

# The Sciences of Global Megaflooding, Paleoflood Hydrology, and Modern Flood Risks

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E. Washington State, 16,000 years ago.



Houston, Texas, August 25-29, 2017



Flood myths in more than 140 ancient societies, based on ethnological and historico-cultural sources.

From: Bruckner and Engel, 2020, Noah's flood—Probing an ancient narrative using geoscience. In: Herget, J., Fontana, A. (Eds.), *Palaeohydrology: Traces, Tracks and Trails of Extreme Events*. Springer Nature Switzerland, Cham, Switzerland, p. 135-151.



**Early “geology” (prior to ca. 1800) considered relationships among the Noachian debacle, biblical literalism, and Earth science, a view that did not get scientifically dispelled until geology’s “axial age” of the latest 18<sup>th</sup> and earliest 19<sup>th</sup> century.**



# First reported use of the word 'geology' (Oxford English Dictionary)

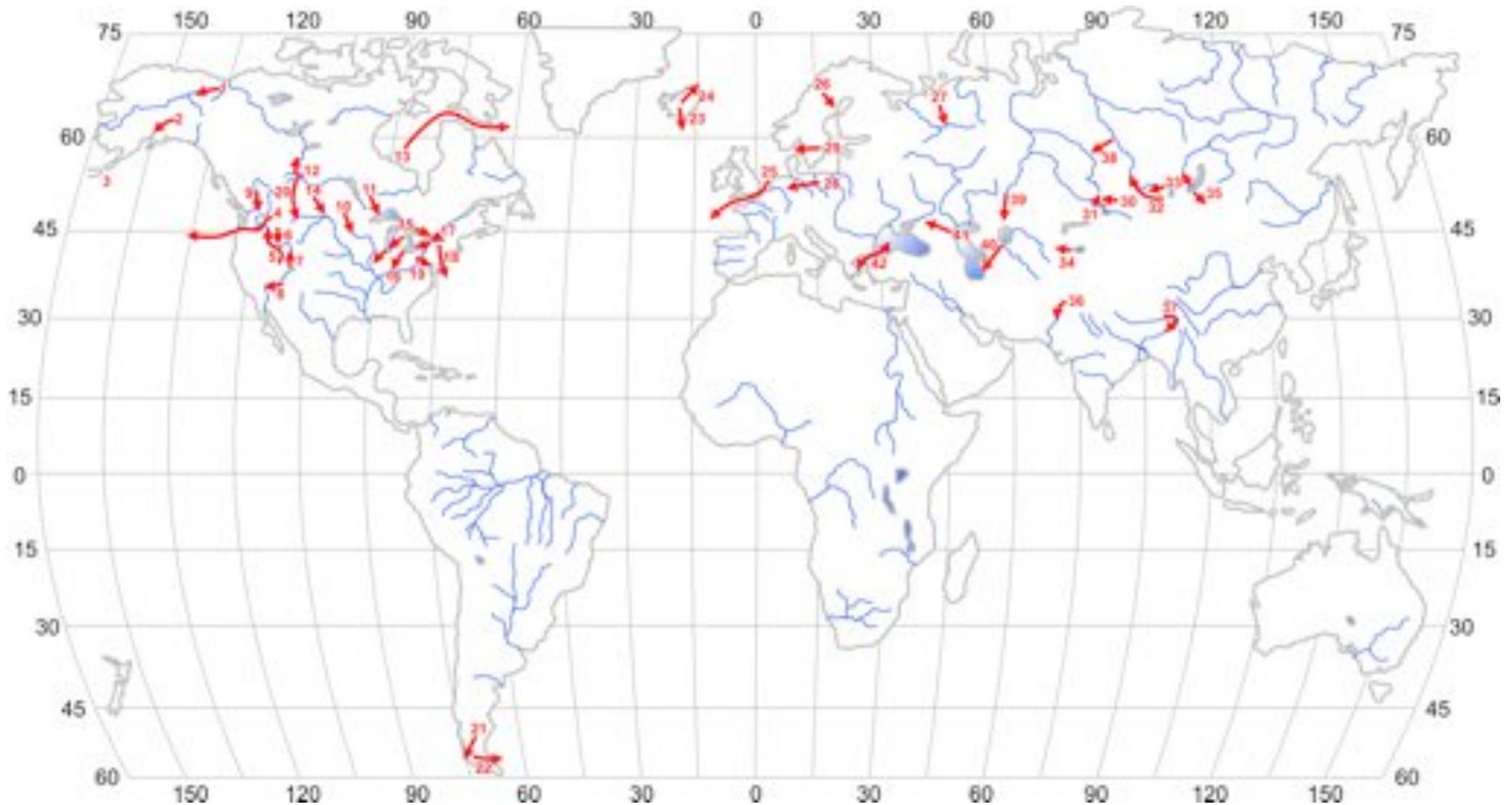


Title of the 1690 book *Geologia: or, a Discourse Concerning the Earth Before the Deluge*, written by Erasmus Warren, and concerned with literal truth of the Book of Genesis. But Warren had to resolve a paradox: Genesis mixes two different accounts of the Noachian Debacle: The Flood derives (1) from “foundations of the great deep” (Genesis 7:11), or (2) from “the windows of heaven,” such that it rained continuously for 40 days and 40 nights (Genesis 7:12). Warren chose the first account, postulating that water burst from great subterranean caverns.

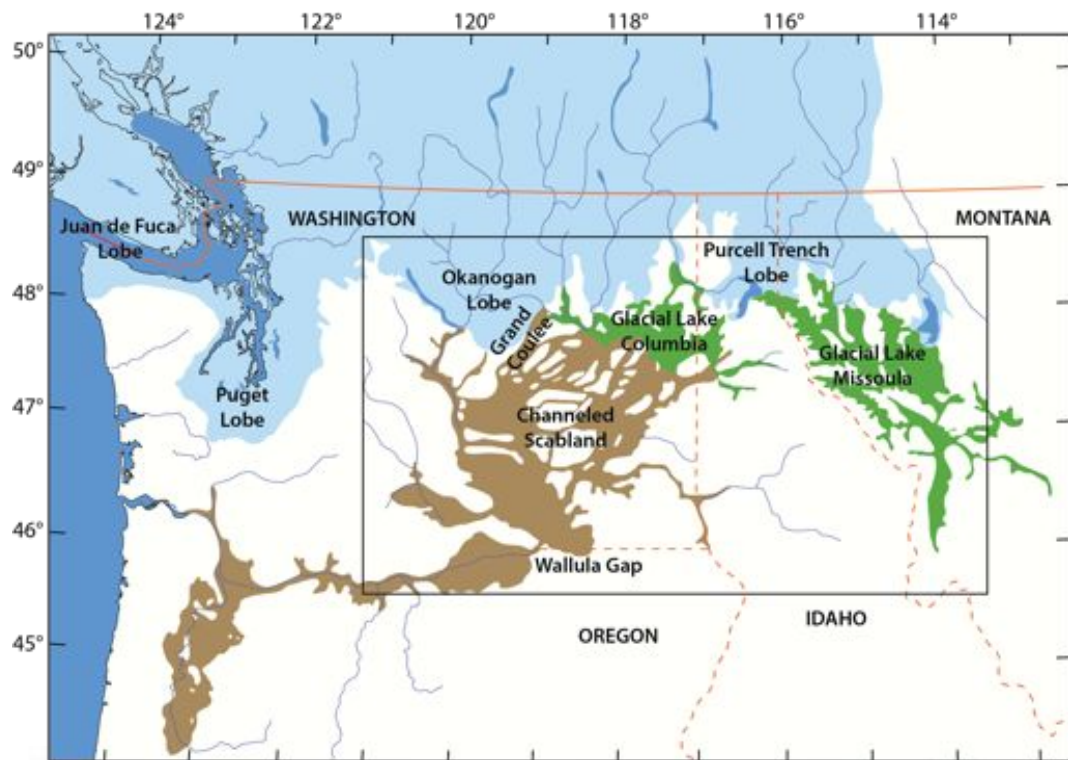


**MEGAFLOODS** – Overflows of water with discharges comparable to those of ocean currents.

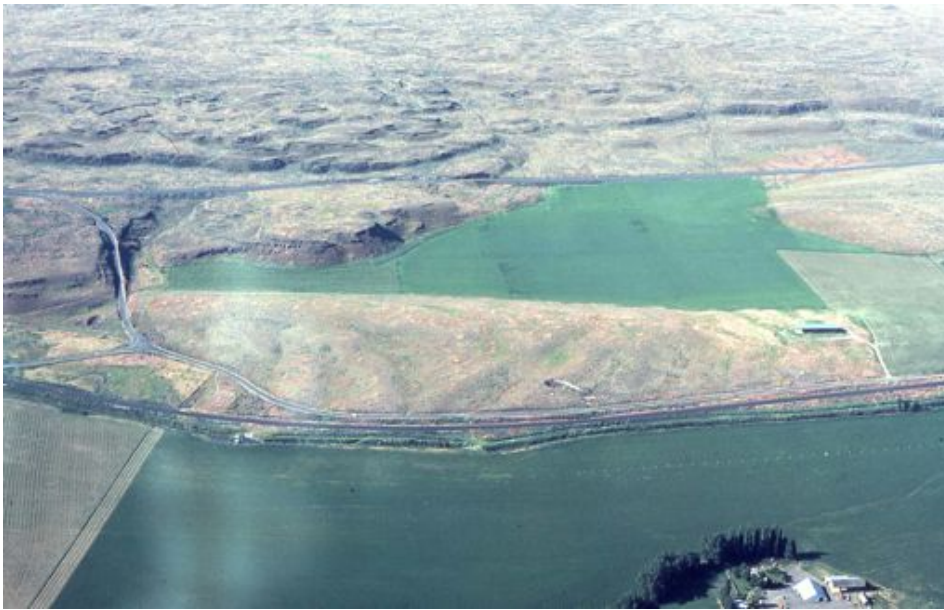
One Sverdrup = One Million Cubic Meters per Second



Baker, V.R., 2013, Global late Quaternary fluvial paleohydrology w. special emphasis on paleofloods and megafloods, in Shroder, (Ed-in-Chief), Wohl, E. (Ed.), *Treatise on Geomorphology*, v. 9, *Fluvial Geomorphology*: Academic Press, San Diego, p. 511-527.







Gravel Bar (Wilson Creek)



Giant Cataracts

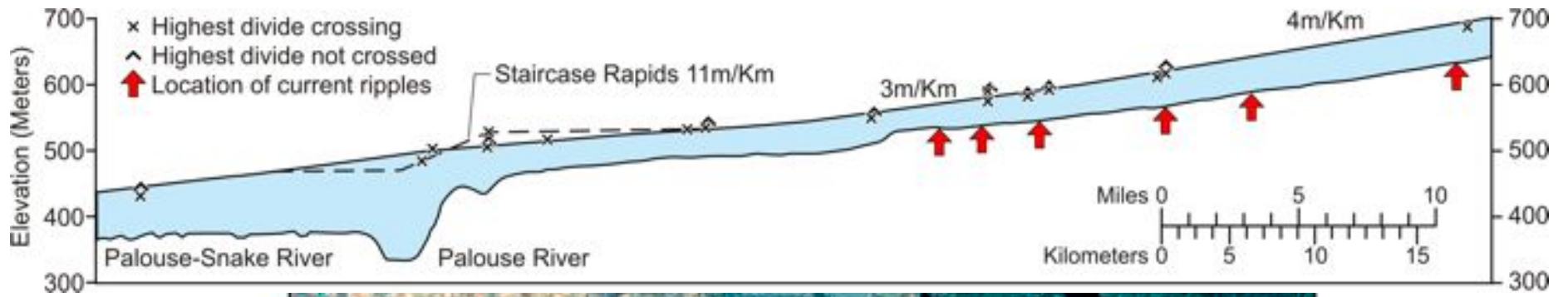


Scabland (Lake Lenore)



Streamlined Loess "Island"





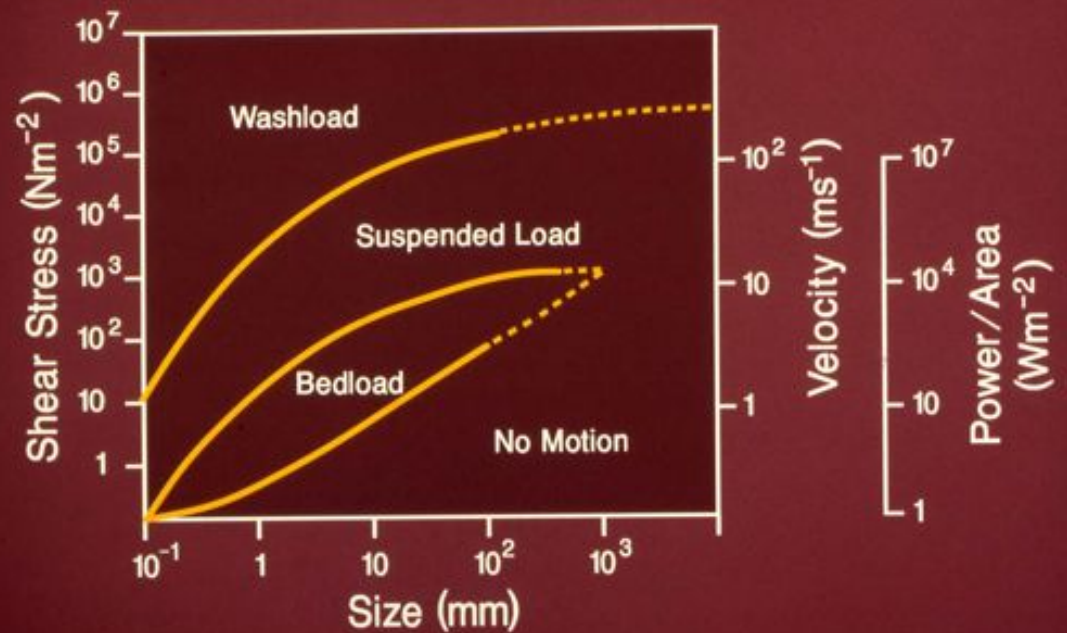
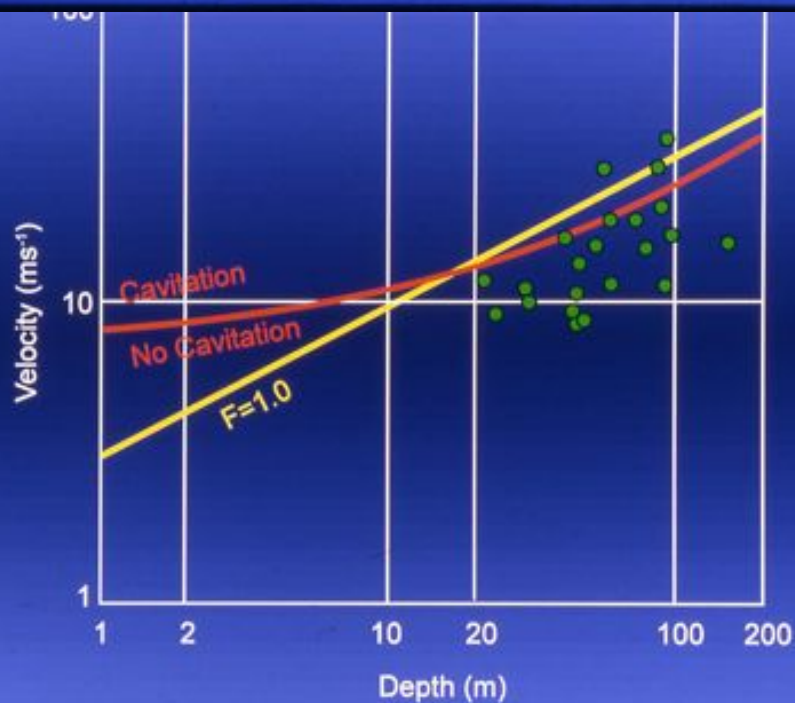


# Boundary Shear Stress

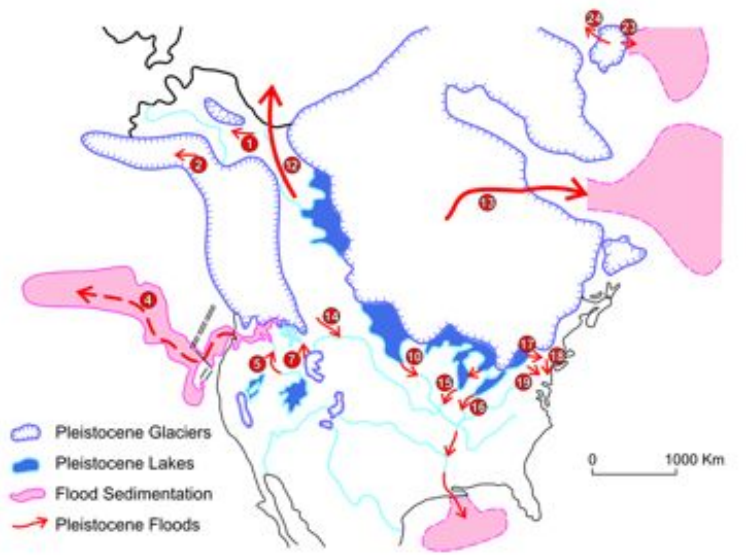
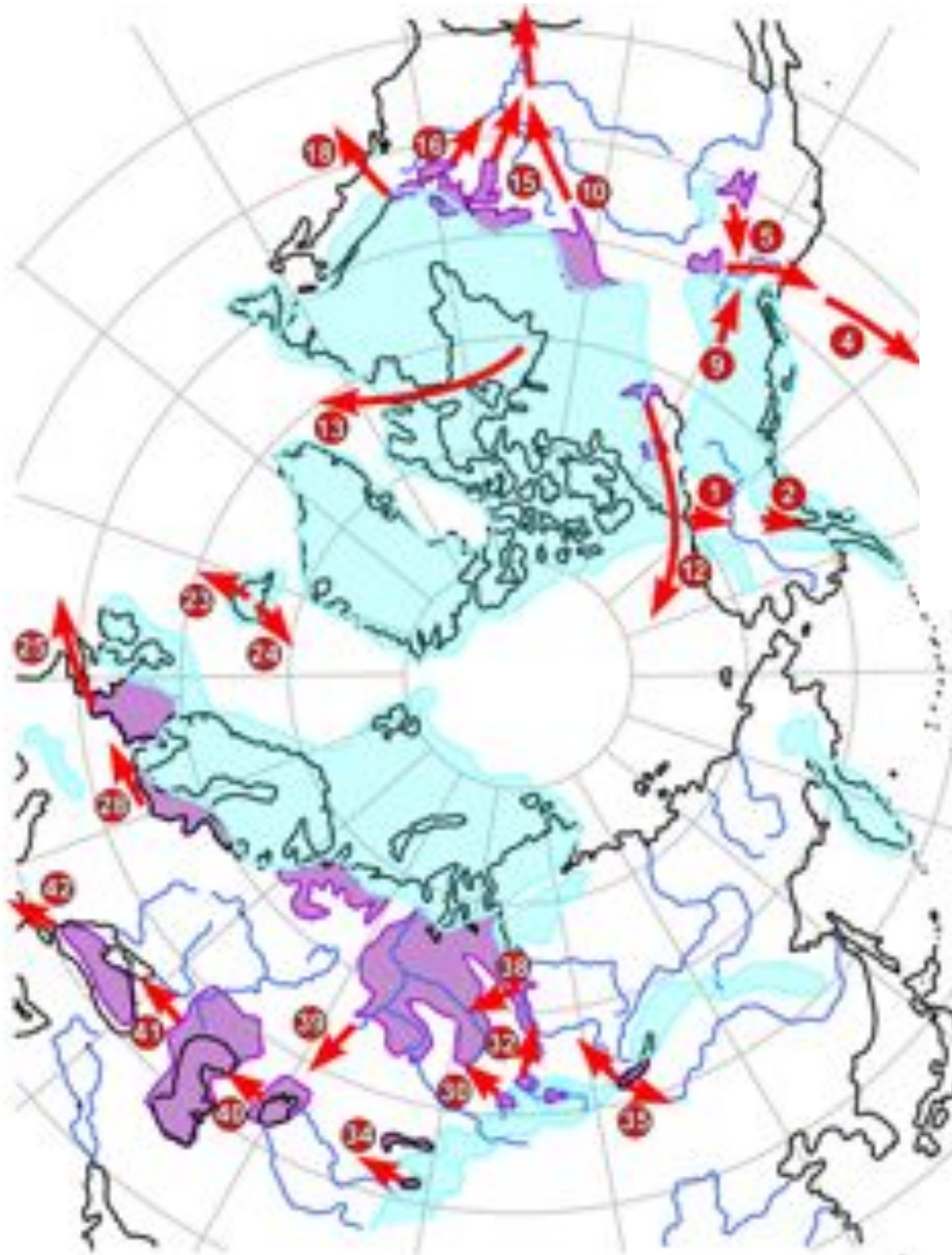
$$\tau = \gamma R S$$

# Power/Unit Area

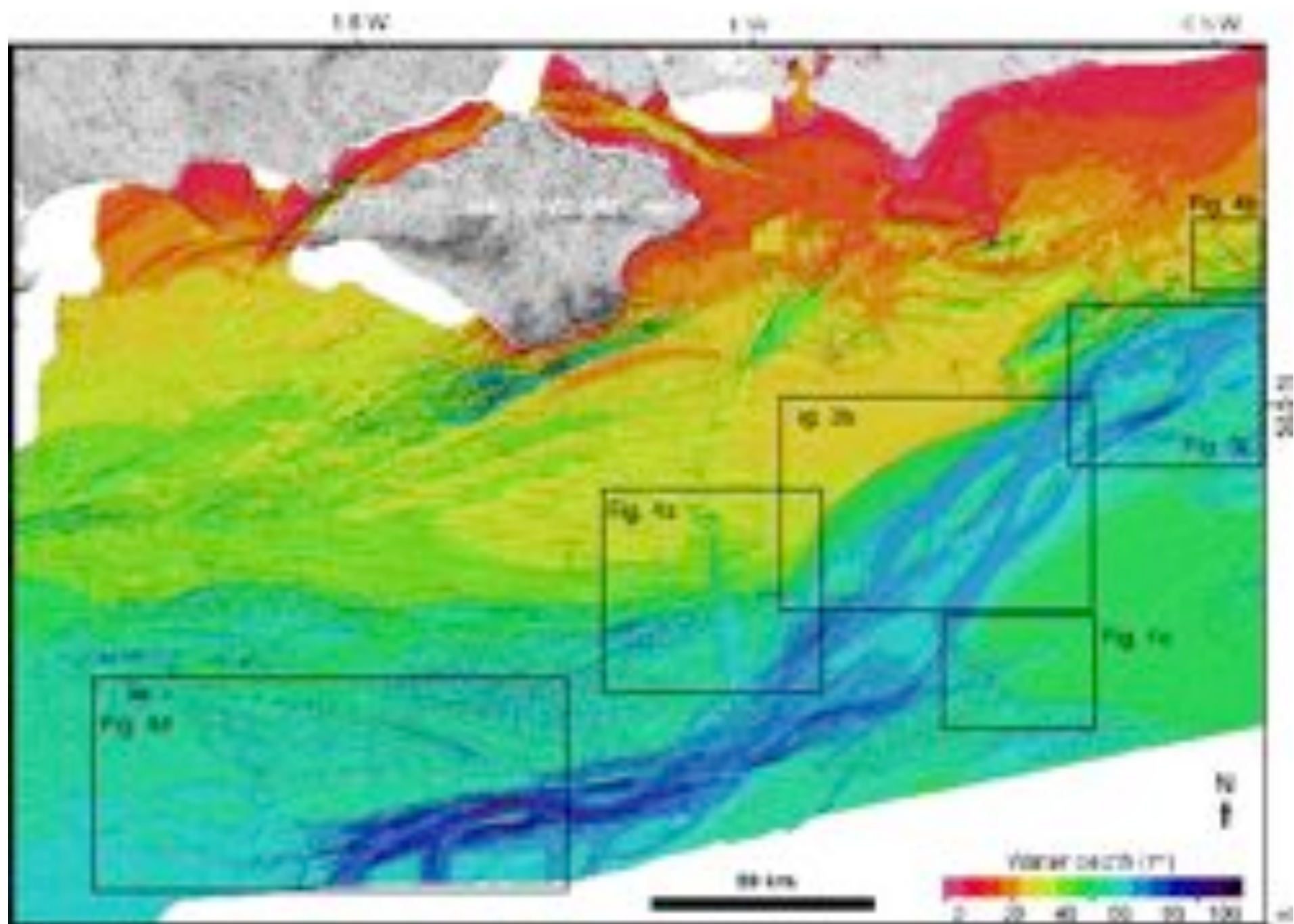
$$\omega = \frac{\gamma Q S}{W} = \tau \bar{V}$$











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54

19th-century Japanese print depicts Chinese hero Yu's mythic battle against a monstrous flood.







*Few photographs exist of the tsunami in Rikuzentakata due to the low survival rate in the inundation zone. One image captured the first wave sweeping across a residential area a mile from the bayfront (the surge can be seen pouring out of the Kesan River at upper left). A local police official filmed the tsunami sequence .*



*Rikuzentakata was the largest city to be directly affected by waves in excess of 60ft. Flow-depths greater than 45ft were found half a mile inland as the tsunami travelled up river valleys lined with densely populated residential neighborhoods. The city suffered the second greatest death toll of any population center affected by the tsunami.*



















# **GREATEST FAILURE TO COMMUNICATE NATURAL HAZARD RISK**

## **2011 Tōhoku earthquake and tsunami**

Death Toll ~20,000

Total Dollar Cost > \$ 300,000,000,000



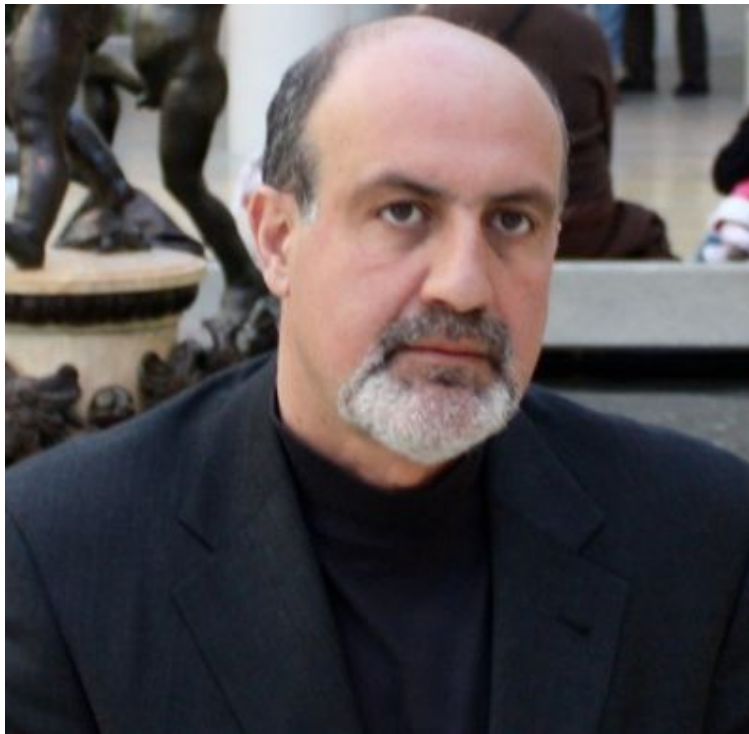
**Tepco executives on trial  
Fukushima nuclear disaster  
(July 2017)**

The **black swan theory** or **theory of black swan events** is a metaphor describing an event that

- (1) is a **surprise** (to the observer). It is an **outlier**, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility
- (2) has a major effect (**extreme** 'impact').
- (3) human nature, in spite of the outlier status, makes us **concoct explanations** for its occurrence after the fact, making it explainable and predictable.

***The Black Swan: The Impact of the Highly Improbable*** (2007, 2010)

**Nassim Nicholas Taleb (b. 1960)**



**“Anything that relies on correlation is charlatanism.”**



Standard tsunami hazard assessment procedures (**international standards** employed by Japan) were followed to design the sea wall at the Fukushima Daiichi nuclear plant:

- (1) a **probabilistic seismic hazard assessment**,
- (2) estimation of the **Probable Maximum Earthquake** (PME),
- (3) creation of a tsunami generation scenario for the PME ,
- (4) **computer modeling** of propagation for this presumed tsunami,
- (5) resulting **prediction** of the tsunami runup on the Sendai Plain,
- (6) estimation of the hazard at the Fukushima Daiichi Plant (a 5-m high wave).

After adding a **factor of safety** of 0.7 m, the sea wall at Fukushima was constructed to a height of **5.7 m**.

**The March 11, 2011, tsunami wave height was 15 m !!**

(A geological study published in 2001 showed that a similar magnitude tsunami occurred in the same area in 869 C.E. Uncertain probabilities were believed; the certainty Earth's possibilities were not.)



### The 869 Jōgan tsunami deposit and recurrence interval of large-scale tsunami on the Pacific coast of northeast Japan

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**Published in 2001!!!**

#### ABSTRACT

The fore-arc region of northeast Japan is an area of extensive seismic activity and tsunami generation. On July 13, 869 a tsunami triggered by a large-scale earthquake invaded its coastal zones, causing extensive deposition of well-sorted fine sand over the coastal plains of Sendai and Soma. Sediment analysis and hydrodynamic simulation indicate that the tsunami inferred to be triggered by a magnitude 8.3 earthquake spread more than 4 km inland from coast. We postulate that the sand layer was developed by the tsunami's first wave. Traces of large-scale invasion by old tsunami as recorded in the coastal sequences of the Sendai plain show about a 2000-year

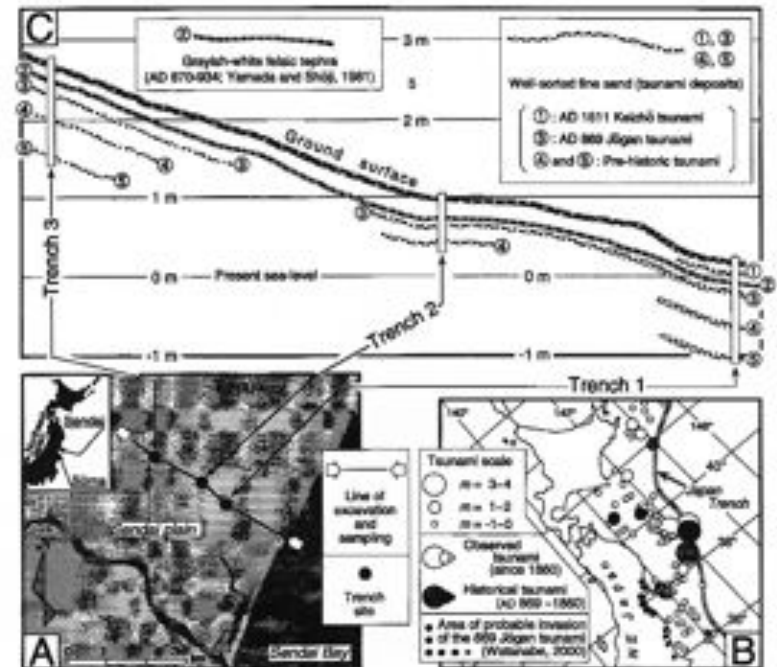


Fig. 1 Stratigraphic section of coastal sequences (C) on the Sendai plain (A). Well-sorted fine sand layers are intercalated in marsh deposits at three horizons. Layer 2 is interpreted as having been developed by the AD 869 Jōgan tsunami. Layer ②. Overlying siltic layers are traceable inland 4.5 km or more from the shore. Historical and observed tsunami (B), which struck the Sendai plain, mostly originated in the region offshore Sendai Bay (Watanabe, 1989).



# Fukushima – **A Human-Caused Disaster**

Unaware of (or suppressing) **Nature's actualities** (the unknown knowns), impressive-appearing, but **assumption-based physical reasoning** (e.g, modeling) was used to deduce (“predict”) an outcome inconsistent with those unknown (**but geologically accessible**) actualities – Resulting in arguably **the most costly** (hundreds of billions of dollars) **“natural” disaster in human history.**

# We learn from nature, not from assumptions!!!

Reasoning in science requires accessing and **making discoveries** about the phenomenon of interest, i.e., **rare, great flooding**---not the making of arbitrary assumptions about things that are **presumed to be beyond any capability to access for study**. We learn nothing when we assume in advance that nothing can be learned.

A truly scientific approach to extreme flooding requires attention to a reverse kind of scaling: **extrapolating downward to rare**, but potentially hazardous (and/or **geologically important**) **floods**, using whatever evidence can be obtained for the **most extreme kinds of flooding phenomena to found in nature**.



# Prediction of Extreme Floods: Science, Engineering, or “Dilettantism” ?

**Predictive models explicate what is already known.** While this is potentially useful as engineering, it is incomplete in regard to being science. Its role in regard to the latter occurs in the **justification of preexisting knowledge**. The more important goal of science is to **generate new understanding**. The comparison of models to data may produce some new insights, **BUT** the inductive logic involved is very limited in regard to that purpose because of the “**under-determination of theory by data**” (Duhem-Quine Thesis).

In order to advance understanding of extreme floods it is essential to have **information** on extreme floods. **Models will not solve this problem. Models do not create real-world flooding; only nature does, and nature does so only rarely.** It follows from this that when nature produces extreme flooding we better pay close attention, both when to it happens and **to the evidence of what happened.**



At the townsite of Aneyoshi the tsunami surge rose to a height of 40 m. But the community had **no loss of life and negligible financial loss.**



The seemingly less elegant scientific understanding of what **nature says to us** as opposed **to what scientists can say about nature** has better prospects in regard to conveying wisdom to our current ("scientifically illiterate") society.

For example: **hazardous Earth processes are best understood in terms of what has actually happened** and therefore involve the sorts of things that actually can happen (**real-word possibilities**)---as opposed to being **unrealistic abstractions** conveyed by experts who make law-based, mathematical predictions of **what "should" happen** (if all the assumptions are absolutely correct—which they most always are not).

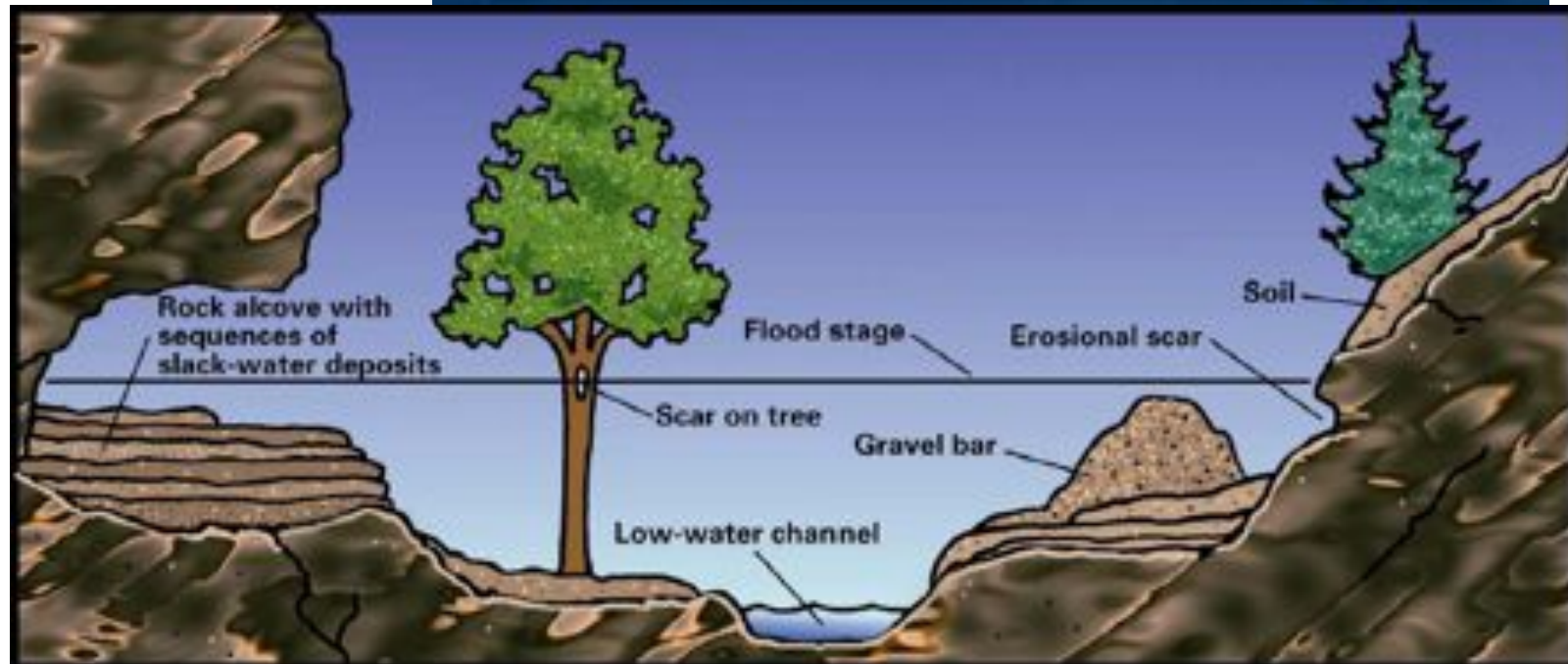
# I listen to floods

I have been doing this as a scientist for more than 50 years. I developed a kind of science for this:

## PALEOFLOOD HYDROLOGY

Look for  
Natural  
SIGNS

Evidence  
of Past  
Floods



## Paleoflood Hydrology

The study of past or ancient floods which occurred prior to the time of (a) direct measurement by modern hydrological procedures, or (b) documentation by other human records (historical floods).

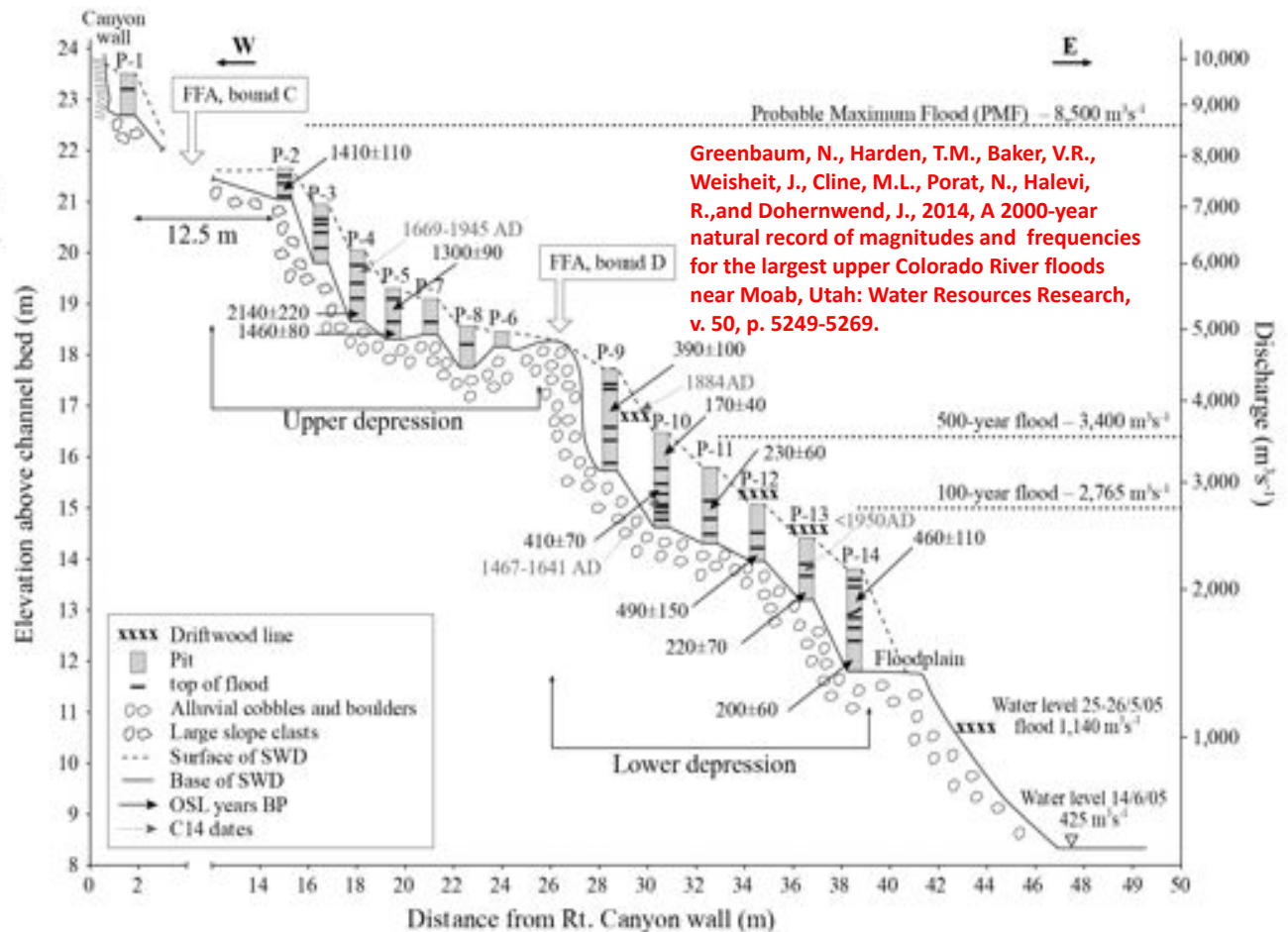




An aerial view of the Fort Calhoun Nuclear Power Plant in eastern Nebraska, surrounded by Missouri River flood waters June 24, 2011.



Though much media and political attention highlights the ongoing drought, a far greater potential for catastrophic disruption of water and energy supply could come **from loss of the Colorado River dams during a major flood**, which almost occurred in 1983 (lower left). Recent paleoflood hydrology results reveal that **the extreme flood risk for the upper Colorado River basin has been greatly underestimated** by the conventional hydrological methods (bottom right).





Recent spectacular global flood damage increases may derive from **extreme flooding that is generally unprecedented in stream gage records**. This is occurring when current foci of “flood hydrology” are (1) flood-frequency analysis (FFA) that **unrealistically extrapolates** from small, common floods to unknown extremes, and (2) calibration of preconceived models to data on small, frequent floods that are **causally unrelated to the extremes of greatest societal relevance**.

Extreme risk assessment involves a probability P that can be defined as the extreme case of concern E divided by the total range of possibilities for the class, R, to which the case belongs. For flooding these factors most commonly get expressed relative to a period of time in years divided by the ranked magnitude of an event in that time range.

$$\text{Extreme Flood Probability} = \frac{\text{Extreme Flood Case (E)}}{\text{Total Range of Extreme Flood Possibilities (R) for the Class to which that Particular Flood Case belongs}}$$



Conventional practice must make assumptions about R in order to determine P, but these **assumptions are untested, and even commonly assumed to be untestable** -- the latter being one of the definitions of what it is to be “unscientific.” Uncertainties get expressed in an **aleatory sense, relying on assumptions about randomness, and informed only by the statistical record of the small common floods.** While this methodology may afford the appearances of quantitative precision, it ignores **the epistemic uncertainty associated with lack of knowledge concerning extremes**, both as to their magnitudes and to their ranges of possibility.

Just because conventional records do not contain evidence of great, rare extremes does not justify the all-too-common assumption that such information does not exist. Yet, this kind of **anti-scientific thinking dominates in much conventional hazards science.**

# Climate Change is Enhancing Extremes

## Extremes of Temperature, Drought, Flooding

**How should we prepare for extreme flooding?**

**Listen to Official Gov't Policy:** FEMA and "100-Year Flood"

This is engineers calculating Flood Probabilities

These numbers are highly UNCERTAIN.

Normal people do not understand Probabilistic Risk Assessment

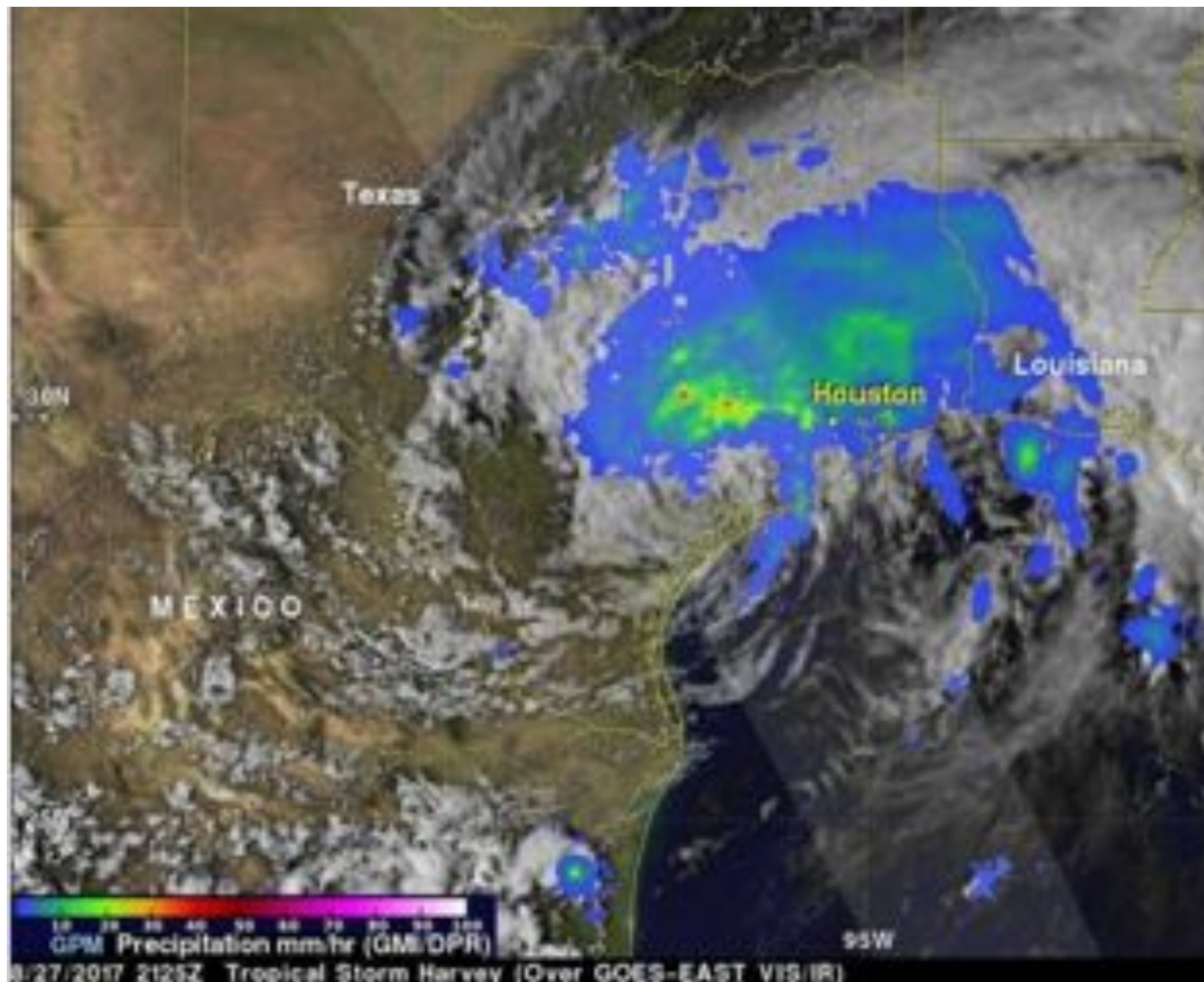
- OR -

**Listen to Nature.** Look to **Natural Signs** of Flooding

Nature provides CERTAINTY:

What has happened can happen. Real Possibilities.



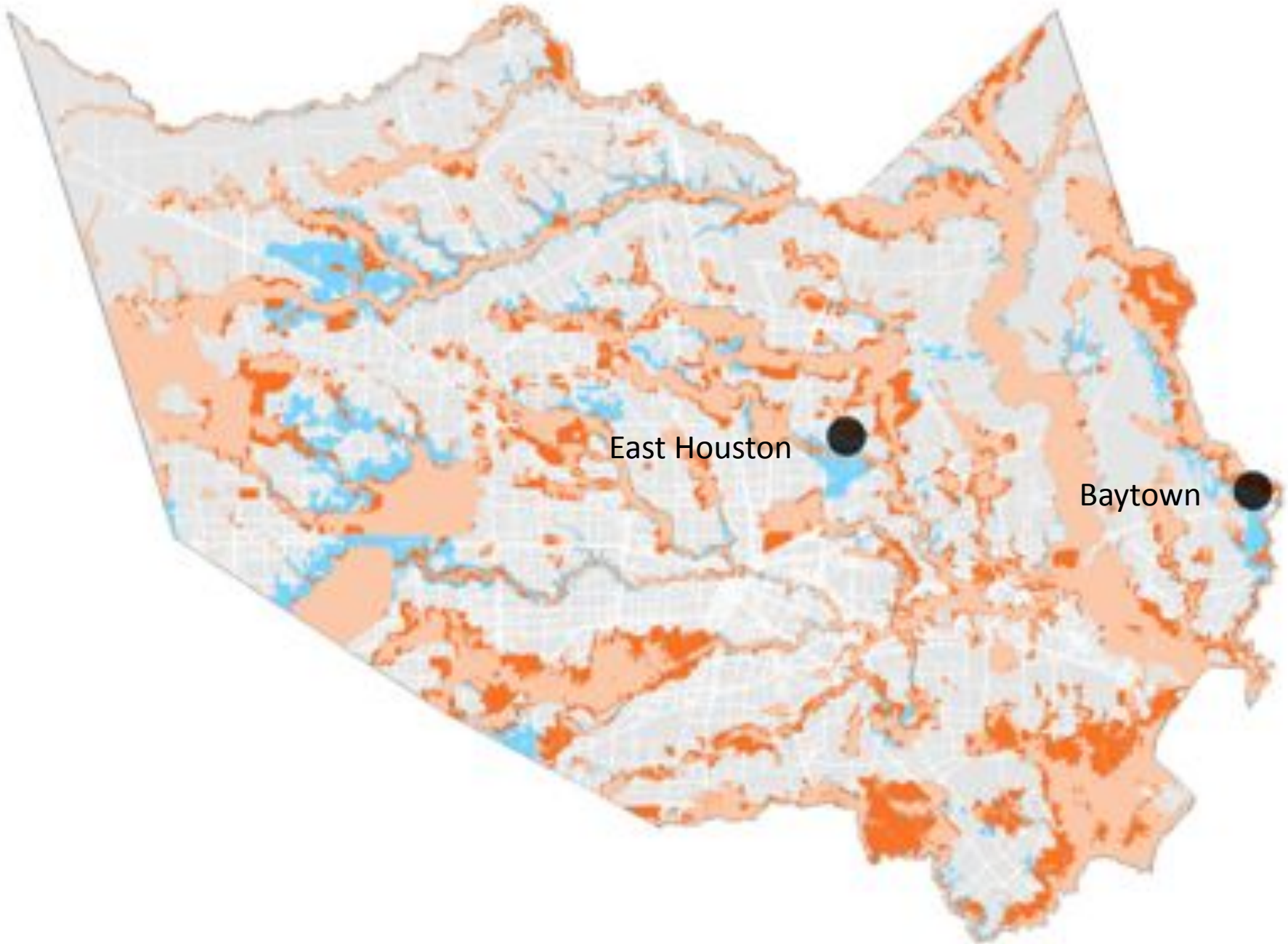


## FEMA flood risk zones

100-YEAR 500-YEAR

## Building Damage

OUTSIDE FLOODPLAINS





## **THE PROBLEM: REDUCING FLOOD IMPACTS**

**PART OF THE ANSWER: STOP FAILING TO COMMUNICATE!**

### **The “hundred-year flood” Concept**

(1) is nearly universally misunderstood by those who must cope with flood hazards, including political leaders, decision-makers, and (most of all) the general public.

(2) defies common-sense understanding of time as duration by equating time to the inverse of an annual exceedance probability--an abstraction that merely has the units of time.

### **Probabilities Instead of Possibilities**

The concept of probability is not understood by a public that is not inclined to read textbooks on statistics and probability theory.

Despite public and political infatuation about **predicting the future**, it is the responsibility of **SCIENCE** to emphasize most emphatically that its role is **NOT TO PROPHECY**, but rather to **Provide Reliable Guidance**. The most reliable guidance for extreme phenomena is **The Absolute Certainty That Can Be Provided By NATURE**, which **neither tells lies nor makes mistakes**. It is up to **HYDROLOGISTS** to reliably **Report What NATURE Tells Us** about hazardous processes. They are therefore enjoined to assume a much greater role in communicating Earth's message.



With one exception, the only certainty about future happenings is that the what we can know about them is absolutely and irreducibly UNCERTAIN. That exception is this **Real Possibility**:

**WHAT HAS  
HAPPENED  
CAN HAPPEN**

## A PERVASIVE FAILURE TO COMMUNICATE

The “Hundred-Year Flood” concept combines a Fake Concept of Time (“Hundred-Year”) with a Fake Concept of a “Flood” to yield an idealized construct that only has meaning to those few who fully understand the definitions of the respective fake concepts.

### “Hundred-Year” Flood

#### *A Doubly Fallacious Concept*

It has nothing to do with *real* years

It has very little to do with *real* floods

It has everything to do with highly dubious *assumptions* about reality





PFH is most effective in producing **records of the most extreme floods** – exactly those phenomena that are commonly either missed or poorly measured by conventional hydrological stream gaging. PFH produces extreme flood data records that extend back thousands of years, and it also provides for the objective quantification for subjective historical observations made by humans before the advent of modern hydrological measurements.

