Subsidence of Delta Islands

Delta Vision Stakeholder Coordination Group Meeting

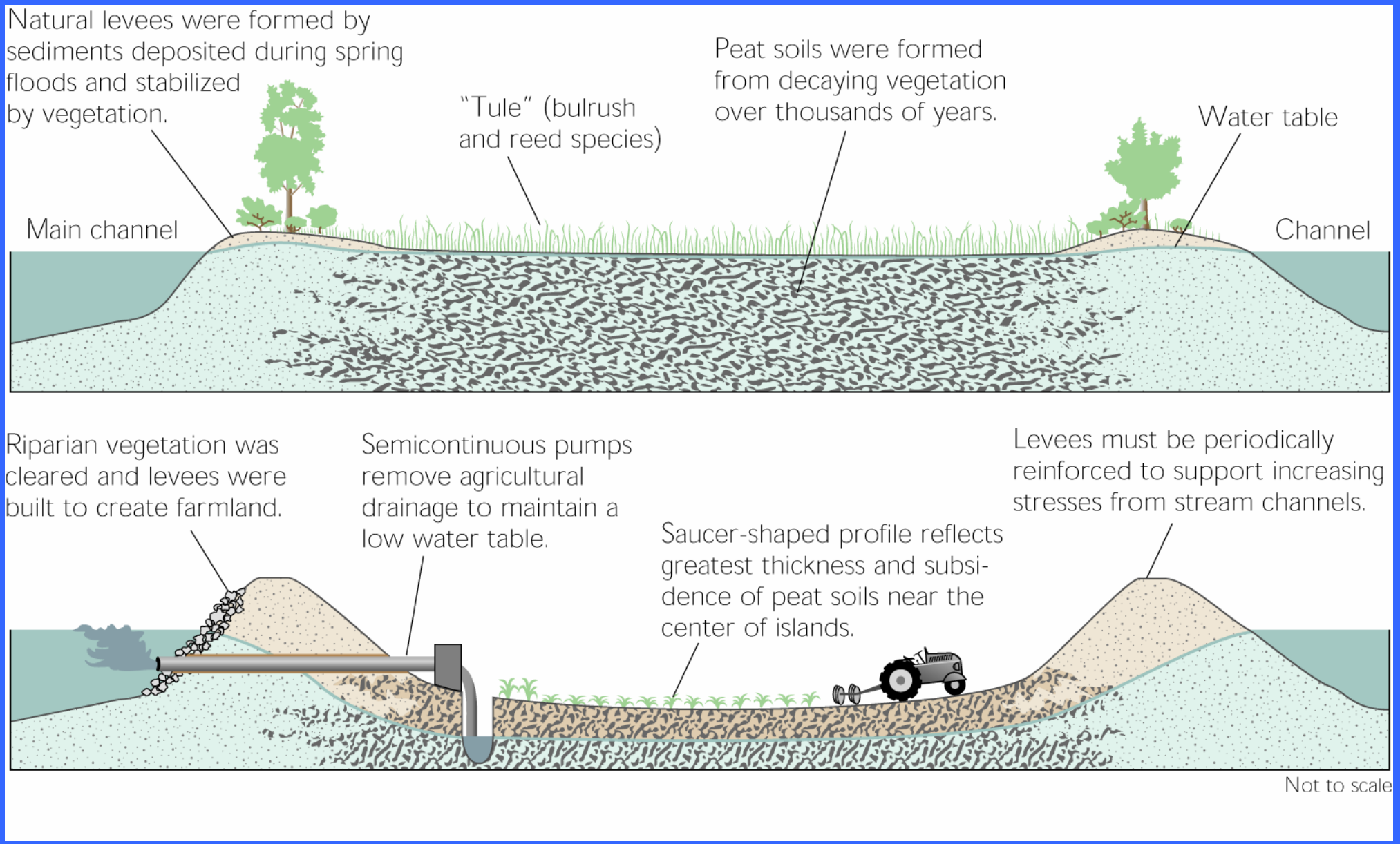
April 3, 2007

Three questions

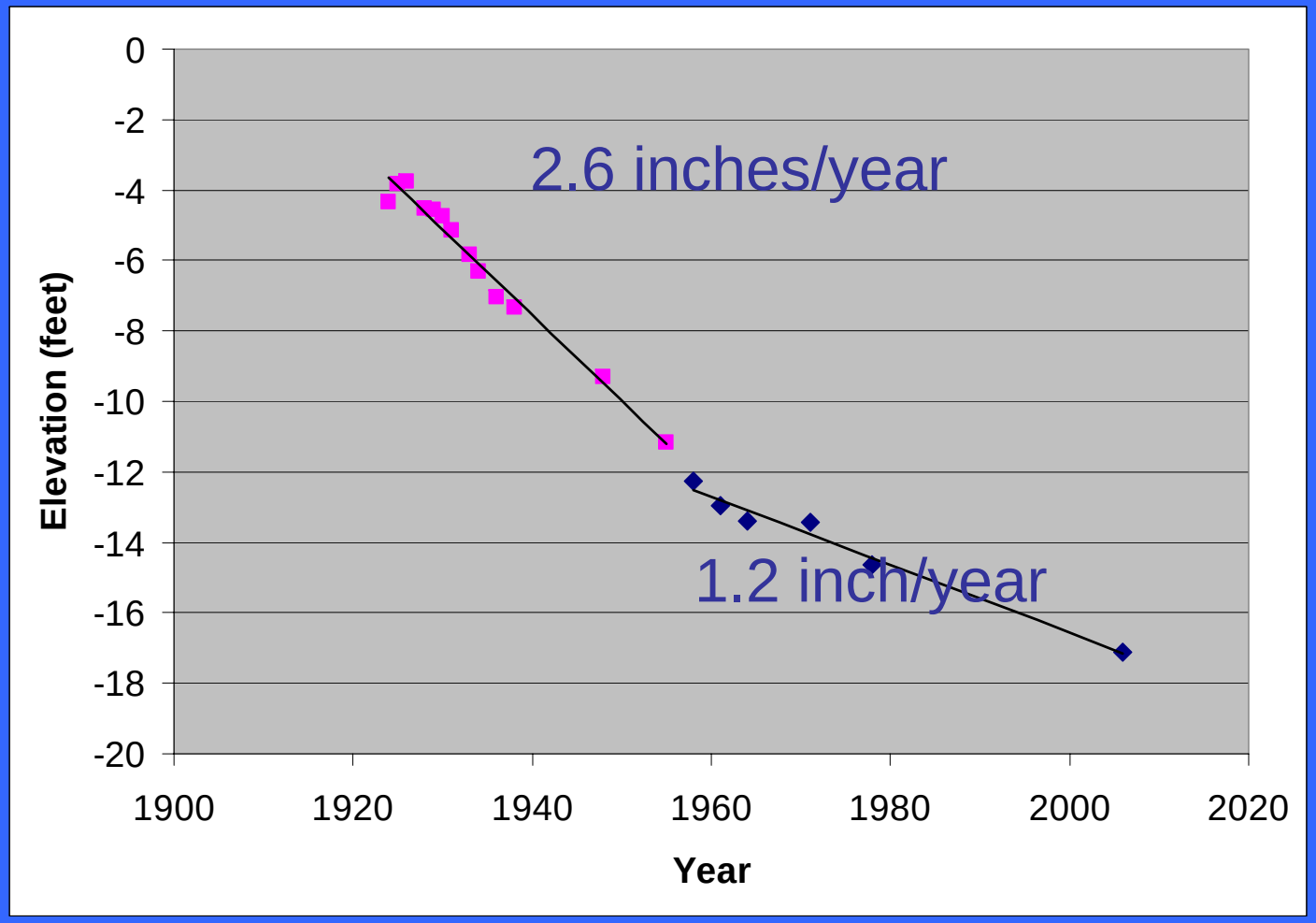
- *What do we know and don't know and what is the scientific basis for this?*
- *What would it take to address what we don't know and can it be available within a year?*
- *How might subsidence impact the planning for the Delta?*

What we know and don't know about Delta subsidence?

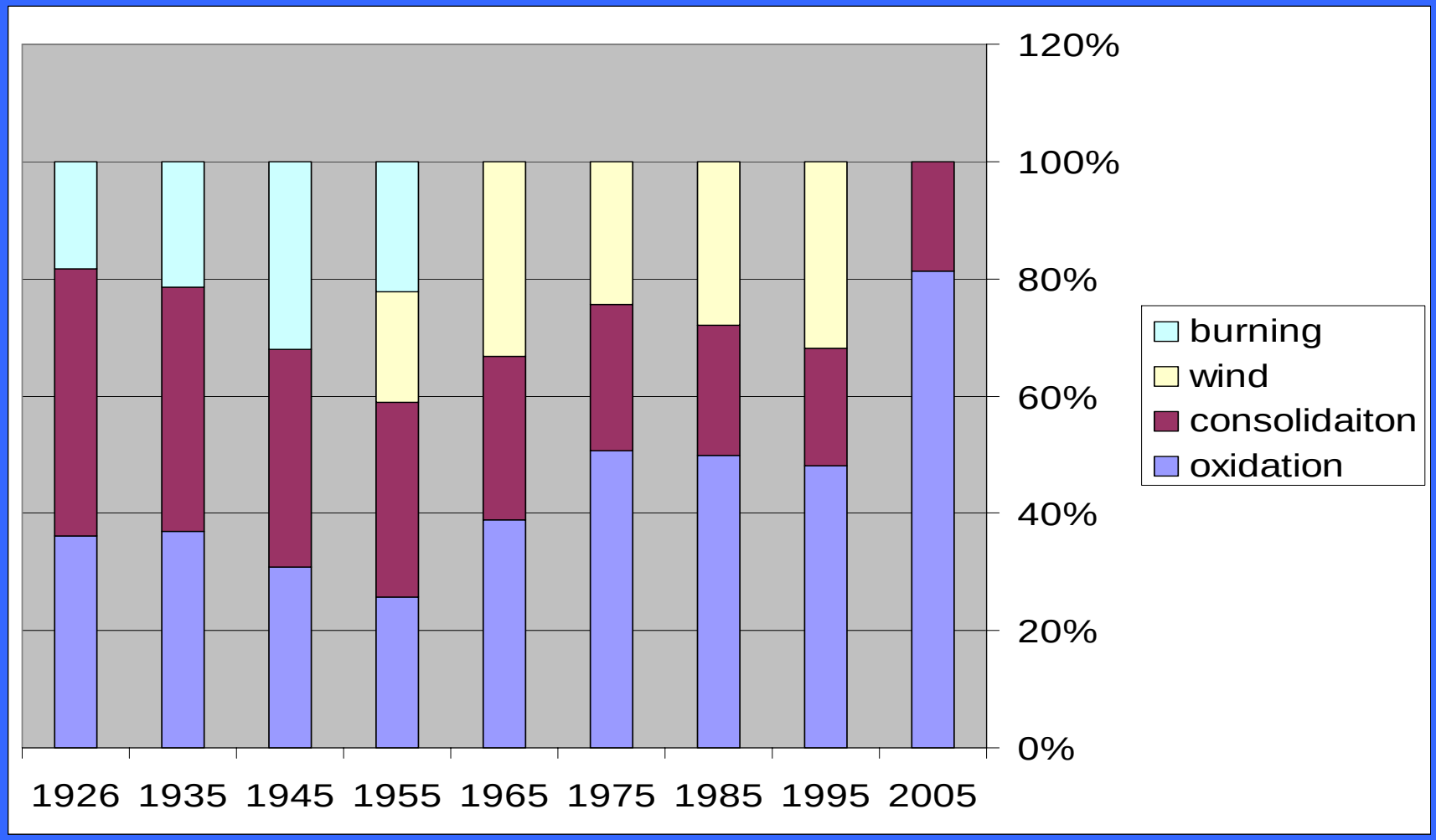
- Microbial oxidation of soil organic matter is the primary cause today,
  - Compaction is a secondary cause.
  - Burning, wind erosion, historically important, not today.
- Subsidence rates proportional to:
  - Amount of soil organic matter,
  - Depth to groundwater,
  - Soil temperature
- Land-surface elevations have declined from near sea level in the late 1800's and early 1900's to over 15 feet below sea level today.
- We have a few data for present-day subsidence rates for organic soils and highly organic mineral soils ~ 0.5 to 1.2 inch per year
  - Rates have slowed over time
- There is little information about distribution of current subsidence rates in the Delta or Suisun Marsh.


Natural levees were formed by sediments deposited during spring floods and stabilized by vegetation.
"Tule" (bulrush and reed species)
Peat soils were formed from decaying vegetation over thousands of years.
Water table
Main channel
Channel
Riparian vegetation was cleared and levees were built to create farmland.
Semicontinuous pumps remove agricultural drainage to maintain a low water table.
Saucer-shaped profile reflects greatest thickness and subsidence of peat soils near the center of islands.
Levees must be periodically reinforced to support increasing stresses from stream channels.
Not to scale

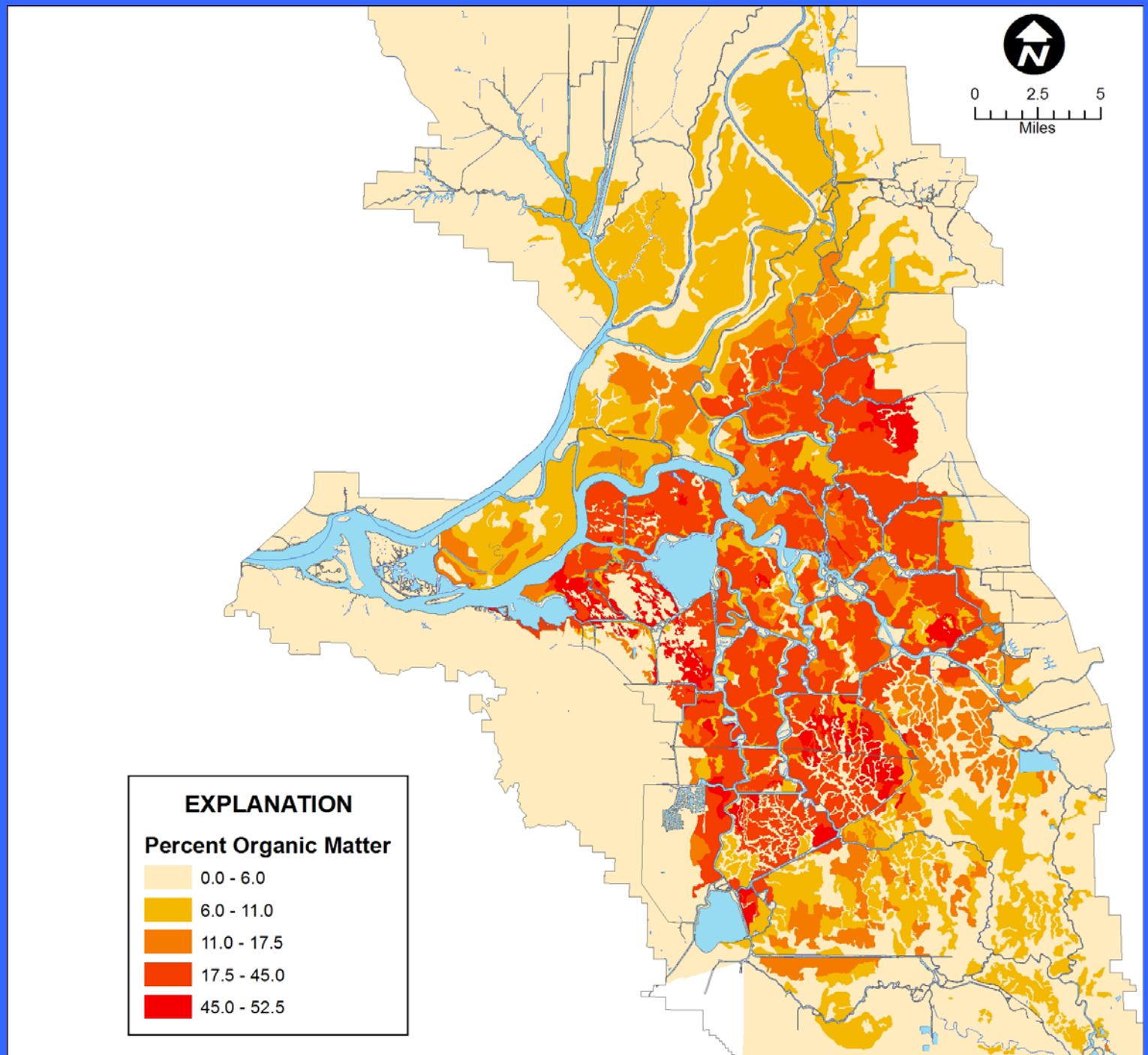
Subsidence example: Bacon Island



CAUSES


120%
100%
80%
60%
40%
20%
0%
1926
1935
1945
1955
1965
1975
1985
1995
2005
burning
wind
consolidaiton
oxidation

Distribution of Soil Organic Matter



Scientific basis for what we know

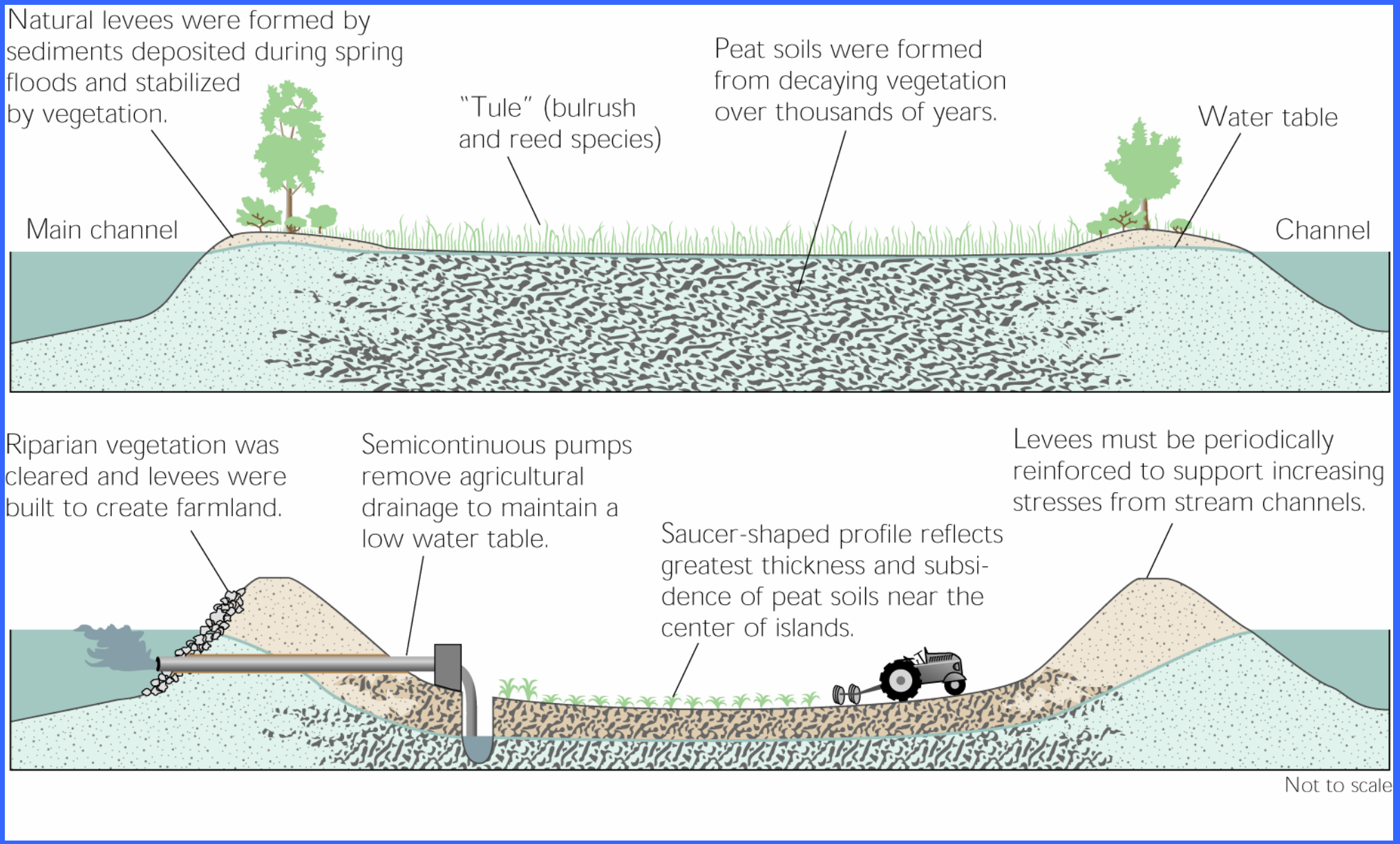
- Summarized in peer-reviewed publications of the USGS, Soil Science Society of America, American Geophysical Union, University of California, Society of Engineering Geologists.
  - Subsidence rates from the 1920”s through 1970’s.
  - Field studies of organic soil subsidence
  - Measurements of oxidation rates
  - Measured effects of temperature.
  - Measured deep subsidence.
- Future subsidence estimates and impacts (Mount and Twiss, 1985, *San Francisco Estuary and Watershed Science*).
- Measurement of recent rates as part of DRMS process.
- Department of Water Resources data collection in 1970’s and 1980’s.
- Research from other subsiding places (e.g. Florida, Netherlands).

What would it take to address what we don't know?

- Current distribution of subsidence rates requires:
  - Measurements of changes in land-surface elevations throughout the Delta during some time interval.
    - Time interval depends on measurements precision and frequency.
    - Affected by groundwater levels and cultivation.
    - One year is not enough.
- We probably know enough about current subsidence rates for regional planning.

Examples of how subsidence might impact planning for the Delta?

- Under current agricultural practices, subsidence will continue until peat disappears.
- Subsidence increases levee instability
  - Increases seepage through and under levees.
  - Hydraulic forces on levees increase
- In event of levee failure and flooding, continuing subsidence increases volume that can fill with flood waters.
  - Water quality degradation due to salt water intrusion.
- Water quality
  - Continuing oxidation and deepening of drainage ditches causes increasing organic carbon loads.
- Limits future land use.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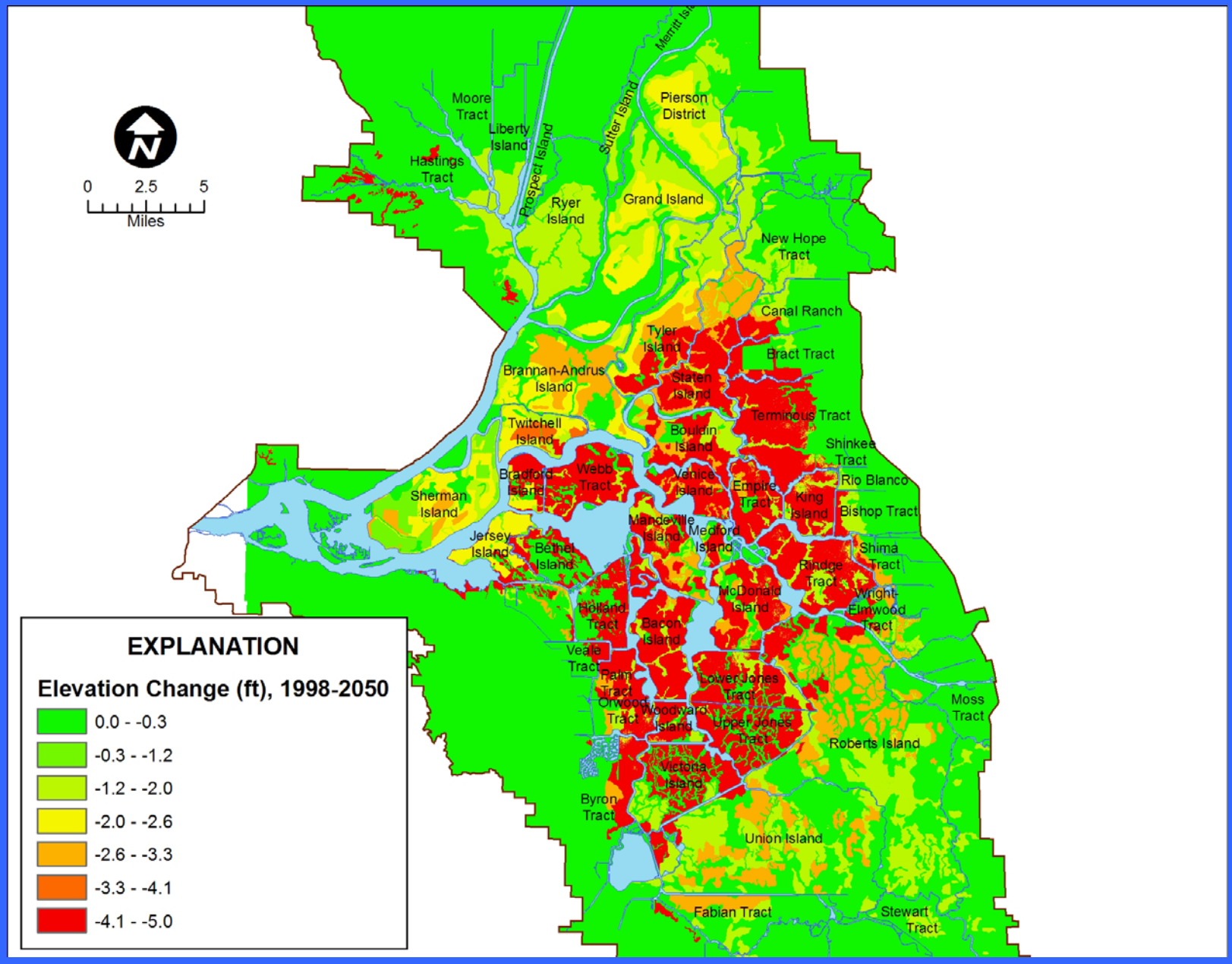
Future Subsidence



Estimated Volume Changes Below Sea Level (Thousand Acre Feet)

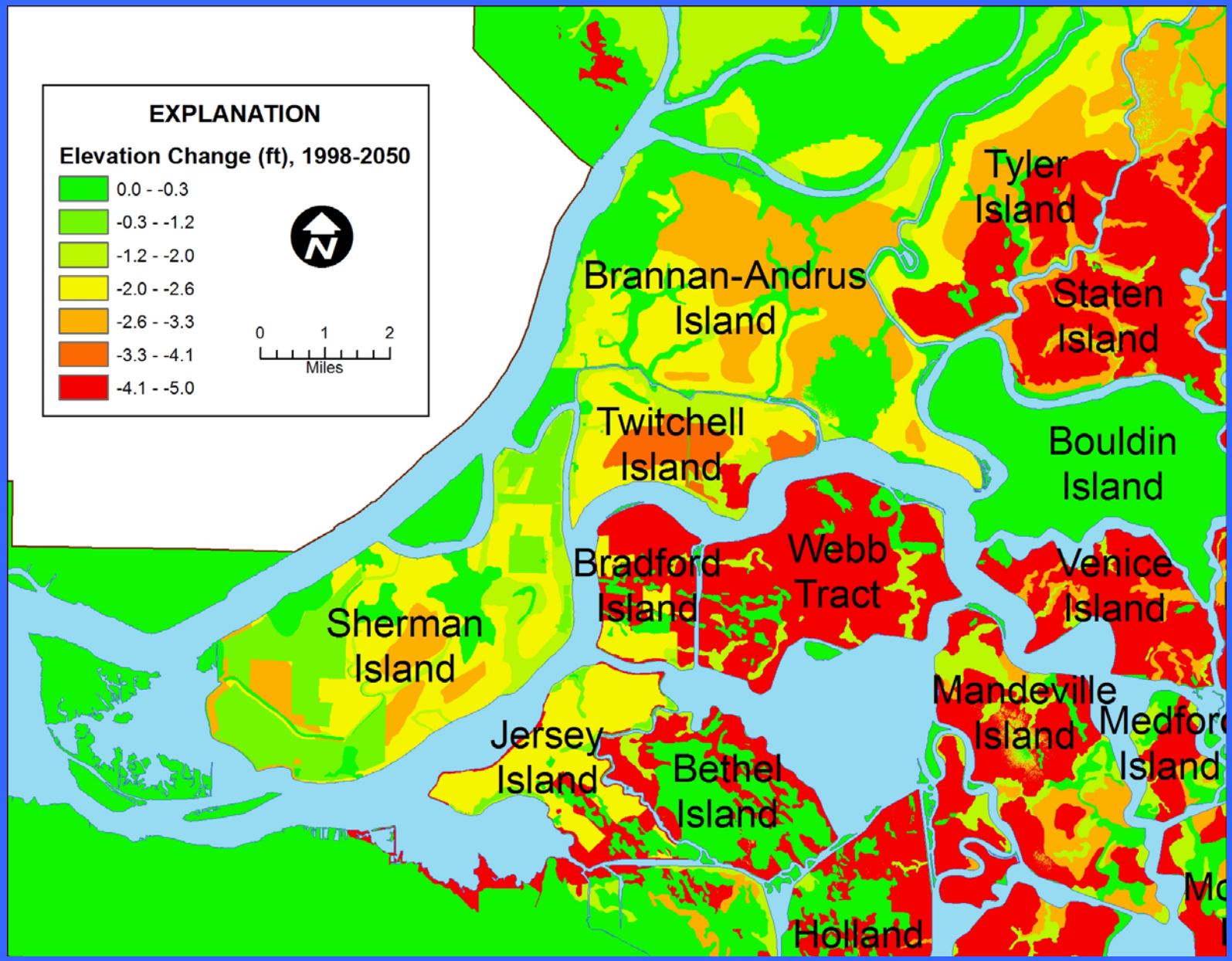
Year	low estimate (5%)	Inter-mediate low (25%) estimate	mean estimate	Inter-mediate high (75%) estimate	high estimate (95%)
2050	396	544	674	768	988
2100	787	1,058	1,307	1,570	1,924

Key points

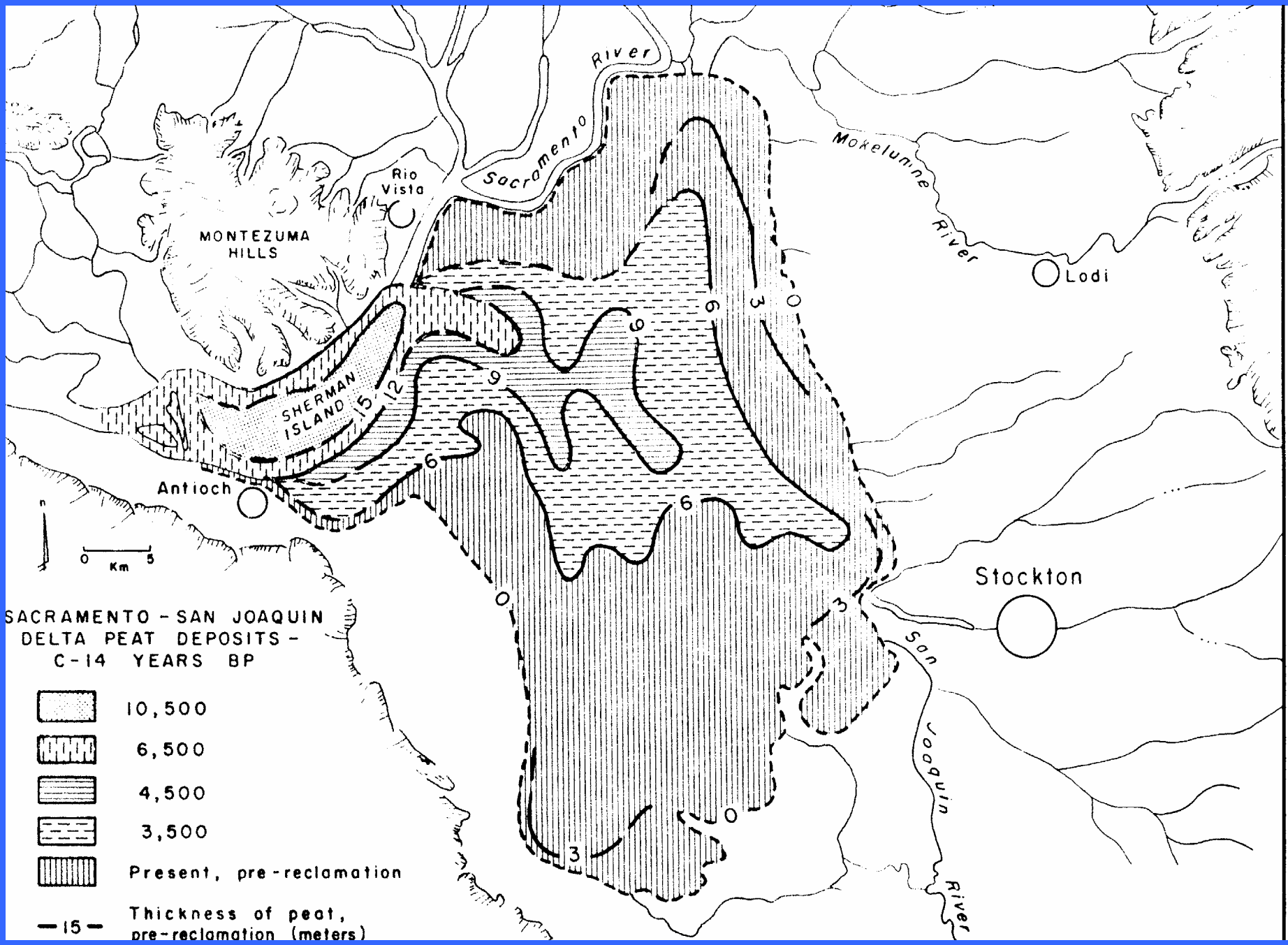
- *What do we know and don't know*
  - *Oxidation is the primary cause*
  - *Rates range from about 0.5 to 1.2 in/year but spatial distribution uncertain*
  - *Subsidence will continue until peat is gone under current practices.*
- *What would it take to address what we don't know and can it be available within a year?*
  - *Distribution of rates can't be determined within a year.*
- *How might subsidence impact the planning for the Delta?*
  - *Levee stability and water quality.*
  - *Limits future land use.*

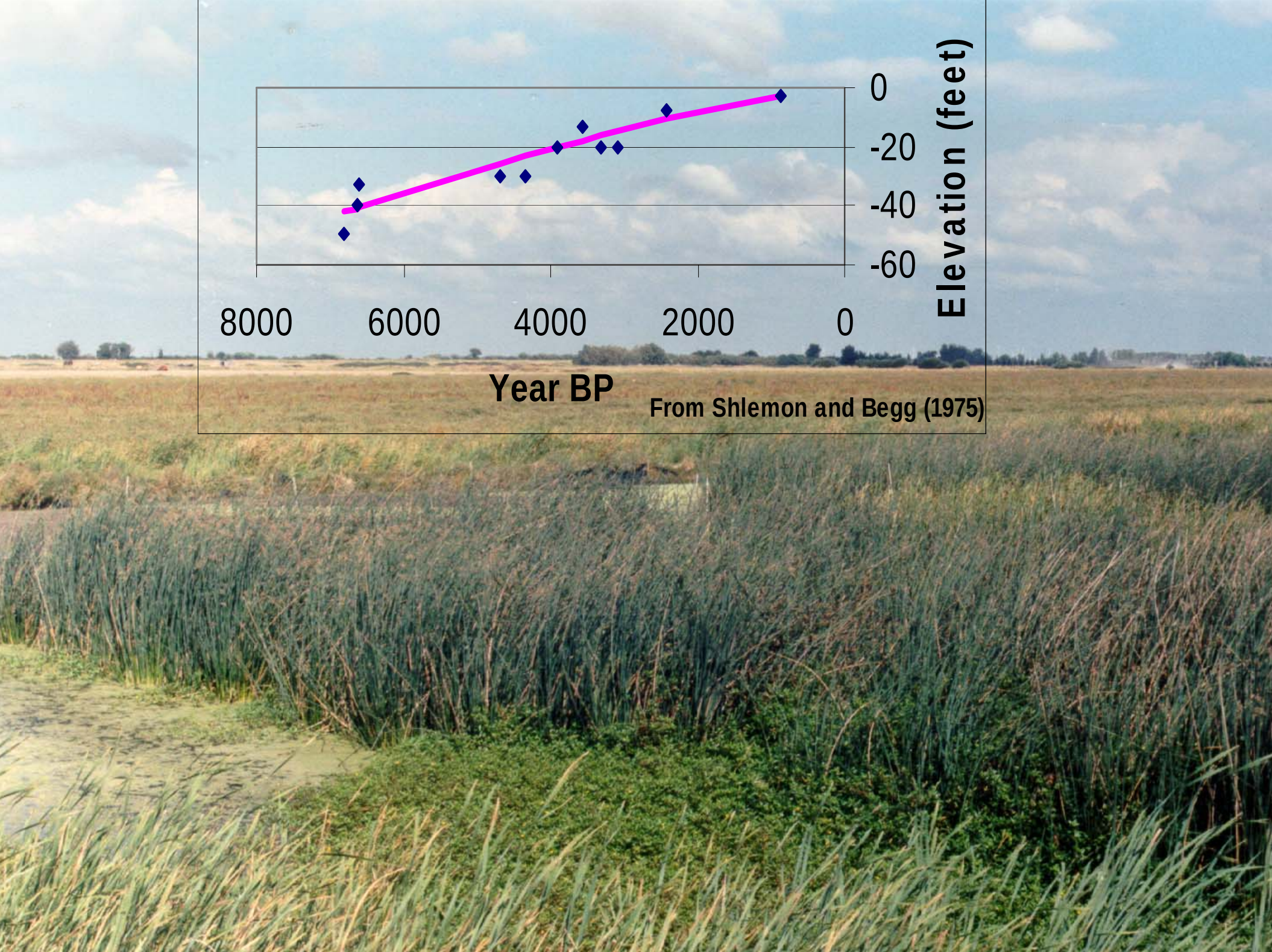
Discussion slides

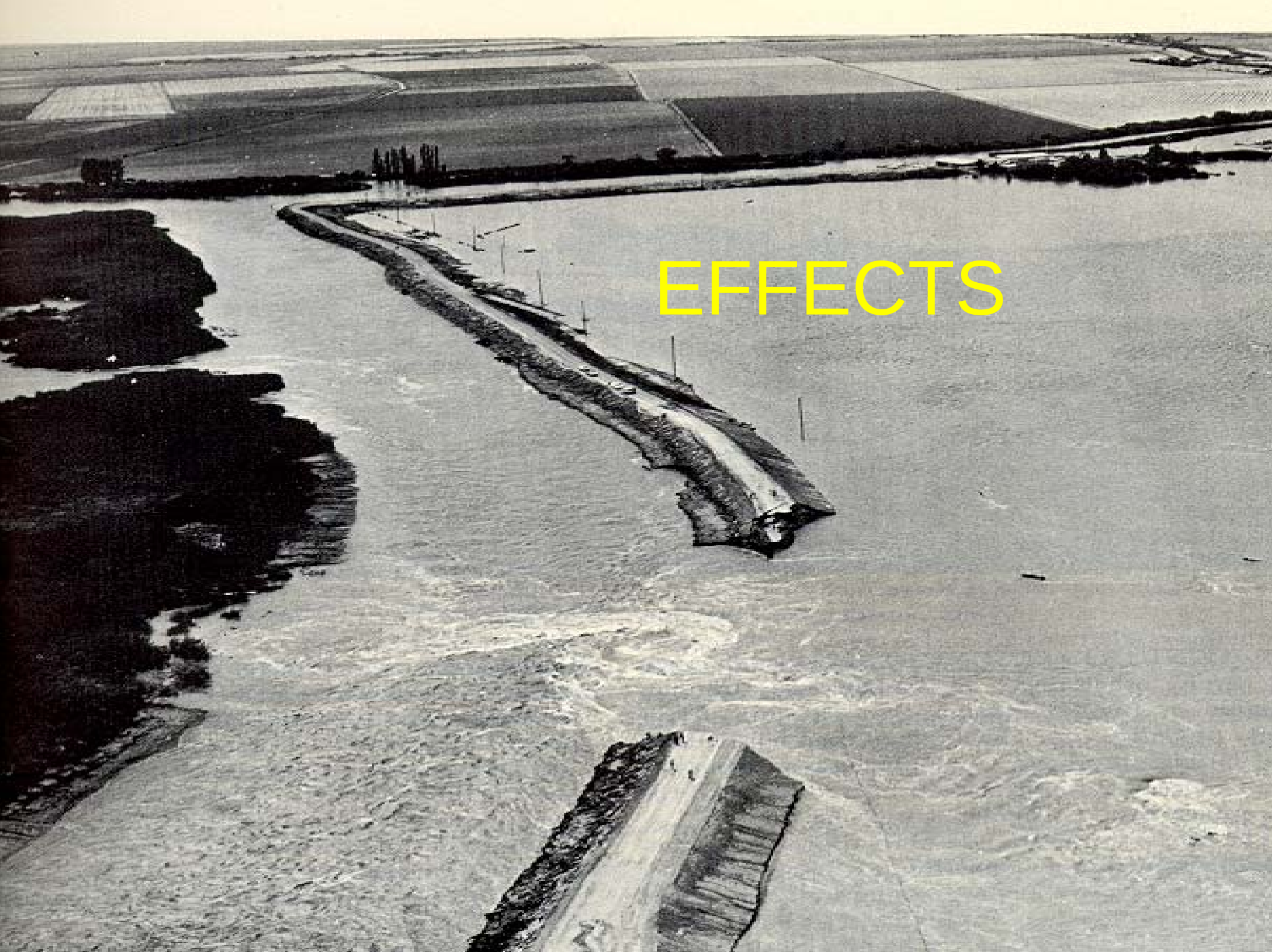
Western Delta 2050



HOLOCENE ACCRETION



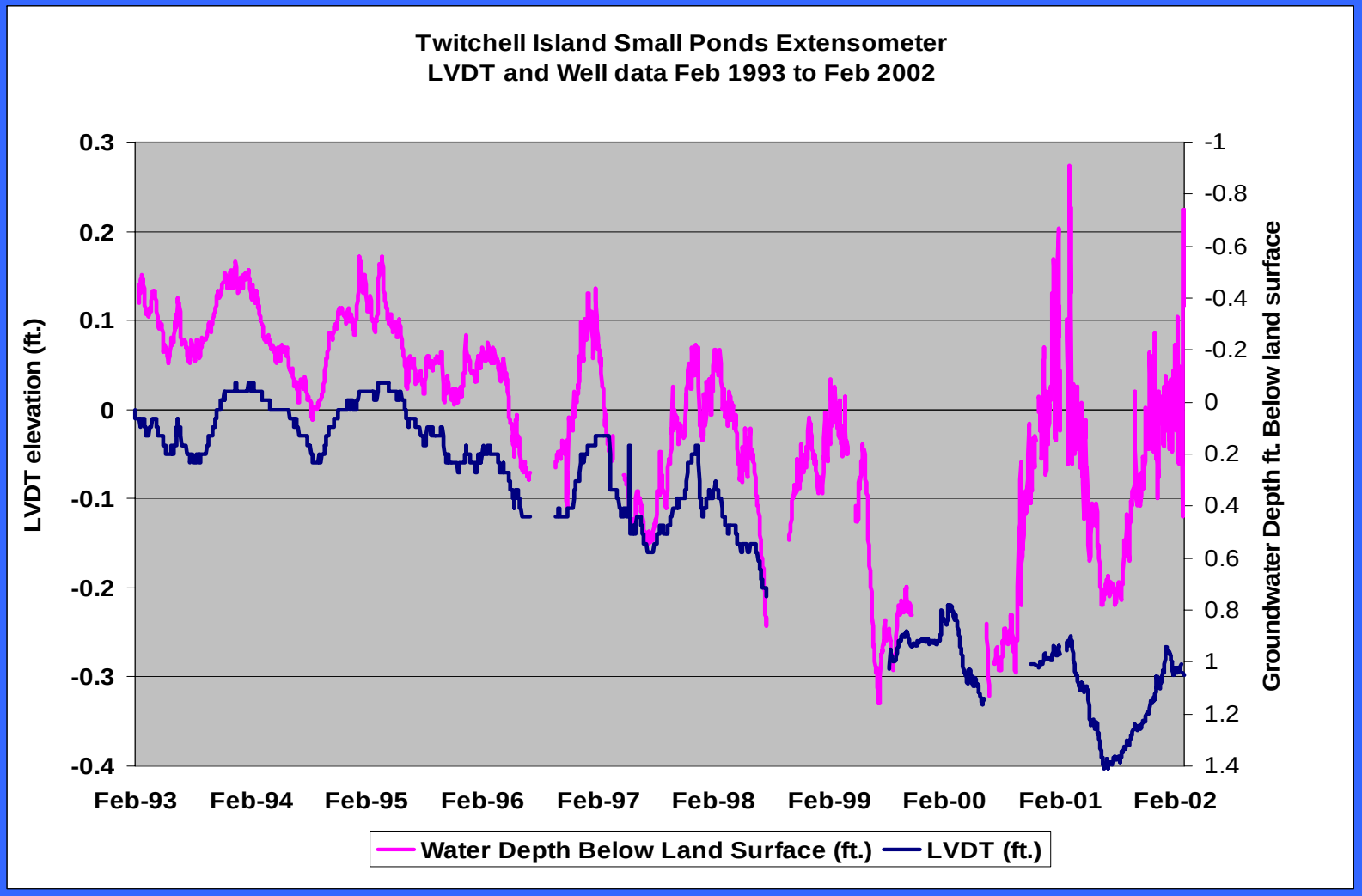

0
-20
-40
-60
Elevation (feet)
8000
6000
4000
2000
0
Year BP
From Shlemon and Begg (1975)


EFFECTS

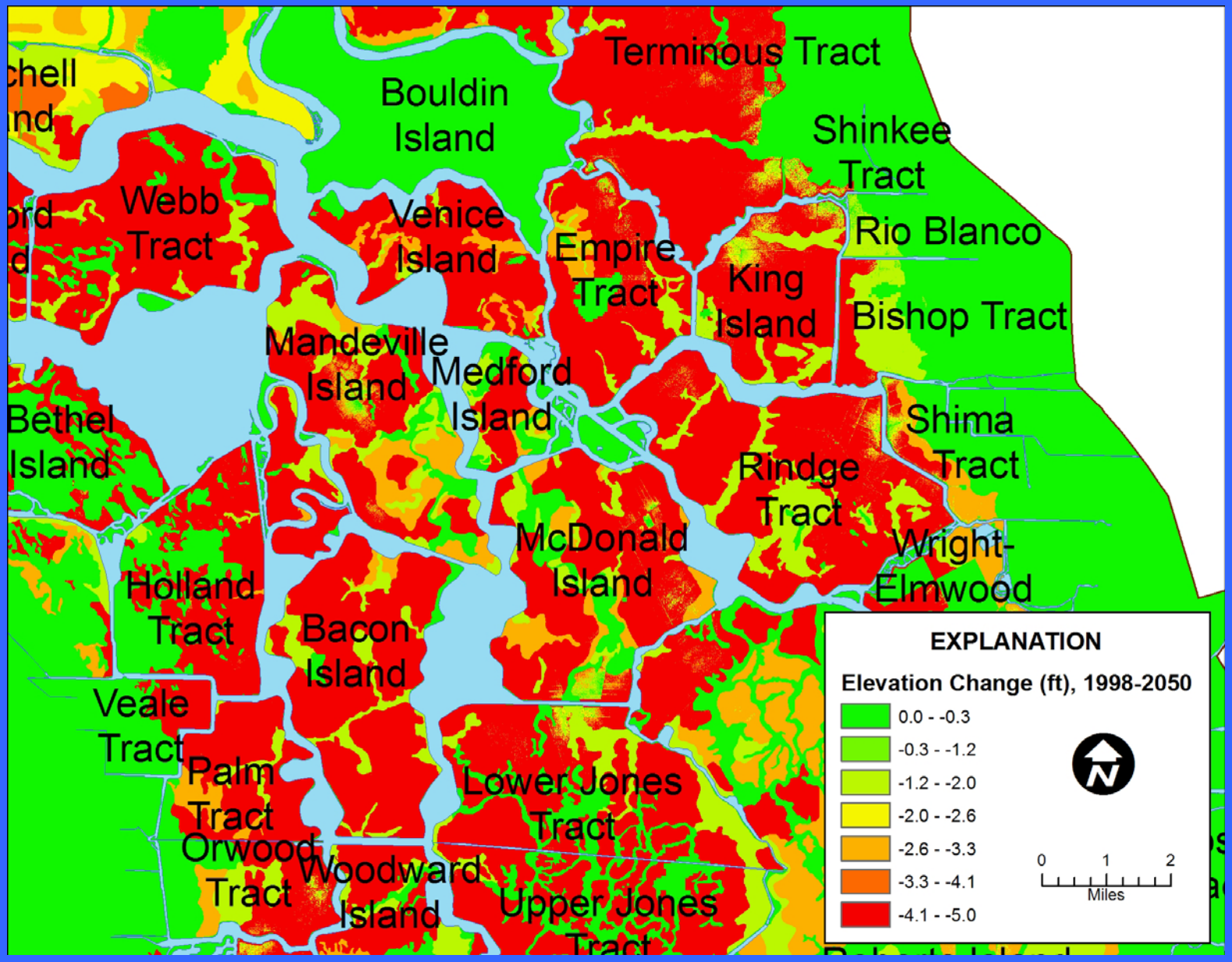
WATER QUALITY EFFECTS: BRANNAN-ANDRUS EXAMPLE, JUNE 1972

- 150,000 acre-feet flooded island, higher salinity water drawn from the west.
- 50,000 tons of extra salt exported.
- Salinity increased 2.5 to 4 x for Delta exports.
- State water project shut down for 1 month.
- Additional 300,000 acre-feet released from water projects.
- Over $22 Million spent.
- In future, subsidence will continue to increase volume drawn onto islands during flooding.

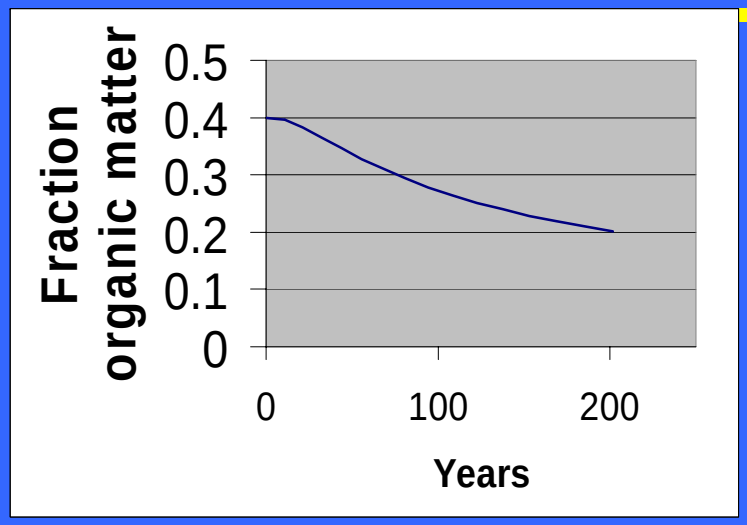
Illustration of temporal variation in land surface elevation

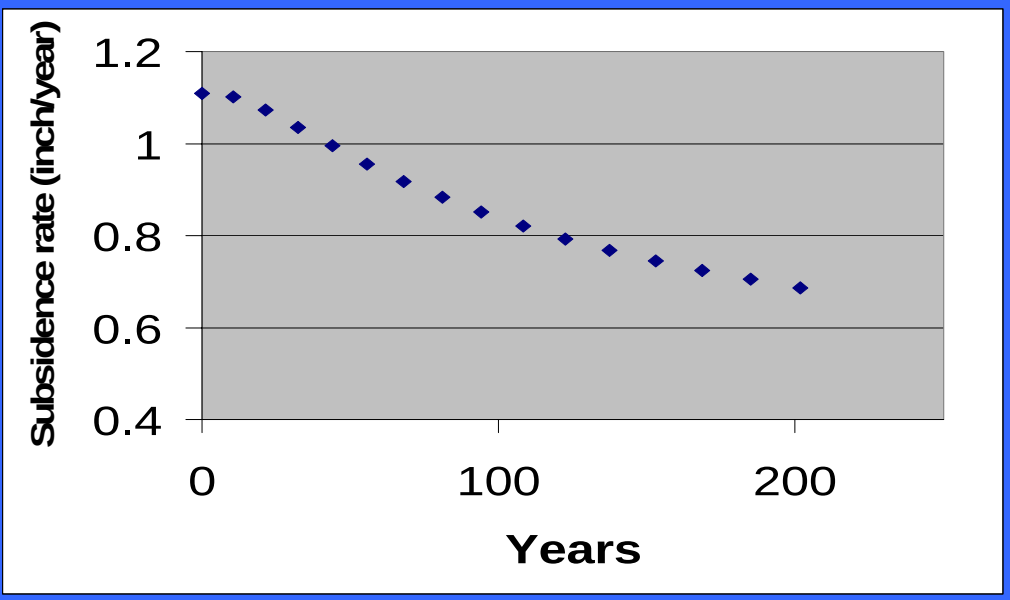


Central Delta 2050



Future Soil Organic Matter Estimates



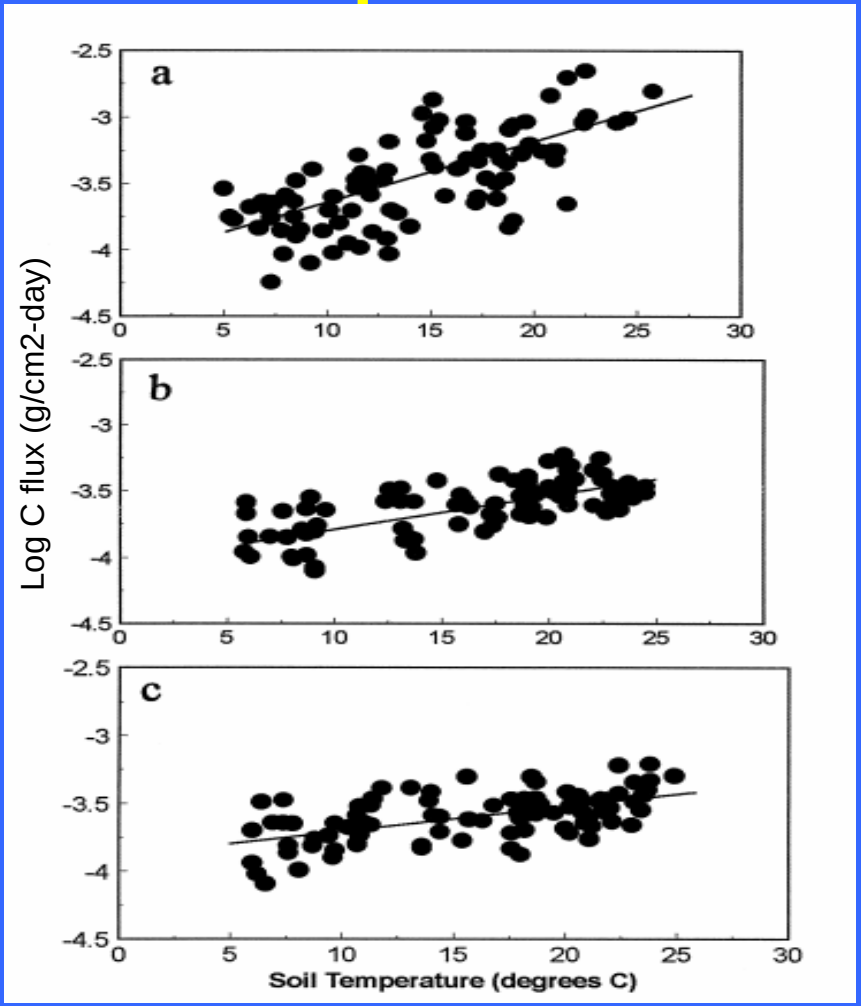


- We used a simple model that estimates the organic matter content change as organic matter disappears.
- Results in an exponential decrease in organic matter and subsidence rate with increasing time

Temperature Effects

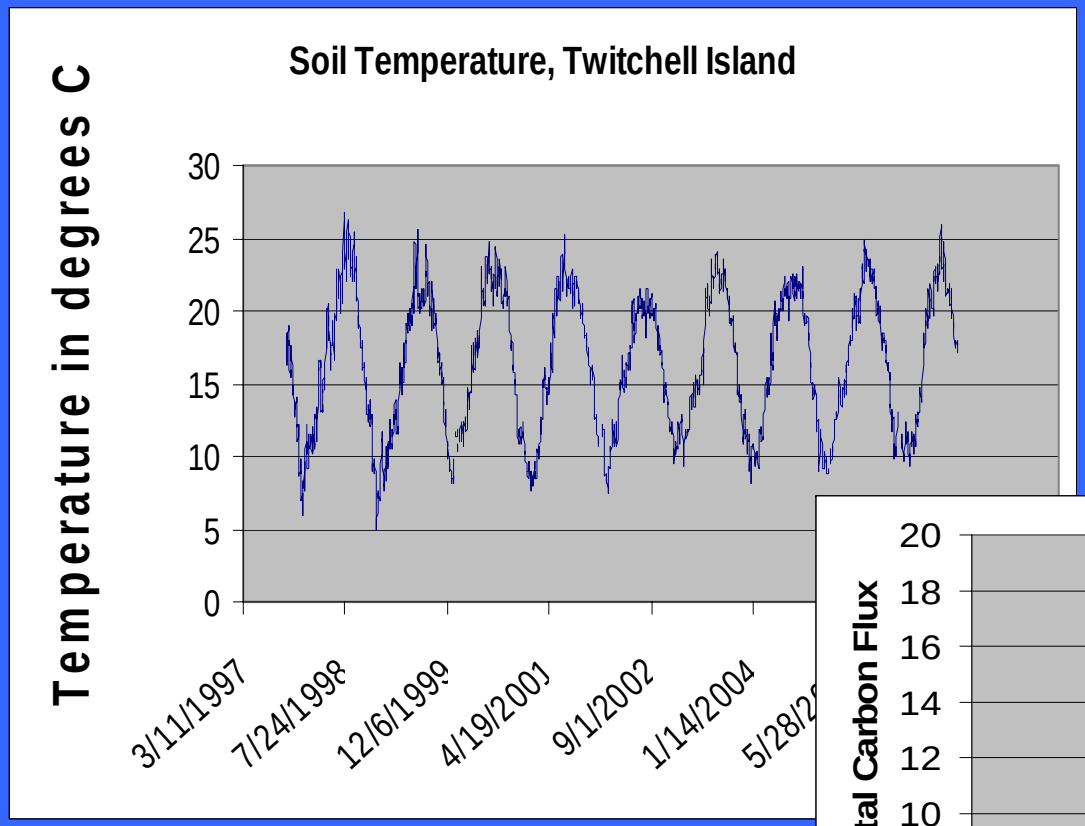
- Climate change modeling indicates:
  - 1.6 to 2.6^{O} C increase to 2050 and
  - 2.4 to 3.7 ^{O} C increase to 2090,
- Seasonal variation: highest projected increases during summer and fall.
- Logarithmic effect of temperature increase on carbon loss.
- Used log relation and seasonal weighting to estimate future increase in subsidence rate due to temperature increase.
- Assumes:
  - Soil moisture regime will not change. substantially
  - Air temperature increase will translate directly to soil temperature increase.
  - 90-year rate of increase will persist to 2200.

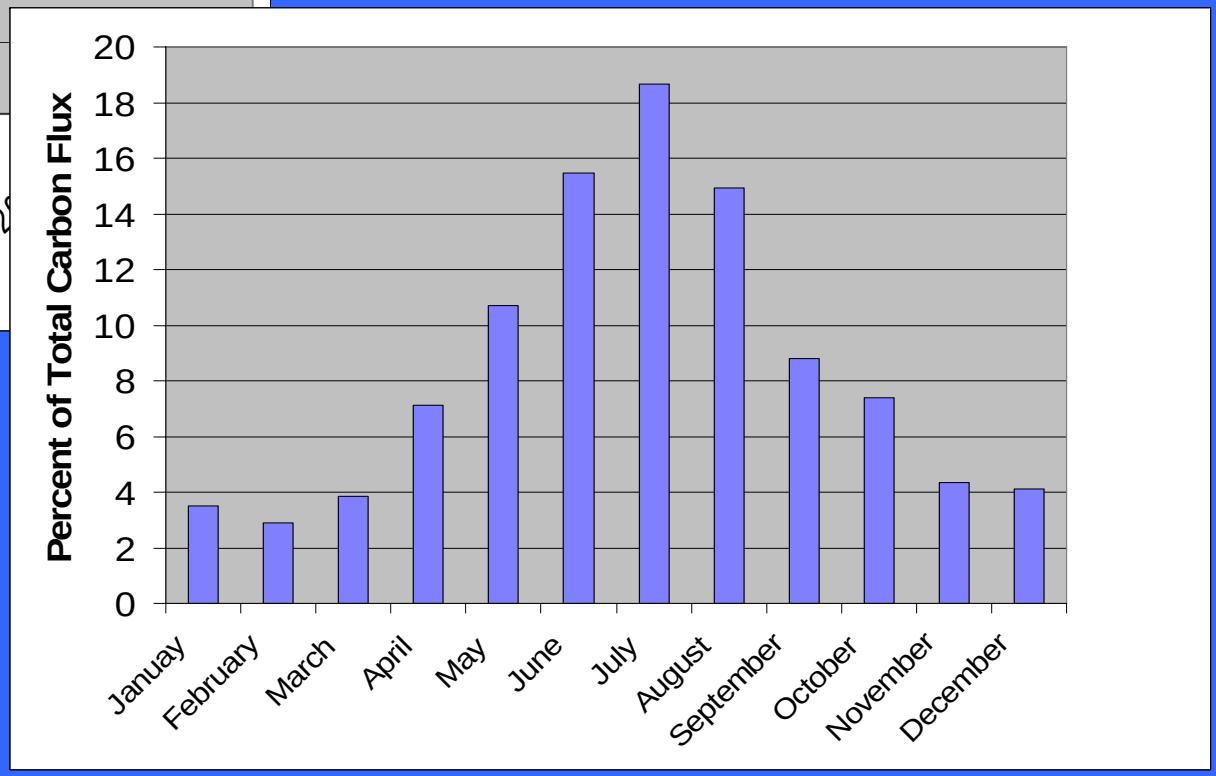
Carbon Flux Temperature Dependence



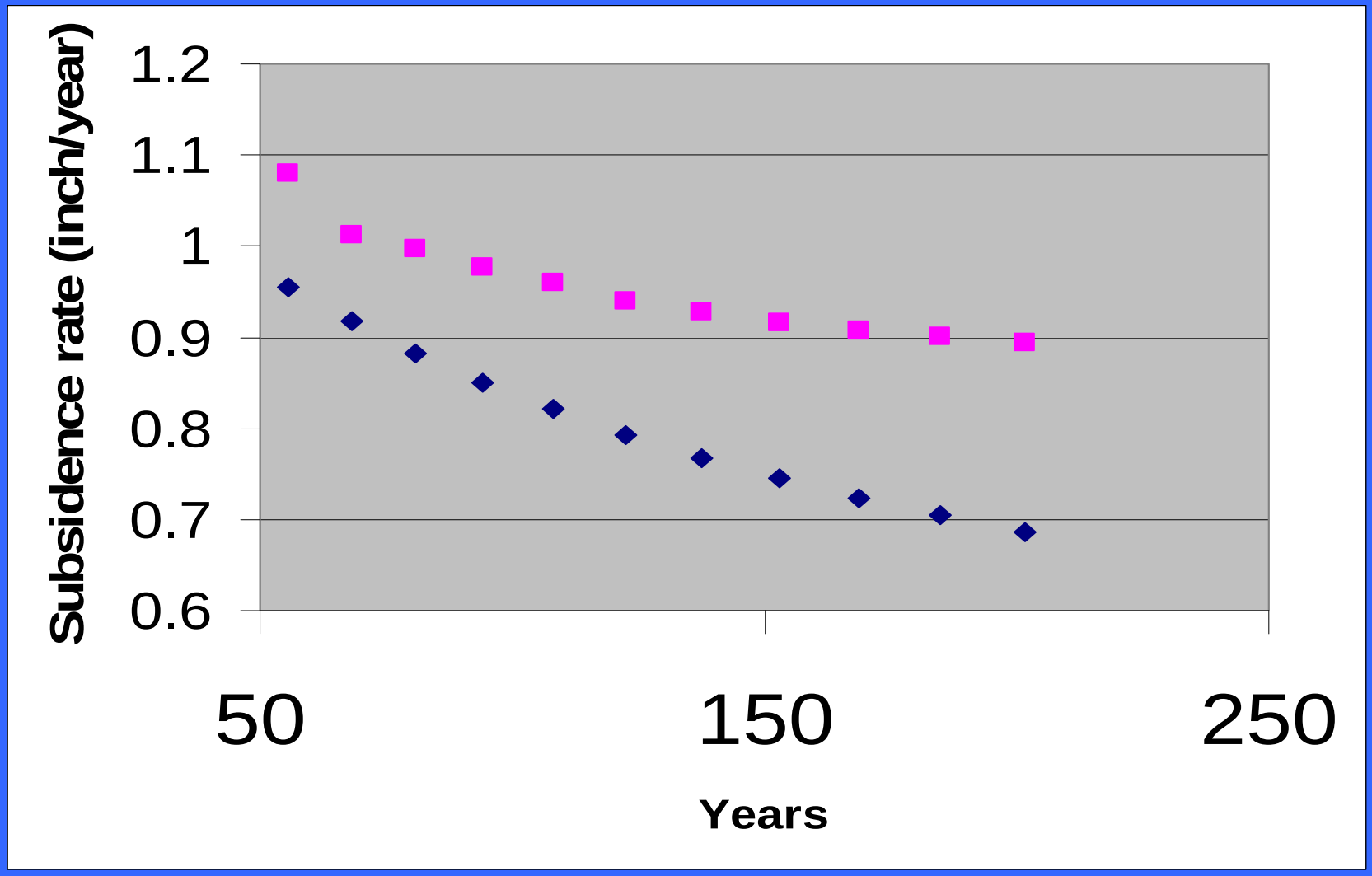
From Deverel and Rojstaczer (1996) Water Resources Research

Seasonal Variation





Temperature Effect on Subsidence Rates



Uncertainty – random (aleatory) and deterministic (epistemic)

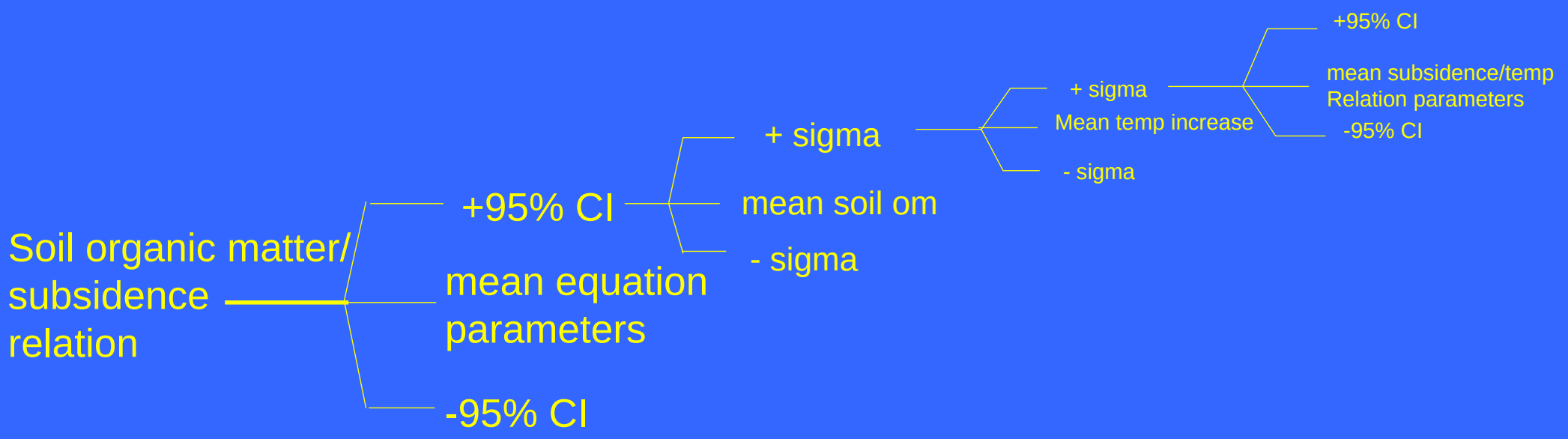
- Distribution of soil organic matter and subsidence rates
- Subsidence rate- organic matter correlation.
- Temperature effects
- Future land use
- Water table effects

Estimated Epistemic Uncertainty in Delta Subsidence Rates Includes:

- Range of soil organic matter content for soil series;
- Range of projected temperature increase;
- Range of soil oxidation response to temperature increases:
- Confidence interval for soil-organic matter –subsidence regression equation.
- Variation in land use – effect on groundwater table.

- We chose to ignore effects of random or aleatory uncertainty based on analysis of spatial effects on volume estimates.

Scheme for epistemic uncertainty estimates for Delta



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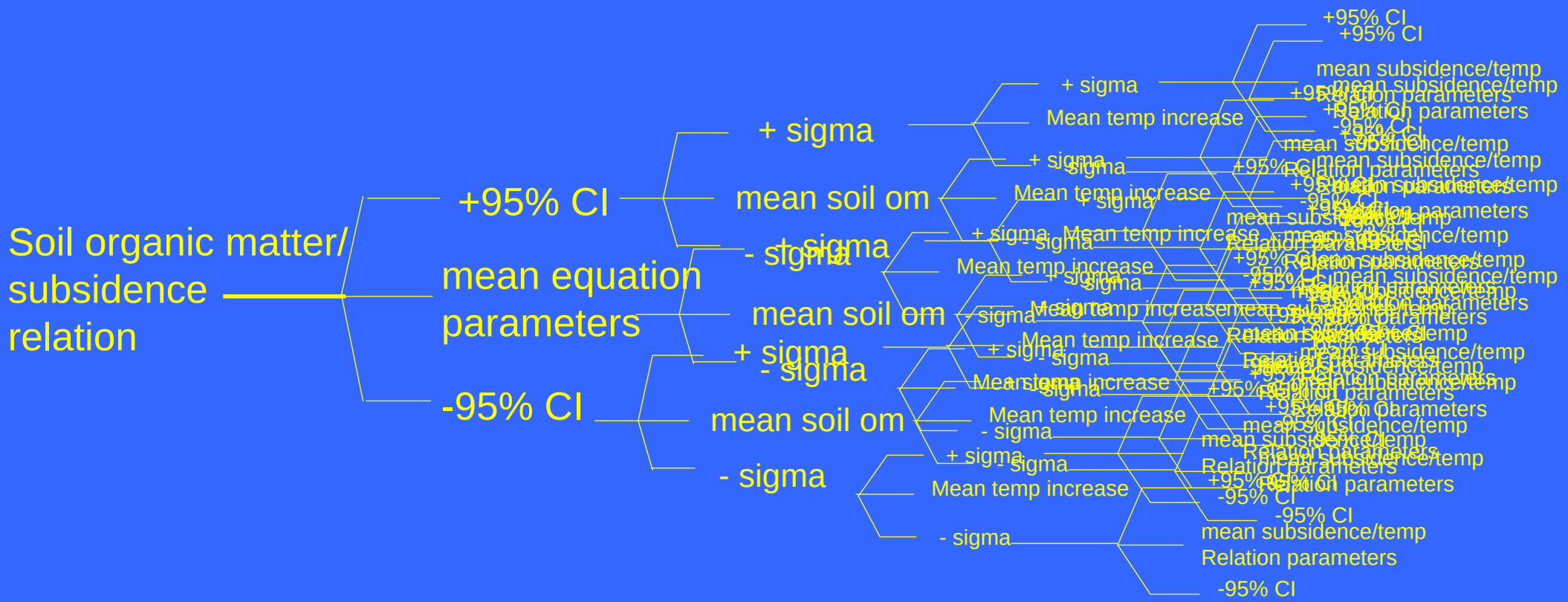
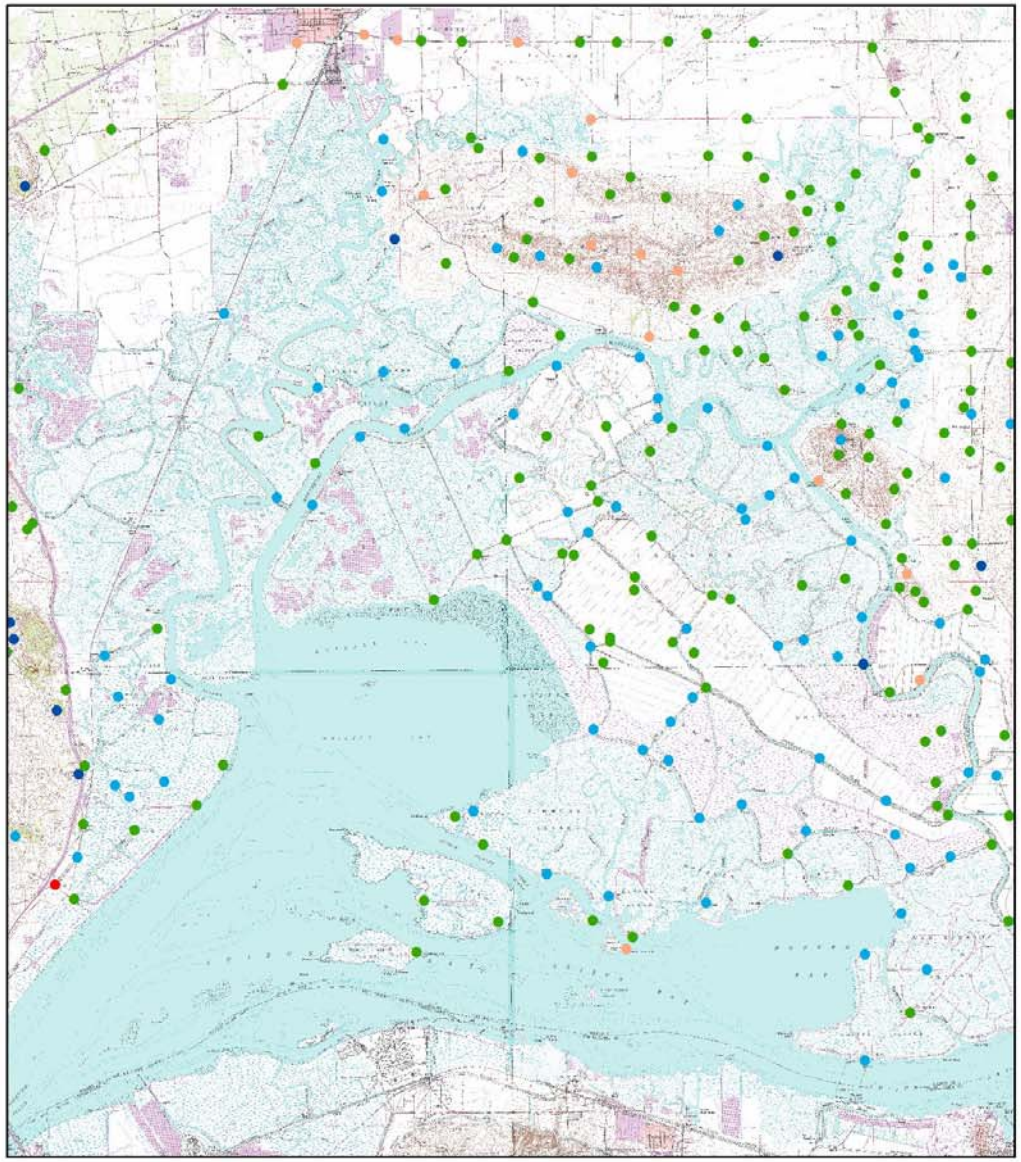


Suisun Marsh Subsidence Estimates

- Evaluated historic rates based comparison of mapped 1940's and 1950's elevations with 2006 LIDAR data.
- Rates generally ranged from 0.6 to 1 inch per year.
  - Rates varied within and by soil type.
  - Organic soils appeared to have subsided at rates comparable to current Delta rates for similar organic matter content.
- Assigned range of future rates based on range in historic rates (mean and inner quartile range).

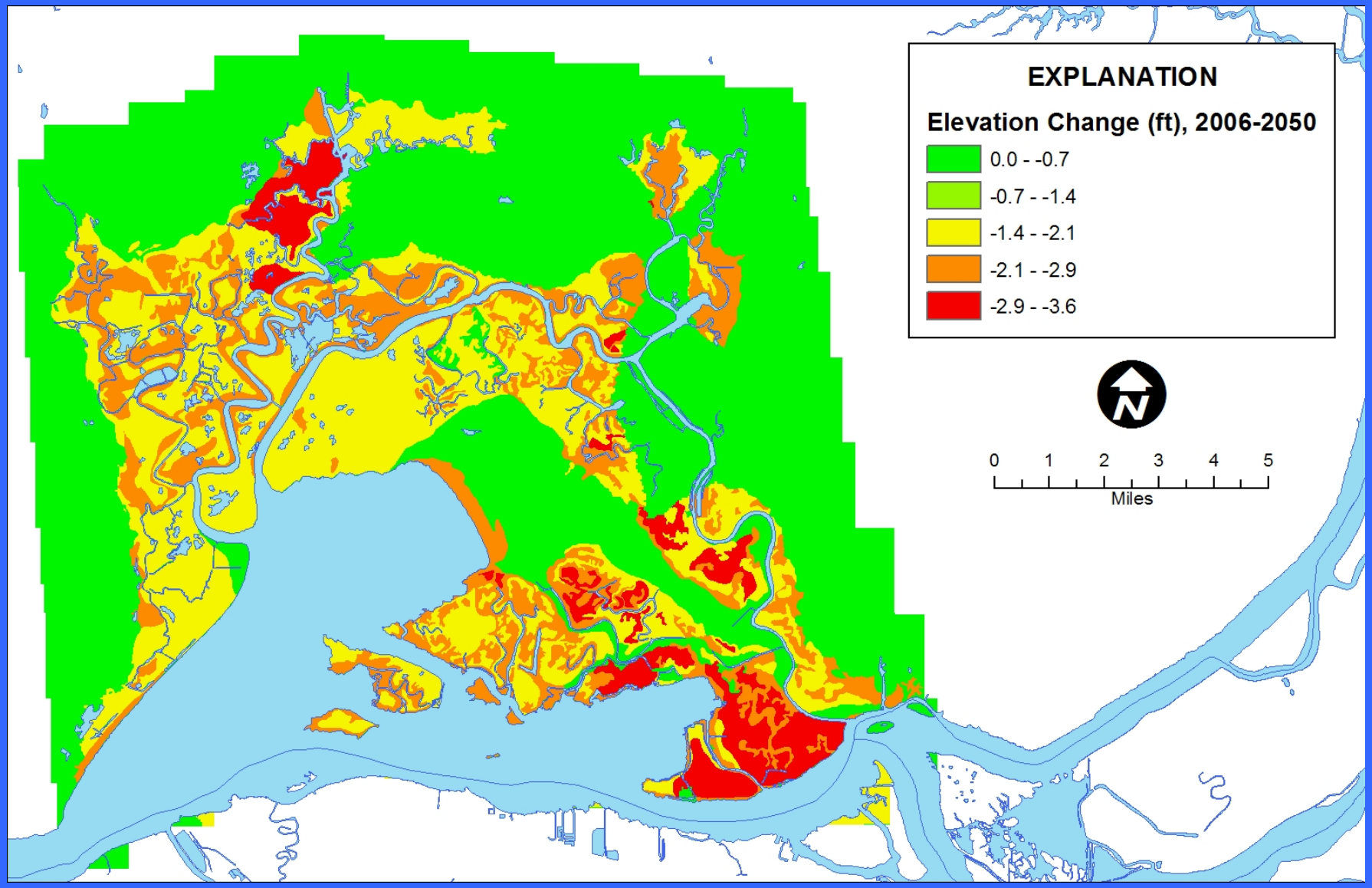


EXPLANATION

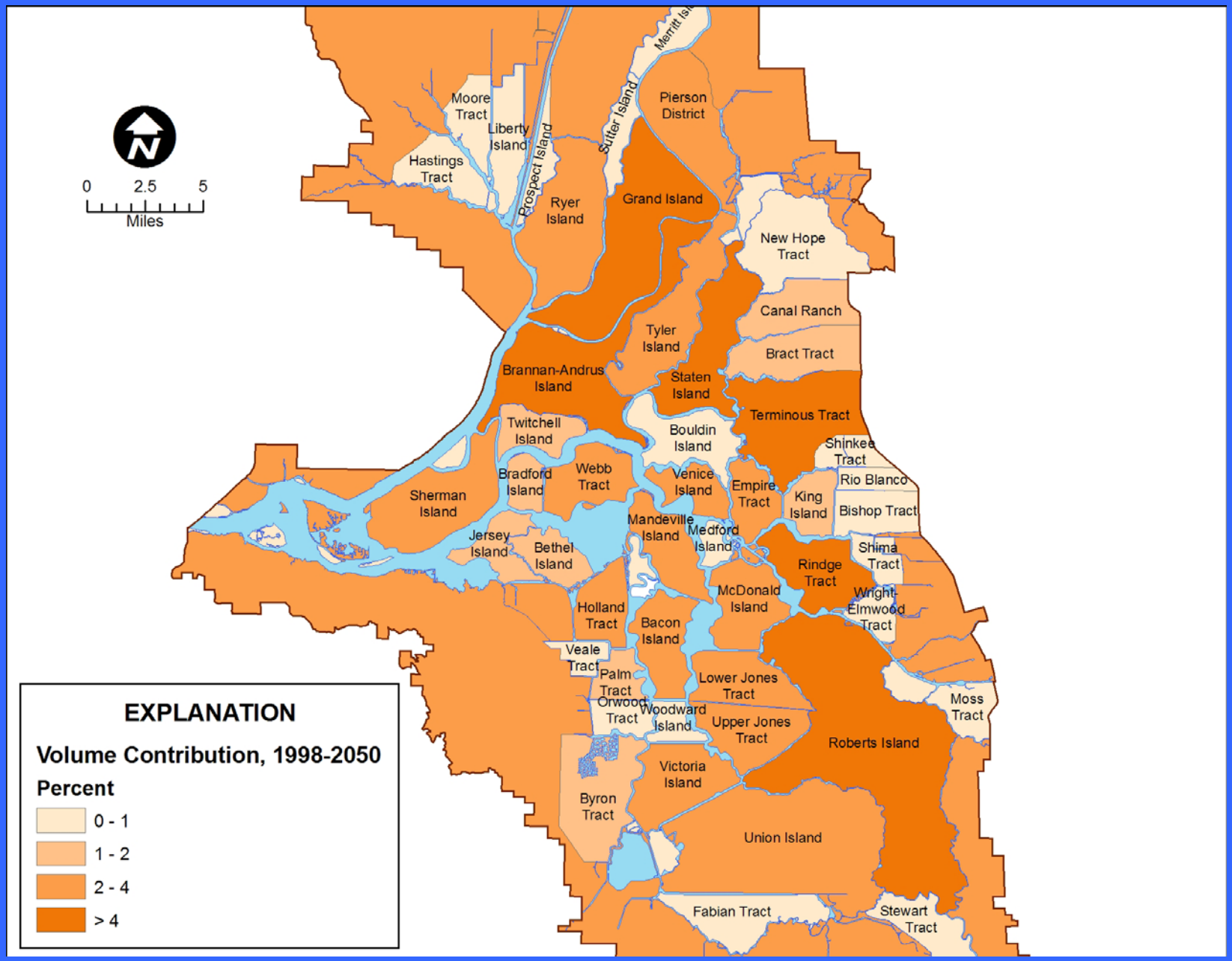
DEM/ Topo Differences, ft.

- -45.6 - -10.0
- -10.0 - -2.5
- -2.5 - 2.5
- 2.5 - 10.0
- 10.0 - 10.7

Suisun Marsh



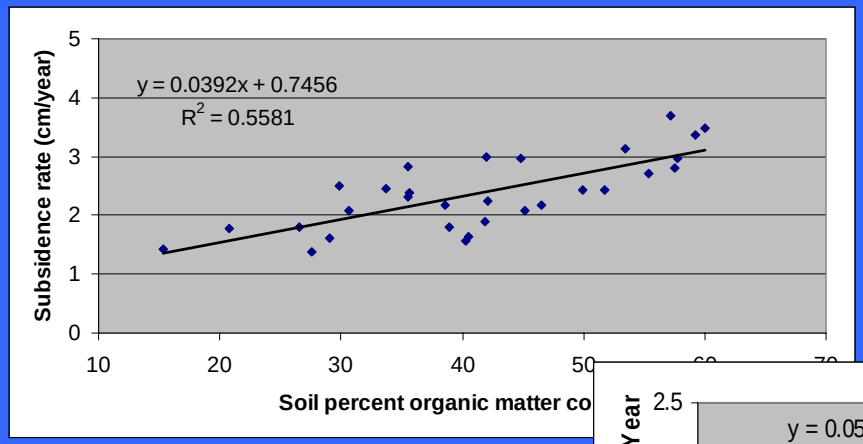
Percent volume increase by island

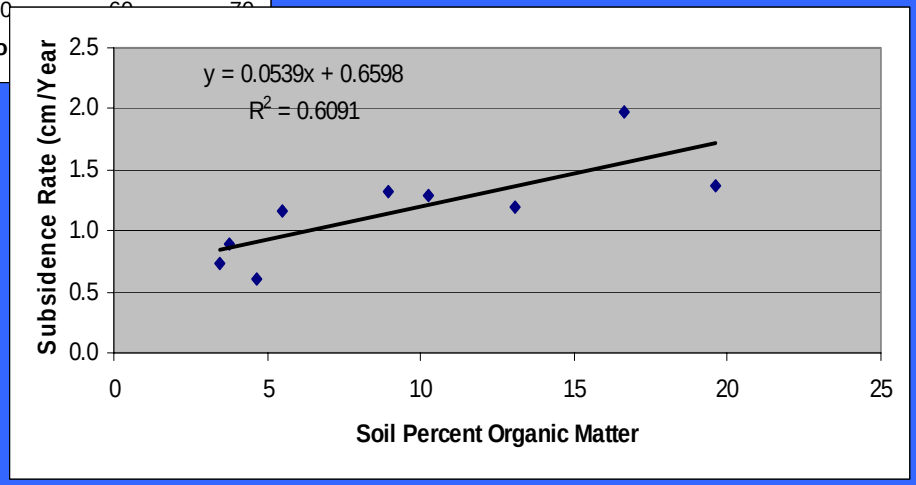


Recent subsidence rates on Sherman Island

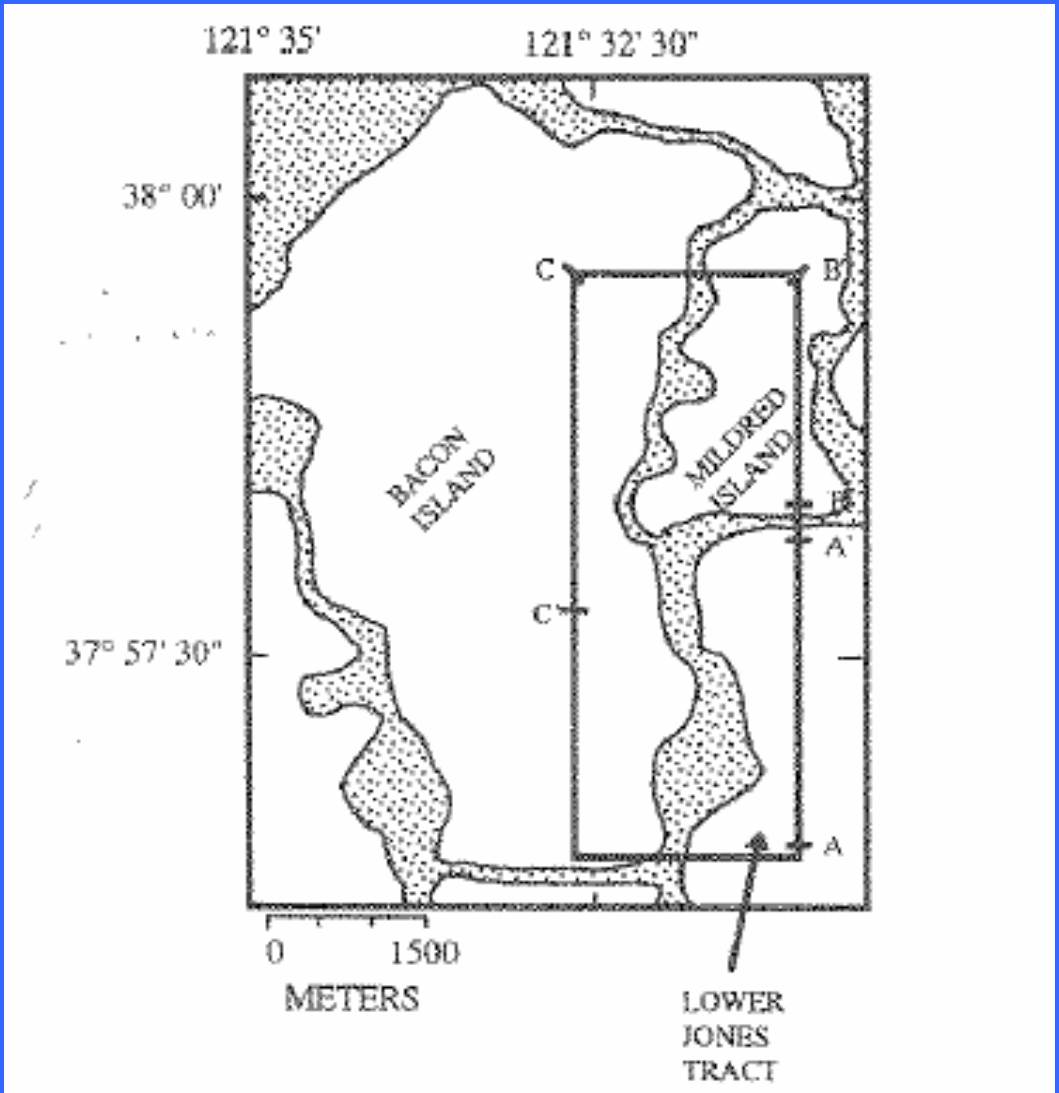
- Measured elevations at 13 power pole foundations measured by USGS in 1988.
- Estimated land-surface elevation changes from 1988 to 2006.
- Rates ranged from to 0.2 to 0.9 inch per year.
- Average rate was about 0.5 inch per year.
- Rates correlated with soil organic matter content.

Bacon and Sherman SOM/subsidence correlations

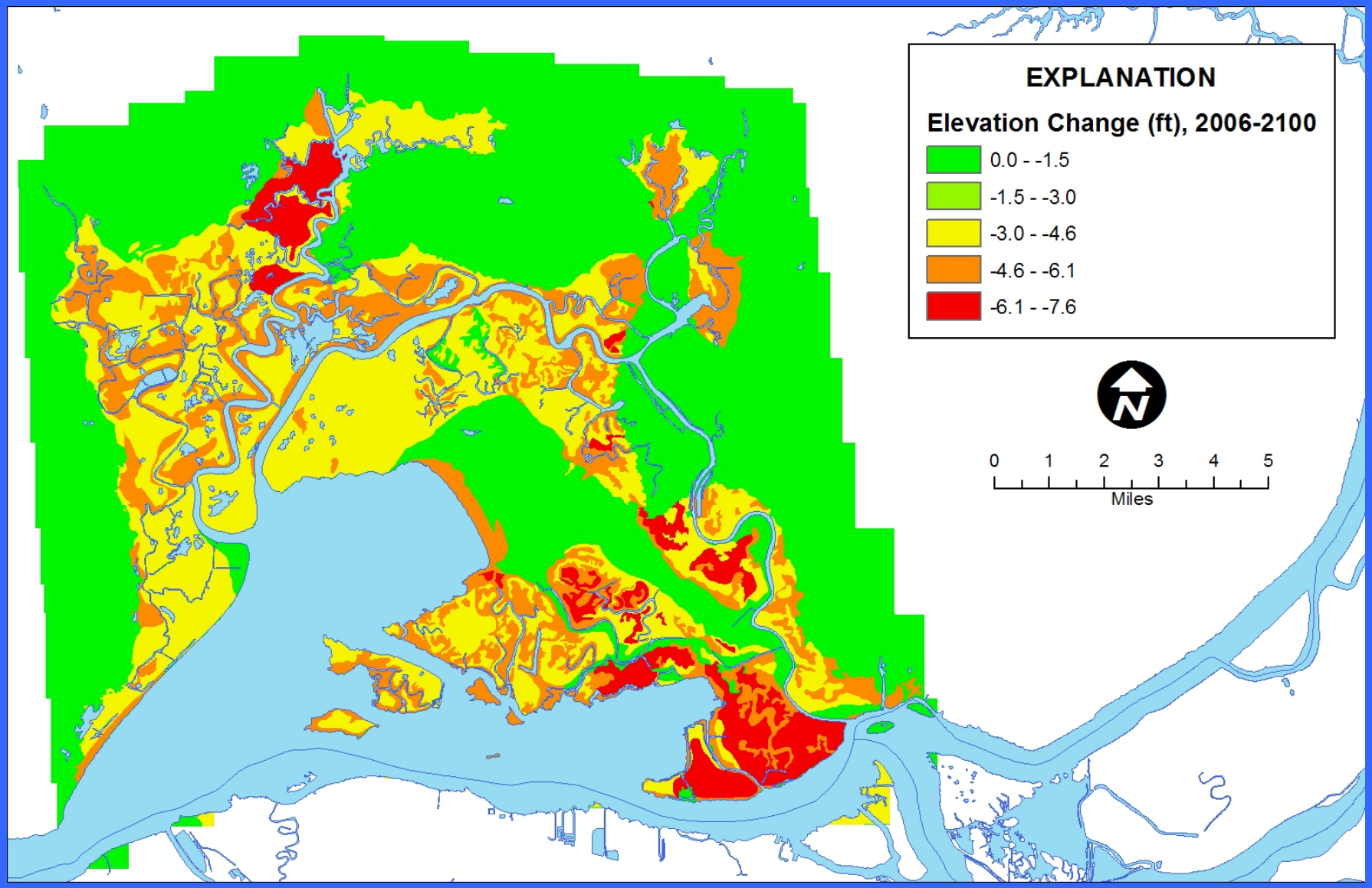




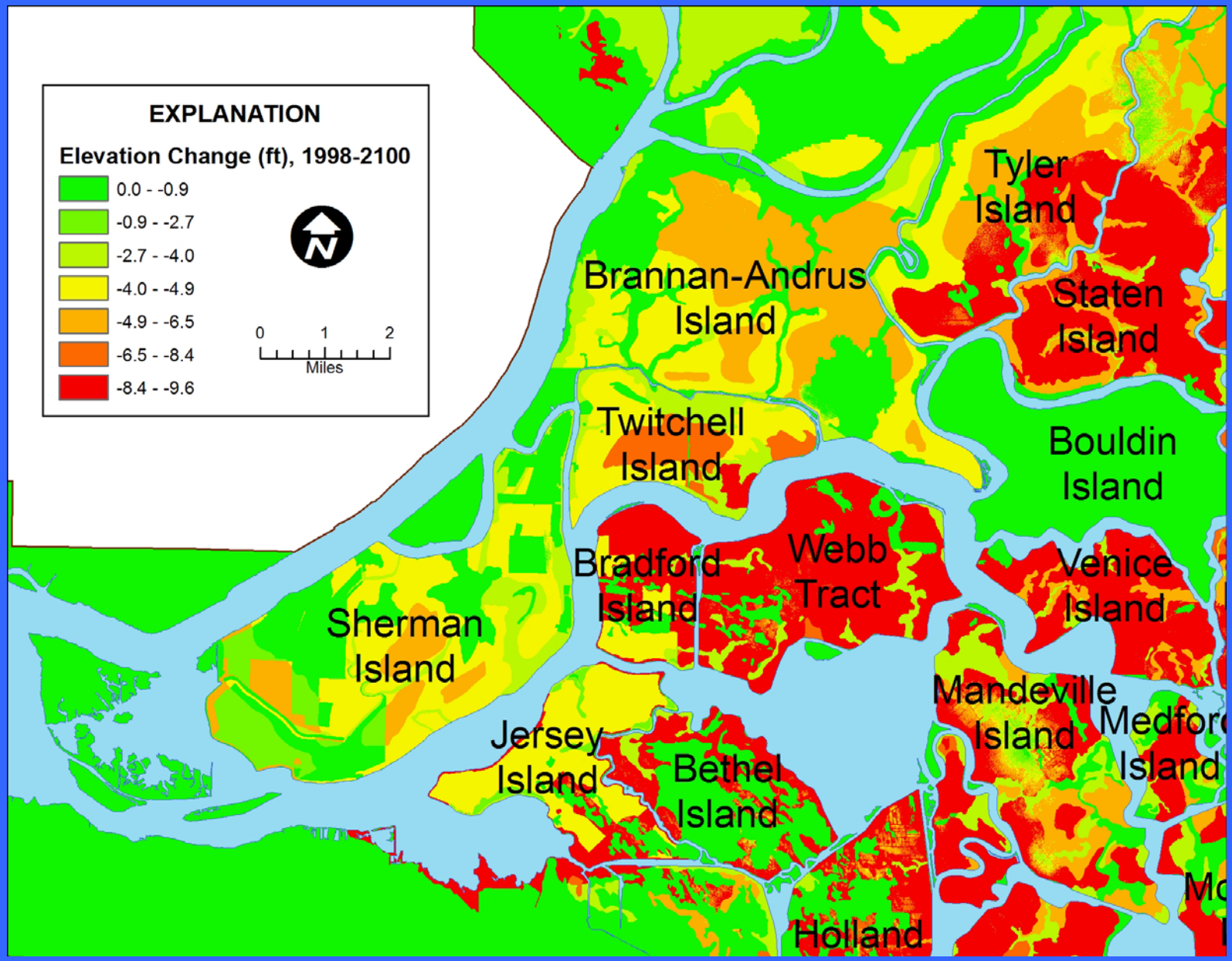
Weir Transect



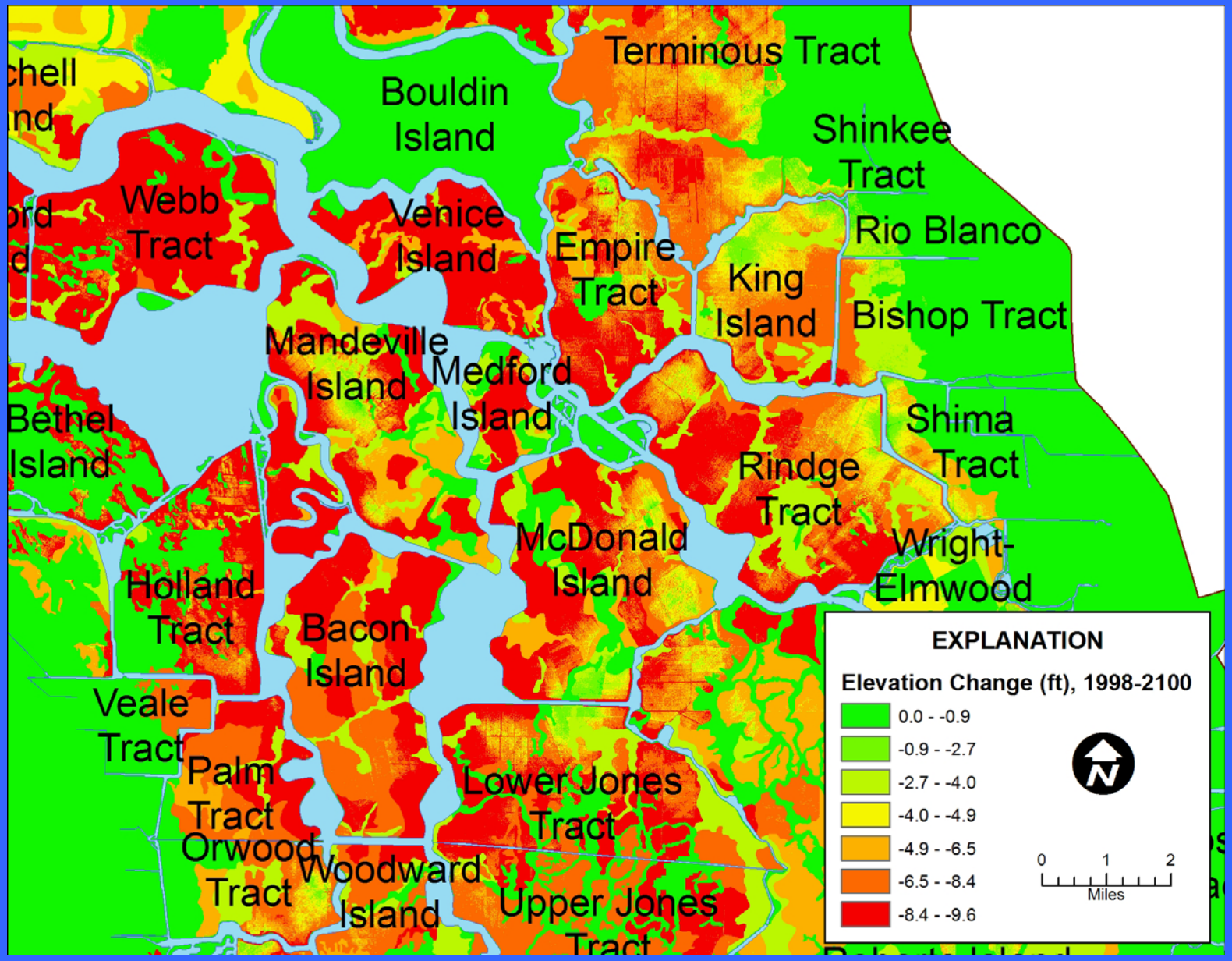
Suisun Marsh 2100



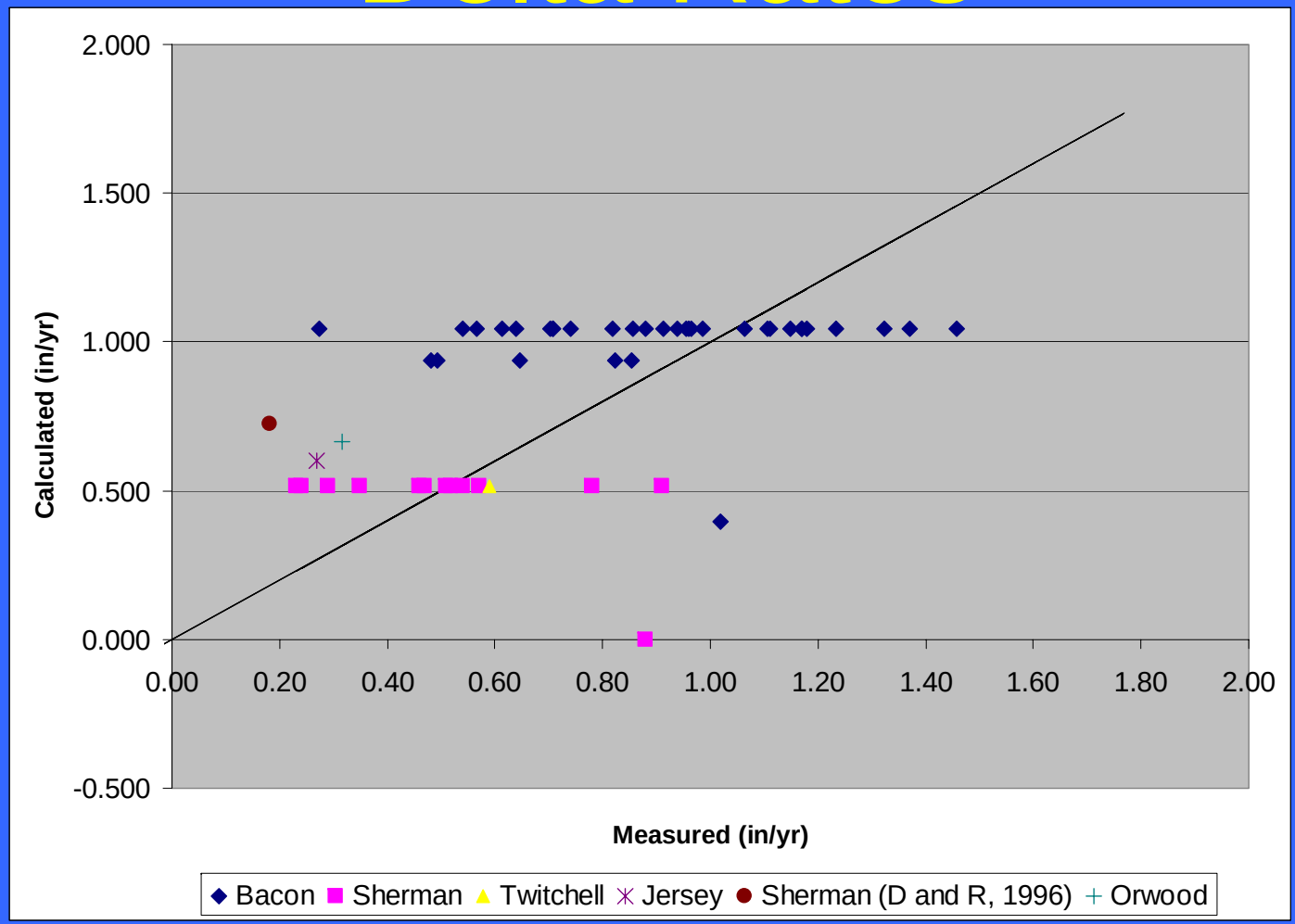
Western Delta 2100



Central Delta 2100



Observed Uncertainty in Current Delta Rates



- Root Mean Square Error = 0.4 inch/year
- Root Mean Square Error percentage = 27%

Uncertainty – random (aleatory) and deterministic (epistemic)

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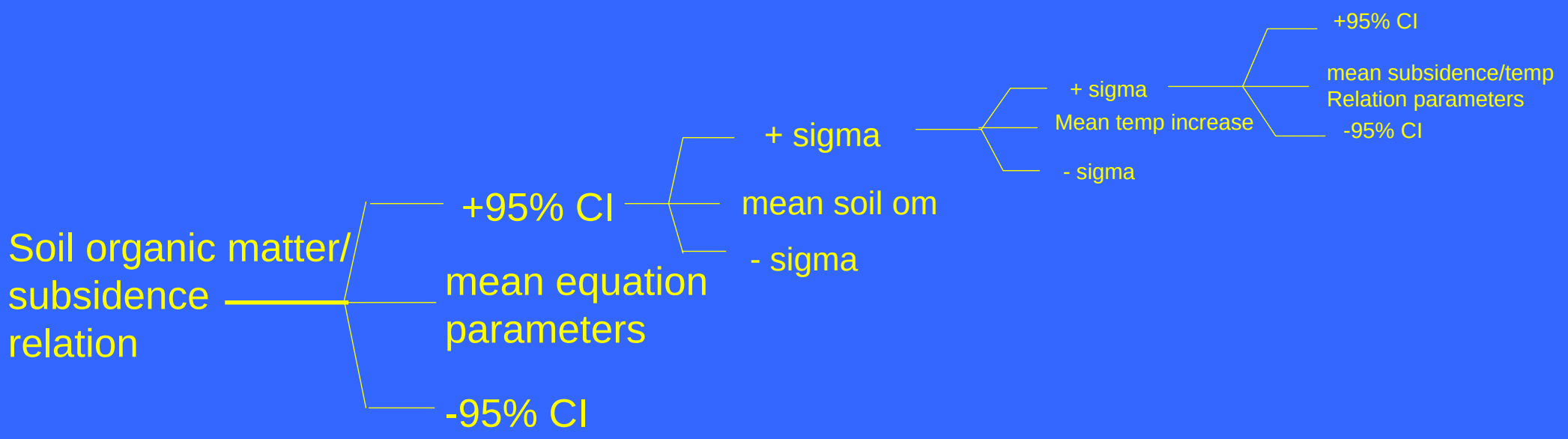

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