Suisun Marsh metrics *and more…*

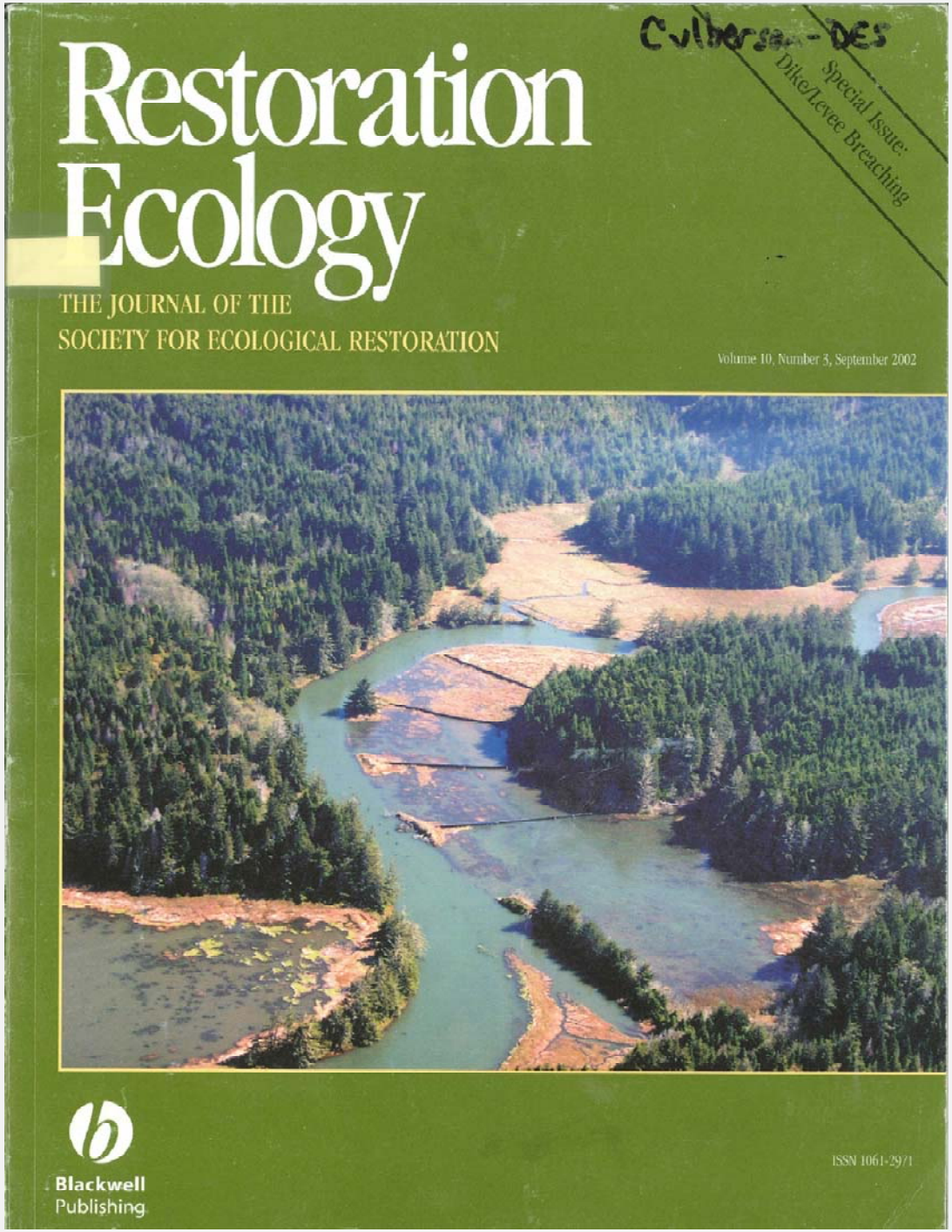
Chris Enright

8-4-10

Too many slides I fear, can’t help it.

- Wetland restoration metrics in the literature
- Is this enough considering where we start?
- Metrics themselves are emergent phenomena
- Adding landscape ecology perspective
- Imagine a Suisun Marsh restoration opportunity… what next?
- Implications for observations.

Special Issue:
Dike/Levee Breaching



Base Map Variables

Table 1. Variables to be included on base map of all monitoring sites.

Variable	*Description*
Core variables	
Locator map	State, province, city, or town of salt marsh monitoring site
Key features	Locator and cultural features associated with monitoring site, such as rivers, roads, and culverts
Wetland area/cover types/ sediment condition	Delineated salt marsh, fresh/brackish marsh, forested wetland, shrub-dominated wetland, open water (creeks, pannes, pools, ditches), invasive species or species of interest, from National Wetland Inventory (U.S.) or Canadian Wetlands Atlas (Canada) if available; soil organic matter content at sampling stations
Manipulations	Location of pre- and post-restoration actions, such as culverts, dredging, removal or addition of fill, excavations, etc.
Sampling locations	Locations of pre- and post-restoration monitoring stations (transects, plots, wells, bird observation stations, etc.)
Base map documentation	Sources of base map (e.g., U.S. or Canadian topographic maps; aerial photographs including scale, type, and date; tax maps; National Wetland Inventory or Canadian Wetlands Atlas database), scale of map and north arrow, latitude and longitude
Additional variables	
Detailed, geo-referenced site information	Detailed cover-type mapping, ownership boundaries, elevation contours, 100-yr floodplain boundary

Restoration Ecology SEPTEMBER 2002

From: A Monitoring protocol to assess tidal restoration of salt marshes on local and regional scales
Neckles et al. 2002

Core variables

Both restoration projects and reference sites

Variable	Description	Sampling Method	Annual Sampling Frequency
		Hydrology	
Tidal signal	Pattern of water level change with respect to a reference point	Continuous water level recorders *or* Tide staff observations at 10-min intervals	2 to 4 week period of operation; 13-hr observation periods during three spring and three neap tides
Elevation	Marsh surface elevation at contour intervals of 15 cm or less	Contour map *or* Hypsometric curve (cumulative frequency distribution of elevation of set of points on marsh surface)	Once
		Soils and sediments	
Pore–water salinity	Parts dissolved salts per thousand (also referenced to Practical Salinity Scale) of soil water collected from 5–20 cm depths	Groundwater wells, soil cores, or sippers	At low tide, six times between early (April/May) and mid (July/August) growing season, including spring and neap tides
		Vegetation	
Composition	Identity of all plant species occurring per m^2	Permanent plots positioned along transects at intervals necessary to maintain independence (>10–20 m)	(Frequency applies to all variables) Once at time of maximum standing biomass (mid-July through August)
Abundance	Percent cover per m^2 by species	Permanent plots on transects	
Height	Mean height of three tallest individuals of each species of concern per m^2	Permanent plots on transects	
Density	Number of shoots per m^2 in plots restricted to species of concern	Permanent plots established within distinct stands of species of concern	
Photo stations	Photographs from permanent stations	Panoramic views of entire marsh from several compass bearings; close-ups of permanent plots	
		Nekton	
Composition	Identity of each animal sampled	(Methods apply to all variables)	
Species richness	Total number of species represented	Throw traps in creeks and channels (small fish) *and* Fyke nets in creeks > 15 m wide (large fish) *and* Fyke nets on marsh surface (fish catch data must be standardized by marsh area)	At mid-tide during two spring tides in August
Density	Number of animals per area (throw traps and marsh surface fyke nets)		Installed at slack high tide: two spring tides during early season migration of diadromous fish; two spring tides in August
Length	Length (fish, shrimp) or width (crabs) of individual animals to the nearest 0.5 mm, by species		Installed at low tide to sample ebb tide, one spring tide in August
Biomass	Wet weight of animals in sample, by species		
		Birds	
Density	Number of birds per ha, by species	(Methods apply to all variables)	(Frequency applies to all variables)
Species richness	Total number of species represented	20-minute observation periods in the morning from site-specific vantage points that provide an uninterrupted view of at least a portion of the salt marsh	At high and low tides: two times during breeding season (May/June); once per week during waterfowl migration (March/April and October/November); once per week during shorebird migration (July–September)
Feeding/breeding behavior	Type of behavior (e.g., feeding, roosting, breeding, preening) per observation interval, by species		

From: A Monitoring protocol to assess tidal restoration of salt marshes on local and regional scales, Neckles et al. 2002

Additional variables for process understanding

Monitoring Protocol for Local and Regional Assessments

Table 3. Additional variables to be monitored as warranted by the goals and resources of specific projects.

Variable Name	*Description*
Hydrology	
Tidal creek cross-section	Cross-section profiles of major tidal creeks measured at permanent locations.
Water table depth	Level of groundwater at permanent wells or piezometers installed within the marsh and along the upland marsh edge. Sampled at low tide, six times between early and mid-growing season, including neap and spring tides.
Surface water chemical and physical characteristics	Water quality parameters sampled in main tidal channel: dissolved oxygen, salinity, temperature, and pH.
Current profiles	Tidal current in main channel assessed over several tidal cycles.
Soils and Sediments	
Organic matter	Organic content of 20-cm soil cores sectioned into 5-cm segments.
Sediment accretion rate	Accumulation of inorganic and organic material above a marker horizon over a known time interval.
Sediment elevation	Short-term changes in sediment elevation measured with sediment elevation tables.
Redox potential	Redox potential at 1- and 15-cm depths.
Sulfide	Concentration of sulfide in pore water.
Vegetation	
Aboveground biomass	Biomass of living aboveground plant material collected from additional randomly positioned quadrat in vicinity of permanent quadrat.
Stem density	Number of shoots per m^2, by species, within permanent quadrats.
Proportion flowering	Proportion of shoots of each species that are flowering within permanent quadrats.
Nekton	
Biomass	Wet weight of individuals in sample, by species, recorded from throw trap and fyke net samples.
Fish growth	Fish condition (length/biomass) within size classes for selected species collected in throw trap and fyke net samples.
Fish diet	Gut contents of subsample of fish collected in throw trap and fyke net samples.
Larval mosquitoes	Dip samples collected weekly from April through August along transects that intersect standing water on the marsh.
Birds	
Small passerines and other cryptic species	20-minute observation periods from center of 50-m radius counting circles established in the salt marsh.
Birds in the buffer	20-minute observation periods from center of 50-m radius counting circles established in the t to the salt marsh. ation periods from site-specific vantage points continued throughout the winter sh is ice free).

From: A Monitoring protocol to assess tidal restoration of salt marshes on local and regional scales, Neckles et al. 2002

“Pentagram” metrics groupings:

1. Physical/chemical/nutrients
2. Vegetation
3. Food web (in-situ)
4. Processes
5. Fish

	A	B	C	D	E	F	G	H	I	J
1					Observation methods					
2	*Southern Suisun Marsh metrics CE 8-4-10*	Conceptual Model/Hypothesis	Link to Logic Chain Subobjectives	Comparison options:[2] treatments (TR); reference (REF); pre-project (PrePr); modeling (MOD).	Ongoing continuous logging	Ongoing discrete sampling	Special study	Remote Sensing	periodic survey (topo, veg, soil)	Modeling
35	**2. VEGETATION**									
36	Area of emergent vegetation by species	System state information; emergent veg is an indicator of elevation, salinity, and habitat association	same as above	TR, REF, PreProj				X	X	
37	Area of SAV and FAV by species and season	System state information; native SAV/FAV provide invertebrate food and structural fish habitat.	same as above	TR, REF, PreProj				X	X	
38	Low, intermediate and high intertidal associated plant community composition	System state information; plant community composition and pattern will ultimately mimic reference sites	same as above	TR, REF, PreProj				X	X	
39	Composition (ID, density, height, richness, aboveground biomass, stem density, proportion flowering)	Restored marshes are on trajectory of change toward native plant species, pattern, and richness								
40	**3. FOOD WEB (in-situ)**									
41	Chlorophyll a	Shallow water habitats are largely autotrophic and will produce an excess of carbon material that may provide energy subsidied to adjacent pelagic habitats.	same as above	TR, REF	X	X	X	X		X
42	Phytoplankton species	System state/census	same as above	TR, REF		X				
43	Primary productivity	Marshes are light and nutrient rich and produce ecosystem food web energy in excess.	same as above	TR, REF			X			
44	Zooplankton species/density	System state/census; Primary consumers are produced in excess in tidal marshes and represent the primary trophic pathway to pelagic productivity	same as above	TR, REF		X				
45	Zooplankton species habitat/structure associations	Tidal marsh abiotic and biotic structure are loci for invertebrate attachement and food acquisition.	same as above	TR, REF		X	X			
46	Bivalve species/density, benthos species/density		same as above	TR, REF		X				

Conceptual Model/Hypothesis

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Link to Logic Chain Sub-objectives

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Comparison options:

reference, treatment, pre-project, modeling

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Observation methods:

log continuous, discrete sample, special study, remote sensing, survey, modeling

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Are these enough? Consider:

1. Initial condition is hyper-degraded (e.g. subsided). Therefore, metrics should change through time.
2. Most metrics themselves are emergent phenomena (e.g. elevation recovery)
3. Little emphasis on landscape perspective, so far.

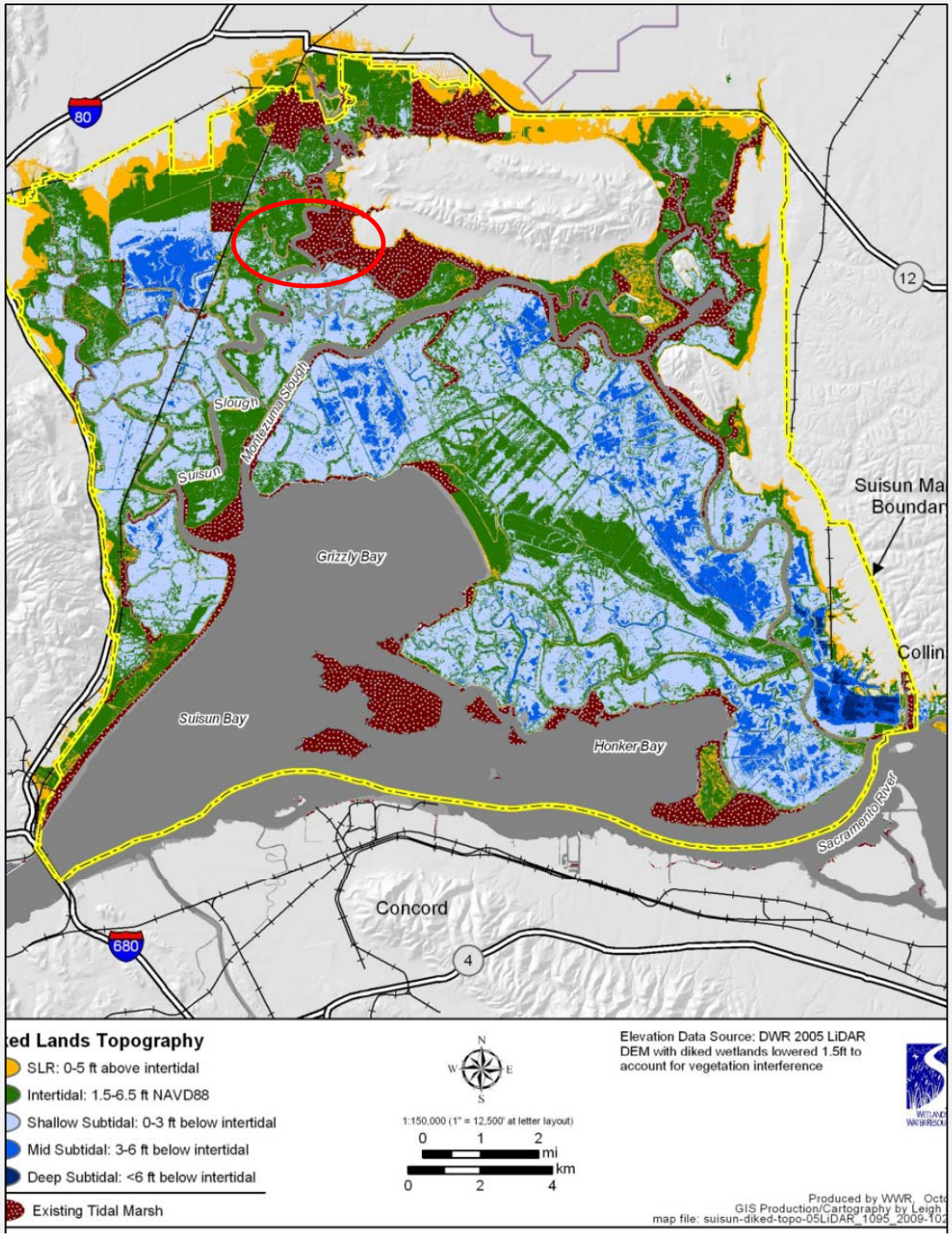
The initial condition is hyper-degraded (e.g. subsided).

1. Metrics should change over time.

Brown = ~Natural tidal marsh

Green = Intertidal elevation

Blue = Below sea-level



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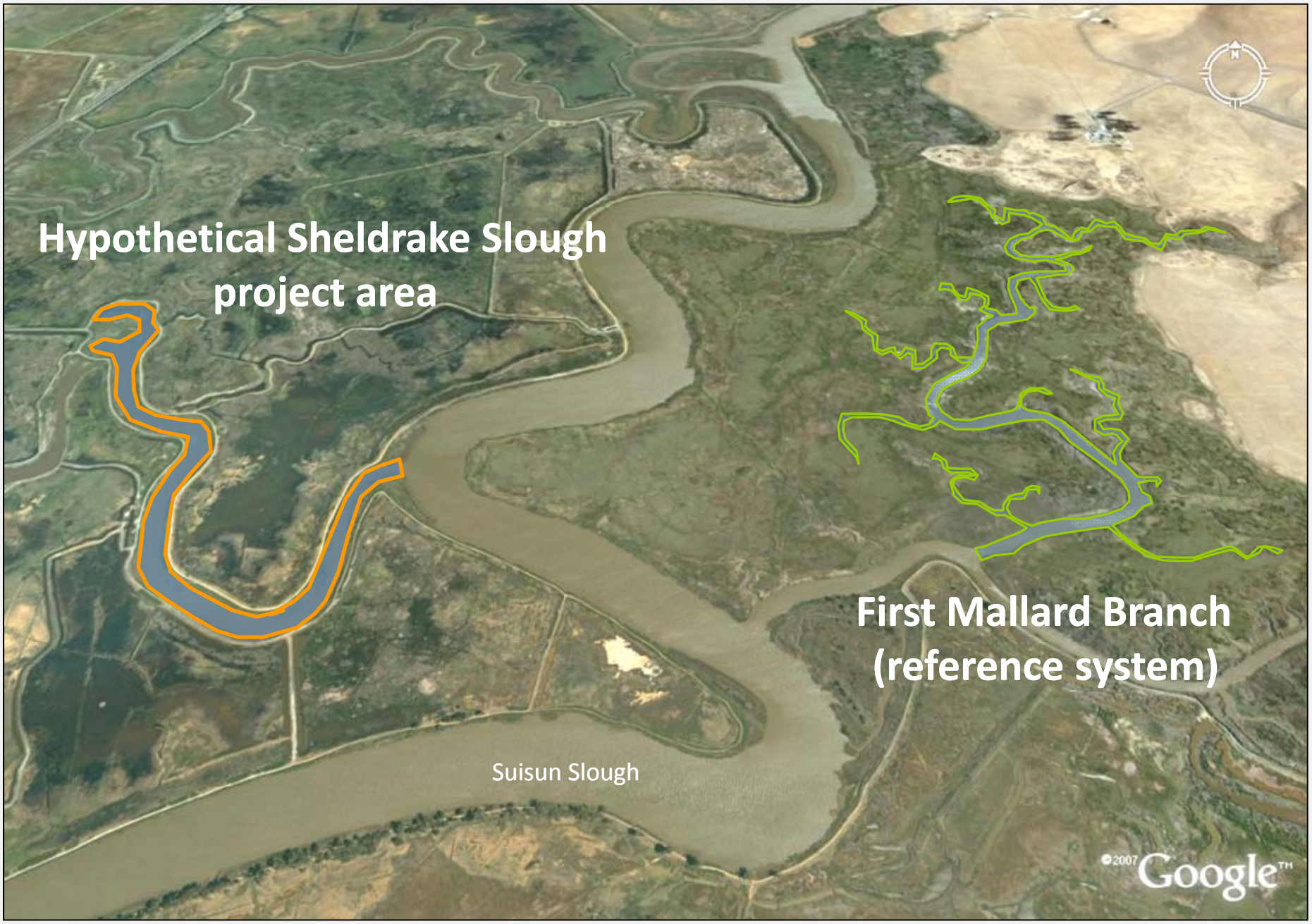


1. Metrics should change over time

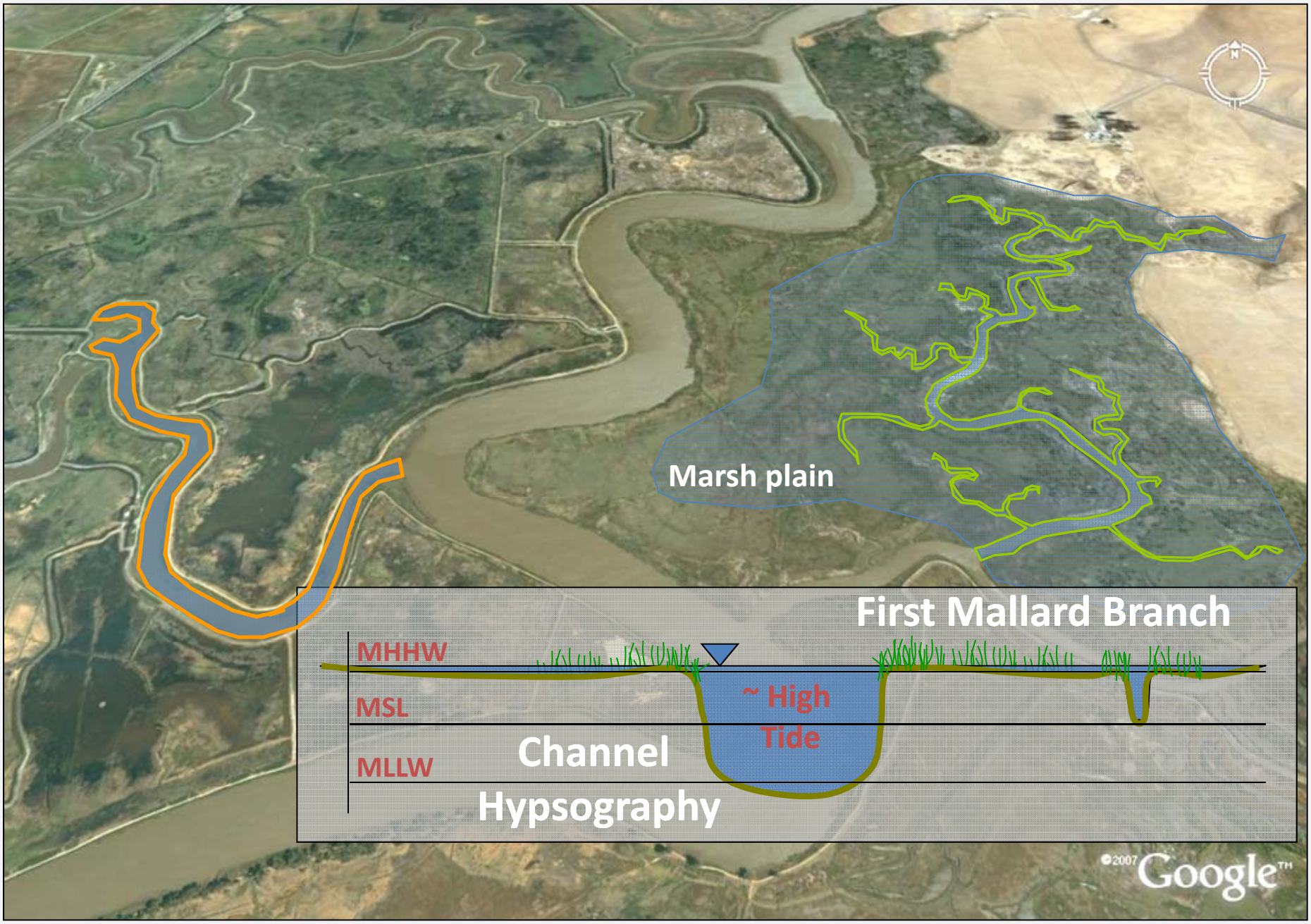
Land-water interface structure

Simple (degraded) L-W interface

≠

Complex L-W interface

1. Metrics should change over time



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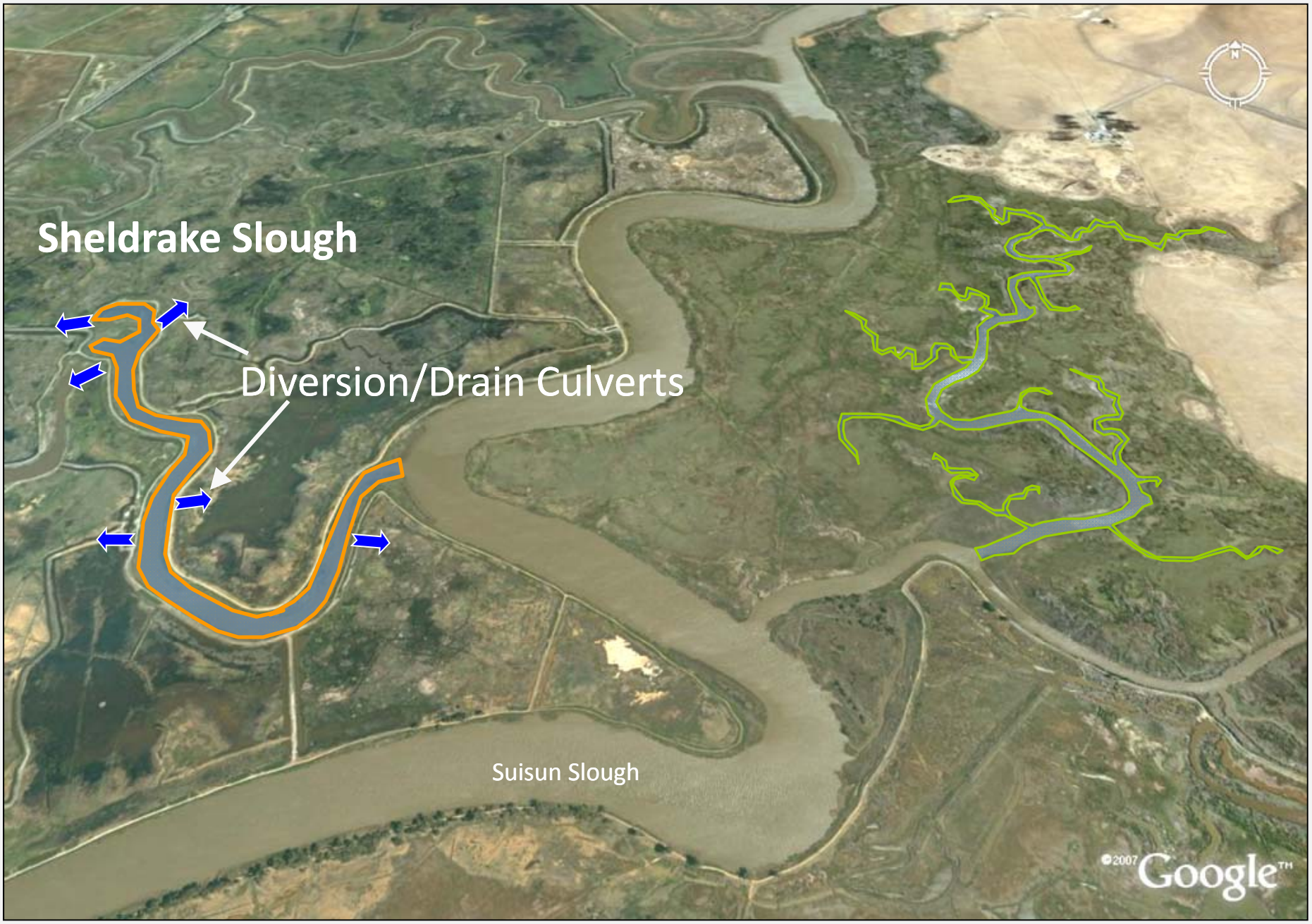

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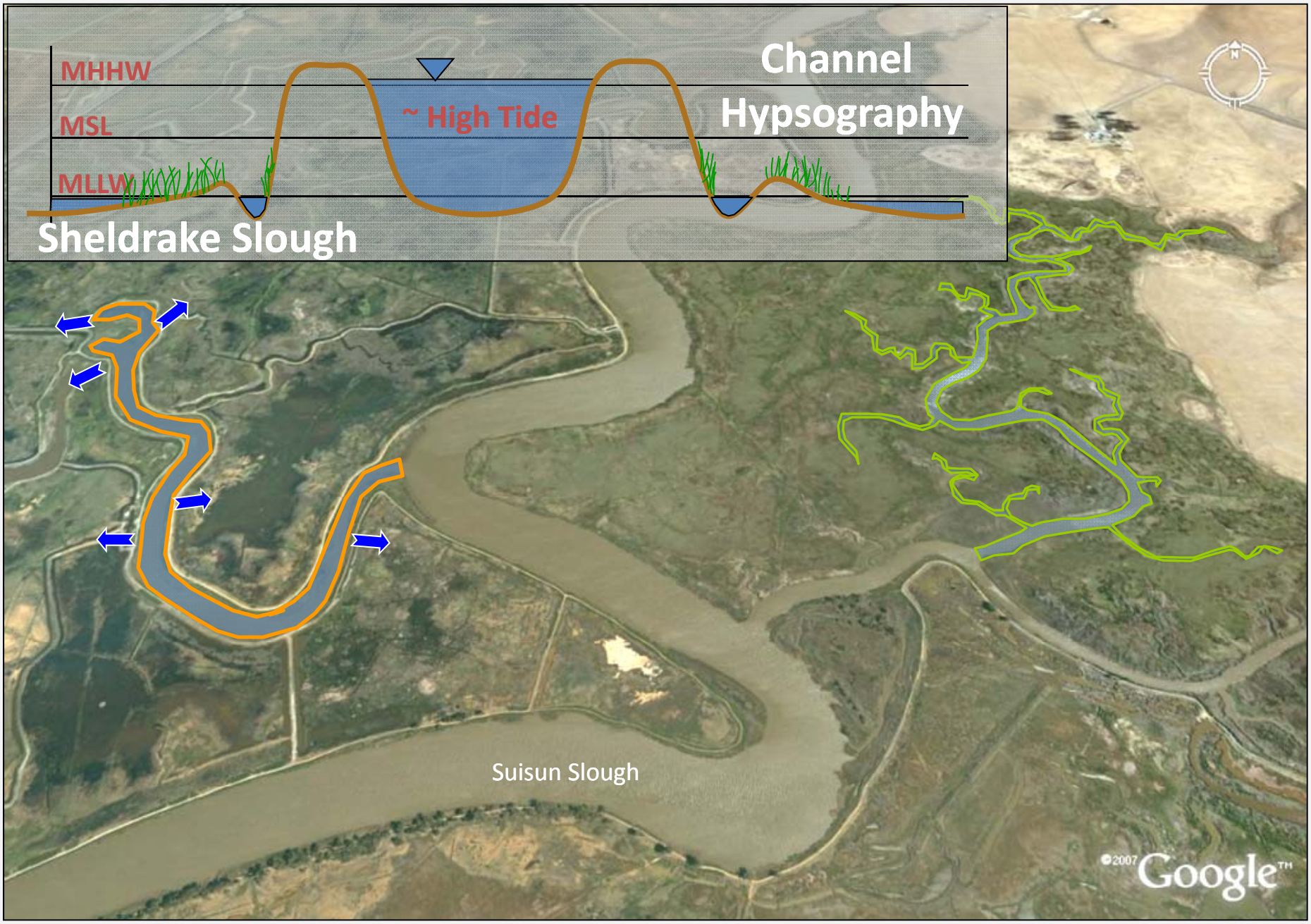

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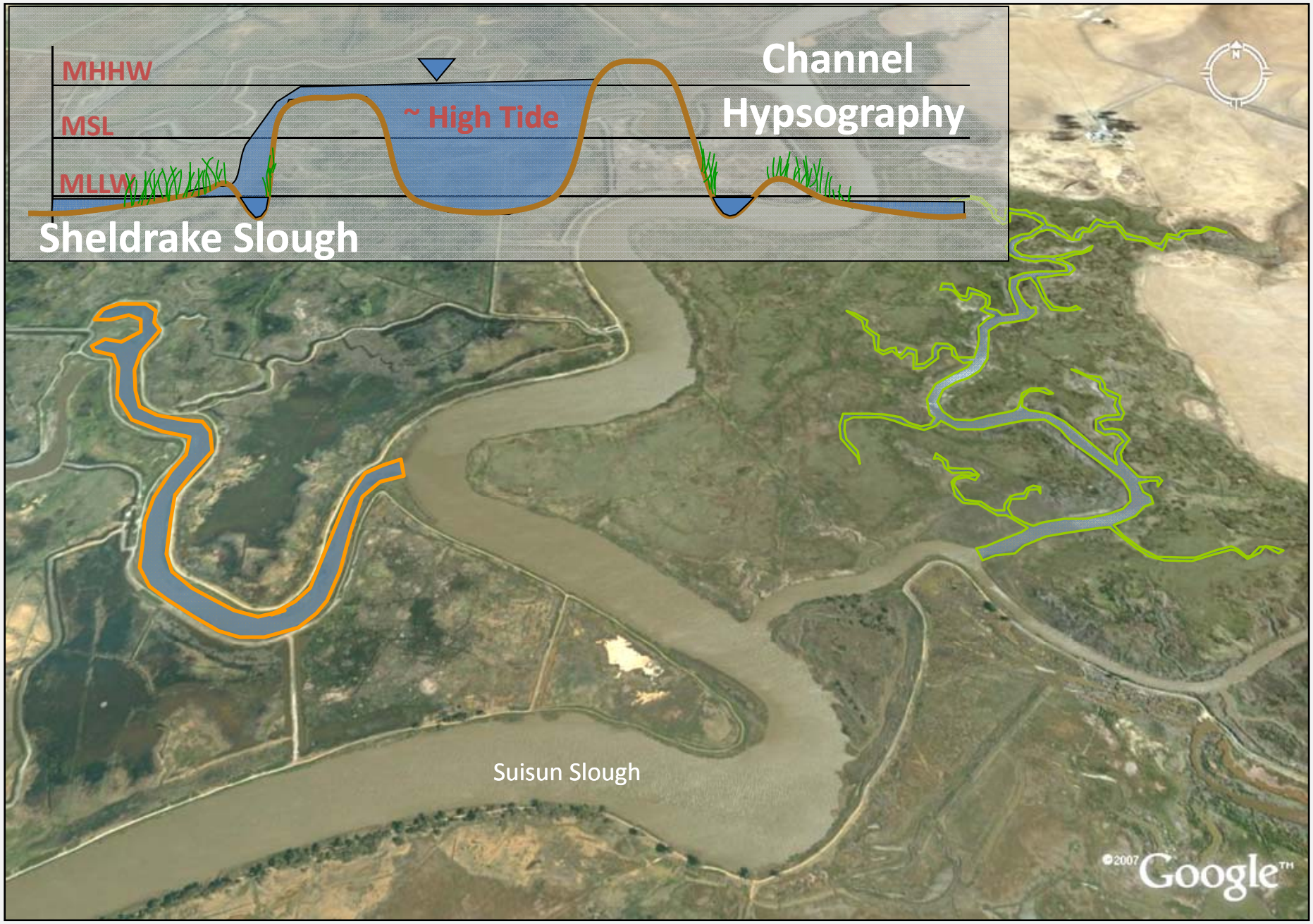

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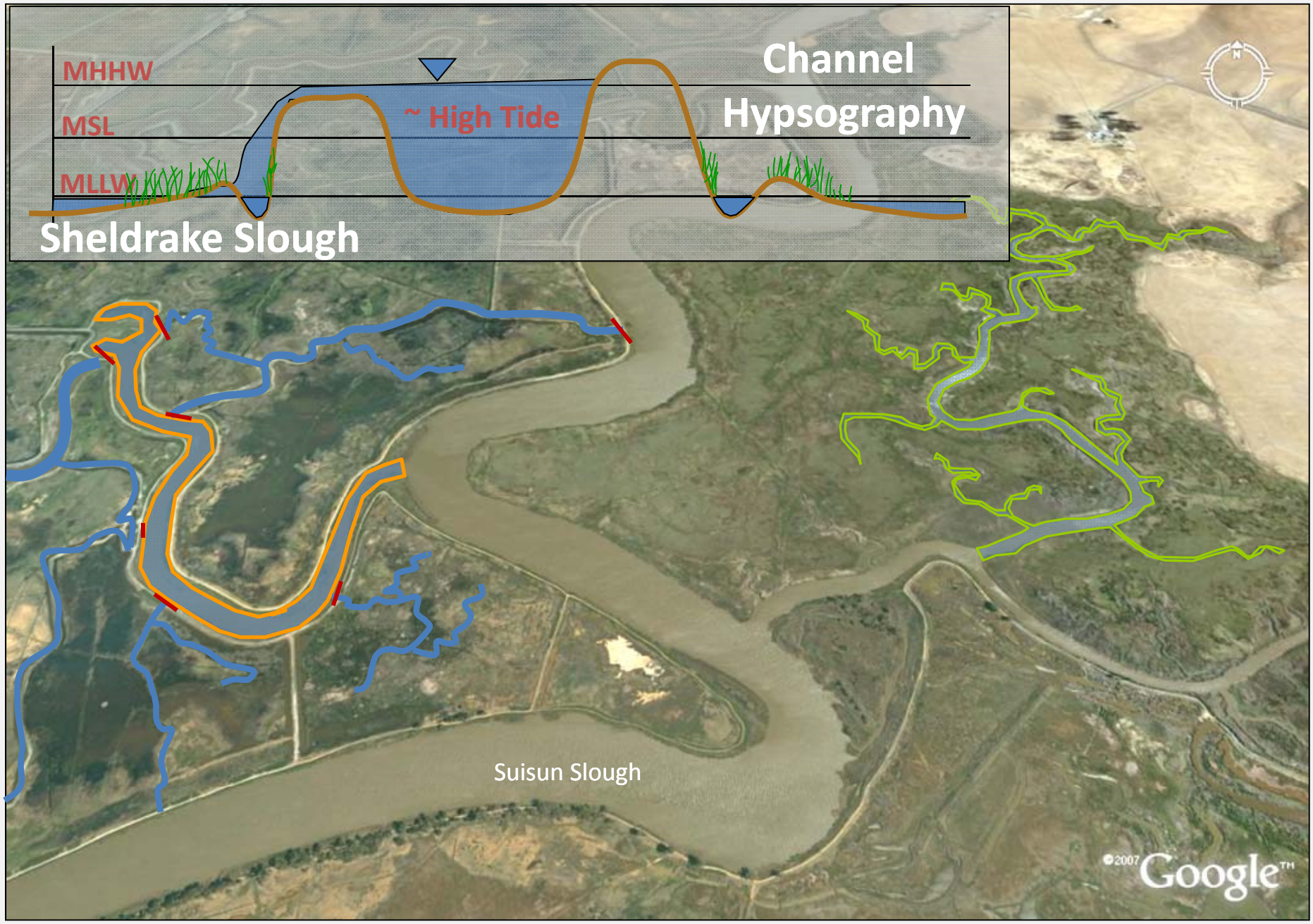

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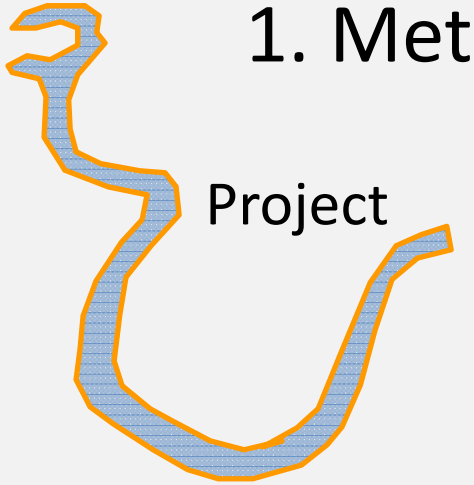


Initial metrics

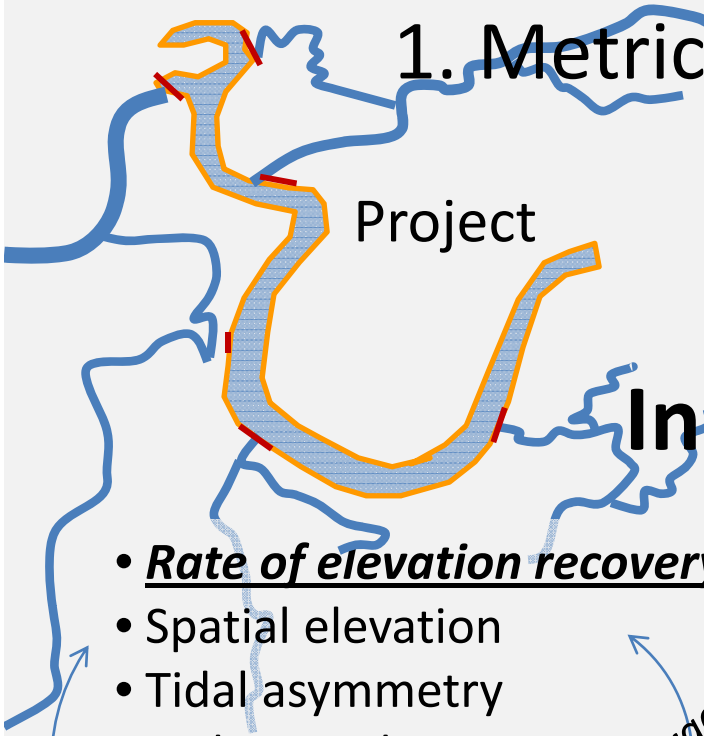
Landscape scale structure and connectivity:

- Tidal signal
- Elevation of everything
- Dendritic channel complexity, density
- Allometric diversity
- Tidal/S-N/Seasonal sediment dynamics
- Soil OM
- Spatial pore water salinity

Veg., Fish, Food Web, Processes:

- Soil OM
- Seasonal plant and animal composition- abundance, height, density, length, biomass
- Species richness
- Veg composition (ID, density, richness, biomass etc)
- Fish abundance by species, diet, percent alien, sub-habitat associations etc.
- Food web (Chl a, phyto species, PP, zoop species, habitat associations, bivalves, benthos, C/N etc.

1. Metrics should change over time



Initial metrics

- ***<u>Rate of elevation recovery</u>***
- Spatial elevation
- Tidal asymmetry
- Sediment dynamics
- Spatial hydroperiod
- Rate of veg. expansion
- Diversity of residence time

Interactions

+

- Veg and animal composition
- Species richness
- Soil profile: OM, redox, etc.
- Community interactions
- etc.

Landscape scale structure and connectivity:

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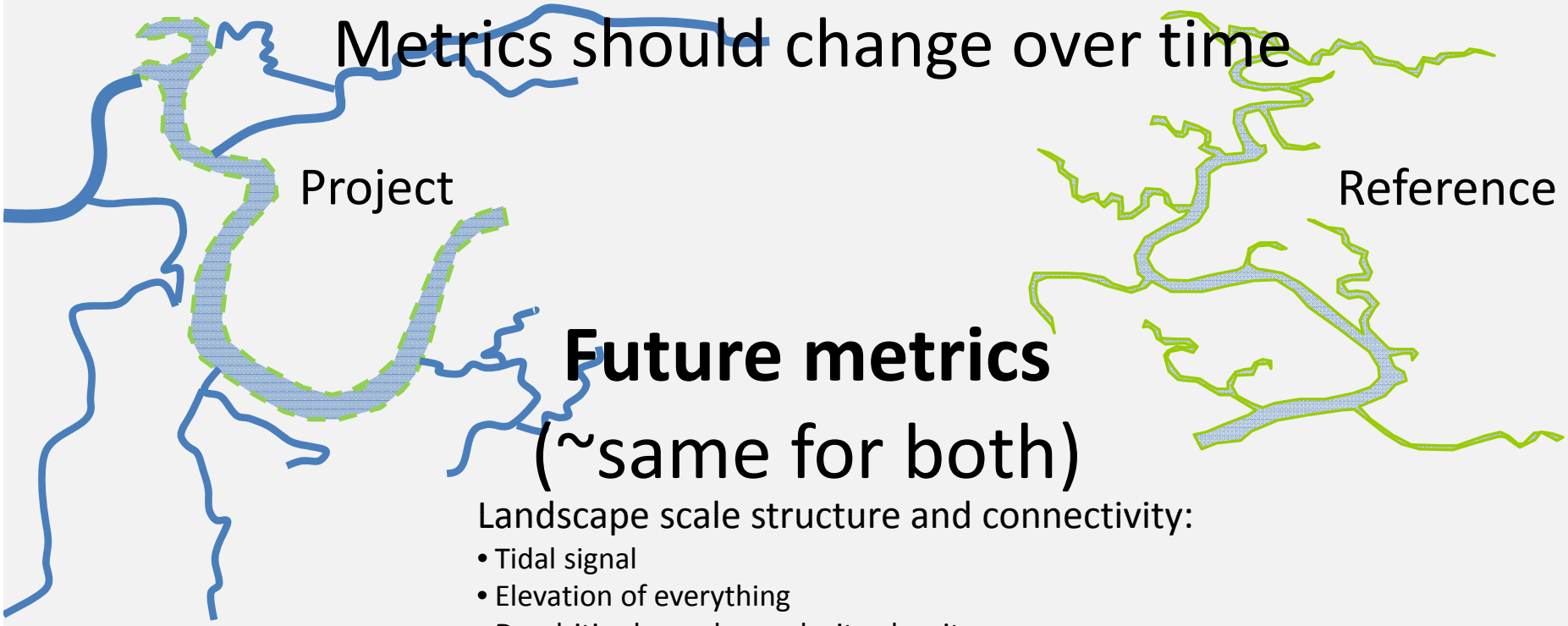
Metrics should change over time



Future metrics
(~same for both)

Landscape scale structure and connectivity:

- Tidal signal
- Elevation of everything
- Dendritic channel complexity, density
- Allometric diversity
- Tidal/S-N/Seasonal sediment dynamics
- Soil OM
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Veg., Fish, Food Web, Processes:

- Soil OM
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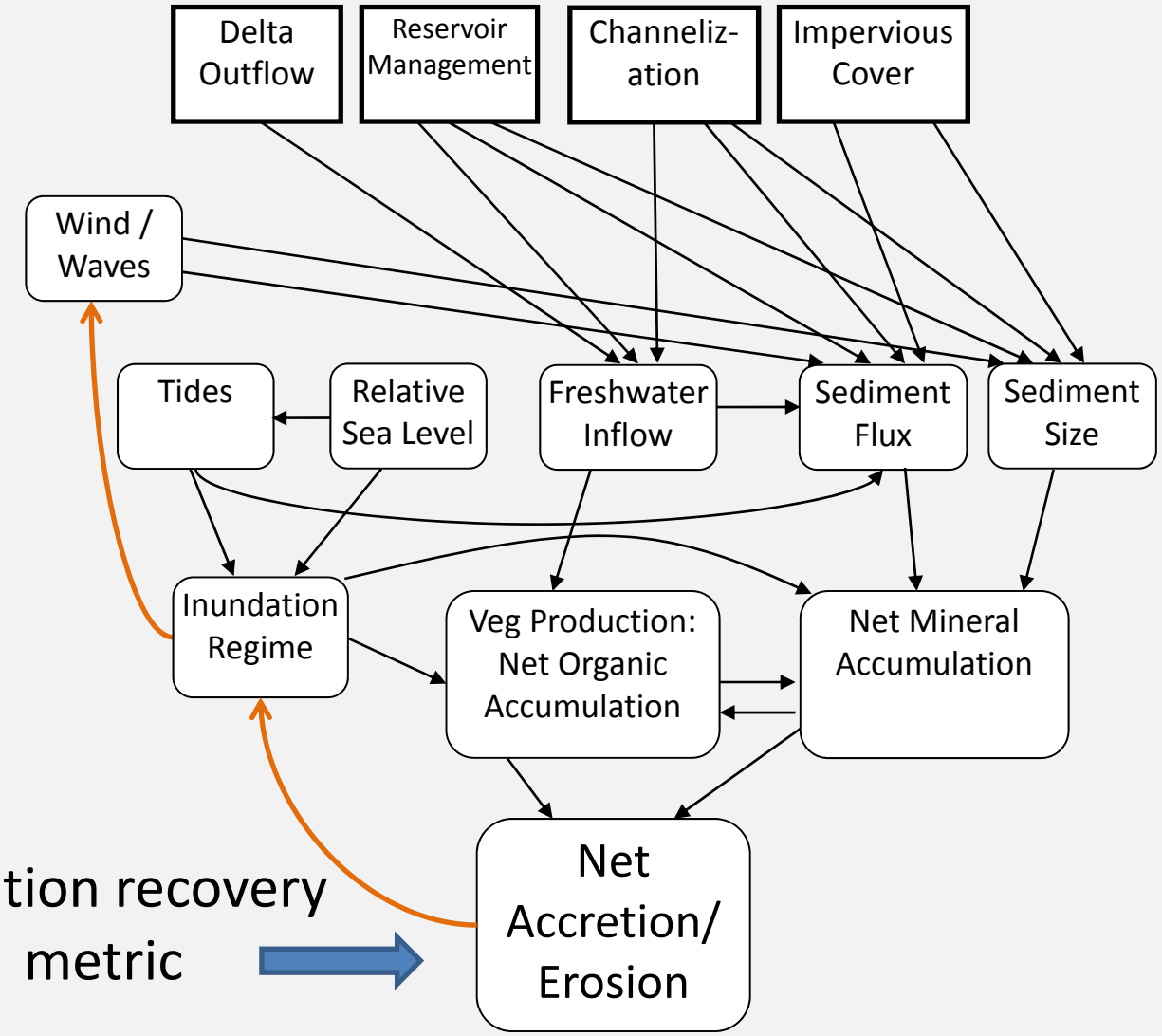
- Food web (Chl a, phyto species, PP, zoop species, habitat associations, bivalves, benthos, C/N etc.

2. Metrics themselves are emergent phenomena. For example: "**Elevation recovery**"

Interactions are affected by

- non-linearities
- feedbacks
- thresholds
- human decisions



Elevation recovery metric

3. Landscape perspective

- Wiens 2002: "…the influence of spatial pattern on ecological processes."
- Simenstad et al. 2001: "...life history strategies depend on structure and scale rather than habitat per se."
- Peterson 2003: "Nekton survival depends on… (1) approaching physiological optima, then (2) searching out life-stage-dependent structure…"
- NRC 1992: "Restoration… is a holistic process not achieved through isolation manipulation of individual elements."

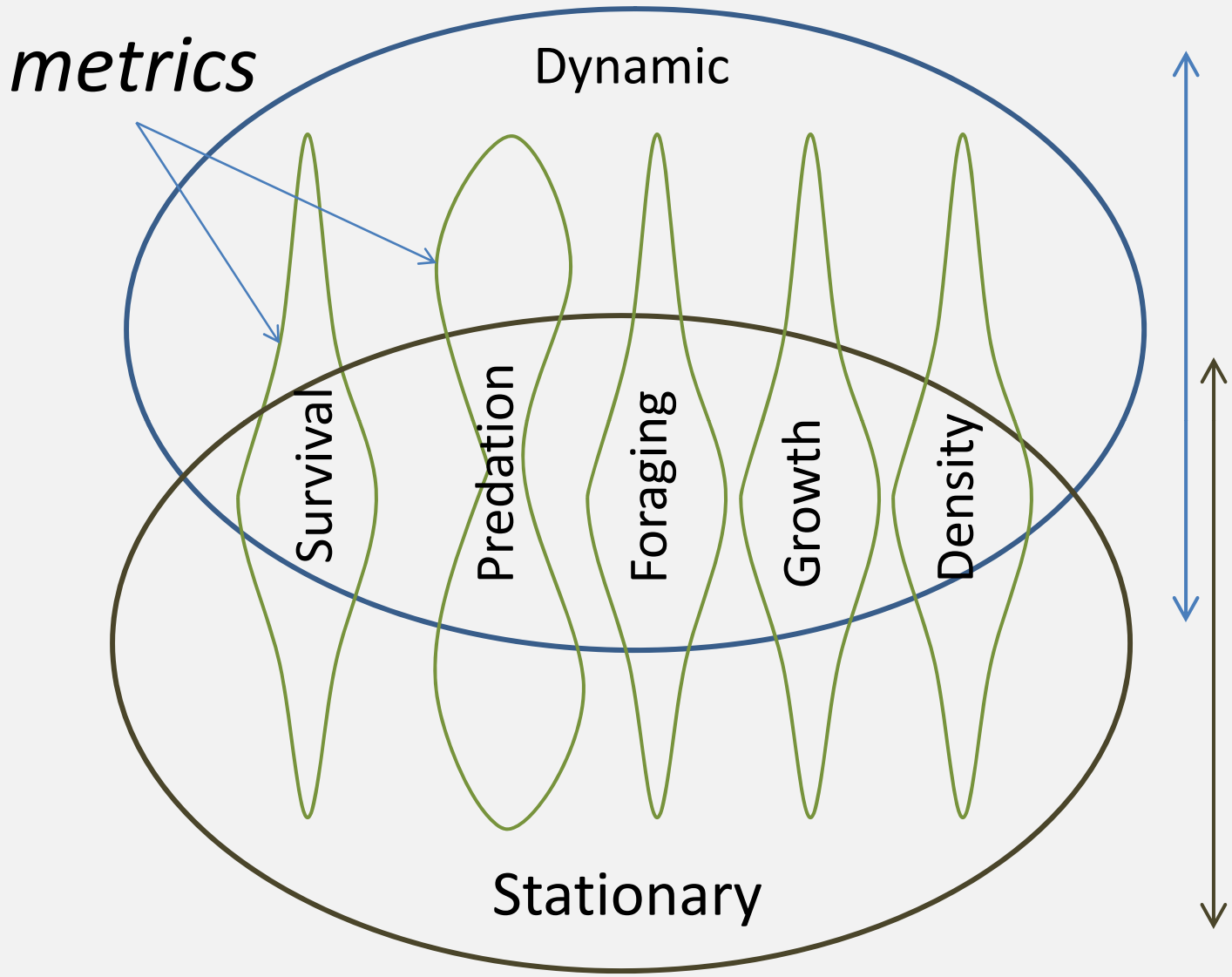
3. Landscape perspective

- Emphasis is on pattern-process relationships
- The landscape is a connected mosaic of patches of variable permeability at multiple scales.
- Organism response to landscape is determined by behavioral, morphological, life-history traits

3. Landscape perspective

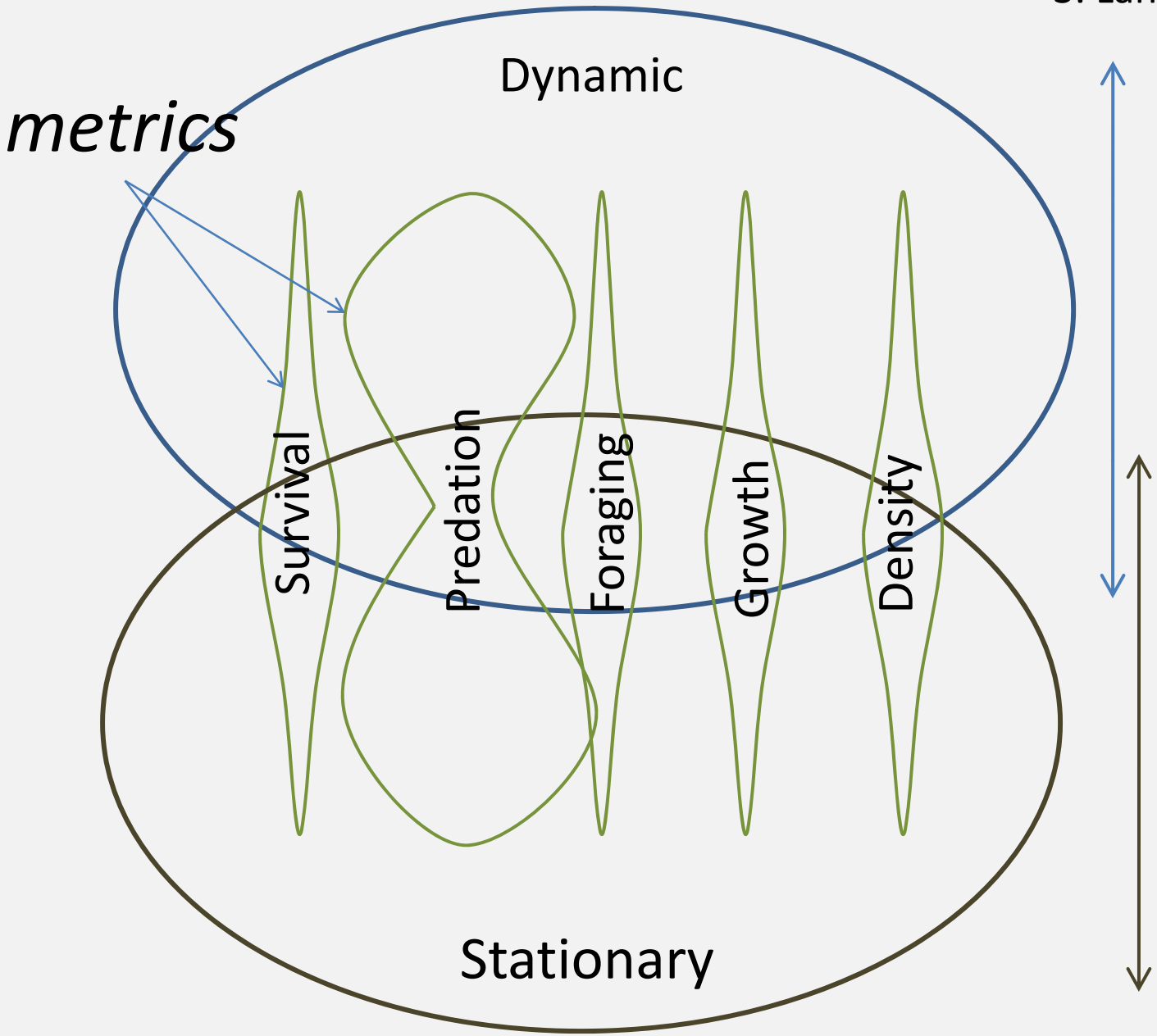
- Fish population metrics for assessing wetland restoration success have not been conclusive (e.g. Simenstad 1997)
- What is the nature of estuarine dependency?

3. Landscape perspective

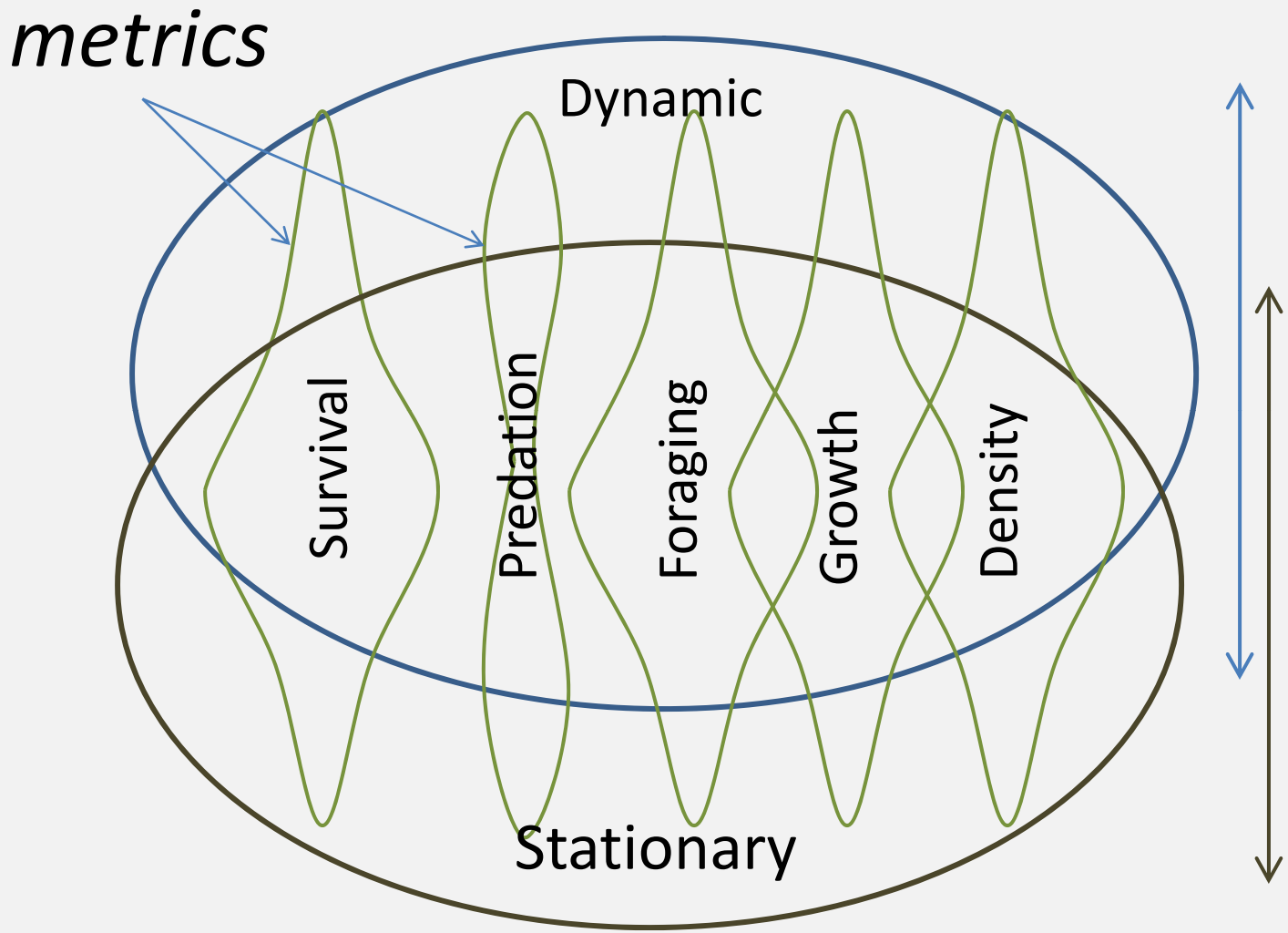


Adapted from Peterson 2003

3. Landscape perspective

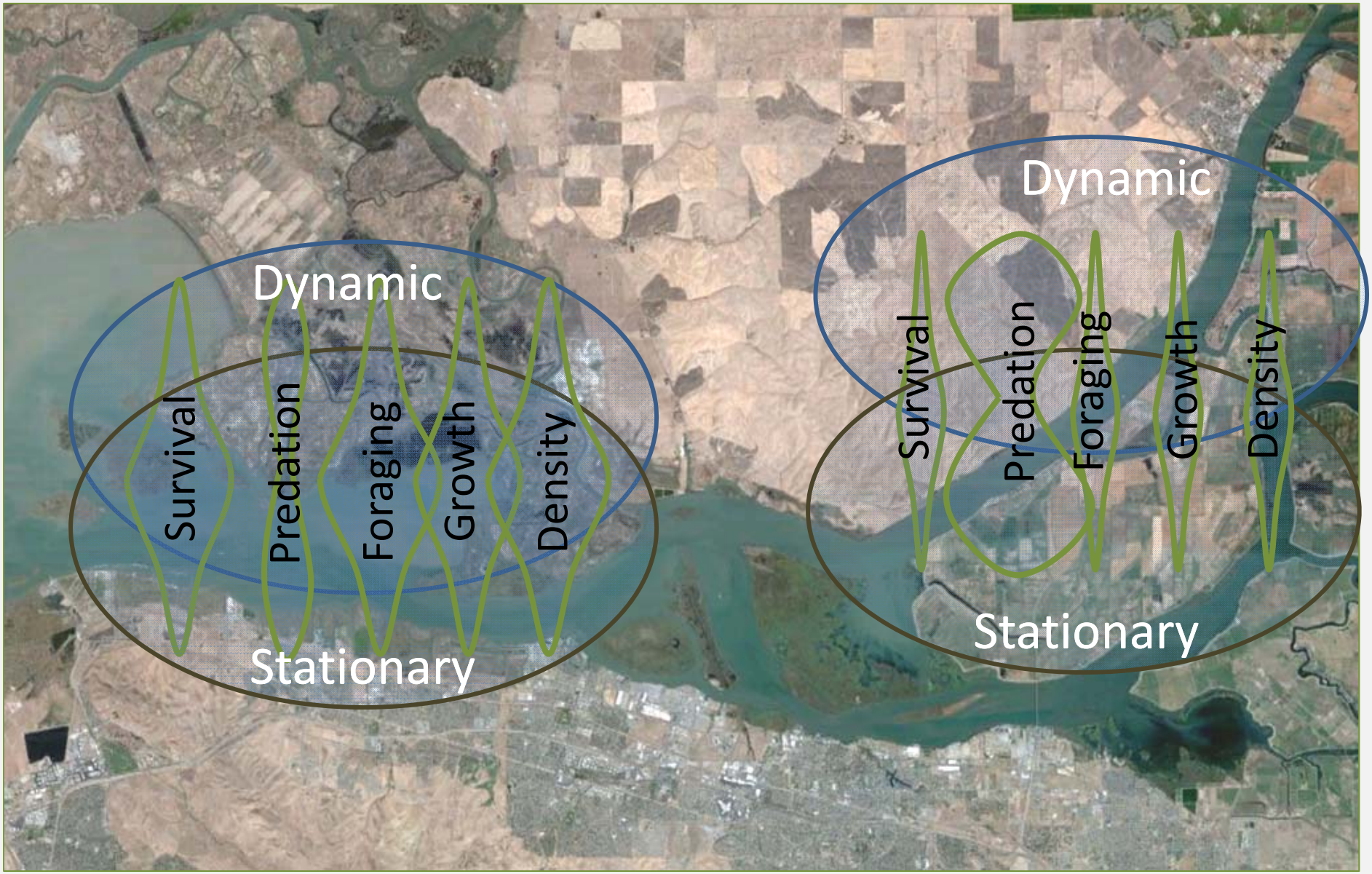


Peterson 2003

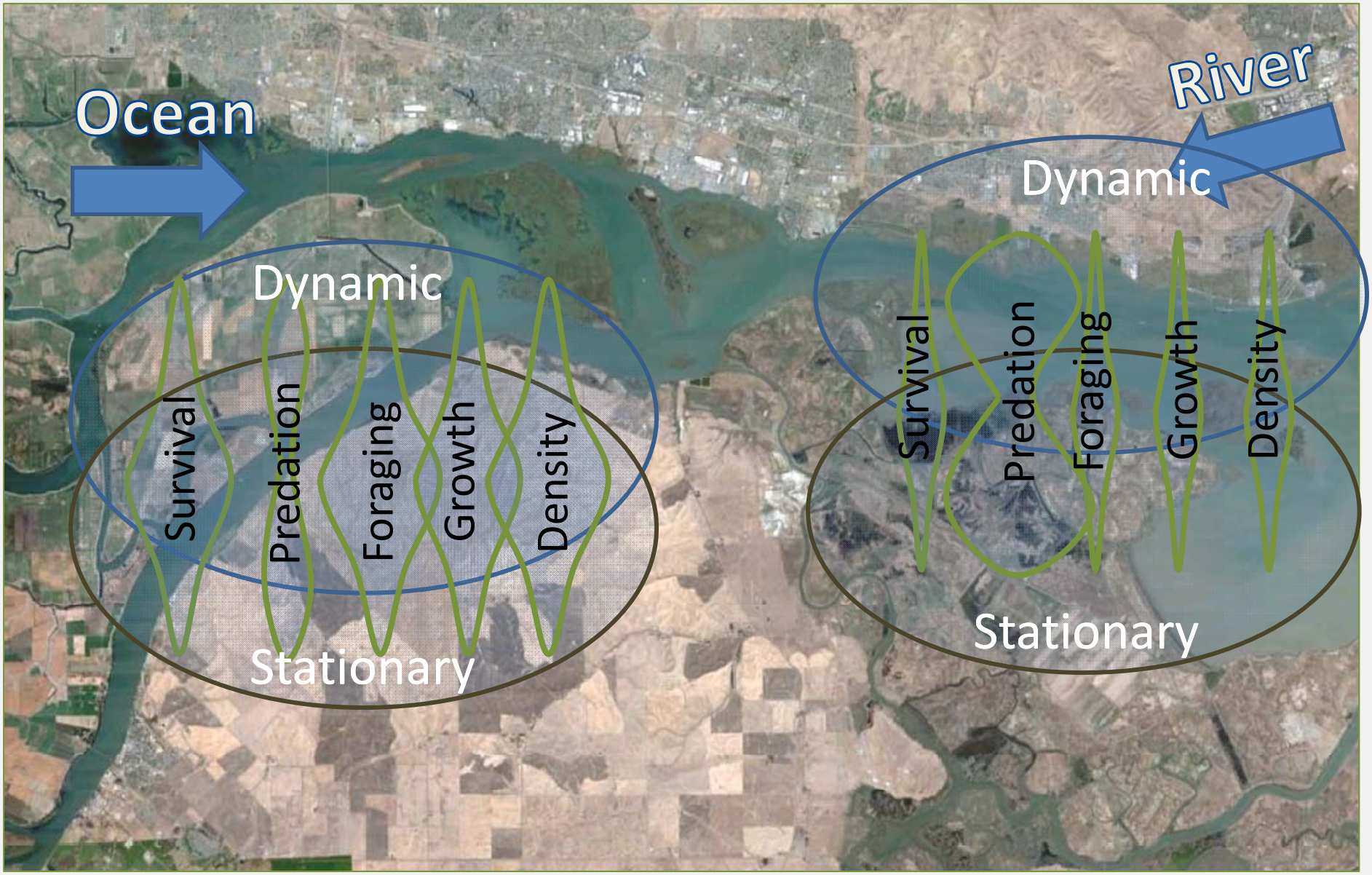


Peterson 2003

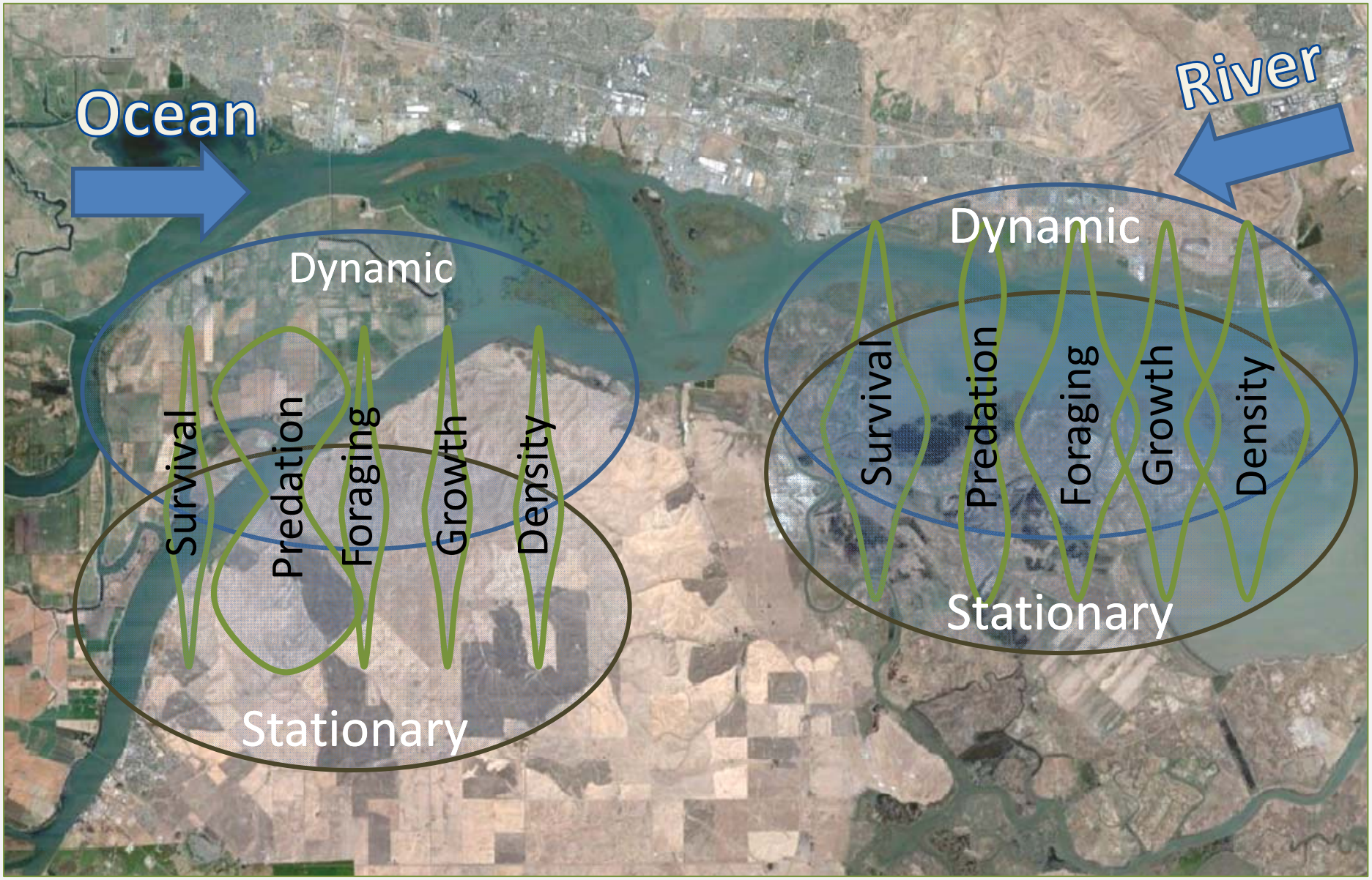
“Flow” and species conservation is contextual



“Flow” and species conservation is contextual

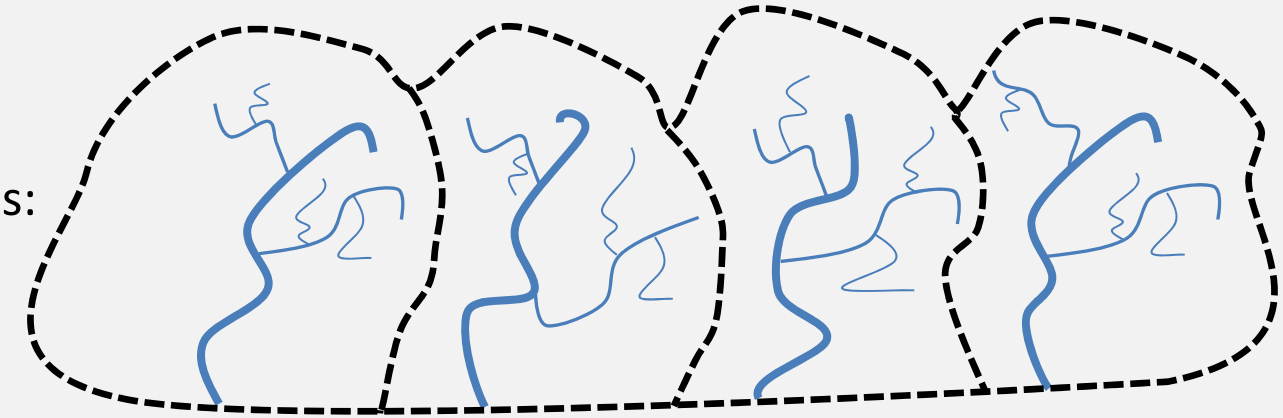


“Flow” and species conservation is contextual



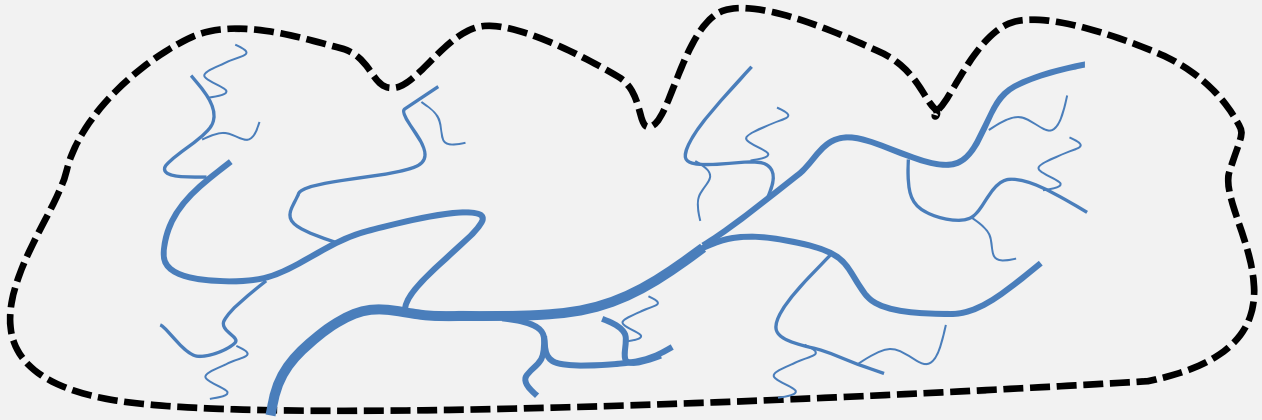
Production = capacity x access

40 acre marsh with
four 3rd order drainages:
- greater access
- less capacity



Marsh front

40 acre marsh with
one 4th order drainage
- less access
- greater capacity

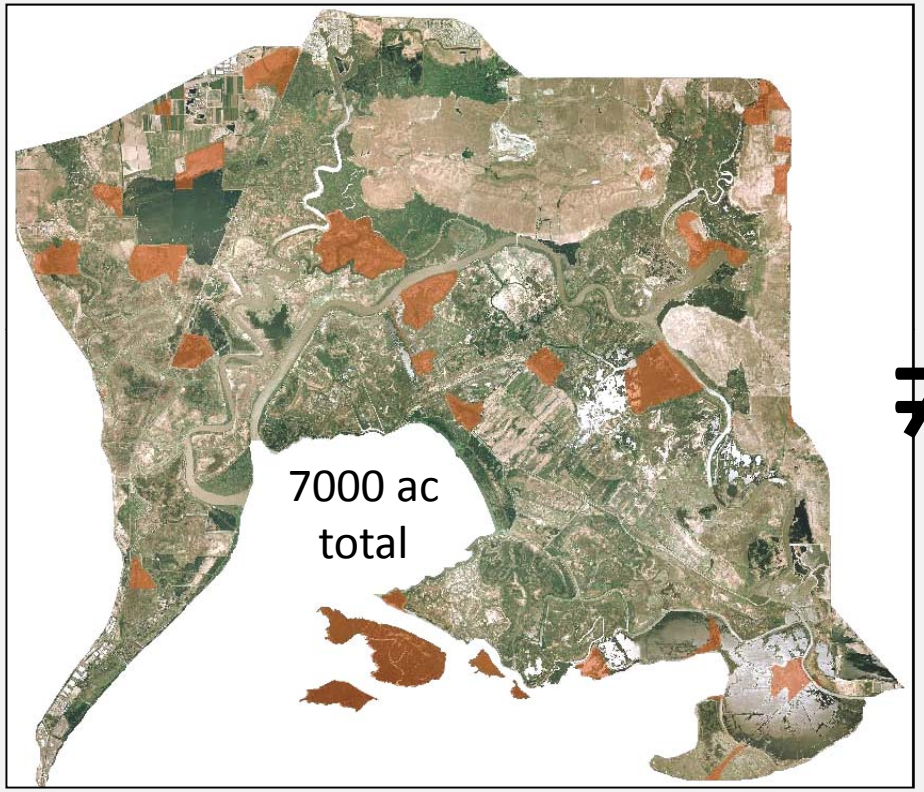


Marsh front

Adapted from Simenstad et al. 2001 from Coats et al. 1995

Alternative restoration approaches

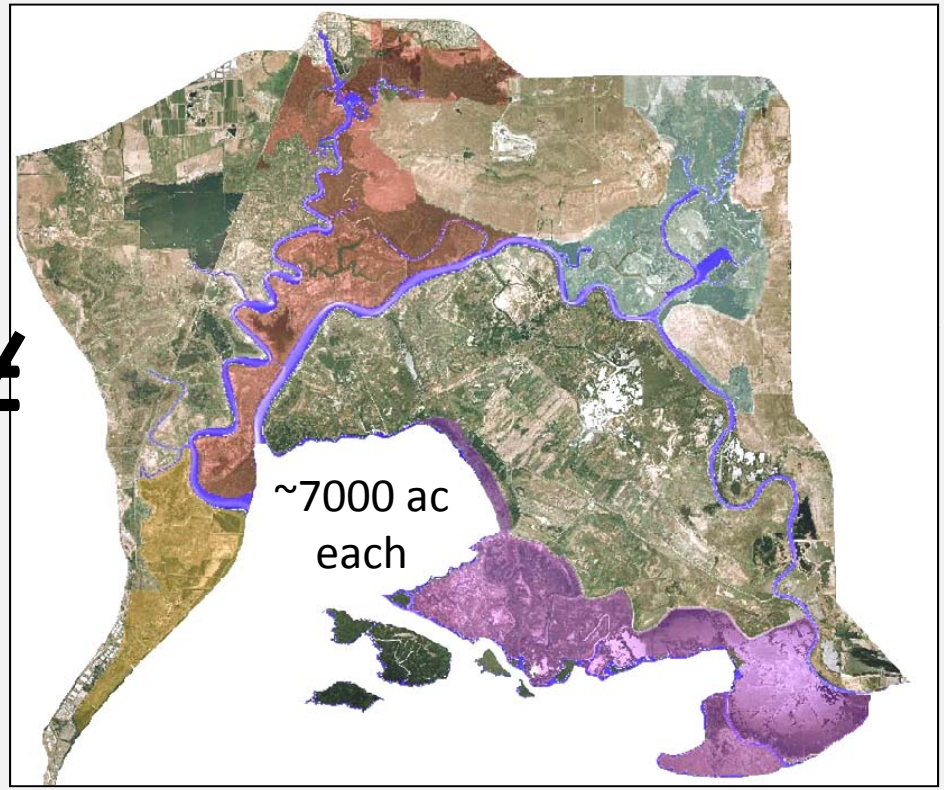
1. "Postage stamp" restoration



- Limited space
- High levee costs
- Little stationary/dynamic overlap

≠

2. Landscape "scaled" restoration



- Space for physical processes
- Stationary/dynamic overlap
- Capacity and access

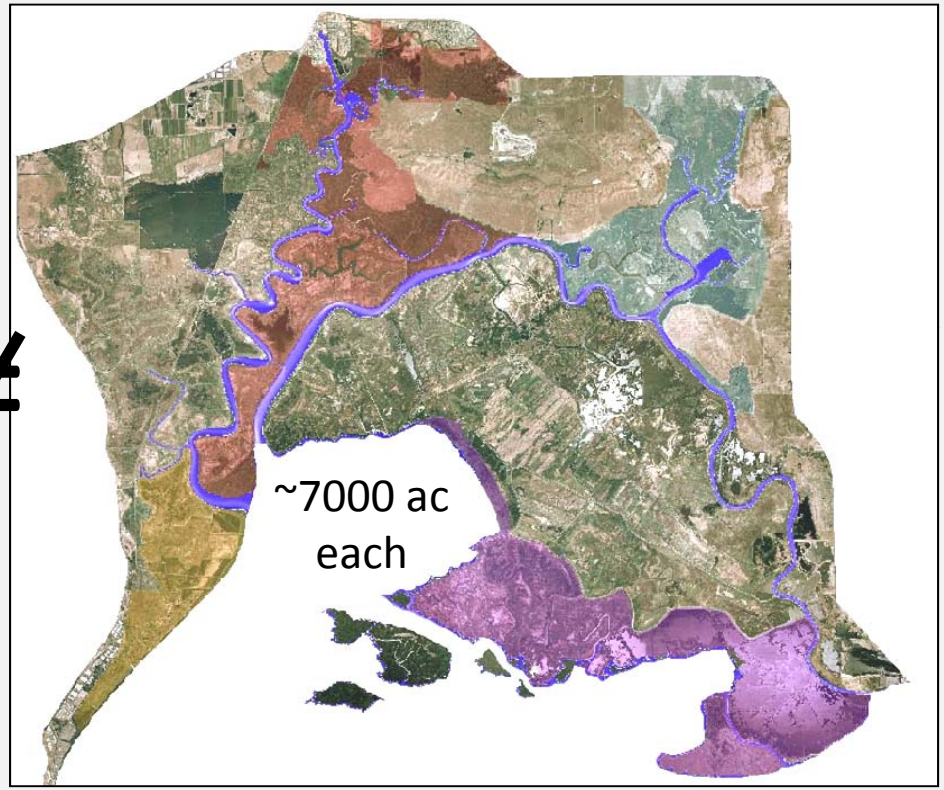
Alternative restoration approaches

1. "Postage stamp" restoration

- Limited space
- High levee costs
- Bad station/dynamic overlap

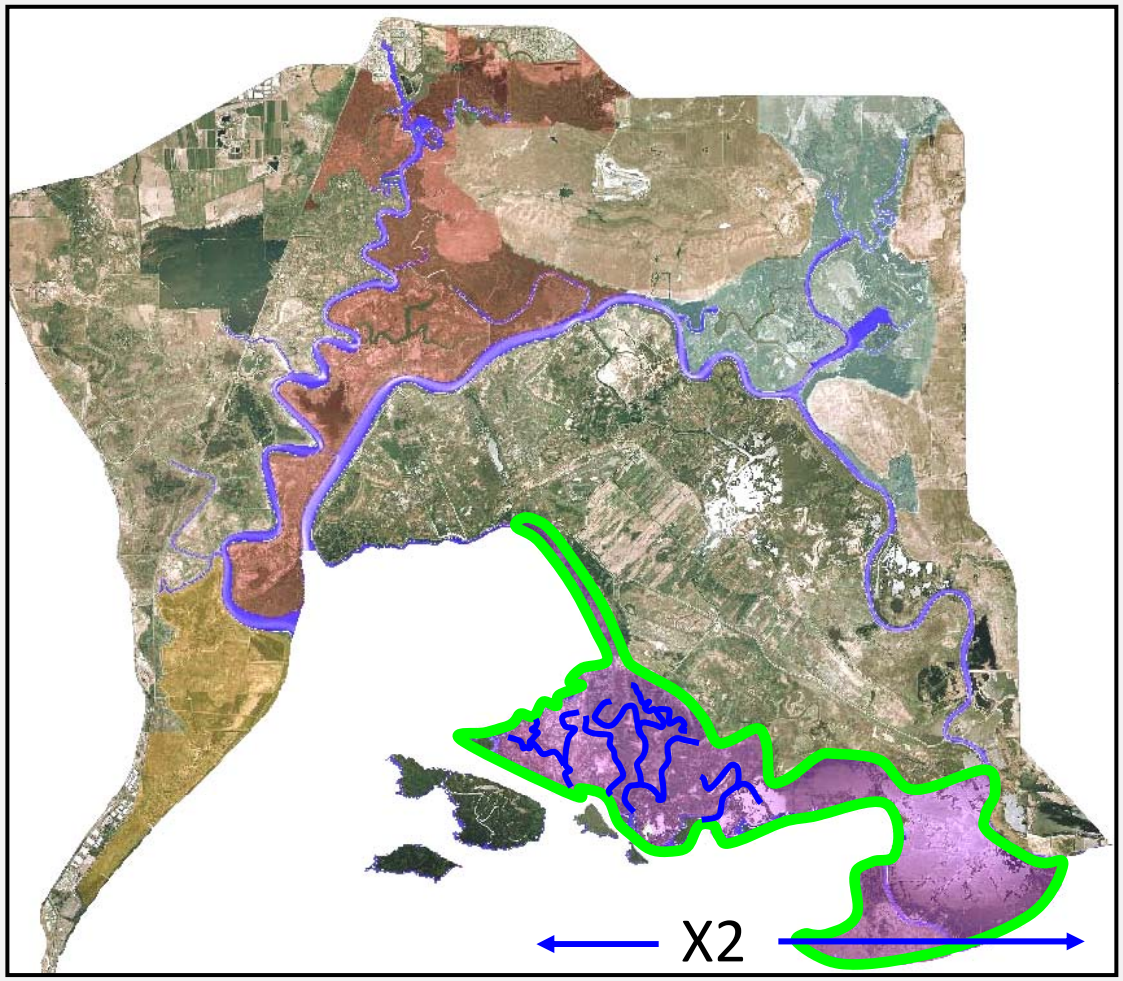
≠

2. Landscape "scaled" restoration



- Space for physical processes
- Stationary/dynamic overlap
- Capacity and access

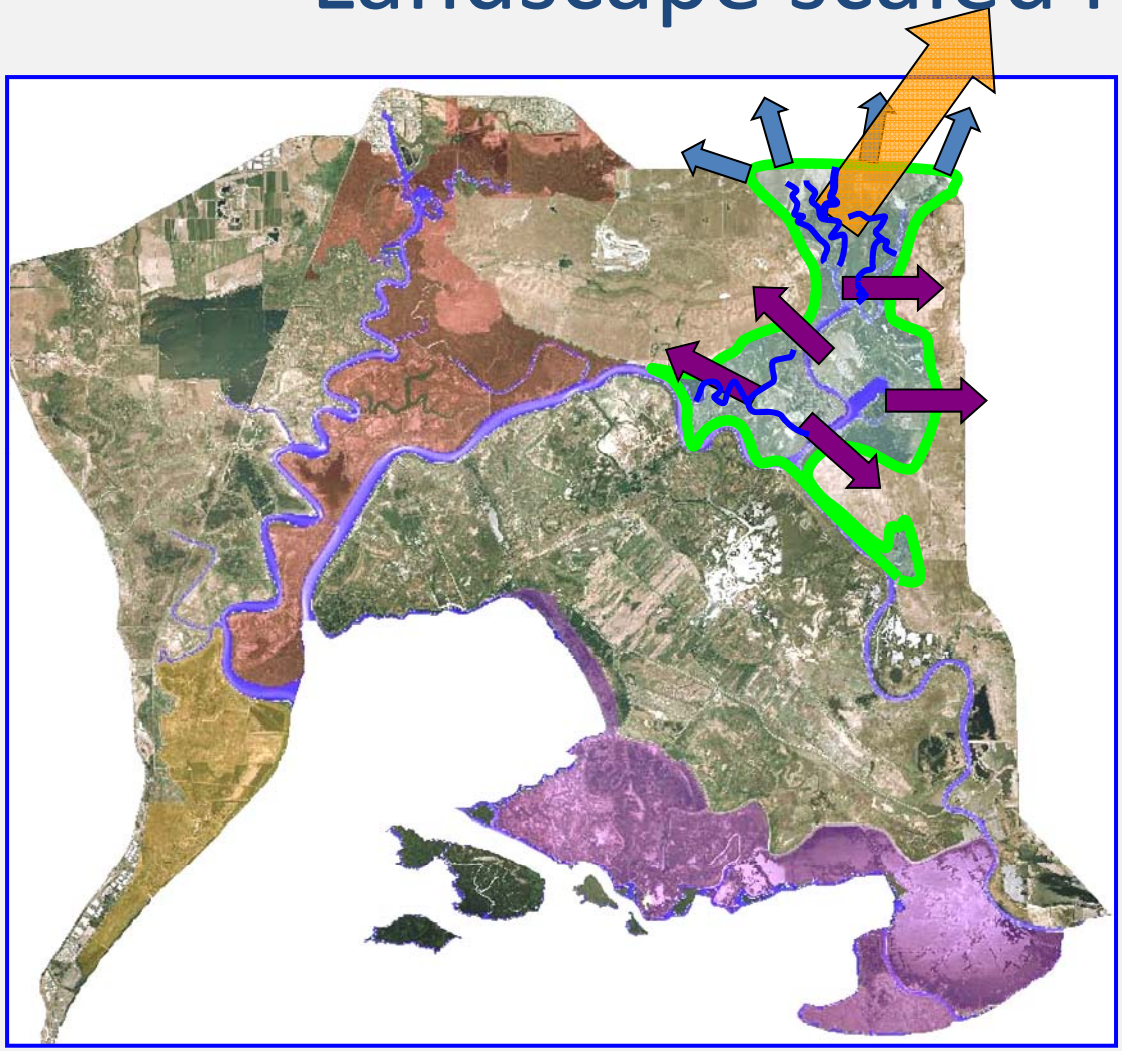
Landscape scaled restoration



South of Roaring River

- Adjacent to X2
- Salinity grad. corridor
- Delta smelt zone
- Sediment source rich
- Large remnant tidal creek systems.

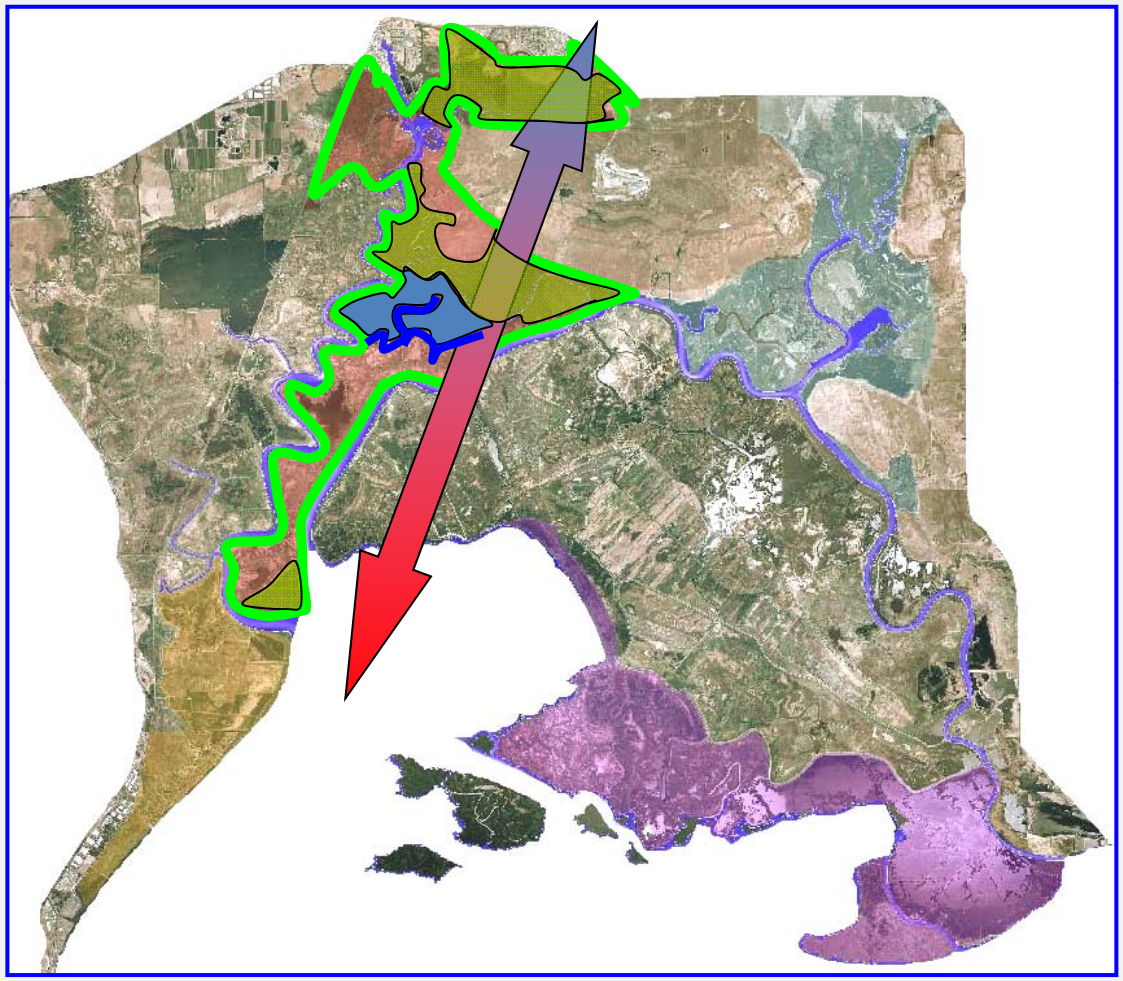
Landscape scaled restoration



Nurse Slough Complex

- SLR accommodation
- Minimal subsidence
- Terrestrial corridor
- Upland trans ecotone
- Large remnant tidal creek systems
- Fringing tule marsh.

Landscape scaled restoration

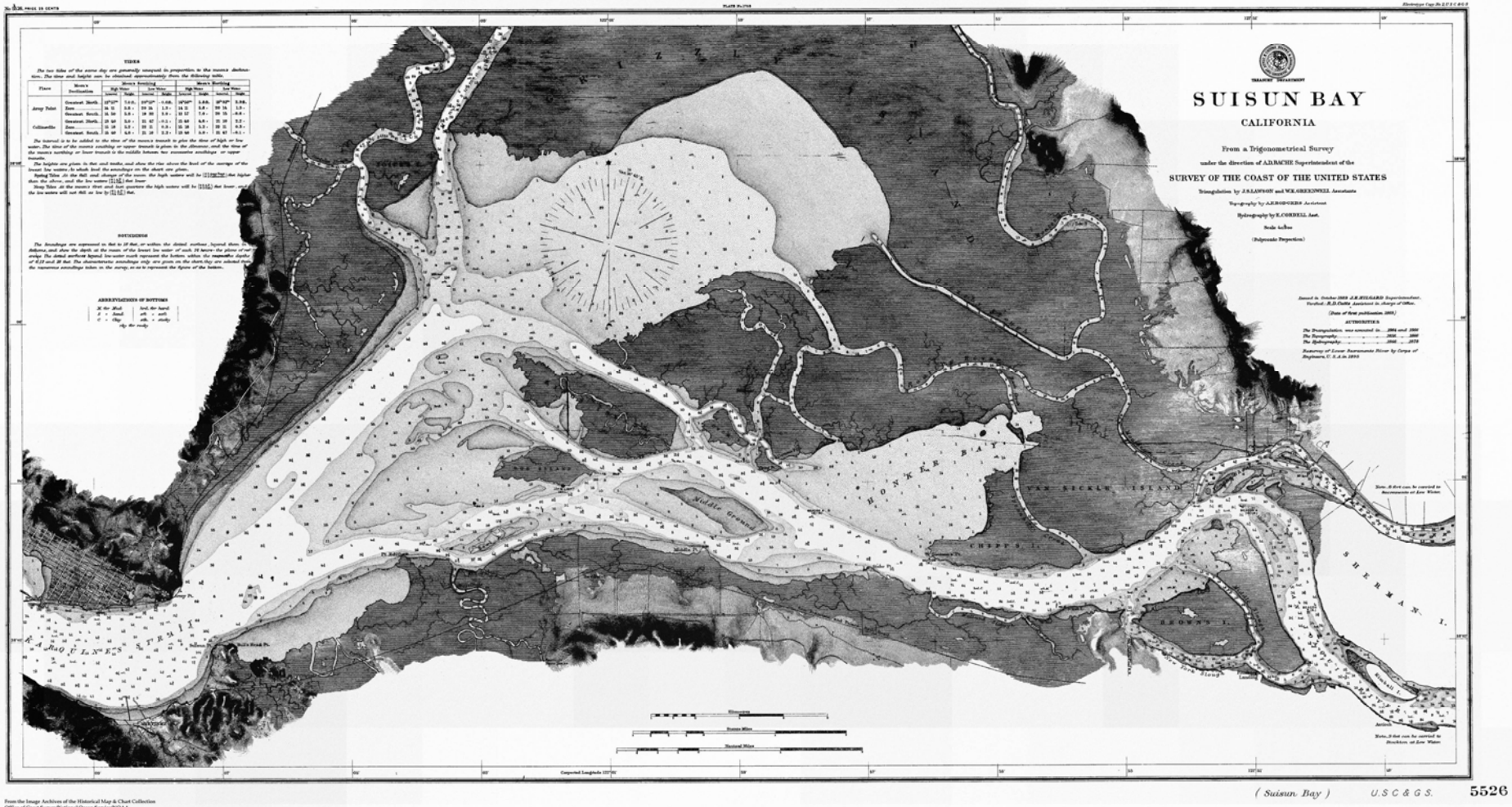


<u>Joice-Rush-Hill Corridor</u>

- Estuarine corridor
- Topographic diversity
- Remnant tidal sloughs
- Existing tidal marsh.
- …mostly public land

Here's how I would do a Southern Suisun restoration.

Consider the historical landscape



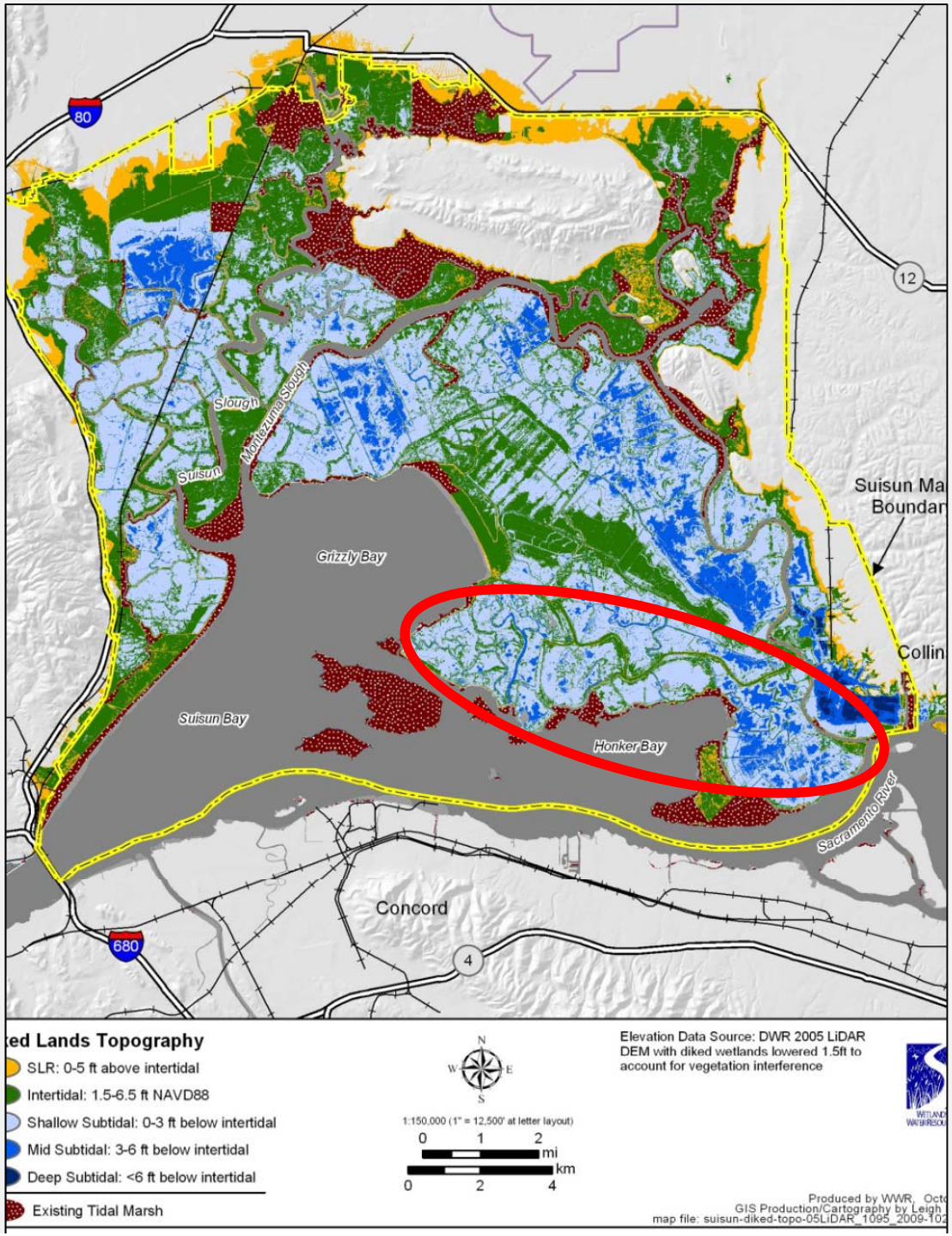
Suisun Marsh circa 1860 - 1870

Consider the modern landscape.

Brown = ~Natural tidal marsh

Green = Intertidal elevation

Blue = Below sea-level



Consider BDCP objectives

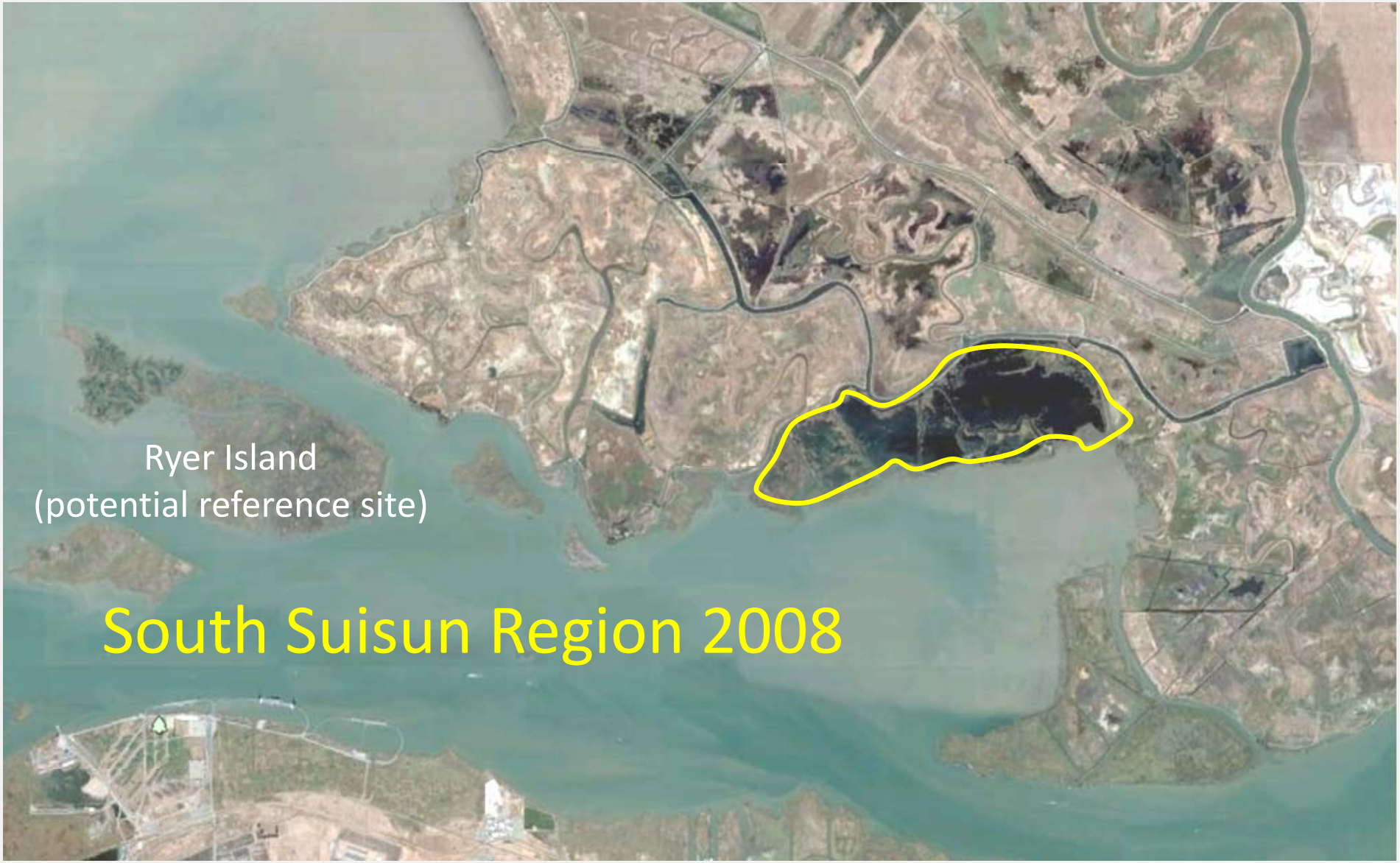
	A	B	C	D	E
3					
4	**Global Goal: Winter- run Chinook salmon will see substantial increases in their population productivity.**				
5	**NMFS Recovery Plan Overarching Goal: Increase Productivity of the Sacramento River winter-run Chinook salmon ESU, DPS to support its removal from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11).**				
6	**BDCP Species Goal**	Increase the proportion of each run of **adult** winter-run Chinook salmon that migrate successfully through the Delta to upstream spawning habitats.			
7	**BDCP Objectives:** *Note that blank (__) variables need additional input on appropriate percentages, measurement, and methodologies intervals for the objectives.*	Increase immigration survival of adult winter run chinook salmon by __% within 20 years of permit issuance. Maintain passage improvements thereafter.			
8	**Stressors/Limiting Factors:** *Note: Stressors summarized from NMFS stressor matrix on 6th tab bottom right. Order reflects relatve importance.*	1) Flow conditions.	2) Short term inwater construction.	3) Passage impediments/barriers.	4) Harvest/ angling impacts.
9	**Sub-objectives:** *Intended to address highest priority stressors.*	1) Maintain through Delta attraction flow conditions for adult winter run salmon in normal, AN, and wet year types and improve through delta attraction flow conditions (by what units?) for adult winter run salmon in BN, dry and CD water years, on 5 water year running average basis, normalized by water year type.	2) Implement construction related BMPs.	3) Remove or modify anthropogenic migration barriers to improve passage in Yolo Bypass within __ years of permit issuance.	4) Reduce illegal harvest of adult winter run chinook salmon by __% within __ years of permit issuance. Maintain this reduced illegal harvest rate throughout the permit period.
10	**Conservation Measures:** ***Note new numbers.***	CM3: Illegal harvest. CM1. North Delta Diversion with Hood Bypass criteria and other measures; CM14. Fremont Wier/Yolo Bypass Habitat Improvements.			
	Expected Outcome: *Question for Group (What is the best metric for this?? Is this something that should be established now, or thru science*	Straying was not evaluated by DRERIP	BMP's were not evaluated by DRERIP	WOCM1-P1e: N.Delta Diversion - Reduced Entrainment	OSCM16-P3: Reduce illegal harvest.

#2 WR_Adult_Survival | #3 WR_Run-time | #4 WR_Hatcheries | NMFS-Stressors | Delta NMFS | #1 Narrative_b

Gather <8 discipline polymaths

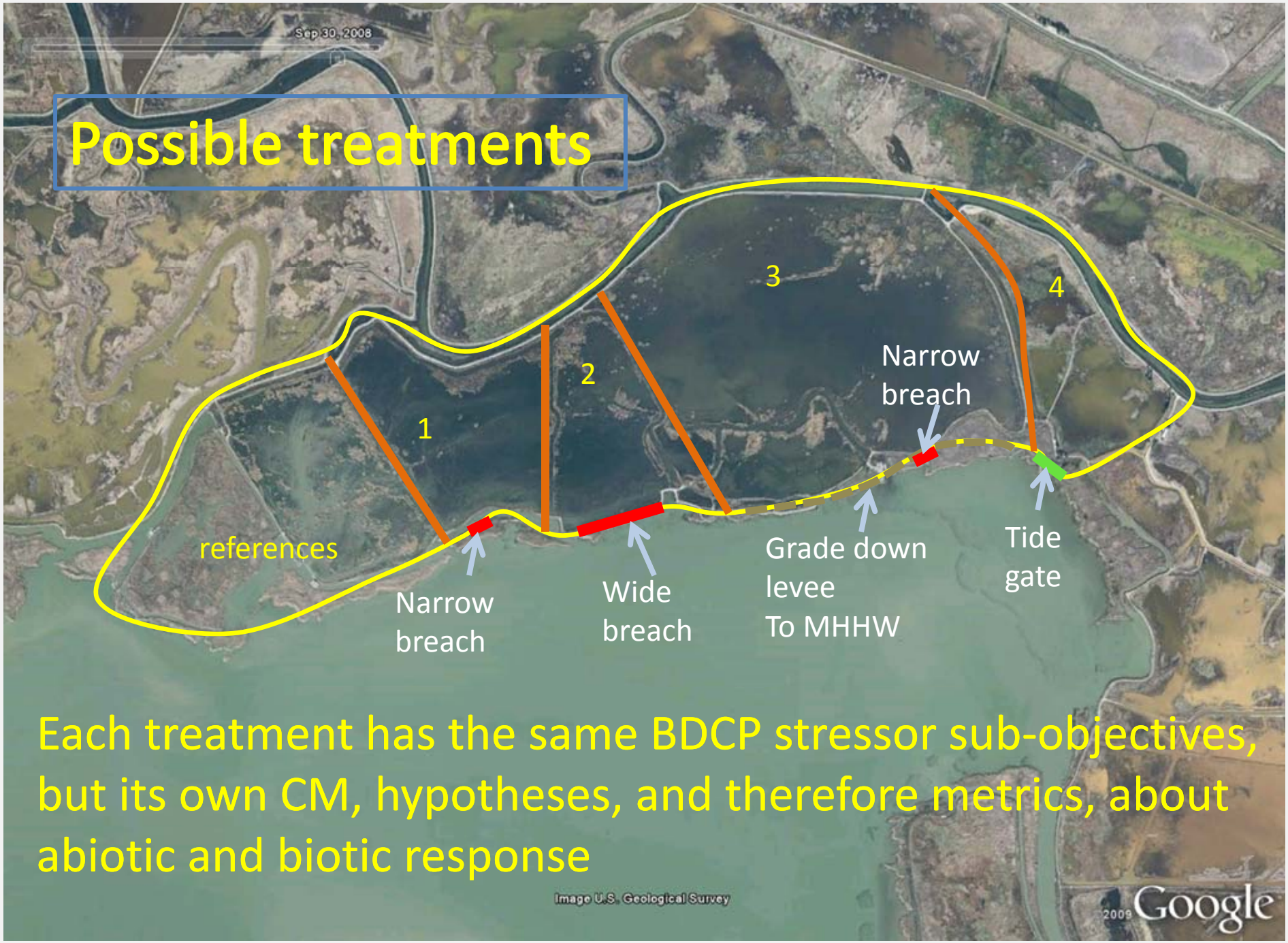
- Generate a site specific conceptual model that considers levee breach configurations.
  - drivers and processes affecting landscape structure trajectory, capacity to produce and give fish access to functions.
  - Develop several best guesses about how to tune levee breaches to maximize function now.
  - Design experiments to test guesses
  - Breach some dang levees
  - *Observe* metrics and processes, analyze, synthesize, write it up ….maybe adapt

Hypothetical restoration area at ~reasonable scale



Potential restoration "landscape scaled" restoration project

Possible reference sites Ryer and Roe Islands


Sep 30, 2008
Possible treatments
1
2
3
4
references
Narrow breach
Wide breach
Grade down levee To MHHW
Narrow breach
Tide gate
Each treatment has the same BDCP stressor sub-objectives, but its own CM, hypotheses, and therefore metrics, about abiotic and biotic response
Image U.S. Geological Survey
2009 Google

Take away's

- Begin studying reference sites now.
  - e.g. Ryer, Roe, Browns Islands, and Rush Ranch.
- Recognize that metrics are emergence phenomena—therefore require mechanistic science observation…
- Proceed boldly, watch carefully, expect surprise, predict with humility, proceed boldly...
- Restoration of native species will be an emergent property of restored landscape structure and process at scale. Metrics and observation programs should reflect this.