018/08/csrer-atse-social-license-communication-jan13.pdf> Access in: 19 January 2018.

KUMAH, A. Sustainability and gold mining in the developing world. **Journal of Cleaner Production**, v. 14, n. 3–4, p. 315–323, 2006. DOI: doi:10.1016/j.jclepro.2004.08.007.

KUNZ, T. H.; DE TORREZ, E. B.; BAUER, D.; LOBOVA, T.; FLEMING, T. H. Ecosystem services provided by bats. **Annals of the New York Academy of Sciences**, v. 1223, n. 1, p. 1–38, 2011.

LACEY, J.; LAMONT, J. Using social contract to inform social license to operate: an application in the Australian coal seam gas industry. **Journal of Cleaner Production**, v. 84, n. 1, p. 831–839, 2014. DOI: http://dx.doi.org/10.1016/j.jclepro.2013.11.047. Access in: 13 February 2018.

LADAN M.T. NO. 8: Mineral resources law and policy in Nigeria. Prof. Ladan's law and policy review research working papers. **Department of Public Law, Faculty of Law, Ahmadu Bello University, Zaria, Kaduna State, Nigeria**. 2014. 71p. Available from: http://mtladan.blogspot.com/. Access in April 2019.

LANDSBERG, F.; OZMENT, S.; STICKER, M.; HENNINGER, N.; TREWEEK, J.; VENN, O.; MOCK, G. Ecosystem services review for impact assessment: Introduction and guide to scoping . **WRI Working Paper,** Washington, p. 1-34, Nov. 2011.

LANDSBERG, F.; TREWEEK, J.; STICKLER, M.; HENNINGER, N.; VENN, O. **Weaving ecosystem services into impact assessment:** a step by step method. Version 1.0. Washington**:** World Resources Institute, 2013. 46 p. Available from: <https://wriorg.s3.amazonaws.com/s3fspublic/weaving_ecosystem_services_into_impact_assessment.pdf> Access in: 24 February 2017.

LARONDELLE, N.; HAASE, D. Valuing post-mining landscapes using an ecosystem services approach - an example from Germany. **Ecological Indicators**, v. 18, p. 567–574, 2012. DOI: http://dx.doi.org/10.1016/j.ecolind.2012.01.008.

LARTER, S. R.; HEAD, I. M. Oil sands and heavy oil: origin and exploitation. **Elements,** v. 10, n. 4, p 277-283, 2014.

LATTANZIO, R. K. Canadian oil sands: life-cycle assessments of greenhouse gas emissions. **Current Politics and Economics of the United States**, **Canada and Mexico**, v. 17, n. 1, p. 157, 2014.

LERCHS, H; GROSSMANN, I. F. Optimum design of open-pit mines. **Transactions of the Canadian Mining and Metallurgical Bulletin**, v. 68, p. 17-24, 1968.

LESSER, P.; SUOPAJÄRVI, L.; KOIVUROVA, T. Challenges that mining companies face in gaining and maintaining a social license to operate in Finnish Lapland. **Mineral Economics**, v. 30, n. 1, p. 41-51, 2017.

LINCOLN, A. Rethinking social license to operate: a concept in search of definition and boundaries. **Environment and Energy Bulletin**. Business Council of British Columbia, v. 7, n. 2, p. 1-10, May 2015. Available from: <

https://bcbc.com/dist/assets/publications/rethinking-social-licence-to-operate-a-concept-in-search-of-definition-and-boundaries/EEBv7n2.pdf>. Access in: 19 January 2018.

LUOMA, T.; PAASI, J.; VALKOKARI, K. Intellectual property in inter-organisational relationships. Findings from an interview study. International Journal of Innovation Management, v. 14, n. 3, p. 399-414, 2010.

MASLIYAH, J.; ZHOU, Z. J.; XU, Z.; CZARNECKI, J.; HAMZA, H. Understanding water based bitumen extraction from Athabasca oil sands. **The Canadian Journal of Chemical Engineering,** v. 82, n. 4, p. 628-654, 2004.

MCKENNEY, B. A.; KIESECKER, J. M. Policy development for biodiversity offsets: A review of offset frameworks. **Environmental Management**, v. 45, n. 1, p. 165–176, 2010.

MCNAB, K.; KEENAN, J.; BRERETON, D.; KIM, J.; KUNANAYAGAM, R.; BLATHWAYT, T. **Beyond voluntarism:** the changing role of corporate social investment in the extractives sector. Brisbane: Centre for Social Responsibility in Mining, the University of Queensland, 2012.

MCWHINNEY, R. **Oil sands environmental impacts.** Alberta: Canadian Energy Research Institute, July 2014. Study, nº 143. Available from: https://www.ceri.ca/assets/files/Study_143_Full_Report.pdf. Access in: 28 March 2017.

MECH, M. **A comprehensive guide to the Alberta oil sands:** understanding the environmental and human impacts, export implications, and political, economic, and industry influences. [Ottawa: Greenparty], May 2011. 111 p. Available from: < https://www.greenparty.ca/sites/default/files/a_comprehensive_guide_to_the_alberta_oil_sands_-_may_2011_-_last_revised_march_2012.pdf> Access in: 20, June 2013

MERCER-MAPSTONE, L.; RIFKIN, W.; LOUIS, W. R.; MOFFAT, K. Company-community dialogue builds relationships, fairness, and trust leading to social acceptance of Australian mining developments. **Journal of Cleaner Production**, v. 184, p. 671-677, 2018.

MEYER, R. F.; ATTANASI, E. D. Heavy oil and natural bitumen-strategic petroleum resources. **U.S. Geological Survey,** Fact Sheet 70-03, Aug. 2003.

MEYER, R. F.; ATTANASI, E. D.; FREEMAN, P. A. Heavy oil and natural bitumen resources in geological basins of the world. **U.S. Geological Survey,** Reston, n. 1084, 2007.

MICROMINE. 2020. https://www.micromine.com/micromine-mining-software/micromine-2020/

MILLENNIUM ECOSYSTEM ASSESSMENT. **Ecosystems and human well-being:** a framework for assessment. Washington: Island Press, 2003. 212 p.

MILLENNIUM ECOSYSTEM ASSESSMENT. Ecosystems and human well-Being: Synthesis. Washington: Island Press, 2005. 156 p.

MILLINGTON, D. **Canadian oil sands supply costs and development projects (2019-2039).** Calgary: Canadian Energy Research Institute, July 2019. Study, n. 183. Available from: < https://ceri.ca/files/publications/509> Access in: 17 September 2019.

MINING, MINERALS AND SUSTAINABLE DEVELOPMENT. **Breaking new ground: t**he Report of the MMSD Project. London: Earthscan, 2002. 441 p.

MINISTRY OF MINES AND STEEL DEVELOPMENT. **Industrial minerals**: Bitumen. 2018. Available from: https://www.minesandsteel.gov.ng/portfolio/bitumen/. Access in: May 2020.

MOFFAT, K.; ZHANG, A. The paths to social license to operate: An integrative model explaining community acceptance of mining. **Resources Policy**, v. 39, n. 1, p. 61–70, 2014. DOI: http://dx.doi.org/10.1016/j.resourpol.2013.11.003. Access in: October, 2016.

MORITZ, T.; EJDEMO, T.; SÖDERHOLM, P.; WÅRELL, L. The local employment impacts of mining: an econometric analysis of job multipliers in northern Sweden. **Mineral Economics**, v. 30, n.1, p. 53-65, 2017.

NATIONAL RESEARCH COUNCIL. **Hardrock mining on federal lands.** Washington: The National Academies Press, 1999. DOI: https://doi.org/10.17226/9682

NATURAL RESOURCES CANADA. **Crude oil facts**. 2019 Available from: <https://www.nrcan.gc.ca/crude-oil-facts/20064> Access in: 29 July 2019.

NEBEL, B. J.; WRIGHT, R. T. **Environmental science:** the way the world works. 5th. ed. Upper Saddle River, N.J.: Prentice Hall, 1996. 698 p.

NEWMAN, A. M.; RUBIO, E.; CARO, R.; WEINTRAUB, A.; EUREK, K. A review of operations research in mine planning. **Interfaces,** v. 40, n. 3, p. 222-245, 2010.

NIGERIAN MINERALS AND MINING ACT. Abuja: **Ministry of Mines and Steel Development**, 2007. Available from: https://www.minesandsteel.gov.ng/. Access in: February 2018.

NIGERIA, ONDO STATE. Office of the Military Government. Department of Research and Statistics. **Facts and figures about Ondo State. 1991.** Available from: <https://books.google.com.br/books/about/Facts_and_figures_about_Ondo_State.html?id=Mg8_AQAAIAAJ&redir_esc=y>Access in: 08 February 2018.

O'FAIRCHEALLAIGH, C. Community development agreements in the mining industry: an emerging global phenomenon. **Community Development,** v. 44, n. 2, p. 222-238, 2013.

OFORI, J. J. Y.; OFORI, D. R. Earning a social license to operate: perspectives of mining communities in Ghana. **The Extractive Industries and Society**, v. 6, n. 2, p. 531-541, 2019.

OIL SANDS DISCOVERY CENTRE. Facts about Alberta's oil sands and its industry. Government of Alberta, 2014. Available from: www.oilsandsdiscovery.com. Access in: 06 February 2017.

OIL SANDS MAGAZINE. Bitumen and heavy oil upgraders: Bitumen production, 2019. Accessed August 2019. https://www.oilsandsmagazine.com/projects/bitumen-upgraders

OIL SANDS MAGAZINE. Mining for bitumen. Available from: <https://www.oilsandsmagazine.com/technical/mining> Access in: September 2018a.

OIL SANDS MAGAZINE. OPP-dry: materials handling facilities. Available from: <https://www.oilsandsmagazine.com/technical/mining/ore-preparation-plant/opp-dry-materials-handling> Access in: September 2018b.

OIL SANDS MAGAZINE. Evolution of mining equipment in the oil sands. Available from: <https://www.oilsandsmagazine.com/technical/mining/surface-mining/equipment> Access in: September 2018c.

OIL SANDS MAGAZINE. Primary separation cells. Available from: <https://www.oilsandsmagazine.com/technical/mining/extraction/psc-primary-separation-cell> Access in: September 2018d.

OIL SANDS MAGAZINE. Froth treatment explained. Available from: <https://www.oilsandsmagazine.com/technical/mining/froth-treatment> Access in: September 2018e.

OIL SANDS MAGAZINE. Bitumen upgrading explained: from diluted bitumen to synthetic crude. Available from: <https://www.oilsandsmagazine.com/technical/bitumen-upgrading> Access in: September 2018f.

OIL SANDS MAGAZINE. In-situ bitumen extraction. Available from: <https://www.oilsandsmagazine.com/technical/in-situ> Access in: September 2018g

OLADIPO, O. G.; OLAYINKA, A.; AWOTOYE, O. O. Ecological impact of mining on soils of Southwestern Nigeria. **Environmental and Experimental Biology**, v. 12, p. 179–186, 2014.

OMATSOLA, M. E.; ADEGOKE, O. S. Tectonic Evolution of the Dahomey basin (West Africa) and its implication on the opening of the North and South Atlantic. International Geological Congress (26; 1980; Paris). Abstracts of the 26th International geological congress: Paris, 7-17 July 1980. v. 1, n. 268, 1980. Available from: <http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=PASCALGEODEBRGM8020398773>

OMOTEHINSE, A. O.; AKO, B. D. The environmental implications of the exploration and exploitation of solid minerals in Nigeria with a special focus on Tin in Jos and Coal in Enugu. **Journal of Sustainable Mining**, v. 18, n. 1, p. 18-24, 2019. DOI: 10.1016/j.jsm.2018.12.001

OMOTEHINSE, A. O.; TOMI, G. D. A social license to operate: pre-mining effects and activities perspective. **REM-International Engineering Journal,** v. 72, n. 3, p. 523-527, 2019.

OMOTEHINSE, A. O.; DE TOMI, G.; BANINLA, Y. Proactive Management of Ecosystem Services in Oil Sands Pre-mining Phase. **Natural Resources Research** 29, 949–965, 2020. https://doi.org/10.1007/s11053-019-09505-5

ONWUBIKO, O.; ASMUNI, A.; IDRIS, K.; OTHMAN, J. The causes, effects and potential solutions to the deep-rooted Niger Delta oil crisis. **International Journal of Social and Behavioural Sciences**, v. 1, n. 6, p. 122-129, 2013.

ORIRE, E. **The techno-economics of bitumen recovery from oil and tar sands as a complement to oil exploration in Nigeria.** Potchefstroom, 2009. Thesis (Master of Science) - North-West University, 2009.

OSAGIE, J.; FUNMILAYO, A.; FRED, A.; SAMUEL, E. Causes of conflicts in the Niger Delta region of Nigeria as expressed by the youth in Delta State. **Procedia - Social and Behavioral Sciences**, v. 5, n. 2, p. 82–89, 2010. DOI: http://dx.doi.org/10.1016/j.sbspro.2010.07.055.

OWEN, J. R.; KEMP, D. Social license and mining: a critical perspective. **Resources Policy**, v. 38, n. 1, p. 29–35, 2013. DOI: http://dx.doi.org/10.1016/j.resourpol.2012.06.016>. Access in: November, 2016.

OYEBAMIJI, A.; AFOLAYAN, A.; BASSAGI, M.; TAJUDEEN, O. Summary of Modelling Safety Factors of Slope Stability in a Tar-Sand Quarry: A Case Study. **Asian Journal of Applied Sciences**, v. 7, N. 5, p 659-665, 2019. DOI: 10.24203/ajas.v7i5.5758. Access in: 10 February 2020.

PARSONS, R.; LACEY, J.; MOFFAT, K. Maintaining legitimacy of a contested practice: How the minerals industry understands its “social licence to operate”. **Resources Policy**, v. 41, n. 1, p. 83–90, 2014. DOI: http://dx.doi.org/10.1016/j.resourpol.2014.04.002.

PERSSON, L.; ARVIDSON, A.; LANNERSTAD, M.; LINDSKOG, H.; MORRISSEY, T.; NILSSON, L.; SENYAGWA, J. Impacts of pollution on ecosystem services for the millennium development goals. Stockholm: Stockholm Environmental Institute, 2010. Stockholm Environment Institute, Project Report – 64p, 2010. Available from: < https://mediamanager.sei.org/documents/Publications/SEI-ProjectReport-LPersson-ImpactsOfPollutionOnEcosystemServices.pdf> Access in: 24 February 2017.

PIKE, R. **The relevance of social licence to operate for mining companies**. Schroders, 2012. 11 p. Available from: <https://www.schroders.com/staticfiles/Schroders/Sites/Americas/US Institutional 2011/pdf/Social-Licence-to-Operate.pdf>. Access in: 22 January 2018.

PIMENTEL, B. S.; GONZALEZ, E. S.; BARBOSA, G. N. O. Decision-support models for sustainable mining networks: Fundamentals and challenges. **Journal of Cleaner Production**, v. 112, pt.4, p. 2145–2157, 2016. DOI: https://doi.org/10.1016/j.jclepro.2015.09.023

PLANT SCIENCE 4 U. Ecosystem **-** Definition, different types and examples. 2019. Available from: <https://www.plantscience4u.com/2016/07/ecosystem-definition-different-types.html#.Xk1YimhKi00> Access in: March 2018.

POVEDA, C. A.; LIPSETT, M. G. A Rating System for Sustainability of Industrial Projects with Application in Oil Sands and Heavy Oil Projects: Areas of Excellence, Sub-Divisions, and Management Intereactions. **Journal of Sustainable Development**, v. 4, n. 4, p. 59–71, 2011. Available from: <http://www.ccsenet.org/journal/index.php/jsd/article/view/10664>.

PRNO, J. An analysis of factors leading to the establishment of a social licence to operate in the mining industry. **Resources Policy**, v. 38, n. 4, p. 577–590, 2013a. DOI: http://dx.doi.org/10.1016/j.resourpol.2013.09.010.

PRNO, J.; SCOTT SLOCOMBE, D. Exploring the origins of "social license to operate" in the mining sector: perspectives from governance and sustainability theories. **Resources Policy**, v. 37, n. 3, p. 346–357, 2012. DOI: http://dx.doi.org/10.1016/j.resourpol.2012.04.002. Access in: November 4, 2016.

PRNO, J.; SLOCOMBE, D. S. A systems-based conceptual framework for assessing the determinants of a social license to operate in the mining industry. **Environmental Management**, v. 53, n. 3, p. 672–689, 2014.

QUAGRAINE, E. K.; PETERSON, H. G.; HEADLEY, J. V. In situ bioremediation of naphthenic acids contaminated tailing pond waters in the Athabasca oil sands region—demonstrated field studies and plausible options: a review. **Journal of Environmental Science and Health,** v. 40, n. 3, p. 685-722, 2005.

QUIGLEY, R. J.; BAINES, J. T. **How to improve your social licence to operate:** a new Zealand Industry Perspective. Wellington: Ministry of Primary Industries, 2014. MPI Information Paper nº 2014/05.

RADON, J.; AVILA, J.; BALAN, Y. J.; DE LA CRUZ, A.; JAVED, M. A.; JIA, S.; KHAN, M.; LEE, J.; MABERRY, J.; NATARAJAN, A.; SAHAY, V.; TAKAHASHI, N. **The peruvian mining sector:** exploring issues related to social license, corruption and the trans-pacific partnership treaty. New York: Columbia University. School of International and Public Affairs, 2016. (SIPA Capstone Report, 2016).

RENDU, J. M.; MISKELLY, N. Mineral resources and mineral reserves: progress on international definitions and reporting standards. **Mining Technology,** v. 110, n. 3, p. 133-138, 2001.

ROGERS, V. V.; WICKSTROM, M.; LIBER, K.; MACKINNON, M. D. Acute and sub chronic mammalian toxicity of naphthenic acids from oil sands tailings. **Toxicological Sciences**, v. 66, n. 2, p. 347-355, 2002

RWANGA, S. S.; NDAMBUKI, J. M. Accuracy assessment of land use/land cover classification using remote sensing and GIS. **International Journal of Geosciences,** v.8, n.4, p. 611-622, 2017.

SBERT, C. Re-imagining mining: the earth charter as a guide for ecological mining reform. **IUCN Academy of Environmental Law E-Journal,** 2015.

SCHRAMM, L. L.; STASIUK, E. N.; TURNER, D. The influence of interfacial tension in the recovery of bitumen by water-based conditioning and flotation of Athabasca oil sands. **Fuel Processing Technology,** v. 80, n. 2, p. 101-118, 2003.

SHAH, A.; FISHWICK, R.; WOOD, J.; LEEKE, G.; RIGBY, S.; GREAVES, M. A review of novel techniques for heavy oil and bitumen extraction and upgrading. **Energy & Environmental Science**, v. 3, n. 6, p. 700-714, 2010.

SHARMA, N. K.; LAMAY, J. B.; KULLU, N. J.; SINGH, R. K.; JEYASEELAN, A. T. Land use and land cover analysis of Jharkhand using satellite remote sensing. **Journal of Space Science & Technology,** v. 1, n. 2, p. 1-10, Aug. 2012.

SMITH, D. C.; RICHARDS, J. M. Social license to operate: hydraulic fracturing- related challenges facing the oil and gas industry. **Oil and Gas, Natural Resources, and Energy Journal**, v. 1, n. 2, p. 1–84, 2015.

SOBKOWICZ, J. **Oil sands tailings technology deployment roadmaps.** Edmonton. Alberta Innovates. Energy and Environment Solutions, 2012. 102 p. (Project Report v. 2-Component 1). Available from: < http://www.ai-ees.ca/media/7361/1906-component_1_report.pdf> Access in: 20 December 2016.

SOUTH AFRICAN MINERAL RESOURCE COMMITTEE. **The South African code for the reporting of exploration results, mineral resources and mineral reserves (The SAMREC CODE).** Johannesburg: Southern African Institute of Mining and Metallurgy and the Geological Society of South Africa, 2007.

STEWART, G. A.; MACCALLUM, G. T. **Athabasca oil sands guide book.** Calgary: Canadian Society of Petroleum Geologists, 1978.

STEYN, P. Oil exploration in colonial Nigeria, c. 1903–58. **The Journal of Imperial and Commonwealth History,** v. 37, n. 2, p. 249-274, 2009.

TENENBAUM, D. J. Oil sands development: A health risk worth taking? **Environmental Health Perspectives**, v. 117, n. 4, p. A150–A156, 2009.

THOMPSON, M.; BARR, D. Cut-off grade: a real options analysis. **Resources Policy,** v. 42, p. 83–92, 2014. DOI: http://dx.doi.org/10.1016/j.resourpol.2014.10.003.

THORLEY, U. **Open pit mine planning: analysis and system modeling of conventional and oil sands applications** 2012. 298 p. Thesis (Doctor of Phylosophy) – Queen's University, Kingston, 2012.

TOMAN, M.; CURTRIGHT, A.; ORTIZ, D.; DARMSTADTER, J.; SHANNON, B. Oil sands and synthetic crude oil. In: **Unconventional fossil-based fuels: economic and environmental trade-offs.** Pittsburgh, PA: RAND Corporation, 2008. p. 15-38. Available from: < https://www.jstor.org/stable/10.7249/tr580ncep> Access in: 26 December 2019.

USANG, E. E.; IKPEME, N. J. The Niger Delta oil rich region: The paradox of fascination and horror. **Academic Journal of Interdisciplinary Studies,** v. 4, n. 1, p. 117-123, 2015.

VANCLAY, F.; ESTEVES, A. M.; AUCAMP, I.; FRANKS, D. M. **Social impact assessment:** Guidance for assessing and managing the social impacts of projects. Fargo: IAIA, 2015. Available from: < https://www.iaia.org/uploads/pdf/SIA_Guidance_Document_IAIA.pdf> Access in: 12 February 2018.

VITOUSEK, P. M.; MOONEY, H. A.; LUBCHENCO, J.; MELILLO, J. M. Human domination of Earth's ecosystems. **Science,** v. 277, n. 5325, p. 494-499, 1997.

WOOD, G. Thresholds and criteria for evaluating and communicating impact significance in environmental statements: ‘See no evil, hear no evil, speak no evil’? **Environmental Impact Assessment Review**, v. 28, n. 1, p 22-38, 2008.

WORRALL, R.; NEIL, D.; BRERETON, D.; MULLIGAN, D. Towards a sustainability criteria and indicators framework for legacy mine land. **Journal of Cleaner Production**, v. 17, n. 16, p. 1426–1434, 2009. DOI: http://dx.doi.org/10.1016/j.jclepro.2009.04.013.

WOYNILLOWICZ, D.; SEVERSON-BAKER, C.; RAYNOLDS, M. **Oil sands fever:** the environmental implications of Canada's oil sands rush. Drayton Valley: The Pembina Institute, 2005. 86 p.

XIANG, J.; XIAO, K.; CARRANZA, E. J. M.; CHEN, J.; LI, S. 3D Mineral prospectivity mapping with Random forests: a case study of Tongling, Anhui, China. **Natural Resources Research,** v. 29, p. 395-414, 2020. DOI: https://doi.org/10.1007/s11053-019-09578-2.

YANG, C.; WANG, Z.; YANG, Z.; HOLLEBONE, B.; BROWN, C. E.; LANDRIAULT, M.; FIELDHOUSE, B. Chemical fingerprints of Alberta oil sands and related petroleum products. **Environmental Forensics**, v. 12, n. 2, p. 173-188, 2011.

YATES, B. F.; HORVATH, C. L. Social license to operate: how to get it, and how to keep it. In**: 2013 Pacific Energy Summit on forging Trans-Pacific Cooperation for a New Energy Era.** Commissioned by the Asia Pacific Foundation of Canada and The National Bureau of Asian Research, p. 1–23, 2013.

YUAN, Y.; XU, B.; YANG, B. Geomechanics for the thermal stimulation of heavy oil reservoirs-Canadian experience. In: SPE Heavy Oil Conference and Exhibition, 12-14 Dec.

2011, Kuwait City. **[Paper].** Richardson: Society of Petroleum Engineers, 2011. (SPE nº150 293). DOI: https://doi.org/10.2118/150293-MS

ZAGAYEVSKIY, Y.; DEUTSCH, C. V. A methodology for sensitivity analysis based on regression: applications to handle uncertainty in natural resources characterization. **Natural Resources Research**, v. 24, n. 3, p. 239-274, 2015.

ZHANG, W. Extraction of energy resources - exploitation of the canadian oil sands. **Natural Resources,** v. 5, p. 507–519, 2014.

APPENDIX

1. IN-SITU MINING

A variety of in situ techniques is used to recover bitumen from deposits that are too deep from surface (CANADA, ALBERTA (GOVERNMENT), 2009; BRANDT, 2012; OIL SANDS DISCOVERY CENTRE, 2014). Despite the variations in in-situ techniques, all techniques involve injection of energy into the ore body, forcing bitumen to exit through two different drilled wells. The first well, called the injection well is where energy is injected into the ore body and the second well, called the production well, is where the bitumen rises to the surface (ZHANG, 2014).

Extraction of bitumen by in situ methods requires the extraction directly from the ground (MCWHINNEY, 2014). The bitumen is separated from the sand without removing the sand from the ground (ZHANG, 2014). To allow the bitumen to be pumped out of the ground, its viscosity must be reduced because it does not flow naturally at the reservoir temperature. This is done by injecting steam into a well to heat the bitumen, thereby reducing its viscosity and allowing it to be pumped from the well (MCWHINNEY, 2014).

Depth of reservoir mostly limit surface mining methods, approximately 80% of the Alberta oil sands and most of the Venezuelan sands are far below the surface therefore limiting its extraction by surface mining (SHAH et al., 2010). The first commercial in situ extraction method was cyclic steam stimulation (CSS) (CANADA, ALBERTA (GOVERNMENT), 2009), and the most commonly applied are steam-assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS) (BRANDT, 2012; OIL SANDS DISCOVERY CENTRE, 2014).

Three techniques are employed in oil sands in situ production: cold production (suitable for resources above 12 API and so not considered further), thermal in situ production via cyclic steam stimulation (CSS), and steam assisted gravity drainage (SAGD) (BRANDT, 2012).

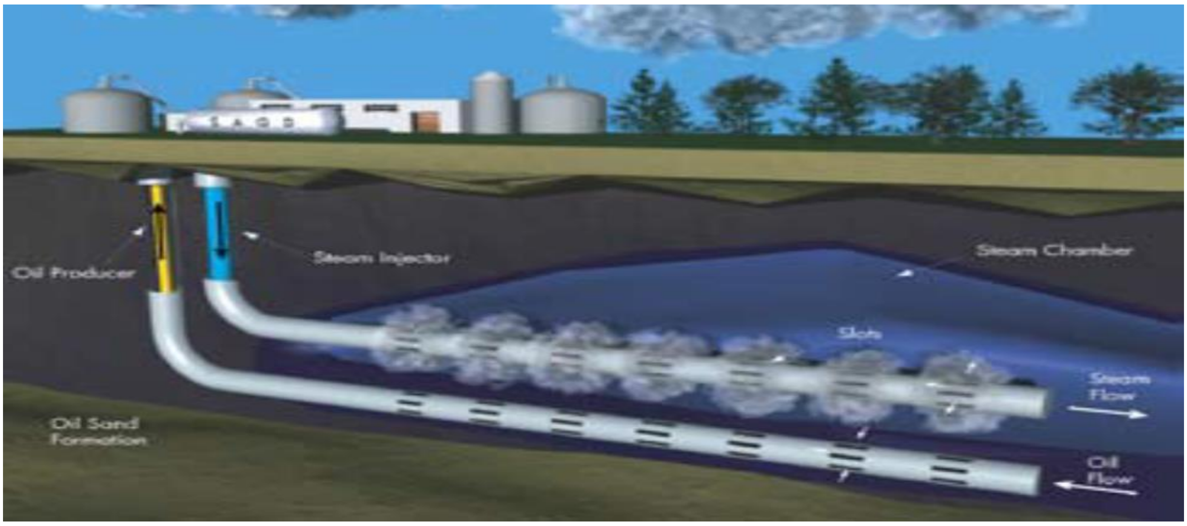
2.1. Steam assisted gravity drainage (SAGD)

SAGD method was developed by Butler for in situ recovery of Alberta bitumen with Imperial Oil (SHAH et al., 2010). **SAGD** is expanding rapidly due to its ability to produce heavy oil from formations from 100 m (CLARK et al., 2007) to a few hundred meters deep (200 – 500 m) (BHATTACHARJEE, 2011), too shallow for conventional steam injection methods and it operates at lower steam pressures than CSS or steamflood wells (CLARK et al., 2007).

SAGD technology requires the drilling of two parallel horizontal wells through the oil-bearing formation with one well directly above the other well. In the start-up phase, both wells are injected with steam to reduce the heavy oil's viscosity (CLARK et al., 2007; BHATTACHARJEE, 2011). In the production phase, steam is injected only into the upper well which is the injection well to reduce the viscousity of the heavy oil and the production well which is about five meters below the injection well, pumps up reservoir fluids to the surface (CLARK et al., 2007; CANADA, ALBERTA (GOVERNMENT), 2009; OIL SANDS DISCOVERY CENTRE, 2014). Between 25 and 75% of the bitumen is recovered, and about 90% of the water can be recycled (CLARK et al., 2007; BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014).

Two processes are used for separating bitumen and water in SAGD operations: *inverted* and *diluted* processes (BHATTACHARJEE, 2011).

Figure 3 - In-situ Extraction Process



Source: OIL SANDS MAGAZINE, (2018g)

2.2 Cyclic steam stimulation (CSS)

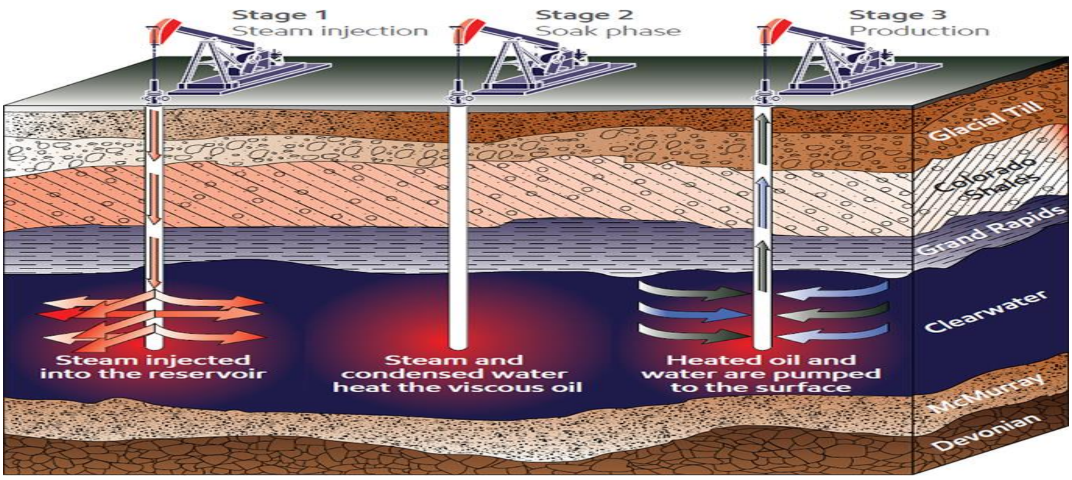
Cyclic steam stimulation CSS also known as the "huff- and- puff" method, is a **thermal *in-situ* production** method of bitumen and heavy oil that was discovered in the late 1950s by Shell in

Venezuela (BHATTACHARJEE, 2011; SHAH et al., 2010) during the production of heavy crude by steamflooding (BUTLER, 1991). The basic CSS operation consists of three stages that are repeated cyclically (BHATTACHARJEE, 2011). In the first stage which is the steam injection, high-pressure steam of up to about 1000 B/d (160 t/d or m3 /d) is injected into the bitumen reservoir through a vertical drilled well until sufficient temperature and pressure is developed (BHATTACHARJEE, 2011; SHAH et al., 2010; BANERJEE, 2012).

The pressure of the steam fractures the oil sand, while the heat of the steam melts the bitumen (BUTLER, 1991). This stage, which generally takes about 4–6 weeks, is also known as *huff*. The well is shut down after the steam injection period is stopped and the second step, soaking is initiated, and the well is allowed to soak for a few weeks, until the bitumen becomes mobile. During this period, the reservoir is heated to melt the bitumen, and viscosity is reduced enough to make the bitumen flow. In the third stage, which is the production of the bitumen, hot steam that was injected had made the "solid" bitumen less viscous so that it can flow through the reservoir and pumped through the same well that will be acting as a production well. This step, which usually takes several months to a year, is also known as *puff* (BHATTACHARJEE, 2011; SHAH et al., 2010; BANERJEE, 2012).

This process can be repeated several times in a formation of between 120 days and two years to complete a steam stimulation cycle (BUTLER, 1991; OIL SANDS DISCOVERY CENTRE, 2014). In the CSS, the maximum recovery obtained is about 20%–25% of original bitumen in place (BANERJEE, 2012), CSS technology uses only one vertical well, for both injection and production.

Figure 4 - Cyclic steam stimulation process



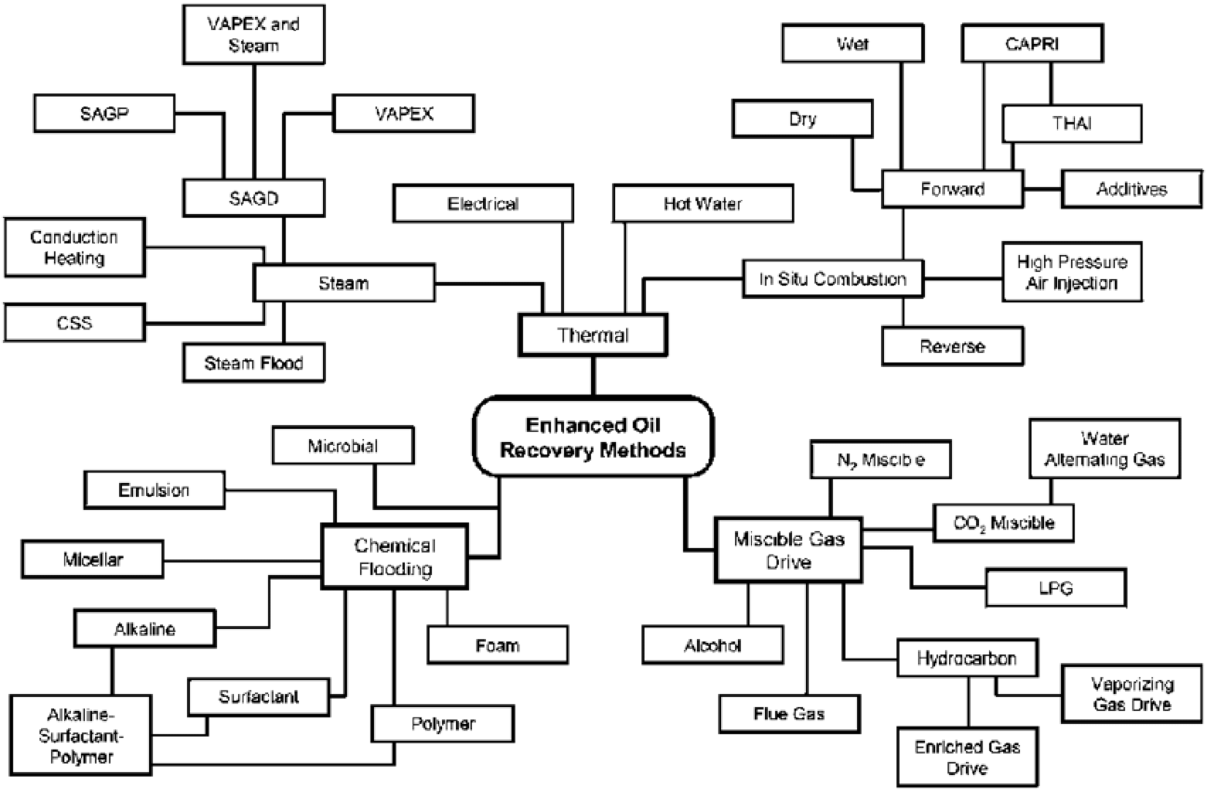
Source: IMPERIAL OIL, (2018).

2.3 Enhanced oil recovery (EOR) methods

Enhanced Oil Recovery (EOR) also referred to as tertiary recovery or improved oil recovery is considered as the third stage of production where the oil left behind by the low risk primary and secondary methods is extracted. EOR techniques improve oil displacement efficiency in the reservoir by reducing the viscosity of the oil to ease flow or by literally pushing it through the reservoir. In addition, it improves the sweep efficiency, which is the volume of reservoir that is contacted during extraction (SHAH et al., 2010). There are three major branches of EOR: Miscible displacement, chemical flooding and thermal recovery (BUTLER, 1991; SHAH et al., 2010).

The concept of in situ processes are similar to thermal EOR processes for heavy oil extraction. The viscosity of bitumen is reduced by heat from injected steam thereby allowing it to flow to the wellbore under existing pressure gradients (BRANDT, 2012). The applications of thermal methods are mostly for the recovery of heavy oils that are too viscous at the original reservoir conditions to flow (BUTLER, 1991).

Figure 5 - Enhanced oil recovery (EOR) technologies.



Source: SHAH et al. (2010).

2.3.1 Thermal EOR

In thermal recovery methods, energy is injected in form of heat, which is generated by combustion. The heat generated by the combustion of the hydrocarbon fuel in the reserve reduces the viscosity of the bitumen with increase in temperature (SHAH et al. 2010; BRANDT, 2012; ZHANG, 2014). The lighter component vaporises (SHAH et al., 2010) and becomes it more mobile (SHAH et al., 2010; ZHANG, 2014) and it gets to a stage that it flows out for recovering (BRANDT, 2012; ZHANG, 2014). The high temperatures results in coking of the oil thereby upgrading the bitumen as it moved towards the production well (ZHANG, 2014). Most oils can use thermal methods, but the high cost of energy usually makes them an economical choice for the hard to extract, high viscosity heavy oils and oil sands (SHAH et al., 2010). SAGD and CSS differ in the well configuration used for steam injection and bitumen extraction (BRANDT, 2001).

2.3.1.1 In-situ combustion (ISC)

In situ combustion (ISC) was first documented in Canada in 1920 when the technique was applied at a reservoir near Fort McMurray. ISC or fire flooding as it is sometimes called is favourable for heavy oil reservoirs because the viscosity of the bitumen is greatly reduced due to increased temperature (SHAH et al., 2010). It involves the generation of heat by combustion within the reservoir by injecting air or oxygen to the combustion zone and the bitumen ahead of the front becomes heated (BUTLER, 1991; BANERJEE, 2012) by using downhole gas burners, electrical heaters or in some cases auto-ignition may occur (BHATTACHARJEE, 2011; SHAH et al., 2010). Volatile fractions are distilled from the oil and then, and with increase in temperature, thermal cracking reactions occur and the bitumen is cracked into lighter fractions that move upward, away from the heated zone (BUTLER, 1991; BHATTACHARJEE, 2011; BANERJEE, 2012).

The heavier portion, or coke, formed during the process is further burned and generates heat. The hot lighter fraction (BUTLER, 1991) also melts the bitumen in the reservoir and makes it mobile. The mobile oil then moves ahead of the combustion zone, toward the production well (CLARK et al., 2007; BHATTACHARJEE, 2011; BANERJEE, 2012). The advantage of in situ combustion is that there is no need for steam generation to heat the reservoir; however, significant energy is still required to compress and pump air into the formation (BUTLER, 1991; CLARK et al., 2007; BHATTACHARJEE, 2011). Due to the difficulty of controlling the process, ISC has not achieved wide acceptance rate (BHATTACHARJEE, 2011; SHAH et al., 2010). Heat loss during steam injection is also a cause for concern (BANERJEE, 2012).

2.3.1.2 Toe-to-heel air injection (THAI)

THAI is an ISC process developed by Petrobank of Calgary, Alberta. An air injection well is drilled vertically at the toe of the horizontal production well. Once the bitumen is mobile at the required temperature, air is injected into the formation (BANERJEE, 2012; OIL SANDS DISCOVERY CENTRE, 2014) and a combustion reaction starts. The vertical combustion front moves along the horizontal well (from the toe to the heel of the production well), sweeping the reservoir and with increase in temperature, the bitumen is heated to high temperature, at which partial upgrading occurs (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014). The upgraded bitumen is recovered through the production well (BANERJEE, 2012).

THAI technology has many potential advantages over SAGD, which include higher resource recovery of the original oil in place (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014), lower production and capital costs (BHATTACHARJEE, 2011; BANERJEE, 2012; OIL SANDS DISCOVERY CENTRE, 2014), minimal usage of natural gas and fresh water, reduced diluent requirements for transportation and significantly lower greenhouse gas emissions (OIL SANDS DISCOVERY CENTRE, 2014).

2.3.1.3 Vapor extraction process (VAPEX)

The VAPEX process is similar to SAGD but instead of steam, solvent is injected into the oil sands resulting in significant viscosity reduction (CLARK et al., 2007; OIL SANDS DISCOVERY CENTRE, 2014). Vapex is a non-thermal solvent-based technology (CLARK et al., 2007) that uses gaseous and liquid hydrocarbon solvents such as ethane or propane (OIL SANDS DISCOVERY CENTRE, 2014) injected into the oil sands reservoir (BANERJEE, 2012), a vapor chamber is formed through which the oil flows due to gravity drainage (CLARK et al., 2007; OIL SANDS DISCOVERY CENTRE, 2014). The gas phase of the solvent mixture fills the chamber and increases the pressure of the reservoir while the liquid phase dissolves into the bitumen at the oil/gas interface, reducing its viscosity and causing it to drain by gravity into a horizontal production well (BANERJEE, 2012). The process can be applied in paired horizontal wells (CLARK et al., 2007; BANERJEE, 2012; OIL SANDS DISCOVERY CENTRE, 2014), single horizontal wells or a combination of vertical and horizontal wells (OIL SANDS DISCOVERY CENTRE, 2014). It is a cold (40°C), low pressure process that does not involve the usage of significant amounts of energy (CLARK et al., 2007).

The advantages include re-use of the solvent (CLARK et al., 2007; BANERJEE, 2012), reduction in emissions by as much as 85% (BANERJEE, 2012), simpler recovery procedure than SAGD, as the VAPEX solvent floats on the aquifer surface, and it is easily separated by distillation (BHATTACHARJEE, 2011) and application to thin reservoirs (OIL SANDS DISCOVERY CENTRE, 2014). VAPEX reduces the need for natural gas (CLARK et al., 2007) and water (CLARK et al., 2007; BANERJEE, 2012).

The disadvantage, however, is the high cost of the hydrocarbon solvent, which increases VAPEX operational cost. In addition, the initial production rate is slow compared to conventional SAGD as the injected gaseous hydrocarbon slowly diffuses during the operation, and therefore requires a longer induction period (CLARK et al., 2007; BHATTACHARJEE, 2011). The major technical challenges are that it has yet to be field-tested and field injection and production strategies have yet to be developed (OIL SANDS DISCOVERY CENTRE, 2014).

2.3.2 Chemical flooding

Chemical flooding is the process of injecting chemicals to decrease interfacial tension and improve sweep efficiency. Reservoir characteristics place a particular restriction as carbonates and clays absorb the chemicals. Forty percent (40%) recoveries can be achieved but the technique is limited by the high cost of chemicals and is little used on large reservoirs (SHAH et al., 2010).

2.3.3 Miscible displacement

Miscible displacement (also referred to as miscible flooding and miscible drive) is the process of injecting a fluid into the reservoir, however, a fluid is employed that dissolves in the oil either at first contact or after multiple contacts, thereby reducing interfacial tension and improving oil displacement on a microscopic level. Gases are used as the greater density difference between the oil and fluid improves sweep efficiency. The technique is only economical for the lighter end of heavy oils because the displacement efficiency decreases rapidly with increasing oil density and viscosity since fingering of the gas becomes problematic (SHAH et al., 2010)

2. UPGRADING PROCESSES

The main product of upgrading is SCO that can be refined like conventional oil into a range of consumer products (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014) like jet fuels, gasoline and other petroleum products (BHATTACHARJEE, 2011; MECH, 2011). It is called "synthetic" because it is altered from its naturally occurring state (bitumen) by a chemical process (OIL SANDS DISCOVERY CENTRE, 2014). Syncrude and Suncor upgrade their bitumen on their own lease sites. Albian Sands sends diluted bitumen down their pipeline to the Scotford Upgrader where it is upgraded into synthetic crude oil (SCO) (OIL SANDS DISCOVERY CENTRE, 2014). Oil Sands companies process bitumen into either SCO or bitumen blends (dilbit: bitumen + diluent, or synbit: bitumen + SCO). Some companies may decide to sell the bitumen as dilbit or synbit, to refineries that have the capability to both upgrade and refine the bitumen and not to upgrade them (MECH, 2011).

The upgrading comprises two stages (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005); primary and secondary upgrading (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; GOSSELIN et al., 2010; BANERJEE, 2012). Primary upgrading is carried out either thermally, by the coking process, or catalytically, by the resid-hydrocracking process (BANERJEE, 2012) or both (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005). In the primary upgrading, the bigger hydrocarbon molecules are cracked into lower-molecular-weight molecules (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; GOSSELIN et al., 2010; BANERJEE, 2012) also there is increase in hydrogen content to break down polyaromatic hydrocarbon molecules (GOSSELIN et al., 2010). Coking has been a predominant process for primary upgrading (GOSSELIN et al., 2010) for rejecting carbon (BRANDT, 2001). A competing upgrading approach relies on hydrogen addition for primary upgrading. Treating the bitumen with hydrogen addition results in larger volumes of SCO produced from a given bitumen stream, and a high quality product (BRANDT, 2012).

An alternative method, hydrogen addition, or "*hydrocracking*," which is also referred to as catalytic hydroconversion is a catalytic conversion process that produces almost no solid waste (BHATTACHARJEE, 2011). Metallic elements in bitumen are mostly captured either in the coke product of the primary upgrading or on the spent catalyst of hydroconversion (GOSSELIN et al., 2010). Catalytic hydroconversion, an alternative technology for primary upgrading not only cracks large hydrocarbon molecules, but also adds hydrogen to the cracked molecules, partially converting aromatics to cycloparaffins (GOSSELIN et al., 2010). Catalytic hydroconversion results in high yield of liquid product without producing a solid waste product, but it does produce heavy residue, which needs to be further treated by coking (GOSSELIN et al., 2010). Hydrocracking of heavy crude comprises a combination of reactions namely, cracking the bigger molecules, followed by their hydrogenation (BANERJEE, 2012).

In the secondary-upgrading stage, the resulting liquid oil from the primary step is further processed to produce a syncrude that meets the refiner feedstock specifications (BANERJEE, 2012). Secondary upgrading treats resulting SCO fractions to remove impurities such as sulfur, nitrogen (GOSSELIN et al., 2010; BRANDT, 2012) and metals (BRANDT, 2012) without significant further conversion to lighter products (GOSSELIN et al., 2010). In secondary upgrading the heavier fractions of primary upgrading processes which contain the majority of the contaminants are hydrotreated (i.e., treated through the addition of H_2 in the presence of heat, pressure, and a catalyst) (GOSSELIN et al., 2010; BRANDT, 2012; BANERJEE, 2012). This reduces sulfur concentrations and improves the quality of the product (BRANDT, 2012). Adding hydrogen and/or removing carbon then creates hydrocarbon molecules like those in conventional light crude oil (CANADA, ALBERTA (GOVERNMENT), 2009).

There a**re** four various methods or processes to the upgrading process: Thermal Conversion (coking), Catalytic Conversion, Distillation, and Hydrotreating (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014).

(i) Thermal conversion (Coking)

Upgrading processes aim to break the large molecules in bitumen thus reducing its viscosity and the most effective way is by heating the bitumen in a process called thermal upgrading (ZHANG, 2014). Coking is an intense thermal cracking process that involves cracking of long heavy hydrocarbon molecules into smaller molecules using heat (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014) between the range of temperature of 465 - 530° C (ZHANG, 2014). In the process, excess carbon is removed (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; BHATTACHARJEE,

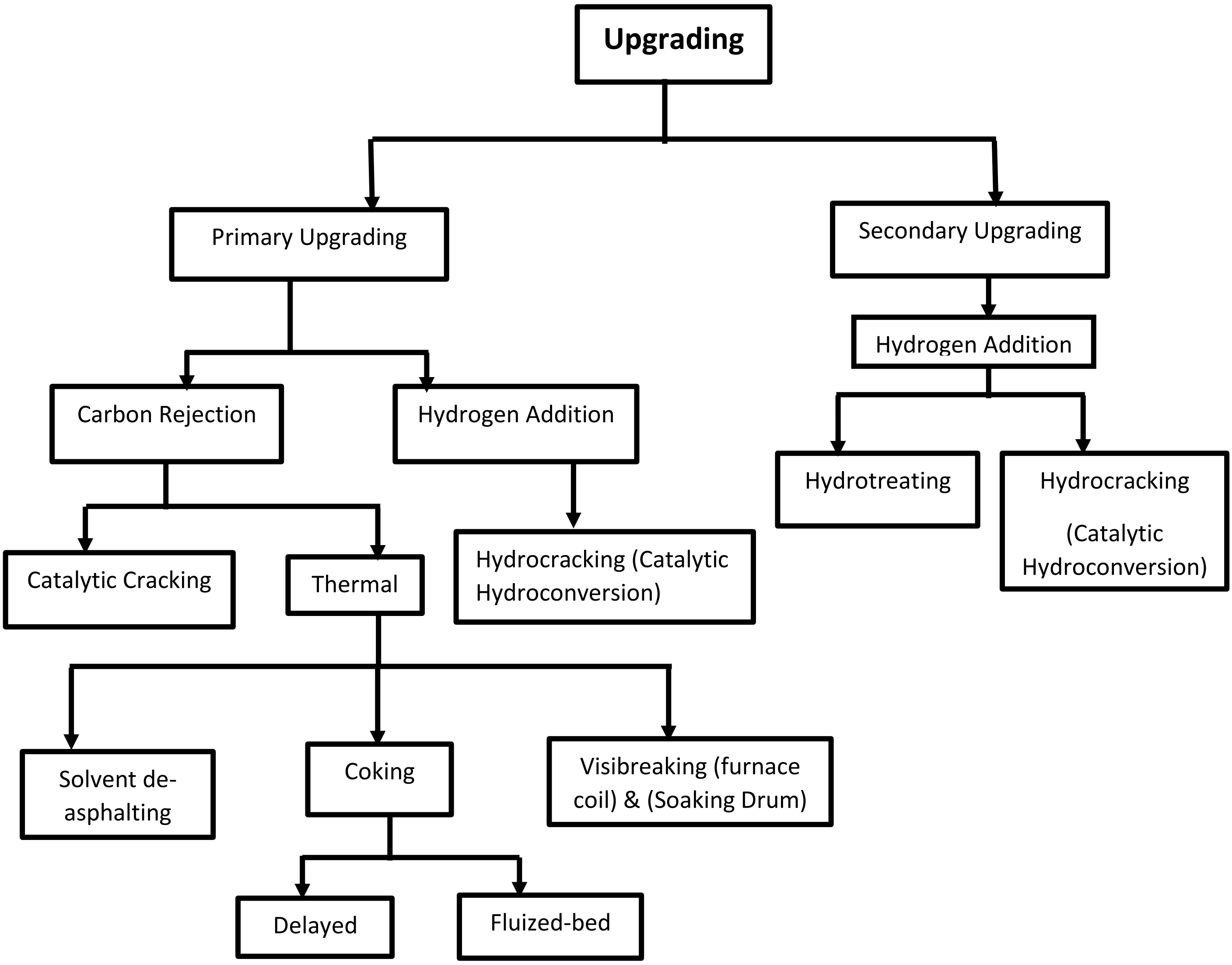
2011) when high temperatures (500°C) crack the bitumen molecules by vaporizing them (GOSSELIN et al., 2010). The excess carbon forms a solid residue called coke which is stockpiled as a by-product (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; GOSSELIN et al., 2010; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014) and the process is known as "coking" (ZHANG, 2014).

The most prevalent method of processing bitumen is "***carbon rejection*"** which typically uses a coking process and produces solid waste as a byproduct (BHATTACHARJEE, 2011). Coking is the most widely used thermal commercial process (BANERJEE, 2012). Oil sands commercial companies use two types of coking process to upgrade bitumen: delayed coking and fluid coking/ flexicoking (GOSSELIN et al., 2010; BRANDT, 2012; BANERJEE, 2012; OIL SANDS DISCOVERY CENTRE, 2014) and majority of the commercial coking processes use the delayed coking technology (OIL SANDS DISCOVERY CENTRE, 2014).

(ii) Catalytic conversion

This helps in transforming hydrocarbons into more valuable forms (BHATTACHARJEE, 2011). It is an enhanced form of thermal conversion because it requires high temperatures and another way in which oil molecules can be cracked into smaller, refined hydrocarbons (OIL SANDS DISCOVERY CENTRE, 2014). Processes exist whereby the thermal upgrading process can be enhanced by use of a catalyst (ZHANG, 2014), and different types of catalysts can be used (shaped like beads or pellets) with the most common being Ni/Mo (Nickel/ Molybdenum) or Co/Mo (Cobalt/Molybdenum) (OIL SANDS DISCOVERY CENTRE, 2014). The process takes advantage of the catalytic surface area to induce molecular breakage or cracking (ZHANG, 2014) when heated bitumen contacts active sites on the catalyst (OIL SANDS DISCOVERY CENTRE, 2014). Sometimes high-pressure hydrogen is added in the process of catalytic cracking. This is called hydroprocessing (OIL SANDS DISCOVERY CENTRE, 2014). Adding hydrogen helps to produce lighter, hydrogen rich molecules (OIL SANDS DISCOVERY CENTRE, 2014). Catalytic conversion has the capacity of producing more upgraded hydrocarbon for refining and is more expensive than thermal conversion or upgrading (OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014).

Figure 1 – Types of upgrading process



Source: Personal file (created by putting different ideas together)

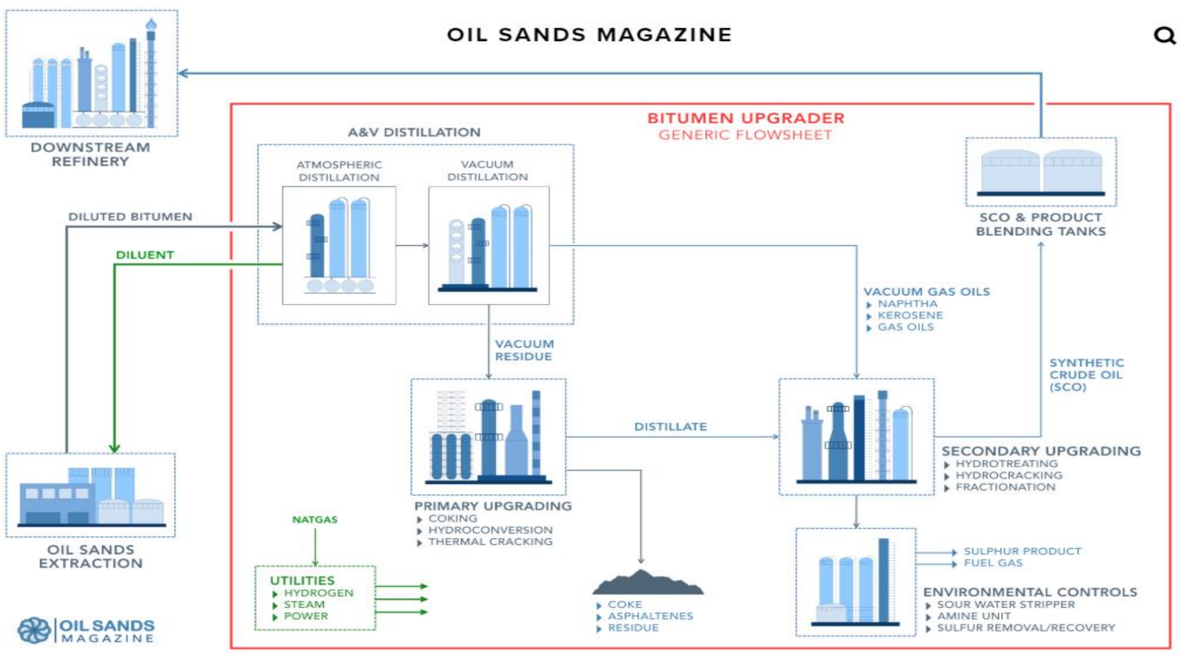
(iii) Distillation

Distillation is a process used to sort mixtures of hydrocarbon molecules into their components part (BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014) taking advantage of the varying boiling points of materials. The lightest hydrocarbons with the lowest boiling points is collected as vapour at the top of the distillation column, while heavier and denser hydrocarbons with higher boiling points collect as liquids at the bottom of the column. The gas vapour condenses into a variety of heavy and light gas oils; kerosene and naphtha (OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014).

(iv) Hydrotreating

The high contents of sulphur and nitrogen in the distillates create the need for extensive hydrotreating (BUTLER, 1991). Hydrotreating is the final stage of a refining process where the hydrocarbon feed is heated to a temperature ranging from 300 to 400°C (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014). In the process, hydrogen is added to the bitumen to bond with the carbon in the molecule, creating more product (OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014), while also removing impurities like sulphur and nitrogen (WOYNILLOWICZ; SEVERSON-BAKER; RAYNOLDS, 2005; BHATTACHARJEE, 2011; OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014). The product, which is a stable crude oil product, can be shipped for conventional final refining (OIL SANDS DISCOVERY CENTRE, 2014; ZHANG, 2014). The carbon-rejection options are all commercially proven and economically attractive residue upgrading options as compared to hydrogen addition (BANERJEE, 2012).

Figure 2 – Upgrading cycle



Source: OIL SANDS MAGAZINE, (2018f)

Carbon-rejection processes: this can be done by a thermal process or by a physical process in which bigger carbon structures, such as asphaltenes, are physically separated by solvent extraction (BANERJEE, 2012). Carbon rejection uses a coking process and a great deal of solid waste is produced as a byproduct (BHATTACHARJEE, 2011). Example of carbon rejection processes is visbreaking (BANERJEE, 2012).

Hydrogen-addition processes: Hydrogen is essential in both primary upgrading by hydroconversion and secondary upgrading by hydrotreating (GOSSELIN et al., 2010). A major step in the upgrading of heavy oil or bitumen is addition of hydrogen and because bitumen is highly deficient in hydrogen and contains high concentrations of heteroatoms and metals as impurities, it is necessary to remove the impurities in the upgraded bitumen to improve the quality and this is done by adding hydrogen (BANERJEE, 2012). Hydrogen addition process, which is hydroprocessing of residue, undergoes a series of reactions:

Hydrocracking: In this first reaction, bigger molecules are cracked, and then the free radicals thus formed are capped by hydrogen, to prevent polymerization reaction toward coke formation (BANERJEE, 2012).

Hydrotreating: In this reaction, heteroatoms and metals are removed. Hydrotreating is a combination of the following: Hydrodesulfurization (HDS), Hydrodenitrogenation (HDN), Hydrodemetallization (HDM) (BANERJEE, 2012) and Aromatic/olefin saturation) (BANERJEE, 2012).

Hydrogenation: This is the simultaneous saturation of aromatics (i.e., done in concert with hydrotreating) (BANERJEE, 2012).

3. ECOSYSTEMS AVAILABLE IN FORIKU-AGBABU AREA OF ONDO STATE, NIGERIA

Probable Affected Ecosystems

Ecosystem	Short description	Pictures
Oil sands fields	Oil sands deposits cut across four different states in Nigeria (Ondo, Ogun, Edo and Lagos States). Most deposits occur in Odigbo and Irele Local Governments area of Ondo State. The oil sands deposits can be mined both by surface mining and secondary recovery methods. Iron ore caves are known for sheltering several new invertebrate species while studies on *campos rupestres* have been revealing so far unknown strategies of plant adaptations to low nutrients soils. *Picture: Oil sands deposit in Mile 2 area of Odigbo Local Government.*	
Forest	Part of the Atlantic rainforest, a biodiversity hotspot (Myers et al., 2000), local forest is characterized by well-defined dry and rainy seasons and high diversity (Ribeiro et al., 2009). This ecosystem is more degraded than the rock fields ecosystem, because it was historically exploited for timber and cleared for agriculture and cattle raising, resulting in a fragmented landscape. The greatest richness of species in the study area is to be found in this ecosystem (MMX/BRANTD, 2007). *Picture: Forest stand in the project area.*	
Aquatic	The iron ore formation is an important aquifer that feeds springs and several small streams themselves draining in a river where water is abstracted for mining purposes. Small rural communities depend on local sources for freshwater supply, recreation, fishing and supplying small ponds for aquiculture. Analyses of water quality indicated a moderate level of pollution, probably caused by local communities without sanitary facilities. *Picture: A large river that runs in between Ilubirin and Mulekangbo communities.*	
Artificial or Human-modified	Agriculture and livestock areas and rural settlements comprise a significant portion of project footprint and its surroundings. This patchy landscape comprises modified ecosystems featuring small forest fragments with low biodiversity and no threatened species, but important as habitat for avifauna and for protecting water springs. *Picture: Ilubirin community featuring cropland, small-scale agriculture and a small homelet.*	

4. IDENTIFICATION AND PRIORITIZING ECOSYSTEM SERVICES

From Step 1			Sub-step 2.1: Could the project affect the ability of others to benefit from this ecosystem service?		Sub-step 2.2: Is this ecosystem service important to beneficiaries' well-being?		Sub-step 2.3: Do beneficiaries have viable alternatives to this ecosystem service?		Priority Ecosystem Service
Relevant ecosystem services	**Potentially affected beneficiaries** *Note: If one ecosystem service benefits more than one group of beneficiaries, add a line.*	**Potentially affected benefits.**	***Y*** *Yes* ***N*** *No (go to next line)* ***?*** *Unknown*	**Comments or supporting information**	***Y*** *Yes* ***N*** *No (go to next line)* ***?*** *Unknown*	**Comments or supporting information**	***Y*** *Yes* ***N*** *No* ***?*** *Unknown*	**Comments or supporting information**	***1*** *Priority ecosystem services* ***0*** *Non-priority ecosystem services*
Impacted ecosystem:	**Forest**								
Wild Food	Farmers	Cocoa	**Y**	The project will supress the forest where the cocoa is been grown	**Y**	They collect cocoa once in four months to sell.	**N**	That is their major source of income	**1**
Wild Food	Farmers	Palm Tree	**Y**	The project will supress the forest where the palm tree is been grown	**Y**	They collect palm tree and process it to palm oil, use it as broom once in four month to sell or to eat.	**N**	That is their major source of income	**1**
Wild Food	Farmers	Bush meat	**Y**	The project will supress the forest where the bush meat is been gotten and most of them will be killed or run away	**Y**	The bush meat can serve as source of income and also as source of food	**Y**	Bush meat can only be found in forest	**0**

Wild Food	Farmers	Fruits	**Y**	The project will supress the forest where the fruits is been gotten	**Y**	The fruits can serve as source of income and also as source of food	**?**		1
Biomass Fuel	Farmers	Charcoal	**Y**	The project will supress the forest where charcoal is been grown	**Y**	The charcoal can serve as source of income and also as source of food	**N**	That is the major thing used in cooking	1
Timber and wood product	Farmers	Paper	**N**	The farmers cant convert timber and wood product to paper	**N**	Most of the people there are not literate	**?**		0
Fibre and Resins	Farmers	Rubber	**Y**	The project will supress the forest where the rubber is been grown	**Y**	They collect rubber once in six months to sell.	**N**	That is their major source of income	1
Impacted ecosystem:	**Pasture**								
Livestock	Families	Chicken	**Y**	The noise from the project activities will scare away livestock	**Y**	It serves as source of livelihood and food.	**?**		1
Livestock	Families	Pig	**Y**	The noise from the project activities will scare away livestock	**Y**	It serves as source of livelihood and food.	**?**		1
Impacted ecosystem:	**River**								
Capture fisheries	Families	Fishes	**Y**	The Project will pollute the river	**Y**	They eat the fishes	**N**	That is a source of food	1
Capture fisheries	Fishermen	Fishes	**Y**	The Project will pollute the river	**Y**	They sell the fishes	**N**	That is their major source of income	1
Capture fisheries	Fishermen	Crabs	**Y**	The Project will pollute the river	**Y**	They sell the crabs	**Y**	Fishes	0
Fresh Water	Families	Drinking	**Y**	The Project will pollute the river	**Y**	They drink majorly water from the river	**N**	That is the major source of water	1
Fresh Water	Families	Mode of Transportat ion	**N**		**?**		**Y**	Road Transportatio n	0
Fresh Water	Families	Household chores	**Y**	The Project will pollute the river	**Y**	The water from the river is majorly used for household chores	**N**	That is the major source of water	1
Fresh Water	Families	Bathing	**Y**	The Project will pollute the river	**Y**	They bath in the river or fetch the water home for bathing	**N**	That is the major source of water	1
Fresh Water	Families	Cooking	**Y**	The Project will pollute the river	**Y**	The water is used for cooking	**N**	That is the major source of water	1
Aquacultur e	Families	shrimps	**Y**	The Project will pollute the river	**Y**	They are major source of income and serve as food.	**N**	Fish cannot replace shrimps during sales.	1

Fresh Water	Families	Reduced flooding	**Y**	The Project will cause flooding of the river	**Y**	Flooding reduces the number of fishes	**N**	River is the only source	**1**
Fresh Water	Families	Reduced siltation	**Y**	The Project will cause siltation of the river	**N**		**?**		**0**
Impacted ecosystem:	**Water**								
Hand dug well	Families	Drinking	**Y**	The Project will pollute the well	**Y**	They drink majorly water from the river	**N**	That is the major source of water	**1**
Hand dug well	Families	Household chores	**Y**	The Project will pollute the well	**Y**	The water from the well is majorly used for household chores	**N**	That is the major source of water	**1**
Hand dug well	Families	Bathing	**Y**	The Project will pollute the well	**Y**	They bath in the river or fetch the water home for bathing	**N**	That is the major source of water	**1**
Hand dug well	Families	Cooking	**Y**	The Project will pollute the well	**Y**	The water is used for cooking	**N**	That is the major source of water	**1**
Impacted ecosystem:	**Land**								
Crops	Families	Vegetables	**Y**	The project include clearing of lands	**Y**	It's a source of food	**N**	Because its free for them, they can easily plant at the back of their house	**1**
Crops	Families	Plantain	**Y**	The project include clearing of lands	**Y**	It's a source of food	**N**	Because its free for them, they can easily plant at the back of their house	**1**
Impacted ecosystem:	**Forest and River**								
Regulation of water timing and flow	Families	Good health	**Y**	The project include clearing of lands and siltation of rivers	**Y**	It reduces flooding of the community	**N**	It's only the forest that can serve this purpose	**1**
Regulation of disease	Families	Good health	**Y**	The project include clearing of lands and siltation of rivers	**Y**	It keeps the community in good health	**N**	It's only the river that can serve this purpose	**1**
Water purification and waste treatment	Families	Good Health	**Y**	The project include clearing of lands and siltation of rivers	**Y**	It keeps the community in good health	**N**	It's only the river that can serve this purpose	**1**
Pollination	Families	Good health	**N**	The ecosystems are not affected	**N**	No pollination needed	**?**	No alternative needed, since there is no pollination	**0**
Regulation of natural hazards	Families	Good health	**N**	The ecosystems are not affected	**?**	There are no natural disasters	**?**	No alternative needed, since there is no hazard	**0**

Impacted Ecosystem:	Forest and River								
Ethical and spiritual values	Families	Life style	**Y**	The project include clearing of lands and siltation of rivers	**Y**	The river serves as a place of worship	**N**	The river is of spiritual value	**1**
Educational and inspirational values	Families	Added knowledge	**Y**	The project include clearing of lands and siltation of rivers	**Y**	The forest increases the student knowledge	**N**	The forest add to the knowledge of the community	**1**
Recreation and ecotourism	Families	Knowledge and lifestyle	**N**	The area cannot be used for recreation	**N**	Most of the villagers are not educated	**Y**	Other recreation facilities can be used	**0**
Impacted Ecosystem:	Forest and River								
Habitat	Families	Health	**Y**	The project include clearing of lands and siltation	**Y**	The forest serves as habitat for plant and animals	**N**	It's only the forest that can serve this purpose	**1**

5. PROJECT'S IMPACTS ON ECOSYSTEM SERVICES

Project	ES associated with each Project	Comments or Supporting Information
Deforestation	Wild food, Biomass fuel, Fibre and Resins, Crops, Regulation of disease, Educational and inspirational values	Activity includes majorly cutting of trees that will majorly affect Wild Foods, Biomass Fuel, Fibre and Resins, which are all trees in the forest. It will have major impact both on the community and the ESs because it destroys the ESs will be destroyed and the services rendered to the community which is their daily job (farming) will also be destroyed. The crops will be destroyed too, which is a major effect. It also has a major effect on the educational and inspirational value because once this ES is destroyed the value is destroyed with it. It moderately affect Regulation of disease; and regulation of water timing and flow, the service provided by forest helps in the reduction of occurrence of stagnant water, which is a breeding are for mosquitoes thereby preventing malaria.
Road Construction	Livestock, Wild food, Biomass fuel, Fibre and Resins, Crops, Aquaculture, Fishes	During road construction, there will be deforestation and clearing of bushes, which will majorly affect Wild food, Biomass fuel, Fibre, and Resins. This will majorly affect the Crops because the crops will be cleared during the construction of roads. Aquaculture and fishes will be affected in a minor way because of dust pollutions in ponds. Noise pollution can drive away livestock land they will tend to leave the area, which will cause a minor impact.
Site Planning	Wild food, Biomass fuel, Fibre and Resins, Habitat	During site planning, deforestation will occur which will majorly affect Wild food, Biomass fuel, Fibre and Resins. In addition, habitats, which is a natural survival area for animals, will be affected in a moderate way.
Equipment and Machineries Installation	Livestock, Habitat, Crops	Noise from this activity will moderately affect habitat. Dust will have a minor effect on the livestock.
Construction of Mine, Site Buildings and offices	Wild food, Biomass fuel, Fibre and Resins, Habitat	It will majorly affect Wild food, Biomass fuel, Fibre and Resins, because during construction, there will be cutting and clearing of trees. It will moderately affect Habitat.
Hole drilling and blasting activities	Water purification and waste treatment, Habitat, Freshwater, Fishes, Aquaculture	This activity involves dust pollution. It will moderately affect the services of Water purification and waste treatment; Freshwater; Ethical and spiritual values; and Habitat. It will have minor effect on livestock, fish and aquaculture through noise pollution.

Major significance: This shows that the extent of the impact is in large scale as a result of high sensitivity to change, and the impact is of regional importance and will be long term in nature, certain or likely to occur.
Moderate significance: This is where the extent of the impact is in medium scale as a result of lower sensitivity to change, and the impact is of district or local importance and will be medium or short term in nature and likely to occur.
Minor significance: This is where the extent of the impact is low or barely noticeable as a result of low sensitivity to change, and the impact is of local importance and will be short term in nature and unlikely to occur. (WOOD, 2008)

6. PROJECT'S IMPACTS ON ECOSYSTEM AND HUMAN WELL-BEING

	PRIORITY ECOSYSTEM SERVICE	SUB-CATEGORIES	BENEFITS OR E.G OF SERVICE	BENEFICIARIES	PRE-MINING IMPACT ON ECOSYSTEM	PRE-MINING IMPACT ON HUMAN WELL-BEING
Provisioning	Livestock	**Food**	Livestock can be raised for Human Consumption; Domestic Purpose; and Commercial Purpose	Communities	There will be loss of lands used in raising livestock due to conversion of rural areas to industrial area.	There will be decrease in income and food obtained from livestock rearing
	Crops		Crops can serve as Food for Human Consumption; Animal Consumption; and for Commercial Purpose.	Communities	**There will be loss of croplands due to conversion of rural areas to industrial area.**	**There will be decrease in income and food obtained from livestock rearing**
	Captured Fishes		Captured Fishes can serve as Food, and for Commercial Purpose	Communities	There will be reduction of numbers of fishes in the river due to siltation of rivers	There will be loss of food and income obtained from fish sales
	Aquaculture		Aquaculture can serve as Food, and for Commercial Purpose	Communities	There will be reduction of numbers of aquaculture due to siltation of rivers	There will be loss of food and income obtained from aquaculture sales
	Wild foods		Wild Food can serve as Food and also for Commercial Purpose	Communities	**There will be deforestation**	**There will be loss of jobs due to deforestation of cocoa and palm trees**
	Biomass Fuel	**Fuel Wood**	Fuel wood Like Charcoal Use for Cooking and also for Commercial Purpose	Communities	**There will be limited access to timbers and firewood because of deforestation**	**There will be increase in the cost of living**
	Freshwater	**River**	Fresh Water for Drinking and Cooking, Cleaning, Household Chores, Bathing and Mode of Transportation	Communities	*There will be pollution of river by siltation*	*There will be increase in the cost of living because freshwater is a major source of water*
	Fibre and Resins	**Biological Raw Material**	Product can serve as Food, Paper and for Commercial Purpose.	Communities	**There will be deforestation**	**There will be loss of jobs and means of living**
Regulating	Regulation of disease (forest)	**Forest**	Wetlands remove harmful pollutants from water by trapping heavy metals	Communities	*There will be deforestation and thereby increasing the occurrence of stagnant water*	*There will be increase in the breeding of mosquitoes which causes malaria*
	Regulation of water timing and flow (river)	**River**	River Floodplain and Wetland retain water which can decrease flooding	Communities	*There will be increase in erosion and flooding*	*There will be loss of land and property*
	Water Purification and Waste Treatment		Wetlands and rivers helps in the purification of waters	Communities	*Siltation of river*	*It affects the health and well-being of the community*
	Regulation of disease (river)		Some Forest reduces the occurrence of stagnant water (a breeding area for mosquitoes) which causes malaria	Communities	*There will be pollution and alteration in the water quality because of siltation of the river*	*There will be increase in health care services*
Cultural	Educational and Inspirational values	**Forest**	School fieldtrips to nature preserves aid in teaching scientific concept and research skills	Communities	**There will be loss in ecosystem value**	**There will be reduction in area of research and field trip areas**
	Ethical and Spiritual value	**River**	It provides spiritual fulfilment to the community	Communities	*Siltation of river*	*The spiritual and ethical value is lost*
Support	Habitat	**River and Land**	It serves as reproduction places for plants and animals	Plants and animals	*There will be pollution of river by siltation and destruction of forest*	*It reduces the numbers of animals and affects plants growth*

BLUE: Impact of major significant, *Black Italics*: Impact of moderate significant, and Red: Impact of minor significant

7. SOCIAL LICENSE TO OPERATE

There are many controversies and misunderstandings involving mining companies and communities (SMITH; RICHARDS, 2015), which may be a result of different expectations by both parties and distrust from the community (QUIGLEY; BAINES, 2014). The oil sands communities expressed their feelings on the commencement of mining activities. The *bituminous natural effects* were of major concern to the community, despite the non-exploitation activity in these communities; the oil sands have posed several natural threats to the villagers. The community members complained of contamination of farmland as a result of seepage of bitumen during the dry season, which affects their vegetables, plantains, cocoa, and rubber plantations. Majority of these community members are farmers and are therefore of the opinion that the *bituminous natural effects* is a threat to their major source of income. This bitumen also seeps inside the hand-dug well, which is a major source of water for the community.

The company must therefore have a better understanding of the community of whom they are dealing with. Before starting negotiations, they should hire professionals, especially anthropologists and sociologists, trained to understand other people's points of view, to assess the communities and to know the different types of stakeholders that exist within and outside them. This is important because the communities are not homogeneous, and different communities have different views and attitudes towards mining, as could be seen in this study, where the mere application of the questionnaire led to difficulties in one of the communities while not in the other two. In order to obtain an SLO from the communities, there must be transparency on the impacts of pre-mining activities, both the negative and the positive impacts, also, there must be conviction that the mining of the oil sands deposit will be of advantage to the communities.

Some strategies to address the challenges identified in the results are presented and discussed below.

Addressing the socio-environmental and economic aspects of pre-mining activities using the sustainability approach. The challenges associated with ways to mitigate the negative impact of pre-mining activities on socio-environmental and economic aspects of the community were addressed using the sustainability approach. This approach balances the economic, social and environmental considerations in the pre-mining phase.

The environmental effects of pre-mining activities, which include ecological disruption, water pollution, soil pollution and contamination of farmlands (KUMAH, 2006) will be detrimental to the local community. The mining company can minimize the disruptive effects of its activities on the environment, the communities' livelihood sources and the socio-cultural aspects through technological solutions. Mitigating measures, which include using mining methods that impact the smallest surface area possible, controlling pollution of air, land and surface and ground water, and promoting the maintenance of social and cultural aspects in the relocated settlements, should be implemented. There should be compensations for unavoidable negative impacts by improving other aspects of the community's livelihood, which may include improvement of the infrastructure and access to microcredit services. These actions lie outside the company's specific sphere of activities; they are a compensation for impacts that cannot be mitigated, like disturbance of the landscape, destruction of cultural or affective values, and disruption of the community members' way of life. This pre-mining stage is usually considered as the stage in which the mining company can establish its commitment to the community because the major activities carried out during this stage have lots of negative impacts on the community.

In the case of the communities studied, this is true because their farmlands will be destroyed and their rivers will be polluted. Therefore, compensating farmers by offsetting for loss of farmlands, provision of wells or boreholes and spraying of water during dust pollution can help mitigate the environmental effects of pre-mining.

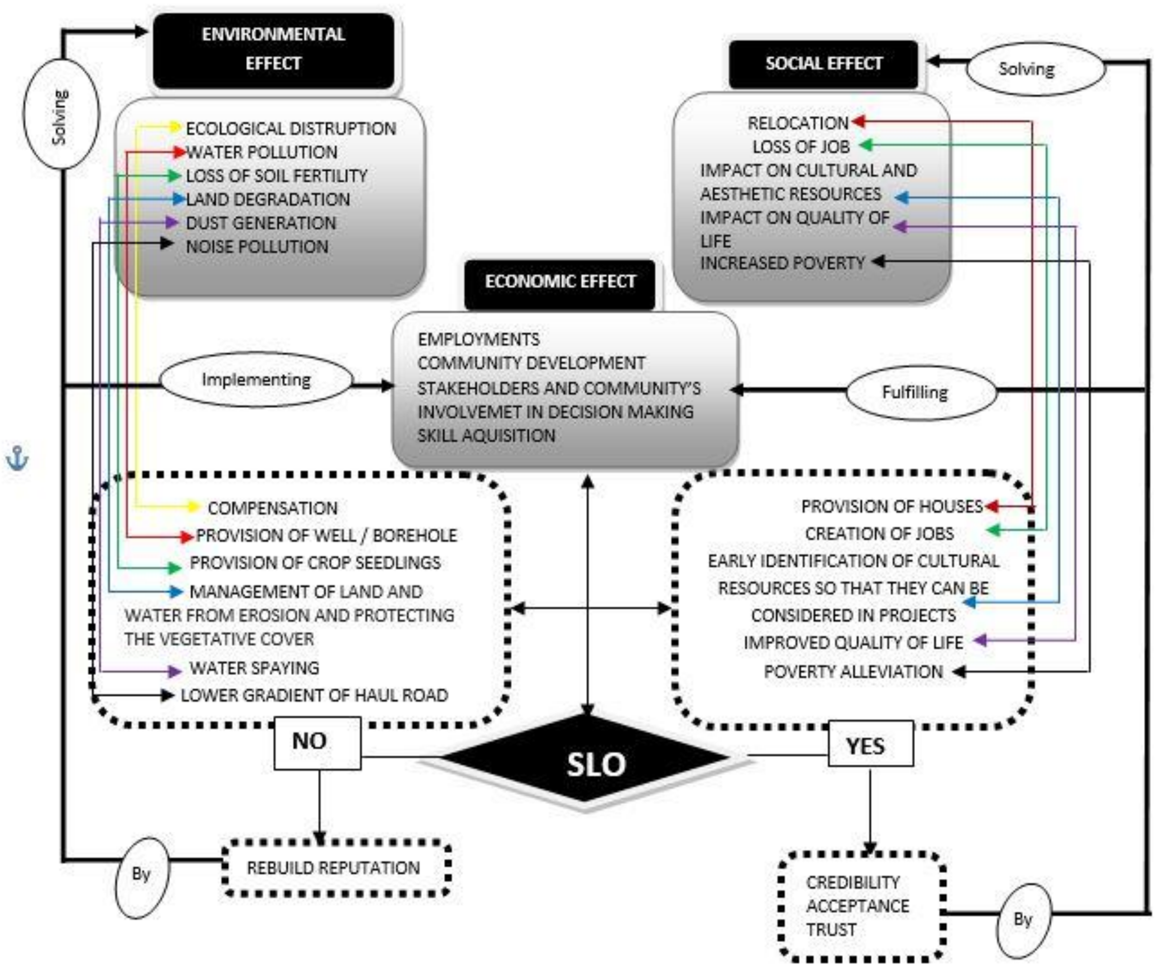
Pre-mining social effects, which include relocation, loss of jobs, and impacts on cultural and aesthetics resources (KUMAH, 2006) will negatively affect the community**.** As previously stated, the oil sand blocks are located less than one kilometer from the study area, and therefore relocation of some communities will be necessary for the mining company to proceed to the exploitation phase. Although many of the people questioned agreed to relocate if properly compensated, an effective resettlement plan needs to be drafted by the mining companies. In addition, the possibility of farmers securing immediate jobs is low; therefore, the mining company should endeavor to provide jobs to alleviate poverty in the region. There should be an early identification of cultural and aesthetic resources in the communities for consideration of alternatives during the pre-mining project phase. Involvement of community leaders in issues related to cultural and aesthetic resources is important, as it may encourage the community to accept the project and provide a cooperative work atmosphere.

The economic aspects are not a result of pre-mining activities, but refer to those conditions that already exist in the communities before the mining company arrives in the region. The results of this study evidenced a lack of infrastructure, bad roads, lack of health care and lack of technical knowledge about mining activities in the communities investigated. Optimization of positive economic impacts, which include the payment of royalties, is very important, as it will allow the improvement of living standards in the region without putting the responsibility of developing it entirely on the company, opening opportunities for local people to work in the mine and offering training and capacitation in new professions. This will ensure that part of the money generated by the operation returns to the community.

The economic benefits are considered as a positive contribution given by the mining company to the community (MOFFAT; ZHANG, 2014; WORRALL et al., 2009).

The action taken by the mining companies to solve the pre-mining effects can lead to either the approval or withdrawal of the SLO. Mining companies must have plans to dialogue with the communities on how to go about relocation and deforestation. After this dialogue, actions should be taken to implement some of the proposed solutions to the socio-environmental and economic problems, thus leading to obtain the social license, which may be either approved or withdrawn depending on whether the project yields benefits to the communities. GOSSELIN et al., (2010) describe the economic factor as the major driver in decision-making and that the implementation could affect the approval of SLO. GUNNINGHAM; KAGAN; THORNTON (2004) said the level of support 'granted' is considered dependent on society's expectations on the company conducts of operations and the extent to which those expectations are met. This implicates that the fulfilment of the agreement made by the company can have a big impact on the approval of SLO by the community (OMOTEHINSE; TOMI, 2019).

Figure 6: The critical elements of a social license to operate (SLO)



Source: Personal file

If the license is approved, it means the actions taken fulfilled the company's promises and it is thus considered credible. At this level, the company can have access to the mineral resources, with the community having a positive outlook towards the project and expecting fair dealings (SMITH; RICHARD, 2015). If the SLO is withdrawn, it means the legitimacy of the interested company is unknown and the SLO has not been granted; the company can review its actions and work towards rebuilding its reputation in order to be able to develop the resources (SMITH; RICHARD, 2015; BOUTILIER; THOMSON, 2011). When the company fulfills the boundary criteria of legitimacy and credibility, it will reach the SLO's level of psychological identification because it will have gained the community's full trust (SMITH; RICHARD, 2015; BOUTILIER; THOMSON, 2011). The company must gain its credibility and trust from the community in order to reduce or prevent delays that might increase the cost of production (OMOTEHINSE; TOMI, 2019).

Addressing the challenges of communication and lack of communities' knowledge of the impacts of mining activities through education. Nigeria is a country with very diverse languages, and it will be difficult for all the community members, especially the elders, to learn a new language. Therefore, for the company to be able to communicate with the community's members and inform them about oil sands mining activities and their impacts, a liaison officer is needed. The officer must be a literate person who understands the region and the language, probably a mining engineer, who will communicate easily, educate the people of the local community about the mining project and adequately provide the information they require.

The impacts must be explained to community members, making sure they understand that some negative impacts will be unavoidable. The company, indisputable representatives of the communities, and all interested parties must discuss the possible measures for mitigation, compensation and optimization. Local disputes must be addressed and resolved, there must be ongoing dialogue between both parties, and the mining company must be prepared to convince the community to reach an agreement that its members fully understand and that takes into account their needs and wishes.

Reaching a company-community agreement through the establishment of a relationship with the community. For an agreement between the company and community to work both parties have to respect it. The company must not give benefits only to bribe the communities into accepting whatever it wants to do and whatever impact the mining activity will cause, but must be genuinely willing to improve the local population's living standard, thus generating peaceful coexistence and cooperation and ensuring an uneventful mining operation.

The oil and gas sector conflicts in Nigeria demonstrated that the conflict between the communities and the company was not resolved until the company took on its social responsibility (GROVES, 2009). The challenge of how to reach an agreement between the company and the community can be solved through the establishment of company-community relations that help the company learn how to contribute to the community in terms of CSR. The mining company must have a representative that will monitor each project in a given community; this will help to reduce corruption among community leaders and to assess the progress of each project.

Other areas where the company can undertake actions to establish a good relationship with the community are:

- Health: At present, only 15 out of the 100 respondents of the communities surrounding the mine have access to potable water, so the installation of potable water will give the remaining of these communities new access to potable water, thereby contributing to the overall increase in access to potable water. In addition, it can be seen that the health center built by the government is old and dilapidated, so that building new facilities and bringing new medical technology to the area might be useful measures to compensate the community for the disruption caused by pre-mining activities**.**
- Education: as the results show, there are no schools in the communities; the nearest school is located outside. Therefore, building modern schools with good teachers and teaching facilities might be an additional measure for gaining approval of an SLO.
- Providing support for businesses: Mining companies may provide microcredit loans for serious and interested people for a short period, thereby expanding the project's contribution to the socio-economic development of the region.
- Quality of life: Improving the living standard for many families might be another measure to get an SLO. Providing electric power might also contribute to the overall increase in quality of life, since, as the results show, electricity is not available to the communities.
- Employment: If the company can employ some of the villagers that are willing to be part of their workforce as drivers, technicians or in some other capacity, and set up an institutional capacity to train the local workforce in skills that will be needed, it might prove greatly advantageous to both the company and the community.

Gaining the trust of the community by explaining the positive consequences of the mining project and fulfilling the agreement. The mining company must be able to convince the community that the exploitation activities will benefit them, and that the previously described benefits present an ample array of possibilities. Implementation of benefits will depend on the guidance of the community itself, as it must state what it wants. Fulfilment of these promises is also very important. The social demands of the stakeholders must be considered a priority in decision making. A spirit of trust and cooperation needs to be established between the company and the community. The mining company must gain the full trust of the communities and avoid losing credibility, for, once it is lost, the company's reputation will suffer. Any form of distrust would incur in greater expense than what would be spent to gain the community's trust. Trust is a major factor in social acceptance of mining activities (MERCER-MAPSTONE et al., 2018).

Addressing the hypothetical or possible challenges

***Demand for greater portion of benefits than the ones envisaged by the company*.** A proper economic and environmental assessment must be made to obtain knowledge about the areas that will be affected by mining activities. A technical detail of how many hectares of land are available, the types of plants grown and the landowners should be carried out. The mining company must offer a reasonable price when offsetting and this should be discussed with all the community members involved in the ownership of the land or businesses, either male or female, young or old. Negotiations should include all the affected members before offsetting. The community must not become greedy and demand more than it has agreed to receive. Excesses and faults from both parties – from the company and the community - must be detected and addressed, before any unrest or violence arise. In addition, it is important to have an external neutral observer/judge to help decide any disputes that may arise.

Community demands to be part of the decision-making process. This mostly happens when the mining company is not truthful about the impact its operations will cause and does not fulfil its promises, which may lead to protests. The company's representatives must be in constant communication with the community to identify important issues, especially culture-related ones. In addition, mining companies should make the interest of the community a priority.

***The actual impact of the pre-mining operation on the community might differ from the expected impact, which may lead to protests*.** This can be resolved by educating the community members, as discussed above. The mining company should be transparent and truthful about the impacts of mining, without withholding any information from community members.

Identification of the people that comprise a given community. In order to identify the group of people that comprise a community, we must know what a community is. Authors such as

VANCLAY et al., (2015) and HOWITT (2011) have defined the concept of community. However, the definition from PRNO; SLOCOMBE (2012), given in the context of SLOs, is the one adopted in this work. According to these authors, local communities are often authorities in the granting of SLOs because they are located in the mining project's vicinity and have the ability to affect its outcome. Therefore, communities are local residents living within the mining region, referred to as a host community, i.e. a group of people that are/will be affected by the mining project or a group of people that can influence the development of the project at the local level (LESSER; SUOPAJÄRVI; KOIVUROVA, 2017).
Mining companies must therefore be able to map out the different communities in the sense described above, in order to minimize marginalization of local inhabitants.

Ensuring an equal distribution of benefits among different communities and groups. To address this problem, the company must identify the areas that mining activities will affect, i.e. farmlands and houses that will be demolished. Communities must coordinate themselves to know what to demand from the mining companies during offsetting. Different groups' representatives must be vocal and share the same interests and views. The mining company must have a local representative that will help with interactions with the local communities and bargain with them.

Encounter with different communities that do not share a common vision of the project. The company needs to undertake a social assessment of the communities to understand their social structure. The company must spend money, time, and effort to understand the needs and visions of the communities that will be impacted. It should hire an anthropologist that can analyze the local network and the issues of the various individuals and groups in the community.

After much deliberation, most of the community members believed that oil sands mining will eventually bring development to the community and if properly compensated, most of the community members will be ready to accept relocation as supported by the findings from the questionnaire. Most of the people (85%) acknowledged that the community has been in isolation for a long time, and consequently believe that if mining starts, it will be an advantage for both the government and the immediate society.