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Resilient Design for Dynamic Landscapes

An Action Plan for Working with Nature to Build Infrastructure that Lasts

Presented by:

Alex Strouth and Emily Mark


Date:

April 23, 2026

With funding from:



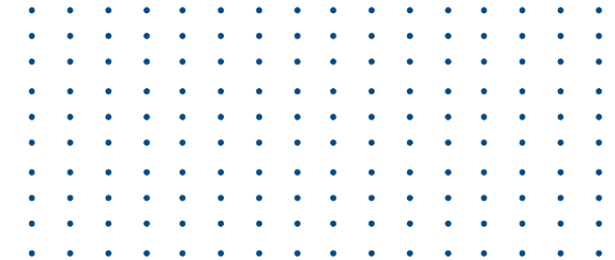
ACIiFF

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Presentation Outline

- Landscape change and nature-based solutions
 - 3 Actions for Resilient Infrastructure
 - Case Study: Melamchi Water Supply, Nepal
 - Path Forward
- 



Presentation Outline

- **Landscape change and nature-based solutions**
 - 3 Actions for Resilient Infrastructure
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- 

Water supply



Agriculture



Energy



To be “resilient”, infrastructure design needs to account for landscape change.

Transport



Urban development



Landscape changes include changes to ground and water, in the short and long term.



Changes to ground, including rocks and soil



Changes to water, including quantity and location

Causes of landscape change

Contributing factors

Glacial melt
High intensity rainfall
Permafrost degradation

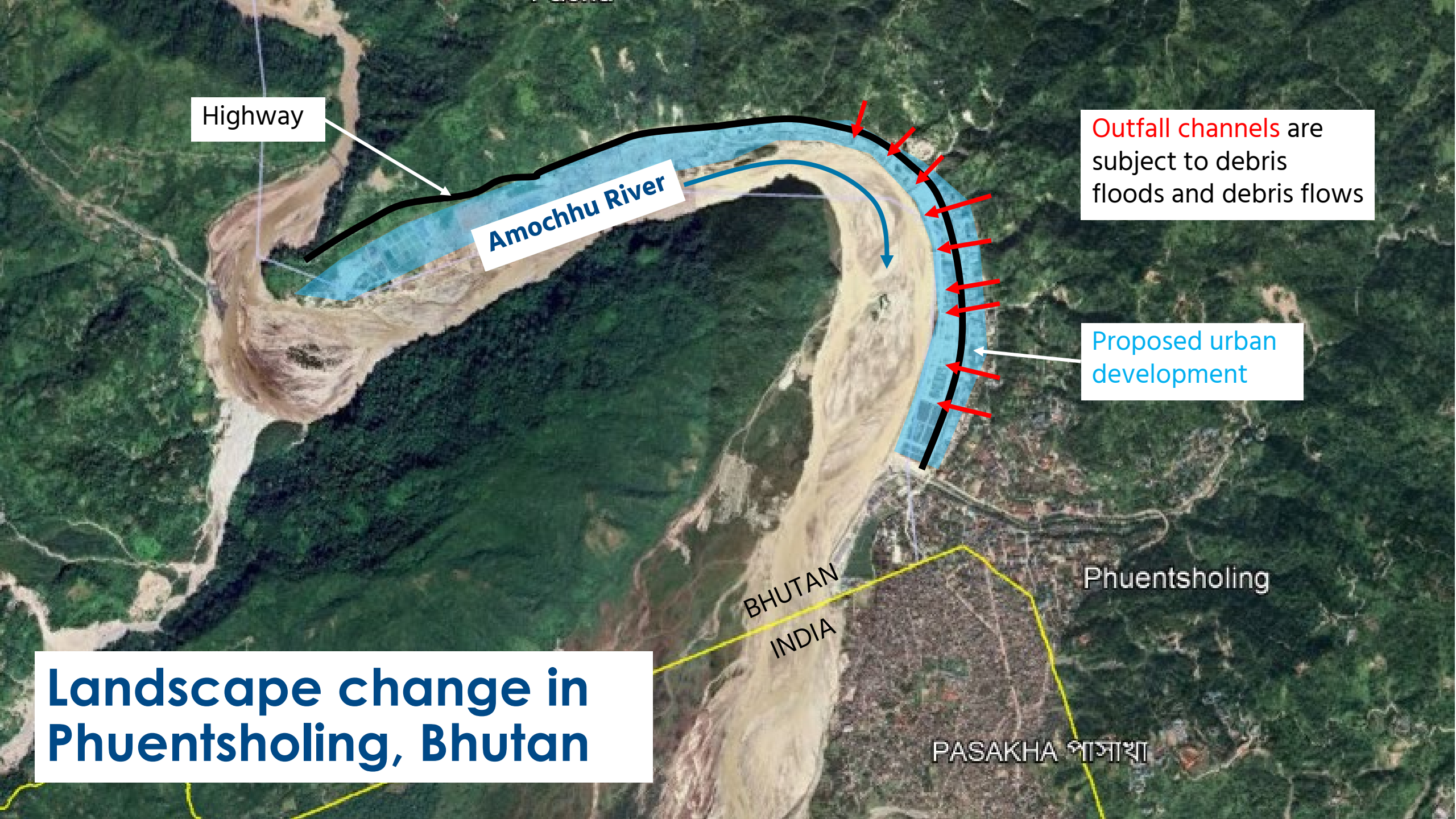
Routine Processes and Hazards

Floods
Landslides
Debris floods and flows

Landscape change

More sediment or debris
Less sediment or debris
More water
Less water





Highway

Amochhu River

Outfall channels are subject to debris floods and debris flows

Proposed urban development

Landscape change in Phuentsholing, Bhutan

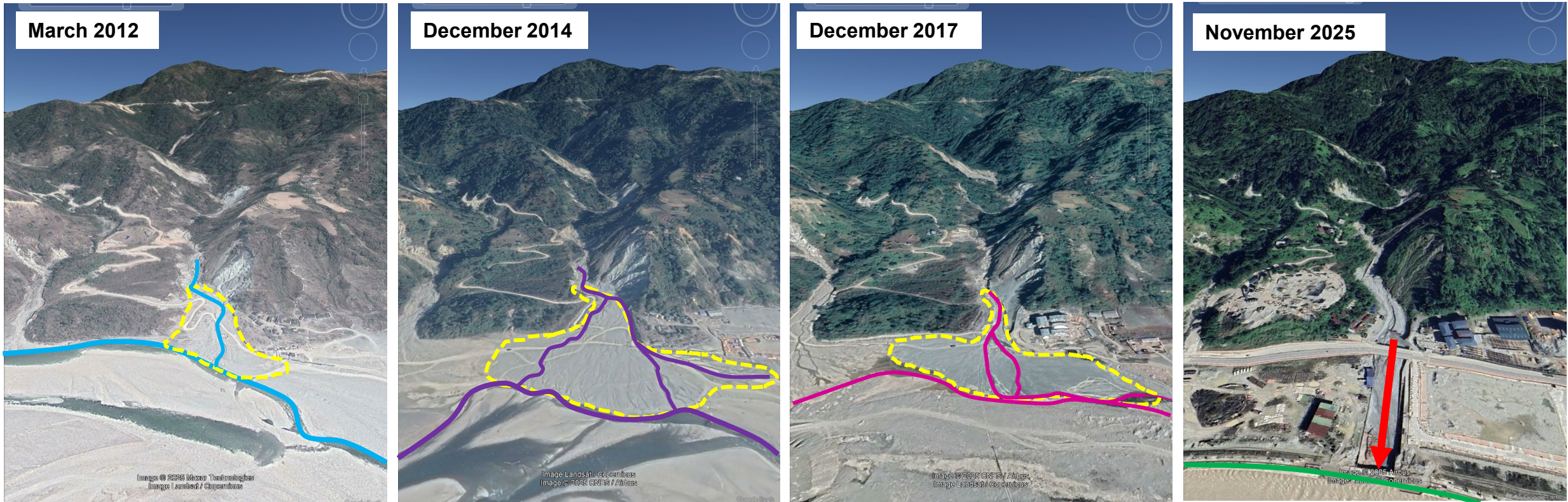
BHUTAN
INDIA

Phuentsholing

PASAKHA पासखा

Landscape change in the Himalayas is rapid.

Infrastructure design needs to account for sediment and water change.



Satellite imagery from an ADB project area in Phuentsholing, Bhutan

To be “resilient”, infrastructure design needs to ~~account for landscape change.~~ be nature-based.

Nature-based solutions involve:

- Working with natural processes
- Allowing natural processes to continue
- Using natural processes to benefit infrastructure performance (if possible)





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Actions for Resilient Infrastructure



1. Define realistic performance objectives

2. Build project teams that understand landscape change

3. Use design scenarios to account for change and uncertainty



Gandaki province, Nepal, May 2025

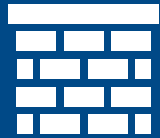
Resilient Infrastructure Action #1: Define realistic performance objectives



Image is AI generated for educational purposes only

Use the principles of resilient infrastructure design to set performance objectives.

Create resilient infrastructure with...



Robustness



Redundancy



Rapid Recovery



Resourcefulness

Hypothetical Beni bridge performance objectives

1. The bridge is fully functional up to the 50-year monsoon flood.
2. The bridge may be damaged by a glacial lake outburst flood, but another nearby bridge has a higher capacity and would provide an alternate route.
3. If required, monsoon flood repairs should take less than one month. Necessary materials will be stockpiled locally.



Robustness



Redundancy



Rapid Recovery



Resourcefulness



Resilient Infrastructure Action #2:
Build project teams that
understand landscape change.

The design team should be able to describe the range of possible landscape change outcomes:



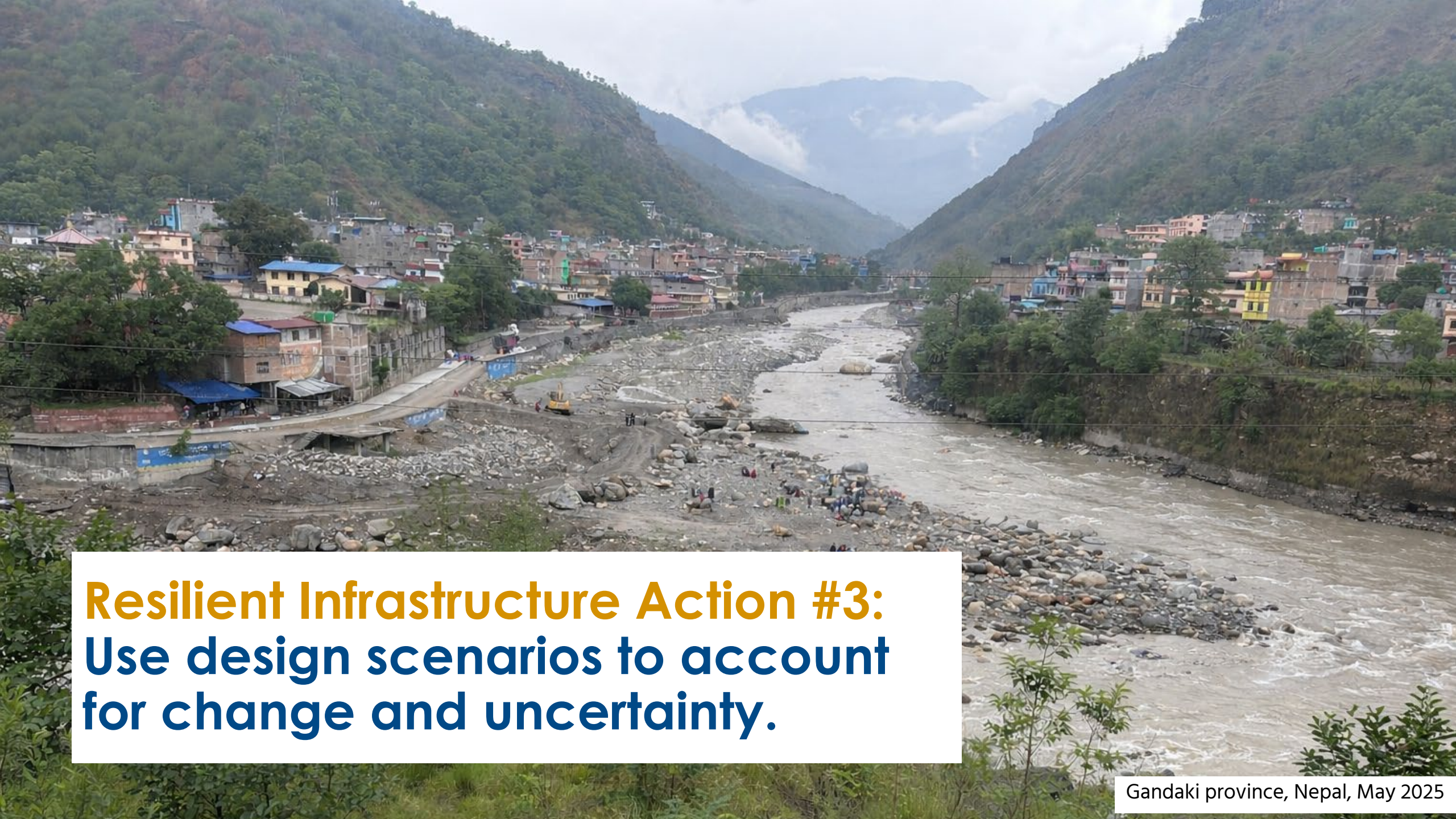
The 50-year monsoon flood is estimated at 500 m³/s.



The riverbed level may fluctuate here by up to 15 m.



A glacial lake outburst flood could be up to 2000 m³/s here.

A wide, shallow river with a rocky bed flows through a valley. The river is filled with large, smooth rocks and has a muddy, brownish water. On both sides of the river, there are densely packed buildings, mostly multi-story structures with colorful roofs. The buildings are built on a hillside, and the valley floor is covered with more rocks and debris. In the background, there are steep, forested mountains under a cloudy sky. The overall scene suggests a rural or semi-rural area in a mountainous region.

Resilient Infrastructure Action #3:
Use design scenarios to account
for change and uncertainty.

The design team should be able to describe the range of possible landscape change outcomes:



The 50-year monsoon flood is estimated at 500 m³/s.



The riverbed level may fluctuate here by up to 15 m.



A glacial lake outburst flood could be up to 2000 m³/s here.



Possible bridge design scenarios:
1. Current conditions



Possible bridge design scenarios:

1. Current conditions

2. 50-year monsoon flood



Possible bridge design scenarios:

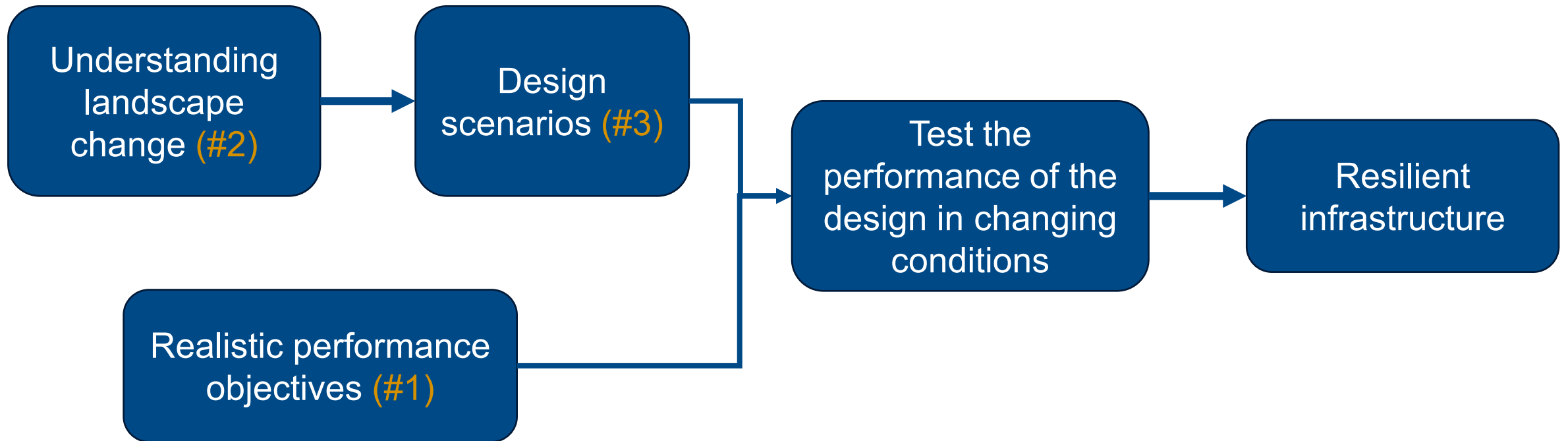
1. Current conditions
2. 50-year monsoon flood
- 3. 15 m of river bed erosion**

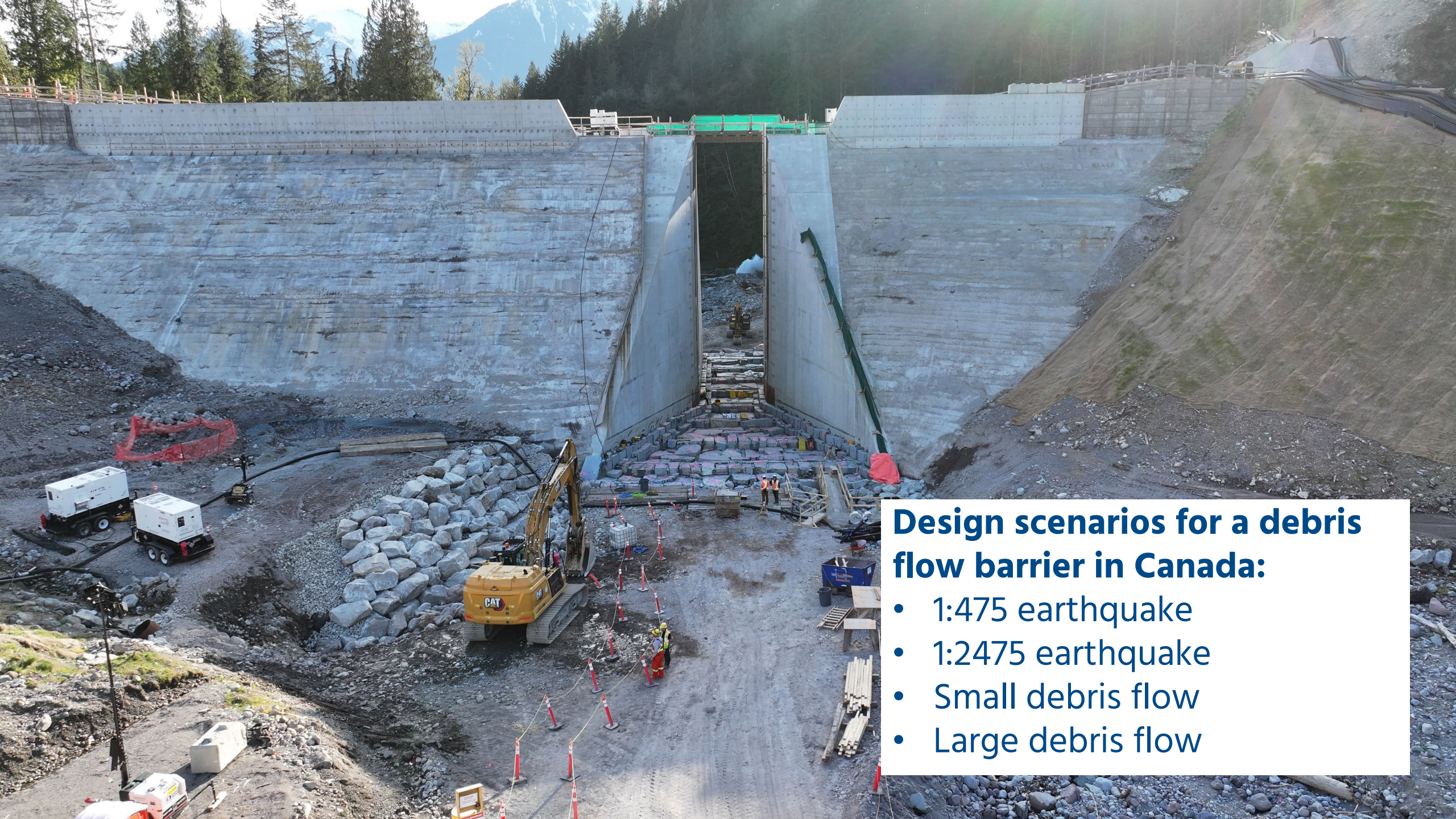


Possible bridge design scenarios:

1. Current conditions
2. 50-year monsoon flood
3. 15 m of river bed erosion
- 4. Outburst flood**

Resilient infrastructure comes from putting the three actions together.





Design scenarios for a debris flow barrier in Canada:

- 1:475 earthquake
- 1:2475 earthquake
- Small debris flow
- Large debris flow

Actions for Resilient Infrastructure



1. Define realistic performance objectives

2. Build project teams that understand landscape change

3. Use design scenarios to account for change and uncertainty



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Actions for Resilient Infrastructure



1. Define realistic performance objectives

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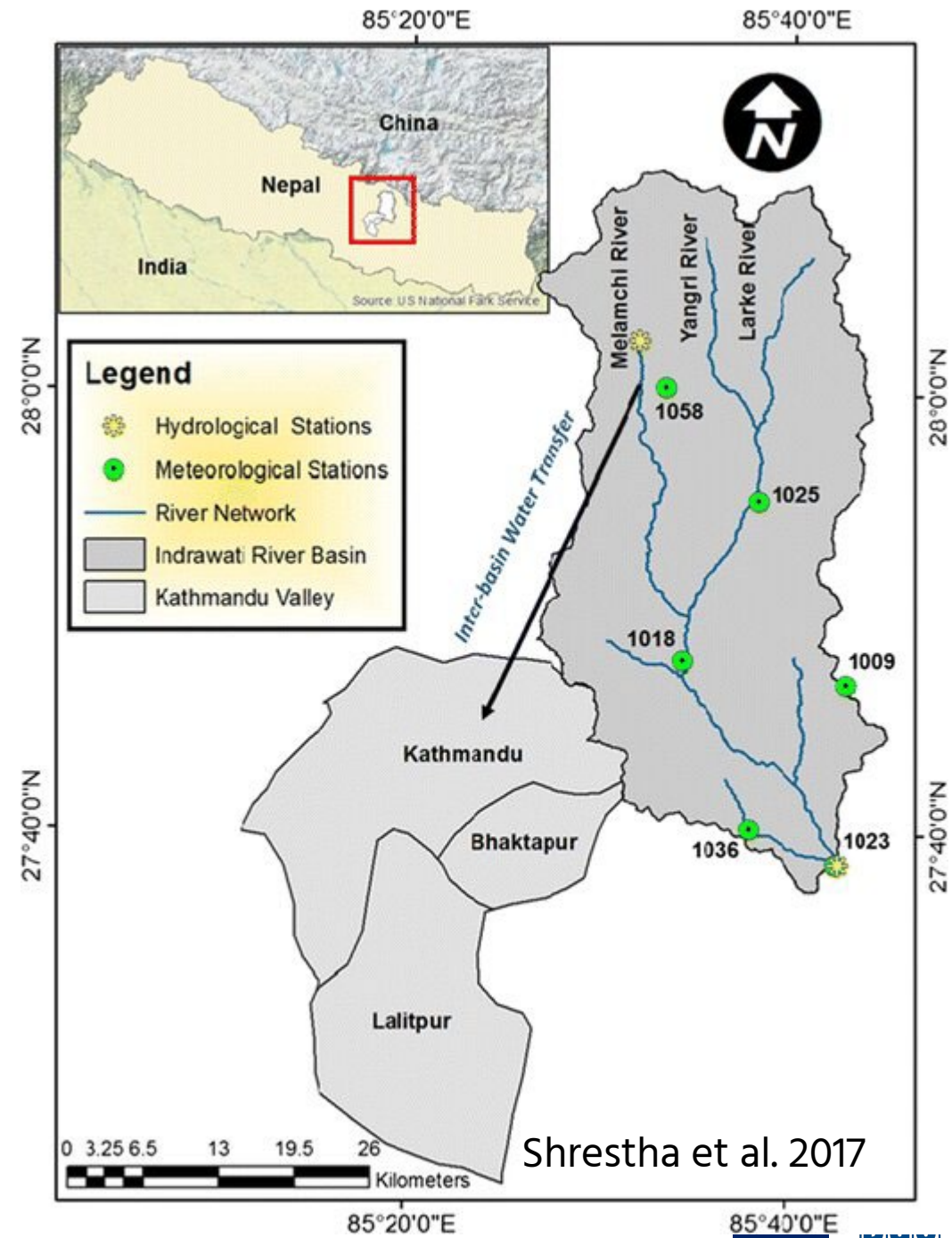
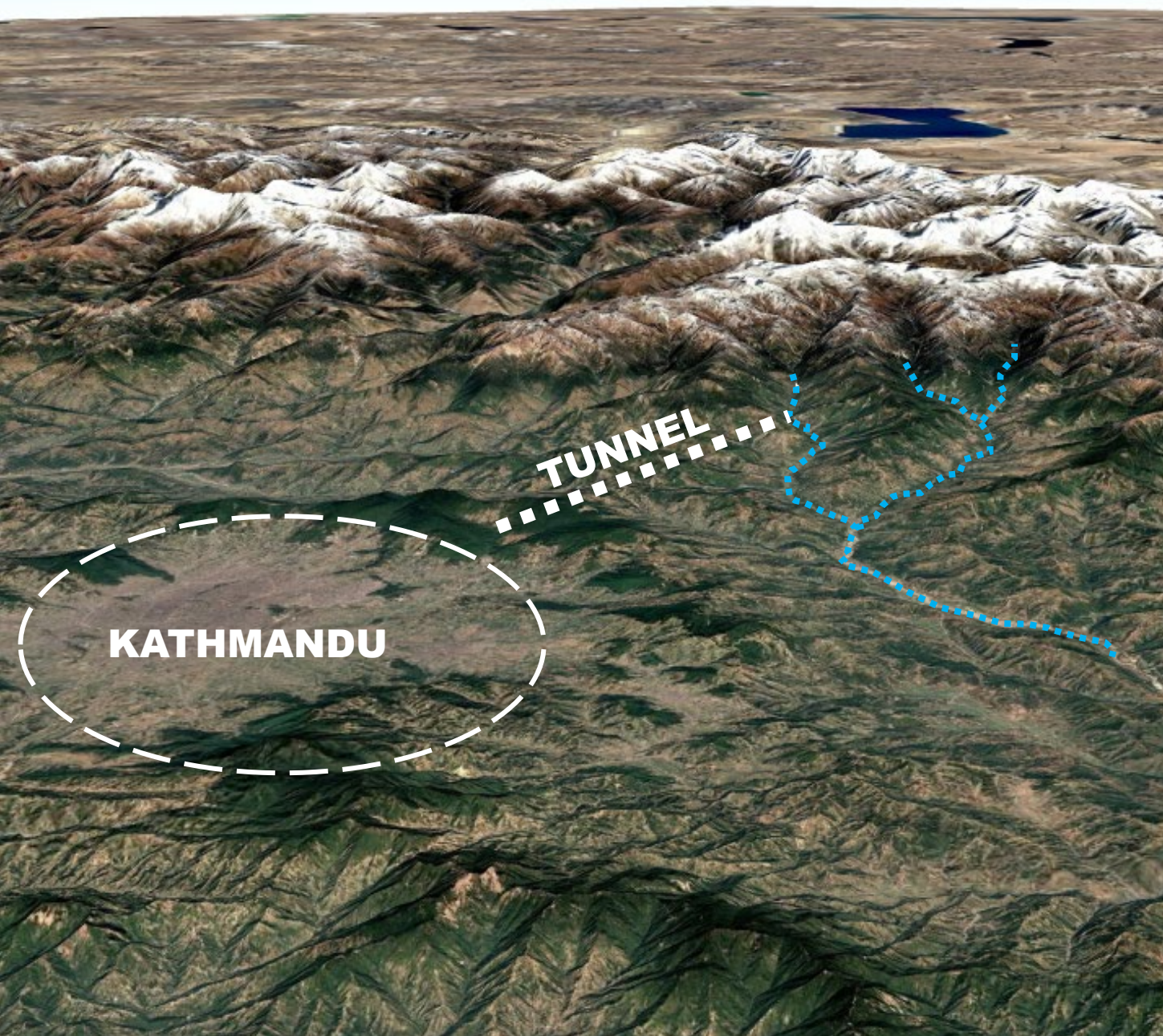


Photo from Babita Neupane



Photo from Rest, 2020

Melamchi Water Supply





g M











Photo from BGC, 2022



Photo from BGC, 2022







Asian Development Bank

Nepal Resident Mission

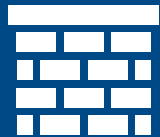


Resilient Infrastructure Action #1: Define realistic performance objectives



Use the principles of resilient infrastructure design to set performance objectives.

Create resilient infrastructure with...



Robustness



Redundancy



Rapid Recovery



Resourcefulness

Performance objective #1: Water enters intake during low-flow periods.



January 2022

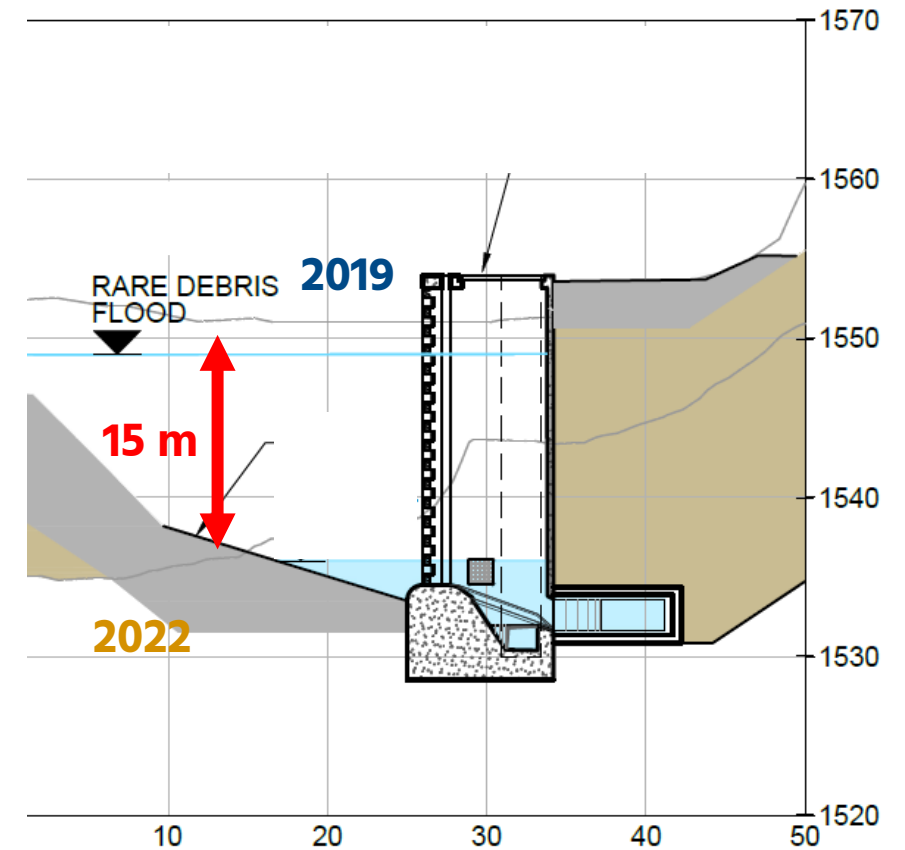
Image © 2025 Maxar Technologies
Image © 2025 CNES / Airbus

Google Earth

Performance objective #2: Intake operates during monsoon floods.



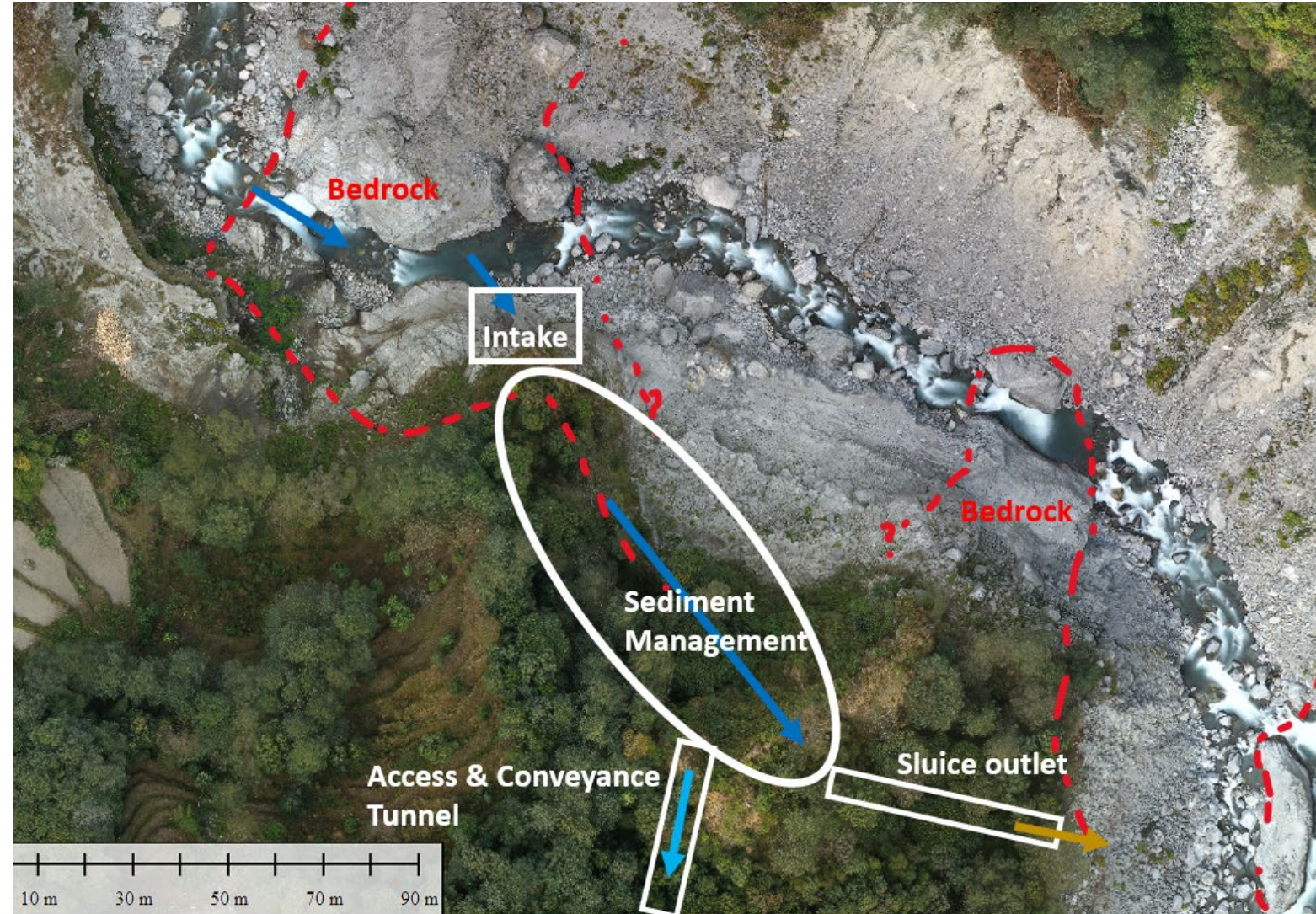
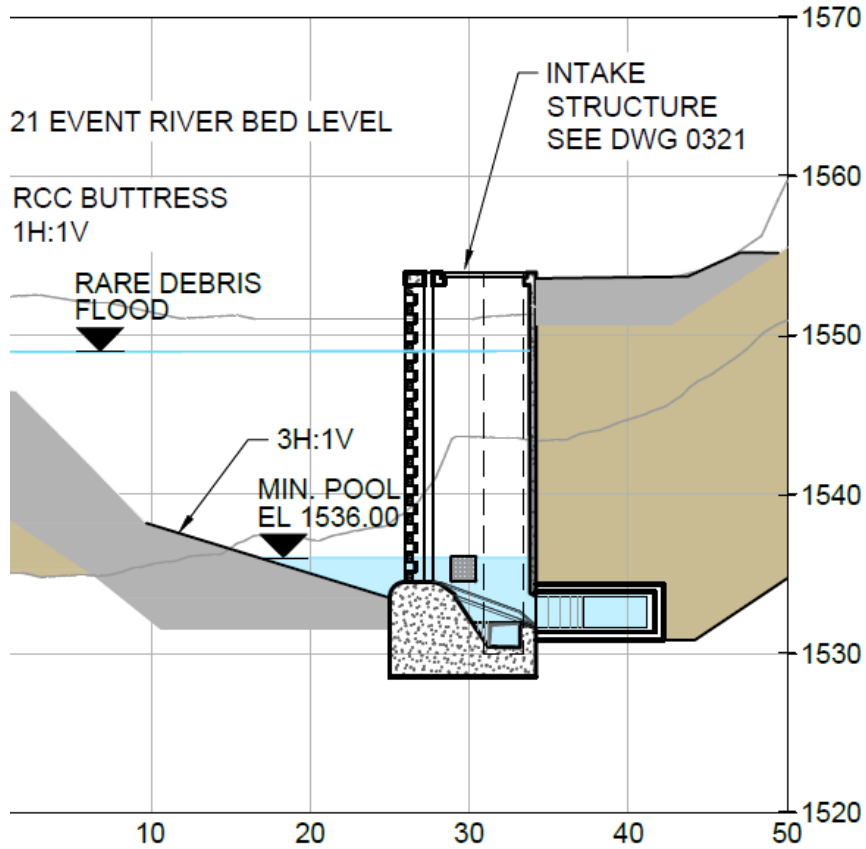
Performance objective #3: Intake operates despite large changes in bed level



Performance objective #4: Allow for continuous maintenance.



Layout design components to meet performance objectives.



Resilient Infrastructure Action #2:
Include experts who understand landscape change.



The key landscape change was the change in the riverbed elevation at the Headworks.

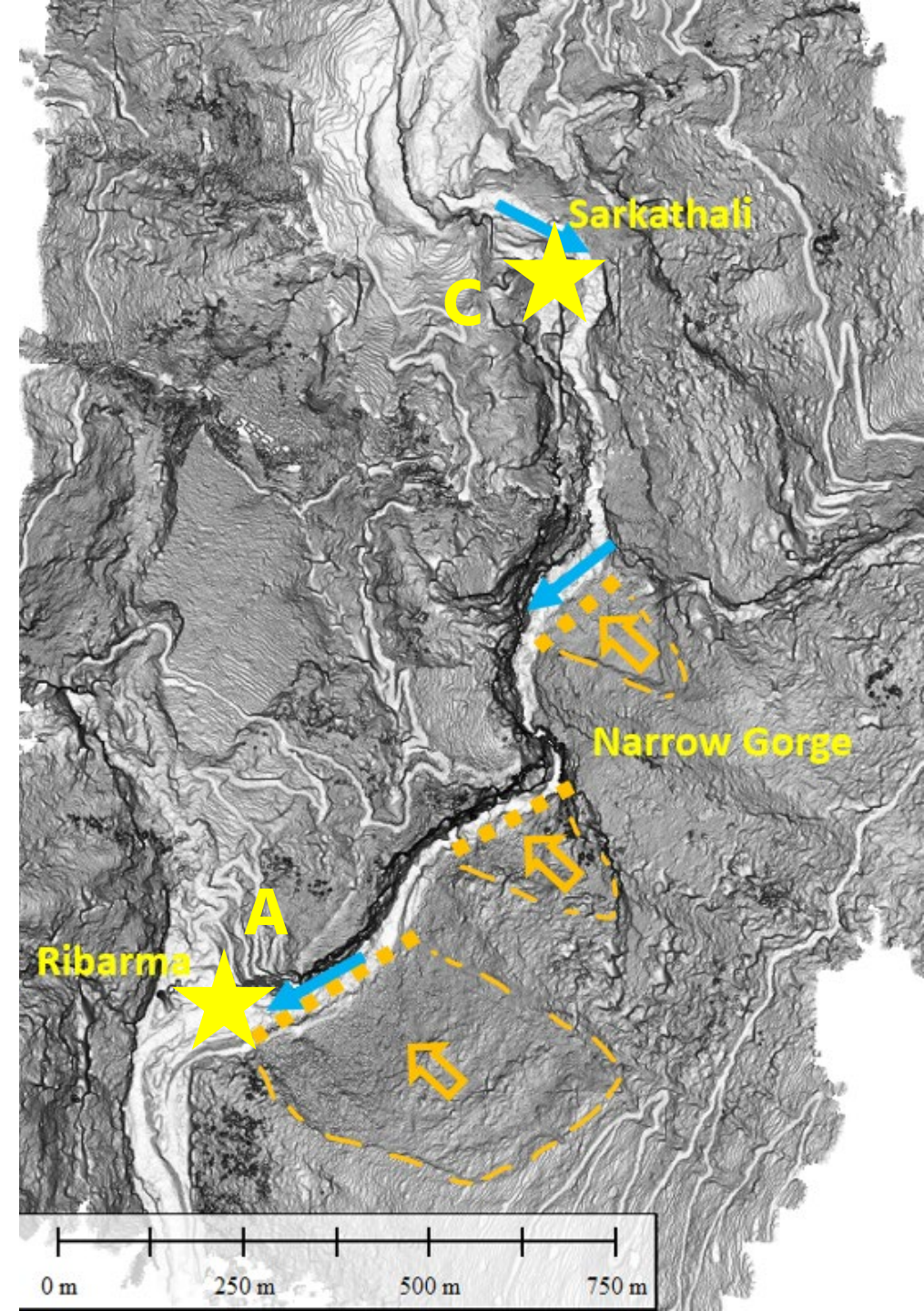




Headworks
landslide

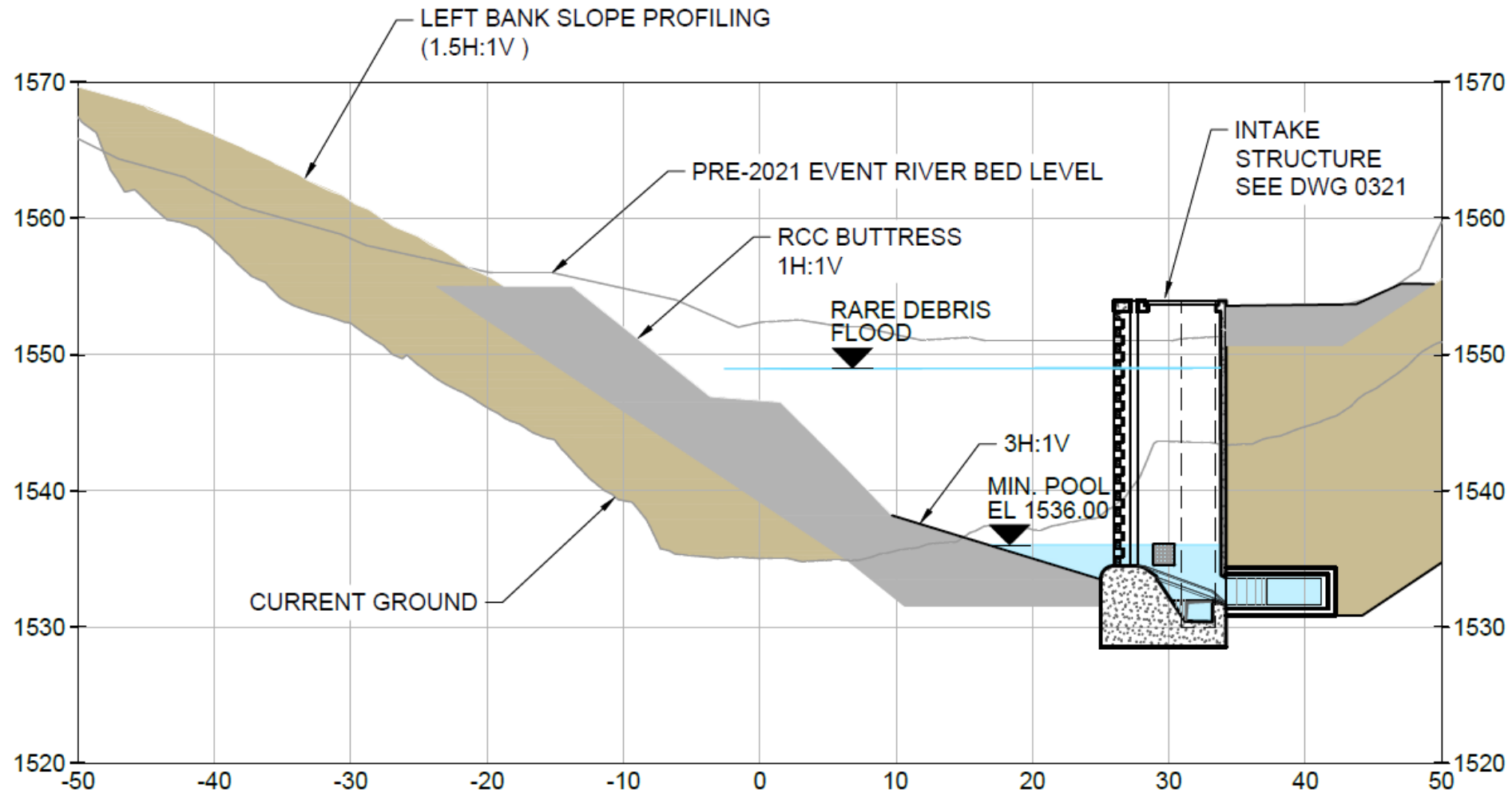
Area with
cracks, scarps
that indicate
retrogression

**We found a new location
that avoids large dip-slope
landslides**





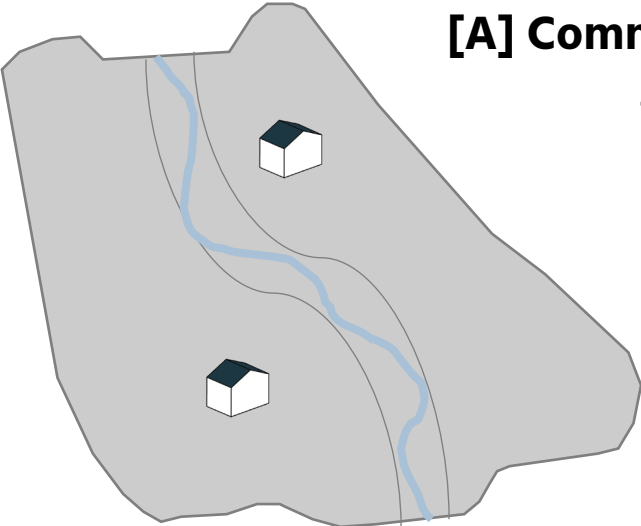
Design components allowing for landscape changes.



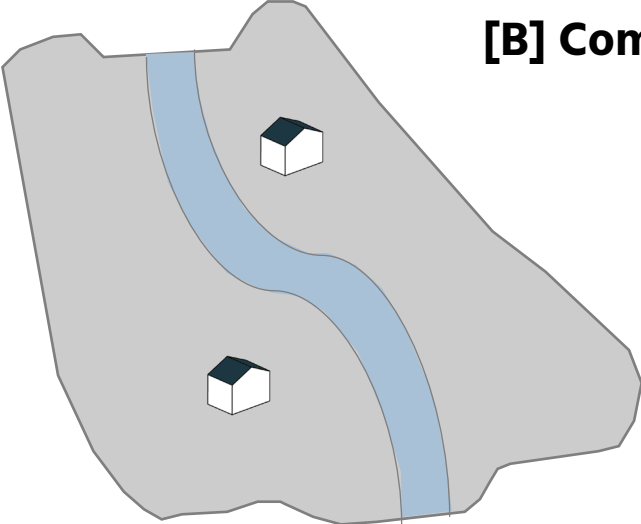
An aerial photograph of a mountain valley. In the foreground, a large, light-colored debris flow or landslide covers a significant portion of the valley floor. The surrounding slopes are covered in dense, green and brown forest. In the background, rugged mountain peaks are visible, some with patches of snow. The sky is blue with some light clouds.

Resilient Infrastructure Action #3:
Use design scenarios to account for change.

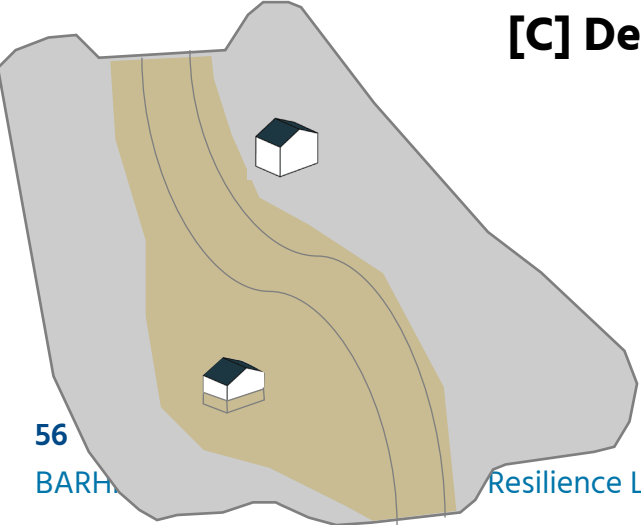
Define design scenarios



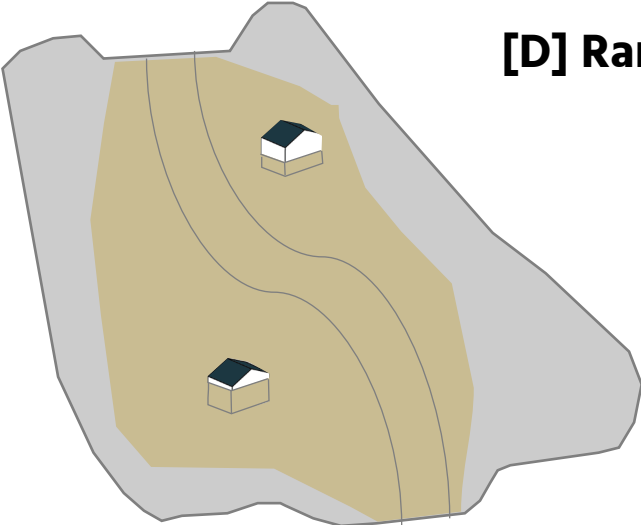
[A] Common Low Flow
3 m³/s
< 1 m deep



[B] Common Flood
300 m³/s
4 m deep

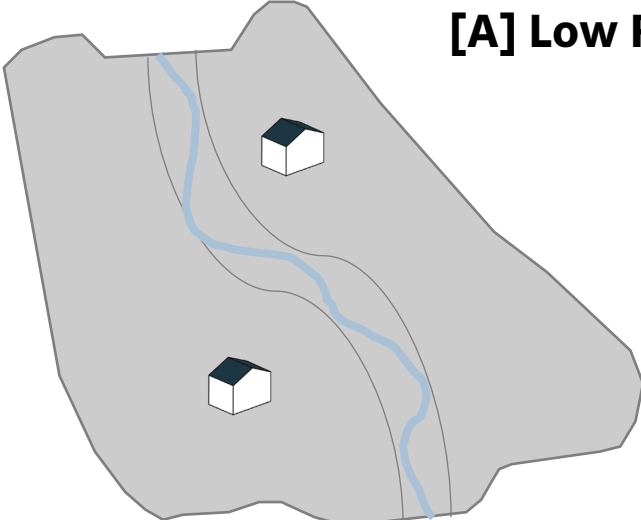


[C] Debris Flood
3,000 m³/s
10 m deep

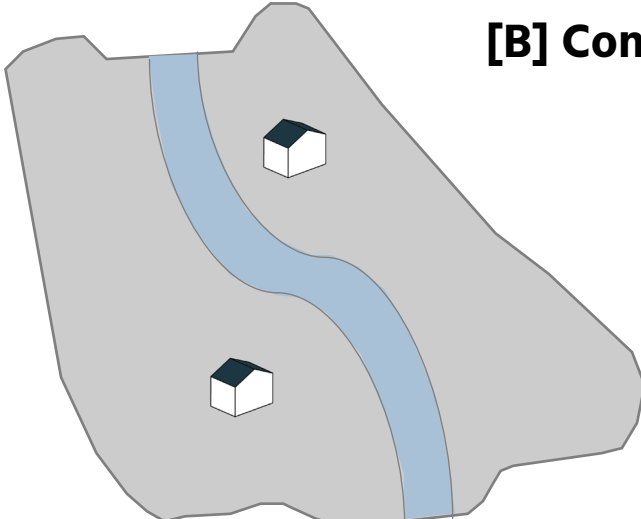


[D] Rare Debris Flood
5,000 m³/s
13 m deep

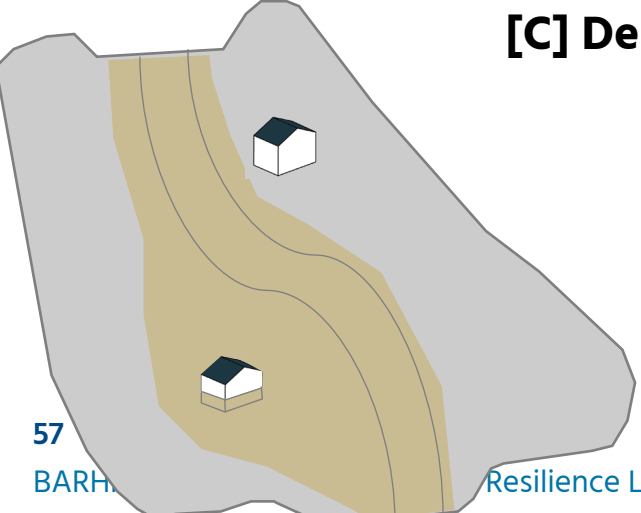
Define design scenarios



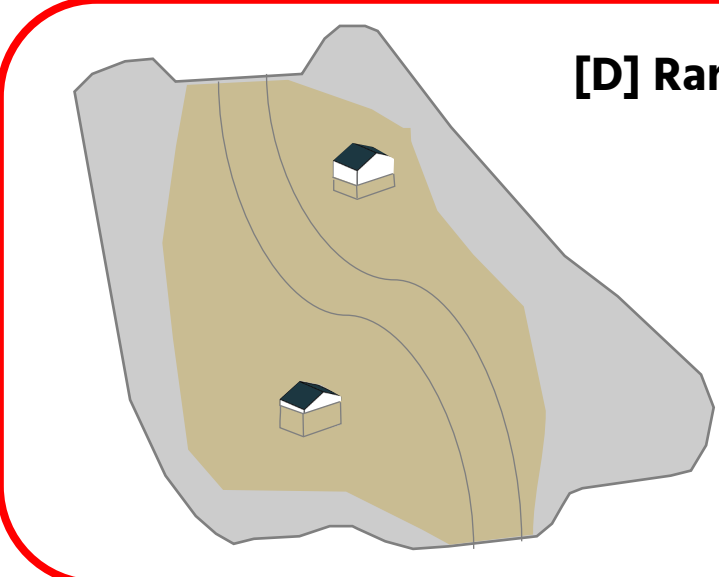
[A] Low Flow
3 m³/s
< 1 m deep



[B] Common Flood
300 m³/s
4 m deep

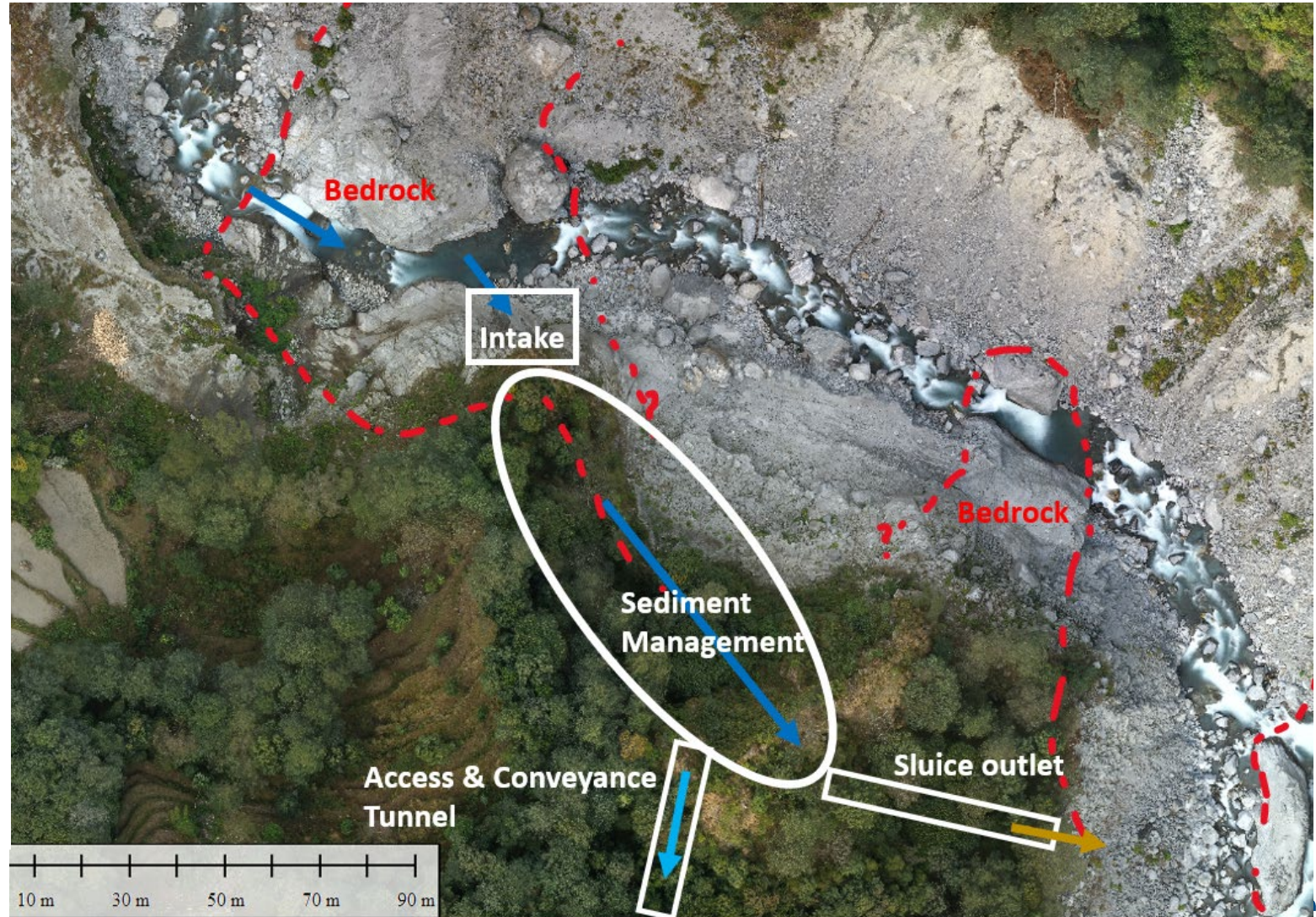
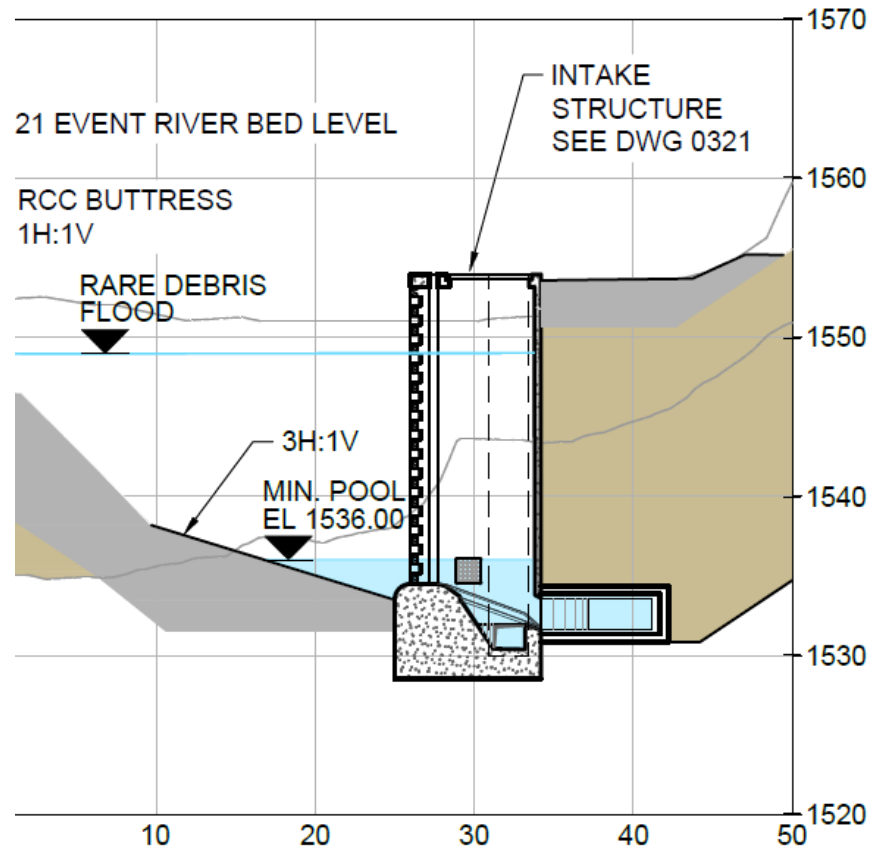


[C] Debris Flood
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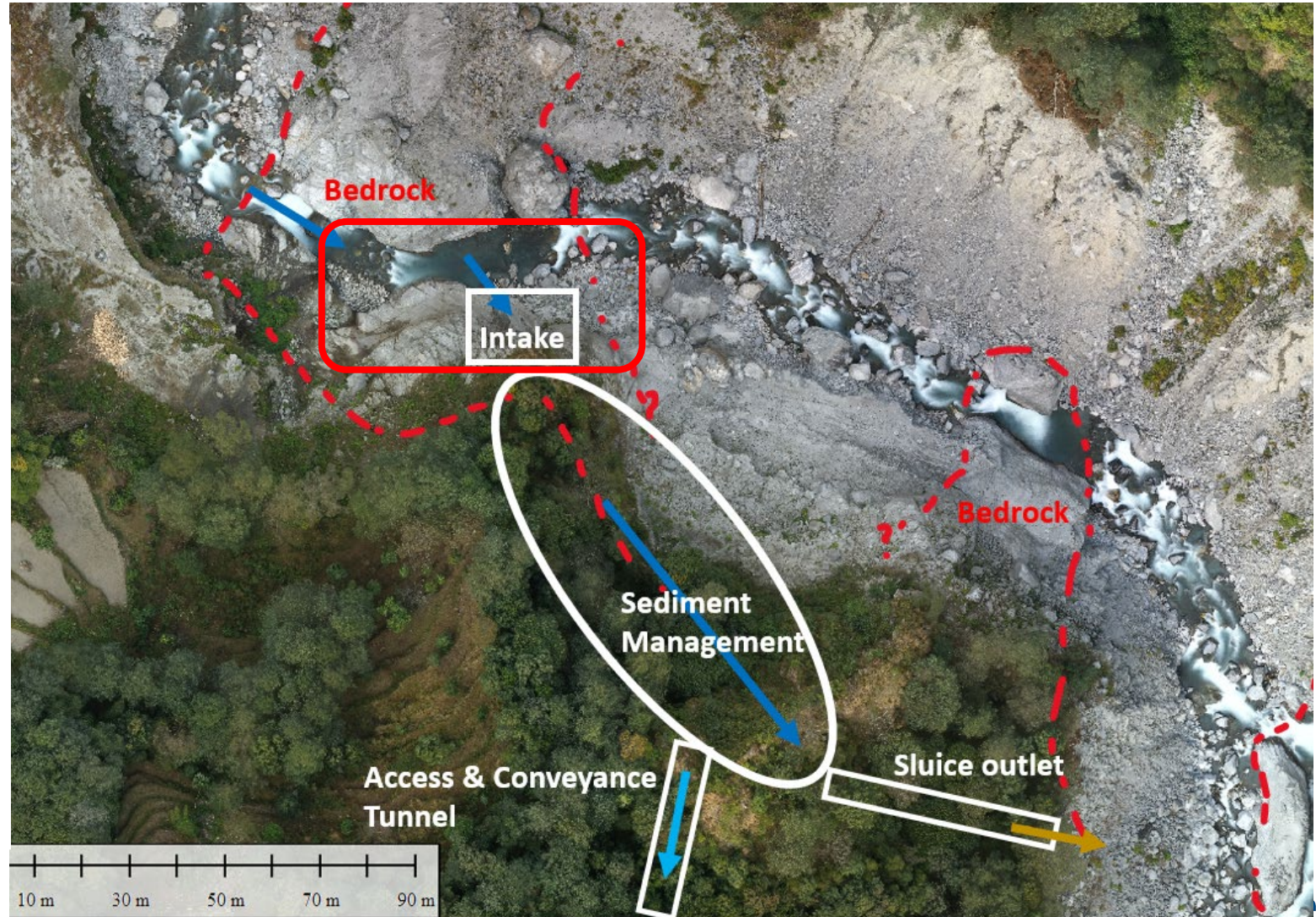
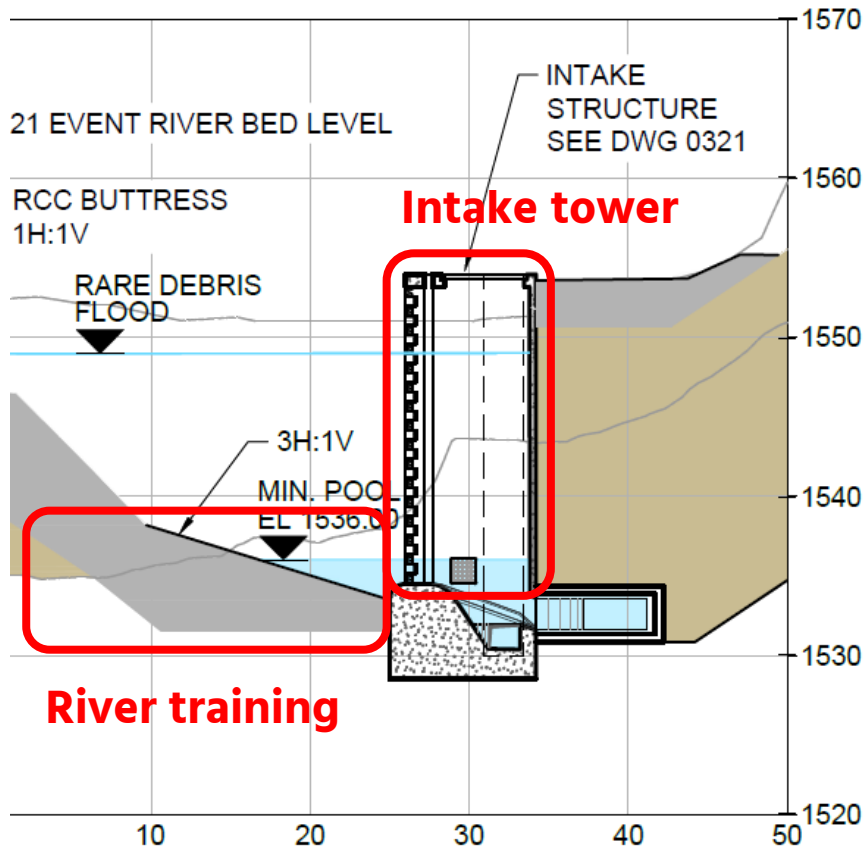


[D] Rare Debris Flood
5,000 m³/s
13 m deep

Optimize design components for scenarios



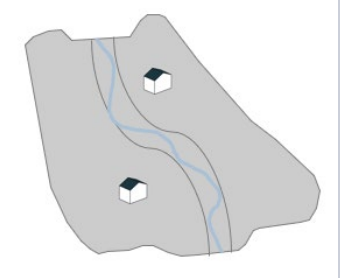
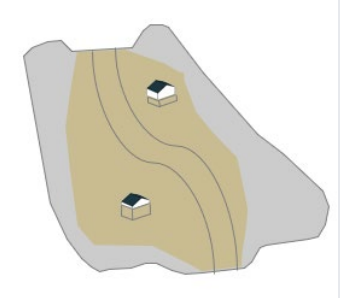
Optimize design components for scenarios



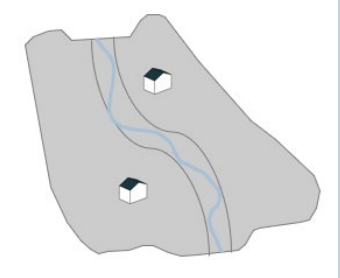
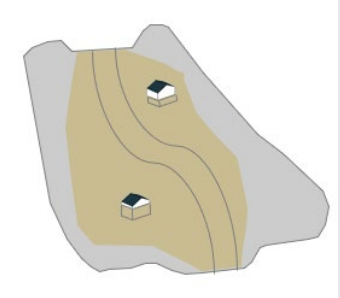
Define realistic performance objective for each component

Design scenario	River Training	Intake Tower
<p>Low flow</p> 		
<p>Rare debris flood</p> 		

Define realistic performance objective for each component

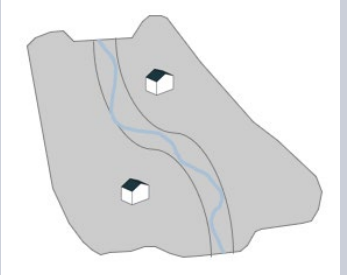
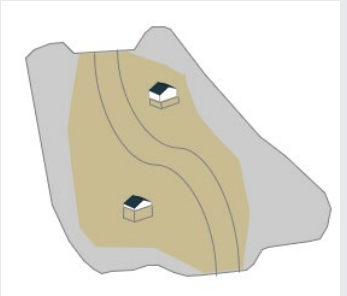
Design scenario	River Training	Intake Tower
<p>Low flow</p> 	<ul style="list-style-type: none"> • Directs water into intake • Critical during low flow • Routine maintenance 	
<p>Rare debris flood</p> 		

Define realistic performance objective for each component

Design scenario	River Training	Intake Tower
<p>Low flow</p> 	<ul style="list-style-type: none"> • Directs water into intake • Critical during low flow • Routine maintenance 	
<p>Rare debris flood</p> 	<ul style="list-style-type: none"> • Buried or eroded • Full loss allowed • Replace after event 	

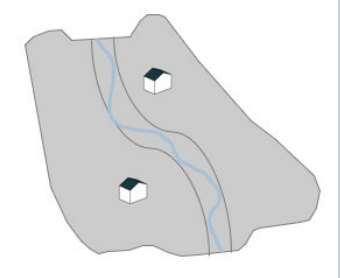
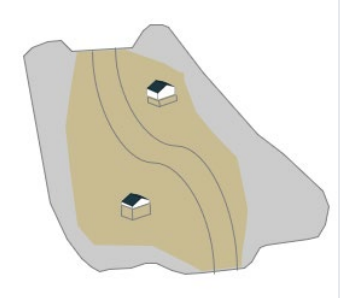
Rapid Recovery

Define realistic performance objective for each component

Design scenario	River Training	Intake Tower
<p>Low flow</p> 	<ul style="list-style-type: none"> • Directs water into intake • Critical during low flow • Routine maintenance 	<ul style="list-style-type: none"> • Receives water • Routine maintenance
<p>Rare debris flood</p> 	<ul style="list-style-type: none"> • Buried or eroded • Full loss allowed • Replace after event 	

Rapid Recovery

Define realistic performance objective for each component

Design scenario	River Training	Intake Tower
<p>Low flow</p> 	<ul style="list-style-type: none"> • Directs water into intake • Critical during low flow • Routine maintenance 	<ul style="list-style-type: none"> • Receives water • Routine maintenance
<p>Rare debris flood</p> 	<ul style="list-style-type: none"> • Buried or eroded • Full loss allowed • Replace after event 	<ul style="list-style-type: none"> • Taller than deposited sediment • Damage allowed, no collapse • Repair after damage

Rapid Recovery

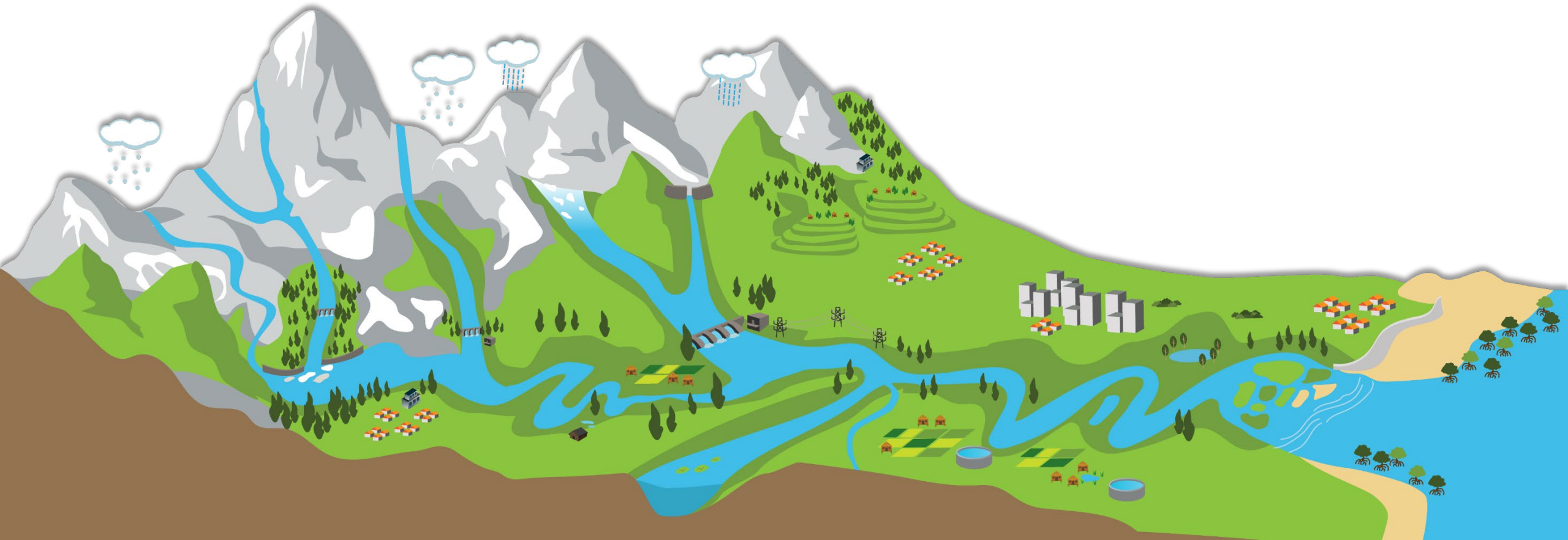
Robust



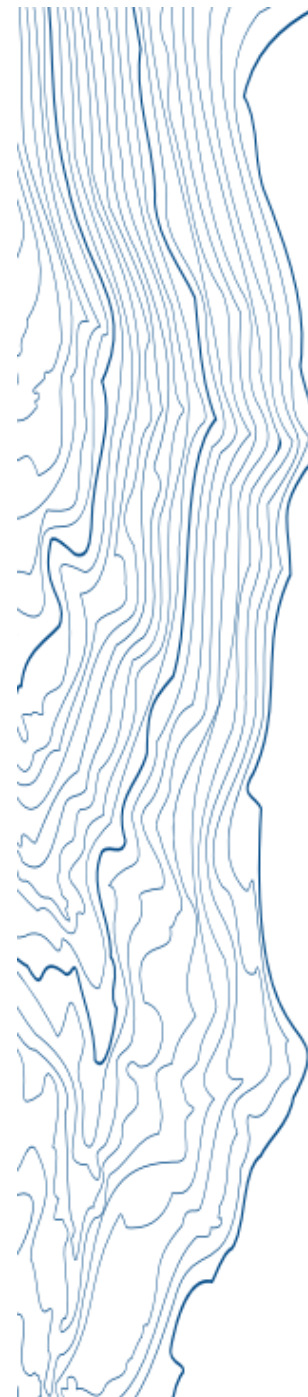
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The mission of BARHKH is to reduce risks related to climate change-driven mountain hazards in the Hindu Kush Himalaya Region.



BARHKH's Creation and Use of Risk Information report provides tools and examples that support resilient infrastructure design.



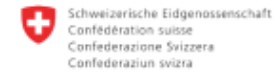
BARHKH Project Creation and Use of Disaster Risk Information

Prepared by BGC Engineering USA Inc. for:

Asian Development Bank



With funding from:



Swiss Agency for Development and Cooperation SDC
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October 24, 2025

Revision 1

Project 2300-005

Actions for Resilient Infrastructure

An aerial photograph of a valley with a river, showing infrastructure like roads and bridges, and surrounding hills. The image is slightly hazy, suggesting a high-altitude or distant perspective.

1. Define realistic performance objectives

- Accept that hazards will occur
- Resilient objectives – robust, redundant, rapid recovery, resourceful

2. Build project teams that understand landscape change

- “Geo” – geomorphologist, geological engineer

3. Use design scenarios to account for change and uncertainty

- Design for change

Download reference materials here:



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