AFTER LITHIUM

RECLAMATION STRATEGIES FOR
SALAR DE UYUNI, BOLIVIA

Derek Rayle

AFTER LITHIUM

MASTER THESIS

UNIVERSITY OF OREGON
DEPARTMENT OF LANDSCAPE ARCHITECTURE

← **Cover Bolivian Salt Flats** (Data from LANDSAT,2015)

AFTER LITHIUM
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SUBMITTED BY
Derek Rayle

PROJECT CHAIR
David Hulse, Knight Professor of Landscape Architecture

SUBMITTED ON
June 18th 2018
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› All the Interviewees who participated in this project

For their love and support :

› Family
› Friends

All maps of Lithium Pilot Plant are presented on **1 : 40.000 scale**

This project uses i
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explore the future
Lithium Pilot Plant
Uyuni, Bolivia, as
responds to the ris
global lithium dema

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landscape of the
in Salar de
its development
se and fall of
nd

it depicts a
speculative future
scenario and uses it to
explore the transition

through the
implementation of
post-mining landscape
reclamation

AFTER LITHIUM

MASTER THESIS

DEPARTMENTAL APPROVAL

AFTER LITHIUM
RECLAMATION STRATEGIES FOR SALAR DE UYUNI, BOLIVIA

SUBMITTED BY
Derek Rayle

SUBMITTED ON
June 18th 2018

Submitted in partial fulfillment of the
Master of Landscape Architecture
Department of Landscape Architecture
University of Oregon

PROJECT CHAIR
David Hulse, Knight Professor of Landscape Architecture

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Approval Date

COMMITTEE MEMBER
Chris Enright, PhD., Landscape Architecture

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Approval Date

ABSTRACT

This project uses interview responses from local, impacted people to explore the future landscape of the Lithium Pilot Plant in Salar de Uyuni, Bolivia, as its development responds to the rise and fall of global lithium demand. As technology changes, so do the materials that support it. Recent research suggests that lithium could become obsolete in the next fifty years despite current trends towards lithium-ion based technology. Such a shift could leave mass quantities of mining remnants and would constitute the next step in a continuous history of Bolivian resource exploitation.

This project explores a speculative future scenario where solutions for the gradual transition from current mining practices constructively deal with mining waste and prepare the study area for a post-mining era. Through this exploration, the project deviates from more standard approaches to mined landscape reclamation, which conceive of returning the landscape to its original state.

The overarching premise is that, if a reclamation program framework is established, it could permit the territory to transition to alternative, productive uses. Based on several local interviews and my personal evaluations about the future land use and cover classes, I developed a reclamation program for the study area depicted in a 2070 scenario master plan. The proposal establishes a new economy of infrastructure tourism in the region, using agriculture, energy production and celestial movements in a new form of territorial restructuring.

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↓ LIST OF ACRONYMS

MINERALS

KCL _ Potassium Chloride
MgCl2 _ Magnesium Chloride
B _ Boron
Li2Co3 _ Lithium-Carbonate
Nacl _ Sodium Chloride

STAKEHOLDERS

COMBIOL _ Corporación Minera de Bolivia
YLB _ Yacimientos de Litio de Bolivianos
GNRE _ Gerencia Nacional de Recursos Evaporiticos
FRUTCAS _ Regional Federation of Peasant Workers of the South Altiplano

TECHNOLOGY

CSP _ Concentrated Solar Power
SHC _ Solar Horizon Calendar

LAND PLANNING

LU _ Land Use
LC _ Land Cover
Salar _ Salt Flat

AFTER
LITHIUM
FOREWORD

↓ POINT OF DEPARTURE

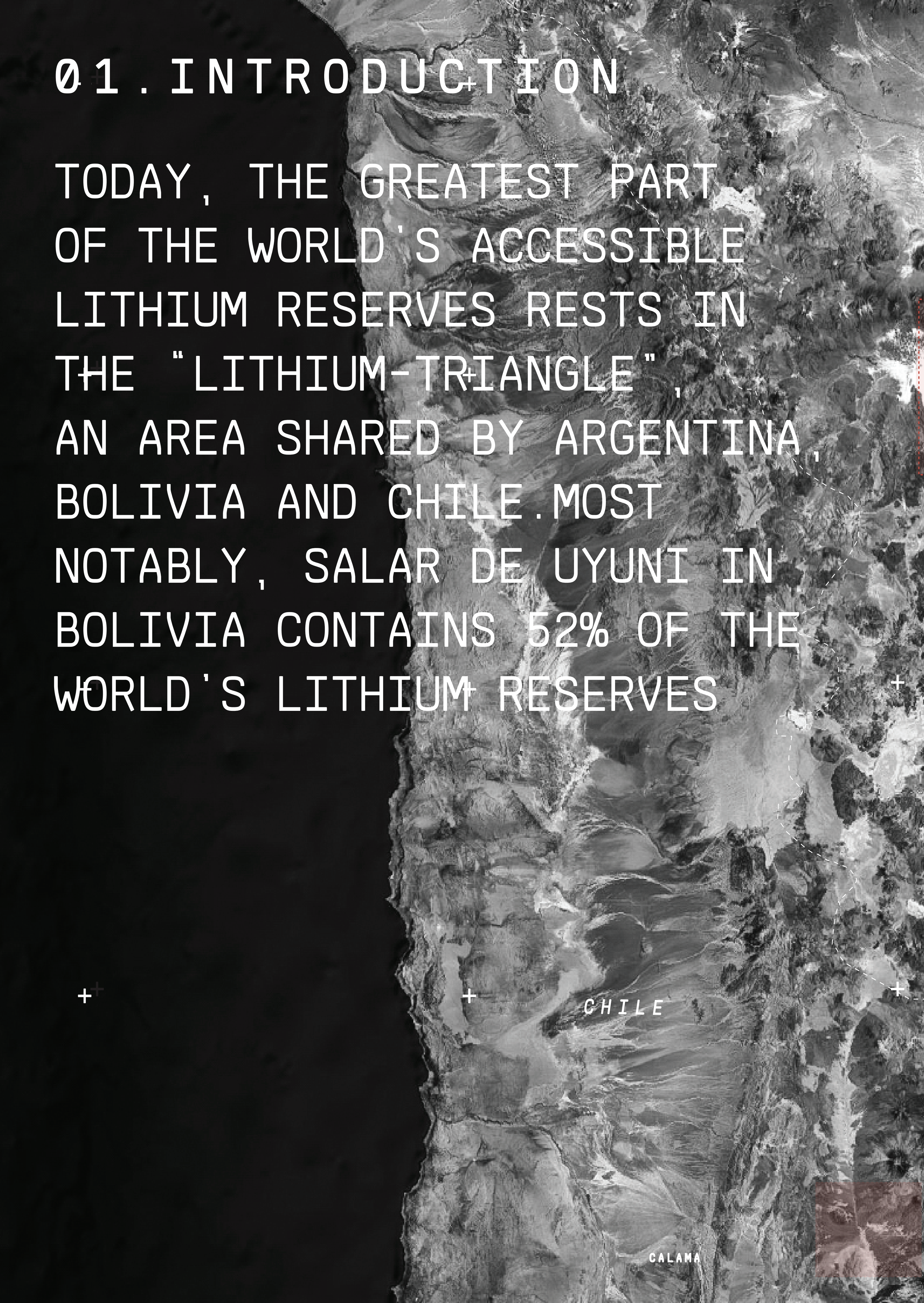
This research began with an aspiration to understand what constitutes a landscape of the Anthropocene, an environment based in a contemporary geological epoch in which people have become the dominant geologic force altering the earth (Tarolli; 2014). At a time in which our current technological path is increasingly shifting towards rare earth minerals, I was interested in understanding how landscapes influence the development of technological systems and how those technological systems in turn reshape the landscape. Recent discoveries have shifted the spotlight on mineral rich Andean territories to supply the forthcoming technological demand (Kraul;2014). However, South American countries have had an extensive mining history shaped by foreign interests. Would these new mining operations be any different from the past? Thus, I wanted to understand how a specific territory and its development would evolve with the rise and fall of the mineral in demand. I traveled to the study area and conducted a series of interviews with key stakeholders and regional professionals. Eight hours of recorded interviews were documented and transcribed. Their responses led to a vison aimed at a desired future for the territory. I contend that the foundation of this research is these interview responses. Often interviews in research documents are tucked away, out of sight, and buried in an appendix. For this reason, I have chosen to use an insert in the Operational Methods Chapter and Discussion + Evaluation Chapter to feature interviewee responses categorized into themes. Although this project has multiple visual components, I believe the collected stories and answers could be the most evocative.

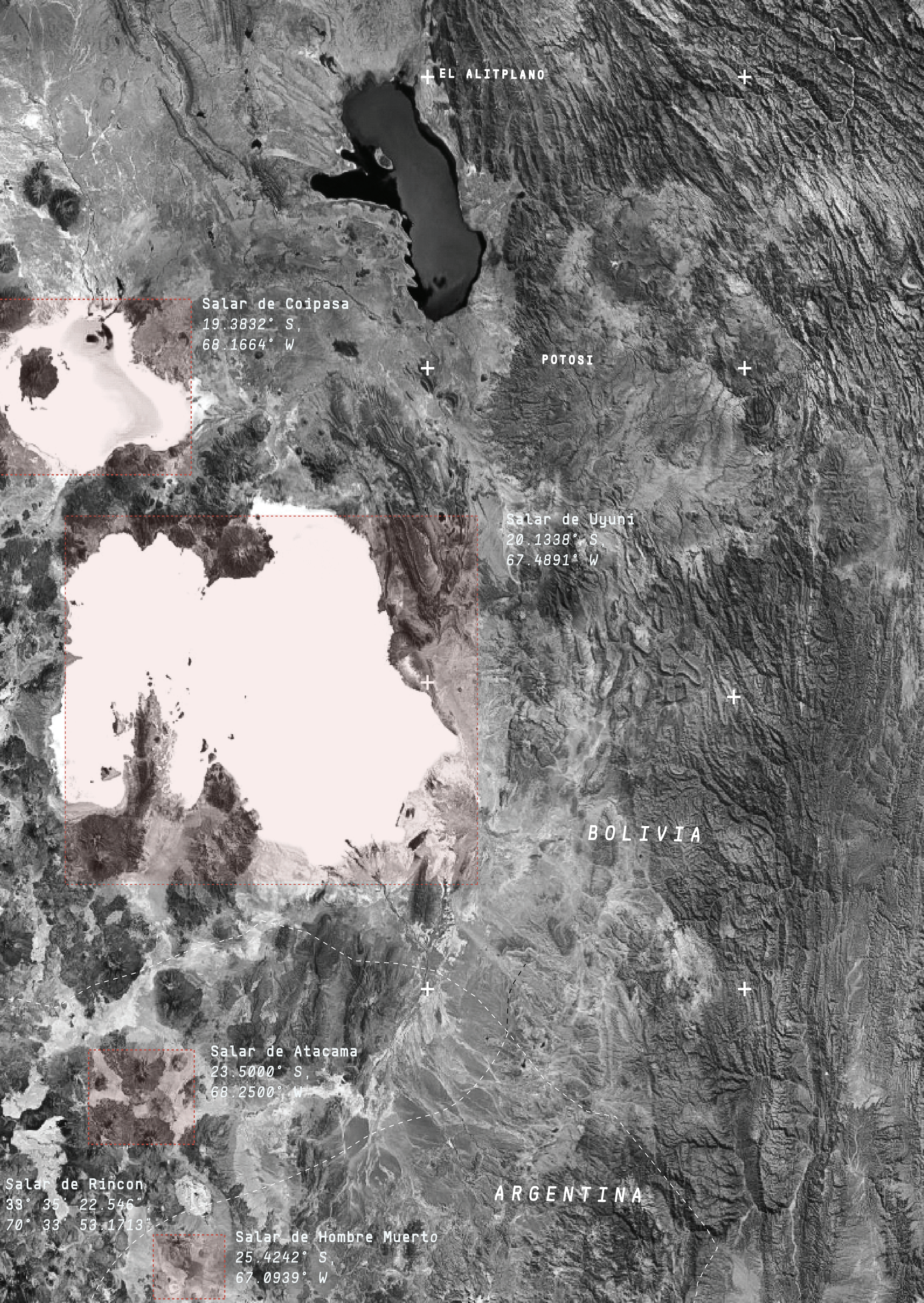
The insights provided by the interviewees were not simply shaped by politics, economics, technology, and environmental ethics; but by cultural values. The interviews shed light on a much broader issue of dualism, based on earth displacement to yield minerals of value. I contend that any extraction practice is a complex issue that requires the collaborative efforts of various stakeholders and disciplines. As fabricators of the current geological era, people hold the potential to mindfully shape the earth to endure beyond our current existence. To envision a future landscape narrative that supersedes historical trends, environmental consequences, and economic uncertainties allows the reclamation of a desired future.

→ ***IMG 0.1*** Lithium Brine Pool
(Photo by Derek Rayle)

01. INTRODUCTION

TODAY, THE GREATEST PART OF THE WORLD'S ACCESSIBLE LITHIUM RESERVES RESTS IN THE "LITHIUM-TRIANGLE", AN AREA SHARED BY ARGENTINA, BOLIVIA AND CHILE. MOST NOTABLY, SALAR DE UYUNI IN BOLIVIA CONTAINS 52% OF THE WORLD'S LITHIUM RESERVES




EL ALITPLANO
Salar de Coipasa
19.3832° S,
68.1664° W
POTOSI
Salar de Uyuni
20.1338° S,
67.4891° W
BOLIVIA
Salar de Atacama
23.5000° S,
68.2500° W
Salar de Rincon
33° 35' 22.546"
70° 33' 53.1713"
ARGENTINA
Salar de Hombre Muerto
25.4242° S,
67.0939° W

AFTER LITHIUM

INTRODUCTION

GLOBAL LITHIUM DEMAND

↓ WHITE GOLD

Every time we pick up a cell phone, look at a watch or plug in a computer, we are recharging a lithium ion battery. Increased global interest in renewable energies has triggered a transition towards lithium as it is a major component of battery fuel-cells (Tahil; 2007). Between 2003 and 2010, the world consumption of lithium increased over 12% per year (Roskill; 2011). Battery manufacturers have pursued the rare earth mineral as its structural makeup rendered it the lightest metal on the periodic table with extraordinary energy storage capabilities. As energy sources continue to transition from fossil fuels towards alternatives, lithium helps facilitate the shift. By 2060 the global demand for lithium is projected at 400 million metric tons, an increase of 350 million metric tons of lithium per year (Evans;2016). This rare earth mineral is not uniformly spread throughout the planet. Instead, it occurs in small units, in primarily igneous rocks and soils such as brine salt flats.

SALAR DE UYUNI

↓ SAUDI ARABIA OF THE ELECTRIC AGE

Ten thousand years ago, a series of lakes formed on the Andean Altiplano plateau. Today, the largest portion of the world's accessible lithium reserves is found in an area know as "The Lithium Triangle" (figure 1.1), which is bordered by three salt flats, Salar de Atacama in Chile, Salar de Uyuni in Bolivia and Salar de Hombre Muerto in Argentina. The Bolivian Salar de Uyuni stretches across ten thousand square kilometers and contains 52% of the world's lithium reserves (Evans, 2008; Tahil, 2007; MIR, 2008). Resources have always been extracted by the indigenous cultures of the region, but precious metals and stones were traditionally thought to be alive. Here, gold is not mined, it is grown, and mountains give birth to minerals.

"In my community, it is said the salt lake was once a vast plain where the Incan giants lived. Among them was the beautiful Tunupa, who was courted by all the men of the tribe. She chose to marry Cuzco, a strong young man, and had a son called Calicatin, who was soon born from their union. Cuzco would only leave her to trade salt, bartering for food and resources across the valley. While away on one of his journeys, he became infatuated with a pretty young woman called Cruzuña and they ran off together, never to return. Driven by curiosity, Calicatin went in search of his father and Tunupa chased after him. All day and all night she searched and tried in vain to bring her child back. The gods tired of the giant lies, secrecy and betrayal and decided to punish them all by petrifing them as mountains. When Tunupa began to cry, a volcano spewed ash and rock from the depths of the planet; rich in light elements like magnesium, potassium, boron, and lithium. While her tears rolled down her cheeks, her breasts began to lose the milk that her son had not suckled. Millennia of meltwater from the snowcapped peaks of her mountain seeped

→ COVER _ ***FIGURE 1.1*** Lithium Triangle
(Data from LANDSAT,2015)

1 : 250.000

down through her milk crystallized as the crusty salt skin that now stretches across the plateau".

(Teodoro Pierz and other community members from the province of North Lipez, Southwest Potosi; 2017).

Before the Spaniards arrived, indigenous groups referred to the salt lake as Lake Tunupa, but now it is identified as Salar de Uyuni (figure 1.2). The flattest, whitest place in existence, it is so large and consistent that orbiting satellites use it to calibrate their altimeters (WRI;2005). This natural wonder has become a lucrative asset and led Bolivia in recent years to be referred to as the "Saudi Arabia of the electric age" (Piers;2009). Despite this good fortune, the country ranks among the lowest in South America in terms of life expectancy, health, education, and basic services; and highest in inequality (INE; 2016). The region of Salar de Uyuni in the province of Potosi is considered the most impoverished area in the country (INE;2013). Nearly all the economic activity in the region revolves around salt harvesting, quinoa production, llama herding, mining, and more recently, tourism (REA;2009). For several decades, communities near the Salar have felt neglected; however, recent government interest in the region has began to alter their viewpoints (Teodoro Pierz;2017). In 2008, the Bolivian government purchased all land rights from surrounding communities and declared the Salar and its mineral resources a "Fiscal Reserve". Since 2010, the industrialization of Salar de Uyuni for lithium mining has taken a more central role in the anticipated future of the Bolivian economy. Evo Morales, the current President of Bolivia, has placed the lithium industry under the control of a division of the state-run mining corporation, Yacimientos de Litio de Bolivianos (YLB), a branch of the Gerencia Nacional de Recursos Evaporiticos (GNRE). Their strategy aims "to industrialize the evaporative resources of the salt flats in Bolivia, through sustainable, public and social projects, that respond to the regional, departmental and national development, that allows the responsible supply, in particular of lithium, to the international community" (COMIBOL EVAPORATIVOS;2009).

AFTER
LITHIUM
INTRODUCTION

TERRITORIAL
FACTS

Index

Govermental

↘ Fiscal Reserve
↘ Goverment Mining Site
↘ Brine Test Pump
↘ Light Duty Road
↘ Interstate
↘ Railway
↘ Town
↘ Village
↘ Border

Natural

↘ Major River
↘ Streams
↘ Agro pasture
↘ Agro quinoa
↘ Brush
↘ Salares (Salt flat)

El Planta Piloto de Lito

↘ Study Area

Salar de Uyuni

Context

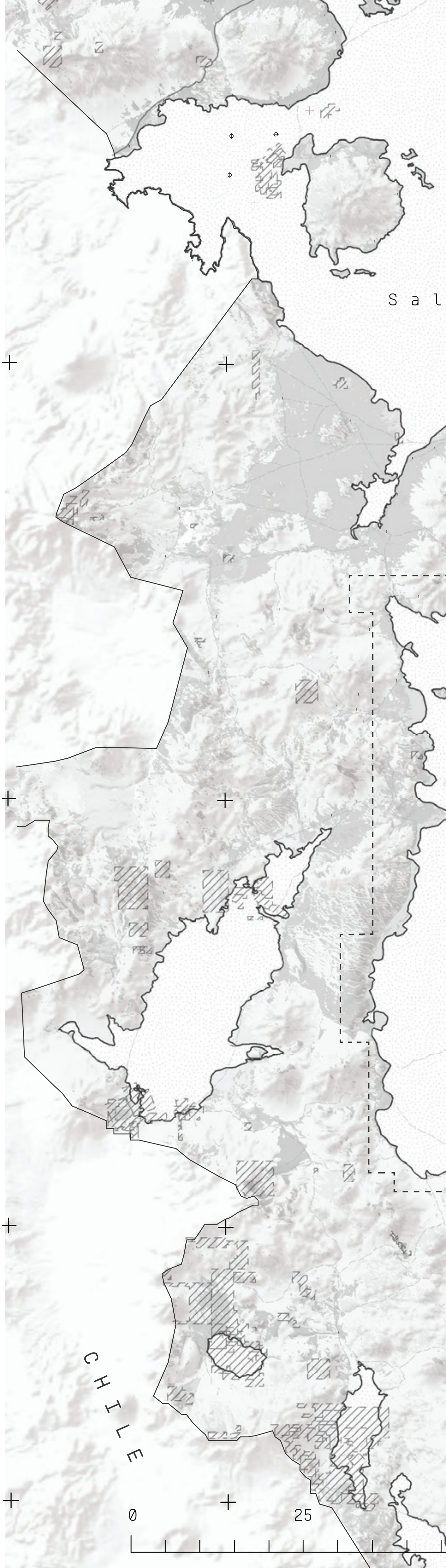
↘ Elevation	3854m
↘ Position	20°13'38" S, 64°89'01" W

Dimensions

↘ Expanse	10.582 km²

Climate

↘ Average in summer	21°c
↘ Average in winter	10°c
↘ AverageSnowfall	1 cm
↘ Average Rainfall	168mm



→ *FIGURE 1.2* Salar de Uyuni
(Data from GEOBOLIVIA,2017)
1 : 75.000


ar de Coposia
Tahua
Cerro Tunpa
Salar de Uyuni
Colchani
Uyun
El Planata Piloto
Chuvica
Sur Lipez
San Cristóbal
ARGENT
50
100
150
200Km

STUDY AREA

Index

Built Features

- Material refinement
- Barracks
- Waste storage
- Hydraulic pump
- Pump line
- Brackish water
- Infrastructure storage
- Evaporative pools
- Light duty roads

Mineral extraction sites

- Li2CO3
- KCL
- Mg
- B
- Evaporative pools medium concentration
- Evaporative pools low concentration
- Evaporative pools under construction

El Planta Piloto de Litio

Context

Elevation	3850m
Position	20.6000° S, 67.6100° W

Dimensions

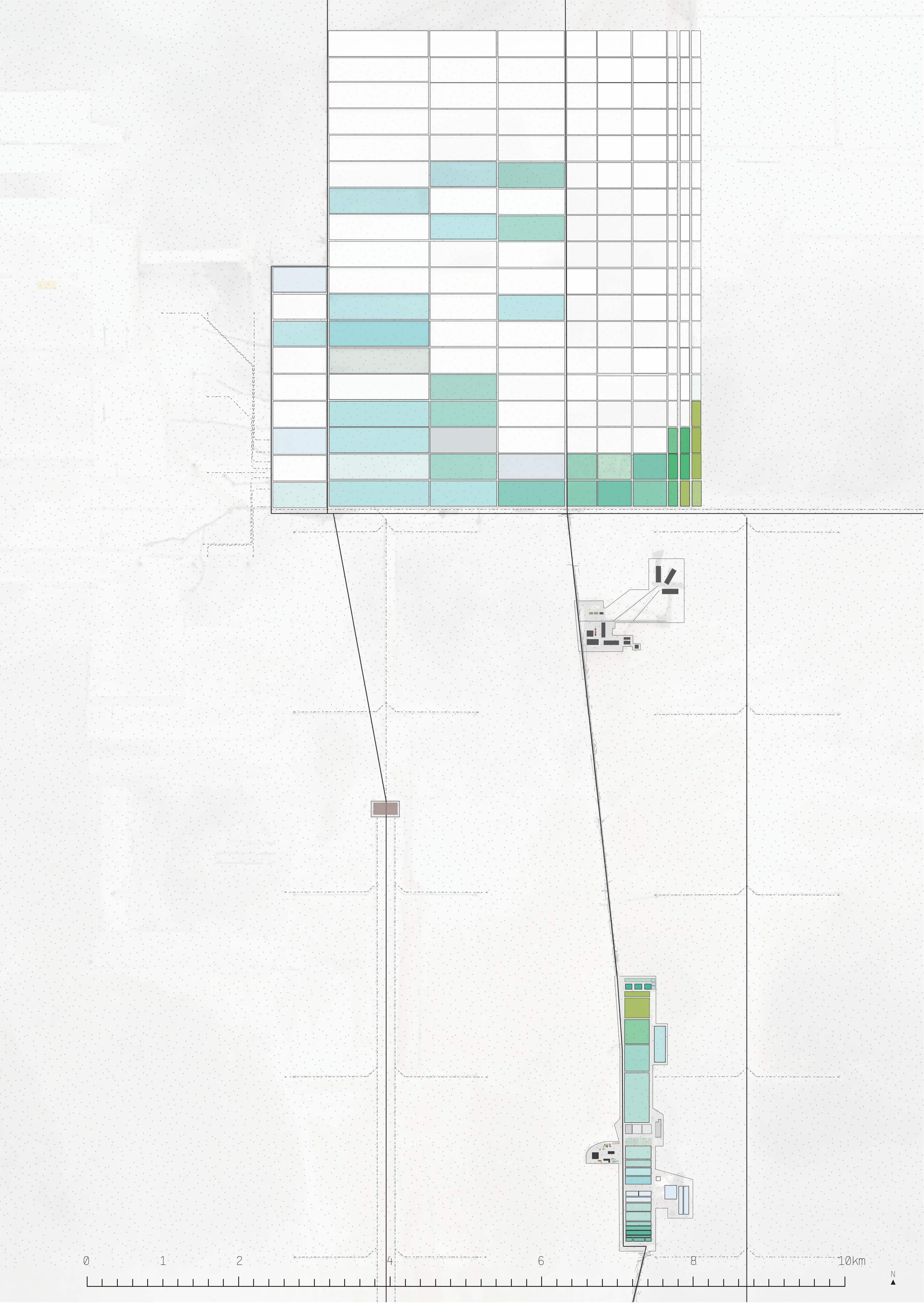
Expanse	2.100 ha

→ *FIGURE 1.3* El Planta Piloto de Litio (Data from COMIBOL,2017)

1 : 40.000

↓ EL PLANTA PILOTO DE LITIO

Energy production consumes not only the natural resources extracted from the earth to produce power – it consumes territory itself. At 2100 hectares, it is potentially the most expansive industrial project to be implemented in Bolivia, and will be constructed in Salar de Uyuni. Nested in the southeastern edge of the salt flat, it is the country's first evaporative mining project, El Planta Piloto de Litio (Lithium Plant) (Figure 1.3). Due to economic and technological constraint, the government has decided to implement the project in four phases. The first phase commenced with the extraction of potassium chloride (KCL), magnesium chloride (MgCl2), Boron (B) and lithium-carbonate (Li2Co3) over 81 hectares (YLB, 2010). Phase two, the most extensive stage of the project, occupies 2,000 hectares and will yield between 120,000 to 130,000 tons of Li2Co3 and 350,000 tons of KCL per year by 2025. The production of lithium-ion batteries and cathode materials concludes the third phase of the project that will take place off site in a nearby town, Nor Lipez. The final phase will be the development of nine micro evaporative mining facilities around Salar de Uyuni basin over a twelve-year period (COMIBOL;2015). Extraction displaces materials of value and creates unwanted by-products. Currently, mining remains are discarded in multiple open pit locations. The largest containment of chemical by-products is situated on the northeastern corner of the Lithium Plant. The continued growth of waste residues has been recognized by regional experts as a potential concern for the sensitive ecosystem.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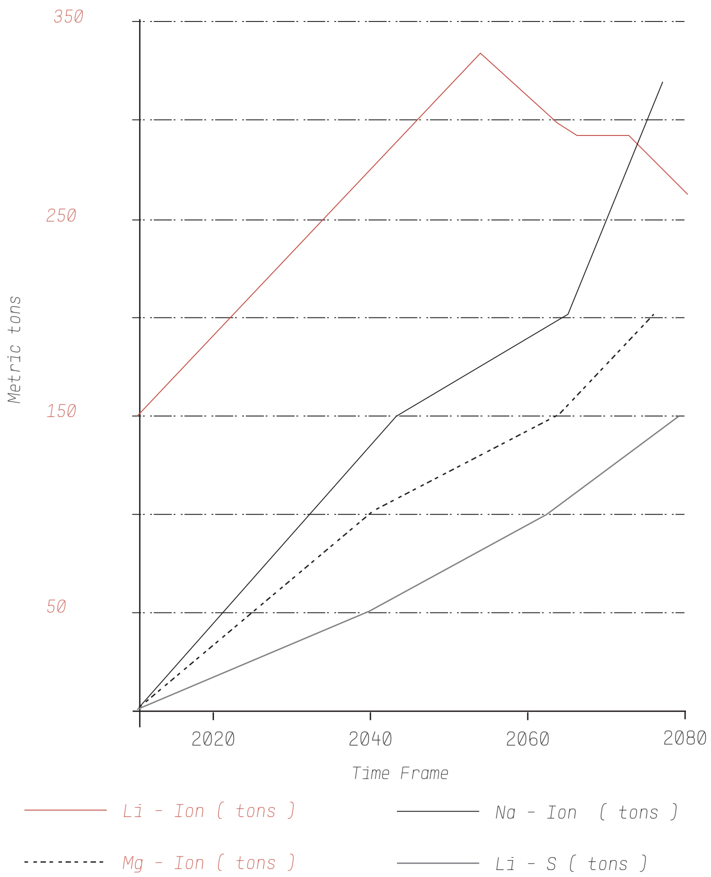
2
4
6
8
10km
N



↑ *FIGURE 1.4* E-Batteries Paradigm Shift
(Redrawn from Braga ; 2017)

As energy sources continue to transition from fossil fuels towards alternatives, lithium is said to help facilitate the shift. By 2060 lithium demand is forecasted to peak. At which time a transition will begin to other minerals that are cheaper, lighter and less geo-politically controlled.

↓ FINAL VOIDS

Mining is a spatial practice. Its infrastructure deploys at large scales to yield minerals of value. Extensive evaporative mining could denude environmental qualities of the landscape. Experts caution that the sensitive ecosystem in the Salar could be severely impacted by any large-scale mining project (Hollender;2010). Primarily, this is because the operation will require the use of chemicals, copious quantities of water, and the production of discarded by-products. Situated in an arid environment where average annual rainfall does not exceed 250mm, the limited water supply is essential for the inhabitants and ecosystem. A number of studies have been conducted on potential environmental effects of extensive lithium mining in the region; primarily, its effects on soil and water quality (Kszos et.al; 2010). The mass accumulation of sodium chloride (NaCL) sludge and powder was noted in the reports as a latent effect of industrial evaporative mining. Additionally, brackish water (water with increased amounts of salinity) and briny water (a water mixture of mineral and chemicals brine) were indicated as an impending threat to surrounding communities and the ecosystem. When mining operations are approved in Bolivia, it has never been a requirement for companies to plan for mines to be filled in or treated after they close (Kszos et.al;2010). Often gaping holes, also called "final voids", are remnants in the landscape. Bolivia has an extensive mining history due to its mineral wealth.

↓ RESOURCE CURSE

There is a curious phenomenon that social scientists call the "resource curse." Countries with large endowments of natural resources, such as oil and gas, often perform worse in terms of economic development and good governance than do countries with fewer resources. Paradoxically, despite the discovery and extraction of oil and other natural resources, such endowments all too often impede rather than further balanced and sustainable development" (Humphreys; 2007). Historically, the exploitation of Bolivia's natural resources has proven to be tremendously profitable for the elites and foreign corporations involved. In the province of Potosi, agricultural and mining practices have allowed the region to play a significant role in the country's economy. Cerro Rico (Rich Hill) in Potosi exemplifies the country's greatest legacy on how the resource curse has flourished. For nearly three centuries, this now hollowed mountain bankrolled the Spanish Empire with silver and tin. The city flourished during the 16th century and its population surpassed some of the largest cosmopolitan centers at that time. But, when gold was discovered in Brazil, the city and the mine were cast aside in an instant. The surrounding landscape was left with the toxic remnants of the mining operations and economic ruins from a deserted town. Potosi is still struggling today with its open wounds.

↓ OBSOLESCENCE

President Morales has repeatedly emphasized how the lithium industry is crucial to the growth, development and sovereignty of Bolivia (R. S. Goncalves; 2010).

The government has stressed that it does not want to be a mere exporter of raw material, but rather a hub where the entire chain of value-added activities involving lithium takes place. That includes, for instance, refinement of lithium, battery plants, and car factories in Bolivia.

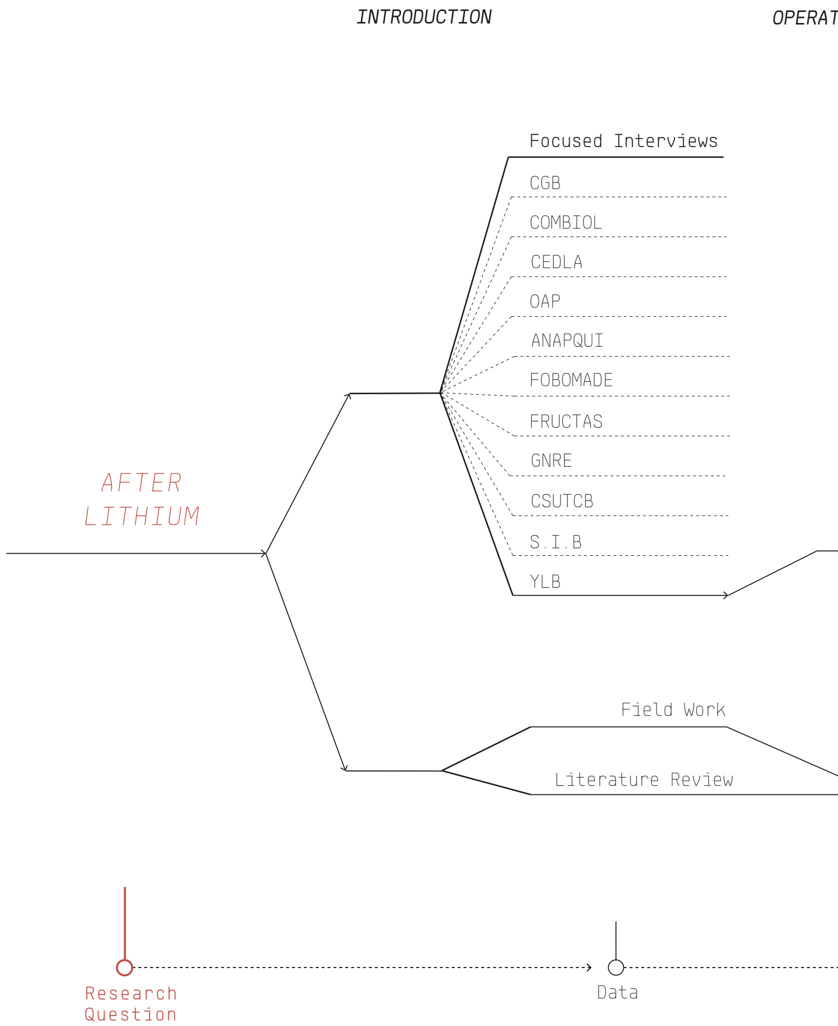
As technology changes, so do the materials that supply it. Today, recent industrial estimates predict an insatiable need for battery farms to store renewable energy such as solar, wind and tidal energy (Abate; 2017). Even though lithium may offer high-performance batteries, the mineral is still rare, costly and geo-politically controlled. In August 2017, researchers at Stanford University published a study on a sodium-chloride based battery that could store the same amount of energy as lithium-ion battery, but with substantially lower costs. These findings suggest that lithium could become obsolete in the near future, despite recent trends towards lithium-ion based technology.(see figure 1.4) E-batteries paradigm shift.

↓ RESEARCH PURPOSE

Extraction sustains our society. We depend on rare earth materials for our disposable electronics. However, technology is rapidly shifting. How can the future Lithium Pilot Plant in Salar de Uyuni be equipped for a post-lithium era? This project uses survey responses from local, impacted people to explore the future landscape of the Lithium Pilot Plant in Salar de Uyuni, Bolivia, as its development responds to the rise and fall of the global lithium demand. The intent of this project is to develop an exchangeable framework, which applies interview responses from local, impacted people and spatial analysis to evaporative mined landscapes as a way to project speculative reclamation strategies.

↓ APPROACH + METHOD

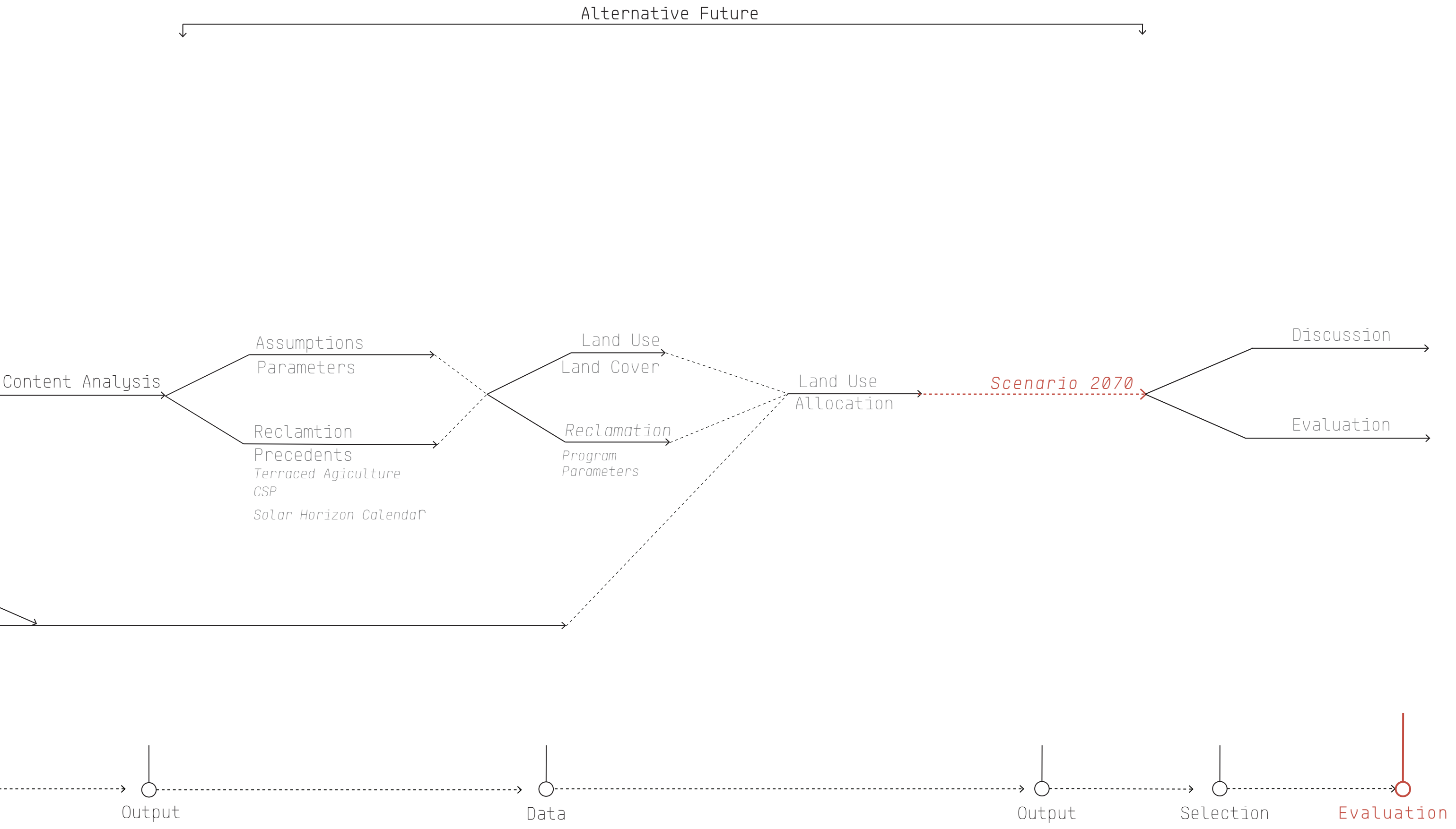
The project is guided by a series of methods in order to convert qualitative survey responses into quantitative information, see methods diagram (figure 1.5). A qualitative content analysis method is first used to process input from key interviews.These interview responses frame assumptions and define parameters for a speculative future scenario. The input is then expanded by a field visit, represented in synthesis drawings, and explored via theoretical and scientific research. The research includes reviewing existing literature to understand the method of alternative future scenarios, particularly for land and water use. A precedent study is conducted to comprehend landscape reclamation strategies for evaporative mines. I use mapping, diagrams and models to illustrate and explain lithium extraction in its multi-scalar, multi-temporal extents, and to investigate the potential for treatment of waste and water by-products at specific locations. The project concludes with a discussion and evaluation of the generated results. The evaluative component of the research is based on interviewees responses. A presentation of the results of the project was provided to the interviewees to gather further input on its adequacy in representing their visions for the future. The evaluation ends by comparing current land use and land cover patterns to modeled future patterns.



↓ FOCUSED INTERVIEWS

During the summer of 2017 I conducted interviews with regional professionals and agencies in Bolivia to gain further background knowledge on the lithium pilot plant, current mining practices used to fuel new green technology, and the future that awaits Salar de Uyuni if these practices continue. The landscape reclamation aspect of the research was informed by these conversations. The focused interviews frame assumptions and parameters for a speculative future scenario.

→ *FIGURE 1.5* Research Methods Diagram



CONTRIBUTION FROM LITERATURE

↓ CONTENT ANALYSIS

To construct assumptions and parameters that inform the speculative future, qualitative survey responses were processed into quantitative information. I used qualitative content analysis to examine the numerous survey responses in a systematic fashion. The method is best known for empirically identifying and clarifying topics of interest (Weber;1990). Qualitative content analysis was chosen for this project since it is typically used to dissect interview transcripts. The method can be understood as "an approach of empirical, methodological, controlled analysis of text or verbal data within the context of communication, following content analytic rules and step-by- step models, without rash quantification" (Mayring;2000). The ability to make inferences from the coded interview responses is essential for drawing relationships between the gathered answers and constructing the alternative future. Qualitative content analysis does not produce statistical significance. Instead, it uncovers patterns, themes and categories important to the surveyed population. This project uses the conclusions from the qualitative content analysis to form the speculative future parameters and assumptions. I argue that the ability to draw inferences from the coded data is highly subjective and solely based on the researcher's reasoning ability (Bradley;1993). However, despite its subjectivity, the method continues to be used by social scientists.

↓ ALTERNATIVE FUTURE SCENARIOS

Citizens have the potential to define narrative assumptions about future landscape trajectories through an alternative futures method. The framework of alternative future scenarios is used throughout the project to explore the implications of decisions about potential consequences of lithium mining in the Salar de Uyuni Basin. A scenario may be understood as "a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold" (Mohammed;2009). The spatial arrangement of land use and land cover types in a digital map defines an alternative future. Citizen stakeholders describe a future that scientists may then evaluate. Their insights may be used to help define the future transition rules and choosing future land and water conditions. The land-use and land-cover types play a key role within the representation and the evaluation of the future scenarios. This project intends to create a series of depictions of the future Lithium Pilot Plant over a sixty-year period using land use/land cover (LU/LC) data gathered from focused interviews.

↓ RECLAMATION

Salar de Uyuni will be altered by future mining operations, and the magnitude of these alterations will determine the extent of the environmental transformations. Through the use of reclamation or restoration practices, designers can cope with widespread environmental devastation and ecological uncertainty. Reclamation may be understood as the process by which derelict or highly degraded lands are returned to some form of productivity, and by which some measure of biotic function and productivity are restored. In designing the reclaimed landscape, Alan Berger presents the notion that through the incorporation of ecological succession, the designer has the potential to transition mining sites to a productive reuse (Berger;2008). Berger outlines several imperative steps in order to guide a successful ecological reclamation project, "(1) Ensure that the the substrate can support the growth of plants, (2) promote the growth of beneficial microorganisms, such as mycorrhizal fungi and nitrogen- fixing bacteria, (3) not limiting planting designs to plants that historically grew on site. (4) the acknowledgment of ongoing maintenance" (Berger;2008). How can the management of evaporative mining by-products reform the post mining-landscape? I assert, that through collaborative efforts with varied disciplines and the blending of technological solutions with culture, innovative strategies can emerge for such an endeavor to occur.

↓ RECLAMATION PRECEDENTS

Salar de Uyuni presents several challenges in implementing any type of reclamation project. Biotic stress in the Andean Altiplano plateau is intense due to high elevation (3850m) frost, frequent droughts, soil salinity, and temperatures down to -20 °C. How might landscape reclamation take place in an extreme environment during mining operations? I will review precedents for reclamation strategies that were developed by interviewee assumptions and parameters, and my own assumptions about the future landscape. The studies provide further insights for a proposed reclamation program and its specific parameters in an arid climate.

PROJECT SIGNIFICANCE

↓ IMPORTANCE

This project depicts one of many speculative scenarios that can serve as a reference for those working in the Bolivian lithium industry such as YLB, FRUCTAS (Federación Regional de Trabajadores Campesinos del Altiplano Sur) and environmental planners in this region pursuing a desirable alternative future in the face of economic and environmental uncertainty. Moreover, it could invite a dialogue with the people of Bolivia who seek a better future for the Salar de Uyuni basin.

↓ KNOWLEDGE GAPS

Research on lithium as the new "techno-paradigm" continues to draw attention from economists and car and battery manufacturers. Even with this attentiveness to lithium, there is a lack of insight about long-term evaporative mining practices in Salar de Uyuni and its potential to alter the region. Additionally, there is an absence of understanding about how the Lithium Pilot Plant could gradually transition from current mining practices to other economically viable solutions and reclamation.

GOALS + OBJECTIVES

↓ PROJECT AIMS

1. Use input from key interviews to define assumptions and parameters for a speculative future scenario.

2. Explore solutions for gradually transitioning from current mining practices while constructively dealing with mining waste and preparing the study area for a post mining era.

3. Depict one future scenario for the Lithium Pilot Plant from 2010, 2025 and 2060.

4. Construct a 2070 scenario master plan.

5. Present results to original interviewees.

02. OPERATIONAL METHODS

TWO METHODS FOR INFORMATION GATHERING WERE USED WHILE IN BOLIVIA. THE FIRST RECORDED STAKEHOLDER RESPONSES AND THE SECOND DOCUMENTED THE BIO-PHYSICAL CONDITIONS OF THE STUDY AREA

AFTER LITHIUM
OPERATIONAL METHODS

INTRODUCTION

↓ METHODS

Although this project emphasizes lithium mining, the methodological framework could be applied to all future evaporative mining sites in the Bolivian Altiplano. At its core, the framework addresses the four goals presented in the Introduction Chapter:

1. Use input from key interviews to define assumptions and parameters for a speculative future scenario.

2. Explore solutions for gradually transitioning from current mining practices while constructively dealing with mining waste and preparing the study area for a post mining era.

3. Depict one future scenario for the Lithium Pilot Plant from 2010, 2025 and 2060

4. Construct a 2070 scenario master plan.

5. Present results to original interviewees.

This project seeks to present one speculative future for the Lithium Pilot Plant. The process in which data are collected and amalgamated is essential for the goals outlined above. To review, this project used interview responses to gain further background knowledge on the Lithium Pilot Plant. The collected responses from the interviews were synthesized via content analysis that aided in framing assumptions and parameters for a speculative future scenario. Parameters are defined as numerical conditions about the future of the Lithium Pilot Plant, for example, the amount of territory required for evaporative mining pools. Assumptions are interviewee and my own personal perspectives about the future of the Lithium Pilot Plant. Personal perspectives can be subdivided into pre interview field visit and post interview field visit. A precedent study of proposed techniques for a mining reclamation program was carried out to identify strategies and parameters for constructively preparing the study area for a post mining era. Future land use and land cover pattern types for a 2070 scenario master plan were framed by the assumptions, parameters and precedent study.

OPERATIONS

As most future land use and land cover patterns are not currently present on the Lithium Pilot Plant, this project asserts that suitability analysis and aerial photography interpretation are appropriate tools in identifying plausible locations for future pattern types. The methods may be deemed as appropriate tools since they are already being used within land planning to identity suitable locations for alternative pattern types (Baker;2004). This project seeks to apply this established method of inquiry to a new end: projecting speculative future land use and cover typologies that gradually transition from current evaporative mining practices while preparing the study area for a post lithium era.

→ COVER _ ***IMG 2.0*** *Harvesting Brine* (Photo by Derek Rayle)

FOCUSED INTERVIEWS

↓ OPERATION 01

This project required multiple tasks to be completed prior to generating suitable locations for future land use and land cover patterns. Initially, during the Summer of 2017 interviews were conducted in La Paz, Uyuni and Nor Lipez, Bolivia. The ten interviewees represented regional professionals and agencies with expertise in agriculture, hydrology, engineering, geology, economy, evaporative mining and environmental studies (see figure 2.1). Two series of survey questions were constructed for governmental and non-governmental officials, intended to serve as a starting point for the interviews, which regularly transitioned into conversations (see Appendix_A). The content from these meetings was recorded in both analog and digital formats to be accessible for future referencing. Two methods for collecting information were used while in Bolivia. The first documented the bio-physical conditions at the study area and surrounding context. The second method recorded interview responses about value-laden qualities for the future Lithium Pilot Plant. I have chosen to use a pseudonym to protect the identity of the participantes involved in research.

CONTENT ANALYSIS

↓ OPERATION 02

To convert the interview responses into quantitative information, I used qualitative content analysis. This process allowed me to examine the various responses in a timely fashion while identifying and clarifying topics of interest. The output from the content analysis informed the speculative future assumptions and parameters portion of this research. The method involves a set of organized and transparent procedures for processing data. Qualitative content analysis is structured into a five step method: first, preparing the data; second, defining the unit of analysis; third, developing categories and coding scheme; fourth, coding all text; and fifth, drawing conclusions from the coded data (Weber;1990).

Data preparation began with transcribing the interview recordings and then translating the interview text from Spanish to English. The translated text was reviewed by a professional translator to ensure the accuracy of the content. Next, I defined the unit of analysis. In this case, since the data that were analyzed were from interviewee responses, the unit of analysis established for this project was the individual. A series of categories and a coding scheme was then developed to examine the interview response data. All twelve translated texts were coded using the established categories and coding scheme. One of the most critical steps within the final stages of the method is the ability to make inferences from the coded interviewee answers. This information is essential for drawing relationships between the gathered responses and speculative future parameters and assumptions. It's important to note, qualitative content analysis does not produce statistical significance. Instead, it uncovers patterns, themes and categories important to the surveyed population (Weber;1990). An overview of the systematic process is depicted in the Content Analysis Matrix (see figure 2.1) as well as the processes position in the project framework (see figure 2.2).

OPERATIONAL METHODS

SEPTEMBER INTERVIEWS

↓ STRUCTURED INTERVIEWS

Each participant was asked a few guiding questions, but the conversations were designed for data collection based on individual experience and opinion. The specific questions are listed in Appendix_A .Two series of survey questions were constructed for governmental and non-governmental officials, intended to serve as a starting point for the interviews, that regularly transitioned into conversations. To record these conversations, I used note taking and an audio device during the interviews and I will use a pseudonym to protect the identity of the participates.

INTERVIEW RESPONSES

↓ SAMPLES

Listed below is a small sampling of the numerous responses collected from several hours of interviewing governmental agencies and local officials. The responses have been categorized into themes which were used for the content analysis process of this research. The listed themes are: infrastructure, waste, technology, environmental impact, economy, politics.

THEMES

↓ POLITICS

"Let me make this very clear for you to hear. I'll try to say it in English for you. The previous imperialist model of exploitation of our natural resources will never be repeated in Bolivia. Maybe further down the line there could be the possibility of foreigners accepted as minority partners, or better yet as our clients. This is our ideal. We want to overcome the so called curse. "

- Elisandro Rincón Jáquez. Engineer

"Since then, we've decided to exploit our natural resources for our own benefit, because we see companies that come here and exploit and loot and all that's left is toxic waste, ruins and cemeteries. "

- Periandro Lozano Ulibarri. Farmer

OPERATIONAL METHODS

SEPTEMBER INTERVIEWS

"The current political situation in Bolivia outlines the need for this country to develop its own state and social project. Whose purpose is to empower the state and the country via a domestic industry that produces and markets lithium derivatives and other minerals found in the brines of the Salar de Uyuni "

- Lemuel Esperanza. Engineer

"We want to have the best knowledge to get the most benefit for the country. We don't want to act too hastily or precipitate any political action such as we've experienced with sliver and tin"

- Antares Castro Riojas. Geologist

"Many people say that our natural resources are a curse others say it's a blessing from god"

- Teodoro Pierz. Community member from North Lipez, Potosi

↓ INFRASTRUCTURE

"We are certain that in five year Bolivia will produce at least 30,000 tons of lithium carbonate. These are not our dreams, this is our strategy. We've already started to implement. Within five years we hope that these four plants will be fully operational. And in twenty years we plan to have hundred plants operational"

- Elisandro Rincón Jáquez. Engineer

"We depend on hydroelectric projects in the north to power the brine pumps, generators and overall mining process. This source, often is not dependable and occasionally we have outages. We should be powering our own energy right here".

- Nacho Ontiveros Bernal. Extractor

"Uyuni has much more to offer than just it's minerals. There is so much sun here we could be powering this country."

- Galo Tejada Villegas . Economist

"We want to become the energy hub of South America. Harnessing the renewable power and transporting it throughout the country and beyond. Uyuni has very unique traits. The white salt ground creates a very high albedo. Which in theory you could use two solar panels to collect the suns rays and the reflected rays off the ground. Now where else can you do something like that? "

- Lemuel Esperanza Bermúdez. Engineer

"The sun is much stronger when you are at these altitudes, you know. Why isn't somebody collecting it? I don't know. It seems like there is a potential lasting future in that."

- Rafel Meraz Ávila. Environmentalist

↓ WASTE / ENVIRONMENTAL IMPACT

"Now obviously, we have to use some chemicals during some stages of the process- that's inevitable. However, our true intention is not only to obey Bolivians environmental laws but also that our industrial processes be the least harmful on the environment, water resources, soil, air as possible."

- Elisandro Rincón Jáquez. Engineer

"We're paying a lot of attention to this. They'll building pools but our fear is that perhaps chemical residues will contaminate."

- Periandro Lozano Ulibarri. Farmer

"Like any mining process, it is invasive, it scares the landscape, it destroys the water table and it pollutes the earth and the locals wells. This isn't a solution

SEPTEMBER INTERVIEWS

for "clean energy", its not a solution at all."

Reuquén Pena Perales. Tour Guide

"There's no information, no water use nor hydrological studies, so how can they begin to project what the long-term effects might be? This is supposedly a project to improve the region, but what if it makes living impossible? How could it be called sustainable development?"

- Pelayo Llarnas Cantú. Hydrologist

"Not one environmental impact assessment has ever stopped a potentially risky project in Bolivia. And the worst of all is that Bolivia's constitution does not require mining companies to create a "closing plan for extraction activities". So these areas are hollowed, abandoned and the landscape remains in ruins."

- Alan Duran Echevarría. Environmentalist

"There is not enough water for the people, for the factory, for the tourism. So, there needs to be some type of the water. We need a study of the real effect of the contamination of the environment"

- Galo Tejada Villegas. Economist

"Mining is a complicated story in Bolivia, We live with mining, it's part of every-one's livelihoods. It's embedded in their culture. There are little mining gods they pray to that will help them show where "gold" is."

- Rafel Meraz Ávila. Environmentalist

"You need solvent, chloric acid, all stuff that will contaminate the environment and the water. If you see a gold mine there are no trees—the same will be true in the Salar de Uyuni,"

- Alan Duran Echevarría. Environmentalist

"I am in love with lithium. Because I think it's the last opportunity for Bolivia to end poverty. But we have to move very fast, otherwise the country will lose a window of opportunity,—the last opportunity."

- Galo Tejada Villegas. Economist

"Some so-called experts tried to convince us to start with a massive production, but we know that wasn't the best course of action." he says. "In the capitalist system, nothing is certain."

- Periandro Lozano Ulibarri. Farmer

"The Ministry is focused on production rather than finding a market, They may end up putting an enormous amount of effort into production and find themselves with no one to sell to. Its ridiculous—first you need a market."

- Galo Tejada Villegas. Economist

"We are certain that in five years time Bolivia will produce at least 40,000 tons of battery grade lithium carbonate."A significant amount of this will be used inside the country for the purpose of manufacturing battery-related products: this means we'll be producing cathode materials [to make battery electrodes] at an industrial level and eventually a battery manufacturing plant with cathodes made in Bolivia"

- Elisandro Rincón Jáquez. Engineer

"What will they do when lithium is no longer needed? When something lighter, stronger and faster comes along?"

- Reuquén Pena Perales. Tour Guide

SEPTEMBER INTERVIEWS

"By Bolivia, for Bolivia, in Bolivia."

- Nacho Ontiveros Bernal. Extractor

"If they're wanting to compete in a global market, they have a hell of a long way to go technology-wise".

- Rafel Meraz Ávila. Environmentalist

" The lithium dreams of this country will one day come to an end".

- Periandro Lozano Ulibarri. Farmer

OPERATIONAL METHODS

↓ UNDERSTANDING LOCAL PERSPECTIVES

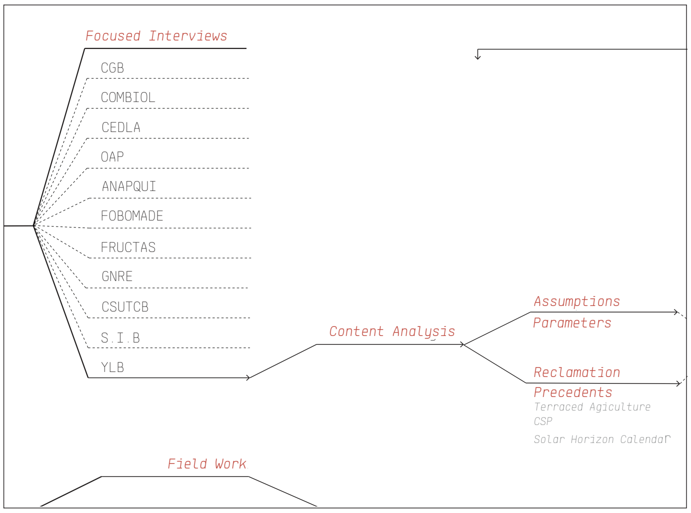
Two broad categories were established from the content analysis process: alternative energy and legacy.

↓ ALTERNATIVE ENERGY

The first assumption noted is that the energy needs of the mining process and country were important to the interviewees. To maintain evaporative mining, the process requires electrical energy at various stages. The power used to sustain the Lithium Pilot Plant is currently sourced from off site power plant facilities (COMIBOL;2008). Despite Bolivia producing its own energy, the country has seen an increase in power demands and shortages in recent years (WORLDDATA; 2017). A popular theme from the interviewees was the future Lithium Pilot Plant should incorporate alternative forms of energy to sustain itself and support the local region. Solar power was suggested by interviewees as the best suited alternative energy form, given annual irradiance conditions in Salar de Uyuni. Several interviewees envisioned the Lithium Pilot Plant transforming into the "energy hub of South America" where large quantities of power could be harnessed and exported to other neighboring countries.

↓ LEGACY

The second assumption indicated a common premise that the future Lithium Pilot Plant should actively mitigate the potential environmental consequences through productive solutions.The Lithium Pilot Plant is potentially the largest industrial mining project to be realized in Bolivia. The future significances were understood in two ways by the interviewees. First, the future project presents potential environmental repercussions.If not addressed properly,the implications could alter the surrounding region's hydrologic system. Second, the territorial extent of the project will leave remnants across the study area. A shared interest among the interviewees was that a Future Lithium Pilot Plant should mindfully cope with the potential landscape traces left by the mining practice.



→ *FIGURE 2.1* Content Analysis Matrix
(Data collected from interviews)

↑ *FIGURE 2.2* Postion in Project Framework
(*From Research Methods Diagram*)
The Operational Methods Chapter presents several steps used to collect information while at the study area.

Engineer | Geologist | Farmer | Environmentalist | Hydrologist | Engineer | Environmentalist | Extractor | Tour guide | Economist

Hand Written Notes

Audio Recordings

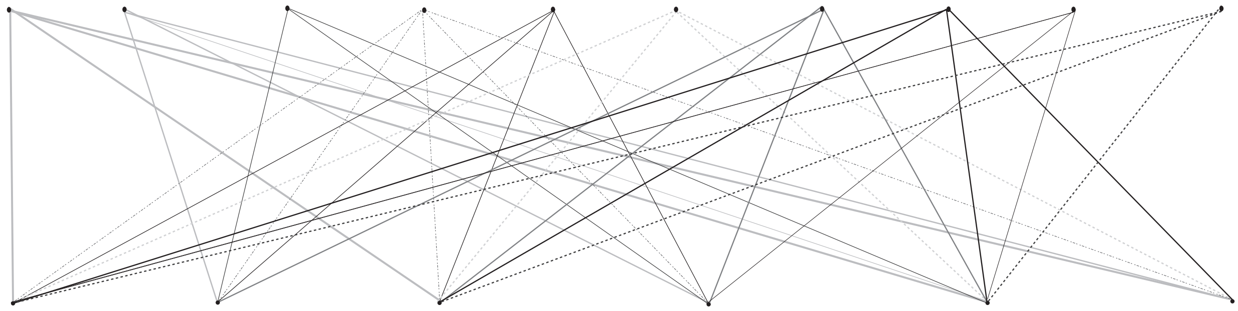
Transcribe Spanish to English

Transcription Review by Translator

Data collected from Interviewee → Unit of Analysis to establish → **Individual**

Transcribed Interviews in Numerical Order

01 02 03 04 05 06 07 08 09 10



(IF) Infrastructure | (W) Waste | (T) Technology | (EI) Environmental Impact | (E) Economy | (MD) Mineral Demand

Alternative Energy

"Salar de Uyuni could become the energy hub of South America. Providing much more than just minerals."

- Nacho Ontiveros Bernal. Engineer

A popular theme from the interviewees was the future Lithium Pilot Plant should incorporate alternative forms of energy to sustain itself and support the local region

Legacy

"What will remain in the Salar after large scale extraction ?"

- Requén Pena Perales Hydrologist

A shared interest between the interviewees was the Future Lithium Pilot Plant should mindfully cope with the potential landscape traces left by the mining practice.

ASSUMPTIONS+
PARAMETERS

↓ OPERATION 03

The information I learned from the content analysis aided my understanding of stakeholders' current and future values for the study area. The assumptions portion of this research can be divided into four section: first, my own personal assumptions of the study area that were informed by research prior to arriving in Bolivia, second, personal speculations of the study area that were shaped by the information gathered from these conversations, third, interviewee assumed outlooks for the present state of the Lithium Pilot Plant, and fourth, interviewee opinions of the future Lithium Pilot Plant. The assumptions table highlights the core anticipated perspectives for the study area (see table 2.1).

↓ PARAMETERS

Upon distilling the content analysis assumptions, I realized I was unable to find specifications about detailed parameters for the future Lithium Pilot Plant. For example, I did not gather content that clarified territorial extents of future waste management locations. Having only one series of interviews limited the information I was able to collect. The alternative future parameters created from knowledge that was not collected from the interviews were created by me interpreting the results of the content analysis. The parameters diagram highlights the current and future parameters for the study area speculative future. (see table 2.2).

↓ ALTERNATIVE FUTURE

The future trajectory of the Lithium Pilot Plant faces technological, political and economic uncertainties. The scenario in this project is not intended to be a prediction of a possible future state of the landscape, but rather an alternative image of how the future could progress. Defined parameters and assumptions that were distilled using the content analysis helped form the spatial arrangement of land use and land cover types for a 2070 scenario speculative future.

→ *TABLE 2.1* Assumptions Chart
(Data collected from interviews)

→ *TABLE 2.2* Parameters Chart
(Data collected from interviews)

Assumptions	Type	Numbered Description
↘ Personal	Pre - Interview	01 _ "The communities surrounding Salar de Uyuni are anticipating improved economic opportunities as result of lithium"
		02 _ "Future extraction will expand at unprecedened rates across Salar de Uyuni"
		03 _ "Foreign technologies will be vital to improving the lithium extraction process"
↘ Personal	Post - Interview	01 _ "Industrial activities could be diversified with other land use types"
		02 _ "Renewable energy is vital for remote mining operations"
		03 _ "Future mining automation may limit human employment at mine and destabilize local economy"
↘ Interviewee	2017	01 _ "The mass quantities of waste should be studied, controlled and ideally recycled into the mining process"
		02 _ "Dependable renewable energy should be considered to aid daily electrical demands"
		03 _ "A complete industrial phase should begin within the next two to three years. "
↘ Interviewee	2070	01 _ "The Lithium Pilot Plant will redefine Bolivian mining history. It will not succumb to foreign corporations or an environmental disaster"
		02 _ "The Lithium Pilot Plant should be able to adapt to the technological, economic and political uncertainties"
		03 _ "Solar energy should be deployed for mining practices and potentially regional use"
		04 _ "Some form of preventative measures will need to occur in order to avoid large scale environmental alterations. "

Parameter	Year	Bases
↘ Infrastructure	2018	01 _ Planned expansion of all evaporative pools to meet industrial mining phase goals. Area to be constructed is in the northern potion of the study area.
↘ Infrastructure	2070	01 _ Mining operations will permit varied uses not just extraction practices. Operations will support the harvesting of a variety of minerals. Planned expansion 500 - 700 ha.
↘ Enviromental Impact	2070	02 _ The Lithium Pilot Plant should be actively mitigating waste processes.

AFTER LITHIUM

OPERATIONAL METHODS

FIELD WORK

↓ OPERATION 04

While I was in Bolivia, I conducted landscape analysis to understand and depict the complexities and realities of the territory. A multifaceted analysis approach required the use of diverse tools to collect and document insights. Drone surveillance was used to obtain higher resolution aerial imagery of the Lithium Pilot Plant and its surrounding context. Photography was used for the purpose of recording human-scale perspectives of the study area and the nearby region (see Appendix_B). Of the limited vegetation that was encountered in the proximate area, botanical trimmings were taken to document species. GPS recordings were noted at the locations of each photograph, drone flight and botanical trimming to serve as an additional spatial reference for the collected materials. A variety of insights were gained from the landscape analysis portion of this project, which later aided future steps of the research. The field work map displays the spatial referenced data collected during the field work (see figure 2.3).

PERSONAL ASSUMPTIONS

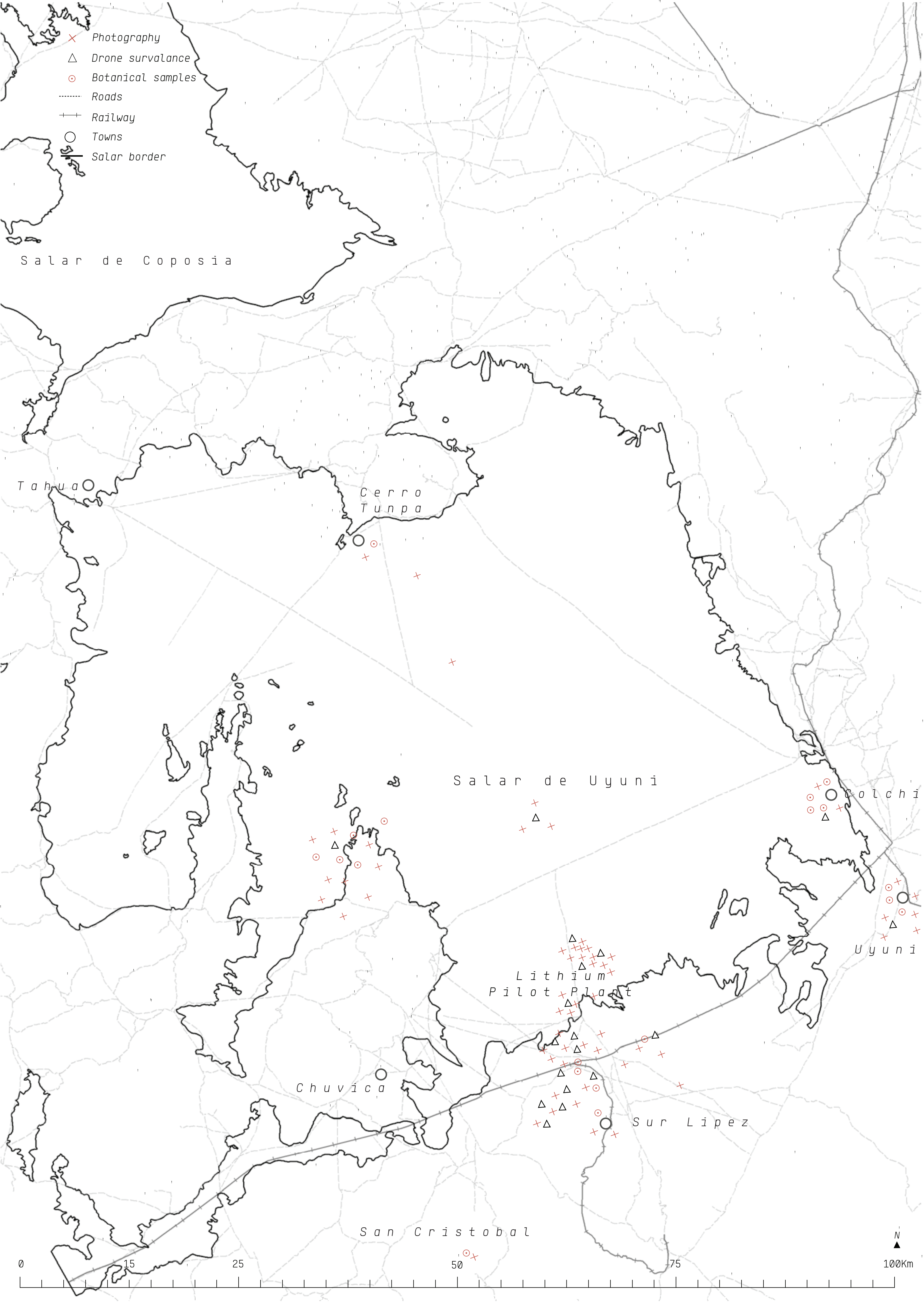
↓ OPERATION 05

New insights about current and future value-laden perspectives of the Lithium Pilot Plant were learned from the interviews, qualitative content analysis process and field work. However, despite communicating with local officials and agencies, I was unable to clarify certain aspects about the future Lithium Pilot Plant. One of these uncertainties was how to embody the local perspectives learned from the content analysis in the 2070 future scenario. To interpret the information, I relied on data gathered from field work, current land use and land cover classes for the study area, and comparable precedents.

My interpretation of how to implement an alternative energy source was informed by my experiences during the study trip. I observed that the study area's topographic condition, altitude and solar patterns are beneficial features for a future energy source.

↓ *IMG 2.1 DRONE SURVEILLANCE. LITHIUM PILOT PLANT* (Photo by Derek Rayle)

Figure 2.3 (GIS data from GEO.BOLIVIA) →


Photography
Drone survalance
Botanical samples
Roads
Railway
Towns
Salar border
Salar de Coposia
Tahua
Cerro
Tunpa
Salar de Uyuni
Colchi
Uyuni
Lithium
Pilot Plant
Chuvica
Sur Lipez
San Cristobal
N
0
15
25
50
75
100Km

AFTER LITHIUM
OPERATIONAL METHODS

Additionally, I witnessed small scale solar energy collection in the communities surrounding the study area. I came to realize that solar energy could satisfy an alternative energy source for the future Lithium Pilot Plant and surrounding region.

My understanding of how to decipher the assumption "legacy" was formed by examining land use and land cover types surrounding the study area. I observed the existing agricultural uses (see IMG 2.2) and terracing practices as promising techniques that could be adopted as a reclamation strategy for future unused lithium evaporative pools for two reasons: first, to attempt to mitigate soil impairment a planting regime is needed (Berger; 2008), second, future unused evaporative pools can be reclaimed by an alternative productive re-use.

My perception of mindfully coping with the potential landscape traces left by the mining practice was clarified by initially defining what waste constitutes for the study area. Waste in mining practices may be understood as "any substance or material which is discarded after primary use."(Carlisle;2015).I contend that the practice of mining generates two forms of waste: first by-products, which are immediate types of waste produced by extraction practices; second, future unused or abandoned landforms and infrastructural arrangements across the landscape I argue are also varieties of waste. Within the scope of this project, I am unable to address all the immediate waste forms generated from the lithium mining process.
After reviewing historical land planning methods in Bolivia and South America, I propose a form of territorial restructuring, known as celestial calendar planning as a method for productively coping with future waste. To orient proposed reclamation techniques to the sun, its new source of energy would provide an enduring spatial framework for the study area. The configuration of the reclamation program would reference the use of celestial calendars by indigenous populations in Bolivia and could transition the study area to become a future landscape artifact.

↓ *IMG 2.2 Uyuni Quiona Fields* (Photo by Derek Rayle)

After reviewing this information, I came to understand that the future Lithium Pilot Plant could house a mined land reclamation program that would prepare the study area for a post-lithium era by providing an alternative energy source, constructively dealing with waste, and producing a landscape relic. Although this method of reclamation does not return the landscape to its original state, I argue, it establishes a new framework that permits the territory to transition to alternative productive uses. To accurately depict the mined land reclamation program, I examined precedents for solar energy, terraced agriculture, and celestial calendar planning.

LANDUSE ALLOCATION

↓ OPERATION 06

If implementation of any type of reclamation program in the Lithium Pilot Plant were to occur, it would be challenged with numerous environmental and technical obstacles. Therefore, to illustrate a future reclamation program precedents were reviewed to acquire insights about needed parameters for solar energy, terraced agriculture, and celestial calendar planning.

There are two promising means to harvest solar power directly: by converting heat into electricity, and transforming light into energy. The first technique is commonly referred to as Concentrated Solar Power (CSP). The second technique is the solar cell, also known as the photovoltaic cell (PV). Of the two techniques mentioned above, CSP plants require a smaller spatial footprint. For example, to supply enough energy for a million households (3,397 Gwh), a CSP plant would require 339 hectares (Pitchumani;2017). Using current PV technology would need an area of 2,000 hectares (Pitchumani;2017).

Of the four types of CSP collecting technologies; the central tower system has been noted with the highest Mw capacity and annual solar to Kwh efficiency net (IEA;2011). After reviewing current solar power technologies, I came to the conclusion that the CSP tower system is the most appropriate form of solar energy for a mined land reclamation program in the study area, because of the energy capabilities, cost, mineral requirements and use of molten salt (Parrado;2016). I further determined that this strategy for power generation could be combined with other reclamation elements.(see Appendix_C)

To transform the harsh Altiplano ecosystem to an environment that was more congenial for humans, ancient Andean farmers engineered the landscape through a variety of methods. Agrarian researchers contend that agricultural terraces are a best management strategy for conserving soil quality and managing water for growing crops in arid environments (Langlie;2016). By design, terraces increase the fertility and agricultural preeminence of the landscape in three ways: first, terraces increase soil fertility, second, terraces capture rainwater runoff and ensure soils are sufficiently moistened, and third, the design of terraces increases the soil temperature thus preventing nighttime frost damage (Cook 1925; Dick et al. 1994; Inbar and Llerena 2000; Treacy 1989).

OPERATIONAL METHODS

Altiplano agricultural terraces have been classified into two categories based on function and masonry: bench terraces and broad field terraces (Spencer; 1961). Bench terraces are constructed on slopes that are greater than 20% gradient and involve constructing vertical stacked-stone riser walls parallel to the declivity of the hillside and embanking soil behind risers. Where as, broad field terraces are plowed areas on natural breaks of shallow hills. These field systems are built on slopes with gradients less than 20%. To create a broad field terrace, farmers construct short embankments of mounded earth, rocks, or small stacked-stone walls parallel to the hillside gradient. Through time, agricultural activities such as tilling, planting, harvesting, and other erosive processes result in soil naturally mounding against constructed riser walls. With minimal effort, farmers capitalize on gravity and erosion to construct broad flattened agricultural plots. As most evaporative pools have slopes greater than 20%, I determined bench terracing was an appropriate method for the proposed reclamation program.

For centuries, civilizations have used astronomical observations as a means to orient built structures, record time and territorial arrangement. In South America, accounts dating to the 16th century record various details of indigenous practices relating to Inca state-regulated sun worship and cosmological beliefs. Various forms of landscape timekeeping were used to record the path of the sun in Inca cultures. The solar horizon calendar is a systematic technique for astronomical observation of the changing position of the rising and setting sun along the horizon (Ghezzi;2007). The observation practice has been widely used by pre-Columbian civilizations and most notably in the Andean culture (Ghezzi;2007). Instruments such as stones, pillars and towers have often been used to record specific annual solar events. Once the tools are calibrated to the solstice, equinox, and zenith; they remain self-sufficient landscape artifacts. As such, the solar horizon calendar continues to function thousands of years after it was created. (see Appendix_C)

Solar horizon calendars can be organized into two categories based on project scale and function: monumental and land art (HAO;2009). Monumental horizon calendars were constructed on buildings or within a planned city. They served the public as an informative means for tracking time and the cycles of the sun (HAO;2009). Land art horizon calendars were built over vast extents and were in some cases isolated from civilization. This technique made use of surrounding geography to aid in recording the annual solar phases. Both methods were calibrated to four solar events: the summer and winter solstice, and the spring and fall equinox. I regarded land art horizon calendars as the best suited type for this project as the location of the Lithium Pilot Plant is remote and the reclamation area is expansive.(see Appendix_C)

LAND USE ALLOCATION

↓ OPERATION 07

Suitability analysis was used to locate viable areas for future land use and land cover patterns and a reclamation program on the study area. It was deemed as an appropriate method for this project as land-use suitability mapping and analysis is widely used for spatial planning and management by landscape architects and land planning practitioners (Malczewski;2004). The process is understood as a method for selecting a suitable site location (Malczewski;2004). Spatial parameters were required to depict suitable areas for future land use and land cover patterns and a reclamation program. Additionally, current land use and land cover GIS data were needed to accurately represent viable locations. I used the parameters and assumption tables 2.1 and 2.2 created from the content analysis process to form the future spatial parameters. Because this project is located in a remote region in a foreign country, I was challenged with receiving access to all GIS data for the study area. As a result, I used aerial photography interpretation to help form future suitable locations for areas that had insufficient GIS data. The aerial photography was captured during the field work portion of this research by drone surveillance. I cross referenced the aerial photographs with recent high resolution satellite imagery to ensure the accuracy of the pictures with the current study area.

SUMMARY

↓ REVIEW

This chapter outlined the methods of inquiry used in this project. It highlights one of many frameworks that could be developed in order to depict a speculative future scenario for a specific time period. The next chapter presents the proposed reclamation program and its spatial parameters.

03. RECLAMATION PROGRAM

A DESCRIPTION OF THE PROGRAM IS USED TO UNDERSTAND ITS COMPONENTS, FUNCTIONS AND SPATIAL PARAMETERS.

AFTER LITHIUM
RECLAMATION PROGRAM

↓ INTRODUCTION

This chapter presents the framework for a proposed reclamation program. One of the underlying premises of this project's conceptual structure is to explore solutions for gradually transitioning from current mining practices while constructively dealing with mining waste and preparing the study area for a post mining era. If a reclamation program is established, it could permit the territory to transition to alternative productive uses as lithium becomes obsolete. Local perspectives about the future Lithium Pilot Plant were collected from the interviews and qualitative content analysis process. The gathered information helped guide my understanding of a reclamation program that would prepare the study area for a post-mining era by providing an alternative energy source serving as an agricultural supply while constructively dealing with waste and generating a new economy. My interpretation of how to embody the programmatic elements was formed by my experiences during the study trip. To accurately depict a scenario 2070 reclamation program, precedents (see figure 3.1) were reviewed to acquire insights about parameters for terraced agriculture, CSP solar power and a solar horizon calendar.

The content I learned from the precedent studies(see IMG 3.1, 3.2, 3.3), helped aid how to design a framework for each program element. In this chapter, I dissect each program element to understand its components, functions and spatial parameters. Through this process, I comprehended how the three program types: terraced agriculture, CSP energy and solar horizon calendar could be integrated and housed in one location.

↑ COVER _ ***IMG 3.0*** *Heilostat Atacama 1*
(Photo by Abengoa)

→ ***IMG 3.1*** _ *Morray Ruins*
(Photo by Benjamin Dumas)

→ ***IMG 3.2*** _ *Heilostat Atacama 1*
(Photo by Abengoa)

→ ***IMG 3.3*** _ *Tiwanako Ruins*
(Photo by Silvia Carreno)

AFTER
LITHIUM
RECLAMATION PROGRAM

TERRACED AGRICULTURE

↓ INTRODUCTION

Agricultural practices have existed throughout history in the Bolivian Altiplano despite the extreme arid climate. High levels of salinity and volcanic loam render the soils less fertile than other regions of Bolivia. Additionally, topographic conditions vary throughout the region of Uyuni because of the many types of volcanos in the surrounding area. Due to the environmental constraints, cropland types principally used a series of broad field terraces and small crop beds (canteros). This form of terracing can still be seen in practice in the numerous farms surrounding the salar. Four dominant components in terraced agriculture in the Uyuni region were identified using the precedent studies. They are : access points, irrigation systems, planting regimes, and terrace structures (see figure 3.1). In reviewing the precedent studies, I acquired the average spatial extents for the terraced agricultural components (see table 3.1).

↓ COMPONENTS

Terraced agriculture requires ongoing maintenance of soils, crops and infrastructure. Four thresholds are created around the terraced structure at equal distances to accommodate pedestrians and vehicular traffic. The access points contain widths of ten to fifteen meters that allow for maintenance and viewing purposes of the terraced structures.

The environmental constraints in the study area present several challenges for any implementation of a planting regime. With an average mean rainfall less than 250mm a year, the cultivation of crops requires an irrigation system to accommodate new plant life in the salar (Cruz;2014). The proposed watering network is connected by traditional Inca irrigation channels in the terrace structure. Concrete water channels and pipes transport the water supply throughout the study area from its point of origin.

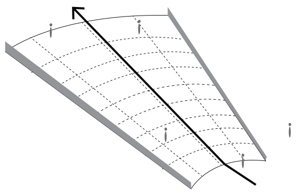
Chenopodium quiona has been consistently cultivated in the Uyuni region, as it is one of the few crops that can withstand the arid climate (Cruz;2014). A planting regime is deployed that uses three prominent cultivated local species : Chenopodium quiona, Chenopodium quinoa var. melanospermum and Chenopodium pasankalla quinoa. (Cruz;2014). The plants were selected based upon requirements for cultivation.

Terrace structures within the region range in size and are often constructed from the surrounding stone (Spencer;1961). The proposed terraced structure uses traditional Altiplano terrace construction techniques. Several modifications are added to adapt to the environmental conditions. ACF geotextile fabric is used to line the planting bed and act as a buffer from the salinized soils. The planting beds are created with sandy, well-drained soils sourced from the surrounding region.

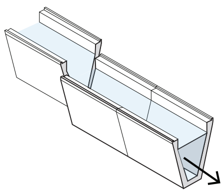
COMPONENT	ESTIMATED SPATIAL EXTENT (Ha)
↘ Access points	(1 HA)
↘ Irrigation Systems	(10 Ha)
↘ Planting Regimes	(10 Ha)
↘ Terrace Structures	(10 Ha)
↘ Terrace Unit	(50 Ha)

↑ ***Table 3.1*** _ Spatial Estimations
(Source based on precedent studies. See Appendix_B)

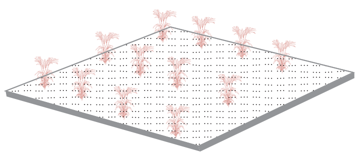
→ ***Figure 3.1*** _ Terrace Unit System



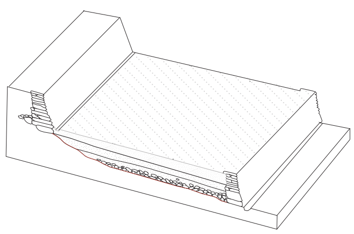
Access Points



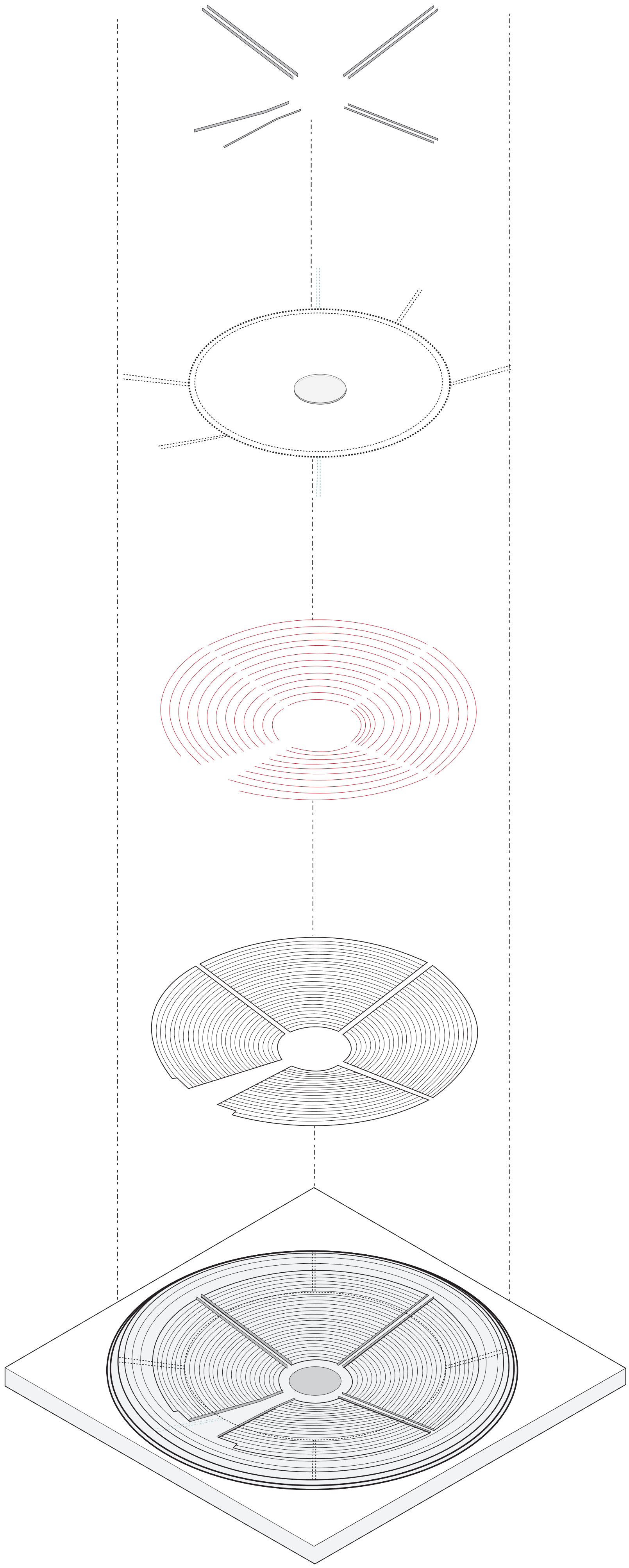
Irrigation System



Planting Regime



Terrace Structure



Terrace Unit

AFTER LITHIUM **RECLAMATION PROGRAM**

CONCENTRATED SOLAR POWER

↓ COMPONENTS

CSP solar technology utilizes the concentration of solar energy on one central location to achieve relatively high temperatures, thereby increasing the efficiency at which heat is converted into electricity, and reducing the cost of thermal storage. In addition, the concept is flexible, allowing designers to choose from a variety of receivers, transfer fluids, power blocks and spatial layouts. CSP projects have the ability to range in scale and annual Mwh production. Three main components in commercial CSP systems were recognized with the precedent studies. They are : CSP core, transmission networks and heliostats (see figure 3.2). In reviewing the precedent studies, I acquired the average spatial extents for the CSP components (see table 3.2).

Commercial CSP systems contain a variety of components to convert harnessed solar energy into usable electricity. CSP core units are comprised of molten salt storage, a steam generator, a condenser unit, and a solar receiver tower (Pitchumani;2017). The proposed reclamation program uses one 100 MW solar tower receiver per CSP unit. The tower stands at 139m with 30m tall receiver panels. Each tower is combined with two condenser units, two molten salt storages and one steam generator.

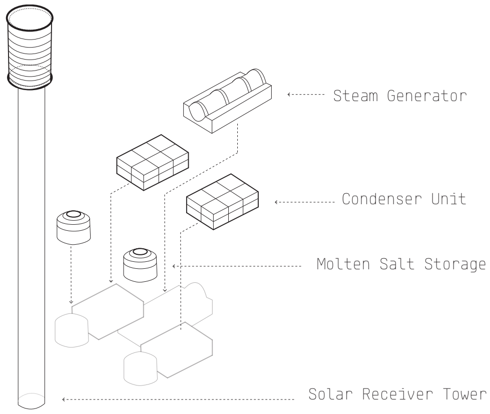
As this proposal has several towers that feed into one power block, a transmission network is needed to transport collected solar energy to the existing energy grid in Uyuni. Two sizes of transmissions units were identified with the precedent studies that could adequately accommodate power generation (Jorgen; 2013). A 765 kv transmission unit is used in close approximation to the CSP system, whereas a 135kv is installed outside of the reclamation area to transport the solar energy to nearby mining activities and other uses.

To review, CSP solar towers use hundreds or thousands of small reflectors called heliostats to concentrate the sun's rays on a central CSP Core. This program deploys 2650 heliostats per CSP unit. Solar Reserve Technology was identified through the precedent studies as a suitable form of technology able to withstand high levels of salinity (Jorgen;2013).

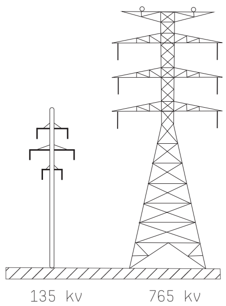
COMPONENT	ESTIMATED SPATIAL EXTENT (Ha)
↘ CSP Core	(50M)
↘ Tranmission Unit	(10Ha)
↘ Heilostat	(90Ha)
↘ CSP Unit	(100Ha)

↑ *Table 3.2* _ Spatial Estimations
(Source based on precedent studies. See Appendix_B)

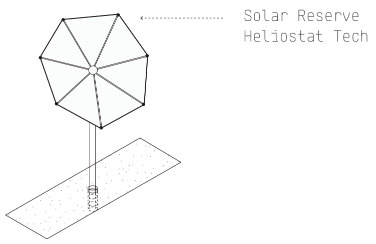
→ *Figure 3.2* _ CSP Unit System



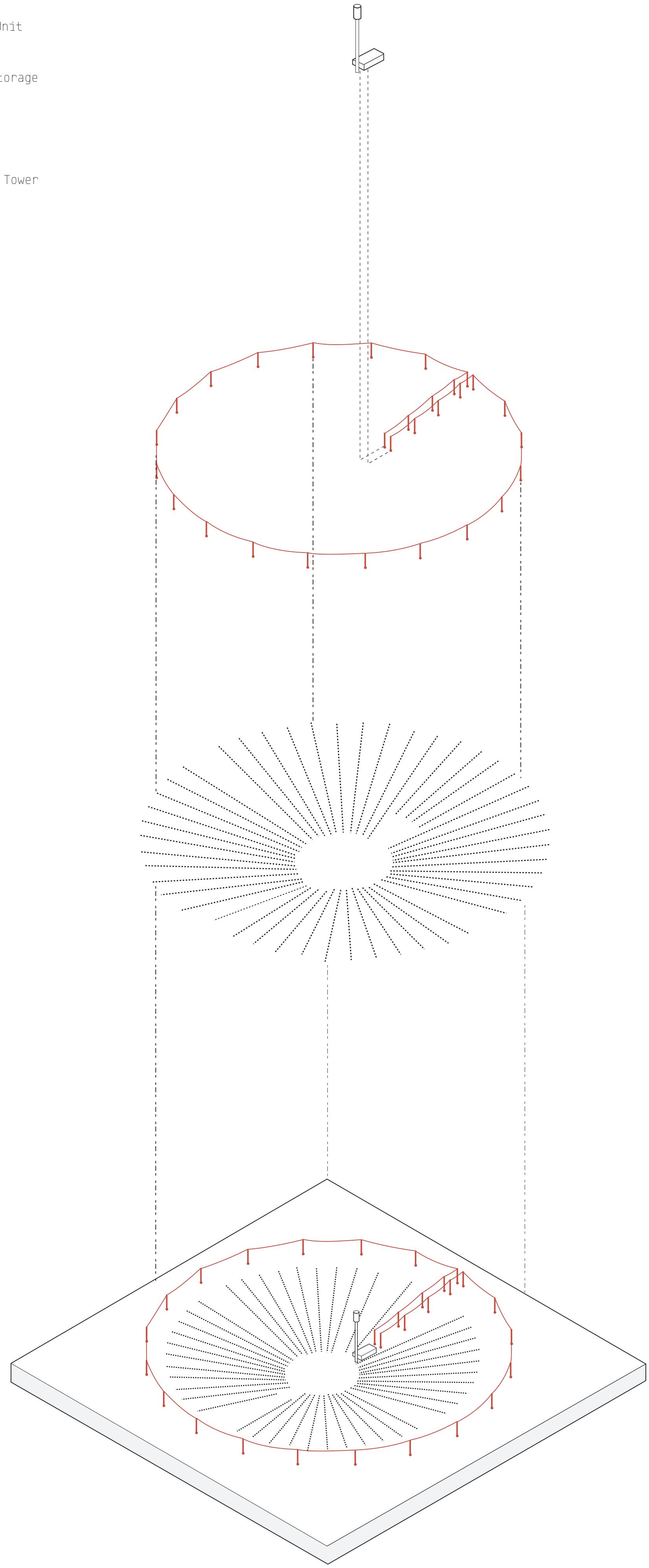
CSP Core



Transmission Unit



Heliostat



CSP Unit

SOLAR HORIZON CALENDAR

↓ COMPONENTS

Diverse forms of landscape timekeeping have been used to document the path of the sun in Andean societies. The solar horizon calendar is a methodical system for astronomical observation of the changing position of the rising and setting sun along the horizon (Ghezzi;2007). Instruments such as stones, pillars and towers have often been used to record specific annual solar events. Once the tools are calibrated to the solstice and equinox, they remain self-sufficient landscape artifacts. Three main components in Andean solar horizon calendars were recognized from the precedent studies. They are: solar orientation, false horizon and observation deck (see figure 3.3). In reviewing the precedent studies, I obtained the average spatial extents for the Solar Horizon Calendar components (see table 3.3).

Solar Horizon Calendars were typically oriented toward four specific dates. To effectively implement a solar horizon calendar as a method for territorial organization requires an awareness of the spring and fall equinox, and the winter and summer solstice (HAO;2009). Astronomical data from NASA were used to inform specific dates, times and angles for each solar event in relation to the study area. Each Program unit is oriented to a specific solar event.

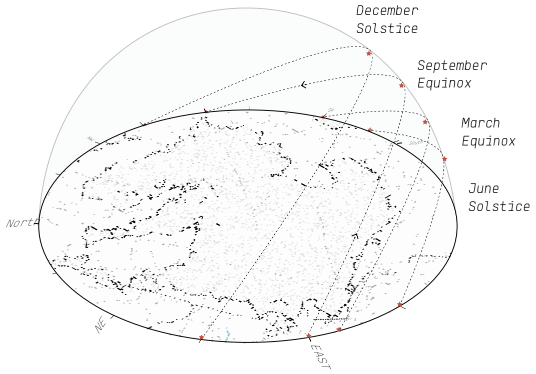
To effectively view the solar events and their relation to the reclamation program requires the construction of a false horizon. Typically, constructed below grade, the false horizon established an optical illusion that the solar event was oriented to a specific built object in the landscape (Kolata;2003). A proposed platform is constructed below the plane of sight to view a specified solar event.

To observe other solar events across the landscape, an elevated viewing platform is used. The observation deck offers onlookers the opportunity to gaze at annual solar events oriented to other program units.

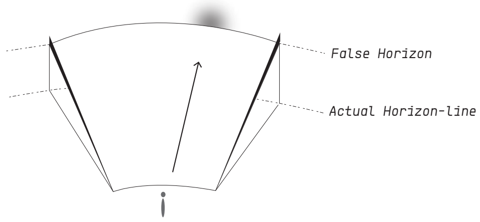
COMPONENT	ESTIMATED SPATIAL EXTENT (M)
↘ Solar Orientation	(NA)
↘ False Horizon	(50M)
↘ Viewing Platforms	(10M)
↘ Compass Paving Pattern	(50M)
↘ Solar Horizon Calendar Unit	(110M)

↑ ***Table 3.3*** _ *Spatial Estimations*
(Source based on precedent studies. See Appendix_B)

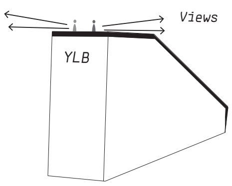
→ ***Figure 3.3*** _ Solar Horizon Calendar



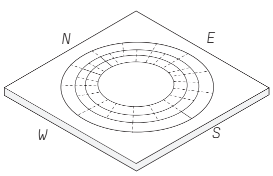
Solar Orientation



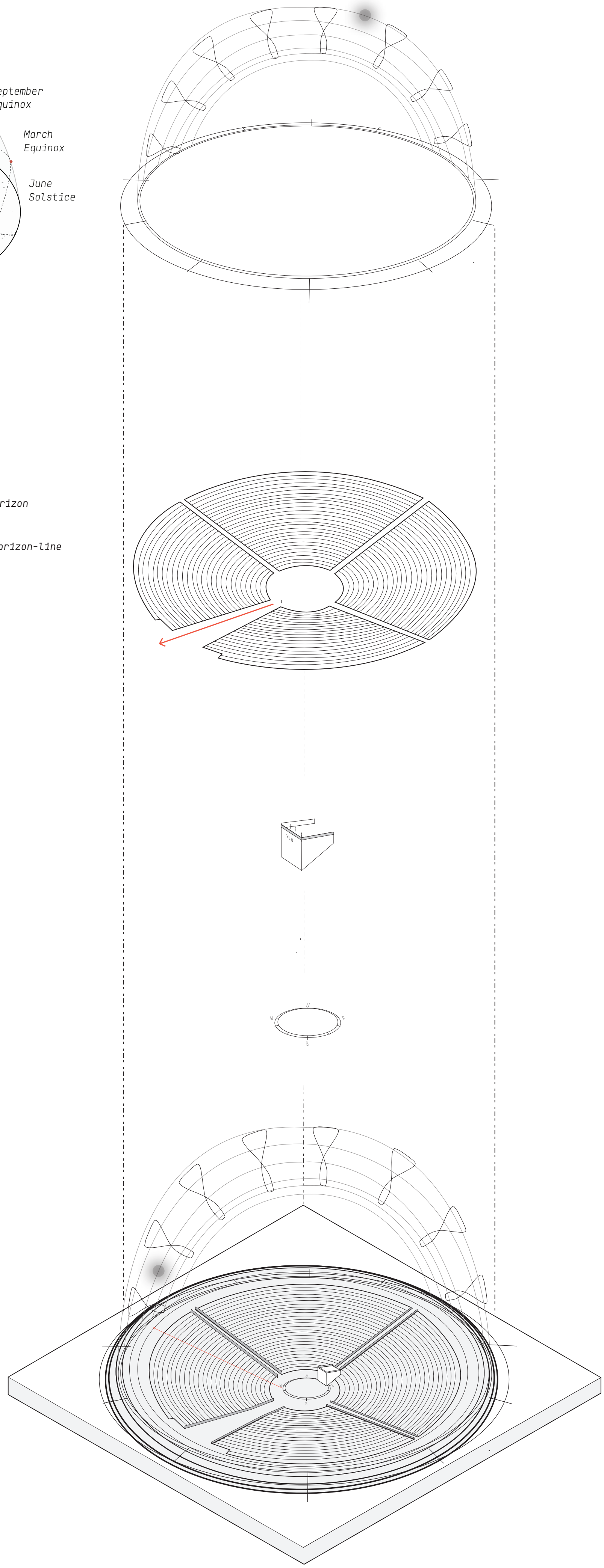
False Horizon



Viewing Platform



Compass Paving Pattern



Solar Horizon Calendar Unit

SUMMARY

↓ RECLAMATION

To reclaim is understood as "to bring back to a proper state". However, the definition does not imply returning to an original state, but rather to a useful one (Kuter;2013). A rational reclamation program, I argue, should not only aim to create a landscape that is compatible with surrounding undisturbed lands, but also consider environmental quality, aesthetics and intended use, when shaping the land into a resource with maximum versatility for future generations (Kuter;2013). The proposed reclamation program seeks to satisfy both the alternative future assumptions established by the interviewees and the conditions on the landscape. The program sets forth speculative viable uses for the study area,(see IMG 3.4) and proposes strategies for the recovery of a desired future as expressed by the represented regional professionals and agencies of the Bolivian Salar de Uyuni.

This chapter outlined the proposed reclamation program types, their components and spatial extents.The following chapter presents a reclamation program in a 2070 scenario master plan.

→ *IMG 3.4 _ Brine pool construction*
(Photo by Derek Rayle)

04.SCENARIO 2070

A SPECULATIVE DESIGN EXPLORED ACROSS A TERRITORY IN TRANSFORMATION

AFTER LITHIUM

SCENARIO 2070

INTRODUCTION

↓ PROCEDURES

This chapter displays one master plan for the study area depicted in a 2070 scenario. The scenario is one of many speculative futures for the Lithium Pilot Plant and explores a series of reclamation prescriptions that transition from lithium extraction to other viable land uses. The outcomes from the land use allocation process are presented in this chapter. The results highlight suitable locations on the study area to house the proposed program. As there are many preparations required to begin laying the framework for the 2070 scenario plan, a phasing schedule is proposed to understand the operational procedures. The chapter concludes with an example of a reclamation unit (terraced agriculture, CSP and solar horizon calendar) that is explored to comprehend its relation to the proposed master plan, the operators and the surrounding landscape.

To locate potential areas for a future reclamation program and land use and cover patterns on the study area, suitability analysis was used. Spatial and program element parameters for each component outlined in the previous chapter aided with forming the potential territory to nest the proposed program and its specific requirements. Additionally, the interviewee defined parameters and assumptions helped guide potential locations for future land use and cover patterns. However, the remote location of this project presented several obstacles when attempting to localize future land use and cover types. It resulted in relying upon aerial photography interpretation to help reveal areas that were poorly represented with GIS data. Aerial photography was captured during the field work portion of this research and cross referenced with recent high resolution satellite imagery to ensure the accuracy of the pictures with the current study area conditions. Moreover, the limitation of available data narrowed the minimal mapping unit and the spatial extent depicted.

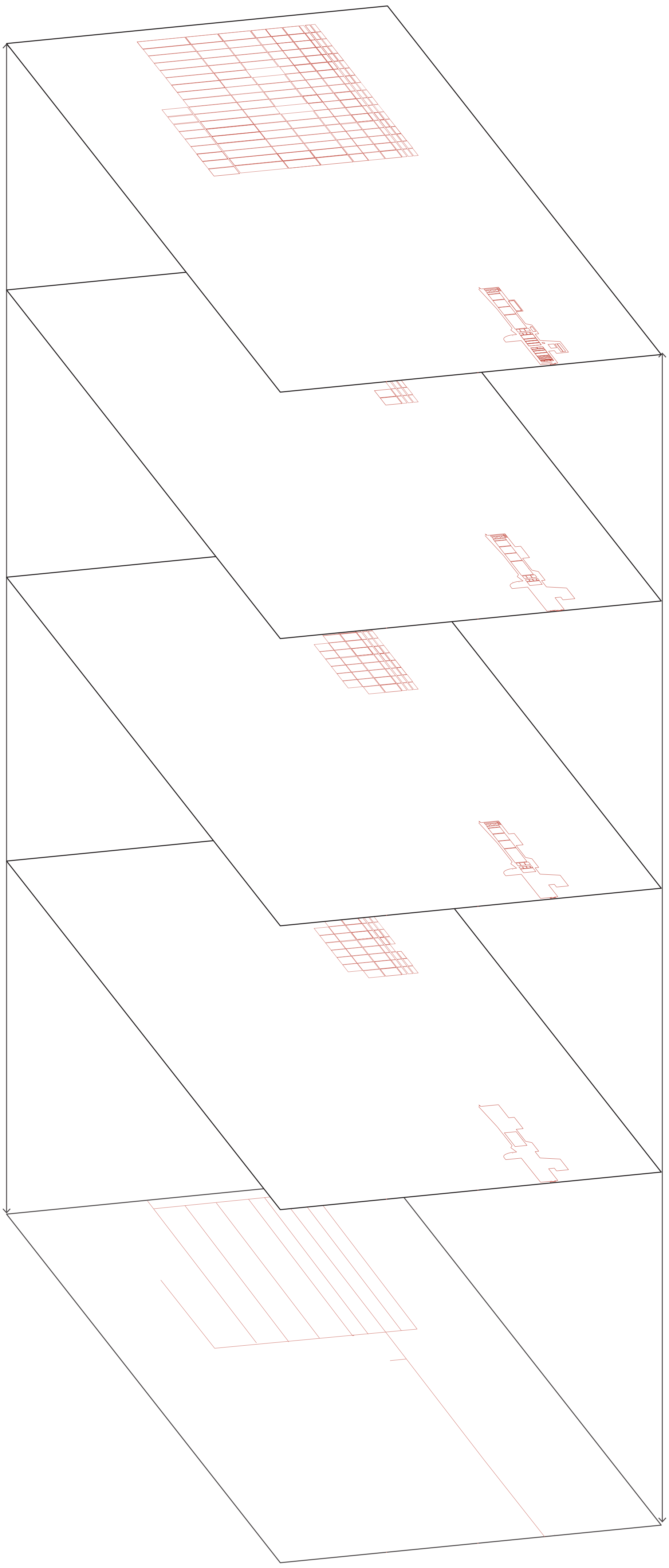
LAND USE ALLOCATION RESULTS

↓ OUTCOMES

The results are a sample of six identified suitable locations for terraced agriculture, CSP and a solar horizon calendar. It is important to note that the reclamation program is being housed only on current and or future lithium evaporative pool sites. As such, current and future planned lithium pool sites influenced potential locations for the proposed program. Additionally, evaporative pools with an area greater than five hectares and a proximity to a transmission line were factors used for positioning the alternative uses. Land use Allocation diagram (see Figure 4.1).

↑ COVER _ ***IMG 4.1*** Sunset in the Salar
(Photo by Derek Rayle)

→ ***Figure 4.1*** Land Use Allocation Diagram



EVAPORATIVE POOL AREAS
LI POOLS 2010
LI POOLS 2060
EVAPORATIVE POOL AREA
> 5 HA
TRANSMISSION NETWORK

AFTER LITHIUM
SCENARIO 2070

2070 SCENARIO MASTER PLAN

Index

Built Features

- ↘ Material refinement
- ↘ Barracks
- ↘ Waste storage
- ↘ Hydraulic pump
- ↘ Pump line
- ↘ Brackish water
- ↘ Infrastructure storage
- ↘ Light duty roads
- ↘ Reclamation Program area
- ↘ Transmission line
- ↘ Vistors center

Mineral extraction sites

- ↘ KCL
- ↘ Mg
- ↘ B
- ↘ Evaporative pools medium concentration
- ↘ Evaporative pools low concentration

El Planta Piloto de Litio

Context

↘ Elevation	3850m
↘ Position	20.6000° S, 67.6100° W
↘ Year	2070

Dimensions

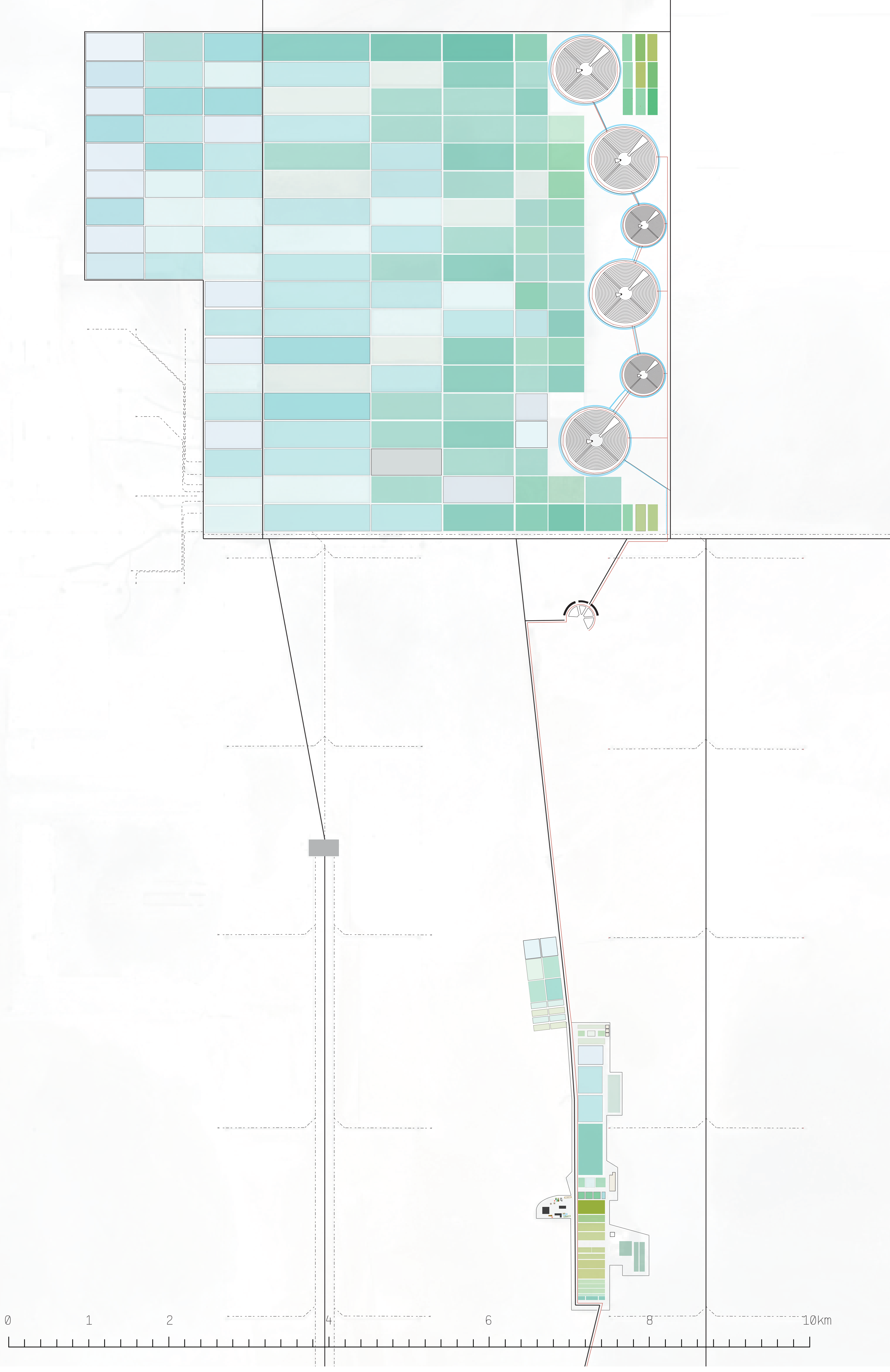
↘ Expanse	2.600 ha

→ *FIGURE 4.2* Scenario 2070 Master Plan (Data based on speculations)

1 : 40.000

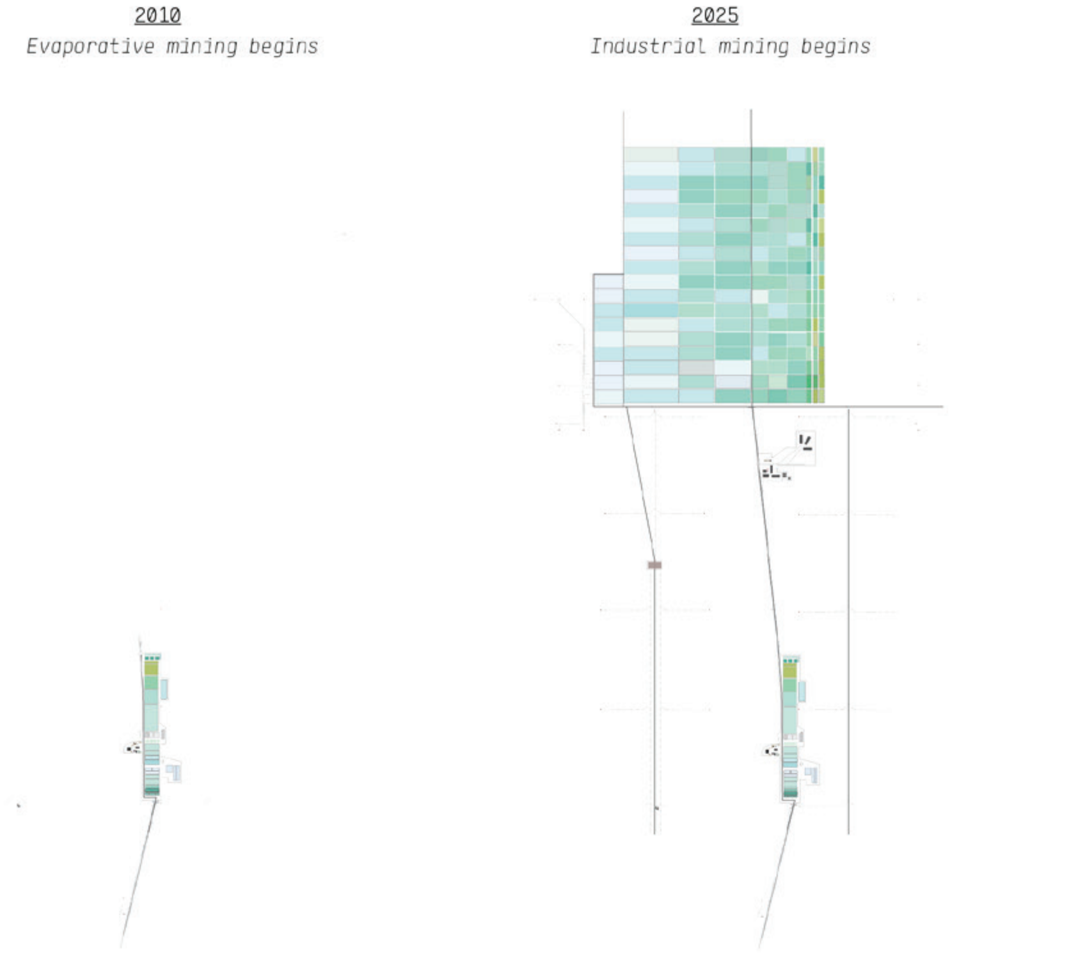
↓ INTRODUCTION

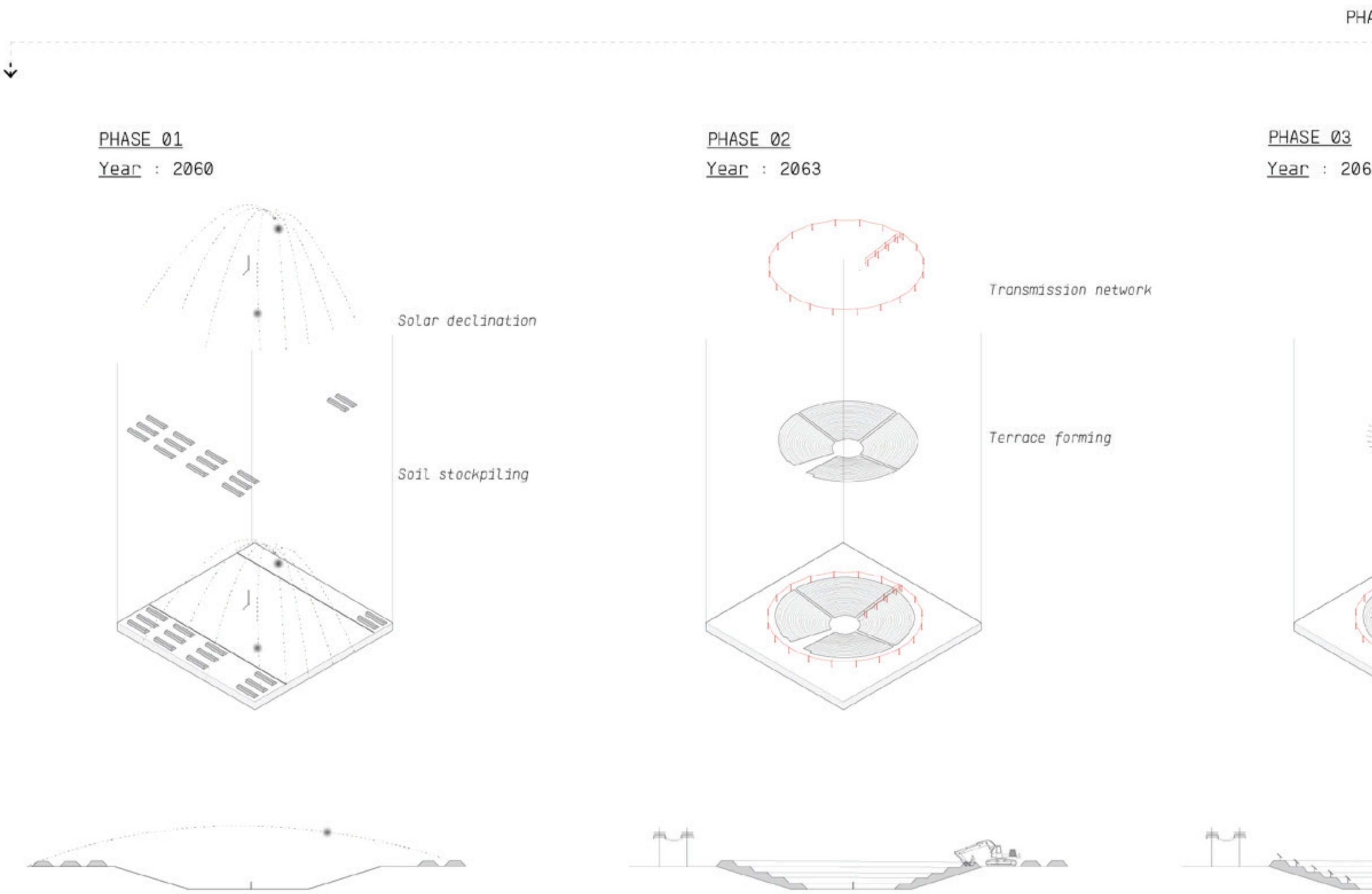
The Proposed master plan illustrates increased evaporative mining practices throughout the study area. The continued extraction process requires 500 hectares of territory. Potassium chloride pools represented in teal are constructed over 100 hectares. Magnesium pools shown in bright green are built across 100 hectares. And at 300 hectares, Boron, highlighted in light blue, will be the most expansive practice. Future lithium brine pool sites are transformed by the reclamation program represented in a circular pattern in grey. The reclaimed sites are linked by a series of new roadways that allow for the transportation of harvested material and access. A storage and processing center shown in black is adjacent to a visitor's center. The structures denote the entrance route to the new landscape program elements. A Phasing sequence is used to understand the study areas evolution.(see figure 4.3).



0
1
2
4
6
8
10km

AFTER
LITHIUM
SCENARIO
2070

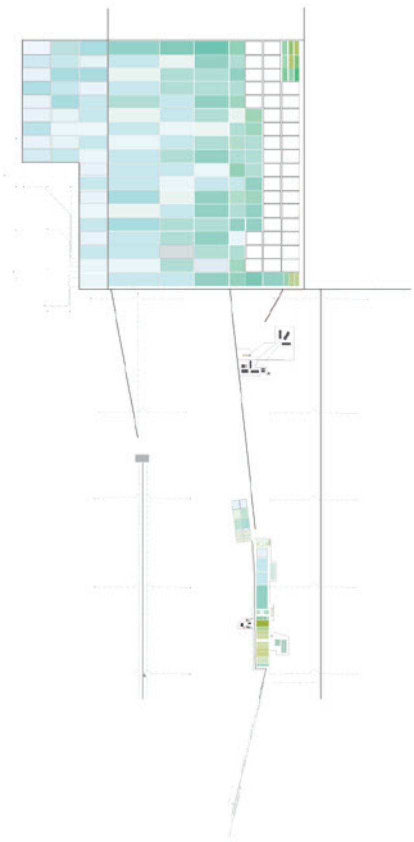




→ *FIGURE 4.3* Phasing Sequence
NTS

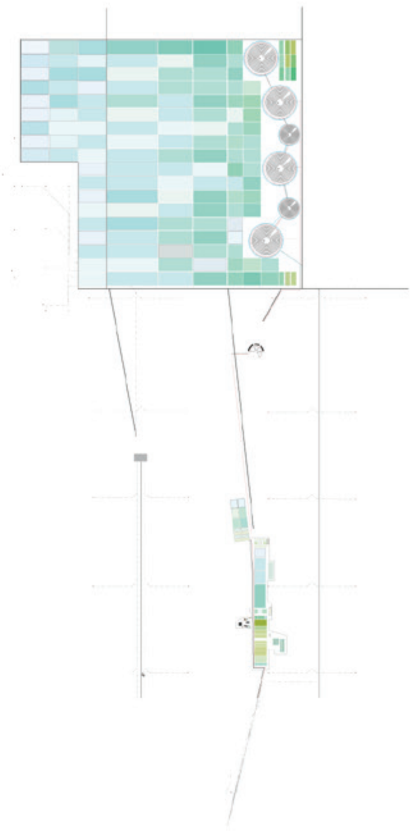
2060

Reclamation program begins



2070

Mining + Alternative Uses



ASING 2060 -2070

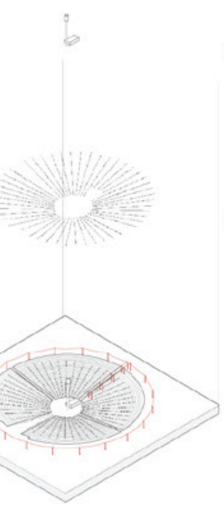
5

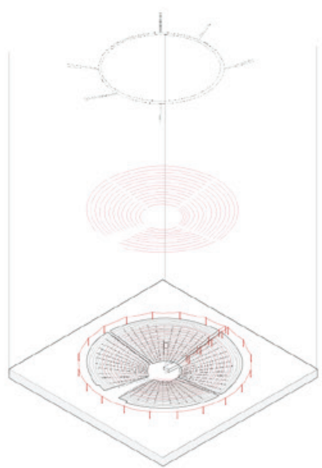
PHASE 04

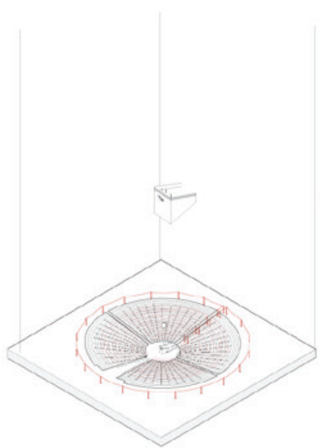
Year : 2068

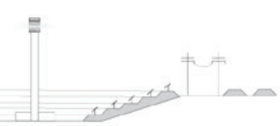
PHASE 05

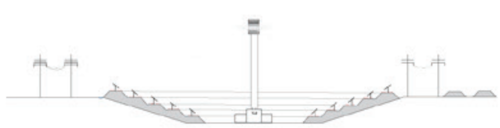
Year : 2070











AFTER LITHIUM

SCENARIO 2070

EXAMPLE OF A RECLAMATION PROGRAM

Index

Built Features

- Transmission line
- Irrigation line
- CSP tower location
- Infrastructure storage
- Light duty roads
- Reclamation Program Unit

Mineral extraction sites

- KCL
- Mg
- B
- Evaporative pools medium concentration
- Evaporative pools low concentration

→ *FIGURE 4.4* Area of Reclamation Program
(Data based on speculations)

1 : 20.000

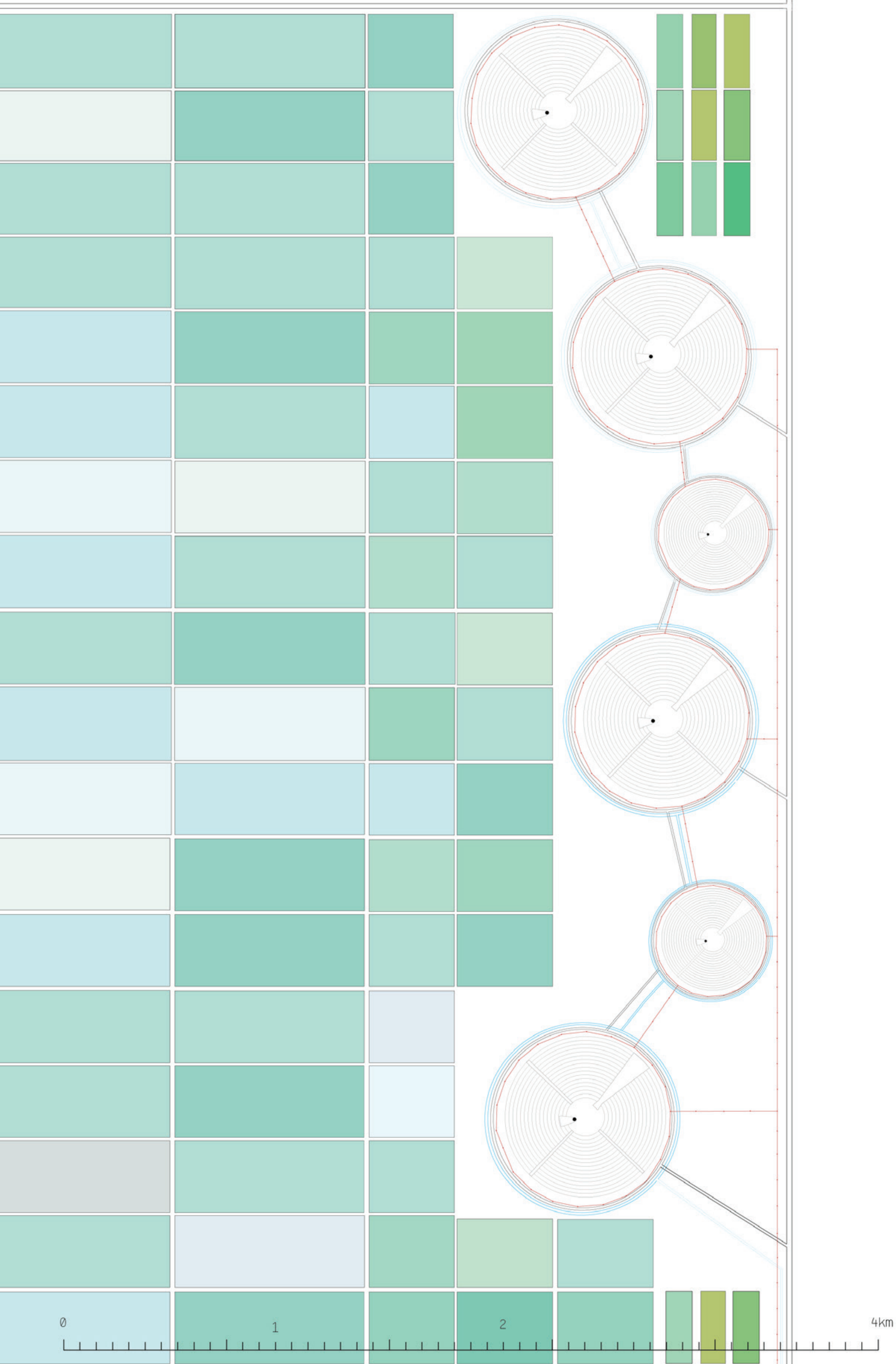
↓ INTRODUCTION

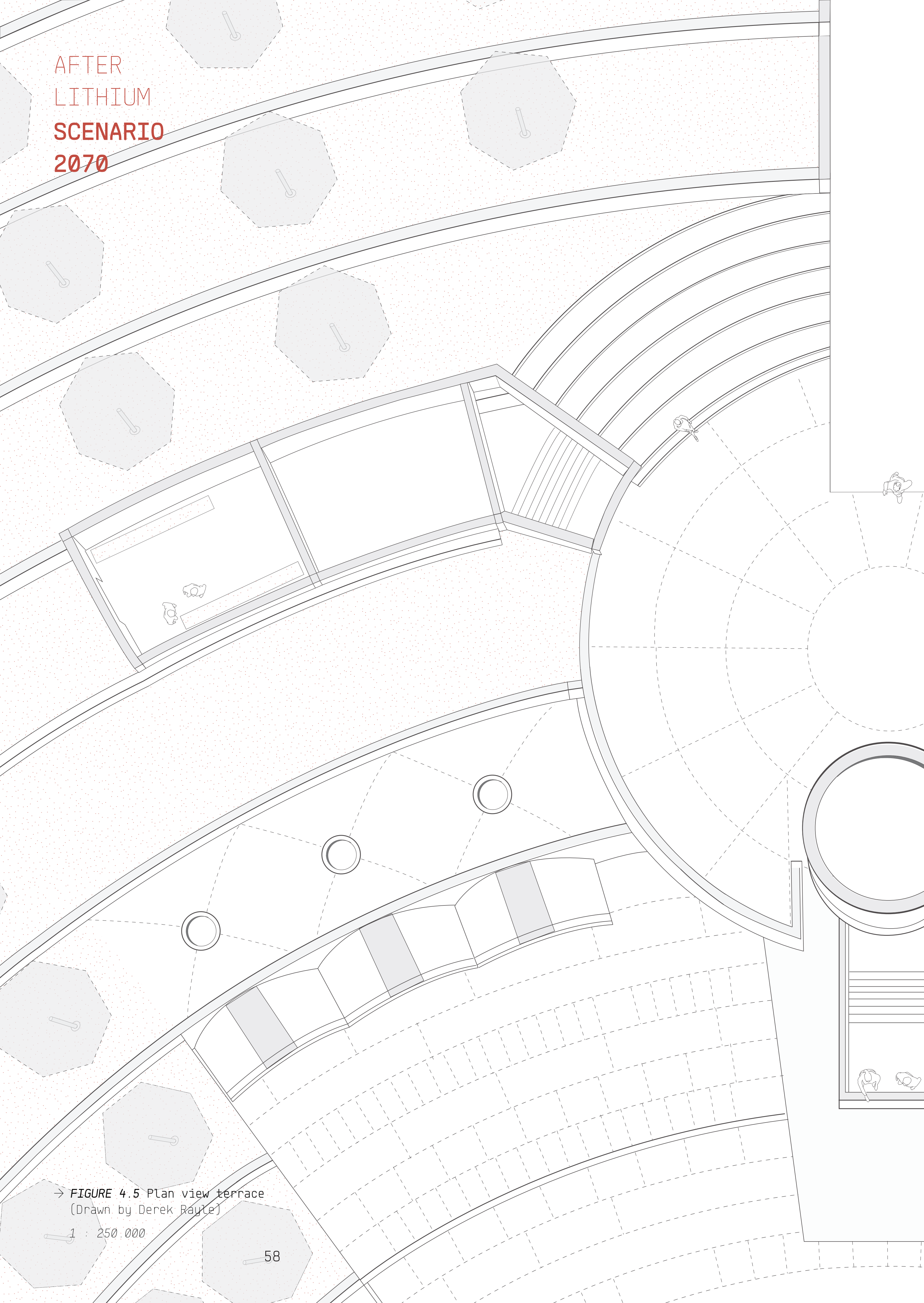
The proposed reclamation modifies future unused lithium brine pools with a unified program. As such, it allows for other forms of evaporative mining (boron, magnesium and potassium chloride) to continue while accommodating other viable uses. The result merges local agricultural practices and solar technology with indigenous land planning techniques. Area of Reclamation Program (see Figure 4.4).

The program deploys a planting regime capable of providing an agricultural supply for the surrounding communities. Plan of program unit (see figure 4.5), Section view of program unit (see figure 4.6). The result adapts the practice of artificial islands once developed by the Quechua and Aymara populations in Salar de Uyuni as areas of respite (Schull;1990). Terraced islands of Chenopodium quinoa are clustered around the heliostat panels and CSP towers. An irrigation system connects the agricultural supply to its water source fueled by desalinized recycled brackish and briny water.

The program uses four 100 hundred Mwh CSP towers and two 50 Mwh towers. A network of power transmission lines is established to transport the energy source to locations on the study area for mining activities and to near by communities.

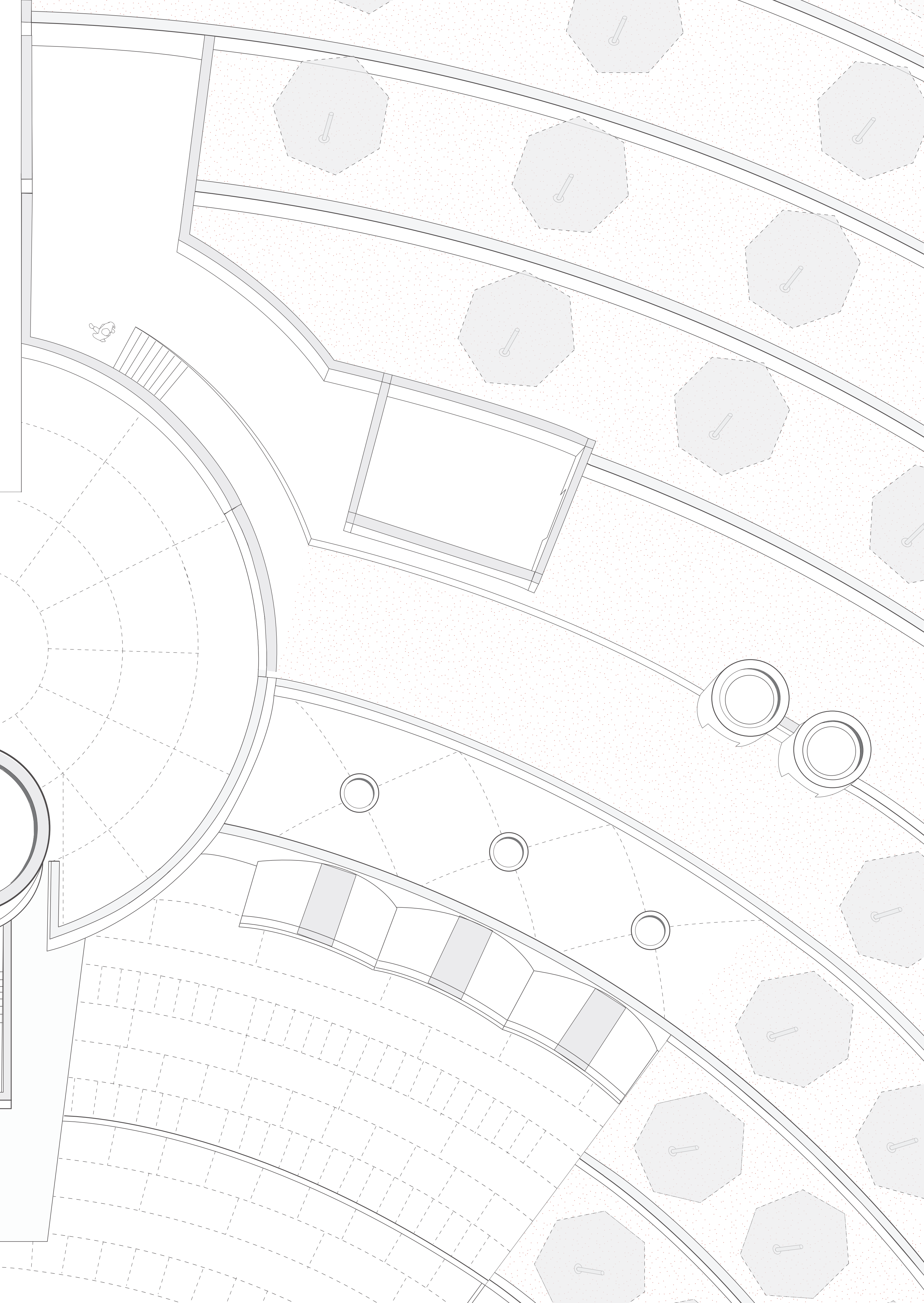
The program marks four annual solar events with the alignment of the CSP towers to the winter and summer solstice and spring and fall equinox. A new form of tourism emerges in the 2070 scenario which permits viewing opportunities of the annual solar events. Sightseeing events allow spectators to engage in solar tourism, where solar phenomena and energy production may be observed. Perspective view of solar event(see figure 4.7), Aeral view of solar event (see figure 4.8).


0
1
2
4km



→ *FIGURE 4.5* Plan view terrace
(Drawn by Derek Rayle)

1 : 250.000



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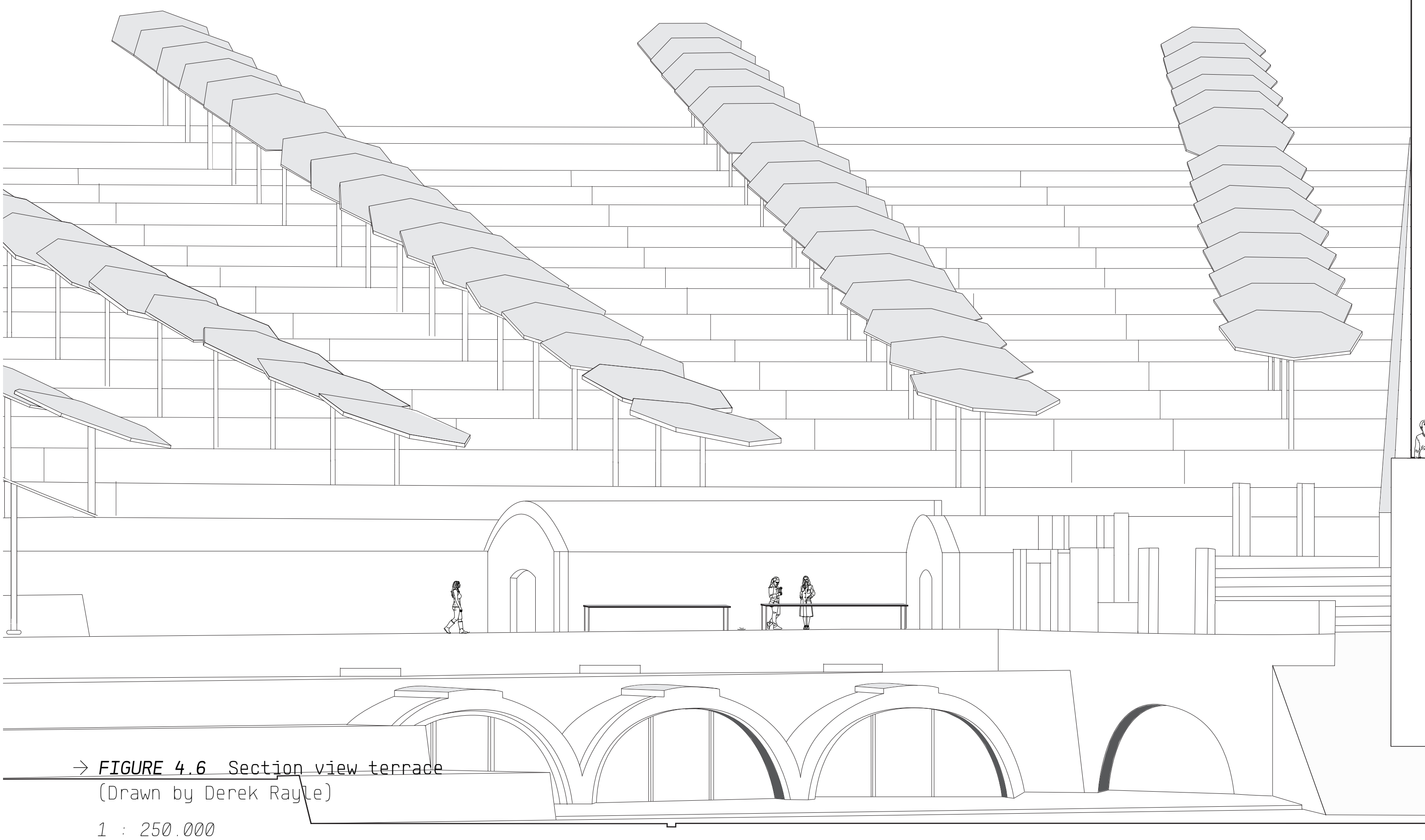
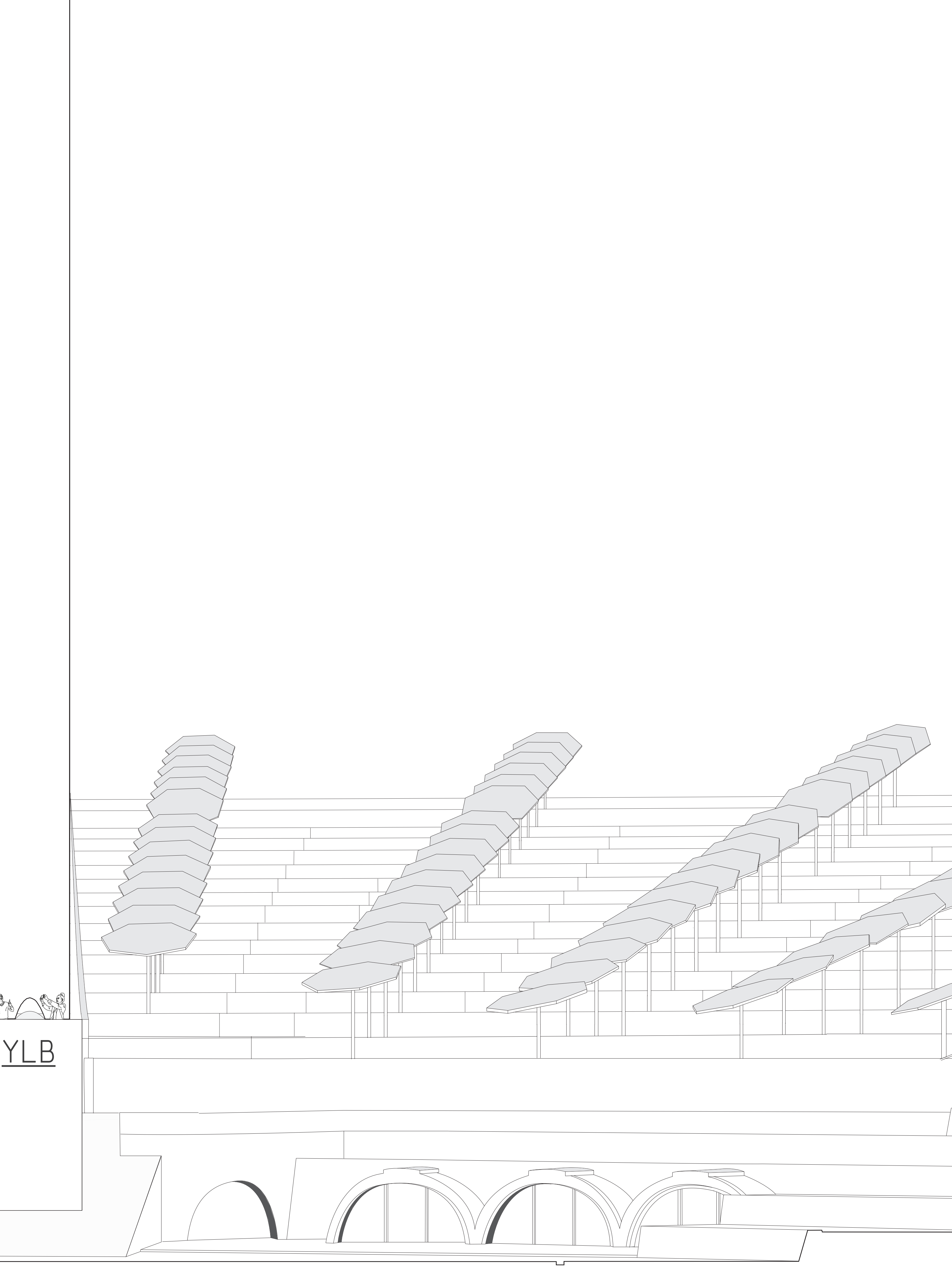
LITHIUM
SCENARIO
2070



→ *FIGURE 4.6* Section view terrace
(Drawn by Derek Rayle)
1 : 250.000


YLB

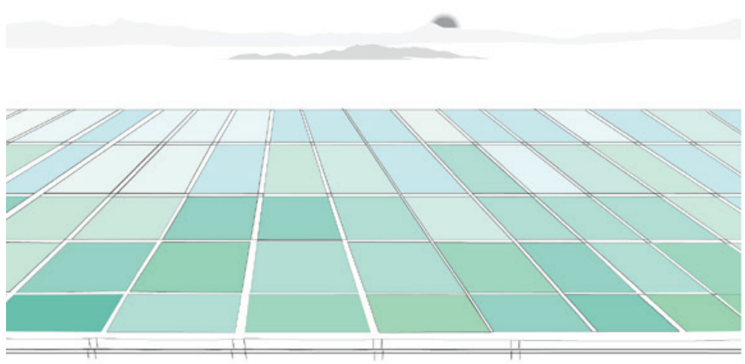
AFTER LITHIUM
SCENARIO 2070

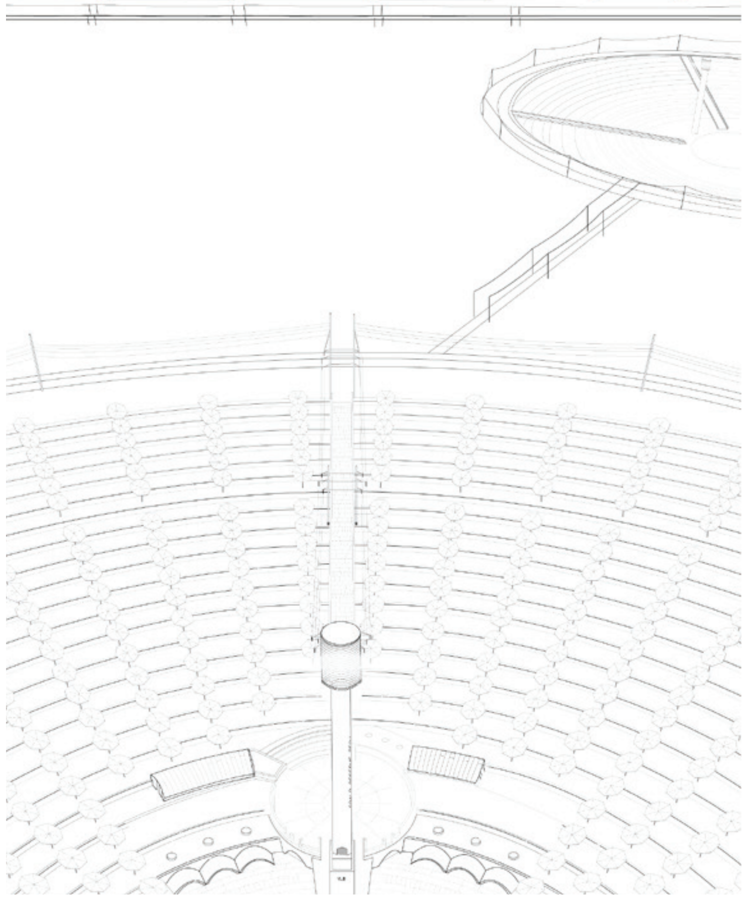
SUMMARY

Naturally, not every industrial evaporative mine will have the same assumptions for future alterations. The motivating forces for future speculative change I argue are rooted in factors of determinism, where previous events on the landscape can predestine the trajectory of the future. Therefore, I contend it necessary to discover the unique potential of the mined land prior to choosing appropriate methods and measures for a reclamation program. Landscapes disturbed by mining activities inherit some economic, recreational and aesthetic potential (Kuter;2012). With this understanding, a transition can be designed that allows for the simultaneous integration of mining and reclamation activities to optimize the opportunities offered by mining operations.

The suggested reclamation program for the Lithium Pilot Plant makes use of abandoned industrial mining territory while permitting extraction activities to continue.

This chapter presents a 2070 scenario for the Lithium Pilot Plant. It highlights a defined narrative by the interviewees for future landscape alterations. A master plan depicts future land use and land cover types and a reclamation program for the study area. The following chapter evaluates this project using responses from the interviewees.





→ *FIGURE 4.7* Perspective view of solar event (Drawn by Derek Rayle)

→ *FIGURE 4.8* Aerial view of solar event (Drawn by Derek Rayle)


SOLAR RESERVE TECH
YLB

05.DISCUSSION+EVALUATIO

AN ASSESSMENT OF THIS PROJECT'S ABILITY TO ADEQUATELY DEPICT THE INTERVIEWEE RESPONSES IN A FUTURE SCENARIO

N


SALARES DE UYUNI Y COIPASA
DE RECURSOS EVAPORITICOS
DISPOSABLE FACE MASK
BOTIQUIN
HECHO EN BOLIVIA
CONTENIDO:
Alcohol
Algodón
Agua Oxigenada
Mercurio
Curitas
Gasa
Tijera
EVAPORITICOS
2016

DISCUSSION + EVALUATION

↓ INTRODUCTION

This chapter assesses this project's ability to accurately depict the interviewee responses in a future scenario. Two methods for evaluation were used. First, I presented the outcomes generated in the previous chapter to the interviewees' through a video conference presentation and discussion. I concluded the online presentation with an analysis of the interviewees responses to the future proposal. Second, an online survey was administered after the presentation as an additional means to obtain specific feedback. The collected survey responses aid a comparison of current land use and land cover patterns to future patterns. The chapter concludes with my impressions and lessons learned from this project and additional research opportunities.

EVALUATIVE CRITERIA

The act of translation existed throughout every stage of this project. It began with an interpretation of words and phrases in the Spanish language to speculative concepts and values about the future. Cultural backgrounds and ideologies I contend have the potential to influence any translator, thus allowing the translator to be susceptible to error and biases. I was tasked with converting the gathered intangible information from the interviewees to spatial representations fifty years into the future. The evaluative criteria used for this project are based on my ability to adequately represent the original interviewee values gathered while in Bolivia.

METHOD FOR EVALUATION

The assessment of this project consists of two parts. Part one used an online platform to present the results to the interviewees and to gather their feedback on the findings created from their original responses. The process focused on collective criticism and allowed for open dialogue. Part two used a two question survey administered through an online platform. This method emphasized individual anonymous responses about the results presented.

Online presentations were conducted in two phases as a means to divide the group of seven interviewees by their organization and profession. The presentations were shown via Skype. Conversations were recorded with QuickTime, an audio-video plugin, for future referencing and analysis. The presentations took place over a 30-minute duration, in which fifteen minutes were used to present the evolution of the project since meeting them in September 2017. The remainder of the time opened with a few guiding questions which gradually transitioned into open dialogue about the reclamation program and the 2070 scenario vison for the Lithium Pilot Plant. The informal conversation was intended to gauge my adequacy to translate their responses and my own personal evaluations for the future. The group setting provided the interviewees with the opportunity to converse about speculative visions for a post lithium world and how might the Lithium Pilot Plant adapt as minerals become obsolete. As group situations can often influence answers, each individual was emailed a brief online survey upon completion of the online presentation. The intention behind the survey was to obtain unbiased anonymous responses. Surveys were administered through the digital platform Qualtrics. Two questions were used

→ COVER _ ***IMG 5.1*** YLB Operator
(Photo by Derek Rayle)

to measure the interviewees' opinions about the progression and results of the project. The collected responses highlighted the overall effectiveness of this research.(see Appendix_A)

RESULTS

Two online interview series took place on May 16th and May 17th, 2018. The groups were organized by governmental and non-governmental organizations. Seven out of the ten original interviewees participated in the discussions. The results from the conversations and their responses are summarized below.

The interviewees who attended the online meetings were curious about several aspects related to the project outcomes. One question they had was how a project conducted by a landscape architect student could arrive at unconventional concepts for land planning and design. They assumed I would have returned and presented primarily on horticulture and its potential integration into the mine. This new insight about the breadth of the discipline altered their notions of the limits of landscape architecture. Furthermore, they acknowledged the proposed plans and concepts have an interdisciplinary dimension to them. They saw the suggested plans as combining and addressing topics such as energy, engineering and anthropology.

Moreover, the interviewees commended the project for not berating or eradicating mining practices through a future narrative solely based on the "redemption" of a landscape. Rather, the outcome they saw in the 2070 scenario was structured around the preparation for speculative change. The proposed ideas provoked new thoughts specifically related to transitioning mining practices with energy production. However, the interviewees all agreed, that despite the ingenuity of the projected scenario, and its resourcefulness to adapt to speculative unused mined territory, for such an endeavor to be realized, it would be confronted with limitations and require foreign aid and assistance.

The proposal for large scale CSP solar technology to transform abandoned lithium pools was recognized by the interviewees as the most promising potential alternative use. They saw it as the most conceivable option to produce the longest continual revenue source. Some stakeholders expressed concern about how the CSP is proposed in the 2070 scenario plan, as it could nullify their neo-liberal strategies for resource extraction, "By Bolivia, for Bolivia". Much of the CSP solar technology that was proposed for the 2070 scenario does not currently exist in the country and only recently has entered the continent.

The proposal for a solar horizon calendar was perceived by some participants as a poetic gesture for attempting to link ancient culture with contemporary society as a way to address mining waste. They recognized and agreed that waste can come in many forms and not just toxic debris. When the strategy was presented in both meetings, it was confronted with many questions and skepticism. Particularly, the stakeholders were unsure about the true intention of the solar horizon calendar. Was the main purpose to benefit the solar optimization of the CSP tower, or to serve as a tourist attraction, or to establish a new "land planning framework to address mining waste"?

DISCUSSION + EVALUATION

MAY INTERVIEWS

↓ STRUCTURED INTERVIEWS

Each participant was asked a few guiding questions, but the online conversations were designed to gather their feedback on the findings created from their original responses. The process focused on collective criticism and allowed for open dialogue. The specific questions are listed in Appendix_A. Two series of survey questions were constructed for governmental and non-governmental officials, intended to serve as a starting point for the interviews, that regularly transitioned into conversations. To record these conversations, I used note taking and an audio device during the interviews and I will use a pseudonym to protect the identity of the participates.

INTERVIEW RESPONSES

↓ SAMPLES

Listed below is a small sampling of the numerous responses collected from several hours of interviewing the stakeholders in this project.

THEMES

↓ RESPONSE TO PROPOSAL

"Please, tell me where you think you could extract that amount of soil for this project? And correct if I am wrong but to fill voids by creating additional voids somewhere else is not fixing the problem its only creating more holes to fill holes. At least that's what I see happening here."

- Lemuel Esperanza Bermúdez. Engineer

"These types of technologies you are proposing will require foreign investment of both finances and machinery. And to do that could jeopardize this country to repeat the same mistakes as the past. You understand?"

- Periandro Lozano Ulibarri. Farmer

"To combine that amount of infrastructure and not to mention the solar rays with tourism could be dangerous, no? That would
rmer

MAY INTERVIEWS

need to be monitored very closely. But perhaps it could connect to the other numerous tourism locations in the salar?"

- Elisandro Rincón Jáquez. Engineer

"If I were you, I would have planned the reclamation program like the Lithium Pilot Plant. What I mean is that I would have tested it in a small location first and then progressed it. Rather than proposing it over the ten-year period. Or else It would be a large investment almost all at once."

- Galo Tejada Villegas. Economist

"This gives us fresh ideas about the inevitable closure and different uses for mine."

- Elisandro Rincón Jáquez. Engineer

"This is a very curious proposal. On one hand, you have adapted ancient and traditional Bolivian culture to a modern practice and on the other hand you have somewhat mixed culture with technology. I think we need something like this. To be proud of our country and culture and to use it and its resources to progress"

- Lemuel Esperanza. Engineer

"Mining and energy production, what an interesting idea! I think the Chileans are doing something like that, we should too."

- Antares Castro Riojas. Geologist

"Are you suggesting a temple to the sun? Is that what I am seeing here? A 21st century sun-worshiping society? "Solar energy would be perfect fit for the Lithium Pilot Plant. But not a Solar temple, sorry."

- Rafel Meraz Ávila. Environmentalist

"Why not plant on the salar? Why not experiment with planting out there? Radical idea but who knows, it might work?"

- Periandro Lozano Ulibarri. Farmer

"The sun is much stronger when you are at these altitudes, you know? Why isn't somebody collecting it? I don't know. It seems like there is a potential lasting future in that."

- Reuquén Pena Perales. Tour Guide

"Perhaps further research might explore the effects of technology optimizing evaporative mining techniques and its effects across the landscape?"

- Nacho Ontiveros Bernal. Extractor

"The proposed scenario 2070 only views one future, why did you not explore another?"

- Alan Duran Echevarría. Environmentalist

"Yes, yes Concentrated Solar Power! That could be Bolivia's future not those colored pools!"

- Periandro Lozano Ulibarri. Farmer

"I could see CSP power being used to fill in unused spaces on the mine".

- Galo Tejada Villegas. Economist

"I thought you said you studied landscape architecture? This is much more than what I thought."

- Pelayo Llarnas Cantú. Hydrologist

MAY INTERVIEWS

"What about the water? You have not discussed water at all in your scenario."

- Rafel Meraz Ávila. Environmentalist

"Perhaps your next project could look at scenarios for the Rio Salado? Because I recall that was a topic of interest of yours when we spoke in September".

- Nacho Ontiveros Bernal. Extractor

"Sorry, who is going to eat such an alien plant that has grown out there?"

- Elisandro Rincón Jáquez. Engineer

DISCUSSION + EVALUATION

Before presenting the use of agriculture terraces to transform speculative unused evaporative pools, I reminded the stakeholders how ancient populations surrounding the Salar de Uyuni once created artificial islands to cross the salt flat. The story resonated with them and assisted with conveying the landform reclamation concept to the interviewees. They applauded me for recycling the ancient practice into the design scenario. Some felt that the proposal appeared much more like a land art project and did not take into consideration that it would be quite a significant land engineering endeavor. Thus, questions of practicality arose such as: Who would eat these plants? Do they become another waste form? Where would you extract that amount of soil? Are you trying to make this habitable? I confronted their concerns by restating that this research project was an exploration of ways to transform unused areas. Perhaps a land use type that exists twenty kilometers away could one day in the future exist on the Lithium Pilot Plant too. Aided by technology and engineering, it could potentially serve an alternative purpose.

When mining transformations occur, they can take place at any scale, function or rate. The stakeholders reminded me that mining is shaped and influenced by a complex network of global markets and politics. As such, they stated that to present conclusions solely on technological influences to mineral demands was somewhat limiting in its scope of exploration. Therefore, some interviewees proposed a second future scenario that would explore the development of technology optimizing evaporative mining techniques and its effects across the landscape. Instead of technology creating resource obsolescence, the second scenario technology would work towards optimizing evaporative extraction potential.

↓ SURVEY RESPONSES

The anonymous survey responses revealed much more about the interviewees' thoughts on the research outcomes than the online conversations did. The response rate was high for the online survey, where 71% of the participants agreed that a portion of the reclamation program could be implemented on the Lithium Pilot Plant. Only 42% agreed that the scenario 2070 proposal adequately represented their values and beliefs for the Lithium Pilot Plant.

↓ LIMITATIONS

As this project is based in a remote region of the world, several new questions and limitations arose at each step of the project. Unanswered questions were organized into two sets: data limitations and environmental conditions.

One of the paramount obstacles with this project was not having enough GIS data. The limited spatial data restricted what I was able to map and project into the future. For example, I did not have accurate locations or territory extents for many land use and land cover types for the study. I came to realize the constraints of the data were not solely based on access, but also on non-existent data. Bolivia is technologically limited. Therefore, most geo-spatial referenced data are mapped through foreign organizations such as the

United States Geological Survey (USGS) and the French Bureau De Recherches Géologiques Et Minières (BRGM) (Fernando Molina;2013). Often, mapping conducted by these organizations is done over territories with a wide spectrum of land use and land cover types (Fernando Molina;2013). A salar is rather limited to what can exist on the landscape. Thus, it is typically mapped as one category.

The extreme environment where the study area is situated presented numerous limitations to future reclamation proposals. Above all, the plant palette was confined to a small number of local quinoa varieties. Given the Andean desert climate, aridity and soil quality, few species of plants exist there. Numerous preparations would have to be taken to permit the study area to support a planting regime. Thus, throughout many stages of the project I was confronted with the environmental realities which hinder various stages of this research.

↓ FURTHER RESEARCH

From solar energy to power evaporative mining operations to landform reclamation strategies, there is an assortment of future research possibilities. For example, although the literature reviewed landscape reclamation principles, there is much room for future research into techniques for solar energy for remote mining operations. (Awuah-Offei;2017). Mining operations, particularly those off-grid have a unique set of requirements for power supply. As most mines operate almost every day of the year, operators demand reliability from available power systems (Awuah-Offei; 2017). Additionally, off-grid mines may not have backup from a utility transmission system to obtain reserve power or other grid services. The mine's power source must supply all these attributes itself. Often the nearest transmission lines or natural gas pipelines may be hundreds of kilometers away in South America (Sordi; 2017). Solar energy has the potential to meet mining needs while being a reliable source.

As industrial evaporative mining is a fairly new practice, there is much research to be conducted about future unused pools in salar environments. How might these voids be transformed to benefit future mining practices? What techniques exists to reclaim expansive evaporative pools? This research will require a combination of professional knowledge from disciplines such as chemistry, engineering, geology and landscape architecture. What might emerge from these spaces when evaporative mining is no longer needed?

↓ LESSONS LEARNED

The ability to make inferences from the coded data during the content analysis process is favorably subjective and based on the researcher's reasoning and attentiveness. This process requires the researcher to be as unbiased as possible when drawing conclusions from the coded text. Reviewing the transcribed interviews revealed two obstacles that inhibited me during the interview process in Bolivia. First, as an interviewer, I was selectively listening for responses that would justify the exploration of designs I had envisioned for the study area prior to arriving in Bolivia. Second, essential phrases and words from the

DISCUSSION + EVALUATION

in Bolivia. Second, essential phrases and words from the interviewees were misinterpreted or undetected. Only in using the content analysis method did I discover my pre-established assumptions and unnoticed expressions. Once acknowledging this bias, I was able to infer conclusions about the future of the Lithium Plant Plant that I missed at the time of the interviews.

Proposing a reclamation plan based fifty years in the future,makes the scope of this project extensive. However, my intellectual desire to understand the specificity of each program element, the surrounding culture, landscape and political atmosphere only amplified the scope. Thus, my inability to define clear limitations during several stages of the project complicated the project's goals and objectives. Once admitting my weakness as a researcher, I was able to better fit my yearning for information to the time available, which in turn simplified each chapter.

↓ SATISFACTION OF PROJECT GOALS

To review, the project had five objectives to be achieved during this research. They were:

1. Use input from key interviews to define assumptions and parameters for a speculative future scenario.

2. Explore solutions for gradually transitioning from current mining practices while constructively dealing with mining waste and preparing the study area for a post mining era.

3. Depict one future scenario for the Lithium Pilot Plant from 2010, 2025 and 2060.

4. Construct a 2070 scenario master plan.

5. Present results to original interviewees.

I contend that all of the project goals were explored and realized during the life span of this project.

↓ REFLECTIONS

The results from this master's project propose site specific reclamation strategies, if this method's framework were to be applied to future evaporative mining sites in the region:

1. The mineral being extracted must be deemed obsolete within the near future, as a means to reclaim mined land areas that are no longer of value.

2. A future reclamation program should support the existing mine infrastructure.

Collectively, the damages the Lithium Pilot Plant would experience if future reclamation strategies are not taken into consideration are many: abandoned evaporative pools would leave gaping holes scattered throughout the landscape along with contaminated soils and mining wastes. But this would have an equally important effect on the surrounding communities' psyche. The mining degradation would constitute the next chapter of Bolivia's ongoing resource curse. Mining in Salar de Uyuni therefore raises questions about ethics, politics and history.

The ultimate drive behind this project was to develop a transferable framework, which applies interview responses from local, impacted people and spatial analysis to evaporative mined landscapes as a way to project speculative reclamation strategies. Essentially, the message is that landscapes influence the development of technological systems and those technological systems in turn shape the landscape. However, narratives envisioned by stakeholders, shaped by cultural values and politics, have the ability to define a landscape for future generations.

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GOVERNMENTAL OFFICIALS

↓ SERIES 01 SEPTEMBER 2017 INTERVIEW QUESTIONS

1. What role does Salar de Uyuni have in Bolivia?

2. How would you describe Salar de Uyuni as you think it will be in the next fifty years?

3. How do you see Bolivia serving future global lithium economies needs?

4. What importance do technological improvements have for the future of lithium extraction in the Salar de Uyuni?

5. How would you describe water consumption and demand placed by lithium mining over the next fifty years?

6. What is the life cycle of water within the lithium extraction process?

7. What importance does Rio Salado have for the future of lithium carbonate mining?

8. How do you see increased mine infrastructure until 2070 and its distribution over the landscape?

9. Where do you foresee the future of lithium carbonate mining occurring in Salar de Uyuni until 2070?

10. How do you envision the rate of extraction of lithium carbonate until 2070?

11. What is the lifecycle of mining waste? And where do you foresee the mining waste being treated until 2070?

12. Do you have any other recommendations for resources that would be helpful to investigate contact?

REGIONAL EXPERTS

↓ SERIES 02 SEPTEMBER 2017 INTERVIEW QUESTIONS

1. What role does Salar de Uyuni have in your life?

2. What role does Salar de Uyuni have in your community?

3. What are the most important features defining the quality of life in Salar de Uyuni?

4. What is your opinion about the future of lithium extraction in Salar de Uyuni?

5. How do you foresee the future of lithium extraction and water usage over the next fifty years?

6. What do ancient Quechua mythology say about the Rio Salado?

7. What does ancient Quechua mythology say about the Salar de Uyuni and lithium?

8. How would you describe Salar de Uyuni as you think it will be in the year 2070?

9. Where do you foresee the future of lithium carbonate mining occurring in Salar de Uyuni until 2070?

10. Where do you see mining waste being discarded within Salar de Uyuni now until 2070?

11. Do you have any other recommendations for resources that would be helpful to investigate/contact?

GOVERNMENTAL OFFICIALS

↓ SERIES 01 MAY 2018 VIDEO CONFERENCE QUESTIONS

1. To what extent do you see the methodology used for this project being adapted to future evaporative mining sites in Salar de Uyuni?

2. How would you describe the interpreted information gathered from the content analysis process?

3. If solar energy were to be implemented at the Lithium Pilot Plant, where would it occur?

4. Do you have any other recommendations or suggestions that would be helpful to investigate for further research?

REGIONAL EXPERTS

↓ SERIES 02 MAY 2018 VIDEO CONFERENCE QUESTIONS

1. How would you describe the interpreted information gathered from content analysis process?

2. To what extent do you see the methodology employed for this project being adapted to future evaporative mining sites in Salar de Uyuni?

3. Do you feel that the proposed reclamation strategies would aid the transition of the Lithium Pilot Plant towards a productive space?

4. Do you have any other recommendations or suggestions that would be helpful to investigate for further research?

BOTH

1. Does the scenario 2070 proposal adequately represent your values and beliefs for the Lithium Pilot Plant?

2. Could a portion of the reclamation program be implemented on the Lithium Pilot Plant?

FIELDWORK
IMAGES

→ *FIELD WORK IMAGES*
(Source; Rayle)

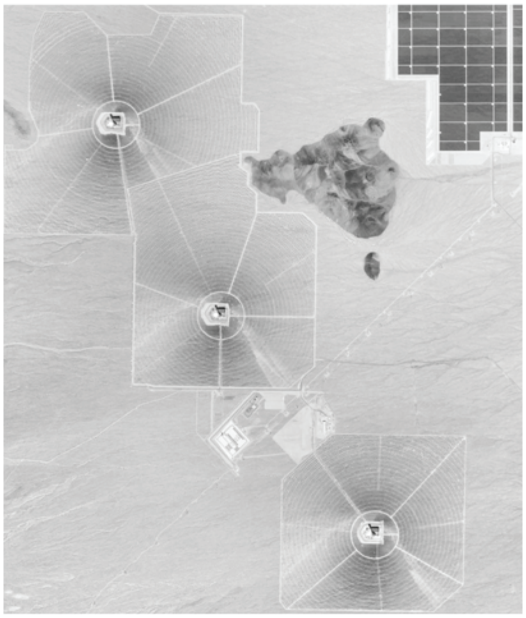
APPENDIX_B

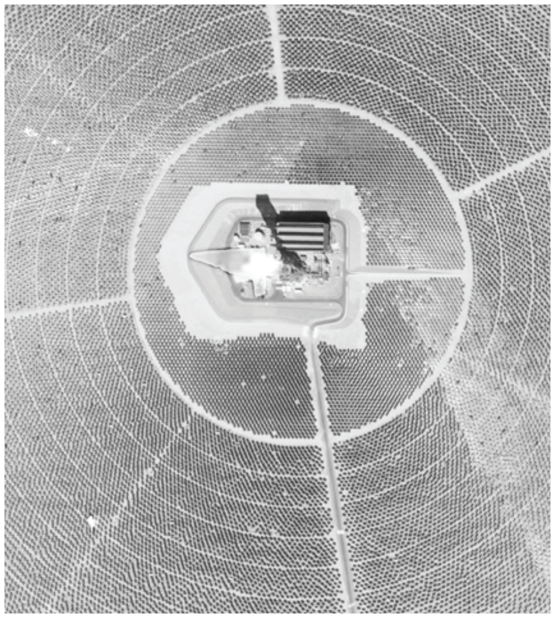
→ *FIELD WORK IMAGES*
(Source: Rayle)

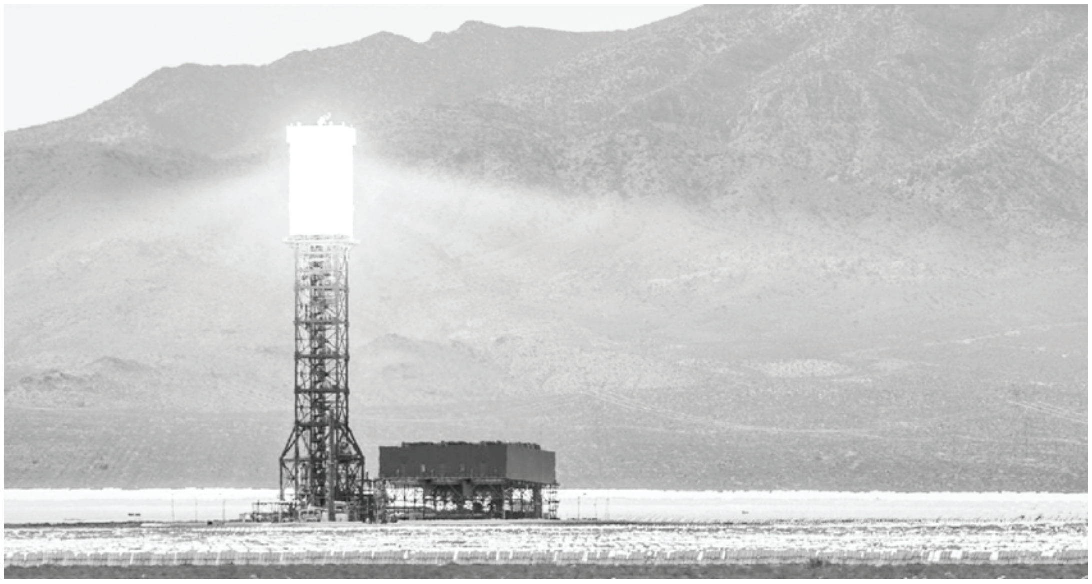


RECLAMATION
PROGRAM PRECEDENT

↓ Concentrated Solar Power



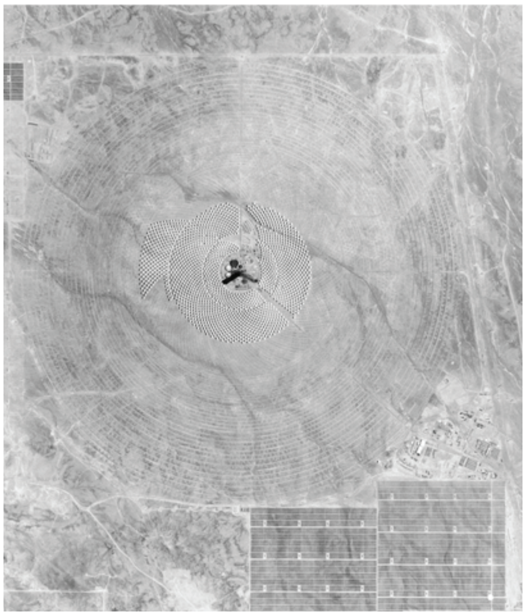


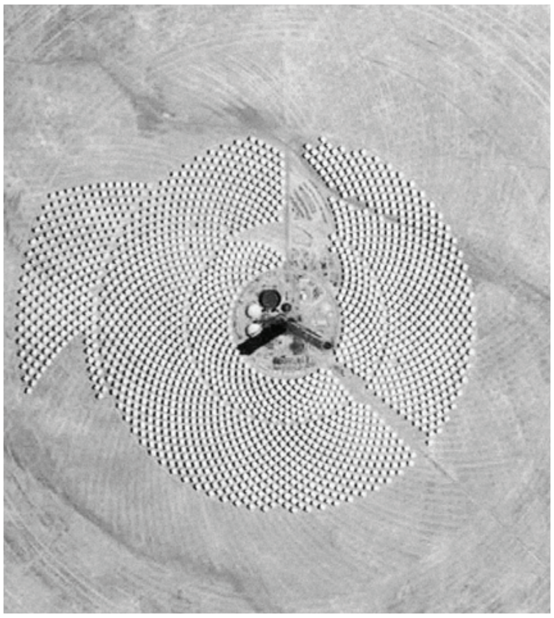


Ivanpah Solar Electric Generating Station

Context	
↘ Location	Primm, Nevada,USA
↘ Position	35°.33.85 N , 115°27.30 W
Dimensions	
↘ Land Area	3.500 ha
Solar Field	
↘ # of HelioStats	173.500
↘ # of CSP Towers	3
↘ Tower Height	139m
↘ Receiver panel height	30m
↘ Receiver Outlet Temp	556°C
↘ Heat-Transfer Fuild	Steam Generator
Output	
↘ Electricity	1.079.232 Mwh/yr
Company	
↘ Owner	Bright Source Energy & Google

Solar Facility Statistics (NREL; 2014)



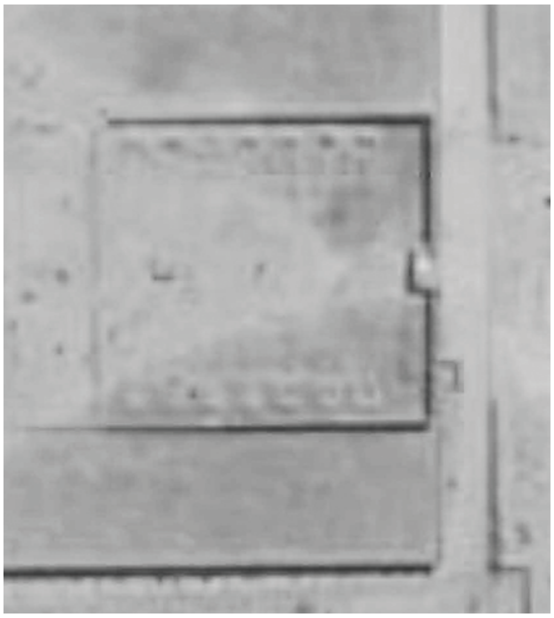


Atacama-1 (Planta Solar Cerro Dominador)

Context	
↘ Location	Region de Antofagasta, Chile
↘ Position	23.8634° S , 69.1328° W
Dimensions	
↘ Land Area	700 ha
Solar Field	
↘ # of HelioStats	10.600
↘ # of CSP Towers	1
↘ Tower Height	243m
↘ Receiver panel height	32m
↘ Receiver Outlet Temp	550°C
↘ Heat-Transfer Fuild	Molten Salt
Output	
↘ Electricity	560 Mwh/yr
Company	
↘ Owner	Abengoa Solar

RECLAMATION
PROGRAM PRECEDENT

↓ Solar Horizon Calendar



Tiwanaku

Context	
↘ Location	Tiwankau, Bolivia
↘ Position	16.5556° S , 68.6739° W
Dimensions	
↘ Land Area	800m
Enineering Method	
↘ Solar Horizon Calendar	
Type	Monumental
Astronomical Declination	
↘ Orientation	Solar, Lunar
Viewing Opourtunties	
↘ Tourism	Open to Public

Solar Horizon Statistics (HAO ; 2009 , Kolata ; 2003)

Chankillo

Context
↘ Location — Ancash Region, Peru
↘ Position — 9.5635º S , 78.2277º W

Dimensions
↘ Land Area — 400m

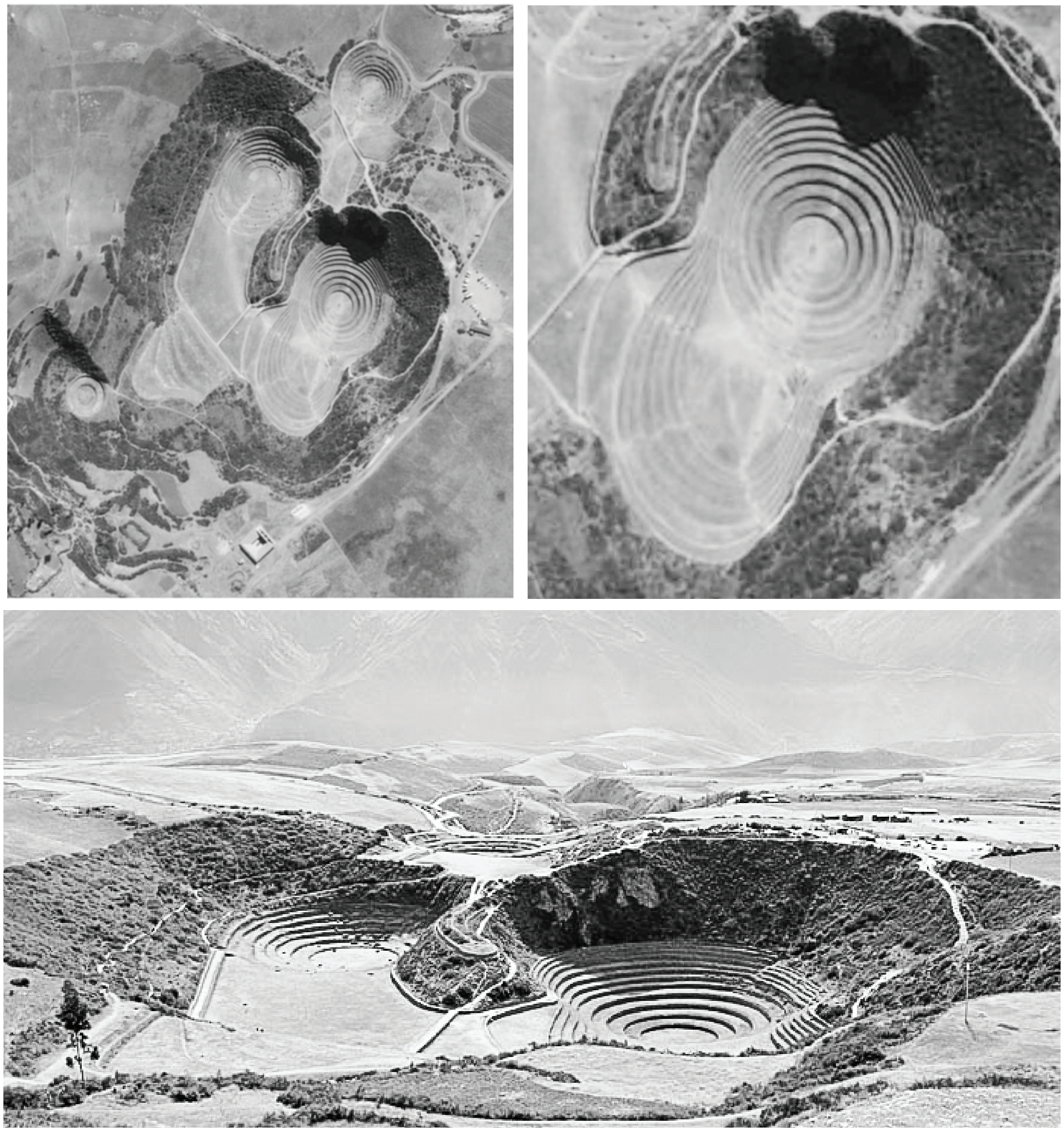
Enineering Method
↘ Solar Horizon Calendar
Type — Land art

Astronomical Declination
↘ Orientation — Solar

Viewing Opourtunties
↘ Tourism — Open to Public

RECLAMATION
PROGRAM PRECEDENT

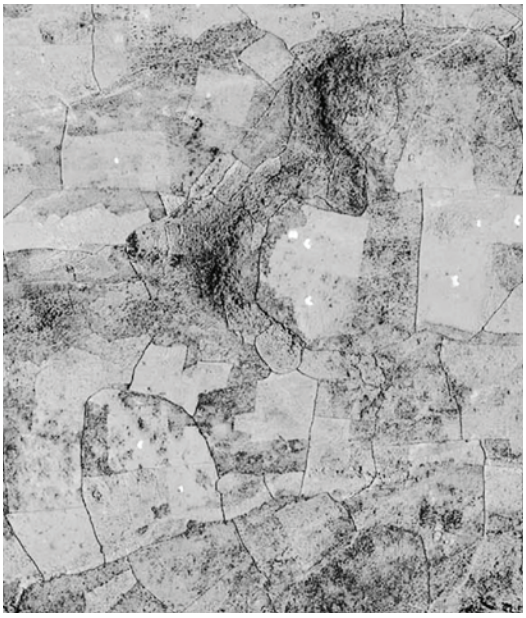
↓ Terraced Agriculture



Moray Ruins

Context	
↘ Location	Maras, Peru
↘ Position	13.3299° S , 2.1971° W
Dimensions	
↘ Land Area	0.66ha
Enineering Method	
↘ Terrace Type	Bench Terrace
↘ # of Terraces	10
↘ Irrigation	Steps
Method	
↘ Construction Type	Inca

Agricultural Terrace Statistics (Spencer ; 1961 , Wright ; 2014)



Uyuni Quinoa Fields

Context

↘ Location	Sur Lipez, Bolivia
↘ Position	22.2698º S , 67.1894º W

Dimensions

↘ Land Area	unknown

Enineering Method

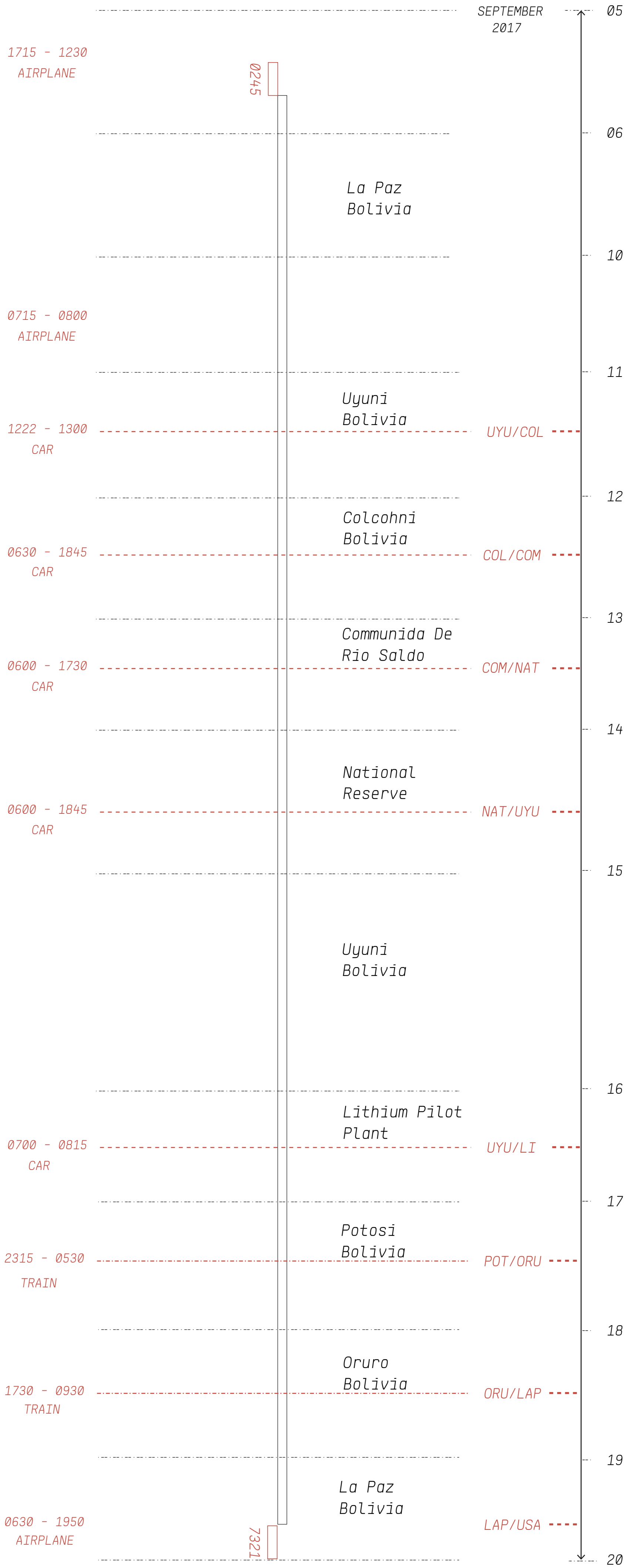
↘ Terrace Type	Broadfield Terrace
↘ # of Terraces	unknown
↘ Irrigation	Steps

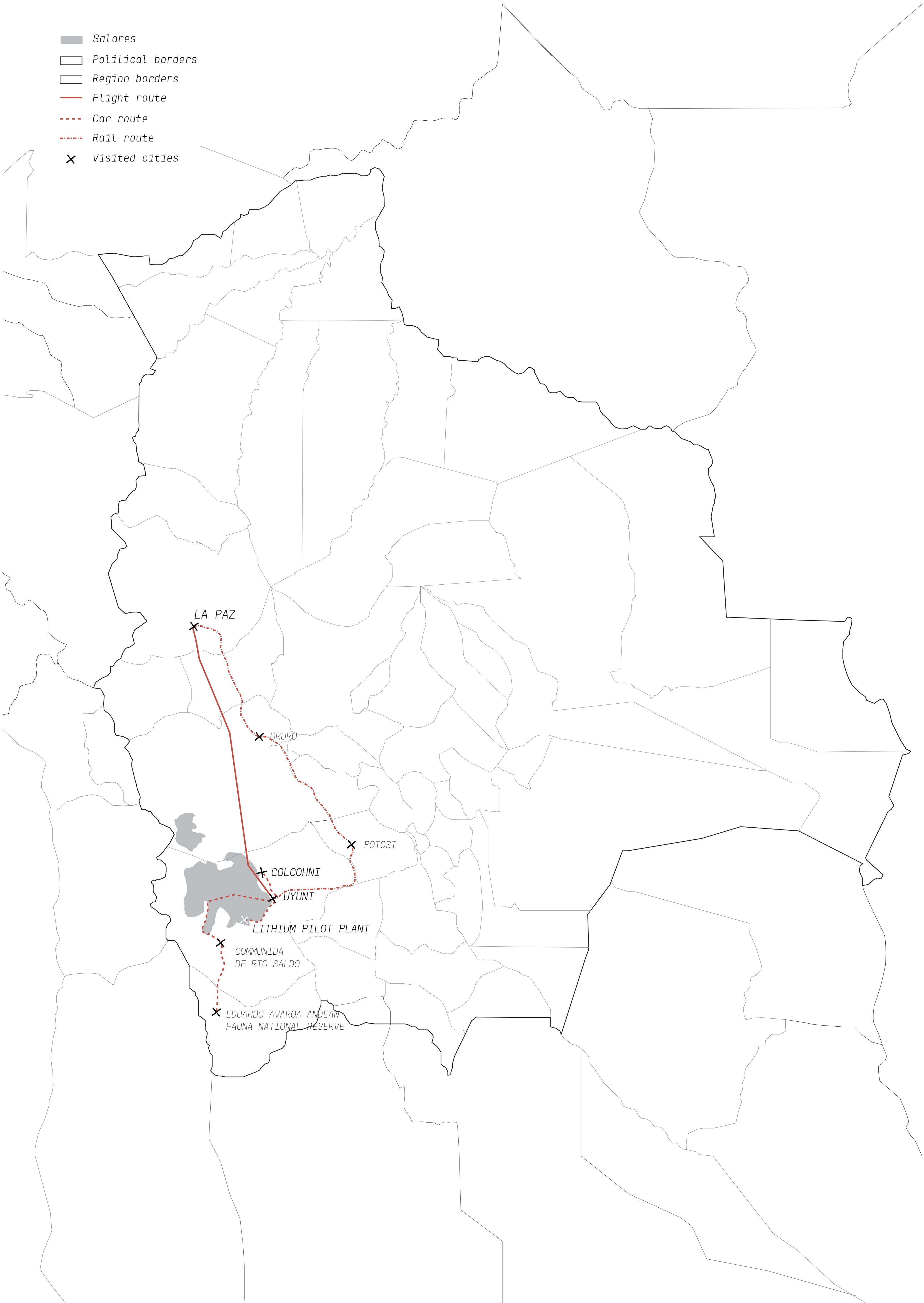
Method

↘ Construction Type	Aymara / Quechua

AFTER LITHIUM STUDY TRIP

SCHEDULE





Salares
Political borders
Region borders
Flight route
Car route
Rail route
Visited cities
LA PAZ
ORURO
POTOSI
COLCOHNI
UYUNI
LITHIUM PILOT PLANT
COMMUNIDA
DE RIO SALDO
EDUARDO AVAROA ANDEAN
FAUNA NATIONAL RESERVE

AFTER
LITHIUM

AFTER LITHIUM
RECLAMATION STRATEGIES FOR SALAR DE UYUNI,BOLIVIA

EDITORIAL +
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Derek Rayle

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© Andale Mono

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Eugene,OR June 2018

COVER _ *Salar de Uyuni* , *Bolivia* (Data from LANDSAT,2015) →

This project depicts a speculative future scenario for the Lithium Pilot Plant in Salar de Uyuni

and uses it to explore the transition from current mining practices through the implementation of post-mining landscape reclamation

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