I. FLOOD HAZARD

A. Definition

1. Hazard: probability of water height
2. At a Specific XY floodplain location;
3. Z can be expressed as elevation (NAVD88); gauge height; height above ground (depth).
4. Or probability of a discharge (CFS) at a stream location.
5. Probability—Expected Annual Exceedance Probability (AEP); = 1/ Average Return Period (Yrs).
6. Often use particular discrete probability as surrogate—e.g., 100-yr; BUT hazard is the full probability curve—*Cumulative Distribution Function (CDF)*

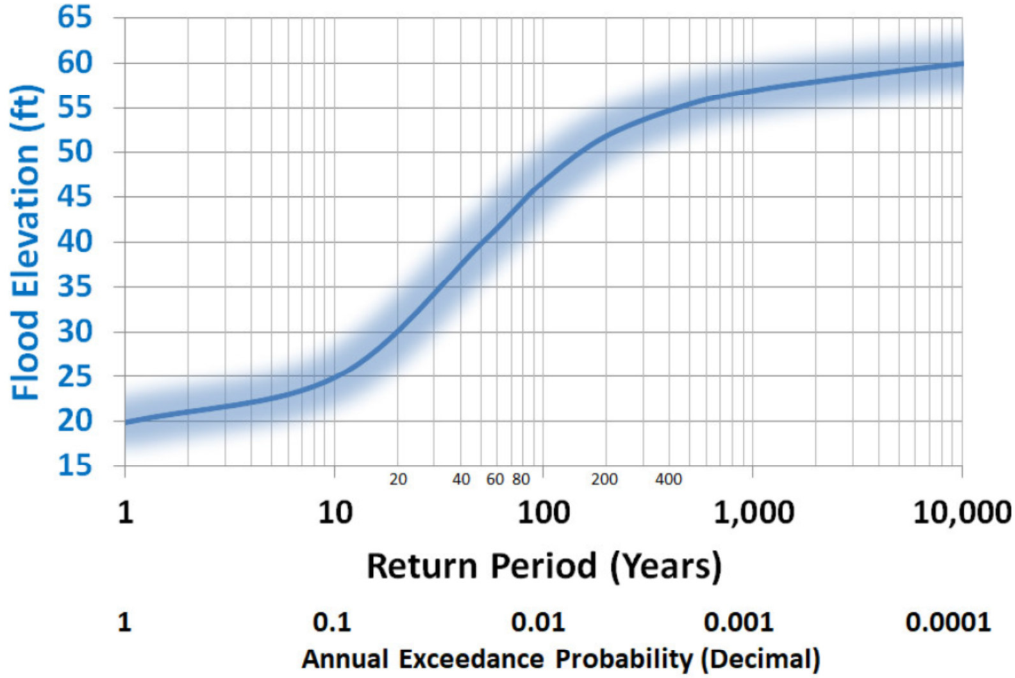


Figure 10. Example of Full Spectrum Flood Hazard

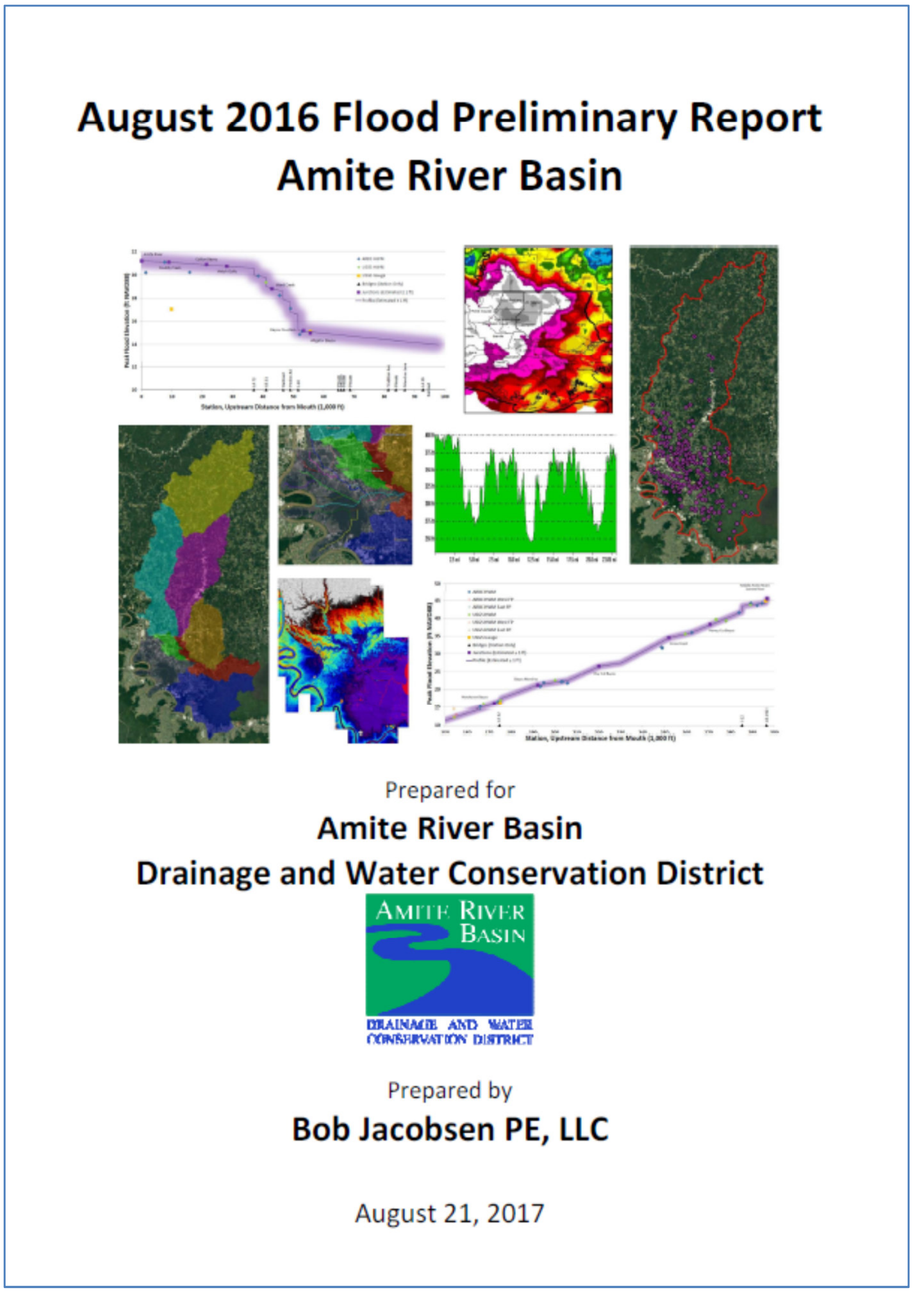
7. Understand effect of multiple annual exposures—e.g., 30-yr period—and multiple independent locations.

100-yr event over 30 years—26%	Draw a Heart
500-yr event over 30 years—5.8%	Rolling 11
1000-yr event over 30 years—3%	Rolling snake eyes
500-yr event over 30 years, 1/5 locations—26%	Draw a Heart

B. Types of Flooding

1. Flash—flooding of local topographic “bowls;” from direct rainfall in vicinity
2. Riverine-Headwater—depends on watershed characteristics of river segment
3. Riverine-Backwater—also depends on downstream tailwater—and thus other streams in overall basin.
4. Coastal—Tide +Wind-driven flow (fetch dependent).

Review background studies for your Area of Interest, past floods.



August 2016 Flood Preliminary Report
Amite River Basin

Prepared for

Amite River Basin
Drainage and Water Conservation District

Prepared by

Bob Jacobsen PE, LLC

August 21, 2017

C. How are Flood Hazards Determined

Two Approaches. Statistical analysis of:

1. *Actual Flood Record*—gauge data

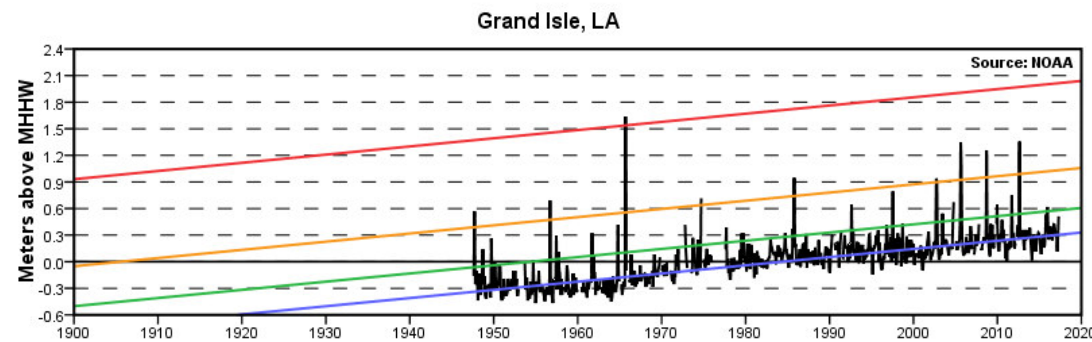
   a) Rank peaks and calculate observed frequency

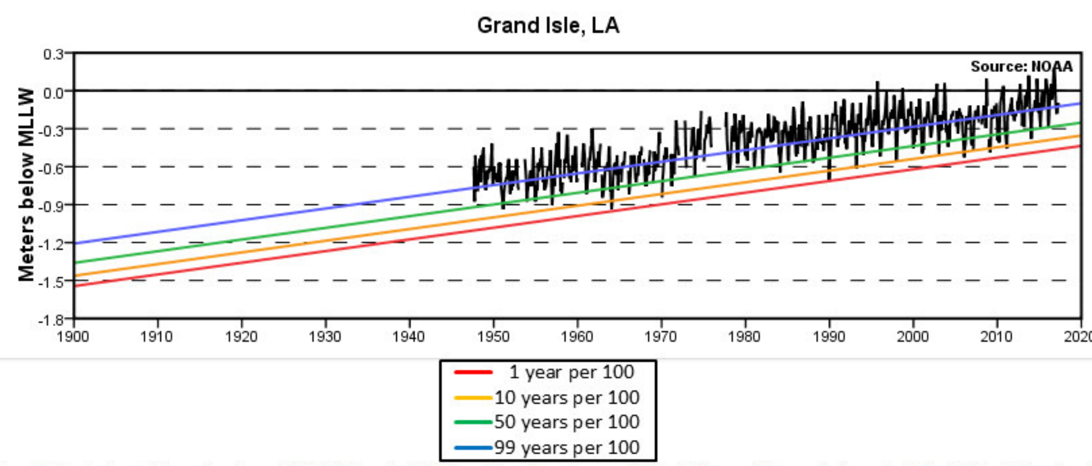
   b) Curve type is selected and parameters are adjusted to "fit" observed frequency

   c) Interpolation and extrapolation.

Extreme Water Levels

8761724 Grand Isle, LA





The monthly extreme water levels include a Mean Sea Level (MSL) trend of 9.24 millimeters/year with a 95% confidence interval of +/- 0.59 millimeters/year based on monthly MSL data from 1947 to 2006 which is equivalent to a change of 3.03 feet in 100 years.

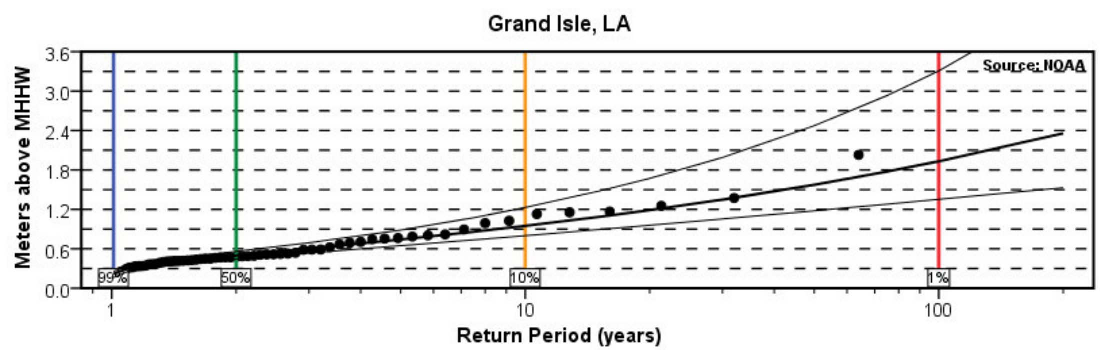
The plots show the monthly highest and lowest water levels with the 1%, 10%, 50%, and 99% annual exceedance probability levels in red, orange, green, and blue. The plotted values are in meters relative to the Mean Higher High Water (MHHW) or Mean Lower Low Water (MLLW) datums established by CO-OPS (1 foot = 0.3 meters). On average, the 1% level (red) will be exceeded in only one year per century, the 10% level (orange) will be exceeded in ten years per century, and the 50% level (green) will be exceeded in fifty years per century. The 99% level (blue) will be exceeded in all but one year per century, although it could be exceeded more than once in other years.

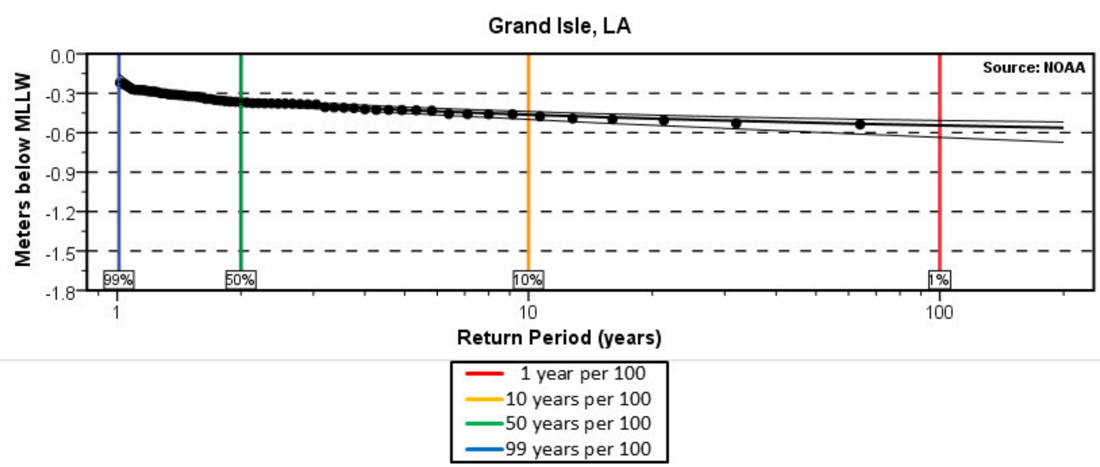
https://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=8761724

Annual Exceedance Probability Curves

8761724 Grand Isle, LA

The annual exceedance probability curves with 95% confidence intervals shown below indicate the highest and lowest water levels as a function of return period in years. The dots indicate the annual highest or lowest water levels after the Mean Sea Level trend was removed, which were used to calculate the curves. The levels are in meters relative to the Mean Higher High Water (MHHW) or Mean Lower Low Water (MLLW) datums established by CO-OPS (1 foot = 0.3 meters). The horizontal position of the rightmost dot indicates the number of years of data used in the calculation.





https://tidesandcurrents.noaa.gov/est/curves.shtml?stnid=8761724

2. *Synthetic Flood Record*: Most common since gauge records can only be used very close to the gauge location. Involves:

   a) Numerical model code capable of simulating "physics" of flood scenarios

      (1) For Riverine Flood model rainfall runoff and channel routing:

         (a) Hydrologic models (e.g., HEC-HMS) degree to which process and spatial factors are "lumped" vs "distributed."

         (b) Hydraulic models (e.g., HEC-RAS) modeling channels/floodplains (1D vs 2D) and urban pipe flow.

      (2) Coastal—2D model (ADCIRC) for wind, surge, waves.

      (3) Models have "physical" and "numerical" limitations!

   b) Model geometry setup

      (1) Resolution, fidelity—especially for major topographic breaklines and conveyance features.

      (2) Boundary conditions.

      (3) Hydrodynamic roughness/drag properties-- spatially (and maybe depth) variable.

   c) Calibration/validation

      (1) Event data—quality and quantity.

      (2) Improve model geometry.

      (3) Tune local roughness (Manning's n)--maybe.

   d) Flood scenarios

      (1) "Full"—wide range to determine a CDF—maybe hundreds

      (2) "Limited"—only to provide a discrete hazard level—maybe tens

      (3) Flash Flood and Riverine Headwater Scenarios—variety of ***intensity-duration*** rainfall events; for larger basin variety of spatial distributions

      (4) Backwater Riverine Flood Scenarios—regional headwater scenarios PLUS tailwater scenarios

      (5) Coastal Flood Scenarios—hurricane characteristics and landfall locations; PLUS rainfall and river scenarios.

   e) Assigning probability to each scenario (rainfall, hurricane)—issues of "joint probability."

   f) Computational power; post processing—can affect choices about model geometry and number of scenarios

   g) Statistical analysis (curve fitting) of synthetic record

   h) Additional "what if" scenarios for proposed project or change in critical conditions

D. Who Does Flood Hazard Analysis

1. In past, rigorous “Full” analyses expensive and time consuming—only done for
   a) Big flood public infrastructure projects—levees, dams, river modifications (Corps, Bureau of Land Reclamation).
   b) Massive private facilities/federal installations (DOD Bases, Nuclear Power Plants, etc.)
2. Since 1968 the federal National Flood Insurance Program (1968) has sponsored “Limited” analyses
   a) “Flood Insurance Studies” and “Flood Insurance Rate Maps”
   b) For virtually all floodplain communities
   c) Focused on programmatic delineations of “Special Flood Hazard Areas” and Base Flood Elevation (1% AEP) not full CDF.
   d) Some done by Corps, some by private consultants; local communities may undertake themselves with consultants.
   e) May be modified by landowners with analysis by consultant.
   f) Often the local FIS/FIRM is woefully outdated.
3. Local development regulations require drainage impact studies. Increasingly, the requirements for synthetic analysis are becoming more rigorous due to concerns of neighbors.

E. How Good Are Flood Hazard Analyses

1. Uncertainty
   a) Historic data quality and sample size”
      (1) Length of an actual record for gauge analysis
      (2) Rainfall/hurricane events for synthetic approach
      (3) Capture magnitude of very infrequent events
      (4) Climate cycles
   b) Model calibration/validation for synthetic approach
   c) Statistical Analyses

Uncertainty gets bigger with rarer hazard. Estimates of a 100-yr coastal flood stage or river discharge can have 95% UCL >30 percent.

2. Key Sources of Bias
   a) Ignoring trends—climate change; geometry change
   b) Institutional tendencies to under- or over-state hazard; to accept outdated analyses

Both uncertainty and bias are important for developing a Factor of Safety.

FOS depends on Flood Risk Management purpose of site-specific design

II. FLOOD RISK

A. Definition

1. Same as any kind of risk--Probability (hazard) * consequences
2. At XY Specific Location.
3. Risk can be aggregated over common area subject to a flood event/scenario (watersheds, coastal communities)
4. Flood risk probability must also incorporate the “sub-probability” for failure of any flood control measure.
5. Location-specific and aggregate risk expressed as CDF.

B. Types of Risk (Consequences)

a) Death (fire risk much worse in Louisiana)

b) Economic loss

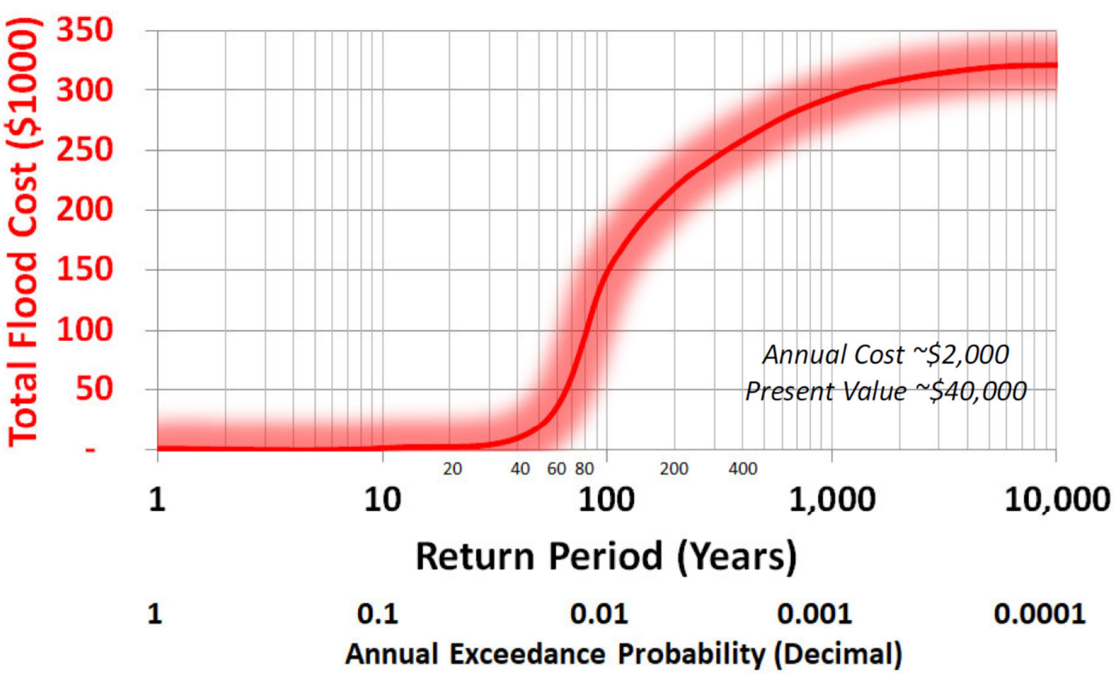
(1) Property Damage—businesses, homes, public facilities, infrastructure, automobiles

(2) Decline in economic activity—business and personal income, tax receipts, etc.

(3) Indirect expenses—relocation, health care, PTSD, etc.

Economic Risk CDF can be converted to annualized cost and present value.

c) Social/Cultural



C. Flood Risk Management—Death

1. "Flood Protection" Eliminate the risk

   a) For "forecastable" flooding this defaults to evacuation/sheltering.

   b) Where evacuation/sheltering not feasible, requires extremely rigorous analysis.

   c) Flood Protection Projects have *HIGH Factors of Safety*.

D. Flood Risk Management—Economic Loss

1. Self-Finance

   a) Budget/save for higher probable damage in O&M—just like other repairs

   b) Purchase flood Insurance for more remote possibilities of damage—cost of insurance is also part of O&M.

   NOTE that a) + b) = annualized cost of $ CDF

2. "Flood Risk Reduction"–bend $ CDF; reduce annualized cost/present value

   a) Relocate if O&M too expensive—OK for private and some infrastructure decisions; problematic for community-level decisions

   b) Private mitigation (elevation and flood proofing) measures for existing structures—if cost effective vis-à-vis saving/insurance cost

   c) Community mitigation (elevation and flood proofing) —regulations spurred by insurance (like other codes).

   d) Public flood reduction projects—drainage improvements, levees, etc.—

      (1) Economic Benefit:Cost Ratio—compare present values of reduction in flood costs—aggregated over the affected area—to cost of implementing Flood Risk Reduction Measure: design/construction/O&M

      (2) The "theory" of Benefit:Cost analysis is well established—Corps References. Tools to implement rigorous Benefit:Cost analysis are only now beginning to emerge:

         (a) Rigorous Flood Hazard Analysis—producing CDF

         (b) Big Data (Cloud) on community structure inventory, depth-damage estimates

         (c) Used in CPRA Louisiana Coastal Master Plan—see Coastal Louisiana Risk Assessment (CLARA).

      (3) Uncertainty and bias in BC Ratio primarily from Flood Hazard Analysis. *95% UCL > ±20 percent.*

      (4) Public Flood Risk Reduction Projects typically have *LOW FOSs.*

      (5) Politics—special interests can override Benefit:Cost decisions.

EXAMPLES?

E. Role of Flood Insurance

1. Cost of flood insurance (+ saving for deductible) in a *competitive private market* is a good surrogate for annualized cost of flooding.

2. Flood insurance is often the cheapest management approach for moderate risk. (It is lower than other property insurance costs.)

3. Community resiliency is drastically improved if there is broad participation in flood insurance.

4. Where you have No. 1, sensible public flood reduction projects are pursued when paid for through reductions in cost of flood insurance. Similar to public investments in fire protection.

5. NFIP—very political—subsidizes a lot of High Risk policies at the expense of Moderate Risk policies.

   Effect is to encourage too much risk and discourages insurance!

   Plus the over-emphasis of single, artificial threshold (100-yr BFE)—and outdated and inherently imprecise mapping of Special Flood Hazard Areas—distort perception of hazard/risk.

   Related local policies and practices have driven substantial development at margins of SFHAs—Baton Rouge, Houston—where risk is actually high.

   See "*Modernizing Post-NFIP, Climate-Change Flood Risk Management*"

References, see www.bobjacobsenpe.com

Amite River Basin August 2016 Flood Preliminary Report (August 2017)

Hurricane Surge Hazard Analysis: The State of the Practice and Recent Applications for Southeast Louisiana (May 2013)

New Orleans East-Bank Hurricane Surge Residual Risk Reduction Report (February 2016)

Hurricane Surge Hazard Primer

Hurricane Surge Hazard Uncertainty in Coastal Flood Protection Design, for The Journal of Dam Safety Vol 13, Issue 3, 2015.

White Papers

Real Flood Risk a 3-minute video
Real Flood Risk: The Grassroots Revolution
The Flood Risk Game
Modernizing Post-NFIP, Climate-Change Flood Risk Management

NOTE that a) + b) = annualized cost of $ CDF