Deltares

# More than 100 years of vertical ground movement in New Orleans

## *Assessment of past and actual causes, subsidence vulnerabilities, measures to be taken*

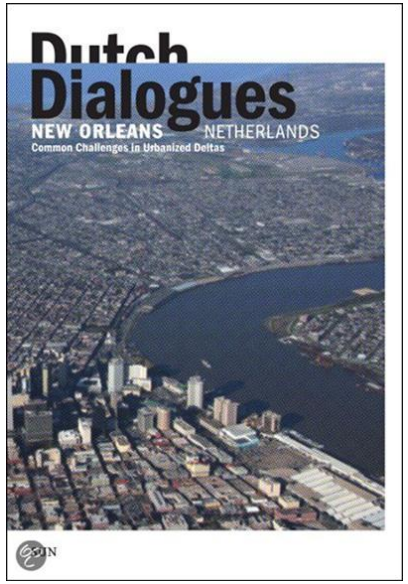
Roelof Stuurman (ROELOF.STUURMAN@DELTARES.NL)

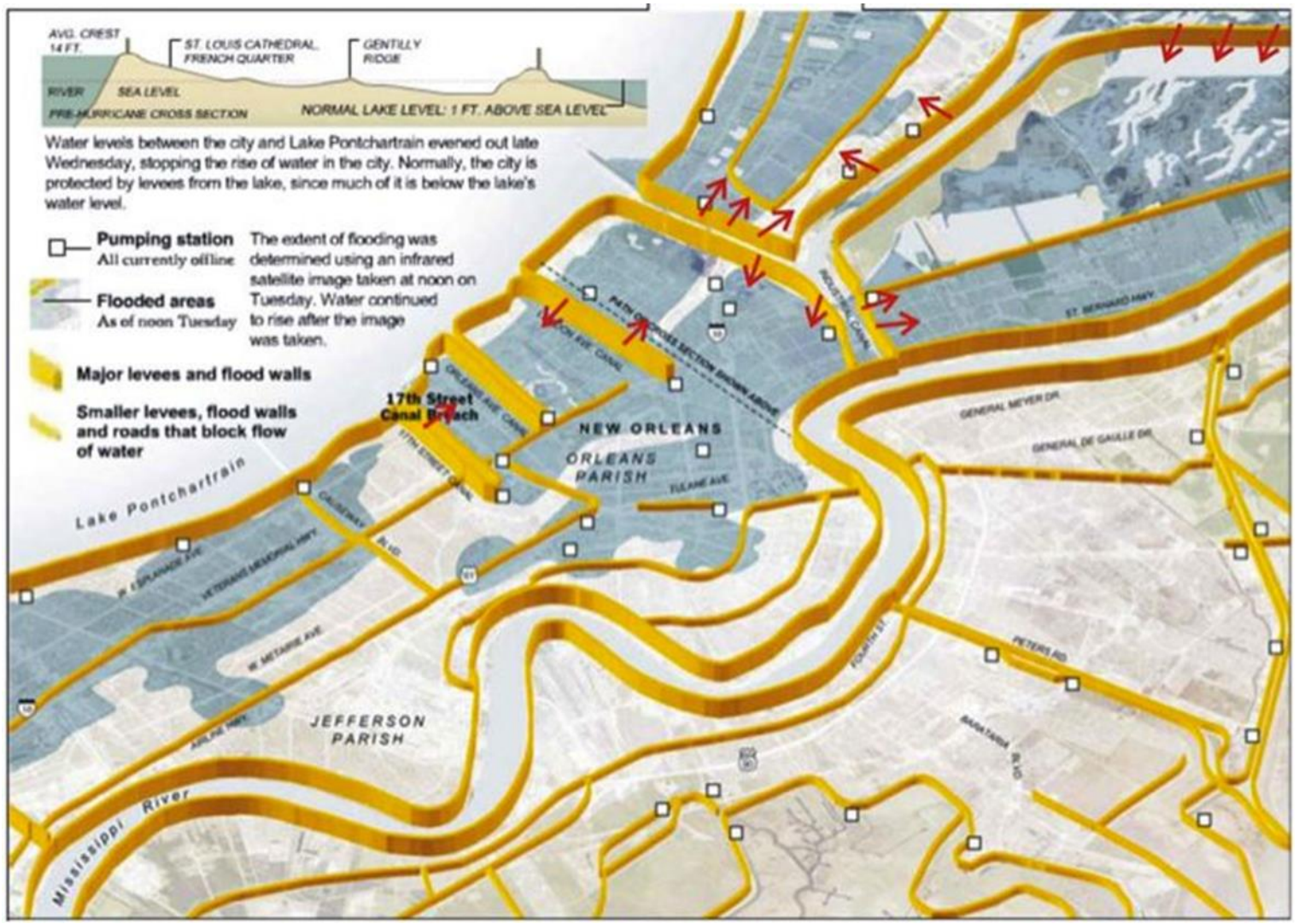
Sanneke van Asselen

Henk Kooi

Delft, April 20th 2023

# Reason for this study


Deltares

Greater New Orleans
# Urban Water Plan

## Vision

Waggonner & Ball *Architects*

September 2013

*"We've been planning for 10 years.*

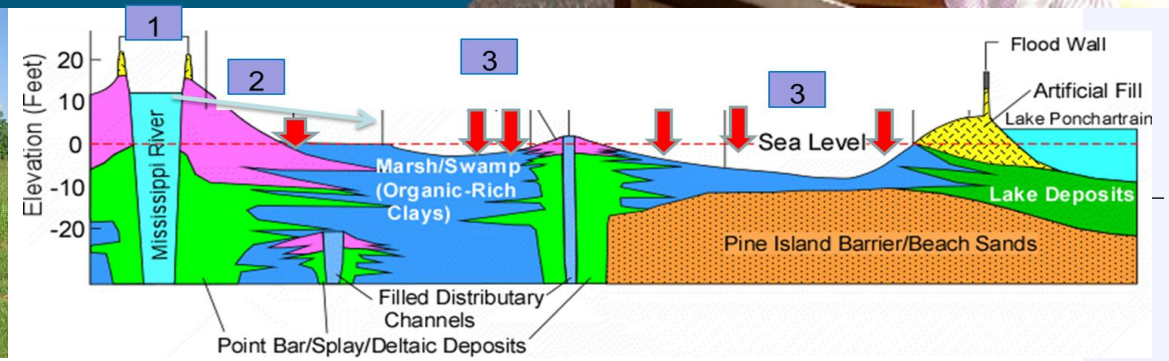
*People are tired of planning.*

*This is a strategy for implementation."*

**Jeff Hebert**
Chief Resilience Officer
New Orleans

#ResilientNOLA

RESILIENT NOLA



# NEXT STEP: Conducting this research



Dutch researchers dig into New Orleans to study subsidence

Updated Nov 15; Posted Nov 15

Gallery: Dutch soil borings on November 13, 2018

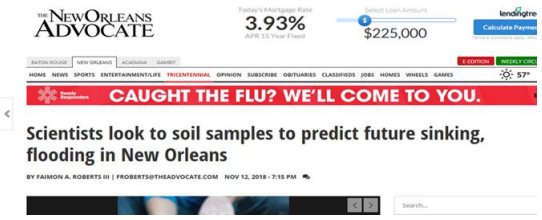
CITY OF NEW ORLEANS

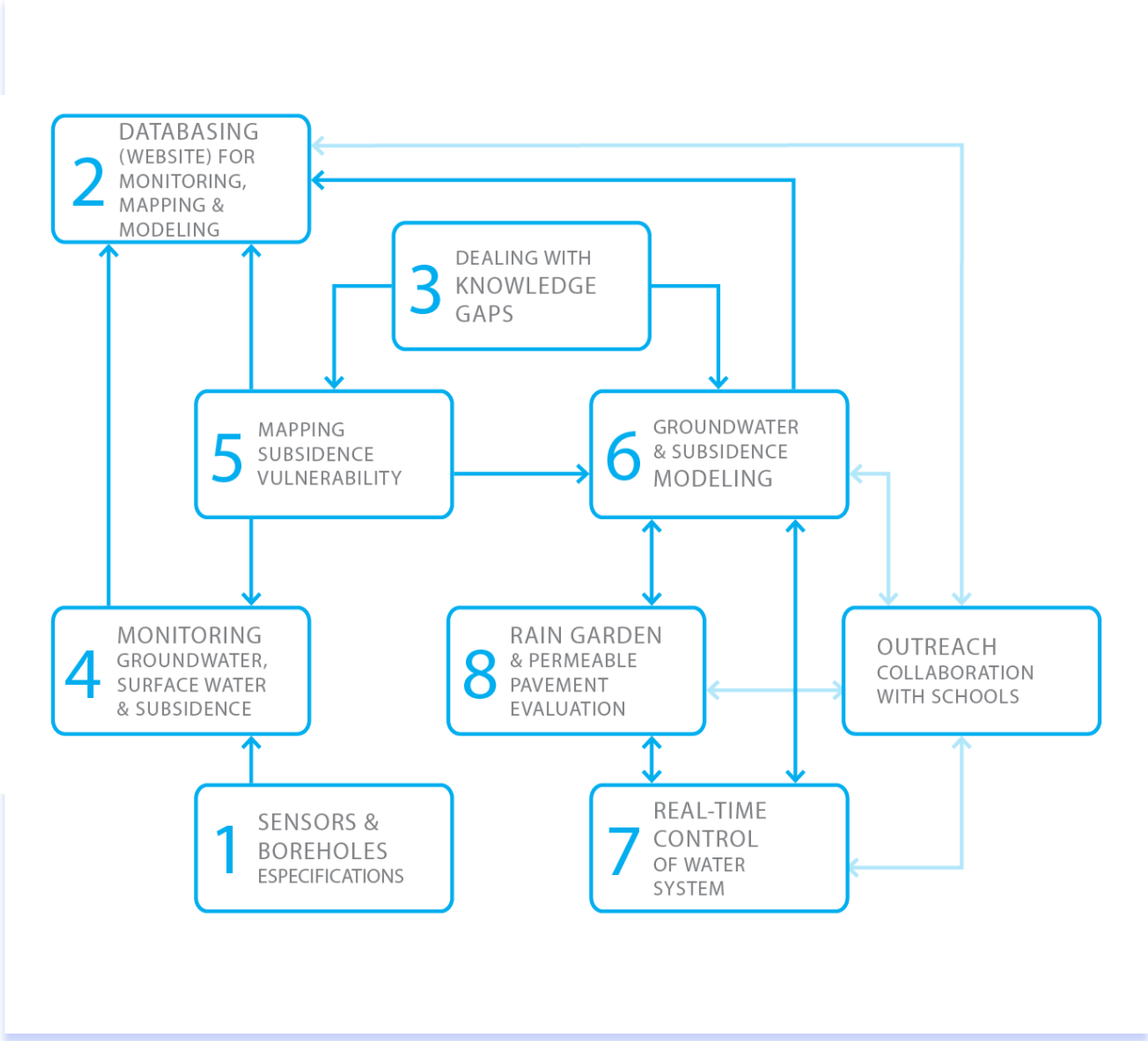
GROUNDWORK New Orleans

Deltares

**Nature Base Solutions in New Orleans: Opportunities and limitations**

Testing, Observing, Discussing



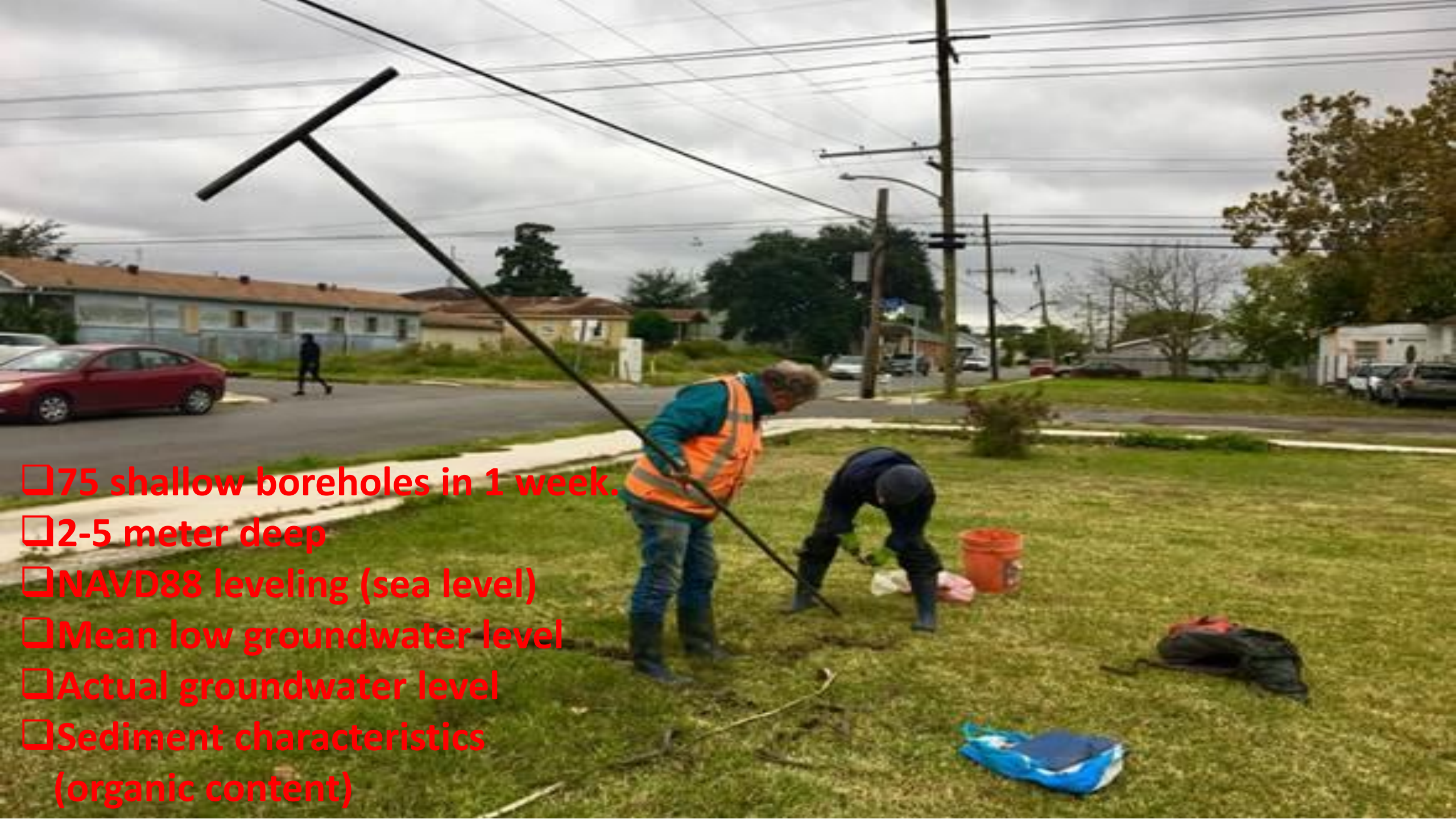
# LAKE PONTCHARTRAIN


DRAINAGE & CHANGING LANDSCAPE
CAUSING “SHALLOW SUBSIDENCE”


LAKE TERRACE - OAKS
UNO Lakefront Arena
Rouses Market
The University of New Orleans
Lakeshore Park
Benjamin Franklin High School
PONTCHARTRAIN PAR
Papa Johns Pizza
ST. ANTHONY
MILNEBURG
GENTILLY
FILLMORE
GENTILL
Brother Martin High School
GENTILLY TERRACE
Motel 6
Image Landsat / Copernicus
DILLARD


Google Earth


Google Earth



- ❑75 shallow boreholes in 1 week.
- ❑2-5 meter deep
- ❑NAVD88 leveling (sea level)
- ❑Mean low groundwater level
- ❑Actual groundwater level
- ❑Sediment characteristics (organic content)

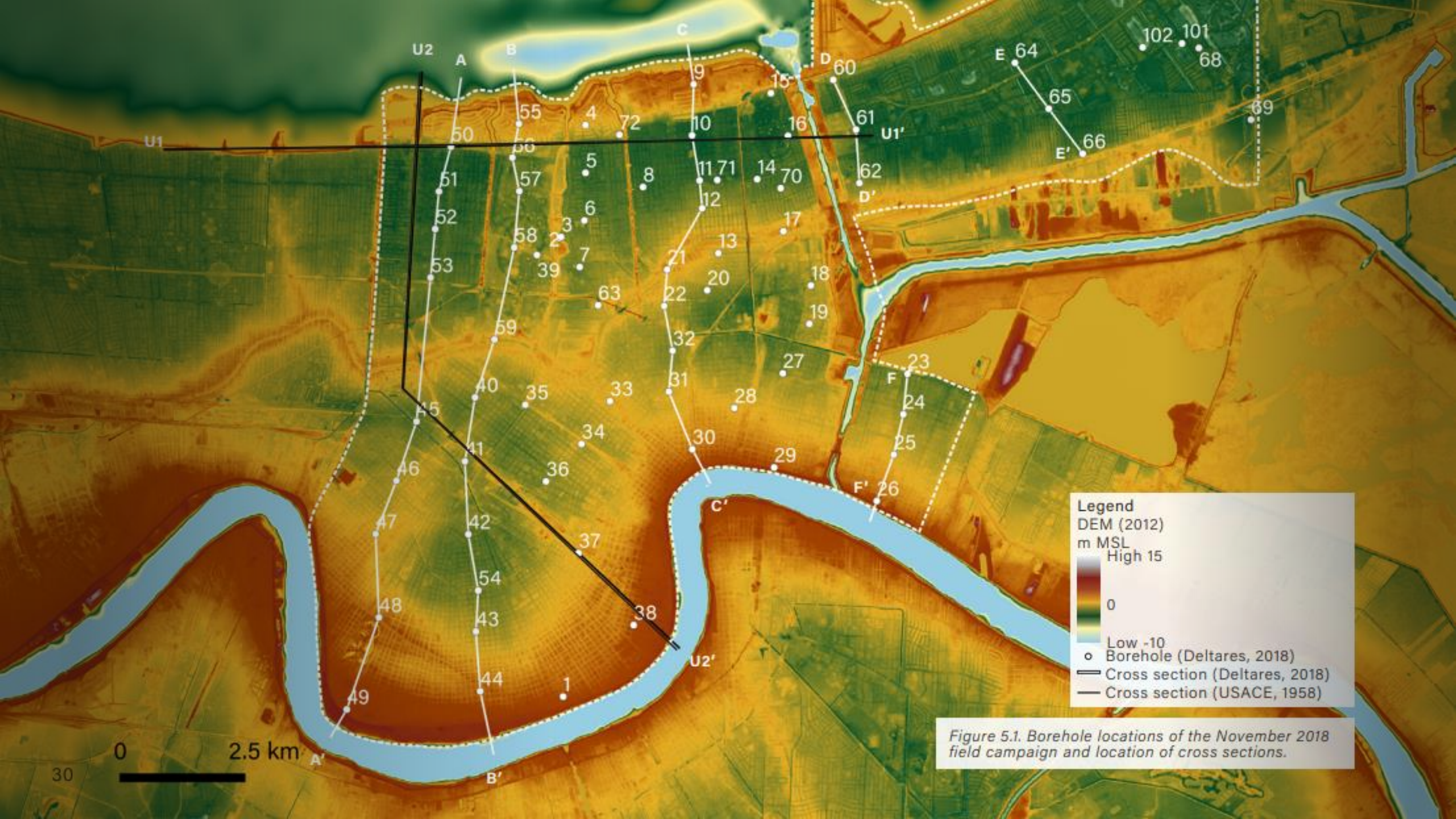
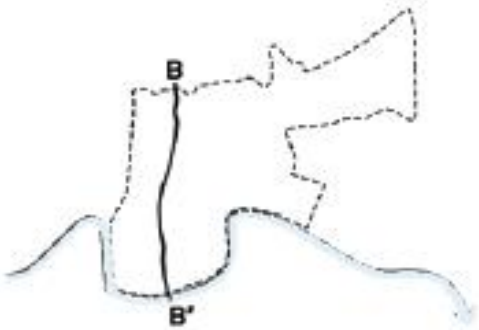



*Figure 5.1. Borehole locations of the November 2018 field campaign and location of cross sections.*




Borehole number

6018.96.055 6018.96.056 6018.96.057 6018.96.058 6018.96.059 6018.96.040 6018.96.041 6018.96.042 6018.96.054 6018.96.043 6018.96.044

B B'

Lake Pontchartrain

City Park

Metairie-Gentilly Ridge

Mississippi River

m MSL

6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6

Pine Barrier Island

0 500 m

Legend

- Peat, humus, organic matter
- Organic clay
- Clay
- Clayey silt, silty clay
- Sandy clay, clayey sand
- Silt
- Silty sand, sandy silt
- Sand
- Fill
- Dike
- ⊥ End of borehole


MEAN LOWEST
GROUNDWATER LEVEL

# Phreatic groundwater level and groundwater flow based on 75 boreholes

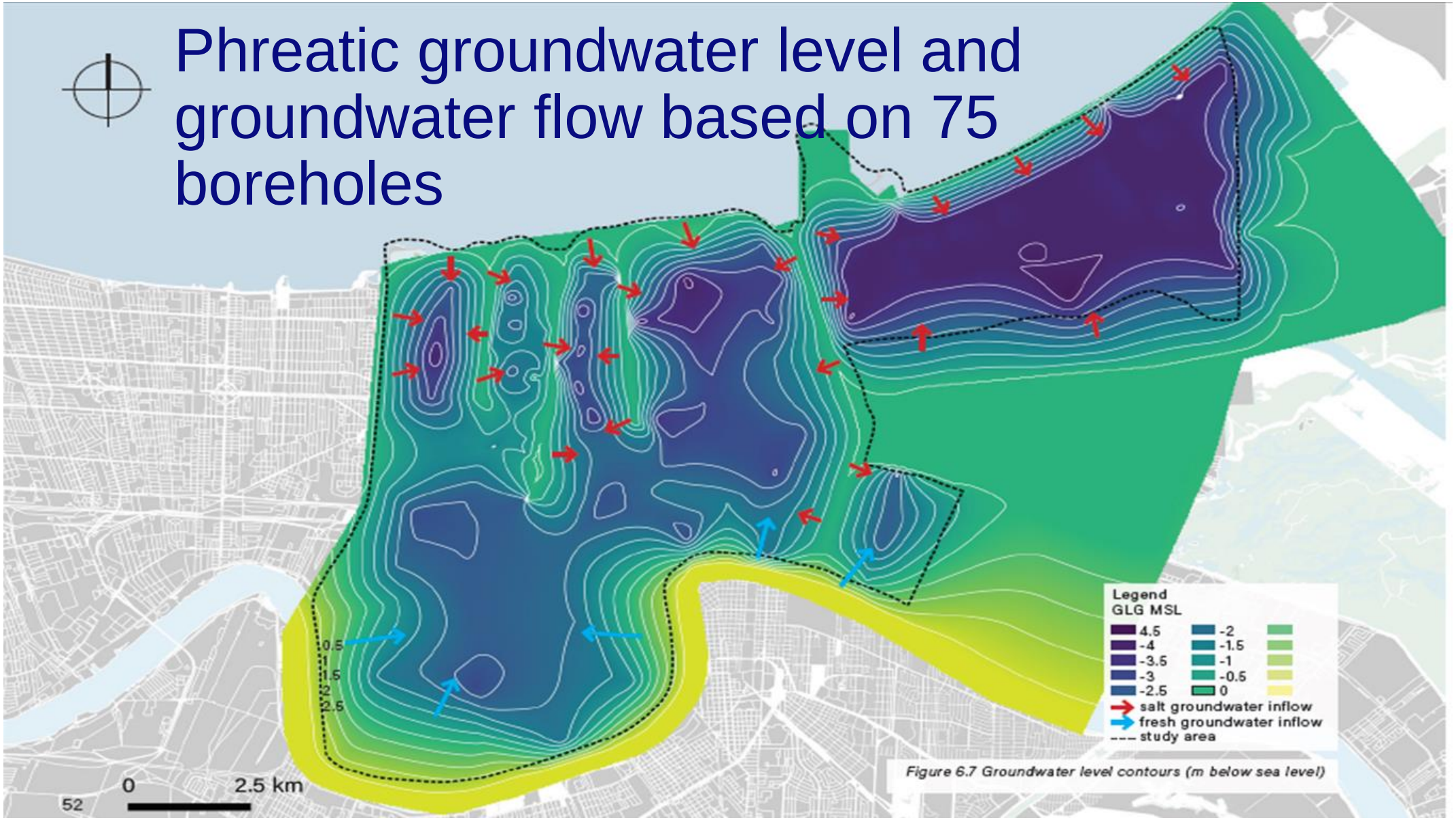
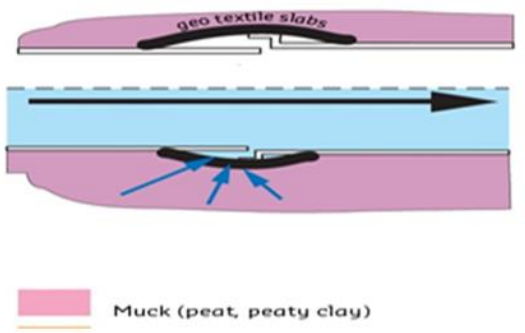
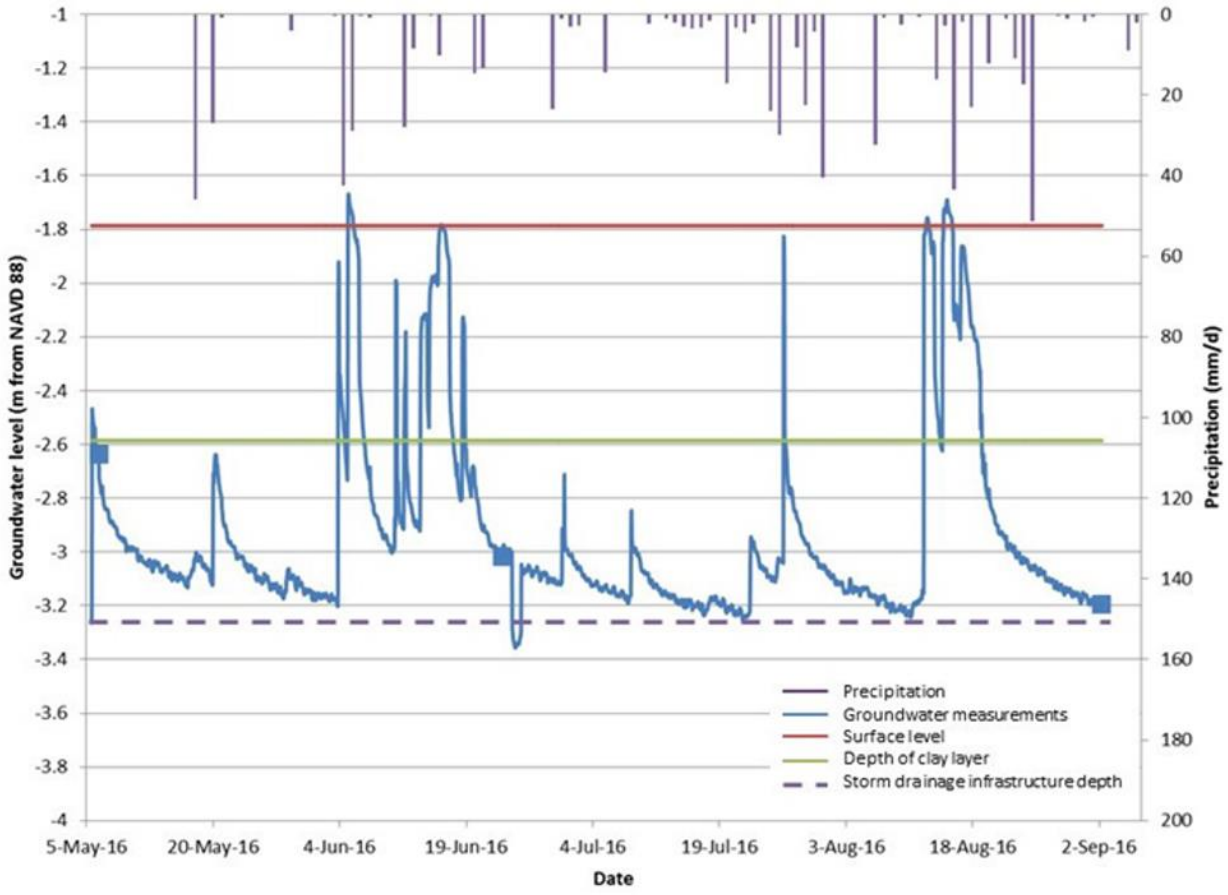



*Figure 6.7 Groundwater level contours (m below sea level)*

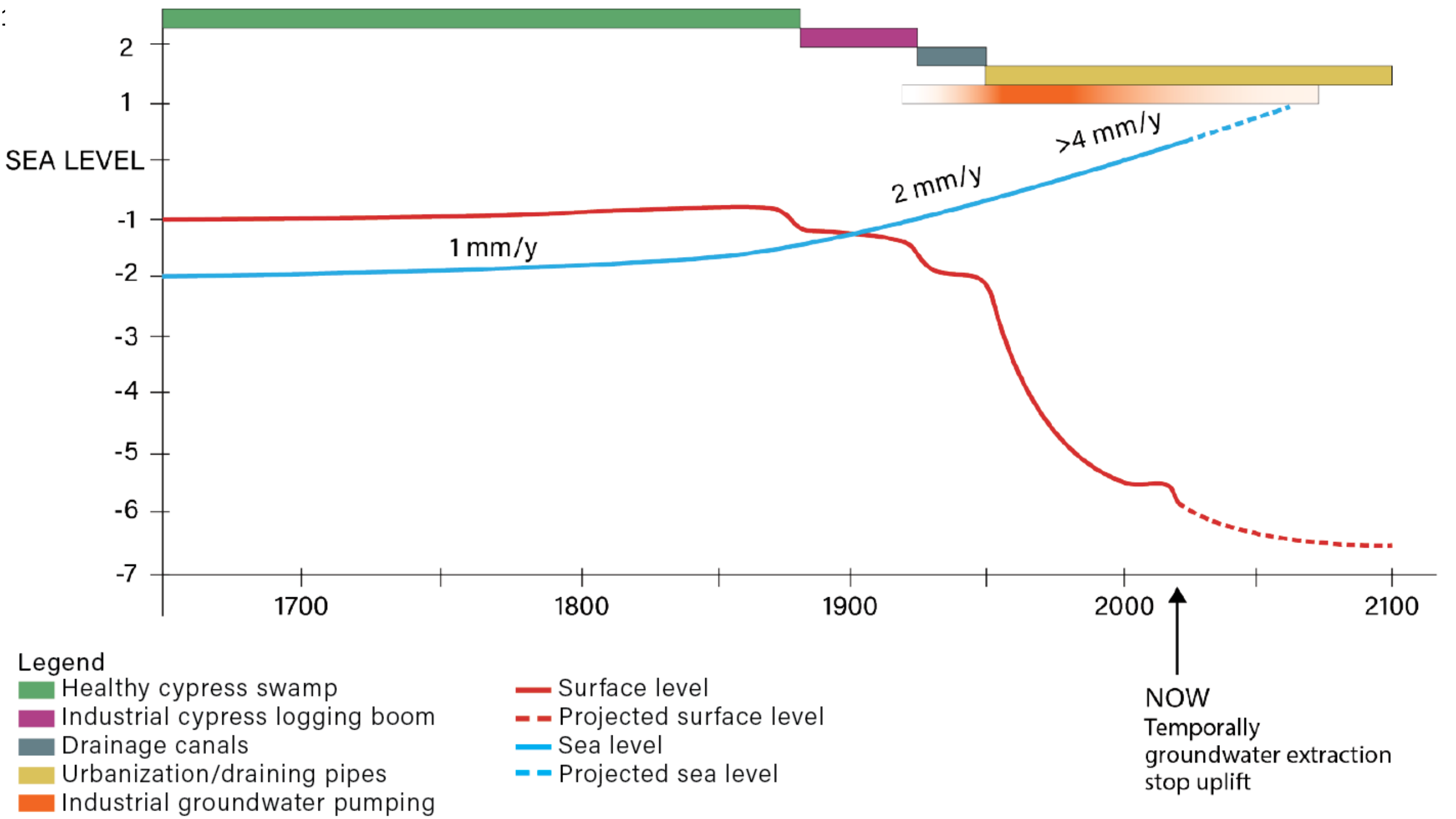
# SHALLOW SUBSIDENCE DUE TO UNINTENDED DRAINAGE




- Nearly all urban groundwater is drained by underground pipes;
- Groundwater levels rise fast, and drops relatively fast towards depth of pipes;
- Therefore, nowadays existing Green Infrastructure will not help to reduce subsidence
- After renovation the groundwater level it will help!



# A particular urban water balance


2
1
SEA LEVEL
-1
-2
-3
-4
-5
-6
-7
1700
1800
1900
2000
2100
1 mm/y
2 mm/y
>4 mm/y
NOW
Temporally
groundwater extraction
stop uplift
Legend
Healthy cypress swamp
Industrial cypress logging boom
Drainage canals
Urbanization/draining pipes
Industrial groundwater pumping
Surface level
Projected surface level
Sea level
Projected sea level

# Seas have drastically risen along southern U.S. coast in past decade

Multiple new studies highlight a rate of sea level rise that is 'unprecedented in at least 120 years' along the Gulf of Mexico and southeastern U.S. coast

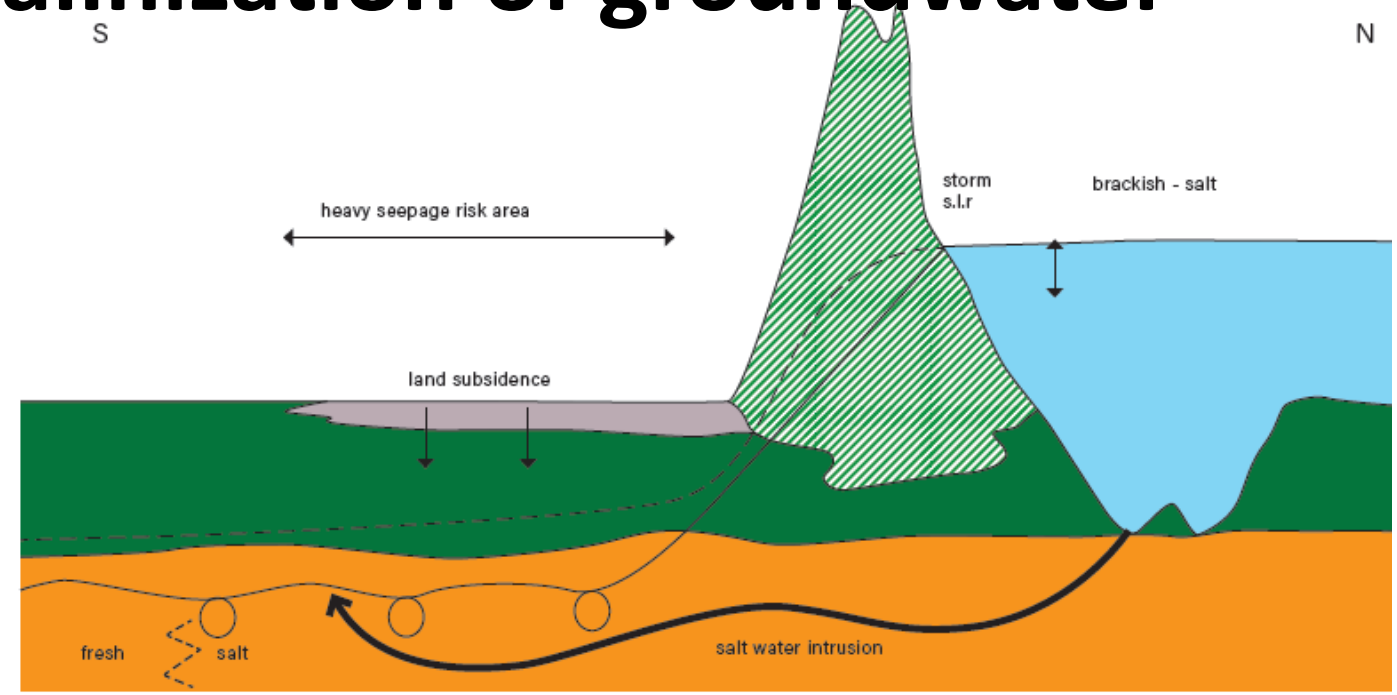
By Chris Mooney and Brady Dennis
April 10, 2023 at 5:00 a.m. EDT

VIOLET, LA - APRIL 2: An aerial view of a waterway destroyed by Hurricane Katrina in 2005, can be see from a drone on April 2, 2023 in Violet, La. (Ricky Carioti/The Washington Post)

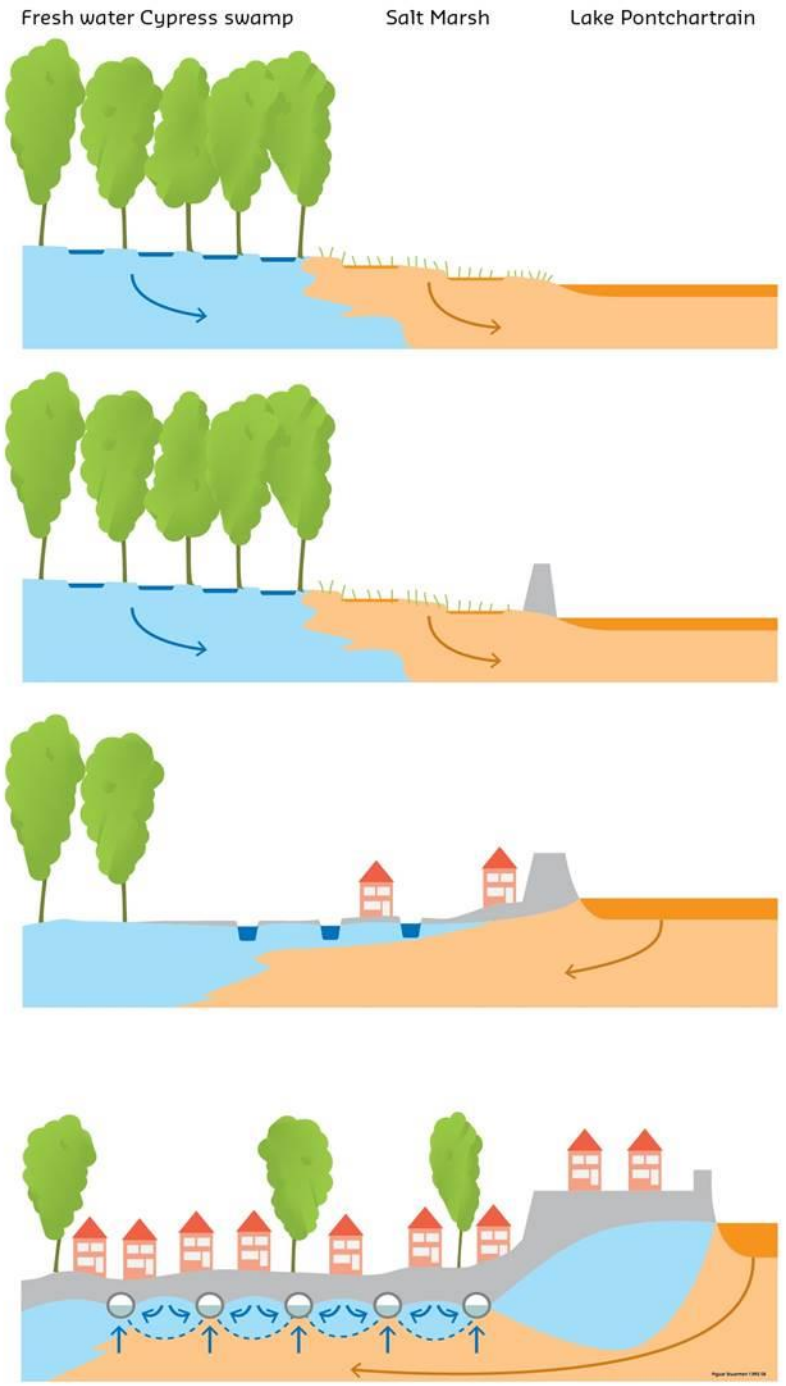


The Washington Post

# Salinization of groundwater







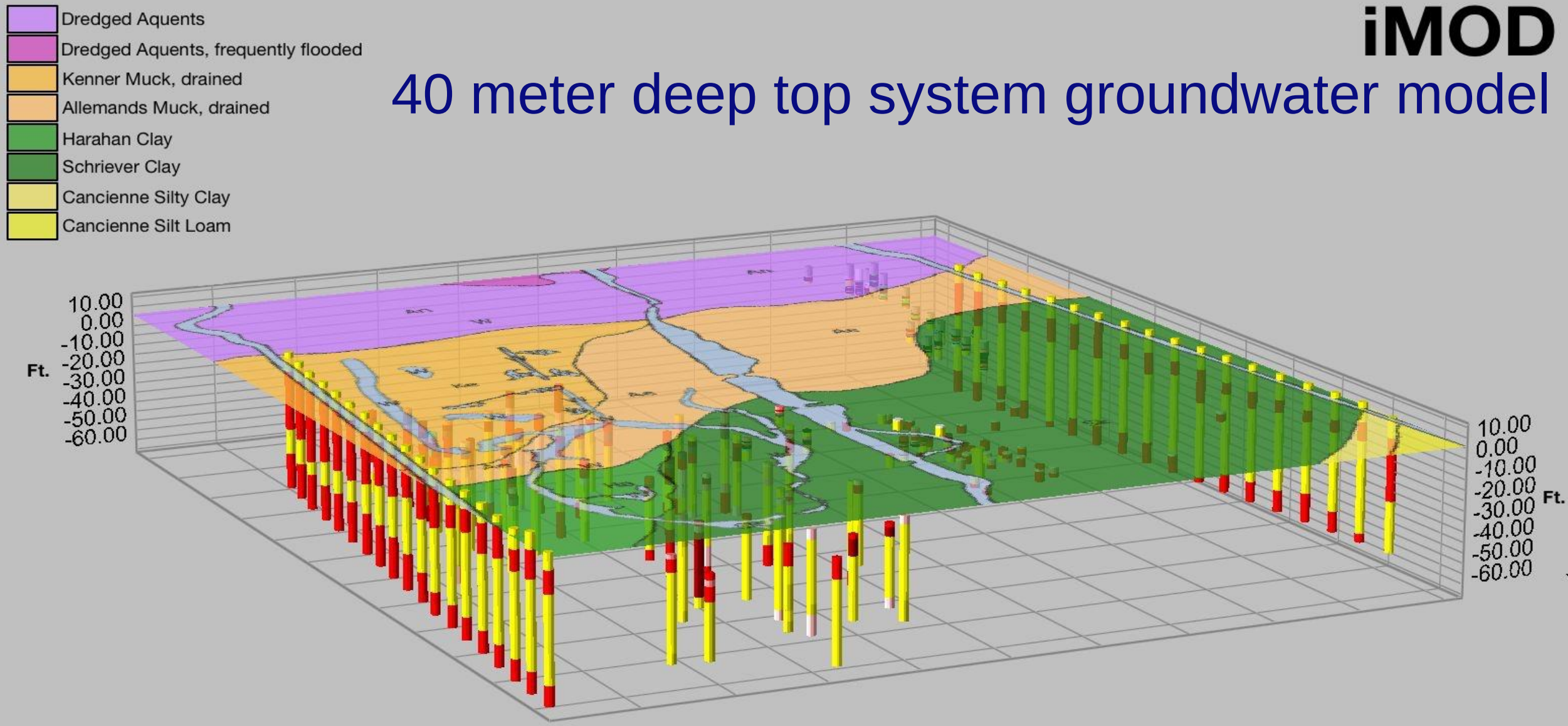
# Building damage

# Broken storm drainage and sewer pipes and Road damage

# *Rain water flooding*

iMOD

# 40 meter deep top system groundwater model

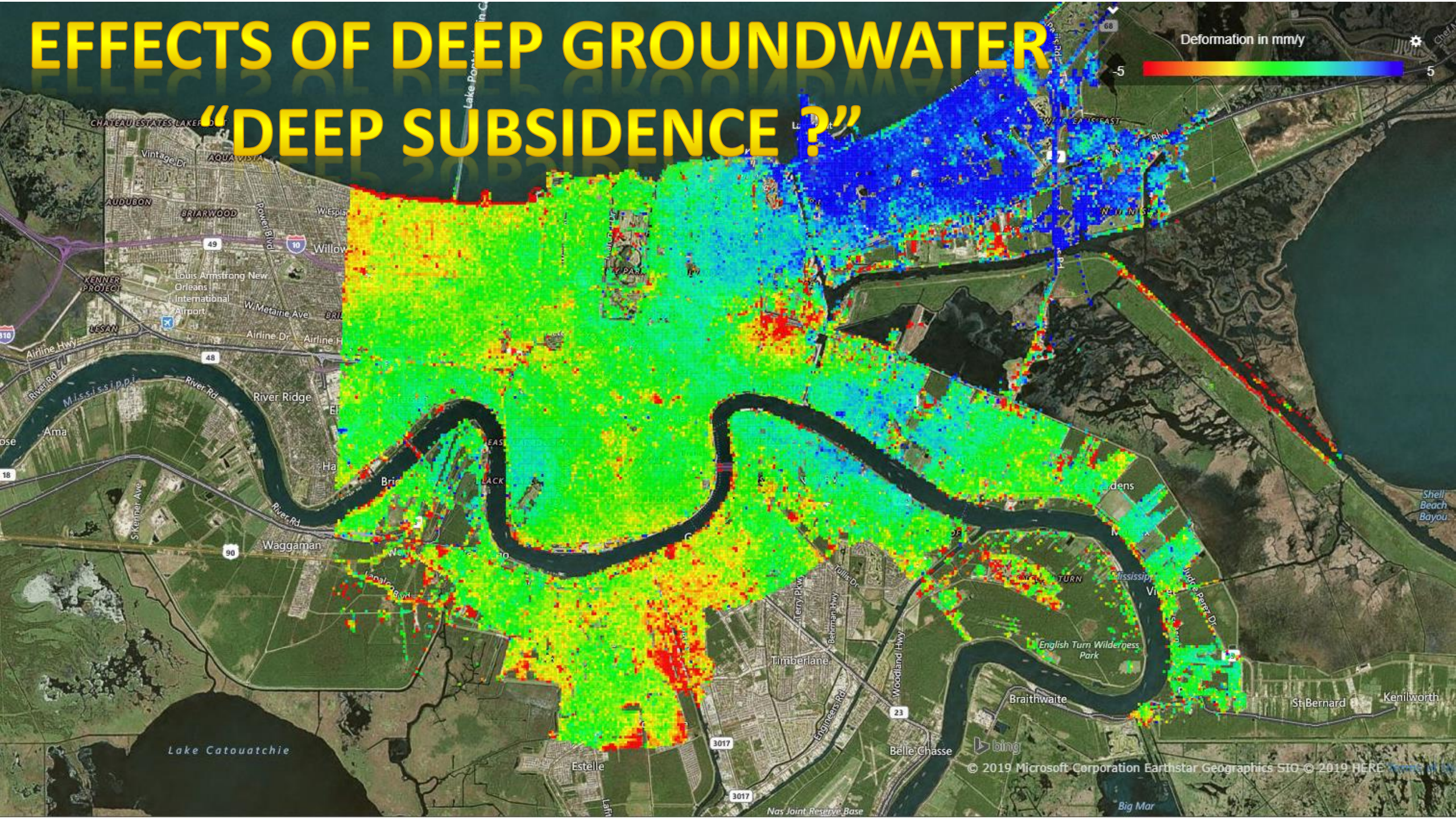



Deltares

Enabling Delta Life

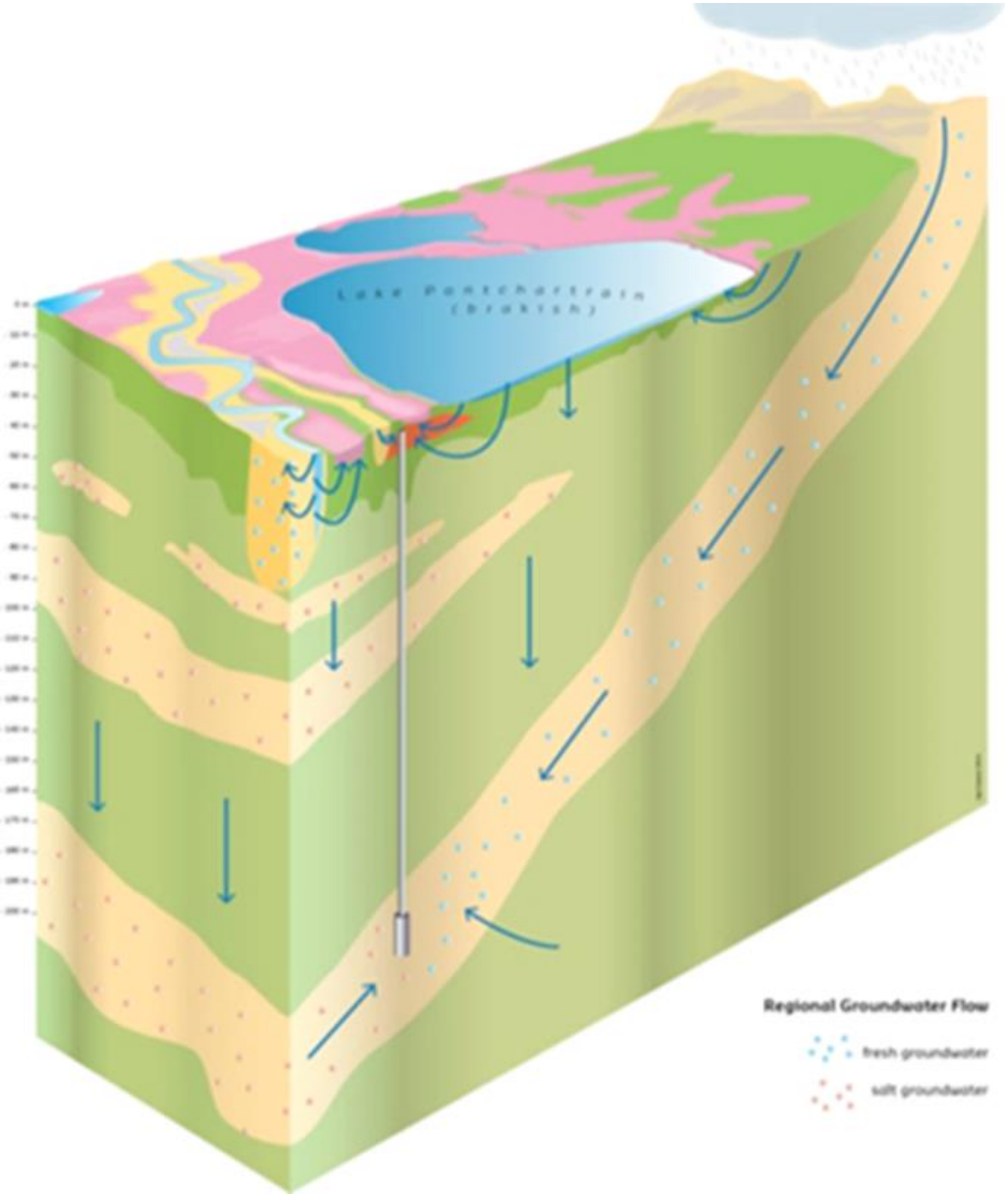
# EFFECTS OF DEEP GROUNDWATER

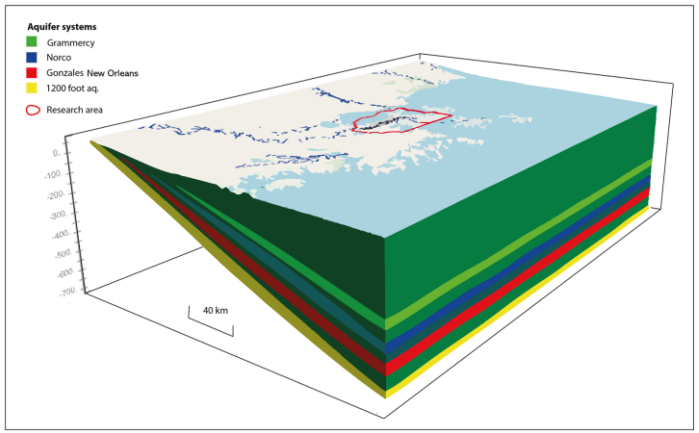
# "DEEP SUBSIDENCE ?"



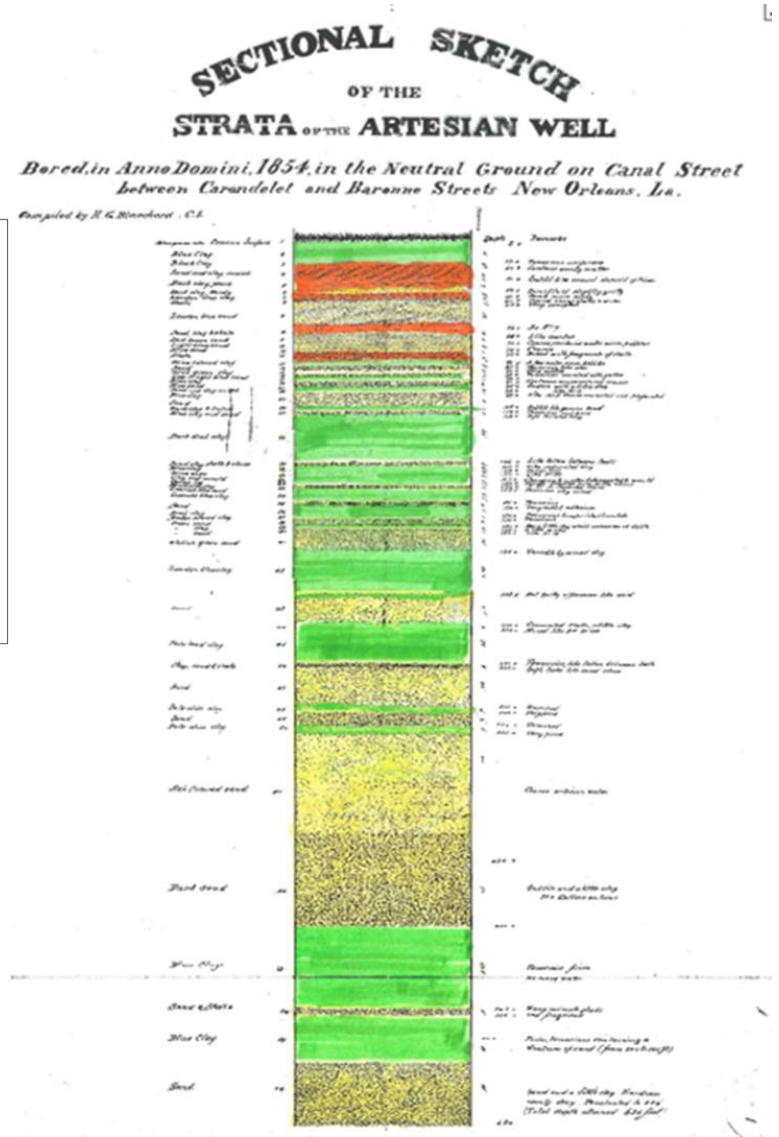
# *Subsidence by groundwater pumping?*

# Deep groundwater-subsidence model







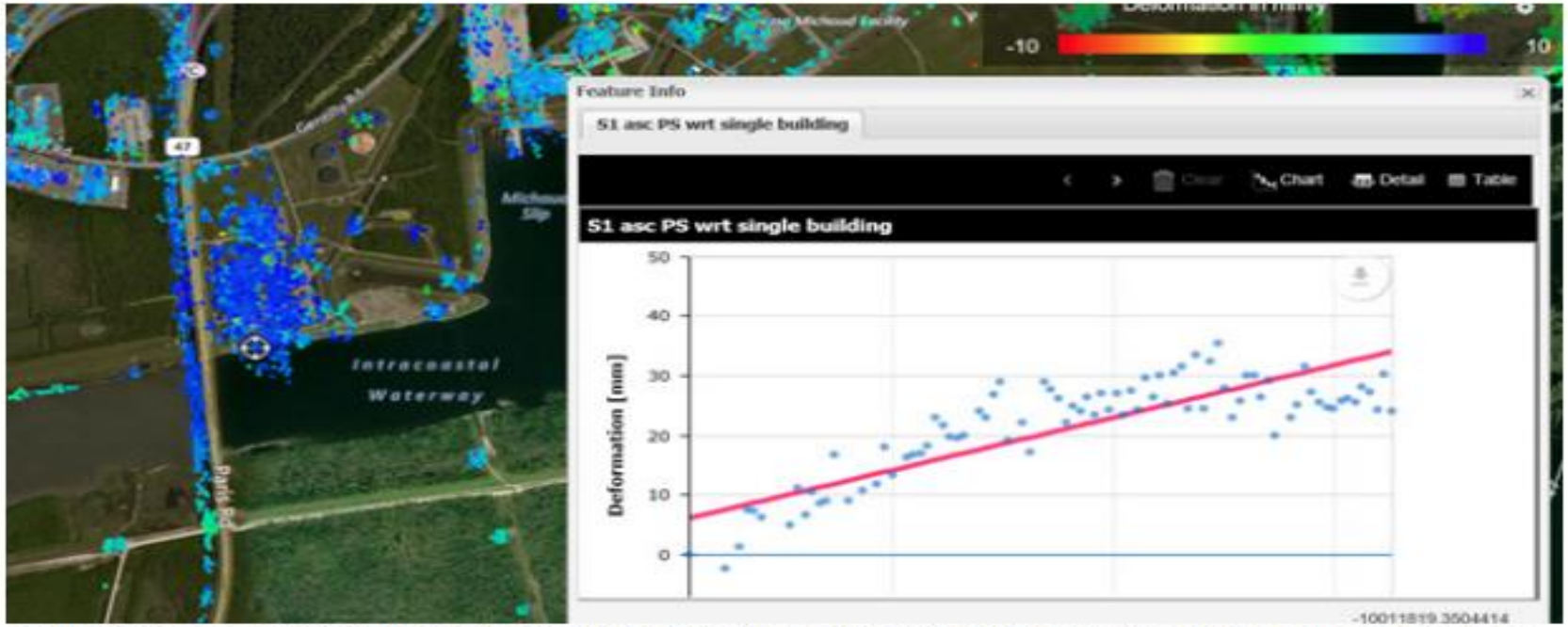
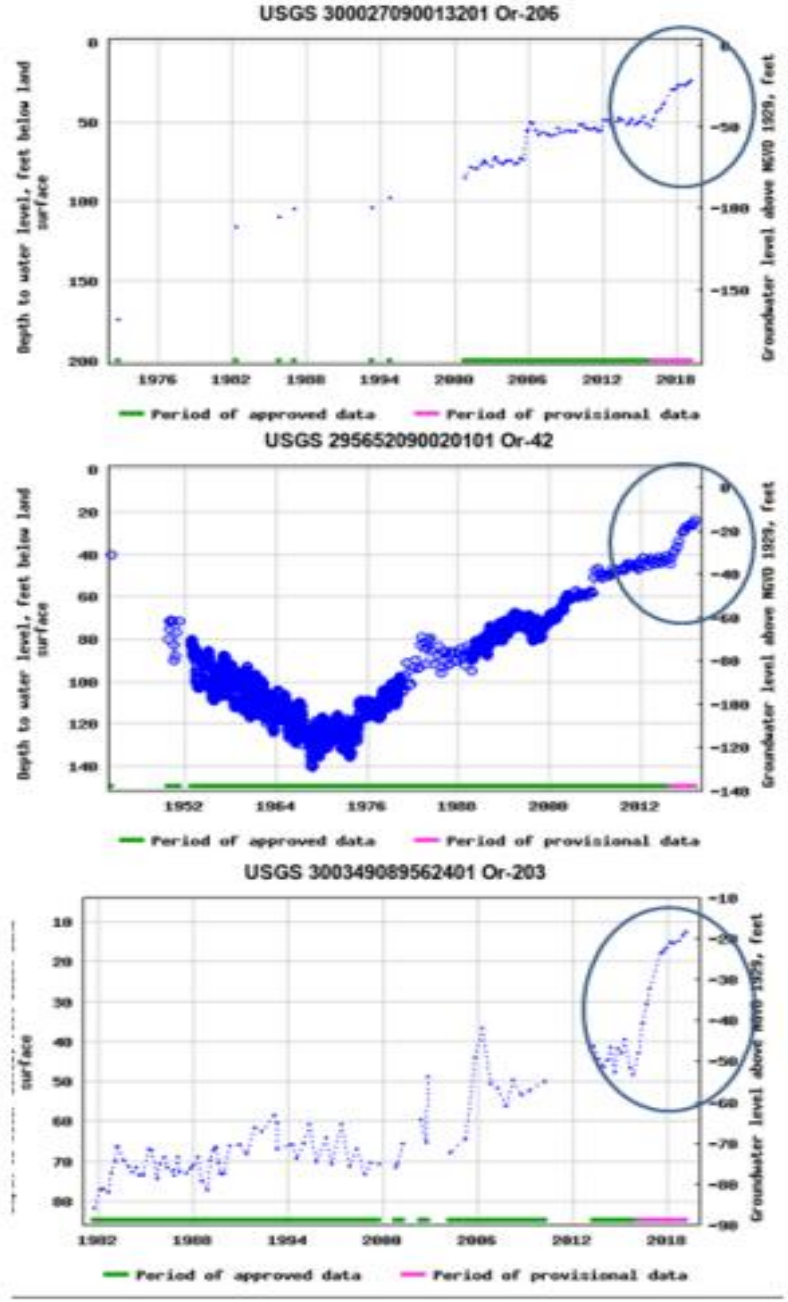



*Figure 3.34 Time series of the uplift near the Paris Road Bridge (location indicated with a white circle). Also note the power line structures south of the waterway.*


*Figure 3.35 Figure 4.29 Increased rate of head rise in observation wells in the Gonzalez-NO aquifer in the period 2016-2019.*



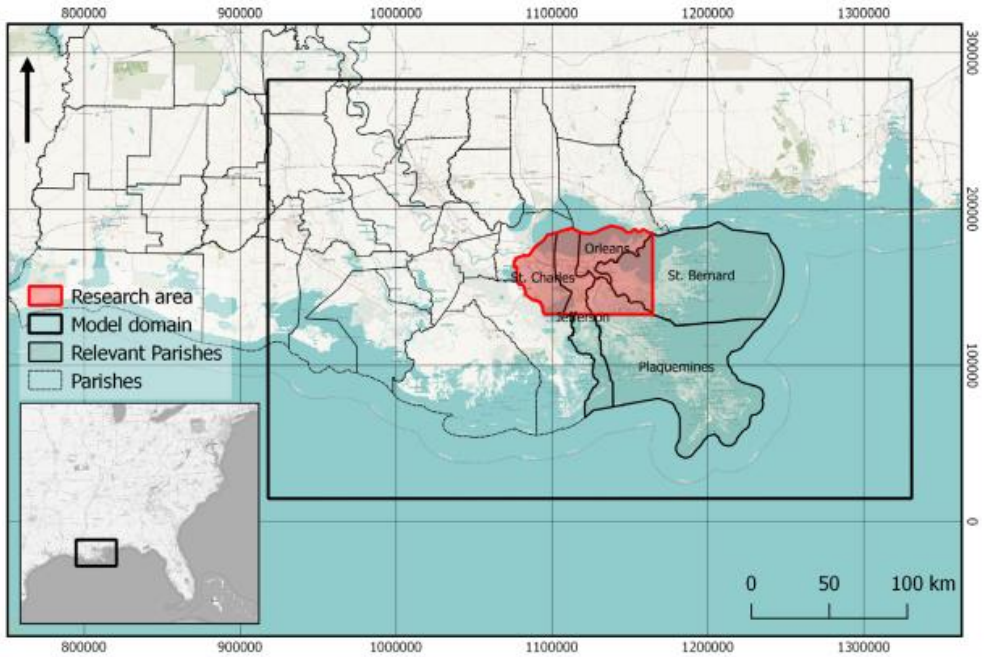
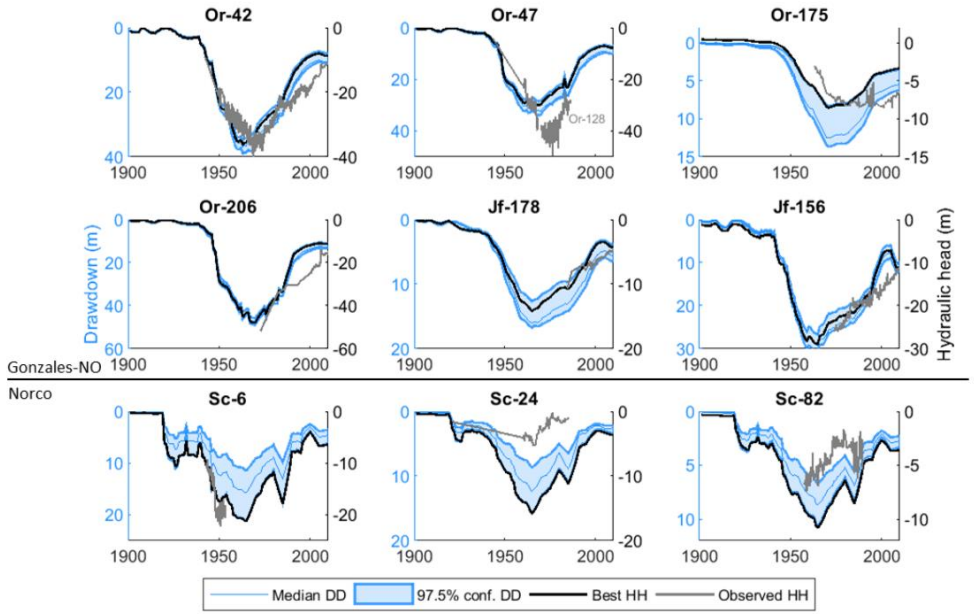
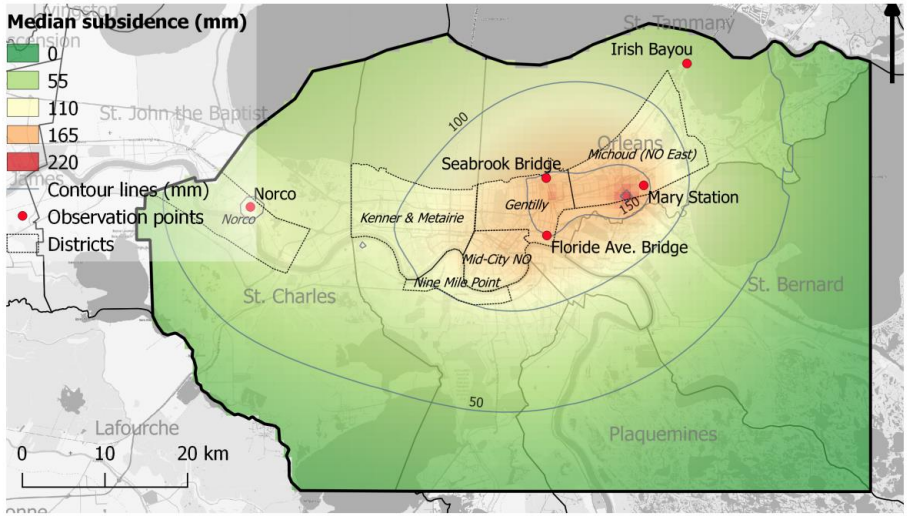



*Figure 2.1. Delineation of the model domain in map view (large box).*

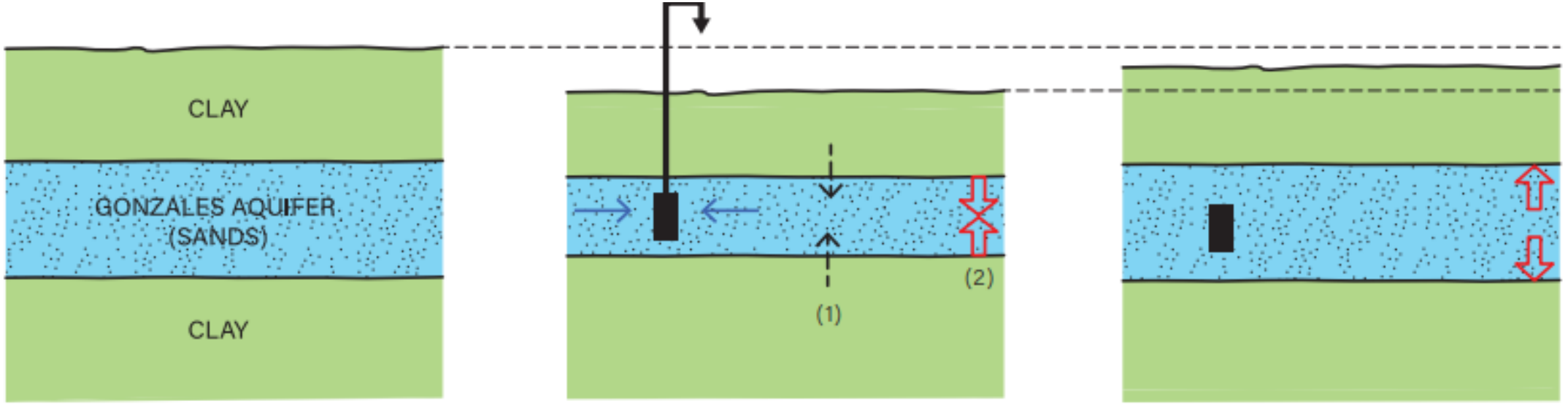



- Review of literature
- Modeling subsidence due to groundwater abstraction
  - The model domain extends significantly beyond the area of interest around GNO and consists of 268*413 grid cells of 1*1 km.
  - Modeling was done with iMOD (groundwater flow modeling) in combination with the SUB-CR package (land subsidence). See Kooi et al, 2023 and Melman, 2019.
- Acquisition and analysis of InSAR satellite data (Envisat, Sentinel-1)




*Map view of modeled land surface subsidence starting at 1900 in mm for 1970 (best-fit model of hydraulic data)*

# REBOUND OF GROUND LEVEL




Initial situation

After start pumping, subsidence starts by (1) drainage and compaction of the under- and overlaying aquitards, and (2) compaction of the sand in the aquifer.

After pumping stops, the elastic compaction of sand grains partly recovers and relative uplift develops. The subsidence caused by drainage of aquitards will not recover.

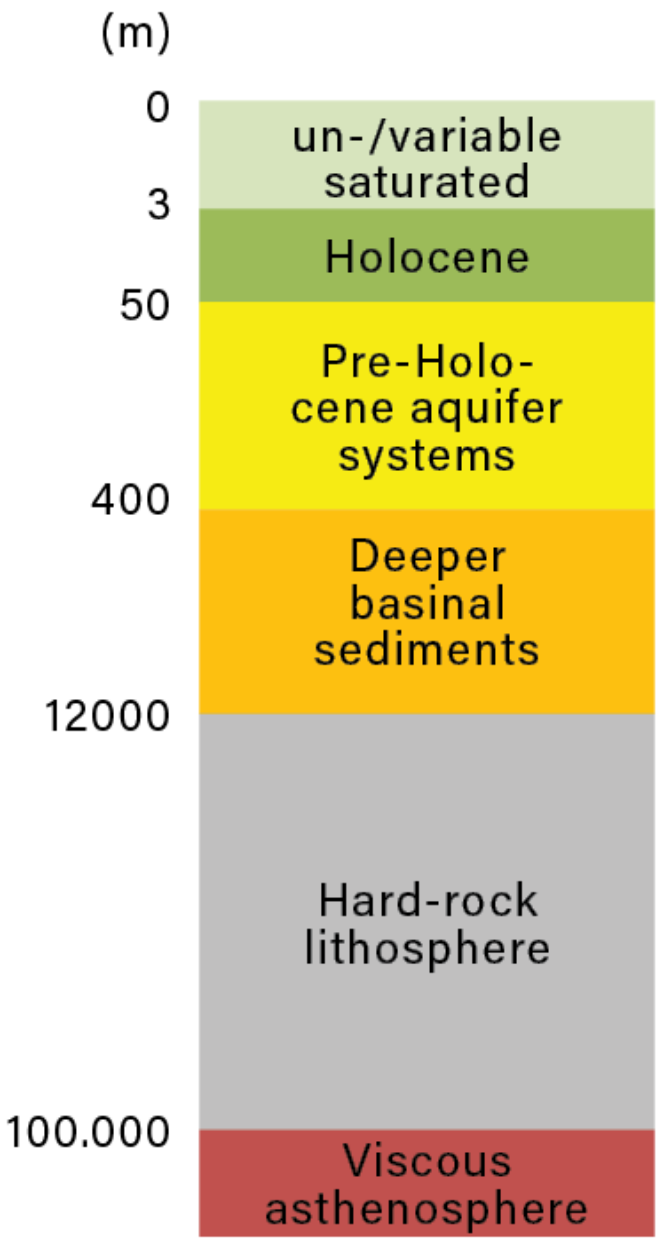
**Legend**

Compaction/decompaction

Groundwater flow

*Figure 3.2 Effect of pumping on the Gonzales aquifer*

# SUMMARY




| | Since start of urbanization (mm/yr) | Present (mm/yr) | Total subsidence in the past 100 years |
|---|---|---|---|
| loading-compaction | 0-50 | 0-15 | nihil-300cm |
| shrink-swell drainage-oxidation | 0-50 | 0-25 | |
| natural compaction drainage-oxidation | 0-3 | 0-2 | |
| groundwater pumping | 0-10 | -1- -10 | 10-30cm |
| growth faulting oil-gas production salt tectonics | 0? | 0? | ? |
| tectonics | 0-20? | 0 | ? |
| Isostasy | 0.5-1.5 | 0.5-1.5 | 10cm |

# STATE OF THE ART…….

- **Subsidence vulnerability varies greatly across New Orleans. After more than 100 years of rapid subsidence due to land reclamation and urbanization, in most areas the subsidence rate has reduced significantly.**
- **Remarkably, due to the cessation of groundwater pumping at the Michoud plant in 2016, subsidence shifted into uplift in New Orleans North-East. This uplift was still active in 2020, but**
- **additional research is needed to understand the possible continuation.**
- **Still, more intense local subsidence areas also exist or can develop because of the presence of shallow peat or muck deposits (also in the uplift area). These areas are vulnerable for groundwater drainage by leaking pipes and pumping during construction works.**

Deltares

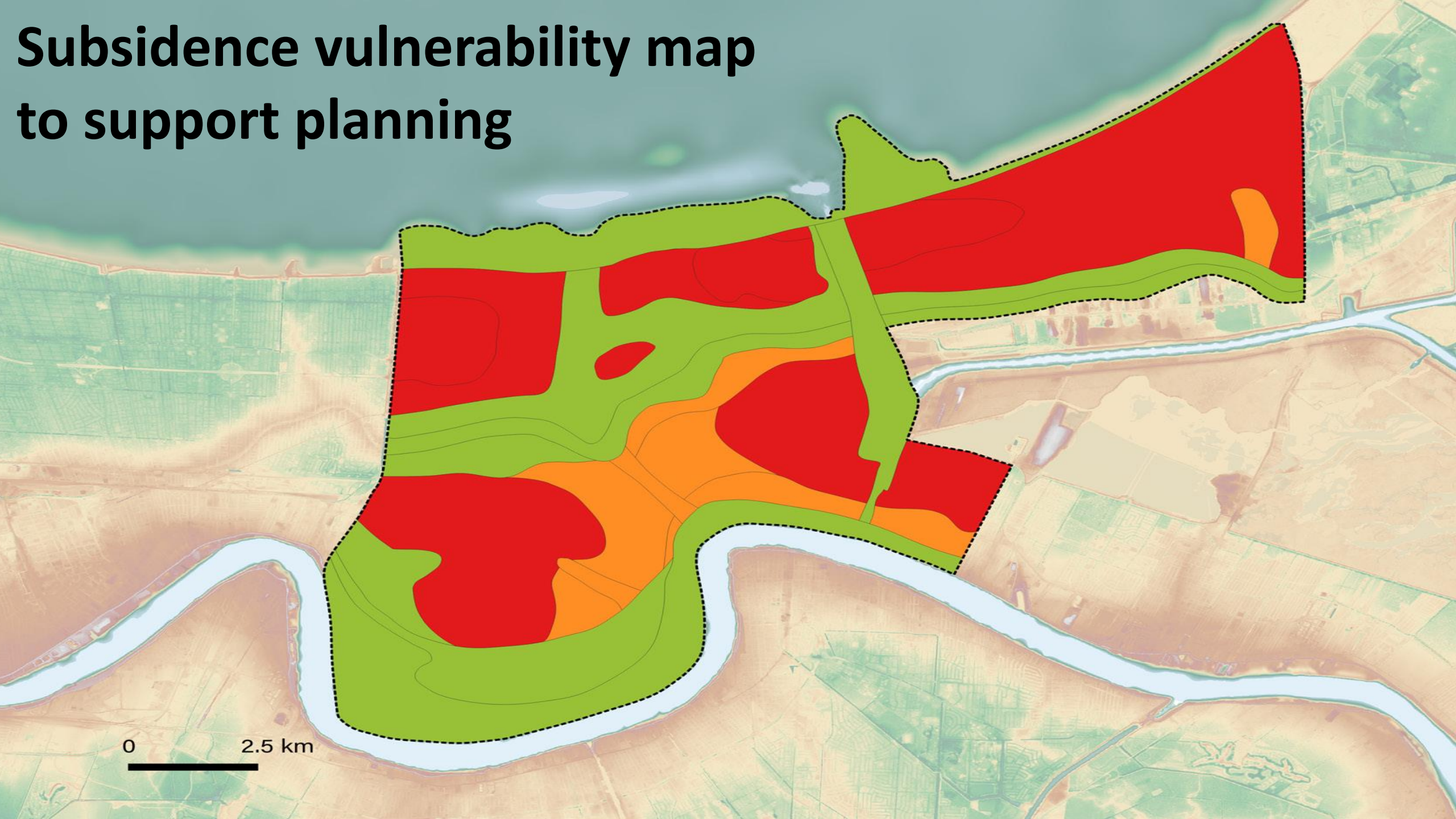
# What to do?

- Use geo information in urban planning (subsidence vulnerability map)
  - Explain how to use these maps
- Keep groundwater level as high as possible in vulnerable (“organic”) areas
  - By control (reduction) of groundwater drainage
- During renovation street system (streets, cables and pipes)
  - Pre-loading considering long term creep.
  - More effective pre-loading requires heavier load and longer pre-loading time.
  - Pre-loading first, renovation pipes next.

OR,

  - Use of light materials (Pumice, Argilex etc.)
  - Now, pipes can be renovated at the same time.
  - Possible in combination with rain water storage, e.g. pvc bufferblox’s
- MONITOR groundwater levels and subsidence (InSAR) at city scale supported regular (bi-yearly) reporting.
- In New Orleans nobody (like many other cities!) is responsible for groundwater and subsidence. ORGANIZE a governance framework.

# Subsidence vulnerability map to support planning




Thanks
for your
patience