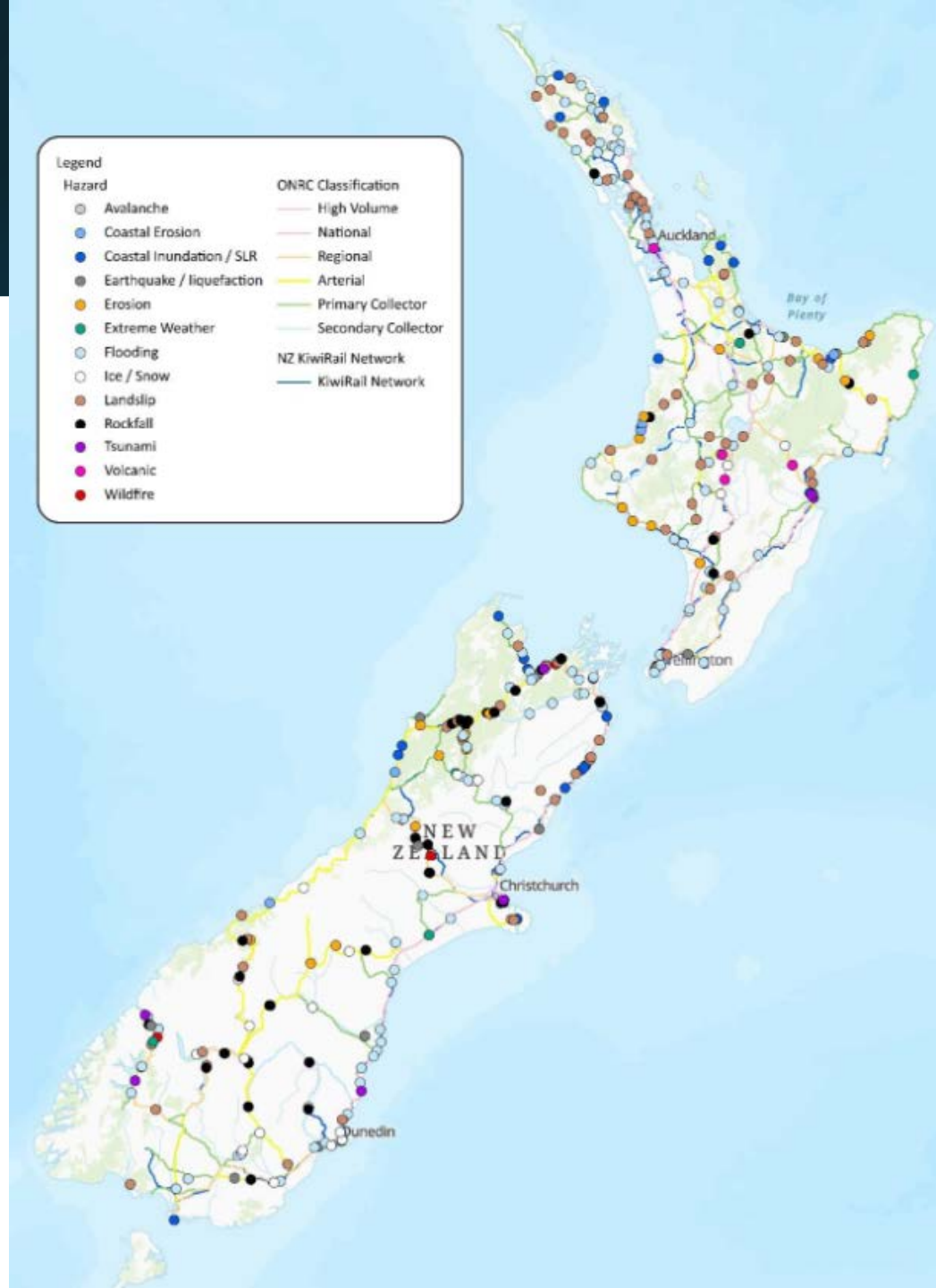
Investing in Resilience versus Recovery

Making the Case for Value

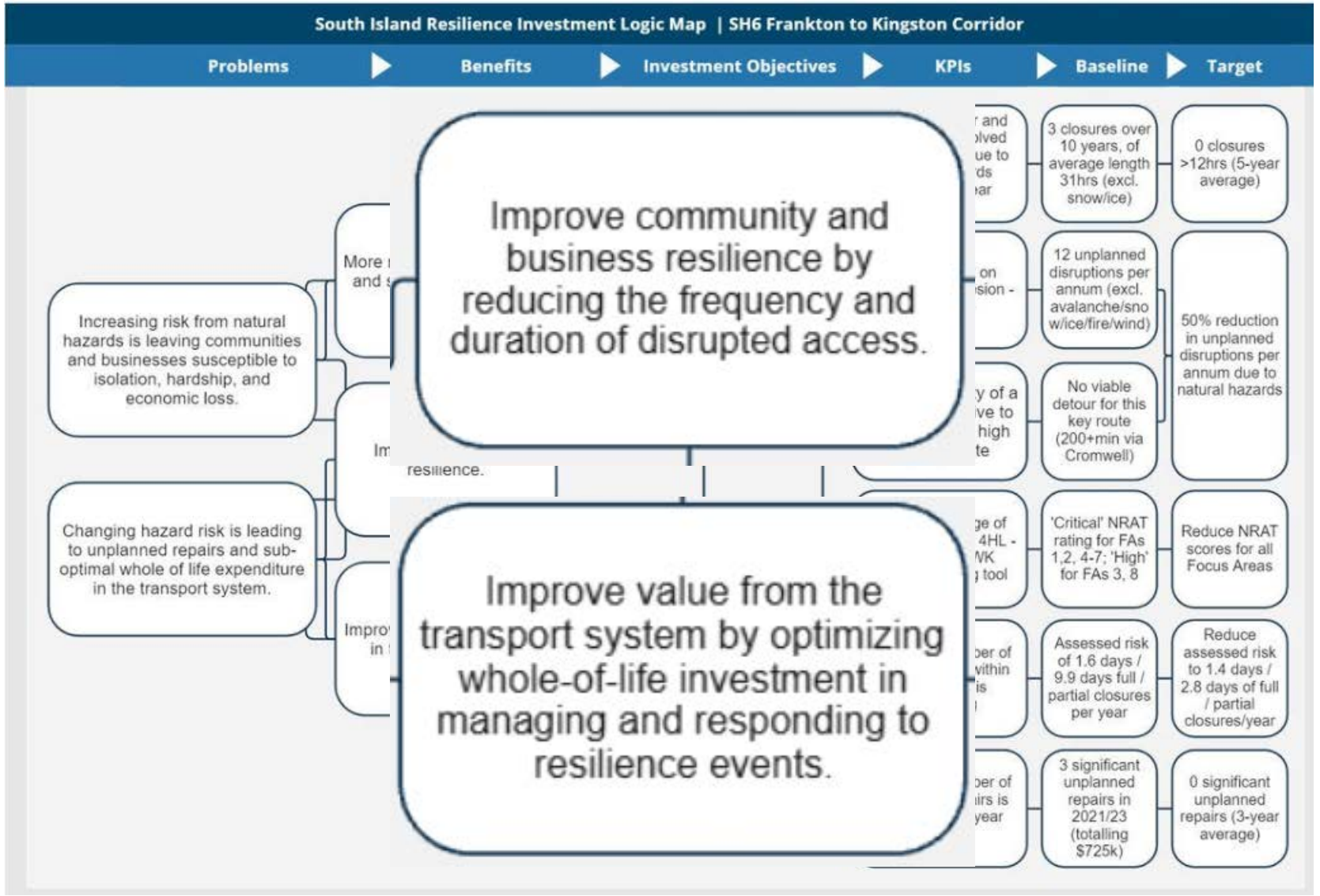
Alex Dean
Courtney McCrostie
Bryce Carter

SI Resilience Panel

- GHD, Beca, Stantec + Tonkin and Taylor
- Assessing natural hazards impacting State Highway
- Streamlined, agreed approach
  - Assessing risk
  - Economics
  - Risk registers
- Information sharing



Strategic Case



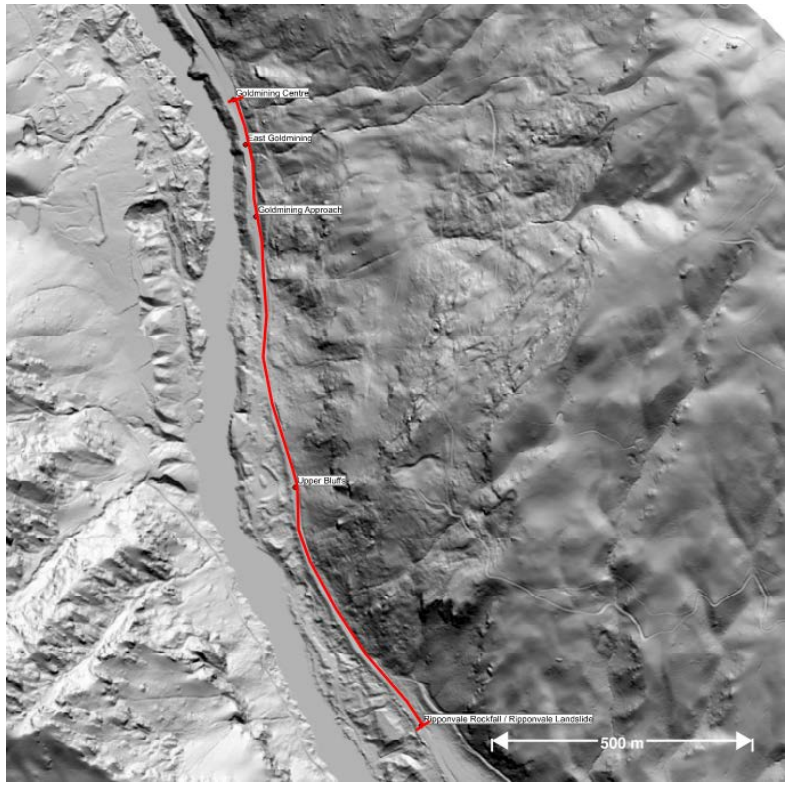
The Corridors

- SH60 Takaka Hill
- SH6 Dellows Bluff and Rockfall Sites
- SH6 Haast to Hawea
- SH94 Milford Road to Te Anau Downs
- SH6 Cromwell to Frankton
- SH6 Frankton to Kingston

Common Hazards on Resilience Corridors

Landslides

Including large scale landslides, and smaller underslips/overslips within landslide deposits.



Rockfall and Rockslides

Within bedrock outcrops or dislocated blocks upslope, and road cuts

Contractors work to clean and secure the rock face yesterday morning. Photo by James Beech.

Compromised Retaining Structures

Existing retaining structures above and below the road showing signs of distress and noted to be deteriorating over time.

Common Hazards on Resilience Corridors

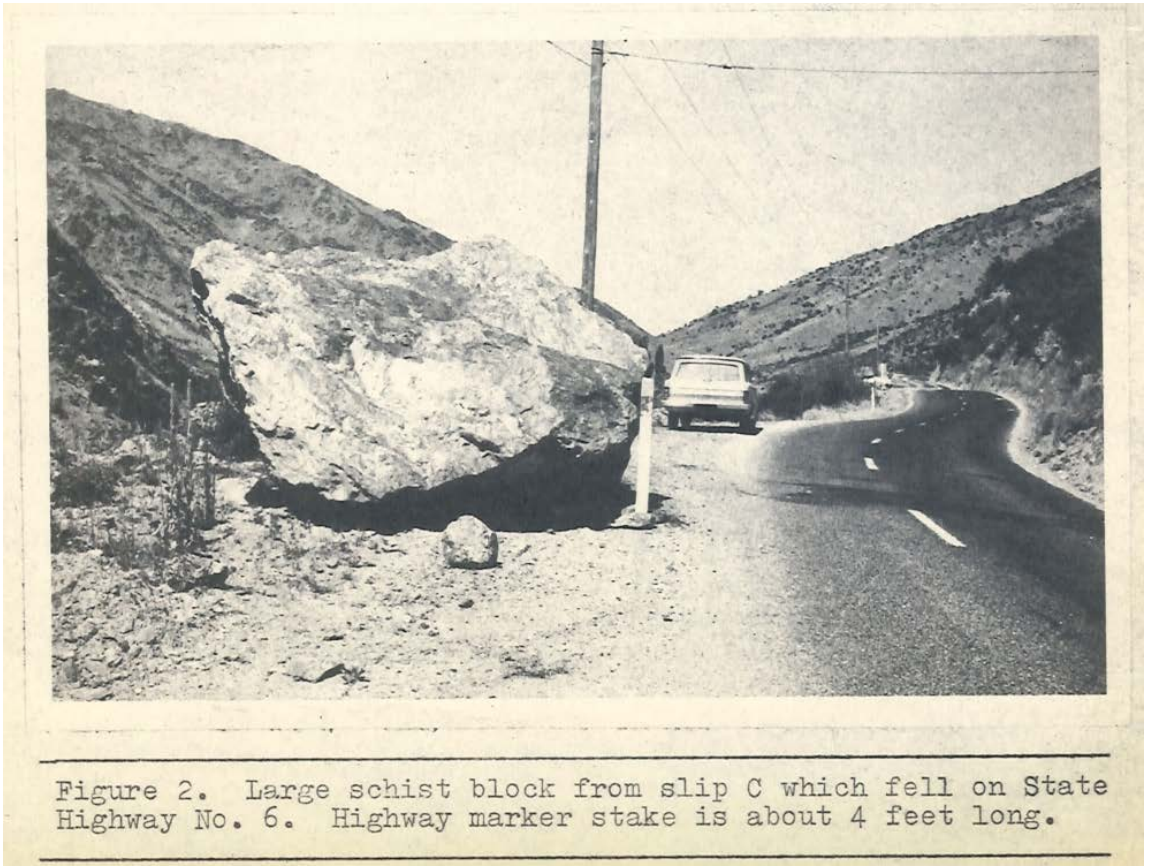


Figure 2. Large schist block from slip C which fell on State Highway No. 6. Highway marker stake is about 4 feet long.

Corridor Assessments

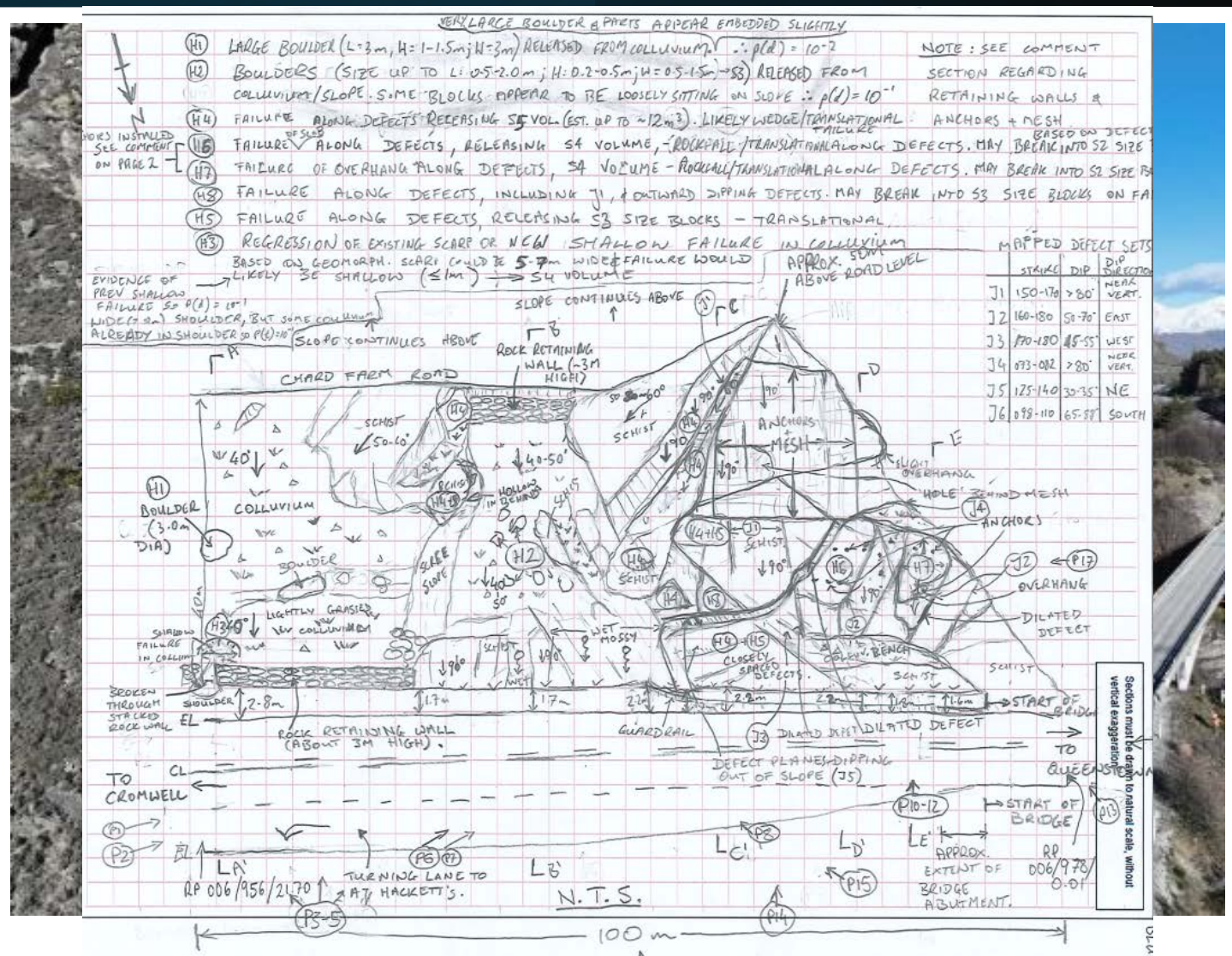
ARL

NRAT

PGAR

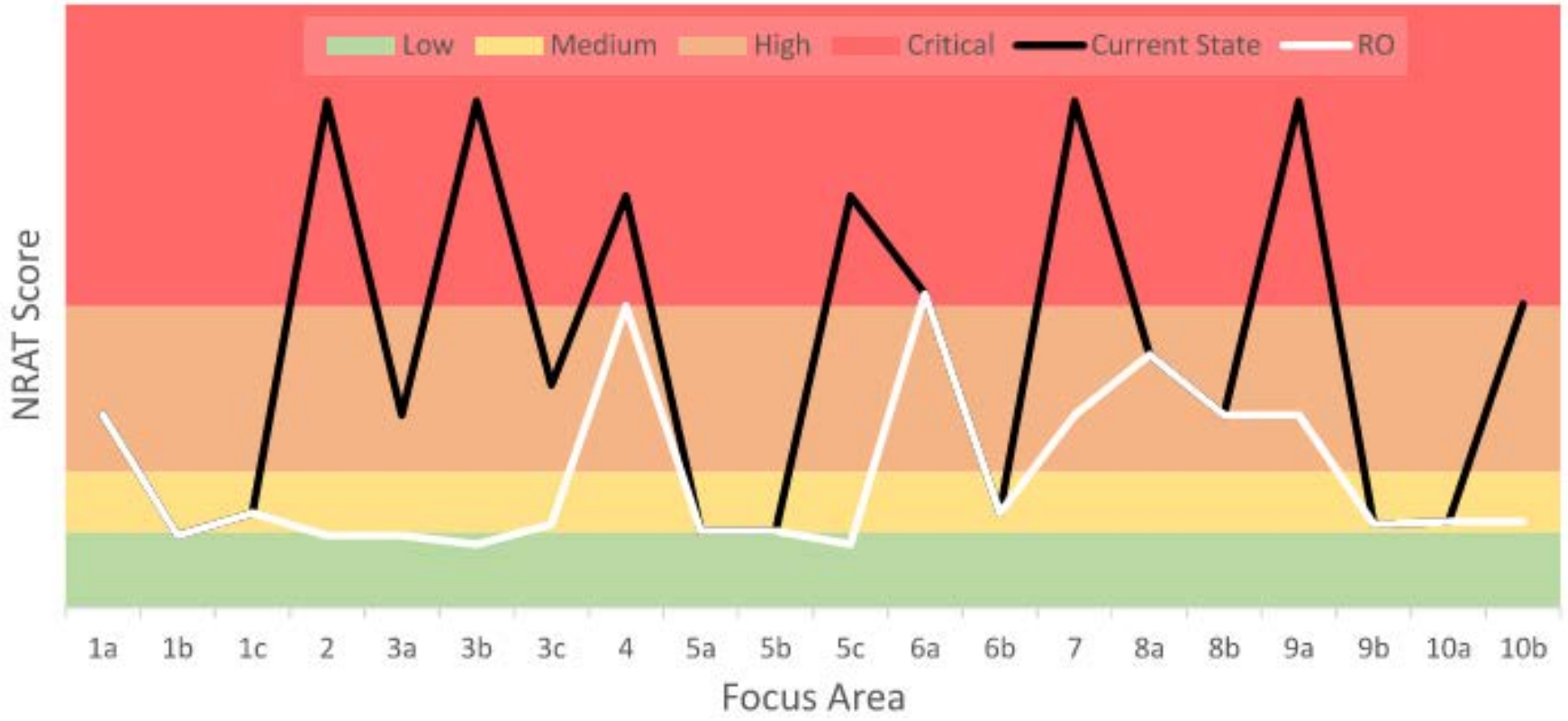
Assessed Risk Level (ARL)

- Comes from NSW
- Considers aspects of the slope
  - Scale
  - Velocity
  - Magnitude
  - Hazard type
- Consequence vs Likelihood gives ARL
- ARL1 and ARL2 are highest, most relevant for our assessments
- Experienced geotechs applying engineering judgement



National Resilience Assessment Tool (NRAT)

- Used in PBC
- Consequence Criteria
  - AADT
  - ONRC
  - Criticality
  - Detour Length
  - Scale of closure
  - Duration of closure
- Likelihood
- Application within a corridor



$$NRAT\ Score = \left[\begin{matrix} AADT + ONRC + Criticality + \\ Detour\ Length + Scale + Duration \end{matrix} \right] \times Likelihood$$

Preliminary Geotechnical Appraisal Report (PGAR)

Summarises
- NOC Reports
- Archives
- Previous projects
- Site inspections
- Boreholes and investigations
- ARL and NRAT

Provides
- Hazard types
- Potential interventions

Recommendation and Pre-Implementation

7 Focus Area - Pigeon Rock

Assessed hazard types

Landslide, Rockfall
At-risk retaining structure

Location (RSRP)

006/0956/2.898-3.67

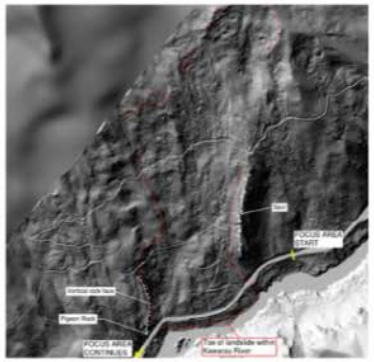
Section length

~760m

Recommended Option Treatment(s)

7. Landslide | *Detailed landslide assessment + enhanced & telemetered instrumentation and monitoring + install additional inclined drains*

Estimate Cost: $3,823,000



- The Pigeon Rock Landslide is an actively moving, relatively deep-seated landslide, resulting in ongoing deformation of both lanes of SH6 as well as retaining walls at the site. It has the potential to significantly impact the resilience of SH6.
- Groundwater is understood to be a key driver of landslide movement, and therefore **we recommend that additional inclined drains are installed to lower groundwater levels** and thereby lower the likelihood of landslide movement impacting the highway. Surface water drainage improvements and repairs should be completed at the same time.
- **We recommend that the locations of these additional inclined drains are informed by a detailed engineering geological model, and geotechnical/hydrogeological analyses.** These models and analyses should be informed by engineering geological mapping, intrusive ground investigations and telemetered monitoring of the landslide (see PGAR for details).
- Limited information is available regarding Edney's Slip. **We recommend that Edney's Slip be investigated further during pre-implementation (as part of the mapping of Pigeon Rock Landslide).**
- The prominent rock at Pigeon Rock has been identified as a potential rockfall source. However, available information suggests that the risk of rockfall to resilience at the site is relatively low and as such we are not currently proposing any rockfall mitigation measures. **We recommend the site continues to be monitored by the NOC as part of the six-monthly slope check program.**

7.1(a) Continued landslide movement		*7.1(b) Accelerated landslide movement*		*7.2 Rockfall from the bluff*	
Current NRAT	*Post-treatment NRAT*	*Current NRAT*	*Post-treatment NRAT*	*Current NRAT*	*Post-treatment NRAT*

NRAT score — *Critical* | *High* | *Medium* | *Low*

Full or partial road closure — *Full* | *Partial*

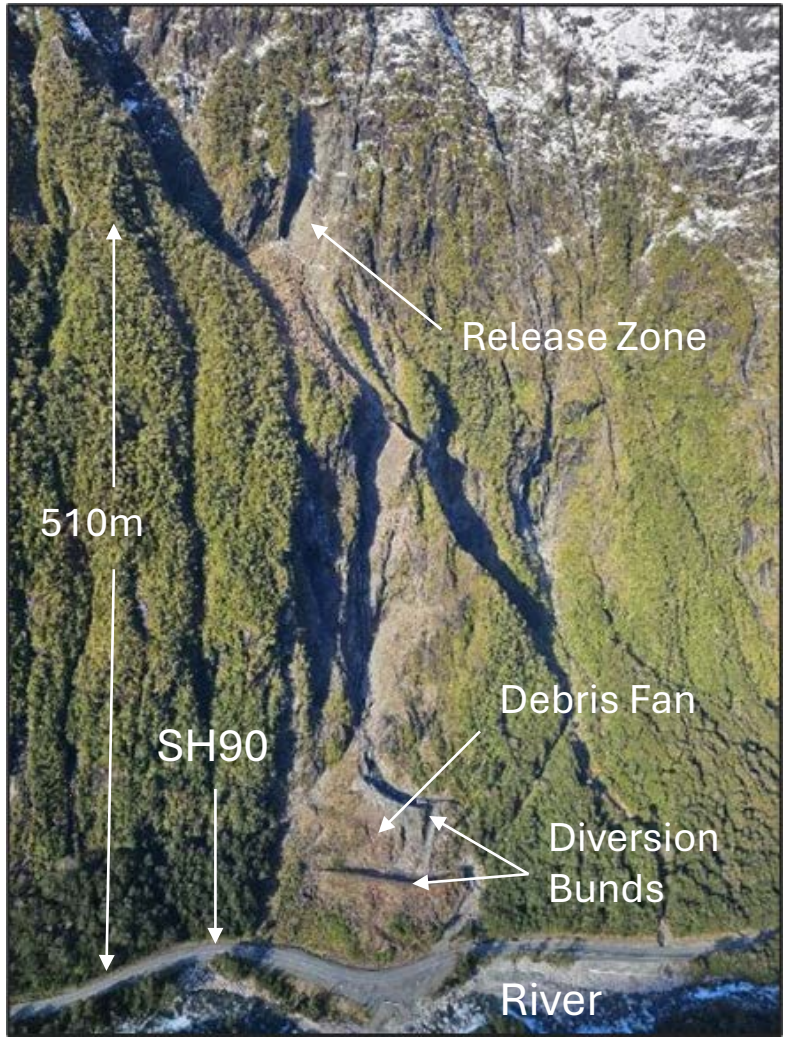
Case Study: Red slip, Milford Road

SH90 - Milford Road

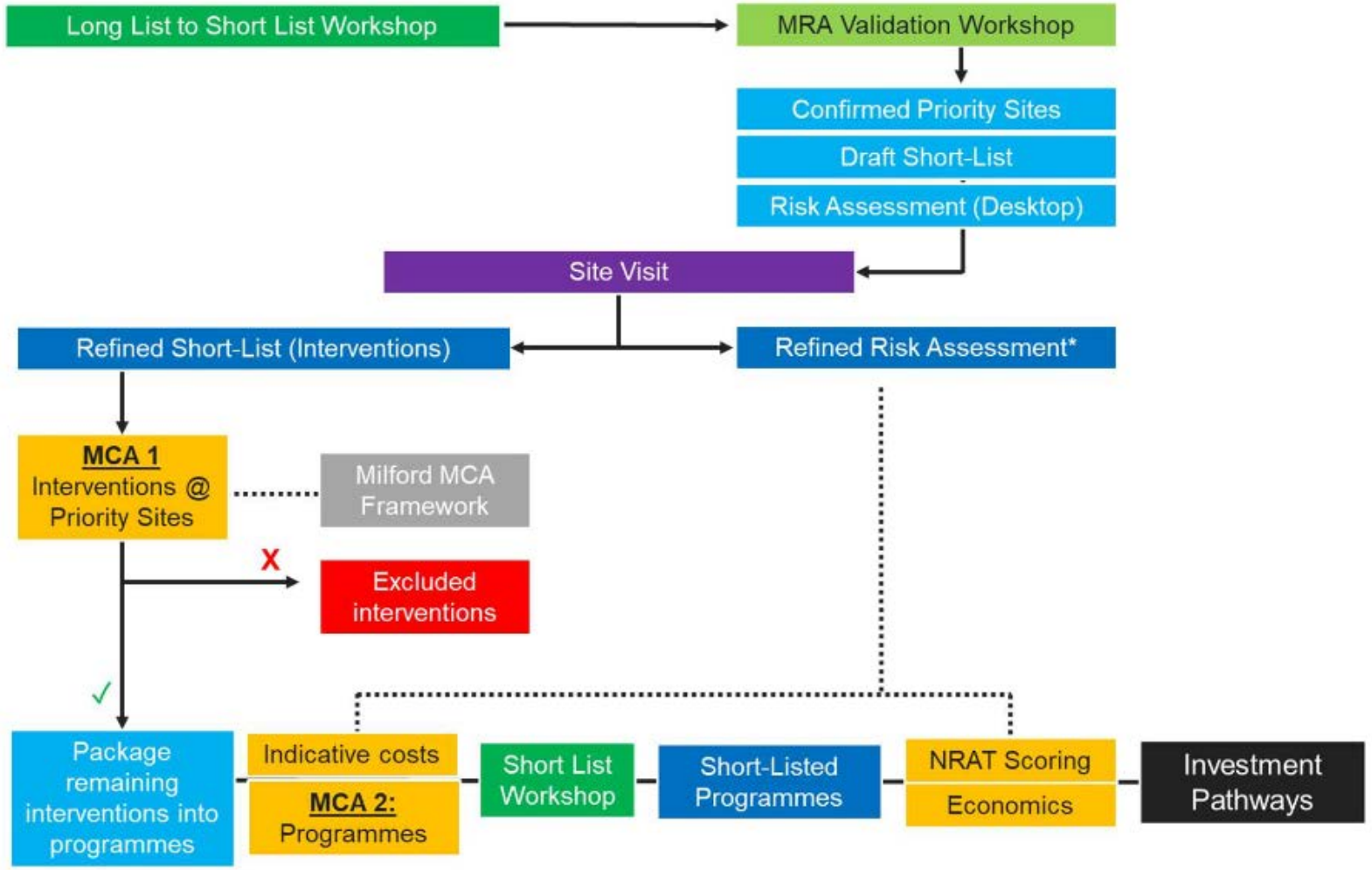
- International Tourist Destination - $190m to local economy in 2019.
- Effectively a dead-end road – key lifeline to Milford Sound
- Hazards - rockfalls, flooding, trees falls, avalanches, and landslips.
- Not isolated to one small part of the corridor

Example Site - Red Site

- Reoccurring high volume rockfall with large individual boulder falls
- Likely large volume failure in the future
- Current ARL assessment is ARL2, borderline ARL1
- Range of failure scenarios with different likelihoods and consequences considered
- High degree of engineering judgement required



Red slip, Milford Road: Assessment Process



Red slip, Milford Road: Assessments

1. Long List Options Assessment

Problem		Existing Risk	Confidence	Intervention	Site Suitability	Effectiveness			Risk after	Cost	Short-List	Confidence
						Low	Medium	High				
DN	Rockfall	Medium	Good	Status Quo	YES	Y			Medium	$	NO	
1				Monitor (visually)	YES	Y			Medium	$	NO	
2				Monitor (with instrumentation)	YES	Y			Medium	$$	NO	
3				Light scaling (hand tools, targeted individual rocks)	YES	Y			Medium	$$	NO	
4				Heavy scaling (mechanical tools, explosives, area wide)	YES		Y		Medium-Low	$$	YES	Good
5				Rock Bolting	YES		Y		Medium-Low	$$$	YES	Good
6				Slope Retention System / Active Mesh Support	YES		Y		Medium-Low	$$	YES	Good
7				Dislodging Loose Rocks	YES	Y			Medium	$$	NO	
8				Reshaping the Slope / Removal of Debris	YES		Y		Medium-Low	$$$	YES	Good
9				Shotcrete in Initiation Zone	NO				-		NO	
10				Drape Nets / Meshes	NO				-		NO	
11				Rockfall Barriers (Road)	YES		Y		Medium-Low	$$	YES	Good
12				Anchors / Grouting	YES	Y			Medium	$$$	NO	
13				Catch Fences (Slope)	NO				-		NO	
14				Rock Sheds	YES			Y	Low	$$$	YES	Good
15				Catch Ditches	YES		Y		Medium-Low	$	YES	Good
16				Heli Sluicing	YES	Y			Medium	$$$	NO	
17				Earthbund/embankments or MSE (debris entrainment)	YES		Y		Medium-Low	$$$	YES	Good
18				Rigid rockfall barrier / wall	NO				-	$$$	NO	
19				Shallow landslide barrier systems / deformable barriers	YES		Y		Medium-Low	$$$$	YES	Good
20				Road realignment	NO				-	$$$$$	NO	

2. Scenario and confidence assessments

			Likelihood				
			HIGH	H/M	MEDIUM	M/L	LOW
			Almost Certain	Likely	Possible	Unlikely	Rare
Closure duration	V HIGH	>6 months	VERY HIGH	HIGH	MEDIUM-HIGH	MEDIUM	MEDIUM
	HIGH	1-6 month	HIGH	MEDIUM-HIGH	MEDIUM	MEDIUM	MEDIUM-LOW
	MEDIUM	2 days to 1 month	MEDIUM-HIGH	MEDIUM	MEDIUM	MEDIUM-LOW	LOW
	LOW	Less than 2 days	MEDIUM	MEDIUM	MEDIUM-LOW	LOW	LOW

- Good confidence
- Moderate confidence
- Low confidence

3. Revised NRAT scores

Key Site	NRAT Score Range (Across all problem types)[38]		Average Resilience Improvement
	Do Minimum	Preferred Programme	
Eglinton Bluff 1	129-559	43-127	64%
Eglinton Bluff 2	129-903	43-559	56%
Eglinton Bluff 3	129-903	43-559	50%
Eglinton Bluff 4	132-903	88-559	37%
Eglinton Bluff 5	129-903	86-559	42%
Marian Hill	129-903	129-903	8%
Red Slip	162-903	108-559	43%
Monkey Creek	1029	147	86%
Hollyford Forks	1029	147	86%

NRAT ranges

Low < 100

Medium = 101-180

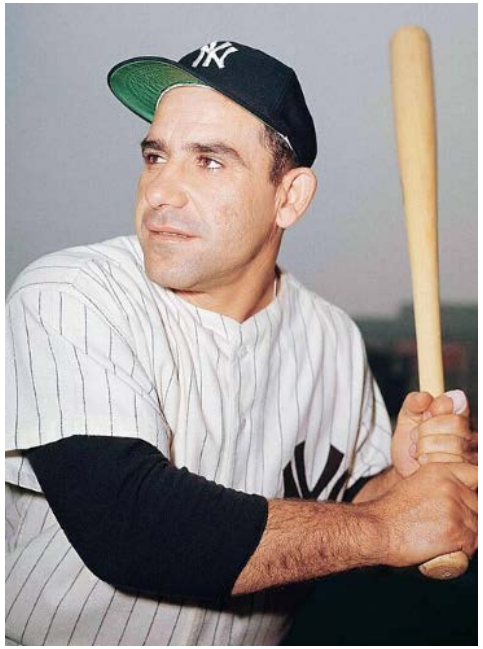
High 181-400

Critical >401

Reflections

- Panel allowed a consistent approach
- Higher levels of uncertainty
- Historic Records / Data is key
- Reducing not eliminating risk

Reflections



“The future ain’t what it used to be"
Yogie Berra

American baseball player