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Oil sands

A landscape based design approach towards a more sustainable landscape system

Anne Nijland and Floortje Goossens

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Master Thesis Landscape architecture, 2014
[LAR-80436]
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 This publication is written as a fi nal master thesis in landscape architecture by order of the chairgroup of landscape architecture at Wageningen University.

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Preface

In front of you, you see the presentation of the results of our Thesis. We, Anne Nijland and Floortje Goossens two landscape architecture students, worked on this project to finish our master program.

This thesis, focused on the oil sands industry in Alberta Canada all started with a newspaper article in combination with our fascination for industrial landscapes. In here we mainly refer to the contrasts and tensions between the cultural and natural systems in these landscapes. The journey of this thesis started in the Netherlands. After some research we came to the conclusion that more in-depth knowledge according the topic was necessary to obtain an objective view as a researcher. For that reason we continued our research at the University of Edmonton for three months. Here we talked with as many people as possible about the oil sands industry and its developments. By doing this we were able to gain knowledge which we otherwise would not acquired.

This knowledge served as the main input for our further research and helped us to delineate our research, to finally develop a more sustainable approach in dealing with the occurring problems in the oil sands industry.

During the timespan of this thesis several people helped and motivated us time after time and we would like to thank them for that. First of all both our supervisors: Dr. Ir. Ingrid Duchhart, thanks for your enthusiasm and your advice and Ir. Paul Roncken, for all your comments and inspirational talks.

We further want to thank our external supervisors Dr. Ir. Kristof Van Assche for sharing his vision with us according the developments and Dr. Beverly Sandalack for her inspiring words during our fieldtrip and further advices.

We also want to thank Chris Geerling for sharing his experiences with us in the field of the oil industry. Last but certainly not least, we want to thank our friends and family who kept on motivating us and distracted us from work when this was necessary.

Summary

The oil sands industry in Alberta, forms the third biggest oil resource in the world nowadays (Government of Alberta, 2014). When the first mine opened located North of Fort McMurray, people were skeptical whether this method of oil extraction could ever be profitable. This mainly had to do with the fact that the oil containing components which are called bitumen are mixed with sand, water and clay. This means a complicated and highly energy consuming process is necessary to separate the bitumen to finally upgrade it to synthetic crude oil.

Bitumen, has to be removed from the sands using either open pit mining or in situ methods, we will focus on the mining which takes place in the Athabasca area. This leads to massive surface disturbance. To separate the bitumen from the sand and clay, it is mixed with hot water This water is extracted from the nearly located Athabasca River, which is an important landscape element from both socio-historical perspective as well as natural perspective. After the separation process water is too polluted to be returned back into the river and stored in enormous tailings ponds. While a significant amount of water, 40-70%, from the tailings ponds can be recycled and used again as process water (Pembina institute, 2009), a significant amount of polluted water remains in the tailings ponds, possibly indefinitely (NRTEE, 2010). As a result, more and larger oil sands tailings ponds have been developed over the years and extraction from the Athabasca river continues.

Besides these environmental problems, the region also struggled with various social problems. From an isolated region in the sub-arctic, dominated by first nations accustomed to a life style of hunting and gathering, the region, with Fort McMurray as regional hub, had to deal with an intense and prolonged flow of people who came to work in the area (Pembina Institute, 2005). This city has come to embody the challenges and pressures of an archetypal boomtown (Alberta Municipal Affairs 1980; LeRiche 2006, Ferguson, 2001).

A lot of research and developments are going on to tackle these diverse problems caused by the oil sands industry. Operating companies taking it at heart and willing to change things, however problems are tried to solve very discipline-specific and mainly done from an industrial, environmental or social perspective. A more comprehensive way of looking at these integrated problems are not taken into account.

We as landscape architects known for taking a comprehensive and integrative approach, when addressing problems like the developments taking place in the oil sands industry, can help to bridge the contrasts between industry, environment and society.

In here we start from the systems way of thinking about landscape to finally develop a more sustainable landscape for the Athabasca oil sands region. To be able to achieve this we asked ourselves the following research question:

How can a more sustainable landscape system be developed in the Athabasca oil sands industrial region by using a landscape based design approach?

To be able to answer this question, in-depth knowledge about the landscape system was necessary, we therefore used several methods. We first did a landscape analysis on three different levels: the landscape, the industrial workings and peoples perspective, all this to get a better understanding of the landscape system how these processes influence each other. The method research through designing played an important role to get grip on these data as well. Besides that, several semi-structured interviews where done to obtain knowledge about people's perspectives and requirements for the future landscape.

The data gathered in these three analysis parts where used as input for our design towards a more sustainable landscape. Important to mention is that this design is not a blue print design but a design consisting of several design solutions which develop in time. These design solutions involve a wetland treatment system to clean the process affected water, a new way of reclaiming the open pit mine and a robust recreational network to fulfill people's requirements .

In final, when returning back to our main research question, it can be said that we are able to develop a more sustainable landscape, by means of our developed design solutions that seek to integrate the social, environmental and industrial layers together.

Samenvatting

De oliezand gronden in Alberta vormen tegenwoordig de derde grootste olie-bron in de wereld (Government of Alberta, 2014). Toen de eerste mijn opende in het gebied ten noorden van Fort McMurray, waren de meeste mensen sceptisch over deze vorm van olie-winning. Dit werd voornamelijk veroorzaakt door het feit dat het olie houdende component in deze gronden, die ook wel bitumen worden genoemd, is gemixt met zand water en klei. Dit betekend dat een ingewikkeld en een energieverslindend proces nodig is om de bitumen te verwerken tot synthetische ruwe olie.

De extractie van bitumen uit de grond wordt gedaan middels twee methoden: de eerste methode betreft open pit mijnbouw en de tweede methode door middel van stoom- injectie. In deze thesis wordt er gefocused op het gebied waar mijnbouw plaatsvindt, dit is het Athabasca gebied. Deze activiteiten veroorzaken enorme oppervlakte verstoringen. Om vervolgens de bitumen van het zand en klei te scheiden, wordt het gemixt met warm water. Dit water wordt onttrokken uit de nabij gelegen Athabasca rivier. Deze rivier vormt een belangrijk element in het landschap zowel vanuit het sociale-historische perspectief als het natuurlijke perspectief. Na dit scheidingsproces is het gebruikte water te vervuild om terug te storten op het rivier systeem, daarom wordt dit water gedeponeerd in enorme afvalbassins. Van dit water wordt ongeveer 40% - 70% weer gebruikt in het industriële proces (Pembina institute, 2009). Dit betekend dat een grote hoeveelheid vervuild water achter blijft in deze afvalbassins. Dit resulteert in steeds groter wordende afvalbassins en het voortduren van de extractie van het rivieren systeem.

Naast deze milieu gerichte problemen, kampt de regio ook met een aantal problemen op sociaal gebied. Van een geïsoleerde sub-arctisch regio bewoond door indianen kenmerkend voor hun levensstijl die bestond uit jagen en verzamelen, moet de regio nu omgaan met een intense en langdurige stroom van mensen die naar het gebied komen om te wonen en te werken. Hierin is Fort McMurray aangewezen als het centrum (Pembina Institute, 2005).

Op het moment is er veel onderzoek en ontwikkeling gaande om beter om te kunnen gaan met deze genoemde problemen veroorzaakt door de oliezand industrie. De opererende bedrijven zijn bereid dingen in hun werkwijze te veranderen. Maar meestal wordt geprobeerd deze problemen discipline specifiek op te lossen. En wordt hierin voornamelijk geopereerd vanuit een industrieel, milieu of maatschappelijk perspectief. Een meer alomvattende manier van het kijken naar deze problemen komt niet in aanmerking.

Wij als landschapsarchitecten staan bekend voor onze alomvattende en integratieve manier van werken. Deze aanpak zou kunnen werken om de contrasten tussen de industrie, het milieu en de maatschappij

te overbruggen. Hierin zien wij het landschap als een systeem om uiteindelijk een meer duurzaam landschap te ontwikkelen voor de Athabasca oliezand regio. Om dit te kunnen bereiken hebben wij onszelf de volgende vraag gesteld:

Hoe kan een meer duurzaam landschapssysteem ontwikkeld worden in de Athabasca olliezand industriële regio, door gebruik te maken van een op het landschap gebaseerde ontwerp aanpak?

Om een antwoord te kunnen geven op deze vraag, was diepgaande kennis over het landschappelijke systeem nodig. Hiervoor hebben we verschillende methodes gebruikt. We zijn begonnen met een landschapsanalyse op drie verschillende vlakken: het landschap, het industriële proces en het perspectief van mensen tegenover de ontwikkelingen. Dit allemaal om een beter begrip te krijgen van het landschappelijke systeem en hoe bepaalde processen elkaar beïnvloeden. De methode ontwerpend onderzoek heeft in dit proces een belangrijke rol gespeeld. Daarnaast hebben we semi- gestructureerde interviews gedaan om kennis te verkrijgen van bepaalde perspectieven van mensen en hun wensen voor het toekomstige landschap.

De data gegenereerd in deze drie analyse onderdelen werd gebruikt als belangrijke input voor het ontwerp. Belangrijk om te weten is dat het ontwerp geen blauwdruk ontwerp is, maar dat het zal bestaan uit verschillende ontwerpoplossingen die ontwikkelen met de tijd. Deze ontwerp oplossingen betreffen een natuurlijk purificatie systeem om het proces beïnvloeden water schoon te maken, een nieuwe manier van omgaan met het herstel van de open pit mijn, en de ontwikkeling van een robuust recreatie netwerk om te voldoen aan de wensen van de mensen wonende in het gebied.

Om uiteindelijk terug te keren naar onze centrale onderzoeksvraag kan er gesteld worden dat het mogelijk is een meer duurzaam landschap te ontwikkelen. Dit door middel van het ontwikkelen van ontwerp oplossingen die proberen het industriële, de sociale en de milieu gerelateerde laag met elkaar te verbinden.

Content

1. Introduction

This chapter is an introduction into the topic of this thesis: “The Athabasca oil sands region”. This first starts with the fascination we as researchers have for the industrial landscape in contrast with natural system. After this a global context will be outlined in order to be able to introduce the problems that occur in the area. From here the research questions will be explained, with these questions we try to find the answers to tackle the several problems occurring in the Athabasca oil sands region.

Introduction

1.1 Fascination

In the pre-industrial world, solar-powered ecosystems supported the human economy. There was a low generation of pollutants and a high degree of recycling (Day et al., 2009). This changed dramatically about two centuries ago, with the beginning of the industrial revolution.

Population growth leaded to an increase in the use of fossil fuels

Human population grew tremendously and the use of fossil fuels expanded. We nowadays have already used up half of our conventional resources. Industrialization in the Athabasca oil sands region began, of course, a lot later. The opening of the first commercial mine in 1967 can be seen as the beginning of this period.

This resulted in more industrial landscapes and that is where our fascination starts

Its about the tension between the natural and cultural system

This industrial landscape is, where our fascination started. To our opinion they are one of the most outspoken cultural landscapes. They represent a reflection of today's society. The beauty lies in the dynamics of such a place, and the tension between the natural system and the cultural system where technological and economic progress is accompanied with industrial development. Which is perfectly shown in the following photo (fig 1.1). This picture is taken

Fig 1.1: ´The tension between the natural and cultural system´

from an airplane and immediately shows the tension between the two worlds.

Developments are horrifyingly beautiful, in a very surprising way. The scale and extent of the operations, and the disturbance, is really shocking, however, there is also something about the scale and extent that is also equally impressive (Interviewee 14, 2013).

The oil sands developments are shocking but overwhelming as well

Besides the beauty that this area, to our opinion, possesses it is also a highly discussed and debated topic since the intensifying industry causes a lot of harmful effects on human health and nature.

This highly debated topic causes a lot of problems on human and nature

Over time, three different worlds have been developed, the people living in the area with Fort McMurray as centre, the oil sands industry and their enclosed mine sites, and nature which is fragmented between these worlds.

Since industrial developments going on three different worlds have been developed: the industry, people an nature

As a landscape architect, you can't just let this happen. Reading about these developments happening in the oil sands, triggered us as landscape architects to do better.

We have seized this challenge with both hands. Of course we have dealt with several difficulties, it was an intense process of searching for a solutions, we however managed, and have been able to see, experience and learn from this incredible challenge called thesis.

We as landscape architects want to do a better job

1.2 Problem setting

As oil prices continue to reach records, the search for new energy sources has led the world to Alberta, Canada and its enormous oil sands. Canada, known for its wilderness and nature (fig. 1.2) is now caught in the middle between fuelling the worlds hunger for oil and the ecological destruction and rising greenhouse gas emissions that the industry produces.

Since the industry leads to ecological destruction and rising greenhouse gas emissions

Alberta's woods, rivers and animals are in danger as the world's oil rush keeps accelerating. Companies like Shell, Total, Imperial and most other big oil companies invested in this area (Vidal, 2008).

When the first mine opened located North of Fort McMurray, people were sceptical whether this method of oil extraction could ever be profitable. The impact of the industry was fairly minor at that time, it was nothing more than a dot on the map, surrounded by vast areas of forests, lakes and rivers.

Today hundreds of square kilometres of tailings ponds, mines and pipes are spread out over the area. Every day brings a stream of trucks from and to the plants (fig. 1.3) as well as young men from all over the world who want to earn quick money.

Today hunders of square kilometers are taken over by the industry

Fort McMurray has come a long way since its origins as a fur trade post established by the Hudson's Bay Company in 1870. In 1900, it was described as "abandoned" after the company relocated its trade

Fig 1.2: Northern Alberta´s Boreal forest

Fig 1.3: The open pit mine in operation

centre on the Athabasca River from Fort McMurray to Fort McKay, this all changed when Fort McMurray was selected by industry and government to be built up as a community to house incoming industrial workers (fig. 1.5) (EUB, 2000).

Fort McMurray which was selected by the government to house all the industrial workers struggled from the beginning with these rapid developments

Fort McMurray struggled from the beginning, in terms of the financial costs of rapid growth and the social impacts of intense and prolonged flux, and has come to embody the challenges and pressures of an archetypal boomtown (Alberta Municipal Affairs 1980; LeRiche 2006, Ferguson, 2001).

By 2030, Fort McMurray is expected to grow into a city of 250,000 inhabitants. If the oil price stays high and new technology permits to dig out the far deeper oil, Alberta could be the second largest oil producer in the world, which could mean the end of the current oil supply crises (Vidal, 2008).

All these developments and problems start to alarm the Canadians and other countries

The downside of this industry, ecological destruction and souring greenhouse gas emissions, are now beginning to alarm Canadians and other counties, which led to accusation from the media "being the dirties oil in the world", it however forced them to convert a change in motion.

Besides the accusations, this unique situation also offers a lot of opportunities. It's about creating a new city, a new community, which generates its own wealth in the near future, not solely dependent on oil. Maybe Fort McMurray could even be an example for similar situations in the future.

The oil sands companies also want to change and try to figure out the best way

Companies are taking it at heart and try to change things. However, everybody is new in this game still trying to figure out the best way. Therefore a lot of research is being done trying to tackle the environmental problems caused by the industry.

Current developments are very discipline specific and mostly taken from an industrial, social of ecological approach

This current research is very discipline specific and mostly done from an industrial, ecological or social perspective. A more comprehensive way of looking at these problems, to bridge the contrasts between the rapid developments of the industry, people and nature is not taken into account.

Fig 1.5: An Aerial of Fort McMurray´s downtown area

We as landscape architects known for taking a comprehensive approach, since this is the way we are educated. Want to start bridging these contrasts within this thesis and work towards a more sustainable landscape for the Athabasca oil sands region.

We as landscape architects known for a more comprehensive approach want to work towards a more sustainable region

This landscape known for its pristine nature and river system (fig. 1.6) Is taken over by the industrial developments nowadays (fig.1.7)

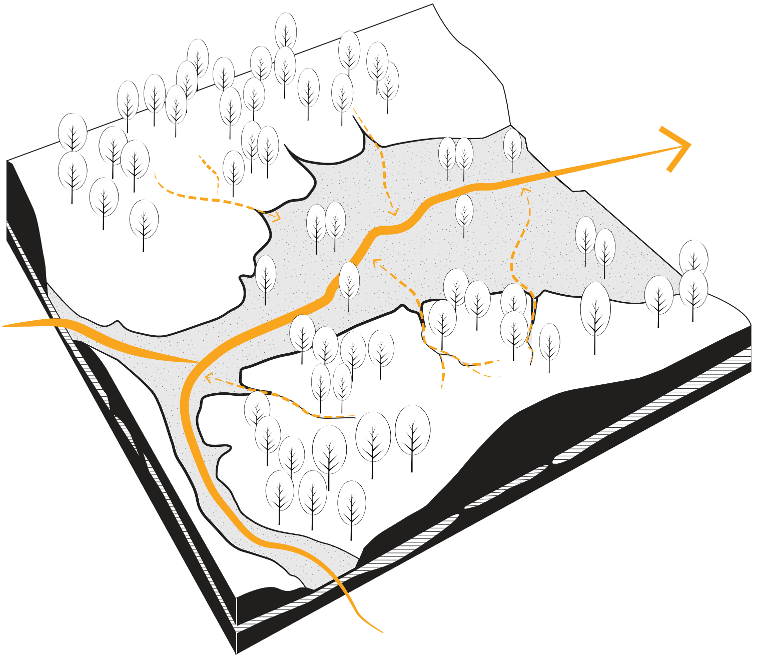

Fig 1.6: The Alberta oil sands region known for its nature and River sytem

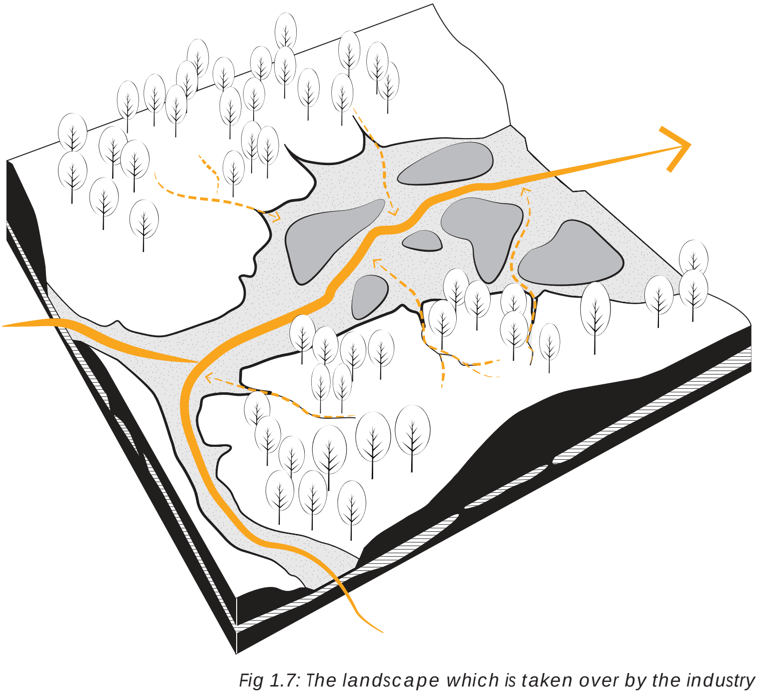

Fig 1.7: The landscape which is taken over by the industry

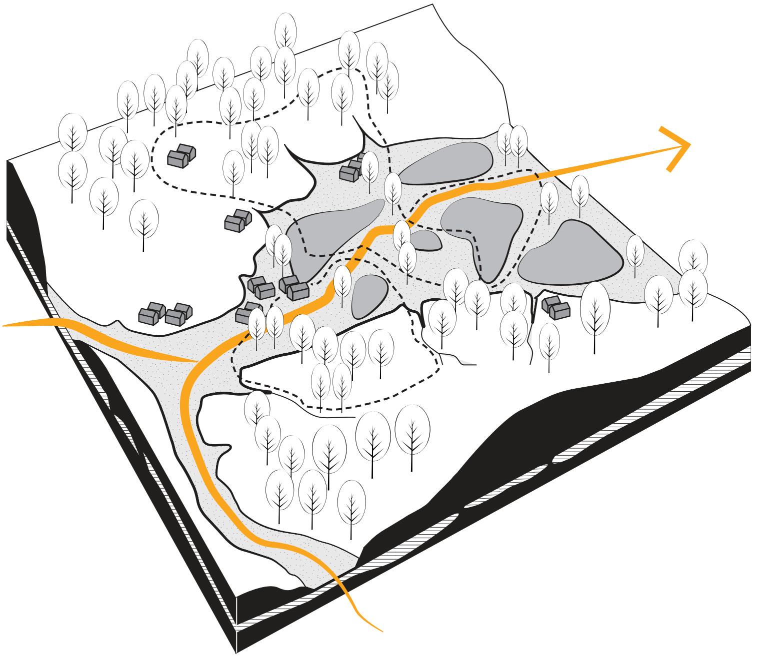

Fig 1.8: A landscape where industry people and nature benefit from each other

We do not see sustainability in a landscape where the industry is taking over its environment, but a landscape where industry nature and people can benefit from each other (fig.1.8).

1.3 Research questions

We going to search for a balance between the industry, people and nature

To be able to do this we developed several research questions

The first three questions are focussed on understanding the several systems

This means a new balance needs to be found in order to recalibrate the relationship between the industry, nature and people. To be able to achieve this we asked ourselves the following research question:

How can a more sustainable landscape system be developed in the Athabasca oil sands industrial region by using a landscape based design approach?

To be able to answer this question and find a new balance between the natural, industrial and social system, the first purpose within this research is to get an understanding of these several systems. For that reason we come up with three research questions to get an understanding of these systems and how the influence each other. The first question touches upon the first pillar nature and is formulated like this:

What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays?

The purpose of this question is to get a better understanding of the landscape.

The second question is focused on the industrial landscape, which is called the workings within this research and is formulated in this way: *How does the industry work and what are the effects on the contemporary landscape?*

The purpose of this question is to get an understanding of the industrial workings and this influenced the landscape.

The third question touches upon the social layer, inhere we ask ourselves the question:

What are the perspectives of different stakeholders regarding the developments of the oil sands industry?

The purpose of this question is finding out peoples perspective and future requirements towards the future industrial developments.

The outcome of these questions is a better understanding of how these systems work and how these influence each other. The activity of designing will play an important role in this process. In the practice of landscape architecture design is seen as the core activity (Creswell and Plano Clark 2011 cited in Lenzholzer, Duchhart and Koh, (2013).

The outcomes of these three questions will be used in the design process to design for a more sustainable system

In this research designing is used to first get an understanding of the different systems, secondly to bridge the gap between research done on the three pillars, to finally design for a more sustainable landscape system.

To bridge the contrast between research and design, wherein a translation is made from the outcomes of our research into a design, we asked ourselves two architectural research questions. These questions are formulated as followed:

To bridge the contrast between this research and design phase we askes ourself two architectural research questions

What measures can be taken in order to develop a more sustainable landscape system?

How can these measures be implemented in order to achieve a more sustainable system?

In figure 1.9 the above-mentioned research questions are showed once again in a scheme. Within this scheme also the corresponding methods are viewed. In the following section a reader's guide of this thesis is given.

Descriptive RQ	Explorative RQ	Architectural RQ
The Landscape - What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays? **The Workings** - How does the industry work and what are the effects on the contemporary landscape?	**Peoples perspective** - What are the perspectives of different stakeholders regarding the developments of the oil sands industry?	**Design** - What measures can be taken in order to develop a more sustainable landscape system? - How can these measures be implemented in order to achieve a more sustainable system?
Methods	**Methods**	**Methods**
- Litererature study - Research through designing - Map study - Field trip - Interviews - Modeling (maquette)	- Interviews - Personas method - Card sorting - Literature study	- Research through designing - Reference study - Design experiment: sketching, cross-sections, visualizations, mapping, drawing

Fig 1.9: Research questions and the corresponding methods

1.4 Readers guide

An answer to these question will be given in several chapters of this thesis

To be able to give an answer on the above-mentioned questions this thesis first needs a context. This has to do with the occurring problems in the landscape which are mainly caused by the industrial developments. In order to get an understanding of these problems, we first have to understand the different processes that cause these problems. For that reason the following chapter will set this context.

This thesis will start with a chapter to set the context

This is followed by the theoretical context in chapter 3

The context setting which will be done in chapter 2 is followed by the theoretical context in chapter 3. This chapter elaborates on the outlined context and focuses on our perspective as researchers towards all these developments.

In chapter 4 we will continue with the research framework

From the theoretical context we continue with the research framework in chapter 4. In this chapter a start is made with the knowledge gap, from this the problem statement can be formed. Then again the above mentioned research questions will be explained.

From there we touch upon our philosophical assumption and landscape architectural lens. Since this influences the way we did our research it also influenced the methods we used in this research. This and the research process will be explained in the section 'methods'. This chapter clearly shows that this research is built up on the basis of three pillars: the landscape, the workings and peoples perspective. Since we try to find a balance between these pillars within our design for a more sustainable landscape the following chapters are focused on these pillars.

This chapter clearly shows that this research is built op on the basis of three pillars

In chapter 5 the focus lays on the landscape system. Inhere we analyze the landscape and try to get grip on this system. This is followed by the workings in chapter 6 where we try to get an understanding of the industrial workings and how this influences the landscape. In chapter 7 an analysis is done on people's perspective and their requirements for the future landscape. Important to mention is that these three systems are all interrelated with each other.

The first pillar which will be focused on in chapter 5 is ´the landscape´

Followed by ´the workings´ in chapter 6

An the last one ´peoples perspective´ in chapter 7

In chapter 8 the generated data from the analysis part will first be processed into design challenges in order to bridge the gap between research and design. Sketching was used as important method to decide on which problems to focus in our design. this finally led to several measures which we in turn translated into design solutions.

In chapter 8 the generated data from the former chapters will be processed

In chapter 9 the design is explained. Within this design we tried to implement the above mentioned measures as best as possible. This is done in three different layers: the Athabasca River system, the industrial water system and the networks. This design will be focused on one mine to be able to reflect back to the regional scale later.

In Chapter 9 our design will be explained

In the last chapter a conclusion and discussion will be given. The conclusion answers the research questions, and in the discussion a reflection will be given on the overall research process, and the design.

The last chapter contains the conclusion and discussion part

In figure 1.10 a scheme is given of this readers guide. Within this scheme you can see different chapters with their main outcome and to which research question this can be linked.

Chapter	Purpose	Answer to RQ
Chapter 1	Introduction	
Chapter 2	Context setting	
Chapter 3	Set a theoretical context	
Chapter 4	Explaining the research setup	
Chapter 5	Understanding the landscape	What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays?
Chapter 6	Understanding the industrial workings and its effects on the landscape	How does the industry work and what are the effects on the contemporary landscape?
Chapter 7	Understanding peoples perspective	What are the perspectives of different stakeholders regarding the developments of the oil sands industry?
Chapter 8	Ccompare data to form design challenges and measures	What measures can be taken in order to develop a more sustainable landscape system?
Chapter 9	Implement measures and design for a more sustainable system	How can these measures be implemented in order to achieve a more sustainable system?
Chapter 10	Reflection and disscusion on process	How can a more sustainable landscape system be developed in the Athabasca oil sands industrial region by using a landscape based design approach?

Fig 1.10 The readers guide in a scheme

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2. Context setting

The following chapter gives a general context of the oil sands industry. This is needed to understand the complex problems which are occuring nowadays.

First describing in short how this unconventional oil source became profitable and then continuing with geography, how the oil sands developed in this region , who found the resource (historical overview) and how the oil is finally excavated.

Context setting

In the previous chapter our thesis subject is introduced. Due to the complex problems raised by the oil sands industry and the continuous changes in this area, a general context will be outlined to provide you with the basic knowledge to understand the subject.

This chapter thus actually precedes the actual thesis but is necessary to get acquainted with the oil sands industry.

2.1 Changes in global oil supply

Crude oil is of major importance for mankind

Crude oil is of major importance for mankind. About 40 % of the world's total supply of energy, and 95 % of the energy need of the transporting sector comes from oil (Söderbergh, 2005)

Global oil consumption has increased

Global oil consumption has increased to more than 80 million barrels per day. According to BP Energy Outlook 2035, global primary oil demand is projected to grow by 41% between 2012 and 2035, with a projected growth of 1.5% per year on average (BP, 2014).

Mainly driven by the fast growing energy markets in China and India. This results in a widening gap between supply and demand. Therefore It is often claimed that Canada's huge reserves of unconventional oil, may play an important role in bridging the coming gap (Söderbergh, 2005).

and conventional oil resources are depleting, Canada's oil sands could play role in bridging the gap between supply and demand.

This has everything to do with the dramatic decline in the number of new oilfield discoveries, since the 1960s, despite the improved and more sophisticated technologies. In the last decade, oil discoveries have only replaced half of the oil produced (Söderbergh 2005).

There were approximately 2000 Giga barrels of conventional oil in the ground when commercial extraction of oil was initiated. We have already found 90 % of this oil and have soon consumed half of it. (Campbell, 2004 cited in Söderbergh, 2005)

In January 2003, the United States' Energy Information Administration (EIA) and the Oil and Gas Journal formally recognized Canada's oil sands as an economically viable resource, vaulting Canada's proven oil reserves from the 21st position in the world to third (Pembina Institute, 2005), only surpassed by Saudi Arabia and Venezuela.

Canada's estimated proven reserves increased from 5 to 180 billion barrels, when Canada's large reserves of unconventional oil – the oil sands deposits - were included (Söderbergh, Robelius, and Aleklett, 2007)

Figure 2.1 compares the world biggest conventional oil reserves and Canada's oil sands. Since 2003, Canada's proven oil reserves slightly declined. The oil sands now account for approximately 170 billion barrels, or 98 percent, of Canada's oil reserves (EIA, 2012).

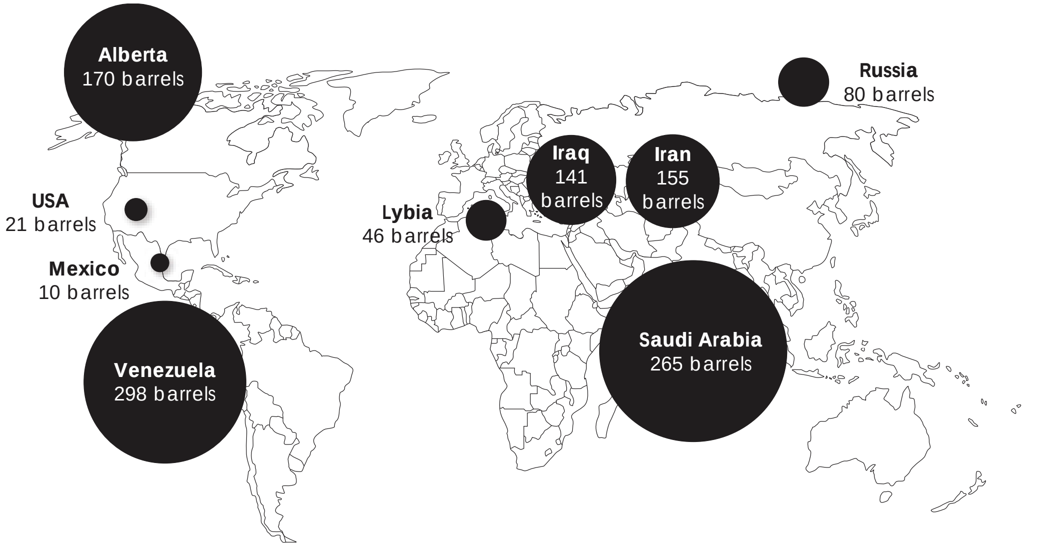


Figure 2.1 : Comparitive oil reserves (billions of barrels)
Based on source: (Government of Alberta, 2014)

Figure 2.2 : Canada's oil sands are located in the province of Alberta near the city of Fort McMurray

2.2 Alberta's oil sands region

2.2.1 Geography

Bitumen occurs entirely within the province of Alberta

Canada's resources of bitumen occurs entirely within the province of Alberta in sand and carbonate formations in the northeastern part of the province as is showed in fig. 2.2. The city of Fort McMurray, located within the Regional Municipality of Wood Buffalo, serves as the regional hub for oil sands development (Pembina Institute, 2005).

Oil sands could supply total worlds energy needs for up to 15 years

When looking at current production rates, resources coming from the Alberta's oil sands could supply the total worlds energy needs for up to 15 years. 39% of Canada's total oil production is coming from Alberta's oil sands. Currently, approximately 1.3 million barrels are produced per day and production is expected to grow to three million barrels per day by 2020 (Oil Sands discovery centre, n.d.).

The oil sands consist of three regions

Alberta's oil sands consists of three major regions defined as the Athabasca, Cold Lake and Peace River Oil Sands Areas (Söderbergh, 2005). Together, covering an area of 141,000 square kilometers (Cleveland and Morris, 2009) as showed in fig. 2.3.

The oil sands industry is located in Boreal forest region

This forest corresponds with the colder climates

These three areas represents 21% of Alberta and 37% of Alberta's Boreal Forest Natural Region (Mech, 2011), as showed in figure 2.4. As you can see the boreal forest region covers most of northern Alberta, the oil sands industry is surrounded by this landscape. This type of forest corresponds with colder climates. On the next page two pictures of the Boreal forest are showed in figure 2.5 and 2.6.

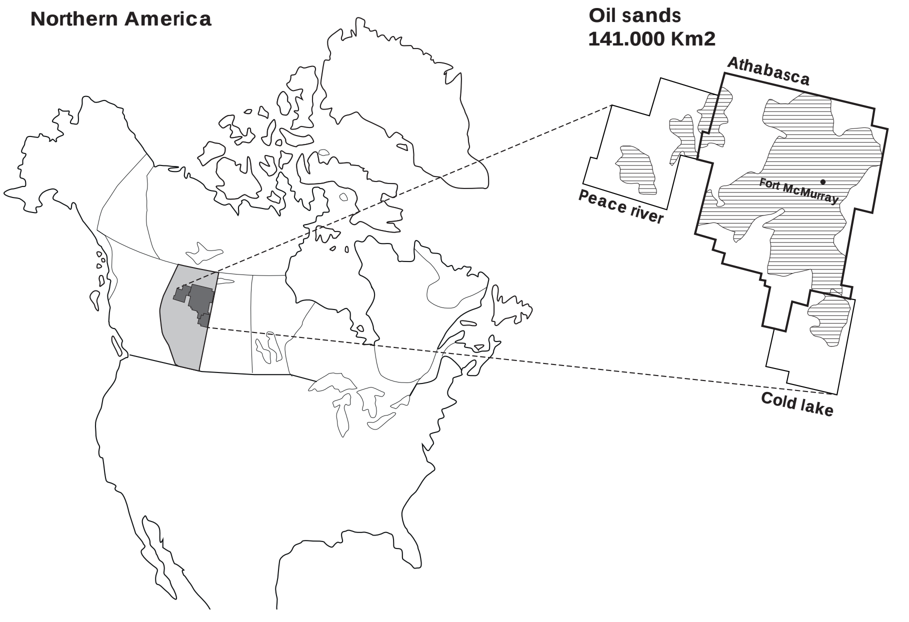


Figure 2.3 : Location of the Athabasca, Cold Lake and Peace River oil sands in Alberta . Based on source: (AGS, 2013)

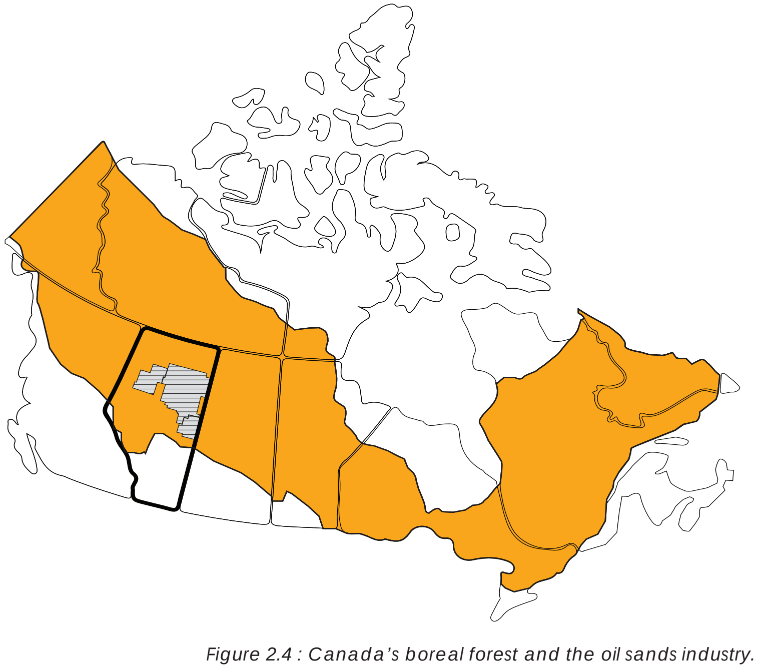


Figure 2.4 : Canada's boreal forest and the oil sands industry. Based on source: (Shell, n.d.).


Figure 2.5 : A landscape that is characterized by streams, wetlands and forest

Figure 2.6 : Athabasca river in the area of Fort McMurray

Canadian oil sands begin their formation when Alberta was covered by an inner sea

2.2.2 How is oil sand formed?

The Canadian oil sands began their formation process many millions of years ago when Alberta was covered by a warm tropical inland sea (fig. 2.7), the Western Interior Seaway, splitting the continent of North America into three landmasses.

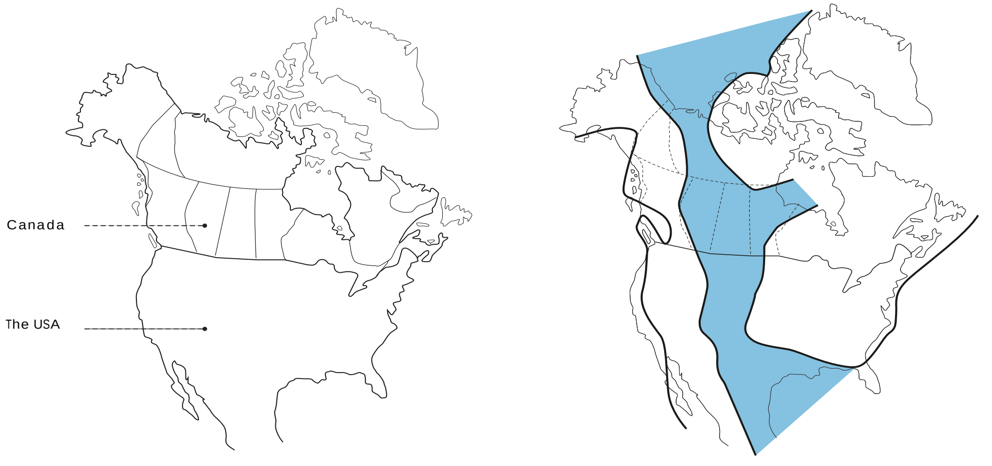


Figure 2.7: Millions of years ago a tropical inland sea covered Alberta. Based on source: (Williams and Stelck, 1975)

The oil was formed in the south of Alberta when plants and organisms died

The oil was formed in the southern part of Alberta, when plants and marine organisms, such as plankton, died. Sediments containing their remains accumulated in the bottom of those seas. (Oil Sands discovery centre, n.d.)

Heat, pressure, time and the activity of bacteria transformed the remains into crude oil

Throughout time, more and more layers were added, and the sediments were buried deeper. Heat, pressure , time and the activity of bacteria transformed these remains into hydrocarbons, and crude oil was formed (Patel, 2012 and Oil Sands discovery centre, n.d.).

Due to the formation of the Rocky Mountains crude oil was pushed north and to the surface

In northern Alberta, many rivers flowed away from the sea and deposited sand and sediment. When the Rocky Mountains formed (fig. 2.8), geological pressure was put on the land,

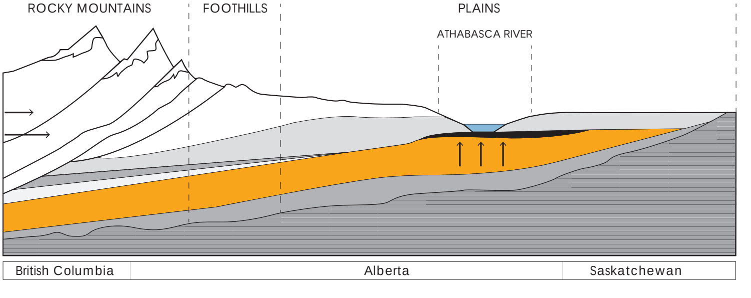


Figure 2.8: Due to pressure from the Rocky Mountains, the oil was pushed toward the surface. Based on source: (Canadian Centre for Energy Information, n.d.)

and most of the seaway was closed off (fig. 2.9) and the deposits of crude oil (being a liquid) were pushed toward the surface, and the oil was squeezed northward and seeped into the existing sand deposits left behind by ancient river beds, forming the oil sands.

Due to the pressure the inner sea was closed off

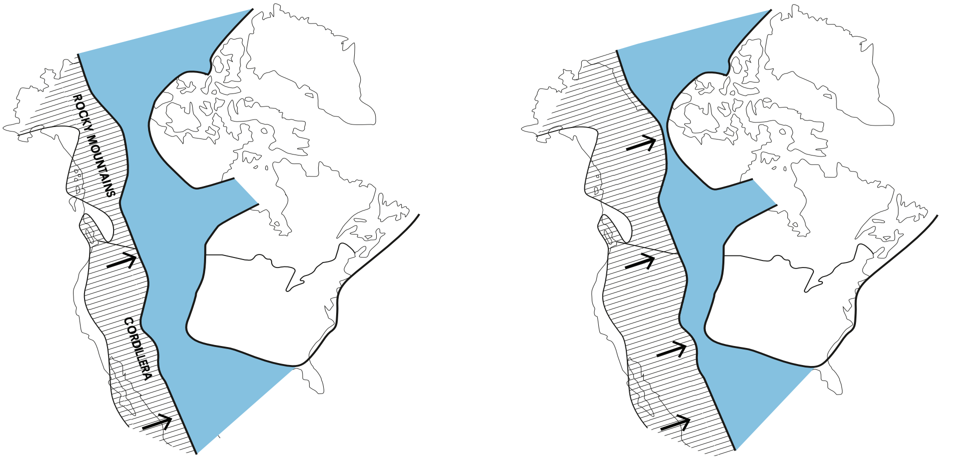


Figure 2.9: Closure of the Western Interior Seaway. Based on source: (Williams and Stelck, 1975)

A logical consequence of this Western Interior Seaway also explains the location of other larger oil boom towns in the United States and Canada as is visualized in figure 2.10.

Today large oil boom towns are located in the old bedding of the sea

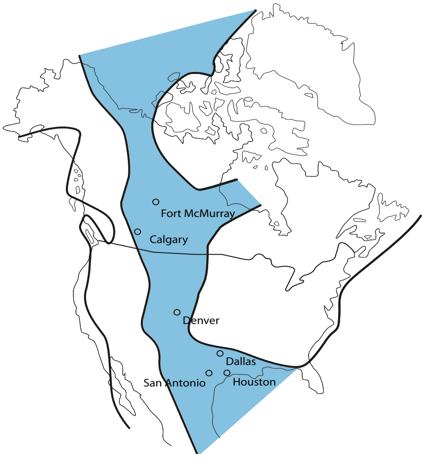


Figure 2.10: Location of big oil towns. Based on source: (Williams and Stelck, 1975)

2.2.3 Two extraction techniques

There are two ways to excavate the oil, mining and SAGD

As mentioned before the oil sands contain of three main areas. Each area is covered by a layer of overburden consisting of muskeg, glacial tills, sandstone and shale. Due to the different characteristics of every area and deposit, different techniques are required to extract the bitumen. The oil sands industry should therefore be viewed as two separate forms of oil production, in situ production (similar to conventional oil production) and mining, this is showed in fig. 2.11.

In the Athabasca area around Fort McMurray they use mining

In the Athabasca area around Fort McMurray, the oil sands are close enough to the surface to be mined. In the other two areas, the bitumen has to be recovered by in situ methods (Oil Sands discovery centre, n.d.). Both processes to extract the oil are complex, energy-intensive and expensive – but high oil prices finally made the oil sands industry profitable.

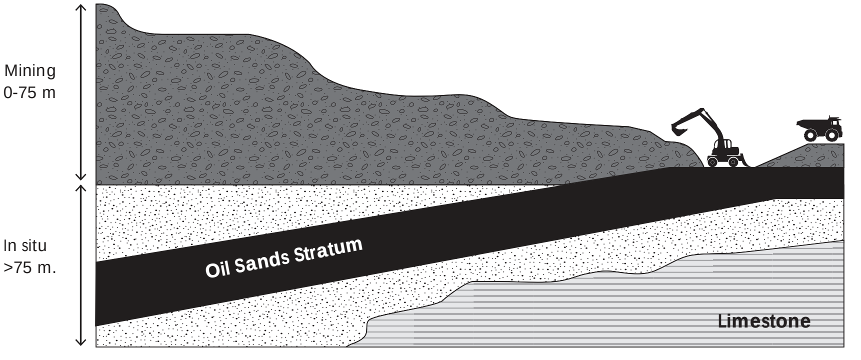


Figure 2.11: zones of oil sands formation and the different extraction techniques employed. Based on source: ()

In our thesis we have chosen to focus on the Athabasca area around Fort McMurray since this is the only region where the oil sands can be mined and thereby this area is the largest and most heavily developed area.

2.2.4 What is oil sand?

Oil sand is a naturally occurring mixture made up of grains of quartz sand, surrounded by a layer of water and clay, and then covered in a slick of heavy oil called bitumen. Figure 2.12 contains the composition of oil sands.

Oil sands are a mixture of sand, water, clay and bitumen

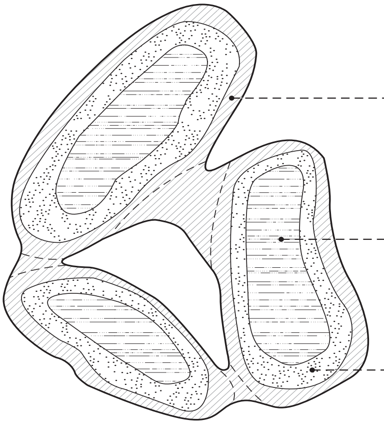
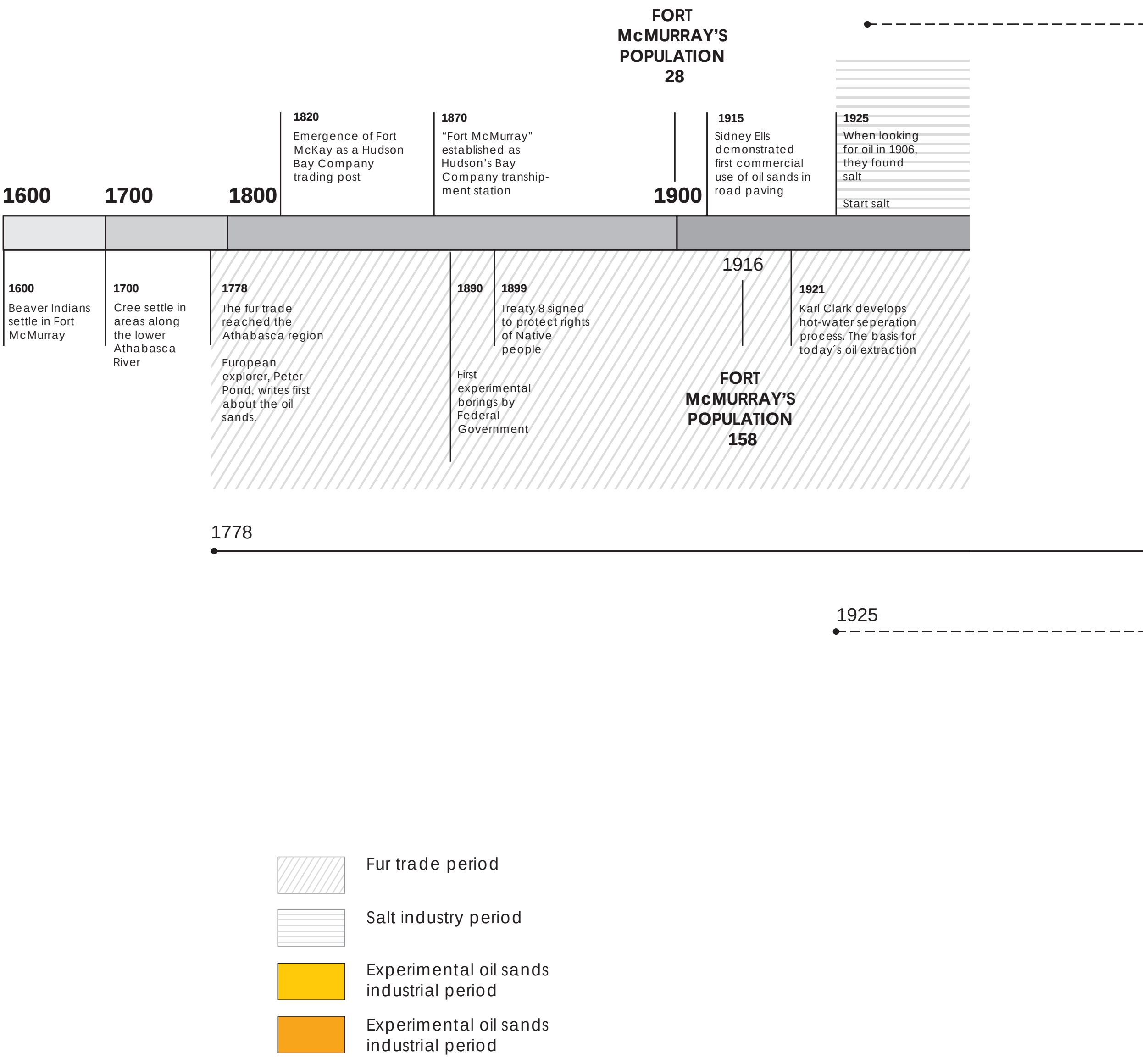


Figure 2.12: The composition of oil sands. Based on source: (Government of Alberta, n.d.)

The bitumen content in the deposits varies from 1% – 18%. More than 12% bitumen content is considered high, and less than 6% is low and usually not considered economically feasible to mine. On average, it takes 2 tonnes of mined oil sand to produce one barrel of synthetic crude oil which is 159 litres (Oil Sands discovery centre, n.d.).

2.3 Historical overview of the Fort McMurray area and the oil sands industry

In the following paragraph a historical overview of the developments in the Athabasca oil sands region will be given. Figure 2.13 shows a timeline, the different developments will be explained in more detail on the following pages.



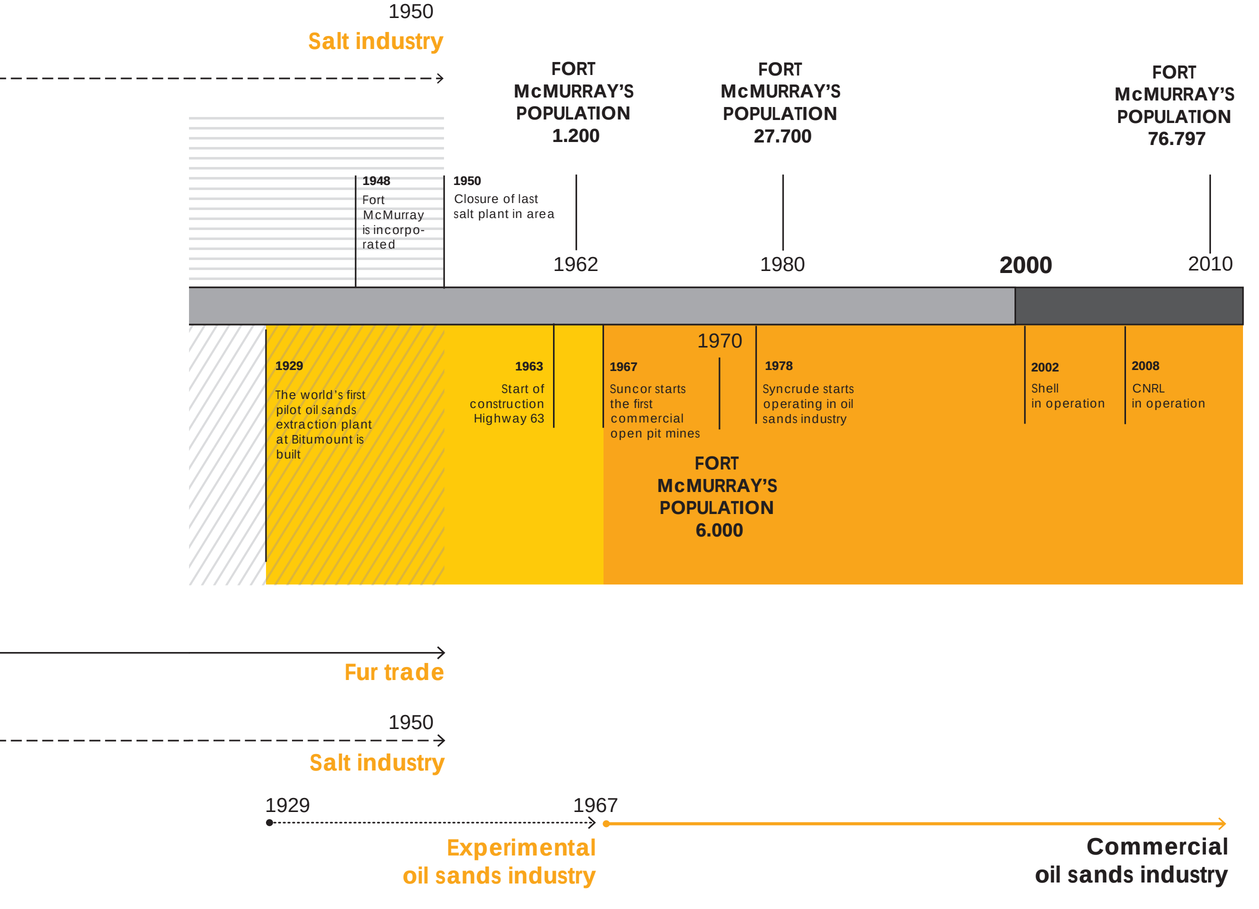


Figure 2.13: History of the Athabasca oil sands region. Based on source: (RMWB, 2012).

The first inhabitants of the Athabasca oil sands area were First Nations and Metis people

1600 - 1778

Originally the Athabasca oil sands area was inhabited by First Nations and Metis people, including the Cree, Chipewyan, Prairie dene, and Anzac Metis. For thousands of years they lived a nomadic life that revolved around fishing and hunting The indigenous people knew about the bitumen occurring along the Athabasca River (EUB, 2000). They mainly used washed-out bitumen as caulking mixture for their canoes (Berkowitz and Speight, 1975).

From 1778, the Athabasca region was part of a fur trade route

1778

During the last two decades of the eighteenth century, the fur trade reached the Athabasca region. From about 1778, the Athabasca River, the Clearwater River, which enters the Athabasca River from the east at Fort McMurray, were part of the main fur trade route from the Mackenzie (Parker and Tingley, 1980) as showed in fig. 2.14.

Figure 2.14: a Hudson Bay Company scow on the Athabasca River. Source: (wikipedia, n.d.)

In 1778, a European wrote first about the existence of the oil sands

It was Peter Pond, a fur trader who became the first European to enter the Athabasca region and establish the first fur trade post. To subsequently be credited as the first person writing about the existence of the oil sands in 1778 (EUB, 2000). Over the years, many descriptions about the oil sands along the Athabasca river system followed.

European colonization brought major changes in the life style of the Native people

The European colonization however brought major changes in the means of subsistence in the society of the Native people. The Cree, who were among the first native people to profit from contact with the European traders, proved to be a reliable ally of the fur trade, especially in hunting for the fur trade posts. Their lifestyle began to revolve around the fur posts where the native people brought in provisions in exchange for European trade goods like metal implements and firearms, liquor and cloth objects (Parker and Tingley, 1980).

As the fur trade declined in importance, the native people not only lost a viable means of livelihood but also their cultural identity. New economic developments tended to by-pass these indigenous peoples.

1820
In 1820 Fort MacKay was established by the Hudson Bay Company as a trading post (RMWB, 2012) .

In 1820, Fort MacKay was established

1870
In 1870 Fort McMurray was founded by the Hudson's Bay Company, a fur trading post located at the confluence of the Clearwater and the Athabasca River. The Hudson's Bay Company closed Fort McMurray from 1898 till 1912 due to the declining fur trade. However they opened the fort again to serve as a large-freight storage warehouse. Fort McMurray was only accessible by river, the fort therefore served as the "gateway" to the Arctic. These developments opened the isolated north of the fur trade to the expanding industrial frontier of southern Canada.

in 1870, Fort McMurray was founed as trading post

Until the foundation of Fort McMurray, the Athabasca region remained relatively isolated, as transportation improved, the Athabasca region underwent a transition from a fur trade based economy towards an economy based on resources like commercial fishing, logging, lumbering and the newly emerging development of the vast oil sands resources. (EUB, 2000)

Due to improvements in transportation lots of people invested in the area to build up the oil sands industry

1870- 1900
Since the first documentation in 1778 and the further improvements in transportation lots of entrepreneurs, scientists and the government invested in the Athabasca area to build up the oil sands industry like it is today. During the last three decades of the nineteenth century, a considerable part of the Athabasca Oil Sands region was surveyed and mapped (Parker and Tingley, 1980). Many reputable scientists stressed the widespread presence of oil sands and their economic potential for the region.

1890
The Federal government, who controlled the resource development in the area until 1930's, began to lay the groundwork for the first major experimental borings in the area. Three wells were dug, however with no success. This federal experiment led to doubts upon the government's handling of the region's resources. However, people were still convinced of the vast amounts of oil in the ground.

The Federal government started the first borings in the area, with no success.

1899
Throughout this period of growing interest in the Northern regions and its resources, native peoples had been pretty well left on their own. During the 1890's it was discovered that the native peoples were suffering as a result of changes in living styles, the introduction of alien ailments like measles, and a decline in game resources. By game resources is meant, any animal hunted for food or not normally domesticated. To protect the rights of the native people in this region

Despite the growing interest in the Athabasca area, native people had been left on their own

Government entered into treaty with the native people to protect their rights and living situation

the government entered into treaty negotiations for the region which were concluded in 1899 (Treaty No. 8). The Treaty was seen by the native people as a friendship pact between the Europeans and the natives (Parker and Tingley, 1980). While Europeans considered the treaties as transfers of title to land, Aboriginal nations perceived them simply to be agreements to share the land, as they did with the animals and other groups (AJIC, n.d.).

The treaty promised that they could continue their lifestyle of hunting and trapping

The main concerns of the native people were that signing the treaty would interfere with their hunting and trapping activities upon which they depended. The treaty however promised them payments in cash and goods; the right to hunt, fish and trap in certain areas; access to medical services; and an agreement to create reserves in the future (Gageldonk, 2013). Today, native people believe their treaty rights have become a series of broken promises (AJIC, n.d.).

Until the 1930's government didn't interfere directly in the lives of the Treaty 8 native people, apart from regulating hunting and trapping to support the economic initiatives of entrepreneurs in the region. This however changed with the further developments in the Athabasca region and the search for oil (Gageldonk, 2013).

Besides the federal government individuals became interested, hoping to find oil, they found salt

1906
After the failed attempts by the federal government a number of private individuals became interested in the potential of the region (Parker and Tingley, 1980). In 1906 they started to drill for oil along the banks of the Athabasca River. He was hoping to discover "free" oil, he however found salt. Which led to the development of a salt mine in 1925 (EUB, 2000).

Sidney Ells, demonstrated the first commercial use of oil sands in road paving

1915
Although much explorative work on the oil sands was done by other people, the recognized 'father of the oil sands' was Sidney Ells. Sydney Ells, an engineer with the federal Department of Mines, demonstrated the first commercial uses of the oil sands. He shipped several tons of bitumen by water, sleigh and rail to Edmonton for an experiment in road paving (fig. 2.15).

Figure 2.15: oil sands used for road paving. Source: (Gismondi and Davidson, 2012)

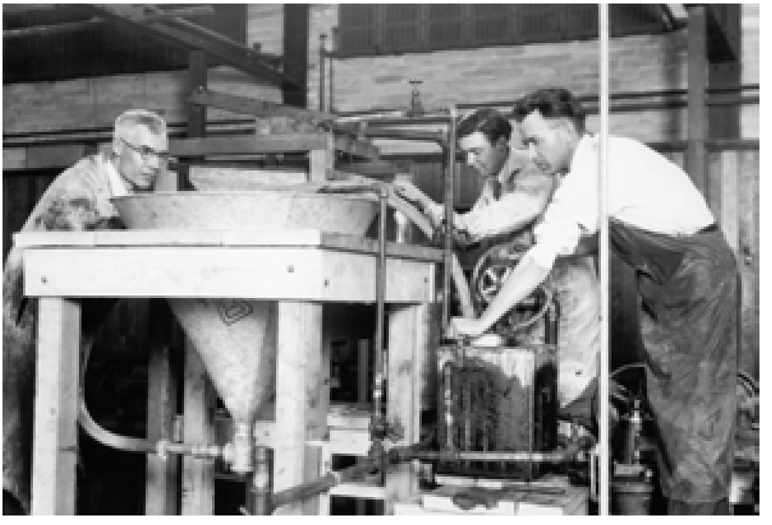


Figure 2.16: Karl Clark of the Alberta Research Council developed a method for separating bitumen from sand. Source: (oil sands today, n.d.)

1921

However using bitumen for road paving could never become commercially viable. Another researcher , Karl Clark, was therefore asked to review the findings of engineer Sidney Ells to investigate how to make the extraction of bitumen commercially viable. He therefore improved the hot water separation technique, in order to separate the bitumen from the sands. This hot-water separation process became the basis for today's thermal-extraction process (fig. 2.16).

Using bitumen for road paving could never become profitable, Karl Clark investigated how to make the extraction of bitumen profitable

1929

In 1929 the first commercial oil sands hot-water separation plant on the Bitumount lease was opened (fig. 2.17). This represented a major milestone in the history of the development of the oil sands resources. Confirming that commercial extraction of the oil sands was possible, with Bitumount as example, major developments in the Athabasca area did not occur.

In 1929, the first oil sands plant on Bitumount was opened

Major developments in the region did not occur

Figure 2.17: Bitumount plant . Source: (Gismondi and Davidson, 2012) Originally published in the Calgary Herald, February 12, 1951

1950

The government's attitude during the 1950's was conditioned by the fact that Alberta's conventional oil supplies were rapidly increasing. "Between 1947 and 1951, 17 new oil fields had been discovered in the province, and during 1955, 5440 active oil wells accounted for 90% of Canadian production" (Parker and Tingley, 1980, p. 130).

The fundamental problem is money. Extraction has to be cheap enough

"The fundamental problem in the development of the oil sands has always been one of economics, as whatever method of extraction Is used it must be simple enough and cheap enough to allow for the oi1 to be sold in competition with oil extracted in the more normal 'conventional' manner" (Parker and Tingley, 1980, p. 130).

In 1956, oil sands approached market demand

1956

The time that the oil sands approached market demand was accelerated when in 1956 Egypt blocked the Suez Canal and thereby endangering the supply of oil from the Middle East to North America. This event marked the beginnings of a new era of economic prosperity for the Athabasca oil sands region.

Figure 2.18: Fort McMurray - Suncor. Source: (Gismondi and Davidson, 2012)

In 1967, the first commercial oil sands plant was opened

1962

A milestone in the history of the oil sands industry was the development of the world's first large-scale commercial plant of Suncor. It pioneered technology for bitumen extraction and upgrading, in the early years it was not particularly profitable, but the plant was nonetheless able to cover operating expenses from the sale of its own production (fig. 2.18).

Fort McMurray, which in 1962 only had a population of 1200 grew within 8 years to a population of 6000 people (RMWB, 2012).

From a small little village as shown in the postcards in fig 2.19, Fort McMurray grew tremendously in a short period of time.

Figure 2.19: Postcards from Fort McMurray around 1950.
Source: (VES Fort McMurray, n.d.)

2.4 The effects of the industrial process on its environment

Since the start of the first commercial oil sands developments the region went through a huge transformation. This transformation is caused by the industrial process and its effects. In this paragraph a description of the several effects of the process are given.

2.4.1 The extraction process

The mining extraction process includes six steps

The mining extraction process includes six different steps: mining, conditioning, separation, secondary separation, froth treatment and upgrading. In the following section these steps will be explained more clearly.

Step 1: Mining

First step is mining

In the mining phase the surface is stripped (fig. 2.20) in different layers to finally reach the bitumen containing layer. First they strip the topsoil, in many cases this layer consists of peat. The second layer is the subsoil. This layer is low in nutrients. Both of these layers will be reused in the reclamation process.

Everything below the subsoil is called the overburden. This material is used to build roads and dikes and located on top of the bitumen containing layer. After the overburden they dig out the bitumen containing layer which is called the ore. This is loaded into large trucks and transported to the oil sands crushers where it is prepared for extraction (Interviewee 5, 2013).

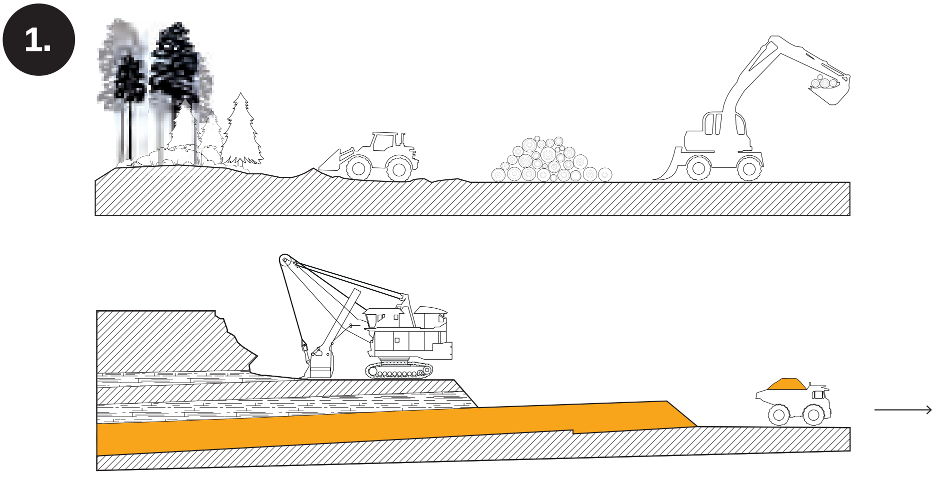


Figure 2.20 : step Mining

Step 2: Conditioning

The conditioning phase (fig. 2.21) is the first step in separating the bitumen from sand and clay. The oil sands are crushed and mixed with water to dilute the material. This results in a slurry-like substance which makes (hydro)transport by pipelines possible (Oil Sands discovery centre, n.d.).

Second step is Conditioning, where the sand is crushed and mixed with water

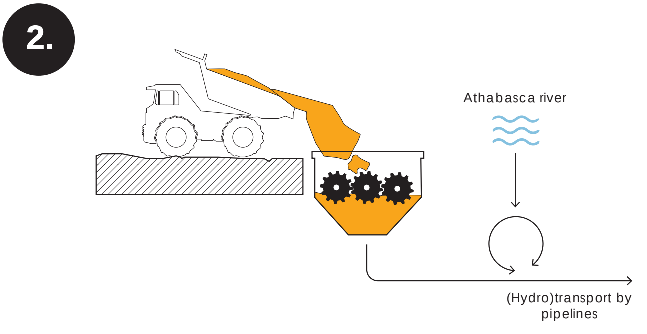


Figure 2.21: step Conditioning

Step 3: Separation

In the Separation phase (fig. 2.22) the slurry from the pipelines is put into a Primary Separation Vessel (PSV). Within this PSV the slurry settles into three layers. The bitumen froth floats on top, the sand sinks to the bottom and a combination of bitumen, sand, clay and water is in the middle which is called the middlings. After this process the bottom layer (sand) is pumped into tailing ponds (Oil Sands discovery centre, n.d.).

Third step is Separation, where the slurry is put in PSV. The slurry settles in three different layers: bitumen froth, middlings and sand.

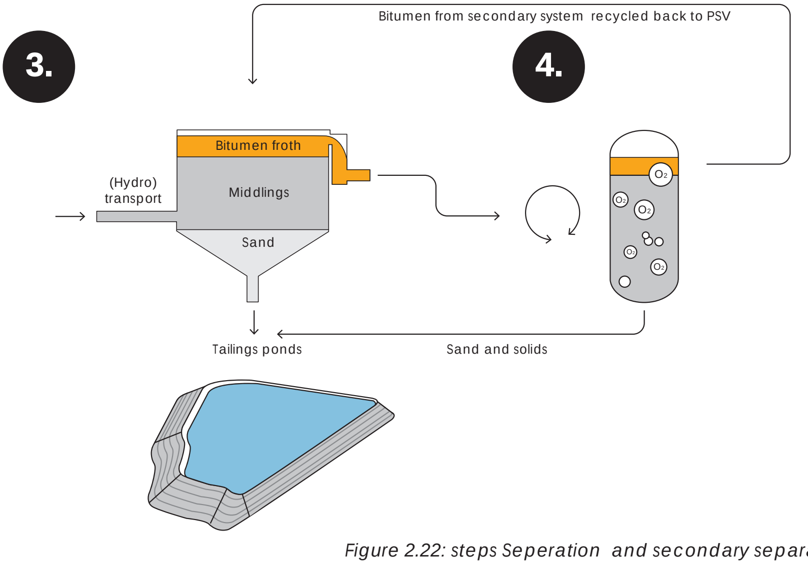


Figure 2.22: steps Seperation and secondary separation

Secondary separation implies that middlings are injected with air to encourage further recovery of bitumen

Step 4: Secondary Separation

In the Secondary separation step (fig. 2.22) the middlings are pumped to a secondary vessel where air is injected to encourage a further recovery of the bitumen. The bitumen from this secondary system will be recycled back to the primary system (Oil Sands discovery centre, n.d.).

The fifth step cleans water and solids from the bitumen froth

Step 5: Froth Treatment

In this phase the bitumen froth from the PSV is cleaned from its water and solids (fig. 2.23). The bitumen froth is diluted with Naphtha to make it flow easier through the centrifuges. This centrifuge spins out the water and the clay. The bitumen which is the product of this process consists of less than 5 % water and only 0,5% of solids and is ready for upgrading. The tailings (water, solids and solvents which mainly consists of Naphtha) will be discharged to the tailing ponds (Oil Sands discovery centre, n.d.).

5.

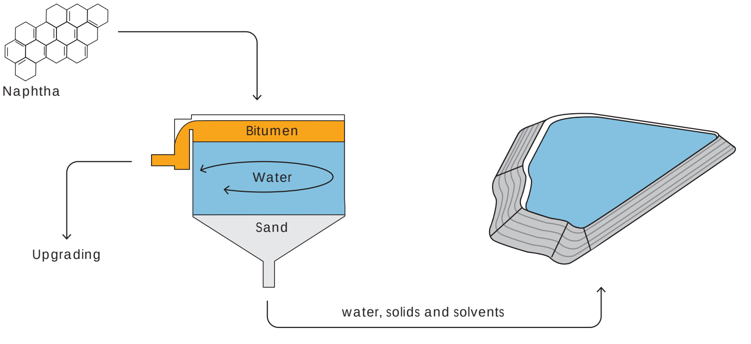


Figure 2.23: Step froth treatment

In the last upgrading step, bitumen will be changed into a lighter form of crude oil.

Step 6: upgrading

In the last step of the process (fig. 2.24) the bitumen will be changed into a lighter form of oil. This is done by removing carbon or the addition of hydrogen. In the upgrading phase the bitumen are also sorted and used to produce several additional products or byproducts but the main product is synthetic crude oil (Oil Sands discovery centre, n.d.).

6.

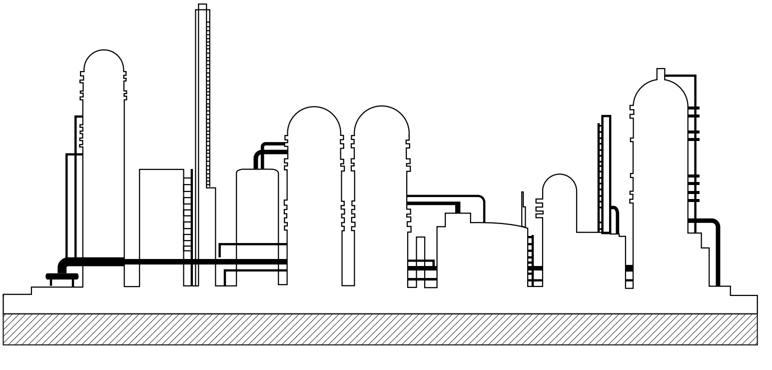


Figure 2.24: step Upgrading

2.4.2 The effects of the industrial process on its environment

The previous mentioned extraction process results into several effects on its surrounding environment. In this section the main effects will be described.

First, the mining operations and the associated processing of the bitumen causes huge surface disturbance. These activities affect the forest, woodlands and wetlands and have a negative impact on wildlife populations (Söderbergh, 2005).

Mining causes surface disturbance which affect forest ecosystems and wildlife

Besides loss and fragmentation of habitats the industry has a major impact on the river system. As described before to dilute and process the bitumen large volumes of water are necessary. With an amount of approximately 170 million cubic meters of water in 2011 the water consumption is comparable with the water use of 1.7 million Canadians.

Since fresh water is extracted from the Athabasca River the Industry has a major impact on this system

This water is extracted from the Athabasca River. Because only 40 to 70 percent is reused in the industrial process the extraction from the river will continue. This affects the annual water flow and its surrounding aquatic ecosystems which dehydrate (Pembina institute, 2013).

After the extraction process the process affected water mixed with sand clay and residual bitumen is too polluted to be returned to the river. For this reason the so called tailings are stored in tailings ponds. This results in a landscape with big artificial lakes of polluted waste water which together occupy an area of 130 square kilometers (Pembina institute, 2013) as showed in figure 2.24.

Process affected water is too polluted to be dumped back in the river therefore it is stored in tailings ponds

Due to seepage of these tailings ponds water is released into the groundwater or surface water which again affects the Athabasca River. Several studies are done on this issue but it is still uncertain what exactly is seeping, how much and what the effects are (Pembina institute, 2013).

Due to seepage of tailings ponds polluted water is released to groundwater

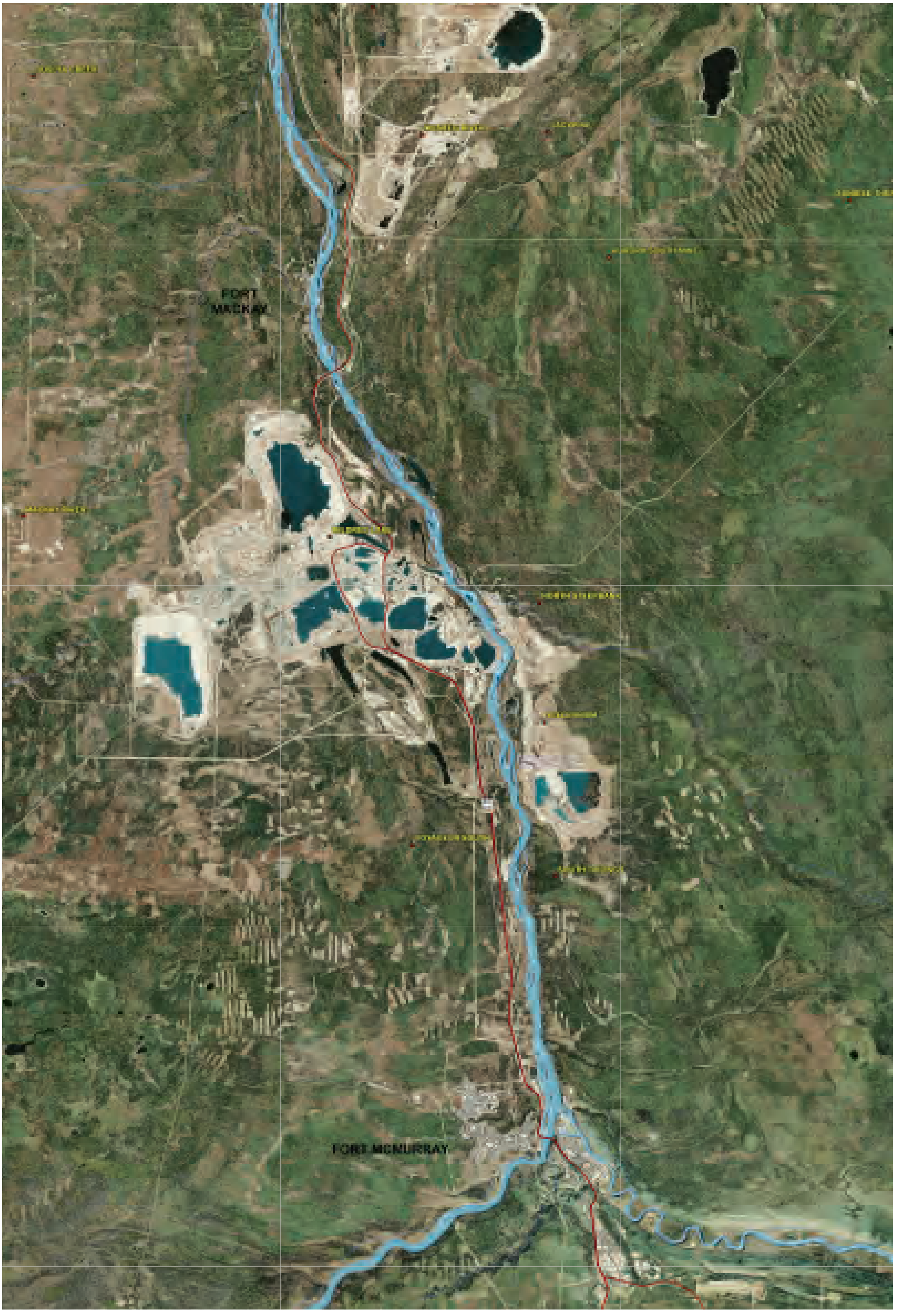


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Figure 2.25 :The effects of the industrial process on its environment,, with a clear overview of the tailingsponds. Source: (BGC Engineering Inc., 2013 (b))

2.4.3 *Change in lifestyle*

Besides the former described effects on the environment the industry also has an effect on the original inhabitants of the area. This population who were accustomed to a life style consisting of hunting and gathering for living, is now working for the oil sands industry. Due to the industrial developments they are not able to use the boreal forest for their traditional land uses anymore. The community of Fort MacKay is in particular affected by the industry. This community is located in the middle of the mines. At the moment these people are economically dependent on the industry (Interviewee 8, 2013)

2.4.4 *Population growth*

Besides the original inhabitants of the region many laborers from all over the world find their way to Alberta to have a temporary or permanent job at the oil sand industry. These people mainly live in the city of Fort McMurray or in the developed work camps located near the industry. This huge immigration flow results in an enormous population growth.

In a short amount of time the popuilation in and around Fort McMurray has grown tremendously

In 1960 just before the first commercial industrial developments took place the Regional Municipality of Wood Buffalo only had a population of 1200 inhabitants.

In 2030 they expect the population has grown to 230.000 inhabitants (RMWB, 2013) as is shown in figure 2.26.

This enormous expansion results in a lack of retail services, recreational facilities, affordable housing and infrastructure that is made for these amounts of traffic (Interviewee 16, 2013).

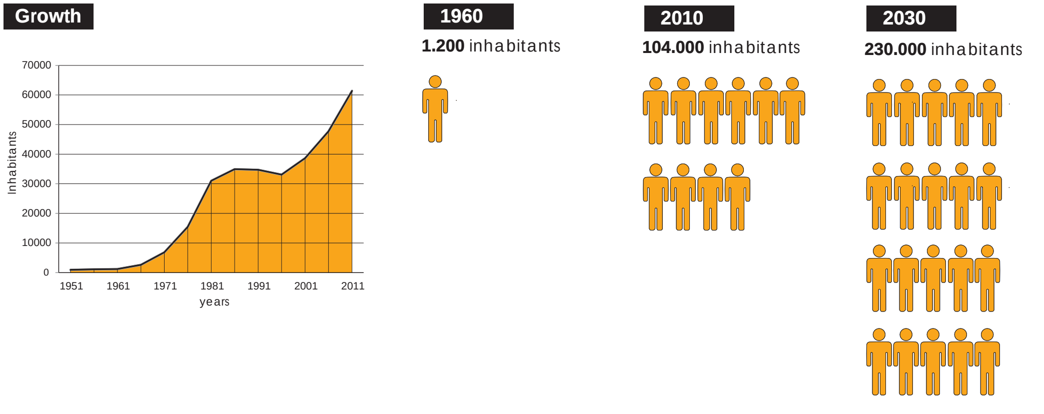


Figure 2.26 : Growth of Fort McMurray. Based on source: (RMWB, 2013)

2.5 The future of the oil sands industry

2.5.1 The end of mine life

The mining area is still increasing, despite some observations who suggested that growth may be over

"Observers have suggested that the oil sands' development growth may be over" (Suncor Energy Inc., 2013), noting that some companies have not been able to sell oil sands assets. However, when we look at the status of oil sands mining projects yet to be developed and currently operating, the mining area will certainly increase in the future, with production ramping up significantly.

Looking at figure 2.27 as shown below, confirms an increase of the oil sands industry in the future. Figure 2.28 shows the different operators and their mines.

Figure 2.27 : Current and planned mining projects in the Athabasca oil sands region Source: (BGC Engineering Inc., 2013. OSIP, n.d. and Junewarren-Nickle's energy group, 2013)

OPERATOR	PROJECT	STAGE	START OF PRODUCTION	YEAR OF CLOSURE
Imperial Oil Ltd	Kearl	Operating	2013	2070
Canadian Natural Resources Ltd. (CNRL)	Horizon	Operating	2008	2050
Shell	Muskeg	Operating	2002	2055
Shell	Jackpine	Operating	2010	2049
Shell	Jackpine mine expansion	Application	2017	n.d.
Shell	Pierre river mine	Application	2018	n.d.
Suncor Energy Inc.	Base	Operating	1967	2070
Suncor Energy Inc.	Fort Hills	Approved	2017	2070
Syncrude Canada Ltd.	Mildred Lake	Operating	1978	2080
Syncrude Canada Ltd.	Aurora North	Operating	2001	2050
Syncrude Canada Ltd.	Aurora South	Development	2016	2044 (1)
Total E&P Canada	Joslyn	Approved	2021	2034
Teck Recources Ltd.	Frontier	Application	2021	n.d.

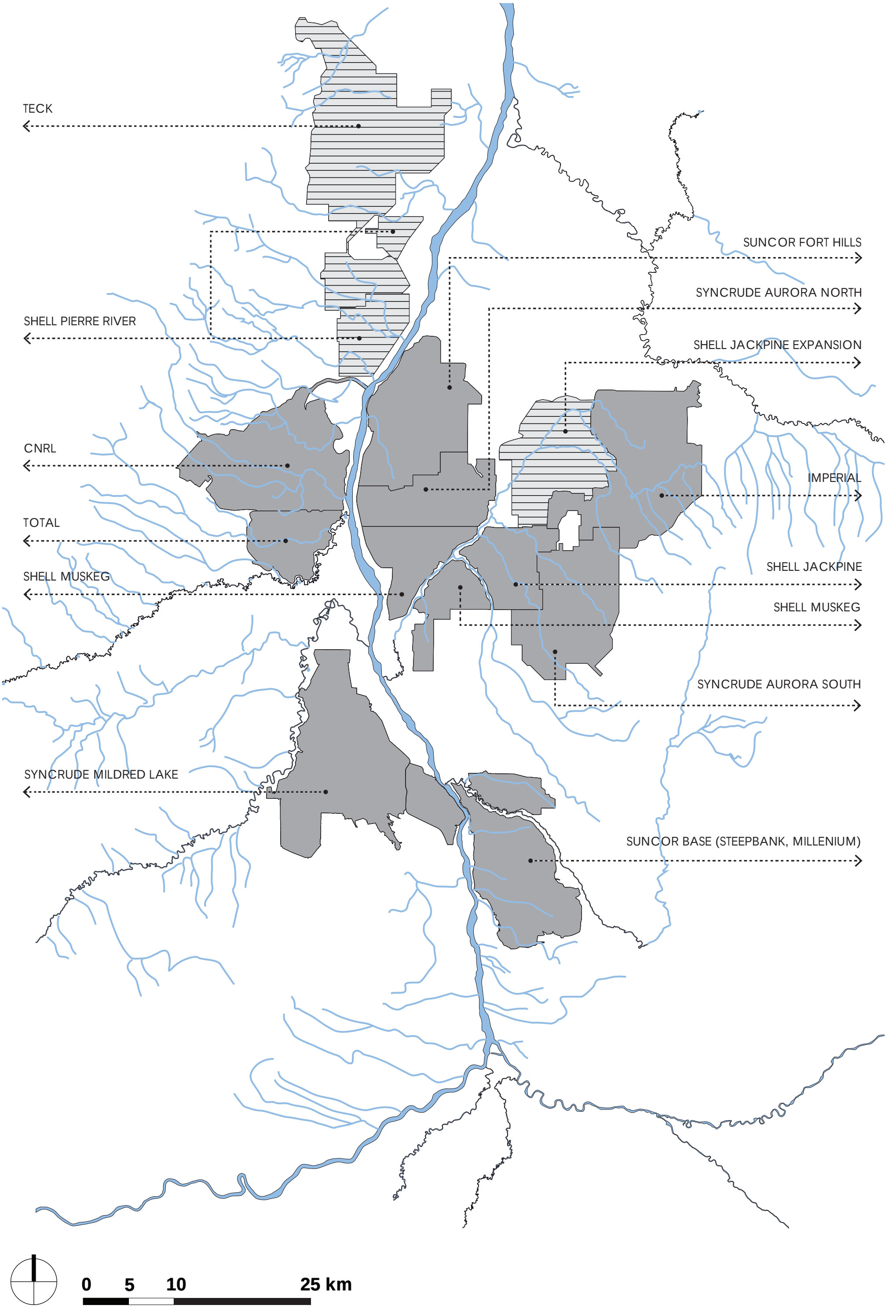


Figure 2.28: The different operators and their mines. Based on Source: (BGC Engineering Inc., 2013 (a) and Junewarren-Nickle's energy group, 2013)

The mining area is still expanding it's borders

In the following image is shown how the area will further develop in the future and which operators are situated where. To keep it more clear we divided the developments into four different time phases, as showed in fig. 2.29, these are as follows: the current situation (2014), 2030, 2050 and 2080. These four different phases provide a good impression of how the area looks like during its peak, around 2030, and when all mines are closed in 2080.

2.5.2 Current reclamation process

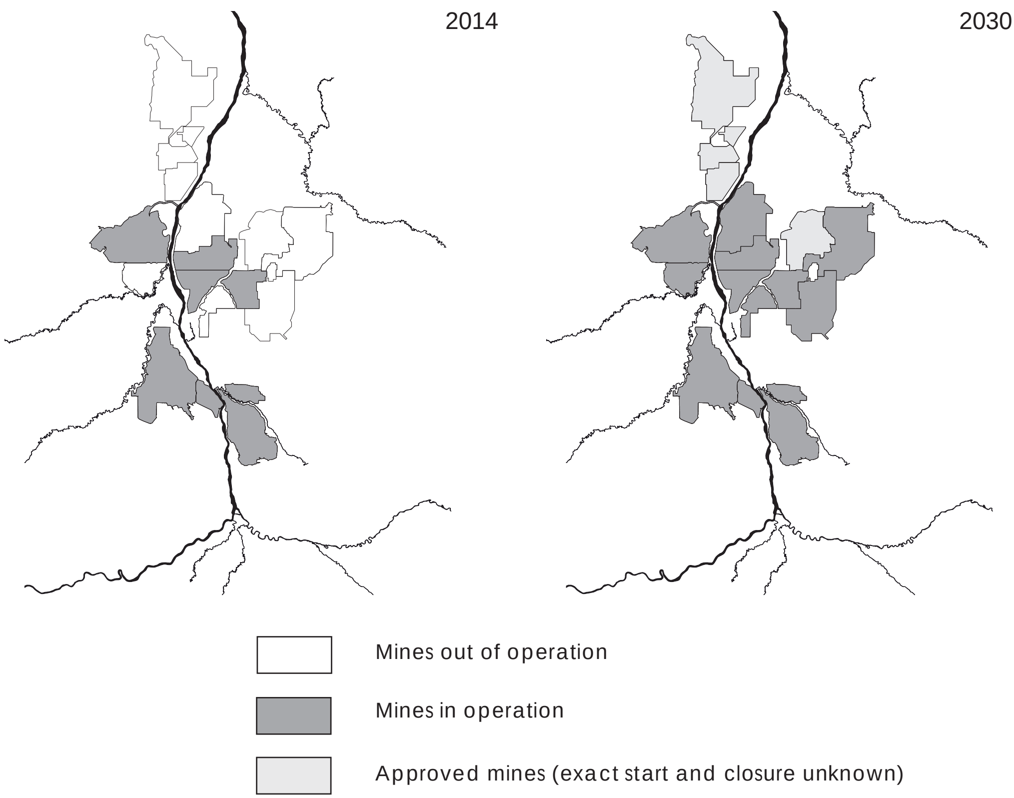
Mining is a temporary activity

Mining is a temporary activity, with the operating life of a mine lasting from a few years to several decades. The last mine in the oil sands will close in 2080. Mines are closed when the supply of ore (bitumen) runs out or the commodity prices drop, making the mine no longer profitable (Fraser Institute, 2012)

Most regulators now require a mine closure plan

companies have the liability to bring back the mined land into wildlife habitat or forestry

As part of the initial permitting process for new mines and as part of ongoing permitting of existing operations most regulators now require a mine closure plan (McKenna, 2002). This plan shows that the site will not pose a threat to the health of the environment or society in the future. In the case of the oil sands industry, companies have the liability to bring back the mined land into productive ecosystems similar to those existing prior to disturbance, for the majority of mines in Canada this means wildlife habitat or forestry, to finally return the land to the Government of Alberta (BGC Engineering Inc., 2010).



Mine closure activities typically consist of several steps: shut-down, decommissioning, reclamation and monitoring. All these steps are part of the mine closure plan, which are specific to each mine.

There is however much to gain in terms of mine closure. As mentioned by McKenna (2002) common flaws of many mine closure plans is that they are very optimistic and often rely on the positive outcome of a high-risk assumption. A proper mine closure plan often uncovers costly deficiencies in existing mine plans, for example, poor placement of a particular waste dump. Another deficiency is that mine plans change frequently so most mines update their mine closure plans about every five years.

There is much to gain in term of mine closure

"The mining industry and its regulators are starting to recognize that reclamation and closure need to be planned and integrated throughout a mine's life" (McKenna, 2002). However, at opening, mining companies are strongly focused on immediate matters of securing the necessary permits, mine planning and site preparation mines, and less willing to invest effort into closure planning activities during the initial stages of mine development (McKenna, 2002). People need to "design for closure", a mine begins to close the day it opens (Interviewee 1, 2013). While early planning for closure might involve more upfront costs, it can reduce the ultimate cost of closure and increase the likelihood of rehabilitation success (Interviewee 1, 2013).

Industry starts to recognize that reclamation and closure need to be planned and integrated throughout a mine's life

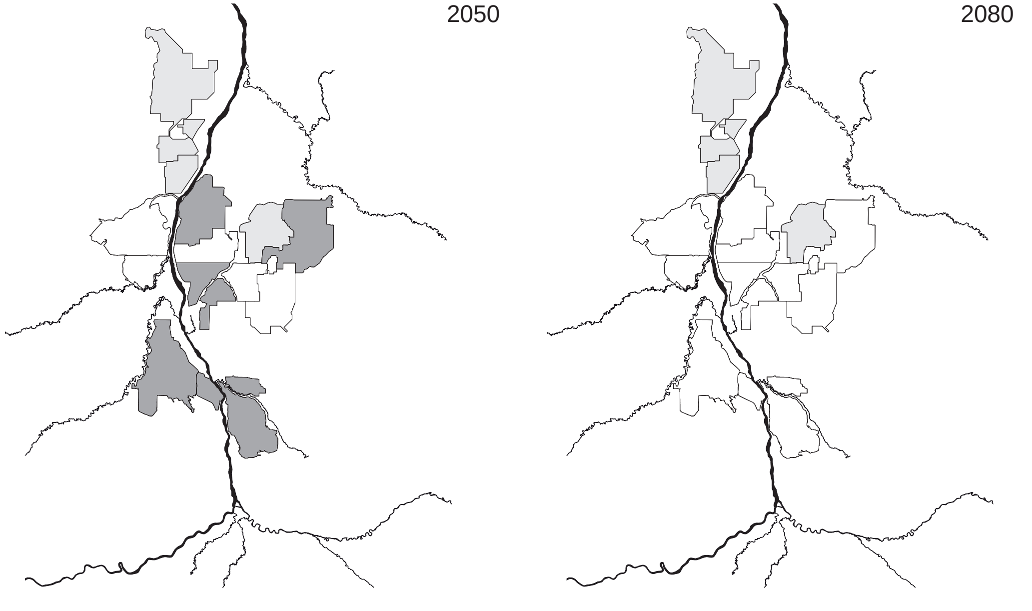


Figure 2.29: The different mine expansions in four different time phases. Based on Source: (BGC Engineering Inc., 2013 (a) and Junewarren-Nickle's energy group, 2013)

2.6 Conclusion

The purpose of this chapter was to give an introduction into the subject. Since we have to deal with complex problems caused by the oil sands industrial activities, a general context of these problems is necessary to understand how these are caused. As a conclusion of this chapter a first problem statement will be given.

As mentioned before the mining activities have an enormous impact on the environment. In the first place it causes huge surface disturbance. Besides that, to process the bitumen fresh hot water is used. This water is extracted from the Athabasca River system. This affects the annual flow and the surrounding aquatic ecosystems.

When the water is used in the process it is too polluted to be stored back into the river system. For that reason the so called tailings are stored in tailings ponds. This result in a landscape of artificial lakes filled with polluted waste water. Due to seepage of these tailings ponds this polluted water is released into the ground or surface water which again affects the river system.

Besides these environmental problems the region also has to deal with effects caused by the industry on a social level. The region dominated by first nations who were accustomed to a life style consisting of hunting and gathering, changed in a short time in a multicultural male dominated industrial society. This enormous population growth results in a lack of retail services, recreational facilities, affordable housing and infrastructure since the region is not able to cope with the rapid developments of the industry.

To conclude the main problems which can be outlined from the context chapter are:

- Huge surface disturbance;
- Extraction of fresh water from the Athabasca river system;
- Huge tailings ponds that have a major visual impact on the landscape;
- Huge tailings ponds that have a hydrological impact on ground and surface water due to seepage;
- A change in lifestyle for the first nations;
- Huge immigration flow of people who come to work and live here, leading towards a lack of various facilities.

From this initial problem statement, we will continue with the theoretical context in the following chapter. Inhere we touch upon our perspective as landscape architects towards all the developments in the region. From there we will do a more in-depth analysis on three different pillars: the landscape, the workings and people's perspective. This will be done to further delineate our problem statement and focus for the design towards a more sustainable system.

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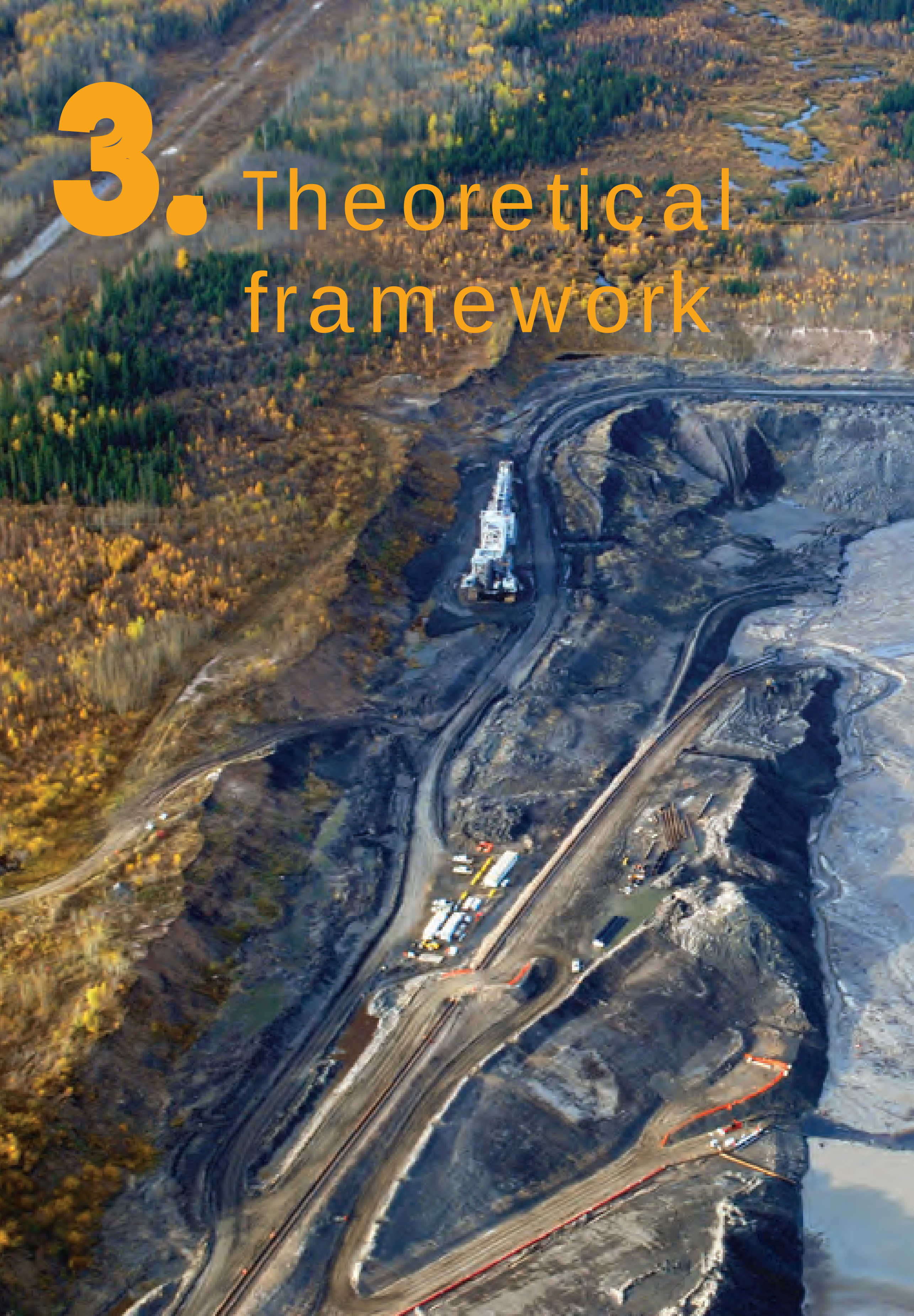
3. Theoretical framework



In the following chapter we will explain our perspective towards the oil sands industry and the future developments in the region.

Starting with our fascination for industrial regions, the problems that occur in the Athabasca oil sands region, the Canadian way of dealing with those problems, how we landscape architects want to deal with these problems, and the associated theoretical concepts that match our line of thought.

Theoretical framework

3.1 Fossil fuel dependent societies and energy-scarce futures

SInce human existence, functioing of ecosysems and health of human economy has been linked

Since the very beginning of human existence, functioning of natural ecosystems and the health of the human economy have been linked. “With the development of the industrial revolution, massive increases in fossil-fuel use spurred dramatic growth of the human population and the economy and widespread environmental degradation” (Day et al., 2009).

Athabasca oil sands in subject to change in order to meet society’s demand for oil

The Athabasca oil sands region is one of these examples, a typical landscape that is subject to change in a more or less chaotic way in order to meet the social and economic need for fossil-fuel (Antrop, 2006). Today, natural ecosystem services, like fossil-fuel, are still necessary. It is fundamental upon which our industrialized way of life and our very existence depend (de Groot et al., 2002).

Due to decline in conventional resources, Canada’s oil sands may bridge the gap between supply and demand

Due to the dramatic decline of conventional oil resources, Canada’s huge reserves of unconventional oil, may play an important role in bridging the coming gap (Söderbergh, 2005). Therefore, large tracks of pristine boreal forest gave way to trucks, bucket wheel excavators, drag liners, to extract the so-called black gold hidden in the sand.

Due to associated environmental impacts the oil sands industry became controversial

The developments in the Athabasca oil sands region therefore became highly controversial due to the associated environmental impacts (Hrudey et al., 2010). Herein a lot of attention has been given to major surface disturbance from open pit mining; massive tailings ponds holding wastes; associated seepage from tailings ponds; the consumption of large amounts of water and accelerating greenhouse gas emissions.

the oil sands industry also has a major social impact on society

Besides the environmental impacts the rapid industrial developments also had a great social impact. From a sparsely populated area in the late 1950s, where economic activities consisted of fur trapping and salt mining, the area grew within a few decades to 104.000 inhabitants in 2010 and is expected to grow towards 230.000 inhabitants in 2030 (RMWB, 2013). From all over the world people (mostly men), came to

Fort McMurray to live and work in the oil sands, leaving their wives and children behind. The question and struggle is whether an inclusive, stable and socially sustainable community will develop in the future.

From all over the world people come to Fort McMurray to work

Developments in this area have thus resulted in a controversy between local and regional economy versus landscape quality and health (Vos and Meekes, 1999). Despite the growing awareness of the importance of ecosystems and biodiversity to human welfare, loss of biodiversity and degradation of ecosystems still continues on a large scale and fundamental changes are therefore needed (De Groot, 2010).

Developments led to controversy between local and regional economy versus landscape quality

Based on today's society and their ever-growing demand for energy we assume that the Athabasca oil sands industry will continue to grow in the next decades.

However these developments have the following effects on the landscape:

Most important effects caused by the oil sands industry are social and environmental in nature

- Degradation of the natural boreal forest and habitat of first nations;
- Large immigration flows of people around the world who come to work and live in the area, resulting in a fast changing society (resulting in shortages in facilities, gender issues);

All the effects that arise are related to each other and industry. Even though the industry operates as a separate entity, the effects developed by the oil sands industry do not stop at their administrative boundaries. The developments in the industry can't be separated from the social problems that occur in the city of Fort McMurray, and vice versa, the city is also fully dependent on developments that take place in the oil sands industry. We therefore need to find a new balance, in order to recalibrate the relationship between people, planet and profit.

All the effects that arise are related to each other and industry, inhere a new balance needs to be found

3.2 The role of landscape architecture

Human society threathens earth's living systems, a transition has to be made

3.2.1 The current way of addressing the environmental problems

"In an increasingly industrializing world, like the Athabasca oil sands, the consequences of human actions on the environment have become increasingly apparent. In different scientific fields, experts seem to agree that within a few decades several crises will occur if no effective action is undertaken" (Brandsma et al. , 2010). It comes down to the fact that human society threatens the earth's living systems, we therefore have to make a transition towards a society based on ecological principles.

Oil companies see the problems that arise as complicated insead of seeing it as a complex problem

The current way oil companies approach the occurring problems is as if they are doing an engineering project. Instead of seeing it as a complex process they see it as a complicated process, which indicates that they do not understand what they are getting themselves in to(Interviewee 17, 2013). The problems that occur due to the developments in the oil sands industry go beyond the discipline of an engineer, they are social in nature, but also environmental.

Complex problems have the need to draw on multiple perspectives

According to Weber and Khademian (2008), such complex or wicked problems have the need to draw on multiple perspectives from various disciplines.

Landscape architecture can be a promising field to adress the problems

Landscape architecture can therefore be seen as a promising field to address these environmental problems (Johnson and Hill cited in Brandsma et al., 2010), not only for their ability to combine natural and cultural processes, but also because of their experience with uncertainty and complex problems (France, 2008 cited in Papenborg and van der Togt, 2013).

The integrative and multidisciplinary approach landscape architects take when addressing complex problems, like the developments in the Athabasca oil sands, can be very enriching and potentially shed new light on current discussions.

3.2.2 The landscape architectural way of addressing the environmental problems

Our educational background as landscape architects starts with the landscape

Prior to explaining how we, as landscape architects, position ourselves and think about how to address the current problems, we will shortly explain our educational background as landscape architectural students from the Wageningen University.

Landscape is the visible result on the surface of the earth of the interactions between man and nature

Our background as landscape architectural students, starts with the landscape, which is the object we study. The landscape is seen as the visible and tangible result on the surface of the earth of the interactions between man and nature (Kerkstra and Vrijlandt, 1988).

Landscape should be seen as one coherent system

The landscape does not consist of separate layers which function independently, the layers work together and make the landscape work as a system. "The landscape can be seen as a system, a web of structural elements of interconnected biological and geological systems, such as food chains and river valleys, and the vast interrelationships of trade and industry" (Vroom, 1976, cited in Duchhart 2007). The task of the landscape architect is to let this system function as one.

For this reason we see the Athabasca oil sands region as one coherent system where industry, people and nature are part of. To visualize these interactions between people and nature we used the Dutch Triplex model developed by Kerkstra and Vrijlandt (1988).

We thus see the Athabasca oil sands region as one system

This model consists of three different layers: the anthropogenic (geomorphologic), the biotic (nature) and the abiotic (occupational, human) as is showed in figure 3. 1.

The landscape comprises of an anthropogenic, biotic and abiotic layer

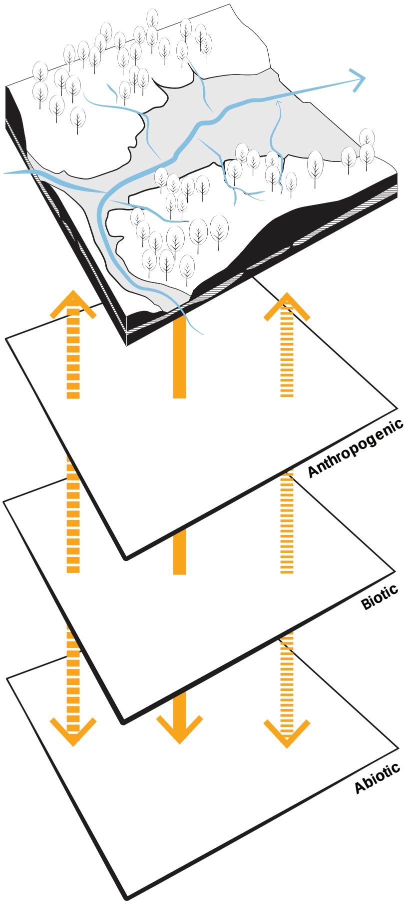


Figure 3.1: Triplex model

These taken together are landscape forming processes, all affecting and interacting with each other over time (Kerkstra et al., 1976 in: Hidding, 2006). In the case of the oil sands industry, the industrial processes (anthropogenic) can affect the natural processes (biotic), this can however also happen vice versa.

These layers taken together are landscape forming processes all affecting and interacting each other

The ecological method by McHard corresponds to our systematic line of thought

The Ecological method developed by McHarg corresponds with this system way of thinking "the particular interest of landscape architecture lies in the study of physical and biological processes, as dynamic and interacting, responsive to laws, having limiting factors and exhibiting certain opportunities and constrains" (1967 stated in Swaffield 2002 p. 39). He believes that this ecological way of thinking is essential and indispensable in planning and design.

In order to understand the three different layers a thorough understanding of the entire system is needed

In order to understand the three different layers that together form landscape forming processes, a thorough understanding of the entire system is very important. Therefore we have developed three different analytical chapters, that all deal with these different layers, Chapter 5 covers the abiotic and biotic processes and chapter 6 and 7 deal with the anthropogenic processes which are called the workings (chapter 6) and people's perspective (chapter 7).

The model of Duchhart takes the layer approach even a step further by including driving forces

Duchhart (2007) even takes the triplex model a step further and combines it with the model developed by Kleefmann (1992), to study the driving forces that create the visual landscape (fig. 3.2). Inhere cultural, political and economical forces are also incorporated which are in the case of the Athabasca Oil Sands of great importance.

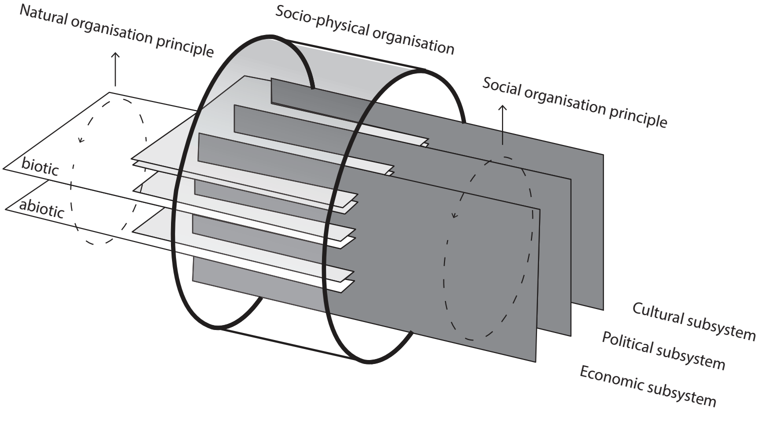


Figure 3.2: Driving forces underlying the visual landscape
Source: (Duchhart, 2007, p.194).

The systems way of thinking falls within the landscape based design approach

This systems way of thinking about landscape falls within the "landscape based design approach", which is the way we researchers are taught at the Wageningen University.

Starting from a landscape based design approach, which sees the landscape as a coherent system, we developed the following vision to address the current problems in the Athabasca oil sands.

3.3 A landscape architectural vision for the future of the Athabasca oil sands region

The position that we take on the oil sands industry, is a position in which we take responsibility for the changes in the landscape, we recognize the environmental and social impacts caused by the oil sands industry, but are also aware of the fact that current society still needs oil. As landscape architects, we want to ensure that transitions in the landscape are led in the right direction, to ultimately achieve a more sustainable and valuable landscape in the future.

The position we take on the industry, is a position where we take responsibility for the changes in the landscape. While acknowledging society's need for oil

These transitions should take place according to the three pillars of sustainability (fig. 3.3): people, nature (planet) and industry (profit), since these are the pillars where the various problems occur. To finally bridge the contrasts and find a new balance between the economic development and the environment (Elkington 1994, Schultz, 2008, Wu 2013).

All transitions should be considered along the three pillars of sustainability: people, planet, profit

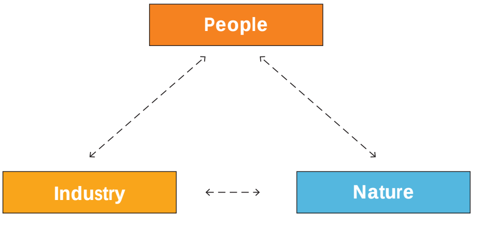


Figure 3.3: Three pillars of sustainability

John F. Kennedy once said;

"There are risks and costs to a program of action. But they are far less than the long-range risks and costs of comfortable inaction" (J.F. Kenney quoted by interviewee 11, 2013)

Changes we make have to survive in the long term

If we do nothing, we will survive in the short term, but we won't survive in the long term. But if we chose to do something, it will be rough in the short term but it will make you survive in the long term and even makes you stronger. Which is of course tough, since we humans are present focused. We however need to make changes, because we can't continue the way we are living right now.

These changes have to be applied from now on if possible, by using natural processes

Our objective is to take responsibility for the harm we do to the landscape and start changing things from now on to create a more sustainable and more qualitative landscape in the long term. We therefore want to use natural processes (instead of engineer-like manufactured processes)to resolve the current issues in the oil sands industry, to eventually come ever closer to a natural balance and increase the quality of the landscape, as showed in fig. 3.4. While manufactured engineer-lilke solutions lead to a certain amount of landscape quality, natural processes however transcend this, due to their growth and succession in time.

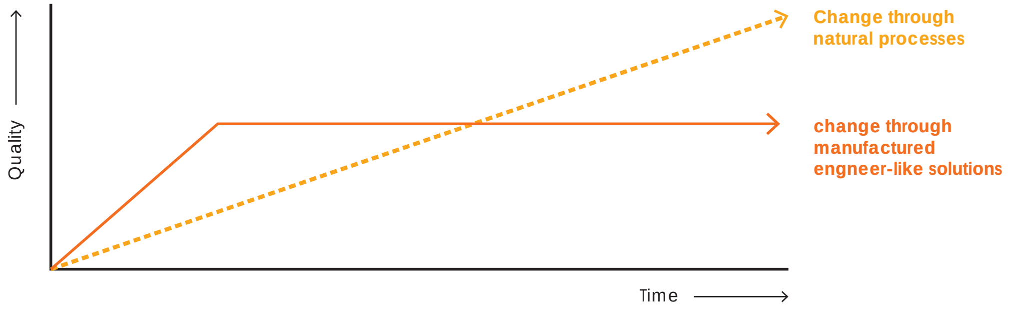


Figure 3.4: Solutions have to be sought that survive in the long term

The focus of our design solutions lies on implementing them right away where possible, even during the operational phase of the mine, to further reduce the impact of the oil sands industry. In here we start from the systems way of thinking and combine the environmental and social problems, to eventually develop a comprehensive solution which seeks to reduce both problems.

We finally want to redirect the current future we are heading to and provide a richer future in the long term (fig. 3.5).

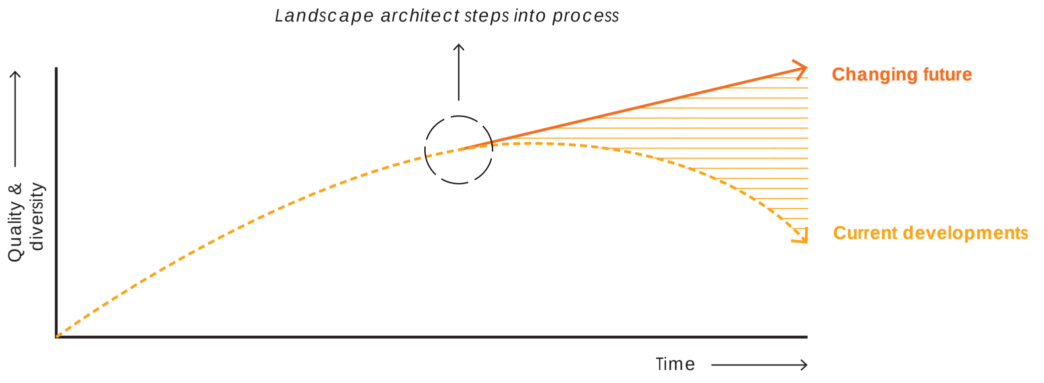


Figure 3.5: A richer future in the long term

However a remark must be made "these types of problems have an infinite number of possible solutions that might offer a slight improvement over the current state, there is however no absolute answer if the solutions really improves or worsens the situation" (Papenborg and van der Togt, 2013).

A remark however is that these kind of problems have an infinite amount of solutions, there is no absolute answer if it will really improve

In order to make progress, educated guesses have to be made based on empirical research but with a high level of uncertainty (Papenborg and van der Togt, 2013), because much of the data remains within the four walls of the large oil magnates.

We therefore had to make educated guesses since a lot of information was kept confidential

The following figures show the purpose of our thesis. The development curve will gradually increase and after time gradually decrease

In the following figures our purpose for this thesis is shown. At first we accept that current society still needs oil. The development curve in the Athabasca oil sands will have a peak, in which most of the mines will be in operation and then gradually decrease (fig. 3.6).

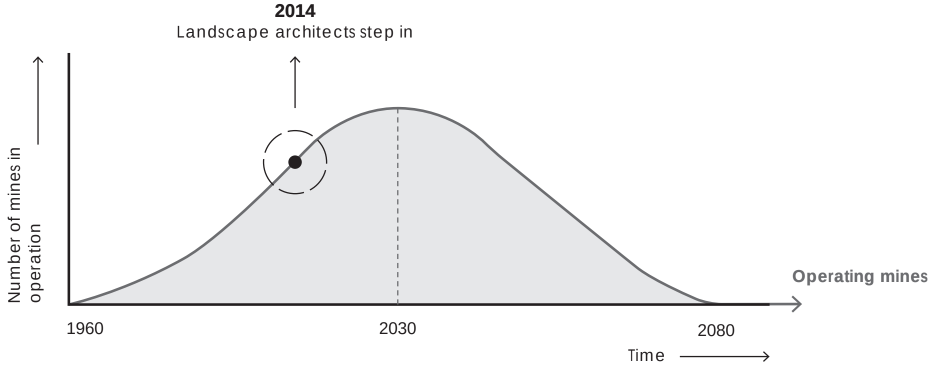


Figure 3.6: Oil sands developments have a peak and then slowly decrease

Our design will be an integrated solution for the current environmental, social and economical problems

Our design will be an integrated solution for the current environmental, social and economical problems occurring in the area which can be implemented right away (fig. 3.7).

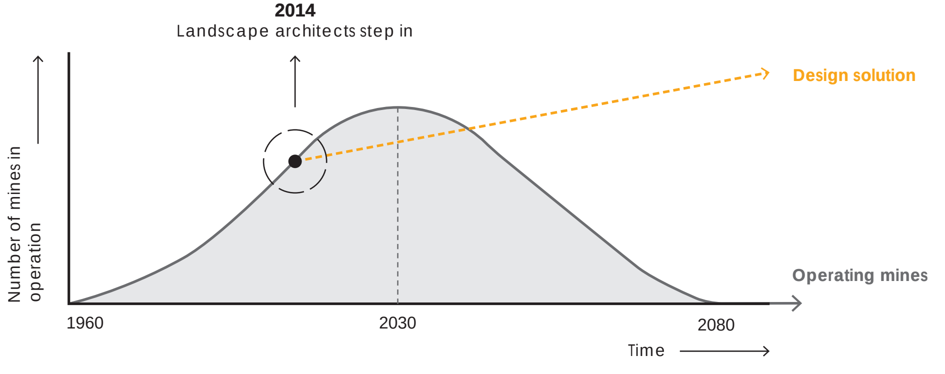


Figure 3.7: The design will be an integrated solution for the current problems, to be implemented right away

When we, landscape architects, step in to the process, we assume that the problems that occur in the area will decrease and the landscape quality will increase. Since we work with natural processes which needs to grow, in the beginning quality will not immediately be visible. However on the long term it will pay off as shown in figure 3.8 resulting in an increased landscape quality.

We will step into the process from now on and assume that quality will increase and problems decrease

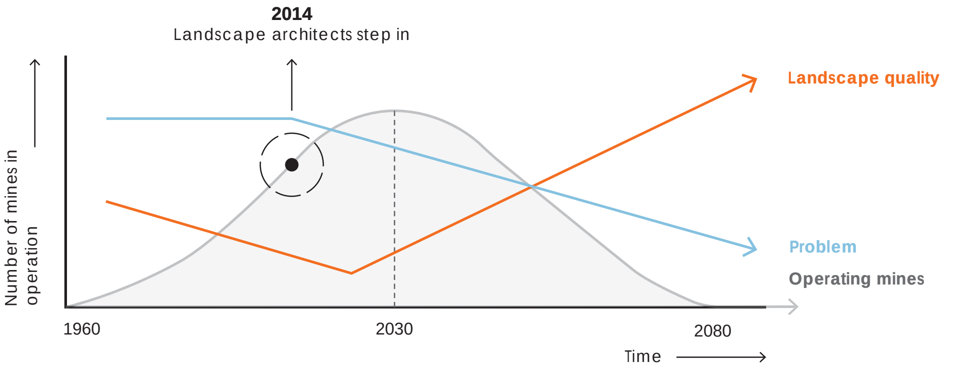


Figure 3.8: Current problems will decrease and landscape quality will increase

To finally develop a landscape where the environmental problems are outweighed by landscape quality (fig. 3.9). We do not expect that all the problems will disappear, this will probably take centuries.

To eventually outweigh environmental problems by landscape quality

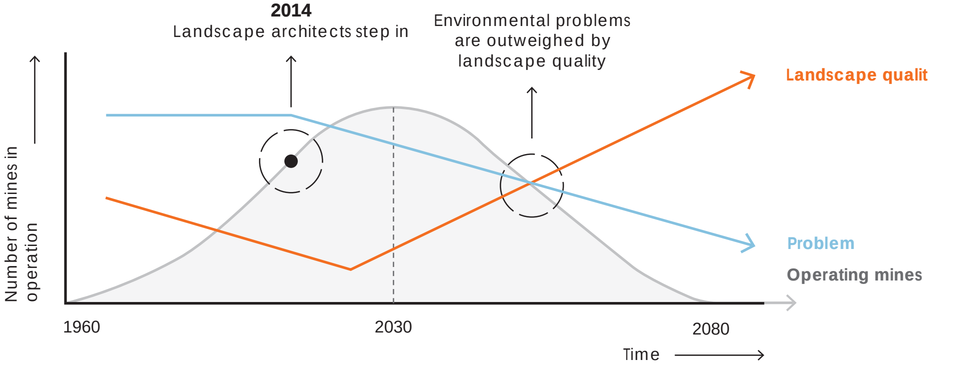


Figure 3.9: Environmental problems will be outweighed by landscape quality

We thus see the landscape as a system, the mining industry is a system par excellence, with input and output

What we want to emphasize is that we see the landscape as a system, as just described in paragraph 3.2. The Athabasca oil sands region, and in particular the current mining area, is a system par excellence. Oil sands ore is put in to the system, it's processed and subsequently crude oil comes out.

By looking at the problems from a landscape architectural perspective, we hope to divert the problem, leading to new insights.

Different problems that occur are social and environmental in nature. The current engineer-like approach to the problems will of course help and decrease the problems to a certain level, however not solve it. A more integrated and multidisciplinary approach is therefore needed. Our aim is to try to divert the problem by looking at the problem from a landscape architectural perspective. This is something not done before and can lead to new insights and ideas on how we can deal with complex problems like these.

The concept of landscape machines and hybrid landscapes fit to our line of thought

The concepts of landscape machines and hybrid landscapes correspond to our line of thought and help to assist in dealing with these dilemmas.

3.4 The Landscape as a machine

A malfunctioning system form the basis for the landscape machine

The objective of addressing the malfunctioning of the Athabasca oil sands industry forms the basis of the landscape machine, developed by Roncken (2011).

Two aspects define a landscape machine.

1. At first the aspect of a machine must be taken literally,

2. natural processes constantly interfere with each other and thus affecting type, shape, size of the machine

According to Roncken et al. (2011), there are two important aspects which define a landscape machine. The first one is that the aspect of the machine must be taken literally. "These are machines that have a certain material input and output and are driven by a critical amount of energy input" (Roncken et al 2011, p. 10). A site specific example for the oil sands could be vegetation planted on tailings ponds. This vegetation should have the ability to clean up the water, and can be used for biomass energy.

Secondly, "the natural processes within the landscape machine are continuously interfering with each other and therefore affecting the type, shape, size and position of the resulting landscape components" (Roncken et al 2011, p. 10).

The concept matches with the Athabasca oil sands, since they both start from a dysfunctional system

The corresponding lines of thought when comparing the oil sands industry with the concept of a landscape machine deals in particular with similar ideas about how to cope with a dysfunctional system. It should however be mentioned that we do not develop a landscape machine, we see the oil sands industry as one big landscape machine, we landscape architects step into this process, acquire knowledge about this process and make adjustments by adding natural operational processes.

At this moment, they approach the problem as if they are doing an engineering project (Interviewee 17, 2013). Nature, is to our opinion cosmetic and only used in the final phase of reclamation to cover everything. The concept of the landscape machine is based on naturally – yet dormant – operational processes instead of manufactured as they are doing at this moment.

Currently is dealt with problems like if they do an engineering project

Due to these natural processes, the machine is constantly reacting and interacting with ecological, physical and chemical processes that the landscape has to offer, therefore the actual product of the machine and the way of producing will change with time (Roncken et al., 2011).

By using natural processes a more dynamic and diverse system arises

The aim of the final design is not focused on a maximized efficiency – as in Victorian hard-cast machines – but the delivery of abundant and diverse ecosystem services. By using natural processes to resolve the current issues in the oil sands industry, one comes ever closer to a natural balance and bridge the contrasts between people, nature and industry, which eventually lead to a more sustainable landscape (Roncken et al., 2011).

We do not aim to maximize efficiency, but about delivering an abundance of ecosystem services.

3.5 The development of a hybrid system

The concept of hybrid landscapes does not aim to divide natural, industrial and social functions from one another but rather looks for an integration between these different functions (Papenborg and van der Togt, 2013), a landscape of multiple activities and processes (Hou, n.d.). Distinction between these different functions therefore becomes less.

The concept of hybrid landscapes starts from integrating different functions

According to Neef (1982) cited in Golley (1982), 'hybrid' means the mixture of natural components derived from the original landscapes and new components introduced by man, all manipulated by human activity. Inhere biological entities are impacted by a variety of human actions. Inhere different dynamics are mixed with each other and therefore creates new forms and possibilities (Delbene, 2009 cited in Papenborg and van der Togt, 2013).

'hybrid' means the mixture of natural components and artificial components

Linking this back to the Athabasca oil sands industry, creates a more dynamic and diverse landscape since different functions are integrated rather than separated. In this case industrial, natural and social processes are being integrated instead of separated.

The concept matches with the Athabasca oil sands since we aim to mix functions together, to develop a more sustainable system

3.6 Summary

To summarize, we have discussed the following in this chapter: our fascination for industrial regions, the problems that occur in the Athabasca oil sands region, the Canadian way of dealing with those problems, how we landscape architects want to deal with these problems, and the associated theoretical concepts that match our line of thought.

The main problems that occur are social and environmental in nature

Two main effects have been mentioned in the beginning of this chapter caused by the growing oil sands industry, which were as followed:

- Degradation of the natural boreal forest and habitat of first nations;
- Large immigration flows of people around the world who come to work and live in the area, resulting in a fast changing society (resulting in shortages in facilities, gender issues);

Canadians have a very engineering-oriented way of thinking. However the occuring problems surpass the discipline of an engineer

Canadians have a very engineering-oriented way of thinking. Instead of seeing it as a complex process they see it as a complicated process, which indicates that they do not understand what they are getting themselves in to(Interviewee 17, 2013). The problems that occur due to the developments in the oil sands industry go beyond the discipline of an engineer, they are social in nature, but also environmental.

A systems way of thinking is important

We therefore have to start thinking and seeing the Athabasca oil sands region as one coherent system, where all the different levels in the landscape and their associated problems (social, industrial and natural) mutually influence each other.

Landscape architecture can therefore be a promising field

A more integrative and comprehensive approach is therefore needed and landscape architects in contrast with engineers are able to combine natural and cultural processes, and deal with high level of uncertainties and complex problems (France, 2008 cited in Papenborg and van der Togt, 2013).

To create a more sustainable system on both an industrial, natural and social level

This eventually creates a more dynamic and diverse landscape since different functions and processes (industrial, natural and social) are integrated rather than separated.

In the end we take responsibility for the harm we do to the landscape and want to start changing things from now on to create a more sustainable and more qualitative landscape in the long term. We therefore want to use natural processes (instead of engineer-like manufactured processes)to resolve the current issues in the oil sands industry, to eventually come ever closer to a natural balance and increase the quality of the landscape.

The concepts of the landscape machine and hybrid landscapes are in line with our ideology because:

- They deal with landscape processes, opposed to engineer like solutions, to solve malfunctioning systems. Which brings us closer to a balance between people, nature and industry, which eventually leads to a more sustainable landscape system;
- Both start from the idea that the landscape is based on integration/ mixture of different elements instead of separation;
- Both concepts finally want to achieve a more dynamic and diverse landscape in the long term.

These theoretical concepts form the basis of how we think about the Athabasca oil sands and how our expertise and our perspective can divert the problems by looking at the problem from a landscape architectural perspective. With the aim to generate new ideas about the current problems and clarify people, connected to the oil sands industry, the added value of landscape architecture.

The theoretical concepts of a landscape machine and hybrid landscape fit towards our vision

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4. Research Framework

In this chapter the research framework will be described. This framework starts with the knowledge gap followed by the problem statement and the research questions. The way we approach this study is strongly influenced by our philosophical ideas and landscape architectural lens, which form the second section in this chapter. Eventually this chapter ends with the methods we used in this research.

Research Framework

4.1 Knowledge gap

4.1.1 Current research on the oil sands

current research on the oil sands industrial developments is very discipline specific

A comprehensive literature study has revealed that there is a lot of research already done and going on regarding the industrial oil sands developments. This research is mainly approached from three different disciplines/perspectives. Firstly the technology and engineering sciences, focused on a more positivistic way of thinking. Whith research focused on improving the industrial processes. Secondly the environmental sciences which mainly concerns the effects of the industry on its surrounding environment. At least the social sciences which research is focused on the indigenous people of the region and the effects of the enormous population growth. Research which combines these different disciplines in a more comprehensive study is hardly ever done.

4.1.2 *An integrated approach towards landscape sustainability*

There is a lack of research which is integrating this discipline specific knowledge

From the previous sub-paragraph there can be concluded that the performed research is very discipline-specific, mainly focused on one part of the problem. The knowledge gap can be found in combining and integrating different disciplines and their derived knowledge to tackle the complex issues related to the oil sand industry. According to Weber and Khademian (2008) such complex or wicked problems have the need to draw on multiple perspectives from various disciplines.

A more comprehensive appraoch is needed!

We as landscape architects can play a key role in closing this gap and work towards a more comprehensive approach. This can be done by using the generated knowledge from all these different disciplines from a landscape based design approach towards a more sustainable landscape for the Athabasca oil sands region. In figure 4.1 the just explained process is depicted.

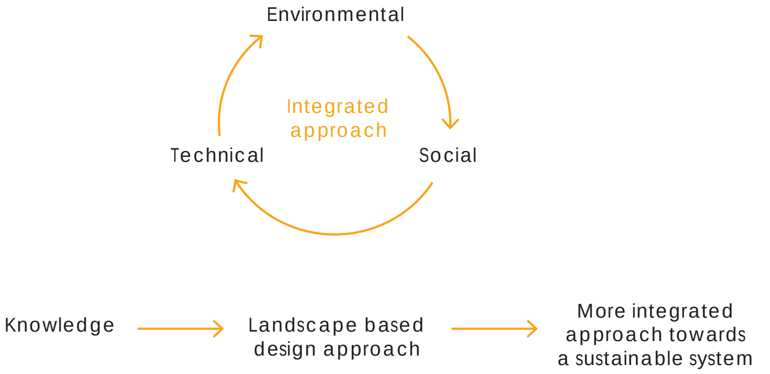


Fig 4.1: From discipline specific towards a more integrated approach

4.2 Problem statement

From our introducing chapters there can be concluded that the Industrial region is affected by the industry on a social and environmental level. The region functions as a business model and economically depends on the industrial developments. This means that the developments going on are done from a perspective which is profitable for the industry and this has most of the times adverse effects on people and the environment.

The region functions as a business model, developments going on from an industrial perspective

Nowadays more and more people starting to realize that this way of approaching the region will not result in a sustainable environment. To achieve this, a more comprehensive approach is needed which includes knowledge from different disciplines to finally come up with developments which are besides profitable for economy also profitable for people and the environment. We think that the landscape based design approach can play a key role in these future developments.

Future developments need to be profitable for economy, people and environment

4.3 Research questions

Derived from the knowledge gap and the problem statement the main research question is as followed:

To be able to achieve this we asked ourselves several research questions

How can a more sustainable landscape system be developed in the Athabasca oil sands industrial region by using a landscape based design approach?

Several in-depth studies are done on three topics, to find the best way possible leading towards a more sustainable landscape system. These consist of the landscape, the workings and peoples perspective and form three analysis parts within this research (fig. 4.2).

Analysis for Design

The landscape →	Understanding the landscape
The workings →	understanding of the industrial process and how this affects the landscape
Peoples perspective →	Finding out people's perspectives towards the industry and requirements for the future landscape

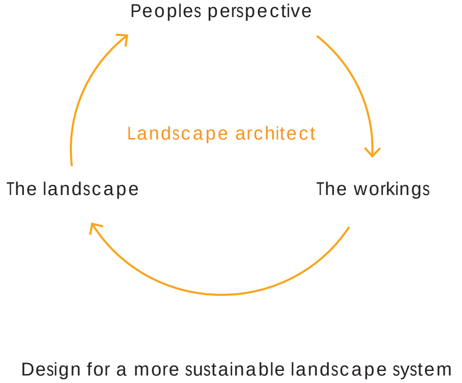


Fig 4.2: Three parts of analysis as input towards a sustainable landscape system

The first question is developed to get a better understanding of the landscape

The first topic is the landscape with a purpose to get a better understanding of the landscape, the question we therefore asked ourselves is as follows:

What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays?

The second question is about the industrial workings and how this effects the landscape

The second topic is the workings with the purpose to get a better understanding of the industrial process and how this process affects the landscape, the question we therefore asked ourselves is as follows:

How does the industry work and what are the effects on the contemporary landscape?

The third question is developed to get to know people's perspectives and requirements for the future landscape

The third topic is people's perspective with a purpose to find out peoples perspectives towards the industry and their requirements for the future landscape. The question we therefore asked ourselves is as followed:

What are the perspectives of different stakeholders regarding the developments of the oil sands industry?

To finally combine the gathered knowledge in the design process is very important. Inhere combinations and considerations will be made that will eventually lead to the desirable result, a more sustainable landscape system. Therefore this research contains two architectural research questions which are formulated as follows:

What measures can be taken in order to develop a more sustainable landscape system?

How can these measures be implemented in order to achieve a more sustainable system?

In figure 4.3 an overview of these questions is given. Before we continue with a description of the methods, which we used to find answers to our questions, our philosophical assumptions and landscape architectural lens will be described. These sections have a major impact on how we address this research.

The last two questions are architectural research questions and focus on what measures can be taken, and how these measures can be implemented to achieve a more sustainable system

Descriptive RQ	Explorative RQ	Architectural RQ
The Landscape - What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays? The Workings - How does the industry work and what are the effects on the contemporary landscape?	Peoples perspective - What are the perspectives of different stakeholders regarding the developments of the oil sands industry?	Design - What measures can be taken in order to develop a more sustainable landscape system? - How can these measures be implemented in order to achieve a more sustainable system?

Fig 4.3: The sub-research questions

4.4 Philosophical assumptions

As mentioned before the practice of research is largely influenced by philosophical ideas. In order to remain as objective as possible (Creswell, 2009, p.5), we must therefore be open and clear about our philosophical ideas.

Pragmatism is the main worldview in this research

Creswell(2009), uses the term 'worldview' in order to describe people's philosophical ideas that guide action.

Our research can be seen from a pragmatic worldview. Pragmatism is strongly associated with the mixed methods research, "instead of focusing on methods, researchers emphasize the research problem and use all approaches available to understand the problem" (Creswell, 2009, p.10), they therefore use different knowledge claims both objective and subjective (Lenzholzer, Duchhart and Koh, 2013).

This worldview is strongly associated with mixed method research

A pragmatic worldview is thus problem-centered, pluralistic and focuses on practice and 'what works' (Creswell, 2009, p. 6 and Lenzholzer, Duchhart and Koh, 2013).

This worldview is strongly associated with mixed method research

Our main research question is in connection with our worldview. However, since the 'pragmatic' is known for using mixed methods, which applies that researchers can draw liberally from both quantitative and qualitative assumptions, the researcher is not committed to any one system which makes the use of different methods depend on the research questions formulated by the researchers and the context (Lenzholzer, Duchhart and Koh, 2013).

Different methods we used have a constructivist or post - positivist approach

The sub-research questions also fall under a particular worldview depending on their objective. The most important worldview for the sub-research questions and the different methods we used is constructivism. However some of the methods we used in order to find answers to our questions are also (partly) covered by the post-positivistic worldview.

The aim of social constructivist research is the generation of theory or meaning. It's not the intent of the researcher to find quantitative knowledge, but about 'making sense' of situations in a qualitative and contextual way (Lenzholzer, Duchhart and Koh, 2013). When looking at our thesis our landscape analysis and stakeholder analysis all contributed to increase our understanding. In figure 4.4 is showed how the pragmatic worldview dominated this research with several influences from constructivism and post – positivism.

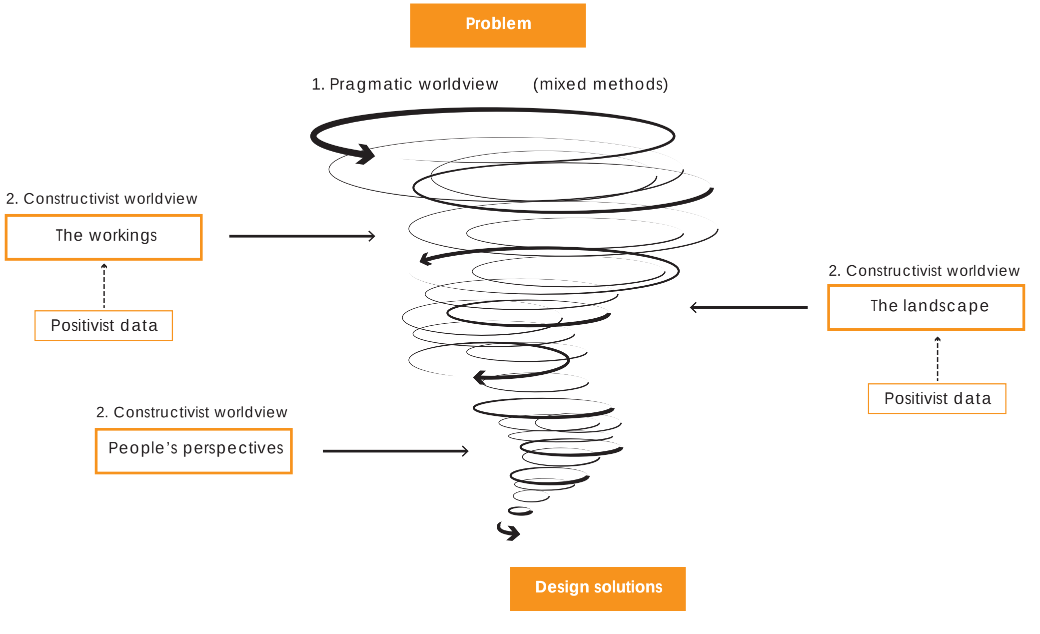


Fig 4.4: The philosophical assumptions in this thesis

However to fully understand the different processes going on in the landscape, we also had to do several inquiries in order to deepen our understanding of various issues, this often included the translation of specialist knowledge (hydrology, landscape ecology, geo-technology) into applicable knowledge, these inquiries were post-positivistic in nature.

4.5 Landscape architectural lens

The philosophical worldview precedes defining a theoretical lens. "A theoretical lens in turn forms a guiding perspective for a mixed methods research" (Creswell, 2009, p. 68) and shapes the different steps that need to be taken in a research process.

Our landscape architectural lens is based on the way we are educated

Besides that it indicates how a researcher positions him or herself in the qualitative study (Creswell, 2009, p.62), our lens is landscape architectural in nature and is developed by the knowledge and experience obtained during our study at Van Hall Larenstein and the Wageningen University.

As mentioned before this starts with the landscape, which is the object we study. We see this landscape as a system of different layers which interact with one another. Our position we take on the oil sands industry, is a position in which we take responsibility for the changes in this landscape. Our system way of thinking will play a key role in this position since we want to find a solution in finding a balance again between the different layers within this landscape.

Inhere we see the landscape as a system of different layers which interact with one another

4.6 Methods

4.6.1 Data collection

As described before our research can be seen from a pragmatic worldview, which is strongly associated with the mixed methods research. This means we have seized upon everything to get a better understanding of the problem.

Mixed method research

This research was started with a proposal phase. This phase started with data collection by means of a literature study and map studies. This resulted in a preliminary proposal for our research (fig. 4.5).

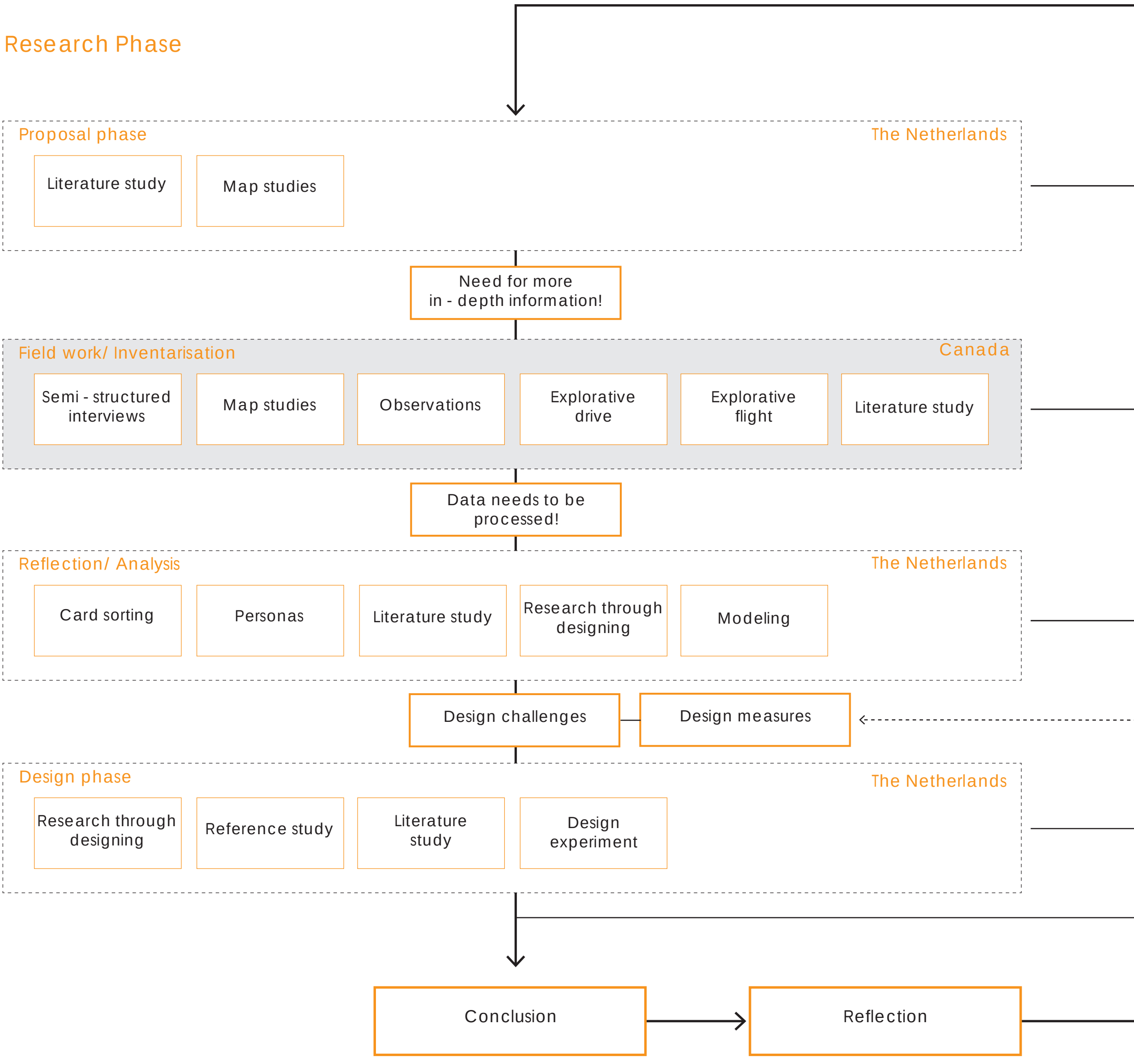
We started with the proposal phase of this research

From this research also revealed that current studies on the oil sands industry are very discipline specific. Research done from an environmental view puts the oil sands industry in an unfavorable light, while the more technical research talks in favor of the industry. Because of these conflicting interests it was hard to obtain an objective view about the industrial developments for us as researchers.

It was hard to form an objective view for us as researchers

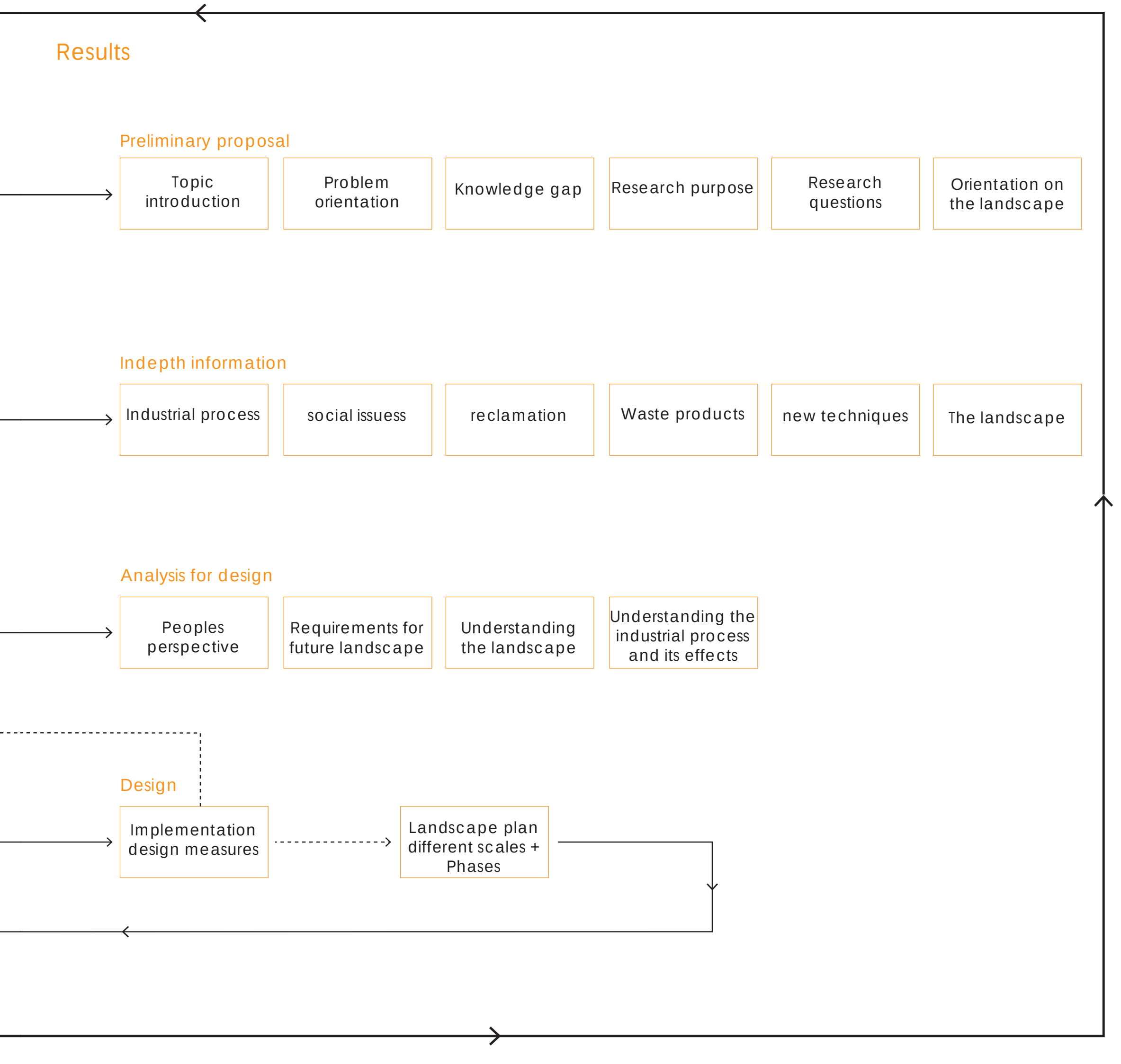
Another issue we faced within this first phase of data collection is that much information is not publicly available. This constituted as well as a barrier in understanding the problem and in getting an objective view.

A lot of data is not publicly available



Research Phase
Proposal phase
The Netherlands
Literature study
Map studies
Need for more in - depth information!
Field work/ Inventarisation
Canada
Semi - structured interviews
Map studies
Observations
Explorative drive
Explorative flight
Literature study
Data needs to be processed!
Reflection/ Analysis
The Netherlands
Card sorting
Personas
Literature study
Research through designing
Modeling
Design challenges
Design measures
Design phase
The Netherlands
Research through designing
Reference study
Literature study
Design experiment
Conclusion
Reflection

Fig 4.5: Flowchart of the research process



In order to collect in-depth data a fieldwork phase was started

In order to collect in-depth knowledge about the topic we continued our research at the University of Alberta in Edmonton. At this University many researchers and experts in the field of the oil sand industry are employed. Inhere data was collected on different topics by means of semi- structured interviews with many different experts.

During this fieldtrip we did a lot of interviews

Besides these interviews we made several field trips to the Athabasca oil sands region. This together gave us the opportunity to collect more in-depth data which seemed unreachable before. This phase of which is called our fieldtrip is showed in figure 4.5.

Most oil sands operating companies have an obligation of confidentiality

Because of the highly debated topic of the non - conventional oil sands mining a lot of data was and still is unreachable for us as researchers. Most of the companies operating in the oil sand industry have an obligation of confidentiality. This means that in this research several assumptions based on the data which was available had to be made.

'Research through designing' was also an important method in this research

An important method we used to do this is research through designing. This will be explained more comprehensive in the following section by firstly discuss the relation between research and design in landscape architecture to finally explain the method of research through designing and how this method was important in this research.

4.6.2 Research and design

Research as important element within landscape architecture

Within the discipline of landscape architecture there is an increasing eagerness to deal with more complex issues. Since the movement from modernism to post – modernism more landscape architects focus on issues as social responsibility, sustainability, the environment and human health instead of the perception of the designer as an artist or creator. This change makes research within landscape architecture a very important element to come to a responsible design (Milburn and Brown, 2003).

Design is the core activity in landscape architecture

In the practice of landscape architecture design is seen as the core activity. This means that most of our methods consist of a combination of research and design (Creswell and Plano Clark 2011 cited in Lenzholzer, Duchhart and Koh, 2013).

Three groups of research and design interactions: research for design, research on design and research through design

Within the literature several relations between research and design are discussed. According to Lenzholzer, Duchhart and Koh (2013) three groups of research and design interactions can be distinguished. The first one is research for design. Inhere research informs the design. In our case this was mainly done by means of a literature study and interviews. The second one is research on design. Inhere research is done on finished design products for example in the form of a reference study. The third one is research through designing. This is developed as a method to combine research with the design process, and focused on the activity of designing as a research method (Lenzholzer, Duchhart and Koh, 2013; Deming & Swaffield, 2011; Duchhart, 2011).

4.6.3 Research through designing

Within this research, research through designing played an important role in understanding the industrial process. By means of sketching we were able to validate the generated data from the proposal phase and our field trip to finally get a better understanding of the industrial process and its influences on the landscape. By doing this new data was generated as well. This step in our research is showed in the reflection/analysis phase of figure 4.5.

Research through designing played an important role in understanding several processes

Besides research through designing we also used methods as card sorting, the personas method, the interest influence matrix and modeling in this phase. These methods were mainly used to get a clear overview of people's perspective towards the industrial developments and to understand the landscape.

Besides understanding we also used research through designing to combine the research with the design process. Within the designing process we sketched and several design measures were developed. To make these measures applicable more in-depth research by means of a literature study and a reference study was needed. By doing this research and by sketching with this new knowledge new measures were developed and others were adapted to finally be able to make responsible choices for the design. This fourth step in our research is showed in the design phase of figure 4.5.

Besides that we used research through designing to combine the research with the design process

4.7 Conclusion

The research framework explains our thesis process and the way we will approach it. The way of approaching this research is influenced by the main philosophical assumption for us as landscape architects, which is called pragmatism. This worldview is strongly associated with mixed method research. Parts of this research are also influenced by social constructivism and post positivism, since the pragmatic worldview enables the researcher to draw liberally from both quantitative and qualitative data, the pragmatic worldview therefore makes researchers able to use different methods depending on the research questions (Lenzholzer, Duchhart and Koh, 2013).

These philosophical assumptions play an important role in the determination of the used methods. Research through designing that comes from a more pragmatic approach was significant in this research. In the first place it helped to get a better understanding of several processes going on and in the second place it was used to combine the research with the design process. In the upcoming chapters the results of the several phases will be explained more comprehensive.

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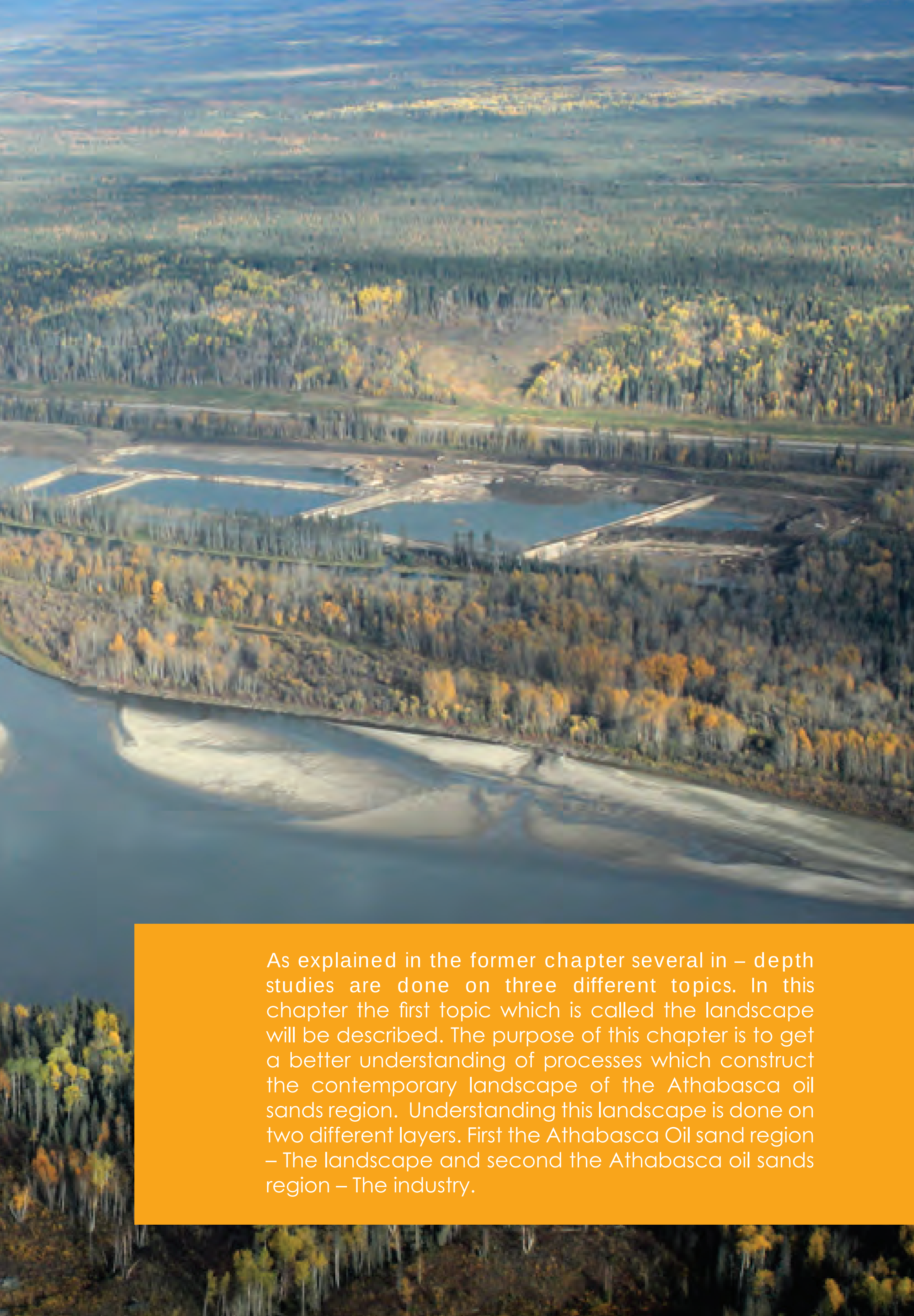
5. The Landscape



As explained in the former chapter several in – depth studies are done on three different topics. In this chapter the first topic which is called the landscape will be described. The purpose of this chapter is to get a better understanding of processes which construct the contemporary landscape of the Athabasca oil sands region. Understanding this landscape is done on two different layers. First the Athabasca Oil sand region – The landscape and second the Athabasca oil sands region – The industry.

The Landscape

5.1 The purpose

The purpose of this chapter is to get a better understanding of the different landscape processes

The purpose of this chapter is to get a better understanding of the different landscape processes that construct the contemporary landscape of the Athabasca oil sands region. The question we therefore asked ourselves is as follows:

What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays?

For us, landscape architects, the landscape analysis is the basis for doing research

For us as landscape architects the landscape analysis is a significant tool to really get a grip on the different processes, it forms the basis for all the three analysis chapters. Since they all interact with one another. Inhere the relationship between man and nature is also explained. In the following section the process of the landscape analysis will be described.

The constructivist worldview is related to the landscape analysis, since this focusses on understanding

As discussed before the constructivist worldview is the main assumption related to this landscape analysis. All the analysis parts first started with an inventarisation, this was mainly done during the phase of our field work. Methods we used to gather data for the analysis are: semi-structured interviews, map studies, observations, explorative drives, explorative flights and literature study (fig. 5.1). The generated data is translated into this analysis.

This phase was followed by the reflection/ analysis phase. In this phase we used several methods to process the generated data (fig. 5.2) to finally get a better understanding of the landscape, the industrial workings and people's perspective and to further focus our research.

In this chapter a landscape analysis will be done on two different levels first on the landscape of the Athabasca oil sands region which is mainly focused on the landscape forming processes and the resulting landscape typologies and second the industrial layer, which focuses on the industry and the way humans altered the landscape through the years.

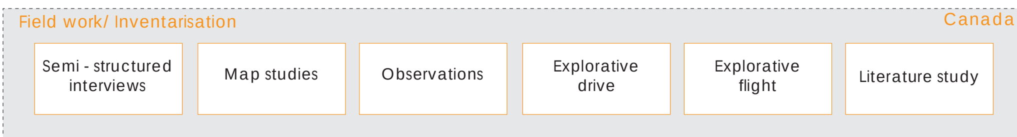


Fig 5.1: Fieldwork phase within the research

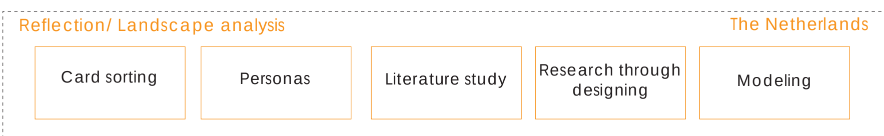


Fig 5.2: Reflection/landscape analysis phase within research

For both parts it is important to mention that there was a limited amount of data available. For that reason several assumptions based on knowledge from professionals and our own interpretations had to be made.

5.2 The Athabasca oil sands region – The Landscape

In our thesis we focus on the surface mineable area, since this technology impacts the landscape most

As mentioned before this thesis is focused on the surface mineable area because this way of extraction has the most influence on the landscape, our analysis is therefore mainly focused on this area as well.

In figure 5.3 the surface mineable area is showed, with the city of Fort McMurray south of this area and the Athabasca River that runs through the area.

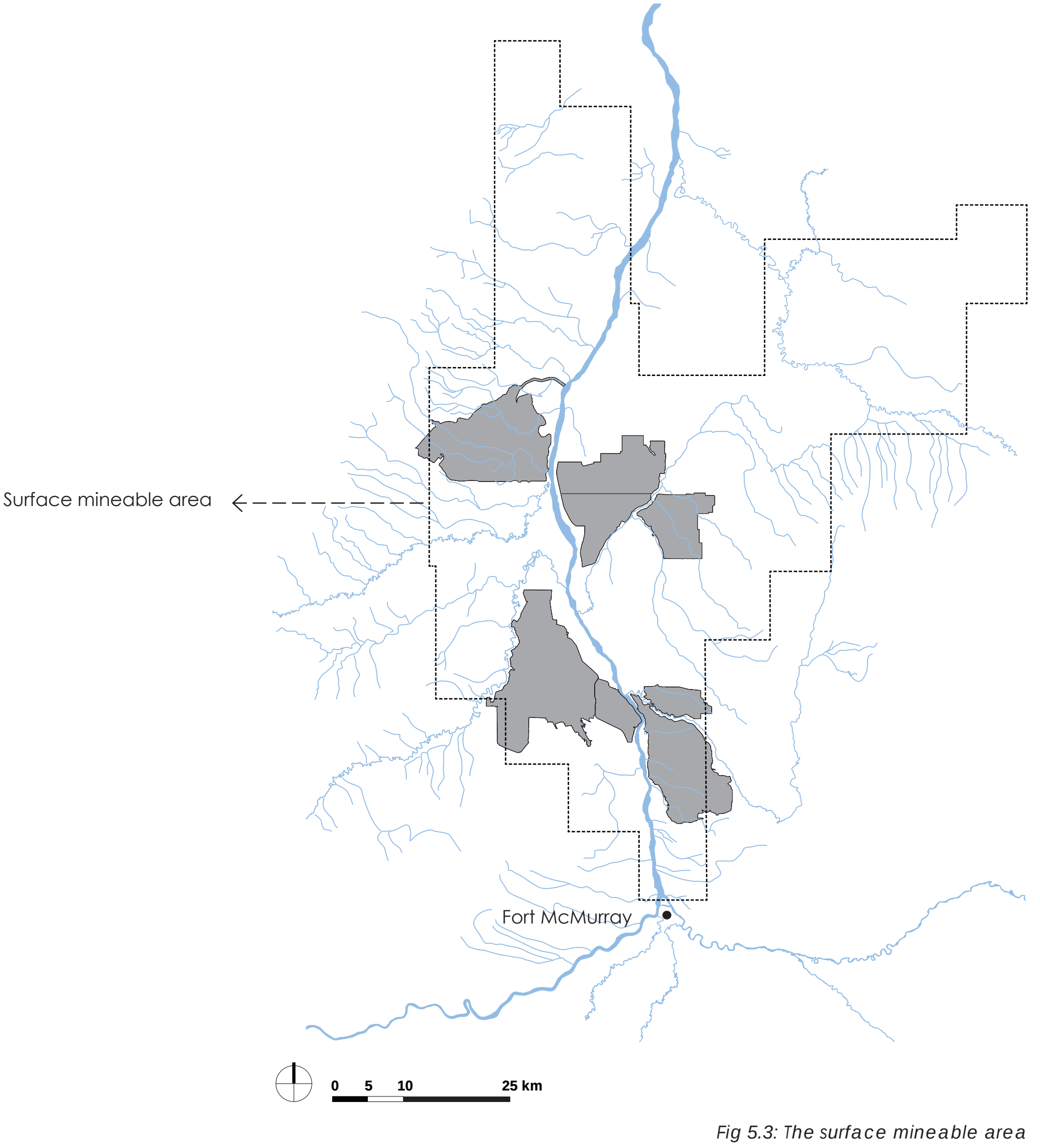


Fig 5.3: The surface mineable area

5.2.1 *The Athabasca river*

The Athabasca River and its tributaries is the longest river in Alberta and besides that the longest undammed river. The source of this river comes from the Rocky Mountains and flows to the Peace-Athabasca Delta and Lake Athabasca (fig. 5.4).

The Athabasca River Comes from the Rocky Mountains and flows into Lake Athabasca

Because it is such a big river system, the Athabasca River is strongly influenced by the climate. The climate in the region consists of cold winters which are followed by warm summers. In these warm summers the river is filled by glacial melt waters from the river's headwaters in combination with local melt water. This results in low flows in the late winter with an approximately flow of 88.6 m3/ s and peak flows in summer with an approximately daily flow of 4.700 m3/s (Government of Alberta, 2014).

Fig 5.4: The Athabasca River within the province of Alberta

Fig 5.5 & 5.6: Picture of the Athabasca River

The river exist of three different reaches.

The river basin exist of three different reaches starting in the Rocky Mountains with the higher reaches which flows into the middle reaches and the lower reaches which starts at the city of Fort McMurray up north. From here the Athabasca River is joined by several smaller tributaries, the MacKay and Ells River from the West and the Steepbank, Muskeg and Firebag River from the east (fig. 5.5).

The Athabasca River served and still serves as a backbone of human development in the region.

The Athabasca River and its tributaries form an essential ecosystem for plants and people. Besides that it served and still serves as the backbone of human development in Northern Alberta. The first nations of the area used the river as a major transport route in the fur trade period. Nowadays the river plays an important role in the oil sands industry. Because the river and its tributaries incised into the landscape, the oil sands were first exposed in the Athabasca river bed. The ecological and human significant of this river system makes the Athabasca River and its tributaries the determining landscape element in this region (Government of Alberta, 2014).

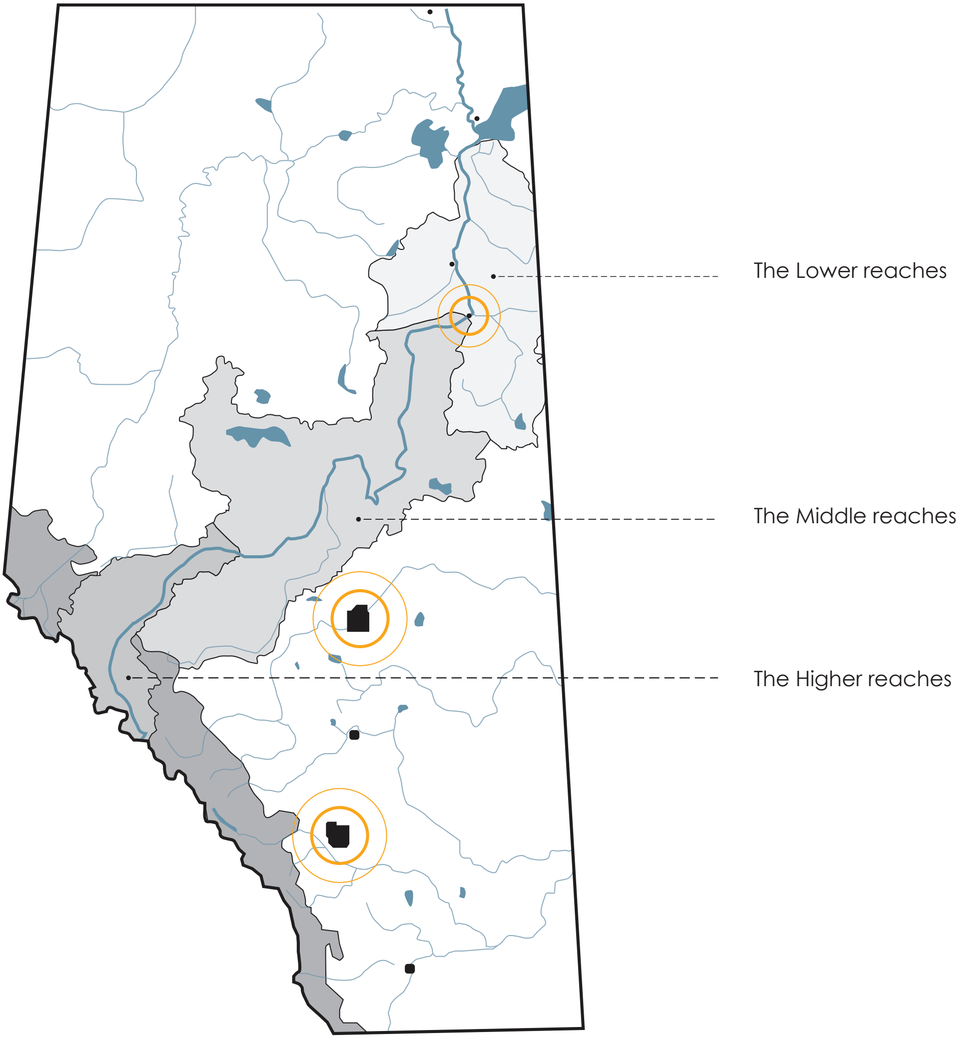


Fig 5.7: The Athabasca River reaches

In the following sections some more information will be given on how the landscape is formed, the biodiversity in the area and different land uses in the area. All these different elements have a clear and strong connection with the Athabasca River system.

The McMurray formation forms the Athabasca oil sands deposit nowadays,

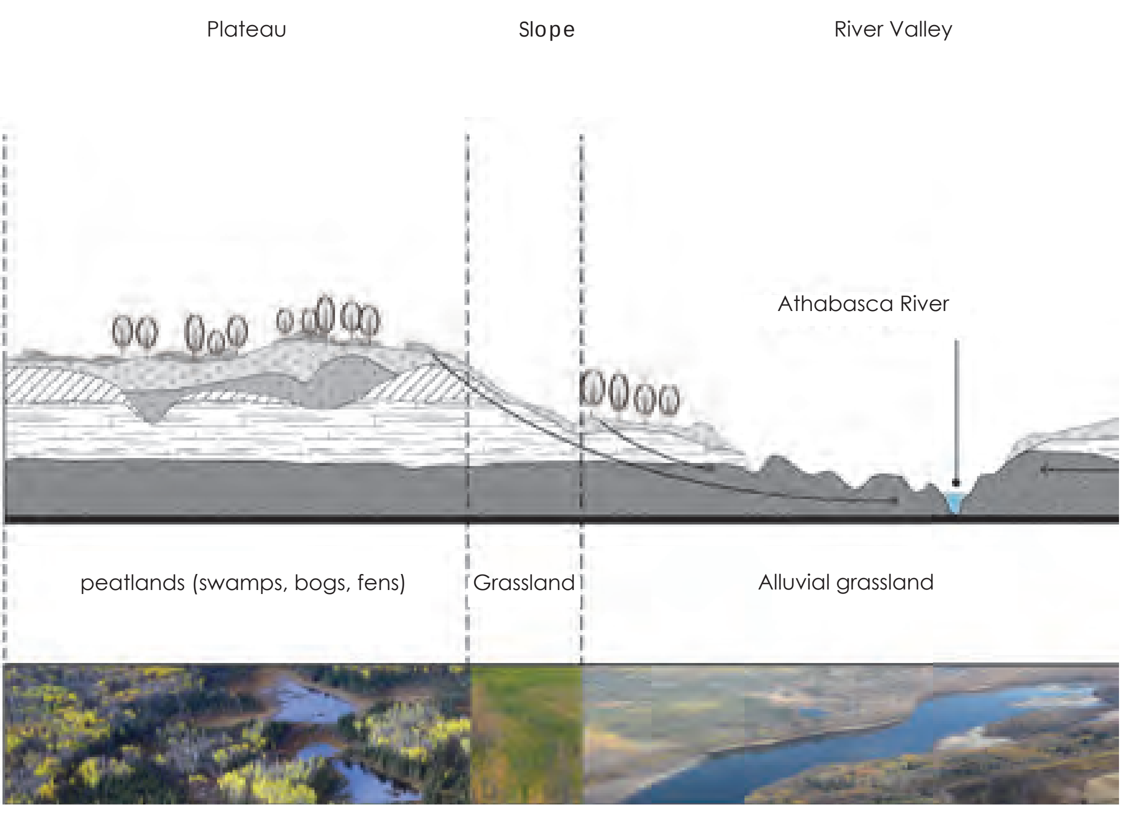
5.2.2 *The formation of the landscape*

The landscape of northern Alberta has been shaped by geologic activity over millions of years. In the mid cretaceous period mountain development took place on the west coast of British Colombia. While the mountains were rising Alberta sank.

This allowed the Arctic Ocean to migrate south and it crossed northern Alberta. Because of this ocean imbedded in Alberta the north flowing rivers deposited their sediments. By these processes the McMurray formation was formed.

This formation consists of a layer of shale, sandstone and oil containing sands. Nowadays this formation forms the Athabasca oil sands deposit. The oil is this layer was first formed in the southern part of Alberta by a process of dying plants and marine organisms.

Due to heat, pressure and time these remains were transformed into hydrocarbons. By mountain development as explained before this oil containing layer was pushed to the surface and northwards and seeped into sand deposits of the McMurray formation (RAMP, 2014; Oil Sands Discovery Centre. n.d.).



Approximately 85 million years ago the global sea level started to rise again, which flooded Alberta for the second time. The Clearwater formation which is on top of the McMurray formation was formed by these processes and comprises of marine shale and sandstone. This process was followed by increased tectonism which formed the Grand Rapids formation on top of the Clearwater formation. This layer is mainly formed by sandstone (Government of Alberta, 2014).

In the quaternary period which took place in a span of 2 million years ago up till today, processes of advancing and retreating ice took place . This took place in approximately 80 glacial cycles. The most recent took place 70.000 to 10.000 years ago.
Meltwater from this ongoing process formed many rivers and lakes present in the landscape nowadays. The Boreal forest which forms the main landscape type nowadays can be found on the land shaped by these movements of ice. In figure 5.8 a cross-section of the different formations is shown.

Meltwater from several glacial cycles formed many rivers and lakes which form the current landscape.

The cross-section is made from the higher plateaus, into the lower river valley which makes the differences in height clearly visible. In addition, the cross-section shows what kind of landscape types occur in this region. In the following section the landscape types which form the landscape will be explained more detailed (RAMP, 2014).

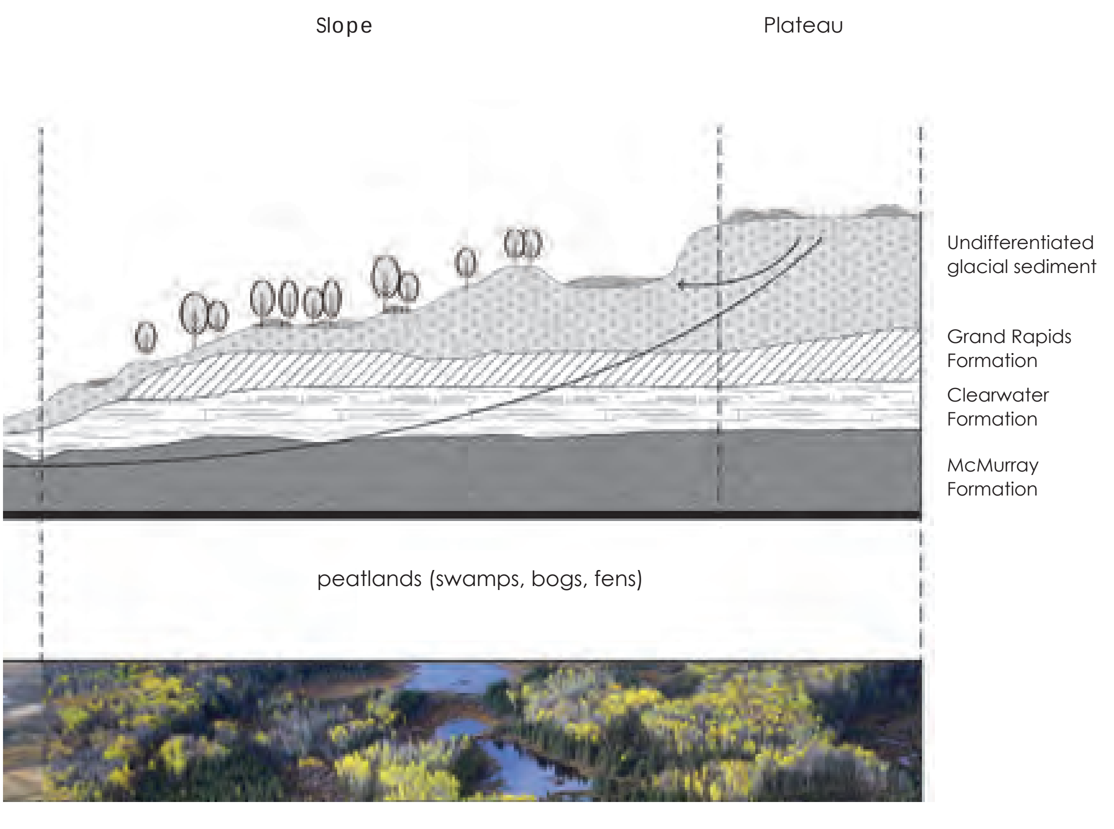


Fig 5.8: Crossection of the formation of the landscape

5.2.3 landscape typologies

The Boreal forest started to develop in the last ice age.

The Athabasca oil sands region is a landscape consisting of mainly boreal forest. As mentioned before this forest started to develop at the end of the last ice age. In this era spruce and the northern pine started to migrate northwards this developed a forest (Canadian forest service, 2004, 2005).

Nowadays the Boreal forest is formed by more different species. The most common coniferous species are: black spruce (Picea mariana), white spruce (Picea glauca), balsam fir (Abies balsamea), Jack pine (Pinus banksiana) and tamarack (Larix Laricina).

The soils are thin, acidic and poor in nutrients

The most common deciduous species in this forest are: white birch (Betula papyrifera), trembling aspen (Populus tremuloides) and the balsam poplar (Populus balsamifera) (WWF, 2008). These species are all adapted to the soil conditions, which are known for being thin, acidic and poor in nutrients (Government of Alberta, 2014).

This together results in a soil unsuitable for agricultural uses but supports the adapted tree species, this led to the development of the forest industry.

Besides forest the Boreal landscape contains many lakes and wetlands. These (predominantly forested) wetlands occur in the poorly drained areas. These poorly drained areas occur in the river basin and on the higher located plateaus as well. The wetlands mainly consist of fens, acidic peat and bogs (The Canadian encyclopedia, 2014). In the pictures below these forested wetlands and wetlands are shown.

These wetlands support a unique group of vegetation, in addition to that the wetlands and forests also provide a habitat for several species of birds and mammals. This will be further explained in the following section (Government of Alberta, 2014).

These conditions make it an unsuitable area for agricultulture but suitable for forest industry

Beside fores the Boreal forest contains many lakes and wetlands

These unique landscapes provide a habitat for several species

Fig 5.9 & 5.10: Pictures of the (forested) wetlands

The Boreal forest forms a habitat for many mammal spe

The industry forms an obstacle for the migration of these animals

5.2.4 *Animal species in the Boreal forest*

The Boreal forest forms a habitat for more than 85 mammal species. These are species like the wood bison, black beer, moose, deer, wolverine and gray wolf. Besides mammals the Boreal forest forms a nesting site for many birds. Some of these birds form permanent residents of this landscape despite the cold winters.
These habitats are affected by the oil sands industrial developments. Due to roads, pipelines and open pit mines many species which depend on large intact landscapes are disturbed and displaced (Government of Alberta, 2014), as you can see in figure 5.11.

This means several species are endangered or threatened. The government of Alberta made a list of these endangered and threatened species of the Boreal Forest.

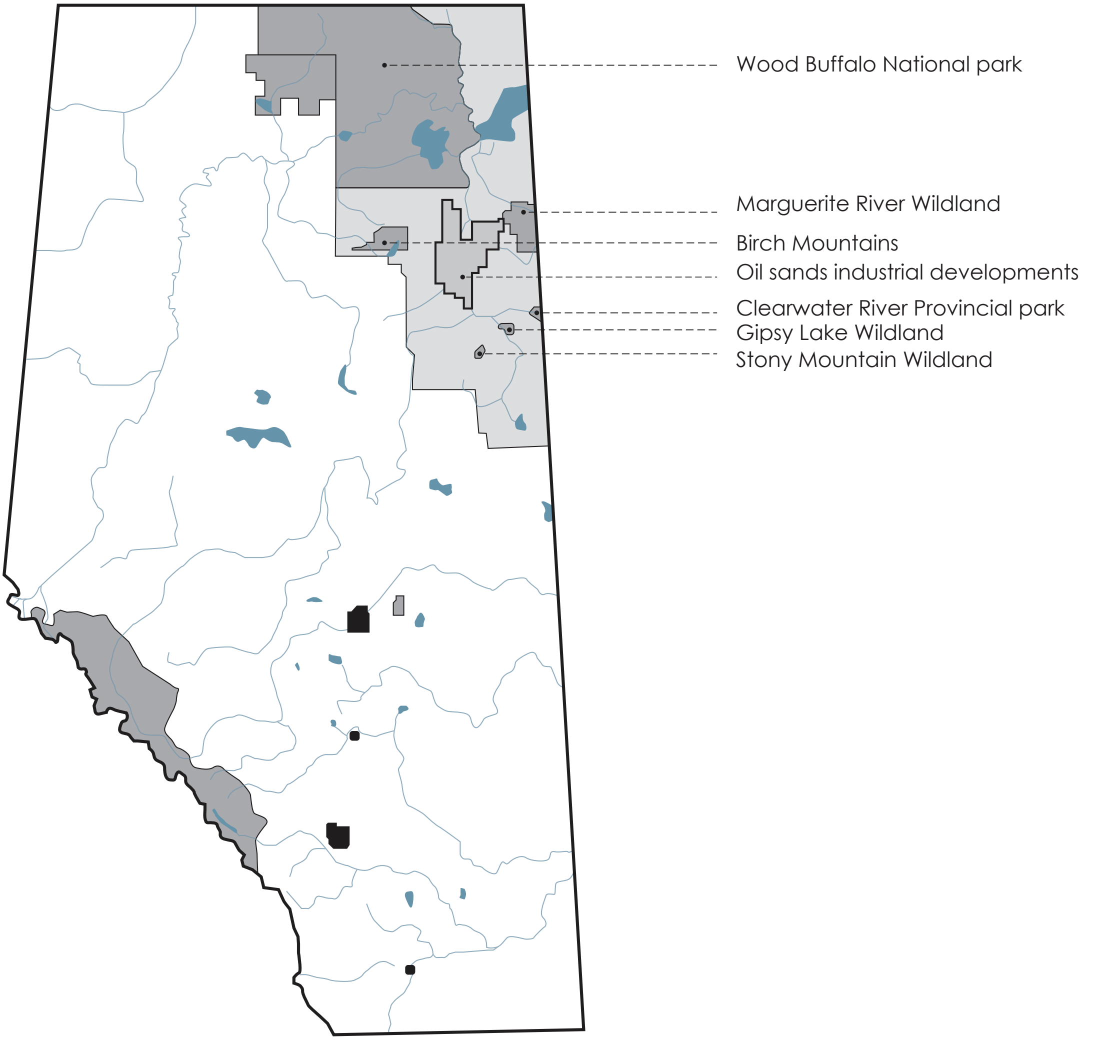


Fig 5.11: National and regional parks within the municipality

Because it is impossible within this research to focus on all the species living in the boreal forest we will focus on several endangered and threatened species of this list. These animals are the wood bison, the woodland caribou, the whooping crane, the peregrine falcon and the trumpeter swan (Government of Alberta, 2013).

The wetlands form an important habitat for several species in the Boreal forest

To this list we added the beaver and moose, since these animals are two of the keystone species mentioned by the indigenous community of the area (Garibaldi, 2009). The different species we will focus on are shown in figures 5.12 - 5.18. In figure 5.19 is shown what kind of habitat is important for these 7 species.

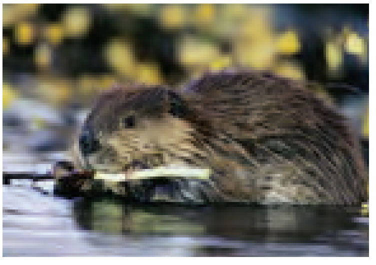


Fig 5.12: Beaver

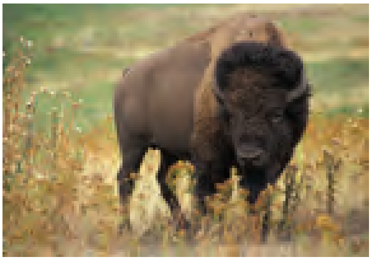


Fig 5.13: Wood Bison

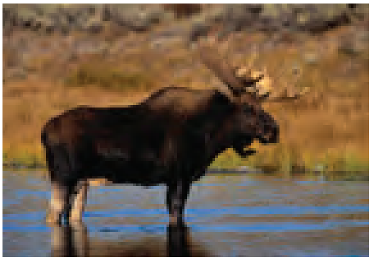


Fig 5.14: Moose

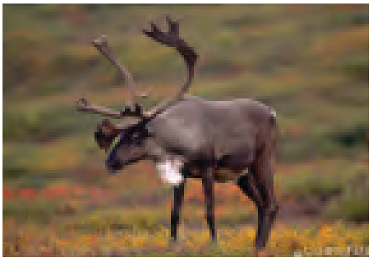


Fig 5.15: woodland caribou

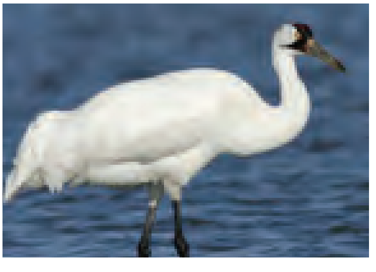


Fig 5.16: whooping crane

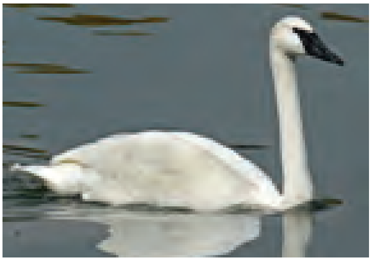
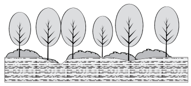
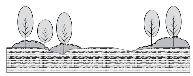
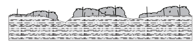


Fig 5.17: trumpeter swan

Fig 5.18: peregrine falcone

	Forests	Brushwoods	Brushy meadows	Wetlands
				
Beaver 				X
Moose 		X	X	X
Wood Bison 			X	X
Woodland Caribou 	X	X		X
Whooping crane 				X
Peregrine falcon 				X
Trumpeter swan 				X

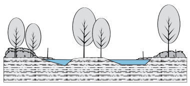
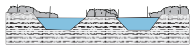
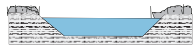
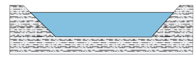
Forested wetlands 	Ponds 	Lake 	River and streams 
X	X	X	X
X			
X			
X			
	X	X	X
X			
	X	X	

Fig 5.19: habitat types key species

When looking at the table shown above, we can conclude that the wetlands in particular form an important habitat for most of these species.

Which is not surprising when considering that wetland cover in the Athabasca oil sands development region can be up to ~62 %, of which ~95 % is peatland (Suncor Energy Ltd., 2005 cited in Scarlett and Price, 2013).

wetland areas with shelter through bushes and shrubs are thus important for the animals that we focus on.

5.2.5 The trappers landscape

The Cree and chipewyan tribes were the first inhabitants of the region

The Athabasca oil sands region which was inhabited by first nations since 1600 is known for a history in the fur trade. The First nations which consisted of the Cree and Chipewyan tribes settled in the area first. They lived a life of hunting, gathering and fishing, and already used the Athabasca River as an important element to travel up and down streams through the area (Government of Alberta, 2014).

The furtrade became an important source of income

When these First nations came in contact with the Europeans the fur trade started. Alberta was first reached by the Europeans in 1754, and since 1778 the Athabasca River was part of the main fur trade route (Government of Alberta, 2014; Parker and Tingley, 1980). This Fur trade changed the lifestyle of the First nations. Their nomadic lifestyle was from then focused on transporting and trading furs with the Europeans (Government of Alberta, 2014).

The Méetis people played an important role in the furtrade

During the 19th century some Europeans married native women. The children from these couples were called the metis which means mixed (Government of Alberta, 2014). The metis people played an important role in the fur trade. They had the ability to understand the customs from both societies which formed a bridge in communicating between the first nations and the commercial market of the Europeans (Fort McMurray metis local 1935, 2012).

Fig 5.20: Métis people on the Athabasca river, which was part of the main fur trade route (source: Beaver Bark Canoes, 2011)

The routes along which they trapped are called traplines

During the furtrade they used certain routes along which they set their traps. These routes are called traplines. In the early 1940's the Government of Alberta introduced the trapline registration system. The trappers were provided with exclusive trapping lines. In figure 5.21 the traplines of the Athabasca oil sand region are showed. Most of these traplines cross the Athabasca River from east to west or have their starting point at Fort McMurray or FortMckay which both formed important trading posts (Fort McMurray metis local 1935, 2012).

The families who lived from the trapping as source of income, lived along these traplines in small cabins. In figure 5.21 locations of these cabins are shown, most of the cabins are located close to these traplines. These traplines and the cabins are still an important part of the heritage for the Métis families nowadays.

Families lived on these traplines in so called cabins

They still go there to live their traditional lifestyle, while most of them work in the oil sands industry to be able to support themselves (Fort McMurray metis local 1935, 2012).

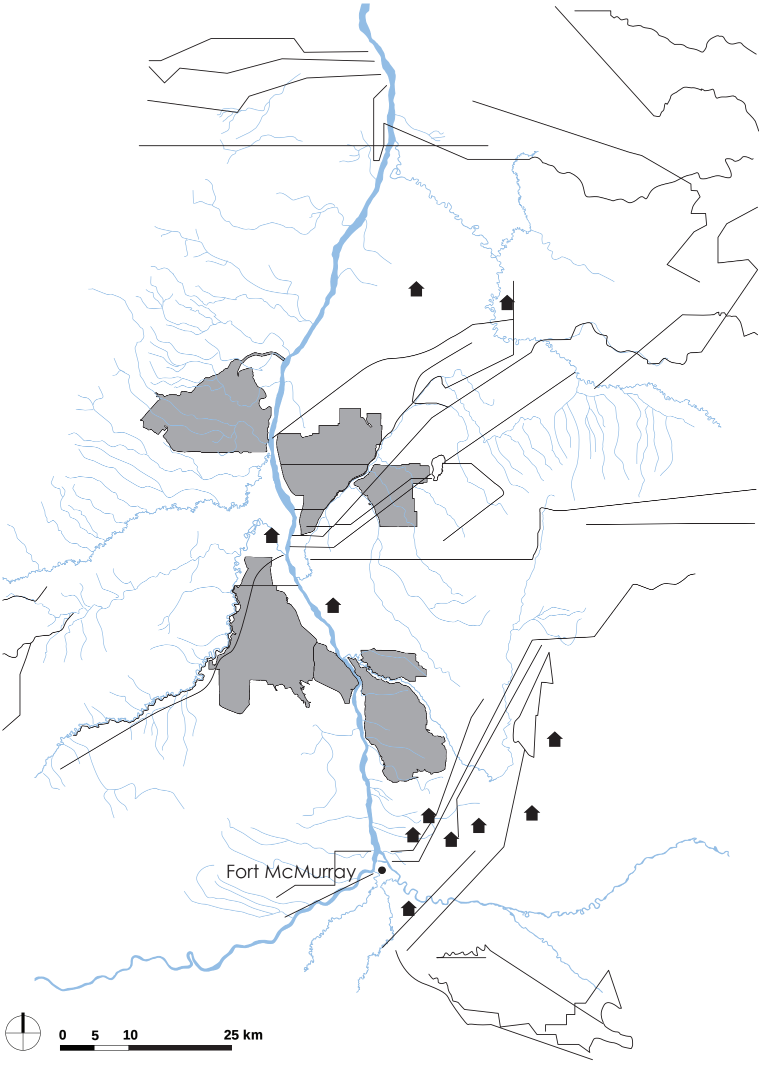


Fig 5.21: Metis traplines and cabins

5.3 The Athabasca oil sands region – The industry

5.3.1 The oil sands leases

Companies lease the grounds from the government of Alberta

When the first commercial oil sands mine was opened in 1967 the entire region went through major changes. Different companies took positions in oil sands development projects and started to lease land owned by the province of Alberta. The different leases in the Athabasca area is showed in figure 5.22.

Companies that produce bitumen compensate the province by paying royalties on production.

The first company that started production was Suncor followed by Syncrude and Shell, and as mentioned before these mining activities are still in development and will continue the coming 50 years.

When companies are granted permission to access a certain area, discussion takes place between government and companies about which parts are economically feasible to dig out and which parts not, this is all part of the approval process.

The planning of operations is based on the quality of bitumen and less on the qualities of the landscape

Within this process discussion takes place as well about protected habitats or watercourses. When these are located in an area with high quality bitumen a tradeoff between the costs and benefits will be made. If it is still profitable, the area will eventually be mined (Interviewee, 2013).

This process in which discussions take place whether to conserve or destruct a certain (natural) area, are predominantly based on the quality of the bitumen and thus about the profit the company and government can make.

When looking at the leased landscape, as shown in figure 5.22, and the orthogonal grid pattern that is laid over it, together with the whole decision making process about where to mine, nature always draws the short straw. It’s a money making business.

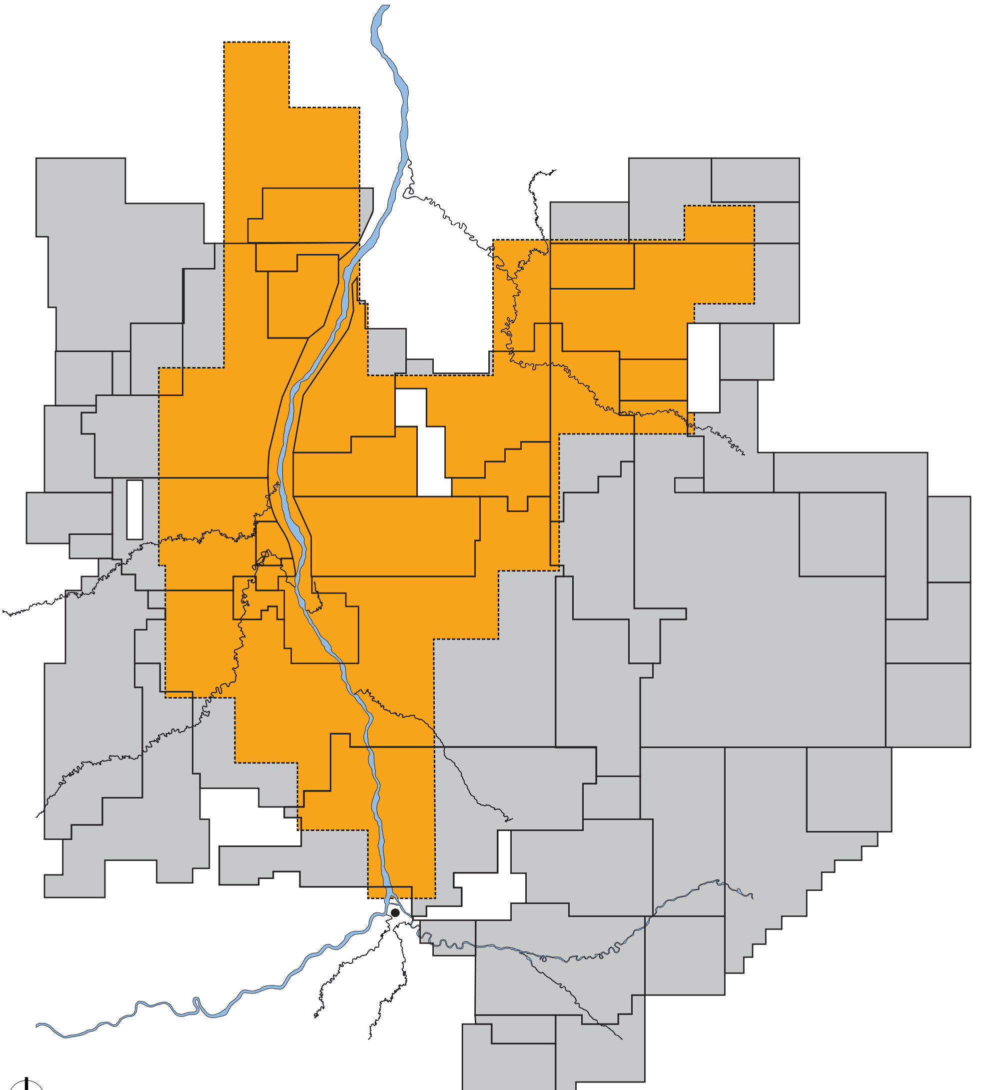


Fig 5.22: Oil sands leases

5.3.2 *The infrastructural network*

Highway 63 is the only roads which connects Fort McMurray with the oil sands industry

The only highway that connects the urban service area of Fort McMurray with the oil sands industry is highway 63, as shown in figure 5.23. This means that this highway is used as transportation road for goods and by people who work in the oil sands industry. A daily trip to work from Fort McMurray, which is only 28 km to reach the Suncor mine and 70 km to reach Shells Albian sands, becomes unpleasant due the high pressure on highway 63 which results in traffic jams (CRISP, 2012).

This highway has to cope with a lot of pressure of the daily traffic

Models of the future scenarios show that the pressure on this highway will increase. With a scenario of Fort McMurray as the only major urban community and the oil sands industry that is increasing Highway 63 needs to be extended into a 12 lanes highway to cope with this pressure. Introducing a new growth node more north will result in significant reduction of this traffic pressure (CRISP, 2012).

Pressure can be reduced by introducing new roads

Models also showed that pressure can be reduced by introducing new roads north and south of Fort McMurray and a new ring around the city. This will connect the whole area better with the east and west industrial developments and heavy loaded trucks are not forced anymore to drive through downtown Fort McMurray (CRISP, 2012).

Or by considering other ways of transportation like for example trains

Besides another growth node, they also consider other ways of transportation for example by train. The current freight rail in the region ends at the south of Fort McMurray. By extending this rail northwards into the oil sands industrial region would reduce the big trucks which are now using highway 63 to transport goods. This will also make it easier to import goods but also to export goods like waste products (CRISP, 2012).

This means highway 63 which forms an important link between the city of Fort McMurray and the Athabasca oil sands industry needs improvement. This road which is of great economic and symbolic importance did not move along with the rapid transformation of the industrial region, which now causes problems (Regional municipality of Wood Buffalo, 1999).

Fig 5.23: picture of Highway 63

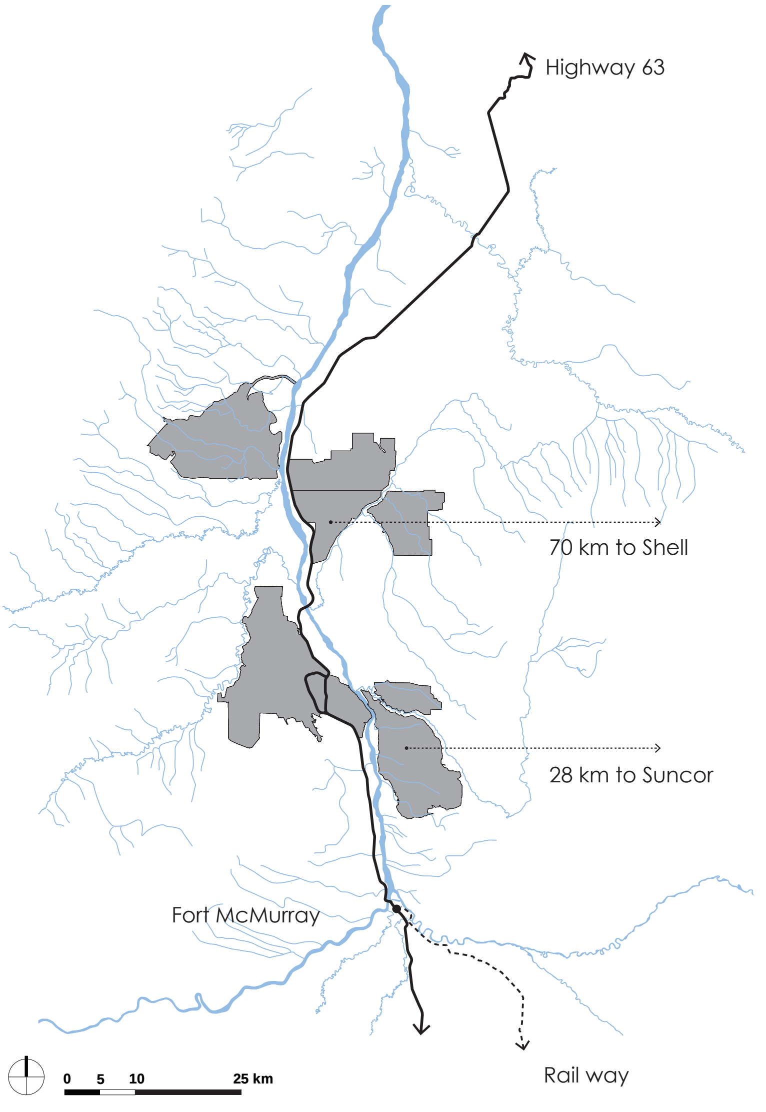


Fig 5.24: Main infrastructure in the area

The region is going through a process of enormous population growth

5.3.3 *The population*

As mentioned before the Athabasca oil sands region is going through a process of enormous population growth. In 2030 they expect to grow till 250.000 people living in the Regional Municipality of Wood Bufallo (RMWB, 2012). People from all over the world come to Fort McMurray for a job in the oil sands industry (fig. 5.25). Some people only stay for several years, some stay for 10 years. These workers can be divided in two groups: the Non-resident workers and the resident workers (Shields, 2012).

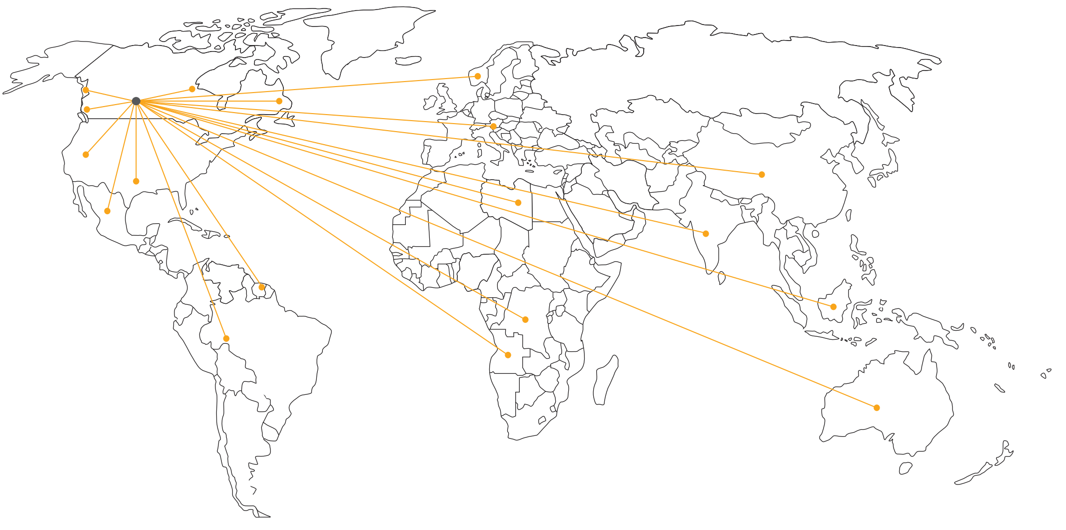


Fig 5.25 People all over the world go to work in Fort McMurray

The Non-resident workers often come from across the continent for several weeks. They (Mostly men) fly in on the private oil sands airports, rent a room in Fort McMurray or live in large work-camps which are located close to the industrial areas. Approximately 20.000 people live in these work-camps. In figure 5.26 a map of the different workcamps in the region is shown and in figure 5.28 a picture of the work camps.

For some people Fort-McMurray can be called home for others it is only a work destination

When they are done working they fly back to their families for a couple of weeks and after that come back again to work. This results in a fly in fly out and unstable live style.

The resident workers stay for a longer period of time, buy a house in Fort McMurray where they live with their families (Shields, 2012). "For many who live there it represents home and history, while for many others it represents work-but-no-home" (Dorow and O'Shaughnessy, 2013, p.121).

The Regional Municipality of Wood Buffalo aspires to develop a community

The residents of Fort McMurray and the Regional Municipality of Wood Buffalo aspire to develop a community and make Fort McMurray a place to stay. They already do this by expanding the suburbs of the city in a family-oriented community form and by redeveloping the downtown area (Shields, 2012; RMWB, 2012).

Developments are going on, like providing affordable housing and facilities, developments however are not keeping pace with the speed and amount of people that come to this area. “At the height of the boom in 2007, residents of Fort McMurray spoke of a boomtown on steroids, of a place experiencing an adolescent phase, and/or of a lack of time to catch up to the pace of development.

Some blamed various levels of government for a lack of planning or regulation; some blamed the more than twenty thousand mobile workers who seemed to be there only to work and make money rather than invest in the community”(Dorow and O’Shaughnessy, 2013, p.127).

Developments can not keep pace with the speed of people coming to this area, which results in a lack of facilities, it is like a boomtown on steroids

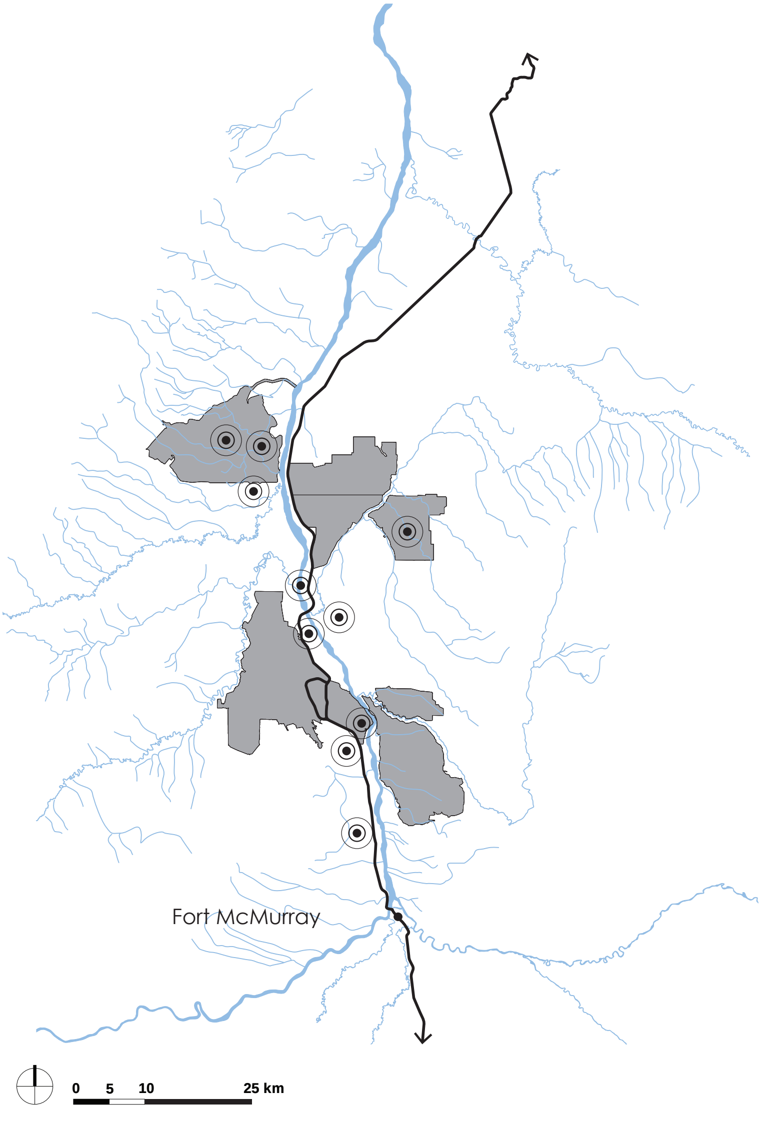


Fig 5.26: Workcamps in the region

Fig 5.27: The suburbs of Fort McMurray

Fig 5.28: A workcamp during wintertime

5.4 Conclusion

By means of this analysis we achieved the purpose of this chapter. As mentioned in the beginning the purpose was to understand the different landscape forming processes and the way humans influenced this landscape. We therefore asked ourselves the following question:

"What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays?"

The method we therefore used was the landscape analysis, inhere we look at all the different layers in the landscape that influence each other. Two main layers were formed the landscape layer and the industrial more anthropogenic layer so to say.

The first level mainly focused on the formation of the landscape resulting in the current landscape with its different landscape typologies and habitats for animals. Inhere the Athabasca river and its tributaries form an important element in this landscape, this for the following reasons:

- the river and the wetlands form an important ecosystem for several key species in the area;
- the river provided a good living area for the first nations, since it provided fresh water a transport route and animals to hunt, the river can be seen as backbone of human development;
- the river today serves as important fresh water resource for the oil sands industry.

The industrial layer, as explained in the second part of our landscape analysis, has caused major changes to this natural landscape. The first nations cannot make use of their lands anymore, and several animal species that depend on large intact habitats are disturbed. Many valuable nature has therefore given way to industrial activities. Other changes in the region deal with the enormous population. People go to Fort McMurray for a short or long period of time. This changes the region into a place to work instead of a home for many people.

This huge flow of people, led to a lack of facilities, since developments are not keeping pace with the speed and amount of people that come to this area. This also applies to the infrastructural network, which makes the region isolated and the travel from Fort McMurray to work in the oil sands industry unpleasant.

Arising from this landscape analysis, we can draw the following conclusions which will be explained in more detail with reference to Figure 5.28. In this figure we divided the landscape in to a geomorphologic layer, landscape typologies, animal species, the human/ occupational layer and the industrial layer. As you can see all these different layers are somehow connected.

We will now briefly discuss the layers, the first (geomorphologic) layer tells us something about the structure of the soil and the landscape forming processes that led to this. In addition to that erosion processes of the river caused a lower river valley and high plateaus. This exposed the oil sands containing layer (McMurray formation).

The second layer, the different landscape typologies gives us a simplified idea how these landscape forming processes led to different landscape typologies. Open river valleys and higher forested plateaus.

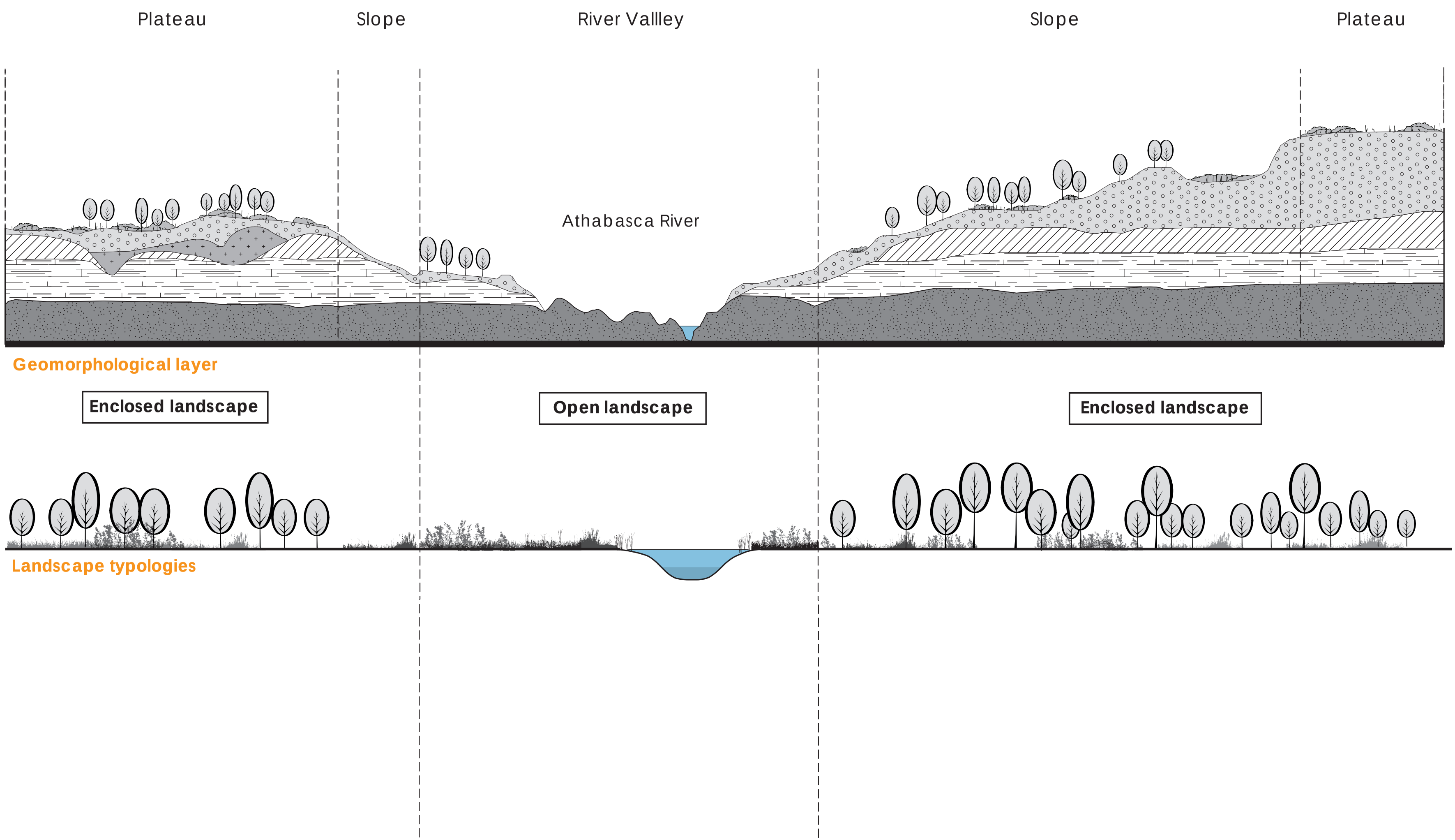
These landscape typologies provide a good habitat for several animals species, the bigger mammals tend to live on the more higher and drier places, while the smaller mammals like the beaver and the birds live close to the river. However, there is no strict separation of animals living in a particular place since moose and caribou for example migrate back and forth between different places.

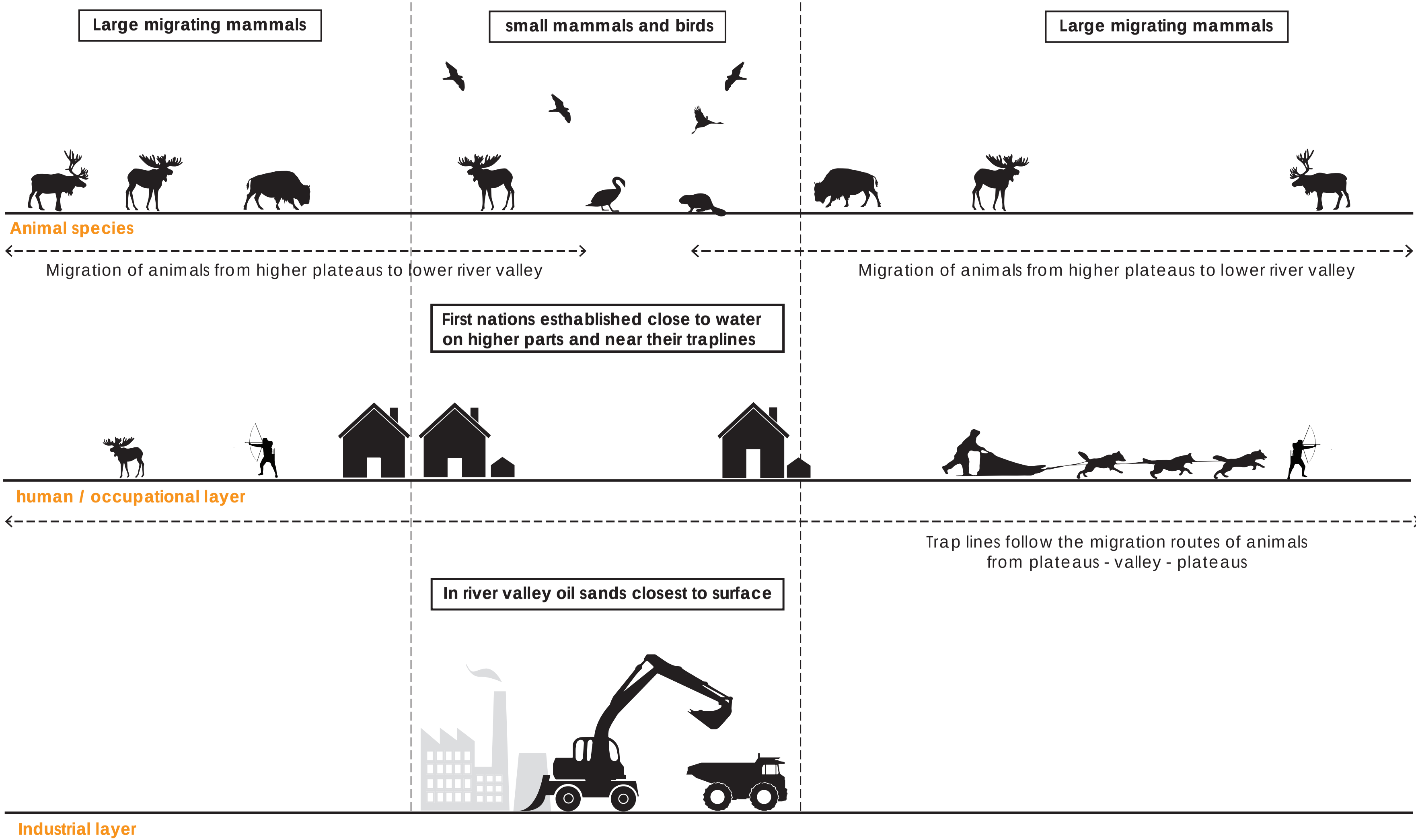
The presence of the river along with the animals led to the establishment of first nations who lived by hunting and gathering. By means of trap lines they hunted on different animals, these lines crossed the landscape. The first nations eventually discovered the oil which led to the development of the oil sands industry.

Since the oil sands containing layer is closest to the surface near to the Athabasca river, most of the mines are situated here. All this taken together shows the relationships between the different layers. everything is interconnected and can therefore not be separated from each other.

In the following chapter we will continue with the workings, in which we want to achieve a better understanding of the different industrial processes. This elaborates on the last layer , the industrial layer, as shown in figure 5.28.

Fig 5.28: All the different landscape layers are interrelated and interact with one another





Large migrating mammals
small mammals and birds
Large migrating mammals
Animal species
Migration of animals from higher plateaus to lower river valley
Migration of animals from higher plateaus to lower river valley
First nations esthablished close to water on higher parts and near their traplines
human / occupational layer
Trap lines follow the migration routes of animals from plateaus - valley - plateaus
In river valley oil sands closest to surface
Industrial layer

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6. The Workings

From the landscape analysis we will continue with an analysis on one specific mine, the Suncor mine. Suncor was the first commercial mine that started operating in the oil sands industry in 1967.

Zooming in provides a further understanding on the industrial processes and in particular where these processes take place in tthe Suncor mine. Starting with the mining and ending with the upgrading phase.

The Workings

The previous chapter explained the different processes that construct the contemporary landscape. Which was the first analysis chapter of the three. In this chapter we will continue with the second topic which is the workings.

Analysis is done on two different levels, the landscape scale and the mine scale

For the workings we will zoom in on one specific mine in the area. Our analysis will thus be done at two different levels : the whole landscape as described in the previous chapter and one specific mine as will be described in this chapter.

6.1 The purpose

The purpose of this chapter is to get a better understanding of the industrial process

The purpose of this chapter is to get a better understanding of the industrial process and how this process affects the landscape, the question we therefore asked ourselves is as follows:

How does the industry work and what are the effects on the contemporary landscape?

Knowing how the industrial process works is very important for us, as we will eventually propose alternatives within the industrial process.

The most important method used was research through designing

The most important method we used in this analysis chapter was research through designing. As described in chapter 4 we used research through designing as a method in combination with generated data from the proposal phase, aerial photographs taken during our field work and satellite images from the internet. The generated data from the proposal phase mainly comprised of reports written by the big oil sands operators like Suncor, Shell and Syncrude. Important to mention is that all these several forms of collecting data was necessary to get an understanding of this work in progress since we did not had access into one document which contains all these data.

All this together finally enabled us to sketch how the mines roughly operate, which is showed in the industrial flow maps in the coming chapter. This gave answers to questions like: which industrial landscape features can be distinguished from each other, where is the overburden going, where are the tailings stored?

By doing this new data was generated as well. This step in our research is part of the reflection/ landscape analysis phase.

6.2 The Suncor mine

6.2.1 Site selection

To get a better understanding of the industrial process and how this process affects the landscape, we chose to zoom in on the Suncor Base mine as can be seen in figure 6.1.

We will zoom in one the Suncor mine

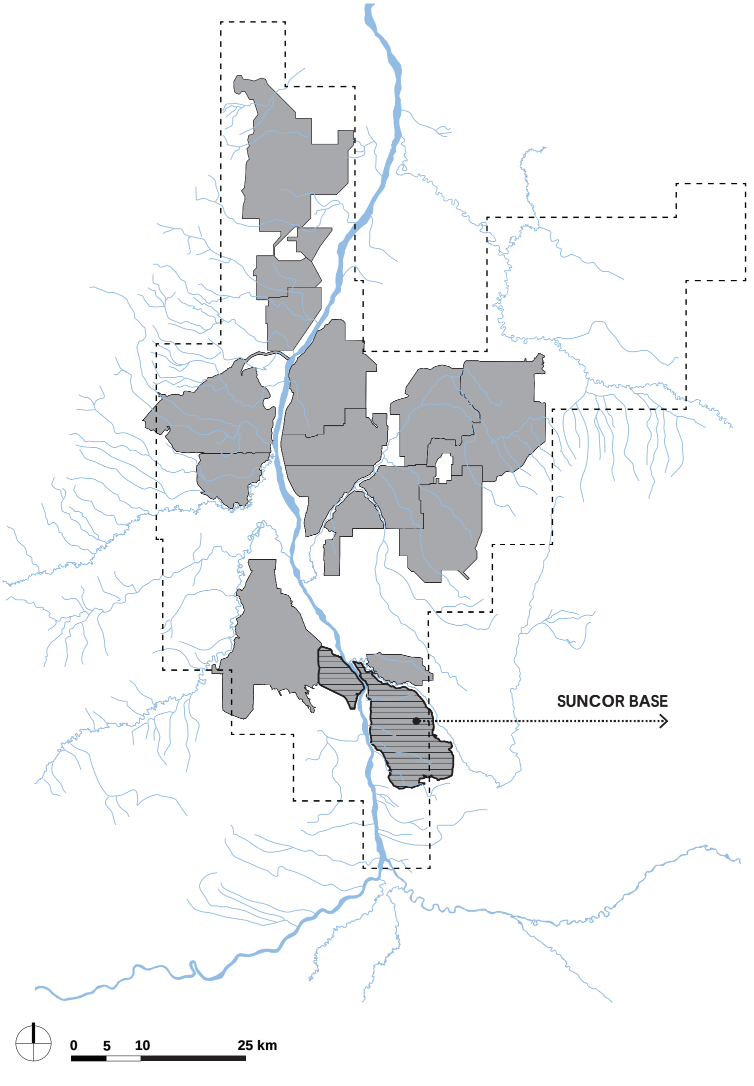


Figure 6.1 : The Suncor Base mine and it's surroundings

We chose for this mine because:

We have chosen this mine for a number of reasons:

The mine is located closest to Fort McMurray

The first reason is because this mine is nearest to Fort McMurray, 35 km north of Fort McMurray (Infomine, 2012). Fort McMurray has been designated as the centre of urban growth in the region and we therefore think that suggestions we do with our design must be closest to the people as possible to have a greater chance of success.

The mine developed on both banks of theAthabasca River

The second reason is that this is the only mine that is developed on both banks of the Athabasca River. This makes the area much more interesting and challenging.

A lot of data available

The last reason for choosing this mine was the availability of data on this specific mine. Because it is the oldest and one of the largest mine, a lot of research has already been done on this particular mine and its impact on the landscape.

6.2.2 General information

Suncor developed the world's first commercial oil sands plant

Before going in to depth some more general information will be given about the Suncor mine. Suncor developed the world's first large-scale commercial plant in 1967. They therefore pioneered technology for bitumen extraction and upgrading (EUB, 2000).

Suncor's Oil Sands Base operations are located near Fort McMurray in northern Alberta and includes both the Millennium and North Steepbank sites. Suncor still has enough reserves to sustain production for the next 50 years (Infomine, 2012).

Current production is 501,000 barrels of crude oil per day

Suncor's Oil Sands Base operations currently produces 501,000 barrels of crude oil per day (Junewarren-Nickle's Energy Group, 2013). The upgraders are located on the west bank of the Athabasca River and the Steepbank and Millennium Mines are on the east side of the Athabasca river (Infomine, 2012). Figure 6.3 shows a map of the Suncor mine.

Our analysis is limited to the Steepbank mine, the Millenium mine and the upgrader on the west bank of the river

Our analysis of the Suncor mine is limited to the Steepbank mine, the Millennium mine and the upgrader on the west bank of the Athabasca river (Fig. 6.2). The North Steepbank extension is not included in our analysis. This has to do with a lack of data about the North Steepbank Extension and it's workings. We could not get a clear understanding of the different operations and flows within this extension. On the contrary, the Steepbank mine, Millenium mine and it's upgrader really function as one coherent system.

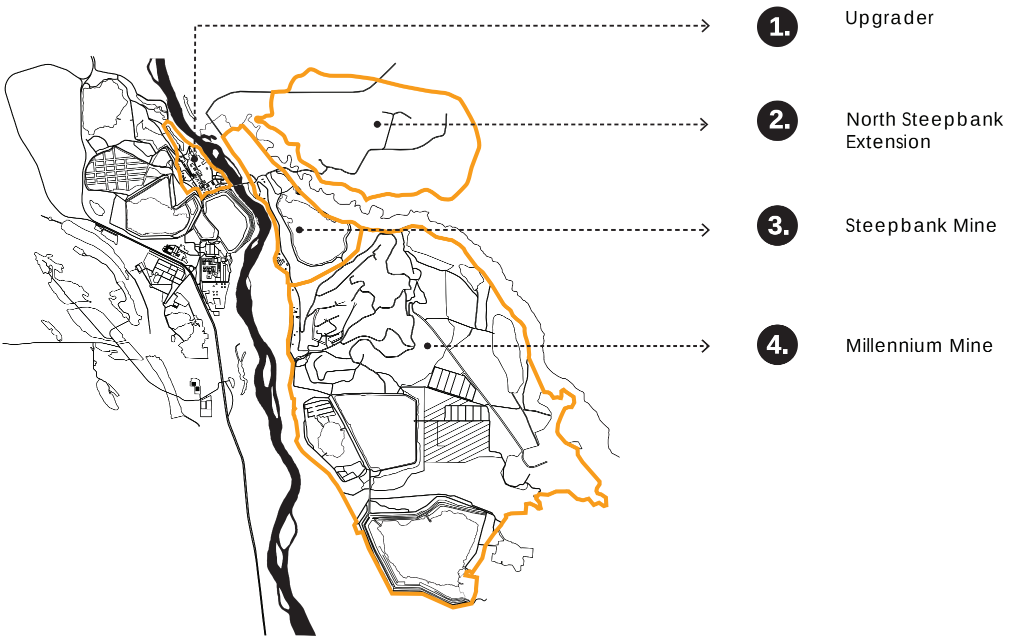


Figure 6.2 : Location of the mines and upgrader

Figure 6.3: Map of Suncor Base mine

First 6 different industrial landscape features have been distinguished

6.2.3 Industrial landscape features

In order to understand the various flows of different materials in the Suncor mines we need a basic understanding of the different industrial landscape features. These features can be seen as nodes within the industrial process where different material flows start, end or are temporarily stored.

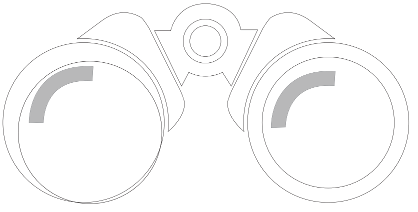
We therefore distinguished six different industrial landscape features :

1. Athabasca river,
2. Upgrader,
3. The mine,
4. Overburden dumps,
5. drying areas,
6. tailings ponds.

In figure 6.4 is showed where these industrial landscape features are located in the mine.

Figure 6.4 : The industrial landscape features

“Let’s take you on an excursion”



6.3 The industrial workings

In the following section a description of the industrial process will be given

In the following section will be described how the industrial process is going. From the first steps of excavating the overburden till the upgrading phase in the upgrader facility

As has been described in the previous section different industrial landscape features have been distinguished: the Athabasca river, the upgrader. the mine, overburden dumps, drying area and tailings ponds

The fluid tailings are the major problem in the oil sands industry, therefore emphasis will be put on how is dealt with these vast amounts of fluid tailings.

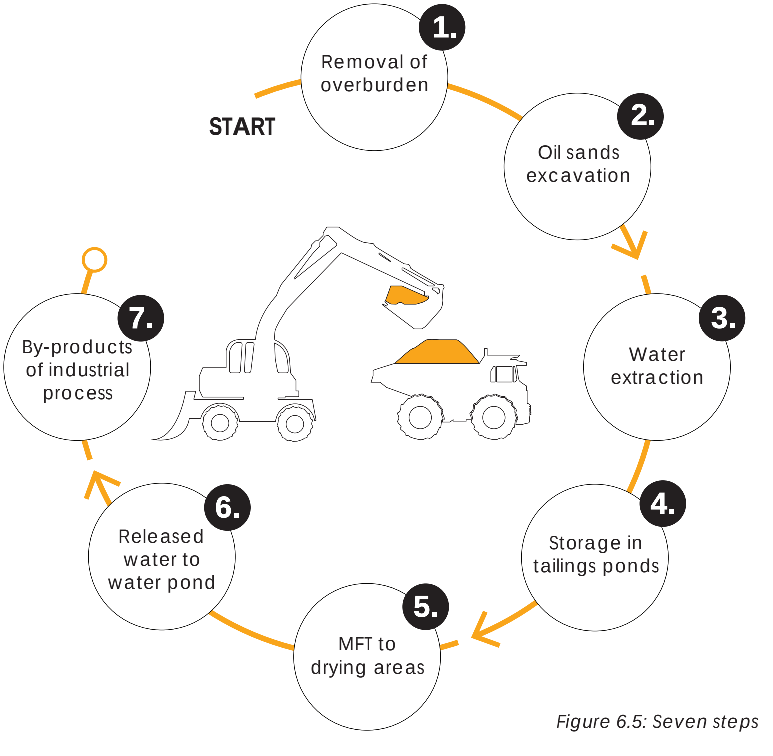


Figure 6.5: Seven steps

The process of the Suncor mine will be told in seven steps as is showed in figure 6.5. Starting with the removal of the overburden (6.3.1), ending with the generated by-products from the process (6.3.7).

In 7 steps the industrial process will be told

6.3.1 The removal of overburden

In order to prepare the area for surface mining, bulldozers, backhoes, loaders, water trucks, scrapers, side booms and graders are all used to remove the overburden (the muskeg and layers of soil on top of the oil sands deposit) to finally expose the oil sands.

First the overburden is removed

The overburden is subsequently stored in overburden dumps and saved for later use in reclamation (Oil Sands discovery centre, n.d.) as is showed in figure 6.6 by means of the orange arrows.

and stored in overburden dumps

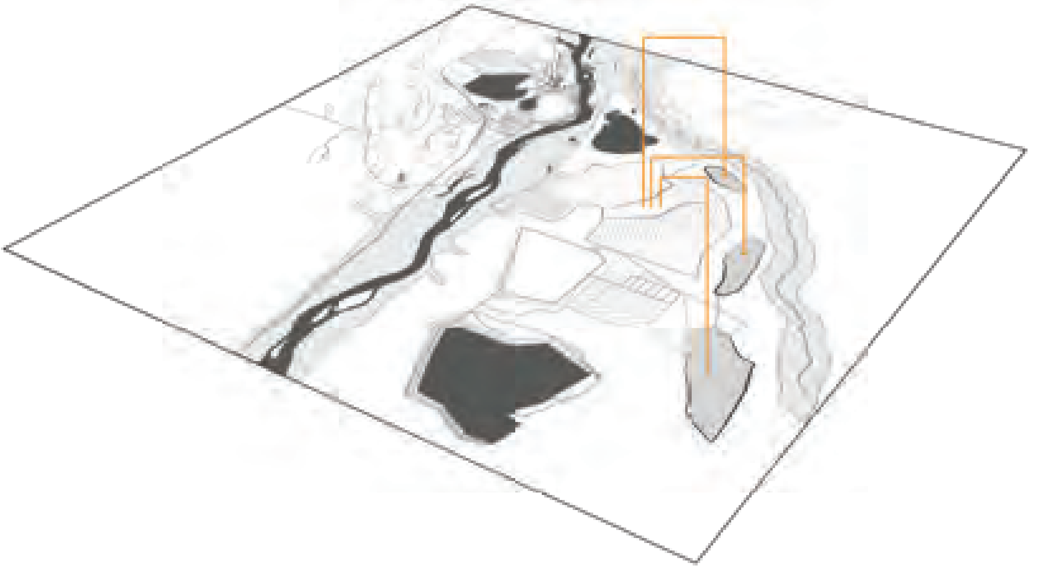


Figure 6.6 : Storage of overburden in overburden dumps

Intermezzo:

Machines of the old days

When Suncor started in 1967 as Great Canadian Oil Sands, they mined oil sand with huge bucket wheel excavators which dug directly into the side of the open mine pit (fig. 6.7). The oil sand was picked up by the buckets and deposited onto a conveyor belt system that transported it into the extraction plant.

When Syncrude opened their mine in 1978, they used draglines, which are known as the largest walking machines on earth (fig. 6.8), and bucketwheel reclaimers. The dragline first scooped up the oil sand and dumped it into a pile which was called a windrow. Subsequently the oil sand was scooped up from the windrow and then deposited onto a conveyor system that transported the oil sand to the extraction plant.
In the 1980s, trucks and power shovels began to replace the bucketwheels and draglines and today, all the operating mining companies in the Athabasca oil sands use the truck and shovel technology (Centre for Energy, n.d.).

Figure 6.7: Photograph of bucketwheel reclaimer

Figure 6.8: Photograph of bucketwheel and dragliner. Source: (Pistonheads, 2012)

6.3.1	Impacts of overburden removal on the landscape
-	Storage of overburden results in the development of artificial (overburden) hills in the landscape
-	Open pits are developed due to excavation, resulting in a fragmented landscape

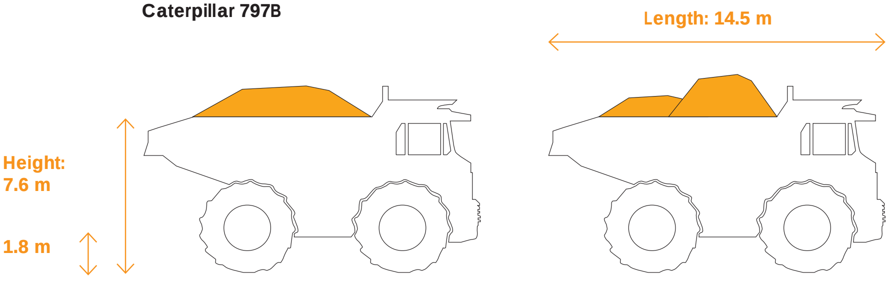


Figure 6.9 : Oil sands are loaded into hauler trucks and transported to crushers

All the mining companies use truck and shovel technology to mine

6.3.2 The excavation of the oil sands

At this moment, all the operating mining companies use the same technology, truck and shovel. Truck and shovel mining is more mobile, requires less maintenance and has less effect on production if certain machines break down (Oil Sands discovery centre, n.d.).

When arrived at the oil sands containing layer, huge hydraulic power shovels dig into the oil sand and load it into 400-ton heavy hauler trucks as can be seen in figure 6.9 (Oil Sands discovery centre, n.d.). The landscape that then arises can be seen in figure 6.10.

Figure 6.10: The mined landscape

The trucks then transport the oil sands to the crushers that breaks up lumps and remove rocks. Then the oil sands is mixed with water at either 35°C or 50°C, depending upon the mine, this is called the Clarke hot water extraction process.

Trucks transport the oil sands to crushers and then mix the oil sands with water, then slurry is piped to extraction plant and upgrader

Then, a slurry of oil sands and water is piped to the (primary) extraction plant (fig. 6.11) and after that to the upgrader (fig. 6.12). During hydrotransport, the bitumen begins to separate from the sand, water and minerals

Figure 6.11: The primary extraction plant

Figure 6.12: The slurry of oil sands and water is transported to the upgrader

In the following figure (6.13) the different material flows are showed by means of the orange arrows.

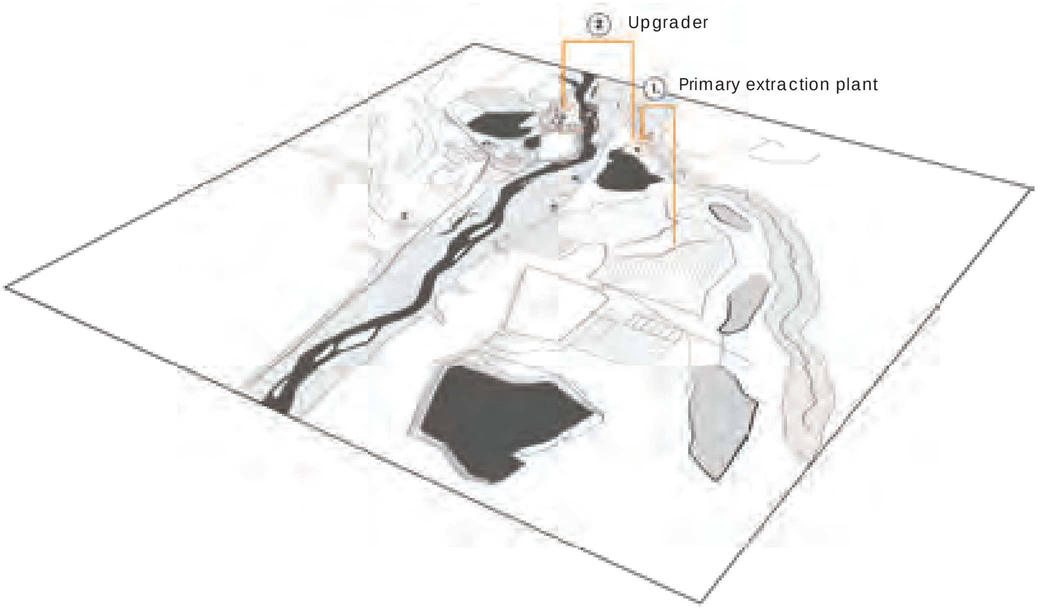


Figure 6.13 : The different flows of mined oil sands within the Suncor mine

6.3.2	Impacts of excavation of the oil sands on the landscape
-	The excavation of the oil sands leads to big open pits
-	Excavation requires a lot of machines, a dense network of roads, pipes and extraction/ upgrading plants and thus disturbs a large surface area

6.3.3 Water extraction from the Athabasca river

2 to 4 barrels of water per barrel of bitumen is used

For the production of bitumen from mining a lot of water is needed. Current oil sands production uses from 2.0 to 4.0 barrels of water per barrel of bitumen produced (NRTEE, 2010 and Jordaan 2012). Water is needed to be able to separate the bitumen from the sand.

Water isnt of sufficient quality once it's used in the extraction process, and thus stored in tailings ponds

Once water is used for bitumen extraction in the Clarke hot water extraction process, the water isn't of sufficient quality anymore to return the water to the environment. The water is therefore stored in tailings ponds (Jordaan, 2012).

A significant amount of water can be recycled

While a significant amount of water from the tailings ponds can be recycled and used again as process water, a significant amount of polluted water remains in the tailings ponds, possibly indefinitely. For this reason tailings management is one of the greatest concerns of the local community and environmental groups (NRTEE, 2010).

The oil sands industry thus always needs a certain amount of fresh water, since not all the process water can be reused, therefore water extraction from the Athabasca river will always be needed.

The advantage of this area is that there is a relative abundance of water as opposed to the south, where water is already scarce.

There is a relative abundance of water in the Athabasca oil sands area

Water use is however not without impacts for the environment, water availability in the Athabasca river is expected to decline due to climate change in the future, while oil sands development expands (Mannix, Dridi and Adamowicz, 2010).

Possible impacts on the environment will be most likely during winter when flows are naturally lower (Jordaan, 2010). However adequate monitoring and transparent data is still missing, which makes the significance of the impacts of oil sands water extraction on the environment uncertain (Hrudey, et al., 2010 and Dillon, et al., 2010).

Impacts of water extraction from river will be highest during winter

In figure 6.14 is showed by means of orange arrows how the extracted water from the river is going to the extraction plants and the refinery, and in figure 6.15 you see a photo of the Athabasca river.

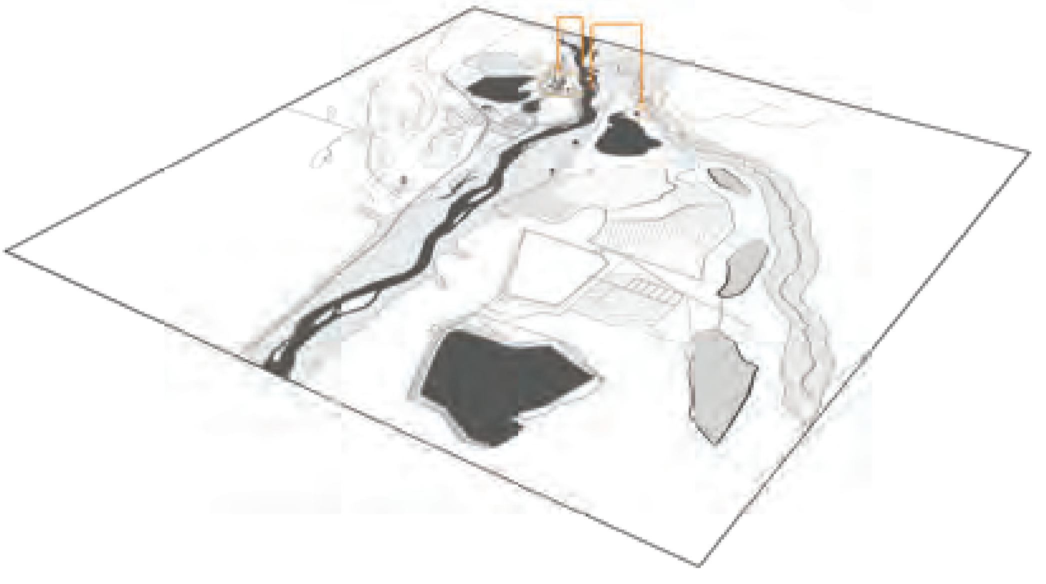


Figure 6.14: The extraction of water from the Athabasca river

Figure 6.15: The extraction of water from the Athabasca river

6.3.3 Impacts of water extraction of river on the landscape

- Extraction of water from river has impact on aquatic habitat (Feeding, migration, overwintering)
- Perched lakes, wetlands, and waterways are also sensitive to small changes in the level of the Athabasca River (Schindler et al., 2007).
- Once water from river is used in the process, it is too polluted to discharge and thus stored in tailings ponds

6.3.4 Storage of tailings into tailings ponds

After hydrotransport the oil sands slurry goes into seperation vessel, and seperates bitumen from water, sand and clay

After hydrotransport, the slurry goes into a vessel and separates the bitumen from the water, sand and clay. The bitumen, that floats to the top as froth, is skimmed off and spun in centrifuges to further remove the remaining water, sand and clay (Oil Sands discovery centre, n.d.). The bitumen then goes to the upgrader to be further processed.

Leftover sand, clay and water are stored in tailings ponds

The leftover sand, clay, and water are then pumped to large storage areas called tailings ponds or settling basins (Oil Sands discovery centre, n.d.).

Tailings ponds pose several risks on the environment

However, the storage of tailings is not without risks, three major problems occur:

1. Very slow settling of fine clay particles, which are suspended in water, uncertain time scales therefore arise associated with their existence (Hrudey, et al., 2010);
2. Tailings contain harmful chemicals, from heavy metals to residual bitumen and naphthenic acids, which are of concern due to their toxicity to aquatic organisms, birds and wildlife (Jordaan, 2012);

3. Due to seepage of these tailings ponds water is released into the groundwater or surface water (Jordaan, 2012). Several studies are done on this issue but it is still uncertain what exactly is seeping, how much and what the effects are (Pembina institute, 2009).

The first problem stands on its own, the second and third problem are interrelated, if the tailings were not polluted than seepage was not a huge issue.

When focussing on the first mentioned problem, the slow settling of the fine clay particles, the problem arises during sedimentation. When tailings are being deposited in tailings ponds three different layers develop in the tailings ponds, namely: coarse solids (sand), MFT and released water.

First of all:

Fine particles settle very slow

The coarse solids, mostly sand, settles quickly to the bottom and do not cause any difficult environmental challenges. On top of the sand a layer of mature fine tailings (MFT) develops, which is made up of fine clay particles suspended in water. However, MFT have been a major concern in the oil sands industry because of their extremely slow settling and consolidation. Decades may be required to consolidate MFT.

Without any treatment, on average 1m3 of Synthetic crude oil (SCO) production from oil sands produces on average about 2m3 of MFT. Hrudey, et al., 2010). As a result, more and larger oil sands tailings ponds have been developed over the years.

for 1m3 of SCO on average 2m3 of MFT is produced

For this reason, to avoid larger and more tailings ponds, MFT is dredged from the ponds and laid out to dry, to be able to store more tailings. This will be explained in more detail in the paragraph 6.3.5.

Released water eventually floats at the top as the third layer in the tailings ponds and is being recycled back to the bitumen extraction. However, only 40 to 70 percent is reused in the industrial process. Therefore water extraction from the river will continue. This will have an impact on the annual water flow and its surrounding aquatic ecosystems (Pembina institute 2009).

40-70% of the process water can be recycled, this means water extraction from the river is always needed

This stratification of the different leftover materials are shown in figure 6.16.

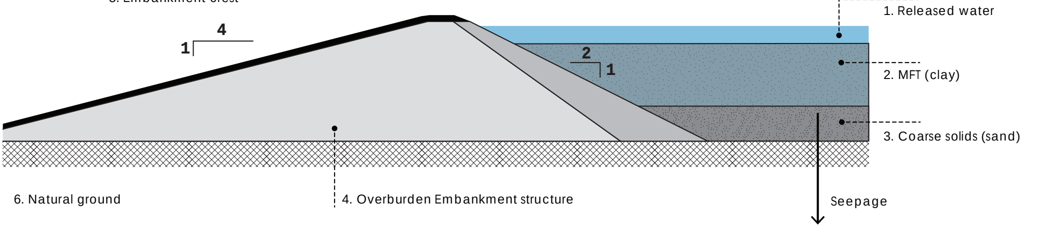


Figure 6.16: Stratification of different layers in tailings ponds.
Based on source: (Norwest corporation, 2003)

"For a typical plant of 47,700 m3/d (300,000 bbl/d) bitumen production, 250,000 m3/d (540,000 t/d) of oil sand ore are processed, producing close to 1,000,000 m3/d of tailings" (Royal Society of Canada, 2010). The current tailings ponds in operation occupy an area of about 130 km2 with an estimated tailings volume of 72 million m3 (Hrudey, et al., 2010).

Second and third:Tailings are polluted and seepage of tailings ponds may occur

The second and third problem are interrelated, tailings are polluted and tailings ponds seepage may occur on surface water or to ground water.

In order to reduce and monitor seepage flows all tailings ponds are constructed with groundwater monitoring and seepage capture facilities. "Where seepage is detected, government requires a recapture system to return the process-affected water to the pond" (Government of Alberta, 2013), an example of a recapture system is shown in figure 6.17.

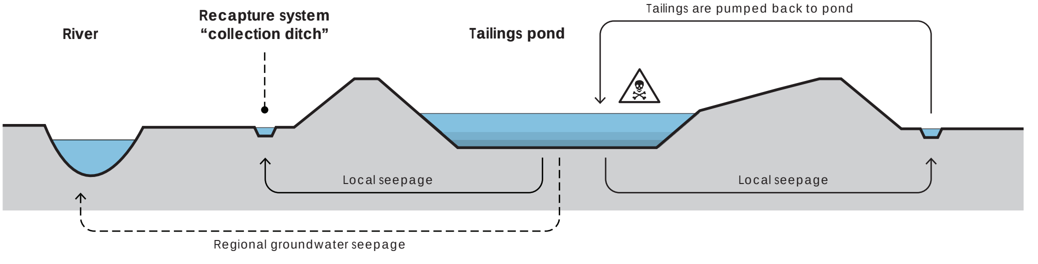


Figure 6.17: Recapture system for seepage

In summary, the tailings ponds thus have two important functions:

1. Storage of waste material, since it's not of sufficient quality to return it back to the environment;
2. Sedimentation basins for consolidation of coarse and fine solids and extract released water for recycling.

In figure 6.18 is showed by means of orange arrows, how the tailings coming from the upgrader and the extraction plants, is stored in the tailings ponds. In Figure 6.19 and 6.20 two photographs are showed.

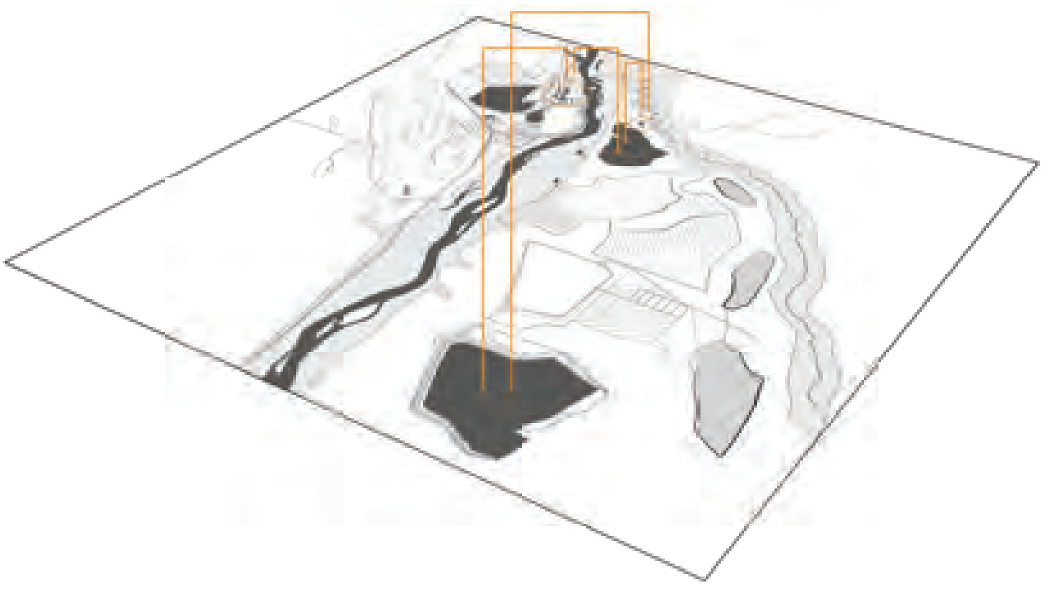


Figure 6.18: Storage of leftover sand, clay and water into tailings ponds

6.3.4	Impacts tailings ponds storage on the landscape
-	Storage of tailings leads to huge tailings ponds of several kilometers in width and length, surrounded by containment dykes
-	Tailings ponds seepage may occur which pollutes surface and groundwater


Width: 3,2 km

Figure 6.19: Photograph taken from airplane, with a view on a tailings pond in the front and the upgrader in the back

Figure 6.20: Photograph taken from airplane, with a view on one of the tailings ponds which is 3.2 km in width

Intermezzo:

Tailings ponds design

There are two methods of tailings storage in the oil sands industry:

a. Surface tailings ponds
b. Surface tailings ponds using topography as containment
c. In-pit tailings ponds (see fig. 6.21)

The first method uses abandoned open pit surface mines for tailings storage in the second and third method tailings are stored in impoundments (tailings ponds) created by embankments constructed from overburden material, tailings sand or the natural relief in the area.

However due to a lack of data, there are uncertainties about which tailings ponds uses what method, in-pit or surface? To continue with our research, several assumptions had to be made.

We have therefore drawn one line when it comes down to the tailings ponds:

- All tailings ponds have a containment dyke (high or low)
- All tailings ponds release a certain amount of contaminated water into groundwater or surface water (seepage)
- All tailings have a recapture system for seepage flows in the form of collection ditches

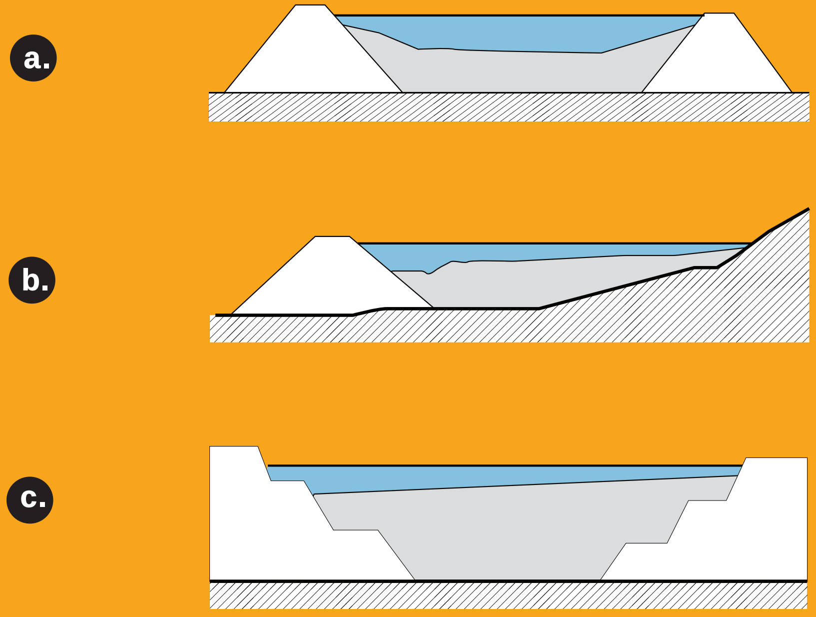


Figure 6.21: Methods for tailings storage. Based on source: (INAP, n.d.)

When talking about the surface tailings ponds, (ring) dykes are constructed to store the tailings in.

The surface tailings ponds are developed as follows, as can be seen in figure 6.22:

At first the surface is cleared(1), to continue with the development of the dyke structure (2). il response to the quantity of tailings, a tailings pond is raised with time. This results in several lifts depending on the quantity of tailings to be stored.

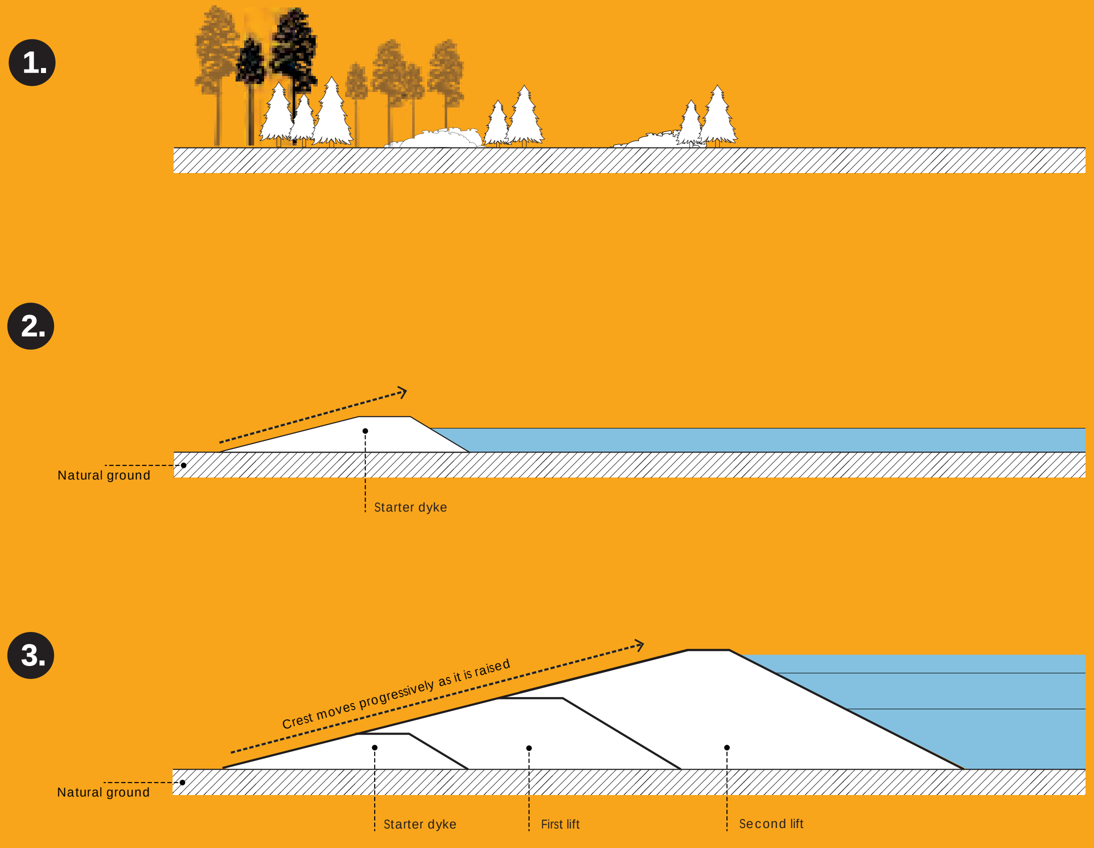


Figure 6.22: Tailings pond development. Based on source: (Engels, n.d.)

Main objective in treating oil sands tailings is to remove water

Current techniques add a polymer flocculant to speed up the consolidation process

6.3.5 The movement of Mature Fine Tailings to drying areas

The main objective in treating the oil sands tailings is to remove water so that a trafficable (load-bearing) surface develops in order to start reclamation (BGC Engineering Inc., 2010). As mentioned before, mature fine tailings therefore pose the biggest problem because of their extremely slow settling and consolidation,

Current mining companies therefore developed the following technique MFT is mixed with a polymer flocculent, and potentially centrifuged to thicken the tailings, to subsequently deposit the tailings in an open field with shallow slopes (fig. 6.24) in thin layers to let it dry naturally, this however requires a large landscape and a lot of water is lost due to evaporation.

The end products however is a dry material capable of being reclaimed. This drying process occurs over a matter of weeks, allowing for more rapid reclamation activities to happen (BGC Engineering Inc., 2010 and Hrudey, et al., 2010).

Figure 6.23 shows the different drying areas throughout the Suncor mine.

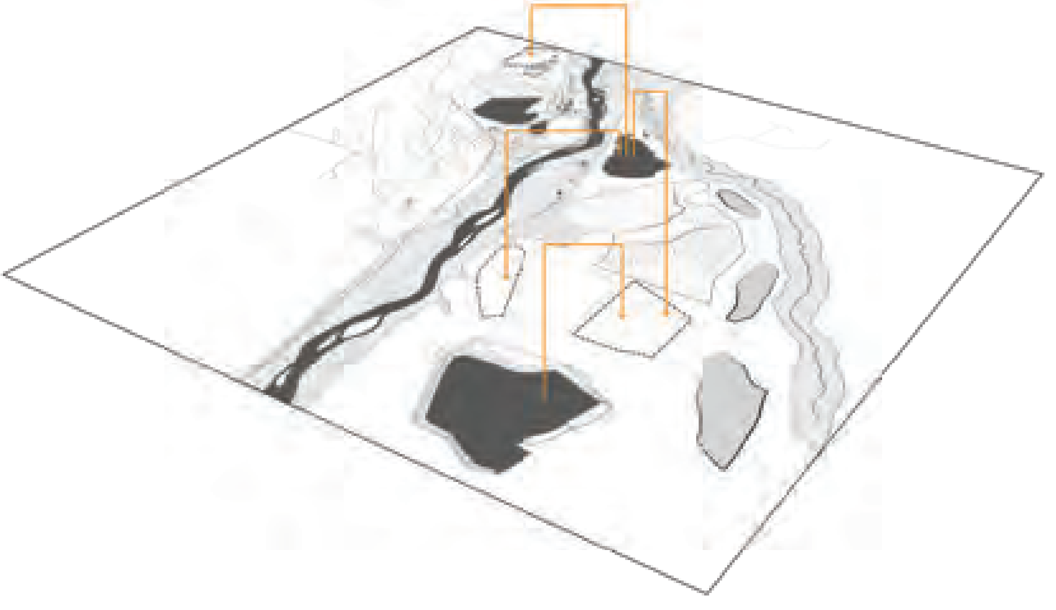


Figure 6.23: MFT is laid out to dry in drying areas

6.3.5	Impacts of drying areas on the landscape
-	Drying areas requires a large landscape leading to the disruption of even more space

Figure 6.24: Drying area

6.3.6 The movement of released water to water ponds

Released water from the tailings ponds will be sent to a so-called water pond. Herein water will be stored and when necessary extracted to be reused in the industrial process for bitumen extraction (Suncor Energy Inc., 2009), this is shown in figure 6.25 and 6.26.

Released water from the tailings ponds will be send to a water pond

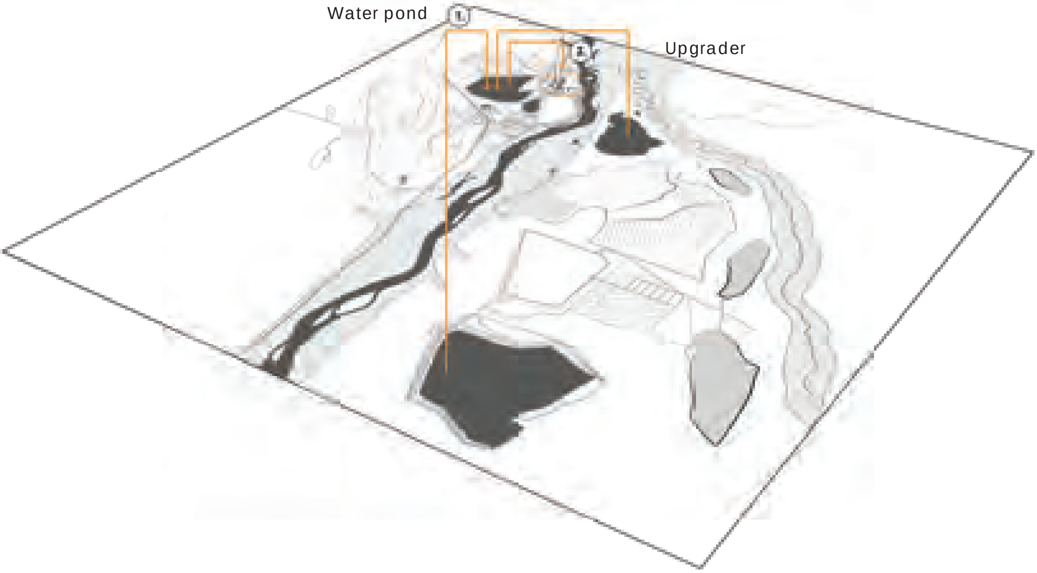


Figure 6.25 : Released water from the tailings ponds is sent to the water pond

Figure 6.26: Water pond in the back with the refinery in the front

6.3.6 Impacts water ponds on the landscape

- Water ponds are in form and size similar to tailings ponds, they just have a different function (storage of water). They have containment dykes as well.

6.3.7 Process resulting by-products

During process several by-products are generated. Tailings, elemental sulphur, petroleum coke and fly ash

From beginning to end during oil sands processing a number of by-products are generated. These by-products are generated in different phases in the process. As explained in the previous sections a large amount of tailings are produced consisting of water mixed with, clay, sand, solvent, residual bitumen, salts, metals and organic compounds (Government of Canada, 2013). However during the upgrading phase several by-products are generated as well. These by-products are elemental sulphur, petroleum coke and fly ash (Hrudey, et al., 2010).

Some of the by-products, such as the tailings are considered industrial waste of environmental concern, while the others have the potential to be used as raw material with economic value.

A plant producing 16,000 m3/d (100,000 bbl/d) Synthetic crude oil (SCO) will need to process roughly 200,000 t/d oil sands ores, generating 50,000 m3/d of coarse solids (sand), 20,000 m3 MFT (or 40,000 m3 fluid fine tailings), 2000 m3/d petroleum coke, 600 m3 sulphur/ d and 100 m3/d fly ash (Majid and Sparks, 1999).

(Petroleum) Coke looks and acts like coal, it however emits 5 to 10 percent more carbon dioxide than coal during combustion (Stockman, 2013). Besides a fuel source, Coke can for example be used as additive for enhanced consolidation of oil sands or as ingredient for road construction. Coke can be thus be used for many purposes and will probably become a valuable by-product rather than a waste of bitumen upgrading (fig. 6.27).

Coke looks and acts like coal

Fly ash is only produced if Coke is combusted by a so-called coke burner to generate heat for oil sands processing and bitumen upgrading. Currently fly ash is disposed by landfill.

Fly ash is produced when coke is combusted

Elemental sulphur is considered a commodity material which is mainly used for the production of fertilizers. Because of the remote location of the oil sands operation sites, most of the sulphur produced during upgrading is stockpiled in large blocks of hundreds of metres in length and width.

Elemental sulphur is considered a commodity material, which is mainly used in fertilizers

The development of a sulphur-based product for local or regional consumption would be important. Efforts therefore have been made to develop sulphur concrete for the construction of haul roads (fig. 6.27) (Hrudey, et al., 2010).

In the end the oil sands industrial process is very energy intensive and consumes big amounts of natural gas, electricity, and diesel which results in greater greenhouse gas emissions than the process of conventional sources.

Figure 6.27: A pile of Coke (L) and a block of Sulphur (R).

6.3.7 Impacts of generated by-products on the landscape

- The generated by-products in the process resuls into huge piles of Coke and Sulphur

6.4 Conclusion

By means of this analysis we achieved the purpose of this chapter. As mentioned in the beginning the purpose was to get a better understanding of the industrial process and how this process affects the landscape, the question we therefore asked ourselves was as follows:

“How does the industry work and what are the effects on the contemporary landscape?”

Each different paragraph explains a part of the industrial process, ending with the major effects on the landscape by means of bullets. Combining this information all together led to the following overarching conclusion.

Once water is used for bitumen extraction, water isn’t of sufficient quality anymore to return the water to the environment. The water is therefore stored in tailings ponds, however only 40-70% of the process water can be recycled.

This implies two things: water extraction from the Athabasca river continues and tailings ponds have to expand. Part of the solution would be to improve recycling rates of process affected water.

If we want to improve the recycling rates of process affected water several design solutions can be proposed:

- Increase amount of released tailings water in tailings ponds, due to consolidation of fine particles
- Clean the tailings water more sufficiently

MFT that develops when fine particles settle, accumulate in tailings ponds. They are laid out to dry in the mine to make a trafficable and dry surface. This is done to make more space available in the tailings ponds for the storage of new tailings. These dried tailings are subsequently used for reclamation purposes. This however, takes a lot of space.

It may even disturb parts of the environment, that would perhaps not be affected when using other methods, it thereby may again result into release of tailings water due to seepage. This means this issue is an important thing to deal with in our design towards a more sustainable landscape.

Finally, more use should be made of the various by-products that are generated in the industrial process. As already mentioned, most of them could have economic value, however due to the remote location of the oil sands operation sites most of the material is stockpiled. This can and must be dealt with differently in the future.

In the following chapter we will continue with an analysis on the social level, which is callled people’s perspective.

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7. People's perspective

In the following chapter we will dig deeper into the perspectives of the people involved in the oil sands industry. While the oil sands are an economic key player for Canada, the term has gained a great political charge the last decade.
We therefore wanted to know what people's perspective towards these developments are. Besides people's perspective we wanted to gather objective data, since much information is hidden or confidential. We have done this by means of interviews.

People's perspective

The previous chapter explained the industrial processes and their affects on the landscape

The previous chapter explained the different industrial processes and how these processes affect the landscape. Which was the second analysis chapter of the three. In this chapter we will continue with the third topic which is people's perspectives.

The generated data is derived from twenty interviews we conducted with various stakeholders.

7.1 The purpose

The purpose of this chapter is to understand people's perspective regarding the developments

The purpose of this chapter is to get a better understanding of people's perspectives on the current developments in the oil sands industry. Since concerns of environmental risks and impacts received a lot of attention on a local, national and international level. This has led to an ongoing debate between the oil sands industry and the environmentalists. Everyone holds its own version of the truth.

Before we went to Canada, our view towards the oil sands industry was strongly influenced by what we read in the media, as being the "dirtiest oil in the world". We however wanted to hear both sides of the story in order to determine our own point of view, the question we therefore asked ourselves is as follows:

What are the perspectives of different stakeholders regarding the developments of the oil sands industry?

Semi- structured interviews served as main input for this analysis

To get an answer to this question, we did a stakeholder analysis, in which interviews served as the input. To determine what people think can be improved in the future, or what is still lacking in the area, which stakeholder is directing the developments in the area for example.

Conducting interviews has been very useful to achieve this, which in turn led to a further delineation of our research and design focus.

We have taken several steps in the stakeholder analysis which are as followed:

There are four steps that need to be taken in the analysis

1. Selection of stakeholders;
2. Interviewing stakeholders;
3. Identifying and categorizing stakeholders;
4. Investigating relationships between stakeholders.

Each step in the stakeholder analysis will be further elaborated on by the use of different methods.

Each step in the stakeholder analysis will be further elaborated on by the use of different methods.

7.2 Selection of stakeholders

The selection of the various stakeholders mainly took place on the basis of the criterion knowledge and abilities, which refers to stakeholders assumed to have specific knowledge and skills on a specific issue (André et al, 2012). We talked among others with: ecologists, biologists, engineers, soil chemists, environmental microbiologists, sociologists and consultants. Who all had in common that they had very specific knowledge on a particular topic regarding the oil sands industry.

First the Selection of stakeholders. This took place on basis of their knowledge and abilities

The majority of the stakeholders were selected before the interviews had started.

Subsequently we also used the snowball sampling method to select our stakeholders; this wasn't a considered method in advance. But, when emailing people to make an appointment or while doing interviews, It often happened that we were brought into contact with other experts working in a specific area in the oil sand industry. In figure 7.2 is shown how we finally got in touch with our interviewees.

Snowball sampling was another method to select these stakeholders

This gave us the ability to engage and talk with the 'hard to reach people'. However, the deficiencies of the use of this method lie in the fact that the people with whom you talk are not randomly drawn, but are dependent on the subjective choices of the respondents first accessed; therefore most snowball samples are biased (Atkinson and Flint, 2001). However, we used the snowball sampling method purely as a method of contact in a practical sense.

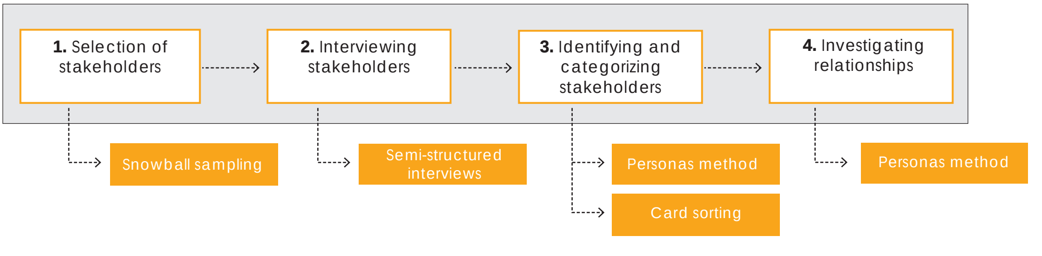


Figure 7.1: Taken steps and used methods

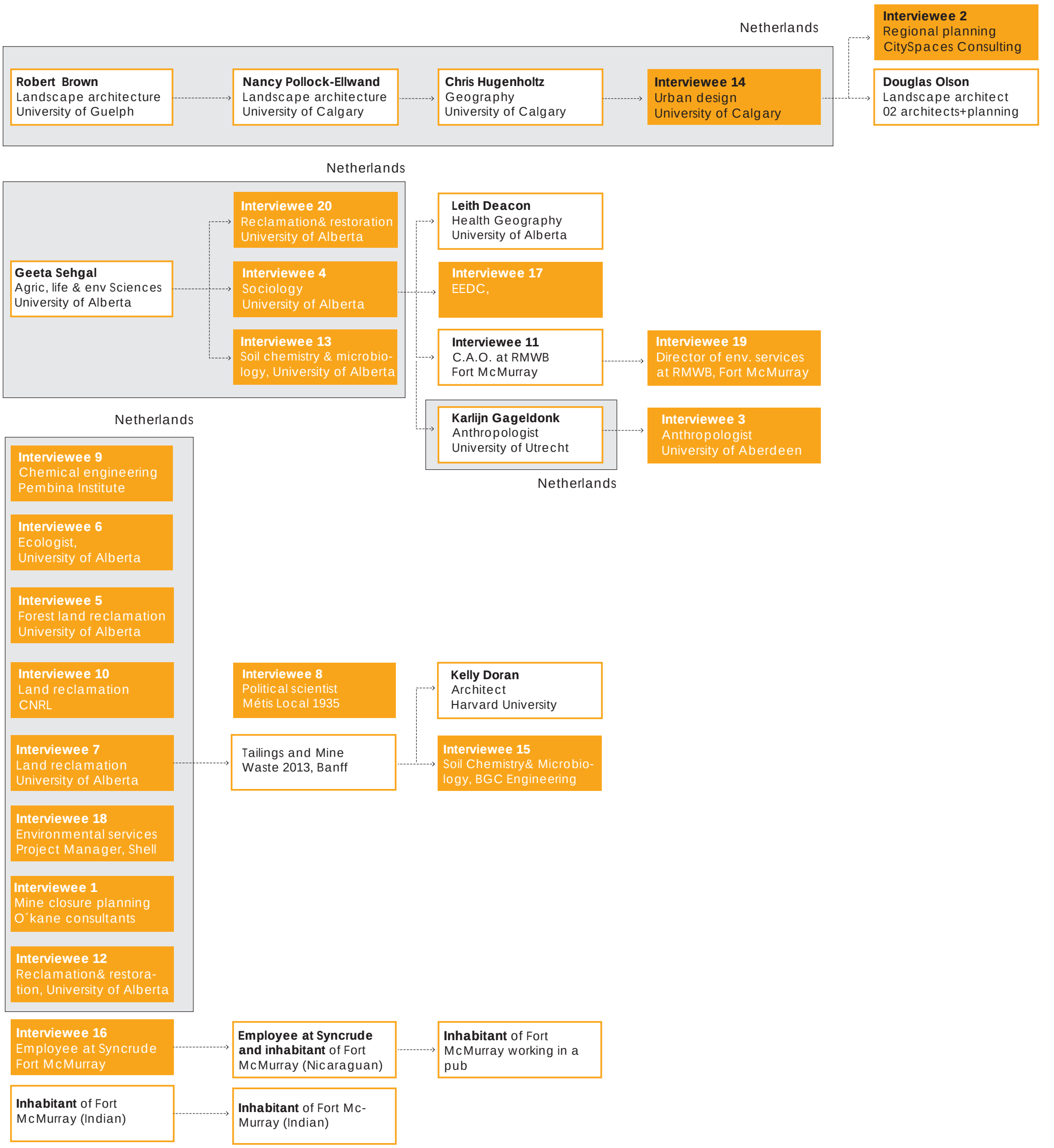


Figure 7.2: Snowball sampling

The orange boxes stand for the people we have interviewed, and the white boxes represents who connected us with them. So in some cases we contacted people directly and in some cases their names where mentioned in interviews. The boxes in grey represent the people we already contacted before we went to Canada.

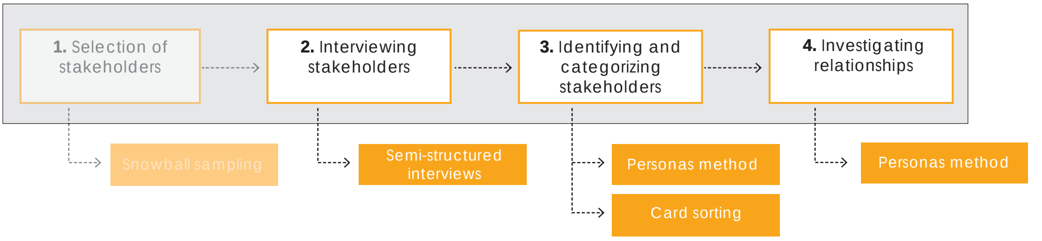


Figure 7.3: Step 2, interviewing stakeholders

7.3 Interviewing stakeholders

The second step (fig. 7.3) taken in the stakeholder analysis, was interviewing the stakeholders, in order to get more in-depth knowledge and clarifications about certain complex matters in the industrial process. We therefore used the method of semi-structured interviews.

After selection of stakeholders we interviewed them with semi-structured interviews

Why carry-out semi-structured interviews?

Simply seen, semi-structured interviews are guided conversations, as a researcher you know to some extent what the conversation will be about, but it is not fully pre-determined, such as is the case for structured interviews. The researcher tends not to stop the person being interviewed, which gives a person a fair degree of freedom in what to talk about, how much to say, and how to express it. This is useful when you can only meet the person once (Bernard, 1988).

Which are "guided conversations" to give a person freedom in what to talk about

We, researchers, consider this freedom from the person being interviewed as an advantage, since it gives us the ability, with complex issues like the oil sands industry, to get a further explanation/ clarification about certain complex matters, for example to get a better understanding of the extraction and treatment process.

This freedom is an advantage when talking about complex and sensitive issues like the oil sands industry

In final, we carried out semi-structured interviews because the topic is very sensitive. Due the negative media coverage, people are very hesitant in giving their opinion. By doing an informal and open interview a person can decide whether they want to give their personal opinion or not (Miles, 2005).

In preparation for the interviews we had generally written down several questions to guide the scope of the conversation to some extent.

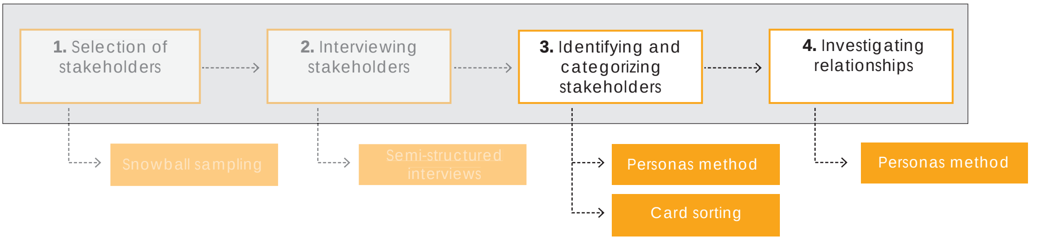


Figure 7.4: Step 3,Identifying and categorizing stakeholders

7.4 Identifying and categorizing

The third step was identifying and categorizing by using the personas method

As the third step (fig. 7.4), the derived data from the interviews needed to be processed; therefore we used the personas method.

Which focuses on finding commonalities between stakeholders to finally cluster them in archetypes

The Personas method, as described by Hanington and Martin (2012), "focuses on finding commonalities between different stakeholders. To eventually cluster the similarities between the different stakeholders to begin forming synthesized, aggregate, categories or so-called archetypes".

We first made a personal sheet for every interviewed person

To find out these so called archetypes and work them out into personas we first developed a personal sheet for every interviewed person. In the personal sheet the following characteristics of the stakeholders are described:

- Title;
- Location;
- Company description;
- Field of expertise/ function;
- Summary interview.

These personal sheets served as input for the development of the personas. By looking for similarities across stakeholders, different clusters were made, which eventually formed the personas.

On the right page an overview of the 20 interviewed people is given .

Then, the card sorting method was used to explore how participants cluster these personal sheets

In order to be able to make clusters, we made use of the "card sorting" method. "Card sorting is a participatory design technique that can be used to explore how participants group items into categories and relate concepts to one another (Hanington and Martin, 2012 p. 50).

We printed the personal sheets on half an a4 and asked several participants to sort them in different groups. The results of the participants were subsequently compared, to finally make different clusters of stakeholders based on the results from the card sorting method. On the next two pages (fig. 7.5) four examples are given of the personal sheets.

Interviewee 1	Geotechnical Engineer and President, O'Kane Consultants
Interviewee 2	Regional planner and Manager, Alberta & Prairies , CitySpaces Consulting Ltd.
Interviewee 3	PhD Candidate in Social Anthropology, University of Aberdeen
Interviewee 4	Associate professor in sociology, University of Alberta
Interviewee 5	Professor in Forest Land Reclamation and Applied Forest Ecology, University of Alberta
Interviewee 6	Professor in wetland ecology, University of Alberta
Interviewee 7	Head of OSRIN and Co-chair of land working group (LWG) at The Cumulative Environmental Management Association (CEMA).
Interviewee 8	General Manager, Fort McMurray Métis Local 1935
Interviewee 9	Technical and Policy Analyst, Pembina institute
Interviewee 10	Lead, Environment, Reclamation and Planning , Canadian Natural Resources Ltd (CNRL)
Interviewee 11	Chief Administrative Officer, Regional Municipality of Wood Buffalo (RMWB)
Interviewee 12	Scientific Director of the Centre for Oil Sands Innovation (COSI), University of Alberta
Interviewee 13	Assistant professor in soil chemistry, University of Alberta
Interviewee 14	Associate Dean environmental design and planning, University of Calgary
Interviewee 15	Geotechnical engineer, BGC Engineering
Interviewee 16	Process Operator, Syncrude
Interviewee 17	Executive Director, Edmonton Economic Development Corporation (EEDC)
Interviewee 18	Approvals Project Lead, Shell
Interviewee 19	Director of environmental services, Regional Municipality of Wood Buffalo (RMWB)
Interviewee 20	Professor Land Reclamation and Restoration Ecology , University of Alberta

Title: Executive Director EEDC

Location: Edmonton

Company description: The Edmonton Economic Development Corporation is responsible for "helping to lead the business community as well as contributing to the strategy for economic growth in the region, with specific accountability for supporting industry growth and diversification" (EEDC, 2013).

Field of expertise/function: Social media savant and lawyer, past Executive Director of the OSDG, always looking for the next narrative in a sweeping range of interests from business and environment to social concerns and community development (Oilsands Ken, 2013).

"We are going beyond the competitive model of doing business, not abandon it. For some things the model works really well, but not for everything. We have to start using synergies in our various activities"

His goal is to improve the well-being of the people, communities and enterprises in the Athabasca Oil Sands Region, how to develop the oil sands more responsible and sustainable. "It has everything to do with a new way of doing business. If we want to solve the environmental and socio-economic problems, a shift is needed from a more competitive business model towards a collaborative business model".

Besides the pursuit of collaboration and mutual understanding between stakeholders, he advocates that companies working in the oil sands must commit to a triple bottom line approach in their practices. "creating genuine prosperity, stewardship of the planet and enabling better lives for people. The new attitude has to be towards a quadruple bottom line by adding posterity. We have to leave a positive legacy from our efforts to the benefit of future generations"
"If we do this right, the prosperity we leave to the planet, will be reclamation technologies. That's a technology we can sell, that fits our mythology of Canada. It serves the planet and it moves our culture to be more globalized, integrated and interdependent" (Interviewee 17, 2013).

Title: Professor in Wetland ecology and management, participant in the Land Reclamation Interntational Graduate School

Location: Edmonton

Company description:
University of Alberta

Field of expertise/function:
His research focusses on wetland management, disturbance, reclamation and wildlife habitat. Besides that he is doing research on plant physiology and competition in relation to altered growing environments, like the mined areas in the oil sands, in order to improve reclamation (University of Alberta, 2013).

"For an untrained eye it looks green and reclaimed, to an ecologist or scientist it is a duck death trap"

"Reclamation folks often say that they have succeeded the reclamation, however the salinity is often too high, which prevents plants from growing normally. It's easy to pay the bill and construct something, in comparison with ushering nature and reassembling nature".

The interviewee completely understands that there is money to be made. Businesses do not have the mandate to be green citizens or do good things for society. "So to ask businesses to willingly do reclamation is like asking a pig knitting a sweater. "
He does not expect that to change. But he does expect that environmental organizations and society will put more pressure on the companies.

The government should take a more dominant role in this. They have to make sure reclamation is properly regulated in advance.

However, "one must keep in mind that the concentration of relatively few large multinational oil companies, makes them an easy target to oppose on. It's like clubbing baby seals, these are iconic environmental issues, they are symbolic as much as practical". (Interviewee 6, 2013).

Title: Geotechnical engineer

Location: Vancouver

Company description: BGC engineering is an international consulting firm specializing in geotechnical and water resources engineering and applied earth sciences.

Field of expertise/function: The ineterviewee has 26 years of experience in the mining Industry. This includes 17 years of working at Syncrude and 9 years of working as a consultant. He is specialized in mining geotechnique, soft tailings, landform design, and closure planning (Interviewee 15, 2013).

"Sustainable mining is needed to ensure future generations on earth enjoy the same opportunities that we were bequeathed from the generation that came before us, but it is about more than that"

The interviewee is specialized in Mine closure planning. Mine closure is a common activity in the oil sands industry of Canada. "A conceptual closure plan is developed as part of initial mine permitting and updated periodically. These plans form the basis for assessment of financial assurance" (McKenna et al 2013, pp. 1).

"The closure plan will be aligned with the long-range mine plan, and will provide at least one viable path through the states of mining: development/ construction, operation and production, and reclamation/closure" (McKenna et al 2013, pp. 2).

An important aspect within mine closure planning is landform design. This landform design incorporates: settling clear landscape performance goals, designing and constructing mining landforms (Like overburden dumps, tailing areas, pits), with a multidisciplinary team, typically working over many decades (Interviewee 15, 2013).

Title: Process operator

Location: Fort McMurray

Company description: Syncrude is one of the largest oil producers from Canada's oil sands.

Field of expertise/function: As a process operator you have a crucial role in the production process. He has to check and control the production process, when a fault occurs he is the one who has to solve it. To be capable to do this a broad base of knowledge about the industrial process is needed (Interviewee 16, 2013).

"I would never feed my children from the food that has grown on oil sands industry grounds"

When we talked with the interviewee and some of his colleagues about other forms of land use than just nature, they told us the industrial sites are too contaminated to develop something on. They mainly referred to food. "I would never feed my children from the food that has grown on oil sands industry grounds".

Besides that, we talked about what they would like to see changed in the future, to which he replied that he misses varied amenities and services like reasonably priced restaurants, libraries, live music venues, outdoor recreation, higher education and research facilities. Furthermore traffic to and from work is a disaster, when shifts change you are easily stuck in traffic for a few hours.

When we asked them about their ideal Fort McMurray, interesting answers were mentioned. One sees Fort McMurray as a "northern Canadian former oil boomtown and model for major environmental reclamation projects worldwide". Someone else sees Fort McMurray as a metropolitan type of city, "the community has all the amenities and services of any other town of its size in Alberta, housing prices are stable and affordable" (Interviewee 16, 2013).

Figure 7.5: Four examples of personal sheets of interviewees 17, 6, 15 and 16)

Finally six different clusters were made, eventually forming the personas

After comparing the results of the card sorting methods six different clusters of stakeholders, could be made.

These clusters eventually formed the personas.

The six different clusters are mainly made on the basis of expertise. One persona for example (Persona 1) comprises of stakeholders who are all doing research in the field of ecology and reclamation.

The six clusters are shown below in the grey box

1. Scientist in ecology and environmental sciences:

Interviewee 5	Professor in Forest Land Reclamation and Applied Forest Ecology
Interviewee 6	Professor in wetland ecology University of Alberta
Interviewee 7	Head of OSRIN and Co-chair of land working group (LWG) at The Cumulative Environmental Management Association (CEMA).
Interviewee 9	Technical and Policy Analyst Pembina institute
Interviewee 20	Professor Land Reclamation and Restoration Ecology University of Alberta

2. Inhabitant of Fort McMurray and working in the industry:

Interviewee 4	Associate professor in sociology University of Alberta
Interviewee 16	Process Operator Syncrude

3. Visionair about the future of Fort McMurray and the oil sands industry:

Interviewee 2	Regional planner and Manager, Alberta & Prairies at CitySpaces Consulting Ltd.
Interviewee 11	Chief Administrative Officer Regional Municipality of Wood Buffalo (RMWB)
Interviewee 14	Associate Dean environmental design and planning University of Calgary
Interviewee 17	Executive Director Edmonton Economic Development Corporation (EEDC)
Interviewee 19	Director of environmental services Regional Municipality of Wood Buffalo (RMWB)

4. The Métis (aboriginal group):

Interviewee 3	PhD Candidate in Social Anthropology University of Aberdeen
Interviewee 8	General Manager at Fort McMurray Métis Local 1935

5. Engineer in developing innovative technologies in the oil sands industry:

Interviewee 1	Geotechnical Engineer and President O'Kane Consultants
Interviewee 15	Geotechnical engineer BGC Engineering
Interviewee 12	Scientific Director of the Centre for Oil Sands Innovation (COSI) University of Alberta
Interviewee 13	Assistant professor in soil chemistry University of Alberta

6. Employee at operating oil company in the region:

Interviewee 10	Lead, Environment, Reclamation and Planning Canadian Natural Resources Ltd (CNRL)
Interviewee 18	Approvals Project Lead at Shell

We subsequently developed the six different personas. In the personas the following characteristics of the stakeholders are described:

- Field of expertise;
- Perspective towards industry:
- Goal.

The six personas are shown on the next six pages.

“Companies are by law required to put that land back into its original state, or at least to similar capability”

Scientist in ecology and environmental sciences

Persona 1

Field of expertise:

Research of this person mainly focuses on restoration ecology, reclamation, re-vegetation, soil reconstruction of disturbed lands like the oil sands lands. He works for a research institute, which has a main focus on issues in the oil sands industry. He is certainly not against industry, yet critical.

Perspective towards industry:

When people talk about land reclamation in Alberta they talk about equivalent land capability. This means disturbed land should be returned to a capability (end land use) that is equivalent to, or greater than what existed before. Oil sands companies therefore bring back the disturbed land into its original state, without considering doing things differently. However, equivalent land capability can be interpreted in different ways. In the case of Fort McMurray it maybe makes more sense to develop a park instead of wilderness.

Reality is that one must consider is the following: “What do you want this land to do?”. At the moment they do reclamation with the approval they made 30 years ago, demands might have changed. The ideas about proper reclamation should be more flexible.

Government should therefore take a more dominant role in this. They have to make sure reclamation is properly regulated in advance. Environmental organizations and society can exert pressure, to make these changes take place faster.

In the end researchers, industry and the government all want the land to be left behind in a good condition. Therefore a lot of cooperation between these parties is going on in Alberta. Which is not the perception people have about the situation.

Goal:

As a researcher in Land Reclamation you want the land to be reclaimed as good as possible, it has to be part of the system again, whether the surrounding system has changed or not.

“I would never feed my children from the food that has grown on oil sands industry grounds”

Inhabitant of Fort McMurray and working in the industry *Persona 2*

Field of expertise:
He is an inhabitant of fort McMurray and works for Syncrude, one of the biggest synthetic crude oil producers in the oil sands industry. He has a crucial role in the production process. He checks and controls the upgrading process, when a fault occurs he is the one who has to solve it. This puts a great responsibility on him. Nine out of ten times, however, nothing happens, but if something really goes wrong, then he is the one who has to solve it and the consequences are great if not acted properly.

Perspective towards industry:
He spoke with pride about all the knowledge he has about the industry and its processes. However, it is mainly for the money that he is doing this job. He is particularly critical of the high level of pollution caused by the industry. “I would never feed my children from the food that has grown on oil sands industrial grounds” (Interviewee 16, 2013). He misses varied amenities and services like reasonably priced restaurants, libraries, affordable housing, outdoor recreation and a decent road network.

Their ideal Fort McMurray would be a northern Canadian former oil boomtown and model for major environmental reclamation projects worldwide, a metropolitan type of city.

Goal:
His goal is to earn as much money as possible in the shortest possible time, to have the opportunity to go on holidays and later on move to his dream house on Victoria Island.

“A new discourse towards the city of Fort McMurray has started to develop: a real city built on the oil sands”

Visionair about the future of Fort McMurray

Persona 3

Field of expertise:

This person is a driver for change. He puts emphasis on a more responsible and sustainable development of the oil sands. Sustainability for oil sands means we must steward the environment, create genuine prosperity and a fairly distributed high quality of life for people. The visionair therefore focuses on more and new forms of collaboration. “ Start using synergies in our various activities. Opposed to trying to be a winner and letting somebody else be the loser” . (Interviewee 17, 2013).

Out of the box thinking and thinking off the beaten path, is in this case of great importance to achieve change. It’s about seeing possibilities rather than problems.

“It must be remembered that there is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage, than the creation of a new system” (Interviewee 11, 2013).

Perspective towards industry:

His perspective to the industry is critical, because things can be done better, but he sees the industry mainly as an opportunity for new developments in the region to become an example for the world. “What is a better place to show North America that change is possible, in the place that everyone sees as the worst example. That’s why we are trying to do the things we are doing” (Interviewee 11, 2013).

Goal:

His goal is to improve the well-being of the people, communities, enterprises and environment in the Athabasca oil sands region. To achieve this, change is needed in order to survive in the long term. It will be rough in the short term but necessary to survive in the long term (Interviewee 11, 2013). Climate change, environmental health and community building are urgent matters in this case.

“Their history actually started with the industry, they are the descendants of the European fur traders and first nation women”

the Métis (aboriginal group): *Persona 4*

Field of expertise:
The Métis are recognized as one of the aboriginal groups in Canada’s constitution. As a representative of the Métis you stand up for their interests. Their history actually starts with the industry, they are the descendants of the European fur traders and the first nation woman. They nowadays still hold on to their culture of hunting, gathering and setting traps. These cultural habitats need to be ensured. They try to achieve this by engaging in multi stakeholder groups like the wood buffalo environmental association, to finally come up with recommendations that can be send to the government of Alberta.

Perspective towards industry:
Assuming that the Métis people would encounter a lot of problems with the current developments many of them however, work in the industry. They need a work for living and therefore a lot of them work at Suncor or Syncrude.

They are not necessarily against the developments going on in the area, they however want to ensure that the developments are done in the most sustainable way possible.

Goal:
Ensure industrial developments are done in the most sustainable way possible and make sure the concerns of the Métis will be taken serious by the government.

“People need to design for closure. You need to align the mine planning and closure planning right from the beginning.”

Engineer in developing innovative technologies in the oil sands industry *Persona 5*

Field of expertise:

His expertise mainly focuses on the development of innovative techniques and solutions to decrease the environmental impacts of the industrial processes and developments. These techniques range from mine closure planning, degradation of hydrocarbons in tailing ponds, completely new oil sands extraction technologies to technologies to diminish GHG emissions.

Perspective towards industry:

He recognizes the importance of the industry, but considers that it can be improved in many ways. The industrial process should therefore be more controlled, this can be done by monitoring in order to make a proper assessment of the impacts on the environment, the derived data can then be used to counteract the problems. There is a continuous development going on within this field to achieve better and more efficient technologies.

The engineer predominantly focuses on mine closure, starting from the first day a mine opens. Planning for closure is very important since the likelihood of rehabilitation success increases. “Mining that creates financial and social wealth and wellbeing in a way that does not undermine or otherwise damage the aesthetic and productive capacity of natural capital for present and future generations” (Abbott Strategies, 2012)

Goal:

His goal is to develop new innovative oil sands techniques in order to diminish the environmental impacts, to strive for a more sustainable industry. Design for closure is therefore very important.

“Companies are by law required to put that land back into its original state, or at least to similar capability”

Employee at operating oil company in the region *Persona 6*

Field of expertise:
He works as a leader in environmental services, for one of the big operating oil companies in the area. He tries to minimize the effects of the oil sands industry on its environment where possible in every state of the industrial process. This can be in the regulation phase, before they actually start digging for oil, as well as in the operating phase by for example re-connecting the waste products to the industrial process again, but also in the reclamation phase when they reached the point of closure.

Perspective towards industry:
He agrees on the fact that industry is dirty and has a lot of negative effects on its environment. But he also believes in the industry that they are able to do a better job, because they are doing lots of good research to achieve this. Besides trust in the industry he also believes that it brings new opportunities for the region.

However, economic feasibility is an important aspect when working for the big oil companies. When a tradeoff between the environment or revenues has to be made, revenues always count heavier. That’s the downside of working for a profit oriented company.

Goal:
His goal is to minimize the effects of the industry on its environment by controlling different phases of the industrial process and working on new technologies which addresses the tailings problem and the reuse of industrial waste products. However, economic feasibility always remains an important aspect.

The following text shows through bullets a point by point summary of the six derived personas.

1. Scientist in ecology and environmental sciences (Persona 1)

- Research focuses primarily on questions related to the reclamation of disturbed lands to self-sustaining boreal forest ecosystems.
- Close collaboration between industry and government.
- Recognizes that there might be other options / functions to consider during reclamation than just boreal forest and wildlife habitat. However people find it difficult, to accept and visualize the possibilities of alternative land uses.
- Government should therefore take a more dominant role in these discussions, to make sure reclamation is done properly. They should consider which land use fits the purpose/ needs of the people and the environment best.

2. Inhabitant of Fort McMurray and working in the industry (Persona 2)

- Money is the driving force, to work in the oil sands and live in Fort McMurray.
- Is sceptical towards new (sustainable) developments like growing food on reclaimed oil sands industrial grounds. He would never feed his children with the food that has grown there.
- Misses varied amenities and services like, outdoor recreation, research facilities and affordable housing.
- Traffic to and from work is a disaster, when shifts change one can be stuck in traffic for hours.
- As soon as he has enough money, he quits his job to go and live in Victoria, BC.

3. Visionair about the future of Fort McMurray and the oil sands industry (Persona 3)

- Strives for more responsible and sustainable development of the oil sands region, to improve the well-being of the people, communities, enterprises and environment.
- Believes that new ways of collaboration, more transparency between stakeholders and sharing of knowledge is needed.

- Thinks out of the box, focused on the post-mining era, Is confident that the oil sands industry is an opportunity for new developments in the region to become an example for the world.
- Sees the beauty and potential in the horrifying oil sands developments.
- Is aware of the fact that Fort McMurray cannot be compared with a city like Vancouver or Toronto.

4. Representative of the Métis (Persona 4)

- The Métis are recognized as one of the aboriginal groups in Canada's constitution.
- Métis are not against the industrial developments, they want to ensure that developments are done in the most sustainable way possible. To be able to continue their customs and traditions like hunting, gathering and setting trap lines.
- The history of the Métis starts with the industry, they are the descendants of the European fur traders and first nation woman.
- A lot of the Métis people work for the industry because they need work to make a living.

5. Engineer in developing innovative technologies in the oil sands industry (Persona 5)

- Continuous development of new (more sustainable) technologies to reduce environmental impact (e.g. tailings and air emissions).
- Focus on closure of the mine right from the beginning.
- Strives for a more controlled industrial process.
- Strives for more monitoring to measure the industries impact on its environment, to subsequently use the information to counteract the problems.

6. Employee at operating oil company in the region (Persona 6)

- All interventions should be primarily economically feasible.
- Is convinced that industry brings a lot of new opportunities for the region, besides the impact on the environment.
- Committed to improving the industrial process and make it more sustainable. Strives for development of industrial ecosystem, where waste products are re-connected to the process.

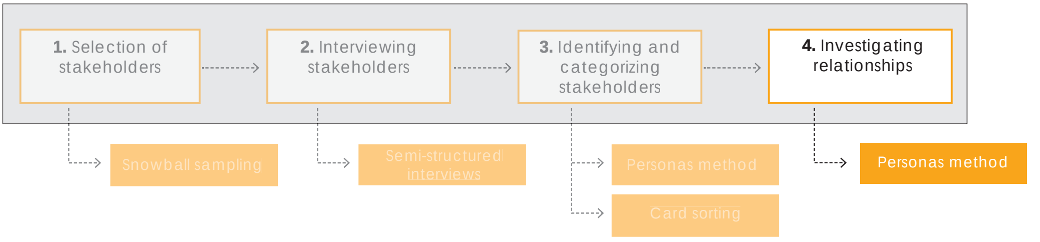


Figure 7.6: Step 4, Investigating relationships

7.5 Investigating relationships between personas.

The last step concerns the investigation of relationship between personas

The last step that needs to be taken concerns the investigation of relationships between the personas (fig. 7.6).

By clustering the stakeholders a realistic representation of the key stakeholders are given, a manageable design focus is maintained and extreme outliers are avoided (Hanington and Martin, 2012 pp. 304).

On the next pages the personas are once again displayed, in a cartoon-like way (fig. 7.7a,b,c,d,e,f) and in figure 7.8 is shown how the relationships between these personas are. We are however aware that we have to be careful with these statements, because this is our outlined idea of the situation.

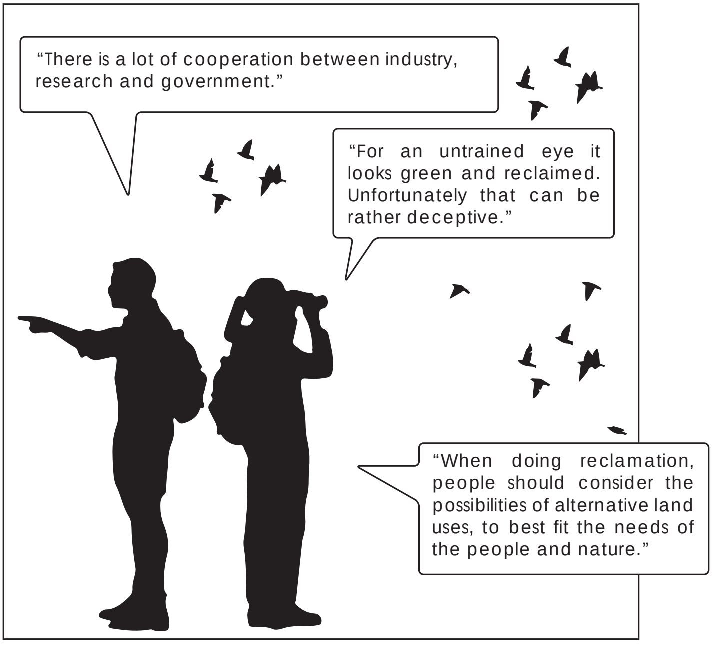


Figure 7.7 a: Scientist in ecology and environmental sciences

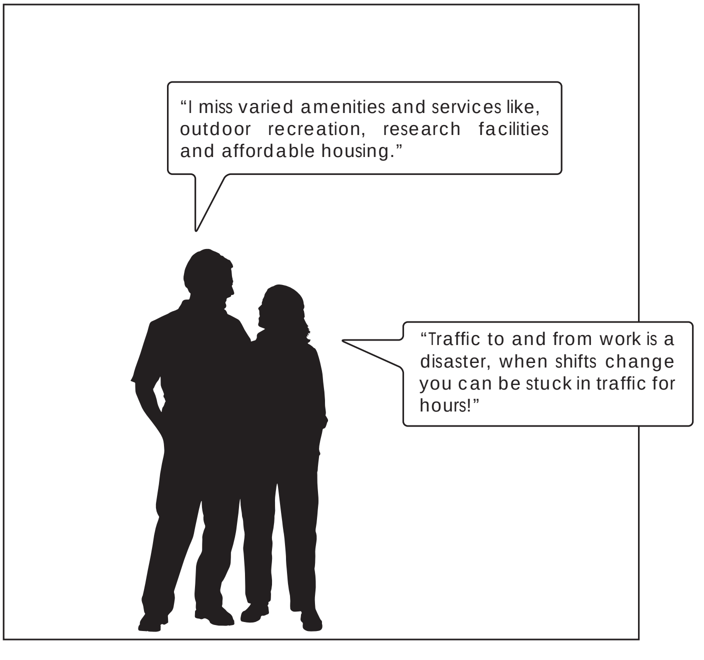


Figure 7.7 b: Inhabitant of Fort McMurray and working in the industry

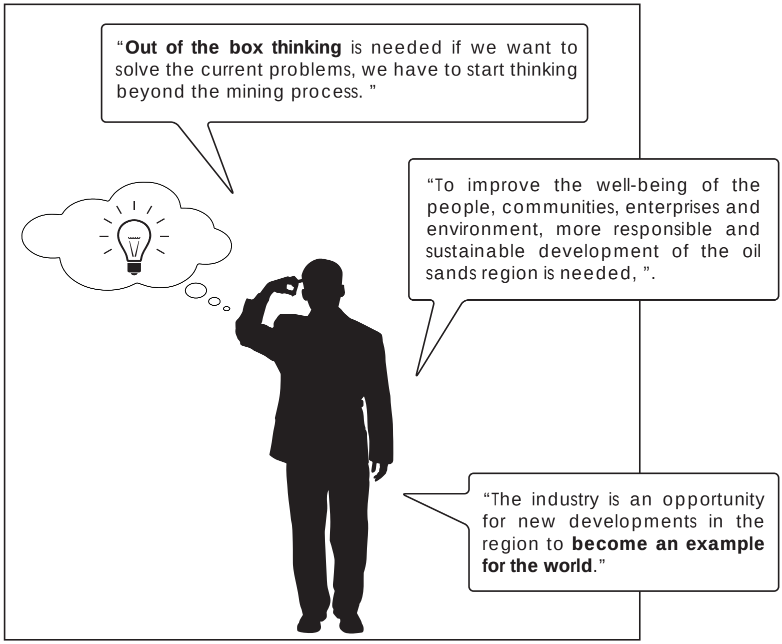


Figure 7.7 c: Visionair about the future of Fort McMurray and the oil sands

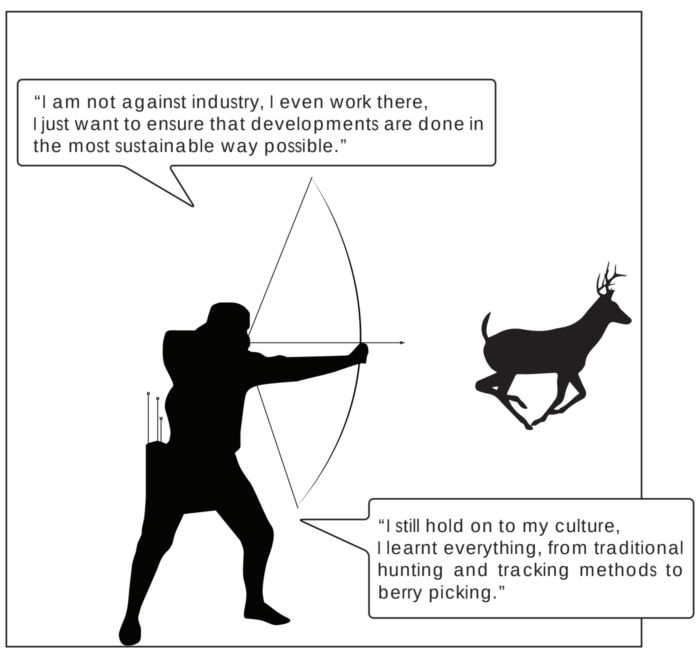


Figure 7.7 d: The Métis (aboriginal group)

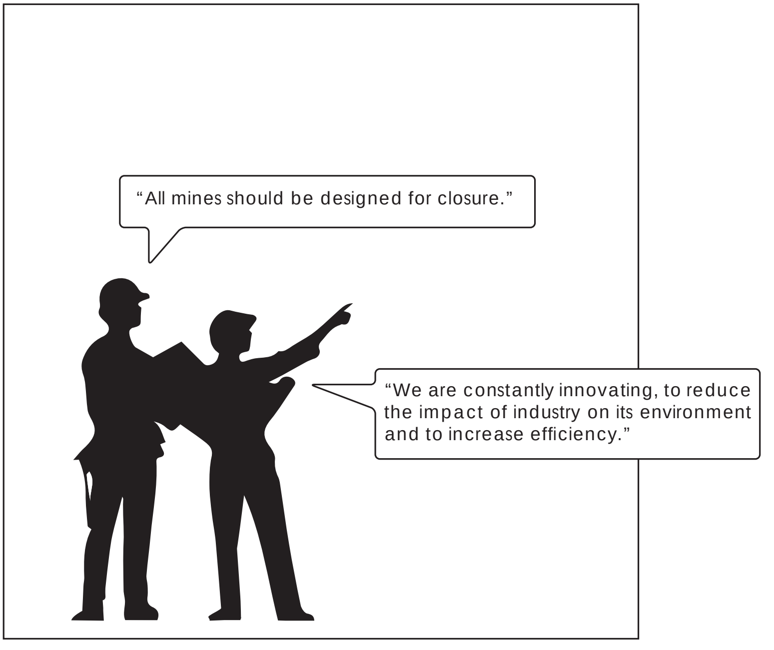


Figure 7.7 e: Engineer in developing innovative technologies in the oil sands

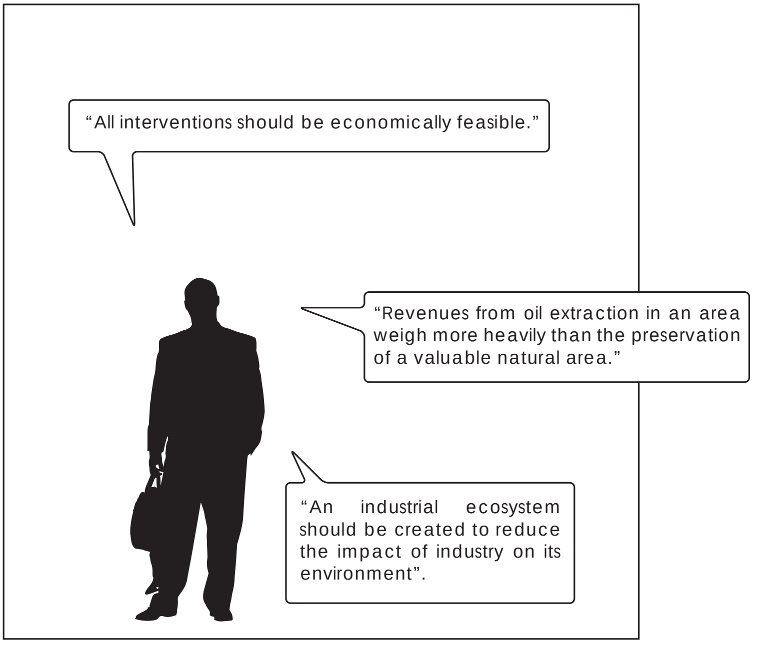


Figure 7.7 f: Employee at operating oil company in the region

There can be stated that the Industry is the most decisive stakeholder. There is a good cooperation between research institutes and industry

Most noticeable is that the industry is the most decisive and controlling stakeholder. There is a good cooperation with research institutes, from an environmental/ ecological point of view as well as an engineer point of view, which you can see in figure 7.8 as the grey box surrounding these three personas.

(native) inhabitants have less power

It's the (native) inhabitants that can less easily penetrate the industry when it comes to a more sustainable industry. They can however exert pressure or engage into different stakeholder groups. Things are however changing, more and more stakeholder engagement and consultation and between the different stakeholders is taking place. This creates a bond of trust between the different stakeholders, which ensures that the industrial operations can continue.

Trust between stakeholders plays a critical role in facilitating a social license to operate.

Trust plays a critical role in facilitating a social licence to operate. Social license generally refers to a local community's acceptance or approval of a company's project or ongoing presence in an area (Yates and Horvath, 2013). It is increasingly recognized by various stakeholders and communities as a precondition to development. If trust is lost and thus their social license to operate a whole individual site, company or entire industry can be affected.

If trust is lost, industry is vulnerable. Consultation is thus very important

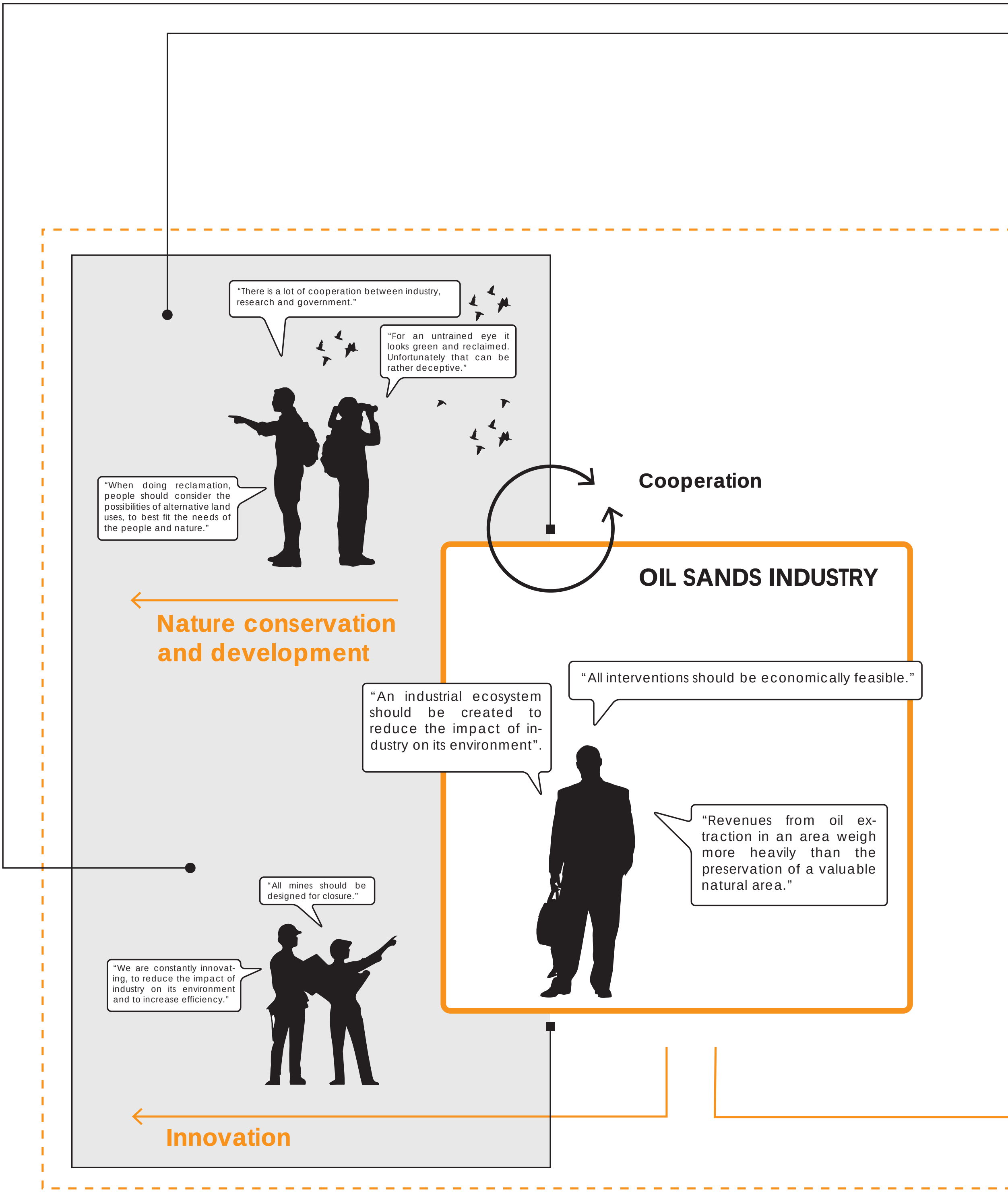
Of course, this should be seen in perspective. The oil sands industry have to take all stakeholders into account and thus all personas. Although there is a lot of cooperation between the research institutes, industry always needs to be cautious, because as the saying goes, "even your best friend can become your worst enemy." Research institutes pose a great risk for the industry, since they can bring certain negative research outcomes into the public. Industry must therefore constantly balance between the various parties. This is shown in figure 7.8 by means of the orange striped box.

Last, is the visionair. the persona with a comprehensive view and a vision for the future

Then there is one persona left, the visionair, this person has a progressive and umbrella look to the future. They use information from all the different personas as is shown by means of the arrows in figure 7.8.

They are the ones who have a vision, who want to do create a better world. Those with a smooth talk and an extensive network. They often hold high positions and therefore can trigger change, they pull strings here and there, like a large marionette player.

This roughly gives an idea of how we see the relationships between the different personas. We repeat once again, this is our idea of the current situation and the key stakeholders. We acknowledge that if we had interviewed other people, for example people from the government or more native inhabitants, our representation of the key stakeholders might have been completely different.


"There is a lot of cooperation between industry, research and government."
"For an untrained eye it looks green and reclaimed. Unfortunately that can be rather deceptive."
"When doing reclamation, people should consider the possibilities of alternative land uses, to best fit the needs of the people and nature."
Cooperation
OIL SANDS INDUSTRY
Nature conservation and development
"All interventions should be economically feasible."
"An industrial ecosystem should be created to reduce the impact of industry on its environment".
"Revenues from oil extraction in an area weigh more heavily than the preservation of a valuable natural area."
"All mines should be designed for closure."
"We are constantly innovating, to reduce the impact of industry on its environment and to increase efficiency."
Innovation

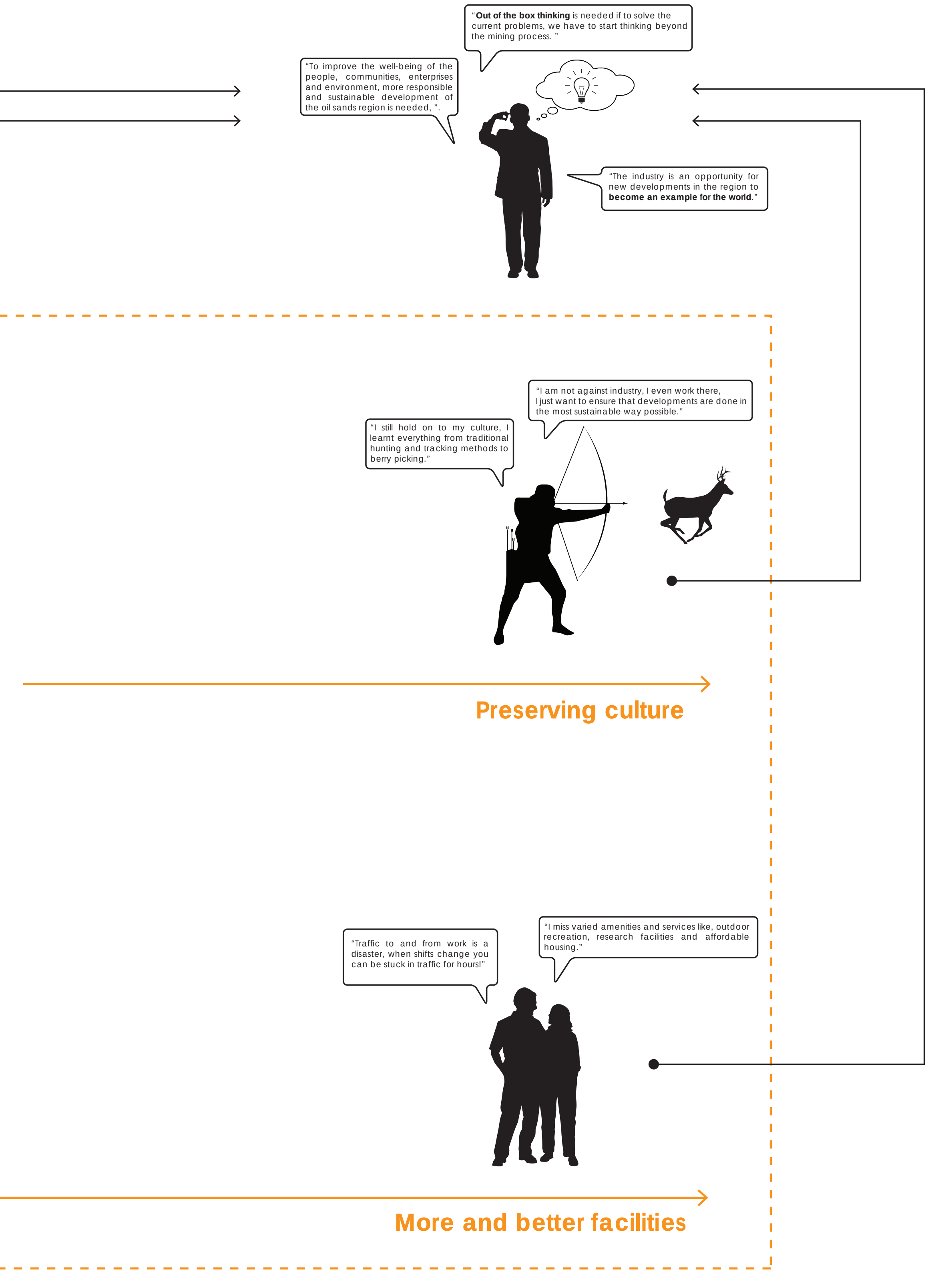


Figure 7.8: Relationships between the industry and the other personas

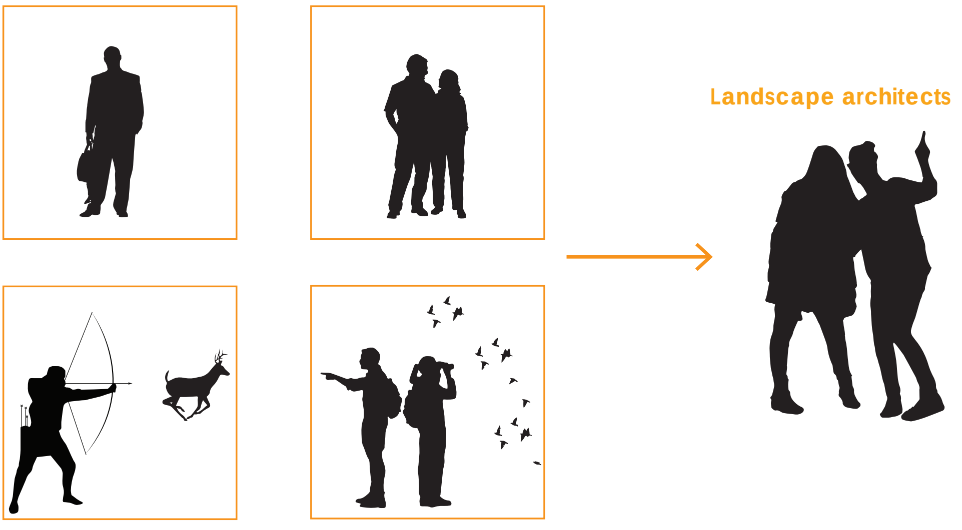


Figure 7.9: Most important personas for design

7.6 Conclusion

By means of this analysis we achieved the purpose of this chapter. As mentioned in the beginning the purpose was to know how people perceive the current developments happening in the oil sands and what they think could still improve, the question we therefore asked ourselves was as follows:

“What are the perspectives of different stakeholders regarding the developments of the oil sands industry?”

We did this by means of the personas method, each paragraph explains a step in this method. We used the personas method because there are so many different opinions and stakeholders in the oil sands industry, and since the personas method makes use of clustering a manageable design focus could be maintained.

Of course, not every piece of information in the interviews contributed to our design, however they did contribute to the characterization of the personas, which in turn gave us more insight into the various stakeholders and their perspective on developments going on in and around the oil sands industry.

There were four personas that gave us the most input for the design. This is showed in figure 7.9 and were as follows: the inhabitant of Fort McMurray and working in the industry, the scientists in ecology and environmental sciences, the Métis (aboriginal group in the area of Fort McMurray) and the employees working for an operating oil company.

We will now explain how these findings have resulted in the further delineation of our design research.

One important conclusion that can be drawn from this method was that oil companies, government and research institutes acknowledge that they need a more holistic approach to solve the problems that the industry is struggling with. The industrial processes can no longer be seen in isolation from the landscape processes. We must look at the entire system, both in terms of input, output and waste. Start using synergies in our various activities.

Another important conclusion coming from the personas contributes to a more sustainable society was reducing the pressure on the roads caused by commuter traffic. This results in a very direct design issue for us landscape architects.

Besides an insufficient road network, Fort McMurray also lacks sufficient affordable housing (Interviewee 16,2013). Differences in income are huge, when you work in the mining business you do well. However when working in retail you are struggling. Fort McMurray is an unsustainable society (Interviewee 17, 2013), not only because Fort McMurray lacks sufficient affordable housing, it's also about providing a diverse range of services and amenities (Interviewee 16, 2013).

When we talked with the people who work and live in Fort McMurray, they missed facilities such as outdoor recreation, reasonably priced restaurants, libraries and live music venues. But despite the deficiencies most of the people seem to have a positive vision for the future of Fort McMurray.

As a "northern Canadian former oil boomtown and model for major environmental reclamation projects worldwide, a metropolitan type of city" (Interviewee 16, 2013). If we once again look at all the personas, it appears that most of them are, despite their critiques, fairly confident about the success and future of Fort McMurray.

One last thing which should not be overlooked are the First Nations and aboriginal groups living in the area of Fort McMurray. They were the first inhabitants in this area and lived from hunting, fishing and gathering. One of the aboriginal groups are the Métis, the descendants of the European fur traders and first nation woman (Interviewee 8, 2013). We see the importance of preserving their culture, we therefore want to take their culture as well as an important part in history, with us in our design.

All these different findings provide us with points of departure for a design. In the next chapter the findings of the last three chapters will be bundled and translated into design challenges and design measures.

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8. Design interpretations

In the former three chapters an analysis is done on three different topics: the landscape, the workings and peoples perspective. The gathered data will first be translated in design challenges and later on into the design. This chapter explains how this process went and how the research is combined with the design process.

Design interpretations

8.1 Problems and findings

In this chapter we want to give an answer on the question: What measures can be taken in order to develop a more sustainable system?

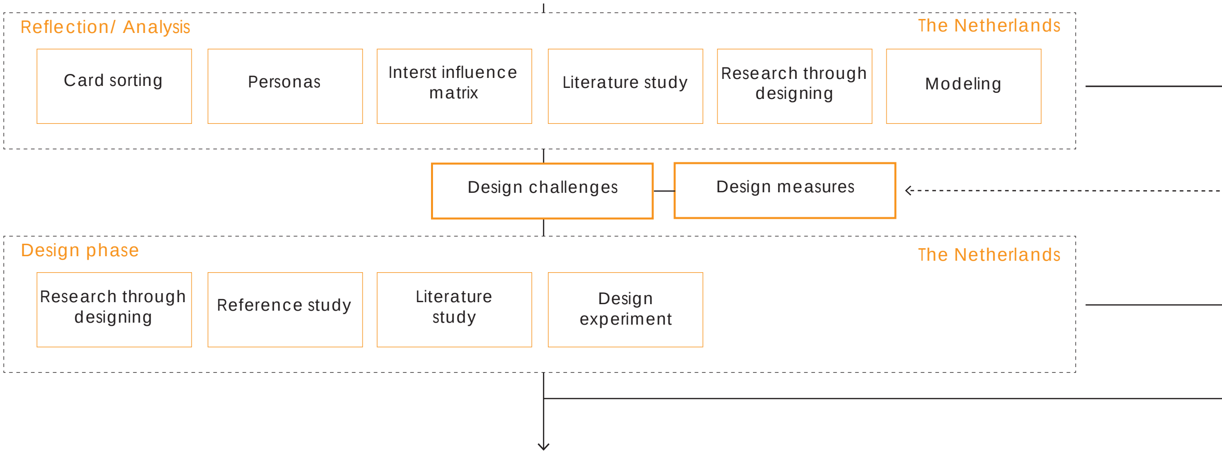
The measures will be developed on the basis of the outcomes of the three analysis parts

Within this chapter we want to answer the question:

What measures can be taken in order to develop a more sustainable landscape system?

These measures will be developed with the outcomes of the three different analysis parts. As explained these analysis parts consist of: the landscape, the workings and peoples perspective.

Within this reflection/analysis phase the generated data from the major part of our fieldtrip was processed. The purpose of these analyses was to get a better understanding of the landscape, to understand the industrial process and its effects on the landscape and to get an understanding of people's perspective and their future demands and requirements for the landscape.



With the outcomes of the analysis chapters we were able to make a translation leading towards so-called design interpretations and our design challenges. As you can see in figure 8.1 arising from the analysis phase interpretations and challenges will be formed to bridge the gap between the research and the design part. In the further sections this process will be described.

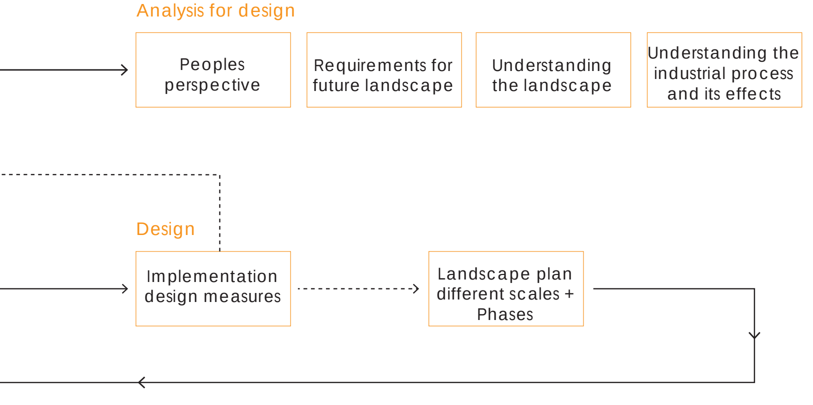
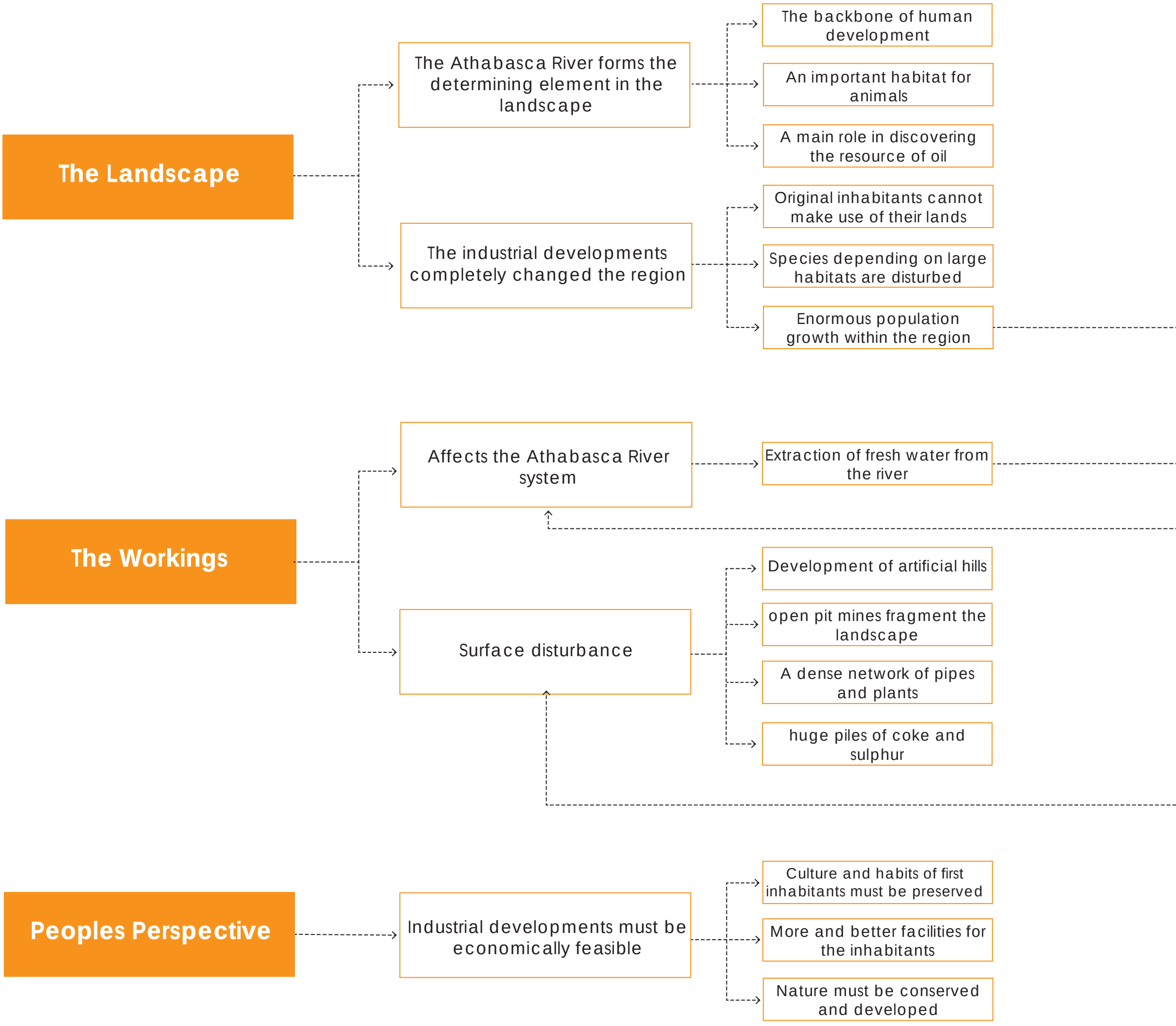


Fig 8.1; From reflection/analysis phase to design phase

The conclusions from these analysis parts consist of problems and important findings

Out of this analysis we were able to draw several conclusions, these conclusions mainly comprise of problems that occur in the area caused by the industry. In addition to that, several important conclusions could be drawn about the landscape and peoples perspective. These conclusions cannot be called problems but can better be described as important findings.

In figure 8.2 the three parts of analysis with their main conclusions are showed in a scheme. In the following sections will be described how the data from the analysis was compared to form conclusions and how the main conclusions were translated into design challenges.



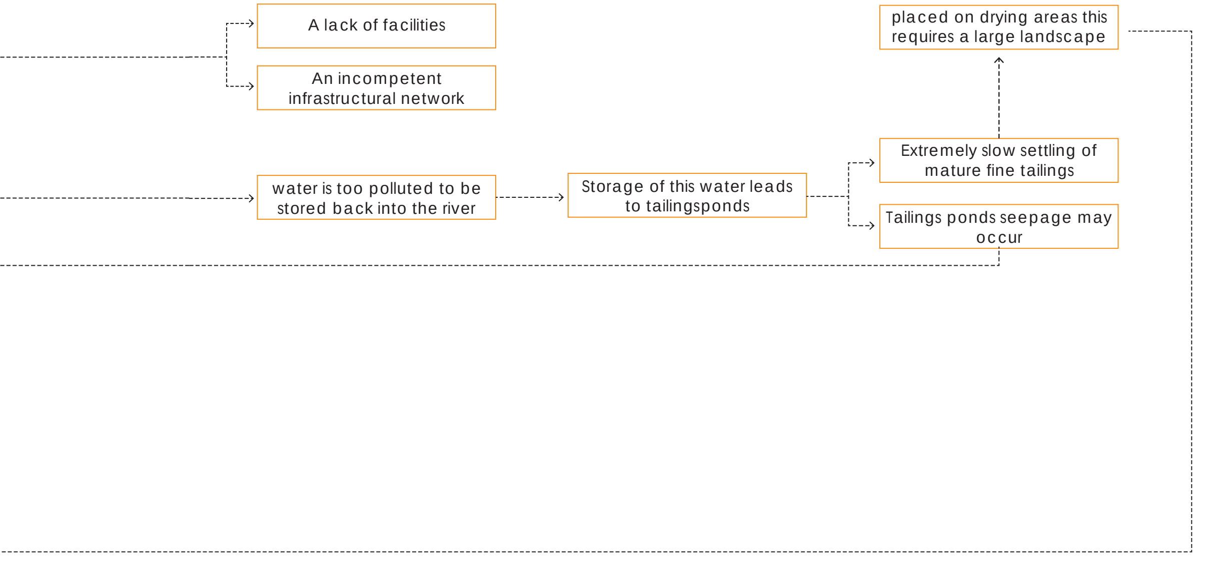


Fig 8.2: The conclusions per analysis part

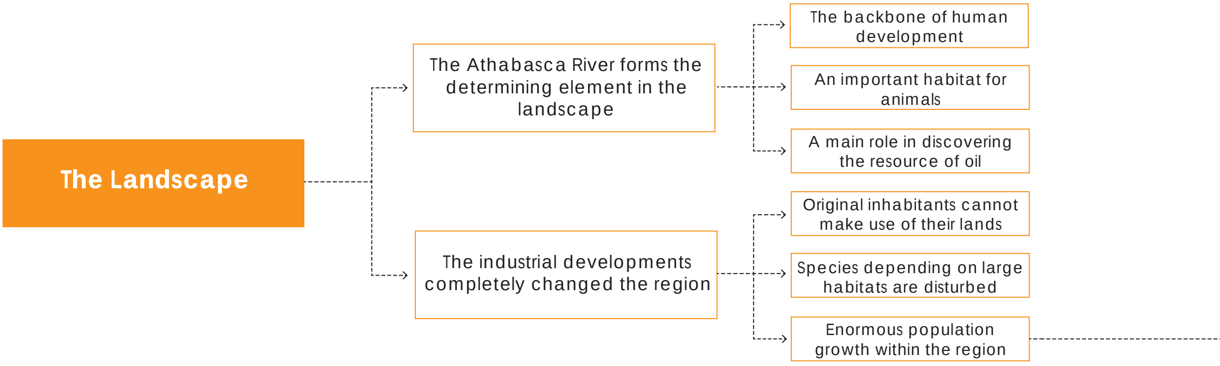
8.2 Interpretation from analysis

8.2.1 The landscape

To get grip on different landscape processes research through designing was a very important method

Within the three parts of analysis the generated data from our fieldtrip was processed. To do this several methods were used. Most of the data was generated by means of literature study, map studies and interviews. By processing these data an important method we used was research through designing. By sketching with the generated data on several maps we could get a grip on the landscape and the industrial process.

To get a better grip on the landscape we dealt with the geomorphological processes in the first part and in the second part the changes of this landscape due to the industrial processes. The generated data of both parts enabled us to draw several conclusions to continue with in the further research.



These conclusions are shown in the section of the landscape in figure 8.3. Out of the scheme you can state that the Athabasca River system is the determining element within the landscape. It formed the backbone for human and industrial development and in addition to that, an important ecosystem for animals in the region.

The Athabasca River system is the determining element whitin the landscape

When the industrial activities started to develop the region went through an enormous change. This change influenced the landscape because large areas of nature were removed which resulted in disruption of animal habitats, but also disturbed the habits of the first inhabitants who traditionally used these lands to hunt and gather.

The industrial developments completly changed the region , socially as well as environmentally

Lastly, the area went through an enormous population growth which resulted in urban expansions and simultaneously with these developments, a lack of facilities and functions.

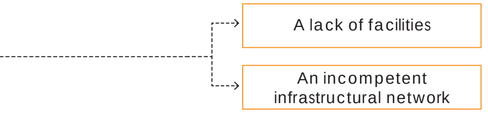


Fig 8.3: The conclusions for the landscape part

8.2.2 The workings

The interaction between the workings and the landscape made us able to address the main effects on the landscape

As mentioned before we sketched a lot to fully understand the industrial process. Within this analysis the generated knowledge of the analysis part 'the landscape' was very important. By first understanding the landscape and how this works as a system and secondly the industrial workings, we were able to understand the interaction between these two layers. This made us able to address the main effects of the industry on the landscape.

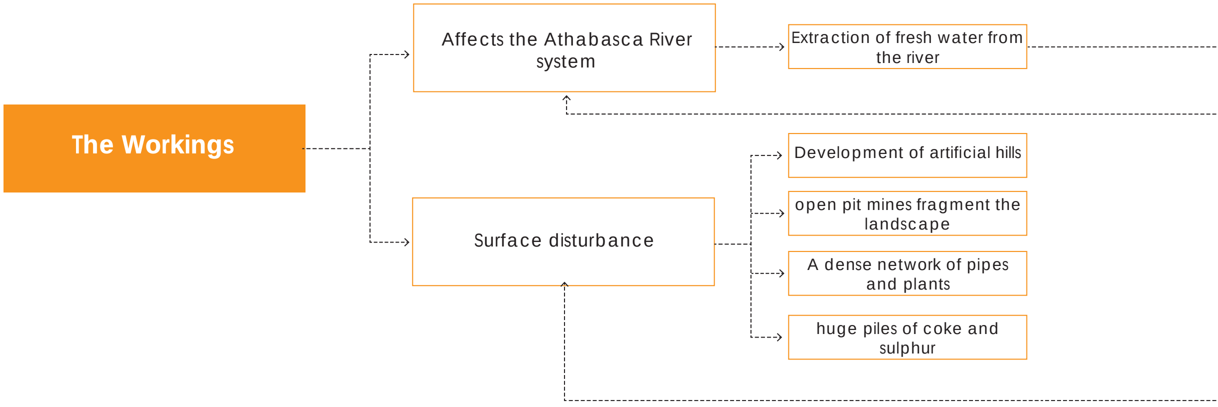
Besides surface distrubance the industry has an enormous impact on the Athabasca River system, caused by water extraction and seepage from tailings ponds

The main effects that the industry has on the landscape are showed in the workings part of the scheme (fig. 8.4). Out of this scheme can be stated that besides surface disturbance of big open pit mines, a dense network of pipelines and waste products which form several piles and hills in the landscape, the industrial workings have an enormous impact on the Athabasca River system. This is caused by the water that is extracted from the river and seepage of process affected water into the river system. Besides that an important problem is formed by the mature fine tailings which have an extremely slow settling process within the tailings ponds. Large drying areas are used to dry this material. This requires a large landscape which is disturbed again.

8.2.3 Peoples perspective

To get a grip on people's perspective about the oil sands, the personas method was an important method

To get a grip on the perspective of people about the oil sands industrial developments we interviewed people specialized on several different disciplines, but inhabitants of the region as well. Out of these interviews we learned a lot about people's ideas about the developments but



also much data was generated the get a better understanding of the industrial process. To process all this data the personas method was an important method. By creating an accountable number of personas we were able to structure the data and draw some main conclusions.

The main conclusions out of this analysis part are shown in the people's perspective part of the scheme (fig. 8.5). Out of this analysis there can be derived that the industrial developments play a key role within the region.

An important statement made in this section is that the industrial developments must be economically feasible and that all the oil must be extracted. Within the developments nowadays this constitutes the most important underlying principle.

The industrial developments play a key role within the region

Besides that many stakeholders indicated that a change is needed in these developments and that nature must be better conserved and developed. There is also a need for better and more facilities for the inhabitants within the region. This mainly refers to the inhabitants who came to the region to work here. The first inhabitants of the area require a place for their culture and habits.

However a lot of people indicated that a change is needed in the region, to better conserve and develop nature and develop more diverse functions

Since we are not able to deal with all the problems that occur in the area several choices had to be made. Research through designing formed an important method by making these choices. In the following section is explained how we used designing as a method in this process.

We however deal with several problems, since dealing with all of them would not be possible

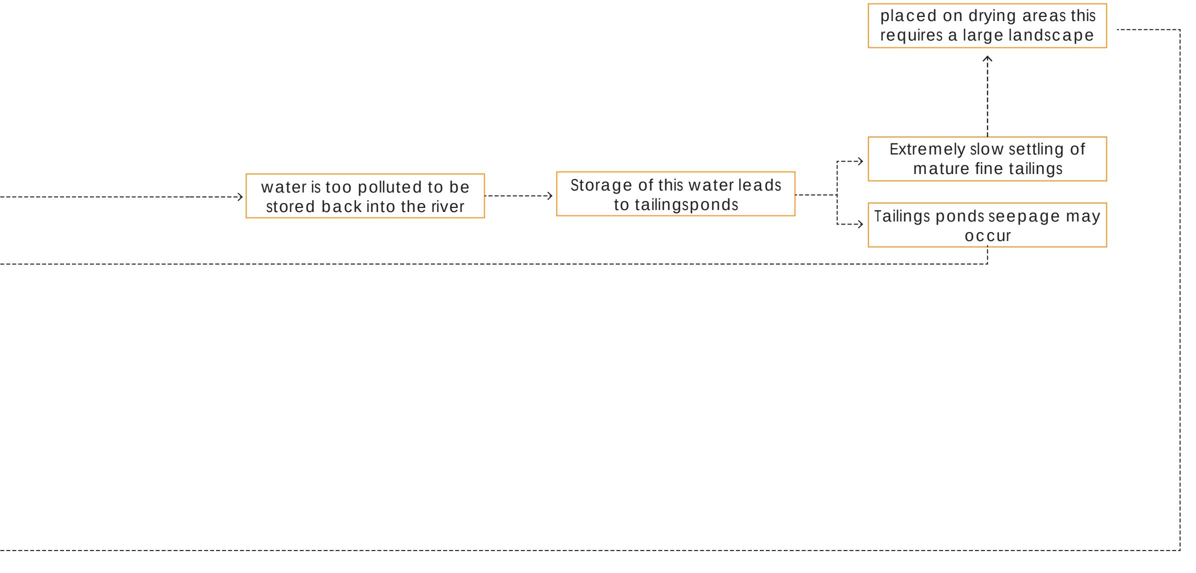


Fig 8.4; The conclusions for the workings part

Fig 8.5: The conclusions for the peoples perspective part

8.3 Designing to compare data

To compare the data and to further deliniate our research the activity of designing played an important role

The activity of design played an important role in comparing the data. By sketching with the generated data of our analysis phase we were able to get grip on certain processes and how they interlink with each other. By doing this it became easier to come to the core of the problems and address them. In the attachment the different developed sketches with an explanation, the intended purpose and the conclusion of the sketch is shown. Explaining all these sketches in detail would be too extensive, we therefore only discuss the main conclusions of the developed sketches.

Sketching played an important role to be able to address the main problems, we started more regional to subsequently zoom in

The first sketches were made on the regional scale. While sketching we came to the conclusion that it was necessary to start sketching on a more detailed scale to be able to really address the occurring problems. For that reason we started sketching on the Suncor mine,

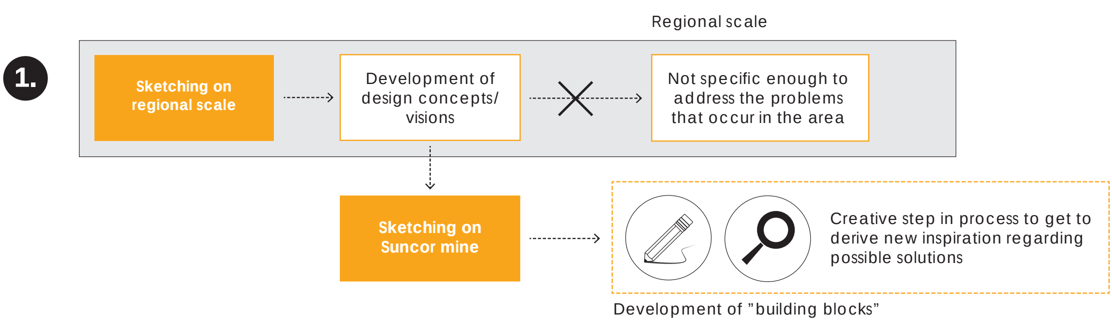


Fig 8.6: the taken steps in our sketching process

which is the same mine we analyzed in chapter 6.
Within this sketching process the formation of building blocks was an important method we used. The main purpose for using this newly developed method was to get beyond the beaten track and derive new inspiration, thus mainly a creative step in our design/sketching process.

To be able to think out of the box and make a creative step we created building blocks

How we developed these building elements and how they were used in the sketching process will be explained in the following section

8.3.1 The ingredients of the building blocks

The building blocks were formed by making combinations of the existing industrial landscape features as explained in chapter 6 and external elements which can be seen as the results of our analysis phase.

These building blocks were formed by combining the existing industrial landscape features with external elements

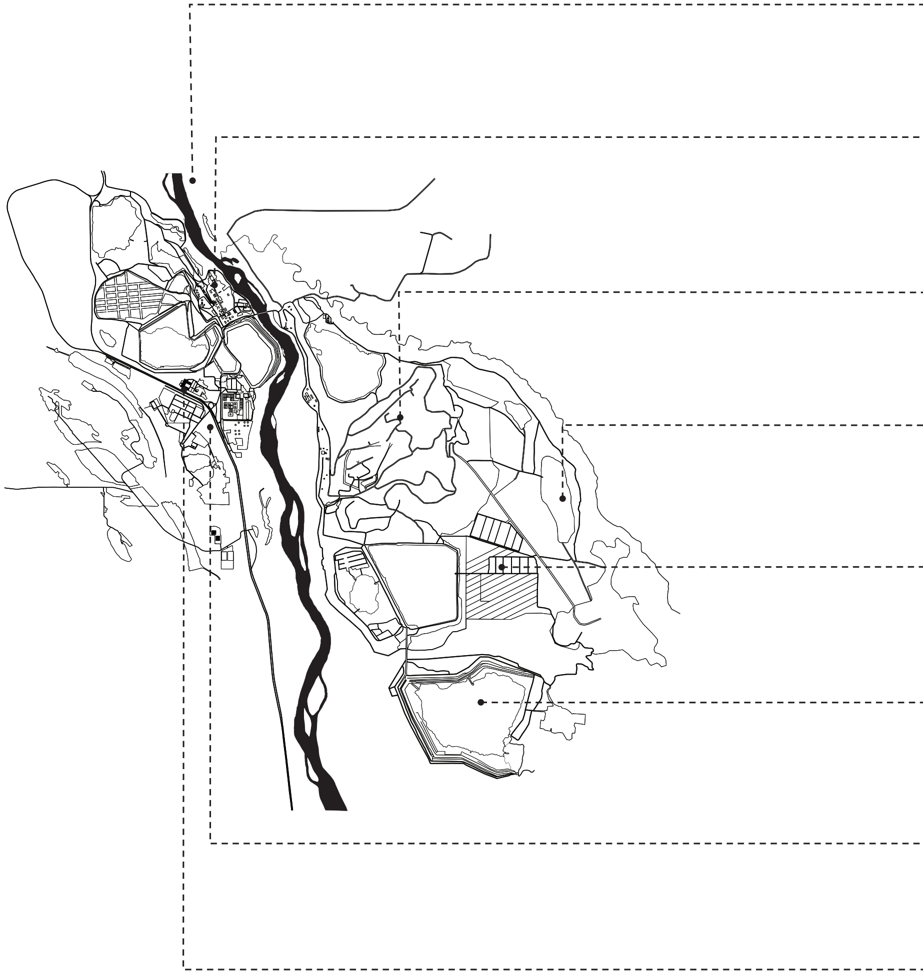
As mentioned before the oil sands industry is still in operation and will keep on developing the coming decades, it is therefore important to start thinking about a design which can be implemented from now on. For that reason it is of importance to know how to deal with the existing industrial landscape features.

The industrial landscape features were already formed while analyzing the workings

While analyzing the industrial workings of the Suncor mine as showed in chapter 6, six different landscape features could be distinguished. This analysis was mainly focused on the industrial process. In this part we focus on designing for multiple uses for the existing industrial landscape features, therefore two extra features will be added to the already named six features. These are the work-camps and the industrial infrastructure (fig. 8.7).

We however decided to add two other features: the work camps and the industrial infrastructure

These features are added because they do not play a key role in the industrial process but can definitely be important in the design process.



The external elements are based the outcomes of the diffferent analysis parts

The external elements that will be defined in this part are based on the outcomes of the three different analysis parts. Since we want to reduce the impacts of the industry on the Athabasca River system and reuse waste energy and material flows we firstly introduced the external element **waste treatment.**

the first focusses on waste treatment

The chapter people's perspective clearly showed that there is a lack of certain facilities in the region. This is translated in the external element of **socio-cultural needs**. This element includes aspects as: housing, recreation, traditional land use, infrastructure and food.

The second on the socio-cultural needs

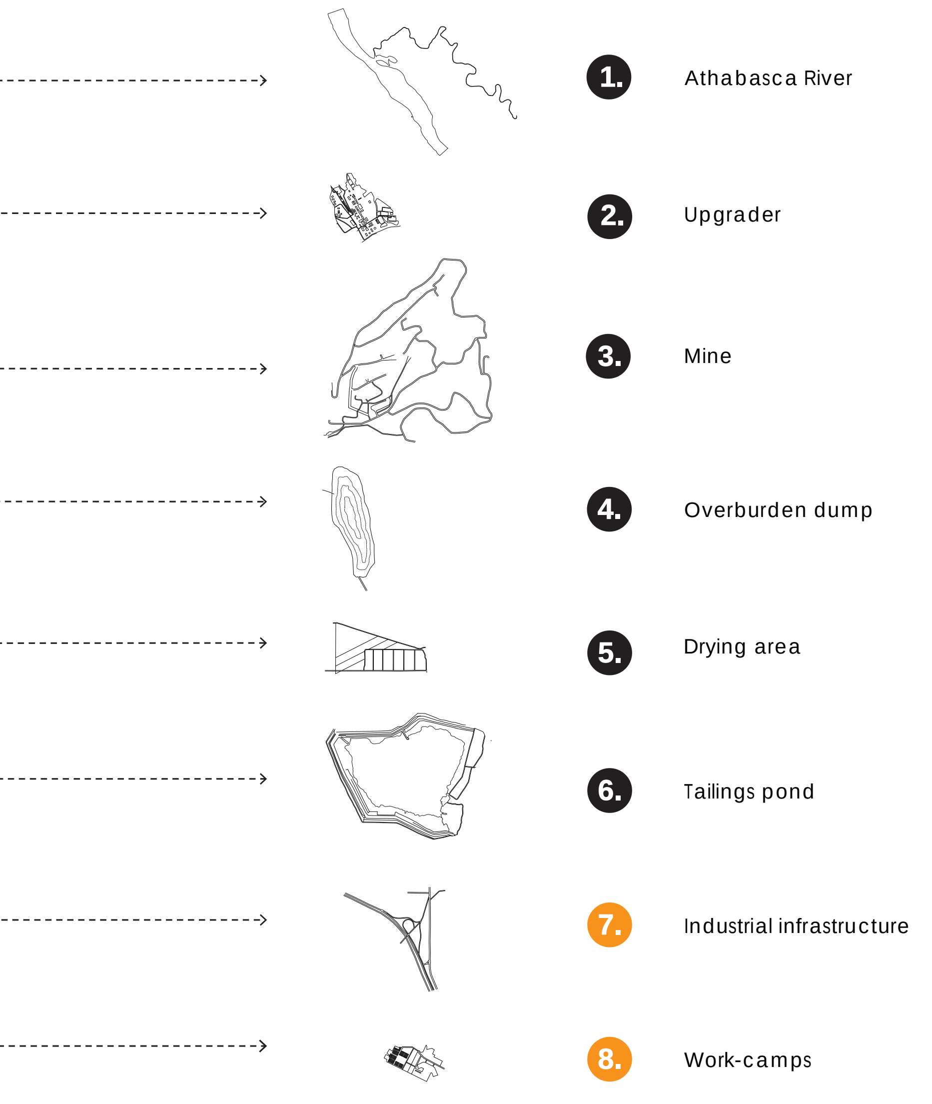


Fig 8.7: The industrial landscape features

Besides that many stakeholders indicated that a change is needed in the current developments and that nature must be better conserved and developed. This challenge is translated in the external element **nature development**. This nature can have a recreational and ecological purpose.

the third one on nature development

Besides these external elements which are coupled to the design challenges we added one other external element. This is the element **renewable energy** which includes elements as: wind power, hydro power, solar power and energy crops. Since we want to design for a more sustainable landscape system for the Athabasca oil sand region making use of renewable energy may be a key factor within this design.

Besides that one other element is introduced, this is renewable energy

8.3.2 The formation of building blocks

To form building blocks a combination of the existing landscape features and the external elements is made. For this reason we put them both in a matrix, with the landscape features on the Y axis and the external elements on the X axis.
Within this matrix every possible combination of an industrial landscape feature together with an external element can be made. The combination of an industrial landscape feature and an external element can be translated in a certain building element.

To which building element, the combination will result is entirely subjective. We as landscape architects made this translation with the generated knowledge gained by doing this thesis and with our landscape architectural point of view, it is likely another person would have made other translations. The matrix is showed in figure 8.8. These are the building blocks we started the sketch process with. To get a clear overview of the above mentioned process about the formation of the building blocks a scheme is made. This is showed in figure 8.9.

	Wind power	**Hydro power**	**Solar power**	**Energy crops**	**Food**
Tailings pond	Windmills on tailings dike	Hydropower by flows or gravity	Solar panels on top	Algae farm	Saline cultivation
Mines	Windmills on pit crest	Hydropower by flows or gravity	Solar panel on mine ridges	Energy crop plantation	Glasshouses on pit crest
Overburden dump	Windmill park on hill	Hydropower by flows or gravity	Solar panel field on top of dump	Energy forest	Glasshouses on dump
Upgrader	Windmill park	Hydropower by flows or gravity	Solar panels on buildings	Energy crops borders	Reuse buildings for food production
Industrial infrastructure	Windmills along roads	Hydropower network	Smart road	Lane of energy crops along roads	Food transport
Drying area	Windmills on highest points	Hydropower by flows or gravity	Solar panel field	Energy forest	Glasshouses
Work camps	windmill park	Hydropower by flows or gravity	Solar panels on top of buildings	Energy forest	Glasshouses
River system	Windmills on islands	Hydropower by flows or gravity	Solar panels on islands	River valley energy crops plantation	Fish farm
Residual space	Windmills park	Hydropower by flows or gravity	Solar panel field	Energy crop plantation	Glasshouses

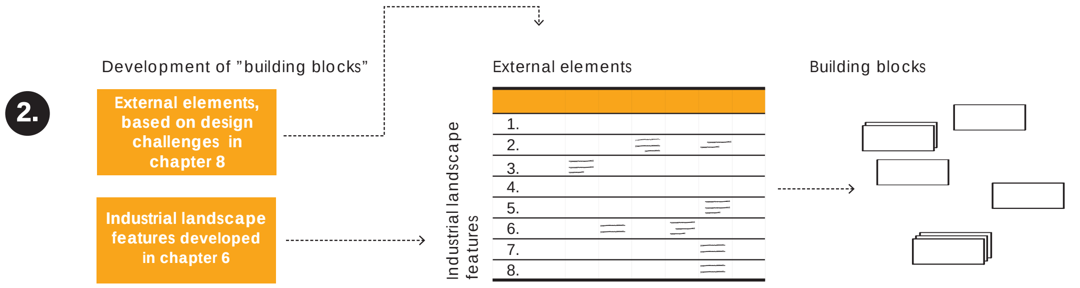


Fig 8.9: An overview of the formation of the building blocks

Fig 8.8: The matrix of the building blocks

Housing	Recreation	Traditional Land use	Infrastructure	Waste treatment	Nature
Floating houses	Educational route	Fish farm	Board walk	Water treatment facility	Lake district
Housing on mine ridges	Sports cluster	Trapping zone	High transport network	Phytoremedia-tion	Artificial wetland
Hilltop housing	Ski slope	View point	Cable way to intersting point	Capping of tailings with overburden	Upland forest
Reuse of buildings for housing	Entertainment park	Trading post	High transport network	Reuse of sulpher	Industrial park
Casco for housing development	Recreational routes	Trap lines	High transport network	Transport of waste	Nature trails
Hillside housing	Toboggan slope	Berry garden	Raw material for infrastructure	Reclaimed hill	Forest
New work camps	Hotel	Bring back Metis cabins	High transport network	Household waste gasifier	Greening the camp
Floating houses	River trails	Natural fishing areas	Transport by boat	Water treatment facility	Riparian area
Residential cluster	Thermal baths	Trap lines	Parkway	Waste treatment park	Forest

By sketching with these bulding blocks we were able to come up with ideas we would rather not think about,.

8.3.3 *Sketching with building blocks*

By creating these building elements it gave us the ability to come up with ideas applied to the industrial landscape features where we would rather not think about. This means it was mainly a method to inspire and to come up with new ideas for the design sketching process. In the attachment several sketches are showed.

It also helped in our process to get grip on the data and the occuring problems

Besides that it helped us to get grip on the situation and the problems occurring in the area. Mainly the Athabasca River system played an important role and the developed sketches were mainly focused on strengthening this system. In addition to that, the tailings ponds also formed an industrial landscape feature which often came back in our sketch sessions. When reflecting on these ponds and the way they affect the landscape, it can be stated that they form the key factor in affecting the Athabasca River system.

Knowledge of the interacting systems is necessary to design for sustainability

From here there can be concluded that knowledge about the different systems as the landscape, the industrial workings and people's perspectives is important while designing, since they are all interlinked with each other. This means the outcomes of the different analysis parts all play a role in our design towards a sustainable landscape system. In the following section an explanation will be given on what kind of role the several analysis parts will have in the further process and how this data can be compared.

8.4 How to compare the data

Within this section the data will be compared

Within this section the data will be compared. Out of the former section the conclusions from the different analysis parts were showed, besides that several sketches where made based on these conclusions. In the time available for this thesis it is impossible to focus on all these conclusions within the design phase. This means rephrasing the focus is necessary.

The problems that occur in the area are all related to the industrial workings

First a balance needs to be found between the several analysis parts. The problems that occur in the area are related to the industrial workings. The first part was mainly about understanding the landscape. Because prior to understanding the landscape and how the landscape is affected by something you have to know how the landscape is composed. This means the landscape analysis forms a very important basis set of data for the further research.

The landscape and the workings form an important basic data set to understand the system and make a design for it

Another basis set we needed was getting an understanding of the industrial workings. By understanding the landscape and the industrial workings and linking these two systems together, the effects of the industry on the landscape could be distinguished. This makes the analysis part about the workings and its conclusion very important in this research.

Future requirements of stakeholders form an important input for the design as well

Since a landscape analysis is built on the interaction between human and nature the third part, the people's perspective, forms a very important part for this research. By talking with all these

different people it revealed that the oil sands industry is a polluting and disruptive activity but people in the region are economically dependent on this industry. Another important focus point for our research are the requirements and needs that the inhabitants have for this area.
In figure 8.10 you can see the three different analysis components and their outcomes, how they are related to each other and what will form the input for the design challenges.

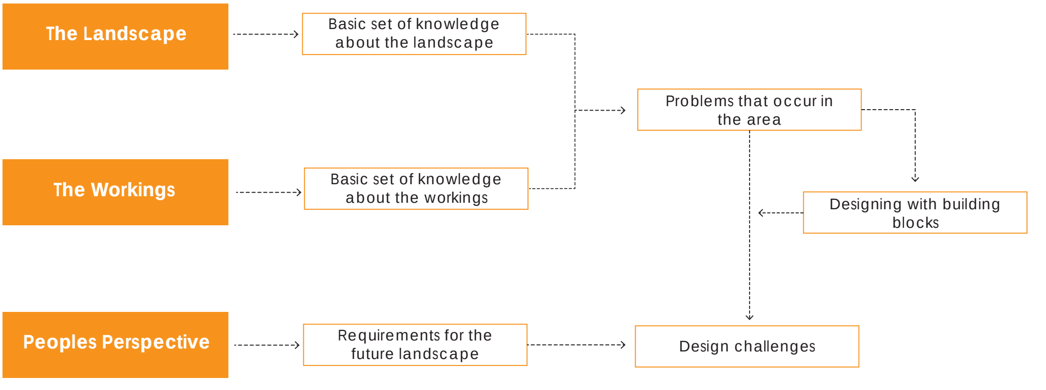


Fig 8.10: Scheme of the three analysis parts and their relation to design challenges

8.5 Design challenges

Within this section the design challenges will be formed. Out of the former section revealed that the industrial workings cause the problems which occur in the area. This means that this part weighs heavily within this further research. Besides that, certain requirements and demands that several interviewees mentioned for the future oil sands industrial landscape form an important input for the design process.

The problems caused by industry and the requirements and needs of people form an important input for the design challenges

While looking at the conclusions of the workings there can be concluded that many problems in the area are water related. This means the industrial water system forms a main issue. Water is extracted from the river system, when used in the process it is too polluted to be returned back. This means it is stored in big tailings ponds, which again affects the river system due to seepage. Since our analysis on the landscape revealed that this river system is the determining element in the landscape for several reasons.

We as landscape architects feel the need to protect this river system. For that reason the first design challenges is:

'Reduce the impacts of the industry on the Athabasca River system (seepage of process affected water, extraction of fresh water)'

First challenge: Reduce the impacts of the industry on the Athabasca River system

Second challenge: Reuse waste energy and material flows

Another main problem which reflects back on the industrial water system is the extremely slow settling of the mature fine tailings. These are now exposed on the drying areas, which require a large landscape. This problem forms the second challenge for our design:

'Reuse waste energy and material flows (with a focus on the MFT)'

Third challenge: Create a robust infrastructural and recreational network

Fourth challenge: Provide extra housing and leisure facilities

As mentioned before the requirements of people for the future landscape weigh heavily within this research. Out of both the landscape analysis part and peoples perspective revealed that there is lack of facilities and an incompetent infrastructural network. The following two design challenges will be linked to these requirements. These are:

'Create a robust infrastructural and recreational network'

'Provide extra housing and leisure facilities'

Fifth challenge: The disturbed land should be returned into a high quality landscape for people and the environment

The last design challenge is linked to the surface disturbance the industry causes. The surface disturbance is caused by many industrial features as the open pit mines, the network of roads and pipes, the industrial plants, the tailings ponds and the drying areas. It is a problem which clearly affects nature, animals but people as well. This means it forms an important challenge to do deal with in our design and is formulated as:

'The disturbed land should be returned into a high quality landscape for people and the environment'

To meet these challenges several measures need to be taken

These five design challenges explained in this section will form the basis for our design. To meet these challenges several measures need to be taken. These measures will be explained in the following section.

8.6 What to focus on in the design process?

The first one deals with the Athabascar river system

After reflecting back on our design challenges and the ideas we already sketched with. There can be said that there are four measures which need to be taken in the design process. The first one is the Athabasca River system. Since the analysis on the landscape explained that this is the determining element in the landscape we feel the need to protect this river and make it more visible in the landscape.

The second one has to deal with the industrial water system

The second one has a direct relation with this element, this is the industrial water system. The industrial water system has great influences on the river system. This means a design which reduces the impacts on this system is necessary. The tailings ponds will play a role in this design.

The third one focusses on a robust recreational network

The third one is the recreational network and affordable housing facilities which forms an important requirement from the inhabitants. This will be done on the mine scale as the regional scale as well.

The last measure deals with the surface disturbance. This is caused to a large extent by the big open pit mines. A design solution needs to be developed on how to deal with this disturbance and create a high quality landscape for people and nature.

And the last one deals with the disturbed land

8.7 Conclusion

In this chapter we tried to close the gap between data and design. This was a very difficult process because a lot of data first needed to be generated and processed in the several analysis parts. Especially when dealing with these kind of developments, a lot of data remains hidden or confidential. Within these analysis parts the method research through designing and the personas method played a very important role to process the data, order the data and make decisions.

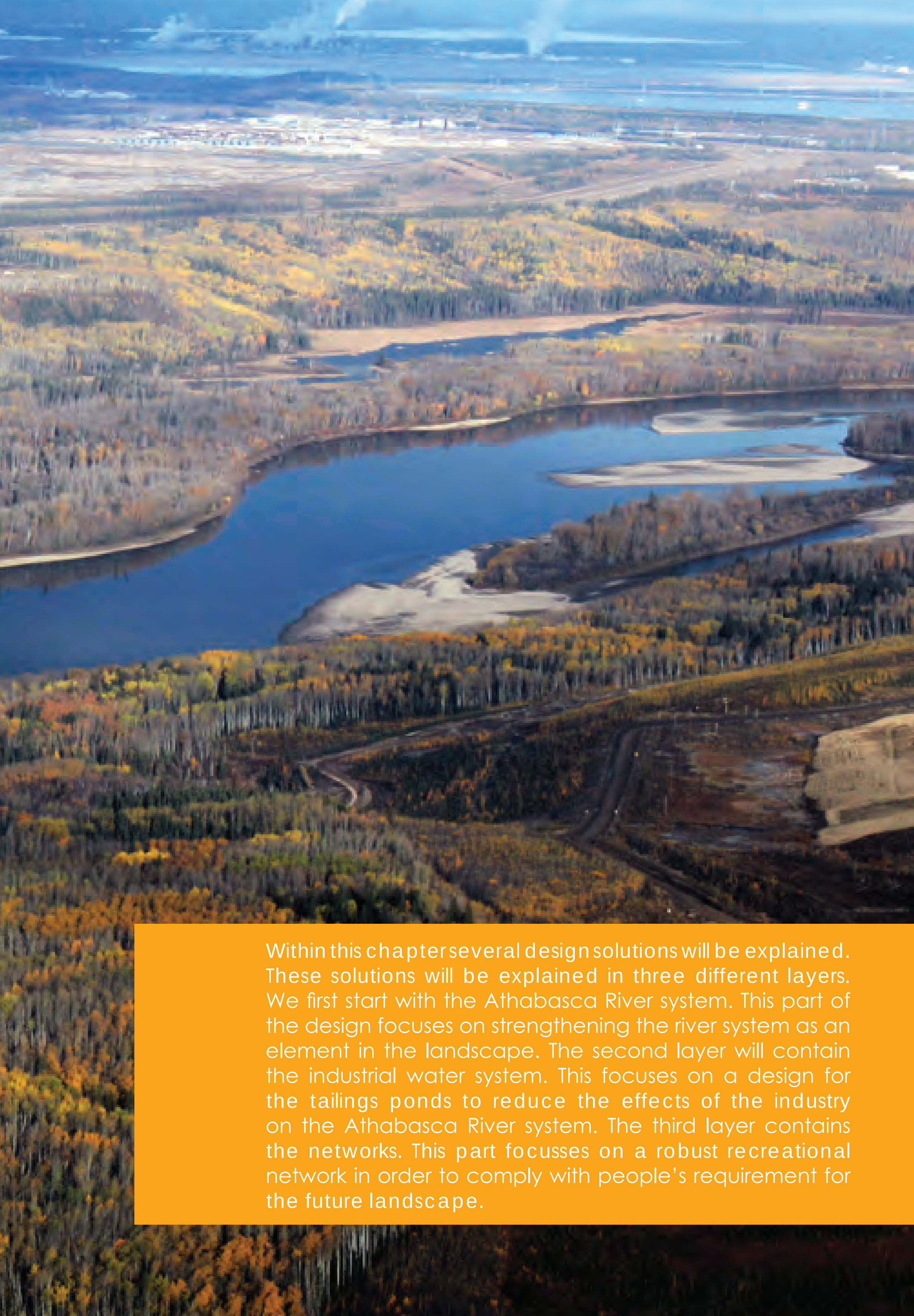
The conclusions formed within these analysis parts were compared and translated into design challenges. The first two challenges are linked to the industrial water system which forms the biggest polluter of the Athabasca River system. The following two are focused on the requirements people have for the future landscape. The last challenge is linked to the other big effect the industrial process has on the environment.

The conclusion can be made that the outcomes of the workings and peoples perspective are predominantly translated into design challenges. As explained before the knowledge generated from the landscape analysis part formed and important basis set to form these challenges but are not directly related to the challenges. To meet these challenges four measures where formed. These measures link to:

- The Athabasca River
- The industrial water system
- The recreational network
- The disturbed land

The following chapter will go into these measures more detailed and after that there will be explained how these measures can be implemented in the landscape by several design solutions.

9. The design



Within this chapter several design solutions will be explained. These solutions will be explained in three different layers. We first start with the Athabasca River system. This part of the design focuses on strengthening the river system as an element in the landscape. The second layer will contain the industrial water system. This focuses on a design for the tailings ponds to reduce the effects of the industry on the Athabasca River system. The third layer contains the networks. This part focusses on a robust recreational network in order to comply with people's requirement for the future landscape.

The design

9.1 The design process

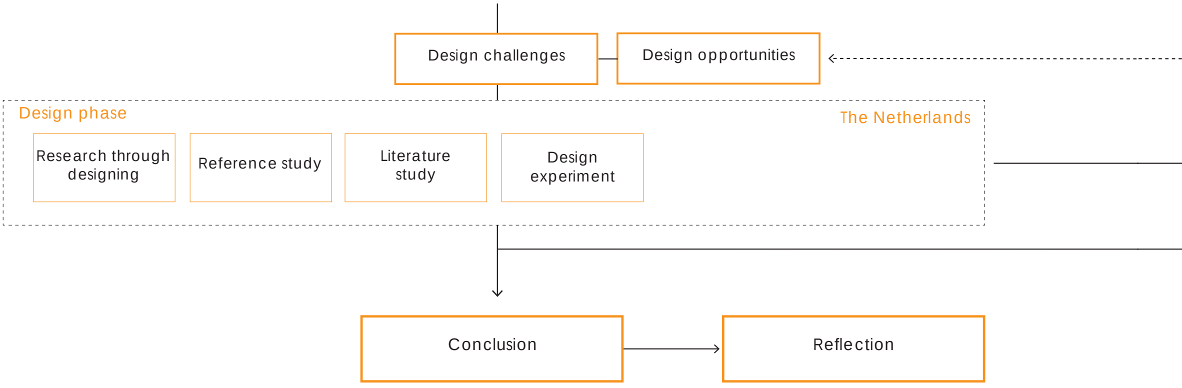
9.1.1 The gap between research and design

The purpose of this chapter is to come up with design solutions for a more sustainable landscape system

In the former chapter we tried to bridge the gap between research and design. Within this chapter we reached the last part of this process 'the design'. The purpose is to finally come up with a design for a more sustainable landscape system for the Athabasca oil sands region. Important to mention is that this design is one of the many solutions. In addition, the design will not be a blueprint, it will develop in different phases and grow in time. In the end this design tries to link people nature and industry, to finally bridge the contrast and find a balance between the industrial developments and the environment.

To finally bridge the contrasts between industry, people and nature

To bridge these contrasts, we first did a thorough analysis on the landscape, the workings and people's perspective, this is showed in chapter 5, 6 and 7. The results of these chapters were used as input for sketching, which led to a further delineation of our research and eventually led towards the formulation of design challenges and measures for our design, this was all done in chapter 8. With the measures we mean the topics where our design solutions focuses on.



The formulated measures are as follows:

- The Athabasca River
- The industrial water system
- The recreational network
- The disturbed land

In the design we focus on four topics, which we call measures

This part of our research is showed in figure 9.1 as you can see the design challenges served as the input for the design process. This design process is a circular process which constantly reflects back to the design challenges.

First the Athabasca River

Within this chapter we start to design with the four measures as mentioned before. The first measure, the Athabasca River, will focus on protecting and enhancing the river landscape.

Secondly the industrial water system

The second measure, the industrial water system, is closely related to this because our purpose in the end focuses on reducing the impact of industrial processes on the Athabasca River system by developing a design for the tailings ponds and its system. These two points are strongly linked to the landscape and the industrial workings.

Third the recreational network

The third measure, the recreational network, focuses on people's perspective and their future requirements for the landscape. A robust recreational network will be developed. This will be a high quality network for people and nature.

And the last: dealing with the disturbed land

To create this network an attractive and diverse landscape is necessary. This automatically brings us to our fourth measure, if we want to achieve a high quality landscape for people and several animal species, we need to deal with the disturbed land in this industrial landscape as well. These four measures need to be taken to be able to design for a more sustainable landscape system for the oil sands region.

This chapter will finally give an answer to the sub-question:
How can these measures be implemented in order to achieve a more sustainable system?

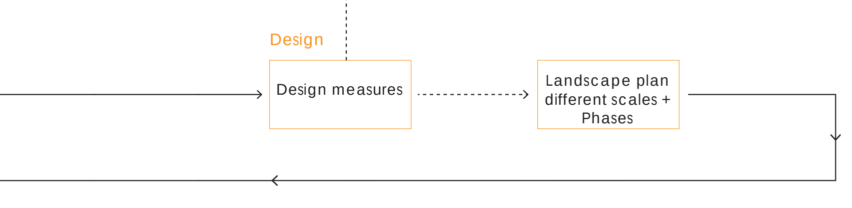


Fig 9.1: scheme of the design process

In the following section the different design layers will be explained. These solutions are again linked to these measures.

9.1.2 The design layers

The design will be explained in three different layers

This chapter explains the different developed design solutions and how these solutions are subsequently implemented into the landscape. Within these solutions we tried several possibilities. This was a process of sketching, doing research, and sketching again to finally come to the best suitable solution. The design solutions we developedbwill be explained in three different layers: the Athabasca river, the industrial water system, and the recreational network.

These layers interact with each other and are part of the same system

Important to mention is that these layers are pulled apart and explained separately to get a better understanding of the interventions, they of course are all in interaction with each other and part of the same system.

The first layer is the Athabasca River system

First we will start with the Athabasca River. This focuses on the river as a landscape defining and shaping element, and how to make the river system more visible in the landscape.

The second layer is the Industrial water system

Then we continue to the second layer, the industrial water system. This layer is focused on interventions to reduce the industrial impacts on the Athabasca River system. These interventions mainly contain a water treatment design for the tailings ponds to improve the water quality. Besides that a new way of dealing with the mature fine tailings will be introduced which results in a decrease of surface disturbance.

The last layer is the recreational network

The last layer contains the recreational network, which focuses on a robust recreational network. This network will consist of several routes which can be used by multiple users. Besides creating a high quality landscape for people, we also developed a high quality network for several animals species. If we want to achieve this, a transformation of the disturbed land (caused by the oil sands industrial operations) will be necessary.

In figure 9.2 the different layers in which we will explain our design solutions are showed. In the next part the different layers will be explained, starting with the Athabasca River.

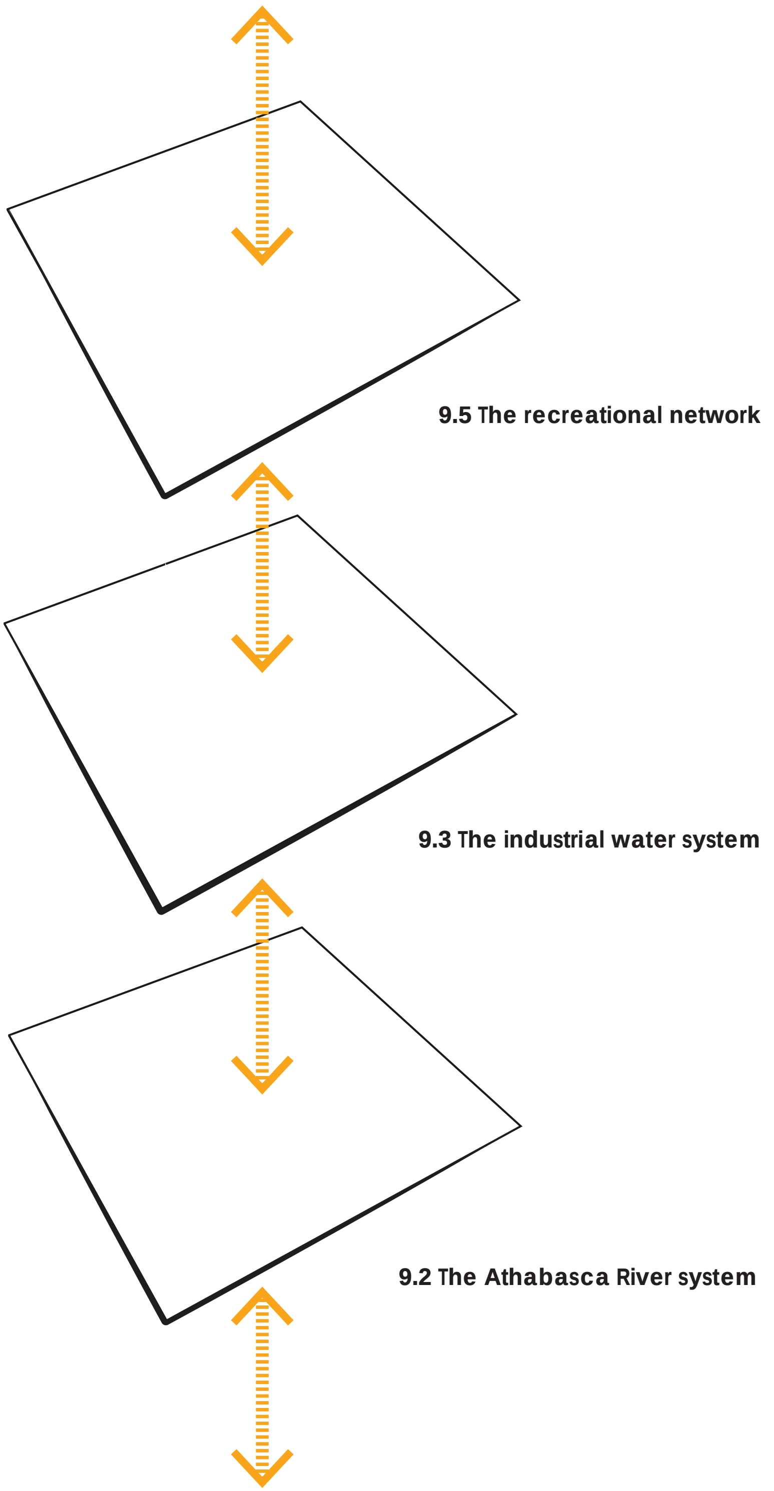


Fig 9.2: The design layers

9.2 The Athabasca River

9.2.1 The river and its tributaries

As mentioned in the analysis part on the landscape in chapter 5 the Athabasca River forms an essential ecosystem for plants, animals and people, as shown in fig. 9.3. It also served and still serves as the backbone of human development in the region. The first nations used the river as a major transport route during the fur trade, and nowadays the river plays an important role in the oil sands industry. Due to the strength of the flowing water, the Athabasca River cut into the landscape. Resulting in a landscape of lower valleys, in these lower river valley the oil came for the first time at the surface and was then discovered by the first nations. (Government of Alberta, 2014).

The Athabasca River can be seen as the backbone for the whole Athabasca landscape system

We therefore see the Athabasca river, as just mentioned, as the backbone of not only human development but the whole Athabasca landscape. Because of the river the oil came here in the first place, and due to this river first nations came to live in this area and discovered the oil. Up to today, oil sands industrial operations can still continue, because of the presence of fresh water coming from the Athabasca river.

Fig 9.3: Photo of The Athabasca River

Everyone is closely connected to source, since many people nowadays work in the oil sands industry, however to our opinion as landscape architects the river is not visible enough in the landscape.

Metaphorically speaking: the river functions as artery supplying the oil sands industry (the beating heart of the region) of blood. By strengthening this landscape element we want to emphasize the human and ecological significance of this river system (Government of Alberta, 2014).

We want to emphasize the human and ecological significance of the river system

The first step to do this is by strengthening the riparian area along the river system (fig. 9.4). Industrial developments are excluded in this area. However exclusion in this case, doesn't necessarily means separation. In this case it re-connects the river system with the industrial system.

The first step in this is by strengthening the riparian area along the river

The second step we take is bringing back the rivers tributaries (fig. 9.4). Several of these still exist, others are disturbed by the industry. By bringing back these tributaries a symbiotic relationship between industry and nature is further strengthened. Bringing back the tributaries is therefore beneficial for several animal species that can use these tributaries as migration routes, from the higher parts of the landscape to the lower Athabasca river valley.

The second step is bringing back the rivers tributaries

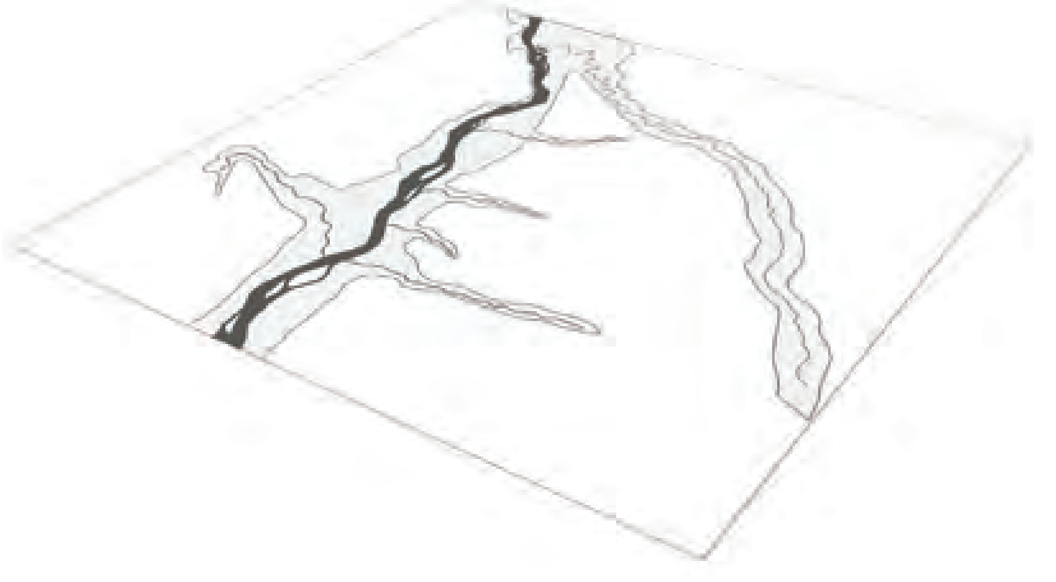


Fig 9.4: Strengthening the Athabasca river and its tributaries

Besides that, we also want to protect the existing forest

Besides protecting the Athabasca river valley and its tributaries we also want to protect the existing forest (fig. 9.5). We propose this because in the case of the Suncor mine the existing forests are in particular, located at the edges of the mine, this thus forms a natural transition zone between nature and industry. Future industrial developments should to our opinion therefore be excluded from this area to reduce any possible impact from industry on the river system.

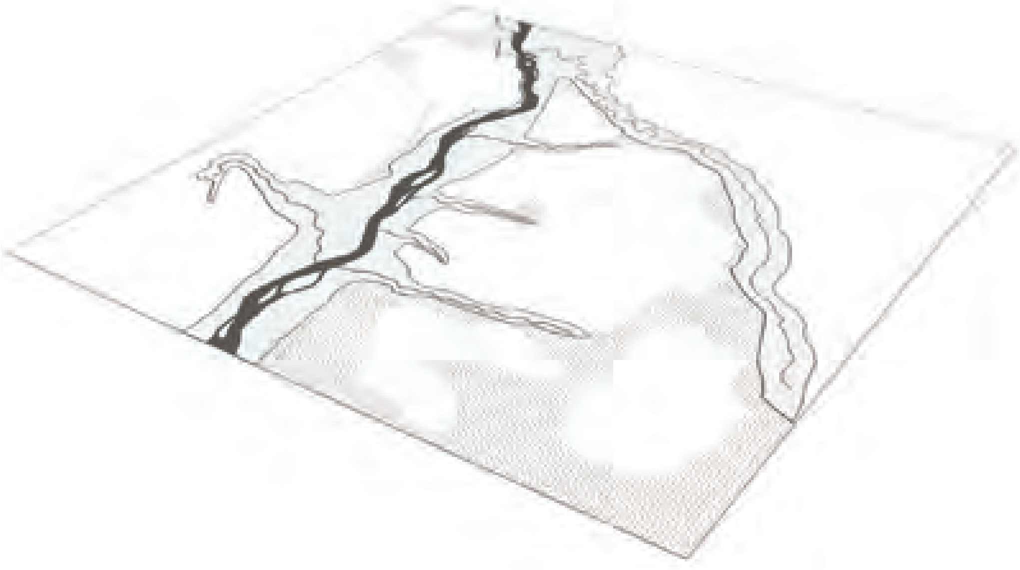


Fig 9.5: Protecting the existing forest

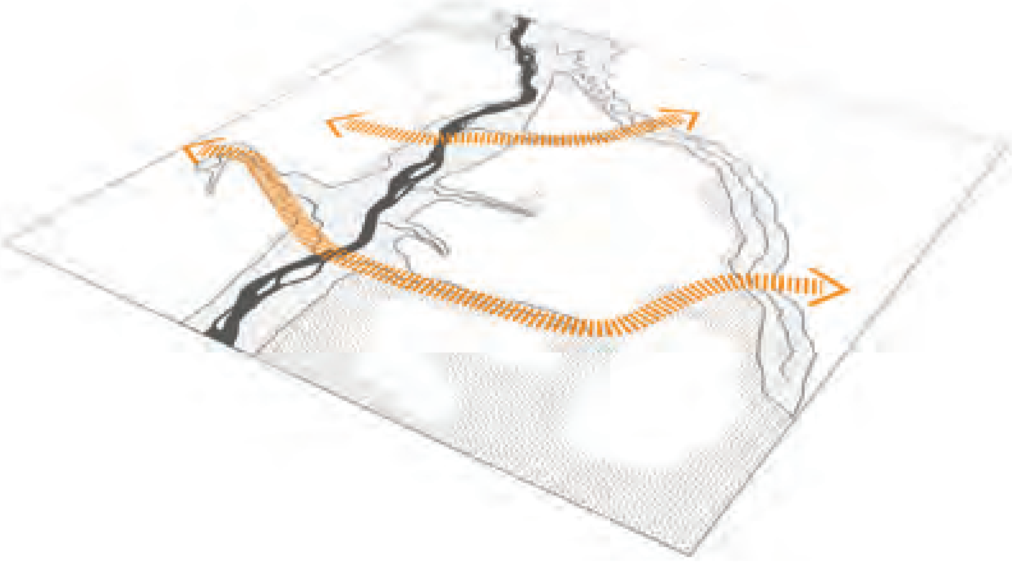


Fig 9.6: Possible corridors

We proposed the following interventions:

- Strengthen and re-establish the Athabasca river as the backbone and artery of the Athabasca oil sands region;
- Bringing back the tributaries to further strengthen the symbiotic relationship between industry and nature;
- Protecting the existing forest which serves as a natural transition zone and thus develops a clear framework for future developments.

Within this framework several corridors can be made which utilizes the tributaries and the leftover/ unused space between the industrial developments (fig. 9.6). This results in the further embedding of the mine with the surrounding landscape, makes boundaries between nature and industry less harsh and reduces disturbance to animals.

By doing this several corridors can be made already

This means a stable corridor can already be developed during operations for several purposes like recreation, migration routes and habitat for several animal species.

This space can be used for several purposes as recreation and migration routes for animals

9.2.2 Highway 63

Highway 63 is the only road which connects the urban service area of Fort McMurray with the oil sands industry (fig. 9.7). This road which is located along the Athabasca River can form an element to make the river more visible in the landscape for the inhabitants, since this is a drive they make every single day (fig. 9.8). This can be done by creating an open view towards the river side, but since the river is still quite far situated from the road this intervention does not have the desired impact.

Highway 63 is located along the Athabasca River

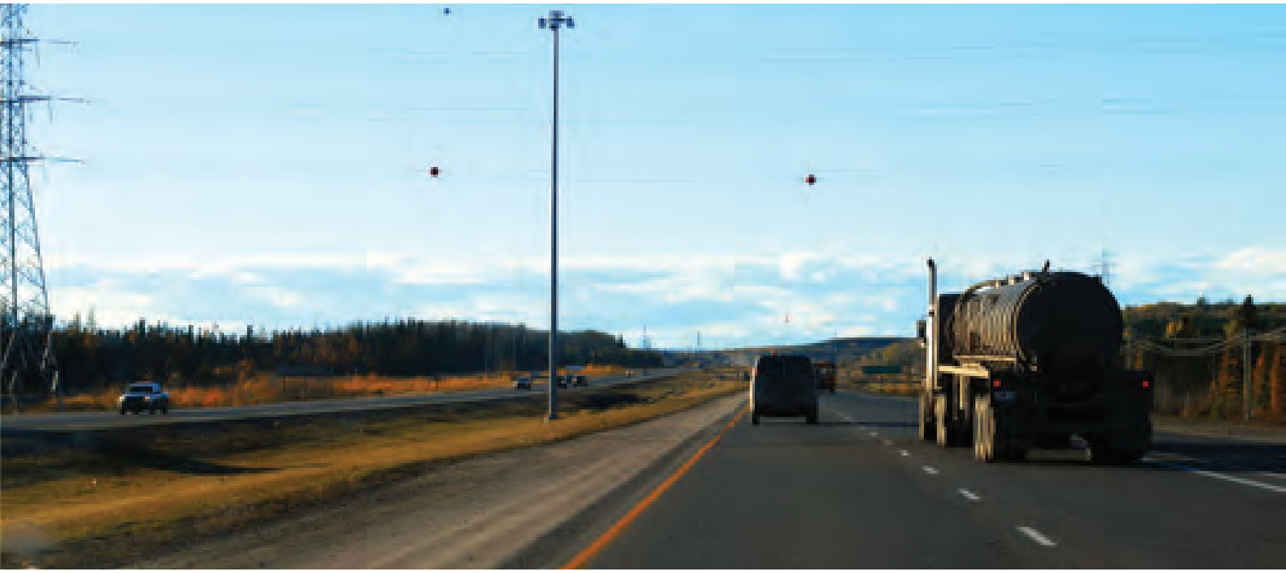


Fig 9.7: Photo of highway 63

We want to enhance the connection of the highway and the river by making a by-pass

For that reason a by-pass is created along the river. This new road is very closely located to the river and with the industrial activities at the other side. Besides that it gives people the opportunity to take a detour and experience the river during their journey to work, it also takes away some pressure on the current highway 63 (fig. 9.9).

This also takes away some pressure on highway 63

In the current situation the pressure on this highway is enormous. The road did not move along with the rapid transformation of the industrial region, which now results in everyday traffic jams. This means this network needs to be improved. Since we do not want to disturb more of the landscape that is already been done, the intervention focusses on different forms of transport which can take place on multiple lanes. This may include a tram lane and several bus lanes to spread the pressure. In figure 9.10 several options of how highway 63 can be developed are given.

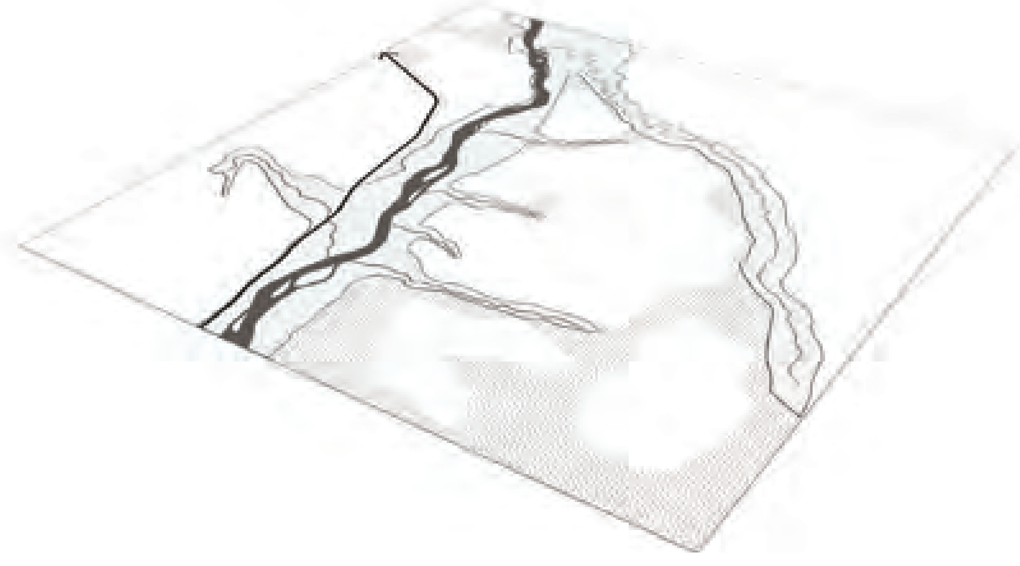


Fig 9.8: Highway 63

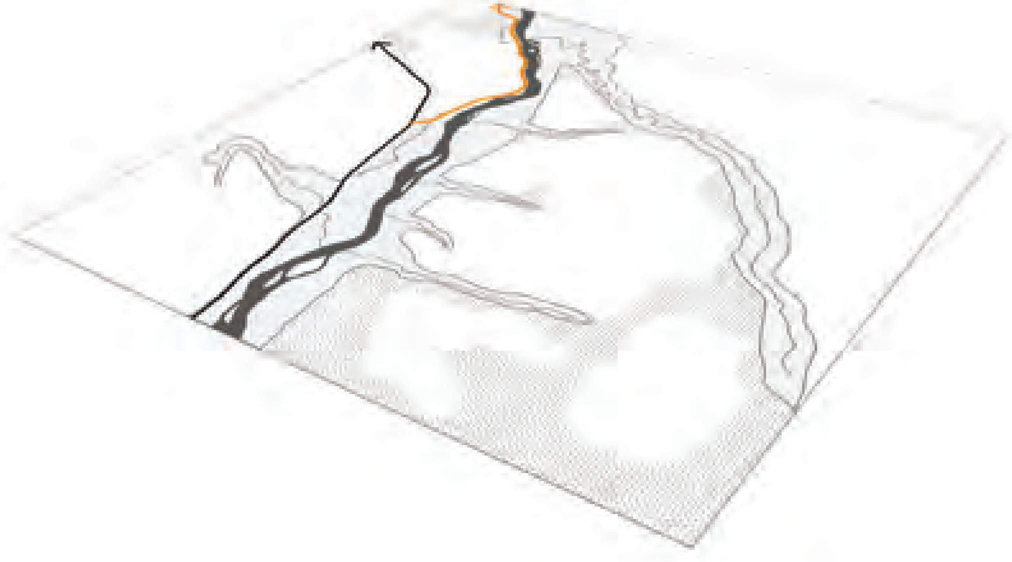
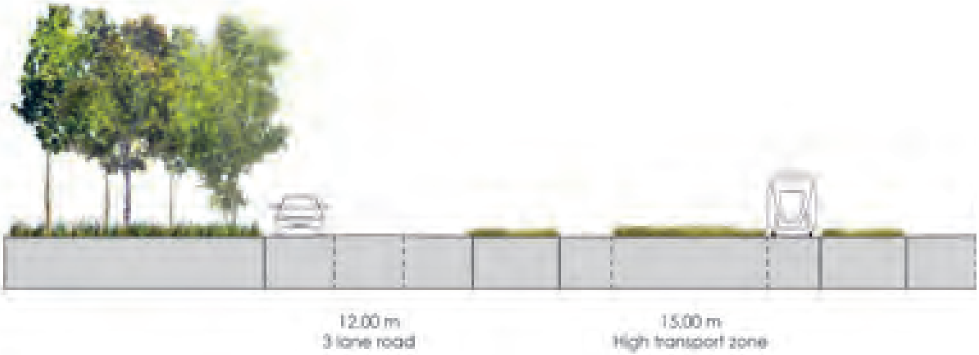
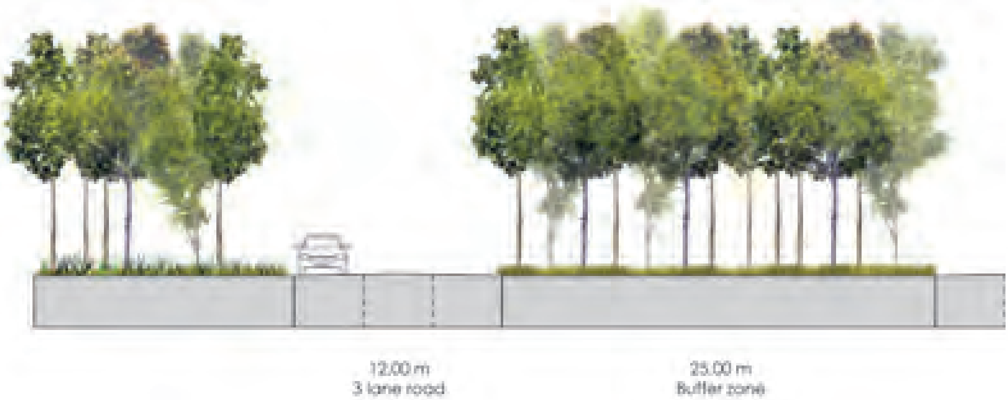
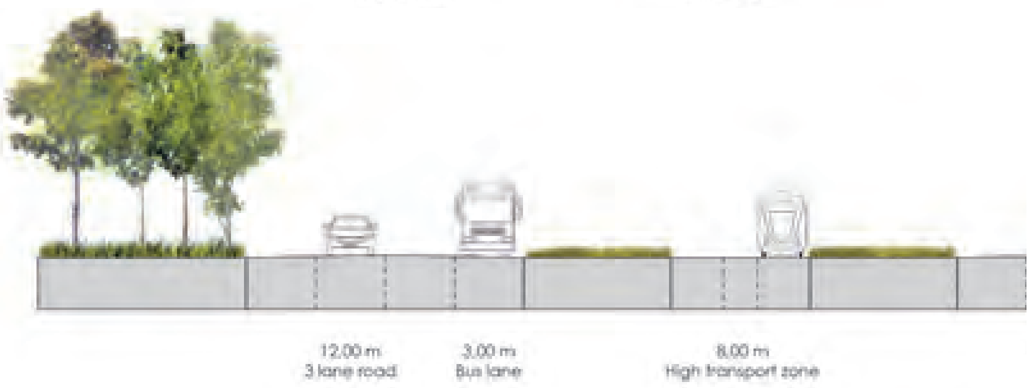


Fig 9.9: The new by-pass


12.00 m
3 lane road
15.00 m
High transport zone


12.00 m
3 lane road
25.00 m
Buffer zone


12.00 m
3 lane road
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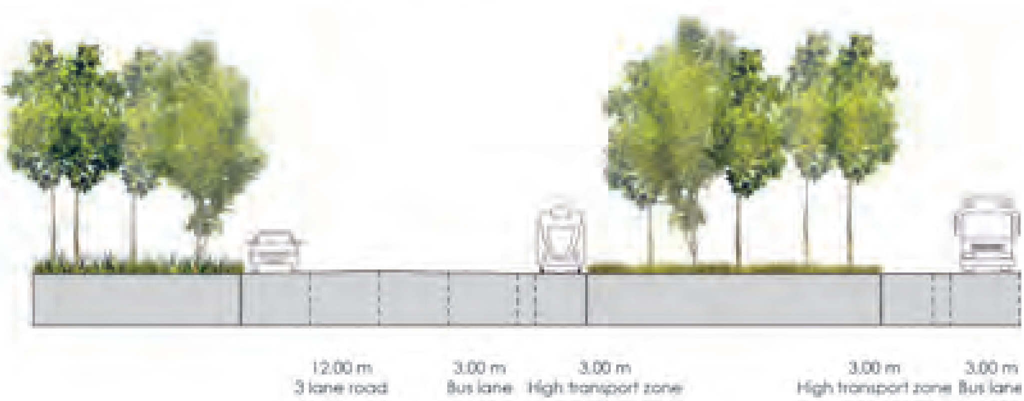
Bus lane
8.00 m
High transport zone


12.00 m
3 lane road
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Bus lane
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High transport zone
3.00 m
High transport zone
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Bus lane

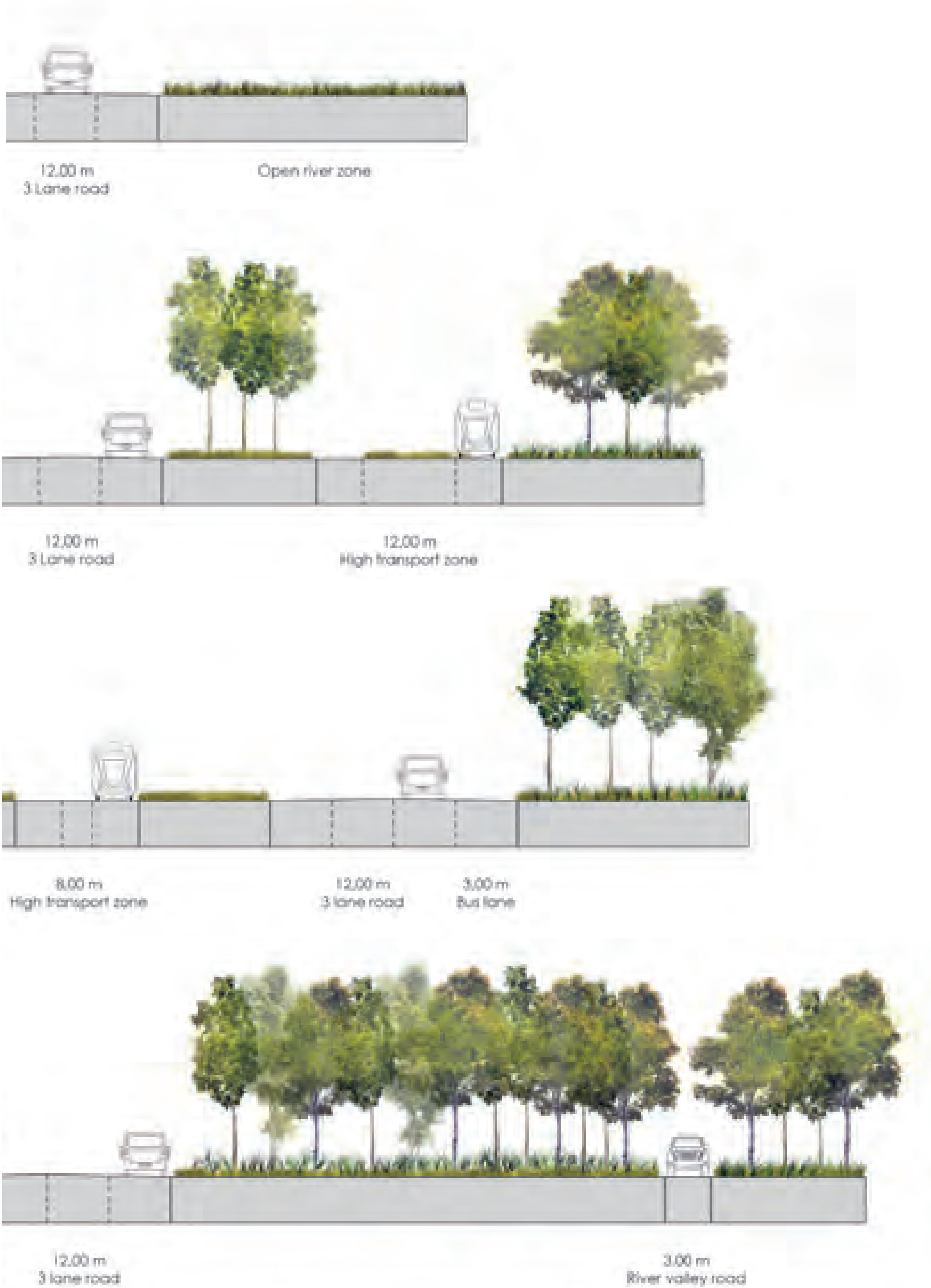


Fig 9.10: Several redevelopment opportunities for highway 63

9.3 The industrial water system

9.3.1 The occurring problems

A design for the industrial water system is necessary to reduce the impacts on the Athabasca River system

Since we want to decrease the impact of the industry on the Athabasca River system a design for the industrial water system is necessary. Inhere we see the tailings ponds as the key factor in polluting the River system (fig. 9.11). Fresh water is extracted from the river and used in the industrial process. After the industrial process, tailings remain which consist of a mixture of water sand, clay particles and harmful chemicals. These tailings are too polluted to be stored back in the river and for that reason these tailings are stored in big tailings ponds.

Inhere tailings ponds can be seen as the key factor to design for

This means extraction from the Athabasca River continues since the water cannot be fully reused in the process. Besides that the storage of tailings in tailings ponds is not without risks. First of all water is released into the ground and surface water due to seepage (Jordaan, 2012).

Another problem is formed by the settling of fine clay particles.
When tailings are stored in the ponds three different layers develop in the tailings ponds (fig. 9.12), namely:

- Coarse solids (sand);
- MFT;
- Released water.

Fig 9.11: Photo of a tailings pond located in the Suncor plant

Coarse solids, mostly sand, settles quickly to the bottom and do not cause any difficult environmental challenges. On top of the sand a layer of mature fine tailings (MFT) develops, which is made up of fine clay particles suspended in water.

However, MFT have been a major concern in the oil sands industry because of their extremely slow settling and consolidation. Decades may be required to consolidate MFT.

Without any treatment, on average 1m3 of Synthetic crude oil (SCO) production from oil sands produces on average about 2m3 of MFT (Hrudey, et al., 2010). As a result, more and larger oil sands tailings ponds have been developed over the years. While looking at the occurring problems we need to come up with a design for the tailings ponds which fulfills these three points:

This design has to fulfil the following: Clean the water, enhance the sedimenation process and collect and treat seepage.

- Clean the water from organic and in-organic pollutants;
- Enhance the sedimentation process of mature fine tailings;
- Collect the seepage.

9.3.2 The tailings ponds

To be able to come up with suitable design solutions for the problems that occur in and around these tailings ponds located on the Suncor plant we have to know how they function. In chapter 6 we already analyzed the industrial workings and with this also the workings of the tailing ponds.

There are two types of tailings ponds: the sedimentation pond and the water pond.

In chapter 6 is mentioned that there are two types of tailings ponds: the sedimentation pond and the water pond.

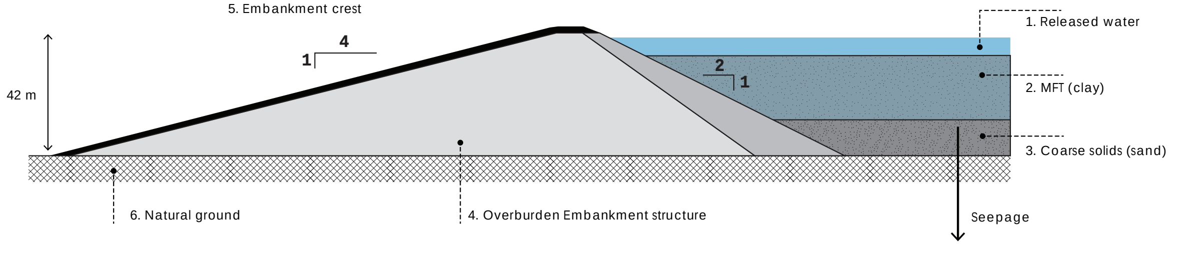


Fig 9.12: Stratification of different layers in tailings ponds. Based on source: (Norwest corporation, 2003)

First the tailings are stored into the sedimentation ponds, to let the tailings settle. As mentioned before the tailings settle in three layers. The coarse solids, mainly sand, settles to the bottom, the water floats on top and in between a layer of fine clay particles arises, which are called the mature fine tailings (MFT).

The water located on the top layer is pumped out the sedimentation pond and is subsequently transported to the water pond. In the water pond the water is stored, and for 40% to 70% percent reused in the industrial process again. In figure 9.6 the location of the various ponds are showed in the Suncor plant. At the moment they make use of two sedimentation ponds and one water pond (fig. 9.13).

10.3.3 Water treatment

Both types of tailings ponds contain polluted water.

From the former section it became clear that both tailings ponds types have a different function, but both types contain polluted water, consisting of water mixed with, clay, sand, solvent, residual bitumen, salts, metals and organic compounds (Government of Canada, 2013).

To clean this water it is necessary to: remove organic and inorganic pollutants and enhance the sedimentation process.

Another reason why water is too polluted to be fully re-used in the industrial process is the fact that most of the water is still mixed with fine clay particles. For these reasons we want to come up with a industrial water treatment facility for the tailings ponds which is able to:

- Remove organic pollutants
- Remove inorganic pollutants
- Enhance the sedimentation process

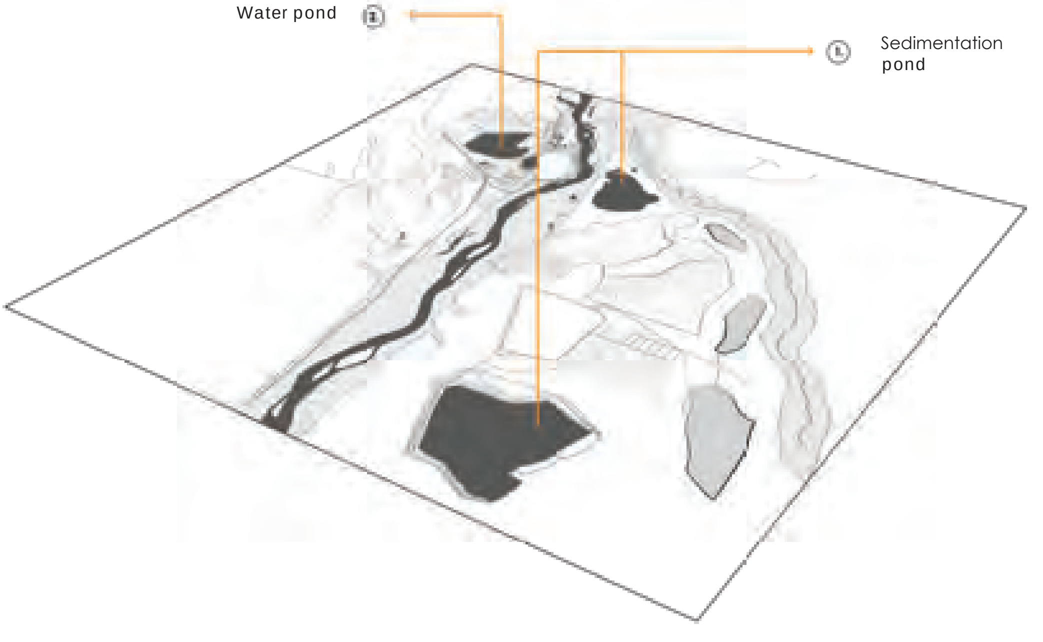


Fig 9.13: Location of sedimentation ponds and waterpond

Since we as landscape architects want to make adjustments in this system by making use of natural processes and believe in the regenerative capacity of nature recovering itself. We started to do research on constructed wetland treatment systems, inhere pollutants are removed by plants.

We want to clean tailings water by making use of wetland treatment systems

9.4 Wetlands

9.4.1 An introduction in wetlands

Constructed wetland treatment systems involves natural processes resulting in the efficient conversion of hazardous compounds (Ye et al., 2006).

These systems make use of natural processes to remove the pollutants.

"Natural wetlands are complex and integrated ecosystems in which water, plants, micro-organisms and the environment interact to improve the water quality" (Guirguis, 2004 cited in Eke, 2008). Constructed treatment wetlands are artificial wetlands developed and managed to treat hazardous compounds in wastewater that flows through them.

Our main objective in the use of constructed wetland treatment systems lies on the reduction of hazardous compounds present in the tailings.

Specific design solutions for hazardous compounds removal on this scale, the Suncor mine, has (to our knowledge) never been conducted before. The tailings ponds we focus on are several kilometers in width and length.

These systems never been applied on this scale before

What we actually do is applying proven techniques on a scale that is almost inconceivable. We actually upscale proven techniques, the question is whether this increase in scale does not affect the operation and functioning of the system. Only practice can tell whether this is indeed the case.

Hazardous compounds that are of environmental concern in tailings water include :

- Organic pollutants: which mainly consist of hydrocarbons (due to the long chains of hydrocarbons that are poorly biodegradable);
- Inorganic pollutants: ammonia, sulphate, chloride;
- Trace metals (due to lack of data not included into constructed wetland treatment) (Allen, 2008)

Trace metals detected in tailings water include aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), molybdenum (Mo), titanium (Ti), vanadium (V), and zinc (Zn) (MacKinnon and Retallack 1981; Siwik et al. 2000, Allen, 2008).

However the scarcity of recent data makes it difficult to determine if current concentrations are problematic.

We therefore chose to not further investigate the relation between constructed wetlands and possible metal contamination due to a scarcity of current data (Allen, 2008).

After thorough research done on hazardous compounds removal, literature revealed that the removal of chloride cannot be accomplished by settling or natural processes (Flynn, et al., n.d.).

The only reasonable way to reduce the salt load in the tailings water is to make changes in the production plant itself, or develop chemical or special filters to remove dissolved salts. However due to a lack of knowledge and data about these processes we decided not to go further on this specific pollutant. (Gielen, 2012)

The pollutants we focus on in these wetlands are hydrocarbons, ammonia and sulphate

This means that Hydrocarbons, ammonia and sulphate as mentioned by Allen (2008) are the chemicals of environmental concern we will focus on.

In order to remove these pollutants we work with three types of wetlands which are all part of our industrial water treatment facility.

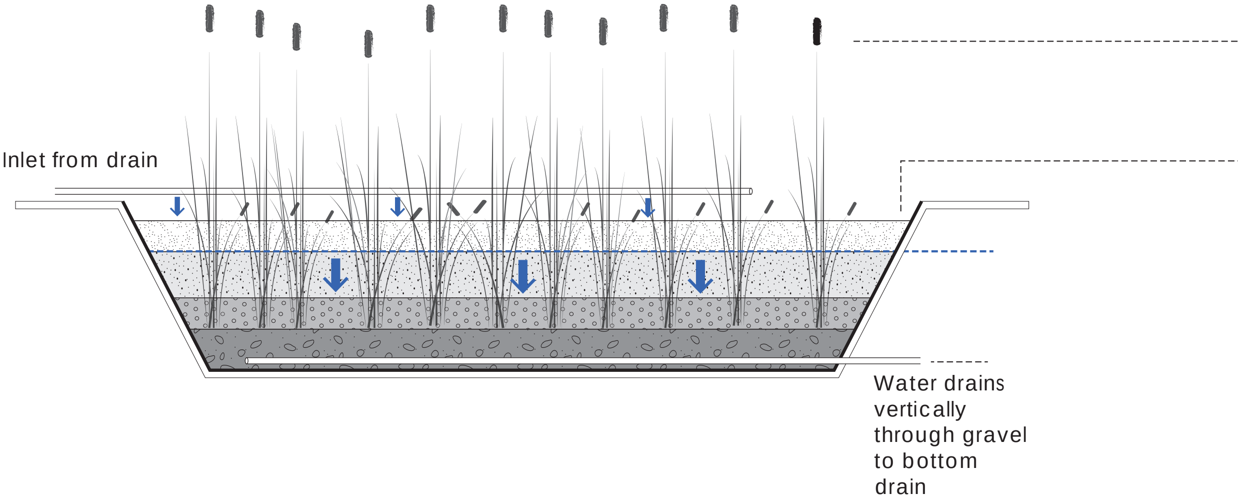
To be able to do this we come up with three different wetland types.

- Sub-surface water flow wetland (SSF)
- Surface water flow wetland (FWS)
- Floating treatment wetland (FTW)

The first one is the Subsurface flow wetland system (SSF).

9.4.2 Subsurface flow wetland systems (SSF)

Subsurface flow wetland systems (SSF), are generally constructed with a porous material such as soil, sand, or gravel for a substrate. The SSF wetland is shown in figure 9.14.



They are designed so that tailings water flows below the ground surface through the substrate (ITRC, 2003). The tailings water flows vertically through a constructed media bed planted with wetland vegetation (Eke, 2008). Through an inlet pipe water enters the wetland and flows slowly below the ground surface, passing through the roots of the plants, until it finally reaches the outlet drain.

The depth of the gravel bed in which the tailings water flows through is 0.9 m deep and the substrate varies in size from sand to gravel.
The rhizomes of reeds and other species grow horizontally as well as vertically, this provides openings in the substrate, which allows tailings water to flow through (Cooper, 1993).

SSF wetlands combines aerobic and anaerobic zones. Aerobic zones are located in the rhizosphere, which is the soil zone that is surrounded and influenced by the roots of plants. This is also the zone where most of the water purification takes place, since large populations of anaerobic and aerobic bacteria grow here. The bacteria are responsible for the degradation of the hydrocarbons and the nitrification of ammonia (Eke, 2008).

This type of wetland is mainly focussed on the removal of organic pollutants as hydrocarbons

"SSF wetlands have the primary benefit that water is not exposed during the treatment process, minimizing energy losses through evaporation. This makes SSF system more suitable for winter application". (Wallace et al., 2000 cited in Eke, 2008, p. 39).

To further increase the degradation of hydrocarbons and nitrification of Ammonia, conducted field research of a pilot system in Casper, Wyoming, indicated that the SSF wetland configuration (with a surface mulch layer for insulation) was the most effective in hydrocarbon removal. (Wallace, Schmidt and Larson, 2011).

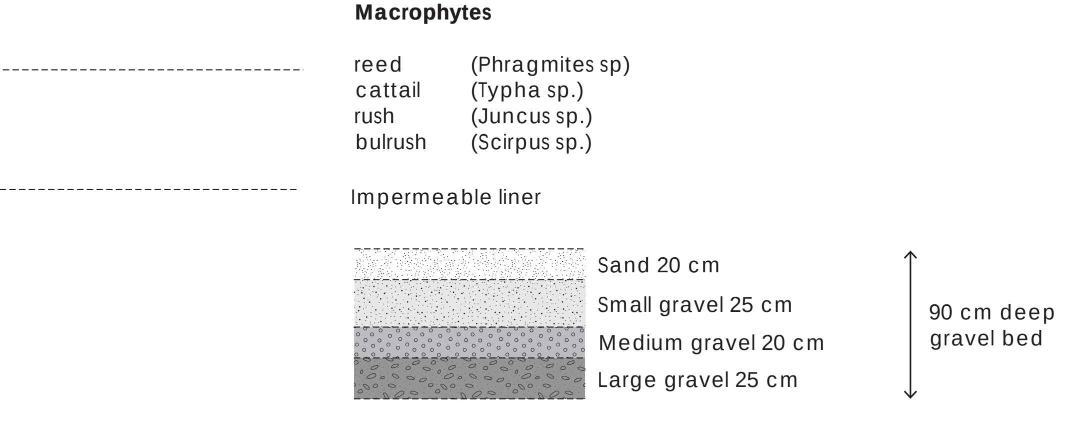


Fig 9.14: Subsurface flow wetland system (Eke, 2008)

The second type is the Surface water flow wetland (FWS).

This type of wetland is mainly focussed on the removel of inorganic pollutants as Sulphate and Ammonia

9.4.3 *Surface water flow wetland systems (FWS)*

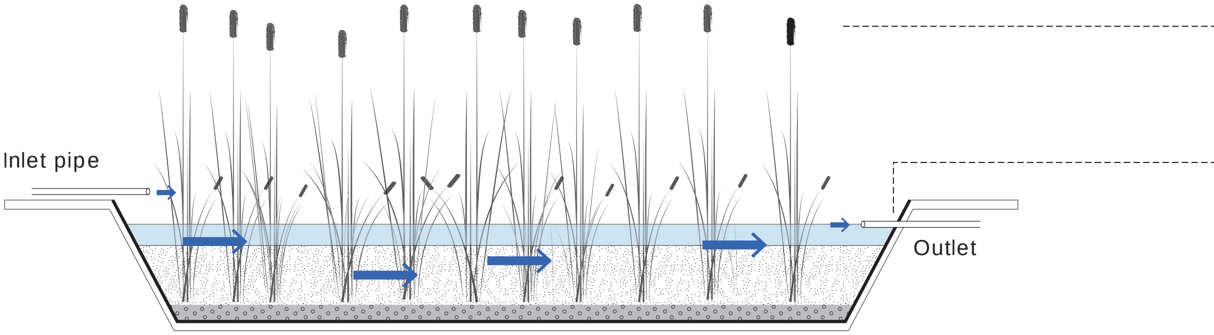
Surface water flow wetland systems (FWS) are constructed with a layer of gravel at the bottom of the wetlands and a mixture of soil and spent mushroom compost on top. A cross-section of the FWS wetland is shown in figure 9.15.

FWS wetlands are designed so that tailings water flows horizontally on top of the wetland soil, infiltrates in the soil or is evaporated as the water surface is exposed to the atmosphere (Eke, 2008). Conditions are anaerobe in FWS wetlands.

Results from conducted research showed that, a mixture of soil and spent mushroom compost, appeared to be a well suited organic substrate for populations of sulfate-reducing bacteria (SRB) (O'Sullivan, Murray, Otte, 2004), these bacteria require anaerobic conditions and are therefore applied to FWS wetlands.

This organic substrate may be an important factor for sulphate removal in FWS wetlands (INAP, 2003 and O'Sullivan, Murray, Otte, 2004). As mentioned by Allen (2008) sulphate is one of the chemicals in the tailings that are of environmental concern.

The depth of the substrate bed in which the tailings water flows through is between 0.45 – 0.75 m deep. Key processes in the treatment involve interactions with the entire substrate, in order to optimize tailings



treatment processes (INAP, 2003). Permeability of the substrate is therefore very important, if permeability is too low, tailings water will flow over the substrate (Wolkersdorfer, 2008). We therefore chose for a mixture of soil and spent mushroom compost.
Surface wetlands are usually not the preferred type in cold climates. This is because they tend to freeze over in the wintertime, which results in significantly lower contaminant removal rates (Eke, 2008). However these wetlands appeared to be best suited for the removal of sulphate and potential other metals (INAP, 2003). We therefore did chose for this wetland system, despite the harsh and cold climate in the Athabasca oil sands. During the winter one will have to think of some kind of cover or isolation of these wetlands.

10.4.4 Floating treatment wetland (FTW)

Floating treatment wetland systems (FTW), generally consists of a floating raft or frame supporting a mesh on which plants are grown" (Headley and Tanner, 2006).

The third type is the Floating treatment wetland system (FTW)

FTWs consists of emergent wetland vegetation growing on a mat or structure which floats on the surface of, in our case, the tailings ponds. These floating mats are typically 40-60 cm deep and supports plant growth. The planting media consists of intertwined live, dead decaying roots with some litter and peat on the bottom.

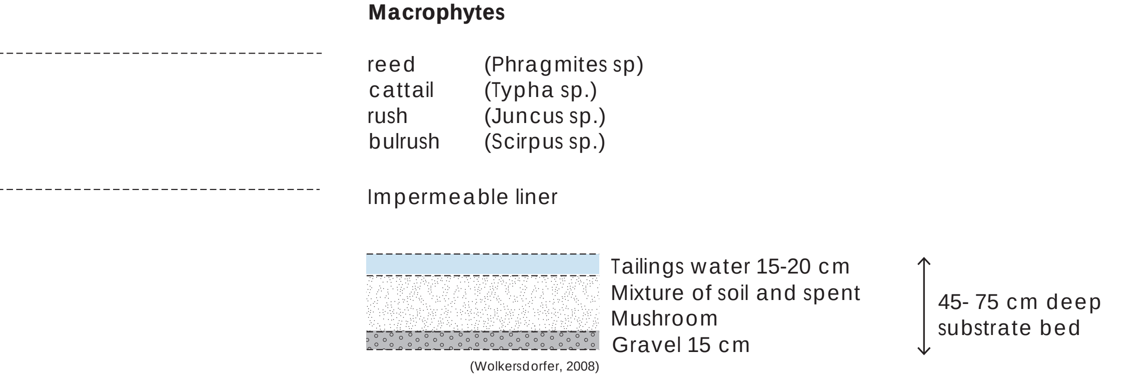


Fig 9.15: Surface flow wetland system (Eke, 2008)

The plant stems remain above the water level, while the roots grow down through the floating structure into the water.

This wetland focusses on the removal of inorganic and organic pollutants, it also enhances the sedimentation process.

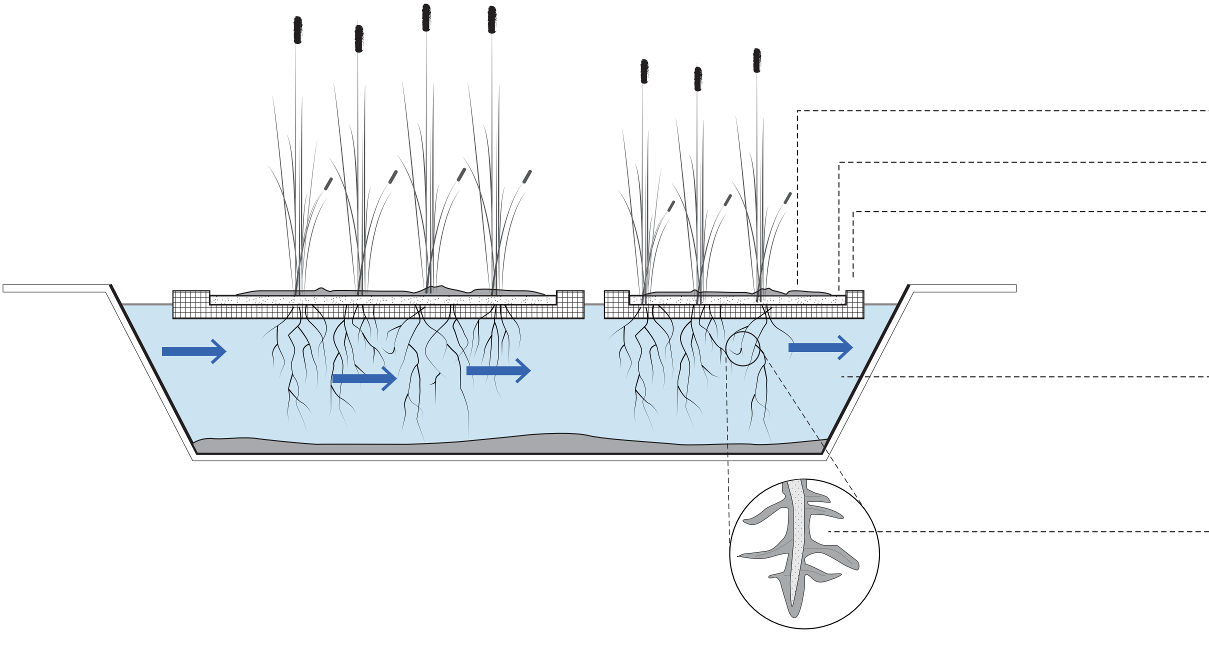
"Beneath the floating mat, a hanging network of roots, rhizomes and attached biofilms is formed. This hanging root-biofilm network provides a biologically active surface area for biochemical processes as well as physical processes such as filtering and entrapment" (Headley and Tanner, 2008). A cross-section of a typical floating treatment wetland and pond is showed in figure 9.16

9.4.5 Used wetland vegetation in all the wetland systems

The removal of these pollutants is mainly done by plants (or actually bacteria that are attached to the root surface of plants)

Plants are a significant component in wetland systems. Both vascular plants (the higher plants) and non-vascular plants (algae) are important in all the constructed wetland types. Macrophytes for example can assimilate pollutants in their tissue and also provide a surface and environment for microbes to grow (Vymazal, 2002).

The growth of roots within wetland systems help to decompose organic matter, and prevents wetland systems from clogging by creating channels for the water to pass through (Eke, 2008).



Macrophytes are mostly used within wetland treatment systems (Scholz, 2006). The most common plants used in wetlands are:

Macrophytes are mainly used in these systems

- Reed (Phragmites sp);
- Cattail (Typha sp.);
- Rush (Juncus sp.);
- Bulrush (Scirpus sp.).

The three different wetland types which have been mentioned in the preceding paragraph, will all be implemented on and near the different types of tailings ponds in order to fulfill these three points:

- Clean the water from organic and in-organic pollutants;
- Enhance the sedimentation process of mature fine tailings;
- Collection of seepage.

We will now continue how these objectives have been translated into design solutions.

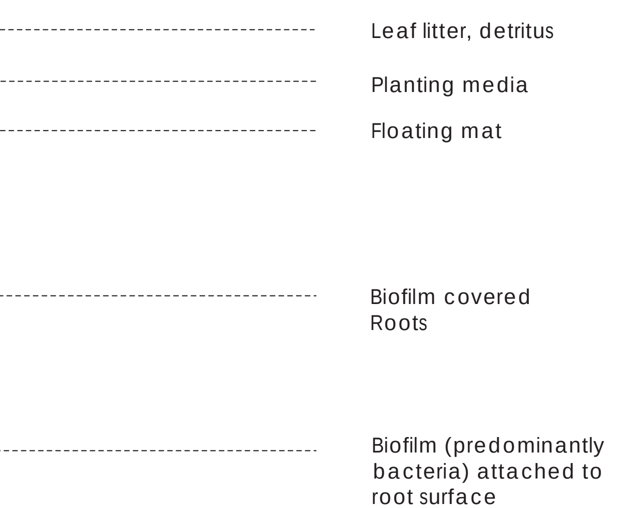


Fig 9.16: Floating treatment wetland system (Eke, 2008)

9.5 A design for the sedimentation pond

9.5.1 Design focus

For the sedimentation pond we focus on enhancing the sedimentation process and the collection and treatment of seepage

Since two different types of tailings ponds occur in the Suncor plant we want to come up with a design which is best suitable for the function of these ponds. In this part we start with the design for the sedimentation ponds (fig. 9.17). From the upgrader and extraction plants process affected water is stored in sedimentation ponds (fig. 9.18).

For these ponds the design is focused on:

- Enhancing the sedimentation process ;
- Collecting and treatment of the tailings seepage.

For this design the focus will be on the South tailings pond

Because there are two sedimentation ponds in the Suncor mine we decided to focus on one pond to be able to clearly explain the design. The design for this pond will be suitable for every sedimentation pond in the area. Inhere we designed for the South tailings pond. This pond is located most south in the mine (fig. 9.19).

Fig 9.17: Photo of the sedimentation pond (the South tailings pond)

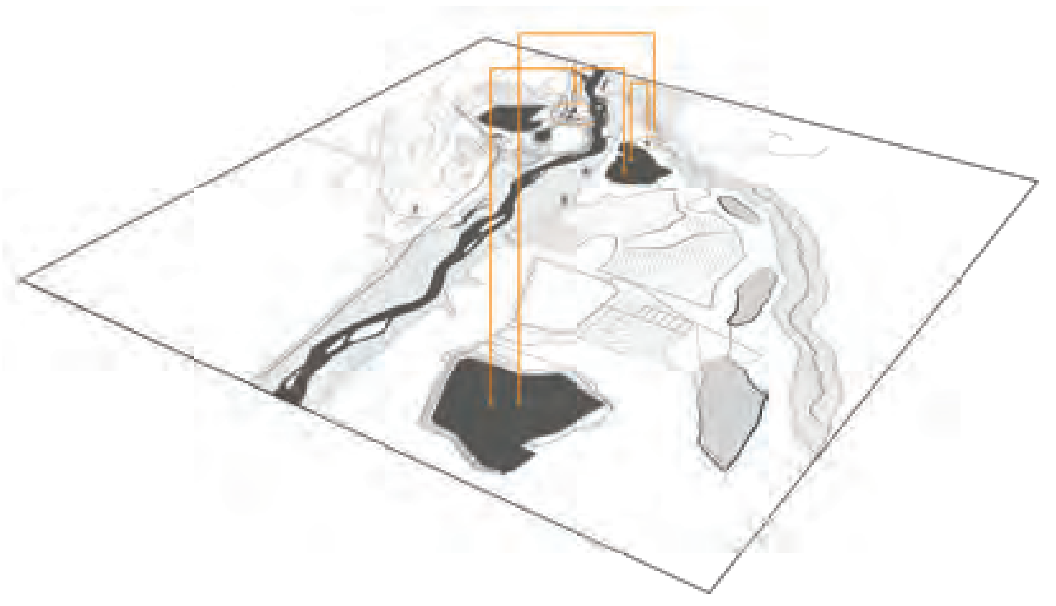


Fig 9.18 Processed affected water is stored in sedimentation ponds

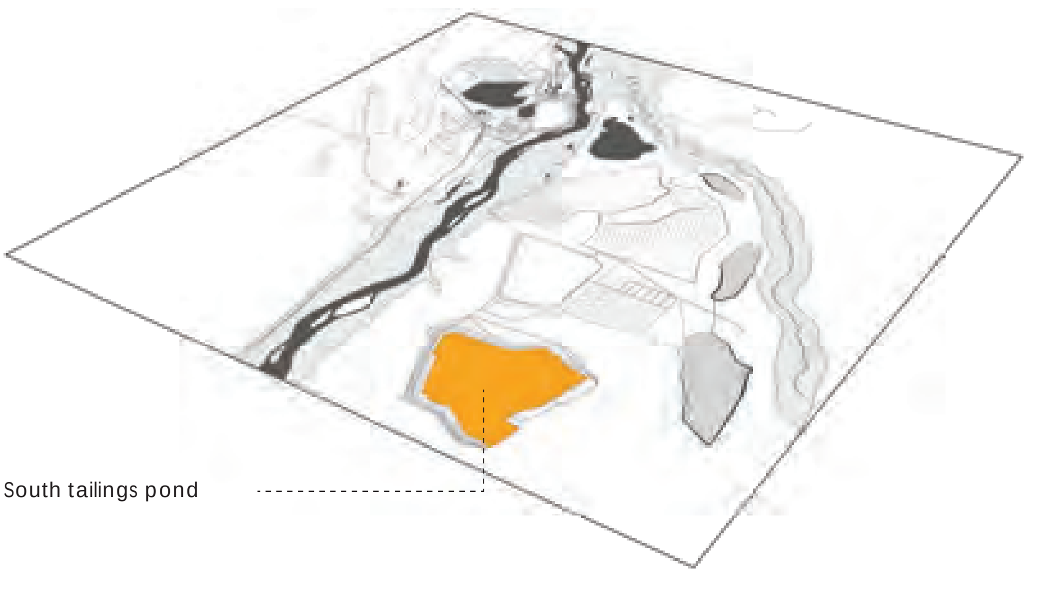


Fig 9.19 Location of the South tailings pond (STP) shown in orange

9.5.2 The seepage collection treatment system

The first intervention is showed in different models of the south tailings pond. The first model (fig. 9.20) shows the current inlet of tailings into the pond. The pond is a surface pond with dikes placed on the surface, as already explained in the industrial workings in chapter 6 .

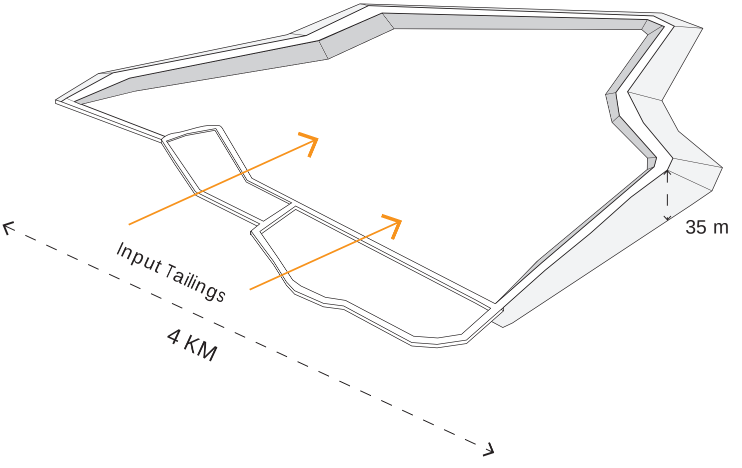


Fig 9.20: Model 1, the current situation of the South tailings pond

Currently seepage is collected in a collection ditch

Model two (fig. 9.21) shows the current seepage system. A collection ditch is located along the dyke to collect the seepage.

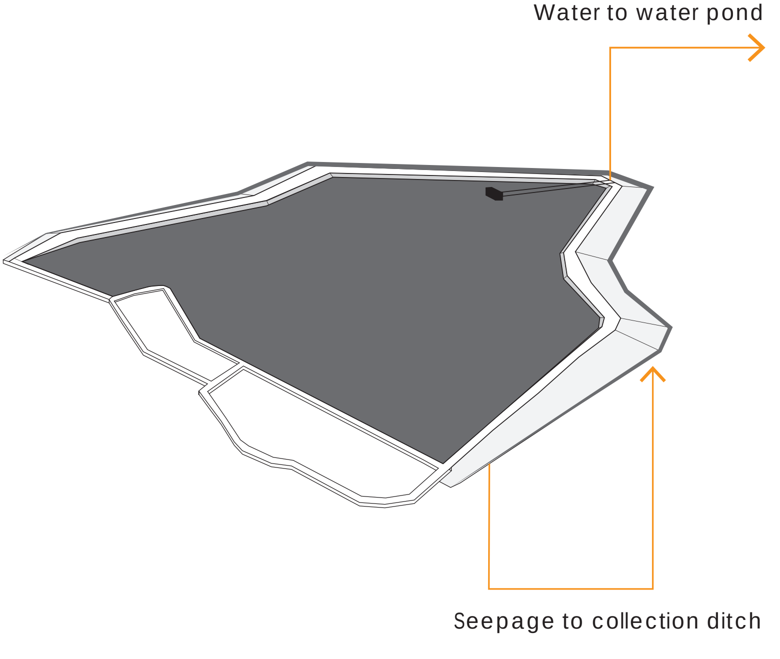


Fig 9.21: Model 2, the current seepage system of the South tailings pond

Model three (fig. 9.22) shows our first intervention. By pumping the seepage which is collected in the ditch into a wetland treatment facility, the water can be cleaned already.

Our design solution collects and pumps seepage into a wetland treatment system

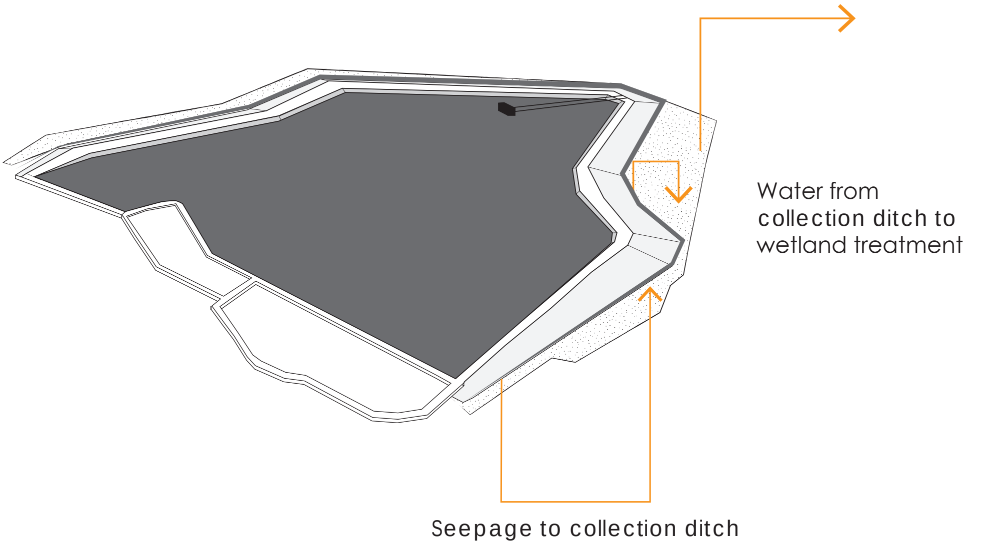


Fig 9.22: Model 3, the wetland treatment system around the tailings pond

This process is again showed in figure 9.23. In this cross section you see that the shallow seepage is collected in the ditch and the deep seepage is collected by a drain and pumped into the collection ditch. From this ditch the water is pumped in the wetland for treatment. This wetland is a sub-surface water flow (SSF) wetland and thus focused on removing organic pollutants. From this wetland the water is transported to the water pond for secondary treatment.

This wetland is a Sub-surface water flow wetland and thus focused on removing organic pollutants

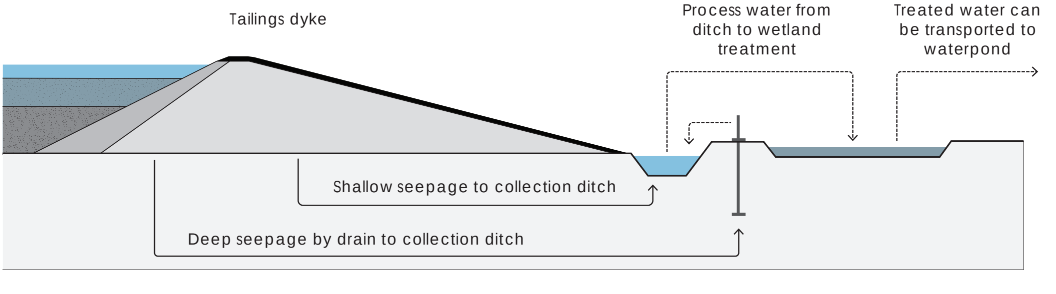


Fig 9.23: The wetland treatment system along the collection ditch

In this case we have chosen for SSF wetlands for the following reasons:

- Reduced risk of exposing humans or wildlife to toxics (decreased waterfowl use for example);
- Increased accessibility for upkeep (no standing water).
- SSF wetland systems provide more surface area for bacterial biofilm, resulting in increased treatment effectiveness while requiring smaller land areas.
- Due to better insulation by the earth, SSF wetlands are better suited for cold weather climates. (Eke, 2008).
- SSF wetland systems have minimal ecological risk since an exposure pathway to hazardous substances does not exist for wildlife and most organisms (ITRC, 2003).

9.5.2 An introduction in Floating wetlands

The second intervention focuses on enhancing the sedimentation process by floating wetlands

The second intervention we did focused on enhancing the sedimentation process, this can be done in two different ways:

- Reducing the surface disturbance in order to prevent re-suspension of fine clay particles;
- By enhancing the degradation of hydrocarbons (organic pollutants).

According to interviewee 13 (2013), several conducted experiments confirmed that the process of hydrocarbon degradation by microbes also increased the settling of fine clay particles.

We therefore proposed the following design solution, Floating Treatment Wetlands (FTWs)

Due to the development of FTWs the sedimentation process will be enhanced by:

These wetlands will reduce the re-suspension of fine clay particles

provide a continuous carbon source

and direct the water flow for further treatment

- FTWs will reduce the re-suspension of fine clay particles by wind-driven water on tailings ponds;
- FTWs will provide a continuous carbon source for microbes who are responsible for the degradation of hydrocarbons in the tailings water, this also increases the settling process of fine clay particles
- FTWs will direct water flows to further enhance water treatment

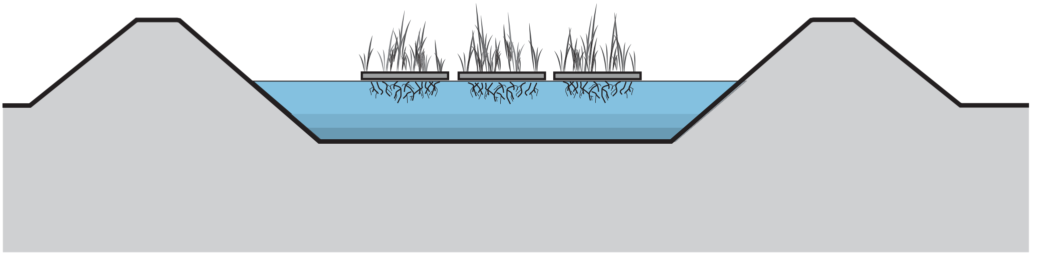


Fig 9.24: Floating rafts on which plants are grown located in the tailings pond

"The most common approach to constructing FTWs is through the creation of a floating raft or frame supporting a mesh on which plants are grown" (Headley and Tanner, 2006) (fig. 9.24).

FTWs are more and more used nowadays due to the fact that pond and wetlands based systems offer advantages when talking about maintenance and complexity. These systems are passive and low in maintenance and offer an operationally simple treatment solution when talking about polluted water (Headley and Tanner, 2008).

FTWs have been used with varying success for several purposes such as water quality improvement, habitat enhancement (Brugess and Hirons, 1992) and aesthetic purposes (Headley and Tanner, 2008). When talking about the improvement of water quality, main purposes of FTWs as reported today, which are of interest for our research, have been for the treatment of:

- Sewage (Ash and Truong, 2003);
- Stormwater (Headley and Tanner, 2007);
- Acid Mine drainage (Smith and Kalin, 2000).

Besides an improved water quality FTWs also provide animal habitat and have aesthetic purposes.

FTWs are however not yet used for the treatment of tailings in tailings ponds, however we see a lot of similarities with the above mentioned contamination.

9.5 Addition to FTW system

One difficulty when talking about tailings ponds is their depth, there is little information about the exact depth, we however know that it is on average 20m (McKenna, 2014). The roots of the plants however, do not reach that deep.

Since tailings ponds are very deep and the roots of the plants on the FTWs do not reach that deep, synthetic textile curtains are added to the FTW's to increase the treatable surface

We therefore proposed the following: develop synthetic textile curtains hanging beneath the floating wetlands attached to a frame, to provide additional substrate for biofilm attachment. All this to maximize and enlarge the contact between the root-biofilm network to increase the treatable surface and to direct water flows, creating a serpentine flow path, to further optimize tailings treatment (Headley and Tanner, 2006). A model of of the floating wetlands with the attached curtain are showed in figure 9.25.

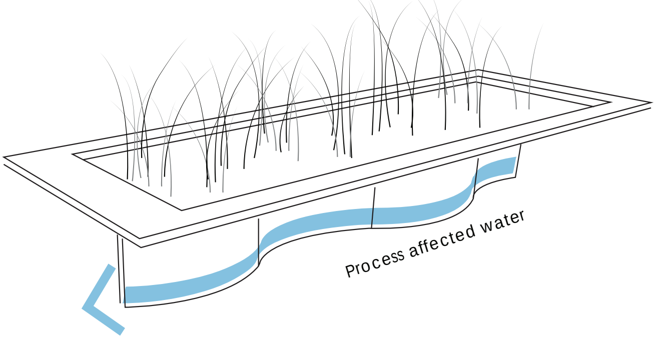


Fig 9.25: The floating wetland construction with attached curtain

We have developed this floating wetland system with the synthetic curtains, in response to the developed approach called the AEES "restorer" by Oceans Ark International (fig. 9.26). However we upscale this approach again, corresponding to the size and scale of the (sedimentation) tailings ponds (Headley and Tanner, 2006).

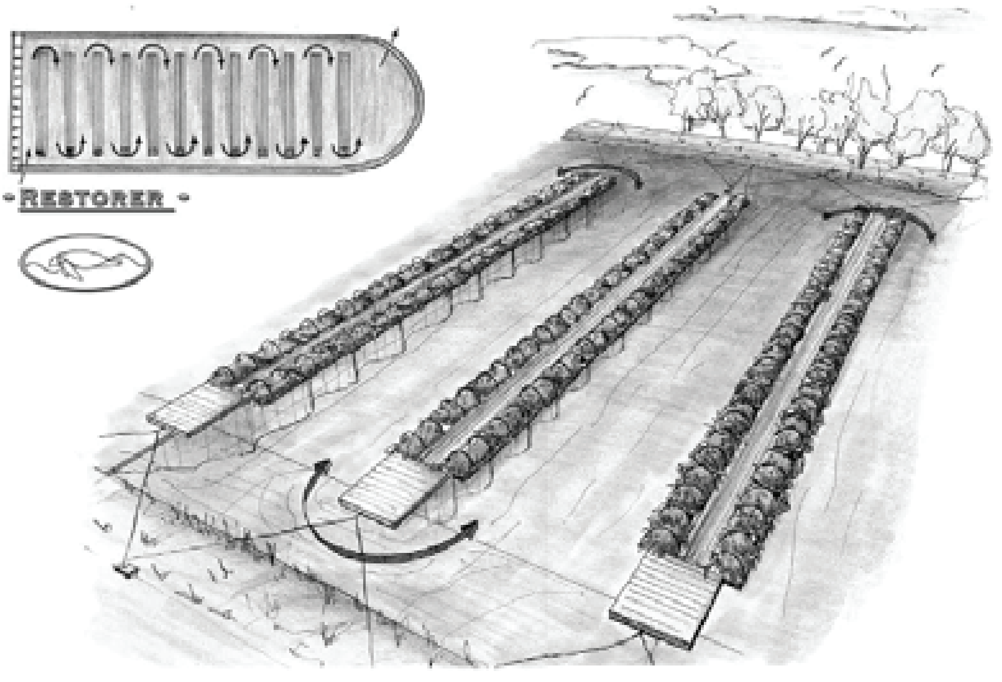


Fig 9.26: The AEES restorer (Headley and Tanner, 2006)

This developed system is based on the developed approach called the AEES restorer.

This system is in particular designed to be retrofitted onto ponds (such as waste stabilization ponds) in order to improve treatment performance (Headley and Tanner, 2006). This corresponds closely with our ideas, since we also propose to develop floating wetlands on already existing tailings ponds to further improve treatment.

We subsequently sketched on different forms of the FTWs, round hexagonal or rectangular as shown in figure 9.27.

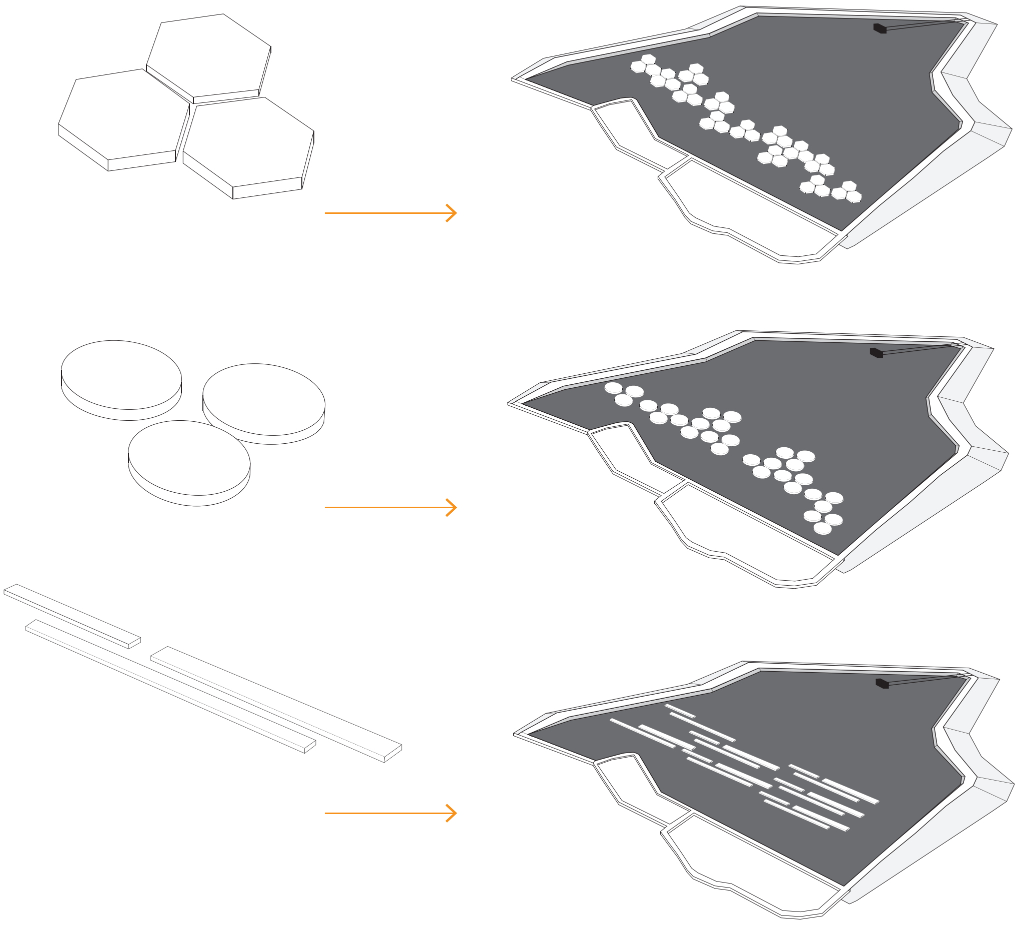


Fig 9.27: Form study for floating wetlands

By doing several form studies we came to the conclusion that rectangular shaped FTW's are in this case the best solution

We finally came to the conclusion that rectangular shaped FTWs are in this situation the best solution for two reasons:

- Reed (or any other Macrophytes) which grows on these wetlands is easiest to harvest when a minimum amount of turns need to be made. The harvested reed can subsequently be used as an energy source;
- We assume that rectangular shaped FTWs direct the water flows the best in comparison to the other forms.

The rectangular floating wetlands will have an enormous size, since it has to be in ratio with the tailings pond

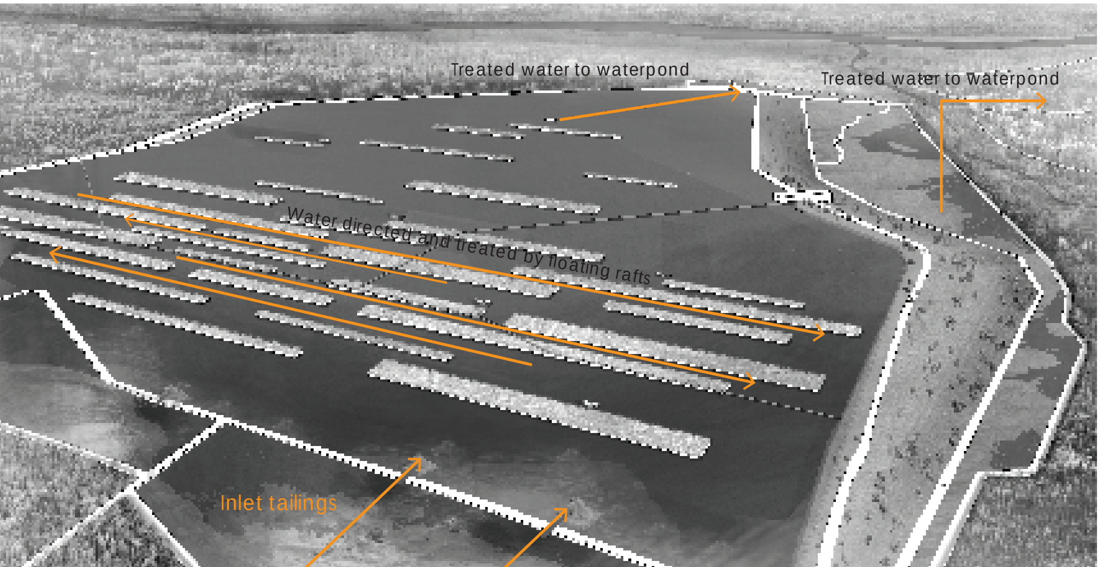
In figure 9.28 the rectangular floating wetlands are again showed in a model. Since the tailing ponds have an enormous size, we also designed floating wetlands of an enormous size to keep it in ratio. This is showed in the first model. These platforms reduce the surface disturbance. In the second model vegetation is planted on top of the rafts to enhance the degradation of hydrocarbons. In the third model the curtain is added to increase the surface for better treatment and to better direct the water flows.

On the following page the whole water treatment system of the south tailings ponds is showed in a visualisation (fig. 9.30). The image below first explains the whole system once again (fig. 9.29).

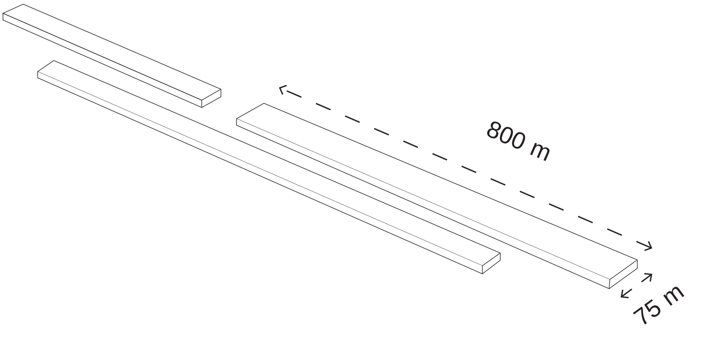
First the tailings are pumped into the sedimentation pond. The water is treated and directed by the floating wetland system. These floating rafts also enhance the sedimentation process and reduce surface disturbance, as explained before. When the water has flowed through the system is pumped out and transported to the water pond for secondary treatment.

Around the pond a wetland system is created. Seepage is first collected in the collection ditch and then pumped into this wetland system. This wetland is a sub-surface water flow (SSF) wetland and thus focused on removing organic pollutants. After cleaning also this water is transported to the water pond for secondary treatment. In the following section the design for secondary treatment facility of the water pond will be explained.

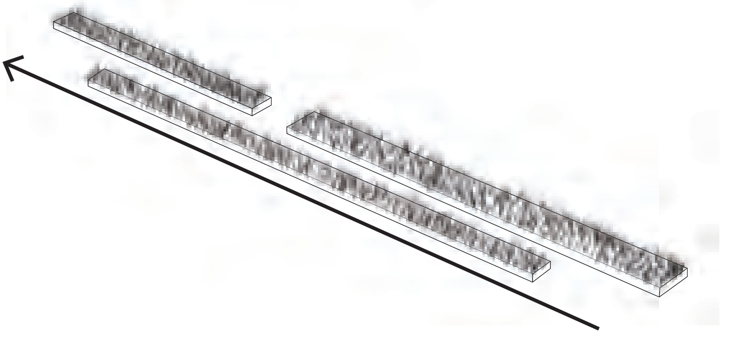
Fig 9.29: The water treatment process of the South tailings pond



Reduction of surface disturbance



Degradation of hydrocarbons by roots



Increasing of surface for better treatment

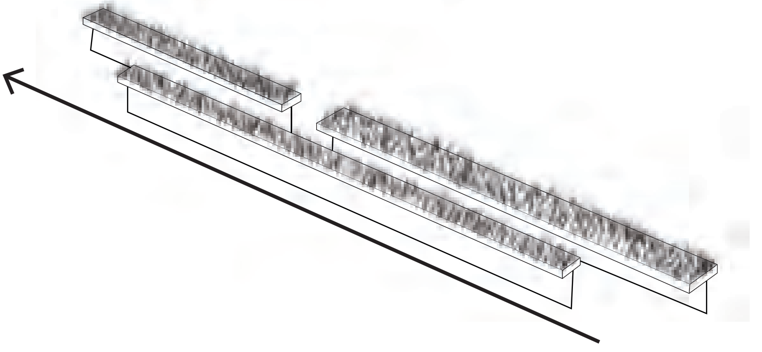


Fig 9.28: The rectangular floating wetland system

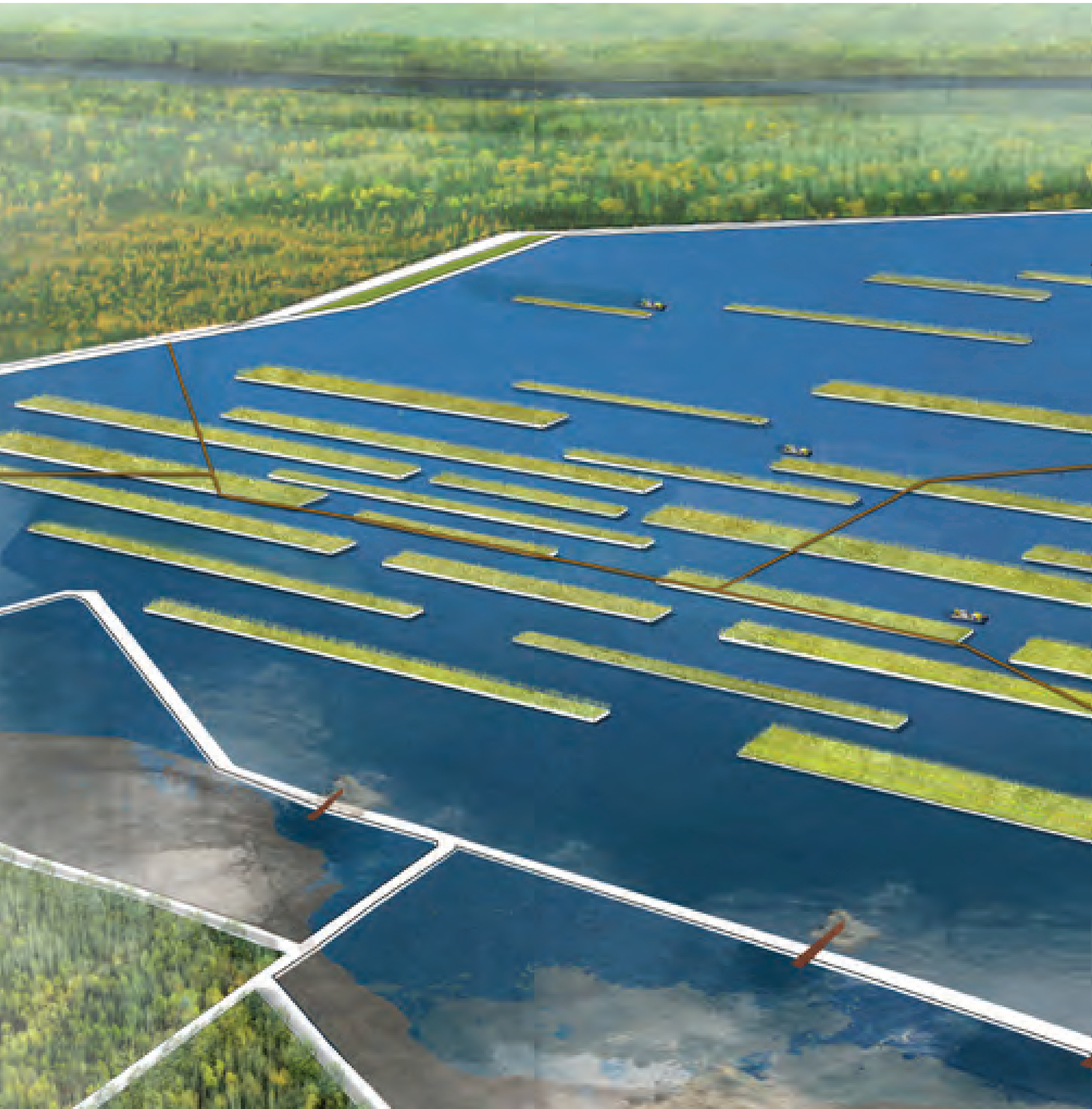


Fig 9.30: A visualization of the water treatment system of the South tailings pond

9.6 A design for the water pond

9.6.1 The design focus

The treated water from the sedimentation pond goes to the water pond for secondary treatment

We will now continue with our developed design solutions for the water pond, which is shown in figure 9.31. From the sedimentation ponds tailings water is send to the water pond (fig. 9.32), for secondary treatment to be reused again in the industrial process (fig. 9.33).

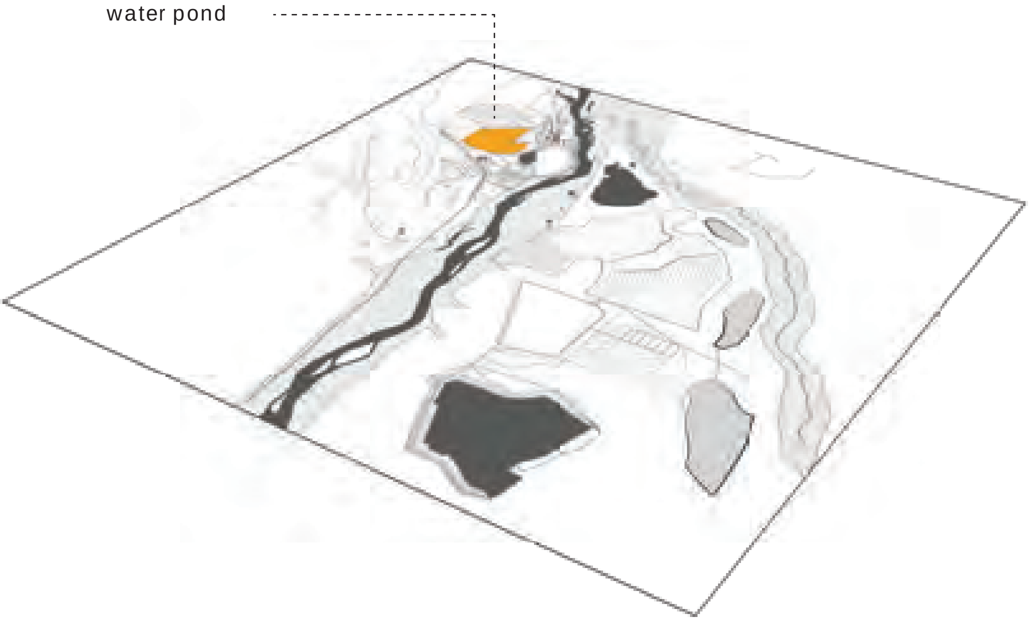


Fig 9.31: The location of the water pond

Fig 9.32 A Photo of the waterpond located behind the upgrader

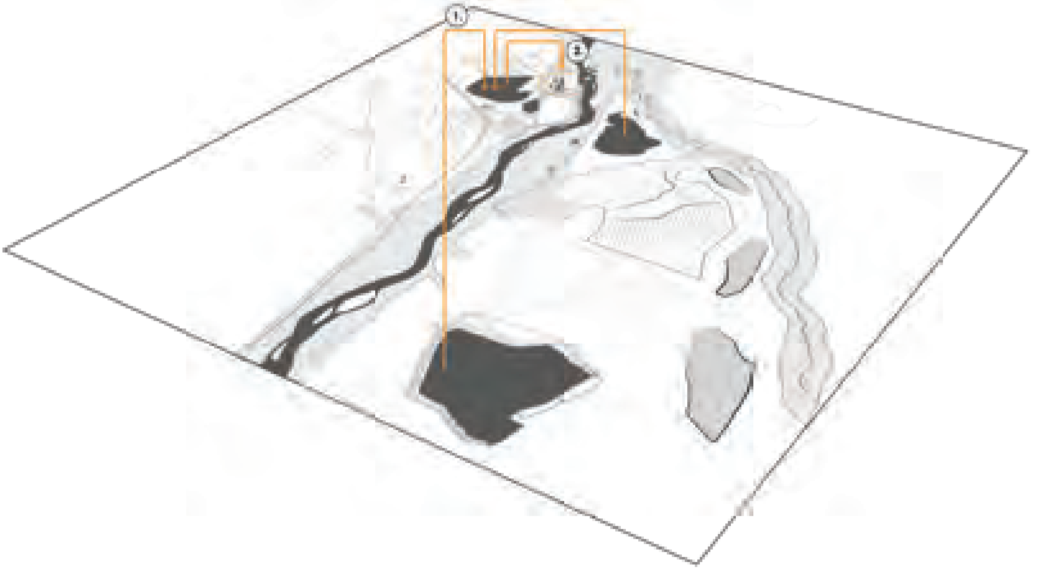


Fig 9.33: The treated water goes to the waterpond for secondary treatment

At this moment, tailings water is stored here and subsequently withdrawn and send to the upgrader to be reused in the industrial process. Unfortunately only 40 to 70 percent of the tailings water is reused in the industrial process. Therefore water extraction from the river will continue. This will have an impact on the annual water flow and its surrounding aquatic ecosystems (Pembina institute, 2009).

We therefore propose to develop a secondary treatment plant on the water pond in order to increase the percentages of reused water in the industrial process and a reduction of water extraction from the Athabasca river.

The focus for this secondary treatment in the water pond lays on: removal of inorganic and organic pollutants and collection and treatment of seepage

For the water pond the design is focused on:

- Removal of organic pollutants (hydrocarbons);
- Removal of inorganic pollutants (Ammonia and Sulphate);
- Collecting and treatment of the tailings seepage.

Surrounding the water pond the same seepage treatment wetland is implemented as before

9.6.2 *The seepage collection treatment system*

Since we assume that all tailings ponds release a certain amount of contaminated water into the ground of surface water due to seepage, we also implement a seepage treatment system around the water pond. In figure 9.34 the current situation of the water is shown. Water is flowing into the water pond and 40 % to 70% is reused in the industrial process again. The seepage is collected in a collection ditch along the dyke.

In the second model (9.35) the collected seepage is pumped into a wetland treatment system for treatment. This is SSF wetland and thus

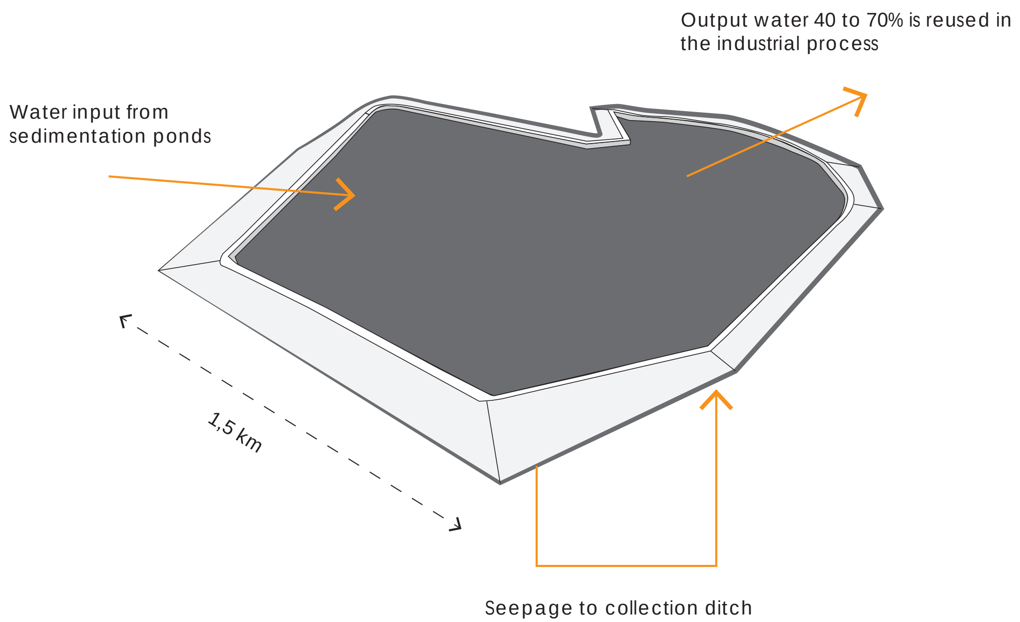
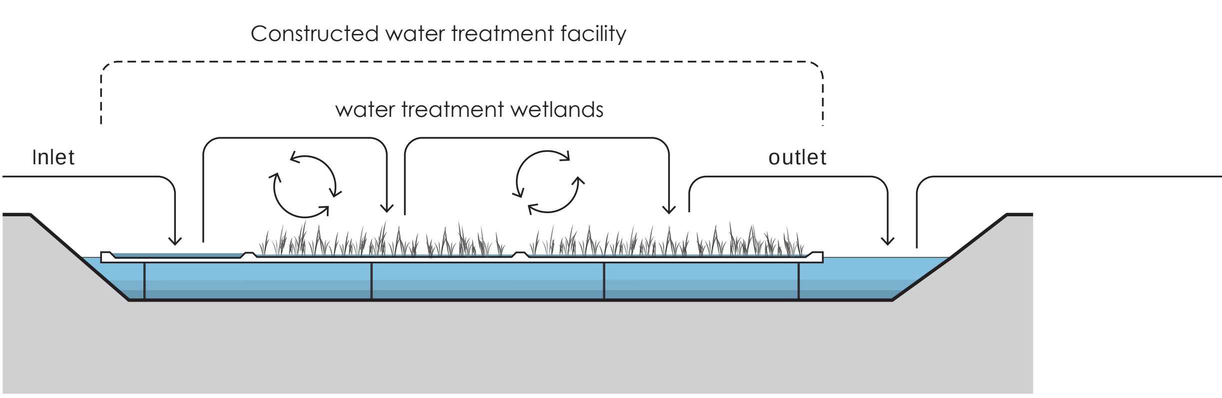


Fig 9.34: The current situation of the water pond



focused on removing organic pollutants. From this wetland the water can be reused in the industrial process again. This is the same design we already implemented on the South tailings ponds and suitable for every tailings pond in the region.

9.6.3 *The secondary treatment plant*

What we actually developed is a big rectangular shaped water treatment facility, which floats above the water surface of the water pond, as shown in figure 9.36 The water treatment facility is fastened by means of pillars to the bottom of the water pond. One thing that must be mentioned is that the water treatment facility is not in direct contact with the tailings water in the water pond.

In the water pond a big rectangular shaped water treatment facility is developed

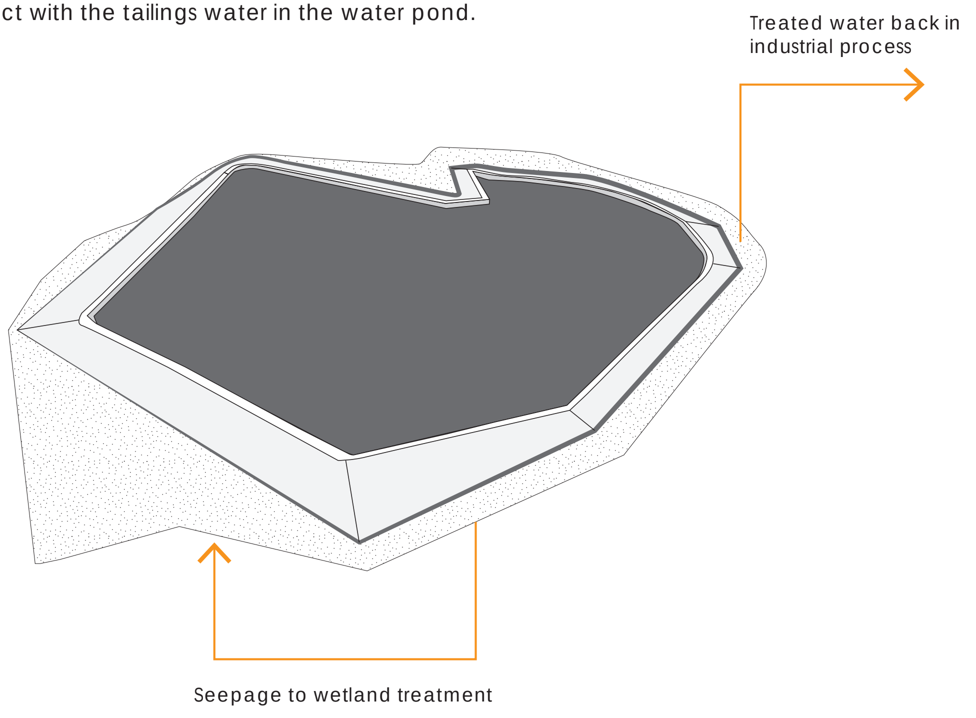


Fig 9.35: The wetland treatment system to treat the seepage

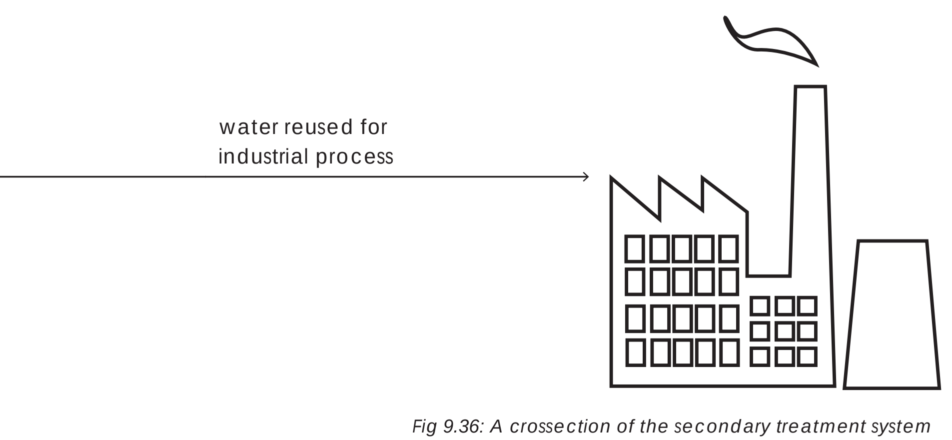


Fig 9.36: A crossection of the secondary treatment system

We will now explain step by step the functioning of this water treatment facility. At first water from the sedimentation pond is send to the water treatment facility by means of pipes.

Within this treatment facility the water first flows in the first basin: the inlet

From here water is send to the second basin the FWS wetland to remove inorganic pollutants

Water is subsequently stored in the first basins called the "inlet". From here water is send to the second basin the FWS wetland, to remove inorganic pollutants and possible other metals. As mentioned before, metals are not the pollutants we focus on due to a lack of accurate data, however research revealed that concentrations of several metals decreased after flowing through FWS wetland system. In this water treatment facility focus lies on sulphate reduction.

Then it flows into the third basin, the SSF wetland to remove organic pollutants

The third step in the water treatment facility comprises of a SSF wetland system. Inhere predominantly organic pollutants, like hydrocarbons, are removed. This system is showed in figure 9.37.

The BP former refinery in Casper, Wyoming served as an important reference case in designing the system

9.6.4 BP former refinery in Casper, Wyoming as a reference

The British Petroleum (BP) former refinery in Casper, Wyoming served in our case as an important reference for the development of this water treatment system (Wallace, Schmidt and Larson, 2011).

At first because the dominant pollutants were similar, namely hydrocarbons. We therefore assumed that the design of this wetland treatment system should have a lot of similarities with our system. Which has resulted in a corresponding succession of wetland types in our designed water treatment facility. In figure 9.38 you first see

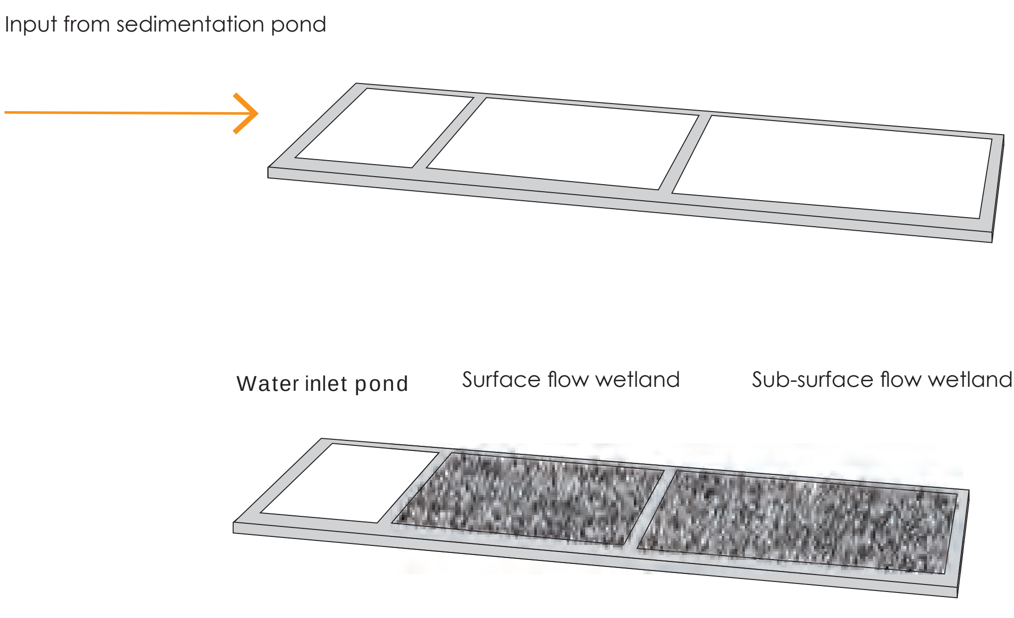


Fig 9.37: The secondary treatment system

the system of Casper, Wyoming and below the system we used for or water treatment facility. As you can see we used the same order and types of wetlands.

In here they dealt with similar pollutants

Besides appearance and type of wetlands, an important aspect in which we used the former BP refinery as an reference, was the determination of the size of the water treatment facility.

The following data was mentioned in the article:

This reference was also used to determine the size of the faciity

- In the former BP refinery the FWS wetlands have a combined area of 0.6 ha ad the SSF wetlands have a combined area of 1.3 ha.
- The design flow rate for the system is 6,000 m3/d (Wallace, Schmidt and Larson, 2011).

We have the following data when it comes to the production process of the Suncor mine:

- 294,000 barrels of oil are produced per day
- 294,000 barrels of oil equals 105,125 m3 of water per day
- 105,123 m3 / 6000 = 17

17 is the factor by which our water treatment system thus must be increased.

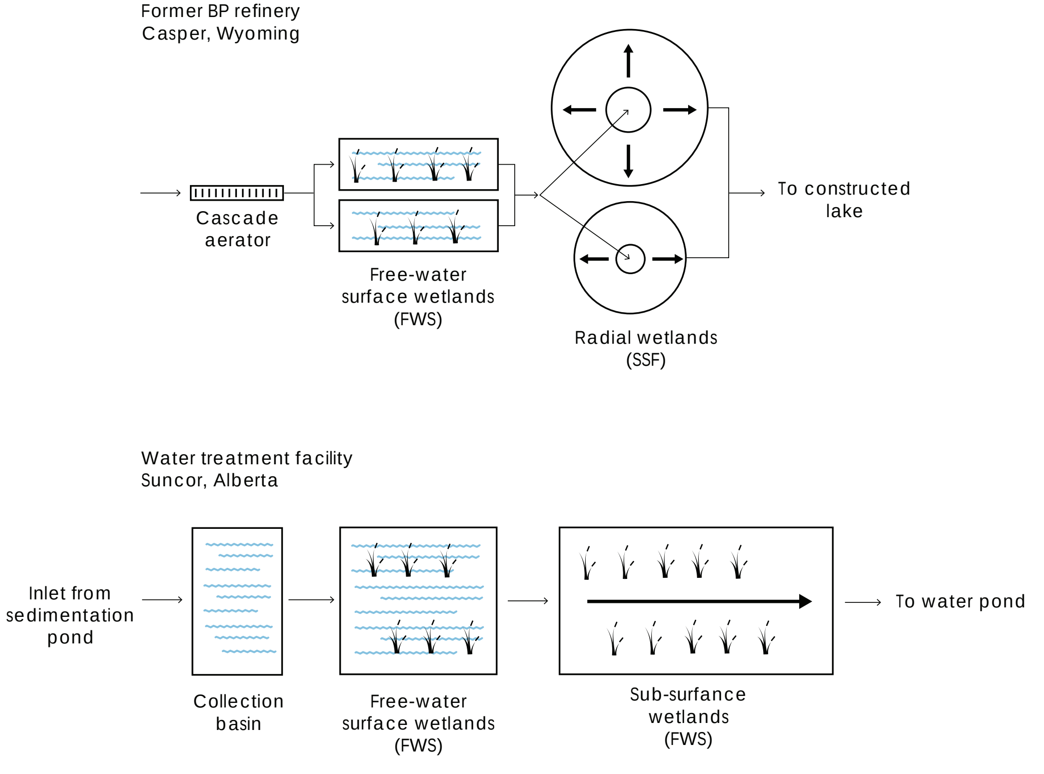


Fig 9.38: The Wyoming system compared to our system (Wallace, Schmidt and Larson, 2011)

This comes down to the following:
0.6 x 17 = 10.2 hectares
1.3 x 17 = 22.1 hectares

This watertreatment facility has a size of at least 32.3 hectares

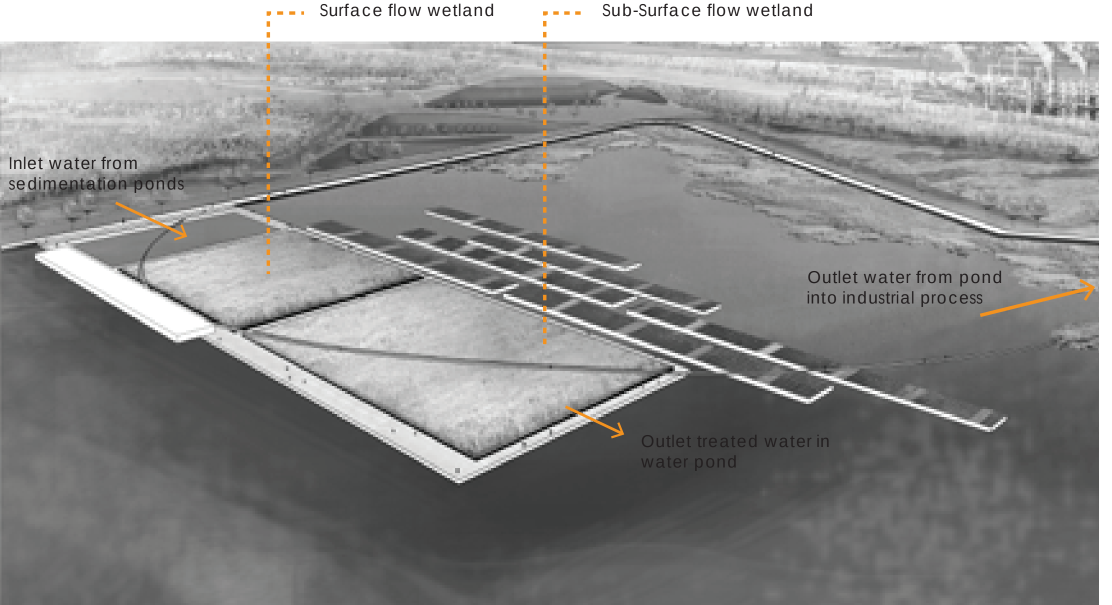
Our water treatment therefore has to be at least 32,3 hectares.

In the image on the next page a visualization (fig. 9.40) is showed of the water treatment facility in the water ponds. Next to the water treatment floating algea basins are developed, since research showed that algae grow well in polluted waters with high organic content.

In the following image (fig. 9.38) this visualization is showed in a smaller version to explain the process again. First the water from the sedimentation pond is pumped into the inlet pond; from here it is pumped into the Surface flow wetland to remove inorganic pollutants. Then it flows into the last pond which is the Sub-surface flow wetland. Inhere organic pollutants are removed. From here the water is released into the water pond. From the water pond the water is pumped out and ready to be used in the industrial process again.

In figure 9.39 all the steps taken in the water process from the sedimentation pond to the water pond is showed. As mentioned before, not only the contaminated water in the tailings ponds is a problem. The mature fine tailings in these ponds form a main issue for reclamation. In the following section we continue with the industrial water system. This part will be focused on dealing with the mature fine tailings.

Fig 9.38: The secondary treatment system of the waterpond



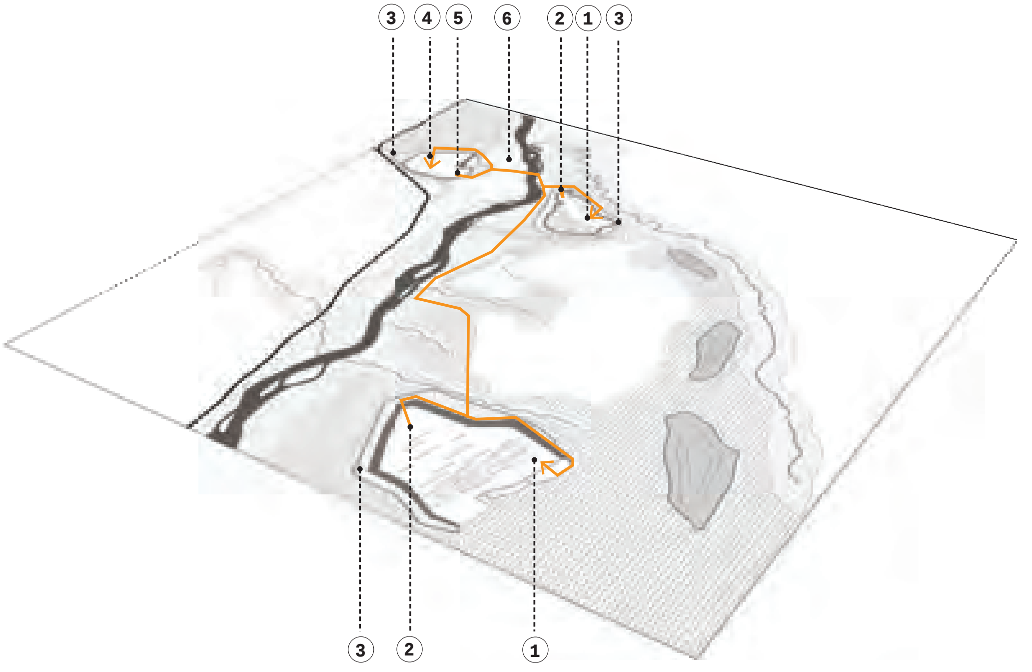


Fig 9.39: The process from sedimentation pond to water pond

1. Tailings pumped into sedimentation pond

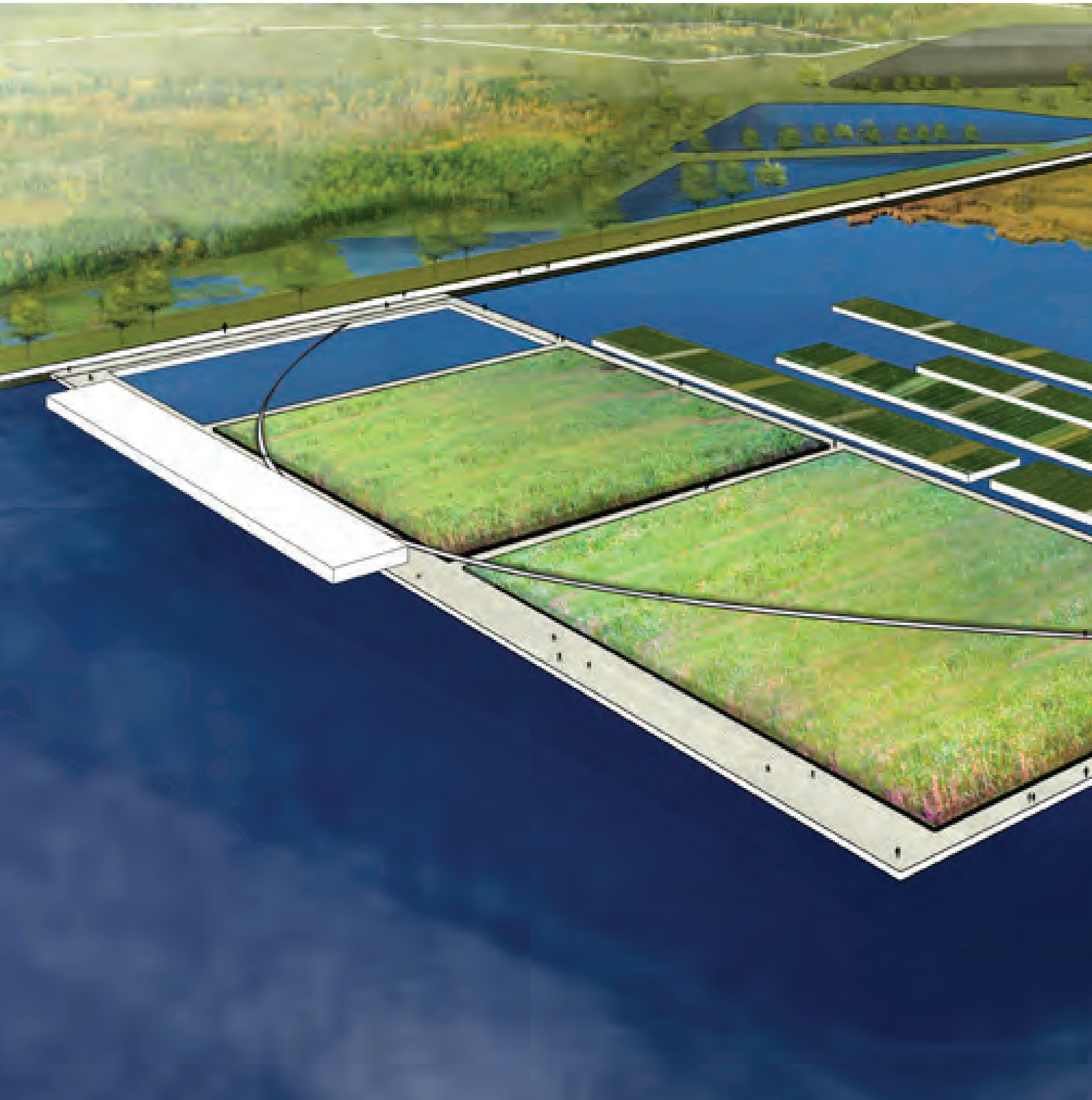
2. Treated water transported to water ponde

3. Due to surrounding wetlands seepage will be collected

4. Input of water in water pond for secondary treatment

5. Output treated water which can be reused in the industrial process

6. In the upgrader less extraction from river is needed



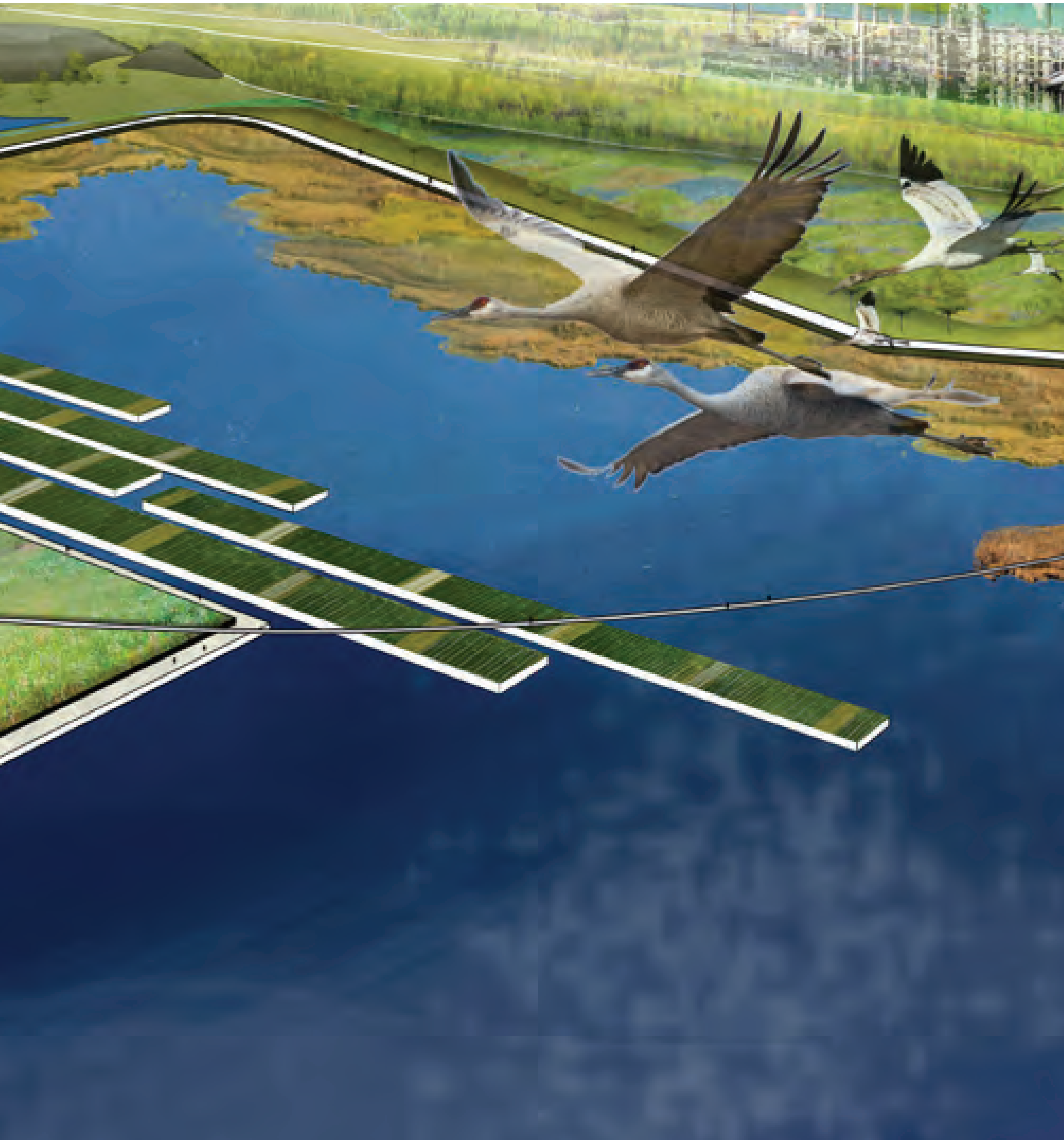


Fig 9.40: A visualization of the waterpond

9.4 A design for the mature fine tailings

This part of the design is focused on dealing with the mature fine tailings (MFT)

The former explained tailings pond designs were focused on enhancing the sedimentation, treating the water, and capture the seepage. This part of the design is focused on how to deal with the mature fine tailings which form a main problem in current reclamation. This will be explained in the following section.

9.7.1 The current method

MFT form a big problem in reclamation because of their extremly slow settling

The main objective in treating the oil sands tailings is to remove water so that a trafficable (load-bearing) surface develops in order to start reclamation (BGC Engineering Inc., 2010). As mentioned before, mature fine tailings therefore pose the biggest problem because of their extremely slow settling and consolidation, which may even take decades.

Currently they deali with MFT by depositing it on so called drying areas.

The operating companies developed a technique to deal with this issue. Within this technique the MFT is first mixed with a polymer flocculent, and centrifuged to thicken the tailings. After this process the tailings are deposited in thin layers on an open field with shallow slopes to let it dry atmospherically (fig. 9.41). This process takes several weeks, which is a positive aspect. After this drying process a trafficable surface is developed, to subsequently start reclamation. Which means returning it back to forest and wildlife area.

This technique requires a large landscape

However this technique requires a large landscape, which results in more surface disturbance and a lot of water is lost due to evaporation, which means that less water can be reused again (BGC Engineering Inc., 2010 and Hrudey, et al., 2010). This means this technique contradicts with the challenges we want to achieve in our design.

Fig 9.41: A photo of a so called drying area

We want to return the already disturbed land into a high quality landscape and counteract further disturbance of the landscape.

Once again people tend to look at the current problems through the eyes of a engineer, it lacks a comprehensive approach to solve the problems that occur at all levels in the landscape.

Inhere we strive for a more comprehensive approach as well

All kinds of machines and chemicals are imported from outside of the area to solve the problems. We want to establish a more sustainable living environment, importing everything from outside of the region does not correspond to our line of thought. We see sustainability as the regenerative capacity of nature recovering itself within time during and after disturbance has taken place. To finally develop a high quality landscape.

Inhere we want to use the MFT to create a whole new landscape. The first step in this process is placing the mature fine tailings in a place which is already disturbed, in order to avoid further disruption of the landscape.

We therefore prpose to use the MFT to create a new landscape

While looking at the industrial activities, the mining activities disturb the land the most, since this results in big open pit mines. This combination of thoughts made us come up with the idea to deposit the MFT in the open pit. In figure 9.42 is showed how we want to store MFT in the mine instead of store the MFT throughout different places in the whole plant. This results in less surface disturbance. In doing this we have the challenge to return this disturbed land into a high quality landscape for people and the environment. The following section explains how we tried to address this.

We will use MFT to reclaim the open pit mine

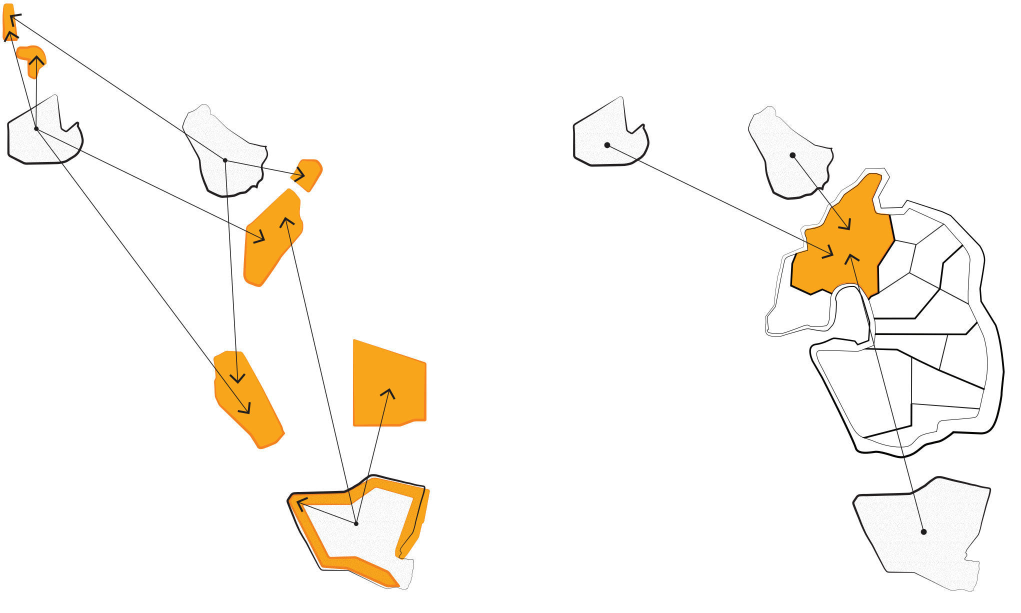


Fig 9.42: Storage of MFT in mine instead of different places throughout plant

9.7.2 *A new way of reclamation*

At first the mine is filled with a cover layer of sand

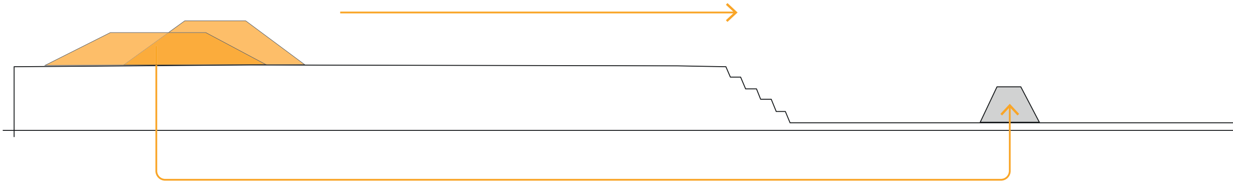
On top of that MFT is stored

Since we as landscape architects believe in the regenerative capacity of nature recovering itself within time during and after disturbance has taken place we tried to find a solution along these lines. In current mine reclamation processes a dike is placed between the active mine floor and the area which is already mined out (fig. 9.43 step 1). The in between area that occurs is filled up. In our design this will also be done. First a dike will be created and the area that arises will first be filled with sand from the overburden dumps (fig. 9.43 step 2). This material is not only functioning as a infill material, but also as a cover layer to prevent seepage caused by the layer of MFT flowing to the groundwater. So A layer of MFT is stored on top of the sand layer (fig. 9.43 step 3)

To achieve a diverse landscape: we developed four different reclamation principles

Because we want to achieve a diverse and high quality landscape for people and nature we come up with 4 different principles to reclaim the mine. Within these principles layers of MFT are dumped in various thicknesses, substances and manners. This finally results in a landscape which varies in height and landscape typologies. This means a diverse landscape will be created which forms an interesting landscape for recreational purposes and besides that different animal species will be attracted to this area.

Step 1



Step 2

Step 3

Fig 9.44: A photo of the open mine pit in operation

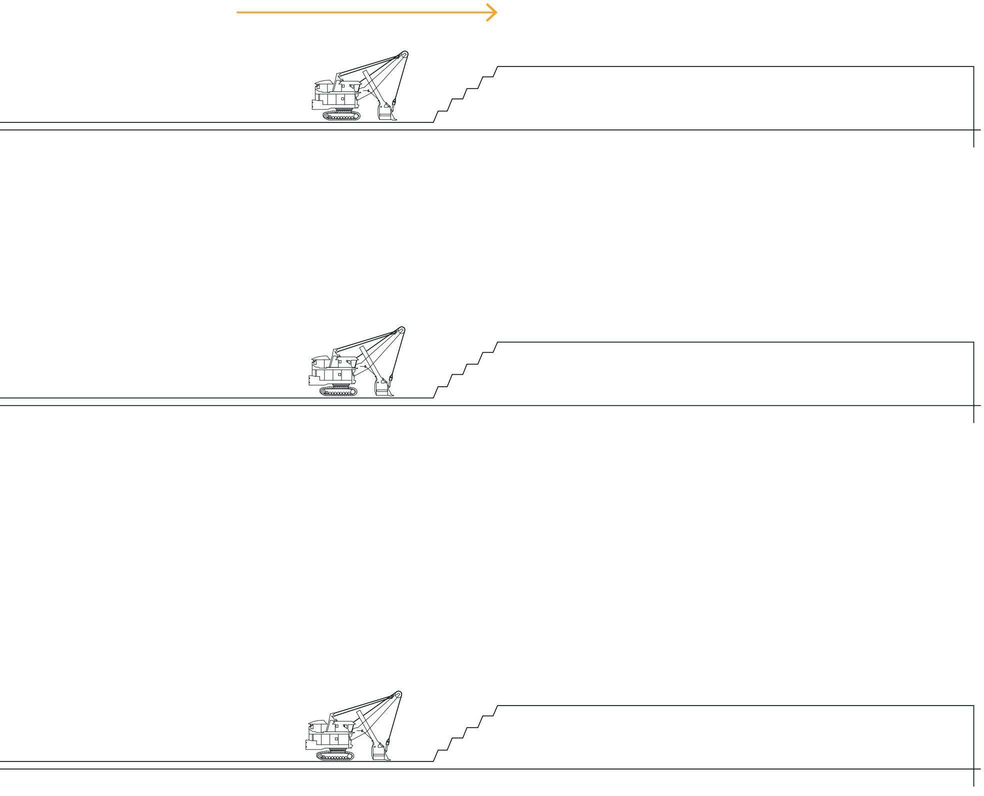


Fig 9.43: The reclamation process

In the first Principle no MFT is stored,

In the first principle only a layer of overburden sand will be added. Normally the mine pit is about 70 meters deep. By filling this up to a pit of 45 meters deep the area will still be experienced as a mine pit but will be more accessible.

These parts will be experienced as an open pit

Within this area a barren expanse of sand will arise. In a time period of about 30 years some perennial plants and grasses with scattered bushes of shrubs will emerge. Because the area is still located 45 meters below surface groundwater will come up her more quickly, which results in some swampy areas (fig. 9.45).

In the second principle a thick layer of MFT is added, due to sedimentation processes a lake will emerge

In the second principle, again a layer of overburden sand will be added. On top of this a layer of about 6 meter of MFT is added. Within time, sedimentation of the fine clay particles takes place. While the fine particles settle to the bottom a lake will emerge (fig. 9.46).

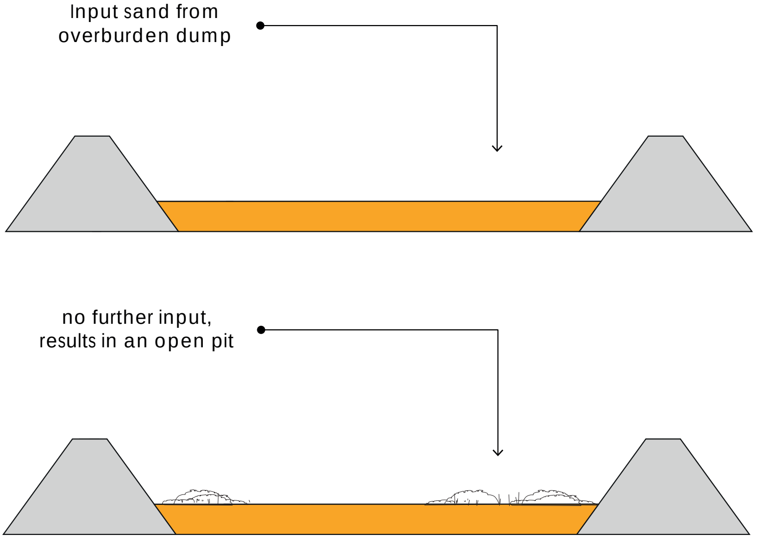


Fig 9.45: Reclamation principle 1

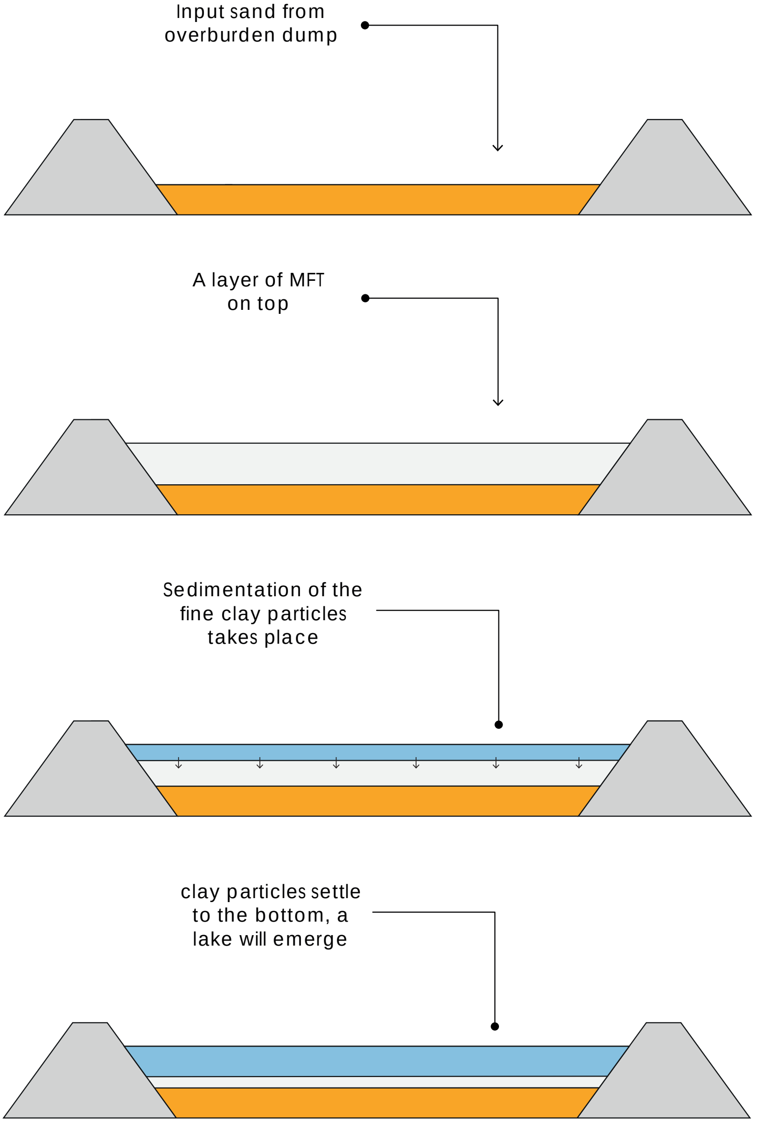


Fig 9.46: Reclamation principle 2

In the Third principle a mixed layer of MFT, woodchips and peat is added.

In the third principle a layer of overburden sand is first added used as both infill and cover system. On top of this a thin layer of about 1, 50 meters is added on top of this. The layer of sand prevents leakage of the MFT layer with its surroundings. Within this principle the MFT is mixed with peat and woodchips (fig. 9.47).

As mentioned before in the current method a polymer flocculent is added to thicken the MFT. Before thickening, the MFT contain a solids content of about 30% which can be compared with yogurt (OSRIN, 2014). Within the layer we add, peat and woodchips to thicken the tailings up to 50% solids. In this way local products are used in the process, since the surrounding areas primarily consist of peat lands and timber production forest. Besides that it also stimulates the vegetation growth, since a suitable organic layer will develop.

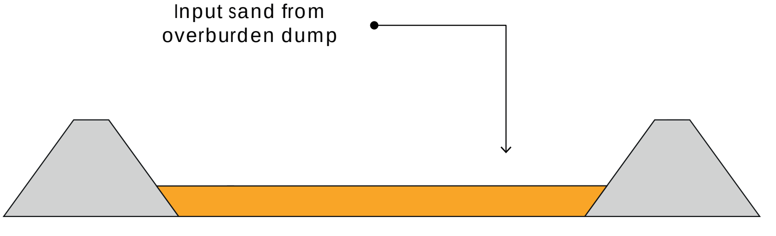
On top of that reed vegetation is planted to absorb the water

On top of this mixed layer reed vegetation is planted. This reed absorbs the water which is also conducive for the thickening process. After a year a new mixed layer will be stored on top of this. Again reed vegetation is planted on top of this, and the absorption process will start again.

By repeating this process different organic layers will emerge

Which eventually results in a wetland typology

By doing this for a several years, the mine will be filled by several layers of organic material. Since no further drainage takes place the area will develop as a wetland, first a swamp with some emergent vegetation and later this probably develops in marsh vegetation (fig. 9.48).



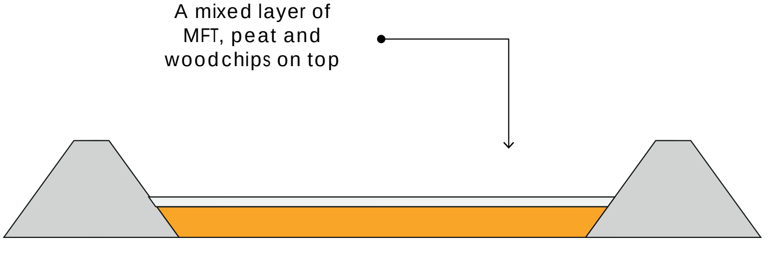


Fig 9.47: Reclamation principle 3 (part 1)

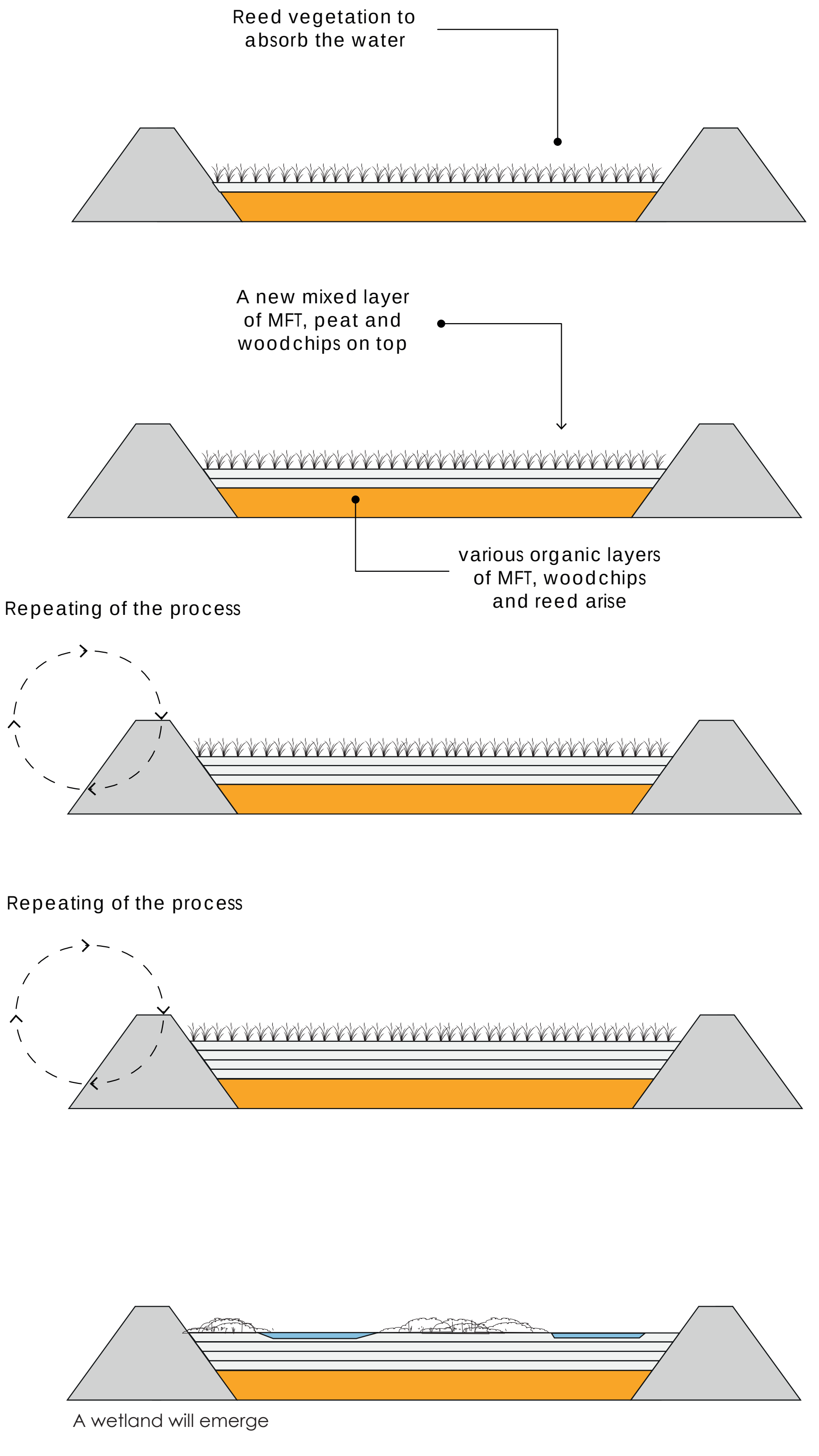


Fig 9.48: Reclamation principle 3 (part 2)

In the fourth principle a mixed layer of MFT, woodchips and peat is added as well

Drainage will take place by means of canals to enhance the soil compaction process

The fourth principle also starts with a layer of overburden sand. On top of this a layer of about 2,50 meters of MFT is placed. This layer is also mixed with peat and woodchips. On top of this layer again reed vegetation is planted to absorb the water. Besides that drainage canals are dug to drain extra water in order to enhance the soil compaction process (fig. 9.49). This way of doing reclamation can be compared with the way they reclaimed the land in the Dutch polders. Which means this is already a proven technology of doing reclamation.

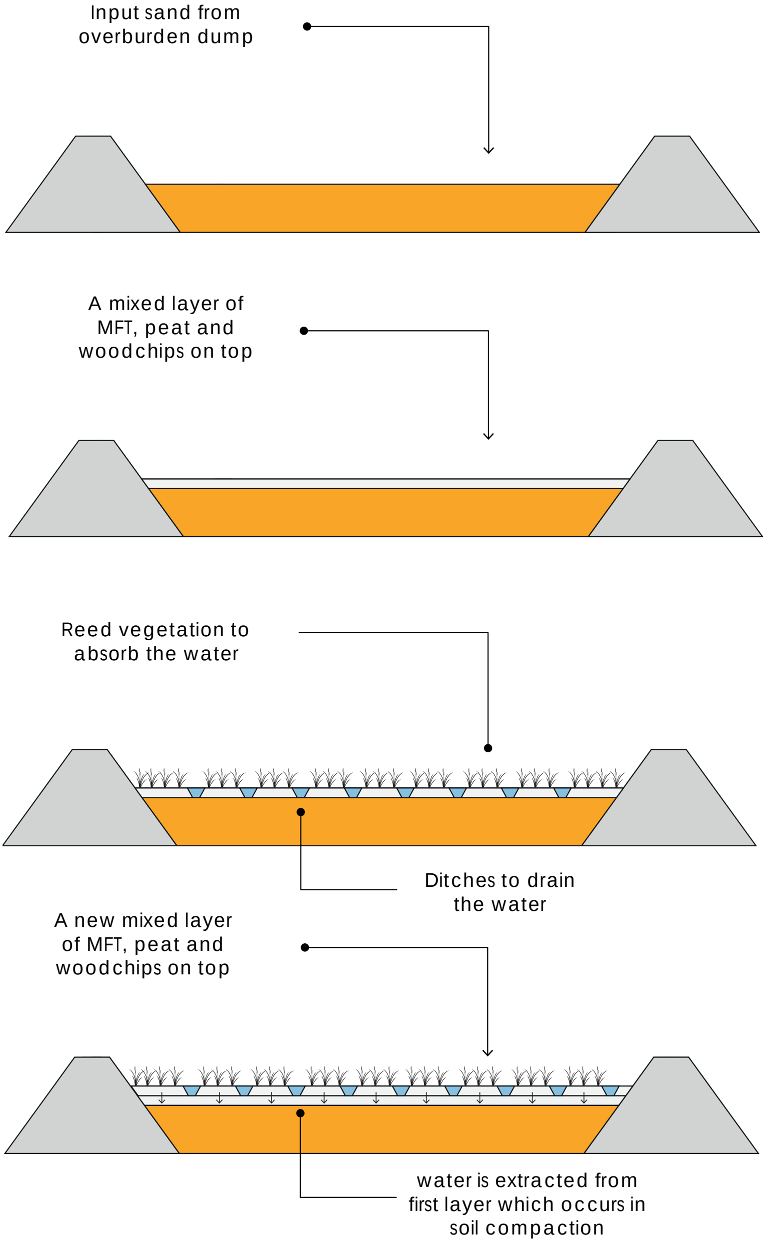


Fig 9.49: Reclamation principle 4 (part1)

In the Netherlands hundreds of square meters below sea level are reclaimed.
Every year a new layer will be placed on top of the former layer, and also reed vegetation will be planted again. By constant drainage, this principle will finally result in a stable and trafficable soil consisting of several organic layers. This makes it possible for grassland vegetation to grow quickly on these soils. Later on this grassland vegetation will develop in shrubs to finally grow to a forest in time (fig. 9.50).

To be able to implement these four principles in the open pit, we first did research on the mining process. By getting an understanding of the way they mine and in which period of time, we were able to design for reclamation. This will be explained in the following section.

By repeating this process a dryer soil consisting of several organic layers will emerge

Which eventually leads to the development of a forest

To be able to implement these principles we first did research on the mining process

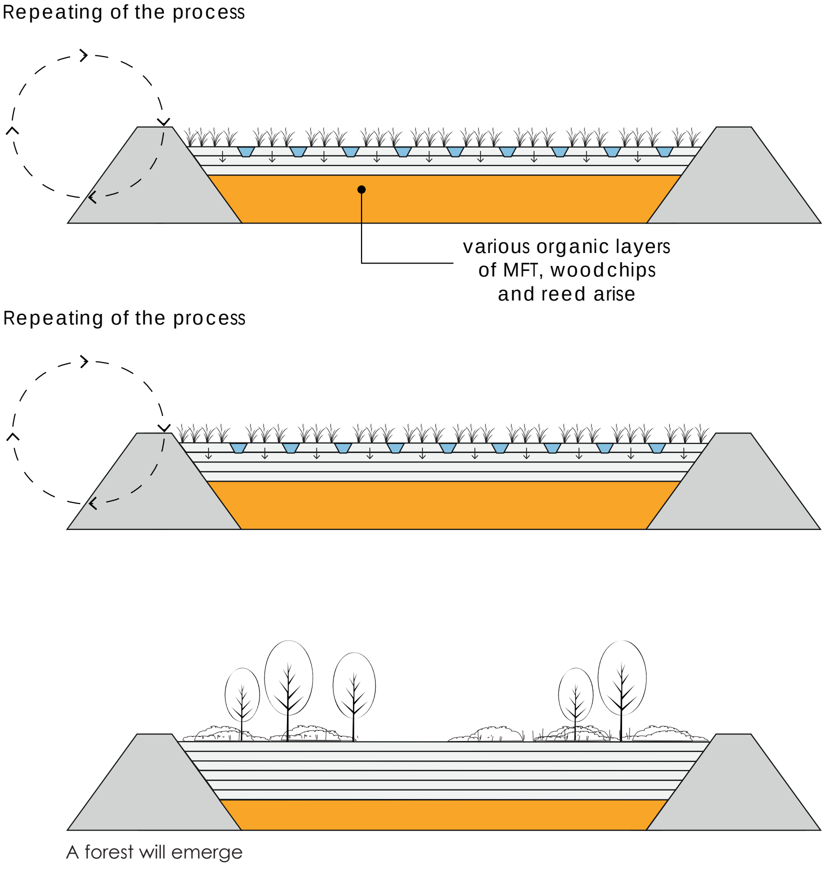


Fig 9.50: Reclamation principle 4 (part 2)

This research focuses on Suncor´s Millennium mine

9.7.3 *The new reclamation process*

As mentioned before we first did research on the mining process. Important to mentions is that this research is focused on Sunor's millennium mine, this forms the biggest mine in the area which is in fully operation (fig. 9.51).

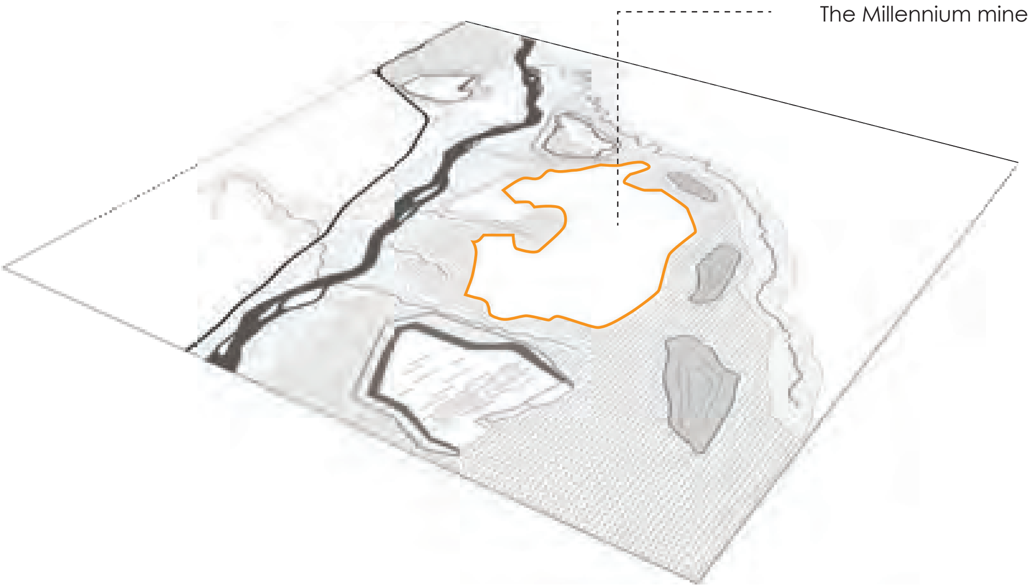


Fig 9.51: The location of the Millennium mine

this research was mainly about the mining activities in relation with time

The research on this mine was mainly focused on the direction in which they mine and in which period of time an area is active and which period of time an area is closed. In figure 9.52 the mine is showed and the arrow displays in which direction mining activities take place. Because these activities move forward, the area which is left behind and not used any more can be reclaimed already.

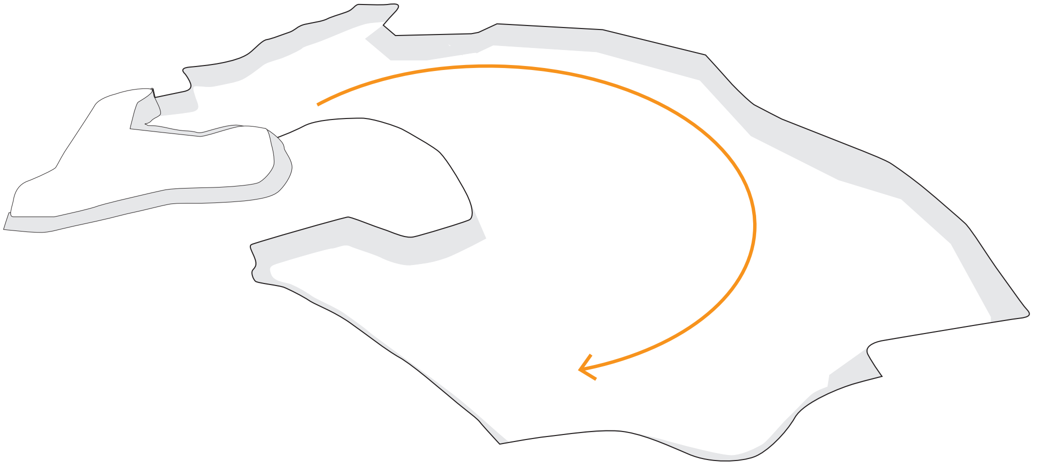


Fig 9.52: The direction in which mine activities take place

By analyzing this movement in comparison with time we were able to divide the reclamation process in 5 different phases. This is showed in figure 9.53, in the first area reclamation can start in 2014, the second can start in 2018 and so on.

By doing this we were able to divide the reclamation process in 5 different phases

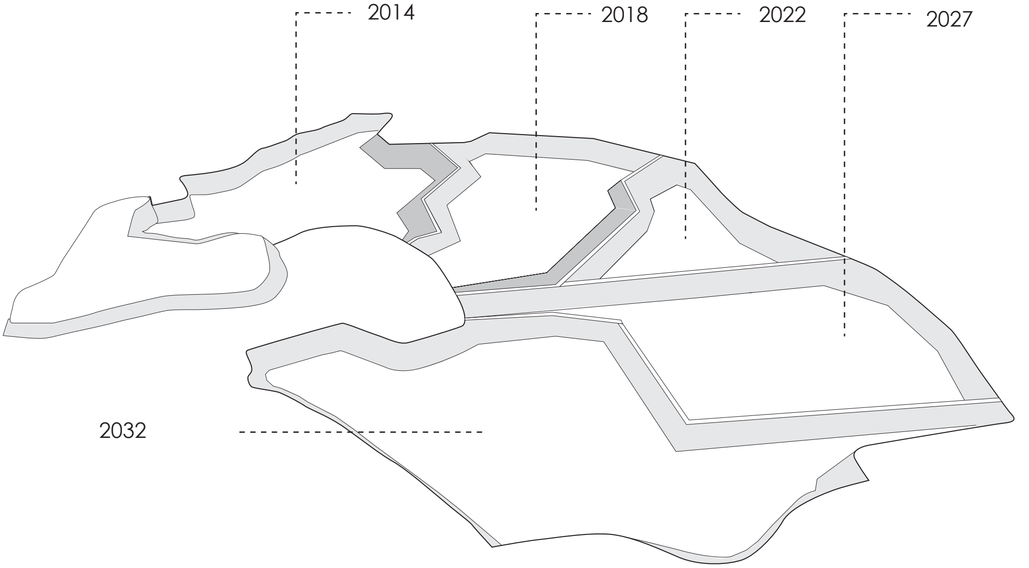


Fig 9.53: Start of reclamation phases

At this moment, we know in which time phase which part of the mine can be filled up by using one of the former explained reclamation principles, since we however want to achieve a diverse landscape, which varies in vegetation and height, we decided to divide the 5 different phases in smaller compartments by means of dikes. By doing this more variation in the landscape will arise because the different principles of reclamation can be used in more areas and in different time phases.

Since we want to develop a diverse landscape which varies in height and vegetation the 5 phases will be divided in smaller compartments

Besides a diverse landscape the other purpose of doing this form of reclamation is the storage of MFT. Since we focus on reclaiming Suncor's Millennium we want to be able to store the MFT which is produced by this mine.

Besides that we also want to store all the MFT in this process

In the current industrial processes about 1 barrel of oil produces ¼ m3 of mature fine tailings (WWF-Canada, 2012 ; Beier and Sego, 2013). Suncor's millennium mine produces 294.000 barrels of synthetic crude oil every day (Oil sands developers group, 2012). This means a year production of 107.310.000 barrels.

Currently the Millennium mine produces 26.827.000 m3 MFT per year

107.310.000 x 0.25 = 26.827.500 m3 MFT production per year

On basis of that calculation we started to design for every mine phase with the different reclamation principles

Since we add 20% of solids (peat and woodchips) to thicken the MFT we come to a sum of:

26.827.500 m3 MFT per year
+ 20 % solids = 32.193.000 m3 material which needs to be stored in the mine every year.

On the basis of these data we started to make calculations for every mine phase, and made it possible to store all the produced MFT by making use of the different reclamation principles mentioned in 9.4.2. The calculations made for every phase can be found in the attachment.

By making use of these calculations we were able to store all the produced MFT. Besides storing all the produced MFT we have achieved to store the MFT according to our four developed reclamation principles as explained earlier. In the following figures is showed how this mine exactly is filled every mine phase, and which principle of reclamation is used to do this.

In the following figures (fig. 9.54 - 9.58) this process is showed. These figures indicate in which parts reclamation can start, in which part they will still mine and which principle of reclamation will be used in which area.

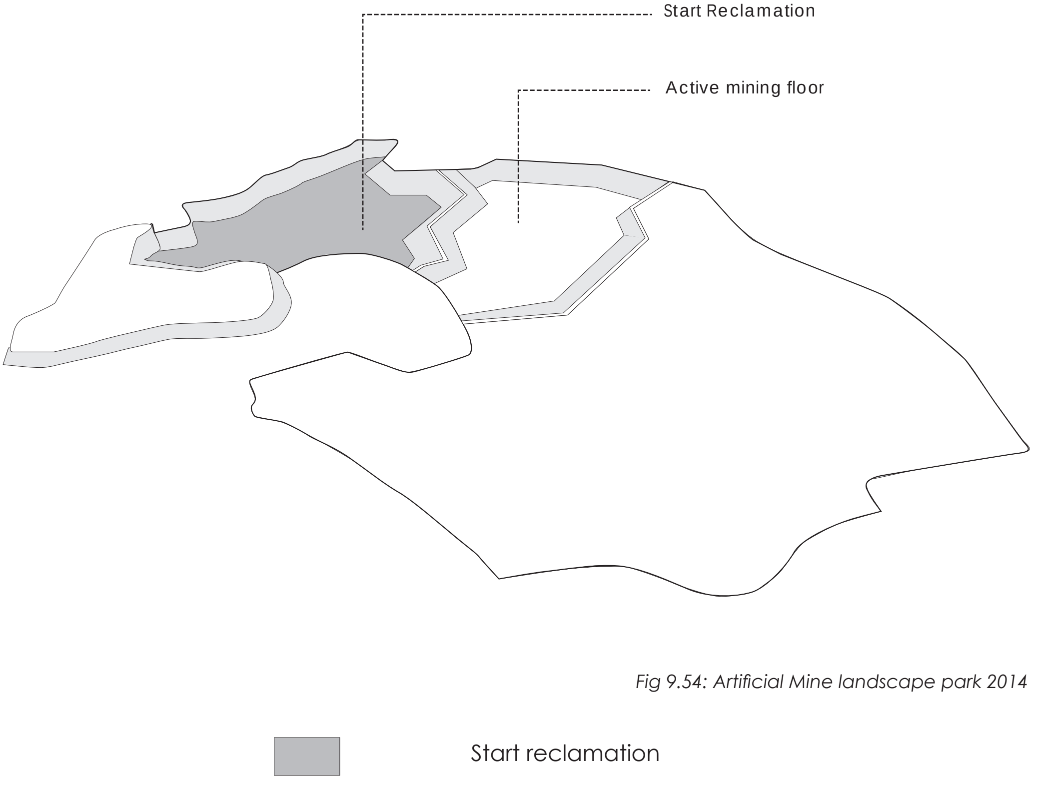


Fig 9.54: Artificial Mine landscape park 2014

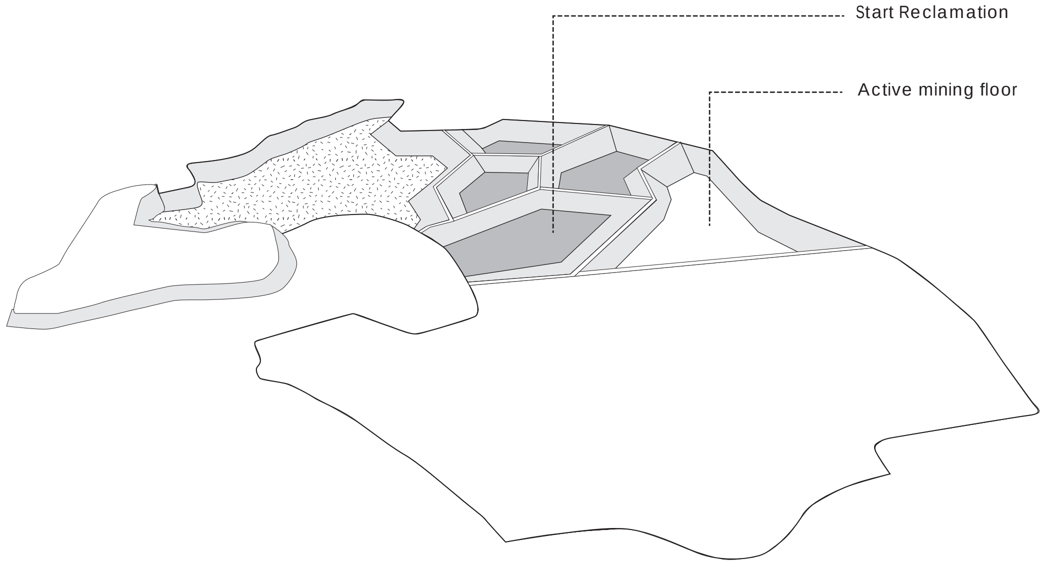
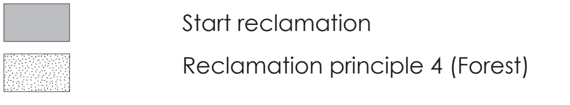


Fig 9.55: Artificial Mine landscape park 2018



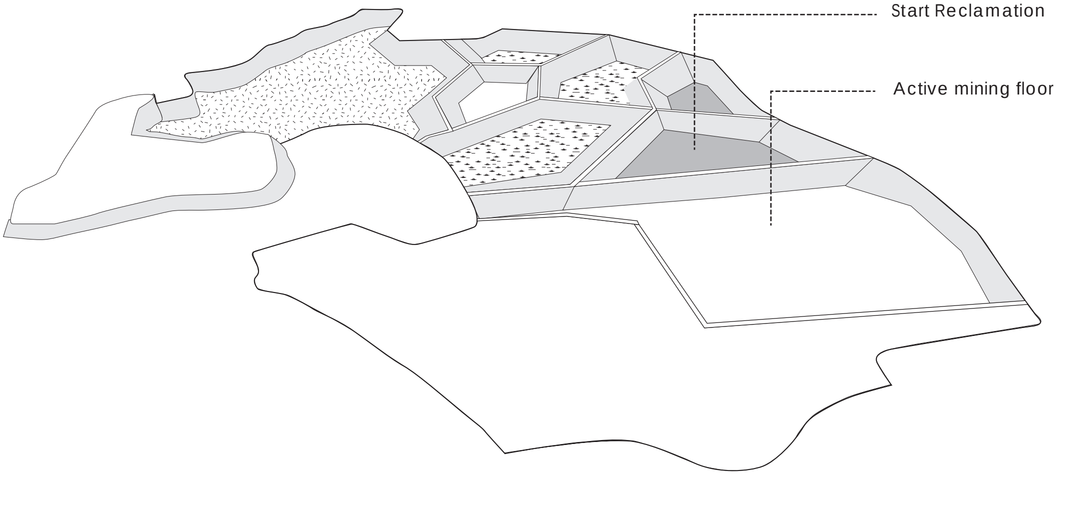
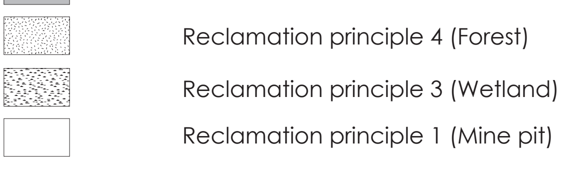


Fig 9.56: Artificial Mine landscape park 2022



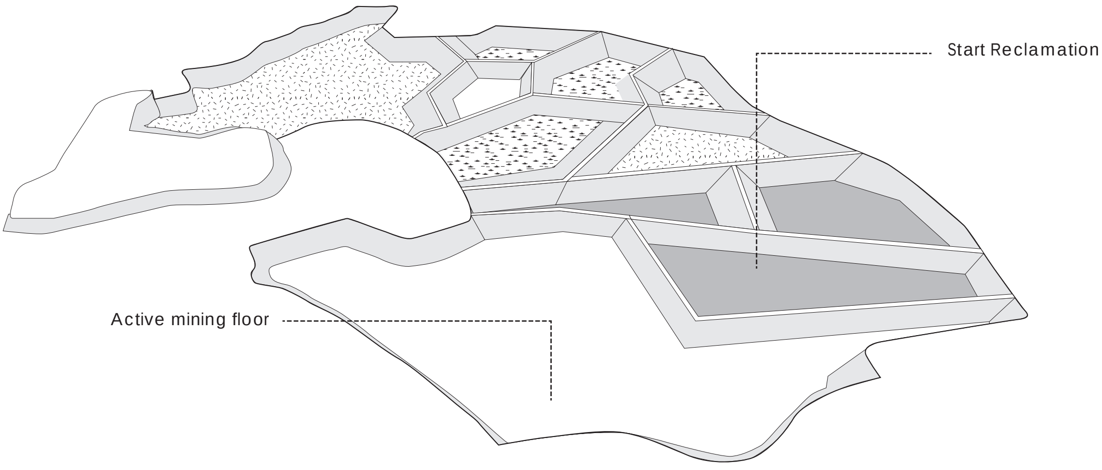
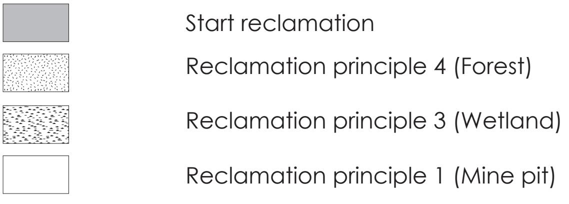


Fig 9.57: Artificial Mine landscape park 2027



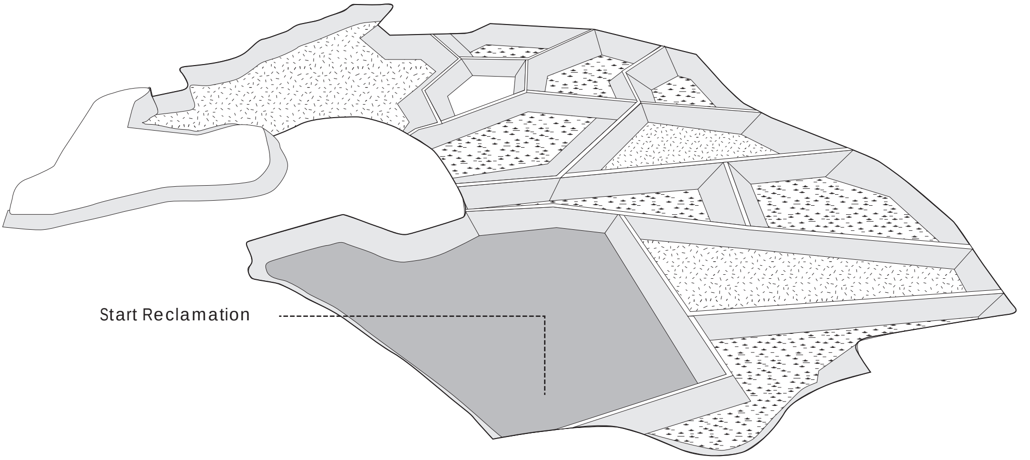
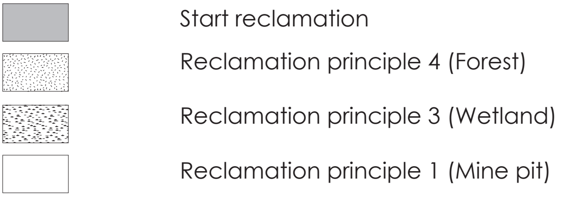


Fig 9.58: Artificial Mine landscape park 2032



In the end a diverse and artificial mine landscape will emerge. This landscape varies in height and vegetation because the created principles of doing reclamation are applied in several areas. In figure 9.59 a height model is showed. This figure also indicates which principle of doing reclamation is applied in which area.

In the end a reclaimed artificial mine landscape park will be created

In figure 9.60 and 9.61 on the next page two cross sections of the mine landscape park are showed. In these cross sections is clearly viewed how the different reclamation principles develop between the several dikes and how the areas differ in height.

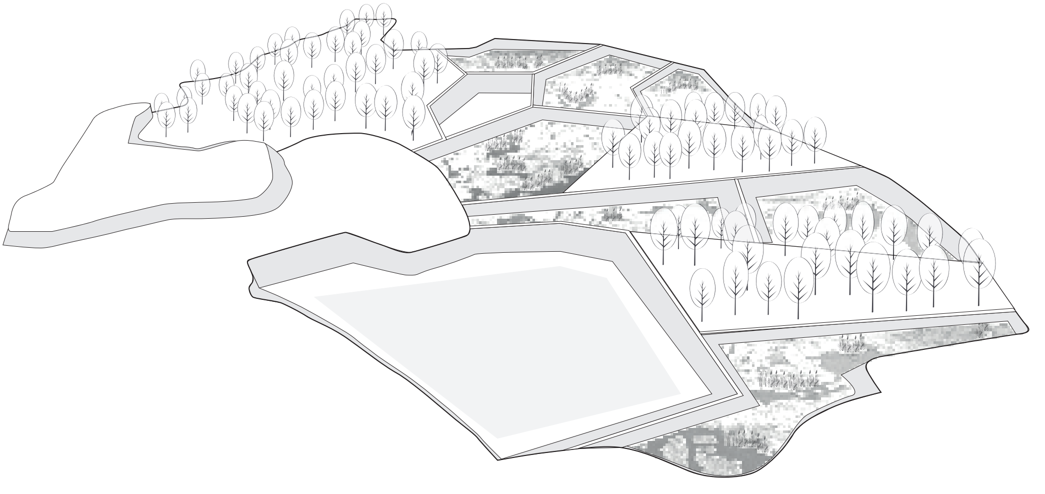
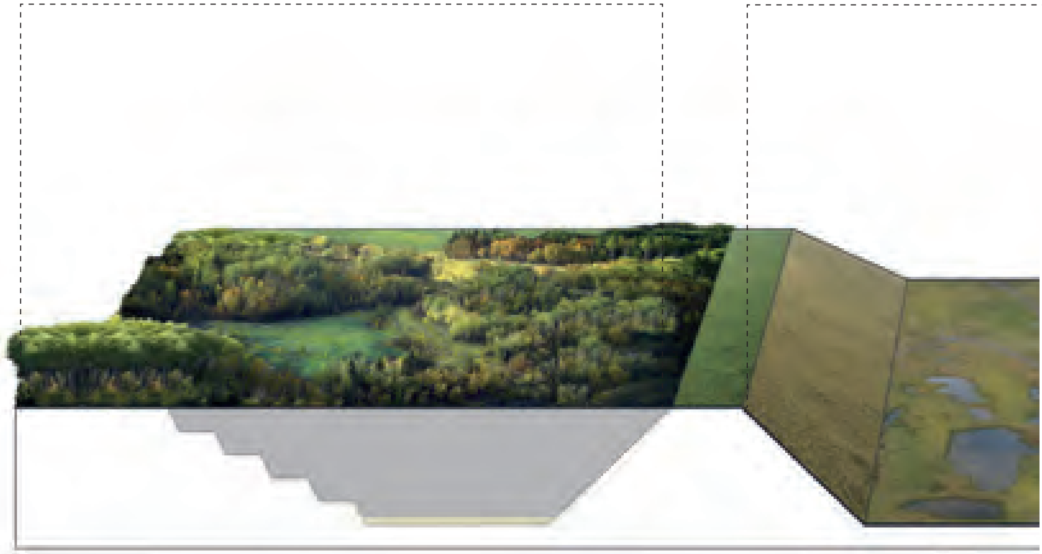
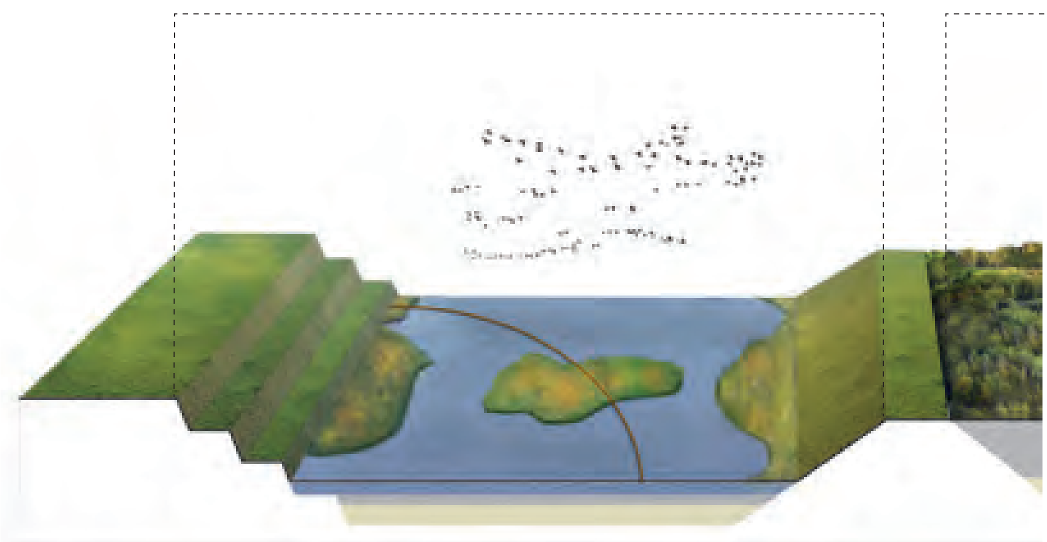


Fig 9.59: Totally reclaimed Artificial Mine landscape park

Forest (Principle 4) Mine pit (principle 1)



Lake (principle 2)



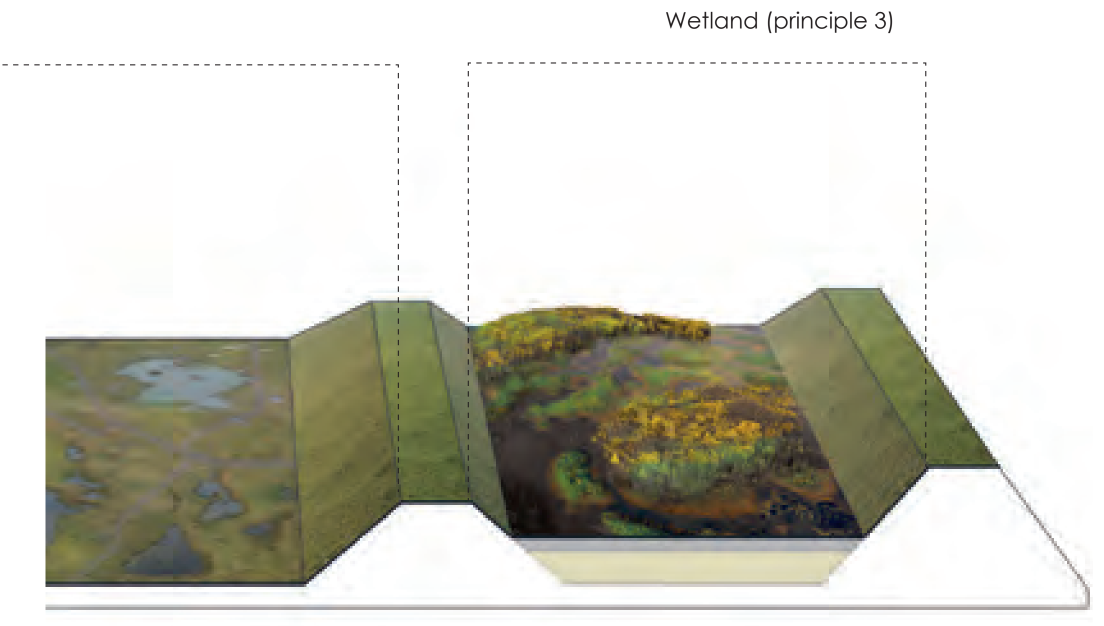


Fig 9.60: Crossecion 1 Artificial Mine landscape park

Fig 9.61: Crossecion 2 Artificial Mine landscape park

This whole park developes in time, this means that in every phase one can experiene a different landscape

9.7.4 Transformation of Artificial mine Landscape Park

As mentioned before we developed 4 principles for reclamation. These principles are applied in every phase of mine reclamation in the different compartments created by dikes. In the following schemes these principles are showed, for every area is indicated how vegetation will develop in time, and when it forms a habitat for certain animal species. To get an understanding of which area in the mine is mentioned in the scheme we numbered the different areas. This is showed in figure 9.62.

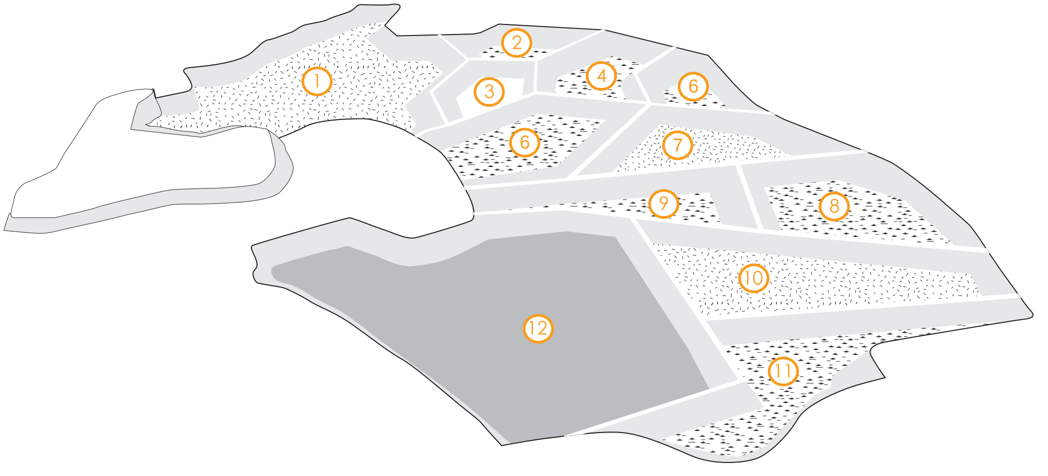


Fig 9.62: The numbered areas

In scheme 1 (fig. 9.63) reclamation principle 1 and 2 are showed. These principles are applied to area 3 and area 12. In principle 1 no MFT is added to the sand layer. First of all a barren expanse of sand will arise. In a time span of about 40 years succession will take place from annual grasses and forbs to perennial plants and grasses to finally end with a landscape of grasses and scattered bushes of shrubs. While succession takes place different animal species will enter the area. In the starting phase this will mainly be birds which need an open area. Later on more large grazing animals as the wood bison and the elk will move to this area.

In principle 2 a thick layer of MFT is added to a sand layer. While the fine clay particles settled to the bottom a lake will emerge. This will finally result in open water with some submergent vegetation. This area mainly forms a habit for waterfowls, the trumpeter swan and the whooping crane.

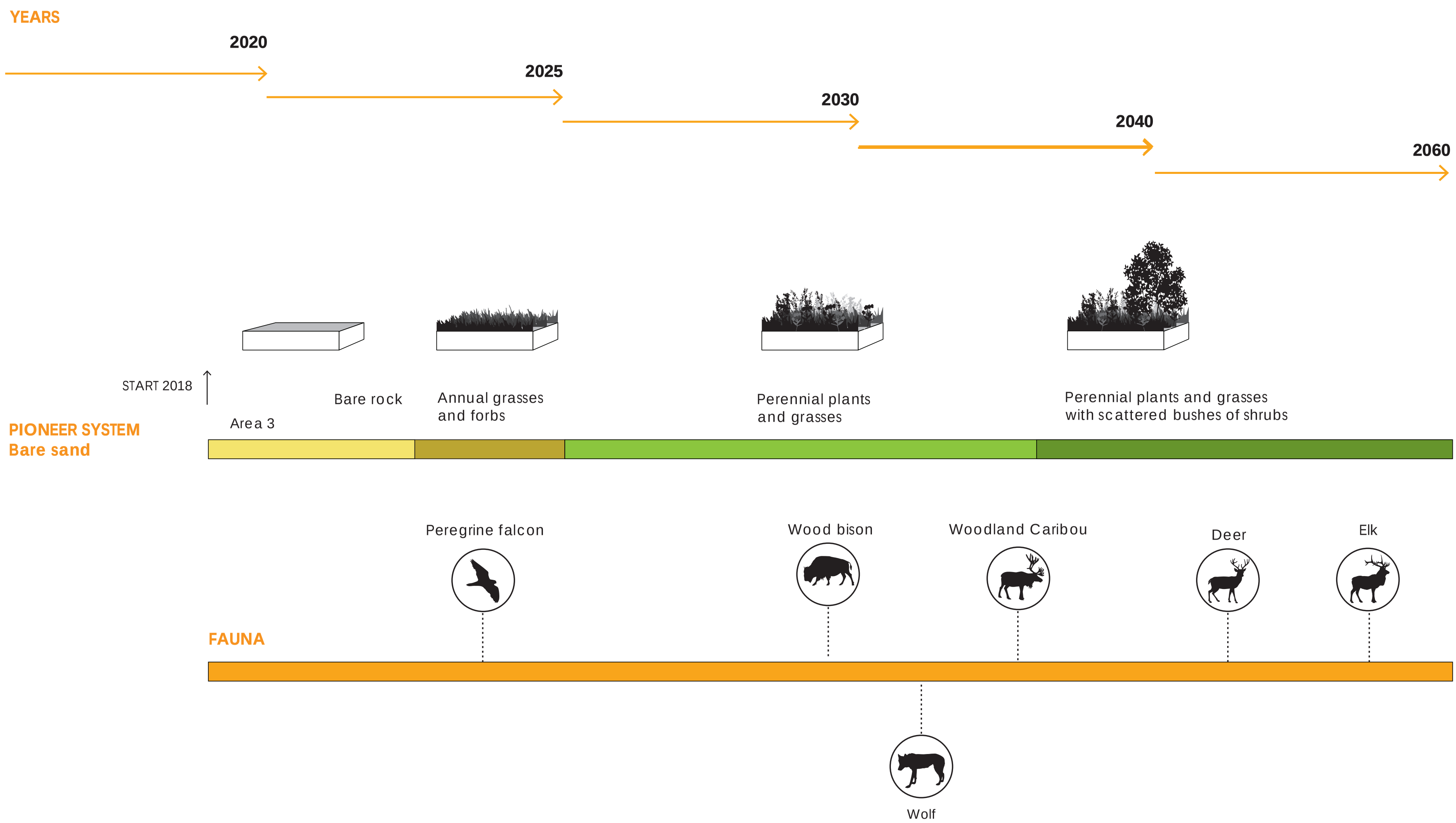
In scheme 2 (fig.9.64) principle 3 is showed. In this principle a mixed layer of MFT, peat and woodchips is added to a layer of sand and planted with reed vegetation. For several years a mixed layer is stored on top of this. The first areas where this principle is applied are area 2,4 and 5. When all the MFT is stored in the areas, several organic layers form the soil, which will still be swampy because no drainage has taken place. Within this swamp some emergent vegetation will arise. In a time span of about 30 years this swamp will get dryer and transform into an area with more marsh vegetation. If nothing is done in this area a forested wetland will eventually develop.

The development of this vegetation is based on our own knowledge, since we have to deal with a cold climate and a soil structure which is not common, further research is necessary. The animal species that could occur in this area are in the starting phase mainly waterfowls. Later on when the area transforms with some marsh vegetation this will be the perfect area for the moose.

In this scheme the differences in phases are showed very clearly. While in area 2,4 and 5 vegetation is already developing area 6 is still in operation. When area 6 starts to develop, area 8 and 9 are still in operation. This means the same principle is used in all these areas, but because reclamation starts on a different moment, the development of the landscape is also in a different phase. This also contributes to the variation of the landscape in experience but also in biodiversity.

In scheme 3 (fig.9.65), principle 4 is showed. In this principle a mixed layer of MFT, peat and woodchips is added to a layer of sand. Reed vegetation is added to absorb the water and besides that the area is drained by canals to enhance the compaction process of the landscape. This principle is applied to area 1, 7 and 10. Important to mentions is that these areas are used in the reclamation process for a longer period of time, because this type allows many layers of MFT which was necessary to be able to store it all. When the reclamation process stop some grasses will already emerge in 1 to 2 years.

In a time span of 2 to 15 years these grasses will transform to shrub vegetation to finally develop into a forest after 16 to 60 years (Pidwirny, 2006). After 40 to 100 years it will reach the climax forest vegetation. In the figure with the arrows is shown how these types of vegetation alternate. This development in vegetation also influences the animal species which occur in this area. When the vegetation start to rise, the area starts to transform into a habit for animals like: the woodland caribou, deer, bear, wolf, wood bison and elk.



YEARS
2020
2025
2030
2040
2060
START 2018
PIONEER SYSTEM
Bare sand
Area 3
Bare rock
Annual grasses
and forbs
Perennial plants
and grasses
Perennial plants and grasses
with scattered bushes of shrubs
FAUNA
Peregrine falcon
Wood bison
Woodland Caribou
Deer
Elk
Wolf

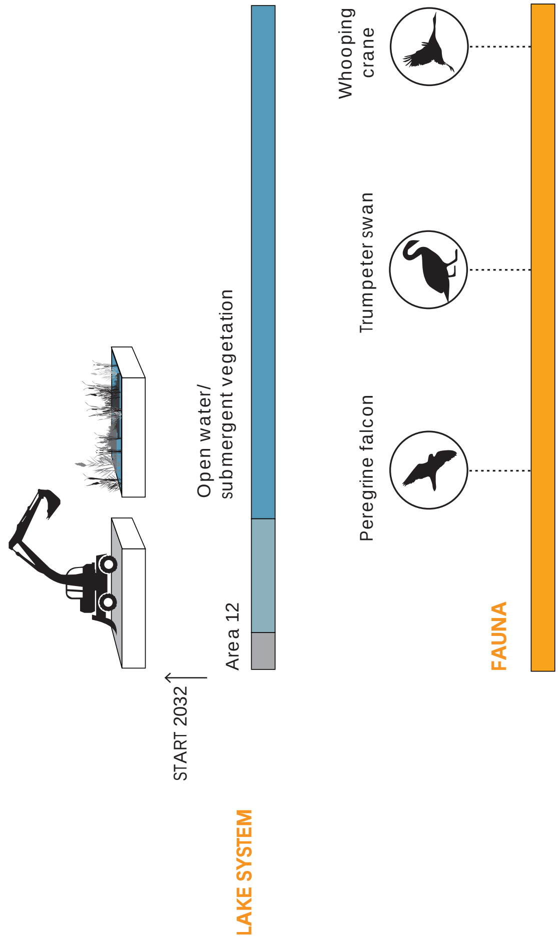
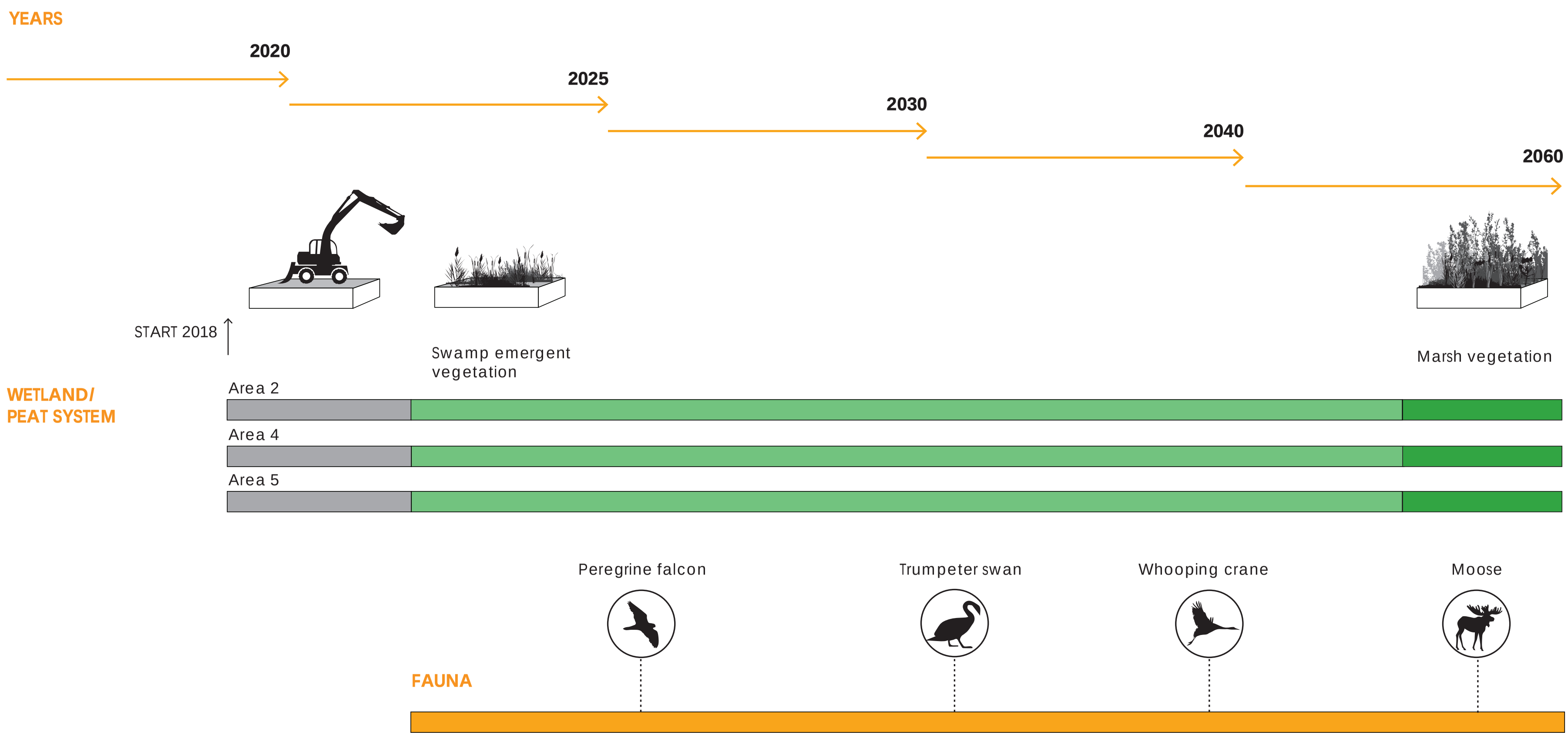


Fig 9.63: Scheme 1 development of principle 1 and 2


YEARS
2020
2025
2030
2040
2060
START 2018
Swamp emergent vegetation
Marsh vegetation
WETLAND/ PEAT SYSTEM
Area 2
Area 4
Area 5
Peregrine falcon
Trumpeter swan
Whooping crane
Moose
FAUNA

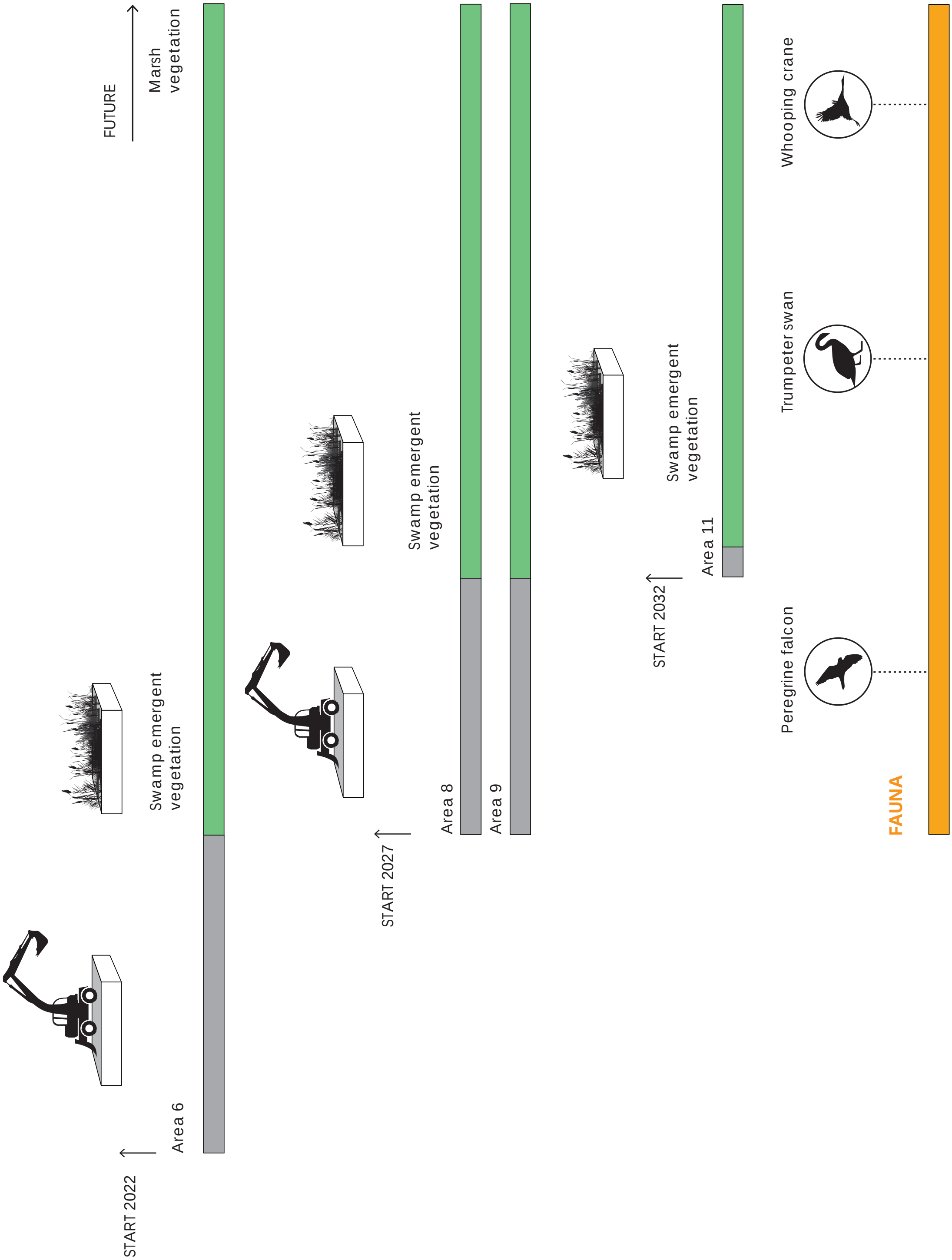
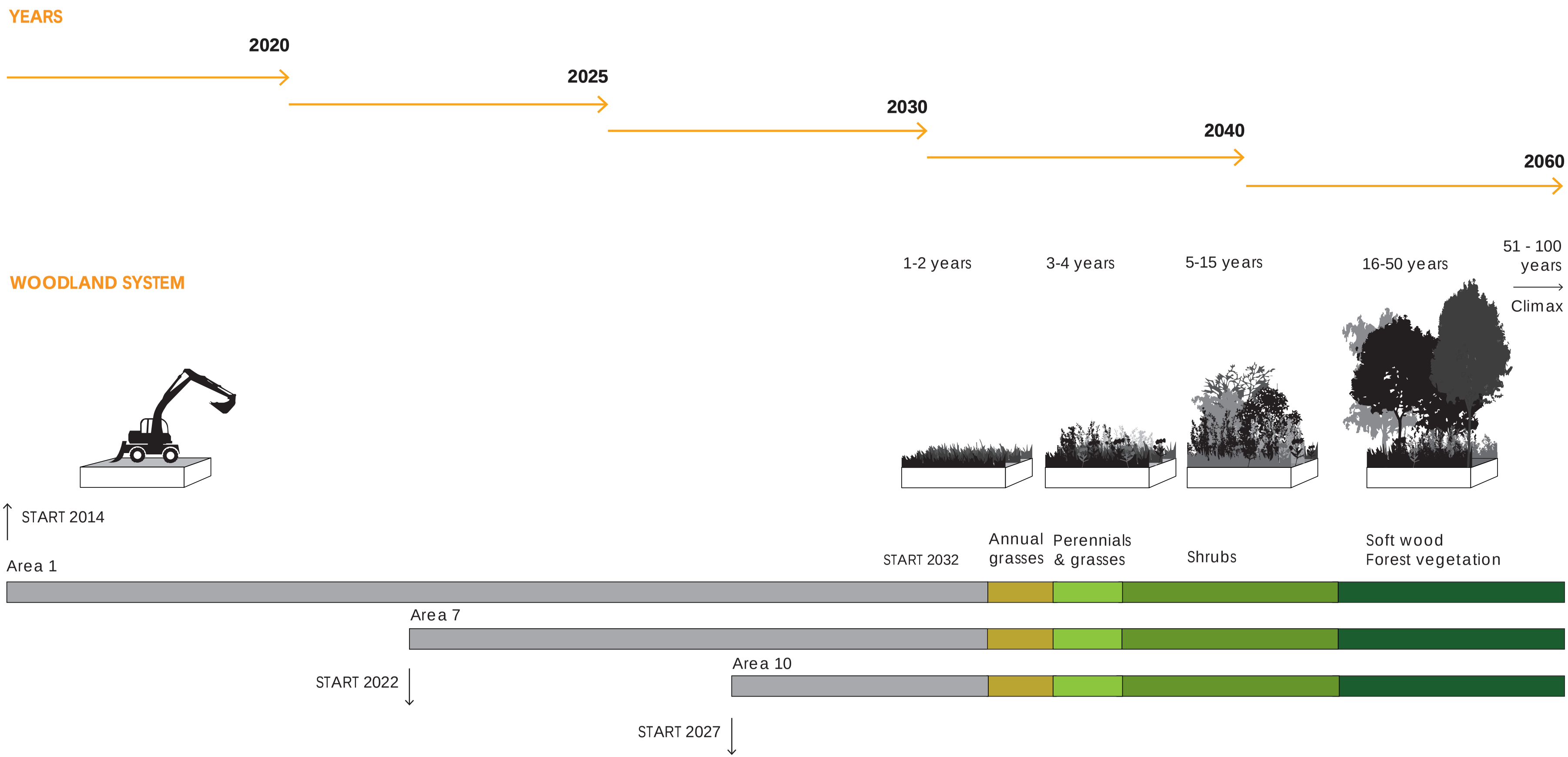
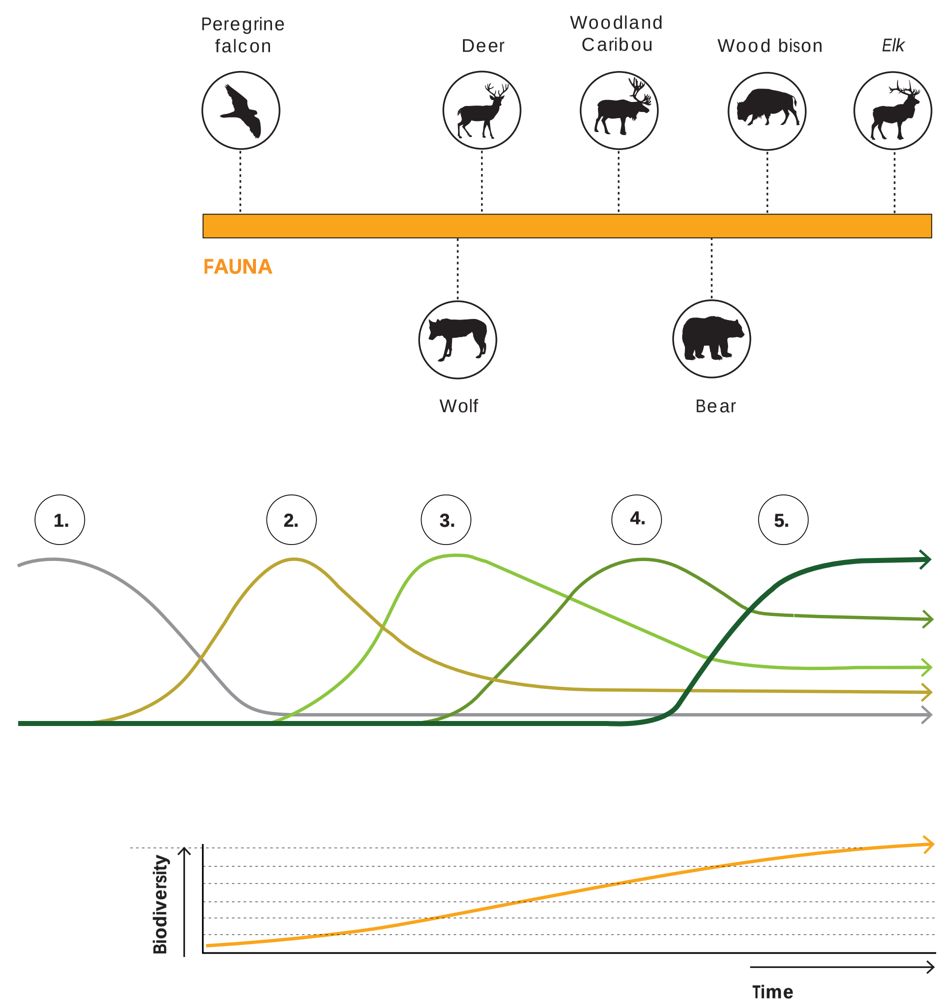


Fig 9.64: Scheme 2 development of principle 3


YEARS
2020
2025
2030
2040
2060
WOODLAND SYSTEM
1-2 years
3-4 years
5-15 years
16-50 years
51 - 100 years
Climax
START 2014
Area 1
START 2032
Annual grasses
Perennials & grasses
Shrubs
Soft wood Forest vegetation
Area 7
START 2022
Area 10
START 2027



BIODIVERSITY

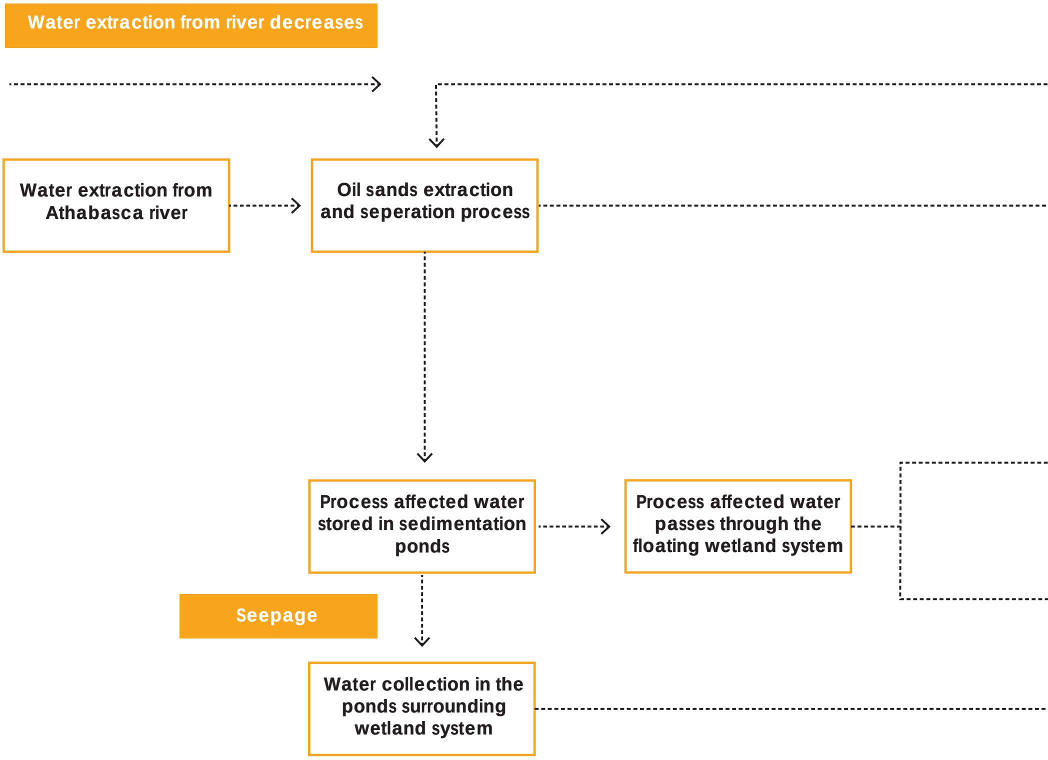
1. Bare ground, drained MFT
2. Pioneer (annual) vegetation
3. Perrenial plants and grasses
4. Shrub vegetation
5. Forest vegetation

Fig 9.65: Scheme 3 development of principle 4

In figure 9.66 the total process and design solutions of the industrial water system is once again showed in a scheme. First water is extracted from the Athabasca River to be used in the industrial process.

After this process the affected water is stored in the sedimentation pond. In here the water passes through the floating wetland system for treatment. The treated water is transported to the water pond. The seepage is collected in the collection ditch and also treated by a wetland system; this treated water is transported to the water pond as well.

In the water pond the water flows through a secondary treatment system. From here it is pumped into a holding pond to be reused in the industrial process again. With this system more water can be reused. This means less water from the river will be extracted.



Besides water treatment the sedimentation process will also be enhanced in the sedimentation ponds. The fine clay particles which settle to the bottom, called the mature fine tailings (MFT) will be dredged out and deposited in the open pit mine.

By doing this an artificial mine landscape park will be developed by different landscape processes. This leads towards a high dynamic, resilient and diverse landscape which can be used for several purposes. It will form a habitat for several animal species and besides that it serves as a recreational area. How this recreational network will be developed is explained in the following section.

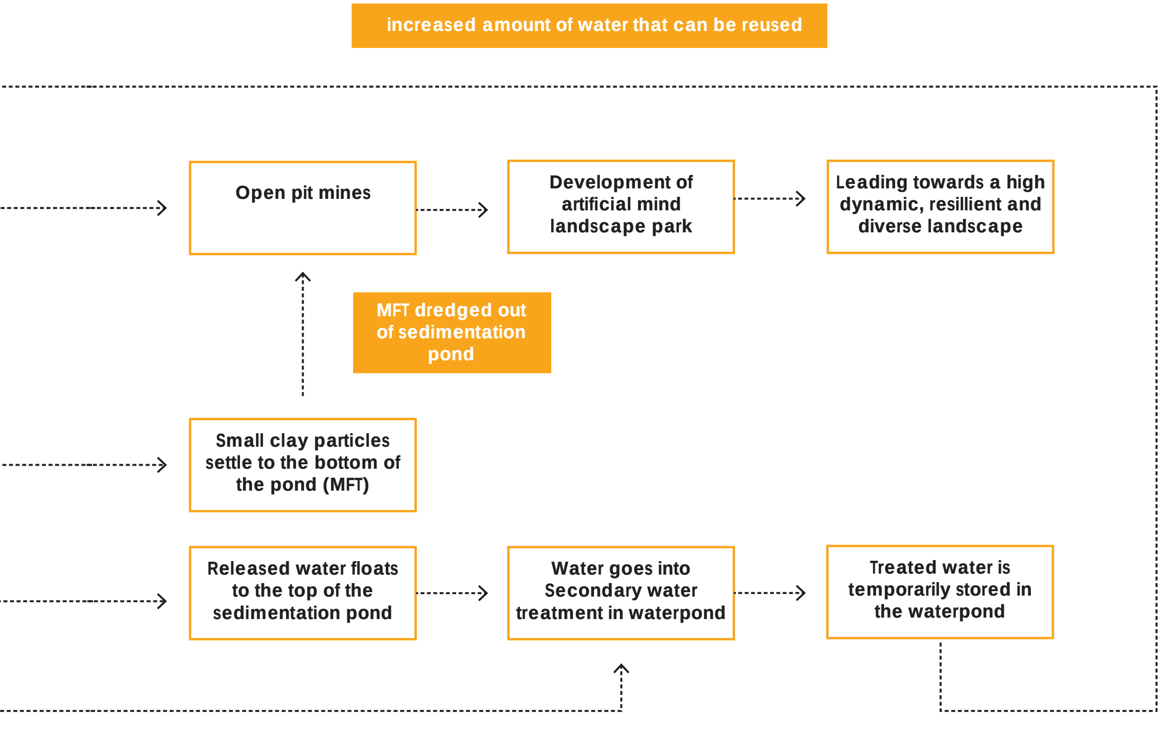


Fig 9.66: Process scheme of the industrial water process

9.8 An expanding recreational network anticipating on the reclamation phases

The recreational network will expand in four different time phases

As explained in paragraph 10.4 mining activities move forward in time, the area which is left behind and not used any more can be reclaimed. The former paragraph explained our design for reclaiming the mine, our design for the recreational network takes that a step further.

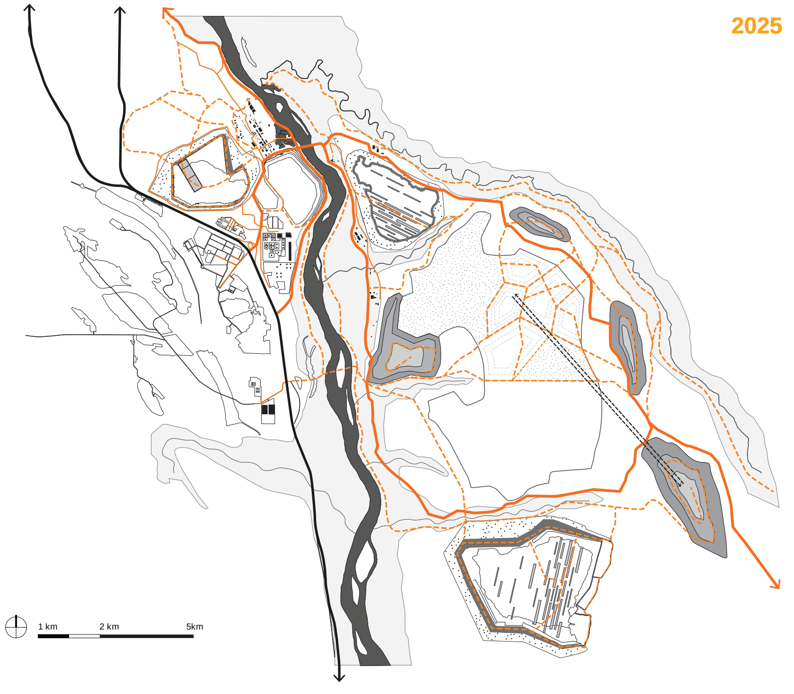
How will the recreational area expand, depending on time? How can they experience the four different principles, resulting in different landscape typologies, to reclaim the mine? By which routes and which vehicles? This is what we will discuss in the coming part.

The following four figures (10.67 -10.70) show the different phases in which the recreational network will expand in time.

Phase one shows the circular trail that will be developed around the mine

2020

Figure 10.67: Phase one of the development of a recreational network



2025

Phase two shows the development of paths in the reclaimed parts of the mine, including a cable car from the overburden dump to the mine

Figure 10.68: Phase two of the development of a recreational network

2030

Phase three shows the further development of the recreative network

Figure 10.69: Phase three of the development of a recreational network

Phase four shows the further development of the recreative network in the reclaimed parts of the mine

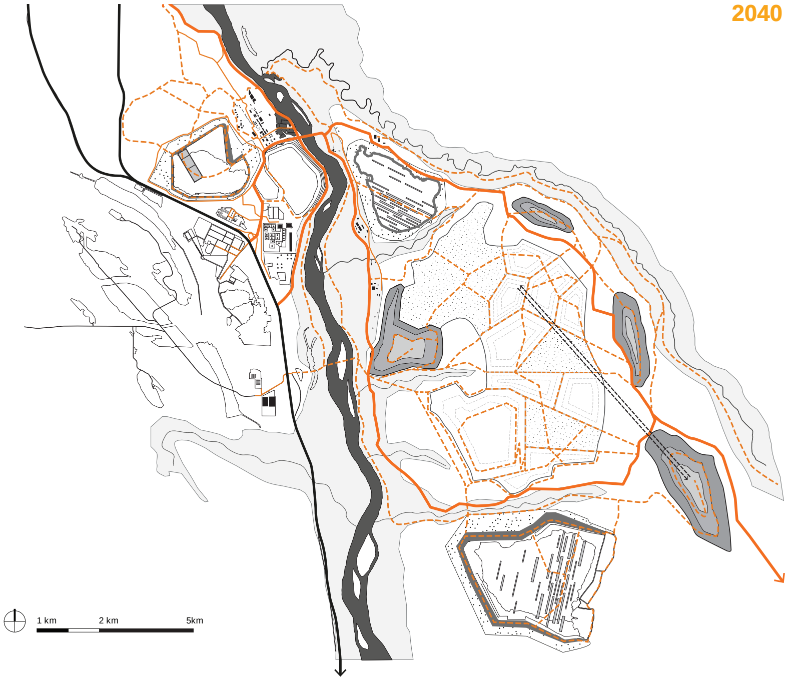


Figure 10.70: Phase four of the development of a recreational network

Legenda:

- Tailings pond surrounding wetland
- Overburden dump
- Industrial buildings
- Athabasca river
- FTWs
- River valley
- (not) motorized recreational paths
- Motorized recreational paths
- Cable car

It's of course hard to imagine how these paths will look like throughout the Suncor mine, therefore we developed several visualizations that show the four different mine reclamation principles in combination with a typology in paths.

The first reclamation principle, as shown in figure 10.71, leads to an open landscape with scattered bushes and scrubs, water is likely to come to the surface in some places leading to swamps here and there. Paths in this area will therefore look like board walks, however people can of course choose to go off the beaten path and make their own. leading to more informal unpaved paths.

The second reclamation principle, as shown in figure 10.72, eventually leads to a lake. Paths on this water will be of a boardwalk type, however the main activity on this reclamation principle will be sports like: canoeing and abseiling.

The third reclamation principle, as shown in figure 10.73, will lead to a wetland type landscape. With mainly emergent vegetation. One must therefore again think of a boardwalk-like path.

The fourth reclamation principle, as shown in figure 10.74, will lead to a forested landscape. Due to drainage of the MFT the landscape that arises will be trafficable and thus strong enough to walk on. Paths will therefore be unpaved.

Figure 10.71: The first reclamation principle, leading towards an open field with perennial plants and grasses with scattered bushes of shrubs

Figure 10.72: The second reclamation principle, leading towards a lake

Figure 10.73: The third reclamation principle , leading towards a wetland

Figure 10.74: The fourth reclamation principle, leading to a forest in time

Without nodes a recreational network can't exist

9.8.1 Nodes as part of the recreational network

A recreational network however doesn't have a foundation without the concept of 'nodes', as mentioned by Kevin Lynch (1960) "the concept of node is related to the concept of path, since junctions are typically the convergence of paths, events on the journey (Lynch, 1960 cited in Giesking, et al. 2014, p. 51).

Nodes, are points or strategic spots where there is an extra focus, or added concentration of features. In our case these features are as just mentioned, convergence of paths or landscape types, overview points.

We therefore developed several nodes in the suncor mine, which are strategic spots with an extra focus

On the basis of the following criteria, we have determined the different nodes:

1. Elevated landscape elements that give an overview over the mine;
2. Places where one can experience the various industrial and reclamation processes;
3. Places where people live;
4. Places where the Athabasca river joins the anthropogenic network layer.

This led to the following nodes in the Suncor mine as visualized in figure 10.75

Figure 10.75: The different nodes in the Suncor mine

All the different nodes can have differences in their appearance in the landscape. Some nodes will likely look like an observation tower, while other nodes can for example be a recreational facility like a sauna.

The different nodes can have differences in appearance in the landscape

We therefore developed several options/ principles, representing a selection of possible features that can be developed on certain nodes as showed in figure 10.76. These different principles will subsequently strengthen the recreational network, since everyone walks/ cycles/ drives with a purpose and these nodes provide a purpose to enter the area.

We divided the nodes into the following functions:

- Educational point;
- Panoramic view;
- Recreational hub for people.

Depending on the funtion of the nodes a variety of forms have been attached to this function

Associated with these functions one can in turn think of a number of options in terms of shape / design.

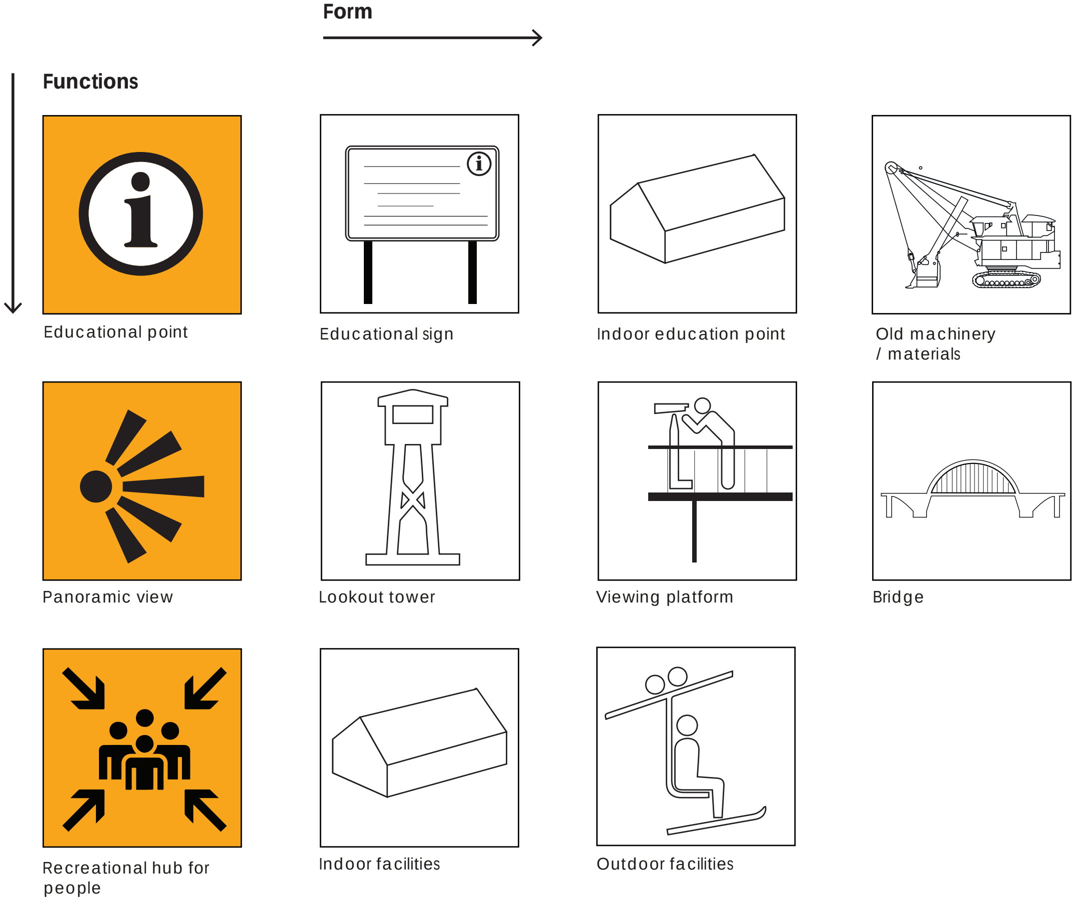


Figure 10.76: Principles representing possible features that can be developed on certain nodes.

Figure 10.77: Landmarke "Rostiger Nagel" - am Sornoer Kanal (source: IBA, 2013)

A good reference image for the node with the function panoramic view, would be the "Rostiger Nagel" at the Internationale Bauausstellung Fürst-Pückler-Land (fig. 10.77). There is enough steel in the Athabasca oil sands industry that could be used as input to build a lookout tower comparable to this.

Figure 10.77: Infomab10 Pavillion (source: Sickline.org, 2012)

Another good reference image for the node with the function of education point would be the INFOMAB 10 (fig. 10.78), installed temporarily as information centre of the public art programme in Madrid. It's an old polyester water tank.

The idea of repurposing old industrial elements could be very suitable, when thinking of the Athabasca oil sands, old pressure vessels for example can be used as well, to make small information centers.

Other ideas for the development of educational nodes could be a modern interpretation of the old wooden cabins of the first nations, a reference image is shown in fig 10.79, which is a design by Philip Baumhauer. The wooden folly, can be spread at different nodes throughout the mine, providing people with information.

Figure 10.79: Folly by Philip Baumhauer (source: dezeen.com, 2013)

Other ideas for the development of the different nodes in general. Is the idea of ASPECT Studios, where they delivered a new, vibrant and attractive public realm for the Hart's Mill Surrounds in Port Adelaide. The whole design is themed around the old industrial history.

Figure 10.80: Hart's mill surrounds (source: landezine.com, n.d.)

Linking the picture shown above (fig. 10.80) to the Athabasca oil sands, several similarities exist. The bright yellow tubes could be old pipelines in the case of the Athabasca oil sands, sulfur for example can be an ingredient for the yellow color.

The last idea for the development of a recreational hub for people is shown on the next page (fig. 10.81), which is a luxurious spa. The suggested location gives an impressive view on the confluence of the Athabasca river and the industry. Inhere residual heat coming from the industry can be used to heat the baths. This creates an interesting mix of different functions and landscape features coming together.

Figure 10.81: Example of a node, with the function recreational hub for people

At last several suggestions of routes have been developed, each with their own way of transport.

9.8.2 Suggested routes

After the development of a recreational network together with the nodes, the next step is a suggestion for different routes people can take in the artificial mine landscape park. These routes are based on a fully reclaimed mine landscape, after 2032.

Route A

Route A shows a relatively short route of about 20 km, starting at one of the Work camps close to the mine. The different icons show the different modes of transport. In here we imagined a kind of transferium points where one can change the means of transport and grab a bike for example. This enables people to experience the area in different ways and speeds. The different routes all pass several nodes, this gives people the possibility to rest for example and, read some information regarding the landscape (fig. 10.82).

Route B

Route B shows a longer bicycle loop, again starting from the work camp. Passing the tailings pond and the floating wetlands, to subsequently to traverse the river valley in the east and make a climb to reach the top of the overburden dumps, to stop for a few minutes and experience the view. To eventually head back to the work camp (fig. 10.83).

Route C

Route C focuses on people coming from Fort McMurray using the eastern entrance. Parking their car and subsequently walk to the cable car, which gives them a breathtaking overview of the landscape machine, and the new nature that evolves here in time (fig. 10.84).

Route D

Route D again focuses on people coming from Fort McMurray, entering the old entrance taking their quad or snow scooter with them. Making a loop across the artificial mine landscape park (fig. 10.85).

Route E

Route E gives people the opportunity to do this by bicycle or foot. It leads people along the different tailings ponds in the Suncor mine (fig. 10.86).

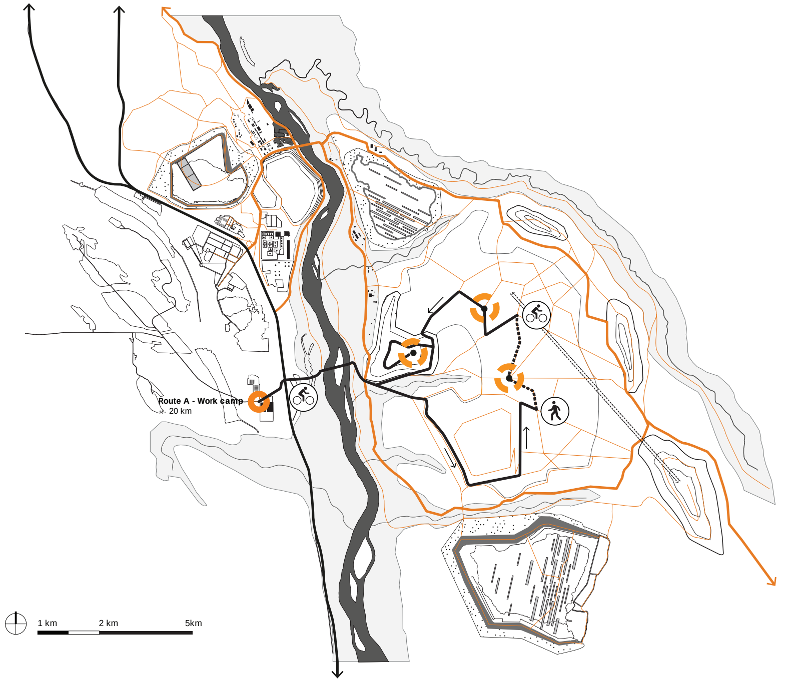


Figure 10.82: Route option A - starting from work camp, the small loop

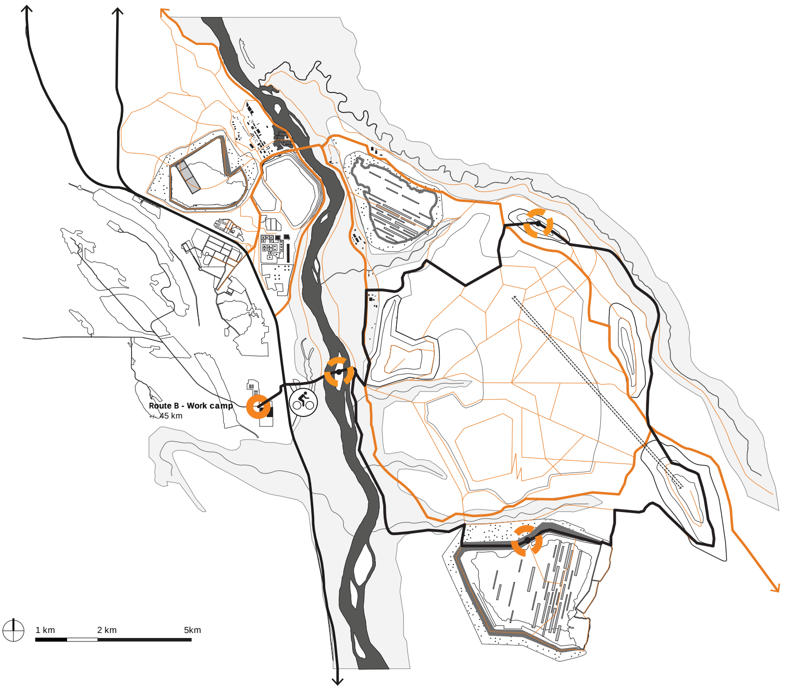


Figure 10.83: Route option B - Starting from work camp, the big loop

Figure 10.84: Route option C - Coming from Fort McMurray, starting from parking lot at new 'eastern' entrance and taking cable car

Figure 10.85: Route option D - Coming from Fort McMurray, starting from parking lot at existing 'northern' entrance and take quad

Figure 10.86: Route option E - Starting from work camp exploring the tailings ponds

A well developed local network is interrelated to the regional network scale

9.9 The regional infrastructural network layer

However, a well developed network at the local mine scale is interrelated with the network at the regional scale. Our design for the Suncor mine can be seen as an incentive to improve the regional infrastructural network. In order to ensure that Fort McMurray is taken out of its isolation and is incorporated into the regional infrastructural network.

Highway 63 is at this moment the only highway connecting Fort McMurray with the rest of the province

At this moment Highway 63 is the only major highway connecting Alberta's oil sands to the rest of the province. The highway has become known for its many fatalities (Modjeski, 2013). There are no other roads to enter the area, we therefore propose to develop several other roads, which decreases the pressure on Highway 63 as is shown in figure 10.87.

We propose several bypasses to decrease the pressure on highway 63

In addition to that, interviewees often mentioned that the pressure on highway 63 from Fort McMurray to the oil sands industry is a big problem as well (Interviewee 16,2013), when shifts change one can be stuck in traffic for about an hour. We therefore propose to make several bypasses, to further reduce the pressure on the highway.

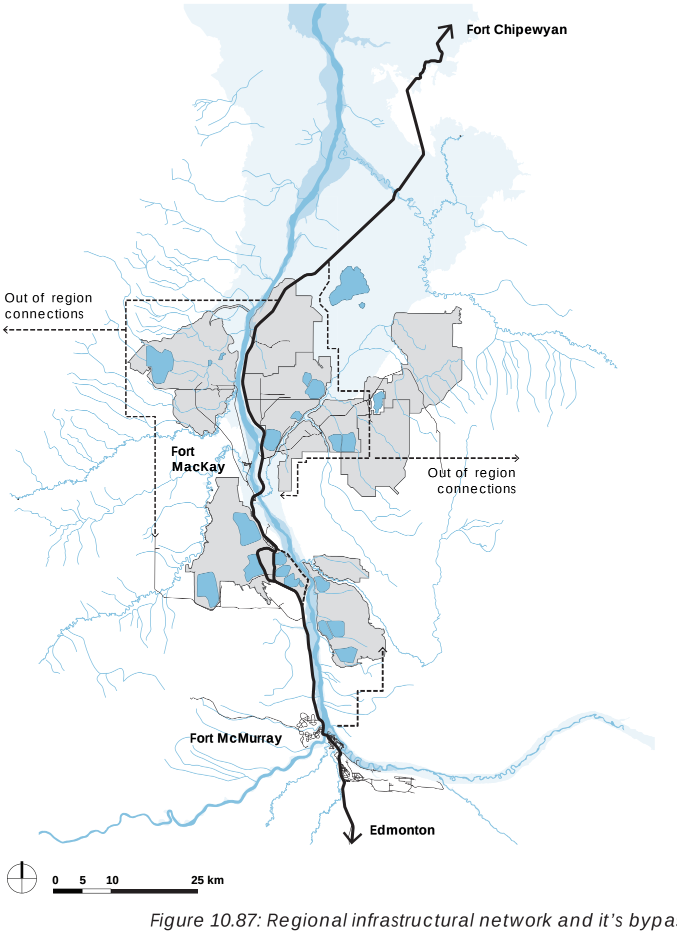


Figure 10.87: Regional infrastructural network and it's bypasses

When linking these improvements back to the provincial scale, Fort McMurray will no longer be a final destination as shown in figure 10.88.

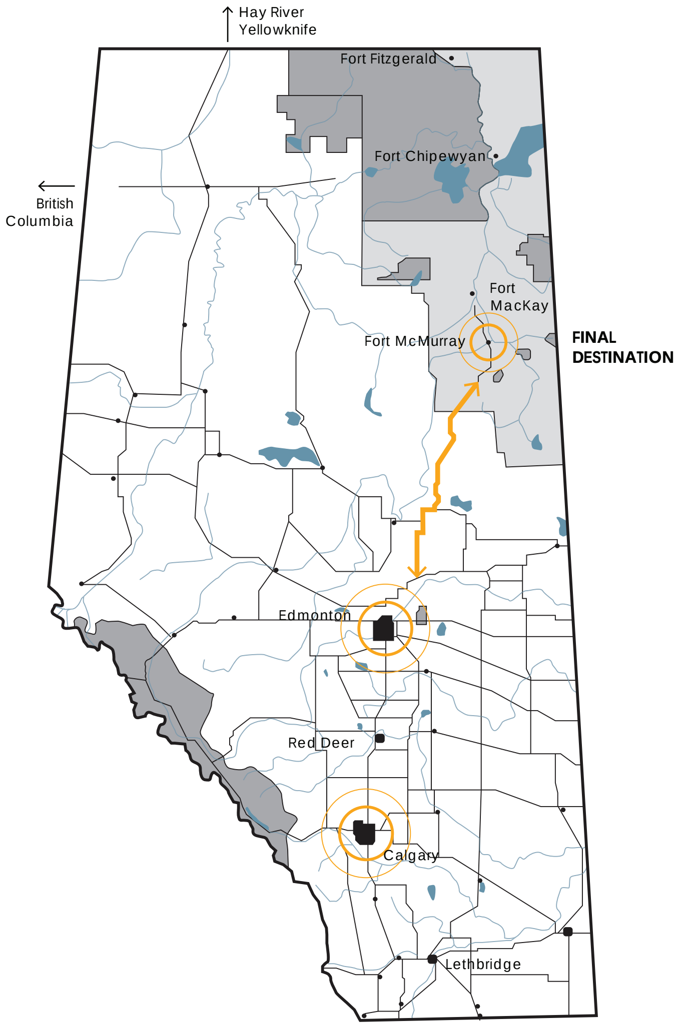


Figure 10.88: Fort McMurray as isolated city in the North of Alberta

Fort McMurray will then be better connected with its surrounding landscape

Which changes the current image of Fort McMurray as final destination to entrance of the Artic

In the future Fort McMurray will be a connected city with its surrounding landscape (fig. 10.89). Where people can take other roads to explore the area, instead of first heading south to Edmonton.

This changes the current image that one has of Fort McMurray, instead of being a final destination isolated in the sub-arctic. Fort McMurray can become the entrance of the Arctic. As visualized in figure 10.90.

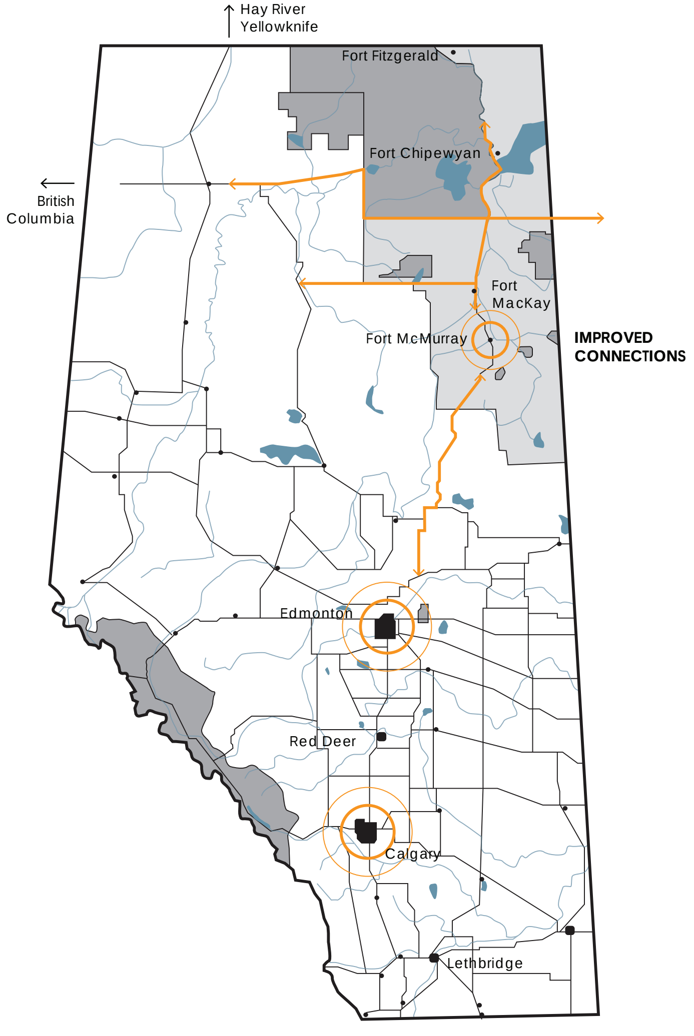


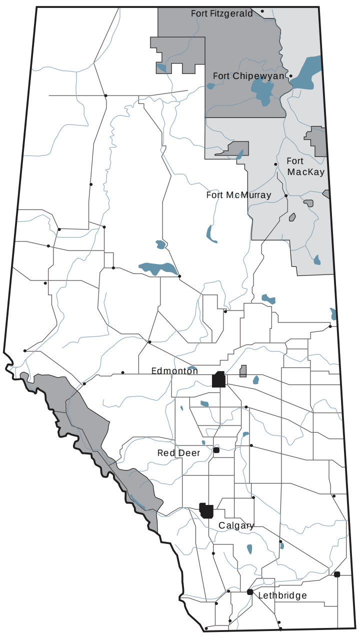
Figure 10.89: Fort McMurray as interconnected city in the North of Alberta

Figure 10.90: Fort McMurray as entrance of the Arctic

Besides improving the anthropogenic network layer we also improve the natural network layer

However infrastructure and networks can be seen in different ways, you have the anthropogenic network layer as just described and the natural network layer. This natural network layer comprises of migration routes of different animals throughout the area.

By developing our artificial mine landscape park in the Suncor mine, the boundary between nature and industry boundaries blur and become more transparent. Therefore the mining area can all of a sudden become a natural steppingstone/ corridor where animals pass through to get to the different parks in the region (fig. 10.91).



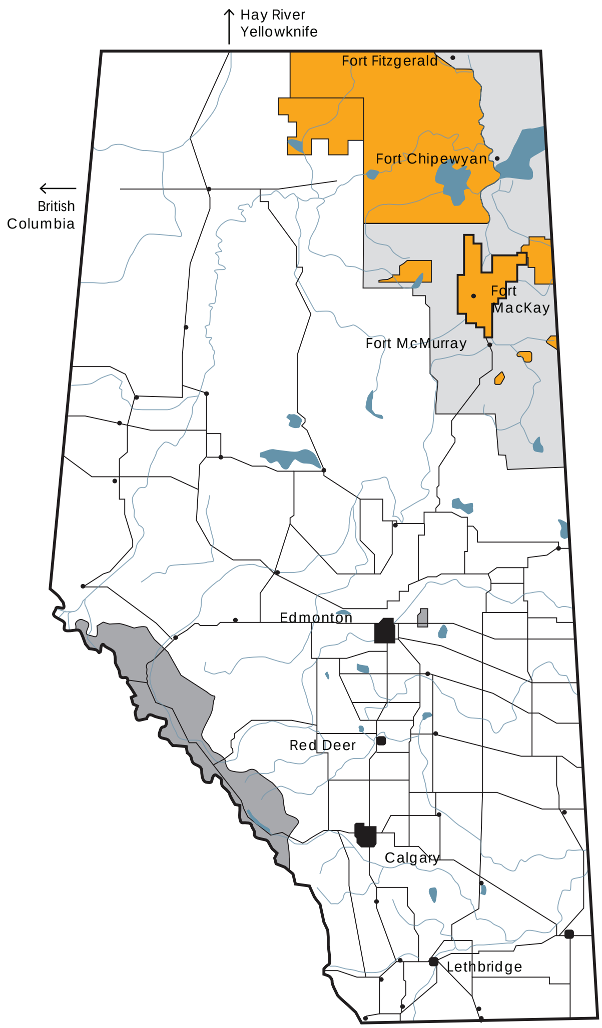


Figure 10.91: The mining area as stepping stone in the middle of the different parks

9.10 Conclusion

In this chapter we tried to answer the sub question: How can these measures be implemented in order to achieve a more sustainable system?

The first measure we took for our design was making the Athabasca River system more visible in the landscape again. In the design this was done in two ways:

1. strengthening its riparian area, by excluding industrial development;
2. bringing back the rivers tributaries.

The second measure we took in order to protect the Athabasca River was done with the development of an industrial water system with a focus on the tailings ponds. The main objectives in this design were:

Clean the water from organic and inorganic pollutants and enhance the sedimentation process. By doing this more water could be used in the industrial process again which means that less extraction of the river system is necessary. Besides that we want to collect and clean the seepage, in order to eliminate contamination on the river system.

We did this by the development of three different wetlands types:

1. a sub-surface flow wetland to remove inorganic pollutants;
2. a surface flow water wetland which is focused on the removal of organic pollutants;
3. a floating treatment wetland which focusses on the inorganic and organic pollutants and besides that enhances the sedimentation process.

By implementing these wetlands in different forms on the different tailings ponds, we are able to clean the water, enhance the sedimentation process and collect and treat the seepage. This means less water needs to be extracted from the Athabasca river and the river is protected from contaminated seepage flows.

The third measure dealt with the disturbed land in the landscape to subsequently develop this into a high quality landscape for people and nature. Within this design we developed the artificial mine landscape park. In here the mature fine tailings (MFT) are used to fill up the mine landscape and by doing this with four different reclamation principles, resulting in different landscape forming processes, a diverse landscape of different landscape typologies will emerge. Besides that this design enhances the biodiversity in the area.

The last measure we took for our design was the creation of a robust recreational network. This network develops through time with a start in the non-active industrial areas. Later on this network will be extended through the artificial mine landscape park. Within this network several routes can be taken by different means of transport. This means several recreational activities can take place in the area.

In the following scheme the different design layers are showed, which are as follows:

- the Athabasca river system;
- the industrial water system;
- the networks

When plotting the different layers against one another in time, it clearly shows how these layers and design solutions interact and influence each other.

This scheme starts with the Athabasca river system. Since the aim within our design was to protect the river system. The layer of the Athabasca river system is closely connected with the industrial water system, since this is the main polluter of the river system. Our intervention increases the water quality of the industrial water system, which means more water can be reused in the process again and less water needs to be extracted from the river. This is clearly showed in the two layers of the scheme.

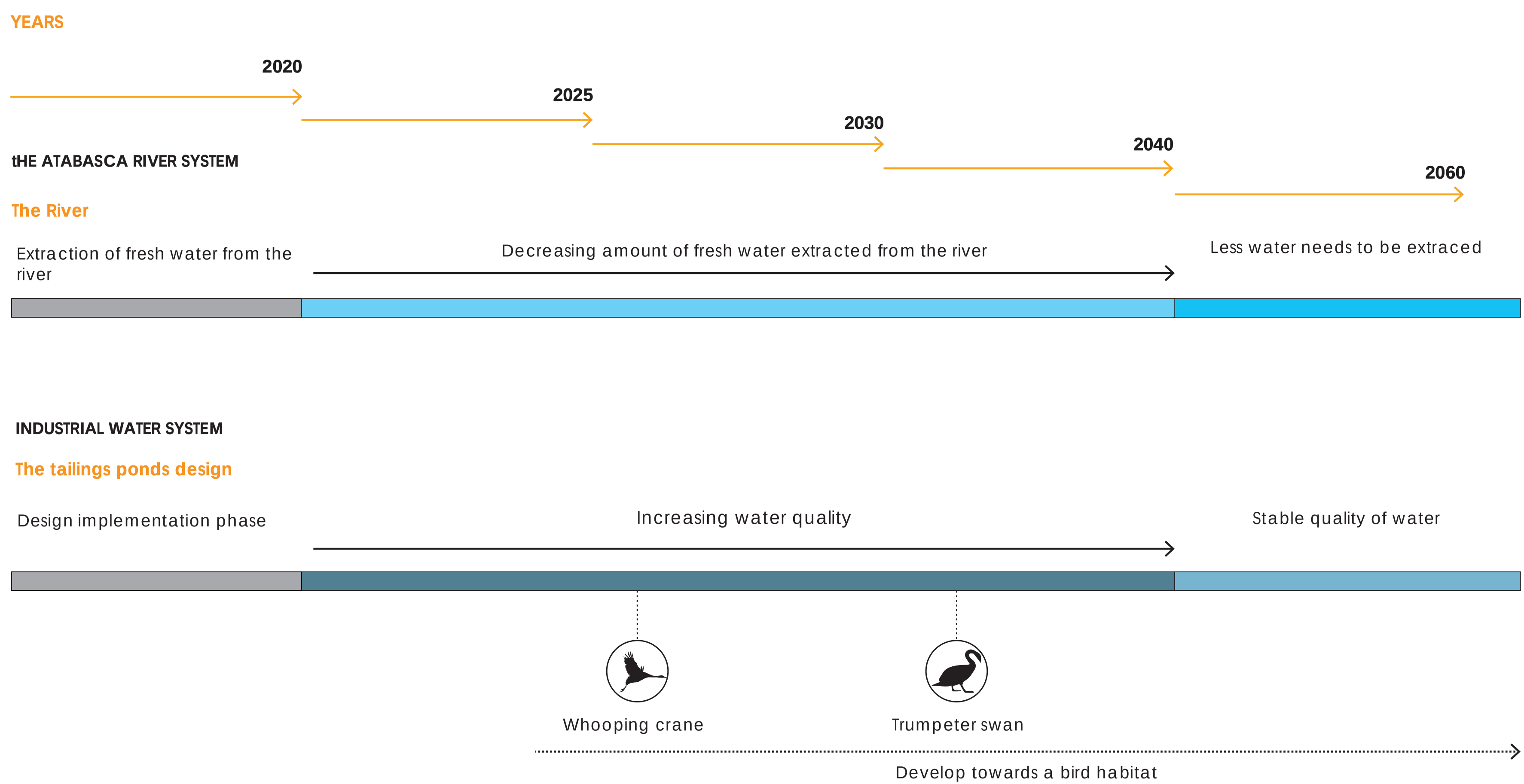
While the water quality in the tailings ponds is increasing by making use of wetland treatment systems. The tailings ponds can become a habitat for several bird species. This is already possible while the ponds are still in use for industrial purposes. While the ponds are not in use anymore the ponds can totally transform into an important habitat for bird species as the trumpeter swan and the whooping crane.

The third bar shows the mine reclamation process which is also part of the industrial water system, since it deals with the mature fine tailings which are pumped out of the tailings ponds. This process shows that one can already start with the reclamation process. Doing this by means of several reclamation principles the biodiversity will start to increase from 2022.

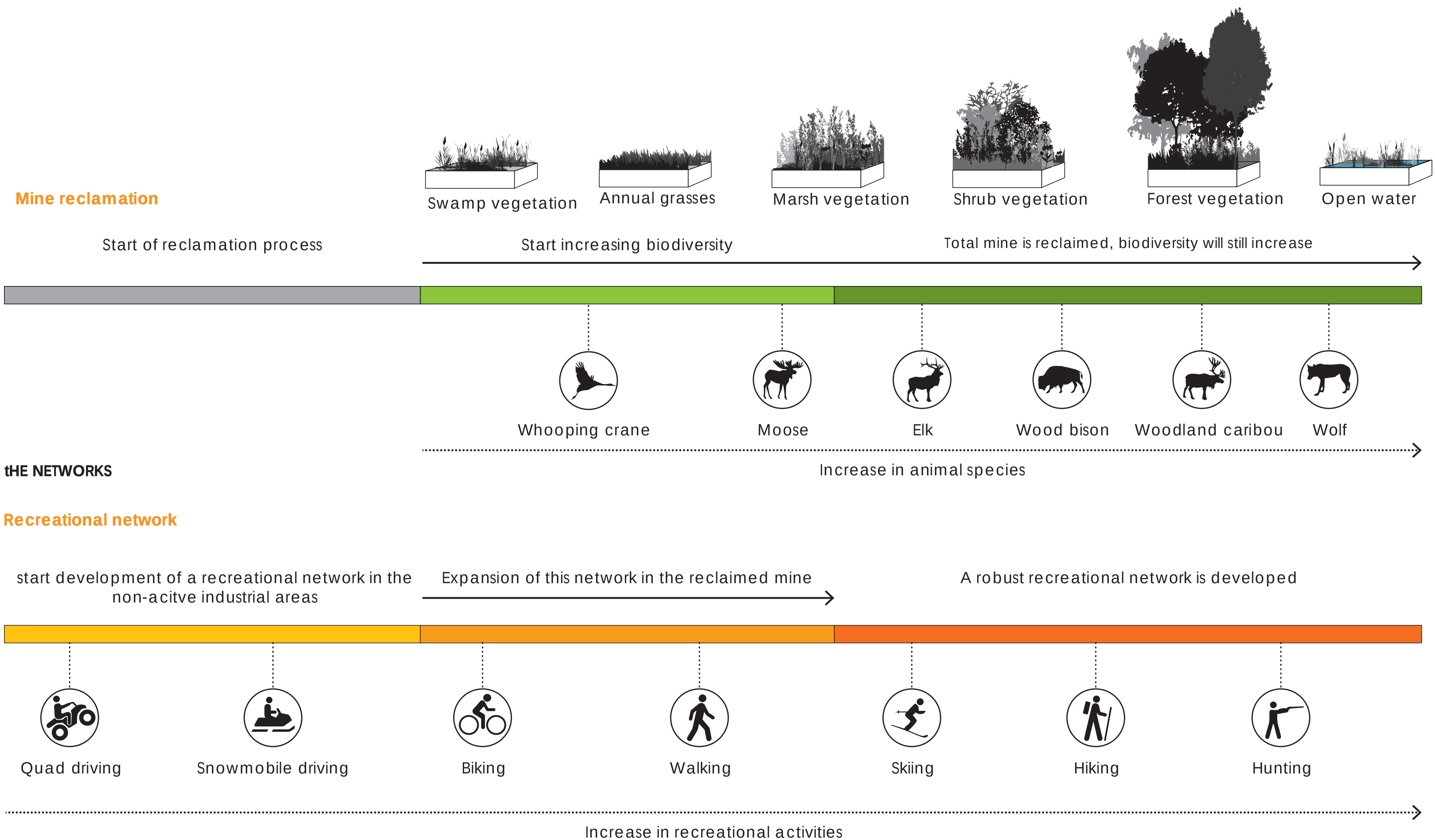
Within this time span the mine landscape will mainly exist of swamp vegetation, grasses and later on marsh vegetation. From 2033 the reclamation processes are done, the different landscape processes and the process of ecological succession will change the vegetation towards shrubs, forest and open water. Besides diversity in vegetation this also influences the diversity of animal species, which will increase.

The network layer which forms the last bar is again closely related to this mine landscape park. From now one a recreational network of several paths and roads can be developed in the non-active industrial areas. While the mine is partly reclaimed in 2022 the network will keep on expanding in several areas in the mine.

When the mine is fully reclaimed the total network can be developed. Within this network there is room for several recreational activities. In the beginning of the developments this will primarily consist of movement through the area by different motorized vehicles, since the network is not very dense at this moment. Later on when the network becomes more dense it also becomes more attractive to pursue other activities as walking, hiking and hunting.



YEARS
2020
2025
2030
2040
2060
tHE ATABASCA RIVER SYSTEM
The River
Extraction of fresh water from the river
Decreasing amount of fresh water extracted from the river
Less water needs to be extraced
INDUSTRIAL WATER SYSTEM
The tailings ponds design
Design implementation phase
Increasing water quality
Stable quality of water
Whooping crane
Trumpeter swan
Develop towards a bird habitat



Mine reclamation
Swamp vegetation
Annual grasses
Marsh vegetation
Shrub vegetation
Forest vegetation
Open water
Start of reclamation process
Start increasing biodiversity
Total mine is reclaimed, biodiversity will still increase
Whooping crane
Moose
Elk
Wood bison
Woodland caribou
Wolf
Increase in animal species
tHE NETWORKS
Recreational network
start development of a recreational network in the non-acitve industrial areas
Expansion of this network in the reclaimed mine
A robust recreational network is developed
Quad driving
Snowmobile driving
Biking
Walking
Skiing
Hiking
Hunting
Increase in recreational activities

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Figure 10.12: Norwest corporation, 2003. *Conceptual tailings dam design*. [electronic print] Available at: <http://www.sec.gov/Archives/edgar/data/1173420/000106299303001067/exhibit-19.htm> [Accessed on: 2 August 2014]

Figure 10.14: Eke, P,E., (2008) *Schematic representation of a standard planted constructed wetland with a vertical flow*, In: Hydrocarbon removal with constructed wetlands. P. 43.

Figure 10.15: Eke, P,E., (2008) *Typical configuration of a surface flow wetland system*, In: Hydrocarbon removal with constructed wetlands. P. 37

Figure 10.16: Headley, T.R. and Tanner, C.C., (2006) *Cross-section of a typical floating treatment wetland and pond showing main structural elements*, In: Application of floating wetlands for enhanced stormwater treatment: A review. P. 39

Figure 10.26: Headley, T.R. and Tanner, C.C., (2006) *Drawing of wastewater treatment pond fitted with floating AEES Restorers*, In: Application of floating wetlands for enhanced stormwater treatment: A review. P. 31

Figure 10.38: Wallace, S., Schmidt, M and Larson, E., (2011) *Schematic of the full-scale treatment wetland at Casper, Wyoming*, In: Long term hydrocarbon removal using treatment wetlands. P.3.

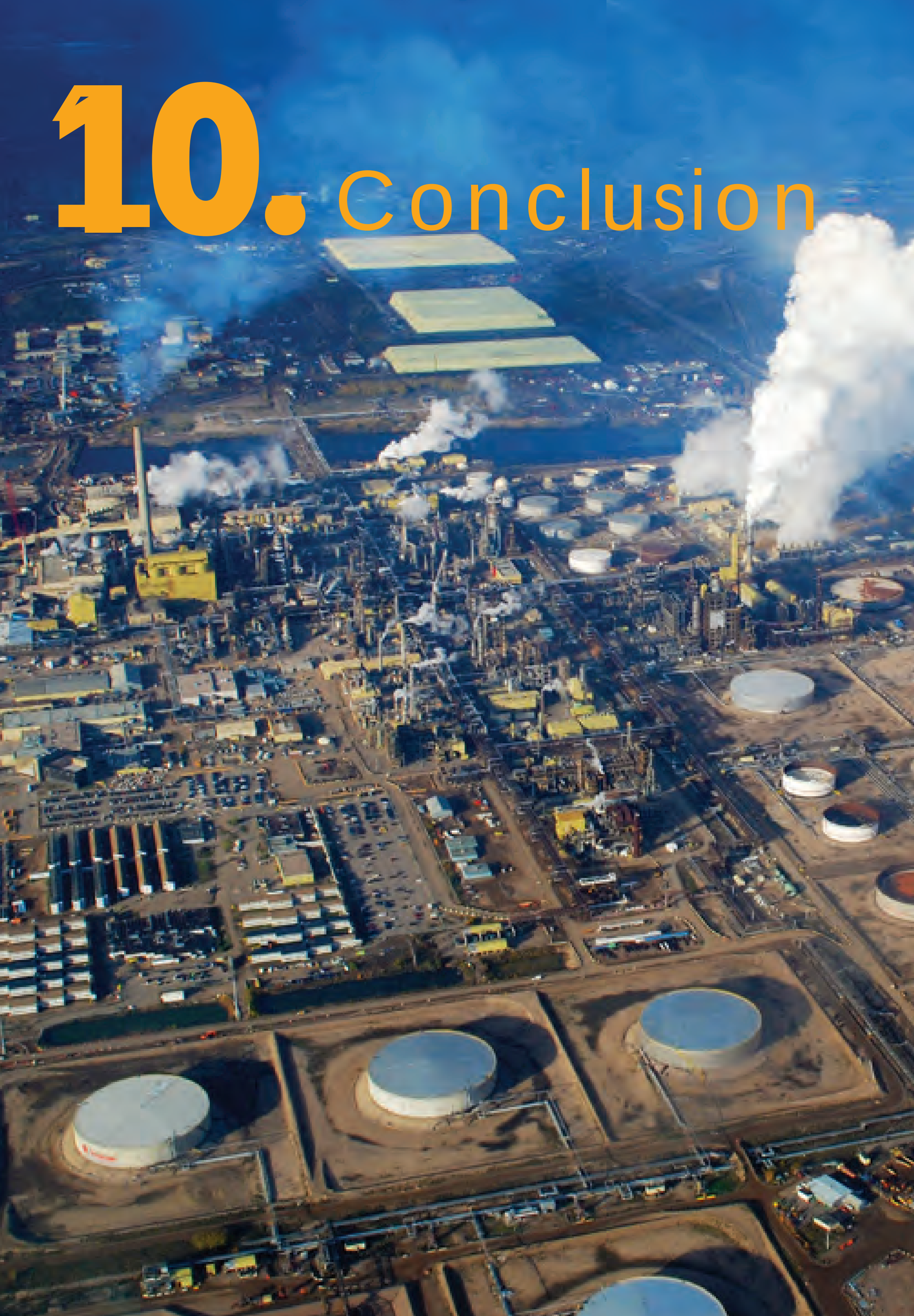
Figure10.76: IBA (Internationale Bauausstellung), 2010. *Rostiger Nagel*. [online] Available at: <www.iba-see2010.de> [Accessed 1 September 2014]

Figure 10.77: Sidraa, n.d. Infomab10 Pavilion by Studio Kawamura Ganjavian in The City of Madrid in Spain. [online] Available at: < www.architectureticker.com> [Accessed 29 August 2014]

Figure 10.78: Lanoo, J., 2010. Folly by Baumhauer. [online] Available at: <http://www.dezeen.com/2010/08/05/folly-by-baumhauer/> [Accessed 28 August 2014]

Figure 10.79: Brice, D., 2014. Hart's Mill Surrounds by ASPECT Studios. [online] Available at: < http://www.landezine.com/index.php/2014/07/harts-mill-surrounds-by-aspect-studios/ > [Accessed on 01 September 2014]

10. Conclusion



The different chapters 1-9 all end with their own conclusion, which both reflect on the chapter as well as partly introducing what is coming next.

This final chapter will first give an answer on the formulated research questions and the significance of this thesis.

To finally end with the discussion and recommendations of the design and used methods.

Conclusion

10.1 Conclusion on research questions

In our MSc thesis in landscape architecture we have seen how the expanding Athabasca oil sands industry, where we focus on the extraction process of mining, leads to several problems on different layers in the landscape. With the current way of problem solving, which tends to look at the problems from the perspective of one single discipline, one is not able to solve the complex problems. These kind of problems need to draw on multiple perspectives from various disciplines.

Landscape architecture, and their integrative and multidisciplinary approach when addressing complex problems like the developments in the Athabasca oil sands, can therefore be seen as a promising field. Design solutions we have developed can be very enriching and potentially shed new light on current discussions and eventually lead towards a more sustainable future.

First, we will answer the sub research questions, which will finally lead towards answering our main research question.

10.1.1 What landscape processes construct the contemporary landscape and have led to the oil sands industry nowadays?

The landscape forming processes that construct the contemporary landscape began millions of years ago, when Alberta was covered by a warm tropical inland sea, the Western Interior Seaway. All kinds of plants and marine organisms, such as plankton lived in the sea. When these plants and organisms died, sediments containing their remains accumulated in the bottom of the sea. Throughout time, more and more layers were added, and the sediments were buried deeper. Heat, pressure , time and the activity of bacteria transformed these remains into hydrocarbons, and crude oil was formed.
This all took place in the Southern part of Alberta.
However when the Rocky mountains formed, geological pressure was put on the land, and most of the seaway was closed off and

the deposits of crude oil (being a liquid) were pushed toward the surface, and the oil was squeezed northward and seeped into the existing sand deposits left behind by ancient river beds, forming the oil sands.

The Athabasca river has played an important role in the formation of the contemporary landscape, leading to higher plateaus and lower river valleys. The Athabasca river flows through a landscape which is dominated by wetlands, meadows, and black spruce forest.

Besides the fact that the Athabasca River plays an important role in the formation of the contemporary landscape, it also served and still serves as a vital resource for plants, animals and people.

The First Nations and Métis people, who first inhabited the area used the river as an important transport route during the fur trade. Due to eroding processes, the river cut into the landscape, which eventually exposed the oil sands containing layer, and was then discovered by the first nations. This eventually led to the development of the oil sands industry.

We therefore see the Athabasca river, as the backbone of not only human development but the whole Athabasca landscape. Due to ancient river beds the oil came here in the first place, and due to this river first nations came to live in this area and discovered the oil. Up to today, oil sands industrial operations can still continue, because of the presence of fresh water coming from the Athabasca river.

10.1.2 How does the industry work and what are the effects on the contemporary landscape?

The oil sands industry should be viewed as two separate forms of oil production, in situ production (similar to conventional oil production) and mining. We focused on the mining technology, which has the largest impact on the landscape.
Six steps can be distinguished in the mining process, the bullets show the effects on the landscape:

1. Mining, surface is stripped (topsoil, subsoil and overburden) to finally reach the oil sands containing layer. Oil sand is mixture of sand, water, clay and heavy oil called bitumen. The oil sands are subsequently loaded into large trucks and transported to the oil sands crushers where it is prepared for extraction.

- Storage of overburden results in the development of artificial (overburden) hills in the landscape;
- Open pits are developed due to excavation, resulting in a fragmented landscape;
- Excavation requires a lot of machines, a dense network of roads, pipes and extraction/ upgrading plants and thus disturbs a large surface area.

2. Conditioning, the crushed oil sands are mixed with water to dilute the material, which is extracted from the Athabasca river. This results in a slurry-like substance.

- Extraction of water from river has impact on aquatic habitat (Feeding, migration, overwintering);
- Perched lakes, wetlands, and waterways are also sensitive to small changes in the level of the Athabasca River ;
- Once water from river is used in the process, it is too polluted to discharge and thus stored in tailings ponds.

3. Separation, the slurry is put into large (centrifuge like) separation vessels. Within the separation vessels the slurry settles into three layers. The bitumen froth floats on top, the sand sinks to the bottom and a combination of bitumen, sand, clay and water is in the middle which is called the middlings. After this process the bottom layer (sand) is pumped into tailing ponds.

4. Secondary separation, the middlings are pumped to a secondary vessel to further encourage recovery of bitumen.

5. Froth Treatment, the bitumen froth is further treated to clean it from its water and solids. The tailings (water, solids and solvents) are discharged in to tailings ponds

Steps 3-5 in the industrial process all have the same effects on the landscape:
- Storage of tailings leads to huge tailings ponds of several kilometers in width and length, surrounded by containment dykes;
- Tailings ponds seepage may occur which pollutes surface and groundwater.

6. Upgrading, the bitumen will be changed into a lighter form of oil.
- This results into huge upgrader facilities in the landscape

10.1.3 What are the perspectives of different stakeholders regarding the developments of the oil sands industry?

The different perspectives of stakeholders regarding the developments in the oil sands industry served as an important input for our design, we did this by means of interviews. Perspectives is perhaps not the right word, since we did not personally talk with opponents of the oil industry, we would therefore rather call it ambitions or visions for the area.

One important conclusion that can be drawn was that oil companies, government and research institutes acknowledge that they need a more holistic approach to solve the problems that the industry is struggling with. The industrial processes can no longer be seen in isolation from the landscape processes. We must look at the entire system, both in terms of input, output and waste.

With this need for change, they also see great opportunities, Fort McMurray has the potential to become a great icon for the rest of the world. A shining example of a brilliant place, a zero-waste community or an icon in reclamation technologies. In order to Show North

America that change is possible, in the place that everyone sees as the worst example. The concept of sustainability plays an important role in this need for change. However, there is still a long way to go.

Other important more practical conclusions were about reducing the pressure on the roads caused by commuter traffic, a lack of sufficient affordable housing and a diverse range of services and amenities. People missed facilities like outdoor recreation, reasonably priced restaurants, libraries and live music venues. But despite the deficiencies most of the people seem to have a positive vision for the future of Fort McMurray.

A last thing, which should not be overlooked are the First Nations and aboriginal groups living in the area of Fort McMurray. They were the first inhabitants in this area and lived from hunting, fishing and gathering. They are not against the developments happening in the oil sands, since most of them work in industry, they however want to make sure that developments are done in the most sustainable way.

10.1.4 What measures can be taken in order to develop a more sustainable landscape system?

This sub research question served as the translation between research and design. The main conclusions we could draw from our analysis chapters were still too many and too diverse, due to limitations in time a further focus was necessary, this was a nonlinear and time-consuming process. This eventually led to our five formulated design challenges:

1. Reduce the impacts of the industry on the Athabasca River system (seepage of process affected water, extraction of fresh water);
2. Reuse waste energy and material flows (with a focus on the MFT);
3. Create a robust infrastructural and recreational network;
4. Provide extra housing and leisure facilities;
5. The disturbed land should be returned into a high quality landscape for people and the environment.

With these design challenges we were eventually able to develop our four measures.

1. the Athabasca River system, since the analysis on the landscape showed that this is the determining element in the landscape, we therefore feel the need to protect this river and make it more visible in the landscape;
2. the industrial water system. The industrial water system has great influence on the river system. A design which reduces the impacts on this system is necessary. The tailings ponds should play an important role in this design;

3. the open pit landscape. A design solution needs to be developed on how to deal with this disturbance to subsequently create a high quality landscape for people and nature;
4. the recreational network which forms an important requirement from the inhabitants. This should be done on both the mine scale and the regional scale.

10.1.5 How can these measures be implemented in order to achieve a more sustainable system?

The four developed measures, all need to be implemented leading towards design solutions. The numbers indicate the measures and the bullets explain our design solutions.

1. The Athabasca river system;
- strengthening the riparian area, by excluding industrial development
- bringing back the rivers tributaries

2. The industrial water system;
- Clean tailings water from organic and inorganic pollutants
- enhance the sedimentation process, by the development of different wetland treatment systems
- Collect and treat seepage coming from the tailings ponds, to further reduce the impact of the oil sands industry on the water system.

3. The open pit landscape;
- The post mining areas are filled up with a waste product (MFT) coming from the tailings ponds, by using four different reclamation principles, resulting in different landscape forming processes, leading to a diverse landscape. Regenerative capacity of nature is used to restore nature.

4. The network layer.
- Concomitant with the reclamation of the mine, a network for humans and animals is developed on the post mining landscape. Resulting in the merging of natural, social and industrial processes at the same place.

10.1.6 How can a more sustainable landscape system be developed in the Athabasca oil sands industrial region by using a landscape based design approach?

As landscape architects, our education and philosophy is based on the principles of a landscape based design approach. The object we study is the landscape, which is the visible result of interactions between human and natural processes.

The landscape should therefore not be seen as separate entities, but as a one coherent system (Kerkstra and Vrijlandt,1988). The first three sub research questions therefore deal with the social, environmental and industrial layer, that constantly influence each other.

The fourth and fifth sub research question deal with the translation of the occurring problems that emerged from the first three sub research questions into a design.

However, how does these design solutions eventually lead towards a more sustainable landscape system? We see, sustainability as the integration of the problems that occur on the social, environmental and the industrial level. Integration of these problems bridges the contrasts to finally find a new balance between the economic development and the environment.

With our design solutions we achieve, a reduction of the occurring problems caused by the oil sands industry on the environmental and social level. The water treatment system in which we use wetlands to clean and collect tailings water increases the percentage of tailings water that can be reused, and therefore automatically reduces the percentage of extracted water from the river.

Therefore we use MFT, which is a waste product that has developed in the tailings ponds, to rebuild the disturbed mining landscape, again natural processes are used to restore and re-build the landscape. To eventually change it into a diverse landscape for people as well as for the animals. Leading towards an integration of the social, environmental and industrial layers. To eventually create a more sustainable landscape system.

10.2 Significance

Environmental significance: Our research offers new opportunities in dealing with the occurring environmental problems. We use natural processes to reduce impacts caused by the oil sands industry as well as to restore and re-build the landscape.

Industrial significance: When looking at the oil sands industry, our research is significant since it shows a new way of dealing with tailings as well as a new way of landscape reclamation. Instead of returning it back to productive ecosystems similar to those existing prior to disturbance, we propose a new type of landscape, which is more diverse and restores itself.

Thereby, the method of atmospheric drying of MFT will not be necessary anymore, since MFT are used to fill up the post mining areas. This could be an economic benefit for mining companies since less surface will be disturbed. Another and last economic benefit is that the design solutions we propose accomplished by wetland treatment systems is relatively inexpensive.

Social significance: Seen from the social more practical perspective, our research is significant because it is in line with the needs of the current society, it offers a new recreational area which was asked for by the inhabitants of the region.

At this moment, as we experienced, there is a lack of functions and facilities in the area, one in particular was outdoor recreation. The unique landscape we create in which the mining area is opened for the public, new landscape typologies are created, can help to ensure that people no longer go out of the region for recreational purposes. This again contributes to community building.

In addition, the separation between the social world and the industrial world becomes less. People may regain trust since industries black box is opened.

Landscape architectural significance: Seen from an architectural point of view our research is very significant since it sheds new light on the current way of dealing with complex problems. People currently deal with the problems like if they are doing an engineering project. However, according to Weber and Khademian (2008), such complex or wicked problems have the need to draw on multiple perspectives from various disciplines.

A more integrative and comprehensive approach is therefore needed and landscape architects in contrast with engineers are able to combine natural and cultural processes, and deal with high level of uncertainties and complex problems (France, 2008 cited in Papenborg and van der Togt, 2013).

Thereby we really take responsibility for the changes taking place in the landscape, we want to ensure that transitions in the landscape are led in the right direction, to ultimately achieve a more sustainable and valuable landscape in the future. We therefore developed a thorough understanding about the industrial processes, made it our own, to subsequently convert the derived knowledge into a landscape architectonic design solution.

In addition to this, our research in an added value in the field of landscape architecture. Since not many landscape architects dealt with the problems occurring in the oil sands industrial area and if they did it was focused on the phase after mine closure. We however want to come up with a solution which is applicable right now instead of after mine closure, it's about fostering for the landscape not only about offering not only aesthetically pleasing solutions, that would never work anyway, we really tried to make it better.

Academic significance: Debates and discussions about the developments taking place in the oil sands industry are held on a global scale. Our research touches on issues like increased greenhouse gas emissions, transition to sustainable economies by means of renewable energy, it's all about drastic changes that today's society has to make in order to prevent further degradation of natural ecosystems. Our research, in which we do not proclaim to have the solution, elaborates on these discussions

10.3 Discussion and recommendations on used methods

10.3.1 Landscape analysis

By the landscape analysis we mean our two analysis chapters (chapters 5 and 6). We think that we have been able to give a fairly complete image of all the different processes going on in the landscape and the Suncor mine. However several assumptions had to be made during this process, since a lot of data was confidential, lacking or very discipline-specific. The main limitations for doing a proper landscape analysis were as follows:

- A proper database or portal of all the landscape forming processes. The data we needed was hard to find and spread out throughout the web, you really have to know where to look for data;
- A lot of data and research is confidential, we therefore were obliged to make several assumptions during the research;
- A lot of research is very discipline- specific, which makes it hard for people like us, who are not known and educated in this specific field, to get a grip on the results.

Of course we did find a lot of data ourselves, we were however strongly dependent on the data we got from people we interviewed, which makes our data collection no longer of unbiased. Our field trip to Canada was therefore a very important and strong move in our research.

In order to keep our data as valid, objective and transparent as possible we made use of different sources to verify the data we got from our interviewees (asking other interviewees the same question, double-checking received data with literature) (Creswell, 2009 p. 191-192).

10.3.2 Interviews

The method of interviewing was an important source of information for our research. As mentioned already, a lot of information regarding oil companies and their operations remains confidential or hidden. This made it difficult to fully get a grip on the different industrial processes. By asking certain questions during the interviews a lot of ambiguities in the industrial process were clarified.

The main limitations/ points of discussion with doing interviews deals with the bias and the interpretation of the researcher. We recorded all the interviews transcribed the interviews and summarized them. This process of transcription and summarizing makes the data less objective.

Another point of discussion is the selection of the different interviewees, since we were stationed in Edmonton at the University of Alberta, most of the people we interviewed are somehow related to the University of Alberta. Which makes most of the interviewees researchers. Important people we did not spoke with are the environmentalists, that are strongly against the developments happening in the oil sands industry. This would have been very interesting to really talk with opposing interests. Another group of people we did not spoke enough with are the residents of Fort McMurray. To be able to better respond on people's requirements it would have been interesting to talk with people on the streets of Fort McMurray.

A recommendation for future research would therefore be to talk with a more mixed group of interviewees with opposing interests.

Validity strategies we undertook to keep our data as objective as possible focused on checking the transcripts of our interviews for mistakes (Gibs, 2007 cited in Creswell, 2009 p.190) and triangulated the data from interviewees with literature.

10.3.3 Personas method

The personas method is probably the most innovative method we used. We used the personas method to process the derived data from the semi-structured interviews.

We used the personas method to investigate relationships between the different interviewees, to eventually cluster the interviewees on the basis of similar perspectives towards the industry or discipline, to form categories. We did this to maintain a manageable design focus, which in turn led to a further delineation of our research and design focus.

The main limitation in using this method deals with the fact that forming groups to be able to make categories, is still very un objective, our bias as a researcher plays a crucial role in this. Despite the fact that we asked several students to create clusters this method remains un objective. By extensively explaining our method and indicate where assumptions have been made, we try to remain as transparent and objective as possible.

10. 4 Discussion and recommendations on design solutions

This paragraph is structured as follows, all the different design solutions will be discussed. For each design solution we will first short explain the purpose of the design solution, then discuss the strengths, followed by the points of discussion and finally possible recommendations for further research.

10.4.1 Seepage collection treatment system

This design solution focuses on the collection of (shallow and deep) seepage coming from the tailings ponds, to subsequently treat it by means of the wetlands and transport the treated water to the water pond for secondary treatment.

Strong points: A strong point of this design solution is that the impact of seepage to the environment is reduced. However a similar solution for this problem is already in use, a collection ditch. The addition of our design solution is that seepage does not have to be pumped back to the pond, since water is already treated in the surrounding wetland. Secondly, the cleaned water can be transported directly to the water pond for secondary treatment, instead of pumped back to the tailings pond.

Discussion points: A discussion point is however that we did not know how seepage exactly flows, this was due to limitations in data and a lack of hydrological knowledge. Another discussion point is whether these wetlands will really reduce the pollution, since exact and recent data about the type and amount of contamination was missing, thereby we do not know how long the residence time of water in the wetlands should be, before it has any effect. To finally end with the climatic conditions in this area, which is sub-arctic, this could be a limiting factor for the efficiency of bacterial processes, that are ultimately responsible, for the removal of contamination.

Recommendations:

- More research and monitoring into seepage flows coming from tailings ponds;
- More research into the type and amount of contamination in tailings water;
- Influence of the sub-arctic climate on the efficiency of bacterial processes present in the wetland;
- Better accessible and less discipline-specific data;
- More research into the use of wetland treatment systems in the oil sands industry.

10.4.2 Floating wetland system

The development of a floating wetland system on the tailings ponds focuses on enhancing and accelerating the consolidation (coagulation) and settling process of mostly fine clay particles. Which in turn results in an increase in released water which can subsequently be reused in the industrial process.

Strong points: The strong points for the development of a floating wetland system is that it ensures that re-suspension of fine clay particles by wind-driven water on tailings pond will be reduced, secondly a continuous carbon source is provided for bacteria who are responsible for the degradation of hydrocarbons in the tailings water. The degradation process of hydrocarbons and other pollutants in turn results in a faster consolidation process. In the third place tailings water flows will be directed to further enhance water treatment and consolidation processes. This is partly due to the floating parts in the water and partly through the synthetic textile curtains hanging beneath the floating wetlands attached to a frame.

Thereby, reed growing on the floating wetlands can be harvested, which can again serve as an source for energy. Finally these wetlands provide a habitat and food source for birds and through the addition of floating wetlands a the number of landings of birds in the water will decrease.

Discussion points: A discussion point for this design solution, which focuses on the consolidation and settling process of fine particles, how much faster will the settling process go by adding the floating wetlands? On the basis of our literature research, it can take decades for these particles to settle. Another point of discussion is again the sub-arctic climate, to what extent is this system influenced by that? The last point is the size of the floating wetlands, they already have been used with varying success for several purposes, however never on a scale like this. However the size of the tailings ponds also needs an intervention comparable with the size and scale of the tailings ponds however this often provides the most confusion.

Recommendations:

- More research on the functioning of the floating wetlands when it comes to the enhancement of the consolidation process of fine particles;
- More research is needed about the Influence of the sub-arctic climate on the efficiency of the floating wetland systems;
- More research must be done to further determine the dimensions of the floating wetland.

10.4.3 Secondary water treatment system

The development of a secondary water treatment system is to further treat the tailings water in order to increase the percentages of reused tailings water in industrial processes. Which will eventually lead to reduction of water extraction from the Athabasca river. The system floats on top of the water, water coming from the tailings ponds is let in, it then flows through the wetlands and is subsequently send to the water pond.

Strong points: A strong point of the development of a secondary water treatment system is that water is again going through a treatment process, to further treat and clean the water. We do this by two types of wetlands, removing both inorganic and organic pollutants, the water flows through both wetland types. Simultaneously, a recreational attraction is offered where people can see how this wetland system works. The system thus as an educational purpose, treatment purpose, an energy purpose through reed harvesting and possibly a habitat purpose.

Discussion points: The question is whether it will really improve the water quality. Since the whole tailings pond system is disturbed by the placement of a huge water treatment system, re-suspension of settled clay particles may take place. Whether this disturbance than outweighs the benefits is the question. In addition, the system also requires a certain hydraulic gradient which makes the water flow from one point to the other, this is however difficult with a floating system. Another discussion point is in what way this system is affected by the climate, SSF wetlands appeared to be suitable for colder climates, however FWS wetlands tend to freeze in winter, one therefore may have to think about a sort of cover system, to ensure that temperatures remain above zero. You therefore may need both a pumping system and a heating/ cover system which makes this water treatment system all of a sudden less passive, low in maintenance and operationally simple. At last is was very difficult to find data about the flow rate of tailings water in the Suncor plant. We therefore designed this system on the basis of a reference project which had many similarities.

Recommendations:

- More research should be done on re-suspension of fine particles when an element like our water treatment system is placed;
- More research should be done on the flow rate of tailings in the Suncor mine, to decide which size this water treatment system should be in order to deal with the incoming tailings flow from the sedimentation ponds;
- More research is needed about the Influence of the sub-arctic climate on the efficiency of the water treatment system;
- More research should be done on the added value of such a large water treatment system, to which extent does a system like this contribute to the further cleaning of tailings water?

10.4.4 Artificial mine landscape park

This design solution focuses on the reclamation process of the post mining area, and filling them by means of tailings sand and MFT coming from the sedimentation ponds. We developed four different reclamation principles, resulting in different landscape forming processes, leading to a diverse landscape. Regenerative capacity of nature is used to restore nature.

Strong points: A strong point of this design solution is that a whole new way of reclamation is developed. The process of filling the post mining areas is not very different than the way they currently do it. We however propose to fill the mine with a layer of tailings sand (which functions as a natural cover layer in order to prevent seepage) and the MFT which is a waste product dredged from the tailings ponds. The current methods focuses on a mechanical man-made way of dewatering the MFT, we however do it by means of natural processes. In this way natural processes are ultimately responsible for restoring the disturbed nature, which resolves in a new kind of landscape in the boreal forest area. The solution might not be as fast as the human interventions, but it for sure leads towards a more durable and diverse landscape. In 100 years time, more biotopes, more animals and more plants will be present in this area than if we would continue as they currently do. Thereby, one step from the current production process will be eliminated, the drying areas. Resulting in less surface disturbance and thus a more sustainable landscape.

Discussion points: The fact that we use natural processes is also one of the main discussion points. Since natural processes are also difficult to control. Due to these natural processes, the machine is constantly reacting and interacting with ecological, physical and chemical processes that the landscape has to offer, therefore the actual product of the machine might change. This is of course related to the nature of MFT, as already mentioned we don't know the exact composition of the material. How the material settles, how reed responds to it, how it goes together with the cold sub-arctic climate, will the animals eventually enter the area? Will it really evolve into four different landscape typologies as we assume? These are all insecurities which have to be researched and tested in more detail. It however sheds new light on how to deal with waste and the development of a new kind of nature.

Recommendations:

- More research needs to be done on the nature and composition of MFT;
- The potential impact of such an intervention on the environment in terms of hydrology;
- More research needs to be done on atmospheric evaporation (possible impact on environment) and absorption of tailings water by plants (and the possible impact this has on their growth), to determine the settling speed of MFT together with the development of vegetation and nature.

10.4.5 *Local and regional network layer*

Together with the reclamation of the mine, this design solution focuses on the development of a network for humans and animals on the post mining landscape. Resulting in the merging of natural, social and industrial processes at the same place. This design solution also serves as an incentive to improve the regional network, instead of being a final destination, Fort McMurray is integrated into the wider regional network, allowing Fort McMurray to become the entrance of the North.

Strong points: A strong point for the development of a recreational network is that the area is already opened for the public, during the operational phase of the mine. This reduces the character of the oil sands mine as being a 'black box'. It thereby expands in time to eventually evolve into a dense network of different paths and nodes. It enables people to reconnect to this landscape instead of distancing from it, since this is for most of the people for being here, the oil sands industry. This ideology again stimulates and strengthens the formation of a community.

Thereby it triggers the development of a better regional network. Since people need to be able to enter the area properly. Which hopefully leads towards the development of several roads to and from the area, to further reduce the pressure on highway 69. This provides a further embedding of fort McMurray in its region.

Discussion points: One major discussion point in the design for a recreational network is how to deal with the mine that is still in operation? Trucks will drive from and to the mine 24 hours a day. How is this combined with the recreational network? We however first did thought about it, how could these different modes of transportation be combined? However there were so many limitations regarding industrial infrastructure, since the only map we had was the Google map satellite map. On the basis of this image we were not able to say anything about the infrastructural system. We have therefore chosen to not include this information in the design, since it hindered us from making a design in the first place.

These industrial activities therefore put remarks on animal migration towards this area as well. The question therefore is whether the mining area will really function as a semi-transparent corridor and habitat for animals.
A last discussion point is whether our design solution will really function as a trigger for the development of new roads, connecting and embedding Fort McMurray with the rest of the region.

Recommendations:
- More research on the infrastructural network within the mine, what are main routes, what kind of roads are present? Could any combination of recreational and industrial infrastructure be possible?
- To what extent are different animals species disturbed by industrial operations?

10.5 General discussion and recommendations

The first and foremost limitation in our research was the limited availability of data. A lot of data was hidden or confidential, which made it very difficult to get a grip on the industrial process. Since exact data about for example the amount of pollutants was not up to date. We therefore had to make a lot of assumptions to continue with our research.

A second limitation was the fact that most of the gathered data was developed by engineers or chemists, resulting in articles written in a professional jargon that we did not master. This unfamiliarity with a certain professional jargon and our lack of knowledge into these disciplines, made it sometimes very difficult to get a grip on the different processes going on. This was mainly the case for the industrial workings in the mine.

Due to time difference and distance between the Netherlands and Canada we were not able to ask every small detail since that would just take too much time. We therefore had to rely on our own knowledge and logical reasoning regarding the workings of a particular process and were obliged to make several assumptions.

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Glossary

Barrels
The unit which is used in the oil sands industry. One barrel consists of 159 liters of synthetic crude oil

Bitumen
A viscous tarry, black hydrocarbon. Which forms the main product of the oil sands industry and processed into synthetic crude oil (BGC Engineering Inc., 2010)

Coarse solids
When the tailings are deposited in the tailings ponds three layers develop. The coarse solids are the most heavy material and settles to the bottom. This consist mainly of sand.

Coke
This is a byproduct of upgrading the bitumen to synthetic crude oil. It looks and acts like coal but has even higher carbon emissions

Drying area
Areas that are used and developed to let mature fine tailings dry atmospherically. This area is an open field with shallow slopes.

Extraction
The process of separating bitumen from oil sand, typically with hot water and centrifuge techniques (BGC Engineering Inc., 2010).

Fine tailings
A suspension of fine silts, clays, residual bitumen and water derived from extraction process. The suspension of these tailings is 85% water and 15% fine particles by volume. After about two years the fine tailings reached a content of 30% solids. From then they are called Mature Fine Tailings.

Froth
This are air-entrained bitumen which are the product of the primary extraction plant which is further processed into synthetic crude oil.

Mature fine tailings (MFT)
After about two years the fine tailings which consist of fine silts, clays, residual bitumen and water have reached a content of 30% solids. This substance is called the mature fine tailings. After this point settling occurs much more slowly (BGC Engineering Inc., 2010).

Mine
The big open pits where the bitumen are excavated

Released water
When the tailings are deposited in the tailings ponds three layers develop. The released water floats on top as the third layer and is being recycled back to the bitumen extraction process.

Oil Sands
A sand deposit containing bitumen. A naturally occurring mixture made up of grains of quartz sand, surrounded by a layer of water and clay, and then covered in a slick of heavy oil called bitumen

Overburden
The overburden is located under subsoil and on top of the bitumen. This material might contain a very low rate of bitumen. It is dumped at the overburden dumps to subsequently be used for reclamation or as material to build dikes and roads.

Overburden dumps
Places where the overburden is dumped which eventually develop into artificial dumps in the landscape

Process-affected Water
Water which is used in the process and has come in contact with oil sands, and may contain hydrocarbons, salts, and other chemicals (BGC Engineering Inc., 2010).

Sedimentation pond
The sedimentation pond is the tailings ponds where the tailings are stored first in the process. The function of these ponds is the consolidation of coarse and fine solids and extract released water for recycling.

Sulphur
Elemental sulphur is considered a commodity material which is mainly used for the production of fertilizers. Because of the remote location of the oil sands operation sites, most of the sulphur produced during upgrading is stockpiled in large blocks of hundreds of metres in length and width.

Solids Content
Ratio of the mass of dry solids to total mass of tailings, expressed as a percentage (BGC Engineering Inc., 2010).

Subsoil
The subsoil is the layer located between the topsoil and the overburden. This layer is low of nutrients and has no limitations to plant growth. This layer does not contain any bitumen (Interviewee 20, 2013).

Suncor
Suncor energy Inc. is a company operating in the oil sands industry. They developed the world's first large-scale commercial plant in 1967.

Synthetic crude oil
This is the main output of the oil sands upgrader facility. The synthetic crude oil is transported to several refineries to be further processed into finished products

Tailings
A by-product of oil sands extraction which comprises of process water, sand, clay with minor amounts of residual bitumen (BGC Engineering Inc., 2010).

Tailings Ponds
Man-made enormous basins containing tailings. These ponds are enclosed by dikes. The function of these ponds is to store tailings, as a settling basin and to release water to be reused in the process.

Topsoil
the topsoil is the first layer they excavate when they start digging for oil. This layer has the highest concentration of organic material. This layer is stored and later on used in the reclamation phase (Interviewee 20, 2013)

Water pond
This is the pond where the released water from the sedimentation pond is transported to. Inhere the water is stored and extracted to be reused in the industrial process when necessary.

Upgrader
The facility where the bitumen are upgraded to synthetic crude oil

List of References

BGC Engineering Inc., 2010. Oil Sands Tailings Technology Review. Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment, Edmonton, Alberta. OSRIN Report No. TR-1, p.136

Interviewee 20, 2013. Interview about land reclamation and restoration of ecology. Interviewed by Floortje Goossens and Anne Nijland. [personal conversation] 20 November 2013.

Appendix

Sketches
- Sketches on the regional scale
- Sketches on the mine scale with building blocks

Studies on sustainability
- Study on energy crops
- Study on energy consumption of households
- Study on energy consumption of the industry

Stakeholder analysis
- Interviews
- Factsheets
- Personas

Reference studies

Artificial mine landscape park
- Calculations of Mature fine tailings

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MSc thesis Landscape Architecture | Wageningen UR | 2014

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