The Role of Conceptual Models in Ecosystem Restoration

"All a man needs is confidence and ignorance, and he will be sure to succeed in life."

- *Mark Twain*

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Why Discuss Conceptual Models?

Environmental Advisory Board recommended that:

"The Corps should encourage the explicit use of conceptual models to guide ecosystem restoration planning and implementation. Conceptual models should be required as a first step in the planning process, as they provide a key link between early planning (e.g., an effective statement of problem, need, opportunity, and constraint) and later evaluation and implementation."

(EAB 2006)

Why Discuss Conceptual Models?

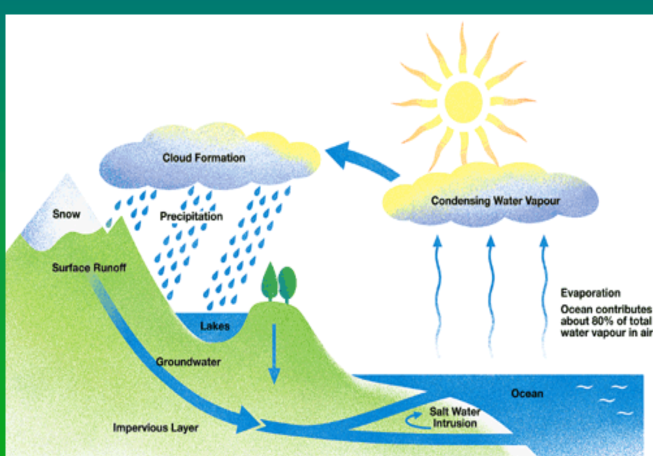
Aug 13, 2008 Memo from CECW-CP
Re: Policy Guidance on Certifying Models

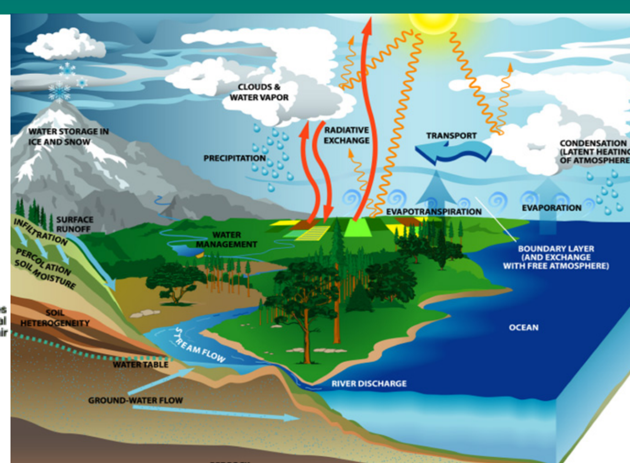
"*Recommendation regarding the importance, use and review of conceptual models is adopted*" (refers to ECO-PCX white paper):

Conceptual models should be developed for all ER projects, but will be reviewed as part of the normal ITR process and do not require certification.

What Are Conceptual Models?

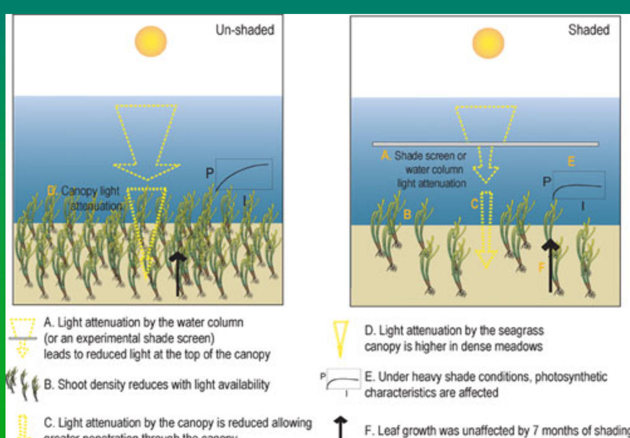
A conceptual model is a tentative description of a system or sub-system that serves as a basis for intellectual organization.

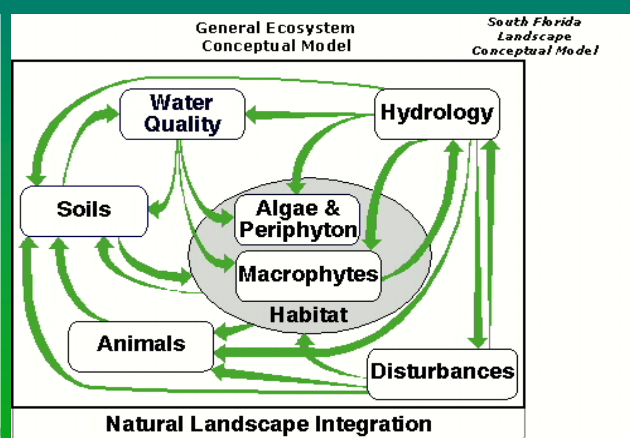




What CM's Do

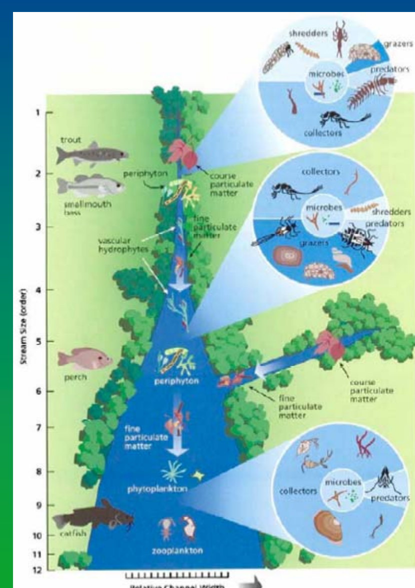
Conceptual models describe general functional relationships among essential ecosystem components. They tell the story of "how the system works."





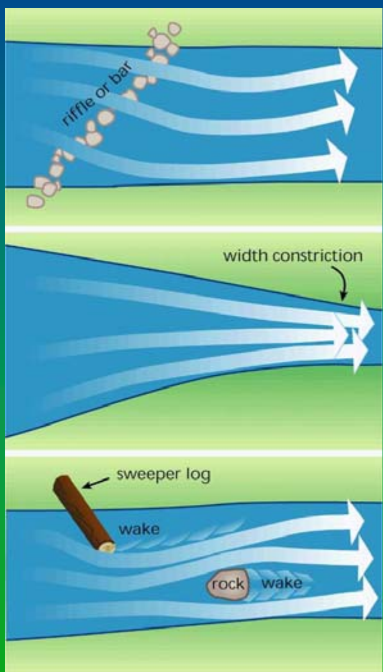
Example – River Continuum Concept

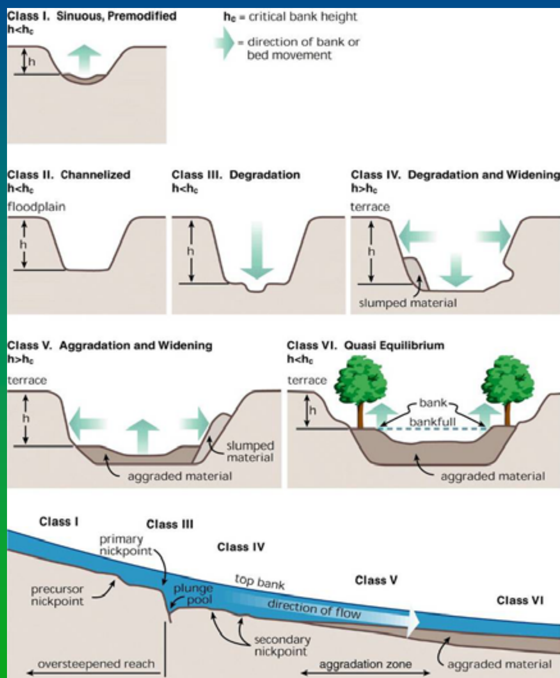
A river's biological and chemical processes correspond to its physical attributes. The nature of biological communities changes in a downstream direction in relation to the changing, but predictable physical structure. This means that the structure of the biological communities is also predictable and that the communities adapt to the particular conditions of a stretch of stream.



(Vannote et. al. 1980)

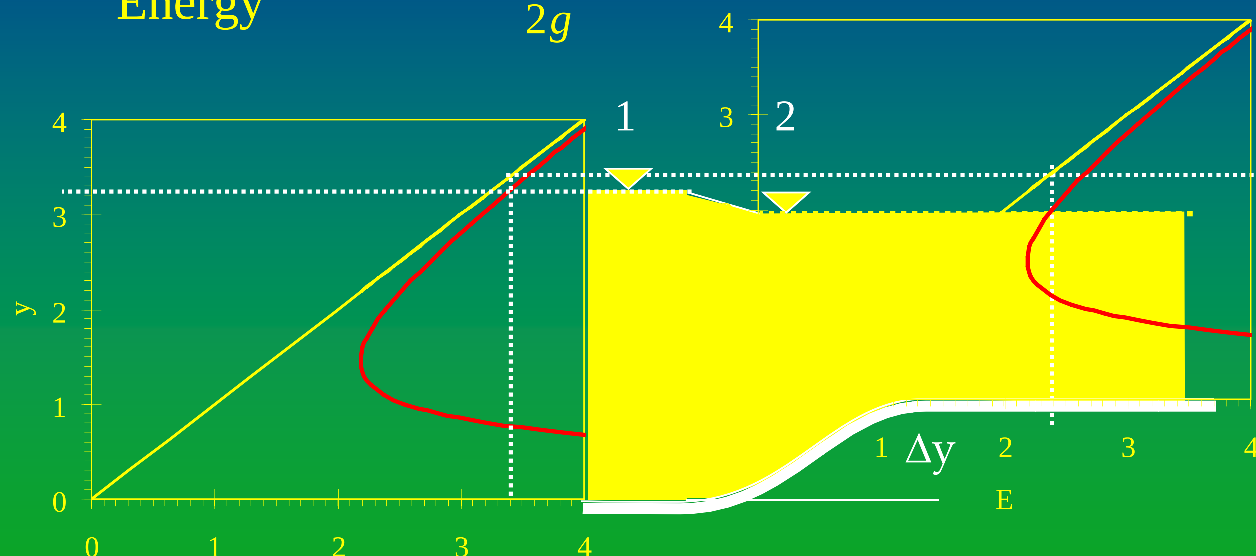
Examples – Hydraulic Structure and Channel Evolution Model





Bed Rise in Rectangular Channel

Specific Energy $$E = y + \frac{V^2}{2g}$$



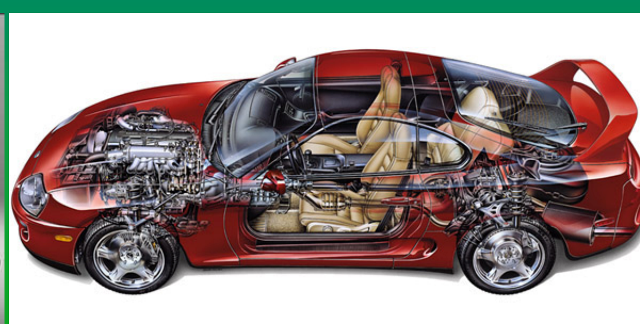
E

$E_1 = E_2 + Dy$

Increase step height?

Perspective Matters

- The same system can have many potential conceptual models
- CMs reflects our personal understanding and viewpoint

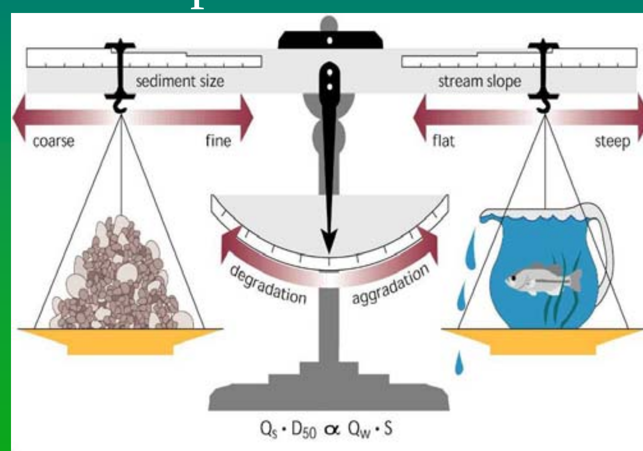


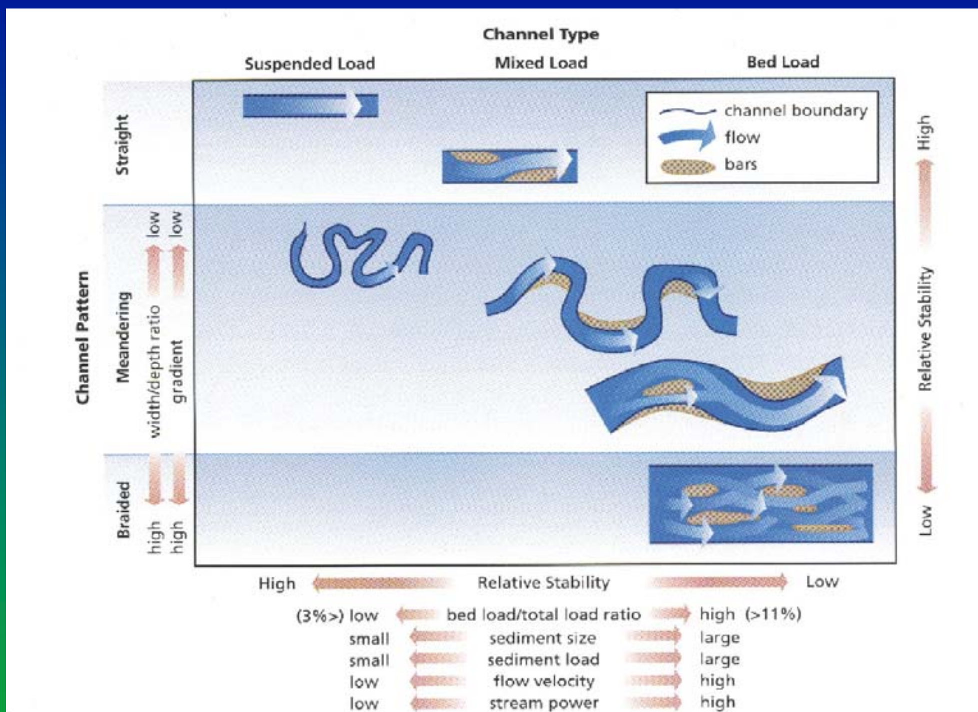
Conceptual Models are NOT:

- *The truth* – they are simplified depictions of reality
- *Comprehensive* – they focus only upon those parts of an ecosystem deemed relevant while ignoring other important (but not immediately germane) elements
- *Final* – they provide a flexible framework that evolves as understanding of the ecosystem increases

How are Conceptual Models Used?

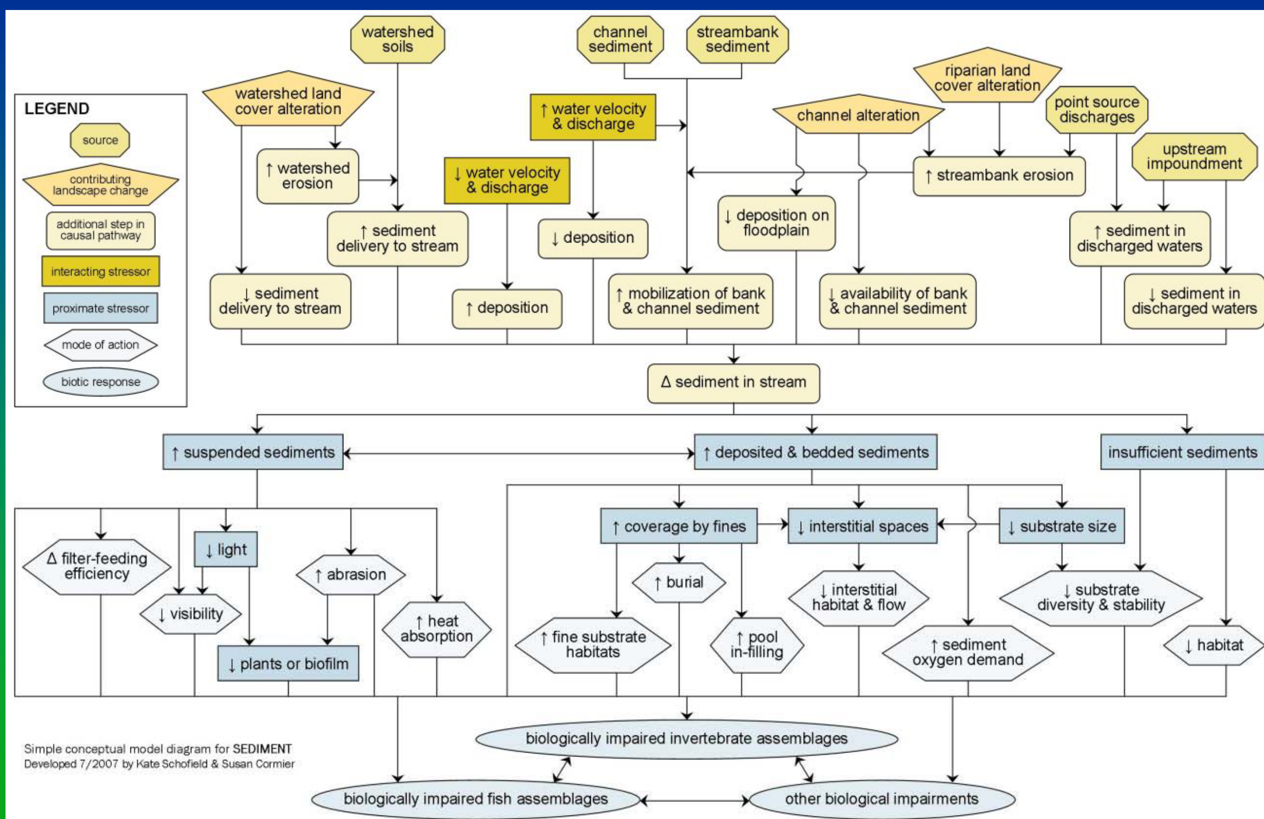
- Means of Organization and Communication
- Facilitate Detailed Analyses
- Metrics, Monitoring and Adaptive Management



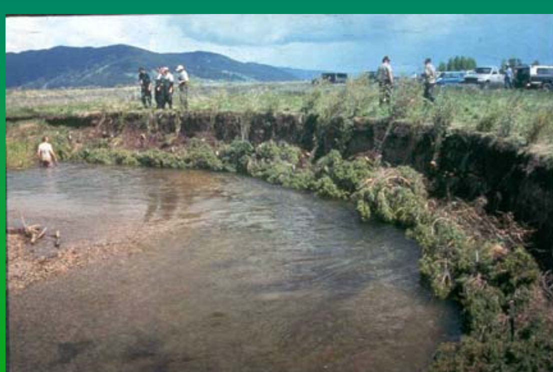


Schumm's classification system relates channel stability to kind of sediment load and channel type. Risk* is similarly scaled.

Stream Sediment Model



System Response?



Common Misconceptions

A model cannot be built with incomplete understanding.

Managers make decisions with incomplete information all the time! This should be an added incentive for model-building as a statement of current best understanding.

A model must be as detailed and realistic as possible.

If models are constructed as 'purposeful representations of reality', then design the leanest model possible. Identify the variables that make the system behave and join them in the most simple of formal structures.

(Starfield et al. 1997)

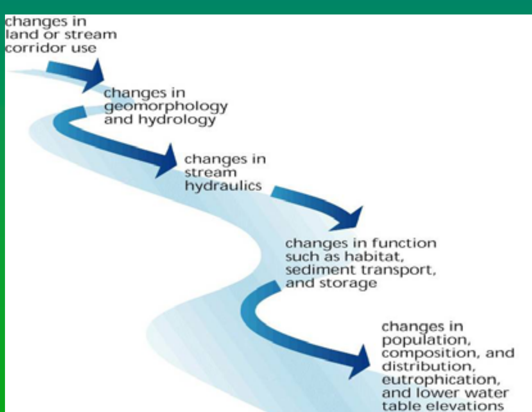
Approach to Development

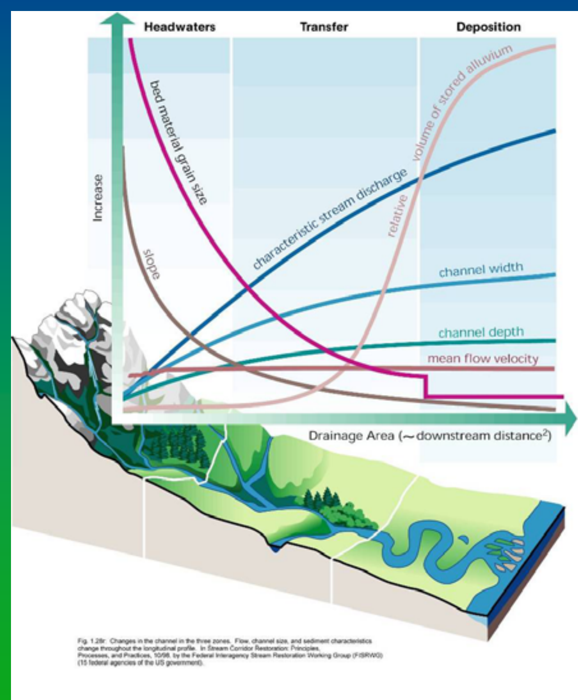
1. State the model objectives.
2. Bound the system of interest.
3. Identify critical model components within the system of interest.
4. Articulate the relationships among the components of interest.
5. Represent the conceptual model.
6. Describe the expected pattern of model behavior.
7. Test, review and revise as needed.

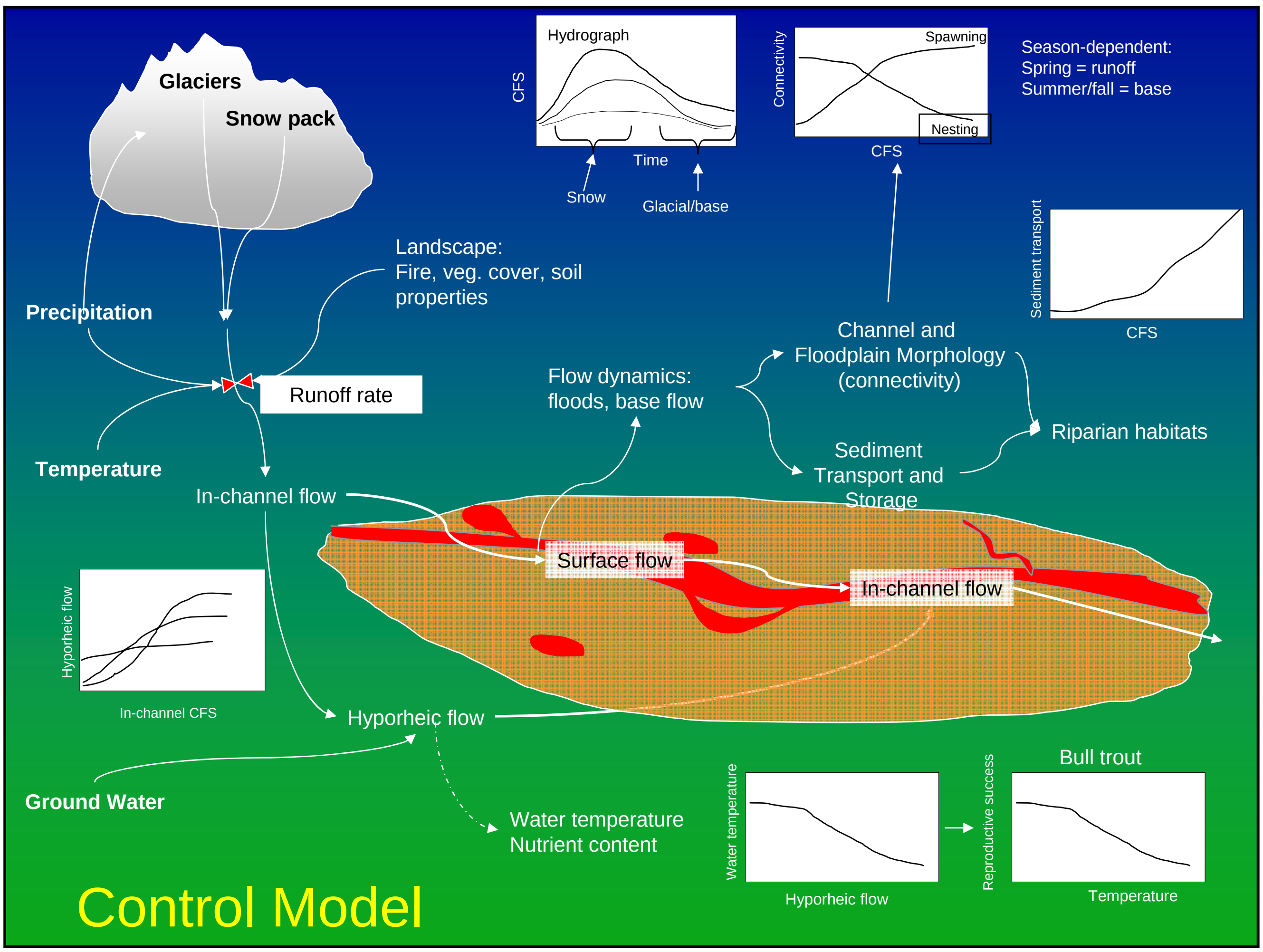
Classes of Conceptual Models

Three Common Constructs:

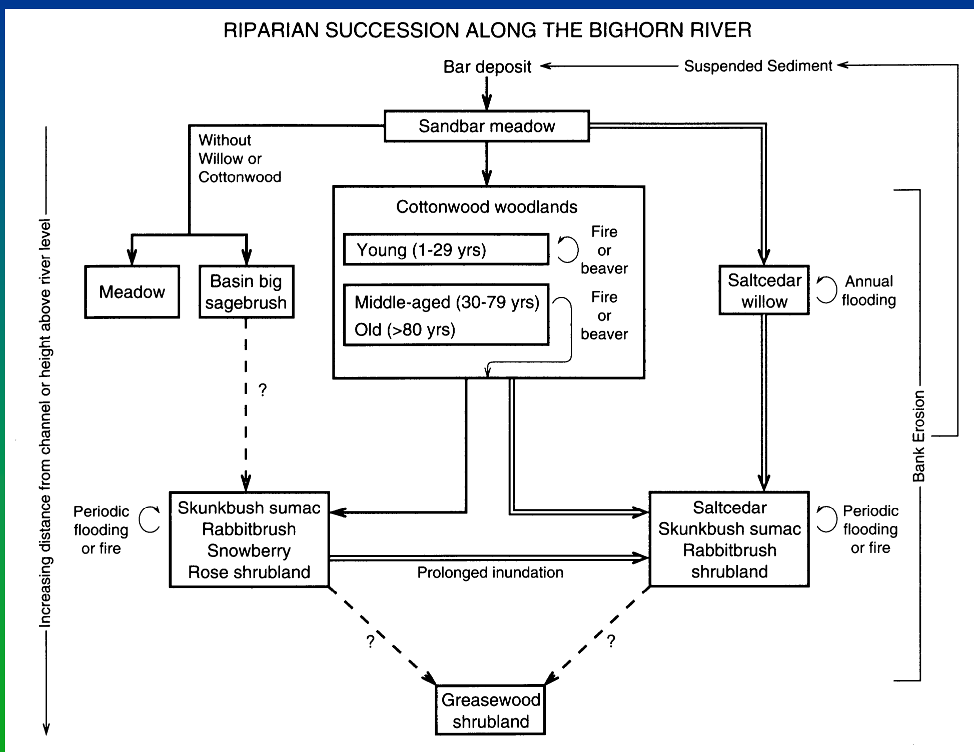
1. Control
2. State and Transition
3. Driver-Stressor





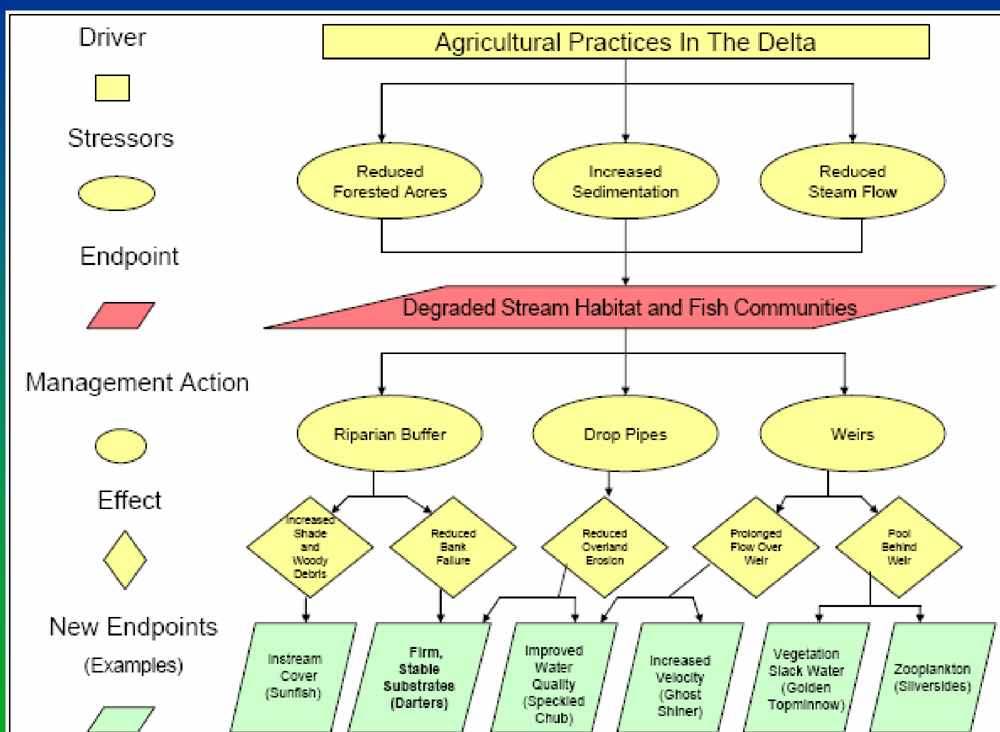

Glaciers
Snow pack
Hydrograph
CFS
Time
Snow
Glacial/base
Connectivity
Spawning
Nesting
CFS
Season-dependent:
Spring = runoff
Summer/fall = base
Sediment transport
CFS
Landscape:
Fire, veg. cover, soil properties
Precipitation
Runoff rate
Temperature
Flow dynamics:
floods, base flow
Channel and
Floodplain Morphology
(connectivity)
Sediment
Transport and
Storage
Riparian habitats
In-channel flow
Surface flow
In-channel flow
Hyporheic flow
In-channel CFS
Hyporheic flow
Ground Water
Water temperature
Nutrient content
Water temperature
Hyporheic flow
Bull trout
Reproductive success
Temperature
Control Model

State-Transition



(Knight 1992)

Driver-Stressor



(Killgore 2007)

Model Strengths and Weaknesses

Control models
- accurately represent feedbacks and interactions
- usually most realistic structure
- insights from construction
- often complicated and hard to communicate
- state dynamics may not be apparent

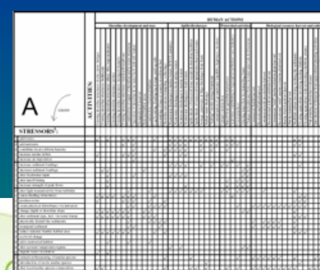
State and transition
- clear representation of alternative states
- can be simple
- excellent communication with most audiences
- generally lack mechanism
- usually too general to directly link to vital signs

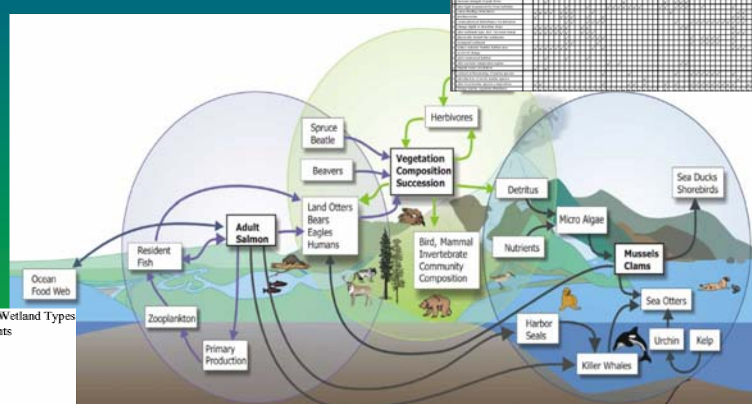
Driver-stressor models
- provide clear link between agent of change and state
- simple and easy to communicate
- no feedbacks
- few or no mechanisms
- frequently inaccurate and incomplete

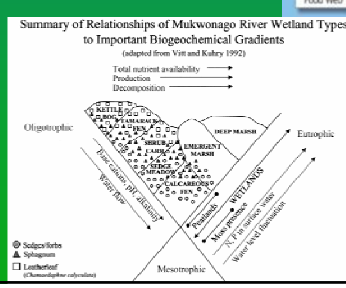
Forms of Conceptual Models

Most commonly expressed as:

- Narrative
- Graphical
- Box Diagram
- Matrix





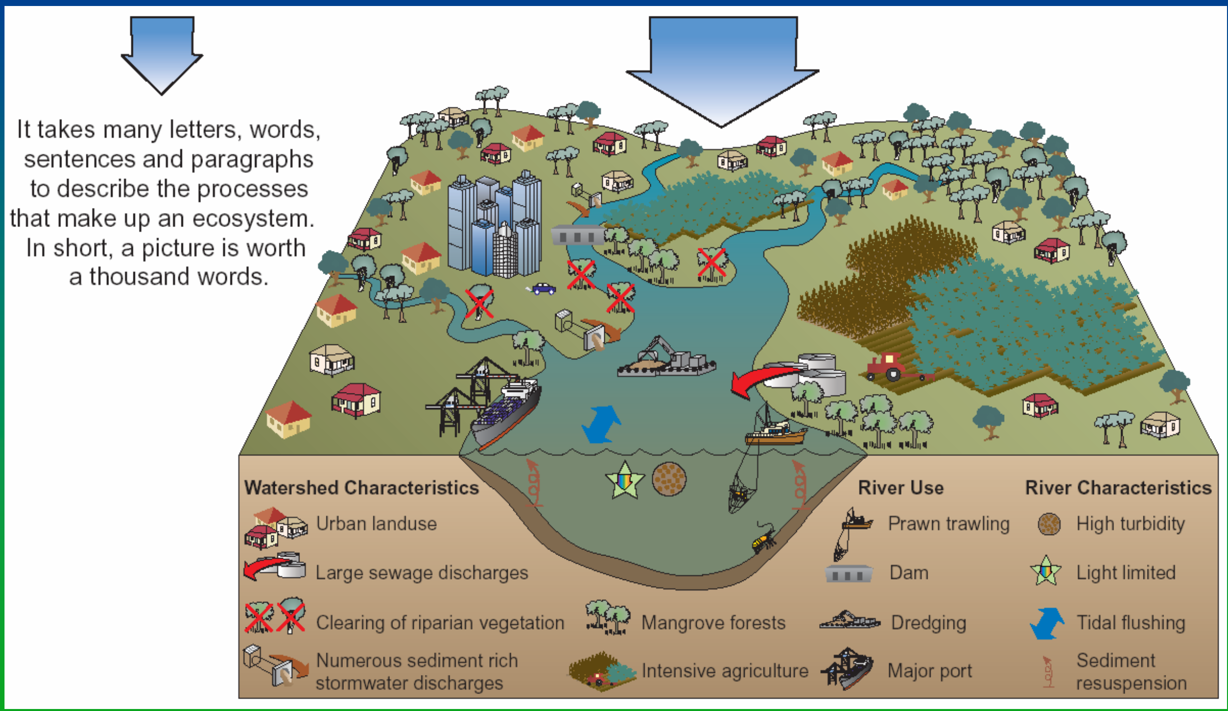


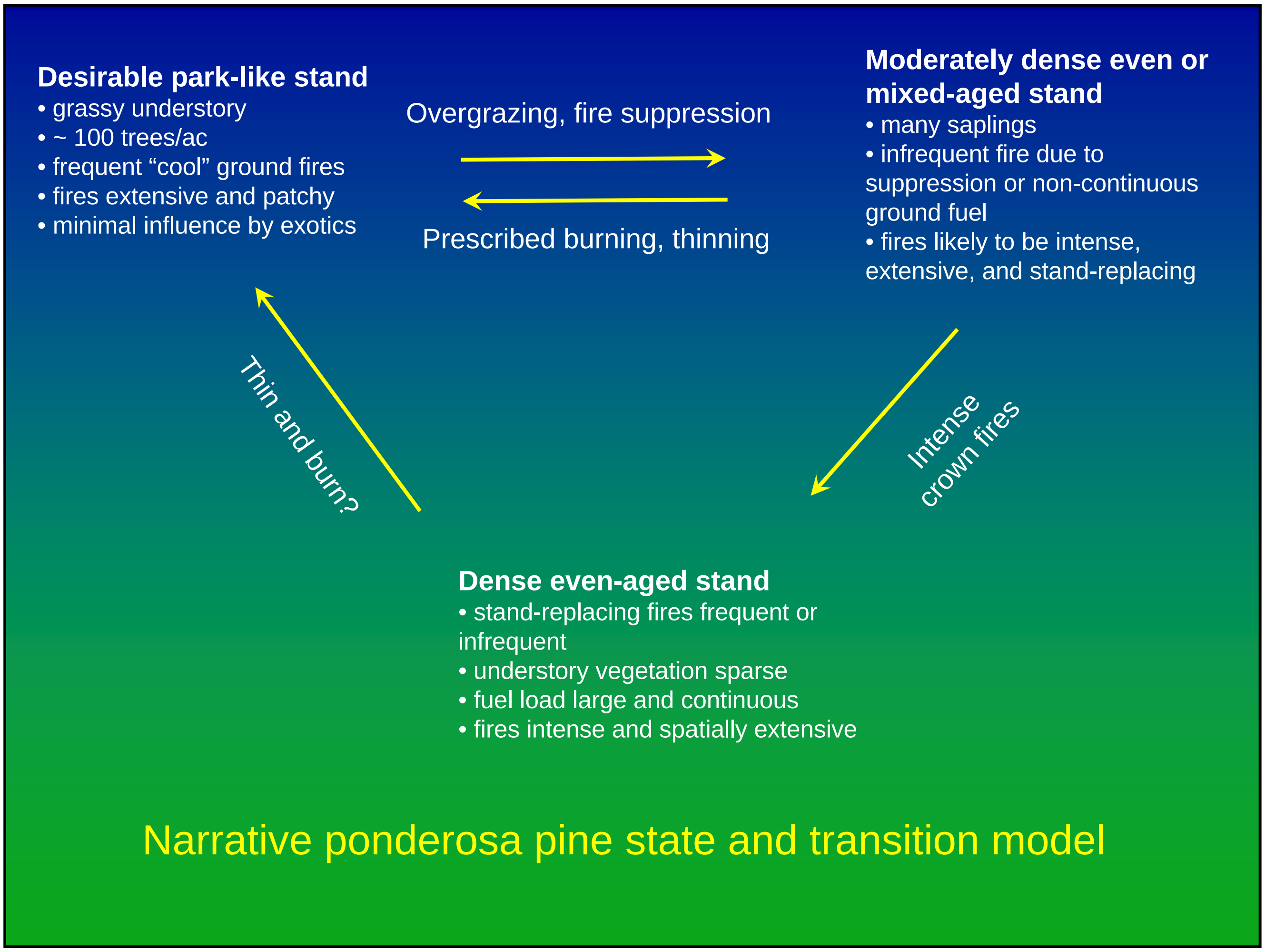
Jorgensen (1988) lists 10 forms

Tabular

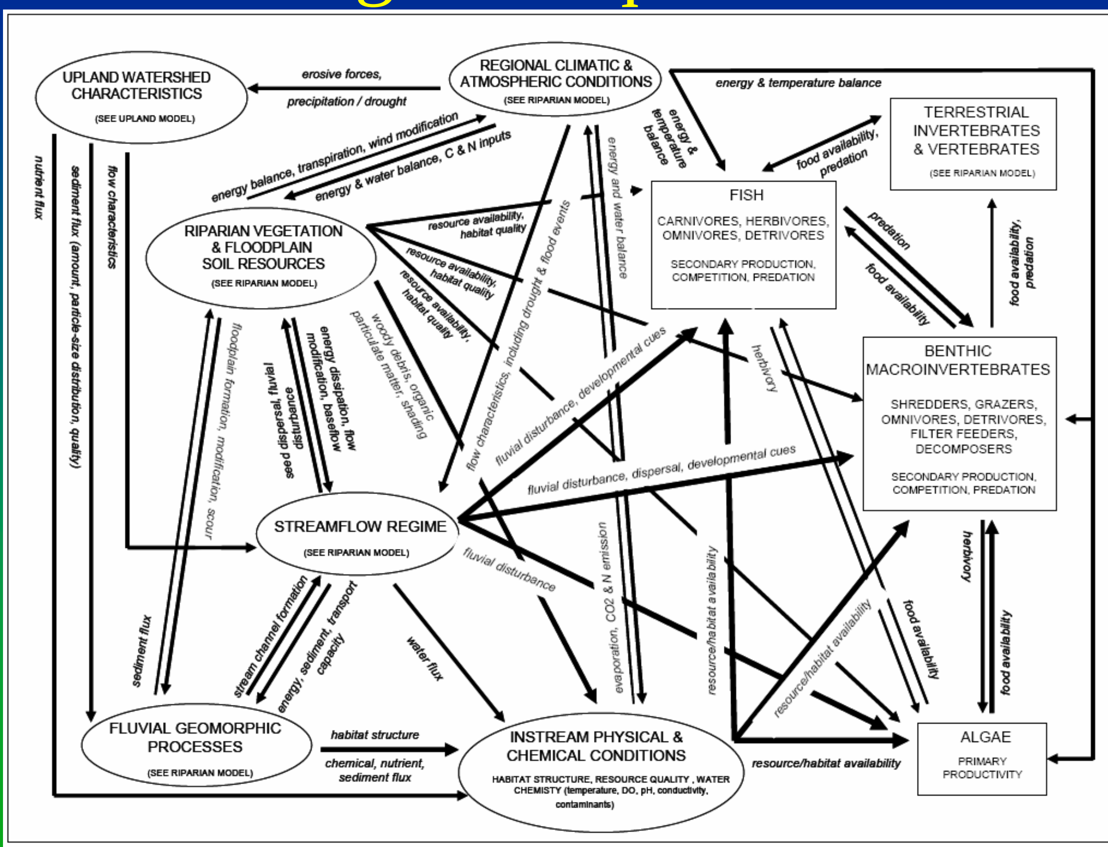
Habitat	Salinity (yearly average)	Source for Salinity Restrictions	Inundation (% of year)	Source for Inundation Restrictions
Bottomland Hardwood	< 2 ppt	Conner et al. (1997)	< 30%	Conner et al. (1997)
Swamp Forest	< 4 ppt	Höppner (2002)	Up to whole year if not stagnant	Höppner (2002)
Fresh Floating Marsh	< 2 ppt	Chabreck (1970), Hester et al. (2002)	Not Applicable	
Fresh Attached Marsh	< 2 ppt	Chabreck (1970)	Up to whole year if not stagnant and below 30 cm of water on marsh	Evers et al. (1998)
Intermediate Marsh	2-6 ppt	Chabreck (1970)	Up to whole year if not stagnant and below 30 cm of water on marsh	Evers et al. (1998)
Brackish Marsh	6-15 ppt	Chabreck (1970)	< 64%A	Sasser (1977)
Saline Wetlands	> 15 ppt	Chabreck (1970)	< 80%A	Sasser (1977)

Graphical


It takes many letters, words, sentences and paragraphs to describe the processes that make up an ecosystem. In short, a picture is worth a thousand words.
Watershed Characteristics
Urban landuse
Large sewage discharges
Clearing of riparian vegetation
Numerous sediment rich stormwater discharges
Mangrove forests
Intensive agriculture
River Use
Prawn trawling
Dam
Dredging
Major port
River Characteristics
High turbidity
Light limited
Tidal flushing
Sediment resuspension


Desirable park-like stand
• grassy understory
• ~ 100 trees/ac
• frequent “cool” ground fires
• fires extensive and patchy
• minimal influence by exotics
Overgrazing, fire suppression
Prescribed burning, thinning
Moderately dense even or mixed-aged stand
• many saplings
• infrequent fire due to suppression or non-continuous ground fuel
• fires likely to be intense, extensive, and stand-replacing
Thin and burn?
Intense crown fires
Dense even-aged stand
• stand-replacing fires frequent or infrequent
• understory vegetation sparse
• fuel load large and continuous
• fires intense and spatially extensive
Narrative ponderosa pine state and transition model

Box Diagram Aquatic Model

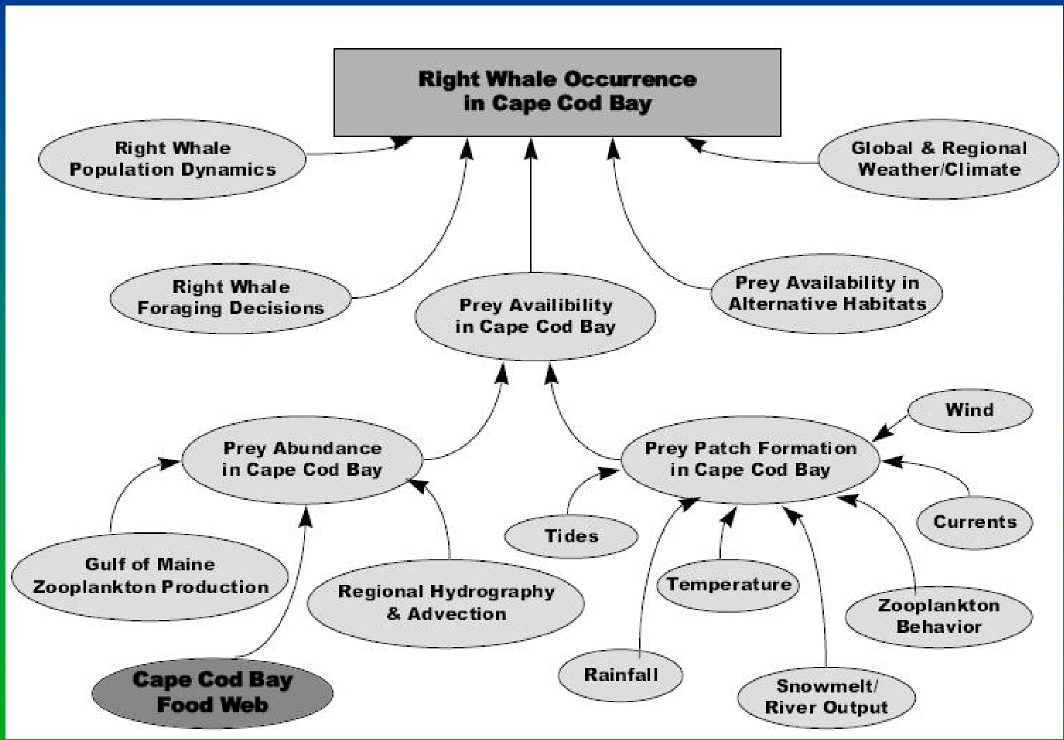


Comparison of Model Types

Type of model	Description	Strengths	Drawbacks
Narrative	Use word descriptions, mathematical or symbolic formula	Summarizes literature, information rich	No visual presentation of important linkages
Tabular	Table or two-dimensional array	Conveys the most information	May be difficult to comprehend amount of information
Picture models	Depict ecosystem function with plots, diagrams, or drawings	Good for portraying broad-scale patterns	Difficult to model complex ecosystems or interactions
Box and arrow (Stressor model)	Reduce ecosystems to key components and relationships	Intuitively simple, one-way flow, clear link between stressor and vital signs	No feedbacks, few or no mechanisms, not quantitative
Input/output matrix (Control model)	Box and arrow with flow (mass, energy, nutrients, etc.) between components	Quantitative, most realistic, feedback and interactions	Complicated, hard to communicate, state dynamics may not be apparent

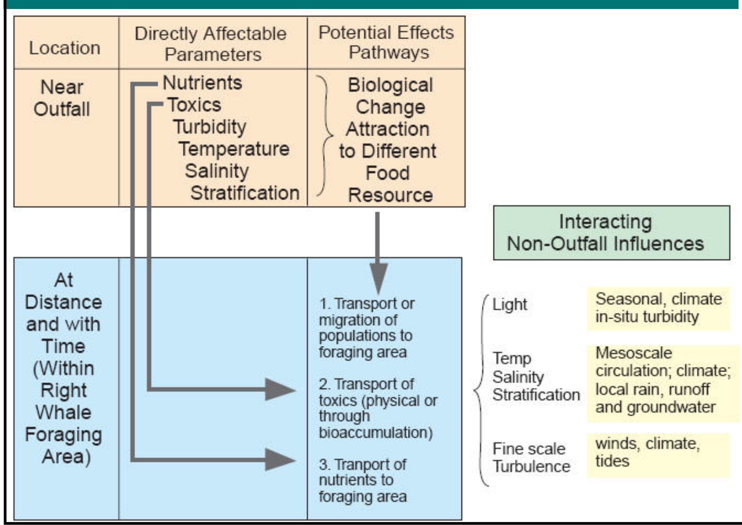
(Gucciardo 2004)

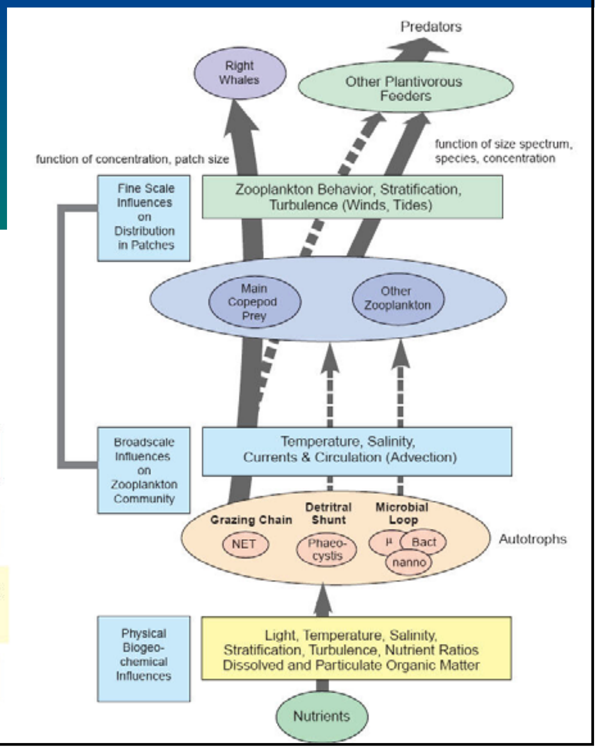
Nested Models

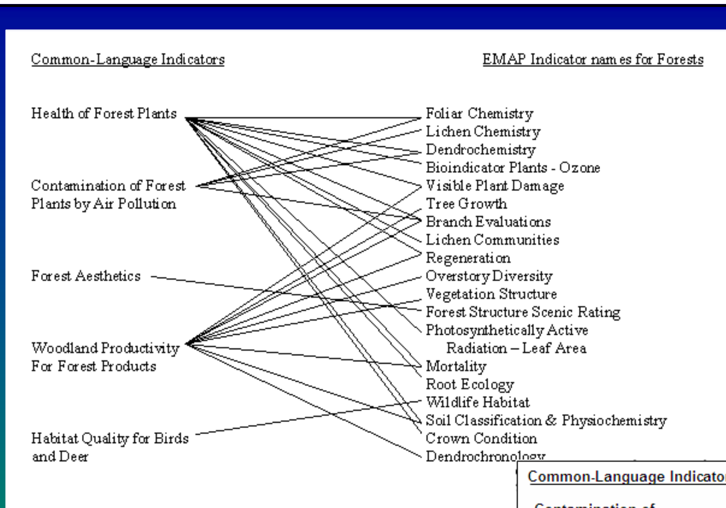


Nested Models (Cont'd)

More detailed representation of food web and outfall influences over time and space.





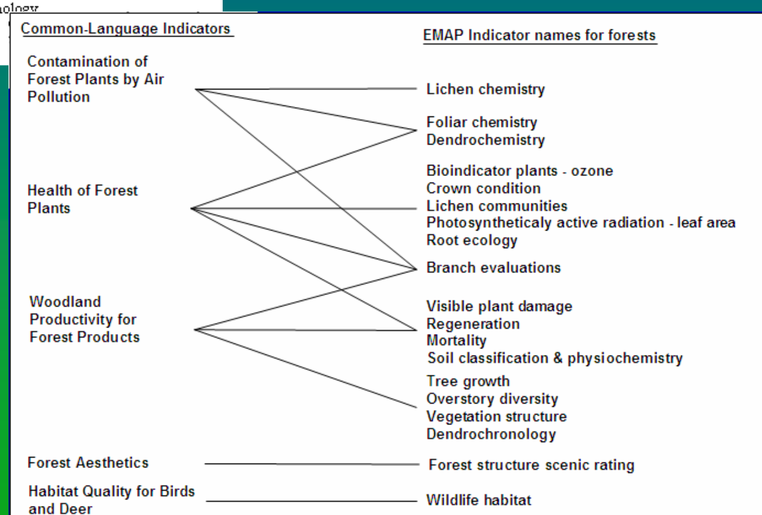


Schiller et al. 2001. Cons. Ecol 5(1)19.

Craft Matters

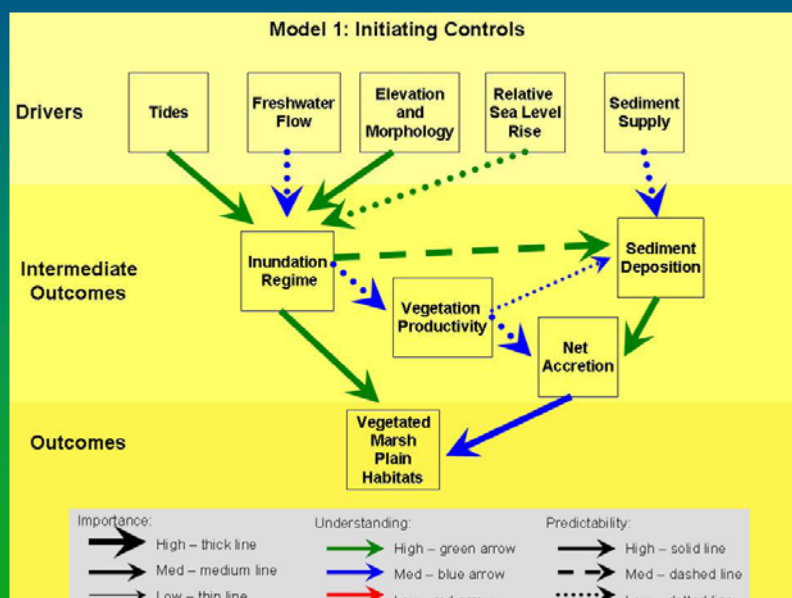
Help readers by grouping related elements, aligning elements, and minimizing crossed lines.

These are the same!



Presentation Tips

- Combine graphical and narrative descriptions
- Align boxes, both horizontally and vertically
- Use line weights to show significance of linkage
- Avoid shaded boxes that photocopy poorly
- Use colors and shapes, but limit complexity
- Aggregate lines when possible
- Maximize ‘content’



Good conceptual models should include the following:

- Those physical, chemical and biological attributes of the system that determine its dynamics.
- The mechanisms by which ecosystem drivers, both internal (e.g., flow rates) and external (e.g., climate), cause change with particular emphasis on those aspects of the system where the Corps can effect change.
- Critical thresholds of ecological processes and environmental conditions
- Discussion of assumptions and gaps in the state of knowledge, especially those that limit the predictability of restoration outcomes.
- Identification of current characteristics of the system that may limit the achievement of management outcomes.
- Adequate references to substantiate the model.

Example: Diversions in Louisiana Coastal Wetlands

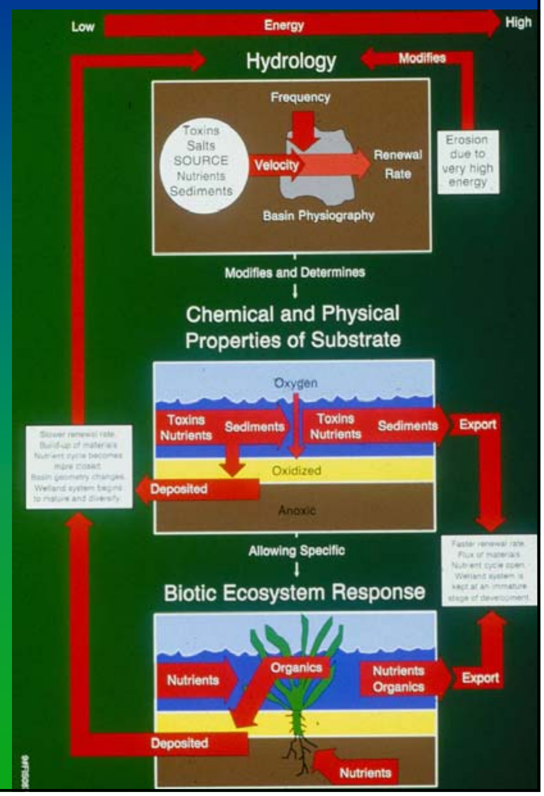
Need:

- Formulate alternatives for coastal restoration
- Identify suitable metrics for Risk-Informed Decision Framework (RIDF)
- Assess environmental impacts and benefits from structural, non-structural and coastal restoration measures (for both RIDF and PEIS)

Underlying Questions

What components and processes of the real system are essential to the model and problem?

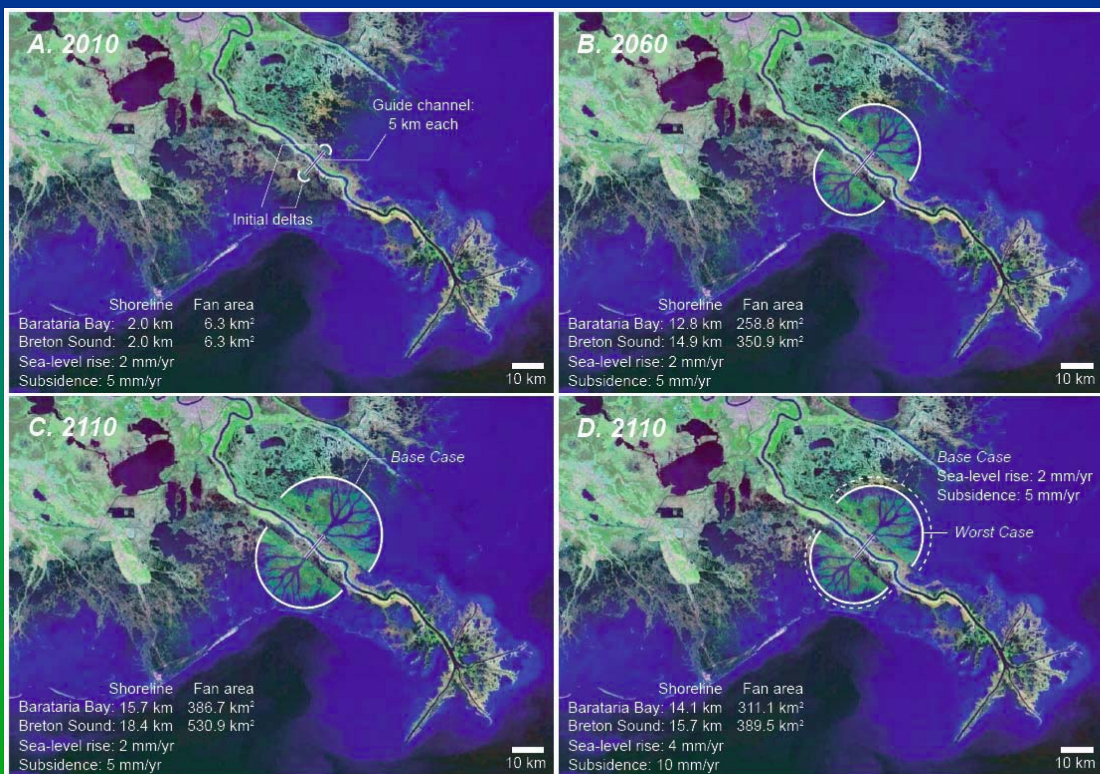
Why? How?



LA Freshwater Diversions

- Sediment and nutrient inputs offset losses due to consolidation, subsidence, SLR, erosion, etc.
- Limited replication of historic deltaic processes.

Alternative Scenarios

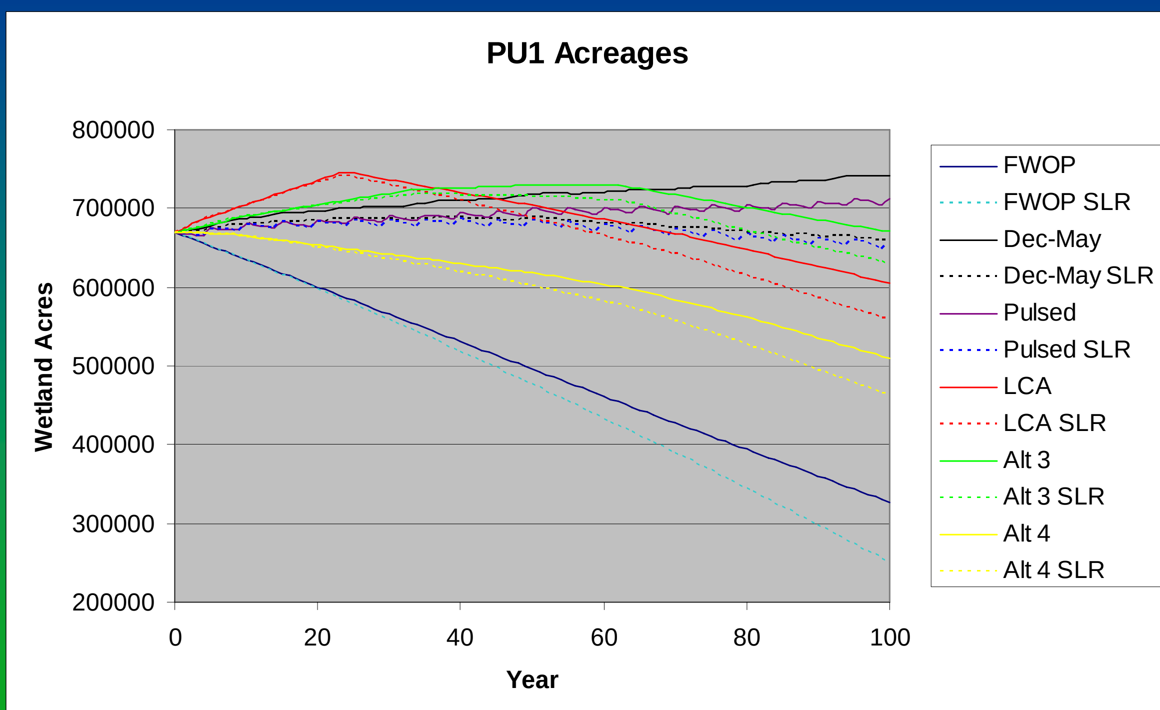


Desktop Model

A1 | fx Number of Monte Carlo Iterations

	A	B	C	D
1	Number of Monte Carlo Iterations	50	Clear Monte Carlo Data	
2	**Diversion Hydrograph**	Flow Duration		
3		User Specified		
4		Constant	Run Monte Carlo Analysis	
5	**River Hydrograph**	User Specified		
6	Only used if sediment rating is used.	Flow Duration		
7				
8	Annual Discharge Volume, V_{ann} (L)	3.3452E+12	Note:	St Dev = (Max-Mean)/3
9				
10	**Nutrients**		Mean	Std Dev
11	Plant Productivity Rate, P_r (g/m^{2}y^1)	2842.046404	3000	500
12	% Retention	0.604570128	0.5	0.083333333
13	Percent of N and P in Plant Biomass, $\%_{TNP}$	0.005766244	0.0068	0.001133333
14	TNP_{req} (kg/ac)	66.313		
15	Background Conc of N and P, $TNP_{background}$ (mg/L)	0.301177888	0.35	0.08
16	Source Conc of N and P, TNP_{source} (mg/L)	2.060549827	2	0.22
17	TNP_{av} (kg)	5885455.1		
18	Nutrient Potential Acres, A_{npot} (ac)	53657		
19	Land Loss Rate	-0.002546402	-0.0044	0.000733333
20	Nutrient Acres	**136.6**		
21				
22	**Wetland Flow Geometry**			
23	Initial Land Area, A (ac)	125155	125155	0
24	Initial Water Area, A_w (ac)	134723	134723	0
25	Initial Project Area, A_p (ac)	259878		
26	Average Water Depth, H (ft)	2.897486805	3	0.1
27	Average Water Width, B (ft)	60998.84984	59521	3333.333333
28	Average Length, L (ft)	96207		

Wetland Acreages



References

Fischenich, C. 2008. *The Application of Conceptual Models to Ecosystem restoration*. EBA Technical Notes Collection. ERDC TN-EBA-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *www.wes.army.mil/el/emrrp*.

Henderson, J. E., and L. J. O'Neil. 2007a. Template for conceptual model construction: Model review and Corps applications. ERDC TN-SWWRP-07-4. Vicksburg, MS: U.S. Army Engineer Research and Development Center. https://swwrp.usace.army.mil/

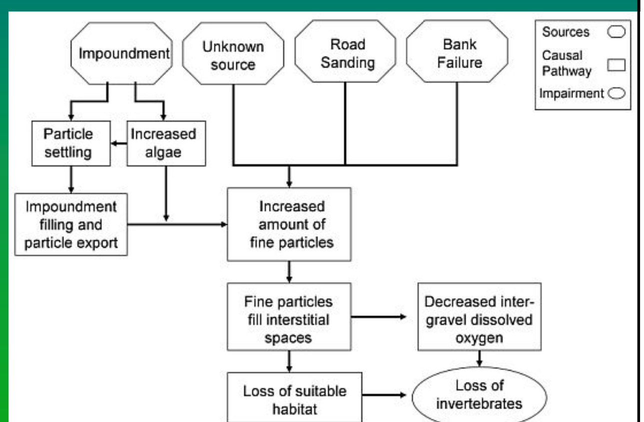
Henderson, J. E., and L. J. O'Neil. 2007b. Template for conceptual model construction: model components and application of the template. SWWRP Technical Notes Collection, ERDC TN-SWWRP-07-x. Vicksburg, MS: U.S. Army Engineer Research and Development Center. https://swwrp.usace.army.mil/

Several upcoming publications under the EBA Program – Stay Tuned!

Support Tools?

- Graphic Template/Tool
- Assessment Support

  (e.g. CADIS – EPA)



Excerpted from: U.S. Environmental Protection Agency. (2003) Reduced Macroinvertebrate Diversity in the Willimantic River Connecticut. USEPA, Office of Research and Development; Cincinnati, OH

"Just because a man is an Engineer, it does not mean he knows much about engineering.

It merely means he knows much less about everything else."

\- *Mark Twain*