INDUSTRIAL LANDSCAPE REHABILITATION: RE-IMAGINING THE FUTURE OF DECOMMISSIONED COAL-FIRED POWER PLANTS IN SOUTHEAST MICHIGAN

by

DEVYN MICHELLE QUICK

(Under the Direction of Jon Calabria)

ABSTRACT

The quickening rate of decommissioned coal-fired power plants has potentially transformative repercussions in the form of emergent landscapes. A mixed methods approach informs data collection for analysis *(research for design)* and generates knowledge from design precedents *(research on design)*. The resulting framework integrates ecological design principles with standard decommissioning activities to restructure and improve the closure-to-restoration process and enhances future recovery efforts. The framework is validated by evaluating three study sites in Southeast Michigan scheduled for decommissioning in 2023 and transform them into hybrid landscapes through phased implementation design plans *(research by design)*. The results of this research facilitate increased discussion on identifying early interventions for restoration and designing multifunctional, hybrid landscapes on industrial, urban forms by providing the field with new strategies that better integrate utility companies, communities, ecologists, and designers, and promote rehabilitated industrial landscapes.

INDEX WORDS: Landscape architecture, coal-fired power plants, ecological planning, rehabilitation, research design, restoration

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DEVYN MICHELLE QUICK

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DEVYN MICHELLE QUICK

Major Professor:	Jon Calabria
Committee:	Marianne Cramer
	Stephen Ramos
	Pratt Cassity

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
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DEDICATION

I dedicate this thesis to my father, James Randolph Quick,

who passed on to me his hazel eyes and his love of the environment,

who inspired me to crave knowledge, be fearless, and live passionately,

and who taught me the value of a crossword puzzle and a porch with a view.

His unyielding love, wisdom, and support will forever be unmatched.

I owe every accomplishment to you, Dad, and I miss you dearly.

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I would like to thank my major professor, Jon Calabria. Without your endless support, extensive knowledge, and witty comments, this process would not have been possible and definitely not as enjoyable. You have my endless gratitude and respect. My reading chair, Marianne Cramer, your passion is inspiring. You instill life into every design idea. To Stephen Ramos, your invaluable feedback and encouragement is never in short supply. And lastly, Pratt Cassity, my favorite social justice warrior, you joined my committee only weeks beforehand, and yet, you embraced my research with the same intensity you do with every project. I am beyond grateful and honored for my dream team of a committee.

I would also like to thank my friends and family whose guidance and encouragement can be found etched throughout this journey. Brandon, you are so dear to me, and your patience as I labored through this process is a constant source of light. Mom, your compassion, even from thousands of miles away, knows no bounds. And to my fellow classmates, the joy, wisdom, and memories that have been shared during our time together could fill a hundred books. I hope there are many more volumes are to follow.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Context

While the term *migration* is commonly used to describe the patterned movements of an individual species within their environment, landscapes also migrate over time. Similar to understanding the recurring movements of humpback whales or monarch butterflies, migrating landscapes can tangibly move from one physical location to another. This can be observed when sediment flows down a river delta or when plate tectonics shift causing an earthquake. Yet, landscapes are subject to migrate in a number of different ways as well, and thus, they can also experience migration in place and at a much broader range of time such as over several years or even centuries (Milligan 2013). This occurs when, over time, "the materials, entities, and actors" that form the landscape shift in such a way that a "qualitatively different landscape" develops (Milligan 2015). In today's geological epoch, known as the Anthropocene, this form of migration can be seen in highly urbanized environments, like those of Southeast Michigan, through shifting infrastructure, economic patterns, and the resulting effects on the landscape.

For more than a century, Michigan has been dependent upon coal as an energy source due to its wide availability and relatively low cost. That is, until recently, as in 2016, coal fueled less than 40 percent of the state's net generation, down from more than 65 percent in 2000 (U.S. Energy Information Administration 2017). Attributed to an aging coal fleet, changing environmental policies, and less expensive alternative energy sources, Michigan's energy providers have begun to transition away from their coal-based facilities. However, this shift also holds true nationwide as the United States' share of electricity generation has changed more rapidly in the past decade than any other time since World War II (Logan et al. 2017). Together, this has presented an unstable environment for the future of coal, and for major Michigan providers like DTE Energy, who provides energy to half of the state's population (DTE Energy 2017), this means taking a proactive role during this industry-wide revolution.

As such, in recent years, the Detroit-based diversified energy company has committed to decreasing its dependence on coal-based electricity generation and increasing its renewable energy sources as part of an overarching company transformation and in recognizing climate change as a key long-term policy issue that must be addressed. The objective is to create a reduction in greenhouse gas emissions of 75 percent below their 2005 levels by 2040 with milestone reductions of 20 percent by 2020 and 45 percent by 2030. Actions to be taken include building new natural gas facilities, continuing operations at its nuclear power plant, developing more wind and solar projects, and naturally, retiring existing coal-fired power plants. (DTE Energy 2017).

Although DTE Energy has already retired two of their coal-based facilities in the past five years, in the summer of 2016, the company announced plans to decommission three of its remaining five coal-fired power plants by 2023. They are the Trenton Channel Power Plant in the City of Trenton, River Rouge Power Plant in the City of River Rouge, and St. Clair Power Plant in the Township of East China, and combined, generate about 25 percent of the total electricity produced by DTE Energy in 2015, or enough to power 900,000 homes. (DTE Energy 2017). With their locations along the Lake Huron-Lake Erie corridor (see Figure 1.1 and 1.2), the closures of these facilities have potentially transformative repercussions in the form of emergent landscapes that can be restored for ecosystem function and improved ecological integrity.

Figure 1.1. Location of study sites in relation to the State of Michigan (left) and along the Lake Huron-Lake Erie corridor (right). Imagery: ©2018 Google, NOAA, Landsat / Copernicus.

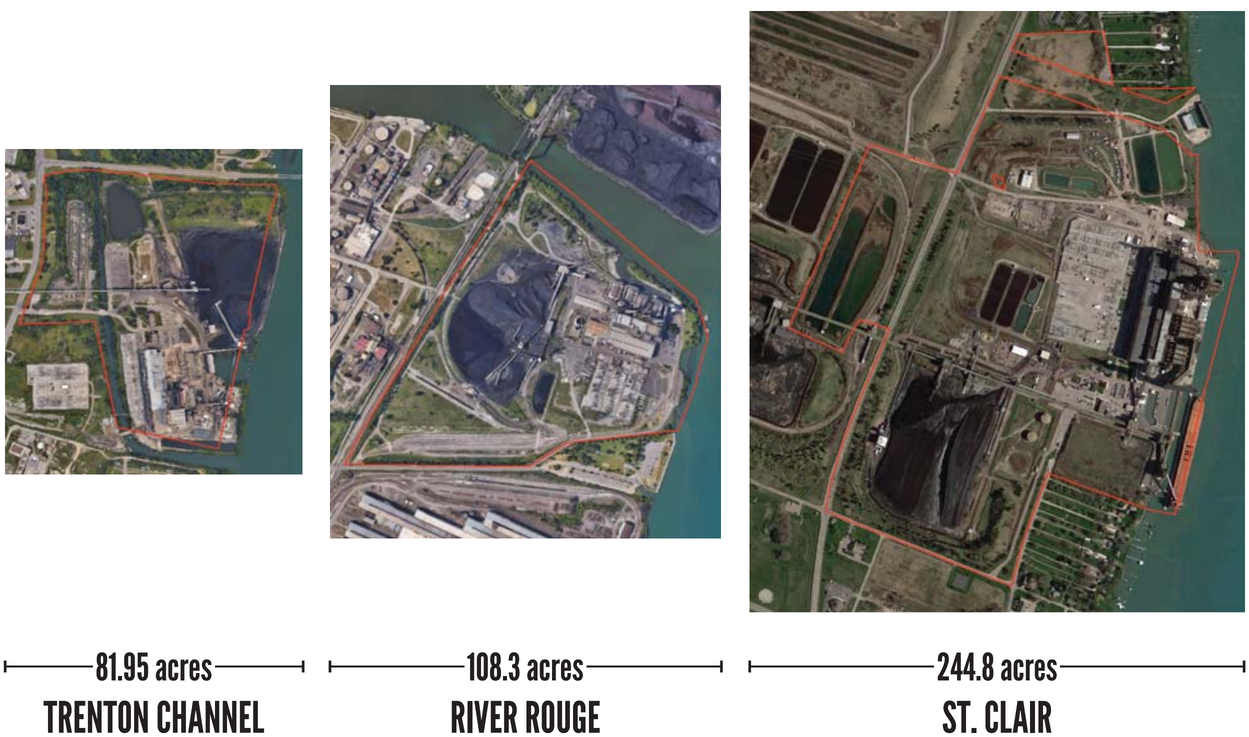


Figure 1.2. Size comparison of the study sites. Imagery: ©2018 Google.

This need for restoration stems from centuries of for trade, commerce, and urbanization significantly altering the landscape of the Lake Huron-Lake Erie corridor. Since the settlement of Detroit in 1701, rivers were dredged to allow larger shipping vessels, wetlands were drained and filled for agriculture and development, shorelines were hardened, and industrial pollutants left behind a legacy of contamination. However, despite the damage to the landscape, the corridor is one of global importance as it remains a major migration route for fish, butterflies, raptors, waterfowl, and neo-tropical birds (Hartig and Bennion 2017).

Purpose

The purpose of this thesis is to seek a new trajectory for the potential future of Southeast Michigan's decommissioned coal-fired power plants that differs from how these landscapes have been typically treated in the past. By developing a more comprehensive decommissioning process, this thesis proposes the creation of a new framework restoring ecosystem function and informing new programming for future recovery of these sites. Not only will this research establish an alternative future for the decommissioned coal-fired power plants, but it will also foster resiliency and support the mitigation of anthropogenic impacts. This thesis also intends to apply the framework to three selected study sites in Southeast Michigan creating series of conceptual designs that cultivate a restored landscape within an urban, cultural form.

Then, using a contemporary lens on Ian McHarg's ecological planning concepts, this research applies the principles of ecological design to transform these sites into hybrid landscapes exhibiting both natural ecologies and productive elements. This transformation concentrates on the restoration of natural communities, but rehabilitation efforts will be employed when necessary. To accommodate the diverse social and economic demands of Southeast Michigan, and post-industrial communities in general, productive elements that acknowledge human ecosystems will be introduced through community assets and green technology.

In doing so, this thesis seeks to answer the question: *How can ecological design transform decommissioned coal-fired power plants into hybrid landscapes that improve ecological function?* Furthermore, through the creation of the framework and subsequent conceptual designs, this thesis will address the sub-question: *What interventions and implementation strategies can be applied to address possible post-contamination treatment and enhance standard decommissioning practices that generally inhibit the restoration process?*

Significance

The significance of this research lies in its ability to be proactively applied to the landscape architecture profession as the actions taken by DTE Energy not only signify a substantial shift in Michigan's emergent landscapes but are also part of a much larger transformation that is underway across the entire United States. However, due to the recent trend in closures and limited amount of case studies, the ecological restoration potential of decommissioned coal-fired power plants has yet to be fully realized. Instead, current approaches concentrate on economic or political motivations that result in equally land-use intensive developments such as hotels, office buildings, and high-density residential units. Amidst the retirement of over half of the nation's coal-fired power plants, with many more expected to follow, this research is vital in developing new strategies to reprogram the environmental legacies and large tracts of land left behind and to establish an alternative future for decommissioned coal-fired power plants focused on producing ecologically-informed, hybrid landscapes.

Goals, Aims, and Objectives

This research aims to accomplish the following goals as they relate to the proposed transformation of the decommissioned coal-fired power plants in Southeast Michigan.

Ecological Goals

1. Restore the biotic and abiotic components of the sites to improve ecosystem function.
2. Restore essential habitat for wildlife such as waterfowl and fish.
3. Use remediation tactics to clean soil, air, and stormwater runoff.
4. Create connectivity with surrounding corridors and hubs to avoid fragmentation.
5. Design resilient landscapes to withstand undesirable natural and human stresses.

Productivity Goals

6. Design community assets that produce tangible and intangible services.
7. Demonstrate renewable energy systems and regenerative processes.
8. Create educational opportunities that foster stewardship of the new landscape.
9. Acknowledge culture and history through repurposed infrastructure and buildings.
10. Activate the landscape through responsible development and public engagement.

The phasing and spatial organization of these goals are determined by a number of driving factors. First, the ecological goals of the framework are guided by the location of existing natural resources and intact habitats that establish landscape connectivity with adjacent environments, and opportunities for the creation of essential habitat and rare natural communities. The arrangement of ecological components is also guided by the desired spatial and landscape setting for the site.

The productive goals are then organized based upon the current infrastructure's architectural quality and historical characteristics as well as the location of existing industries and planned development. This is supplemented by an analysis of the surrounding community identifying goals and concerns for future planning.

Scope and Delimitations

The term hybrid is used in this research to describe a landscape that possesses both ecological and productive qualities, but due to the severe damage on the sites and urbanization of Southeast Michigan, this research prioritizes efforts directed at restoring ecosystem function as well as improving large-scale connectivity. However, productive elements remain an important part of the design as a means of activating these sites for human interaction and to serve as community assets. Thus, to remain dedicated to the design goals established by this research and to continue the promotion of an integrated natural and urban fabric, the productive elements are defined as those that support the growth of green industries, renewable energy, public engagement, and adaptive re-use.

The end results from this investigation include a design framework and its application. To develop comprehensive design alternatives for these large and complex sites under a designated timeframe, this study limited the research of several items that were identified as outside of the scope of this thesis but are still considered essential to its future exploration. This includes items such as identifying potential funding and designating project ownership. Instead, this thesis relies upon the literature review, analysis, precedent studies, and the resulting framework to suggest decommissioning and restoration alternatives for the transformation of the selected study sites. This can then be used by post-industrial communities and landscape architecture professionals as a resource in promoting informed, local decision-making. Other elements or approaches that will be discussed, but will not result in specific designs or implementation plans, include the re-use of on-site structures, construction documents, and detailed planting plans.

Lastly, the site boundaries for the design applications are limited to the parcel limits and do not factor in adjacent parcels owned by DTE Energy as it cannot be determined if operations there would cease after decommissioning as well (see Figures 1.3, 1.4, and 1.5). However, intact land that extends past the parcel boundary into the adjacent water body is assumed as part of the main parcel and, thus, is included in the design. This includes area such as the land that extends east past the Trenton Channel Power Plant parcel boundary into the Detroit River.

Figure 1.3. Trenton Channel Power Plant parcel and adjacent DTE Energy properties. Imagery: ©2018 Google.

Figure 1.4. River Rouge Power Plant parcel and adjacent DTE Energy properties. Imagery: ©2018 Google.

Figure 1.5. St. Clair Power Plant parcel and adjacent DTE Energy properties. Imagery: ©2018 Google.

Thesis Structure

This thesis will begin by exploring the research design methodology used for this research. The general findings and definitions behind each method will be discussed, and then it will describe how the chosen methods were used specifically for this research.

The next chapter explores the transformation of Southeast Michigan's landscapes from its glacial beginnings to modern urbanization. After analyzing the past, present, and future state of the landscape in question and identifying the primary habitat types for the subsequent framework and design phase, this thesis will then investigate design theories and applications from the landscape architecture field as they relate to the research. The case will be made for the use of a contemporary lens on the ecological planning principles of Ian McHarg as it applies to the ecological restoration of the Southeast Michigan landscape.

Chapter Four examines the use of coal-fired power plants and its correlation to the current trends in electricity generation nationwide as well as an in-depth look into the state of the three selected study sites. This will result in context and infrastructure layout diagrams of each study site as the research begins to develop a framework for their transformation. The chapter continues this exploration by identifying standard decommissioning processes upon which a review of current knowledge surrounding the post-retirement potential of coal-fired power plants. To supplement these findings, precedent studies are presented that have resulted in a number strategies for transforming severely degraded or altered landscapes. Analysis of these projects and insights will highlight goals or strategies that have been incorporated into the research. This chapter will also produce examples of design goals, remediation tactics, and community-scale development, and end with the developed framework.

In Chapter Six, the finalized framework is discussed and applied on all three study sites resulting in series of phased implementation design plans illustrating the effectiveness of the framework and its ability to restore ecosystem function and create multifunctional, hybrid landscapes. This chapter will also provide a design critique that evaluates the ability of the framework and resulting designs to address the research questions of this thesis. A conclusion chapter reflects on the process and its future implications.

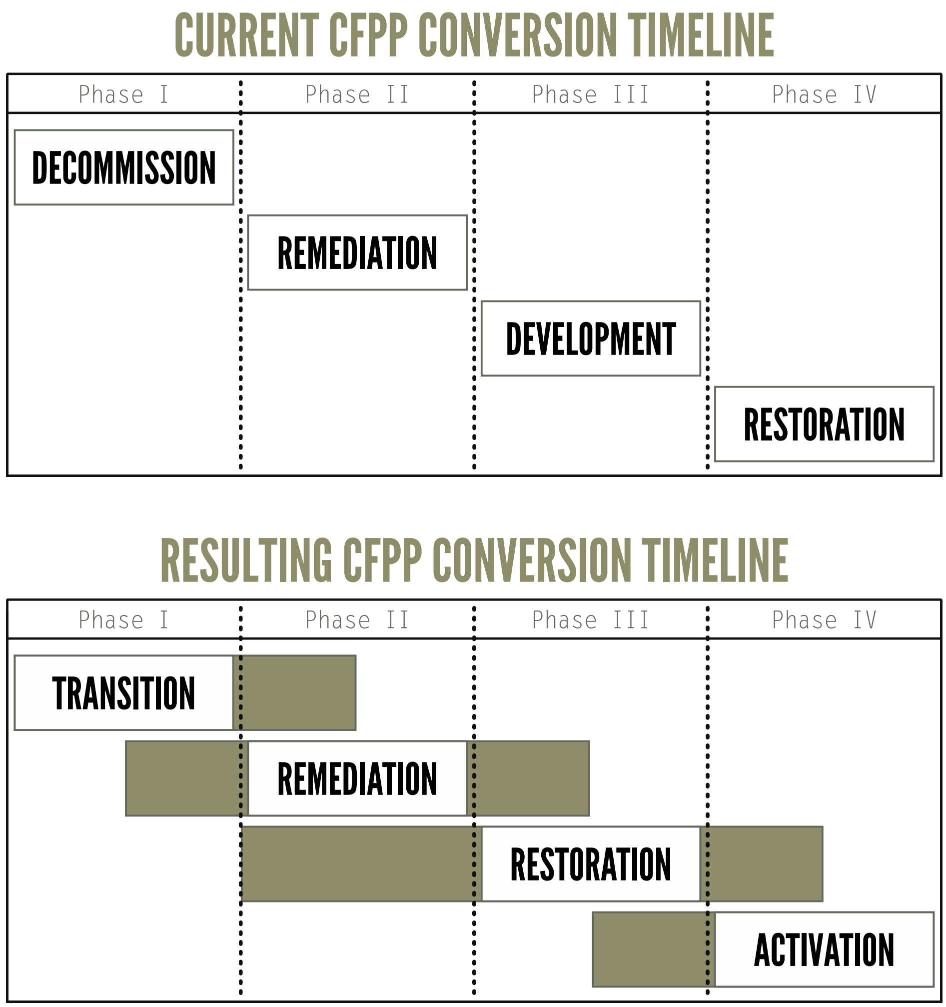


Figure 1.6. Current transformation process of decommissioned coal-fired power plant (CFPP) process compared to results.

CHAPTER TWO

USING A MIXED METHOD RESEARCH DESIGN STRATEGY

Introduction

Due to the increasingly complex nature of human-altered landscapes, such as those found at decommissioned coal-fired power plants, coupled with the continuously developing design theories from the field, design has become an invaluable tool in aiding the research of landscape architecture and ecological planning. However, while design allows researchers to deal with problems that require constant adaptation and helps define the future (Frayling 1993), it is still subjective in nature, and a consensus on its exact usage as a research method is ill-defined. Instead, researchers and academics have been attempting to categorize and define the different situations where research design can be applied.

The most notable of these attempts has come from the work of Lenzholzer (2010) who has combined several research design methods into one comprehensive process to aid in her research on thermally comfortable urban squares in the Netherlands based on microclimates. Upon investigating the merit of this work as compared to using only a singular research design method, an adapted form of Lenzholzer's contribution to the research design discussion was applied to this thesis and helped inform its strategies using the following method classifications: research *for* design, research *on* design, and research *by* design (see Figure 2.1). Thus, the rest of this chapter is dedicated to discussing the general findings behind each research design method and how each one was applied to address the research questions.

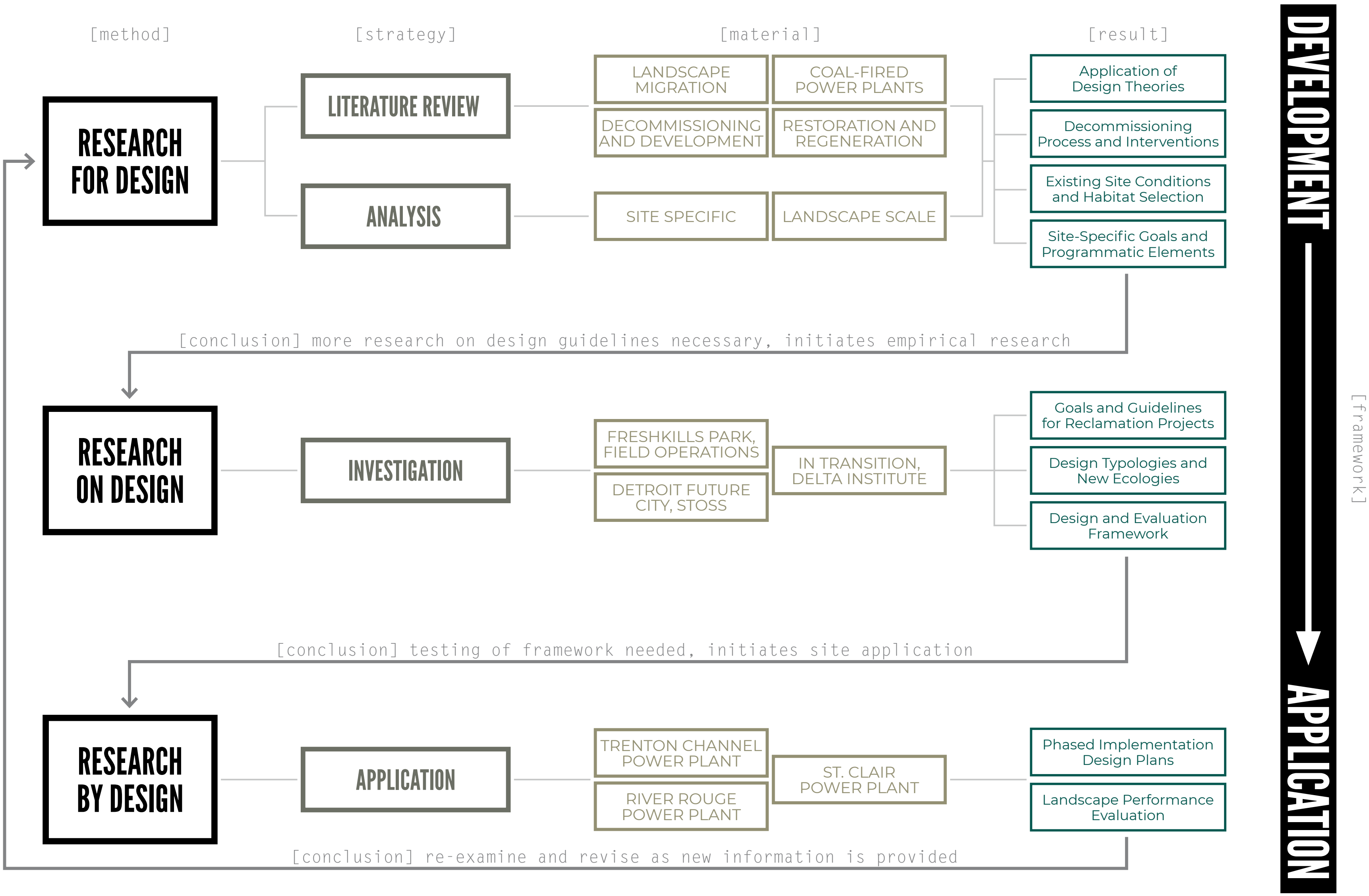


Figure 2.1. Diagram of mixed method research design approach.

Research for Design

Research *for* design is a clinical research approach considered the most straightforward and routine out of the methods investigated as it is factual in nature. It is used to provide all the information, implications, and data needed to inform or support a design product or process. This includes quantitative research methods that are measured, objective, and unbiased such as land surveys, demographics, property values, and structural testing, as well as qualitative methods such as observations, interviews, and focus groups. Thus, the data collected may be generated from the researcher or may be secondary research that was previously published by an outside source. The results, or new knowledge, collected from this research method are then used to inform the design product or process. (van den Brink and Bruns 2014, Lenzholzer et al. 2013).

After applying the research *for* design method to the research of this thesis, the resulting knowledge was generated by gathering supporting literature and theories, conducting site analysis, and collecting all other data deemed necessary. This data included, but is not limited to, existing conditions of the sites, socio-economic characteristics of the communities, demographics, future development plans, cultural history, and large-scale connectivity of the region such as through pre-settlement habitats and migration routes. Thus, the goal of this method was to collect abundant information and interpret it in a manner that generated new knowledge benefiting the development of the framework and the subsequent design application. Because design and research in landscape architecture is a highly interdisciplinary undertaking, from social sciences and ecology to local history and humanities, the research came from a wide range of resources and disciplines. The specific strategies taken to conduct this method included literature review, site identification, and landscape analysis.

Literature Review

The literature review strategy is divided into three primary themes investigating the multiple layers and components attached to the research questions and are shown in Chapter Three and Chapter Four. The first theme examines the environmental history and transformation of the Southeast Michigan landscape from its glacial history through current urbanization highlighting the historic natural communities of the area and their resulting structure due to human development. This human-nature relationship is then used to investigate the work of Ian McHarg and design practices such as restoration, rehabilitation, resiliency, and ecological design in order to apply the appropriate principles to the research. The final theme studies the history, infrastructure, organization, and environmental concerns of coal-fired power plants as they've been used over the past century. This information is then carried forward in analyzing the future of coal-fired power plants as it relates to the current trends in electricity generation in Southeast Michigan and nationwide.

Site Identification and Landscape Analysis

The site identification and landscape analysis strategies are seen at different stages throughout the thesis as they were critical in understanding the relevant context of each selected study site, identifying potential constraints and opportunities, and addressing the design goals and objectives. Since most of the information gathered was not conducted by the researcher but by other sources, after data collection, the information was interpreted and translated into meaningful design directives and diagrams applicable specifically to the study sites and the research.

The information generated from these strategies were produced using a number of resources including Geographic Information Systems (GIS) software, Google Earth imagery, personal observations and photographs, and reports generated by DTE Energy or government agencies. Using this new knowledge, an in-depth site and landscape analysis was performed to develop maps, diagrams, and imagery that effectively analyzed the larger connections of the sites. Landscape characteristics collected include topography, floodplains, soil composition, historic vegetation, wildlife, history and culture, recreation, demographics, land-use, and existing structures. These characteristics were chosen based on knowledge gained through previous design experience and through the evidence provided in the literature review. Again, the goal of this analysis was to comprehensively consider all relevant factors and collect any and all information that would inform or support the research and design process.

Research on Design

The second method, research *on* design, is a diagnostic approach characterized by the act of reflecting, reviewing, and analyzing design products, processes, core concepts, and paradigms in order to acquire specific design knowledge. The resulting knowledge can be interpreted from many viewpoints such as historical, aesthetic, philosophical, or technical (Frayling 1993). This method plays a vital role in establishing, improving, and validating the design in progress by drawing conclusions from the analysis of completed designs (van den Brink and Bruns 2014, Lenzholzer et al. 2013). Its most common form in the field and in research can be seen through the use of case studies and design criticism. This provides the research with a design reflection from a theoretical or critical perspective.

For this thesis, the research *on* design method was utilized to aid in the development of the proposed framework. The precedent studies selected provided a range of design products and processes that focused on transforming severely degraded or altered sites using an ecological, economic, or hybrid focus. The purpose of this research method was to generate items such as design guidelines, remediation strategies, and organizing typologies that would advance the framework in progress.

This involves analyzing all relevant aspects of the design precedent's composition. The layout includes spatial form, such as framing and function. The metaphorical form identifies iconographic images and structural components that promote stewardship and create community engagement. Lastly, the programmatic form is analyzed for its functionality in relationship to the shifting parts on the site and the development of new ecologies. After acquiring conceptual, theoretical, spatial, and typological design knowledge, the resulting conclusions, which are shared in Chapter Five, are used to refine and finalize the developing framework allowing for the next phase of design application to begin.

Research by Design

The final type of research, research *by* design, is used to generate new design knowledge through the physical act of designing. The focus is not on the final design solution, but on creating design knowledge through a cognitive activity. This method can be interpreted in two different ways. The first, experimental design, is about the application and transformation of principles found through research and existing knowledge. The goal is to not only attempt to make better use of the knowledge available, but to also track various design scenarios and evaluate their contribution to improving the spatial qualities of the problem. The second, design study, is about modelling and expression by thoroughly thinking about a problem, carrying out experiments, and processing and analyzing data. The design process is used as an explorative, or experimental, research task, and testing designs is seen as an example of how to carry out such an experiment like with prototyping. (van den Brink and Bruns 2014, Nijhuis and Bobbink 2012).

When incorporated into the research of this thesis, research *by* design was used to test and apply the framework produced on the selected study sites in Southeast Michigan which is presented in Chapter Six. The goal was to not only validate the framework, but to also generate new knowledge and thought processes as the information gathered from the previous research methods would be processed and interpreted in a second, new form. The main strategy used to carry out this method involved executing the predefined design goals and restoration objectives of the research resulting in series of phased implementation design plans. Due to the many interdependent steps and activities surrounding the decommissioning, remediation, and restoration of the decommissioned coal-fired power plants, these designs helped visualize and comprehend the moving pieces into a coherent plan through multiple design tools such as sketches, testing designs, and producing section views all while using the developed framework.

Lastly, critiquing the resulting designs was necessary to validate and memorialize the processes. This evaluation will be taken in two steps. First, diagrammatically through analyzing the resulting site designs based on typologies, and then by using performance metrics which enables a researcher to show a design's value and make the case for its implementation. To perform this second evaluation, the landscape performance metrics and methods established by the Landscape Architecture Foundation (n.d.) as part of their *Case Study Briefs* will be incorporated into the design framework and used to evaluate the phased implementation plans post-design.

Conclusion

On their own, each of the methods discussed have proven resourceful and valuable as they are developed and refined for use in the landscape architecture field. However, when research questions, such as the ones raised by this thesis, demand investigations at varying scales and across multiple systems, the development of a mixed method strategy proves necessary. This process also provides an exploratory response to a post-industrial problem, or "a projection of a possible future landscape in response to a change of condition or need" (Deming and Swaffield 2011). Since the obstacles inhibiting restoration efforts at the site have yet to be fully realized, the research design process must remain adaptive to changing conditions and must cover a broad range of information as one method would be insufficient in identifying all of the constraints on the sites especially as they transition through decades-long transformation. Thus, to provide a new, ecologically-informed trajectory for the future of decommissioned coal-fired power plants, the research approach must be as dynamic as the landscape in question, and thus, using a combination of research design methods provides the ability to build upon the study sites' evolving conditions, not just the existing ones. The success of this approach can also be seen throughout the thesis in the results presented in the following chapters.

CHAPTER THREE

LANDSCAPE TRANSFORMATION IN SOUTHEAST MICHIGAN

Introduction

As Detroit strives to rebuild after longstanding issues of urban decay, the surrounding communities of Southeast Michigan must also come to terms with their neglected landscapes. For centuries, trade, commerce, and the industrial revolution transformed the area significantly altering the landscape and adjacent shoreline. In turn, these changes negatively altered ecosystem function of the landscape as wetlands that provided essential habitat were drained, areas where migratory birds once found refuge were destroyed or contaminated, and invasive aquatic species were introduced to the waterways through intercontinental shipping freighters. Although some species and natural communities adapted to these extremely altered conditions, many did not. Thus, this chapter seeks to examine the environmental history of Southeast Michigan resulting in an understanding of how the landscape has migrated and transformed over time, where it might go, and how the ecological restoration of decommissioned coal-fired power plants can aid in its recovery and increased resiliency.

Glacial History and Natural Communities

Approximately 14,000 years ago, retreating ice sheets of the last glacial period began carving its way through the Great Lakes watershed leaving behind unique landforms, sediment types, and erosion patterns. During this warming period, as water drained from glacial lakes in

Southeast Michigan, the resulting physiographic region known as the Maumee Lakeplain was formed (see Figure 3.1). A flat, vast plain spanning over 2,300 square miles, the Maumee Lakeplain is characterized by poorly-drained loamy and clay soils dissected by broad glacial drainageways of sandy soil that evolved from deposits of fine silts and clays left by the glacial lakes. (Albert 1995) These soils supported a variety of vegetation communities, but prior to European settlement, the area was, by far, dominated by closed-canopy, hardwood forests. However, variations in glacial topography, soils, and moisture resulted in both upland and wetland forests, lowland grasslands, and marsh communities. (Appel et al. 2002).

First, growing in damp, loamy clay soils of the lakeplain, beech-sugar maple forests favored soils with high water-holding capacity and nutrient content. Covering vast areas of level to rolling, loamy uplands in Southeast Michigan, the beech-sugar maple forest represents the highest order of forest community succession. They are characterized as multigenerational, with old-growth conditions lasting centuries. Naturally, the primary species of this community are the American beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*) which often form more than 80 percent of the canopy composition. Less dominant tree species include basswood (*Tilia americana*), red oak (*Quercus rubra*), white oak (*Quercus alba*), white ash (*Fraxinus americana*), shagbark hickory (*Carya ovata*), black walnut (*Juglans nigra*) and tulip tree (*Liriodendron tulipifera*). However, due to its dense canopy, these forests experience a well-developed, shade-tolerant herbaceous forest floor but little to no shrubs. Forb species and ephemeral flowers include jack-in-the-pulpit (*Arisaema triphyllum*), wild ginger (*Asarum canadense*), cut-leaved toothwort (*Cardamine concatenate*), wild geranium (*Geranium maculatum*) and common trillium (*Trillium grandiflorum*). (Appel et al. 2002, Cohen 2004).

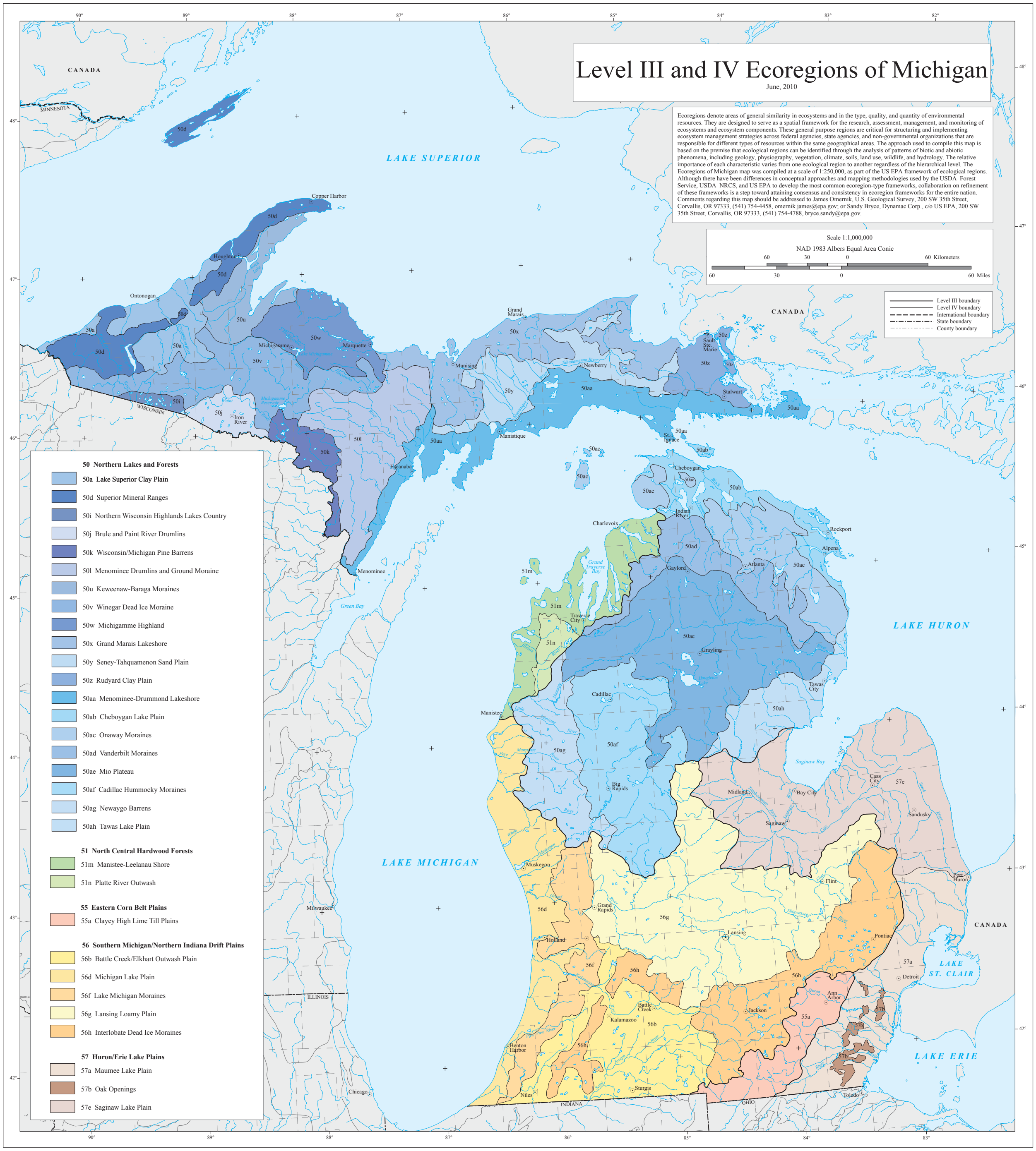


Figure 3.1. Level III and IV ecoregions of Michigan.
Source: ftp://newftp.epa.gov/EPADataCommons/ORD/Ecoregions/mi/mi_eco.pdf

On well-drained sandy lakeplains and glacial outwash plains, beech-sugar maple forests were replaced by oak-hickory communities favoring the drier conditions. Historically, frequent wildfires started by lightning or Native Americans maintained its semi-open conditions and promoted oak regeneration and plant diversity. Because fires strongly influenced vegetation patterns, oak-hickory forests typically occurred over a broad landscape matrix interspersed with prairies, oak savannas, mesic forests, and wetlands, and boundaries were determined by fire dynamics such as fire frequency, fire intensity, and the presence of fire breaks. Dominant species of this dry-mesic southern forest were red oak (*Quercus rubra*), white oak (*Quercus alba*), black oak (*Quercus velutina*), pignut hickory (*Carya glabra*), and shagbark hickory (*Carya ovata*). Then, typical understory species included witch hazel (*Hamamelis virginiana*), choke cherry (*Prunus virginiana*), downy arrowwood (*Viburnum rafinesquianum*), and wild blueberries (*Vaccinium* spp.). (Appel et al. 2002, Lee 2007).

Interspersed within or adjacent to the oak-hickory forests were the oak savanna communities which acted as a transition community between prairie and forest. Also fire-dependent, it is characterized by widely spaced trees with shrubs, grasses, sedges, ferns, and wildflowers occupying the understory. The community is dominated by white oak (*Quercus alba*) with bur oak (*Quercus macrocarpa*) and chinquapin oak (*Quercus muehlenbergii*) as common co-dominants. The open canopy areas of the savanna support more sun-tolerant plant species such as butterfly weed (*Asclepias tuberosa*) and flowering spurge (*Euphorbia corollata*) while in shadier areas, fire-tolerant forest shrubs like blueberries (*Vaccinium* spp.) and huckleberry (*Gaylussacia baccata*) grow. The grassy understory is then filled with plants species associated with both tallgrass prairie and forest communities including big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), milkweed (*Asclepias spp.), prairie coreopsis (*Coreopsis palmata*), and aster (*Symphyotrichum* spp.). (Appel et al. 2002, Cohen 2001).

Another fire-dependent, matrix community is the tallgrass prairie. In the pre-settlement Lake Huron-Lake Erie corridor, tallgrass prairies occurred mostly on sandy portions of the lakeplain, but were also intermittently dispersed on well-drained, sandy-gravelly kames, moraines, and glacial outwash landforms. Each of these different landforms supported distinct prairie plant communities as the species composition varied greatly depending on moisture, soils, and topography which ecologists use to define tallgrass prairie types applying the terms wet, mesic, and xeric. These factors dictate the species of grasses and wildflowers that form in the prairie structure, but because changes in topography and soils are often subtle, different types of prairies may grow next to each other. In Southeast Michigan, the tallgrass prairie communities are specifically represented by lakeplain wet prairies and lakeplain wet-mesic prairies. (Appel et al. 2002).

The lakeplain wet and wet-mesic prairies are native lowland grasslands that occurred on on moist, level, seasonally inundated glacial lakeplains. Some plant species that thrive in these natural communities are restricted to the southern Great Lakes region making its continued presence important in maintaining biodiversity on a global scale. Both of the community's species composition and structure were influenced by natural processes including seasonal flooding, cyclic changes in Great Lakes water levels, flooding by beavers, and fire, yet the lakeplain wet prairie is dominated by grasses, sedges, rushes, and a diversity of forbs. Primary species include blue-joint (*Calamagrostis canadensis*), cordgrass (*Spartina pectinata*), Baltic rush (*Juncus balticus*), and switch grass (*Panicum virgatum*). The lakeplain wet-mesic prairie, on the other hand, is comprised of prairie grasses, sedges, and a diversity of forbs such as big bluestem (*Andropogon gerardii*), cordgrass (*Spartina pectinata*), switch grass (*Panicum virgatum*), Indian grass (*Sorghastrum nutans*), common mountain mint (*Pycnanthemum virginianum*), tall coreopsis (*Coreopsis tripteris*), and marsh blazing star (*Liatris spicata*). (Albert and Kost 1998). Together, these prairie communities accounted for an estimated 122,425 acres of pre-settlement vegetation in Southeast Michigan (Appel et al. 2002).

The final natural community found extensively throughout pre-settlement Southeast Michigan was the Great Lakes coastal marsh, a wetland ecosystem distinct to the Great Lakes Basin. The vegetation patterns and diversity of this community are strongly influenced by water-level fluctuations, the configurations of the shoreline, and the major aquatic system, defined largely on water flow and resident time, that it sits along. For example, the Detroit River and St. Clair River are classified as connecting channels as they refer to the major rivers linking the Great Lakes and are characterized by a large water flow, but seasonally stable hydrology. When wetlands are present along the main shoreline of these connecting channels, they are exposed to current and wave action, and thus, vegetation is frequently limited to a thin fringe paralleling the shore. However, when formed inside an embayment along the connecting channel, the wetland community is protected from erosion and extensive wetland development can occur. (Albert 2001).

Many factors affect the overall composition of the Great Lakes coastal marsh, yet the vegetation zones generally include a deep marsh with floating-leaved and submergent plants, an emergent marsh of mostly narrow-leaved species, and a sedge-dominated wet meadow that can be flooded by storms. The wet meadow zone often functions as a transition zone from deeper water wetlands to upland communities (see Figure 3.2) and usually reaches a maximum water depth of around six inches. Characteristic plants include bulrushes (*Schoenoplectus* spp.), broad-leaved cat-tail (*Typha latifolia*), sedges (*Carex* spp.), blue-joint (*Calamagrostis canadensis*), sweet-scented

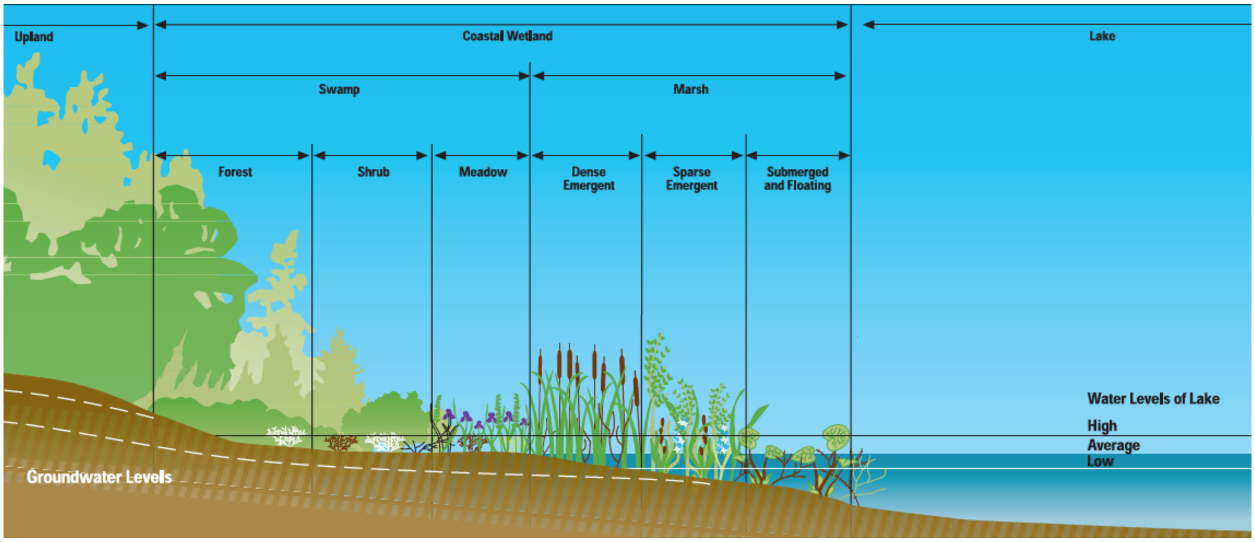


Figure 3.2. Vegetation zones of the Great Lakes coastal marsh system.
Source: Appel et. al. 2002.

waterlily (*Nymphaea odorata*), yellow pond-lilies (*Nuphar variegata*), duckweeds (*Lemna* spp.), and pondweeds (*Potamogeton* spp.). (Cohen et al. 2015, Appel et al. 2002). However, whereas these descriptions illustrate the pre-settlement conditions of the Maumee Lakeplain natural communities in Southeast Michigan, they do not reflect the current conditions of those same landscapes today.

Human-Altered Landscapes

Prior to the arrival of European settlers, scientific evidence suggests Native Americans arrived in the Lake Huron-Lake Erie corridor 10,000 to 12,000 years ago. However, by the 18th and 19th centuries, the Potawatomi and Wyandot lived near the Detroit River, and the Ojibwe lived in villages in the St. Clair River Delta. While the tribes harvested natural resources from the area, overall they had little effect on the landscape. The most notable alterations were seen through mound building and burning practices aimed at improving hunting grounds and maintaining grassland habitat. Rules for human interaction with the environment were even incorporated into their lifestyles as the location of where a tribe lived was usually dictated by seasonal migration between hunting and farming grounds to harvest the resource that was most plentiful at that time. (Appel et al. 2002). European settlement activities, on the other hand, were not as mindful.

French explorers were the first Europeans to enter the Great Lakes region, and in 1701 Antoine de la Mothe Cadillac founded Detroit as a French trading post and fort to expand trade and commerce. To help establish it as a self-sustaining community, Cadillac began bestowing ribbon farms, or long, narrow, land divisions lined up perpendicular to the Detroit River, soon after his arrival (Hartig and Bennion 2017). Such agricultural practices most likely represented some of the first European impacts upon the shoreline and coastal marshes as wetlands were filled for agricultural use.

As Detroit grew into a center of commerce and trade, a number of wharfs were constructed along the river starting in 1760. Projecting into the Detroit River and continuing the loss of coastal wetland habitats, the river soon became dominated by commercial and excursion vessels. Improvements in water transportation also resulted in an expansion in population, and in the 1820s, settlement of Southeast Michigan begin in earnest. Within a generation, the land was cleared, and towns, farms, and mills were constructed throughout the Rouge River watershed. The 1820s also saw the opening of the Welland Canal which for the first time allowed invasive species, such as the sea lamprey, to migrate westward from Lake Ontario. (Appel et al. 2002).

With the improvements to the navigable rivers, the pattern of settlement in the region followed the major river systems. Tallgrass prairies were the first ecosystems to be converted to farmland, as the wet, flay clay soils of the lakeplain were not suitable for farming. However, after exhausting for former, the Swamp Lands Act of 1850 encouraged settlers to drain the latter and convert it into farmland. (Appel et al. 2002). These drained areas actually proved to be some of the most valuable agricultural lands in Michigan, and by 1870, both sides of the shoreline of the Detroit River were colonized by farmers and small merchants. While, at first, the wetlands along the river were essential for survival of the settlers and were used in many ways, eventually they were diked and cleared for pasture and cropland (Manny, Edsall, and Jaworski 1988).

Unfortunately, wetlands and prairies were not the only natural resource to be removed. The lumbering boom of the area began in the early 1800s and lasted for nearly 80 years as forests were logged until exhaustion. Often lumber companies would purchase land, log it, then sell it to settlers who would remove stumps and complete the conversion from forest to farm. Between 1870 and 1880, lumbering peaked in Southeast Michigan as lands were stripped of forests. The peak also coincided with the beginning of the Steam Age. (Appel et al. 2002).

In 1900s, industrialization began to dominate the shorelines of the Detroit River with the primary focus on producing steel, paper, chemicals, automobiles, and other manufactured goods. Large thermoelectric power plants began to be built along the shoreline for easier access to the large volumes of water required for their cooling systems. Power plant operations also altered the chemical characteristics of the environment from pollutants discharged into the soil, rivers, and groundwater (Great Lakes Environmental Assessment and Mapping Project, n.d.). As the industrial development began to spread throughout Wayne County, population growth and land-use intensity in the Detroit River area accelerated after 1910, and by 1930, the development of heavy steel, chemical, and refining industries in the surrounding towns of River Rouge, Ecorse, Trenton, and Wyandotte dominated the metropolitan area (Manny, Edsall, and Jaworski 1988).

Half a century later, due to infilling, channelization, and bulkheads, 55 percent of the United States' mainland shoreline of the Detroit River had been hardened with steel sheet piling or concrete breakwater by 1985 (Hartig and Bennion 2017), and by the turn of the century, 97 percent of the Detroit River's coastal marshes had been depleted with related losses occurring along the shorelines of Lake St. Clair and the St. Clair River. These losses were then coupled with chemical pollutants that began altering the natural communities as contamination from heavy metals, oil, dioxins, PCBs, and other toxic chemicals were found throughout the Detroit River and St. Clair River. (Appel et al. 2002).

After centuries of alterations, the quality of the Lake Huron-Lake Erie corridor has been transformed by human use at a cost to the natural environment and native biodiversity. The rivers have been dredged to allow larger shipping vessels, wetlands have been drained and filled for agriculture and development, shorelines have been hardened, and industrial pollutants have left a legacy of contamination. Fish and wildlife communities have also been affected by loss of habitat, contaminated sediments, poor water quality, and unintentional introduction of invasive species. (Derosier et al. 2015). Currently, more than 280 endangered, threatened, and special concern plant and animal species are struggling to survive with loss of habitat as the primary reason for their decline (Appel et al. 2002).

When compared to pre-settlement numbers, the losses are staggering. Of the 1.8 million acres of pre-settlement forests in Southeast Michigan, only 380,000 acres remain (Bull and Craves 2003). Both the lakeplain wet prairie and lakeplain wet-mesic prairie have been nearly eradicated from the landscape as they previously covered an estimated 122,425 acres in St. Clair, Macomb, Oakland, Washtenaw, Wayne, and Monroe counties prior to settlement. Today, those numbers are less than 800 acres. Lastly, wildfire suppression by humans has greatly altered the distribution and extent of fire-dependent communities like the oak savanna. Compared with pre-settlement distribution, oak savannas have become nearly extinct without periodic fire to prevent the invasion of woody and invasive species. Many plants that were once common in lakeplain prairies and oak savanna ecosystems are not only at risk for being lost to the region, but also for becoming completely extinct. (Appel et al. 2002).

However, despite this exploitation, the ecosystems of the Lake Huron-Lake Erie corridor remain a globally important migration corridor for fish, butterflies, raptors, waterfowl, and other birds (Appel et al. 2002). Of the 174 species of fish recorded in the Great Lakes Basin, 116 have been recorded in this channel system (Bull and Craves 2003). The Lake Huron-Lake Erie corridor also sits along the intersection of the Atlantic and Mississippi flyways with over 350 species of birds being brought into the corridor including 23 species of raptors and 30 species of waterfowl. Of those, about 150 are known to breed in the area. (Hartig and Bennion 2017, U.S. Fish and Wildlife Service 2012). Furthermore, coastal marshes have also been able to persist in the area, particularly in the St. Clair River Delta and the islands of the lower Detroit River, providing crucial habitat for many species of plants and animals, and representing the most biologically significant habitats for migratory birds in the region (Derosier et al. 2015).

With the upcoming decommissioning along the corridor, the potential exists to use these sites to improve the natural communities of the area. This would also allow efforts that work to reverse the human alterations that were first placed upon the landscape so many years ago. Yet, the surrounding areas of these sites are no longer even comparable to their pre-settlement conditions. For example, a majority of the connecting channels in the Great Lakes Basin have been modified (see Figure 3.3) to accommodate shipping resulting in increased shoreline erosion. Water-level control through the ports have also altered natural wetland dynamics. Thus, in order to effectively shift the future of these landscapes towards a more integrative approach, the appropriate principles of ecological design must be identified for its application on these sites.

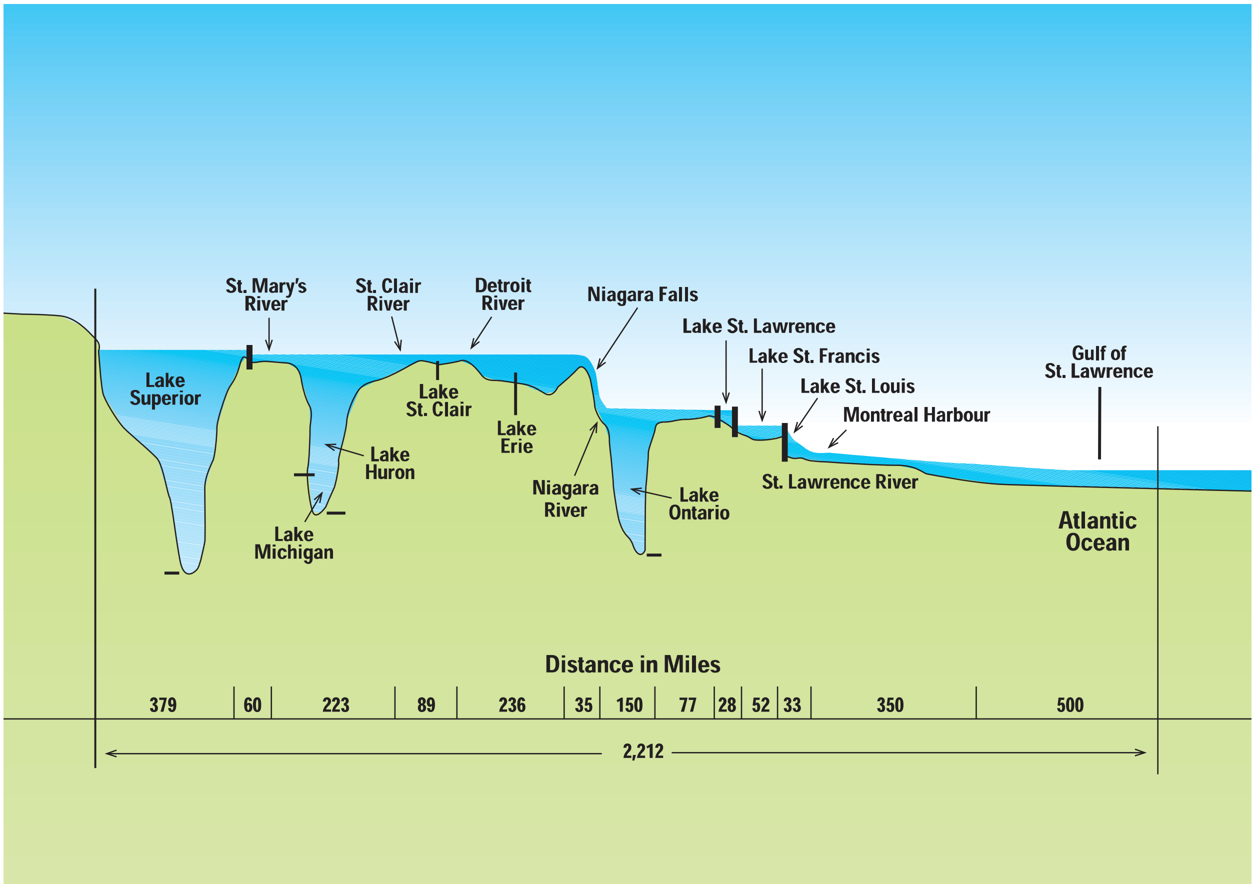


Figure 3.3. Depth and elevation of the Great Lakes and connecting systems.
Source: Appel et al. 2002.

Ecological Design and the Human-Nature Relationship

Ecology is defined as, "a branch of science concerned with the relations of organisms to one another and their physical surroundings" (Rottle and Yocom 2010), and in the design field, the contemporary practice of incorporating ecology into the design can be traced back to Ian McHarg's work in the late 1960s and early 1970s. Through the analysis and assessment of natural resources, McHarg popularized the idea of creating nature-informed design decisions (Reed and Lister 2014). His work not only claimed to result in the best places and strategies for social occupation, but it also stressed the idea that there were opportunities for interconnectedness between the built and natural environment. This led to the formulation of a design practice that prioritized incorporating nature throughout the urban landscape and insisted that urban design should be led by nature (McHarg 1969). However, with the development of more contemporary ecological design theories, the works of McHarg have seen both praise and criticism.

Ecological Design

Today, ecological design is described as “the process of actively shaping the form and operations of complex environments in such a way that composition and processes help to maintain and, if possible, increase the integrity of a region’s ecological relationships” (Rottle and Yocom 2010). Although it is not a design style, it works to address the design aspect of the human-nature relationship in the landscape where traditional forms of development have only focused on meeting human needs and disregarded the landscape’s natural processes. Instead, ecological design seeks to disrupt the depletion of natural resources, aid in species diversity, maintain habitat quality, and preserve the natural cycles of the environment. (Van der Ryn and Cowan 1996).

An important organizing concept in ecological design is understanding that ecological processes operate at a variety of spatial scales, and the flow of energy and materials between ecosystems, or its functional connectivity, is directly correlated to its structural connectivity. In human-altered environments, these flows are usually managed through a host of constructed infrastructure or political organizational systems designed for permanence and control restricting the necessary elasticity and exchanges of ecosystems. In a natural ecosystem, the efficiency and assemblage of theses flows are dictated by the structural behavior of a landscape organized in a pattern of patches, corridors, and matrices that vary widely in size and shape. (Forman 1995).

Another organizing practice in ecological design is considering "humans and other organisms collectively, as distinct ecology, mutually affecting and influencing the dynamics that support environmental systems" (Clewell and Aronson 2013). Ecosystems support wildlife and natural communities, but they also provide critical support for humans, and thus, the human and natural layers of the environment should be effectively intertwined. Conventional design practices are usually imposed upon nature to provide control and predictability and meet defined human needs, but ecological design is seen as a way to connect culture and nature allowing humans to adapt and integrate ecological processes with human development. By integrating human activities with the structure and the natural flows and cycles of materials, organisms, and energy, the degradation of landscapes and depletion of natural resources can be vastly diminished (Van der Ryn and Cowan 1996).

Resilience

Along the shorelines of the Lake Huron-Lake Eric corridor, the ecological degradation that occurred was dramatic, but it did not occur overnight. While some actions had immediate effects on certain components of the landscape, the ecosystem took decades to transform to its current state. Ecological design seeks to prevent the loss of ecosystem function, but is also contributes to its resiliency against future human and non-human stressors. All social-ecological systems possess this potential capacity to withstand, self-organize, learn, and adapt to a disturbance and other stressors. However, the degree to which the disturbance can be withstood or absorbed before the system changes its critical structures and processes can be improved through environmentally-sensitive design interventions. (Holling 1973, McDonald, Jonson, and Dixon 2017)

The scientific concept of resilience is based on C.S. Holling's adaptive cycle and panarchy theory. The adaptive cycle is a conceptual model that suggests most systems are dynamic and change over time. Though they are not entirely predictable, these changes often follow a four-phase cycle of growth, conservation, collapse, and reorganization, emphasizing two major transitions between them. The first, from growth to conservation, is slow and incremental as a system successfully reorients post-crisis and moves towards rapid growth and controlled development. After a disturbance occurs, the second transition from collapse to reorganization, begins by rapidly releasing its accumulated capital. If not completely depleted by the disturbance, the system will reorganize positioning itself for a subsequent growth phase (Holling and Gunderson 2002, Holling 2001).

Structurally, as a whole, adaptive cycles are nested in hierarchies, one within each other, across scales of space and time and form social-ecological systems. A single nested hierarchy of adaptive cycles is then known as a panarchy. It represents the multiple connections between phases of the adaptive cycle at one level and phases at another level (Holling, Gunderson, and Peterson 2002). Adaptive cycles acknowledge periodic stressors and disturbances can cause systems that have accrued capital and are built adeptly to suddenly collapse and reorganize. Panarchy, on the other hand, describes how a structure can sustain experiments, test results, and allow adaptive evolution as well as preserve itself from destabilizing stressors (Holling 2001). It also demonstrates a system's inherent mobilities and flexibilities by showing multiple possible semi-stable states for any given system "arrived at through diverse processes of creative destruction and renewal" (Milligan 2015).

Together, these models show how systems cannot be comprehended simply by concentrating on a single scale as they exist and function at multiple scales of space and time.

Early ecological models had a propensity to favor stability and linear progressions in place of prolonged states of unpredictability, but they tended to backfire, producing undesirable feedback and spillovers. When revelations such as panarchy theory were discovered, the previous models were replaced with those that acknowledged human agency and emphasized uncertainty, disturbance mechanisms, and non-linear dynamics. (Milligan 2013, Milligan 2015). While still conceptual, panarchy theory and adaptive cycles remain models that help expose the instruments that can support or prevent resilience in systems (Biggs et al. 2012) and are critical to restoring ecosystem function on a damaged landscape.

Fortunately, when human-induced disturbances are low, recovery through resilience may be able to occur without assistance. However, where impacts are considerably higher or sufficient recovery time or populations are not available, correspondingly higher levels of restoration efforts and intervention are likely needed.

Restoration

Ecological restoration is defined in this research as "the process of assisting the recovery of an impaired system" (Clewell and Aronson 2013) with impaired referring to an ecosystem or landscape that has been "degraded, damaged, or destroyed as a result of extraordinary impact or disturbance from which spontaneous recovery to its former state is unlikely" (Clewell and Aronson 2013). The goal of this widely used practice is to either restore self-renewing ecosystem function or improve resilience (Radford, Williams, and Park, n.d.). These efforts may include remediation of the physical and chemical properties of the site, supplementing populations, or reintroducing missing species or ecological processes (McDonald, Jonson, and Dixon 2017).

To enhance the likelihood of long-term restoration success and maximize resilience-related benefits of restoration, efforts should be directed at restoring ecosystem function and improving large-scale connectivity. A guiding principle of this approach is re-establishment of appropriate physical-chemical conditions. In some situations, the environment has become so impaired that there is no longer an intact, functioning ecosystem even with respect to its physical components. In extremely degraded ecosystems, improvements in basic physical and chemical conditions are needed before biotic manipulations are worthwhile. In such cases, restoration aims to restore terrestrial and aquatic habitats, geomorphic structures, hydrologic regimes, and water, soil and air quality to a former state before it was damaged. (Keenleyside et al. 2012).

Sometimes historic levels of ecosystem function may never by fully restored. However, successful restoration can still guide the design towards a state resembling the ecosystem's pre-existing structure by studying the historic conditions and comparable intact ecosystems (SER 2002). This new goal is to then "create built sites and a collective urban fabric that enables valued environmental processes and structures to be resilient to changes over time, while also promoting diversity and health in both natural and human communities" (Clewell and Aronson 2013). In other cases, rehabilitation becomes the new ecological design process as it still looks to halt degradation and recover ecosystem services, the focus is not placed on achieving the fullest possible reestablishment of historic conditions in terms of its species composition and community structure. Instead, focus is usually placed on productivity and the reparation of ecosystem processes and services rendered by substituting other species for those that occurred in the past. (Clewell and Aronson 2013).

For both restoration and rehabilitation, in principle, the use of reference sites for the orientation of interventions and recovery is shared. The reference ecosystem can be an actual site or a conceptual model created from numerous reference sites, field indicators, and historical records. It includes local indigenous plants, animals, and other biota characteristic of the ecosystem before degradation. Where local evidence is incomplete, regional information can also help inform identification of likely local indigenous ecosystems. Identifying a reference ecosystem involves analysis of the ecosystem's species, structure, and functions to be restored. The reference should also include descriptions of successional states that may be characteristic of the ecosystem's decline or recovery (McDonald, Jonson, and Dixon 2017).

Conclusion and Findings

Since the settlement of Detroit, Southeast Michigan has experienced dramatic changes to its landscape. One by one, natural resources of the region were depleted and structural alterations were made to the shorelines and waterways for agricultural production and transportation needs. Unfortunately, the ecosystems of Southeast Michigan have continued to suffer under the pressures of urbanization, and today, it is large-scale development, pollution, and both aquatic and terrestrial invasive species that threaten natural communities and the wildlife they support. While protecting the intact habitats of the region should be executed to aid in their continued existence, due to the severe decline in numbers and resulting fragmentation, improving and increasing the connectivity of the area's natural communities is also essential confirming the design goal of this research to prioritize restoration before rehabilitation where able.

Primary Selected Habitats

As a result of the data collected in the first part of the *research for design* method, ten natural communities categorized by three primary habitat types (see Figure 3.4) are proposed to that can remain resilient to change should remain a key objective. Ecological design principles should also be incorporated into the framework to recognize the dynamic relations present in the landscape.

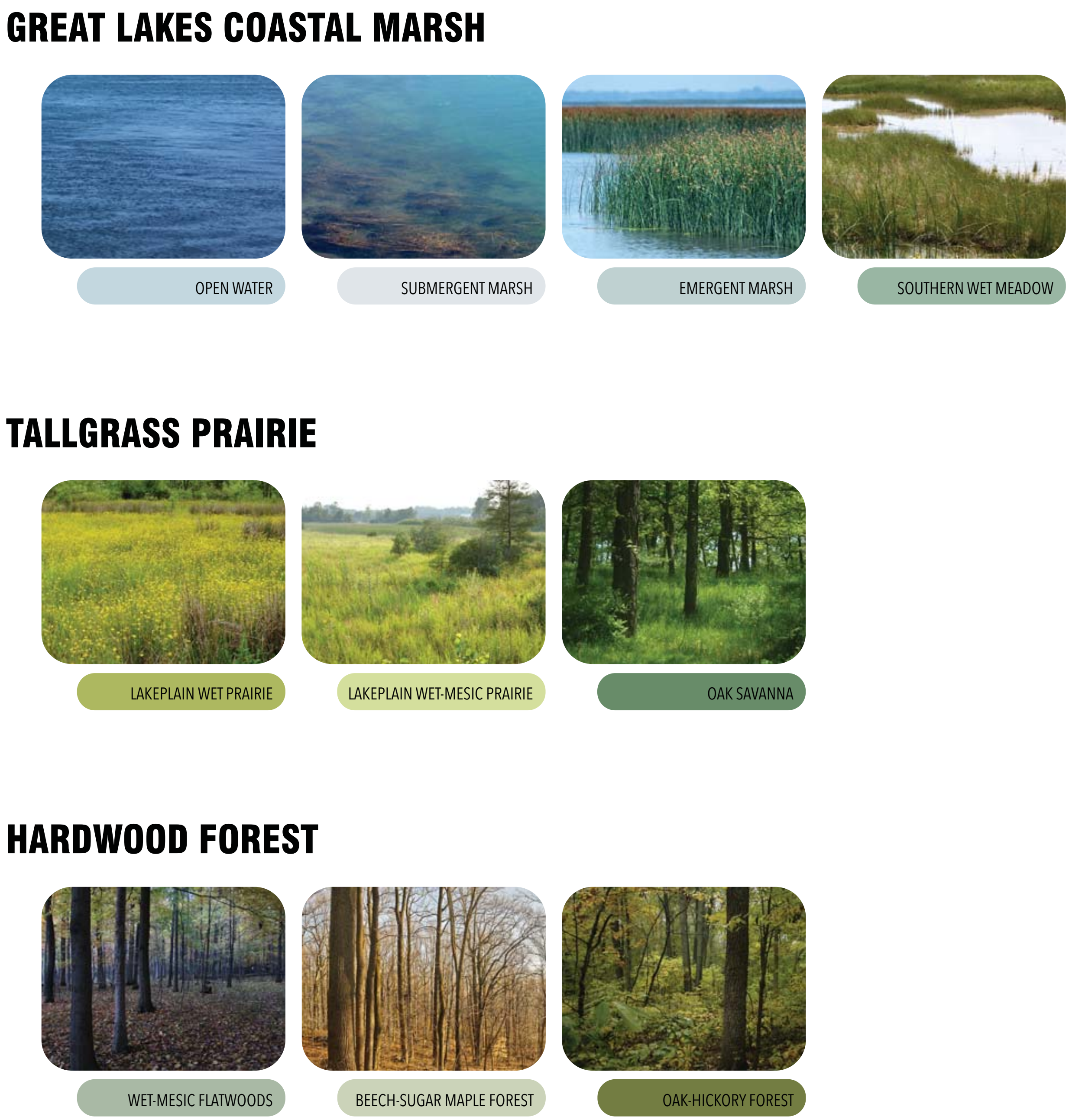


Figure 3.4. Selected primary habitat types

be restored or cultivated at the study sites to develop resilient landscapes that support biodiversity including migratory birds and aquatic species. While all the habitats chosen were identified as those being native to the Maumee Lakeplain and the Southeast Michigan landscape prior to settlement, three additional deciding factors were used. First, and most notably, was if the habitat was identified as a pre-settlement vegetation found at one of the study sites as the primary ecological design principle is restoration before rehabilitation. The second deciding factor was if, based on literature review, the habitat in question was known to grow in mosaics with the previously chosen habitats. This form was most common between the prairies and early to mid-successional forests. The third set of habitats chosen were those listed as imperiled or critically imperiled using the Michigan's state element ranking criteria identifying the community as one of extreme rarity, in steep decline, or very vulnerable.

Framework Development

Lastly, at this stage of the research, framework development is mainly conjectural as the data gathered is processed into organizing factors to be used such as framing, scales, and hierarchy. Also, ecological thinking remains a powerful design lens for understanding the complex systems being investigated as shown through the information presented in this chapter. Then, based on the environmental history of Southeast Michigan and its current state, creating an adaptive framework that can remain resilient to change should remain a key objective. Ecological design principles should also be incorporated into the framework to recognize the dynamic relations present in the landscape.

CHAPTER FOUR

THE FUTURE OF COAL-FIRED POWER PLANTS

Introduction

Whereas the research presented in Chapter Three shows the importance of restoring natural communities in Southeast Michigan, the goal of Chapter Four is to determine the capacity to which coal-fired power plants can be used as the medium for restoration as, currently, a case study documenting such a transformation does not exist. To accomplish this objective, this chapter examines the complex workings of coal-fired power plants, the impact they have on the environment, the standard decommissioning process once they close, and the current post-retirement potential through examining precedent studies. The proposed framework will be presented after these findings.

Infrastructure and Mechanisms

While coal is the main element of coal-fired power plants, the infrastructure used to generate electricity represents the major physical components as they structure the built landscape. This includes the furnaces and boilers where the coal is burned to produce steam, the turbines which uses the heat from the steam and converts it to mechanical energy, and the generators where the mechanical energy is converted into electrical energy. Even though this process is usually all done within the main building or powerhouse, ancillary equipment can be seen throughout the site aiding in the coal-based energy generation. This includes cooling systems, coal storage and handling facilities, and the smoke stacks. (Dvorak 1978).

As part of the site analysis phase, the major equipment, components, and infrastructure were isolated and identified on each site. This was performed to generate knowledge about how the sites currently function, detect hazardous or heavily contaminated areas, and identify how the landscape has been physically or chemically altered. The knowledge generated during this process was then used to identify the appropriate methods and strategies needed to decommission, remediate, and restore the landscape. The presence of these structures was relatively consistent across all three sites, but details such architectural integrity, treatment systems, and layout varied based on the power plant's age, additional buildouts, and contaminants generated.

Trenton Channel Power Plant (TCPP)

The TCPP (see Figures 4.1 and 4.2) was originally constructed in 1924 and currently generates electric power utilizing coal-fired boilers and steam driven generators. Most coal used at the facility is delivered via rail and is unloaded at the rail car dumper located across the street from the power plant. The coal then transported conveyed over West Jefferson through an enclosed conveyor to the coal storage yard, which are separated based on type of coal. Some coal is also delivered via freighter from the Detroit River. The coal storage yard sit on top of grates, which allow the coal to drop to below-ground conveyors which carry the coal to coal bunkers inside the plant. Water sprayers are used to control fugitive emissions with the coal ash runoff being channeled into one of two coal ash basin.

The plant utilizes the Detroit River as a source of cooling water for its once-through cooling system. All water discharged from the plant as a result of activities such as electric power

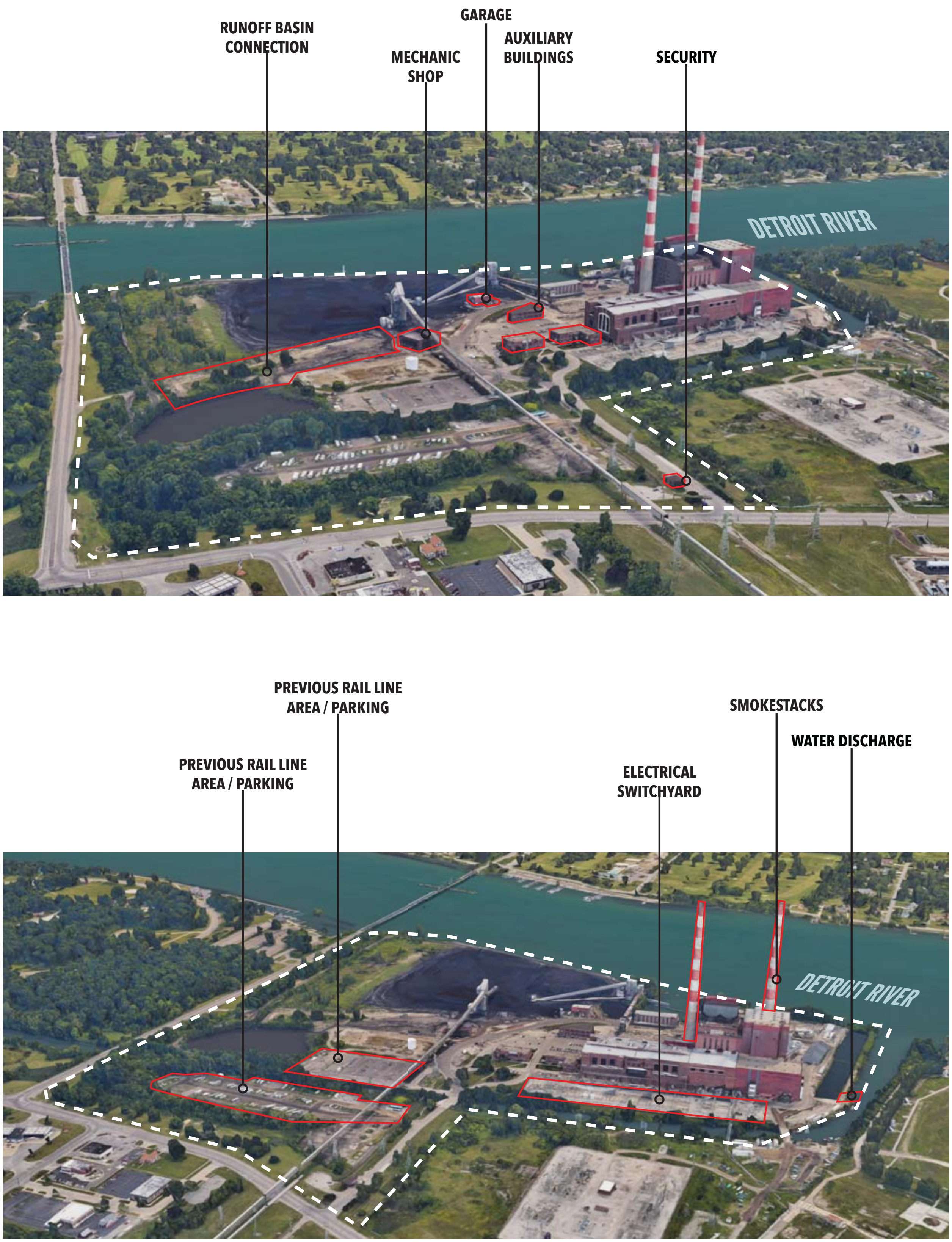


Figure 4.1. Trenton Channel Power Plant infrastructure diagram, view 1 and 2

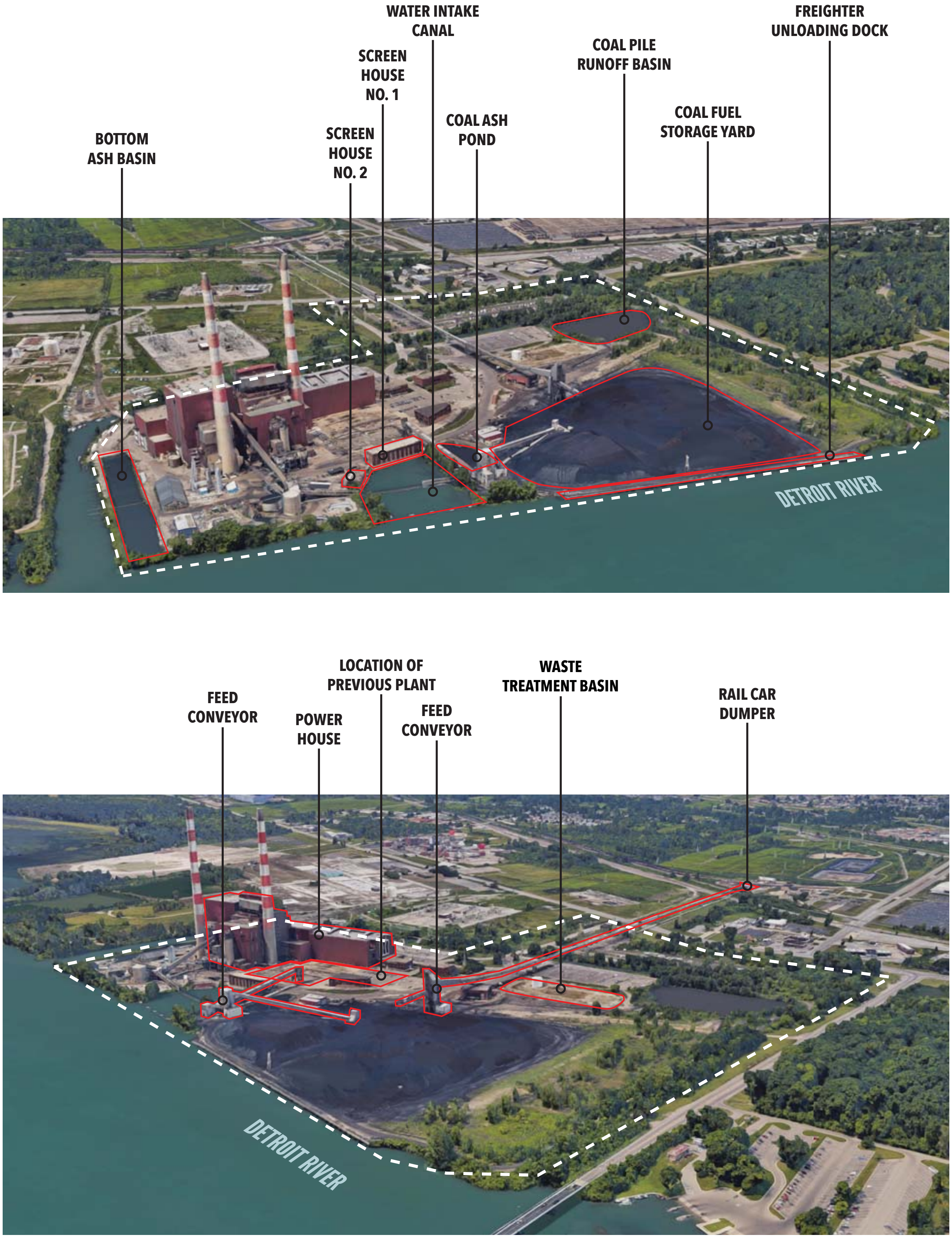


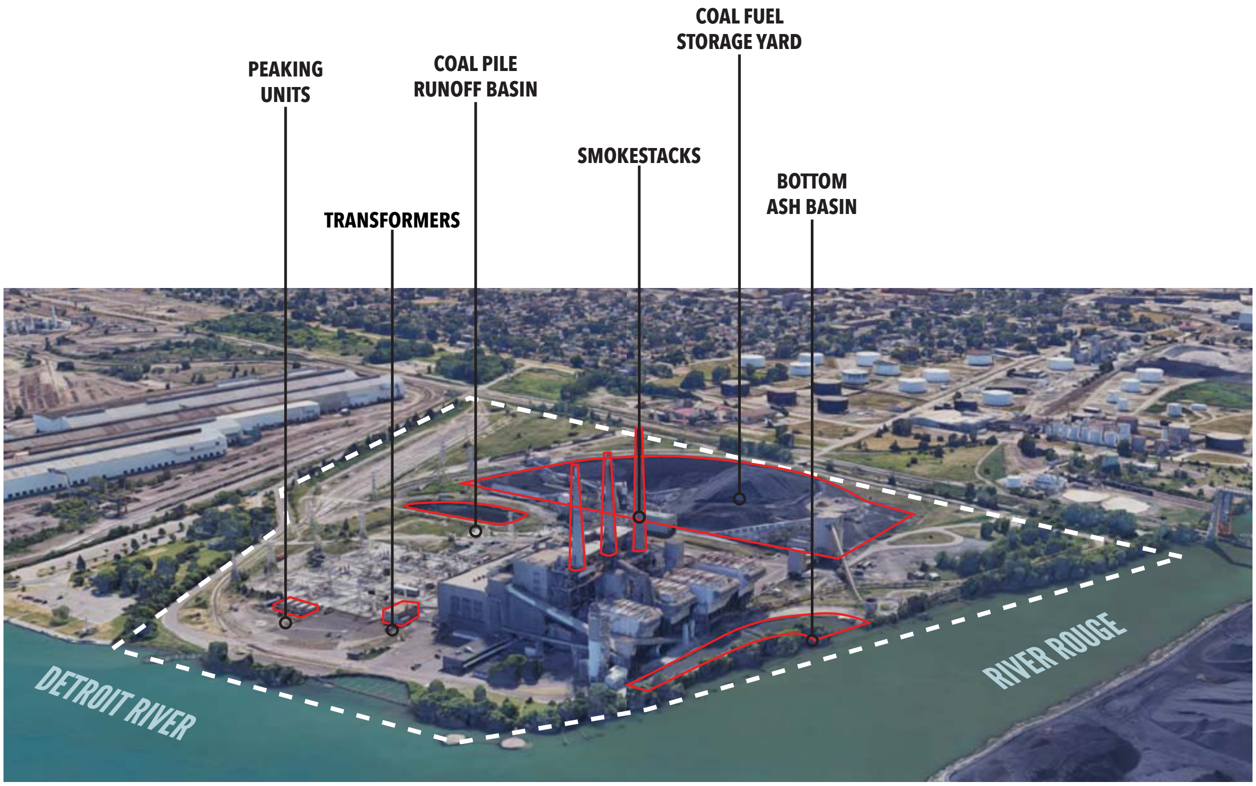
Figure 4.2. Trenton Channel Power Plant infrastructure diagram, view 3 and 4

generation, chemical metal cleaning wastes, coal pile runoff, and storm water runoff is released back into the Detroit River except for sanitary waste and send out steam. The water waste is discharged at three points into a drainage canal that flows into the channel south of the plant. Based on EPA's Toxic Release Inventory data (2016), TCPP released 1,990.01 pounds of polluted surface water discharge containing barium, manganese, mercury, vanadium, and zinc.

River Rouge Power Plant (RRPP)

The RRPP (see Figures 4.3 and 4.4) is an electrical generating plant with operations beginning in 1957. The plant is comprised of three large steam boilers and associated turbines, an auxiliary steam boiler, coal and ash handling equipment, and four diesel turbine peakers. Out of the three steam boilers, one is used for natural gas and the other two fire primarily western subbituminous coal with additional amounts of eastern bituminous coal, natural gas, coke oven gas, blast furnace gas, and dried paint solids. RRPP receives the coal by railcar and offloads it into an underground known as the rail car dumper house. It is then transferred to the coal storage yard through a covered conveyor system that includes the drive house, unloading house, and breaker house.

The RRPP bottom ash basin is a sedimentation basin that is an incised coal combustion residuals surface impoundment and is sheet-piled around the perimeters to approximately 30 feet below ground surface into the native soil. The basin is used for receiving sluiced bottom ash and other process flow effluent pumped from the power plant to its eastern end. The water in the western portion of the basin is maintained at a certain elevation for circulation flow before being recirculated back to the RRPP or is discharged into the Rouge River in accordance with a National Pollution Discharge Elimination System (NPDES) permit. Other water discharged from RRPP



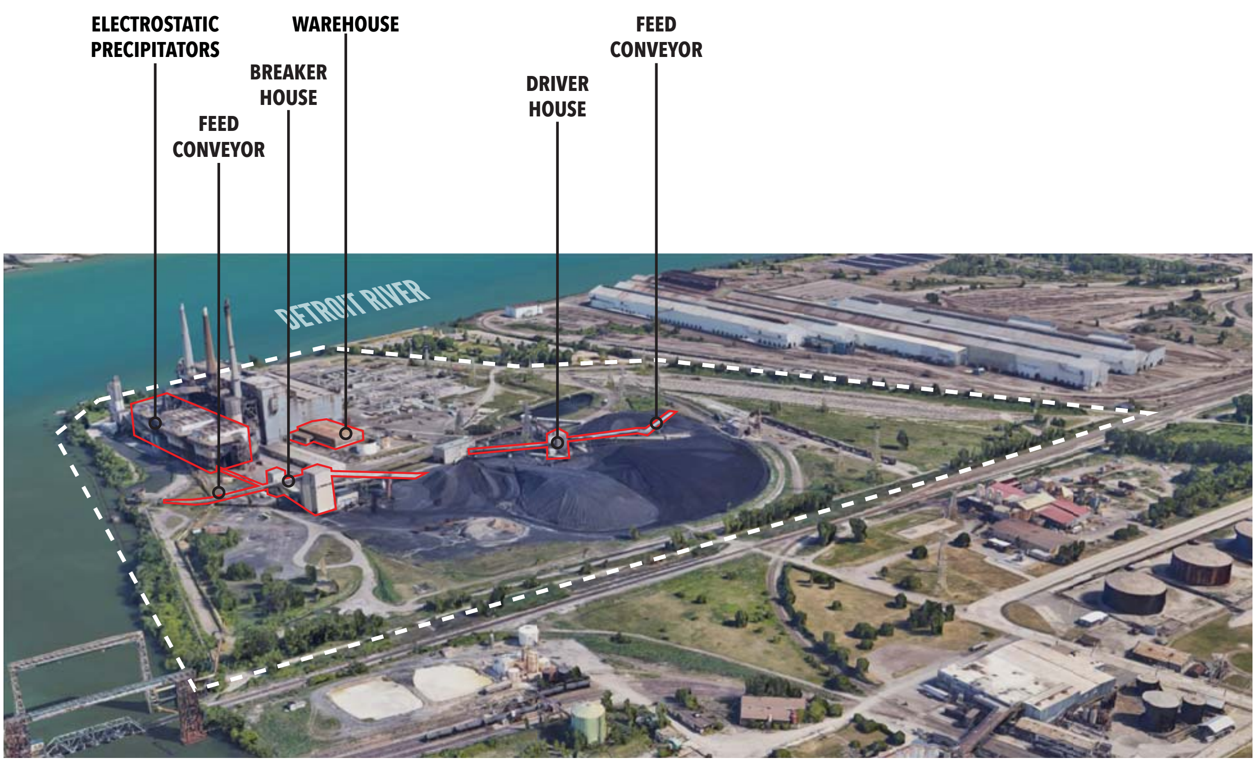


Figure 4.3. River Rouge Power Plant infrastructure diagram, view 1 and 2

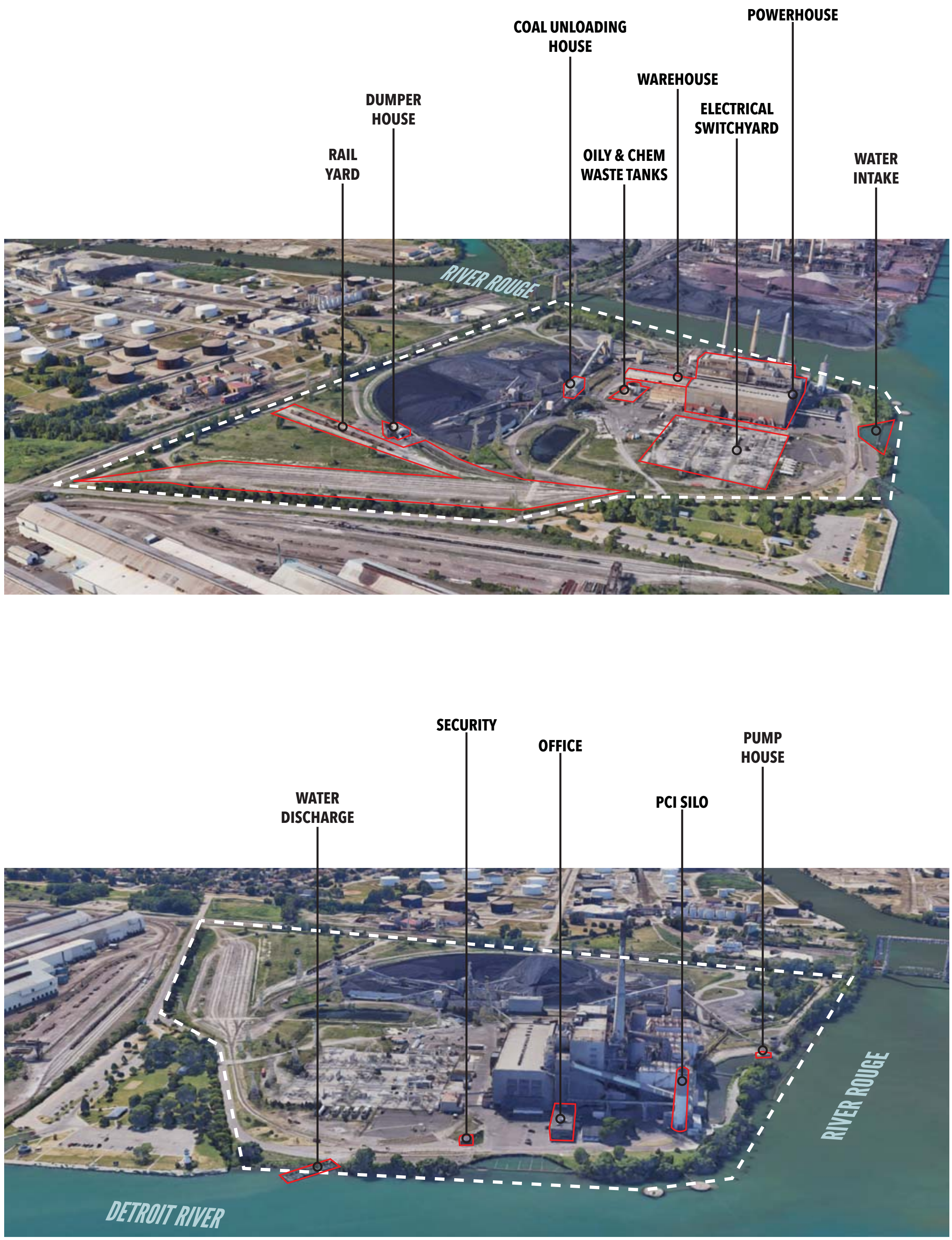


Figure 4.4. River Rouge Power Plant infrastructure diagram, view 3 and 4

includes low volume wastes, chemical metal cleaning wastes, non-chemical metal cleaning wastes, coal pile runoff, and storm water runoff. Water from the Detroit River is used in the plant's condensers as non-contact cooling water and low pressure service systems while city water and storm water is used for all other processes. Similar to the Trenton Channel Power Plant, other than sanitary sewage, all water waste ends up back in the Detroit River including 160.13 pounds of polluted surface water discharge containing barium and lead during 2016 (EPA 2016).

St. Clair Power Plant (SCPP)

The SCPP (see Figures 4.5 and 4.6) began operations in 1953 and is located on the peninsula formed by the St. Clair and Belle Rivers. The property and some of its infrastructure is now bisected by a major road and the Belle River's intake house along the shoreline. Similar to the previous sites, SCPP generates electric power utilizing coal-fired boilers, steam turbines, and generators.

The SCPP has two adjacent sedimentation basins that are incised coal combustion residual surface impoundments. The impoundments are sheet piled around the perimeters to approximately 13 feet below ground surface. Located south of SCPP and adjacent to the St. Clair River, they are used for receiving bottom ash and other process flow water from the power plant. Discharge water from the basins flows with other site wastewater into the overflow canal in accordance with an National Pollution Discharge Elimination System (NPDES) permit. All other water discharge, minus sanitary sewage, also ends up in the river through a number of outlets. In 2016, SCPP released 3,383.63 pounds of polluted surface water discharge containing barium, chromium, copper, lead, manganese, mercury, nickel, vanadium, and zinc into the St. Clair River (EPA 2016).

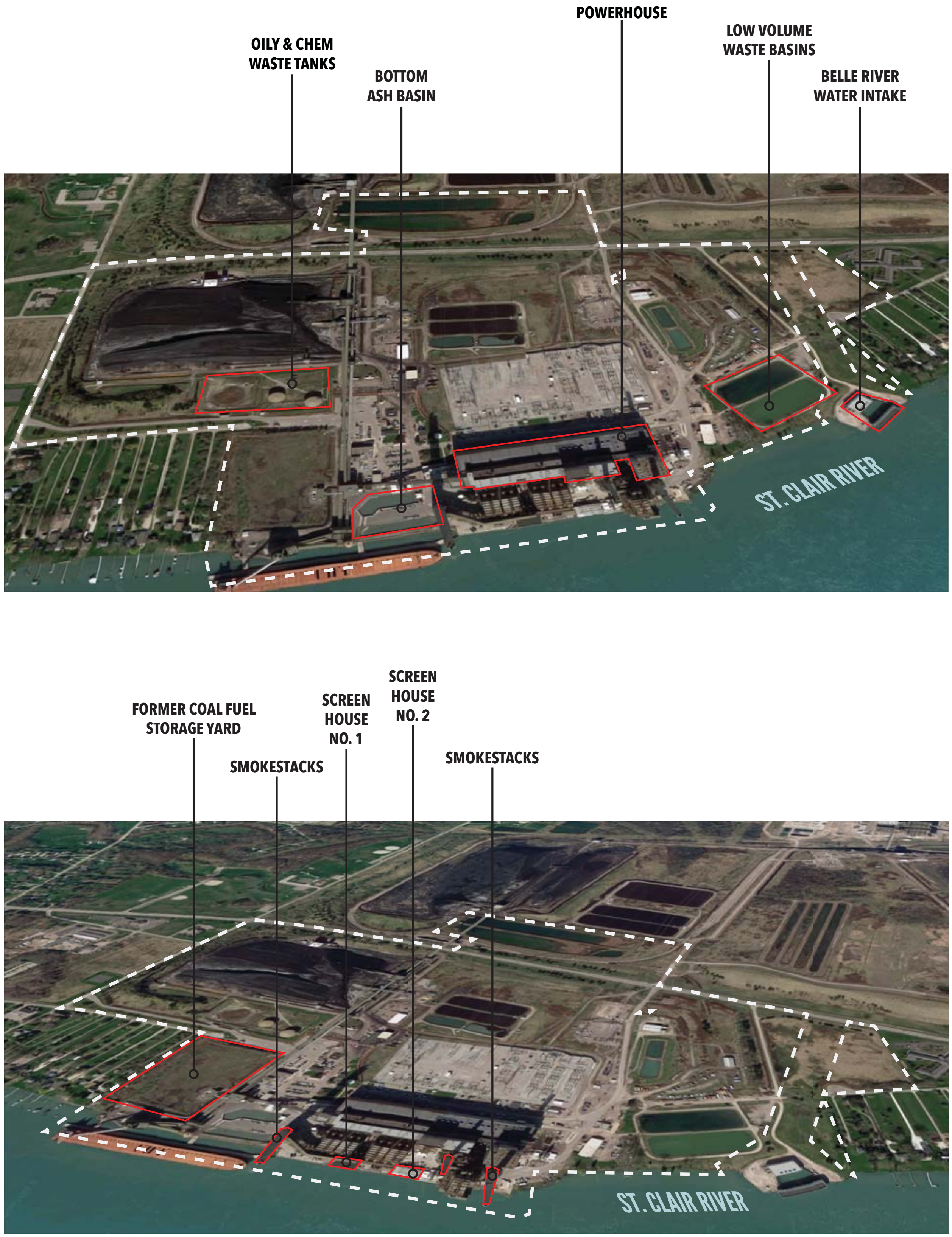
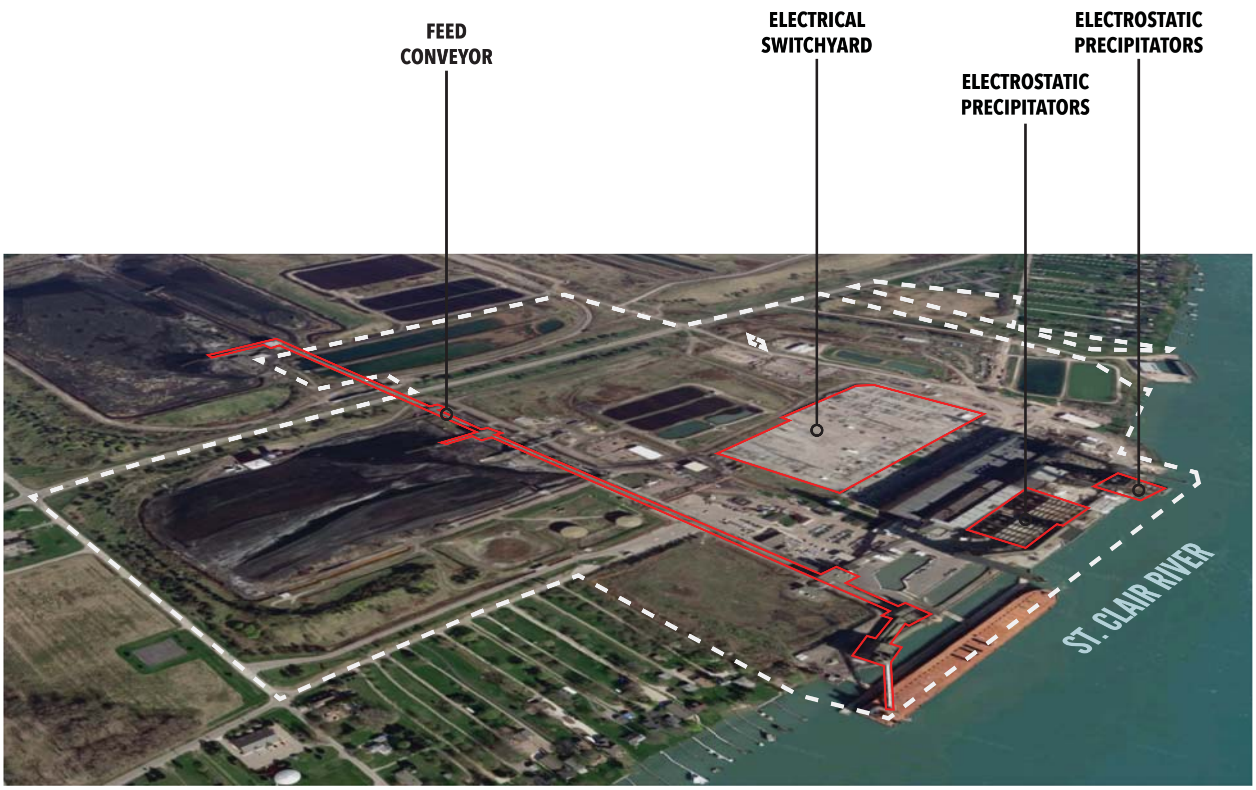


Figure 4.5. St. Clair Power Plant infrastructure diagram, view 1 and 2



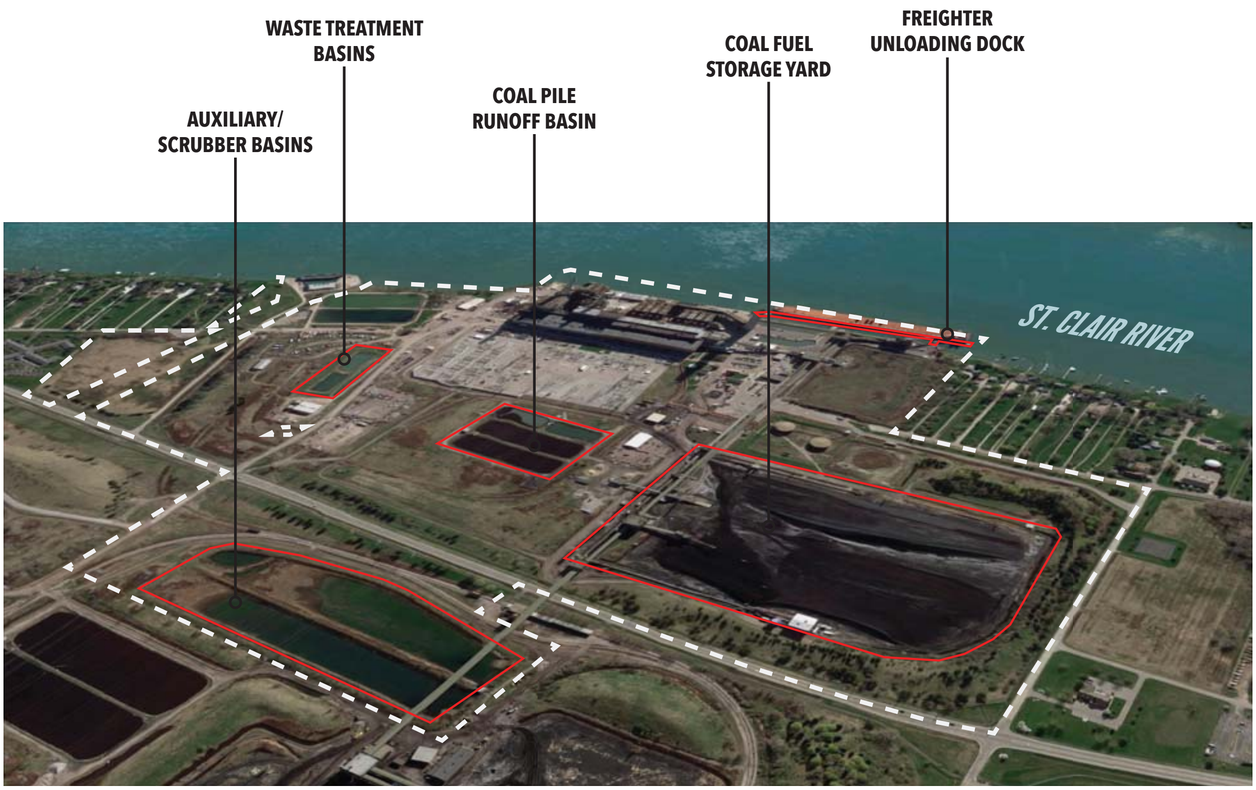


Figure 4.6. St. Clair Power Plant infrastructure diagram, view 3 and 4

Current Trends in Electricity Generation

For more than a century, Michigan has been highly dependent upon coal as an energy source due to its wide availability and relatively low cost. That is, until recently. At the turn of the century, more than 65 percent of Michigan's electricity came from coal, but almost twenty years later, that number has dropped to roughly 36 percent. This transformation also holds true nationwide as the share of electricity generation in the United States has changed more rapidly in the past decade than at any other time since World War II (Logan et al. 2017). Coal-generated electricity for the entire United States has fallen 23 percent since 1990 (U.S. Energy Information Administration 2017c), and this trend has resulted in the closure of coal-fired plants throughout the region as well as Michigan.

This relatively sudden shift away from coal-generated electricity is attributed to an aging coal fleet, local and federal environmental policies, and less expensive alternative energy sources (DTE Energy 2017, Logan et al. 2017). For instance, the expected service life for coal-fired power plants averages between 30 and 50 years, with the assumption that all power plants are subject to retirement when they reach the end of this designated useful service life. That is because, as they age, generators become unreliable and inefficient, which in turn increases maintenance and capital costs unless they undergo expensive, life-extending renovations (Campbell 2013). Michigan is currently home to one of the oldest coal-fired power plant fleets in the nation with 95 percent of its built before 1988 and roughly a third beginning operation more than 50 years ago (U.S. Energy Information Administration 2017a).

On top of upkeep costs, operators must also comply with new environmental policies by modernizing older power plants with updated pollution controls which can be relatively expensive. For example, when the U.S. Environmental Protection Agency (EPA) announced the Mercury and

Air Toxics Standards and the Cross-State Air Pollution Rule, many of the power plants that closed in the following years did so instead of complying as they were already too old and outdated to recover the costs of modernization. Even with current EPA environmental regulations being loosened or reversed, utility companies across the nation are still continuing to announce plans to remove coal from their energy portfolios. Furthermore, previous closures were dominated by older and smaller plants, but the closures announced for 2017 were characterized by younger and larger plants thus showing that environmental regulations are not solely to blame. (Logan et al. 2017, Kennan 2017).

Lastly, alternative energy sources have drastically reshaped the energy market with DTE Energy specifically citing the emergence of cost-competitive natural gas and renewable energy sources as affecting Michigan's changing portfolio (DTE Energy 2017). A majority of Michigan's renewable electricity that is generated in-state comes from wind and biomass from municipal landfills. As for natural gas, Michigan has the most underground natural gas storage capacity in the nation with more than one-tenth of the United States' capacity, and the second-largest number of natural gas storage fields after Pennsylvania. Thus, it is seen as one of the most economical sources of energy for the state (AWEA 2014, U.S. Energy Information Administration 2017b).

Even though a consensus has yet to be reached to the exact cause for the shift away from coal-based energy production, in the past decade over half of the nation's coal-fired power plants have retired or announced that they will retire because of the falling demand and production of coal attributed to the previous theories. According to the U.S. Energy Information Administration (EIA), nearly 90 gigawatts of coal capacity could be added to those retirement numbers between 2017 and 2030 (Kennan 2017). Unlike larger, newer coal plants often built in relatively unpopulated areas, many of the older plants slated for retirement are located in or near dense urban areas (Lydersen 2012). Thus, upon decommissioning, the removal of this infrastructure will vastly change the fabric of the cities, communities, and shorelines the power plant currently occupies.

Standard Decommissioning Practices

Although the decommissioning process of decommissioning a coal-fired power plant can differ by utility owner, location, and extent of decommissioning. These factors are largely driven by the planned reuse of the site as the U.S. Environmental Protection Agency (EPA) has remediation standards depending on whether the property reuse is to be residential, commercial, or industrial. The inherent value of the property and overall cost of decommissioning is another driving force, so some utilities approach decommissioning by simply performing minimal dismantling and demolition in addition to maintaining the site to meet environmental compliance and ensure safety. However, due to the goals of this thesis, a full decommissioning process was investigating. Full decommissioning requires that the plant site be remediated to meet full environmental compliance to the extent that the site can be fully used in the future.

Based on investigating multiple resources including demolition study released for DTE Energy conducted by Black & Veatch Ltd. (2009), after announcing the plant closure, the process frequently begins with shutting down the electrical generating units, terminating all operating permits, and removing any unused coal and hazardous materials (U.S. EPA 2016). Coal-fired power plants typically maintain large volumes of various chemicals and materials such as fuel oils, metal-cleaning chemicals, mercury, degreasers, solvents, and general refuse materials. Some of these are treated and disposed onsite in permitted facilities, and others are sent offsite for recycling or disposal (EPRI 2004).

Once the site is prepared for dismantling, demolition can begin. This includes stripping all materials and equipment from the buildings and demolishing the buildings and separate support facilities. Structures to be demolished include boiler and turbine buildings, coal handling facilities, warehouses, maintenance buildings, and screen houses. Basement walls, where applicable according to DTE Energy standards, will be demolished to 36 inches below existing grade and will be backfilled with rubble, such as concrete and bricks. Most plants will have many concrete foundations and underground piping throughout the site, of which, DTE Energy generally clears any underground obstacles for three to four feet below the ground. (Black & Veatch Ltd. 2009).

On the shoreline, intake and discharge structures are removed and areas behind the riverbank are backfilled. Once the water intake and discharge channels are removed, sheet pile is installed along the shoreline to tie in with any existing shoreline protection system. Dismantling also includes cleanup of the coal storage yard. For DTE Energy, this means removing three feet of surface below the coal pile, backfilling the site with imported, clean fill. The area is then covered with one foot of topsoil, seeded, mulched, and contoured for stormwater runoff. The same holds true for any other contaminated areas of the site outside of the storage yard. (Black & Veatch Ltd. 2009).

One of the most lengthy and costly decommissioning activities is the closing of any coal ash ponds on the site. Ash ponds are a type of surface impoundment for the disposal of the byproduct coal combustion residue (CCR). These engineered ponds are filled with ash slurry, allowing the water to separate from the ash over time. The ash is then either left in place or moved for permanent disposal at an offsite landfill (EPRI 2004). In accordance with federal regulations, DTE Energy has submitted their closure plan for existing CCR surface impoundments. The estimated two-year process includes dewatering the ash pond to facilitate removal and decontamination, CCR removal by excavation from the ash pond, removal or decontamination of any affected areas, demolition or abandonment of associated non-earthen features, and regrading to the final desired grades using borrowed soil for fill, as needed (DTE Energy 2016).

After dismantling, the next step is remediation which involves the investigation and cleanup of hazardous materials and defining site-specific needs for redevelopment (U.S. EPA 2016). Historically, contaminants of concern for coal-fired power plants include: (1) arsenic, cadmium, chromium, iron, lead, mercury, nickel, selenium, manganese, and zinc from the fly ash and coal pile areas; (2) polychlorinated biphenyls, polycyclic aromatic hydrocarbon, BTEX (benzene, toluene, ethyl benzene, xylene), and other petroleum hydrocarbons from oil storage and mechanical and electrical equipment; and (3) copper, iron, nickel, chromium, and zinc from metal cleaning and cooling tower blowdown wastewaters (Brown et al. 2017). Water bodies adjacent to the power plants must also be addressed. If low levels of contamination are to be left in place, future site uses may be restricted such as drilling drinking-water wells or building residential dwellings (Brown et al. 2017, U.S. EPA 2016).

Again, the cost and extent of the cleanup will depend on the anticipated re-use of the site and the type and location of hazardous materials on the property. The re-use and redevelopment possibilities of coal-fired power plants are seen as diverse, but they are also often site dependent based on existing infrastructure and contamination. These sites often offer a large land footprint, waterfront access, historic architectural value, and proximity to populated urban areas, all of which should make them appealing to developers. Yet, these sites also usually come with a number of challenges as well especially if only minimal decommissioning efforts occurred. This includes oversized and unconventional buildings, unknown remediation costs, difficulty securing financing, and a lack of models demonstrating best practices. Thus, the average time from closure to planned completion for coal-fired power plants is 27 years. However, of that timespan, on average, almost 19 years is from retirement to sale to a new owner (Delta Institute 2014) meaning after decommissioning, these sites are left abandoned for years or decades creating blight for the surrounding community (see Figure 4.7).

In an attempt to make use of these idle landscapes, one solution is the placement of solar panels as either an interim or permanent solution allowing it to remain productive even during lengthy transition phases. The unique characteristics of these sites make them ideal candidates as they are typically cleared of above-ground structures and provide a flat unshaded area often in proximity to the necessary infrastructure. This can even be done during decommissioning and remediation if strategically placed. This also allows the site to transition into a community asset promoting cleaner and more cost-effective energy technologies while reducing the environmental impacts instead of remaining idle and unproductive. (Hollander, Kirkwood, and Gold 2010, Marcacci 2017).

Post-Retirement Potential

To find other possible transformative strategies to incorporate into the development of the framework, design processes and products were investigated as part of the research on design method. As no other precedent could be found involving the restoration or reclamation of a decommissioned coal-fired power plant site, a series of processes were identified that focused on an element that would help facilitate the overall visions of these sites as hybrid landscapes. This included the ecological strategies implemented at Fresh Kills Park, economic strategies used by Delta Institute as they support coal plant communities in transition, and typologies used in the strategic framework Future City Detroit.

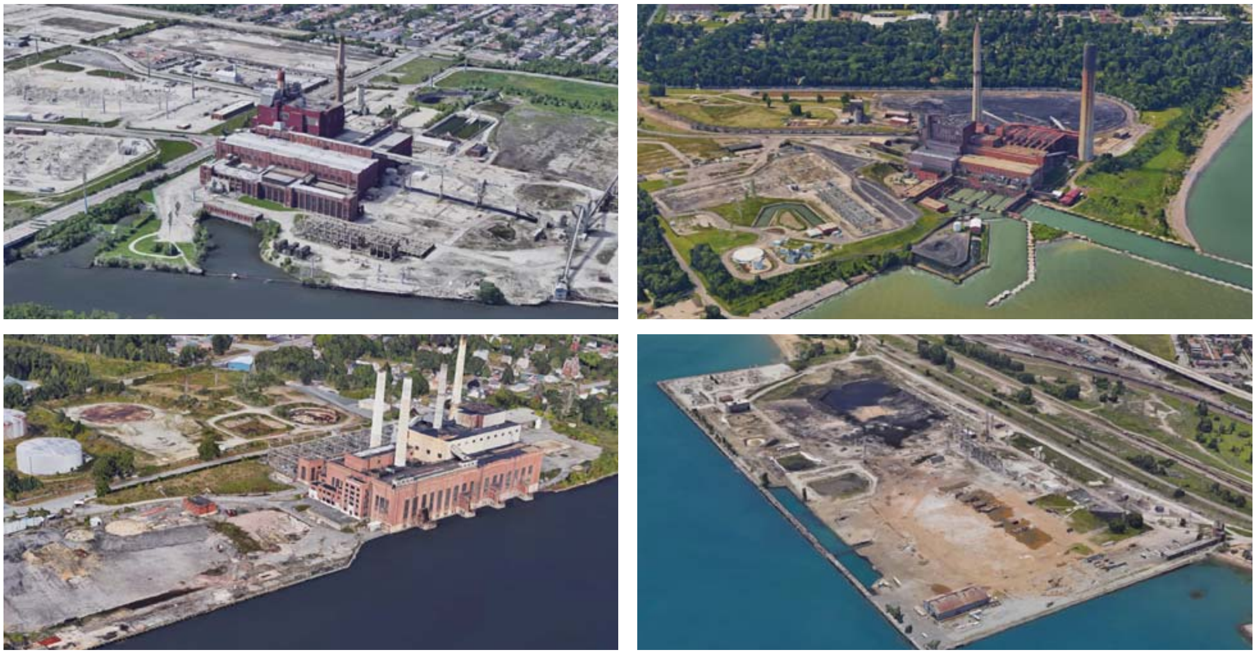


Figure 4.7. Examples of coal-fired power plants in transition. Imagery: ©2018 Google.
(Clockwise from top left) Crawford Generating Station, Chicago, IL; Lake Shore, Cleveland, OH; State Line Power, Hammond, IN; Montaup Station, Somerset, MA.

Figure 4.8. Examples of coal-fired power plants converted for re-use.
(Clockwise from top left) Homan Power House, Chicago, IL; Pratt Street Power Plant, Baltimore, MD; Seaholm Power Plant, Austin, TX; Muncipal Power House, St. Louis, MO.

Economic Strategies

Established in 1998, Delta Institute is a Chicago-based nonprofit organization that uses community-driven redevelopment to restore vacant sites and brownfields. This is done by helping communities come up with strategic plans for the closure and potential reuse of their coal plants in ways that "promote environmentally sustainable and socially equitable economic development" (Delta Institute 2017), as they have found that the redevelopment process is more efficient when there is early planning and strong community engagement. They also do this work in broad partnership with community-based organizations, coal plant owners, electric utilities, private foundations, local government agencies, elected officials, federal agencies, and labor organizations. We have worked with coal plant communities across the country from New York to Montana. (Delta Institute 2017).

Upon purchase and redevelopment, potential end uses that have been realized include public spaces, private uses, or both. End uses can be public spaces, private uses, or both. Some sites capitalize on existing infrastructure and begin using alternate energy sources, and others are rebuild from the ground up. For plants occupying strategic locations in urban areas, these sites present opportunities for new civic such as shops, offices, and other community amenities. Examples include the transformation of Homan Square Powerhouse in Chicago, Illinois, into mixed-use housing, a community center, and charter school, and the transformation of the Municipal Power House in St. Louis, Missouri into Cannon Design offices (Delta Institute 2017).

The successful examples documented by Delta Institute show the value of comprehensive redevelopment planning and the innovated ways the sites and infrastructure can be renewed enhance communities and improve their economic outlook. Yet, after investigating these potential redevelopment uses, it is shown that the preferred options remain economically motivated, and for the landscape, that can mean the placement of land use intensive projects such as offices and high-density residential units. This is an understandable response by communities who fear the loss of job, income tax revenue, and indirect impacts, such as housing value decline. However, the goal of the proposed framework is to do more for the health of the environment other than just removing the highly-polluted operations of the coal-fired power plant and be proactive in restoring its ecosystem functions.

Ecological Strategies

To effectively shift towards a more integrative approach, the principles of ecology must be applied to the current transformation of the sites. Ecology provides a fundamental, relational view of landscapes as it focuses on the interactions between living organisms and their environment making it integral to the understanding of landscape migration (Milligan 2015). Therefore, the investigation into the designs and remediation strategies represented in the Fresh Kills Park master plan was utilized for the development of the framework.

Fresh Kills Park master plan looks to transform the world's once largest landfill consisting of more than 2,000 acres on the western edge of Staten Island, New York into an ecologically innovative urban public park. The goal is to transform the damaged landscape into "a tangible symbol of renewal and an expression of how our society can tap into natural processes and help to restore the proper functioning of our landscape" (James Corner Field Operations 2006). However, while the master plan also included a number of programs and facilities into the design, such as recreation facilities, restaurants, and market spaces, for the purpose of this thesis, the investigation focused on the master plan's strategy to restore ecological systems across the enormous site and cultivate a diverse, sustainable landscape. (James Corner Field Operations 2006).

Like the Lake Huron-Lake Erie corridor, the landfill and surrounding area was once the largest and most productive marshes in the Hudson River Estuary. However, like with the landscapes of the decommissioned coal-fired power plants, decades of land filling and industrial operations have impaired the health and productivity of these ecosystems. Thus, to cultivate a diverse, resilient landscape exhibiting ecological connectivity, biodiversity, and sustainability, the master plan developed a habitat restoration plan that would be achieved over a number of years through a range of remediation and cultivation techniques.

After fully investigating the work presented by the Fresh Kills Park master plan, the knowledge gained was then processed, interpreted, and ultimately incorporated into the development of the framework in the form of remediation strategies and habitat diversification. The most notable of these strategies is the proposal of an adaptation on agricultural strip cropping to renovate soils in situ before establishing the new habitat (see Figure 4.9). “By gently plowing and cultivating the slopes of the mounds, fast-growing plants can be repeatedly grown and then plowed into the soil to create a green manure, adding organic matter and depth to the soil over time” (James Corner Field Operations 2006), the goal is to provide a potentially less expensive industrial-scale technique for improving poor quality soils. Then, when the soil structure has improved to a suitable level, a final meadow mix may be sown and established beginning the habitat restoration.

The information collected from this investigation also further validated some of the design strategies that had already been utilized in the research or were in development. This includes the design goals previously stated in Chapter One, the selection of a plant palette and primary habitat types, and through the idea that the framework would represent an implementation strategy that would take several different phases over a number of years to effectively reintroduce native plant communities, remove industrial contaminants and fill, and restore ecosystem functions.

Figure 4.9. Selected primary remediation materials.

Typologies Strategies

With a goal of the framework to create multifunctional, hybrid landscapes, the landscape must exhibit both productive and environmental elements that boast a wide range of uses. However, to be successful and sustainable, the elements at each site must representative of the communities, cultures, and its context. Thus, the use of typologies, or a classification according to general type, programming, or composition, was selected as an organizing design and development strategy, and to investigate the use of typologies in design, the work produced by Stoss in their Detroit Future City strategic framework project (Detroit Future City 2013) was selected.

To create a city of distinct, attractive neighborhoods, Stoss developed a series of traditional and innovative neighborhood typologies to directly engage the city's existing challenges and to leverage the strengths and assets of the neighborhoods and places with unique characteristics. Stoss's implemention strategies included identifying vacant land parcels and existing landscape characteristics and formulating a framework to determine their potential futures. This resulted in new land-use typologies that generated different design functions but could still work in conjunction with one another. The five main designing typologies were: community open spaces, ecological landscapes, blue-green infrastructure, working and productive landscapes, and transitional landscapes. These typologies provided a tool for decision making by providing the building blocks for a future land-use map. Thus, utilizing this new design concept, a set of typologies specific to this thesis's design and evaluation framework were created leading to improved design decisions.

Conclusions and Findings

After the investigation into coal-fired power plants, the decommissioning process, and their post-retirement potential, the information collected was used to develop the framework of this thesis (see Figure 4.10). This resulting product was formed as an imperative tool to identify and organize the design interventions identified by this research, inform sustainable and effective remediation techniques, assigned productive and interactive programming elements, and lastly, create multifunctional, hybrid landscapes with restored ecosystem functions. This framework also exhibits a transformation from theory to practice in the thesis as it translates all the research gathered into an action-oriented roadmap for decision-making usable in the field. The integrated solutions presented suggest new strategies for decommissioning, new forms for ecological restoration, and new pedagogies for post-industrial communities.

By establishing this framework, it is shown how a integrative, comprehensive process can be implemented to not only ensure the restoration of ecosystem functions and the creation of multifunctional, hybrid landscapes, but also to create a structure that integrates the decommissioning, remediation, and redevelopment process. The goal of decommissioning is to remove the operations and remnants of the retired coal-fired power plant, but the goal of the restoration process shouldn't be to also remove the operations and remnants of the decommissioning phase. Instead, they are integrated for the final goal of returning the site to a sustainable, usable landscape void of negative legacies that could have potentially be left by the coal-fired power plant.

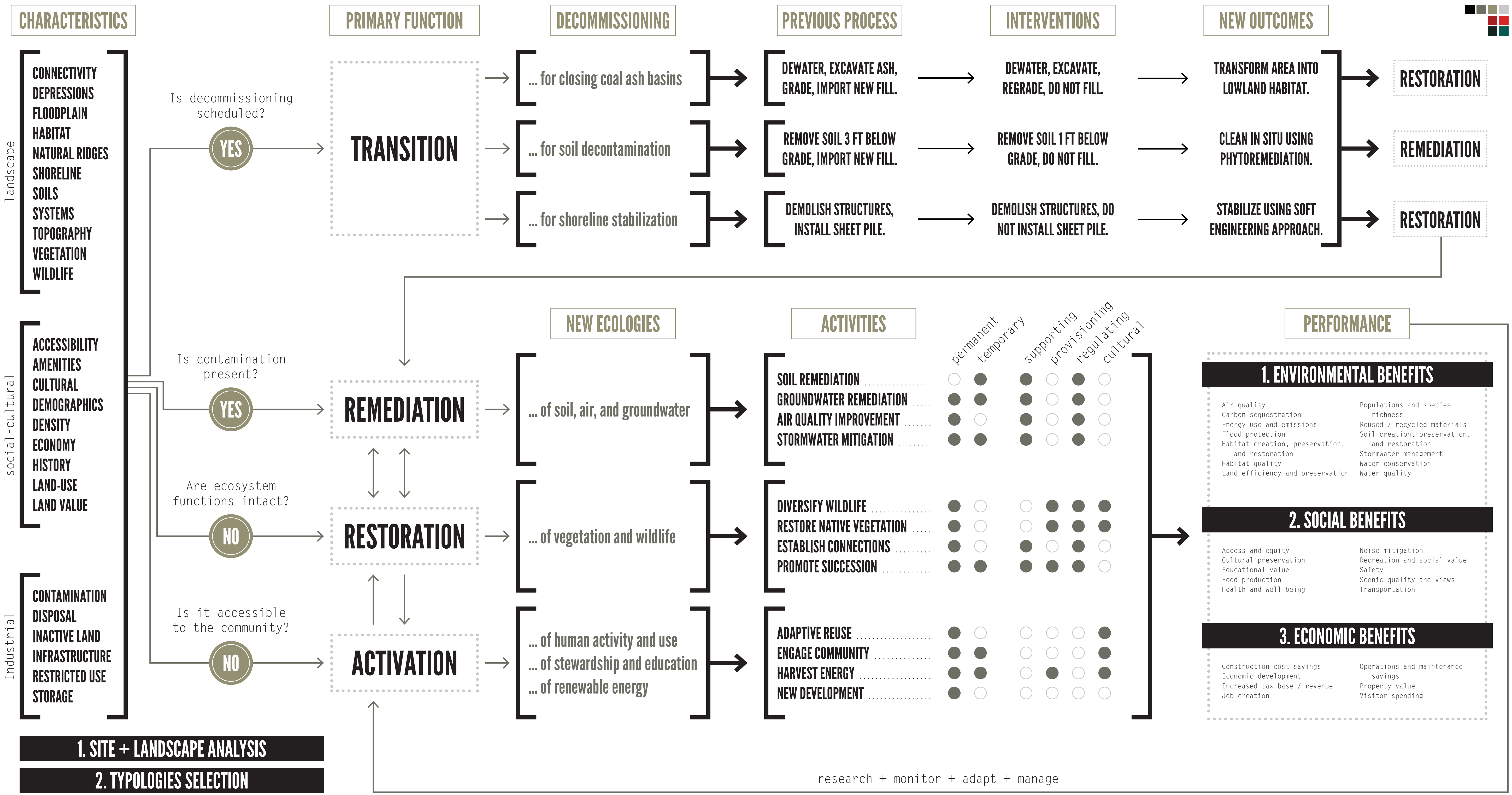


Figure 4.10. Transformation of coal-fired power plants framework.

CHAPTER FIVE

APPLYING THE FRAMEWORK

Introduction

To take a proactive role during this industry-wide shift, DTE Energy has committed to significantly lowering its dependence on coal-based electricity generation and increasing its renewable energy sources as part of an overarching company transformation. While DTE Energy has already retired two of their coal-based facilities in the past five years, in the summer of 2016, the company announced plans to decommission three of its remaining five coal-fired power plants in 2023. They are the Trenton Channel Power Plant in the City of Trenton, River Rouge Power Plant in the City of River Rouge, and St. Clair Power Plant in the Township of East China. (DTE Energy 2017).

By selecting all three sites for this research, a gradient of design scenarios are created due to their differences as well as their similarities. For example, all three are owned by DTE Energy, scheduled for decommissioning in 2023, governed by the Southeast Michigan Council of Governments, and located within the Lake Huron-Lake Erie corridor with one on the western shoreline of the St. Clair River and two on the western shoreline of the Detroit River. For their differences, while their variations in physical size is easily recognized, the following site- and landscape-analysis will show that the differences included environmental conditions such as soil composition and pre-settlement vegetation, social characteristics such as demographics, and economic qualities including medium household income and developed settlement type.

This chapter presents the application of the developed framework to the selected study sites in Southeast Michigan and is organized by the sections of the framework and its use on each site. The goal of this process is to not only validate the framework through restoring ecosystem function, improving large-scale connectivity, and activating the site for responsible human use, but to also generate new knowledge and compelling designs for the transformation for communities who must prepare for a post-industrial future. The design goals presented in Chapter One will also be an organizing decision factor for site-specific programming or location decisions.

Ecological Goals

1. Restore the biotic and abiotic components of the sites to improve ecosystem function.
2. Restore essential habitat for wildlife such as waterfowl and fish.
3. Use remediation tactics to clean soil, air, and stormwater runoff.
4. Create connectivity with surrounding corridors and hubs to avoid fragmentation.
5. Design resilient landscapes to withstand undesirable natural and human stresses.

Productivity Goals

6. Design community assets that produce tangible and intangible services.
7. Demonstrate renewable energy systems and regenerative processes.
8. Create educational opportunities that foster stewardship of the new landscape.
9. Acknowledge culture and history through repurposed infrastructure and buildings.
10. Activate the landscape through responsible development and public engagement.

Characteristics

The characteristics section of the framework represents the information gathered from site- and landscape-analysis to fully understand where the site has been and where it is now. These characteristics are divided into the categories: landscape, social-cultural, and industrial. This information can be collected in numerous ways such as through GIS data, interviews, and historical documents. While this list is exhaustive, more or less analysis may be needed as it is site-specific. Such examples include the locality of the coal-fired plants to urbans settings which warrants analysis into how the surrounding views, goals, and history of the community shape the landscape as well as discover possible historic or cultural metaphors that can be implemented in the design. The following descriptions and diagrams document how this process was conducted on each of these sites.

Trenton Channel Power Plant

The Trenton Channel Power Plant (see Figure 5.1) is located at 4695 West Jefferson Avenue. It spans 81.95 acres and is surrounded on three sides by waterways, the lower Trenton Channel of the Detroit River and a man-made canal. It is also within the City of Trenton in Wayne County, Michigan (see Figure 5.2) which is considered one of the most affluent of the downriver communities, a term used to refer to the 18 suburban cities and townships in Wayne County. The site is surrounded by recreational opportunities (see Figure 5.3) and a number of industrial sites with Elizabeth Park, the state's first county park, to the north and a Chrysler plant and Solutia Chemical plant to its west and south. A little further south of the site lies Humbug Marsh, and the Detroit River International Wildlife Refuge. This refuge consists of nearly 6,000 acres of islands, coastal wetlands, shoals, and marshes, including Humbug Marsh. Grosse Ile also hosts a number of the open woods and nature preserves.

For physical character, the contours of the site show a relatively ridged site separated by the canal running through the middle and bounded by the Detroit River to the east (see Figure 5.4). Due to the high ridges, the 100-year and 500-year flood zones do not affect much of the site other than the southeast corner. The land formation of the site is largely attributed to its pre-settlement vegetation pattern showing oak-hickory forest was found on the ridges with emergent marsh on the lower sections. However, due to the emergent marsh, the land has been heavily altered to create land suitable for the power plant operations. This was done through filling the marsh and dredging the canal that now separates the sites from the mainland. The aerials shown in Figure 5.5 show how that land continued to drastically change even after its original construction as well. Then, the pictures shown in Figure 5.6 were taken in July 2017 during a site visit.

Figure 5.1. Trenton Channel Power Plant study site

Figure 5.2. Trenton Channel Power Plant context diagram

Figure 5.3. Trenton Channel Power Plant parks and open space

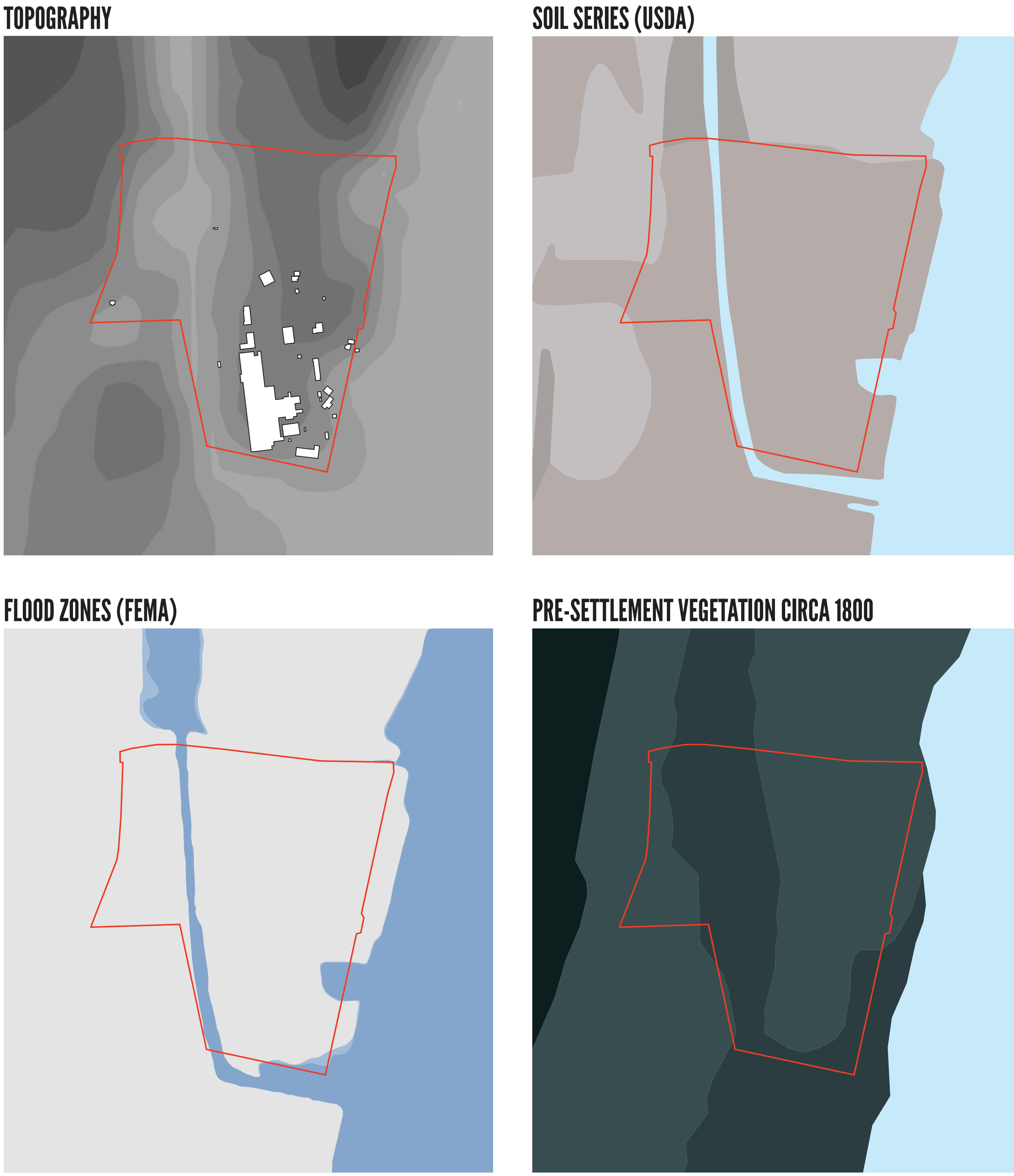


Figure 5.4. Trenton Channel Power Plant site analysis

Figure 5.5. Trenton Channel Power Plant historic aerial photographs
Source: http://digital.library.wayne.edu/dte_aerial/index.html

Figure 5.6. Trenton Channel Power Plant site photographs

River Rouge Power Plant

The River Rouge Power Plant (see Figure 5.7) is located at 1 Belanger Park Drive and spans 108.3 acres. Surrounding waterways include the Detroit River and a man-made channel creating a shorter, straighter access route to the Rouge River. It sits within the City of River Rouge (see Figure 5.8) in Wayne County, Michigan, and is located in one of the most heavily industrialized suburbs of Detroit, notorious for its pollution statistics. Such examples include the steel- and coke-producing Zug Island (see Figure 5.8), the Rouge River which was named the most polluted river in the United States in 1969, and the 48217 zip code, named Michigan's most polluted according to a 2010 analysis by environmental scientists the University of Michigan (Lam 2010). However, recreation opportunities, though spare, do exist (see Figure 5.9) as it shares the shoreline with Belanger Park and across the river is Canada's Ojibway Prairie Complex featuring black oaks and tallgrass prairie. A future international bridge and port is also in the design stages and will be placed north of Zug Island. This presents the opportunity for making the to a potential demonstration area as it will be viewable from the bridge.

For physical character, the site consists of a very flat terrain (see Figure 5.10) as the power plant was constructed on an area that was formerly all emergent marsh. This causes the 100-year and 500-year flood zones do affect more of the site than the others. Its previous vegetation also makes it also heavily affected by structural soil with approximately 10 feet of various composition including gravel, sand, silt and clay, brick and/or concrete fragments on most areas of the site. The aerials shown in Figure 5.5 show how the site was altered since its construction, and the pictures shown in Figure 5.6 were taken in July 2017 during a site visit.

Figure 5.7. River Rouge Power Plant study site

Figure 5.8. River Rouge Power Plant context diagram

Figure 5.9. River Rouge Power Plant parks and open space

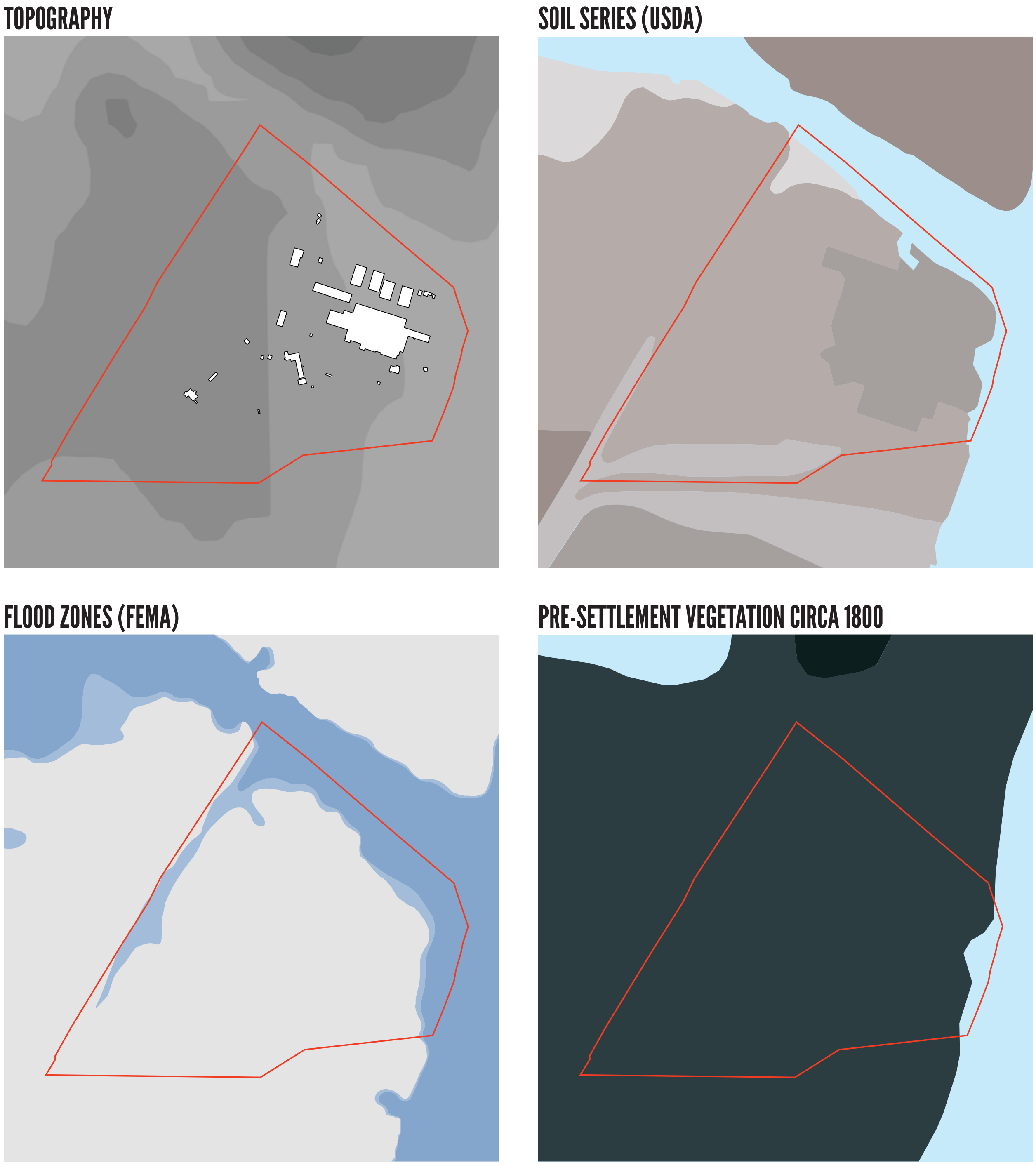


Figure 5.10. River Rouge Power Plant site analysis

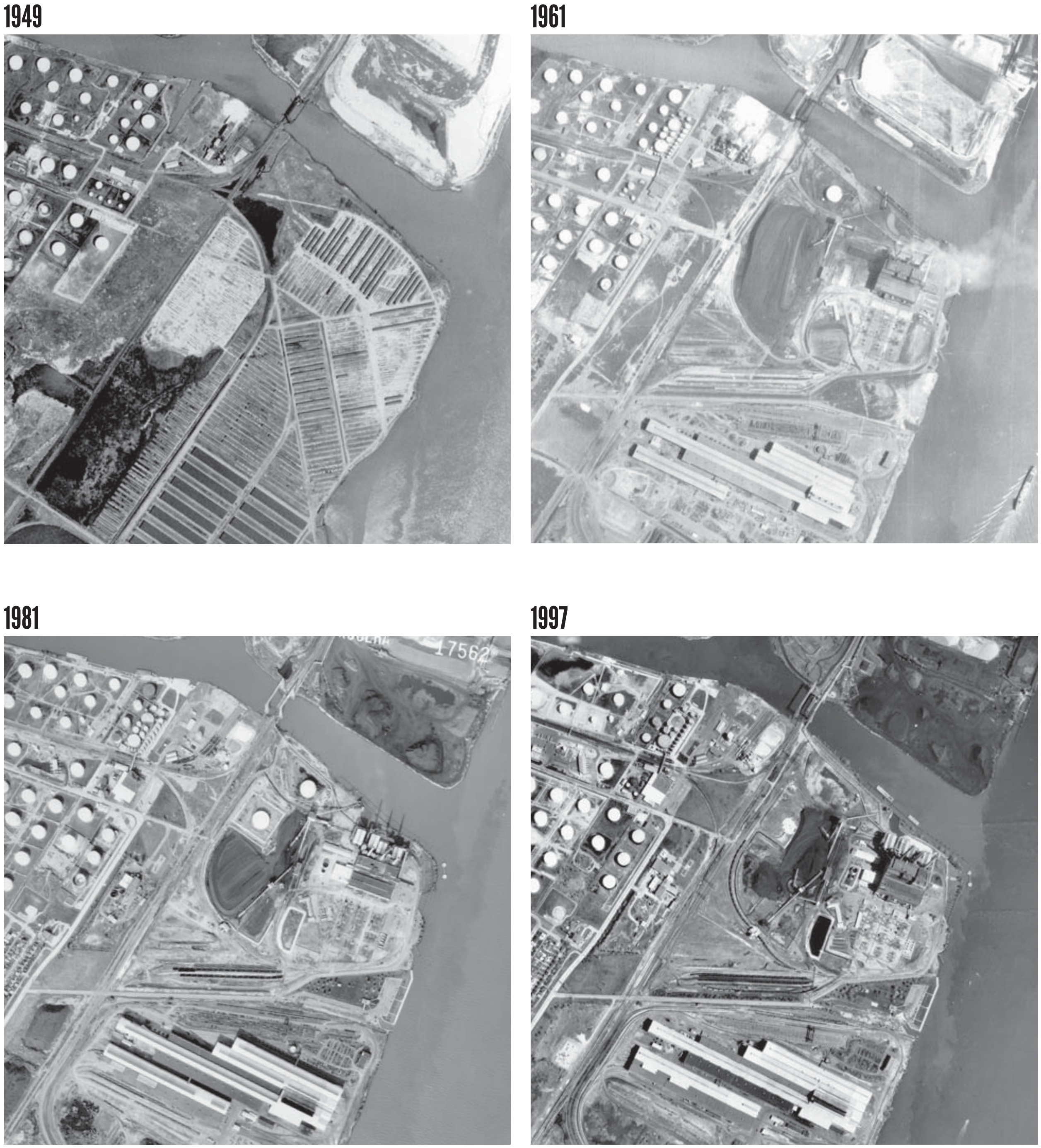


Figure 5.11. River Rouge Power Plant historic aerial photographs
Source: http://digital.library.wayne.edu/dte_aerial/index.html

Figure 5.12. River Rouge Power Plant site photographs

St. Clair Power Plant

The St. Clair Power Plant (see Figure 5.13) is located at 4901 Pointe Drive and is the largest of the sites occupying 244.8 acres. The power plant is located on the peninsula formed by the St. Clair and Belle Rivers within the Township of East China in St. Clair County, Michigan (see Figure 5.14) which is a primarily residential and agricultural community in rural Michigan. The site is unique in the fact that it is part of over 1,100 acres owned by DTE Energy in East China Township, sits across the road from DTE Energy's second power plant in the county, Belle River Complex, and is also adjacent to the to-be-constructed natural gas facility currently being designed. The site also has immediate access to the Bridge-to-Bay trail (see Figure 5.15), but waterfront access is mostly through private property.

The physical character of the site is an uneven terrain on a site once covered in upland beech-sugar maple forests prior to the logging era of the 1800s and then the subsequent agricultural practices that followed and continue to this day (see Figure 5.16). While the site presents an extremely hardened shoreline compared to the previous two sites, St. Clair Power Plant does not present any cut and fill land based on two separate sources. Unfortunately, a lack of historical aerials (see Figure 5.17) does not show much of its progression through time other than the addition of the Belle River Power Plant. Then, the pictures shown in Figure 5.18 were taken in July 2017 during a site visit.

Figure 5.13. St. Clair Power Plant study site

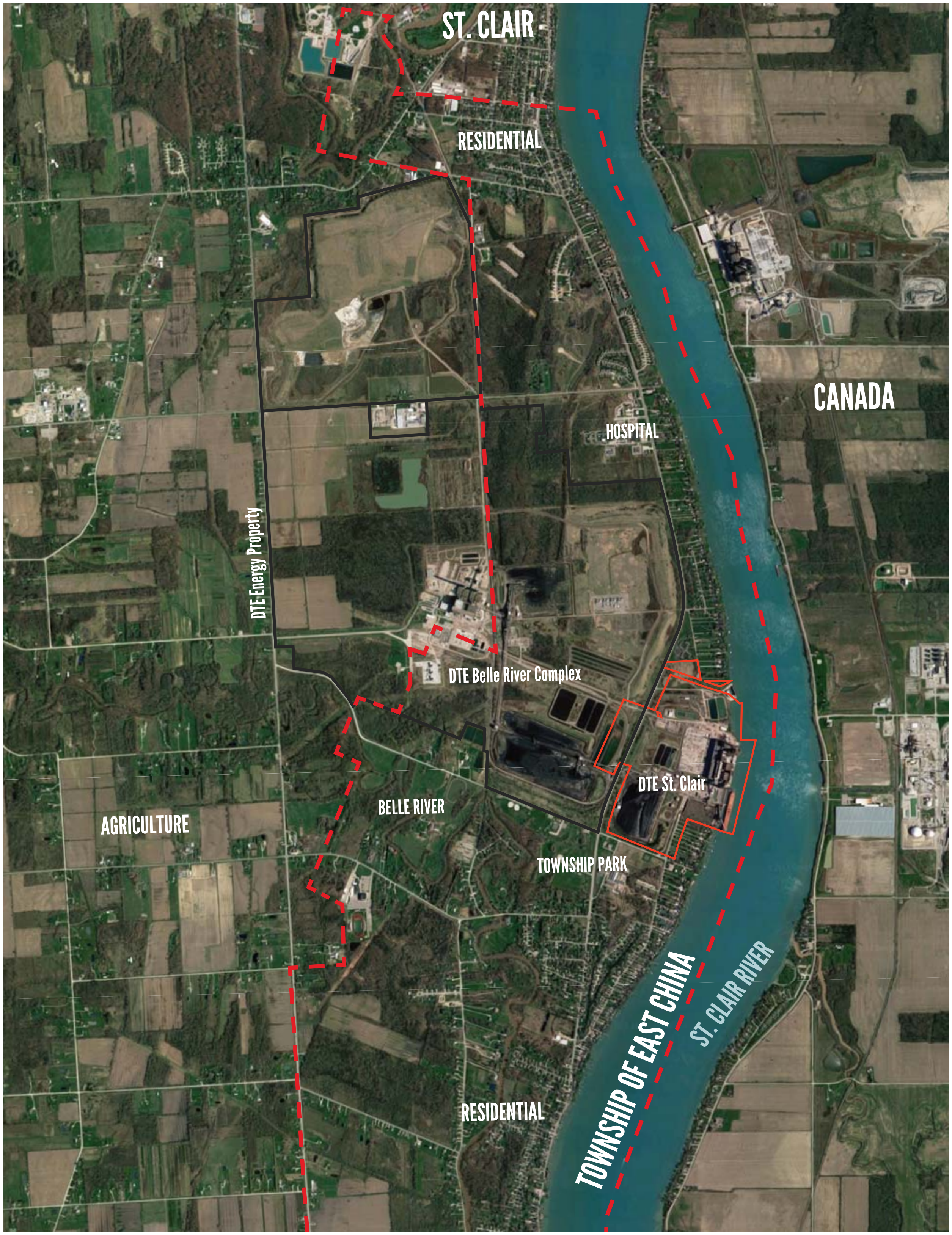


Figure 5.14. St. Clair Power Plant context diagram

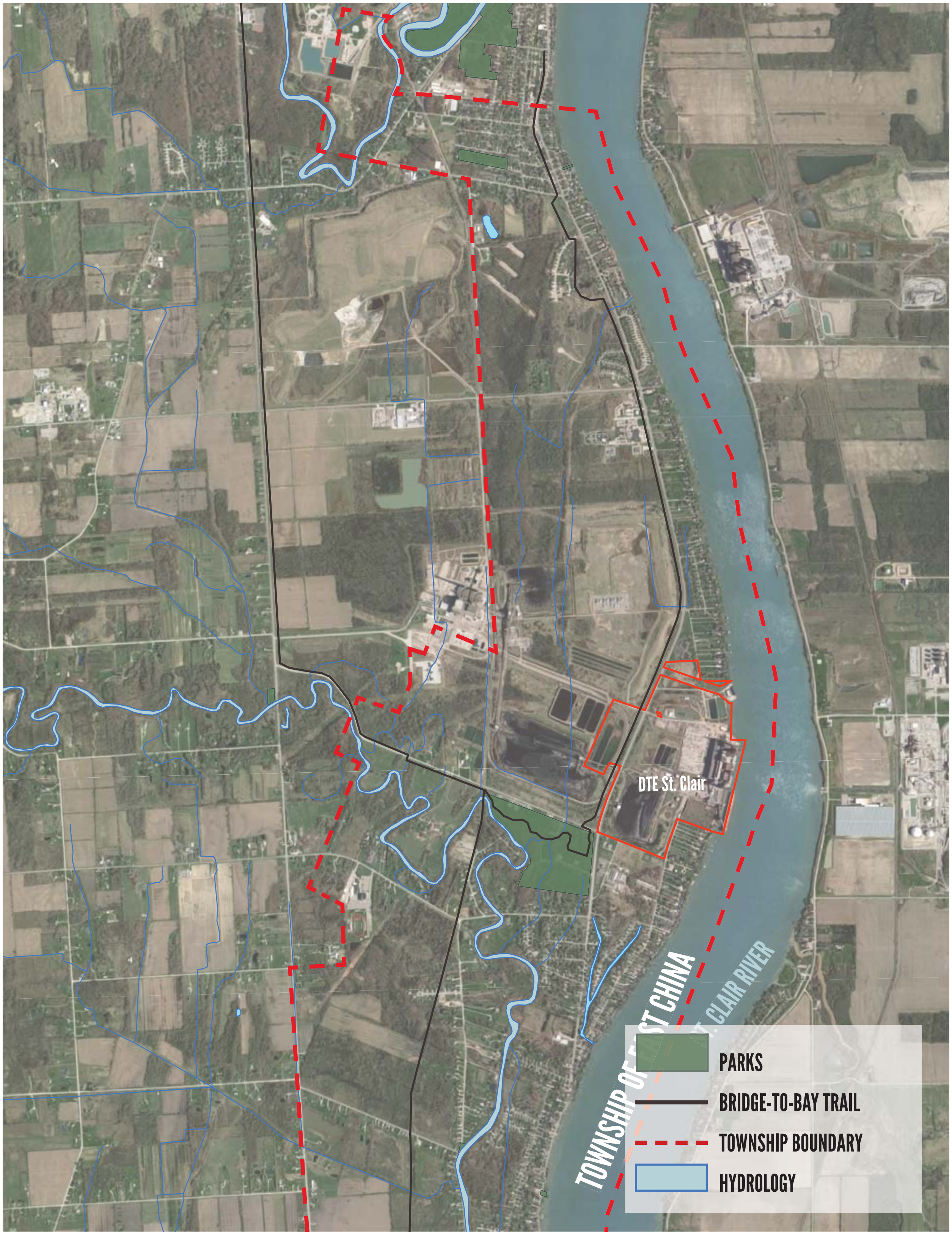


Figure 5.15. St. Clair Power Plant parks and open space

Figure 5.16. St. Clair Power Plant site analysis

Figure 5.17. St. Clair Power Plant historic aerial photographs
Source: http://digital.library.wayne.edu/dte_aerial/index.html

Figure 5.18. St. Clair Power Plant site photographs

Typologies

Based on the analysis of the sites and the overall goals and outlooks gathered from the community's master plans, six design typologies were formed (see Figure 5.19). They are: community, development, habitat, production, recreation, and blue-green infrastructure. These typologies were selected as they all represent the type of programming elements and intervention strategies that are desired to be placed on the sites. The goal of each site is to represent at least a minimal effort from each typology, but each site will result in a different mixture and emphasis based on the sites' specific goals. At the end of the framework, these typologies will be used as an evaluation tool to compare the overall design outcome of each site.

Trenton Channel Power Plant Design Approach

The Trenton Channel Power Plant's site will be used to restore its historic great lakes coast marsh and oak-hickory forest across much of the site. However, their main powerhouse building and administrative offices are the only buildings from all three sites that exhibit historic architecture quality with its red brick façade from the original 1920s construction. Thus, a key design approach for this site it to demonstrate the adaptive re-use of these buildings for commercial use or as community assets. The second key design approach is to create a potential ecological corridor for landscape connectivity between the site and Humbug Marsh. This would be done in anticipation that in the future, the land between them would eventually be able to be restored as marsh and oak-hickory forest as well creating a miles-long corridor for wildlife. Some light recreation would also be placed on the site to capitalize on the Iron Belle Trail that is planned to be completed along West Jefferson Avenue and to allow people to observe the natural communities of their area.

River Rouge Power Plant Design Approach

Due to the surrounding development of the River Rouge Power Plant, the design approach for this site is to use it to create contrast between the heavily industrialized surroundings and the site through the promotion of renewable energy that could also be used for community solar as the surrounding residents as the city will lose one-third of its tax revenue upon the plant's closure. Furthermore, upon the completion of the future international bridge, it would become a demonstration area as it will be seen from the bridge. The second design goal is to use the site as an area of scenic quality and public waterfront access as Belanger Park currently provides the only public access for the city. As for habitat restoration, due to the site's location, the site will restore some historic marsh communities, but will also create lakeplain prairie habitats as they are in such a vulnerable state as a natural community and to also continue the approach of making the site a demonstration area for the public.

St. Clair Power Plant Design Approach

The size of St. Clair Power Plant's site creates the opportunity to provide new development options for the community while also restoring a large area of beech-sugar maple forest. This new development will promote green industries and diversify the township's jobs by constructing a closed-system aquaculture facility that reuses decontaminated coal ash basins for their operations. The facility will promote renewable energy through solar panels that provide power for the aquaculture facility as well as the surrounding community. Another key design approach is to create public waterfront access and fishing pier as current access to the St. Clair River is primarily through private property.

Figure 5.19. Selected primary typologies for site designs.

Primary Functions

After analyzing the characteristics and creating the guiding design typologies, four questions analyzing the severity of the situations present on the site and lead to the primary functions necessary for transformation. They also dictate the first four phases presented in the design applications. The order these functions are taken, from transition to activation, has been assigned based on literature review and design precedents with the phase, transition, occurring first. However, the following three phases, while they follow a general order, are expected to have overlapping roles during site development. These function are meant to be dictated by the characteristics of the site, and thus, areas of the site will respond to certain actions differently or a different order of actions might need to be taken.

Decommissioning

This section of the framework represent the transition phase and begins the day after the plant closure and lasts for two years. At this future time, the plant operations have ceased, and while some activities may have already taken occurred in preparation of the decommissioning, such as removal of equipment and materials, overall, it is assumed decommissioning activities have not begun. During this phase, standard decommissioning activities are completed, such as the dewater and decommissioning of the coal ash basins. However, the framework also identifies the decommissioning activities that were deemed not seen as conducive to improving ecosystem function and resiliency in the landscape.

First, due to the water-intensive nature of coal-fired power plants, most facilities have extensive infrastructure placed on or near the shoreline of the adjacent water body. Although shoreline hardening practices can achieve commercial, navigational, and industrial benefits, it typically results in negative ecological impacts. This includes water intake buildings, discharge channels, piers, and docks for shipping freighters. However, even though these structures are removed during decommissioning, DTE Energy retains the hardened shoreline by heavily relying on sheet piling to secure the shoreline after removal.

Other environmentally-insensitive activities can then be seen during the management of contaminated or disturbed areas on the site. Per a DTE Energy report (Black & Veatch Ltd. 2009), remediation of the coal storage area typically involves removing three feet of surface below the coal pile, backfilling the area with clean, imported soil, and finally, covering with one foot of topsoil that is seeded and mulched. This is the same process for any disturbed areas of the plant site, including roads, as they are covered with two feet of soil, sloped to prevent ponding, seeded, and mulched. Ecologically-informed interventions to replace the decommissioning practices deemed detrimental to the restoration process include limiting the amount of soil removal and imported fill by promoting in situ remediation or transforming the natural depressions or basins left behind after decontamination into wetland habitats or seasonal vernal pools. Another intervention includes using soft shoreline engineering instead of placing sheet piling along the disturbed shoreline.

The following designs are the design results from the application of the framework through the transition phase. Actions in italics represent an action that is part of DTE Energy's and other sources decommissioning standards. Then, actions that are in bold represent actions that are intervening to alter a decommissioning standard that is deemed unfavorable for the restoration process.

Trenton Channel Power Plant – Phase I: Transition (0-2 years post-closing)

1. *Remove all equipment and materials from the site*, such as trailers, chemicals, and unused coal. Upon their removal, *demolish all the buildings and structures not designated for reuse* (see Figure 5.20). The structures to remain include the smokestacks and sections of coal conveyor to be used as industrial art symbolizing the site's previous use, the 1924 powerhouse footprint and administrative office buildings for commercial or community use, sections of the rail line to be converted as a walking path, and finally, the water intake building to be converted into a wetland observation building. Instead, these structures will be prepped for renovations.

2. Next, *demolish all shoreline items such as structures, docks, and other hardened edges* along the canal south of the entrance road as well as along the entire Detroit shoreline. Upon their removal, **do not use sheet pile** as it inhibits natural communities. These areas are to be transitioned into soft engineered edges during the following phases.

3. At the coal storage yard, oil tank storage area, and original rail yard, *remove soil at least 3 feet below grade*, and *dewater and decontaminate the two coal ash basins*. However, **do not fill with imported soil** as to restore marsh communities, the site has to be lowered to restore hydrology due to all the structural fill. Instead, capitalize on the soil removal that already has to occur for decontamination by incorporating these areas into the wetland restoration boundary.

4. Continue removing all other soil, even if it is not contaminated, from the areas designated for wetland restoration. For non-contaminated soil, reuse on site for filling basements and other large depressions left behind by demolition.

5. Start generating seed bank, and clear site of debris and vegetation.

Figure 5.20. Trenton Channel Power Plant Phase I Design Plan

River Rouge Power Plant – Phase I: Transition (0-2 years post-closing)

1. *Remove all equipment and materials from the site*, such as trailers, chemicals, and unused coal. Upon their removal, *demolish all the buildings and structures not designated for reuse* (see Figure 5.21). To show contrast between this site and the heavily industrialized surroundings, the only structure to remain is the railyard which will be converted later into a rail park and trail expanding River Rouge's recreation areas, and creating a tourist attraction.

2. Next, *demolish all shoreline items such as structures, docks, and other hardened edges* along the Rouge River and Detroit River shoreline. Upon their removal, **do not use sheet pile** as it inhibits natural communities. These areas are to be transitioned into soft engineered edges during the following phases.

3. At the coal storage yard and oil tank storage area, *remove soil at least 3 feet below grade*, and *dewater and decontaminate the two coal ash basins*. **Do not fill with imported soil** as to restore marsh communities and lakeplain prairies, the site has to be lowered to restore hydrology due to all the structural fill. Instead, capitalize on the soil removal that already has to occur for decontamination by incorporating these areas into the lowland habitat restoration boundary.

4. Continue removing all other soil, even if it is not contaminated, from the areas designated for wetland or lakeplain prairie restoration. For non-contaminated soil, reuse on site for filling basements and other large depressions left behind by demolition.

5. Start generating seed bank, and clear site of debris and vegetation.

Figure 5.21. River Rouge Power Plant Phase I Design Plan

St. Clair Power Plant – Phase I: Transition (0-2 years post-closing)

1. *Remove all equipment and materials from the site*, such as trailers, chemicals, and unused coal. Upon their removal, *demolish all the buildings and structures not designated for reuse* (see Figure 5.22). However, since the site shares some facilities with the Belle River Power Plant that isn't anticipated to retire until 2040, the main coal conveyor, loading docks, and access roads will have to remain until that time. The structures to remain for adaptive re-use include the smokestacks and sections of coal conveyor to be used as industrial art symbolizing the site's previous use, and the electric pad which will house the solar panels.

2. Next, *demolish all shoreline items such as structures, docks, and other hardened edges* along the St. Clair River that are not being used for the Belle River Power Plant operations. Upon their removal, **do not use sheet pile** as it inhibits natural communities. These areas are to be transitioned into soft engineered edges during the following phases.

3. At the coal storage yard and oil tank storage area, **only remove 1-2 feet of soil and do not fill with imported soil.** This site will be using phytoremediation tactics instead due to the limited amount of structural soil that would inhibit the restoration of any habitat.

4. *Dewater and decontaminate the coal ash basins and all other waste basins*. **Do not fill with imported soil**. Instead, the basins in the middle of the site will be repurposed for the aquaculture facility, and at the remaining basins, shape and grade to create undulations in the landscape for future vernal pools and other forms that mimic structural conditions found in old-growth forests.

5. Start generating seed bank, and clear site of debris and vegetation.

Figure 5.22. St. Clair Power Plant Phase I Design Plan

New Ecologies and Activities

This section of the framework represents the cultivation of new relationships between organisms and their environments, or new ecologies. Whether that organism be a person or a fish, these new relationships help promote and restore resiliency, function, and collaboration on a site by promoting dynamic interactions. These relationships start to begin during the next three phases known as remediation, restoration, and activation.

While the previous transition phase worked to prepare the site for the transformation, the remediation phase works to begin healing the site allowing for the initial restoration activities to begin. This naturally leads into the restoration phase as remediation tactics are transitioned into restoration tactics. During this third phase, all areas of the site not being used for development or human use should be ready for restoration or have already begun the process. The last phase, activation, focuses on finalizing all human-focused programming as the site should be free of any construction, contamination removal, and vulnerable or fragile habitats. Thus, humans can be fully reintroduced to the landscape.

Also, as shown in the framework, while the general process moves from remediation to restoration to activation, these are not concrete phases and instead, the activities that occur during these phases should be dynamic and respond to the landscape. Thus, as one moves through the framework, the scope of the framework begins to narrow as the interventions and transformation activities become specific and tailored to the site. For example, there are multiple approaches to remediating soil, but due to the dynamic relationships between systems, the same approach could have very different outcomes based on the site. Therefore, the knowledge and information collected from the first phase of the framework must be consistently evaluated and utilized during each step of the framework to identify the best tactic.

Trenton Channel Power Plant –Phase II (2-6 years post-closing)

1. Renovations occur on the buildings and structures designated for adaptive re-use (see Figure 5.23).

2. Reduce the amount of impervious surfaces by removing parking lots and other paved areas that are no longer needed as part of decommissioning and are not part of the final design layout. Instead, replace these areas and the area around the renovated buildings with fast-growing natives that will be tilled into the ground each season during this phase to increase the organic matter of the soil.

3. Upon removal of all designated soil, shape and grade depressions for future wetland restoration. This includes making use of microtopography and macrotopography. Once completed, remove the remaining barriers that inhibit hydrologic connections with the Detroit River and the canal to restore the Great Lakes coastal marsh community. Use berms and other select openings to protect the future marsh from wave and tidal energy as well as to direct water flow.

4. On the remaining shoreline of the site where demolition took place, use soft engineering techniques, which is the use of ecological principles and practices to reduce erosion and achieve stabilization and safety of shorelines, while enhancing riparian habitat and improving aesthetics (Hartig and Bennion 2017).

5. During the completion of the Iron Belle Trail by the state of Michigan, incorporate the trail into the site design to improve accessibility.

6. Plant poplars hybrid poplars (*Populus deltoids x Populus nigra*) on the area north of the coal storage area and west of the original rail yard to uptake and stabilize environmental pollutants in the soil. Since they mature rapidly, the wood will be harvested for biofuel upon harvesting.

Trenton Channel Power Plant – Phase III (6-10 years post-closing)

1. Harvest hybrid poplars for biofuel (see Figure 5.24) upon maturity which is approximately five to seven years. If soil quality is still not up to standards, plant a second round of hybrid poplars, or begin planting trees plugs for future oak-hickory forest. Since poplars are considered pioneer species of the oak-hickory natural community, a combination of layouts can occur utilizing the tree whether it will be harvested in the next phase or not.
2. Once wetland soils are hydric, plant first set of native wetland plants.
3. Phase out fast-growing native plants and replace them with native seedings for the restoration of lakeplain wet prairies and lakeplain wet-mesic prairies.
4. Begin fish spawning habitat restoration in the Detroit River.
5. Begin to activate the site for human use through limited trails and overlooks allowing the community access to the site. This allows them to observe and become involved in the restoration process, and increasing community awareness can help the success of the restoration. Also, strategically place the trails to create fire breaks for prescribed burnings. These are recommended every three to five years to maintain the lakeplain prairie and oak-hickory forest communities.
6. Upon completion of building renovations, place rooftop solar panels on them to produce electricity for the building and to promote renewable energy.

Trenton Channel Power Plant – Phase IV (10+ years post-closing)

1. Finalize the site for human use by finishing all trails and overlooks (see Figure 5.25).
2. Plant the next set of tree plugs or native seeds to diversify plant composition and aid in oak-hickory restoration and in the lakeplain prairie areas.
3. Continue restoring wetlands by planting next set of native wetland plants, and monitor.

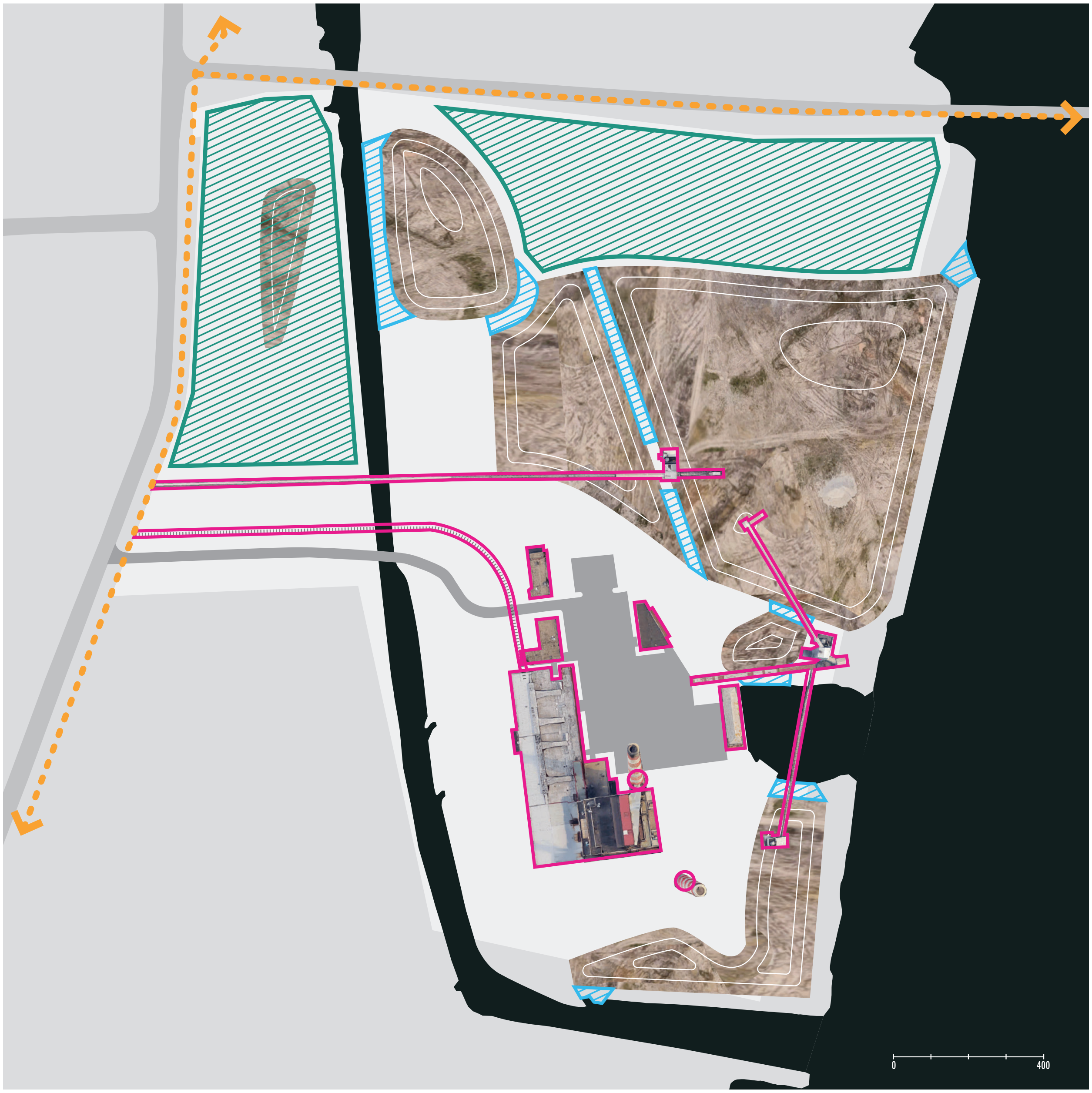


Figure 5.23. Trenton Channel Power Plant Phase II Design Plan

Figure 5.24. Trenton Channel Power Plant Phase II Design Plan

Figure 5.25. Trenton Channel Power Plant Phase IV Design Plan

River Rouge Power Plant – Phase II (2-6 years post-closing)

1. Renovations occur on structures designated for adaptive re-use (see Figure 5.26).

2. Construct 11-acre solar park on area north of the rail yard to produce community solar for the City of River Rouge.

3. Reduce the amount of impervious surfaces by removing parking lots and other paved areas that are no longer needed as part of decommissioning and are not part of the final design layout. Instead, replace these areas and the area around the renovated buildings with fast-growing natives that will be tilled into the ground each season during this phase to increase the organic matter of the soil.

4. Upon the completion of shaping and grading the wetland restoration area, remove the remaining barriers that inhibit hydrologic connections with the Detroit River and Rouge River to restore the Great Lakes coastal marsh community. Use berms and other select openings to protect the future marsh from wave and tidal energy as well as to direct water flow. However, do not restore hydrology to future lakeplain prairie areas.

5. On the remaining shoreline of the site where demolition took place, use soft engineering to enhance riparian habitat and improve aesthetics.

6. Plant sunflowers and corn in varying strips on areas designated as future lakeplain prairie to remediate soil through strip cropping technique. Harvest each season and use as biofuel and till remnants into the soil to create organic matter.

River Rouge Power Plant – Phase III (6-10 years post-closing)

1. Once wetland soils are hydric, plant first set of native wetland plants (see Figure 5.27).

2. Phase out sunflowers and corn on strip cropping areas and replace with native seedings for the restoration of lakeplain wet prairies and lakeplain wet-mesic prairies.

3. Begin to activate the site for human use through limited trails and overlooks allowing the community access to the site. This allows them to observe and become involved in the restoration process, and increasing community awareness can help the success of the restoration. Also, strategically place the trails to create fire breaks for prescribed burnings. These are recommended every three to five years to maintain the lakeplain prairie communities.

River Rouge Power Plant – Phase IV (10+ years post-closing)

1. Finalize the site for human use by finishing all trails and overlooks (see Figure 5.28).
2. Plant the next set of native seeds to diversify plant composition in the lakeplain prairie areas.
3. Continue restoring wetlands by planting next set of native wetland plants, and monitor.

Figure 5.26. River Rouge Power Plant Phase II Design Plan

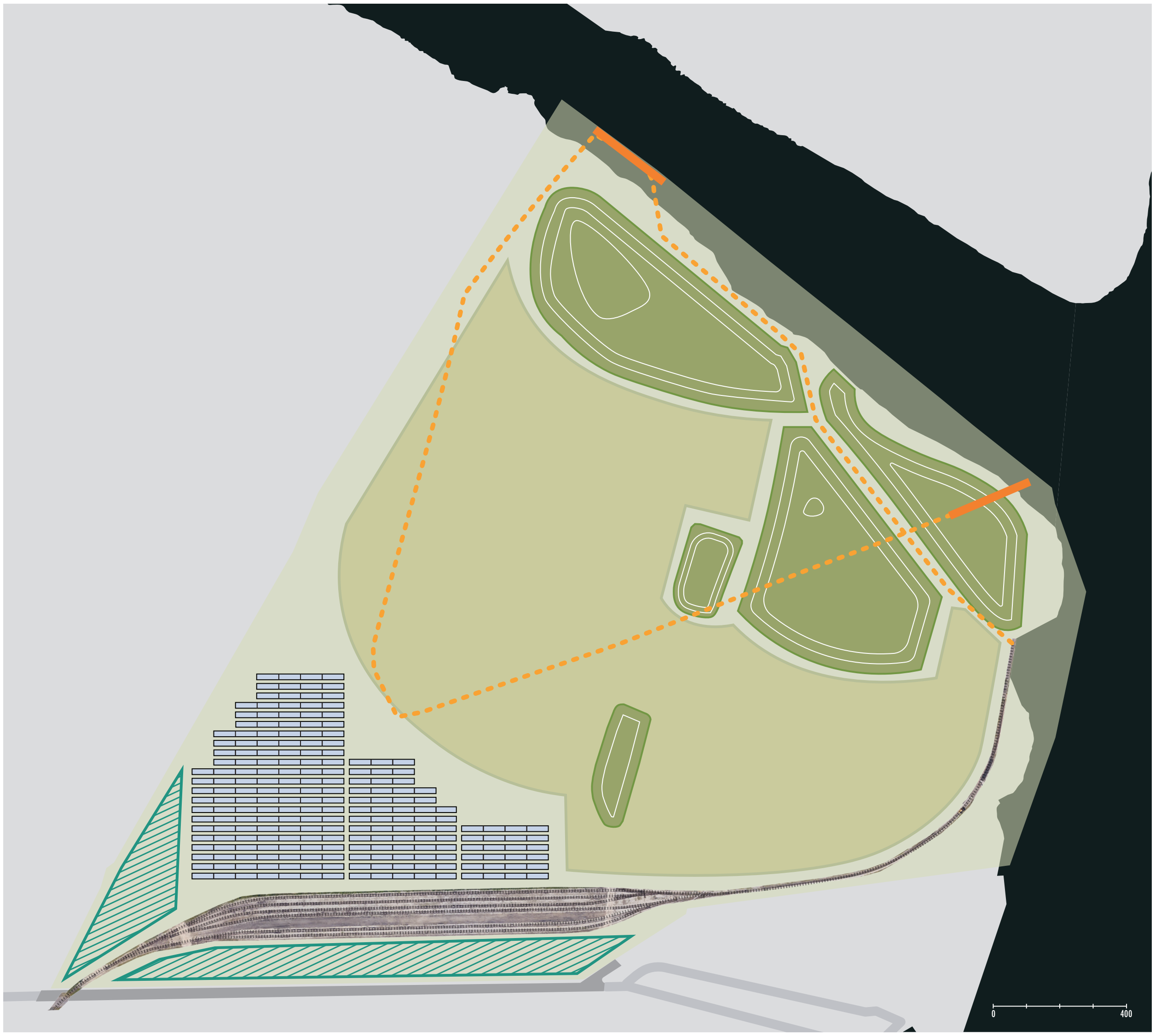


Figure 5.27. River Rouge Power Plant Phase III Design Plan

Figure 5.28. River Rouge Power Plant Phase IV Design Plan

St. Clair Power Plant – Phase II (2-6 years post-closing)

1. Renovations occur on structures designated for adaptive re-use (see Figure 5.29).

2. Construct closed-system aquaculture facility west of the electric pad that uses previous coal ash basins for spawning and breeding ponds. Also construct solar park on electric pad to promote renewable energy and produce energy for the facility.

3. Reduce the amount of impervious surfaces by removing parking lots and other paved areas that are no longer needed as part of decommissioning, not part of the final design layout, and not needed for operations at the Belle River Power Plant.

4. On the shoreline where demolition took place, use soft engineering techniques to enhance riparian habitat and improve aesthetics.

5. Plant poplars hybrid poplars (*Populus deltoids x Populus nigra*) on all contaminated areas to uptake and stabilize environmental pollutants in the soil. Since they mature rapidly, the wood will be harvested for biofuel upon harvesting.

6. Establish native seedings for successional meadow on all other areas of the site.

St. Clair Power Plant – Phase III (6-10 years post-closing)

1. Harvest hybrid poplars for biofuel (see Figure 5.30) upon maturity which is approximately five to seven years. If soil quality is still not up to standards, plant a second round of hybrid poplars, and if it is, begin planting trees plugs for future beech-sugar maple forest. Since poplars are considered pioneer species of the beech-sugar maple natural community, a combination of layouts can occur utilizing the tree whether it will be harvested in the next phase or not.

2. Continue aiding succession on areas previously seeded with successional meadow with second set of seedings and strategically placed tree plugs.

3. Begin fish spawning habitat restoration in the St. Clair River.

4. Begin to activate the site for human use through limited trails and overlooks allowing the community access to the site. This allows them to observe and become involved in the restoration process, and increasing community awareness can help the success of the restoration.

5. Incorporate existing Bridge-to-Bay trail into site design improving the site's accessibility.

St. Clair Power Plant – Phase IV (10+ years post-closing)

1. Demolish remaining Belle River Power Plant structures in 2040 including the water intake structure to the north and the loading dock. However, renovate sections of the coal conveyor to be used as industrial art.

2. Finalize the site for human use by finishing all trails and overlooks (see Figure 5.31). Upon demolition of loading dock, create a new fishing pier and waterfront access at

3. Mow some successional meadow areas to act also as light recreation sports fields for the community as the community has a higher median age for population and wants to try and attract young professionals to the area.

4. Plant the next set of tree plugs to diversify plant composition and aid in beech-sugar maple restoration.

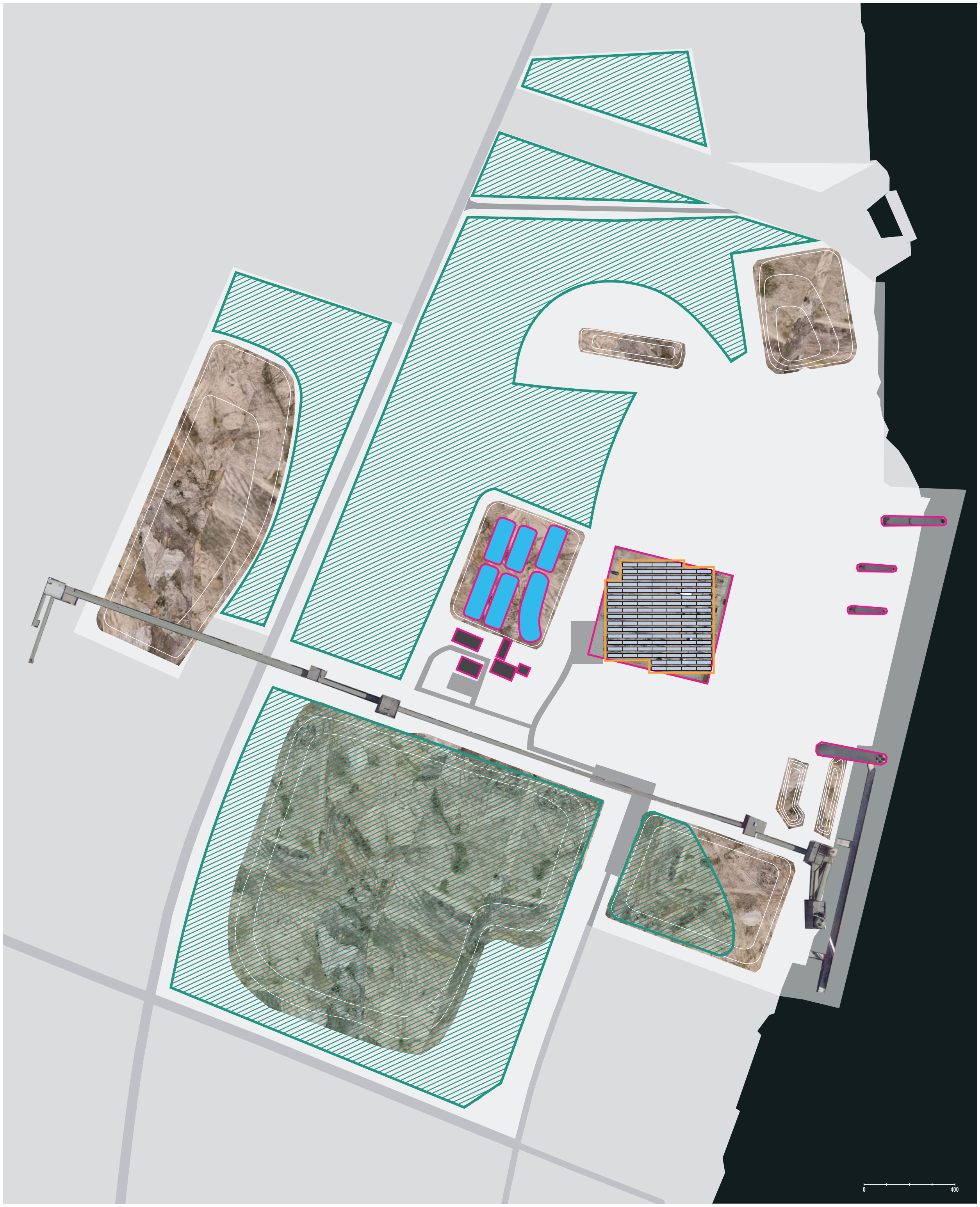


Figure 5.29. St. Clair Power Plant Phase II Design Plan

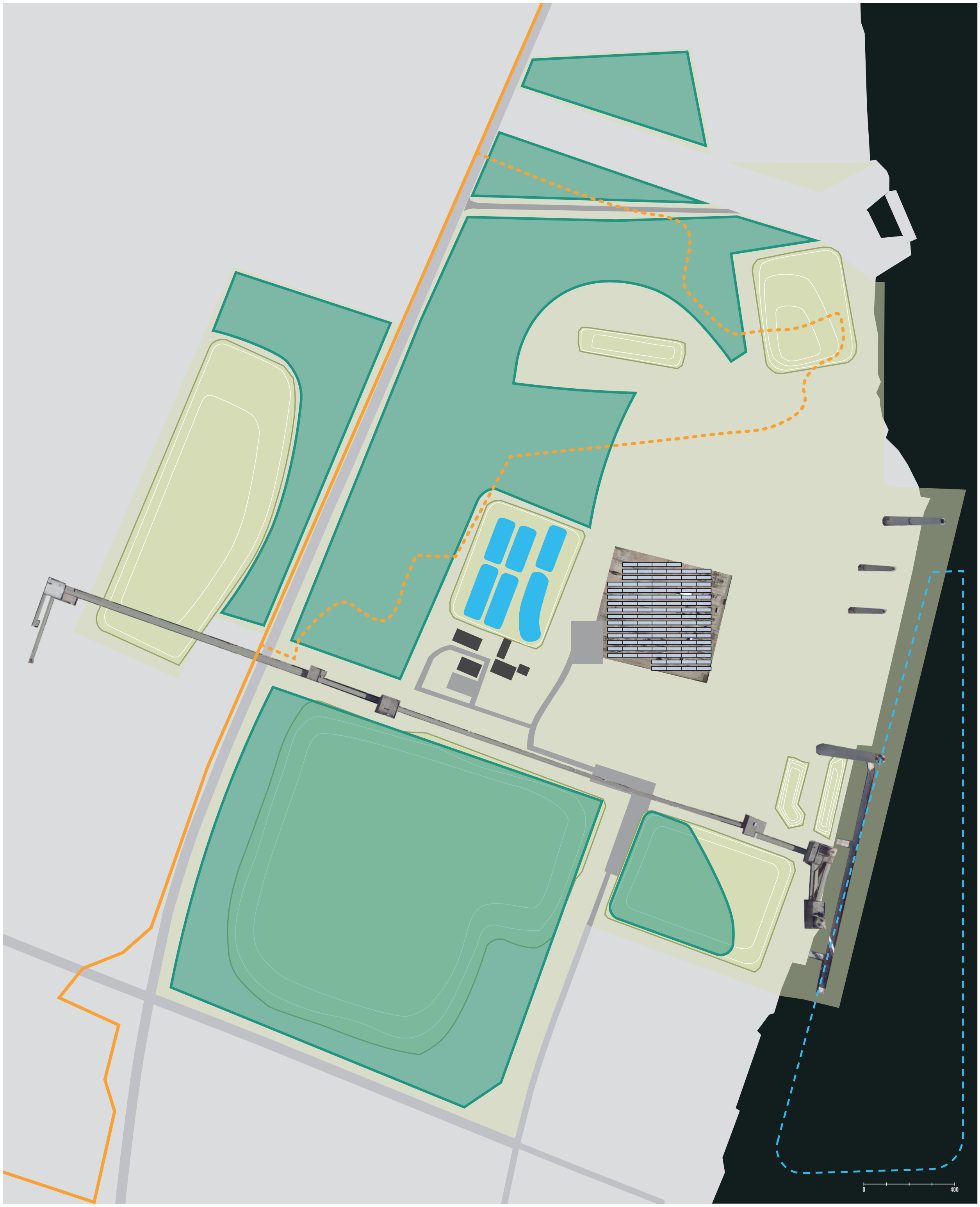


Figure 5.30. St. Clair Power Plant Phase III Design Plan

Figure 5.31. St. Clair Power Plant Phase IV Design Plan

Performance

The performance metrics listed were obtained from the Landscape Architecture Foundation's (n.d.) *Landscape Performance Case Study Briefs*. This type of metric approach was selected as it is not a rating system, but instead are used to "measure of the effectiveness with which landscape solutions fulfill their intended purpose and contribute to sustainability" (Landscape Architecture Foundation n.d.) through quantifying environmental, social, and economic benefits. While there are 34 benefits in total, 24 were chosen for this framework based on the characteristics of the sites and the desired outcomes and goals of the designs. Thus, these metrics are crucial in validating the design and measuring ecosystem services provided through ecosystem functions.

The following designs (see Figure 5.32, 5.33 and 5.34) represent the last phase, adaptive management, and show how the sites are expected to look in fifty or more years. If successful, the ecosystem functions should be restored and the site is also more resilient to human and non-human stressors. Yet, as shown in the framework, this is not meant to be a final phase in the sense that the site restoration has been completed. As dynamic systems, the ecosystems should be continually monitored and researched to ensure they are functioning properly and to adapt management practices as needed. For example, while the coal-fired power plants have been removed from these landscapes, other industrial sites and manufacturing facilities remain in close proximity and may cause unforeseen stress upon the landscape. Also, climate change and shifting USDA Planting Zones may cause certain species to not be as regenerative, so monitoring should ensure that invasive species are capitalizing on these losses.

Figure 5.32. Trenton Channel Power Plant Phase V Design Plan

Figure 5.33. River Rouge Power Plant Phase V Design Plan

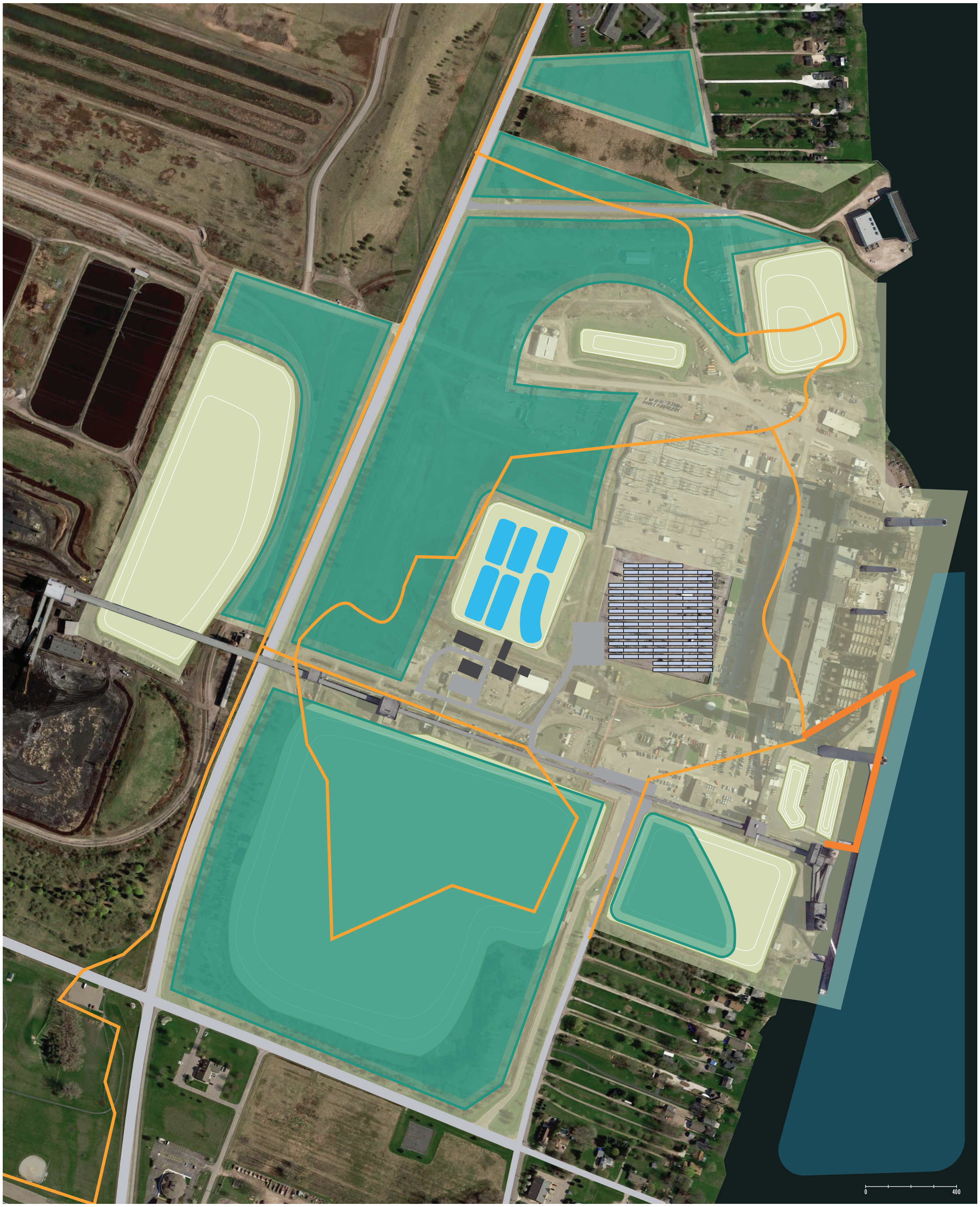


Figure 5.34. St. Clair Power Plant Phase V Design Plan

Evaluation

This diagrammatic evaluation (see Figure 5.35) is used as an assessment to compare the overall design outcomes of each site. While each site was successful in producing the landscape performance benefits shown in the framework to some degree, the evaluation diagram shows the magnitude of the effort for each site. For example, while all three study sites received above average effort for habitat, the design approach for Trenton Channel Power Plant focuses on community and development as compared to the other two sites due to the efforts taken to re-use the power plant buildings for community or commercial activities. The River Rouge Power Plant and St. Clair Power Plant on the other hand, received a higher level of effort in creating productive uses on the site in order to diversify the economic conditions of each community. This was established through the creation of renewable energy and green industries on both sites.

Figure 5.35. Typology-based design evaluation

Conclusion and Findings

Using the principles of ecology as a design lens means viewing the landscape not as a single, static entity, but instead as a set of moving parts inherently linked through multiple dynamic connections. Landscapes are constantly changing, but unless it follows a dramatic event, most of the time, the change is occurring at a scale that isn't detectable by day-to-day observation. Then, there are situations when the change is so drastic, that the idea of restoration seems near impossible. However, by looking beyond the standard set of existing conditions and recognizing where the landscape has been and where it might go, landscape architects can begin realigned the fractured pieces of the landscape to restore ecosystem functions, structures, and resiliency.

As it applies to decommissioned coal-fired power plants, if these landscapes are viewed as a set of dynamic moving parts, the idea that there is a fix-all design solution becomes invalid. Instead, ecological design encourages designers to embrace the landscape's natural ability to be responsive to change. When human-alterations have removed the landscape's ability to do so, restoration of the site's historical processes and ecosystem function is the first place to start. This concept also helps transform these landscape by promoting responsible human development and programming that ensures resiliency remains intact to remain flexible against human and non-human stressors. The resulting evaluation diagram shows how different elements were incorporated into the design process for each site, and ultimately all were transformed into multifunctional, hybrid landscapes. Furthermore, through the development of the framework, interventions for standard decommissioning process and possible post-closure contamination were able to be identified and led to more streamlined restoration and redevelopment processes.

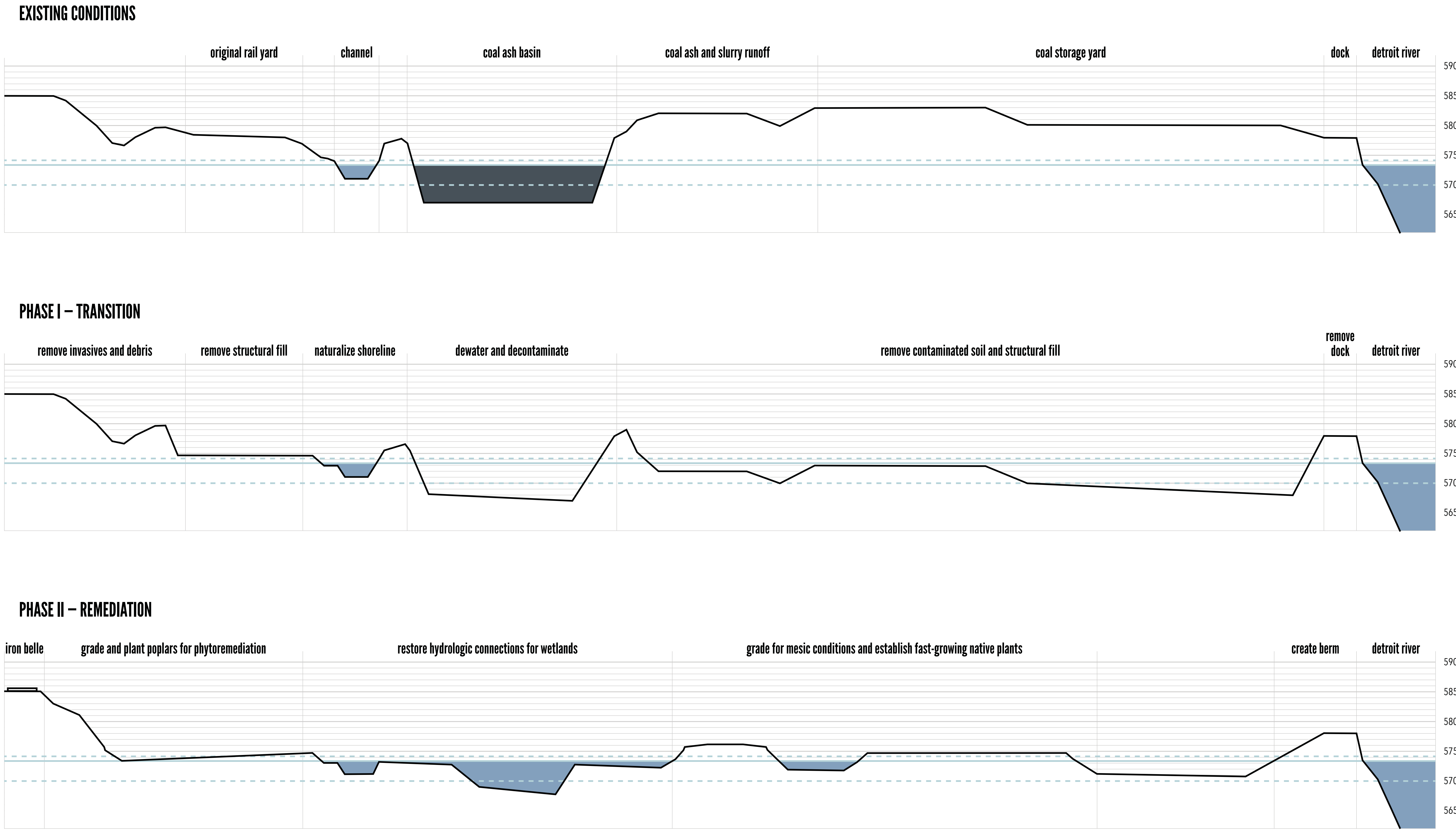
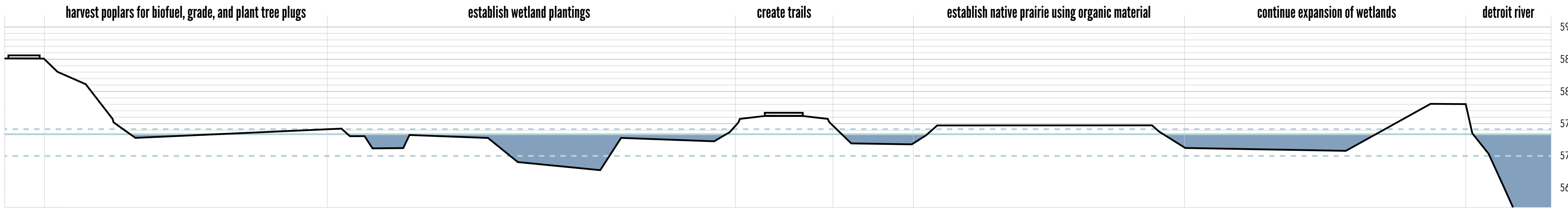
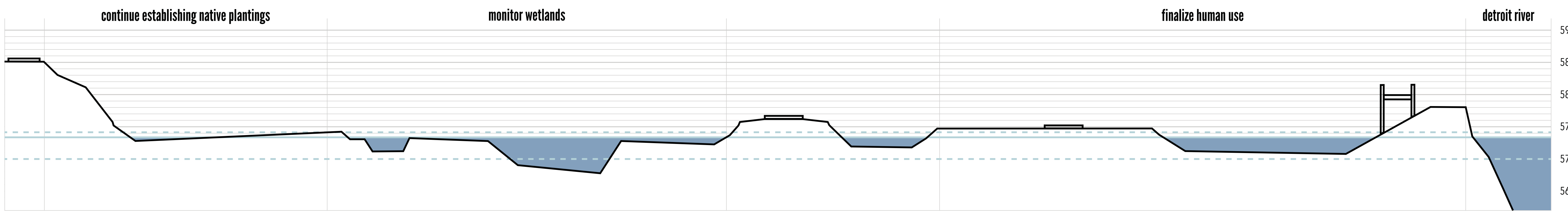


Figure 5.36. Trenton Channel Power Plant Sections, Existing Conditions to Phase II

PHASE III – RESTORATION



PHASE IV – ACTIVATION



PHASE V – REGENERATION

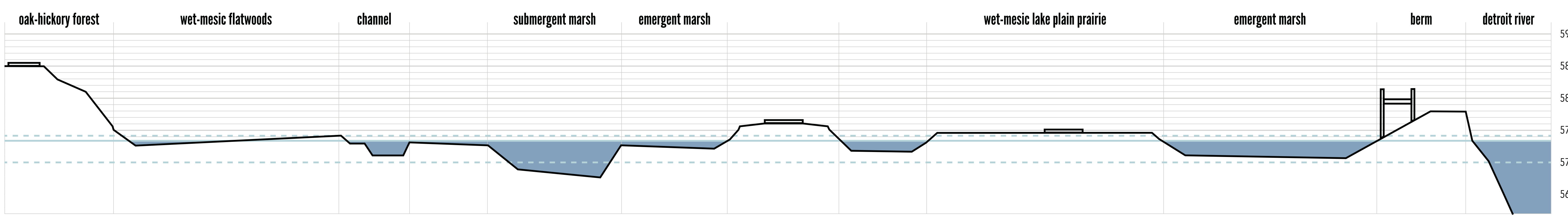


Figure 5.37. Trenton Channel Power Plant Sections, Phase III to Phase V

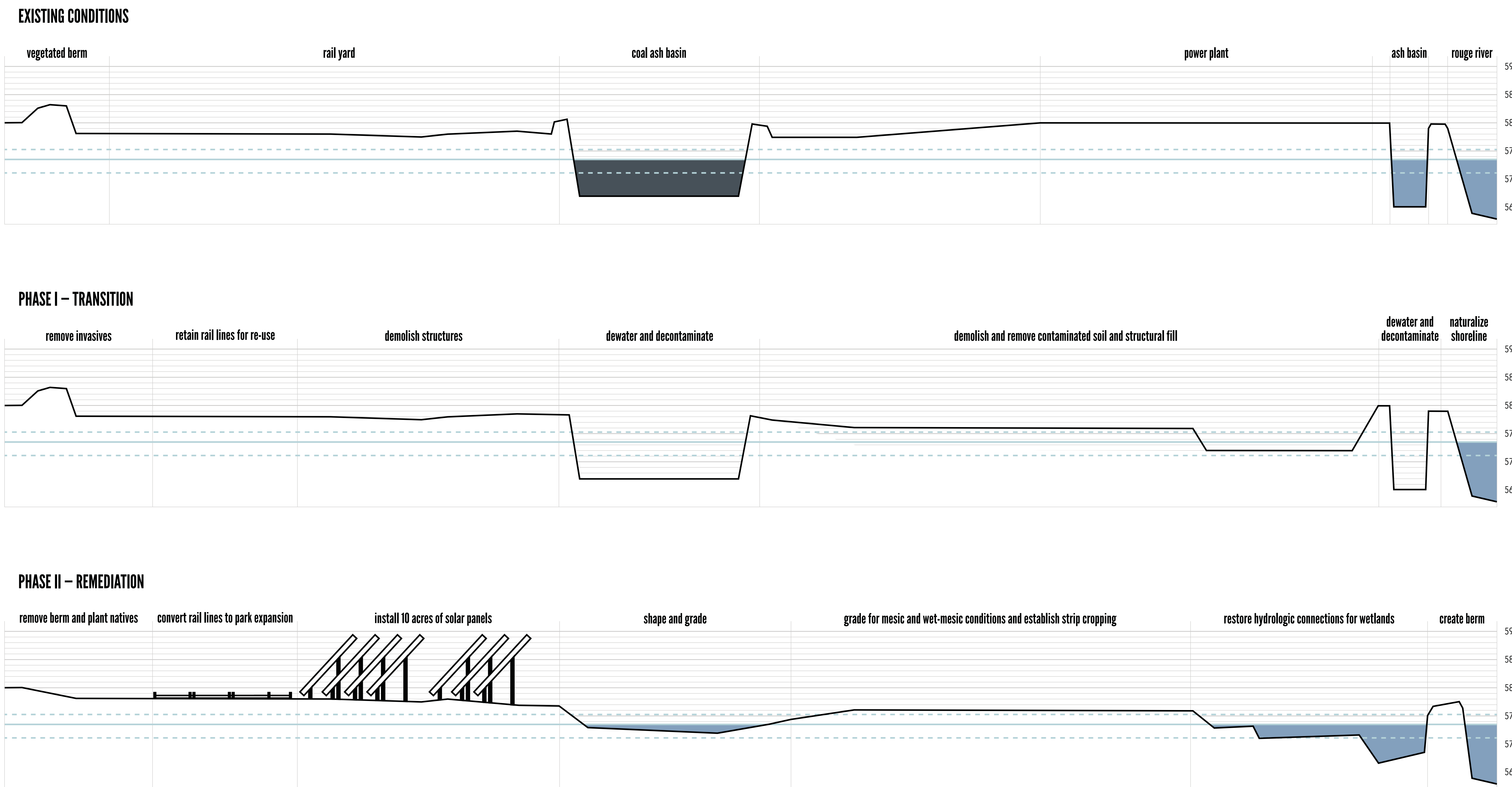


Figure 5.38. River Rouge Power Plant Sections, Existing Conditions to Phase II

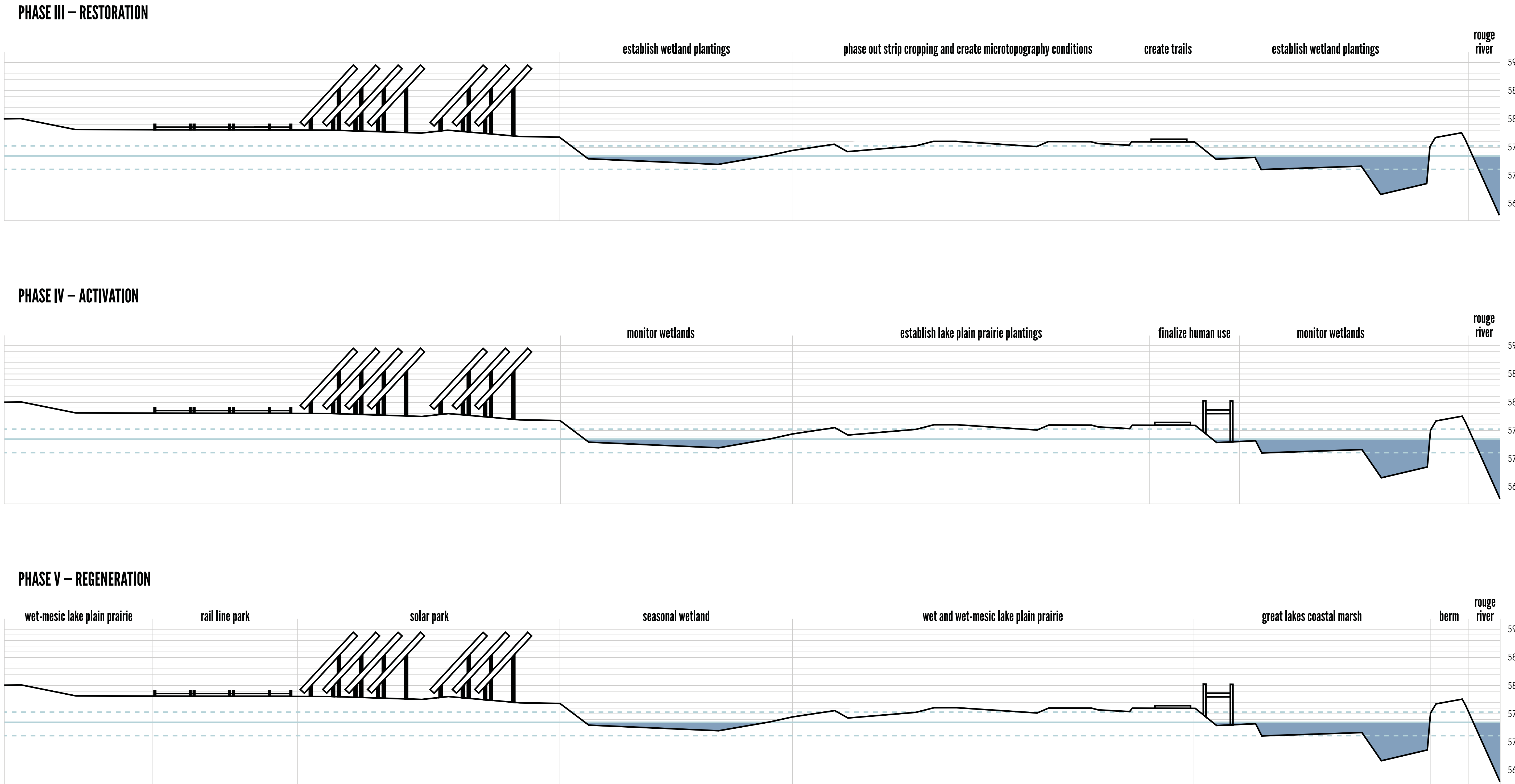


Figure 5.39. River Rouge Power Plant Sections, Phase III to Phase V

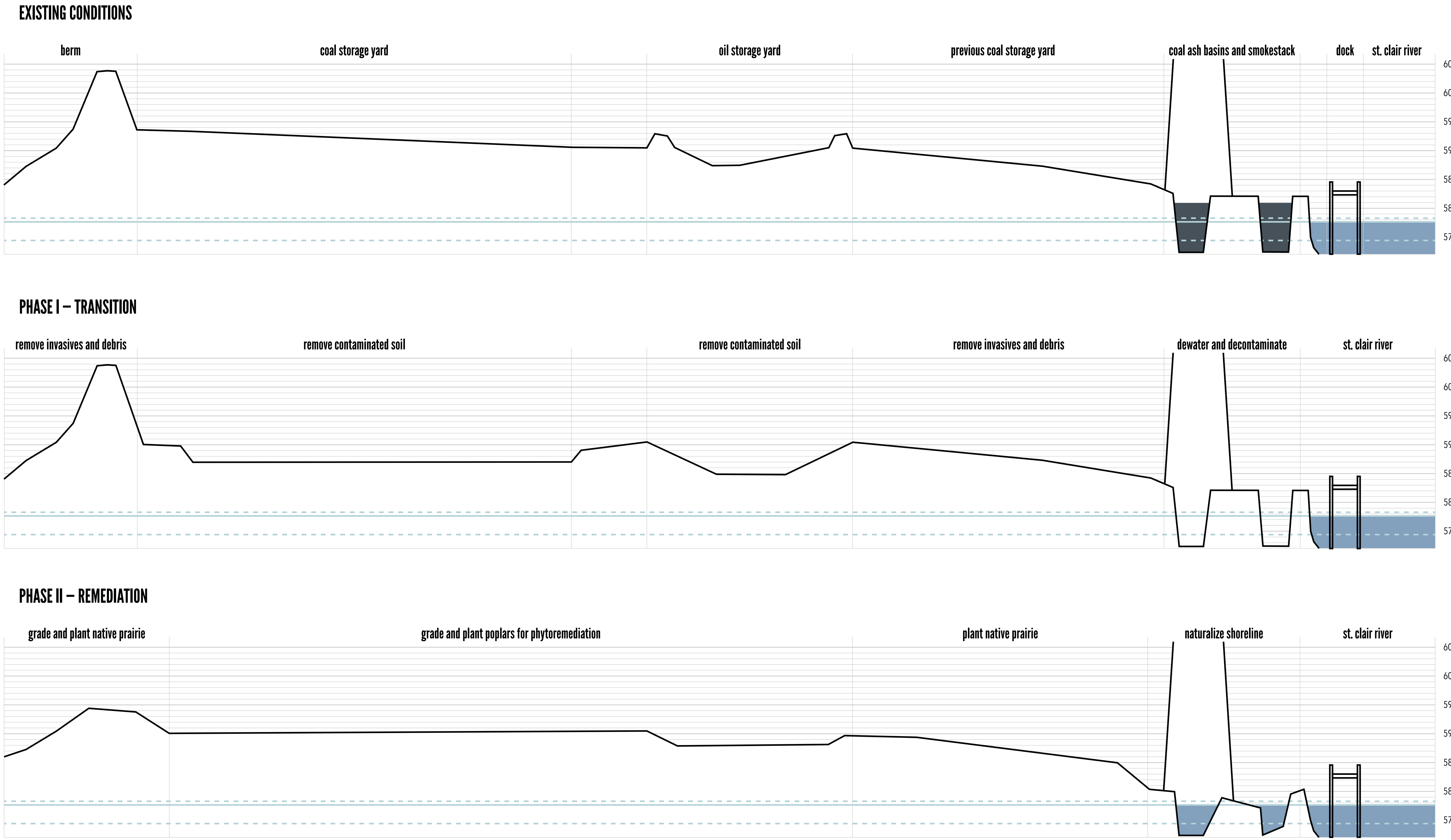


Figure 5.40. St. Clair Power Plant Sections, Existing Conditions to Phase II

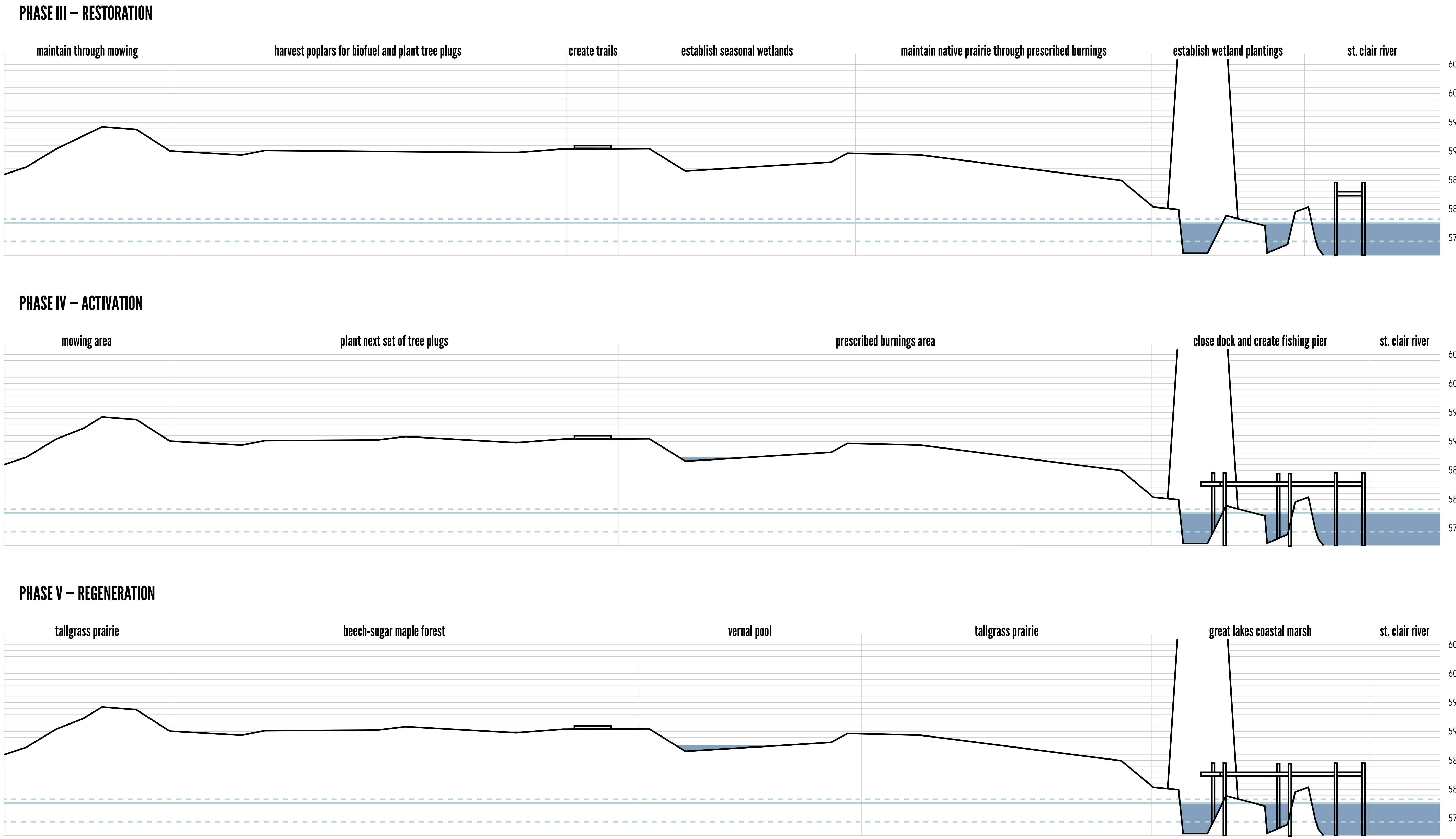


Figure 5.41. St. Clair Power Plant Sections, Phase III to Phase V

CHAPTER SIX

CONCLUSION

Summary

Across the nation, modernizing pollution controls and less expensive alternative energy resources have led to the decommissioning of more than half of the United States' coal-fired power plants. While re-use possibilities are diverse, once closed, a majority of these industrial sites are often forgotten and abandoned for decades. For the sites that are able to secure a new future, end uses tend to focus on further land-intensive developments such as hotels, commercial or residential complexes, and office buildings. However, for the communities faced with losing a significant contribution to their tax revenue, the economic incentive for such development can serve as a strong influencer. Yet, what the community does not know is that these decisions disregard the social and economic benefits that can ultimately be achieved through a balanced, functional ecosystem.

This thesis began by identifying a potentially transformative shift occurring on the landscape due to the changing demands for coal. Thus, to provide a new trajectory for these coal-fired power plants set to be decommissioned and to disrupt the notion that the only future for these sites is one of continued intense development, this thesis evaluated three coal-fired power plants scheduled to retire in 2023 in Southeast Michigan to identify the capacity in which they could be used to restore ecosystem function while being converted into hybrid landscapes, exhibiting both ecological and productive capabilities.

Reflection and Critique

By looking beyond the existing conditions and investigating the past, present, and potential future of coal-fired power plants and Southeast Michigan's historic habitats, as well as theories behind ecological design and hybrid landscapes, new knowledge about restoration strategies, reclamation goals and guidelines, and new ecological design were achieved. It was through this approach that the most significant findings were made as several untapped opportunities for restoration of ecological and cultural forms were discovered as early as the decommissioning phase, but only when designers and ecologists are involved from the beginning. By altering the standard decommissioning practices, remediation and restoration could be achieved more effectively and efficiently instead of designers and ecologists being brought into the project after the fact leaving additional work to be done.

To enhance the likelihood of long-term restoration success and maximize resilience-related benefits of restoration, efforts should be directed at restoring ecosystem function and involve large-scale connectivity. However, the selection of design scenarios could be described as a success and a failure. The choice to select the three study sites for this research was guided by the ability to test the proposed framework across a gradient of design scenarios with sites possessing a common function but across several different social, economic, and environmental characteristics. However, it was also their commonalities that drove the decision as they are all owned by DTE Energy, governed by the Southeast Michigan Council of Governments (SEMCOG), scheduled for decommissioning in 2023, and located along the Lake Huron-Lake Erie corridor. Combined, these similarities and differences produced ideal design scenarios and added to the success of the resulting design applications that stemmed from the framework.

The benefits from the similarities provided relatively consistent data across all the sites in terms of permits and pollution reporting, infrastructure identification, and accuracy with data accuracy. This base of commonalities led to a more streamlined process in data collection and development, and it also provided for a more compelling framework as the end result was comparing "apples to apples" with a more detailed level of interventions and implementation strategies. Then, even with all these streamlined processes in data collection, due to the surrounding community and demographics, infrastructure layout, natural communities, and physical size of the sites, enough differences were presented to result in end designs producing site-specific design solutions and programming elements producing hybrid landscapes.

However, due to the regional specificity of the sites, it was a natural progression for those specifics to be incorporated into the framework making it invalid if it was to be implemented in another region of the country. This is most notable in the decommissioning interventions as the successful implementation of these items are dependent on the governing bodies of the utility company and the alterations they allow to occur on the shoreline. First, this framework is specific to urban settings as human ecosystems play an important role in its creation. For coal-fired power plants in a rural setting, the separation from communities and other developments would vastly change how the process would function, the typologies created, and the resulting activities.

Secondly, this decommissioning section of the framework is tied closely to the standard decommissioning process of DTE Energy. For example, all permanent storage of waste and coal ash occurs off-site for all three facilities, so the process of capping a landfill or disposal area was not required. Also, during DTE Energy's operations and decommissioning preparation, a number of agencies are in charge of watching over these activities. Michigan Department of Environmental Quality (MDEQ) and the United States Environmental Protection Agency (EPA) govern the disposal of hazardous waste and the release of wastewater and air pollution, the Michigan Public Service Commission protects the public by ensuring safe, reliable, and accessible energy, and U.S. Army Corps of Engineers has to be involved if any changes are to be made to any structure in or on the shoreline including bulkheads and loading docks. Thus, their standards have been developed to interact with these agencies.

Future Directions

The proposed framework and design applications presents an overlooked opportunity for the design field to play a significant role in tapping into the natural processes of the region to help restore the proper functioning of the ecosystem in a landscape largely left out of the restoration discussion: coal-fired power plants. As an ecologically-minded field, there is a responsibility to actively seek situations that would benefit from that expertise, and now with the quickening rate of coal-based facilities, the transformative repercussions are salient. By intervening now, the field has a chance to establish a precedent in ecological design and emphasize the importance of engaging landscape architects and ecologists from the beginning of the process. As shown in the design applications, all of the interventions implemented occurred only in the first phase, which was the decommissioning phase. If this framework wasn't applied to the site until after the decommissioning process was completed, the restoration would not only be healing the site from the coal-fired power plant damage but also reversing the damage from the decommissioning phase. However, to truly establish a role in this emergent landscape, much work remains.

While this thesis was able to contribute to the larger body of knowledge concerning ecological design and the integration of landscape architecture and ecology with other fields to produce innovative design solutions, the work completed has only provided foundational information on which future research must continue. By investigating the entire decommissioning and transformation process at a master planning scale as well as across three different sites, this research was not able to investigate the exact workings of many of the proposed implementation. To convince professionals from other fields the feasibility of this study and the importance of our work, details are needed. Thus, next steps of this research must include small-scale investigations into each of the interventions and remediation tactics discussed in the thesis such as using strip cropping on industrial sites, best materials and techniques for soft shoreline engineering, and planting schedules and plans for habitat restoration.

Another future step is to continue the conversation by engaging with potential stakeholders and partners at all levels. This includes community leaders of the study sites, DTE Energy administrators, the Delta Institute, and other design professionals whose input and resources would be extremely valuable. This thesis promotes the idea of involving the designers and ecologists from the beginning of the process, and so the same must happen during engagement by involving the community and professionals in the research as soon as possible to continue cultivating innovate solutions that manifest into ecologically-informed hybrid landscapes serving the people and the environment.

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