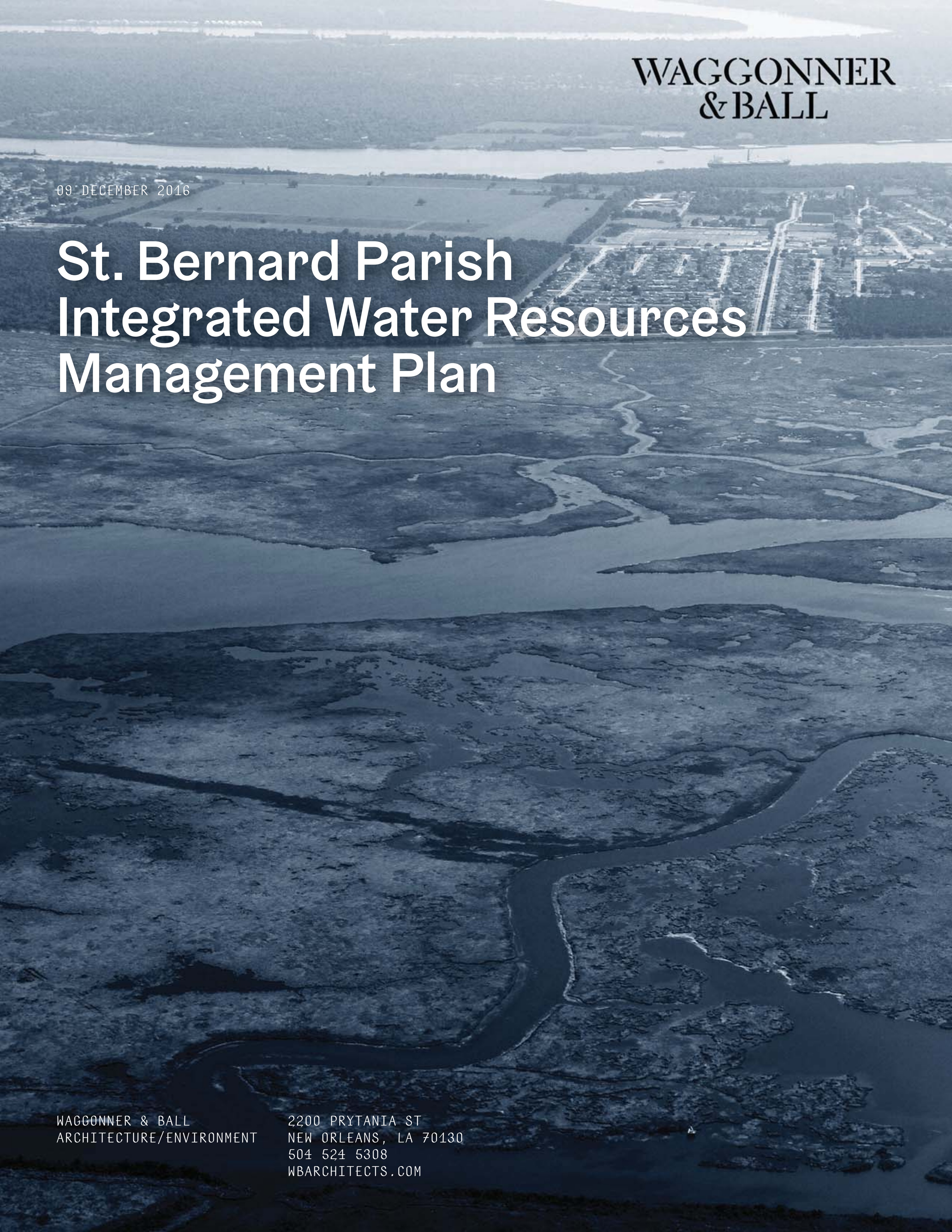

WAGGONNER & BALL

09 DECEMBER 2016

St. Bernard Parish Integrated Water Resources Management Plan

WAGGONNER & BALL
ARCHITECTURE/ENVIRONMENT

2200 PRYTANIA ST
NEW ORLEANS, LA 70130
504 524 5308
WBARCHITECTS.COM

Cover: view from the air looking across St. Bernard Parish towards the Mississippi River, with the Central Wetlands Unit in the foreground
Image courtesy of Jonathan Henderson, Vanishing Earth Advocacy + Consulting + Photography

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Aerial view looking across the Mississippi River as it meanders down to the Gulf of Mexico, with Chalmette in the foreground

Image courtesy of Jonathan Henderson, Vanishing Earth Advocacy + Consulting + Photography


ST BERNARD PORT

Aerial view looking northeast towards the Central Wetlands Unit with Paris Road at left and the 40 Arpent Canal at right in the foreground.
Image courtesy of Jonathan Henderson, , Vanishing Earth Advocacy + Consulting + Photography

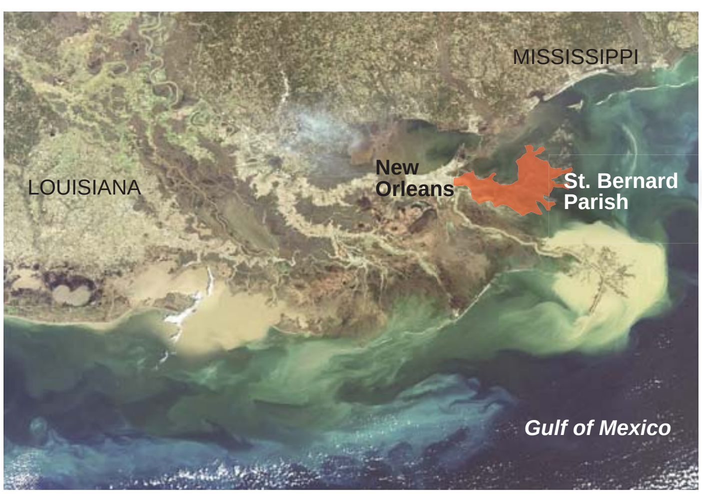
Aerial view looking southwest towards the parish line and New Orleans beyond with Paris Road and the Central Wetlands Unit the foreground.
Image courtesy of Jonathan Henderson, , Vanishing Earth Advocacy + Consulting + Photography

Delta Ecosystems
The muddy waters and soft soils of southeast Louisiana's bayous, swamps, marshes, and estuaries make up the complex and fragile deltaic landscape of St. Bernard Parish.

1
OVERVIEW

The Integrated Water Resources Management plan provides a framework for understanding the relationships between soils and water and between urbanized areas and local water resources. It also provides a range of implementable projects with which St. Bernard Parish can improve those relationships, and it provides an overview of possible implementation pathways.

FOREWORD



Gateway to the Gulf
St. Bernard Parish, directly adjacent to New Orleans, is surrounded by water: the Mississippi River, Lake Borgne, coastal wetlands, and the Gulf of Mexico..
Source: ESA Envisat, 2007

The importance of water management is becoming more and more apparent for all coastal regions, especially with the pressures exerted by sea level rise and climate change upon municipal infrastructural systems. This is particularly evident in southeast Louisiana, where an eroding coastline, soil subsidence, and the ever-present threat of heavy rainfall and tropical storms exact high costs and require constant attention and investments from local parishes and their citizens.

Our goal with this plan is to analyze existing systems, provide a plan for integrated water resource management to benefit parish residents, to illustrate possibilities with projects and programs, and provide a framework for implementation. This report builds on work of the Greater New Orleans Urban Water Plan – which provided the basis for shared regional principles and approaches to water management for the City of New Orleans, Jefferson Parish, and St. Bernard Parish.

With those principles, these parishes, all neighbors in the Mississippi River Delta, are beginning to adapt long-held approaches to water management based largely on forced drainage and hiding or pumping water towards managing stormwater and the abundant waterways and wetlands of the region as critical assets. 20th century drainage systems and the management of wastewater, groundwater, and surface waters have made modern life in the delta possible, but have also compromised the health of our habitats, urban environments, water quality, and even the stability of the soils upon which we live. The new approaches to water management outlined in the Urban Water Plan and in this document provide integrated solutions that address those concerns.

Notes on this Planning Document

- The area of design study and proposed projects and programs are focused on the urbanized area upstream of Violet Canal, within the levees, and also includes the Lower Ninth Ward of New Orleans, because it belongs to the same hydrological basin as Arabi and Chalmette.
- This document is intended to serve as a resource for public officials, community advocates and activists, environmentalists, engineers and designers, developers, and residents to understand ways in which water flows through the parish and the interrelationship of water flows, soils, nutrients, and infrastructural systems.
- The frequent use of images is intended to illustrate existing conditions as well as proposed conditions. The plan includes precedents from around the region and other parts of the world that help the reader to imagine what the proposed approaches to water management might mean for their daily lives, in terms of how public spaces are shaped and use, how water resources are accessed, and how water can reinvigorate planning and development practices throughout St. Bernard while also enhancing the identity of the parish.

A Note from the Parish President

"Over the past decade, the need for a comprehensive stormwater management strategy for St. Bernard Parish has never been short of paramount for civic leaders and citizens. From robust engineering infrastructure implementation to visionary land use approaches by our architects and planners, St. Bernard Parish Government is committed to ensuring the health, safety, and welfare for all Parish residents and property with regard to water management.

I feel the following Integrated Water Resource Management (IWRM) strategy, along with our recently adopted Municipal Separate Storm Sewer Systems (MS4) codes, will guide St. Bernard Parish well into providing a both sustainable and resilient future for our citizens. With the prolonged cooperation of Parish citizens, municipal government, and private development, I am confident that as we enjoy the time honored traditions of local industries based upon water then we can also learn to live and thrive with water."

– Guy McInnis
St. Bernard Parish President
September 28, 2016

Integrating the management of water resources means approaching the planning, design, construction, and operation of infrastructure networks, regulation of surface water and groundwater flows, and management of open spaces in a way that reflects multiple viewpoints on how water should be managed. Water systems are managed to reduce flood risk and provide basic utility, but also to support economic development, and to enhance quality of life by supporting a broader range of human activities and uses as well as wildlife and habitats.

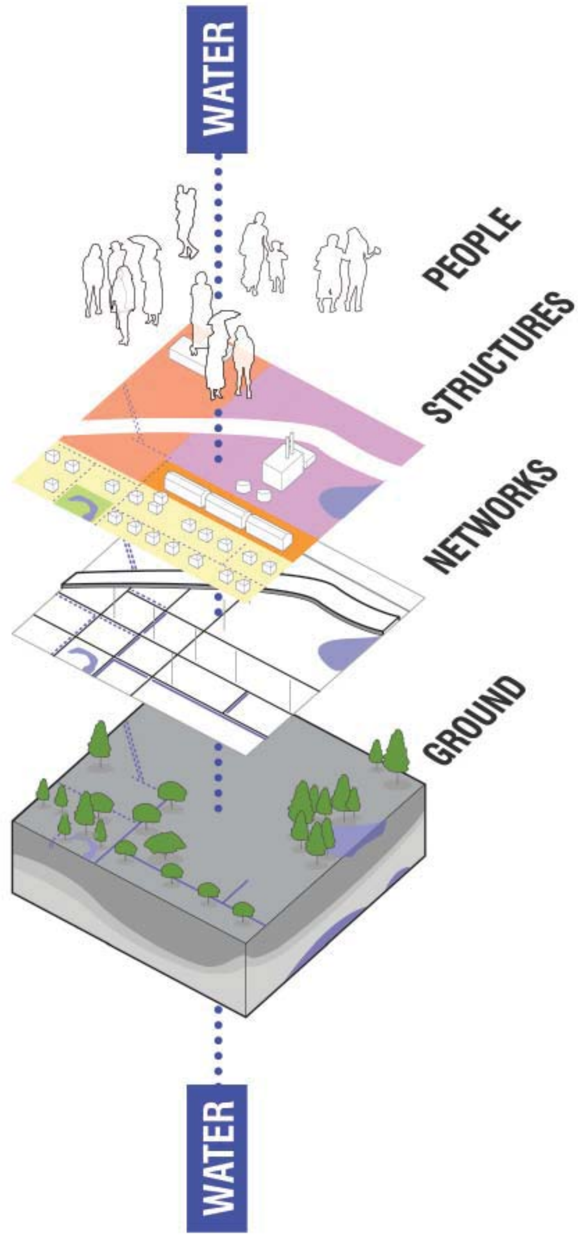
1a INTEGRATED WATER RESOURCES MANAGEMENT

Public Park and Stormwater Storage
Designed to hold shallow depths of stormwater spread out across a large area, Wally Pontiff, Jr. Playground in Jefferson Parish becomes a temporary pond, and is an attractive place for children to play.

In this plan, integration refers to increased coordination, knowledge sharing, and collaboration in these realms: planning, design and construction, and management.

Integrated Planning means coordinating strategic planning for water systems, including stormwater, drinking water, sewer, and the road networks that organize the flows of water through the parish.

- This requires coordination not only between utilities, but also with land use planning and community development goals – the latter two are inextricable from any discussion of environmental planning.
- This requires a convener at the parish and regional level who has the capacity and the power to bring planning entities together in order to coordinate approaches, philosophies, mandates, jurisdictions, and budgets, while also sustaining the activity of



Layered and Integrated Planning

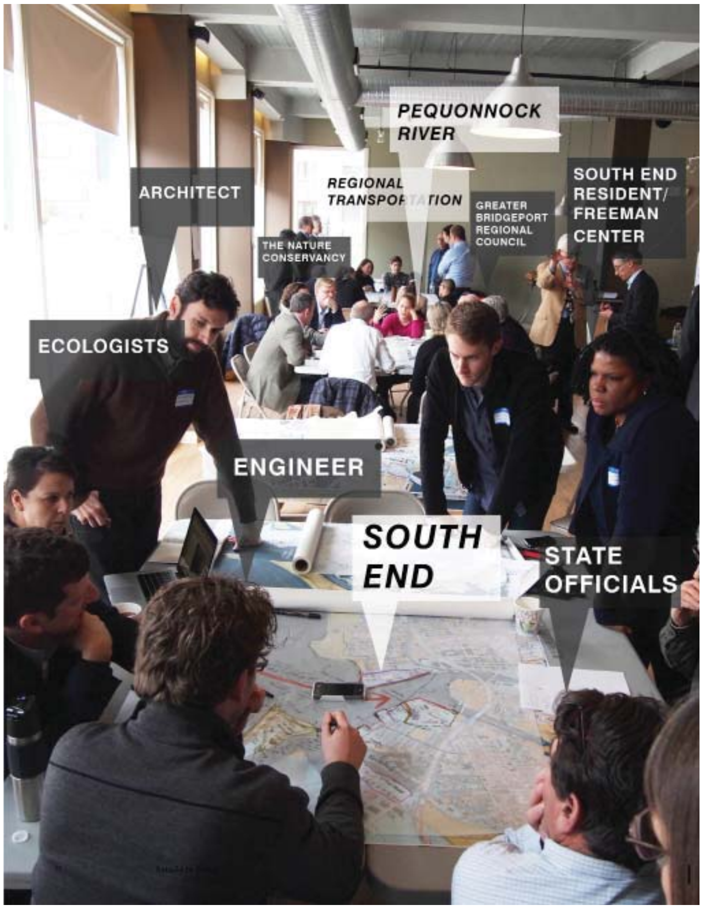
Integrated planning and water resources management also requires a deeper understanding of how different layers interact. Soils and waters are the basis for planning and designing infrastructural networks, which in turn help to shape the urban fabric and human activity. At the same time, policies and human activities fundamentally change the shape of the land and the flow of water and nutrients across the landscape. These interactions are visible throughout St. Bernard Parish.

connecting across agencies and between multiple stakeholder groups and actors. The chief resilience officer in New Orleans and other cities, for example, has filled that role. This will likely be a person, or people, experienced in working across disciplines. They will need to help identify funding sources and implementation strategies that are adaptable, flexible, and accommodating of the specific needs and objectives of the partnering entities.

- It is important for agencies and stakeholders to share basic underlying philosophies or at least to coordinate so that one agency's directive or mandate does not contribute to higher costs or negative consequences for another entity (e.g., one entity working to reduce flood risk inadvertently contributing to subsidence and higher road repair costs)

Integrated Design and Construction means coordinating the design of systems to make the most efficient use of available space and to provide the most benefits to the community and environment, while also adopting construction practices and timelines that are more cost effective and consume fewer resources.

- Road repair work and pipe replacement work that are ongoing throughout the parish show how lack of coordinated design and construction increases waste. In tearing up a street to replace an old pipe, for example, is also an opportunity to replace the existing asphalt with permeable pavers or to install a roadside bioswale. These efforts are rarely coordinated, however, so that asphalt may need to be turn up twice if drainage improvements and stormwater management enhancements are implemented separately, for example.



Integrating Community Engagement
New project efforts should include consistent involvement of parish residents through workshops and forums where citizens have a voice in how integrated water management principles are incorporated into the design, building, and operation of projects. Image above shows a planning workshop in Bridgeport, CT, where citizens and key local stakeholders worked directly alongside government officials as well as design and engineering professionals to develop water management and resiliency strategies for the city's low-lying areas.

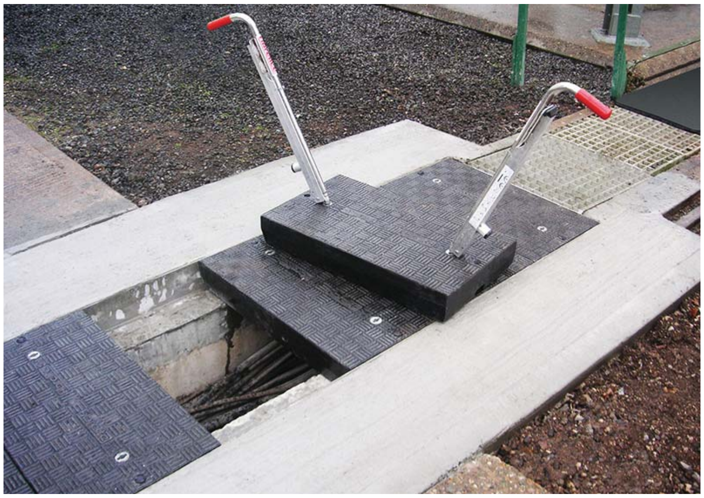
- Because design and construction schedules are determined by funding sources and periods, and because funding sources are tied to specific needs and outcomes, the parish will need to proactively manage these factors and to seek concessions, variances, and adjustments where possible to allow for more efficient use of resources and space.
- Design of utilities and streets can help to increase efficiency, for initial construction, for operations, and for replacements and repairs. For example, some cities have begun constructing readily accessible utility trenches where all conduits are organized and easily reached.

Integrated Management means coordinating operational regimes, maintenance cycles, and retrofits to benefit multiple systems and accomplish multiple goals.

- Integrated systems will be more complex. For example, a stormwater retention park may be more beautiful, clean more water, and provide more co-benefits as a habitat and recreational space than a grey infrastructure system. The grey infrastructure system, however, will typically be simpler and easier to maintain. Maintaining complex systems will require a greater diversity of skills and more advanced knowledge of plants, ecology, hydrology, and chemistry.
- Operational regimes will also need to be more attuned to seasonal cycles and changes in the environment, the health of the flora and fauna that are vital to the proper functioning of green infrastructure, for example, is vital to the performance of that green infrastructure.

Integrating Infrastructure Operations and Maintenance
Upgrades to drinking water in Old Arabi took place in 2016 without consideration for how the resulting roadwork could also have enhanced stormwater management for the neighborhood.

- This is a challenge for public works departments that have come to rely on low-skilled labor and operational regimes, but is also an opportunity for job creation and diversification of the economy.
- Operational regimes that truly harness natural processes, such as nutrient uptake and filtration by plants or using soil layers to infiltrate stormwater for example, will reduce costs in the long-term. Nature-based systems, however, can also be more adaptable.
- Investments in infrastructure, whether grey or green, are immense – living in the delta requires tremendous resources. Investments in distributed and integrated systems that are nature-based, however, will provide many more benefits, in the form of jobs, ecological health, and quality of life.



Integrating Utilities and Access
Accessible utility trench covers provide flexibility with repairs, upgrades, and access, and could also function as a sidewalk or to infiltrate water back into the soil.
Source: Fibretite

The Mississippi River Delta is a place of flowing water and soft soils, constantly reshaped by the many human and natural forces that act upon it.

The delta is a place of change, with the flow of water continually depositing fresh soils or carving new channels through soft land. Though the delta has always been a difficult environment to live in, humans have occupied southeast Louisiana for 10,000 years because the delta is also a place of opportunity. Its waters have provided humans with shellfish, shrimp, and crabs. Its forests were once rich with deer, bear, and other large mammals. Palmetto fronds were used to create shelter, and other plants provided hunter gatherer s with sustenance and medicine. To this day, the delta is the source of an unparalleled array of resources, rich and diverse habitats, and a place of economic activity that connects the heartland of the United States to the rest of the world.

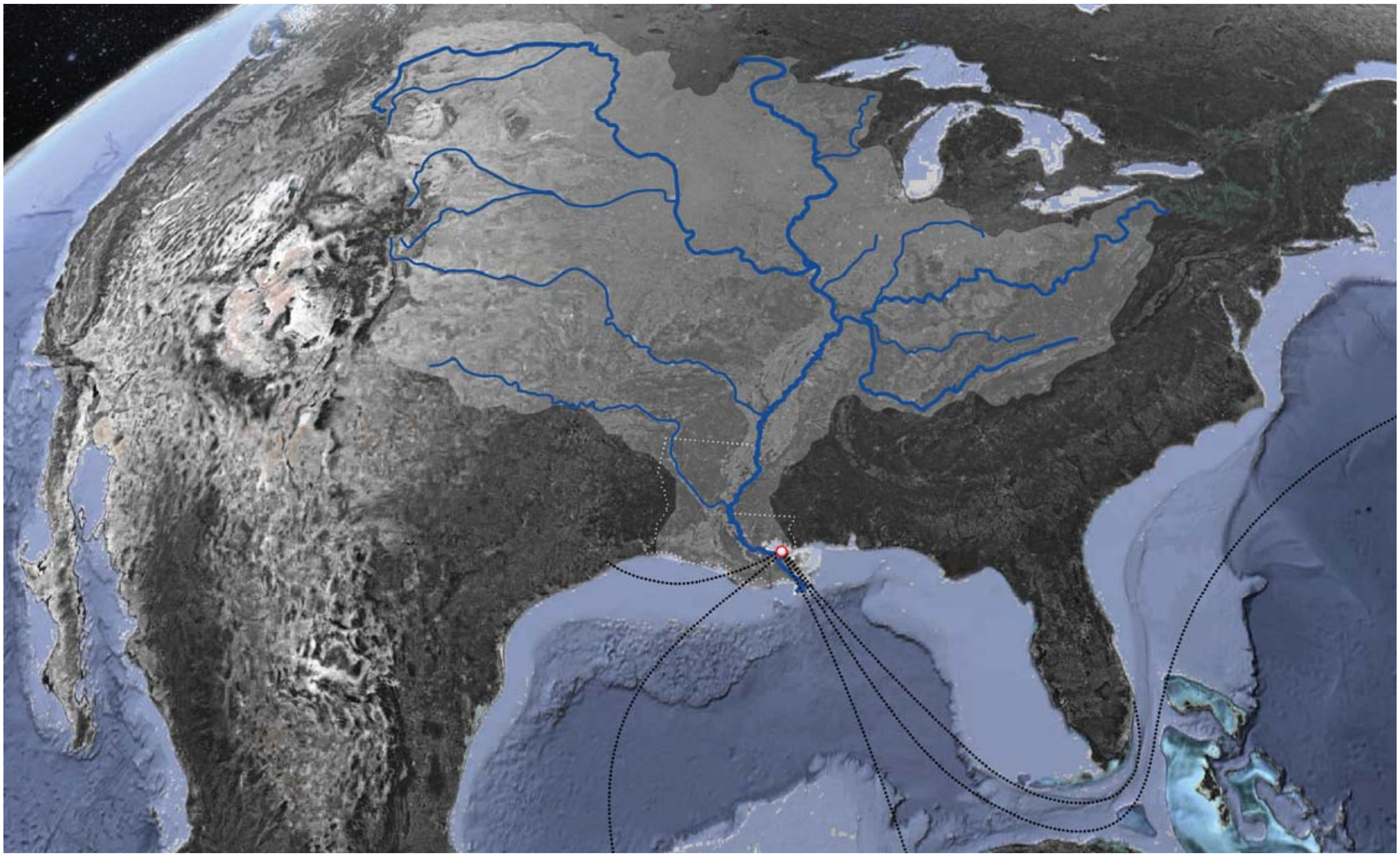
Understanding the water systems of St. Bernard starts with an understanding of how Mississippi has coursed through the region, and the ways in which humans have sought to control it. Everything from the soil layers upon which homes, businesses, and roads are built, the topography of the parish as it slopes from river bank out to the Gulf of Mexico, the presence of industry along the riverfront and in St. Bernard, and the patterns of settlement that have resulted in the places we know today are all a result of the flow of the Mississippi.

The river drains 40% of the lower 48 states. As the Mississippi swells, it collects sediments from its many tributaries. These muddy waters are the delta's life source, creating land wherever water is allowed to slow enough for sediments to fall out. St. Bernard exists on these fresh soils, each new layer formed when the river and its distributaries overflowed their banks and spread out far enough for the waters to stop flowing and the fine grains carried in those waters to settle and create new land.

The soils of the delta, and St. Bernard, are fine-grained and wet. Aside from the relatively high and dry ground of river and bayou banks, there is little ground that is truly stable. Poorly drained clays, silt, and muck are common

1*b*
MISSISSIPPI RIVER DELTA

Water Across Boundaries
Water basins in Greater New Orleans extend beyond political boundaries; the city's Lower Ninth Ward is in the same basin as St. Bernard Parish.



A Vital National Asset
Greater New Orleans links America's heartland and the Mississippi River Valley to the Gulf of Mexico and the rest of the world. It is a vital center of commerce and culture, and is positioned to become a global leader in water management and climate adaptation as well. Base image source: Google

throughout. Interleaved with soil particles are organic materials, leaf litter, branches, and other flora and fauna deposited over time, and trapped in anaerobic conditions by the high water table of the swamp.

The high ground in the parish, as is the case throughout the delta, is by the river. This is where humans first settled. Here the soils are most stable, the land least often flooded, and the river available as a source of water and as a means of conveyance. This is true, too, of the river's distributaries and their natural levees like the Bayou Terre aux Boeufs in Lower St. Bernard. These were places where one could build a home, move goods by land, and live above the level of the water.

Over time, humans have built up levees, revetments, dug canals, installed pumps and sought to make the delta inhabitable by trying to stabilize soils and the flow of water. Throughout the 19th and 20th centuries, increasing control of water became the basis for expanding settlement, expanding commerce, and for improving public health and safety. To do so, settlers had to learn to control the flow of water, prevent devastating floods caused by high water in the river or hurricanes, improve sewerage, and reduce mosquito-borne illnesses.

It was not until the 20th century that new technologies and civic and development impulses made control of local water resources and water flows a reality. Modern pumps, extensive levee- and floodwall-building programs, and a systemic approach to water management made it possible to drain and develop what had once been marsh and swamp, and for the St. Bernard and adjoining parishes to take the form that we are familiar with today.

These changes, though, have fundamentally altered deltaic processes. Riverfront levees no longer permit overbank flooding, which means that soils are not replenished with fresh sediments, even as the delta subsides. Flood protection levees and channels carved through the marshes and swamps for navigation and for oil and gas exploration have also had a deleterious effect on the delta, with flows of water cut off, or saltwater introduced into freshwater environments and severely damaging local habitats.

As a result, the delta is an environment that is vulnerable, with hundreds of square miles of wetlands lost, and hundreds more at risk in the coming years. The impact on St. Bernard and other communities throughout the region has been devastating, with livelihoods and ways of life founded on the abundance of the delta compromised, and the loss of wetlands that serve as buffers, shielding communities from the brutal forces of hurricanes and storm surges.

Great levees, walls, and floodgates protect St. Bernard from the direct force of hurricane storm surges and flooding from the river. This system reduces risk, and it fundamentally changes the flow of water and sediments through the delta.

1c BOUNDED CONDITION

Walled In
The levee at the 40 Arpent Canal separates the urbanized area of the parish from the Central Wetlands Unit, which is itself contained within levees.

The urbanized areas of St. Bernard are protected by the regional Hurricane and Storm Damage Risk Reduction System (HSDRRS), which is designed to protect a three-parish region, including Jefferson and Orleans Parish, from a 100 year storm. That is storm with a 1 % chance of occurring or being exceeded in any given year.

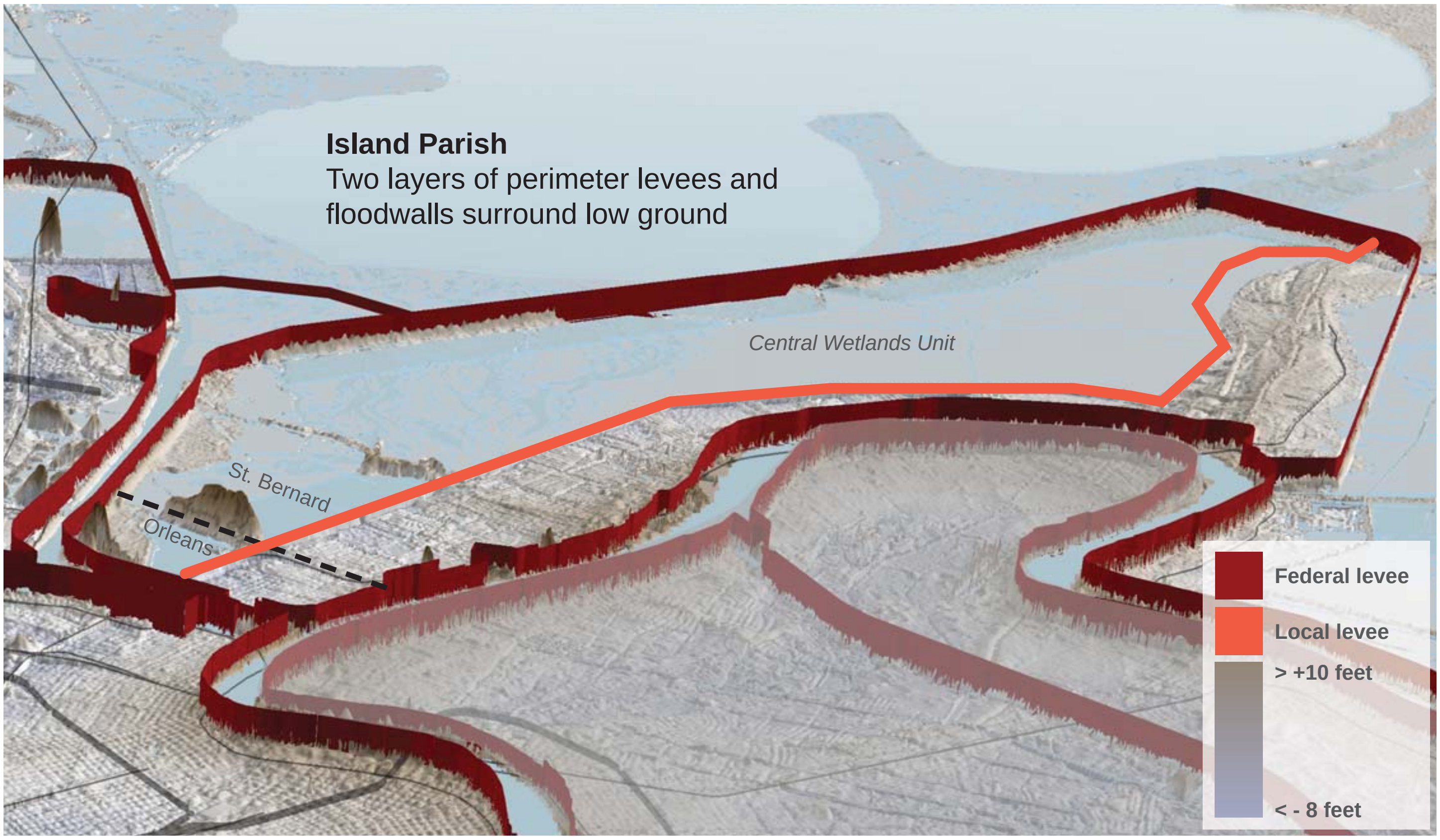
This system failed at multiple points in 2005, with the surge of Katrina pushing through floodwalls along the system's Lake Borgne edge and at the Industrial Canal. The surge filled the Central Wetlands Unit and destroyed the local levee between the CWU and the parish, resulting in flooding up to the parish's river levee. Since 2005, the system has been rebuilt and reinforced, but the operation and maintenance of this system will always be an important issue for St. Bernard residents to address.

The HSDRRS consists of massive levees, floodwalls, floodgates, surge barriers, and pump stations. This system defines the ways in which water flows through the region because protected areas are now separate hydrological basins. Protected areas are like bowls. They have high edges and require forced drainage (pumping) in order to stay dry, even during regular rain events and in the absence of storm surge. At the same time, these areas are also at greater risk of subsidence.

Levees, floodwalls, and surge barriers also reduce interaction between saltwater and freshwater areas. Water flows are dependent on the opening and closing of gates and the operation of pumps, with winds and tides having less of an influence. This, in turn, changes the flow of nutrients as well as salinity levels, which then changes ecological conditions.

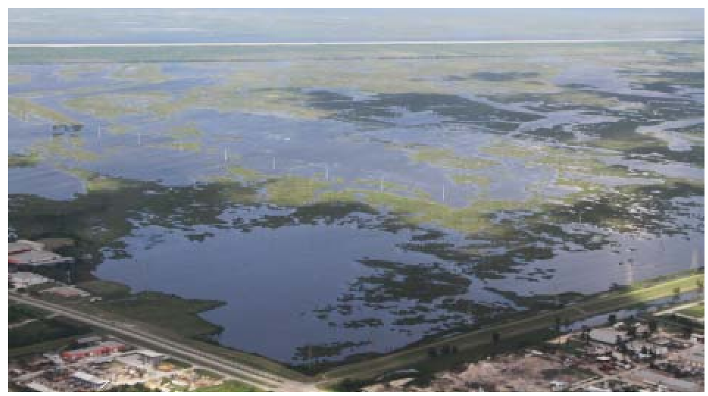
The HSDRRS is designed to ward off storm surge, but does not guarantee complete flood protection. Regardless of the elevation of levees and floodwalls, heavy rainfall can cause flooding within the levees. This form of "residual risk" is one of the main areas of focus for the IWRM plan.

Built by the Army Corps, and operated and maintained by the Corps and by local entities, the HSDRRS also binds together St. Bernard, Orleans, and Jefferson Parish. With a shared levee system, the future of all three parishes requires cooperation between the parishes, and between local and federal entities. The Lower Ninth Ward of Orleans Parish and Arabi exist within the same hydrological basin. Just as was the case in 2005, extensive flooding in Arabi will likely mean flooding in the Lower Ninth Ward, and vice versa.



Perimeter Protection
Levees and hurricane protection features reduce risk and lower the cost of flood insurance. Maintenance and continued investments are necessary to maintain the level of safety that these defenses provide today. With these systems, the largest residual or remaining risk to St. Bernard Parish residents is from flooding due to excess rainfall, which can only be addressed through improvements in urban water management.

The flow of water and deposition of soils over centuries created the delta landscape and distinct landscape types upon which St. Bernard is situated. Traveling from the Mississippi River towards the Gulf of Mexico, one moves from the ridges and backslopes of natural levees into low-lying bowls, and from there out into the Central Wetlands Unit.

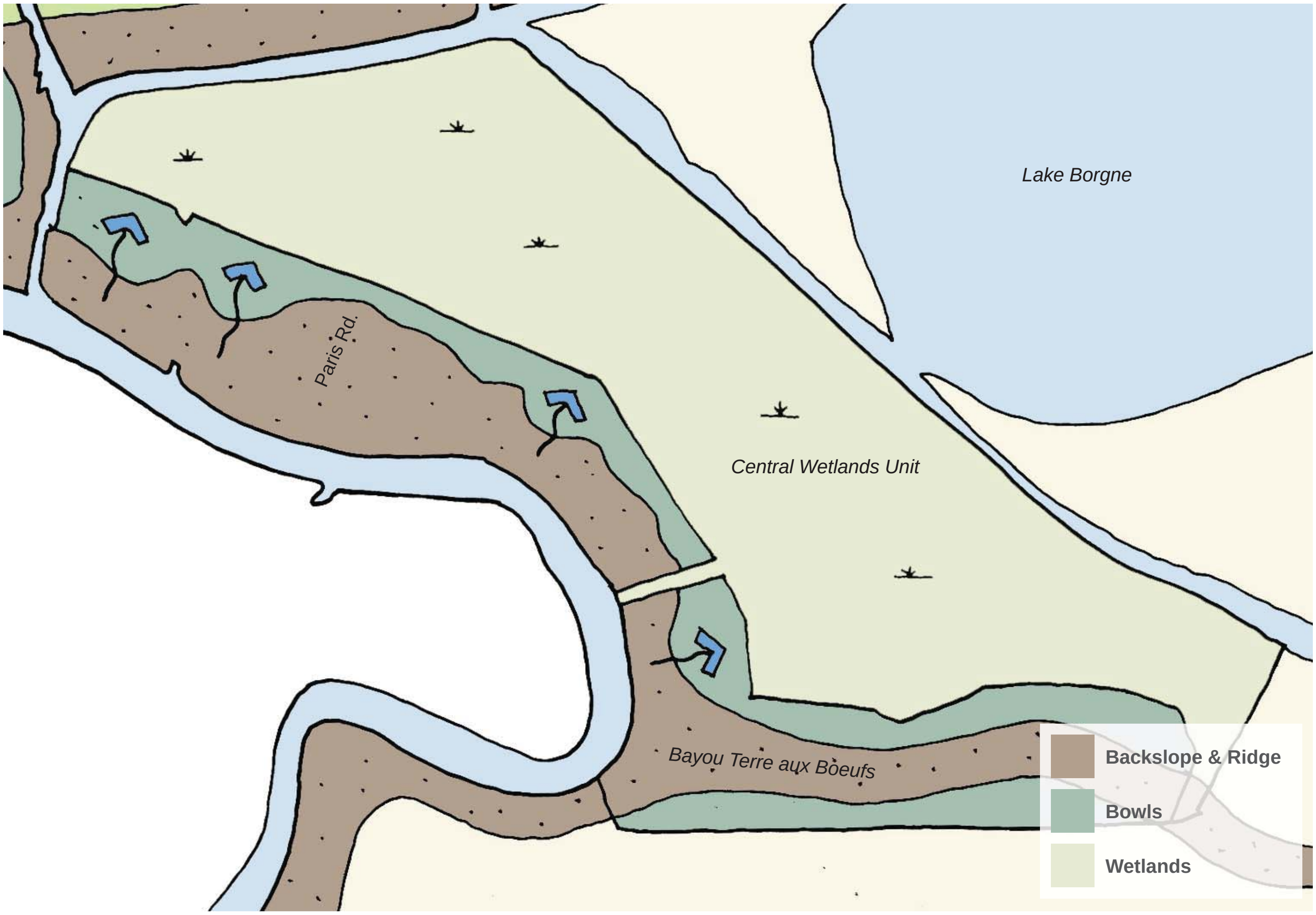


1*d* LANDSCAPE TYPES

Bowls, Low and at Risk
Once low lying swampland, the highly organic soils in bowl landscapes are prone to both subsidence and flooding. Bowls are the lowest areas in the parish and, coupled with slab on grade development, as shown above, suffered the worst flooding after Hurricane Katrina.

St. Bernard's location at the juncture of land and water, river and gulf, makes for distinct landscape types. Areas of the same landscape type share commonalities in terms of soil types and stability, ecology, period of initial settlement, land use, urban patterns, flood risk, subsidence risk, and potential for continued flooding and subsidence. The location of these landscape types can be roughly understood in relation to the major longitudinal corridors that run through the parish (St. Claude, Judge Perez, Patricia/Genie).

Backslope: Early settlements such as Old Arabi were situated on the backslope, close to the river. This more stable land follows the curves of the Mississippi and is largely above sea level. Its clay and silty clay soils are less prone to subsidence. Commercial and industrial land uses historically developed along the riverfront, with larger scale industries such as refineries taking root in the 20th century.



Backslope
High ground that slopes away from riverbanks towards the wetlands, this stretch of more stable, drier ground was the first area to be settled by Europeans in the 18th century. The backslope is largely above sea level, and has relatively stable clay and silt soils.

Ridge
Geologic remnants of old river courses and distributaries, ridges are strips of relatively stable clay and silty clay soils. Like the backslope, ridges also served as sites for early settlements on highest ground.
Facing page, top.

Bowls
These areas of low ground are situated between the backslope and local ridges. Once swampland before the introduction of forced drainage and later urbanization, these areas have highly organic soils that are prone to subsidence.
Facing page, second from top.

Wetlands
Bowls used to be wetlands. These rich ecosystems surround the parish, and are also impounded behind levees and floodwalls. They serve as natural buffers to storm surge, critical habitats, and recreational amenities.
Facing page, third from top.

Ridges: These include areas such as Paris Rd. and the Bayou Terre aux Boeufs, areas with higher elevations and more stable soils that were deposited previously by crevasses, rivers, and distributaries of the Mississippi. These areas show the land-forming capacity of flowing water, and also the constant force of the river pushing against its banks.

Bowls: once uninhabitable swampland before the introduction of forced drainage and urbanization in the 20th century, bowls have low elevations and highly organic soils that are prone to subsidence. When rivers overflowed, the bowls were typically the first to fill up and the last to dry out. Today, St. Bernard's bowls lie close to or just below sea level, and are dependent on pumps for staying dry. In recent decades, these areas haven been the site of extensive suburban development, particularly in Arabi, Chalmette, and Meraux.

Wetlands: These marshes, swamps, and degraded wetland areas constitute vast portions of the parish both inside and outside of the levees. The Central Wetlands Unit is a large basin separating the urbanized parts of the parish from the HSDRRS's levees and Lake Borgne. This area's swamps were devastated by saltwater intrusion in the 20th century and became an area of patchy marsh, open water, and cypress stumps. To the east and southeast, extensive wetlands are also at risk. These are especially critical because they protect not only St. Bernard from storm surge, but also New Orleans and Jefferson Parish.

1e
A CHANGING LANDSCAPE

First Inhabitants
The first humans to live in the delta landscape that is now St. Bernard Parish were Native Americans, shown above in a painting by Alfred Boisseau, *Louisiana Indians Walking Along A Bayou*, 1847.
Collection of New Orleans Museum of Art

The ever-changing shape of the delta has long determined the locations of human settlement in St. Bernard. Human inhabitation has fundamentally altered the delta as well. Planning for the future requires first understanding how these interactions have created the landscape that we see today.

The shape of the land in the delta is fluid because of the impact of flowing water on soft soils, and the urban fabric and infrastructural networks that exist today are reflective of colonial and modern efforts to inhabit and draw resources from this difficult location. Pre-European and early European settlement took advantage of the available high ground and relatively stable soils of the riverbanks. The Isleños, too, settled on high ground in the late 18th century, on the banks of the Bayou Terre aux Boeufs that flows from the Mississippi out to the Gulf of Mexico.

As evidenced by the French "arpent" system of agricultural land division, access to the river and to the wetlands was critical to early European settlers, with the river providing a means of conveying goods and the wetlands as a source of timber, food, and other natural resources. Most activities were situated along the narrow backslope of the river and local bayous. Historic structures that still exist today show through their architecture what life was like in the 19th and 18th centuries. Buildings were elevated because river flooding was still a common occurrence.

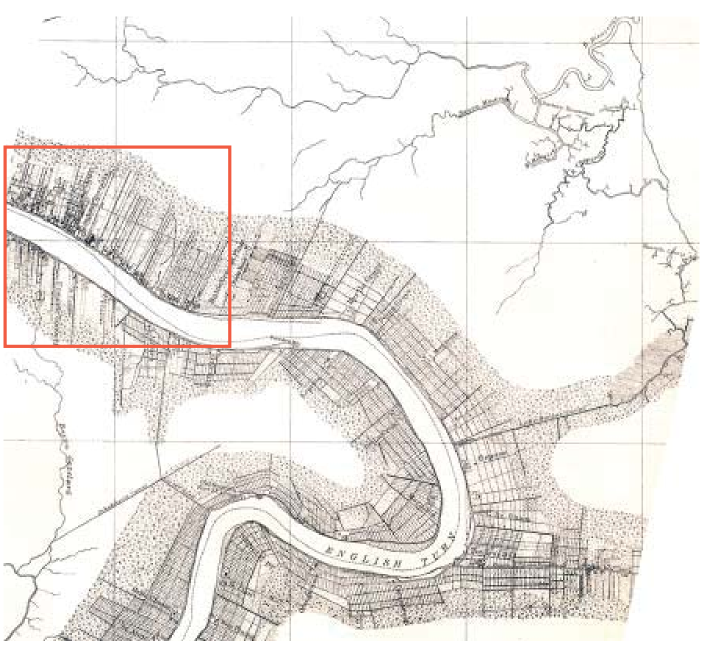
With the advent of modern drainage systems and urban expansion out from the core of New Orleans, what had been small villages and agricultural communities has become a varied mix of urban and suburban areas upriver in Arabi and Chalemette to fishing villages at the parish's furthest extremities, such as Delacroix or Yscloskey. The urbanization of upper St. Bernard occurred in the second half of the twentieth century in the form of suburban sprawl, connected by Judge Perez Boulevard and St. Bernard Highway.

This form of suburban development has begun to elide boundaries between formerly distinct areas like Arabi and Chalmette, and also alter the land cover and hydrology of the parish. With more urbanization, runoff volumes are greater, which means that more resources have to be expended on conveying and pumping stormwater over the local levee and into the Central Wetlands Unit. In the 20th century, modern drainage and the construction of federal

Second Inhabitants
Starting in the late 1700s, European settlers gradually established communities and settled the landscape, as shown above in George Coulon's *Bayou Baureguard, St. Bernard Parish*, 1887.
Collection of the Ogden Museum of Southern Art.

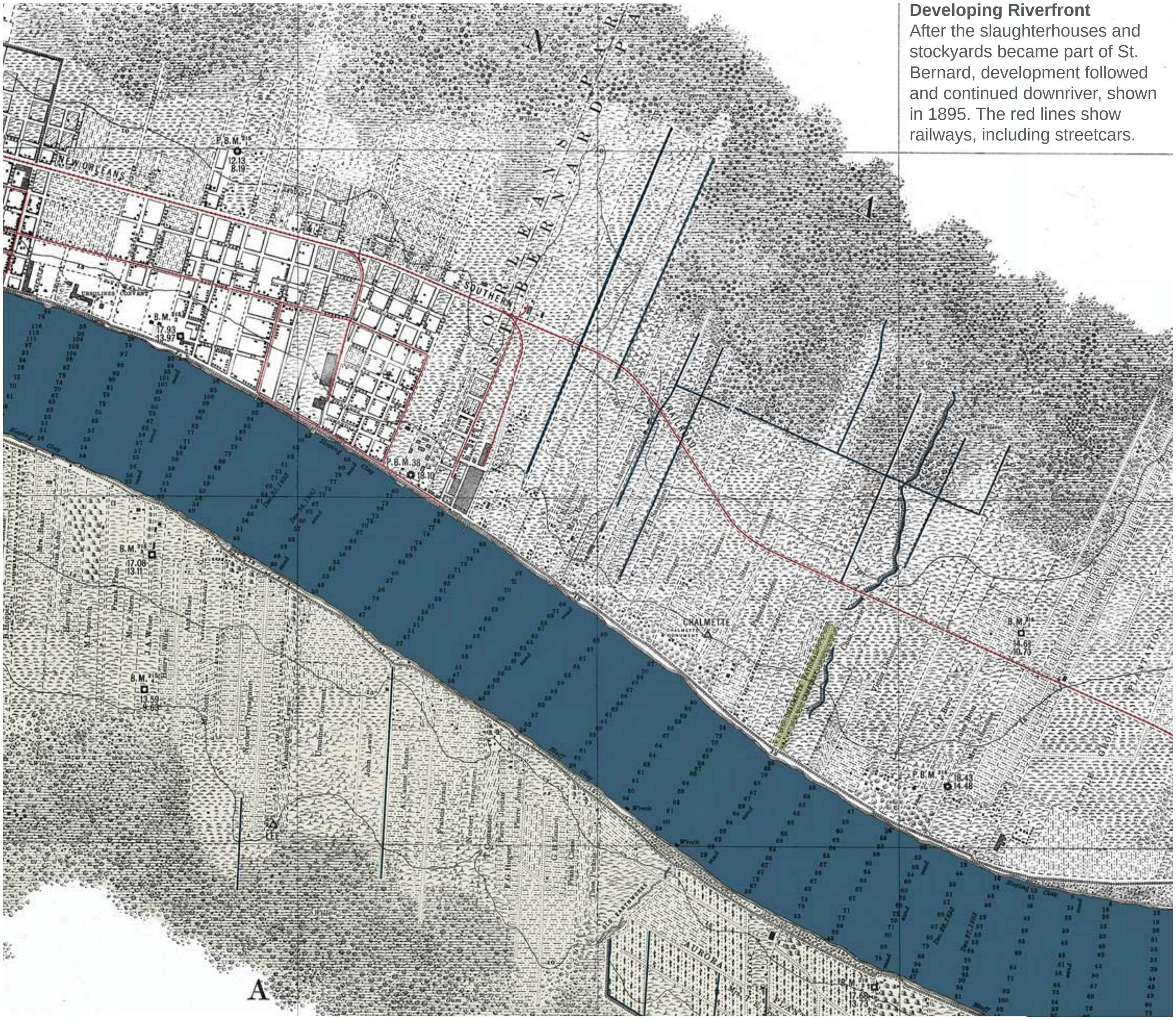
Battle of New Orleans
Jean Hyacinth Laclotte's *Battle of New Orleans,* 1815, depicts the American victory. The river is visible in the foreground, and the defensive line extends from the river to the backswamp, which served as an additional line of defense for American troops.
Collection of New Orleans Museum of Art

Agricultural Neighbor
Mississippi River Commission map from 1882 shows the street grid of New Orleans extending downriver into St. Bernard, with canals, plantations, and settlements close to the river

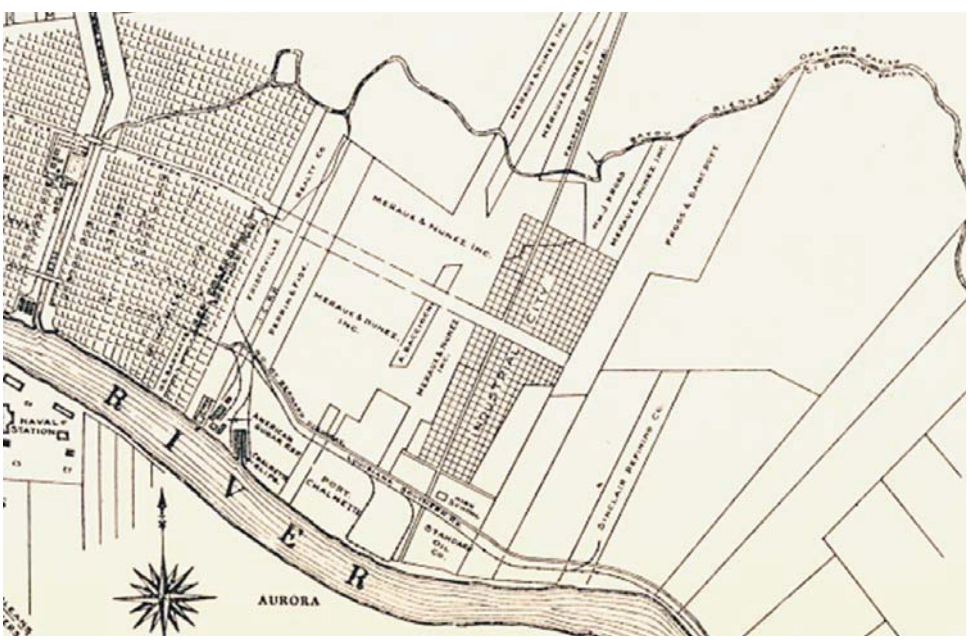


levees changed perception of risk, which is reflected in the architecture of homes and commercial structures being built on grade rather than elevated on piers as they had been in the past.

The 20th century also saw the growth of industries along the river, with Domino Sugar's facilities in Arabi and large oil and gas refineries in Chalmette and Meraux still occupying vast swaths of the riverfront and batture. Most of these areas are inaccessible to the public, so that residents and visitors have few points at which to access the river. On the wetland side of the parish, the 40 Arpent Canal and the local levee limit possibilities for accessing the Central Wetlands Unit. Communities that once depended on access to both river and wetlands are now largely cut off. Improving access to waterfronts, wetlands, and the parish's abundant water resources is one of the primary objectives of the IWRM plan.



Developing Riverfront
After the slaughterhouses and stockyards became part of St. Bernard, development followed and continued downriver, shown in 1895. The red lines show railways, including streetcars.

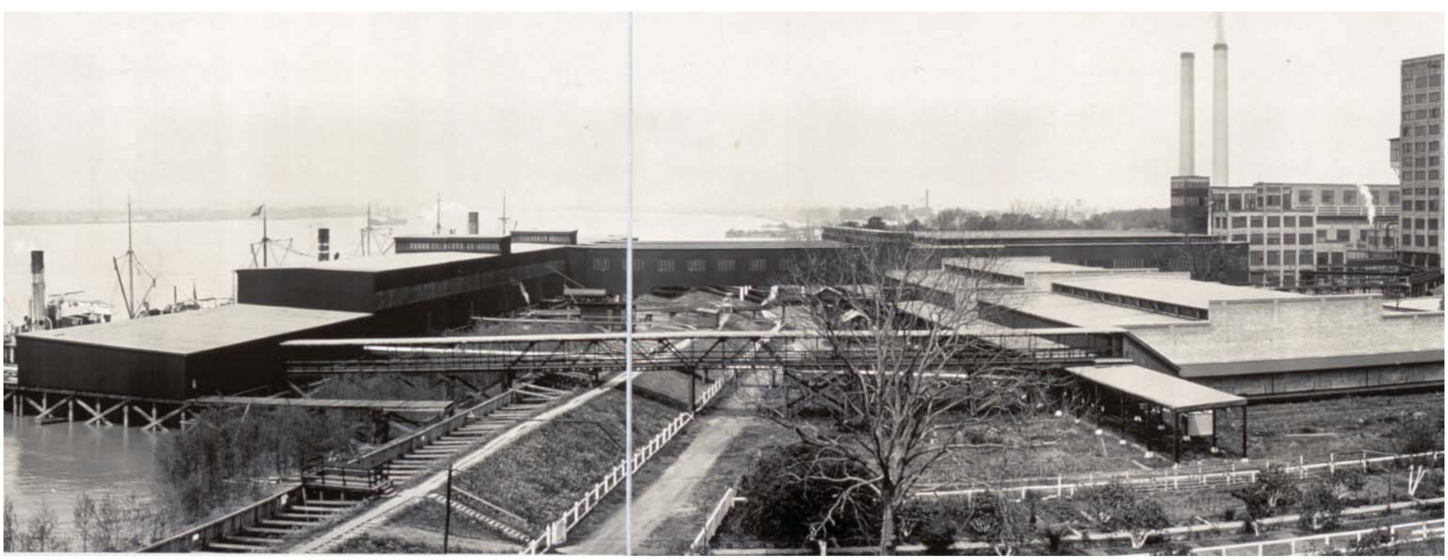


Industrial Development
A proposed plan from 1927 shows recently constructed riverfront oil refineries as a catalyst to develop Chalmette into an “Industrial City,” extending deep into what is now known as the Central Wetlands Unit. These plans were only partially realized.

Resilient Architecture
Earlier buildings in St. Bernard were elevated to stay above flooding, such as in Violet, above, in 1922.
Source: Louisiana Digital Library

Economic Adaptation
Taking advantage of abundant wildlife, Islenos were know for fur trapping, especially in Delacroix, shown in the early 1940s.
Source: WIkimedia Commons

Resilient Transportation
Earlier residents in the lower part of the parish found ways to move around, even in floodwaters, shown in Toca, 1922.
Source: WIkimedia Commons



Early Large Scale Industry
The Domino Sugar Refinery in Arabi, shown above in 1915, was the first major industrial land use in the parish, located on the river.
Image courtesy United States Library of Congress

DISASTERS IN ST. BERNARD

St. Bernard Parish has survived a number of catastrophes since European settlers arrived in the late 1700s, including war, flooding, and rising seas.

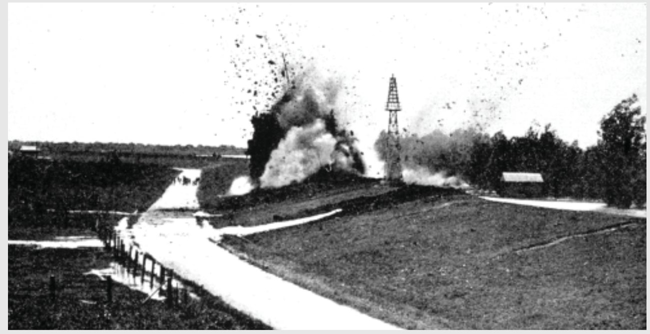
The defeat of the British at the Chalmette Battlefield ended the War of 1812, a major symbolic victory for the young United States. After the Civil War, a national cemetery was established next to the battlefield to honor Louisiana soldiers who died in the War of 1812 through the Vietnam War. In the 1960s the National Park Service controversially acquired Fazendville, St. Bernard's largest historic black community, founded after the Civil War, and demolished the village to expand the park.

During the Mississippi River Flood of 1927 the river levee at Caernarvon was blown up - creating an artificial crevasse - to flood lower St. Bernard in order to save upstream population and property, specifically New Orleans. A system of modern engineered control structures and levees followed, and is visible in expanded form today.

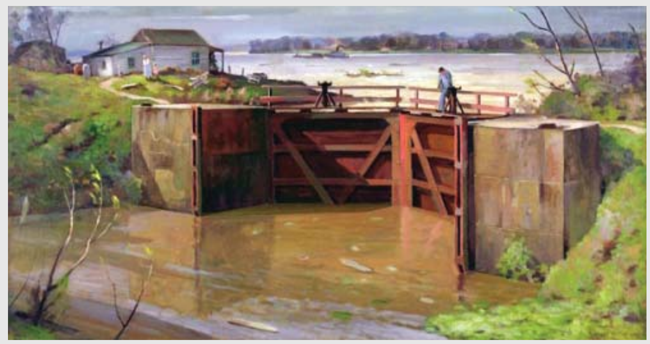
Hurricane Betsy in 1965 brought flood depths similar to Hurricane Katrina, yet was overlooked; 40 years passed without a hurricane significantly impacting St. Bernard Parish. This likely encouraged further construction of buildings that were not elevated, such as suburban style slab on grade developments (shown at right).

In 2005 the levee failures after Hurricane Katrina flooded most of the parish, and to the rooftops in many cases. The storm also exposed the vulnerabilities and lack of preparedness in petrochemical industry facilities when a storage tank became dislodged and ruptured at the Murphy Oil refinery, spreading crude oil across an entire neighborhood in Chalmette. A buffer zone several blocks wide was created to prevent rebuilding in the contaminated area.

Today, sea level rise and climate change threaten St. Bernard, both on the coast and in its inhabited areas. Much of the parish is below sea level, and with continued subsidence and lack of consistent funding to maintain the protection system of new levees, integrated planning and regional cooperation between governments, corporations, and citizens are critical in order to limit the impact of future events.



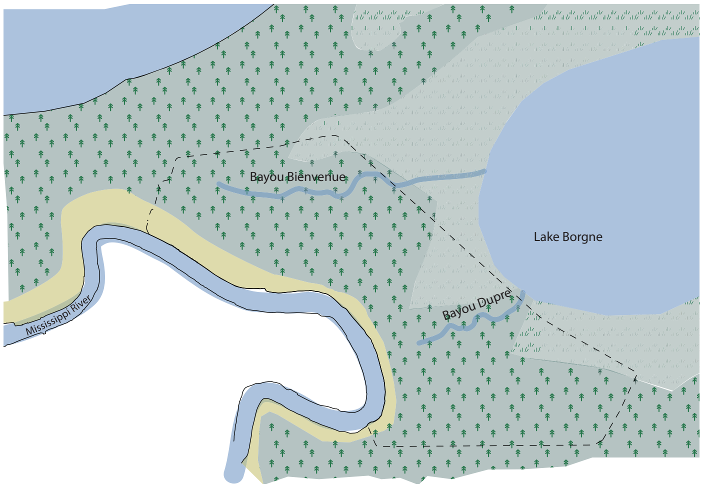
During the 1927 Mississippi River flood, the levee in Caernarvon was partially destroyed to relieve pressure on New Orleans.
Image courtesy nola.com



Clarence Millet's *Violet Locks,*1950, shows relatively new structures to control the river. Collection the Ogden Museum of Southern Art.

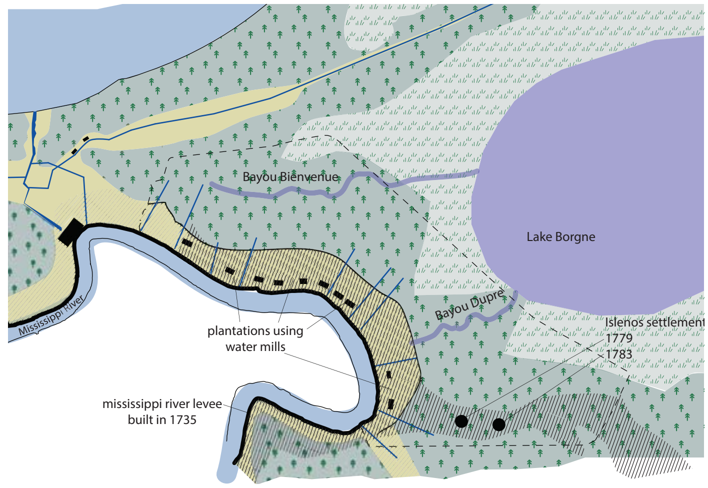
Flooding after Hurricane Betsy in 1965 left some parish residents stranded on roofs, awaiting rescue.
Image courtesy Chalmette Church of Christ

Water, Then Oil
Crude oil spill at Murphy Oil refinery after Hurricane Katrina.
Image courtesy Louisiana Department of Environmental Quality



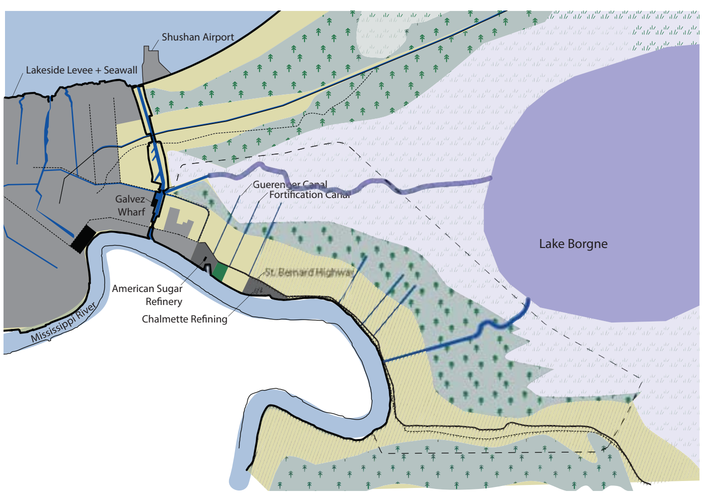
Pre–1718

This densely vegetated deltaic landscape was inhabited by Native Americans. These were hunter gatherers who depended on the bounty of the estuary for sustenance. Water flowed to and from the estuary of Lake Borgne, and the Mississippi River regularly overflowed its banks, replenishing the landscape with freshwater and sediment. The river was already forming the present-day Plaquemines-Balize delta lobe, in between abandoned Lafourche and St. Bernard lobes.



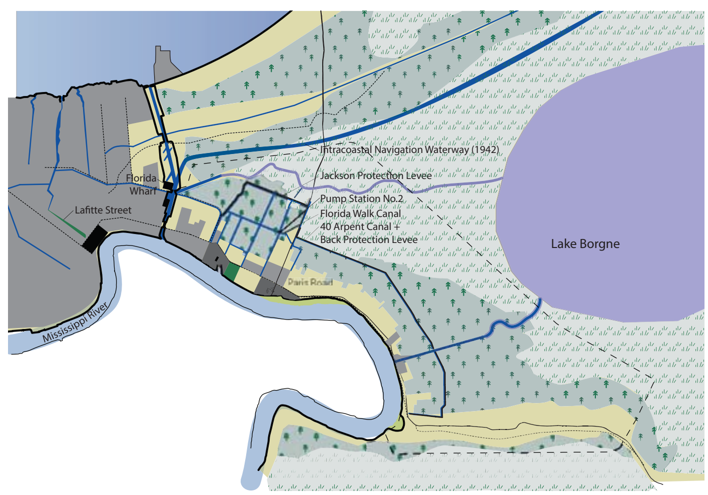
1718–1803

Early European settlement was located primarily along the banks of the Mississippi and local bayous. Millraces were cut into the riverbanks to harness the power of flowing water to saw logs harvested from the nearby forests, accelerating deforestation and helping to open up land for agriculture. The extension of canals, perpendicular to the flow of the river and out towards the wetlands reflect the "arpent" system of land division, which provided each property owner with access to the river and access to the natural resources of the swamp. The first Isleños settlements took root along the banks of the Bayou Terre aux Boeufs in the late 18th century.



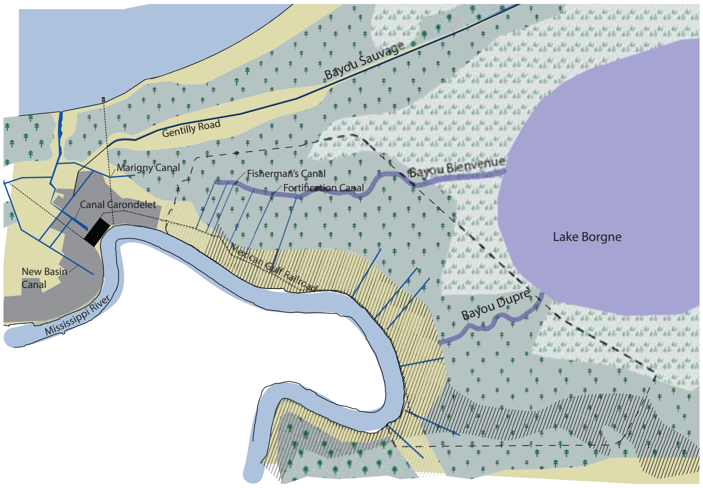
1905–1930s

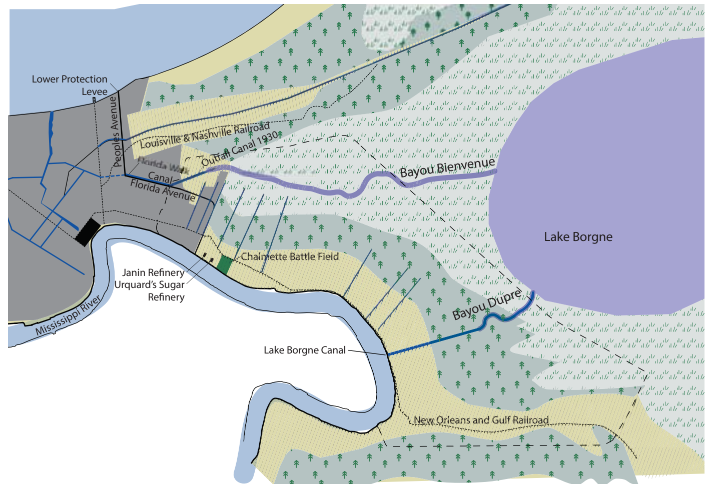
This was a growth period for the oil and gas industry along the riverfront, with a number of refineries and other facilities first being constructed. Refineries are still especially prominent in Chalmette, where they limit access to the riverfront in the heart of the parish. An extensive network of oil and gas pipelines connects these facilities to other facilities throughout the region. In 1923, the Industrial Canal opened, providing navigational access between Lake Pontchartrain and the Mississippi River, but dividing Orleans Parish and separating the Lower Ninth Ward and St. Bernard from the core of New Orleans. The population grew to over 6,500 in 1930.



1940s–1950s

Construction of the Florida Walk canal, perpendicular drainage canals, back levees, and pump stations outlined some of the key boundaries within the parish and its urbanized areas that are still recognizable today. They also defined the basic approach to drainage and settlement that would allow Arabi to Chalmette to develop as urban areas. Between 1940 and 1950, the population of St. Bernard grew by over 50%. That rate of growth increased in the 1950s, where the parish population tripled in one decade, due to the rapid growth of petrochemical jobs and new residential subdivisions.



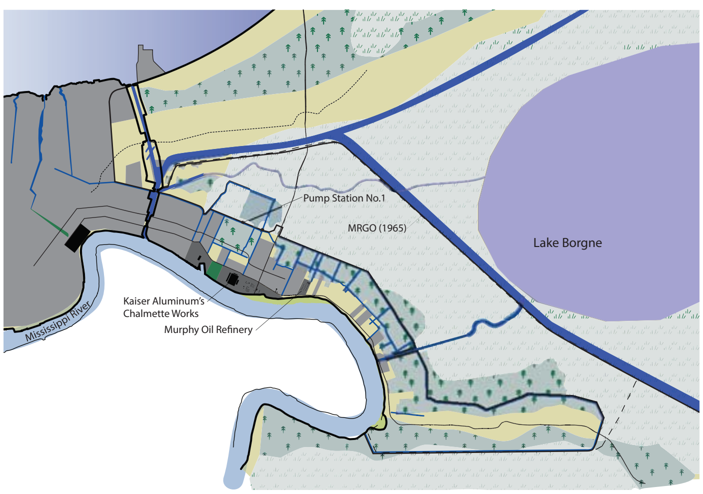


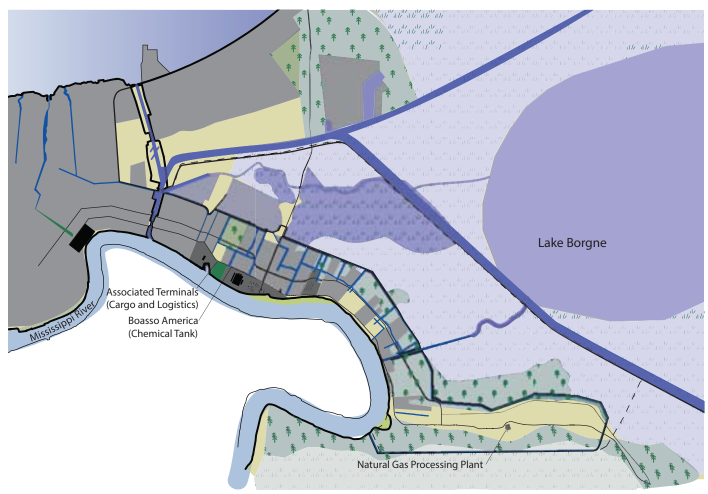
1803–1860

This period of development for New Orleans as an urban center saw St. Bernard become an agricultural provider for the more densely populated areas just upriver. Drainage and navigation canals were extended deeper into the wetlands, and connected the backslope of the levee to Bayou Bienvenue. During the 1815 Battle New Orleans, the backswamp was still dense enough to serve as a second line of defense for American troops, who were able to narrow the approach for attacking British troops to the land between the river and swamp. The parish population grew from under 1,000 to over 4,000 during this time.

1860–1905

The Lake Borgne Canal connected the riverbank to Bayou Dupre, providing navigational access to Lake Borgne from the area known today as Violet. This connection still exists today as the Violet Canal, which divides the parish into two hydrological basins, and provides shelter for fishing vessels during hurricanes. During this time, sugar refineries were constructed along the riverbanks, and are still visible today in the form of the massive Domino Sugar refinery in Chalmette. The population declined slightly during and after the Civil War, but reached over 5,000 in the 1900 census.



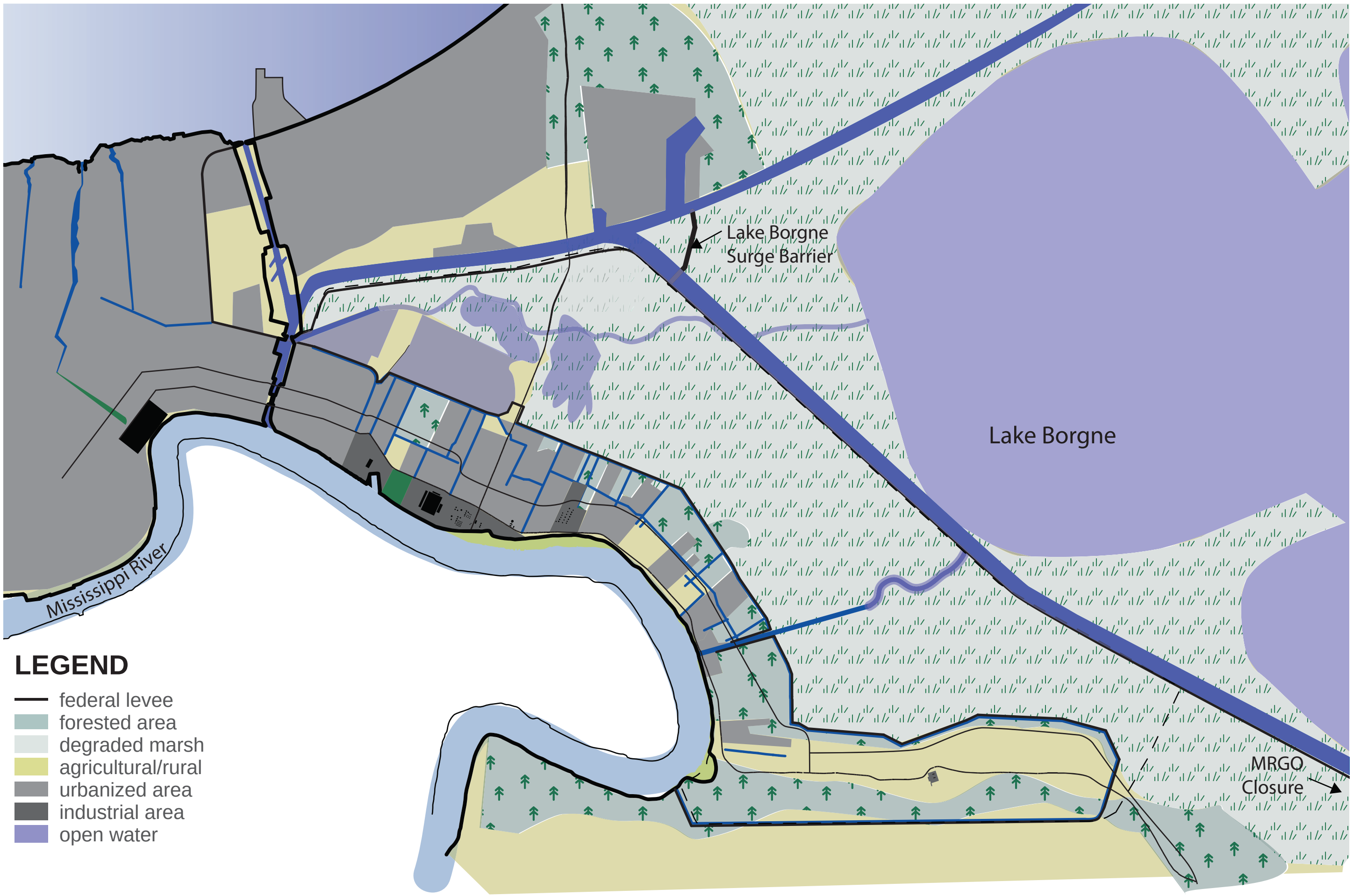


1960s–1970s

This postwar era saw the greatest growth in the parish's history, with large parcels of agricultural land subdivided and developed as tract housing, and industry continuing to thrive along the riverfront. Additional drainage canals and the extension of the back levee facilitated continued urban expansion. The construction of the Mississippi River Gulf Outlet (completed in 1965), however, generated few economic benefits, and led to significant saltwater intrusion that quickly killed the cypress swamp of the Central Wetlands Unit. Following Hurricane Betsy (1965), construction of federal levees and floodwalls that define the outermost ring of protection for the whole region began in earnest. Population grew by 66% in the 1960s.

1980s–2005

Continued development of St. Bernard as part of suburban expansion out from New Orleans led to a population peak in the mid-1980s, followed by modest declines and economic stagnation in the 1990s and early 2000s. More wetlands were drained, and urban sprawl and strip developments came to characterize large swaths of the parish. As agricultural lands disappeared, so did distinctions between previously separate areas like Arabi and Chalmette. In 2005, Hurricane Katrina and failures throughout the federal and local levee systems inundated the entire parish, wiped away thousands of structures, displaced thousands of families, and resulted in the Murphy oil spill.



2005–present

After Hurricane Katrina, the Mississippi River Gulf Outlet was closed, which eliminates one point of entry for future storm surge and reduces saltwater intrusion. Construction of the $14 billion federal Hurricane & Storm Damage Risk Reduction System now provides protection from a 100-year storm with new structures such as the Inner Harbor Navigation Canal Surge Barrier, but subsidence and uncertainty about how the region will manage operations and maintenance for that system remain as challenges for St. Bernard and its residents. In 2010, five years after Katrina, the population of the parish was only half of pre-storm numbers, but has steadily recovered over the past five years. Estimates from 2015 show that St. Bernard's population is around 30% smaller than before Katrina. The urbanized area remains the same, but with far fewer residents, which is challenging for utilities and service providers who are dependent on property taxes for operational funding.

CURRENT CONDITION

The colonial and modern history of St. Bernard is one of development alongside water and wetlands. It is one of rapid change, driven in large part by the attempts of inhabitants to manage the forces of the river and the Gulf of Mexico. In the last three centuries, humans have dramatically changed every aspect of the landscape and its topography, hydrology, and ecology.

These changes to the landscape have made continued inhabitation possible, and allowed the parish to serve the region and the nation as a place for agriculture, harvesting seafood, processing and transporting oil, various forms of industrial production, and also as a port. These changes have also resulted in a degraded environment, with high levels of air pollution, stagnant urban waterways, and the brackish open water and cypress tree stumps of the Central Wetlands Unit serving as reminders of the unintended consequences of human activity.

The parish is also a place not yet recovered from the aftermath of Hurricane Katrina. Large swaths of land remain unoccupied, and the parish continues to struggle with a diminished tax base and inadequate revenues with which to support the maintenance of the drainage and flood protection infrastructure that allow its residents to make a home in the delta. It is important to note, too,

that the parish began struggling with population loss and diminished tax base decades before Katrina.

The opportunity, then, is not just to reshape water management in the parish and to improve healthy and safety. It is to harness the water resources and waterways that are so abundant here in the delta, and to use them to establish a clearer identity and understand of what it means to live at the juncture of river and gulf in the 21st century, with all of the attendant risks but also the undeniable opportunities that exist only here.

Fewer Residents, More Open Land
Over ten years after Hurricane Katrina, many low lying neighborhoods, such as this one near the 40 Arpent Canal in Chalmette, struggle with high rates of property vacancy.

Global climate change elevates the risks that are already associated with life in the delta. In particular, sea level rise and the potential for more extreme weather will require St. Bernard to adapt its flood protection and drainage systems, streetscapes and public spaces, land use policies and planning practices, and the mindset of its residents to meet the challenges of the 21st century.

1*f* CLIMATE CHANGE, SEA LEVEL RISE, AND RESILIENCE

Local Causes
Petrochemical refineries, such as Exxon Mobil in Chalmette, likely worsen the larger problem of climate change, which directly impacts St. Bernard.
source: AP Photo/Gerald Herbert

Due to emissions from the burning of fossil fuels over the last century, humans have been the cause of global climate change, creating new stresses for infrastructural systems and creating new vulnerabilities and elevated risk for communities around the world. Sea level rise, in particular, is one of the consequences of climate change that is already having an impact on coastal communities. Here are some of the ways in which climate change and sea level rise are affecting the coastline of St. Bernard:

Oceans

If sea levels rise 3' feet in the next fifty years, storm surge that is 15' today will be 18'. Levees that may not have been overtopped previously will be overtopped or breached as sea level rise raises water elevations. Higher water levels will exert more forces on existing levees and floodwalls, and require expensive lifts and reinforcements. Higher water levels may also make it more difficult to pump stormwater out of the parish.

Climate and Weather

Warming oceans affect global weather patterns, such as the path of the jet stream. Warmer air also holds more water, which means that rainfall may come in greater volumes, with greater intensity, and/or with greater frequency.

Ecosystems

Changes in local weather conditions and advancing saltwater will alter relationships between nutrients, water, plants, and animals. Some species will migrate or die out, and others may encroach into new territory.

Buildings and Urban Systems

For coastal areas, rising seas can lead to higher groundwater levels and saltwater intrusion, which can compromise building foundations and aquifers. Heavier rainfall can overwhelm drains, gutters, and urban stormwater and sewer systems.

Communities with aging infrastructure, shrunken tax bases, and disadvantaged residents are particularly vulnerable. Poorly maintained drainage and sewage systems are more easily overwhelmed. Families struggling to make ends meet will have more difficulties preparing for and recovering from big storms. Hurricanes and other intense storms stress poor communities disproportionately, and climate change and rising sea levels will only exact greater costs in the coming years, especially for those living in low-lying areas that are particularly exposed.

Resilience is defined as "The capability of a strained body to recover its size and shape after deformation caused especially by compressive stress" (Merriam–Webster). At its simplest, resilience describes the ability to recover from or adapt to hardship or change.

In the context of cities and communities, events such as hurricanes, floods, and earthquakes can be catastrophic, taking lives and properties, causing billions of dollars in damage, and necessitating resource-intensive emergency response and recovery efforts that can drag on for years.

A resilient community is not completely incapacitated by acute shocks. A resilient community is able to maintain power and communications, as well as access to food and water. Businesses are able to resume activities and citizens able to resume their normal lives. A resilient community is also one that is able to thrive even as conditions around it change, and that can accommodate unpredictability and uncertainty (ecological resilience).

With climate change and sea level rise as defining factors for all coastal communities in the 21st century, resilience has become a critical concept for planning and infrastructure design. For St. Bernard, planning for climate change and sea level rise, and building resilience through efforts such as the Integrated Water Resources Management Plan, are critical to the well-being and safety of its residents.

Vulnerable and Valuable
Delacroix, at the eastern edge of the parish, is increasingly at risk for disruption from rising seas and extreme weather, yet remains an important center for commercial seafood and the economy of St. Bernard.
Photo courtesy Jonathan Henderson

Evacuating to Better Ground
During Hurricane Isaac in 2012, Plaquemines Parish residents evacuated upriver to be inside of St. Bernard's levee protection system.
Source: nola.com

Coastal Infrastructure at Risk
Oil storage tank platforms in coastal St. Bernard are vulnerable to flooding and wind damage, which could cause them to spill, rupture, or explode.
Photo courtesy Jonathan Henderson

Variety of Land Use and Ecosystems
In a limited area, St. Bernard Parish has a range of land uses in close proximity, including residential, industrial, and commercial, along with drainage canals, undeveloped forested areas, swamps, marshes, and open water.
Image courtesy of Jonathan Henderson, Vanishing Earth Advocacy + Consulting + Photography

2
EXISTING CONDITIONS

An understanding of how water flows through and across St. Bernard Parish begins with an understanding of the shape of the land, how that land was formed over time, the types of soils that are common throughout the parish, and how human activities have altered the landscape. This understanding, in turn, informs approaches to water resources management that are truly sustainable.

2a SOILS + TOPOGRAPHY

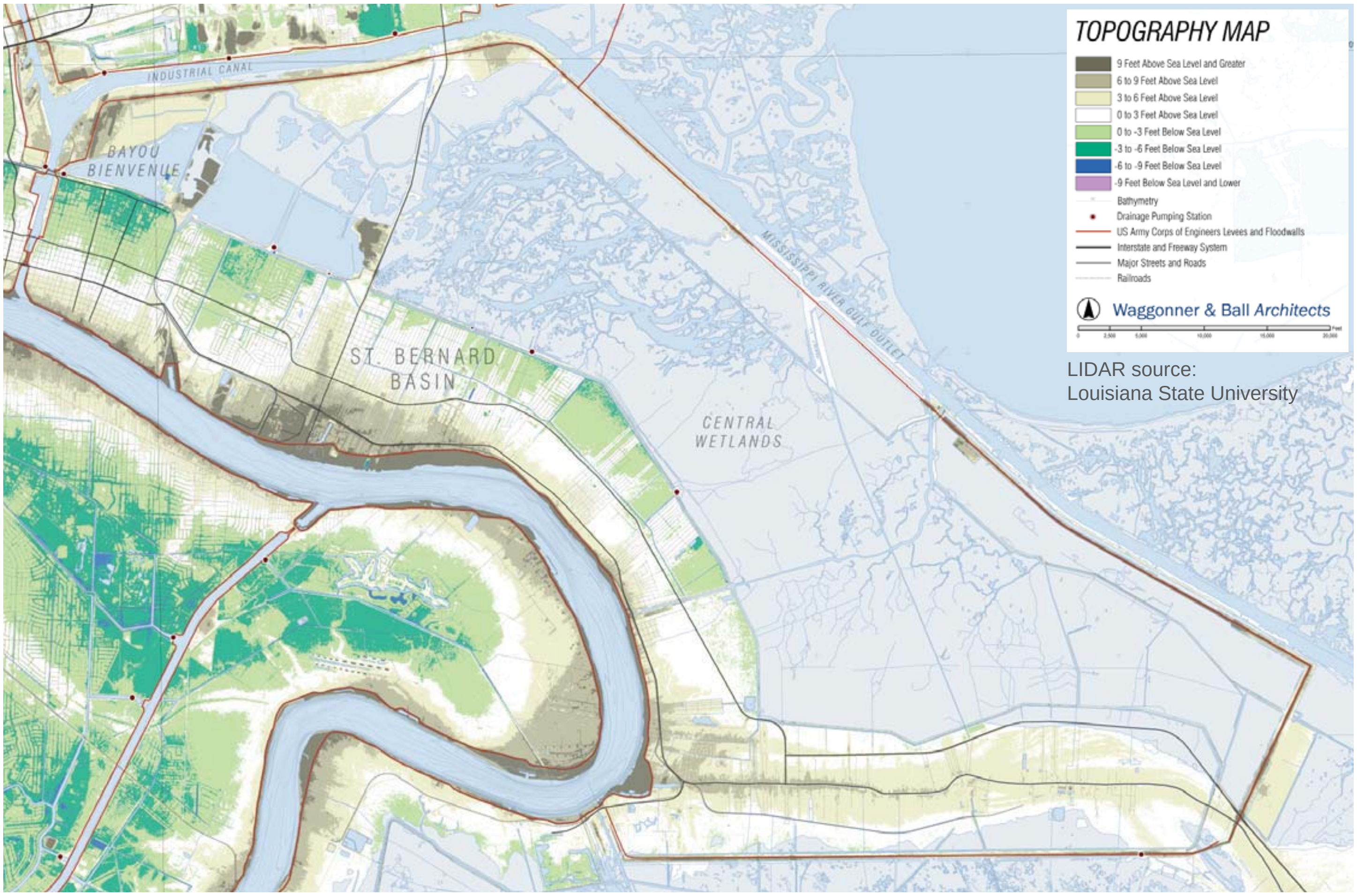
Building on Soft Ground
Layers of soil at a construction site near the 40 Arpent Canal. The organic matter in the soil is visible, and makes the soil more prone to subsidence.

Before the coordinated construction of artificial river levees, the Mississippi would regularly swell during each year with melting ice and spring rains, raising water levels until water and sediments from upstream would spill over the riverbanks and out into the surrounding landscape downstream. As these floodwaters flowed across bottomland hardwood forests and through the swamps and marshes of the delta, the heaviest soils would fall out closest to river. Finer sediments would settle out further away, as the floodwaters lost their velocity.

The characteristic high to low profile of the land as one moves away from the river and other waterways, and the distribution of different soil types, are both results of the physical properties of soils as they are carried by water. At the same time, the force of water flowing through a channel also exerts force laterally on the riverbanks. As the river meanders, water flowing around the outside of a curve carves away the land (cut banks), while depositing soils on the inside of the curve (point bars). Crevasses are more likely to form where the riverbanks are the weak, such as at a cut bank, where erosive force of water has undermined the natural levee. Water is also more likely to flow through sandy soil layers, which means sand boils, crevasses, and other disruptions are more likely to form where river water or water from the Gulf of Mexico is able to flow below ground and through sand layers that may have formed previously as a point bar or barrier island.

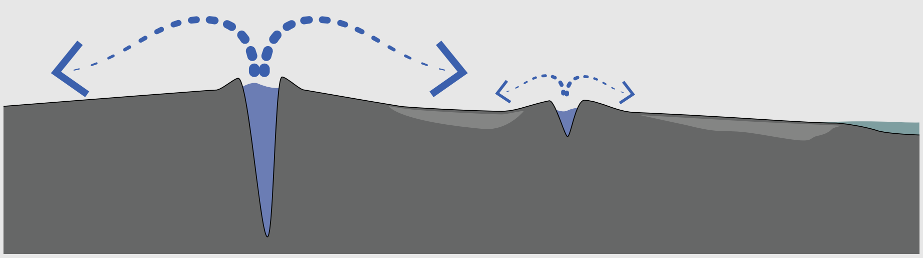
Present day topography reflects human-induced changes. The nearly complete elimination of overbank flooding has prevented the river from replenishing local soils with fresh sediment. Another big driver of change is modern drainage, which has allowed inhabitants to drain swamps for agriculture and new development. Draining wetlands lowers the water table and is a primary cause of subsidence (explained in further detail on following spread), which has resulted in a loss of elevation throughout the region, and in the low-lying parts of St. Bernard. Lower elevations mean that it is more difficult to drain urbanized areas, which means elevated flood risk.

Industrial facilities also contribute to subsidence, with groundwater extraction at the Entergy plant in New Orleans East, for example, dramatically lowering deep groundwater levels.

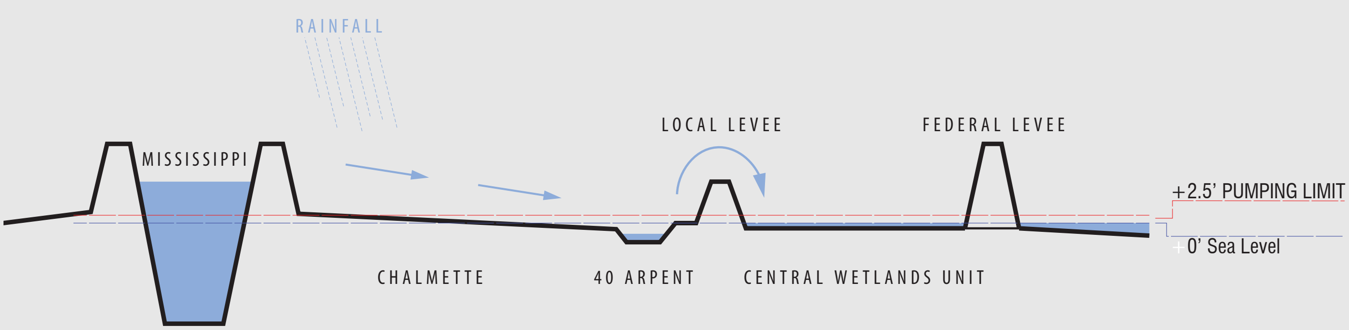


LIDAR source:
Louisiana State University

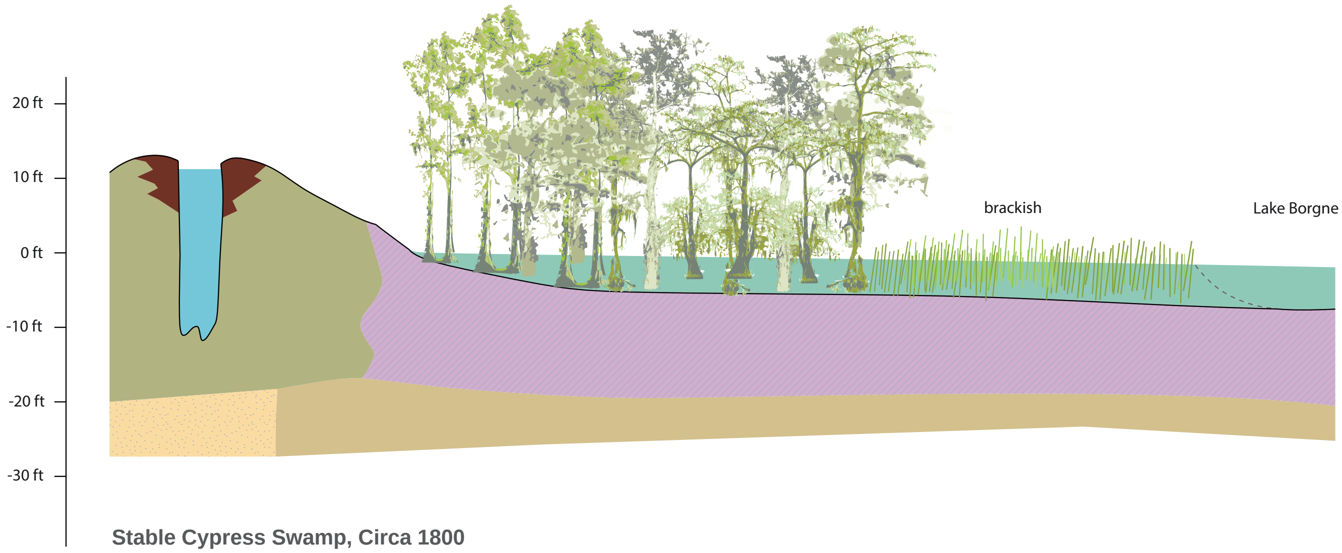
TOPOGRAPHY AND WATER FLOW



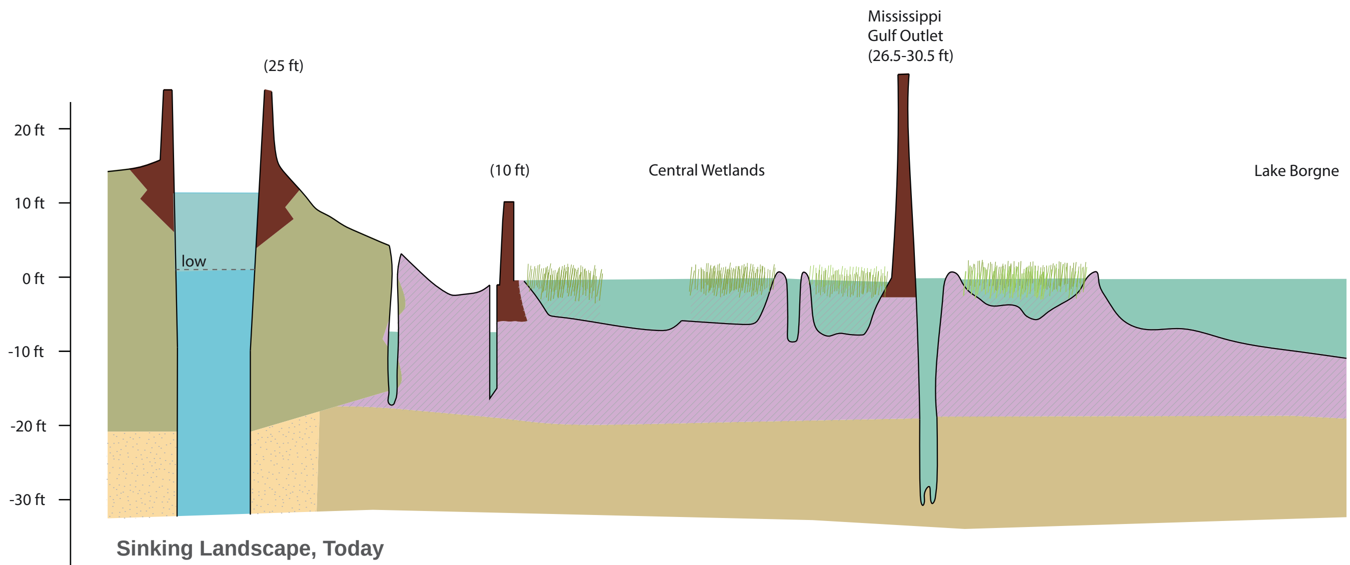
A Shifting Landscape
The construction of artificial levees along the riverfront and the installation of perimeter pump stations have reshaped the landscape of St. Bernard Parish into distinct hydrological basins. In the image to the left, blue arrows indicate the natural over-bank flooding that resulted in sediment deposits from the river and bayous.



Down, Back, Up, and Over
In contrast, the present-day landscape of St. Bernard is much more constrained, with levees and pumps shaping the flow of water. Rainfall hits the ground and follows the backslope away from the river's ridge, into the bowl, and then to the 40 Arpent Canal, where it is pumped over the local levee and into the Central Wetlands Unit.



Stable Cypress Swamp, Circa 1800
Just two centuries ago, most of St. Bernard Parish was a cypress swamp, with organic soils that remained stable because they had consistent groundwater levels, and transitioned into a brackish coast.



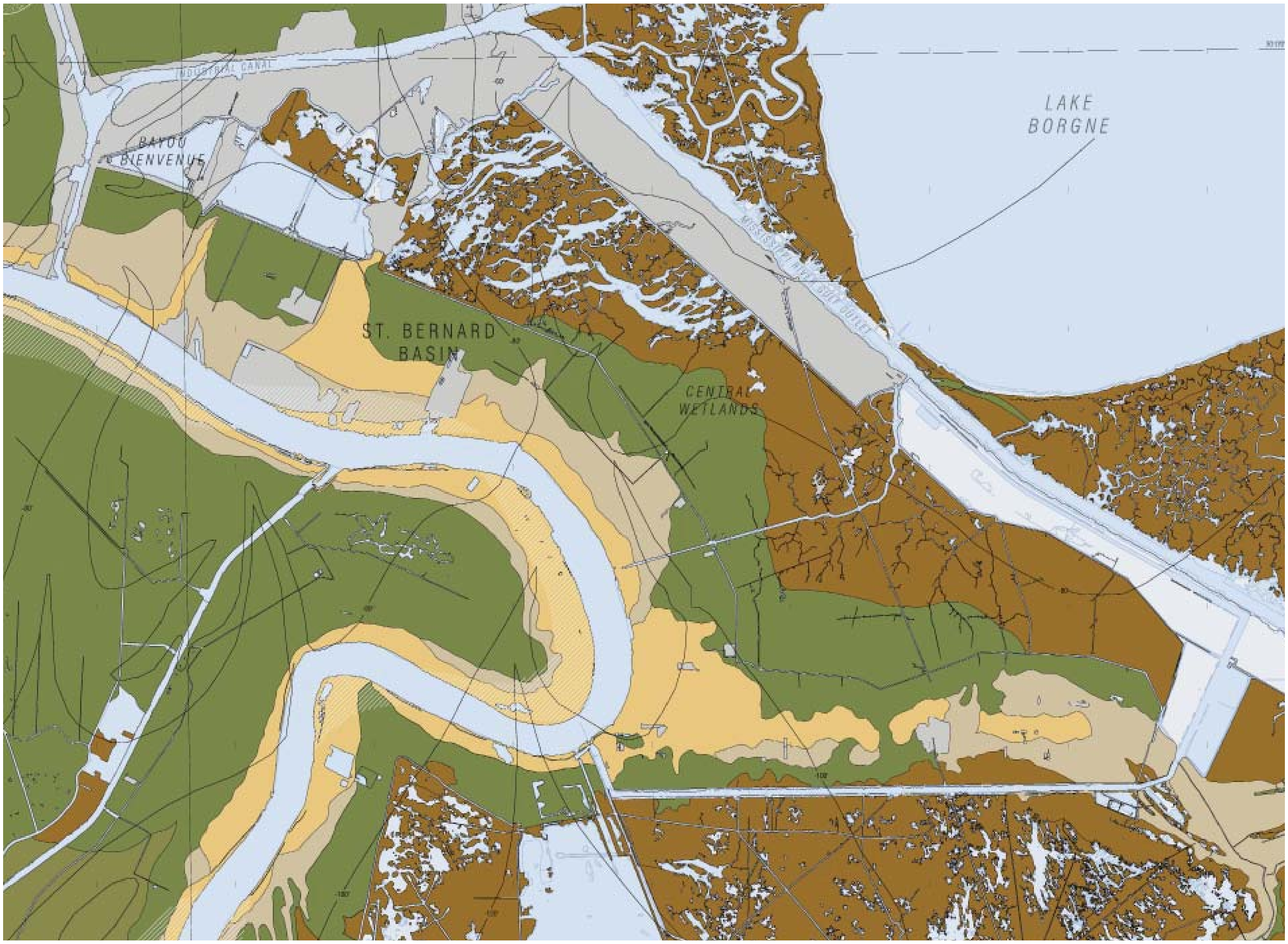
Sinking Landscape, Today
The existing drainage and flood protection systems divide St. Bernard Parish with canals and levees. One of the unintended consequences is unbalanced surface and groundwater levels, which is a cause of subsidence. The cypress swamp has been killed by logging and saltwater intrusion.

SUBSIDENCE

Subsidence is the sinking and compaction of land that occurs when organic soils dry out. Groundwater is water that flows slowly underground, keeping soil wet and stable by filling in spaces between soil particles. Soil oxidation is the decomposition and compaction of organic matter that occurs in the presence of oxygen. Oxidation is a primary cause of subsidence in St. Bernard Parish, in areas where highly organic soils with lowered water tables are exposed to oxygen.

While sand layers underlie large parts of St. Bernard Parish, the area's characteristic soil types are clay and muck. Clay particles are smaller than sand and drain poorly, and shrink and swell with fluctuations in moisture content. Muck is the fertile but highly organic soils that exist in drained wetlands, which characterizes much of the region's inhabited areas. Mucks are soft, unstable, and must remain saturated to prevent compaction and oxidation, which causes subsidence through the irreversible loss of organic matter in soils (Independent Levee Investigation Team, 2006).

The mass and imperviousness of asphalt and concrete can be unstable on top of clay, while running fragile utilities through sinking muck poses difficult engineering challenges. Subsidence affects the stability of building foundations, roads, sidewalks, utilities, and levees.



Clay

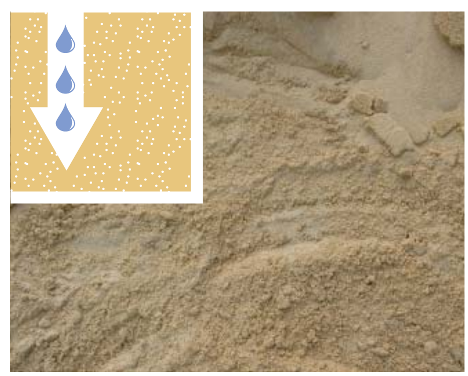
Sand

Muck

Sand/Clay Mix

Artificial Fill

Federal Levee



Muck
Formed through the artificial drainage of swampland, muck may contain larger decomposing organic elements ranging from cypress stumps to shells. Mucks provides poor drainage and poor retention capacity, and are especially prone to subsidence.

Clay
A variety of clay soil types make up the areas closest to the banks of the Mississippi and its associated tributaries and distributaries. Clay soils are fine grained, with small air pores, and are typically poorly drained. They may contain varying amounts of organic material.

Sand
Sandy soils consist of larger-grained particles, which give sand layers the best drainage characteristics that are available in St. Bernard Parish.

The inhabited landscape alternates between urban areas, suburban residential areas, and open spaces. The balance of land covers and land uses shifts as one moves downriver, from the parish line shared by St. Bernard and Orleans towards the Violet Canal and Lower St. Bernard.

2b LAND USE AND LAND COVER

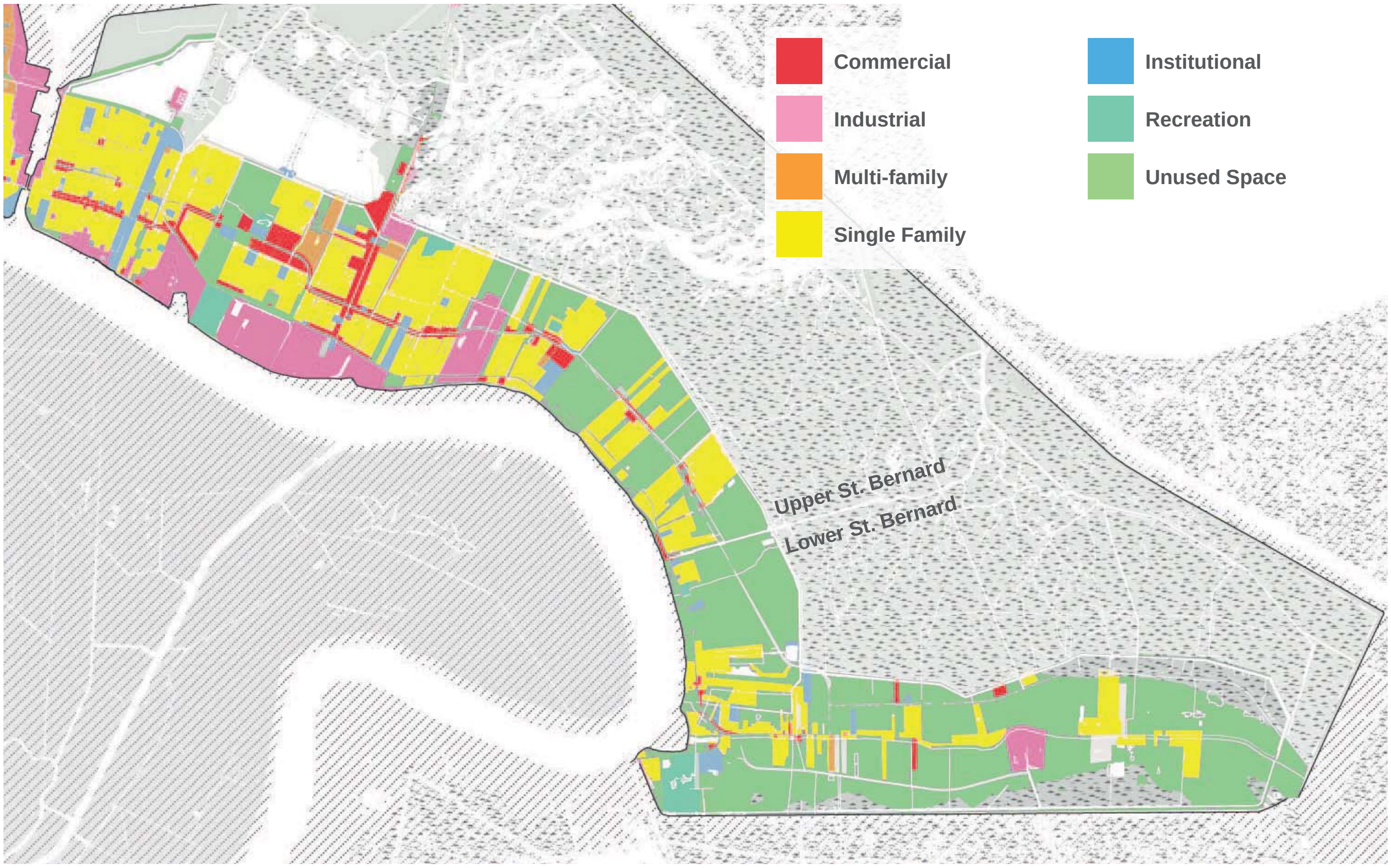
Contrasting Land Uses and Landscapes
Residential subdivisions in Chalmette adjacent to the Murphy Oil Refinery, with oil spill buffer zone in the vacant lots between, and the Central Wetlands Unit in the background.

Land use and land cover are directly related, and land use is often a good proxy for land cover, where land cover data is not available. The first specifies the activities that are common to an area, while the second refers to the materials and vegetation that characterize an area. Residential, single family neighborhoods are more likely to have lawns and trees, for example, whereas commercial strips and industrial areas are more likely to have large areas of impervious surfaces. This means that areas with high concentrations of commercial and industrial uses are likely to have higher rates of runoff, which means that they place a greater burden on the parish's canal network.

Arabi and Chalmette are more densely populated, with large concentrations of commerce and industry. In Meraux, Violet, and Lower St. Bernard, smaller residential areas and strip developments are interspersed with large undeveloped or agricultural parcels, some of which are slated for development.

Large parts of the parish consist of suburban style residential areas, with single family homes, and a handful of townhomes and apartment complexes. The lower-density suburban development is more common as one moves away from the river. In low-lying areas, there are also swaths of green space because of the many vacant parcels that have not been reoccupied since Hurricane Katrina.

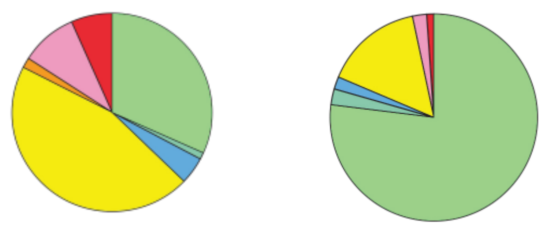
Most industry is situated along the riverfront, and many of these are largely paved and inaccessible areas. Commercial activity is concentrated along Judge Perez Boulevard, St. Bernard Highway, and Paris Road. Automobile-oriented development along these three primary corridors has resulted in large parking lots, wide roadways, and other forms of impervious surfaces that generate large volumes of stormwater runoff. While commercial activity can be found along these corridors and especially in Arabi and Chalmette, there has never been a real downtown core or historic main streets. While creating higher density and more pedestrian-friendly "smart growth" patterns may be desirable for environmental and transportation purposes, doing so in St. Bernard runs somewhat counter to historic patterns of development, and will require new approaches to land use policy and development that are tailored to the specific needs of a long, linear parish where density varies greatly from one mile to the next, and from Upper St. Bernard to Lower St. Bernard.



Existing Land Use
Most of St. Bernard's developed land is residential, followed by industrial and commercial uses, yet a significant area remains undeveloped.

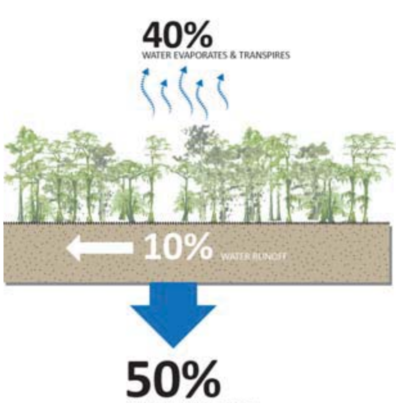
Existing Characteristics
- Low density residential areas in several clusters throughout parish
- Large areas between are undeveloped
- High level of vacant lots in low-lying areas near 40 Arpent Canal
- Predominantly modern, suburban style development
- Major thoroughfares designed for automobile use only

Land Distribution

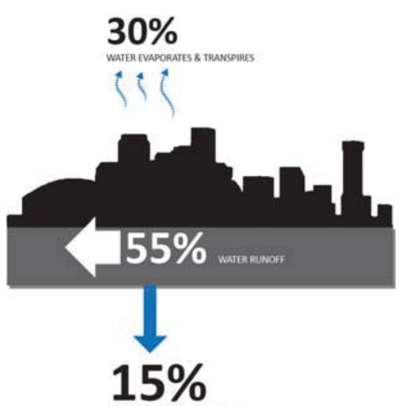


Upper St. Bernard | **Lower St. Bernard**

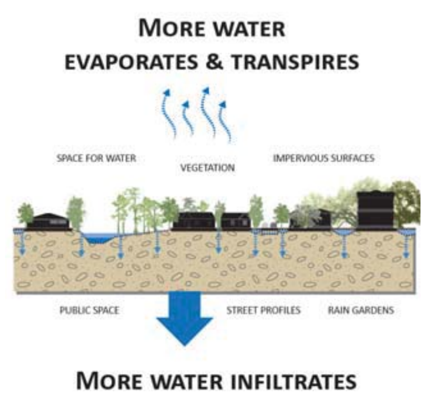
Ground as Sponge



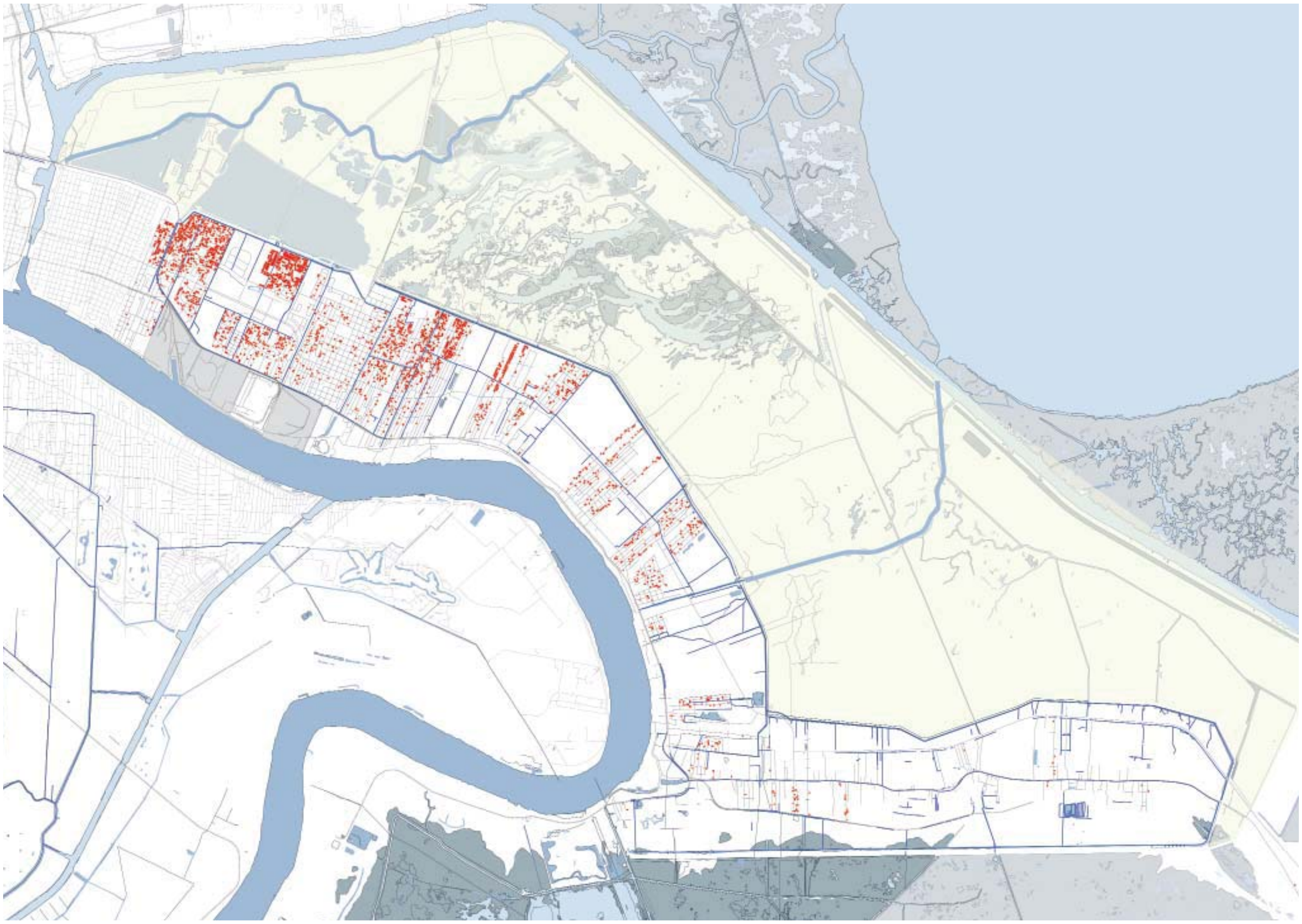
Natural Landscape
Soil and vegetation naturally absorb 90% of rainfall through infiltration into the ground and evapotranspiration into the air and have adapted to the wet environment.



Hard Urban Surfaces
Rooftops and paved surfaces shed water. Developed areas are responsible for over five times the runoff from non-urbanized landscapes of the same size.



Ground as a Sponge
In an integrated living water system, pervious paving, trees, plants, and other soft infrastructure allow the ground to slow, filter, and absorb runoff.



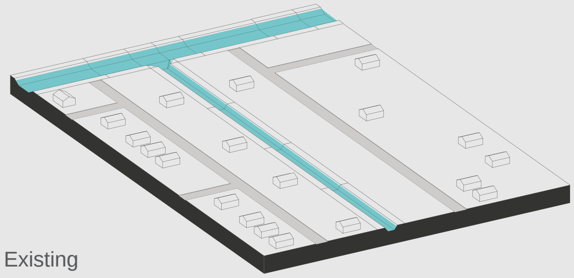
Potential in Vacant Properties
Reducing flood risk requires space and time. The red dots above indicate publicly-owned vacant parcels. After Hurricane Katrina, the parish owned over 4,000 such parcels. This means that even in urban areas, significant amounts of open space are available for water management as well as development.
Data source: St. Bernard Parish Government

Post-Katrina tree loss
Areas most affected by flooding in 2005, such as low-lying “bowl” areas close to the 40 Arpent Canal, lost 80-90% of their canopies, such as in this Arabi neighborhood before (left) and after Katrina (right).

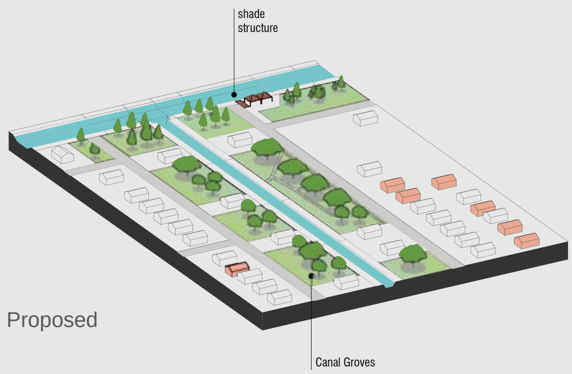
LLT VACANT LOTS

Working closely with the Parish government, Waggonner & Ball mapped the 4,000+ Louisiana Land Trust (LLT) vacant properties in St. Bernard Parish after Hurricane Katrina, and developed strategies and a re-utilization plan to foster recovery and growth in these unused parcels.

Key strategies to improve the vacant lots are to incorporate the creation of amenities such as pocket parks and community gardens into the homebuilding process, to expand the parish drainage system's stormwater capacities, to improve neighborhood aesthetics by planting trees along canals (at right), and to bolster the local economy by dedicating open space along the 40 Arpent Canal to recreational, agricultural, ecological, and educational uses. Remaining LLT lots have great potential as pilot project sites for integrated stormwater management.



Existing



Proposed

The shape and arrangement of neighborhoods in St. Bernard reflect the arpent pattern of development that was common to southeast Louisiana during the colonial era. Long strips of land stretching from the Mississippi to the wetlands have been subdivided to create the many residential developments that are connected by St. Bernard Highway and Judge Perez Drive.

2C NEIGHBORHOODS

Hidden Backbone of Neighborhoods
Canals run through many residential areas throughout St. Bernard but are overlooked as potential public spaces for circulation and recreation.

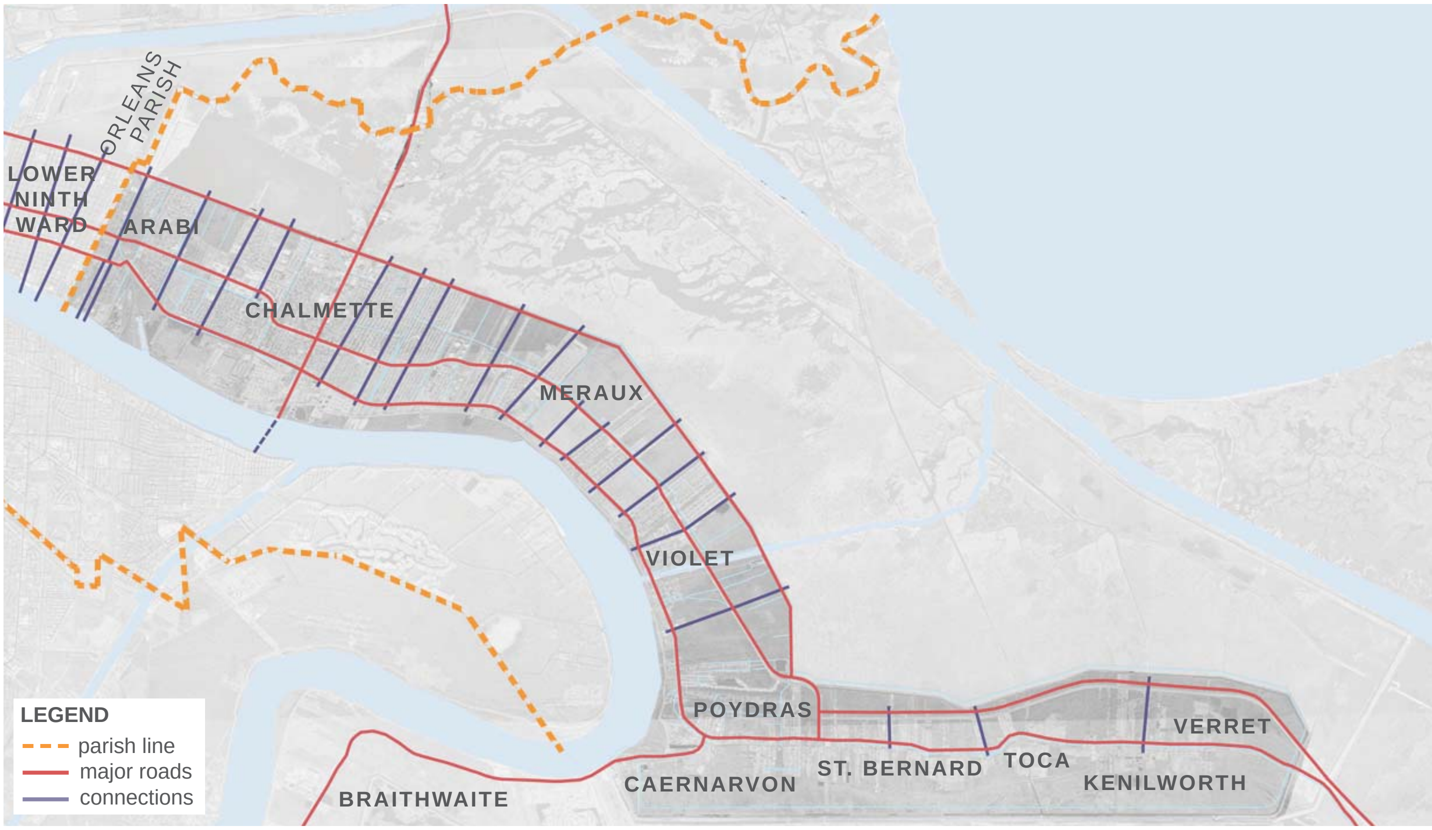
The parish exists as a series of neighborhoods strung along the major longitudinal corridors of Judge Perez Boulevard and St. Bernard Highway. Some neighborhoods have distinct boundaries and identities, such as Old Arabi. Other neighborhoods are merely subdivisions, houses arrayed along isolated roadways, with no lateral connections to other subdivisions to other subdivisions and with institutions and businesses reachable only by car. The result is a parish that is almost completely automobile dependent.

Arabi was formerly part of New Orleans area, and is rich with historic architecture. And because of parish-led revitalization efforts and because of its proximity to the Ninth Ward, Bywater, and Marigny, Arabi is beginning to see development and an infusion of artists and other new residents and commerce.

Chalmette is very much the core of the parish, with key civic facilities, major roadways, heavy industry, and big box stores, and the highest number of residents concentrated here. Meraux and Violet are more agricultural in feel – as one drives downriver, space opens up, anchored by Violet Canal and Meraux properties, fields, groves, and scenic, oak-lined roadways.

The distinction between Arabi and Chalmette is no longer as clear, but the large unpopulated and undeveloped parcels between Chalmette, Meraux, Violet, and Poydras support the more rural feel and distinctive feel of neighborhoods that is so important to parish residents and to the overall identity of the parish. In contrast to the denser urban fabric of New Orleans, there is a sense of openness and space that is common to neighborhoods in St. Bernard.

An objective of the IWRM plan is to enhance the identity of individual neighborhoods, while also improving connectivity between neighborhoods, especially along the lines of water infrastructure (e.g., canals and levees) that are already vital to the functioning of the parish.



Subdivisions, Neighborhoods, and Identities

Top: Map of towns and settlement in St. Bernard Parish

Left: 20th century urban and suburban development in St. Bernard has contributed to both sprawl and fragmentation of the landscape, with numerous subdivisions platted in piecemeal fashion, with little regard for connectivity, public space, or any sense of a shared landscape.

Above, left: Historic Old Arabi near the Mississippi River

Above, right: Typical suburban street in Arabi

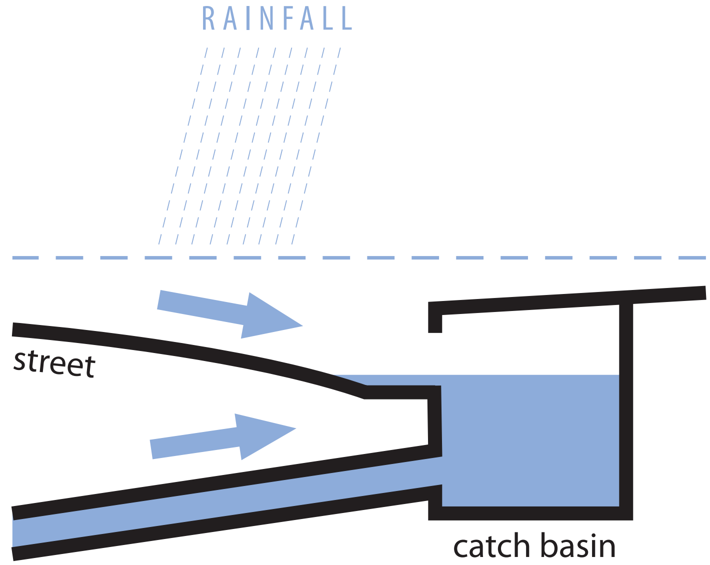
Stormwater runoff becomes a public responsibility when it leaves private properties and enters the street. Water flowing along parish roadways enters into gutters and storm drains, and from there into the parish's drainage canals. Sewer lines, drinking water lines, and other utilities also run beneath the streets. Because streets are publicly owned, and because they are vital to the function of the parish's water systems, new approaches to designing and managing streetscapes are critical to integrated water resources management and long-term planning.

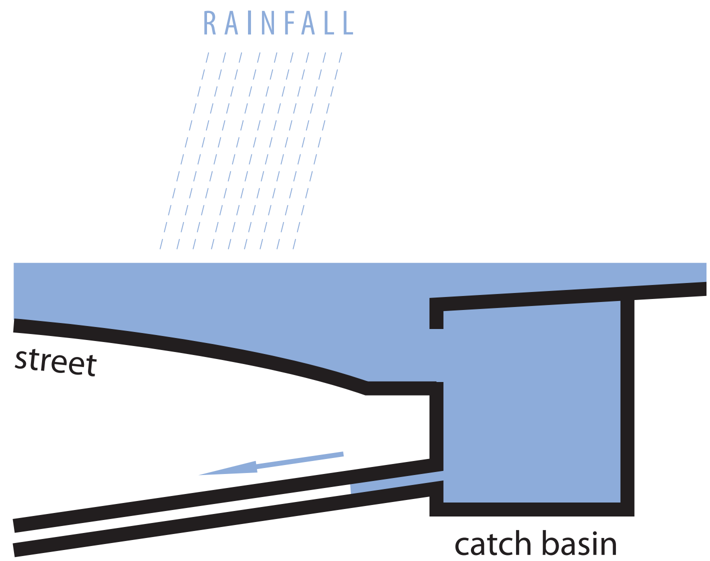
2*d* STREETS

Multifunctional Roadways
Streets are for moving vehicles and can also convey stormwater, with catch basins and large swales that connect to the drainage system, as in this neutral ground on Jean Lafitte Parkway.

Streets are fundamental to urban infrastructure, not just for transportation, but also as the right of way for utilities, including stormwater, drinking water, and sewer pipes. In urban areas, the flow of water is governed by the street grid, as stormwater collects in gutters and catch basins and flows into small pipes that direct water towards drainage canals, typically located between neighborhoods. Streets also comprise large impermeable areas, and the parking lots that connect to roadways add to that total. Water that hits the asphalt or concrete of the parish's roadways and parking lots immediately becomes runoff. Little of it is able to soak into the ground, to the detriment of the groundwater balance and soil stability. And especially at the beginning of a rainstorm, this runoff (known as the first flush) is oftentimes polluted because of all of the oil, debris, and other contaminants found on roadways that are washed away and into local canals and local wetlands.

The design of each street also determines the look and feel of a neighborhood. Streets that are tree-lined, for example, are more attractive and absorb more stormwater. Houses that front tree-lined streets often have higher property values. In contrast, streets with no trees or other vegetation contribute to the urban heat island effect, which raises ambient air temperatures. Signage, lighting, sidewalks, street furniture, parking infrastructure and other aspects of the street can make the difference between a welcoming urban environment that supports public activities, and one that is inhospitable and unsafe for everyone except motorists.





The two diagrams above shows two forms of flooding common in urban areas. At the top, a system backs up and water entering a catch basin has nowhere to go. Below, the catch basin and pipe draining an area are too small to accommodate the volume of water attempting to enter the system.

The images to the left track the flow of stormwater: rain hitting the roof of a building: hitting the roof of a building, then into the gutter and downspout, then as runoff onto grass or impervious surfaces, then flowing into catch basins at the curb or in the street, which connect to a canal or underground drainage pipe.

Replacing pipes and drains with larger pipes and drains can solve some flooding problems, but these solutions are far more expensive than retention features and other "green infrastructure" measures that reduce runoff volumes.

Curb to Canal
A catch basin directs runoff into an underground pipe in the sloped bank, which flows out of the exposed pipe into the canal just a few feet away.

Function Over Form
St. Bernard's drainage infrastructure is designed to move water quickly away from inhabited areas, but provides little in the way of aesthetics.

Smaller Scale Parking
Smaller paved areas with large curb cuts directly off roadways in St. Bernard increase runoff into streets and can also create dangerous conditions for drivers, cyclists, and pedestrians.

Each street should be thought of as integrated system serving multiple user groups. Currently, though, each system embedded within the street is thought of separately. In St. Bernard, the automobile has long driven land use decisions and also the design of streets, to the detriment of other needs and non-motorists. Investments in enhancing the street grid for water management purposes can have a positive impact on transportation safety, quality of life, and commercial activity as well, as long as those enhancements are conceived of as part of an integrated approach to street design.

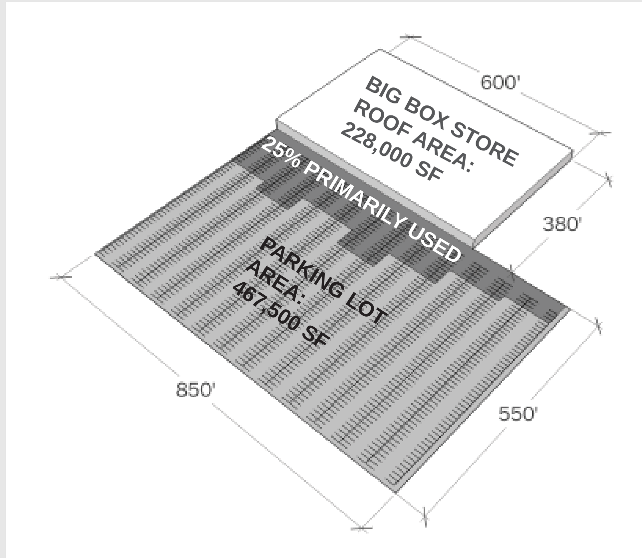
PARKING LOTS

Parking lots – especially large ones that are characteristic of big box stores, institutions such as schools and hospitals, commercial strips, and also industrial areas – are responsible for some of the highest volumes of runoff in St. Bernard. Finding ways to mitigate this runoff through water detention and retention would benefit the rest of the parish.

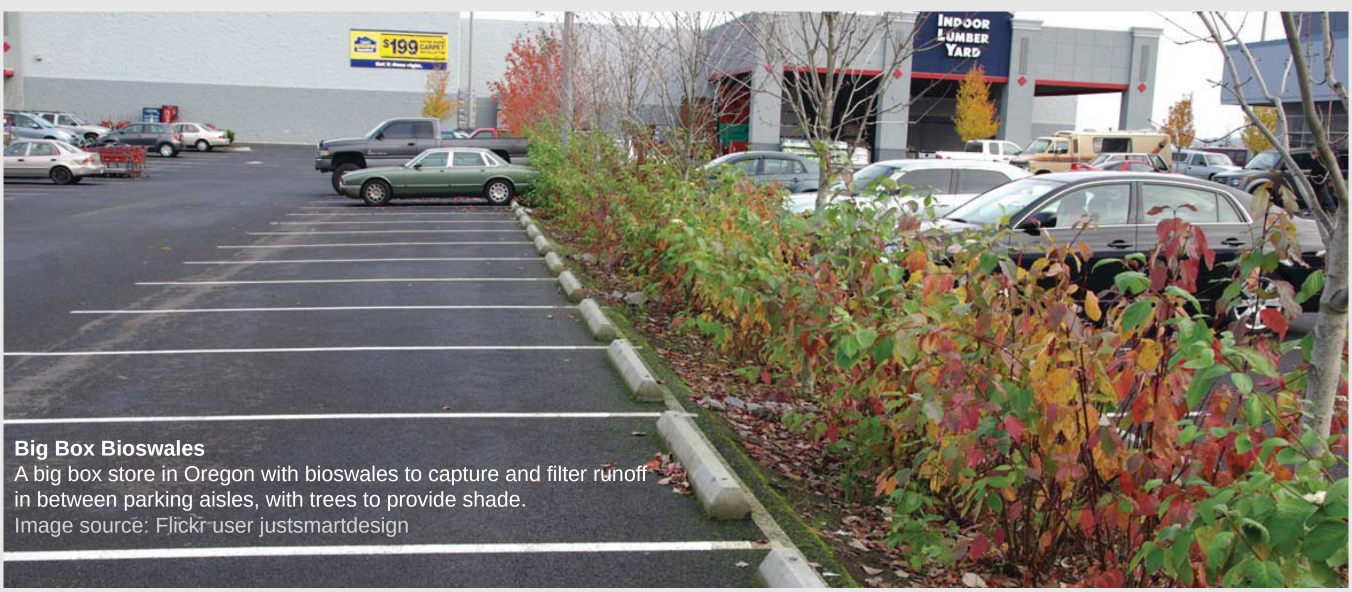
These large areas are also some of the most underutilized land; parking lots are sized for peak demand, which for a big box store would be shopping around the holidays, but this condition is only reached a few times a year. For a typical big box store, as little as a quarter of the parking lots sees heavy usage. Changing parking requirements and enhancing shared parking throughout the parish can reduce the amount of hardscape dedicated to parking.

Furthermore, parking lots are significant sources of the urban heat island effect, which raises ambient air temperatures, and often lack vegetation, which exacerbates the problem. Streets and parking lots also create water quality issues due to deposits and pollutants that are washed off of asphalt and concrete surfaces and carried into the drainage system by runoff, and then into canals and wetlands. Parking lots large and small also typically lack safe circulation areas for pedestrians, such as sidewalks or marked walkways.

Integrated design of a big box store parking lot accounts for runoff volume and water quality impact, urban heat island effect, ecology, and aesthetics.



Big Box, Big Runoff
A big box store in Chalmette with a parking lot sized for the limited peak shopping season. Impervious surfaces direct large volumes of water into catch basins, which can overload the drainage system.



Big Box Bioswales
A big box store in Oregon with bioswales to capture and filter runoff in between parking aisles, with trees to provide shade.
Image source: Flickr user justsmartdesign

St. Bernard has a backbone canal system – canals draining different neighborhoods connect to the 40 Arpent Canal, which runs along the northern edge of the parish. These canals form a critical network, and provide significant opportunities for enhancing the parish's stormwater management practices, for improving groundwater balance and soil stability, for new recreational amenities, and for strengthening the identity of the parish.

2e CANALS

Missed Opportunities
The typical canal condition in St. Bernard: low water levels, exposed outfall pipes, unstable banks, and encroachment by adjacent properties, all of which create a negative perception instead of a good public space.

Storm drains and pipes feed into canals, which constitute the next level of the drainage system and are also important features in the landscape. Many serve as boundaries between neighborhoods, dividing lines that are difficult to cross. In most cases, buildings turn their backs on the canals -- there is little visual or physical access.

Often unsightly, canals are treated and understood more as ditches that need to be covered over as soon as funds allow rather than as beloved assets that need to be properly maintained, celebrated and used by citizens. Exposed outfall pipes, and canal banks that are barren and steep reinforce negative perceptions. In addition, the water quality is often poor, with stagnant water and invasive species such as the water hyacinth prominent during the warmer months. Canal water levels are also kept low so that there is storage capacity in anticipation of rain events. This lowers the water table for surrounding areas, however, which is a primary cause of subsidence.

Canal banks are often sloughing in, with encroachment by homeowners exacerbating conditions. Nick Cali of the Lake Borgne Basin Levee District attributes this to a result of a lack of understanding of the importance of canals and their role in keeping communities safe – people will dump trash in canals, not realizing this can cause flooding. Encroachment means, too, that the canals are difficult to access. Where the canal is accessible and beautiful, like the 40 Arpent, boating is not allowed, though this is starting to change with the construction of the boathouse in Chalmette.

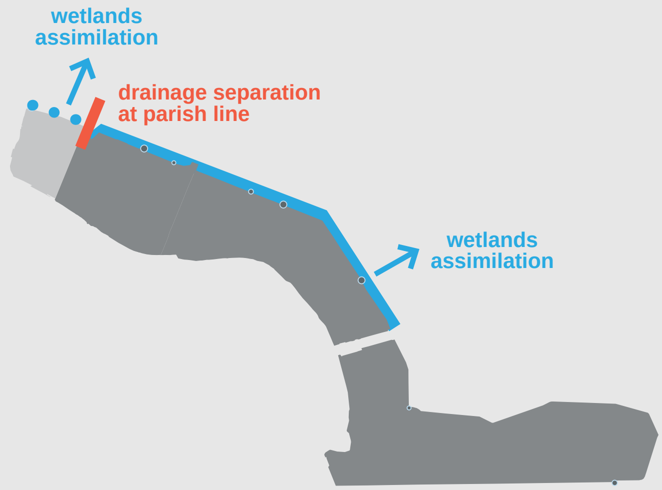
As part of the drainage system, canals take water from streets and neighborhoods and convey it downstream to the backbone 40 Arpent Canal. From there, pump stations lift water out of the 40 Arpent and up and over the levee into the Central Wetlands Unit. The capacity of the drainage system is determined by the size of these canals and the pump stations – the Parish maintains "freeboard" or space in the canal in order to provide room for water when it does rain . The effect of keeping water levels low, though, is continued subsidence, as the water table in surrounding areas is drawn down to the level of the water in the canals.

Connectivity and free flow between canals in St. Bernard's system provides redundancy, so that canals and pump stations throughout the parish can support each other. During Hurricane Isaac, one pump station that was being repaired was not used; this was fine because water is able to flow from one part of the parish to another to be drained, which is provides benefits and more opportunities to the parish.

PARISH LINE CONNECTION

Stormwater that falls on the St. Bernard basin is managed separately, by the Sewerage & Water Board on the Orleans Parish side and by the Lake Borgne Basin Levee District on the St. Bernard side. The two systems were disconnected for political reasons in the 1980s. What exists today are overgrown ditches and stagnant water separated by a dirt road.

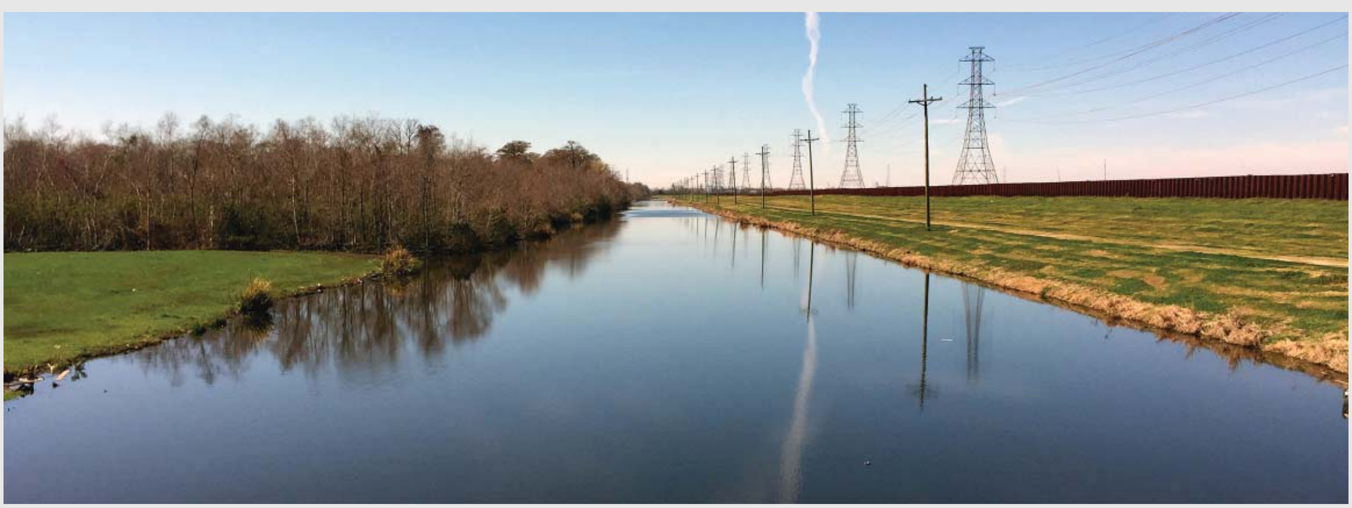
Reestablishing this connection would benefit both parishes by allowing water to flow more freely between the two parishes, and provide a measure of redundancy in case pumping stations fail. Just as levees are correctly understood as a regional concern, water should also be managed regionally. The effort to develop more wetlands assimilation in both parishes, currently in planning, shows some of the possibilities of inter-parish collaboration.



The Same Water, the Same Basin
The Lower Ninth Ward (light gray) of New Orleans is within the St. Bernard Basin, but drainage canals between the two parishes are cut off at the political boundary

Disconnected Systems
The rear canals of both St. Bernard and Orleans Parishes used to connect, but today the mostly subsurface Florida Canal in the Lower Ninth Ward emerges as a ditch and is cut off at the parish line.

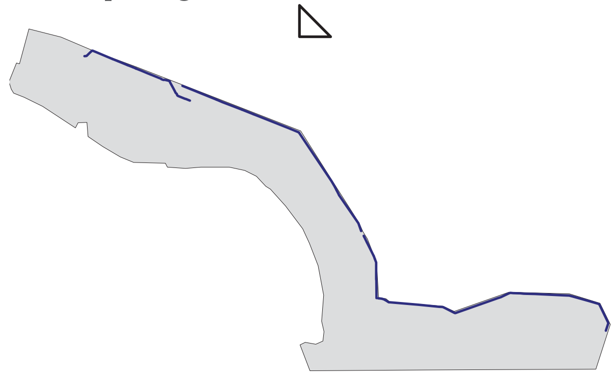
Rebuilding the Bayou
Aerial view of wastewater treatment plant in New Orleans near the parish line, which will be a source of treated sewage effluent to restore cypress swamp habitat in Bayou Bienvenue in Orleans Parish.



Backbone of the Parish
The 40 Arpent Canal is the backbone and the largest part of St. Bernard's canal system, and has the potential to be an even more attractive and useful waterway useful waterways, for both recreation and to connect people across the parish and to the Central Wetlands Unit.

40 ARPENT CANAL

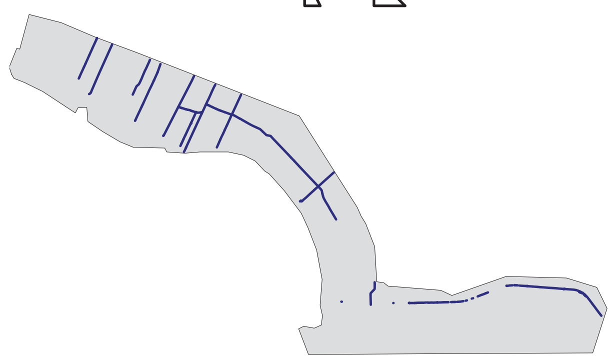
channel width: 85'-100'
right of way width: 130'-170'
bank slope range: 1:1



Mapped Locations in Basin

CANALS

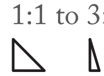
channel width: 30'-120'
right of way width: 60'-140'
bank slope range: 2:1 to 1:1

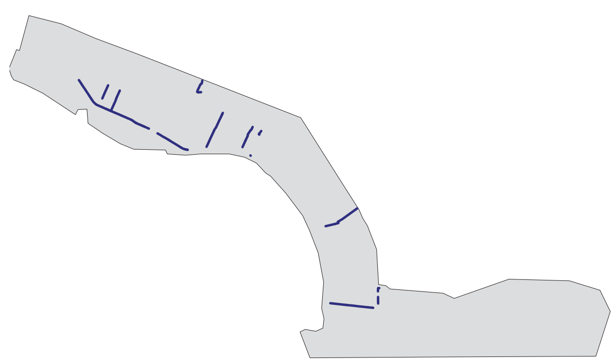


Mapped Locations in Basin

DITCHES

channel width: 6'-30'
right of way width: 10'-65'
bank slope range: 1:1 to 3:1





Mapped Locations in Basin

WATER ELEVATION

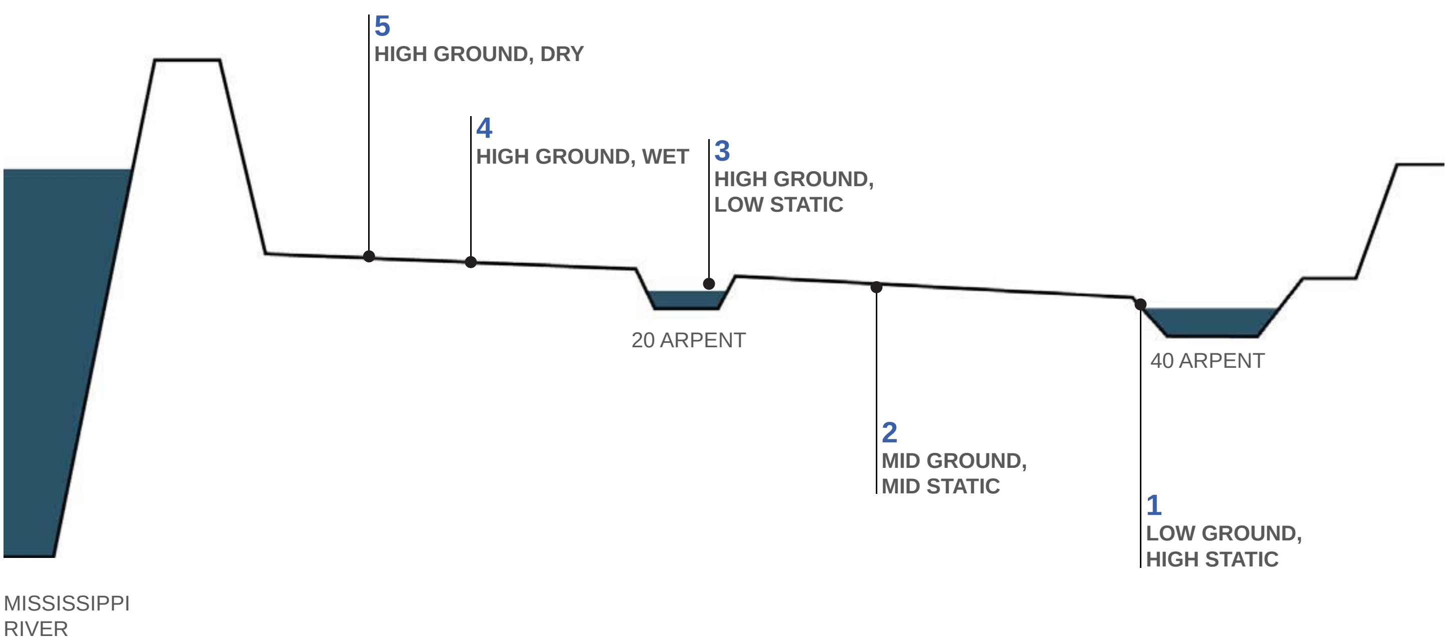
1. Low Ground Elevation, High Static Water
Land areas near the 40 Arpent / Florida Canal and the undeveloped parcels in the lowest lying land in the polder, 3-5 feet below sea level. Static water level of canals is close to adjacent ground, 2-3 feet of freeboard.

2. Mid Ground Elevation, Mid Static Water
Land areas generally north of Patricia and Genie Streets, 1-3 feet below sea level. Static water level of canals is 4-6 feet below adjacent ground level.

3. High Ground Elevation, Low Static Water
Land areas generally near Judge Perez and at the 20 Arpent Canal. 2 feet above to 1 foot below sea level. Static water level of canals is very deep, 6-9 feet below adjacent ground level.

4. High Ground Elevation, Wet
Areas generally near St. Bernard Highway and in Old Arabi. Canals and ditches slope away from the river with a static water level 2-6 feet below adjacent grade.

5. High Ground Elevation, Dry
Areas generally close to river and along St. Bernard Highway. Swales, ditches and canals are generally dry, 2-4 feet below adjacent land.



ADJACENCIES

Road || Road

Public right-of-way with roads or streets on either side of a canal.

Road || Open Land

Public right-of-way with roads or streets on one side of a canal with undeveloped land or vacant site on the opposite.

Open Land || Open Land

Undeveloped land or vacant site adjacent to canal.

Building || Open Land

Backyard condition or building adjacent to canal with vacant lot opposite. Limited public right-of-way and access to canal.

Building || Road

Backyard condition or building adjacent to canal with road or street opposite. Limited public right-of-way and access to canal.

Building || Building

Backyard condition or building adjacent to both sides of canal. Limited public right-of-way and access.

Building || Building
Canal with residential buildings on either side and limited access, typically fenced off and treated like a backyard.

Road || Road
Canal with roadways on either side, usually lower traffic streets, which extends the right of way into a wide, yet inaccessible, public space.

EDGE CONDITIONS

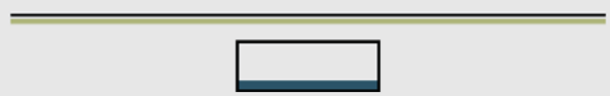
Shallow Slope
Canal bank with a gradual slope that is accessible to pedestrians and friendly to flora and fauna.

Steep Slope
Canal bank with a steep slope. This is the typical condition of the canal banks in the parish. Banks are inaccessible, easily eroded and difficult to establish plantings other than turf grass. These are sometimes reinforced with geo-textiles or concrete.

Retaining Wall
Wood, steel, or concrete bulkhead. Common in commercial areas and in some backyard conditions.

Flume
Wood, steel or concrete retaining wall. Common in commercial areas and in some backyard conditions.

Culvert
Typically concrete-sided box or pipe that runs beneath roadways or other surfaces. Pipes can also be made of metal or plastic. Common in urban areas where automobile traffic and development are prioritized.



Culvert
Concrete tunnels for water that are typically connect canals underneath roadways.

Steep Slope
Typical canal in St. Bernard, with a trapezoidal section, and oftentimes unstable banks that provide little public access.

Stormwater flows by gravity through the parish's drainage canals down towards the 40 Arpent Canal. Pump stations situated along the 40 Arpent Canal lift that water up and out into the Central Wetlands Unit. These pumps are vital to the safety of St. Bernard residents, but refinements to their operation can help reduce costs and energy expenditures in the long term, while improving groundwater balance and slowing the rate of subsidence.

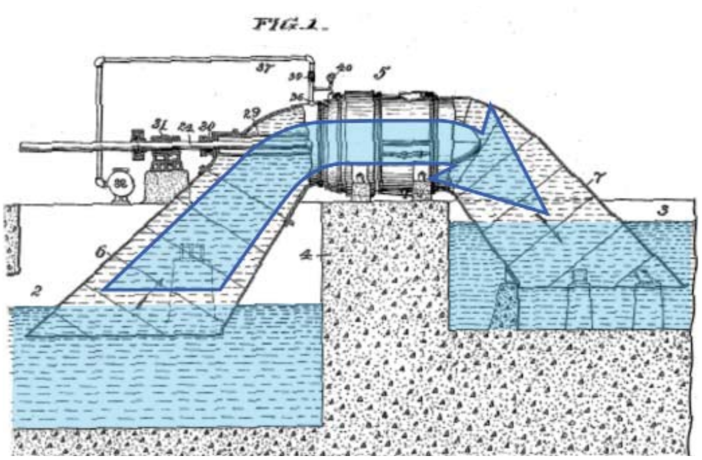
2*f* PUMPS

St. Bernard's drainage pump stations are located along the parish's 40 Arpent Canal, which serves as a backbone for the parish's entire canal network. The pump stations are able to lift large volumes of water out of the canal, over the local levee, and into the Central Wetlands Unit. Without these pumps, stormwater would collect in low-lying areas, trapped behind the levee, and flood large portions of the parish. The importance of pumps only increases as low-lying areas sink further due to subsidence.

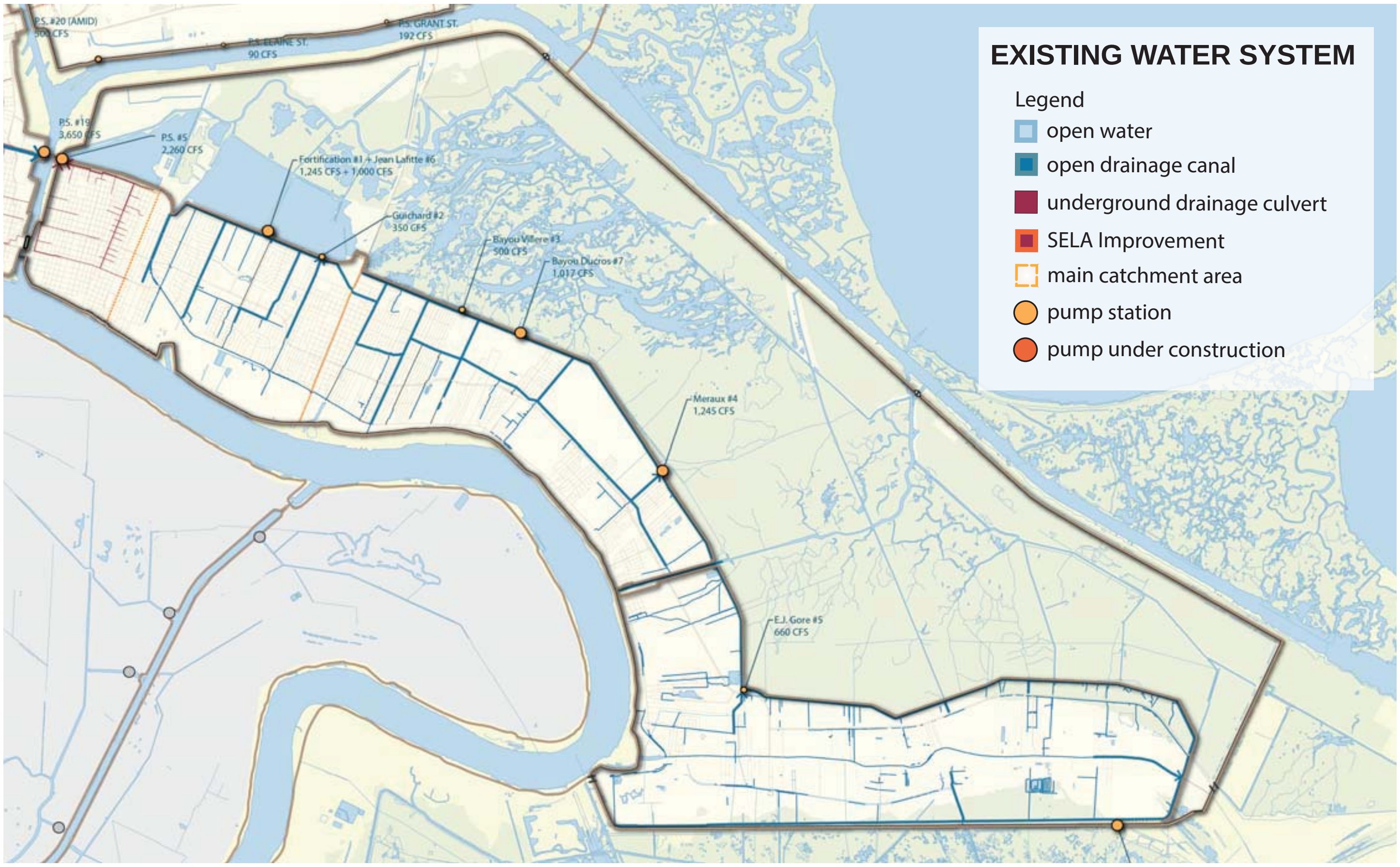
The parish's pumps typically have pumping capacities ranging from 300 cubic feet per second (CFS) to over 1,000 CFS. A pump with a 1,000 CFS capacity can empty an Olympic-sized swimming pool in less than 90 seconds. In advance of big storms, the Lake Borgne Basin Levee District (LBBLD) begins running the pumps in order to draw down water levels in the 40 Arpent, which lowers water levels throughout the canal network. In this way, the LBBLD creates greater storage capacity within the canal network. The 40 Arpent also provides redundancy, in the sense that the pump stations arrayed along the canal can support each other in case one pump station fails.

The parish's levees and pumps reorganizes the flow of freshwater – instead of soaking into the ground, or sheeting off and distributing across the landscape, directing stormwater to the 40 Arpent Canal and pumping it into the Central Wetlands Unit concentrates freshwater at a few points, which changes the salinity gradient within the Central Wetlands Unit. This is especially apparent at the E.J. Gore Pumping Station, where the pump station provides a source of freshwater that has supported the growth of a healthy stand of cypresses in an environment that has generally been brackish and unable to support cypresses in other areas.

The LBBLD is tasked with maintaining the parish's canals and pump stations. The LBBLD, however, is also tasked with maintaining the St. Bernard portion of the federal levee system, so that it is simultaneously responsible for surge protection and for interior drainage. The LBBLD relies on a shrunken tax base, and is consequently under-resourced and under-staffed, with constant budget shortfalls and only one engineer on staff. Finding ways to reduce runoff volumes and combat subsidence is critical not only for reducing flood risk, but also for reducing the burden on the LBBLD and the pump stations that it operates.



The Pump that Drained the World
The Wood screw pump, invented in 1913 by A. Baldwin Wood, the first superintendent of the New Orleans Sewerage & Water Board, was the first pump efficient and reliable enough to make possible the draining of large low-lying areas in the New Orleans area, including St. Bernard Parish. The image above describes the flow of water through a Wood screw pump.



Pumping the Parish
St. Bernard's pumping stations, situated along the edge of the 40 Arpent Canal, send the parish's stormwater into the Central Wetlands Unit.
Middle: E.J. Gore #5 station near Poydras
Above: Fortification #1 and Jean Lafitte #6 in Chalmette

System Components
The parish drainage network also includes a range of smaller features that control the flow of water before it reaches the larger pumping stations. These help manage water before it reaches the larger pumping stations. Above: Gate at culvert below Paris Road in Chalmette

Heavy rainfall often causes nuisance flooding. At the same time, the 20th century response to combating flooding through forced drainage is a primary cause of subsidence in urbanized areas. An integrated approach to water and soils management will allow the parish and its residents to address both issues, and improve the quality of parish's streets, canal network, public spaces, and development opportunities.

2g ISSUES: FLOODING, SUBSIDENCE AND URBAN QUALITY

Street Flooding: Reality Compared to Models
Flooding on Angela Street, shown above, and elsewhere in Old Arabi is consistently reported, yet does not appear in the model (opposite, top). Courteous Of Blaise Pezold

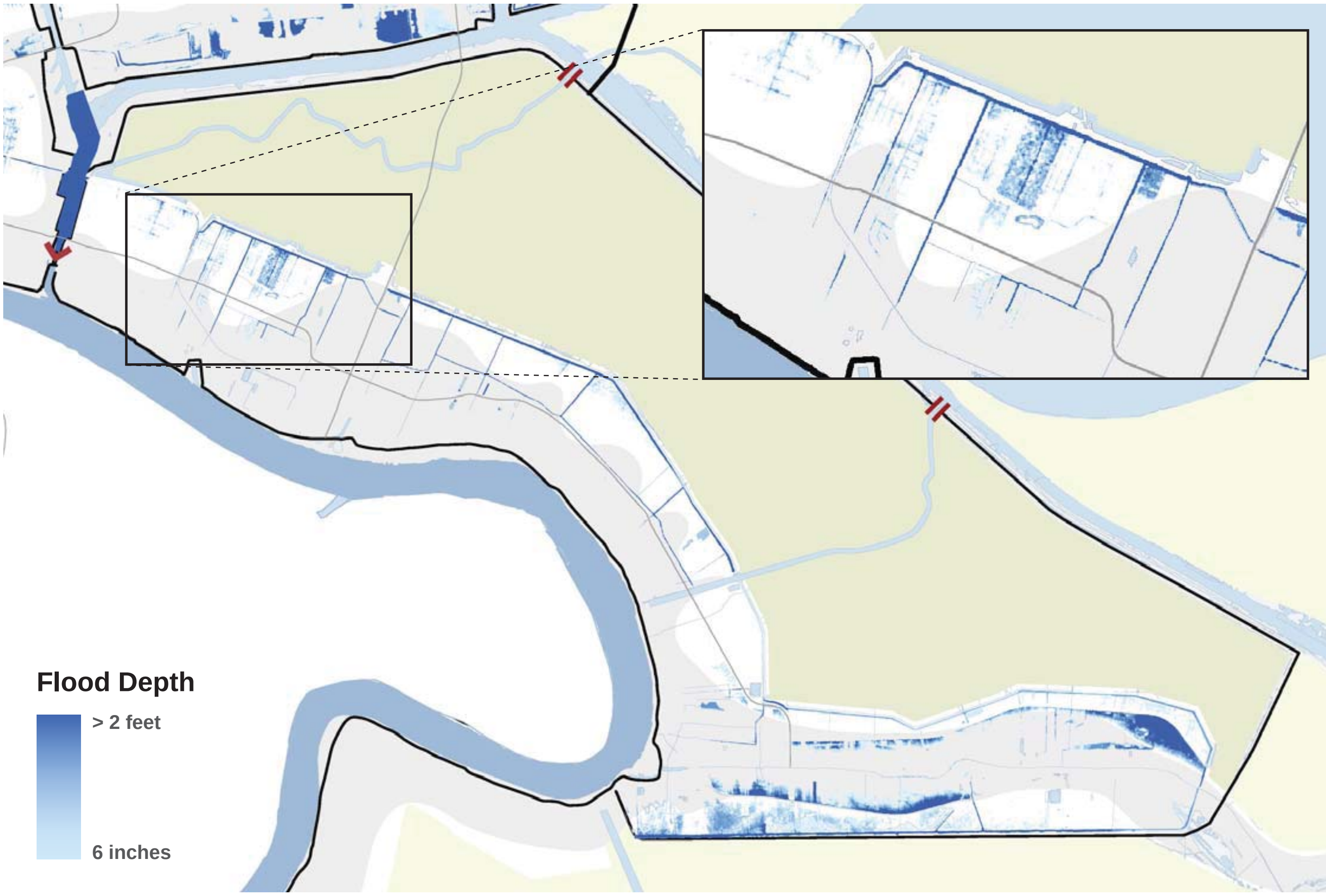
Looking at the ways in which streets, canals, pump stations, soils, pipe networks, and wetlands interrelate yields a deeper understanding of how an integrated approach to managing water and soils will make it possible to address flooding and subsidence, while also improving quality of life.

St. Bernard is situated in one of the wettest regions in the country, averaging 62 inches of rainfall every year. Much of this water falls in intense bursts, sometimes as much as 5 or 6 inches in a single hour. This climate poses tremendous challenges to keeping dry, and requires the operation of large banks of pumps in order to prevent the parish's low-lying areas from filling up with water when heavy rain falls.

In the summer months, thunderstorms and intense rainfall are common, if sometimes unpredictable phenomena. Isolated showers can unexpectedly inundate one area, while another area remains dry. The uneven distribution of rainfall during storms stresses drainage systems by placing heavy loads on different points in the system, so that the sizing of pipes and pumps can be rendered inadequate.

In response to these challenges, the parish's canal network and pumps provide the capacity to 1) store water and 2) convey water. This combination sets the threshold, beyond which additional runoff becomes flooding. In seeking to create more capacity, the LBBLD maintains a lower water table than would naturally exist in a deltaic environment like St. Bernard, which is a primary cause of subsidence. As a result, the present-day approach to managing stormwater actually exacerbates long term flood risk because it lowers land elevations over time.

The parish's canal networks are managed as infrastructure, rather than as vital waterways central to the identity of the parish and its neighborhoods. Most neighborhoods turn their backs on the canals, and activities along canal banks and in the water are restricted due to safety concerns. But because these canals are not maintained and operated as public spaces, they are also unsightly and oftentimes befouled with trash. Furthermore, they contribute little to parish in terms of aesthetics and in terms of ecology, even though they are visible in every neighborhood, and are as much a part of the urban fabric as the parish's streets and homes.



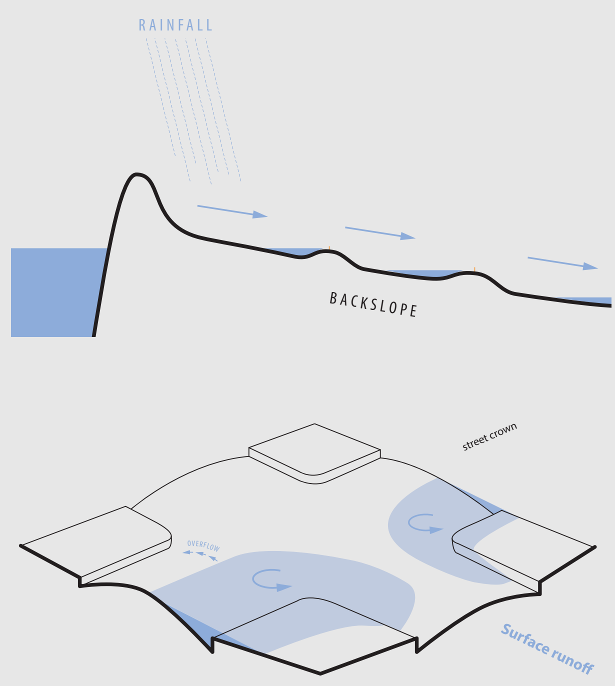
10 year storm
Localized flooding shown from a “10 year storm,” one defined as having a 10% chance of occurring in any year (these storms actually occur approximately four times each year). 10 year storms and 100 year storms have similar amounts of rainfall, so reducing flooding for a 10 year storm would also reduce the impact of larger storms.

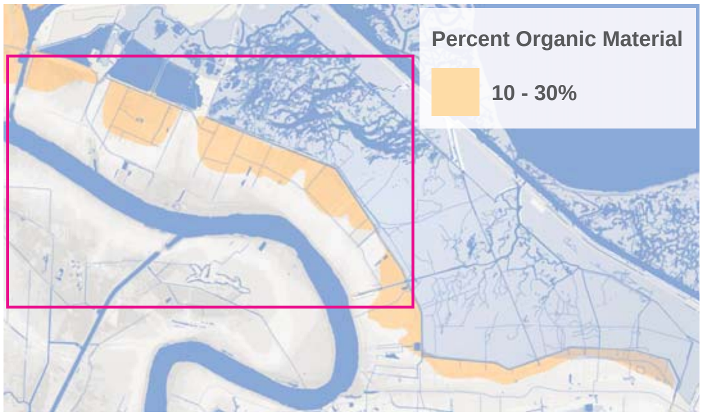
FLOODING

Flooding in the parish has multiple causes. In addition to the catastrophic flooding that occurred in 2005 due to levee breaches, there is chronic street flooding caused by rainfall. That is, pipe networks, canals, and drains back up at specific locations when large volumes of runoff reach a chokepoint, overwhelming a catch basin or a canal so that water ponds in the street. Modeling of rain events predicts that flooding occurs around the parish’s perpendicular canals and in the lowest-lying areas around the 40 Arpent Canal. Anecdotal evidence suggests that water backs up where undersized culverts pass beneath St. Bernard Highway. The excess stormwater for a 10 year storm is 640.5 acre feet, which can be managed with additional storage capacity. Chronic flooding has a negative impact on transportation, commerce, safety, and overall quality of life. Continued subsidence and changing rainfall patterns may also exacerbate existing conditions, increasing flood risk and raising the costs of pumping.

Flooding on the High Ground

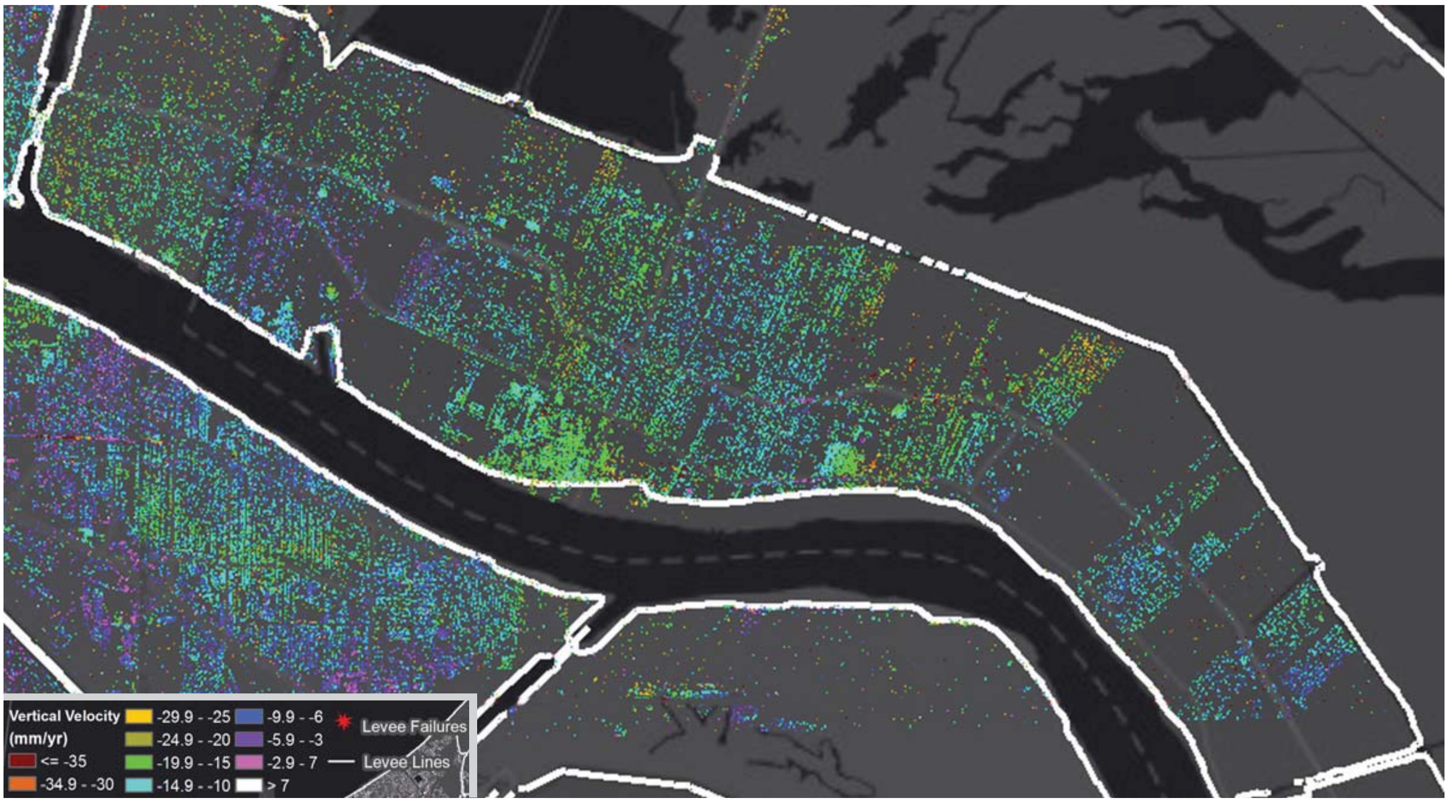
High ground in St. Bernard — not just areas below sea level — can also be prone to localized flooding because runoff easily overwhelms inadequate storm drains and drainage pipes.





At Risk Areas
Right: Map showing highly organic soils, which have the greatest subsidence potential, that comprise a large part of the parish, primarily the rear half of Chalmette and Meraux.

Below: NASA and LSU released a report in May 2016 that shows detailed subsidence rates in the Greater New Orleans region; St. Bernard Parish as a whole is shown to be subsiding at a relatively higher rate than the rest of the area.



SUBSIDENCE

Modern forced drainage lowers the water table and is the primary cause of subsidence in St. Bernard Parish because it lowers the water table. Impermeable surfaces such as streets and parking lots prevent water from infiltrating into the soil. Low water levels in canals provide storage capacity, but mean that the water table is always lower than it should be, causing the dried soil to oxidize and sink. Areas that are already low, such as the neighborhoods nearest the 40 Arpent Canal, are most susceptible and will continue to subside as organic soils oxidize. In spring 2016, NASA and LSU released a report that indicates St. Bernard Parish having higher relative rates of subsidence compared to the region, as shown above. The fastest subsiding areas in the parish correspond with higher organic content in soils.

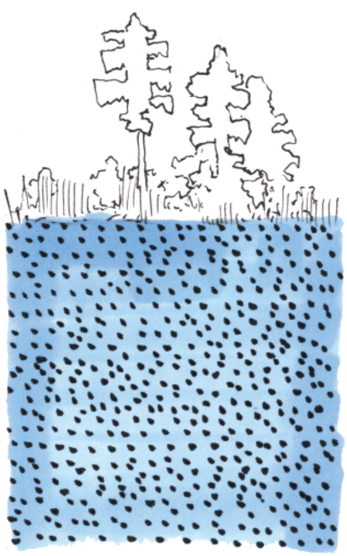
Subsidence damages roads, foundations, utilities, and reduces the capacity of the existing drainage system, while increasing risk long term – these costs are borne by both public and private – with homeowners having to address subsidence on their properties and local government having to fix more streets and other infrastructure, which goes back to the taxpayer to cover.

Subsidence is a slow and nearly imperceptible process, but an issue that can and must be addressed. It requires smarter management of water, and a realization that a drainage-oriented water management system actually compromises safety over time. Currently, no entity is responsible for groundwater, and there is a real lack of data and technical expertise throughout the region, with which to support better groundwater management.

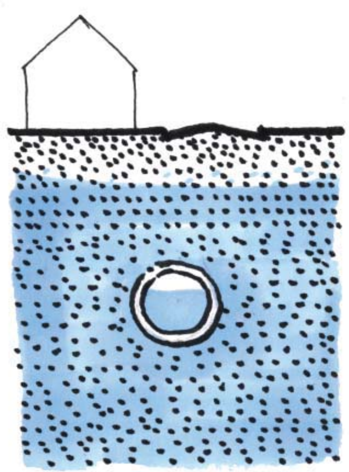
Sinking Land, Higher Costs
Collapsed roadways are one of the effects of localized subsidence (which can be caused by broken pipes) of subsidence on St. Bernard's infrastructure, which is expensive to repair and is a public safety hazard. This portion of Jean Lafitte Parkway in Chalmette has continued to worsen, with a large part of the road and neutral ground now unusable.

Crumbling Systems
Unstable, subsiding soils can also damage St. Bernard's drainage system, highlighting the vulnerability of subsurface utilities. Shown above is a catch basin near Judge Perez Drive in Chalmette

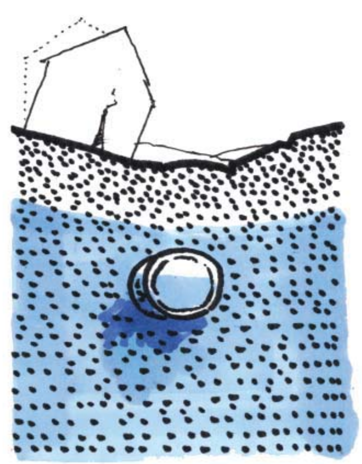
Unsupported Foundations
Subsiding ground can gradually expose structural slabs and cause driving surfaces to fail, as shown above at a house in eastern New Orleans East.



In an undeveloped wetland environment, rainwater is absorbed by soils and vegetation, and organic soils are saturated with water.



Forced drainage and impervious land cover limit the infiltration of rainwater into the ground, which causes subsidence and imbalances in groundwater levels.



Subsidence compromises infrastructure, and leads to unforeseen maintenance and operations costs for property owners and public works departments.

Gateway to the Parish
Large areas of impervious surface on Paris Road make parking vehicles convenient, but miss opportunities for stormwater management with bioswales or rain gardens, as well as designated paths for pedestrians and bicyclists. Improved right of way design could include new trees, lighting, and signage to mark this area as a gateway into and out of St. Bernard.

Suburban Thoroughfares
Judge Perez Drive in Chalmette is one of the major roadways in St. Bernard, but was designed for vehicular traffic through the parish, not as a place for connecting water, ecology, or people.

URBAN QUALITY

Water resources are underutilized as an asset, generally seen as a blight or nuisance rather than something integral to parish identity and to urban landscape as a place for recreation, beauty, and restoring ecological health. The urban quality of St. Bernard could be transformed by considering the abundance of local waterways as being central to landscapes, public spaces, and new developments. Places like the 40 Arpent Canal are already beautiful, and improvements to canal banks, water levels, plantings, and access points would allow many of the parish's canals to serve neighborhoods as beautiful amenities.

Regional, national, and international examples of waterways are shown later in the report.

Living Waterways
Trees and grasses grow along the 40 Arpent Canal down in Meraux, resembling more of a bayou landscape. St. Bernard's network of canals provide opportunities for ecological and habitat creation, which could improve air and water quality as well.

Parish Wide Recreation
The 40 Arpent Canal is the widest and deepest in St. Bernard, and is arguably the most attractive, but recreational boating is currently prohibited. With proper consideration for safety and the operation of pump stations (visible in the background), this waterway could be an easily accessible place for kayaking and canoeing, in conjunction with a trail system along the levee banks.

Neighborhood Networks
Vacant lots to the left face the backyards of houses arrayed along the opposite bank. These types of spaces throughout the parish could be transformed into vibrant and attractive public spaces for enhancing water storage, passive recreation, and ecology.

In addition to the pipes, canals, and pumps that drain St. Bernard, wastewater and drinking water plants, wells, lift stations, sewer pipes, and drinking water pipes are critical to the functioning of the parish. The interactions between these systems, rainfall, groundwater flows, nutrients, and pollutants determine the overall "water balance" of the parish. These interactions also impact operations and maintenance costs, water quality, soil stability, and ecological health.

2*h* DRINKING WATER, SEWER, WETLANDS ASSIMILATION, AND GROUNDWATER EXTRACTION

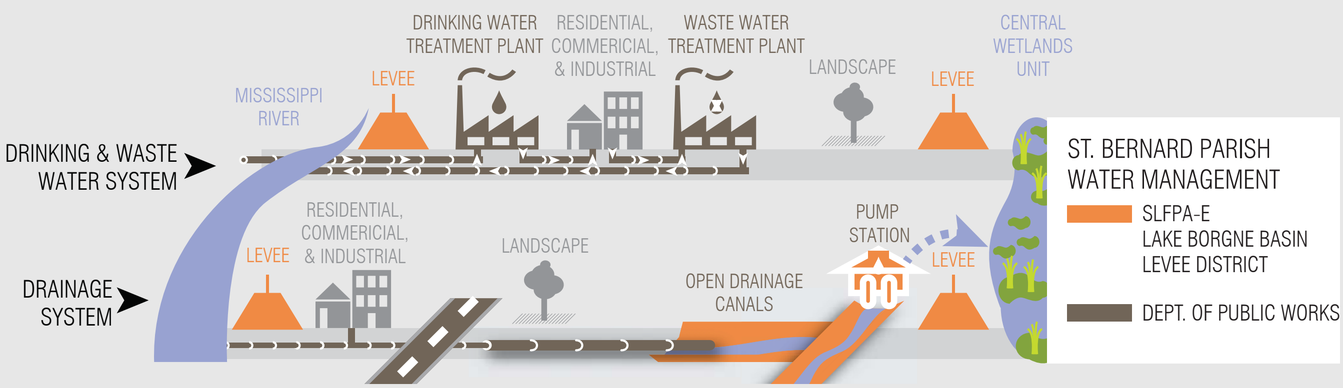
Wetlands Assimilation Pilot Project
Above, Bayou Bienvenue in the Lower Ninth Ward of New Orleans, shown in 2012 at the beginning of construction of the wetlands assimilation project, which will use treated sewage to nourish new vegetation and rebuild the swamp that existed in this location before.

Drinking water and sewer systems also have an impact on the flows of water and nutrients through St. Bernard. They also have an impact on groundwater levels and water quality. At the same time, industries located along the riverfront have water systems separate from the public networks. Some of these systems extract groundwater for industrial uses, which likely have an impact on water levels and water quality.

Drinking Water

The parish draws water from the Mississippi River. At a plant located on St. Bernard Highway in Chalmette, the Public Works department treats and filters that water until it is suitable for human consumption. That water is distributed under pressure to customers throughout the parish, through a pipe network that has aged and experienced some problem with contamination in recent years. Old pipe networks often have breaks and leaks at

EXISTING WATER SYSTEMS



Systems and Flows

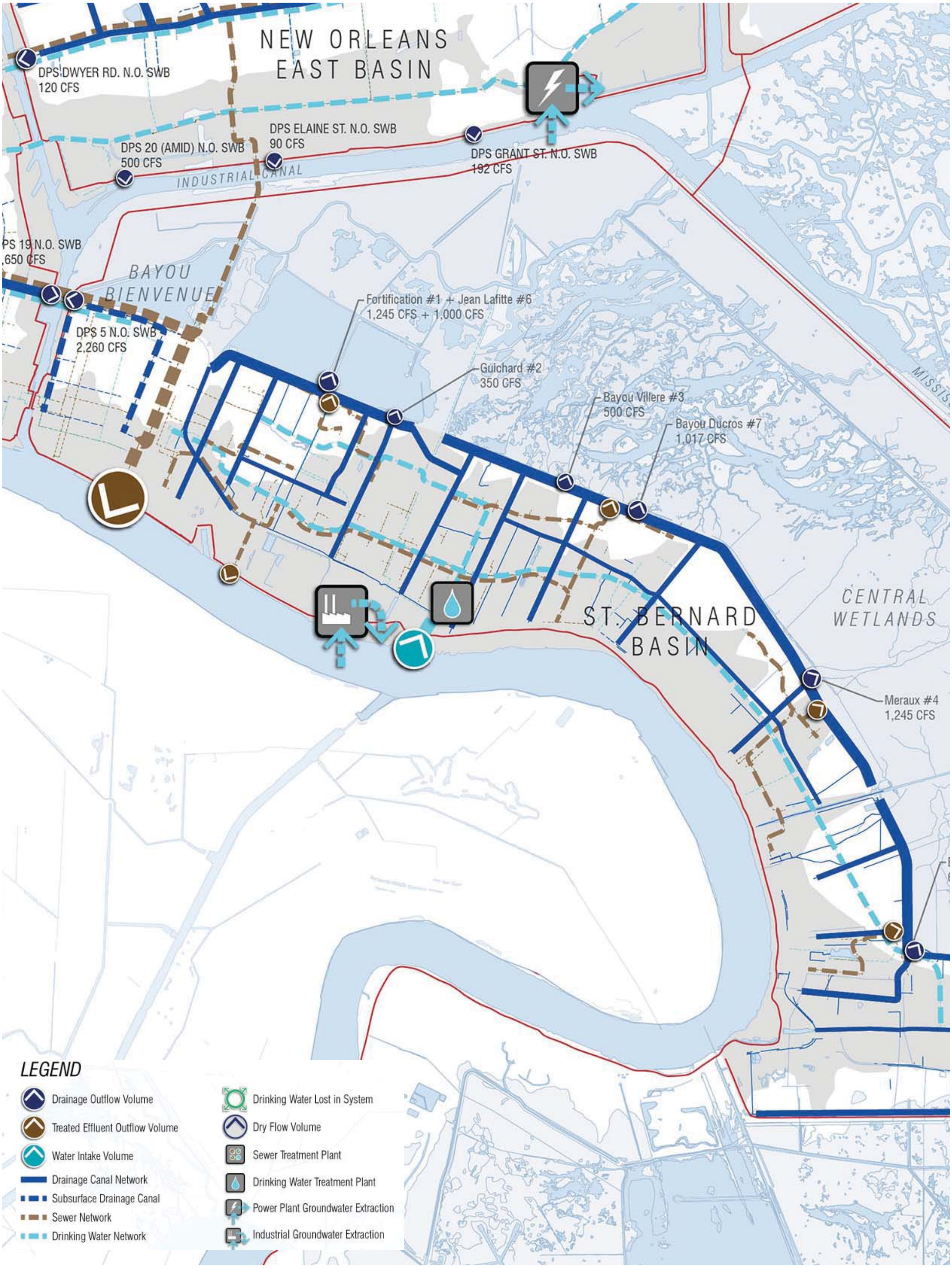
Diagrams showing the path of drinking water intake and waste water (sewage) outfall, both of which use the Mississippi River. St. Bernard's drainage system, shown at the bottom, pumps stormwater over the 40 Arpent Canal levee into the Central Wetlands Unit.

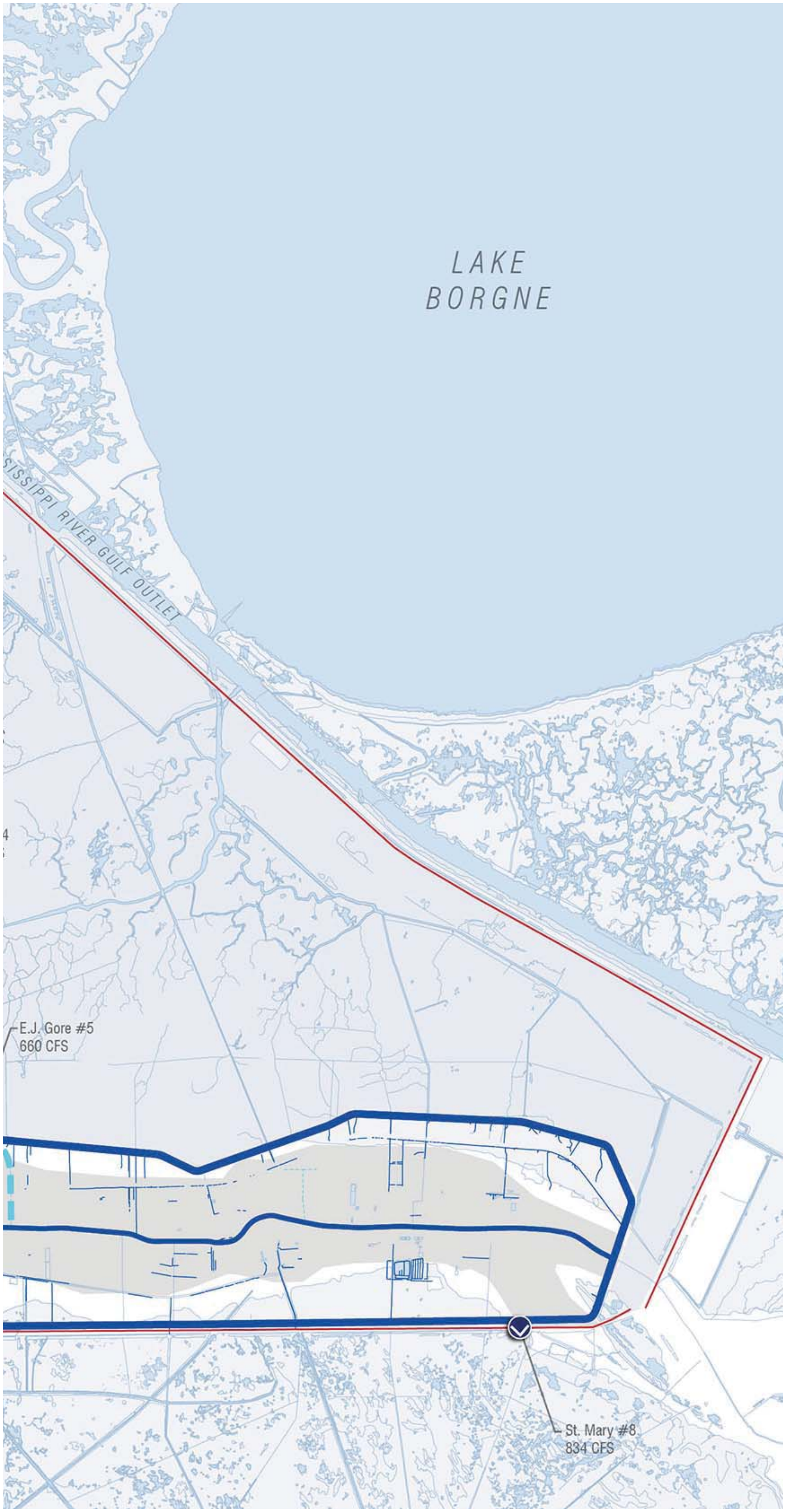
different points, which means large volumes of clean water are lost on the way to people's homes. In response to these problems, the parish is addressing contamination concerns by elevating chlorine levels, and has also obtained funding and raised water and sewer fees in order to fund ongoing projects that replace aging cast iron pipes with new plastic pipes in neighborhoods such as Old Arabi.

Sewerage

Households and businesses consume potable water, some for drinking and cooking, some for washing and cleaning, some for watering lawns and gardens, and some of it for flushing toilets. The water that comes back into the public realm is a combination of greywater (e.g., soapy water from washing machines and sinks), and blackwater (e.g., water with feces and urine). This sewage is collected by a pipe network that, like the drinking water system, is also integrated into the street network. In this case, sewage flows beneath parish roadways to four sewage treatment plants, each of which is located along the 40 Arpent Canal. These plants then pump the treated wastewater into the Central Wetlands Unit, while sludge extracted from that effluent is trucked out of the parish and disposed of in other locations. The sewer pipe network, too, is aging, and is a source of contamination for neighboring soils and groundwater where there are breaks and leaks in the system.

It is important to note that water used to water lawns and wash cars typically washes off into the street, carrying with it cleaning fluids, lawn litter, fertilizer, and other pollutants. This water then flows into storm drains and that pipe network, which means that there is a continual trickle of water and pollutants in the parish's storm drain pipes and canals, even during dry weather.


NEW ORLEANS
EAST BASIN
DPS DWYER RD. N.O. SWB
120 CFS
DPS ELAINE ST. N.O. SWB
90 CFS
DPS 20 (AMID) N.O. SWB
500 CFS
DPS GRANT ST. N.O. SWB
192 CFS
INDUSTRIAL CANAL
PS 19 N.O. SWB
,650 CFS
BAYOU
BIENVENUE
DPS 5 N.O. SWB
2,260 CFS
Fortification #1 + Jean Lafitte #6
1,245 CFS + 1,000 CFS
Guichard #2
350 CFS
Bayou Villere #3
500 CFS
Bayou Ducros #7
1,017 CFS
ST. BERNARD
BASIN
CENTRAL
WETLANDS
Meraux #4
1,245 CFS
LEGEND
Drainage Outflow Volume
Treated Effluent Outflow Volume
Water Intake Volume
Drainage Canal Network
Subsurface Drainage Canal
Sewer Network
Drinking Water Network
Drinking Water Lost in System
Dry Flow Volume
Sewer Treatment Plant
Drinking Water Treatment Plant
Power Plant Groundwater Extraction
Industrial Groundwater Extraction



One Parish, Many Water Systems
Map showing major components of the different water systems that exist alongside the drainage network in St. Bernard, including above ground and underground drainage, sewage, drinking water, treatment plants, and industrial groundwater extraction.

Pilot Project Progress
Above: Bayou Bienvenue shown in 2010, one year before construction of the wetlands assimilation project. Above, right: test plots constructed, shown here in 2016. Top: Future phase of wetlands assimilation will transport treated effluent from New Orleans across the parish line to help rebuild St. Bernard's CWU.

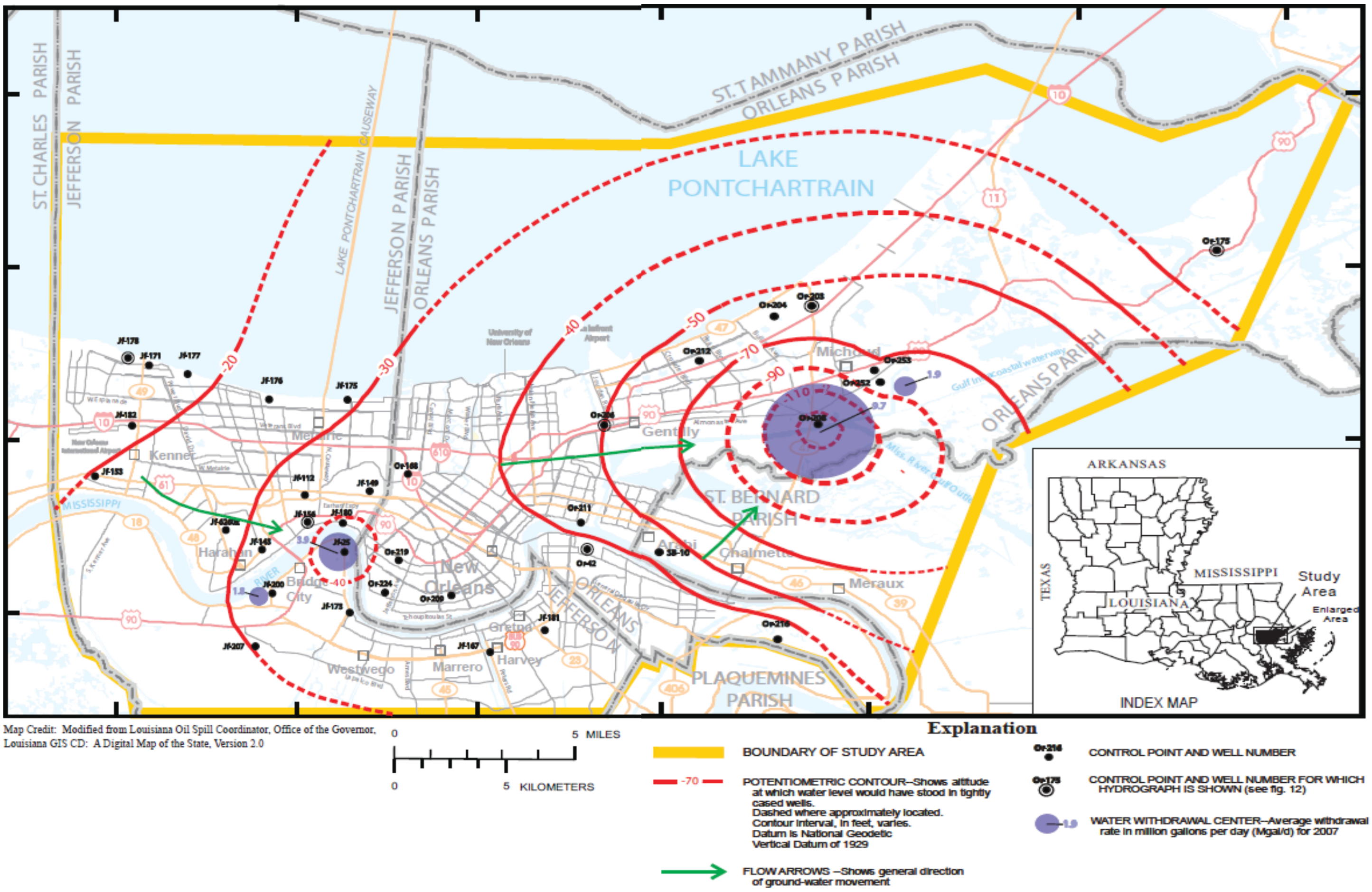
Bayou Bienvenue Central Wetlands Assimilation

For many agricultural communities around the world, sewage is an invaluable source of nutrients. With modern sewerage, however, feces and urine are collected and concentrated so that it becomes a noxious substance and environmental hazard that has to be, through resource intensive processes, heavily treated before it can be released back into the environment.

One exciting project that begins to address this issue is the wetlands assimilation project in the Central Wetlands Unit. This is a joint effort led by the Sewerage & Water Board of New Orleans and the Lake Borgne Basin Levee District. The initial test plots take partially treated wastewater from New Orleans's wastewater treatment plant, located in the Lower Ninth Ward, and use a mix of cypress and tupelo trees and also floating islands planted with bulrush to filter that water as it mixes with the surrounding waters.

Future phases will extend into St. Bernard Parish and utilize effluent from St. Bernard wastewater treatment plants in a band along the wetland side of the local levee and 40 Arpent Canal. At the moment, however, the Sewerage & Water Board has not been able to obtain the necessary servitude through the Central Wetlands Unit that is necessary for expansion beyond Paris Road and into St. Bernard Parish.

If ultimately successful, this effort will harnesses natural processes such as nutrient uptake by plants in order to bolster existing sewerage. At the same time, the flow of this effluent into the Central Wetlands Unit will help to lower salinity levels, provide nutrients to support plant growth, and aid the restoration of the cypress tupelo swamp environment that once existed in the CWU.



Impacts of Groundwater Extraction
The contours of groundwater hydraulic heads (pressure) in deep aquifers. Nearly all deep groundwater flows towards Michoud in New Orleans East, a major site for groundwater extraction in the metro area.

Groundwater Extraction

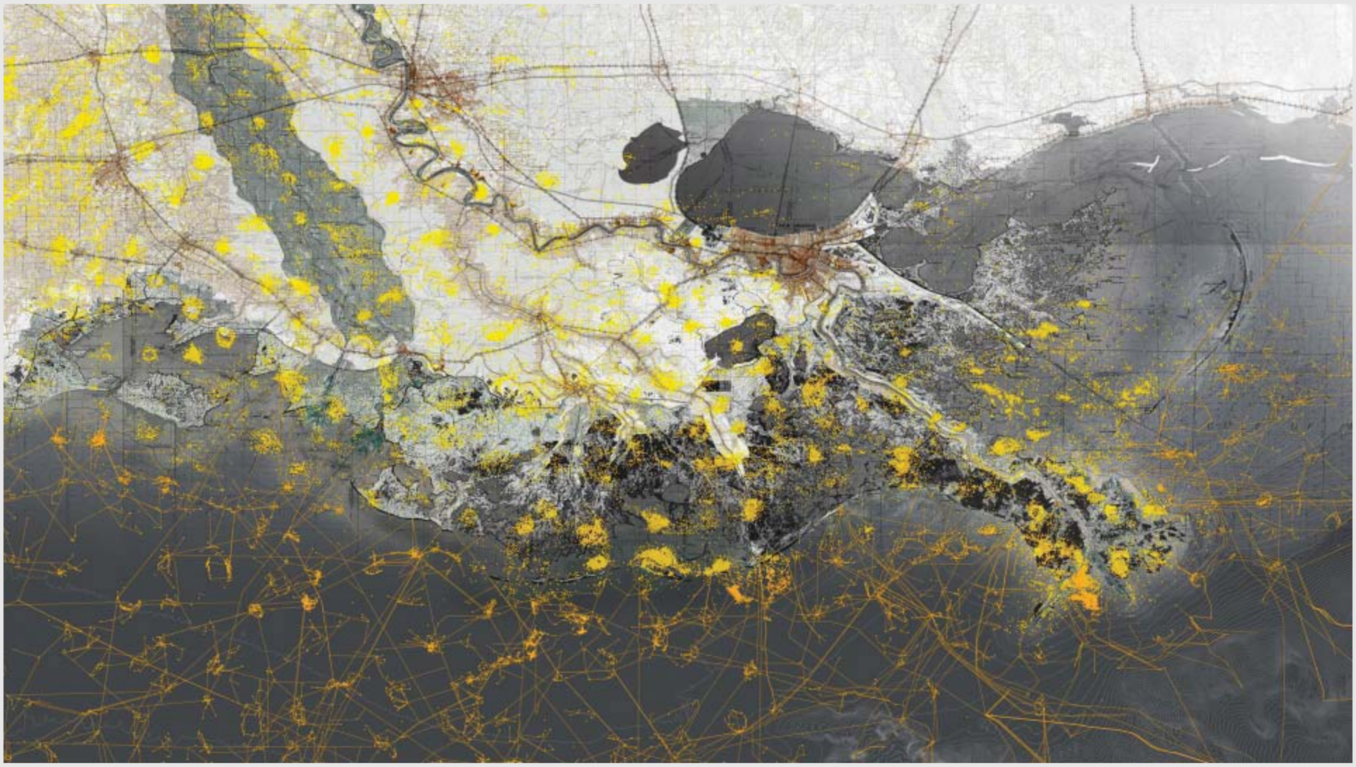
Utilities and industries throughout the region extract groundwater from deep aquifers for use in cooling, irrigation, and other industrial processes – they maintain their own intakes and outfalls. This has an impact on both ends. Groundwater extractions radically redefine the shape of aquifers, which in turn affects soils and contributes to subsidence. And after that groundwater is used, it is expelled into surrounding waterways and water bodies, such as the Mississippi River or the Gulf Intracoastal Waterway. This water can be of higher temperature if used for cooling, or may introduce contaminants and pollutants that are a byproduct of industrial use.

Integration and Closing Loops

In the long run, it is important to look for ways to integrate systems and close loops. Using drinking water to water lawns and irrigate parks, even while stormwater is pumped, makes little sense. Similarly, trucking nutrient-rich sludge as a byproduct of the sewage treatment process out of the parish makes little sense when there is a degraded wetland that needs that organic matter and those nutrients. The wetlands assimilation project is a step towards addressing such issues, but more collaboration across political boundaries and between different departments will be necessary to fully integrate the parish's water systems. Encouraging and supporting stormwater harvesting parish combined with planting more drought tolerant and climate appropriate species throughout the parish, for example, would reduce dependence on drinking water for irrigation purposes. This would reduce costs and improve the ecological health of the parish.

OIL AND GAS PIPELINES

In addition to drainage, sewerage, and stormwater pipe networks, there are also hundreds of miles of oil and gas pipelines that extend through the parish and its wetlands. These obey a different logic than the other networks, though, as they run alongside, through, and beneath roadways and canals, connecting St. Bernard to regional and national distribution, storage, and refining facilities. There is, however, no comprehensive understanding within the parish of where all of these pipelines are located, as they are managed by industry and by state agencies. All public work in the vicinity of these lines requires prior notice and approval.



Hidden Network
The expansive system of oil wells and pipelines throughout the greater New Orleans region.
Image credit: Landscape Metrics

Pipes In The Ground

The parish faces three challenges in regards to its water systems and pipe networks. The first is that many of the pipes that carry drinking water, stormwater, and sewage are old and broken in many locations. This means that not only are large volumes of drinking water lost and that there is a risk of contamination from pipe to surrounding soils and vice versa, but that these pipes also impact road conditions and other infrastructure. A broken sewer pipe, for example, can draw soils from the surrounding area, causing sinkholes and other deformations. These negatively impact quality of life and exact costs upon the parish government as street repair costs mount.

The second challenge is related to changes in population over the last four decades. While the parish's infrastructural networks cover a geographic area as large as when the parish population was nearly 40% greater in the 1980s, there are significantly fewer households and paying customers to support these networks, even while other costs have gone up.

The third challenge is that these networks are managed separately. Extensive street repairs that were made in the aftermath of Hurricane Katrina did not take into account changing demographics or the need to adapt utilities that run beneath those streets. Similarly, projects that replace drinking water pipes and that necessitate tearing up streets in order to access those pipes do not take into account the possibility of integrating new road surfaces and in-road stormwater retention features at the same time.

This means that each year sees new opportunities pass by to address the management of water, soils, and nutrients holistically when large sums of money are expended to plug holes and fix aging systems. Furthermore, work on

Industrial Groundwater Extraction
Currently unregulated, petrochemical facilities extract freshwater from deep aquifers for cooling equipment and irrigation, which can further subsidence and cause pollution when the water expelled after use.

Irrigation
To fill park ponds and irrigate landscape, the Parish uses drinking water, while nutrient rich treated sewage is removed for disposal to a landfill.

Drinking Water
St. Bernard requires ongoing maintenance of its aging water systems, including replacing old pipes, which can cause water to leak or allow contamination.

Stormwater
To minimize flooding, all stormwater is pumped out of the parish, untreated, directly into the Central Wetlands Unit. This prevents groundwater recharge, which impacts the water table and causes

one system often has an unintended consequence for other systems. The current approach to storm drainage, for example, contributes to subsidence. Subsidence, in turn, compromises the stability of soils and contributes to breaks in pipes. Broken pipes, then, can lead to contamination or localized deformations.

Integration of systems will lead to solutions that benefit multiple systems and stakeholders, that do not create unintended and costly consequences, and that strengthen local ecosystems. This means integration in the planning, design, construction, operations, and maintenance of water systems, both public and industrial. This means learning to address water, soils, nutrients, and ecology as a whole. And this means learning from other places and initiatives such as the wetlands assimilation project how to collaborate with regional partners and to harness natural processes in order to reduce long term costs and restore local habitats.

Resilient Retrofit
The water treatment plant for St. Bernard Parish completed a renovation to increase capacity and elevate plant services above the base flood elevation, mitigating potential future damage.

Local Example
Remnant waterway, live oaks, and Spanish moss at the site of the Poydras Crevasse and at the head of the Bayou Terre aux Boeufs.

3
PROPOSAL | GOALS & PRINCIPLES

The Integrated Water Resources Management Plan builds upon the work of the Greater New Orleans Urban Water Plan, the Louisiana Coastal Master Plan and ongoing planning processes throughout Greater New Orleans as a roadmap for addressing the parish's and the region's urban water challenges. The plan envisions a St. Bernard where "living with water" is a foundational planning principle that guides the transformation of existing drainage systems, improves soils and groundwater management, supports healthier ecosystems and sustainable development practices, and improves connectivity and the quality of public spaces throughout the parish.

3 SYSTEMS & ENVIRONMENT

Slow and Store
Green infrastructure designed with water adaptive vegetation that slows down and stores stormwater, as well as restores ecological habitats, similar to existing landscapes at St. Bernard State Park, shown above.
Source: nola.com

The IWRM Plan builds upon existing flood protection systems by broadening the concept of "multiple lines of defense" to include urban water management. Here, urban means urbanized or developed, rather than in the sense of a dense city. The plan's approach is based on applying science, engineering, and design to transform existing drainage systems and the urban landscape using proven strategies and technologies, as well as insights developed through the Dutch Dialogues workshops and the two-year Greater New Orleans Urban Water Plan planning process.

As a living document, the IWRM Plan is meant to make an immediate impact with a range of practical, feasible interventions that will make a difference. Another goal is to inspire and guide long-range planning and strategic investments for the next 50 years. The plan also includes systems proposals along with designs for pilot projects and implementation strategies.

Structured as practical retrofits rather than replacements, the proposed projects embody the following principles:

Live with Water: Water is a fact of life in a delta. Making space for water, and making it visible across the urban landscape, allows it once again to be an asset to the region.

Slow and Store: Stormwater moving fast is hard to manage. Holding it where it falls, slowing the flow of water across the landscape, and storing large volumes of rainfall for infiltration and other uses are fundamental management strategies. Pump stations are activated only when necessary, rather than by default every time it rains.

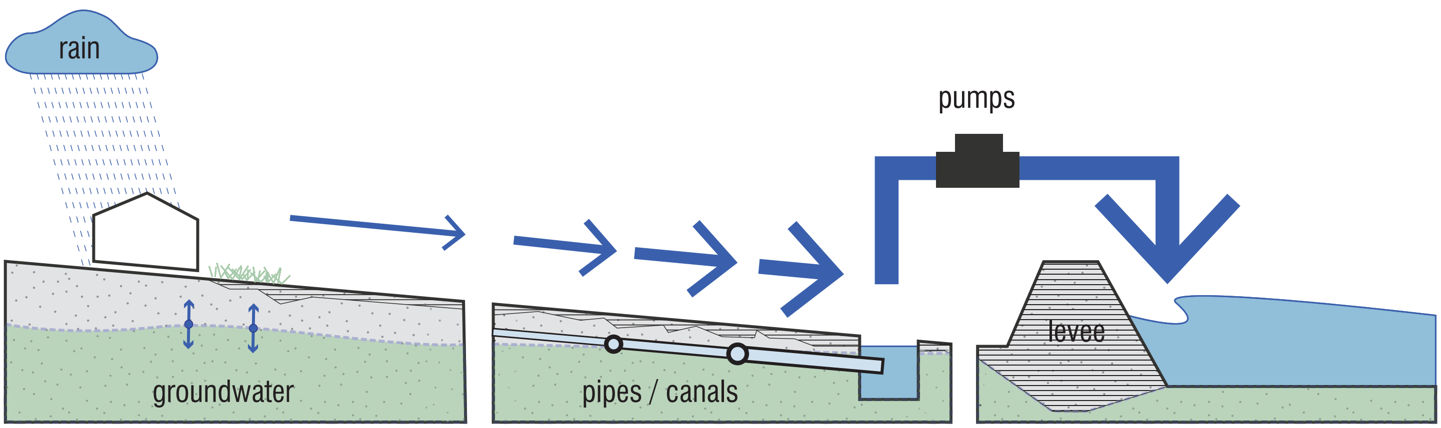
Circulate and Recharge: Surface water and groundwater move naturally across and within every delta. Incorporating surface water flows and higher water levels into water management improves groundwater balance, water quality, and ecological health.

Work with Nature: The region's diverse native topography, soils, flora, and fauna provide myriad possibilities for storing, filtering, and growing with water.

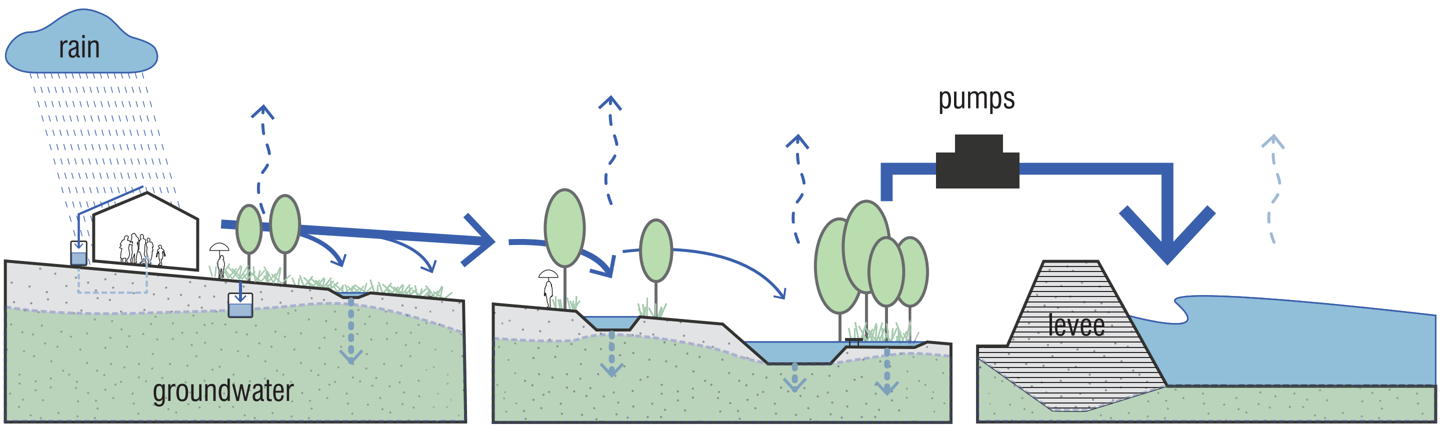
Design for Adaptation: Change is constant on the delta. Designing systems for dynamic conditions, and to support diverse uses, economic development, and environmental restoration maximizes the value of water infrastructure investments.

Work Together: Water knows no boundaries. Collaborations across neighborhood, cultural, and political lines, and developing solutions at all scales – from individual properties to regional networks – are necessary.

EXISTING CONDITION: PAVE, PIPE, PUMP



PROPOSED: SLOW, STORE, DRAIN



Slow

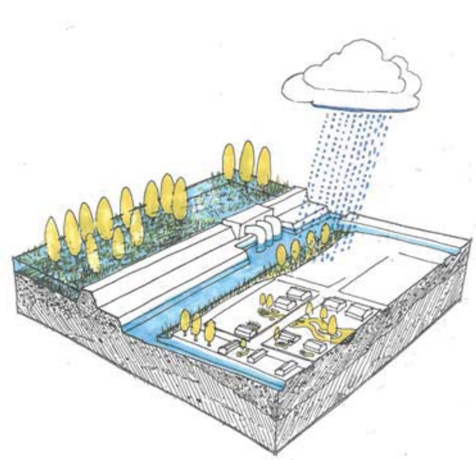
Impervious rooftops, driveways, sidewalks, and streets can be redesigned to catch rain where it falls, allowing some of this water to soak into the ground, which stabilizes groundwater levels and limits subsidence.

Store and Use

Small and large scale detention and retention features integrated into canal networks and public spaces provide additional storage capacity. Stored water can be used for irrigation and recreation, such as kayaking and boating.

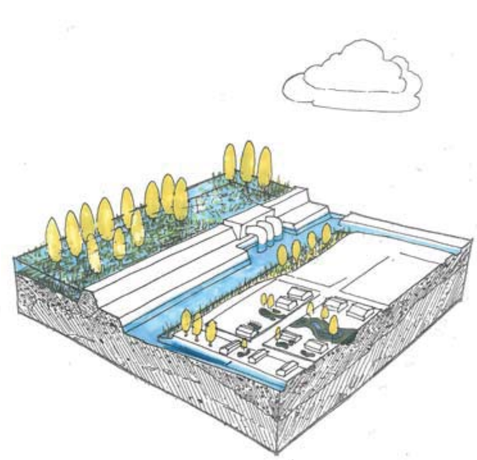
Drain When Necessary

Pumping should not be the only solution to manage stormwater. Slow and Store features lessen loads on pumping stations, provide additional safety, and enhance the capacity of the overall drainage system.



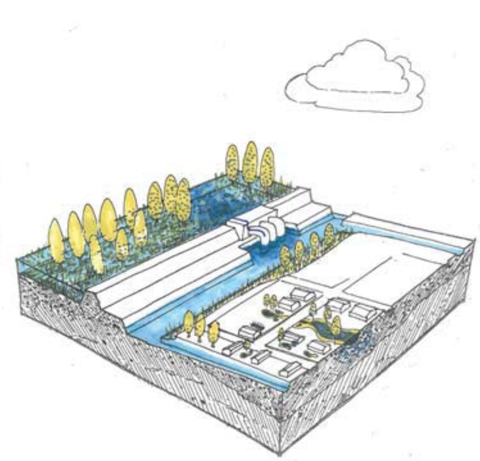
Keep rainfall in the parish

Greater New Orleans averages 62 inches of rainfall every year. Storms can deliver water in intense bursts, sometimes as much as five or six inches in just one hour. Runoff from impervious surfaces can quickly overburden the existing drainage system.



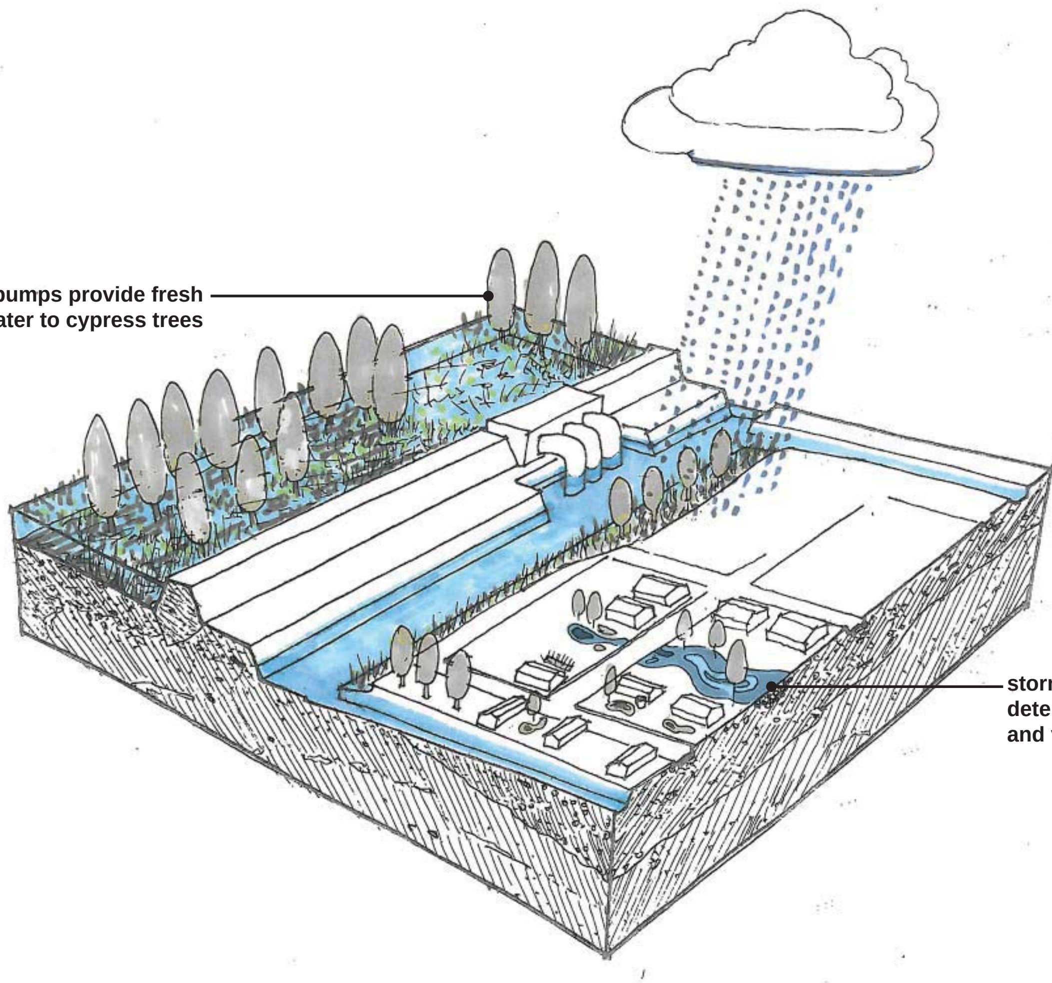
Slow water

Rain gardens, bioswales, and other green infrastructure that infiltrate water, along with increased canal storage capacity, can reduce runoff rates and lessen flooding while filtering pollutants from stormwater.



Reduce Pumping

Slowing down and storing rainfall would lessen the load on pump operations and reduce energy consumption. When necessary, excess water that has been filtered by green infrastructure could still be pumped into the Central Wetlands Unit and create a healthier ecosystem.



WATER

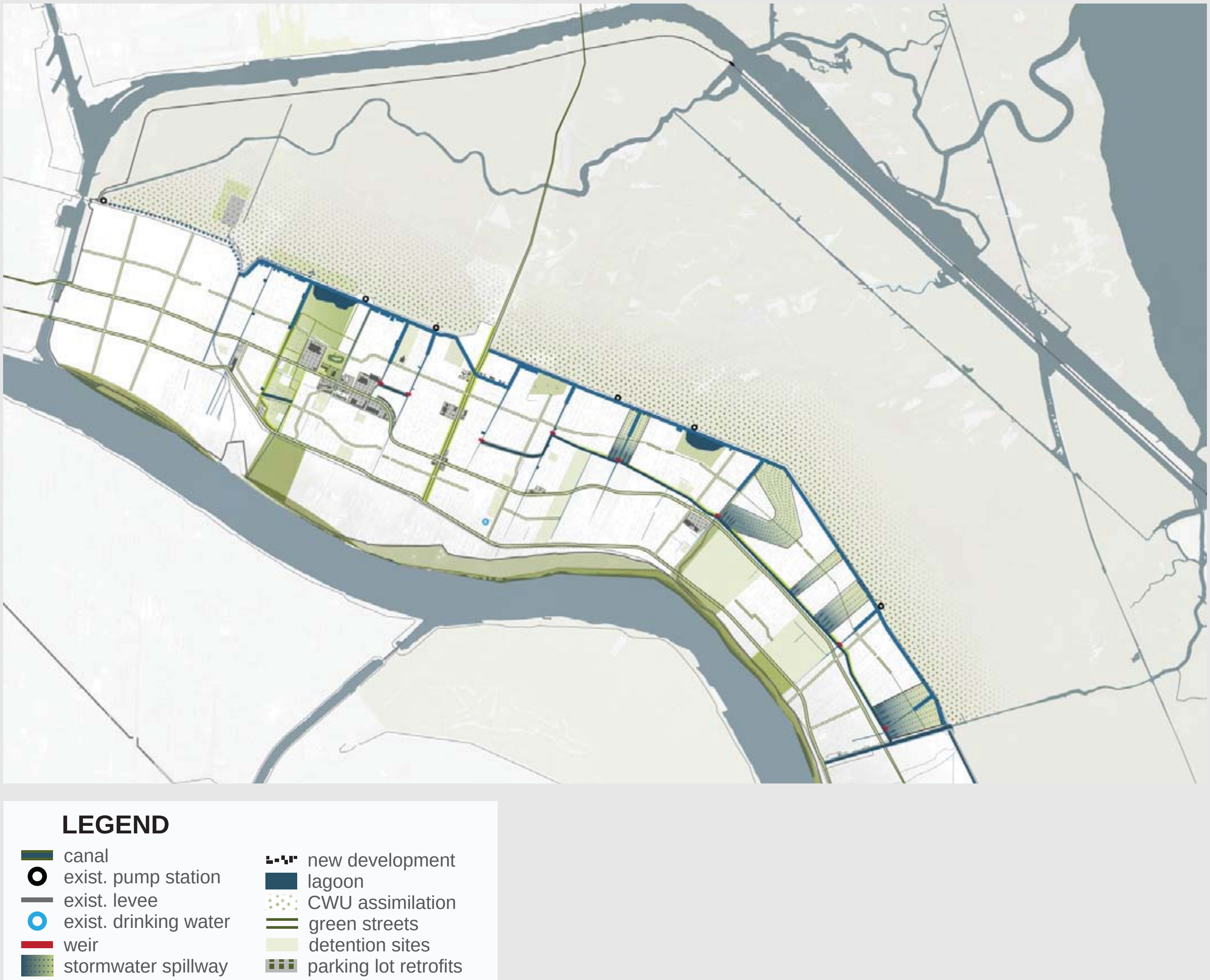
Integrated Water Spaces
Existing drainage canals that run through neighborhoods in St. Bernard have the potential to increase storage capacity and create public spaces, enhancing areas similar to St. Avide Dr., shown above.

Make space for water. Slow and store stormwater in order to reduce reliance on pumps.

Through an integrated approach to water management, St. Bernard can reduce flood risk, reduce dependence on pumping, improve water quality, improve system-wide connections, and improve day to day flow and relationships to water. A fundamental shift is necessary, from pumping water out as the primary means of dealing with stormwater toward finding ways to "live with water."

This means holding on to water where it falls, allowing it to soak into the ground, and storing for infiltration and use. And this means pumping as little as possible without compromising safety.

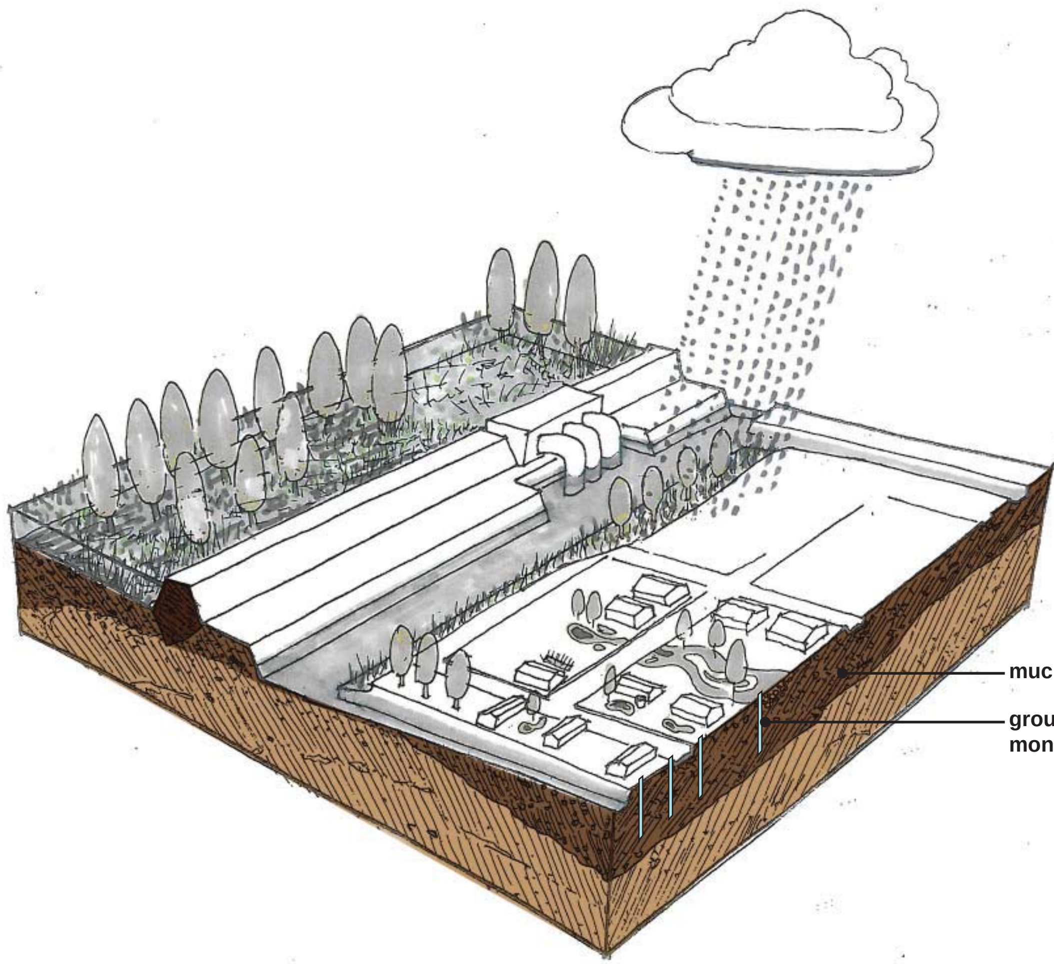
PROPOSED WATER SYSTEM



Harnessing natural processes – allowing soils and plants and sun to do much of the work, instead of relying entirely on pipes, canals, and pumps – is more cost effective and results in improved ecology, beauty, and water quality. In an urban context, plants absorb water, improve infiltration, and clean and hold onto water, while at the same time cooling air around them. This reduces the urban heat island effect, which reduces quality of life for St. Bernard's residents.

Making space in the landscape for detention and retention requires a reshaping of land and of the way in which we think about streets, properties, and parks. We have to be able to see water in the landscape and to understand how it flows. With planning and design, spaces for water management can be beautiful rather than a nuisance.

Spaces for Water and New Habitats
A series of new lagoons with islands off the 40 Arpent Canal could create opportunities for wildlife habitat and vegetation, as well as balancing soil cut and fill from excavation. Human-made lagoons and wetland vegetation thrive in Lafreniere Park in Jefferson Parish, shown above.



SOILS AND GROUNDWATER

Monitor and balance higher surface water and groundwater levels. Circulate and recharge water throughout the parish's canal network.

Integrating Groundwater Monitoring
Future construction projects provide opportunities to study and improve subsurface conditions and to implement groundwater management networks, particularly in public spaces like the 40 Arpent boat launch..

Groundwater is often completely overlooked, primarily because it is not visible, but it is just as important as surface water, stormwater, and storm surge. The larger subsurface condition is affected by each of those, and groundwater generally determines the stability and strength of soils.

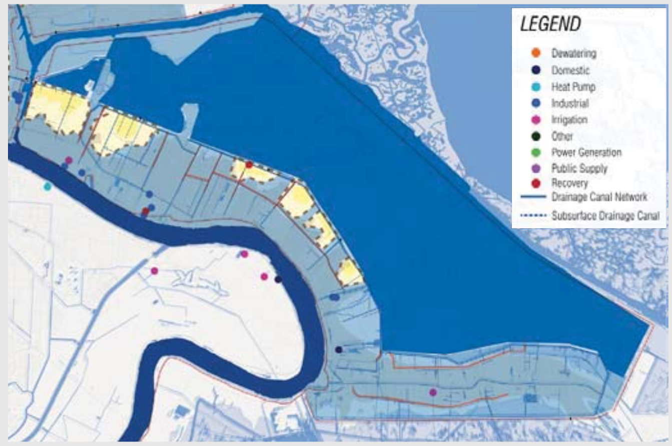
In St. Bernard, groundwater is at risk of becoming more brackish with wetland loss and sea level rise. Also, groundwater extraction changes hydraulic gradients throughout the region, which may have consequences for St. Bernard Parish that are not yet understood.

GROUNDWATER MONITORING

No entity in St. Bernard Parish is currently responsible for monitoring groundwater levels and maintaining groundwater levels for improved soil stability and minimizing subsidence. This means that the operating water levels in region's drainage networks are maintained with the singular purpose of preventing flooding, and not maintaining soil stability. The result is an approach to stormwater management that creates imbalances of ground and water, the costs of which are paid by citizens, business owners, utilities, and government as they contend with the effects of subsidence every day.

Establishing a groundwater monitoring network is critical to integrated water resources management and planning. Without adequate knowledge of groundwater level and water quality, it will be difficult, if not impossible, to set effective water level targets and to measure the impact of the proposed water systems and measures.

Groundwater monitoring will be useful for understanding critical relationships between water and soils, between the water that surrounds St. Bernard and urbanized areas, and between infrastructure and subsurface conditions. Shown above is a map indicating high organic soil content, which is the most at risk for subsidence, and existing processes that impact groundwater relationships throughout the parish.



These relationships include, but are not limited to:

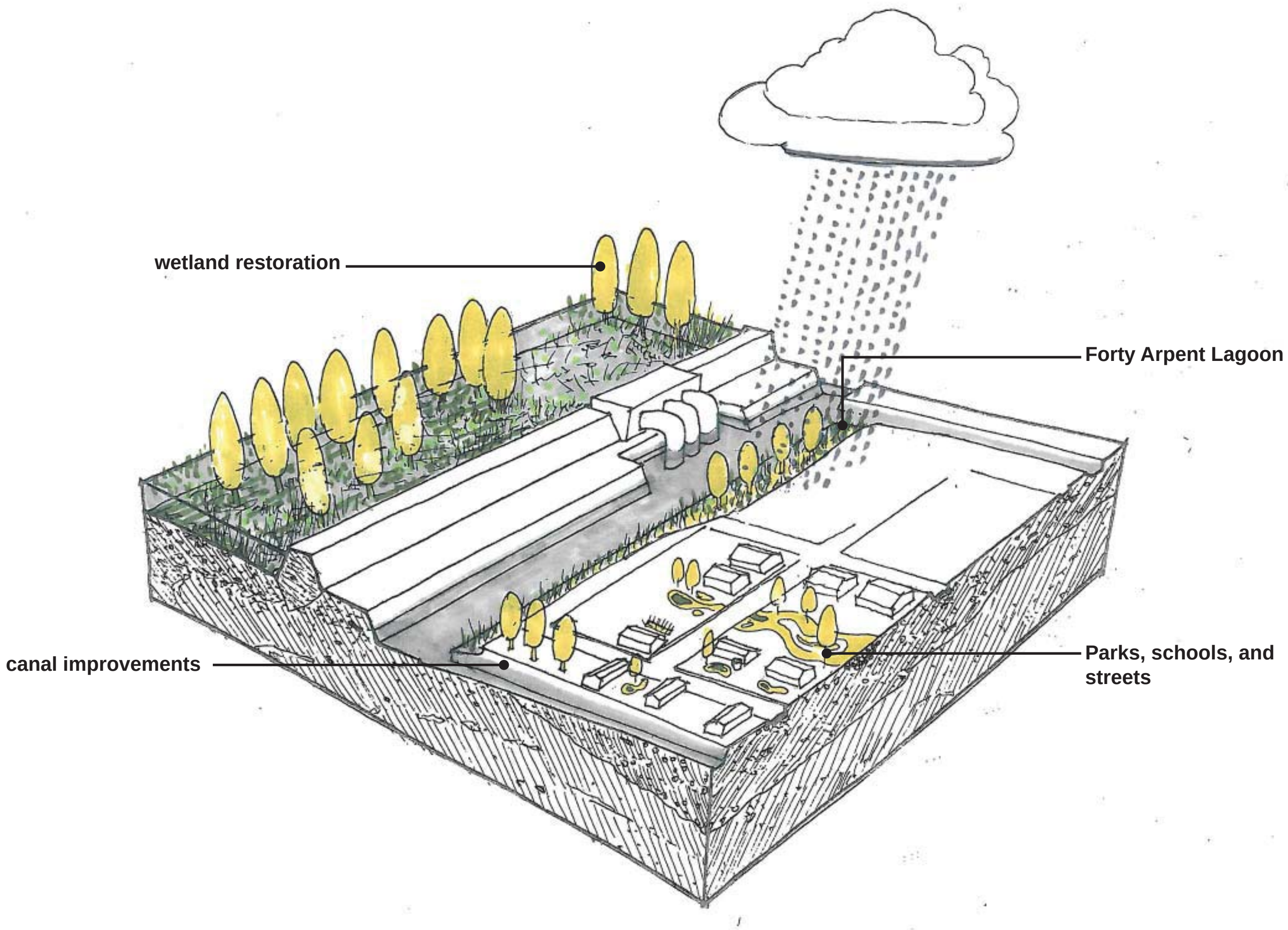
- Seepage and groundwater flow that result as a result of higher water levels in the Mississippi River and the Central Wetlands unit relative to urbanized areas
- Groundwater flow through sand layers and point bars
- Water elevations and infiltration rates across the parish, depending on soil types and for both current and proposed operating levels
- Salinity and other measures of water quality throughout the parish
- Leaks and other defects in existing infrastructure networks that may lead to localized subsidence or pollution of water resources
- Effect of resource extraction (e.g. sand pit mining, or groundwater wells) associated with industrial facilities and their impact on water levels, soil stability, and water quality

High water levels in the Mississippi River also push water outward, especially in areas with sandier soils that are indicative of past crevasses. In these locations, sand boils can be visible close to the river levee during high water. And as mentioned in Chapter 2, stormwater drainage has the greatest impact currently on subsidence rates.

The starting point to understanding groundwater levels and quality is to install a network of wells so the parish can develop a comprehensive set of strategies for managing groundwater. Such a network will also make it possible for the parish to monitor the impact of projects on water quality and soil stability. This is further explained in Chapter 5.

A primary goal of the IWRM Plan is to reduce subsidence by stabilizing groundwater levels closer to the surface of the ground. Not so much that the ground returns to swamp and becomes uninhabitable, but high enough so that the depth of soil that is not saturated – where organic matter is exposed to oxygen and then compacts, causing subsidence – is greatly reduced. This requires system-wide adaptations, and maintaining generally higher water levels in drainage canals. This has the effect of reducing the amount of storage capacity in those canals, however, so it is critical to always integrate groundwater and stormwater planning.

To conserve and reuse soil, the proposed projects strategically balance excavation cut and fill. Because excavated soils are used on the project site or elsewhere in the parish, this invaluable local resource is not taken elsewhere for disposal.



ECOLOGY

Manage urban water systems to strengthen and enrich ecosystems. Utilize natural processes to improve the function, beauty, and adaptability of the parish's infrastructure and landscape.

Accessible Eco-tourism
A boardwalk runs along, above, and through the bayous, swamps, and marshes of the popular Jean Lafitte National Historical Park and Preserve in nearby Jefferson Parish.

Beyond the shift to seeing more water in the landscape, we also need to expect more benefits from our landscape by integrating ecological functions that improve the quality of water, air, and habitat. Vegetated areas in public rights of way, such as neutral grounds and green strips alongside roadways, should be put to use as functioning ecosystems where plant communities are designed to thrive as part of a hydrophilic (water-loving) environment. For example, native Louisiana irises in a rain garden are beautiful to look

ECOLOGY & DEVELOPMENT

The parish's drainage canals and the historic arpent system of land division are visible in the existing street grid, and also provides opportunities for creating continuous habitats and corridors that extend from the backslope of the river levee to the 40 Arpent Canal and the Central Wetlands Unit.

Such habitats and corridors would encompass a full range of landscape types, and provide ecologically rich amenities that enhance the identity of the parish while providing a variety of water management functions.

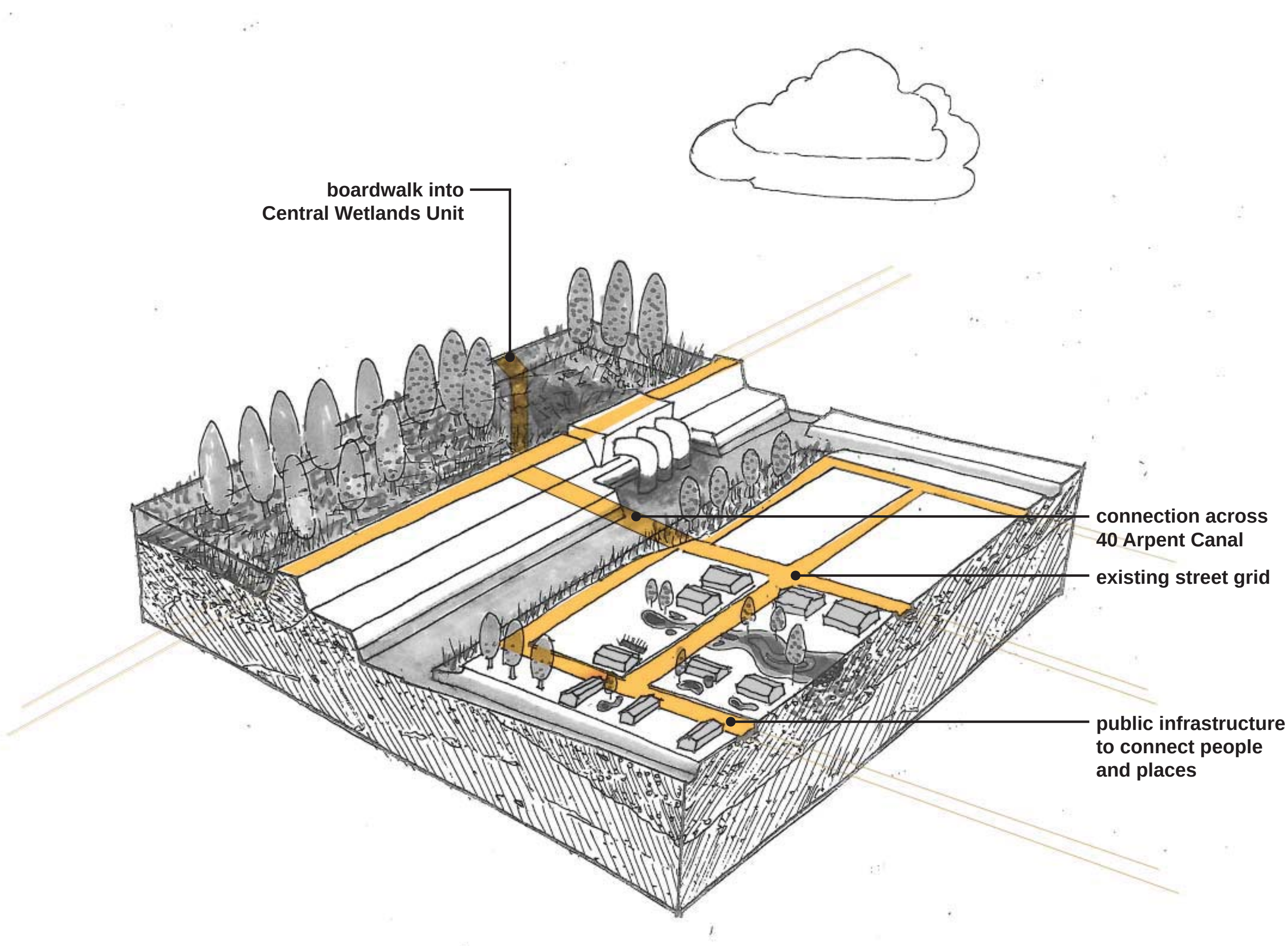
at, but they also use local ecology to meet water goals.

Similarly, the drainage system should be thought of as a "living water" system where flows are managed to improve groundwater and ecology. This would greatly enrich the urban landscape, where waterways act as connecting corridors for both people and a wide range of species, extending into attached gardens and park spaces that strengthen their recreational and ecological functions.

Planting trees is a central part of the green infrastructure strategy that provides a range of benefits. Trees support water function by slowing flow, storing, and using water, as well as restoring the canopy that was severely damaged during Katrina, by up to 90% in some parts of St. Bernard. An large scale effort to plant trees across the parish would also improve air quality, provide shade, and change the quality and character of the landscape.

The Central Wetlands Unit is a unique environment in the region as a former cypress swamp in the process of being restored. The 40 Arpent Canal zone works as the interface, a starting point for people to explore the CWU and the ways in which the parish exists between river and wetlands.

Mosquito control is very important because water that stands for more than a few days can enable breeding. Projects can be designed to have water soak into the ground and/or drain away within a day or two of rainfall, or to have continuously flowing water that disrupts breeding. Predatory fish and amphibians can also be used to control mosquitoes, and salinity levels can be adjusted to create an inhospitable environment for mosquitoes as well as invasive species such as the apple snail.



Recreational Network
The canals of St. Bernard are opportunities to provide access for kayaking, canoeing, and fishing, like in the bayous farther downriver.
Source: islenos.org

ACCESS & CONNECTIONS

Fully integrate surface water networks, waterfronts, wetlands, and water access into local and regional transportation and recreational networks.

Public infrastructure can be a system for connecting people and places, and to key assets like the 40 Arpent Canal and the Central Wetlands Unit. Creating an integrated blue-green network that provides pedestrians, cyclists, and boaters with continuous access would also link together neighborhoods. Longer connections along and through spillways and other undeveloped areas can bring people to new landscapes across the parish. By viewing water itself as a connector, and making use of existing surface water networks, people may one day be able to boat from Arabi to Paris Road, and from Chalmette to Meraux and Violet. This system could also become the basis for development and new types of communities.

Existing
Above: The 40 Arpent Wetland Observatory creates direct access to the canal in Chalmette, with a dock surrounding a new lagoon that preserved a mature cypress tree, and a pedestrian bridge across the water.

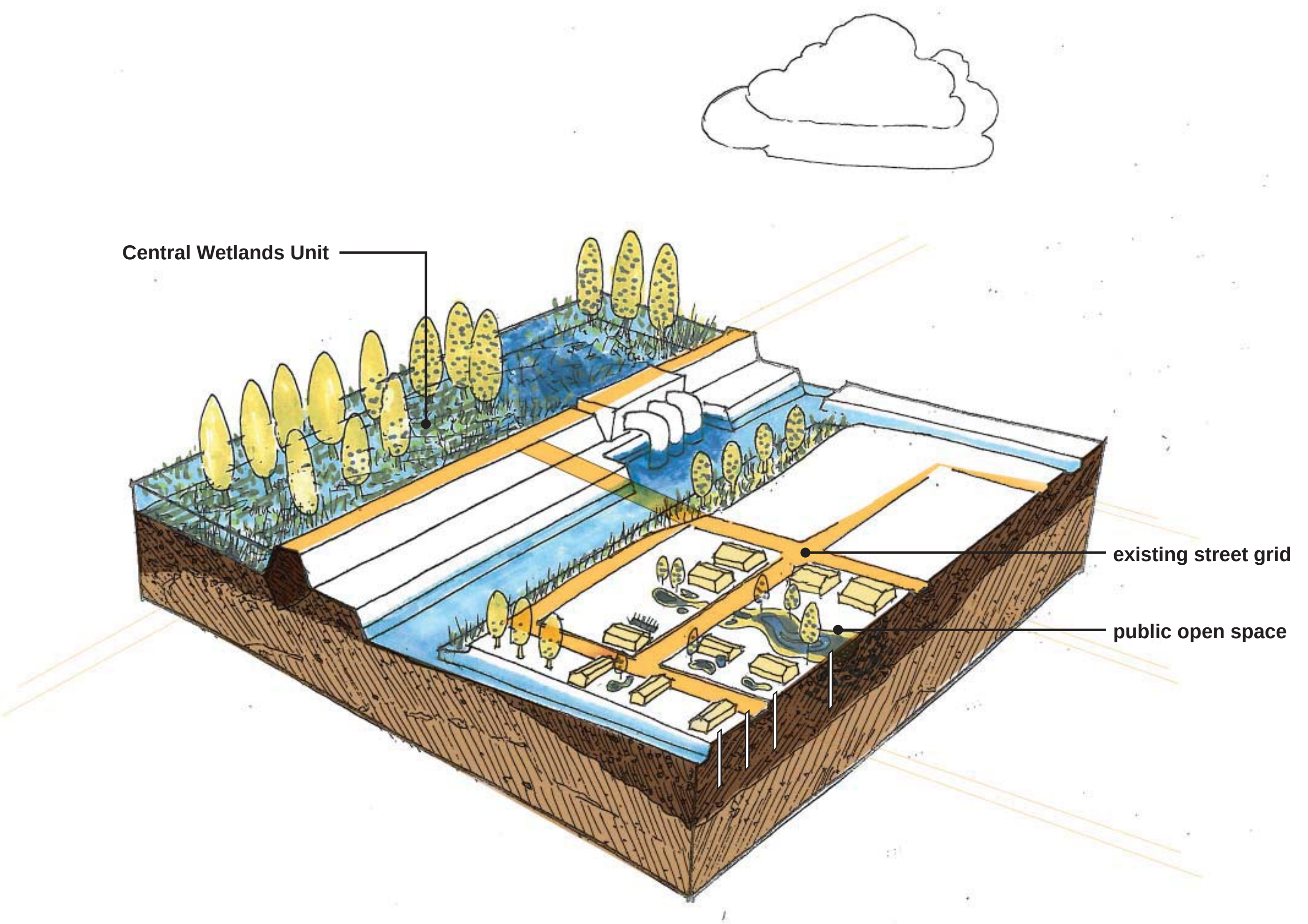
Proposed
Right: Overlook platforms as gathering spaces, with boat launches and pedestrian bridges linked by new trails.
Shown: Qunli Stormwater Wetland Park, Harbin, China

Existing
Above: ATV riders on the gravel trail in a large tract of undeveloped land next to the Central Wetlands Unit, with expansive views along the parish line.

Proposed
Right: System of new trails, trees, and low maintenance native vegetation at a large site along the water.
Shown: Riem Landscape Park, Munich, Germany

Existing
Above: A family explores the concrete embankment of the St. Avide Canal. The concrete is unattractive, but the canal is still frequented by nearby residents looking to get closer to the water.

Proposed
Right: Restored, accessible waterways with wide shared use paths and adjacent terraces for seating, with trees.
Shown: Guadelupe River Park, San Jose, CA



Backyard of the Parish
The vast Central Wetlands Unit, looking east toward Paris Rd, lies at the rear of urbanized St. Bernard, just beyond the 40 Arpent Canal levee, but is largely inaccessible and unused.

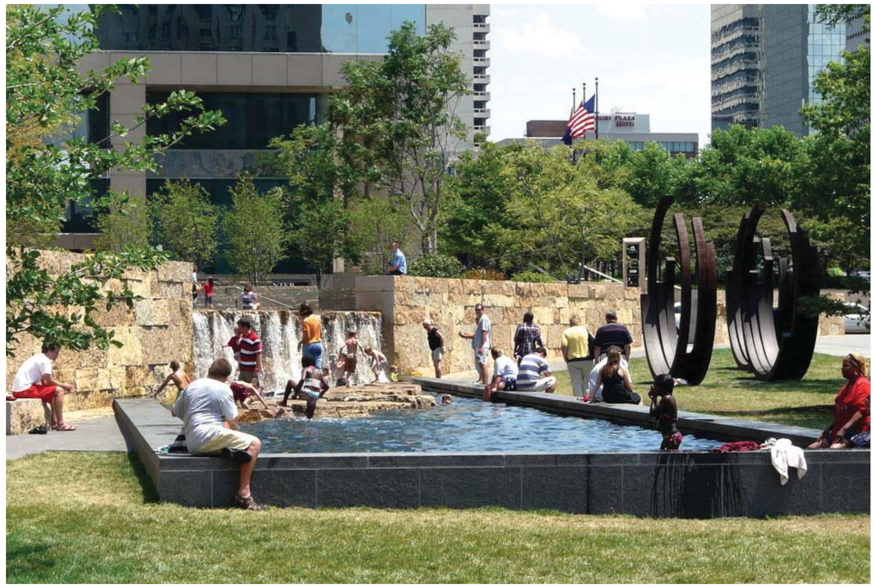
PLACES & IDENTITY

Create memorable and beautiful spaces that connect residents and visitors to the land, water, urban systems, and ecosystems that make St. Bernard unique.

New projects can improve the general understanding and appreciation of landscape and infrastructure, providing access to environments people actually want to be in. A simple path can itself be a destination, like the multiuse paths around Val Riess Park. Another goal is to create beautiful places for gathering and to be outside. The parish could become a regional destination, with access to wetlands, boating, and navigable canals only 10-15 minutes away from the French Quarter. The story of St. Bernard's wetlands restoration, levee protection system, and coastal land loss are are of the parish, the region, and the river delta.

Existing
Above: Sidney Torres Park, behind the St. Bernard Parish government buildings on Judge Perez Drive, has recreational landscapes and water features designed as a landscape.

Proposed
Right: Safe, interactive water features and spaces for recreation and socialization, including a splash park for children on hot days. *Shown: CityGarden, St. Louis, MO*

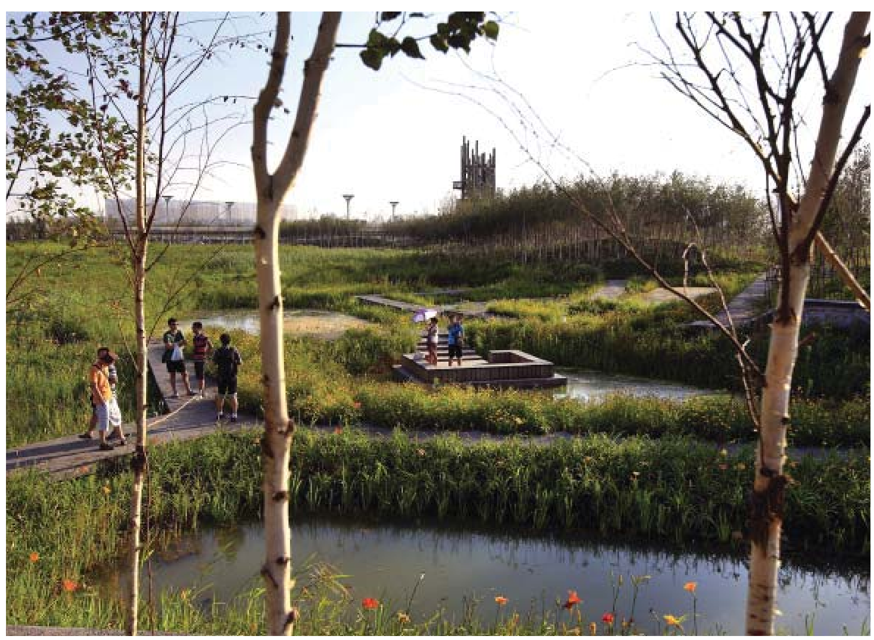


Existing
Above: The historic Pakenham live oak trees off St. Bernard Highway frame a depression that naturally retains water and provides wildlife habitat, adjacent to industrial land use and infrastructure.

Proposed
Right: More landscapes designed to integrate water storage with existing infrastructure to create habitat and public spaces. Many cities are now retrofitting urban waterways to store more water, while enhancing habitats and public spaces. *Shown: Buffalo Bayou, Houston, TX*

Existing
Above: Val Riess Park, along the 40 Arpent Canal, provides parish residents direct access to a waterway with adjacent public recreational spaces, such as concrete paths and playing fields.

Proposed
Right: Greater access to waterways and vegetation through a series of shared use pathways that connect spaces for water storage and recreation.
Shown: Qunli Stormwater Wetland Park, Harbin, China



Parish Scale System
Existing pump stations along the 40 Arpent Canal efficiently remove large volumes of stormwater, but this network could be adjusted to function in a more strategic way, with benefits and opportunities for the parish.

4
PROPOSAL | SYSTEM

The proposed stormwater system expands the capacity of the existing pipe and canal network with the addition of stormwater spillways, widened and improved canals, and retrofits to streets, parking lots, and parks that enable a parish-wide shift towards "living with water." In addition, new approaches to urban development, pump operation, the management of soils and water will continue to grow system capacity and improve system function over time.

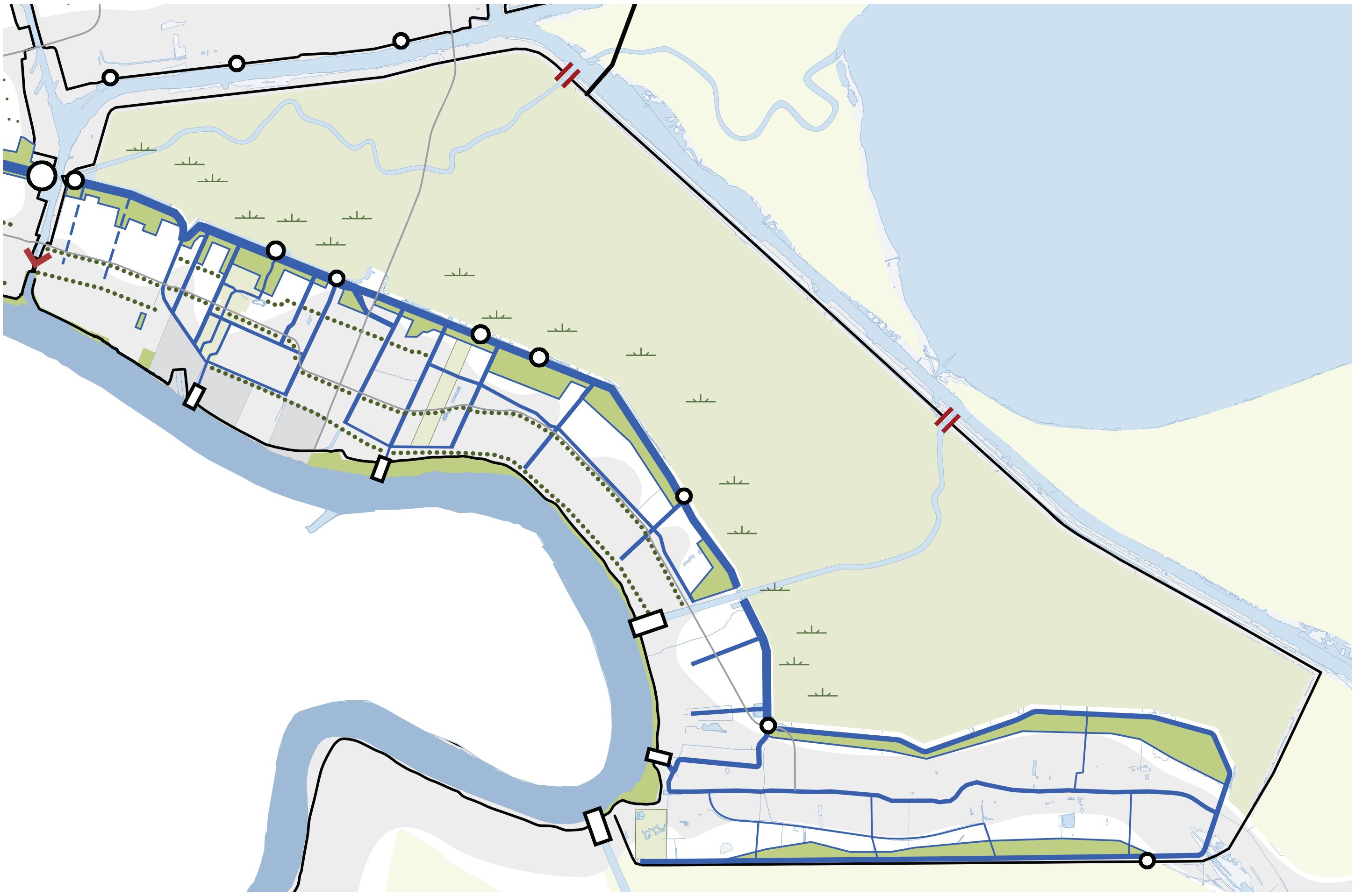
4a SYSTEM OVERVIEW

Strategic Parklands

Jefferson Parish's Wally Pontiff Park is the region's foremost example of a strategic parkland. Its 35 acre site is bounded by low levees, which contain stormwater pumped from adjoining neighborhoods into the park during heavy rainstorms.

The IWRM Plan team was able to build upon a range of lessons learned while studying, analyzing, and proposing projects for St. Bernard Parish during the creation of the Greater New Orleans Urban Water Plan. Compared to New Orleans, St. Bernard has a different set of flooding issues: most of the parish is on a backslope with less dense development patterns; this means that less stormwater runoff is produced. Most of the flooding is in localized areas, often related to individual culverts and junctures rather than a system-wide failure. St. Bernard has the potential, more so than in other areas, to be creative about reducing flood risk with both large and small scale measures.

To support the development of pilot projects, district scale planning, and systems scale framework for reducing flood risk, the projects proposed in this report were tested in a Stormwater Management Model (SWMM). The goals of the modeling process were to understand how a range of interventions would work within the overall parish systems.



The Integrated Living Water System
The IWRM Plan builds upon the strategies and concepts first developed for the Greater New Orleans Urban Water Plan, completed in 2013. The diagram above shows the overall GNOUWP proposal, which covers St. Bernard and the east banks of Orleans Parish and Jefferson Parish.

Small-scale Retrofits in streets, on individual properties, in parks, and in squares and plazas slow and store stormwater, catching and infiltrating water where it falls. Interceptor streets on high ground are a critical subset of small-scale retrofits.

Circulating Canals in the region's bowls and lowlands recharge groundwater and sustain local habitats. During wet weather, they continue to serve as drainage conduits.

Strategic Parklands at key junctures of the integrated living water system contain vast quantities of stormwater during heavy rains, while providing valuable open space and recreational amenities.

Integrated Wetlands located within strategic parklands and distributed throughout the region store and filter stormwater and dry weather flows. Existing wetlands are restored with treated wastewater and filtered stormwater.

pump

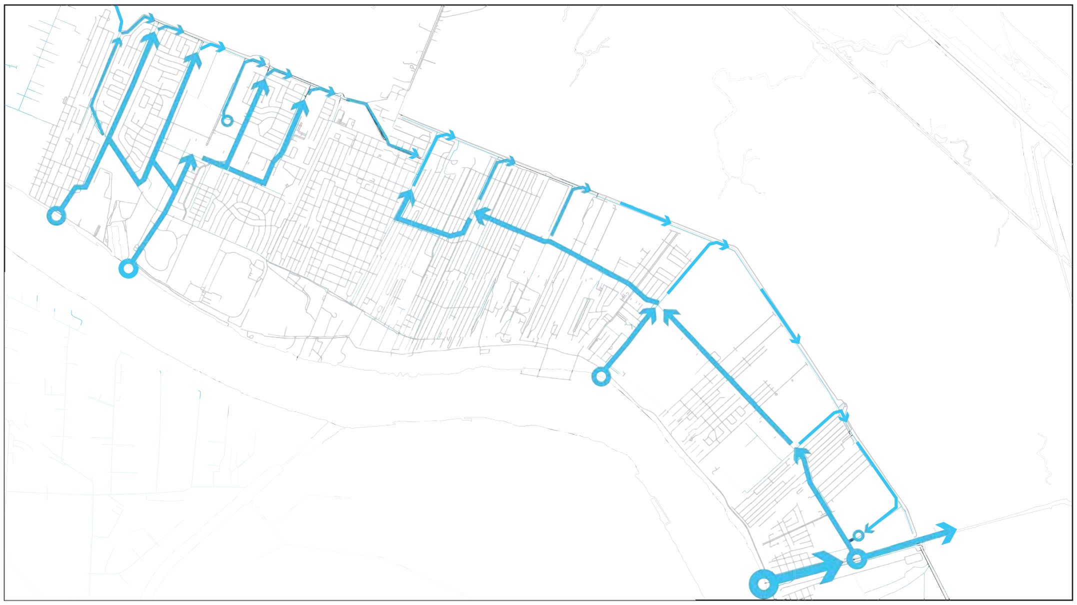
siphon

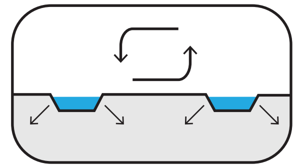
Integrated Waterworks are the water treatment plants, drainage pumps, siphons, sluices, weirs, and gates that contain, draw, redirect, and filter stormwater, surface water, groundwater, drinking water, sewage, and industrial wastewater. They are the components that establish the flows and rhythms of the living water system.

Larger scale concepts in the Integrated Living Water System:

Regional Monitoring Networks for surface water and groundwater provide system managers with real-time data that are necessary to address immediate drainage needs and long-term trends in water levels and water quality, and to maintain higher water levels without compromising safety.

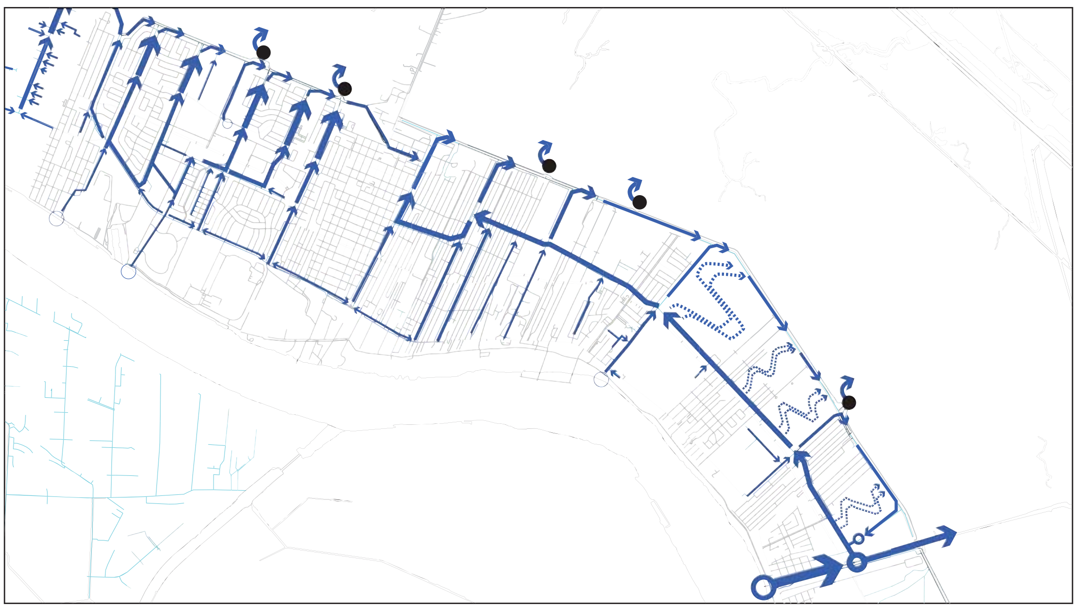
Waterfront Development Zones around key waterways and parklands anchor the development of higher-density, multi-use districts defined by urban water assets.

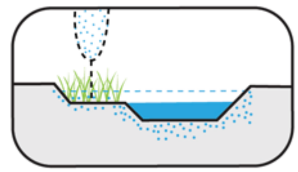




Dry Weather Flow

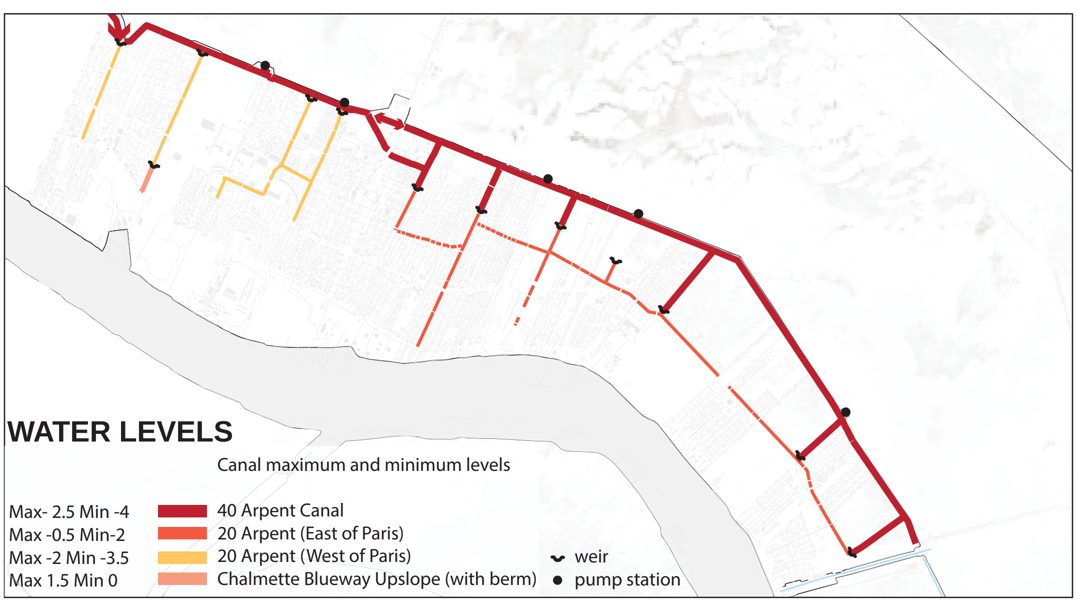
The proposed canal improvements and weirs would create flows throughout the entire system, improving the ecological and groundwater balance

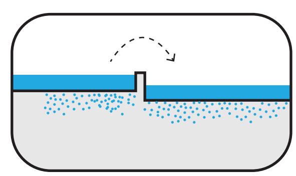




Wet Weather Flow

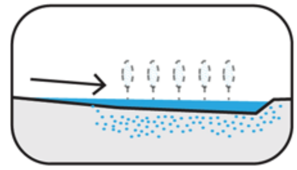
During rain events, new spillways would increase water flow throughout the system, while pump stations would have less volumes of stormwater to lift and pump over the levees





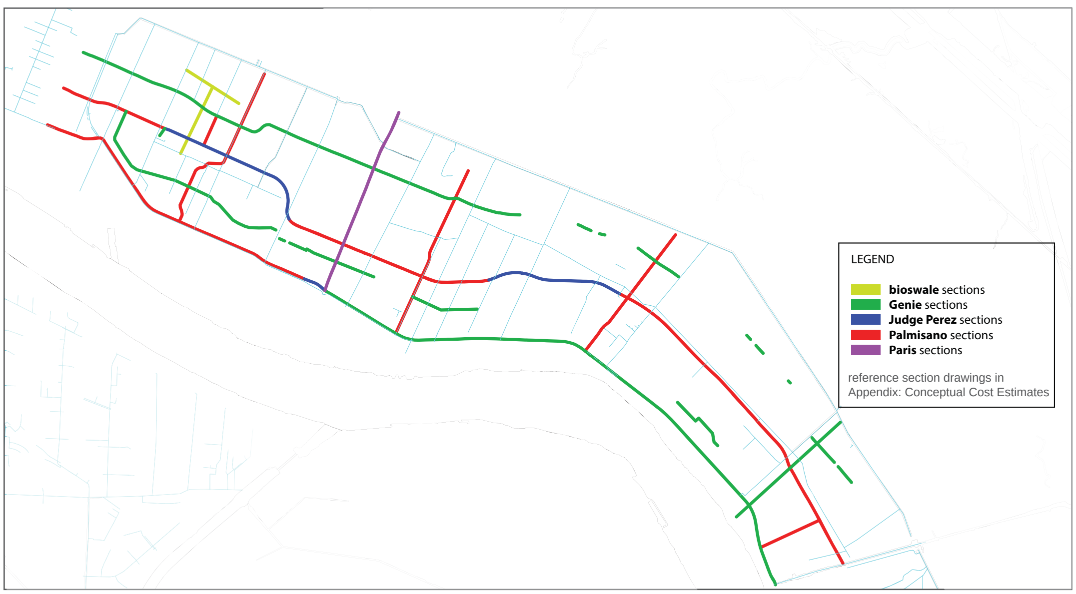
Strategic Water Levels

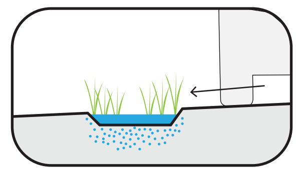
A system of weirs in canals would hold water upslope to lessen the initial demand on pumping stations and temporarily raise water levels, before overflowing towards lower ground



Stormwater Spillways

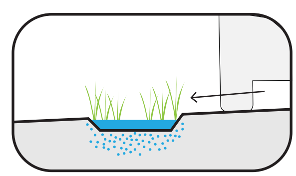
Large, undeveloped tracts of land along the 40 Arpent Canal at the lower end of Chalmette and in Meraux would slow and store vast amounts of stormwater.





BMPs

BMPs (Best Management Practices) combine a range of smaller scale measures that integrate increased storage capacity with improved urban design, including bioswales, pervious sidewalks, and street trees.



Retention and Detention on Publicly Owned Property

Large parcels of land, including existing public schools, would have a range of water storage elements with different capacities.

The addition of weirs throughout the canal network, introducing new sources of water, and adapting the use of the parish's existing pumps will allow greater control over water levels and water flow. This will benefit groundwater balance, water quality, aesthetics, and ecological health.

The likelihood of heavy and unexpected rainfall is far greater during spring and summer months. Operating stormwater systems to reflect these differences throughout the year will allow the parish to reduce flood risk while minimizing subsidence.

4*b*
WATER LEVELS AND FLOW

Raising Water Levels for Ecology and Aesthetics
Higher water levels are critical to maintaining the stability of soils, and would also make existing waterways more attractive as public spaces.

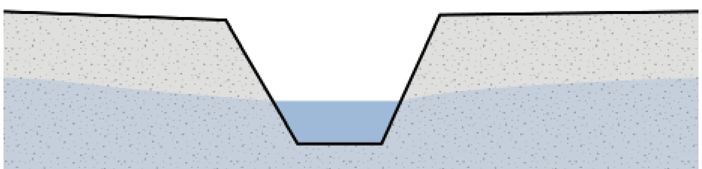
The system modeling conducted for this plan also explored options to raise water levels and introduce new sources of flow. Higher water levels are critical to maintaining the stability of soils – at the same time, raising water levels reduces the overall system storage capacity, both of soils and waterways. This is both an aesthetic and ecological strategy. Higher water means less distance between surrounding roads, ground, and people to the surface of the water. Thus, waterways become more attractive and less threatening. Otherwise, they appear as ditches, as large cuts in the ground with stagnant water at the bottom, often with unsightly banks and outfall pipes. Raising water levels requires a wholesale shift in engineering and understanding of ditches and canals, while seeing them as potential urban waterways instead.

Flow is critical because it improves water quality, prevents mosquitoes from breeding, moves nutrients, and flushes debris and sediments out. Aesthetically, stagnant water is often unsightly, evident in most of the parish's waterways.

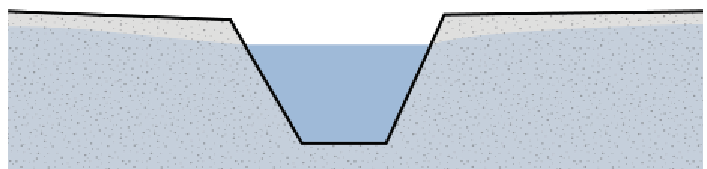
One option of establishing a system-wide flow is to use the existing power of the Mississippi River, which already pushes water through the Violet Canal and into the Central Wetlands Unit. That force could drive flow into St. Bernard's network of canals. As the Parish and US Army Corps of Engineers consider changes to the Violet Canal, including a new route, the need for water sources to feed

Low Levels and Flow, System-wide
St. Bernard's canals are typically shallow – which leads to subsidence – or are stagnant or choked with invasive aquatic vegetation, such as the intersection of the 20 Arpent and Dubouchel Canals in Meraux.

Weirs to Increase Levels and Flow
Passive systems like a weir, shown above at City Park in New Orleans, hold back water at a higher level until it spills over, which delays the need for pumping as well as creates flow.



Low Water Levels and Flow
Top: Low water in canals lowers groundwater levels, causing subsidence
Above left: 40 Arpent Canal with low flow and invasive water hyacinth
Above right: Stagnant canal in Chalmette with oxygen-depriving algae



High Water Levels and Flow
Top: Higher water in canals raises groundwater levels, stabilizing soils
Above: Circulating water creates flow to improve water quality

into the urban canal network could be integrated. Water from the river, however, is highly polluted. Ideally, a new intervening filtration wetland would clean water from the river before using it to drive flow into the canals. Another possibility is drawing water from the Central Wetlands Unit via existing pump stations, but complexities include introducing higher salinity levels, and that pumps use energy to move water uphill over the levee whereas the river works with gravity.

Since extreme weather is common in St. Bernard and the region, the operation of systems may need to be more finely tuned according to the seasons. Real time control of the parish pump system, based on weather forecasts, could be feasible. Deltares, the IWRM Plan team's geohydrology consultant, plans to study the application of this operation in the New Orleans area.

Wetter spring and summer months, until end of hurricane season, bring high levels of rainfall. The unpredictability of weather patterns requires sufficient storage capacity across the system, so water levels may need to be maintained lower than the ideal for limiting subsidence in order to accommodate runoff from a storm. At same time, proposed spillways, lagoons, and BMPs would change the level of moisture in the landscape to closely resemble natural patterns of rainfall. Similarly, the flow of waterways would resemble precolonial patterns.

Dry weather in the late fall and winter is more predictable, and not as prone to heavy rainfalls. Generally, it would be safer to maintain higher water levels with time for the pump stations to draw down canals in advance of large storm events. The parish, like the rest of the region, will still likely experience shrink and swell cycles, along with occasional drought conditions. To alleviate subsidence,

Reducing pumping by increasing the storage capacity of the landscape and stormwater infrastructure will reduce the cost and environmental footprint of the drainage system. Pump operations can be adjusted as new storage capacity is added to the system, in response to the specific duration and geography of different storm events, and in accordance with broader environmental and planning objectives.

4C PUMPING OPTIONS

Effective but not Energy Efficient
Existing pump stations along the 40 Arpent Canal form a redundant network; if one fails the others keep pumping the same water. This system is effective, but also uses a tremendous amount of energy.

Pumping millions of gallons of stormwater and lifting it up and over levees every time it rains requires tremendous resources, both in staffing operations and in energy. The system modeling process conducted for this plan shows that integrating spillways, BMPs, and other measures would allow the parish to turn off certain pumps completely during many storm events. St. Bernard's interconnected system of canals creates redundancy between pumps and waterways; power failures during Hurricane Isaac shuttered some pumping, but the parish did not experience significant flooding.

This is possible, partly because of the parish's interconnected system of canals, where pumps and waterways provide mutual redundancy. This is also possible because the parish's landscape is primarily a backslope condition, which is relatively high ground, and with large undeveloped areas and generally lower density of development. This means that overall, there is less stormwater runoff.

SWMM modeling results show that turning all pumps off is not feasible, but leaving some of the pumps off – those downstream of Paris Road – is possible, due to lower levels of urbanization. Selective pumping would be paired with large scale measures that provide replacement storage so that there is no added risk.

Less pumping would be a tremendous benefit to St. Bernard because the pumping capacity is still maintained, but the reliance on the pumping is reduced. The overall capacity of the parish grows, but relies less on fossil fuel powered mechanisms to maintain same level of safety. This is a land use and land cover solution to an engineering problem, rather than furthering reliance on pumping, which only exacerbates the rate of subsidence. Reduced energy consumption that results from less frequent pump operation would also save the Parish a significant amount of money, which could be used for other related efforts.

Note that none of these options suggest reductions in pumping capacity. Pumping is and will continue to be vital for the safety of the parish. These options describe ways in which the pumps can be operated, in parallel with other projects and programs proposed in this plan, to reduce dependence on pumps, especially for smaller rain events.

Option 1: All Pumps On

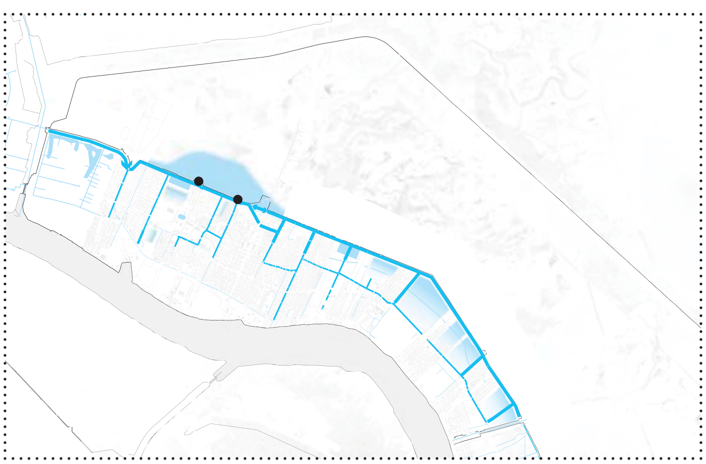
Current operation utilizes all pumps. Connected by the 40 Arpent Canal, there is built in redundancy, because failure at one pump station can be addressed by utilizing the pumping capacity of another station. These pumps can also be used to drain the parish in the case of a levee breach.

Option 2: No Pumps On

This scenario would only be possible for very small rain events and if enough storage capacity is added and runoff reduction measures are implemented so that the landscape can safely accommodate all of the runoff from a rain event.

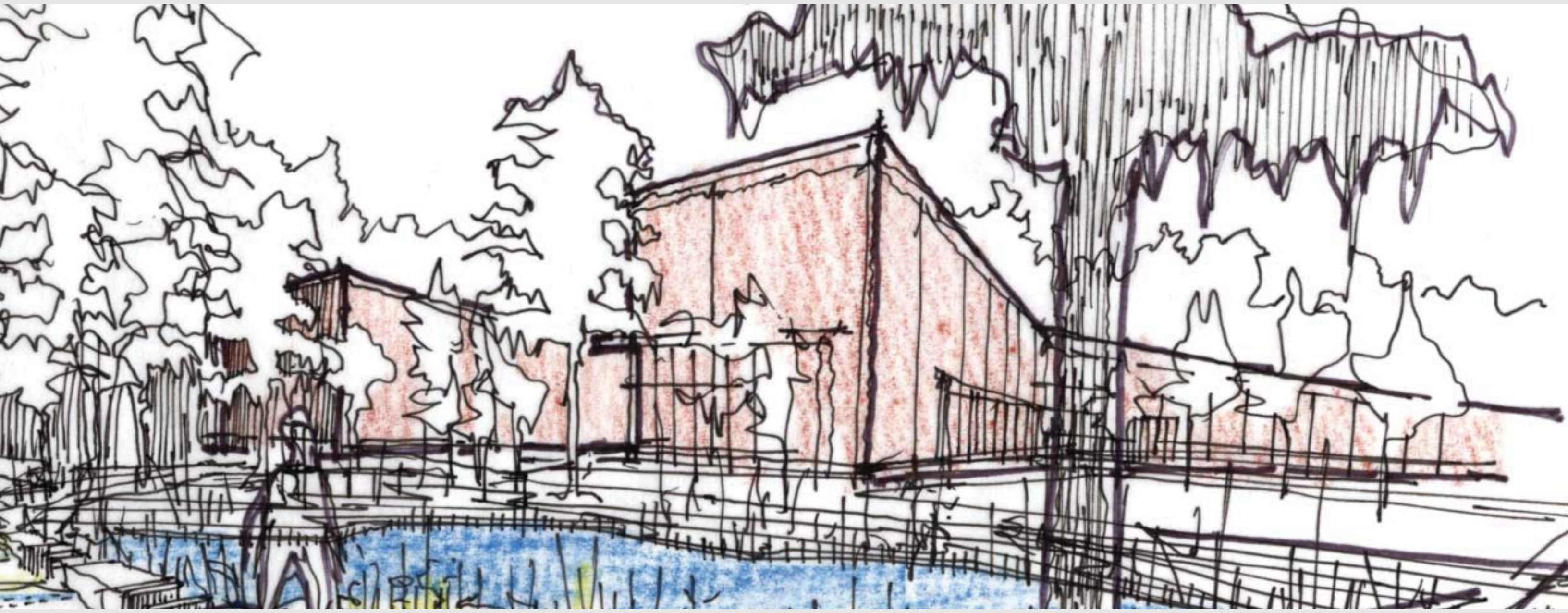
Option 3: Half Pumps On

This proposed scenario utilizes every other pump station along the 40 Arpent Canal – shown here, DPS #5, Guichard, Bayou Villere, and Meraux – in order to balance better the need for drainage and the need to reduce pumping costs. This is only feasible, however, for smaller rain events, and would contribute to flooding during heavier rainfall, even if all other proposed adaptations are fully implemented.

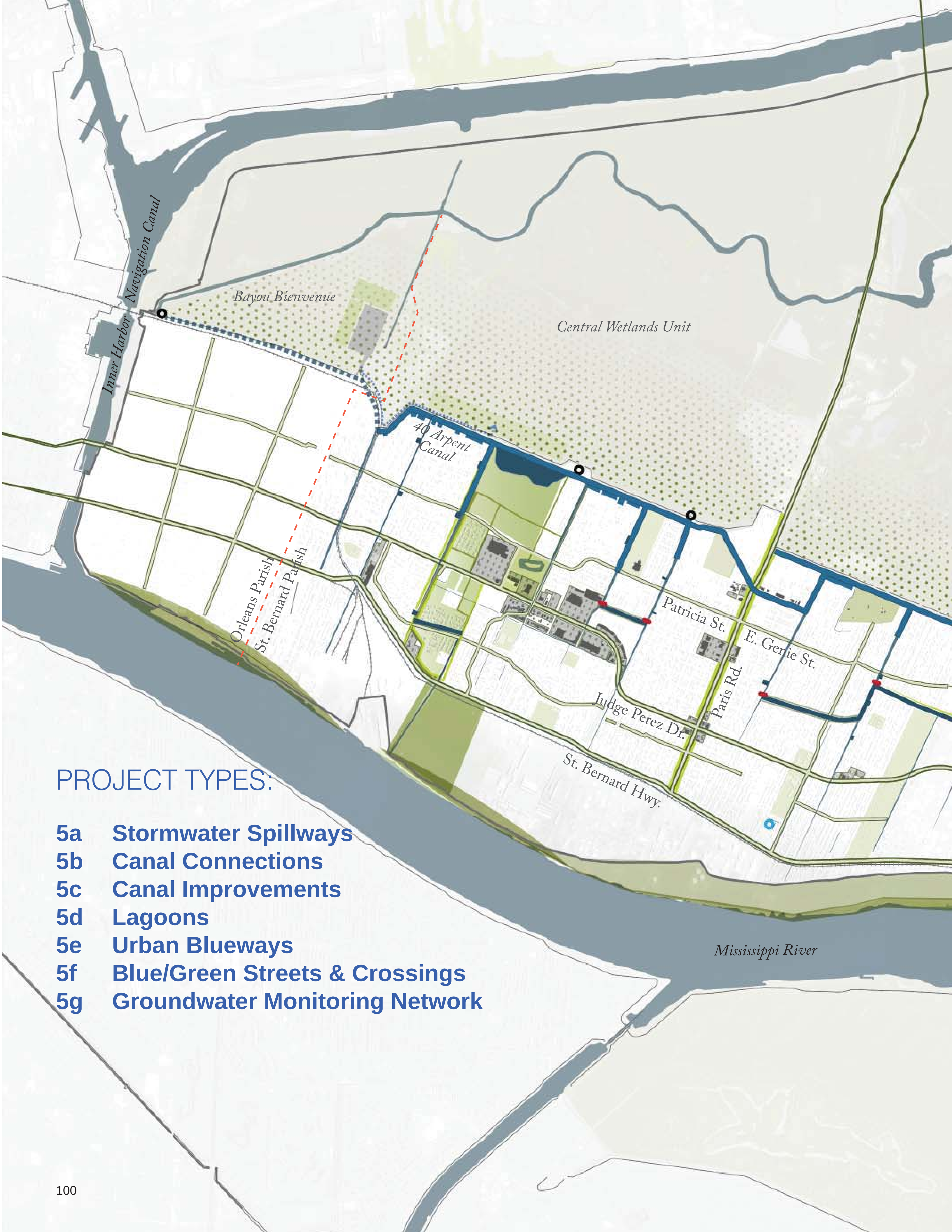


Option 4: Selected Pumps On

This proposed scenario includes operation of two pump stations – Jean Lafitte and Guichard – to reflect the greater density, rates of runoff, and dependence on pumping in Arabi and Chalmette. This option encourages greater opportunities for using improved canals and stormwater spillways to manage stormwater in less densely settled parts of the parish, like Meraux and Violet.



5
PROJECTS



PROJECT TYPES:

5a Stormwater Spillways
5b Canal Connections
5c Canal Improvements
5d Lagoons
5e Urban Blueways
5f Blue/Green Streets & Crossings
5g Groundwater Monitoring Network


Mississippi River Gulf Outlet
Lake Borgne
Central Wetlands Unit
20 Arpent Canal
40 Arpent Canal
Violet Canal
limit of study area
LEGEND
canal
exist. pump station
exist. levee
exist. drinking water
weir
stormwater spillway
new development
lagoon
CWU assimilation
green streets
detention sites
parking lot retrofits

5a
STORMWATER SPILLWAYS

Proposed stormwater spillways are large system scale measures that utilize the existing topography to store large volumes of water in order to relieve the drainage canal network during heavy rain. The starting point is improved control of water at a higher level in the landscape. Rather than allowing runoff to rush unchecked down to the 40 Arpent Canal, the spillways rely on manually operable weirs along the length of the 20 Arpent Canal to hold back water. When water in the 20 Arpent reaches a certain level, the weirs at the head of each spillway would allow water to spill over into open land and flow, by gravity, slowly down towards the 40 Arpent.

Each spillway is designed so that half of the land is still available for development. By considering the spillways as amenities, the design of new developments and spillways should be integrated to enhance St. Bernard's identity, and draw attention and improve access to the spillway. As public spaces that serve the whole parish, the spillway's infrastructural function should be evident as one passes by.

Some spillways will require low berms in the 1-3 foot range to ensure that water does not spill over into adjacent neighborhoods. The concept takes advantage of the historic arpent system's geometry, where swathes of land extend perpendicular to the river, out to the wetlands.

The proposed spillway development model embodies the notion of "living with water," maximizing the length of time that water stays in the landscape rather than rushing it out of the system. Water then has a chance to infiltrate into the ground, and also be cleaned by vegetation. The overall effect is a reduction of pumping. By adding a significant storage capacity, during smaller storm events and in large swathes of the parish, pumping won't even be necessary. For larger rain events, there will be less pumping, and also a non-mechanical system that reduces the overall load on the rest of the system.

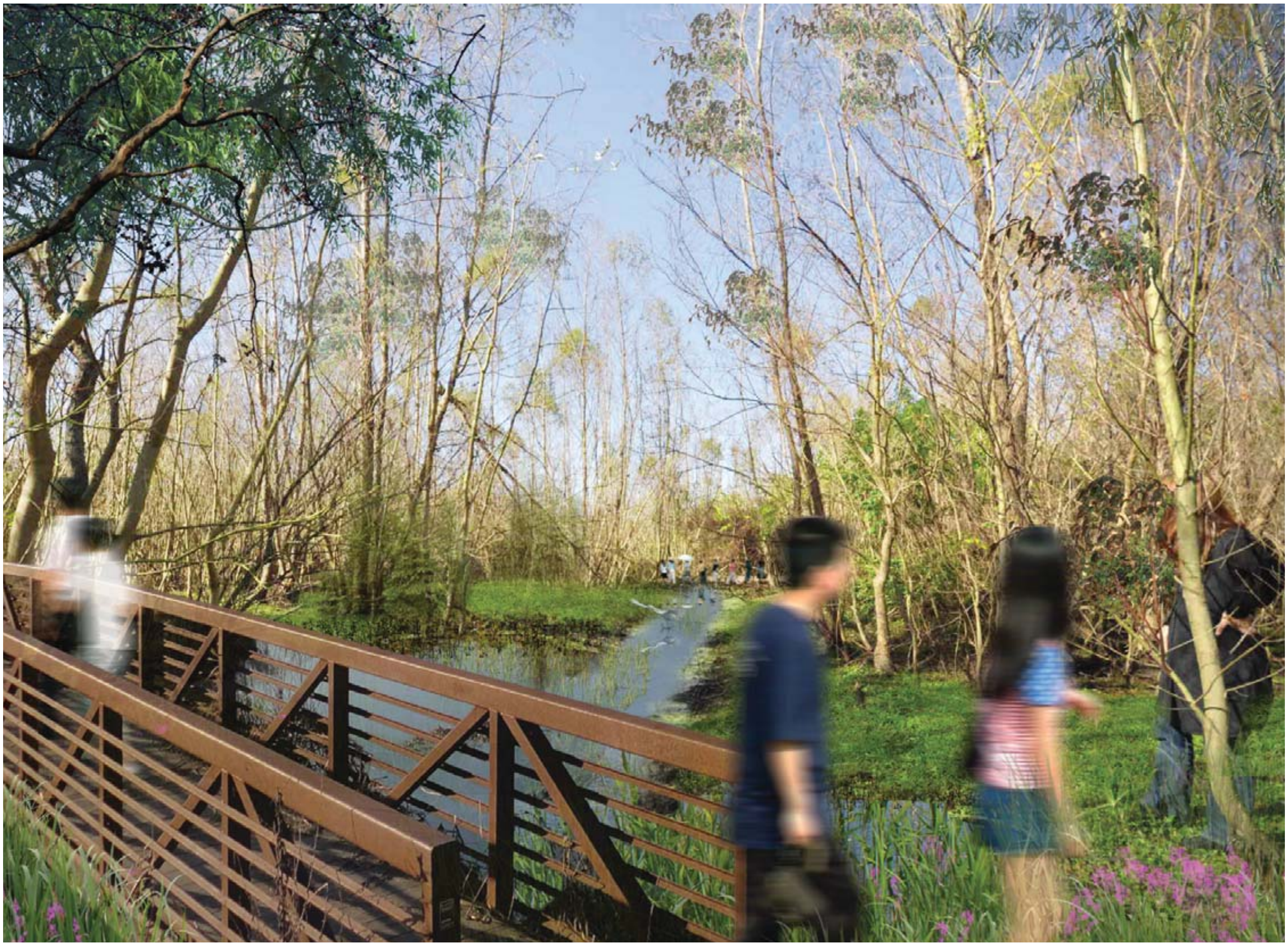
The spillways restore the seasonal overbank flooding that characterized a pre-European delta landscape, where spring high waters sent river water and sediments over levees and through crevasses into the surrounding landscape. The stormwater won't be sediment rich, but the freshwater that would flow through the spillways could transform the ecology of these areas. This temporary inundation of 1-2 feet of water would likely eliminate some invasive species that cannot withstand such high water levels.

If weirs, levees, spillways, and canals, and maintenance paths are thought of as part of the same system, then this is an opportunity to create a network of pathways and amenities for parish residents and visitors. Boating, along with walking/jogging/hiking paths, and educational opportunities make a largely unknown part of the landscape accessible at a large scale.

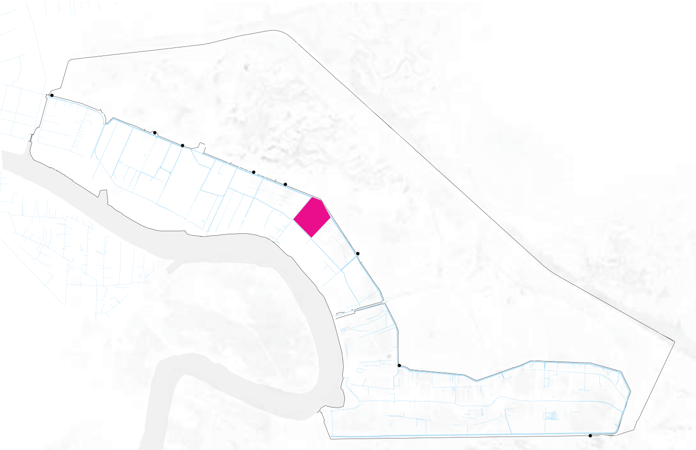
Spillways also promote conservation and keep land out of development in a way that reinforces identities of St. Bernard settlements; green space in between urbanized areas maintains this distinction, threatened by conventional suburban development. Encouraging use of the spillways as publicly accessible systems provides an economic basis for maintaining and operating them. Designed to be low cost in operation, with no mechanical equipment other than the weirs, low water levels and flow through uninhabited areas requires much less maintenance than canal systems.

Existing swaths of open land can be adapted to store and infiltrate large volumes of stormwater, reducing risk, and enhancing water quality and ecology.

Implementation requires commitments from landowners, land trusts, and other entities to ensure the use of undeveloped parcels as spillways. This is a big ask, but not insurmountable; the Meraux Foundation is interested in a spillway as a pilot project. Spillways can also serve institutions as a place to study the restoration of wetlands.



New Trail Network
The Meraux Spillway would tie into a proposed system of new trails throughout St. Bernard, connecting to a river levee bike path and the 40 Arpent levee trail



MERAUX SPILLWAY

This proposed stormwater spillway occupies a large area of undeveloped land between the Twenty Arpent Canal and 40 Arpent Canal. Similar smaller sites, as shown on the previous page, are also candidates for spillways. Water that collects in the Twenty Arpent Canal would safely overflow into a gradually sloping landscape, bounded by low berms, flowing towards the lower ground of the 40 Arpent Canal. Gravity would drive water movement, eliminating the need for pumps. The spillway slows and cleans the water, which would be controlled by a series of manually operated weirs. Protected by berms, the adjacent higher land could be developed into a unique wetland neighborhood.

Economic: reduced operation of Parish pumps; water management and habitats serve as recreational amenities
Quality of life: reduced flooding, improved ecosystems
Ecological: restored seasonal overland flow of water

Using Gravity
The existing 20 Arpent Canal would overflow, controlled by weirs and berms, and run into the spillway through bank cuts, flowing to lower ground and into the 40 Arpent Canal.

Developable zones
Potential for unique wetland neighborhoods, protected by berms

Spillway
Slows and cleans large volumes of water, significantly reducing Parish pump operations

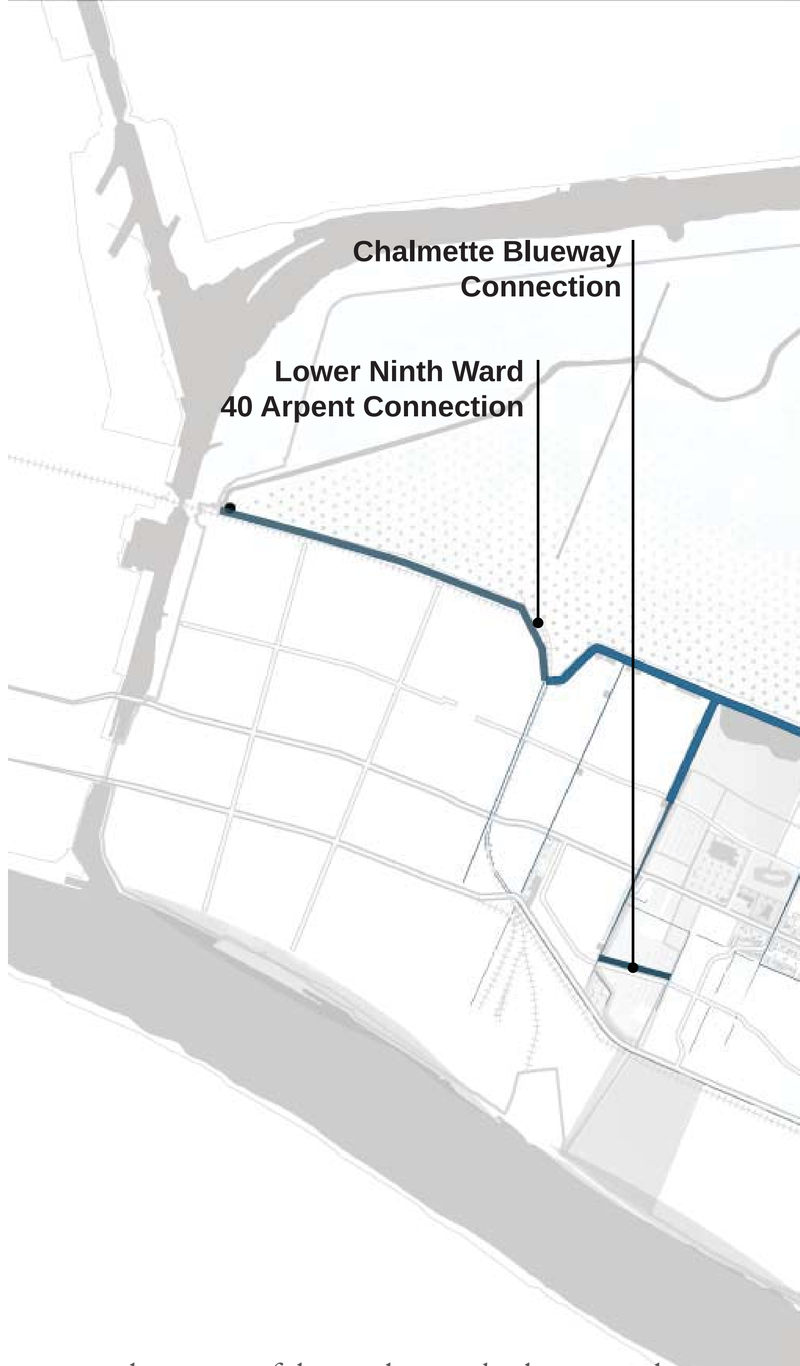
5b
CANAL CONNECTIONS

Canal Connections are targeted interventions that enhance the overall function of the parish's stormwater network. New and expanded lateral canals and culverts improve the flow of water between different sub-catchment areas. This increases the redundancy and adaptability of the overall system.

One of the advantages of St. Bernard's canal system is that the canals drain to a single backbone canal, the 40 Arpent Canal. This means that water can flow laterally along that backbone canal, so that when one pump station is not in use, other pump stations can still provide the needed pumping capacity to keep all sub-catchments dry.
Just as the 20 Arpent Canal already provides a lateral connection all the way from Chalmette to Violet, the IWRM plan proposes the introduction of new lateral connections higher up in the watershed. These new canals are designed to function as retention areas that infiltrate stormwater into the ground, and also as conveyance channels that help to drain stormwater from new development sites into existing perpendicular canals.

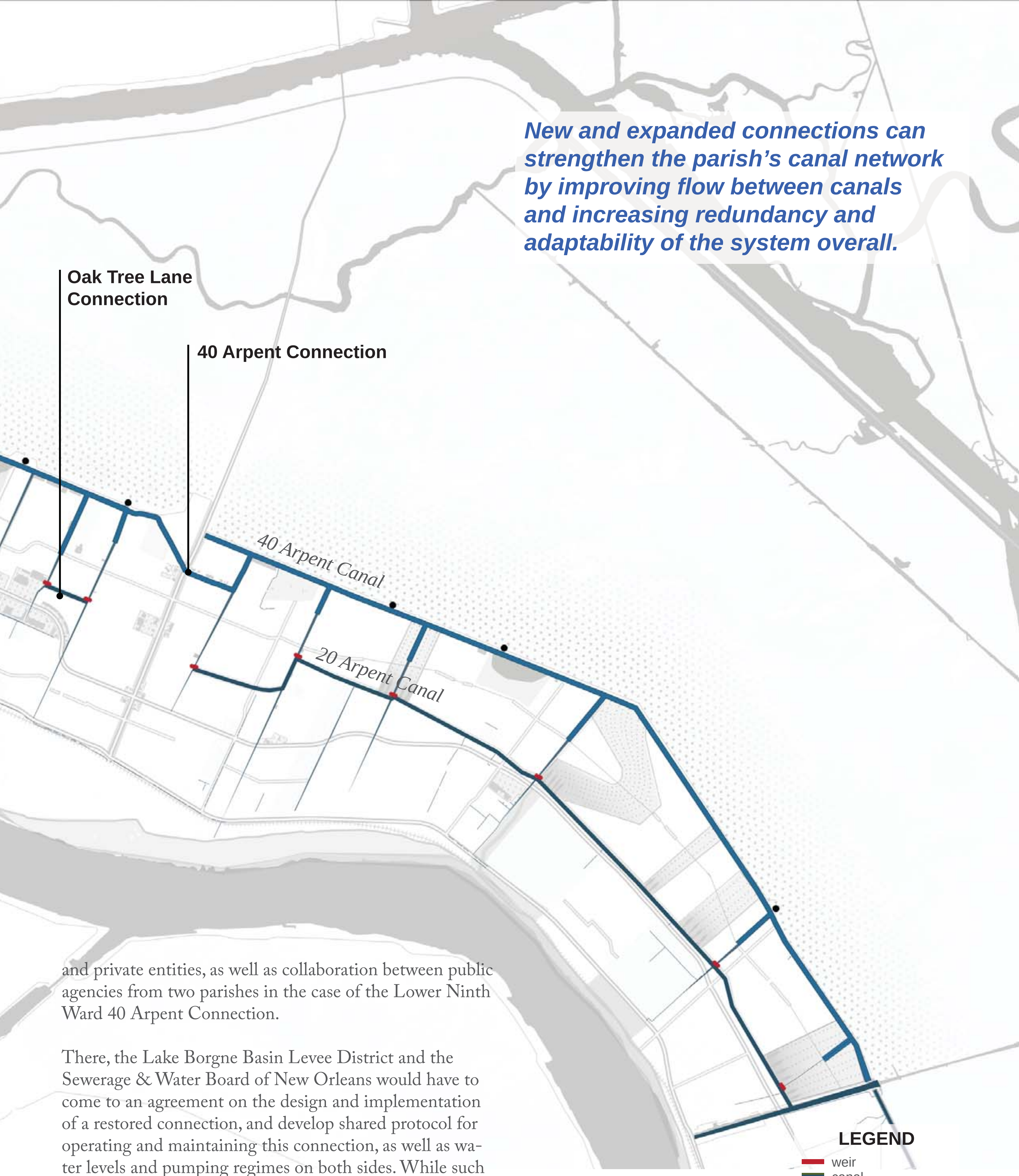
The IWRM plan also proposes restored and expanded lateral connections at two critical junctures along the 40 Arpent. The first is at the parish line, where the Ninth Ward butts up against the western boundary of St. Bernard. the pipe and culvert network of New Orleans is separate from the open canal network of St. Bernard – the connection between Orleans Parish's Florida Canal and St. Bernard's 40 Arpent Canal was closed off for political reasons in the late 20th century. The two sides of this political boundary, however, still belong to the same hydrological basin. Reconnecting these two sides would extend the redundancy and resilience of the St. Bernard system to the Lower Ninth Ward, and the inclusion of Orleans Parish's Drainage Pump Station 5 would expand the overall capacity of the reconnected system
.

The second is at Paris Road, which is a ridge extending from the river out into the Central Wetlands Unit that divides the catchment area for the 40 Arpent Canal into two. Expanding the existing culvert that conveys water between the two sides will improve the flow of water along the 40 Arpent Canal. Because of the different patterns of land use upriver and downriver of Paris Road, an expanded lateral connection at Paris Road can help to balance differing rates of runoff. That is, this expanded connection, like the other proposed connections, can help distribute runoff more evenly, as parts of the canal network where water levels are lower can more readily provide relief for parts where there are greater volumes of runoff and higher water levels.



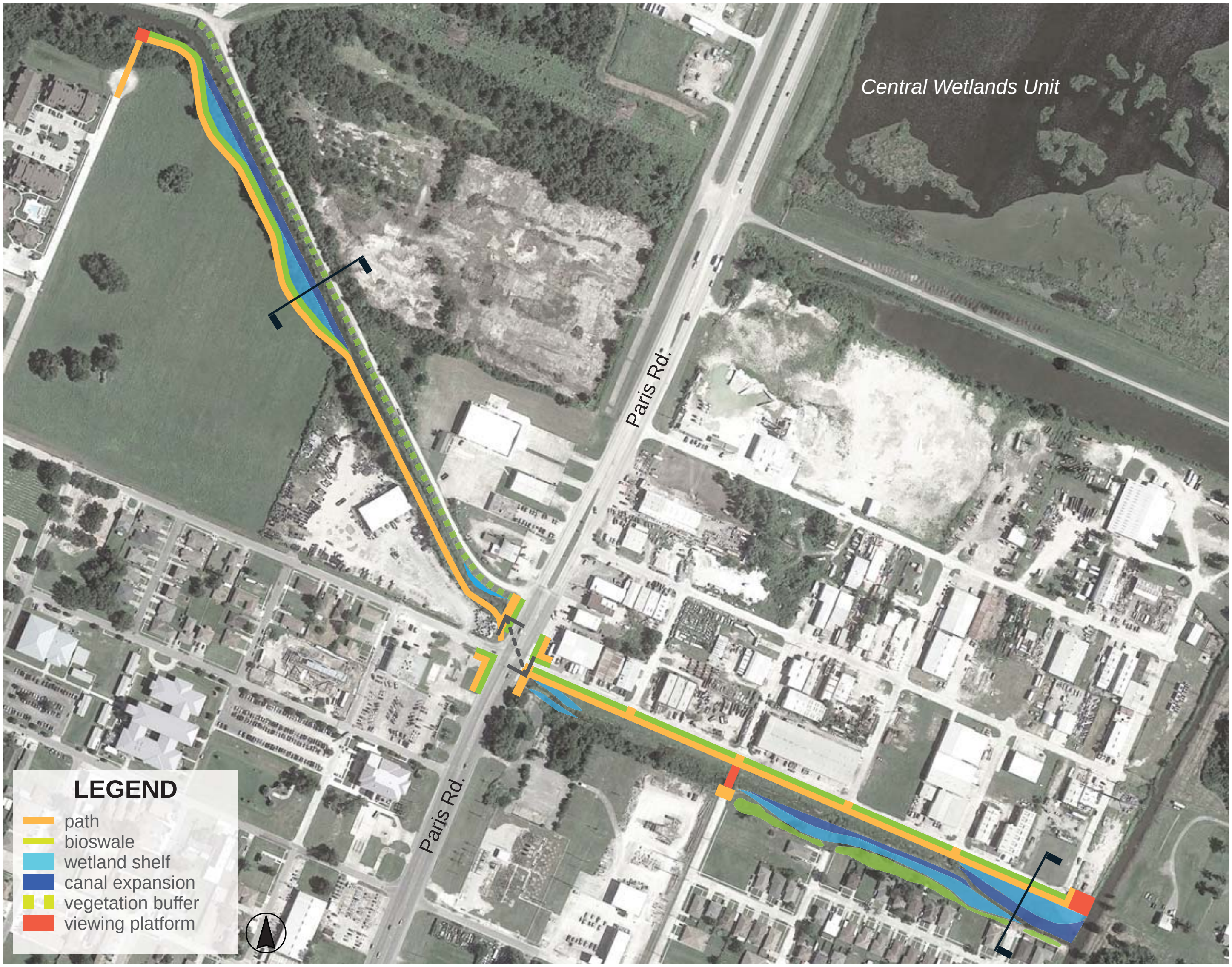
With wet weather conditions, the new and expanded canals will provide additional storage capacity, and improving the lateral connectivity of the canal network should reduce flood risk and improve the efficiency of system overall. With dry weather conditions, improved connectivity will enhance the ability of the parish to manage water flow and groundwater conditions. There will be fewer dead ends in the system, so that there are fewer areas of stagnant water. And introducing new lateral canals increases the density of waterways in the parish, which is an important indicator of the ability to infiltrate water into the ground and balance groundwater levels.

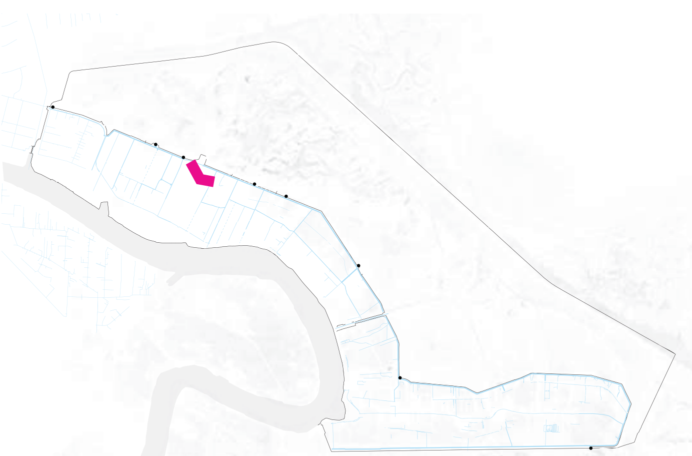
The proposed lateral connections (either expanded, restored, or new) will require collaboration between public



and private entities, as well as collaboration between public agencies from two parishes in the case of the Lower Ninth Ward 40 Arpent Connection.

There, the Lake Borgne Basin Levee District and the Sewerage & Water Board of New Orleans would have to come to an agreement on the design and implementation of a restored connection, and develop shared protocol for operating and maintaining this connection, as well as water levels and pumping regimes on both sides. While such cooperation may have been infeasible in the past, current collaboration on the wetlands assimilation project in the Central Wetlands Unit between those two entities shows that high-level cooperation is not out of the question.



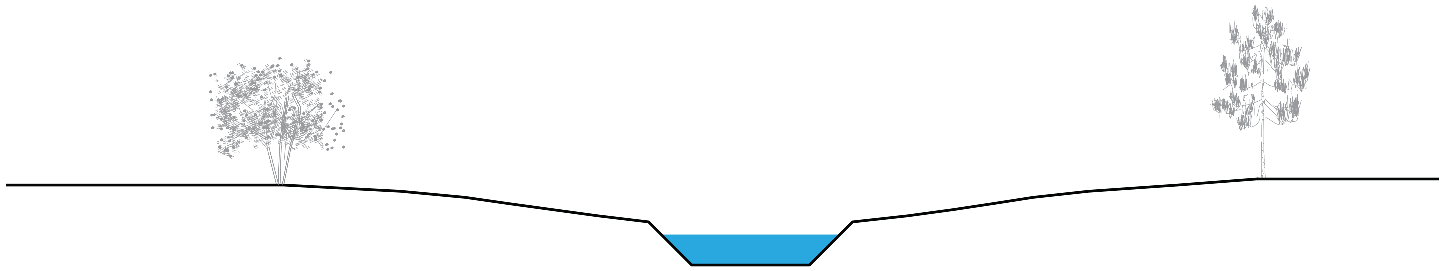


40 ARPENT CONNECTION

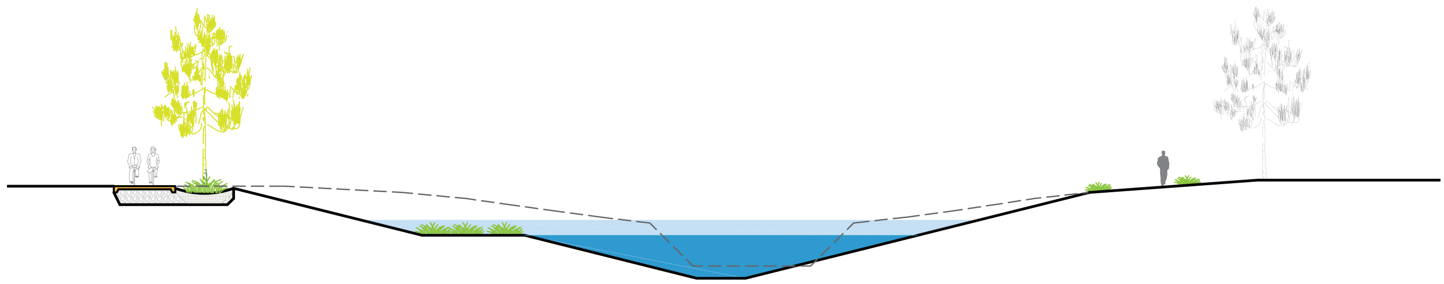
The project goal is to expand the movement of water in the 40 Arpent Canal at Paris Road, where it currently flows through two culverts below the roadway. Widening the existing canal and adding wetland shelves provides additional water storage while creating new habitat. New pervious paths alongside bioswales and trees make the improved canal accessible, along with a pedestrian bridge. These urban design elements link the commercial zone to the northeast, while the west side becomes more like a nature trail. The intersection of Paris Road, a major gateway to the parish, with the 40 Arpent Canal, St. Bernard's primary interior waterway, is highlighted here as a critical place for improved ecological and urban design.

Economic: new gateway enhances redevelopment potential for key commercial area
Quality of life: improved urban design and connectivity
Ecological: healthier hydrology creates habitat

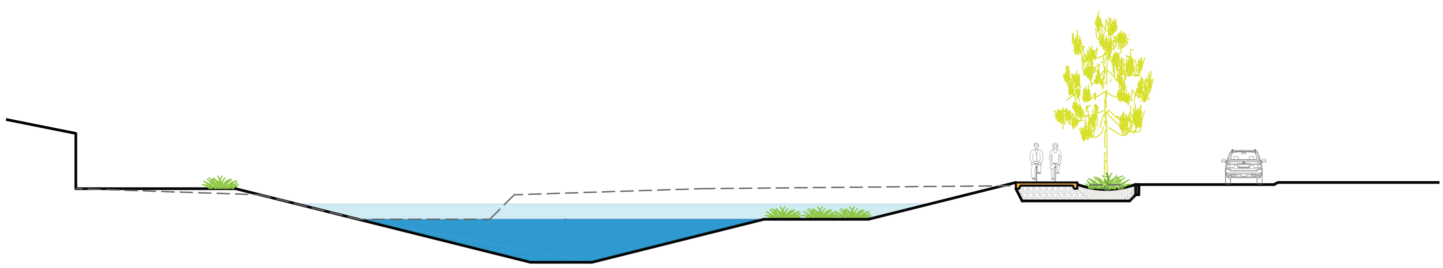
WEST SIDE - EXISTING



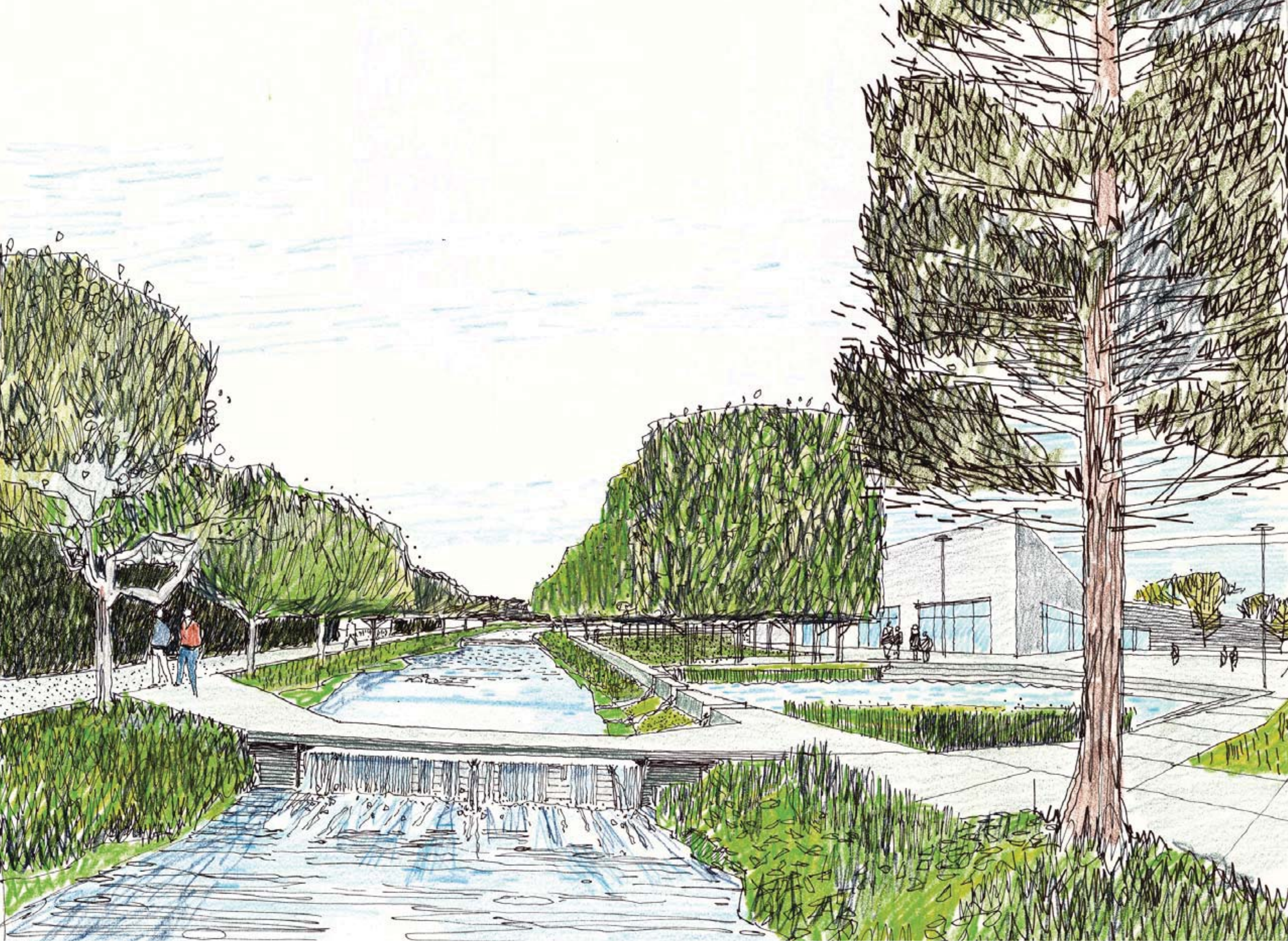
WEST SIDE - WIDENING AND WETLAND SHELF



EAST SIDE - WIDENING AND WETLAND SHELF

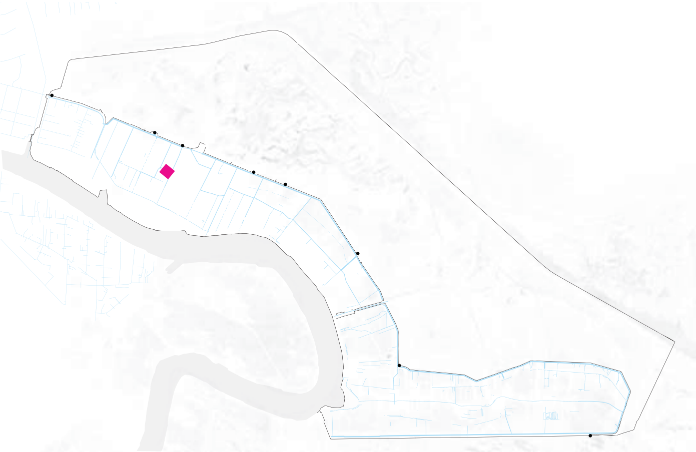


Connecting Water and People
Diagram showing widened canal to increase water storage, wetland shelves with vegetation, multiuse pathway along the canal, trees, and a pedestrian plaza at the street intersection which extends to the existing culvert closure gate, providing a close up view of the water.



Linking Water and Neighborhoods
Spaces for people, habitats, and water along a new canal connect neighborhoods, and encourage redevelopment.

OAK TREE LANE

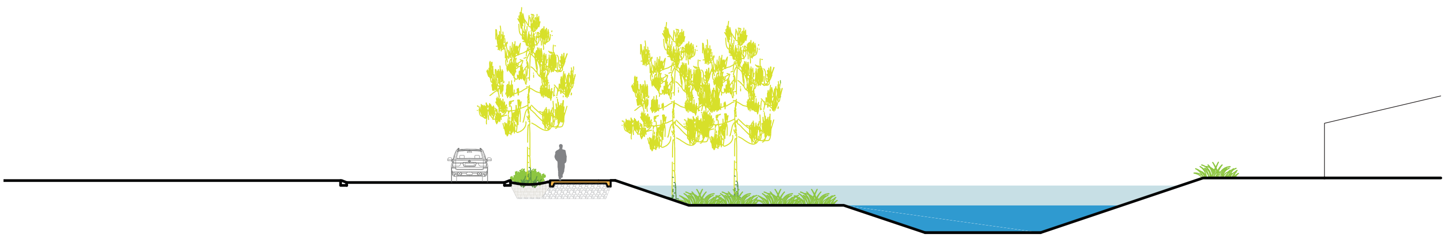


Located in a vacant zone of land just north of Judge Perez Drive, this project proposes a new canal as to store water, connect the landscape, and to encourage new development. Next to a demolished apartment complex, the new waterway and public spaces would stitch together disparate areas while alleviating flooding and increasing property values. Wetland shelves and bioswales provide areas for water filtration and habitat, and a pervious multiuse pathway running alongside is shaded by new trees that also absorb water. The pathway expands into a mini plaza at the end of a street, inviting access, and two pedestrian bridges link both sides of the water and join two neighborhoods.

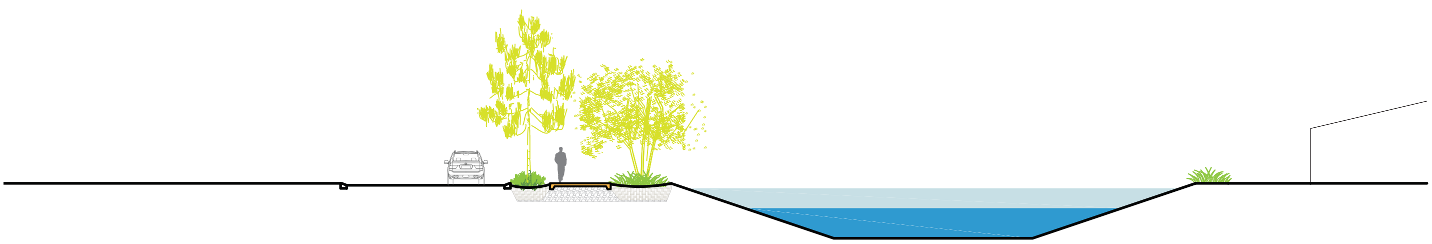
Economic: new public space encourages redevelopment
Quality of life: improved urban design and connectivity
Ecological: significant additional water storage capacity, new habitat creation, and improved hydrology

EXISTING CONDITION

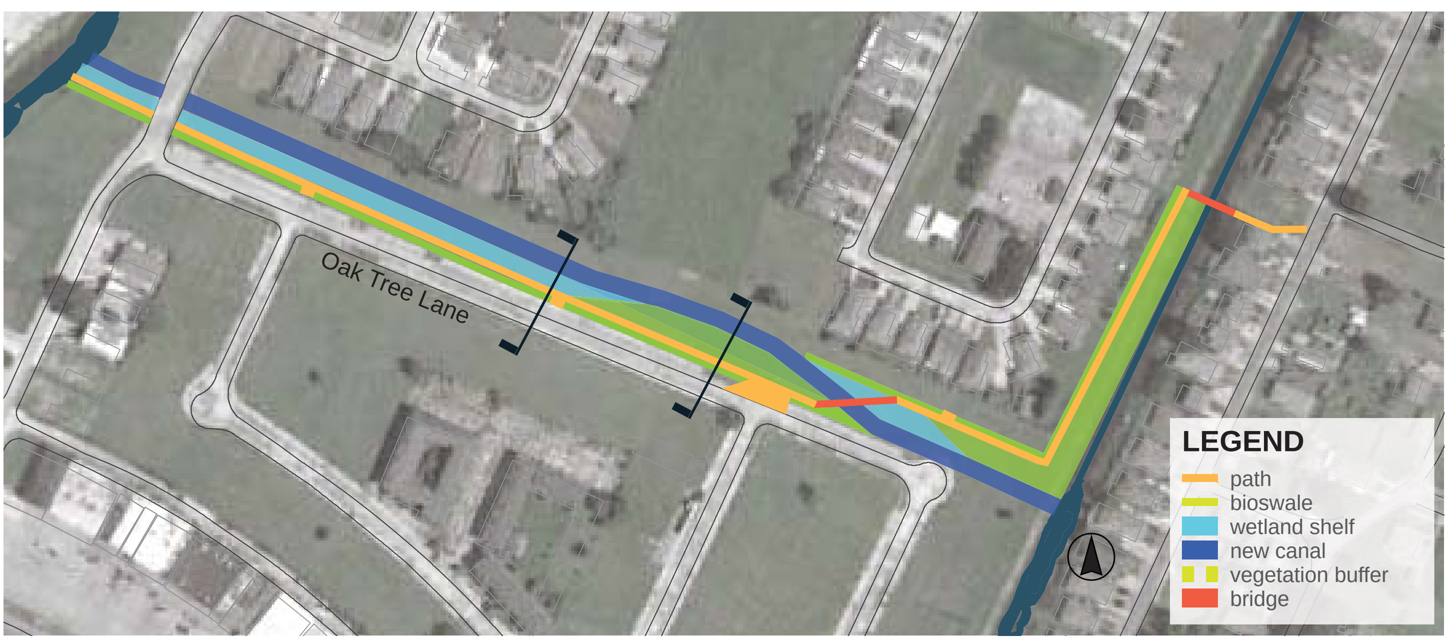
WETLAND SHELF



PATH



Connective Canal Landscape
A vacant strip of land adjacent to the road is reclaimed to excavate a new canal, both for additional water storage and to improve water quality by connecting two existing drainage canals.



5c
CANAL IMPROVEMENTS

Canal improvements are a range of neighborhood scale retention areas that capture runoff from nearby streets to alleviate flooding, filter runoff, and reduce runoff flowing into drainage waterways. They also function as small green spaces that provide access to canals, working as a large rain garden that serves the neighborhood.

Design begins at the street, where curb cuts allow water to flow from the street into the park, slowing the water down and beginning the filtration process with rocks, before flowing into a bioswale zone. Excavation of the ground at key locations, situated along drainage canals and at intersections with greenways and other landscape features, repurposes existing vacant lots. Lowering the ground surface then creates a pocket of space where water can flow.

Canal banks are maintained, but a weir inserted at the juncture of the existing canal and new canal park allows overflow of stormwater. Excavated soil is reused on site, mounded up to create higher areas with benches, and walking and maintenance trails, surrounded by vegetation. Design of the low areas makes water flow from the street towards the canal in a long, winding route. This maximizes the time spent flowing through vegetation, which cleans the water and encourages infiltration into the ground.

The design is adaptable, so if neighboring lots become open they can be added on in the same way. The basic lot module can be stretched or added to without changing its basic function and performance, which is also to encourage people to come to the canals, seeing them as public assets.

Canal Parks would reduce runoff for the neighborhood, but also reduce flooding and reliance on pumps for downstream neighborhoods. Effects will mostly be local, but if a significant number of canal parks are implemented they will start to have an impact on the overall system.

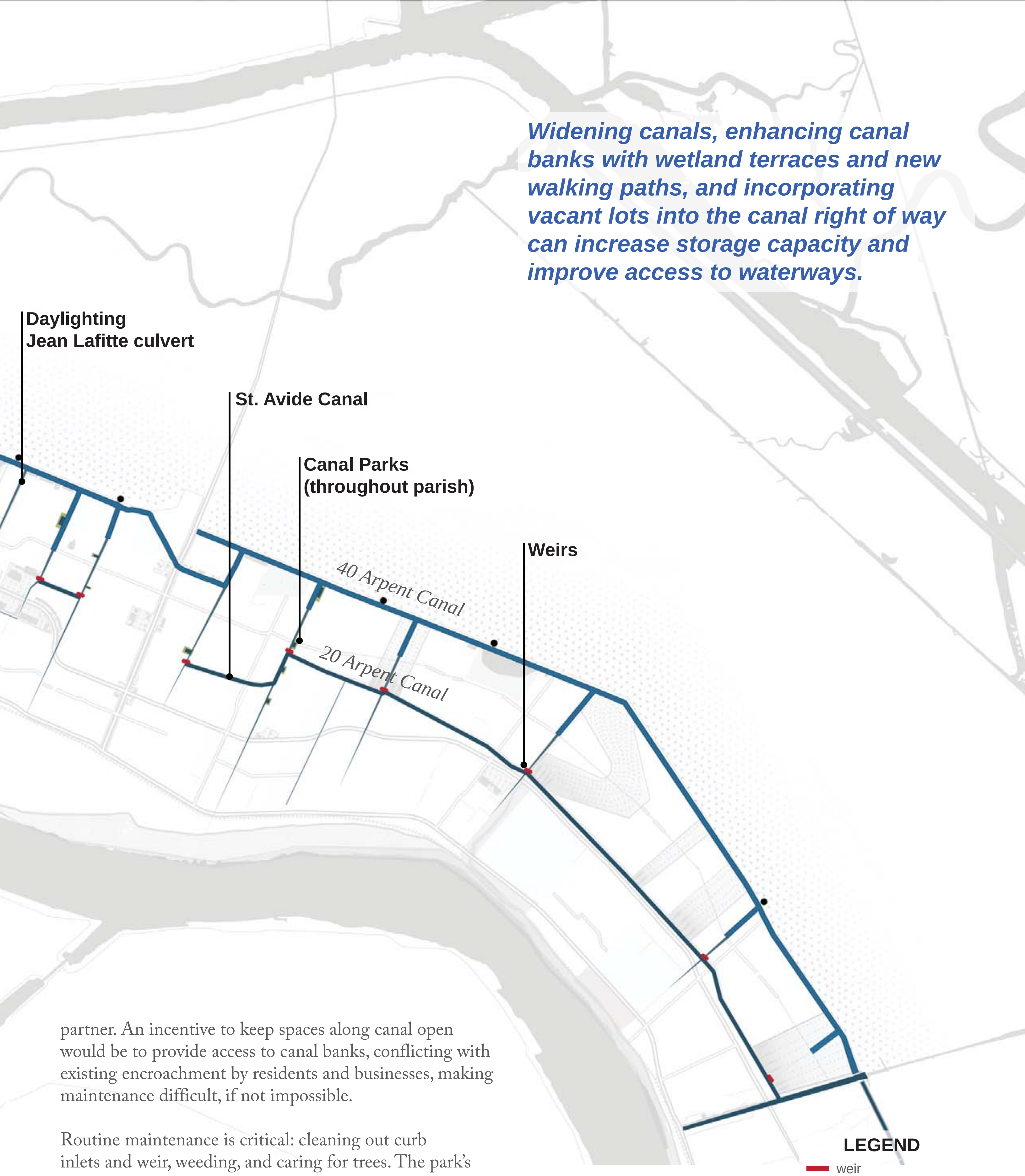
Filtration of water flowing from streets means improved water quality; this is critical to meet the goal for the 40 Arpent Canal and CWU to become amenities for residents and visitors. Within a network of green and blue spaces, Canal Parks are important for humans as well as habitat. If these parks extend along lengths of canals with available open space, eventually each canal could be buffered with green space that holds and cleans water, while providing access and pathways alongside.

The goal is to create a low-maintenance space that provides beauty and value through shaded recreational space next to the water, rather than an active park. These canal parks should be in every neighborhood as a complement to the existing park system. Located at highly visible and accessible open spaces, they have the potential to improve quality of life by reinforcing the green grid - and neighborhood revitalization - throughout the parish.

Canal Parks are one of the easiest projects to pilot; they use publicly owned land, are small in scale, and can serve an immediate purpose. While adding water storage capacity, they are not dependent on other things happening upstream or downstream in order to be effective. A local example are the NORA rain gardens in Orleans Parish.

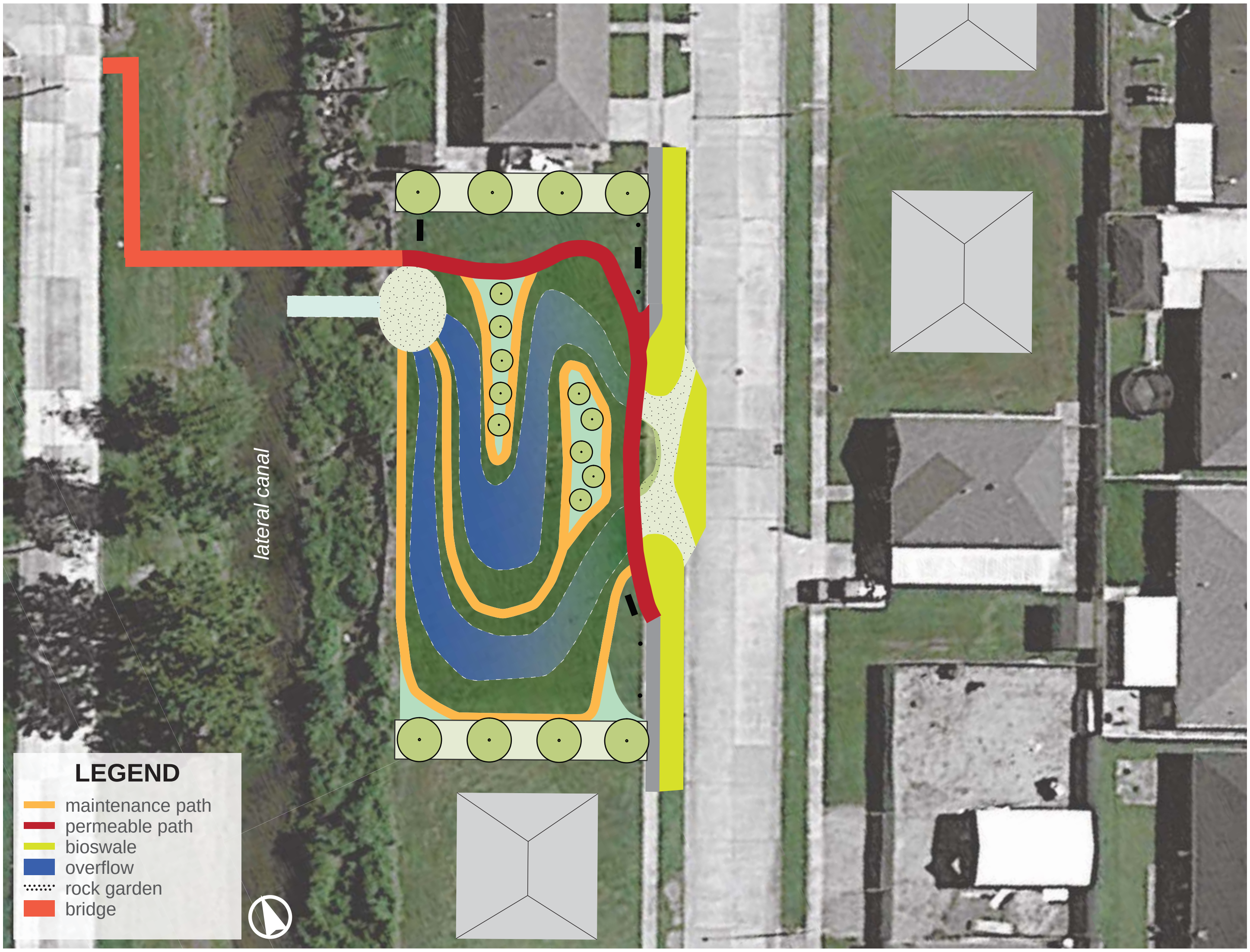
The Lake Borgne Basin Levee District (LBBLD) receives revenues for lots that they own, and would be a key

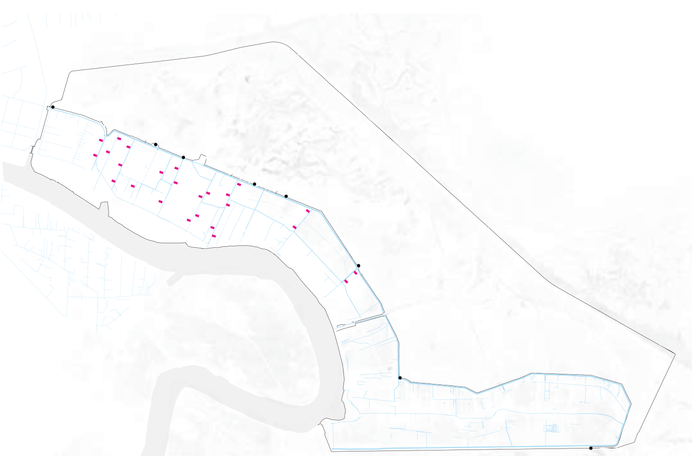
Widening canals, enhancing canal banks with wetland terraces and new walking paths, and incorporating vacant lots into the canal right of way can increase storage capacity and improve access to waterways.



partner. An incentive to keep spaces along canal open would be to provide access to canal banks, conflicting with existing encroachment by residents and businesses, making maintenance difficult, if not impossible.

Routine maintenance is critical: cleaning out curb inlets and weir, weeding, and caring for trees. The park's performance is dependent on all components working; this could be an opportunity for neighborhood associations to participate in taking care of their canal parks.



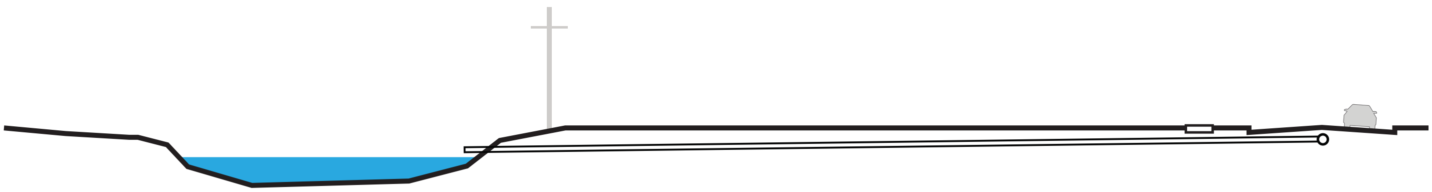


CANAL PARKS

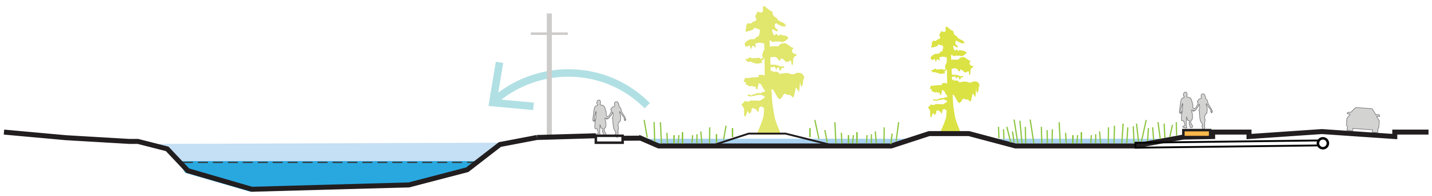
Proposed canal side parks slow and filter runoff into existing canals while doubling as a public space, scaled for a residential neighborhood. The parks combine functions of water storage, filtration, and a community park while providing access to canals with pathways, benches, and a pedestrian bridge that links neighborhoods. A curb bumpout diverts street runoff into two shallow depressions of wetland vegetation, which slow down water before it reaches another rock garden, and then overflows into the canal. Developed as a prototype that can be implemented across the parish, the canal parks take advantage of publicly owned vacant land to transform blight into an asset.

Economic: new public space encourages redevelopment
Quality of life: new park space and connectivity
Ecological: improved water storage and infiltration

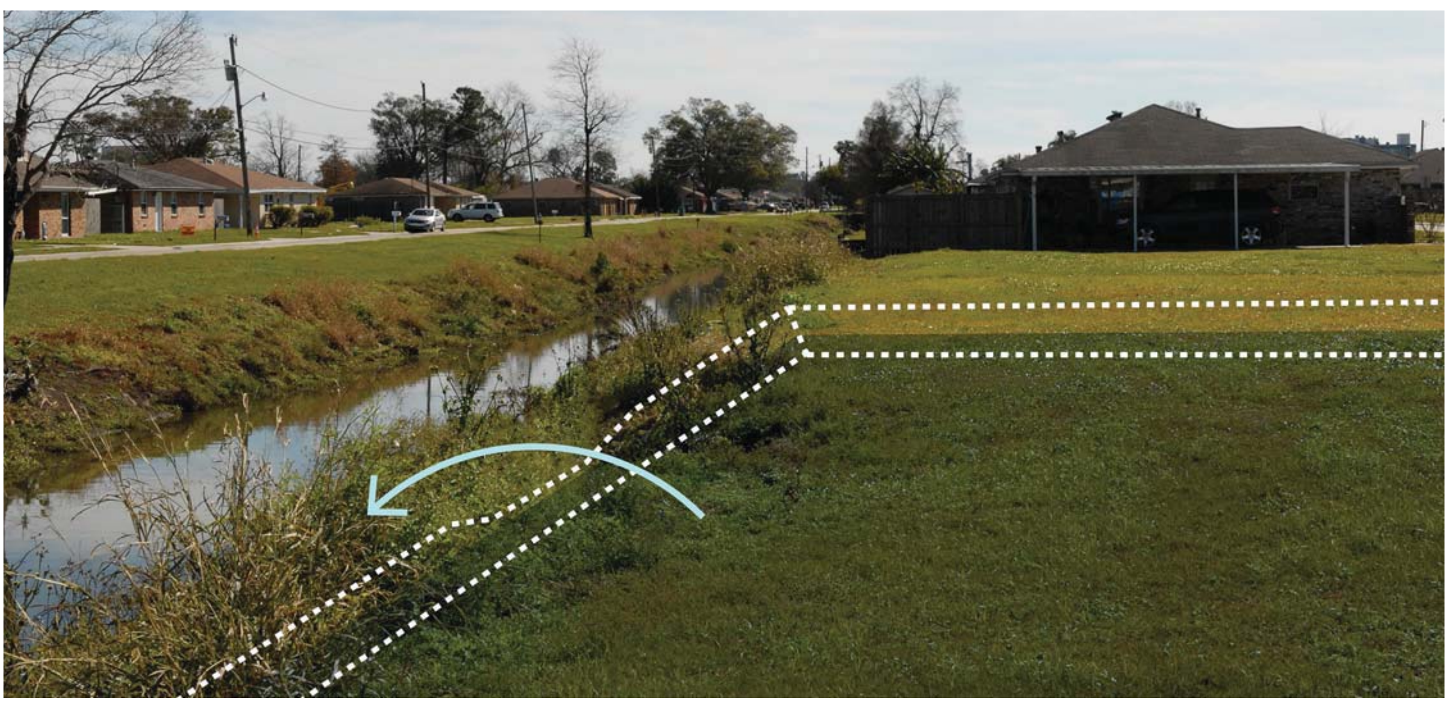
EXISTING CONDITION

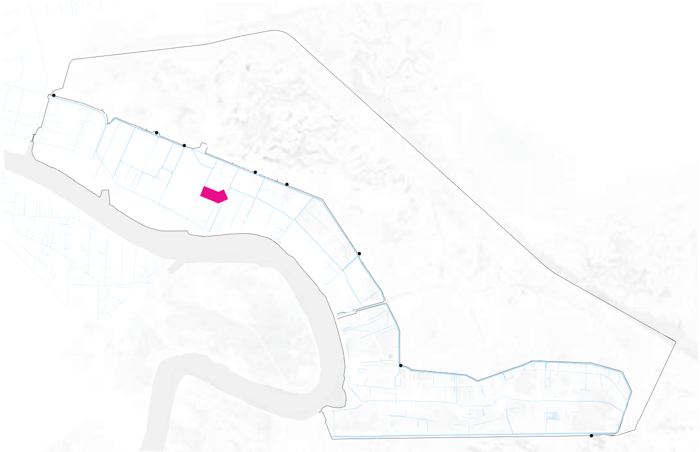


SECTION



Neighborhood Scale Storage and Park
A small curb bumpout into the roadway diverts street runoff into the canal park's bioswales and rock gardens, which slow and filter stormwater and allow some of it to infiltrate into the ground before overflowing into the canal.



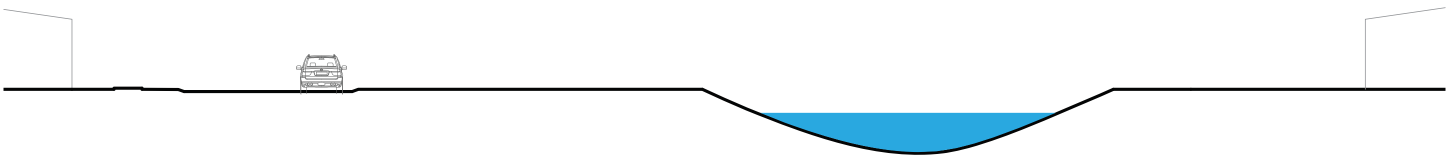


ST. AVIDE CANAL

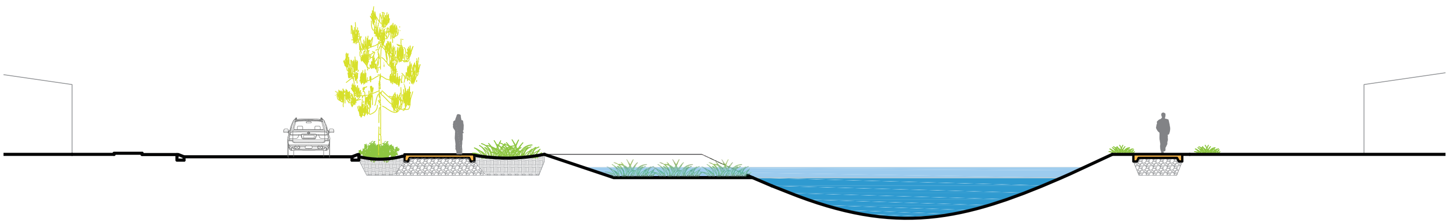
This neighborhood has a unique canal condition; unlike most residential areas in St. Bernard, almost all local streets cross the waterway with a bridge, providing access. The canal is not as strong a boundary as in most other neighborhoods. Like a neutral ground, but full of water, residents already use the right of way along the banks, though not designed to be accessible. Proposed pathways, bridges, trees, and platforms, along with benches and lighting, encourage recreation close to the water, while responding to the nuanced character of the neighborhood. Where feasible, new wetland shelves create additional storage and habitat. The goal is for St. Avide to become a model neighborhood in St. Bernard that lives with water.

Economic: linear park network adds value to properties
Quality of life: new public amenities and connectivity
Ecological: improved water storage and habitat

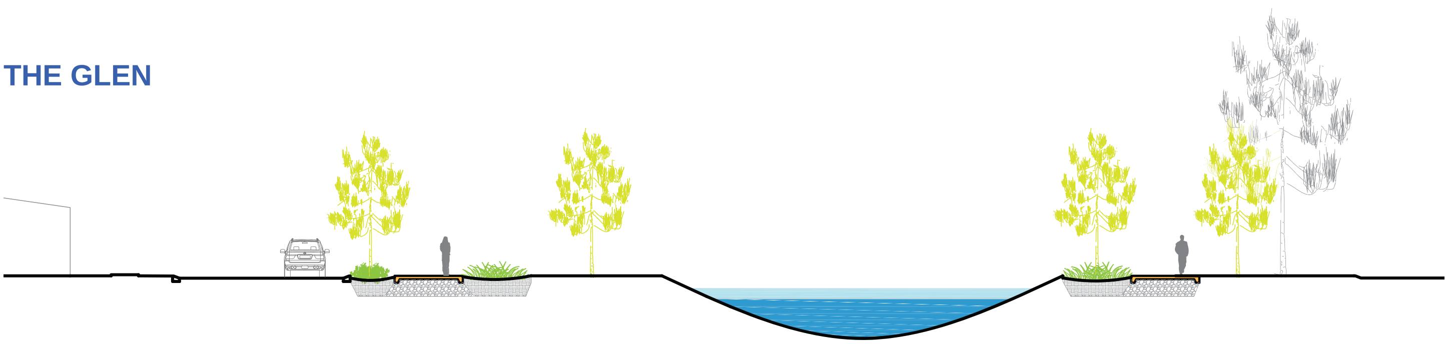
EXISTING CONDITION



WETLAND SHELF



THE GLEN



Neighborhood Waterfront Connections
Underused canal banks would have wetland shelves, bioswales, and tree lined, pervious multiuse pathways that cross the water to link both sides of the neighborhood.

5*d*
LAGOONS

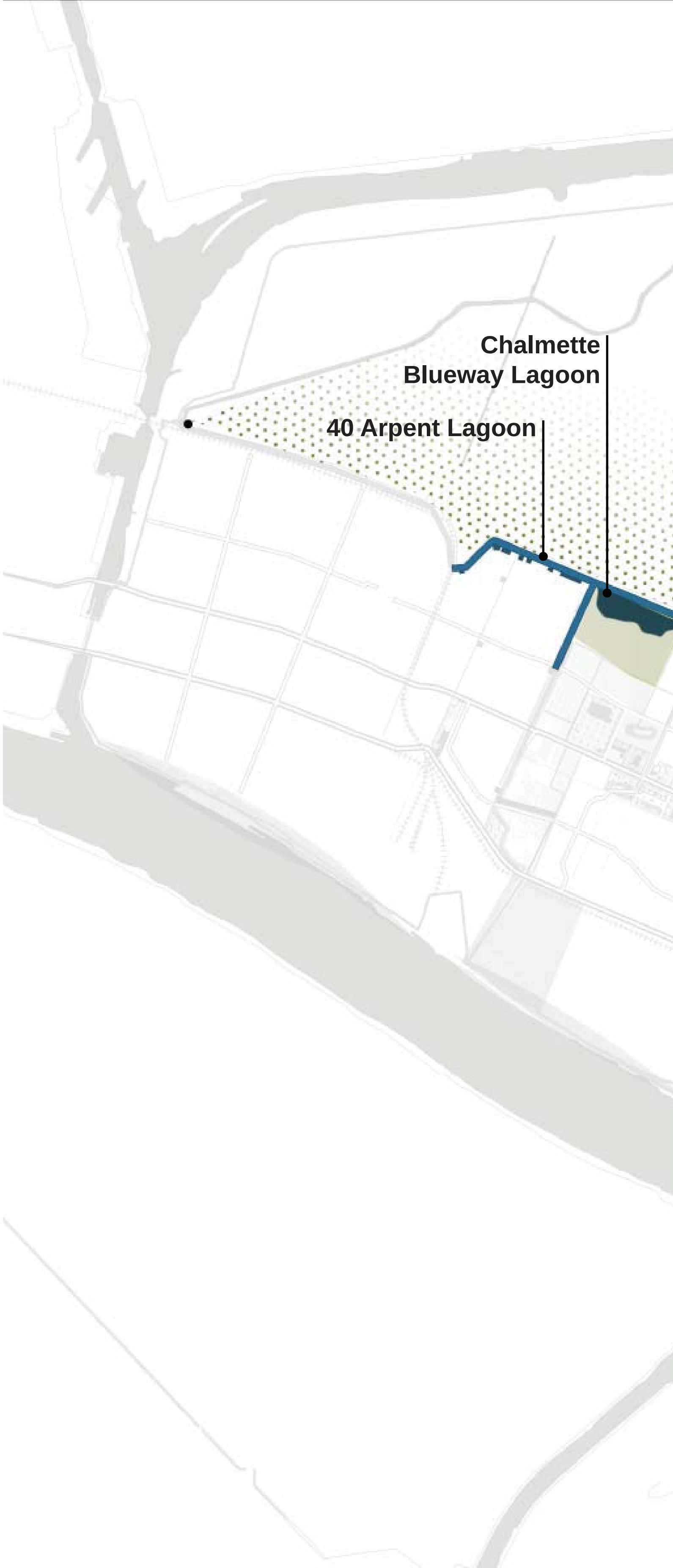
Proposed lagoons would strategically expand the existing backbone canal, the 40 Arpent, to provide additional storage capacity in the system, provide new habitat, and improve the function and aesthetics of the canal as an amenity for parish residents and visitors.

In specific areas, excavated soils would create small islands which are planted with trees and grasses, like an urban wetland, that balance the cut and fill. This concept can be applied to vacant lots immediately adjacent to the 40 Arpent. Similar to the Canal Park prototype, the lagoon design is modular, so it can be implemented at a number of points along the 40 Arpent, and to vacant areas of different widths and depths. Geotechnical research would be critical to identify the potential for sand boils if clay layers rupture.

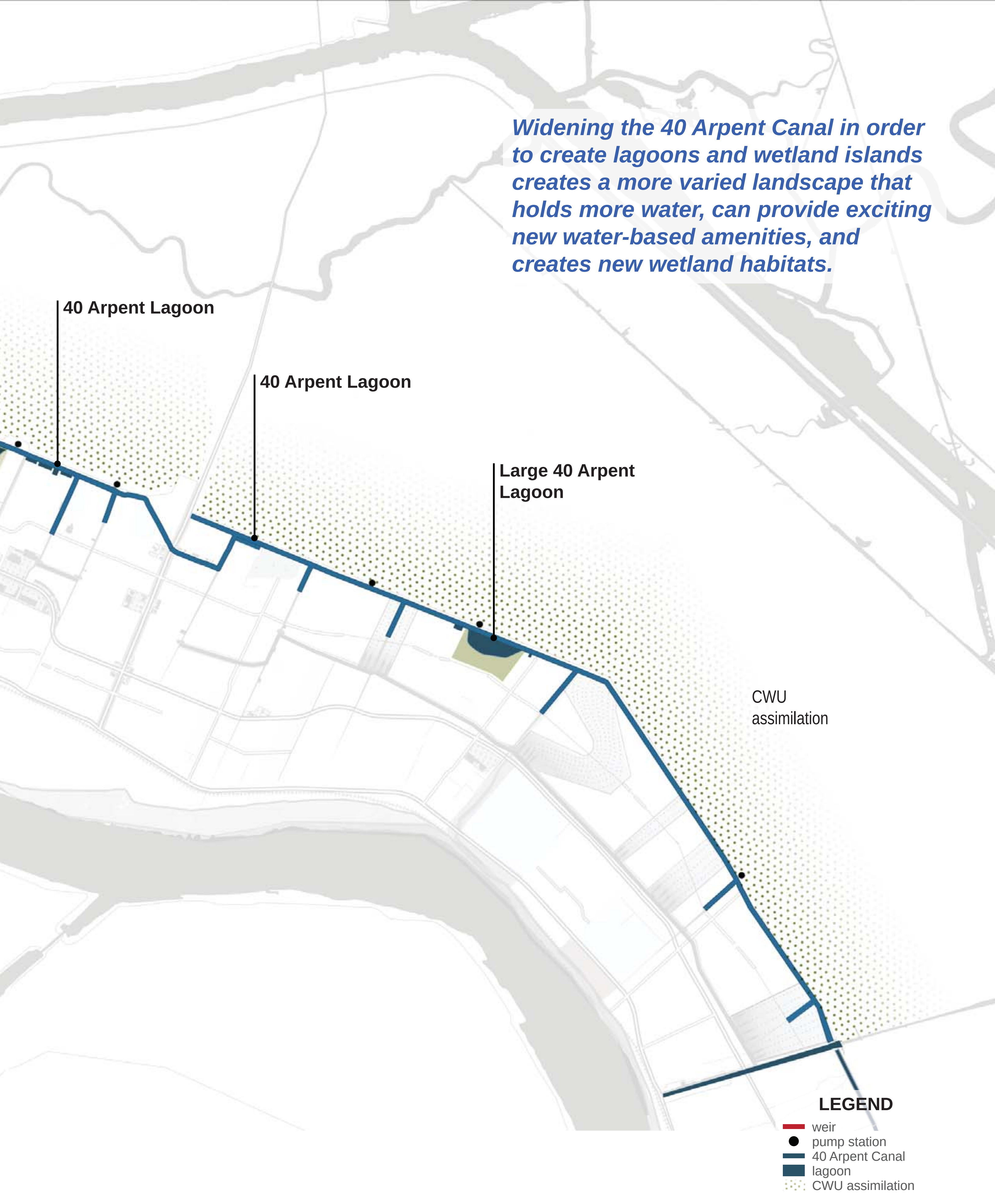
Greater capacity in the 40 Arpent means flood risk reduction for the whole parish because all drainage canals empty there. Replacing the existing grass edges with denser plantings of cypresses, irises, and other water-loving species would enrich the ecosystem and serve as habitats for birds and other fauna. These excavations also removes some of the lowest lying properties in the parish, which are the most at risk for flooding. This directly relates to the Louisiana Land Trust study recommendations, accomplishing dual goals.

The first example of a lagoon along the 40 Arpent is at the relatively new boat launch facility owned by the Meraux Foundation in Chalmette (shown in Chapter 3 in the Access and Connections images in the upper left). New lagoons can continue to create this rich wetland zone by extending and creating new ones. This will require consolidation of properties to create larger stretches, where this design is most effective, potentially requiring removal of some utilities as well as Army Corps approval due to the adjacent levee.

These multifunctional lagoons also require monitoring both during construction and after to ensure successful replication. Hydrologically, the lagoons must be designed so that water does not stagnate. Construction activities should also be studied for potential sand boil creation if the clay layer is disrupted.



Widening the 40 Arpent Canal in order to create lagoons and wetland islands creates a more varied landscape that holds more water, can provide exciting new water-based amenities, and creates new wetland habitats.



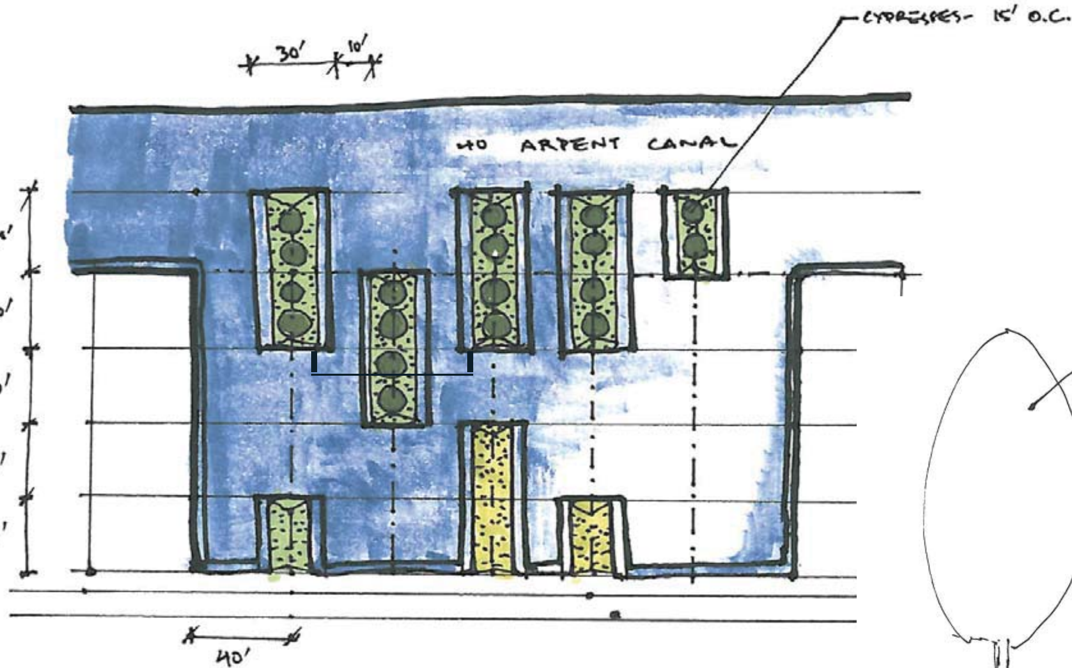
Expanding Water and Wildlife Networks
Lagoons extending off the 40 Arpent Canal with small peninsulas and islands would create habitat areas and access to the water.

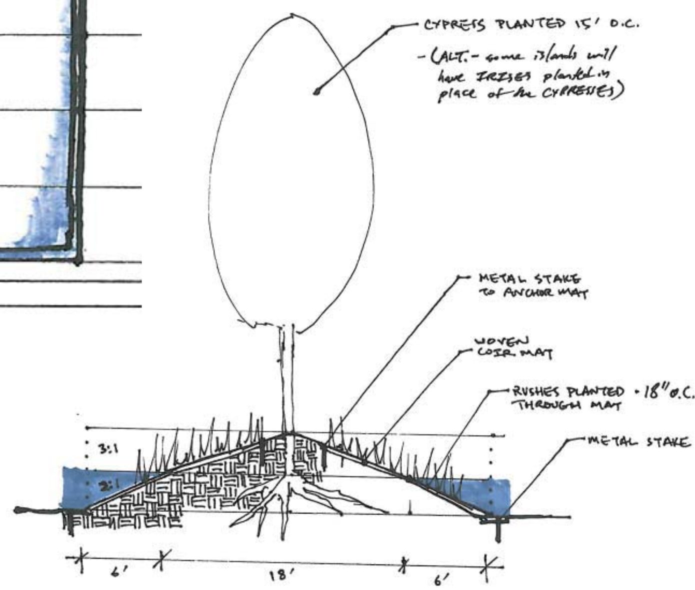
40 ARPENT LAGOON

New lagoons at different locations along the 40 Arpent Canal would create large areas for wetland habitat, future development, and regional recreational and educational destinations. On the upriver side of Chalmette, proposed lagoons will be used for water storage; these would be paired with the lagoon that has already been dug out at the existing boat launch facility. New bridges would allow residents and visitors to access the levee and the Central Wetlands Unit on the other side off the canal. This could also encourage small scale residential development, similar to the elevated fish camps across coastal Louisiana.

Economic: waterfront development sites, regional recreational amenities for boating, fishing, birdwatching, biking, and hiking
Quality of life: transformation of the 40 Arpent into a beautiful, accessible public space, connecting neighborhoods, wildlife habitats, and recreation
Ecological: expanded aquatic habitats within the levees

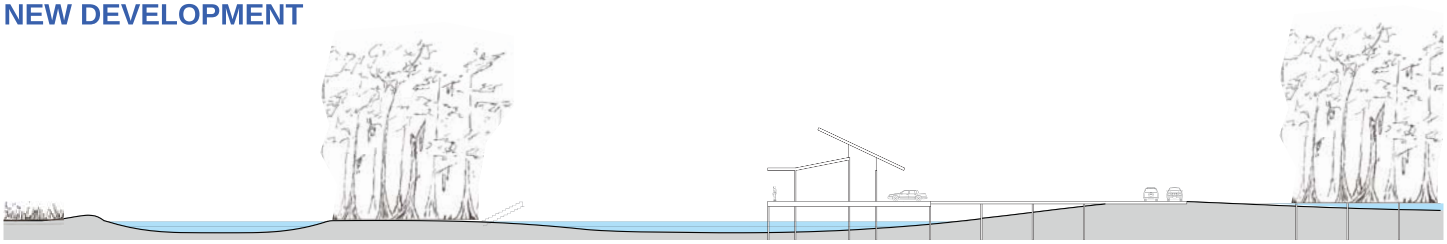
LAGOONS

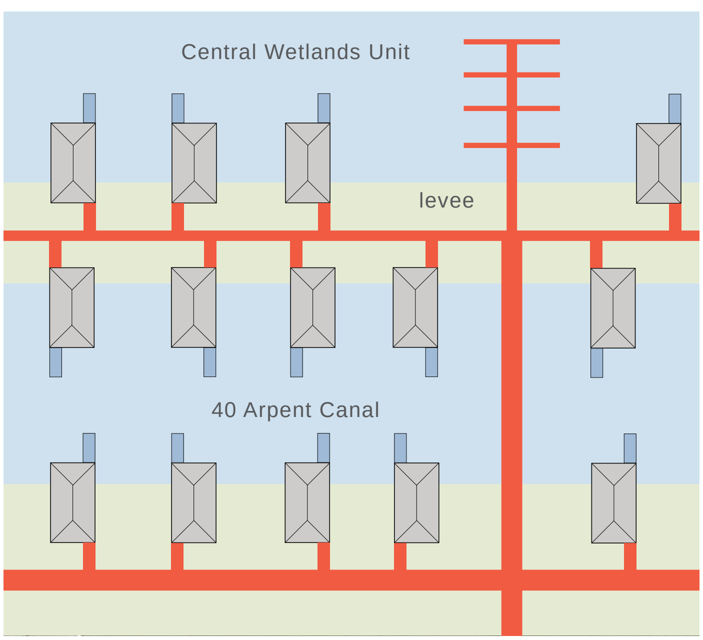




Different Options for Different Habitats
Lagoon islands would be designed with stable banks that can support trees and wetland vegetation, while creating smaller areas for aquatic life as well.

NEW DEVELOPMENT





Living in Water
New development in the 40 Arpent Canal and across the levee in the Central Wetlands Unit (left) could be similar to the common type of elevated fish camps in southeast Louisiana (above), and would provide direct access for hunting and fishing.

5e
URBAN BLUEWAYS

Urbanized areas are the greatest contributors to excess stormwater runoff, and thus the source of flooding for urban areas. A systematic approach to transforming areas in St. Bernard that have been developed is necessary to reduce runoff and flooding. At same time, this is a major opportunity to improve quality of life for parish residents and address other issues at the same time, such as transportation, access to open space, sustainable and resilient development, air quality, and water quality.

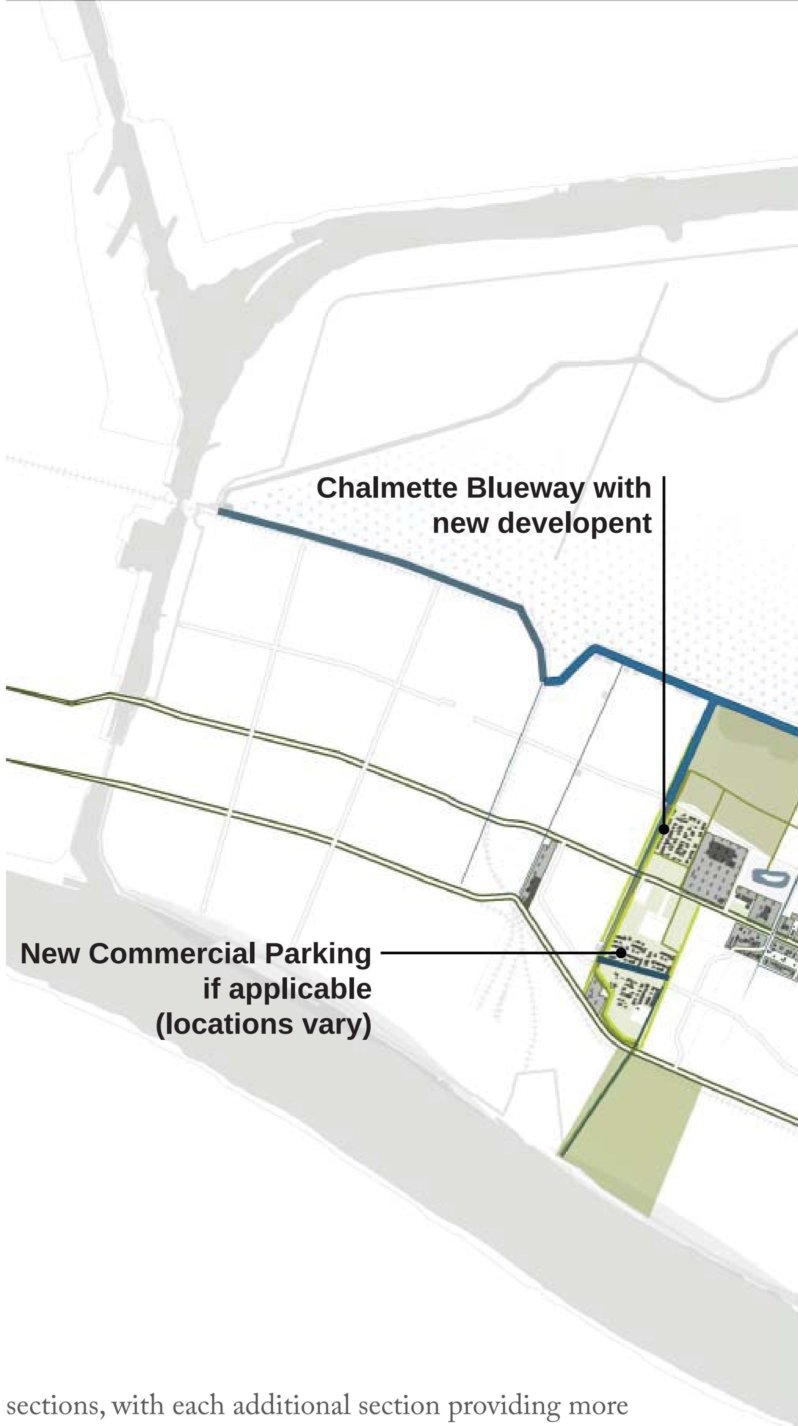
A basic goal is reducing the amount of impervious paving where possible, either by demolition or replacement with pervious paving that allows water to infiltrate into the ground, reducing subsidence. Landscape design improvements such as extensive tree planting, along with bioswales and rain gardens would help. As the backbones of new development or significant redevelopment projects, new open canals would be designed to improve inter-connectivity between the perpendicular canals and thus the parish's overall system function.

The vast, existing parking lots across the parish could be transformed by integrating rain gardens and bioswales in such a way as to capture runoff before it enters drains. Special attention was paid to big box stores due to the massive volumes of runoff they generate. The following proposed projects are flexible, and show a range of in approaches, strategies, and design; basic ideas can be adapted to a range of site specific conditions while also creating new parking lot types.

Expected impacts are a significant reduction of the total pollutant load, reduction in runoff and flooding, and an increase in tree canopy and vegetated areas, which help reduce the urban heat island effect, and enhance aesthetics for businesses owners and residents.

Best Management Practices (BMPs) include measures such as pervious paving, rain gardens, and bioswales, and are critical components of comprehensive stormwater management. By slowing down and temporarily storing stormwater where it falls, overall runoff volumes are reduced and pollutants are filtered out; water that is pumped into the Central Wetlands Unit is then cleaner.

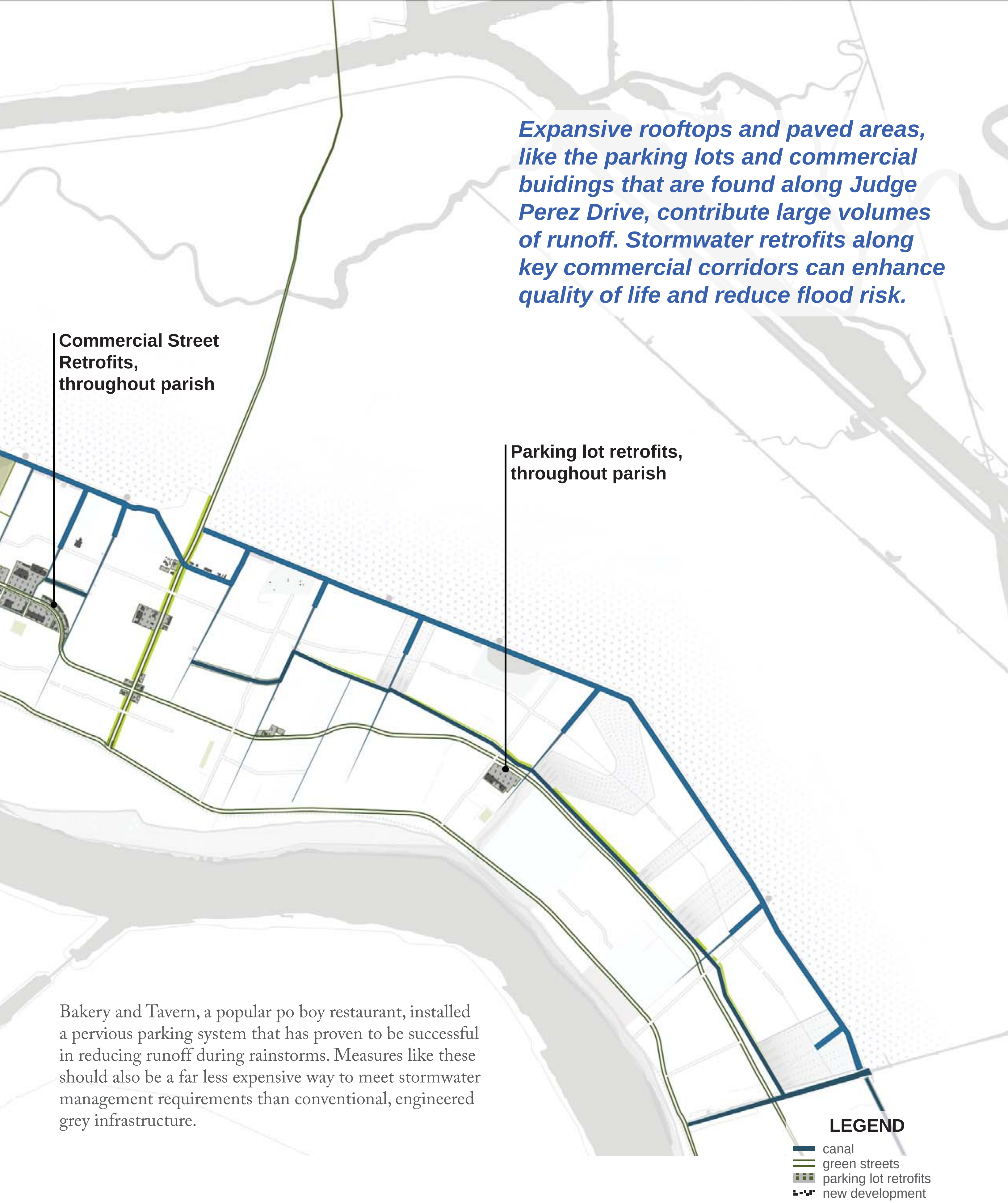
Green infrastructure like the BMPs mentioned are ideal for incremental implementation over time. A broader network of stormwater features can be implemented in



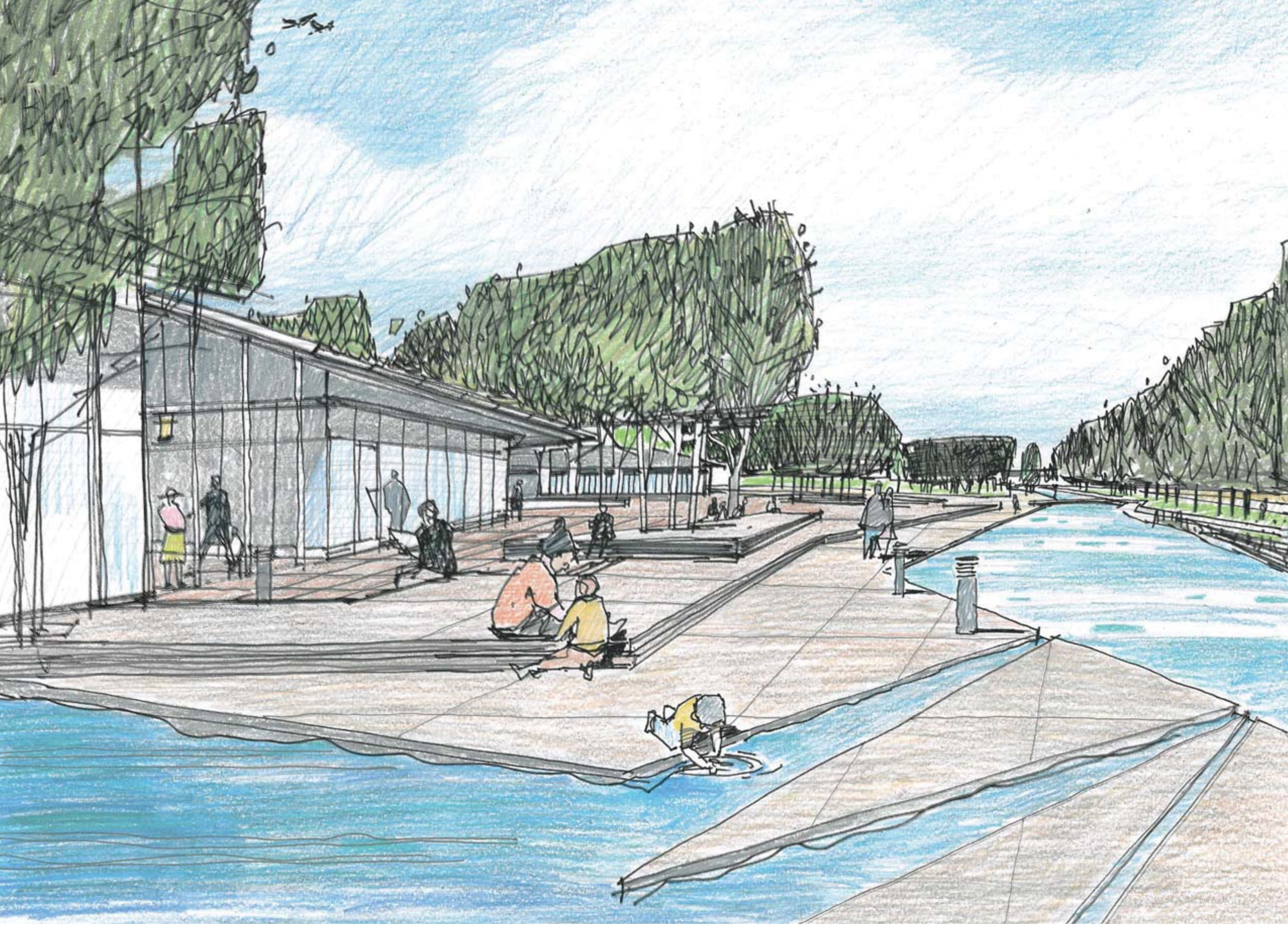
sections, with each additional section providing more capacity and benefit. BMPs such as bioswales, rain gardens, and new trees are also visible, adding aesthetic value while also reconnecting people to natural systems.

Implementation would require new forms of maintenance, including vacuum trucks as well as more skilled labor to properly weed and maintain rain gardens and bioswales. This step is relatively easy to achieve, as private and public entities could collaborate to develop new best practices. As more and more institutions and businesses complete the initiatives suggested in this report, local expertise will grow and lead to new jobs and workforce development. For example, Jefferson Parish recently explored the feasibility of retrofitting the vast parking lot at the Yenni Building, their parish government office building, to remove concrete paving and replace it with bioswales, trees, and water storage areas. In New Orleans, the Parkway

Expansive rooftops and paved areas, like the parking lots and commercial buidings that are found along Judge Perez Drive, contribute large volumes of runoff. Stormwater retrofits along key commercial corridors can enhance quality of life and reduce flood risk.



Bakery and Tavern, a popular po boy restaurant, installed a pervious parking system that has proven to be successful in reducing runoff during rainstorms. Measures like these should also be a far less expensive way to meet stormwater management requirements than conventional, engineered grey infrastructure.



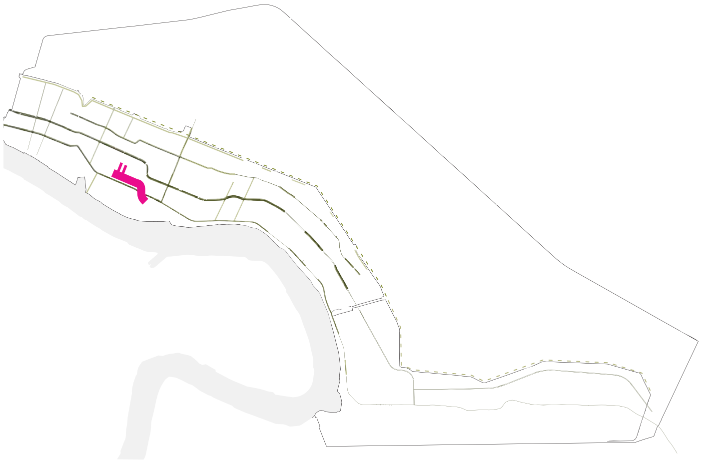
Joining the River to the Wetlands
New canals for water storage would also create large, publicly accessible green spaces, connect different land uses across a swath of the parish, and encourage new development.

CHALMETTE BLUEWAY

One of the most visible sites for transformation, the Chalmette Blueway would connect a new canal to an existing canal, providing additional water storage and infiltration farther upslope. The surrounding open areas would be periodically inundated and serve as a publicly accessible green space that connects the Chalmette Battlefield to the parish hospital. A system of bioswales, overflows, and weirs extend back across Judge Perez into land along the 40 Arpent. This rich and diverse landscape integrates gravity-driven water management that utilizes the slope of the land to move water. Connecting major roadways, assets, and neighborhoods, new commercial and housing could be developed at the perimeter.

Economic: potential commercial and residential development
Quality of life: public space, neighborhood connections
Ecological: improved water quality, new habitat

Integrated Water Transect
The Chalmette Blueway crosses an entire swath of the urbanized parish to link the Mississippi River back to the Central Wetlands Unit.

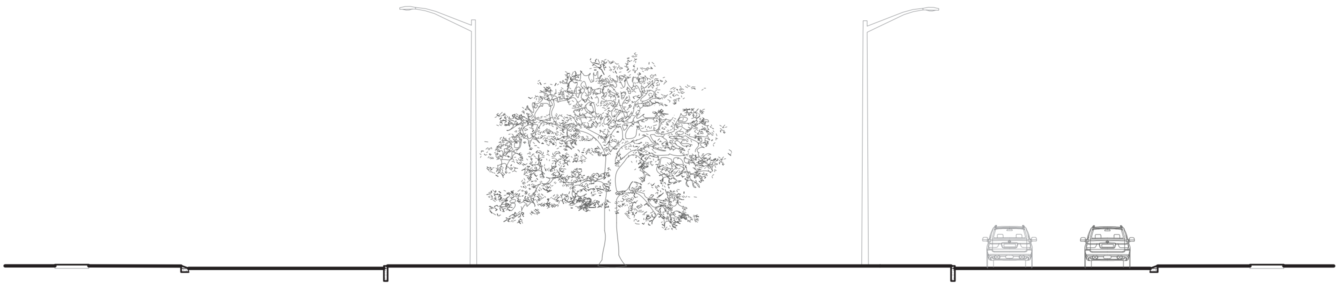


COMMERCIAL STREET RETROFITS

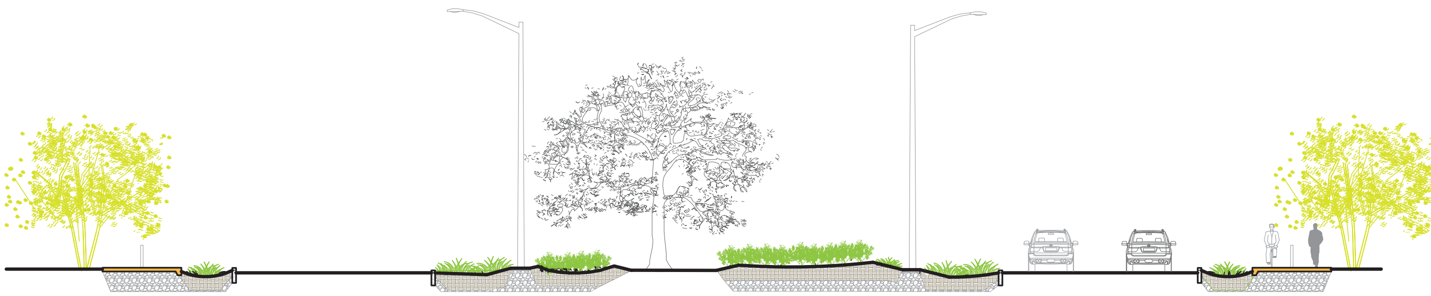
By situating BMPs along critical corridors such as Judge Perez Drive (featured here), along with St. Bernard Highway, Patricia Street/Genie Drive, Paris Road, and other visible roadways, investments in green infrastructure such as trees and bioswales improve the aesthetics and livability of each street. Together, these retrofits to already developed properties would also enhance the overall walkability, bikeability, and connectivity throughout the parish while reducing flooding, the amount of energy used to pump stormwater, and the heat island effect. Most corridors have sufficient space in the right of way to install new bioswales alongside pervious multiuse paths and trees, as shown at right.

Economic: encouragement of commercial redevelopment
Quality of life: multiuse paths for walking, biking, and running; improved streetscape design and aesthetics
Ecological: improved water quality, reduced runoff

JUDGE PEREZ - EXISTING CONDITION



JUDGE PEREZ - HIGH NEUTRAL GROUND

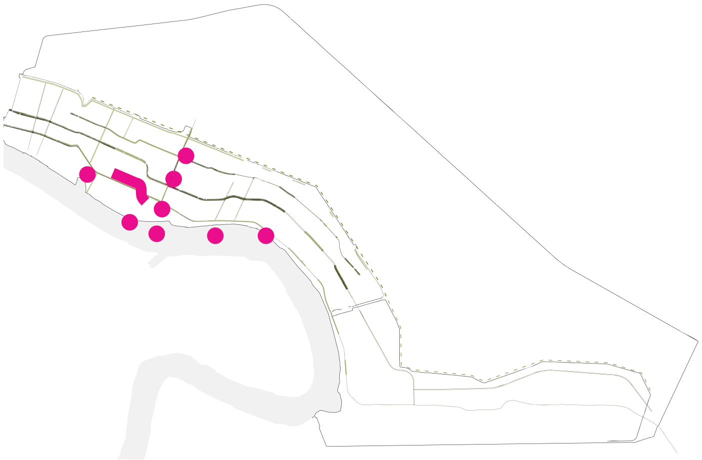


JUDGE PEREZ - LOW NEUTRAL GROUND

Places for Water and People
New pervious pathways alongside bioswales would reduce stormwater runoff and allow the water to infiltrate back into the ground, while also creating a buffer from the heavy traffic on commercial streets.

From Gray to Blue-Green
Large, impervious parking lots and roofs throughout the parish could alleviate runoff and flooding, while reducing the heat island effect and creating attractive, safe pedestrian circulation.

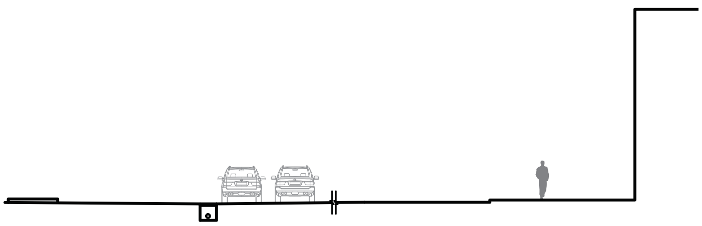
COMMERCIAL PARKING RETROFITS

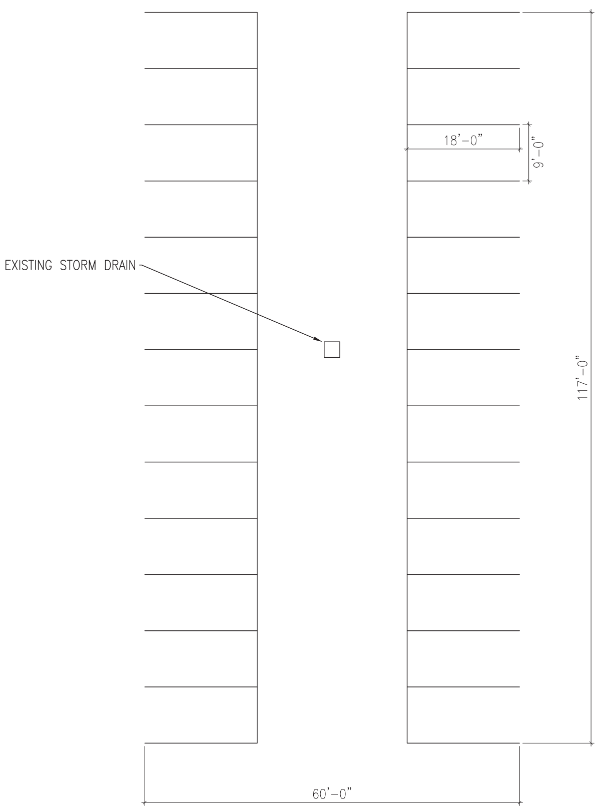


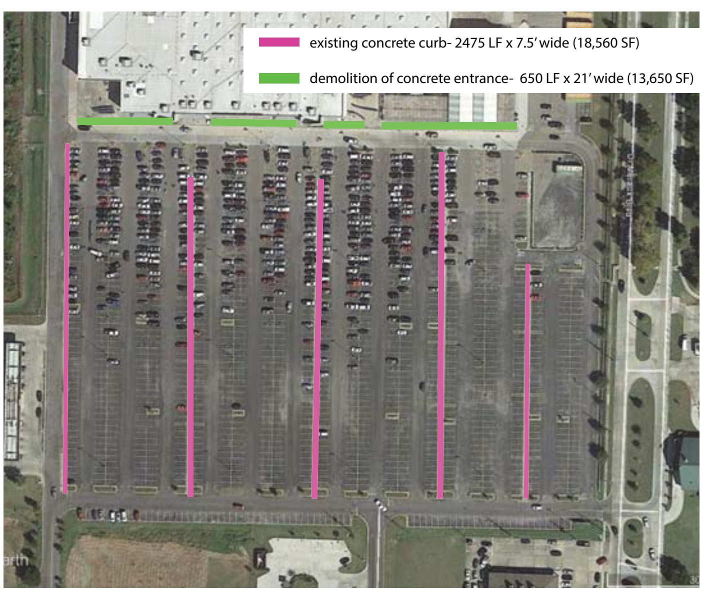
Space for water is good for business. The vast expanses of impervious rooftops and parking lots in strip malls across St. Bernard contribute to high levels of runoff and street flooding, which negatively impact low lying neighborhoods. With a range of simple site design retrofits, parking lots can be transformed into a network that collects and filters stormwater, becoming a model for the region. Low areas near catch basins can be converted to bioswales, and existing catch basins can be elevated to work as overflows. New pedestrian circulation should also be integrated to increase safety. Theses BMPs can be replicated in parking lots of all scales and sizes, changing the identity of commercial areas. Similarly, Jefferson Parish is exploring retrofits to their government building's vast parking lot.

Economic: encouragement of commercial redevelopment
Quality of life: improved aesthetics and safety
Ecological: improved water quality, reduced runoff and heat island effect

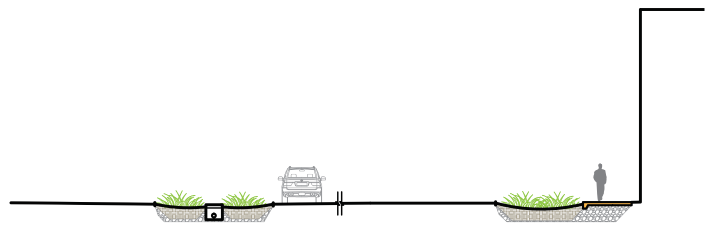
EXISTING

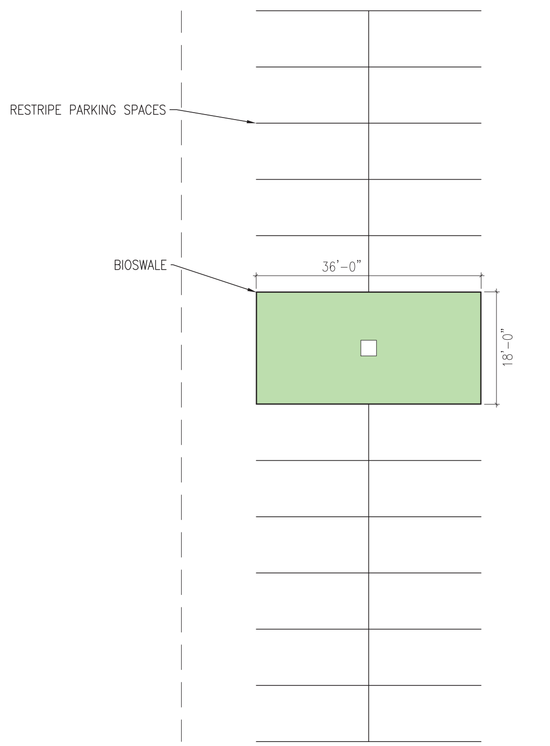


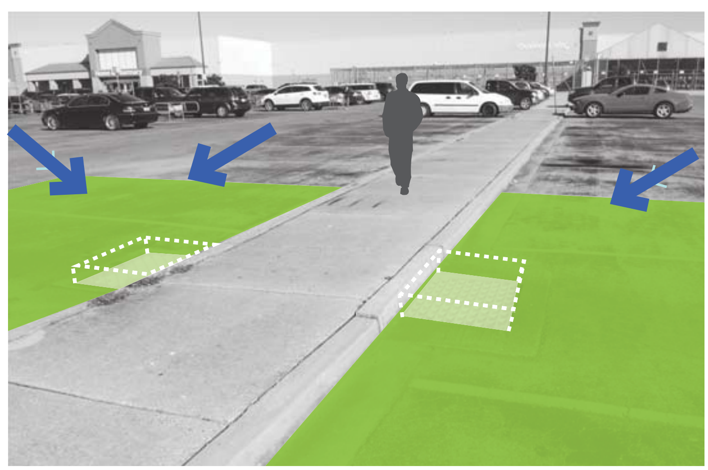




PROPOSED







Flipping Parking Spaces for Water Storage
Parking lot retrofits would restripe spaces so that existing catch basins are elevated as overflows; surrounding bioswales would slow and clean runoff before it goes into the drainage network.

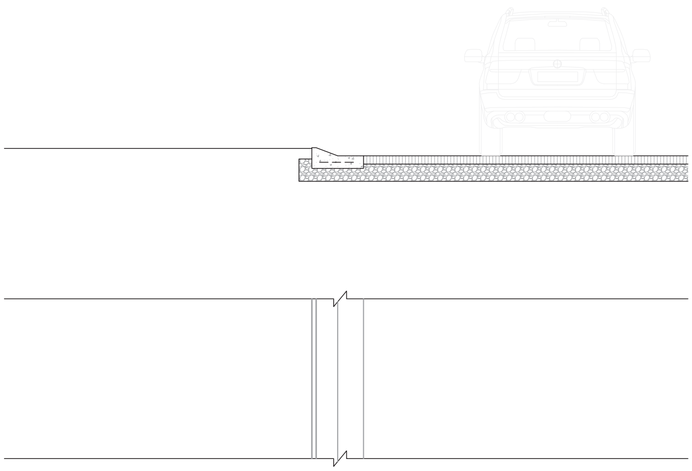
Integrated Infrastructure
New commercial parking lot developments provide the chance to plan for stormwater management upfront, perhaps more easily than retrofit projects.

NEW COMMERCIAL PARKING

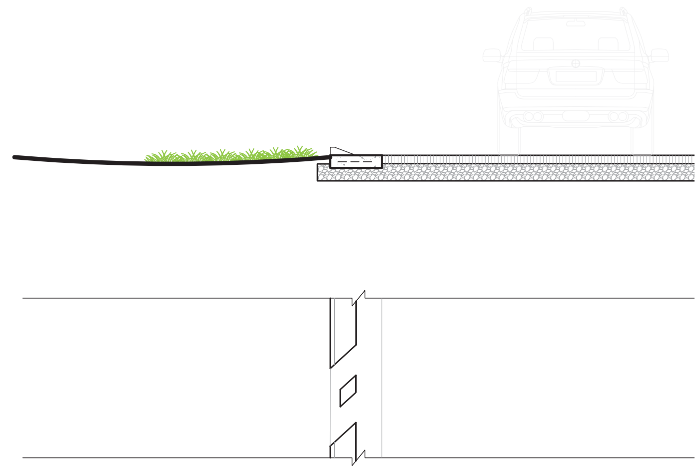
In new developments, green infrastructure BMPs should be integrated from the start of project design to move the parish closer to achieving water management goals. Through zoning, St. Bernard could require new construction to include BMPs, shifting the cost to the private developer; the parish could offer tax incentives or other initiatives, discussed further in the Implementation chapter. Instead of retrofits, new green infrastructure such as bioswales, pervious paving, and temporary water detention could be designed from the outset to capture as much runoff as possible. Site elements like curb cuts to divert surface runoff, pedestrian circulation, and trees are more easily implemented when planned from the outset, rather than retrofitted.

Economic: new model for commercial redevelopment
Quality of life: improved aesthetics and safety
Ecological: improved water quality, reduced runoff and heat island effect

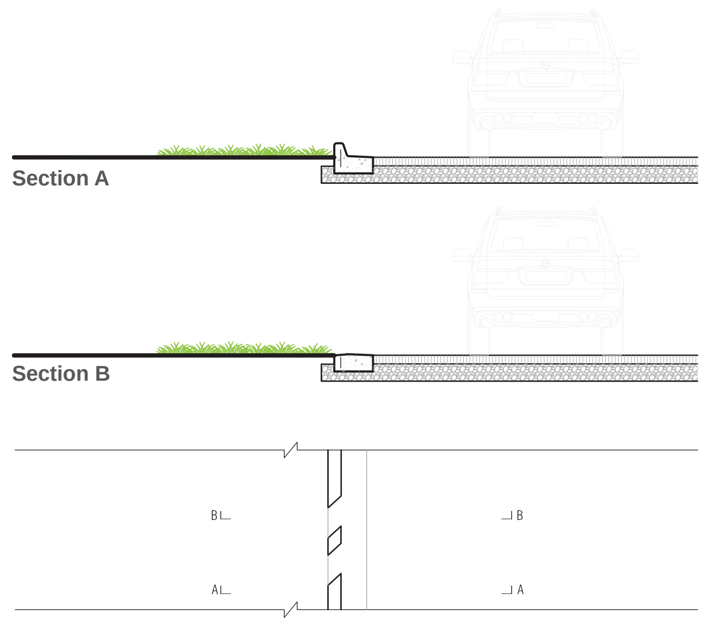
EXISTING CURB



SLOPED CURB CUT



NEW BARRIER CURB WITH CUTS



Designed for Green Infrastructure
New parking lot construction provides opportunities to integrate green infrastructure into the initial design, including trees, habitat, bioswales, rain gardens, and pervious paving that allows water to infiltrate into the ground and reduces the heat island effect.

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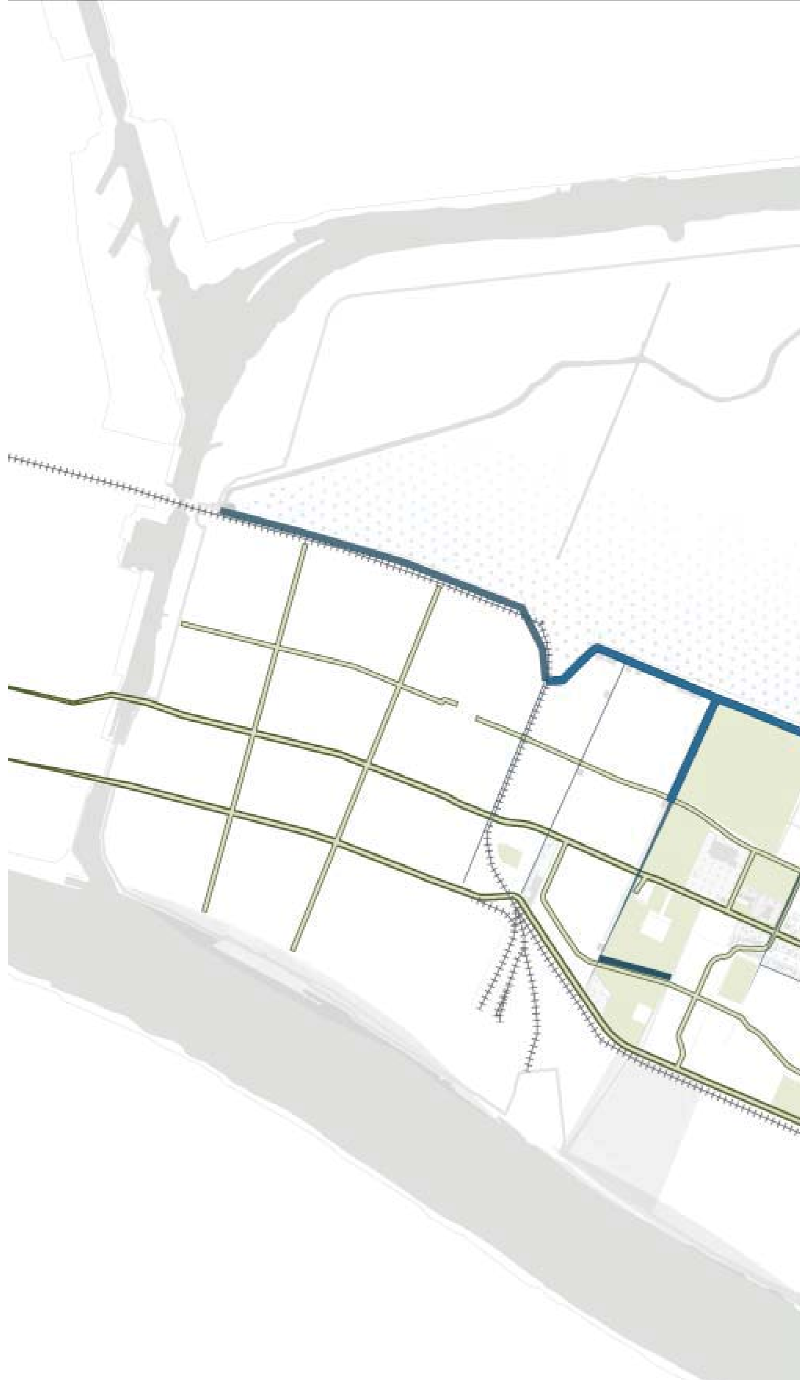
BLUE/GREEN STREETS & CROSSINGS



Proposed blue/green streets and crossings target strategic corridors, from major commercial thoroughfares as described in the previous section, to smaller scale neighborhood streets, and implement a range of BMPs that manage water as well as improve safety, connectivity, and quality of life. In addition to ecological benefits, the goal is that all parish residents have access to a pleasantly walkable street in their neighborhood.

The design and function of this network is similar in type to the commercial retrofits, but applies green infrastructure in conjunction with urban design elements to highlight best practices in water management, along with pedestrian, bicycle, and transportation design. Proposed projects feature design elements that are multilayered: pervious walkways, corner bump outs, trees, bioswales, rain gardens, and pervious parking lanes.

Overall, the impact is to increase water storage and quality, define streets with improved landscape design and air quality, and make walking and bicycling safe and accessible. Roadside bioswales and corner bump outs at intersections create narrower, safer view corridors for motorists, with a shorter crossing distance for pedestrians. They also create stormwater retention and filtration areas in public rights of way, and help define key corridors and intersections to improve wayfinding and overall urban quality, as well as new spaces for public interaction. Existing curbs can be cut to allow runoff from the street to flow into the bioswales. The result is a lush and colorful streetscape that floods less frequently, and that absorbs and filters large volumes of runoff.

Sidewalks ensure connectivity between divided neighborhoods and commercial districts. New pervious pathways would reduce reliance on automobiles and encourage physical activity while improving accessibility so that people of all abilities are able to get around. New tree plantings would create a full canopy that defines the entire neighborhood and improve air quality, reduce runoff, and reduce ambient air temperatures.

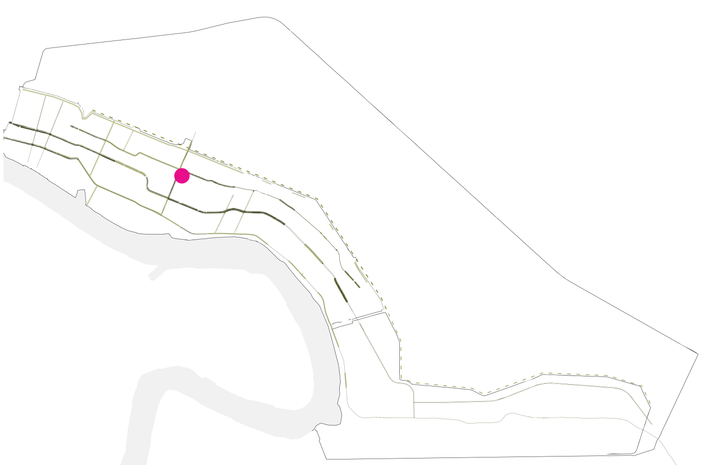
The advantage to these improvements is that they form a network that can be implemented incrementally. Because utilities are fully interwoven with the street grid, the blue/green streets and crossings projects are an opportunity for the entire street to be improved so that many issues, from parking to old drinking water pipes, can be efficiently addressed at the same time rather than as separate projects. Doing so can be significantly expensive, however.

The green infrastructure proposed here replaces ditches and piped networks with a network of bioswales that have a thick drainage layer, which requires excavation and replacement of existing soils with gravel and bioretention soil mix. Appropriate street tree species include cypresses, oaks, magnolias, and fringe trees; consult the LSU Ag Center's publicly available Native Tree Guide and other resources. Equally important is planting trees on private properties. The Parish could work with neighborhood associations, community foundations, and local tree planting organizations to implement at a lower cost.

The St. Claude Avenue streetscape improvements, currently under construction, is an example pilot project of

An extensive "green grid" of streets can reduce runoff and flood risk throughout the parish, while enhancing the tree canopy, water quality, and access to parks and institutions.

this type of work in St. Bernard. As a key gateway into the parish, the project redefines the corridor and includes new pedestrian crosswalks and ADA accessible ramps, roadway improvements, new street trees and other low maintenance plants, and new street lamps. The goal is that future work also includes significant stormwater management.



PARIS ROAD ENTRY

In addition to St. Claude Avenue and Judge Perez Drive, Paris Road is the other primary gateway into and out of St. Bernard parish, presenting a major opportunity. The existing condition is dominated by impervious surfaces: a wide roadway with large curb cuts for parking lots, and lack of consistent sidewalks, landscape definition, or water management. The goal is define spaces for cars, pedestrians and cyclists, and blue/green infrastructure. Large public right of ways would accommodate new bioswales, trees, and pervious paths that connect to larger paths along 40 Arpent Canal. Pervious mini plazas at corners allow the chance to look down into an underground culvert through steel grating, also at the roadway intersection.

Economic: encouragement of commercial redevelopment
Quality of life: multiuse paths; improved streetscape design; accessible waterways, connectivity
Ecological: improved water quality, reduced runoff

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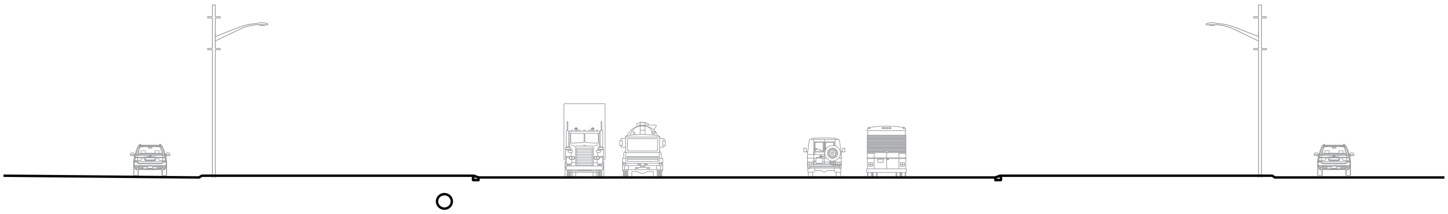
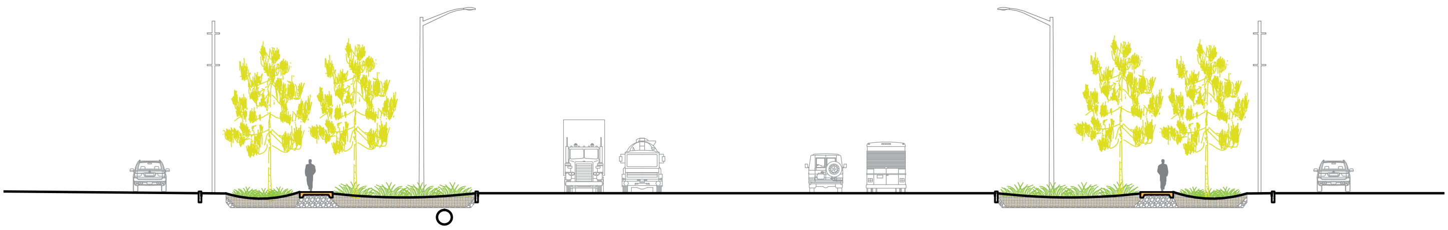
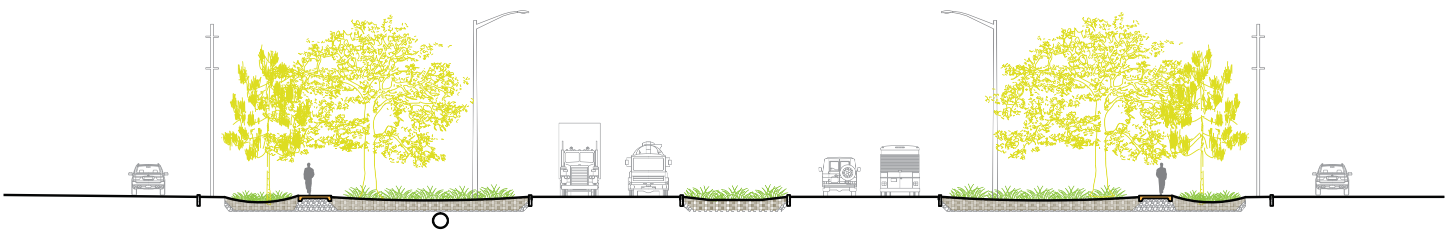
EXISTING CONDITION



PROPOSED - WITH BUMP OUTS

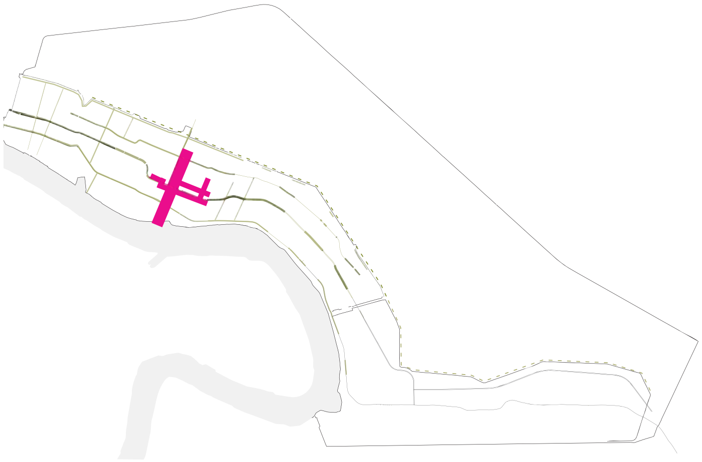


PROPOSED - NO BUMP OUTS



Gateway into the Parish
Creating neutral ground areas or curb bump outs would add space for new bioswales, trees, and pervious sidewalks, altogether making a safe and attractive entrance into St. Bernard Parish.

Safe, Blue-Green Crossings
A typical corner along the Green Grid shows a curb bump out with bioswales, trees, and safer pedestrian crossings.

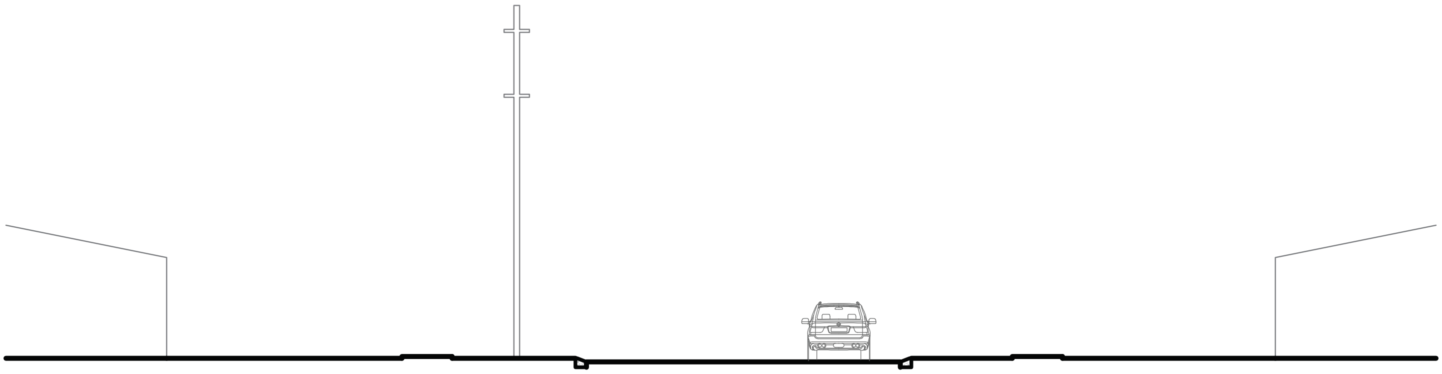


GREEN GRID

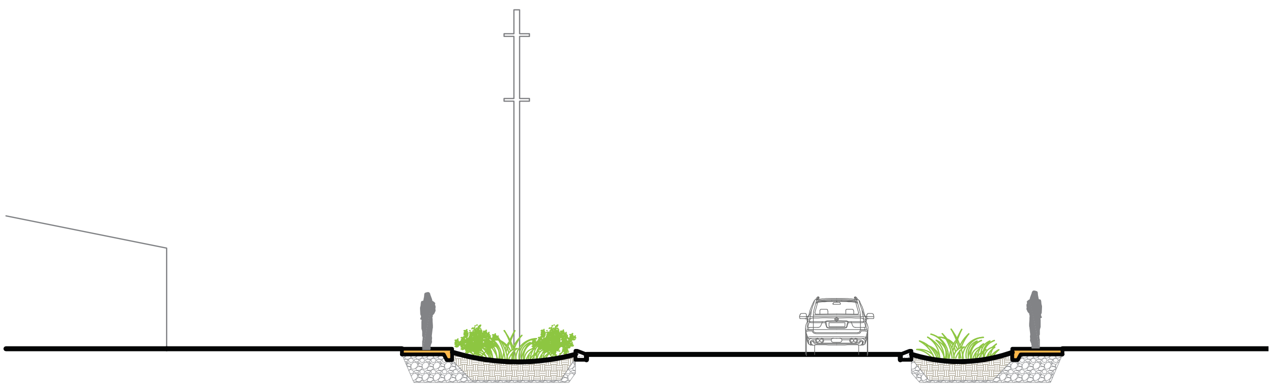
Building upon a strategy first proposed in the *St. Bernard Parish Louisiana Land Trust Vacant Lot Study* in 2012, the Green Grid connects neighborhoods, parks, schools, and water resources through a series of BMPs that buffer residential areas from adjacent land use and heavy traffic. The project aims to reduce runoff and improve water quality, along with safety. Curb bumpouts add space for bioswalses while reducing the crossing distance for pedestrians. BMPs such as pervious paving and rain gardens should also be situated on private properties. The Green Grid would connect neighborhoods on either side of Paris Rd to the main thoroughfare as well as to other proposed projects.

Economic: added value to residential properties
Quality of life: improved aesthetics, safety, connectivity
Ecological: improved water quality, reduced runoff and heat island effect, new habitat creation

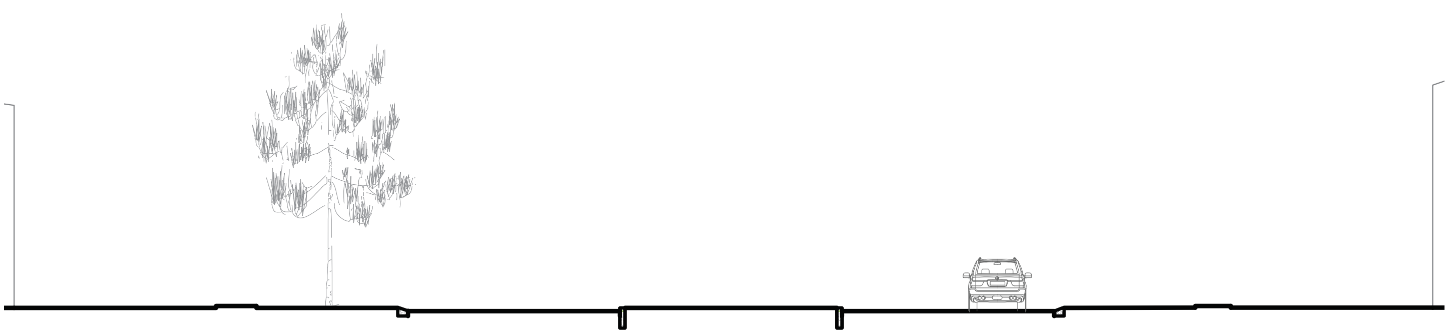
GENIE ST - EXISTING



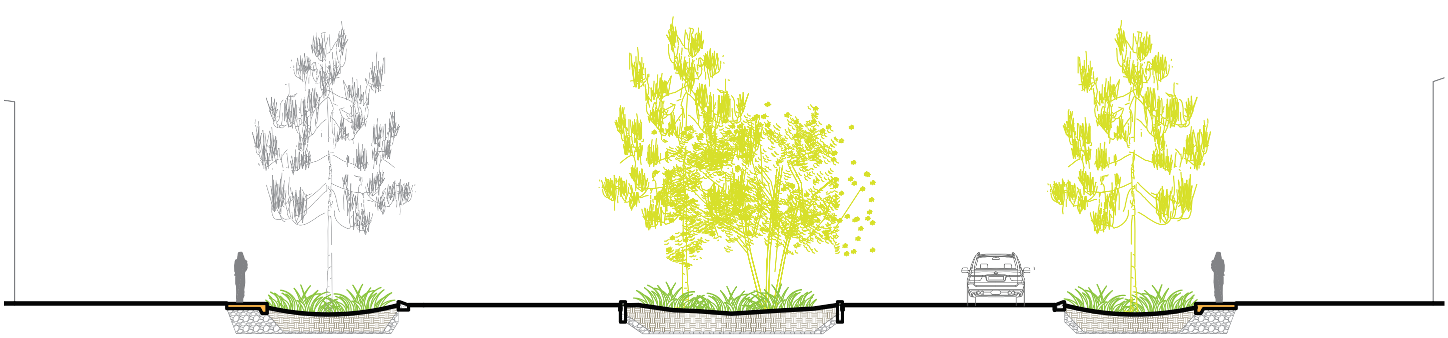
GENIE ST - PROPOSED



PALMISANO BLVD - EXISTING



PALMISANO BLVD - PROPOSED

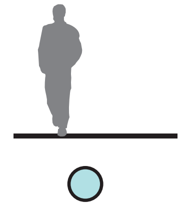


Recreation, Access, and Green Infrastructure
Retrofits to the park include bioswales, berms, and a canal bridge.

VAL RIESS PARK

The goal encourage a broader range of uses at a key regional park situated along the 40 Arpent Canal, and to provide a demonstration of interventions that are possible for other parks, school grounds, and large institutional sites. A major community asset, Val Riess Park would include new bioswales and rain gardens to slow and filter parking lot runoff, and use the excavated soil to create berms that would help prevent flooding of athletic fields if canal levels rise. To connect residents with water, a new pedestrian bridge across the 40 Arpent could link into the potential future trail system along the Central Wetlands Unit. The park could add to its role as a place for athletic health to also improve the ecological quality of the neighborhood.

Economic: added value to public recreation facilities
Quality of life: improved aesthetics, safety, connectivity
Ecological: improved water quality, reduced runoff and heat island effect, new habitat creation



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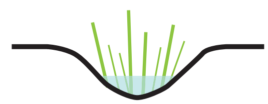
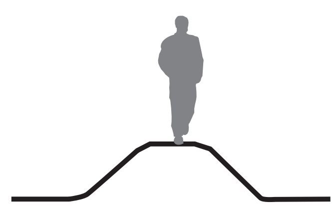


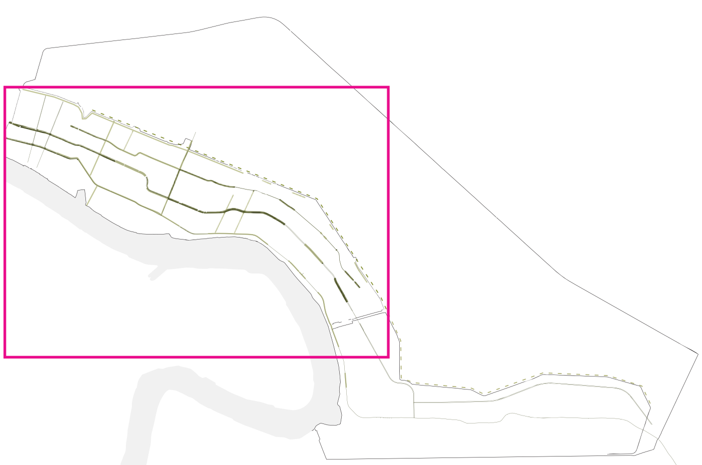
CUT - BIOSWALES



FILL - BERMS

Implementing a groundwater monitoring network and building knowledge of the relationship between soils and water is critical for designing and implementing sustainable water management projects and practices.

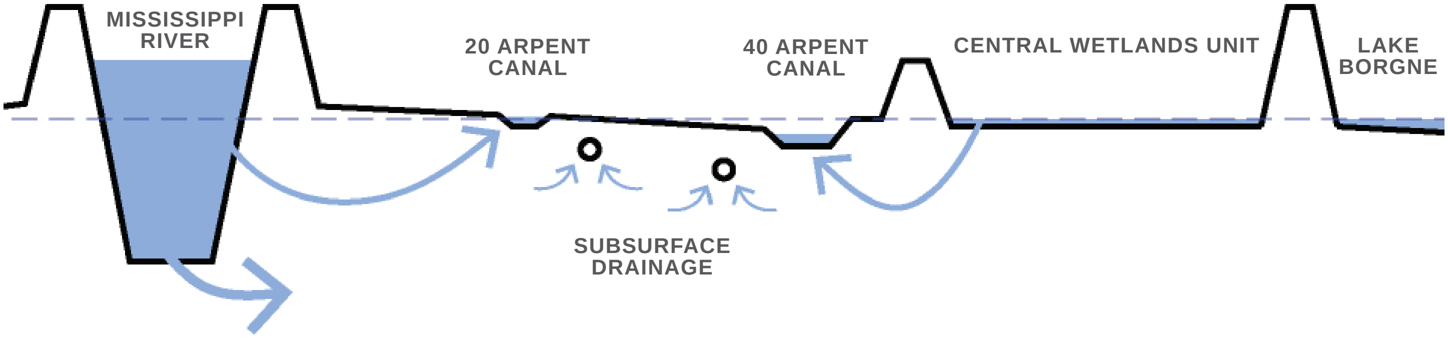
5g GROUNDWATER MONITORING



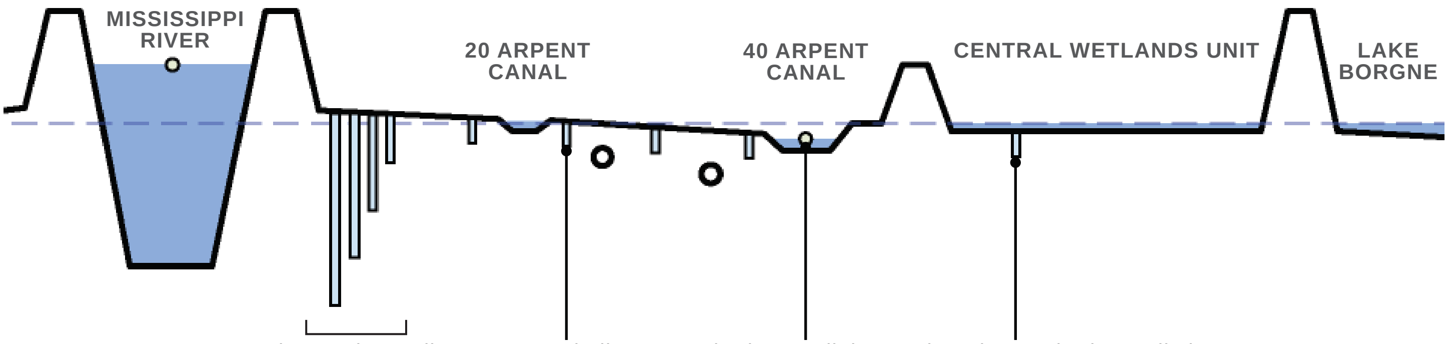
St. Bernard Parish can support this comprehensive integrated water management effort with a centralized groundwater monitoring network that provides the necessary data for smart and responsive systems. A monitoring network and associated data collection is critical to refining the operations of pilot projects. Understanding of groundwater conditions will provide information to guide the design and implementation of each of the proposed projects, and will also inform future infrastructure projects throughout the parish.

As part of a Regional Monitoring Network for surface water and groundwater, St. Bernard Parish could provide system managers with real-time data necessary to address immediate drainage needs and long term trends in water levels and water quality, and to maintain higher water levels without compromising safety. Surface water monitoring gauges already exist. Sharing data between water management authorities across parishes will enable a truly regional approach to stormwater and surface water flows. New data collection points for water levels and water quality will allow managers to fine tune operations to a better informed level of detail, tailored to each particular rain event and the needs of individual catchment areas instead of a general, system wide approach.

The goal of a monitoring system is to understand these sets of relationships relative to specific areas, such as proposed project sites. A network similar to a grid, as shown in the drawing, would create transects through different conditions, for example, from the river back to the 40 Arpent Canal. These section cuts through the parish would help establish general depths and reveal patterns about groundwater and its changes over time. As a network with many monitoring locations, this data would guide future projects and allow the parish to make informed decisions at the beginning, rather than learning the hard way after construction is complete.



Groundwater Dynamics
Subsurface water levels and characteristics are influenced by adjacent waterways and drainage systems, including subsurface pipes.

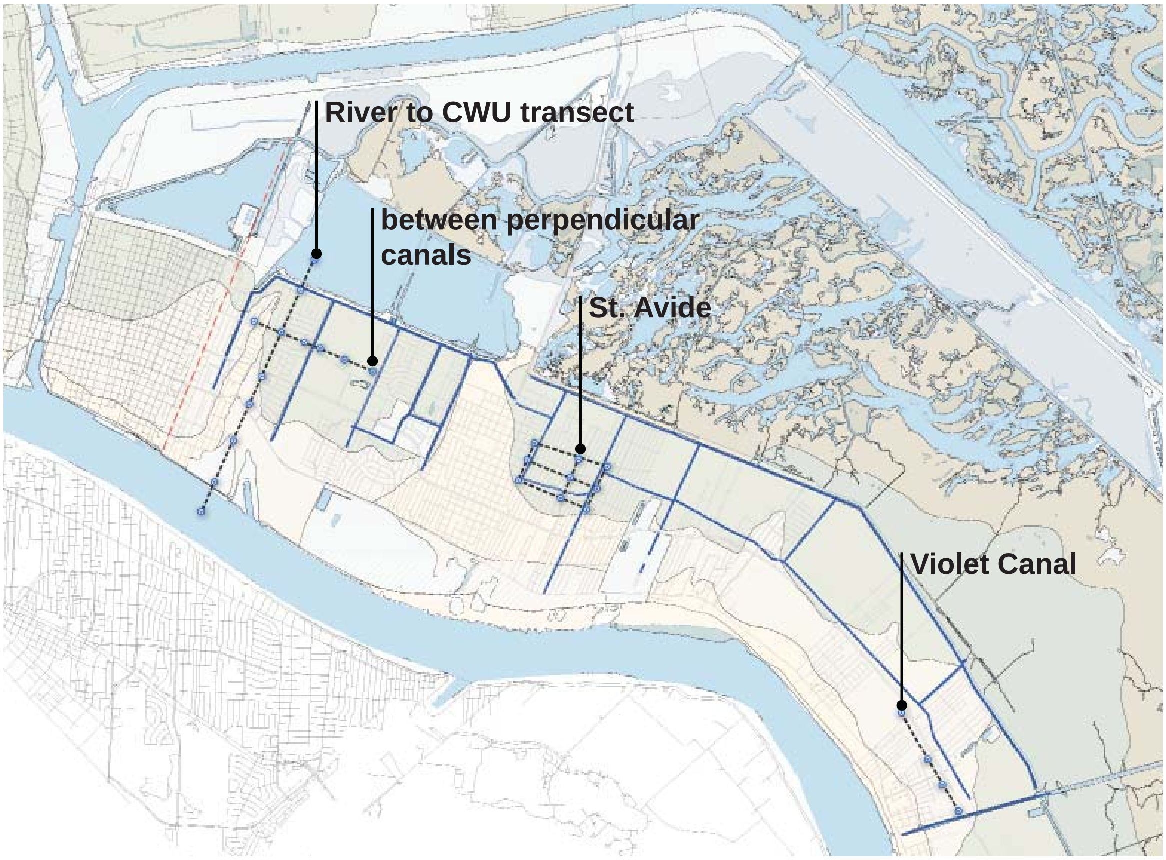


Range of Data Collection
In addition to typical shallow monitoring wells, data should be collected near the Mississippi River through observation wells at various depths, in the Central Wetlands Unit, and to also show salinity levels in the 40 Arpent Canal and the river.

A groundwater monitoring network will also build upon the data already being collected at monitoring wells distributed throughout the region. Additional wells in St. Bernard are necessary to study:

- Soil and water dynamics in subsidence prone areas
- Exposure of wooden piles to aerobic conditions
- Relationship between groundwater levels and surface water levels
- Influence of the Mississippi River and Central Wetlands Unit on groundwater levels
- Capacity of local soils for absorbing and storing stormwater
- Regional saltwater intrusion
- Climate change - rainfall and drought patterns

Understanding Groundwater
Monitoring St. Bernard's groundwater through simple sensors placed in wells, as shown above, would guide the parish's projects and help identify subsidence, stormwater storage capacity, and changes over time.



Phased Network
The groundwater monitoring system would be phased, locating highest priority sites first to collect data before proposed projects are implemented; the four areas shown represent a range of conditions that are typical throughout the parish

If groundwater is better managed, along with water in the canals and culverts, the quality of life for all who live and work in the parish will increase. A report from 2016 by NASA and LSU on subsidence in Greater New Orleans shows that St. Bernard is sinking at a relatively higher rate than the rest of the area; better groundwater management would help slow this alarming and costly process. Both private and public sectors would see major economic benefits, from more stable building foundations and roads to reduced flooding.

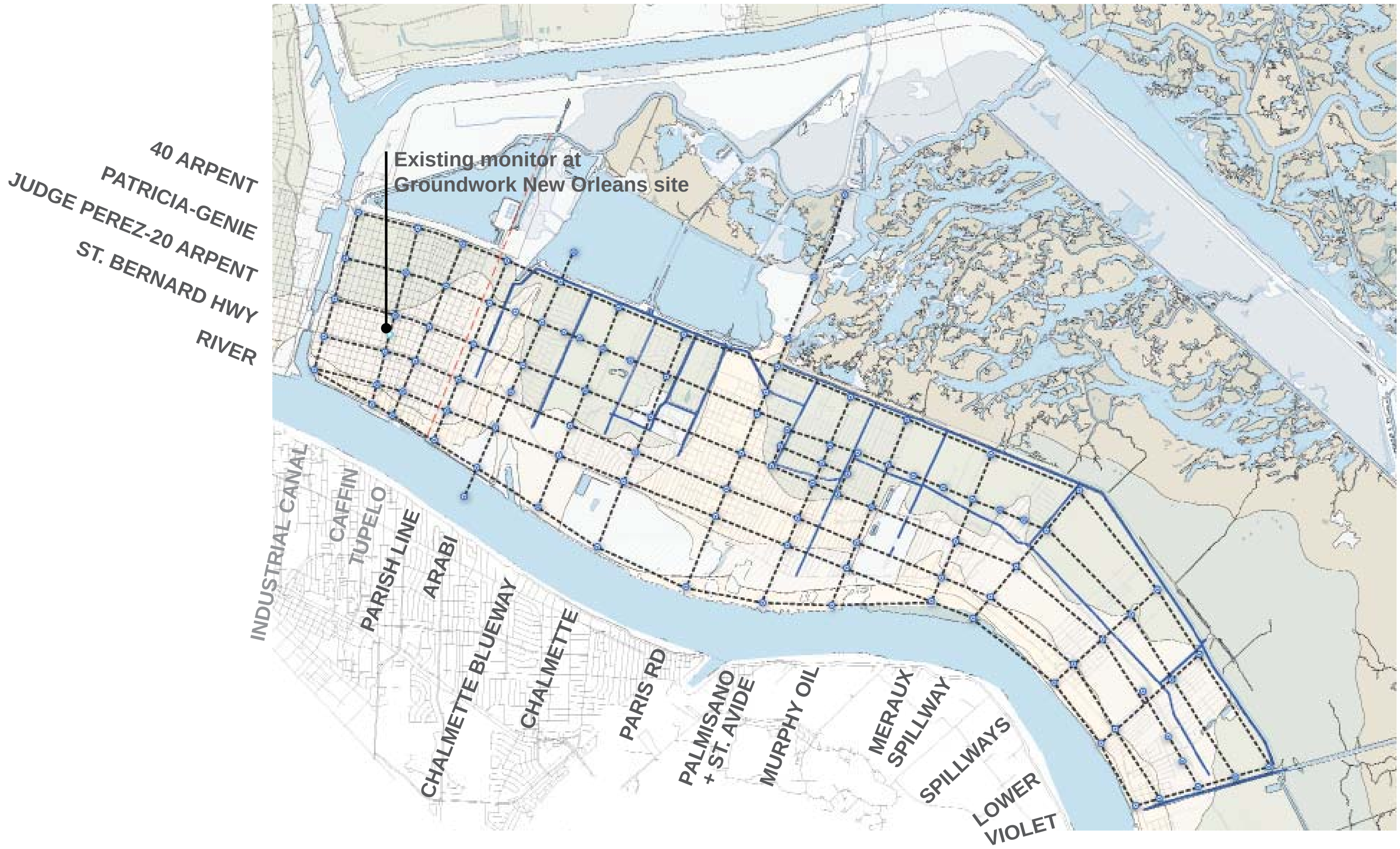
Implementing a groundwater monitoring network is a low cost initiative that could be launched in phases to gradually expand the system. New monitoring wells can be coordinated to collect data on upcoming projects; for example, sensors could be installed before construction to compare before and after conditions, measuring the impact.

The goal of the first phase of monitoring should be to understand general conditions, including infiltration rates, groundwater and surface water relationships, and other aspects of subsurface flow. Another goal should be to develop and test monitoring and data evaluation protocols, and also to develop costs for constructing and operating wells before scaling up.

Initial Phase

The creation of a groundwater monitoring network should start with key transects. A series of soil borings and both shallow and deep groundwater wells should be located along lines that intersect a variety of conditions. For example, by following a line from the riverfront all the way to the Central Wetland Unit, as described in the diagram above, monitoring of water levels along that line can provide invaluable information on the relationship between water levels in the river and groundwater levels in the parish. The first phase of borings and well construction should take look at the following transects and conditions:

- Mississippi River to Central Wetlands Unit
- Between perpendicular canals, parallel to the river
- Along or perpendicular to waterways such as the Violet Canal and 40 Arpent Canal
- At, alongside, or through proposed pilot projects, such as the St. Avide neighborhood

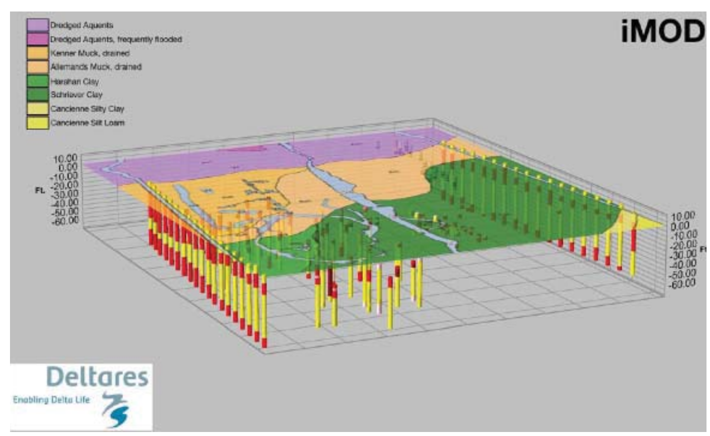


Groundwater Grid, Fully Developed
The full monitoring network based on all proposed project locations, existing areas with high rates of subsidence, and in areas with different soil types and land uses, including existing canals and other drainage systems. The network should continue across the parish line into New Orleans so the entire basin is studied and understood.

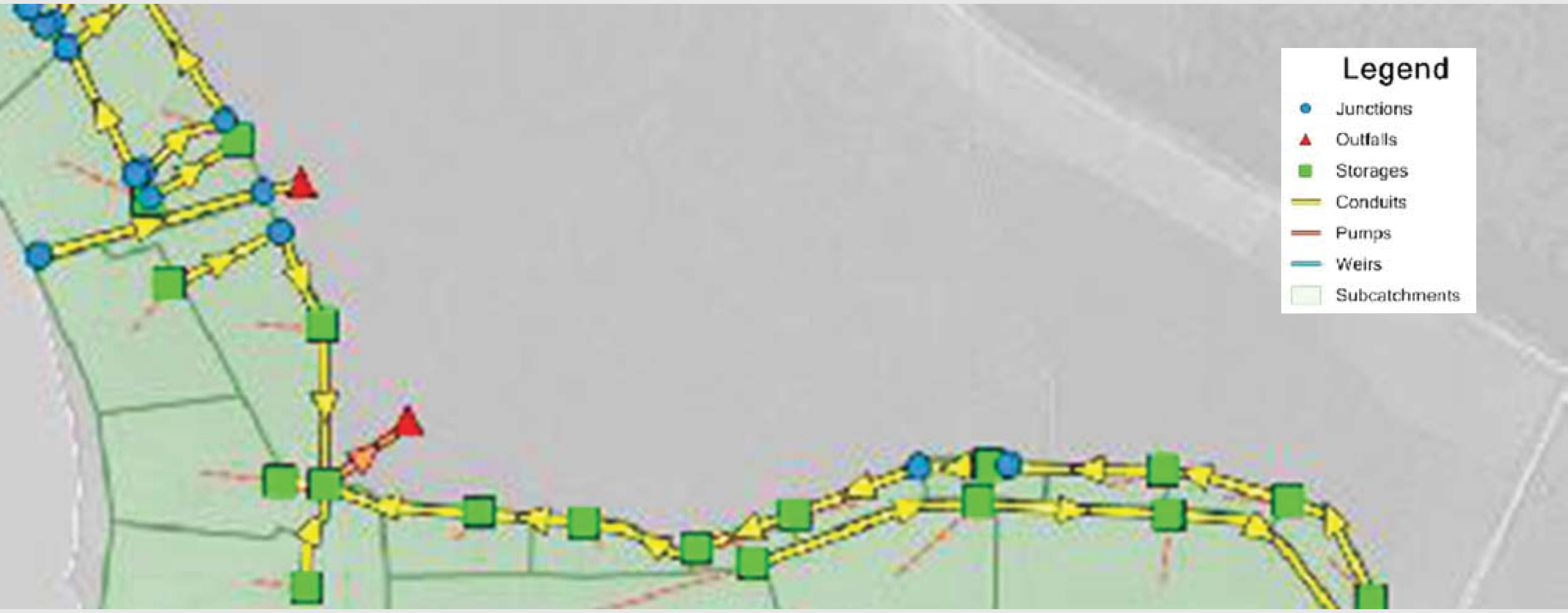
Full Network

In partnership with regional partners (like the Sewerage & Water Board of New Orleans as well as research institutions), the parish should construct a full parish-wide network of monitoring wells in order to collect critical data that will provide a nuanced understanding of the following:

- Soil and water interactions across all soil types and elevations
- Changing conditions in relation to precipitation and drought, river levels, tides, and sea level rise
- Changes in salinity and water quality
- Fluctuations in shallow groundwater and deep aquifers
- Rates of subsidence
- Impact of industrial groundwater extraction
- Existing conditions with which to guide integrated planning efforts
- Evaluate performance and impact of implemented projects



Useful, Applicable Data
Benefits of groundwater monitoring include visual data from sensors in wells across a site that would help inform decisions about planned projects. Above, 3D data showing groundwater depths and soil types gives designers and engineers critical information to determine which strategies would work best.



Testing Proposed Projects
Screenshot of visual interface for the St. Bernard Parish SWMM (stormwater hydraulic and hydrologic model).
Image: GAEA Consultants

6
MODELING RESULTS

An EPA Storm Water Management Model (SWMM) was used to test and refine the proposed system diagram as well as the design approach to proposed IWRM projects. The results of the modeling effort describe the ways in which the proposed interventions would interact and cumulatively impact the function and performance of the parish's stormwater systems.

6
MODELING RESULTS

Anticipating Improvements
The stormwater modeling process attempts to predict how proposed changes to the existing drainage system might create a greater degree of safety by minimizing flooding, shown above in Meraux.

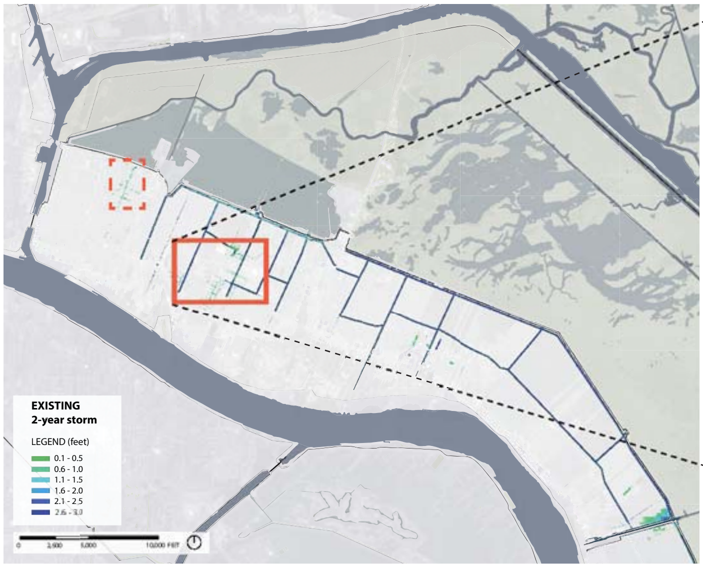
The IWRM Plan includes testing a range of scenarios in a Stormwater Mangement Model (SWMM) to compare their effectiveness. The IWRM modeling process also builds upon the Urban Water Plan, and uses the same SWMM (from CDM Smith) as the basis. Waggonner & Ball worked with GAEA Engineering Consultants through the modeling process to develop the system proposal, and with Waldemar Nelson on cost estimation.

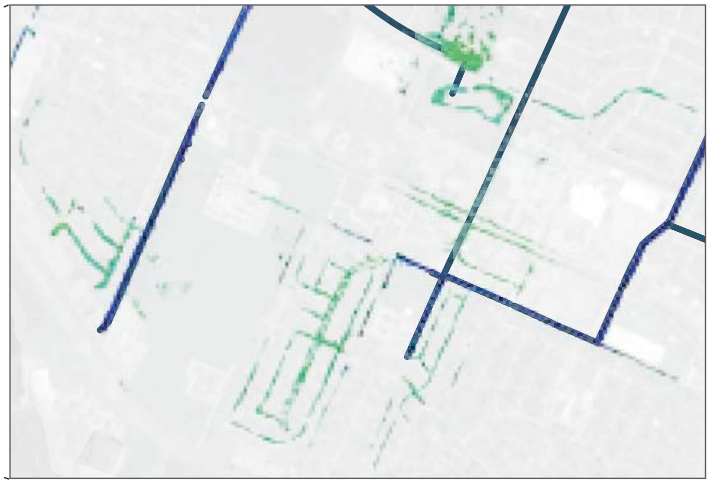
GAEA modeled individual components, each at basic and intensive levels, which results in a more specific understanding of impacts than in the Urban Water Plan. These correspond to the proposed projects from Chapter 5:

- Spillways
- Weirs
- Combined Spillways and Weirs
- Parking Lots
- Canal Parks
- Lagoons
- Street BMPs

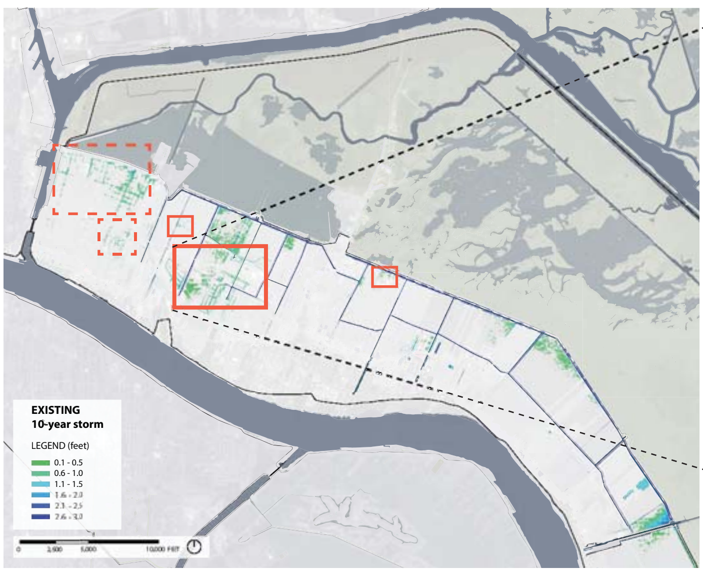
And additional elements not shown in Chapter 5:
- Retention on Parks and Schools (large publicly owned sites)
- 1.25 inches of water detention on properties
- Drainage Improvements

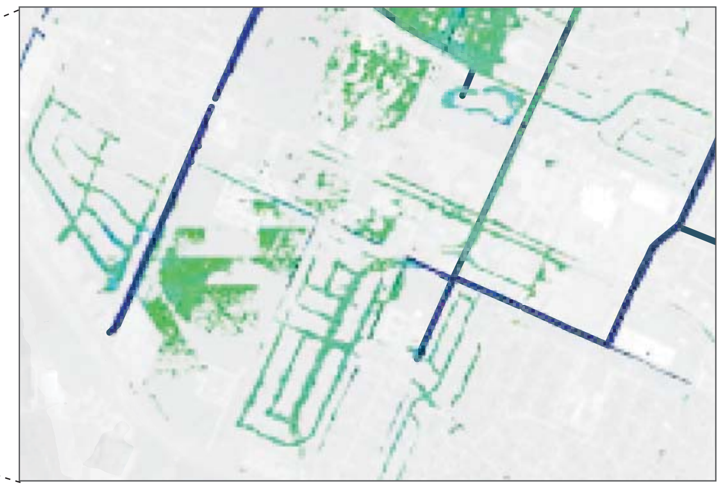
GAEA also modeled two combined scenarios – basic and intensive – along with pump station drawdown times, to establish basic information about sensible operations to maintain higher groundwater levels.





Existing 2 Year Storm Model
Detail of existing SWMM showing street flooding in Chalmette





Existing 10 Year Storm Model
Significant increase in flooding shown in the same area during a 10 year storm event

New types of elements, such as spillways, lagoons, and canal parks, had to be customized in the model, and required more details to understand the smaller scale interventions, like the BMPs, Canal Parks, and Blueways, as well as the larger scale Spillways and Lagoons. Together, Waggonner & Ball and GAEA compared elements to understand how they would be modeled in the SWMM, refining combinations during a daylong workshop. In conjunction, Waggonner & Ball worked with Waldemar S. Nelson to develop cost estimates. For more information on the process and results, see Chapter 9: Hydrologic and Hydraulic Modeling Appendix.

The modeling effort looked at existing conditions and used 2-year, 10-year, and 100-year design storms, so results of modeling the proposed interventions could be compared to a base condition.

The modeling specifically tested:

- The performance of each strategy in a 2-year and 10-year storms, as understood according to the maximum water surface elevation at each node
- Each type of intervention separately, and then in combined scenarios – for example, modeling of just the BMPs or just the spillways each on their own, and then together as part of combined basic and intensive scenario – to understand the impact and help prioritize projects for implementation when this understanding is combined with cost information, land ownership information, and other key factors
- A "basic" and "intensive" scenario, based on different levels of implementation – understanding that not all improvements could be constructed at once, due to availability of funding and other constraints – as a way to show that even limited interventions could make a measurable difference

MODELED COMPONENTS

The following design proposals were modeled during the workshop with GAEA. See Appendix B for details.

Gaea adjusted the existing SWMM to individually test the performance of each strategy to establish a baseline understanding of each strategy's impact on the system and flood risk reduction overall. Results are briefly summarized here for both basic and intensive scenarios.

This modeling strategy does not suggest, however, that any of these measures should be thought of or implemented in isolation. Weirs, for example, will and are intended to raise water levels in order to enhance groundwater balance. This means that their implementation necessitates a corresponding investment in detention and retention measures to offset the impact of the weirs.

Streetscapes (BMPs)

New bioswales and pervious sidewalks were modeled along both sides of major roadways.

Basic: 15.3 miles of BMPs

- Reductions in water surface elevations: 0.5 to 2.0 inches in different areas, with higher reductions in the 40 Arpent Canal west of Paris Road; minimal reduction in water surface levels east of Paris Road

Intensive: 35.6 miles of BMPs

- Relatively greater reductions, ranging from 0.5 to 2.5 inches in the same area

Small reductions in water elevations can provide significant impact, especially for smaller storms and in localized conditions. BMPS also provide significant water quality improvements, which is not quantified through the SWMM model.

Lagoons

Widened portions of the 40 Arpent Canal with constructed islands.

Basic: (4) east of Paris Rd, (1) west of Paris Rd

- Reductions of about 2.0 inches in most canals west of Paris Road

Intensive: (11) east of Paris Rd, (3) west of Paris Rd

- Reductions just over 3.0 inches in the same area

Neither scenario had an impact east of Paris Rd, but detailed modeling may show smaller scale improvements. Benefits are understood in terms of habitat creation.

Canal Parks

Lots that store 1.75 feet of water across the site area before draining into existing canals.

One scenario: (13) parks, totaling approximately 8.2 acres

- Reduction of 0.5 inch in three canals west of Paris Rd

Modeling for lateral parks should be conducted on a smaller scale; they may have a greater local impact. See "Neighborhood Scale Modeling and Results" on page 151.

Parking Lots - Retrofits and New Development

Existing large commercial parking lots that store 1.25 inches of rainfall.

One scenario: Approximately 201 acres

- Reduction of 1.0 inch in three canals west of Paris Rd, and less than 0.5 inches in other areas

Similarly, modeling at a smaller scale would more clearly establish the impact on specific sites and surrounding areas.

Retention and Detention on Publicly Owned Land

Combination of bioswales and water retention across entire sites, including parks and school properties.

One scenario: Approximately 69.6 acres of 1.25 inch retention, and 658.3 acres of 2.0 foot deep bioswales

- Reduction of 3.0 inches in three canals west of Paris Rd, and 1.0 inch east of Paris Rd

Again, greater impacts closer to the proposed retention/detention sites are possible, but can only be determined with a more detailed model.

Retention and Detention on Private Properties through Zoning

Retention of water on all properties in the study area.

One scenario: 1.25 inches retained in the entire study area

- Reductions from 1.25 inches to 9.0 inches in upstream areas west of Paris Rd, and 1.25 inches to 5.0 inches in upstream areas east of Paris Rd. Levels in the 40 Arpent Canal went down by 6 to 9 inches.
- In lower St. Bernard, reductions of up to 2.5 inches upstream, and up to 8.0 inches downstream
- In the Lower Ninth Ward, reductions of up to 1.7 feet

This proposal shows major impacts across the system, and could be implemented through zoning and land use policy.

Spillways

Undeveloped tracts that store and convey water into 40 Arpent Canal.

Basic: Meraux Spillway

- Reductions of 4.0 to 7.0 inches in 40 Arpent, Dubouchel, and 20 Arpent Canals

Intensive: Meraux Spillway plus (4) spillways, (1) lagoon

- Reductions of 1.2 to 1.8 feet in same area, with even greater reductions near Meraux pump station

Results show a major impact across the parish system by using available land to manage water flow.

Weirs

Small structures to slow water from higher elevations to decrease peak demand on pump stations and recharge groundwater.

One scenario: 13 weirs total, and two flap gates

- Reductions from 2.2 to 2.7 feet in 40 Arpent Canal west of Paris Rd, and 1.5 to 1.7 feet east of Paris Rd

Where weirs were shown to exacerbate flooding, flap gates to prevent backwater flooding were modeled instead. Weirs generally lower elevations downstream (40 Arpent) and raise elevations upstream (20 Arpent and lateral canals), which is the intended impact of the weirs. These changes must be accounted for in overall system design so flood risk is not inadvertently increased.

Combined Spillways and Weirs

Weirs hold water in upstream canals and spillways drain the excess water.

One scenario: all weirs and spillways combined

- Reductions in 40 Arpent Canal west of Paris Rd are similar to above, and certain downstream canals also showed lowered water levels, for more storage capacity

It is recommended to pair the spillways with weirs – each supports the other – as spillways make the weirs feasible by outweighing the increased flood risk posed by the weirs, which are put in place to improve control of water levels.

Drainage Improvements

A range of reconfigurations to the existing system should also be considered, along with the proposed projects:

- Converting the box culvert draining towards the New Orleans DPS05 to an open trapezoidal channel
- Reconnecting the drainage systems between New Orleans and St. Bernard across the parish line; Gaea modeled a new open channel parallel to the existing railroad tracks (assumed trapezoidal) and culvert under the railroad tracks (assumed diameter of 5 feet).
- Deepening Eickes Canal
- Adding Jean Lafitte Canal as an open box culvert (not modeled in existing conditions since the existing box culvert has caved in at several locations)
- Connecting the Chalmette Vista and Guichard Canals with an open trapezoidal channel along Oak Tree Lane (this new canal is included in the proposed Oak Tree Lane project)
- Improving 40 Arpent Canal near and under Paris Road to allow unimpeded flow (the existing model does not include any flow under Paris Road). The improvements include a wetland shelf for part of the canal that provides additional storage capacity
- Adding wetland shelves to the canal along East St. Avide Street to provide additional storage

One scenario: all improvements listed were modeled

- Reduction of water levels in Arabi and the Lower Ninth Ward in New Orleans by 6 to 8 inches
- West of Paris Rd, levels in the 40 Arpent and Guerenger Canals increased by 4 to 7 inches. Water levels in the Chalmette Vista, Guichard, and Jean Lafitte Canals decreased by 5 to 16 inches
- East of Paris Rd, the 40 Arpent Canal lowered by 2.5 to 5.5 inches, while the portion of the 20 Arpent Canal in Meraux lowered similarly

Together, these improvements resulted in up to one foot of water reduction in the Lower Ninth Ward and Arabi, and levels in most major canals in Chalmette also reduced.

Violet Canal Dry Weather Flow

In dry weather, flow would help flush the drainage system to improve water quality and prevent mosquito breeding, especially in proposed spillways, which could have large volumes of shallow water.

Basic: Flow of 1 foot/second from Violet Canal in Basic system design

- Goal of 1 foot/second flow in 20 Arpent Canal was achieved as far upstream as east edge of Chalmette; most of 40 Arpent Canal was below desired velocity

Intensive: Same flow, with Intensive system design

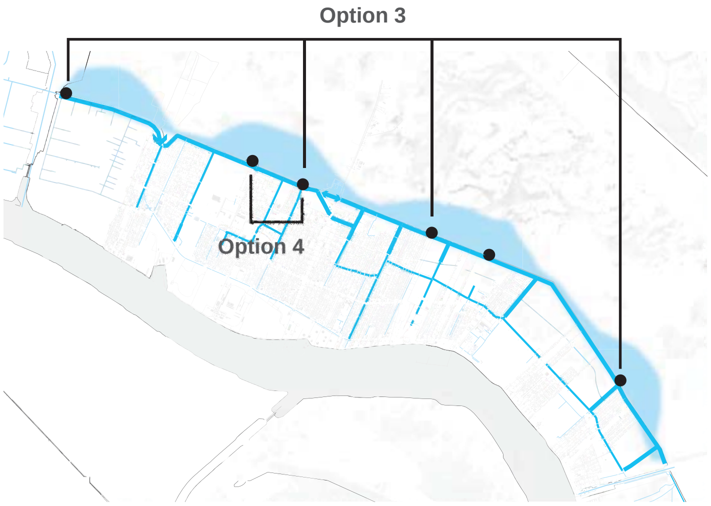
- Lower flows in 20 Arpent Canal but greater velocity in 40 Arpent Canal

Weirs prevent flow farther upstream, but lower lying canals would benefit from higher velocities.

Minor Reductions, Major System Impact
Authorized in 1996 by U.S. Congress, the ongoing SELA (Southeast Louisiana Urban Flood Control) projects in New Orleans invest hundreds of millions of dollars in grey infrastructure, through hardening canals, building new and expanded culverts, and building pump stations. These investments provide storage for 0.25 and 0.5 inches of rain, which illustrates the importance of even small scale interventions for individual neighborhoods, and for St. Bernard's drainage system as a whole.

COMBINED BASIC AND INTENSIVE SCENARIOS WITH PUMPING ALTERNATIVES

Option 1: all pumps
Option 2: no pumps



In addition to modeling each of the proposed system components separately, GAEA Consultants also modeled two combined scenarios to understand the impact of integrating multiple components as well as the difference between a "basic" and "intensive" level of implementation for all pump options, further dexribed in section 4c.

Option 1: All pumps in operation
- Benefit in all storm scenarios

Option 2: All pumps turned off
- No benefit; flooding worsened in all 'basic' scenarios. This option is not recommended.

Option 3: Half of pumps in operation
- Not as beneficial as options 1 and 4

Option 4: Two pumps in Chalmette in operation
- Benefit in the most developed areas of parish

Basic Scenario

This included implementation of the lateral parks, rain gardens and bioswales on publicly owned property, parking lot retention/detention, all weirs, all drainage improvements and connections, and a single stormwater spillway near the bend in the 40 Arpent Canal in Meraux, street BMPs along select corridors, and a few the selected lagoons.

As expected, basic scenario reduces flood risk overall during 2, 10, and 100 year storms if pumps are operated as they are today (Pump Option 1). For all storms, the scenario reduces flooding along the 40 Arpent Canal between Chalmette and the Violet Canal. For 100 year storms, the interventions reduce flooding flooding in the Lower Ninth Ward, Arabi, and parts of Chalmette.

The other pump options would reduce flooding in some areas, but also cause higher levels of flooding in other neighborhoods, and may only be feasible for rain events smaller than the ones modeled as part of this study.

Intensive Scenario

This included the retention/detention of the first 1.25 inches of runoff over the entire area of the parish within the protection levees, implementation of all proposed street BMPs, all stormwater spillways, lagoons, weirs, and drainage improvements.

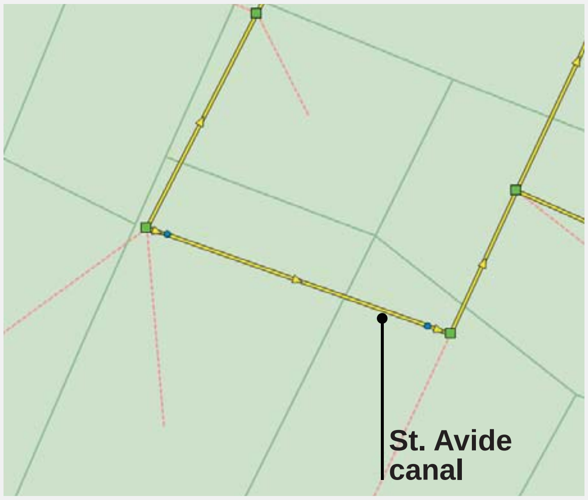
The intensive scenario, for all Pump Options, shows reductions in flood risk over the entire system. With Pump Option 1, flooding would nearly be eliminated for the Lower Ninth Ward and would significantly reduce street flooding in Arabi for the 2 year storm, but would result in some street flooding in Chalmette. As with the Basic Scenario, Pump Options 2 and 3 result in improvements in some areas, but also result in some increased flooding in some other areas, and are not recommended. Pump Option 4 results are almost identical to Pump Option 1 results west of Paris Rd., with higher water levels and flooding along the 40 Arpent Canal east of Paris Road, although flood levels are still reduced compared to the existing condition.

		Storms (Percent of Existing)					
Scenario	Pump	2-year		10-year		100-year	
Existing	1	1372		2448		5546	
Basic	1	1309	95%	2310	94%	4818	87%
Basic	2	2233	163%	3338	136%	5584	101%
Basic	3	1445	105%	2686	110%	4944	89%
Basic	4	1459	106%	2359	96%	5126	92%
Intensive	1	974	71%	1671	68%	4245	77%
Intensive	2	1277	93%	2441	100%	4924	89%
Intensive	3	997	73%	1898	78%	4463	80%
Intensive	4	984	72%	1738	71%	4532	82%

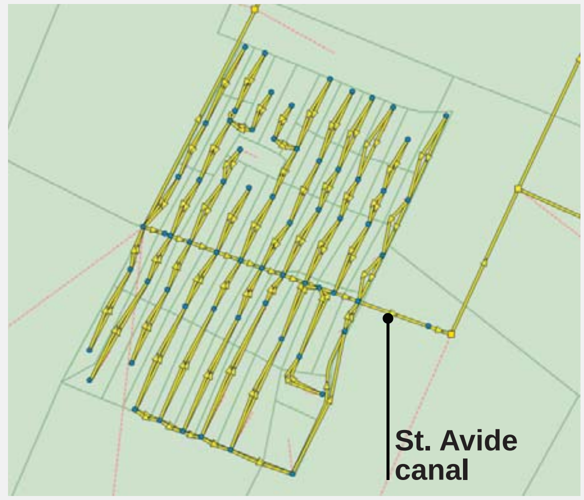
The important takeaway from the modeling of the combined scenario is that St. Bernard Parish and Lake Borgne Basin Levee District could make no upgrades to pumping systems, invest in the proposed non-structural measures, and significantly reduce flood risk, even in a no pumping scenario.

Option 1, where all pumps remain in operation, was shown to have the largest benefit across the system. Option 4, where only the two pumps in Chalmette operate, shows a relatively similar benefit upstream in the more developed areas of the parish; this would save a significant amount of resources, in both staffing and energy use.

NEIGHBORHOOD SCALE MODELING AND RESULTS



System Scale Model
The large SWMM modeling simplifies the neighborhood drainage network, which can include water levels and flows that do not match existing conditions



Smaller Scale Modeling
A detailed effort includes the network of individual drain lines, catch basins, and outfalls into the canal for a more specific understanding of existing conditions

To understand better local effects with more precision and a finer grain, the modeling effort analyzed the proposed project in the St. Avide neighborhood in Chalmette (described in Section 5c: Canal Improvements). The proposed project includes wetland shelves, weirs at both ends of the canal, and BMPs throughout the 200 acre study area in Chalmette. Results below are from a 2 year storm event.

An additional purpose of this finer grained modeling was to test the impact of using weirs to adjust water levels in lateral canals, which can allow these canals to function like retention basins in order to reduce runoff flowing from the neighborhood into the neighboring perpendicular canals.

Gaea modified the exiting SWMM to study this this area in detail, adding drainage conduits and junctions based on existing data and assumptions where exact locations and inverts were not available (described in the Hydraulic and Hydrologic Appendix). GAEA modeled existing, basic, and intensive scenarios, and for 2-, 20-, and 100- year storms.

Compared to the existing large scale system model, the detailed model showed a slightly higher water level in the St. Avide Canal; this is likely because the specific drainage lines increased the flow to the middle of the waterway. Similarly, water levels in adjacent canals also varied by a few inches. Overall, Gaea determined that the neighborhood scale model was a reasonable representation compared to the large scale model.

Basic: (2) wetland shelves, (2) weirs, retention of 1.25 inches of rainfall on 10% of properties, 4.9 miles of BMPs

- Reductions of surface water by 1 to 13 inches; water level in the canal did not change, due to retention and BMPs

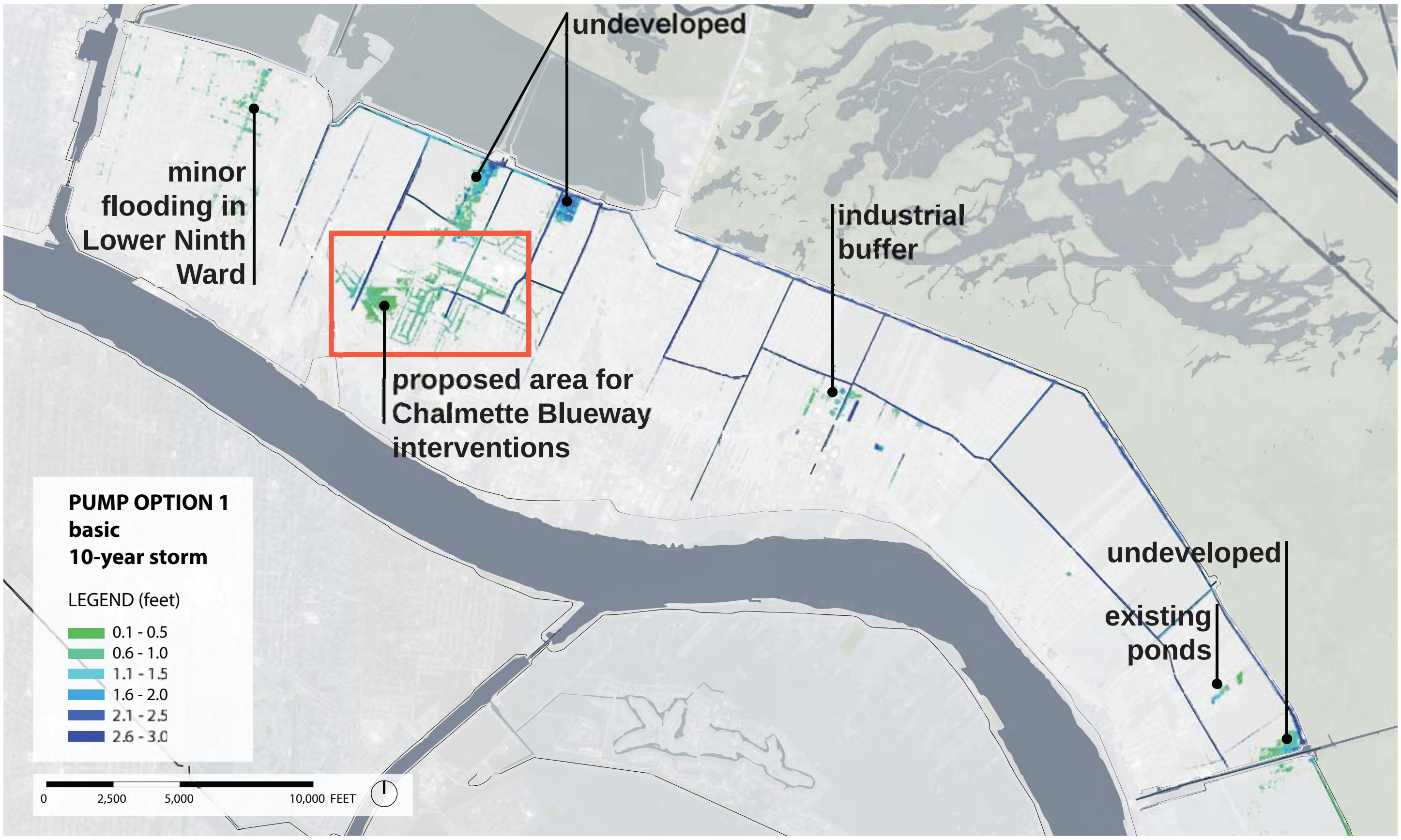
Intensive: all wetland shelves and weirs, retention of 1.25 inches of rainfall on 100% of properties, 8.9 miles of BMPs

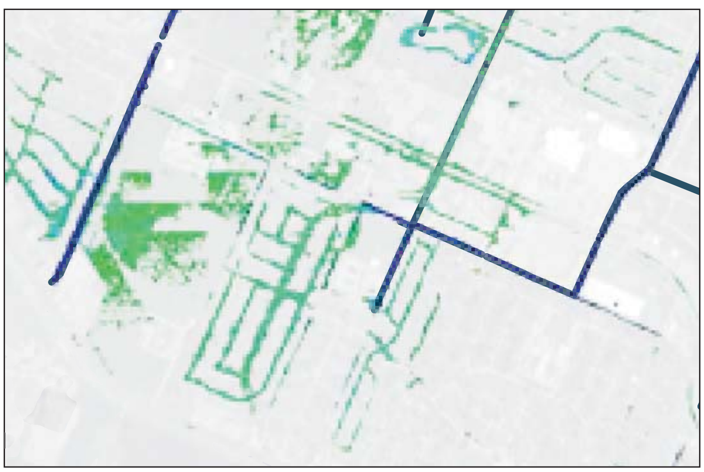
- Reductions of neighborhood surface water by 6 inches to 2 feet; the canal water level lowered by 4 inches

Conclusions: First, the detailed modeling showed that small scale retention and/or detention and BMPs for localized areas are effective, particularly for smaller and more frequently-occurring storms. The 10 and 100 year storm scenarios still showed benefits, but they were somewhat less significant.

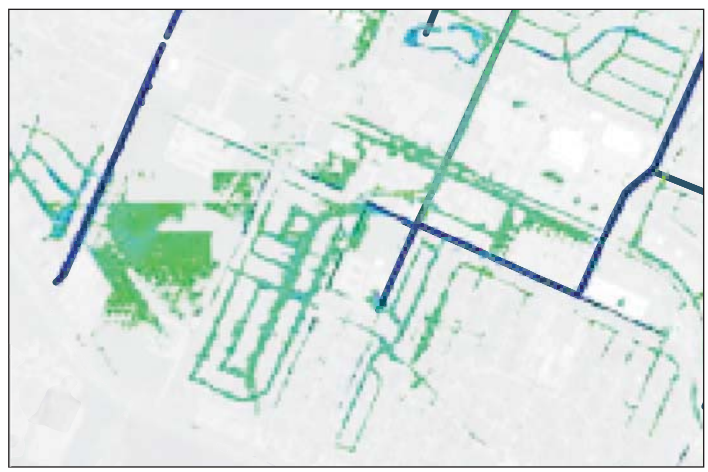
Second, the modeling showed that the retention and detention measures throughout the neighborhood in both scenarios would compensate for the raising of water levels in the canal with the introduction of weirs, which means that flood risk would not be elevated.

Third, the SWMM is coarse; more detailed modeling along the lines of what was conducted for St. Avide, for multiple neighborhoods at the same time, would be necessary to understand the impact of neighborhood



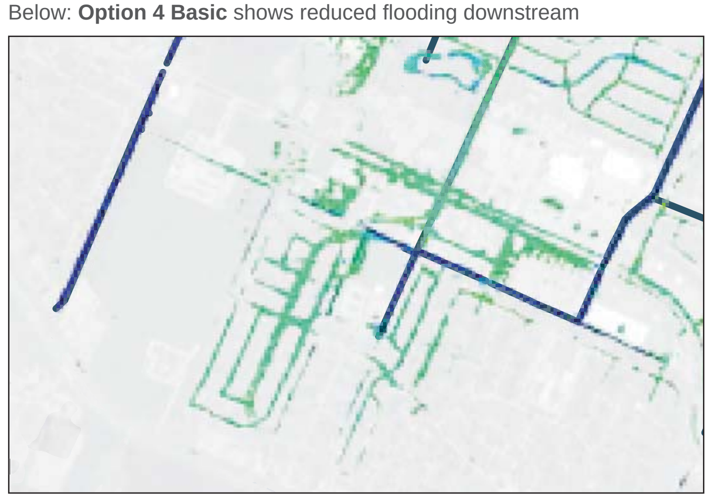


Existing 10 Year Storm
Existing flooding is shown near proposed Chalmette Blueway and BMPs on Judge Perez, the most developed part of the parish.



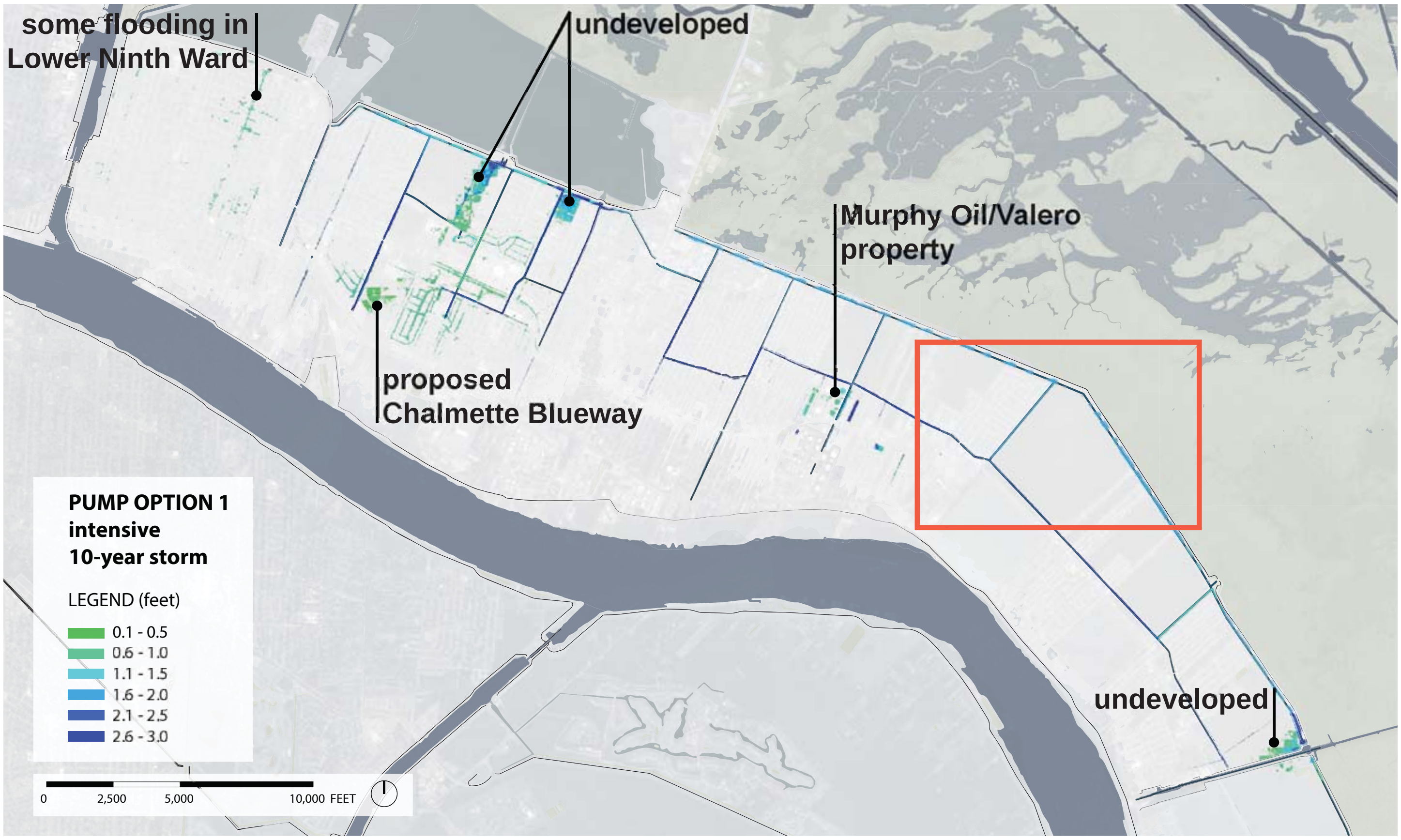
Above: **Option 1 Basic** shows water in Blueway and along BMP streets

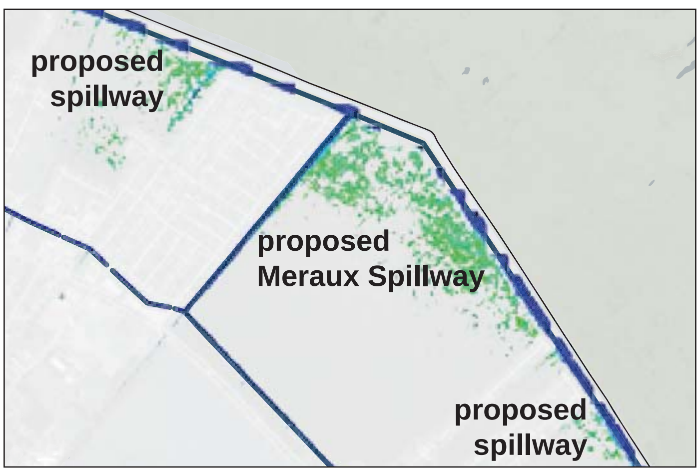
Below: **Option 4 Basic** shows reduced flooding downstream



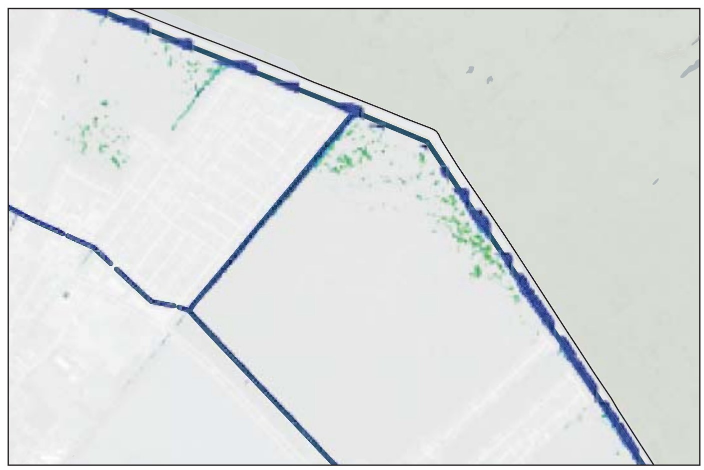
The model shows patterns of existing flooding that align with actual conditions. Lower lying areas adjacent to development, which have higher volumes of runoff, were shown to flood. The highest relative flooding in the parish appeared in urbanized areas like Chalmette, particularly adjacent to Judge Perez Drive and St. Bernard Highway, which are impervious surfaces that act as ridges.

For the Basic scenario, Option 1 shows a benefit to downstream St. Bernard, with a minor increase in water along BMP corridors; this makes sense since more water is held in the landscape. Option 4 shows the same results, with a significant increase in flooding downstream,



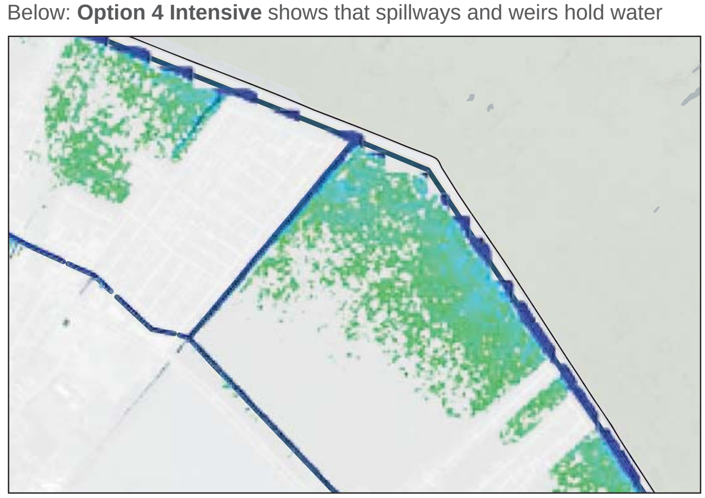


Existing 10 Year Storm
Flooding is shown in the lowest spots along the 40 Arpent Canal



Above: **Option 1 Intensive** shows decreased downstream flooding

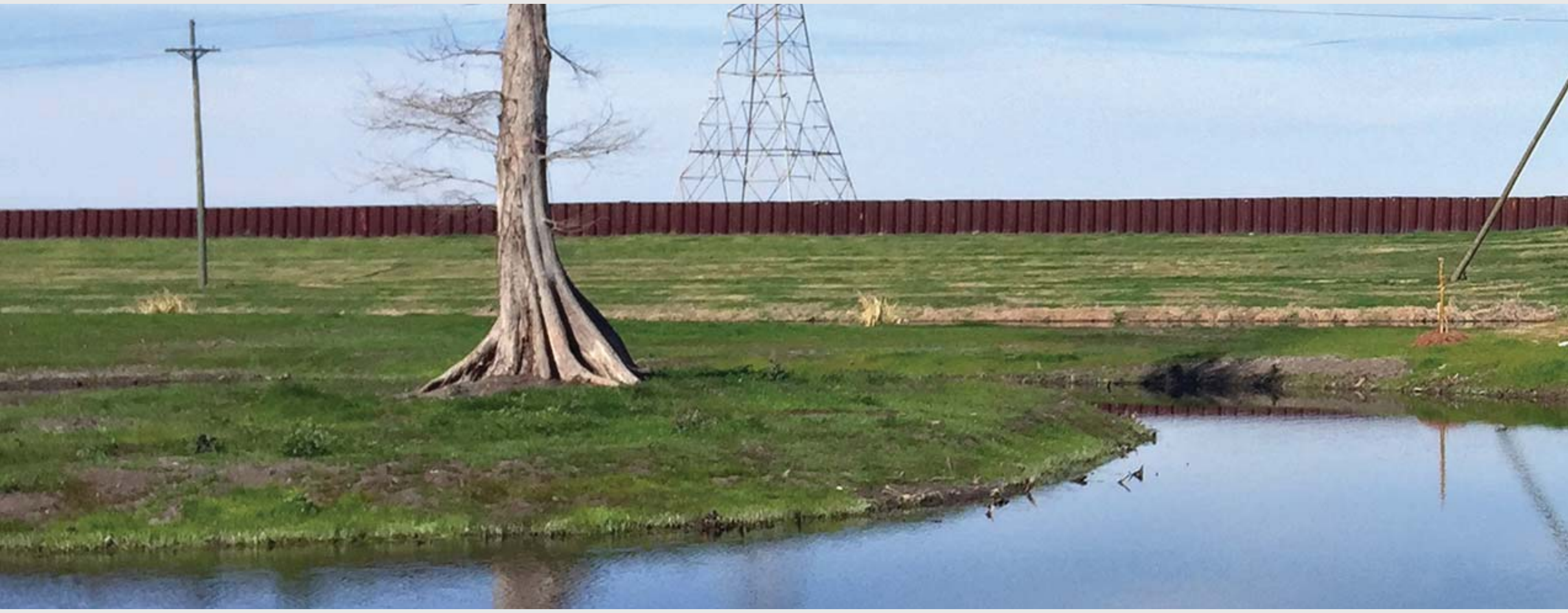
Below: **Option 4 Intensive** shows that spillways and weirs hold water



particularly in undeveloped areas along 40 Arpent that are proposed for spillways, because these areas already flood.

The Intensive scenarios for Option 1 and Option 4 show a major benefit to the lower, downstream parts of the parish. This indicates that spillways and weirs would work as modeled, and confirms that low tech components, instead of new pump stations or levees, could solve system scale problems for far less cost.

Option 4 Intensive shows more downstream flooding than Option 1, but this is limited to the proposed spillway areas.



Improving Access
Recently completed lagoon and boat launch integrated into the 40 Arpent Canal in Chalmette.

7
RECOMMENDATIONS

Leveed Basin
Pontiff Park in nearby Jefferson Parish temporarily stores neighborhood stormwater in a basin that is bounded by levees.

Storage Behind Weirs
As shown above, weirs can hold back water and also introduce flow to lower lying waterways. Higher levels make water more visible.

Treated Wastewater
Effluent that has been treated can be used to nourish wetland restoration and create new land that serves as both storm buffer and habitat.

Internal Wetlands
Connecting people to St. Bernard's delta landscape can create opportunities for recreation, education, and redevelopment.

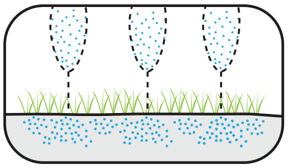
ILLUSTRATED TOOLBOX

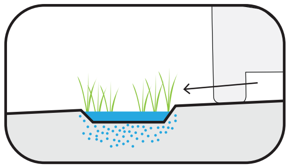
The IWRM Plan outlines a new approach to water management that embraces water as an asset. The proposed water system employs a broad array of proven techniques and strategies to manage rainfall and related water resources in ways that are attuned to landscape types, soil types, local culture, and the potential to derive environmental and economic benefits from new water assets.

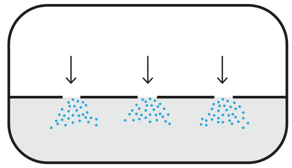
The proposed techniques and strategies are implementable by a wide range of public and private stakeholders, and from the neighborhood scale to basin and regional scale. Strategies that are applicable at the basin scale will require consensus and collaboration between citizens, businesses, institutions, and public agencies. Achieving integrated water resources management is a shared endeavor, with every stakeholder in the region playing a role.

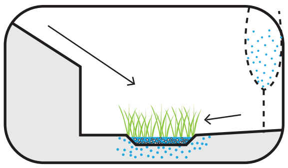
Elements in the illustrated toolbox can be grouped according to their function.

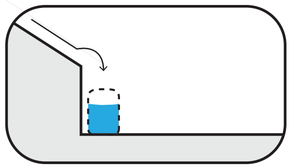
SLOW

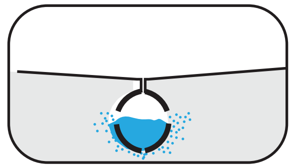

PLANTS


BIOSWALE


PERVIOUS PAVING

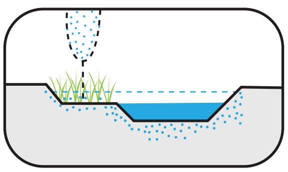

RAIN GARDEN

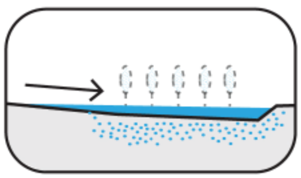

HARVESTING

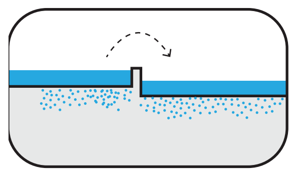

EXFILTRATION

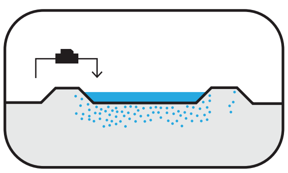
These interventions slow the flow of water and reduce runoff volumes. They are implemented and function at the neighborhood scale, and can be implemented by individual property owners, institutions, and also as part of street and parking lot rebuilding and repaving efforts. These measures will require regular maintenance in the form of weeding, watering, fertilizing, and cleaning.

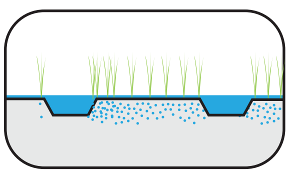
STORE & USE


IMPROVED CANAL


STORMWATER SPILLWAY

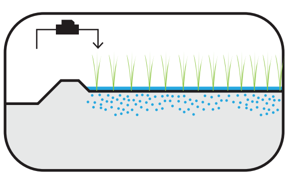

STORAGE BEHIND WEIR

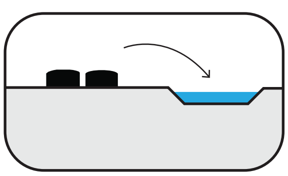

LEVEED BASIN

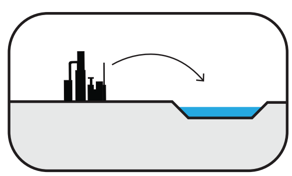

INTERNAL WETLANDS

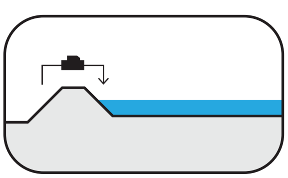
These interventions expand the overall storage capacity of the parish stormwater network. This reduces reliance on pumping, improves infiltration, and creates opportunities for habitat creation and recreational amenities. These measures are implemented and operated at the neighborhood and district scale, and will require regular maintenance in terms of maintaining aquatic habitats, and managing water levels and water flow to ensure regular flushing.

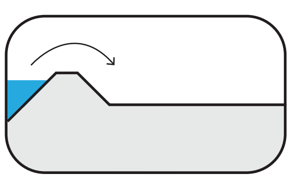
CIRCULATE & RECHARGE

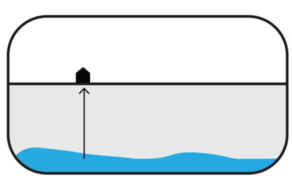

EXTERNAL WETLANDS

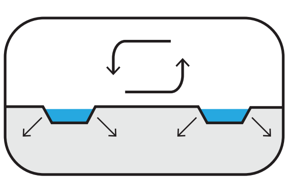

TREATED WASTEWATER


INDUSTRIAL WASTEWATER

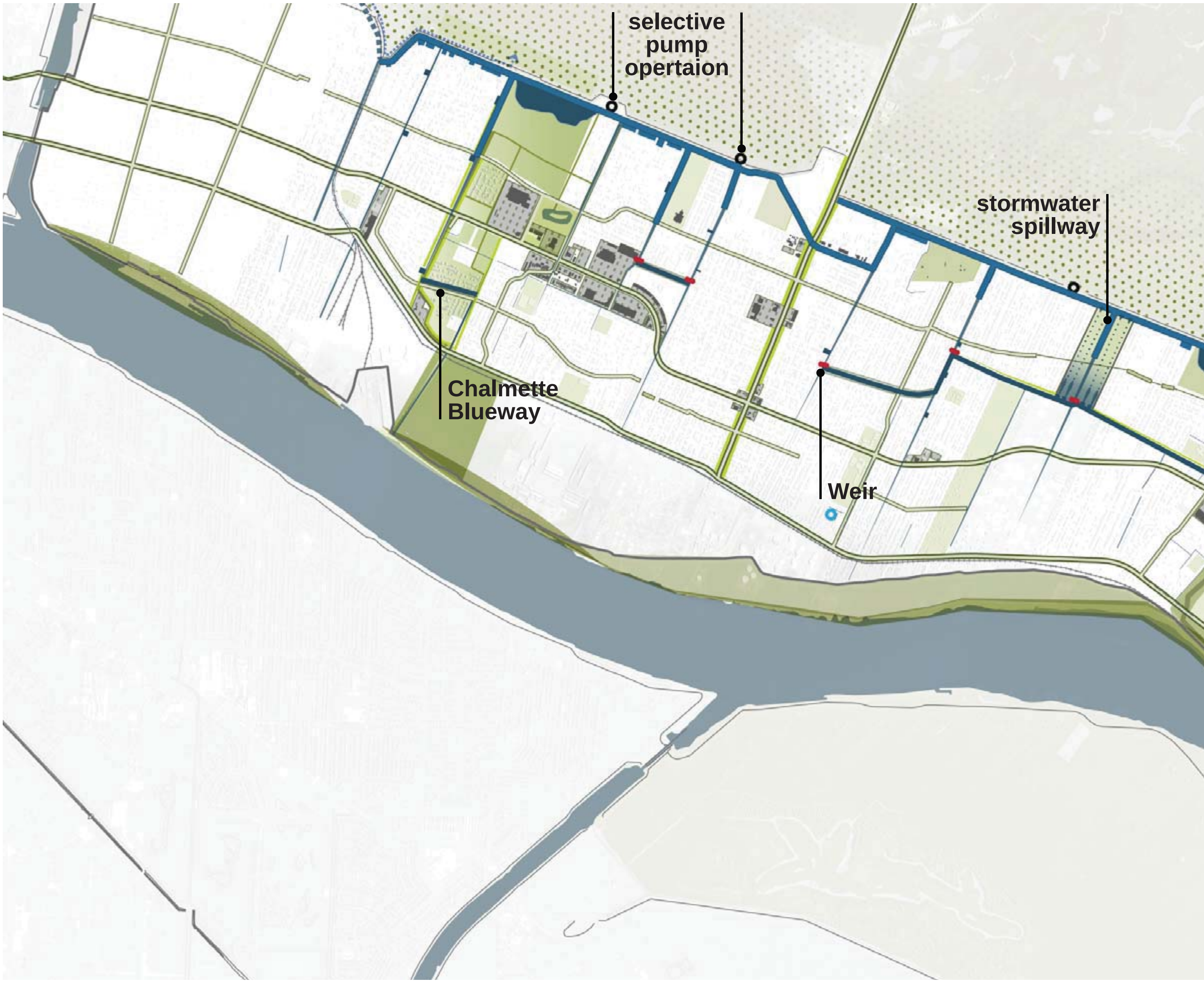

PUMPS

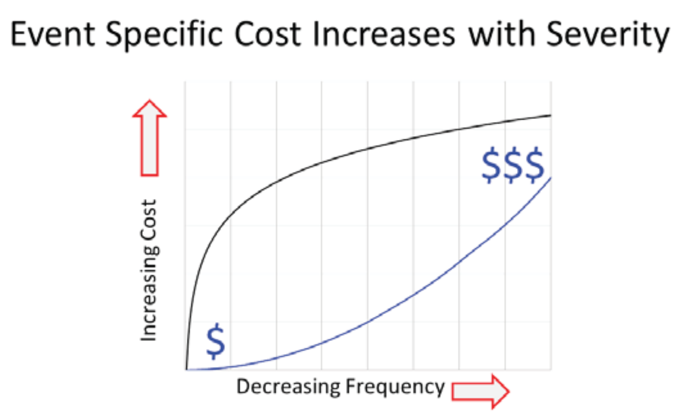

SIPHON (river or lake)

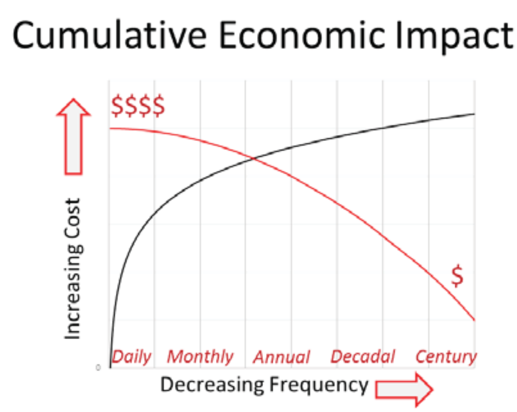

GROUNDWATER PUMP


CIRCULATING CANALS

These interventions are critical for the overall health of the parish's water networks. Adequate base flow and periodic flushing will improve water quality and aesthetics. In addition to rainfall, the Mississippi, treated wastewater, treated water from industrial installations, and groundwater are all potential sources of water with which to feed water networks and nourish wetland habitats. Implementation and operation will require high levels of coordination between public agencies and across parish lines.

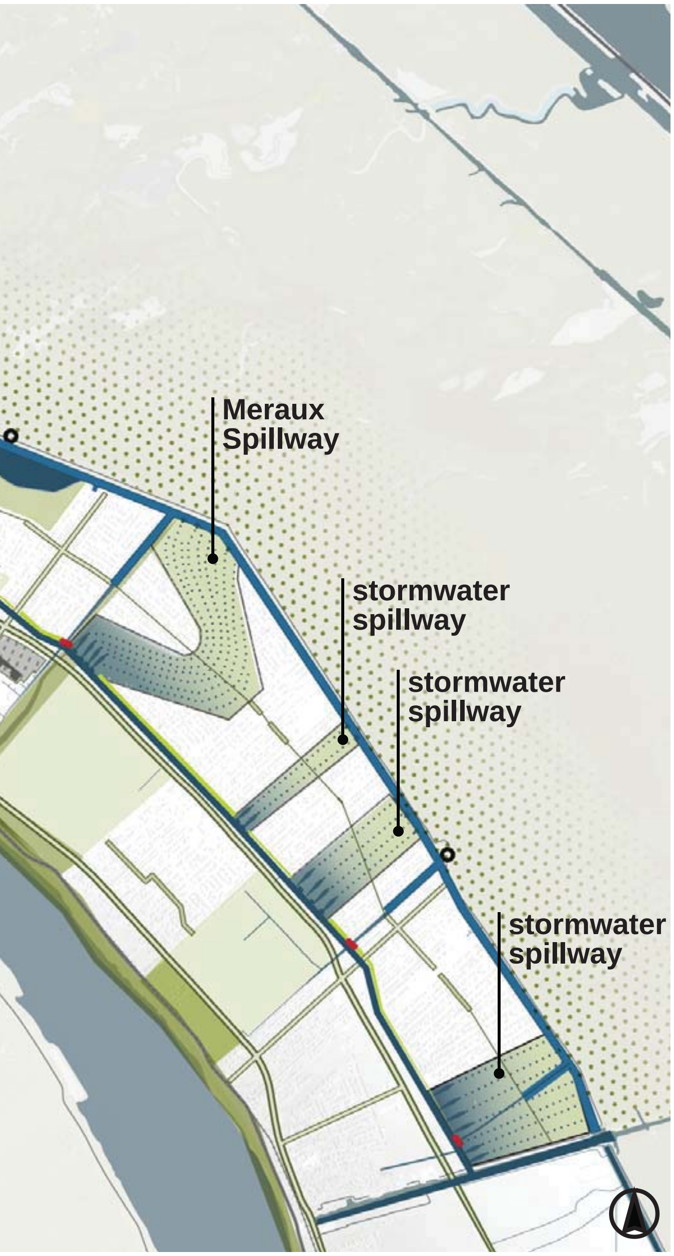


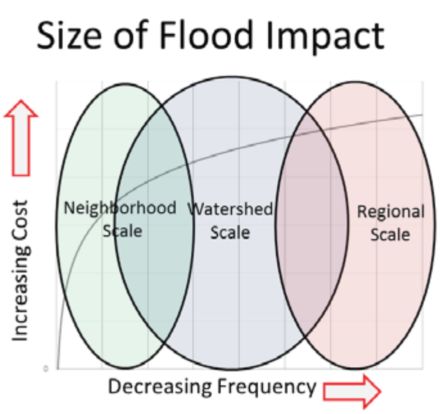




Smaller storms occur with more frequency, and cause less damage and exact lesser economic costs per event than larger storms. Greater New Orleans receives 60+ inches of rain each year, and most of that will fall over the course of smaller events with cumulative rainfall of under 2 inches. Once or twice a year, the region may see storms with rainfall totals of 3-6 inches, and storms with even greater rainfall are likely to occur with less frequency. Multiple big storms in a single year is not unprecedented, and may become even more likely with climate change. Image courtesy Arcadis

The cumulative economic impact of smaller storms, however, can actually be greater than the economic impact of far bigger storms that occur with less frequency. With global climate change, these relationships may shift slightly as bigger storms become more common. However, it remains critical to plan for smaller storms in addition to the bigger events that are easier to remember because chronic flooding also negatively affects quality of life and the local economy. Furthermore, these costs are not distributed evenly, and are borne first and foremost by those living in the most vulnerable, low-lying areas. Image courtesy Arcadis





Each strategy and type of intervention is appropriate for addressing different kinds of storms and levels of rainfall. Neighborhood-scale green infrastructure, for example, will reduce flooding for smaller events, but will not be sufficient to address historically large events. For those, larger scale measures such as the stormwater spillways and improvements to drainage networks and pump stations are necessary. At the same time, those larger measures cannot provide water quality and infiltration enhancements that need to be distributed across the entire parish.
Image courtesy Arcadis

RECOMMENDATIONS

The "Basic" and "Intensive" Scenarios that are described in Chapter 6 are also indicative of priorities for implementation. For example, implementing all of the street BMPs that are described in the Intensive scenario all at once would not only be cost prohibitive and disruptive to daily life for a period of years, it would also be less useful than implementing BMPs along a few key corridors where they would provide the most additional benefits as part of street beautification efforts while also implementing other measures such as stormwater spillways and canal improvements at the same time.

By implementing strategies in stages, and by implementing multiple strategies at the same time, the parish will be able to adapt existing systems gradually, collect important data on design and performance that will improve later efforts, and also begin to understand the interrelationships between different features, both old and new.

In addition, as described in the diagrams to the lower left, implementing an array of strategies and projects at different scales allows the parish to address different kinds and levels of risk. Parish residents and public agencies will begin to see benefits for smaller events as well as larger events, and also in multiple aspects

A History of Living With Water
Earlier residents of St. Bernard lived without floodwalls and pumping systems, and knew how to build safely above water. A raised house is shown along Bayou Terre aux Boeufs.

Opportunity to Embrace Water
The neighborhood of Jumonville in Meraux is centered around an open space that stores water, but the fenced off rear yards of houses do not value this integrated landscape as an asset.

Living on Water
Elevated fish camps and docks along the water in Shell Beach were rebuilt higher to allow water to flow underneath, while also providing direct access to recreational opportunities on the coast.

DEVELOPMENT STRATEGIES

St. Bernard is blessed with open spaces, both in the form of large undeveloped parcels, and also in the form of individual vacant lots and groupings of vacant lots. To maintain the identity of the parish, it is critical to keep as much open space as possible. Land trusts are an option that Parish government could explore in order to keep areas open.

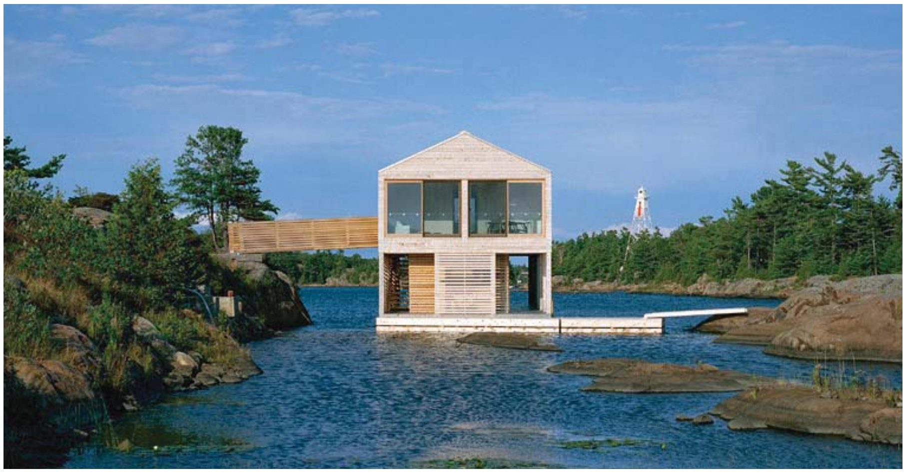
A primary development strategy for St. Bernard is to build as much as possible on the existing vacant lots; this creates a two-fold impact:

- Benefits existing neighborhoods by filling in gaps and restoring urban fabric, and making better use of utilities and existing infrastructure. Developer–builder bundles are an existing tool and should be used for this purpose
- Undeveloped land is critical to water management at a systems scale; a better balance of urbanized land that generates runoff to undeveloped areas, which can be used for proposed measures like the spillways. This also helps with maintaining distinct identities of individual neighborhoods, which is key to the character of St. Bernard as a more rural counterpart to New Orleans

New forms of waterfront development are critical, especially in low-lying areas. This is especially important where the development is planned – water should be incorporated from the very start – and can be central to the identity of new developments. Designing around water as an amenity is a major marketing opportunity, not just for the developer, but for the St. Bernard as a coastal parish built on the delta.

Prioritizing development that is centered around water as an asset – for recreation, habitat, or scenery – takes advantage of the opportunities that have been missed over time. For example, the Jumonville subdivision in Meraux is built entirely around a broad drainage area, but all the houses turn their backs to this open, park-like space.

Incorporating canals and other water features that double as necessary infrastructure benefits the parish and also creates the basis for a lifestyle not available elsewhere. On the following pages, a range of precedent examples show how development can integrate water as an asset into design through different scales, amenities, and densities.



Centered Around Water

A simple vacation house on Lake Huron in Ontario, Canada floats on a steel pontoon and is connected to land by short bridges. This type of development, either small residences or recreational fishing and hunting camps, could make sense in smaller canals and calm inlets of waterways.

Extending Over Water

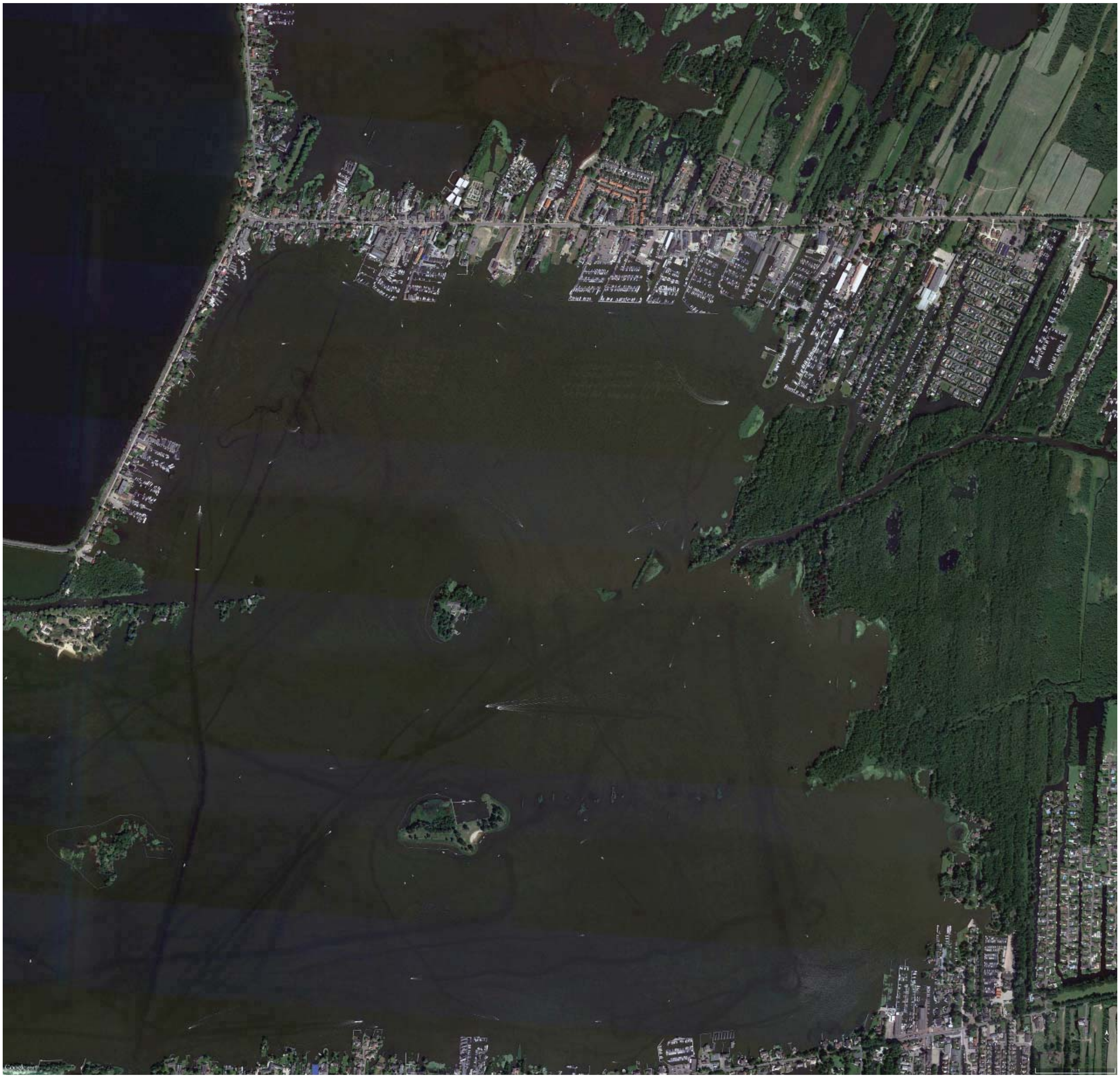
New cabins in Bayou Segnette State Park, on the west bank of Jefferson Parish, are attached to a column structure that enable the houses to rise and fall with changing canal levels. Connected to land by long docks, the cabins are fully on top of the water and feature shaded porches and decks. This local example could feasibly be replicated throughout the waterways of St. Bernard.

Neighborhoods on Water

A row of floating houses on a canal in the Netherlands form a unique aquatic neighborhood that also is close to existing buildings on land, with a path that provides access and visual connection. This could serve as a model for redevelopment of both conventional sites and on water in St. Bernard.

Vinkeeven, Netherlands

Residential development exists on narrow polders, small islands, and larger land bridges in Vinkeveen, Netherlands. This approach to excavation and land making balances earthwork cut and fill, and creates different types of spaces, views, and waterfront access.

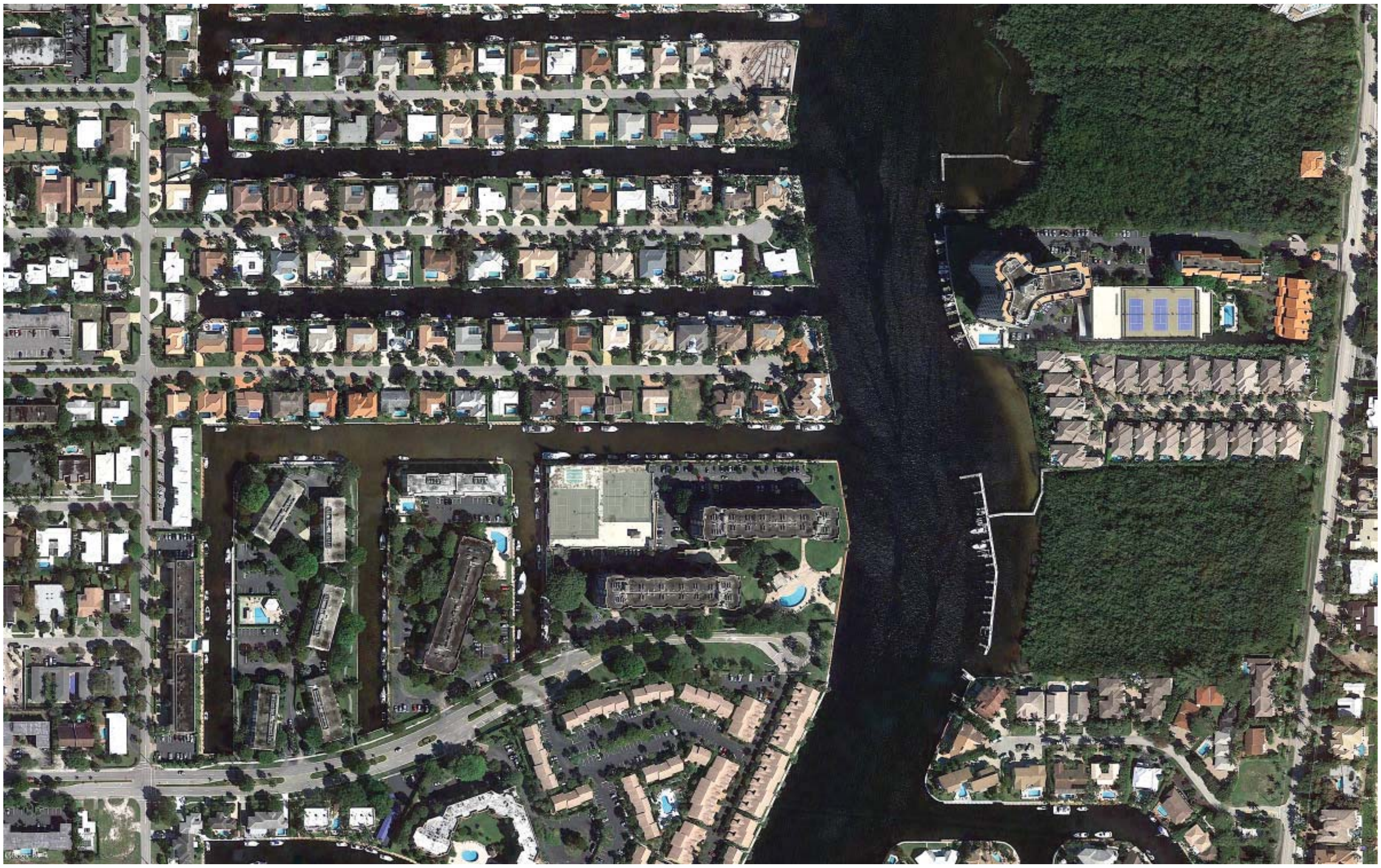


Loosdrecht, Netherlands

Above, thin strips of land with roadways extend out from the land and grow and expand on water. Different edge conditions create a range of ways to access the water, for boating, fishing, or swimming. Views across the water are to other neighborhoods and clusters of islands and undeveloped landscape. These contrast with hard edges and long, linear roadways, similar to the boundaries of the Central Wetlands Unit.

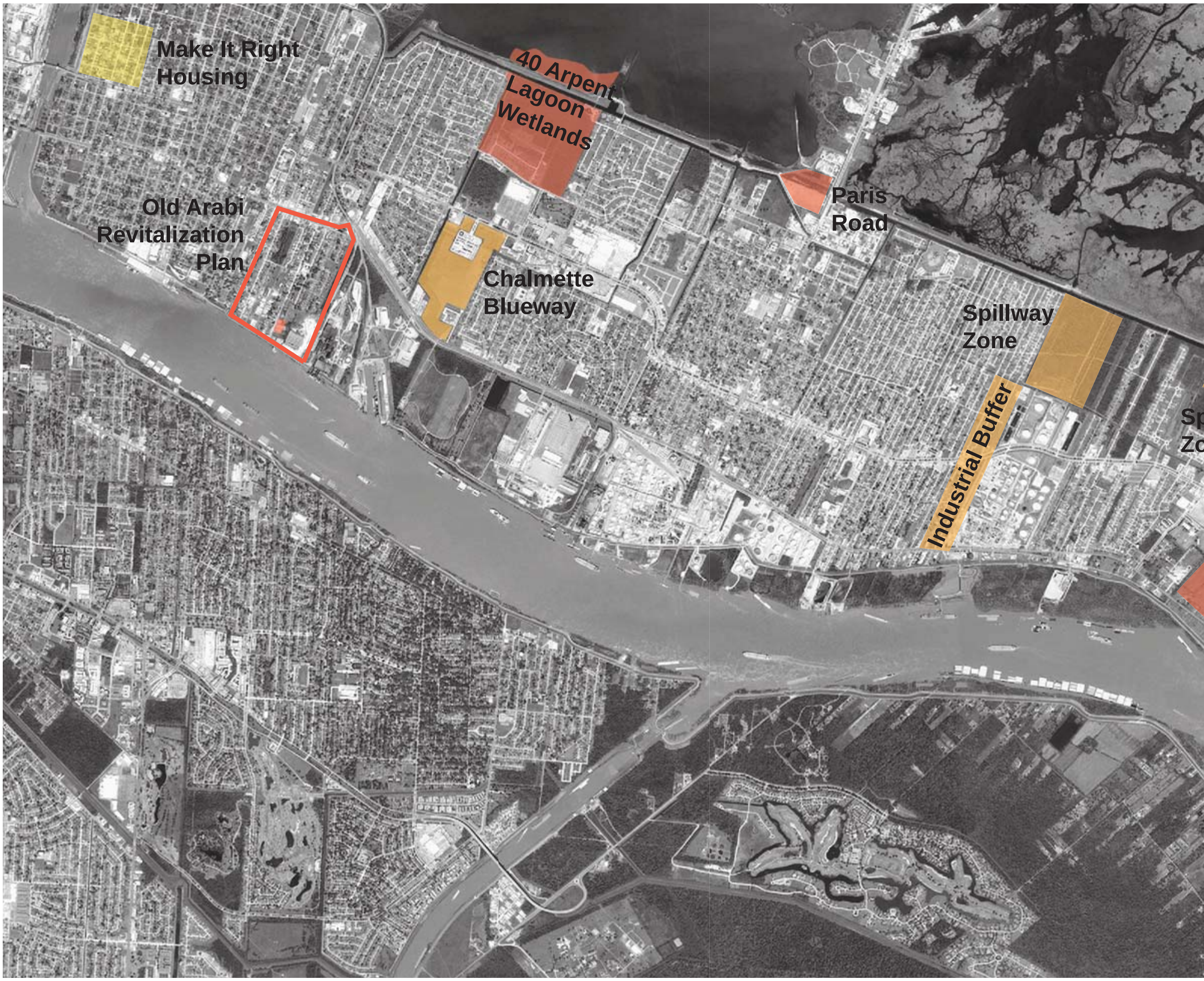
Shaoxing, China

Above, the urban character shows a range of residential and mixed use development at different scales, and bounded by waterways. Each area is defined by a canal, either used for circulation or as a scenic design element. The image at right shows how waterways are treated as alternative roadways, a different approach to planning that could also be replicated in St. Bernard.



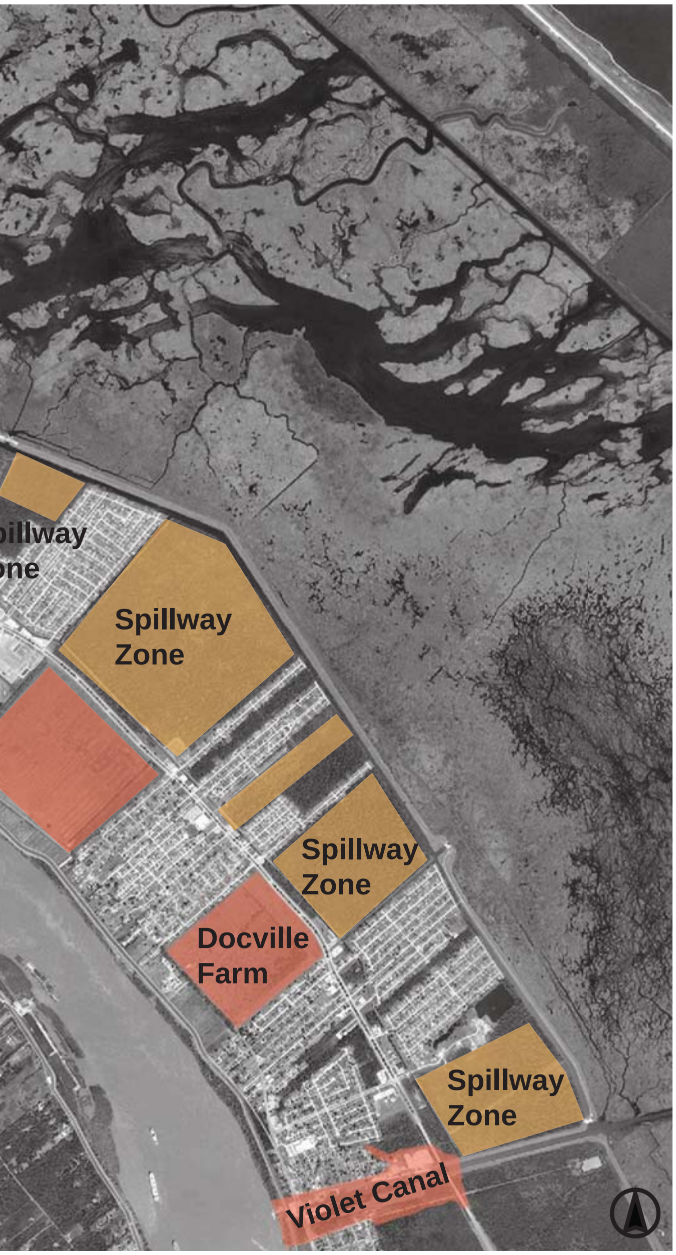
Boca Raton, Florida

Residential and mixed use development along the Intracoastal Waterway is similar to the 40 Arpent Canal. In the top image, neighborhoods are adjacent to different landscape types, where some areas are left open and green, but have direct access to the water for boating. Inlets of water between houses fit with St. Bernard's development pattern of neighborhood streets that are perpendicular to waterways. Another similarity is the relatively compact residential lot sizes with small, low buildings. This regional example, where single family houses are connected to both waterways and land, seems feasible as a strategy for St. Bernard.



Old Arabi Revitalization Plan

- Strong neighborhood that is seeing an influx of new residents, businesses, artist facilities, and community assets such as the Maumus Science Center and the Aycock Barn
- Well located on riverfront, with historic building stock as well as opportunities for new home construction
- Recent and continuing investments in streetscape improvements and water management features that will include bioswales and rain gardens
- Recent improvement in drinking water delivery pipes
- Potential for riverfront plaza at the old Ford plant



Opportunities Throughout the Parish

- Retrofits of existing yards, neutral grounds, and streets – house by house, block by block, and neighborhood by neighborhood – will have a substantial impact on stormwater, while also improving overall quality of life and property values
- A variety of implementation measures will be necessary – in some instances, for example, neighborhood associations will play an important role, whereas other retrofits will require buy-in from individual homeowners

Stormwater Spillway Zones

- Prime example of locations suitable for integrating new, water-based development with large-scale measures for improving parish-wide stormwater management
- Spillway benefits the parish by storing, infiltrating, and filtering massive volumes of stormwater
- When properly designed, can help parish retain the rural and water-based nature of the parish, which makes it an attractive alternative to more developed and urban areas
- Explore different funding, financing, and partnership opportunities for constructing large-scale mitigation measures, including wetlands mitigation banking and land trusts – important to link benefits for the community with benefits for the developer and property owner

Paris Road

- Critical entry and commercial corridor that connects the parish to the Central Wetlands Unit and to New Orleans East and the I-10 corridor
- Currently, Paris Rd. is unsightly and dangerous for pedestrians
- Large parking lots and areas of asphalt contribute to high volumes of runoff
- Located on high ground, which is the ideal location for implementing green infrastructure
- Investments in the very wide public right-of-way could integrate improvements for different modes of travel, public safety, stormwater management, and commercial development

40 Arpent Lagoon Wetlands Observation

- St. Bernard Parish is exploring the possibility of obtaining Hazard Mitigation Grant Program funding to construct this design, which expands the existing lagoon and boathouse to create an attractive wetland landscape that extends from Torres Park and the Civic Center all the way to the 40 Arpent Canal
- Bridge and boardwalks would provide access to the Central Wetlands Unit
- Expanded lagoon would enhance the storage capacity of the 40 Arpent Canal
- Proposed landscape (perhaps managed by Audubon Institute) would provide a landscape for recreation and education


JOHN McELROY
JASON STOPA

Parish Presentation
St. Bernard Planning Commission learning about the IWRM plan during its development in 2016.

8
IMPLEMENTATION

8a
CONTEXT, CHALLENGES, AND OPPORTUNITIES

Realizing Opportunities
The 40 Arpent Wetland Observatory creates direct access to the canal in Chalmette, with a dock surrounding a new lagoon that preserved a mature cypress tree, and a pedestrian bridge across the water.

Recent experience in New Orleans and other cities seeking to adapt to climate change and sea level rise shows that initial progress will likely take the form of a few small projects. Without dedicated and recurring sources of funding, these projects will likely rely on one-time sources of funding, such as hazard mitigation grant programs, urban waters grant programs, disaster recovery dollars, and revitalization and redevelopment grant grants. Provided by entities such as the Federal Emergency Management Agency, the Environmental Protection Agency, or the National Parks Association, these grants will be available for projects that meet specific criteria associated with risk reduction or water quality, for example. This means that projects that are designed to serve multiple needs and stakeholders will be more likely to obtain funding from multiple sources. Other important sources of funding include transportation planning and construction grants, since many proposed projects are in public rights of way, public access grants, and habitat restoration grants. There may also be funding to temporarily cover personnel and planning costs.

The parish will also need to rely on public-private partnerships, private investments, and foundation support, given the scarcity of public dollars. The Meraux Foundation is a good potential partner who has worked with the parish in the past. The Foundation has a deep interest in serving public good, long-term commitment, and also land ownership of some of the most important parcels touched upon by the proposals in this document. Through contributions of land and other resources, they have demonstrated their capacity and willingness to work with public agencies in the interest of improving quality of life, education, and opportunities for St. Bernard residents.

The parish and its partners can also look to the Greater New Orleans Foundation, Greater New Orleans, Inc., and the Greater New Orleans Water Collaborative for support. All of these entities are committed to the implementation of the Greater New Orleans Urban Water Plan, and advancing "living with water" throughout the region. They have worked as conveners, connected business and environmental interests, conducted research, organized outreach events, supported green infrastructure and education projects, connected leaders from the region with leaders in other cities, and otherwise played an important role in shaping civic activity, philanthropy, and action dedicated to improving urban water management. (See Section 9a to learn more about the Greater New Orleans Water Collaborative.)

The parish should also look to the corporations that have a home in St. Bernard and the region for their support. In the long run, the ability of these entities, be they sugar processing facilities, port service providers, or oil refineries,

Timeline and Regional Context

2013
Greater New Orleans Urban Water Plan

livingwithwater.com

pilot projects in Orleans, Jefferson, St. Bernard parishes

2015
IWRM Site Visits
Design Workshops
Cost Estimating
Modeling

2016
St. Bernard Integrated Water Resources Management Plan

Early Spring 2016
Public Meeting

Early 2017
Build Model

2014
Formation of Greater New Orleans Water Collaborative

nolawater.org

5 working groups and 200+ members

2015
St. Bernard Comprehensive Master Plan

norpc.org

2015
HUD's National Disaster Resilience Competition

nola.gov/resilience

$141 million award to New Orleans to establish a "resilience district"

2016
Old Arabi Revitalization Plan completed for Parish
sbpg.net/community-development

Neighborhood scale study of systems and long term vision

Green Workforce Development
Groundwork New Orleans created the Green Team, a program which trains young adults in green infrastructure work, from design to installation to maintenance, such as restoring vegetation in Bayou Bienvenue near the parish line. Source: Groundwork New Orleans

Blue-Green Economy
Design, construction, and operation of green infrastructure could create jobs and revenue to suppliers and manufacturers, with collaborative job training and placement programs for St. Bernard residents.
Source: Make It Right Foundation

will benefit from a parish that is safer and more resilient. These corporations will be able to contribute financial support for projects, in-kind donations in the form of materials or labor, technical expertise. Most importantly, these landowners are entities with the greatest resources in the parish and need to be at the table as decisions and investments are made so that they can contribute to the transformation of the parish.

Implementation efforts will need to address basic issues:

- A lack of funding due to a low population and reduced tax base. St. Bernard is a stressed environment, both ecologically and economically.
- Few cities in the U.S. have successfully created sustained sources of funding for green infrastructure. St. Bernard will need to look to places like the Netherlands, where revenues in parking fees in Amsterdam are dedicated to water infrastructure.
- For many residents, officials, and other stakeholders, it seems nearly impossible to fundamentally shift from a pumping-based water management regime to a storage-based regime.
- St. Bernard does not attract national and international interest the way New Orleans does, which means that it is harder for St. Bernard to attract funding from outside sources. This requires a greater degree of self-sufficiency and creativity, but may perhaps result in greater autonomy in shaping the future of the parish.

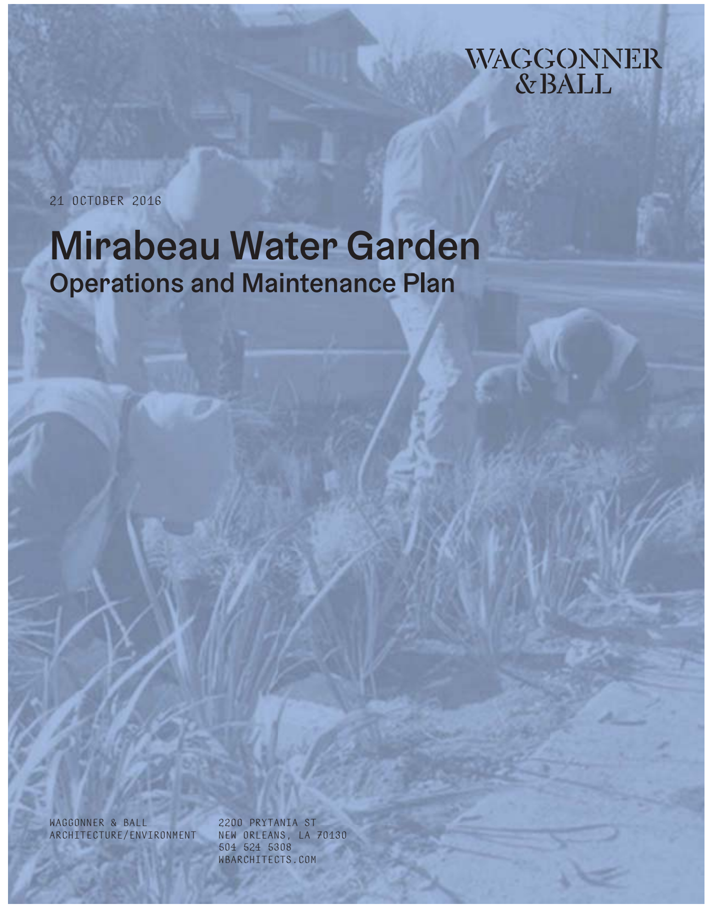
St. Bernard has the advantage of being smaller, with fewer layers of bureaucracy. This means that it is easier for government and institutions here to act more quickly than in New Orleans. St. Bernard has more land and open water resources than its neighbors, and also has less developed subsurface drainage networks. This will make implementation of the proposed measures easier.

OPERATIONS & MAINTENANCE

Developing new approaches to operations and maintenance is critical to the successful implementation of the proposed strategies and project, and must be addressed as part of the planning and design of each project. If project cannot be properly maintained with the resources that are available, the feature will degrade and lose effectiveness over time. This, in turn, could elevate flood risk and have other adverse consequences.
In thinking about operations and maintenance of water systems in St. Bernard, it is important to recognize that the parish population is still considerably lower than before Katrina, which means that the tax base that supports parish-wide infrastructure is limited. This suggests the need for low-maintenance strategies and projects and will likely affect how projects are prioritized. Planning and design should take the following into account:

- Will the proposed feature require direct human inputs in order to fulfill their function? For example, if there is an operable weir that is crucial to the performance of a retention basin
- What is the anticipated maintenance schedule?
- What are the particular skills and equipment that are required?
- What other uses/users are imagined for the proposed feature? Will this create an additional O&M burden and/or will these additional uses be a source of revenue with which to cover O&M costs?
- How might the proposed feature be adapted for changing conditions, as other proposed features and strategeis are implemented and as weather patterns change?

Currently, O&M for most infrastructure is focused on a narrow definition of efficiency, reducing complexity of actions and skills needed in order to reduce the amount of time that personnel need to spend in the field. For example, converting an open canal with earthen banks into a closed concrete box culvert is seen as an improvement, partly because the Lake Borgne Basin Levee District does not have to cut the grass that grows on either side of canals with earthen bank.



Manuals for Maintenance
Cover of a proposed operations and maintenance plan for the City of New Orleans to guide the continued upkeep of the Mirabeau Water Garden project

By W.S. Nelson & Co., Inc. — 1/26/2016

Hours - Half Time Worker - 1040 hours/year	Hourly Rate	Percentage of hours	Description	Cost per category	Materials - Yearly	Total Yearly O/M Cost
1040	$35	50	Landscaping (inc. mowing)	$18,200	$10,000	**$46,400**
		15	Weir Monitoring and Operation	$5,460		
		25	Sweep / Vacuum Pervious Pavement	$9,100		
		10	Miscellaneous	$3,640		
			TOTAL Worker Cost	**$36,400**		

Staffing O+M
The Parish would need to create a budget for new staff to maintain the IWRM projects; shown above is a potential annual cost of one worker dedicated to operations and maintenance, along with anticipated materials

Maintaining Living Systems
The IWRM proposed projects are inherently based on natural systems, and would require maintenance of dynamic elements, such as trees, wetland vegetation, and waterways

New Types of Maintenance Equipment
A shift in operations and maintenance would also require different types of equipment and vehicles, including a vacuum truck shown above that would clean pervious sidewalks and parking lots.

Workforce Skills
This new approach to operations and maintenance also means that a wide range of worker skills would be needed, including tree and plant care, inspection of architectural and engineering elements, and monitoring of groundwater wells

The integrated water management strategies that are proposed in this plan rely much more heavily on nature-based systems than existing systems do. This requires a new approach to O&M that begins with a broader definition of efficiency and efficacy, and with a greater appreciation of the many benefits and economic value that can be provided only through nature-based systems. Proper operation and maintenance of nature-based and integrated systems require:

- Designs that incorporate native plants, materials, and details that are suited for the soils, climate, budgets, and people of St. Bernard. Native plants, for example, should perform better and require less maintenance. And designs that are not only functional, but also beautiful in the eyes of residents will make it easier for residents to care for the features that are constructed.
- Public works employees and contractors with a broader range of expertise, including ecology, botany, chemistry, landscape architecture. Public employees will need additional training and new kinds of personnel will need to be hired. Maintenance of a rain garden, for example, requires knowing which plants to cultivate and which plants to pull out.
- A greater understanding of soil and water relationships, with extensive monitoring of water levels and water quality.
- Broad public understanding of the purpose and value of infrastructural systems. Residents, for example, who understand that green infrastructure reduces their own flood risk will be less likely to leave trash in rain gardens or other features where foreign objects can plug drains
- More real-time data people may need to be retrained – knowing what plants to keep and which ones to pull, for example – also understanding that maintenance and operations has to adapt with changing conditions

These changes in operations and maintenance pose some challenges and may lead to additional costs up front, during the early phases of implementation. They are, however, also an opportunity to diversify the work force by providing new kinds of job training and expanding the definition of what public works is, and also how public works employees serve the parish. In addition to operating pumps and cleaning pipes, they are restoring habitats, creating new recreational amenities, and enhancing the identity and ecology of parish.

8*b*
PRIORITIES AND PHASING

Local Green Infrastructure Pilot Project
The New Orleans Redevelopment Authority (NORA) implemented a rain garden in a flood prone neighborhood as an example of how to transform vacant lots into sustainable stormwater management.

Phase 1

The initial phase of implementation can be understood as the next three to five years. During this time, there would not be dedicated sources of funding, but there will be access to grants and other options.

If the recent efforts to implement "living with water" projects in New Orleans are any guide, it will take two to three years for different agencies and project partners to identify the funding sources and implementation strategies that will work for them. With the Urban Water Plan released in 2013, many projects are only now (2016) in planning and design phases, with a few slated for construction in the near term.

In those intervening years, entities such as the Sewerage & Water Board, Department of Public Works, and the New Orleans Redevelopment Authority have been able to access the funding necessary to implement new kinds of infrastructure. During this time, too, there has been a corresponding growth in awareness amongst the public and elected officials of the importance of integrated and sustainable water management, with contributions from outside such as the Rockefeller Foundation and the 100 Resilient Cities Program that have led to additional funding and broader awareness of water issues and resilience.

Phase 2

The second phase will likely still be piecemeal, and be 5 to 10 years out. This period should see the development of a variety of new mechanisms, partnerships, entities, and individuals specific to St. Bernard that are playing an active role in redefining what water management in St. Bernard will be like in the 21st century.

During this phase, diverse efforts may lead to projects and programs. Examples include, again in New Orleans, the Broadmoor Improvement Association building extensive rain gardens and water management features at the Keller Library as part of a broader program of rebuilding and revitalization, or the Pontilly neighborhood working with the New Orleans Redevelopment authority to obtain federal funding for a neighborhood green infrastructure network that will reduce flood risk.

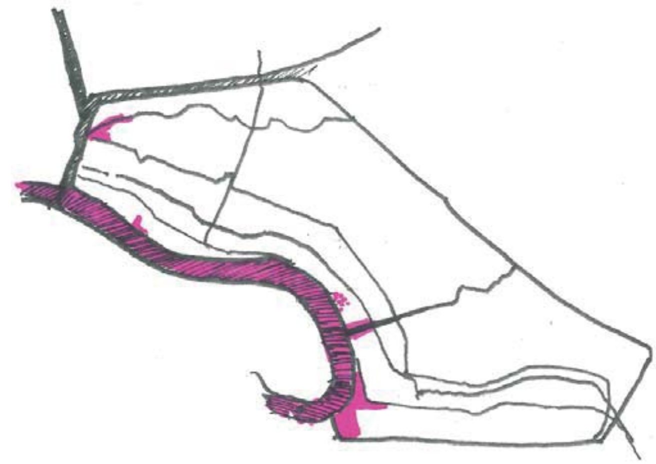
During this time, multiple champions for integrated urban water management strategies will need to arise, so that it is not only the Office of Community Development that is serving as a convener and advocate for Living with Water principles. Other public agencies will need to define their roles in relation to parish-wide changes. The Planning Commission may, for example, begin implementing land use and zoning measures that will increase stormwater retention on both public and private sites. These agencies, too, will need to identify recurring sources of funding, as bringing projects and strategies to scale will require a deeper shift in funding priorities and investment strategies that may not be feasible earlier on. Equally important are the development of efficient operations and maintenance regimes for the projects already constructed and those being constructed, in order to ensure the long-term functionality and quality of these projects.

Phase 3

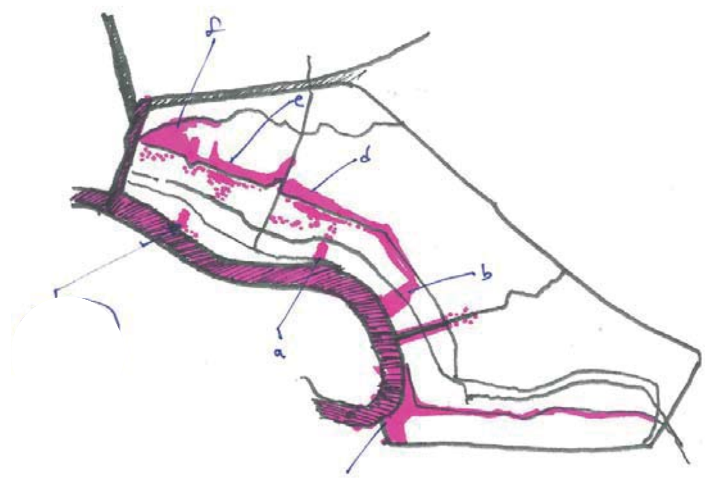
The third phase, 10 to 20 years out, should see St. Bernard becoming a regional partner to neighboring Orleans and Jefferson Parishes. By that time, St. Bernard agencies and institutions will have developed significant capacity, knowledge, and resources around the transformation of urban water management systems. Together, these parishes should work across political boundaries to address joint coastal and urban water management problems. St. Bernard should also be working at the systems level, implementing parish-wide programs for groundwater management, providing dry weather flow through the canal systems, comprehensive retrofitting of roadway networks to incorporate stormwater retention measures into public rights of way. At this point, the parish, residents, and local businesses will be able to take advantage – culturally, politically, and economically – of an identity that is clearly rooted in the delta and local water resources.

All three phases will require a an increasing level of public engagement and education (see Chapter 7) Without buy-in from the broader public, there will not be the buy-in to fund a paradigm shift in infrastructure and water management. The local media will play an important role in drawing attention to water management as a key issue with potential to improve many lives through public spending, stability of infrastructure, homeowner costs due to flooding and subsidence, quality of life, amenities, and air and water quality.

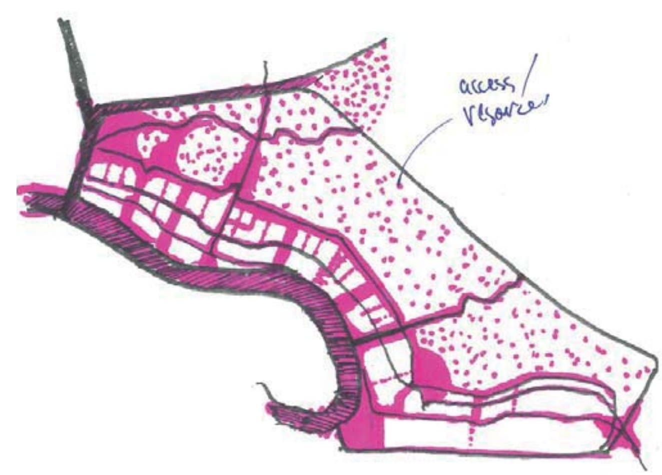
These efforts will also need to provide co-benefits, such as through job creation and entrepreneurship. The Working on Water series put on by Nunez Community College and the Meraux Foundation is a step in that direction, and a number of regional partners such as Propeller and Great New Orleans, Inc. will play a role in ensuring that "living with water" also means more economic opportunity and a diversified economy, with St. Bernard, New Orleans, and the rest of the region becoming known around the world as a hub for water management, education, and entrepreneurship.



Phase 1
Existing



Phase 2
Pilot Projects



Phase 3
Overall framework

Full implementation of the IWRM plan will not be possible without significant changes in policy, planning, and governance. Outlined here are policy principles and recommendations that will support the kinds of changes in capital projects and operations that are necessary to truly integrate water systems.

8C POLICY PRINCIPLES AND RECOMMENDATIONS

Every property owner bears responsibility for runoff and impact on public infrastructure.

- Such a principle would be the basis for instituting drainage fees, penalties, and incentives, all of which are necessary tools for system-wide water management.
- The parish will need to provide significant technical support to stakeholders to support such a policy.
- Adapt existing zoning designations to encourage and enable sustainable waterfront development, water-based commerce and industry, and increase access and investments in local waterways, waterfronts, and wetlands.

Integrate coastal and urban water management so that risk and investments in infrastructure are addressed comprehensively.

- The Lake Borgne Basin Levee District is already responsible for both urban waterways and managing coastal protection systems, but urban and coastal systems are not commonly understood as being related.
- Institute periodic review of water planning, action, and evaluation as well as rewriting of Integrated Water Resources Management Plan in parallel with the 5-year Coastal Master Plan Cycle: 2017/2022/2027.

Incorporate sustainable water management into planning for all public works and recreation projects, including streets, parks, and government buildings.

- Provide technical support and dedicated resources
- The parish will need to develop technical capacity and dedicated resources, especially in the form of new staff with the expertise to implement new kinds of projects.

Cooperation with regional partners and Orleans Parish in particular.

- Projects such as restoring the hydrological connection to the Lower Ninth Ward and the Wetlands Assimilation project are not possible without cooperation.

Establish jurisdiction and accountability in relation to groundwater.

- There is currently no entity responsible for groundwater.
- A partnership with a research institution can support the data collection necessary to support groundwater management.

Establish data collection and coordination in regards to industrial facilities and groundwater extraction.

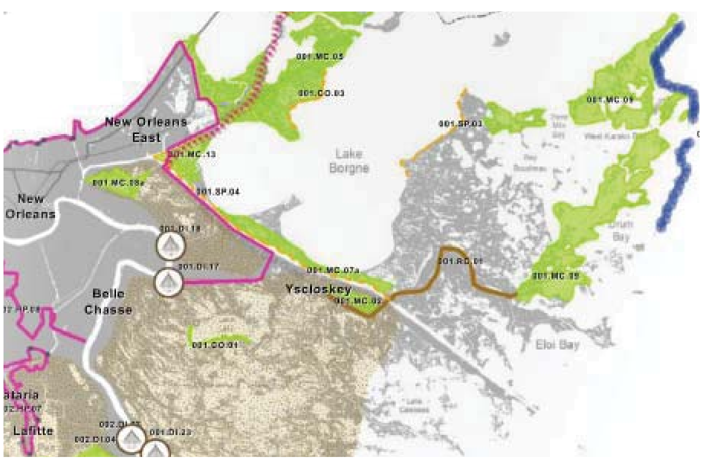
Incorporate "water literacy" into school curriculum and activities.

- See Section 9b for overview of water literacy

Incorporate water management goals and objectives into parish-wide communications and reporting.

8*d*

RELATIONSHIP BETWEEN URBAN AND COASTAL PROJECTS



Master Plan for St. Bernard's Coast
The 2012 Louisiana Coastal Master Plan shows existing and proposed projects for St. Bernard, including structural protection, ridge restoration, shoreline protection, marsh creation, oyster barrier reefs, sediment diversion, and hydrologic restoration.
Source: Louisiana Coastal Protection and Restoration Authority

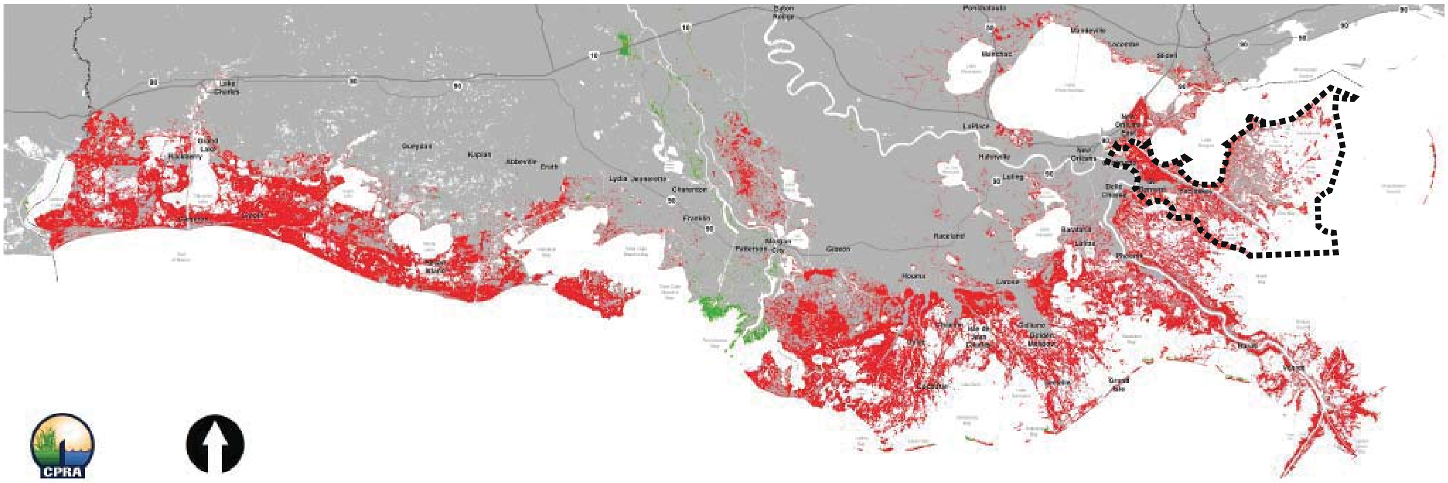
EXISTING COASTAL EFFORTS

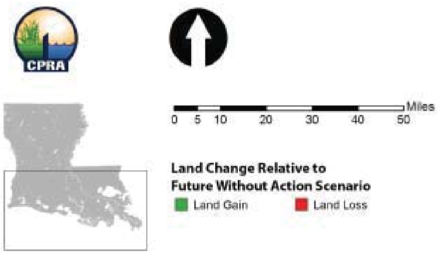
While this document focuses on the urbanized areas of St. Bernard, it is equally important to coordinate planning and management of those systems with the coastal restoration efforts that are taking place throughout the region and southeast Louisiana. Global conditions such as sea level rise and climate change have a direct impact on urban systems as they do on coastal wetlands, barrier islands, and shorelines.

The health of the coast is inextricable from the resilience and health of urbanized areas and urban systems. Coastal wetlands loss was one of the contributing factors that worsened the impact of Hurricane Katrina. Without healthy swaths of wetlands between the Gulf and perimeter protection system, New Orleans, St. Bernard, and Jefferson Parish are all at greater risk. Maintaining levees and operating pumps stations will cost more, and rising seas will require costly lifts and may also contaminate freshwater aquifers and undermine structures as salt water pushes beneath the levees below ground. This plan and the Greater New Orleans Urban Water Plan both build on the "Multiple Lines of Defense" approach to managing risk in coastal Louisiana that the Lake Pontchartrain Basin Foundation has developed, and that is codified in the State of Louisiana's Coastal Master Plan. A community that is protected by multiple lines of defense counts on reducing risk and vulnerability by ensuring that flood protection is multi-layered. Barrier islands, marshes, swamps, land bridges, and other coastal features all help to take energy away from storm surge, even before that surge reaches levees, floodwalls, and floodgates. At the same time, elevating and adapting buildings reduces risk in case of overtopping or levee failure, while evacuation routes can also help to reduce loss of life.

The MLOD approach is inherently an integrated approach to infrastructure planning and risk reduction. The projects and strategies proposed in this document insert urban water management as an additional line of defense and flood risk reduction measure. By making the landscape and urban systems more robust, capable of handling more intense rainfall while reducing rates of subsidence and improving water quality, these proposals are essential to a comprehensive approach to risk reduction – levees and floodwalls may stop storm surge, but rainfall alone can be a cause of both chronic and acute flooding.

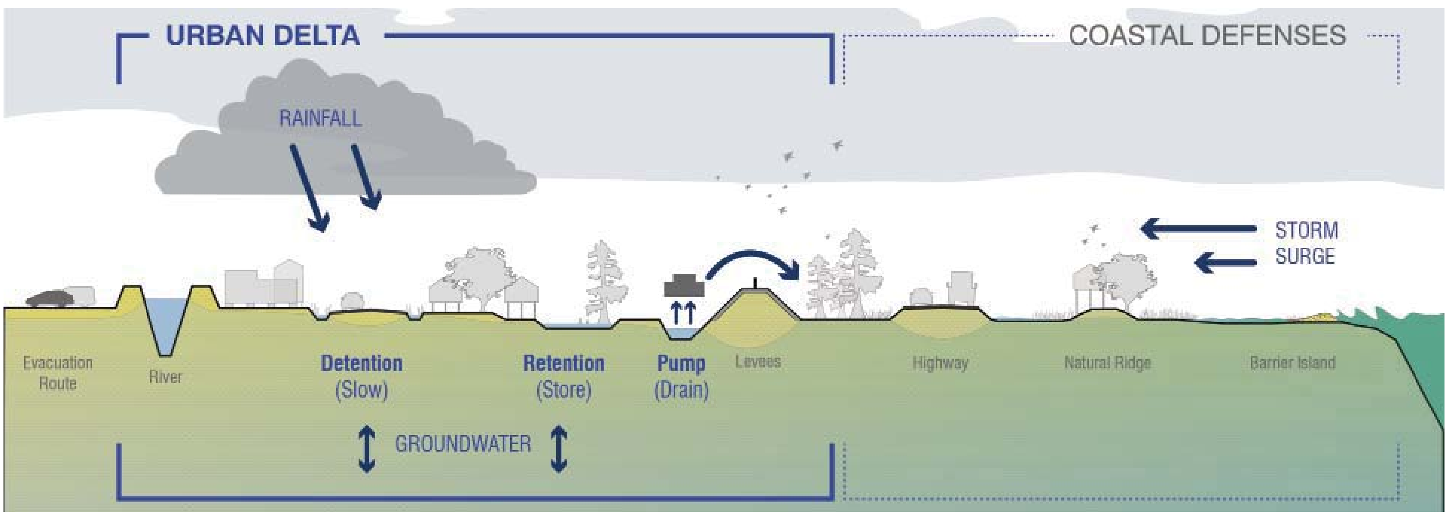
The aforementioned Bayou Bienvenue Central Wetlands Assimilation Project is an example of how integrated planning can benefit coastal and urban water management efforts.



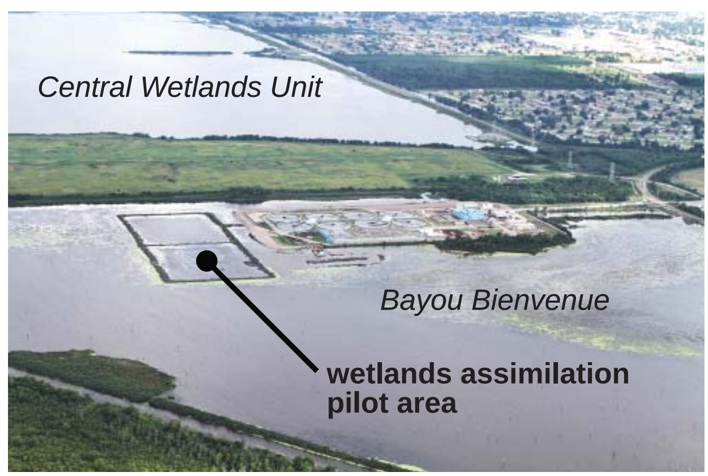


Adapting To A Changing Coast
Louisiana Coastal Protection and Restoration Authority's (CPRA) map of projected coastal land loss in red if no future action is taken. St. Bernard Parish could lose a significant area of its coastal wetlands, which act as a natural buffer to storm surge

Below: Multiple Lines of Defense concept shows how urban deltas like Greater New Orleans can develop layers of protection against coastal storm surge and heavy rainfall.



Growing and Nourishing Land
Middle: The Living Shoreline proposal from the NDRC New Orleans submission shows new habitat areas along Lake Pontchartrain's shore. Above: The Caernarvon freshwater diversion structure carries sediments from the Mississippi River to restore St. Bernard's coastal wetlands.
Image source: US Army Corps of Engineers



Regrowing Cypress Swamps
The New Orleans sewage treatment plant in the Lower Ninth Ward releases treated sewage as a source of freshwater and nutrients to rebuild the degraded wetlands in Bayou Bienvenue.
Image courtesy of Jonathan Henderson

"Coupled with the extensive need to protect our coast, infrastructure, economy, cultural heritage, and property is a need to fund the projects.... St. Bernard has a unique and unprecedented opportunity to leverage funding from different sources...to maximize benefits and long term positive returns."

- St. Bernard Parish Priority Coastal Projects: July 2016 Update

Learning from the Landscape
As an alternative to more costly, engineered armoring strategies, a proposed shoreline protection project includes planting black mangrove trees, shown above on Gardner Island in St. Bernard Parish.
Image source: *St. Bernard Parish Priority Coastal Projects*

PRIORITY COASTAL PROJECTS

In the summer of 2016 the Parish government released *St. Bernard Parish Priority Coastal Projects: July 2016 Update* to serve as a preliminary feasibility analysis for existing coastal efforts. The goal of the document is to clearly define the purpose, benefits, location, construction methodology, and cost for each project, some of which were already in design or permitting phases. New proposals are also included. At the local level, this guide aims to strategically advance projects to be nominated or submitted to a wide range of funding sources.

Initially, the list of projects was drawn from the existing St. Bernard Coastal Zone Advisory Committee (CZAC), whose objectives are to:

- Maximize funding from multiple sources in order to leverage resources to the greatest extent possible
- Proceed through the planning and approval process as expeditiously as possible in order to implement projects quickly
- Continue to monitor State objectives regarding large sediment diversion projects affecting St. Bernard

The process reviewed existing plans from public and private entities, further developed project scopes and work plans, and considered potential funding strategies. Then the CZAC priority projects list was updated and adjusted. The final list divides proposed work into three tiers based on scale, cost, and effort.

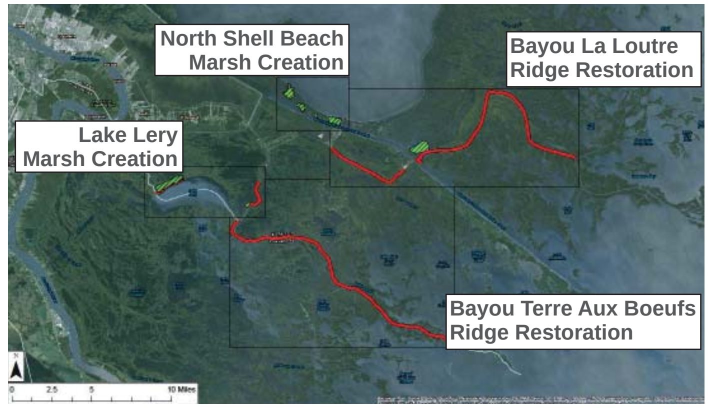
Tier 1 consists of primarily large scale projects that would require a significant federal or state contribution with the greatest net benefit to coastal restoration and protection efforts. Goals of land creation and nourishment would protect adjacent levee systems and communities from storm surge, saltwater intrusion, and associated land loss.

Tier 2 includes mid sized projects with varying scopes, and likely different funding sources and strategies, than Tier 1 projects. Tier 2 efforts provide a local level of protection and restoration, along with layered community benefits.

Tier 3 projects are smaller scale, which could be achieved through partnerships, volunteering, and philanthropy, likely requiring minimal state or federal investment.

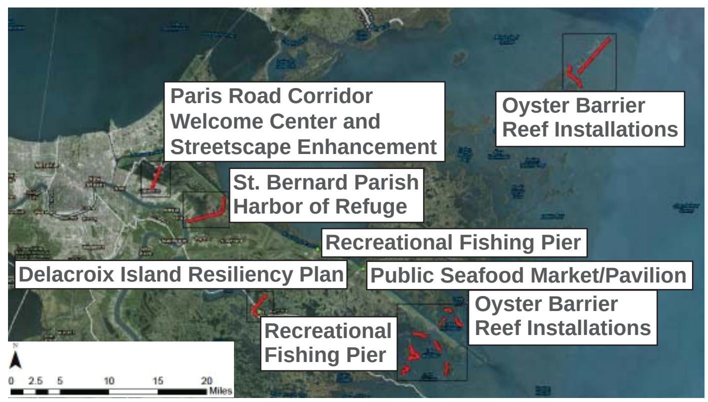
Tier 1 Projects

- **North Shell Beach Marsh Creation**
  Create and nourish 544 acres of marsh with dredged sediment from local sources
- **Bayou La Loutre Ridge Restoration**
  Build up ridges in shallow water with gradual slopes and new vegetation, divided into three phases
- **Lake Lery Rim Restoration and Marsh Creation**
  Pump dredged material into marsh creation cells along the lake shoreline, divided into two phases
- **Bayou Terre Aux Bouefs Ridge Restoration**
  This two phase project would be similar to the proposal for Bayou La Loutre, described above



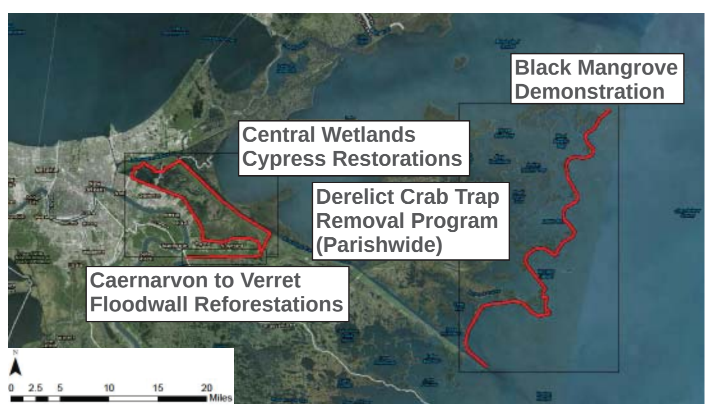
Tier 2 Projects

- **Delacroix Island Resiliency Plan**
  Raise portions of existing highway, create a new recreational fishing pier and a public seafood market
- **Oyster Barrier Reef Installations**
  In accordance with the 2012 CPRA Master Plan, construct new oyster reefs to help reduce shoreline loss
- **St. Bernard Parish Harbor of Refuge**
  Remove sunken debris from the Violet Canal
- **Recreational Fishing Piers and Public Seafood Market / Pavilion**
  Build a new recreational fishing pier and a seafood market to bring tourism to the edge of the parish
- **Paris Road Corridor Welcome Center and Streetscape Enhancement**
  Construct a new welcome center building and improve streetscape to create a gateway into St. Bernard



Tier 3 Projects

- **Central Wetlands Cypress Reforestation**
  Plant over 50 acres of new cypress trees near existing pump stations where water and soil salinity is fresher (in conjunction with Riverbend Oxidation Pond)
- **Caernarvon to Verret Floodwall Reforestation**
  Plant new cypress trees near existing floodwall where water and soil salinity is fresher
- **Black Mangrove Demonstration**
  Plant new black mangrove trees as a more affordable solution to protect Biloxi Marsh shoreline
- **Derelict Crab Trap Removal Program**
  Locate and remove abandoned crab traps, which threaten several species of local fish



Cry You One
Image of performers from the 2013 *Cry You One* production, which took theatrical and musical performers and audience members on a journey alongside the 40 Arpent Canal and Central Wetlands Unit.
Image courtesy of Melisa Cardona.

9
COMMUNITY ENGAGEMENT AND EDUCATION

9a
COMMUNITY ENGAGEMENT PROGRAM

***Cry You One* Performance and Storytelling Platform**
In 2013 *Cry You One*, a series of outdoor performances accompanied by an online storytelling platform about Louisiana's disappearing wetlands, premiered in lower St. Bernard Parish to much acclaim.
Above: The cast and audience march on top of a levee
Previous spread: Cast posing on boats in the wetlands

A shift towards integrated water resources management at a parish-wide level requires more than just buy in from policy makers, planners, and public works employees. As described in the previous chapter, full implementation of the strategies and projects proposed in this document will require a combination of capital projects and changes in policy, planning, infrastructure design, funding structures, and operational regimes. And none of these changes will be possible without a broader shift in mindset towards "living with water."

While this may seem unnecessary in a parish that is surrounded by water, it is important to recognize that the degree to which water has been removed from the urban landscape. Where bayous once flowed through marshes and swamps, there are now subdivisions, asphalt roadways, and concrete parking lots. Development efforts and modern drainage improvements have continually channelized or buried waterways, lowered the water table, and fundamentally altered the hydrology of the parish. The parish's water resources are, to the detriment of the parish, out of sight and out of mind.

Living with water does not mean returning urbanized land to swamp. But it does mean embracing water as the life force of the delta and as something that is central to the identity of the community. And with climate change and sea level rise already beginning to have an impact on weather patterns and local environmental conditions, bringing water to the fore and understanding and reimagining the relationship between humans and local waters is important.

Deep Engagement

Engagement must go beyond simply building awareness. Traditional community engagement methods used by planning practices are not adequate. Systemic change and true integration of different water systems will require deep, creative, and sustained engagement. Deep engagement means reconnecting people to the landscape, building shared vocabulary, fostering water literacy (see next section), and building a sense of ownership and investment in the condition of local water resources. Creative engagement means finding non-traditional partners and non-traditional means for engaging citizens in learning about and acting upon local water issues. Sustained engagement means providing dedicated resources and making extended and recurring investments in providing the time, resources, and support necessary to engage citizens in learning about water systems and the role they play in shaping those systems as users, residents, and members of a ecological whole.

Deep, creative engagement also means connecting with the knowledge of land and water that exists in the community and with the many people who have deep roots in cultures, mindsets, and ways of living that centered on local waters. These are people who can describe what it was like when the Central Wetlands Unit was a thriving swamp full of flora and fauna that could sustain families and livelihoods. These are people whose families make their living in the Gulf of Mexico and the estuaries at the edge of the Gulf. Highlighting and celebrating their knowledge and those ways of living will strengthen the identity of the parish, and also ensure that a stronger relationship to water in the future will be rooted in the parish's past.

Place-based Engagement

Efforts to foster community participation in planning and design processes and to effect a shift towards living with water should make the most of the parish's location. Situated between river and wetlands, and at the juncture of land and water, the parish is replete with places that can be the basis for different forms of learning, sharing, and outreach. Conducting outreach activities on site – for example, introducing residents and visitors to canals and pump stations by visiting them, holding civic events next to the 40 Arpent Canal, or providing school groups access to the Central Wetlands Unit – will yield a greater impact in the long term than traditional outreach efforts. connect people to places, infrastructure systems, and natural forces in ways that are only possible through inhabiting those places and directly engaging those systems. Those connections are critical as citizens and their representatives make decisions in the coming decades about how water systems will function, and how their investments in infrastructure can begin to benefit residents and the environment in many ways.

Precedent

The Greater New Orleans Water Collaborative (*nolawater.org*) has emerged as an umbrella organization that partners with member organizations, individuals, and public agencies in drawing attention to urban and coastal issues. Member organizations include environmental nonprofits, foundations, community advocates, place-based organizations, and businesses that are engaged in water management, planning, and design. The collaborative is organized into five distinct working groups (community education, K-12 education, builders and designers, research and policy, and advocacy), and different forms of community engagement have been vital to its success.

The collaborative's community education group organizes "Walk and Learns," during which experts and public agencies lead tours of infrastructure sites, projects, and other places of interest. The collaborative also organizes "Waterfront," which is a month-long series of events that include kayak tours, walking tours of water treatment plants, water testing demonstrations, social events, peer-to-peer learning events, and a whole host of activities that are open to the public and that broaden the community of people and organizations engaged in improving the sustainability and resilience of urban water systems.

At the moment, Water Collaborative activities have been hosted mainly in Orleans Parish, though it is a regional organization. Though the collaborative has organized events in Jefferson and St. Bernard Parishes, it seeks to strengthen its membership and programming in both parishes. The Water Collaborative can be a vital partner in developing and implementing community engagement programs in St. Bernard.

Family Fun with Water
Ripple Effect's Bayou Day 2016, along Bayou St. John in New Orleans, engaged children and their parents in educational activities about water systems that were also fun for the entire family, such as skimming the bayou banks to examine aquatic life.

Public Updates on Progress
The Water Collaborative's "Opportunities in St. Bernard" workshop in the summer of 2016 featured presentations from local leaders on current efforts in St. Bernard, both along the coast and inside the levees, as well as Orleans Parish.

9*b*
WATER LITERACY

Water Literacy for All Ages
A canoe tour of Bayou St. John during Ripple Effect's Bayou Day 2016 engaged children and adults in educational activities about water systems

During the development of the Greater New Orleans Urban Water Plan between 2011 and 2013, "water literacy" arose as an important concept. In organizing outreach efforts across the three parish project area (Jefferson, Orleans, and St. Bernard), the Urban Water Plan design team (led by Waggonner & Ball) came to understand that there was not broad understanding amongst the general populace of the basics of local soils, hydrology, and water infrastructure, and the systems that are in place to support continued inhabitation of the delta. There was not broad understanding of the relationship between different systems, or the ways in which regional approaches to managing flooding have also caused subsidence and made communities more vulnerable in the long run.

The design team sketched out an idea of what "water literacy" could mean, and emphasized that a real paradigm shift in the relationship between humans and water resources would require a corresponding shift in knowledge and expectations amongst the citizenry. Such a shift would need to begin with the region's youngest citizens, and extend deep into their learning. Water literacy would be as fundamental as verbal or numerical literacy, because living in the delta and confronting the environmental challenges of the 21st century requires entire communities to take part, and not merely the engineers, designers, and planners. The investments that have already been made – $14 billion since 2005 for the Hurricane and Storm Damage Risk Reduction System alone – and the additional billions that are being invested and will continue to be invested in coastal restoration projects, urban drainage improvements, pipe network repairs, canal maintenance, and basic pump and treatment plant operations require the buy-in and support of a water literate and engaged citizenry.

Water literacy cuts across multiple subjects, and can enrich curriculum at every level, while grounding educational objectives with a deeper relationship to place. It means an understanding of environmental history, geology, geography, hydrology, physics, chemistry, and infrastructural systems that supports environmental stewardship and active participation in the design and operation of water systems. It also means understanding how science and engineering intersect with design, policy, civics, and ethical deliberation. By bringing these topics into the classroom, students are preparing to become leaders who can shape the environment around them in positive ways. They are preparing to become lifelong environmental stewards who work as engineers and environmentalists, policy makers and community advocates, and as planners and designers.

Since 2014, Ripple Effect has taken a lead role in defining water literacy and working with teachers, school communities, and other stakeholders in developing

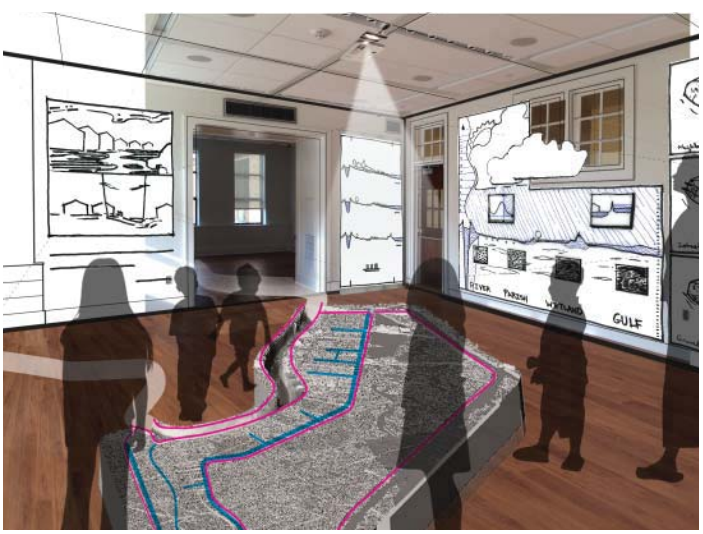
Ripple Effect: Teaching Students how to Live with Water
Guided by teachers, students participate in an activity to understand the rain gardens in Ripple Effect's water literacy campus project, in the previously underused courtyard of a public school in New Orleans

approaches to fostering water literacy that are based in the classroom. Funded initially by the Sewerage & Water Board of New Orleans, and currently by the SWBNO as well as the federal Environmental Protection Agency, Ripple Effect has developed a model in which teachers, water experts, and design educators work together to plan, test, and advance new strategies for fostering water literacy and environmental stewardship through the creation of standards-aligned curriculum and in-school instruction. Each year, Ripple Effect works with a cohort of teachers, and provides approximately 100 hours of professional development through workshops and field trips.

At KIPP Central City Primary, where Ripple Effect was piloted, the effort has already resulted in visible changes in the school environment, where the school community came together to address persistent flooding in the schoolyard and worked together with the Ripple Effect team to transform the courtyard into a "water literacy campus." This environment features two large rain gardens that capture the first half inch of runoff from the surrounding surfaces, and a mix of grasses, rushes, irises, and bald cypresses help to absorb and filter that runoff.

Water literacy is a critical component of the City of New Orleans's resilience strategy, where "Create a culture of environmental awareness at every stage of life" and "develop knowledge and capacity of emerging environmental stewards" is identified as a key action and directive. Fostering stewardship and embedding water literacy and environmental education has become increasingly important in an era of climate change and sea level rise, not just for New Orleans and St. Bernard, but for the many coastal communities and places that are at risk around the world.

9C
ENGAGEMENT AND EDUCATION TOOLS



Interactive Model Space
A dedicated room in a public institution like the Maumus Center would showcase the large model along with supplemental information on the walls to describe the environment of St. Bernard Parish

Publicly accessible facilities and tools will be invaluable to water literacy efforts and community engagement programs. These facilities and tools will need to be available to public officials, institutions, and nonprofits that are seeking to convey critical information and to engage citizens. They will also need to create new ways in which citizens with different interests can engage that information and apply it to any number of yet unforeseen uses in ways that are meaningful to their everyday lives, their teaching, their learning, or their research.

Maumus Science Center

The Maumus Science Center in Old Arabi provides learning spaces and environments that are focused on the environment. These include rain gardens that collect stormwater, rooms dedicated to different aspects of the delta, and a planetarium where visitors can be visually immersed in different environments and natural processes that would otherwise be difficult to access. For example, teachers can take students on an aerial tour of the delta to look for indicators of a changing landscape. While no substitute for a boat tour or actual flyover, the planetarium and other available technologies should be used as much as possible to facilitate learning and outreach when on site activities are not immediately feasible.

Other tools that are available, in development, or that should be considered include interactive models as well as water playgrounds and parks.

Interactive Models

The Meraux Foundation constructed a sand model that is connected to a computer and projector that allows users to quickly manipulate the topography of a landscape and to visually simulate flows of water and other forces on that landscape. This technology is portable, and can be used in different locations and settings for users to learn about hydrology through hands on experimentation.

As part of the IWRM effort, the planning and design team has developed a large topographical model to be housed at the Maumus Science Center or another public facility. Alongside exhibits that examine the parish's Katrina experience, the plight of the coastal wetlands, and a variety of features associated with a planetarium, the proposed model would be the central element in a space dedicated to learning about water management.

The model is designed as a large feature that a group of students and teachers can gather around, with exaggerated topography so that users can easily recognize areas of high ground and low ground. Levees are clearly demarcated, and key locations throughout the parish are marked so users can orient themselves. The canal network is carved into the model, and pump stations are marked as well. The model is a base, designed to serve a range of different purposes:

- As a topographical model that students can touch and walk around, immediately allowing them to perceive the landscape they know from a new perspective
- As a base for projecting different data layers, such as the drainage system or projected flooding from a 1 or 10 year storm
- As a base upon which students can apply additional materials and reshape the landscape through the lens of land cover, land use, housing density, or drainage infrastructure, for example
- As a base upon which a wide range of users can use open source platforms to conduct research, visualize real-time monitoring of water or weather, develop plans and designs for different neighborhoods, test scenarios, illustrate history lessons, or otherwise project data sets onto the model, with geography as the common thread. This could be in partnership with local and regional partners like Nunez Community College, Public Lab, and the Meraux Foundation.

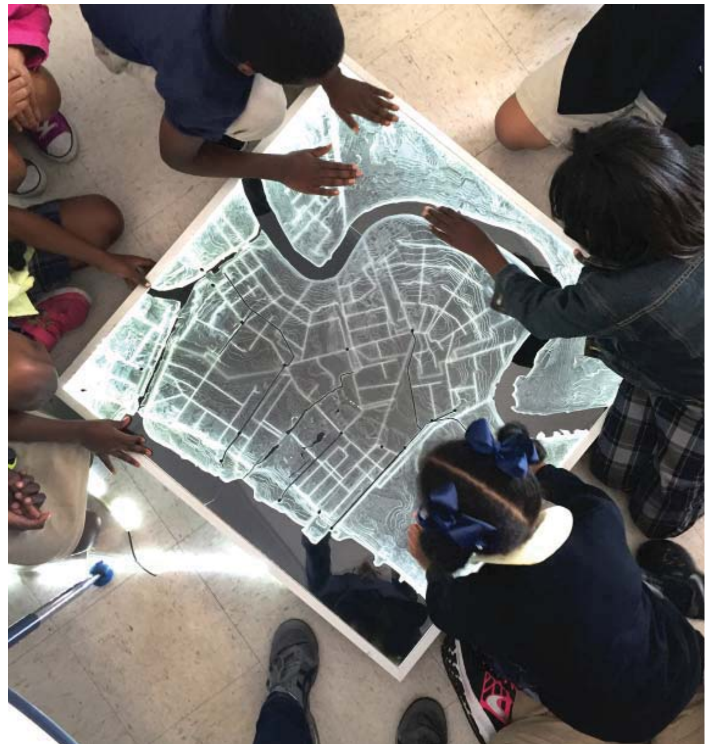
This model would be the first of its kind in the region, and would demonstrate what might be possible in settings as varied as a science museum, K-12 classroom, Department of Public Works, or Children's Museum. With this model, the planning and design team seeks to encourage an open-source example of how people can access and use information about local water systems, rather than relying on expensive and inflexible proprietary projection packages that may limit possibilities for engagement and expression.

Water Playgrounds and Parks

Common in the Netherlands and in some other countries, water-focused play environments provide kids access to structures and mechanisms with which they can explore how water flows and interacts with soils, and how they can manipulate those flows and interactions. This kind of hands on, play-based learning is an important complement to classroom-based water literacy efforts, and increases the range of opportunities available to families and communities to engage water issues.

Precedent

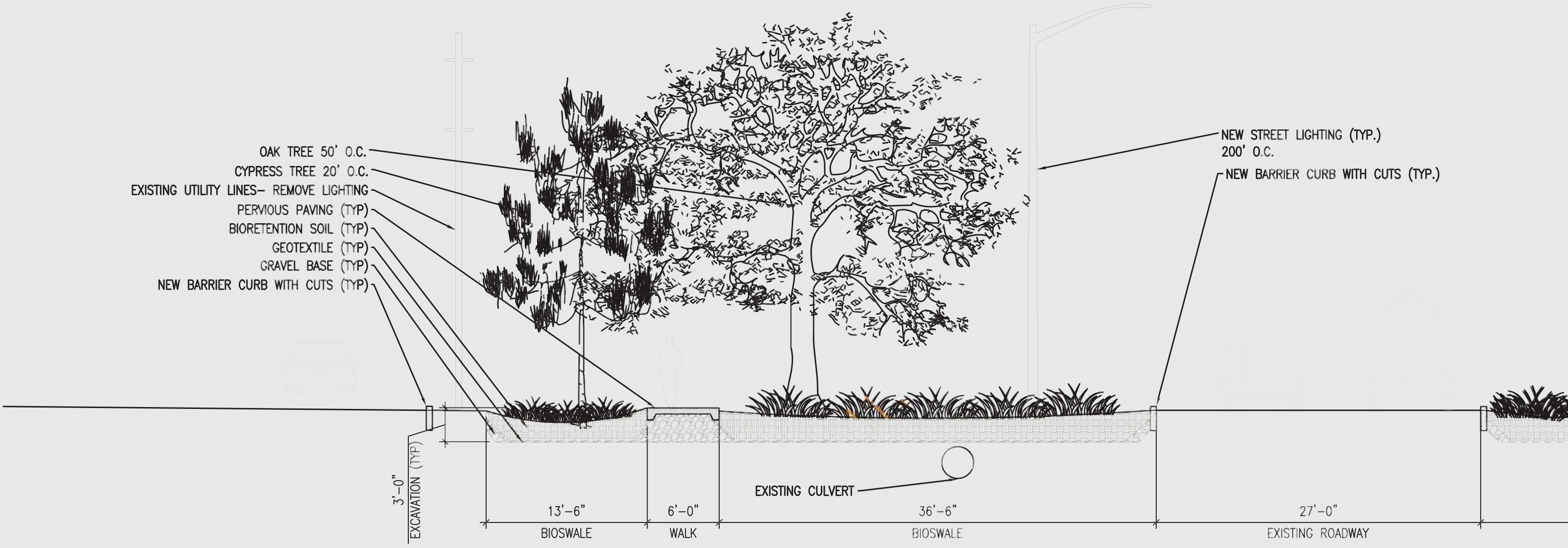
The City of New Orleans is developing the Mirabeau Water Garden, a 25 acre site in the Gentilly neighborhood, as an innovative stormwater management infrastructure that stores and filters stormwater while also serving as an environmental education center. The design of the site will facilitate learning, with pathways, viewing platforms, and other structures to convey key design principles and natural processes. At the same time, the City will work with program partners to ensure that the garden serves stakeholders and residents throughout the community, especially those who live in the surrounding neighborhood.



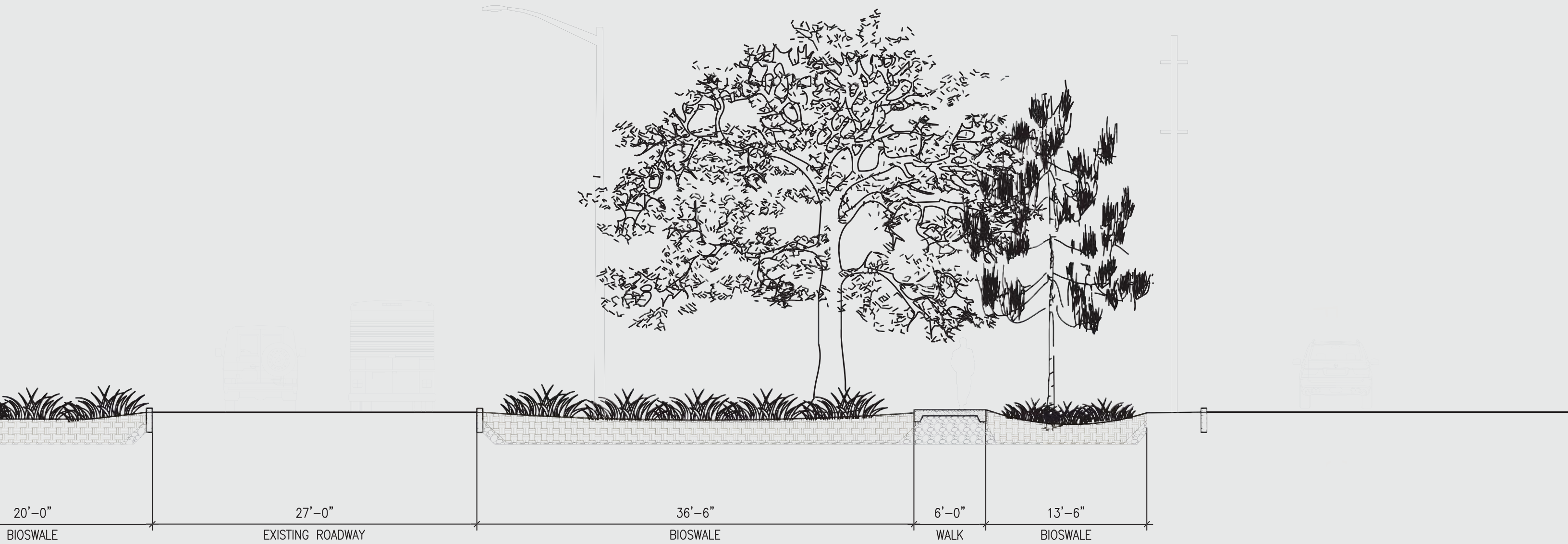
Interacting with a Model
Ripple Effect students learn about water systems in New Orleans through a large physical model that shows the network of canals, pump stations, and waterways throughout the city

Living and Playing with Water
Children in the Netherlands play with small weir structures in a miniature channel, directly learning about how water flow changes work

Neighborhood and City Scale Engagement and Education
The Mirabeau Water Garden, currently in design, will be a 25 acre stormwater park and environmental educational center for the residents of Gentilly and greater New Orleans



OAK TREE 50' O.C.
CYPRESS TREE 20' O.C.
EXISTING UTILITY LINES- REMOVE LIGHTING
PERVIOUS PAVING (TYP)
BIORETENTION SOIL (TYP)
GEOTEXTILE (TYP)
GRAVEL BASE (TYP)
NEW BARRIER CURB WITH CUTS (TYP)
NEW STREET LIGHTING (TYP.)
200' O.C.
NEW BARRIER CURB WITH CUTS (TYP.)
EXISTING CULVERT
3'-0"
EXCAVATION (TYP)
13'-6"
BIOSWALE
6'-0"
WALK
36'-6"
BIOSWALE
27'-0"
EXISTING ROADWAY



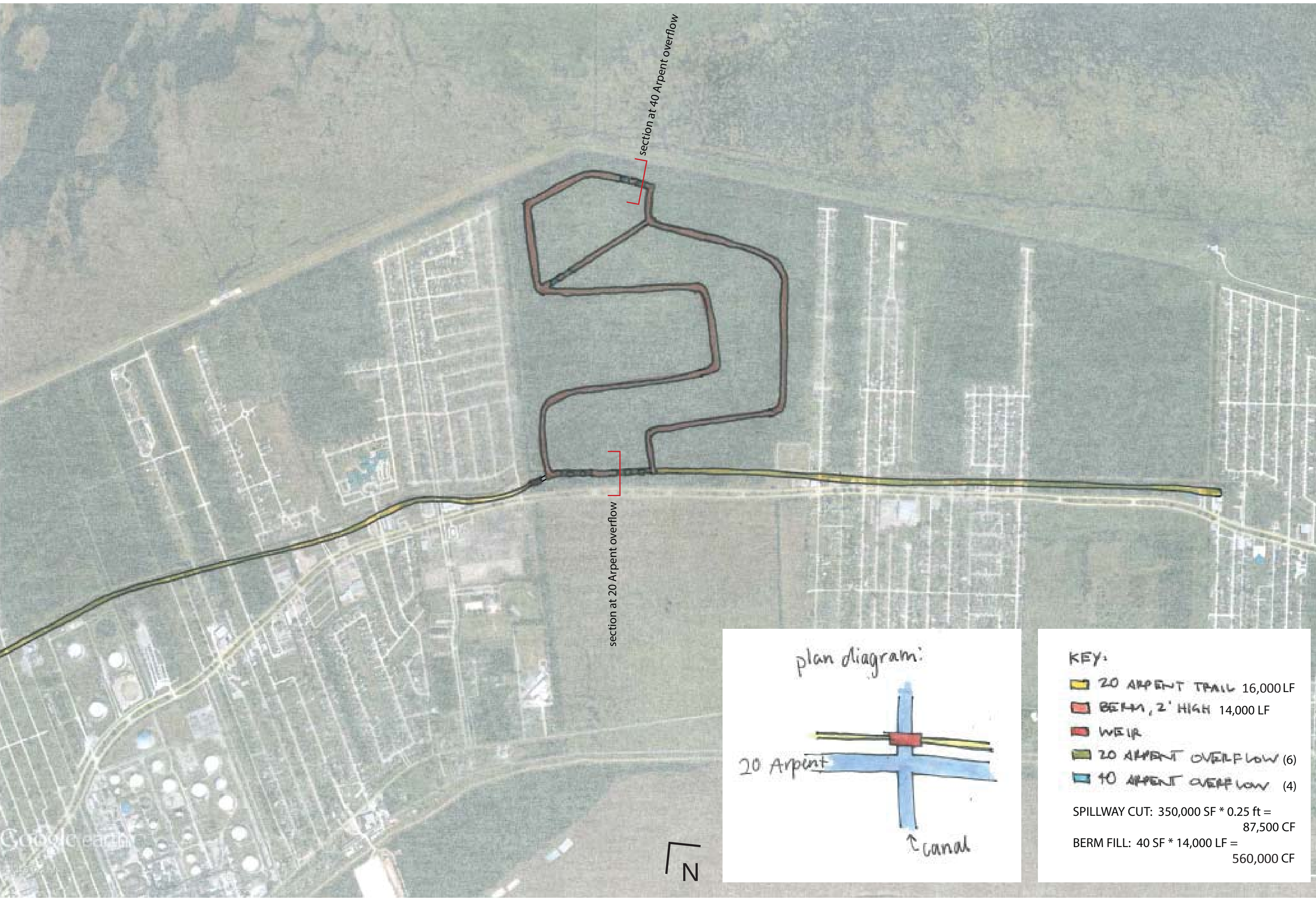
APPENDICES

A. CONCEPTUAL COST ESTIMATES

B. HYDROLOGIC AND HYDRAULIC MODELING

APPENDIX A: CONCEPTUAL COST ESTIMATES

MERAUX SPILLWAY



Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	20 Arpent Trail	$ 903,276	$ 54,197	$ 90,328	$ 27,098	$ 18,066	$ 1,092,964	$ 327,889	$ 1,420,853	LF	$ 89
2	20 Arpent Overflow	$ 116,899	$ 7,014	$ 11,690	$ 3,507	$ 2,338	$ 141,448	$ 42,434	$ 183,882	EA (6)	$ 30,647
3	40 Arpent Spillway & Overflow	$ 738,359	$ 44,302	$ 73,836	$ 22,151	$ 14,767	$ 893,414	$ 268,024	$ 1,161,438	SF	$ 3
4	Weir	$ 243,587	$ 14,615	$ 24,359	$ 7,308	$ 4,872	$ 294,740	$ 88,422	$ 383,163	LF	$ 7,663
	Total Cost	$ 2,002,121	$ 120,127	$ 200,212	$ 60,064	$ 40,042	$ 2,422,567	$ 726,770	**$ 3,149,336**		

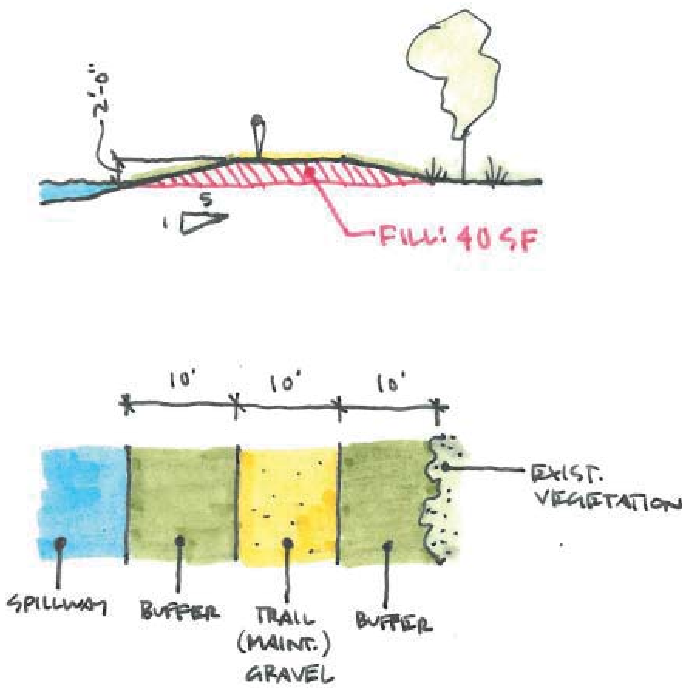
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	20 Arpent Trail						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob					$0	*$100,000*
2	*10' Elevated Boardwalk*						
	10' Elevated Boardwalk	1325	LF	$75	1.00	$75	$99,375
	Total 10' Elevated Boardwalk						$99,375
3	*2' Berm with 10' Gravel Trail*						
	Gravel maintenance path, 4" deep	1955	CY	$75	1.03	$77	$151,024
	Select fill	21724	CY	$20	1.03	$21	$447,514
	path	17778	SY	$3.00	1.03	$3.09	$54,934
	Hydroseed buffer zone	326400	SF	$0.15	1.03	$0.15	$50,429
	Total 2' Berm with 10' Gravel Trail						$703,901
	Total 20 Arpent Trail costs						**$903,276**

	20 Arpent Overflow						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob					$0	*$100,000*
2	*Concrete Overflow (6) total*						
	Excavation and place material on site	480	CY	$15	1.03	$15	$7,416
	Disposal at landfill	480	CY	$3	1.03	$3	$1,483
	Concrete	80	SY	$100	1.00	$100	$8,000
	Total Concrete Overflow (6)						$16,899
	Total 20 Arpent Overflow costs						**$116,899**

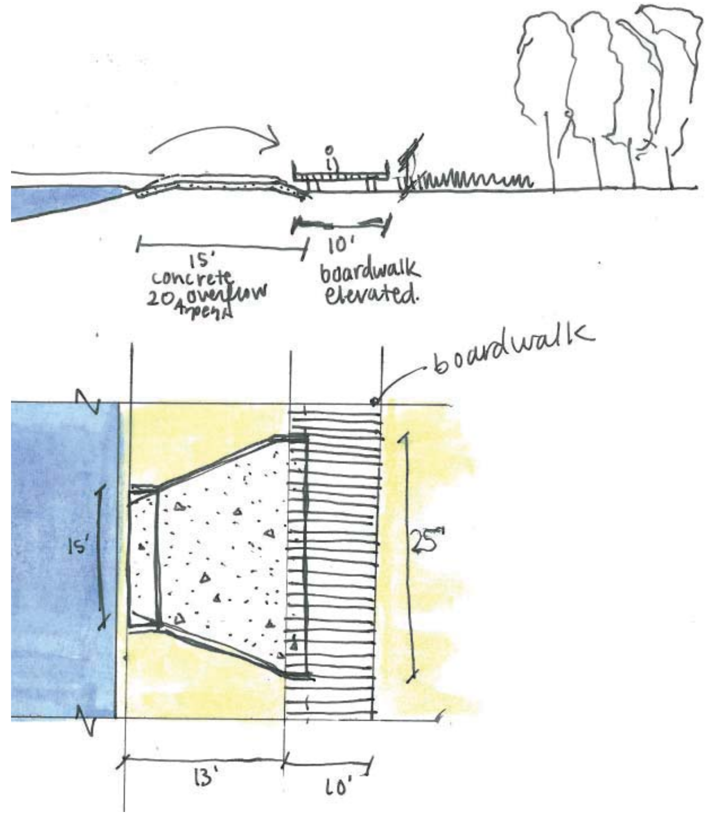
	40 Arpent Spillway & Overflow						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$ 100,000
	Total Mob/Demob					$0	*$ 100,000*
2	*2' High Berm, Site Total*						
	Select fill	20740	CY	$20	1.03	$21	$ 427,244
	Geotextile fabric under gravel maintenance path	9415	SY	$3.00	1.03	$3.09	$ 29,092
	Gravel maintenance path, 4" deep	1035	CY	$75	1.03	$77	$ 79,954
	Hydroseed buffer zone	172890	SF	$0.15	1.03	$0.15	$ 26,712
	Total 2' High Berm, Site Total						$ 563,002
3	*Flexamat Overflow (4) total*						
	Flexamat	5360	SF	$4.72	1.00	$4.72	$ 25,299
	Total Flexamat Overflow (4)						$ 25,299
4	*Spillway Cut*						
	Excavate and transport excess material	3240	CY	$15	1.03	$15	$ 50,058
	Total Spillway Cut						$ 50,058
	Total 40 Arpent Spillway & Overflow costs						**$ 738,359**

	Weir						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob					$0	*$100,000*
2	*Weir*						
	Excavation and place material on site	40	CY	$15	1.03	$15	$618
	Weir materials	1	LUMP	$71,500	1.00	$71,500	$71,500
	Weir installation + pedestrian bridge			$71,500	1.00	$71,500	$71,500
	Total Weir						$143,618
	Total Weir Costs						**$243,618**

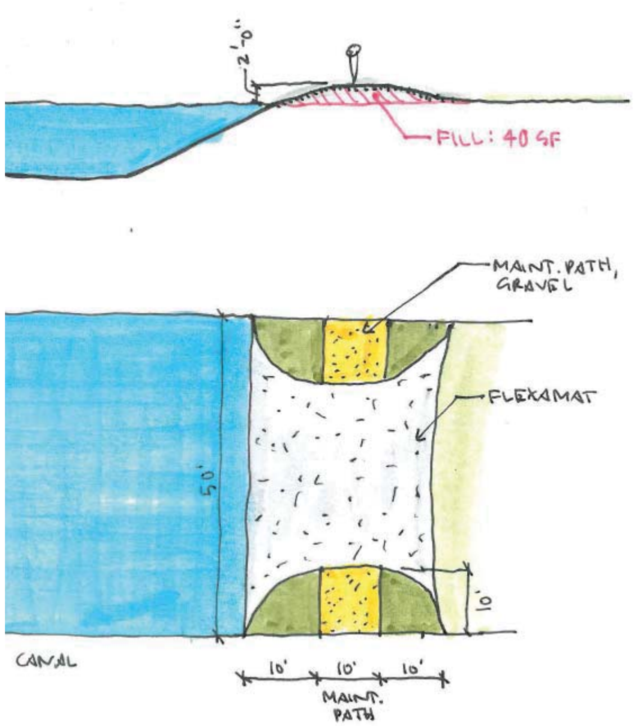
20 ARPENT TRAIL



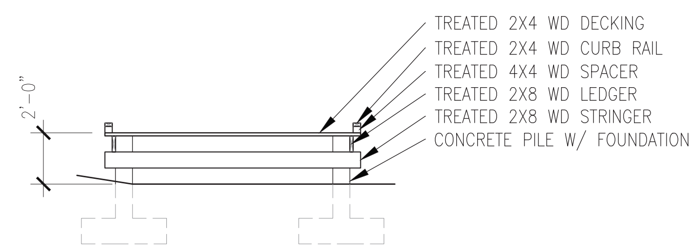
20 ARPENT OVERFLOW



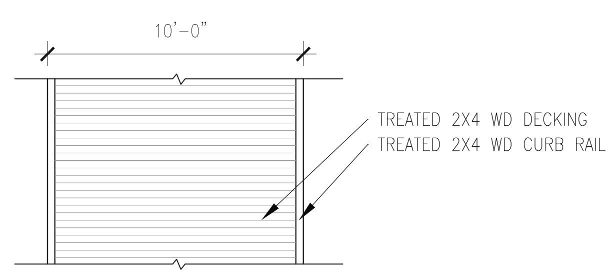
40 ARPENT SPILLWAY & OVERFLOW



BOARDWALK

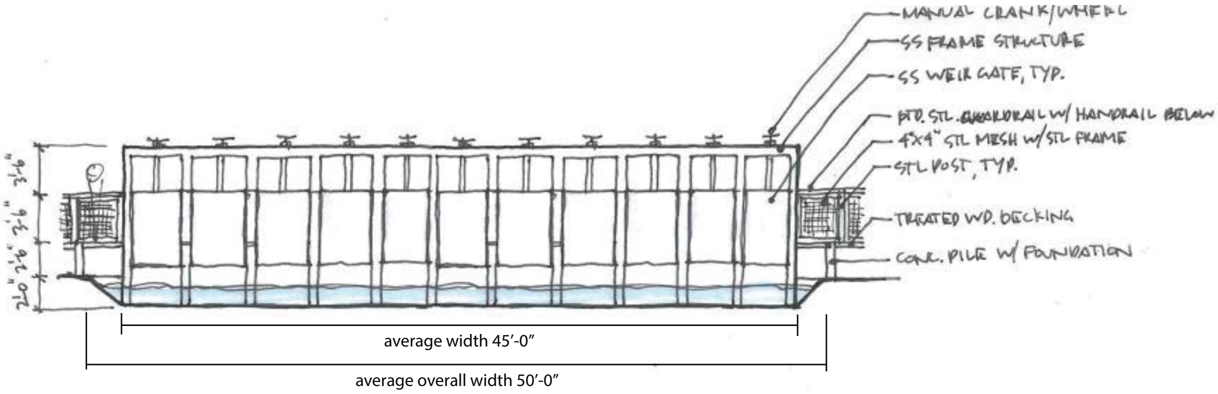


BOARDWALK SECTION, TYP.

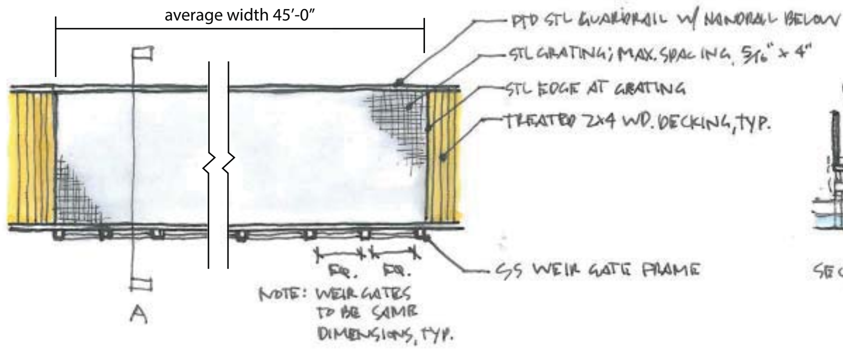


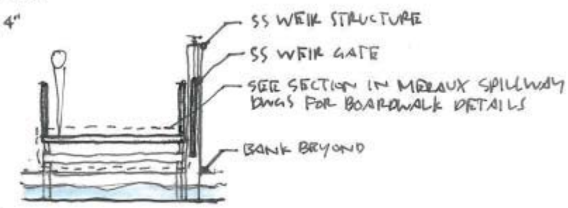
BOARDWALK PLAN, TYP.

WEIR DESIGN



ELEVATION OF WEIR GATES





SECTION A

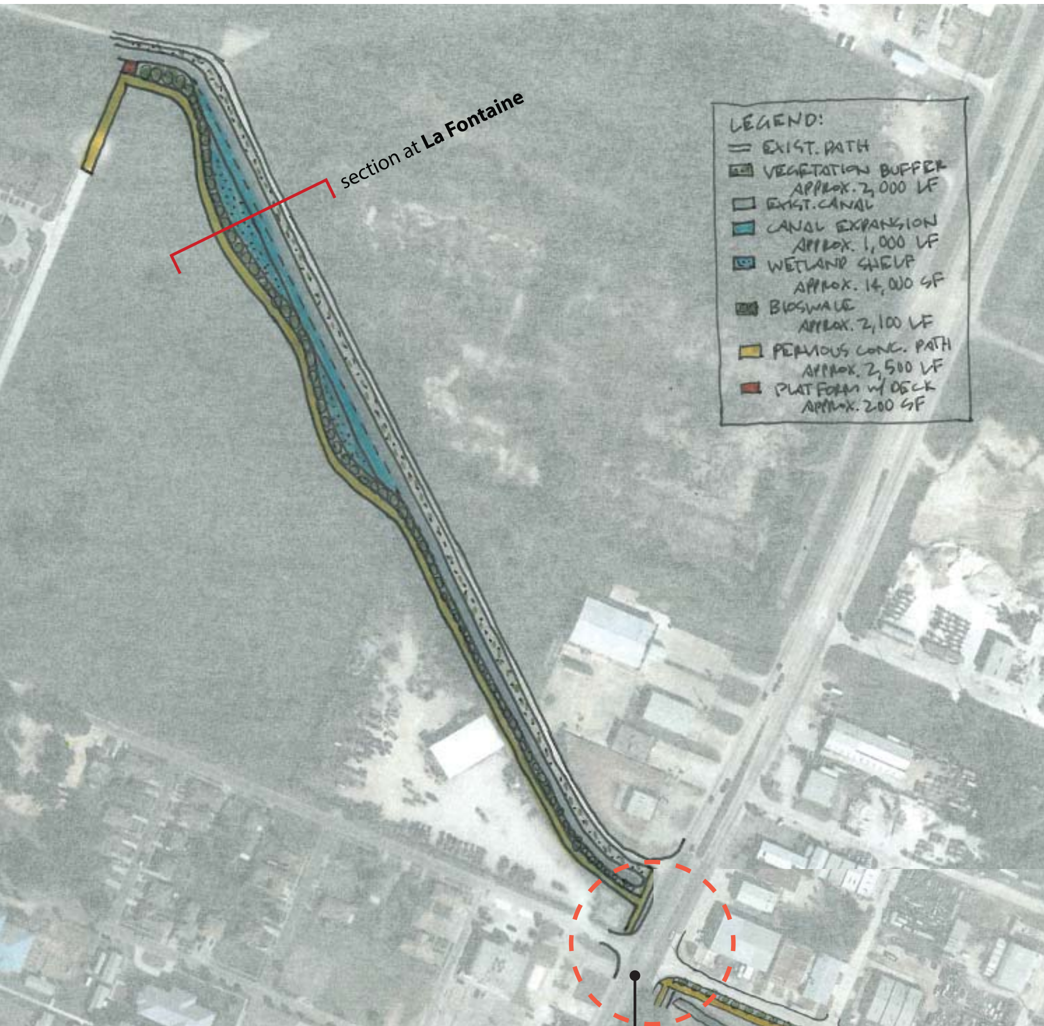
PLAN

PRECEDENTS

Weir Design
Meraux Spillway provides trails throughout lower St. Bernard, connecting to the River Levee bike path and the 40 Arpent levee.
Source: http://www.ducks.org/conservation/glaro/engineering-projects

20 Arpent Recreational Trail
Meraux Spillway provides trails throughout lower St. Bernard, connecting to the River Levee bike path and the 40 Arpent levee.
Source: https://en.wikipedia.org/wiki/Chesapeake_and_Ohio_Canal_National_Historical_Park#cite_note-34

40 ARPENT CONNECTION



See **Paris Rd Entry** project for intersection design and cost estimate information

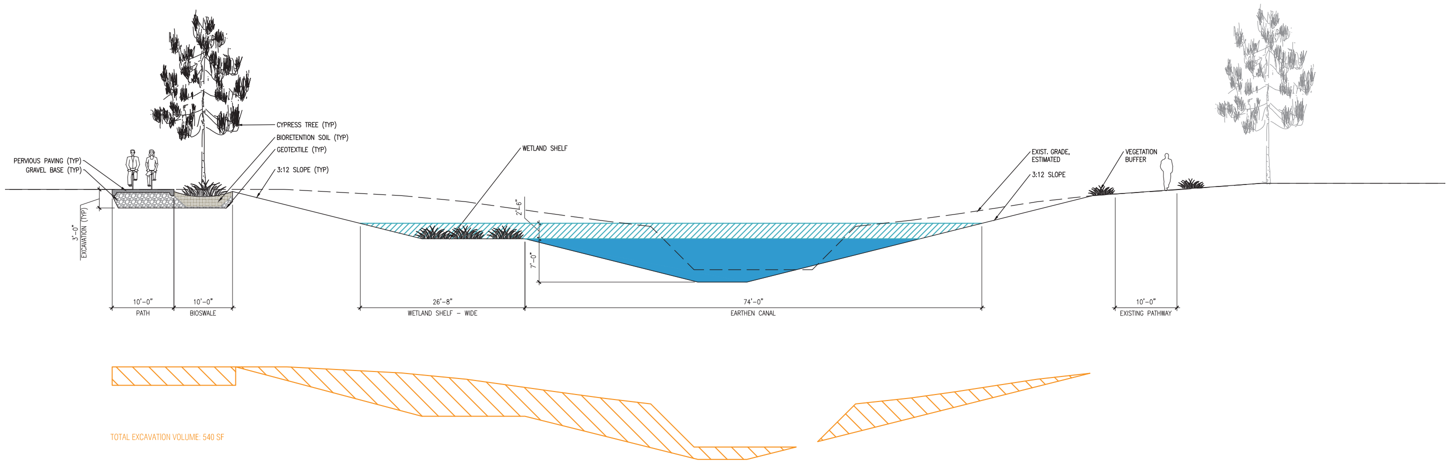
Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**West side (Virtue at La Fontaine)**	$ 957,177	$ 57,431	$ 95,718	$ 28,715	$ 19,144	$ 1,158,184	$ 347,455	**$ 1,505,639**	**LF**	$ 725.61
2	**East side (Virtue at LaPlace, at Richilieu)**	$ 968,360	$ 58,102	$ 96,836	$ 29,051	$ 19,367	$ 1,171,715	$ 351,515	**$ 1,523,230**	**LF**	$ 967.13
3	**Platform with Deck**	$ 108,625	$ 6,518	$ 10,863	$ 3,259	$ 2,173	$ 131,436	$ 39,431	**$ 170,867**	**SF**	$ 179.86
4	**Paris Road Intersection**	$ 401,608	$ 24,097	$ 40,161	$ 12,048	$ 8,032	$ 485,946	$ 145,784	**$ 631,730**	**LF**	$ 902.47
5	**Val Riess Park**	$ 2,408,863	$ 144,532	$ 240,886	$ 72,266	$ 48,177	$ 2,914,725	$ 874,417	**$ 3,789,142**	**SF**	$ 30.63
	Total Cost	$ 4,844,633	$ 290,678	$ 484,463	$ 145,339	$ 96,893	$ 5,862,006	$ 1,758,602	**$ 7,620,608**		

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Virtue at La Fontaine						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	Excavation						
	Excavation and transport to landfill (expanded canal, wetland shelf, bioswale, and path)	15000	CY	$15	1.03	$15	$231,750
	Disposal at landfill	15000	CY	$3	1.03	$3	$46,350
	Total Excavation						$278,100
3	Installation						
	Geotextile fabric under bioswale and path	4660	SY	$3	1.03	$3	$14,399
	Bioswale soil	2330	CY	$37	1.03	$38	$88,796
	Bioswale plants - Wetlands Plants	2330	SY	$11	1.03	$11	$26,399
	Wetland shelf plants	1555	SY	$11	1.03	$11	$17,618
	Vegetation buffer plants	2220	SY	$11	1.03	$11	$25,153
	Trees	75	EA	$330	1.03	$340	$25,493
	Permeable pavement (path - 4" thick)	2780	SY	$100	1.03	$103	$286,340
	Crushed stone base under pervious pavement and under bioswale soil	925	CY	$75	1.03	$77	$71,456
	Solar powered lighting bollards	25	EA	$300	1.03	$309	$7,725
	Benches	10	EA	$1,550	1.00	$1,550.00	$15,500
	Total Installation						$578,879
	Total West side (Virtue at La Fontaine) costs						**$956,979**

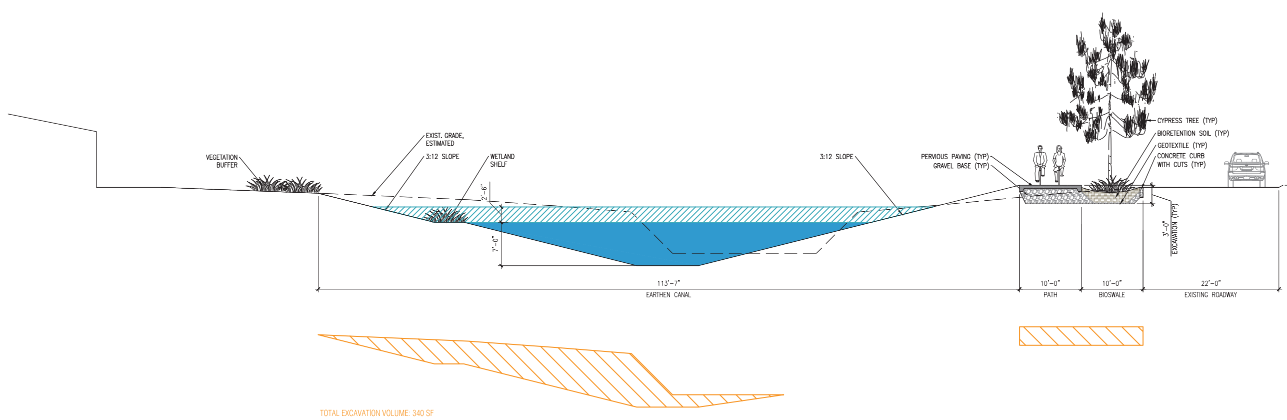
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Virtue at LaPlace, at Richilieu						
1							
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob					$0	$100,000
2	*Excavation*						
	Excavation and transport *to landfill* (expanded canal, wetland shelf, bioswale, and path)	19450	CY	$15	1.03	$15	$300,503
	Disposal at landfill	19450	CY	$3	1.03	$3	$60,101
	Total Excavation						$360,603
3	*Installation*						
	Geotextile fabric under bioswale and path	2000	SY	$3	1.03	$3	$6,179
	Bioswale soil	2000	CY	$37	1.03	$38	$76,220
	Bioswale plants - Wetlands Plants	1890	SY	$11	1.03	$11	$21,414
	Wetland shelf plants	3110	SY	$11	1.03	$11	$35,236
	Trees	90	EA	$330	1.03	$340	$30,591
	Permeable pavement (path - 4" thick)	2000	SY	$100	1.03	$103	$206,000
	Crushed stone base under pervious pavement and under bioswale soil	670	CY	$75	1.03	$77	$51,758
	New sloped curb with cuts	1800	LF	$14	1.00	$14	$24,390
	Solar powered lighting bollards	25	EA	$300	1.03	$309	$7,725
	Benches	10	EA	$1,550	1.00	$1,550.00	$15,500
	Vegetation buffer plants	2890	SY	$11	1.03	$11	$32,744
	Total Installation						$507,757
	Total East side (Virtue at LaPlace, at Richilieu) costs						**$968,360**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Platform with Deck						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob					$0	*$100,000*
2	*Platform with Deck*						
	10' Elevated Boardwalk	115	LF	$75	1.00	$75	$8,625
	Total Platform with Deck						*$8,625*
	Total Platform with Deck costs						**$108,625**

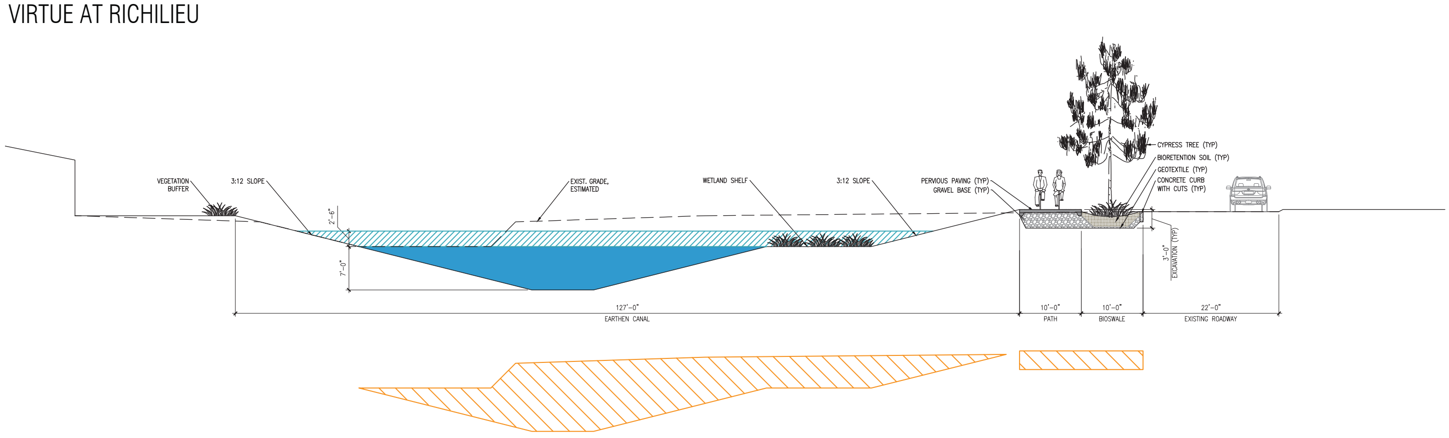
40 ARPENT CANAL - NW
(VIRTUE AT LA FONTAINE)



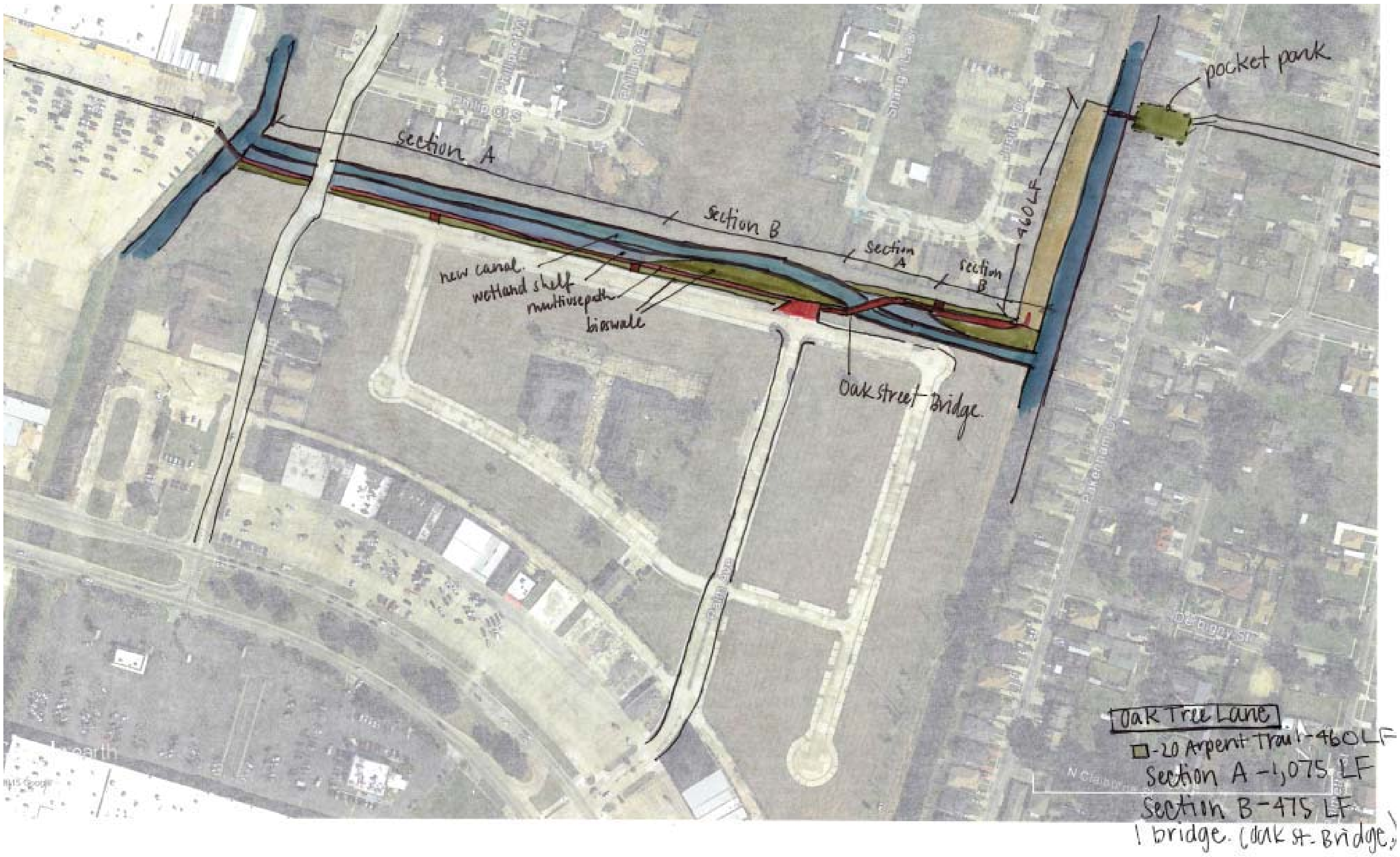
40 ARPENT CANAL - SE
VIRTUE AT LAPLACE



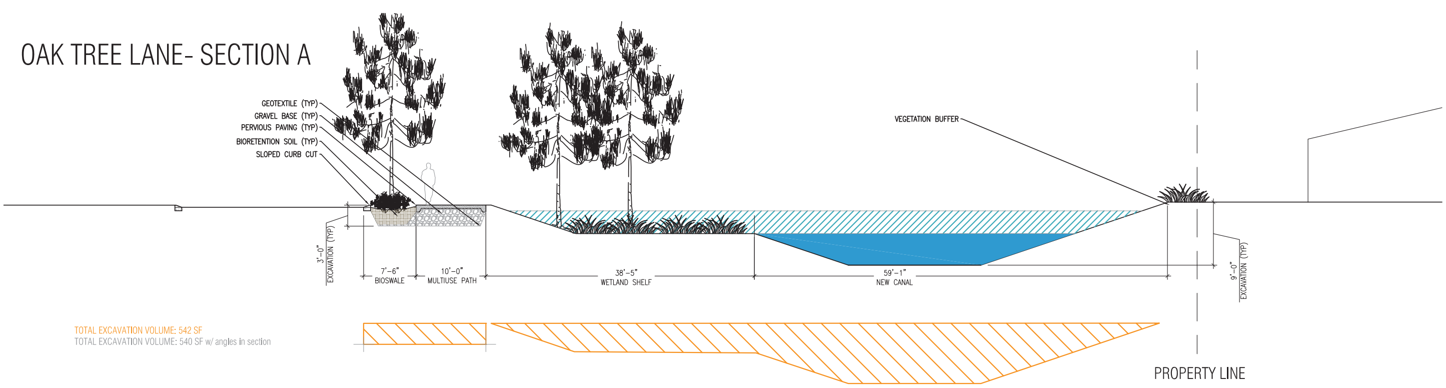
40 ARPENT CANAL - SE
VIRTUE AT RICHILIEU



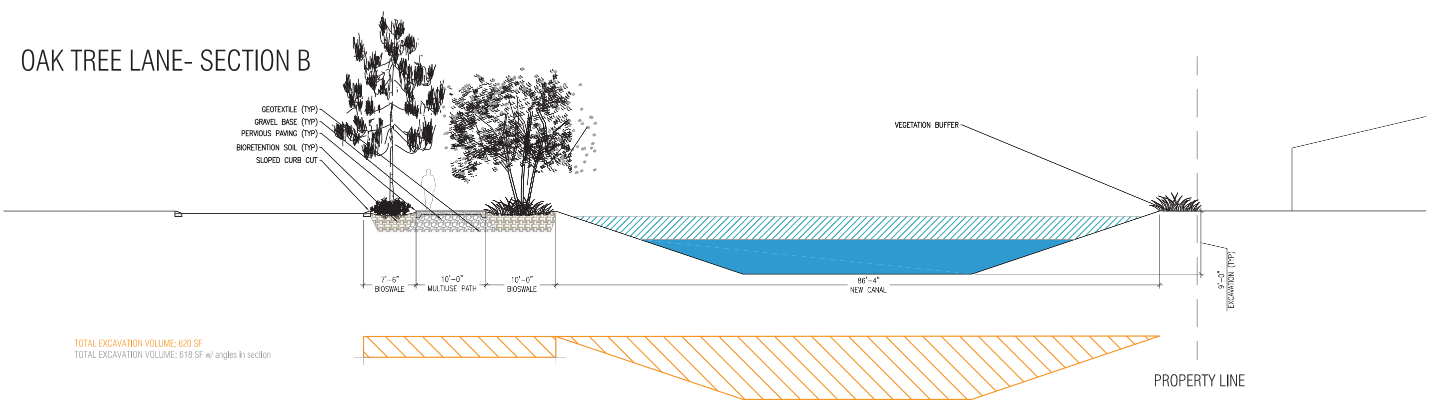
OAK TREE LANE



OAK TREE LANE- SECTION A

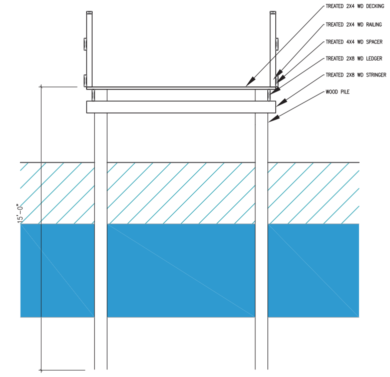


OAK TREE LANE- SECTION B

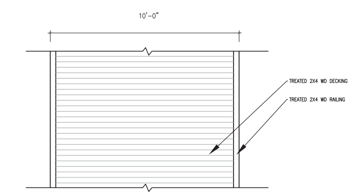


Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						**$100,000**
2	***Section A***						
	Excavation and transport to landfill for wetland shelf and new canal	21580	CY	$15	1.03	$15	$333,411
	Excavation and transport to landfill under bioswale and multiuse path	2090	CY	$15	1.03	$15	$32,291
	Disposal at landfill	23670	CY	$3	1.03	$3	$73,140
	Geotextile fabric under gravel base for pervious pavement and bioswale	2090	SY	$3	1.03	$3	$6,458
	Gravel base under pervious pavement path and under bioswale soil	1507	CY	$75	1.03	$77	$116,416
	Bioretention soil in bioswales	450	CY	$37	1.03	$38	$17,150
	Pervious pavement for multiuse path	1195	SY	$100	1.03	$103	$123,085
	Bioswale plants	900	SY	$11	1.03	$11	$10,197
	Wetland shelf plants	4600	SY	$11	1.03	$11	$52,118
	Hydroseed vegetation buffer	5375	SF	$0.15	1.03	$0.15	$830
	Trees	160	EA	$330	1.03	$340	$54,384
	Total Section A						**$819,480**
3	***Section B***						
	Excavation and transport to landfill for new canal	9455	CY	$15	1.03	$15	$146,080
	Excavation and transport to landfill under bioswales and multiuse path	1450	CY	$15	1.03	$15	$22,403
	Disposal at landfill	10905	CY	$3	1.03	$3	$33,696
	Geotextile fabric under gravel base for pervious pavement and bioswales	1450	SY	$3	1.03	$3	$4,481
	Gravel base under pervious pavement path and under bioswale soil	930	CY	$75	1.03	$77	$71,843
	Bioretention soil in bioswales	460	CY	$37	1.03	$38	$17,531
	Pervious pavement for multiuse path	530	SY	$100	1.03	$103	$54,590
	Bioswale plants	925	SY	$11	1.03	$11	$10,480
	Hydroseed vegetation buffer	2375	SF	$0.15	1.03	$0	$367
	Trees	15	EA	$330	1.03	$340	$5,099
	Total Section B						**$366,568**
4	***Pocket Park***						
	Sawcut existing curb and roadway for bumpout	55	LFT	$6.43	1.03	$7	$364
	Demolition and removal of curb and street section	40	CY	$40	1.03	$41	$1,648
	Excavation and transport to landfill under bioswales and permeable pavement path	630	CY	$15	1.03	$15	$9,734
	Disposal at landfill	630	CY	$3	1.03	$3	$1,947
	New sloped concrete curb with cuts	65	LF	$13.55	1.00	$14	$881
	Geotextile fabric	6230	SF	$3	1.03	$3	$16,042
	Gravel base under bioswale soil and permeable pavement	315	CY	$75	1.03	$77	$24,334
	Permeable pavement (sidewalks - 4" thick)	55	SY	$100	1.03	$103	$5,665
	Mob / Demob for pilings for multi-use bridge	1	EA	$1,500	1.00	$1,500	$1,500
	Pilings for multi-use bridge	20	100LF	$2,500	1.00	$2,500	$50,000
	Multi-use bridge ***See Detail Dwg***	200	LF	$75	1.00	$75	$15,000
	ADA Ramp to multi-use bridge	100	LF	$200	1.00	$200	$20,000
	Handrail on multi-use bridge	400	LF	$9.65	1.00	$9.65	$3,860
	Bioswale soil	50	CY	$37	1.03	$38	$1,906
	Raingarden soil	185	CY	$37	1.03	$38	$7,050
	Mulch	65	SY	$8.60	1.00	$9	$559
	Bioswale plants	95	SY	$11	1.03	$11	$1,076
	Raingarden plants	370	SY	$11	1.03	$11	$4,192
	Trees	6	EA	$330	1.03	$340	$2,039
	Total Pocket Park						**$167,797**
	Total Oak Tree Lane costs						**$1,453,844**

OAK STREET BRIDGE

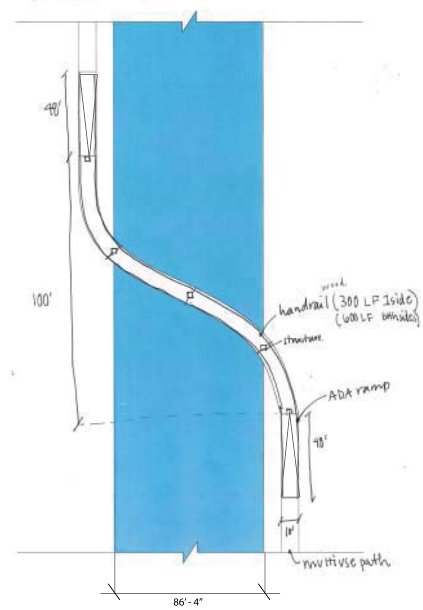


SECTION, TYP.



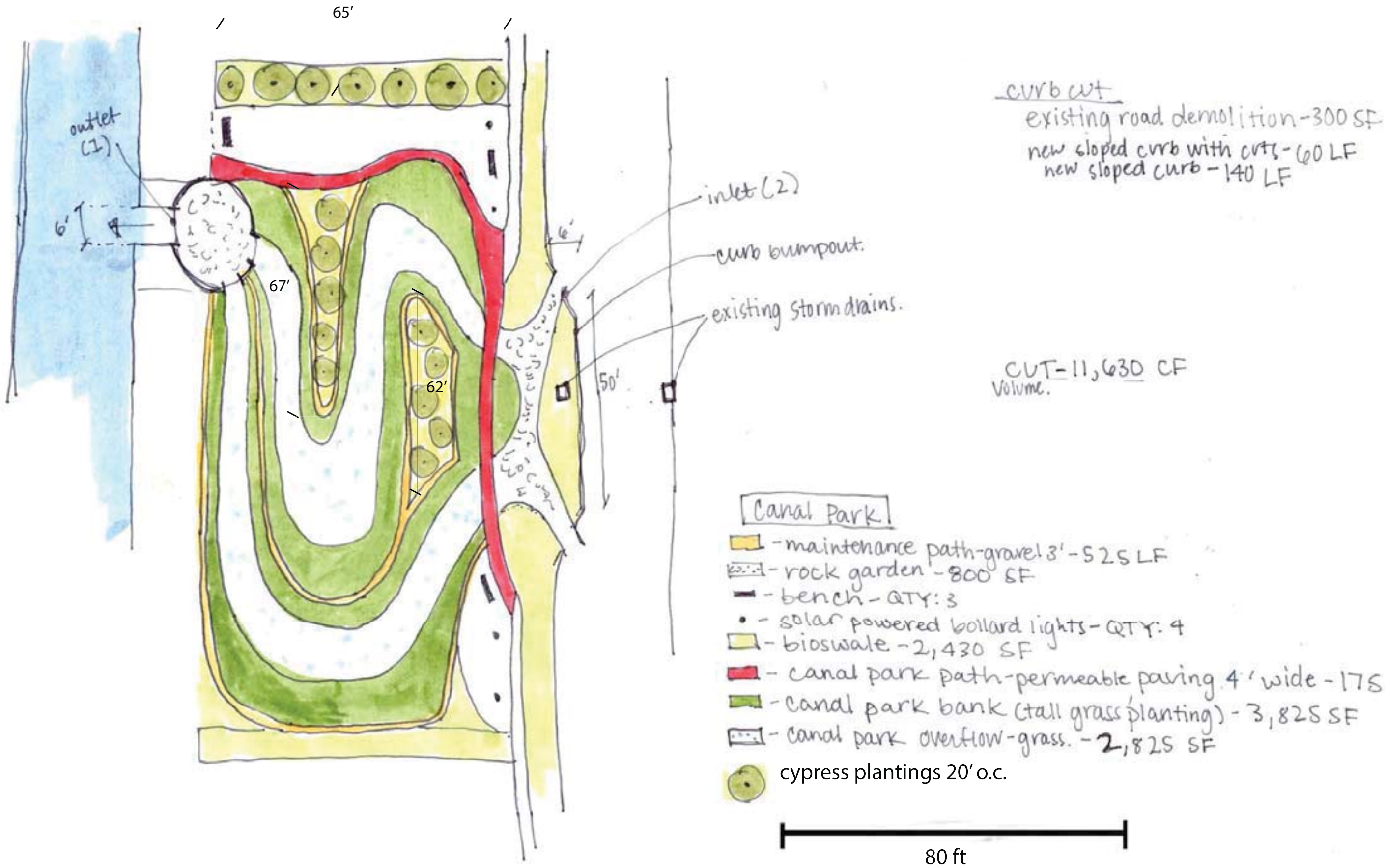
PLAN, TYP.

OAK TREE LANE BRIDGE

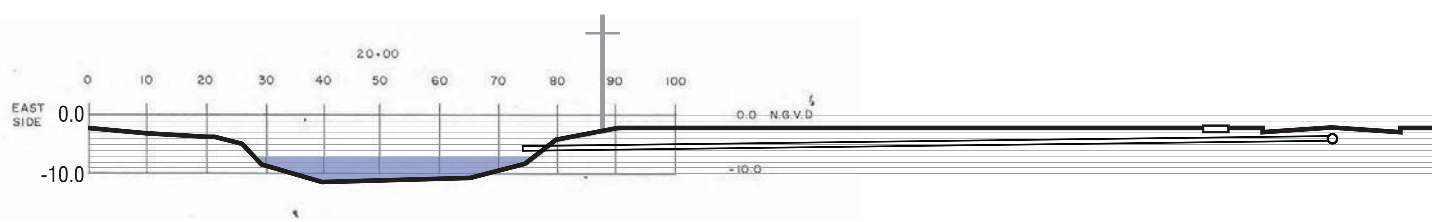


Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
Oak Tree Lane	$ 1,453,844	$ 87,231	$ 145,384	$ 43,615	$ 29,077	$ 1,759,152	$ 527,746	$ 2,286,897	LF	$1,137.76

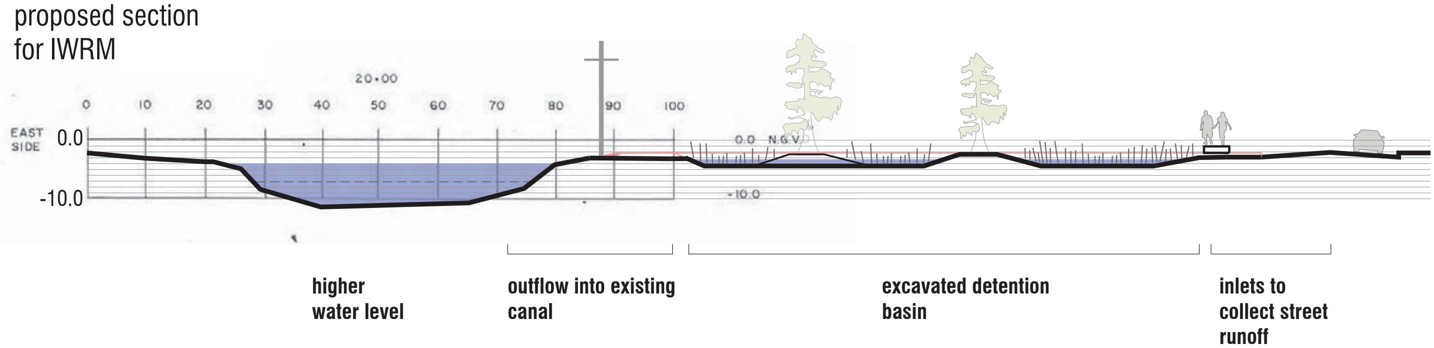
CANAL PARKS



Perpendicular Canal
existing section

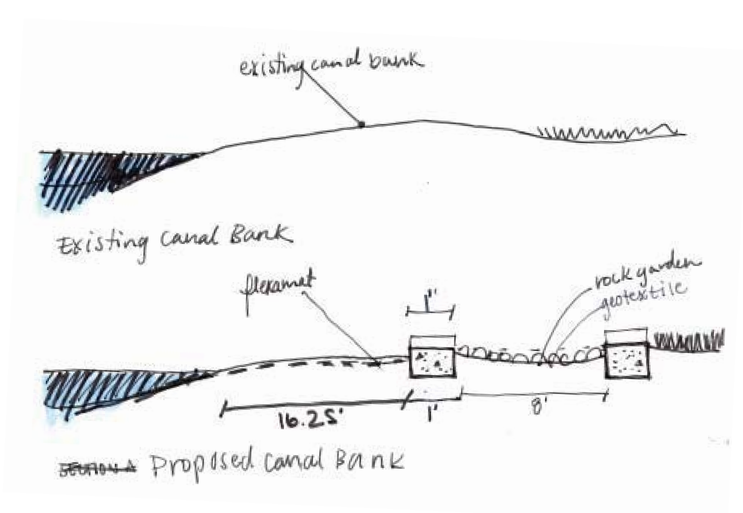


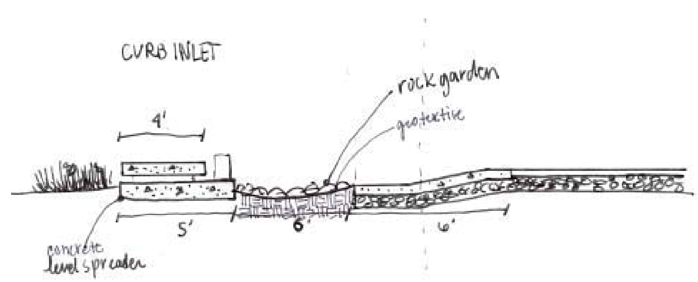
proposed section
for IWRM



Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Canal Parks						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Demolition / Installation*						
	Sawcut existing curb and roadway for bumpout	50	LFT	$6.43	1.03	$6.62	$331
	Demolition and removal of curb and street section	35	CY	$40	1.03	$41.20	$1,442
	Excavation and transport to landfill of soil for detention basin, permeable paving path, and bioswales	435	CY	$15	1.03	$15.45	$6,721
	Disposal of concrete and excavated material at landfill	470	CY	$3	1.03	$3.09	$1,452
	New sloped concrete curb with cuts	60	LF	$13.55	1.00	$14	$813
	New sloped concrete curb (no cuts)	140	LF	$13.55	1.00	$14	$1,897
	Geotextile fabric under pervious pavement, bioswales, and rock gardens	530	SY	$3	1.03	$3.09	$1,638
	Gravel for maintenance paths, under bioswale soil and permeable pavement base	225	CY	$75	1.03	$77.25	$17,381
	Compacted fill under rock gardens "select fill"	75	CY	$20	1.03	$20.60	$1,545
	Rip rap or half man rock for rock gardens	15	CY	$65	1.00	$64.50	$968
	Pervious pavement for path	80	SY	$100	1.03	$103.00	$8,240
	Flexamat at rock garden outlet	100	SF	$4.72	1.00	$4.72	$472
	Bioretention soil under bioswales	135	CY	$37	1.03	$38.11	$5,145
	Bioswale plants	270	SY	$11	1.03	$11.33	$3,059
	Tall grass on banks and grass in overflow sections	740	SY	$11	1.03	$11.33	$8,384
	Cypress trees	7	EA	$330	1.03	$339.90	$2,379
	Solar powered lighting bollards	4	EA	$300	1.03	$309	$1,236
	Hydroseed area by benches and bollards	500	SF	$0.15	1.03	$0.15	$77
	Benches	3	EA	$1,550	1.00	$1,550.00	$4,650
	Total Demolition / Installation						$67,830
	Total Canal Parks costs						**$167,830**

Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**Canal Parks**	$167,830	$ 10,070	$ 16,783	$ 5,035	$ 3,357	$ 203,075	$ 60,922	$ 263,997	SF	$ 22.70
	Total Cost	$ 167,830	$ 10,070	$ 16,783	$ 5,035	$ 3,357	$ 203,075	$ 60,922	**$ 263,997**		

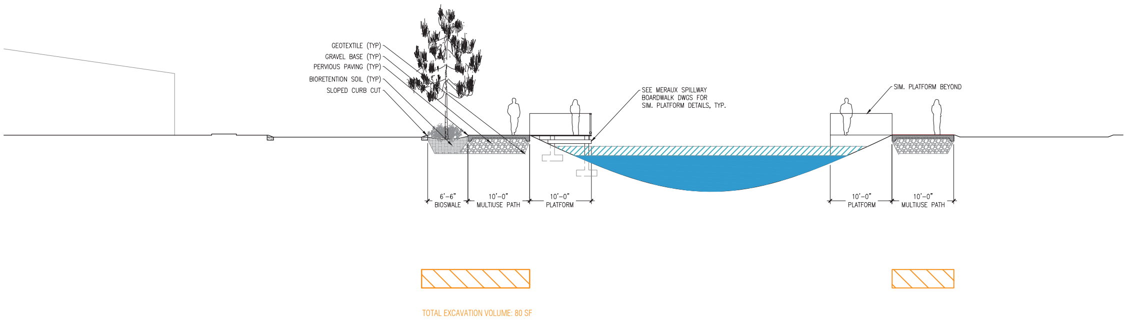




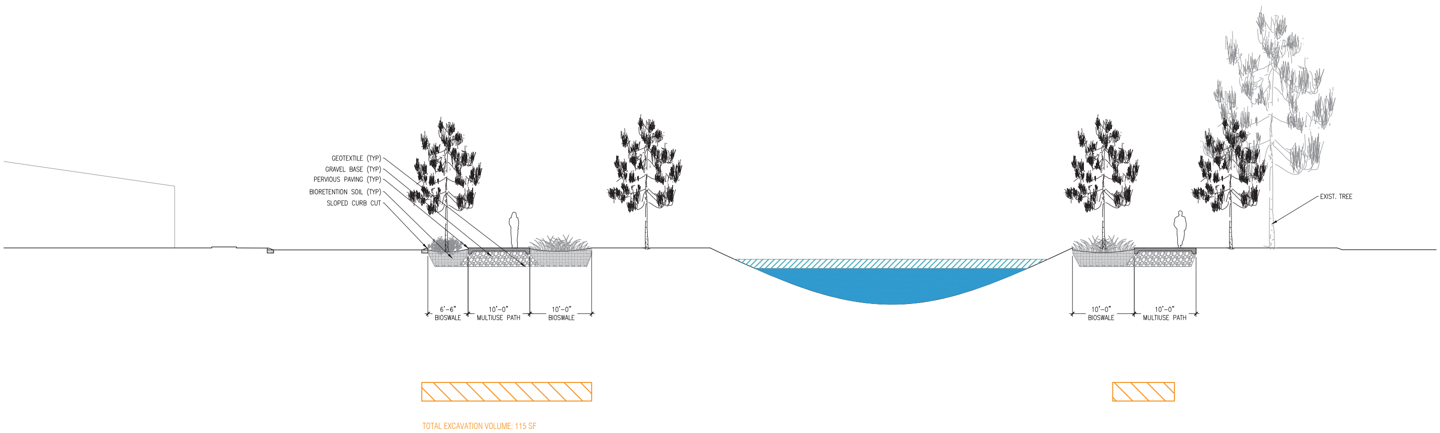
ST. AVIDE

Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
	St. Avide Street	$ 2,238,297	$ 134,298	$ 223,830	$ 67,149	$ 44,766	$ 2,708,340	$ 812,502	$ 3,520,841	LF	$ 678.27

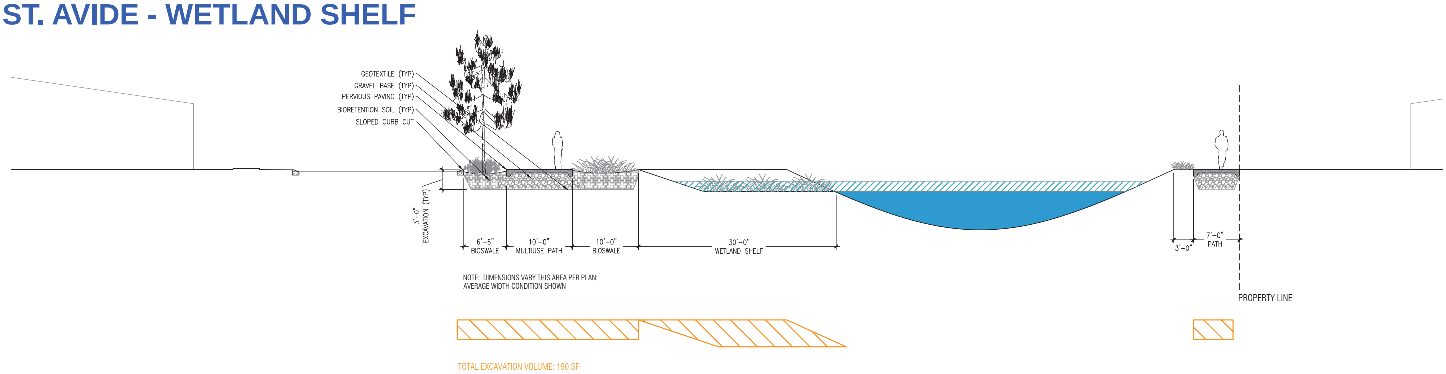
ST. AVIDE - PLATFORMS



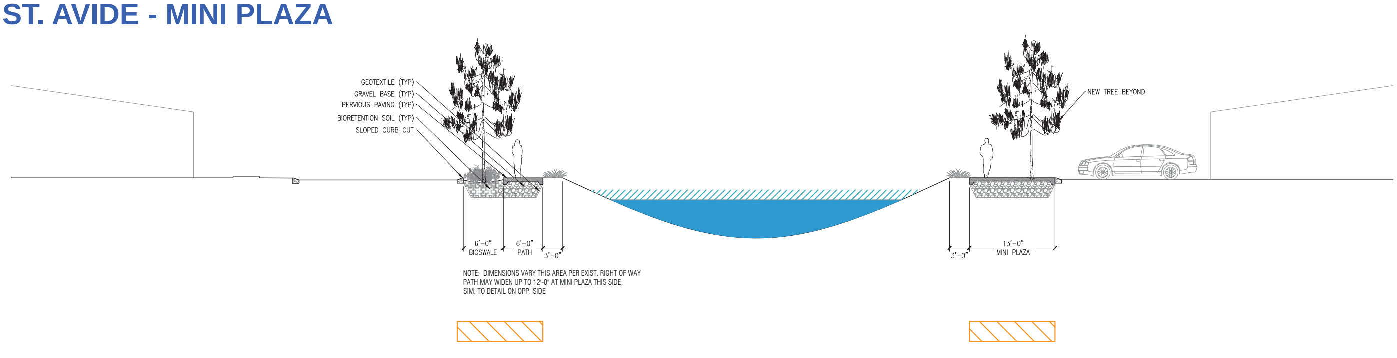
ST. AVIDE - THE GLEN



ST. AVIDE - WETLAND SHELF

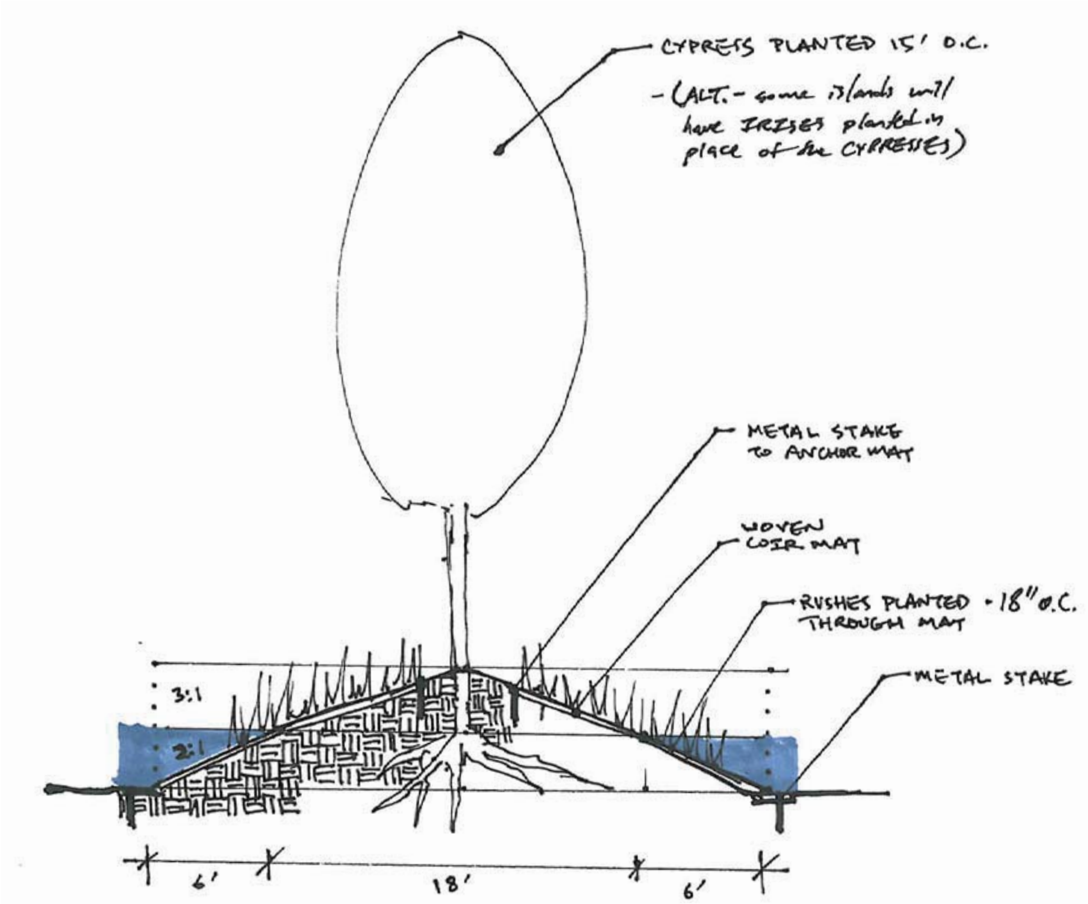


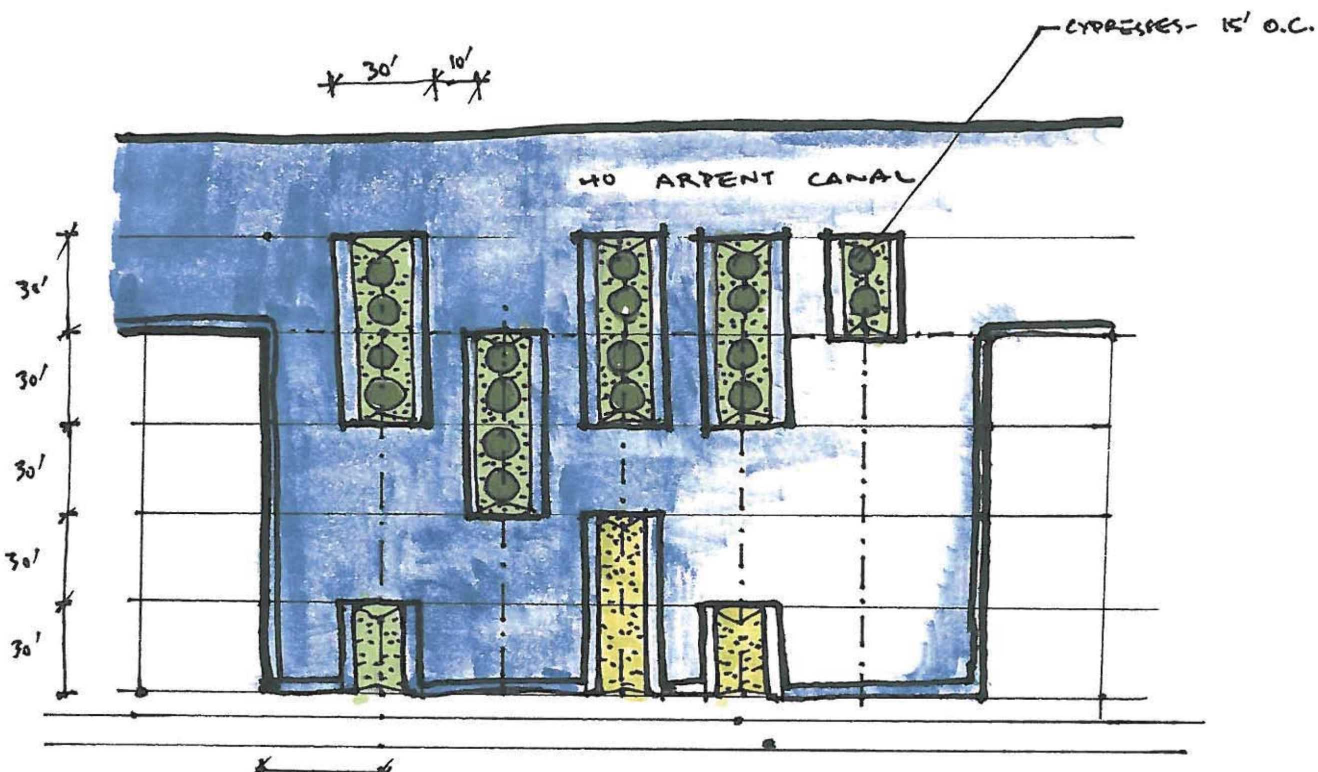
ST. AVIDE - MINI PLAZA



Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
							$100,000
2	***Wetland Shelf (3)***						
	Excavation and transport to landfill to create wetland shelf (3)	29715	CY	$15	1.03	$15	$459,097
	Wetland shelf plants	1225	SY	$11	1.03	$11	$13,879
	Vegetation buffer plants on opposite side of canal	120	SY	$11	1.03	$11	$1,360
	Total Wetland Shelf						**$474,336**
3	***Bioswales, Pervious Paths***						
	Excavation and transport to landfill under bioswales, multiuse path, and mini plazas	8795	CY	$15	1.03	$15	$135,883
	Sloped curb cuts	28	EA	$175	1.00	$175	$4,900
	Geotextile fabric under gravel base for pervious pavement and bioswales	8795	SY	$3	1.03	$3	$27,177
	Gravel base under pervious pavement paths and bioswale soil	6630	CY	$75	1.03	$77	$512,168
	Bioretention soil in bioswales	1510	CY	$37	1.03	$38	$57,546
	Pervious pavement for multiuse path	5780	SY	$100	1.03	$103	$595,340
	Bioswale plants	3020	SY	$11	1.03	$11	$34,217
	Trees (total)	200	EA	$330	1.03	$340	$67,980
	Vegetation buffer plants on opposite ends of lateral canals	240	SY	$11	1.03	$11	$2,719
	Solar powered lighting bollards	50	EA	$300	1.03	$309	$15,450
	Benches	20	EA	$1,550	1.00	$1,550.00	$31,000
	Total Bioswales, Pervious Paths						**$1,484,379**
4	***Mini Plazas***						
	Excavation and transport to landfill under mini plaza	170	CY	$15	1.03	$15	$2,627
	Sloped curb cuts	4	EA	$175	1.00	$175	$700
	Geotextile fabric under gravel base for mini plaza	170	SY	$3	1.03	$3	$525
	Gravel base under pervious pavement and under bioswale soil	150	CY	$75	1.03	$77	$11,588
	Pervious pavement for path and mini plaza	170	SY	$100	1.03	$103	$17,510
	Total Mini Plazas						**$32,949**
5	***Platforms***						
	Excavation and transport to landfill under platforms	335	CY	$15	1.03	$15	$5,176
	Sloped curb cuts	6	EA	$175	1.00	$175	$1,050
	Geotextile fabric under gravel base for platforms	170	SY	$3	1.03	$3	$525
	Gravel base under platforms	170	CY	$75	1.03	$77	$13,133
	10' wide platforms like Meraux Spillway	150	LF	$45	1.00	$45	$6,750
	Total Platforms						**$26,634**
6	***Concrete Weir***	2	EA	$60,000	1	$60,000	$120,000
	Total Concrete Weir						**$120,000**
	Total St. Avide Street costs						**$2,238,297**

40 ARPENT LAGOON





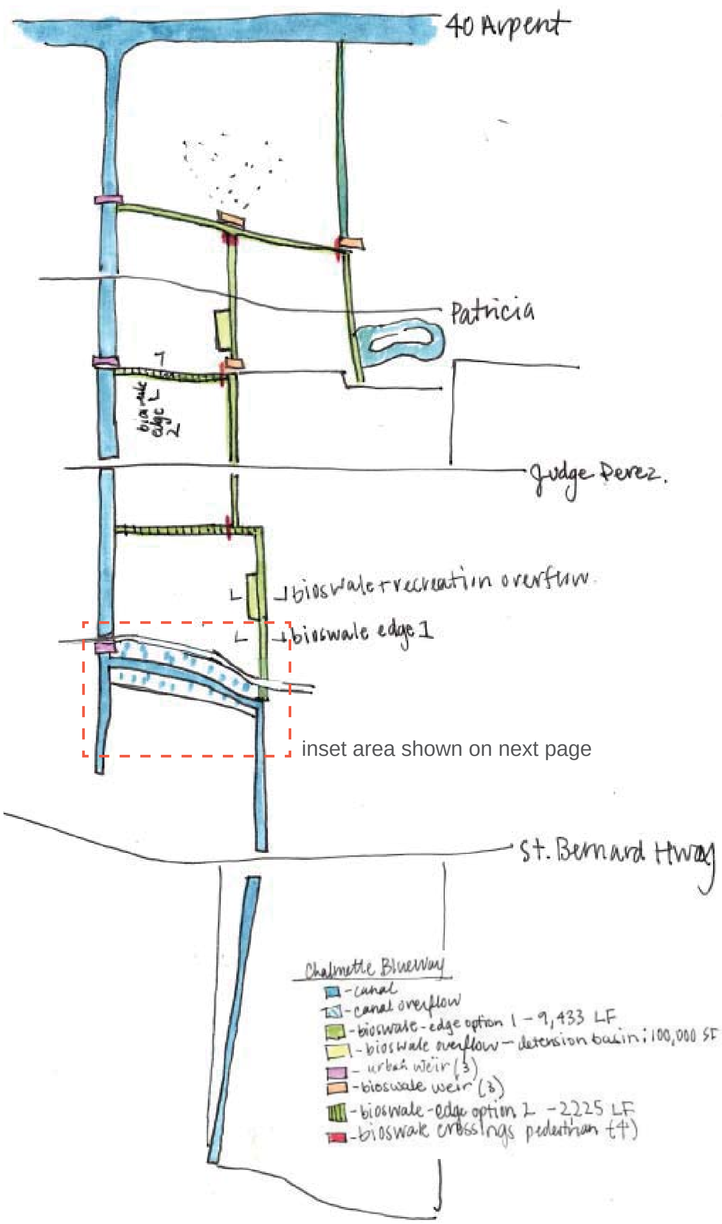
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	40 Arpent Lagoon						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						*$100,000*
2	*Island with cypress*						
	Excavate and place excavated material on site to create islands / lagoons	1182	CY	$5.55	1.00	$5.55	$6,560.10
	Excavate and transport to landfill excess material	588	CY	$15	1.03	$15	$9,084.60
	Disposal at landfill	588	CY	$3	1.03	$3	$1,816.92
	Woven coir mat with wooden stakes	1020	SY	$1.81	1.00	$1.81	$1,846.20
	Cypress trees (15' O.C.)	18	EA	$330	1.03	$340	$6,118.20
	Rushes	570	SY	$11	1.03	$11	$6,458.10
	Total Island with Cypress						$31,884.12
2	*Island with iris (no cypress)*						
	Excavate and place excavated material on site to create islands / lagoons	1529	CY	$5.55	1.00	$5.55	$8,485.95
	Excavate and transport to landfill excess material	1467	CY	$15	1.03	$15	$22,665.15
	Disposal at landfill	1467	CY	$3	1.03	$3	$4,533.03
	Woven coir mat with wooden stakes	453	SY	$1.81	1.00	$1.81	$819.93
	Iris plants	40	SY	$11	1.03	$11	$453.20
	Rushes	213	SY	$11	1.03	$11	$2,413.29
	Total Island with Iris (no cypress)						$39,370.55
	Total 40 Arpent Lagoon cost						$171,254.67

Waldemar S. Nelson Company
St. Bernard Parish Integrated Water Resources Management Plan - Waggonner and Ball Architects
Cost Estimate for 40 Arpent Lagoon
By: MSM / TBG 1/18/2016

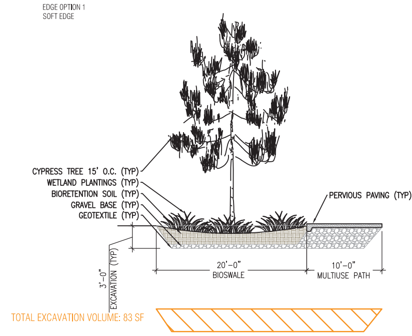
Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**40 Arpent Lagoon**	$171,255	$ 10,275	$ 17,125	$ 5,138	$ 3,425	$ 207,218	$ 62,165	$ 269,384	SF	$ 9.35
	Total Cost	$ 171,255	$ 10,275	$ 17,125	$ 5,138	$ 3,425	$ 207,218	$ 62,165	**$ 269,384**		

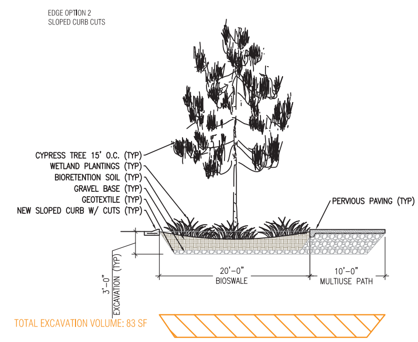
* unit cost assumes similar cut/fill ratio as proposed design.

CHALMETTE BLUEWAY

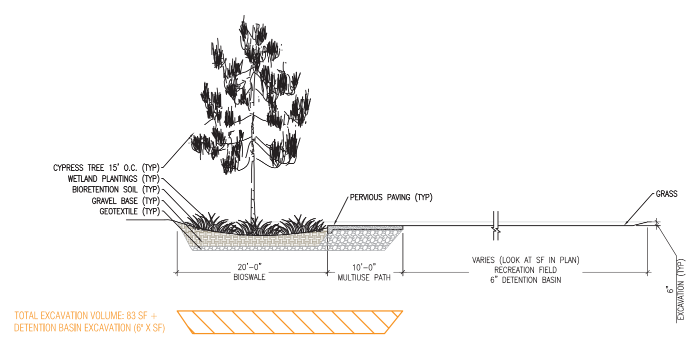


BIOSWALE





BIOSWALE + RECREATION SPACE AS OVERFLOW



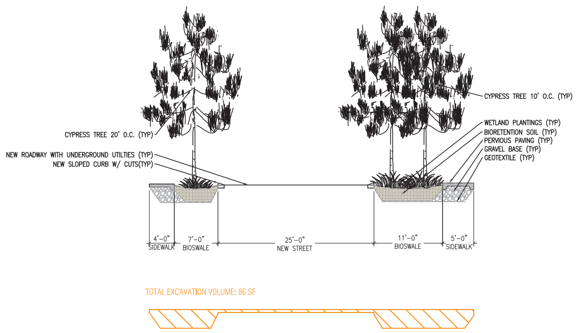
Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**Bioswale 1**	$3,677,303	$ 220,638	$ 367,730	$ 110,319	$ 73,546	$ 4,449,537	$1,334,861	$ 5,784,398	LF	$ 613.21
2	**Bioswale 2**	$ 974,641	$ 58,478	$ 97,464	$ 29,239	$ 19,493	$ 1,179,315	$ 353,795	$ 1,533,110	LF	$ 689.04
3	**Recreational Space**	$ 145,840	$ 8,750	$ 14,584	$ 4,375	$ 2,917	$ 176,467	$ 52,940	$ 229,407	SF	$ 2.29
4	**Bioswale Pedestrian Crossing**	$ 107,632	$ 6,458	$ 10,763	$ 3,229	$ 2,153	$ 130,235	$ 39,071	$ 169,306	EA	$ 42,326.40
5	**Bioswale Weir**	$ 129,650	$ 7,779	$ 12,965	$ 3,890	$ 2,593	$ 156,877	$ 47,063	$ 203,939	EA	$ 67,979.82
6	**Lateral Canal Section A**	$1,540,555	$ 92,433	$ 154,055	$ 46,217	$ 30,811	$ 1,864,071	$ 559,221	$ 2,423,292	LF	$ 1,429.67
7	**Lateral Canal Section B**	$ 239,400	$ 14,364	$ 23,940	$ 7,182	$ 4,788	$ 289,674	$ 86,902	$ 376,577	LF	$ 941.44
8	**Lateral Canal Section C**	$ 579,450	$ 34,767	$ 57,945	$ 17,383	$ 11,589	$ 701,134	$ 210,340	$ 911,474	LF	$ 911.47
9	**Lateral Canal Section D**	$ 218,521	$ 13,111	$ 21,852	$ 6,556	$ 4,370	$ 264,410	$ 79,323	$ 343,733	LF	$ 1,374.93
10	**New Perpendicular Canal**	$ 840,550	$ 50,433	$ 84,055	$ 25,217	$ 16,811	$ 1,017,066	$ 305,120	$ 1,322,185	LF	$ 806.21
11	**Plaza Crossing**	$ 209,200	$ 12,552	$ 20,920	$ 6,276	$ 4,184	$ 253,132	$ 75,940	$ 329,072	SF	$ 81.25
12	**Pedestrian Bridge**	$ 108,804	$ 6,528	$ 10,880	$ 3,264	$ 2,176	$ 131,652	$ 39,496	$ 171,148	LF	$ 1,645.65
13	**Urban Weir**	$ 235,129	$ 14,108	$ 23,513	$ 7,054	$ 4,703	$ 284,506	$ 85,352	$ 369,857	EA	$123,285.77
	Total Cost	$9,006,674	$ 540,400	$ 900,667	$ 270,200	$ 180,133	$10,898,075	$3,269,423	$ 14,167,498		

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Bioswale Edge Option 1 (soft edge)						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000.00	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill under bioswale and pervious paving for multiuse path	29000	CY	$15	1.03	$15.45	$448,050
	Disposal at landfill	29000	CY	$3	1.03	$3.09	$89,610
	Geotextile fabric under gravel base for pervious pavement and bioswale	31445	SY	$3	1.03	$3.09	$97,165
	Gravel base under pervious pavement path and under bioswale soil	12230	CY	$75	1.03	$77.25	$944,768
	Bioretention soil in bioswale	12230	CY	$37	1.03	$38.11	$466,085
	Pervious pavement for multiuse path	10485	SY	$100	1.03	$103.00	$1,079,955
	Bioswale plants	20965	SY	$11	1.03	$11.33	$237,533
	Cypress trees (15' O.C.)	630	EA	$330	1.03	$339.90	$214,137
	Total Excavation / Installation						$3,577,303
	Total Bioswale Edge Option 1 (soft edge)						**$3,677,303**

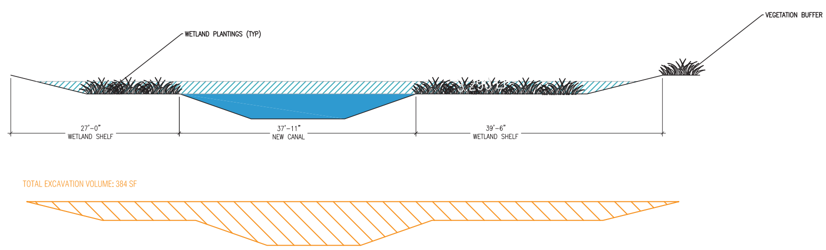
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Bioswale Edge Option 2 (sloped curb cuts)						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000.00	$100,000.00
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill under bioswale and pervious paving for multiuse path	6840	CY	$15	1.03	$15.45	$105,678.00
	Disposal at landfill	6840	CY	$3	1.03	$3.09	$21,135.60
	New sloped curb with cuts	2225	LF	$13.55	1.00	$13.55	$30,148.75
	Geotextile fabric under gravel base for pervious pavement and bioswale	7420	SY	$3	1.03	$3.09	$22,927.80
	Gravel base under pervious pavement path and under bioswale soil	2885	CY	$75	1.03	$77.25	$222,866.25
	Bioretention soil in bioswale	2885	CY	$37	1.03	$38.11	$109,947.35
	Pervious pavement for multiuse path	2475	SY	$100	1.03	$103.00	$254,925.00
	Bioswale plants	4945	SY	$11	1.03	$11.33	$56,026.85
	Cypress trees (15' O.C.)	150	EA	$330	1.03	$339.90	$50,985.00
	Total Excavation / Installation						$874,641
	Total Bioswale Edge Option 2 (sloped curb cuts)						**$974,641**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Recreational Space						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation for recreation field (6" detention basin)	1855	CY	$15	1.03	$15	$28,660
	Disposal at landfill	1855	CY	$3	1.03	$3	$5,732
	Geotextile fabric under gravel base for pervious pavement	3705	SY	$3	1.03	$3	$11,448
	Total Excavation / Installation						$45,840
	Total Bioswale + Recreation Space as Overflow						**$145,840**

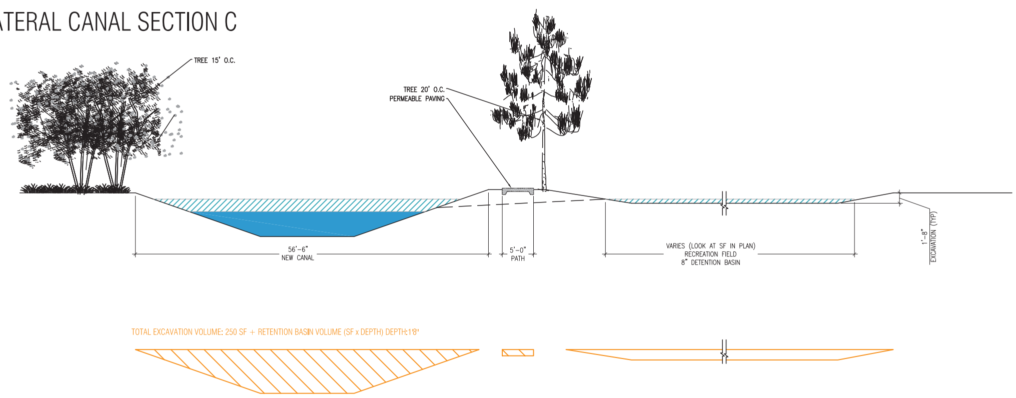
LATERAL CANAL SECTION A



LATERAL CANAL SECTION B

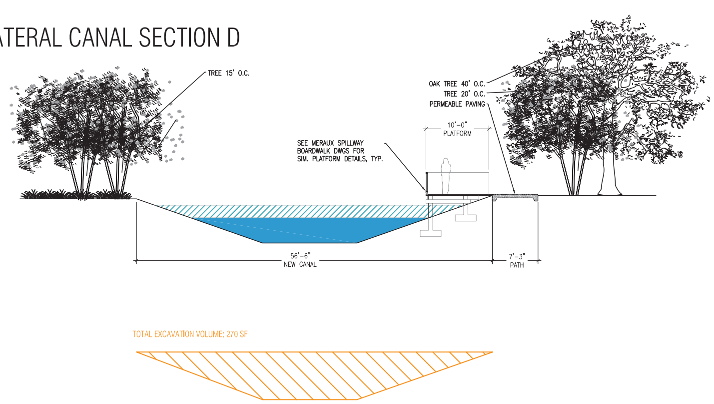


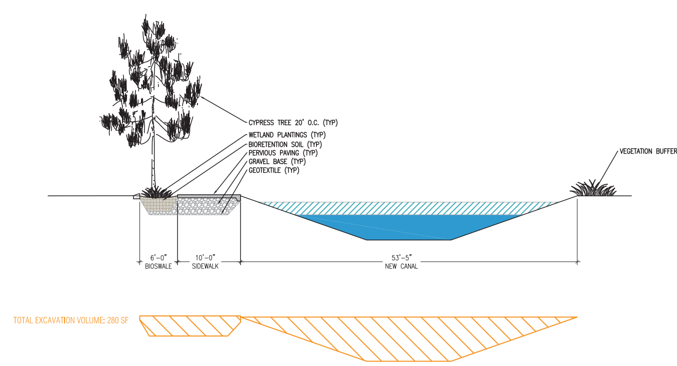
LATERAL CANAL SECTION C

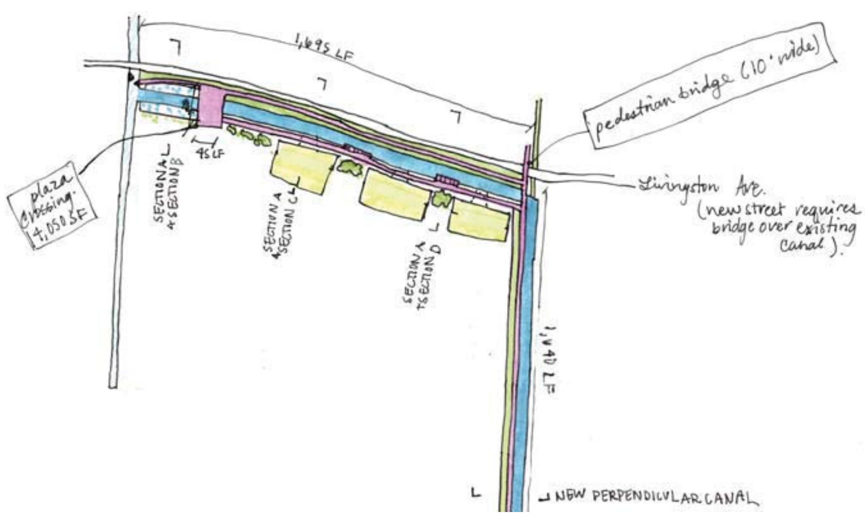


NEW PERPENDICULAR CANAL

LATERAL CANAL SECTION D

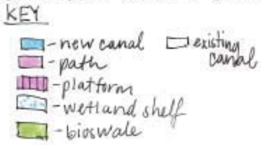






SECTIONS W/ LF
NEW PERPENDICULAR CANAL - 1,640 LF
LATERAL CANAL SECTION A - 1,695 LF
LATERAL CANAL SECTION B - 400 LF
LATERAL CANAL SECTION C - 1,000 LF (detention basin 150,000 SF)
LATERAL CANAL SECTION D - 250 LF

CHALMETTE BLUEWAY CANALS
KEY



Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Lateral Canal Section A						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill for bioswale, sidewalk, and new street	5400	CY	$15	1.03	$15	$83,430
	Disposal at landfill	5400	CY	$3	1.03	$3	$16,686
	Pervious pavement for new roadway	4710	SY	$100	1.03	$103	$485,130
	New sloped curb with cuts	3390	LF	$13.55	1.00	$14	$45,935
	Geotextile fabric under gravel base for pervious pavement, roadway, and bioswale	9795	SY	$3	1.03	$3	$30,267
	Gravel base under pervious pavement, roadway, and bioswale soil	5495	CY	$75	1.03	$77	$424,489
	Bioretention soil in bioswale	2200	CY	$37	1.03	$38	$83,842
	Pervious pavement for sidewalks	1695	SY	$100	1.03	$103	$174,585
	Bioswale plants	3390	SY	$11	1.03	$11	$38,409
	Cypress trees (20' O.C. and 10' O.C.)	170	EA	$330	1.03	$340	$57,783
	Total Excavation / Installation						$1,440,555
	Total Lateral Canal Section A costs						**$1,540,555**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Lateral Canal Section B						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill for wetland shelves and new canal	5690	CY	$15	1.03	$15.45	$87,911
	Disposal at landfill	5690	CY	$3	1.03	$3.09	$17,582
	Wetland shelf plants	2960	SY	$11	1.03	$11.33	$33,537
	Hydroseed vegetation buffer	2400	SF	$0.15	1.03	$0.15	$371
	Total Excavation / Installation						$139,400
	Total Lateral Canal Section B costs						**$239,400**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Lateral Canal Section C						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000.00	$100,000.00
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill for new canal, permeable paving, and detention basin	18485	CY	$15	1.03	$15.45	$285,593
	Disposal at landfill	18485	CY	$3	1.03	$3.09	$57,119
	Geotextile fabric under gravel base for pervious pavement	560	SY	$3	1.03	$3.09	$1,730
	Gravel base under pervious pavement path	495	CY	$75	1.03	$77.25	$38,239
	Pervious pavement for path	560	SY	$100	1.03	$103.00	$57,680
	Trees	115	EA	$330	1.03	$339.90	$39,089
	Total Excavation / Installation						$479,450
	Total Lateral Canal Section C costs						**$579,450**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Lateral Canal Section D						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill for new canal and permeable paving	2780	CY	$15	1.03	$15	$42,951
	Disposal at landfill	2780	CY	$3	1.03	$3	$8,590
	Geotextile fabric under gravel base for pervious pavement	205	SY	$3	1.03	$3	$633
	Gravel base under pervious pavement path	180	CY	$75	1.03	$77	$13,905
	Pervious pavement for path	205	SY	$100	1.03	$103	$21,115
	Oak Trees	7	EA	$330	1.03	$340	$2,379
	Trees	30	EA	$330	1.03	$340	$10,197
	Platform (10' - see Meraux Spillway for details)	250	LF	$75	1.00	$75	$18,750
	Total Excavation / Installation						$118,521
	Total Lateral Canal Section D costs						**$218,521**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	New Perpendicular Canal						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000.00	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill for new canal, bioswale, and permeable paving	17010	CY	$15	1.03	$15.45	$262,805
	Disposal at landfill	17010	CY	$3	1.03	$3.09	$52,561
	New sloped curb with cuts	1640	LF	$13.55	1.00	$14	$22,222
	Geotextile fabric under gravel base for pervious pavement, bioswales	2920	SY	$3	1.03	$3.09	$9,023
	Gravel base under pervious pavement sidewalk, bioswales	1765	CY	$75	1.03	$77.25	$136,346
	Pervious pavement for sidewalk	1825	SY	$100	1.03	$103.00	$187,975
	Bioretention soil under bioswale	730	CY	$37	1.03	$38.11	$27,820
	Bioswale plantings	1095	SY	$11	1.03	$11.33	$12,406
	Cypress Trees	82	EA	$330	1.03	$339.90	$27,872
	Hydroseed vegetation buffer	9840	SF	$0.15	1.03	$0.15	$1,520
	Total Excavation / Installation						$740,550
	Total New Perpendicular Canal costs						**$840,550**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Bioswale Pedestrian Crossing						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill under pervious paving	50	CY	$15	1.03	$15.45	$ 773
	Disposal at landfill	50	CY	$3	1.03	$3.09	$ 155
	Geotextile fabric under gravel base for pervious pavement	45	SY	$3	1.03	$3.09	$ 139
	Gravel base under pervious pavement	25	CY	$75	1.03	$77.25	$ 1,931
	Pervious pavement (12:1 slope ADA Accessible)	45	SY	$100	1.03	$103.00	$ 4,635
	Total Excavation / Installation						$7,632
	Total Bioswale Pedestrian Crossing						**$7,632**

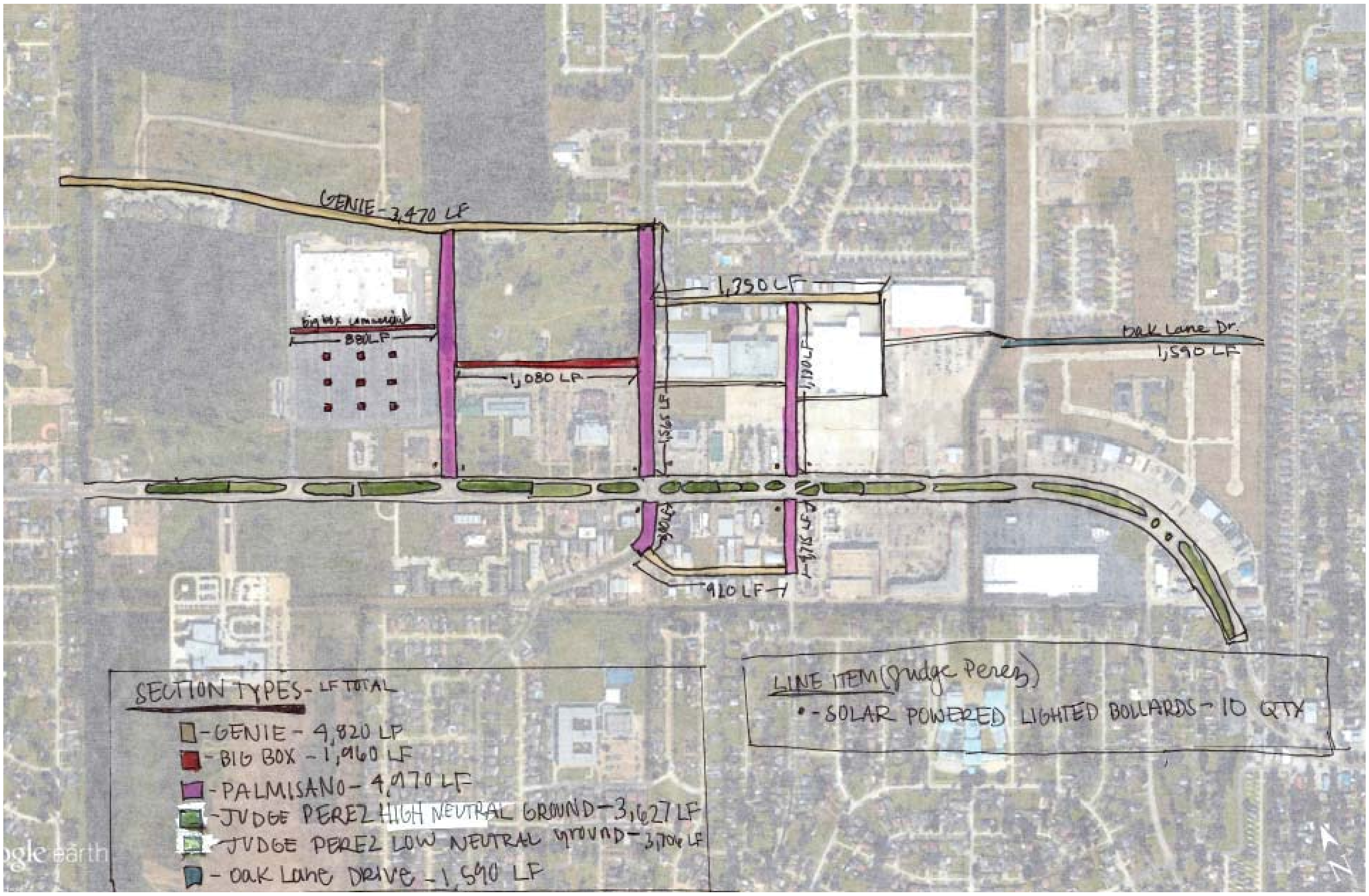
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Urban Weir, qty (3)						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Excavation / Installation*						
	Excavation and transport to landfill	3186	CY	$15	1.03	$15.45	$49,224
	Select fill	2462	CY	$20	1.03	$20.60	$50,717
	Envirogrid	4992	SF	$1.16	1.00	$1.16	$5,791
	Timber pedestrian bridge over weir	3	EA	$800	1.00	$800.00	$2,400
	10' Boardwalk	150	LF	$45	1.00	$45	$6,750
	Wood planks	450	LF	$15	1.00	$15	$6,750
	Wood Staircase	6	EA	$550	1.00	$550	$3,300
	Cypress trees	30	EA	$330	1.03	$339.90	$10,197
	Total Excavation / Installation						$135,129
	Total Urban Weirs (3) costs						**$235,129**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Plaza Crossing						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	*Installation*						
	45' wide Plaza Crossing Decking with railing	312	LF	$350	1.00	$350	$109,200
	Total Installation						$109,200
	Total Plaza Crossing						**$209,200**

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Pedestrian Bridge						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
1	*Installation*						
	Pedestrian bridge (10' wide)	104	LF	$75	1.00	$75	$7,800
	Railings and trim	104	LF	$9.65	1.00	$10	$1,004
	Total Installation						$8,804
	Total Pedestrian Bridge						**$108,804**

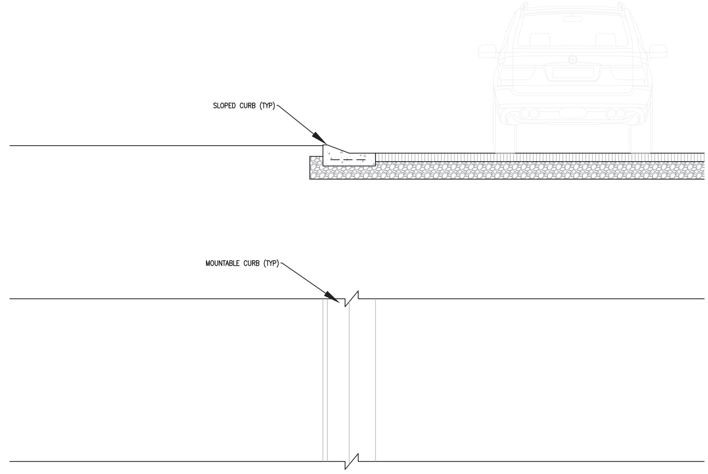
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Bioswale Weir						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
1	*Installation*						
	Concrete foundation (4" x 6" x 2')	1	CY	$100	1.00	$100	$100
	Corten steel plate (1" x 2.5')	3	LENGTH	$9,500	1.00	$9,500	$28,500
	Steel angle	30	LENGTHS	$35	1.00	$35	$1,050
	Total Installation						$29,650
	Total Bioswale Weir						**$29,650**

BMPs/COMMERCIAL STREET RETROFITS

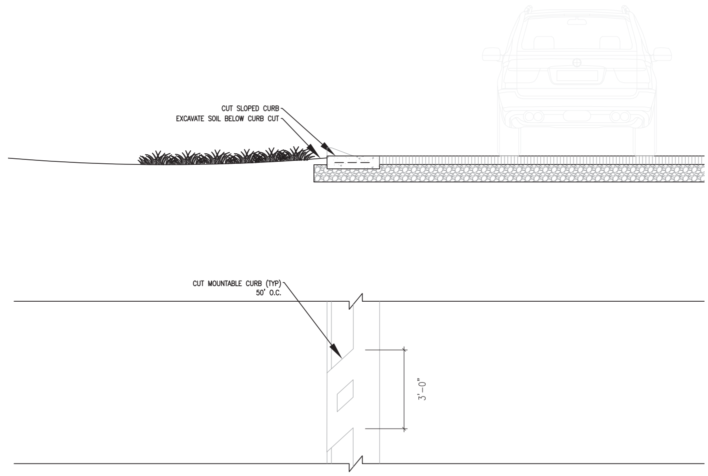


Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**Bioswale 1**	$3,677,303	$ 220,638	$ 367,730	$ 110,319	$ 73,546	$ 4,449,537	$1,334,861	$ 5,784,398	LF	$ 613.21
2	**Bioswale 2**	$ 974,641	$ 58,478	$ 97,464	$ 29,239	$ 19,493	$ 1,179,315	$ 353,795	$ 1,533,110	LF	$ 689.04
3	**Recreational Space**	$ 145,840	$ 8,750	$ 14,584	$ 4,375	$ 2,917	$ 176,467	$ 52,940	$ 229,407	SF	$ 2.29
4	**Bioswale Pedestrian Crossing**	$ 107,632	$ 6,458	$ 10,763	$ 3,229	$ 2,153	$ 130,235	$ 39,071	$ 169,306	EA	$ 42,326.40
5	**Bioswale Weir**	$ 129,650	$ 7,779	$ 12,965	$ 3,890	$ 2,593	$ 156,877	$ 47,063	$ 203,939	EA	$ 67,979.82
6	**Lateral Canal Section A**	$1,540,555	$ 92,433	$ 154,055	$ 46,217	$ 30,811	$ 1,864,071	$ 559,221	$ 2,423,292	LF	$ 1,429.67
7	**Lateral Canal Section B**	$ 239,400	$ 14,364	$ 23,940	$ 7,182	$ 4,788	$ 289,674	$ 86,902	$ 376,577	LF	$ 941.44
8	**Lateral Canal Section C**	$ 579,450	$ 34,767	$ 57,945	$ 17,383	$ 11,589	$ 701,134	$ 210,340	$ 911,474	LF	$ 911.47
9	**Lateral Canal Section D**	$ 218,521	$ 13,111	$ 21,852	$ 6,556	$ 4,370	$ 264,410	$ 79,323	$ 343,733	LF	$ 1,374.93
10	**New Perpendicular Canal**	$ 840,550	$ 50,433	$ 84,055	$ 25,217	$ 16,811	$ 1,017,066	$ 305,120	$ 1,322,185	LF	$ 806.21
11	**Plaza Crossing**	$ 209,200	$ 12,552	$ 20,920	$ 6,276	$ 4,184	$ 253,132	$ 75,940	$ 329,072	SF	$ 81.25
12	**Pedestrian Bridge**	$ 108,804	$ 6,528	$ 10,880	$ 3,264	$ 2,176	$ 131,652	$ 39,496	$ 171,148	LF	$ 1,645.65
13	**Urban Weir**	$ 235,129	$ 14,108	$ 23,513	$ 7,054	$ 4,703	$ 284,506	$ 85,352	$ 369,857	EA	$123,285.77
	Total Cost	$9,006,674	$ 540,400	$ 900,667	$ 270,200	$ 180,133	$10,898,075	$3,269,423	$ 14,167,498		

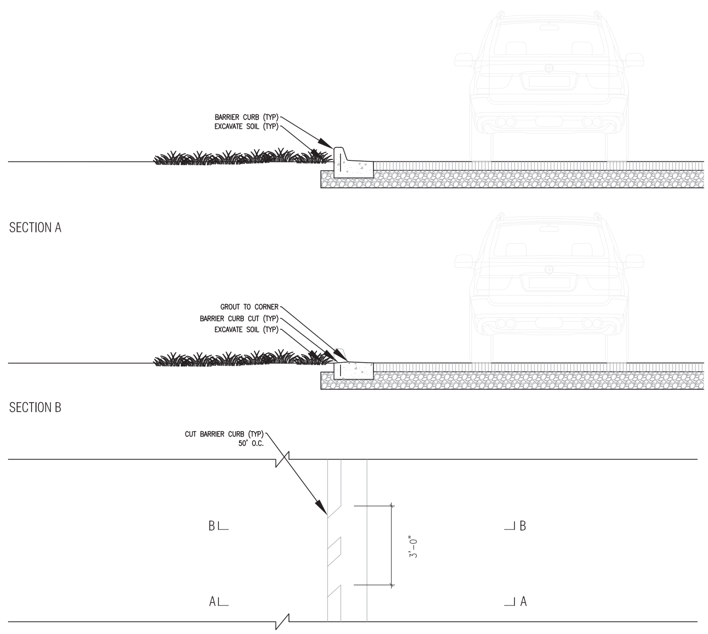
EXISTING CURB

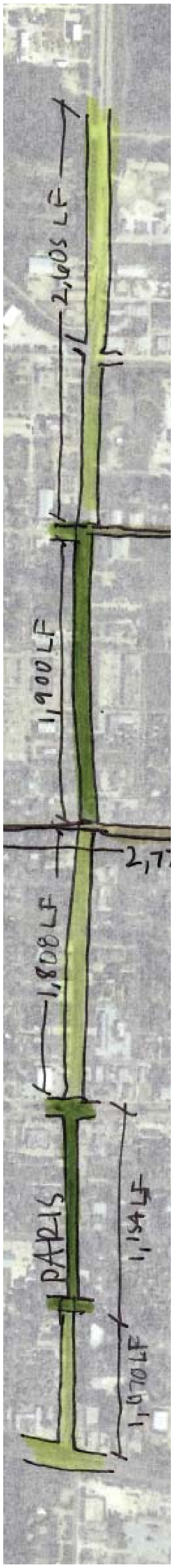


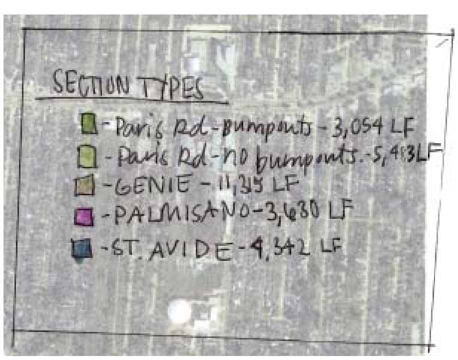
SLOPED CURB CUT



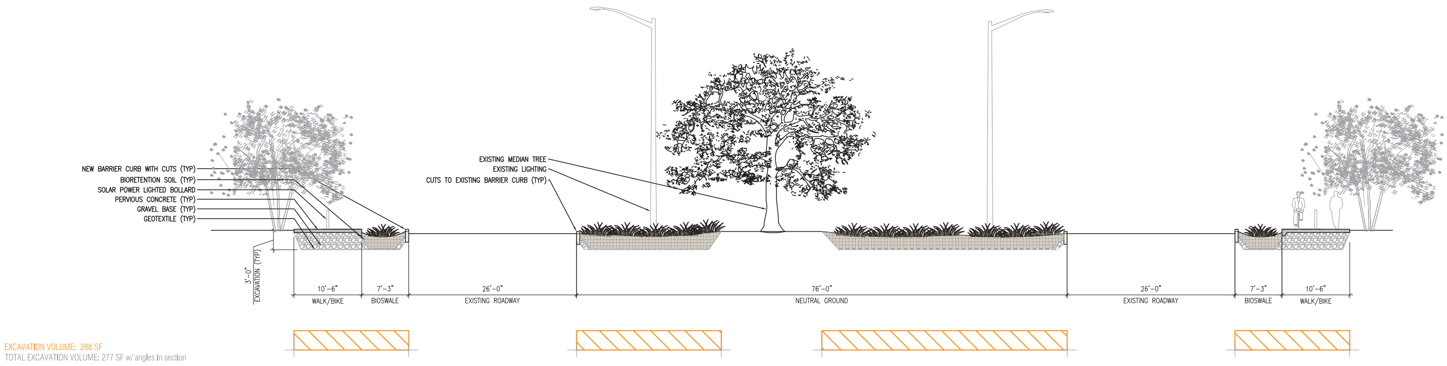
NEW BARRIER CURB WITH CUTS







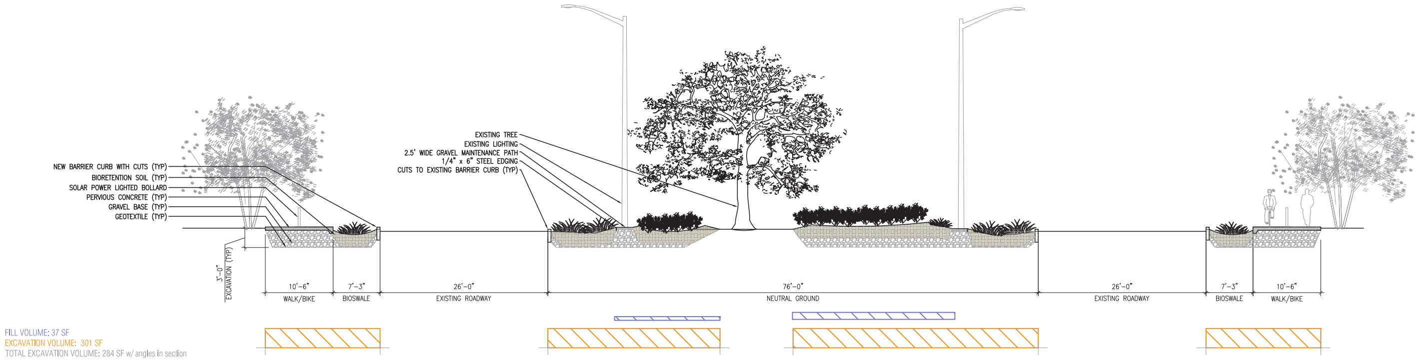
JUDGE PEREZ DR - LOW NEUTRAL GROUND



JUDGE PEREZ DR - EXISTING

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Sidewalk Sides of street (incl. both sides of street)***						
	Sawcut to remove existing curb	7412	LFT	$6.43	1.03	$7	$49,078
	Demolition and removal of curb and sidewalk	1715	CY	$40	1.03	$41	$70,658
	Excavation and transport to landfill of soil for area under pervious pavement and bioswale	14618	CY	$15	1.03	$15	$225,848
	Disposal of concrete and excavated material at landfill	1715	CY	$3	1.03	$3	$5,299
	New barrier concrete curb with cuts	7412	LF	$13.55	1.00	$14	$100,433
	Geotextile fabric under pervious pavement and bioswales	14618	SY	$3	1.03	$3	$45,170
	Gravel base under pervious pavement	7670	CY	$75	1.03	$77	$592,508
	Pervious pavement for walk / bike trail	8647	SY	$100	1.03	$103	$890,641
	Bioretention soil under bioswales	3981	CY	$37	1.03	$38	$151,716
	Bioswale plants	5971	SY	$11	1.03	$11	$67,651
	Trees	370	EA	$330	1.03	$340	$125,763
	Solar powered lighting bollards	10	EA	$300	1.03	$309	$3,090
	Total Sidewalk sides of street						$2,327,855
3	***Neutral Ground***						
	Cuts to existing barrier curb (both sides)	149	EA	$175	1.00	$175	$26,075
	Excavation and transport to landfill of soil for area under bioswales	24913	CY	$15	1.03	$15	$384,906
	Disposal of concrete and excavated material at landfill	24913	CY	$3	1.03	$3	$76,981
	Geotextile fabric under bioswales	24913	SY	$3	1.03	$3	$76,981
	Gravel layer under bioswale soil	8305	CY	$75	1.03	$77	$641,561
	Bioretention soil under bioswales	16608	CY	$37	1.03	$38	$632,931
	Bioswale plantings	24913	SY	$11	1.03	$11	$282,264
	Total Neutral Ground						$2,121,700
	Total Judge Perez Drive Low Neutral Ground costs						**$4,549,554**

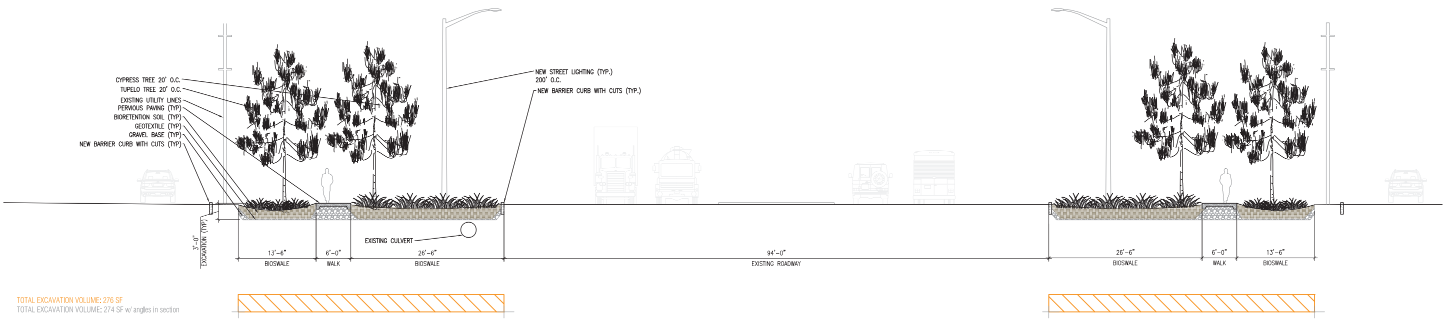
JUDGE PEREZ - HIGH NEUTRAL GROUND



Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Sidewalk Sides of street (inc. both sides of street)***						
	Sawcut to remove existing curb	7257	LFT	$6.43	1.03	$7	$48,052
	Demolition and removal of curb and sidewalk	1679	CY	$40	1.03	$41	$69,175
	Excavation and transport to landfill of soil for area under pervious pavement and bioswale	16724	CY	$15	1.03	$15	$258,386
	Disposal of concrete and excavated material at landfill	1679	CY	$3	1.03	$3	$5,188
	New barrier concrete curb with cuts	7257	LF	$14	1.00	$14	$98,332
	Geotextile fabric under pervious pavement and bioswales	14307	SY	$3	1.03	$3	$44,209
	Gravel base under pervious pavement	7505	CY	$75	1.03	$77	$579,761
	Pervious pavement for walk / bike trail	8463	SY	$100	1.03	$103	$871,689
	Bioretention soil under bioswales	3896	CY	$37	1.03	$38	$148,477
	Bioswale plants	5845	SY	$11	1.03	$11	$66,224
	Trees	363	EA	$330	1.03	$340	$123,384
	Solar powered lighting bollards	10	EA	$300	1.03	$309	$3,090
	Total Sidewalk sides of street						$2,315,966
3	***Neutral Ground***						
	Cuts to existing barrier curb (both sides of neutral ground)	146	EA	$175	1.00	$175	$25,550
	Excavation and transport to landfill of soil for area under bioswales, gravel maintenance path, and raised area	21158	CY	$15	1.03	$15	$326,891
	Disposal of concrete and excavated material at landfill	21158	CY	$3	1.03	$3	$65,378
	Geotextile fabric under bioswales	26095	SY	$3	1.03	$3	$80,634
	Gravel under bioswale soil	8700	CY	$75	1.03	$77	$672,075
	Installation of bioretention soil under bioswales	17397	CY	$37	1.03	$38	$663,000
	Fill material for raised area ("select fill")	4970	CY	$20	1.03	$21	$102,382
	Bioswale plantings	26095	SY	$11	1.03	$11	$295,656
	Plants in raised area	11285	SY	$11	1.03	$11	$127,859
	Total Neutral Ground						$2,359,425
	Total Judge Perez Drive High Neutral Ground costs						**$4,775,391**

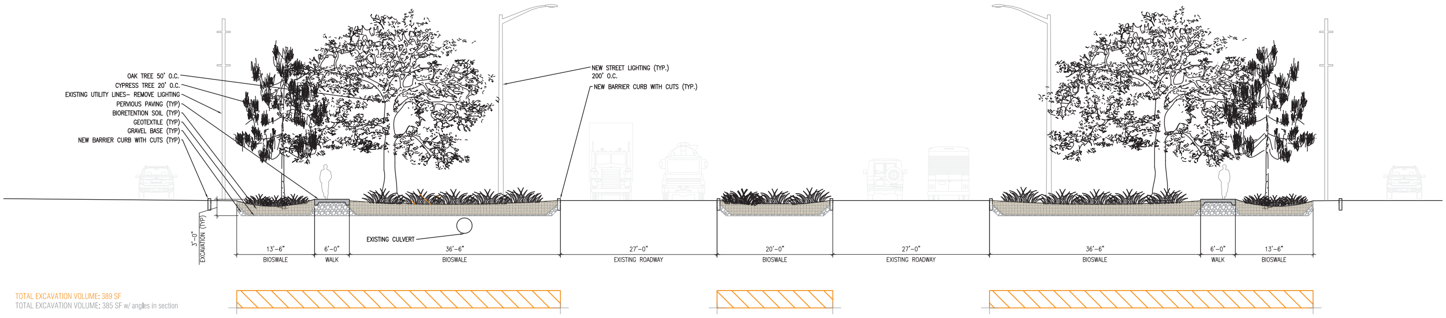
PARIS RD - EXISTING

PARIS RD - NO BUMPOUTS



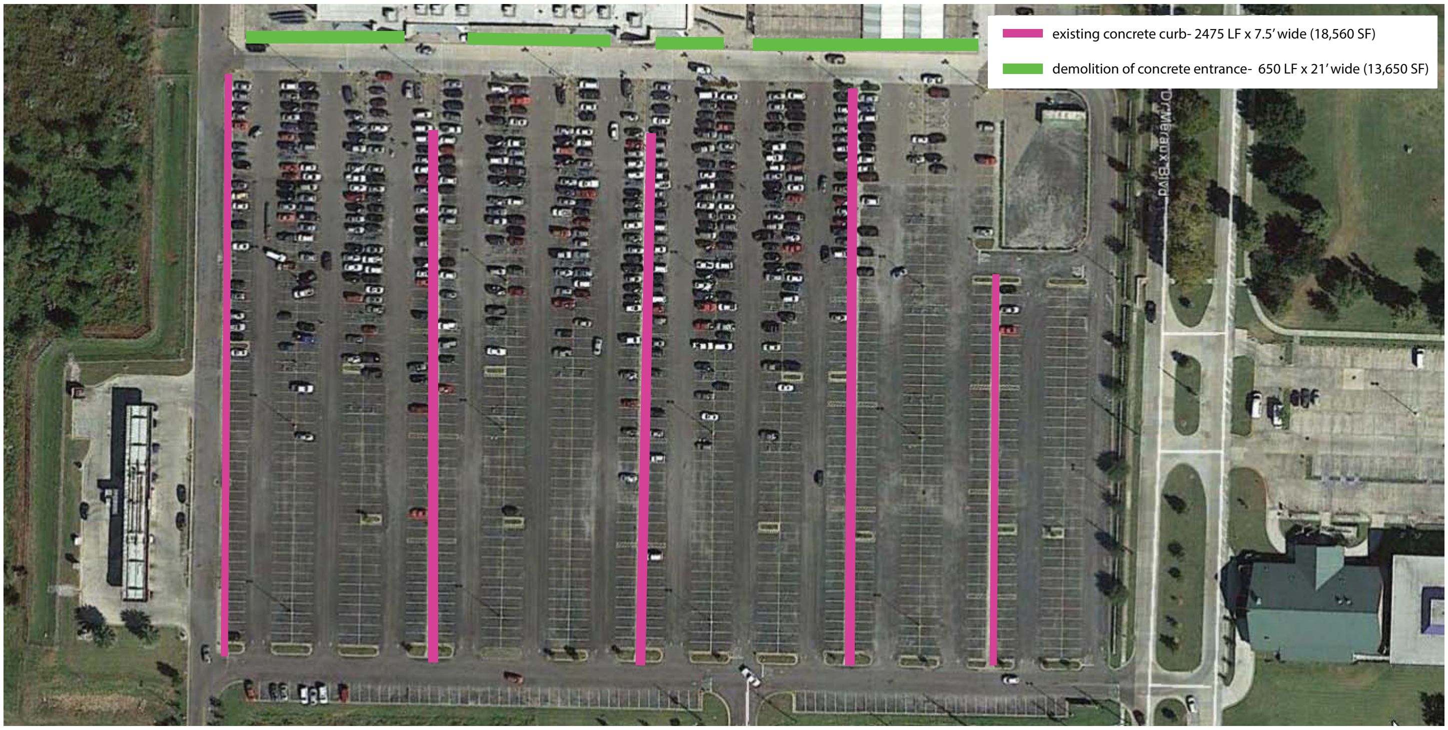
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Demolition***						
	Sawcut existing curb and roadway	10966	LFT	$6.43	1.03	$7	$72,611
	Demolition and removal of curb and street section	813	CY	$40	1.03	$41	$33,496
	Disposal at landfill	813	CY	$3	1.03	$3	$2,512
	Removal of existing street lighting	54	EA	$175	1.00	$175	$9,450
	Total Demolition						$118,068
3	***Installation***						
	Excavation under new bioswales and pervious pavement walk and transport to landfill	56048	CY	$15	1.03	$15	$865,942
	New barrier curb with cuts	10966	LF	$13.55	1.00	$14	$148,589
	Geotextile under pervious paving sidewalks and bioswales	56048	SY	$3	1.03	$3	$173,188
	Gravel base under pervious paving sidewalks and bioswale soil	22728	CY	$75	1.03	$77	$1,755,738
	Permeable pavement (sidewalks - 4" thick)	7311	SY	$100	1.03	$103	$753,033
	Bioretention soil under bioswales	48738	CY	$37	1.03	$38	$1,857,405
	Bioswale plantings	48740	SY	$11	1.03	$11	$552,224
	Tupelo trees (20' O.C.)	548	EA	$330	1.03	$340	$186,265
	Cypress trees (20' O.C.)	548	EA	$330	1.03	$340	$186,265
	New street lighting (200' O.C.)	54	EA	$2,675	1.00	$2,675	$144,450
	Total Installation						$6,623,100
	Total Paris Road no Bumpouts costs						**$6,841,168**

PARIS RD - BUMPOUTS

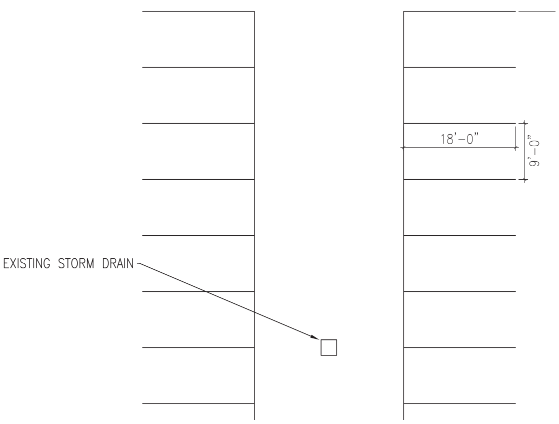


Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Demolition***						
	Sawcut existing curb and roadway	6108	LFT	$6.43	1.03	$6.62	$40,444
	Demolition and removal of curb and street section	6787	CY	$40	1.03	$41	$279,624
	Disposal at landfill	6787	CY	$3	1.03	$3	$20,972
	Removal of existing street lighting	31	EA	$175	1.00	$175	$5,425
	Total Demolition						$346,465
3	***Installation***						
	Excavation under new bioswales and pervious pavement walk and transport to landfill	25903	CY	$15	1.03	$15	$400,201
	New barrier curb with cuts	12216	LF	$13.55	1.00	$14	$165,527
	Geotextile under pervious paving sidewalks and bioswales	44792	SY	$3	1.03	$3	$138,407
	Gravel base under pervious paving sidewalks and bioswale soil	17184	CY	$75	1.03	$77	$1,327,464
	Permeable pavement (sidewalks - 4" thick)	4072	SY	$100	1.03	$103	$419,416
	Bioretention soil under bioswales	27147	CY	$37	1.03	$38	$1,034,572
	Bioswale plantings	40720	SY	$11	1.03	$11	$461,358
	Oak trees (50' O.C.)	122	EA	$330	1.03	$340	$41,468
	Cypress trees (20' O.C.)	306	EA	$330	1.03	$340	$104,009
	New street lighting (200' O.C.)	30	EA	$2,675	1.03	$2,755	$82,658
	Total Installation						$4,175,080
	Total Paris Road with Bumpouts costs						**$4,621,545**

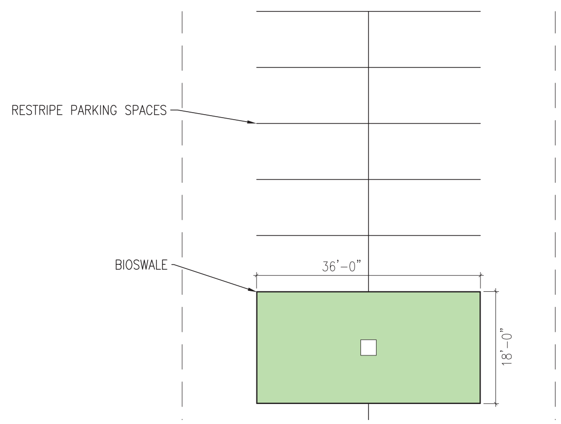
COMMERCIAL PARKING RETROFITS



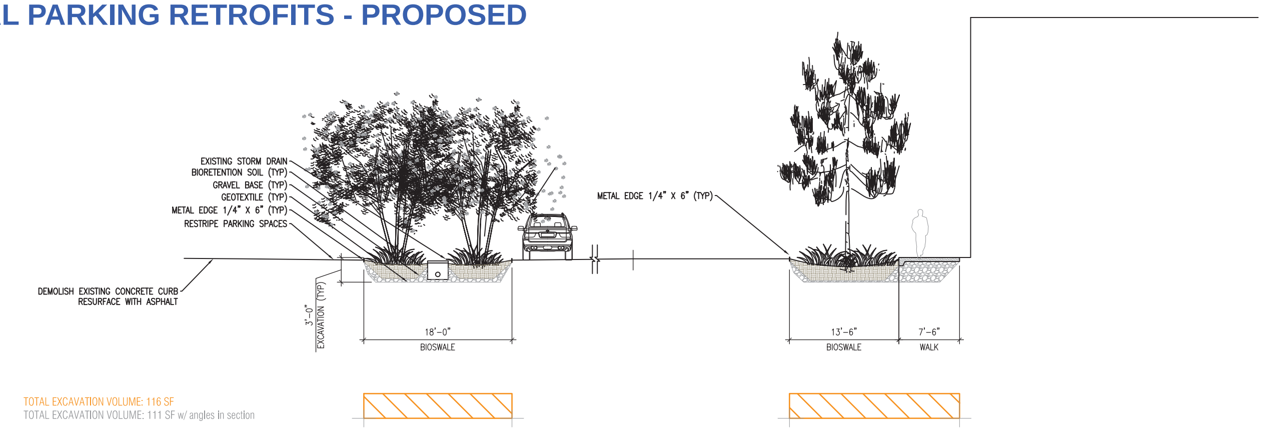
PARKING LOT BIOSWALE - EXISTING



PARKING LOT BIOSWALE - PROPOSED

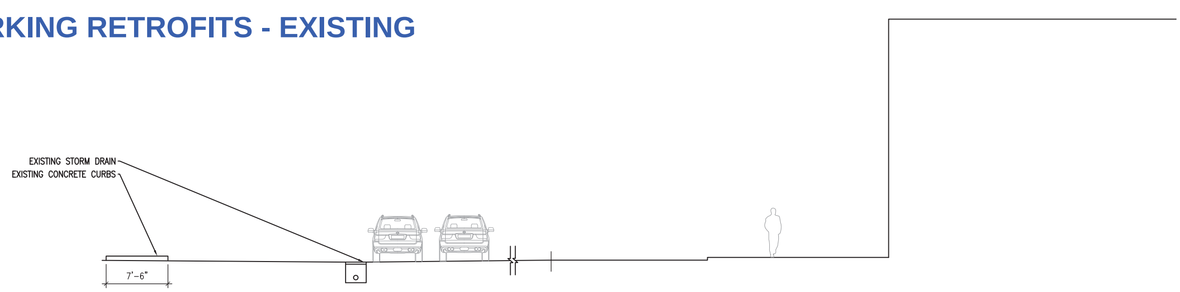


COMMERCIAL PARKING RETROFITS - PROPOSED

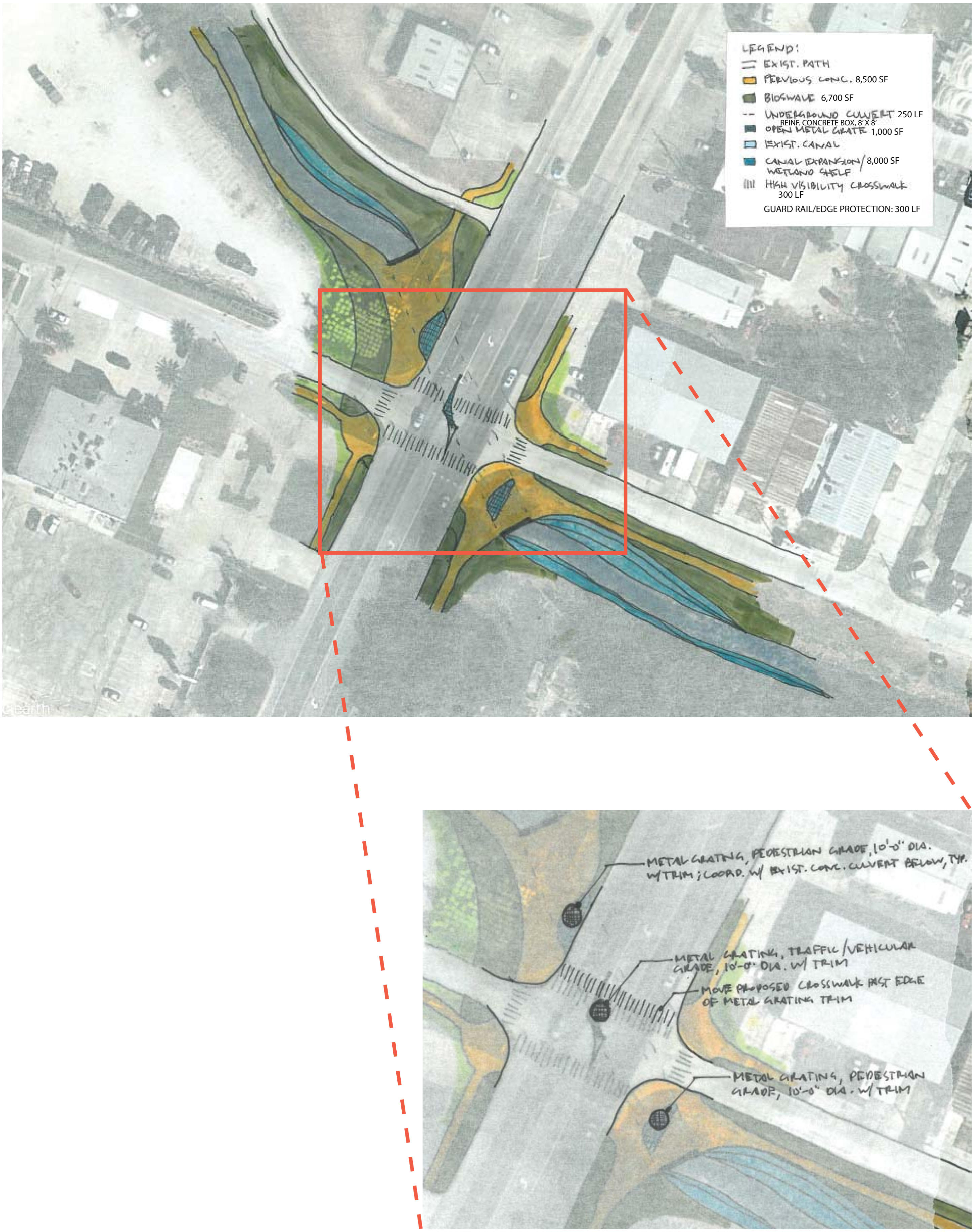


Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Parking Lot Bioswale, qty (25)***						
	Sawcut parking lot pavement to create drop inlet bioswales	25	EA	$694	1.03	$715	$17,871
	Demolition and removal of pavement in area of drop inlet bioswales	25	EA	$480	1.03	$494	$12,360
	Excavation and transport to landfill (for installation of bioretention soil base under parking lot bioswale)	25	EA	$1,080	1.03	$1,112	$27,810
	Disposal of pavement and soil at landfill	25	EA	$216	1.03	$222	$5,562
	Geotextile fabric in parking lot bioswales	25	EA	$216	1.03	$222	$5,562
	Installation of gravel base under parking lot bioswales	25	EA	$2,700	1.03	$2,781	$69,525
	Installation of bioretention soil under parking lot bioswale	25	EA	$2,664	1.03	$2,744	$68,598
	Installation of bioswale plantings in parking lot bioswales	25	EA	$264	1.03	$272	$6,798
	Installation of trees in parking lot bioswales (3 in each bioswale)	25	EA	$990	1.03	$1,020	$25,493
	Installation of metal strip around parking lot bioswale areas	25	EA	$1,188	1.00	$1,188	$29,700
	Total for (1) Parking Lot Bioswale	*1*	*EA*	*$10,492*	*1.03*	*$10,807*	*$10,807*
	Total Parking Lot Bioswales, qty (25)						$269,278
3	***Storefront***						
	Sawcut concrete walk from parking lot asphalt	650	LF	$6.43	1.03	$7	$4,304
	Sawcut concrete walk from front of building	650	LF	$6.43	1.03	$7	$4,304
	Demolition and removal of existing pavement along building entrance	1517	CY	$40	1.03	$41	$62,500
	Excavation and transport to landfill (under bioswale and pervious pavement)	1517	CY	$15	1.03	$15	$23,438
	Disposal of pavement and soil at landfill	3034	CY	$3	1.03	$3	$9,375
	Metal edge at front edge of store front bioswale	650	LF	$11	1.00	$11	$7,150
	Geotextile fabric in store front bioswales	975	SY	$3	1.03	$3	$3,013
	Geotextile fabric under gravel base for pervious pavement	542	SY	$3	1.03	$3	$1,675
	Permeable pavement (store front walk - 4" thick)	542	SY	$100	1.03	$103	$55,826
	Gravel base under store front bioswale and under pervious pavement	6484	CY	$75	1.03	$77	$500,889
	Installation of bioretention soil in storefront bioswale	650	CY	$37	1.03	$38	$24,772
	Installation of bioswale plantings	975	SY	$11	1.03	$11	$11,047
	Installation of trees in storefront bioswale	22	EA	$330	1.03	$340	$7,478
	Total Storefront						$715,770
4	***7'6" Parking Lot Curb Area***						
	Sawcut parking lot pavement to remove 7'6" curbs	2475	LF	$6.43	1.03	$7	$16,388
	Demolition and removal of 7'6" concrete curbs in parking lot	2063	CY	$40	1.03	$41	$84,996
	Disposal at landfill	2063	CY	$3	1.03	$3	$6,375
	Fill under new asphalt ("select fill")	2063	CY	$20	1.03	$21	$42,498
	Asphalt to cover removal of 7'6" curb in parking lot	18560	SF	$4.80	1.00	$5	$89,088
	Remove or paint over old parking stripes	12650	LF	$0.32	1.00	$0.32	$4,048
	Restripe parking spaces	12650	LF	$1.55	1.00	$2	$19,608
	Total 7'6" Parking Lot Curb Area						$263,000
	Total Commercial Parking Retrofits costs						**$1,348,047**

COMMERCIAL PARKING RETROFITS - EXISTING



PARIS RD ENTRY



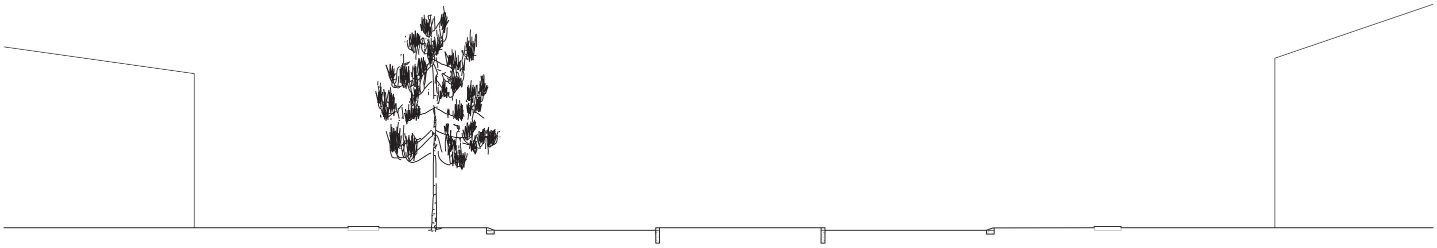
Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
	Paris Road Intersection Grating						
1	*Mobilization/Demobilization*						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob					$0	$100,000
2	*In street*						
	Traffic diversion	40	PER HR	$50.00	1.00	$50	$2,000
	Saw cut existing roadway	105	LFT	$6.43	1.03	$7	$695
	Saw cut existing concrete culvert	105	LFT	$6.43	1.03	$7	$695
	Excavate / transport to landfill	15	CY	$15	1.03	$15	$232
	Disposal at landfill	15	CY	$3	1.03	$3	$46
	Concrete - cylindrical unit w/ metal rim for grating on top	1	EA	$3,500.00	1.03	$3,605	$3,605
	Metal grating - vehicular grade - 10' diameter	1	EA	$12,000	1.00	$12,000	$12,000
	Back fill area around concrete cylinder	5	CY	$20	1.03	$21	$103
	Replace asphalt roadway	500	SF	$4.80	1.00	$5	$2,400
	High visibility crosswalk painting	300	LF	$1.55	1.00	$2	$465
	Total In Street						$22,242
3	*Pedestrian Areas*						
	Excavation and *transport to landfill* for areas underneath pervious paving and bioswale, and wetland shelf	2580	CY	$15	1.03	$15	$39,861
	Saw cut existing concrete culvert	145	LFT	$6.43	1.03	$7	$960
	Disposal at landfill	2580	CY	$3	1.03	$3	$7,972
	Concrete - cylindrical unit	2	EA	$4,500	1.00	$4,500	$9,000
	Metal grating - pedestrian grade - 10' diameter	2	EA	$12,000	1.00	$12,000	$24,000
	Geotextile fabric under gravel base for pervious pavement and under bioswales	1690	SY	$3	1.03	$3	$5,222
	Crushed stone base under pervious pavement and under bioswale soil	745	CY	$75	1.03	$77	$57,551
	Pervious pavement	945	SY	$100	1.03	$103	$97,335
	Bioswale soil	497	CY	$37	1.03	$38	$18,941
	Bioswale plants	745	SY	$11	1.03	$11	$8,441
	Wetland Shelf Plants	890	SY	$11	1.03	$11	$10,084
	Total Pedestrian Areas						$279,367
	Total Paris Road Intersection costs						**$401,608**

Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**West side (Virtue at La Fontaine)**	$ 957,177	$ 57,431	$ 95,718	$ 28,715	$ 19,144	$ 1,158,184	$ 347,455	**$ 1,505,639**	**LF**	$ 725.61
2	**East side (Virtue at LaPlace, at Richilieu)**	$ 968,360	$ 58,102	$ 96,836	$ 29,051	$ 19,367	$ 1,171,715	$ 351,515	**$ 1,523,230**	**LF**	$ 967.13
3	**Platform with Deck**	$ 108,625	$ 6,518	$ 10,863	$ 3,259	$ 2,173	$ 131,436	$ 39,431	**$ 170,867**	**SF**	$ 179.86
4	**Paris Road Intersection**	$ 401,608	$ 24,097	$ 40,161	$ 12,048	$ 8,032	$ 485,946	$ 145,784	**$ 631,730**	**LF**	$ 902.47
5	**Val Riess Park**	$ 2,408,863	$ 144,532	$ 240,886	$ 72,266	$ 48,177	$ 2,914,725	$ 874,417	**$ 3,789,142**	**SF**	$ 30.63
	Total Cost	$ 4,844,633	$ 290,678	$ 484,463	$ 145,339	$ 96,893	$ 5,862,006	$ 1,758,602	**$ 7,620,608**		

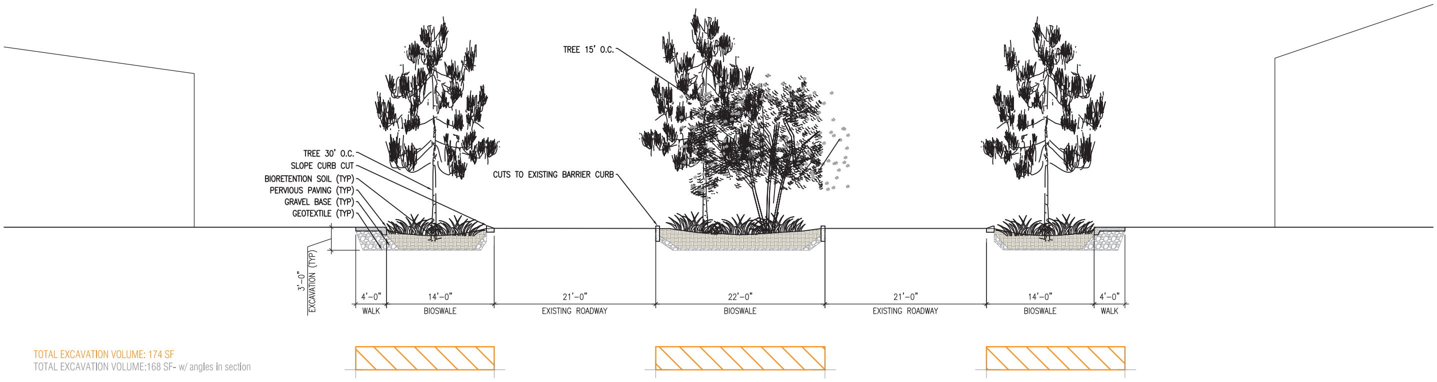
GREEN GRID

Item	Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
			6%	10%	3%	2%		30%			
1	**Genie Street**	$ 4,315,658	$ 258,939	$ 431,566	$ 129,470	$ 86,313	$ 5,221,947	$ 1,566,584	$ 6,788,530	LF	$599.96
2	**Palmisano Blvd.**	$ 2,457,918	$ 147,475	$ 245,792	$ 73,738	$ 49,158	$ 2,974,081	$ 892,224	$ 3,866,305	LF	$1,065.10
	Total Cost	$ 6,773,576	$ 406,415	$ 677,358	$ 203,207	$ 135,472	$ 8,196,027	$ 2,458,808	**$ 10,654,835**		

PALMISANO BLVD - EXISTING

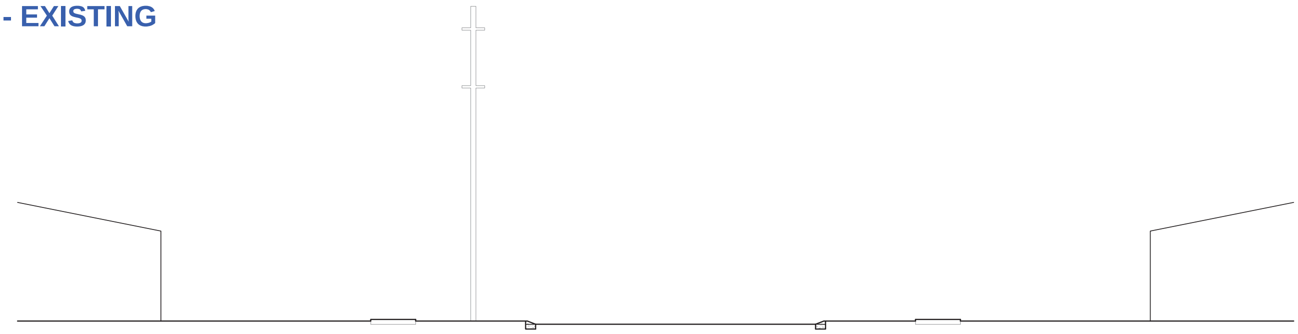


PALMISANO BLVD - PROPOSED

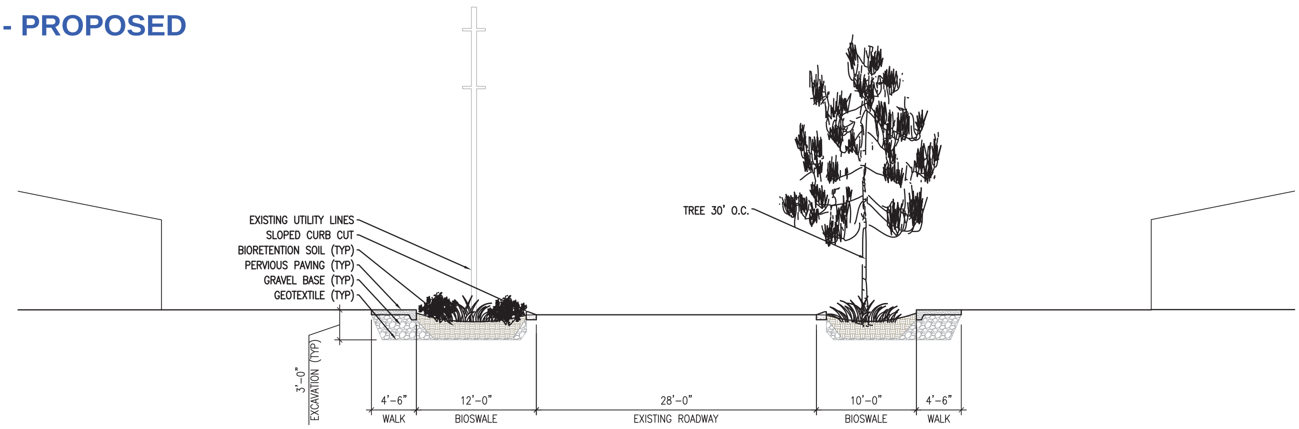


Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Sidewalk sides of street (incl. both sides of street)***						
	Saw cut existing curb and excavate to create sloped curb cuts (50' O.C.) on both sides of street	146	EA	$175.00	1.00	$175	$25,550
	Demolition and removal of sidewalk	1076	CY	$40	1.03	$41	$44,331
	Excavation and transport to landfill of soil for area under pervious pavement and bioswale	14520	CY	$15	1.03	$15	$224,334
	Disposal of concrete and excavated material at landfill	14520	CY	$3	1.03	$3	$44,867
	Geotextile fabric under pervious pavement and bioswales	14520	SY	$3	1.03	$3	$44,867
	Gravel base under pervious pavement and gravel layer under bioswale soil	6625	CY	$75	1.03	$77	$511,781
	Pervious pavement for walk	1076	SY	$100	1.03	$103	$110,828
	Bioretention soil under bioswales	7529	CY	$37	1.03	$38	$286,930
	Bioswale plants	11293	SY	$11	1.03	$11	$127,950
	Trees	242	EA	$330	1.03	$340	$82,256
	Total Sidewalk sides of street						$1,503,694
3	***Neutral Ground***						
	Cuts to existing barrier curb (both sides)	146	EA	$175.00	1.00	$175	$25,550
	Excavation and transport to landfill of soil for area under bioswales	8873	CY	$15	1.03	$15	$137,088
	Disposal of concrete and excavated material at landfill	8873	CY	$3	1.03	$3	$27,418
	Geotextile fabric under bioswales	8873	SY	$3	1.03	$3	$27,418
	Gravel under bioswale soil	2958	CY	$75	1.03	$77	$228,506
	Installation of bioretention soil under bioswales	5916	CY	$37	1.03	$38	$225,459
	Bioswale plantings	8873	SY	$11	1.03	$11	$100,531
	Trees (15' O.C.)	242	EA	$330	1.03	$340	$82,256
	Total Neutral Ground						$854,224
	Total Palmisano Blvd. costs						**$2,457,918**

GENIE ST - EXISTING



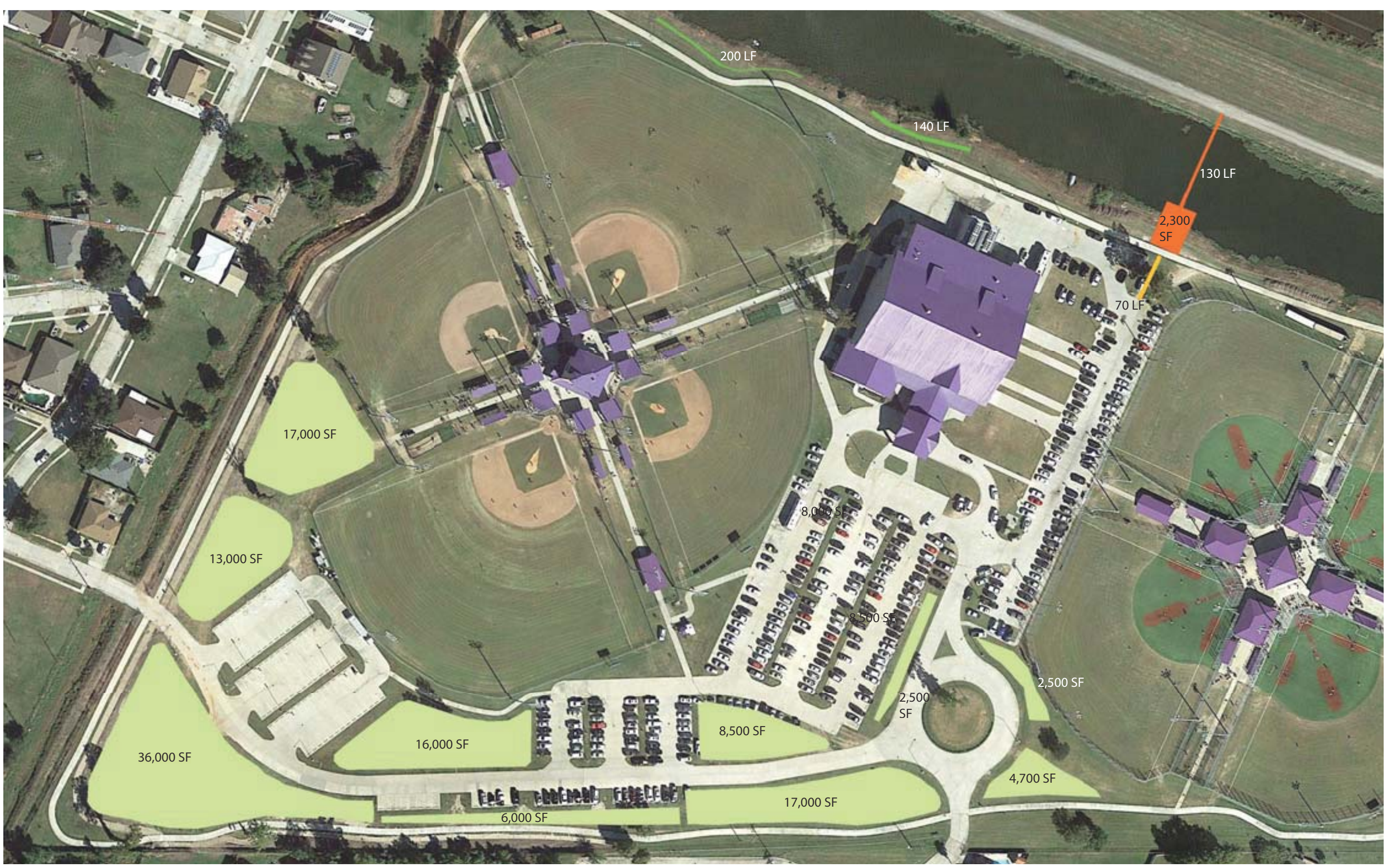
GENIE ST - PROPOSED



TOTAL EXCAVATION VOLUME: 93 SF
TOTAL EXCAVATION VOLUME: 89 SF w/ angles in section

Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Demolition***						
	Demolition and removal of sidewalk	4715	CY	$40	1.03	$41	$194,258
	Saw cut existing curb and excavate to create sloped curb cuts (50' O.C.) on both sides of street	452	EA	$175.00	1.00	$175	$79,100
	Disposal at landfill	4715	CY	$3	1.03	$3	$14,569
	Total Demolition						$287,927
3	***Earthwork***						
	Excavation under new sidewalk (Excavation and transportation to landfill)	11315	CY	$15	1.03	$15	$174,817
	Excavation under bioswale	27659	CY	$15	1.03	$15	$427,332
	Disposal at landfill	38974	CY	$3	1.03	$3	$120,430
	Geotextile fabric under bioswale	27659	SY	$3	1.03	$3	$85,466
	Bioswale soil	18439	CY	$37	1.03	$38	$702,710
	Bioswale plants - Wetlands Plants	27659	SY	$11	1.03	$11	$313,376
	Installation of trees (30' O.C.)	377	EA	$330	1.03	$340	$128,142
	Total Earthwork						$1,952,273
4	***Pavement***						
	Permeable pavement (sidewalks - 4" thick)	11315	SY	$100	1.03	$103	$1,165,445
	Crushed stone base under pervious pavement and under bioswale soil	10033	CY	$75	1.03	$77	$775,049
	Geotextile fabric under gravel base for pervious pavement	11315	SY	$3	1.03	$3	$34,963
	Total Pavement & Sidewalks						$1,975,458
	Total Genie Street costs						**$4,315,658**

VAL RIESS PARK

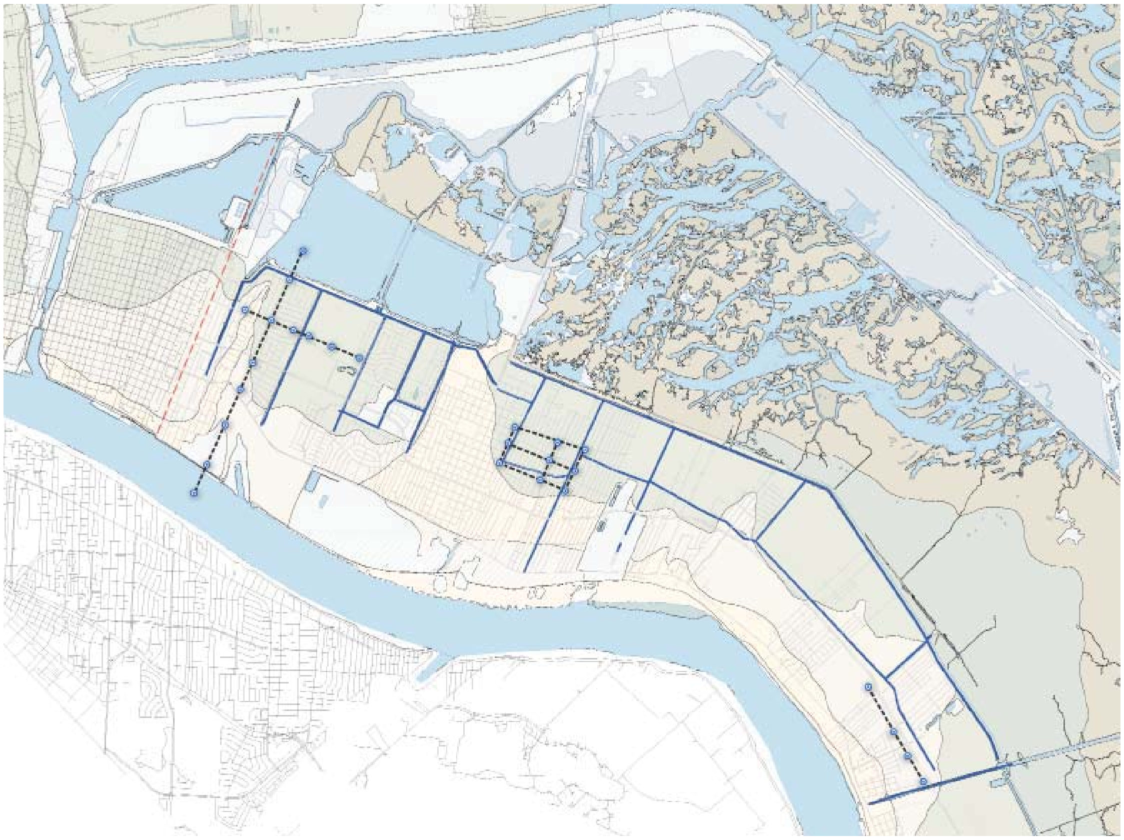


Item	Description	Qty	Units	2013 Unit Material Cost ($)	2013 to 2015 Multiplier	2015 Unit Material Cost ($)	Total Cost ($)
1	***Mobilization/Demobilization***						
	Mobilization/Demobilization	1	LUMP	$100,000	1.00	$100,000	$100,000
	Total Mob/Demob						$100,000
2	***Excavation / Fill***						
	Excavate under bioswales (and transport to landfill)	6010	CY	$15	1.03	$15	$92,855
	Fill to create berms	4730	CY	$20	1.03	$21	$97,438
	Disposal at landfill	6010	CY	$3	1.03	$3	$18,571
	Geotextile under gravel path	78	SY	$3	1.03	$3	$240
	Gravel for gravel path	26	CY	$75	1.03	$77	$2,009
	Hydroseed berms	42575	SF	$0.15	1.03	$0.15	$6,578
	Total Excavation / Fill						$217,690
3	***Bioswales***						
	Geotextile under gravel layer	9015	SY	$3	1.03	$3	$27,856
	Gravel under bioswale soil	3005	CY	$75	1.03	$77	$232,136
	Bioswale soil	6010	CY	$37	1.03	$38	$229,041
	Bioswale plants	9015	SY	$11	1.03	$11	$102,140
	Total Bioswales						$591,174
4	***Pedestrian Bridge***						
	Pedestrian Bridge	200	LF	$7,500	1.00	$7,500	$1,500,000
	Total Pedestrian Bridge						$1,500,000
	Total Val Riess Park costs						**$2,408,863**

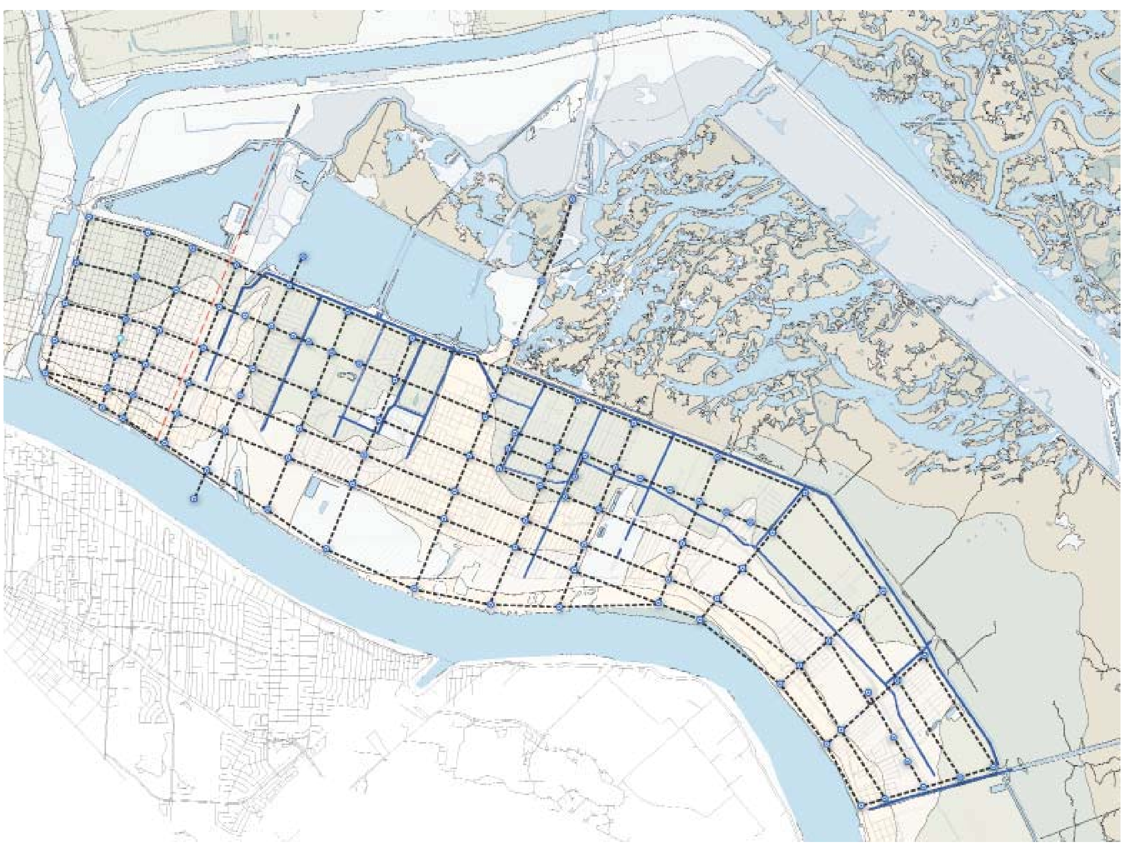
Name	Initial Total	Architecture /Landscape	Engineering	Construction Management	Legal/Public relations	Subtotal	Contingency	Grand Total	Overall Unit	Unit Cost
		6%	10%	3%	2%		30%			
Val Riess Park	$ 2,408,863	$ 144,532	$ 240,886	$ 72,266	$ 48,177	$ 2,914,725	$ 874,417	**$ 3,789,142**	**SF**	$ 30.63

GROUNDWATER MONITORING SYSTEM

PHASE 1



FULL NETWORK

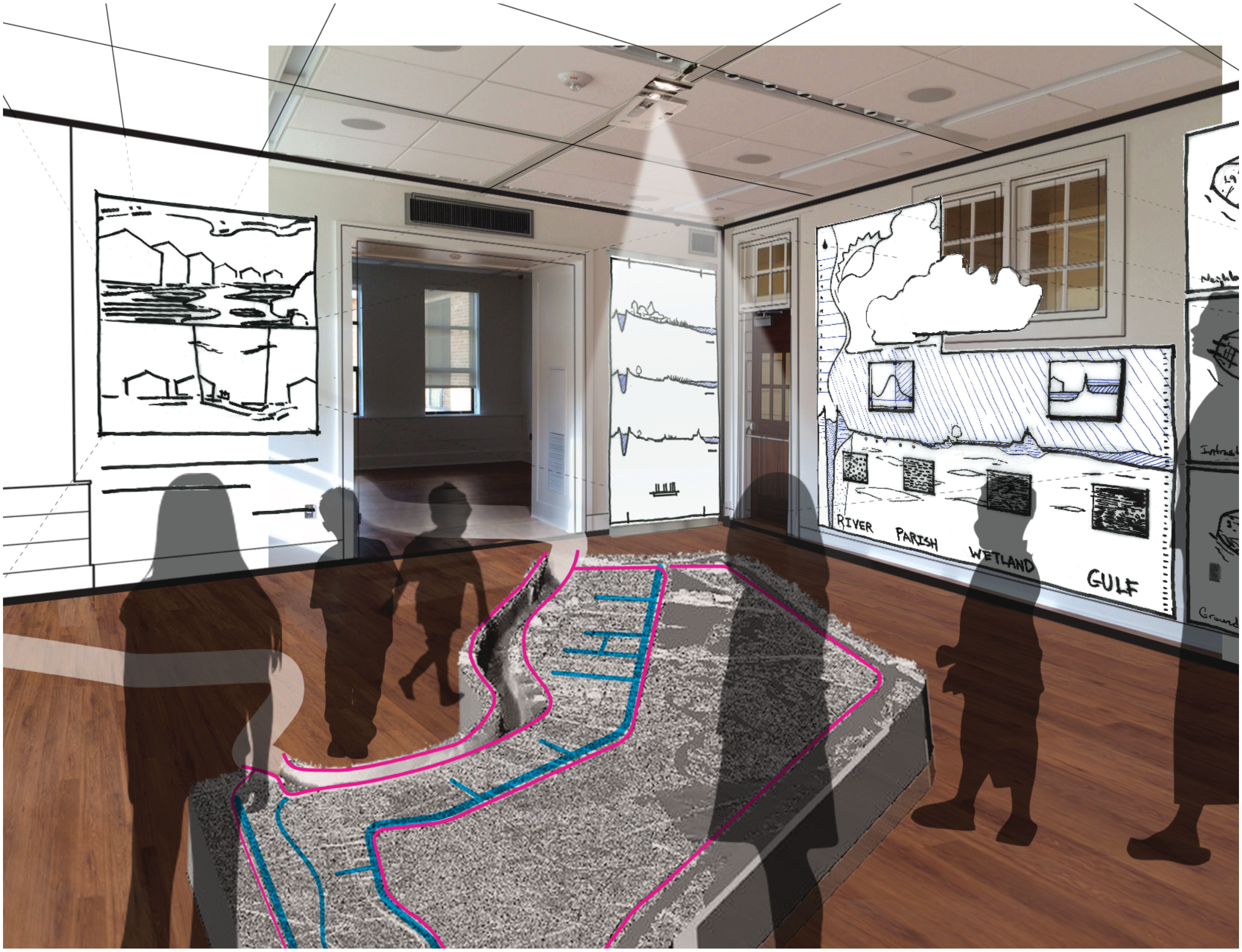


Item	Description	Qty	Units	2015 Unit Material Cost ($)	Total Cost ($)
	Groundwater Monitoring				
1	*Mobilization/Demobilization*				
	Mobilization/Demobilization	2	HOUR	$107	$214
	Total Mob/Demob, qty (4)				$214
2	*PVC piezometer*				
	Develop piezometers	2	HOUR	$107	$214
	Drill crew (incl. sampling)	24	HOUR	$195	$4,680
	Well registration	1	HOUR	$115	$115
	Well supplies	1	LUMP	$1,000	$1,000
	PVC piezometer, qty (4)				$6,009
4	*Administrative costs*				
	Project Manager	2	HOUR	$155	$310
	Associate Engineer	8	HOUR	$85	$680
	Administration	6	HOUR	$55	$330
	Total Administrative costs, qty (4) monitoring wells				$1,320
	subtotal for four (4) monitoring wells	4	EA		$7,543
	subtotal for each monitoring well	1	EA		**$1,886**
	Total Groundwater Monitoring costs, Phase I	24	EA		**$45,258**
	Total Groundwater Monitoring costs, Full Network	60	EA		**$113,145**

Alternate

Item	Description	Qty	Units	2015 Unit Material Cost ($)	Total Cost ($)
2	*Alternate: VW piezometer*				
	VW piezometers, 50 psi	4	EA	$471	$1,884
	Drill crew (incl. sampling)	16	HOUR	$195	$3,120
	Signal cable	250	FT	$1	$260
	12 in steel well cover and installation	1	EA	$100	$100
	1 in dia. PVC piezometer anchor pipe	1	EA	$75	$75
	VW quattro logger	1	EA	$1,440	$1,440
	VW piezometer, qty (4)				$6,879
4	Total Administrative costs, qty (4) monitoring wells				$1,320
	subtotal for four (4) monitoring wells	4	EA		$8,413
	subtotal for each monitoring well	1	EA		**$2,103**
	Total Groundwater Monitoring costs, Phase I	24	EA		**$50,478**
	Total Groundwater Monitoring costs, Full Network	60	EA		**$126,195**

MODEL



COMPONENTS (costs include design, materials, labor, and installation)	
Projector, Mount, and Computer Station	$5,363.00
96" x 144" Topographical Model and Base	$33,068.00
Base Projections (e.g., drainage system, hydrology, flood risk, soils, topography, land cover, streets and neighborhoods)	$4,200.00
Two (2) Teacher/Staff Workshops (determine content of boards & materials)	$1,600.00
Floor Graphic	$1,680.00
Display Boards to complement model	$20,000.00
Public Lab Workshops (open source software and mapping)	$4,500.00
One (1) Training Workshops for Maumus Staff and Teachers	$800.00
Total	**$71,211.00**
ADDITIONAL COMPONENTS	
Interactive Materials for manipulating model surface	$8,000.00
Eight (8) eight-inch 3-D Printed Models for Small Group/Individual Student Use	$3,600.00
Additional Consultation on Open-Source Mapping, Projections, and Modeling	$3,200.00
Additional Consultation and Workshops on Curriculum Development	$4,000.00
Operations and Maintenance (Repairs, licenses, bulbs, and general upkeep)	TBD
Total	**$18,800.00**
	Min.

*based on cost estimate from 2015

Hydrologic and Hydraulic Modeling of Proposed Interventions for the St. Bernard Parish Integrated Water Management Plan

Prepared by:
Gaea Consultants
536 Washington Avenue
New Orleans, LA 70130

Prepared for:
Waggonner & Ball Architects
2200 Prytania Street
New Orleans, LA 70130

Contents

1. Introduction

Waggonner & Ball hired Gaea Consultants to perform hydrologic and hydraulic modeling to assess various interventions proposed as part of St. Bernard Parish's Integrated Water Resources Management Plan (IWRMP). The intent of the IWRMP is to develop strategies for mitigating flooding and subsidence and to turn drainage features into amenities for the community.

The study area includes New Orleans' Lower Ninth Ward (between the Industrial Canal and St. Bernard Parish) and the portions of St. Bernard Parish that are protected by levees. The existing system is essentially divided into three basins: the Ninth Ward, St. Bernard Parish northwest of Violet Canal, and St. Bernard Parish southeast of Violet Canal. In St. Bernard Parish, storm water flows through underground drainage to open canals. The canals flow to 40 Arpent Canal along the storm protection levee northeast of the Parish's most populated areas. Five pump stations northwest of Violet Canal and two pump stations southeast of Violet Canal pump water out of the protected area and into the surrounding wetlands. In the Ninth Ward, a predominately underground system conveys storm water to Drainage Pump Station 5 (DPS05), which pumps the water into the Central Wetland.

2. Model of Existing Conditions

Waggonner & Ball provided Gaea Consultants with an EPA Storm Water Management Model (SWMM) representation of the existing conditions. CDM Smith developed the original model. The SWMM program models the hydrologic and hydraulic components of a drainage system simultaneously. Gaea Consultants worked under the assumption that the existing model was accurate and used it to test the effects of various interventions separately and in combination.

2.1 Subcatchments

The hydrologic portion of the SWMM model includes subcatchments which define areas that drain to single points. CDM Smith delineated the subcatchments based on features that divide the topography such as canals, roadways, railroad tracks, and levees.

Each subcatchment has several hydrologic parameters that determine the volume of stormwater that runs off. These parameters describe the geometry of each subcatchment, percent imperviousness of the subcatchment, roughness of pervious and impervious surfaces, storage depth on pervious and impervious surfaces, runoff routing within the subcatchment, method for calculating infiltration, and Low Impact Development (LID) elements.

2.2 Rainfall Hyetograph

Gaea modeled the existing conditions and the individual interventions for the 10-year storm. This modeling allowed Gaea to gain an understanding of the relative effect of each individual strategy and the general area it affects. For the combined scenarios, Gaea modeled the 2-year, 10-year, and 100-year storms. Gaea used the SCS Type III rainfall volume hyetograph with depths calculated from the

Louisiana Department of Transportation and Development's (LA DOTD) Hydraulic Manual.[1] The total depths for each event were 6 inches for the 2-year storm, 8.5 inches for the 10-year storm, and 14.4 inches for the 100-year storm.

2.3 Drainage Network

SWMM uses a network of nodes and links to define the drainage system.

2.3.1 Nodes

SWMM includes several types of nodes; the two most important types are junctions and storages. Both have areas that SWMM uses for its hydraulic calculations. Junctions have a small default area intended to model a standard drainage manhole, but they can also be used to transition between different cross-sections. Storages have a user-defined relationship between stage and surface area that can be used to model areas that collect water such as ditches and ponds.

2.3.2 Links

Links define the conveyance features of a drainage network. Links may define closed pipes, open ditches and canals, pumps, or weirs. The parameters of each link describe the geometry of the link, its hydraulic roughness, base flow, loss coefficients, and flap gates. The links in the existing model represent current conduits, canals, and pumps that drain the study area.

One pump station drains New Orleans' Lower Ninth Ward, and seven drain the protected areas of St. Bernard Parish. Table B1 summarizes these pump stations.

Table B1: Pump Station Information (capacities from CDM Smith model)

Station Name	Latitude	Longitude	Max Capacity (CFS)
Drainage Pump Station #5	29.980°N	90.019°W	2260
Jean Lafitte	29.966°N	89.975°W	2245
Guichard	29.962°N	89.964°W	350
Bayou Villere	29.951°N	89.934°W	500
Bayou Ducros	29.947°N	89.922°W	1017
Meraux	29.921°N	89.891°W	1245
EJ Gore	29.880°N	89.875°W	660
St. Mary	29.854°N	89.796°W	834

3. Proposed Interventions

Waggonner & Ball is proposing several different interventions to manage stormwater. The interventions were:

- Street Best Management Practices

[1] Louisiana Department of Transportation and Development. *2011 Hydraulics Manual.* 2011. Baton Rouge, LA.

- Lagoons
- Lateral parks
- Retention/detention in large parking lots
- Retention/detention on publicly owned property
- Retention/detention throughout the watershed
- Spillways
- Weirs
- Combined spillways and weirs
- Drainage improvements

Gaea Consultants adjusted the existing model to individually test the performance of each strategy in a 10-year storm. Gaea evaluated each intervention based on the maximum water surface elevation at each node compared to the existing condition. For some of the interventions, Gaea tested a "basic" and "intensive" scenario representing different levels of implementation. The basic scenarios represent a more modest implementation of the proposed improvements, while the intensive scenarios represent widespread improvements. The scenarios correspond to the combined scenarios discussed in Section 4.

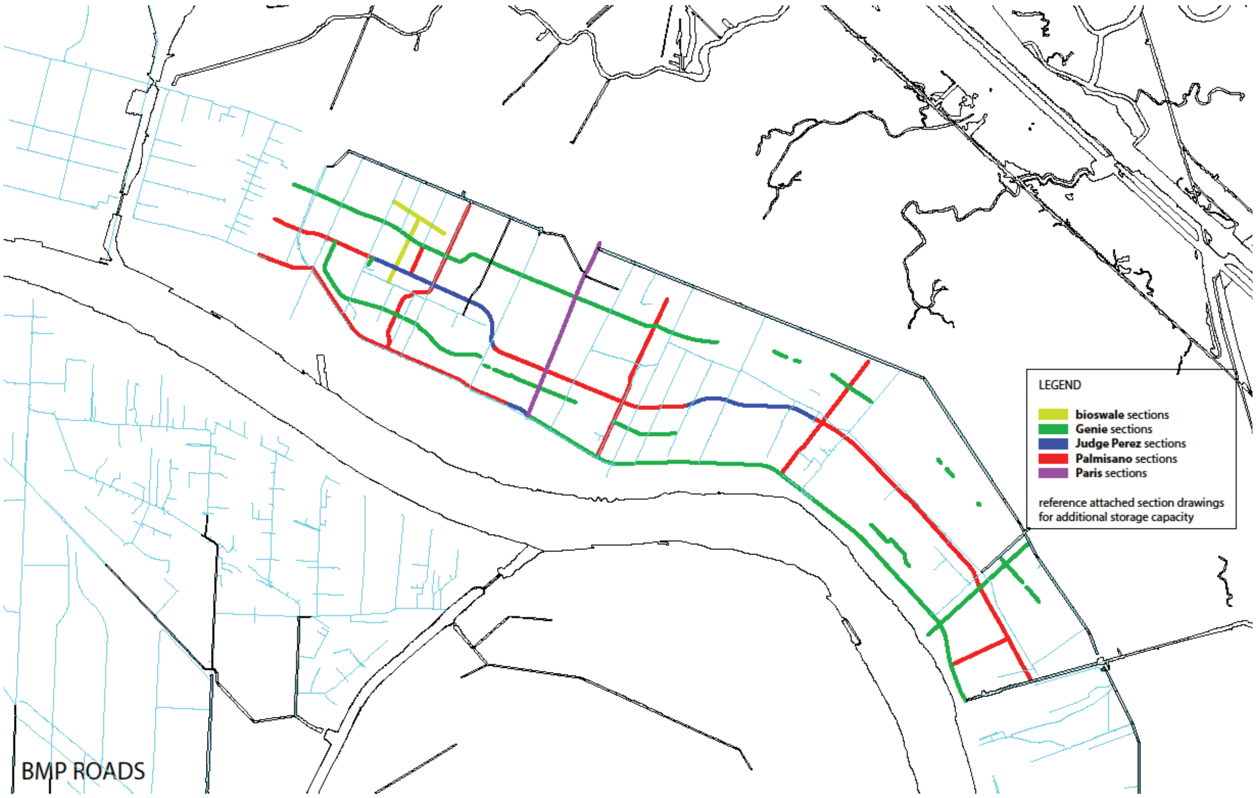
In some cases, Gaea and Waggonner & Ball adjusted the interventions based on the modeling results. After initial set-up and modeling, Gaea and Waggonner & Ball conducted a day-long modeling workshop during which designers from both firms worked together to finalize the conceptual design of the interventions. The final results of the workshop were refined interventions that Gaea considered during the final stages of modeling.

3.1 Street Best Management Practices

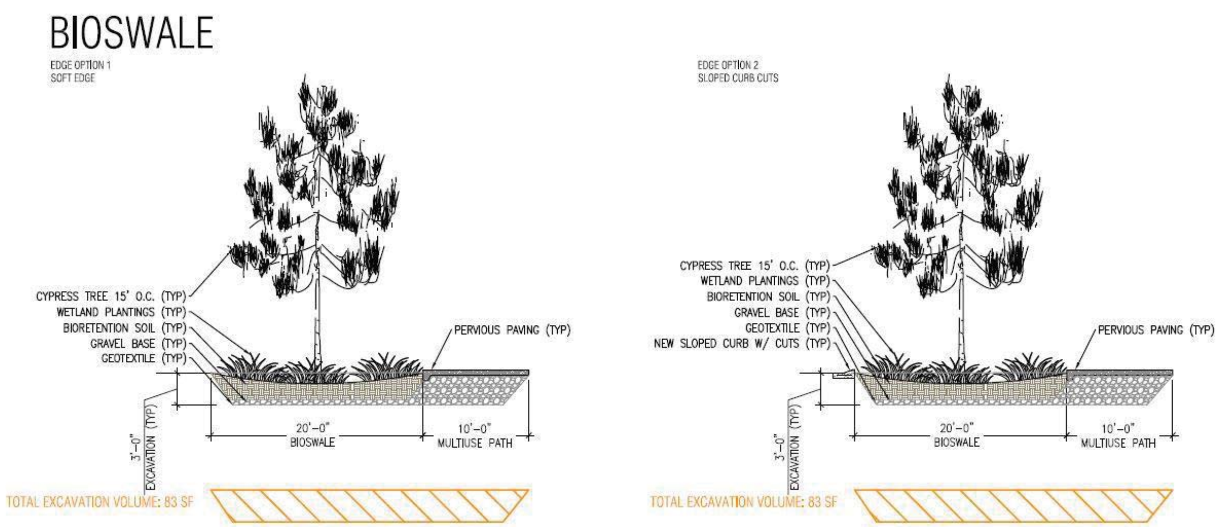
Waggonner & Ball is proposing street best management practices (BMPs) along several of the major roadways through the Parish. The BMPs use bioswales and pervious sidewalks to create storage areas adjacent to the roadways. Figures B1 and B2 show proposed plans and cross-sections. To test the effects of these BMPs, Gaea calculated the storage volume they would provide in each subcatchment containing the BMPs, divided the volume by the area of the subcatchment to determine an equivalent depth, and then added that depth to the surface storage depth parameters of the subcatchments to account for the storage. The end result was that the water volume stored by the BMPs did not enter the hydraulic portion of the SWMM model (the links and nodes representing canals and pipes). The basic scenario included approximately 15.3 miles of BMPs, while the intensive scenario included 35.6 miles of BMPs.

The basic BMPs scenario provided very small reductions in water surface elevations across a widespread area. West of Paris Road, water surface elevations decreased by about 0.5 to 2 inches under the basic scenario. Generally, the greater reductions occurred in the 40 Arpent Canal, while the lesser reductions occurred near the higher ground around Judge Perez Drive. Between Paris Road and Violet Canal, water surface reductions ranged from 0.5 to 1 inch. Again, the higher reductions generally occurred in the 40 Arpent Canal.

The intensive scenario resulted in greater reductions in the same general pattern. Water surface reductions west of Paris Road ranged from 0.5 to 2.5 inches. Between Paris Road and Violet Canal, water surfaces decreased by 1 to 2 inches.



FigureB1: Plan view of roads with proposed BMPs.



total excavation, cross sectional area:	**83 SF**

Figure B2: Typical cross-section of proposed BMPs.

While these reductions appear relatively small, even small reductions in flood depths can realize significant savings in repair costs.[2] Furthermore, implementation may have more significant effects on local nuisance flooding, especially for smaller storms.

3.2 Lagoons

Waggonner & Ball is proposing widening portions of 40 Arpent Canal to create lagoons. The lagoons include constructed islands and serve as storage, ecological, and recreational features. Figures B3 through B5 show schematic plans and a cross-section of the lagoons. Gaea used the schematics and plans to estimate a relationship between water surface elevation and surface area. Gaea then added storage areas to the modeled 40 Arpent Canal to represent the lagoons. The basic scenario included four lagoons west of Paris Road and one east of Paris Road. The intensive scenario added seven lagoons east of Paris Road and two west of Paris Road, for a total of 14 lagoons.

Under the basic scenario, the water surface elevation in most of the canals west of Paris Road decreased by about 2 inches. Under the intensive scenario, most of the canals west of Paris Road experienced reductions of slightly more than 3 inches. Neither scenario had a significant impact east of Paris Road.

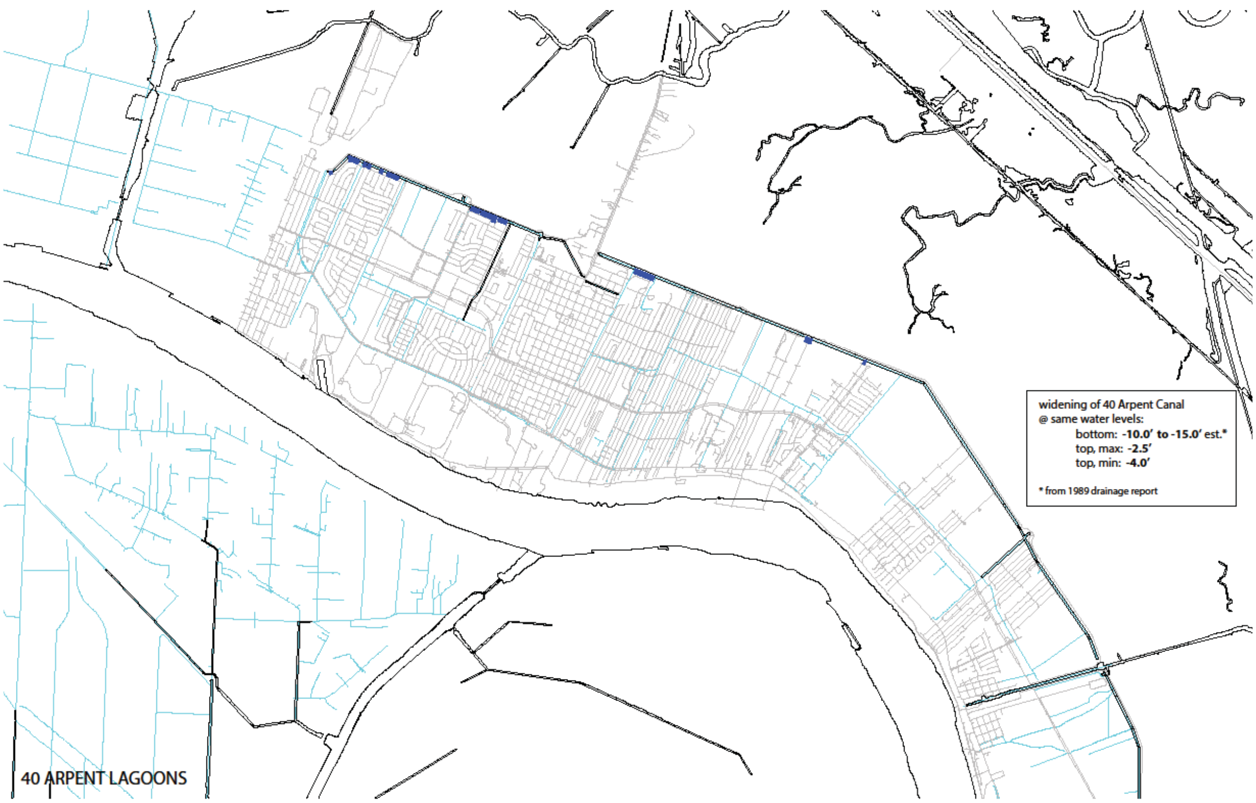


Figure B3: System-level schematic of proposed lagoons on the 40 Arpent Canal.

[2] FEMA's depth damage function (DDF) curves show that, for the first 1 foot of flooding above the floor of one average 1400-square-foot home, each inch of flooding adds approximately $1,352 to the repair costs. See CDM Smith's report *Pontilly Stormwater Hazard Mitigation Grant Program Project, Benefit Cost Analysis Technical Memorandum* dated 9 August 2013 for an example application of DDF curves.

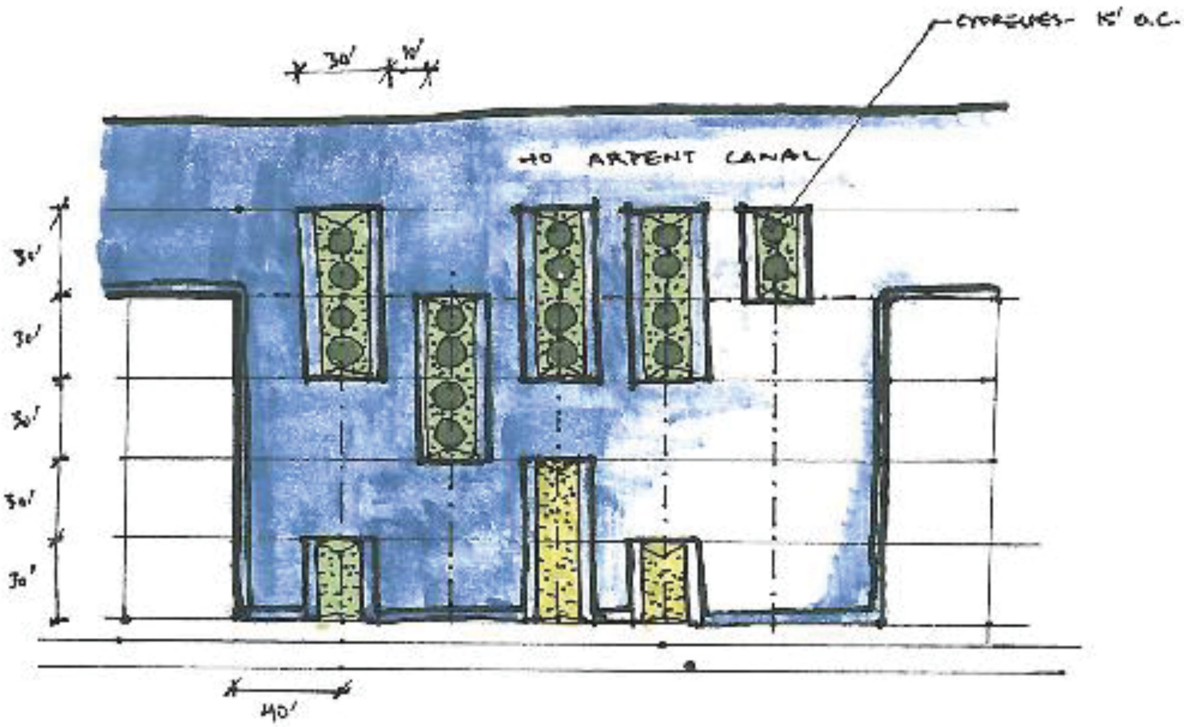


Figure B4: Typical plan for proposed lagoons on 40 Arpent Canal.

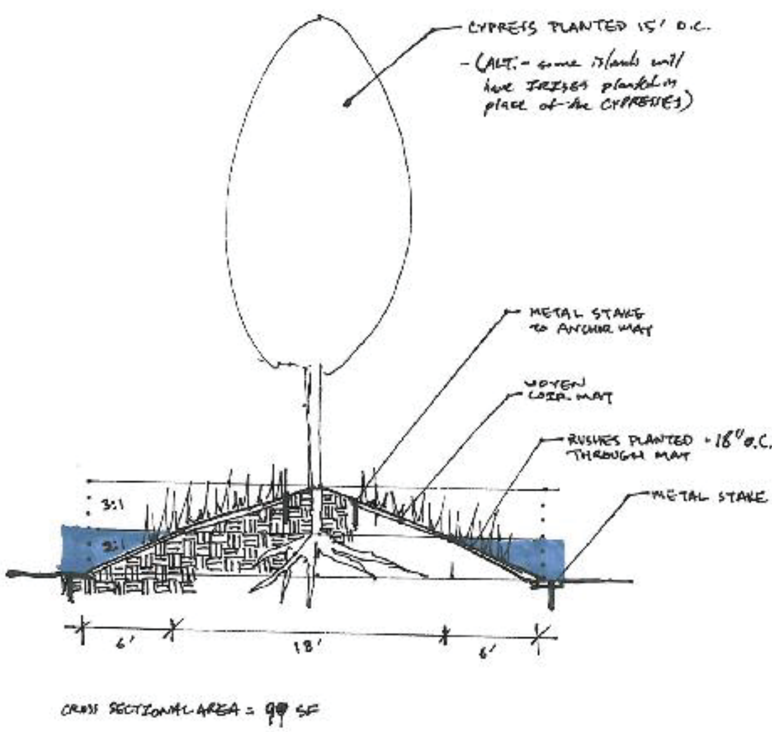


Figure B5: Typical cross-section for cypress plantings in proposed lagoons in 40 Arpent Canal.

3.3 Lateral Parks

Waggonner & Ball is proposing converting vacant lots into parks that can store rainwater to an average depth of 1.75 feet across the site before draining into open canals. Figure B6 shows the locations of the proposed parks. To test the effects of these parks, Gaea calculated the volume each site could store and adjusted the surface storage parameters of the affected subcatchments to account for that volume (using a process similar to that described for Street BMPs). Gaea tested only one scenario, which included 13 parks totaling approximately 8.2 acres.

The effects of the lateral parks on the maximum water surface elevation are very small. West of Paris Road, the 40 Arpent Canal, the Guerenger Canal, and the ditch through "The Woodlands" lowered by approximately 0.5 inches each.

Despite this small effect, it may be worthwhile to study these lateral parks on a smaller scale. The large scale of this modeling effort made it impossible to estimate the area that would drain into each park. More detailed modeling may determine that the effects on flooding in localized areas could be significant.

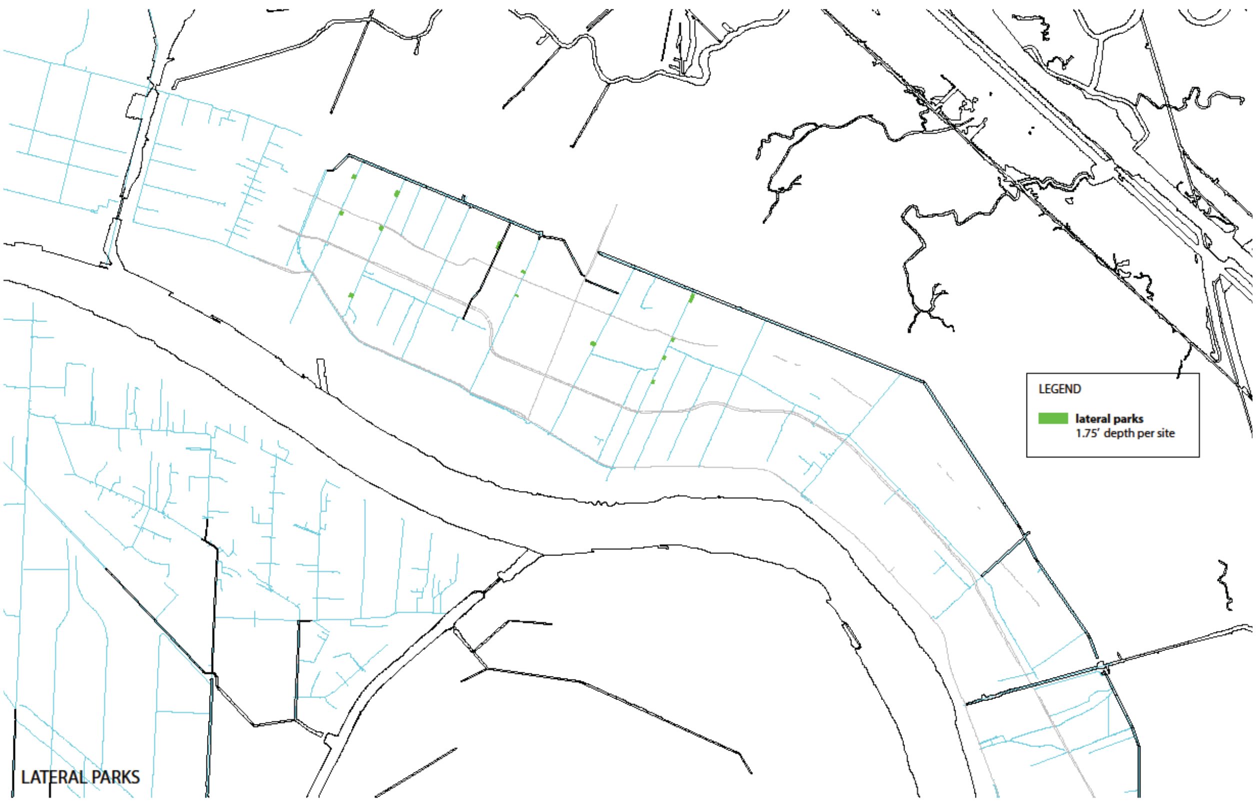


Figure B6: Proposed locations of lateral parks.

3.4 Parking Lots

Waggonner & Ball is proposing interventions to retain the first 1.25 inches of rainfall on several large commercial parking lots in heavily developed areas of the Parish. Figure B7 shows the locations of the parking lots with proposed interventions. Gaea tested the effects of these interventions by calculating the water volume the proposed improvements would retain and adjusting the surface storage parameters of the affected subcatchments to account for this volume (using a process similar to that described for Street BMPs). Gaea tested only one scenario, which included approximately 201 acres of parking lots.

This intervention decreased the water surface elevation in the 40 Arpent Canal west of Paris Road, the Guerenger Canal, and the ditch through "The Woodlands" by about 1 inch each. Elsewhere, the change in water surface elevation was less than 0.5 inches. Again, smaller-scale modeling could determine that local effects are more significant.

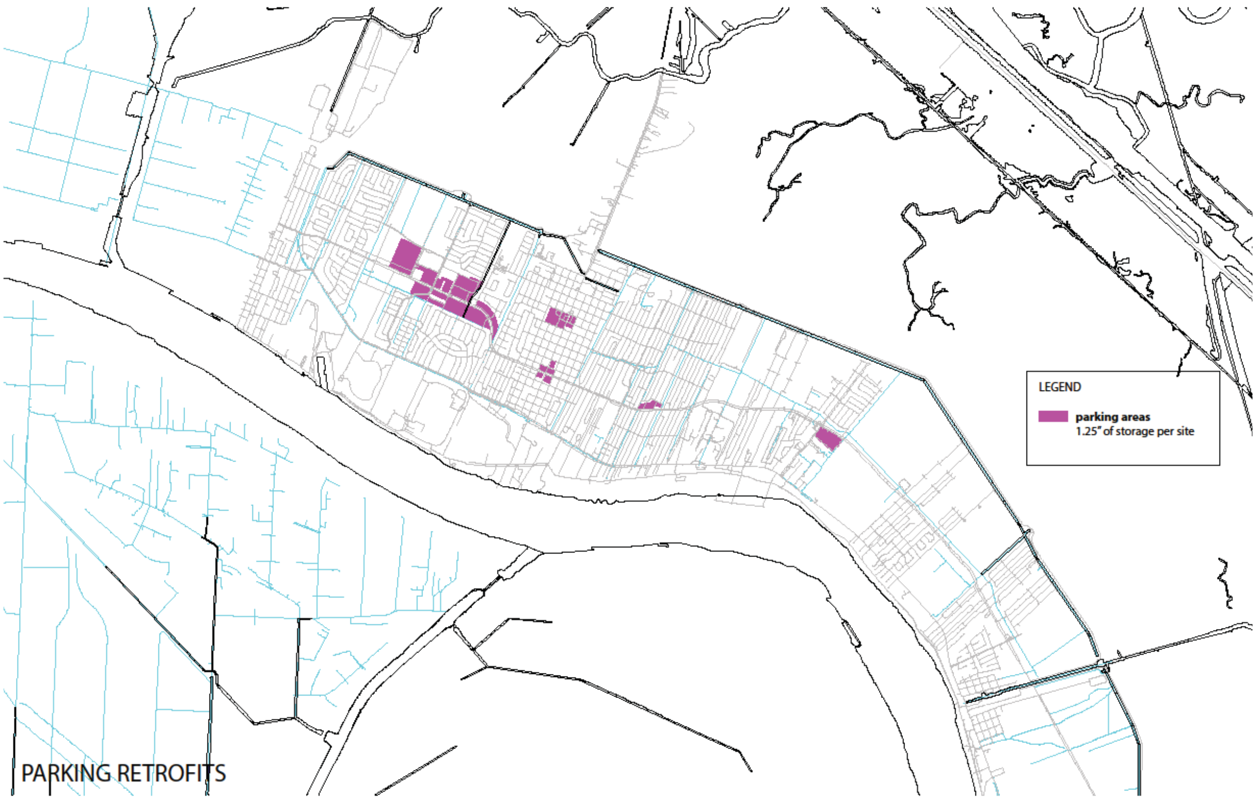


Figure B7: Parking lots with proposed retention.

3.5 Retention/Detention on Publicly Owned Property

Waggonner & Ball is proposing interventions to retain or detain stormwater on publicly owned property such as parks and schools. The single scenario proposes to retain the first 1.25 inches of storm water on approximately 69.6 acres of school property and retain or detain storm water in 2-foot-deep bioswales covering approximately 658.3 acres of parks. Figure B8 shows the locations of schools and parks with proposed improvements. Gaea tested the effects of these improvements by calculating the volume they would retain or detain and adjusting the surface storage parameters of the affected subcatchments to account for this volume (using a process similar to that described for Street BMPs).

West of Paris Road, this intervention resulted in reductions of the water surface elevations in the 40 Arpent Canal, the Guerenger Canal, and the ditch through "The Woodlands" of approximately 3 inches each. East of Paris Road, the 40 Arpent Canal, and the portion of 20 Arpent Canal between Dubouchel and the canal draining towards Meraux all experienced reductions of approximately 1 inch. The water surface in the ditch west of the Valero Refinery fell by approximately 0.5 inches. Not surprisingly, most of these reductions occurred near one of the proposed retention/detention sites.

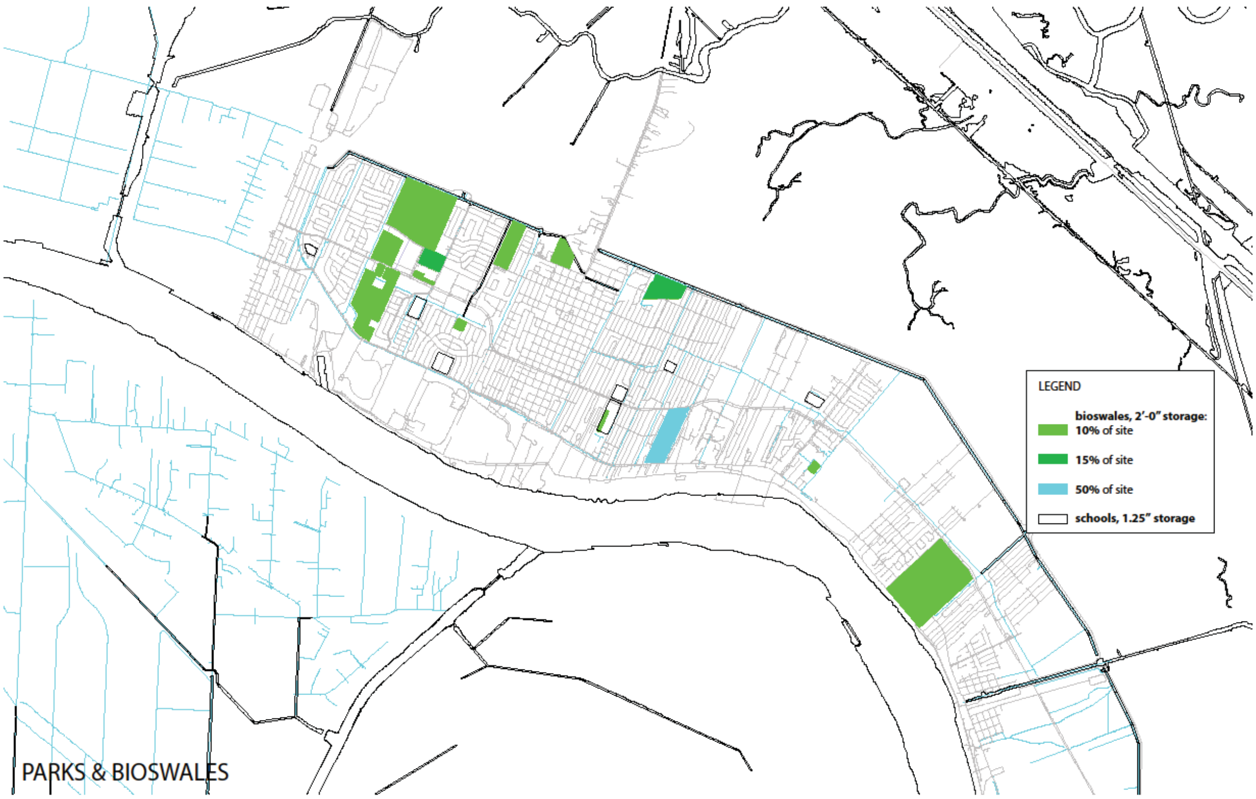


Figure B8: Retention/detantion on public property.

3.6 Retention/Detention Throughout the Watershed

Some municipalities are now incorporating water management into construction ordnances and standards. To test the potential effects of implementation of such ordnances in the study area, Gaea modeled the system with the first 1.25 inches of storm water retained or detained throughout the study area. Gaea determined the volume of water represented by a depth of 1.25 inches in each subcatchment and then distributed this volume across the areas that have surface storage (excluding roofs) to determine a new surface storage depth parameter for each subcatchment.

In the Lower Ninth Ward, the improvement performed just as expected, with water surface reductions of approximately 1.25 inches at the upstream end of the system and greater reductions farther downstream. The reduction at the DPS 05 intake was approximately 1.7 feet.

Between the Lower Ninth Ward and Paris Road, the water surface lowered by 1.25 to 9 inches on the upstream ends of the system, with the greater reductions occurring due to the stage-volume relationship of the storage areas. The 40 Arpent Canal lowered by approximately 9 inches.

Between Paris Road and Violet Canal, the water surface lowered by 1.25 to 5 inches on the upstream ends of the system. Again, storage areas influenced the amount of reduction. The 40 Arpent Canal lowered by approximately 6 inches.

Southeast of the Violet Canal the water surface lowered by 0.5 to 2.5 inches on the upstream ends of the system. Again, storage areas influenced the amount of reduction. The downstream ends of the system lowered by 3 to 8 inches.

3.7 Spillways

Waggonner & Ball is proposing conversion of parts of undeveloped tracts of land into spillways between the 20 Arpent Canal and the 40 Arpent Canal. These spillways would provide additional storage and conveyance between the two major drainage canals. Figure B9 shows the locations of the proposed spillways. The basic scenario included one spillway near the bend in the 40 Arpent Canal in Meraux. The intensive scenario included four additional spillways, one north of the Valero Refinery, two near St. Bernard Grove, and one near the southeast end of both canals, for a total of five spillways. Each spillway would be connected to the 20 Arpent Canal via a weir with inlet elevation at -4.5 feet (1 to 3 feet lower than the weirs discussed in the next section). Waggonner & Ball originally proposed one additional spillway in Cypress Gardens. However, new residential development in that area would make the spillway impractical. During the modeling workshop described above, Waggonner & Ball and Gaea adjusted the proposal to include a large lagoon in the 40 Arpent Canal to utilize the remaining undeveloped area at the site of the previously proposed spillway. Gaea modeled this lagoon with the other spillways and not with the other lagoons discussed above.

The spillways provided a significant volume for storage and resulted in considerable reductions in water surface elevation. The basic spillway reduced the water surface elevation in the 40 Arpent Canal east of Paris Road by 6 to 7 inches. The Dubouchel Canal lowered by approximately 4 inches, the canal draining toward the Meraux Pump Station lowered by approximately 7 inches, and the 20 Arpent Canal lowered by 4 to 7 inches between these two canals.

The intensive scenario resulted in reductions of 1.2 to 1.8 feet throughout most of the 40 Arpent Canal east of Paris Road, with the greater reductions realized toward the southeast end of the canal, near the Meraux Pump Station. Reductions in the 20 Arpent Canal east of the Valero Refinery varied between 4 inches and 1.7 feet, with the greatest reduction occurring near the canal draining toward the Meraux Pump Station.

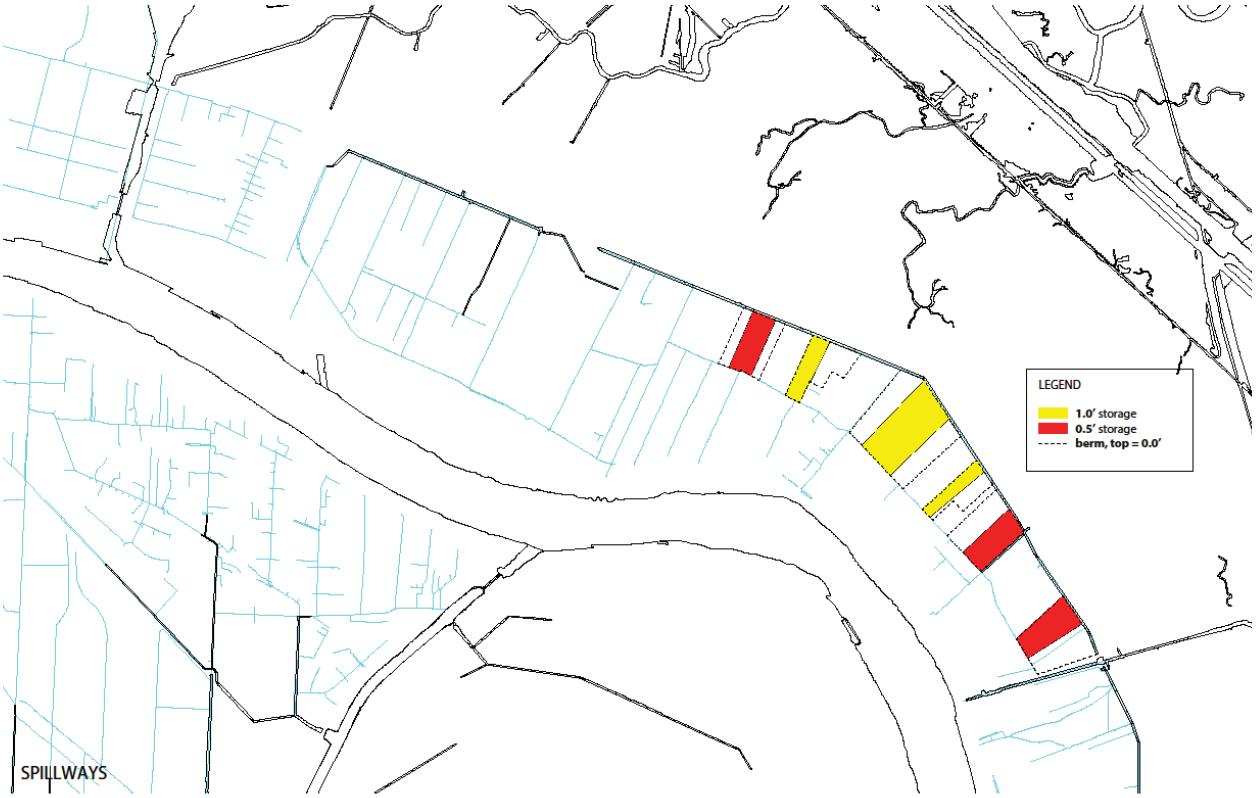


Figure B9: Proposed spillways.

3.8 Weirs

Waggonner & Ball is proposing several weirs in the various drainage canals. The intent of the weirs is to slow the drainage of storm water from the higher elevations near the Mississippi River toward the 40 Arpent Canal, thus decreasing the peak demand on the pump stations. The increased water levels upstream of the weirs would have the additional effect of combating subsidence by allowing water to infiltrate into the surrounding soils that might otherwise consolidate. Figure B10 shows the locations and elevations of the proposed weirs. Gaea tested the effects of the weirs by adding them to the existing model using SWMM's built-in functionality for weirs.

Waggonner & Ball originally proposed weirs on the Eickes and Guerenger Canals, just before their intersections with the 40 Arpent Canal. During modeling, Waggonner & Ball and Gaea realized that these weirs would exacerbate the existing flooding in the nearby neighborhood. Waggonner & Ball and Gaea decided to eliminate those weirs and replace them with flap gates to prevent backwater flooding into that area.

As expected, water surface elevations lowered downstream of the weirs and rose upstream. The 40 Arpent Canal west of Paris Road experienced reductions of 2.2 to 2.7 feet. The Guerenger Canal lowered by 14 to 15 inches, and part of "The Woodlands" lowered by approximately 2.2 feet. The ditch along the Parish border with New Orleans' Ninth Ward rose by approximately 1.7 feet, the Chalmette Vista Canal rose by 6 inches to 1 foot, and the Guichard Canal rose by 2.5 feet at its upstream end.

East of Paris Road, 40 Arpent Canal experienced reductions of 1.5 to 1.7 feet. The canals in the St. Avide area rose by 9 to 15 inches. Most of the 20 Arpent Canal rose by 1.3 to 2 feet, with a more modest increase of approximately 4 inches at the extreme southeastern end.

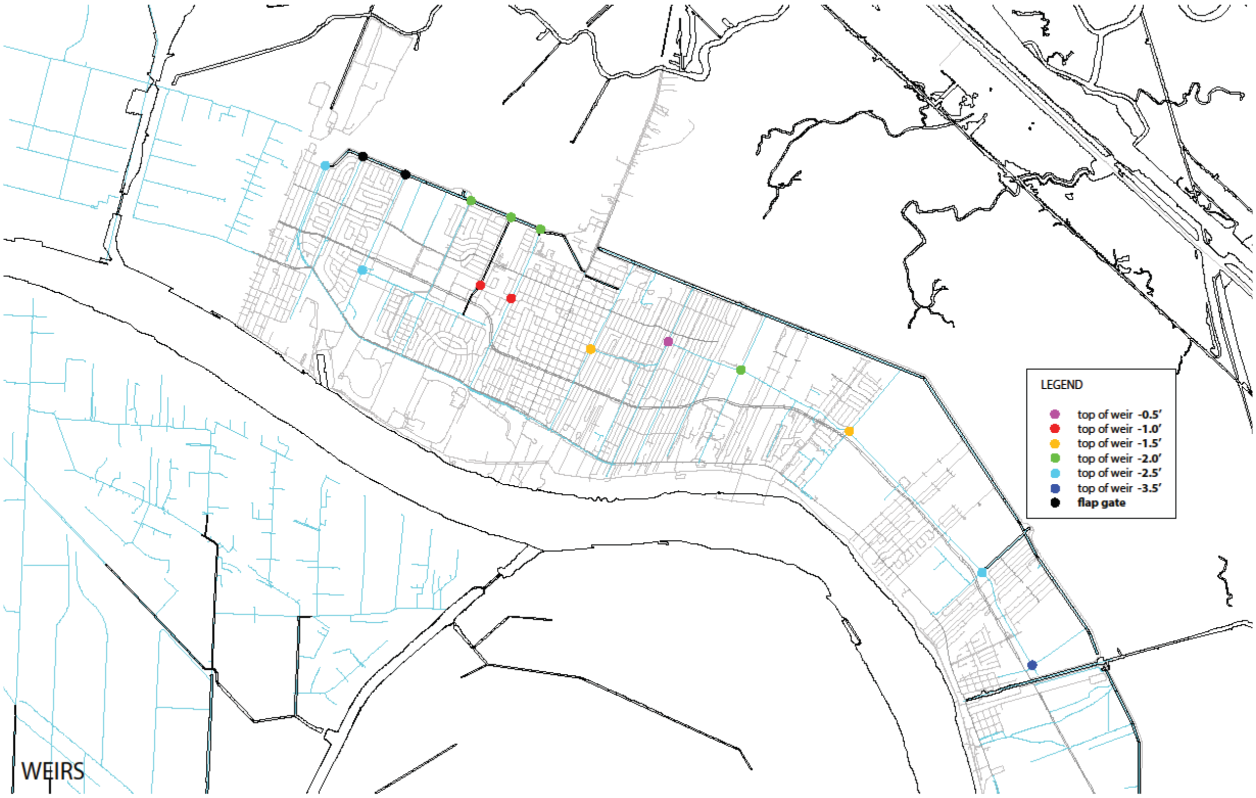


Figure B10: Proposed weirs and flap gates.

3.9 Combined Spillways and Weirs

The spillways and weirs complement each other by design. The proposed weirs would hold water in the upstream canals until they were full, and then the spillways would facilitate drainage of the excess water into the 40 Arpent Canal. Since the two interventions are complementary, Gaea modeled them together without any other interventions to test their effectiveness in tandem.

The spillways worked effectively with the weirs east of Paris Road. With both interventions, water surface elevations in the 40 Arpent Canal decreased by 2.2 to 2.4 feet compared to existing conditions.

East of Paris Road, the canals in the St. Avide area rose by 7 to 11 inches, a slight improvement over weirs alone. The 20 Arpent Canal rose by 11 to 14 inches between the Valero Refinery and Dubouchel Canal, another improvement over weirs alone. Southeast of Dubouchel Canal, the spillways reversed the weirs' effect of raising water levels in the 20 Arpent Canal. With the two interventions combined, the segment between Dubouchel Canal and the canal draining towards Meraux Pump Station experienced reductions of 9 to 14.5 inches compared to existing conditions, and the extreme southeastern end remained at essentially the same level compared to existing conditions.

3.10 Drainage Improvements

Waggonner & Ball is proposing several drainage improvements that would reconfigure parts of the drainage system. The proposed improvements are:

- Converting the box culvert draining toward DPS05 to an open, trapezoidal channel.
- Reconnecting the drainage systems for New Orleans' Ninth Ward and Chalmette. Gaea modeled this by adding an open channel parallel to the railroad tracks along the Parish line (assumed trapezoidal) and the existing culvert under the railroad tracks (assumed diameter of 5 feet).[3]
- Deepening Eickes Canal.
- Adding Jean Lafitte Canal as an open box culvert (not modeled in existing conditions since the existing box culvert has caved in at several locations).
- Connecting the Chalmette Vista and Guichard Canals with an open, trapezoidal channel near Oak Tree Lane.
- Improving 40 Arpent Canal near and under Paris Road to allow unimpeded flow (the existing model does not include any flow under Paris Road). The improvements include a "wetland shelf" for part of the canal that provides additional cross-sectional area for flow once water overflows the shelf.
- Adding "wetland shelves" to the canal along East St. Avide Street to provide additional storage.

In New Orleans' Ninth Ward, these changes resulted in a reduction in water levels of 6 to 8 inches near DPS05. Benefits decreased gradually further upstream, with increases in water level of 0.5 inches or less at the upstream ends of the system. West of Paris Road, the water surface elevation in the 40 Arpent Canal increased by 4 to 7 inches. The water surface rose by approximately 5 inches in the Geurengeh Canal and the ditch draining "The Woodlands." The Chalmette Vista and Guichard Canals and the canals upstream of the new Jean Lafitte Canal experienced a reduction of 5 to 16 inches.

East of Paris Road, the 40 Arpent Canal lowered by 2.5 to 5.5 inches, with the greater reductions near Paris Road. The 20 Arpent Canal experienced reductions of 2 to 2.5 inches between the Dubouchel Canal and the canal draining toward Meraux Pump Station.

4. Combined Scenarios

To test the combined effects of all the proposed interventions, Waggonner & Ball directed Gaea to model two combined scenarios: basic and intensive.

4.1 Basic Scenario

The basic scenario included implementation of the lateral parks, rain gardens and bioswales on publicly owned property, parking lot retention/detention, all weirs, all drainage improvements, the basic spillway near the bend in the 40 Arpent Canal in Meraux, the basic street BMPs, and the basic lagoons.

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[3] Gaea found that connecting New Orleans' Ninth Ward and St. Bernard Parish was a benefit to Arabi. In the model, the conduit connecting the two areas always flowed toward the Ninth Ward. Gaea ran the model without this connection and found that the other improvements reduced water surface elevations in the Ninth Ward by as much as 1 foot, while water levels rose in the 40 Arpent and Guerenger Canals and the ditch draining "The Woodlands" by 7 to 7.5 inches.

4.2 Intensive Scenario

The intensive scenario included the retention/detention of the first 1.25 inches of runoff over the entire area of the Parish within the protection levees, implementation of the intensive street BMPs, spillways, lagoons, and all weirs and drainage improvements. Please note that many subcatchments without street BMPs nonetheless have storage values over 1.25 inches. This is to account for impervious areas modeled without surface storage (e.g. rooftops).

4.3 Pumping Scenarios

Waggonner & Ball directed Gaea to model the combined scenarios under four pumping conditions to test whether the proposed interventions could decrease demand on the pumping system enough to allow some pump stations to be turned off during any of the design storms. Section 2f of Waggoner & Ball's report describes the pump stations and shows their locations.
Pump Option 1: all pump stations operating at full capacity.
Pump Option 2: EJ Gore and St. Mary Pump Stations operating at full capacity. All others off.
Pump Option 3: Jean Lafitte and Bayou Ducros Pump Stations off. All others operating at full capacity.
Pump Option 4: Bayou Villere, Bayou Ducros, and Meraux Pump Stations off. All others operating at full capacity.

4.4 Results

To assess the overall effects of implementing all of the interventions in each scenario, Gaea created GIS shapefiles from the results of each run. Gaea used the shapefiles to create a surface representing the maximum water surface elevations, then subtracted the digital elevation model (DEM) covering the Parish to determine an estimated depth of flooding throughout the Parish. Waggonner & Ball provided the DEM, which is a set of high-resolution elevation data collected by light detection and ranging (Lidar), a highly accurate, aerial technique. No conversions were necessary since elevations in CDM's original model and the Lidar data both refer to the North American Vertical Datum of 1988 (NAVD88). Using the built-in tools in ArcGIS software, Gaea used the resulting dataset to estimate the area flooded under each scenario. Table B2 shows the results.

Table B2: Area of flooding in acres for each scenario. The percentage represents the ratio of flooding under the scenario considered versus the existing condition.

		Storms (Percent of Existing)					
Scenario	**Pump Option**	**2-year**		**10-year**		**100-year**	
Existing	1	1372		2448		5546	
Basic	1	1309	95%	2310	94%	4818	87%
Basic	2	2233	163%	3338	136%	5584	101%
Basic	3	1445	105%	2686	110%	4944	89%
Basic	4	1459	106%	2359	96%	5126	92%
Intensive	1	974	71%	1671	68%	4245	77%
Intensive	2	1277	93%	2441	100%	4924	89%
Intensive	3	997	73%	1898	78%	4463	80%
Intensive	4	984	72%	1738	71%	4532	82%

As expected, the basic scenario with Pump Option 1 was a benefit in all storms. For the 2- and 10-year storms, the interventions reduced street flooding in the Lower Ninth Ward and Arabi and increased flooding in the wooded areas[4] in western Chalmette near the 40 Arpent Canal. They also caused slightly more minor street flooding in the higher areas near the Mississippi River. The increases were due to the proposed weirs. For the 100-year storm, the interventions reduced flooding in the Lower Ninth Ward, Arabi, and some streets in eastern Chalmette without much change to conditions in western Chalmette. The scenario reduced flooding along the 40 Arpent Canal between Chalmette and Violet Canal for all storms.

With Pump Option 2, small areas of nuisance flooding caused by the 2-year storm under existing conditions became widespread street flooding in the Lower Ninth Ward, Arabi, and Chalmette. It also resulted in more flooding along the 40 Arpent Canal east of Paris Road. The results were similar for the 10- and 100-year storms, but less pronounced since the larger storms already caused more flooding.

The basic scenario with Pump Option 3 alleviated some street flooding in the Lower Ninth Ward, and slightly improved street flooding in Chalmette. The scenario caused the wooded areas near the 40 Arpent Canal in Chalmette to flood, along with some minor street flooding west of Paris Road. Flooding conditions between Chalmette and Violet Canal were similar to the existing condition. For the 10-year storm, flooding exhibited a similar pattern, but the street flooding the interventions caused were slightly more extensive and included some streets in Chalmette east of Paris Road. The interventions resulted in slight improvements to flooding in the 40 Arpent Canal between Chalmette and Violet Canal. For the 100-year storm, most streets in Chalmette already flood under existing conditions, so the improvements to street flooding in the Lower Ninth Ward and Arabi represented a net benefit.

The basic scenario with Pump Option 4 had similar results to Pump Option 1 west of Paris Road for the 2-year storm. For the 10-year storm, the scenario decreased flooding in the Lower Ninth Ward, Arabi,

[4] Flooding in wooded areas is, of course, preferable to flooding in developed areas. Some of the interventions flood wooded areas by design to decrease flooding in developed areas. A good example would be a weir that causes water to “back up” in a wooded area and decrease flow to a developed area downstream. Figures # through # show the modeled flood extents for each scenario so the reader can see the impacts of the combined interventions.

and the higher areas of Chalmette near the Mississippi River. In other parts of Chalmette, there was an increase in minor street flooding. In the 100-year storm, there were benefits throughout the Lower Ninth Ward, Arabi, and western Chalmette while flooding increased in the higher areas of Chalmette and eastern Chalmette. For all storms, flooding increased along the 40 Arpent Canal east of Chalmette which was expected since the pump stations in this area would not be operated under this option.

For each storm and pump option, the area southeast of Violet Canal exhibited flooding similar to that under the existing condition. Since the basic scenario did not include any changes to the drainage system in this area, and none of the pump options affected the two pump stations in this area, the lack of improvement to flooding conditions demonstrated that the level of retention and detention for the basic scenario was insufficient to significantly affect flooding on a system scale.

By contrast, the interventions in the intensive scenario did significantly reduce flooding southeast of the Violet Canal. For each storm and pump option, flooding in this area decreased compared to the existing condition.

The intensive scenario with Pump Option 1 nearly eliminated flooding in the Lower Ninth Ward and reduced street flooding in Arabi for the 2-year storm. The interventions flooded wooded areas and some streets in western Chalmette. The weirs and spillways east of Chalmette reduced flooding around the 40 Arpent Canal. The results for the 10- and 100-year storms were similar, although the flooding was too extensive for the interventions to eliminate flooding in any area.

Despite the net improvement for the intensive scenario with Pump Option 2, the flood maps show that the resulting flooding was very similar to the basic scenario. Since the pump stations southeast of Violet Canal still operate under Pump Option 2, the improvements to this area offset the increases northwest of Violet Canal. Gaea recommends against Pump Option 2 in all circumstances.

The results from the intensive scenario with Pump Option 3 were almost identical to Pump Option 1 for the 2-year storm. For the 10- year storm, the interventions reduced flooding in the Lower Ninth Ward compared to the existing condition. Much more of the wooded areas in western Chalmette flooded, along with a few more streets. For the 100-year storm, flooding decreased in the Lower Ninth Ward and Arabi, with only minor increases in western Chalmette. For both of the larger storms, weirs, spillways, and drainage improvements resulted in significant decreases in flooding along the 40 Arpent Canal east of Chalmette.

The results from the intensive scenario with Pump Option 4 were almost identical to Pump Option 1 for the 2-year storm. The results were similar to Pump Option 1 for the 10-year storm, but without the pump stations between Paris Road and Violet Canal operating, the interventions could not eliminate flooding along the 40 Arpent Canal in this area. For the 100-year storm, the results were similar to those for Pump Option 1 west of Paris Road. East of Paris Road, significant flooding still occurred, although it was reduced compared to the existing condition.

5. Neighborhood-Scale Model

To better understand the local effects of some of the interventions described above, the modeling effort included an investigation of storm water management on a smaller scale. Waggonner & Ball designated an area of approximately 200 acres in Chalmette (known hereafter as “the St. Avide Neighborhood”) as the study area. The area is generally bounded by E Genie Street to the north, E Judge Perez Drive to the south, Golden Drive to the west, and Palmisano Boulevard to the east (see Figure B11).

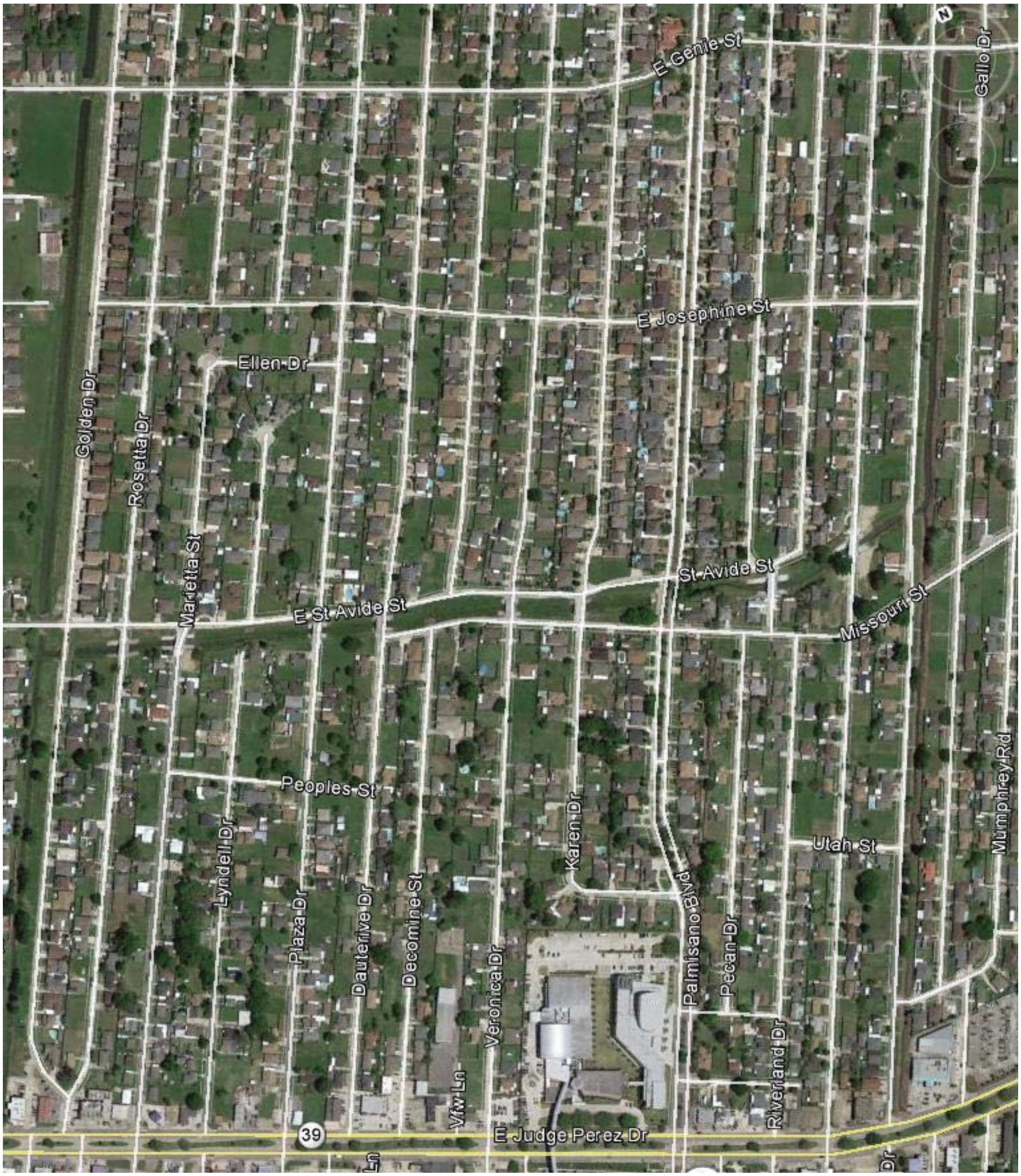

Figure B11: St. Avide Study Area

As in the large-scale tests, Waggonner & Ball and Gaea investigated existing, basic, and intensive scenarios for the neighborhood-scale model. Gaea modeled all three storms for the neighborhood-scale model to investigate the effects of the interventions on different sized storms.

5.1 Existing Scenario

Gaea Consultants modified the existing model to study this area in more detail. Gaea divided the area into 49 subcatchments and modified the subcatchments that had previously included the same area. Gaea then added the major drainage conduits that flow into the canal along E St. Avide Street (known hereafter as "the St. Avide Canal"). Information regarding the sizes and inverts of the conduits was limited, thus several assumptions were necessary. Based on photographs and known drain sizes along two streets, Gaea assumed that all conduits flowing into the canal have a diameter of 30 inches. The one exception to this assumption was the conduit along Lyndell Drive north of the canal. This conduit drains only one block, so Gaea assumed it is 24 inches in diameter. Gaea assumed that all conduits flowing into the canal have a downstream invert of -6.5 feet[5], approximately one foot above the invert of the canal, and assumed a slope of 0.1% to determine the upstream inverts. Gaea assumed that all other conduits in the neighborhood are 24 inches in diameter except for those along Judge Perez Boulevard, which Gaea assumed to be 18 inches in diameter. Finally, Gaea added overland links parallel to the conduits to account for street flow once the conduits were flowing full. Gaea used the Lidar data to estimate the street cross-sections. Since storage area SBP_Junct72 probably accounted for much of the volume in the overland links[6], Gaea converted it to a junction.

After making these adjustments, Gaea ran the model without any improvements to generate existing conditions for the new, smaller-scale drainage network.

Gaea compared the results of the existing model to the results of the large-scale existing model to ensure it represented similar conditions. For the two-year storm, the water surface elevation in the St. Avide Canal was about 3 inches higher than in the large-scale existing model. This was most likely because, in the large-scale model, runoff flowed to the ends of the canal, while in the neighborhood scale model, runoff flowed to the middle of the canal (see Figure B12). This flow routing increased the flow the middle sections of the canal had to convey. The water surface elevation in the canal west of the St. Avide Neighborhood was 2 to 3.5 inches lower compared to the large-scale existing model, again most likely due to flow routing. Differences in the rest of the model were less than 0.5 inches. The increase in the St. Avide Canal was more pronounced in the larger storms (slightly more than 6 inches for the 100-year storm), but differences in the other parts of the model shrank as more runoff rendered the changes less relevant. Overall, Gaea judged that the neighborhood-scale model was a reasonable representation compared to the large-scale model.

[5] All elevations in this report refer to NAVD88.

[6] CDM Smith employees familiar with the model represented to Gaea that most of the volume included in storage areas accounted for the volume of ditches flowing to that node.

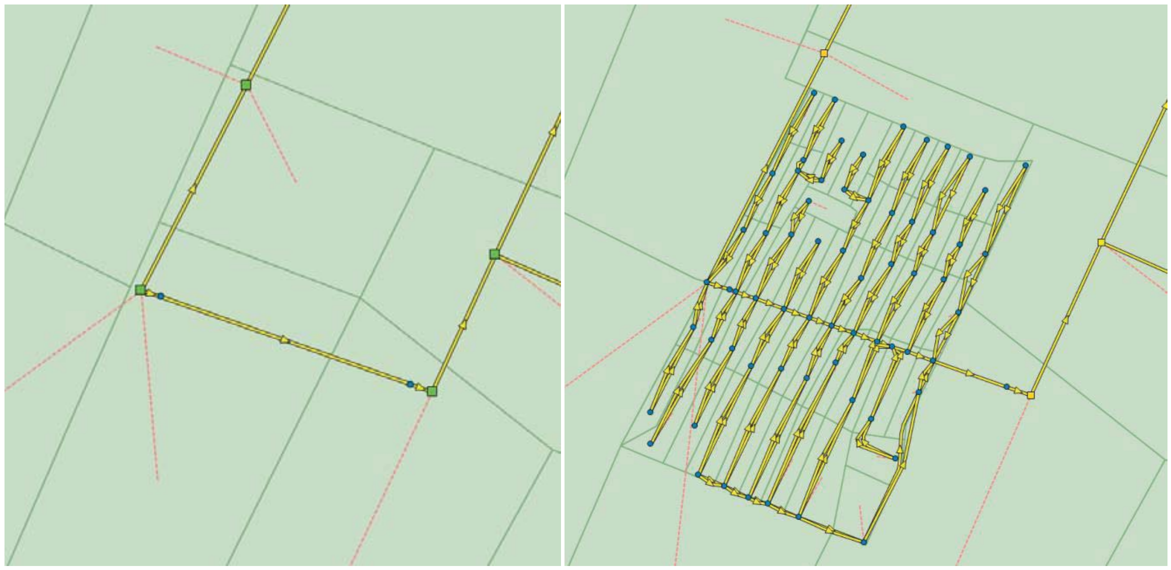

Figure B12: In the large-scale model (left), subcatchments flow to the ends of the St. Avide canal (denoted by dotted red lines). In the nieghborhood-scale model (right), water flows through conduits to the interior of the St. Avide Canal.

5.2 Basic Scenario

The basic scenario included two "wetland shelves" along the canal to provide extra storage, weirs in the canal on either side of the neighborhood (with inverts at -1.5 feet), retention/detention of 1.25 inches of rainfall on 10% of properties, and approximately 4.9 miles of street BMPs with the cross-section shown in Figure B13.

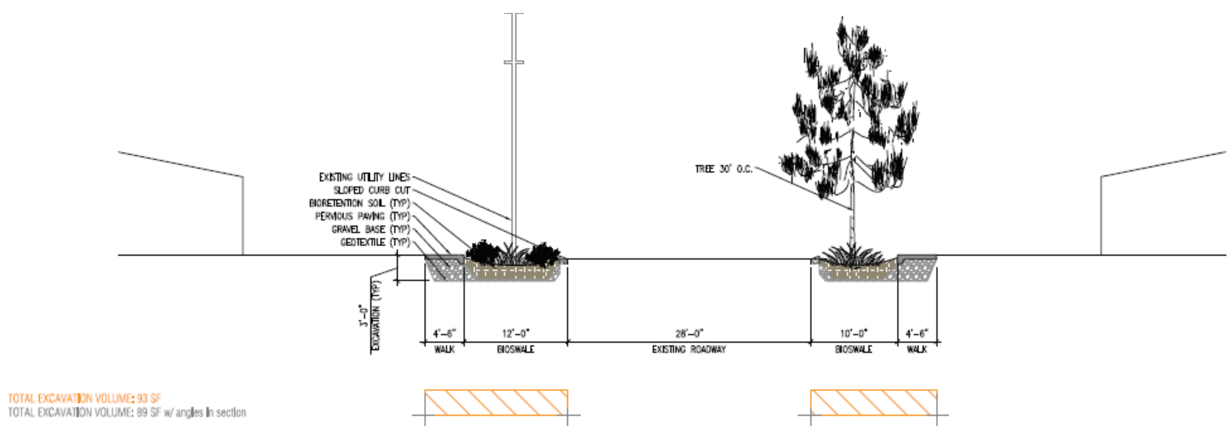

Figure B13: St. Avide BMP Cross-section

For this smaller-scale model, Gaea used the Low-Impact Design (LID) functionality built into SWMM to model the street BMPs. Gaea defined two LID controls based on the proposed cross-section; one for the pervious sidewalk and one for the bioswale. Gaea then measured the length of BMPs in each subcatchment and added the appropriate surface area of each LID control to each subcatchment. Gaea changed the internal routing of each subcatchment so that runoff from the impervious areas would flow over pervious areas (including the BMPs) before leaving the subcatchment. Gaea estimated that, for the basic scenario, approximately 60% of runoff from impervious surfaces flowed onto the BMPs.

The basic scenario increased water surface elevations along Golden Drive by about 4.5 inches for the two-year storm, most likely because it flowed to the junction of the St. Avide and De La Ronde canals, upstream of the proposed weirs. Most of the rest of the neighborhood experienced reductions in water surface elevation between 1 to 13 inches. Generally, the greater reductions occurred closer to the canal. Since the water level in the canal did not change, these reductions were most likely due to retention/detention and street BMPs. The west end of the 20 Arpent Canal lowered by approximately 3 inches. Reductions in the rest of the watershed were less than 1 inch.

Both positive and negative effects diminished with the larger storms. The maximum reductions for the 10-year storm were approximately 5 inches. Very few areas experienced reductions for the 100-year storm, and those that did were only 2 to 3 inches lower. These results demonstrated that retention/detention, BMPs, and weirs were less effective with greater storm water runoff volumes. Future BCA analyses should include smaller storms to capture the benefits these interventions would have during smaller, more frequent storms.

5.3 Intensive Scenario

The intensive scenario included retention/detention of 1.25 inches of rainfall throughout the study area, approximately 8.9 miles of street BMPs, and the "wetland shelves" and weirs from the basic scenario. For the intensive scenario, Gaea estimated that approximately 90% of runoff from impervious surfaces flowed onto the BMPs.

The intensive scenario represented a significant change in hydrologic conditions and resulted in pronounced reductions in water surface elevations for the two-year storm. Most of the neighborhood experienced reductions of 0.5 to 2 feet, with some reductions as much as 3.5 feet. The St. Avide Canal lowered by approximately 4 inches. Outside the neighborhood, the effects were slightly more than in the basic scenario. This suggests that the weirs and wetland shelves, which were common to both scenarios, had greater effects on the surrounding area than the retention/detention and BMPs.

As before, the effects of the interventions were less pronounced for larger storms. Reductions in water surface elevation ranged from 4 to 12 inches for the 10-year storm and 2 to 9 inches for the 100 year storm.

This more detailed modeling effort demonstrated the value of LID components and small-scale retention/detention for localized areas, particularly for smaller, more frequent storms. Though neither scenario significantly reduced water surface elevations outside of the neighborhood, the benefits inside the neighborhood were significant. To investigate what effects improvements to several neighborhoods might have on the system as a whole, Gaea recommends more detailed large-scale modeling.

6. Pump Drawdown

Another proposed change to St. Bernard's water management plan is to hold water in the canals at higher levels during dry weather. This measure would help combat subsidence in the area by allowing more water to infiltrate into the ground and fill void spaces that could otherwise consolidate. This approach could be risky, however, since it leaves less volume available to store rainwater and would require pump capacity to empty the canals ahead of a storm. To minimize this risk, the Parish would need to know the time required to empty the canals in advance of a storm. To estimate this time, Gaea modeled the existing, basic, and intensive scenarios with no rainfall and the canals initially full. Gaea set the initial water surface elevation to -2 feet northwest of the Violet Canal and +2 feet southeast of the Violet Canal. Gaea then examined the water surface elevation over time for the nodes adjacent to the pump stations ("intake") and the nodes at the extreme upstream ends of the model ("remote"). The figures below show the water surface elevation at the sites considered over time in the model (the model had an arbitrary start time of 12:01AM on 1 October 2009). It is important to note that lowering the water surface faster than 1 foot/minute is considered unsafe as it may introduce slope stability issues in unlined channels.

It is convenient to discuss the results of this test by defining four areas: New Orleans' Ninth Ward, St. Bernard Parish west of Paris Road, the area between Paris Road and the Violet Canal, and the area southeast of Violet Canal.

6.1 New Orleans' Lower Ninth Ward

DPS05 drains New Orleans' Lower Ninth Ward. Under existing conditions, the pump intake draws down from -2 to -4.5 feet in about 4.5 hours, then decreases rapidly to -17 feet less than an hour after that. This rapid decrease is due to the depth of the wet well at the pump intake and does not necessarily reflect the draw down in the canals. The remote ends of the area exhibit a similar pattern, drawing down from -2 to -5 feet in about 5.5 hours, then decreasing more rapidly down to -9 feet 30 minutes later. These rapid decreases may be acceptable since most of the major drainage network is comprised of concrete-lined, underground channels. However, future study on the slope stability of unlined channels in the network may be warranted.

The results for the basic and intensive scenarios are virtually identical for this area. The pump intake took slightly longer to draw down under proposed conditions, which was expected since the connection with St. Bernard Parish introduced more water into the Ninth Ward. The intake drew down from -2 to -4.5 feet in about 5 hours before it dropped rapidly to -17 feet less than an hour after that. The remote end took about 15 minutes longer to draw down to -5 feet before it decreased rapidly down to -9 feet. Figure B14 shows a graph of drawdown around DPS05.

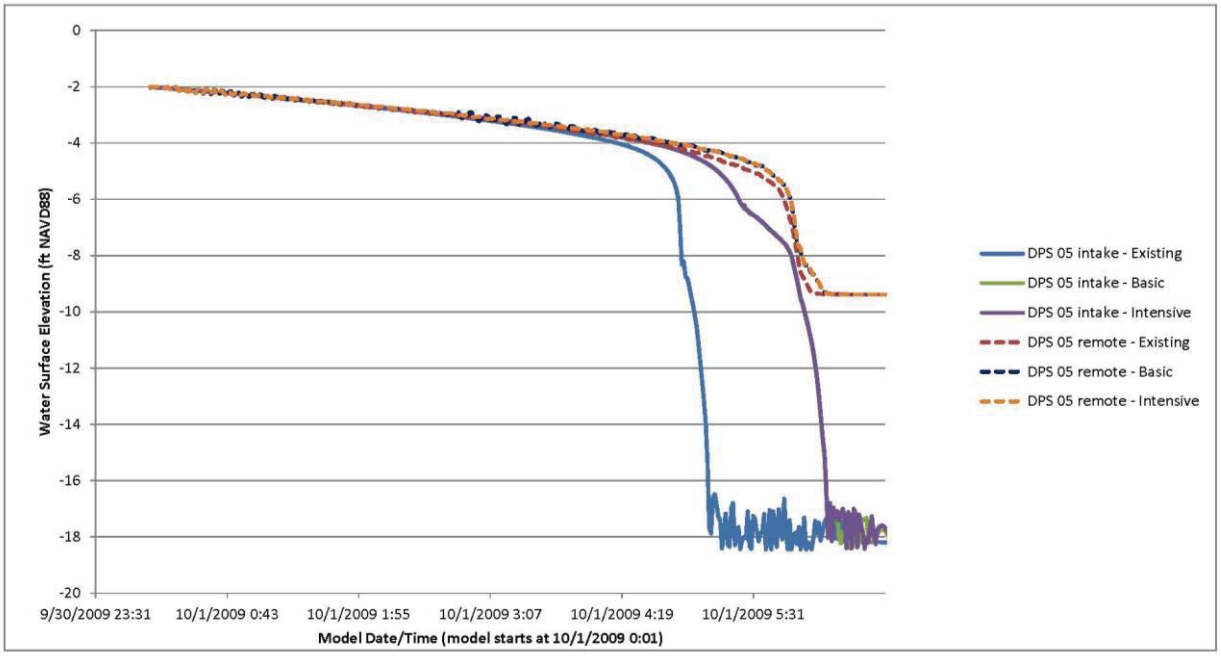

Figure B14: Pump drawdown in the Ninth Ward.

6.2 West of Paris Road

Jean Lafitte and Guichard Pump Stations drain St. Bernard Parish west of Paris Road. Since both pump stations have intakes in 40 Arpent Canal, their hydrographs are similar. Therefore, this section discusses only the Guichard Pump Station for simplicity.

Under existing conditions, the two pump stations drew down from -2 to -3.5 feet in approximately 1.5 hours. They then drew down slightly more rapidly to -6.25 feet over the next hour, an average rate of approximately 2.75 feet/hour. The remote ends of the drainage network drew down from -2 feet to -5 feet in approximately 3.5 hours (about 0.9 feet/hour), after which the drawdown rate decreased, and the water surface elevation leveled off at approximately -6 feet. All parts of the drainage network could flow freely.

Under both proposed scenarios, the initial drawdown at the pump intake was similar to the existing condition. After drawing down to approximately -3.5 feet, the rate of drawdown increased, but not as dramatically as under the existing condition. It took approximately 1.5 hours for the water surface elevation to decrease to -6.2 feet, an average rate of about 1.8 feet/hour. At remote points in the drainage system, the drawdown rate increased to almost 1.1 feet/hour due to drainage improvements. The initial drawdown at the upstream end was much slower than in the existing condition; the water level decreased from -2 feet to -3 feet in approximately 4 hours. After that, the drawdown accelerated, with the water level decreasing from -3 feet to -5 feet in approximately 1.7 hours. Not shown in Figure B15 are the nodes upstream of proposed weirs, which could remain at -2 feet indefinitely since that water surface elevation will not overtop the weirs, and the remote node for the intensive scenario, which had a hydrograph nearly identical to the basic scenario.

Since the rate of drawdown in the 40 Arpent Canal was greater than the safe rate of 1 foot/hour under all scenarios, it may be prudent to use only one of these pumps to decrease water levels prior to a storm. Figure B15 shows a graph of drawdown around Guichard Pump Station.

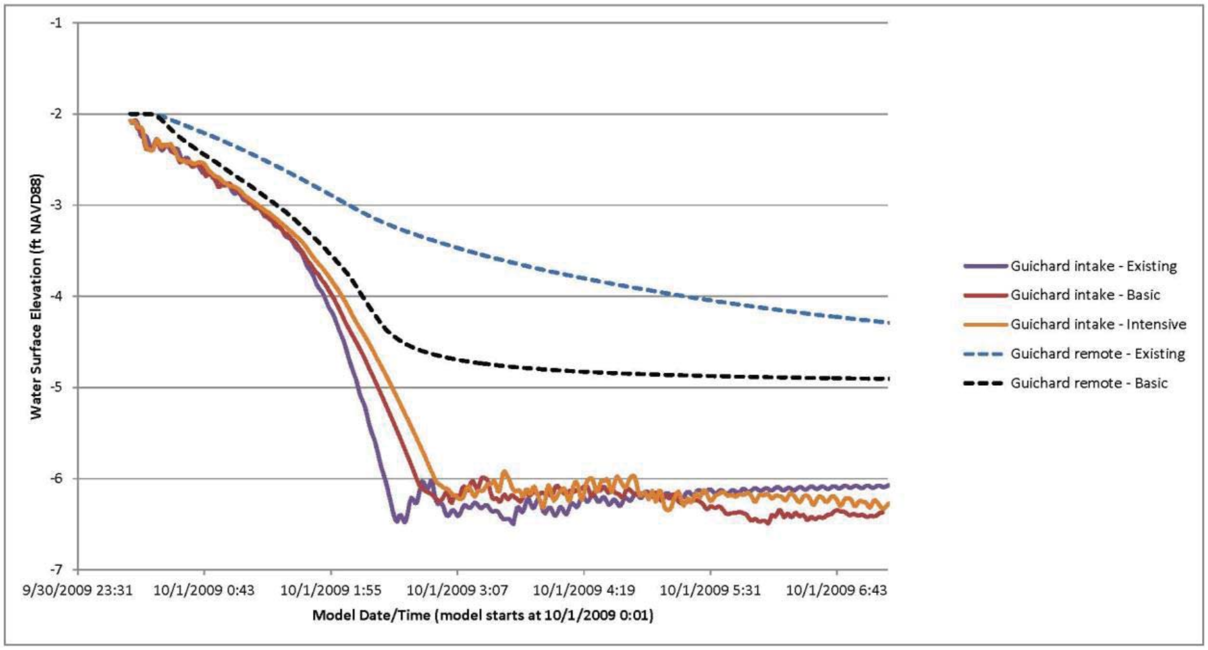

Figure B15: Pump drawdown in St. Bernard Parish west of Paris Road.

6.3 Between Paris Road and Violet Canal

Bayou Villere, Bayou Ducros, and Meraux Pump Stations drain St. Bernard Parish between Paris Road and Violet Canal. Since all three pump stations have intakes in 40 Arpent Canal, their hydrographs are similar. Therefore, this section discusses only the Bayou Ducros Pump Station for simplicity.

Under existing conditions, the water surface at the pump station intake lowered from -2 feet to -4 feet in just under 4.5 hours, after which the drawdown accelerated to slightly approximately 1.1 feet/hour, bringing the water surface down to -6.5 feet over the next 2.25 hours. The remote end of the system lowered from -2 feet to -3.5 feet in approximately 4.5 hours and from -3.5 feet to -6 feet in just under 3 hours (approximately 0.8 feet/hour).

Under the basic scenario, the water surface at the pump station intake took the same length of time to decrease to -6.5 feet, but more time to initially lower to -4 feet, thus the drawdown rate increased. The drawdown at the upstream end of the system was slightly faster than in the existing conditions, most likely due to drainage improvements.

Under the intensive scenario, the additional volume of the spillways increased the time for the pumps to lower water surfaces at their pump intakes to almost 11 hours. However, it is important to note that although the water surface elevation took longer to drawdown, the available storage space was similar to that in the existing and basic scenarios because the spillways provided additional capacity. The remote ends of the system did not change significantly from the basic scenario. Figures B16 and B17 show graphs of drawdown around Bayou Ducros Pump Station (the graphs are separated to make them easier to read).

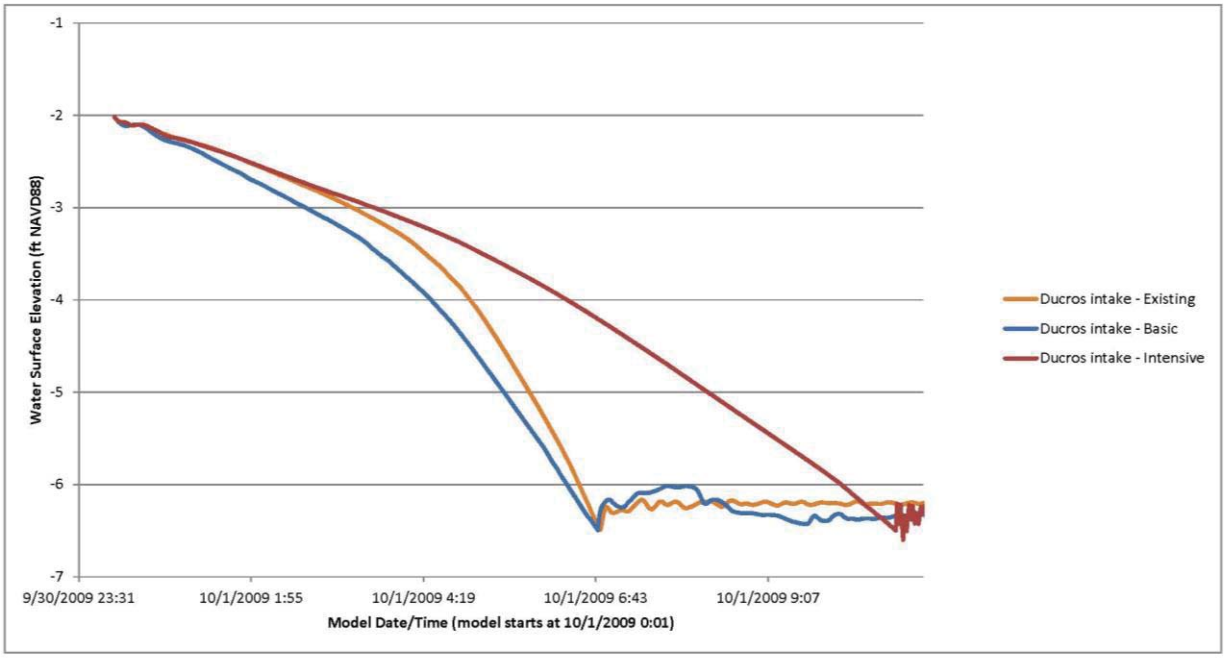

Figure B16: Pump drawdown between Parish Road and Violet Canal (Bayou Ducros PS intake).

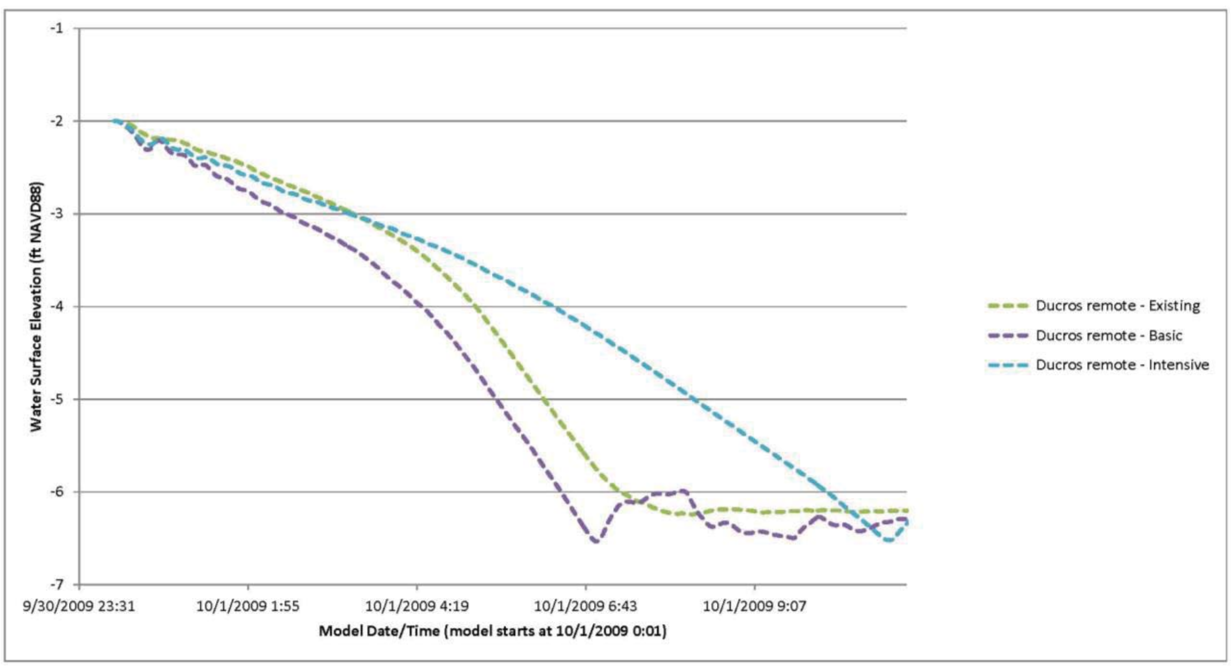

Figure B17: Pump drawdown between Parish Road and Violet Canal (remote point).

6.4 Southeast of Violet Canal

EJ Gore and St. Mary Pump Stations drain St. Bernard Parish southeast of Violet Canal. Since neither proposed scenario includes hydraulic modifications in this area, the hydrographs are nearly identical for all points considered. Therefore, this section discusses only the existing condition for simplicity.

Since several miles of canals separate the two pump stations, their drawdown patterns were significantly different. The EJ Gore Pump Station took approximately 44 hours to pump enough water to decrease the water surface elevation from +2 feet to -1 foot. The drawdown rate increased after this as the water surface lowered to -1.75 feet over the next 5.5 hours. The upstream end of the drainage network near the Violet Canal lowered very slowly, decreasing by less than 1 foot over a period of several days.

The St. Mary Pump Station works much faster than the EJ Gore Pump Station, but is still relatively slow compared to those discussed above. The water surface elevation at its intake decreases from +2 feet to approximately +0.7 feet over a period of about 20 hours, then to -1.75 feet over the next 10.5 hours. The upstream end of the system near Caernarvon lowered from +2 feet to +1 feet in approximately 28.5 hours, then from +1 feet to -1.5 feet in approximately 19 hours. Figure B18 shows a graph of drawdown around in the area under existing conditions.

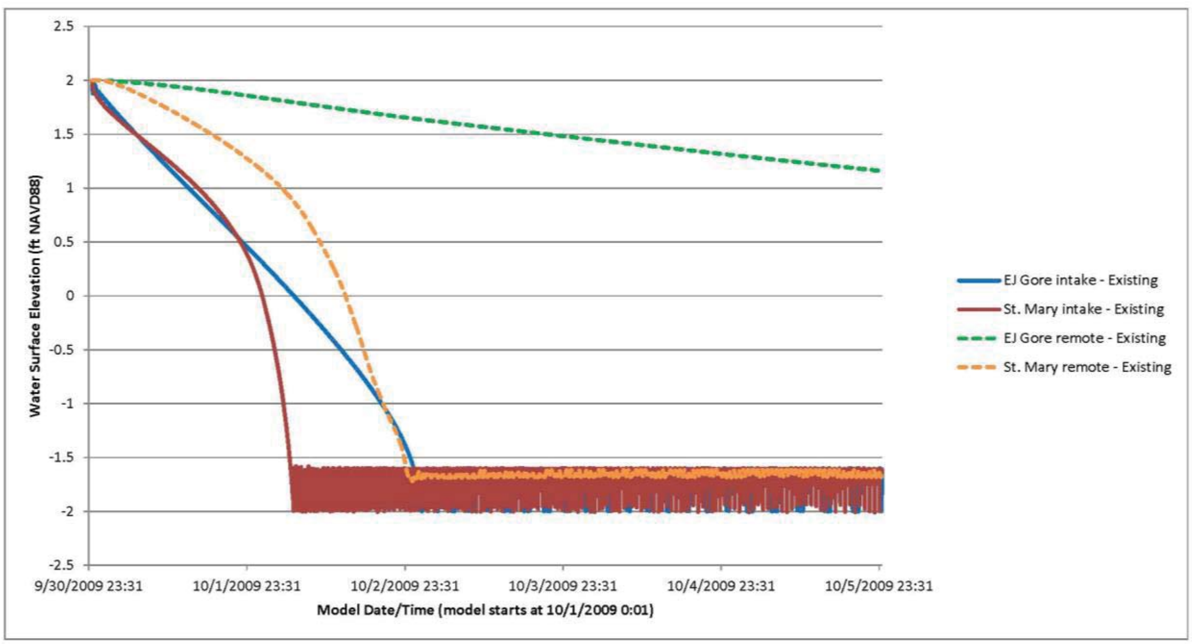

Figure B18: Pump drawdown southeast of Violet Canal

In general, maintaining high water elevations in the canals and then pumping in anticipation of a storm is risky, both in terms water management and geotechnical slope stability. However, the benefits of this strategy for mitigating subsidence could be substantial. To mitigate the risk, Gaea recommends that the Parish manage this strategy with a seasonal approach, keeping water elevations high during dry seasons and low during rainy seasons (as opposed to anticipating multiple storms during traditionally rainy periods).

7. Violet Canal Dry-Weather Flow

For dry weather conditions, Waggonner & Ball is proposing the use of flow from the Violet Canal to flush the drainage system. Flushing the system is desirable to avoid degrading water quality and to prevent mosquito breeding. This is particularly important in the proposed spillways where shallow ponds will form during dry periods. Waggonner & Ball and Gaea considered a flushing velocity of 1 foot/second to be desirable. Gaea modeled a baseline inflow at the node closest to the Violet Canal on the northwest side to estimate the resulting velocities. Several of the storage areas in the system represented small ditch networks. Gaea converted these to junctions since this inflow would be designed not to overflow the main drainage canals. Since the largest pump station in the system (DPS05) has a maximum capacity of 2,260 CFS, Gaea considered that the maximum feasible flow and introduced it to both the basic and intensive configurations.

Under the basic scenario, this inflow achieved the flushing velocity in the 20 Arpent Canal as far west as the Valero Refinery. Flow from the Violet Canal alone was not sufficient to achieve the flushing velocity farther west, and weirs prevented the velocity in most of the connections between the 20 Arpent and 40 Arpent canals from exceeding 1 foot/second. Velocities in the 40 Arpent Canal ranged from 0.4 to 1.3 feet/second.

Velocities in the 20 Arpent Canal were lower under the intensive scenario, with only the section southeast of Meraux reaching the desired flushing velocity. Velocities in the connecting canals and spillways were similar to those under the basic scenario, and since there were more of them, they introduced more flow into the 40 Arpent Canal. Thus, velocities in the 40 Arpent Canal were greater than under the basic scenario, with most of the segment southeast of Bayou Ducros Pump Station achieving velocities of 1 foot/second or greater.