Determining Residual Flood Risk Associated with a Complex Levee System
Fort Bend County, TX
Jonathan Simm, Andre MacDonald and Ben Gouldby
1. The Fort Bend levee system

2. Background on system flood risk modelling
   - What is it
   - What is its purpose
   - What does it look like

3. Applying system flood risk modelling to Fort Bend
   - Phase 1 - Levee reliability analysis

4. Next steps
LEVEES EVERYWHERE

There are 881 counties in the U.S. with levees. Those counties contain more than 50 percent of the nation’s population.

- 881 Counties Nationwide with Levees
- 19 Levee Improvement Districts in FBC
- 41 Flood Control Entities in Fort Bend County
19 Levee Districts in Ft. Bend County
99 miles of levees
27 miles of Brazos River levees
Protect $23+ billion in assessed taxable value
1 in 4 Fort Bend County residents lives behind a levee
What does a levee look like?
What are levees? Or rather, what levees are not.

Flood Control Works

NOT JUST SOME BIG MOUND OF DIRT
Not Landscape Berms
Not Parks
Not Hiking Trails
Not Utility Corridors (Sometimes They Are)
Not Power Company Roads
What level of protection do we have?

- FEMA Minimum Height – 3’ Freeboard above 100-yr BFE on Brazos River
- FBC Added an Additional 1-foot of Freeboard (Ft. Bend Foot)
- FEMA Recognizes 100-yr Protection on FIRMs
- Actual Overtopping Protection Above 500-yr Protection
- Some Districts Have Potential For Being Flanked (+/-500-yr)
- Internal Drainage Systems Designed for Local 100-yr Rainfall, with River well BELOW Flood Stages
- Pump Stations Designed for Coincidental Event
  - Local Rainfall while River is NEAR Flood Stages
5,313 acres protected by levees

11.3 miles of earthen levee and 8.4 miles of drainage channels

Two storm water pump stations
William “Bill” Little Pump Station
- 4 pumps capable of a combined 240,000 gpm
Pump Station “F”
- 4 pumps capable of a combined 80,000 gpm
Special District established in 1975 to provide flood protection from the Brazos River and to convey storm water out of the District

$4,815,810,202 assessed value of property and structures (2016)

About 10,000 homes and hundreds of business

Major transportation arteries – US 59 and SH 6

Sugar Land City Hall, Police, Fire, and Emergency Operations Center

Multiple hospital complexes

Major retail centers including Sugar Land Town Square and First Colony Mall
Flood Risk = probability of consequence
The Traditional (Deterministic) Approach

Assumed Load | Assumed System Performance | Consequence
--- | --- | ---
1 in 100 year WL | Levees perform as designed | ‘α’ properties flooded

The Probabilistic (Risk-based) Approach

Range of Loads | System Responses | Results
--- | --- | ---
1 in 10 year WL | Non Failed | ‘α’ Properties flooded
1 in 20 year WL | Failed | ‘β’ Properties flooded
... | Non Failed | ‘γ’ Properties flooded
1 in 1,000 year WL | Non Failed | ‘δ’ Properties flooded
**Flood risk**

\[ \text{Flood risk} = \left\{ \text{Probability (Load)} \times \text{Probability (Breach or overtopping)} \times \text{Consequence (\$)} \right\} \]
Flood risk is constantly changing

Drivers
Processes that change the state of the system

System Descriptors
Source
rainfall, sea level, marine storms etc.
Pathways
urban surfaces, fields, drains, channels, flood storage, flood defences, floodplains
Receptors
people, houses, industries, infrastructure, ecosystems

Responses
Interventions that change the state of the system

Change in Risk
Risk
Economic, risk to life, social, natural environment etc.

System Analysis

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Likelihood of flooding for the present day
Likelihood of tidal flooding if we do nothing - 2100
Present value damage if we do nothing £5B
Risk attribution to levees

Legend
- Defence Risk Histogram

- Defence risk attribution (£/m/year)
- Crest level (mOD)
- 200-year and 75-year water level (mOD)
- 200-year and 75-year with wave height (mOD)

- Contribution to risk (£/m/year)
  - from overflow
  - from breaching
Attributing risk to levee system: Volume Tracking

Time: 0 s
Fort Bend Risk analysis: Levee segments

Segmentation by:

- Geo-technical information (borehole data).
- Crest-level
- Local features.
### Identification of Limit State Equations (LSE’s): RELIABLE Model

#### Failure mode | Failure mode description
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External erosion | Erosion of rear face of an embankment due to overtopping, leading to down cutting and hence breach
Through-seepage | Seepage through levee in the embankment (based on steady state conditions) which could lead to piping.
Under-seepage | Piping under levee due to under seepage (based on steady state conditions), conditional on the following heave/uplift mechanism
Protected side heave | Heave/uplift behind levee due to under-seepage (based on steady state conditions)
Fragility analysis: LID 2 results

Probability of Failure vs. Freeboard (feet)

Seg FID = 1
Seg FID = 33
Seg FID = 34
Seg FID = 36
Seg FID = 7
Seg FID = 8
Seg FID = 41
Seg FID = 19
Seg FID = 18
Seg FID = 21
Seg FID = 6 and 20
Seg FID = 45
Seg FID = 44
Seg FID = 22
Seg FID = 43
Seg FID = 35

Freeboard (m) vs. Freeboard (feet)

Seg 35
Seg 7
Fort bend system risk modelling
Next steps

- Full dynamic system risk model
  - High resolution (sub-property level), dynamic, FSWE inundation modelling
  - Large numbers of extreme events
  - Large number of breach scenarios
  - Representation of full* probability space
  - Revised levee representation for multiple layers

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“Without flood control, nothing else matters.”
- Association of Levee Boards of Louisiana

André McDonald

director1@fbclid2.com

www.fbclid2.com

www.fbfma.org

Ben Gouldby

b.gouldby@hrwallingford.com

www.hrwallingford.co.uk