LANDSCAPES OF AVULSION: PROPOSED FUTURE ECOLOGIES FOR CANADIAN OIL SANDS RECLAMATION

by Alyssa Magas

A Landscape Architecture Design Practicum
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A Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree

Master of Landscape Architecture

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ABSTRACT

The Athabasca Oil Sands is an extraction industry with many complexities that require reclamation practices following their closure. What could be the future uses of oil extraction mining sites? An opportunity presents itself for landscape architecture in generating adaptations to climate change for the future of this region. Can landscape architecture aid in planning for the resilience of future ecologies and success of these landscapes of avulsion?

The past and present uses of this area have contributed to a wealth of information that is beneficial in determining goals of a renewed ecological function. This research and design practicum proposes a set of ecological strategies for a site known as Tar Island, near Fort McMurray, Alberta. These strategies can be implemented as a framework for similar sites as the industry continues their presence in the Oil Sands with the plans and excavations which leave behind an altered landscape.

Landscape Architecture, Canadian Oil Sands, reclamation strategies, climate change, landscape resilience, ecological function

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DEDICATION

For those with courage.

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CHAPTER ONE

INTRODUCTION

LANDSCAPES OF AVULSION

EXTRACTION LANDSCAPES

a·vul·sion *(n.)*
1. A ripping off; forcible separation.
2. A part removed in this way. *(Morris, 1969, p.92)*

Figure 1-1: Active mining pit at Syncrude Mildred Lake.

Landscapes of oil extraction are a world unknown. To research the processes of altering the land to gain access to an energy resource is by no means a simple endeavour. Complexities of this industry sparked my initial desire to understand how oil extraction industries operate. Perceptions of this industry are contentious; there are a variety of differing viewpoints both for and against production. Debate is divided for the ecological and economical impacts. There are always more questions and numerous possibilities for inquiry as this industry plans, excavates, and leaves the land altered. Taking these factors into consideration, I have focused on the practice of reclamation.

The Canadian Oil and Gas Industry oversees many petroleum production sites which includes the Alberta oil reserves commonly referred to as the Oil Sands. I have chosen to work under the umbrella of the Canadian Oil Sands, or simply the Oil Sands, as these are based in Alberta but considered a national resource for Canada. Extraction of the Oil Sands is done through mining or in-situ (meaning in-place) drilling and include an array of land degradations. Mining extraction is commonly practiced in the Athabasca watershed where reserves are found closer to the surface than reserves that require deeper in-situ drilling methods. This 'surface-mine-able' oil deposit is referred to as the Athabasca Oil Sands (NRCAN, 2013). Extraction landscapes describe any land altered through processes such as excavation or drilling which reduce or eliminate ecological function - leaving behind voids such as gaping pits and cleared sites in the landscape. Following extraction, the responsibility of industry is to return these landscapes of avulsion to an equivalent use prior to production (NRCAN, 2016). Ecological viability of a landscape is dependent on the return of the ecological functions removed during extraction. The planning and implementation strategies are known as land reclamation practices.

A focus on the land itself and its capacity for ecological function guides my research. The long term success of extraction landscapes is dependent on the return of ecological function, but the overall loss of ecology remains as reclamation processes can never replace what was once there. What could be the future uses of oil extraction mining sites in Canada? Climate change data anticipates drastic changes to the land and its ecological function. The role of spatial design through landscape architecture envisions a future at a large scale which attempts to balance a variety of needs and has implications at the ground level. Can landscape architecture aid in planning for the resilience of future ecologies and success of these landscapes of avulsion? Understanding the past uses and looking to the future capacities of these landscapes could provide an important opportunity for landscape architecture in generating adaptations to climate change.

To understand the approach of the oil industry's reclamation strategies for the Athabasca Oil Sands, I have divided my research into five chapters: introduction; Oil Sands production and reclamation; site analysis; site design strategies; and implications.

An introduction to this region's scale, context, geography, and language are established to characterise the world of oil as it exists in this region. The Oil Sands production and reclamation chapter explains processes through the use of diagrams and photographs to understand current industrial functions and the regulations pertinent to reclamation. A review of the relationship of reclamation to landscape architecture is included. Case studies of current reclamation projects provide an overview of present solutions leading to speculation regarding the proposed future transition of reclamation in the wake of changing climatic conditions. Chapter three offers a comprehensive site analysis using mapping and photography to aid in the understanding of the character of the site. Modelling past and present land uses that include geologic and climatic factors, can inform the future capacity of these landscapes. An understanding of the function of industry as a system and the mapping of features of this landscape provide a spatial understanding of present land uses.

Soil scenarios are determined to inform intervention outcomes to shift landscape reclamation to well-suited future ecologies. The site design chapter outlines design strategies based on the opportunities identified in the site analysis. Implementing strategies for ecological reclamation can provide resilient outcomes for these landscapes with potential application to other similar sites. The final chapter discusses conclusions from the implications of this research. The role of landscape architecture practitioners and practices is essential in the approach land reclamation for sites such as the Oil Sands landscapes of avulsion. The potential for new inquiries exist through further exploration and landscape architectural practices.

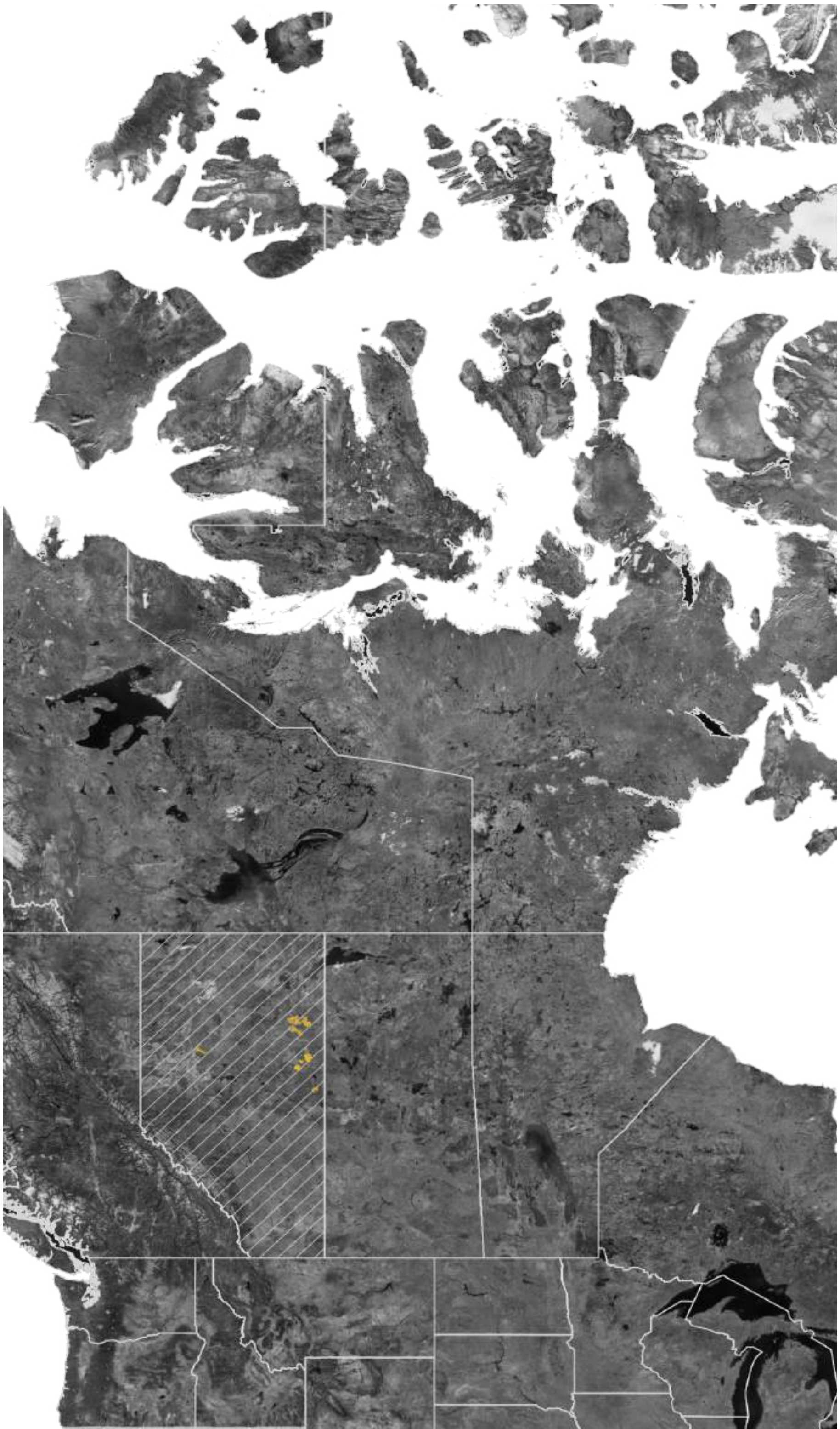


Figure 1-2: GIS map showing active mining footprint in the province of Alberta, Canada.

ATHABASCA OIL SANDS
CONTEXT

Comprehending the scale of Canadian Oil Sands begins with an understanding of its location and industrial practices. The industry exploits an energy source that is extracted from oil deposits below-ground in the boreal forest of northern Alberta. Oil reserve locations are determined by deposits formed in different geologic compositions. There are three formations found within Alberta: the Peace River, Cold Lake, and Athabasca deposits (NRCAN, 2013). The Peace River deposit is located in north-west Alberta, and the industry primarily depends on in-situ methods of extraction. The Cold Lake deposit is found in mid-eastern Alberta and also depends on in-situ methods. The Athabasca Oil Sands are the largest deposit and are found in shallower geologic compositions near Fort McMurray, in north-eastern Alberta. Both in-situ and strip mining from the surface can be used here for extraction (Oil Sands Discovery Centre, n.d.). Areas with underlying oil deposits are owned by the Canadian Government and are leased to extraction companies for the purpose of developing the resource found beneath the surface.

A focus has been placed on an area known as Tar Island near Fort McMurray, Alberta. Although pit mining forms a very small percentage of production in the Canadian Oil Sands, this site has a disproportionately large industrial footprint due to extensive alterations of the land. The reach of industry has ecologic, economic, social, and cultural implications. The networks of power lines and roads that allow access to and from extraction sites are found throughout Alberta. Specifically, cutlines and pipelines map the flows in and out of extraction sites as well as indicates the vast reach of industry.

This research focuses on the land and its ecological function exclusively. Past, present, and future planning of land use determines the success and resilience of landscapes that sustain human life. Climate change data supports the anticipation of drastic changes to the land and its ecological function. When looking at an industry which alters or inhibits ecological function to support intense production, planning for future uses creates the potential for an alternative landscape following extraction.

The Athabasca Oil Sands mining operations are situated in the boreal forest in an area distant from urban development but situated on the lands of multiple Indigenous communities. The mining sites that sit on both sides of the Athabasca River are approximately 30 kilometres north of Fort McMurray. The Athabasca River originates in the Canadian Rocky Mountains near Jasper, Alberta and flows north-east across the province of Alberta. After flowing through the Fort McMurray area it reaches north to the Peace-Athabasca river delta and the community of

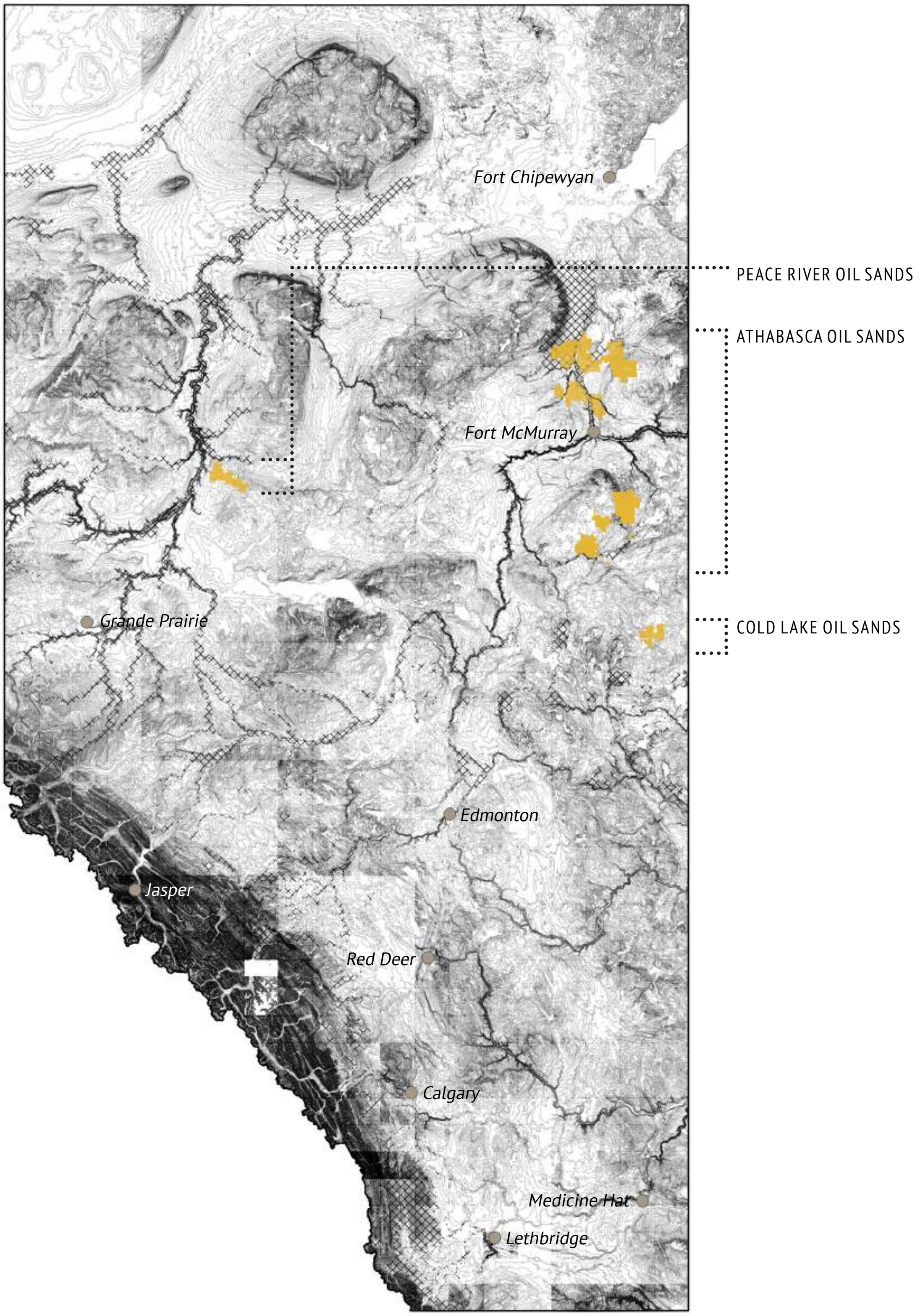


Figure 1-3: GIS map showing active mining footprint within Alberta.

Fort Chipewyan, Alberta which is located on Lake Athabasca. This region is a part of the Regional Municipality of Wood Buffalo. The Lower Athabasca Regional Plan outlines strategies and regulations for optimal economic opportunities and maximising landscape function and protection within the region (Government of Alberta, 2012). The plan does, however, encourage economic growth through industrial production disregarding the rights of Indigenous lands and resources (Adam, 2014, p.15). Thus, this regional plan that is meant to protect lands through industrial development seems to be aimed more directly at the protection of the regional economy than on the protection of the environment.

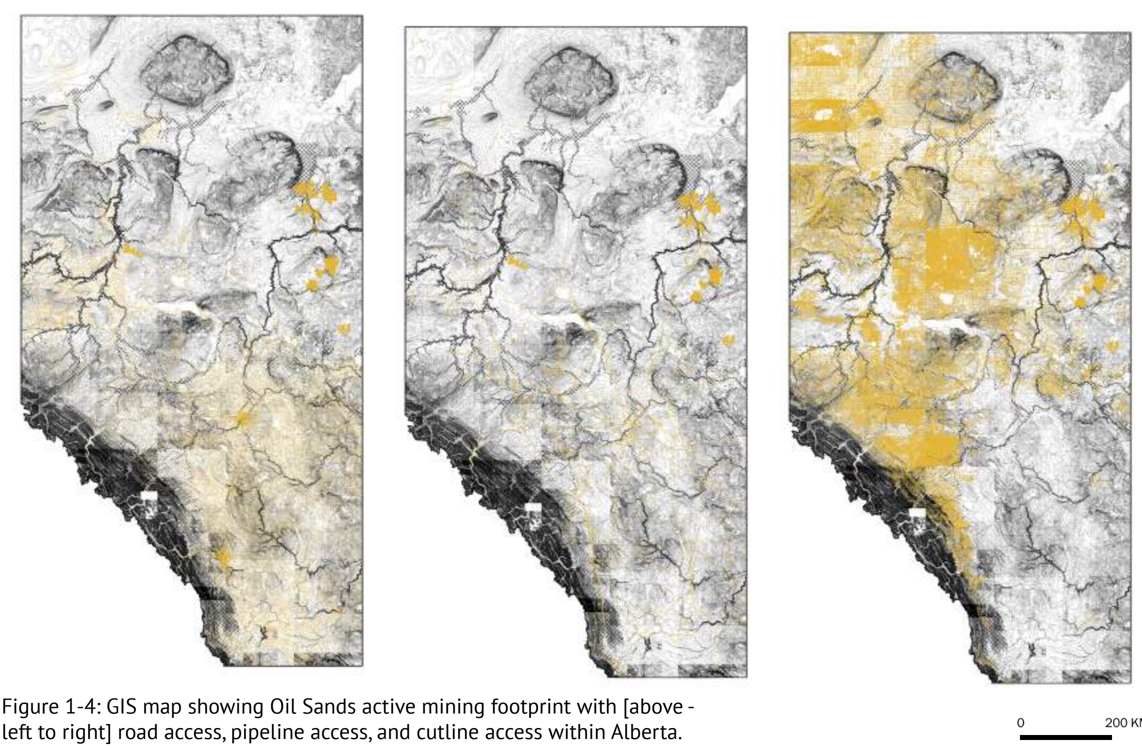


Figure 1-4: GIS map showing Oil Sands active mining footprint with [above - left to right] road access, pipeline access, and cutline access within Alberta.

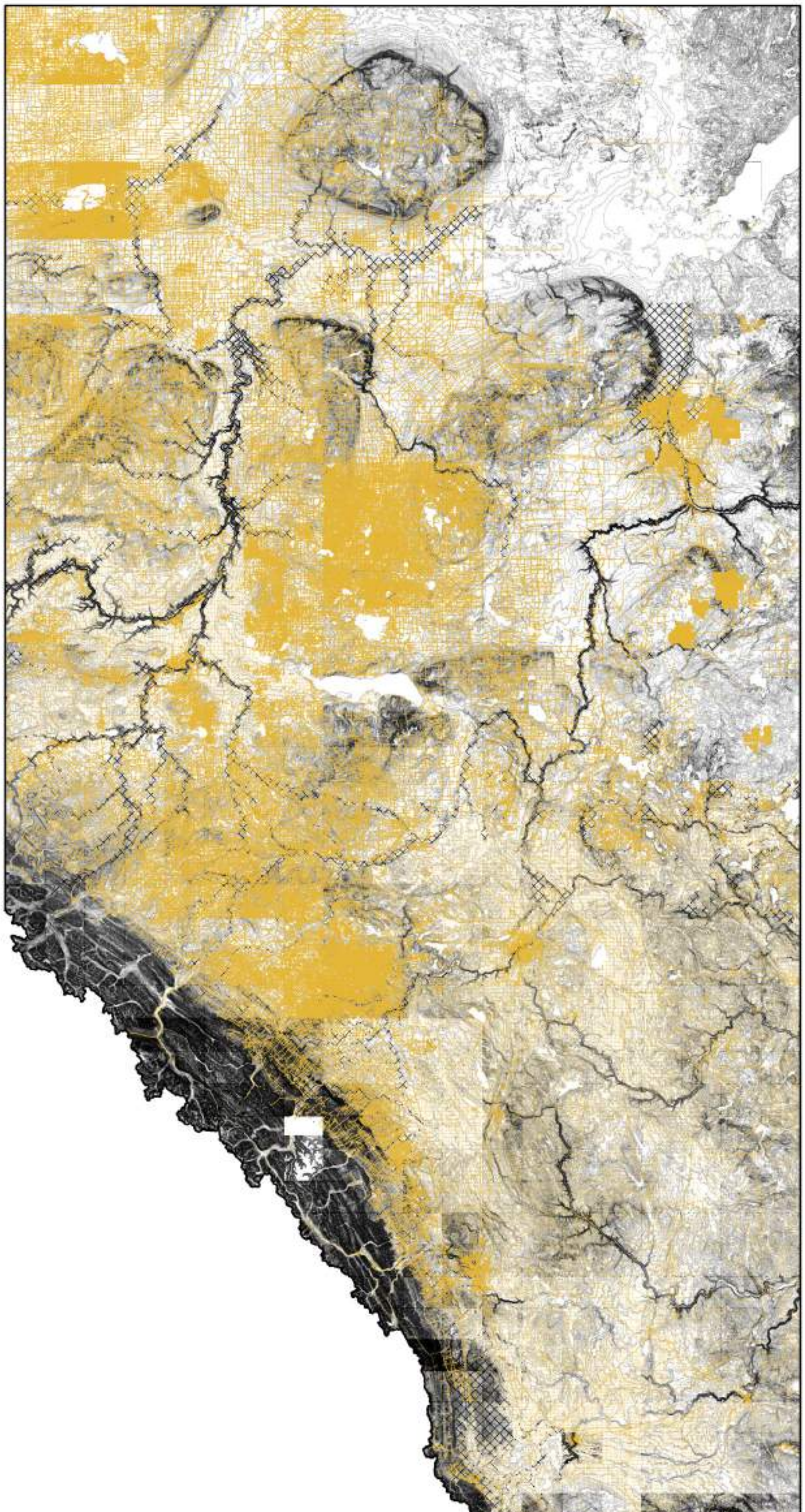


Figure 1-5: GIS map showing Oil Sands active mining footprint with combined road, pipeline, and cutline reach within Alberta.

Figure 1-6: Boreal forest and wetlands in early November near Fort McMurray, in northern Alberta.


FORT MCKAY
McKay River
Athabasca River
Steepbank River
TAR ISLAND - SYNCRUDE AND
SUNCOR OIL SANDS MINING SITES
FORT MCMURRAY
Clearwater River
Athabasca River

The deep Athabasca River valley can be seen as a spine throughout the area of industrial growth. The river valley provides a drastic elevation change from the mining sites that sit above it. Key wildlife and biodiversity zones are commonly found along rivers as environmentally significant intersections, making the ecological displacement due to industrial production of greater consequence. Tar Island refers to an land leased area comprised of Syncrude and Suncor's company mining sites located approximately 30 kilometres north of Fort McMurray.

Figure 1-7: Athabasca Oil Sands GIS satellite imagery context map.


0
5
10
15
20 KM

Figure 1-8: GIS satellite imagery map of Tar Island - Syncrude and Suncor Oil Sands pit mining land lease sites.

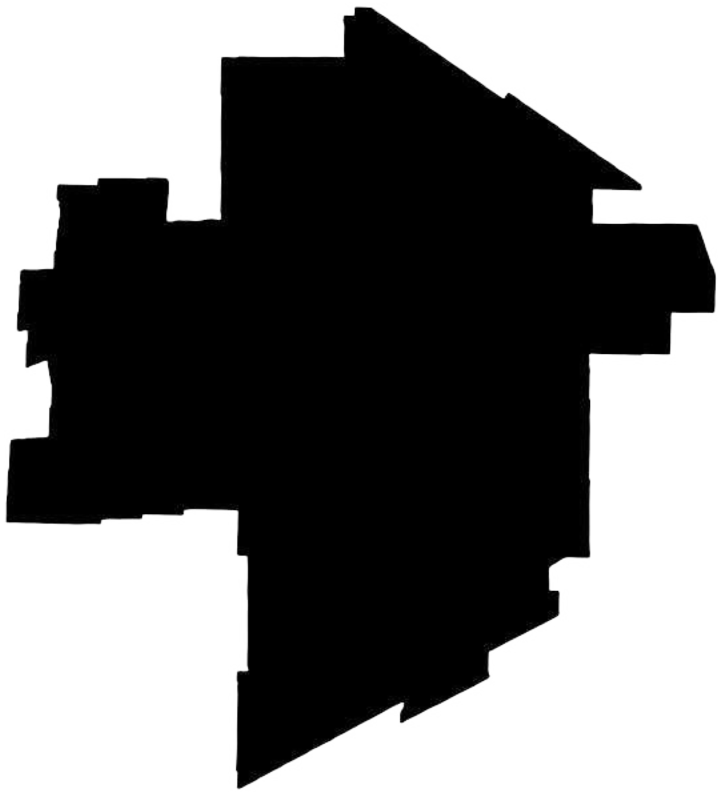


Figure 1-9: Scale footprint comparison between Tar Island mining sites [opposite page] and the City of Winnipeg, Manitoba [above].

The footprint of Tar Island (an area of Syncrude and Suncor's land leased mining sites) covers an area similar to the size of the City of Winnipeg, Manitoba. Excluding the area farthest west of the site which is mainly used for in-situ operations, the pit mining area for Tar Island is approximately 40km in average length by 15km in average width.

LINGUA-OLEUM LANGUAGE OF OIL

GLOSSARY OF TERMS

A language of oil is commonly used among the industries of the Athabasca Oil Sands region. The terms listed here are words or phrases that I have encountered, heard, and read through research and personal communications. Some terms defined here are of my understanding based on the context in which a term has been presented. I have cited other terms to provide for a more precise definition where I was uncertain of details related to this industry. I have introduced these terms as an aid for reference throughout this document. In researching an industry so complex and so extensive, understanding the *lingua-oleum* helps to explain how the land is being used before, during, and after production. The terms are grouped in sections according to location, material, equipment and operations, land use layers (Geographic Information Systems (GIS) industrial features), and ecology translated to reflect the large scale of the Athabasca Oil Sands. Dive into the world and language of oil; the *lingua-oleum.*

Locus LOCATION

Fort Mac: Fort McMurray, Regional Municipality of Wood Buffalo, Alberta
Fort Chip: Fort Chipewyan, Regional Municipality of Wood Buffalo, Alberta
Tar Island: strip mining site approximately 30kms north of Fort McMurray, leased by Syncrude Canada Ltd. and Suncor Energy Inc.
Hwy 63: main highway route reaching between Edmonton, Fort McMurray, and the mining sites north of Fort McMurray
Syncrude Loop: a one-way loop of Hwy 63 surrounding Syncrude's base operations site, reclamation sites, and the Giants of Mining public education site in Tar Island

Materiales MATERIALS

Bitumen: heavy oil found within compositions of sand and water
Crude: oil that has been heavily processed for transportation through pipelines and further upgrading
Effluent: liquid waste deposited into tailing ponds
Ore: bedrock or other earth material
Overburden: rock and soil layers covering parent bedrock below
Petroleum coke/petcoke: a mainly carbon byproduct of oil sands upgrading not unlike coal sold to other markets


Figure 1-10: Hwy 63 following the curves of the Athabasca River to the east.

Slick: streaks of shiny residual bitumen commonly seen on tailing ponds
Sludge: a common reference to the mixture of thick clay and water, and other leftover components in tailings ponds
Sulphur: a mineral extracted from bitumen comprising about 5% of its makeup, yellow in colour and stored in large pyramid-like forms (Helbig, 2014, p.289)
Slash piles: clear-cut vegetation stored in piles for burning or lumber markets
Tailings: liquid waste mix of water, fine clays, silts, salts, soluble organic compounds, solvents, and bitumen reside collected in ponds for settling and drying (Helbig, 2014, p.293)
Tar: common reference to oil but specifically related to the composition of asphalt

Figure 1-11: Sulphur stockpiles near Syncrude's base operations.

Operatio armorum et OPERATIONS AND EQUIPMENT

Bitu-man: a floating 'scarecrow' attached to 45 gallon oil barrel placed on tailing ponds to deter wildlife (Helbig, 2014, p.287)
Capping: applying a layer of water over tailings to create a lake, or petroleum coke over tailings to create trafficable surface while tailings dry
Catwalk: elevated walkways over operations or tailings ponds for monitoring
Cutlines: straight or undulating lines of cleared vegetation often through boreal forested areas due to seismic exploration of oil deposits
Grid: a network of cutlines
Haul road: wide travel routes for large machinery throughout mining areas

Haul truck/mining truck/heavy hauler: up to 400 ton capacity bucket/box trucks that transport excavated oil sands for production

Hydraulic shovel: loader or excavator dig up oil sands that are placed in haul trucks

Ice road: frozen access route in winter months over unstable wetland areas

Lease holders: oil extraction companies gain land and resource leases from the Government of Canada to develop the resource through mining or in-situ operations

Mechanical peregrine falcon: radar controlled motion and sound deterrent for birds placed on tailing ponds, activated by detection up to 2.8km away (Helbig, 2014, p.282)

Pad: plots of cleared vegetation often through boreal forested areas due oil deposit exploration or drilling wells for excavation

Pumpjack: the aboveground mechanism used to operate drilling wells for oil extraction

Pumping vessel: watercraft used to extract water for recycling on tailing ponds (Helbig, 2014, p.292)

Remediation: the purification or removal of toxins from site soil for the safety of public and wildlife

Reclamation: returning land to an 'equivalent use' prior to disturbance

SAGD [Steam-assisted gravity drainage]: the most common type of in-situ drilling method used for oil extraction involving two parallel wells to access deep deposits

Settling: the process of sorting tailings - bitumen is collected, sand is separated, and the remaining clay and water mixture requires up to 30 years to separate and dry out (Helbig, 2014, pp.282, 300)

Standpipe: discharge outlet for placement of effluent, water, tailings, or sand

Pipe yard/lay down yard: staging area to set up operations and equipment

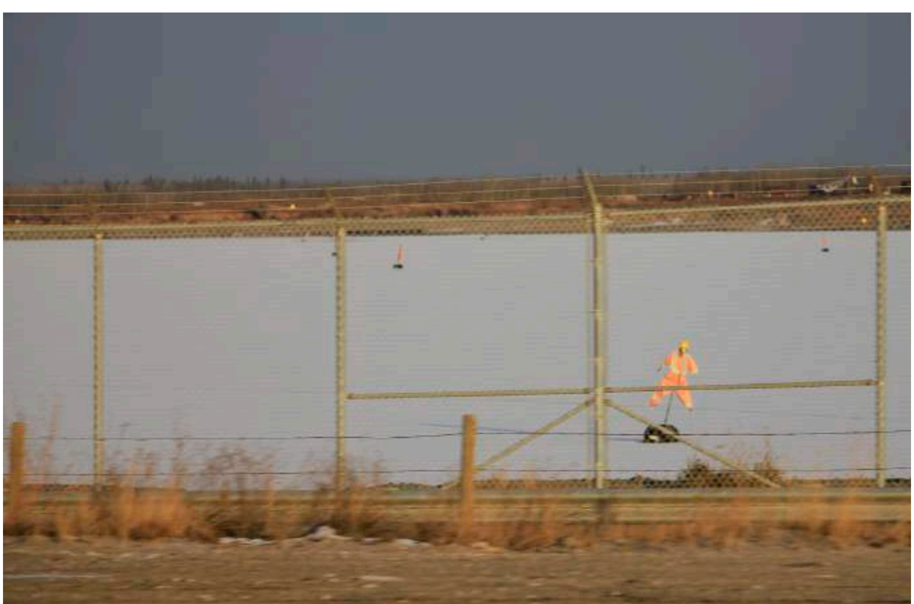


Figure 1-12: Bitu-man on a frozen Suncor tailings pond.

Tanker truck: classification of transport vehicle designed to haul liquids like fuel
Tanks: above ground storage of petroleum products
Refinery: the process of transforming crude oil into other petroleum products
Upgrader: "the process of converting heavy oil or bitumen into synthetic crude oil" (CAPP, 2019)

Stratis LAYERS [GIS LAND USE]

Aerodrome: local airplane runway
Borrow pit: extraction of soil, rock, or other materials for placement elsewhere
Camp housing: lodges situated near company operations for employees to stay during work periods
Central processing facility: a company's refining or upgrading operations
Certified: certified reclaimed land
Cutblock: area cleared vegetation
Dedicated drying area: accelerated drying technique for tailings in sloped rectilinear areas
Disturbed other industry: altered site in a lease area to support operations
Disturbed unclassified: altered site in a lease area for an unspecified purpose
Drainage: directional water flow through a site
Dry tailings: remaining elements in tailing ponds once water has evaporated
Mine pit: open pit access to oil sands in bedrock material for strip mining up to 70m in depth
Natural: land within a company's lease area left undisturbed
Oil sands cleared: cut and removed vegetation and potentially soils in a lease area
Operations: infrastructure to support administrative and operational procedures
Other: undefined, grouped with pits for mapping purposes
Overburden dump: stockpile or spread of overburden
Permanent: permanently reclaimed site in monitoring phase
Pipeline: below-ground network of pipes for transportation of crude oil
Plant site: processing and production infrastructure
Powerline: above-ground electrical network
Ready for reclamation: following mine or other process closure and awaiting reclamation plan implementation
Reclamation material stockpile (RMS): collection of reclamation materials including soil, peat, wood debris, and other organic matter
Road: access network between operations and lease companies
Soil placed: reclamation phase where soil is spread over a closed site required for re-vegetation
Soil salvaged: collection of soil for future reclamation when clearing land, not seemingly documented consistently among lease companies

Tank farm: collection of petroleum product storage tanks
Temporary: temporarily reclaimed sites
Temporary (dam safety): temporarily reclaimed site to support tailings dam safety
Transformer station: distribution station for powerlines
Undergoing remediation: process of toxins purification or removal from soils for public and wildlife safety
Utilities: electric, gas, water, and wastewater infrastructure supply
Waste: unusable byproducts or remains of industry
Wellsite: cleared plot of land used as a in-situ drilling extraction site
Wet tailings: tailing ponds early in the settling phase with a high quantity of water
Wetland trial: test and monitoring of wetland implementation for reclamation
Windrow: collection of reclamation material in rows for storage


Figure 1-13: Suncor windrows of reclamation material.

Ecology ECOLOGY

Industrial ecology: industrial ecology refers to the study of an industry as a system that functions similarly to an ecosystem
Organisms: individuals or groups of machinery that inhabit and shape their environment
Quadrant: a typical 1m x 1m test plot for ecological growth is scaled up to 100m x 100m
Transect: a long, narrow test plot that traverses across multiple landscape types or features, for this practicum it is applied at five kilometres in length

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

LIMITATIONS OF DATA

Discussions regarding a complex industrial site such as the Oil Sands involves grappling with conflicting views and sources. The GIS data used for the site mapping analysis categorises land use types within active mining footprints. The data primarily used is called Oil Sands Industrial Features (OSIF). The shapefile data is made up of spatial polygons that represent geographic features and provides an inventory of land use. The OSIF data files were submitted to Alberta Environment and Parks and provided by the Government of Alberta for public distribution.

The OSIF data is sourced from satellite imagery classification, operator data, and base features (Government of Alberta, 2019). Some of the data collected is provided by the operating lease holders (Alberta Environment and Parks, 2015) which creates a conflict of interest in the level of reliance within the data. How each extraction company defines the features is dependent on their interpretation of the categories and their honesty in accurate representation. The data from lease operators was used as submitted (Alberta Environment and Parks, 2015). As seen in the *lingua-oleum* definitions, some land use terms are a generic understanding of the activities that occur on this type of land as these are not further defined to explain specific uses and capacities. The data was collected and distributed for the 1980's, 1998, 2007, 2010, 2011, 2012, 2013, 2014, and 2015 (Government of Alberta, 2019).

The 2015 GIS data of Oil Sands Industrial Features is the most recent tracking of land use types in the mining area of focus. By referencing these layers to more recent satellite imagery, the 2015 data serves as a manageable representation of current activities in this area. These landscapes will shift as production continues and terminates, however, the 2015 data will serve as a baseline for my research. By creating a framework of strategies based on the remaining conditions, reclamation proposals can be applied to future sites as this area evolves.

Figure 1-14: Hwy 63's Syncrude Loop surrounding Syncrude's base operations site, reclamation sites, and the Giants of Mining public education site.

FUTURE OF THE ATHABASCA OIL SANDS

CONCLUSIONS

As my knowledge of the Canadian Oil Sands grows, so does my interests in this vast and complex industry. My focus on the landscape and its ecological function provide a necessary but limited focus because of the large scale of this area and its intricacies. Through secondary description, classification schemes, and case study analysis of existing production and reclamation practices, an understanding of this site had been gained to inform projective design strategies.

Reclamation within the Oil Sands is currently limited to an attempt to restore landscapes where ecological function has been eliminated. This provides an opportunity for the practice of landscape architecture to address current and future needs of these extraction landscapes in the face of changing climatic conditions. Can landscape architecture aid in a proposal of design strategies for the future uses and resilience of these landscapes of avulsion?

The aim of this research is to propose a set of strategies to aid in a revival of ecological function that does not conceal the industrial past of the Oil Sands extraction landscapes. By providing design strategies and a framework under which they operate, implementation of ecological communities can be determined and applied to sites as conditions change over time.

Figure 1-15: Syncrude's base mine filled with tailings and then water capped to create a reclamation pit lake. Mechanical 'peregrine falcons' can be seen as bird deterrents.

CHAPTER TWO

OIL SANDS RECLAMATION

LANDSCAPE ARCHITECTURE AND RECLAMATION

BALANCED VALUES

Designating a future use for a site can be done through the practice of reclamation. There is a need to reclaim space following a disturbance to a site's previous use. In recent years we have seen projects of reclamation as a skillful re-organisation of space that highlights a past use while allowing freedom in its future potential. Projects such as Fresh Kills Park (Staten Island, USA), The High Line (New York City, USA), and Landschaftspark (Duisburg-Nord, Germany) provide creative, compelling examples of successful industrial site reclamation. Landscape architecture provides an appropriate lens to balance values of representation, aesthetics, and function.

What is reclamation and why do we value it? Insights into questions like these are discussed in *Designing the Reclaimed Landscape* (2007) and *Reclaiming the American West* (2002) by Alan Berger. The word reclaim can "refer to ideas of reform, recover, and rescue" (Berger, 2002, p.60) following human landscape alteration due to industrial production. Reclamation began as a practical need for physical and legal safety (Turner in Berger, 2007, p.3) with a goal of returning the land to an 'equivalent' - depending on how equivalent is defined - state prior to alteration. Frederick Turner, in *Designing the Reclaimed Landscape*, describes a student's experience of an abandoned strip mine that had provided an interesting area for exploration and a flourishing ecology but was later graded for safety. What was left behind was a sloped landscape with a lake at the lowest point which the student had described as boring (Turner in Berger, 2007, p.3). Reclamation serves as a function of space but also considers aesthetic values. The aesthetics of a place are not only visual but a cultural condition understood through 'cognitive processes' (Berger, 2002, p.143). Our aesthetic values change over time as we come to understand processes such as ecological function or development.

An aesthetic of ruins is commonly expressed in industrial reclamation sites. Often described as the theory of the sublime, Philip Shaw's research on this notion describes the sublime as "when experience slips out of conventional understanding" or "an experience that is excessive, unmanageable, even terrifying" (2006, pp.2-4). What if there are no visible ruins of a place? Has its history been erased or forgotten? If a wound has healed, does it not leave a scar? Why is it that we accept altered landscapes in other forms? For example, we identify agricultural fields as equivalent to the previous prairie biome even though their functions differ drastically. Perhaps it is because it serves a purpose that we all value - in this case food production. An oil extraction landscape is not often valued even though it is producing energy, so what does its future use have to say about its history and aesthetic identity?

In addressing reclamation, representation is important in revealing relationships and conditions present in an area. For large scale projects such as oil extraction, aerial photography is well suited to capture its features and describe the massive scale of operations. In *Reclaiming the American West*, Alan Berger references that mines and their reclamation specifically require aerial imagery due to their large scale and an inability to comprehend spatial components from ground level (2002, p.153). Features of a large scale operation sprawl across the landscape and require a view from above to fully understand their spatial implications. Conclusions drawn from my topic study coursework (*LARC 7400*) explored aerial landscape photography as playing a major role in the public perception of the Canadian Oil Sands landscape. Aerial photography has been used as an aesthetic device, as documentation, and as a tool for analysis by landscape photographers such as Edward Burtynsky, Garth Lenz, and Louis Helbig (Magas, 2019, p.6). Through my case study analysis of these photographers, themes interpreted from their work focused on the theory of the sublime; juxtaposition and datum; and geometric patterns and scale.

Through reclamation, conditions are simulated that continue to grow as they adapt to local context and time, independent of their origins (Berger, 2002, p.181). Reclamation practices are implemented with best intentions for the ecological health of a system to stimulate conditions (p.182). ”Landscape space is unique because it transforms through its cultural occupation and production as well as through its natural environment” (Berger, 2002, p.151). This transformation of space that allows for ecological succession is a value commonly seen in landscape architecture practices. Restoration to a previous site condition does not allow the same type of freedom in ecological communities and does not reflect a site’s current function. As James Corner notes in Recovering Landscape (1999, p.xi), ”For a landscape to be properly recovered it must be remade, designed, invented anew; it cannot simply be restored, as an old painting.”

Reclamation (especially at large scales) attempts to set up a new or modified framework from which nature may adapt new natural processes that emerge from the conditions of the new place. Understanding potential ecological processes is therefore vital to identifying strategies for reclamation, as well as the framework and trajectory of the site's future evolution. *(Berger, 2002, p.61)*

Figure 2-1: Fenced reclamation area known as Syncrude's Bison Viewpoint.

CANADIAN OIL SANDS LANDSCAPE
PRODUCTION PROCESSES

In addressing the landscape of oil, it is necessary to understand the complexities of the functions and production in the oil industry. Both physical space, as seen in chapter one, and impact are of massive scale. The Canadian Oil Sands are situated in northern Alberta within boreal forest and prairie ecozones (NRCAN, 2016). Treed, grassland, and wetland systems exist throughout these northern landscapes and are disturbed by industrial processes. The Oil Sands operate through mining and in-situ drilling as a means of extracting crude oil. Mining represents 20% of all oil extraction production in Alberta. Pit or strip mining operates by shovelling and removing oil sands from the ground within 75 metres of the earth's surface. The surficial land area of this process represents 3% of the Oil Sands land area containing oil deposits (NRCAN, 2016). This is a misleading number because of its exclusion of the depth of mass removed from the earth and the alvused landscapes of open pits that are left behind. In-situ drilling represents 80% of all oil extraction production and operates by injected steam into drilled wells to be pumped up to the surface. This method operates more than 75 metres below the earth's surface and can be executed in 97% of the Oil Sands land area deposits (NRCAN, 2016). Crude oil is upgraded or refined into everyday products that Canadians currently depend on. While Canada transitions to renewable energy, the Oil Sands remain an everyday reality that can be addressed for its negative impacts through planning and design.

Environmental, economical, political, and socio-cultural impacts can be seen to varying extents in the Oil Sands industry. Both positive and negative impacts to communities and the land are created through the production of oil resources. Environmental impacts are of great concern to overall ecological health of this area for their detrimental scale. Some negative impacts on the environment caused by oil extraction mining include: vegetation removal; extensive networks of roadways, pipelines, and seismic cut lines; removal of soils and bedrock into Earth's crust; habitat and biomass loss; fragmentation of habitat; soil, air, and water pollution; tailing ponds byproduct; energy intensive production; and a loss of traditional and cultural territory lands (Oil Sands Discovery Centre, n.d.). On the other hand, over 400,000 direct, indirect, and induced employment positions are sustained by the Oil Sands industry and contribute to the Canadian economy (NRCAN, 2016). For many it is a livelihood and a place of residence.

Social and cultural impacts of industry are experienced by Canadians at large. Environmental and economic oppositions create political conflict pushing for or against industry with divisive opinions. Unfavourable conditions are created for workers residing temporarily near production sites in camp housing lodges.

Existing communities nearby or downstream are impacted by pollution associated with the industrial practices. Chief Allan Adam of the Athabasca Chipewyan First Nation notes that the rights of Indigenous lands and their people are not often considered in industry related projects or are the last interest group to be consulted (2014, p.15). Investments have been made by some Indigenous communities along with the formation of service businesses related to the industry. These investments provide an economic opportunity so that the Athabasca Chipewyan First Nation, for example, can be economically independent and continue to be stewards of their lands in the face of the negative environmental impacts of oil extraction (Adam, 2014, p.15). Conflicting voices and sources of information pose a challenge as the researcher attempts to determine value in the conversations surrounding the Oil Sands.

Figure 2-2: View across Syncrude's reclamation lake with the base operations site reflecting in the water capped tailings pond.

OIL SANDS PRODUCTION OVERVIEW

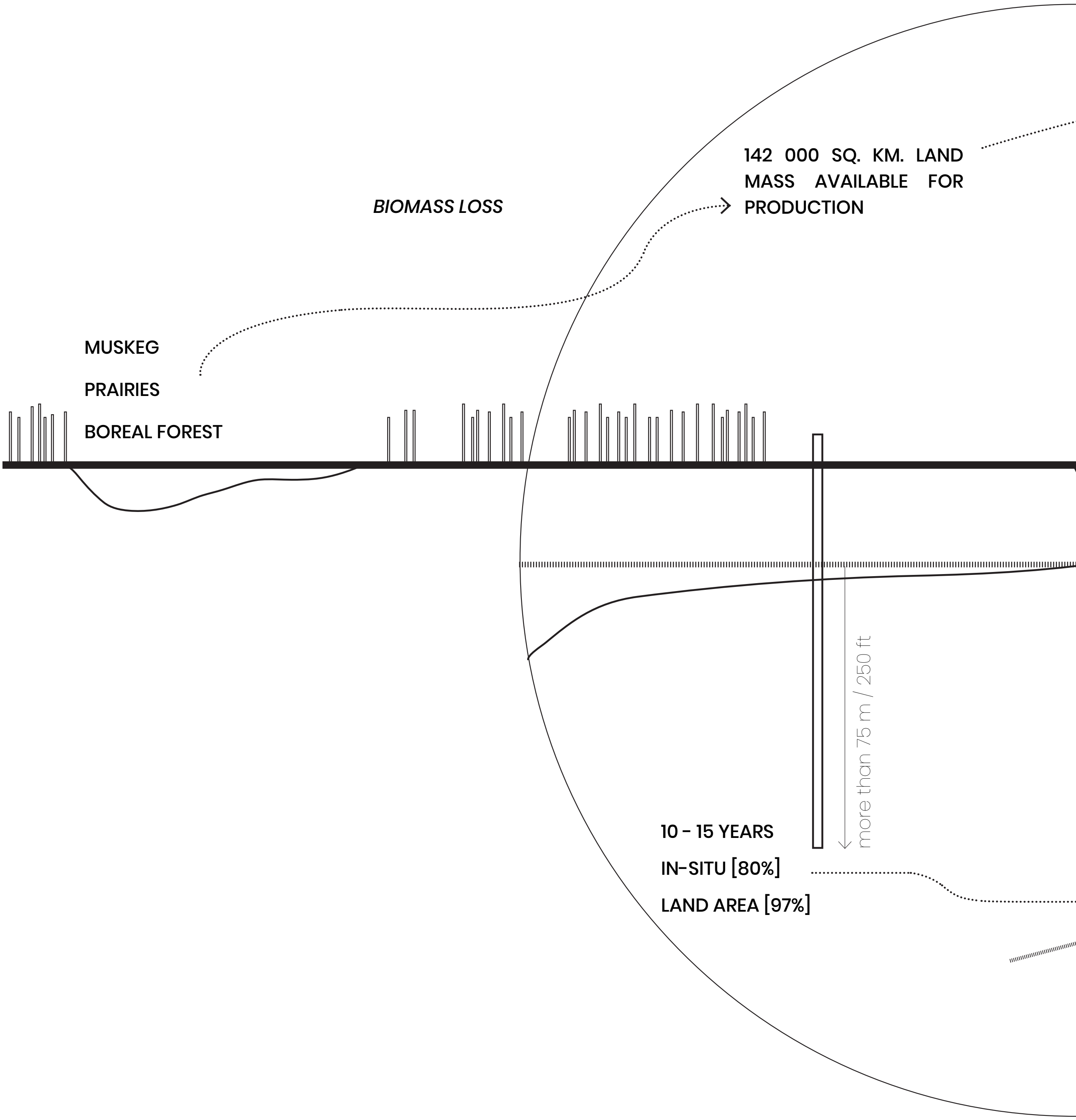


Figure 2-3: Diagram showing overview of Oil Sands production and associated impacts (information from NRCAN 2013 and 2016).

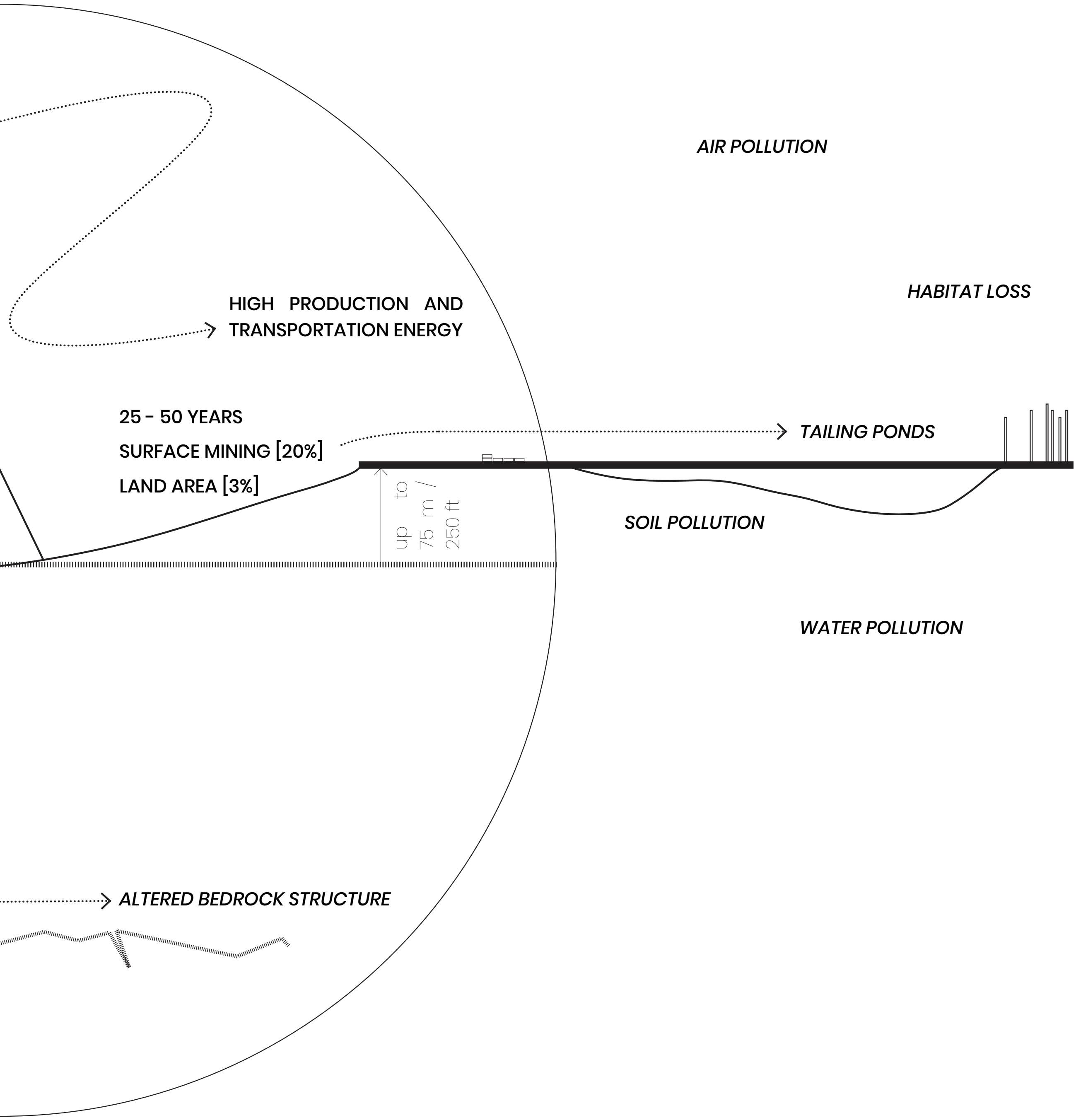

AIR POLLUTION
HABITAT LOSS
HIGH PRODUCTION AND TRANSPORTATION ENERGY
25 - 50 YEARS
SURFACE MINING [20%]
LAND AREA [3%]
TAILING PONDS
up to 75 m / 250 ft
SOIL POLLUTION
WATER POLLUTION
ALTERED BEDROCK STRUCTURE

Figure 2-4: Hydraulic crane and haul trucks within Syncrude's Mildred Lake pit mine operate as the organisms of this industrial environment.

Figure 2-5: A variety of organisms move and shape the landscape at a Suncor pit mine.

Figure 2-6: Haul trucks following haul road networks in a Suncor pit mine.

Figure 2-7: Haul trucks following haul road networks in a Suncor pit mine - a size comparison to the pickup trucks can be made following the same route.

Figure 2-8: Hydraulic crane and haul trucks within Syncrude's Mildred Lake pit mine landscape.

Figure 2-9: A tractor and haul truck pushing back material into a row.
A light cover of snow highlights the routes taken within this area.


Figure 2-10: A Suncor mining site operation follows the curves of Steepbank River and the riverine forest.

[opposite page] Figure 2-11: Cut lines through natural areas adjacent to mining operations in the background.

CANADIAN OIL SANDS LANDSCAPE

SCALE AND FEATURES

Some features of the scale of the Oil Sands production aid in our understanding of its massive scale. Costs, capacities, energy, and materials describe some of the scaled-up features of the industrial production of this landscape. In Louis Helbig's 2014 book, titled *Beautiful Destruction*, he includes a glossary of aerial images and their associated captions that describe many of these features in great detail (pp.282-301). Helbig's photographs and descriptions have narrated many of the features of this area though my own aerial photography. In understanding the work of *Beautiful Destruction*, I was able to depict the components of the Oil Sands through my own site visit and aerial tour in the Fort McMurray, Alberta area. Helbig's work is a beneficial resource in capturing and portraying the Oil Sands landscapes over time through aerial landscape photography and include written pieces from a variety of viewpoints and interest groups within Canada.

Figure 2-12: Scale comparison between pickup truck and large mining haul truck (Magas, 2019, p.15).

REGION

-The Athabasca River flows north to meet the Peace River known as the Peace-Athabasca River Delta. It is the second largest freshwater inland delta in the world and the largest boreal delta in the world (Helbig, 2014, p.287).

-Fort Chipewyan is located on the north shore of Lake Athabasca where the Peace-Athabasca River Delta is located. It is one of the oldest continuously settled communities in North America and the oldest in Alberta. It was founded in 1788 (Helbig, 2014, p.295).

MATERIAL

-Approximately four tonnes on material are extracted to produce one barrel of synthetic crude oil. This is equal to two tonnes of overburden rock removed to access two tonnes of oil sands for extraction (Helbig, 2014, p.283).

-Sulphur is stored for resale as its extraction from bitumen production means there is a surplus. This yellow material is stored in large, pyramid-like forms. In 2011 the average price per tonne of sulphur was $214USD. At the time the estimated surplus was and astronomical 173.1 million tonnes (Helbig, 2014, p.290).

EQUIPMENT

-Haul trucks often used have a 400 tonne bucket capacity. An example of a CAT 797F mining truck measures just over 15 metres in length, almost 10 metres in width, and almost eight metres in height (Oil Sands Discovery Centre, n.d.).

-New large-capacity haul trucks can cost approximately $5-6 million each (2014 estimates) without the cost of tires. Each tire and each replacement tire cost around $60,000. These tires have about a 6,000 hour working lifespan which is roughly a year (Helbig, 2014, pp.297-298).

-Haul trucks are rarely left idling because they burn over 100 litres per hour on average. The fuel tanks can be upwards of a 4500 litre capacity. Engines often include fittings to cap speeds to 50 kilometres per hour (Helbig, 2014, p.297).

-Hydraulic shovels like the Komatsu loader have a 45 cubic metre capacity, meaning it takes about three passes to fill a 400 tonne haul truck with oil sands (Helbig, 2014, p.296).

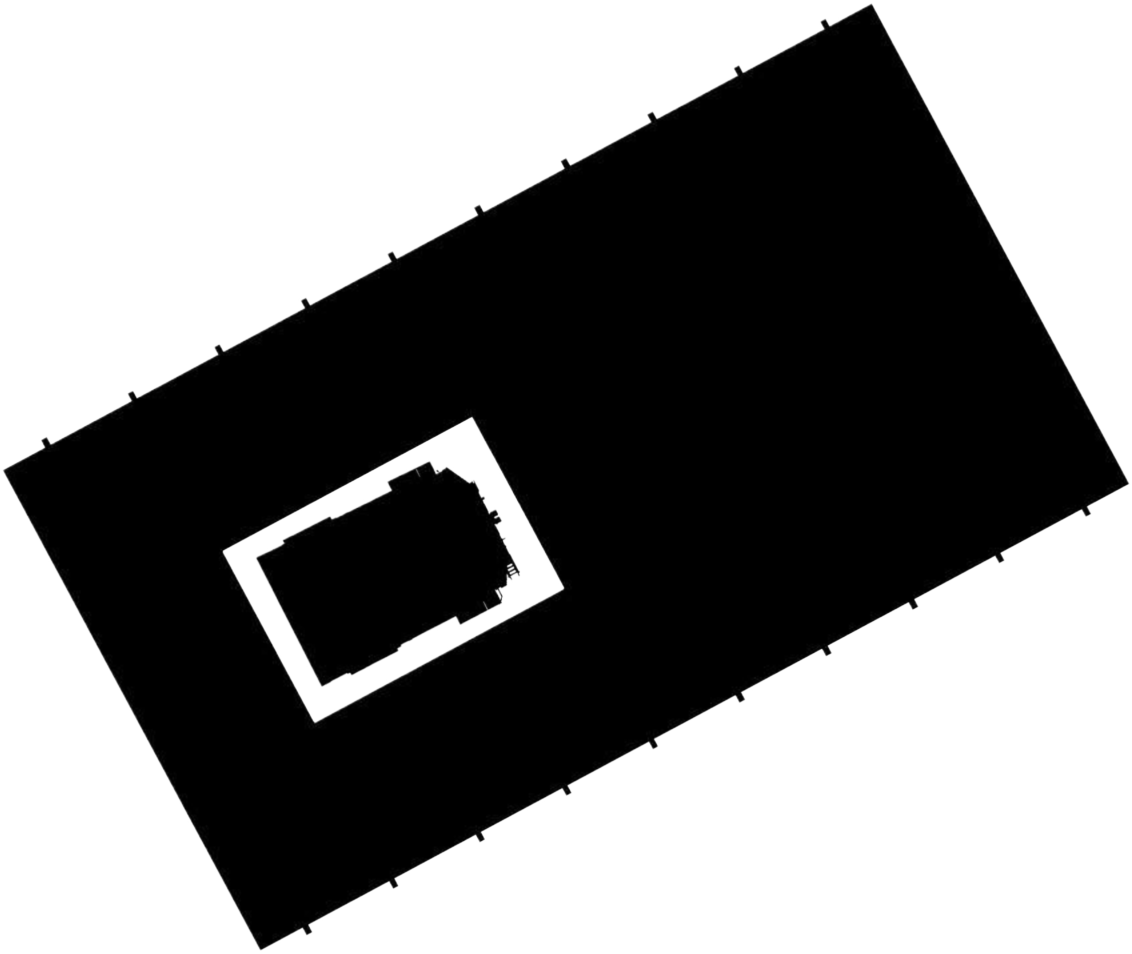


Figure 2-13: Large mining haul truck (400 ton capacity) situated in the courtyard of John A Russell architecture building at the University of Manitoba.

Figure 2-14: Mining haul truck transporting a load of oil sands for processing.

Figure 2-15: Dry tailings pond within Hwy 63's Syncrude Loop.

Figure 2-16: Wet tailings steam rising from the tailings pond within Hwy 63's Syncrude Loop.

CANADIAN OIL SANDS LANDSCAPE

RECLAMATION PROCESSES AND COOPERATIVE PROGRAMS

The Alberta Energy Regulator (AER) oversees implementation of reclamation strategies for the Government of Alberta. Mine approval is administered by the AER and approvals are regulated under the *Environmental Protection and Enhancement Act* that include terms and conditions for reclamation (AER 2020). Typical land-use options for lease reclamation are forestry, natural/conservation areas, and human development (CEMA, 2009, p.17). A 2009 document titled *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region,* authored by the Cumulative Environmental Management Association (CEMA) on behalf of the Government of Alberta, provides a guideline resource aimed at industry operators to aid in their reclamation plans and implementation.

Current requirements for remediating and reclaiming extraction landscapes in the Canadian Oil Sands follow a set of steps to return them to an equivalent use pre-production (NRCAN, 2016). Reclamation usually includes removing equipment, cleaning containments in the earth, re-constructing and grading the subsoil, replacing the topsoil, and re-planting vegetation. The process of reclamation for oil and gas extraction sites as outlined by the AER (2020) include the following steps:

Planning of future uses for when the site is to be reclaimed

Decommission and closure of an extraction site

Remediation of toxins under phase 1 and 2 environmental assessment and tier 1 and 2 soil and groundwater remediation guidelines

Reclamation criteria under the Environmental Protection and Enhancement Act and Conservation and Reclamation Guidelines include duties to minimize land disturbance, salvage, store, and replace soil, and re-vegetate areas

Ongoing site assessment through monitoring

Certification application and approval to return the leased land to the government

Post-certification responsibility continues for 25 years for surface issues (topography, vegetation, soil texture, drainage), and permanently for underground infrastructure

Audits conducted regularly at random intervals or more often for high risk sites

Following the closure of a mine, the goal of reclamation is to return the leased land to the Canadian Government. A site can be returned to the government by gaining a certification of reclamation. To be certified reclaimed, a site will have to complete all stages of reclamation requirements successfully (NRCAN, 2013). The major goals of reclamation are to return a site to an equivalent land use pre-production and ensure ecological growth is productive through ongoing monitoring and assessments over time.

Figure 2-17: Faster forest - rows of sectioned planting seen at Syncrude's Bison Viewpoint reclamation site.

Programs set up and researched by Canada's Oil Sands Innovation Alliance (COSIA) help support the implementation of reclamation plans to ensure successful ecological re-growth practices. COSIA established a charter in 2012 to pledge a commitment to improved environmental performance through innovation. The alliance among Oil Sands companies is a collaborative effort towards research and resources aimed to innovate and aid in reclamation processes (COSIA, 2012a). Some of these important programs (COSIA, 2012a) include:

Topsoil Reconstruction: this research treats the subsoil to speed up reclamation processes by turning earth into nutritious topsoil in five years

Faster Forests: this guideline aims to speed up reclamation in establishing forests adjacent to disturbance sooner

Alberta Biodiversity Conservation Chairs Program: this program provides funding and support for biodiversity research and solutions

Oil Sands Vegetative Cooperative (OSVC) : this program collects and banks seeds of the natural environment at sites prior to mining and adjacent areas that are available for reclamation in ensuring native species are being used. Since 2009, the list of the seeds banked and documented by COSIA (2012b) include:

Acorus americanus - Sweet Flag/Rat Root
Almelanchier alnifolia - Saskatoon
Alnus incana - River Alder
Alnus viridis - Green Alder
Anthoxanthum nitens - Sweet Grass
Arctostaphylos uva-ursi - Bearberry
Betual pumila - Bog Birch
Betula papyrifera - Paper Birch
Carex aquatilis - Water Sedge
Carex atherodes - Beaked Sedge
Carex utriculata - Northwest Territory Sedge
Cornus canadensis - Bunchberry
Cornus sericea - Red Osier Dogwood
Corylus cornuta - Beaked Hazelnut
Dasiphora fruticosa - Shrubby Cinquefoil
Juncus balticus - Baltic Rush
Larix laricina - Tamarack
Linnaea borealis - Twinflower
Lonicera involucrata - Bracted Honeysuckle
Picea glauca - White Spruce
Picea mariana - Black Spruce
Pinus banksiana - Jack Pine
Populus balsamifera - Balsam Poplar
Populus tremuloides - Trembling Aspen
Primula pauciflora – Saline Shooting-star
Prunus pensylvanica - Pincherry
Prunus virginiana - Chokecherry
Rhododendron groenlandicum (Ledum groenlandicum) - Labrador Tea
Ribes glandulosum - Skunk Currant
Ribes hudsonianum - Northern Black Currant
Ribes lacustre – Black Currant
Ribes triste - Red Currant
Rosa acicularis – Prickly Rose
Rubus idaeaus – Wild Red Raspberry
Salix bebbiana – Bebb's Willow
Scirpus microcarpus - Small Fruited Bulrush
Shepherdia canadense - Buffaloberry
Symphoricarpos albus - Snowberry
Triglochin maritima - Seaside Arrowgrass
Vaccinium myrtilloides - Dwarf Blueberry
Vaccinium oxycoccus - Small Bog Cranberry
Vaccinium vitis-idaea - Bog Cranberry
Viburnum edule - Lowbush Cranberry

OIL SANDS REMEDIATION AND RECLAMATION OVERVIEW

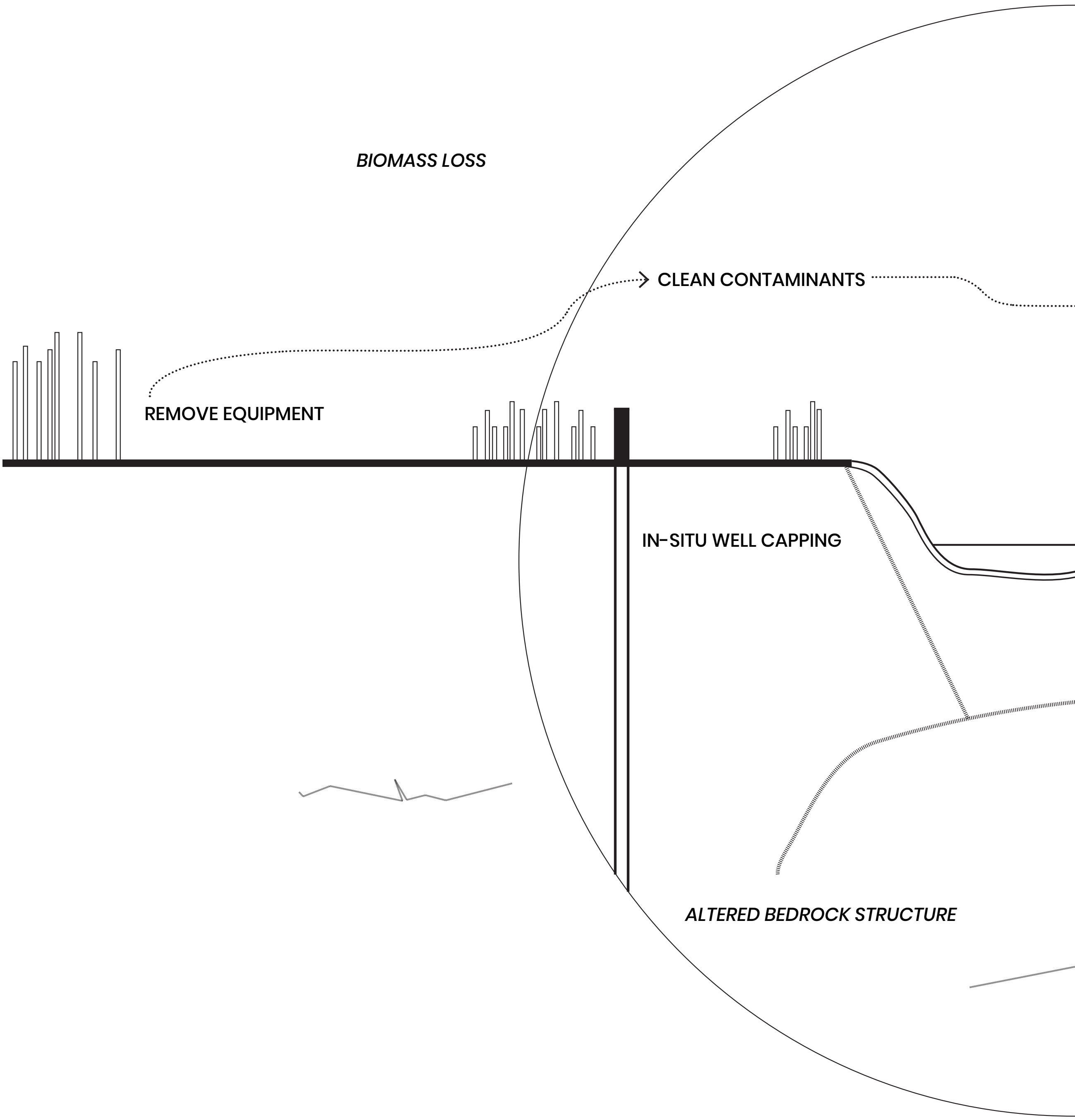
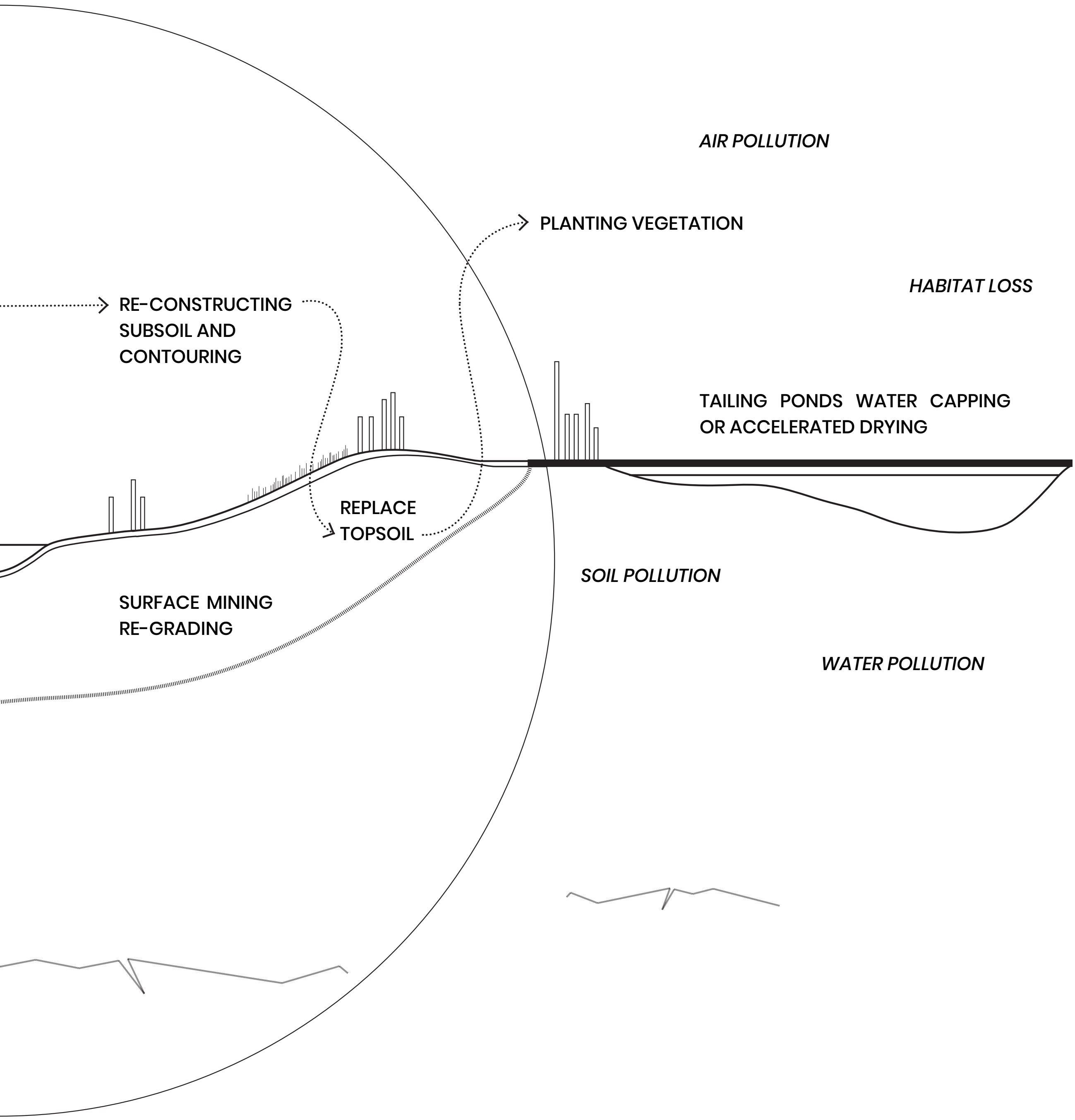


Figure 2-18: Diagram showing overview of Oil Sands reclamation practices (information from AER, 2020).



AIR POLLUTION
PLANTING VEGETATION
HABITAT LOSS
RE-CONSTRUCTING SUBSOIL AND CONTOURING
TAILING PONDS WATER CAPPING OR ACCELERATED DRYING
REPLACE TOPSOIL
SOIL POLLUTION
SURFACE MINING RE-GRADING
WATER POLLUTION

CASE STUDIES

RECLAMATION SITES IN THE ATHABASCA OIL SANDS

Since the beginning of oil sands extraction and production, land uses and function have changed drastically over time. Concern for what the end use of a site will be is anticipated through reclamation planning processes. Once a site is remediated to remove toxins and is considered safe for organisms, reclamation processes determine how the land will be re-constructed and vegetated based on potential future uses. Forestry, natural/conservation areas, and human development are typical future land use options for lease reclamation (CEMA, 2009, p.17). Within the forestry option for reclamation, commercial forestry is considered as the primary use with wildlife habitat, traditional land use, and recreation as common associated uses. Natural/conservation areas include primary uses such as wildlife habitat, traditional land use, and hunting, trapping, fishing, and gathering. Human development land use include primary uses of reclamation research, agricultural production, and industrial developments (CEMA, 2009, p.17).

There are few documented projects of reclamation in the Athabasca Oil Sands area. Reclamation, with an end goal for certification to return the land to Canada, began in the 1980's. The first reclamation project is known as Gateway Hill. It was considered to be a non-toxic site from the start and following construction, monitoring, and application, the site was granted certification for finalised reclamation by the Government of Alberta in 2008 (Syncrude Canada, n.d.). Following the perceived success of Gateway Hill a few other approaches to reclamation have been completed and have entered the monitoring phase where they will remain for whatever time frame is necessary to ensure ecological establishment.

Reclamation sites offer case studies that represent the challenges and successes of reclaiming land in the Athabasca Oil Sands region. These sites act as living laboratories where extraction company reclamationists and educational researchers can monitor site conditions and recommend adjustments to methods to improve upon reclamation practices. By growing the knowledge base associated with reclamation, positive changes can be made to guidelines in assisting oil companies to achieve the greatest degree of success in land reclamation. The "evolution of reclamation practice is typically guided by documents produced in a multi-stakeholder forum called the Cumulative Environmental Management Association (CEMA) and recommended to the Government of Alberta" (Richens, Bergstrom, Purdy, 2015). CEMA's guidelines approach topics such as "landscape design, conservation of reclamation material, revegetation, wetland reclamation, design of end pit lakes, and criteria and indicators for reclamation certification" (Richens, Bergstrom, Purdy, 2015).

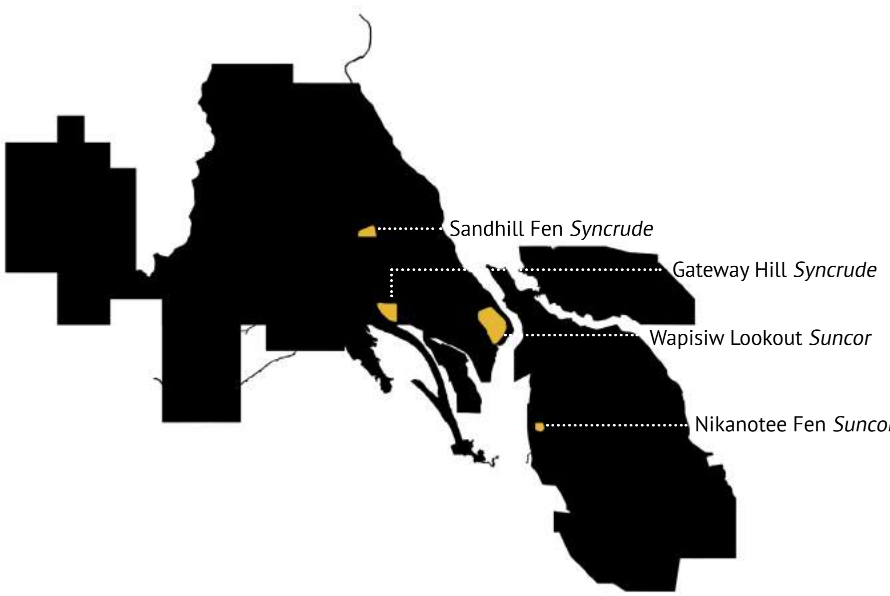


Figure 2-19: Tar Island footprint with the four highlighted case study sites.

By applying the recommendations that were made based on previous reclamation sites, progress is made towards a higher standard of successful grading, soil, and vegetative implementation efforts. An important limitation to note in changing guidelines is the challenges companies may face in order to achieve higher quality regulations. An example of this is when a mine is being excavated, extraction companies are required to salvage and store topsoil and organic material from the site that can aid in reclamation upon mine closure. Placement depths of topsoil and organic matter are regulated to ensure enough material is placed for vegetative growth. A change in regulation in 2007 increased soil placement depth from 0.2 metres to 0.5 metres in depth (Richens, Bergstrom, Purdy, 2015.). This means that reclamation material collected before 2007 was likely only stockpiled to the amount that would allow for a 0.2m soil cover leaving the company short of the regulation amount. This also means that sites reclaimed before 2007, including Gateway Hill, only placed 0.2m of reclamation material (Richens, Bergstrom, Purdy, 2015.). If the soil placement depth was increased to aid in successful ecological function, the lack of soil at Gateway Hill may cause challenges to the long-term succession of the site based on current regulations.

Research authors and professors of landscape architecture, M. Elen Deming and Simon R. Swaffield, describe case studies as a dynamic inquiry into a particular place (2011, p.80). By providing a set of criteria, sites can be compared through an investigation of spatial and temporal characteristics (2011, p.82). By looking into the current methods of reclamation in the Oil Sands area, an identification of strengths and weaknesses can be made to inform future practices.

Gateway Hill, Wapisiw Lookout, Sandhill Fen, and Nikanotee Fen have been organised chronologically and incorporate background information, methods, and implications for each case. Each reclamation project includes aerial imaging of the site and surrounding context before reclamation (where available), during construction, and current (2019) situations. These maps display the change to the spatial characteristics of a site over time and their context. The imagery was selected at the same scale for reference between projects with their size ranging between 32 and 220 hectares. These case studies provide insights into the intensity of land transformation that occur in oil extraction processes and again in current reclamation practices. Why has only one site been certified reclaimed at this time? What implications do individual reclamation projects have on the larger site?

Figure 2-20: Variety of planting types seen at Syncrude's Bison Viewpoint in the foreground, Syncrude's Gateway Hill to the mid-right, and Suncor's Crane Lake in the upper-right.

GATEWAY HILL

CASE STUDY PROJECT

Location: Within the south portion of Syncrude Loop between the north and south highways in Tar Island
Owner: Syncrude Canada [a joint venture project between Imperial Oil Resources Ltd, CNOOC Oil Sands Canada; Sinopec Oil Sands Partnership; and Suncor Energy Inc.]
Completion: 1980s
Construction: 1978-1981
Certification: 2003 application with granted certification in 2008
Cost: not available
Size: 104 ha, raised approximately 40m above original elevation
Former site: low-lying wetland used for overburden stockpiling during industrial production
Implemented habitat type: four ecosystems comprised of a spruce/aspen forest, jack pine forest, grassland, and wetland
Access: accessible to the public by a parking lot off of the Syncrude Loop highway with interpretive signs and trails

(Material for this case study drawn from: Audet, Pinno, Thiffault, 2015, p371; Canadian Oil Sands Trust, Alberta Environment, Energy Resources Conservation Board, 2009; and Syncrude Canada, n.d.)

The purpose of the Gateway Hill project was to return the site to a healthy forested area and to encourage the return of wildlife (Syncrude Canada, n.d.). The methods of implementation included an accessible grade for human access, spread of soil placement across the pile of overburden, and re-vegetation of the area with four ecosystem types (Syncrude Canada, n.d.). Tree were planted in the early 1980's (Syncrude Canada, n.d.). Monitoring was completed by biologists and vegetation specialists for initial growth establishment with continued monitoring to provide enough data over time for the certified reclamation application submitted to the government in 2003 (Syncrude Canada, n.d.).

The atmosphere of this site, as determined by my own site visit interpretation, felt somewhere lost between uses of industrial and natural functions. Traces of industrial remains like pathways and elevation changes were of an industrial scale, however, a full grown forest was also present. Planting was done in large sections which differ from that of a naturally occurring forest and which has created a very different land mosaic when viewed from above. For example, on one side of a path there were pine trees while the other side was filled by poplars

Figure 2-21: Satellite image of Gateway Hill in 2006, prior to certification approval. Other reclaimed lands and tailings ponds surround the site (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2006

RECLAMATION
MONITORING

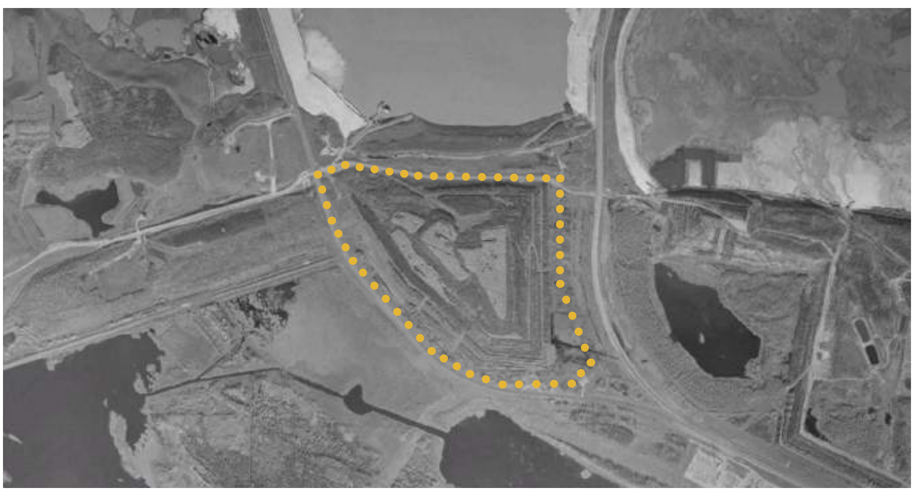


Figure 2-22: Satellite image of Gateway Hill in 2008, following certification approval (Google Earth, 2019 - Image Regional Municipality of Wood Buffalo).

2008

CERTIFIED
RECLAIMED

Figure 2-23: Satellite image of Gateway Hill in 2019, showing current state as certified reclaimed (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2019

CURRENT
CONDITIONS

trees. The site has grown to succeed naturally and is not overly-maintained. It is unclear whether this was a choice to allow succession of the forest or due to a lack of management following certification. The air felt crisp and clean but because of the raised elevation of the site, the sounds of trucking could be heard from the Syncrude Loop highway nearby.

It seems as though the overburden stockpile could have been spread across multiple reclamation sites where needed, rather than incorporating this surplus into the Gateway Hill project. This site is now raised significantly compared to its context and omits the inclusion of viewpoints from this higher elevation to the surrounding industrial and natural areas. Implications of this site do however show the potential to grow a full forest within this industrial area and encourage the return of wildlife. A presence of snowshoe hare, deer, red squirrel, beaver, coyote, songbirds, and grouse have been documented which indicates ecological success in this reclamation site (Syncrude Canada, n.d.).

Figure 2-24: Aerial view of Gateway Hill's site showing the large-scale planting mosaic within Hwy 63's Syncrude Loop, looking south-east.

Figure 2-25: Small trail within Gateway Hill.

Figure 2-26: Unmarked trail or break in planting within Gateway Hill.


Figure 2-27: Small trail along a row of planted trees within Gateway Hill.


Figure 2-28: Large changes of elevation stepping down within Gateway Hill.

Figure #2-29 Long and wide stretch of pathway with a faded red bench showing a different type of tree planting on either side of the path.

Figure 2-30: Wide stretch of pathway winding around a corner and reaching higher within Gateway Hill.
Different planting types are seen on either side of the path with a scale figure in the upper-right background.

WAPISIW LOOKOUT

CASE STUDY PROJECT

Location: Along the west side of the Athabasca River within Tar Island
Owner: Suncor Energy Inc.
Completion: 2010
Construction: 2009-2010
Certification: none
Cost: not available
Size: 220 ha
Former site: Suncor Pond 1 was an active tailings pond from 1967-1997. From 1997-2009 the site was classified as ready for reclamation. In 2010 it was classified as soils placed. From 2010-present the site has been classified as permanent reclamation
Implemented habitat type: a mixed wood forest with streams and a small marsh wetland
Access: tour by appointment only with building, boardwalk, and interpretive signs

(Material for this case study drawn from: Richens, Bergstrom, Purdy, 2015;
Fort McMurray Tourism, 2019; and Suncor Energy, 2020.)

The purpose of this site project was to create the first reclaimed tailings pond to a trafficable surface (Suncor Energy, 2020). The construction methods began with the pumping of wet tailings from the pond into another tailings pond to be treated using a variety of drying processes. Coarse tailings sand was then pumped into Pond 1 with a geo-synthetic clay liner applied to some areas of the site surface (Richens, Bergstrom, Purdy, 2015). Swales were created to direct water to a constructed wetland within the site. Between 2009 and 2010, 65 000 truckloads of a mixture of upland soil, peat-mineral mix, and coarse woody debris were spread at a depth of 0.5 metres across the former pond (Richens, Bergstrom, Purdy, 2015). In 2010, 620 000 trees, shrubs, and grasses were planted (Suncor Energy, 2020). Oats and barley were used as a nurse crop to begin planting. Other habitat features were added including snags (logs used for bird perching) and rock piles to support a variety of wildlife species (Richens, Bergstrom, Purdy, 2015). Monitoring of this project will continue to be completed over a few decades with a focus of soil, water, vegetation, and wildlife assessments (Suncor Energy, 2020).

Figure 2-31: Satellite image of Wapisiw Lookout in 2003 as a tailings pond. More tailings ponds to its west and the Athabasca River the its east (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2003

INDUSTRIAL PRODUCTION

Figure 2-32: Satellite image of Wapisiw Lookout in 2010, during reclamation construction (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2010

RECLAMATION CONSTRUCTION

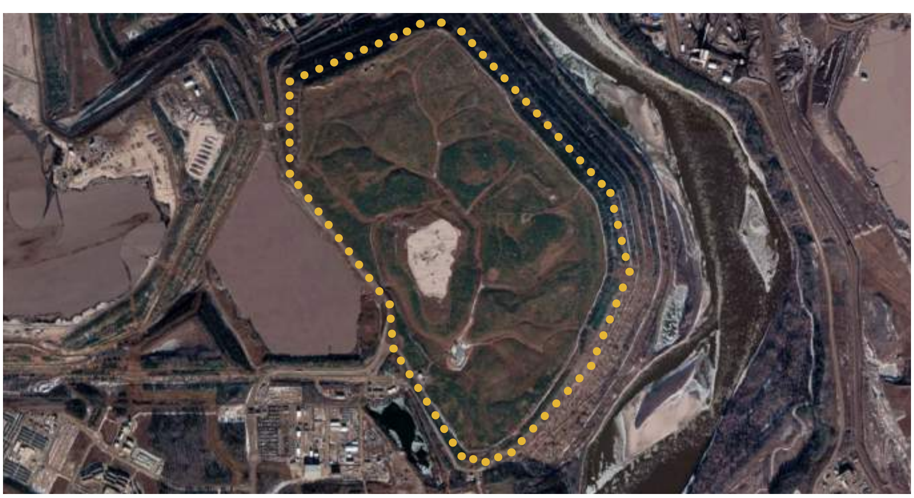


Figure 2-33: Satellite image of Wapisiw Lookout in 2019, showing current state undergoing monitoring (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2019

RECLAMATION MONITORING

Implications of this site indicate the potential to transform a tailings pond into a terrestrial ecosystem. The project reduced the overall drying time of this tailings pond in order to reach a stage of permanent reclamation in less time. The biggest challenge with this site was the method implemented to relocate the wet tailings from Pond 1 to be processed at another site. This project represents a larger scale of reclamation than the other projects that have been completed within the Tar Island area.

Figure 2-34: Wapisiw Lookout planting variety and habitat log snag
(JWN Energy/Jaremko, 2017 - used with permission).

SANDHILL FEN
CASE STUDY PROJECT

Location: Within the north-west portion of Syncrude Loop in Tar Island
Owner: Syncrude Canada [a joint venture project between Imperial Oil Resources Ltd, CNOOC Oil Sands Canada; Sinopec Oil Sands Partnership; and Suncor Energy Inc.]
Completion: 2012
Construction: unknown
Certification: none
Cost: not available
Size: 15 ha main fen and two perched fens in 50 ha implemented watershed
Former site: sand capped soft tailings, originally a tailings pond during industrial production
Implemented habitat type: a fen which is peat-forming wetland fed by groundwater within 0.2m of the surface. Fens are the most common type of wetland in Regional Municipality of Wood Buffalo
Access: No public access with no trespassing signs along highway and video surveillance. Boardwalks exist over the fens for Syncrude access.

(Material for this case study drawn from: BCG Engineering, 2019; COSIA, 2012c; and Ketcheson et al., 2016)

The purpose of both the Sandhill Fen and Nikanotee Fen projects is ”to provide design, construction, and operational experience to guide decisions and strategies for commercial-scale fen reclamation in the future” (Pollard et al., 2012, cited in Ketcheson et al., 2016, p.132). Sandhill Fen provides an outdoor laboratory for research and conclusions that can be recommended for application to the CEMA *Guidelines for Wetlands Establishment on Reclaimed Oil Sands Leases* (BGC Engineering, 2019).

The methods of implementation were based on surrounding groundwater conditions in the area (Ketcheson et al., 2016). Tailings sand was placed to create three upland hummocks (hills to prevent drought in dry climatic conditions), with low-lying streams, and two perched fens adjacent to two low-lying fens. The original design included five hummocks but a lack of reclamation material only allowed for the three that were built. These three hummocks were also built at a smaller size than intended due to the lack of material available (Ketcheson et al., 2016). The vegetation planted on site was applied through seeding methods and included sedges, arrow grasses, rushes, and slough grass (Ketcheson et al., 2016). Monitoring is estimated to be completed within 10 to 20 years following construction completion (CAPP, 2016).

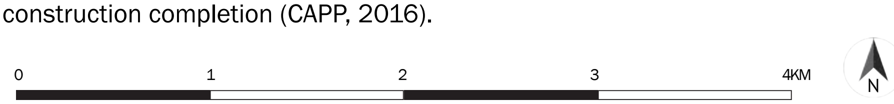


Figure 2-35: Satellite image of Sandhill Fen in 2006 as a tailings pond. Hwy 63's Syncrude Loop circles the site with surrounding operations (Google Earth, 2019 - Image © 2020 Maxar Technologies).

Figure 2-36: Satellite image of Sandhill Fen in 2012, during reclamation construction (Google Earth, 2019 - Image © 2020 Maxar Technologies).

Figure 2-37: Satellite image of Sandhill Fen in 2019, showing current state undergoing monitoring (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2006

INDUSTRIAL PRODUCTION

2012

RECLAMATION CONSTRUCTION

2019

RECLAMATION MONITORING

A professor of plant biology at the Southern Illinois University, Dale Vitt, noted that only parts of the implemented Sandhill Fen ecosystem are working (Vitt in Weber, 2016). Less than half of the species growing are desirable for the fen. Vitt provided an example of one area of the fen transitioning into a poplar forest which is not beneficial to the fen habitat (Vitt in Weber, 2016). Implications of this project provide an example of a re-creation of a common wetland type through reclamation. Time will be the determining factor to see if adjustments can be made successfully to support the growth of the fen species.

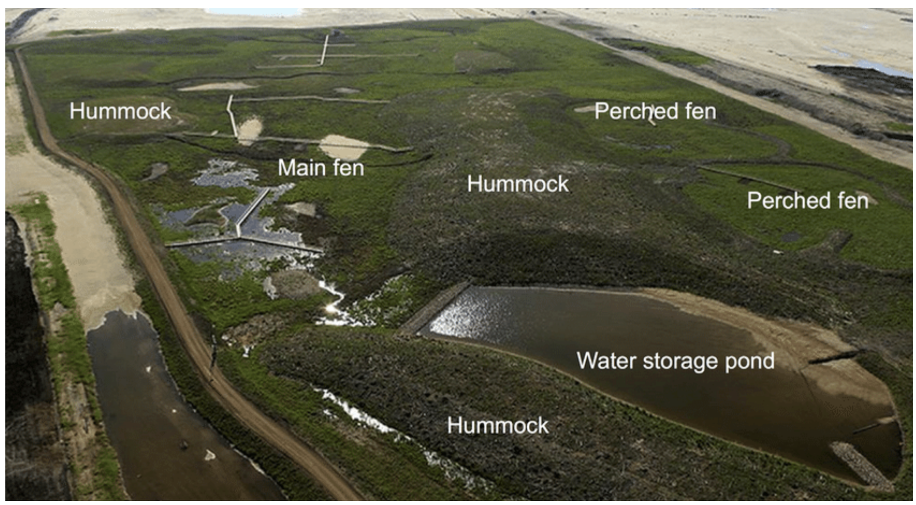


Figure 2-38: Layout of Sandhill Fen features - “Fig. 1. Aerial view of the Sandhill Fen. Image provided by Syncrude Canada Ltd.” (Ketcheson et al., 2016 - used with permission).

Figure 2-39: No trespassing sign and video surveillance post along Hwy 63's Syncrude Loop giving warning to anyone approaching Sandhill Fen.

NIKANOTEE FEN
CASE STUDY PROJECT

[*pronounced Nee-ga-no-tee*]

Location: Along the east side of the Athabasca River within Tar Island
Owner: Suncor Energy Inc. (Suncor lead, Joint Industry Project with Imperial Oil Ltd and Shell Canada, Canadian Natural took on Shell's role in 2017)
Completion: 2013
Construction: 2011-2013
Certification: none
Cost: not available. It was estimated in the tens of millions of dollars by a wetland ecologist and professor at the University of Alberta, Lee Foote. He was originally involved in the Nikanotee Fen project but stepped back from his involvement.
Size: 2.9 ha fen with a surrounding upland of 7.7 ha, within a 32 ha reclaimed watershed
Former site: a mine pit site during industrial production
Implemented habitat type: a fen which is peat-forming wetland fed by groundwater within 0.2m of the surface. Fens are the most common type of wetland in Regional Municipality of Wood Buffalo
Access: No public access. Boardwalks exist over the fens for Suncor access.

(Material for this case study drawn from: COSIA, 2012c; Weber, 2016; and Ketcheson et al., 2016.)

Nikanotee Fen provides an example of one of first co-operative fen construction projects in the Tar Island excavation area. Nikanotee is the Cree word for "future" (COSIA, 2012c). As noted in the Sandhill Fen case study, the purpose of both these fen reclamations is "to provide design, construction, and operational experience to guide decisions and strategies for commercial-scale fen reclamation in the future" (Pollard et al., 2012, cited in Ketcheson et al., 2016, p.132). The Nikanotee Fen project acts as a living laboratory for further methods of implementation through research.

Methods for this projects were based on research from the University of Waterloo to plan the construction of the fen (Ketcheson et al., 2016). The intended goal was to construct groundwater flows to a fen with the inclusion of a natural slope at the south side of the site. Tailings sand was placed on the site to create an aquifer with petroleum coke placed on top of the sand as an underdrain. Two metres of peat were placed to create the fen and then it was divided into multiple test plots for


Figure 2-40: Satellite image of Nikanotee Fen in 2003 as a mine pit. The Athabasca River exists to the west and mine pits exist in surrounding areas (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2003

INDUSTRIAL PRODUCTION


Figure 2-41: Satellite image of Nikanotee Fen in 2012, during reclamation construction (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2012

RECLAMATION CONSTRUCTION


Figure 2-42: Satellite image of Nikanotee Fen in 2019, showing current state undergoing monitoring (Google Earth, 2019 - Image © 2020 Maxar Technologies).

2019

RECLAMATION MONITORING

various vegetation with some un-planted areas to monitor for natural succession (Ketcheson et al., 2016). Eight seed and seedling types of grasses were planted along with a transfer of cultivated mosses to the site (Ketcheson et al., 2016). These eight species are: *Carex aquatilis* - Water Sedge; *Calamagrostis inexpansa* - Northern Reed Grass; *Triglochlin maritima* - Seaside Arrowgrass; *Junctus balticus* - Wire Rush; *Betula pumila* - Dwarf Birch; *Oxycoccus microcarpus* - Small Bog Cranberry; *Sarracena purpurea* - Purple Pitcher plant; *and Drosera rotundifolia* - Round-leaved Sundew (COSIA, 2012c). Following planting, wood straw was placed as a method of weed and moisture control (COSIA, 2012c). Monitoring of the site is ongoing to ensure the fen remains wet. Initial monitoring show indicators of good water quality and growth of vegetation (COSIA, 2012c).

Lee Foot, a wetland ecologist and professor at the University of Alberta, describes some limitations of the project. Foot expresses concerns with the soil and water chemistry changes that occur from being built on leftover tailings sand. Because bitumen has been removed from the sand that was used, the altered sodium and calcium levels determine which species can survive (Foot in Weber, 2016). He also believes this type of project can not be applicable for larger settings because of the cost and requirement to create specific conditions. He notes that because a fen requires access to the water table, the contours, soil, and lower bedrock need intense re-designing and shaping following mining extraction (Foot in Weber, 2016). The implications of this project provide an example of a re-creation of a commonly found wetland type in this area, although the intense construction requirements may not be widely applicable as a case study for future reclamation.

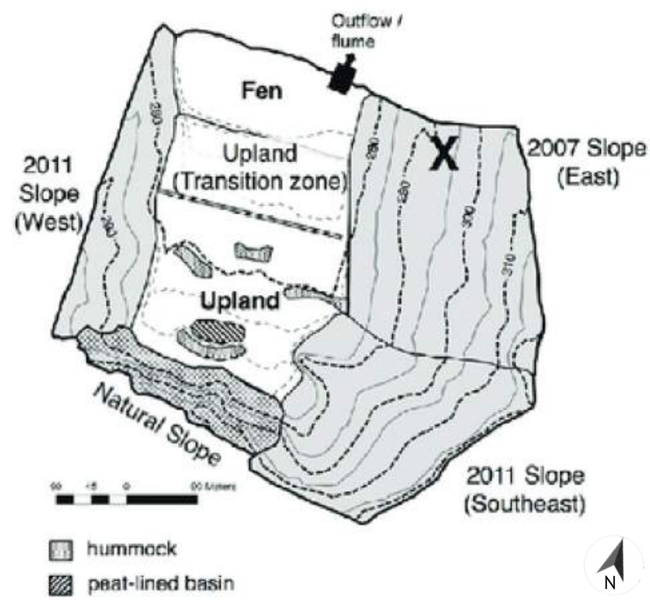


Figure 2-43: Plan of Nikanotee Fen - “Fig. 2. Map and view of the Nikanotee Fen. The photographs were taken facing west from the “X” on the map” [opposite page] (Ketcheson et al., 2016 - used with permission).

Figure 2-44: Views of Nikanotee Fen - ""Map and view of the Nikanotee Fen. The photographs were taken facing west from the "X" on the map" [opposite page] (Ketcheson et al., 2016 - used with permission).

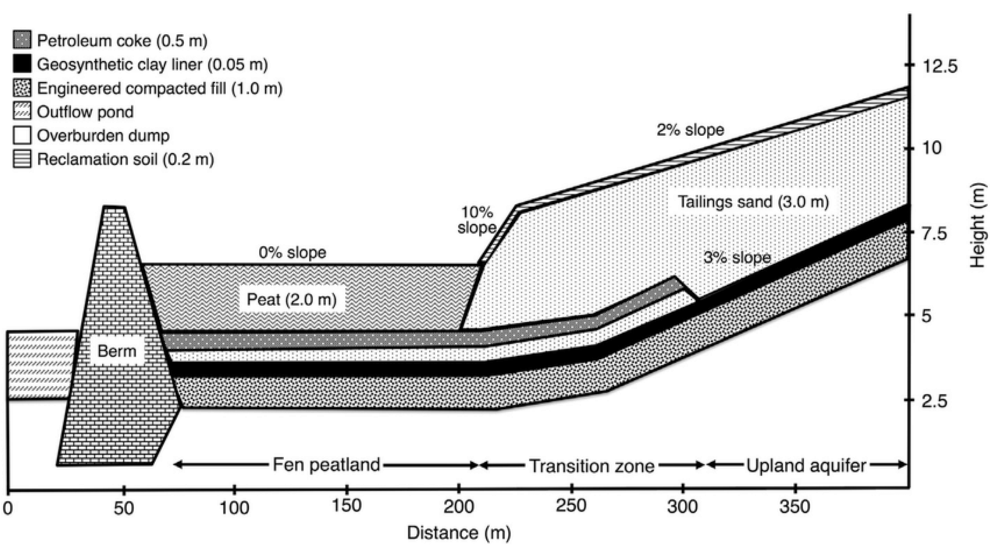


Figure 2-45: "Fig. 3. Cross-section of the Nikanotee Fen watershed. The thickness of each layer is indicated in parentheses. Note that the thickness of the liner in the diagram is not to scale (shown thicker than the ~0.05 m actual thickness)." (Ketcheson et al., 2016 - used with permission).

CONCLUSIONS
CASE STUDY PROJECTS

In searching for answers as to why only one site is certified reclaimed, it is clear that monitoring is the time constraint in ensuring proper ecological succession of a site. In the relatively short length of Oil Sands reclamation, we have seen less than 10 years of monitoring for sites that were considered previously toxic. Long term monitoring may provide better insights to dealing with extraction toxins, but, of course, this takes time. Common to each of the case studies of Gateway Hill, Wapisiw Lookout, Sandhill Fen, and Nikanotee Fen, monitoring over a few decades is thought to provide indicators of a successful reclamation with the intent to gain certification from the Government of Alberta.

Between the industrial size pathways and the fully grown forest that co-exist in Gateway Hill, a sense of place seems to be missing. Perhaps the opportunity has been missed in portraying the change of use this site has gone through. If mining and reclamation are worked at the industry's scale then maybe we need to think bigger, at the proper scale. Landscape architecture provides an important viewpoint in the representation of time for areas like these that have undergone drastic changes.

The selected case study sites do not incorporate a projection of future adaptation for this area. I believe there is an important opportunity in preparing these sites to be well-suited for changes associated with climate change. It appears that this opportunity has been missed in the approaches these projects have taken. Through the analysis of these case studies, I am led to believe that this is the area where there is room for improvement in reclamation practices through the application of landscape architecture practices. Perhaps reclamation methods can be made more accessible to mining companies in ways that prepare this area to incorporate resilient future ecologies.

The high quantity of reclamation materials and estimated costs associated with these case study projects (in comparison to the overall mining footprint) may not reflect practical reclamation for larger sites. At this point of monitoring, they show some success in bringing back important ecological function that was lost in the mining process. The scale of these reclamation projects are limited in their overall reach in this area. The regulations and guidelines currently available aid in individual site projects. Due to the large scale of the Tar Island extraction area, I see a gap where an overall reclamation plan could exist to recommend the implementation of a variety of strategies at the appropriate scale.

CHAPTER THREE

SITE ANALYSIS

ENVIRONMENT OF THE ATHABASCA OIL SANDS
SITE ANALYSIS

The site conditions of the Oil Sands landscapes of avulsion leave behind the emptiness of extraction. When visualising the dense vegetative network surrounding the Tar Island production area, it is important to understand the context. In addition to context, a greater understanding of the environment is required to inform how and why these industrial processes have taken place over time. Important features of the site analysis are the geologic layers that are being exposed, the effects of climate change on ecosystem capacities, and the functions of this industry as a system. These factors explain the types of landscape conditions that remain following mining extraction.

Tar Island represents a largely disturbed area due to Oil Sands extraction mining with a variety of activities and landscape components within the site. This vast area serves as the site for analysis, planning, and implementation for reclamation strategies suited to ongoing ecological success. Conclusions drawn of the case studies, a shift of reclamation practices provides the opportunity to plan for future ecologies and the promotion of resilience in this landscape that will take place over time. What opportunities does this landscape provide? To understand and catagorise the spatial features of this landscape, diagrams and maps are chosen as the primary methods of analysis for this chapter.

The formation of this land begins with the retreat of the last ice age. The Laurentide ice sheet during the Pleistocene Ice Age began retreating approximately 18,000 years ago carving the current landscape topography (Rutter, 2006). The ecologic biome present in this area prior to excavation and found at present time in the surrounding areas is comprised of the boreal forest. The boreal forest consists of cold temperature resilient forests with predominantly evergreen species, wetlands, and areas of permafrost (La Roi, 2013). Industrial mining began at Tar Island in 1967 (NRCAN, 2016). The alvusive processes have altered and extracted soils, overburden, and parent material through various geologic layers to reach oil deposits which are a non-renewable energy resource.

GLACIATION

10,000 YEARS AGO

The Laurentide ice sheet during the Pleistocene Ice Age began retreating approximately 18,000 years ago carving the current landscape topography (Rutter, 2006).

BOREAL FORESTATION

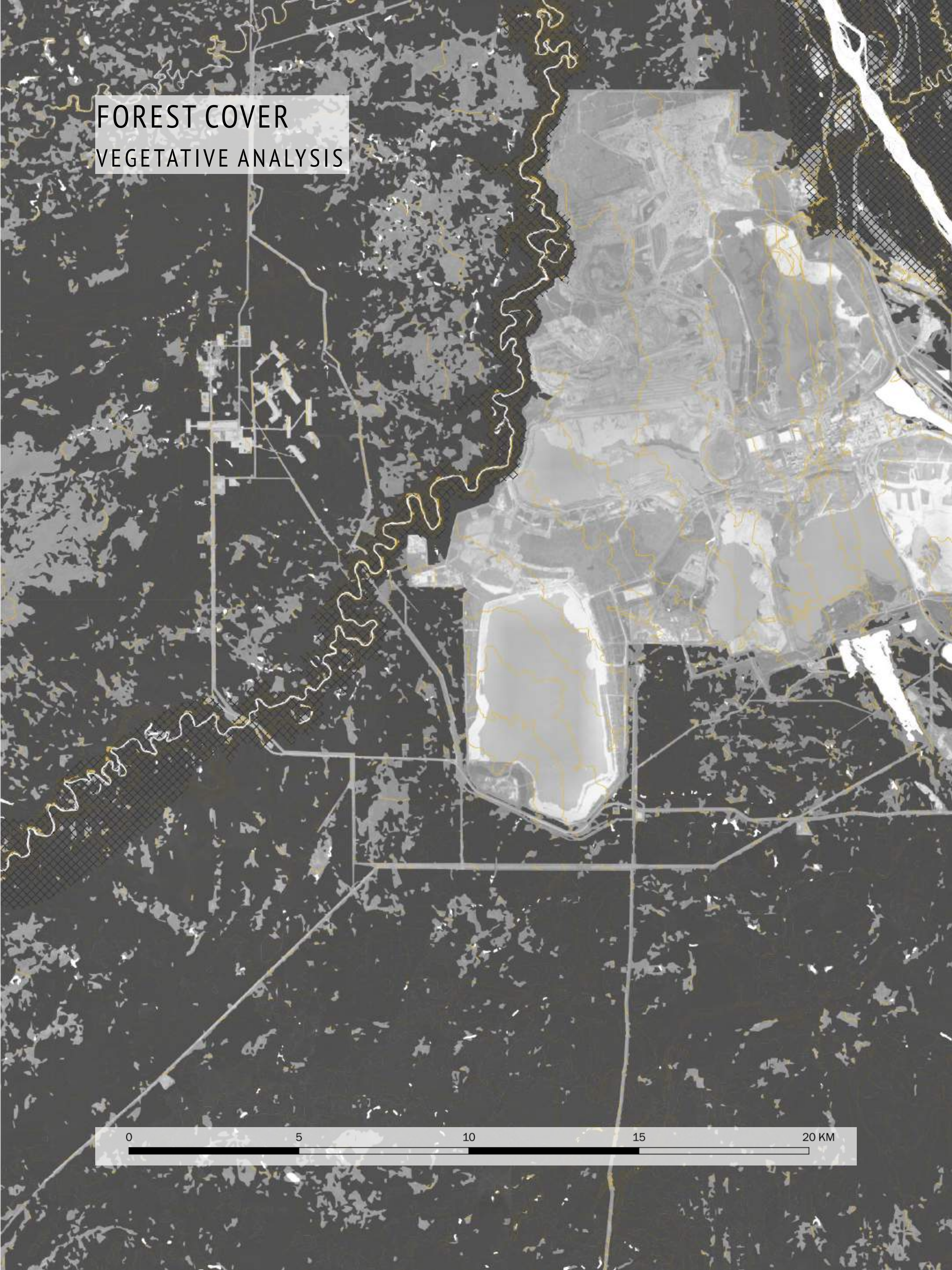
PRE-PRODUCTION

Cold temperature resilient forests with predominantly evergreen species and wetlands, and areas of permafrost (La Roi, 2013).

INDUSTRIALISATION

1967 - PRESENT

Alteration and extraction of the soils, overburden, and parent material of various geologic layers to reach non-renewable energy resources (NRCAN, 2016).


FOREST COVER
VEGETATIVE ANALYSIS
0
5
10
15
20 KM

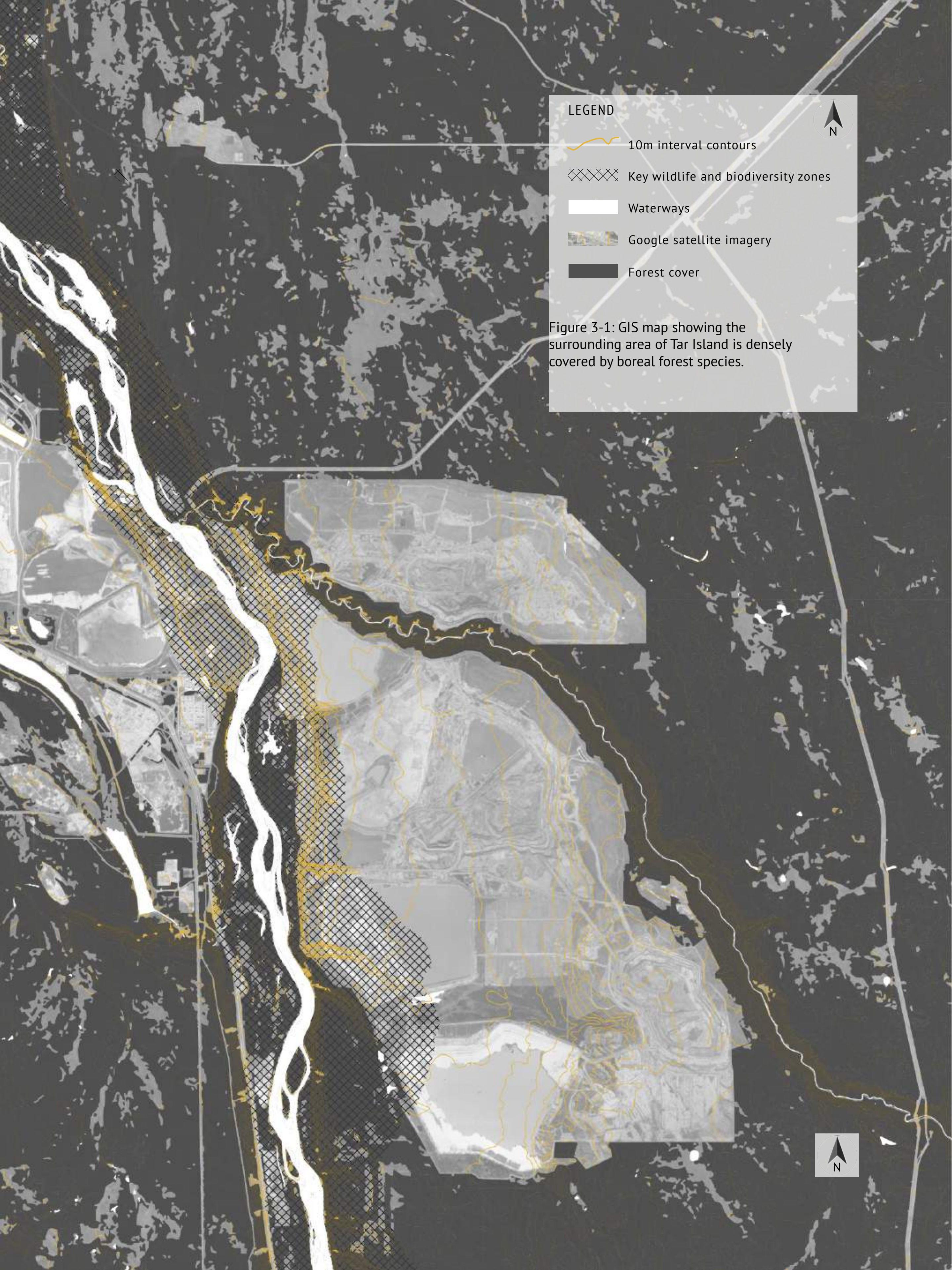
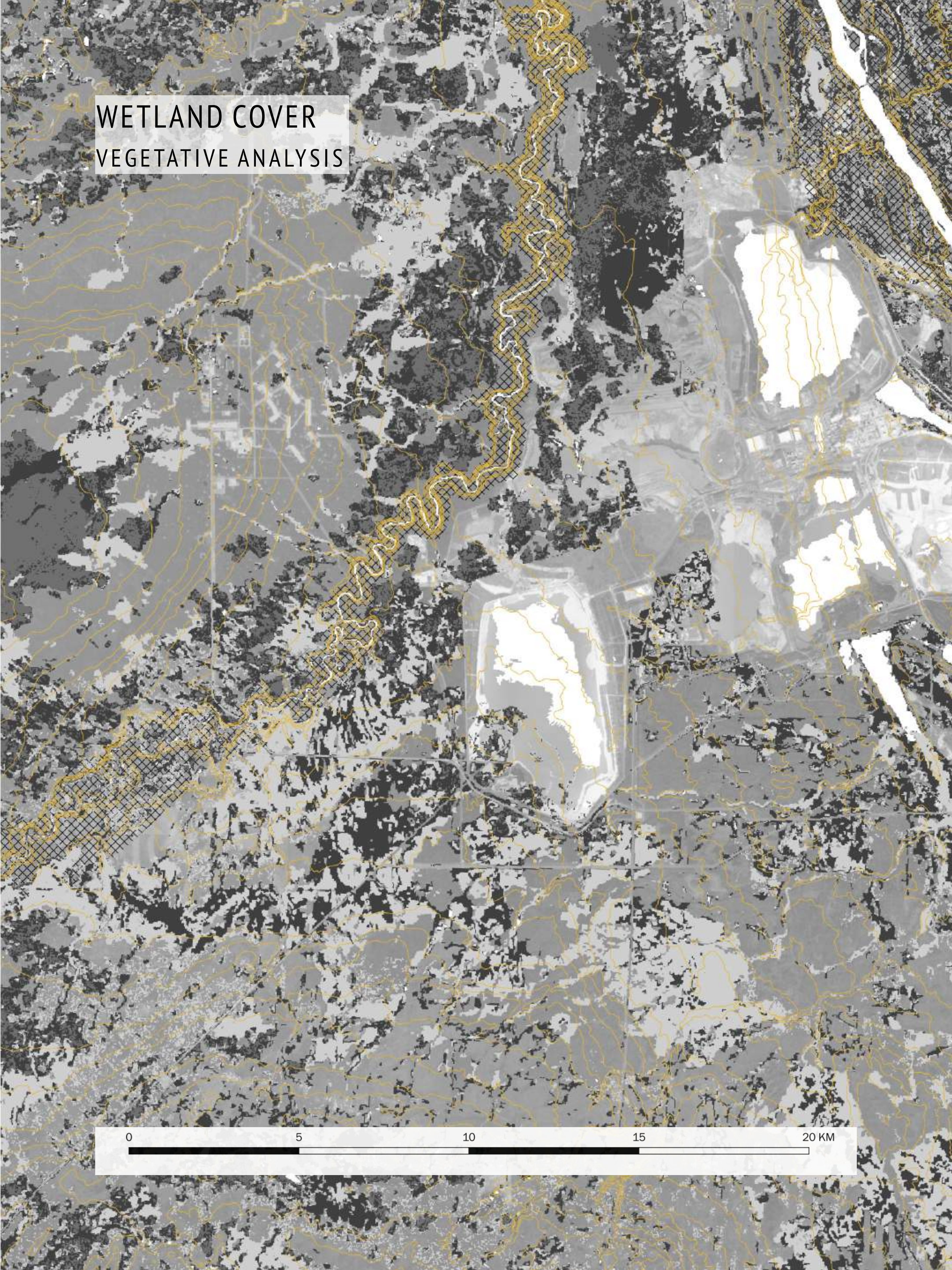


Figure 3-1: GIS map showing the surrounding area of Tar Island is densely covered by boreal forest species.


WETLAND COVER
VEGETATIVE ANALYSIS
0
5
10
15
20 KM

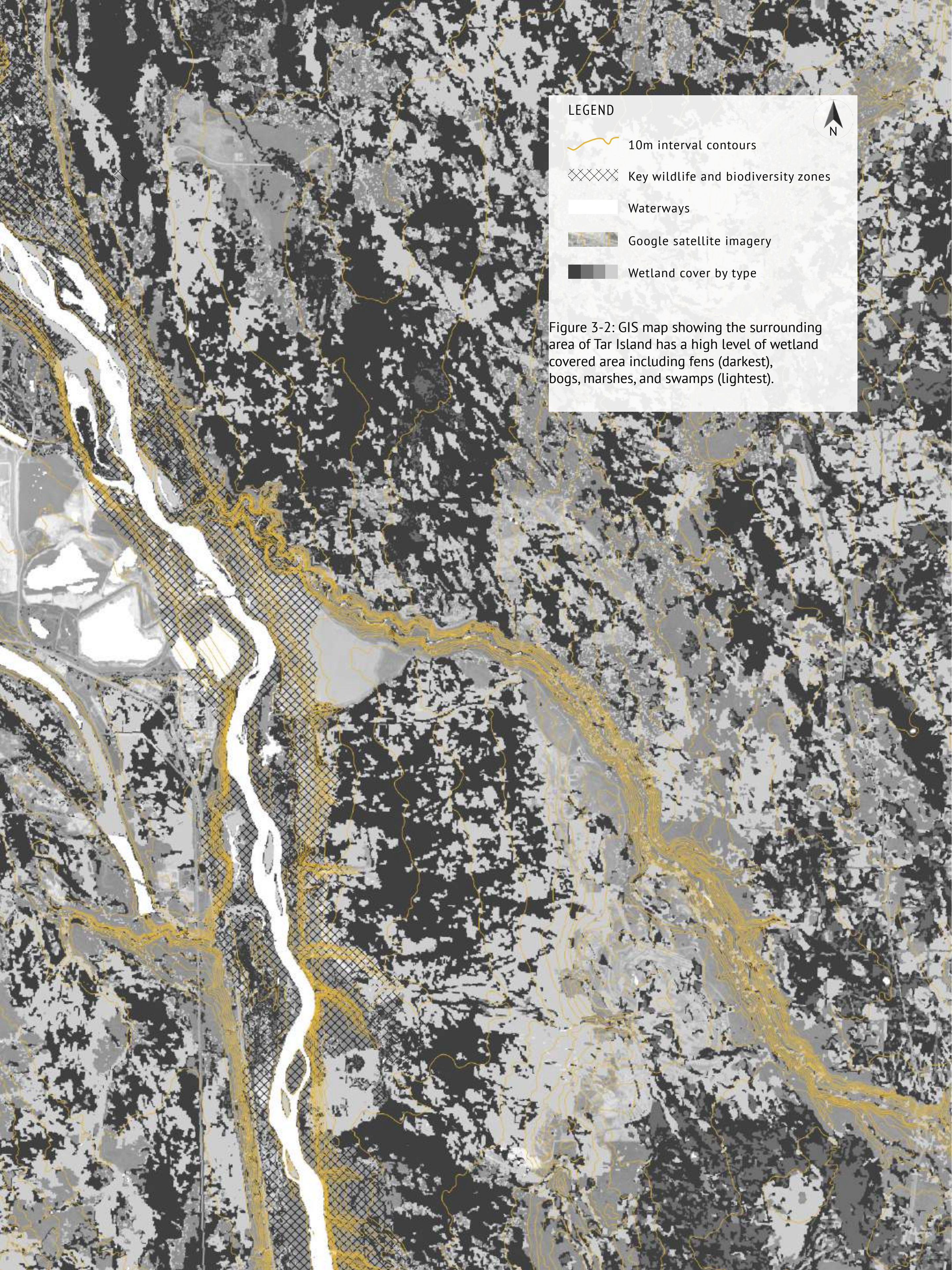
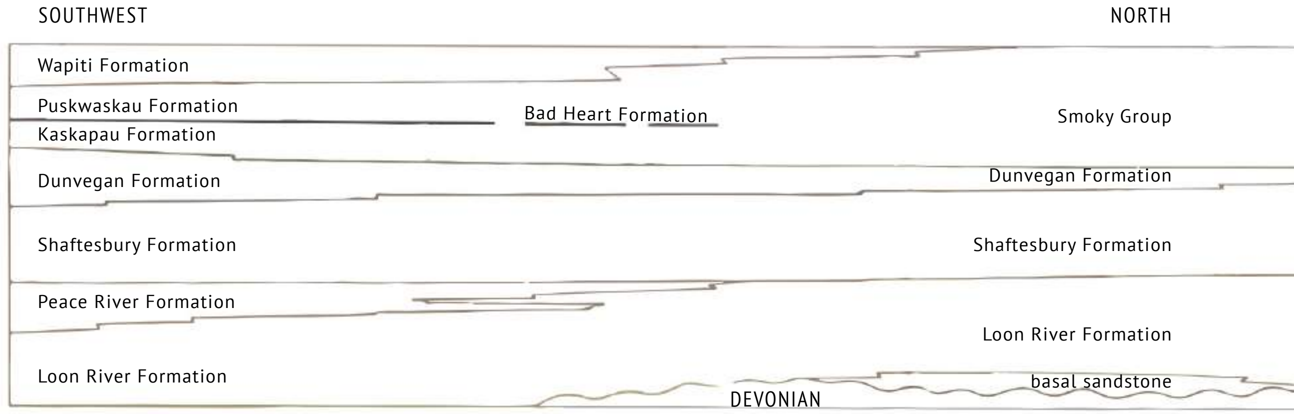


Figure 3-2: GIS map showing the surrounding area of Tar Island has a high level of wetland covered area including fens (darkest), bogs, marshes, and swamps (lightest).

BEDROCK GEOLOGY OF NORTHERN ALBERTA

GEOLOGIC ANALYSIS

CRETACEOUS ROCK RELATIONSHIPS



DEVONIAN ROCK RELATIONSHIPS

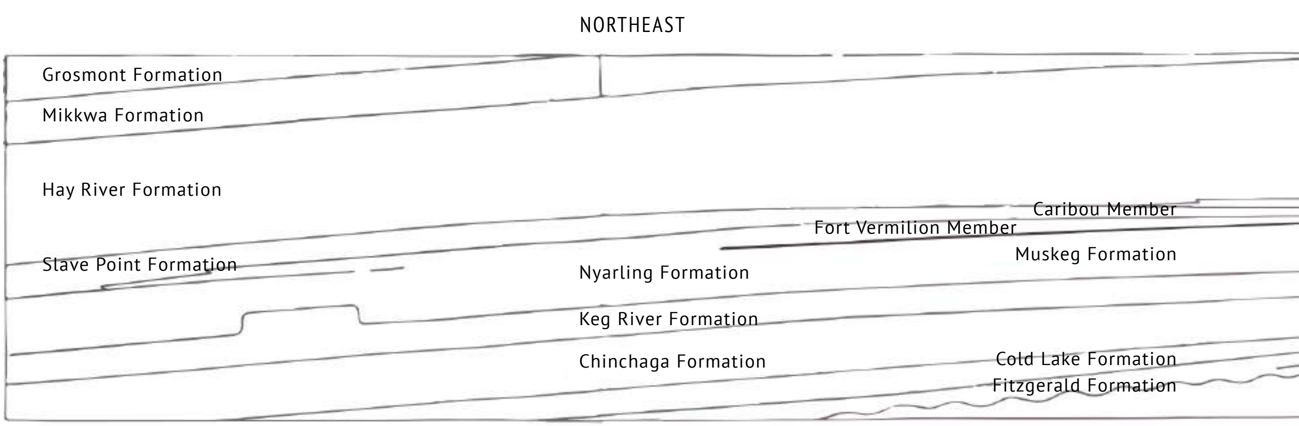
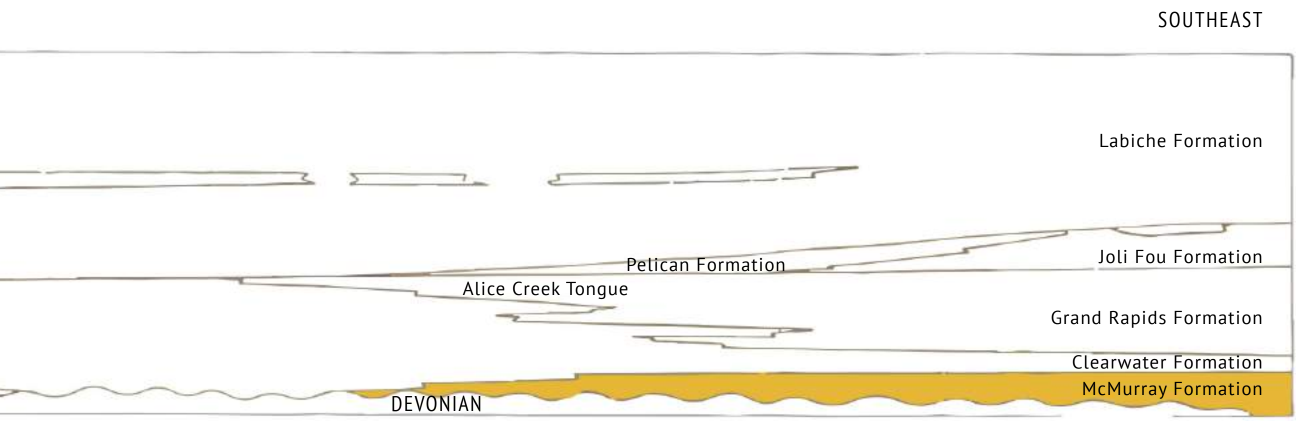
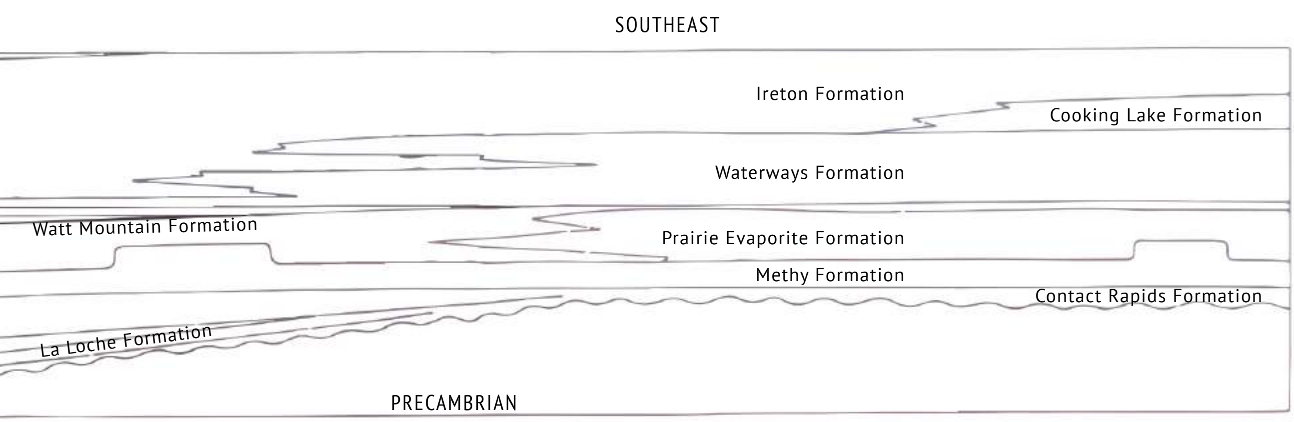


Figure 3-3: Bedrock geology of northern Alberta highlighting the McMurray deposit in north-east Alberta which formed over 100 million years ago (Oil Sands Discovery Centre, n.d.). This deposit is accessible by surface mining near Fort McMurray (Adapted from the Research Council of Alberta, 1970).



SOUTHEAST
Labiche Formation
Joli Fou Formation
Pelican Formation
Alice Creek Tongue
Grand Rapids Formation
Clearwater Formation
McMurray Formation
DEVONIAN



SOUTHEAST
Ireton Formation
Cooking Lake Formation
Waterways Formation
Watt Mountain Formation
Prairie Evaporite Formation
Methy Formation
Contact Rapids Formation
La Loche Formation
PRECAMBRIAN

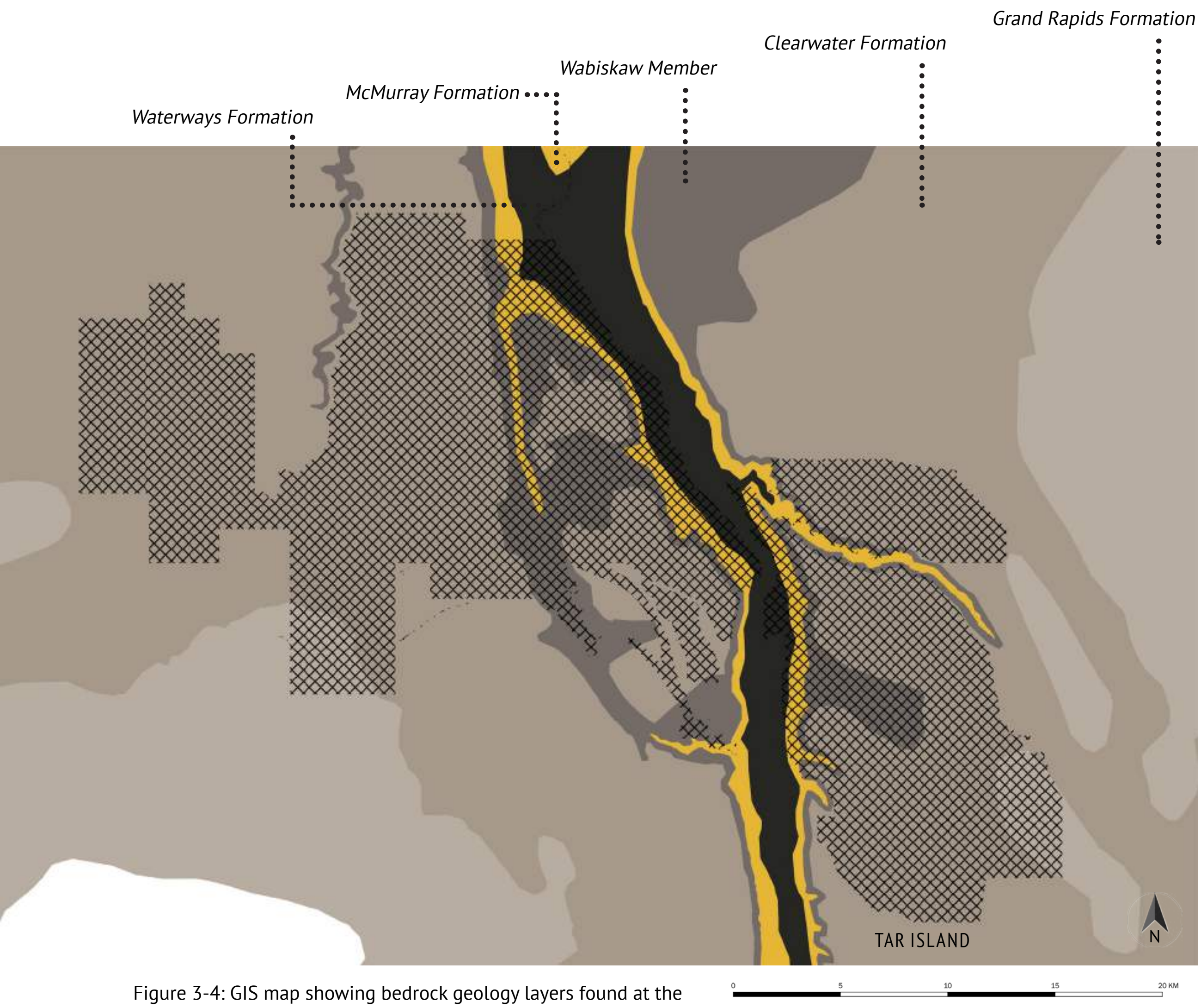


Figure 3-4: GIS map showing bedrock geology layers found at the surface surrounding the Tar Island mining area in the Athabasca Oil Sands.

Bedrock geology layers of northern Alberta are documented by the Research Council of Alberta (RCA) and described in detail on *Map 024: Bedrock Geology of Northern Alberta* (1970). The topography of this area was modified by the Pleistocene glaciation with the cover formed by glacial, aeolian, and deltaic

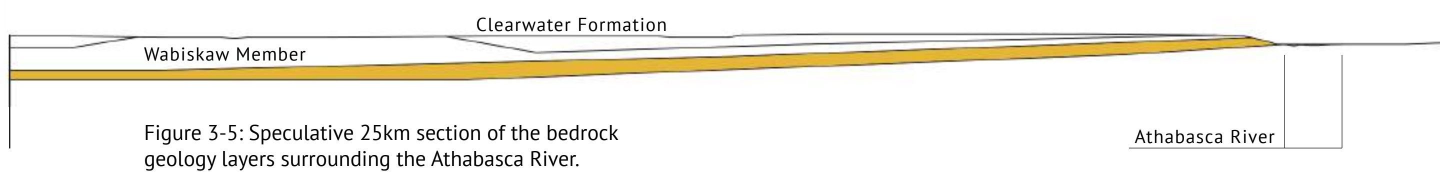


Figure 3-5: Speculative 25km section of the bedrock geology layers surrounding the Athabasca River.

deposits. The McMurray Formation is highlighted and is the geologic layer of interest for oil sands extraction mining.

The Grand Rapids Formation, Clearwater Formation, and Wabiskaw Member are mainly excavated to access the McMurray Formation below. The McMurray layer consists of oil-permeated quartz sands which are extracted and processed to produce an oil energy resource (RCA, 1970). The Waterways Formation is the layer found below the McMurray Formation and remains following the extraction of this oil-saturated layer. The Waterways Formation is comprised of shale, argillaceous limestone, and clastic limestone which are calcareous shales and limestones (RCA, 1970). A further understanding of the site conditions within the Athabasca Oil Sands is gained by identifying which layers are removed, recovered in production, and remain following extraction.

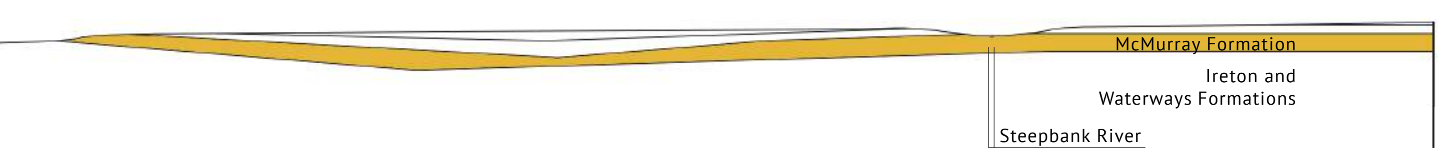
Compositions of each of the geologic layers within Tar Island include (RCA, 1970):

Grand Rapids Formation: [107m thick] Unconsolidated fine-grained quartzose and feldspathic sandstone and siltstone with layers of embedded silty shale. A thick layer of drift cover sits above this formation towards the eastern Alberta border. The lower 30-45m of this layer is glauconitic cherty sandstone conformable with the underlying silty shale of the Clearwater Formation.

Clearwater Formation (and Wabiskaw Member) : [107m thick] There is a gradation of layers transitioning from the Grand Rapids layer above. The Clearwater Formation is comprised of dark grey fossiliferous shale and laminated siltstone with thin beds of fine-grained cherty sandstone. The base layer of the formation is the Wabiskaw Member which consists of thin glauconitic sandstone.

McMurray Formation: [45-92m thick] Lies uncomformably on Devonian period carbonate rock (found in the Waterways Formation). Deltaic sediments of oil-permeated quartz sands exist here with layers of embedded laminated pale grey silt and silty shale.

Waterways Formation: [182-214m thick] Greenish-grey calcareous shale and argillaceous limestone alternating with grey and greyish-brown fine grained clastic limestone area found in this formation. Argillaceous and clastic also refer to calcareous formations, meaning calcareous limestones.



ECOCLIMATIC ZONES OF ALBERTA

CLIMATE AND ECOSYSTEM ANALYSIS

A study was done by authors Brian Rizzo and Ed Wiken that project impacts of shifting ecoclimatic zones. They look for the effects of climate change and what the impacts will be to Canadian landscape ecozones. The 1992 article titled *Assessing the Sensitivity of Canada's Ecosystems to Climate Change* incorporates climatic data modelling related to existing environmental ecozones. The study uses climate modelling data with a 1.5 - 4.5°C global temperature increase prediction over 30 to 50 years (Rizzo and Wiken, 1992, p.38). With almost 30 years since the article's date, these changes are likely to be seen in the next 20 years. By calibrating a model with inputted temperature and precipitation data for Canada, the authors project ecozone ranges based on a doubled carbon impact scenario. An adaptation of Rizzo and Wiken's Canadian ecoclimatic zones [see page 98-99] depict a spatial representation of the current and projected ecozone ranges.

The authors had predicted the shift of ecoclimatic zones would not be a smooth transition (Rizzo and Wiken, 1992, p.53). They believe the vegetation and soils will be under more rapid pressure to move compared to how quickly an ecosystem is usually established over longer periods of time. Soils also develop very slowly which may restrict the migration of plant species depending on the species' needs. A third reason described is that the average rate of warming that is predicted is to be 10-40 times faster since the last ice age (Rizzo and Wiken, 1992, p.38). Although these points present challenges in a successful shift of ecozones, there is potential to plan for and prepare for these changes through landscape architecture.

A method of preparing for climatic changes to ecozones is known as assisted migration. Assisted migration is a strategy that aids in the movement and establishment of plant communities to suit changing climatic conditions. Mary I. Williams and R. Kasten Dumroese wrote a 2013 article titled *Preparing for Climate Change: Forestry and Assisted Migration* that looks at the implementation of assisted migration for tree species over short- and long-term time frames (p.287). The authors note some benefits of assisted migration can prevent species extinction, minimize economic losses, and sustain ecosystems and their biodiversity (p.288). Assisting in migration of species and maintaining these features of an ecozone can contribute to the health of human and environmental communities.

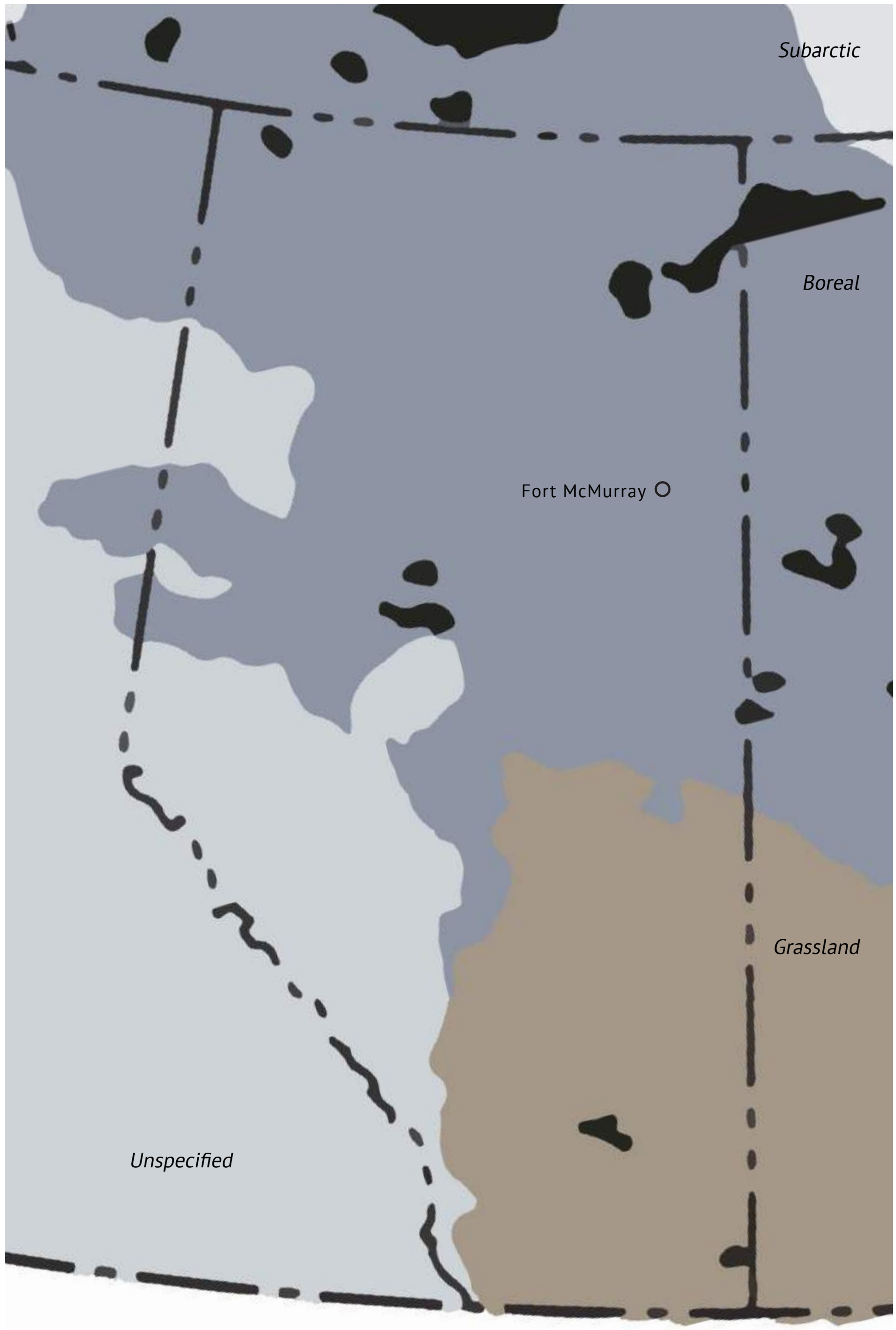


Figure 3-6: Current ecoclimatic zones of Alberta
(Adapted from Rizzo and Wiken, 1992, p.43 - used with permission).

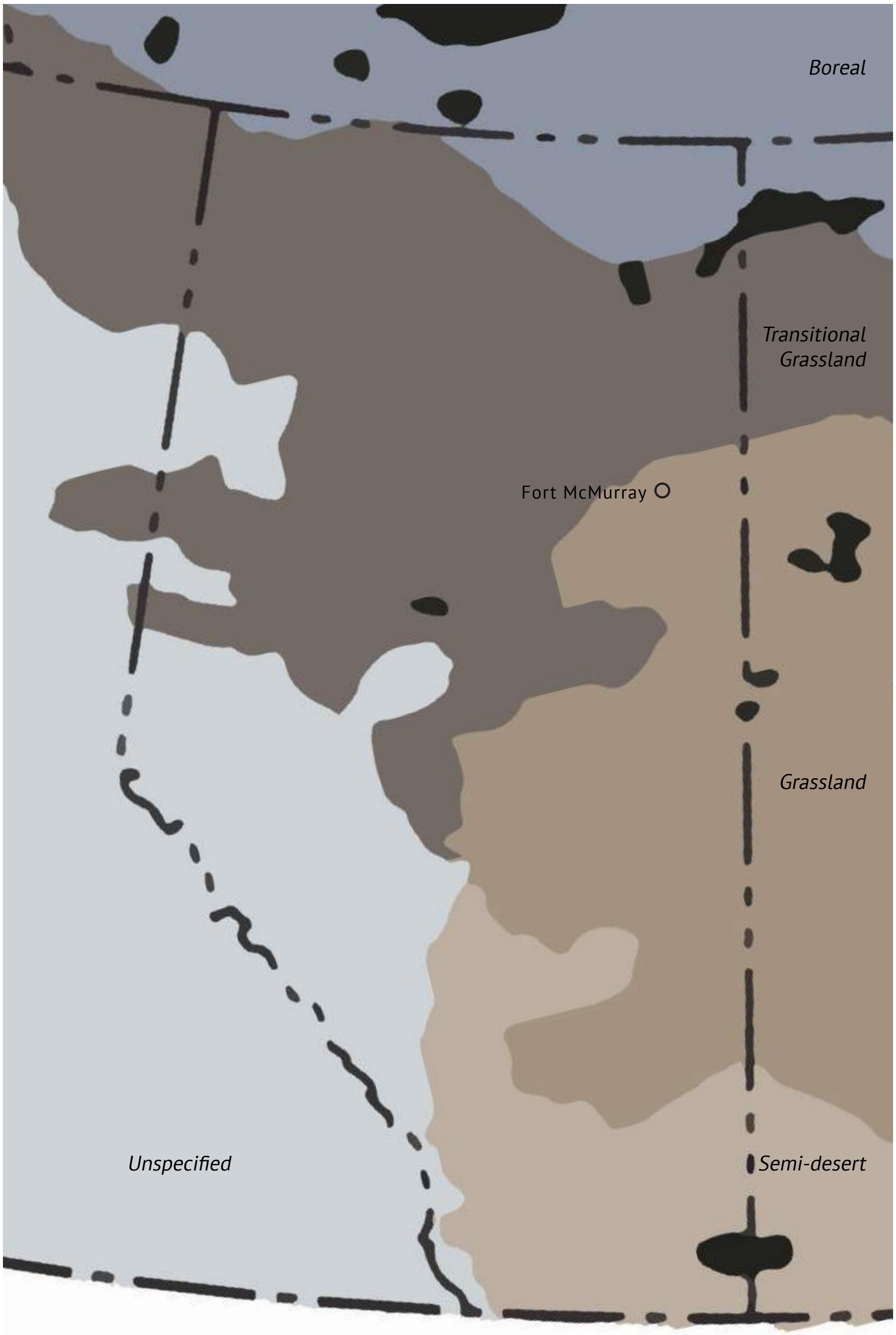


Figure 3-7: Projected ecoclimatic zones of Alberta for a doubled CO_2 scenario (Adapted from Rizzo and Wiken, 1992, p.50 - used with permission).

ECOCLIMATIC ZONES OF ALBERTA

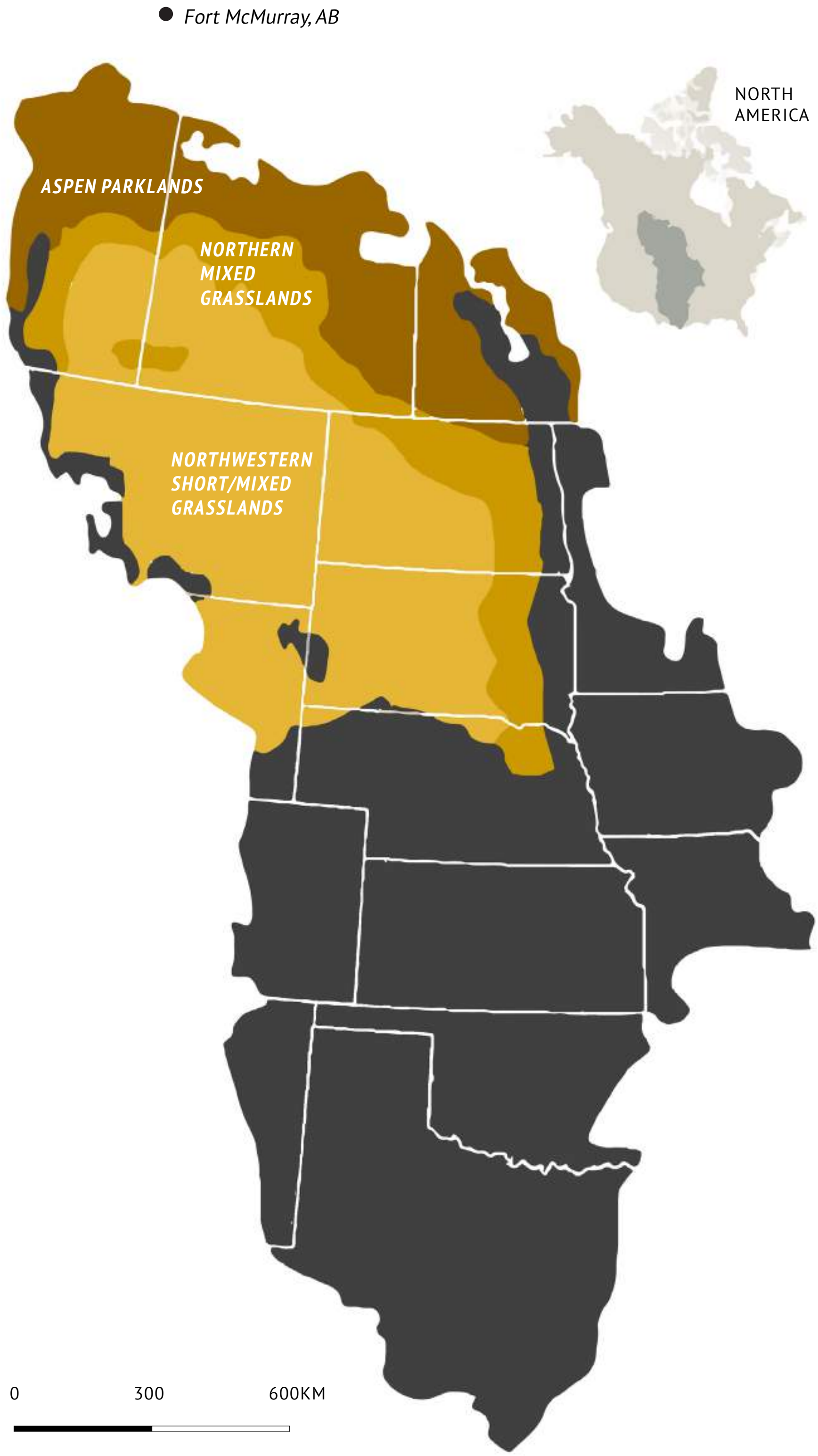
CURRENT GREAT PLAINS GRASSLANDS RANGE

The current range of the Great Plains grasslands [prairies] across North America extend up to the south-eastern part of Alberta. Not much of this original vegetation land cover exists in its functioning form as many of these lands have been taken over by agricultural production. The book *Prairie: A Natural History* by Candice Savage (2011) provides a valuable resource to the processes and types of grasslands that exist in North America. The current range of the Great Plains are what is considered the prairie provinces within Canada. The aspen parklands act as a transition between boreal forest and open plains in more northern climates (2011, p.20). The mixed-grasslands get their name from mixed grass heights as a combination of tall grass prairies and short grasslands (2011, p.20).

When comparing the current range with the predicted ecoclimatic zones within Canada, it is likely that the area around Fort McMurray, Alberta will transition to grasslands over time (Rizzo and Wiken, 1992, p.50). The current range of the Great Plains map is overlaid with the projected ecoclimatic zones [see pages 102-103] that display the shift of mixed grasslands northward.

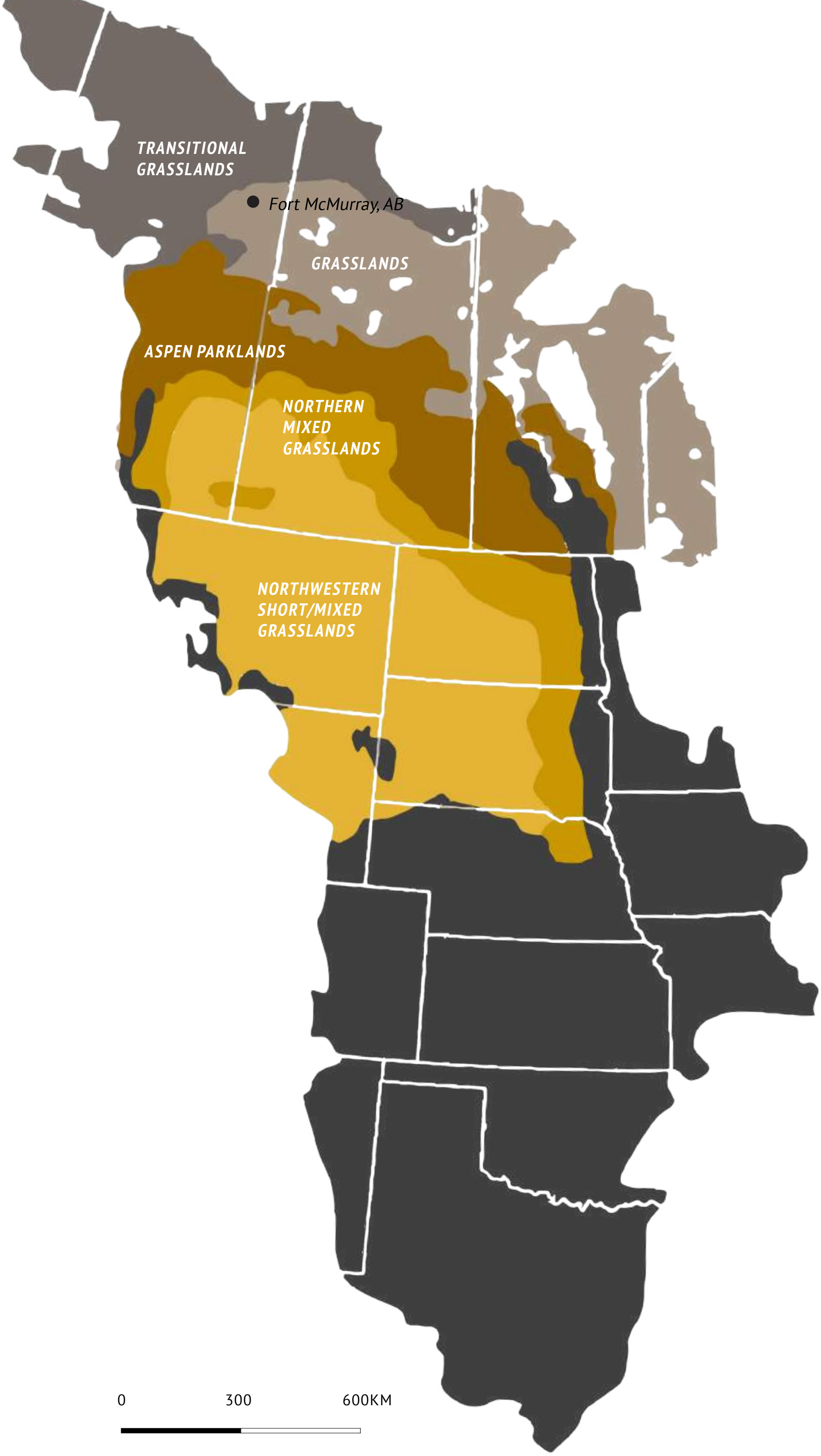
Grasslands are comprised of mainly grasses and flowering forbs (wild flowering perennials), with small clusters of shrubs and deciduous trees. Many of these clusters of trees exist along riparian corridors (adjacent to rivers) and comprise about 15% of the tall grass prairie region (Savage, 2011, p.191). Over time, grasslands have adapted to drought in their establishment. With the pending increase to temperatures globally, droughts may become more common and more extreme over the next 50 years (Savage, 2011, p.78). Survivability of the grassland biome is very possible and likely during changing climatic conditions as it is well-adapted to more extreme conditions (Savage, 2011, p.78).

[opposite page] Figure 3-8: Map of the Great Plains grassland types (Adapted from Savage, 2011, p.22).


Fort McMurray, AB
NORTH
AMERICA
ASPEN PARKLANDS
NORTHERN
MIXED
GRASSLANDS
NORTHWESTERN
SHORT/MIXED
GRASSLANDS
0
300
600KM

ECOCLIMATIC ZONES OF ALBERTA
GRASSLANDS RANGE MIGRATION

[opposite page] Figure 3-9: Map of the Great Plains grassland types and projected Canadian ecoclimatic zones (Adapted from Savage, 2011, p.22 and Rizzo and Wiken, 1992, p.50).


TRANSITIONAL GRASSLANDS
Fort McMurray, AB
GRASSLANDS
ASPEN PARKLANDS
NORTHERN MIXED GRASSLANDS
NORTHWESTERN SHORT/MIXED GRASSLANDS
0
300
600KM

INDUSTRIAL ECOLOGY
ECOLOGICAL SYSTEMS

The development of the oil extraction mining industry has grown its physical footprint significantly over time [see pages 106-107]. The many intricacies and interrelated processes of this industry operate as its system, much like an ecology. Looking at this industry as a comparison to an ecological system is known as the study of an industrial ecology. Studies of ecological systems such as the work of the landscape architect Ian McHarg and the landscape ecologist Richard T.T. Forman, describe capacity and functions of a landscape system.

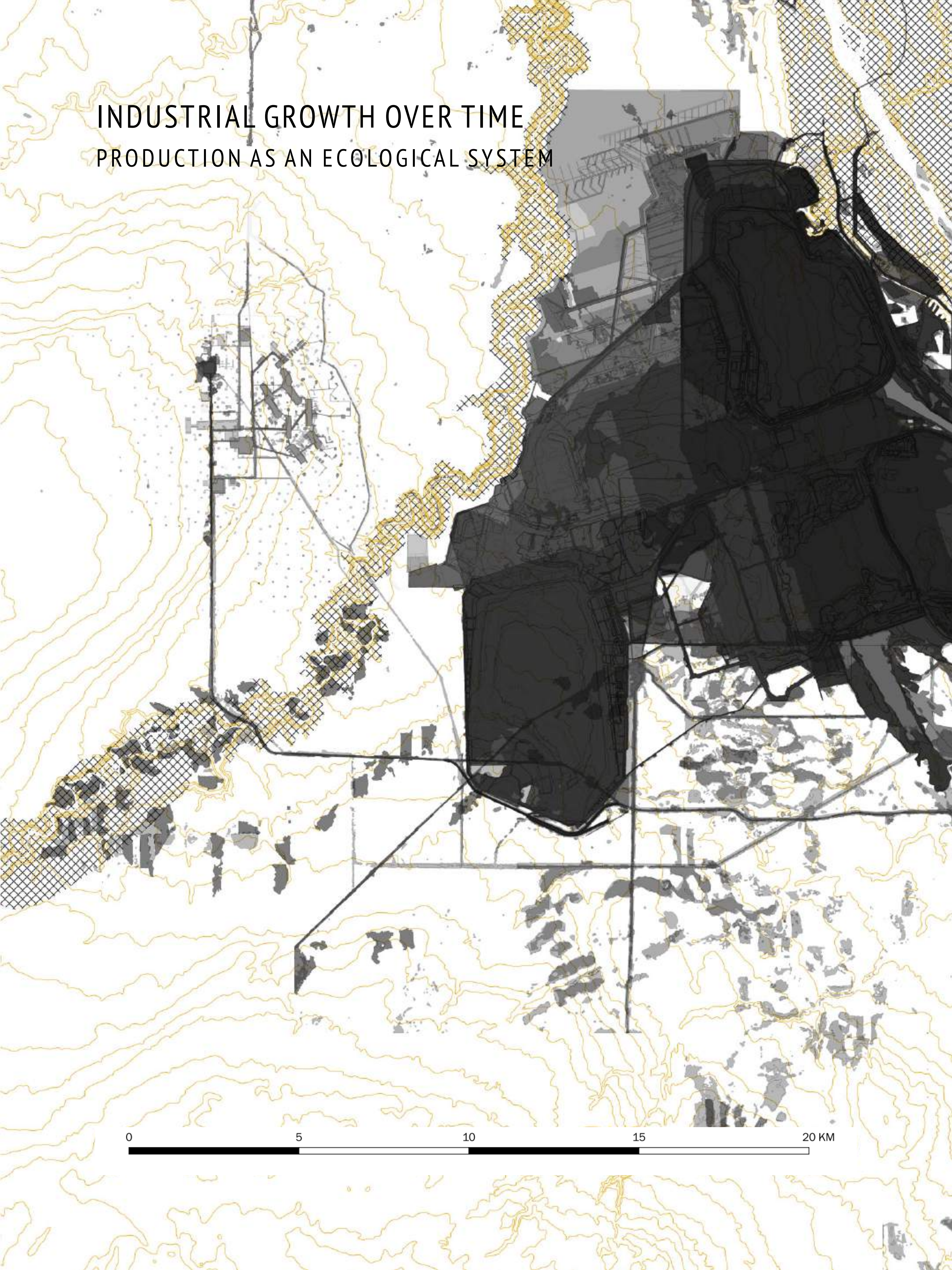
Ian McHarg's most notable work, *Design With Nature* (1992), suggests the use of ecological planning at the regional scale. His concepts of human land use patterns were created on the basis of breaking down regions into their most appropriately-suited functions based on what the land had to offer. McHarg's goal in ecological planning is a balanced approach for "enhancing the creative fit of man-environment" (1992, p.197). T.T. Forman's concept of landscape mosaics, in *Land Mosaics: The Ecology of Landscapes and Regions* (1995), refers to the spatial makeup of landscape components over large areas or regions, as seen from above. The spatial attributes of these mosaics which the author discusses as being highly ecologically beneficial include large habitat patches, high corridor connectivity, multiple small habitat patches, and varied boundary lengths (1995, p428). McHarg and T.T. Forman's approach to understanding an entire ecological system and its functional suitabilities can be applied to the industrial ecology.

> *Landscapes and regions are exactly the right scales for sustainability. Local ecosystems are commonly transformed in days or years, whereas land mosaic transformations usually occur incrementally over generations. Humans avoid long-term planning and decisions, whereas sustained human-land interactions require them. Large area is a surrogate for long-term.*
>
> *(Richard T.T. Forman, 1995, p.xviii)*

By interpreting the Athabasca Oil Sands as a complex system and by translating its functions into the definition of an ecology, an understanding of how the land is used here can be gained.

INDUSTRIAL GROWTH OVER TIME

PRODUCTION AS AN ECOLOGICAL SYSTEM



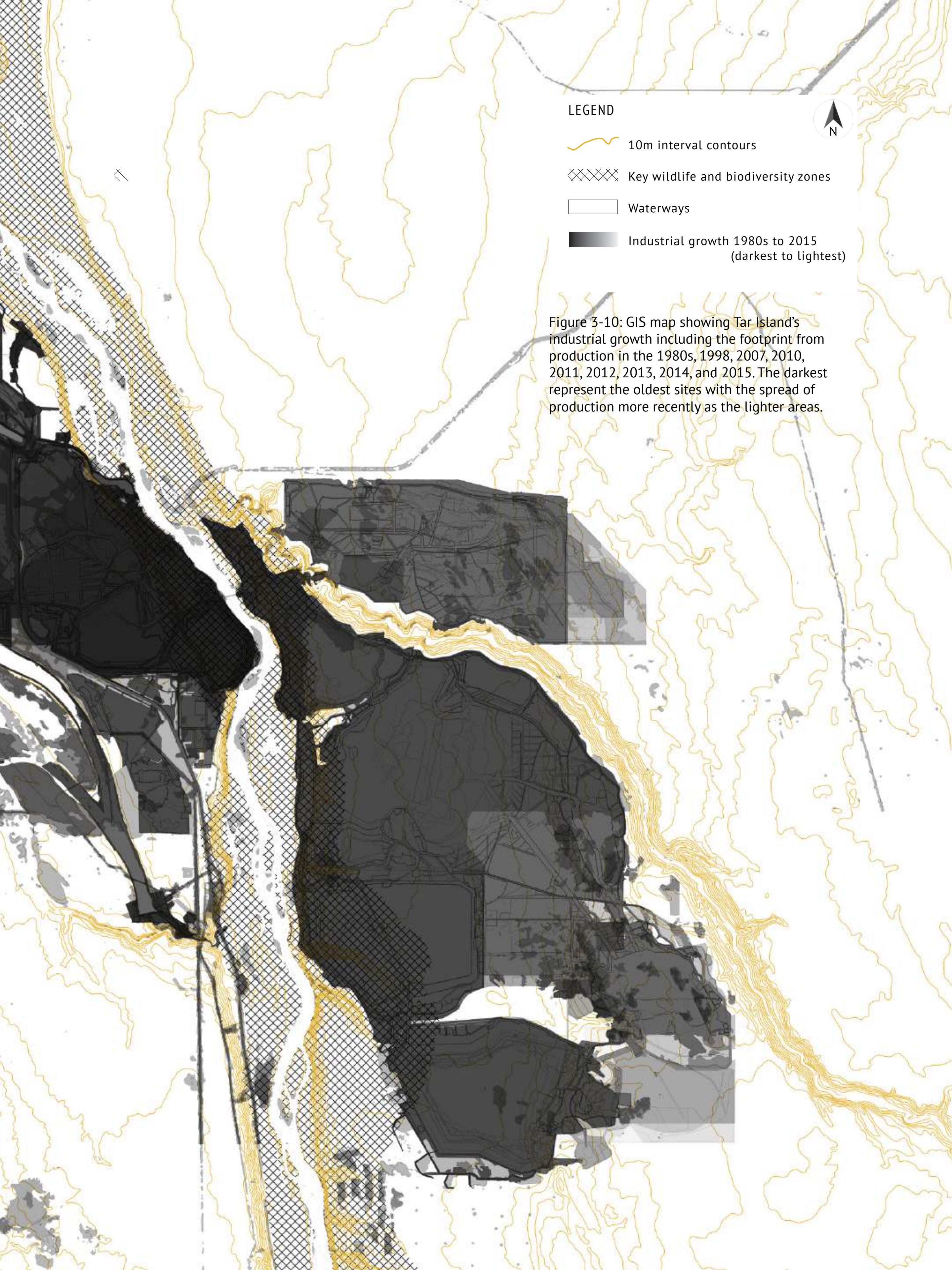


Figure 3-10: GIS map showing Tar Island's industrial growth including the footprint from production in the 1980s, 1998, 2007, 2010, 2011, 2012, 2013, 2014, and 2015. The darkest represent the oldest sites with the spread of production more recently as the lighter areas.

INDUSTRIAL ECOLOGY

THE EXPANDED FIELD OF INDUSTRIAL ECOLOGY

A compilation of landscape components that are derived from ideas presented by Ian McHarg and Richard T.T. Forman help define different functions of the Athabasca Oil Sands. In defining the industrial ecology, instruments of industry like haul trucks and hydraulic shovels represent the organisms inhabiting this environment. They use the landscape in order to support production in these landscape components:

Habitat / Nuclei: the core landscape type that supports function of organisms
Remnants: past or leftover spaces surrounding the main habitat
Corridors: networks for the movement of organisms between areas
Nodes: key spaces that support the overall function and waste of organisms
Patches: small built areas that support functions differing but related to the main landscape type
Voids: unproductive remains
Edges: spaces between different types of organisms' movement

The American art critic and theorist, Rosalind E. Krauss, provides an interpretation of a type of graph known as the Klein group diagram that described sculpture in the expanded field of architecture. In her book, *The Originality of the Avant-garde and Other Modernist Myths* (1985) she describes a mapping of operations within the human sciences. It pairs sets of oppositions and then logically expands

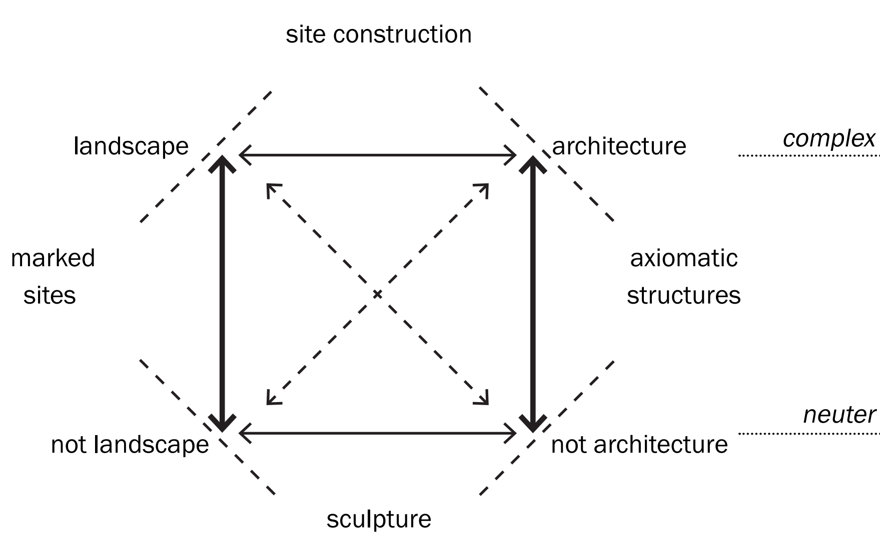


Figure 3-11: Rosalind E. Krauss' sculpture in the expanded field diagram (Adapted from Krauss, 1985).

them. The bottom sets are neuter or referring to a mirror of an idea, and the top is complex referring to a combination of ideas (p.283). Krauss placed sculpture as an expansion of the 'not landscape' and 'not architecture' fields. She continued the expansion to include the three other directions from the 'landscape', 'architecture', 'not landscape', and 'not architecture' fields.

The sculpture in the expanded field diagram provides a framework for the expanded field of industrial ecology. This new expanded field uses Krauss' categories and further assigns ecological landscape components of this site in square brackets to each expansion. The addition of land components was based on a selected fit between the expanded field of landscape architecture categories and characteristics of ecological components.

The addition of ecological components according to Krauss' expanded field of architecture (1985, p.284) allows us to see the relation of landscape spaces in the industrial ecology. This expanded field of industrial ecology represent the functions for Oil Sands extractions site.

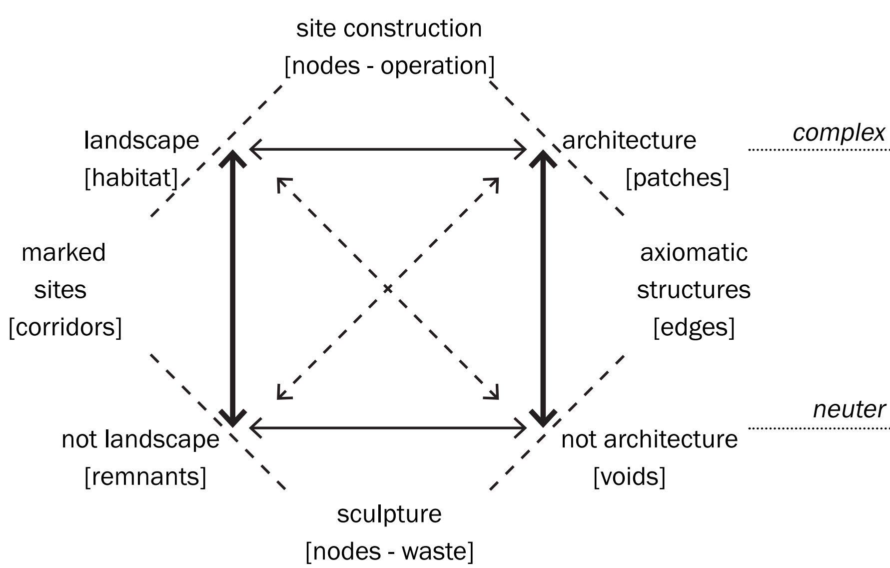
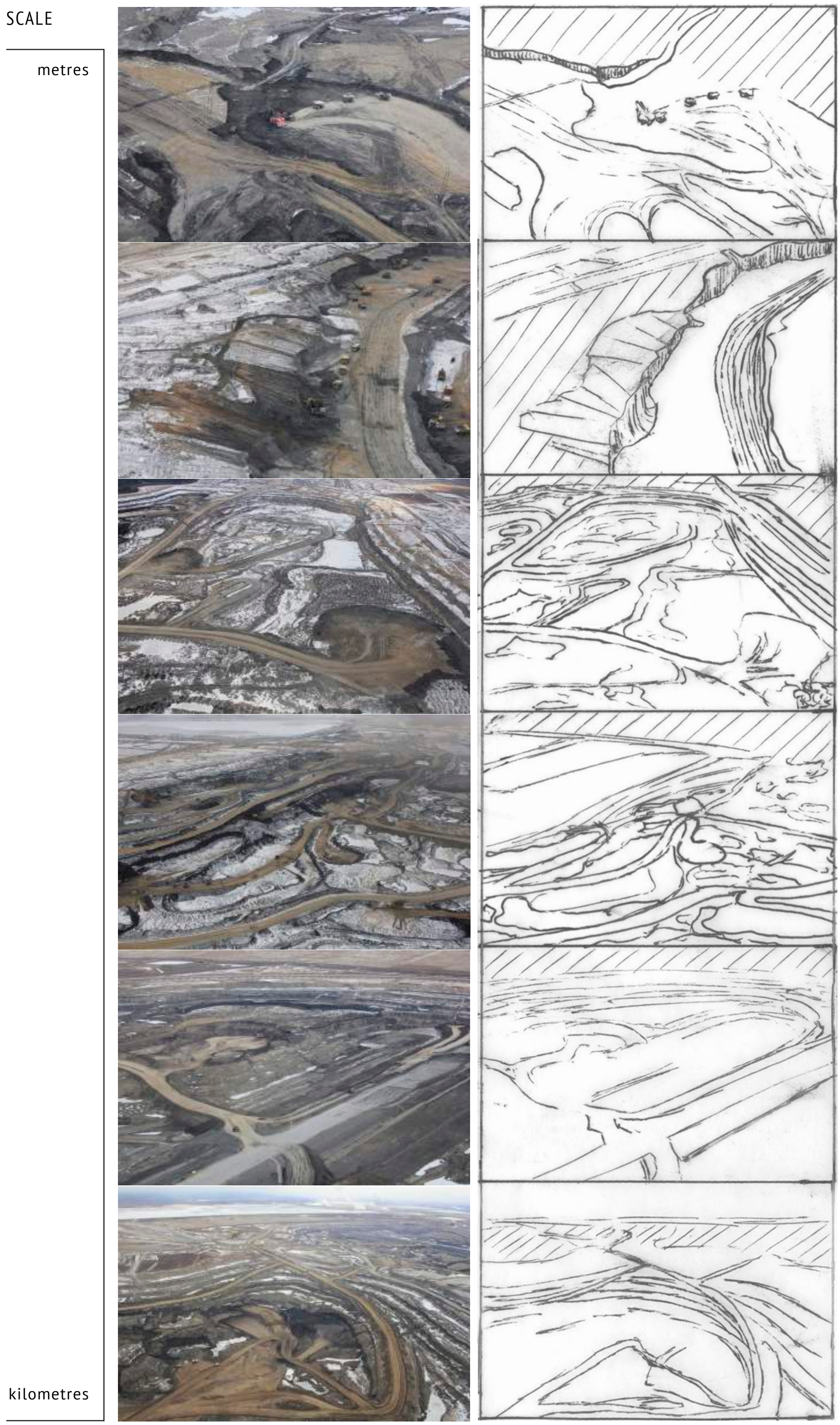


Figure 3-12: An interpretation of the expanded field of architecture relations fit to the Athabasca Oil Sands industrial ecology: *the expanded field of industrial ecology* (Adapted from Krauss, 1985).

The pages that follow include a breakdown of how each landscape component of the industrial ecology operate spatially and functionally. The GIS Oil Sands Industrial Features (OSIF) layers are listed for each landscape component for reference to the maps found directly after each component description. The mapping of each landscape component represents the spatial composition of these features within Tar Island.


SCALE
metres
kilometres

LANDSCAPE HABITAT

The landscape in Krauss' expanded field is the core of this environment that fits the needs of the organisms it supports. Habitat is the productive centre of this landscape, shaped by intensive production flows of the organisms within their environment. Their survival depends on the extraction of layers of soil and bedrock.

The habitat is formed by curvilinear patterns, desire lines, and varying depths of levels of movement. It is mainly comprised of solid ground, however extraction can expose the underlying water table in some areas.

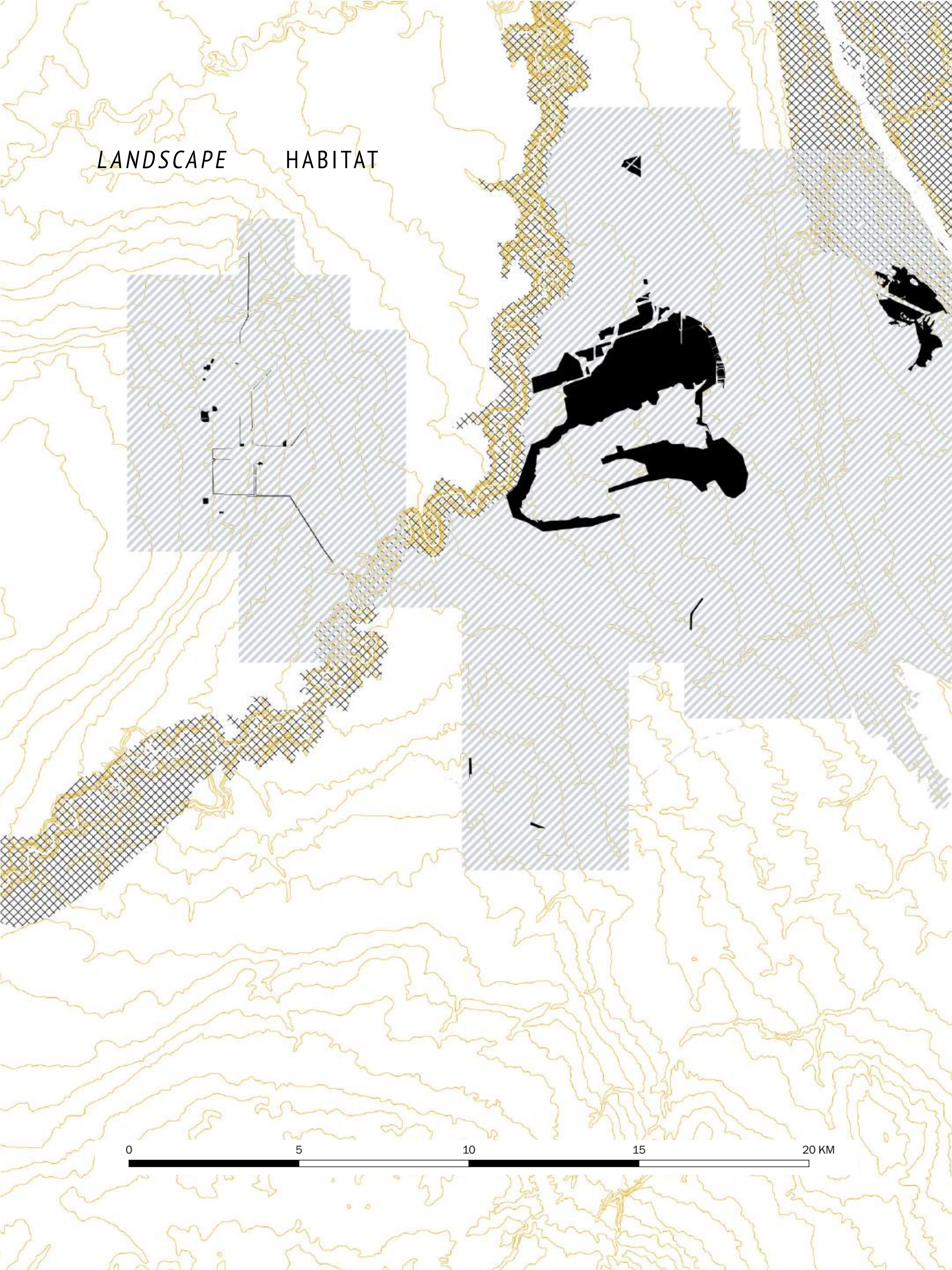
Oil sands found within the McMurray geologic formation are removed to leave the underlying limestone exposed after extraction is complete. Spatial components from GIS data include borrow pit, mine pit, other, and salvaged soil. This landscape component provides no soil as the existing condition post-mining.

HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

[opposite page] Figure 3-13: Relational study of the habitat landscape component by scale, as seen from above within Tar Island.



LANDSCAPE HABITAT
0
5
10
15
20 KM

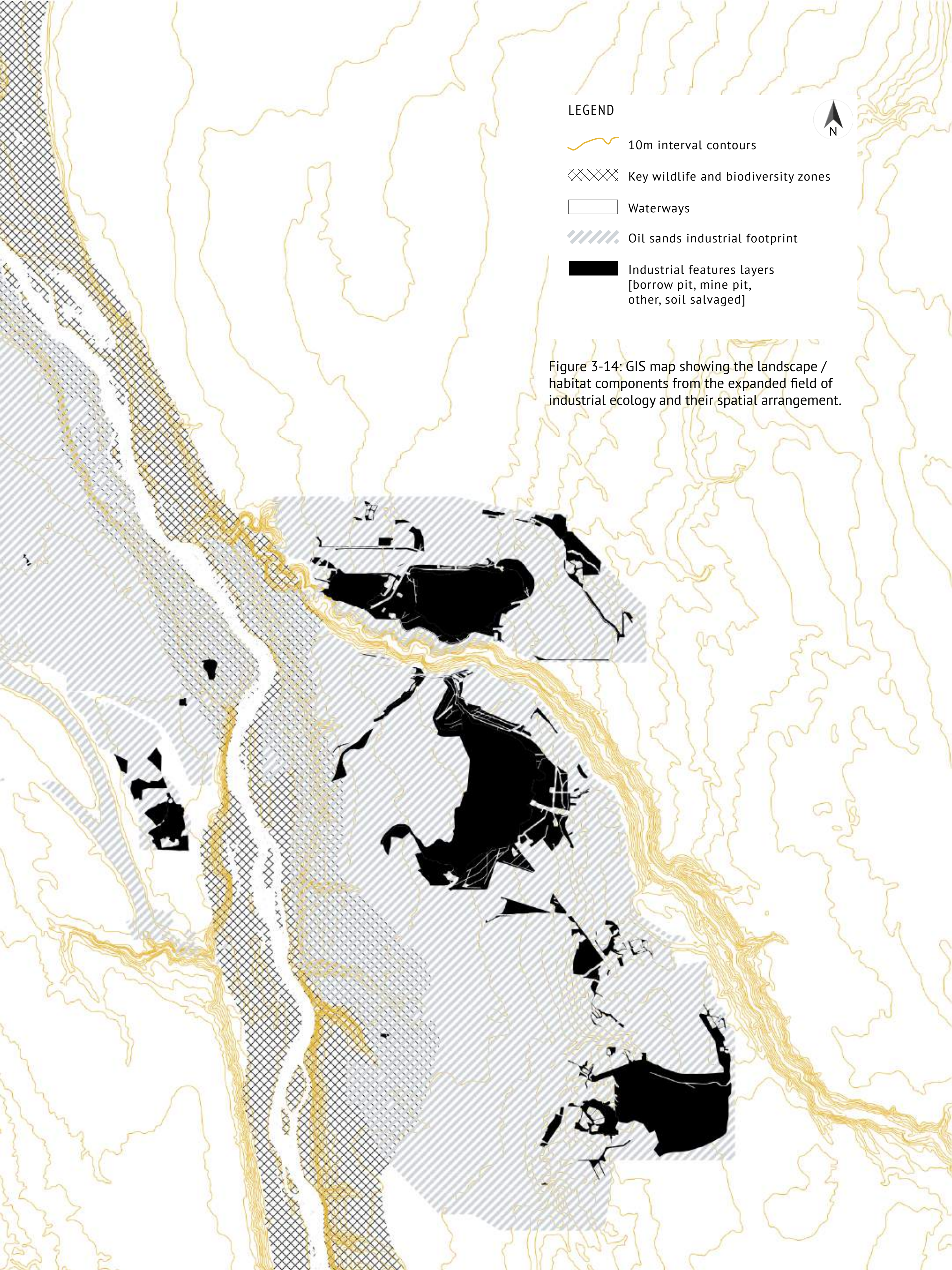
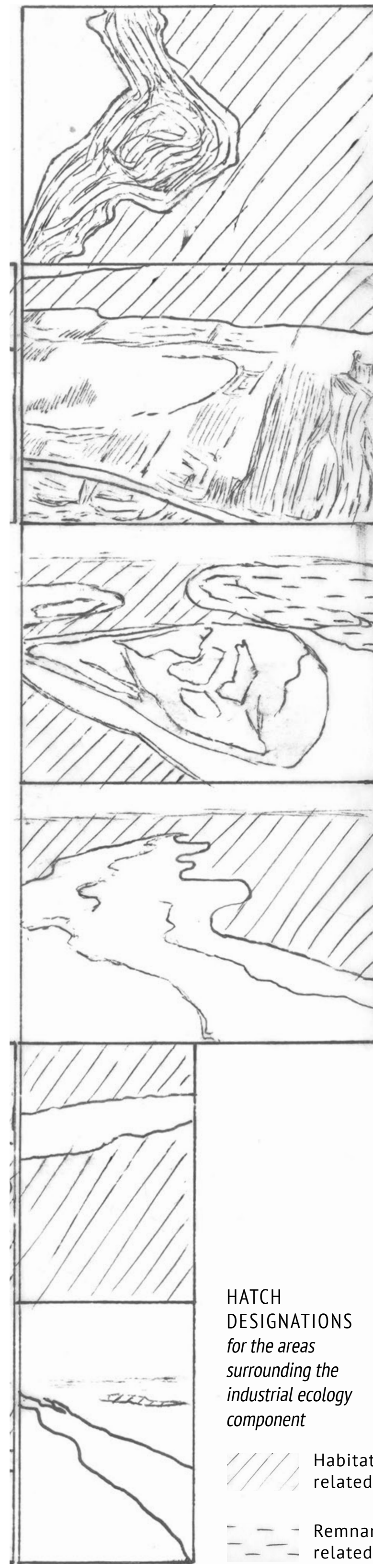


Figure 3-14: GIS map showing the landscape / habitat components from the expanded field of industrial ecology and their spatial arrangement.

SCALE

metres

kilometres



HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

NOT LANDSCAPE REMNANTS

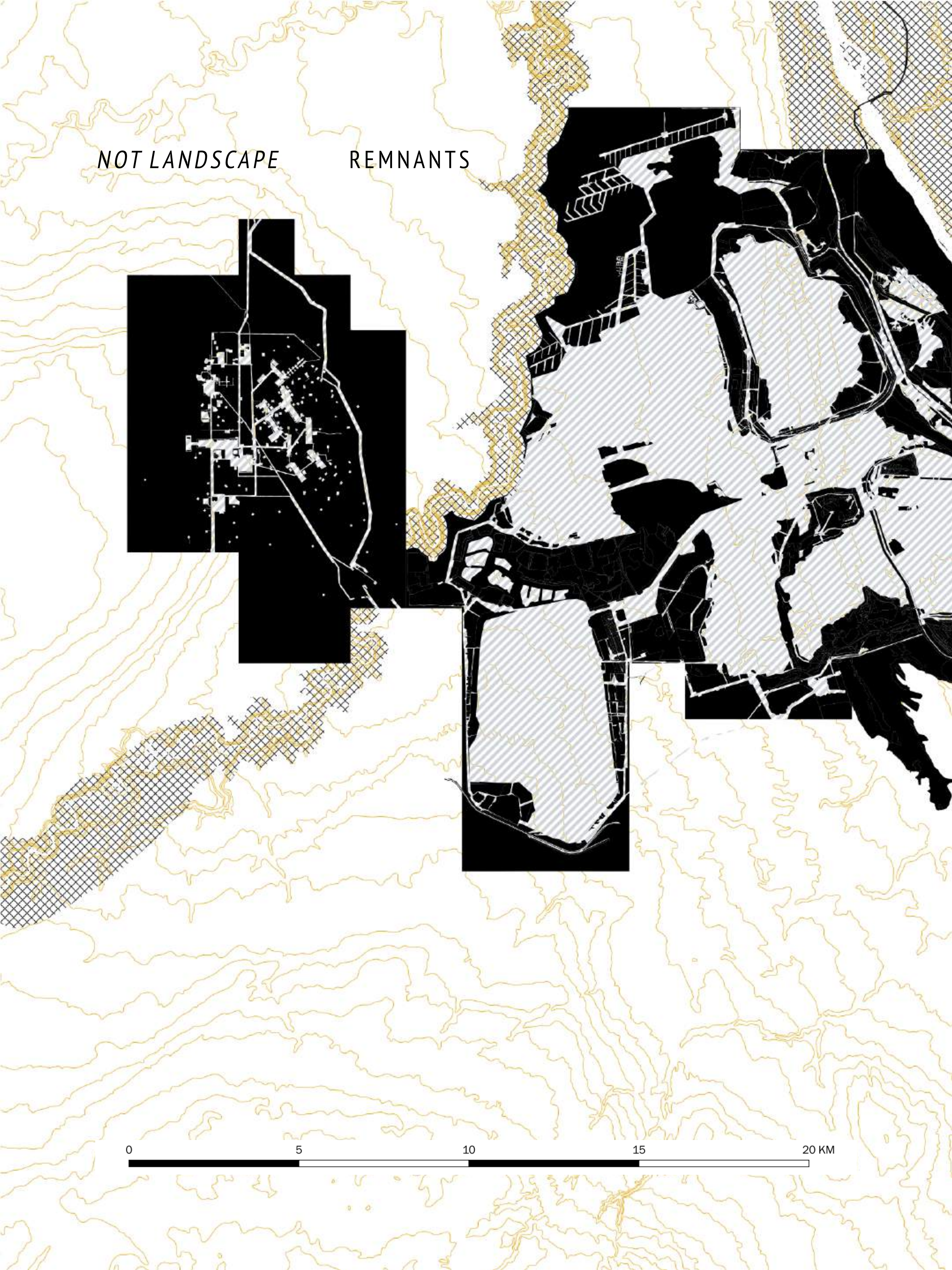
Not landscape in Krauss' expanded field refers to a mirror of landscape, or a gap that does not fit within landscape but is a major part of this environment. Remnants represent the past or leftover spaces surrounding habitat. These spaces are considered obstacles to the function of organisms. A combination of patches and corridors within this component include reclamation sites and watercourses like the Athabasca and Steepbank Rivers.

Both linear and curvilinear components display the scale of the landscape habitat as it is also shaped by the organisms through clearing or reclaiming requirements. The GIS data layers for this type are certified, cutblock, natural, oil sands cleared, overburden dump, permanent, ready for reclamation, reclamation material stockpile, soil placed, temporary, temporary (dam safety), undergoing remediation, and wetland trial.

By either piling or re-filling areas related to past habitat function or areas set aside for future habitat function, these areas are situated next to habitat and other industrial functions. For past habitat areas, soils and vegetation are added to these sites. For areas of future habitat, vegetation is often removed but soils remain until further use. This landscape component provides thin soil following its function to the site.

[opposite page] Figure 3-15: Relational study of the remnant landscape component by scale, as seen from above within Tar Island.

NOT LANDSCAPE REMNANTS



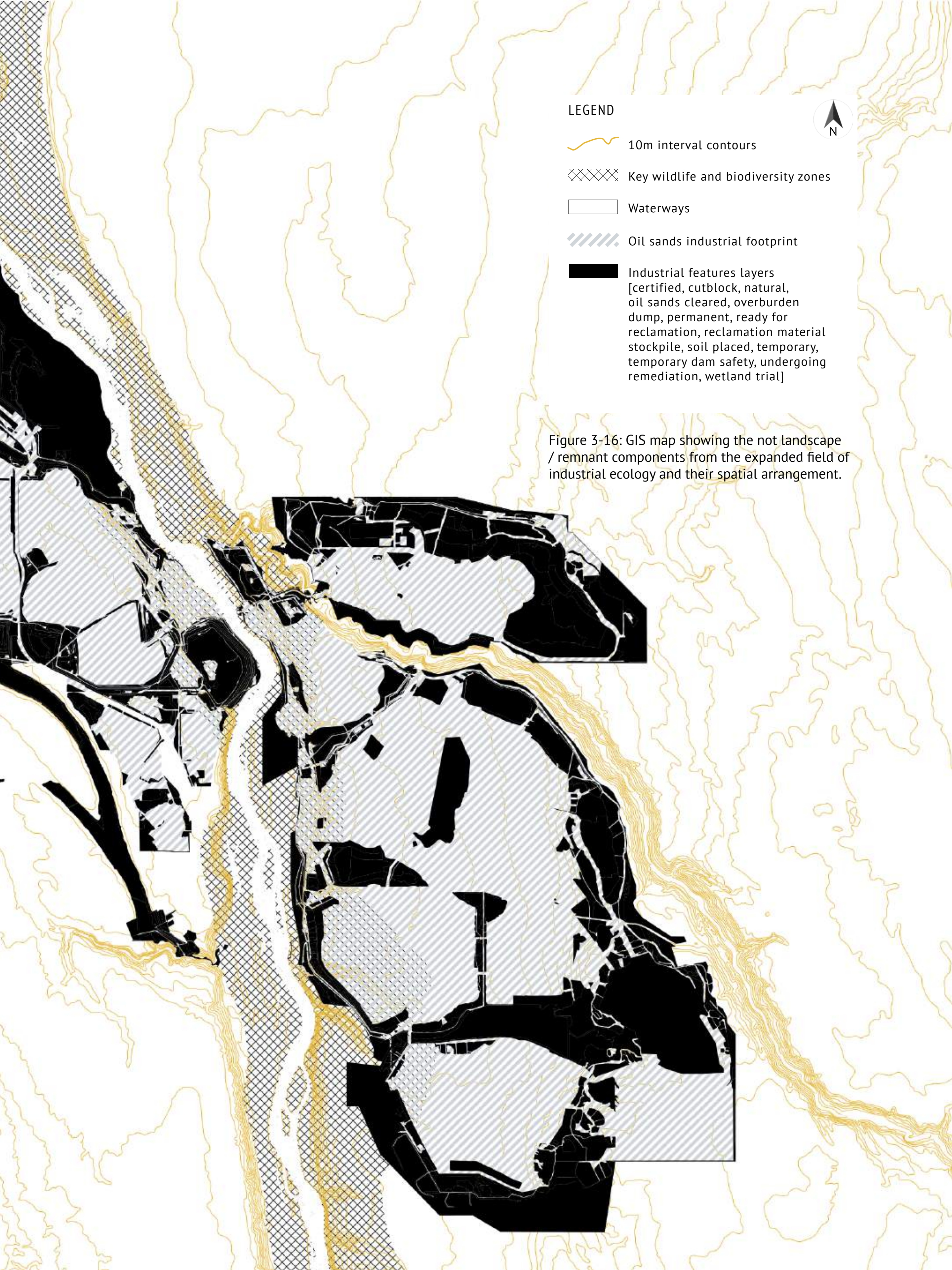
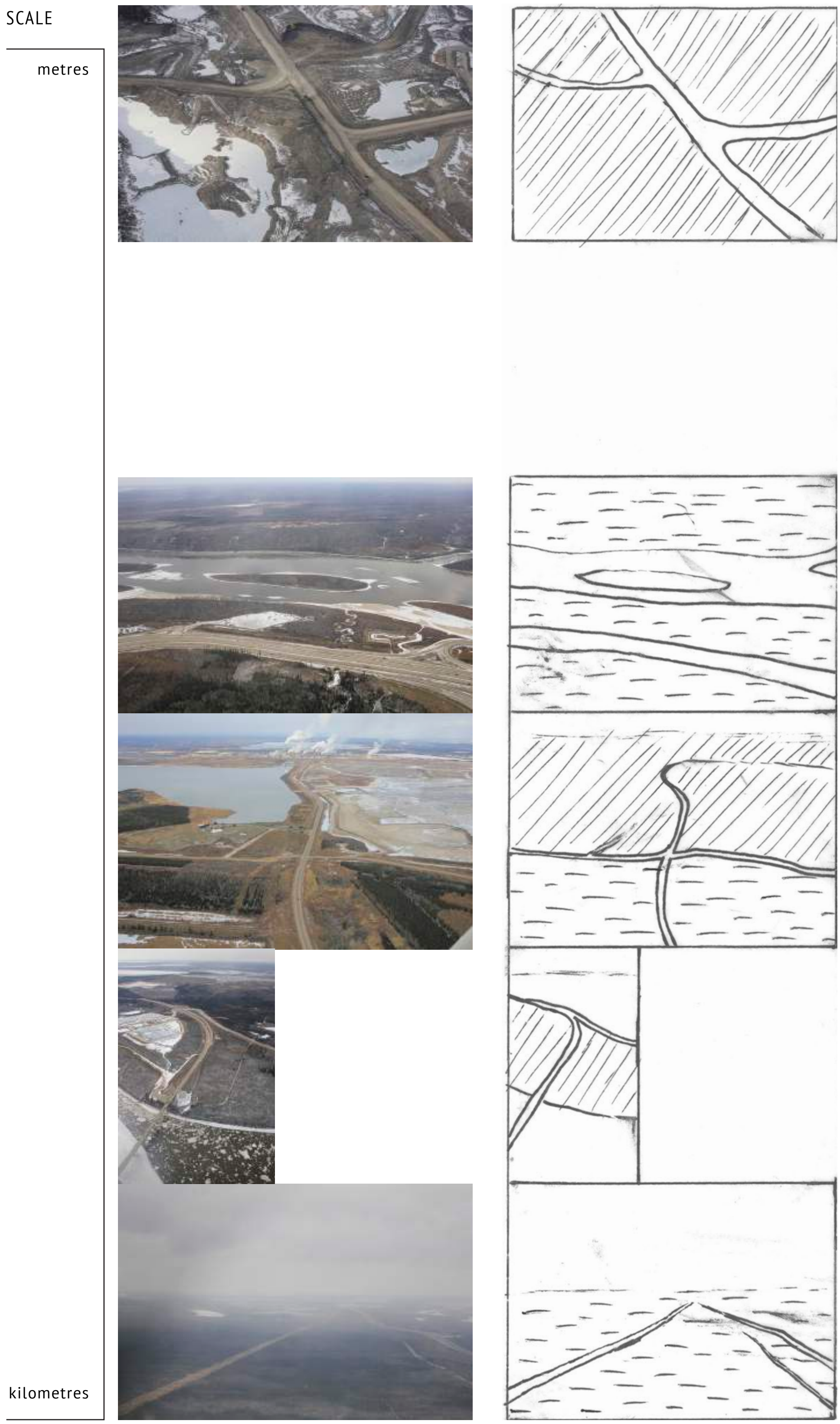


Figure 3-16: GIS map showing the not landscape / remnant components from the expanded field of industrial ecology and their spatial arrangement.


SCALE
metres
kilometres

MARKED SITES CORRIDORS

Marked sites are an expansion of landscape and not landscape components. Known in the industrial ecology as corridors, these networks are for safe movement of the organisms to, from, and throughout habitat sites. These routes connect all parts of the industrial ecosystem but fragment large patches of habitat such as mine pits.

These networks appear linear at a small scale but are often curvilinear at the larger scale of industry as they wind around and through various sites. They provide datum lines among different functions being carried out within the industry. The GIS data layers for this type are pipeline, power line, transformer station, and roads.

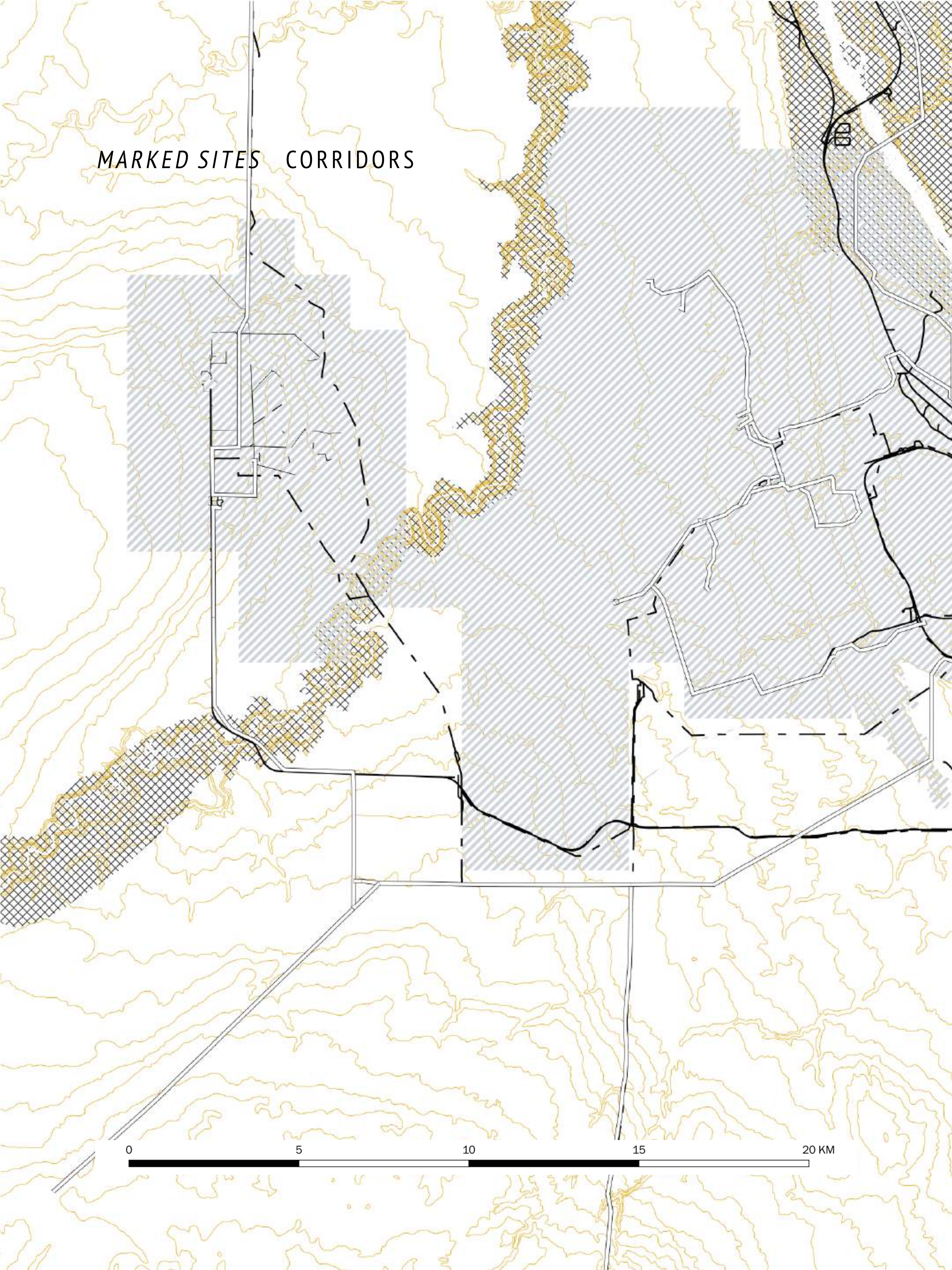
The routes are often cleared of taller vegetation for continuous access. Either gravel roads or cutlines made for power lines leave some soil and low-lying successive species along its edges. This landscape component provides thin soil following its use.

HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

[opposite page] Figure 3-17: Relational study of the corridor landscape component by scale, as seen from above within Tar Island.


MARKED SITES
CORRIDORS
0
5
10
15
20 KM

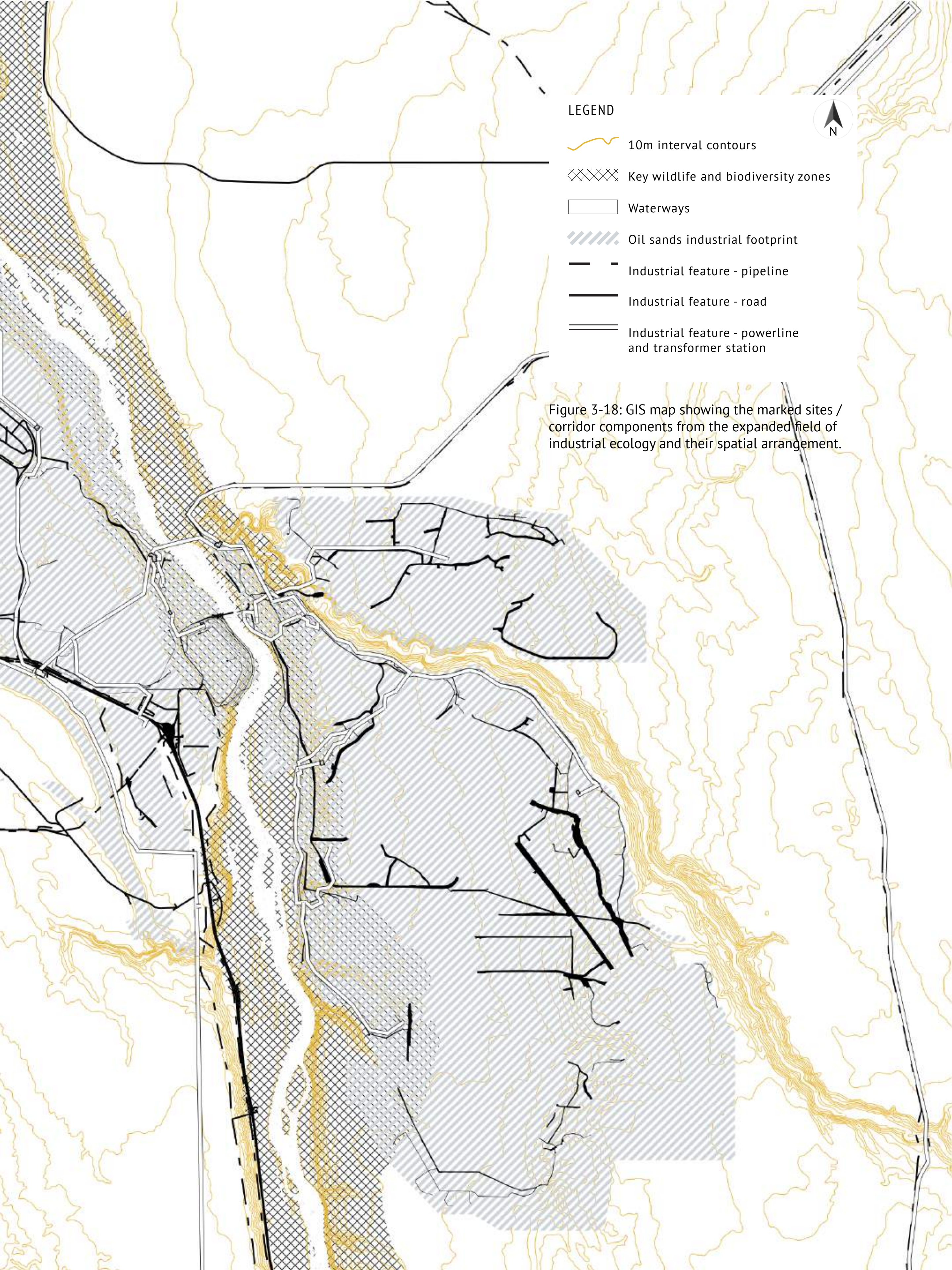
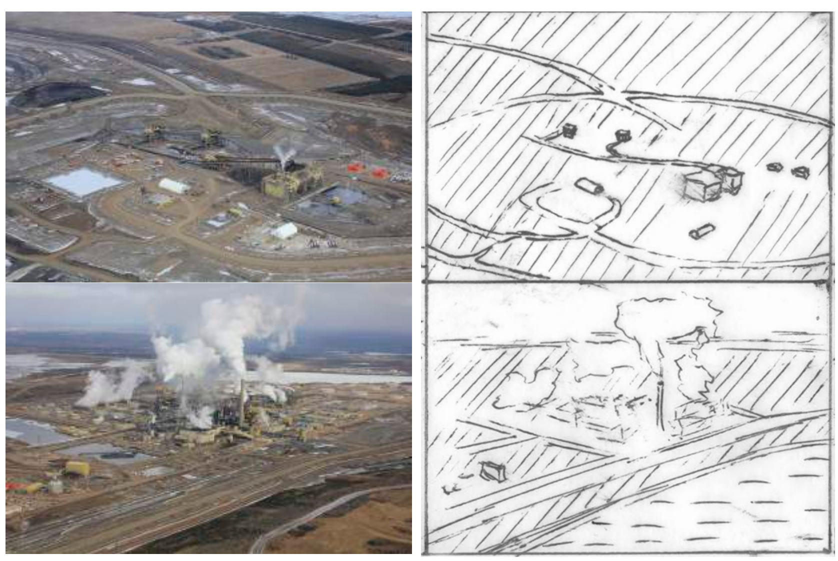


Figure 3-18: GIS map showing the marked sites / corridor components from the expanded field of industrial ecology and their spatial arrangement.

SCALE

metres



kilometres

SITE CONSTRUCTION NODES - OPERATIONS

Site construction is the expansion of landscape and architecture. These operations nodes are pieces of built architecture that are embedded in landscape-related processes such as energy storage. Operations support the function of organisms in shaping their habitat. Processing and storage of energy production provided by the organisms allow for continued habitat use. These nodes also supply energy fuel and administration to the organisms.

These nodes are clustered together at varying scales and spread throughout the industry to provide different forms of support. The GIS layer components of operation nodes are central processing facility, disturbed other industry, disturbed unclassified, operations, plant site, tank farm, and utilities.

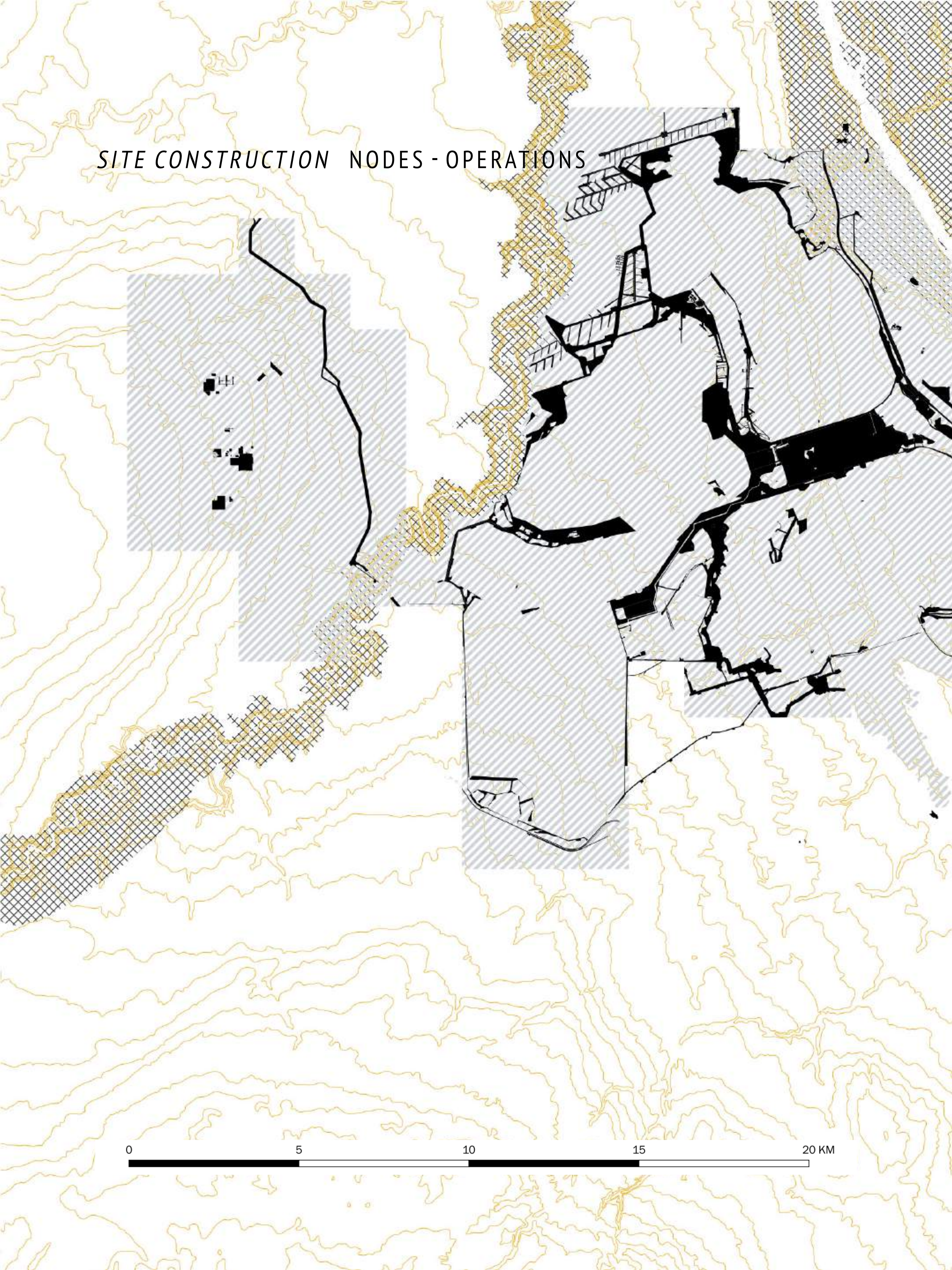
Elements of operation are usually built up as an addition on top of soils cleared of surrounding vegetation. This landscape component leaves behind thin soils following its function.

HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

[opposite page] Figure 3-19: Relational study of the operations node landscape component by scale, as seen from above within Tar Island.



SITE CONSTRUCTION NODES - OPERATIONS
0
5
10
15
20 KM

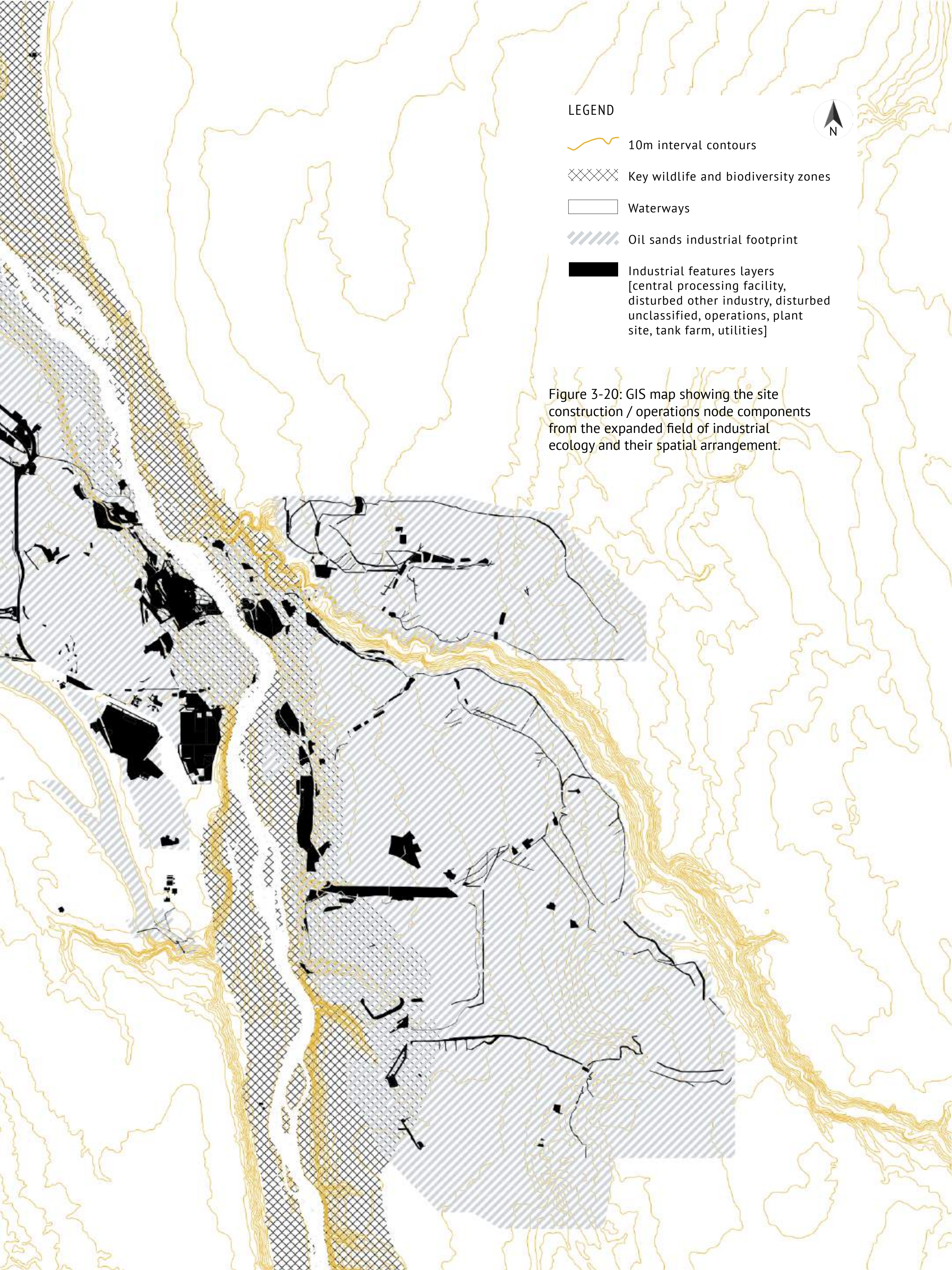
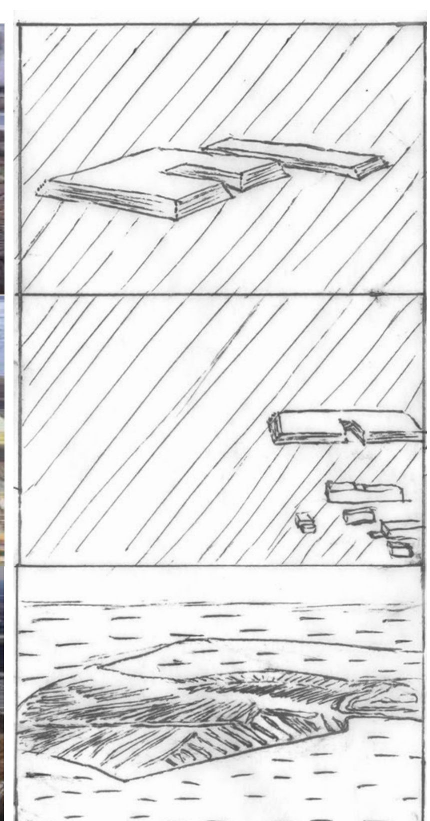


Figure 3-20: GIS map showing the site construction / operations node components from the expanded field of industrial ecology and their spatial arrangement.

SCALE

metres



kilometres

SCULPTURE NODES - WASTE

Sculpture is the expansion of ‘not landscape’ and ‘not architecture’. Neither landscape nor architecture is the notion of sculpture or earthworks. The waste nodes are a sculptural storage created from industry’s byproducts. Stored as remains from production, these areas differ in their function but do not serve further use to the organisms of industry leaving behind abstract industrial forms.

Sculpted into repeating patterns of rows or blocks, these nodes of waste provide either permanent or transforming pieces of land art as they are removed for purposes beyond this ecosystem. The GIS layers it includes are waste, windrow, and aerodrome. Sulphur by-products are stacked in pyramid-like forms and drawn from over time as it is sold to other markets. The windrows follow radiating rows for storage of reclamation material that is also drawn from to be used in reclamation projects. The aerodrome exists as a linear marking of a past airport runway.

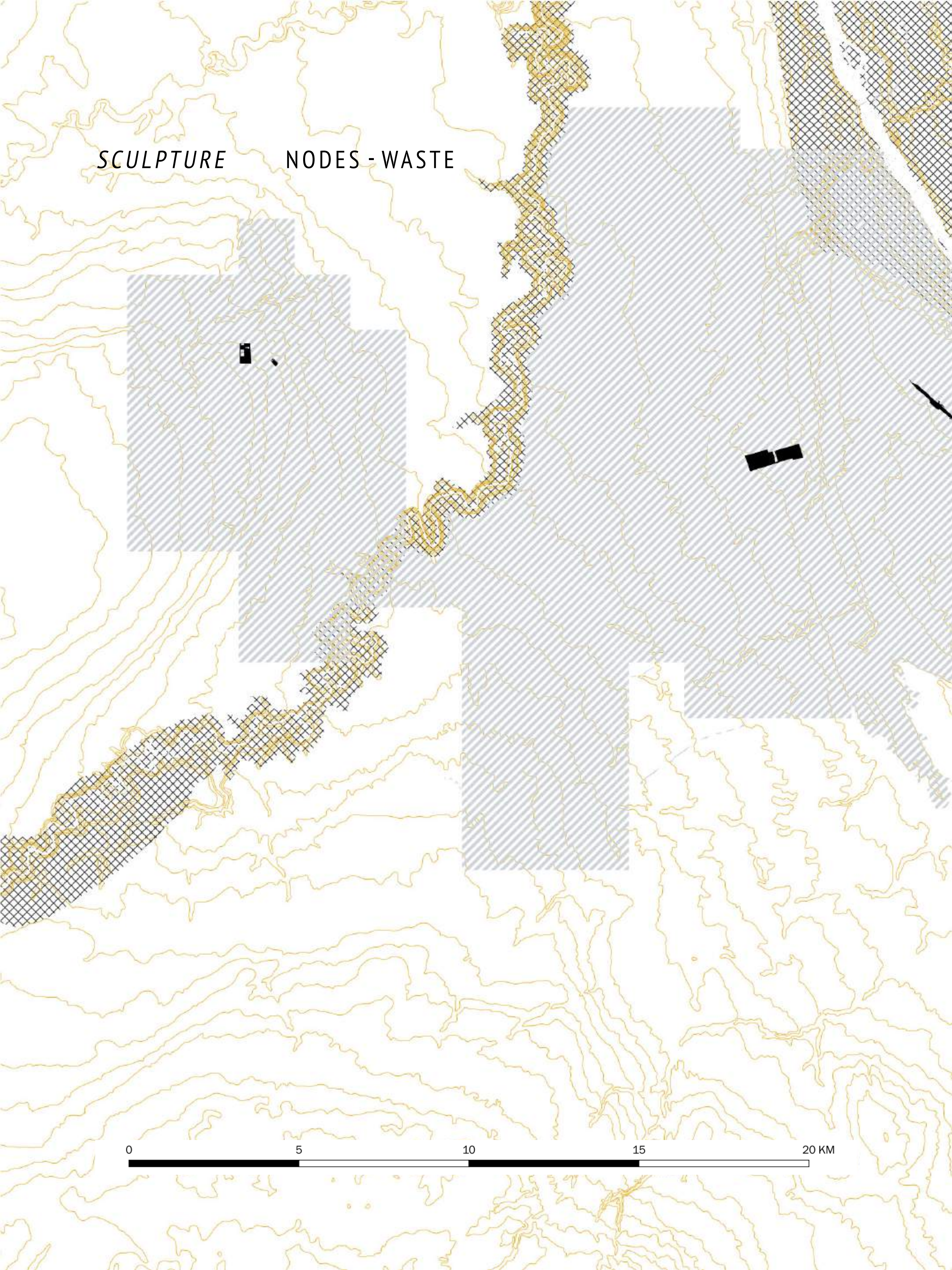
Both waste and aerodromes are considered toxic remains. While windrow is not, it is safer to catagorise waste nodes as toxic soils following its use as issues of toxicity have to be dealt with on site.

HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

[opposite page] Figure 3-21: Relational study of the waste node landscape component by scale, as seen from above within Tar Island.


SCULPTURE
NODES - WASTE
0
5
10
15
20 KM

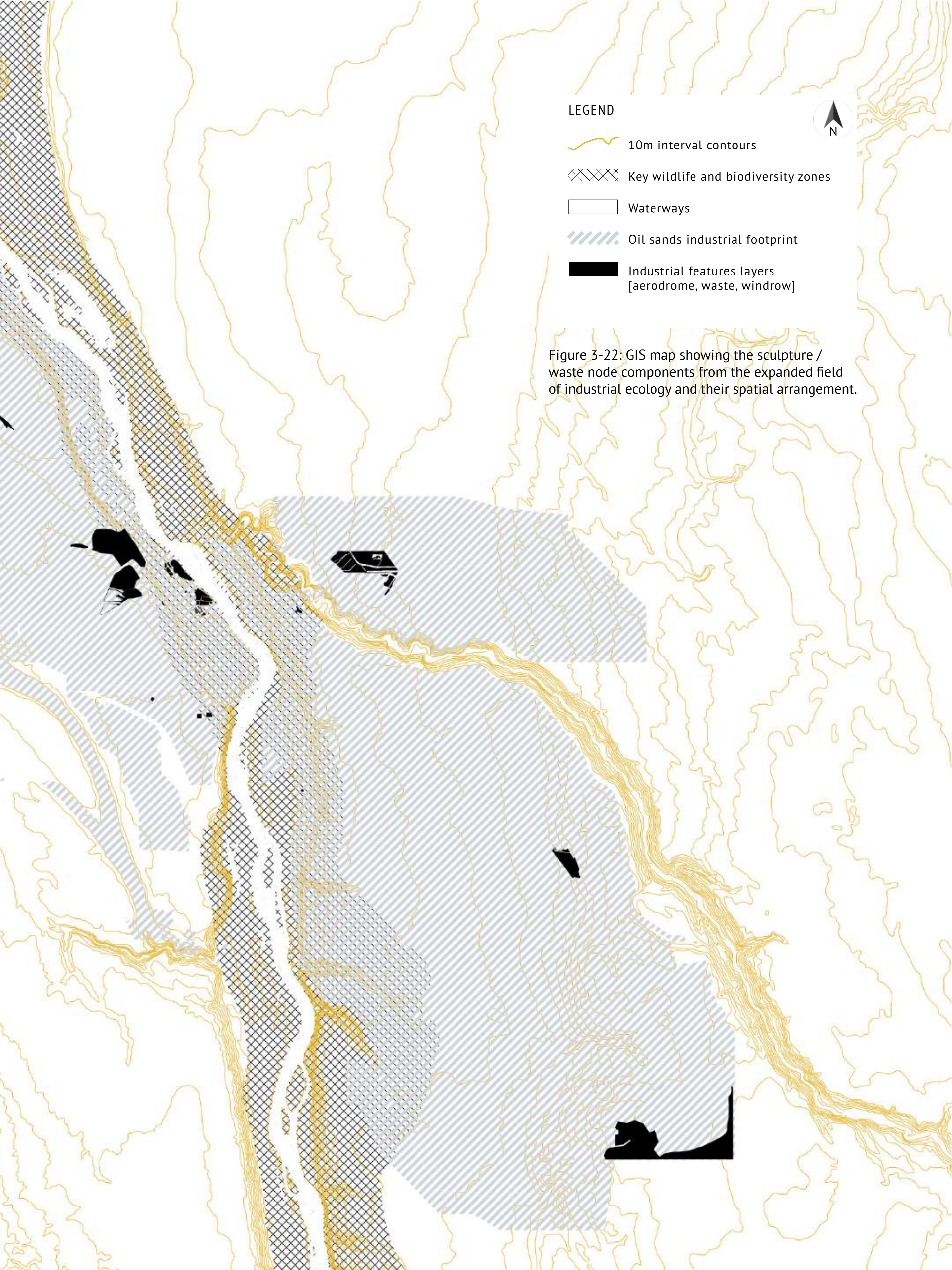
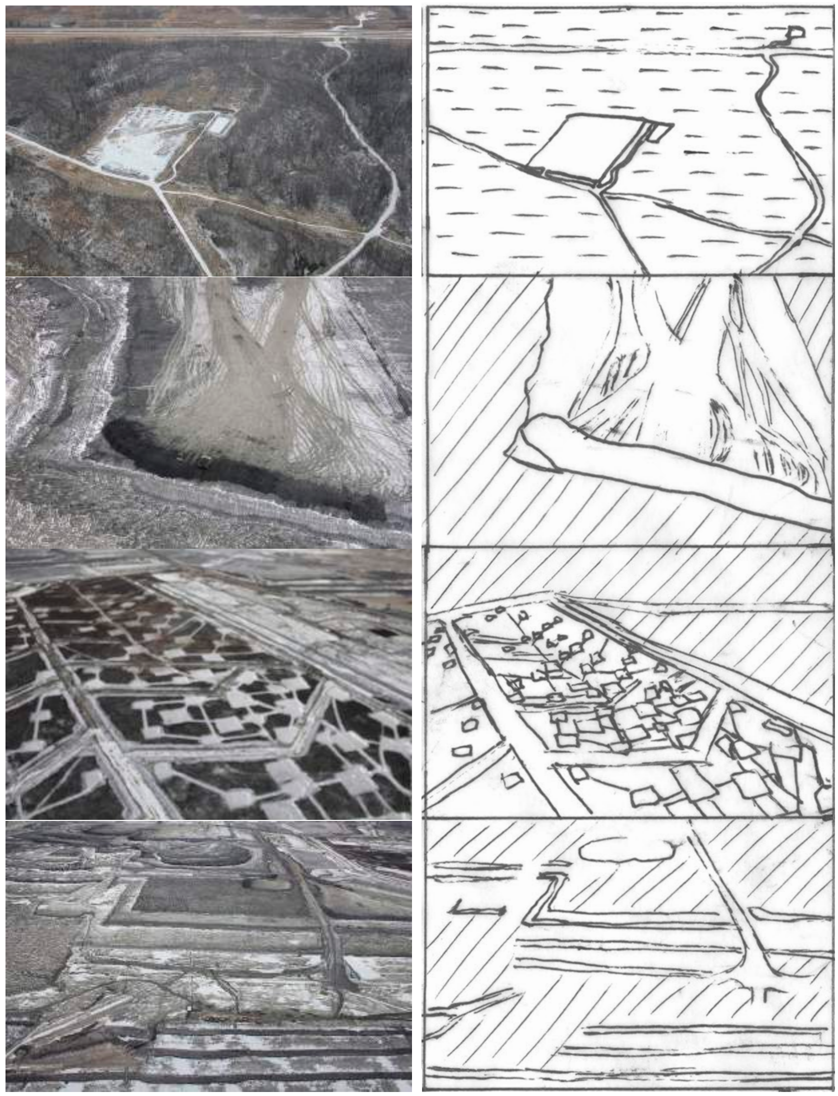


Figure 3-22: GIS map showing the sculpture / waste node components from the expanded field of industrial ecology and their spatial arrangement.

SCALE

metres



kilometres

HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

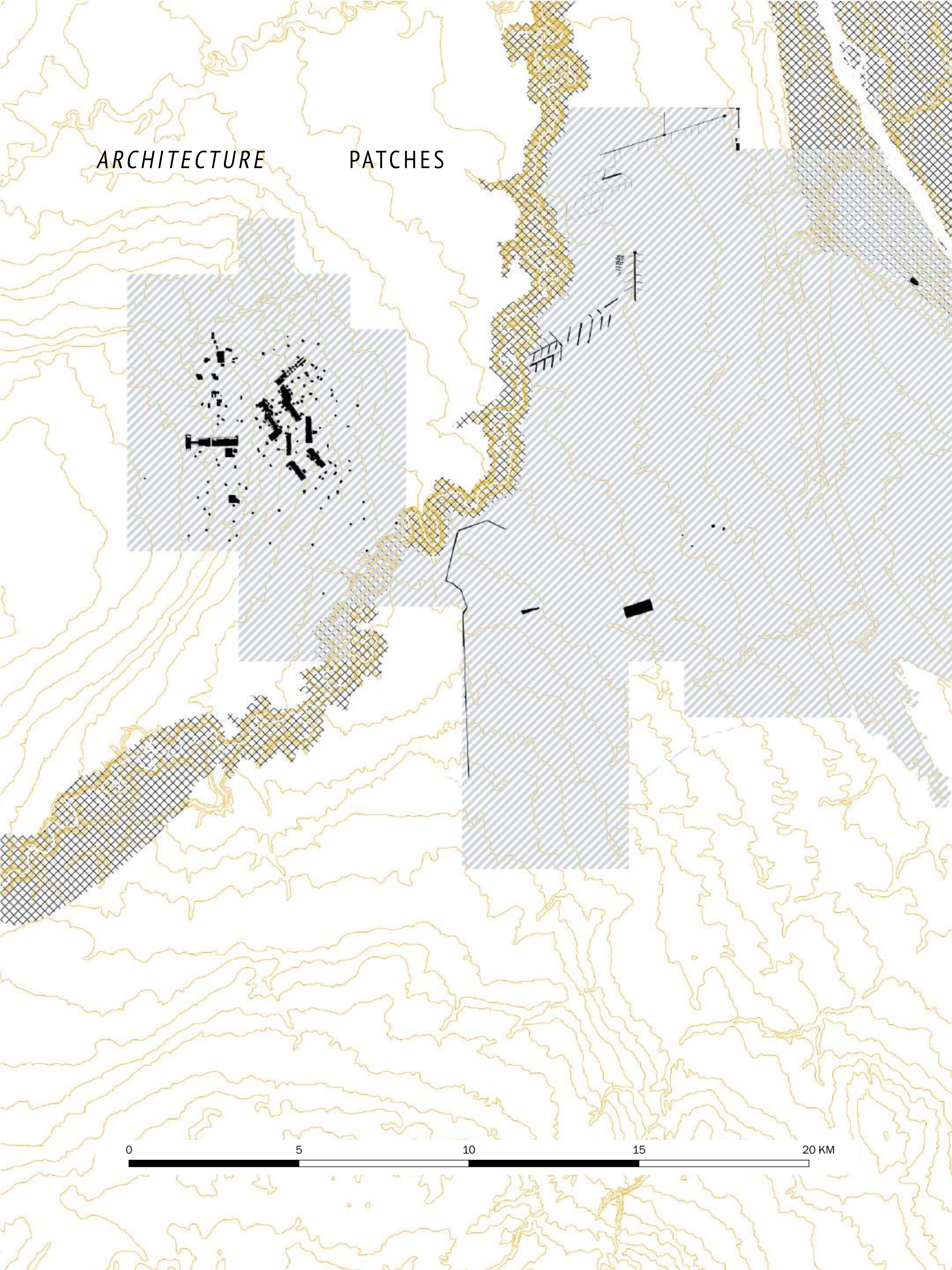
Remnant related

ARCHITECTURE PATCHES

Architecture are built areas in Krauss' expanded field. Patches are small altered areas that promote production by organisms in this environment. Clearing for access points, storage of materials, or areas for exploration and processing are included in this landscape component. These features support the housing and work of the organisms.

Geometric shapes and lines are followed for either removal or piling of the soils and other materials built up on top of the ground. The GIS data layers are camp housing, drainage, and well sites. Vegetation in these areas has been cleared for proper function of the space. The remaining soils of this landscape component are considered thin or minimal.

[opposite page] Figure 3-23: Relational study of the patch landscape component by scale, as seen from above within Tar Island.


ARCHITECTURE
PATCHES
0
5
10
15
20 KM

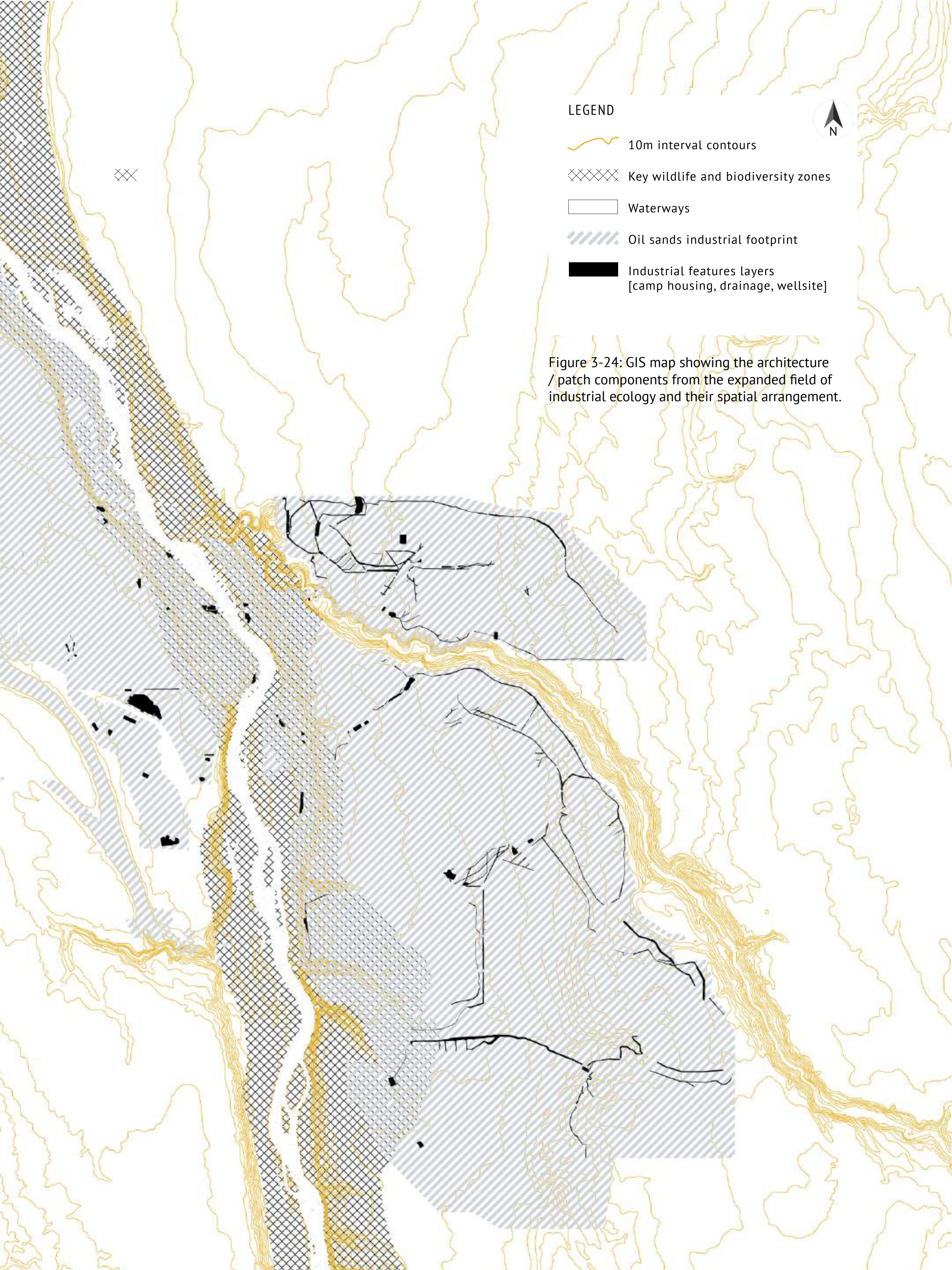
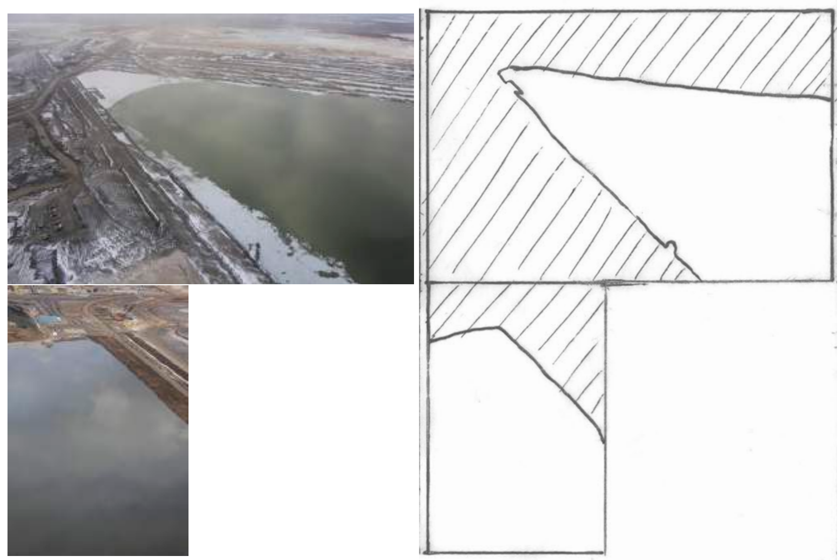


Figure 3-24: GIS map showing the architecture / patch components from the expanded field of industrial ecology and their spatial arrangement.

SCALE

metres



kilometres

NOT ARCHITECTURE VOIDS

Not architecture refers to a mirror or lack of architecture according to Krauss' expanded field. Voids are considered unproductive byproducts of this ecosystem. Much like waste nodes, these remains are stored on site. However, they can not be stored for re-use or left as sculpture due to their major impacts to both organisms and remnant spaces if left as is. Their storage is often found in massive pits that serve as ponds that require energy regardless of their unproductive nature.

Voids are somewhat stagnant, large negative spaces where waste is collected and left to dry over long periods of time. These vast, flat spaces have a hard edge and are often juxtaposed to varying habitat function surrounding the ponds. Inflows and outflows are provided by standpipes that fill or empty these spaces. Occasionally, water vessels are seen floating on top to aid in their management. The GIS data layer for voids are wet tailings.

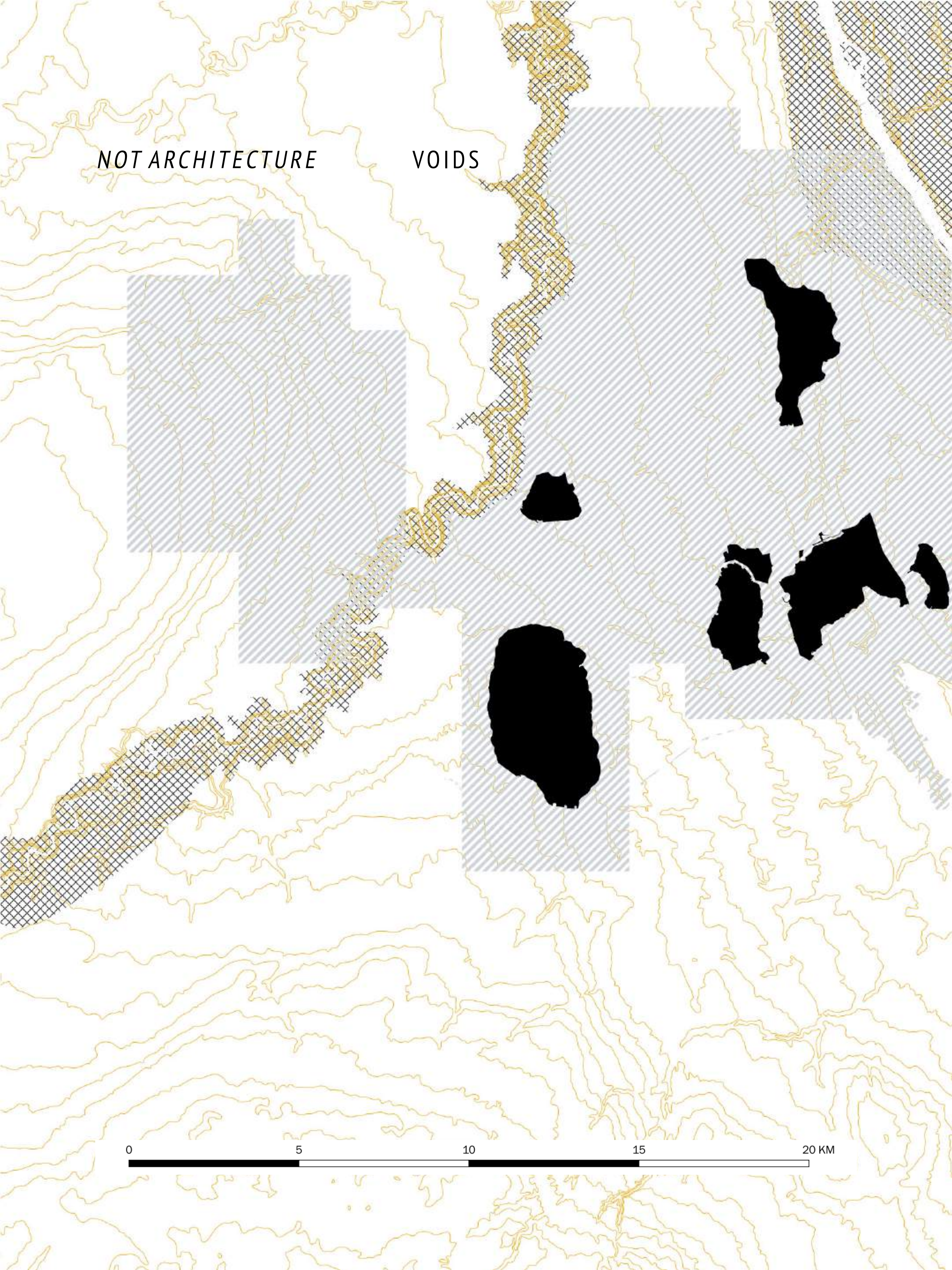
Due to their highly toxic nature and slow timeline, voids often remain unchanged over long periods of time. There is no soil found in these voids.

HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

[opposite page] Figure 3-25: Relational study of the void landscape component by scale, as seen from above within Tar Island.


0
5
10
15
20 KM

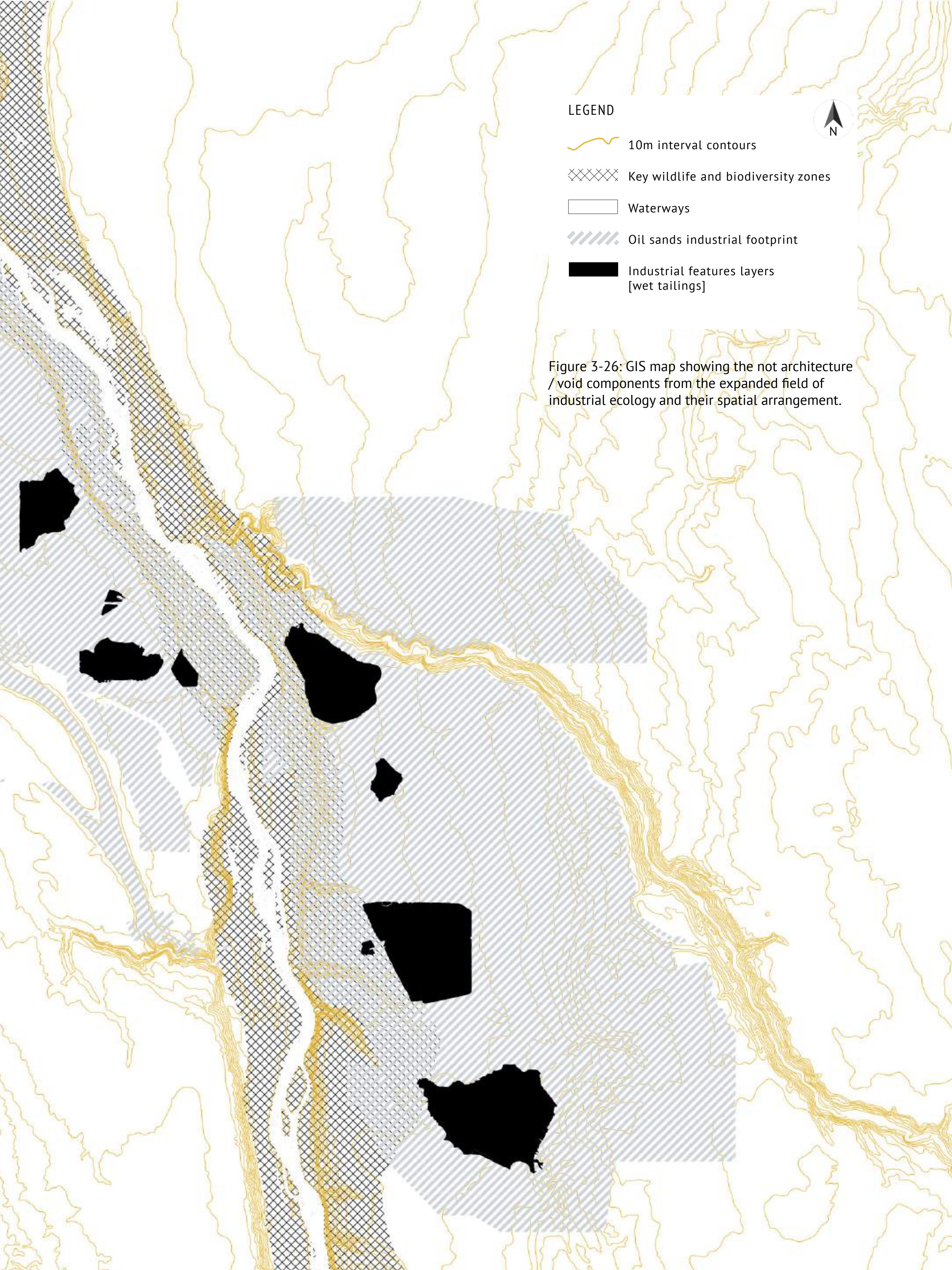
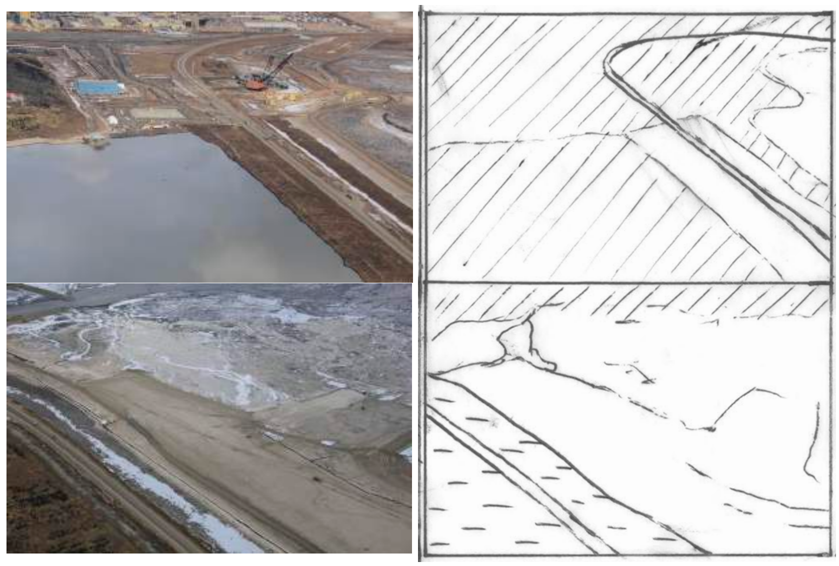


Figure 3-26: GIS map showing the not architecture / void components from the expanded field of industrial ecology and their spatial arrangement.

SCALE

metres



kilometres

AXIOMATIC STRUCTURE EDGES

Axiomatic structures are the expansion of architecture and not architecture. The edges exist between the built-up patches that support functions and the negative voids of the industrial ecosystem. Edges border voids and act as a delineation of differing functions. They serve as a transition between high quantities of movement in the habitat and almost no movement in voids due to their toxic nature.

Comprised of curvilinear paths or geometric blocks, the edges appear as the voids are settled (dried). The GIS layer data for this component consist of dry tailings and dedicated drying areas.

The surfaces of edges are navigable as they are considered a solid surface following the drying of wet tailings. Although edges are not a soil type and common depths of dry tailings are unclear, this layer of remaining tailings is considered toxic following its use.

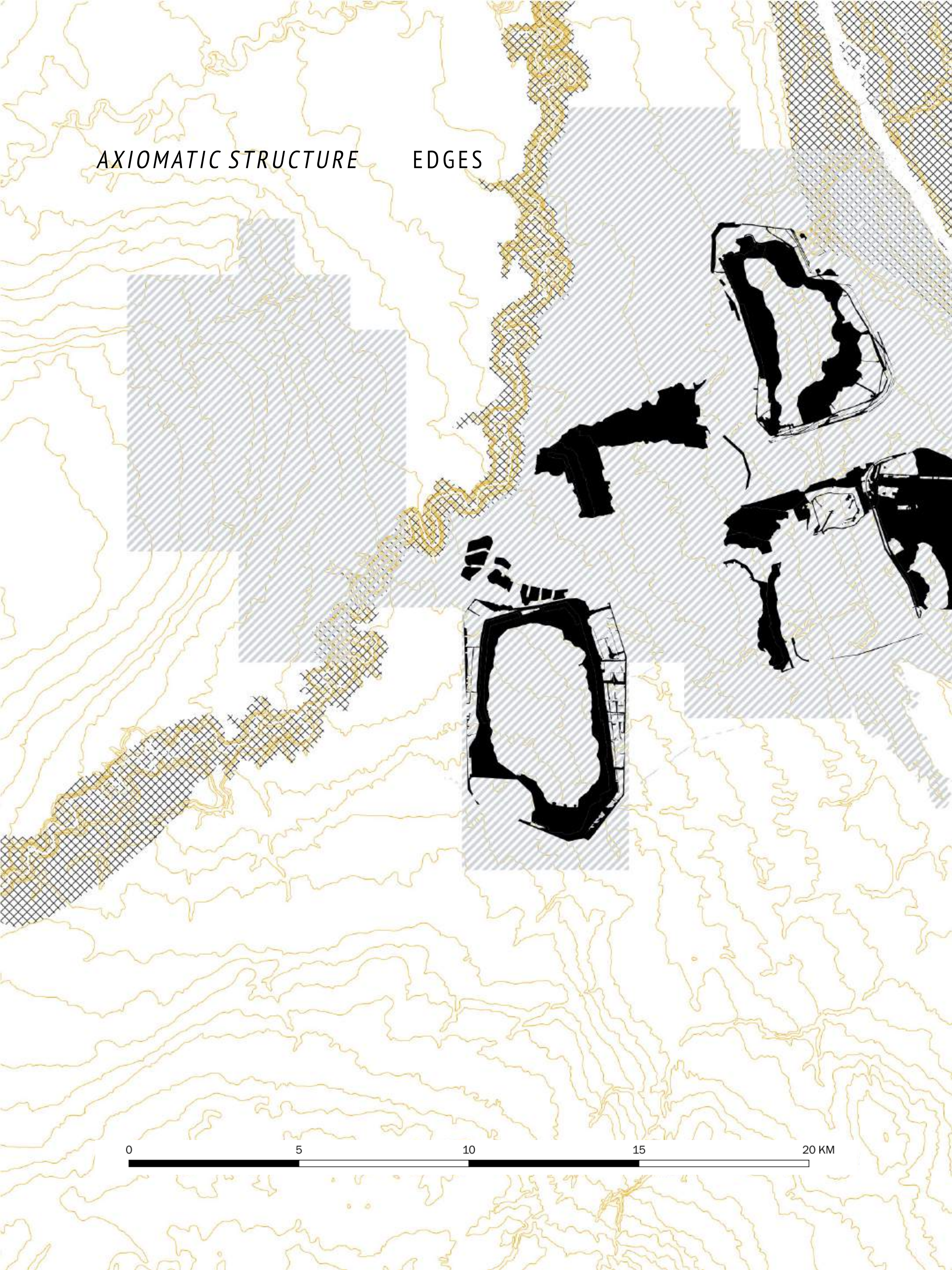
HATCH DESIGNATIONS
for the areas surrounding the industrial ecology component

Habitat related

Remnant related

[opposite page] Figure 3-27: Relational study of the edge landscape component by scale, as seen from above within Tar Island.

AXIOMATIC STRUCTURE EDGES



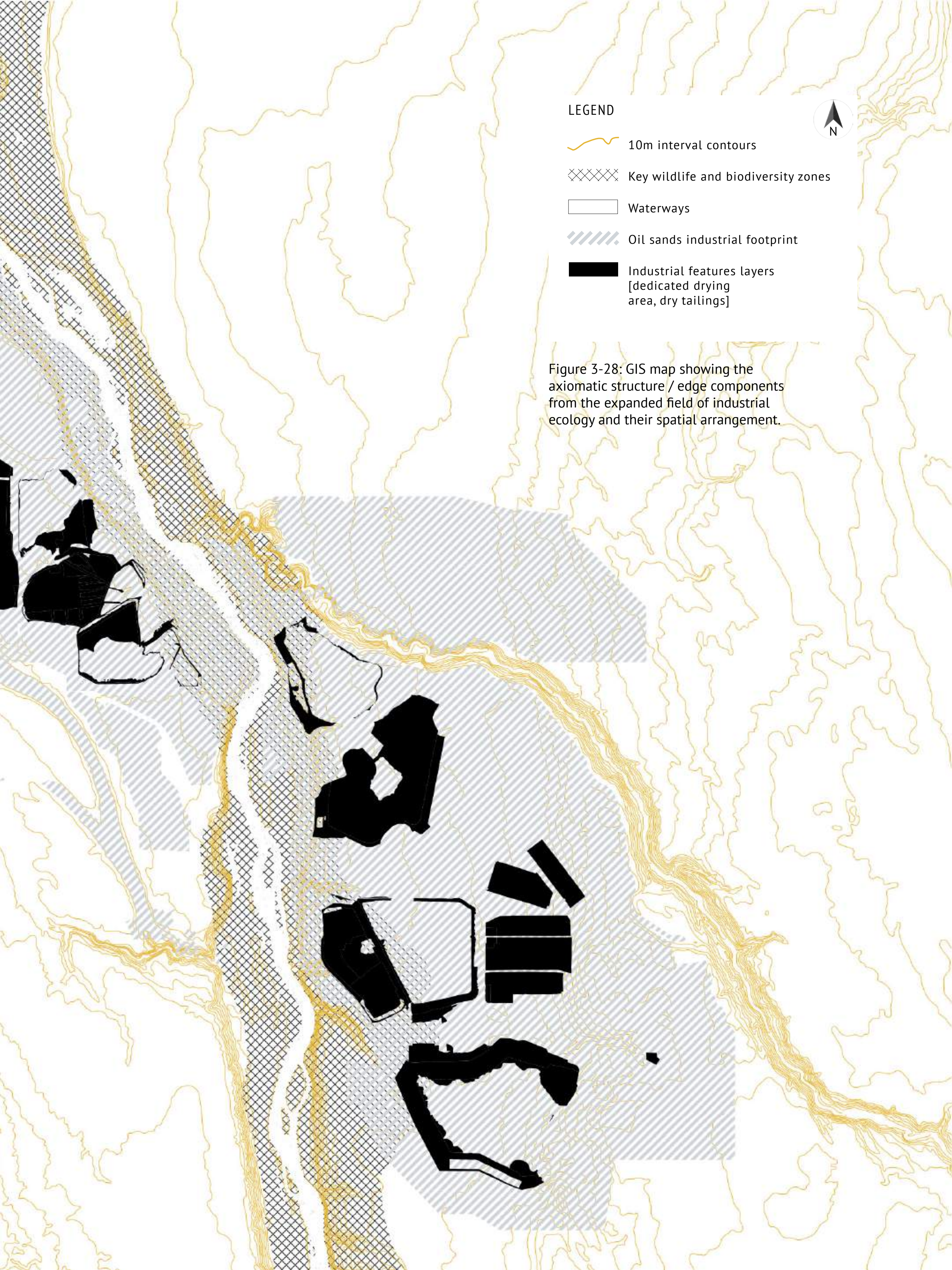


Figure 3-28: GIS map showing the axiomatic structure / edge components from the expanded field of industrial ecology and their spatial arrangement.

SOIL GROUPINGS
EXISTING CONDITIONS AND CONCLUSIONS

The landscape components of Tar Island's industrial ecology provide an overview of their function and spatial composition. Their relationships are organised according to Rosalind E. Krauss' sculpture in the expanded field and further demonstrated in the expanded field of industrial ecology. A breakdown of each landscape component and their functions provide an understanding of how various parts of this environment are used and support the lives of the organisms inhabiting this area. The spatial mapping representation of each landscape component displays the physical composition and organisation of features within this industrial site.

Expanding the expanded field further into soil groupings that remain in each landscape component provides an opportunity for prospective implementation strategies. Following production, the remaining conditions left on site can be grouped into three conditions: habitat leaves behind no soil; waste nodes, voids, and edges leave toxic soils; and corridors, remnants, operation nodes and patches leave thin soils. These soil groupings provide a basis for implementation strategies for encouraging growth where possible and the return of ecological function. A spatial representation of the compiled toxic, thin, and absent soils is identified on a map of Tar Island [see pages 144-145].

An understanding of the existing vegetation, underlying geology, ecoclimatic zones, and industrial ecology components and their functions round out an analysis of the Tar Island site to understand how it functions. These characteristics inform processes of this area in many capacities. The boreal forest and wetland vegetation cover gives context for the surrounding area of Tar Island and provides an idea of how this site would have been characterised prior to the start of the extraction operations. The bedrock geology is important in order to comprehend the layers being removed and exposed in the mining process. Calcareous types of limestone comprise most of the underlying layer to the oil-permeated McMurray Formation that is targeted for extraction (RCA, 1970). The projected shift of grassland ecozones is anticipated in the Athabasca Oil Sands region (Rizzo and Wiken, 1992, p.50). Grasslands are a resilient landscape that is likely to thrive here with changing climatic conditions. The industrial ecology works as a frame for understanding the oil extraction industry's complex and interrelated processes. It provides insights as to which soil conditions will remain on site to propose appropriate scenarios where ecological growth can be encouraged and implemented. The Athabasca Oil Sands currently operate as an ecologic system but will transition to ecologically functional uses over time. Looking at the conditions of this area presents an opportunity to transform this ecologic system of industry into an ecologically productive system in its reclamation.

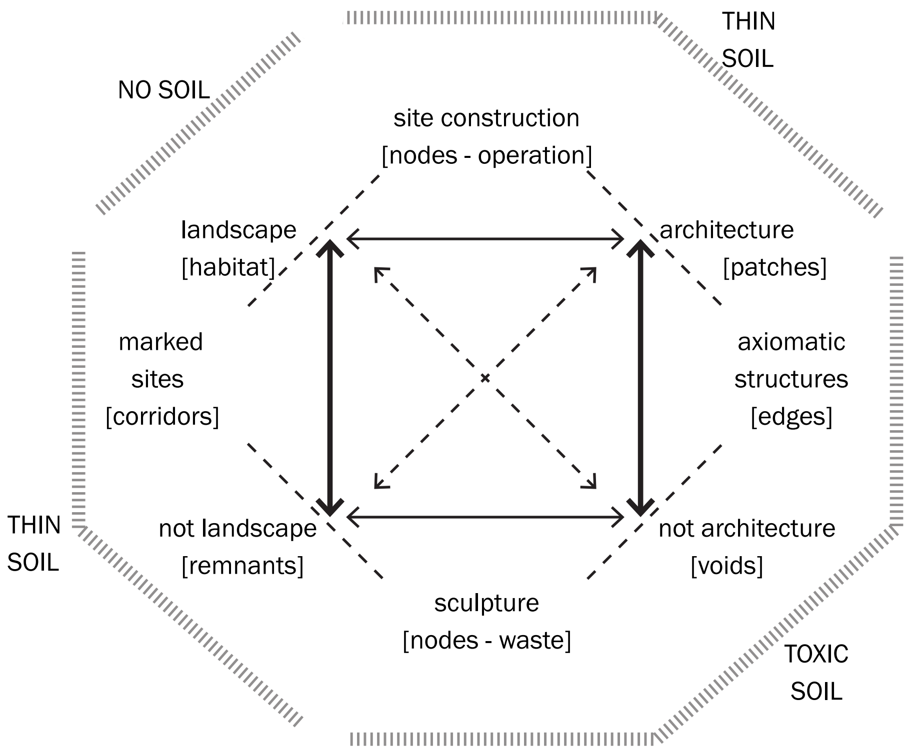
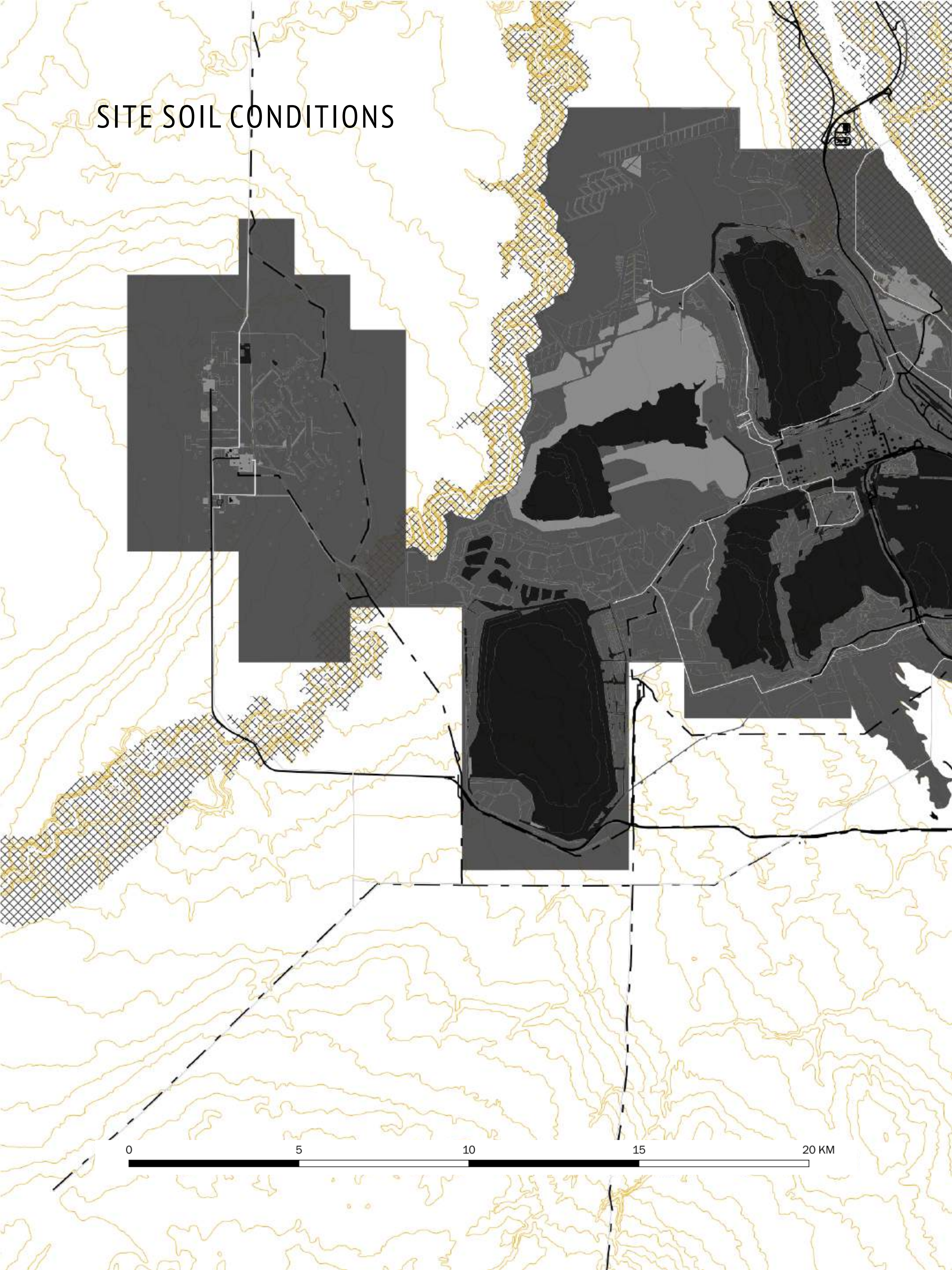


Figure 3-29: The expanded field of industrial ecology with the associated soil groupings (Adapted from Krauss, 1985).

SITE SOIL CONDITIONS



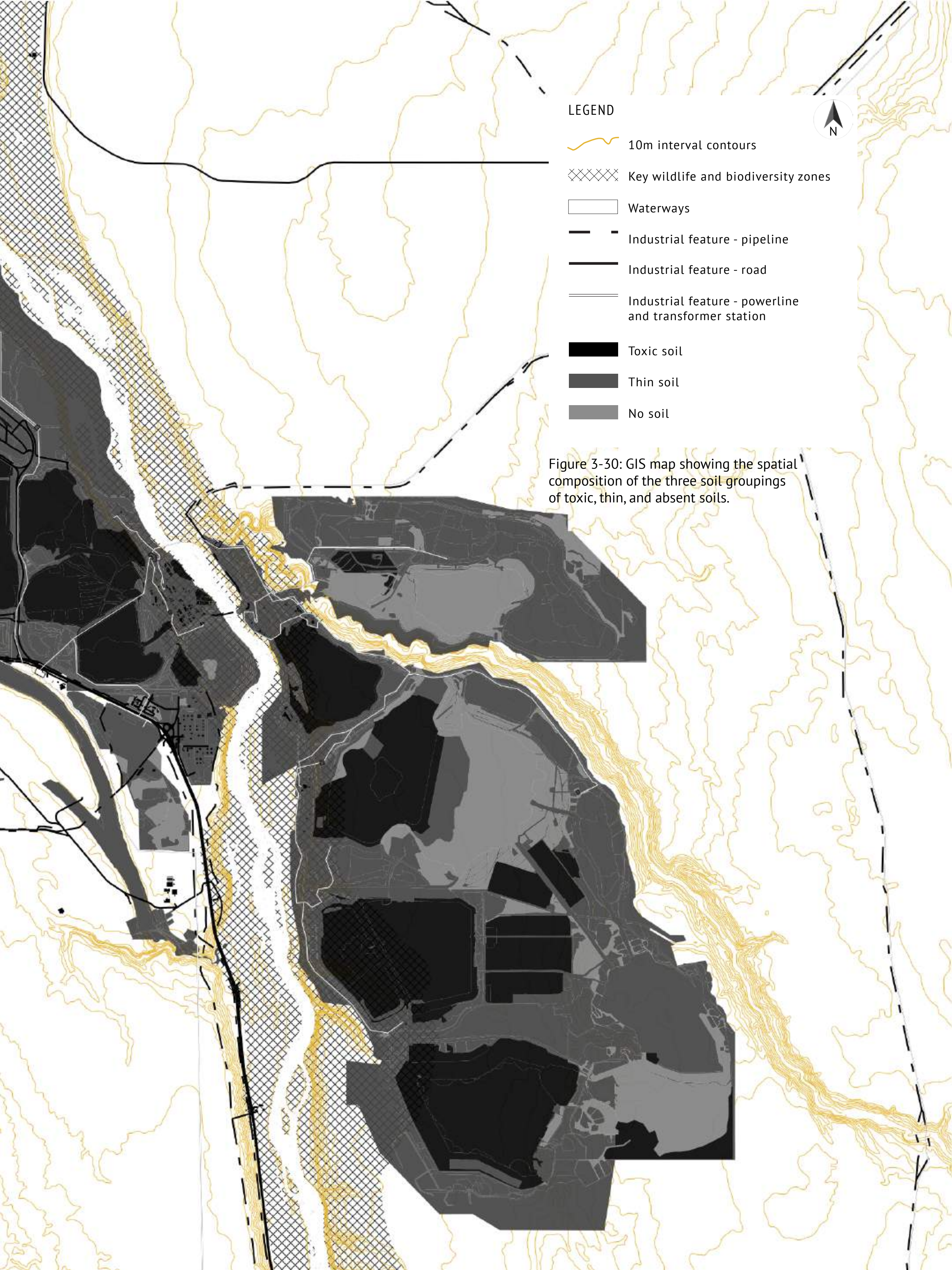


Figure 3-30: GIS map showing the spatial composition of the three soil groupings of toxic, thin, and absent soils.

CHAPTER FOUR

SITE DESIGN

FUTURE ECOLOGIES

SOIL SCENARIO FRAMEWORK

Defining the characteristics and features of the Tar Island site in the Athabasca Oil Sands presents opportunities for reclamation strategies. This area currently operates as a system of industrial ecology. How can this system transition to an ecologically productive environment? An opportunity was identified in the case studies of chapter two for the addition of an overall reclamation scheme that is suited to the changing climate and one that can adapt over time. Reclamation at the scale of the Tar Island site can be completed through a set of strategies for ecological implementation. If the void of avulsion is the open wounded landscape, then the scars are the healed reminder of its past. A successful ecological future and an awareness of its past for this landscape can be proposed based on the opportunities this industry presents following its destructive extraction processes.

Scenarios for encouraging growth and a return of ecological function can be designated by working with the soil type groupings. These scenarios are represented by another expansion of the expanded field of industrial ecology. The unique current functions of each landscape component provides individual conditions that suggest either an encouragement of vegetative growth or that it remain as is following production. The goals for reclamation for these soil groupings are: detoxification of toxic soils; building up of soils and vegetation in areas of absent soils; and an assisted migration to future grassland ecozones for environmental viability in thin soils. Based on the site conditions, the strategies to achieve these goals are proposed through: phyto-remediation techniques for toxic soils; alvar species community encouragement for absent soils; and a phased planting of cool season and warm season grasses for thin soils. These ecological strategies are represented by a final expansion of the expanded field of industrial ecology [see page 151].

For sites with toxic soil, three different landscape components are included. These components are edges, voids, and waste nodes. Edges are used to encourage growth through phyto-remediation technologies. Both voids and waste nodes are left to remain as is. As wet tailings are catagorised under voids, they must be left to dry for up to 30 years before being grouped with edges as dried tailings. Waste nodes include windrows and the sulphur surplus storage. These features are to be left as is for re-use - perhaps viewed as living sculptures. The windrows can be used in spreading reclamation material where it is needed. The sulphur is sold to other markets and will deplete over time.

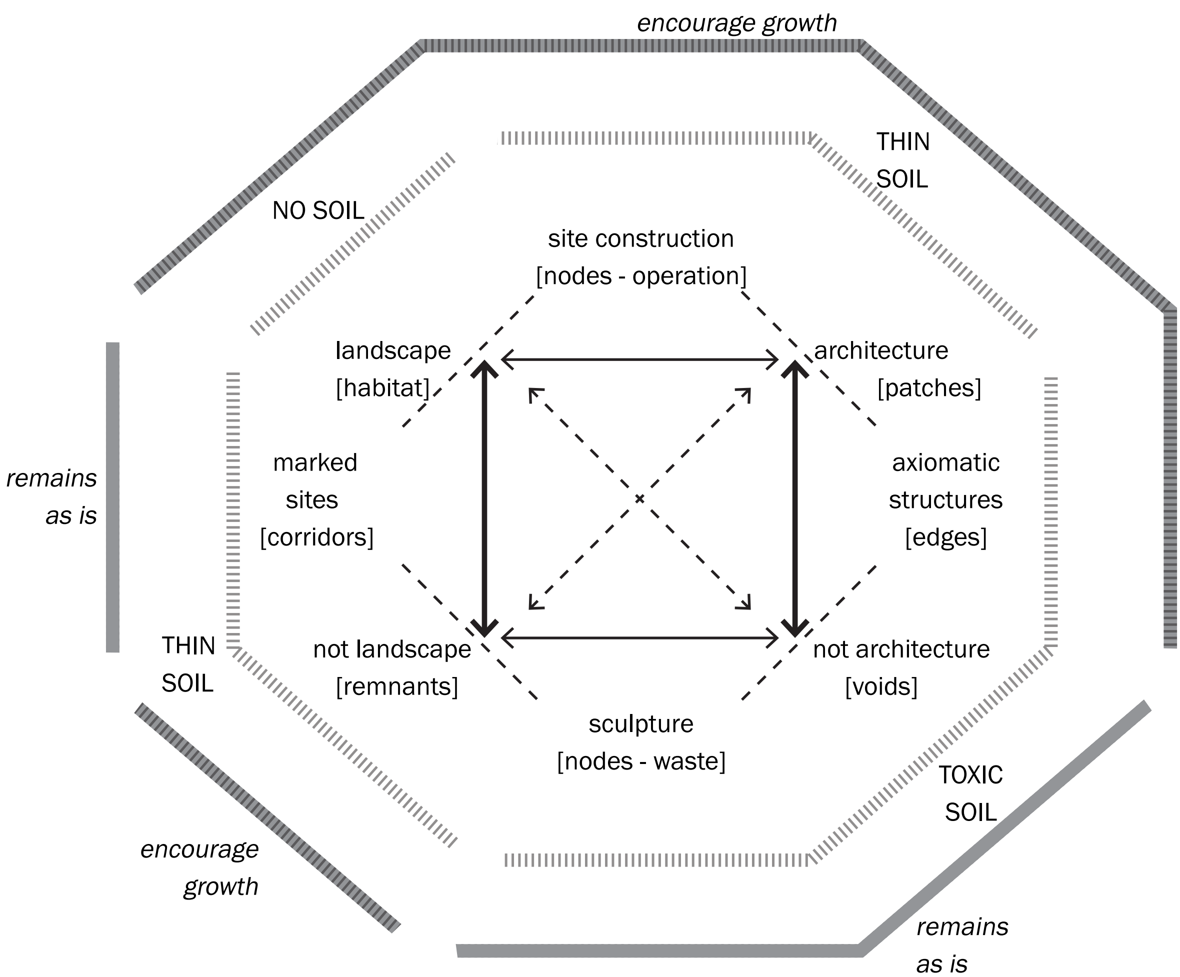


Figure 4-1: The expanded field of industrial ecology with the associated soil groupings and implementation scenarios (Adapted from Krauss, 1985).

Sites with no soil are exclusive to the habitat landscape component which include mine and borrow pits. Where layers of bedrock are stripped away, the exposed limestone of the Waterways Formation provides an opportunity for alvar communities to thrive in these otherwise barren landscapes.

Remaining thin soils include operation nodes, patches, remnants, and corridors. For operation nodes, patches, and remnants, a transition to the grassland ecosystem is encouraged. Filling in vegetative gaps provides the opportunity to introduce a heavier reliance on grassland species within the surrounding boreal forest. Corridors are left as is as access routes throughout the site. Highway 63 provides the main route through and beyond the site to communities to its north and south edges. The access roads and haul roads will remain for reclamation implementation and monitoring access, and then left for natural succession as their use diminishes over time.

The purpose of these reclamation strategies is to return ecological function to the Tar Island site. Negative impacts to the land are mitigated on site through these strategies so that toxins are dealt with on site and material is re-used within this landscape. Although planting is completed at a small scale, the overall scale of the Oil Sands industry should remain relevant.

A shift of language and ecological system are required in the transition from industrial production to reclamation. The industrial ecology landscape components remain relevant in shaping the strategies and rules for where they are implemented. This habitat has been shaped by industrial organisms for over 50 years and they will continue to shape this land through its ecological recovery. The size and capacity of the organisms will guide the transition to future uses. Over time the habitat will shift to grassland ecozones while alvar communities and phyto-remediated areas will become remnants of this landscape. Reclamation will be shaped by the organisms of this area. New organisms at a smaller ecological scale will move in following the departure of the former organisms.

A schematic implementation plan [see pages 154-155] is proposed with these three strategies that fit at a scale consistent with this site. Individual site construction would be carefully planned and based on these strategies and the goals they set for reclamation. The industrial past of Tar Island is not forgotten but remains visible among these future ecologies as the healed scars of production.

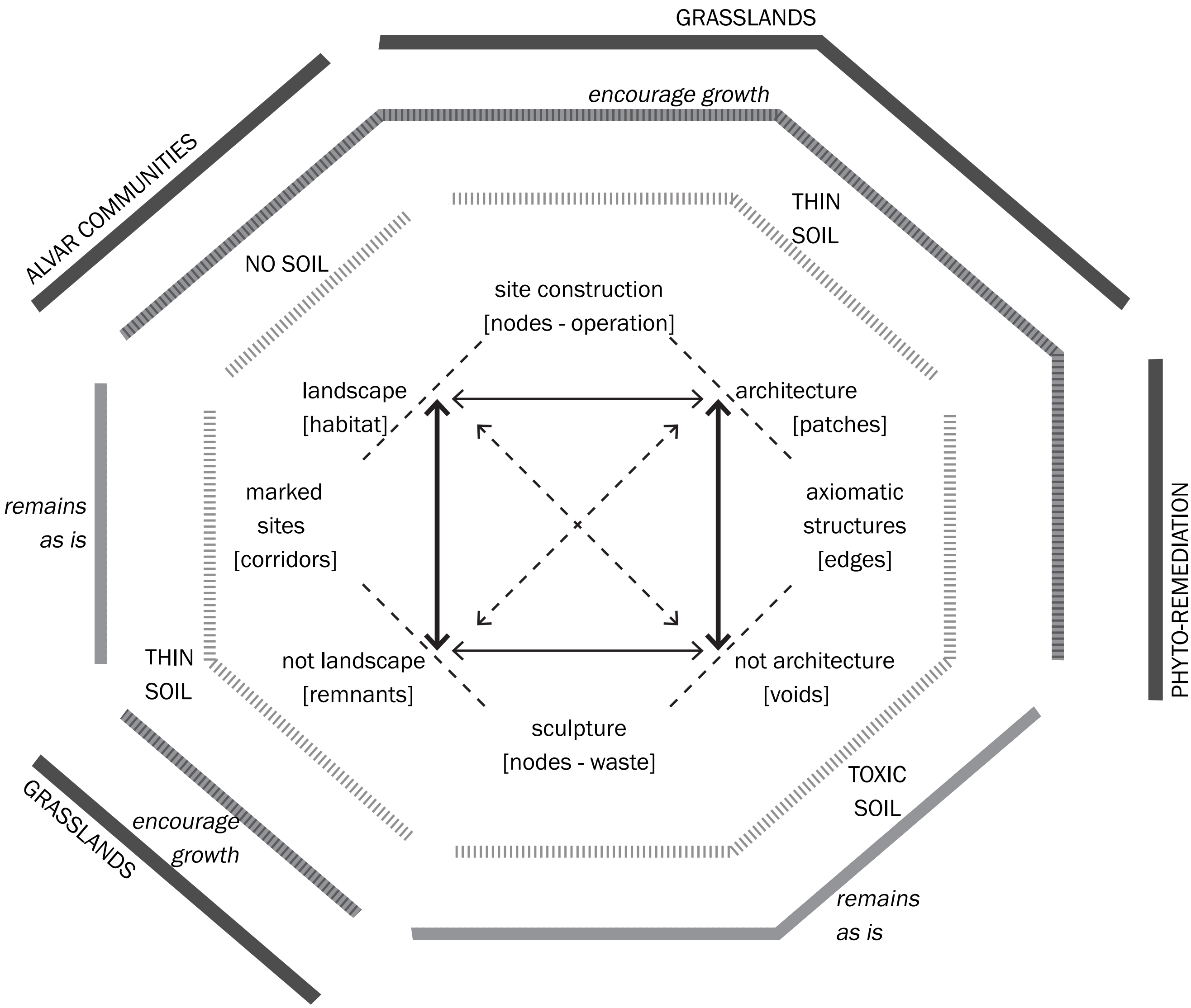


Figure 4-2: The expanded field of industrial ecology with the associated soil groupings, implementation scenarios and ecological strategies (Adapted from Krauss, 1985).

IMPLEMENTING ECOLOGIES

SOIL SCENARIO STRATEGIES

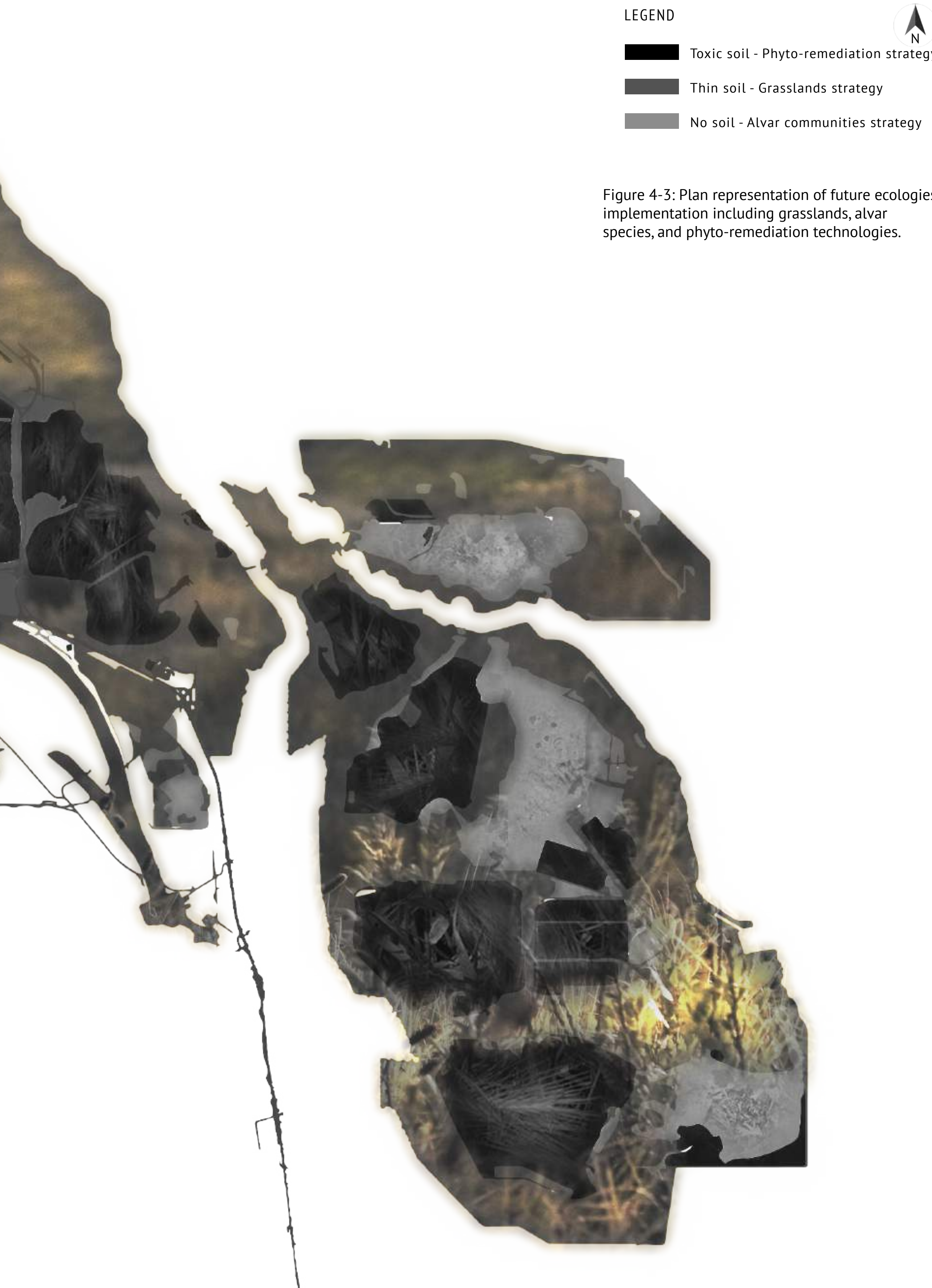
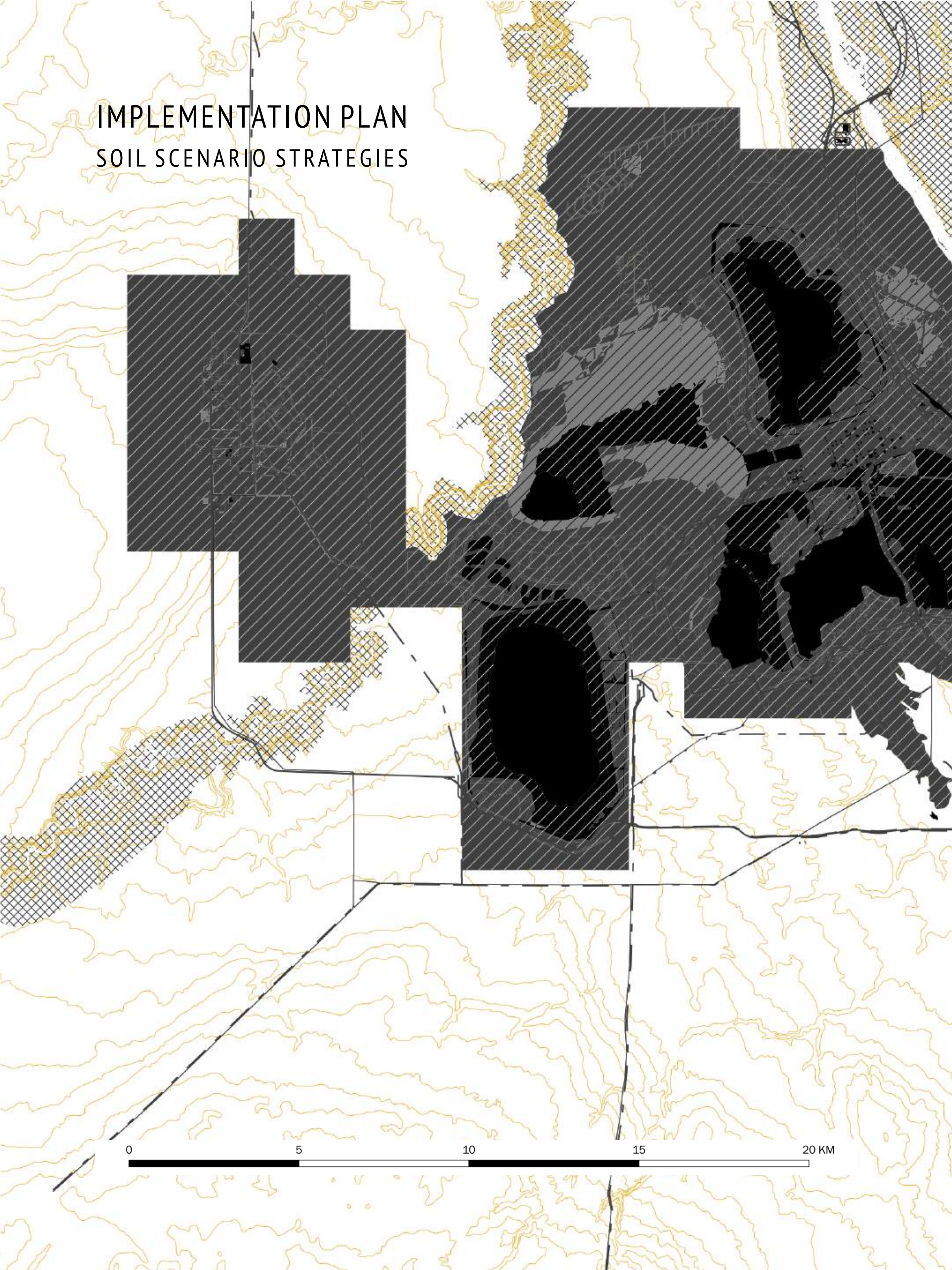


Figure 4-3: Plan representation of future ecologies implementation including grasslands, alvar species, and phyto-remediation technologies.

IMPLEMENTATION PLAN
SOIL SCENARIO STRATEGIES



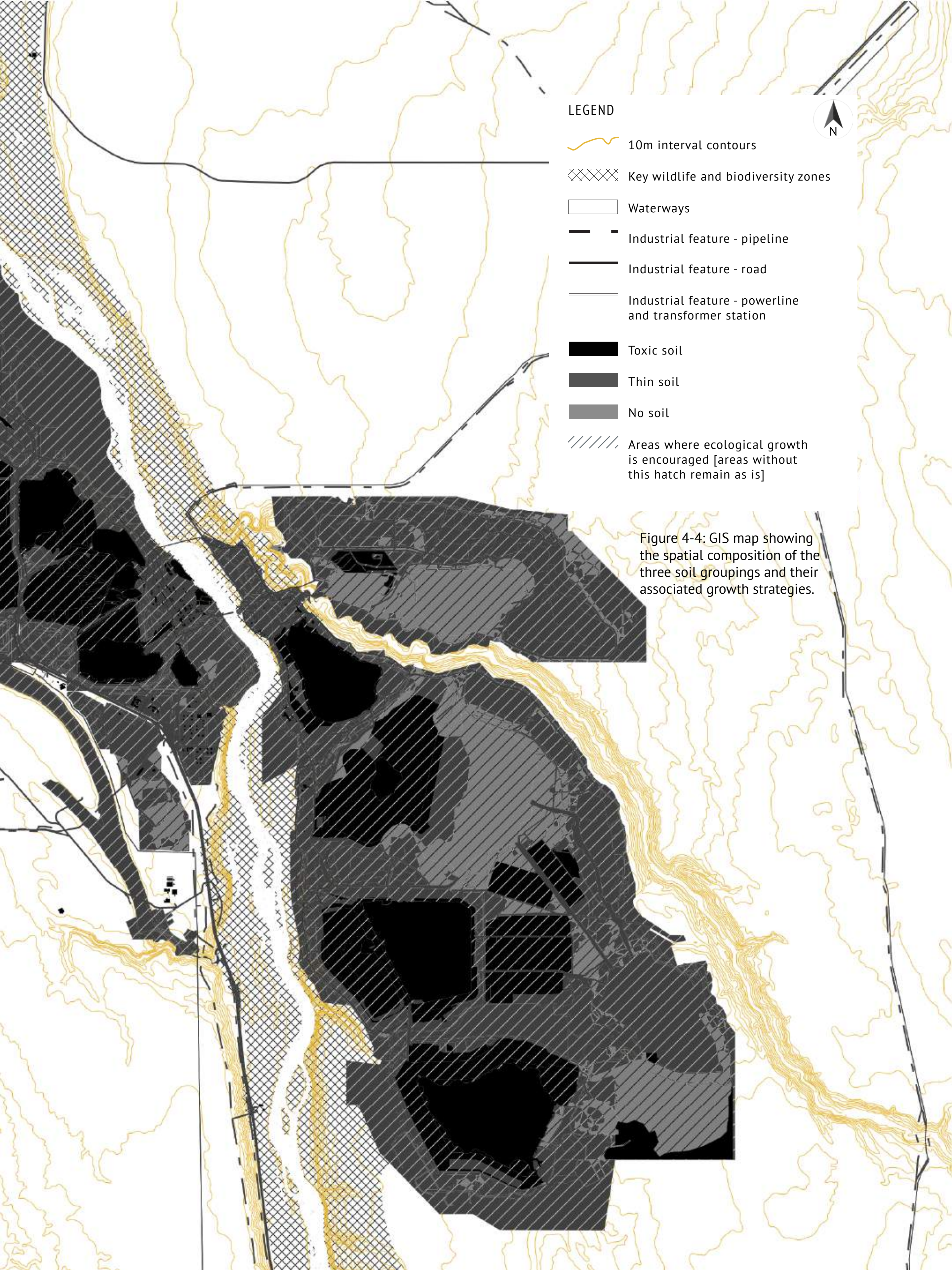


Figure 4-4: GIS map showing the spatial composition of the three soil groupings and their associated growth strategies.

GRASSLANDS MIGRATION INITIATIVE

WESTERN WILDWAY NETWORK STRATEGY

The Western Wildway Network is an international initiative that promotes conservation for core habitats and migration corridors through the three principles of re-connecting, restoring, and re-wilding (Wildlands Network, 2020). The project began in 1991 by scientists Michael Soulé, Reed Noss, and Jim Estes. Their conservation framework is based in science, fieldwork, and policies with staff in USA and Mexico (Wildlands Network, 2020). The project depends on partnerships with local institutions that are experts in their area of habitat conservation. Research and conservation projects contribute to a collection of Wildlands Network Designs (projects of implementation along the Wildway), which they hope will serve as a framework for further conservation efforts (Wildlands Network, 2020). With the proposed ecological strategies and an assisted migration of grasslands northward, an extension of this network can be added across Canadian Oil Sands sites called the Grasslands Migration Initiative. This extension of the Wildway works within the re-wilding principle of the network through the implementation of the three ecological strategies for this site. This extension can provide a living lab for the assisted migration of grasslands.

Figure 4-5: Map of the Western Wildway Network with an extension to include the Canadian Oil Sands area (Adapted from Menke, 2017 - used with permission).


ROUND RIVER CONSERVATION STUDIES
CANADIAN OIL SANDS GRASSLANDS MIGRATION INITIATIVE
YELLOWSTONE TO YUKON CONSERVATION INITIATIVE
CENTER FOR LARGE LANDSCAPE CONSERVATION
CRAIGHEAD INSTITUTE
WESTERN WILDLIFE CONSERVANCY
ADVENTURERS & SCIENTISTS FOR CONSERVATION
SAVE OUR CANYONS
YELLOWSTONE TO UINTAS
HEART OF THE WEST COALITION
WILD UTAH PROJECT
WESTERN ENVIRON. LAW CENTER
WILDERNESS WORKSHOP
ROCKY MOUNTAIN WILD
COLORADO SAFE PASSAGES COALITION
GRAND CANYON WILDLANDS COUNCIL
NEW MEXICO WILDWAYS
SKY ISLAND ALLIANCE
SW ENVIRONMENTAL CENTER
DEFENDERS OF WILDLIFE SW OFFICE
WILDLANDS NETWORK
CUENCA LOS OJOS
NATURALIA
NORTHERN JAGUAR PROJECT
TUTUACA MOUNTAIN SCHOOL

PHYTO-REMEDIATION

TOXIC SOILS STRATEGY

Phyto-remediation is a proposed strategy to deal with toxins on site. This strategy aids in the remediation of soils through specific types of planting. Effluent placed in a tailings pond is comprised of natural materials, solvents, and residual bitumen (Helbig, 2014, p293). These natural materials include water, fine clays, silts, salts, and soluble organic compounds. Toxins that are found in an Oil Sands tailings pond include bitumen, napthenic acids, cyanide, phenols and metals such as cadmium, chromium, copper, lead, zinc, and aresenic [metalloid] (Helbig, 2014, p.293). As the water from the tailings separates and evaporates, the toxins remain in the dry tailings.

Kate Kennen and Niall Kirkwood's book, *Phyto* (2015), provides a valuable resource in classifications of toxins and methods of bio-remediation. The main toxins found on site can be grouped into Kennen and Kirkwood's contaminant types. Petroleum hydrocarbons are considered organic pollutants that often respond quickly and successfully to phyto-remediation technologies (Kennen and Kirkwood, 2015, p.32). This grouping includes residual bitumen and napthenic acids. Napthenic acids are 'polar organic carboxylic acids' considered organic compounds that are increased in quantity by water recycling efforts in tailing ponds (Brown and Ulrich, 2015). Phyto-remediation of petroleum hydrocarbons is achieved with petroleum degradator species.

Two groupings of metals listed as containment types in *Phyto* are considered inorganic pollutants. The first metal grouping is considered to have a successful response to phyto-remediation methods, with arsenic responding in a shorter time frame and cadmium and zinc in a longer time frame (Kennen and Kirkwood, 2015, p.33). The second group of metals are considered not easily responsive to phyto-remediation technologies including copper, chromium, and lead (Kennen and Kirkwood, 2015, p.33). Phyto-remediation of metals can be done with metal excluder and accumulator species.

Monitoring over time will help to determine which species are successfully remediating the soils. The plant species chosen [see page 160] either stablise toxins in the soil or degrade them through their roots and/or herbaceous growth.

PETROLEUM DEGRADATION SPECIES

METAL EXCLUDERS AND ACCUMULATORS

PHYTO-REMEDIATION
VEGETATION SPECIES LIST

Species native to North America within a hardiness zone of three or lower [targeted containment in square brackets]:

PETROLEUM DEGRADATION SPECIES
Bouteloua curtipendula - Side Oats Gramma [TPH, PAH]
Bouteloua dactyloides - Buffalo Grass [TPH, PAH]
Bouteloua gracilis - Blue Grama [PAH]
Elymus canadensis - Canada Wild Rye [TPH, PAH]
Festuca spp. - Fescue [TPH, PAH]
Geranium viscosissimum - Sticky Geranium [PAH]
Helianthus annus - Sunflower [PAH]
Juncus effusus - Common Rush [PAH]
Panicum virgatum - Switchgrass [Anthracene, Pyrene, TPH, PAH]
Pascopyrum smithii - Western Wheatgrass [TPH, PAH]
Poaceae - Grasses [TPH, PAH, BTEX]
Scirpus spp. - Bulrush [Phenol, biological oxygen demand, chemical oxygen demand, oil and gasoline, Phenol, total suspended solids]
Sorghastrum nutans - Indiangrass [TPH, PAH]
Trifolium spp. - Clover [TPH, PAH, BTEX]
Typha spp. - Cattail [DRO, oil and gasoline, Phenol, total suspended solids, biological oxygen demand, chemical oxygen demand]
Vulpia microstachys - Small Fescue [TPH, PAH]
(Kennen and Kirkwood, 2015, pp.74-85)

METAL EXCLUDERS
Festuca rubra 'Merlin' - Red Fescue [zinc, copper]
Oenothera glazioviana - Evening Primrose [copper]

METAL ACCUMULATORS
Bidens pilosa - Spanish Needle [cadmium]
Conyza canadensis - Canadian Horseweed [cadmium, zinc, nickel]
Erigeron canadensis - Canada Fleabane [cadmium, nickel]
Helianthus annus - Sunflower [arsenic, cadmium, nickel, zinc]
Leersia oryzoides - Rice Cutgrass [arsenic]
Nicotania tabacum - Tobacco [cadmium, zinc]
Tagetes patula - French Marigold [cadmium]
(Kennen and Kirkwood, 2015, pp.140-169)

PHYTO-REMEDIATION
IMPLEMENTATION AND IMPACTS

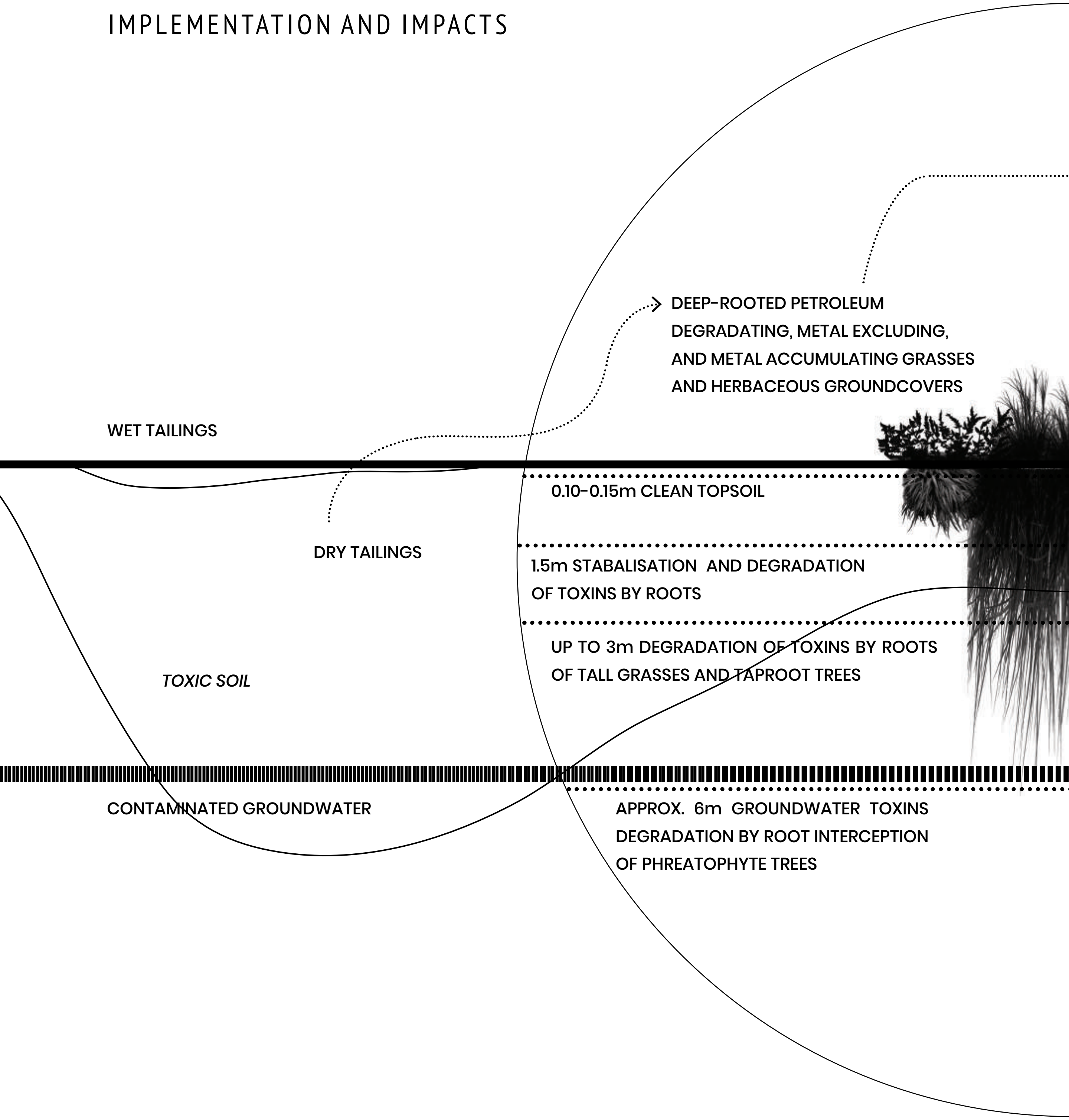


Figure 4-6: Timeline diagram showing phyto-remediation strategies and impacts (information from Kennen and Kirkwood, 2015).

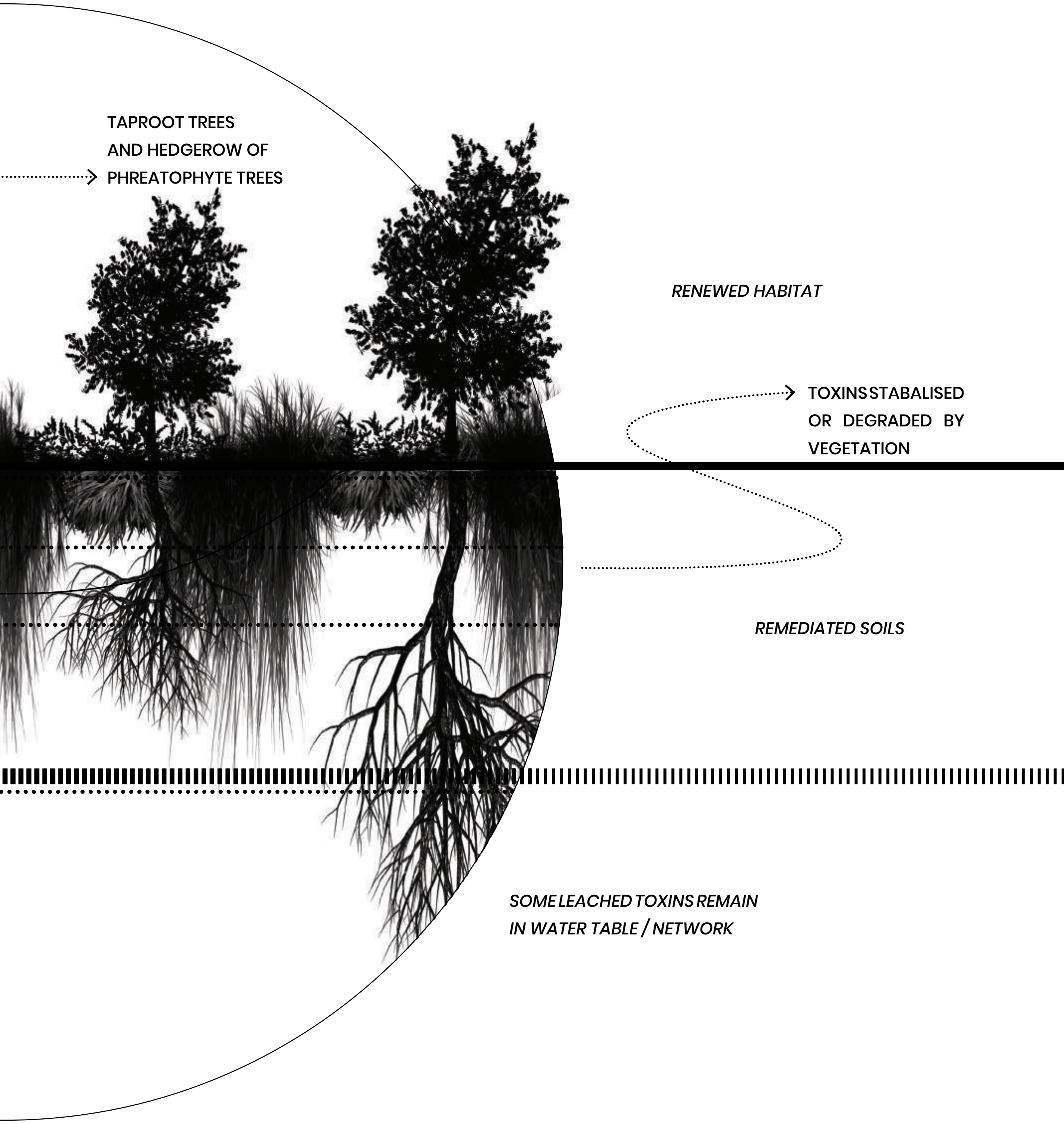

TAPROOT TREES
AND HEDGEROW OF
PHREATOPHYTE TREES
RENEWED HABITAT
TOXINS STABALISED
OR DEGRADED BY
VEGETATION
REMEDIATED SOILS
SOME LEACHED TOXINS REMAIN
IN WATER TABLE / NETWORK

Figure 4-7: A Syncrude tailings pond edge as seen from Hwy 63's Syncrude Loop. The industrial past of the site is seen on the left and an implemented phyto-remediation ecology is seen on the right.

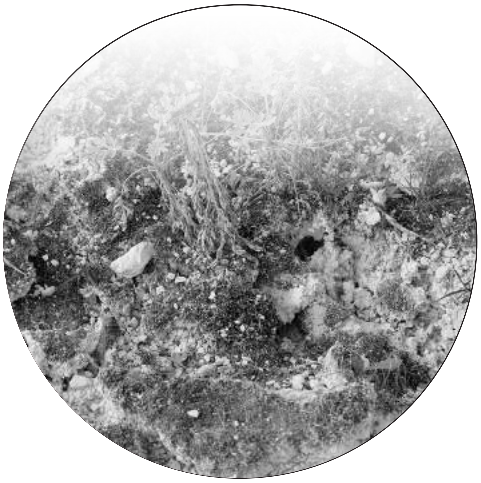
ALVAR COMMUNITIES
ABSENT SOILS STRATEGY

Alvar species are a globally uncommon ecosystem found on limestone bedrock and outcrops (Neufeld, Friesen, & Hamel, 2012, p.1). The vegetative species include mosses, lichen, mixed-grasses, and some shrubs and trees. Vegetation and wildlife that are found in alvar communities thrive in this type of harsh environment that is prone to flooding and drought (Neufeld, Friesen, & Hamel, 2012, p.1).

A 2012 report titled *Alvars in Manitoba: A Description of their Extent, Characteristics and Land Use* serves as a reference for species and habitat information for limestone bedrock alvar communities in a comparable climate (Neufeld, Friesen, & Hamel). Within the mine pits or landscape of the oil sands, the McMurray geologic layer is removed leaving behind mainly calcareous limestone in the underlying geologic layer. By fracturing small plots in the limestone and adding soil, moss, lichen, and grass species, alvar communities are encouraged to flourish. As the plants establish, soil is developed by the species roots and the species can spread throughout this type of landscape.

Because of its suitability to areas of absent soil and the exposed limestone left on site, the implementation of alvar species is the second proposed ecological strategy.

A few types of alvar communities would be suitable to this site. Alvar grasslands typically have 0.05-0.10m of soil depth and patches of bare rock. These areas may include small exposed rock outcrops. The vegetation consists of mostly grasses, a few shrubs, and no trees except where occasionally found along edges (Neufeld, Friesen, & Hamel, 2012, p.12). The alvar shrubland [prairie subtype] often includes bare limestone pavement and less than 0.05m of soil. These areas are prone to periods of flood and drought. The vegetation includes high quantities of mosses and lichens, shrubs, and a few stunted trees (Neufeld, Friesen, & Hamel, 2012, p.13). The alvar shrubland [exposed ridge subtype] typically consists of limestone boulder and exposed ridge or outcrop sites. The unique conditions of these rock faces support cliffbrakes and mosses (Neufeld, Friesen, & Hamel, 2012, p.16). The last type of alvar community, the alvar wetland, is usually found in low-lying areas prone to flooding. There are typically less than 0.05m of soil and some bare limestone patches. The vegetation includes grasses, sedges, mosses, and shrubs (Neufeld, Friesen, & Hamel, 2012, p.20).



MOSS AND LICHENS

GRASSES

SHRUBS

ALVAR COMMUNITIES
VEGETATION SPECIES LIST

ALVAR GRASSLAND
Dominant Grasses:
Antennaria spp. - Pussytoes
Danthonia spicata - Poverty Oat Grass
Bromus porteri - Porter's Chess
Elymus trachycaulus - Slender Wild Rye
Koeleria macrantha - Prairie Junegrass
Geum triflorum - Prairie Smoke
Juncus dudleyi - Dudley's Rush
Poa annua - Annual Bluegrass
Poa sp. - Poa

Dominant shrubs:
Juniperus horizontalis - Creeping Juniper
Dasiphora fruticosa -subsp. floribunda - Shrubby Cinquefoil
(Neufeld, Friesen, & Hamel, 2012, p.12)

ALVAR SHRUBLAND - PRAIRIE SUBTYPE
Dominant Lichen:
Cladonia spp. - Cup Lichen

Dominant Mosses:
Abietinella abietina - Abietinella Moss
Tortella torurorsa - Twisted Moss

Dominant Shrubs:
Juniperus horizontalis - Creeping Juniper
Arctostaphylos uva-ursi - Bearberry

Common Shrubs:
Betula pumilla - Bog Birch
Corylus cornuta - Beaked Hazelnut
Dasiphora fruticosa -subsp. floribunda - Shrubby Cinquefoil

Dominant Grasses:
Andropogon gerardii - Big Bluestem
Danthonia spicata - Poverty Oat Grass
Festuca halli - Rough Fescue

Common Grasses:
All grassland grasses
Gallium boreale - Northern Bedstraw
Solidago spp. - Goldenrods

Trees:
Populus tremuloides - Trembling Aspen
Quercus macrocarpus - Bur Oak
Picea glauca - White Spruce
(Neufeld, Friesen, & Hamel, 2012, pp.13-14)

ALVAR SHRUBLAND - EXPOSED RIDGE SUBTYPE
Specialist Fern Groundcovers
Pellaea glabella subsp. occidentalis - Western Dwarf Cliffbrake [more open crevices]
Pellaea gastonyi - Gastony's Cliffbrake [more areas of deeper crevice]

Moss:
Grimmia teretinervis - Grimmia Dry Rock Moss
(Neufeld, Friesen, & Hamel, 2012, p.16)

ALVAR WETLAND
Grasses/Sedges and Mosses:
Carex spp. - Sedges
Juncus spp. - Rushes
Eleocharis spp. - Spike Rushes
Deschampsia caespitosa - Tufted Hairgrass

Shrubs:
Juniperus horizontalis - Creeping Juniper [on bare limestone with moss]
Dasiphora fruticosa -subsp. floribunda - Shrubby Cinquefoil [on raised patches]
(Neufeld, Friesen, & Hamel, 2012, p.20)

ALVAR COMMUNITIES
IMPLEMENTATION AND IMPACTS

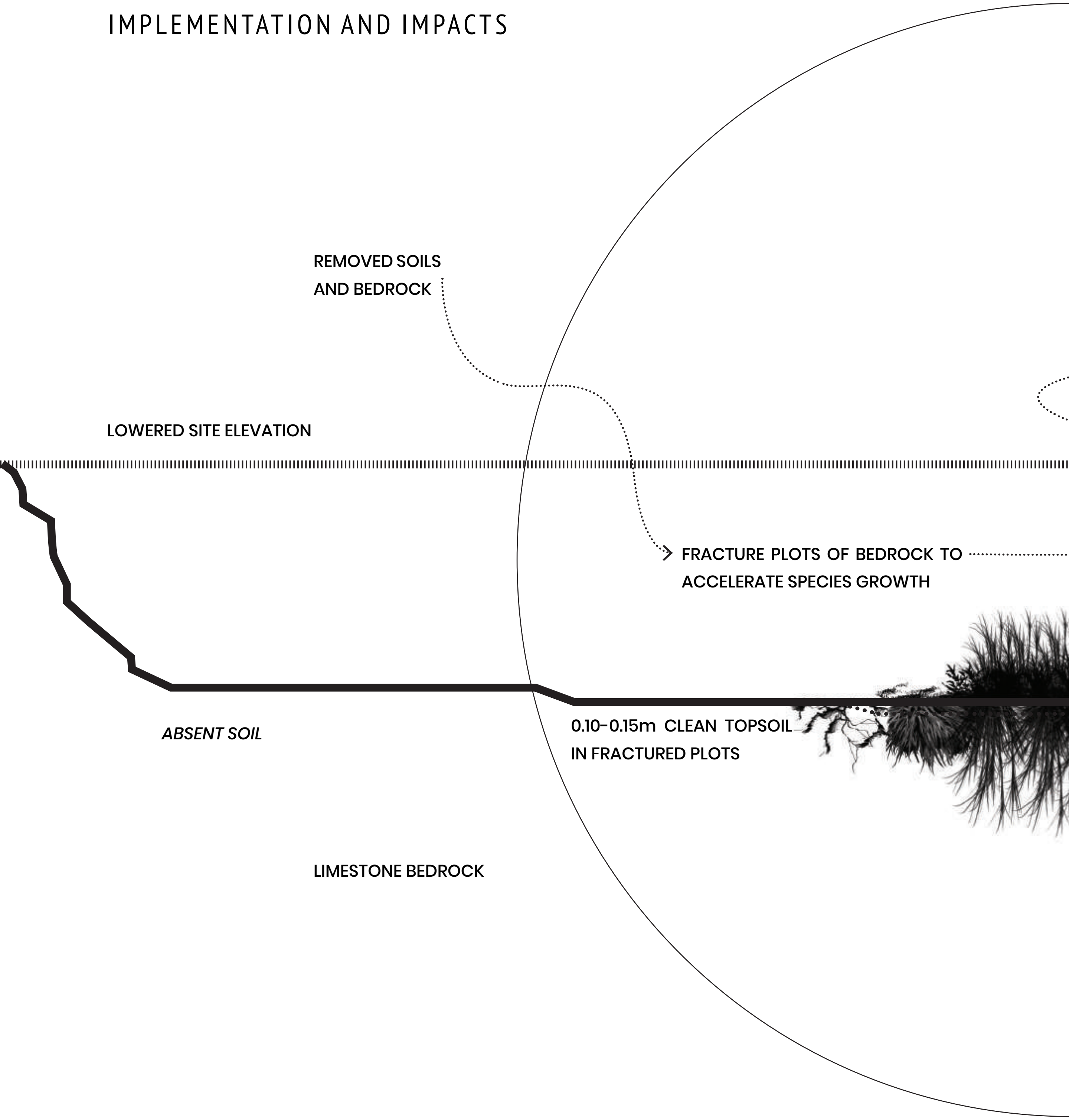


Figure 4-8: Timeline diagram showing alvar community implementation strategies and impacts (information from Neufeld, Friesen, and Hamel, 2012).

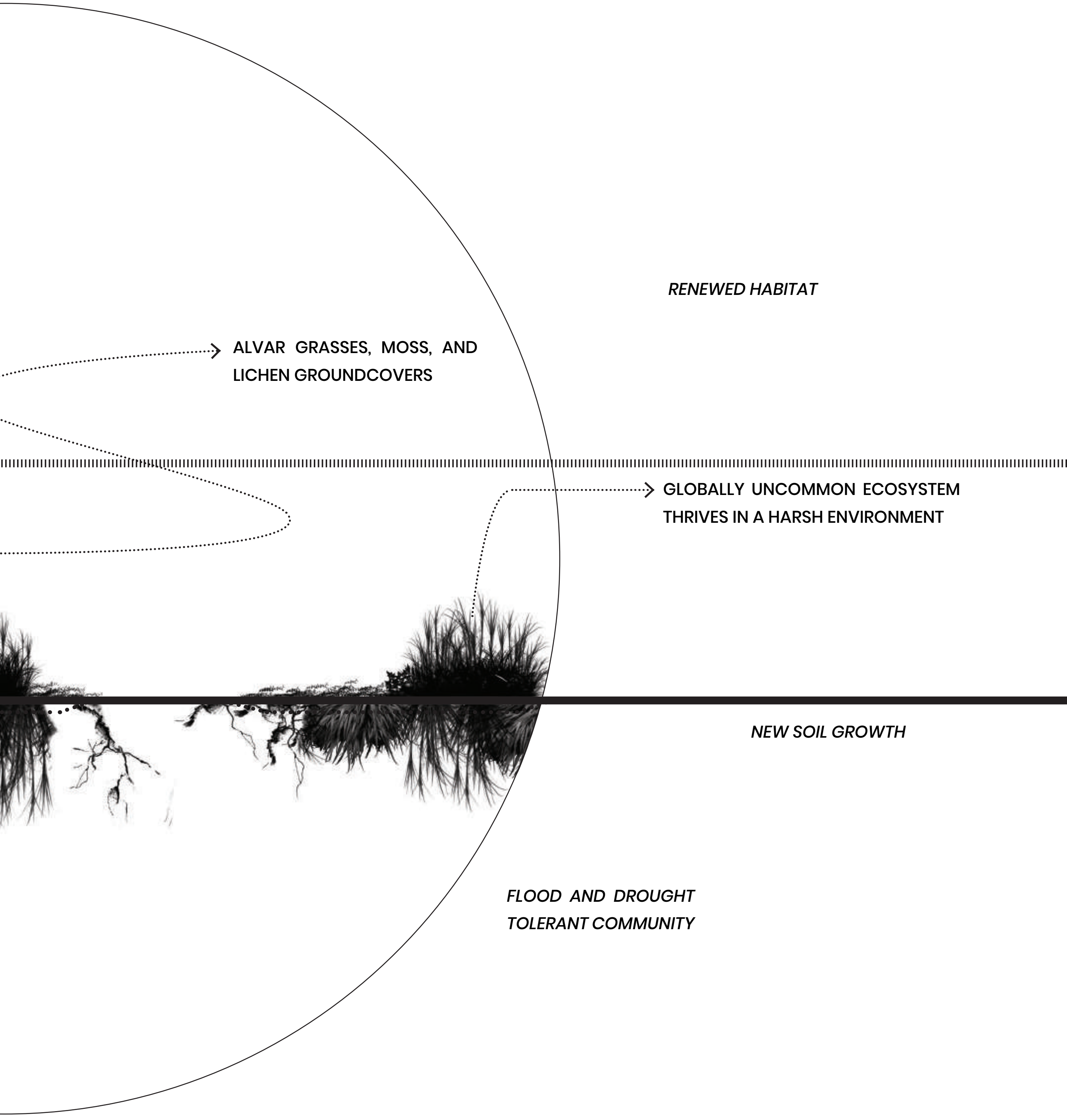

RENEWED HABITAT
ALVAR GRASSES, MOSS, AND LICHEN GROUNDCOVERS
GLOBALLY UNCOMMON ECOSYSTEM THRIVES IN A HARSH ENVIRONMENT
NEW SOIL GROWTH
FLOOD AND DROUGHT TOLERANT COMMUNITY

Figure 4-9: Alvar species thrive in harsh limestone conditions to provide a new landscape in the previous mine pit landscape.

MIXED GRASSLANDS

THIN SOILS STRATEGY

By introducing mixed grassland species, this third reclamation strategy can assist in the migration of this ecozone in preparation for more severe climate change impacts. This ecological community is drought tolerant and depends on fire for its maintenance. Areas for grassland species implementation often have had vegetation cleared from the site but the soils remain.

Candice Savage's book, *Prairie: A Natural History* (2011), provides a valuable resource in the importance of the North American Great Plains biome including species and habitat information for this grassland landscapes. Some shrubs and trees are found within grasslands but are usually found in clusters and along riparian areas (Savage, 2011, p.194). Many of the shrub and tree species of mixed grasslands are already found on site.

Cool-season and warm-season grasses differ in their carbon molecule compositions due to different adaptations over time. Cool-season links three molecules of carbon to produce energy while warm-season links four molecules of carbon. The two types are associated with different growing seasons. Cool has an ideal growing temperature of 20-25°C and warm with 25-30°C ideally (Savage, 2011, p.71). Cool-season grasses are more suited to the current climate of the Athabasca Oil Sands. Current implementation would include cool-season grasses like needle-and-thread and awned wheatgrass. As temperatures rise, warm-season grasses can be introduced such as blue gramma, big and little bluestem, and sand dropseed (Savage, 2011, p.71) .

COOL-SEASON GRASS

Agropyron subsecudum
Awned Wheatgrass

WARM-SEASON GRASS

Sporobolus cryptandrus
Sand Dropseed

MIXED GRASSLANDS

VEGETATION SPECIES LIST - COOL-SEASON GRASSES AND SEDGES

Cool-season grass and sedge species that are native to Alberta:

Agropyron dasystachyum - Northern Wheatgrass
Agropyron spicatum - Bluebunch Wheatgrass
Agropyron trachycaulum var. unilaterale - Awned Wheatgrass
Agrostis scabra - Tickle Grass
Alopecurus aequalis - Water Foxtail
Aristida purpurascens var. longiseta - Red Three-awn [warm-season]

Beckmannia syzigachne - Slough Grass
Bouteloua gracilis - Blue Grama [warm-season]
Bromus carinatus - Mountain Brome
Bromus ciliatus - Fringed Brome
Bromus inermis var. pumpellianus - Northern Awnless Brome

Calamagrostis canadensis - Bluejoint
Calamagrostis inexpansa - Northern Reed Grass
Calamagrostis montanensis - Plains Reed Grass
Calamagrostis purpurascens - Purple Reed Grass
Calamagrostis rubescens - Pine Grass
Calamovilfa longifolia - Sand Grass
Carex aquatilis - Water Sedge
Carex atherodes - Awned Sedge
Carex athrostachya - Long-bracted Sedge
Carex atrosquama - Atrosquama Sedge
Carex aurea - Golden Sedge
Carex brunnescens - Brownish Sedge
Carex capillaris - Hair-like Sedge
Carex eleocharis - Low Sedge
Carex filifolia - Thread Leaf Sedge
Carex geyeri - Elk Sedge
Carex hoodii - Hood’s Sedge
Carex lanuginosa - Woolly Sedge
Carex microptera - Thick-spike Sedge
Carex obtusata - Blunt Sedge

Carex pensylvanica - Sun-loving Sedge
Carex praegracilis - Field/graceful Sedge
Carex praticola - Meadow Sedge
Carex raymondii - Raymond Sedge
Carex rossii - Ross' Sedge
Carex rostrata - Beaked Sedge
Carex scirpoidea - Rush-like Sedge
Carex siccata - Hay Sedge
Carex sprengelii - Sprengel's Sedge

Danthonia californica - California Oat Grass
Danthonia intermedia - Intermediate Oat Grass
Danthonia parryi - Parry Oat Grass
Deschampsia caespitosa - Tufted Hair Grass

Eleocharis palustris - Creeping Spike Rush
Elymus canadensis - Canada Wild Rye
Elymus glaucus - Smooth Wild Rye
Elymus innovatus - Hairy Wild Rye
Elymus piperi - Giant Wild Rye
Elymus trachycaulus - Slender Wheatgrass

Festuca campestris - Foothills Rough Fescue
Festuca hallii - Plains Rough Fescue
Festuca idahoensis - Idaho Fescue
Festuca saximontana - Rocky Mountain Fescue

Glyceria borealis - Northern Manna Grass
Glyceria grandis - Tall Manna Grass
Glyceria striata - Fowl Manna Grass

Helictotrichon hookeri - Hooker's Oat Grass
Hesperostipa comata - Needle-and-thread Grass
Hierochloe odorata - Sweet Grass
Hordeum jubatum - Foxtail Barley

Juncus alpinoarticulatus - Alpine Rush
Juncus balticus - Baltic Rush
Juncus tracyi - Mud Rush

Kobresia myosuroides - Kobresia
Koeleria macrantha - June Grass

Luzula parviflora - Small-flowered Woodrush

Muhlenbergia cuspidata - Plains Muhly
Muhlenbergia richardsonis - Mat Muhly

Oryzopsis asperifolia - White-grained Mountain Rice Grass
Oryzopsis hymenoides - Indian Rice Grass

Pascopyrum smithii - Western Wheatgrass
Phalaris arundinacea - Reed Canary Grass
Phragmites australis - Common Reed
Phleum alpinum - Alpine Timothy
Poa canbyi - Canby Bluegrass
Poa cusickii - Early Bluegrass
Poa interior - Woodland Bluegrass
Poa palustris - Fowl Bluegrass
Poa sandbergii - Sandberg Bluegrass
Puccinellia nuttalliana - Nuttall's Alkali Grass

Schedonnardus paniculatus - Tumble Grass
Schizachne purpurascens - False Melic
Schizachyrium scoparium - Little Bluestem [warm-season]
Spartina gracilis - Alkali Cord Grass
Sporobolus cryptandrus - Sand Dropseed
Stipa columbiana - Columbian Needle Grass
Stipa curtiseta - Western Porcupine Grass
Stipa richardsonii - Richardson Needle Grass
Stipa viridula - Green Needle Grass

Trisetum spicatum - Spike Trisetum

Vulpia octoflora - Six Weeks Fescue

(Wroe, Smoliak, & Wheeler, 2000, pp.3-5)

MIXED GRASSLANDS

VEGETATION SPECIES LIST - FORBS

Forb species that are native to Alberta:

Achillea millefolium - Common Yarrow
Agoseris glauca - False Dandelion
Allium textile - Prairie Onion
Amaranthus graecizans - Prostrate Pigweed
Anemone canadensis - Canada Anemone
Anemone multifida - Cut-leaved Anemone
Anemone patens - Prairie Crocus
Antennaria spp. - Pussy-toes/Everlasting
Arenaria congesta - Ball-head Sandwort
Arnica spp. - Arnicas
Artemisia dracunculus - Narrow-leaved Wormwood
Artemisia frigida - Pasture Sage
Aster spp. - Aster
Artemisia ludoviciana - Prairie Sage
Astragalus aboriginum - Indian Milk Vetch
Astragalus alpinus - Alpine Milk Vetch
Astragalus americanus - American Milk Vetch
Astragalus canadensis - Canada Milk Vetch
Astragalus crassicarpus - Ground Plum
Astragalus dasyglottis - Purple Milk Vetch
Astragalus drummondii - Drummond Milk Vetch
Astragalus flexuosus - Slender Milk Vetch
Astragalus missouriensis - Missouri Milk Vetch
Astragalus striatus - Ascending purple Milk Vetch

Balsamorhiza sagittata - Balsam-root

Campanula rotundifolia - Bluebell
Castilleja spp. - Paint-brush
Cerastium arvense - Field Chickweed
Cirsium undulatum - Wavy-leaved Thistle
Comandra umbellata - Bastard Toad-flax
Corydalis & Impatiens spp. - Corydalis/Touch-me-not
Crepis spp. - Hawksbeard

Equisetum arvense - Common Horsetail
Equisetum hyemale - Common Scouring Rush
Epilobium spp. - Fireweed/Willow-herb
Erigeron spp. - Fleabane
Eriogonum flavum - Yellow Umbrella Plant

Fragaria virginiata - Wild Strawberry

Gaillardia aristata - Gaillardia
Galium boreale - Northern Bedstraw
Geranium spp. - Geranium
Geranium viscosissimum - Sticky Geranium
Geum triflorum - Three-flowered Avens
Glycyrrhiza lepidota - Wild Licorice

Haplopappus spinulosus - Spiny Ironplant
Hedysarum spp. - Hedysarum
Heracleum lanatum - Cow Parsnip
Heterotheca villosa - Hairy Golden Aster
Heuchera richardsonii - Alumroot
Hieracium spp. - Hawkweed

Lathyrus ochroleucus - Cream-coloured Pea Vine
Lathyrus venosus - Purple Pea Vine
Liatris spp. - Blazing Star
Liatris punctata - Dotted Blazing Star
Lilium philadelphicum - Western Wood Lily
Linum lewisii - Wild Blue Flax

Penstemon spp. - Beard-tongue
Petalestemon spp. - Prairie Clovers
Phlox hoodii - Moss Phlox
Polygonum amphibium - Water Smartweed
Potentilla spp. - Cinquefoil

Ranunculus spp. - Buttercup/Crowfoot
Ratibida columnifera - Prairie Cone-flower
Rumex spp. - Dock/Sorrel/Wild Begonia

Selaginella densa - Little Clubmoss
Sisyrinchium montanum - Blue-eyed Grass
Sium suave - Water Parsnip
Smilacina stellata - Star-flowered Solomon's Seal
Solidago spp. - Goldenrod
Sphaeralcea coccinea - Scarlet Mallow
Stellaria longifolia - Long-leaved Chickweed

Thalictrum spp. - Meadow Rue
Thermopsis rhombifolia - Buffalo Bean/Golden Bean

Urtica dioica - Common Nettle

Vicia americana - American Vetch
Viola adunca - Early Blue Violet
Viola canadensis - Western Canada Violet

(Wroe, Smoliak, & Wheeler, 2000, pp.6-8)

MIXED GRASSLANDS

VEGETATION SPECIES LIST - SHRUBS AND TREES

Shrub species that are native to Alberta:

Acer glabrum - Mountain Maple
Alnus spp. - Alder
Amelanchier alnifolia - Saskatoon
Arctostaphylos uva-ursi - Kinnikinnick/Bearberry
Artemisia cana - Sagebrush
Atriplex nuttallii - Salt Sage/Nuttall's Atriplex

Berberis repens - Oregon Grape/Creeping Mahonia
Betula spp. - Dwarf/Bog/Water birch

Cornus stolonifera - Red Osier Dogwood
Coryphantha vivapar - Ball/Pincushion Cactus

Elaeagnus commutata - Silver-berry/Wolf Willow
Eurotia lanata - Winter Fat

Juniperus spp. - Juniper

Loticera spp. - Honeysuckle

Opuntia spp. - Prickly Pear Cactus

Potentilla fruticosa - Shrubby Cinquefoil
Prunus pensylvanica - Pin Cherry
Prunus virginiana - Choke Cherry

Rhus trilobata - Skunk-bush
Ribes spp. - Currants/Gooseberry
Rosa spp. - Roses
Rubus idaeus - Wild Raspberry

Salix spp. - Willows
Shepherdia argentea - Thorny Buffalo-berry
Shepherdia canadensis - Canada Buffalo-berry
Sorbus scopulina - Western Mountain Ash
Symphoricarpos albus - Snowberry
Symphoricarpos occidentalis - Buckbrush/Wolfberry

Viburnum spp. - Bush Cranberry

(Wroe, Smoliak, & Wheeler, 2000, pp.8-9)

Tree species that are native to Alberta:

Betula papyrifera - Paper/White Birch

Latrix laricina - Tamarak

Picea spp. - Spruce
Pinus spp. - Pine
Populus tremuloides - Aspen Poplar
Populus spp. - Balsam Poplar/Cottonwood

(Wroe, Smoliak, & Wheeler, 2000, p.9)

MIXED GRASSLANDS

IMPLEMENTATION AND IMPACTS

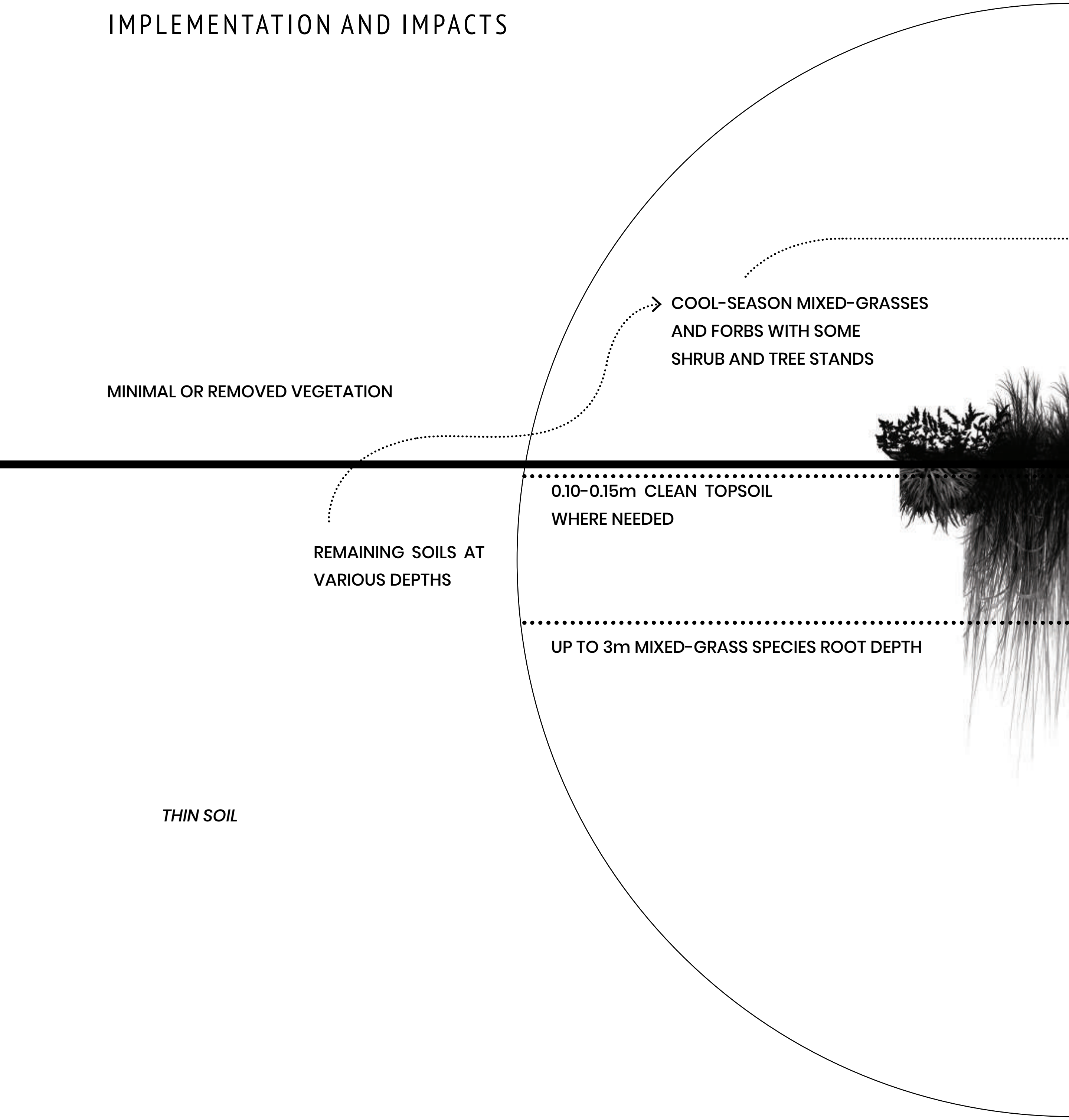
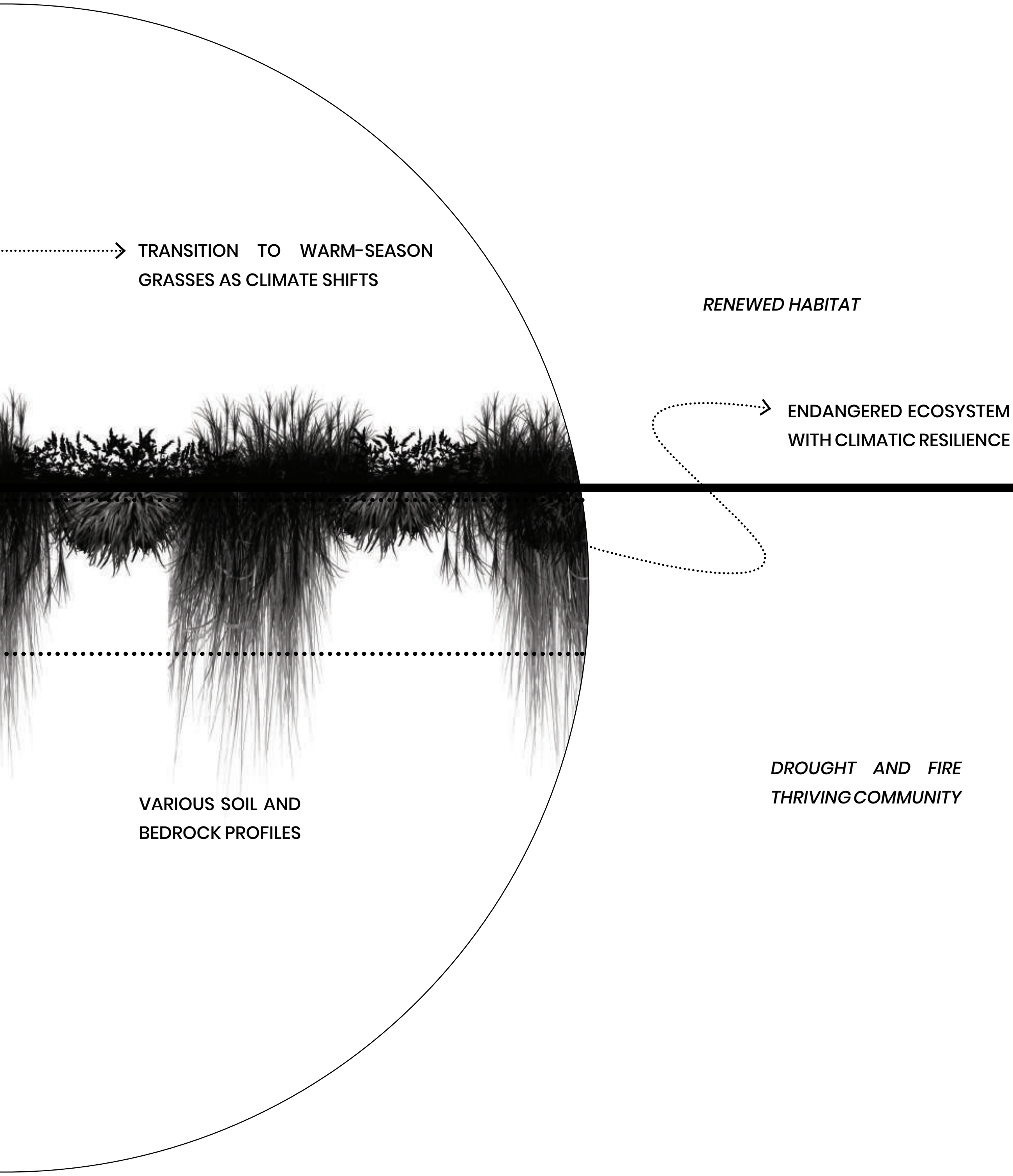


Figure 4-10: Timeline diagram showing grassland implementation strategies and impacts (information from Savage, 2011).


TRANSITION TO WARM-SEASON GRASSES AS CLIMATE SHIFTS
RENEWED HABITAT
ENDANGERED ECOSYSTEM WITH CLIMATIC RESILIENCE
VARIOUS SOIL AND BEDROCK PROFILES
DROUGHT AND FIRE THRIVING COMMUNITY

TRANSECTS
IMPLEMENTATION

Three transects of the site plan are highlighted on the key map. Each transect is a five kilometre length that show the relationships of each of the implemented ecologies with one another among varying conditions.

Transect 1 is an east-west transect of thin, toxic, and absent soils. The transect includes a former operations node and Suncor habitat where grasslands and alvars are implemented. The Athabasca River is to the west of this site.

Transect 2 is a northwest-southeast line of toxic and thin soils. The transect is comprised of voids, edges, operations, waste, and remnant components. The voids are left to dry, phyto-remediation is applied to the edges, the waste nodes of sulphur storage remain as a living land art, and grasslands are applied to the remnant and operations areas.

Transect 3 is an east-west transect of thin and toxic soils. The transect cuts through Highway 63's Syncrude Loop alongside the Giants of Mining open air museum which is left as an educational site along the highway. The edges and remnant areas require phyto-remediation and grasslands implementation.

Transects are used to understand relationships across varying ecologies. The implementation of a physical transect in the form of a steel-grate boardwalk is proposed in the Syncrude Loop area [see page 200]. This intervention stretches five kilometres and is split into one kilometre spans. This industrial-sized 10m wide transect sits just slightly raised over the landscape to serve as a test plot to monitor the implemented ecologies over time. This physical mark of the site is a reminder of its industrial past and available to both the public and researchers for access to the newly implemented ecologies.

[opposite page] Figure 4-11: GIS map key plan showing three five-kilometre transects through the Tar Island site.

LEGEND

10m interval contours

Key wildlife and biodiversity zones

Waterways

Industrial feature - pipeline

Industrial feature - road

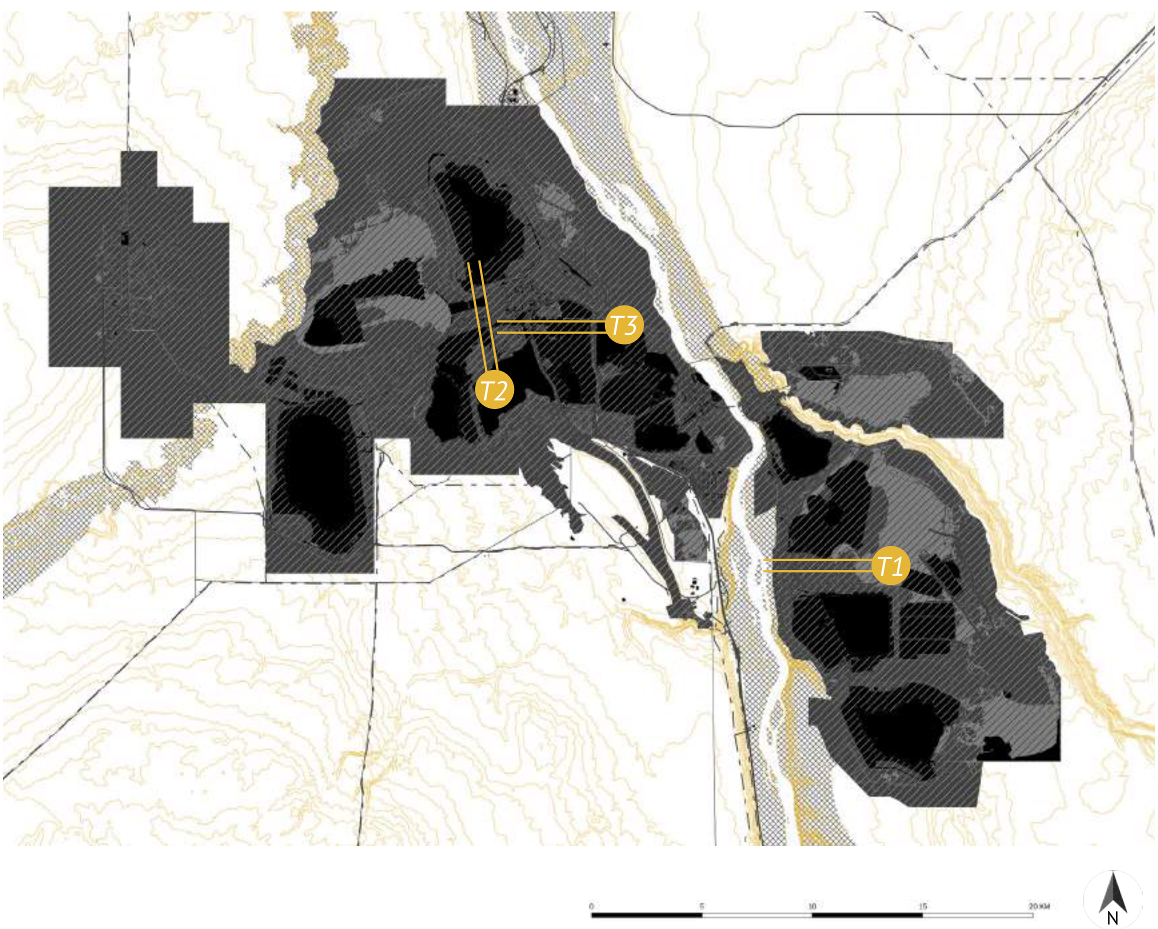
Industrial feature - powerline and transformer station

Toxic soil

Thin soil

No soil

Areas where ecological growth is encouraged [areas without this hatch remain as is]



SUNCOR HABITAT

TRANSECT 1

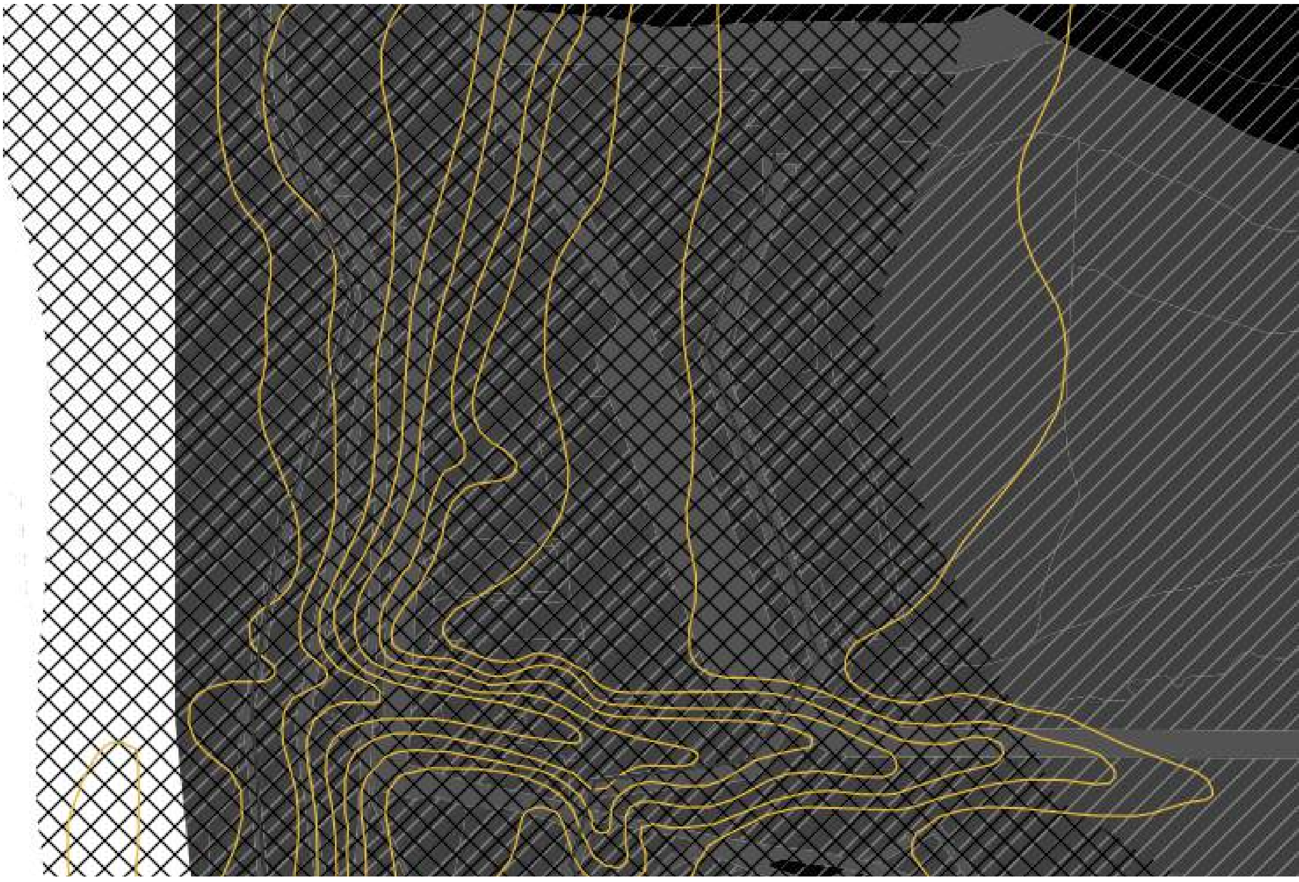
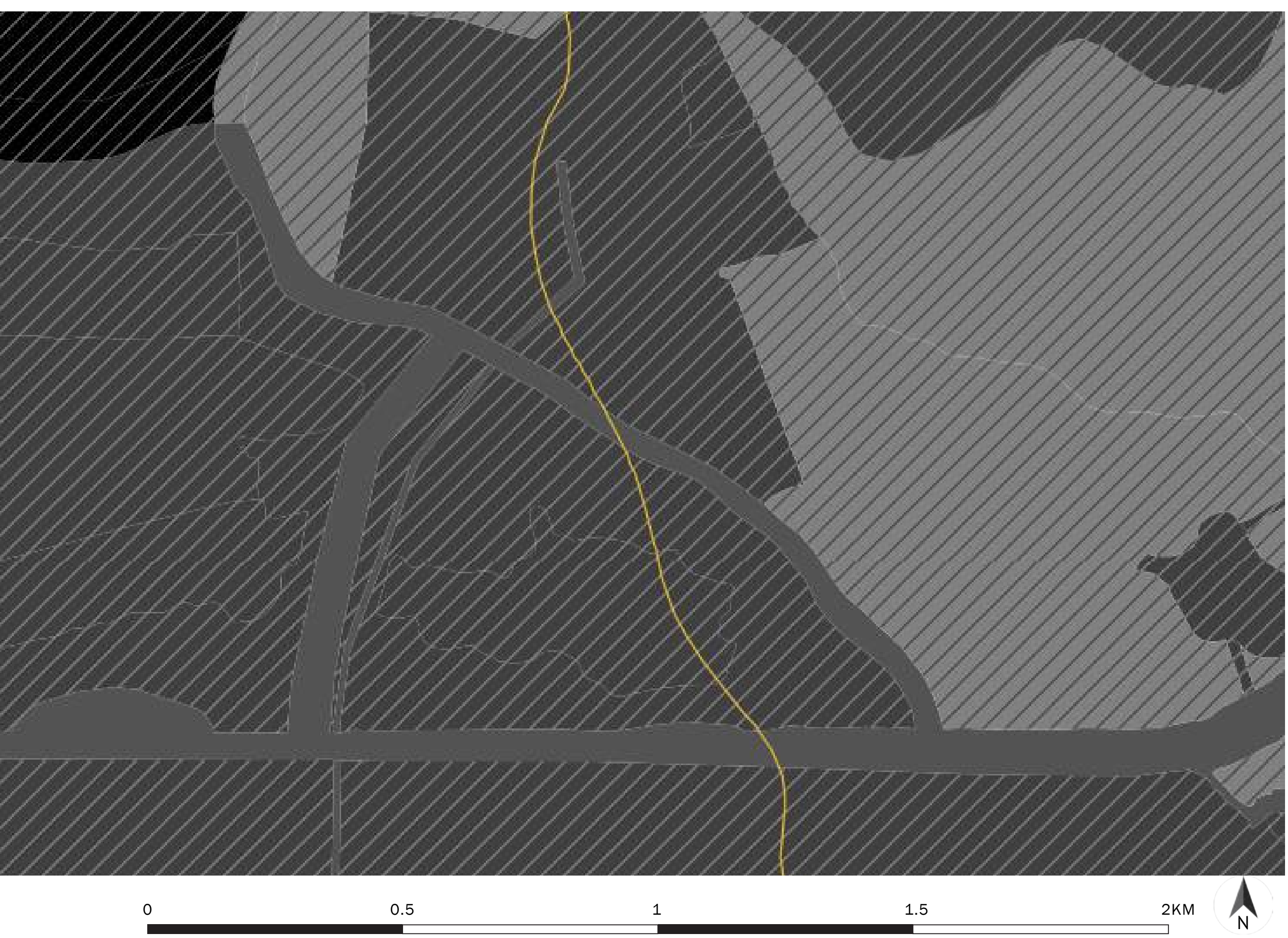


Figure 4-12: GIS map showing an east-west transect of thin, toxic, and absent soils.

LEGEND

- 10m interval contours
- Key wildlife and biodiversity zones
- Waterways
- Toxic soil
- Thin soil
- No soil
- Areas where ecological growth is encouraged [areas without this hatch remain as is]



SUNCOR HABITAT
TRANSECT 1

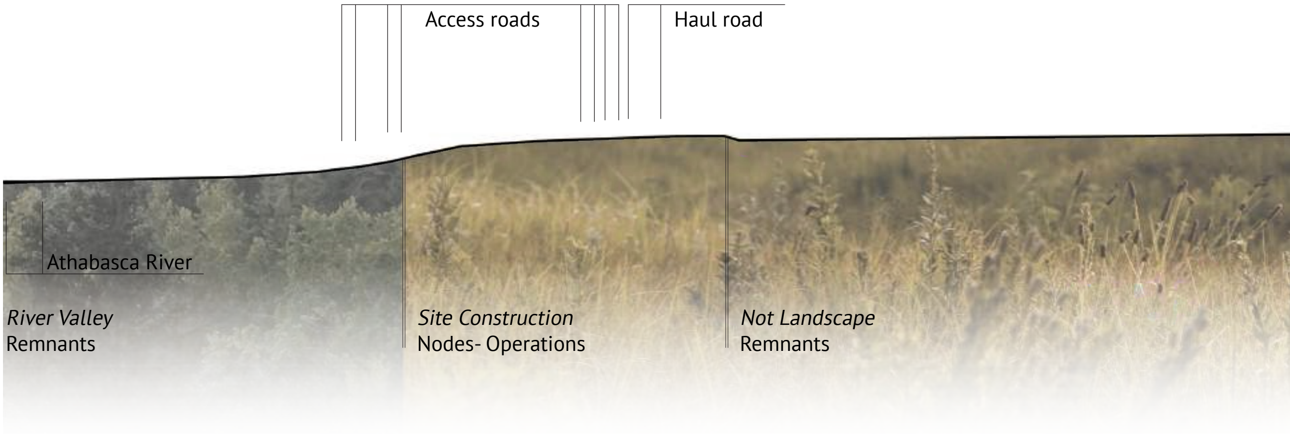
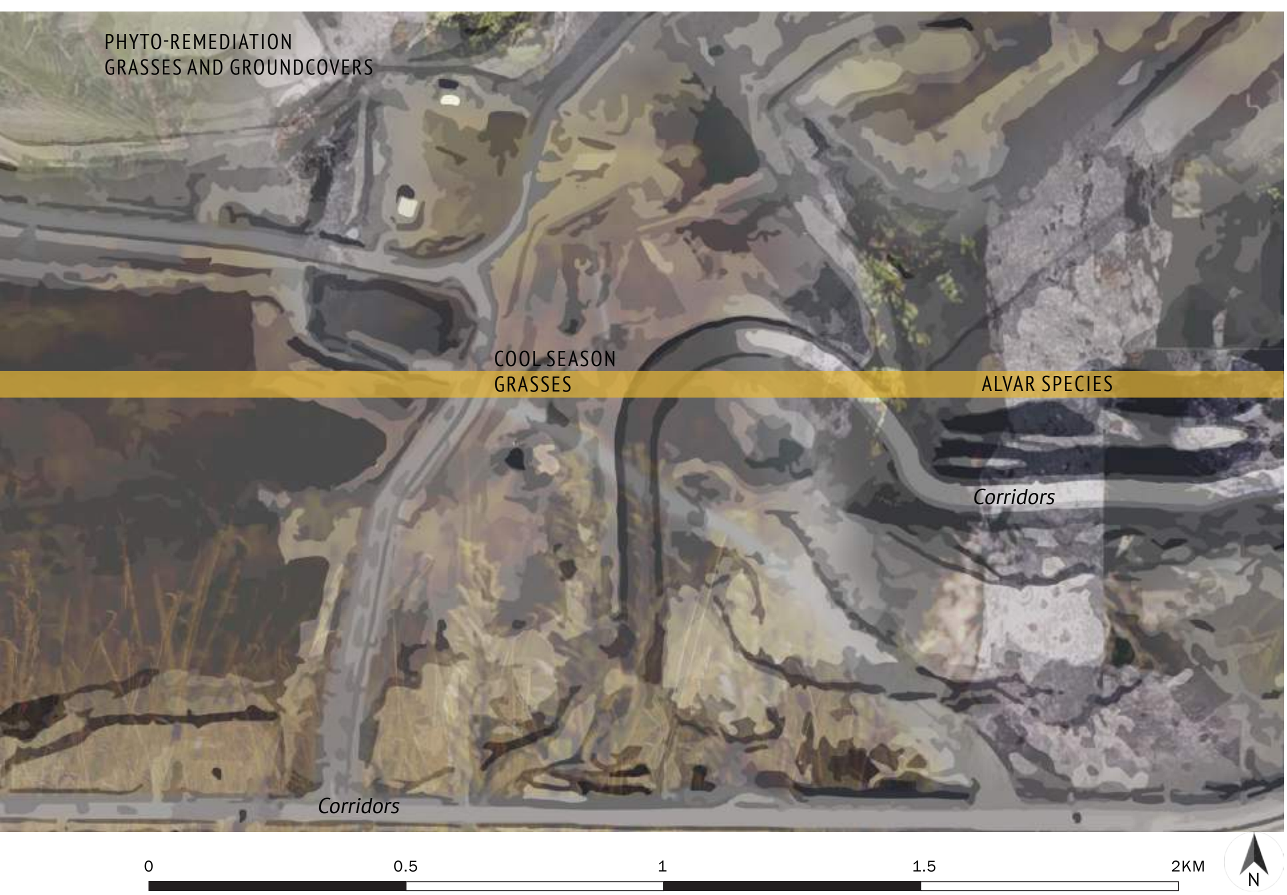


Figure 4-13: 5km section including the Athabasca River Valley and Suncor sites showing soil scenario implementation zones.

Figure 4-14: 5km implementation plan including the Athabasca River Valley and Suncor sites.


Haul road
Access road
Haul roads
Landscape
Habitat


PHYTO-REMEDIATION
GRASSES AND GROUNDCOVERS
COOL SEASON
GRASSES
ALVAR SPECIES
Corridors
Corridors
0
0.5
1
1.5
2KM
N

SYNCRUDE SCULPTURAL SULPHUR

TRANSECT 2

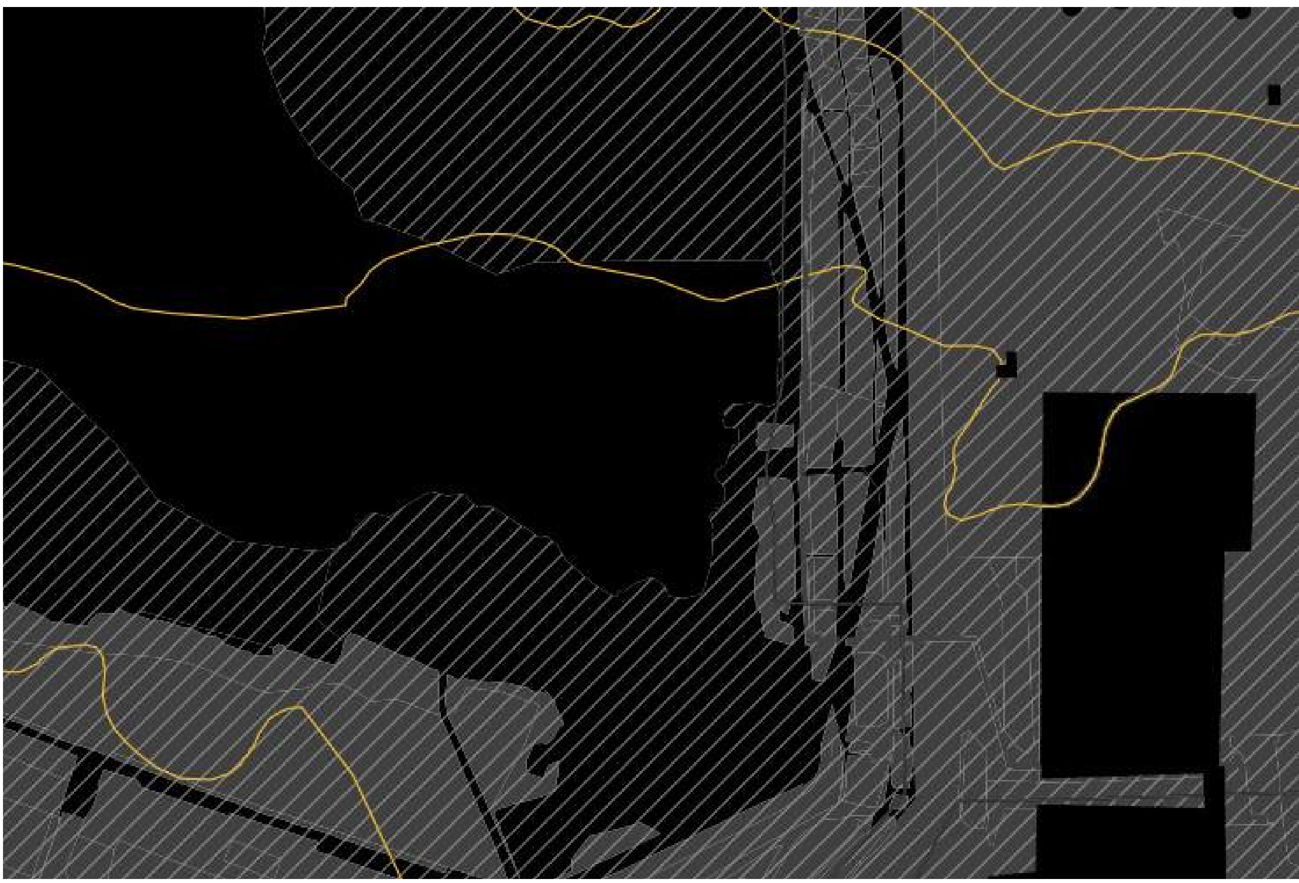


Figure 4-15: GIS map showing a Northwest-Southeast transect of toxic and thin soils.

LEGEND

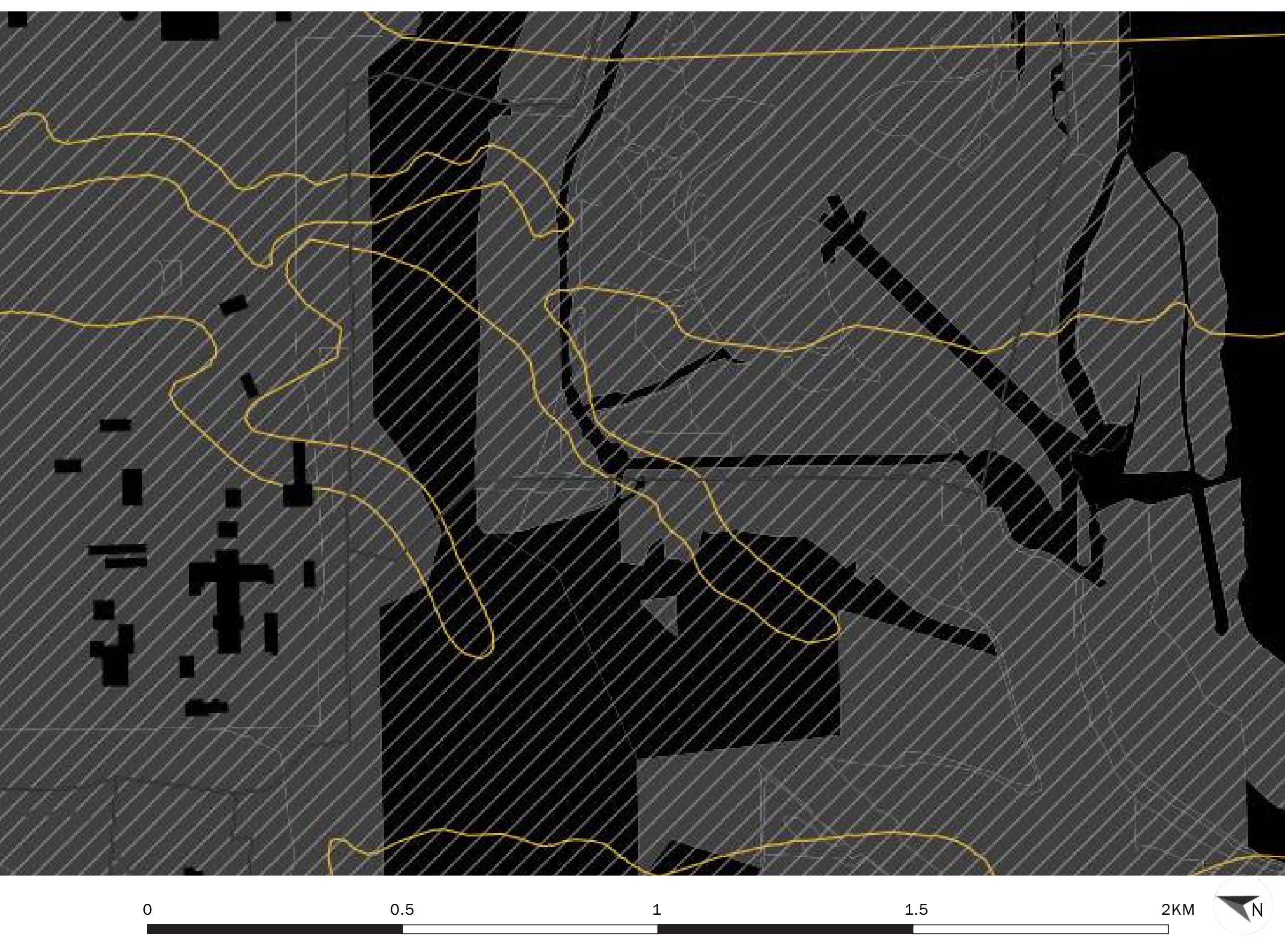
10m interval contours

Key wildlife and biodiversity zones

Toxic soil

Thin soil

Areas where ecological growth
is encouraged [areas without
this hatch remain as is]



SYNCRUDE SCULPTURAL SULPHUR

TRANSECT 2

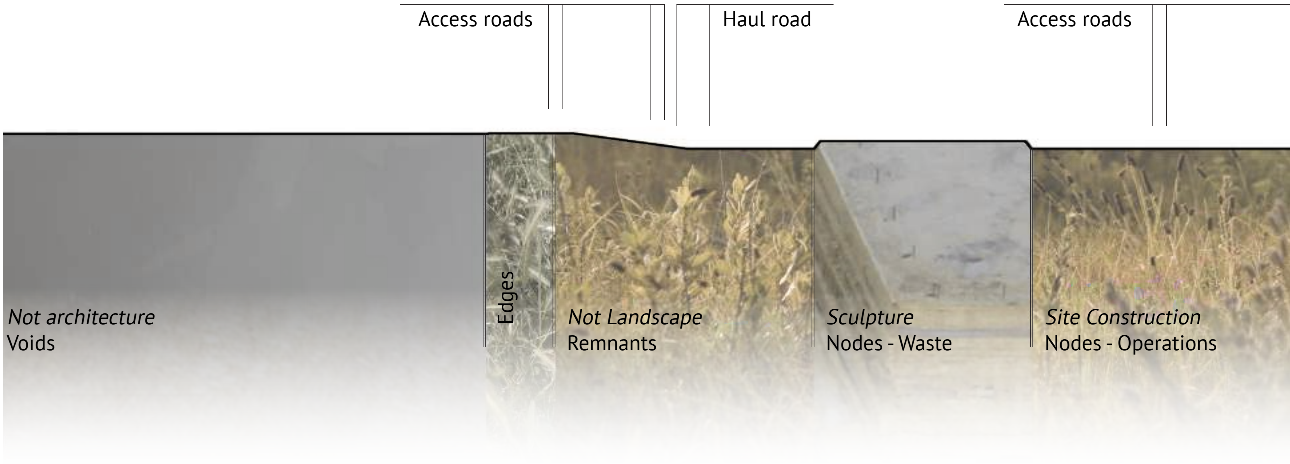


Figure 4-16: 5km section including Syncrude sites and sulphur surplus storage showing soil scenario implementation zones.

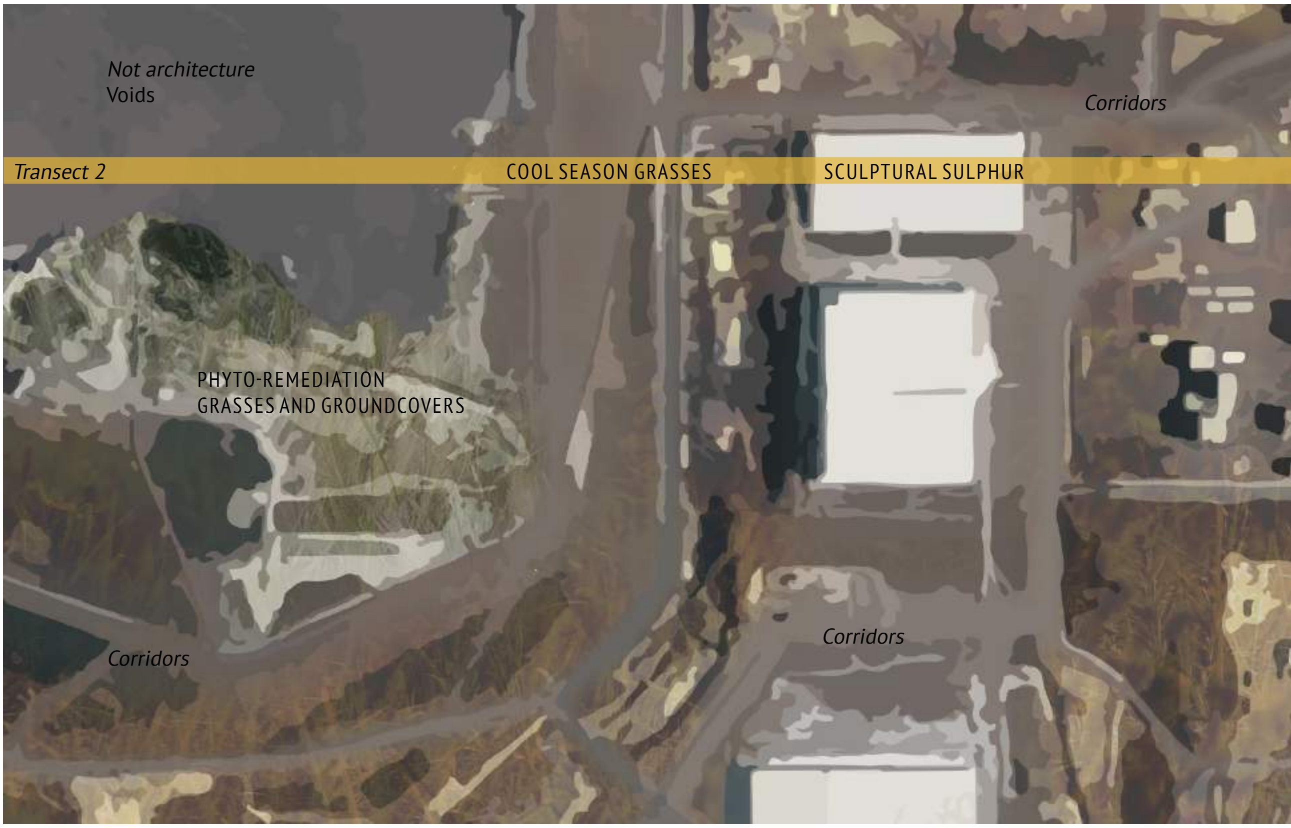


Figure 4-17: 5km implementation plan including Syncrude sites and sulphur surplus storage.


Haul road
Access road
Not architecture
Voids


COOL SEASON GRASSES
Corridors
Not architecture
Voids
Corridors
PHYTO-REMEDIATION
GRASSES AND GROUNDCOVERS
COOL SEASON GRASSES
0
0.5
1
1.5
2KM
N

SYNCRUDE LOOP

TRANSECT 3

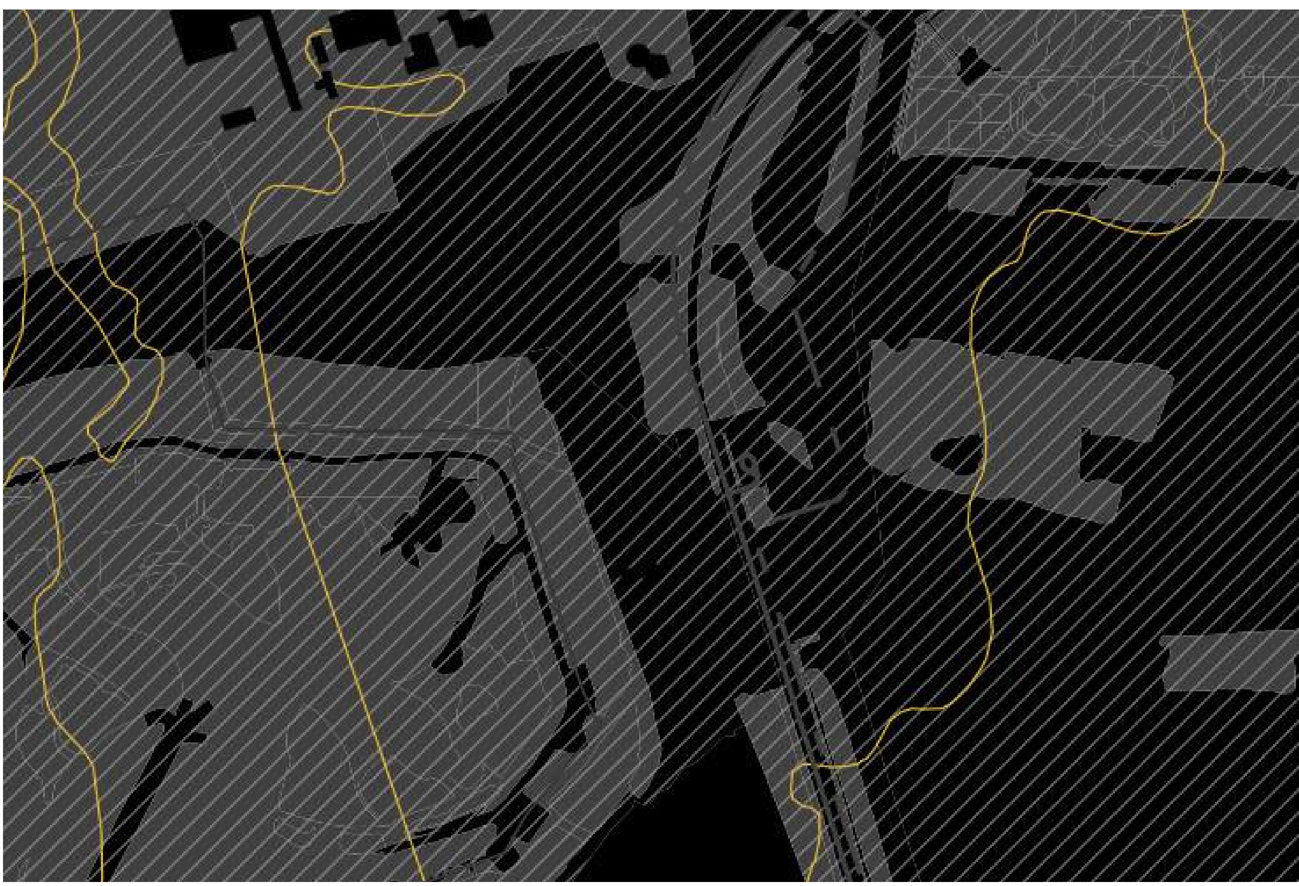


Figure 4-18: GIS map showing an East-west transect of thin and toxic soils.

LEGEND

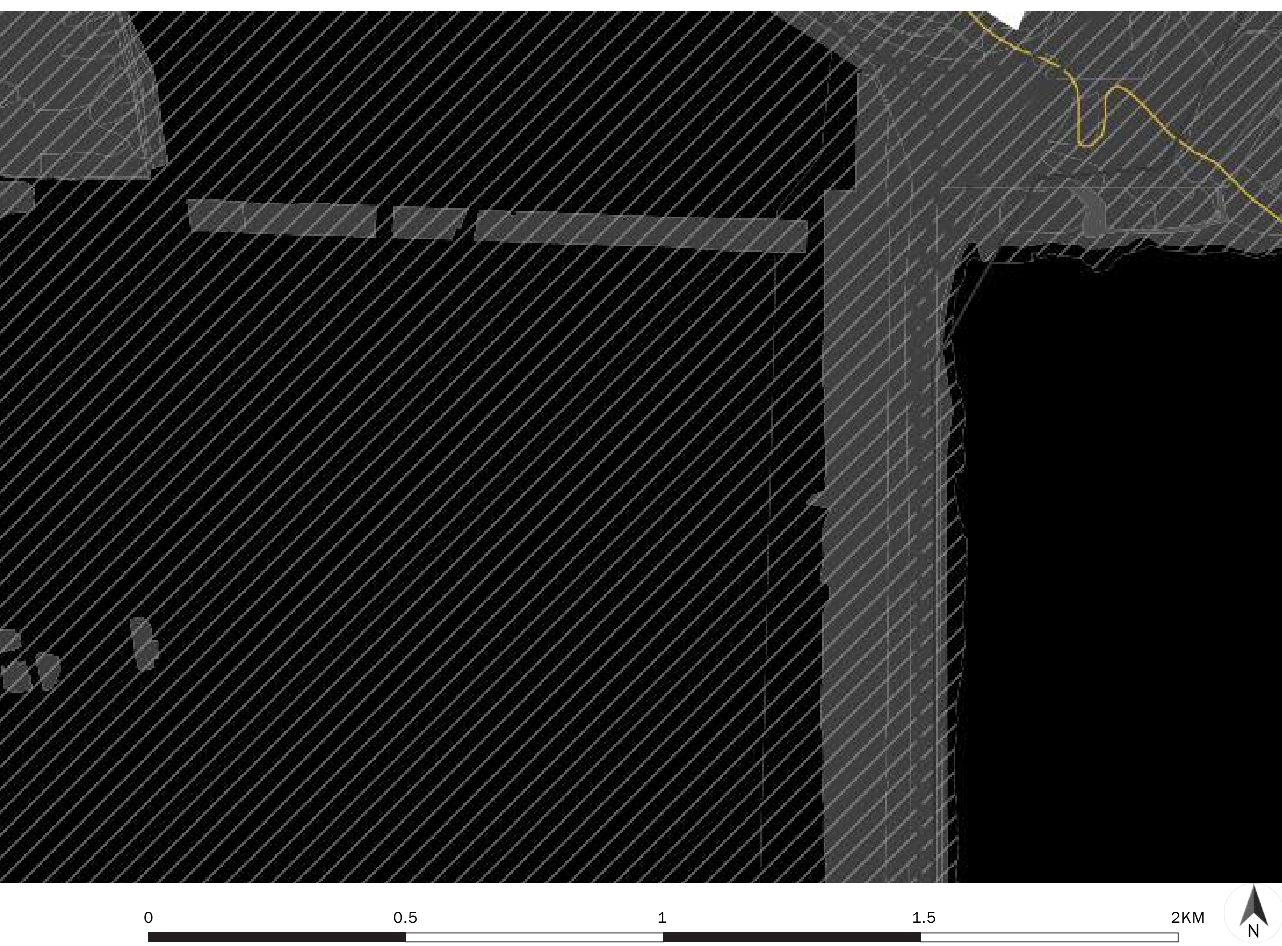
10m interval contours

Key wildlife and biodiversity zones

Toxic soil

Thin soil

Areas where ecological growth
is encouraged [areas without
this hatch remain as is]



SYNCRUDE LOOP
TRANSECT 3

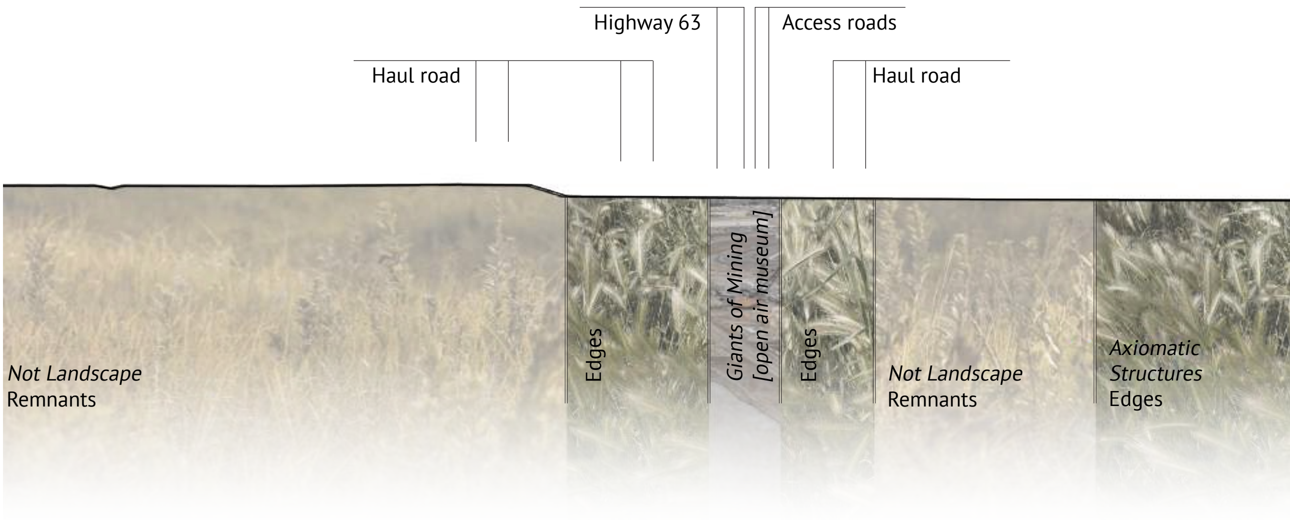


Figure 4-19: 5km section including Syncrude sites and Highway 63 Syncrude Loop showing soil scenario implementation zones.

Figure 4-20: 5km implementation plan including Syncrude sites and Highway 63 Syncrude Loop.

Access roads
Highway 63
Not Landscape
Remnants
Edges
Not Architecture
Voids

PHYTO-REMEDIATION
GRASSES AND GROUNDCOVERS
Highway 63 -
Syncrude Loop
Corridors
COOL
SEASON
GRASSES
PHYTO-REMEDIATION GRASSES AND GROUNDCOVERS
Not architecture
Voids
0
0.5
1
1.5
2KM
N

Figure 4-21: Sulphur sculpture situated in surrounding grasslands.
The sculpture changes as material is removed over time.

Figure 4-22: Plan view showing a physical transect in the form of a steel-grate boardwalk that stretches five kilometres through the area along Highway 63's Syncrude Loop. This industrial-sized intervention in the landscape will serve as a test plot to monitor the implemented ecologies over time.


Mildred Lake
PHYTO-REMEDIATION GRASSES AND GROUNDCOVERS
COOL SEASON GRASSES
HIGHWAY 63 - SYNCRUDE LOOP
BOARDWALK TRANSECT
Corridors
COOL SEASON GRASSES
Not arch. Voids
PHYTO-REMEDIATION GRASSES AND GROUNDCOVERS
0
0.5
1
1.5
2KM
N
COOL SEASON GRASSES

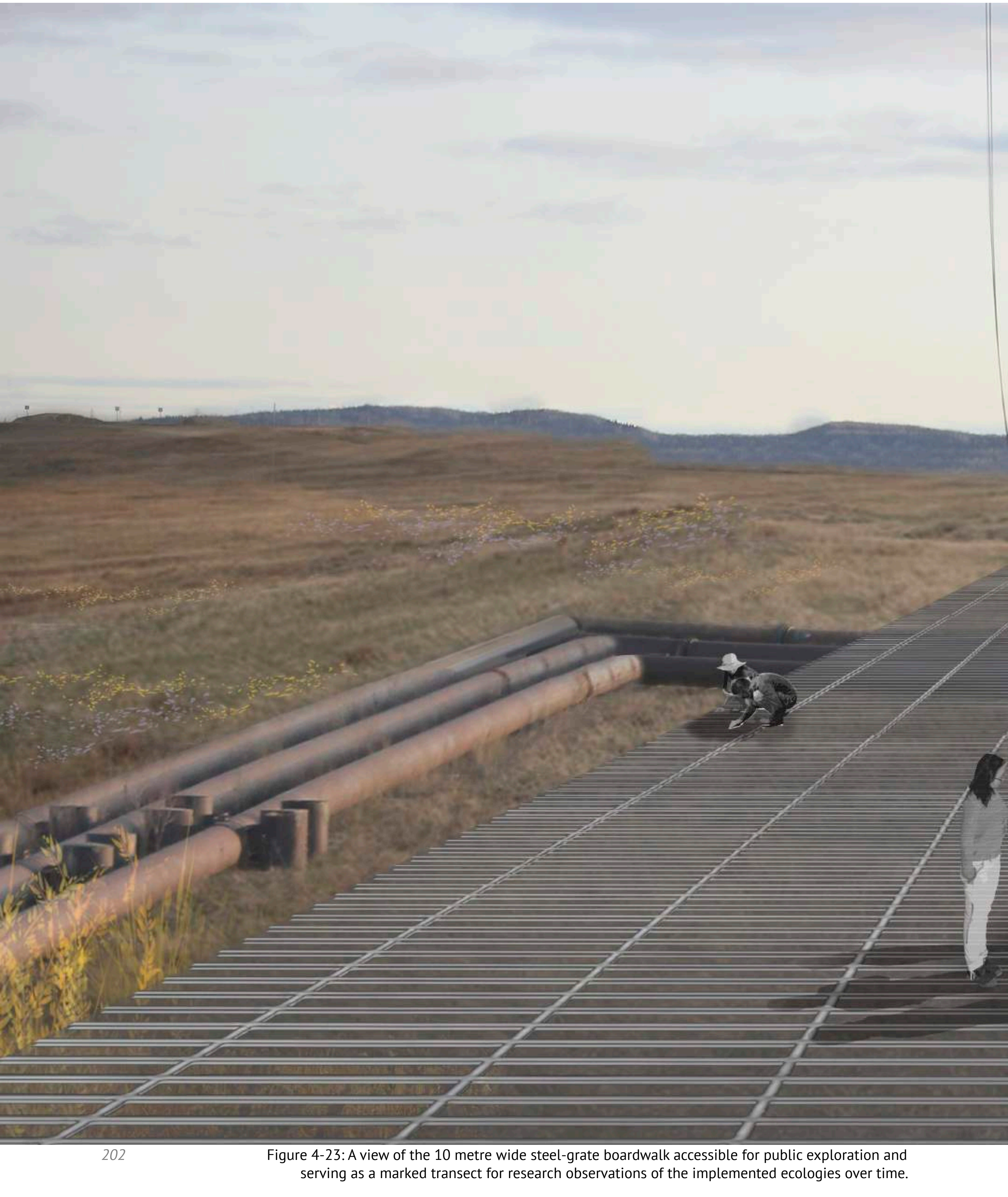


Figure 4-23: A view of the 10 metre wide steel-grate boardwalk accessible for public exploration and serving as a marked transect for research observations of the implemented ecologies over time.

Figure 4-24: Giants of Mining open air equipment museum along Highway 63's Syncrude Loop corridor.

Figure 4-25: The area surrounding Highway 63's Syncrude Loop with implemented ecologies and a 10 metre wide steel-grate boardwalk accessible for research and public exploration.

GRASSLANDS MIGRATION INITIATIVE

STRATEGIES SUMMARY

The three ecological strategies fit well within the larger Western Wildway Network strategy extension. Phyto-remediation supports the reclamation goal to detoxify soils on site. Alvar communities are well suited to areas with no soil and will build up soils with the spread of vegetative cover in harsh conditions. The mixed grasslands provide the opportunity to infill areas to promote a heavier reliance on grassland species. This supports an assisted migration of the grassland ecozone to the Athabasca Oil Sands region. These three strategies can be implemented across varying Canadian Oil Sands sites to create a land mosaic that represents the scars of production through new ecologies. The implementation of these strategies will act as a living lab in the testing of an assisted grasslands migration initiative.

Figure 4-26: Map of the Western Wildway Network with an overlay of the current range of the Great Plains grassland and projected grassland range within Canada (Adapted from Menke, 2017, Savage, 2011, p.22, and Rizzo and Wiken, 1992, p.50). A proposed extension of the Wildway includes the Canadian Oil Sands area.

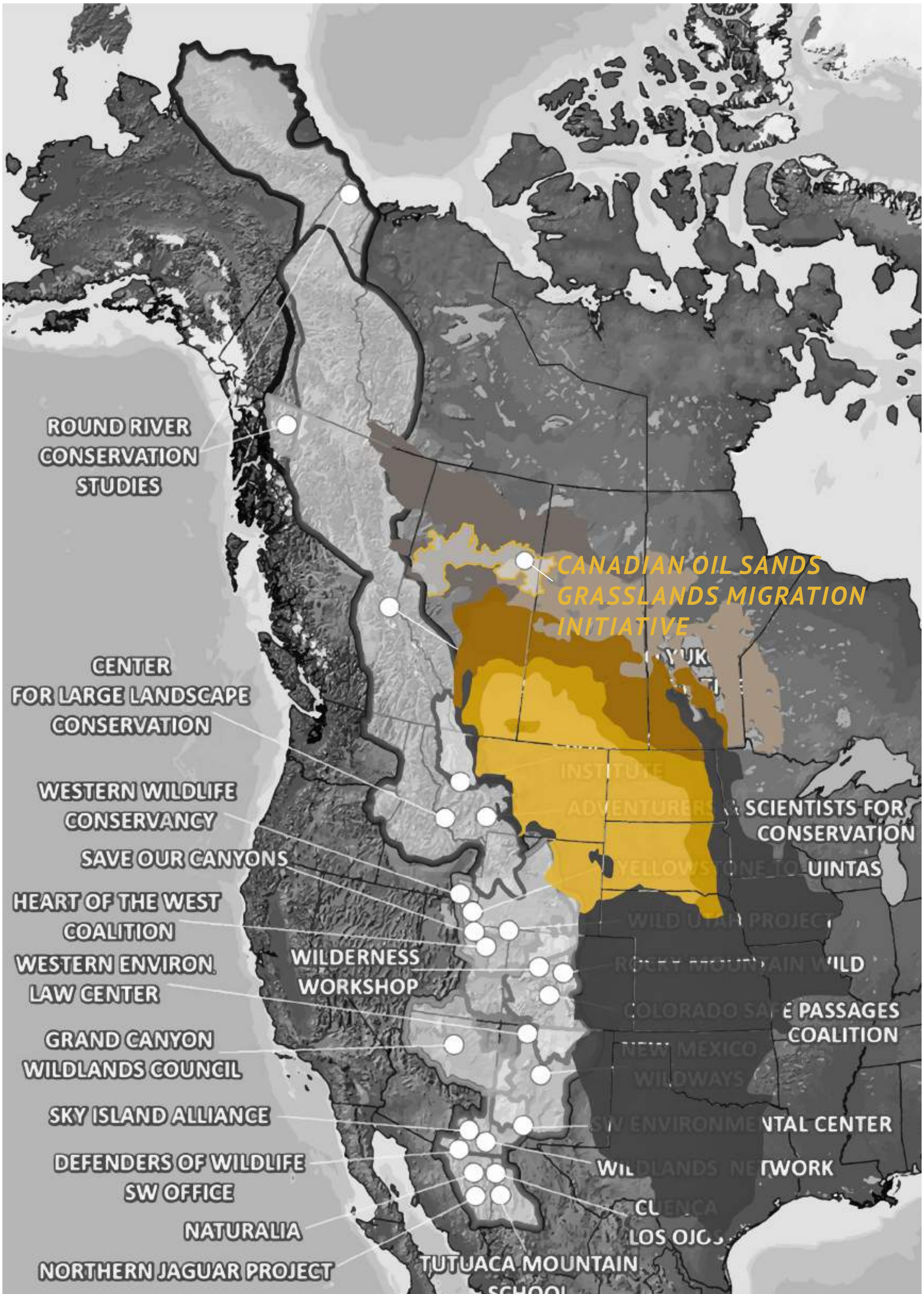

ROUND RIVER CONSERVATION STUDIES
CANADIAN OIL SANDS
GRASSLANDS MIGRATION INITIATIVE
CENTER FOR LARGE LANDSCAPE CONSERVATION
INSTITUTE
WESTERN WILDLIFE CONSERVANCY
ADVENTURERS & SCIENTISTS FOR CONSERVATION
SAVE OUR CANYONS
YELLOWSTONE TO UINTAS
HEART OF THE WEST COALITION
WILD UTAH PROJECT
WESTERN ENVIRON. LAW CENTER
WILDERNESS WORKSHOP
ROCKY MOUNTAIN WILD
COLORADO SAFE PASSAGES COALITION
GRAND CANYON WILDLANDS COUNCIL
NEW MEXICO WILDWAYS
SKY ISLAND ALLIANCE
SW ENVIRONMENTAL CENTER
DEFENDERS OF WILDLIFE SW OFFICE
WILDLANDS NETWORK
CUENCA LOS OJOS
NATURALIA
NORTHERN JAGUAR PROJECT
TUTUACA MOUNTAIN SCHOOL

Figure 4-27: Grasslands support the needs of a variety of wildlife amongst infrastructure of this landscape's industrial past.

ECOLOGIES OVER TIME
SPECULATIVE TIMELINE

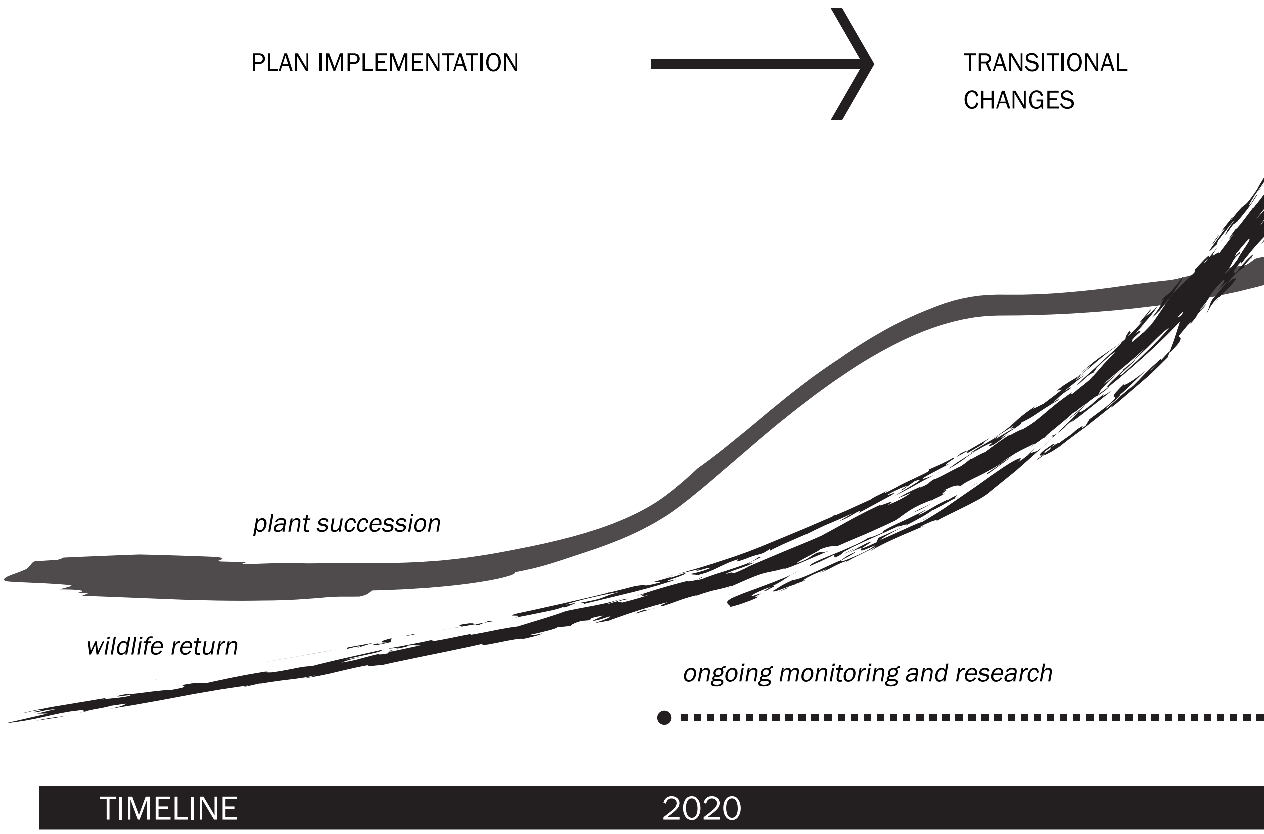
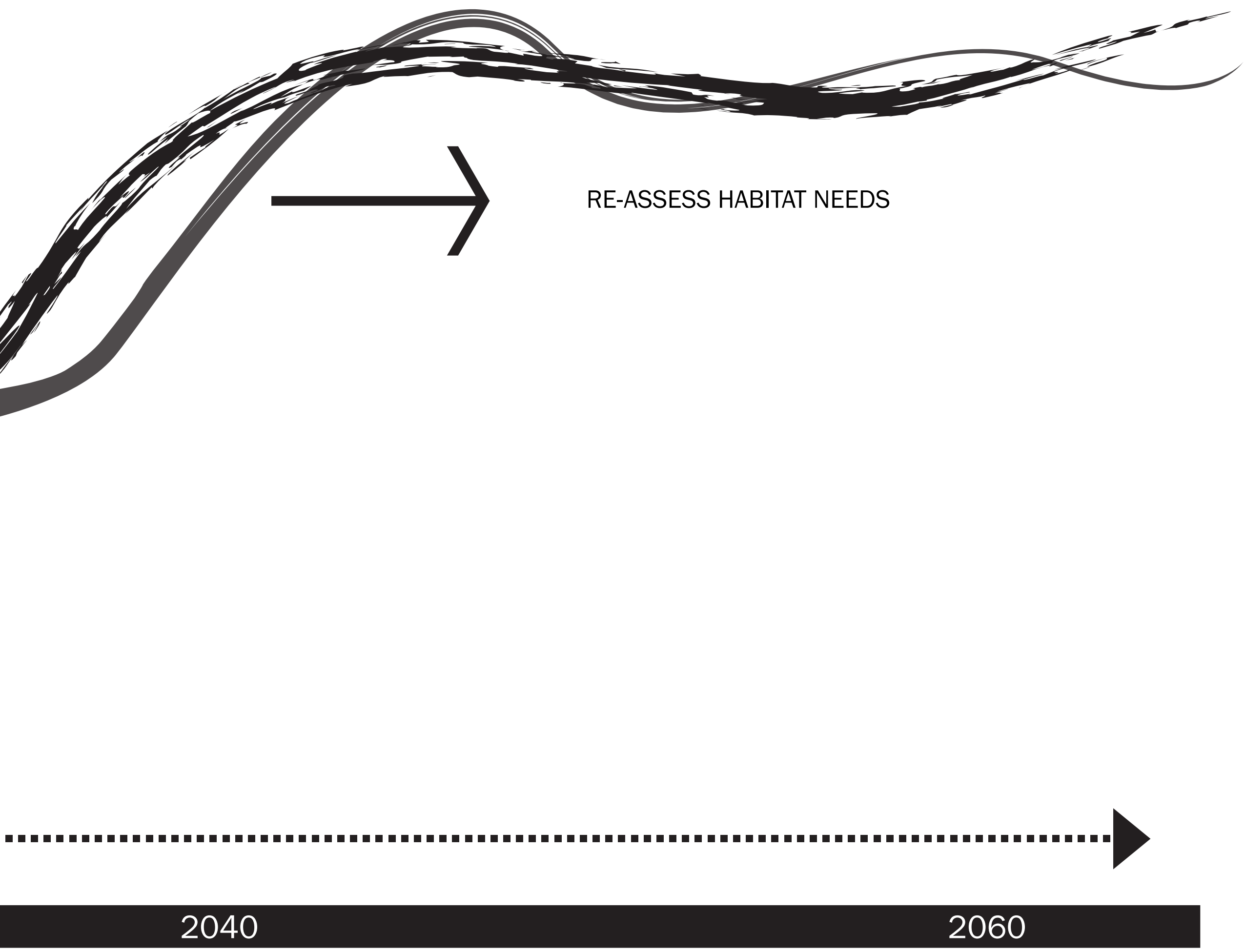


Figure 4-28: Speculative timeline of planting implementation, monitoring, and return of wildlife over time. A transitional change from cool- to warm-season grasses may occur 20 years in the future with a re-assessment of the site's needs following that.


RE-ASSESS HABITAT NEEDS
2040
2060

ECOLOGIES OVER TIME

ECOLOGICAL SUCCESSION

IMPLEMENTATION

Ecologies establish following implementation by the organisms of the site that return a different type of ecological function to this industrial ecology.

NEAR FUTURE

As ecologies grow, wildlife begins to return to the site where researchers and visitors can observe changes to this landscape.

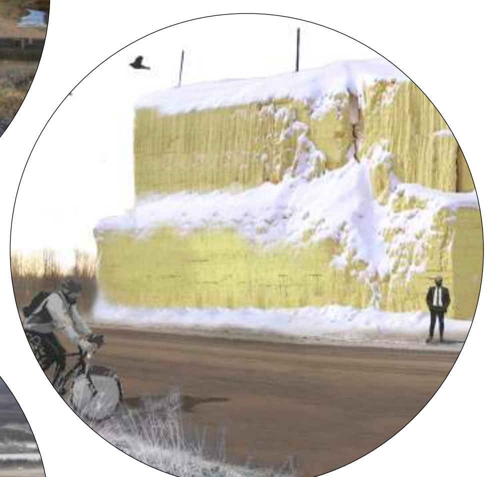
ADAPTATION OVER TIME

A new land mosaic is formed with areas of phyto-remediation, alvar, and grassland ecologies. These areas adapt to their site and support a range of wildlife among remnants of the industrial past.

[Figure 4-7] Edges, Voids

[Figure 4-9] Habitat

[Figure 4-23] Remnants, Corridors



[Figure 4-21] Sculptural waste, Corridors

[Figure 4-25] Corridors, Operations, Remnants

[Figure 4-27] Operations, Patches, Corridors

ECOLOGIES OVER TIME

EXPANDED FIELD OF ECOLOGICAL IMPLEMENTATION

The proposed ecological implementation strategies are represented by a transition from the expanded field of industrial ecology to the expanded field of ecological implementation. This final variation of the expanded fields represents a summary of the soil grouping, implementation scenarios, and ecological strategies.

The landscape components are established and adapted over time. The landscape transitions from an extraction environment to an insertion environment. Habitat thrives as an inserted *alvar abode*. Remnants, operations, and patches become the migrated *grassland drift*. Edges become sandy *phyto-beaches* along the voids which will *remain* to dry out before shifting to become a phyto-beach. Corridors remain as the *networks* throughout the site with the addition of the five kilometre physical transect boardwalk. Waste nodes remain as the sculptural waste of the industrial past as a *living land art*. The shift of focus for the site organisms changes from production to reclamation goals. Their departure from the site occurs after the reclamation practices and monitoring have been implemented. Perhaps a few organisms remain for ecological adjustments over time and choose to stay in this site as sculptural waste; a living art.

Figure 4-29: A summary of strategies from the expanded field of industrial ecology (Adapted from Krauss, 1985).

sculpture [nodes - waste] *LIVING LAND ART*

not architecture [voids] *REMAINS AS IS*

TOXIC SOIL

axiomatic structures [edges]

NO SOIL

landscape [habitat]

not landscape[remnants]

site construction [nodes - operation]

architecture [patches]

THIN SOIL

marked sites [corridors] *NETWORKS*

CHAPTER FIVE

IMPLICATIONS

LANDSCAPES OF FIT

CONCLUSIONS FOR RESEARCH

If the landscapes of avulsion are the open wounds of an industrial ecology, then the scars are the healed reminder of its past. The opportunities that this industry presents following its invasive extraction are the basis for proposing new systems of ecology that are suited to the future resilience of this landscape. The past, present, and future of the Athabasca Oil Sands extraction sites lend themselves to very different functions, capacities, and strategies. The past and present uses of this area aid in determining goals of a renewed ecological function with the capacity of a grassland ecozone migration and strategies for proposed insertion and future growth.

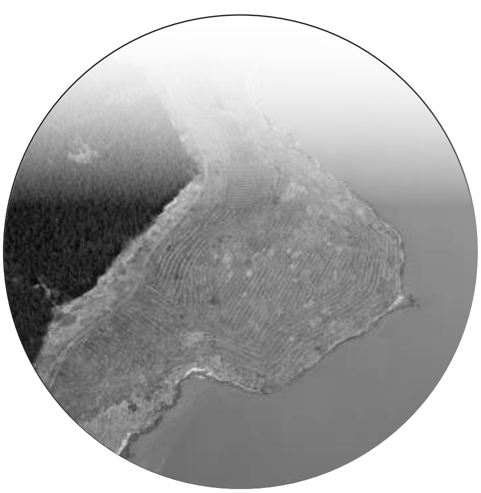
Phyto-remediation, alvar community growth, and an assisted migration of grasslands are ecological strategies proposed through an overall site schematic plan for the Tar Island site found in the Athabasca Oil Sands. These ecological strategies fit within the larger framework of the Western Wildway Network to propose an extension of this network across the Canadian Oil Sands. These strategies compliment the goals to support an extension of this network and can provide a living laboratory for further improvements to assisted migration and reclamation practices.

The strategies allow for a flexible application to other similar sites based on the soil scenarios criteria found on site. The potential exists for an expanded field of industrial ecology to be designated for sites across other areas of the Canadian Oil Sands using the ecological landscape components derived from the work of McHarg and T.T. Forman.

As the future ecologies are implemented and established as a renewed function of the site, the industrial ecology transitions to the production of ecology. The near future anticipates the return of wildlife to the site along with visitors and researchers who will explore and observe changes within this landscape. Adaptations over time create a new land mosaic of established strategies within this drastically altered landscape. Keystone species of this environment will make themselves at home among the remnants of industry. These areas make up the patterns of a scarred landscape renewed by design. The *lingua-oleum* incorporates new terms to describe the future ecologies. Alvar abodes, phyto-beaches, grassland drifts, networks, and living land art comprise the landscape components for the future use of this site. A new list of terms is not needed, but an amendment to the original *lingua-oleum* includes these new landscape ecologies as a final reclamation phase. The landscapes of avulsion become the landscapes of fit by working with opportune conditions and expectations for this area.

	[PAST]
Function	HABITAT
Capacity	BOREAL FOREST
Strategy	SUCCESSIVE SPECIES

	[PRESENT]
Function	ENERGY PRODUCTION
Capacity	REMOVAL OF EARTH
Strategy	AVULSION / EXTRACTION



	[FUTURE]
Function	ECOLOGICAL PRODUCTION
Capacity	GRASSLAND ECOZONE
Strategy	GROWTH / INSERTION

LANDSCAPES OF FIT

IMPLICATIONS

The proposed ecologic strategies apply a new land mosaic for the Canadian Oil Sands. Perhaps aerial landscape photographers will be drawn back to this site to document the changed patterns as viewed from above. The industrial scale of production and the scars of avulsion that are left on the landscape are evident among the growth of future ecologies. At ground level, a variety of implemented habitats allow for a return of traditional and cultural lands to the surrounding communities who have dealt with increasing negative impacts of industry. The economics of reclamation construction require less alteration to the extracted land while maintaining jobs at this site. A need for increased collaboration among landscape architects, soil scientists, environmental engineers, biologists, ecological researchers and other professionals will aid in achieving ecological succession through the proposed reclamation plan.

Reclamation of this area is developed through the proposed Tar Island schematic implementation plan. By having an overall framework that fits within a regional conservation plan, individual site reclamation can be completed under a common set of goals while addressing specific site conditions. Landscape architecture attempts to balance the needs of all interest groups. This proposal provides a valuable opportunity to improve on reclamation practices through landscape architecture design. Design at the larger site scale of Tar Island offers a comprehensive plan that has spatial implications for implementation at the ground level. The profession and practices of landscape architecture are presented with an important opportunity in addressing adaptation to climate change through the challenges and opportunities of this site.

My focus on the landscape and its ecological function has provided a limited focus in addressing reclamation practices through landscape architecture in the face of climate change. My hope is that this work sparks questions for further research of reclamation strategies that address issues and opportunities related to the Canadian Oil Sands. My own additional interests in this area look to the impacts on Fort Chipewyan communities, land use, and water quality issues. Another interest in this area would be the understanding of how wildlife and humans re-populate toxic sites. Many of the unknowns concerning the landscapes of the Canadian Oil Sands are revealed through research. The opportunities presented in this work inspires stewardship of the land through proposed reclamation strategies that promote the resilience of future landscapes.

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LIST OF FIGURES

LIST OF GIS DATASETS

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