A Novel Database-Driven Approach to Shallow Marine Classification: Towards Building a Knowledge Base*

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Abstract

Classification systems that are widely used in sedimentary geology meet the following criteria: (i) they are relatively simple and based on a limited number of variables; (ii) they tend to be shown as two-dimensional diagrams; (iii) they attempt to resolve a practical problem. The output of these classifications is placing the variability of the natural world in discrete categories, which ideally show sufficient commonality in properties and behavior. Since shallow marine systems are often described on basin and local scales, different classification systems are applied to the same package of rock. Sequence stratigraphy, which can be thought of as a classification system based on accommodation change and sediment supply as input variables and systems tracts as output categories, tends to be applied to studies examining basin-scale modes of deposition. Studies focused on local facies variability, on the other hand, usually take a depositional systems approach. They use one of several available process-based classifications, based on waves, tides, and fluvial sediment supply as key variables, and process domination as output categories. Use of separate classification schemes for basin-scale and local deposition deals poorly with the often existing co-dependence between the two.

We propose a new classification scheme for shallow marine systems that utilizes a database-driven approach. In comparison to conventional paper-based classification schemes, database-driven classification can handle numerous variables without compromising ease of use. The new classification system is based on variables that are measurable in the ancient record: (i) wave facies influence (ii) tide facies influence, (iii) fluvial facies influence, and (iv) local accommodation (near-shore water depth)—related to parasequence thickness, (v) grain size. Local accommodation, which has not been previously incorporated in classification schemes, is added because of its first order importance on wave and tide energy, rate of shoreline progradation, and degree of preservation of fluvial

influence. The classification can also be enhanced by other variables such as basin type and shelf width. The classification scheme then places the observed depositional systems in distinct categories with assigned primary (e.g., wave-dominated) and a secondary (e.g., tide-influenced) descriptors. The proposed classification scheme is part of a shallow marine knowledgebase currently under development.

References

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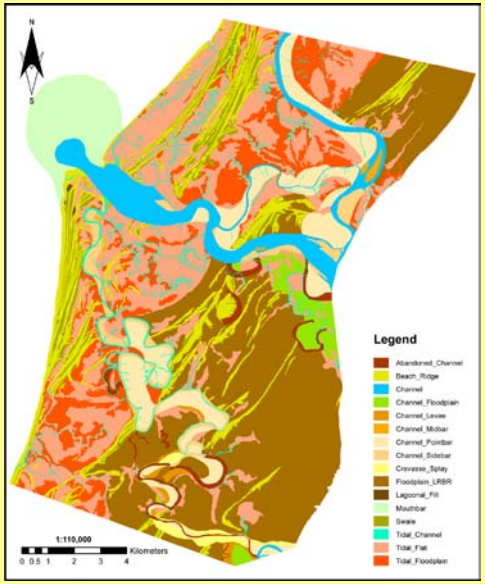
University of Adelaide

AAPG Annual Convention 2010

“Classification” Simplified

Complex Multivariate System



Mitchell River Delta, Northern Australia

Classification

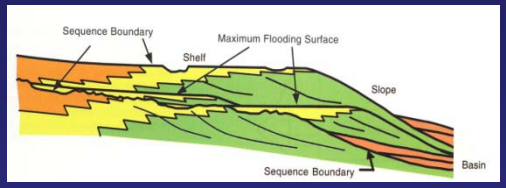
Practical Requirement

- Connectivity
- Flow units
- Distribution of baffles and barriers
- System evolution
- Others

- Usually involves categorization of some type
- Usually focuses on only few aspects of the complex system

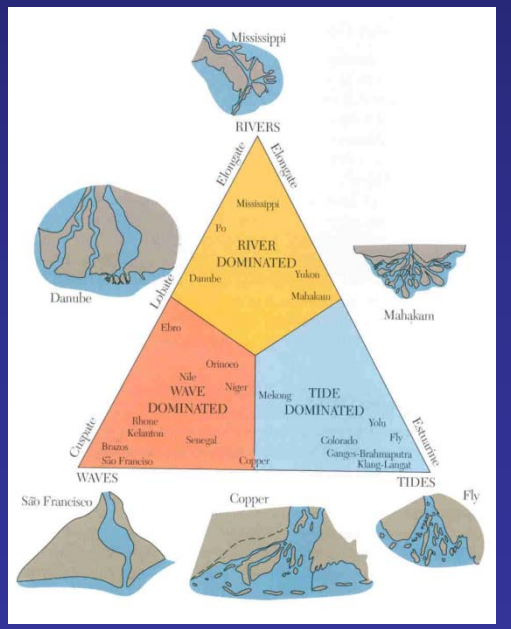
What about marginal marine system classification?

1) Several choices of classifications available
2) All concentrate on 3-4 variables
3) Use simple diagrams



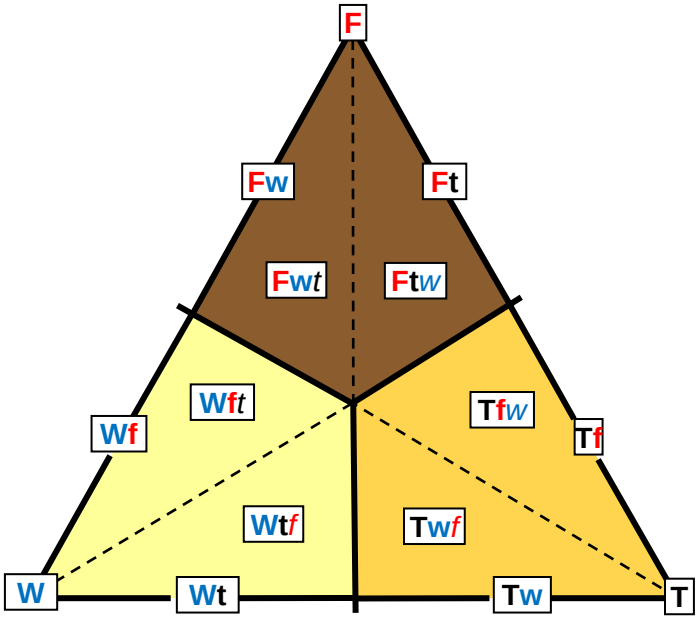
Posamentier and Allen (1999)

4) Focus on either large scale (basins, processes) or small scale (depositional systems, facies)



Galloway (1975)

Updated Marginal Marine Classification



BOLD UPPER CASE = Dominant process
bold lower case = Secondary process
italic lower case = Tertiary process

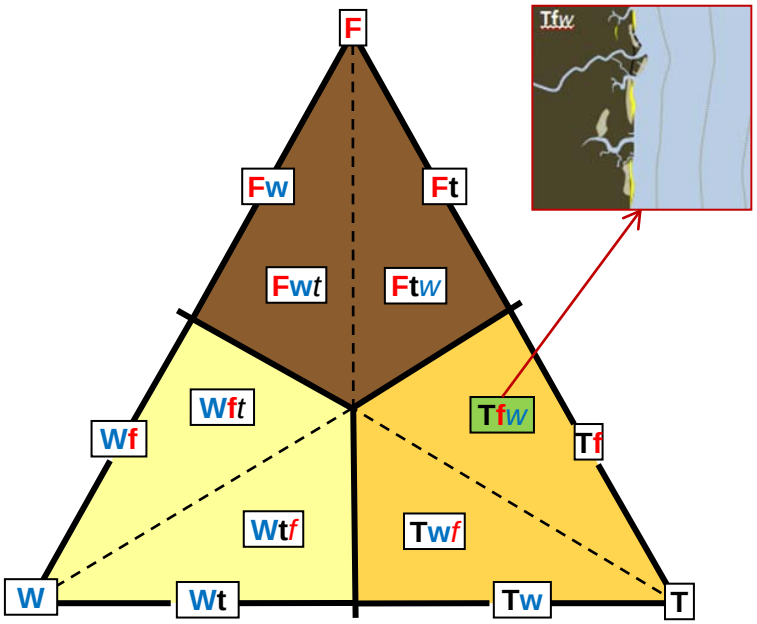
F, f, *f* = Fluvial
W, w, *w* = Wave
T, t, *t* = Tidal

- 15 Classification Categories

Classification Categories

F – Fluvial dominated
Fw – Fluvial dominated, wave influenced
Ft – Fluvial dominated, tide influenced
Fw*t* – Fluvial dominated, wave influenced, tide affected
Ft*w* – Fluvial dominated, tide influenced, wave affected
W – Wave dominated
Wf – Wave dominated, fluvial influenced
Wt – Wave dominated, tide influenced
Wf*t* – Wave dominated, fluvial influenced, tide affected
Wt*f* – Wave dominated, tide influenced, fluvial affected
T – Tide dominated
Tf – Tide dominated, fluvial influenced
Tw – Tide dominated, wave influenced
Tf*w* – Tide dominated, fluvial influenced, wave affected
Tw*f* – Tide dominated, wave influenced, tide affected

Updated Marginal Marine Classification



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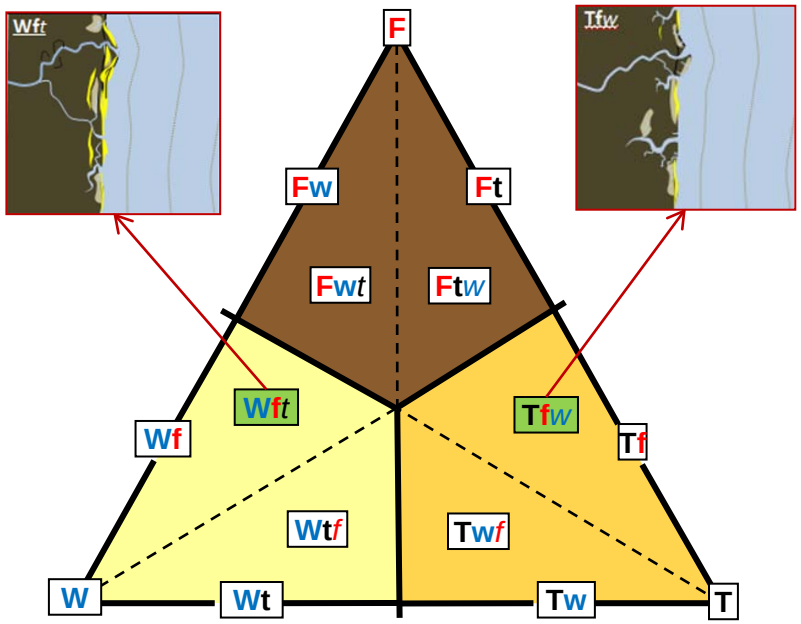

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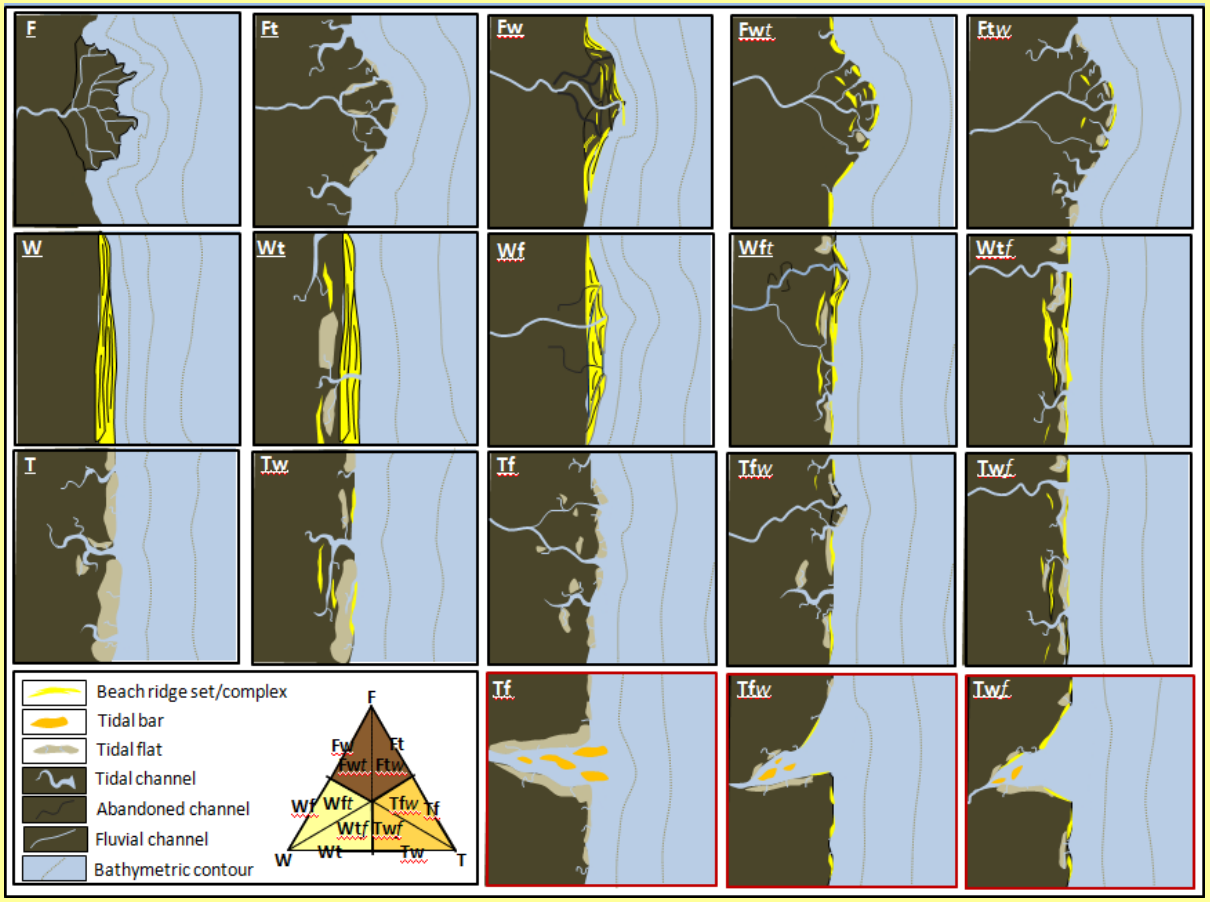
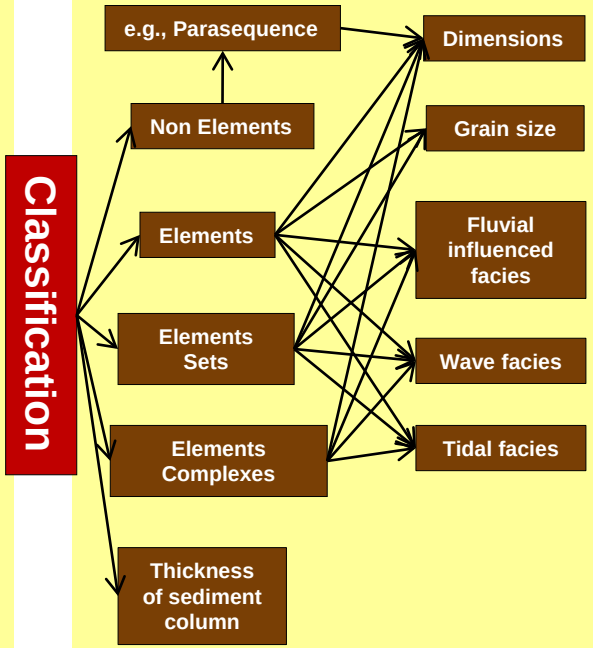
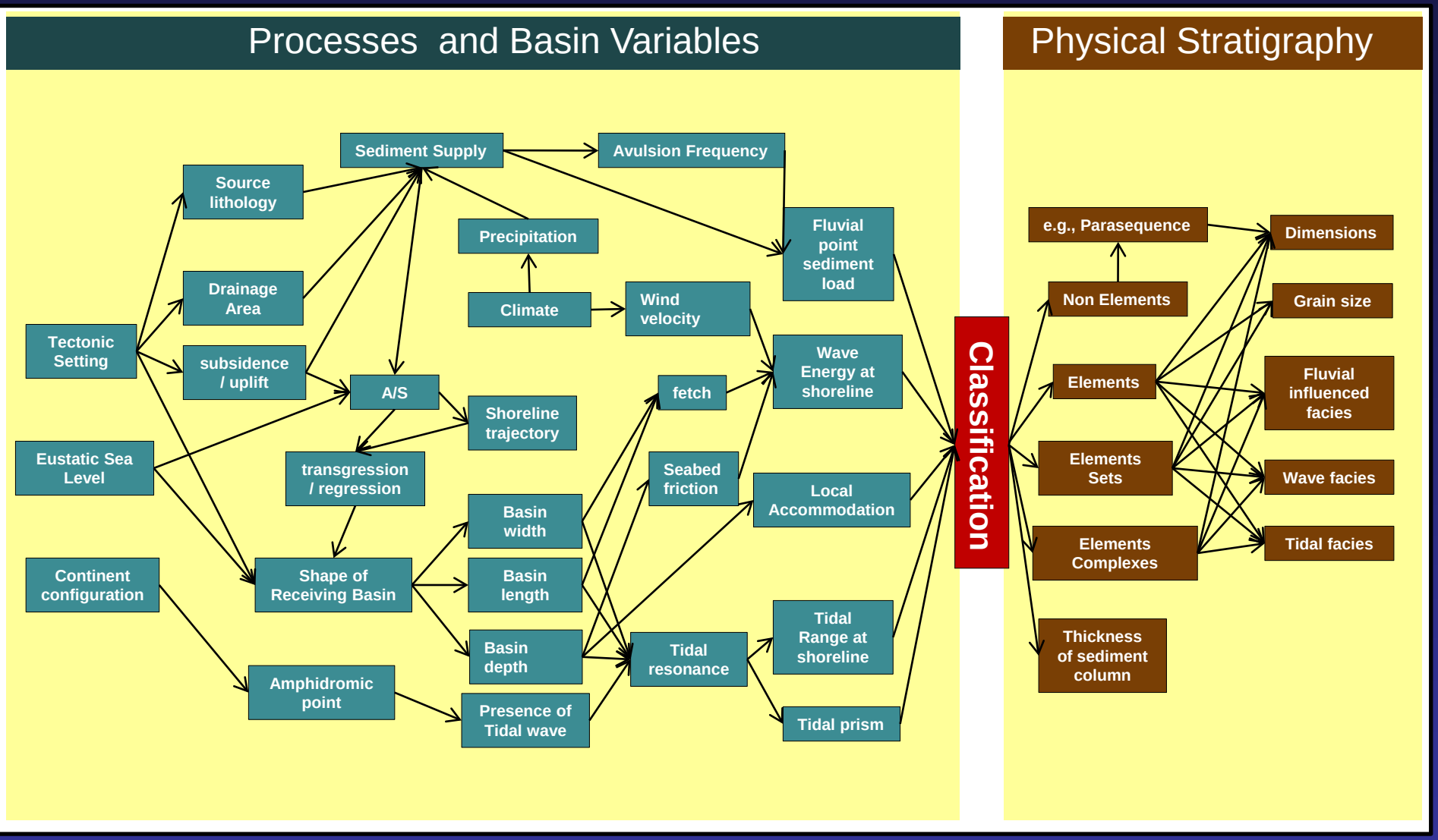
New Classification Categories



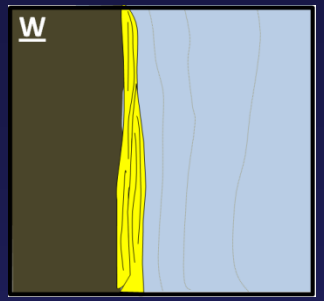
Physical Stratigraphy



Causal Diagram for Marginal Marine Systems



Wave-dominated system (W) on causal diagram



Processes and Basin Variables

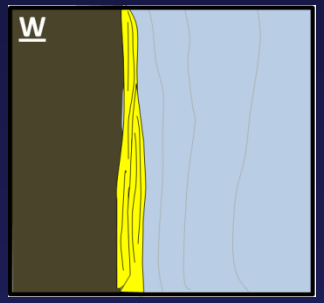
Sediment Supply
Avulsion Frequency
Source lithology
Precipitation
Fluvial point sediment load
Drainage Area
Climate
Wind velocity
Tectonic Setting
subsidence / uplift
A/S
Wave Energy at shoreline
fetch
Shoreline trajectory
Eustatic Sea Level
transgression / regression
Seabed friction
Local Accommodation
Basin width
Continent configuration
Shape of Receiving Basin
Basin length
Basin depth
Tidal resonance
Tidal Range at shoreline
Amphidromic point
Presence of Tidal wave
Tidal prism

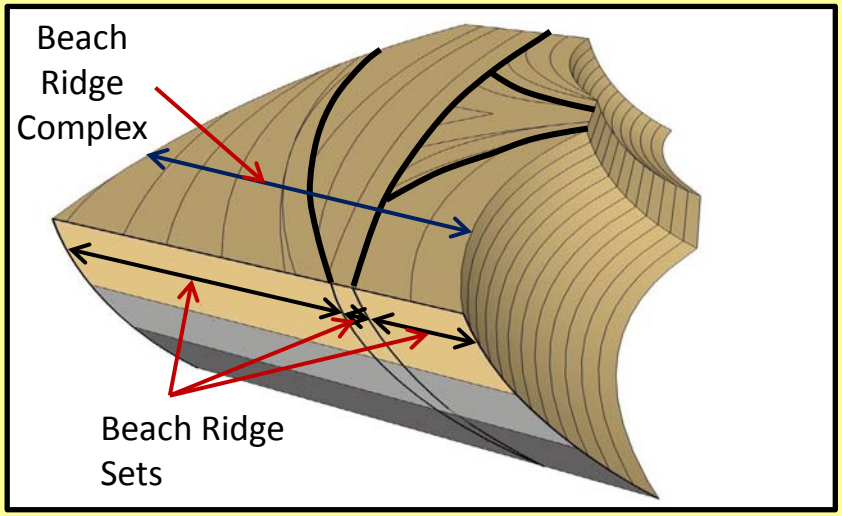
W

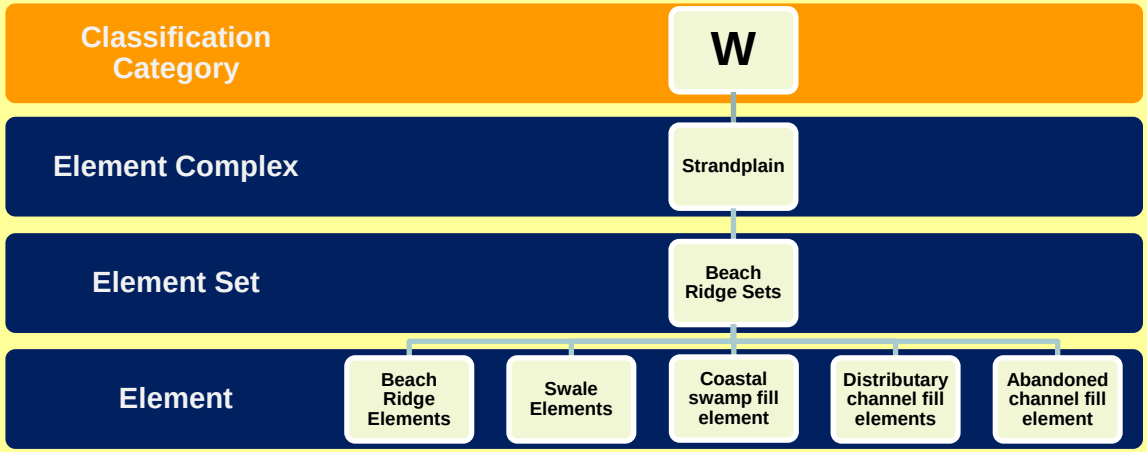
Physical Stratigraphy

e.g., Parasequence
Dimensions
Non Elements
Grain size
Elements
Fluvial influenced facies
Elements Sets
Wave facies
Elements Complexes
Tidal facies
Thickness of sediment column

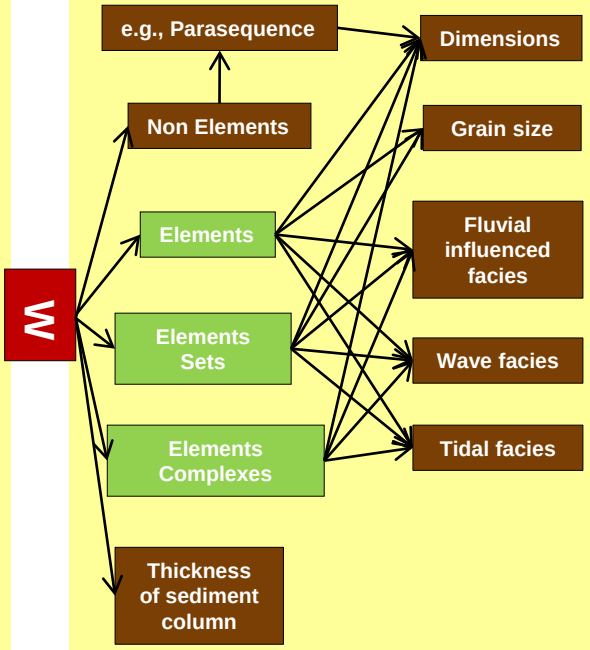
Wave-dominated system (W) on causal diagram







Physical Stratigraphy



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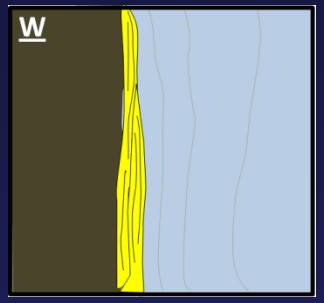

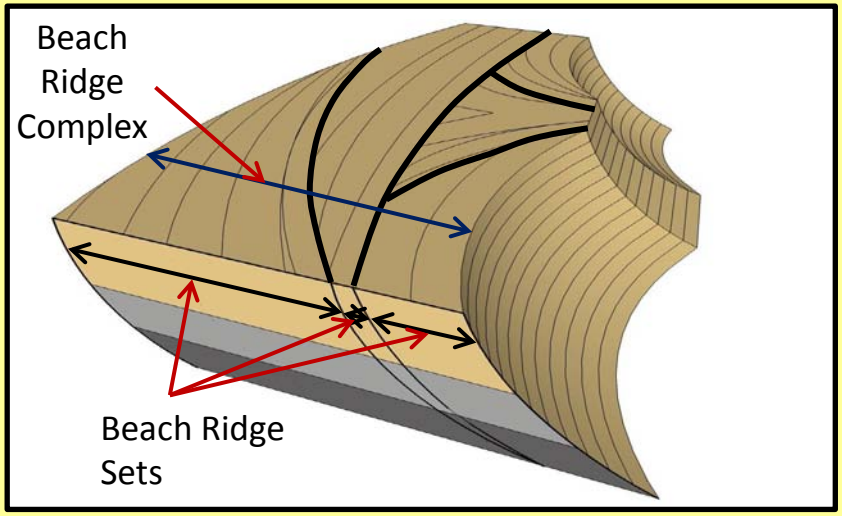

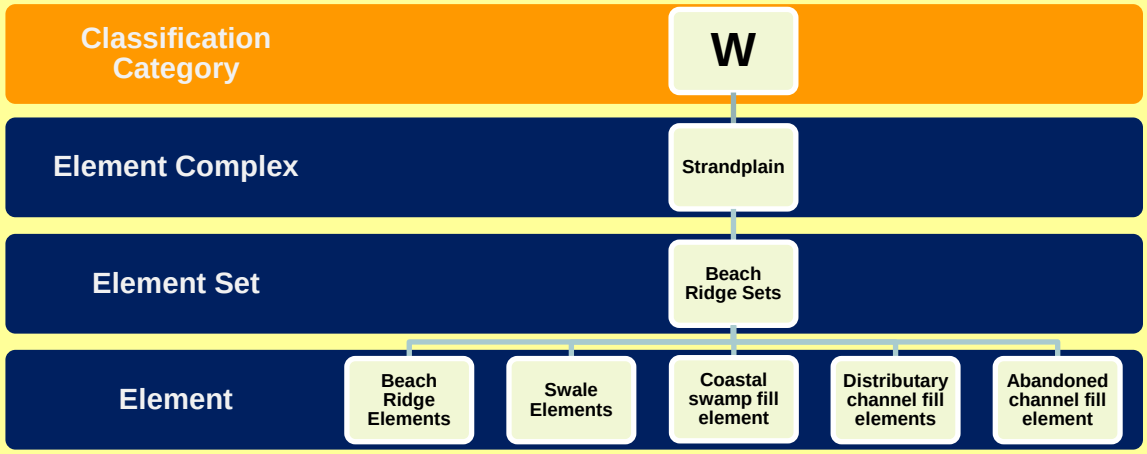

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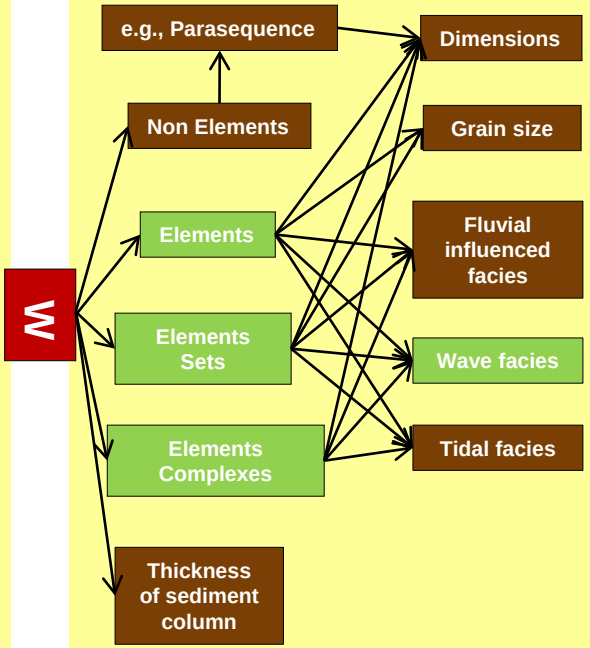

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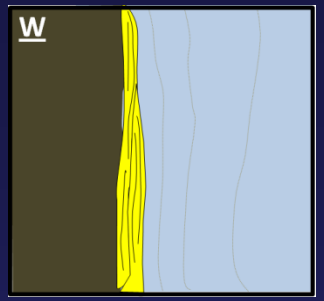
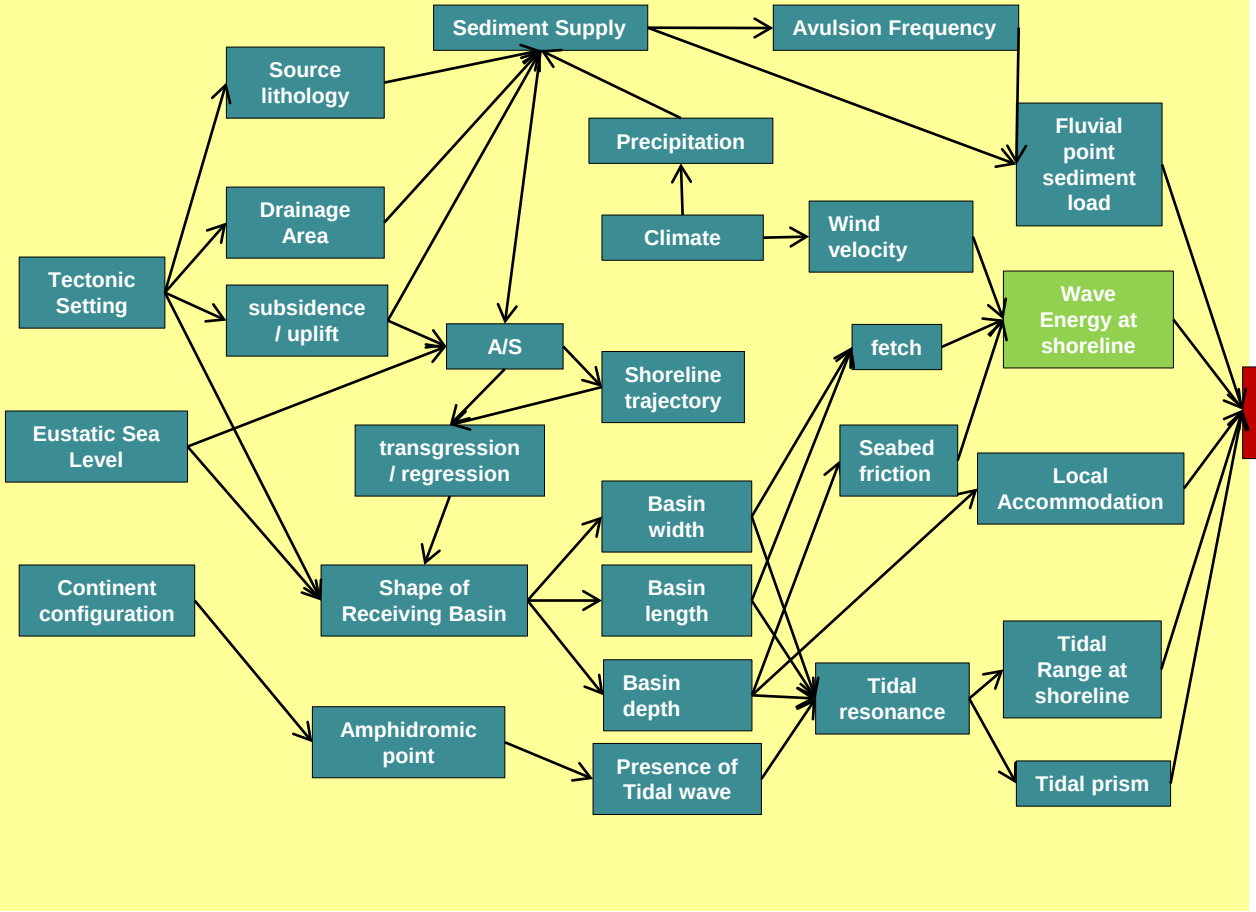


Processes and Basin Variables



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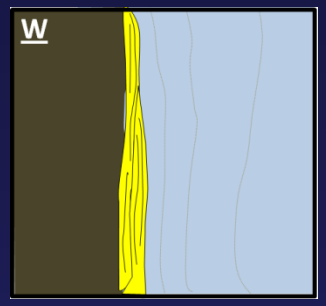

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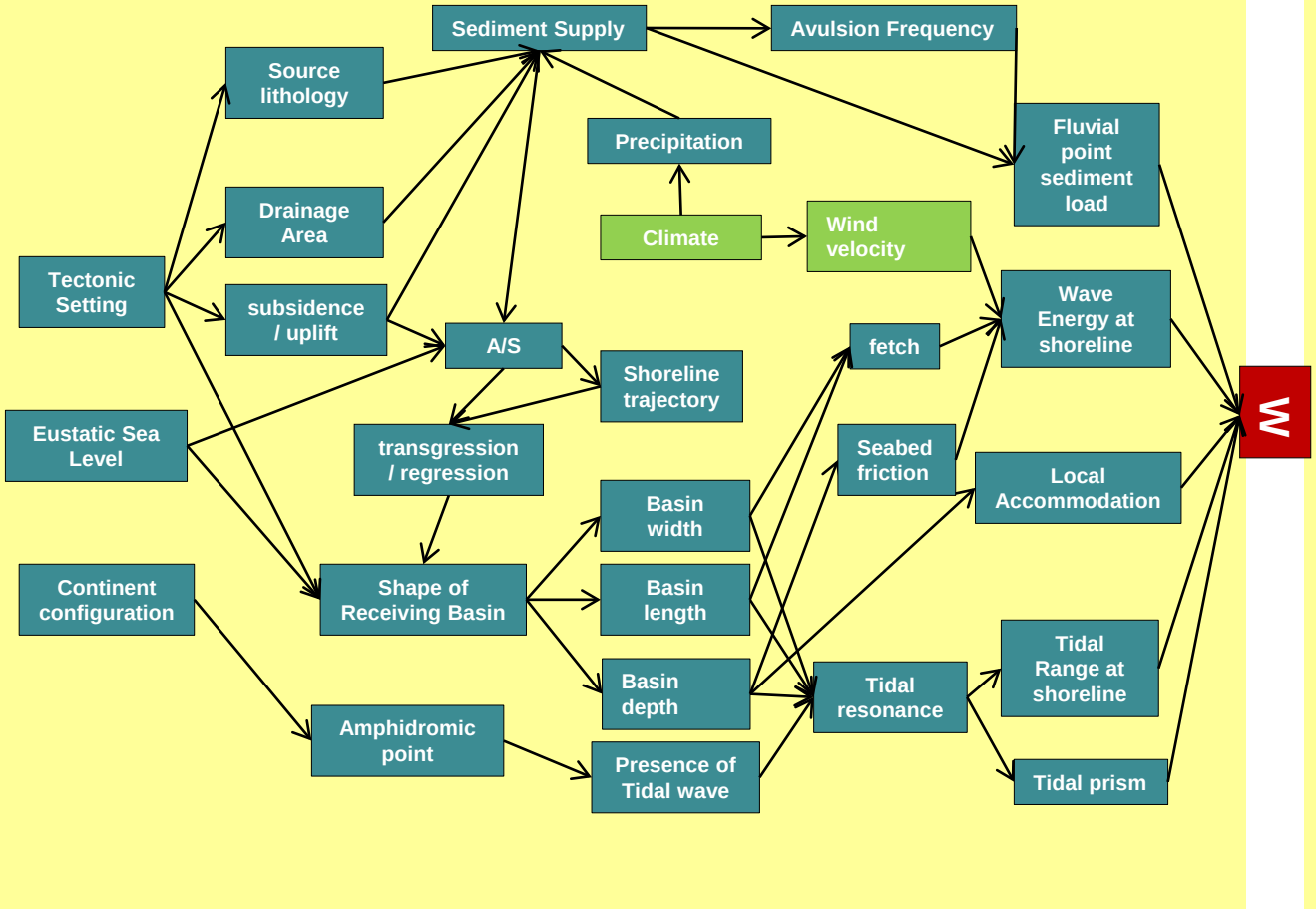

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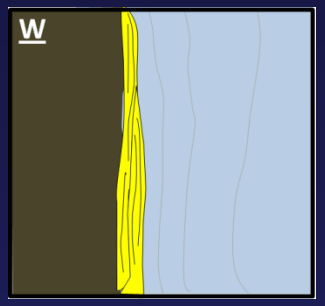

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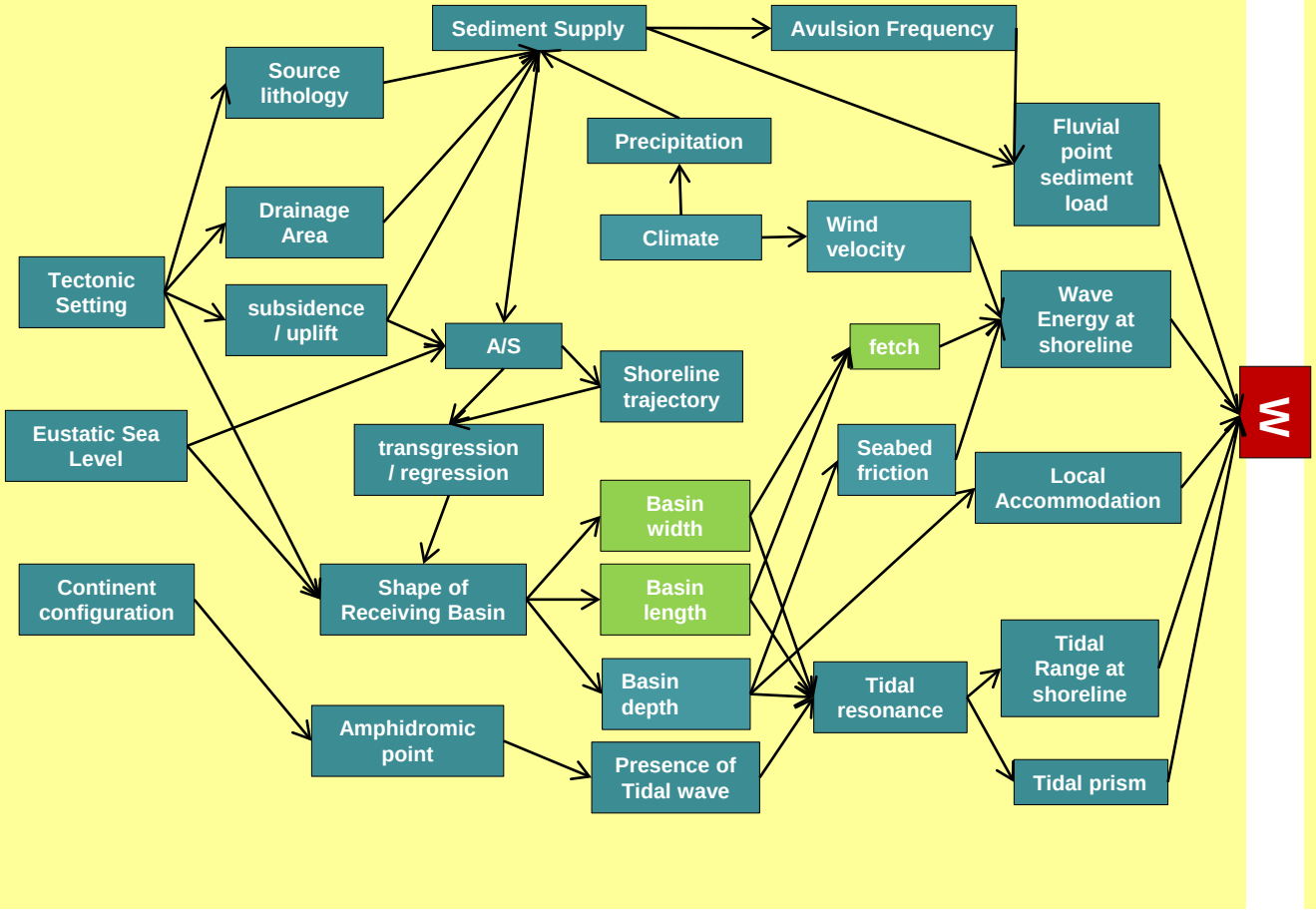

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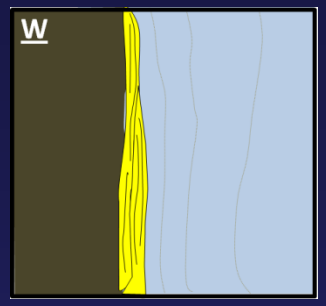

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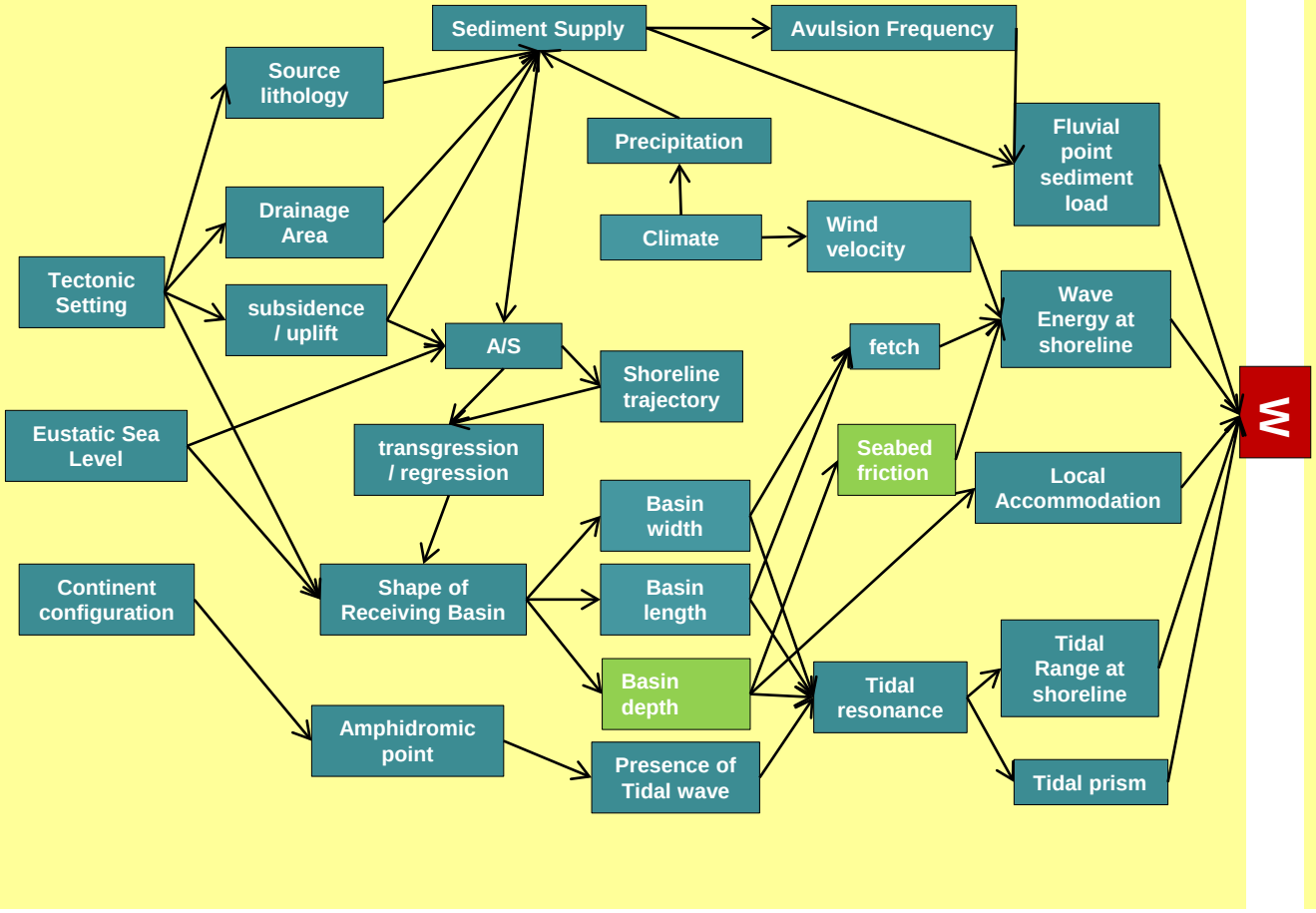
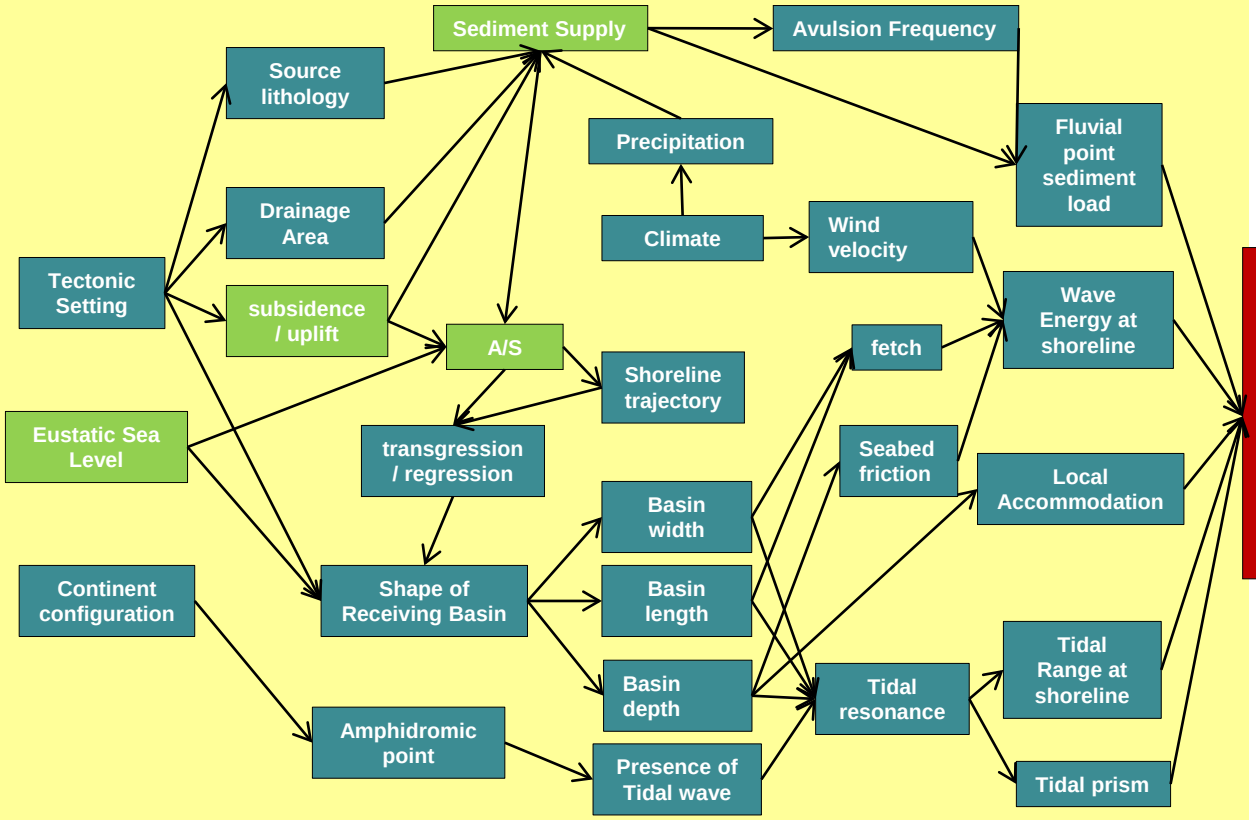
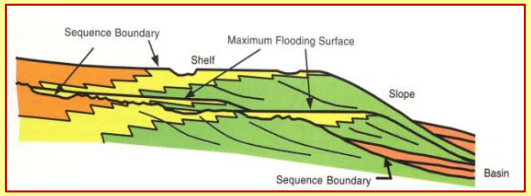


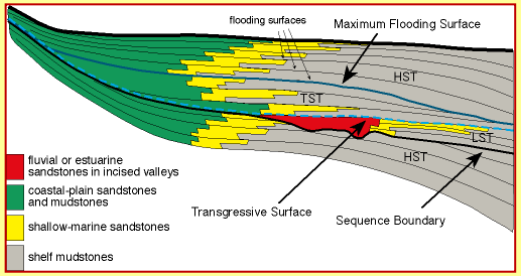
Sequence Stratigraphy

Processes and Basin Variables



Classification



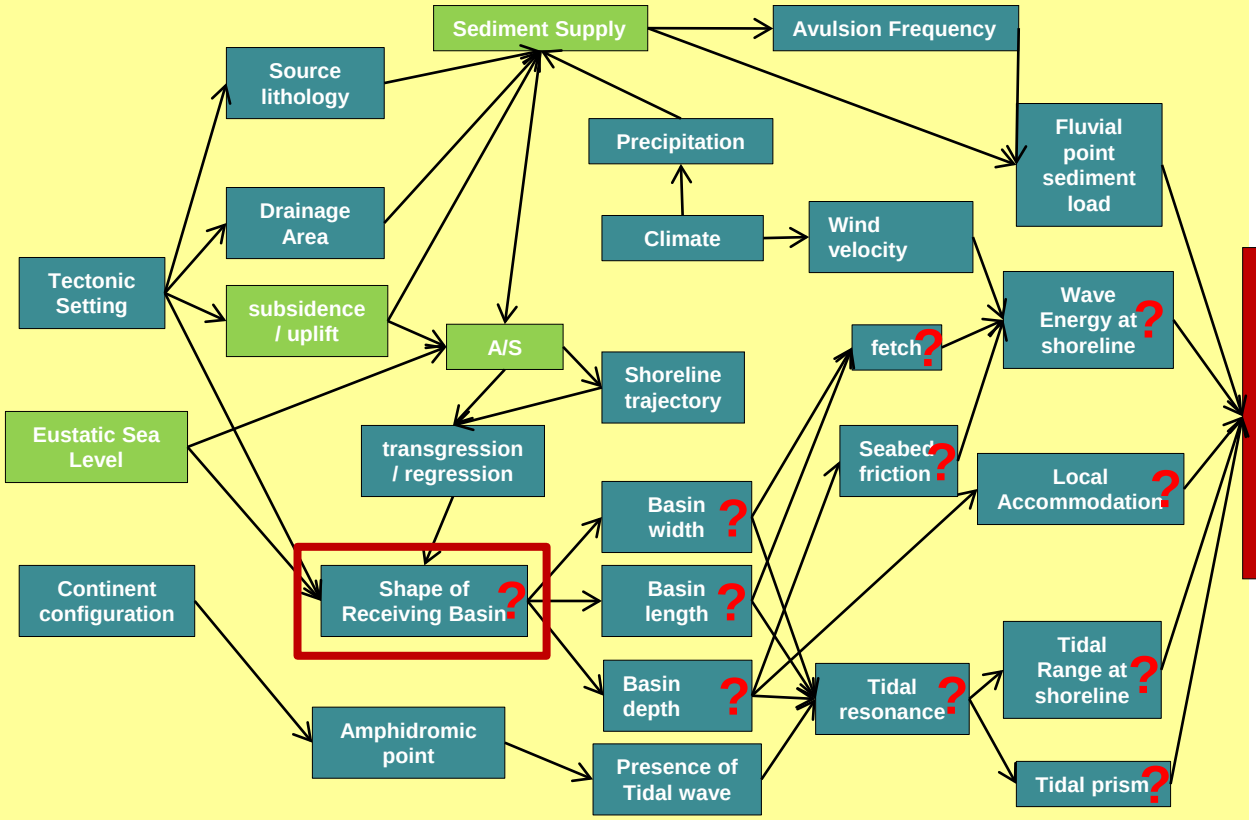


Output Categories

-Systems Tracts

Sequence Stratigraphy

Processes and Basin Variables



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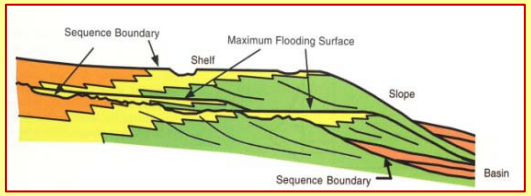
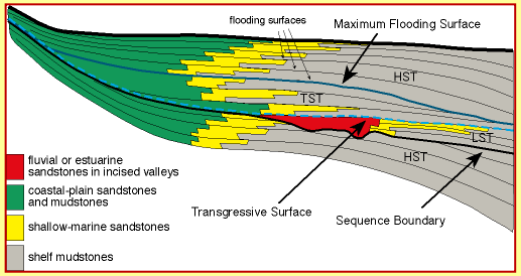




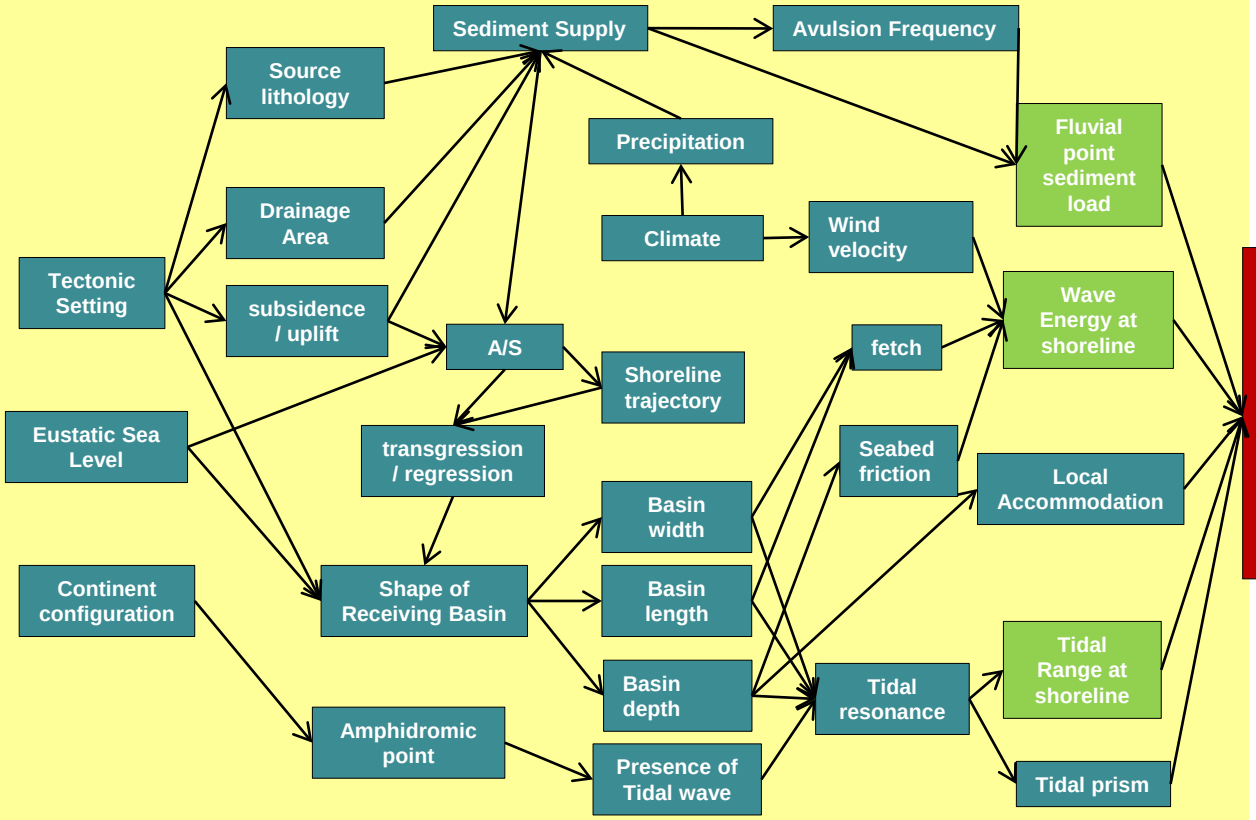
Output Categories

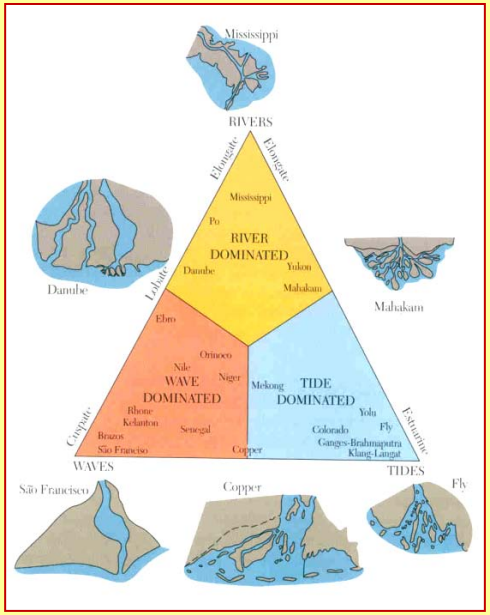
-Systems Tracts

No paleogeography input leads to poor prediction capability for shoreline architecture

Galloway (1975)

Processes and Basin Variables



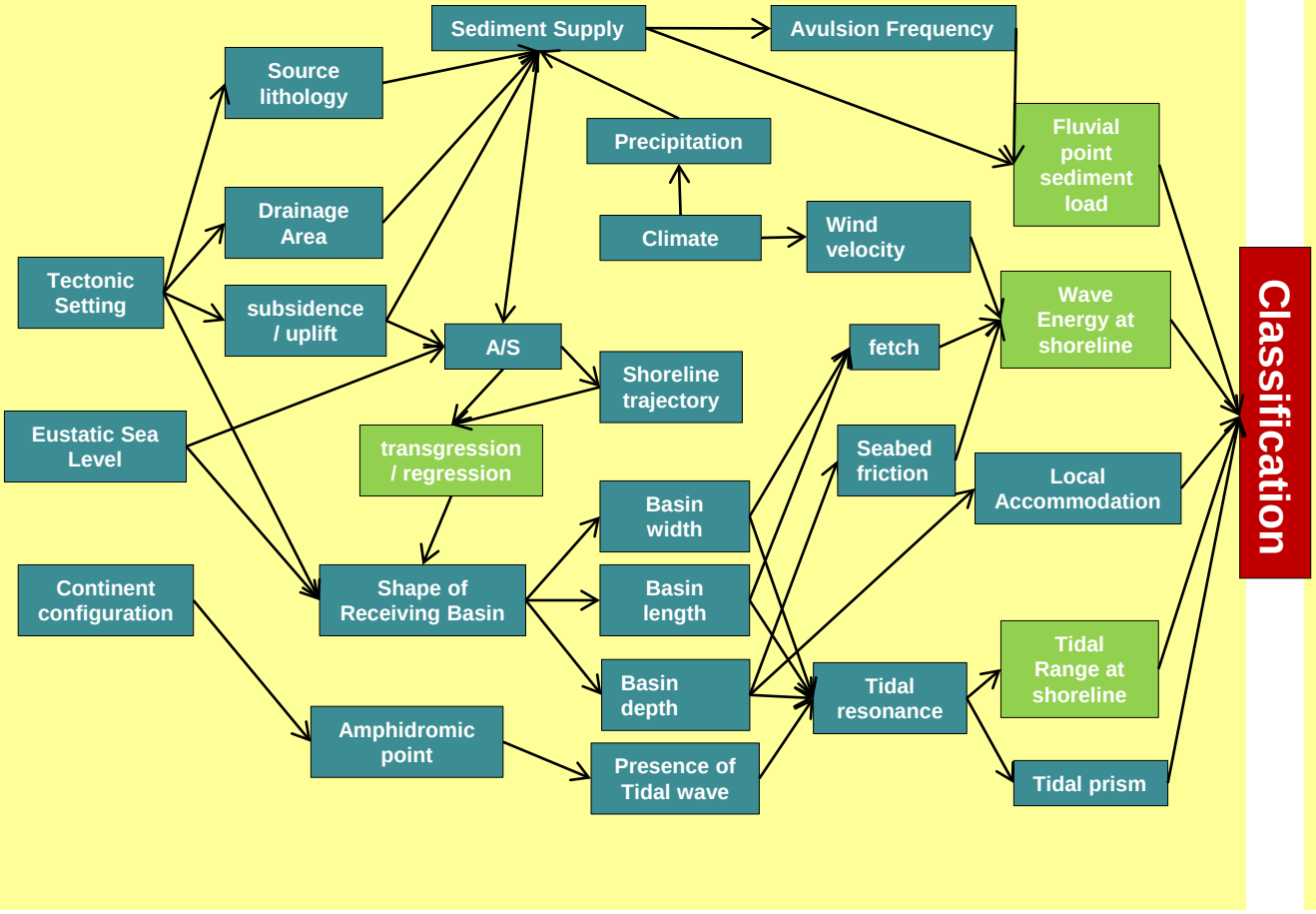


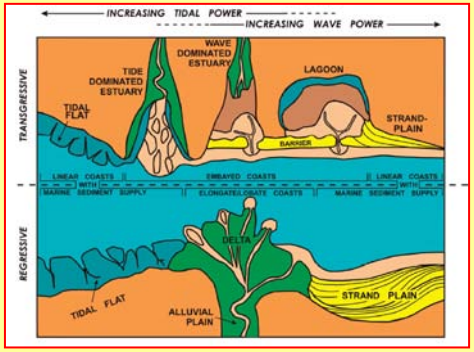
Output Categories

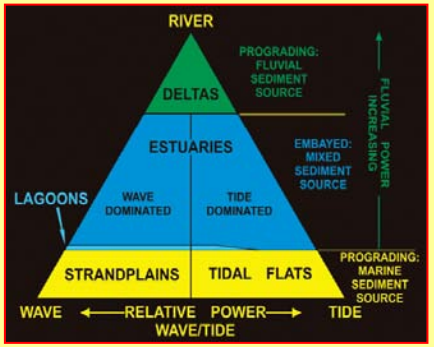
-Fluvial-dominated delta
-Wave-dominated delta
-Tide-dominated delta

Boyd et al. (1992; 2006)

Processes and Basin Variables





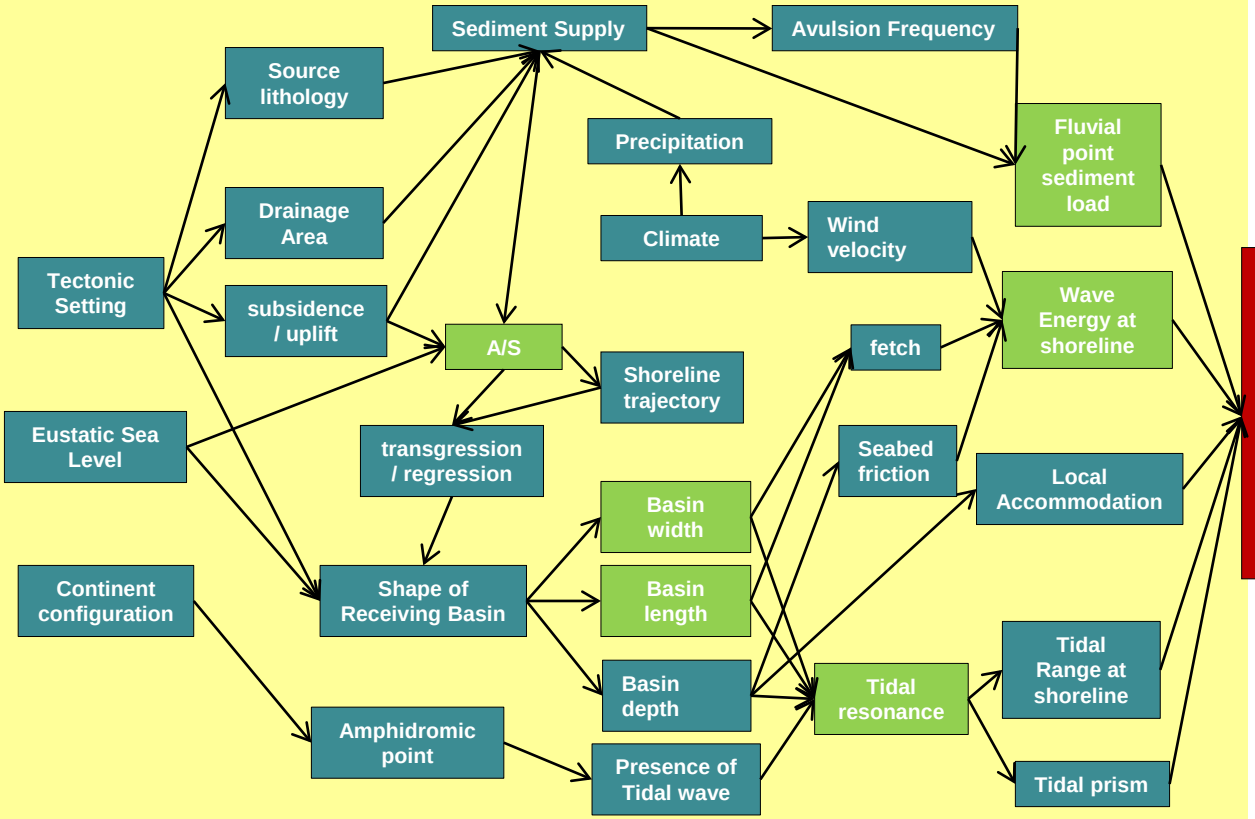


Output Categories

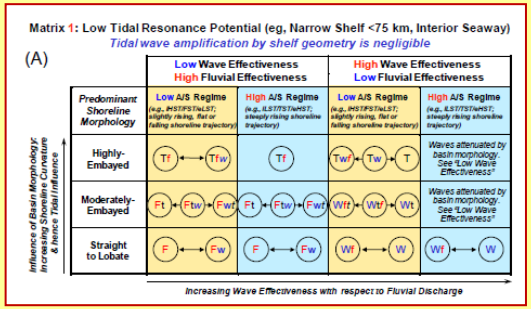
- Delta
- Wave-dominated Estuary
- Tide-dominated Estuary
- Lagoon
- Strandplain
- Tidal flat

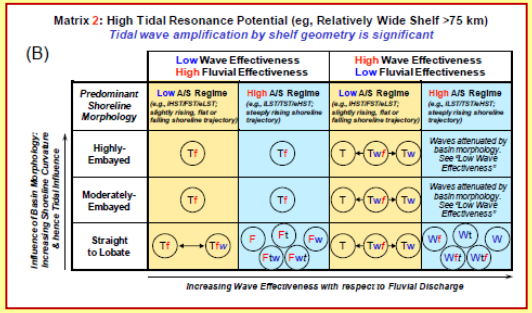
Ainsworth et al. (2008; in review) Predictive Matrices

Processes and Basin Variables



Classification

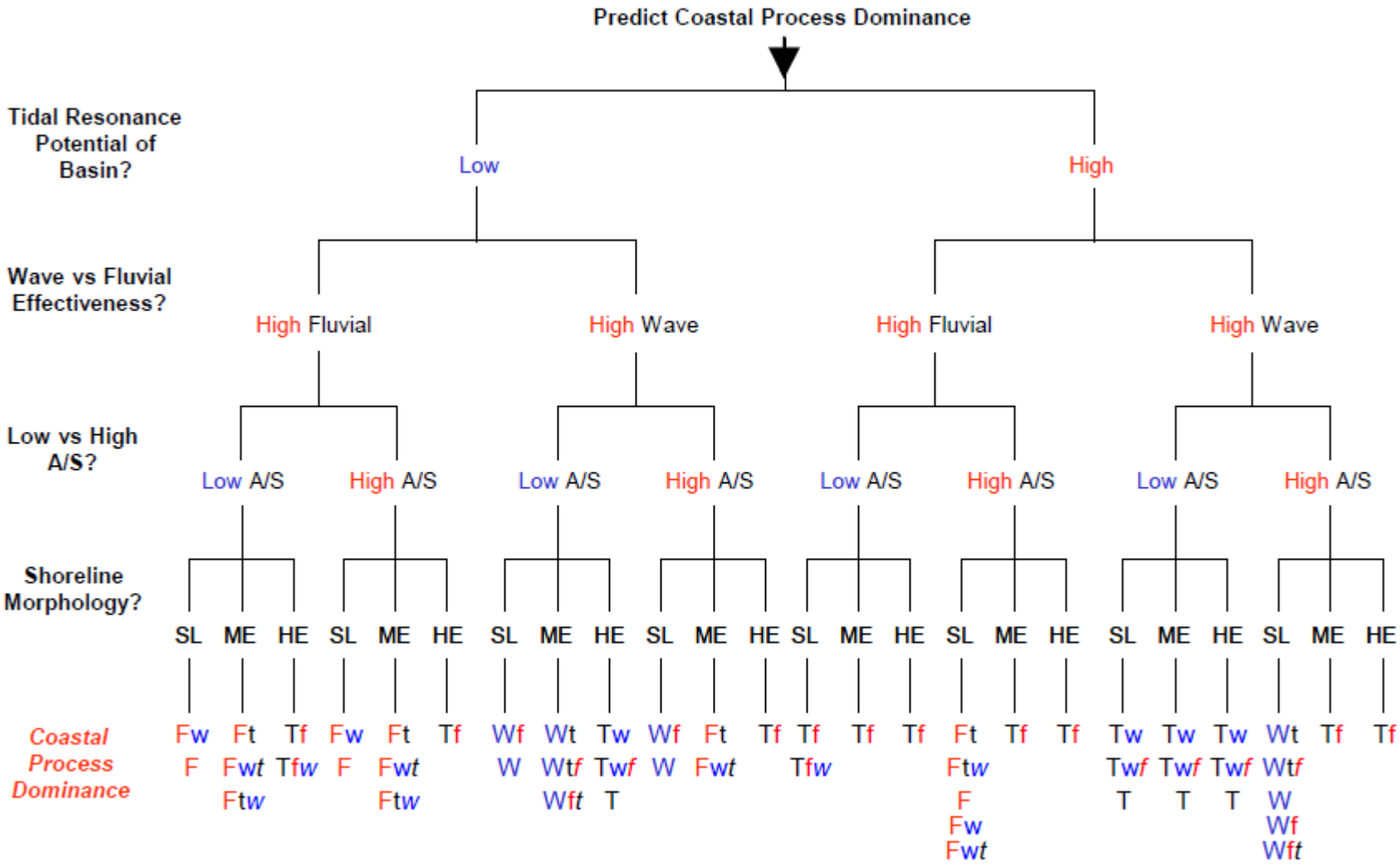




Outputs Ranges of Categories:

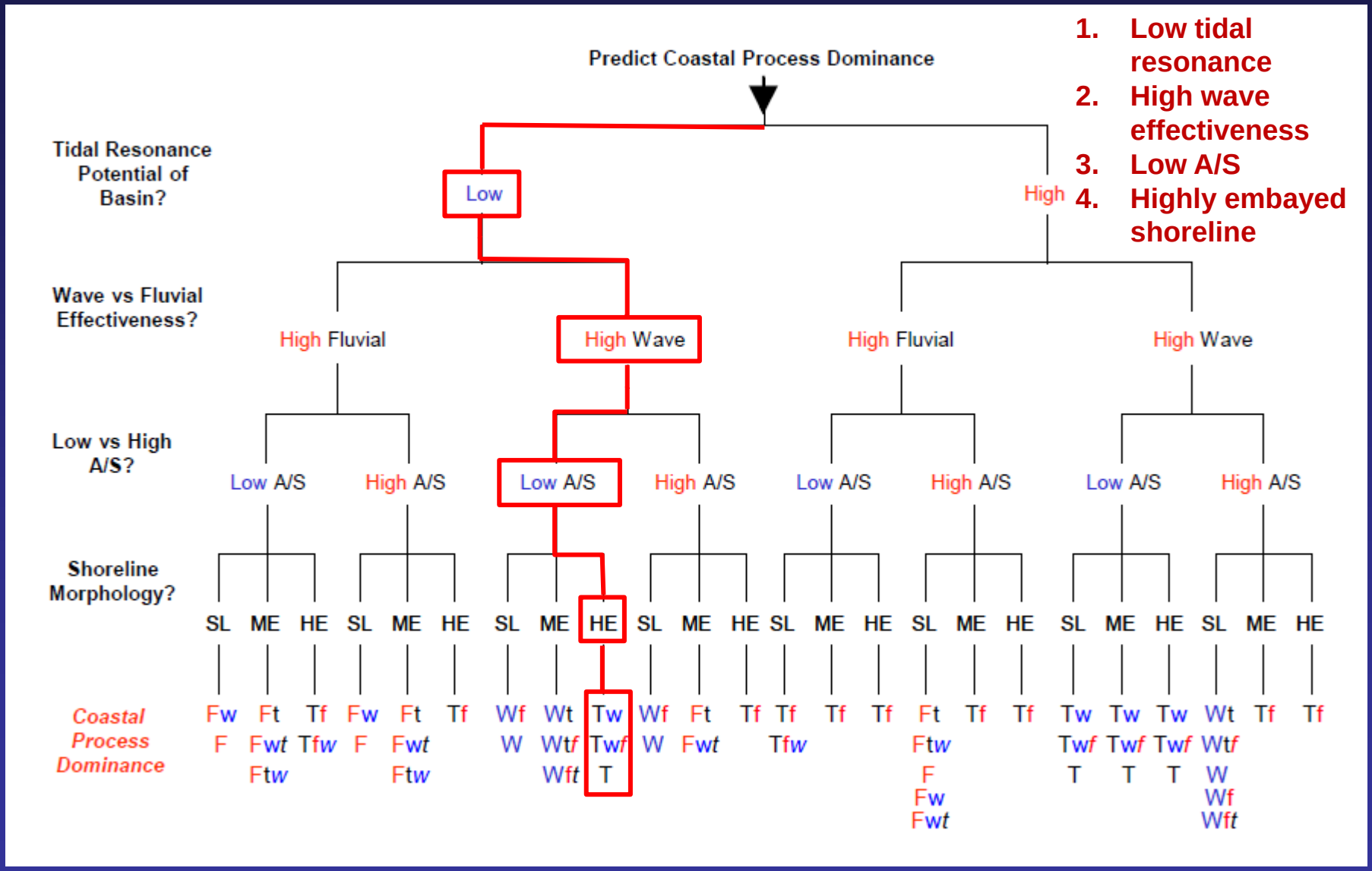
F, Fw, Ft, Fw*t*, Ft*w*, W, Wf, Wt, Wf*t*, Wt*f*,, T, Tf, Tw,Tf*w*, Tw*f*

Predictive Matrix as Decision Tree



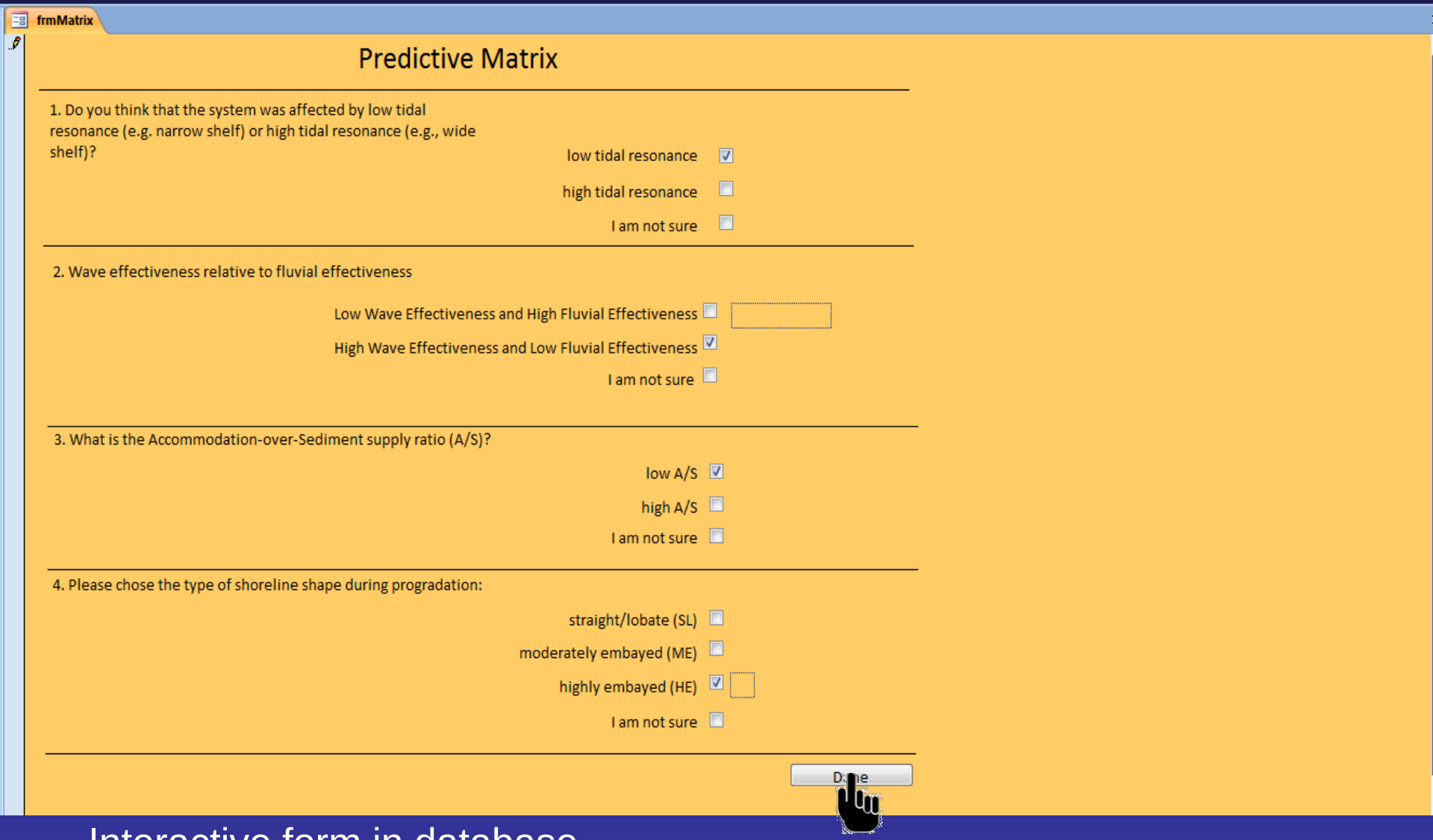
Ainsworth et al. (in review)

Predictive Matrix as Decision Tree



Ainsworth et al. (in review)

Matrix Module in Wave Knowledgebase



Interactive form in database

Matrix Module in Wave Knowledgebase

frmMatrix

Predictive Matrix

1. Do you think that the system was affected by low tidal resonance (e.g. narrow shelf) or high tidal resonance (e.g., wide shelf)?

2. Wave effectiveness relative to fluvial effectiveness

Low Wave Effectiveness and High Fl

High Wave Effectiveness and Low Fl

3. What is the Accommodation-over-Sediment supply ratio (A/S)?

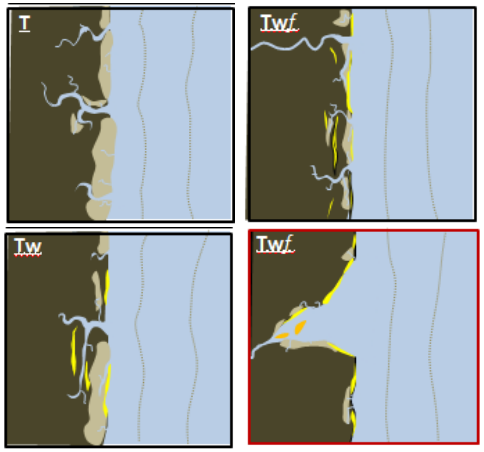
4. Please chose the type of shoreline shape during progradation:

- straight/lobate (SL) ☐
- moderately embayed (ME) ☐
- highly embayed (HE) ☑
- I am not sure ☐

Done

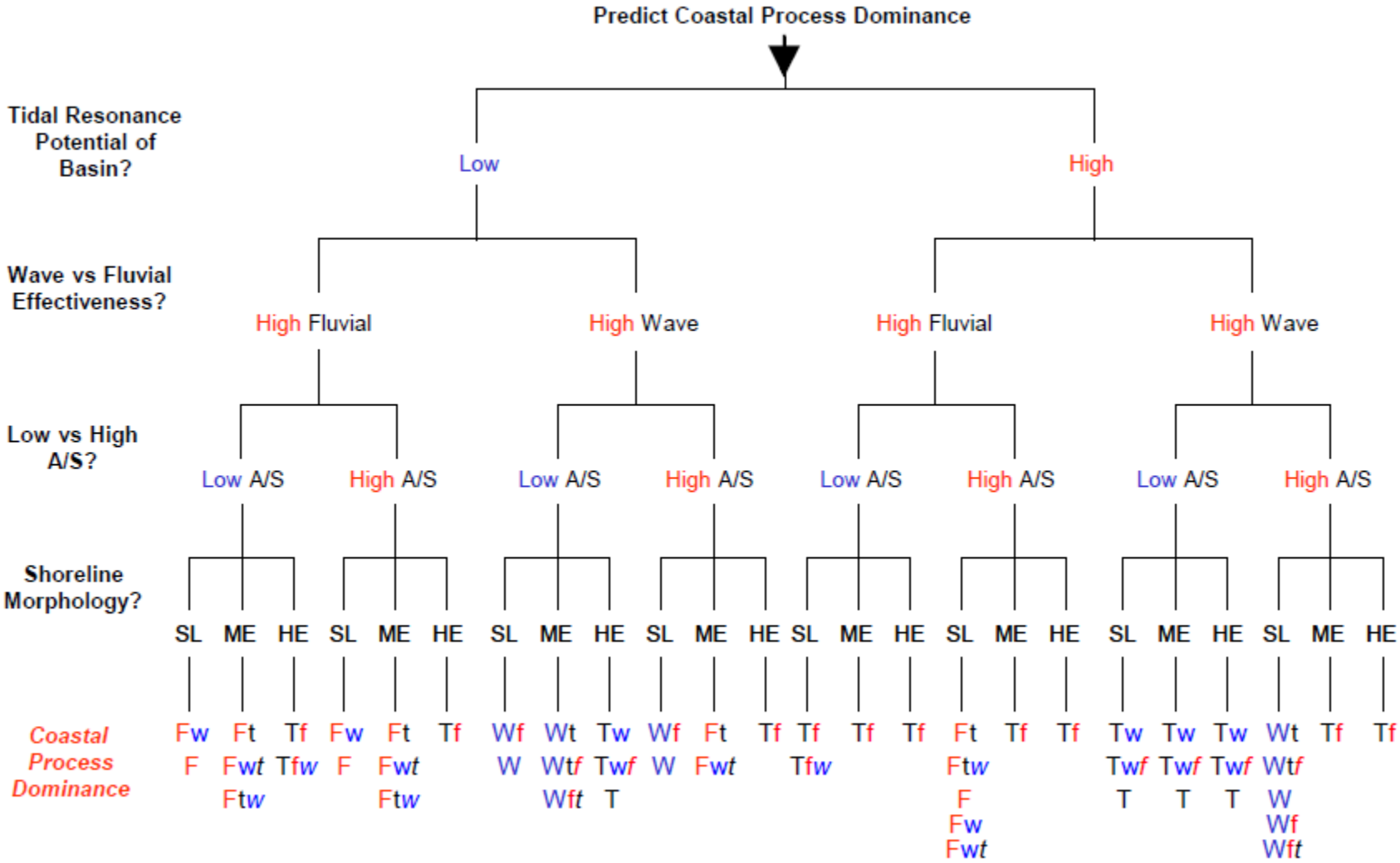
Based on the information you provided, the following classification categories can apply to your system:

Categories: T;Tw;Twf;



Interactive form in database

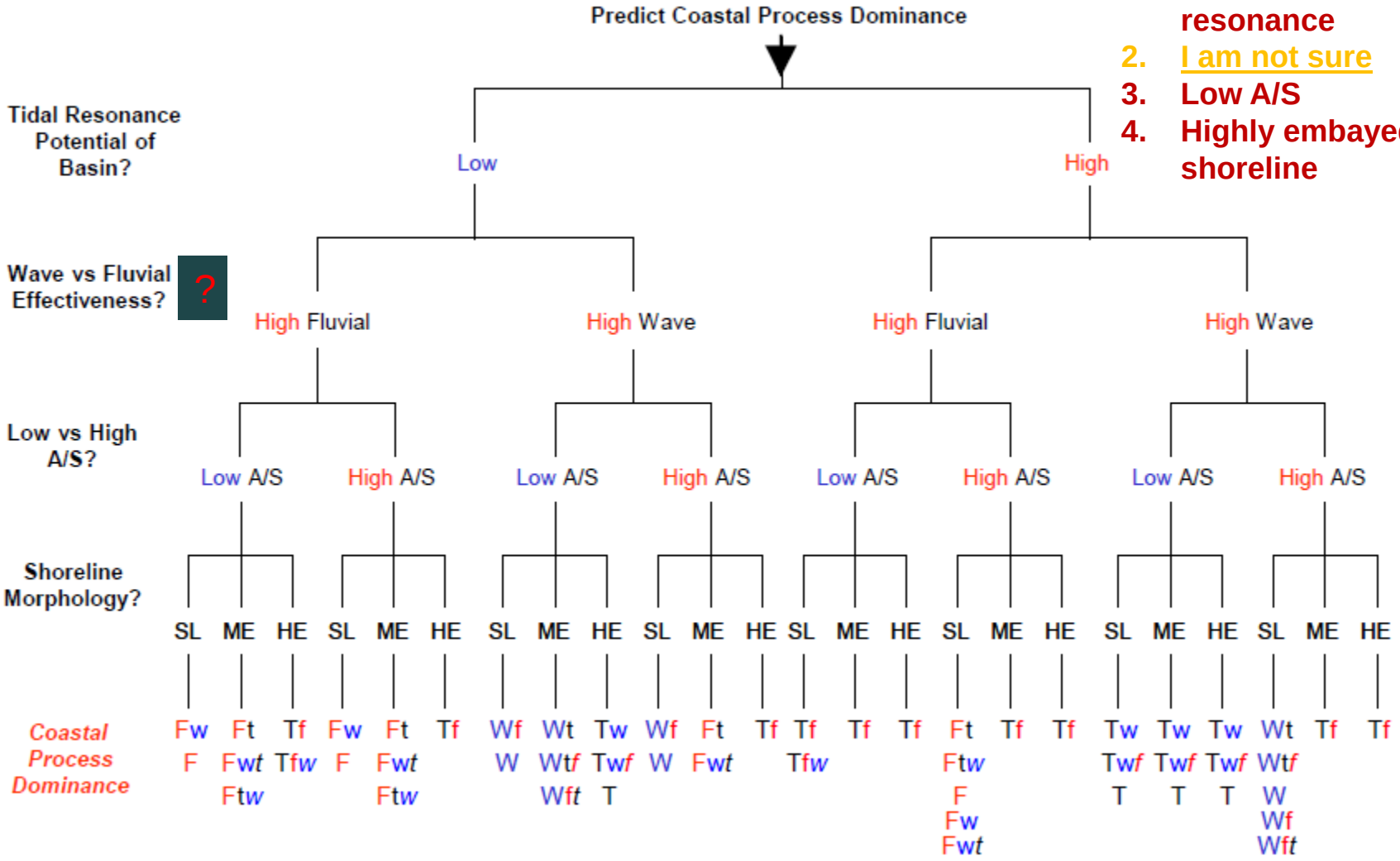
Predictive Matrix as Decision Tree



An effective way of dealing with uncertainty

Ainsworth et al. (in review)

Predictive Matrix as Decision Tree

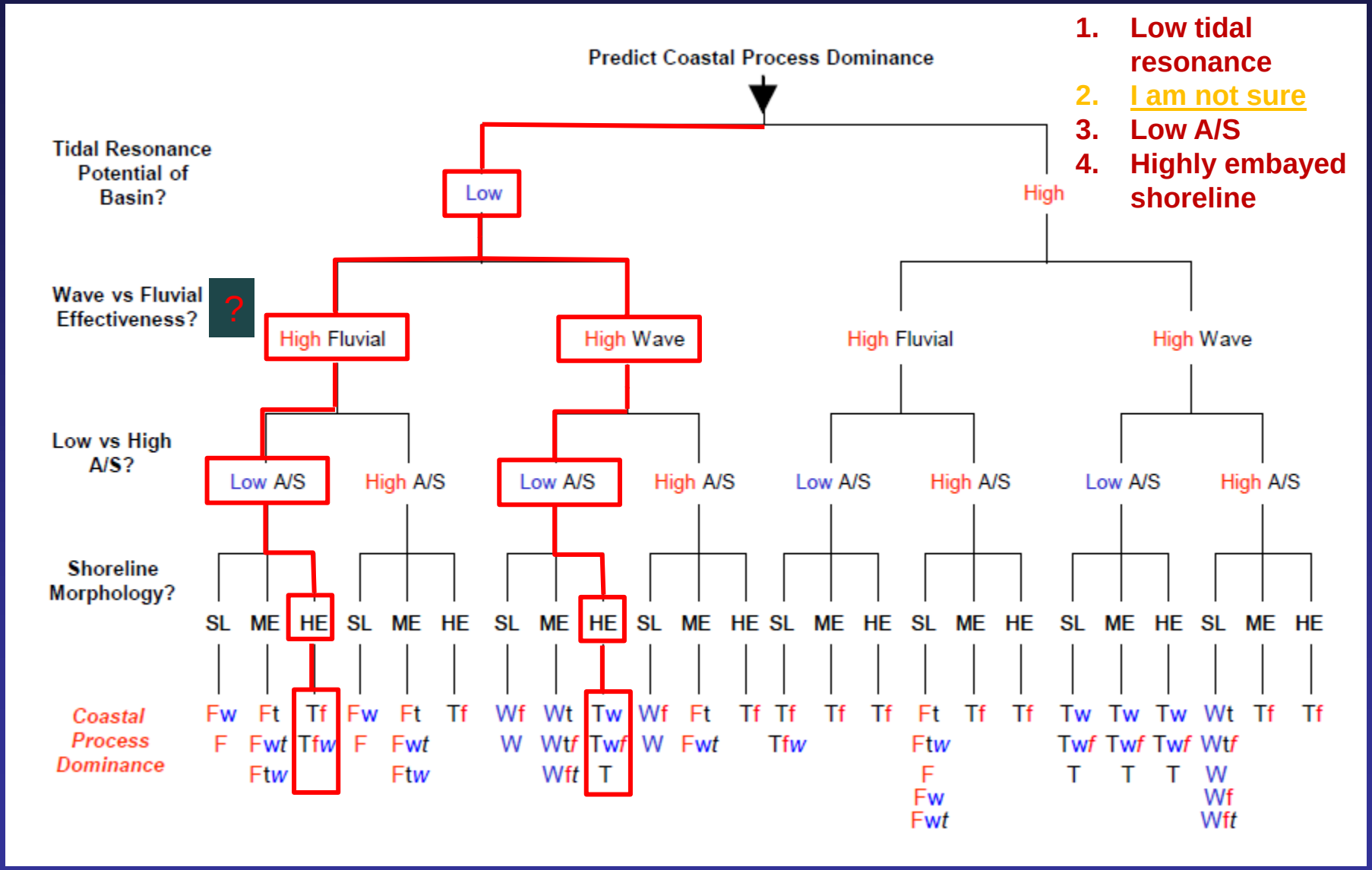


1. **Low tidal resonance**
2. **I am not sure**
3. **Low A/S**
4. **Highly embayed shoreline**

An effective way of dealing with uncertainty

Ainsworth et al. (in review)

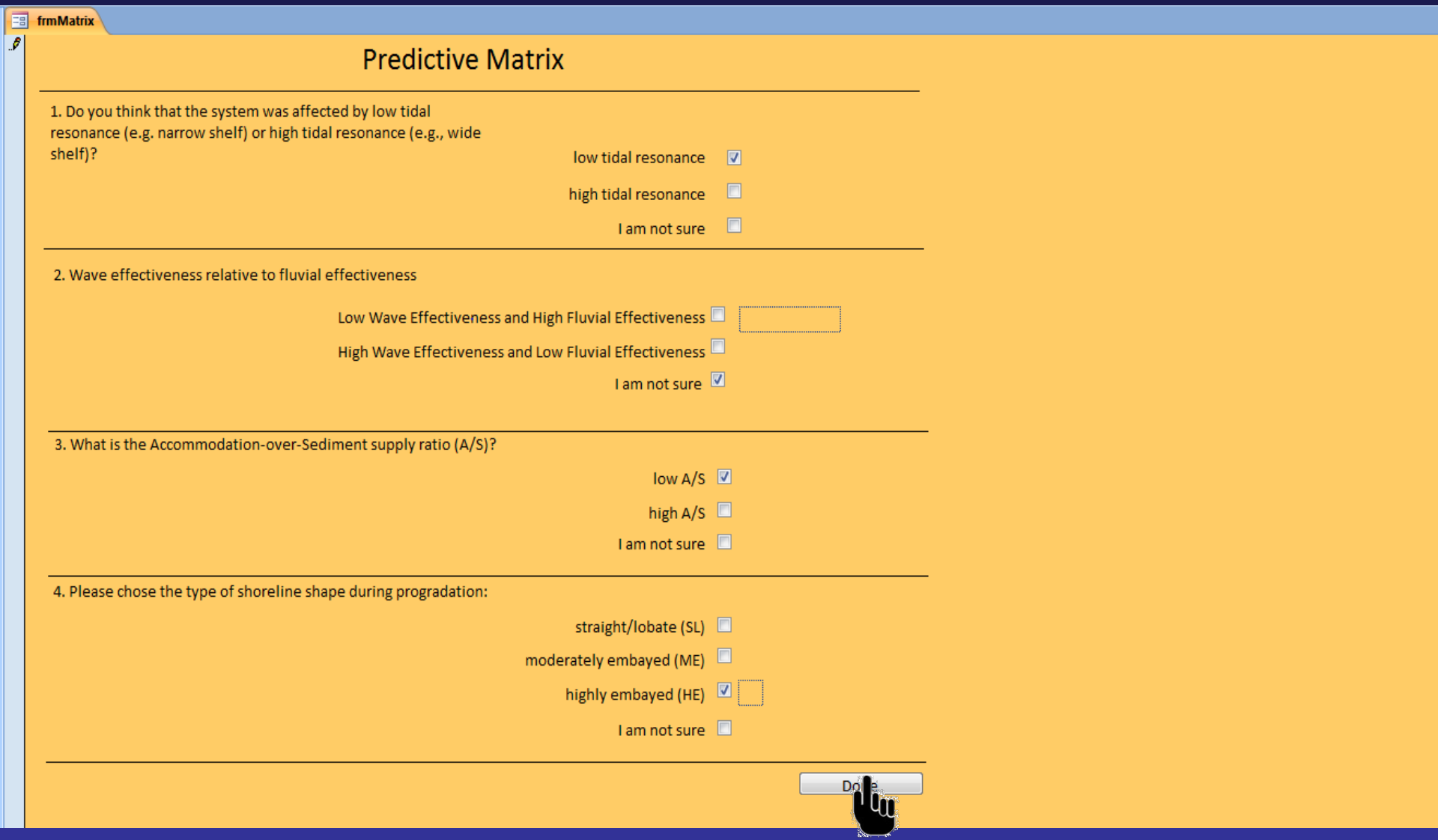
Predictive Matrix as Decision Tree



An effective way of dealing with uncertainty

Ainsworth et al. (in review)

Matrix Module in Wave Knowledgebase



Matrix Module in Wave Knowledgebase

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Done

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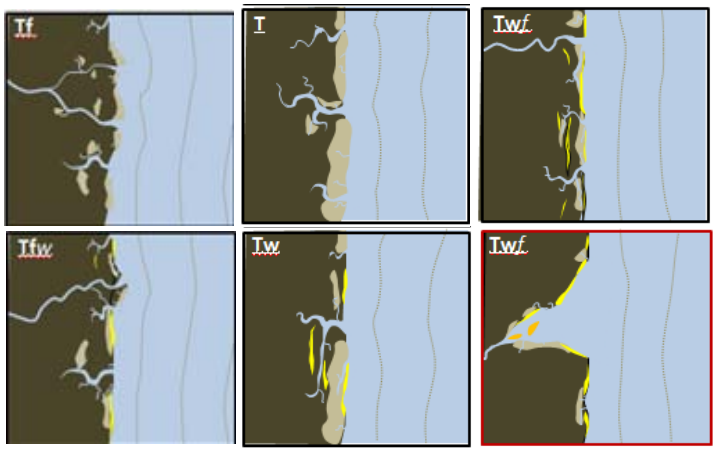

Advantages of such an approach

- Extremely flexible and easily modifiable
- No limit to number of variables used as long as there is a practical need (3, 4, …. 8)
- It effectively links process/basin setting variables to physical stratigraphy but it does not mix the two
- Classification categories can be easily enhanced:

Conclusions

1) We introduce a new classification scheme, which deals effectively with mix influenced systems

2) The classification does not mix processes with resultant stratigraphy

3) The classification has been incorporated into the Wave Knowledgebase (a database under development), which allows:
   - predictive capabilities (process to classification)
   - linking geospatial data to classification

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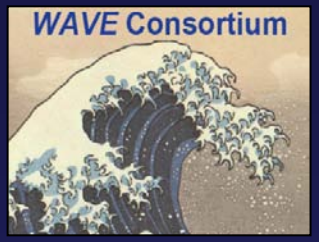

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