Multiple Reference Condition Concept for Ecosystem Restoration

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Objectives for Talk

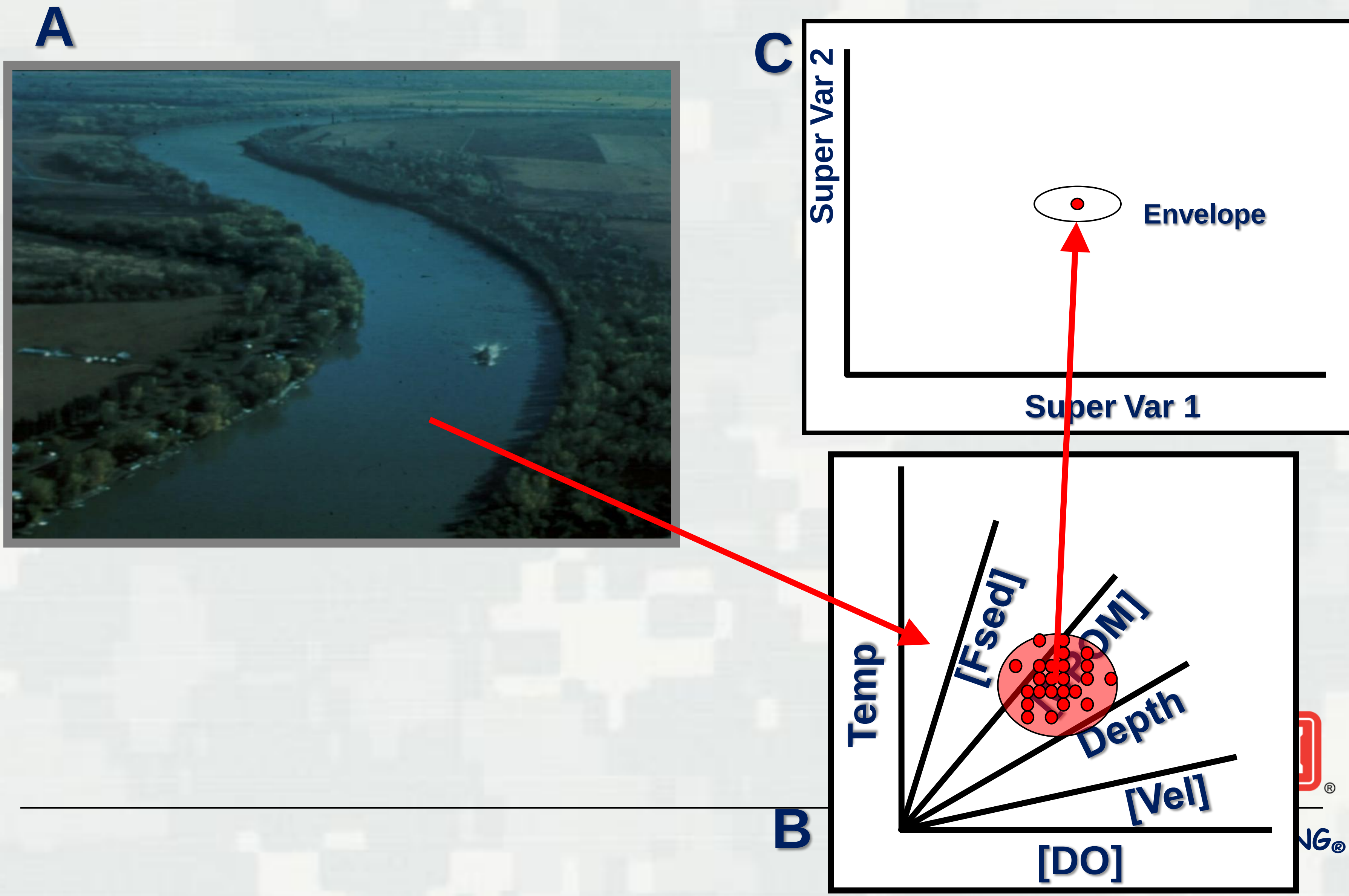
- Introduce Multiple Reference Condition Concept
- Describe UMRS Example
- Expand on Quantitative Framework
- Describe Next Steps

We Need Metrics to Determine Restoration State

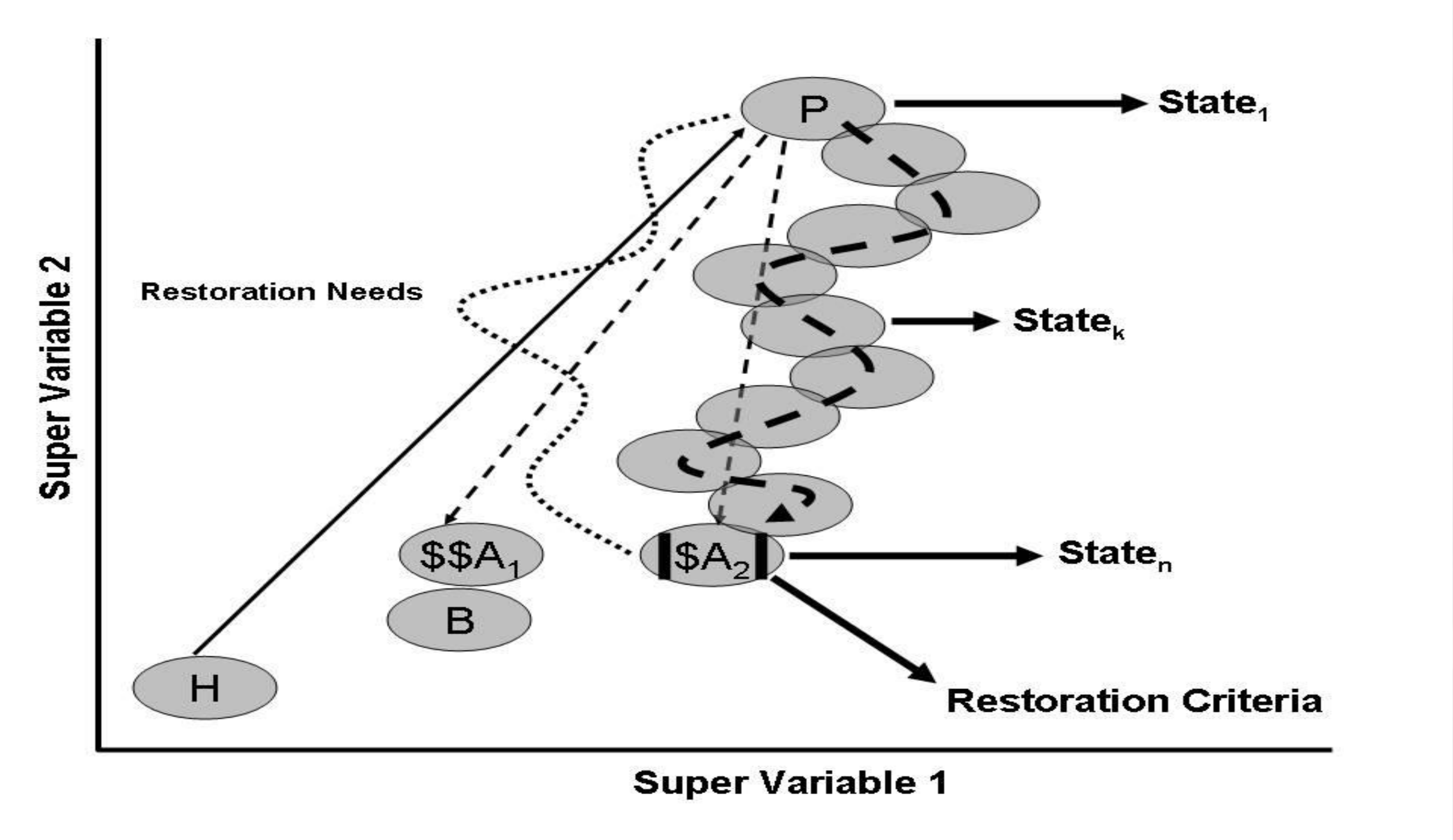
And we use reference conditions to illustrate the range of expectations

- On-site analog
- Off-site analog
- Historic reference
- Virtual
- Regional Index

Reference Conditions Define the State of the System

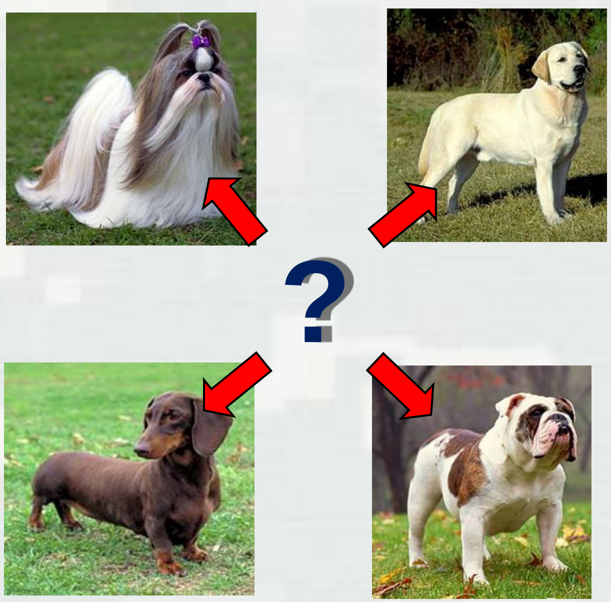


Tracking Ecosystem Condition Trajectory Among Multiple Reference Conditions

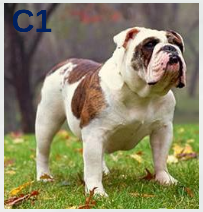


Legend: H = Historical ("Natural"), B = "Best Achievable State", Ai = Competing Alternatives, P = Present.

An Analogy: If Projects Were Dogs, How Would You Pick the Best One?



$Height_C$ $Weight_C$ $Color_C$



Contestant Dogs by Breed

Scores			Euclidean Distance[1]
$Height_{CB1}$-$Height_{SB1}$= 0.15	$Weight_{CB1}$-$Weight_{SB1}$ -0.10	$Color_{CB1}$-$Color_{SB1}$= 0.20	0.27
$Height_{CB2}$-$Height_{SB2}$= 0.10	$Weight_{CB2}$-$Weight_{SB2}$= 0.10	$Color_{CB2}$-$Color_{SB2}$= 0.05	0.15
$Height_{CB3}$-$Height_{SB3}$= 0.25	$Weight_{CB3}$-$Weight_{SB3}$= 0.15	$Color_{CB3}$-$Color_{SB3}$= 0.15	0.33
$Height_{CB4}$-$Height_{SB4}$= -0.35	$Weight_{CB4}$-$Weight_{SB4}$= 0.25	$Color_{CB4}$-$Color_{SB4}$= 0.15	0.46

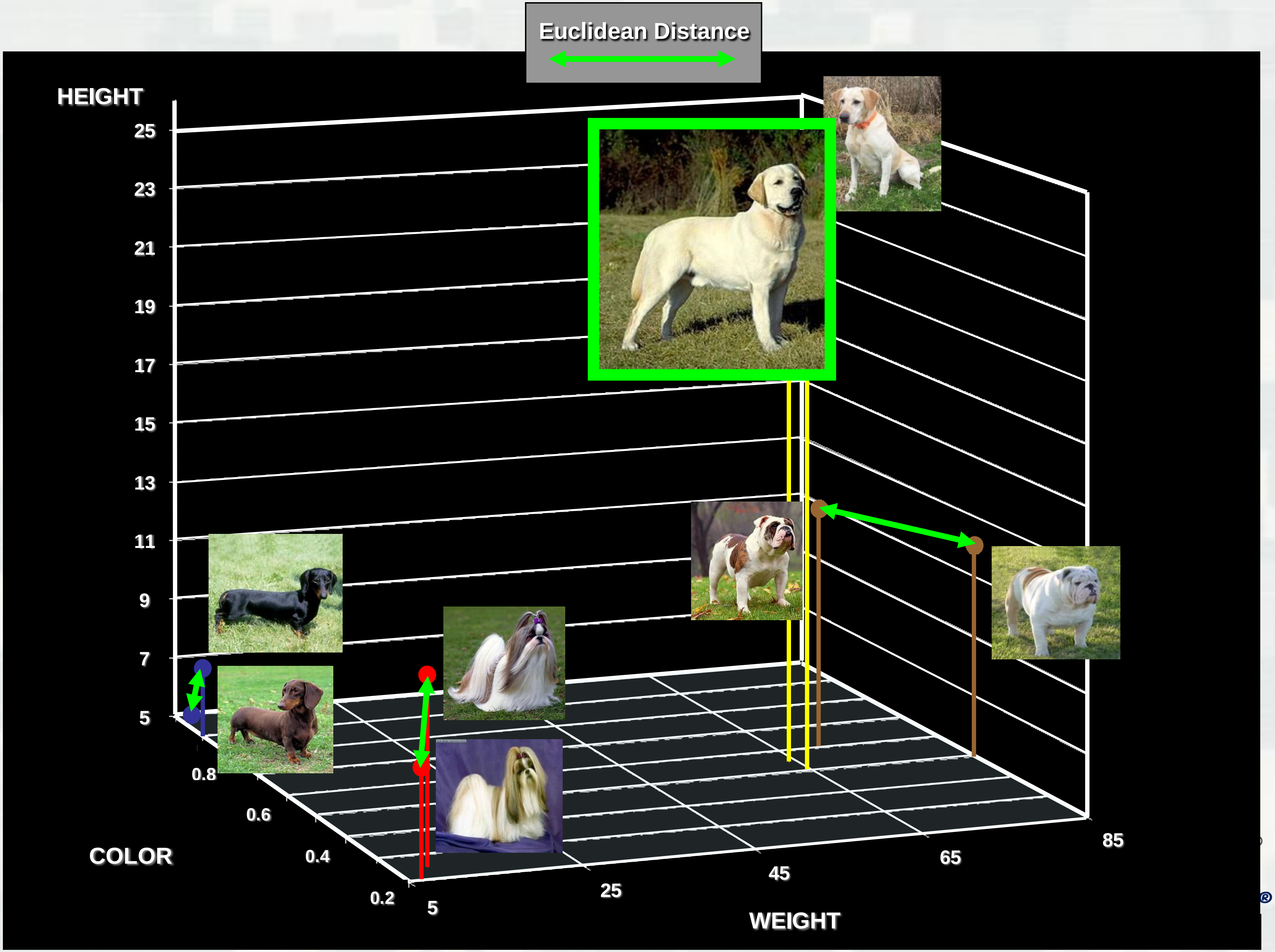
$Height_S$ $Weight_S$ $Color_S$

Breed Standards

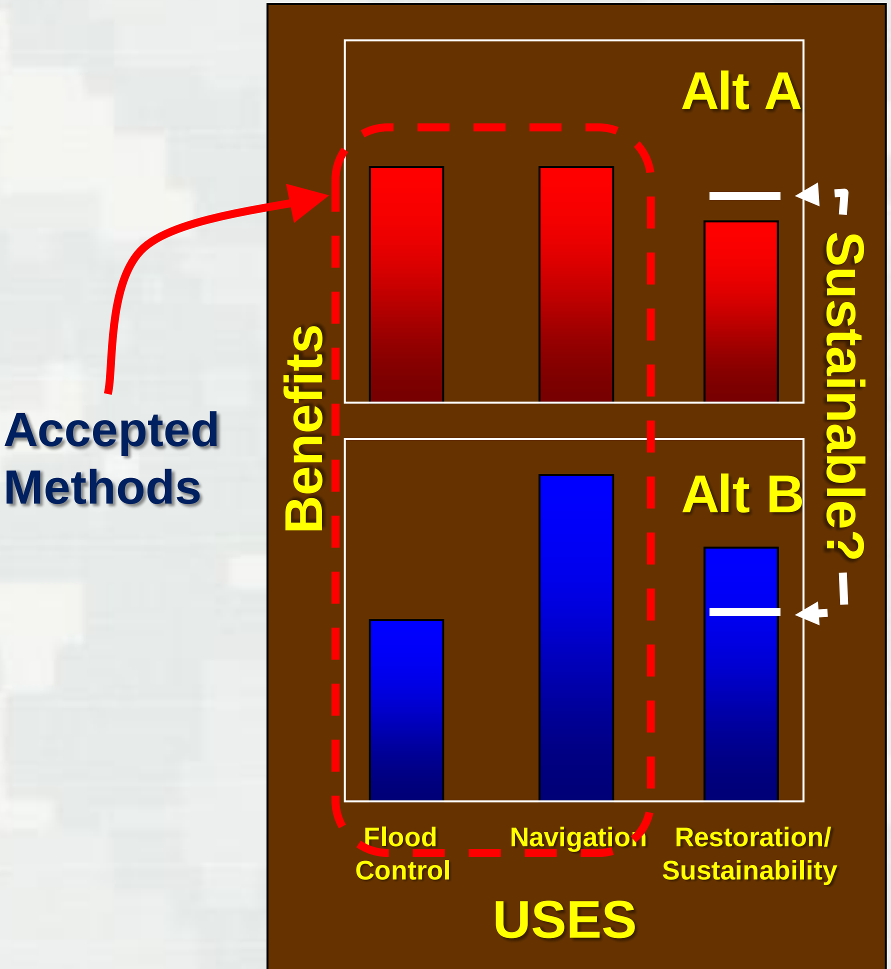
[1]Euclidean Distance=Square root of sum of squares

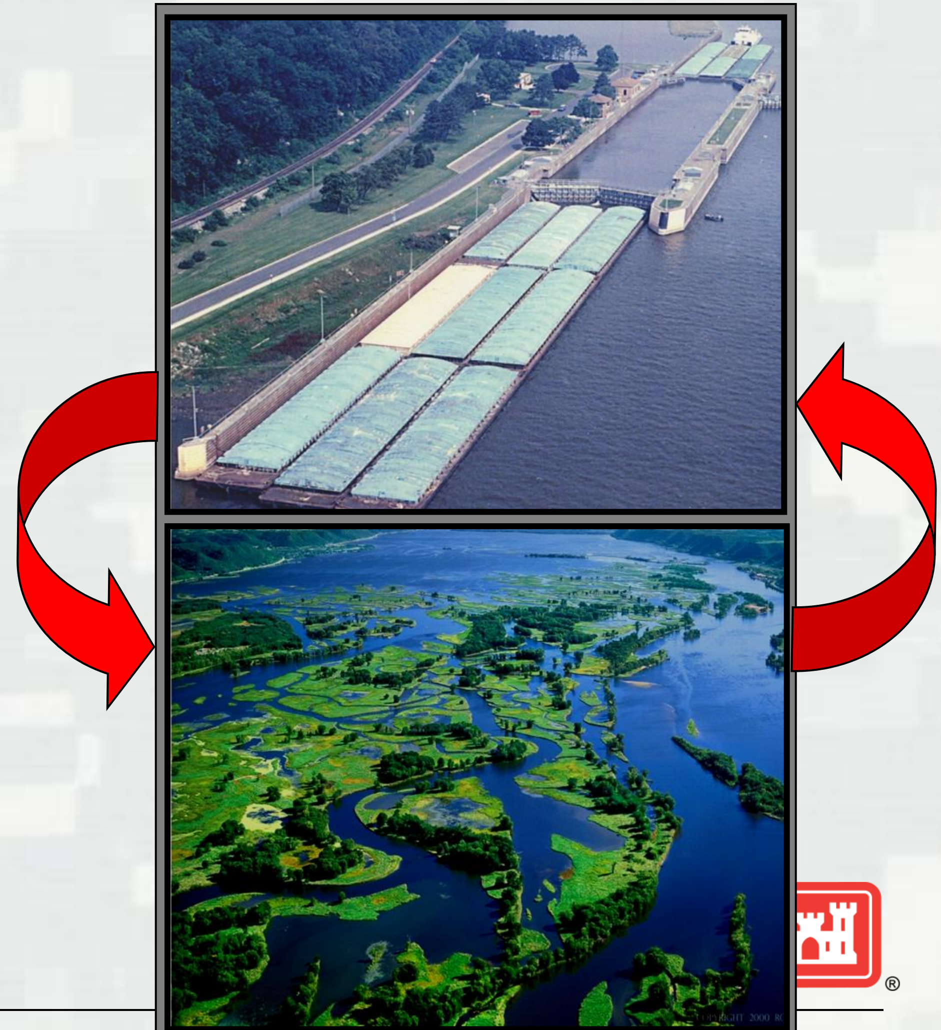
$$= \sqrt{(H_{CB1}-H_{SB1})^2 + (W_{CB1}-W_{SB1})^2 + (W_{CB1}-W_{SB1})^2}$$

Minimum Euclidean Distance=Best Dog!



Balancing Needs in Multiple-Use Systems: Upper Mississippi River System Alternative Uses

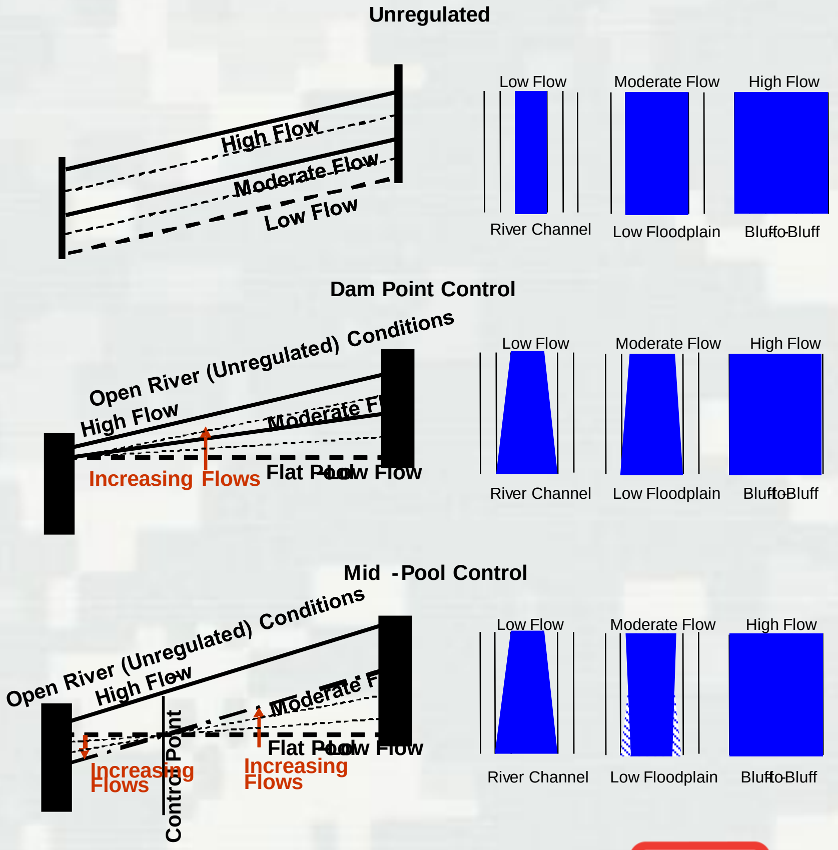




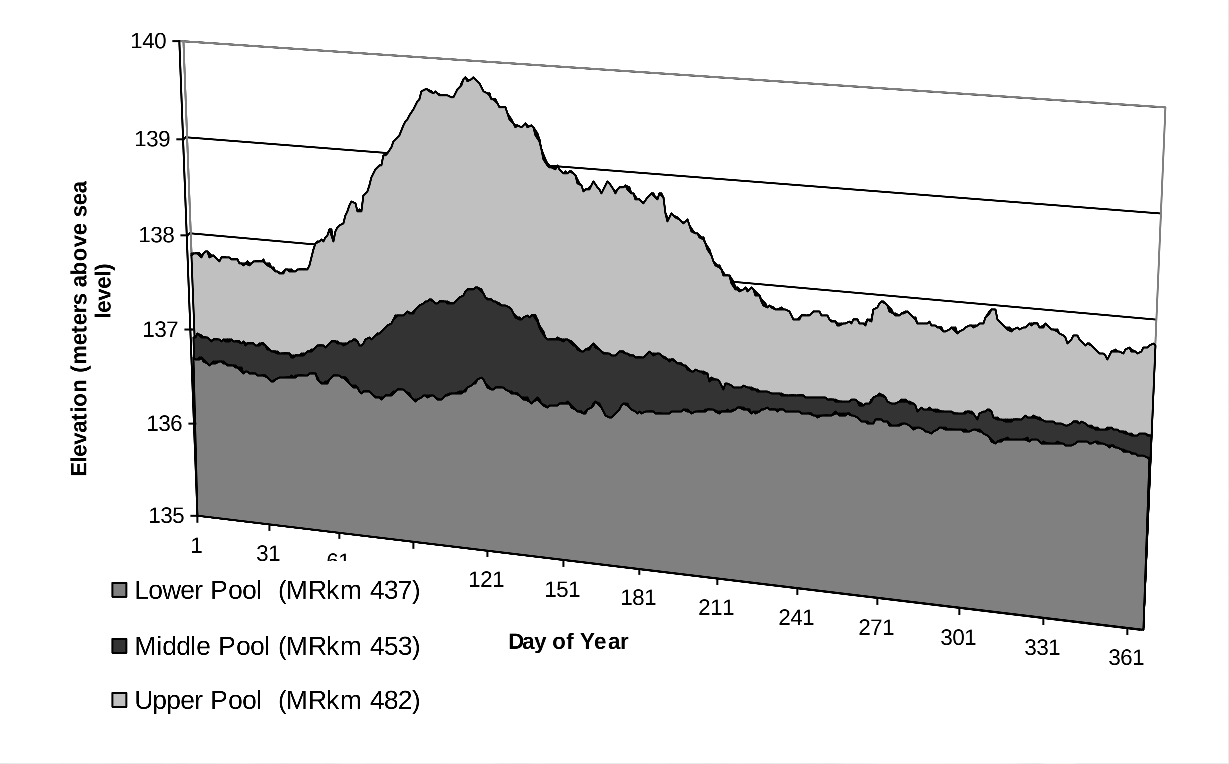
Example With Hydrologic Data

- Geomorphic Reach 3
- Pre-dam reference (A_B)Winona gage
- Contemporary reference (MM) 2 to 4 stage gages in each of six pools
- Each stage gage represents a pool segment (i.e. upper, middle, lower)
-

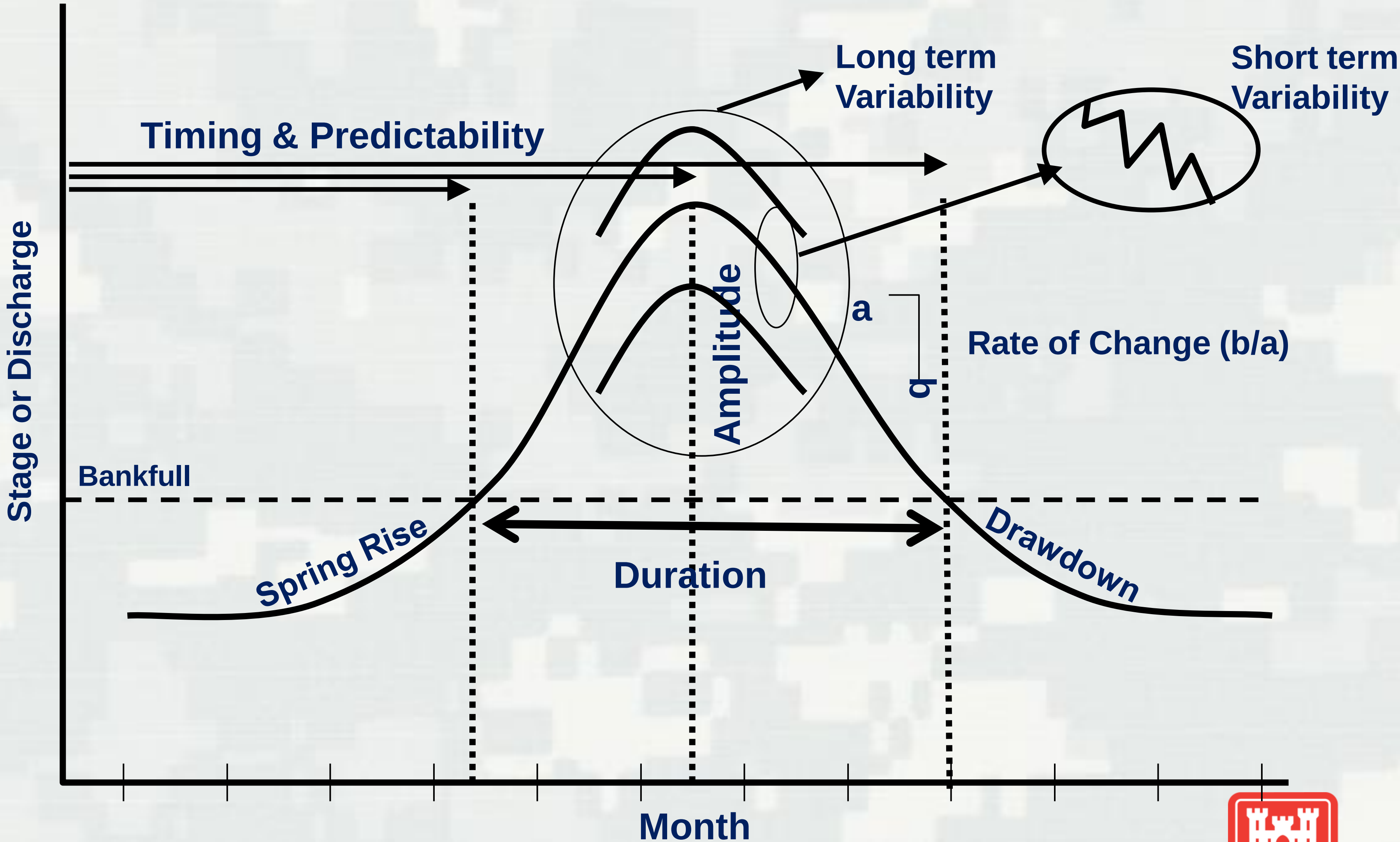
Dam Operating Options



IHA Background: Typical Pool Stage Pattern



Attributes of Flood Pulses



Modified from Welcomme, R. and A. Halls 2004. 2004. Dependence of Tropical River Fisheries on Flow. In Robin L. Welcomme and T. Petr eds., Proceedings Of The Second International Symposium On The Management Of Large Rivers For Fisheries. Volume 2. *Sustaining Livelihoods And Biodiversity In The New Millennium* 11 – 14 February 2003, Phnom Penh, Kingdom Of Cambodia

IHA Metrics of Ecological Relevance In Large Floodplain Rivers

- **Annual Coefficient of Variation – SD of daily flow values / mean annual flow**
- **Predictability – measures (from 0.0 to 1.0) regularity of occurrence**
- **Constancy – measure of flow uniformity**
- **Contingency - measure of the seasonality**
- **Low Pulse Count – number of events < some value**
- **High Pulse Count – number of events > some value**
- **Reversals – number of times flows change slope**
- **Flashiness – mean of LPC and HPC**

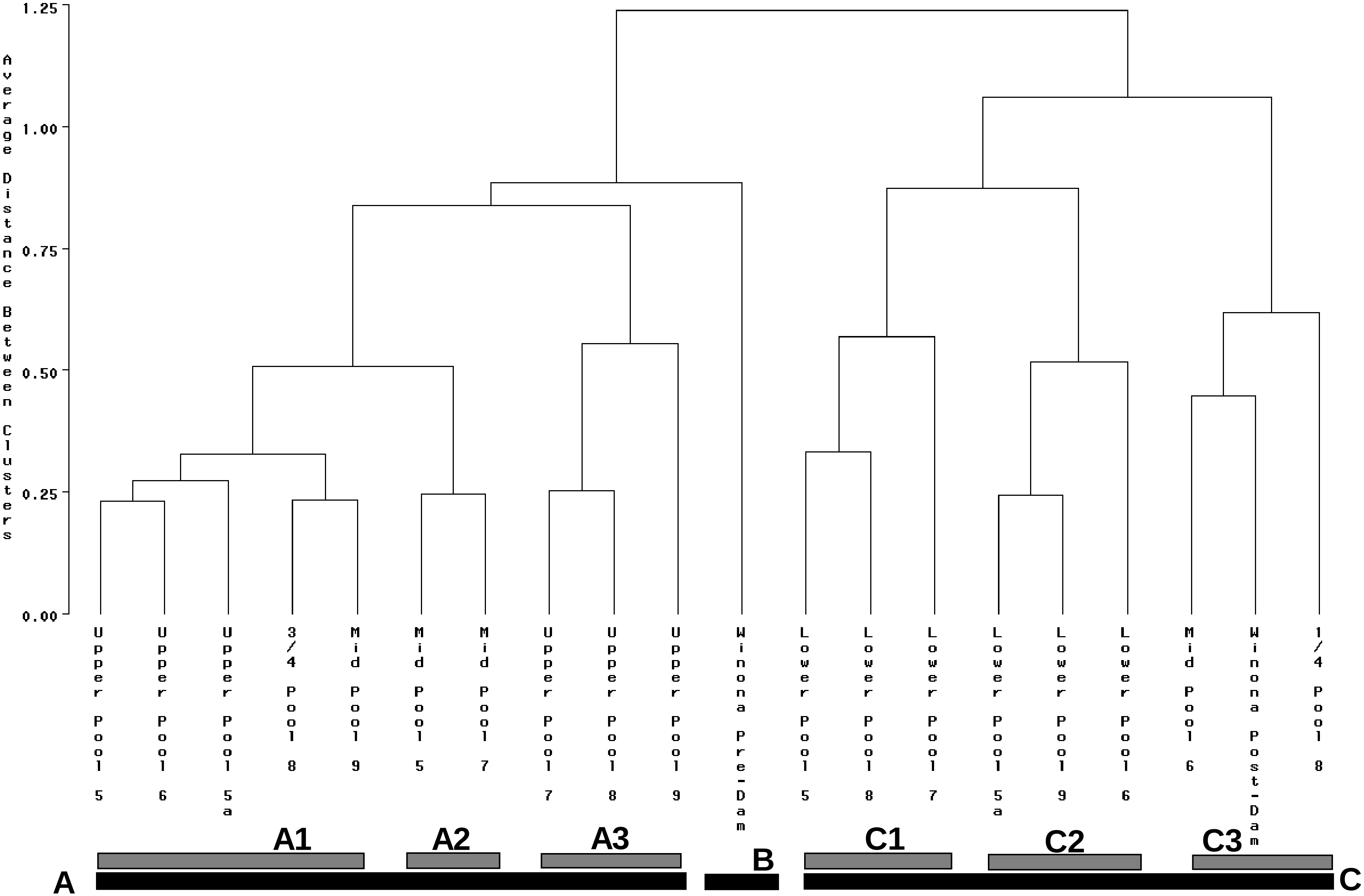
Pearson Correlation Coefficients:

Indicators of Hydrologic Alteration Variables

	Annual Coefficient Of Variation	Predictability	Constancy	Contingency	Low Pulse Count	High Pulse Count	Reversals	Flashiness	Flashiness + High & Low Pulse Count
Annual Coefficient of Variation	1.00	-0.44 0.0512	-0.74 0.0002	0.74 0.0002	-0.40 0.077	-0.40 0.083	-0.41 0.0747	-0.42 0.0643	-0.43 0.0554
Predictability		1.00	0.43 0.057	-0.43 0.056	0.06 0.811	-0.04 0.877	0.12 0.6058	0.014 0.9519	0.06 0.8167
Constancy			1.00	-1.00 <.0001	0.68 0.0009	0.66 0.0017	0.67 0.0012	0.70 0.0005	0.7235 0.0003
Contingency				1.00	-0.68 0.0009	-0.65 0.0017	-0.67 0.0012	-0.70 0.0005	-0.7235 0.0003
Low Pulse Count					1.00	0.81 <.0001	0.86 <.0001	0.96 <.0001	0.96 <.0001
High Pulse Count						1.00	0.68 0.0009	0.94 <.0001	0.8881 <.0001
Reversals							1.00	0.82 <.0001	0.92086 <.0001
Flashiness								1.00	0.98 <.0001

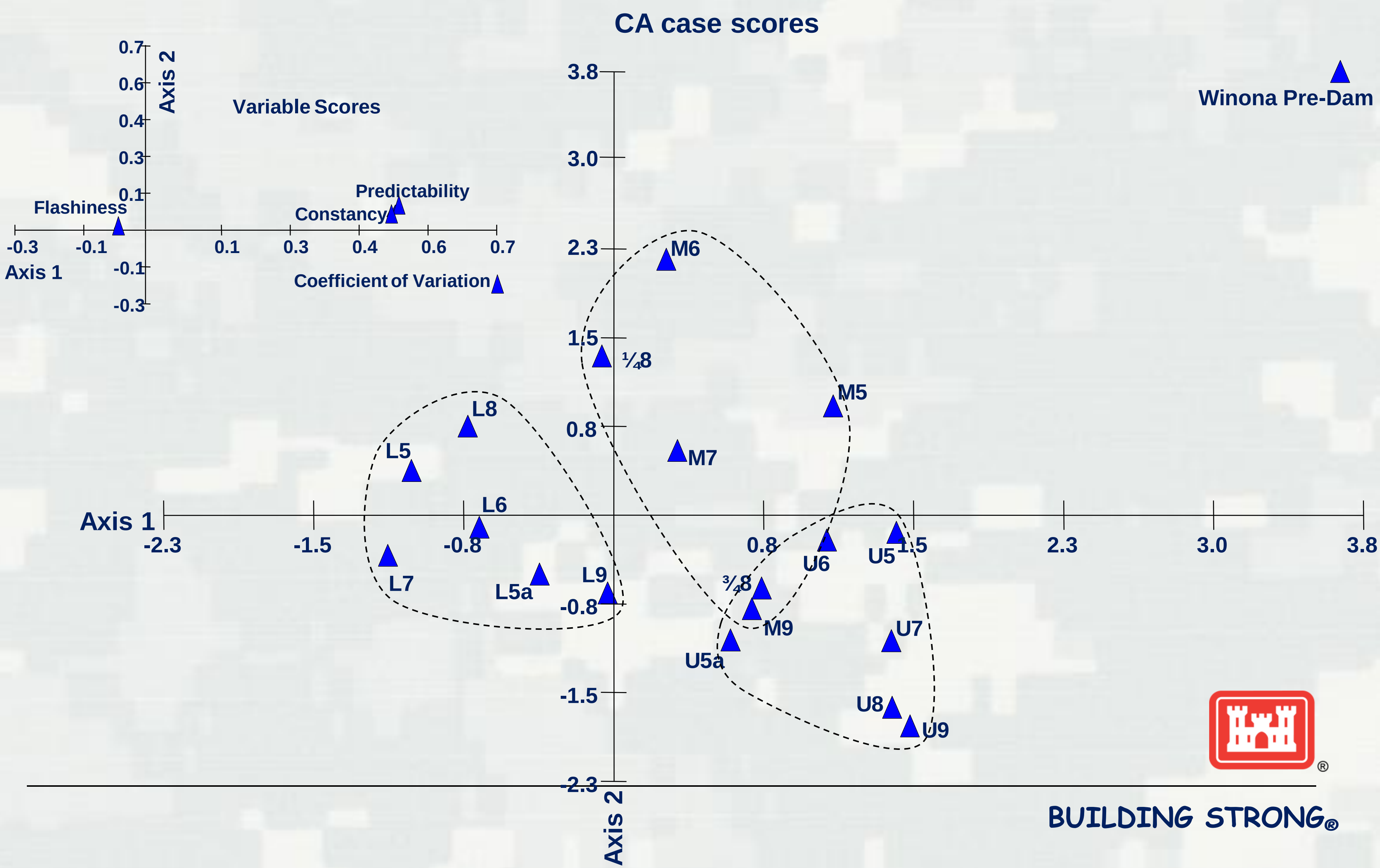
CLUSTER ANALYSIS OF GEOMORPHIC REACH 3 STAGE GAGES AND WINONA PRE/POST DAM

BASED ON STANDARDIZED (0-1) DATA USING UPGMA AND UNSQUARED DISTANCES
USING COEFFICIENT OF VARIATION, PREDICTABILITY, CONSTANCY, REVERSALS, AND FLASHINESS

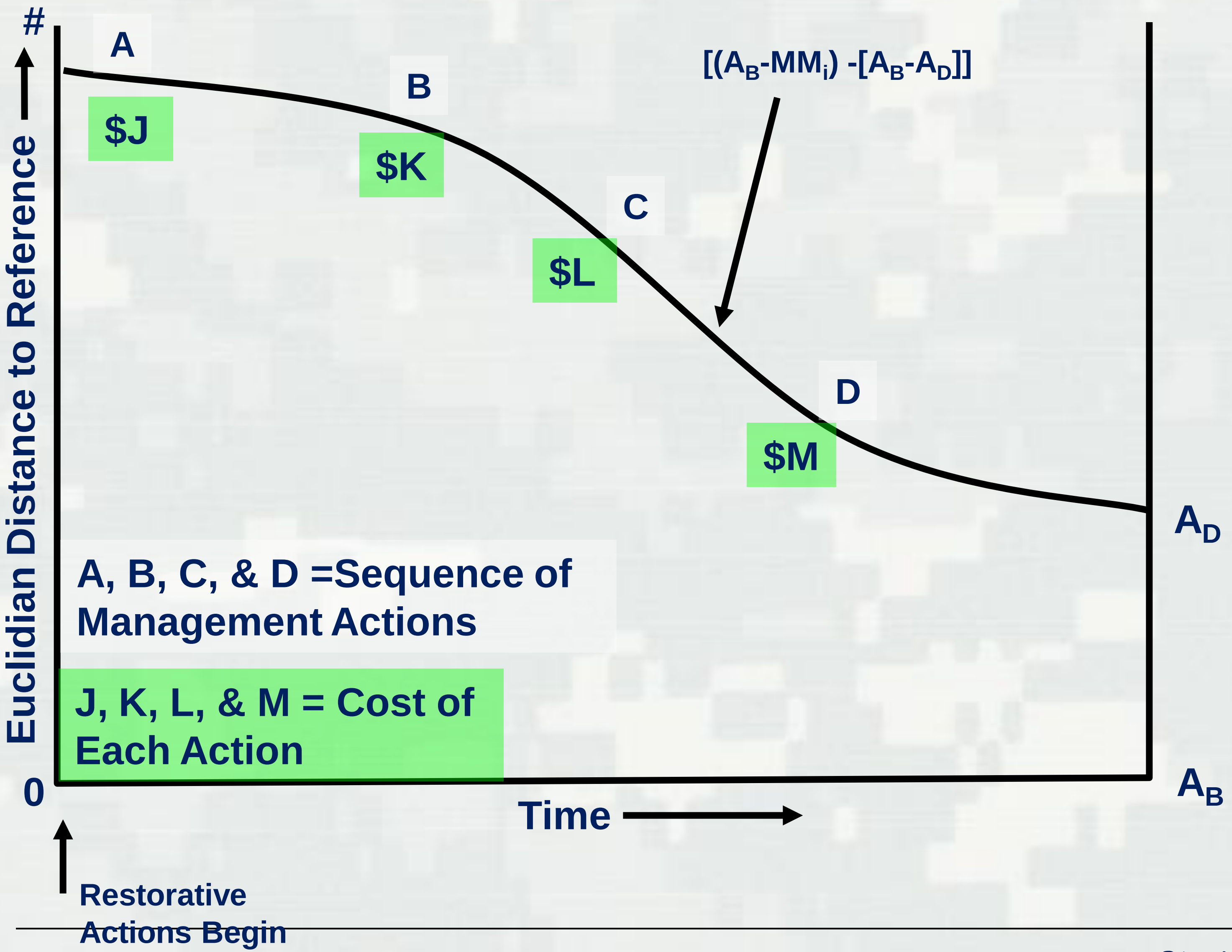


Results of Correspondence Analysis

Gages and IHA Variables



Visualizing Equation 1



Equation for Restoration State

(Including Restoration Planning)

$$\text{Restoration State} = [(\Sigma(A_B\text{-}MM_i)^2)^{0.5}\text{-}[\,A_B\text{-}A_D]]$$

Where:

- **A_B = Best Achievable Condition**
- **A_D = Desired Future Condition**
- **MM_i = Measured Magnitude at time=i based on a monitoring plan (uses same variables that define A_D and A_B)**
- **(A_B-MM_i) = Euclidian distance (ED) separating A_B and MM_i as: ED=SQRT(($Var1_{mm}$-$Var1_{ref}$)^2 + ($Var2_{mm}$-$Var2_{ref}$)^2 + ($Varn_{mm}$-$Varn_{ref}$)^2)**
- **[A_B-A_D]=balance term indicating compromise between best achievable and desired condition**

Attributes of Equation

Restoration State = $[(\Sigma(A_B\text{-}MM_i)^2)^{0.5}\text{-}[\,A_B\text{-}A_D]]$

- Trade-off between maximum restoration & human exploitation
- low at beginning and increases to higher value as program progresses
- RS can be evaluated intermittently to describe restoration progress (report card).
- Society establishes balance between ecological quality and human exploitation
- Can support multi-scale/system analysis
- Trajectory towards A_D = sustainability and biodiversity conservation
- Synergisms and tradeoffs can be addressed
- Provides output for a parallel economic analysis (environmental benefits analysis)

Product – Standardized Euclidian Distances

Elevation Gauges sorted by Euclidean distance	Euclidean Distance A_B in each pool (ascending	Restor-ation State	Elevation Gauges sorted by mean pool Euclidean	Euclidean. Distance to each gage sorted by	Mean Euclidean Distance by Pool	Elevation Gages sorted by ascending order of Sub-cluster (Figure	Euclidean. Distance to each gage sorted by	Mean Euclidean Distance by Sub-cluster	Mean Euclidean Distance by Cluster	Mean Euclidian Distance for Geomorphic Reach 3
Win Pre	0	0.401	Winona Pre-	0		B WinPre	0	B=0	B=0	
M5	0.401	0	Upper Pool 8	0.618						
¾ 8	0.453	0.052	1/4 Pool 8	0.599	0.630	A/A2 M5	0.400	A2=0.446		
M7	0.491	0.09	3/4 Pool 8	0.453		A/A2 M7	0.490			
U7	0.493	0.092	Lower Pool 8	0.849						
U6	0.551	0.15				A/A1 U5	0.551			
U5	0.553	0.152	Upper Pool 9	0.807		A/A1 U6	0.553			
M9	0.570	0.169	Mid Pool 9	0.570	0.678	A/A1 U5a	0.660	A1=0.557	A=0.560	
L9	0.599	0.198	Lower Pool 9	0.658		A/A1 ¾-8	0.453			
¼ 8	0.618	0.217				A/A1 M9	0.570			
U8	0.658	0.257	Upper Pool	0.660	0.683	A/A1 U5	0.551			
L5a	0.660	0.259	Lower Pool	0.707						0.670
U5a	0.707	0.306				A/A3 U7	0.493			
M6	0.712	0.311	Upper Pool 7	0.493		A/A3 U8	0.618	A3=0.639		
L6	0.766	0.365	Mid Pool 7	0.491	0.700	A/A3 U9	0.807			
L8	0.788	0.387	Lower Pool 7	1.116						
Win Post	0.807	0.406				C/C3 M6	0.712			
U9	0.849	0.448	Upper Pool 6	0.553		C/C3 WinPost	0.766	C3=0.692		
L5	1.058	0.657	Mid Pool 6	0.712	0.705	C/C3 ¼-8	0.599			
L7	1.116	0.715	Lower Pool 6	0.788						
			Winona Post	0.766		C/C2 L5a	0.707			
						C/C2 L9	0.658	C2=0.718	C=0.806	
			Mid Pool 5	0.401	0.709	C/C2 L6a	0.788			
			Lower Pool 5	1.058						
						C/C1 L5	1.058			
						C/C1 L8	0.849	C1=1.008		
						C/C1 L7	1.116			

Note: Each restoration action applied to each pool has an associated cost. EBA could be performed if these costs were accumulated.

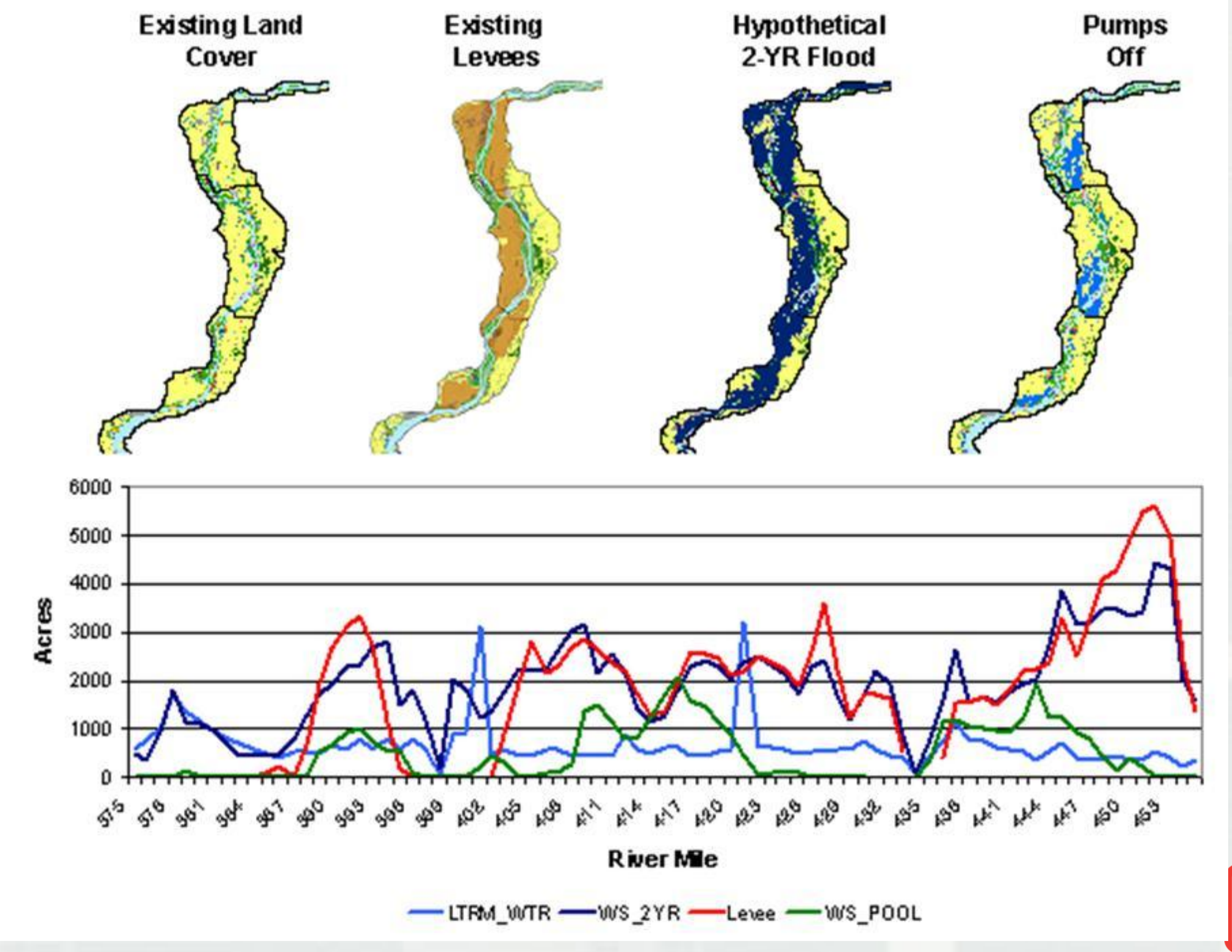
Value of RC Concept
Using Euclidian Distances

1. System-Level embodiment of G&Os
2. Addresses sustainability (assuming reference was)
3. Intuitive and easy to explain to stakeholders
4. Consistent with peer-reviewed concepts on restoration
5. Consistent with requirements for alternative analysis
6. Expandable to ecosystem management

Next Steps:

1. Assess CoE / stakeholders for consensus
2. Expand to multiple geomorphic Reaches
3. Include additional EECs
4. Apply to biotic communities
5. Apply to other ecosystems

Demonstrate for Multiple Reaches



Best Fish Community?