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# Eco-engineering on the Edge:

## Decision Making for Stream Restoration and Stabilization in High Profile or Risk Environments

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# Types of Risk

- **Physical/Structural** = Property loss, pipeline rupture or breach, structural damage to utilities or property.

- **Environmental** = Connectivity, native species loss, species invasions, sedimentation, in-stream or riparian habitat loss, geomorphic adjustment, floodway impacts.

*Photo. Ruptured pipeline in rural Washington state. Photo from Washington UTC.*

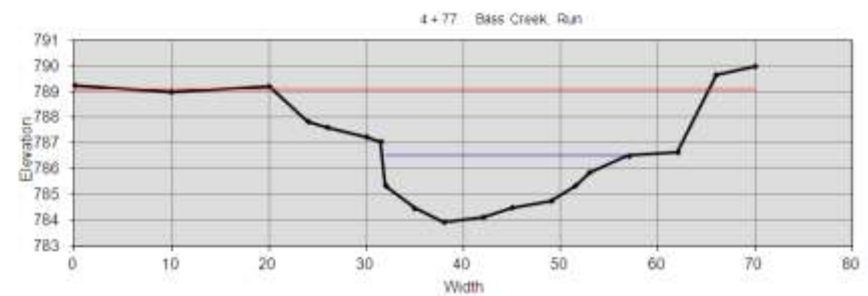
# Environmental Risk

- Considers short-term and long-term environmental impact of project in addition to structural considerations:
  - Biological
  - Hydrological
  - Geomorphic
- Addresses regulatory concerns and needs.
- Results in a more successful project.

*Photo. Ice formation within the backwater of a log vane installed as part of a Brownfield remediation and wastewater pipeline protection project.*

# How do we address risk and uncertainty?

- Identify likely conditions or consequences through decision framework and modeling (conceptual or technical)
- Gain knowledge and understanding through data collection and analysis
- Consider probability of outcomes through experience (Bayesian analysis) and/or measurement.
- A decision-makers approach to risk <u>is a values decision</u> and can be subject to individual biases.




| Bankfull Dimensions | |
|---|---|
| 42.5 | x-section area (ft.sq.) |
| 25.0 | width (ft) |
| 1.7 | mean depth (ft) |
| 2.6 | max depth (ft) |
| 25.4 | wetted parimeter (ft) |
| 1.7 | hyd radi (ft) |
| 14.7 | width-depth ratio |

| Flood Dimensions | |
|---|---|
| 54.9 | W flood prone area (ft) |
| 2.2 | entrenchment ratio |
| — | low bank height (ft) |
| — | low bank height ratio |

| Materials | |
|---|---|
| 0.88 | D50 Riffle (mm) |
| 6.3 | D84 Riffle (mm) |
| 6 | threshold grain size (mm) |

| Bankfull Flow | |
|---|---|
| 3.6 | velocity (ft/s) |
| 153.0 | discharge rate (cfs) |
| 0.49 | Froude number |

| Flow Resistance | |
|---|---|
| 0.020 | Manning's roughness |
| 0.04 | D'Arcy-Weisbach fric. |
| 14.2 | resistance factor u/u* |
| 82.2 | relative roughness |

| Forces & Power | |
|---|---|
| 0.12 | channel slope (%) |
| 0.13 | shear stress (lb/sq.ft.) |
| 0.25 | shear velocity (ft/s) |
| 0.46 | unit strm power (lb/ft/s) |

# How do we address risk and make decisions?

- Many approaches and options based on level of detail and experience.


- Decision frameworks
  - Risk assessment logs
  - Alternatives analysis
  - Decision matrices‘



*Images:*
*1. Davenport, T. 2009. Make Better Decisions. Harvard Business Review.*
*2. http://decision-quality.com*

- Risk involves both the probability that the event will happen as well as the severity of potential impact.

| Probability | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.9 | Very High 71-90% | 0.045 | 0.09 | 0.18 | 0.36 | 0.72 |
| 0.7 | High 51-70% | 0.035 | 0.07 | 0.14 | 0.28 | 0.56 |
| 0.5 | Medium 31-50% | 0.025 | 0.05 | 0.10 | 0.20 | 0.40 |
| 0.3 | Low 11-30% | 0.015 | 0.03 | 0.06 | 0.12 | 0.24 |
| 0.1 | Very Low up to 10% | 0.005 | 0.01 | 0.02 | 0.04 | 0.08 |
| | | Very Low | Low | Medium | High | Very High |
| | | 0.05 | 0.1 | 0.2 | 0.4 | 0.8 |
| | | | | Impact | | |

*From RuleWorks. Online Risk Management Guide. 2011. http://www.ruleworks.co.uk/riskguide/index.htm*

# Mill Creek

- Near Rock Island, IL
- Agricultural watershed
- 2 gas pipelines threatened by downcutting and bank erosion
- Constructed 2010.

*Photo. View downstream at Mill Creek and pipeline area threatened by erosion.*

# Mill Creek

- Design needed to address:
  - Pipeline protection from bank erosion
  - Pipeline protection from downcutting and scour.
  - Unstable reach morphology
  - Minimize agricultural impacts

*Photo. View across the channel where a pipeline is exposed.*

| Structural and Environmental Risk Accounting – Mill Creek Vanes/Stream Barbs and Riffle | | | |
|---|---|---|---|
| **Hazard** | **Impact (1-5)** | **Probability (1-5)** | **Risk Rating (I x P)** |
| Bank erosion compromising stability | 5 | 1 | 5 |
| Potential for future downcutting or scour | 5 | 1 | 5 |
| Negative impact to surrounding agricultural land | 3 | 4 | 12 |
| Long-term potential for geomorphic adjustment | 4 | 2 | 8 |
| Loss of riparian vegetation /streamside access | 1 | 1 | 1 |
| **Evaluated Risk** | | | **31** |

| Structural and Environmental Risk Accounting – Mill Creek Bank and Bed Armoring | | | |
|---|---|---|---|
| **Hazard** | **Impact (1-5)** | **Probability (1-5)** | **Risk Rating (I x P)** |
| Bank erosion compromising stability | 5 | 2 | 10 |
| Potential for future downcutting or scour | 5 | 1 | 5 |
| Negative impact to surrounding agricultural land | 2 | 3 | 6 |
| Long-term potential for geomorphic adjustment | 4 | 4 | 16 |
| Loss of riparian vegetation /streamside access | 3 | 2 | 6 |
| **Evaluated Risk** | | | **43** |

# Mill Creek

- Design protected exposed pipe and prevented exposure of additional pipeline.

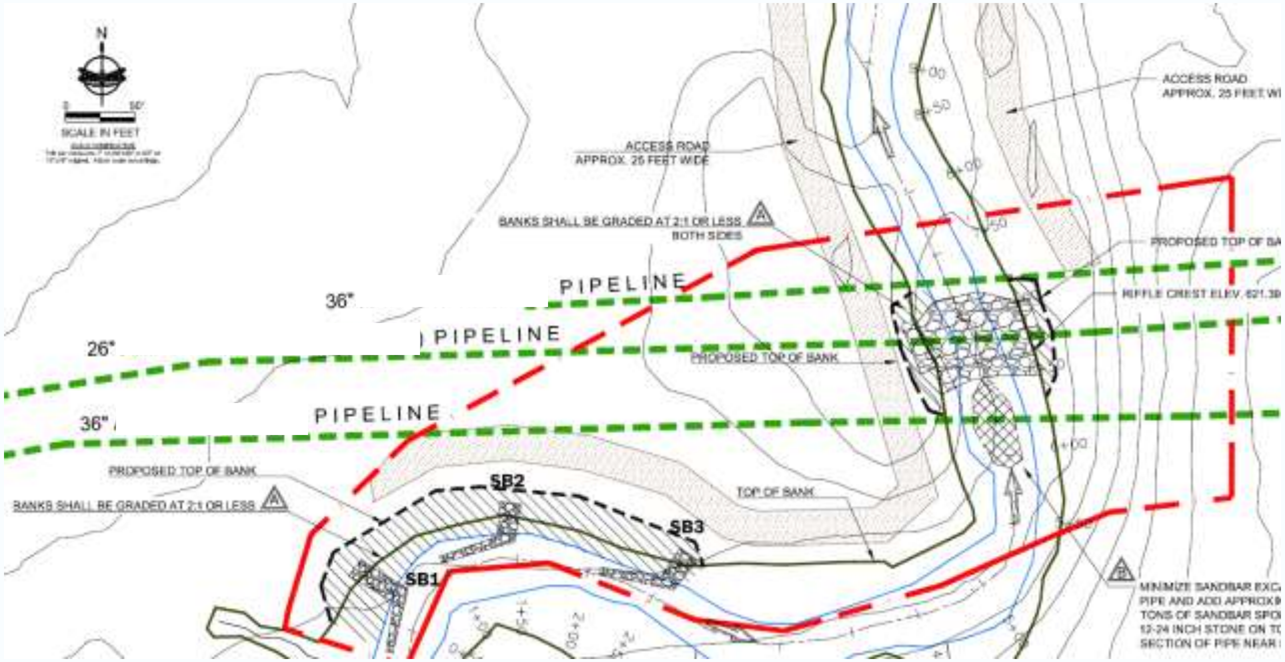



*Image. Mill Creek project layout.*

*Photo. View upstream at riffle construction site – pre-project.*

*Photo. View upstream at riffle construction site – post-project.*

*Photo. View downstream at bank protection site – pre-project.*

*Photo View downstream at bank protection site – post-project.*

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# Mill Creek Aerial View (September 2011)

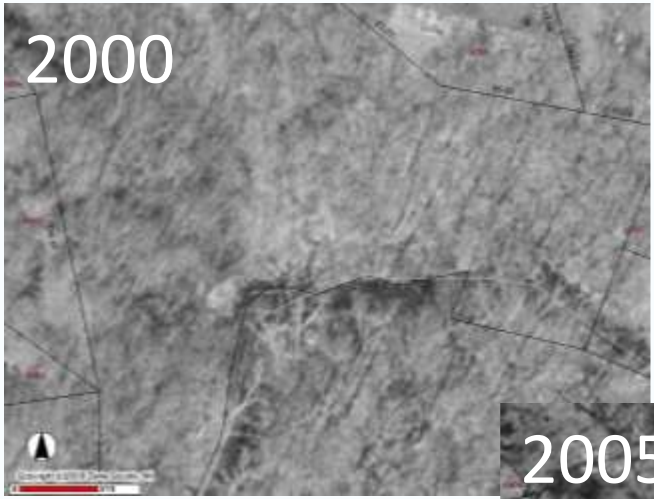
# Pheasant Branch Creek

- Near Madison, WI
- 17 $mi^2$ urbanized watershed
- Private property threatened by bank erosion
- Public park with high visibility.
- Constructed 2008.

*Photo. View upstream at Pheasant Branch Creek and eroded slope area. Photo courtesy of Herb Garn, USGS.*

# Pheasant Branch Creek

- Design needed to address:
  - Property protection from bank erosion
  - Unstable reach morphology
  - Unconsolidated soils (sand)
  - Habitat enhancement
  - Public Use and Aesthetics





*Photos. One* slope eroded 25 ft. in 5 years, or an average of 5 ft./yr.

- Alternatives analysis used to evaluate restoration and stabilization options.

- Costs based on installed projects within the stream corridor.

| Technique | Review of Goal Applicability | Estimated Cost *(based on treatment of 1,000LF)* |
| --- | --- | --- |
| Gabion Baskets | Gabion baskets have historically been used to stabilize portions of Pheasant Branch Creek. However, the natural deterioration of the metal baskets requires their replacement after 20-30 years. Ecologically, these structures create a vertical bank angle that | **$350,000.00** ($350.00/LF) |
| Sheet Piling Toe Stabilization | Sheet piling has also historically been used along several reaches of Pheasant Branch Creek. While this technique results in stabilization of the localized erosion, it does not dissipate near-bank streamflows and often results in additional erosion to portions of stream immediately downstream of the treatment area. Ecologically, these | **$1,000,000.00** ($1,000.00/LF) |
| Stone Rip Rap Bank Protection | Conventional rip rap would provide desired bank stability, but does not achieve the projects green requirements, aesthetic, recreational, and habitat enhancement goals alone. However, stone rip rap may be the most applicable alternative for small | **$100,000.00** ($100.00/LF) |
| Flow Deflection Structures | Flow deflection structures (including stream barbs, vortex weirs, vane structures, etc.) have been utilized for over 30 years throughout all regions of the U.S. under various channel conditions, including incised streams. There is also a large volume of | **$200,000.00** ($200.00/LF) |

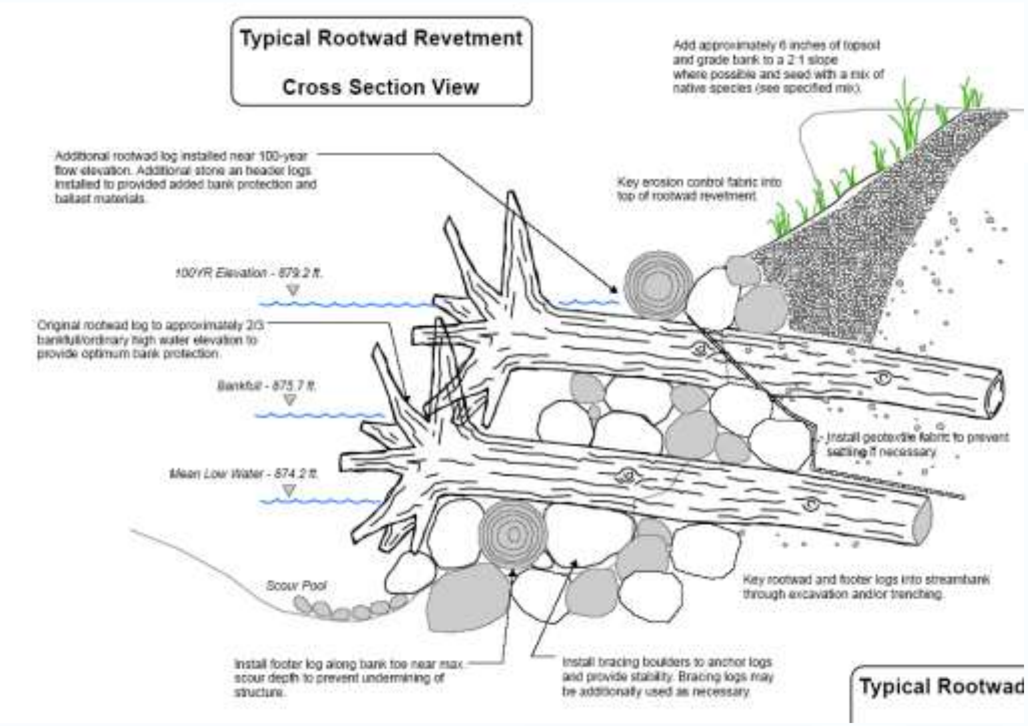
- Alternatives analysis can be normalized and weighted to score and rank options.
- This process allows quantitative comparison of multiple project considerations.

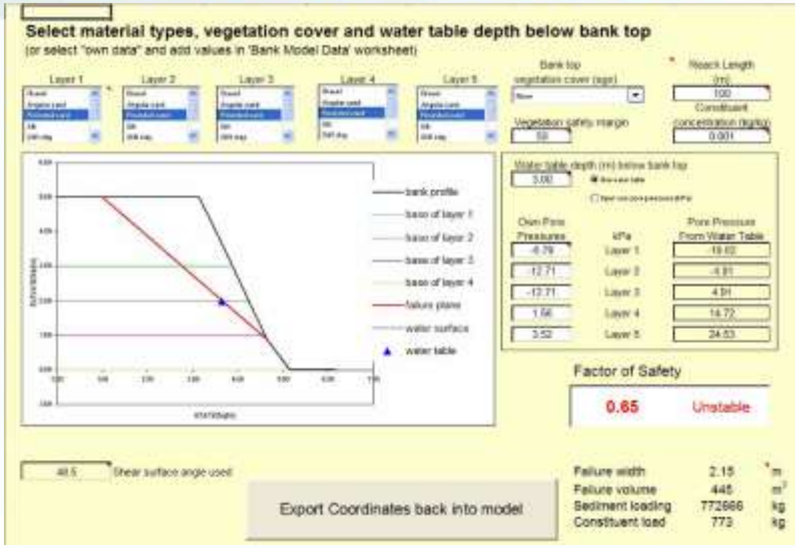
| Objective | Goal | Units | Consequences by Alternative | | | | |
|---|---|---|---|---|---|---|---|
| | | | Rip Rap | Gabions | Rootwads | Vane Structures | Channel Meandering |
| Cost | Minimize | $/LF | 100 | 350 | 200 | 150 | 200 |
| Habitat Improvements | Maximize | 0-5 | 1 | 0 | 5 | 4 | 3 |
| Aesthetics | Maximize | 0-5 | 1 | 1 | 4 | 3 | 5 |
| Access Difficulty | Minimize | Low/Med/High (1-3) | 3 | 3 | 1 | 1 | 2 |

| Objective | Goal | Normalized Scores by Alternative | | | | |
|---|---|---|---|---|---|---|
| | | Rip Rap | Gabions | Rootwads | Vane Structures | Channel Meandering |
| Cost | Minimize | 1 | 0 | 0.6 | 0.8 | 0.6 |
| Habitat Improvements | Maximize | 0.2 | 0 | 1 | 0.8 | 0.6 |
| Aesthetics | Maximize | 0 | 0 | 0.75 | 0.5 | 1 |
| Access Difficulty | Minimize | 0 | 0 | 1 | 1 | 0.5 |

| Objective | Goal | Weight | Weighted Score by Alternative | | | | |
|---|---|---|---|---|---|---|---|
| | | | Rip Rap | Gabions | Rootwads | Vane Structures | Channel Meandering |
| Cost | Minimize | 0.5 | 0.5 | 0 | 0.3 | 0.4 | 0.3 |
| Habitat Improvements | Maximize | 0.25 | 0.05 | 0 | 0.25 | 0.2 | 0.15 |
| Aesthetics | Maximize | 0.1 | 0 | 0 | 0.075 | 0.05 | 0.1 |
| Access Difficulty | Minimize | 0.15 | 0 | 0 | 0.15 | 0.15 | 0.075 |
| | **Final Scoring =** | | **0.55** | **0** | **0.775** | **0.8** | **0.625** |

- Modeled bank stability and rootwad structural stability.



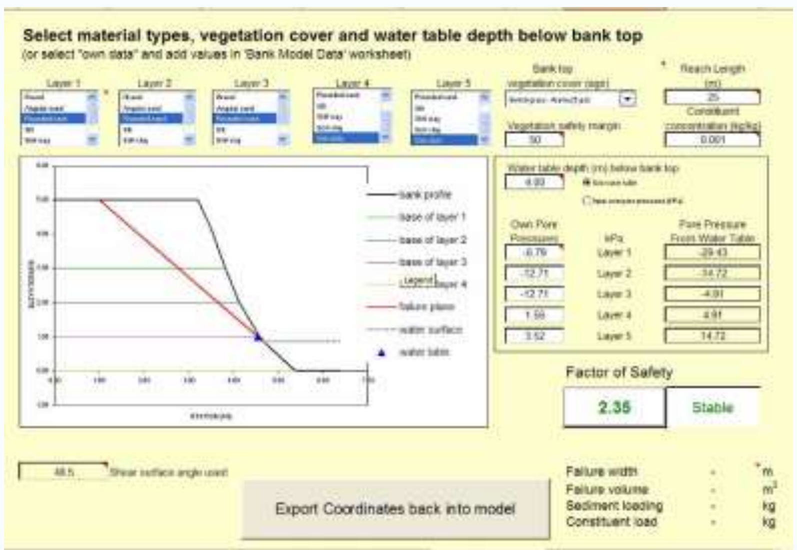



*Photo. View at the graded slope during erosion control blanket installation.*

*Photo. View at graded slope following seed establishment.*

*Photo. View upstream scour pool in front of rootwad revetments.*

*Photo. View downstream at established native vegetation (September 2011).*

# Bass Creek

- South Central WI
- 28 $mi^2$ agricultural watershed
- Pole structure and private property threatened by bank erosion

*Photo. View downstream exposed pole structure (Summer 2011).*

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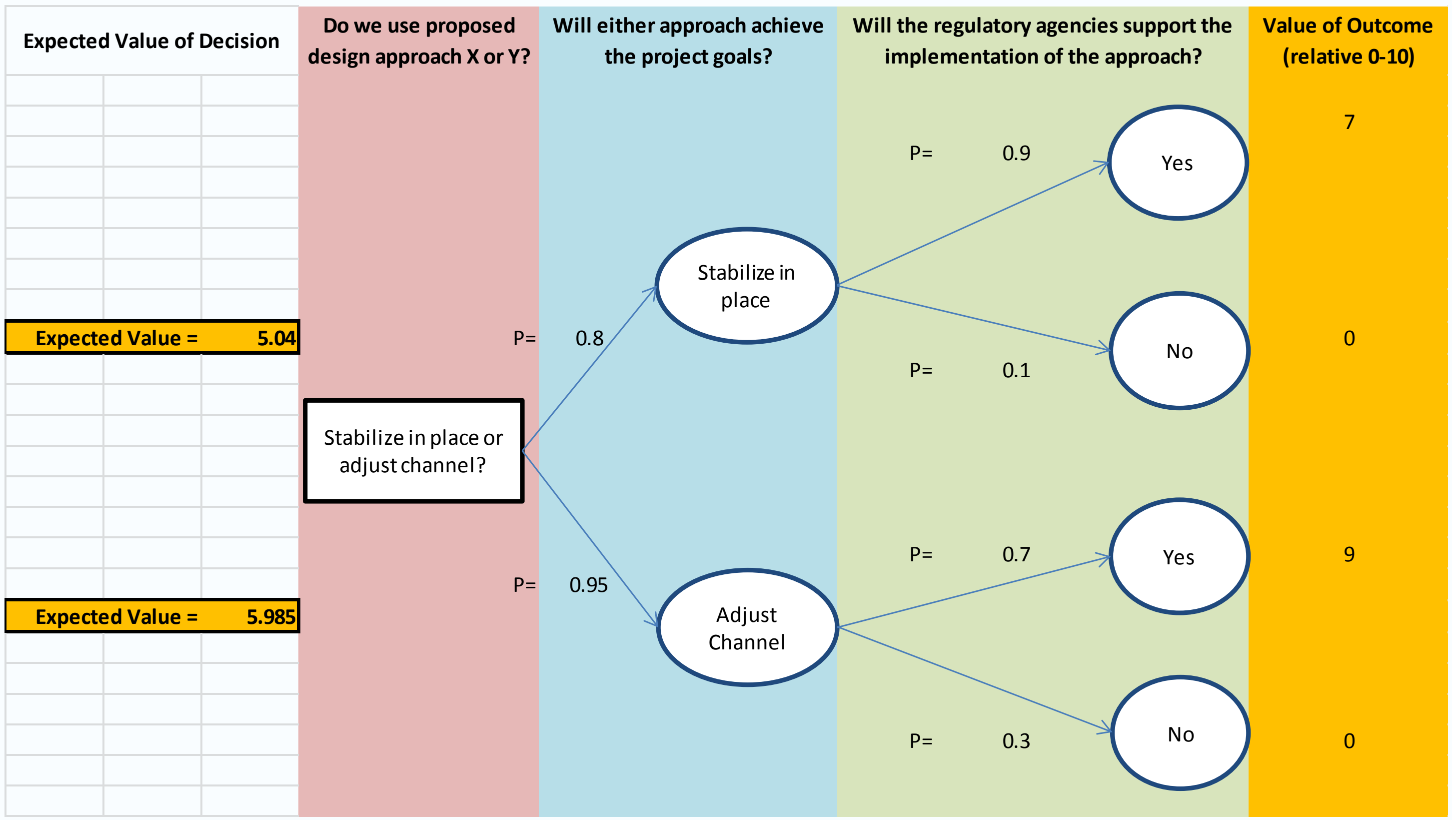
# Bass Creek

- Design needed to address:
  - Transmission line protection from channel erosion
  - Relation to other structures
  - Channel morphologic adjustments
  - Preservation of streamside wetlands and agricultural lands
  - Expedited timeline

*Photo. View of typical eroded streambank in project area (Summer 2011).*

# Bass Creek

- Decision tree used to evaluate the best project approach.



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# Summary

- Risk is a component of all projects.
- Utilizing decision frameworks can:
  - Aid selection of approach
  - Support permit applications
  - Document design rationale
- Experience in a variety of techniques and approaches will reduce biases towards approach and solutions.

# Thank You

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