# Scenario Optimization Tool for CAST

17 July 2019 – Modeling Workgroup Quarterly Meeting

Danny Kaufman

***Project Goal:*** Investigate, develop, test, and implement an optimization system for the Chesapeake Assessment Scenario Tool (CAST) that will facilitate identification of more cost-effective and otherwise optimal approaches to pollutant load reduction for non-federal CBP partners.

# Update

At the Modeling Workgroup quarterly in April, we had the first Beta release of a working, publicly available optimization tool

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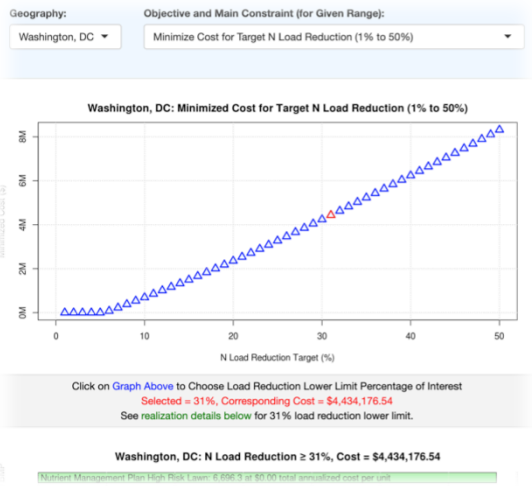
Where do things stand now?

# Current high-level objectives

1. Optimize for non-efficiency BMPs ("The Wall")

2. Enhancements of online VICO tool



# Best Management Practices (BMPs)

(with parameters defined in CAST)

Amount of implementation (# acres, animal units, etc.) → Effect on nutrient load

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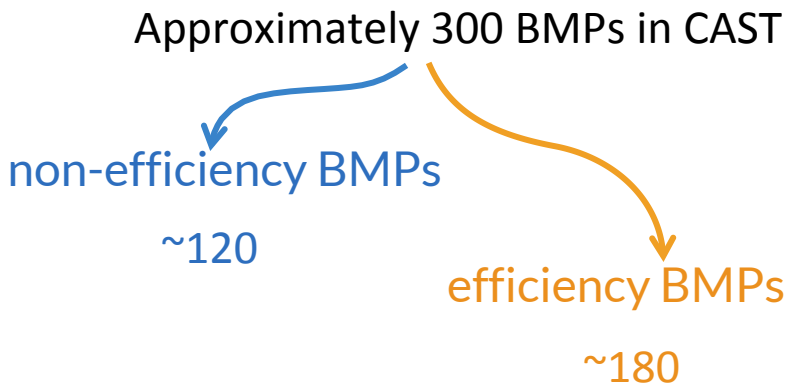

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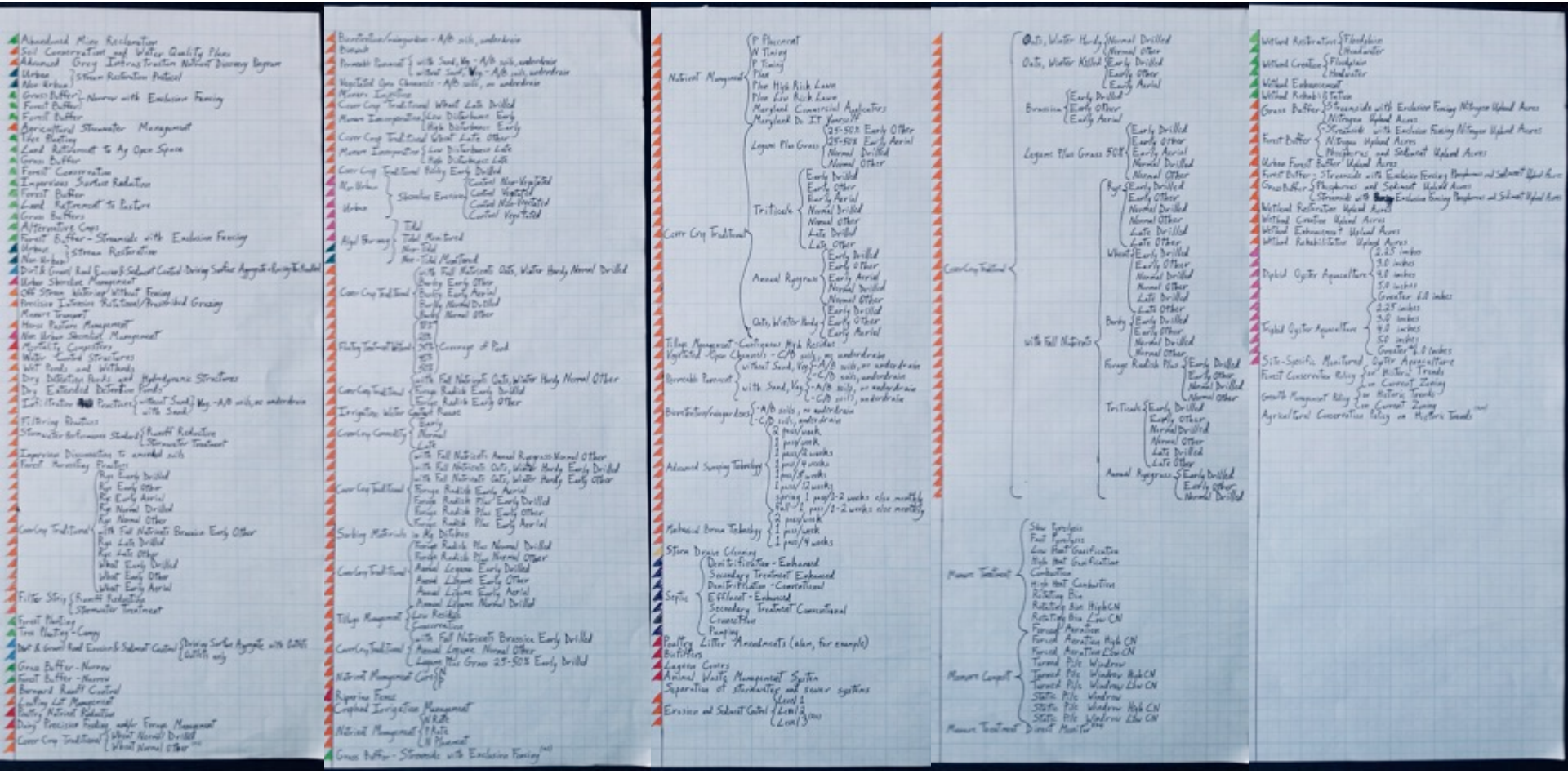

Orange - Efficiency

Light blue – dirt and gravel

Pink – shore

Red - animal

Green – Land use change

Yellow – Load reduction

Teal – stream

# Best Management Practices (BMPs)

(with parameters defined in CAST)

Amount of implementation (# acres, animal units, etc.) → Effect on nutrient load

Approximately 300 BMPs in CAST

non-efficiency BMPs

efficiency BMPs

$$g(x^n, L^0) \bullet h(x^e) = \Delta L$$

# Current high-level objectives

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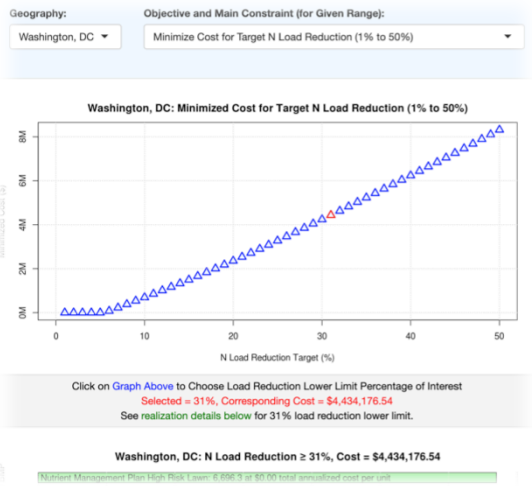


# Optimization Development Timeline (2018-2021)

**Initial Prototyping**
Programming objectives and designs for the prototype were considered and revised

**Straw version**
Evaluation of a "straw" version prototype (formulated for a single land-river segment)

**Beta-1 released**
Online Visualization Interface for Chesapeake Optimization (VICO) developed and made available online

**Tool Updates and Prototyping**
- Efficiency BMP online tool is updated with new features for **Beta-2**
- Non-efficiency BMPs are researched and strategy for including them in optimization is developed.

**Phase 3 WIPs finalized**

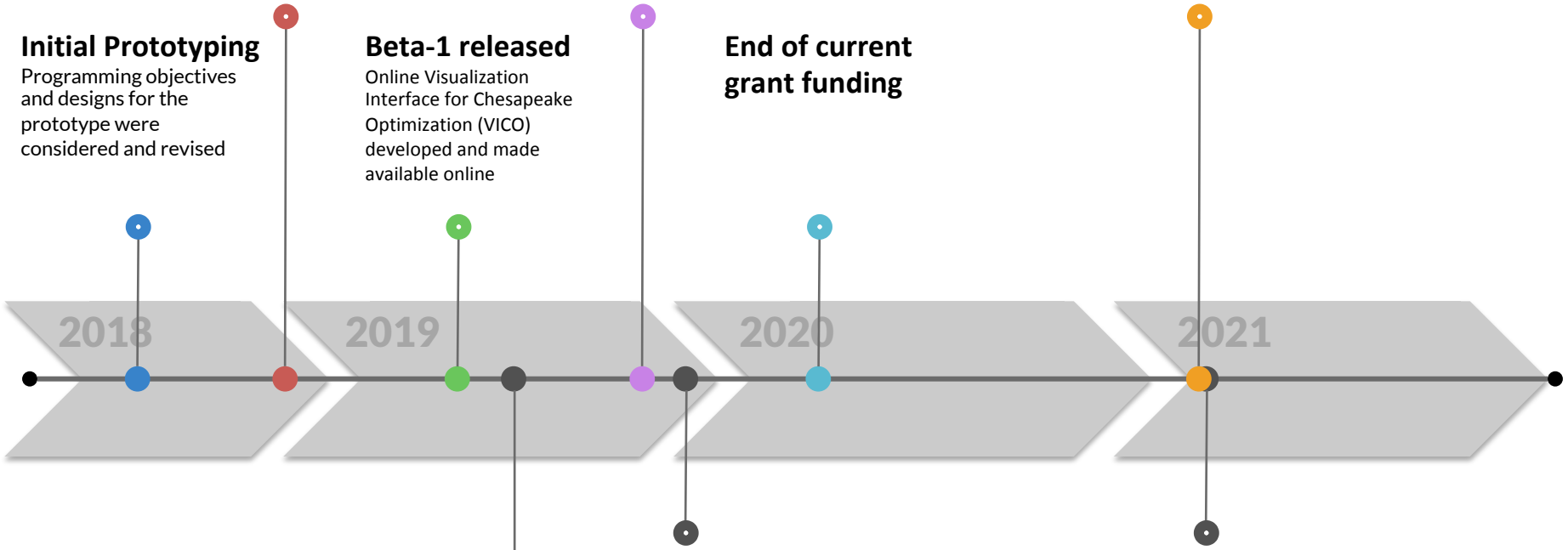
**Climate Change assessment for TMDL**

**End of current grant funding**

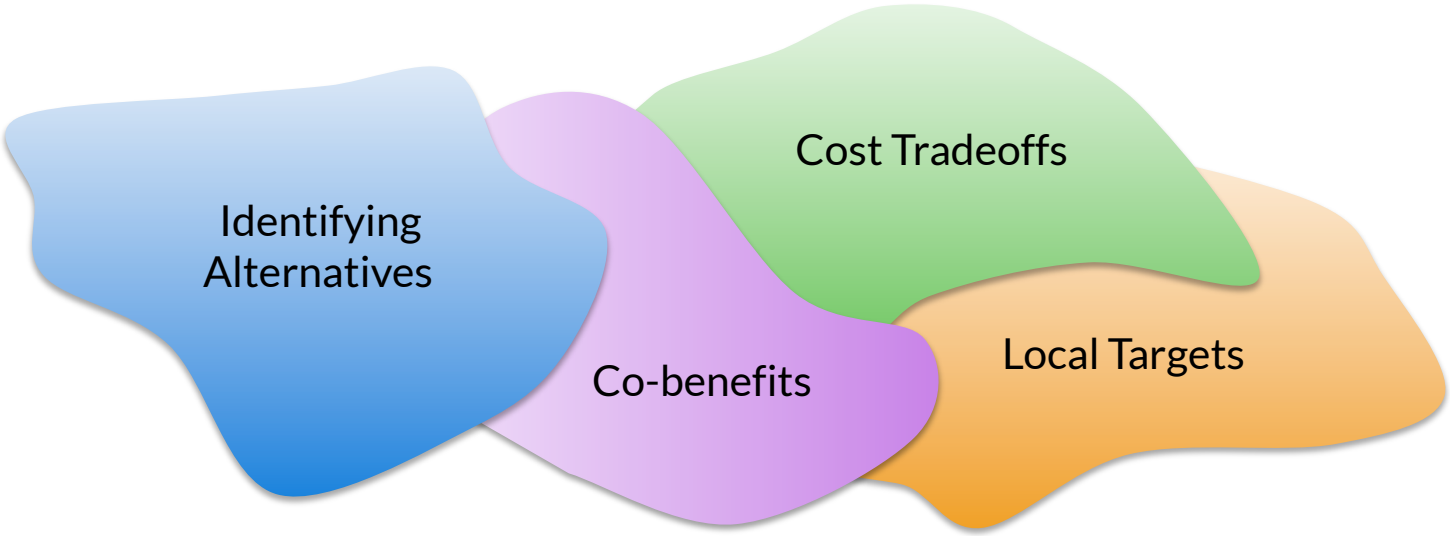
**Optimization application for Climate Change targets**

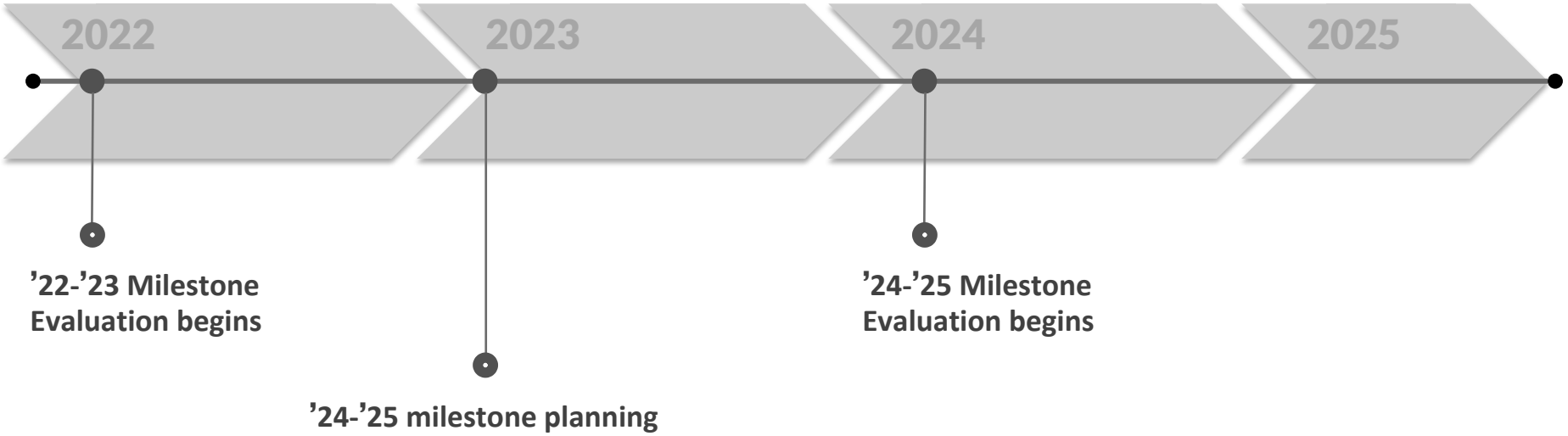
Optimization tool with non-efficiency BMPs begins to be used for climate change target planning

**Incorporation of Climate Change into '22-'23 milestone planning**



# Optimization Development Timeline (2022-2025)



# 3

Methods to optimize non-efficiency BMPs

# Optimization approaches

**How are we going to find the lowest point?**

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# Three optimization approaches

**A) “Exact”**

**B) Surrogate modeling**

**C) Heuristic**

# Optimization approach A

## A) “Exact”

Optimization solves the exact formulation of the CAST load function. May then be tested and refined in a simulation, i.e., screening of candidate solutions. Basically, capturing the ‘essence’ of CAST (Current efficiency NLP prototype is approach A)

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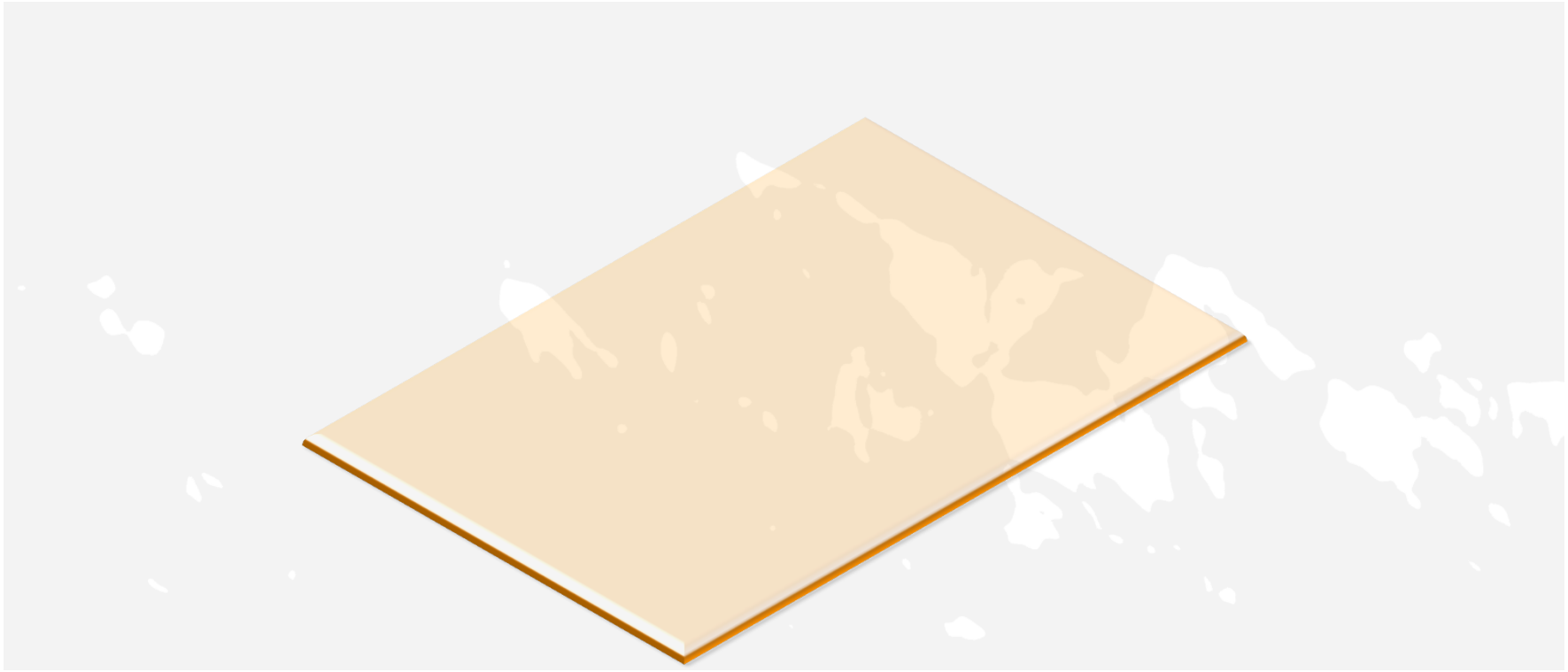

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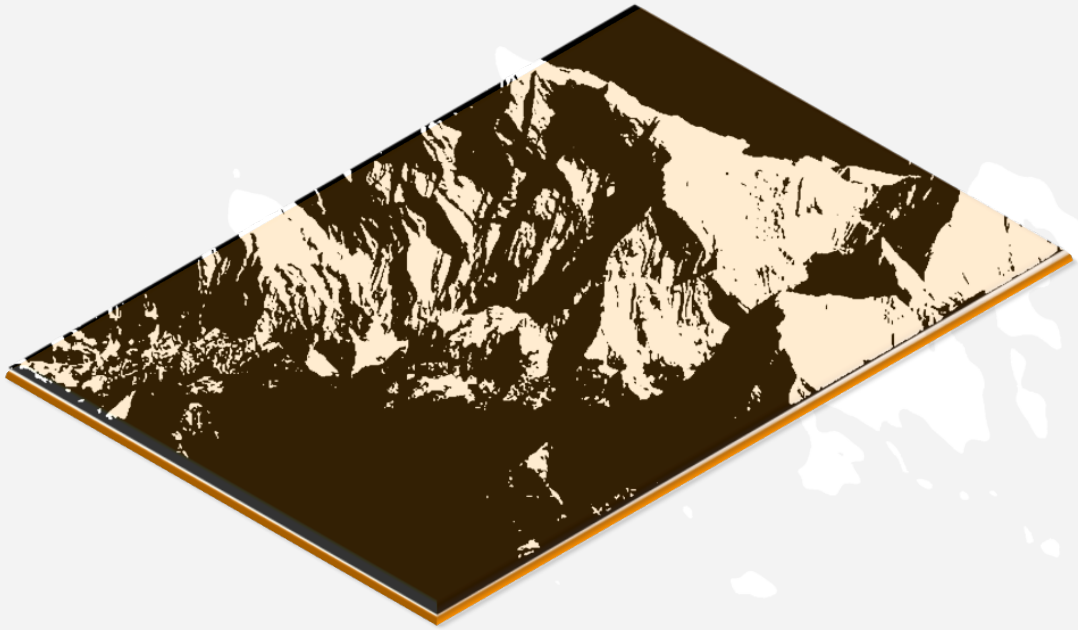

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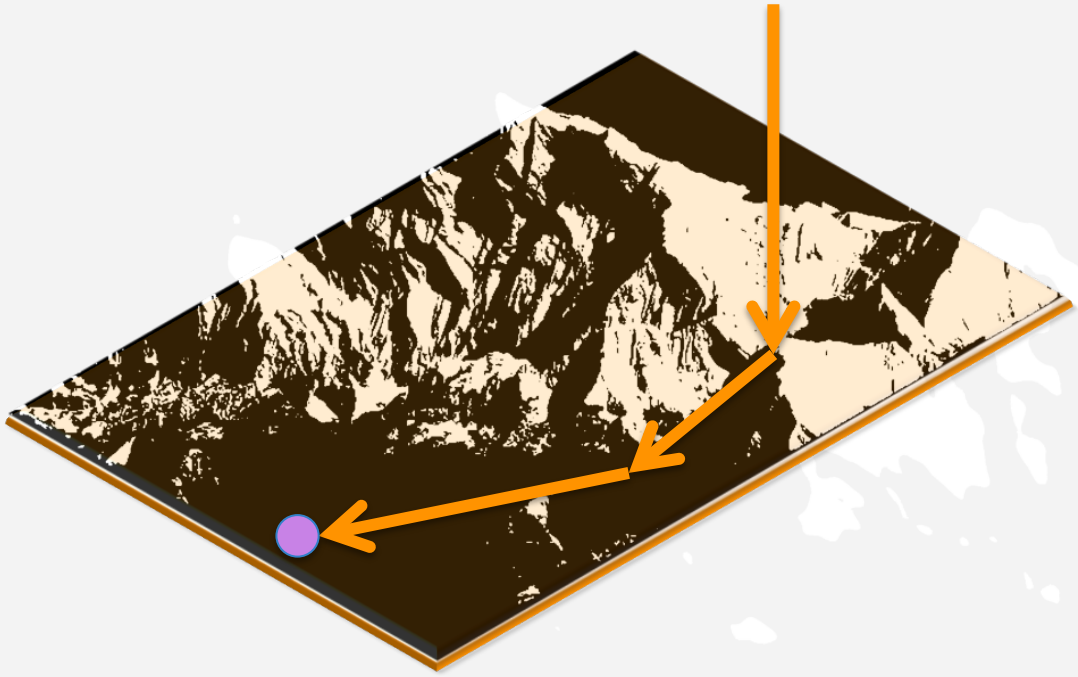

# Optimization approach B

## B) Surrogate modeling

Simulations produce response surfaces, that are then put into an optimization, which suggests additional strategies, which are then tested further.

(One approach that is basically a form of B, could be to take cost effectiveness information from BMP isolation runs, and use them in a simplified LP, to learn about the suite of BMPs that are important at various scales.  Could do the LP for every geography.)

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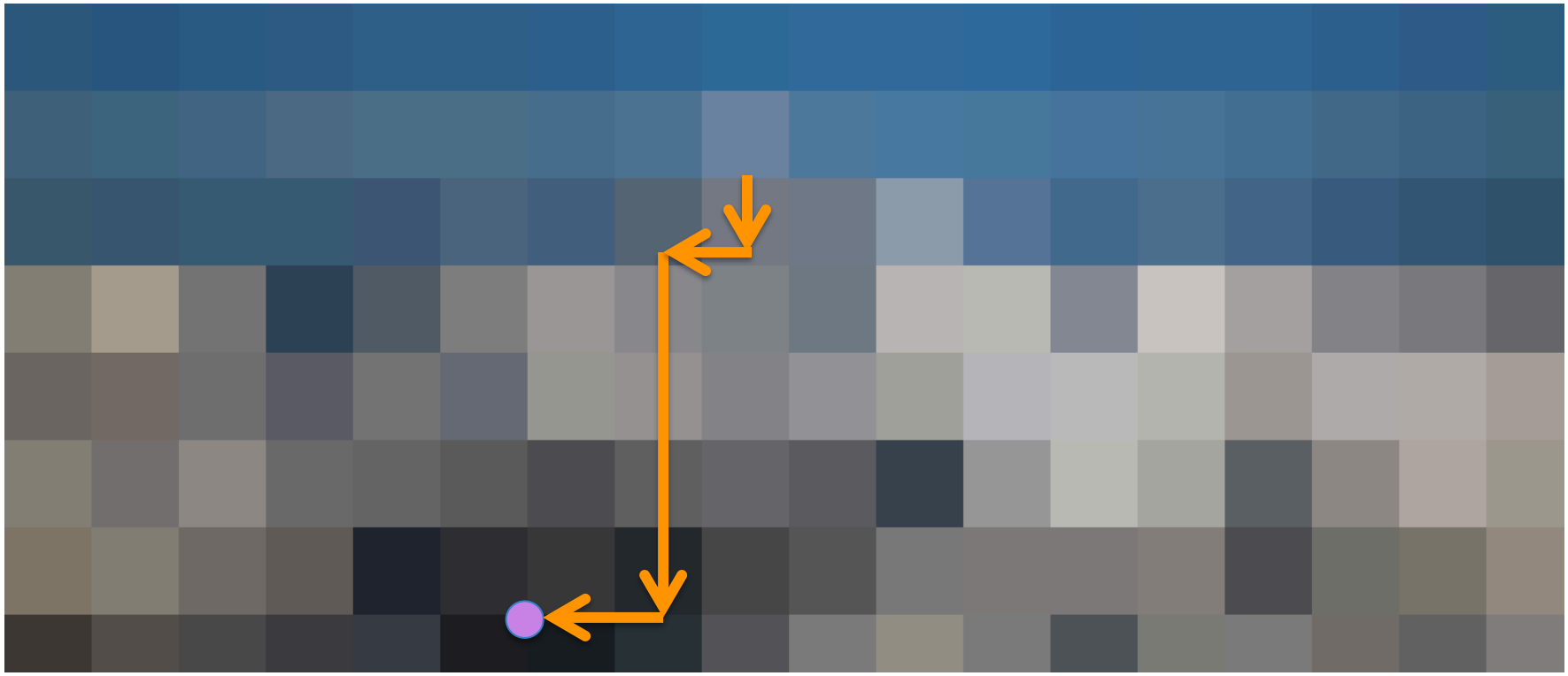

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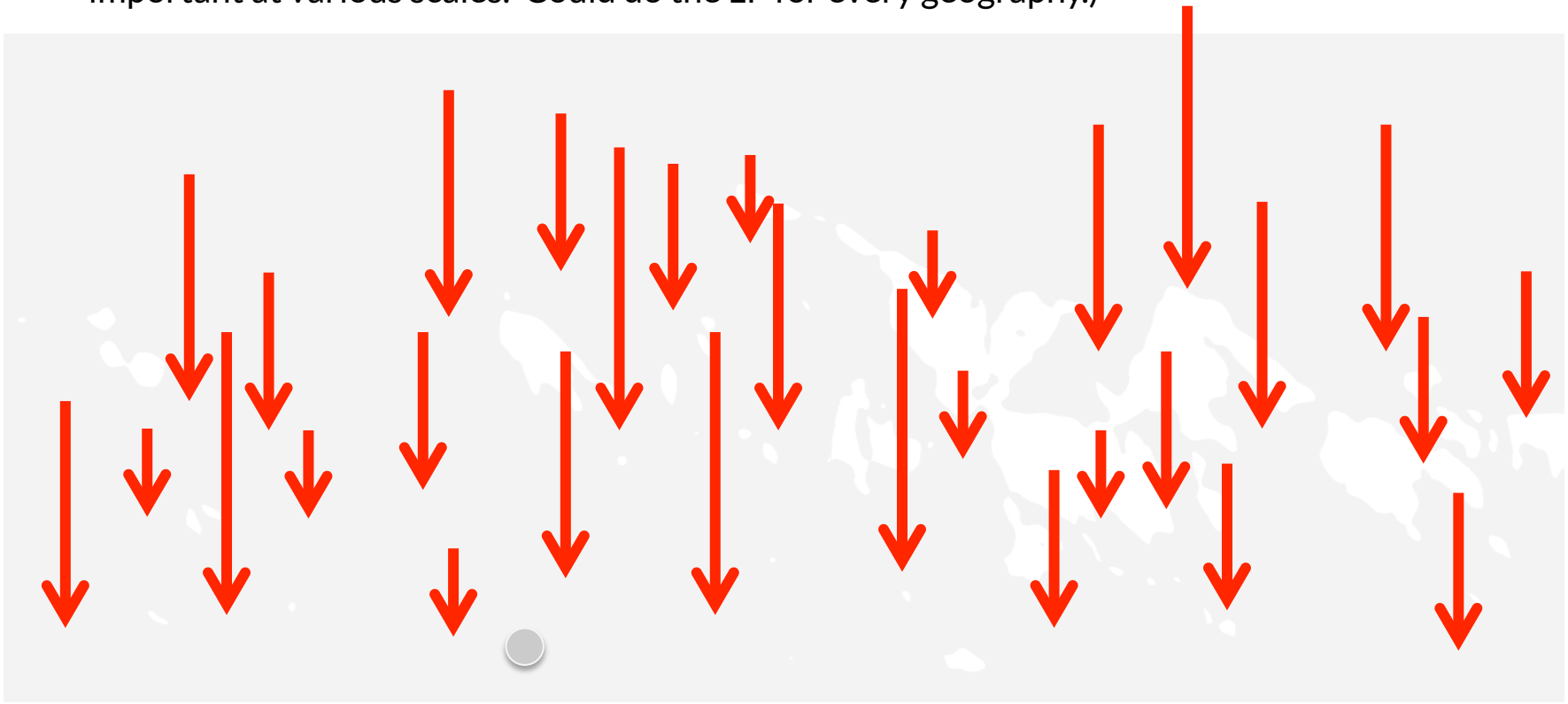

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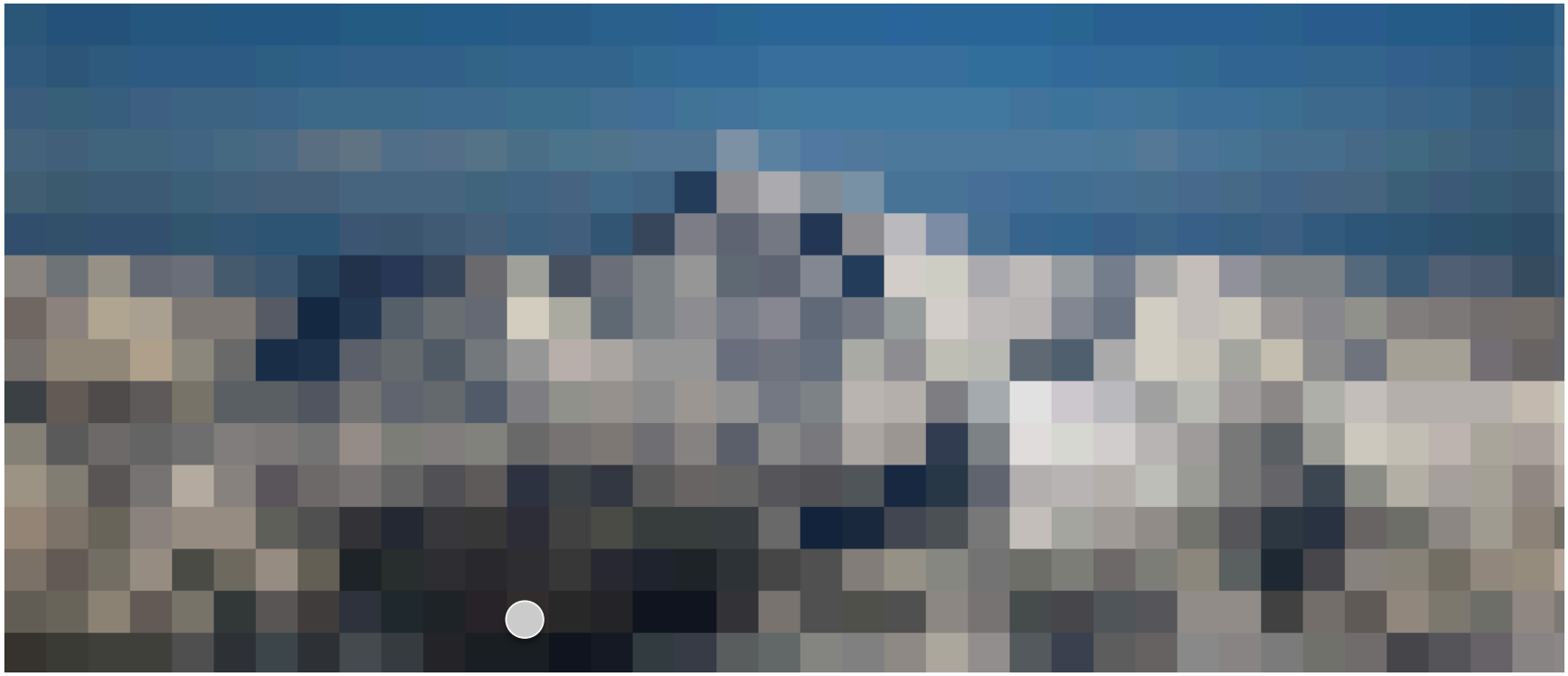

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# Optimization approach C

## C) Heuristic

Optimization intelligently chooses BMP combinations, sends them to CAST, CAST evaluates them, and the information is fed back to the optimization.

(Approach C will probably be worth trying someday but maybe not in this current project period.)

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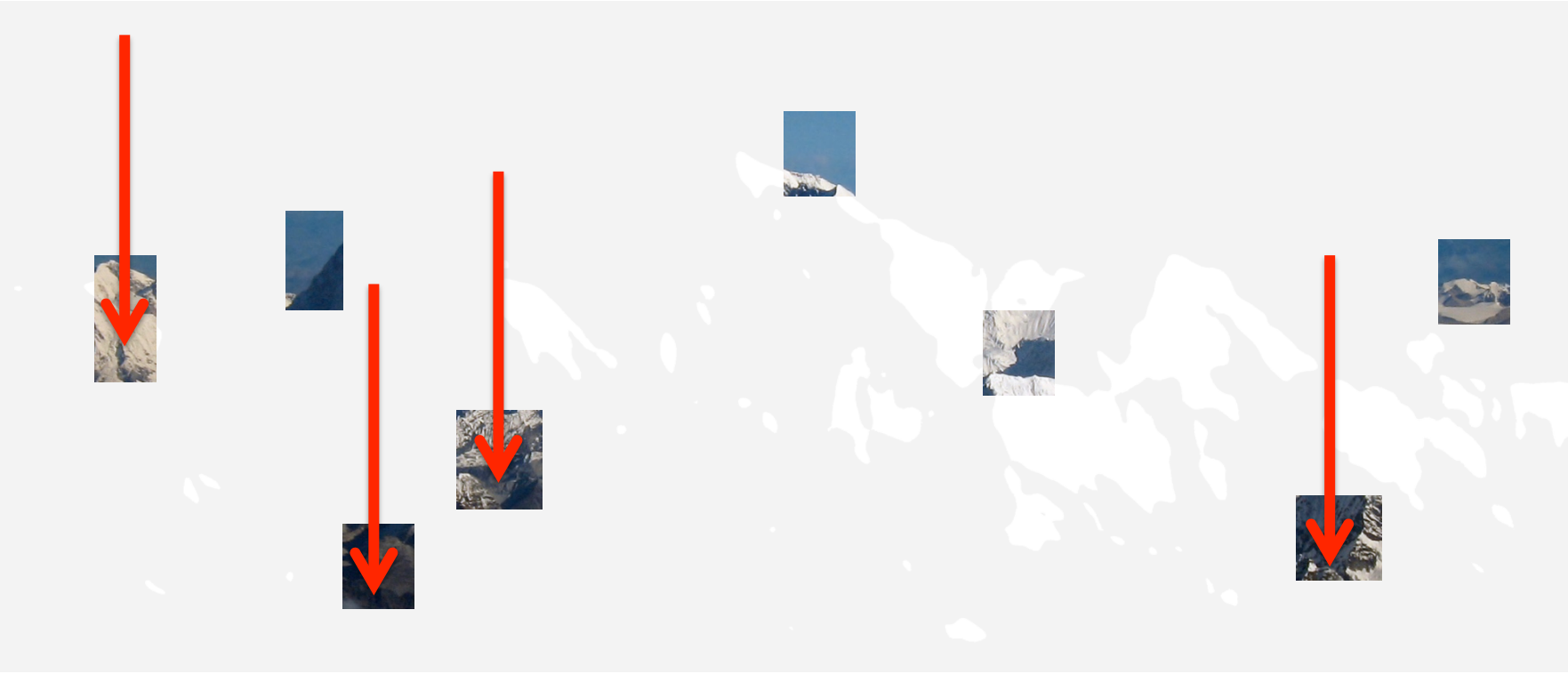

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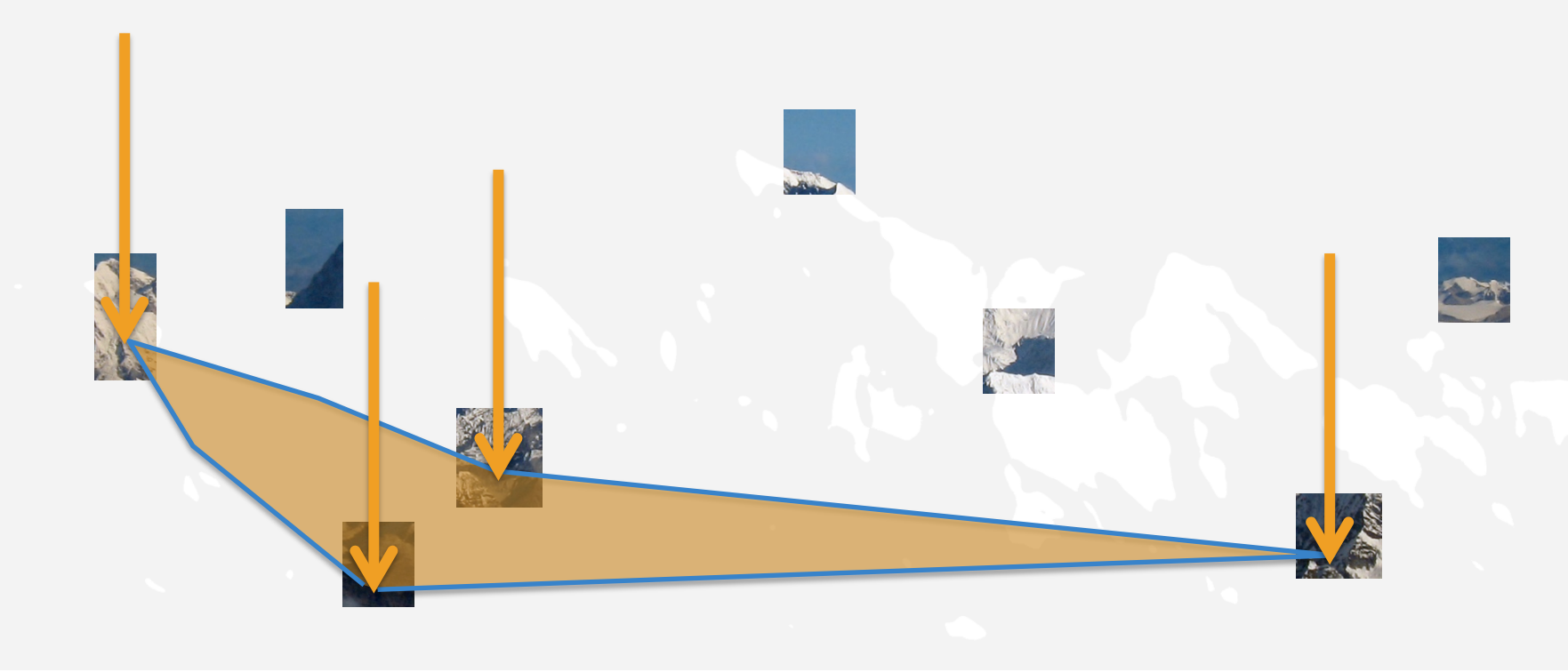

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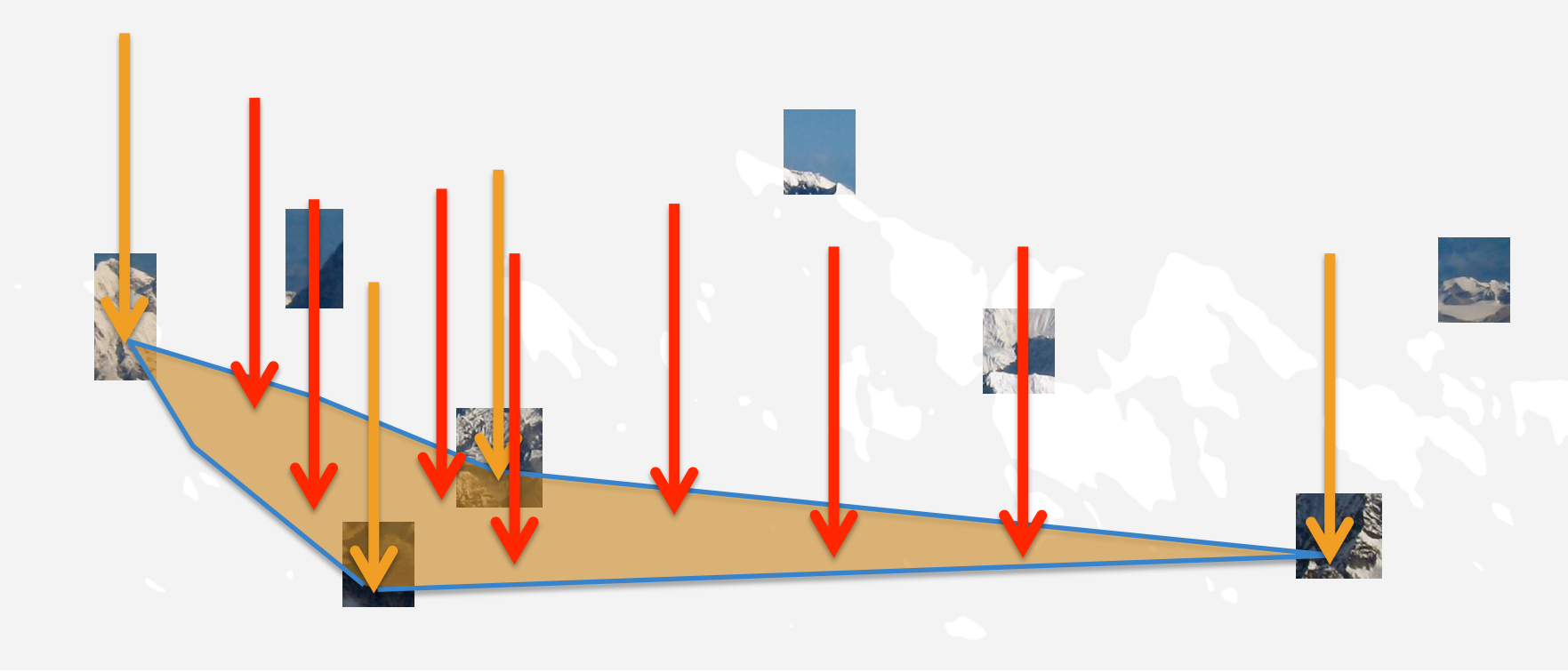

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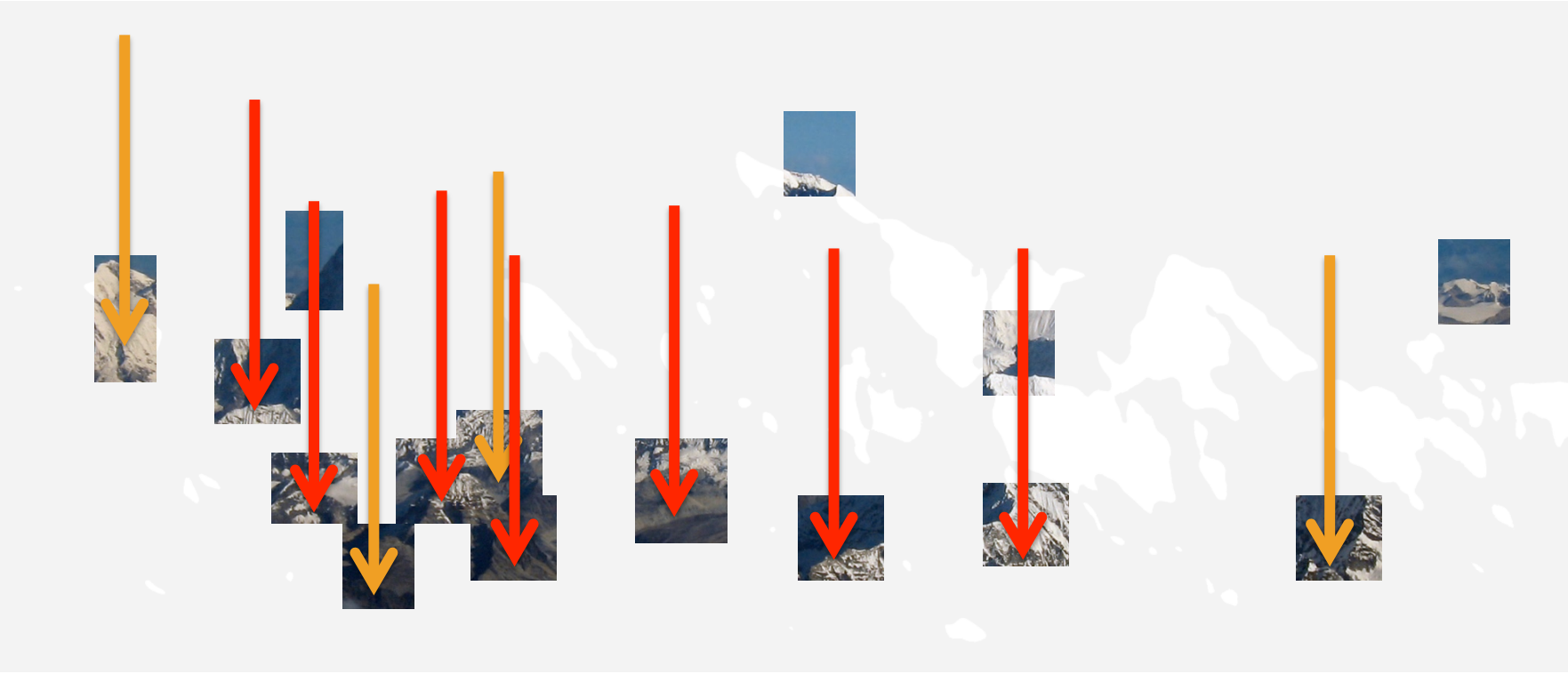

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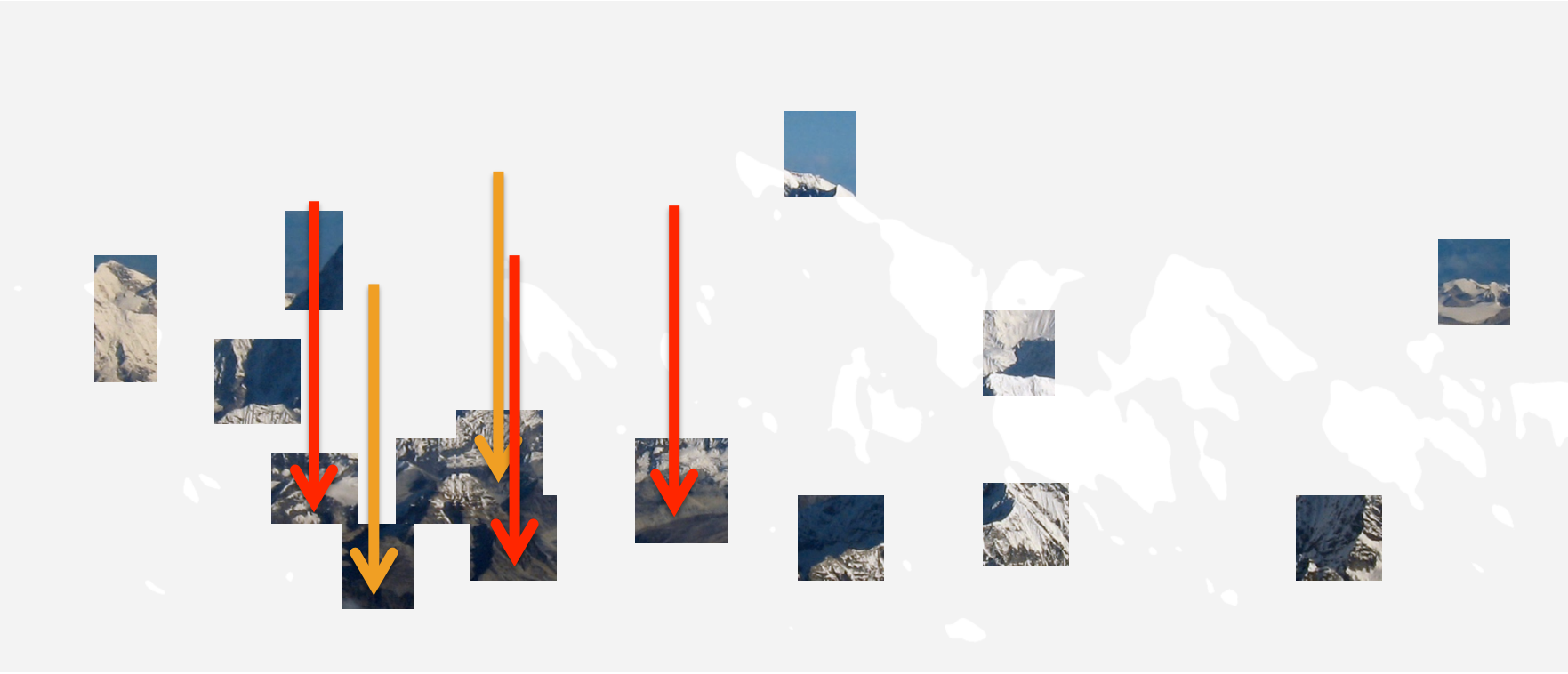

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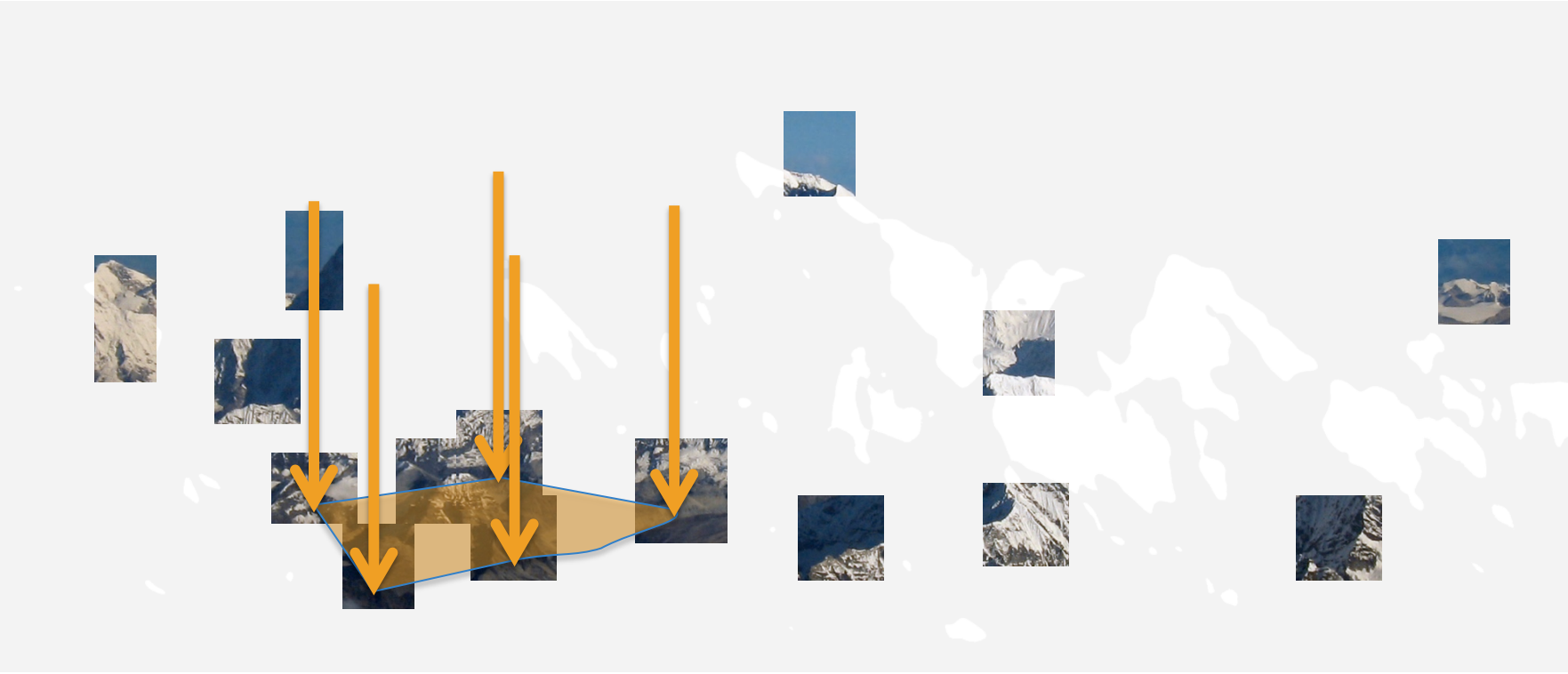

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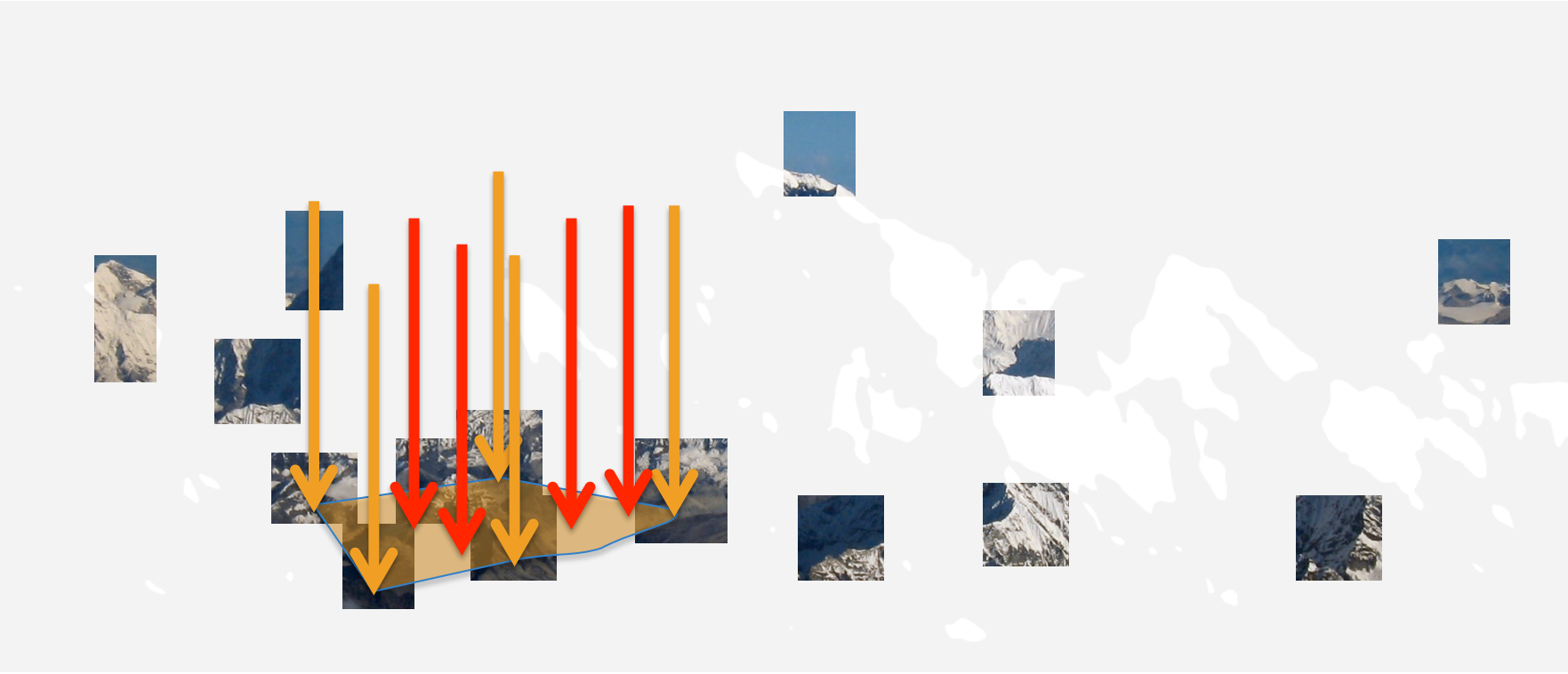

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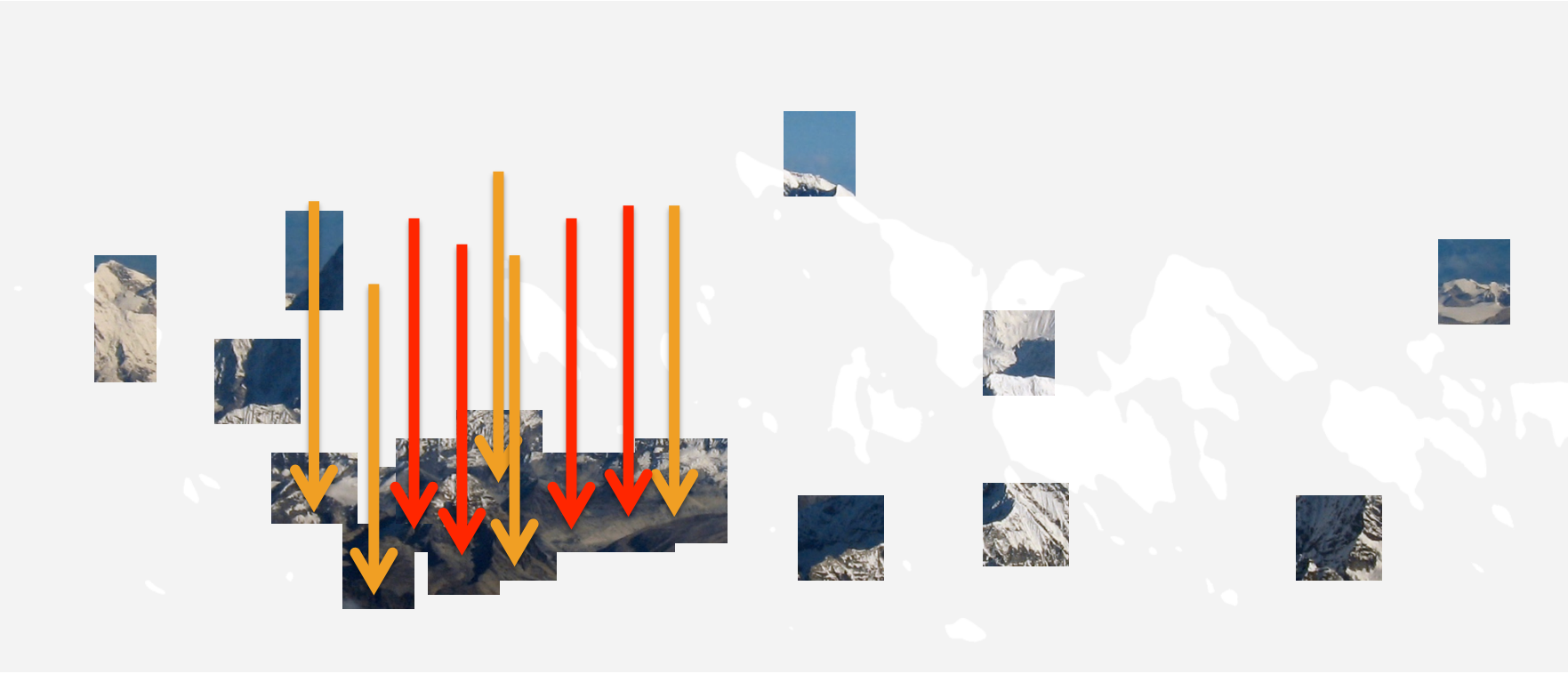

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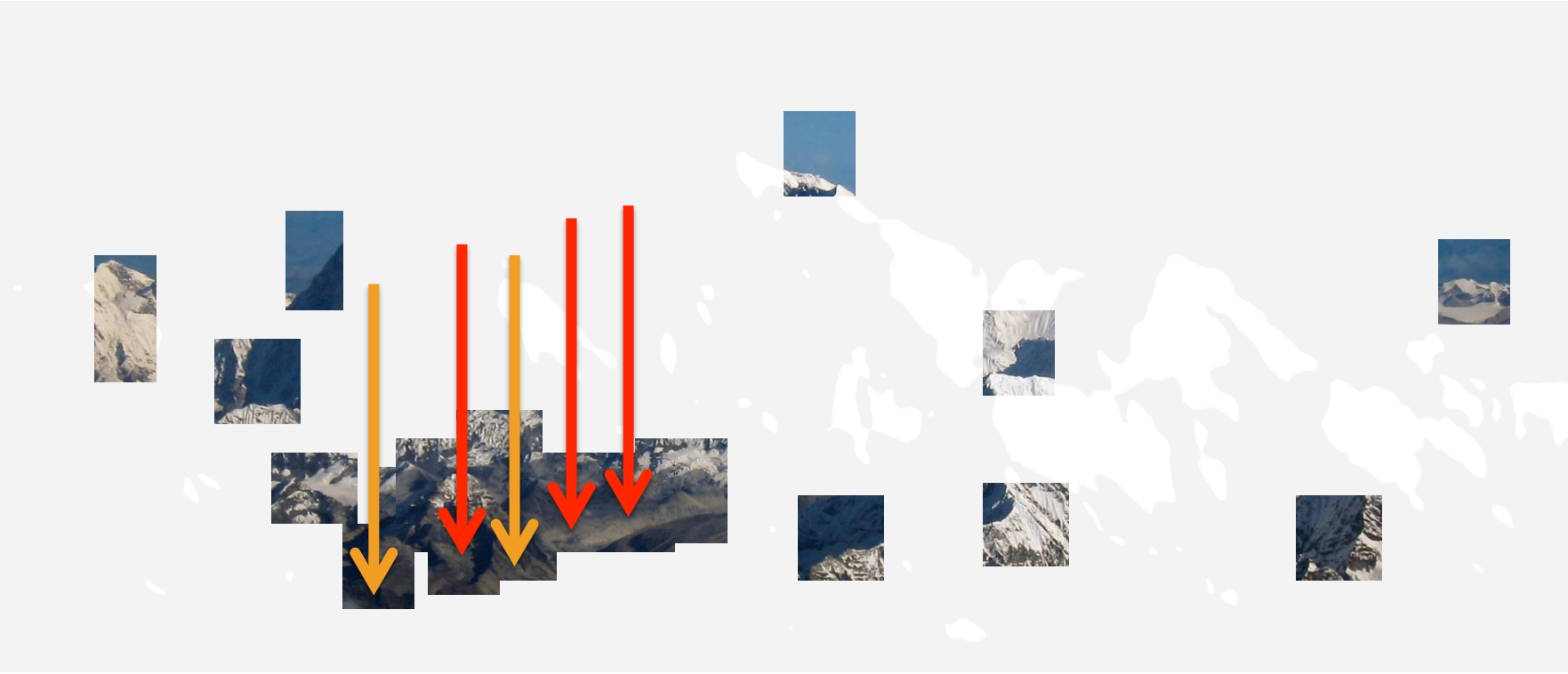

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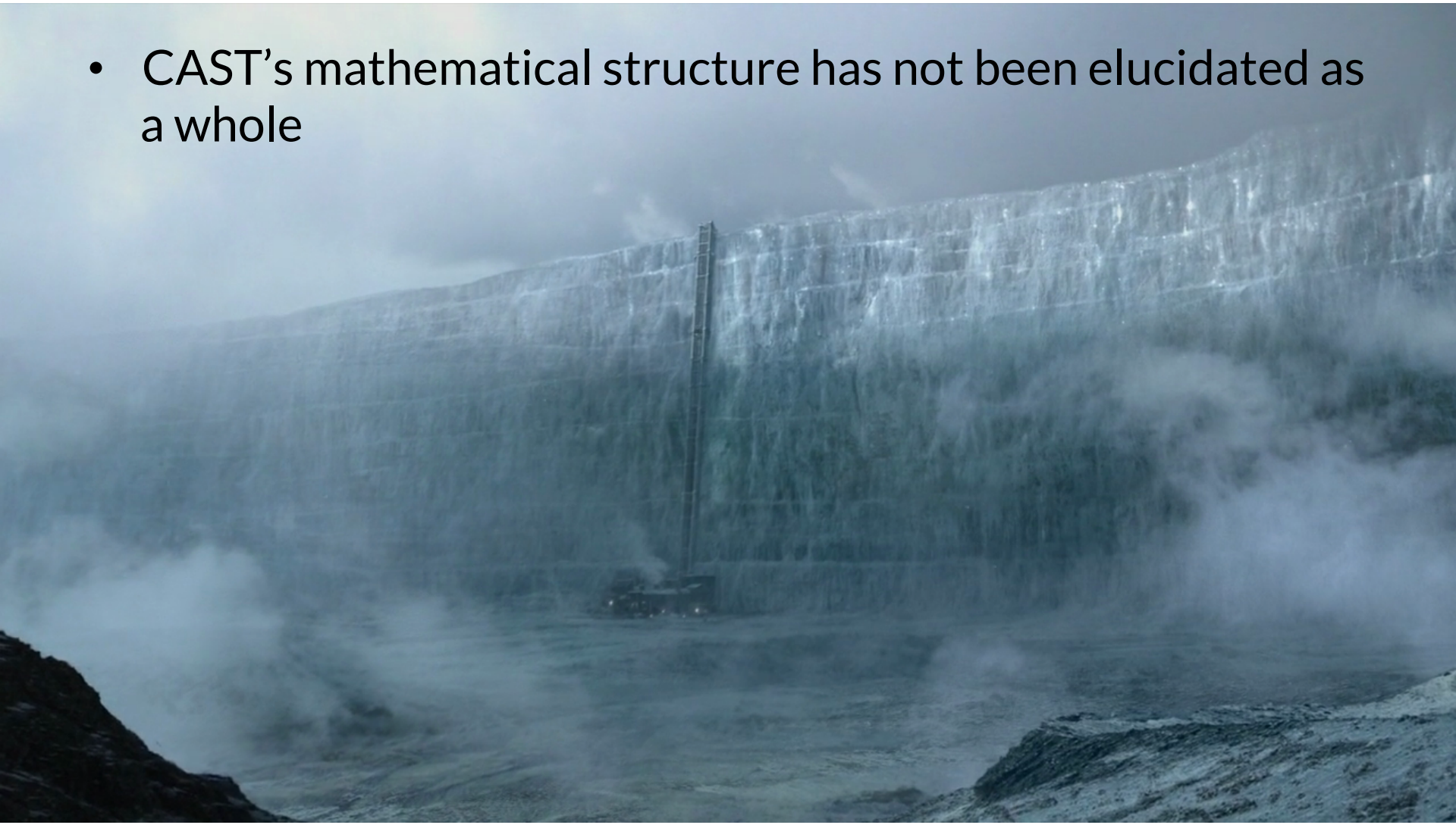

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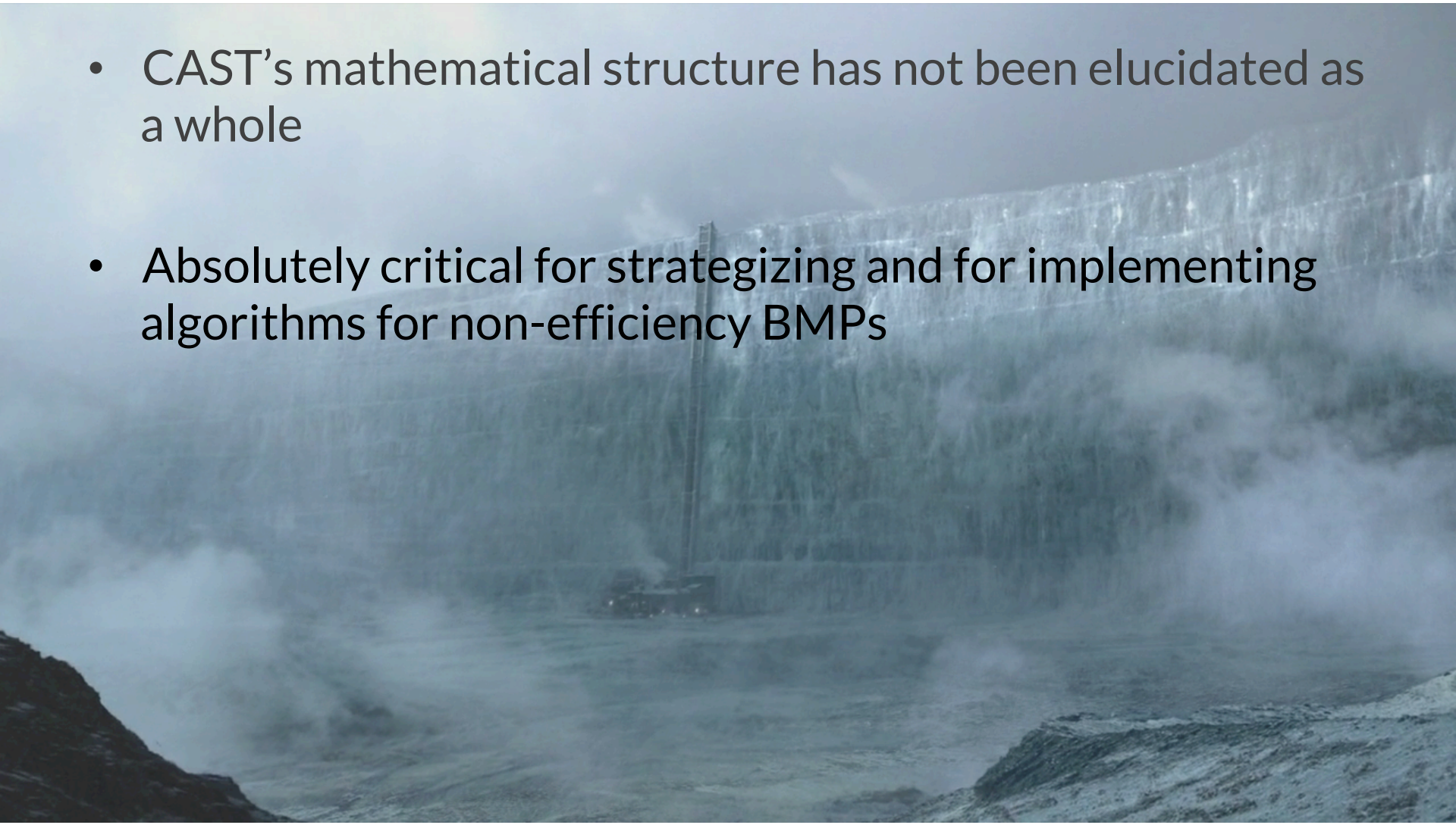

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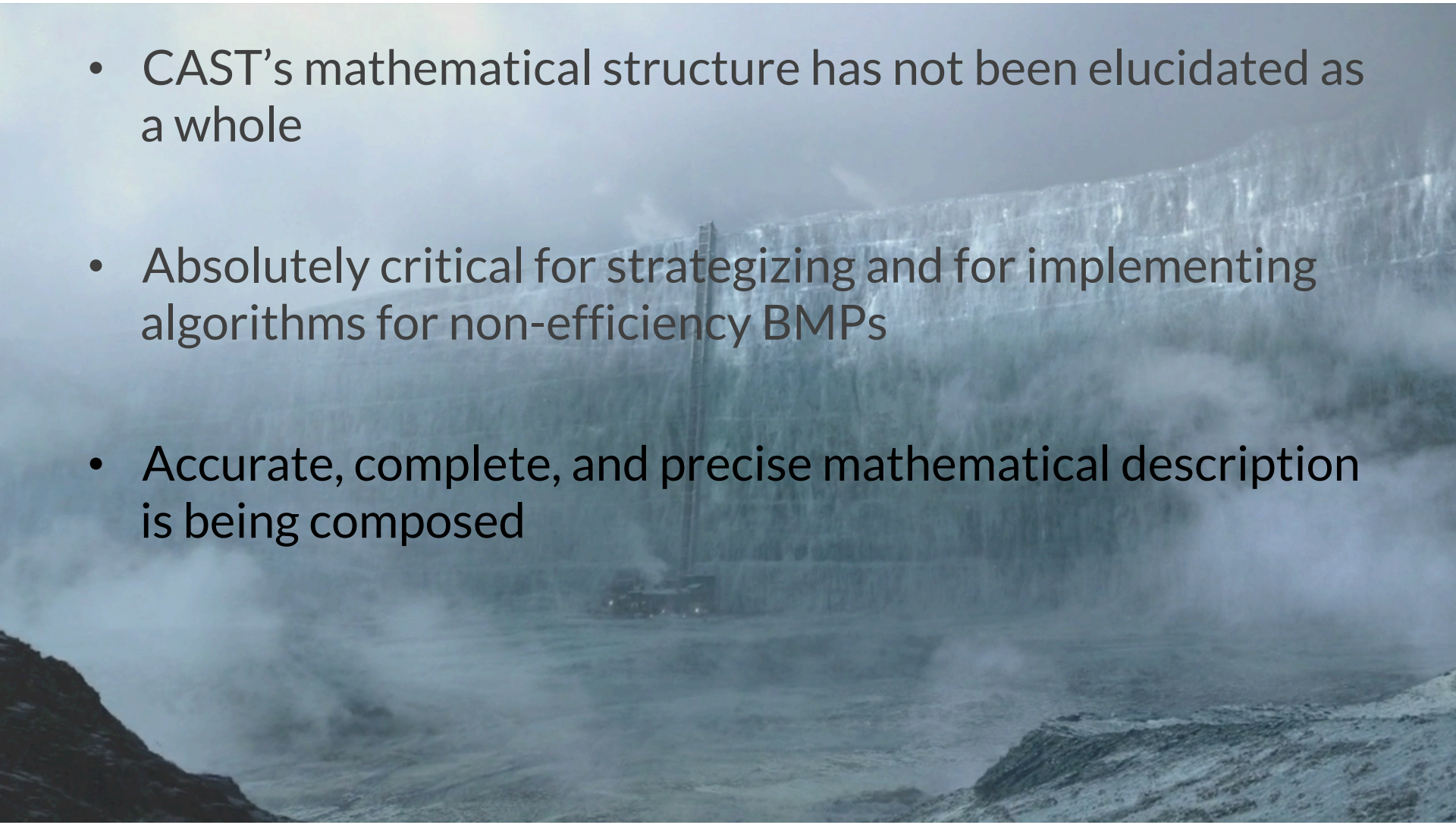
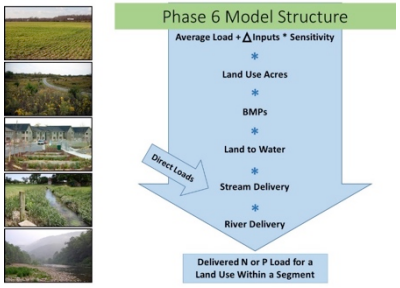


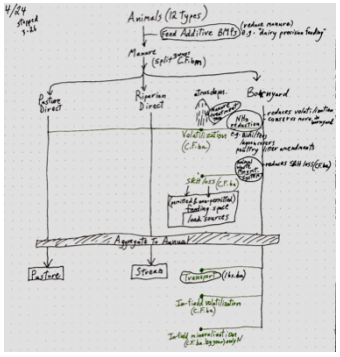
- CAST’s mathematical structure has not been elucidated as a whole
- Absolutely critical for strategizing and for implementing algorithms for non-efficiency BMPs
- Accurate, complete, and precise mathematical description is being composed

# *What is behind the wall?*
# Detailing mathematical structure



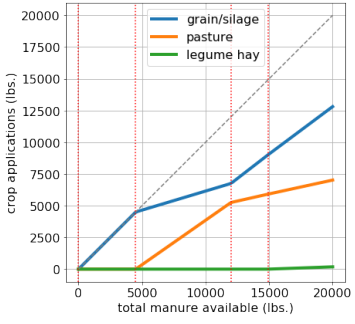

## Big-picture view

$$\mathfrak{L} = \sum_{l \in L} \left\{ \left[ \sum_{\lambda \in \Lambda_N} \left( \left[ \bar{\mathcal{L}}_\lambda + \sum_{t \in \mathcal{T}} \left( (\mathcal{L}_{\lambda,t,k} - I_{\lambda,t}) * S_{\lambda,t} \right) \right]_{\lambda,l} * \mathrm{F}^*_{\lambda,l} * A_{\lambda,l} * D_{\lambda,l} \right) + \sum_{\lambda \in \Lambda_D} \left( (\mathfrak{L}_{\lambda,l} - b_{\lambda,l}) * D_{\lambda,l} \right) \right] * \left( 1 + \frac{\mathfrak{L}_{StreamBedBank,l}}{\mathfrak{L}_l^{calibration}} \right) \right\}$$



## Manure input type
## Animal-to-manure available for crops

$$\mathfrak{M} = \left( \sum_a \left( \boldsymbol{Vloss}^{\mathfrak{b},1} * (\mathfrak{r}_a - \mathfrak{r}_a \boldsymbol{b}^*_a + \mathfrak{r}^*_a \boldsymbol{b}^*_a) * \frac{\mathbf{1}}{\mathbf{12}} * \sum_m (\boldsymbol{c}^{\mathfrak{b}}_m * \mathfrak{M}_a) \right) - \boldsymbol{t} \right) * \boldsymbol{Vloss}^{\mathfrak{b},2} * \boldsymbol{Mloss}^{\mathfrak{b}}$$

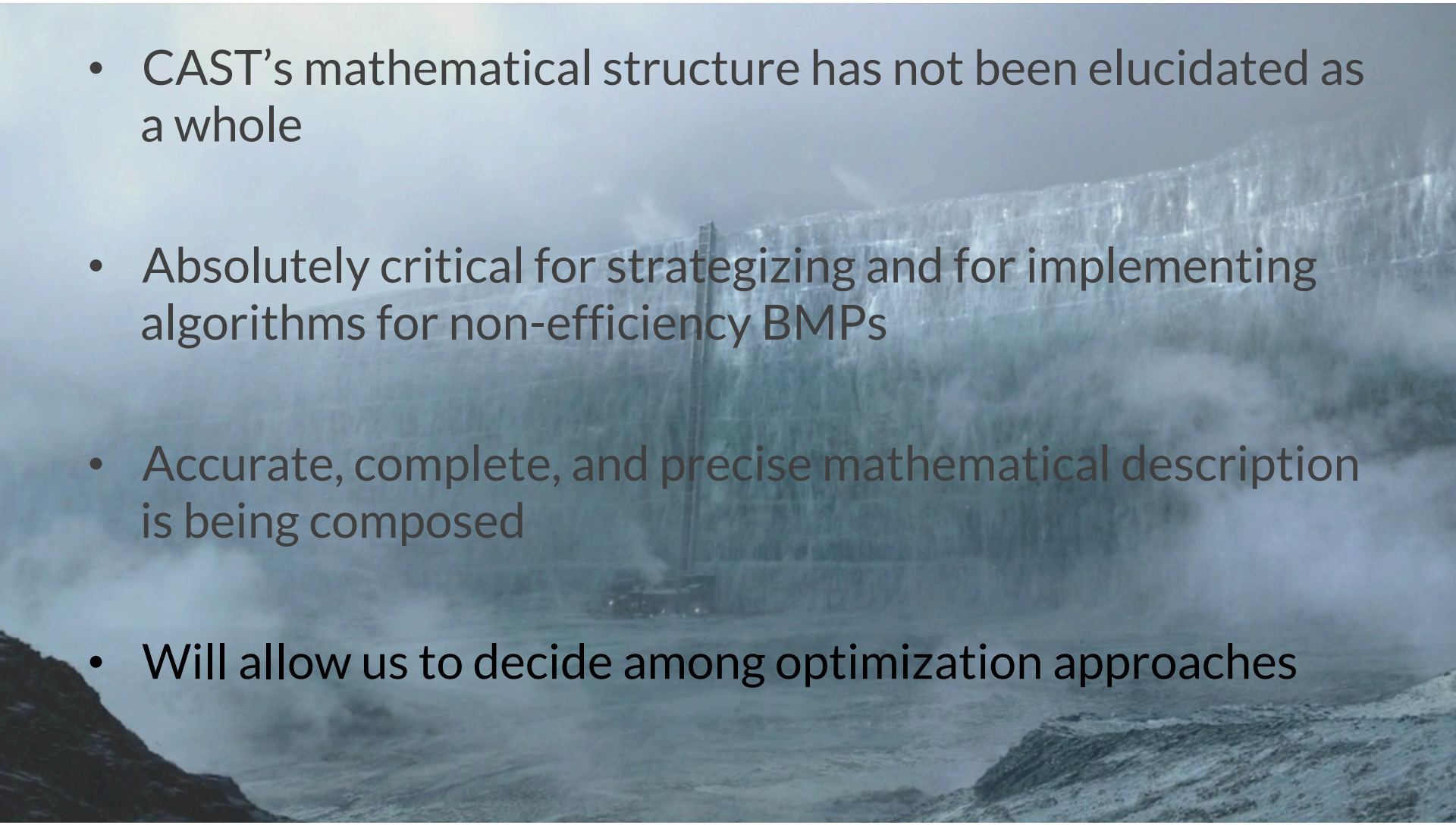



## Manure input type
## Manure-to-crop block

$$\mathfrak{M}_c = A_c \mathfrak{g}_c \left( m_{c,v_i} \left( \frac{\mathfrak{M} - \sum_c b'_{c,v_i} A_c \mathfrak{g}_c}{\sum_c m_{c,v_i} A_c \mathfrak{g}_c} \right) + b_{c,v_i} \right)$$

$$\ldots if \sum_c (v_i m_{c,v_i} + b'_{c,v_i}) A_c \mathfrak{g}_c \leq \mathfrak{M} < \sum_c (v_{i+1} m_{c,v_{i+1}} + b'_{c,v_{i+1}}) A_c \mathfrak{g}_c$$

# *What is behind the wall?*



- CAST's mathematical structure has not been elucidated as a whole
- Absolutely critical for strategizing and for implementing algorithms for non-efficiency BMPs
- Accurate, complete, and precise mathematical description is being composed
- Will allow us to decide among optimization approaches

# *What is behind the wall?*

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**Which approach to use depends upon the landscape**

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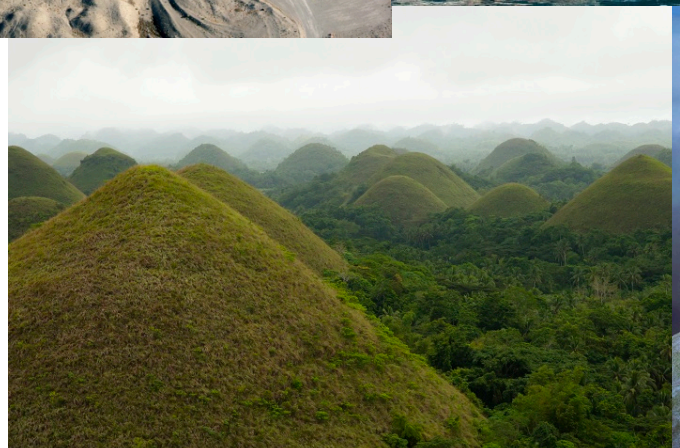
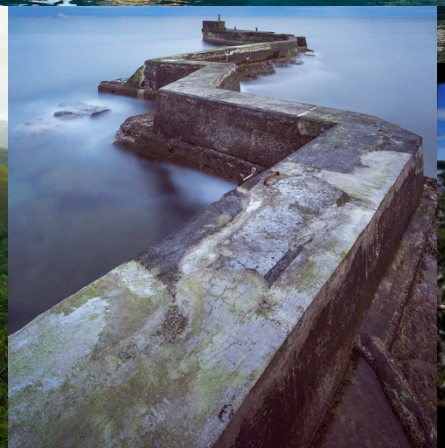
**Which approach to use depends upon the landscape**





# 3 Methods to optimize non-efficiency BMPs

**W**e don't yet know which we'll ultimately use

**T**ests will explore the methods
("operational empiricism")

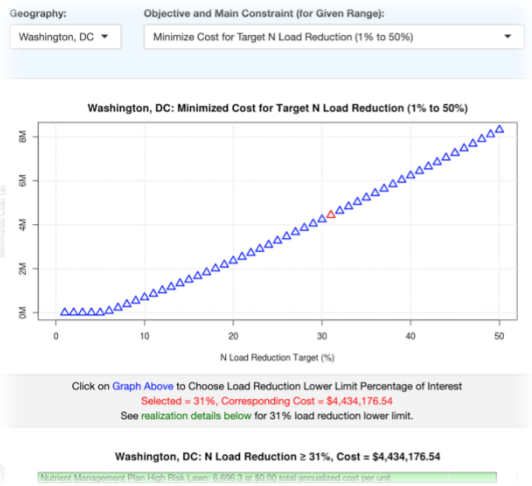
**L**ikely to hybridize

**C**o-benefits can be addressed via each

# Current high-level objectives

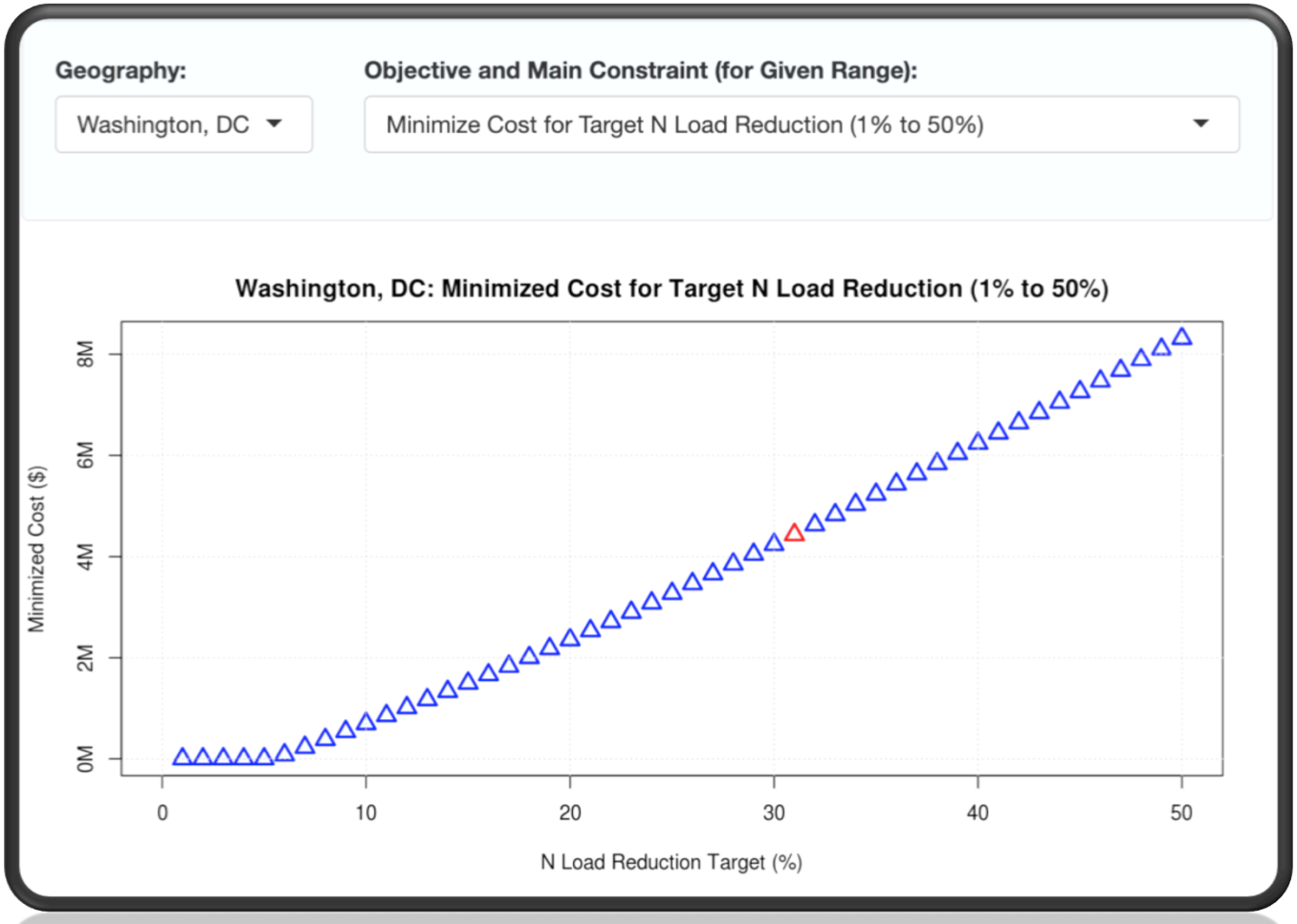
1. Optimize for non-efficiency BMPs ("The Wall")

2. Enhancements of online VICO tool



# Current version (0.1b.1)

**single cost curve for a county**



# What's next for VICO?

# Development in-progress

**Two cost curves for county comparisons**

# Other Development for Beta-2

1. Base loads and BMPs other than 2010 no-action
2. Larger geographies
3. Structural improvements

# Feedback about VICO

- “The interface is simple and looks good to me.”
- “Clicking on the graph is nice for more details.”
- “The tool works well and I had no problem using it.”

- “I believe this tool could provide a good starting point for some folks working on implementation, even though some of them already have a good idea of what is best and feasible to put in the ground.

- “Things I like are that it tells you which BMPs theoretically provide the biggest reductions and overall it can help identify better implementation strategies.”

# Feedback about VICO

- “It might be good to enlarge the text that instructs clicking on the graph.”

- “Are the free Nutrient Management Plans actually free? Or should some dollar value be assigned to those?”

- “It would be helpful to add additional geographic scales (major and minor basins), filters (some bmps might not be feasible in some regions and the user should be able to remove it from the analysis), and downloads.”

# Will continue to be shaped by feedback


*Check it out:*
https://shiny-apps.chesapeakebay.net/vico/

*...and email me (Danny), at:*
dkaufman@chesapeakebay.net

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