INTERACTIVE EMBANKMENT:
TOPOGRAPHY OF FLUCTUATING WATER LEVELS AND HUMAN
INTERACTION

BY

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THESIS

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ABSTRACT

Interactive embankments, as a boundary surface or structure, mediate between land and water, potentially change the landscape, restore the ecosystem, and promote public access to a waterfront. It is a reflection of societal values in direct dialogue with the forces of nature. Water level fluctuations reflect changes in river discharge, a natural attribute caused by climate and human intervention, which also creates the dynamic riverfront landscape. Contemporary urban riverbanks, when armored with levees or floodwalls, usually hide this feature, limit the potential benefits it may bring to the landscape, and often lack public access. This thesis studies precedent embankment types in order to address better riverbank design treatments for fluctuating water levels. It starts by investigating speculative and un-built edge conditions found in architectural and landscape renderings. Existing and speculative (un-built but visualized) interactive embankment types will be categorized and new design prototypes generated. As a demonstration of their values, these design prototypes will then be projected upon real site conditions, especially the riverbank of Hart Plaza Detroit in Detroit, Michigan.
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Chapter 1: Introduction

1.1 Background and purpose

Increased urban development dramatically increases discharge into rivers from rainfall and snowmelt by removing vegetation, adding sloping impermeable surfaces and constructing drainage systems, these practices can lead to the undermining of the storage capacity of urban basins and the acceleration of the surface runoff speed. Data shows that water levels in urban rivers rise more quickly and have larger discharges than is the case for rural rivers (Konrad, 2003) (Figure 1.1).

Figure 1.1 Stream flow in Mercer Creek, an urban stream in western Washington, increases more quickly, reaches a higher peak discharge, and has a larger volume during a one-day storm on February 1, 2000, than stream flow in Newaukum Creek, a nearby rural stream. Source: Effects of urban development on floods. (Konrad, 2003)

Changes in flow discharge the potential to alter the landscapes at the lateral
boundaries of rivers, including riparian habitats (Paul 2001). Due to this potential, we propose design for embankments that interact better with water level fluctuations. Awareness of this potential may strengthen the connection between citizens and the rivers, encourage citizens to come to the riverfront for leisure, and even promote environmental protection.

There are two hierarchical types of urban waterways, rivers and streams. Urban rivers are defined as watercourses that flow towards lakes and oceans, and are fed by urban streams. An urban stream is formally a natural waterway that flows through an urbanized area (Walsh 2005). Issues including polluted runoff and combined sewer discharges affect urban streams. Governments once solved this problem using river engineering techniques such as lining the stream with hard material, or burying the stream underground in an engineered system of pipes (Figure 1.2). These solutions produced additional problems such as downstream flooding, the loss of habitats and water quality degradation. In order to avoid these problems, numerous techniques have been employed to restore urban streams, which often involve replacing the hardscape using "soft" bioengineering approaches (Brown 2000). Under such circumstances, embankment restoration often focuses on protection and stabilization to guard against erosion. These techniques include revetment composed of rip-rap, boulders or dead plant material. Though these techniques have produced successes in restoring the banks and improving the health of the ecosystem to some extent, both the "hard" and "soft"
engineering techniques have failed to provide for human access and activities. Activities such as catching frogs, skipping stones, and observing the restored riparian habitat have not been taken into consideration (Yang 2004).

Many major rivers are closely associated with the cities through which they flow, such as the Thames River in London and the Seine River in Paris. The water level of these rivers remains on a steady level most of the time. Rising water levels and risk of floods can occur due to extreme precipitation and storm surges from feeder streams and lakes, or tidal estuaries and coastal storms. In many urban areas, rivers have been channelized with floodwalls or levees built to support shipping to convey floods. High floodwalls cut off the land from waterway, and hold people back from the water edges.

The typical form of levees and dikes is that of a steep sloping surface that cuts
into river, so it does not favor any human activities. Both floodwalls and levees perform excellent engineering functions, but lack most of the river ‘edge features such as being green, dynamic, and alive. As an alternative, an interactive embankment aims at promoting interactions between land and water, and seeks to create a dynamic landscape that accommodates water flow and daily and seasonal water level fluctuations (fluctuations that do not produce flood risks). It is also intended to enhance ecological habitat and human activities.

1.2 Questions and method

This thesis begins with a literature review to obtain an understanding of current typologies of rivers and river embankments and how waterfront roles and embankments have evolved over time. Regarding precedent studies, I will use a typological approach in distinguishing the primary features of the river edge condition—specifically, whether the channel is in a natural state or is engineered to convey flows. Interactive embankment principles will be proposed for a real site in Detroit, Michigan. Embankment design principles, along with design prototypes, will serve both as evaluation criteria and design guidelines for interactive embankments.

The proposed prototypes, as visualized forms, can serve as design tools for future interactive embankments.

The research questions are:
• What is the best way to construct an interactive embankment? Which design approach achieves the desired outcomes of human activity and habitat preservation?
• What is the best way to evaluate an interactive embankment? Which specific criteria provides the optimal results?

Applying of the prototypes to a real site is essential for evaluating the outcome of this thesis. I selected a site along the Detroit River at downtown Hart Plaza, considering the following aspects:

1. The Detroit river is engineered at the section along this site, but the designer should identify whether or not the hard embankment is a necessity: this leads to a choice among several possible embankment prototypes.
2. The site is situated at a typical urban riverfront environment in downtown Detroit, Human access and activities are essential parts of that interactive embankment.
3. There is sufficient land on the city side to develop the edge, because where larger areas of flexible human-use such as plazas can be created and the design is not limited to such uses as sidewalks and promenades.

This thesis will reveal some of the challenges and demands that designers are likely to confront when applying riverbank strategies. These demands include understanding existing urban river edge conditions, identifying the hydrology of certain watersheds, and choosing the proper strategies and prototypes for application.
Chapter 2: Literature Review

2.1 River typology

According to Booth and Bledsoe (2009), there are two distinctive types of river channels. One is the alluvial channel and the other is non-alluvial channel. Alluvial channels develop due to the buildup of sedimentation over a long period of time (Booth and Bledsoe 2009). Such channels are constantly transformed by water flow transportation and sedimentation. Booth (2009) states that alluvial channels are often bordered by floodplains. Floodplain is a geomorphic term, which means that the land that was formed by deposition or sedimentation over the course of hundreds of years. Floodplains are not occupied by water as often as are river channels. However, when water goes above the “bank full stage” of the channel, the floodplain’s inundation makes itself part of the river channel.

In alluvial channels, floods are the primary disturbance that heavily influences the interface between land and water (Booth and Bledsoe 2009). The floodplain includes riparian zones that feature abundant ecotones, which provide rich biodiversity and function as buffers. It has been noted that the floodplain forests can promote the filtration of nitrates carried by groundwater through bioprocesses (Peterjohn et al. 1984). This can make floodplains significant in urban areas where the groundwater flow is often polluted.

The non-alluvial channel is characterized by immobile edges. The banks of the channel can be fixed by boulders or deeply rooted vegetation. In urban areas the typical
non-alluvial channel is a concrete-armored wall of embankments (Booth and Bledsoe 2009, 95).

In comparison with vegetated riverbanks, using man-made concrete lining or stone walls in urban environments reduces disturbances caused by floods and flows, which are important for maintaining a variety of riparian species (Junk, et al. 1989). Despite this, researchers found that abundant man-made structures in some urban areas can help support ecological communities. This *urban cliff hypothesis* (Larson, et al. 2000) suggests that some types of urban river structures are similar to vertical and horizontal rock surfaces and can support species (in particular plant species) adaption in resource-poor habitats.

Research on man-made river habitats points out that river walls have skeletal structures and can potentially serve as habitats because 1) the surface material is prone to being fractured by flows, 2) walls are inclined and situated at low positions in urban environment, 3) close contact with water can bring in organic nutrients, and 4) there is a humid microclimate (Francis et al. 2009).

Both alluvial and non-alluvial river edges are capable of supporting ecological communities associated with water flow and fluctuations. The urban modifications of river channels make the edges impermeable and rigid, so we cannot ignore the opportunity to promote riverbank diversity and enhance the ecological habitats and opportunities for recreation.
2.2 Embankment typologies

Embankments are defined as “artificial bank[s] raised above the immediately surrounding land to re-direct or prevent flooding by a river, lake or sea” (Petroski, 2006). Contemporary literature (Saraiva et al. 2013) classifies embankment types according to whether or not they are natural valleys/floodplain or armored with constructed floodwalls or levees. Identified types of valley include: 1) Steeply-sloping V-shaped valley, 2) U-shaped valley (glaciated), 3) Vertically walled canyon, 4) Steep-sloped wall with a floodplain (asymmetric), 5) Large, broad floodplain, 6) Terraced floodplain, 7) Broad, braided, semi-arid river channel.

Figure 2.1 Types of valley morphology. Source: Urban River Basin Enhancement Methods. Classification of aesthetic value of the deleted urban rivers. (Saraiva, et al. 2004)
Riverbanks armored with walls are a common type in urban river environment, and define the boundaries of the river and the land. The following diagrams show major types of embankment walls: 1) ①Culverted watercourse, 2) ②③④Vertical banks (walls), 3) ⑤⑥ Trapezoidal watercourse, and 4) ⑦ Asymmetric banks (wall and levee).

Figure 2.2 River embankment typology. (Saraiva, et al. 2004)

In urban areas, banks with valley/floodplain condition are usually rare because the ground adjacent to the river is usually used for massive construction, and may be
designated for storm water basins or parks. When the design of embankment walls takes into consideration only the highest water levels, aiming at a flood protection approach, consequent safety concerns can preclude public access to the water. This approach also ignores the subtle fluctuations that occur between high water marks and the natural rhythms of the river.

2.3 “Connectivity” in urban rivers

Design and research concerning urban rivers often includes the term “connectivity.” However, its meaning may differ or even conflict among different disciplines, for instance, ecology and urban planning (May 2006). May (2006) states that most contemporary urban design approaches seek to enhance human connections with those riverfronts that are controlled by constructed riverfront structures, and which do not favor any biophysical connections. These design approaches rely on remote or detached treatments, such as bridges to cross the river, shoring walls to prevent flood, and landscaping for recreation.

May suggests the win-win situation in both ecological and urban planning where connectivity involves “cognitive connectivity.” This connotation is derived from the idea that human beings are a part of the ecosystem. Urban rivers differ from natural rivers because they are connected to human activities. Restoring the connectivity between human and natural hydrological processes can be a major step towards the development
of healthy urban riverfront environments.

Applying “cognitive connectivity” involves educational efforts, which can include pedagogical materials such as riverfront museums, or “eco-revelatory” designs on a smaller scale that allows people to see and understand ecological processes (May 2006). Spaid (2002) states that “Eco-revelatory” designs by environmental artists point the way towards redesigning urban infrastructures of built environments in order to remind users of their role in everyday ecological processes. Applications of this notion to riverbanks can involve redesigning riverbanks to accommodate water level fluctuations. Given better designs, a better understanding of ecological processes driven by discharge changes can be taught to urban dwellers. With better understanding of urban riparian environments, human behavior can be changed to be more beneficial for river ecosystems.

2.4 History of urban riverfronts and embankment

Thousands of years ago, people became aware of the importance of rivers for survival purposes, and human settlements were often established on riverfronts. During that period in history, there were no interventions on riverbanks, which remained untouched and essentially “natural” space (Wang 2001). As human history progressed, agricultural practices grew highly reliant on rivers. Floodplain soils are fertile and easy to irrigate compared with inland areas. Riverfront mills and irrigation systems on the bank began to emerge. The river embankments of this era were tied to agricultural production.
Flood protection infrastructure came into being to prevent crops from being washed away by overflowing rivers. Stones and stakes were the first techniques used to stabilize riverbanks (Wang 2001).

After the Industrial Revolution, water-based shipping became the most common method of moving goods and materials. By the late nineteenth century, many major rivers had been channelized to meet shipping demand. Industries developed along the river, and ports and massive warehouses were established. During this era, riverfront spaces were used primarily for industrial purposes (Yu 2004).

Riverfront spaces, redesigned to support industrial and transportation usage, used engineered embankments that offered little human access and were maintained for the purpose of purely functional utility. Floodwalls were straight-cut reinforced landforms that led down into the water in order to accommodate transportation activities. This simultaneously precluded recreational use of the river, and also damaged the rivers’ ecosystems.

In the twentieth century, the industrial shipping paradigm changed to include trains and jets, and riverfronts decentralized. The question of how to revitalize abandoned ports and harbors has become a challenge for many post-industrial cities. The simultaneous shift from a manufacturing-oriented economy to an information- and services-oriented economy promoted the emergence of new riverfront spaces intended for
recreation and entertainment purposes including parks, promenades, restaurants, and other commercial and residential spaces (Yu 2004).

This trend continued into the twenty-first century, when extensive programs of open spaces, including landmarks and large parks, came to the riverfront. For example, London has a fabulous skyline along the River Thames. Multi-functional spaces attempt to eliminate the consequences of industrialization, invite the close relationship between people and rivers, and promote the revival of urban riverfronts. The features found along the Seine River banks used to moor boats and unload cargoes, are now modified to providing pedestrian walkways on the lower embankment (Stephen 2010). For example, the narrowed channel formerly used to prevent boats from stopping there now is shaded by the cantilevered street sidewalk (Figure 2.3); and, in some places, the floodwall of the lower walkways has been replaced by a ramp that extends into the water (Figure 2.4) (Stephen 2010).

Figure 2.3 The channel is too narrow for boats to anchor. The street sidewalk is built above the lower walk using a cantilevered structure. Source: Photo by Stephen Murk
Figure 2.4 The wall that extended into the river has been replaced by ramps. Source: Photo by Stephen Murk

Given this trend, it is not difficult to speculate that the urban landscape design of riverfronts will incorporate more creative forms and uses. An architect Kais Al-Rawi proposed a project named "Urban Fluctuation" along Thames River (Figure 2.5). It developed a geo-morphology that manages water levels fluctuations and creates inhabitable edge conditions. Various programs associated with water level fluctuations and river systems could be developed on river edges like these.

Figure 2.5 Urban fluctuation. Kais Al-Rawi. Source: http://archinect.com/rawi/project/urban-fluctuation

Inspired by such urban riverbank innovations, my thesis explores edge construction that might enable a changing landscape by engaging water fluctuation and flow. This
thesis focuses on urban rivers; however, human access and natural habitats are also of primary concern.
Chapter 3: Precedent Study

As established in chapter 2, rivers can be classified into two distinctive types, alluvial river and non-alluvial river. In the urban environment, the embankments associated with these two river types can be seen as engineered embankment (the edge is armored with levees or walls to direct flow and protect flooding) and floodplain embankment (area adjacent to river will be flooded by high river discharge).

Within each of these categories, precedent studies are examined in order to analyze the strategies and principles behind interactive embankments. Precedent studies were selected to illustrate a variety of effects that fluctuating water levels can create for various edge conditions and ecological habitat.

Examples of engineered embankments include 1) ChonGae Canal Restoration project, Seoul, Korea; 2) The Allegheny Riverfront Park, Pittsburgh, Pennsylvania; 3) Mussel Beach, Pier 35 East River Waterfront, New York, New York. They can be classified into 2 types of interactive embankment based on how fluctuating water level (raised river discharge) are integrated into the embankment design (Table 3.1).
### Precedent Studies of Engineered Channel

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Projects</th>
<th>Design Priority</th>
</tr>
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</table>
| Type 1: Fluctuating water levels affects the public use of floodwall’s lower access | ChonGae Canal Restoration project, Soul, Korea | ① Political Symbol  
② Recreation |
| | Allegheny Pittsburgh Riverfront Park, Pittsburgh, PA | ① Recreation  
② Natural Art |
| Type 2: Fluctuating water levels sustains the ecological habitat | Mussel Beach, Pier 35 East River Waterfront, New York, NY | Ecological Habitat |

Table 3.1 Precedent studies of engineered channel

Because floodplain embankments are often larger than the narrow linear strips along engineered embankments, they often designated as urban parks. Floodplain embankments (floodplain parks) can therefore meet the demand for public open spaces as well as the need to withstand occasional floods. Floodplain landscapes are naturally subject to changes with water level fluctuations.

Regarding floodplain embankments (floodplain parks), three additional case studies were selected to illustrate different ways of dealing with floodwater (Table 3.2). The first type is to make the park withstand floods during the recurring flood event. The second type is to mitigate the flood by landform building. Examples include: 1) Louisville Waterfront park, Louisville, Kentucky; 2) Hugo Burkner Park, Dresden, Germany; 3) Qijiang park, Zhongshan, China.


<table>
<thead>
<tr>
<th>Type 3</th>
<th>Criteria</th>
<th>Projects</th>
<th>Design priority</th>
</tr>
</thead>
</table>
|        | Constructing the park to withstand flooding | Louisville Waterfront Park, Louisville, KY | ① Recreation  
 ② Flood protection |
|        |         | Hugo bunker park, Dresden, Germany | ① Flood detention  
 ② Recreation |

| Type 4 | Mitigate the flood by landform building | Qijiang park, Zhongshan, China | ① Recreation  
 ② Education |

Table 3.2 Precedent studies of floodplain embankment/parks

ChonGae Canal Restoration, Seoul, Korea

ChonGae Canal Restoration, Seoul, Korea, designed by Mikyong Kim, can be considered as a good example of interactive embankment design as it manages the canal’s lower spaces, which beautifully accommodates the water fluctuation. The ChonGae Canal was once a natural stream that flowed through the center of the city of Seoul. It became a dumping ground for industrial waste in the 1930s. In 1960s, a highway was built on the top of the ChonGae Canal, which further obscured its existence until 2003, when the city began a campaign to remove the highway and restore the river (Mikyoung Kim Design 2011). The goal of this project was to create a vibrant public space and attract people to this historic waterway. It was also a political metaphor for the future reunification of North Korea and South Korea. This symbolic metaphor was achieved through the use of stones quarried from eight provinces, which pointed to the source of the waterway (Mikyoung Kim Design 2011). These special sloped
stepping-stones were placed incrementally, which allowed people to trace the daily and seasonal changes in water levels, which encouraged direct public engagement with the river (Figure 3.1) (Mikyoung Kim Design 2011 n.d.).

Figure 3.1 Plan of Chon ChoneGae Canal showing the scenario when water level fluctuates. Source: http://www.archdaily.com/?p=174242

In addition, the water was filtered for public health reasons before entering the waterway. It soon became a downtown gathering place for city dwellers and has been the site of festivals and events (Figure 3.2) (Mikyoung Kim Design 2011 n.d.).
This project provides a hardscape approach of interactive embankment design. The incremental elevations of the stepping-stones visualize the changes in water levels. It doesn’t involve any plant material, so the maintenance cost due to the water flushing can be significantly reduced.

Allegheny riverfront park, Pittsburgh, Pennsylvania

Allegheny Riverfront Park, Pittsburgh, Pennsylvania, This park was designed by Micheal Van Valkenburgh Associates, and is another example of designing interactive embankments on the lower parts of river canals. The approaches here involve a 16-foot wide pedestrian walk extended from the floodwall. It sits just above the water, and provides direct access to the river. The strip of soil on the side of the walkway was
planted with trees and vines, which involved “heavily landscaping” the formerly bare wall (Micheal Van Valkenburgh Associates 2005). (Figure 3.3)

![Figure 3.3 Section cut of the lower walkway on Allegheny River. Source: Michael Van Valkenburgh and Associates. http://www.mvvainc.com/project.php?id=5&c=parks](image)

Floodwater raises the Allegheny River 5 to 10 feet every spring, so the safety and maintenance of the lower walk needs to be secured. The plants were selected from among regional species that are resilient to floodwater, and can regenerate after floods. Boulders were placed on the soil to prevent erosion (Micheal Van Valkenburgh Associates 2005). Another innovative design feature of the lower walkway is the concrete walkway, which is imprinted with a reed pattern casting (Mercil 2003, 2) (Figure 3.4). Together with its human scale and dimension, the pattern of marks informs people about the nature of the river and the effect of the water level fluctuates.
This project is a good example of how to construct a recreational riverfront in a densely populated urban area where the floodwalls are too high to allow people down to the river, and where there is limited land available to develop a pleasant riverfront space for pedestrians. This project also provides a planting strategy and environmental art strategy for interactive embankment.

*Mussel Beach, Pier 35 East River Waterfront, New York, New York*

Mussel Beach was designed by the Ken Smith Workshop, and is part of Pier 35 East River Waterfront in New York City. The purpose of this project is to provide a habitat for existing mussel communities in Manhattan’s East River.
An eighteenth-century European map of Manhattan’s riverfront inspired Mussel
Beach. A rocky shoreline was re-constructed by installing huge concrete blocks on a
gentle slope, which allows the water to flush through between high tide and low tide
(Hooper 2013). These concrete blocks were assembled using a folded form to maximize
the available intertidal surface. The tidal range in the East River is 6 feet. However,
extremes may appear according to the state of the moon. The crevice among the rocks,
ranges from 1 to 1-1/2 inches wide and about 3/4 inches in depth, together with the
slope’s surface pattern, serves as perfect mussel habitat (Hooper 2013). (Figure 3.5) A
pedestrian bridge will be provided in the future above the mussel beach to serve as an
observation point for city dwellers.

Figure 3.5 Mussel Beach. Source: http://archpaper.com/news/articles.asp?id=6870

This artificial habitat imitates conditions at the natural river edge, where
fluctuating water levels act as a key factor in sustaining the ecological habitat. Such an
embankment type can play a significant role in preserving the natural heritage of urban rivers.

*Louisville Waterfront Park, Louisville, Kentucky*

The Louisville Waterfront Park, in Louisville, Kentucky, was designed by Hargreaves Associates. The land was reclaimed from a former industrial wasteland and covers 120 acres between the 100-year-flood wall and the river (Figure 3.6).

![Louisville Waterfront Park](http://www.hargreaves.com/projects/PublicParks/LWDOverall/)

The park is a successful riverfront park in terms of design and programming, and is a good example of how floodplain embankments can deal with floods. The park was built above the 100-year flood line. It has experienced several floods since being established, including two 100-year floods (Harris 2002). The approaches used in this
park involve large-scale landforms and smaller scale construction methods. The former include, 1) the angular land edge which is sited pointing downstream in order to minimize erosion by water flow; 2), the great lawn, which has a gentle constant slope (3-1/2 percent), and encourages flood drainage (Harris 2002). The landform design of the Louisville waterfront park embraces flooding, and promotes human awareness of this natural event.

The flood-proof construction method includes several techniques. First, the topsoil of lawns is mixed with shredded material and grass roots, and reinforced with coconut fiber matting to prevent flood erosion. Bank stabilization techniques include gabions planted with riparian species and geo-grid fabric. Pavement is designed to have good drainage ability and durability (Harris 2002).

Reducing flood damage requires floodplain parks to be prepared to withstand extreme flooding and long-term inundation. Cleaning silt and debris that remains after floods recede must also be considered.

_Hugo Burkner Park, Dresden, Germany_

The Hugo Burkner Park, located at Dresden, in Germany, combines the function of both urban recreation and floodwater detention basin around the Kaitzbach stream. The Kaitzbach stream flows through the center of the City of Dresden. The normal flow rate in the Kaitzbach is 35 liters per second. In 2002 the greatest flooding reached 2000...
liters per second, and caused catastrophic damage to the city (Reuris 2011). The establishment of this park is based on the city’s demand for flood protection. Budget limitations and potential maintenance costs for repeated flooding made it impossible to install normal park facilities (Reuris 2011, 16). The artist Joachim Manz designed the unique park island--a triangular wooden deck. (Figure 3.7) These decks will float like rafts when the water rises up during heavy storms. Each island is furnished with benches and trashcans, and solar-power storm lamp making the island free of cables. The ladder on the edge of the island serves to reminds people of the recurring floods (Hölzer 306-307).

Figure 3.7 Floating deck in Hugo Burkner Park. Source: Riverscapes: designing urban embankments, 2008.

Compared with the Louisville waterfront park, the Hugo Burkners Park serves as a model of a smaller scale, in terms of the river flowing through it, as well as its location
in the city. However, it offers an innovative approach to floodplain embankment design: mobile or scattered public access. During flooding, it is impossible for people to approach the river. The key of designing in a floodplain park involves making people aware of the river’s natural process and the risk of flooding.

**Qijiang Park, Zhongshan, China**

The Qijiang Park, designed by TurenScape, is located at the city of ZhongShan, along the Qijiang river in China. This park was established in 2002. The parkland was reclaimed from a shipyard, which was built in 1950. The design of the park seeks to preserve the industrial heritage and provide an urban ecological park destination (TurenScape 2002 n.d.).

The City Water Management Bureau expanded the river width from 60 meter to 80 meter for flood control purpose. In order to preserve the old trees along the riverbank, a parallel ditch was excavated and connected to the river in order to mitigate the floodwater (TurenScape 2002 n.d.).

The Qijiang River flows into the sea, so it is subject to tidal action. The daily water level fluctuates up to 1.1 meters and the river edge is filled with muddy silt (3.5 feet). The theme of the park is to create an ecological park that reflects the cultural and industrial heritage of the shipyard (TurenScape 2002 n.d.). The solution is a terraced landform created by building 3 to 4 stages of walls, enclosing planting beds to grow
native plants from the salt marsh. Crossed pedestrian bridges of various elevations offer observation points that are close to the wetland plants (Yu et al. 2002). When the water rises up, walking on the bridges simulates walking on the water surrounded by thick riparian woods (Figure 3.8). The plants species will be chosen according to the depth of water, and will form a healthy and ecological sustainable riparian community. It may also provide wildlife habitats in the future (Yu et al. 2002).

![Figure 3.8 Terraced planting bed in Qijiang Park. Turen Landscape. Source: http://www.turenscape.com/project/project.php?id=71](http://www.turenscape.com/project/project.php?id=71)

This project offers a good model of interactive embankment for two reasons. The first reason involves dealing with flooding by excavation. By digging a parallel ditch along the river, the floodwater can be stored, therefore mitigate the flood impact; the second reason involves dealing with daily water fluctuation by building a terraced landform on the edge.
Summary

This table (Table 3.3) summarizes the four types of interactive embankments and their design principles.

<table>
<thead>
<tr>
<th>Types Of Engineered Channels</th>
<th>Design Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td></td>
</tr>
<tr>
<td>Fluctuating water levels</td>
<td>• The lower level access needs to be situated between the highest and lowest water levels, close to the normal water surface.</td>
</tr>
<tr>
<td>affect the public access</td>
<td>• The lower level can be integrated with artistic forms that embody the design theme.</td>
</tr>
<tr>
<td>of the levee floodwall’s</td>
<td>• The lower access has to be safe even when closed during floods for public safety.</td>
</tr>
<tr>
<td>lower access</td>
<td>• Plants, if involved, must be resilient to floods.</td>
</tr>
<tr>
<td></td>
<td>• Potential damage by the debris in water has to be considered.</td>
</tr>
</tbody>
</table>

Table 3.3 Summary of design principles. All diagrams made by author.
| Type 2          | Fluctuating water levels sustain the ecological habitat | - Embankment structure mimics the natural habitat between the intertidal zones (such as beaches)  
|                |                                                       | - Separate people away from the habitats while still encourage observation from a distance. |
| Floodplain embankment/parks |
| Type 3  | Constructing the park to withstand flooding  | - Land should accommodate high water, facilitate flood drainage and convey the water flow.  
|          |                                                       | - Apply construction methods to withstand flooding, such as bank stabilization, soil reinforcement and pavement selection.  
|          |                                                       | - Economical management method--islands or bridges fully serve recreation functions. |

Table 3.3 (cont.) Summary of design principles. All diagrams made by author.
| Type 4 | Mitigate flooding by landform building | • Riparian garden: terraced landform of planting bed accommodates changes in water level.  
• Riparian plant communities are selected based on their adaptation to water depth. |

![Diagram showing high and low water levels with different plant beds](image_url)

Table 3.3 (cont.) Summary of design principles. All diagrams made by author.
Chapter 4: Design Prototypes

Design requires creativity. Design prototypes help inform the process and help designers develop their ideas. Regarding interactive embankment design, engineering questions and knowledge of morphology and hydraulics can challenge designers. Therefore, design prototypes can serve as tools, which can aid designers as a starting point for finding solutions.

Prototype can be defined as a “concrete representation” (Beaudouin-Lafon and Mackay 2002, 1) of part of an entire interactive system, rather than an abstract explanation. Prototypes can be used to envision the final system: “prototype are important components of the design process, successful prototypes encourage creativity, help the developer to capture and generate ideas, and facilitate the exploration of a design space” (Beaudouin-Lafon and Mackay 2002, 1).

In this chapter, I designed prototypes of interactive embankments. They are categorized into 4 types. The type 1 and 2 are designed for engineered edges, and type 3 and 4 are designed for floodplain edges. These prototypes are not exclusive, but do provide possible starting points, from which designers can choose.

Type 1

The first interactive embankment uses lower access of the floodwater to accommodate water level fluctuations. There are two design prototypes.
One design prototype (Figure 4.1) of the first interactive embankment type features a print pattern carved on the lower ground. When the water rises, the water will fill up the voids, or sinks. Since the prints are quite shallow, water stored inside the sink will soon evaporate. Artist or could create the prints, such as symbols of any local special features carved on the lower ground.

Fluctuations allow the prints to be viewed from up above on the floodwall, and can be used to impress pedestrians with the movements of the river. At low water, people could walk besides the prints, touch the water and wet their feet. This type of embankment will adapt only to minor water fluctuations (1-2 feet).

Another interactive embankment prototype that involves lower walkways (Figure 4.2) is similar to the Allegheny riverfront walks, except that the walkways are
not cantilevered, and are instead made from two types of bending beams, which provide support for the pedestrian walk. These beams are placed in alternating sequence, therefore can enclose many small spaces for growing riparian plants. According to urban cliff hypothesis, these kinds of interstitial spaces have the potential to become riparian habitats similar to those of half-submerged rocks. This prototype can adapt to a large range of water level fluctuations (0-15 feet), similar to the Allegheny riverfront, and the walkway must be closed during the flood seasons for safety reasons.

Figure 4.2 design prototype bending beams

**Type 2**

The second type of interactive embankment requires extensions from floodwalls. It may resemble natural riparian habitats, such as beach, rocks, pebbles, etc. It also demands a proper method of observation by humans that will not harm the habitat's
integrity. This embankment prototype was developed based on the observer's viewpoint.

One prototype (Figure 4.3) features a plane that slopes down into the water and has a sidewalk next to the floodwall. The ecological habitat will be constructed under the plane, between the high and low water levels. There are openings on the plane, which allow riparian plants to grow upward and outwards. It also allows people to walk through the riparian woods without harming the root zone of their habitat. The size of these openings and their intervals can vary depending upon which particular species are growing beneath the plane. When the habitat is constructed for use by smaller plants, transparent screens instead of openings are better for observation purposes. This prototype can adapt to fluctuation less than 1-2 feet.

Figure 4.3 Design prototype habitats 1
Another design prototype (Figure 4.4) involves a flexi-glass screen or shelter for enclosing people in a tunnel where they can see the water levels rise and recede. The screen's surface can be modified to incorporate a riparian habitat matrix that lies on top of the screen. This kind of embankment allows for the direct observation of river fluctuations and riparian species. It can be applied to a river that has abundant varieties of riparian species. It can adapt to all levels of fluctuations.

Figure 4.4 Design prototype habitats 2

Type 3

The third type of interactive embankment involves constructing river floodplain parks that can withstand flooding.

One principle involves building landforms to accommodate and store excess water and facilitate flood drainage, and flow conveyance, basically by means of slight
slopes and smooth edges (Figure 4.5). This is the most common type of contemporary urban riverfront. Edge area is re-sloped and modified as a piece of water management infrastructure. Sometimes the excessive flood/storm water would be stored on land in detention basins near riverfront wetland habitat, and later recharged back to the river by groundwater flow. This design can adapt to all levels of fluctuations.

Figure 4.5 Design prototype: slight slope

One economical method involves making islands or bridges in the flood basin. This prototype (Figure 4.6) uses connected decks or platforms to provide public access by reaching the nearest point of the river. When the river floods, people can stand on the bridges, and feel as if a lake surrounds them. The wilderness of the natural river edges can be preserved with minimal human intervention. This interactive embankment prototype can adapt to various water level changes.
The last prototype of interactive embankment features terraced landforms that mitigate the floods. The design prototype (Figure 4.7) modifies the edge into a terraces. It combines habitats from various elevations. The plant communities are selected based on their abilities to adapt to the water depth. Like a water garden that stretches some distance into the river, these visually appealing features can attract people to the waterfront. This prototype will adapt to medium scale changes (3-10 feet) in water levels.
Figure 4.7 Design prototype topographical terraces
Chapter 5: Interactive embankment: Proposal for Hart Plaza

The design of the Detroit riverfront at Hart Plaza aims to demonstrate the application of these prototypes for in real site practice. More specifically, the design approach for interactive embankment involves site analysis (primarily focused on the river’s condition), determining the design priority (what type of program and interactive embankment should be applied to the site), the finally selection of the prototype and the transformation of the prototype for adaptation to the site. In response to the thesis question, this approach illustrates the best way to construct an interactive embankment.

5.1 Site introduction

The Detroit River (Figure 5.1) flows from Lake Erie to Lake St Chair. The site is located at riverfront Hart Plaza at downtown Detroit.

Figure 5.1 Site location. Source: Google earth 2012
Hart Plaza (Figure 5.2), covers 14 acres, is an open public park located at the center of the Detroit riverfront. Hart Plaza is surrounded by many landmarks of the city, including Renaissance Center—where General Motor’s headquarters locates, Port Authority—where there is the entry to the tunnel to Canada, and Cobo Hall—a convention center.

Figure 5.2 Hart Plaza. Source: Google earth 2012

5.2 Site analysis

Hart Plaza

Hart Plaza was designed as the city’s town square, and is supposed to be the most utilized park in the city. There used to be many great hotspots, such as the Dodge Fountain and the Gateway to Freedom International Memorial. This site has been host
many festivals since 1970, including Electronic Music Festival, Fireworks, Jazz Festivals, as well as ethnic events celebrating the city’s diversity. The frequency of these events has declined in recent decades and now faces emptiness and isolation. The city’s center moved to the inner city, the location of annual Christmas tree, the ice rink and the concert hall (Detroit riverfront Competition 2012). The reasons are partially the decrease in general population, as well as the lack of riverfront attractions. People love the riverfront since it is associated with shared memories and significant landmarks. Re-vitalizing this unique site by emphasizing its relationship with the Detroit River may change the destiny of the city of Detroit, since this river is very important in the city’s history. Even the name of the city originated from the river Detroit.

_Detroit River_

The Detroit River runs from Lake Erie to Lake St. Clair, and is about 32 miles long. The river ranges from one-third to four miles wide. Boulders cover most of the river’s bottom. The city has grown steadily since 1830 as shipping, ship building, and manufacturing increased (U.S. Fish and Wildlife Service 2006).

It is recorded that the Detroit River in the 18th century was dominated by costal wetlands. In 1815, the shoreline was occupied with costal wetlands up to 1 mile wide along both sides (Figure 5.3). Vegetation types included submerged marsh, emergent marsh, wet meadow and shrub swamp, swamp forest and lake plain prairie. (Manny 1988)
Figure 5.3 An 1815 map of the Detroit River showing coastal wetlands up to a mile wide along both sides of the river for most of its length, prior to shoreline development. Source: http://www.epa.gov/med/grosseile_site/indicators/wetlands.html

The completion of the Detroit-Chicago railroad in 1851 stimulated agricultural development and commercial activities in Detroit. Farmers and small merchants had colonized both shorelines of the Detroit River by 1870. The riverfront wetlands were cleared for pastures and crops initially used to help settlers survive. After 1910, industrial development along the Detroit River area accelerated (Manny 1988).

Today, 87% of the shoreline on the U.S. side has been armored with revetment or hardened for shipping purposes. The result has been that the historical wetlands have
disappeared. This large-scale channelization has greatly altered the shape of the channel and flow activities (US Fish and Wildlife Service 2006 n.d.).

The trendy of protecting and restoring riverfront habitat has taken place many years ago. The coastal wetland is beneficial in flood control, protection from erosion, removal of nutrient and sediment, and provide wildlife habitat. One piece of wetland in the downtown riverfront space may educate public about the river’s nature and beauty.

Normal flow in Detroit River occurs when there is no wind. Strong winds are mostly encountered during fall and early spring, when the wind mainly blows from the southwest and west. During the winter, the upper part of the Detroit River is mostly ice-free, while the lower part is shallow and subject to annual freezing (Blank 2003). This feature requires the design of an embankment that withstands extreme temperatures and ice flows.

Statistics of the monthly average gauge height (January, April, July and October) from 2010 to 2012 was gathered at the station at Fort Wayne at Detroit river shows that gauge height (Figure 5.4) varies within one foot most of the time, and the water level recedes about two feet in the fall.
Each year there is a seasonal fluctuation that involves a two-foot difference in the water level. However, the wind can raise or lower the water level as much as six to eight feet. The change in the atmospheric pressure can also produce a one-foot fluctuation in the water level.

*Detroit river walk*

The Detroit River Walk (Figure 5.5) is an urban renewal project that seeks to help revitalize the decline of the industrial city’s waterfront. This river walk stretches five and half miles along the river. This pathway between Hart Plaza and Detroit River, serving as the main access to the water, still holds people up above the floodwall. With boardwalk and rail, it lacks dynamic water features. This thesis questions whether this is the best possible way to attract people to the water.
This existing engineered bank poses a challenge to the design because it is not a necessity since there are no flood hazards. Therefore whether floodwall should be preserved or demolished is the first decision to make.

5.3 Design goal

Re-vitalizing the site demands waterfront attractions. Interactive embankment serves this goal. It states the close relationship between land and water, and will benefit the city in the long run. The design aims to 1) restore the coastal wetland to provide habitats for riparian species and educates the public, 2) reinvent the plaza to incorporate waterscape associate with the Detroit River fluctuation, 3) unique urban riverfront space allowing more direct observation and providing comprehensive information.

5.4 Prototypes and Master plan

The Detroit River is an engineered channel, but is wide and stable, which makes it different than a narrow city channel that absorbs huge storm water flows. I therefore
propose demolishing the floodwall along the section of site. Because it is not a necessity, given that the river is in stable condition and will not destructively flood.

The fluctuation is subtle: 1-2 feet of change in water level occurs during most of the year. How to make this minor change visible is a challenge. The prototype applied basically is to re-grade the slope to exaggerate the vertical changes in a horizontal manner to visualize the subtle change.

The master plan (Figure 5.6) contains four parts: the River plaza, Viewing box, Wetland marsh, on the shore and a big lawn inland, all interacts with the river’s flow and fluctuation, as well as a big lawn in the back for conventional park uses.
Figure 5.6 Master Plan. Illustrated by author

**River plaza**

The prototype applied in the River Plaza is a pattern or prints carved in the ground. This prototype is expanded to a larger scale to create a topographical variation. One squared slab is big enough to hold 5 to 10 people a time. Combining with the gentle slope,
it will let the water into the sinks when the water rises in the river (Figure 5.7). Under the low water level, it may acts as a sunken public plaza or a gathering place for holding events (Figure 5.8). Some of the slabs are modified into tree planters to provide more canopies, therefore making the plaza suitable for short stays on sunny days. A creative use is to make each slab have different prints on the surface. By making the more detailed, identifiable pattern on each slab, the interaction may even happen at a smaller scale.

Figure 5.7 River plaza under high water level. Illustrated by author

Figure 5.8 River plaza under high water level. Illustrated by author
**Viewing box**

The viewing box drives the observer vision to the underwater scene (Figure 5.9). During the low water level (Figure 5.10) it will became a sightseeing spot for visitors. This walkway starts at the center of the plaza and goes down to the farthest point of the river. The design prototype involves an enclosed space by transparent screen that allows the insider to view underwater scenes. In this particular case, the prototype is transformed into a flat footbridges extending to the edge of the river with glass screens on every face of the box. Thus the water level changes can be viewed and traced. This prototype originally tries to educates the public of the river by attaching a layer of riparian habitat matrix, however, in an engineered urban channel, the living habitat may rarely occur in the former port condition. It is more possible to make the glass walls more informative by making the transparent walls like a museum. Information board or mark the screen will let the visitor know about the river.

Figure 5.9 Viewing box under high water level. Illustrated by author
Coastal wetland

The prototype applied here is a terrace landform. Since it has been recorded that there were wide strips of wetland marshes along the riverside. This coastal wetland area will imitate this condition and restore the habitat. Two levels of boardwalks with wetland plants form the terraces. Because the river fluctuation is only 1-2 feet, therefore the upper level is one foot higher than the lower level. When the water rises at the high level, both levels will be filled with water. People will walk through the wetland marshes on the upper boardwalk (Figure 5.11). While, during the dry seasons, or at the low water level, only the lower terrace would contain water and the boardwalk on both levels are can be used (Figure 5.12).
Figure 5.11 Coastal wetland in high water level. Illustrated by author

Figure 5.12 Coastal wetland in low water level. Illustrated by author
Chapter 6: Conclusion

The outcome of this thesis was the development of prototypes and corresponding applications for an interactive embankment for Hart Plaza Detroit. Interactive embankments reveal the changes in water levels, which are a significant part of the river landscape because it reflects the local hydrology. In comparison, instead of using floodwalls, interactive embankments dissolve the boundary between land and water and thus allow for the exchange of materials and energy. An interactive embankment also attracts people to the waterfront and enhances public awareness of the river.

The outcome of this research can be applied to any urban riverfront, be it a park, a highway or a residence. Prototypes can be further developed on various scales depending upon the site’s condition. This thesis can benefit those who are interested in riverfront landscape design and designers who seek to revitalize riverfronts for public use. The application of this strategy to the Detroit riverfront provides an example that illustrates how to develop design strategies and prototypes, which can be replicated at other potential sites.
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