Climate risks are uncertain but increasing: how do we ‘project’ and respond adaptively?

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Bell Adapt
MANAGING THE UNAVOIDABLE

Seeing the Unseen ….

and the Unknown

Key NZ climate-change impacts (relevant to assets)

Top 3 physical drivers of impacts

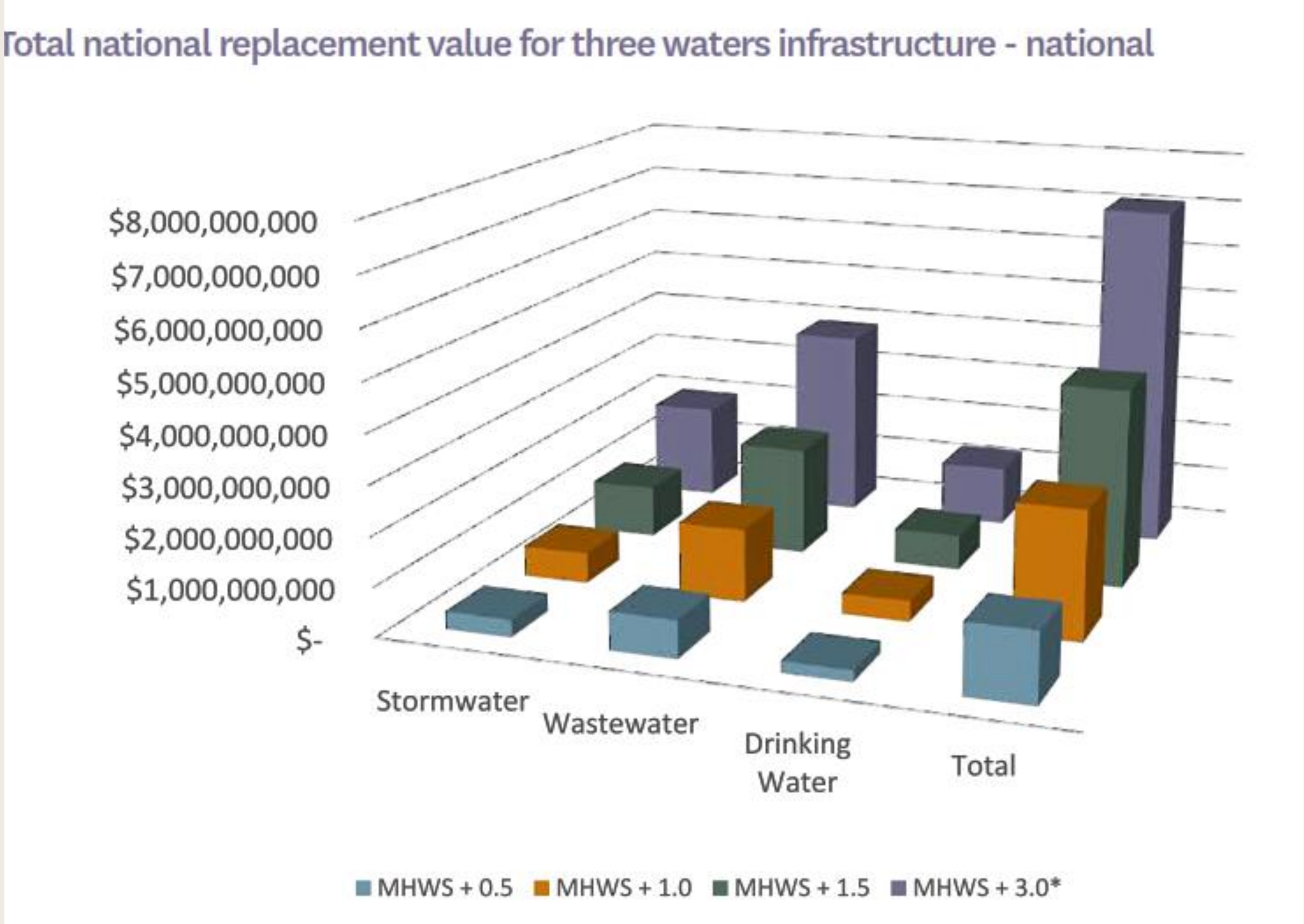
1. **Coastal & lowland areas** - ongoing sea-level rise, g/w rise, erosion, salinization

2. **Not enough water** – increased frequency of droughts, wildfires

3. **Too much water** – flooding, higher intensity rainfall, storms, landslides

Hunua Reservoir (March 2017): WaterCare

National coastal risk exposure – LG 3 waters



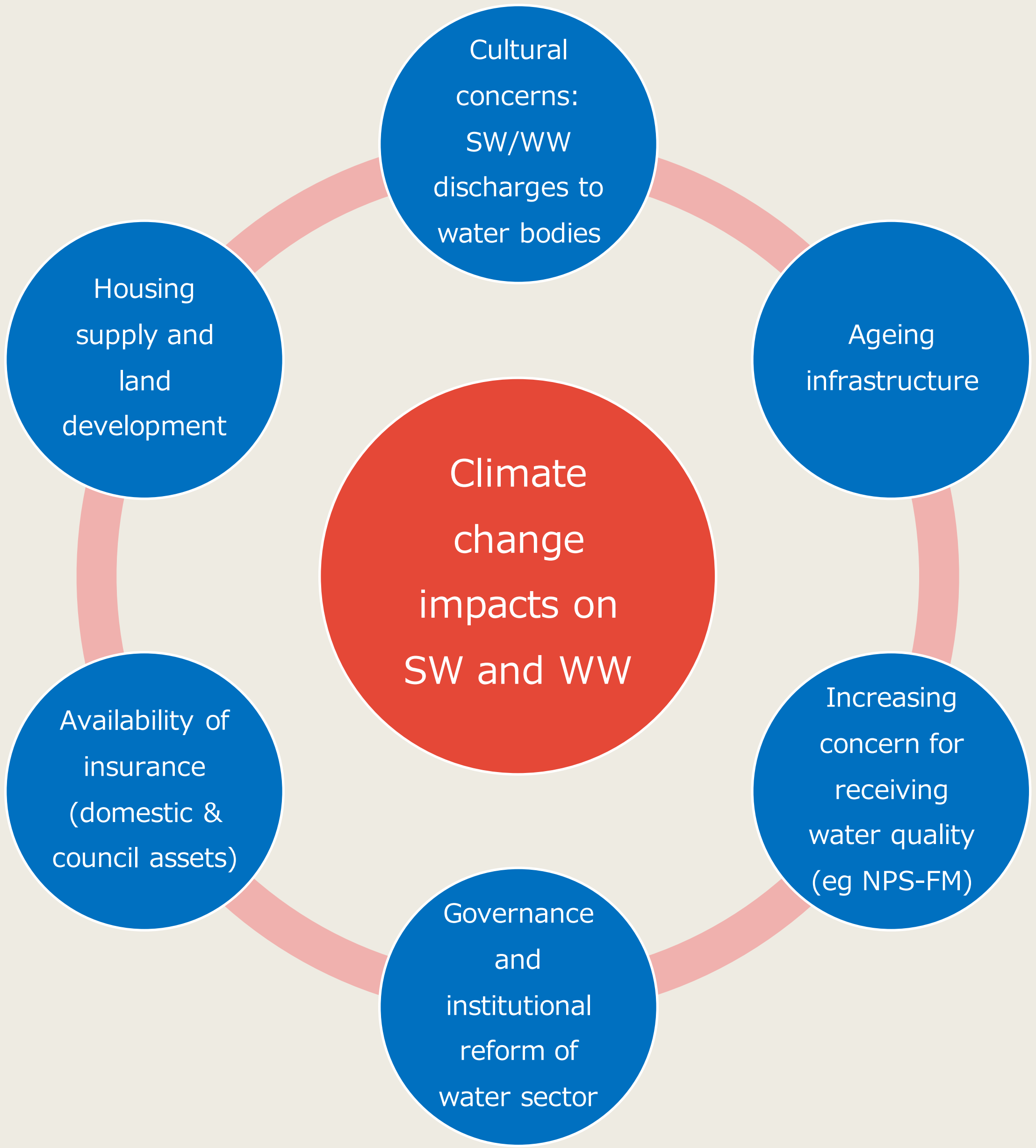
Simonson et al. (2019). LGNZ

Nexus of climate change and complex systems

- Flood/stormwater management
- Drainage schemes
- Potable water supply
- Utilities and lifelines
- Discharges & water quality
- Community & marae assets
- Energy sector
- Primary sector infrastructure
- Ports & marinas
- Legacy landfills

US EPA (2015)

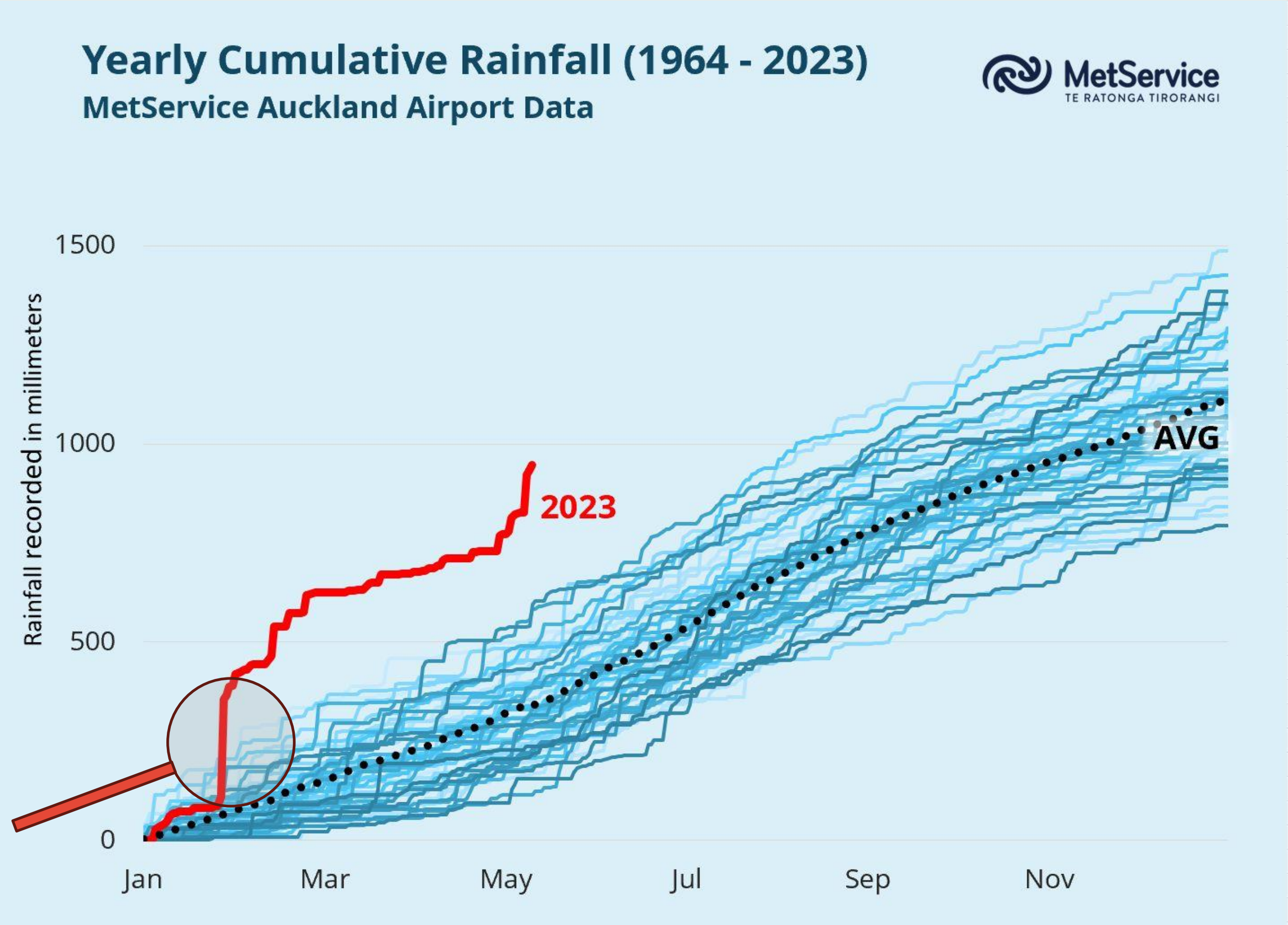
Climate change exacerbates issues with 3 waters



Hughes et al (2019): https://deepsouthchallenge.co.nz/research-project/stormwater-wastewater-and-climate-change/

Surprises (black swans): seen as on the edge of reality

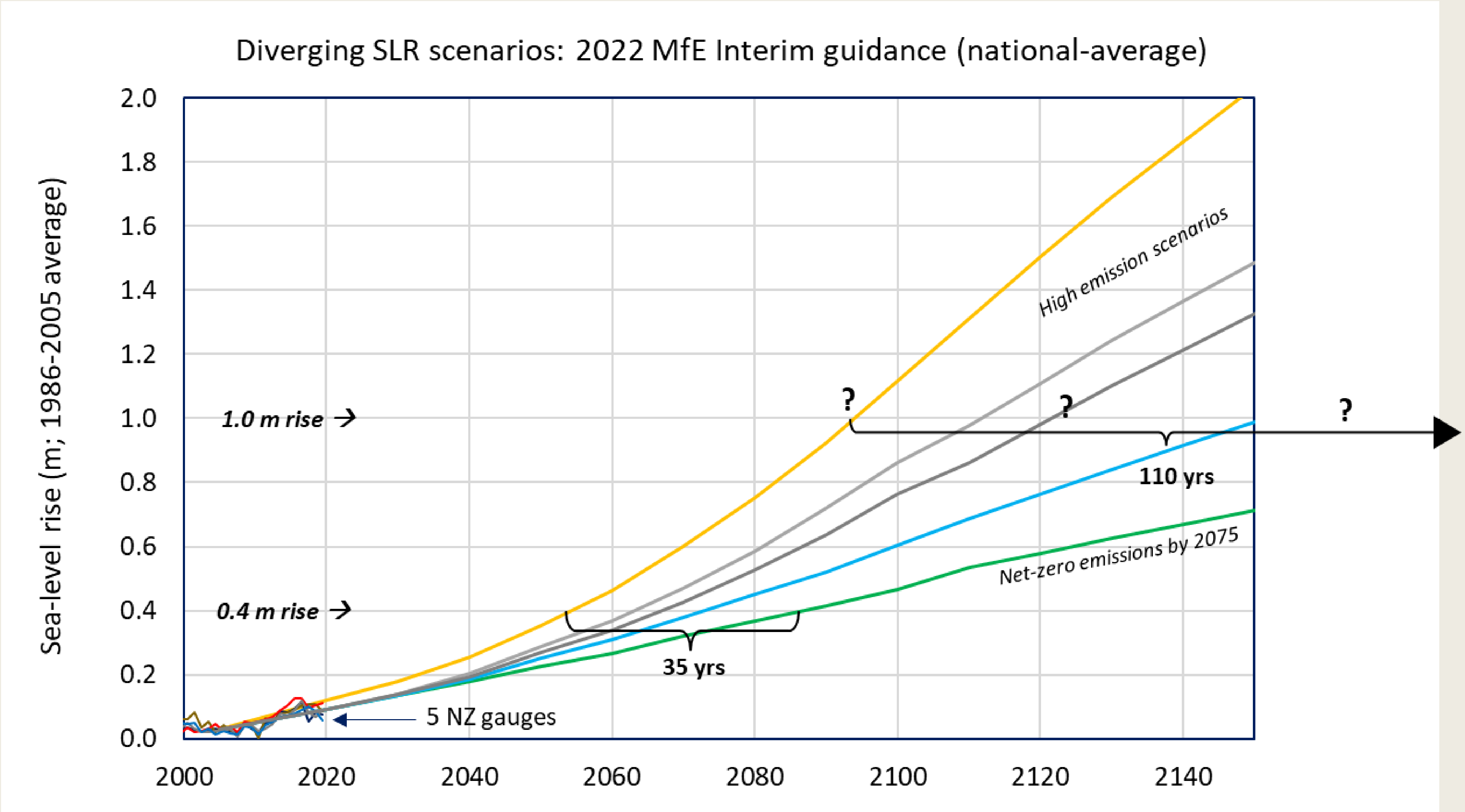
Mt Albert gauge (27 Jan 2023): **200 mm** rainfall in 4 hrs (4-8 pm).
250-year ARI for 4 hours is 109 mm (NIWA), **so approx. twice!**



31 August 2021: west Auckland
80 homes damaged (Covid lock-down)

Wake-up?? preceded 2023 events

Deepening uncertainty in future sea-level rise: predict or track?



<u>Deep uncertainty:</u>
Rate of SLR ∝ global emissions & ice sheet tipping points

Another uncertainty is future trajectory of vertical land movement (VLM) – now available at 2 km intervals in NZ*

Revised 2024 NZ coastal guidance scenarios

Adaptive planning is best fit for deepening uncertainty + tracking change

* https://www.searise.nz/maps-2

Emergence of compound hazards

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Groundwater rise & salinity intrusion

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Drew Lorrey, NIWA. Riverhead, Feb 2023

Intense rainfall/storms: flash flooding

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Impacts from cumulative environmental changes

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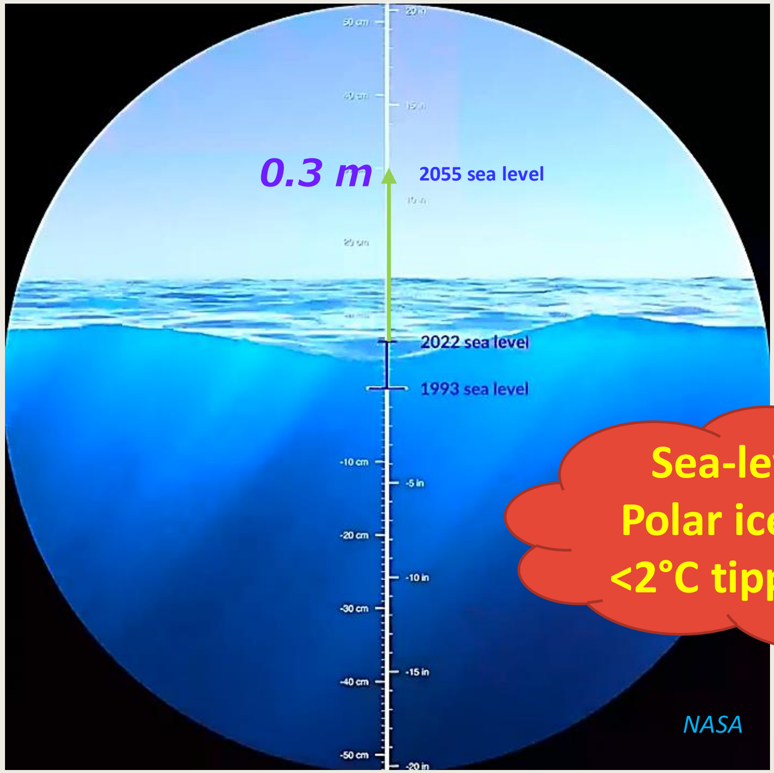


2100:
0.4-1.0 m SLR

Sea-level rise: Polar ice sheets - <2°C tipping point

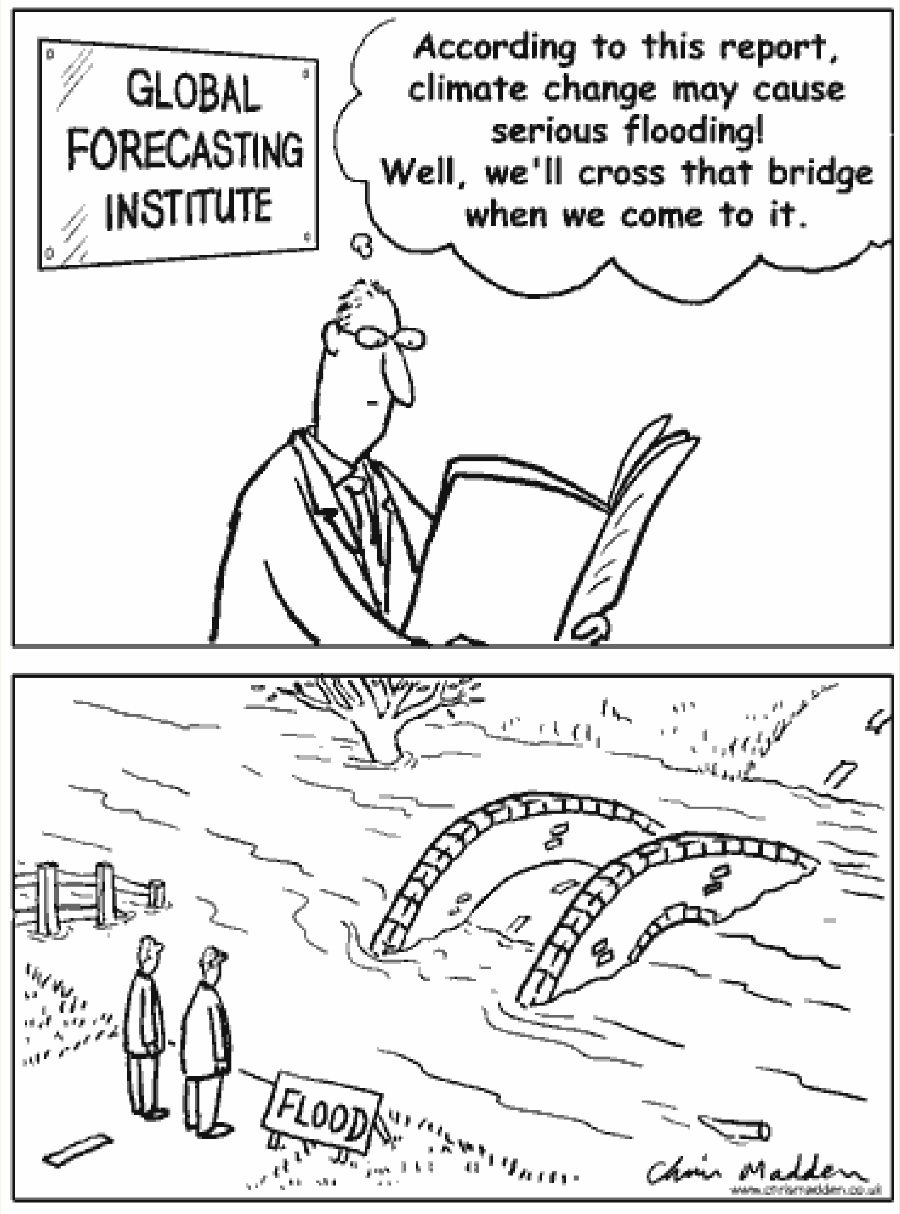
Q: future changes in joint-dependence ?

Rising climate risks: “new norm”

- Widening uncertainty in projections past 2050
- Some climate drivers (eg, SLR) continue for centuries (even after emissions stabilize)
- Increasing cumulative risk from progressive (chronic) changes and frequent nuisance to moderate events ⇒ event fatigue
- More frequent extreme events
- Past events or “norms” not a reliable guide for future risks or design; stationarity is dead!

Near Nelson (2022): Marlborough Rescue Helicopter

DRR vs climate adaptation paradigms



Disaster risk reduction & recovery (DRR) focuses on reducing risk from major events to enable quicker "bounce-back" (short-term focus)

Adaptation pre-emptively <u>adapts to both</u>:

i) ongoing, gradual change & more frequent nuisance events (cumulative & cascading risks),

ii) major events occurring more often

but within an adaptive framework that addresses deep uncertainty and long-run planning horizons

New ways to assess/manage ongoing rising risk

What are realistic limits to existing networks or schemes <u>and</u> the communities they serve?

Do we continually react, mop up after events and stay put?

Can we handle and work with risk/adaptation thresholds across a range of scenarios, rather than pin down future *likelihood* of events?

How do we anticipate, adapt and reduce/avoid risks?

NIWA (2014)

Importance of identifying uncertainties for adaptation

Risk (high-level definition):
The "***effect of uncertainty on objectives***"

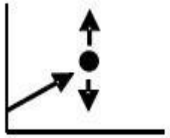
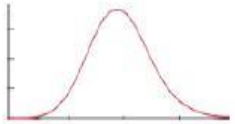
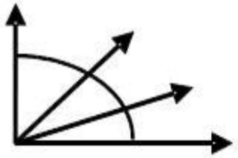
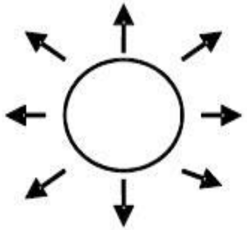
- Match decision-type to type of uncertainty: how sensitive is the decision or decision-maker to uncertainty?
- If the risk is **underestimated**, could be debilitating harm
- If the risk is **overestimated**, incurs social and economic penalties (opportunity cost)
- Making the **type of uncertainty explicit** - helps identify level of assessments, types of models & adaptive frameworks for the decision/design at hand

Knowable *(predict & act decisions)*

Stochastic uncertainty *(trend-based decisions)*

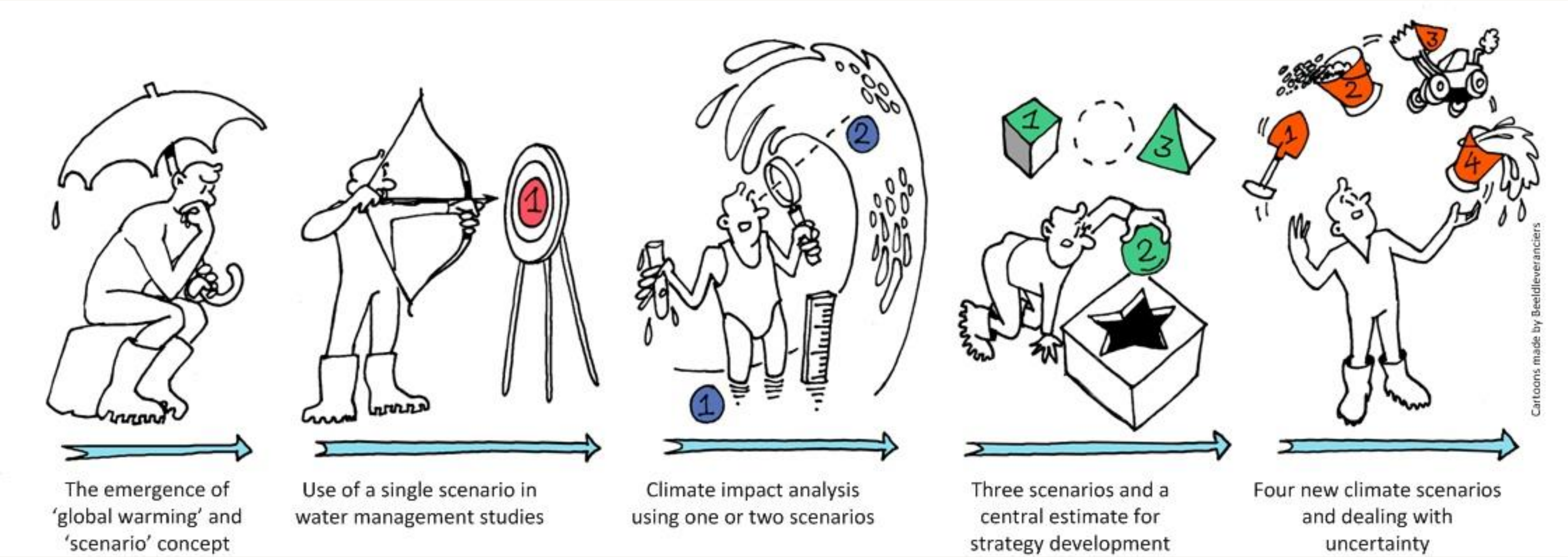
Scenario uncertainty *(static-robust decisions)*

Deep uncertainty *(adaptive-iterative decisions)*

		LEVEL					
			Level 1	**Level 2**	**Level 3**	**Level 4**	
LOCATION	**Context (X)**	Complete certainty	A clear enough future 	Alternate futures (with probabilities) 	A multiplicity of plausible futures 	Unknown future 	Totally unknown
	System Model (R)		A single (deterministic) system model	A single (stochastic) system model	Several system models, with different structures	Unknown system model; know we don't know	
	System Outcomes (O)		A point estimate for each outcome	A confidence interval for each outcome	A known range of outcomes	Unknown outcomes; know we don't know	
	Weights on outcomes (W)		A single set of weights	Several sets of weights, with a probability attached to each set	A known range of weights	Unknown weights; know we don't know	

MfE coastal guidance (after Walker et al. 2013)

Why adaptive planning was developed?



After: Haasnoot & Middelkoop (2012). History of Futures

We need an approach to circumvent deep uncertainties that removes dependency on single numbers, central estimates or middle scenarios or even "worst case"?

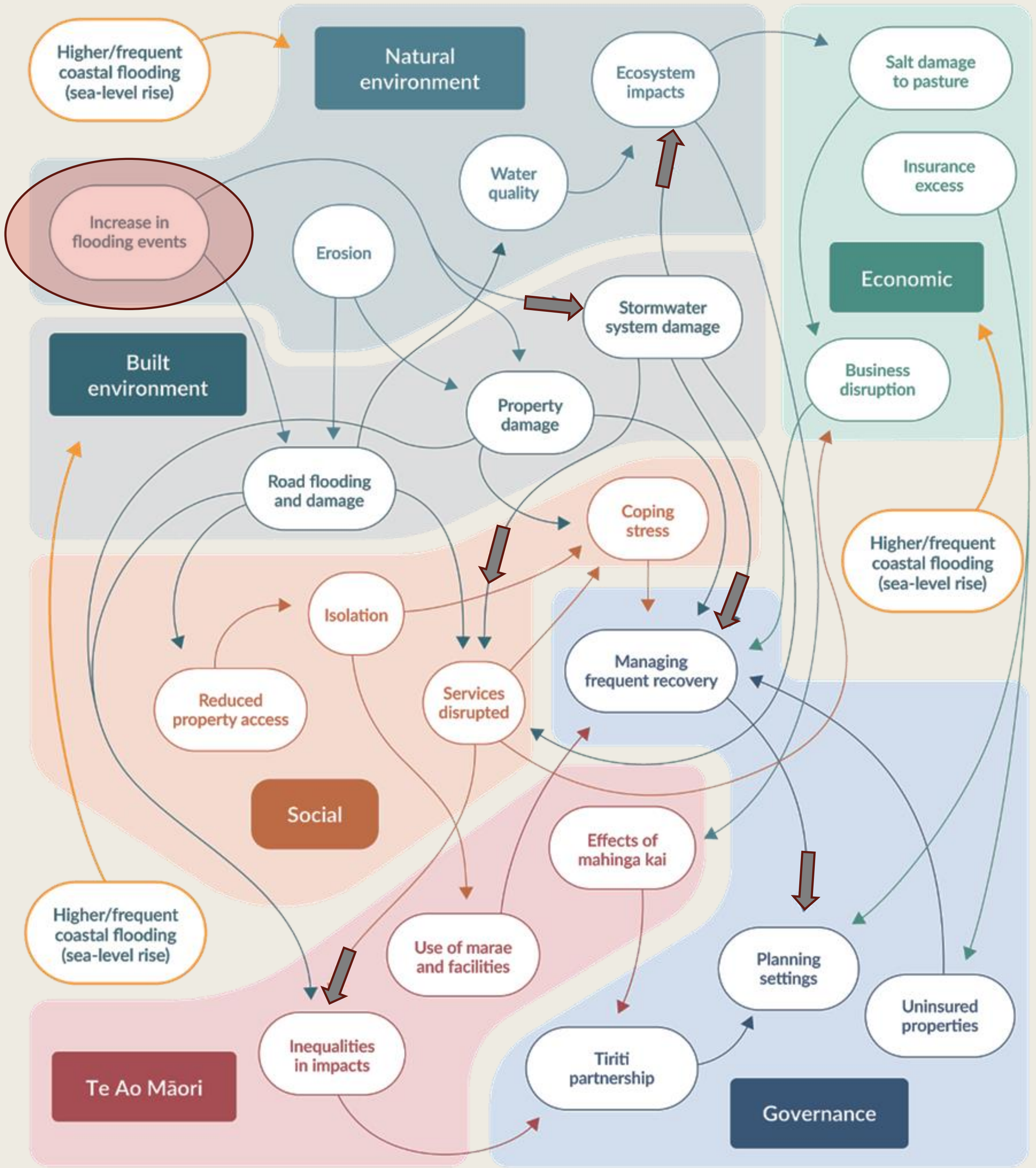
1. *Under <u>what conditions</u> does the policy, plan, network or design <u>no longer meets objectives</u>?*
2. *<u>Assess timing</u> of this threshold using scenarios*
3. *<u>Explore</u> options & adaptive pathways* or *robust decision making*
4. *<u>Stress test</u> preferred options or pathway against a range of scenarios/projections*
5. *<u>Monitor</u> headway to threshold using pre-agreed signals and triggers and review regularly*

Use systems thinking and cascades to set boundaries for "local" adaptation

Adapting in silos can increase chance of maladaptation from interdependencies & impact chains

Adaptation to Climate Change Standard ISO 14090 (2019)

MfE (2024) coastal guidance



Schematic: 2024 MfE coastal guidance

Typologies of adaptation options or actions

Accommodate

Live with and work around the rising hazard

Protect

Manage the hazard head on

Avoid

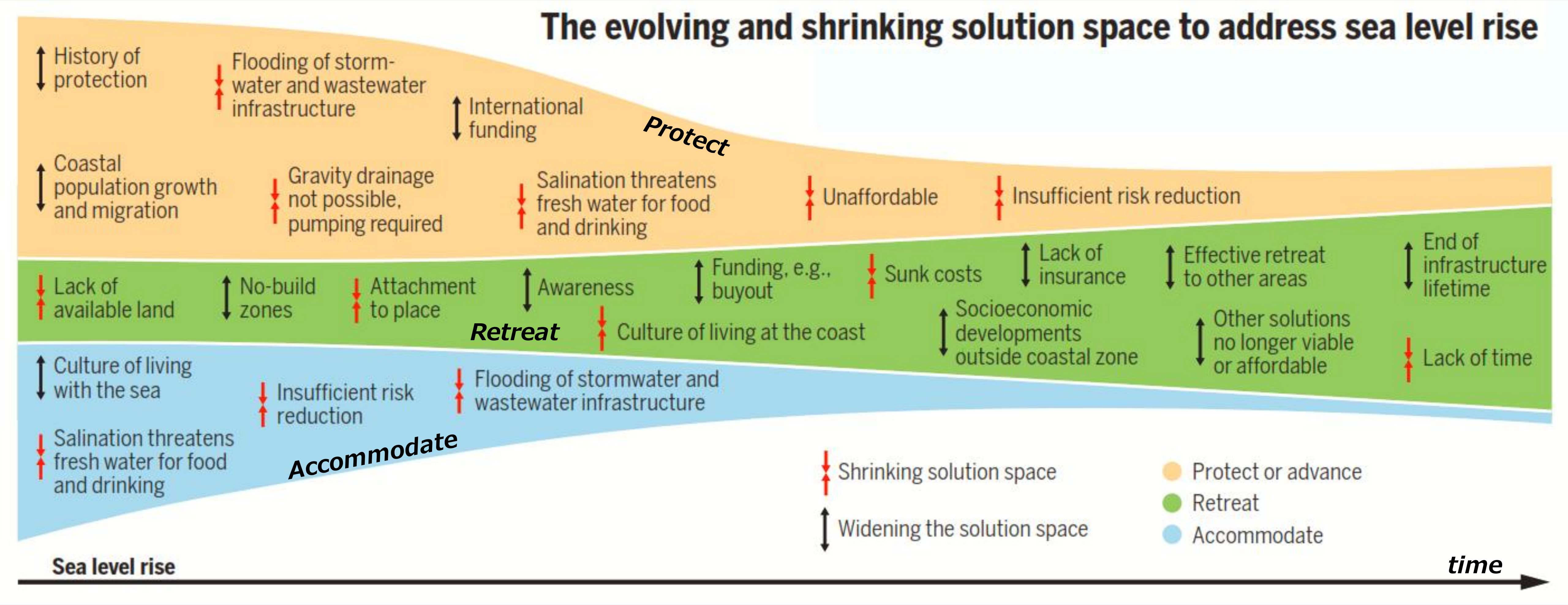
Avoid increasing the hazard risk

Retreat

Managed or planned relocation of people & assets out of hazard-prone areas

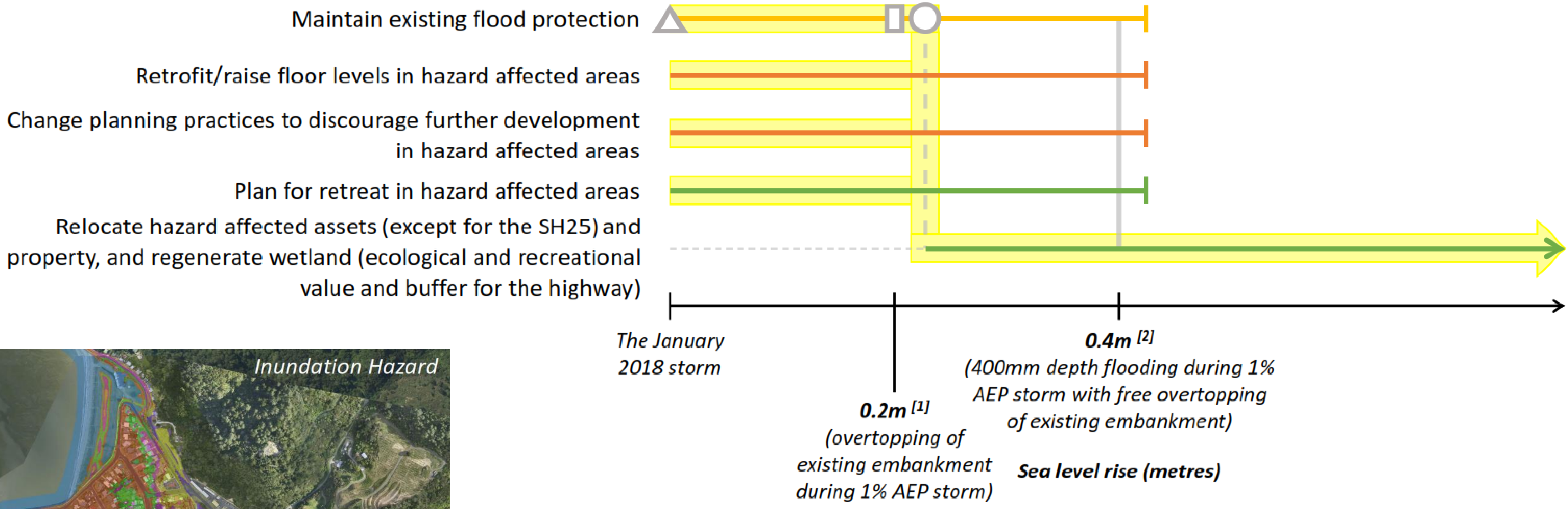
Schematic: Nelson City Council

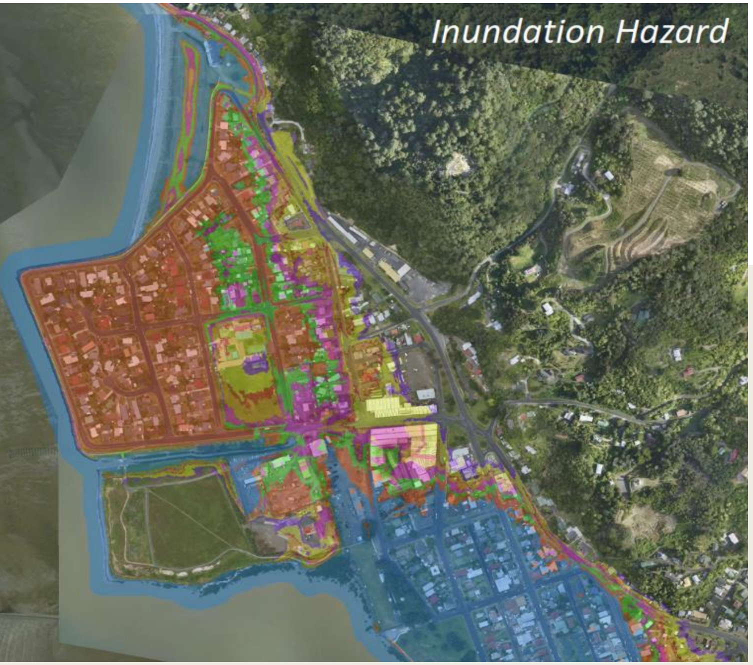
Physical limits of types of options: eg, ongoing SLR



Source: *Haasnoot, Lawrence, Magnan 2021 Science (April 2021)*

Dynamic adaptive pathways planning (DAPP): Thames

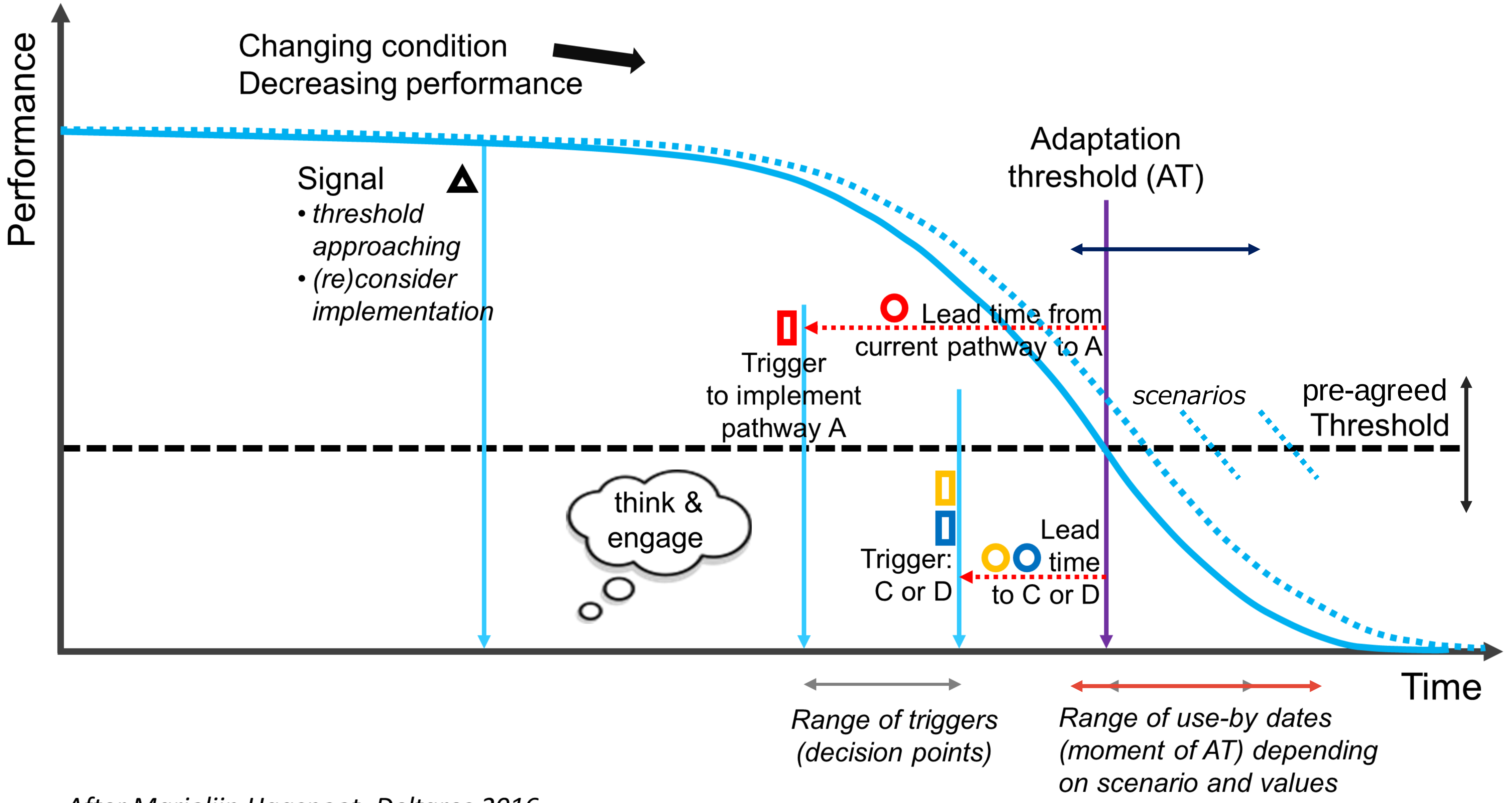




Policy Unit 3, Coastal Panel, TCDC

Underlying Q for adaptive pathways:
Under what conditions does the plan, action or option no longer meet objectives? ▯ = Trigger (decision point)

Monitoring change: Signals, triggers and adaptation thresholds

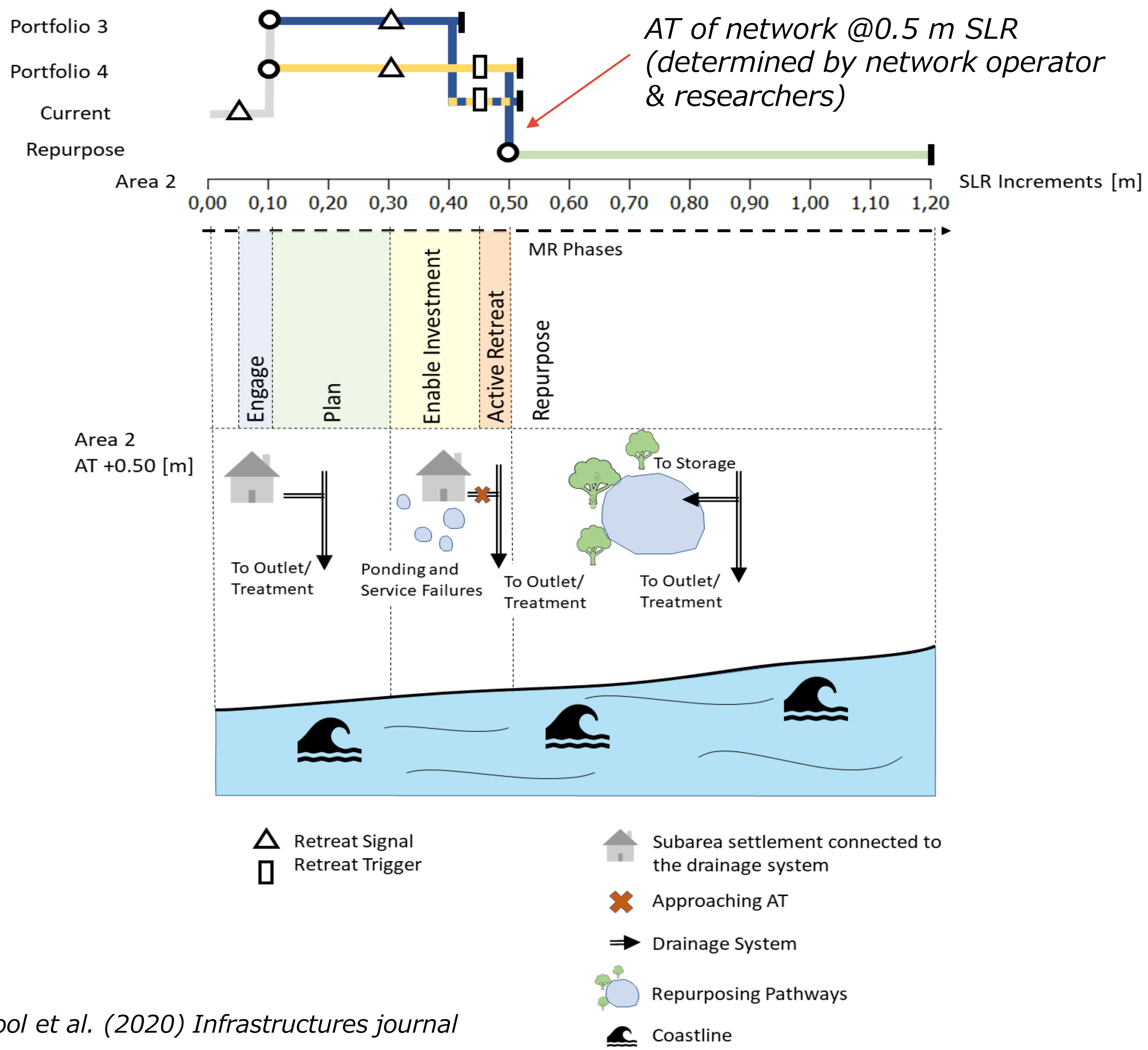


After Marjolijn Haasnoot: Deltares 2016

DAPP: Pilot study of managed retreat for 2-waters network

<u>Underlying Q:</u>
Under what conditions or LoS does the plan or portfolio option no longer meet objectives?

<u>Accommodate (1st):</u>
Portfolio 3: Maintain gravity system
Portfolio 4: Pressurize system
<u>Managed retreat (2nd)</u>
<u>Repurpose land use (3rd)</u>



Kool et al. (2020) Infrastructures journal

Scenario analysis & stress testing plans for climate risks

- Ongoing education and awareness of what scenarios are and are not – they are not “predictions”
- Climate-scenario analysis can underestimate climate risk, if the extreme tails & surprises are not carefully considered
- Challenge of combining qualitative + quantitative information in a climate risk assessment eg, tolerances, social, cultural, values, environmental
- Establish stretch of plans, policies and designs in terms of flexibility, viability, sustainability (to avert path dependency & maladaptation)

Credit: Braden Fastier

Comparing paradigms for infrastructure/communities

Conventional	Dynamic adaptive planning/design
Single-investment perspective: up-front, one-off	**Several timely investment options** mapped out in pre-planned adaptive strategy
Nominal design life (or life cycle): in coastal areas often 100 yrs or buildings 50 yrs	**For each stage or option, determine possible range of "shelf life" from SLR/climate scenarios** (before a switch to next stage/option in a pathway)
Predict-then-act: choose most-likely or worst-case scenario for flood hazards	**Track-then-act**: scenario neutral, tracking the headway to a pre-agreed local adaptation threshold
Uses quantitative predictive models & risk assessment: to optimize solution *vs* cost & benefits for design life	**Applies multiple scenarios to stress-test options or select the most robust decision**: using models, risk assessments & economic evaluation tools
Potential lock-in or path dependency of selected option.	**Flexibility, in options/stages and when to invest, but flexibility still has a cost.**
Monitoring when required: mostly for consenting requirements	**Monitoring ongoing change is indispensable**: tracking indicators of change relative to signals & triggers (decision points)

How adaptive is our infrastructure?

- Context: more infrastructure failures + ageing assets
- Chasing present demands (reactive)
- Emerging & future changes:
  - technology (smarts, materials, modes)
  - funding models (incl. adaptation)
  - population shifts (rural/urban/coastal)
  - de-carbonising the economy
  - environmental change (water use & quality)
  - *climate change and SLR*

M Allis

If the rate of change (*above factors*) outstrips the inertia in cycles for infrastructure renewal and strategic planning
⇒ then it decouples from the wider system it serves

Pre-conditions for adaptive infrastructure

- **Flexible:** willingness of the "system" to respond adaptively & ability to modify (to changing demands/stressors)
- **Agile:** in re-configuring & bolstering functions to keep pace with change – now decadal!
  - Physical options (can they be re-configured? or eventual managed retreat?)
  - Governance & financing (move past single-investment perspective)
  - Practice and standards: less prescriptive- more adaptive, explicitly address uncertainties
  - Asset management (incremental maintenance aligned with pre-emptive adaptation)
- **Needs systems thinking:** cross-cutting and cascading implications across well-beings. Adaptation not just local @village scale!
- **Managed (planned) retreat** – Consider possible need long-term. Requires long lead times but influences near-term maintenance decisions, interim options and investment strategies.

Adapting the messages

- Future pace of change uncertain – but it's going up. ~~*Stationarity*~~
- Adaptive approaches are best dealing with deepening uncertainty
- Consider how incremental asset decisions today affect future adaptation flexibility (or eventually managed retreat)?
- Monitoring & evaluating changes relative to signals & triggers – indispensable for any adaptive approach to inform when to tack
- Successful infrastructure provision will need to have *flexible* systems/governance and *agile* options & approaches. How??
- Needs systems thinking: Implications for infrastructure/services of cascading effects (not just technocratic, nor a local solution).

At least try to “see” the Unknown and keep options open

UK Met Office