Delta Risk Management Strategy

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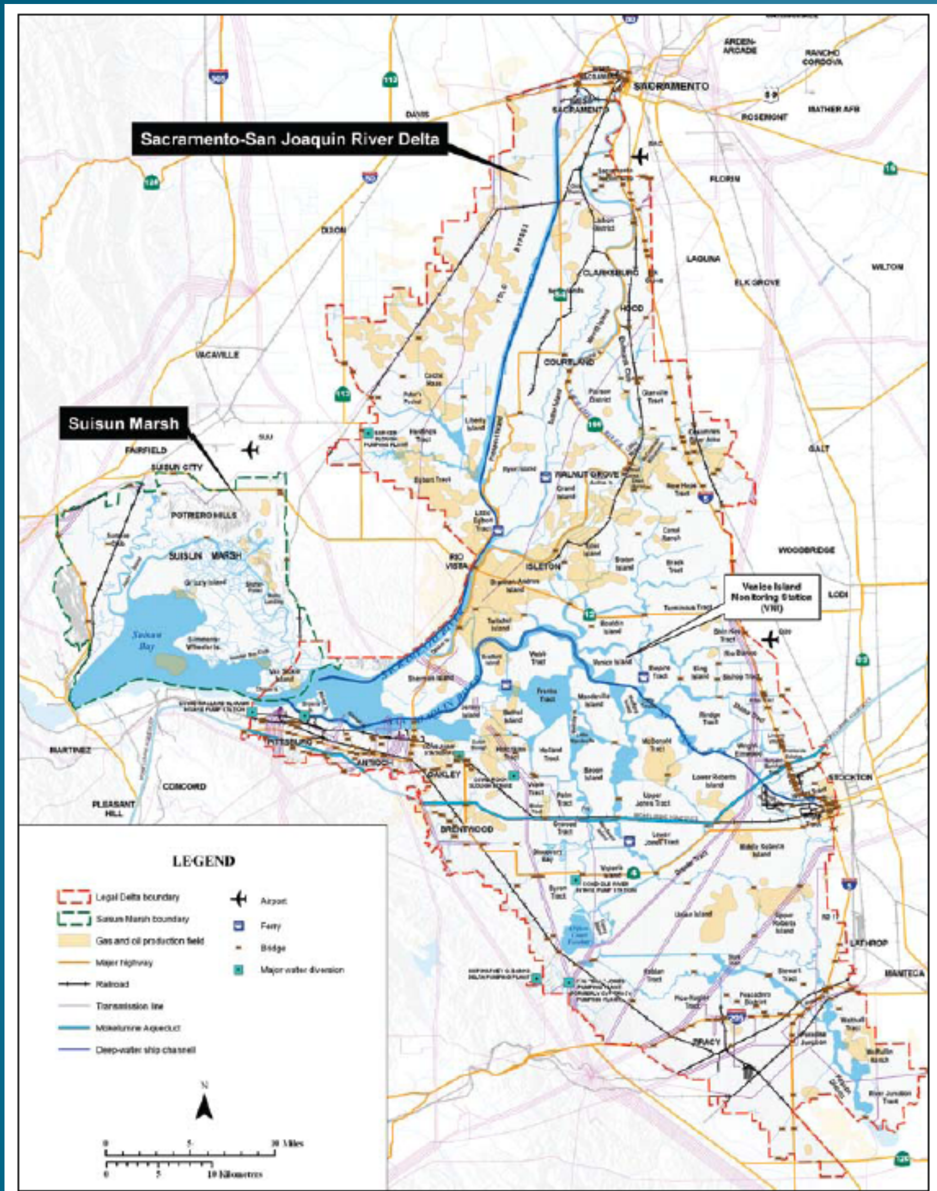
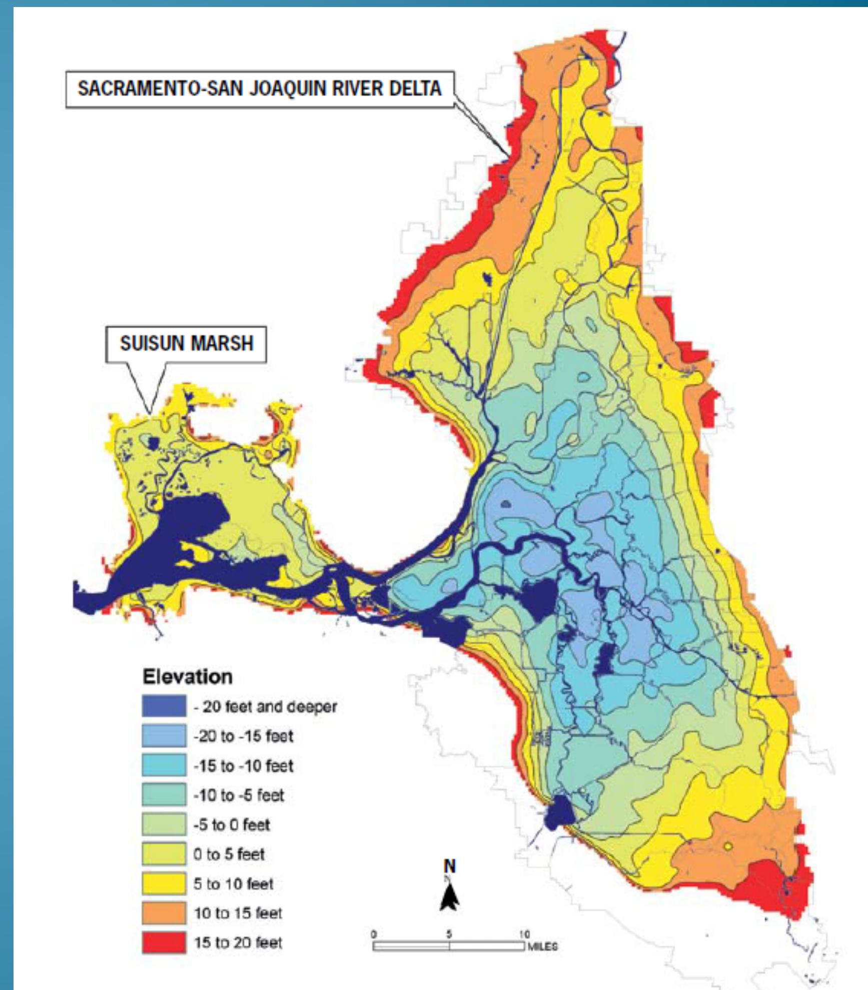
http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf
Accessed: 11/29 @ 3 pm





http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf
Accessed: 11/29 @ 3 pm

- Sacramento-San Joaquin River Delta, including the Suisun Marsh, is one of California's most important natural resources
- Waterways and islands that define the Delta and Suisun Marsh are maintained by levees
- Levees are at risk of failing due to earthquakes and winter storms
- Levee failures and flooding may cause: fatalities, destruction of property and infrastructure, interruption of a large portion of California's water supply, environmental damage, and economic impacts

http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf
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Importance of Delta Region

- Largest estuary in western United States
- Hub of California's water supply system
  - -critical to state's economy
  - -provides water for 25 million people and 3 million acres of farmland
- Key transportation, transmission, and communication lines cross region
- Recreation and tourism
- Soils support farming industry
- One of the top ten national security threats to the US; one of the top civil engineering infrastructure challenges

http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf
Accessed: 11/29 @ 3 pm

Evaluation of Levee Failure Risks – Delta Risk Management Strategy (DRMS) Project

•Divided into two phases

-Phase 1 – analyses risks to levees and the local and statewide consequences of levee failure

-Phase 2 – identifies and analyzes measures to reduce the risks and consequences of levee failure

•Evaluates the potential impacts on water supplies on 50-, 100-, and 200-year projections

•Results will be used to inform decisions to maintain and improve levees and protect the region

•Our focus: Phase 1

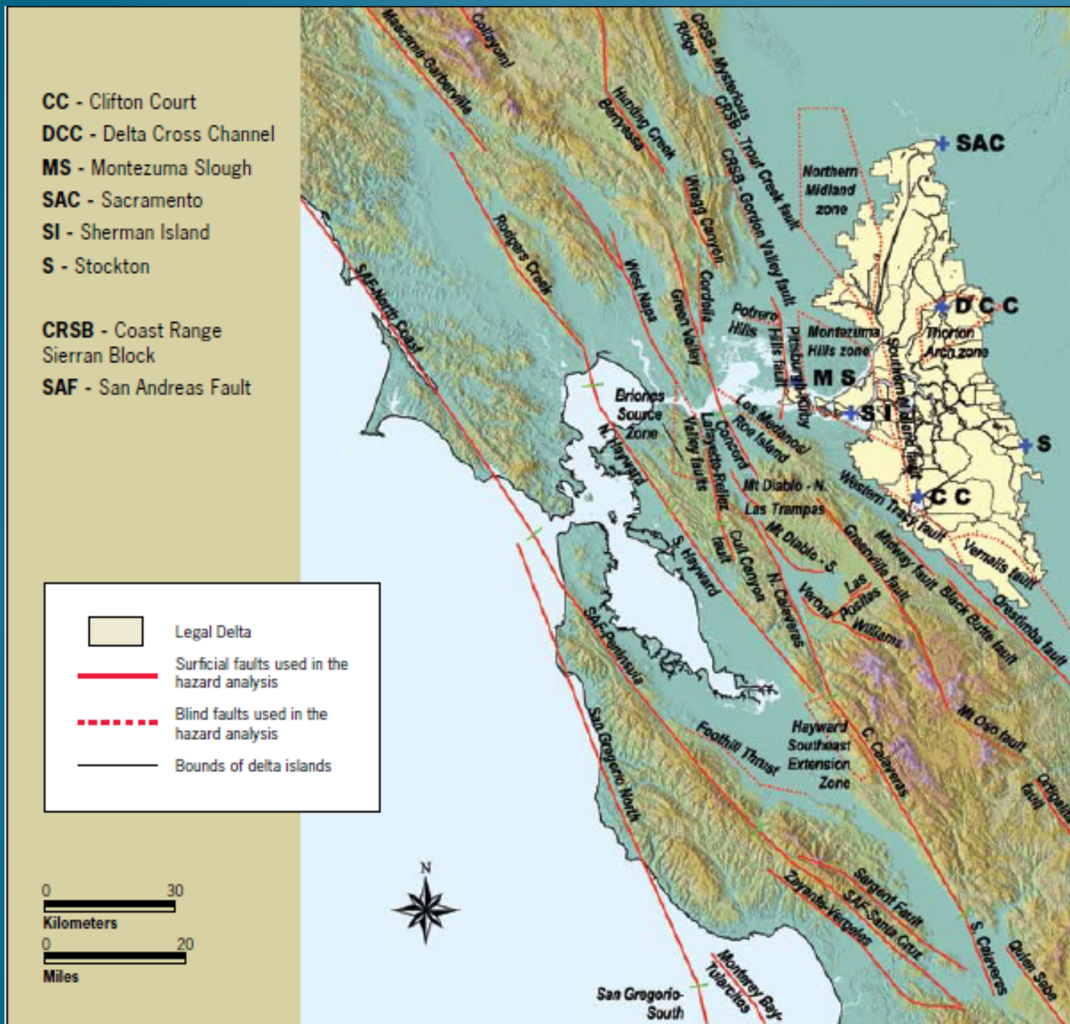
•Phase 2 not available

Phase 1

- Considers current and future risks of levee failures from earthquakes, high water conditions (storms and tides), climate change, subsidence, dry-weather events, and a combination of these factors
- Estimates consequences of levee failures to the local and state economy, public health and safety, and the environment
- Main objective: determine whether current management practices can sustain the Delta Region over the next 100 years

Phase 1 (cont.)

- Conclusion: Delta Region is unsustainable under existing practices
  - Seismic risk, high water conditions, sea level rise, and land subsidence threaten levee integrity
  - A seismic event is the single greatest risk to levees

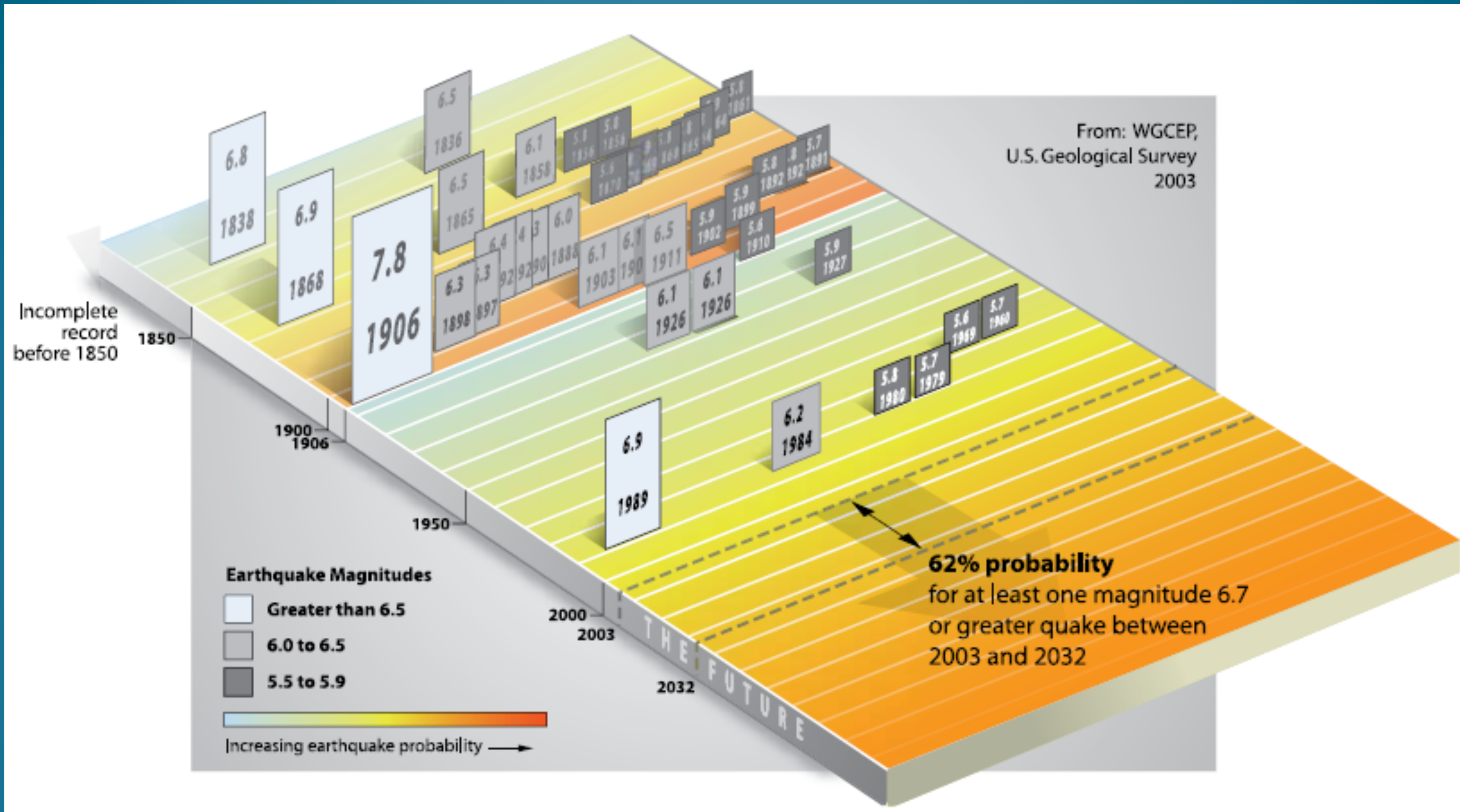


Our Focus : Analysis of Seismic Risks

http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf
Accessed : 11/30 @ 12 pm

Earthquake Risks to Delta Region

- A major earthquake of magnitude 6.7 or greater has a 62% probability of occurring in the Delta Region between 2003 and 2032
  - Could cause multiple levee failures, fatalities, property damage, and adverse economic impacts of $15 billion
  - If it occurs during low-to-moderate fresh water inflow to the Delta, saline water would move upstream into the Delta from Suisun Bay



Past and future earthquakes in the San Francisco Bay Area and the Delta Region

http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf
Accessed 11/30 @ 12 pm

Earthquake Risks (cont.)

- Damage to levees and islands could take years to repair following a major earthquake
  - Water supply losses of up to 8 million acre-feet would be incurred by State and federal water contractors and local water districts
- Levees most likely to fail due to earthquakes are located in the central-west area of the Delta
  - Their failure will cause rapid flooding and leave little time for evacuation

Projections

- If nothing is done and if a major earthquake does not occur in the region before 2050:
  - risk of levee failure in the Delta due to an earthquake will increase by 35% over the next 50 years and by 93% over the next 100 years
  - economic losses will increase by about 200% by 2050 and by about 500% by 2100
  - risk of fatalities may increase by about 250% from 2005 to 2050

Delta Risk Management Strategy (DRMS)

Purpose: to evaluate the risks of levee failures in the Delta and Suisun Marsh

Potential Hazards that affect the Delta

Natural disasters
- Earthquakes
- wind waves
- hydrologic events

People-made disasters
- Terrorism
- Highway, rail, boat accidents
- fires

Intrinsic Factors
- erosion or seepage through levee
- Tidal variations
- Animals burrowing

But to initiate levee failure?

Report mainly focuses on

Outline:

Part 1:
Understanding and quantifying the
risk analysis process
Hazards -> Consequences

Part 2:
Understanding the **methodology** for
calculating the undesired outcomes in
terms of probabilities

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Understanding and quantifying the
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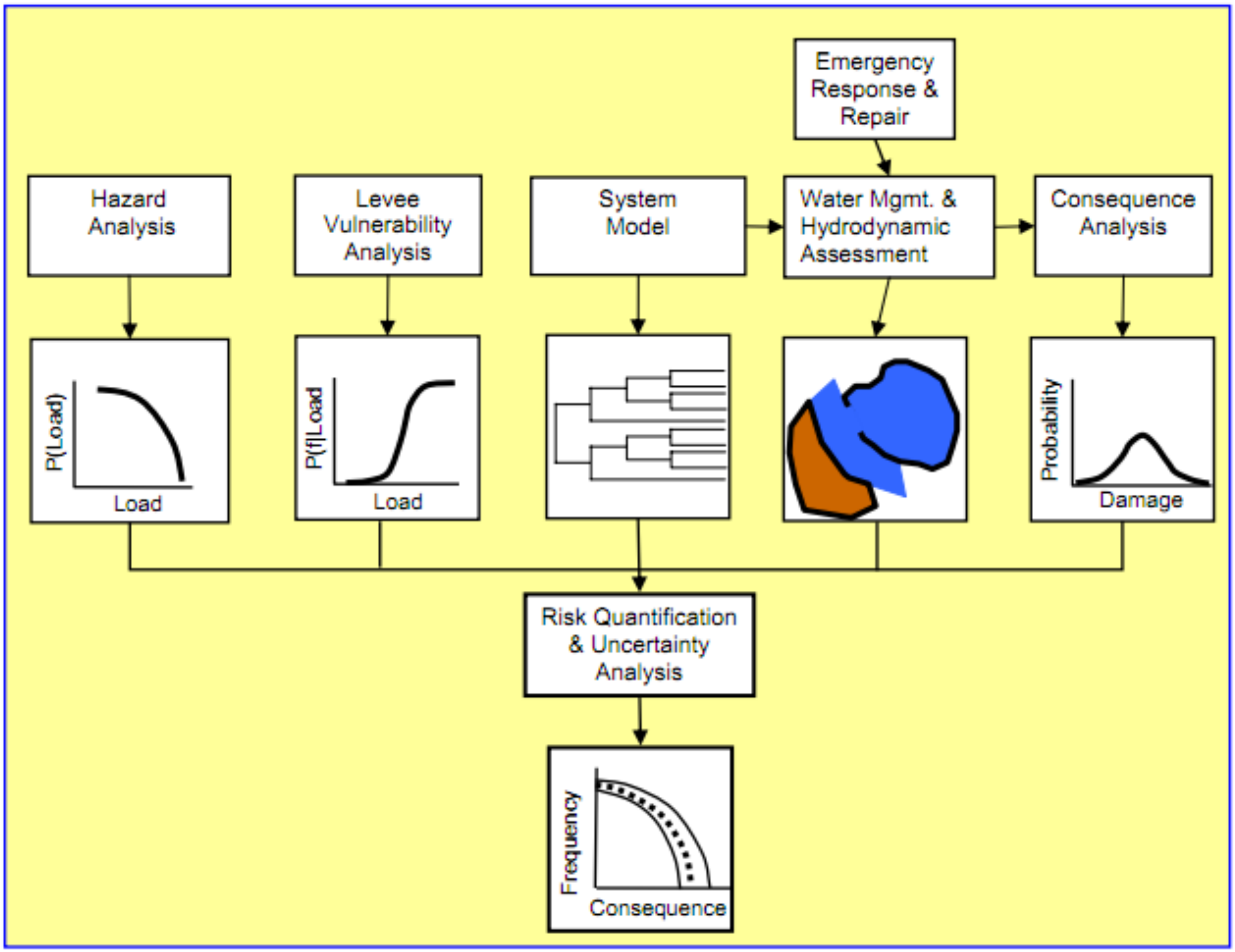

Figure 4-2 **Schematic illustration of the elements of the risk analysis**

Levees

Hazards

Systems

How do we **quantify** all of this?

Hazards

How do we **quantify** all of this?

Hazard analysis assesses the:

- Frequency of occurrence
- Magnitude of hazards (loads)
- Spatial distribution

For seismic events:

hazard is characterized in terms of **peak ground acceleration**

(given an earthquake of specific magnitude and location)

For floods:

hazard is characterized in terms of **peak water surface elevation** at a levee

Levees

How do we **quantify** all of this?

Levee vulnerability analysis

assesses the:

conditional probability of levee breach or damage as f(hazard characterization parameter)

peak ground acceleration for seismic events
peak water-surface elevation for floods

conditional probability of failure or damage
Varies between **0** (low hazard) and **1** (certain failure)

Systems

How do we **quantify** all of this?

Systems model:

- Describes the potential combinations of events
- Sets up framework for calculating frequency of occurrence

focuses on: “state-of-the-Delta” **after an event**

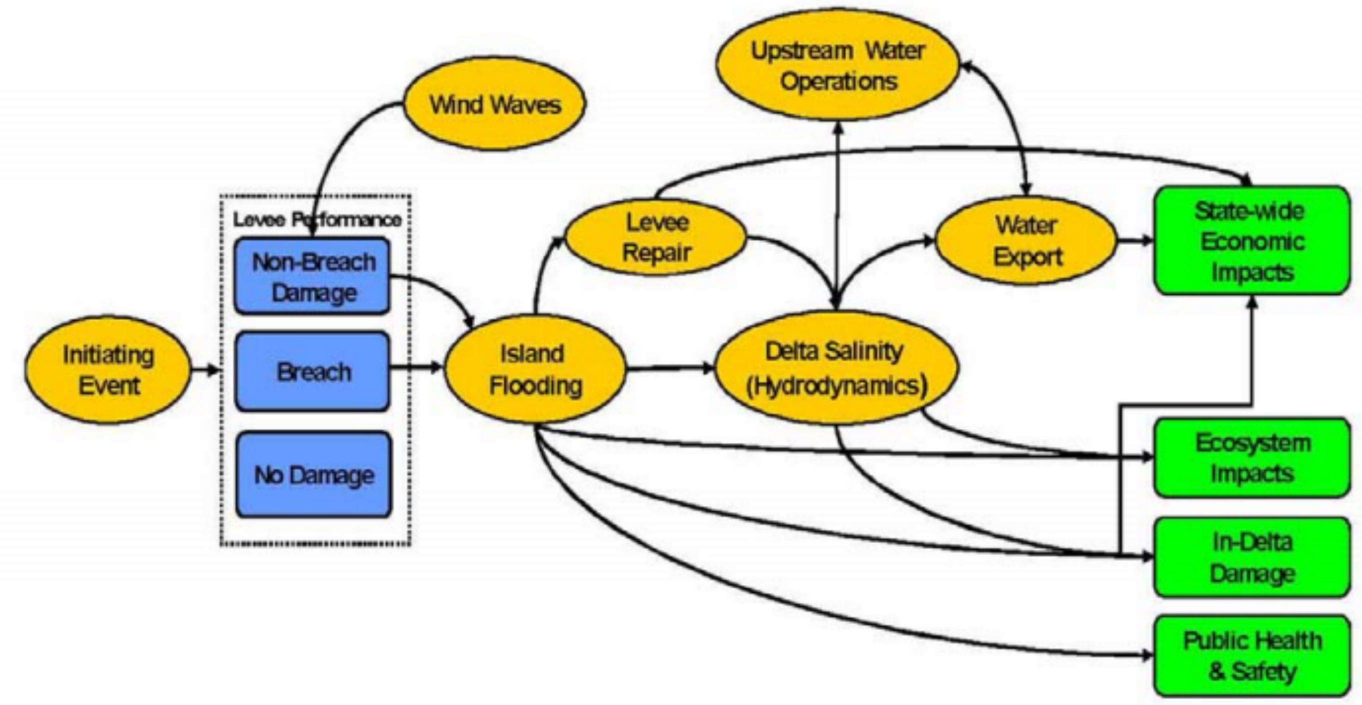

Figure 4-1 Influence diagram illustrating the basic elements of levee performance, repair, and Delta hydrodynamic response after a seismic event

Outline:

Part 1:
Understanding and quantifying the **risk analysis process**
Hazards -> Consequences

Part 2:
Understanding the methodology for calculating the undesired outcomes in terms of probabilities

Methodology

Encompassed in a flow of processes

Risk metrics

Uncertainty

Single site vs event based approach

Present vs future estimations

This is all to obtain **final probabilities** of desired or not outcomes

Encompassed in a flow of processes

Risk metrics

Uncertainty

Single site vs event based approach

Present vs future estimations

This is all to obtain **final probabilities** of desired or not outcomes

Risk metrics:

$\{\nu, C, p\}$

where

ν = frequency of occurrence

C = a consequence metric (e.g., economic cost)

p = probability (measure of the relative degree to which the estimate of ν is the true value)

Encompassed in a flow of processes

Risk metrics

Uncertainty

Single site vs event based approach

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Uncertainty:

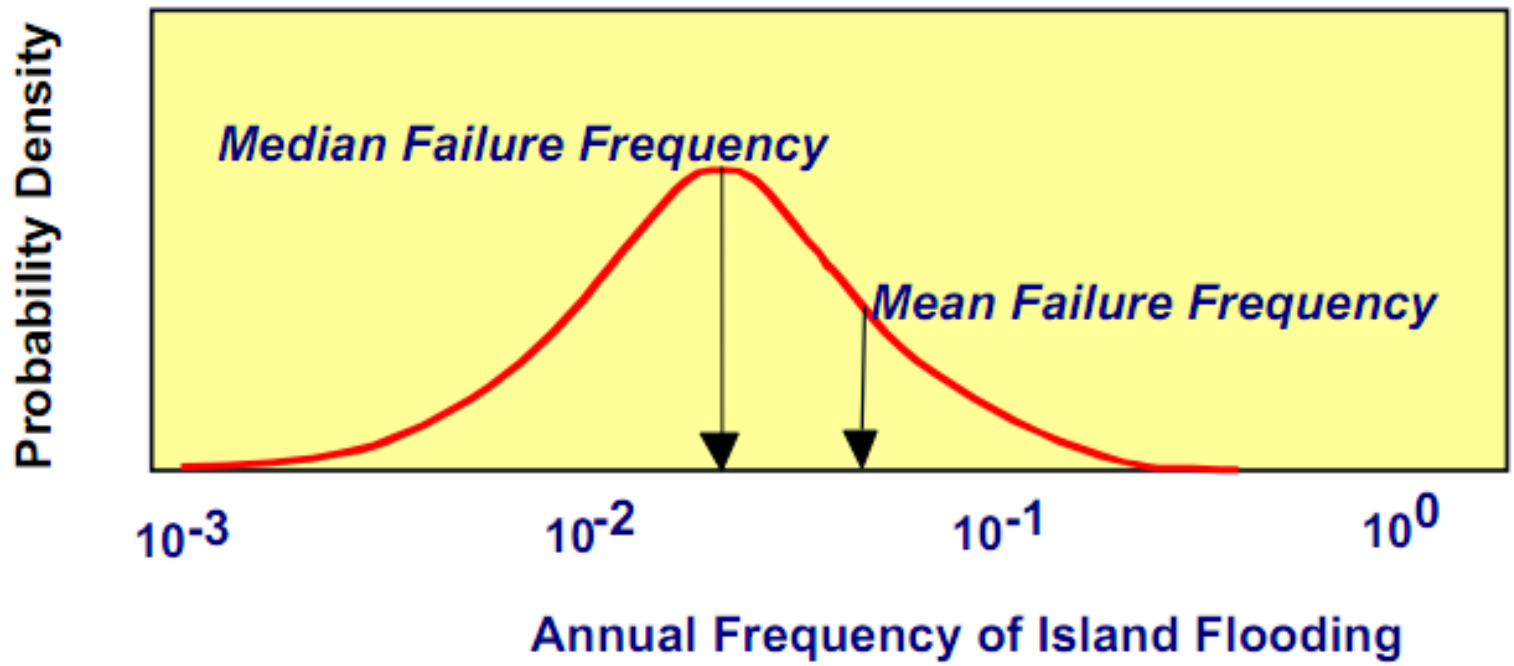


Figure 4-3 Illustration of the epistemic uncertainty in the estimate of the annual frequency of island flooding due to levee failure

Encompassed in a flow of processes

Risk metrics

Uncertainty

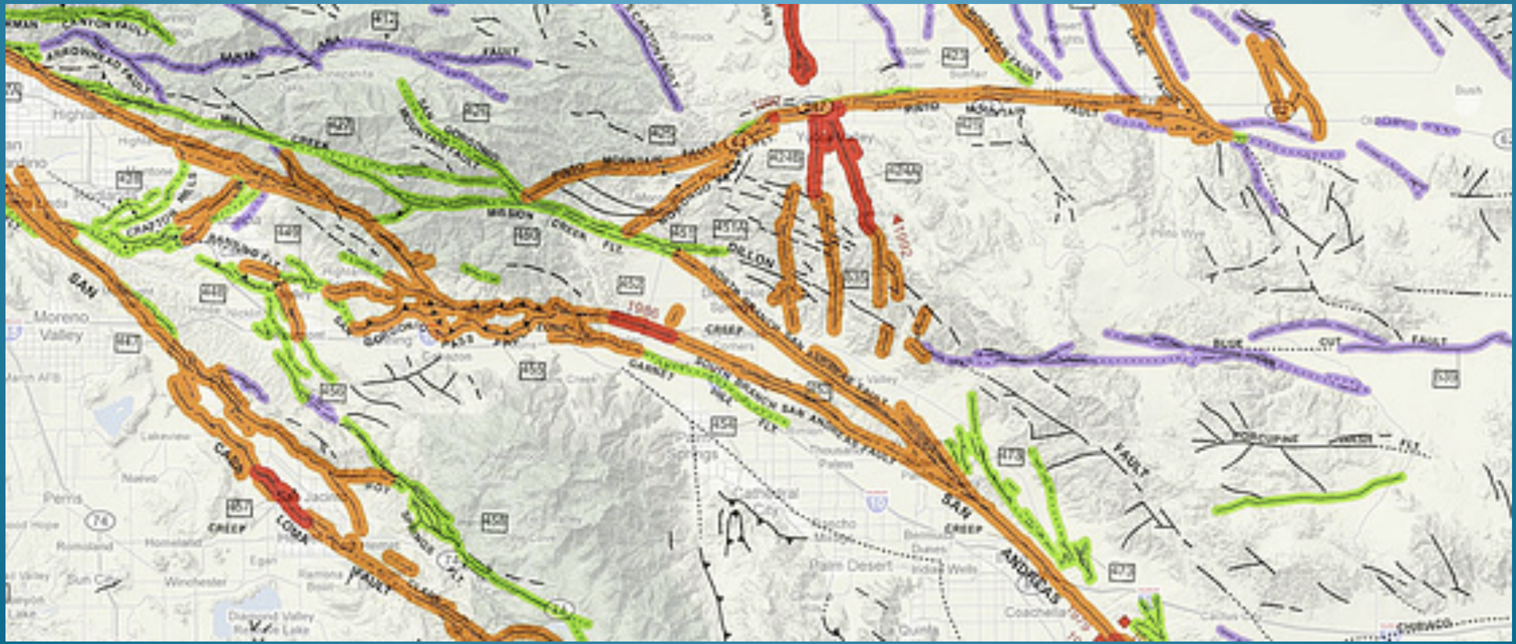
Single site vs event based approach

Present vs future estimations

This is all to obtain **final probabilities** of desired or not outcomes

Single site vs event based approach:

In an “event-based” approach, the performance of the **entire network of levees and islands** are evaluated



http://ronslog.typepad.com/ronslog/2010/04/new-california-seismic-fault-map.html

Encompassed in a flow of processes

Risk metrics

Uncertainty

Single site vs event based approach

Present vs future estimations

This is all to obtain **final probabilities** of desired or not outcomes

Present vs future estimations:

Using the 2005 results as a benchmark,

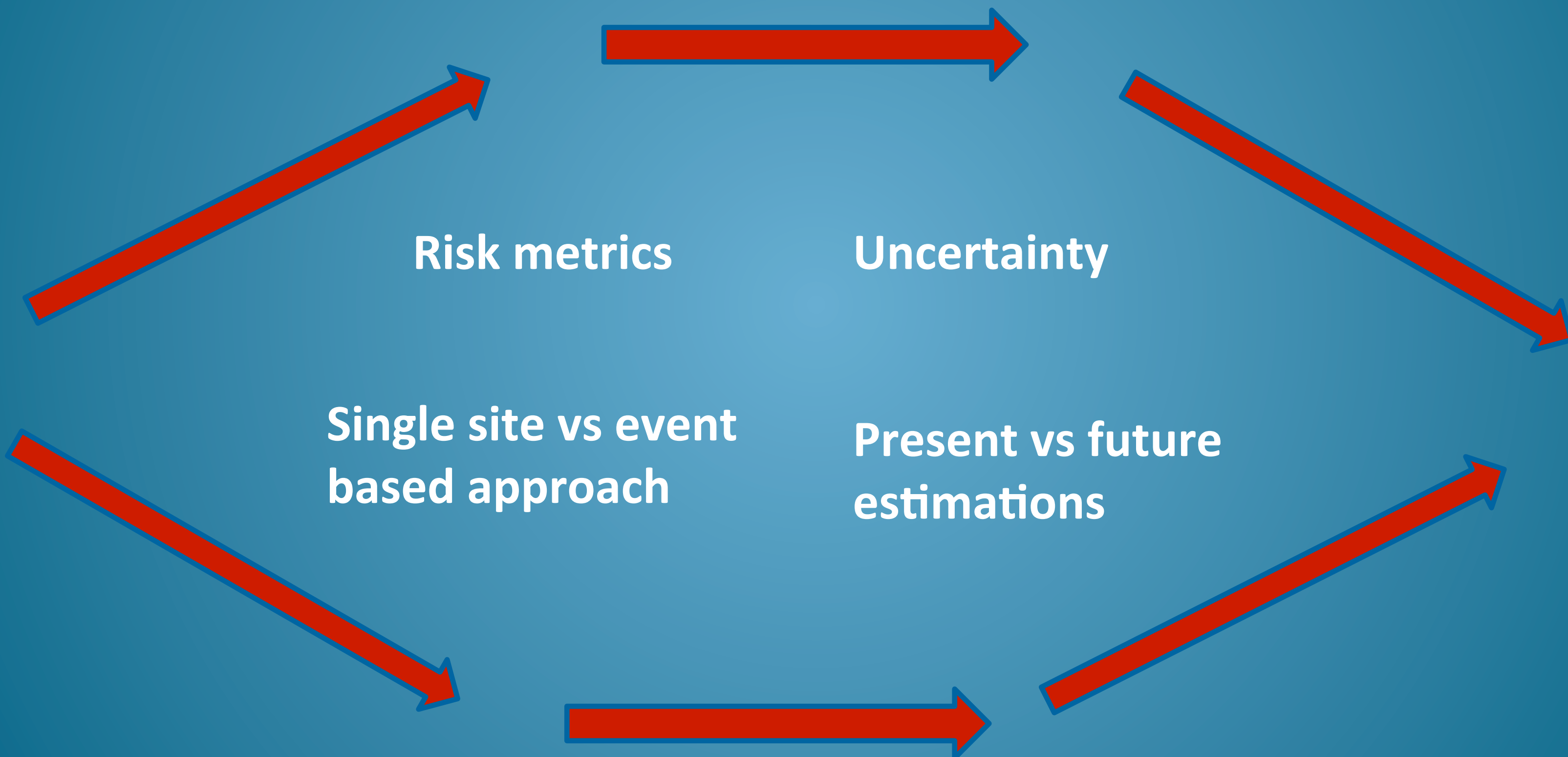
Estimates based on the **percentage change** that is estimated to occur

2005 **Estimated % change** Evaluation year

Table 4-8 Summary of the Information Available to Evaluate Future Hazards and Environmental Factors

		Present	2050	2100	2200
Seismic					
Hydrologic					
Wind					
Normal					
Environmental	Sea-Level Rise				
	Regional Hydrology/Precip				
	Wind				
	Subsidence				

Encompassed in a flow of processes



This is all to obtain **final probabilities** of desired or not outcomes

An event tree is used to model the logical combination of events that lead to outcomes of interest.

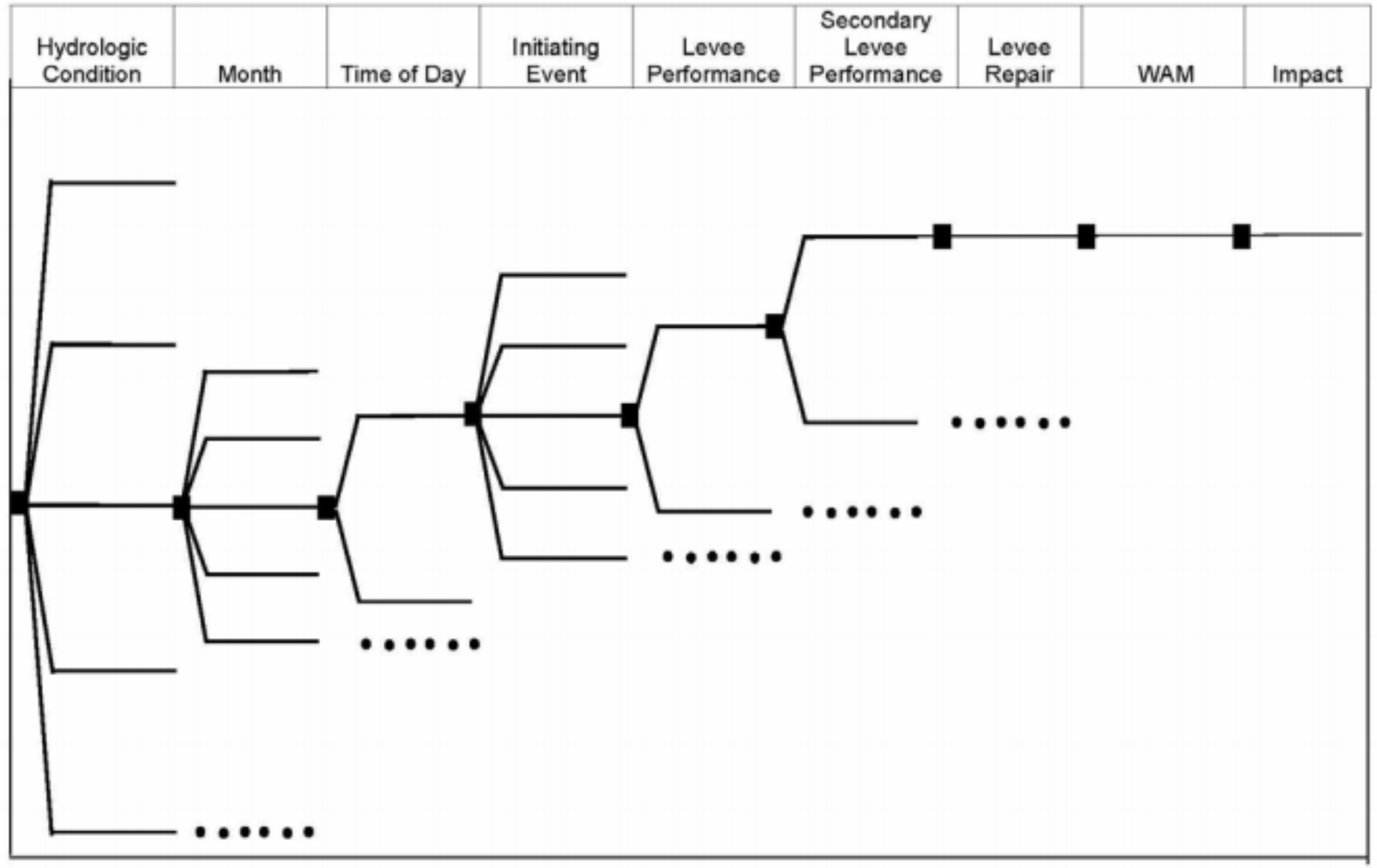
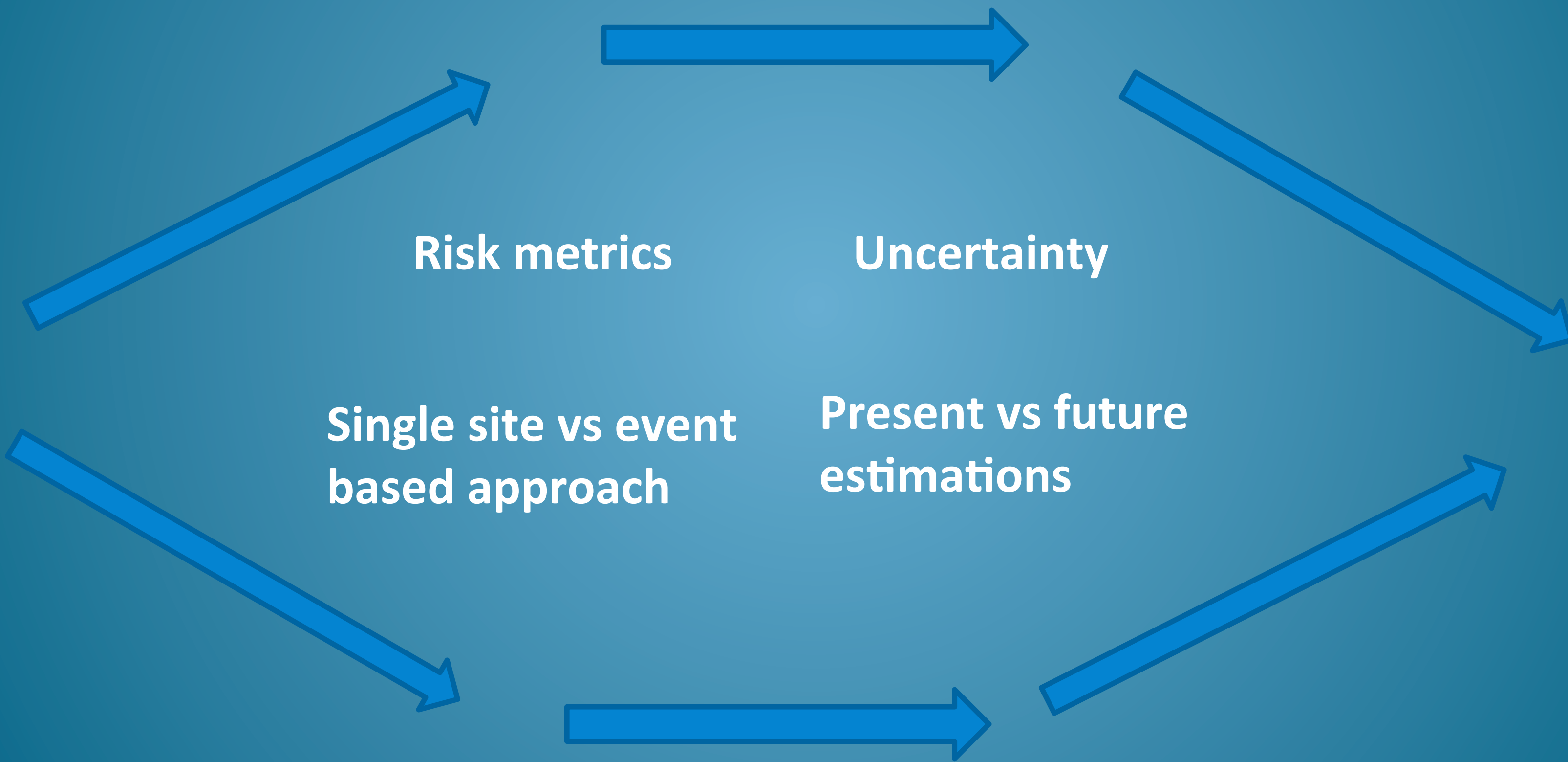


Figure 4-5 Illustration of an event tree used in the system model to organize and assess sequences

Encompassed in a flow of processes



This is all to obtain **final probabilities** of desired or not outcomes

And finally,

Final summed probabilities

{ν,C,p}

where

ν = frequency of occurrence
C = a consequence metric
(e.g., economic cost)
p = probability

$\lambda (C \geq c) = \Sigma\lambda (C \geq c)\ T\ k\ j\ k$
(4-5)
where the sum is carried out for the initiating events considered.

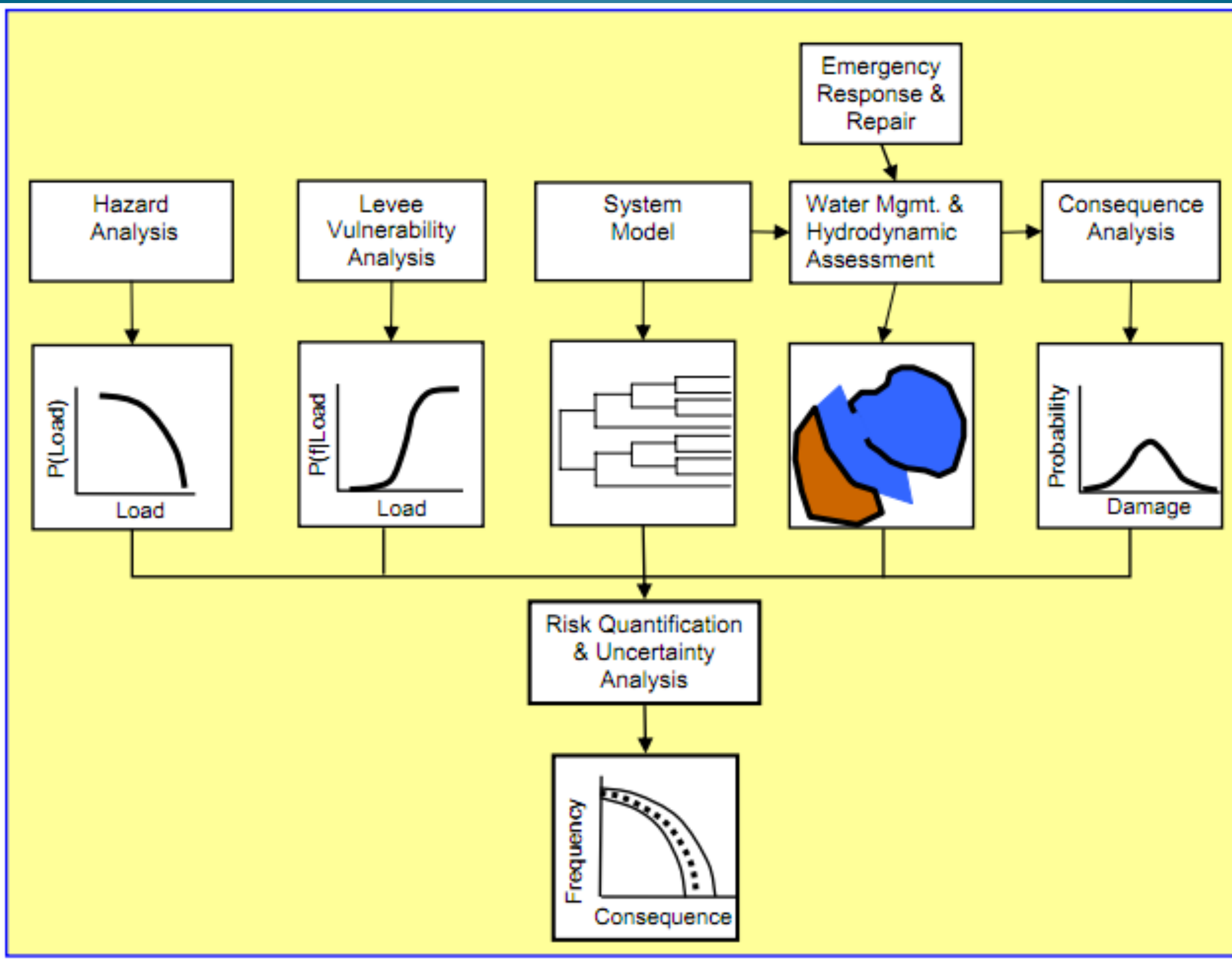


Figure 4-2 Schematic illustration of the elements of the risk analysis

Frequency of Failure of a Single Levee

With the capability to estimate probabilities of various events occurring, an equation can then be created to determine the frequency of failure of a single levee (due to earthquakes on a single fault)

$$\nu_{LeveeReach} = \sum_{m} \nu(m_i) \sum_{r} P(R = r_j \mid m_i) \sum_{a} P(A = a_k \mid m_i, r_j) P(f \mid a_k)$$

$$\nu_{LeveeReach} = \sum_{m} \nu(m_i) \sum_{r} P(R = r_j \mid m_i) \sum_{a} P(A = a_k \mid m_i, r_j) P(f \mid a_k)$$

$\nu(m_i)$ = frequency of occurrence of an earthquake of magnitude m_i

$P(R = r_j \mid m_i)$ = probability that an earthquake occurs a distance r_j from the levee given an earthquake of magnitude m_i.

$P(A = a_k \mid m_i, r_j)$ = probability of ground motions equal to a_k, given an earthquake of magnitude m_i and distance r_j.

$P(f \mid a_k)$ = conditional probability of failure of the levee reach (levee fragility) due to a ground motion of level a_k .

$$\nu_{Levee\,Reach} = \sum_{m} \nu(m_i) \sum_{r} P(R = r_j \mid m_i) \sum_{a} P(A = a_k \mid m_i, r_j) P(f \mid a_k)$$

As previously mentioned, the frequency is determined using the sum of the probabilities of the events on which failure is dependent.

The probabilities build on one another as shown by the conditional statements in the probabilities

ex. $$P(A = a_k \mid m_i, r_j)$$

and the multiplication of these probabilities to form the overall equation

If one or more levee reaches fails, island flooding occurs. Another equation for island flooding which builds off the initial levee failure frequency equation can then be determined.

$$\nu_{IslandFlooding} = \sum_{m} \nu(m_i) \sum_{z} P(Z = z \mid m_i) \sum_{a} P(a(\underline{x}) \mid m_i, z) P(F \mid a(\underline{x}))$$

F = denotes the event that one or more levee reaches fail given an event of magnitude m and a ground motion field, $a(\underline{x})$

$a(\underline{x})$ = spatial field of earthquake ground motions given an earthquake of magnitude m that occurs at a location Z=z on a fault.

$P(a(\underline{x})|m_i, z)$= probability of the ground motion field, given an earthquake of magnitude m_i and that occurs on a fault at a location z.

After the frequencies of levee failure and island flooding are determined, the next step is deciding how to respond to these failures. What is known as the **Levee Emergency Response and Repair Model** is then used. The results of the failure frequency equations along with other data are used to create this model and analysis.

It is from this model that the optimal ways in which the Delta can be made sustainable are determined.

→More accurate frequency of levee failure estimations

→ More accurate island flooding estimations

→More accurate Levee Emergency Response and Repair Model

→Better decisions in how to make Delta sustainable

Assumptions and Limitations

- Analysis cannot completely capture reality of the delta for several reasons:
  - Many holes in data because geographical area is too large to be perfectly accurate
  - Additional surveying and research did not fit into scope of project (in terms of schedule, budget, resources)
  - Assumptions had to be made to complete analysis

Models Based on Historical Data

- Topographic and bathymetric base maps are supposed to be of first order importance but were not updated
- Common problem with complex systems
- Instead, relied on existing historical data
- Engineering judgment for assumptions and extrapolation to fill in data gaps

Predicting risks over 200 years

- Introduce error in forecasting:
  - Account for changing ecosystem, population growth, and economy but each of these factors has some error associated with it
- Models can be used to predict, but these models can't take into account all the factors accurately

Generalizations of Levee Characteristics

- Each levee has its own individual characteristics (such as the state and quality) but generalized characteristics had to be made in order to carry out the analysis

Scour depth

- Assumed to be a function of peat thickness
- Island area and peat volume are factors too but are not taken into account in the analysis

CALSIM

- California Department of Water Resources' simulation model for large systems
- Trends in data continued in simulation when they may not have actually occurred
- Included less than half of the 125 potential 3-year sequences of water years

Material Liquefaction Simulation

- Foundation and fill material were simulated to liquefy
- Simulation only accounted for absolutes, leading to four possible outcomes
  – Both completely liquefied
  – Foundation liquefied
  – Fill liquefied
  – Neither liquefied
- Did not take into account partial liquefaction

Conclusion

- While the analysis in general is a good representation of the delta and its problems, there are many places where errors arise.
- Assumptions in data can alter results.
- Levees should be improved so that the Delta Region will be protected by an up-to-date, safe levee system.
- Urgency: the longer the wait, the higher the risks become, and the greater the dangers become.

References

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