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Application of the Diminishing Returns Concept in Ecosystem Restoration on the Lower Columbia River Floodplain

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Landscape Scale Planning & Assessment

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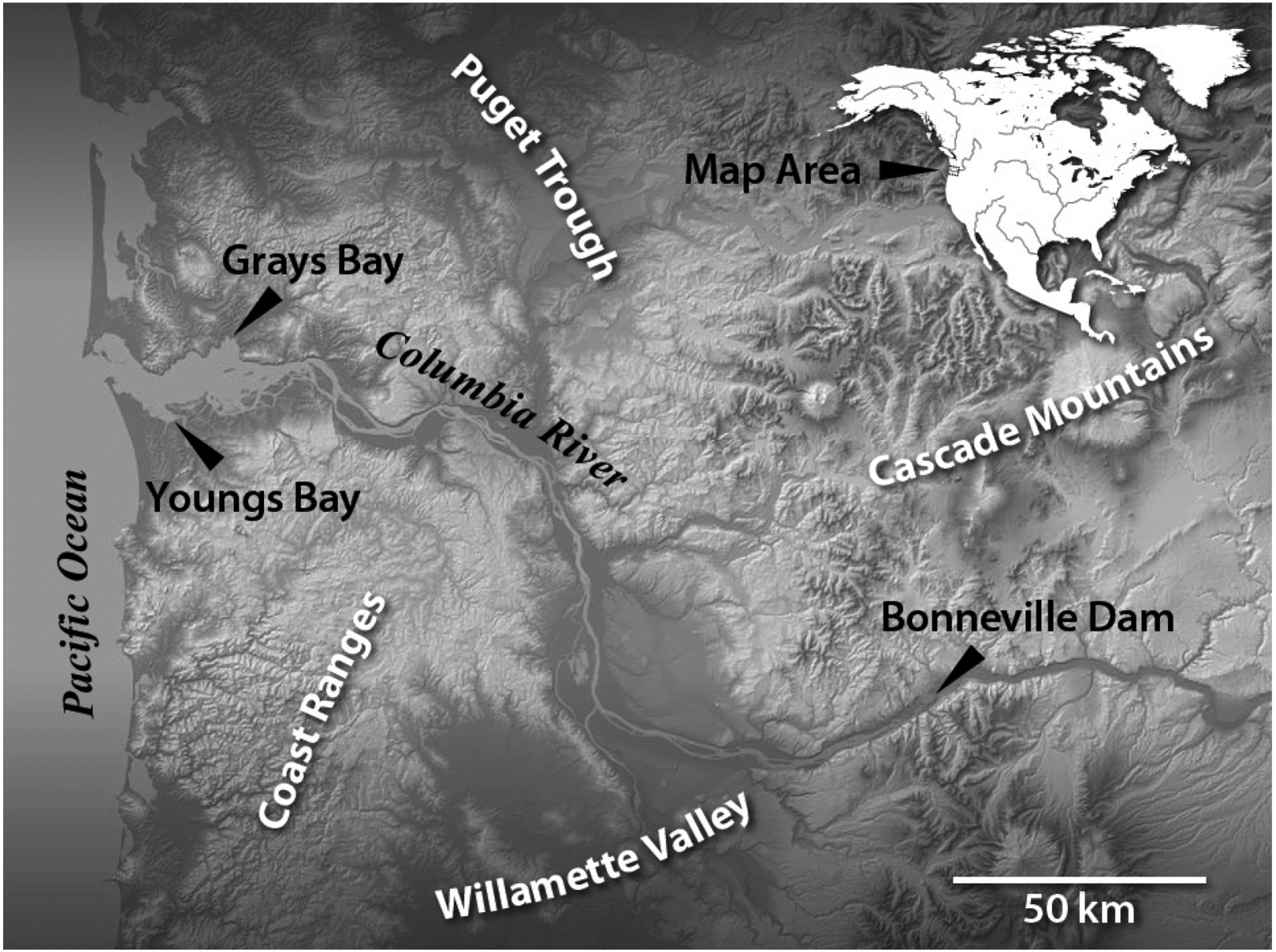

Research Need

Management Question:

How to distribute restoration actions in tidal-fluvial landscapes

- What configuration has the greatest effect on the ecosystem?
- What configuration is most cost-effective?

Suite of Dike Breach and Preservation Actions
Courtesy of Columbia Land Trust

Suite of Tide Gate Replacement Actions
Courtesy of U.S. Army Corps of Engineers

General Research Approach

Statistical Model of Restoration Scenarios

↓

RMA2 Hydrodynamic Model
Output: Water Depth at Nodes

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Arc-GIS Processing
Output: Wetted Area

Study Area

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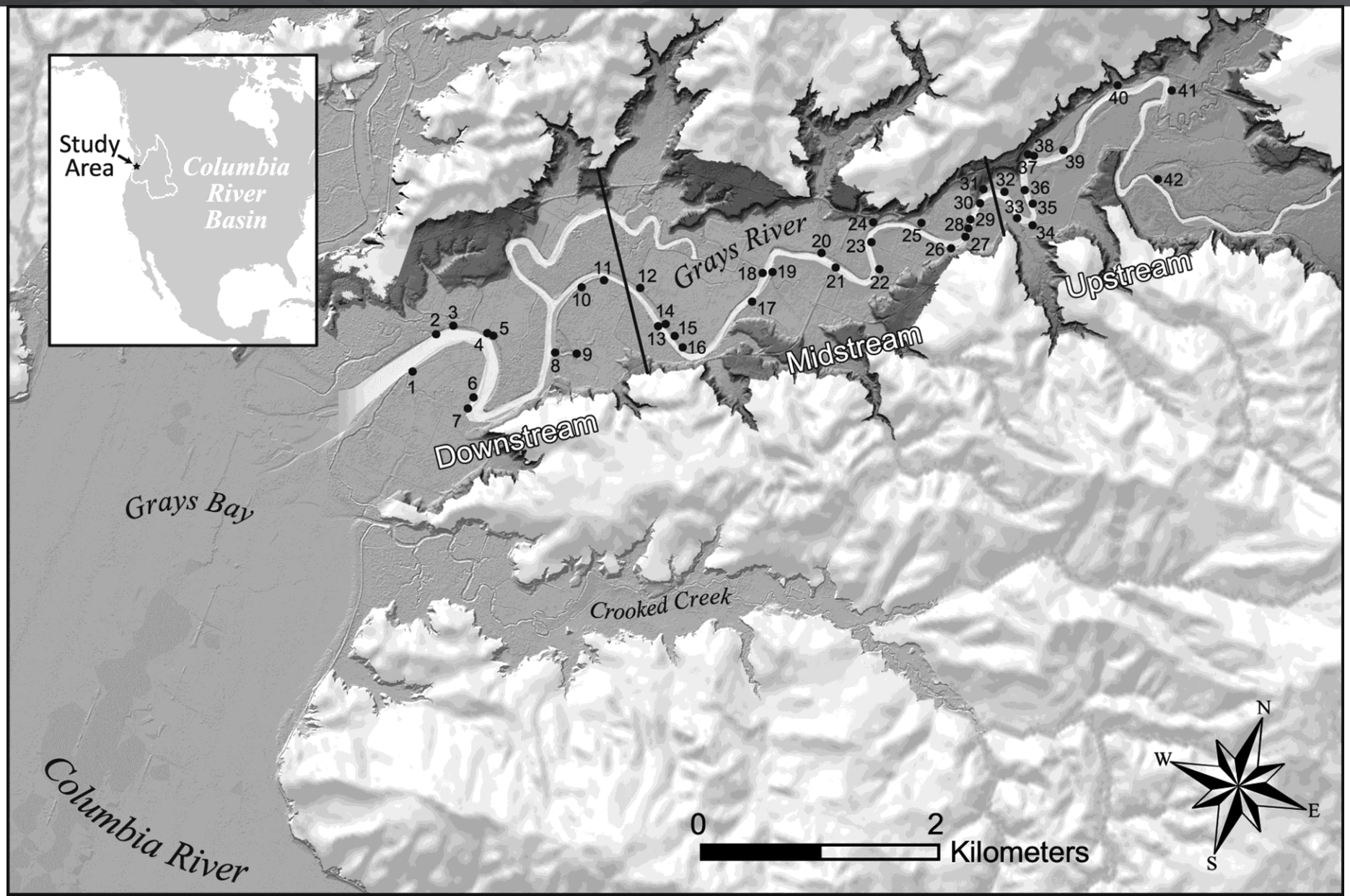

Research Approach - Statistical Model

Test of Synergy: H_0 no trend in mean effect of sets of dike breaches

- 3 Replicates of Sets of Randomly Selected Dike Breaches, Sets of 1, 4, 8, 11, 15, 21, 32 (Includes the 25th, 50th, and 75th percentiles of total 42 channels.)
- 1 Run Each: No Breaches, 42 Breaches

Tests of Spatial Configuration: H_0 no difference in effect of breaches with distance from river mouth or even distribution

- 1 Run Each: Most Upstream 11 Breaches, Most Downstream 11, and Midstream 11
- 3 Replicates: 11 Dike Breaches Evenly Distributed Between Upstream, Midstream, and Downstream Reaches

Research Approach – Data Development

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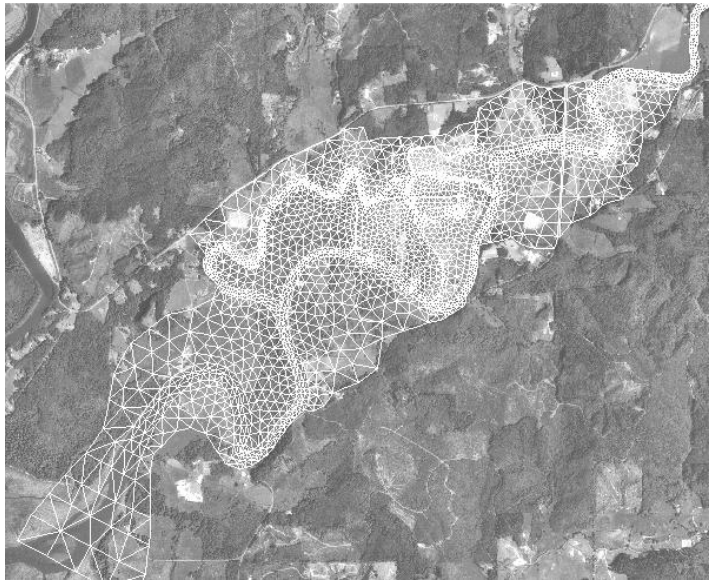
29, 2-Dimensional Hydrodynamic Model Runs

Inputs

- Upstream: Average Grays R. flow – WADOE
- Downstream: Spring to neap tide period Columbia R. water elevation Tongue Point and tidal prediction Harrington Point – NOAA
- Roads and major irrigation ditches removed from topographic surface

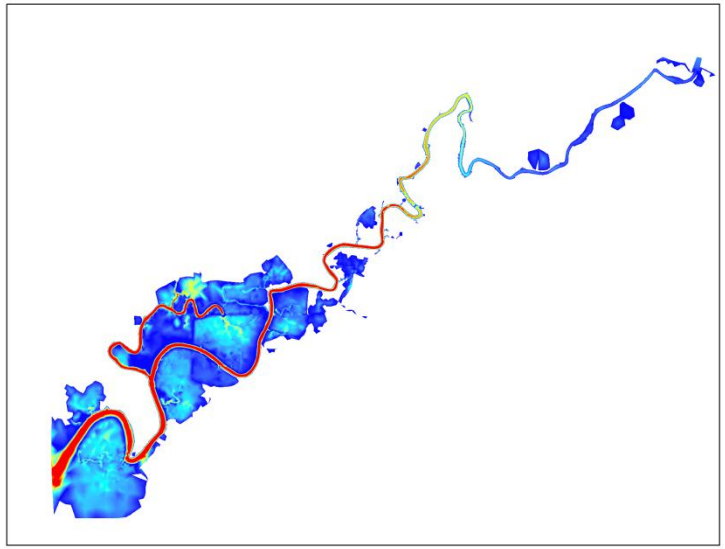
Outputs

- X, Y, Z Water depth data at nodes (see right)



ArcGIS Processing

- Assembled model nodes into 29 Triangular Irregular Network (TIN) Files, with Depth as Z
- Converted to 1.524 m x 1.524 m Raster Files
- Used Conditional Filter to screen out < 0.1m
- Result: Binary dataset of nodes > 0.1m deep
- ArcGIS Interpolation of Wetted Area (right)



Results – Spatial Configuration

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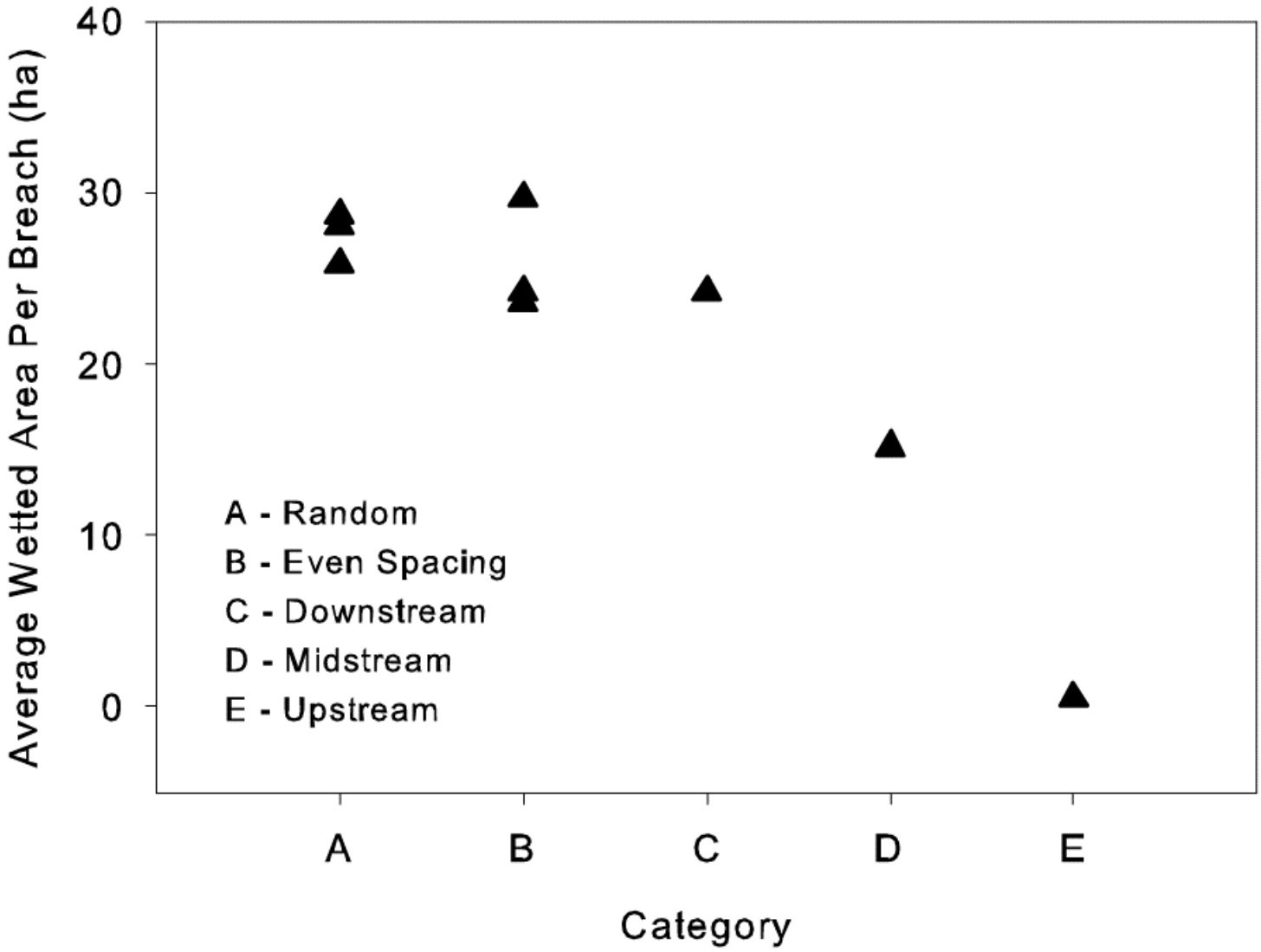
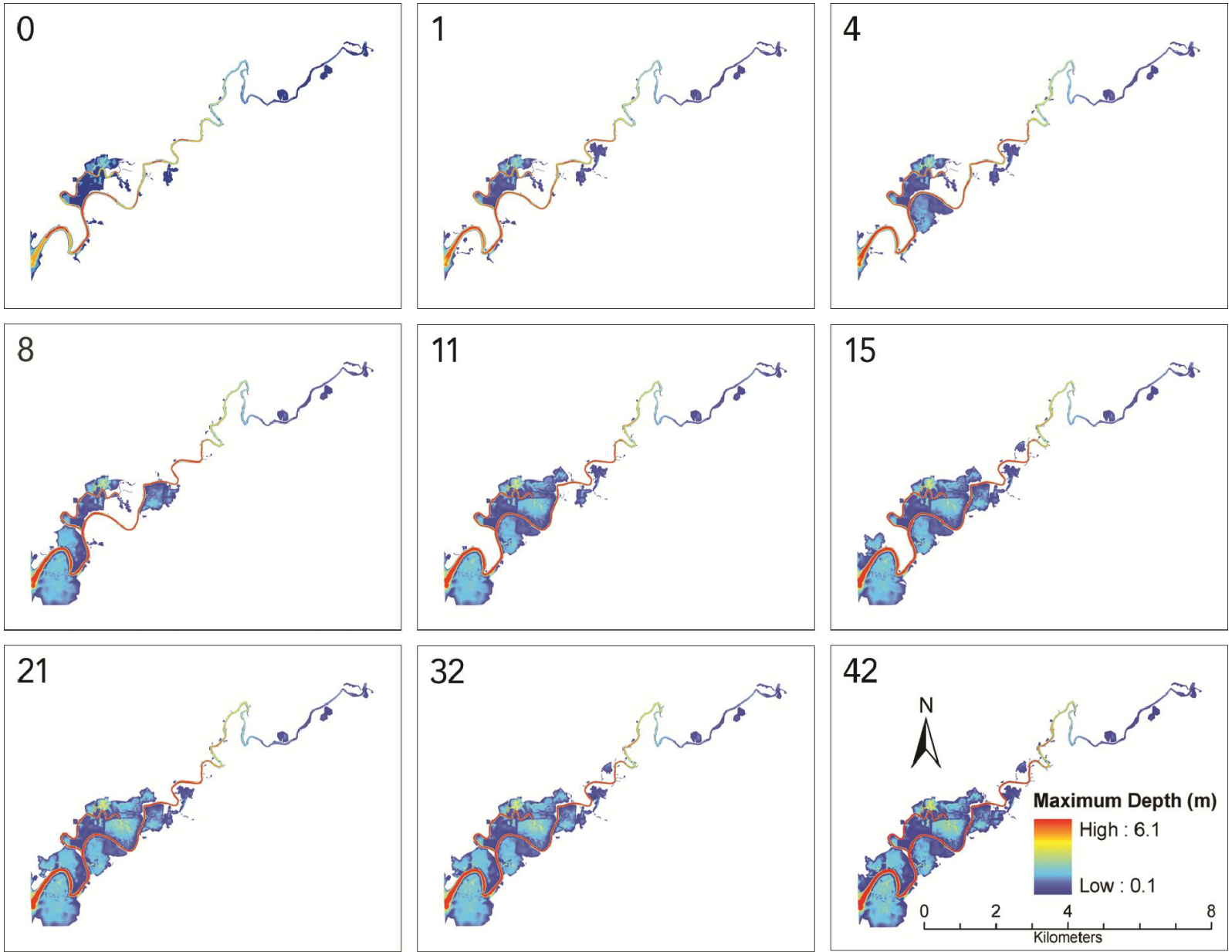
No. of replicates	No. of channels breached	Purpose or effect tested	Average wetted area (ha)	Average wetted area per breach (ha)
3	11	Random (25th percentile)	303	28
3	11	Even spacing	284	26
1	11	Downstream	266	24
1	11	Midstream	167	15
1	11	Upstream	6	1

Results – Spatial Configuration



Results – Randomly Selected Sets



Results – Randomly Selected Sets

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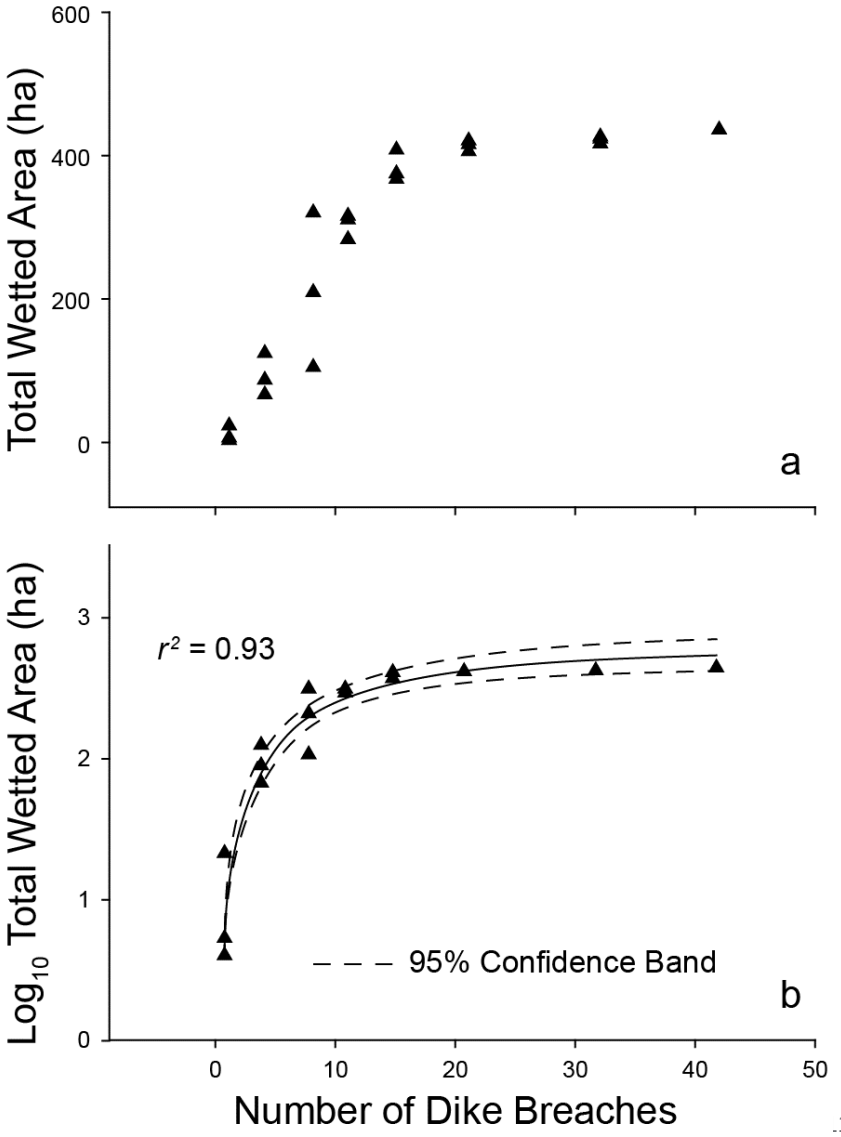
Total floodplain wetted area increases with number of breaches; but reaches a plateau at 11 breaches (25th percentile)

Breaching the dike at 8 channels (19% of 42 channels) yielded 212 ha wetted area, nearly 50% of the maximum of 437 ha with the dike breached at all 42 channels

Nonlinear regression best fit a hyperbola with a $\log_{10}$ transformation of wetted area



Definitions – Synergy and Diminishing Return

Law of the Diminishing Increment (Spillman and Lang 1924) an agricultural yield increases in proportion to investments (e.g., of labor, feed or fertilizer, in the original model) at a decreasing rate.

The economic laws of **diminishing returns on capital** can be derived from this diminishing incremental agricultural yield; they describe its effects on profits.

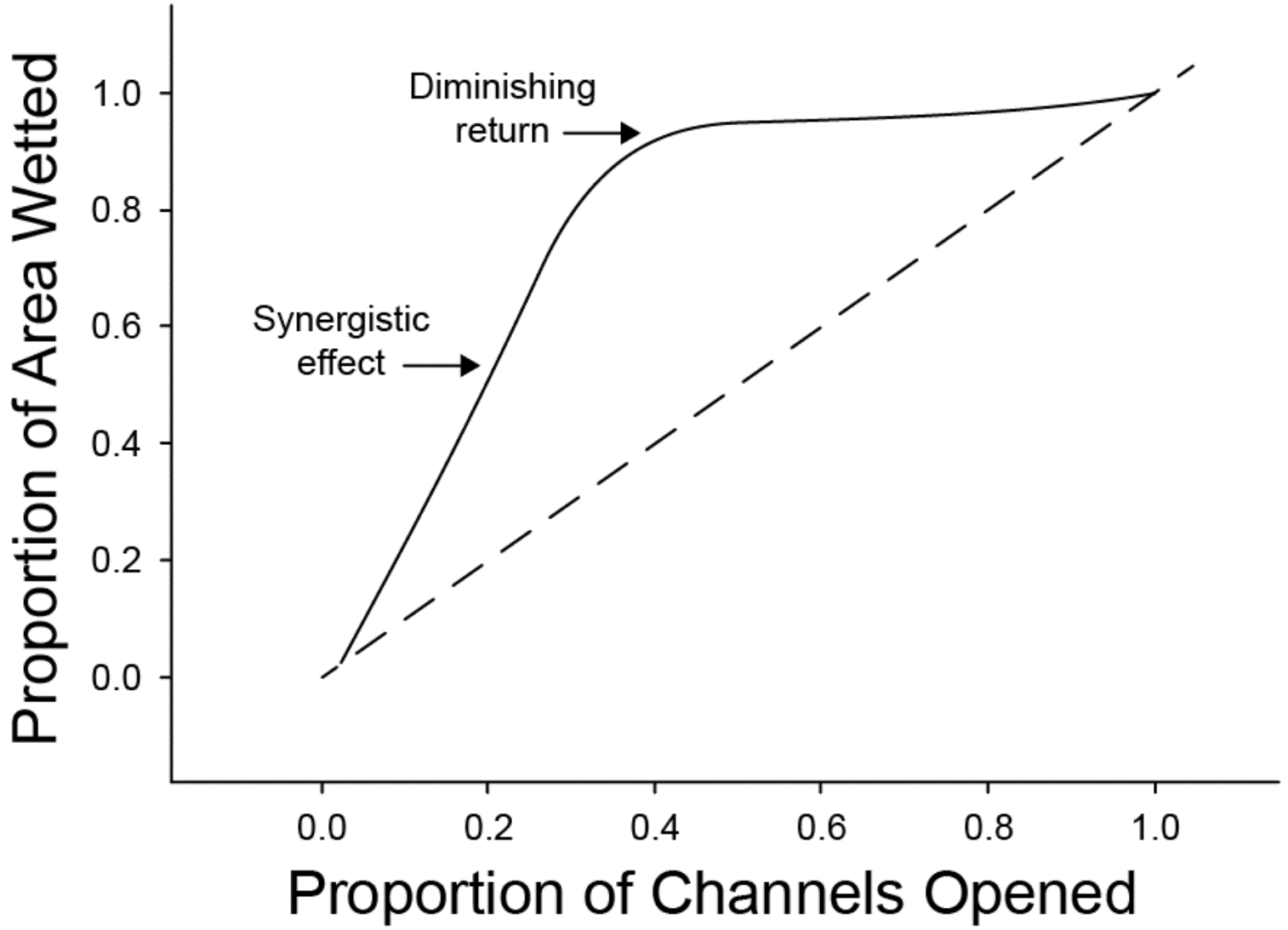
Synergy the total effect of a set of discrete actions is greater than the sum of the effects of each individual action.

Test: Slope >1 between the proportion of area wetted (p_W) and the proportion of channels opened (p_B) would be evidence of a synergistic effect. A declining or zero slope as proportion breached approached 1 would be evidence of the law of the diminishing increment.

Results – Synergy and Diminishing Return

No. of replicates	No. of channels breached	Purpose or effect tested	Average wetted area (ha)	Average wetted area per breach (ha)
3	1	Random	10	10
3	4	Random	94	23
3	8	Random	212	26
3	11	Random (25th percentile)	303	28
3	15	Random	384	26
3	21	Random (50th percentile)	414	20
3	32	Random (75th percentile)	421	13
1	42	All channels open	437 [a]	10 [a]

Results – Synergy and Diminishing Return



Results – Synergy and Diminishing Return

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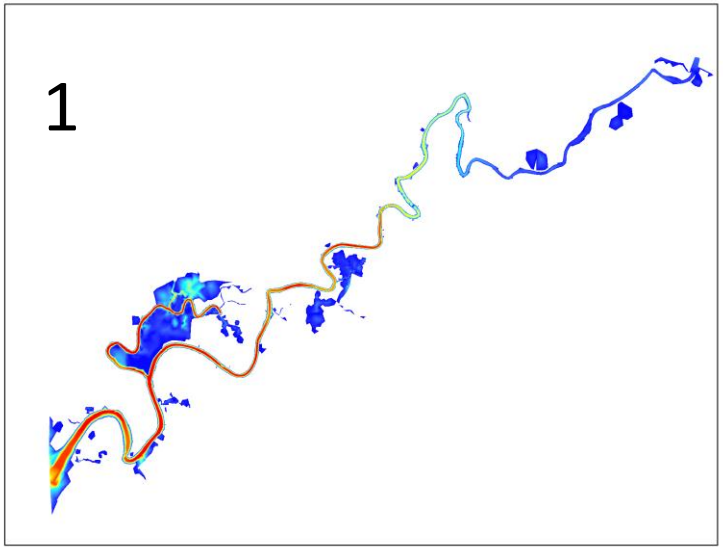
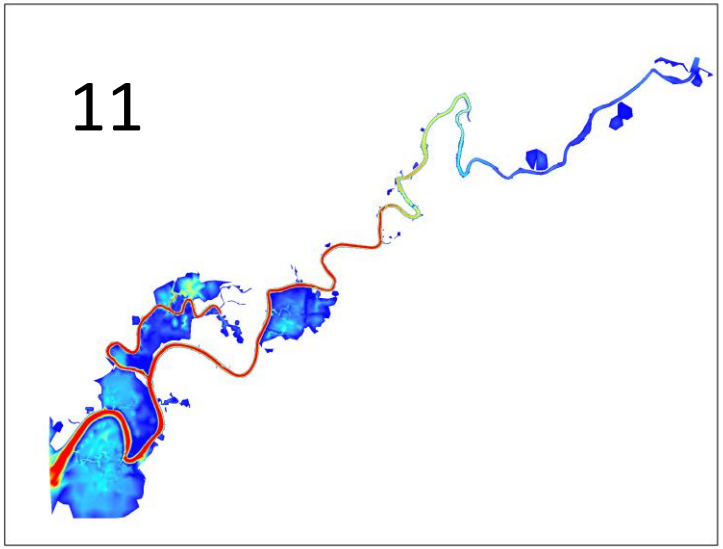
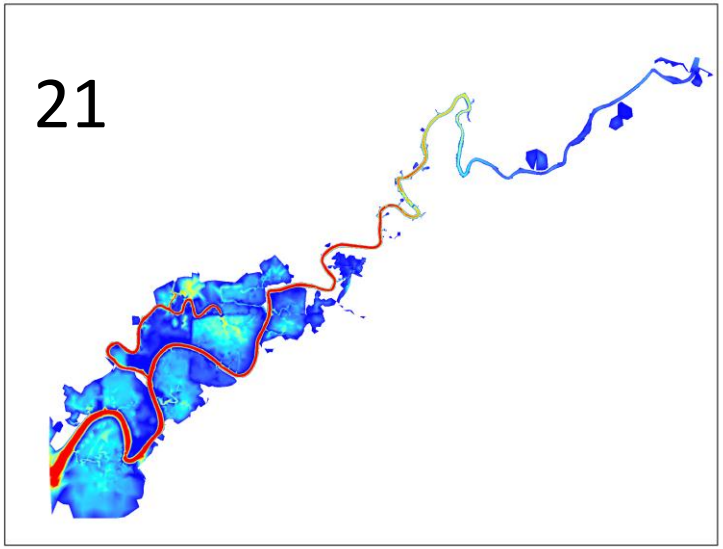
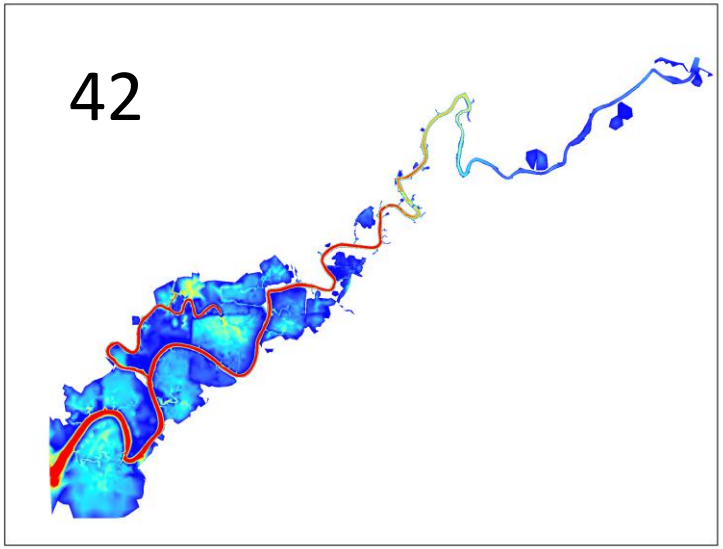
Synergy

Diminishing Returns









Limitations and Future Research Needs

Transfer to Other Tidal-Fluvial Systems

- Geographic scale limitations unknown
- Tidal-fluvial gradient limitations unknown

Restoration Targets

- Assumed ecosystem goal: Floodplain wetted area
- For target T&E Species, other metrics may be important, e.g. the amount of in-channel habitat
- Potential role of infrequently inundated upstream habitats

Implementation on the Ground

- If a subset of all channels is opened, will they enlarge in cross-sectional area at mouth to convey extreme flows?

Potential Applications

Restoration Program Design

- Where to place tide gates or dike breaches
- How many to use

Cost-Benefit Analysis

- What is the ecological benefit of an additional number of tide gates or dike breaches compared to the economic cost

Restoration Benefits Estimation

- What wetted area can we expect to produce from a given design, with associated ecological effects, e.g. on the food web

Acknowledgements

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Dr. Ron M. Thom, PNNL: for his vision, to apply cumulative effects assessment methods to large-scale ecosystem restoration.

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