Appendix

Tampa Bay Regional Atlas
Site Selection & Program Resources
North Tampa Closed Basin Maps & Drawings
R.E. Olds Park / Oldsmar Maps & Drawings
Pass-a-Grille / St. Pete Beach Maps & Drawings
Groundwater Report

Download Report: tbrpc.org/resilient-ready
Study Area Application Locations
Landscape Typologies

LEGEND
- TBRPC County
- Watershed
- Flow Overland
- Flow Underground

TYPOLOGIES
- Developed Areas
- Barrier Island
- Bay Edge
- Scarp
- Tidal Swamp
- Hammock Inland
- Inland Swamp
- Scarp

20 miles
Study Area Application Locations

LEGEND

- TBRPC County
- FEMA 100 Year Floodplain

CITRUS COUNTY
HERNANDO COUNTY
PASCO COUNTY
HILLSBURG COUNTY
PINELLAS COUNTY
MANATEE COUNTY

Oldsmar
North Tampa Closed Basin
Spring Hill
Clearwater
Tampa
St. Petersburg
Pass-a-Grille
Sarasota
Landscape Typologies

Legend
- TBRPC County
- Watershed

Land Surface Elevation

0 ft
10 ft
20 ft
30 ft
40 ft
50 ft
60 ft
70 ft
80 ft
90 ft
100 ft
110 ft
120 ft

Cities and Towns:
- Clearwater
- Tampa
- St. Petersburg
- Sarasota
- Oldsmar
- North Tampa Closed Basin
- Pass-a-Grille

Counties:
- CITRUS COUNTY
- HERNANDO COUNTY
- PASCO COUNTY
- HILLSBOROUGH COUNTY
- MANATEE COUNTY
- PINELLAS COUNTY

Appendix: Tampa Bay Regional Atlas
Land Surface Elevation

Legend

Land Surface Elevation
USGS 2004 - 2017

- Project Locations
- Project Watersheds
- Watersheds
- County Boundary

Legend:

- 120 ft
- 110 ft
- 100 ft
- 90 ft
- 80 ft
- 70 ft
- 60 ft
- 50 ft
- 40 ft
- 30 ft
- 20 ft
- 10 ft
- 0 ft
- -10 ft
- -20 ft
- -30 ft
- -40 ft
- -50 ft

Project Locations:
- Oldsmar
- Pass-A-Grille
FEMA 100 Year Floodplain

Legend
- FEMA 100 Year Floodplain
- Project Locations
- Project Watersheds
- Watersheds
- County Boundary

GULF OF MEXICO
Maximum Possible Storm Surge

Legend:

- **Yellow**
- **Orange**
- **Red**
- **Dark Blue**
- **White**

Project Locations:
- **Oldsmar**
- **Pass-A-Grille**

Watersheds:
- Tampa Bay Watershed
- Gulf of Mexico

Category:
- Category 5
- Category 3
- Category 1
Hurricane Paths 1850-2020

Legend
Hurricane Paths 1850-2020
- Category 5
- Category 4
- Category 3
- Category 2
- Category 1
- Tropical Storm/Depression

Project Locations
Project Watersheds
Watersheds
County Boundary

Gulf of Mexico
St. Petersburg
Sarasota
Lakeland
Tampa

Legend

1 Mile
Parcel Ownership

Legend
- Parks
- City Owned Parcels
- County Owned Parcels
- FEMA 100 Year Floodplain
- Project Locations
- Watersheds
- County Boundary
Geology

Legend
- **Yellow**: Sand, Barrier Islands
- **Light Yellow**: Clay Sands, Historic Ridges
- **Light Green**: Shells, Bayfront
- **Green**: Limestone Dolomite, Karst
- **Orange**: Sand Phosphates
- **Gray**: Fill

- **Red Triangle**: Project Locations
- **Blue Dashed Line**: Watersheds
- **Gray Line**: County Boundary

Map showing Geology of the Tampa Bay Watershed, including locations such as Oldsmar and Pass-A-Grille.
## Precipitation 25 Year 24 Hour Event

### Legend
- **10 Inches**
- **7 Inches**
- **Project Locations**
- **Project Watersheds**
- **Watersheds**
- **County Boundary**

### Precipitation Events

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<thead>
<tr>
<th></th>
<th>Pass-A-Grille</th>
<th>Oldsmar</th>
<th>Inland Tampa</th>
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<tr>
<td><strong>25 year 24 hour</strong></td>
<td>9.5&quot;</td>
<td>8.8&quot;</td>
<td>8.4&quot;</td>
</tr>
<tr>
<td><strong>25 year 2 hour</strong></td>
<td>4.1&quot;</td>
<td>4.2&quot;</td>
<td>4.3&quot;</td>
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<tr>
<td><strong>10 year 24 hour</strong></td>
<td>7.5&quot;</td>
<td>6.9&quot;</td>
<td>6.5&quot;</td>
</tr>
<tr>
<td><strong>10 year 2 hour</strong></td>
<td>3.5&quot;</td>
<td>3.6&quot;</td>
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# Soil Hydrologic Groups

## Watersheds & Water Storage Targets

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<th>Area Acres</th>
<th>Pass a Grille</th>
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<th>NTCB</th>
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<tr>
<td>25 year 24 hour</td>
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<tr>
<td>Rain Inches</td>
<td>9.5”</td>
<td>8.8”</td>
<td>8.4”</td>
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<tr>
<td>Runoff Acre ft</td>
<td>91</td>
<td>136</td>
<td>274</td>
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<tr>
<td>Rain :: Runoff</td>
<td>51%</td>
<td>79%</td>
<td>44%</td>
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<tr>
<td>25 year 2 hour</td>
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<tr>
<td>Rain Inches</td>
<td>4.1”</td>
<td>4.2”</td>
<td>4.3”</td>
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<tr>
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<td>64%</td>
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<tr>
<td>10 year 24 hour</td>
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<tr>
<td>Rain Inches</td>
<td>7.5”</td>
<td>6.9”</td>
<td>6.5”</td>
</tr>
<tr>
<td>Runoff Acre ft</td>
<td>65</td>
<td>101</td>
<td>179</td>
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<tr>
<td>Rain :: Runoff</td>
<td>46%</td>
<td>75%</td>
<td>38%</td>
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<tr>
<td>Runoff Acre ft</td>
<td>22</td>
<td>43</td>
<td>59</td>
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<tr>
<td>Rain :: Runoff</td>
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<td>61%</td>
<td>22%</td>
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## Legend

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<th>B</th>
<th>C</th>
<th>D, /D</th>
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</thead>
</table>

- **Project Locations**
- **Project Watersheds**
- **Watersheds**
- **County Boundary**
Elevation Floodplain & Population Distribution

Land Area Relative to Elevation and Floodplains

Cumulative Distribution of Land Surface Elevation
% In the FEMA 100 Year Floodplain per 1 ft Interval

Population*
*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

Holmes Beach Study Area

MANATEE COUNTY

RESILIENT READY TAMPA BAY
Population Relative to Elevation and Floodplains

**Population** per 1 foot interval
- In the FEMA 100 Year floodplain

384,000 Total Population (2019)

- Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & County Parcels

**MANATEE COUNTY**

Population*: Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

Population Relative to Elevation and Floodplains

County Owned Parcels Relative to Elevation and Floodplains

In the FEMA 100 Year floodplain

Total Population (2019)

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Population Relative to Elevation and Floodplains

Population* per 1 foot interval

In the FEMA 100 Year floodplain

384,000 Total Population (2019)

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

APPENDIX: TAMPA BAY REGIONAL ATLAS

C O U N T Y
Elevation Floodplain & Population Distribution

Cumulative Distribution of Land Surface Elevation
% In the FEMA 100 Year Floodplain per 1 ft Interval

Minimal inhabited space above 150 ft

Land Area Relative to Elevation and Floodplains

Curiosity Creek Study Area
North Tampa Closed Basin Study Area

Population*
*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

Population per 1 foot interval
In the FEMA 100 Year Floodplain
Total Population (2019)
HILLSBOROUGH COUNTY

Population Relative to Elevation and Floodplains

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & County Parcels

**HILLSBOROUGH COUNTY**

Population*

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

Population Relative to Elevation and Floodplains

County Owned Parcels Relative to Elevation and Floodplains

**County Owned Parcels**

**In the FEMA 100 Year floodplain**

Total Population (2019)

Population per 1 foot interval

In the FEMA 100 Year floodplain

County Owned Parcels

RESILIENT READY TAMPA BAY
Hillsborough County

Population Relative to Elevation and Floodplains

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

1,422,000 Total Population (2019)
Elevation Floodplain & Population Distribution

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Safety Harbor, Oldsmar, Madeira, St Pete Beach Study Areas

Cross Bayou, Largo, Bonner Park Study Areas

PINELLAS COUNTY

965,000 Total Population (2019)

Population* per 1 foot interval
In the FEMA 100 Year floodplain

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & County Parcels

County Owned Parcels

In the FEMA 100 Year floodplain

Acres

Elevation NAVD 88

Population*

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

RESILIENT READY TAMPA BAY
PINELLAS COUNTY

Population Relative to Elevation and Floodplains

Population* per 1 foot interval
In the FEMA 100 Year floodplain

965,000 Total Population (2019)

Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map.

APPENDIX: TAMPA BAY REGIONAL ATLAS
Population Relative to Elevation and Floodplains

Population* per 1 foot interval
In the FEMA 100 Year floodplain

525,000 Total Population (2019)

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & County Parcels

County Owned Parcels Relative to Elevation and Floodplains

- **County Owned Parcels**
- **In the FEMA 100 Year floodplain**

Population Estimate Based on 2019 ACS Census Data, Location and Elevation Based on ESRI Land Cover, USFWS Wetlands Inventory and USGS National Elevation Map

Total Population (2019)
PASCO COUNTY

Population Relative to Elevation and Floodplains

Population* per 1 foot interval
In the FEMA 100 Year floodplain

525,000 Total Population (2019)

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & Population Distribution

HERNANDO COUNTY

Land Area Relative to Elevation and Floodplains

Cumulative Distribution of Land Surface Elevation
% In the FEMA 100 Year Floodplain per 1 ft Interval

Minimal inhabited space above 150 ft

Population*

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

Total Population (2019)

Population Relative to Elevation and Floodplains

RESILIENT READY TAMPA BAY
Population Relative to Elevation and Floodplains

Population* per 1 foot interval

In the FEMA 100 Year floodplain

186,000 Total Population (2019)

Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map.
Population Relative to Elevation and Floodplains

Population* per 1 foot interval
In the FEMA 100 Year floodplain
186,000 Total Population (2019)

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & Population Distribution

CITRUS

Land Area Relative to Elevation and Floodplains

Cumulative Distribution of Land Surface Elevation
% In the FEMA 100 Year Floodplain per 1 ft Interval

Population*
*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Population Relative to Elevation and Floodplains

Population* per 1 foot interval

In the FEMA 100 Year floodplain

145,000 Total Population (2019)

*Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map
Elevation Floodplain & County Parcels

CITRUS

County Owned Parcels Relative to Elevation and Floodplains

- County Owned Parcels
- In the FEMA 100 Year floodplain

Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map.

Population* per 1 foot interval

In the FEMA 100 Year floodplain

Total Population (2019)

County Owned Parcels Relative to Elevation and Floodplains

- Acres
- Elevation NAVD 88
Population Relative to Elevation and Floodplains

Population* per 1 foot interval
In the FEMA 100 Year floodplain
145,000 Total Population (2019)

Population estimate based on 2019 ACS Census Data, location and elevation based on ESRI Land Cover, USFWS wetlands inventory and USGS National Elevation Map

APPENDIX: TAMPA BAY REGIONAL ATLAS
Site Selection & Program Resources
Resilient Ready Tampa Bay is a regional technical assistance project that will enhance the capacity of Tampa Bay communities to assess, plan for, and adapt to flood impacts through the expanded use of multi-functional green infrastructure systems and resilient landscape design and construction practices.

Project Overview

The Resilient Ready Tampa Bay project is led by the Tampa Bay Regional Planning Council (TBRPC) and made possible by the Florida Department of Environmental Protection’s (FDEP) Resilient Florida Program. The City of Tampa is the FDEP Grant Coordinator on behalf of the TBRPC. Two local governments in the Tampa Bay region, in addition to the City of Tampa, will be selected to participate in the project and receive technical engineering analysis/design services at no cost.

From January through June 2022, a team of multidisciplinary professionals, including planners, urban designers, architects, landscape architects, engineers, and hydrologists will meet with municipal staff and stakeholders to create adaptive redesign strategies for vulnerable critical assets in the selected study areas.

Through interactive design charrettes, local governments and the Resilient Ready team will develop flood mitigation designs and cost-benefit information which can be used by local governments to apply for State and Federal grants. At the conclusion of the project, local government participants and subject matter experts will convene for a Symposium/Showcase half-day event.

The application is due Friday, January 21, 2022, by 4:00 PM. Email the completed application form and the study area’s Risk Index Report to sarah@tbrpc.org to submit your application.

A Question-and-Answer Session will be held over Zoom on January 7th from 1:00 - 2:00 PM for interested applicants. This session will be recorded and made publicly available. Contact Sarah Vitale (sarah@tbrpc.org) for more information.

Register for the Q/A session:
https://us02web.zoom.us/meeting/register/tZUtduuhpj8jEtXninOKva-FwqdF4ys7J7vs
Eligible Study Areas

To support local governments in their development of flood resilient designs and adaptation projects for application to the Federal Emergency Management Agency (FEMA) Building Resilient Infrastructure and Communities (BRIC) grant program and other grant programs, the Resilient Ready eligibility criteria is modeled after the FEMA BRIC program.

Eligible project study areas should align with FEMA’s examples of eligible Community Flood Mitigation projects; including, but not limited to, localized flood control, floodwater storage and diversion, floodplain and stream restoration, and stormwater management. Potential projects that could develop as a result of the Resilient Ready Tampa Bay project can range in scope and scale, from large-green infrastructure to smaller-scale projects for neighborhoods or community redevelopment areas.

The Resilient Ready Team will select one study area from each of the following categories:

1. Barrier Islands
2. Waterfront Areas
3. Inland Areas - Basins/Tributaries/Rivers/Lakes

Applicants may submit more than one application for each category but will only be awarded for one category.

The Resilient Ready Team will assist in the study area analyses and development of preliminary maps and flood vulnerability assessments, including to collect/develop maps and visuals and produce flood hazard exposure assessments. The Team will use methodology and criteria defined in Florida Statute 380.093, which will include sea level rise using 2017 NOAA Intermediate-Low and Intermediate-High projections for 2040 and 2070; storm surge (tropical storms through Category 5) and tidal flooding (if appropriate to the study area) and compound flooding of these risks.
Eligibility Criteria

1. Local government agency (counties and municipalities) in the Tampa Bay region only. Individuals, businesses, and non-profit organizations are not eligible to apply.

2. Member of the Tampa Bay Regional Resiliency Coalition.

3. The study area must have a flood risk to infrastructure – physical structures, facilities, and/or systems that provide support to the community and economy.

4. The study area must be located on public property. Consider public spaces in areas with known flooding issues.

5. The study area must be suitable for nature-based solutions, or practices that intertwine natural features or processes into the built environment to build more resilient communities (e.g., living shorelines, ecosystem restoration, mangroves, soil stabilization, bioretention systems, etc.).

Resilient Redesign

Resilient Ready Tampa Bay is inspired by the Southeast Florida Regional Climate Change Compact’s Resilient Redesign project from 2015.

Watch the project video: vimeo.com/138213364
Resilient Ready Tampa Bay – Study Area Selection Application

Project Commitments

1. Establish a project team to include a project lead, resilience staff member, public works or engineering or infrastructure department staff member, community services or neighborhood planning staff member, and a floodplain manager.

2. Attendance at the project kick-off meeting (February).

3. Attend virtual meetings (approximately every other week) to provide data, review/discuss study area issues, review designs, etc.

4. Active participation from the full project team for the design charrette (April): The selected local government will assist in the coordination of a walking tour of the study area and secure a location for the multi-day design charrette. If a location in the community cannot be secured, Tampa Bay Regional Planning Council will host the design charrette in its office space in Pinellas Park.

5. Present/participate in the Project Showcase Symposium (June).

Project Timeline

[Diagram showing timeline with key events: Study Area Selection (January 2022), Design Charrettes (April 2022), Kick-off Meeting (February 2022), Showcase Symposium (June 2022).]
Resilient Ready Tampa Bay – Study Area Selection Application

Study Area Selection Application Form

---

Form Completed By (Name) | Date
---|---

Resilient Ready Study Area Local Team

Define the local government staff lead and participating team members. Upon selection, additional team members can be identified and invited to participate in the design charrettes.

Project Lead:

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<th>Organization</th>
</tr>
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<table>
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<th>Phone</th>
</tr>
</thead>
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<tr>
<td></td>
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Resilience Staff Member:

<table>
<thead>
<tr>
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<td></td>
</tr>
</tbody>
</table>
Resilient Ready Tampa Bay – Study Area Selection Application

Public Works or Engineering or Infrastructure Department Staff Member:

Name | Title | Organization
--- | --- | ---

Email | Phone
--- | ---

Community Services or Neighborhood Planning Staff Member:

Name | Title | Organization
--- | --- | ---

Email | Phone
--- | ---

Floodplain Manager:

Name | Title | Organization
--- | --- | ---

Email | Phone
--- | ---

Identify the preferred charrette location:

- [ ] Local government will secure a space to conduct a multi-day design charrette
- [ ] TBRPC office in Pinellas Park
Resilient Ready Tampa Bay – Study Area Selection Application

Study Area Categories

Select one from the following categories.

1. Barrier Islands
2. Waterfront Areas
3. Inland Areas - Basins/Tributaries/Rivers/Lakes

Study Area Category Selection

Study Area Characteristics

Location

Describe the proposed site for analysis, including its address and site boundaries. Consider public spaces in areas with known flooding issues.

Property Ownership Entities:

Study area must contain public property, e.g., City of Gulfport Veteran's Park
Resilient Ready Tampa Bay – Study Area Selection Application

Describe the study area’s existing land use(s), zoning, and future land use(s):

Identify relevant Census Tract(s):

Identify relevant Parcel Number(s):

Approximate size of study area (acres):

Does this study area contain sites that qualify as FEMA Repetitive Loss* properties?

*A repetitive loss is when a home, business, or structure is in an area that has experienced flooding at least two times in any 10-year period. Read more: [fema.gov/txt/rebuild/repetitive_loss_faqs.txt](http://fema.gov/txt/rebuild/repetitive_loss_faqs.txt).

Yes  No
Resilient Ready Tampa Bay – Study Area Selection Application

Approximate number of flood events in the last five years within the study area:

Describe the type(s) and cause(s) of flood waters within the study area:

For example, coastal (storm surge), fluvial (river, lake, or stream), and pluvial (flash flood, high tide, and/or surface water flooding).

Describe the movement of floodwaters within the study area (i.e. on-site retention, drainage activity, hydrological connections, etc.):

250 words or less

What is your organization’s capacity to implement flood mitigation plans/projects?

250 words or less
Resilient Ready Tampa Bay – Study Area Selection Application

How might a flood mitigation investment in this study area reduce flood risks and provide economic, environmental, and community resilience benefits?

250 words or less

What planning studies and/or assessments have been conducted, are currently underway, or are expected to take place in the study area? (e.g., Hazard Mitigation, Small Area Plan)

250 words or less

If applicable, reference recent investments in infrastructure/capital improvements.

250 words or less
Resilient Ready Tampa Bay – Study Area Selection Application

Additional Documentation

FEMA National Risk Index

1. Visit hazards.fema.gov/nri/map. Select “Census Tract View” and input an address within the boundary of the study area.

2. Click on the relevant Census Tract to view the Tract’s Risk Index. Select “Create Report.”
Resilient Ready Tampa Bay – Study Area Selection Application

3. A new window will open. Select “Print Report” and save the file as a PDF.

National Risk Index

December 03, 2021

Census tract 12103027501, Pinellas County, Florida

The application is due Friday, January 21, 2022, by 4:00 PM. Email the completed application form and the study area’s Risk Index Report to sarah@tbrpc.org to submit your application.

A Question-and-Answer Session will be held over Zoom on January 7th from 1:00 - 2:00 PM for interested applicants. This session will be recorded and made publicly available. Contact Sarah Vitale (sarah@tbrpc.org) for more information.

Register for the Q/A session:
https://us02web.zoom.us/meeting/register/tZUtduuhpj8jEtXninOKva-FwqdF4ys7J7vs

Subscribe to the Resilient Ready email list:
https://lp.constantcontactpages.com/su/KyFB1z7/resilientready
Project Applicants
Citrus County

Ozello Community Park & Nearby Lots

Proposed site will be in the Sunny Isles Estates Unit 1 & 2 Subdivision and N. Ozello Trail located in Crystal River, Citrus County. It is a residential neighborhood that includes a boat ramp/park on a barrier island that is connected by a causeway (N Ozello Trail) just west of US 19.

The barrier island is located within an estuary area on the west coast of Citrus County. At this time, there are no existing county-owned on-site retention or conveyance systems within the residential areas. The causeway contains an inadequate conveyance system based on the tidal influence.

This study area presents an opportunity and challenge to incorporate low impact development in an area that experiences multiple events of coastal and pluvial types of flooding. This not only decreases our community’s resiliency, but adversely impacts the environment in and around the study area. This investment will aid an already growing tourism industry within the study area that connects current, new and visiting citizens to the environment through various recreational activities along the causeway and in our park. The community’s recover time frame after flooding impacts will continue to actively impede this growth. The County believes that as our community continues to grow, a flood mitigation investment increases our economical opportunities, reduces our environmental impacts, and provides assurance for our current, new, and visiting citizens that their transportation and drainage systems will provide consistent and safe access throughout the whole year.
Hillsborough County

Curiosity Creek

Two areas to the north, and upstream of the County-owned subject parcel have been identified as flooding areas of concern. Stormwater runoff from residential areas on either side of Curiosity Creek north of Floral Drive is primarily conveyed through 18-inch and 24-inch pipes to the main channel. Factors contributing to this flooding are: highly developed residential areas; limited discharge capacity into Curiosity Creek; limited storage and attenuation; and high tail water and limited flow capacity in Curiosity Creek.

Stormwater runoff from residential areas on either side of Curiosity Creek north of Floral Drive is primarily conveyed through 18-inch and 24-inch pipes to the main channel. Significant street flooding can occur along Floral Drive near the undersized creek crossing, and on Carnation Drive, Leisure Avenue and North Boulevard, despite the implementation of the 2005 Floral Drive Structure Rehabilitation Project consisting of a 36-inch HDPE stormwater outfall just south of the Floral Drive constriction. The watershed model shows street flooding for the mean annual design event and low-lying homes and yards appear to be at risk for the 5-year annual recurrence interval storm event.

Further downstream, over Ambassador Loop, the watershed model demonstrates street, yard, and structure flooding for even a mean annual, 24-hour event. Additionally, 18-inch flood depths and structure flooding are anticipated within Rose Lake Estates MHP during a 25-yr, 24-hr event.

Potential approaches to address flooding in these two areas included lowering the creek profile by increased pipe capacity for the Floral Drive crossing and Rose Lake Estates' Sun Valley Lane crossing, adding new storage to attenuate increased flows and mitigate flood damages, improving channel conveyance and increasing the 2005 Floral Drive Structure Rehabilitation system's conveyance capacity.

The Curiosity Creek watershed model and associated report (described below) identify flood areas of concern (FAC). Improvements on this parcel can benefit flood level of service at two FACs. The free-flowing Curiosity Creek channel discharges to a closed basin as it enters City of Tampa’s Blue Sink and Curiosity Creek Detention Area and Pump Station. There is an opportunity to divert volume from this closed basin to achieve multiple goals. The parcel is large enough to consider innovative solutions with environmental and community benefits. A multi-discipline design charrette can help this parcel become more than a stormwater attenuation and treatment pond. It could have waterfront park space, wildlife habitat, and serve as a model for integrated design in floodways.
Manatee County

Gulf Drive/City of Holmes Beach

The road has experienced about 20 flooding events in the past 5 years. There are risks of flooding due to both tidal and rain event influences. There are stormwater drains, swales, and infiltration at various locations along the road. Anticipated benefits include reduced susceptibility to flooding on Gulf Drive, an evacuation route; improvement to road surface and pedestrian sidewalk/multi-use paths; and additional bicycle paths.

Pinellas County

Cross Bayou

The Cross Bayou Canal (CBC) was constructed in early 1900’s, spanning across the entire Peninsula of Pinellas County and the Cross Bayou Watershed (approximately 8,000 acres, or 12 square miles) from Old Tampa Bay on the east, to Cross Bayou on west. The entire length of CBC is within Flood Zone (AE) and the Sea Level Rise (SLR) Vulnerability Zone. The CBC has been a source of recurring erosion, sedimentation and flooding issues for Pinellas County dating back to 1960’s. With the intensive urbanization of the Cross Bayou Watershed, flooding conditions have become more prevalent and frequent, resulting in property loss due to flood damages. In addition to recurring flooding problems, the CBC watershed has incurred significant degradation to both habitat and water quality associated with increased run-off, erosion sedimentation, and exotic/nuisance species colonization.
The entire run of existing Cross Bayou Canal (CBC) is public drainage pathway. Some easement coordination may be needed during design phase, for access or temporary construction easement. Please see attached Location Flood Map.

Cross Bayou Canal (CBC), as major drainage conduit dissecting the Cross Bayou Watershed, flows in both directions and receives drainage flow from sub-basins on both sides of the canal. CBC is also subject to storm surge and sea level rise influence. Please see Attached SLR Map and Storm Surge Map.

Improvements to entire CBC length has been recommended in various basin wide watershed management plans and other drainage studies. Currently Segment 1 and 2 are in preliminary design phase. This application is for the entire length of CBC with the goal of providing conceptual level typical cross-section / plan view design sketches for various channel configuration and flow rate scenarios, combined with natural base and green infrastructure design elements wherever feasible.

By stabilizing the embankment and restoring maximum cross-section configuration allowable within project boundary, the expanded channel capacity and improved tail water conditions will benefit the overall watershed’s drainage level of service and help reduce flooding. Green infrastructure stabilization approach, combined with significant decrease of sediments from erosion-control improvements, together with removal of exotic and nuisance vegetation, will help improve surface water quality / hydraulic conveyance capacity, and increase overall resiliency. Community and economic growth benefits can also be realized from beautified “green” and stabilized channel to promote multi-modal transportation (trail) and redevelopment opportunities.

Pinellas County
Bonner Nature Park / City of Largo

There are no official accounts of flooding in the area but during field investigations the engineering design team has been made aware of some citizen’s houses having water flood their yards run into their house during major storm events on multiple occasions.

Floodwaters start from 143d St N and travel east between the housing due to no curbing or drainage infrastructure along the road side. The road crowns direct some of the water towards
the stormwater system on Josephine rd. but along some roads the crown has slowly disappeared
due to years of road resurfacing. Due to poor soil conditions and high water table the water sits
in yards and does not drain for days. There is currently no retention/treatment provided for the
area, and directly discharges into the inter-coastal. Larboard has an old stormwater system that
is made of outdated concrete channels that discharges to a swale that leads to the southern
portion of John R. Bonner Nature park.

A flood mitigation investment in this study area could provide better drainage and updated
stormwater infrastructure and best management practices that prevent stormwater from
flooding yards and homes. Flood mitigation could also provide adequate treatment before
discharging to the intercoastal, which is very prevalent along coastal areas in Florida where
outdated and grandfathered stormwater systems often provide no treatment before directly
discharging to the gulf or ocean. Economically, this could raise home property values in the area;
residents have had trouble renting/selling homes in the area due to constant drainage issues.
Also, as residents have to due less maintenance on their homes and properties, this will allow
them more financial freedom which would help this elderly low income community as see in the
FEMA NRI (appendix A).

Pinellas County
Largo Waste Water Reclamation Facility / City of Largo

There has been one instance of flooding in the past five years; the west access road flooded in
2020 and destroyed a Duke transformer, Duke has since replaced that transformer and raised it.
The site topography is sloped towards the west. The west side of the WWRF property has two on
site retention ponds, one to the south of the effluent discharge tank and one to the south of the
chlorine contact chamber. Both ponds drain to the Cross Bayou Canal through stormwater pipes.

The Wastewater Reclamation Facility is Largo’s most critical infrastructure asset in all of the
City. The City has done quite a bit to protect the processes and electrical equipment but has
not addressed the roads and grounds elevations that are needed for technicians to access or
perform maintenance on equipment. Protecting this asset further would guarantee Largo’s
future as we all know wastewater treatment is critical to economics as it allows business and
residents ease of mind about waste products, environmental impacts from overflows during
storm events, and makes the City overall more resilient.
The City has placed large emphasis, time, and funds to protect the plant from future sea level rise and flooding. In recent years, the City has elevated many of the treatment processes and electrical equipment to be higher than the 100 year or 500 year flood plain. The majority of the projects are coming to a close and currently do not have other plans to address other flood mitigation issues.

**Pinellas County**

**Causeway Park / City of Madeira Beach**

There have been three instances of flooding in the last five years. The City is a horizontally “built-out,” narrow, channelized and “fill-island” section on the south end of the Sand Key barrier island, easily susceptible to over-wash from storm surge. A recent tropical storm (that did not attain hurricane status) produced enough surge to witness three feet of flooding in numerous commercial and residential buildings. The built-out nature of the City is associated with much impervious surface. Even light rainstorm events produce persistent street flooding. The stormwater system, primarily piped and independent of sanitary sewer, employs street rights-of-way, and can easily be overwhelmed in places after rain events. The State Road 666 Bridge and Causeway runs up to one of the few bridges from the barrier island beaches to mainland Pinellas County over Boca Ciega Bay and is an evacuation route. The properties the City, County and School Board own, proximate to the hydrological connection of Boca Ciega Bay beneath the bridge could support innovative green infrastructure, living shorelines, and redevelopment interventions that better manage the City’s stormwater. The Gulf Beaches will slowly erode or be inundated by sea level rise. As the limited public vehicle parking areas at City and County beach accesses and parks become damaged beyond repair and become the beach itself, a mixed-use, multi-modal mobility hub, supported by direct transit to the area beaches and to the PSTA beach trolley stops, providing bicycles, alternative non-motorized transportation options to reduce vehicle emissions and a pedestrian-friendly alternative journey through the reimagined green/blue causeway park areas, town center to the beach.

The majority of the proposed study area is hardened with sea-walls. A living shoreline intervention will not only improve the areas resilience to coastal and tidal flooding, but it will improve the water quality and capacity of the bay waters to support native species of plants, fish, and wildlife. The design of the park and marina properties to capture, contain, and passively treat stormwater will not only improve water quality, but provide a very public demonstration, with appropriate interpretation, of the innovative alternatives to traditional stormwater design...
and management. Studying this area for resilient ready Tampa Bay can address flooding and flood-related losses being experienced today, enhance the environment, and increase resilience, while looking forward to the current and future impact of sea level rise by reducing greenhouse gas emissions and help transition to a less automobile-reliant, more pedestrian-friendly built environment.

Pinellas County
Bayshore Blvd / City of Safety Harbor

There have been 5 flooding events over the last 5 years. Tidal flooding from Tampa Bay is impacting the roadway via overland flow. The shoreline is enhanced with mangroves and other aquatic and upland vegetation. There is a low elevation differential between the roadway and the mean high water line. Stormwater/floodwaters are conveyed through a combination of open roadside swales, stormwater pipe and baffle boxes (with media filters) before being discharged into the bay.

A reduction in the frequency and magnitude of flood events will improve roadway safety. The addition of green infrastructure elements will reduce runoff to enhance water quality and promote infiltration and groundwater recharge. Additional shore stabilization may reduce coastal erosion and resuspension of solids to improve habitat.
Pasco County

Green Key Road / City of New Port Richey

6 larger events, plus regular smaller-scale flooding during the rainy season and King-tide periods each year. During heavy rains, stormwater collects in the ditches adjacent to roadways before rushing onto yards and threatening homes. In some low-lying areas, roads retain water and become impassable. During even non-storm high tides, water from the Gulf of Mexico has started to spill onto the roads in the area. Retention areas remain full of water and rainfall exacerbates the situation.

Flood mitigation solutions will include engineering and nature-based solutions, including, as appropriate, Living Shorelines, mangrove and other native plant community enhancement and restoration, soil retention and erosion control techniques, and the use of bioswales to reduce standing water and nutrient runoff. An investment in this area would allow the City and County to find the best solution to the recurring flooding in the area. Seeking alternative solutions serves to keep the residents in their homes, with more stable access to roads and infrastructure, while keeping the area as natural as possible. Further, a study in this area will lead to a new understanding and best practices for other mitigation efforts for the City and County. Improvements will alleviate flooding that prevents road use and access, especially after larger events. This is especially true in the Green Key Neighborhood.

Green Key Neighborhood Drainage Analysis and Concept Plan – The objective of the project was to prepare a conceptual planning level drainage study for the drainage improvements in the Green Key Neighborhood. Concepts considered included raising roadways, improving drainage systems, constructing berms and tidal flood gates. In addition, Pasco County is the recipient for a FDEO / HUD “Resilient Pasco” Grant project comprised of a countywide Resiliency Plan and Vulnerability & Risk Assessment verifying critical infrastructure and identify at-risk critical infrastructure for further analysis.
Pinellas County
Shore Acres / City of St. Petersburg

The study area contains 328 Repetitively Flooded Properties as per FEMA. There has been approximately 60 notifications from residents of flooding within the past 5 years found within the City’s internal complaint reporting system; However, since 2020 a total of 150 properties have had structural flooding. Total flood damage claims since 2020 equals $10,096,811 with an average flood claim of $33,656. This area experiences flooding with each high tidal event. Each year the community may experience upwards of 200 tidal flood events, or approximately 1000 flood events over the past 5 years.

Flooding within Shore Acres is caused by several environmental factors which can act separately or in concert, amplifying their effects. Coastal inflows from high tide, storm surge, tropical storm systems, and intense rain events increase flood staging and surcharge the drainage system. This causes overland flooding damage to roadways and structures. Flood events occur on a routine basis due to inflow from high tide and frequently inundate roadways and sidewalks, further disrupting transportation and daily activities. Due to high tailwater conditions and poor conveyance, flood waters can persistent causing further damage from vehicular wake traffic.

This area is primarily residential and consists of small businesses, commercial properties, neighborhood parks, religious institutions, community centers, schools, and emergency facilities. Flooding continues to be experienced along the primary routes affecting ingress and egress from the community, which can impact daily commute to schools and work and essential services such as sanitation access and police and fire response times. A flood mitigation investment that focuses on providing strategic improvements, mitigates flood risk from tides and major rain events, could redevelop Shore Acres into a resilient community. A resilient community that enhances quality of life, reinforces economic strength, improves reliable access for work, school, and essential services is a better community. The City’s operational cost impacts would also be reduced, further enhancing the community’s economy, sustainability, and viability for futures generations. An investment of this quality could also result in an improved environment with better water quality for the Tampa Bay estuary and a more resilient habitat.
North Tampa Closed Basin
April 18-20th | Charrette Agenda

**Day One** Field Visits
Starting Point: Mary Ave Sink (approx. 9711 Mary Ave, Tampa, 33612)
~ Late arrivals: text Sarah (305-304-6956) or Alana (352-340-7883) for location
1:00 – 4:00 PM: Walking Tour
Optional 2nd Tour: Violet Cury Preserve and/or Lettuce Lake Park
4:00 – 5:00 PM: Precedent Landscape Field Visits

**Day Two** Design Charrette
Location: Harvest Hope Park (13704 North 20th Street, Tampa, 33613)
8:30 – 9:00 AM: Coffee Meet & Greet
9:00 – 10:30 AM: **Framing** - Context Presentations
11:30 AM – 1:00 PM: **Listening** – Work Group Goals, Values, Priorities, & Opportunities
1:00 – 2:00 PM: Lunch & Pin Up
2:00 – 4:30 PM: **Iteration** – Design Session in Working Groups
4:30 – 5:00 PM: **Reflection** – Group Summary & Day Three Priorities

**Day Three** Design Charrette
Location: Harvest Hope Park (13704 North 20th Street, Tampa, 33613)
8:30 – 9:00 AM: Coffee Meet & Greet
9:00 – 9:30 AM: **Recap** – Day Two Development & Day Three Priorities
9:30 AM – 12:00 PM: **Integration** – Design Session in Working Groups
12:00 – 1:00 PM: Lunch & Pin Up
1:00 – 2:00 PM: **Next Steps** – Questions, Needs, Opportunities
2:00 – 3:00 PM: **Open House** – Informal Community & Stakeholder Conversations
Symposium Program

Resilient Ready
Tampa Bay
Symposium

📅 JUNE 23, 2022, 1:30-5:30 PM EDT
📍 TAMPA RIVER CENTER AT JULIAN B. LANE RIVERFRONT PARK
# RESILIENTREADY
Resilient Ready Tampa Bay was a regional technical assistance project that was created to enhance the capacity of Tampa Bay communities to assess, plan for, and adapt to flood impacts through the expanded use of multi-functional green infrastructure systems and resilient site designs.

In April 2022, the Resilient Ready Team, along with local stakeholders, public, and private experts in resiliency, including architecture, engineering, and planning professionals, convened for design charrettes in flood-prone study areas within the cities of Tampa, St. Pete Beach, and Oldsmar. These three study areas exemplify the flood challenges and adaptation needs faced by local governments throughout the Tampa Bay Region, and resulting case studies provide innovative design concepts, strategies, and resources to address them.

Download the Resilient Ready Symposium Report: [tbrpc.org/resilient-ready](http://tbrpc.org/resilient-ready)


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**PROJECT PARTNERS**

Coordinated by the [Tampa Bay Regional Planning Council](http://tbrpc.org)
Funded by the [Florida Department of Environmental Protection's Resilient Florida Grant Program, FY 2021-2022](http://fdep.gov)
1:00 pm  REGISTRATION CHECK-IN / GALLERY EXHIBIT

1:30 pm  WELCOME
Councilmember Brandi Gabbard, City of St. Petersburg, TBRPC Chair; Taylor Ralph, LEED AP BD+C, President and Founder, REAL Building Consultants; & Sean Sullivan, Executive Director, Tampa Bay Regional Planning Council

1:45 pm  MAYORAL REMARKS: ST. PETE BEACH
Mayor Alan Johnson, City of St. Pete Beach

1:50 pm  RESILIENT READY TAMPA BAY SHOWCASE
Alana Todd, Environmental Planner, TBRPC; Sarah Vitale, AICP, Senior Planner/Urban Designer, TBRPC; Andy Sternad, AIA, AICP, Architect & Urban Designer, Waggoner & Ball; & Robbert de Koning, Principal, Landschapsarchitect BNT

2:30 pm  PANEL #1: REFLECTIONS FROM TEAM LEADS
Andy Sternad, AIA, AICP, Architect & Urban Designer, Waggoner & Ball; Whit Remer, AICP, ENV SP, Sustainability and Resiliency Officer, City of Tampa; Mike Clarke, Public Works Director, City of St. Pete Beach; & Ashlee Painter, Sustainability Coordinator, City of Oldsmar

3:00 pm  NETWORKING BREAK / GALLERY EXHIBIT

3:20 pm  MAYORAL REMARKS: TAMPA
Mayor Jane Castor, City of Tampa

3:25 pm  PANEL #2: INTEGRATED DESIGN & COMMUNITY ENGAGEMENT
Taylor Ralph, LEED AP BD+C, President and Founder, REAL Building Consultants; David Waggoner, Founding Principal, Waggoner & Ball; Robbert de Koning, Principal, Landschapsarchitect BNT; Frank Crum, Community Engagement Coordinator, City of Tampa; Councilman Peter Altman, City of New Port Richey; & Laura Thomas, Sustainability Program Administrator, City of Largo

4:15 pm  MAYORAL REMARKS: OLDSDMAR
Mayor Dan Saracki, City of Oldsmar

4:20 pm  PANEL #3: FUNDING & PHASING INNOVATIVE RESILIENCE PROJECTS
Brian Cook, Director of Urban & Environmental Design, Applied Sciences; Kris Kaufman, Marine Habitat Resource Specialist, NOAA Habitat Restoration; Kristin Lentz, Planning Unit Manager, FDEM Mitigation; Mark Llewellyn, Executive Vice President, Halff Associates; & Hank Hodde, CFM, ENV SP, Sustainability and Resiliency Coordinator, Pinellas County

5:25 pm  CLOSING REMARKS
Councilmember Brandi Gabbard, City of St. Petersburg, TBRPC Chair

5:30 pm  COCKTAIL RECEPTION - Sponsored by the Urban Land Institute Tampa Bay
Councilman Peter Altman, for over 34 years, has gathered experience and skill sets for local governments institutional knowledge, strategy development, economic development, accounting, advisory board member, resiliency officer, and environmental consultant. He has served on many advisory Boards, including the following, Tampa Bay Regional Planning Council (currently serving again), Tourist Development Council, Metropolitan Planning Organization, and Tampa Bay Water.

Mayor Jane Castor was elected in 2019 to serve as the city’s 59th Mayor. This longtime public servant and former Tampa Police Chief remains laser-focused on her vision for “Transforming Tampa’s Tomorrow”—a five-pillar strategic plan centered around strengthening community-centric services, enhancing workforce development, increasing housing affordability, improving transportation, and fostering sustainability and resilience.

Michael Clarke was commissioned as a Second Lieutenant in the U.S. Army Corps of Engineers after graduating with a BS in Civil Engineering from Old Dominion University. During his 28-year career, he earned his MS in Engineering Management at California State University, Northridge, and served in a variety of Command and Staff positions across the globe. Mike is currently serving as the Public Works Director for St. Pete Beach, Florida, and is highly engaged in the analysis of Sea Level Rise and developing infrastructure solutions.

Brian Cook is a registered landscape architect with more than 15 years’ experience as a consultant and educator. He has worked on significant public and private projects throughout the United States, including government buildings, campuses, streets, and public spaces. Brian’s recent work has been focused on coastal resilience and the interface of hydrologic and urban systems. He is a recent author for the book Building with Nature Perspectives, published by TU Delft in the Netherlands, and has presented to multiple organizations along the Florida coast.

Frank Crum is a Community Engagement Coordinator within the City of Tampa Community Engagement and Partnerships Department. Crum works with Tampa residents to strengthen neighborhoods, practice civic engagement, and develop community cohesiveness. As a liaison to city government, Crum connects specific communities to the Mayor’s Office and City departments. He also engages with corporate and non-profit entities to leverage opportunities aimed at enhancing the quality of life for all Tampa citizens.

Robbert de Koning studied landscape architecture at the Academy of Architecture in Amsterdam. He has more than 30 years of experience with spatial design and water management in The Netherlands and abroad. In the US he worked in New Orleans, LA, St. Louis and Charleston on issues to make cities and landscape more sustainable. Robbert was awarded as one of the 12 Dutch ambassadors of Room for the River with the Grote Maaskant prize 2018.
Councilwoman Brandi Gabbard represents District 2 and is Vice-Chair of the St. Petersburg City Council as well as 2022 Chair of the Tampa Bay Regional Planning Council. Brandi has fought to make our community stronger by increasing access to affordable housing, lowering flood insurance costs, fighting for small and local businesses, and working to help our neighborhoods be safer and more resilient. A licensed real estate broker for over 15 years, she has served for over a decade in leadership roles with the state, local, and national real estate associations.

Hank Hodde, CFM, ENV SP, is the Sustainability and Resiliency Program Coordinator for Pinellas County, FL, where he oversees a new planning and program initiative aimed at reducing negative impacts to local communities and the environment, adapt to a changing climate, and promoting long term sustainability and resiliency of the County’s resources and residents. He is a Certified Floodplain Manager, ENVISION Specialist, and FORTIFIED Wise Associate, with extensive experience in community resilience, coastal resource management, and climate change adaptation on the federal, state, and local levels.

Mayor Alan Johnson is the current Mayor for the City of St. Pete Beach. He was raised in central Massachusetts and has lived in the Tampa Bay area since 1979. He obtained his Bachelor of Science in Mechanical Engineering from the Lowell Technological Institute in Lowell, Massachusetts and his Graduate Studies from the Union College in Schenectady, New York. Alan is also a licensed Professional Engineer in the states of New York and Florida.

Kris Kaufman works for the National Oceanic and Atmospheric Administration’s Office of Habitat Conservation’s Restoration Center. Kris assists partners with developing and implementing habitat restoration projects throughout the state of Florida focused on resiliency and for the protection and sustainability of managed and recreational fisheries. Prior to joining the NOAA Restoration Center in the Southeast Region, Kris was a Senior Environmental Scientist with the Southwest Florida Water Management Districts’ Surface Water Improvement and Management (SWIM) Program.

Kristin Lentz has worked for the Florida Division of Emergency Management since 2018, as an environmental specialist and planner in the Bureau of Mitigation. Both positions have given her valuable insights in mitigation, most notably in hazard mitigation and planning. In her current role as manager of the planning unit, Kristin is responsible for the State Hazard Mitigation Plan and coordinating with local jurisdictions about their mitigation strategy planning.

Mark Llewellyn Sr. is a graduate of Brigham Young University with over 35 years of civil engineering experience. He has served as Project Manager for numerous private and public sector Civil Engineering projects which have included due diligence analysis, creative planning, complex design, intensive public involvement, and construction support. The projects have included major and minor private and public land development, public parks and recreation, public mobility (complete streets, roadway improvements, sidewalks and trails), and public utilities.
Ashlee Painter is the Sustainability Coordinator for the City of Oldsmar. She has a background in marine biology, coastal sustainability, and water conservation. Since completing the city’s Climate Resiliency Plan in 2021, Ashlee has concentrated on implementing the plan actions and garnering citizen involvement in resiliency projects.

Taylor Ralph, LEED AP BD+C, is the President and Founder of REAL Building Consultants, LLC. His over 15 years of project experience—both in the design/build/development role and as a consultant to diverse real estate development teams—allows him provide clients with valuable guidance in the pursuit of creating high-performance, innovative, and award-winning projects. He has significant experience in the LEED for New Construction, LEED for Homes, LEED for Homes Multi-Family, and specializes in corporate portfolio, district scale and campus scale sustainability planning.

Whit Remer, AICP ENV SP, works at the intersection of sustainability and resilience, helping shape and advance policy focused on environmental protection, disaster preparedness, and thoughtful community development. As the City of Tampa’s first Sustainability & Resilience Officer, Whit is advancing Mayor Jane Castor’s commitment to 100% renewable energy and building a more resilient and equitable city.

Dan Saracki is currently serving his first term as Oldsmar Mayor. Saracki previously served two terms on Oldsmar Council Seat 2 from 2015-2022. He is a graduate of the Institute for Elected Municipal Officials (IEMO), IEMO I through IV. Dan currently serves as President of the Suncoast League of Cities. He served on the FLC Board as a District Director and Chair of the Municipal Administration Policy Committee. He has been named an FLC Home Rule Hero Award Recipient consecutively since 2018.

Andy Sternad, AIA, AICP, is a vice president of Waggonner & Ball and leads the firm’s environments practice, focusing on urban planning and building design projects that integrate issues of climate, landscape, economy, and culture. A graduate of the Yale School of Architecture, he has developed the firm’s Living With Water approach over the past decade to help cities and citizens adapt to changing environments. Andy managed Waggonner & Ball’s Dutch Dialogues Charleston, Living With Water Houston, and Isle de Jean Charles Resettlement projects.

Sean Sullivan leads a team of professional planners and regional thinkers at the Tampa Bay Regional Planning Council, who work throughout the six-county Tampa Bay Region to improve the quality of life for all. He has worked with elected and appointed leaders throughout the region to establish the Tampa Bay Regional Resiliency Coalition, the 18th such initiative of its kind in the United States. Mr. Sullivan has spent over 30 years working in local, regional and federal sectors in the planning, environmental and public transportation fields.
**Laura Thomas** has served as the Sustainability Program Administrator for the City of Largo, FL since the role was created in 2016. She works with local and state elected officials, team members, and the community to address a wide range of emerging issues related to capital infrastructure resilience, greenhouse gas emissions, equitable renewable energy transitions, and climate change adaptation. Her role provides thought leadership to the field through public policy, strategic sustainability and resilience planning, change management, and systems integration.

**Alana Todd** serves as the Environmental Planner for the TBRPC. Alana supports the Council’s work on regional environmental management and resilience-related activities, including the Agency on Bay Management (ABM). She also serves as staff for the TBRPC environmental journal Bay Soundings (now in its 20th Year), the Florida Department of Transportation’s Stormwater Grant Education Funding, and the Stormwater Management Committee.

**Sarah Vitale, AICP** serves as a Senior Planner / Urban Designer for the Tampa Bay Regional Planning Council. She specializes in design-visualization, GIS mapping, and 3D modeling, and provides planning and technical support across the Council’s projects and programs. Sarah holds a Bachelor of Science in Interdisciplinary Social Science and a Master of Science in Planning, both from Florida State University. She is a member of the American Planning Association’s American Institute of Certified Planners, the Urban Land Institute, and the Congress for the New Urbanism.

**David Waggonner** is the founding principal of Waggonner & Ball, an internationally active architecture and environment practice based in New Orleans. David is recognized as a national leader in resilient, water-based planning and design in the face of environmental challenges, as well as in educational architecture and campus planning. He has initiated change through the firm’s Dutch Dialogues™ and Living With Water® efforts, and has played a leading role in major resilience programs of the last decade, including Rebuild by Design, Resilience by Design, and the National Disaster Resilience Competition.
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North Tampa Closed Basin
Maps & Drawings
Elevation

Legend
Land Surface Elevation
USGS 2004 - 2017

- Water
- Wetlands
- ▼ Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary
Flooding & Drainage

Legend

Flooding
- FEMA 100 Year Floodplain
- FEMA Coastal High Hazard Area
- Base Flood Elevations
- Local Depressions

Drainage
- Pipes
- Above Ground

- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary
Flooding & Drainage

Legend

- Parks
- City Owned Parcels
- County Owned Parcels
- Right of Way

- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary
Park Network
Watershed-wide Strategy
Vision Section
Sink
Drains to the Hillsborough River
through Sulphur Springs

Store Water on the
High Ground

APPENDIX: NORTH TAMPA CLOSED BASIN MAPS & DRAWINGS
Water System Diagram

- Stormwater
- Detention Pond
- Weir
- Aquifer Connection
Ecology Diagram

- Drain
- Upland
- Wetland Planting
- Tree Canopy
- Inflow Area
- Open Water
Connections & Open Space Diagram

Sidewalk
Boardwalk
Point of Interest
Park Entrance
Weir Overflow
Weir overflow dissipates water slowly allowing more time for filtration and maximizing storage.
Promenades & Streetscapes

New Promenade & Street Planting
Existing & Proposed Detention Pond Edges

**EXISTING**

**PROPOSED**

- Backyard Rain Gardens
- New Wetland Shelves
Detail Section
Vision Plan

Bioswales treat runoff before entering the detention pond

New Streetscapes along 99th street connect the detention features
Boardwalk meanders through the stormwater park system
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Pass-a-Grille / St. Pete Beach
Maps & Drawings

Resilient Ready
Tampa Bay
Elevation

Legend
Land Surface Elevation
USGS 2004 - 2017

- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary

1 inch equals 500 feet
0.25
Critical Datums – Pass-a-Grille

- **BFE Long Term (=50 Years) 18.2 ft**
- **BFE Short Term (=20 Years) 16.2 ft**
- **Gulf Side Velocity Zone Base Flood Elevation 15 ft**
- **King Tide Long Term (=50 Years) 5.6 ft**
- **MHHW Long Term (=50 Years) 4 ft**
- **King Tide Short Term (=20 Years) 3.6 ft**
- **Current King Tide .4 ft**
- **MHHW Short Term (=20 Years) 2 ft**
- **MHHW 2020 0.78 ft**
- **MLLW -1.48 ft**

*The projections use the 2017 NOAA Intermediate High Sea Level Rise Scenario.*

**Catastrophic Storms (Once per 100 Years)**
- **King Tides (1 or 2 per Year)**
- **Mean Higher High Water (Daily)**

**Groundwater Surfacing ≈50 Years**
Catastrophic Storms (Once per 100 Years)
King Tides (1 or 2 per Year)
Mean Higher High Water (Daily)

Channel Side Base Flood Elevation 12 ft

BFE Long Term (≈50 Years) 15.2 ft
BFE Near Term (≈20 Years) 13.2 ft

10 ft Proposed Dune Raising
≈8 ft Existing Dune Height
≈7.5 ft Beach Knee Wall
≈5 ft Sea Wall

Groundwater Surfacing ≈50 Years

*Projections use the 2017 NOAA Intermediate High Sea Level Rise Scenario. The projected high tide for 2070 is higher than the current King Tide and the projected 2040 King Tide.
Flooding & Drainage

Legend

Flooding
- FEMA 100 Year Floodplain
- FEMA Coastal High Hazard Area
- Base Flood Elevations
- Local Depressions

Drainage
- Pipes
- Above Ground

- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary

1 inch equals 500 feet
0 to 0.25
Parcel Ownership

Legend
- Parks
- City Owned Parcels
- County Owned Parcels
- Right of Way
- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary
Sea Level Rise

Legend

Mean Higher High Water (NAVD)
NOAA Intermediate Sea Level Rise Scenario

*2020 MHHW datum uses NOAA SLR projection
MHHW water datum has not been updated since 2001

- Water
- Wetlands
- Project Locations
- Watersheds
- Municipal Boundary

*1 inch equals 1,000 feet
Overall Strategy
Defend & Adapt Strategies

**DEFEND**

- Pump
- Groundwater

**ADAPT**

- Natural Sediment Accretion
Sea Level Rise Diagram

- Today
- 2040
- 2060
- 2080

- MHHW
- MLLW
- King Tide

30 years minor daily pumping
80 years constant daily pumping substantial overtopping
215

King Tide Overtopping
King Tide Pumping
High Tide Pumping

APPENDIX: PASS-A-GRILLE / ST. PETERSBURG MAPS & DRAWINGS 215
Groundwater Diagram

Groundwater level
1:1 related sea level
Will precipitation increase?

Recharge
P - E + I
P = 1250 mm
I = 800 mm

Excess drainage
K = 20-50 in/hr
= 12-20 m/d

At - goast -> Florida Aquif (Artesian)
Defend & Adapt Strategies

DEFEND - NEAR TERM

ADAPT - NEAR TERM

ADAPT - LONG TERM
Defend & Adapt Visions
Defend & Adapt Strategies

Defend depends on where land is available for infrastructure.
Adapt Strategy

- Stabilized Infiltrating Roadway
- Retaining Flat Concrete Curb
- Storage + Infiltration
- Managed Groundwater Elevation
- Raised Houses
- Groundwater
- Drainage Connection to Pump System
Defend & Adapt Strategies

DEFEND

NEAR TERM

STORMWATER CATCHMENT

LONG TERM

BASIN / POLDER
ADAPT

NEAR TERM

INCREMENTAL ENCROACHMENT

10 ft Small Dunes

Infiltrate + Store
Slow + Store
Conservation Easement
Wall 5 ft

LONG TERM

CONSOLIDATION & CONSERVATION

20 ft New High Dunes

Beach

NEW GULF WAY

Small Dunes
Adaptive New Houses
GULF WAY

Adaptive Houses

5 ft groundland becomes 8 ft wall

Mangroves

5 ft wall becomes barrier
Defend Diagram

Crossing at Pass-A-Grille Park

City owned parcel along private parcels

Private Bulkheads
Adapt Diagram

APPENDIX: PASS-A-GRILLE / ST. PETE BEACH MAPS & DRAWINGS
Defend Section
Adapt Section

Elevate Homes

Mangrove Plantings

ADAPT — FUTURE
Remove Existing Sea Wall

Sea Grass Recruitment

Mangrove and Oyster Wave Break

Small Sheet Pile Wall

Future MHHW

MHHW 2020

+15 ft
Concept Plan Near Term
Concept Plan Long Term
R.E. Olds Park / Oldsmar
Maps & Drawings

Resilient Ready
Tampa Bay
Elevation

Legend

Land Surface Elevation
USGS 2004 - 2017

- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary

10 ft
9 ft
8 ft
7 ft
6 ft
5 ft
4 ft
3 ft
2 ft
1 ft (=MHHW)
0 ft

1 inch equals 1,000 feet

RESILIENT READY TAMPA BAY
## Critical Datums - Oldsmar

<table>
<thead>
<tr>
<th>Datum</th>
<th>Near Term (≈20 Years)</th>
<th>Long Term (≈50 Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFE</td>
<td>11.2 ft</td>
<td>13.2 ft</td>
</tr>
<tr>
<td>Oldsmar Base Flood Elevation</td>
<td>9 ft</td>
<td></td>
</tr>
<tr>
<td>King Tide</td>
<td>.4 ft*</td>
<td>3.6 ft*</td>
</tr>
<tr>
<td>King Tide Near Term</td>
<td>3.8 ft*</td>
<td></td>
</tr>
<tr>
<td>King Tide Long Term</td>
<td>5.6 ft</td>
<td></td>
</tr>
<tr>
<td>MHHW</td>
<td>2 ft</td>
<td>4 ft</td>
</tr>
<tr>
<td>MHHW 2020</td>
<td>0.78 ft</td>
<td></td>
</tr>
<tr>
<td>MLLW</td>
<td>-1.48 ft</td>
<td></td>
</tr>
</tbody>
</table>
Catastrophic Storms (Once per 100 Years)
King Tides (1 or 2 per Year)
Mean Higher High Water (Daily)

*Projections use the 2017 NOAA Intermediate High Sea Level Rise Scenario
*The projected high tide for 2070 is higher than the current King Tide and the projected 2040 King Tide
Flooding & Drainage

Legend

Flooding
- FEMA 100 Year Floodplain
- FEMA Coastal High Hazard Area
- Base Flood Elevations
- Local Depressions

Drainage
- Pipes
- Above Ground

- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary

1 inch equals 1,000 feet
Sea Level Rise

Legend

Mean Higher High Water (NAVD)
NOAA Intermediate Sea Level Rise Scenario

*2020 MHHW datum uses NOAA SLR projection
MHHW water datum has not been updated since 2001

- Water
- Wetlands
- Project Locations
- Watersheds
- Municipal Boundary

NOAA Intermediate Sea Level Rise Scenario

2020

2040 2060 2080 2100

0 NAVD
1.3 ft
1.9 ft
2.7 ft
3.6 ft
4.7 ft

1 inch equals 1,000 feet
Parcel Ownership

Legend
- Parks
- City Owned Parcels
- County Owned Parcels
- Right of Way
- Water
- Wetlands
- Project Locations
- Project Parcels
- Watersheds
- Municipal Boundary

1 inch equals 1,000 feet
Bay Scale Water Flows & Quality

- Oldsmar
- Shallow Water Gyres
- Nutrient Runoff
- Constrictions Created By Bridges
- Storm Surge
Flood Risk Sources
Defend & Adapt Strategies

**KEEP WATER OUT**

**LET WATER IN**
Water Storage Strategy

Runoff & Tidal Flooding

Store on the High Ground
Water Storage Target

16,000 m³ Stored Above
10,500 m³ Stored Below
26,500 m³ Stored
10 Year Storm 68%
100 Year Storm 36%

Large Canal
25 m³ per Linear Meter

Small Canal
3 m³ per Linear Meter
Water Storage Diagram
Concept Section
Concept Plan - Watershed
Street Sections
Vision Plan
Vision
Groundwater Report
Tampa Bay: Quick scan Groundwater, sea level rise and climate adaptation in Urban Planning

By Roelof Stuurman & Daan Rooze

This report is sketching our groundwater impressions and results of an 8 days visit (and approx. 8 days’ work) to the Tampa bay area. This visit was meant to create additional input for the Resilient Ready Tampa Bay project. Resilient Ready Tampa Bay is a regional technical assistance project that will enhance the capacity of Tampa Bay communities to assess, plan for, and adapt to flood impacts through the expanded use of multi-functional green infrastructure systems and resilient site design and construction practices. The Resilient Ready team will work with three local governments to provide technical analyses and design services for their flood-prone study areas. These three case studies exemplify the flood challenges and design opportunities faced by other local governments throughout the Tampa Bay Region, and their adaptation solutions will be translated into regional resources freely available to the Resiliency Coalition members.

This report is focusing on 2 study sites of flood-prone archetypal areas in the Tampa Bay Region: The Barrier Island Site Pass-A-Grille, St Pete Beach and the Waterfront side R.E. Olds Park, Oldsmar.

Locations of the pilot sites in the Tampa Bay area. We visited only Pass-A-Grille and Oldsmar.
1. General System analysis of urban groundwater in Tampa Area

You can’t manage what you don’t know is a quote of the World Bank. This same quote can be applied in urban adaptation: “You can’t design what you don’t know or understand”. So, starting to find and design solutions for climate change and sea level rise at least the urban (ground) water system should be analyzed and understood. Not only the more visible impacts of climate change, but also the invisible underground aspects, such as pipe infrastructure. In addition, there needs to be understanding of the (ground-) water governance processes and demographic developments. Therefore, all long-term developments should be understood (figure 1.1).

Figure 1.1: Considerations in long term delta development

1.1 Analysis quantitative groundwater status and future groundwater situation

This understanding starts with the analysis of the actual groundwater situation:

1. At what depth (below surface level and relative to sea level) does the (shallow) phreatic groundwater level fluctuate?
2. What is the relation between sea level and this shallow groundwater level?
   a. In general, long time?
   b. During low and high tides and during storm tides?
3. How is the actual groundwater level influenced by existing groundwater pumping?
   a. How much will this groundwater level rise after pumping stops?
4. How much is the actual groundwater level influenced by leaking (draining) infrastructure, and/or artificial irrigation?

The future situation can be very roughly estimated with answers on the questions above. Of course, the best forecast can be made by setting up a groundwater model. However, this groundwater model needs input of groundwater monitoring networks, a good description of the subsurface,
including permeability data of the sediment and good rainfall and evaporation data (estimating recharge).

Figure 1.2 presents a good regional schematization of the complex hydrogeology of Tampa Bay. Complex because of importance of the regional upper Florida aquifer, causing may local sinkholes and the presence of shallow (and relative thin) very permeable phreatic aquifers (important for sea water level groundwater interaction).

Figure 1.2: Conceptual drawing showing relative positions of the water table in the surficial aquifer system and the potentiometric surface in the Upper Florida aquifer and the associated vertical flow direction (modified from and used courtesy of St. Johns River Water Management District, Palatka, Florida).

1.2 Stepwise Urban groundwater analysis procedure
In the table 1.1 (below) the method to analyze the urban groundwater system is summarized.
Table 1.1: Stepwise Urban Groundwater analysis

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Characterize shallow sediments and deeper aquifer built-up: Use soil map (presents information about approx. 6 feet below surface) and collect (shallow) geological boreholes. Make use of regional (e.g. USGS) aquifer information.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Characterize groundwater level: try to determine actual shallow (phreatic) groundwater fluctuation. If available using existing observation wells. Using an auger making several boreholes (actual groundwater levels, mean lowest by soil characteristics). Add a few monitoring wells if possible.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Map relevant water system characteristics: (1) surface water drainage network: (a) depths and (width), (b)water bearing condition during wet and dry periods), (2) underground network: understand leakage stage of these networks. Are they draining or losing (ground) water?</td>
</tr>
<tr>
<td>Step 4</td>
<td>Try to understand the phreatic groundwater fluctuation. Under natural circumstances determined by rain, evaporation, surface water drainage and (sea) water levels. In urban situations it will also be influenced by (1) losing drinking water, (2) draining storm drainage and waste water pipes, (3) irrigation (drinking water, reclaimed water), (4) % of impermeability and (5) deep (and/or regional) groundwater extractions</td>
</tr>
<tr>
<td>Step 5</td>
<td>Try to estimate the future groundwater situation. (1) changes due to autonomous processes (e.g. stop or increase existing groundwater extractions, new underground constructions, renovation of leaking pipes infrastructure, increase of irrigation) and (2) changes due to sea level rise, and changes in precipitation and evaporation, including (3) the impact of subsidence.</td>
</tr>
<tr>
<td>Step 6</td>
<td>Ecohydrology: Try to describe ecological stress caused by water system</td>
</tr>
<tr>
<td>Step 7</td>
<td>(ground) water quality: Try to understand groundwater quality facies distribution and related groundwater-surface water quality interactions. Determine the impact on neighboring water systems (e.g. Tampa Bay)</td>
</tr>
<tr>
<td>Step 8</td>
<td>Greenhouse gases: try to estimate actual urban water system related greenhouse gases footprint (energy use pumping, water pollution causing CO2/CH4 emissions etc.)</td>
</tr>
<tr>
<td>Step 9</td>
<td>Analyze groundwater governance system. Who is in charge for what? Who are the groundwater stakeholders</td>
</tr>
<tr>
<td>Step 10</td>
<td>Determine and prioritize actions.</td>
</tr>
</tbody>
</table>

1.2 Urban groundwater balance

The urban groundwater balance differs a lot with the natural water balance. Mainly because of the increased impermeability of the land surface (streets etc.) and an increase in storm drainage flow. The natural drainage system often is adapted in time, causing changes in groundwater fluctuations. In many cities also the underground pipe system (waste water transport pipes, storm drainage pipes, drinking water pipes) determines the groundwater levels. How much is related to the maintenance situation. Often, the older the system, the more this impact. In New Orleans the groundwater level can completely be explained by losing drinking water and drainage by the storm water and waste water pipes.

In the table below (table 1.2) the most important ins/outs of the urban groundwater balance are summarized.

Table 1.2: Urban water balance

<table>
<thead>
<tr>
<th>IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Precipitation</td>
<td>1. evapotranspiration</td>
</tr>
<tr>
<td>2. irrigation (reclaimed or drinking water)</td>
<td>2. (unintentional) drainage by waste water and/or storm drainage system</td>
</tr>
</tbody>
</table>
3. Loss of drinking water
4. Loss of transported waste water
5. Infiltration by open cesspits
6. Loss of transported storm drainage water
7. Flow from surface water (ocean) towards the urban area (polder situations)

1.3 Rising groundwater levels reduce soil water storage and increase storm drainage
Due to rising groundwater levels, also because of capillary rise (figure 1.3) from the groundwater body, the soil storage capacity reduces. Therefore, during a rain event the groundwater level will increase faster and higher. This can cause groundwater flooding. From that moment all rain will be discharged over-land,

[Figure 1.3: Groundwater Unsaturated zone interaction]

1.4 Rain storm intensity versus infiltration capacity
Sediments (including soil structure and vegetation) have different infiltration capacities. If rain storm intensity (inch/hour) increases above the infiltration capacity of a soil type, all rain water will be discharged as “overland flow” towards the lowest locations. In many places, because of climate change the rainfall intensities increase above this critical tipping point. The soil can be treated to improve the infiltration capacity. Also other types of vegetation can help.
1.5 Trees at risk by rising groundwater

Trees and vegetation in general have an important vice versa relation with groundwater. Rising groundwater levels can damage or kill existing, often mature trees. This because the fact that tree roots needs oxygen. In general tree roots grow above the mean highest groundwater level. In groundwater oxygen levels are too low. Not only sea level rise, or stop pumping can increase this groundwater level, but also renovation of groundwater draining infrastructure can cause rising groundwater levels and be responsible for damaged tree structures.

On the other hand, trees and vegetation can be important for climate adaptation: (a) urban heat reduction, (b) lowering groundwater levels by their groundwater consumption, (c) improving the soil permeability by their root structures. This supports “interflow”, horizontal drainage in temporarily perched water situations (figure 1.4).

![Figure 1.4: Interaction between surface, sub-surface (percolation and base flow) and interflow (Najafi et al, 2007)](image)

There are several indications that soil covered by shrubs instead of grass, better drainages infiltrated rain water (figure 1.5). The root depth structure of shrubs is often more than 1 ft deep, and for grass approx. 0,3 ft. Deeper, and a denser system of roots will increase the permeability. Therefore, transformation from shrubs into lawn will possibly create higher groundwater levels.
1.5 The depth of the rootzone. Often limited by saturated zone (groundwater and vadose zone).

1.6 Analysis groundwater quality status including interaction with surface water

Perhaps an even more urgent problem in Tampa Bay are water quality issues. Manatees and other wildlife suffer heavily from nutrient pollution in the Tampa Bay area and the Gulf of Mexico. Urban runoff polluted by fertilizers and organic matter such as grass cuttings exacerbates this problem.

Therefore, the sources of pollution and the transport ways needs to be identified:

1. Fertilizers and other additives used in private and public green,
2. Pollutants arriving from streets, parking places etc.
3. Industrial discharge and drainage,
4. Discharge from waste water treatment plants
5. Discharge from power plants
6. Storm water drainage (creeks, outfalls)
7. Groundwater drainage into ditches, creeks and into sea/ocean and bays.
8. Leaking waste water transport pipes losing water,
9. Open cesspits
1.7 Sea level and groundwater
Rising sea level will often cause rising groundwater levels. In areas without a surface drainage network (like barrier islands) the relation will be 1:1. In area with drainage network groundwater levels can be controlled by this drainage network until a tipping point is reached.

Very important is to understand the permeability of shallow sediments. With high permeabilities storm water levels can be transported by groundwater and causing flooding.

Of course, flooding by salt water ocean and bay storms will have a large impact on groundwater and ecology.
2. Quick-scan St. Pete Beach (Pass-A-Grille)

This barrier island is narrow; it contains only a single line block development. The western side facing the Gulf of Mexico has dunes; the eastern edge is protected by a small seawall. The island’s geology consists of very permeable, coarse sand deposits with a depth of 50 meters on top of a rock formation. In its current state, Pass-A-Grille already suffers from so-called sunny day flooding. Regular high tides cause groundwater to come up through the drainage system, slightly inundating the streets. King tide events will overtop the seawall, even without a storm surge.

Plans to protect the community consist of raising the seawall to the 5 ft. +NAVD88 standard and installing pumps to discharge rainfall runoff – but this is only a short-term solution. Sea level rise is expected to catch up soon, and as groundwater levels will rise proportionally with the sea level, the lowest parts of the island are expected to be permanently inundated by the end of the century. This process cannot be put to a halt due to the deep, permeable sand layer.

This complex problem field requires a new urban design paradigm, which moves from the current ‘hold and defend’ stance towards a more adaptive approach. The pressure to change is high. Increasing repetitive flooding losses on Pass-A-Grille require a drastic change in how urban development and changing climatological conditions can coexist in the future. One of the seemingly radical but effective solutions proposed for Pass-A-Grille consist of relocating the primary access and egress roads towards higher ground and to allow for renaturing of the eastern border. This includes constructing a gradual, layered transition from sea to land by using wetlands and intertidal zones. This design requires participation of private land owners and cannot be realized overnight, but it provides a stable, resilient future for Pass-A-Grille.

2.1 Geology

The subsurface of this narrow (approx. 200 m) wide barrier island exits of unconfined aquifer with a thickness of approx. 150 feet (50 m). The wackstone below this deposit can be considered as aquitard with relative low permeability. The unconfined aquifer exists of (very) permeable shell rich sands (table 2.1). This high permeability supports rather fast groundwater drainage in the present situation, creating groundwater levels several feet above sea level.

Table 2.1: Groundwater Unsaturated zone interaction

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>sediment</th>
<th>permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-150</td>
<td>Shell rich sands</td>
<td>High (12-30 m/d)</td>
</tr>
<tr>
<td>150 – ?</td>
<td>Wackstone (packstone, sandstone)</td>
<td>Low (aquitard)</td>
</tr>
<tr>
<td></td>
<td>Chalk (Florida Aquifer)</td>
<td>Artesian at 900 ft</td>
</tr>
</tbody>
</table>
2.2 Subsurface infrastructure

St. Pete beach possess a modern water infrastructure. Waste water and storm water drainage are separated. Since decades they also use reclaimed waste water (the pink network, see photo). Approx. 80% of waste water is reused for mainly irrigation of parks and private gardens.

Table 2.2 presents the approx. depth of infrastructure. Notable is the relatively shallow position of the storm drainage system. This is needed to discharge stormwater by gravity into the canal/ocean. At the canal side the drainage pipes are just above sea level. Already 1 drainage catchment is provided with a pump station. It’s expected that also the other urban drainage catchments need this transformation.

Table 2.2: Some water infrastructure characteristics.

<table>
<thead>
<tr>
<th>Underground infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drinking water (dbs ?)</td>
</tr>
<tr>
<td>2. Storm drainage (dbs 2ft)</td>
</tr>
<tr>
<td>3. Waste water (dbs 3-12 ft)</td>
</tr>
<tr>
<td>4. Reclaimed water (dbs 3ft)</td>
</tr>
<tr>
<td>5. Gas lines (dbs 1-3 ft)</td>
</tr>
<tr>
<td>No basements</td>
</tr>
<tr>
<td>(dbs = depth below surface)</td>
</tr>
</tbody>
</table>

*Photo: Parts of the reclaimed water network.*
2.3 hydrogeological and groundwater situation
The groundwater situation in St. Pete Beach is characterized by typical “island” hydrogeology:

1. A bulging phreatic groundwater level between the ocean and canal, with the highest groundwater level (referred to sea level) in the middle,
2. A fresh groundwater lens (mainly infiltrated rain water). The thickness of this lens is related to recharge and the difference in densities (weight) of shallow and slat water. Fresh groundwater “floats” on salt water.
3. Groundwater discharges into the ocean and canal or is drained by leaking waste water and storm drainage pipes.

![Figure 2.1: A sketch of the groundwater situation in Pass-A-Grille, showing the fresh groundwater lens.](image)

2.4 Groundwater profile (actual situation)
In Pass-A-Grille groundwater observation wells and time series of groundwater fluctuations are missing. Therefore, the groundwater situation is estimated making use of analytical calculations and available sediment characteristics. Uncertainty was included by using different values.

The groundwater level at the water divide (center of this island), based on high hydraulic conductivity (30 m/day = 20 inches/hour) is < 3 feet above sea level (figure 2.2). A less permeable soil (12 m/d) results in higher peak (4 feet above sea level).
2.5 Groundwater profile with sea level rise

Sea level rise will lead to a structural (one on one) increase in groundwater depth; this will cause groundwater flooding at the sites with low surface elevations. Figure 2.3 presents an indication of the groundwater effect of 1-meter sea level rise. Especially, the eastern part of the island will suffer groundwater flooding.

Figure 2.3: During sea level rise the groundwater level will increase with the same quantity.
In figure 2.4 the groundwater effect of 3 feet sea level rise is visualized. You can’t stop this process by constructing levees. Possible solutions are (1) elevating the island (or streets) and uplifting the houses and (2) constructing a groundwater drainage system (transform into special kind of polder).

Figure 2.4: Groundwater effect of sea level rise (3 feet).

2.6 Estimated Groundwater profile after widening the island
Widening of the island is actually happening at the southeast side of the island but can also be needed to reduce storm energy in future (see design proposal figure 2.5). Widening can have a notable groundwater effect. Especially in situations with relatively small distance between both sides (ocean, canal). Using analytical calculations, the effect of widening the island is estimated. A result is presented in figure 2.6.

Figure 2.5: A design sketch of enforcing and widening the island at the beachside.
Widening (50 m) of island at the beachside in current shape will result in higher groundwater of more than 1 feet (figure 2.6).

Figure 2.6: Effect of widening the island by 50 m, causing more than 1 feet groundwater level increase in the middle of the island.

2.7 Groundwater profile: Fresh-salt transition zone
Because fresh groundwater (mainly infiltrated rain water) is lighter than salt water (mainly infiltrated sea water) a fresh water lens will develop. The depth of the fresh-salt groundwater transition zone is related to the groundwater level above sea level. This water density related process is simplified by Badon Ghyben (figure 2.7):

\[ Z(x) = 40 \cdot h(x) \]

Figure 2.7: The thickness of the fresh water lens \((z+h)\) in relation to the distance of the groundwater level above sea level \((h)\).
Based on this Badon Ghyben formula a 30-meter-deep fresh-salt transition zone is estimated in the center of the island (figure 2.8). This fresh water lens will follow the groundwater rise and not change in volume. Lowering the groundwater level (e.g. by groundwater drainage) will shrink this lens.

![Figure 2.8: The thickness of the fresh groundwater lens](image)

### 2.8 Estimated future groundwater situation

#### 2.8.1 Sea level critical thresholds

Sea level rise projections vary, even a slight sea level rise will have severe implications for Pass-A-Grille. The ‘medium’ sea level rise scenario results in a sea level that is roughly 5 ft higher by 2100. As groundwater and sea level are coupled in the permeable barrier sand, this implies that groundwater will rise 5 ft as well. Figure 2.9 shows the critical thresholds of (wave) overtopping of the current and new seawall, as well as rising groundwater levels. It shows that by 2035 a small wave during king tide already overtops the new, higher seawall. Furthermore, by 2070 groundwater levels on the lowest part of the island will have risen above ground level.
2.9 Estimated groundwater processes (limitations) of potential polder solutions

2.9.1 Introduction

Constructing a polder situation is not possible in Pass-A-Grille. Figure 2.10 shows that if there were an impermeable layer at a reasonable depth (~10 m), seepage could be limited by a sheetpile construction. However, as the permeable sand layer is deep, the constant duty pumping would be enormous.

---

**Figure 2.9**: Critical thresholds of seawall overtopping and groundwater.

**Figure 2.10**: Limitations of a polder in Pass-A-Grille.
2.9.2 Feasibility Polder concept
This section provides a rough estimate of the feasibility of a polder concept in Pass-A-Grille. Figure 2.11 shows the primary geohydrological flows in a polder concept for Pass-A-Grille. The red seepage arrows have to be pumped out.

![Figure 2.11: Primary geohydrological flows in Pass-A-Grille.](image)

Figure 2.12 shows the conceptual cross-sectional area that is used for the seepage calculation.

![Figure 2.12: Conceptual cross-sectional area for seepage calculation.](image)

For the Pass-A-Grille site, it is estimated that a constant groundwater pumping between 370 cfs and 3700 cfs is required. This does not include stormwater drainage; which requires additional capacity. Figure 2.13 shows this principle.

<table>
<thead>
<tr>
<th>Groundwater inflow (constant duty pumping)</th>
<th>St. Pete Beach</th>
<th>The Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low estimate</td>
<td>10.5 m³/s</td>
<td>0.002 m³/s</td>
</tr>
<tr>
<td>High estimate</td>
<td>105 m³/s</td>
<td>0.007 m³/s</td>
</tr>
<tr>
<td>370 cfs</td>
<td>3700 cfs</td>
<td>0.07 cfs</td>
</tr>
<tr>
<td>Gradient (for same situation)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>30 m/day (sand)</td>
<td>0.001 m/day (clay)</td>
</tr>
</tbody>
</table>
2.10 Conclusions, Subsurface Unknowns and Advises

- (Phreatic) groundwater levels in Pass-a-Grille are 1:1 related to sea water levels. But little is known about the actual groundwater levels. Therefore install 3-5 transects of 3 shallow (9-12 ft deep) groundwater observation wells per transect.
  - 1 observation well in the center of island
  - Other 2 at 1/3 and 2/3.

- Better understanding of permeability sands is essential.
- (Phreatic) groundwater levels are also related to rainfall. Monitor local rainfall and evaporation.
- Vulnerability of rising groundwater levels for trees, green in general and health (fungi, mosquitoes etc.), including salinization risks.

- Water quality and soil health impact of the use of reclaimed water.

- What is the relation between soil stability (roads) and groundwater level (“tipping point”).

- Realistic scenarios: Lifting the houses/raising the streets. Elevate or retreat.

- Understand groundwater recharge by irrigation. Water use in St. Petersburg dropped since 1990 after introduction “reclaimed water” system by 30% (St. Petersburg’s Journey of Water, 2015). From 117 to 78 gallons/day (295 l/day). Water use in the Netherlands Vlaanderen is 90 and 130 l/day. The use in Vlaanderen dropped because of a rain water reuse program (mainly water basements in new buildings).

- How much irrigation water is used? This can affect the groundwater level. Drinking water use dropped (Figure 2.15). The question is how reclaimed water is used for irrigation. Perhaps this became an important groundwater recharge factor.

![Figure 2.15: Drinking water use in time](image)
3. Oldsmar

3.1 Introduction
The pilot location in Oldsmar is in a vulnerable position, with water coming from all sides. Sea level rise coupled with groundwater rise, combined with increasing stormwater drainage from upstream catchments cause flooding.

3.2 Geology
The in case of groundwater flow relevant geology in Oldsmar is summarized in table 3.1 and figures 3.2 – 3.3. This area is characterized by a relatively thin sand layer at the surface, with a (impermeable) clay between 2-31 feet below surface. To understand the thickness (and permeability) of this and layer and the top and thickness of this clay layer very important for urban water management in this area. At this moment maps and cross sections are not available.

At approx. 40 feet below surface mudstone (rock) deposits are found.

*Table 3.1: Relevant hydrogeological layers in Oldsmar*

<table>
<thead>
<tr>
<th>Feet : NAVD 88</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface - 15</td>
<td>sands</td>
</tr>
<tr>
<td>15 - 42</td>
<td>clay</td>
</tr>
<tr>
<td>42 - 52</td>
<td>mudstone</td>
</tr>
<tr>
<td>52 - (&gt;425)</td>
<td>limestone</td>
</tr>
</tbody>
</table>
Figure 3.2: Estimate of the hydrogeological built-up. The top of the clay varies between approx. 14 feet below NAVD and 5 feet above NAVD (to be better understood)
Figure 3.3: The hydrogeology of the deeper layers. This picture also shows the thin layer of sand deposits. This layer is responsible for groundwater drainage in the urban area.

3.2 Urban Ground Water Balance
This water balance needs to better understand. For example, the importance of groundwater drainage into the Bay (and upwards flow in the urban coastal zone). When sea level rises this drainage can decrease, stop or change into an influx, causing groundwater flooding.

Table 3.2: Relevant water balance terms.

<table>
<thead>
<tr>
<th>In</th>
<th>Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>Irrigation of reclaimed water</td>
<td>Unintentional drainage by waste water system</td>
</tr>
<tr>
<td>Loss of drinking water (&lt; 10%)</td>
<td>Drainage by local surface water system (ditches, creeks)</td>
</tr>
<tr>
<td>Loss of transported waste water (cesspits?)</td>
<td>Drainage into the Bay.</td>
</tr>
<tr>
<td>Groundwater up flow out of deeper layers (seepage)</td>
<td></td>
</tr>
</tbody>
</table>
3.3 Water Chain infrastructure

Oldsmar maintains its own drinking water production and waste water treatment plant. The locations and some characteristics are summarized in figure 3.4. Pumped groundwater for drinking water production is brackish and needs to be desalinized. Brackish groundwater is transported towards the desalination plant. The brine is transported towards the waste water treatment plant and injected into deeper layers (figure 3.5 and 3.6). The treatment plant also produces “reclaimed water to used for irrigation. This water is first stored at 350-450 feet below surface level.

It’s unclear if and where fresh groundwater is available. In relation of mitigation of climate change (reducing use of “carbon” energy and reduction of CO₂ emissions) it is advised to analyze the carbon footprint of these installations.

*Figure 3.4: Water chain locations.*
3.4 Surface water groundwater interaction

The phreatic groundwater level is depending on the drainage system:

1. Visible drainage: ditches and creeks
2. Invisible drainage:
   a. By leaking pipes,
   b. Groundwater drainage into the bay.
In general, the groundwater level will be at its highest just between drainage ditches or creeks (figure 3.7). In need of lowering groundwater levels additional ditches can be added, or French drains (figure 3.8).

![Figure 3.7: Phreatic groundwater level between draining ditches.](image)

![Figure 3.8: Managing groundwater levels by using French drains.](image)

3.5 “Groundwater adaptation” in relation to sea level rise

Of course, the zone adjacent to the Bay is more vulnerable for sea level rise than the higher parts. At the present situation with open connections of the creeks sea level rise will be transported 1:1 to the groundwater levels. In figure 3.9 (below) a general step-by-step (following sea level rise) approach is elaborated.

![Step 1: Determine your urban area groundwater target or threshold. In the Netherlands this threshold is approx. 2.5 feet below surface (so groundwater level may not exceed this level). Determine actual level and estimate future level due to climate change and other autonomous developments. Design optimal drainage network (for groundwater and surface water drainage)](image)
Step 2: The groundwater effect of sea level rise first needs to be tackled by improving the drainage network. E.g. by adding French drains. For this design more should be understood about the thickness and permeability of the sand layer.

Step 3: There will arrive a moment (“tipping point”) that a tidal gate needs to be added. Surface water drainage can be discharged during low tide. Groundwater flow from the Bay towards the urban area will start.

Step 4: Step 5: After more sea level rise additional interventions are needed. Storm drainage can only be discharged by pumping (adding pumping stations). The rising groundwater effect can be neutralized by adding a sea wall. This is an Oldsmar opportunity because of the shallow clay layer.
Step 4 (alternative); This a better approach creating a bay-wetland zone with lower water levels. This zone could also be used to improve nature quality, in combination with storm drainage water treatment (the final step).

3.6 Water quality. Tackling nutrient rich drainage water

During our visit it became clear that improvement of the water quality of the Bay need urgent actions. Improving the impact of polluted storm drainage water needs multiple interventions. The main reason is that treatment of polluted water needs time (residence time). Therefore, small treatment wetlands won’t help. At may places in the USA urban drainage water is bottleneck. Especially, the use of fertilizers in lawns (the USA “lawn culture” occupies large surface areas in comparison with Europe’s “flower garden and shrubs culture”). So, reducing fertilizers use, perhaps in combination with other garden designs, is the most important treatment step. Also, other polluted water discharges from private properties need to be reduced (e.g. car wash water). A next step is improving the soil health, becoming less dependent on fertilizers and at the same time improving the infiltration capacity for intense rain storms. The street curbs deliver opportunities for treatment (collecting leaves, grass clippings, plastics etc.). The next treatment step could be the outfall locations (pipes, ditches). In this surface water system additional treating wetlands could be designed. So, to reduce the discharge of nutrients (and other pollutants like plastics, oil and pesticides) a “tackling at the source and treating in a network” approach is needed. In the figures 3.10 – 3.12 some treatment designs are presented.
Figure 3.10: Proposed treatment network for Nassau County, Long Island.

Figure 3.11: Public awareness activity in Hempstead, Virginia.
Figure 3.12 The street curb collector from SPLASH, Long Island (https://www.operationsplash.com/). This collector could be improved treating nutrients.

3.7 Next urban groundwater steps
1. Map top clay layer, thickness sand layer
   - Including hydromorphic characteristics
   - Including actual groundwater level
2. Organize citizens (schools) groundwater monitoring network (6-9 feet deep observation wells)
3. Understand shallow groundwater quality distribution and water quality of drained water.
4. Compose a nutrient (and pesticides etc.) budget of the city (in and out)
5. Understand relation deep and shallow groundwater (impact of pumping and injection). Possible impact of groundwater discharge from deeper layers (coastal zone).
6. Construct urban groundwater model. Calculate effects of sea level rise and climate change and evaluate effect design scenarios.
7. Compose a CO₂ balance of the city. Can CO₂ emissions be reduced.
8. Study ecological (soil health) effect of the use of chlorinated irrigation water.
9. Can the actual water chain (drinking water, waste water be optimized): costs, climate footprint.
4. Knowledge gaps for design

Below are a couple of bullet points of knowledge gaps that need to be addressed before a final design can be made.

- What are the geological profiles of the pilot areas? Are there shallow impermeable layers?
- What is the permeability of shallow sand layers?
- What are current groundwater levels in the project areas? How do they fluctuate throughout the year? How do these levels react on storm levels?
- What role does underground infrastructure have in managing current groundwater levels? Are they draining groundwater, or loosing water?
- How are groundwater levels impacted by sea level rise and storm levels?
- Can we quantify recharge of groundwater? Under natural circumstances rainfall – evaporation. In the urban also perhaps also irrigation and water loss by infrastructure. Perhaps this knowledge can help to determine measures to reduce groundwater flooding.
- What groundwater depth is still acceptable for urban development?
- Where is the current fresh-salt groundwater boundary and how will this change with sea level rise and changing recharge (rainfall minus evaporation)?
- With changing fresh-salt conditions, which vegetation can be maintained in the pilot areas?
- Using a detailed model, what is the expected required pumping capacity needed for a polder design? Can we improve our knowledge about expected future groundwater levels?
- Understand water quality relations, especially the impact of polluted water on the Bay area.
- Consider the CO₂ budget? Make CO₂ reduction part of the design.
- Improve soil health? What is the impact of chlorinated irrigation water?