Flexible Adaptation Pathways

An approach to Coastal Flooding and Extreme Heat

State Climate Change Commission Meeting – 28 October 2020

Through the Lens of Iwilei-Kapalama and Heat Wave of 2019

Jack Hogan, PE
Jack-W.Hogan@arup.com

Cole Roberts, PE
Cole.Roberts@arup.com

Objectives

- Describe Flexible Adaptation Pathways
- Demonstrate appropriateness for infrastructure intensive planning projects in Hawaii
- Highlight key benefits and recommendations for implementation

Context

HONOLULU'S TOD PLANS

The City and County of Honolulu is working to ensure that growth in the rail corridor proceeds in concert with the vision and goals of each rail station community. Neighborhood TOD plans have been developed to guide new development and plan for orderly growth and improved accessibility around the stations. These plans are each unique to their context, as highlighted below. The TOD Plans, and the implementation projects that grew out of them, have been developed through extensive community engagement, including public workshops, stakeholder meetings, community surveys, business and student outreach, and more.

EAST KAPOLEI

The East Kapolei Neighborhood TOD Plan presents a framework for buildout of three station areas that are part of the long-term plan to create a "second city" in Kapolei. These stations will provide access for future developments like Ho'opili, as well as existing residents with park-and-ride facilities and a bus transit center. The UH-West O'ahu Station area will continue to grow as a campus and urban community.

WAIPAHU

The Waipahu Neighborhood TOD Plan covers the Waipahu Transit Center and West Loch Station areas. The TOD vision for these stations is to retain and strengthen the historic character of Waipahu, while encouraging appropriate mixed-use development. A Waipahu Town Action Plan has been created to prioritize near-term implementation actions related to pedestrian and bicycle facilities, wayfinding and placemaking, safety, and economic development.

'AIEA - PEARL CITY

With its existing resources and destinations, the 'Aiea-Pearl City area serves as a keystone to the island's TOD goals. With TOD, Leeward Community College could become more than just a daytime campus, and Pearlridge and Pearl Highlands Station areas could become livable mixed-use communities with improved housing, employment, retail, and recreational choices. The Pearl Highlands Station will also serve as a major transit center for residents 'ewa and mauka of the TOD areas.

HĀLAWA/ ALOHA STADIUM

The Aloha Stadium Station will provide high-quality transit access to nearby retail and housing, military facilities, the Pearl Harbor Historic Sites, and Stadium events. A replacement stadium is also proposed by the State of Hawai'i in conjunction with new TOD that may include housing, hotels, offices, retail, entertainment, and sports-related uses. There are also efforts underway to extend the Pearl Harbor Historic Trail to this station area to improve regional bicycle access.

AIRPORT AREA

The Pearl Harbor, Daniel K. Inouye International Airport, and Lagoon Drive Stations will serve residents and visitors alike. The area is envisioned as the gateway to Hawai'i and a premier employment center. The rail stations, along with associated bus and bicycle upgrades, will improve access, allowing for more concentrated infill development. TOD zoning will diversify employment and convenience retail options in the area and improve the pedestrian environment i.

KALIHI

While the Kalihi Station area will likely remain stable following the introduction of rail transit, the Middle Street and Kapālama Station areas have great potential for transformation with projects underway such as the State's modernization of OCCC and the revitalization of Kapālama Canal. The Kapālama/Iwilei area in particular is anticipated to change over the coming decades from a light industrial and commercial district into a mixed-use urban community anchored by Honolulu Community College. The Middle Street Station will also continue to serve as a major transit center.

DOWNTOWN

While largely built out, the Downtown and Chinatown Station areas will benefit from new infill development and ongoing livability improvements. The Chinatown Action Plan and Complete Streets Program will serve to catalyze these changes, focusing on streets and placemaking, cleanliness, safety, as well as events/ activities and park improvements. The Iwilei Station area will see significant shifts from existing industrial/commercial uses to more residential and mixed-use opportunities. The redevelopment of Mayor Wright Homes, along with regional infrastructure upgrades, will catalyze this new TOD district.

ALA MOANA

The Ala Moana Center Station is the terminus for the HART rail project. This high-rise urban district will continue to serve as a regional destination and gathering place for residents and visitors. Passengers will be able to transfer to buses to reach Waikīkī and the University of Hawai'i at Mānoa.

CIVIC CENTER/ KAKA'AKO (HCDA)

The neighborhood around the Civic Center and Kaka'ako Stations is under the jurisdiction of the Hawai'i Community Development Authority (HCDA). TOD in this area is planned as high-rise mixed-use development to support O'ahu's population growth within Honolulu's urban core. The ongoing Blaisdell Center Master Plan is underway to support this new population and quality of life islandwide.

Coastal Flooding and Sea Level Rise

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Challenge

- Infrastructure is ***capital-intensive*** and ***long-lived***
- ***Uncertainty*** in how the future may unfold due ***climate*** and ***socio-economic*** conditions

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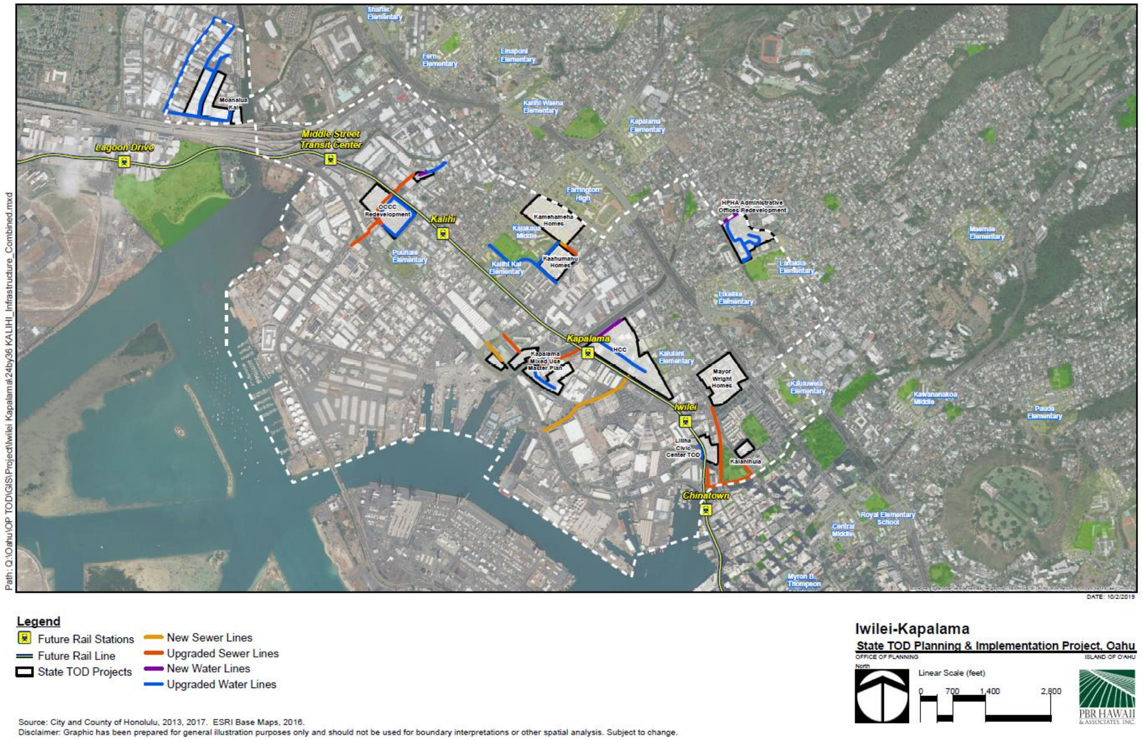
Infrastructure Needs Assessment - Existing



Work in Progress:

- East Kapolei
- Halawa Stadium
- Iwilei Kapalama

Infrastructure	Plans Outlined	Costs Estimated
Sewage	☑	☑
Water	☑	☑
Drainage	☑	☑
Storm water quality	☑	☑
Intersections and roadways	☑	☑
Storm flooding	☒	☒
Coastal flooding	☒	☒

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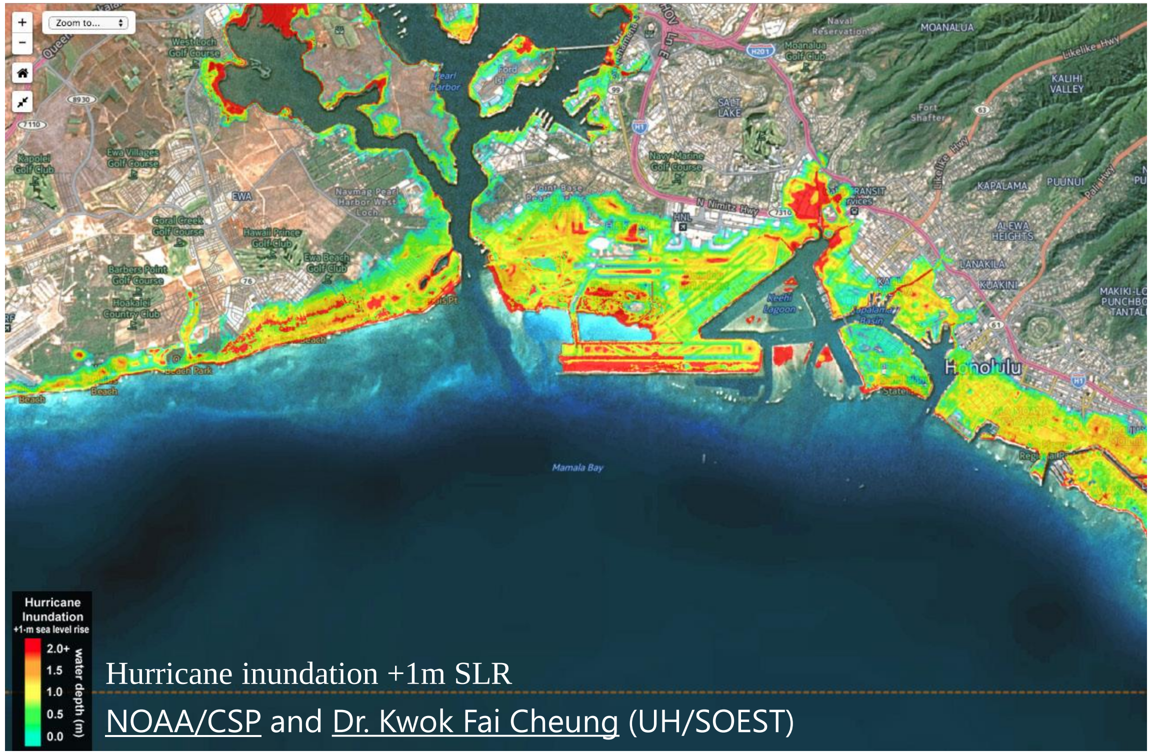
Infrastructure Needs Assessment – Future (Proposed)



(Proposed) Large scale flood infrastructure needs considered for TOD areas

(Proposed) Flexible Adaptation Pathways applicable to infrastructure evaluation and planning

Infrastructure	Plans Outlined	Costs Estimated
Sewage	✓	✓
Water	✓	✓
Drainage	✓	✓
Storm water quality	✓	✓
Intersections and roadways	✓	✓
Storm flooding	✗	✗
Coastal flooding	✗	✗

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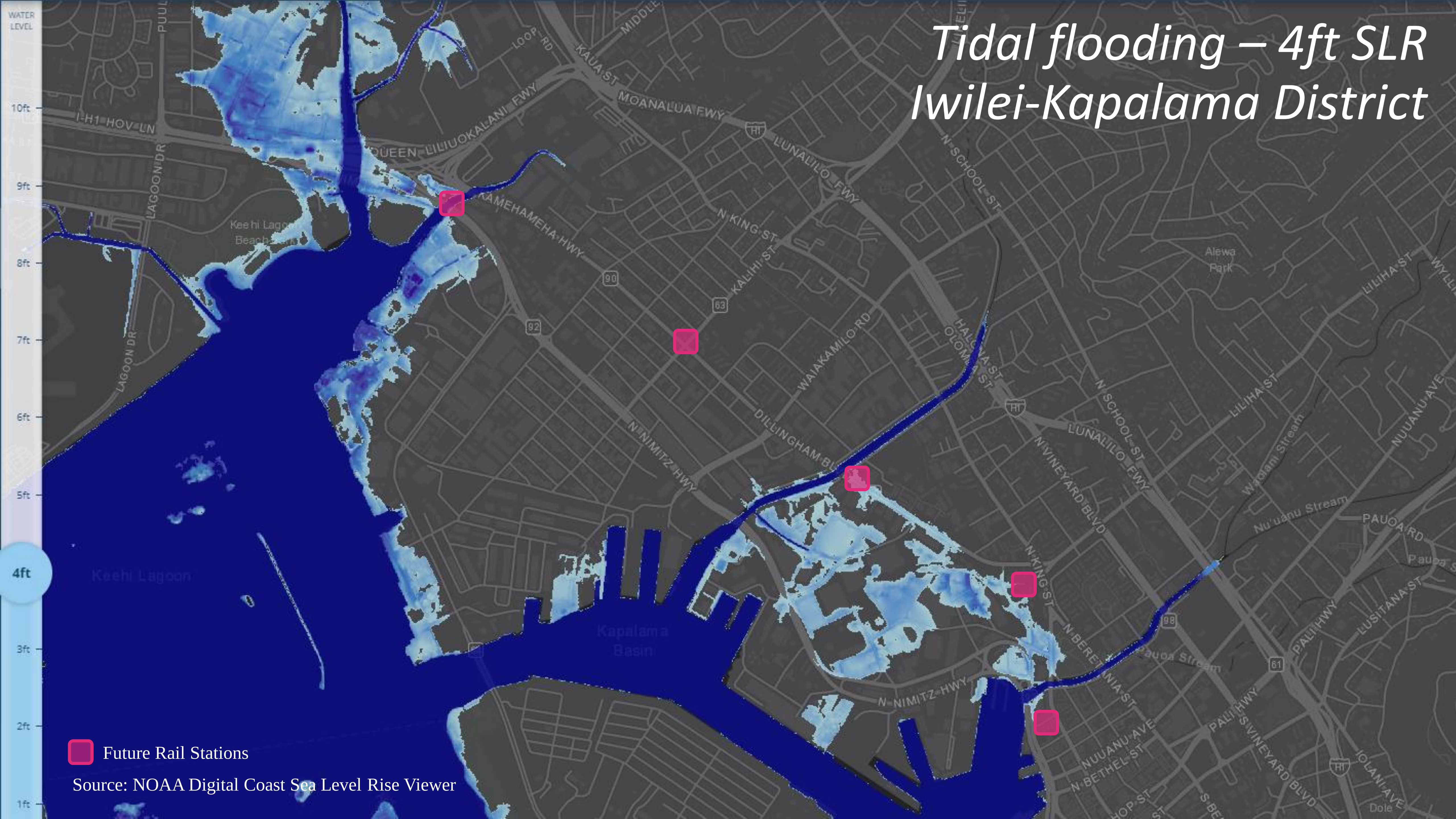
Tidal flooding – 3ft SLR
Iwilei-Kapalama District

Source: NOAA Digital Coast Sea Level Rise Viewer

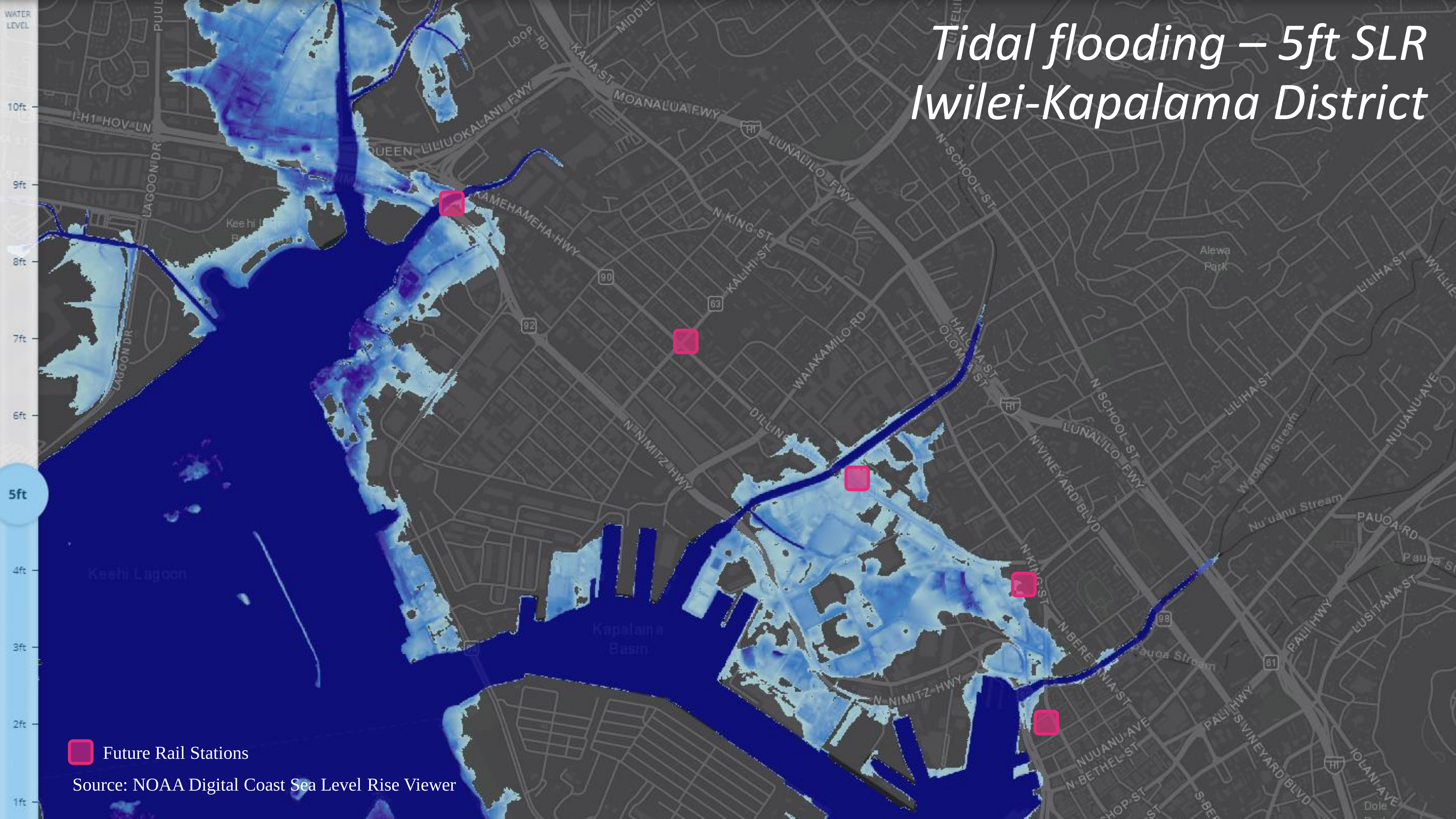
Tidal flooding – 4ft SLR Iwilei-Kapalama District



Future Rail Stations

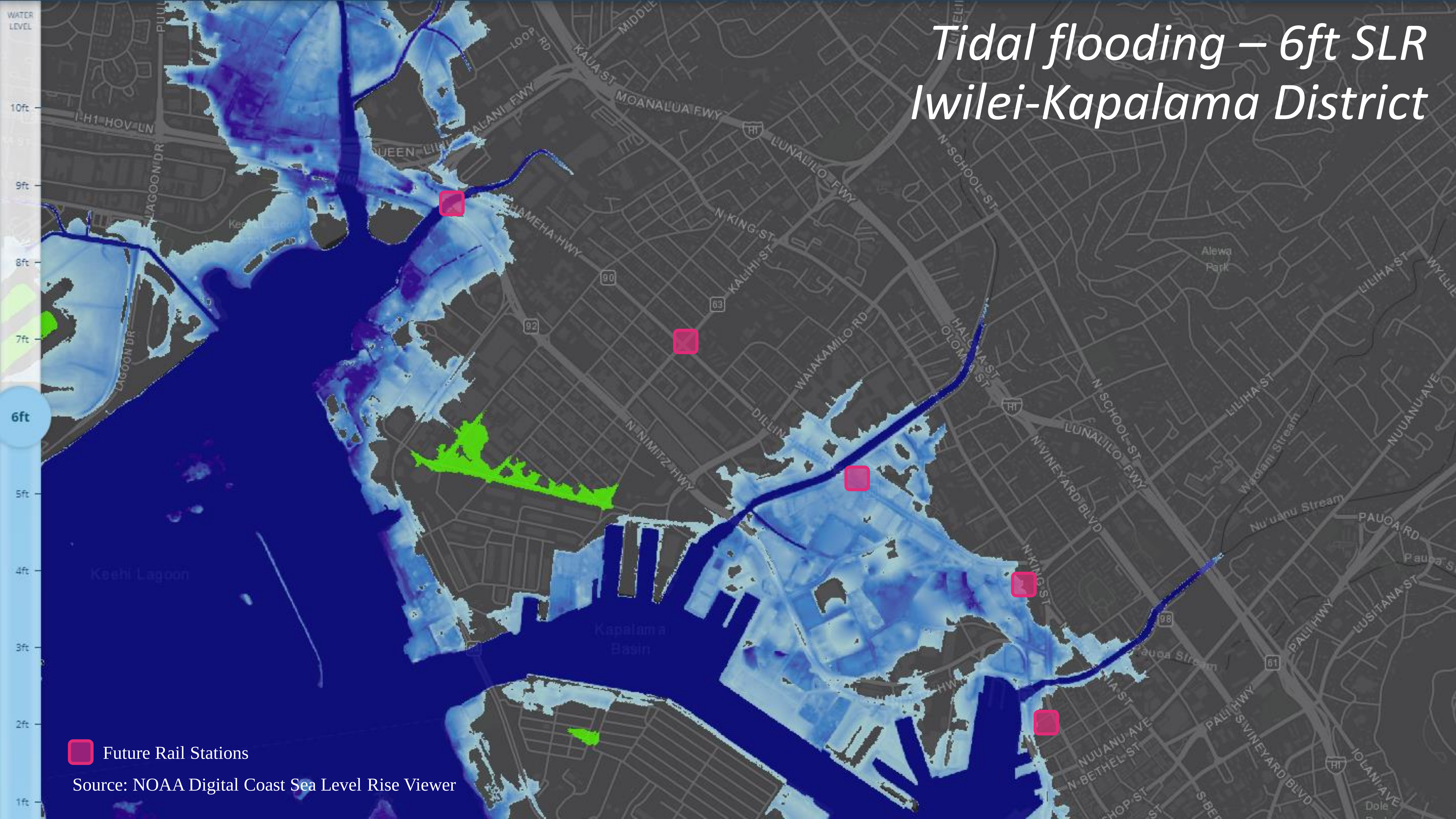
Source: NOAA Digital Coast Sea Level Rise Viewer

Tidal flooding – 5ft SLR Iwilei-Kapalama District



Source: NOAA Digital Coast Sea Level Rise Viewer

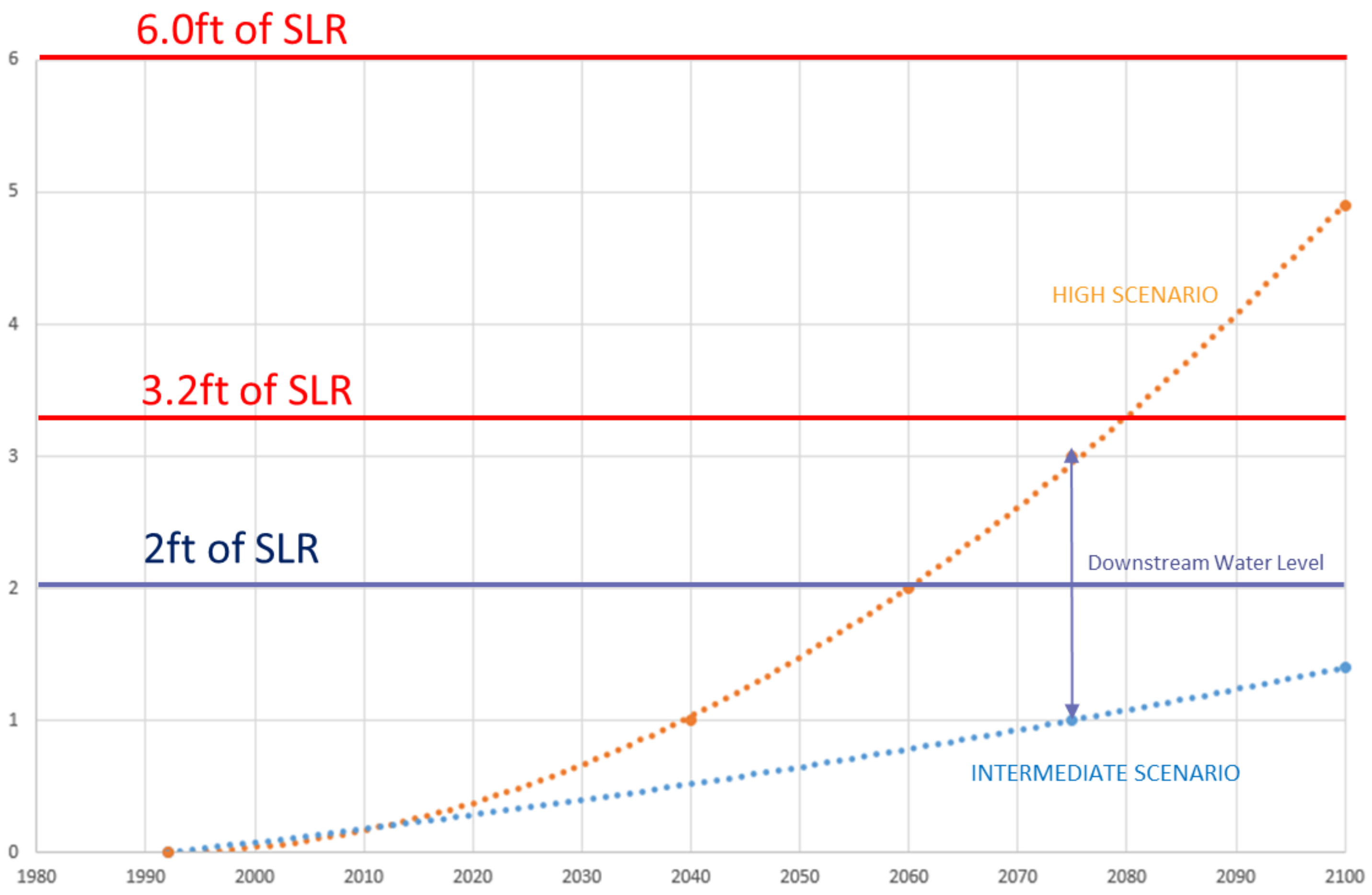
Tidal flooding – 6ft SLR
Iwilei-Kapalama District



Source: NOAA Digital Coast Sea Level Rise Viewer

Uncertainty – When and How Much?

Accumulated Sea Level Rise (feet) at Kapalama Canal



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Response – Infrastructure Planning – Static Approach

- Static ‘optimal’ plan using a single ‘most likely’ future
- Static ‘robust’ plan that will produce acceptable outcomes in most plausible future worlds

BIG U, Manhattan, NY
Bjarke Ingels Group

Resilient Harbor, Boston, MA
SCAPE

(Dessai and Hulme, 2007; Dessai and Van der Sluijs, 2007; Hallegatte et al., 2012).

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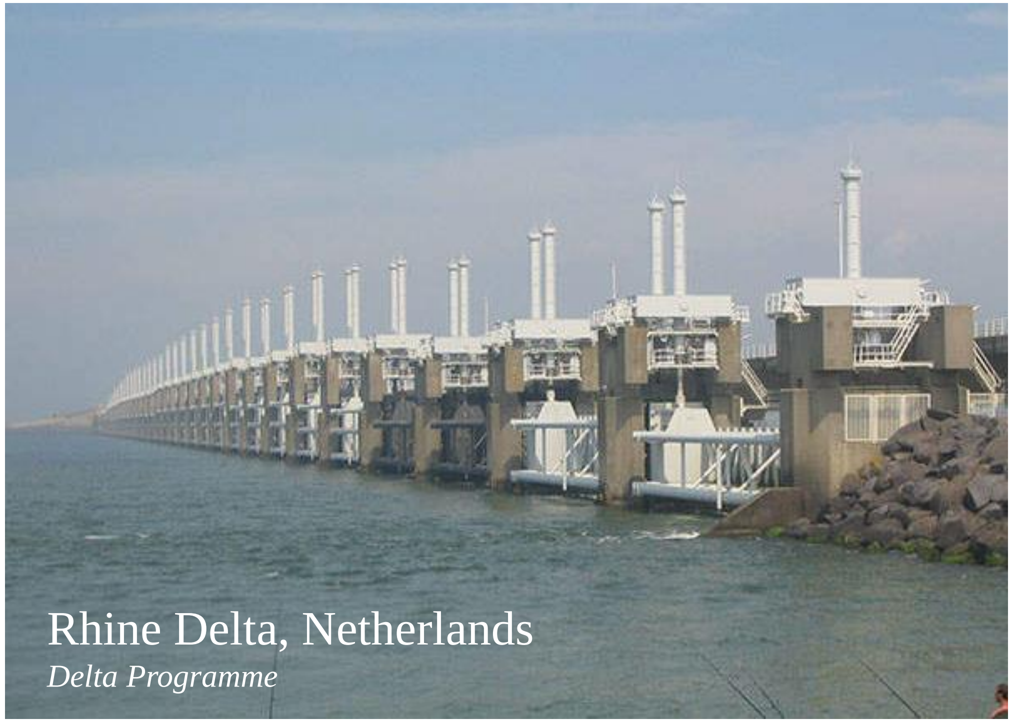
Response – Infrastructure Planning – Dynamic Approach

- Dynamic adaptive plans contain a strategic vision of the future, commit to short-term actions, and establish a framework to guide future actions



Rhine Delta, Netherlands
Delta Programme

Thames Estuary 2100, London, UK
UK Environment Agency

(Albrechts, 2004; de Neufville and Odoni, 2003; Haasnoot et al., 2011; Hallegatte, 2009; Hallegatte et al., 2012; Ranger et al., 2010; Schwartz and Trigeorgis, 2004; Swanson et al., 2010).

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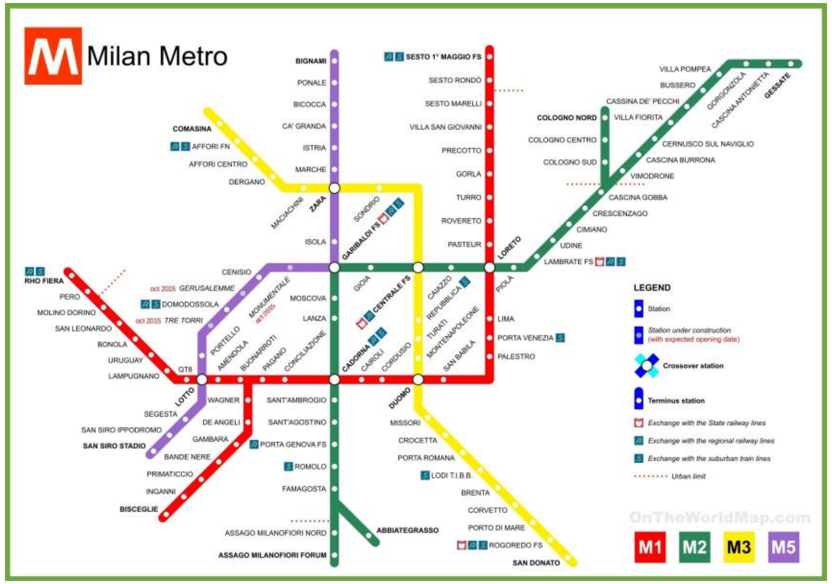
Flexible Adaptation Pathways – Concepts



- Real options – infrastructure options that are fitted with flexibility to adapt to future changes, rather than for a specific design scenario

- Potential lock-ins – when an option leads to a failure to adjust adequately to a changed environment; path-dependency of investment decisions can lead to stranded assets if conditions change

- No regrets options – options which achieve positive outcomes under all plausible projections of climate change

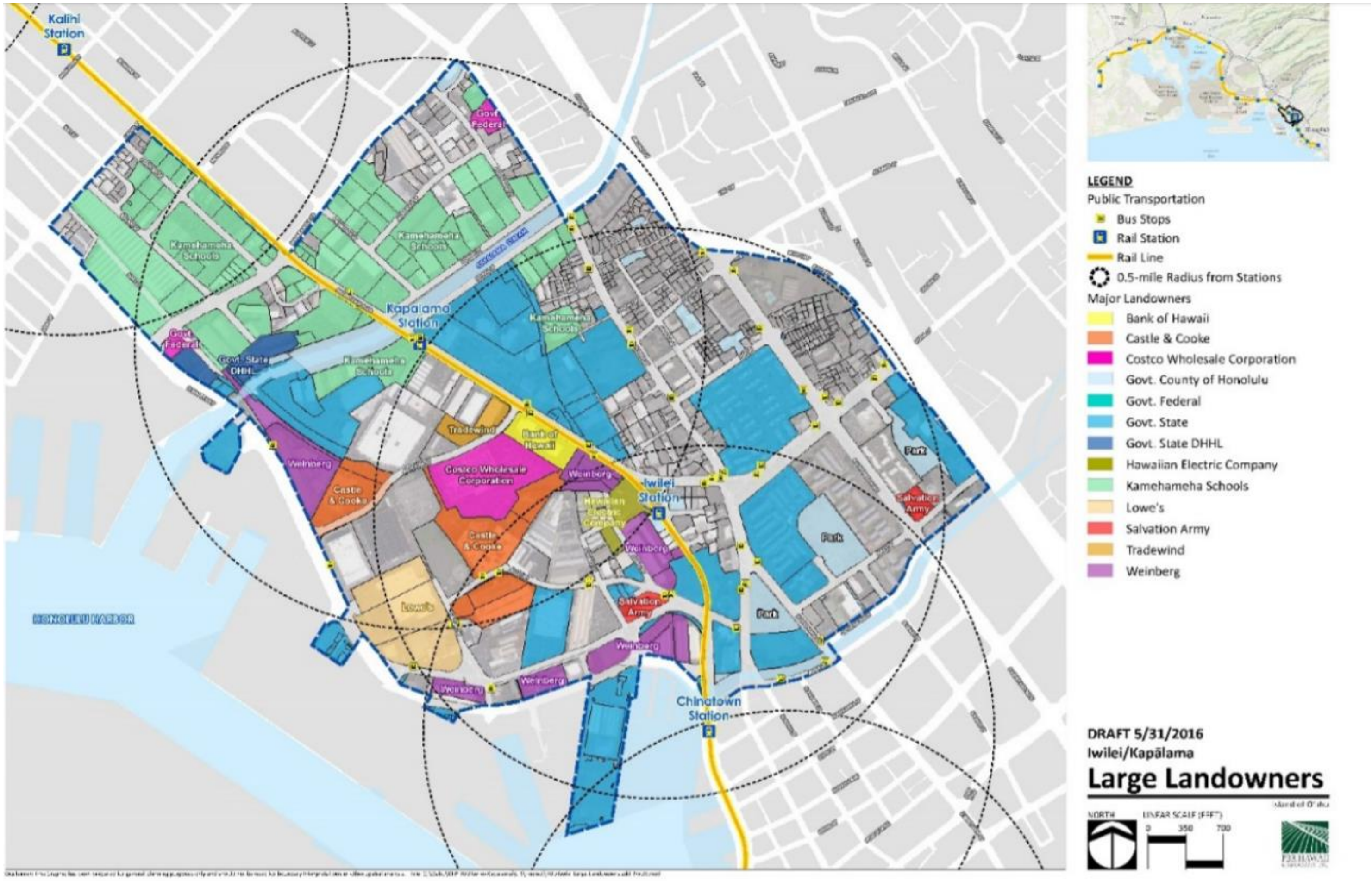
- Trigger and Tipping points - a trigger indicates when a decision is needed for a forthcoming action; tipping point is the point at which a particular action is no longer adequate for meeting objectives

- Flexible adaptation pathway map – path of actions that result in least regrets and achieves overall objectives

(Haasnoot et al. / Global Environmental Change 23 (2013) 485–498)

Iwilei-Kapalama

<u>Objective</u>: Ensure adequate infrastructure capacity and *flood protection* for TOD area investments *through 2100*



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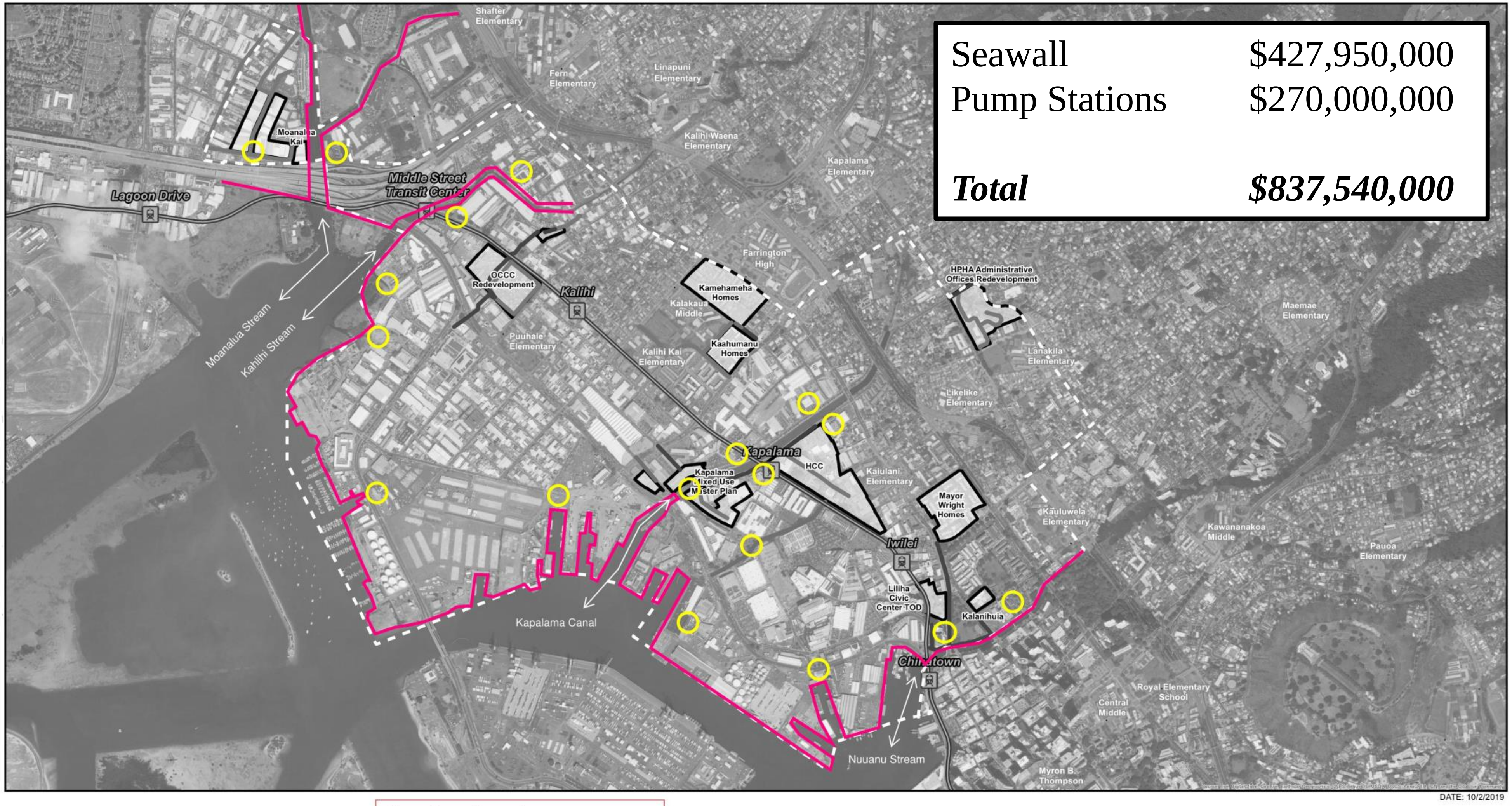
Seawall	$427,950,000
Pump Stations	$270,000,000
Total	***$837,540,000***



Option 1
PROTECT AND PUMP

Infrastructure concept – for demonstration purposes only

Baseline Infrastructure Cost ~$1,579,100,000

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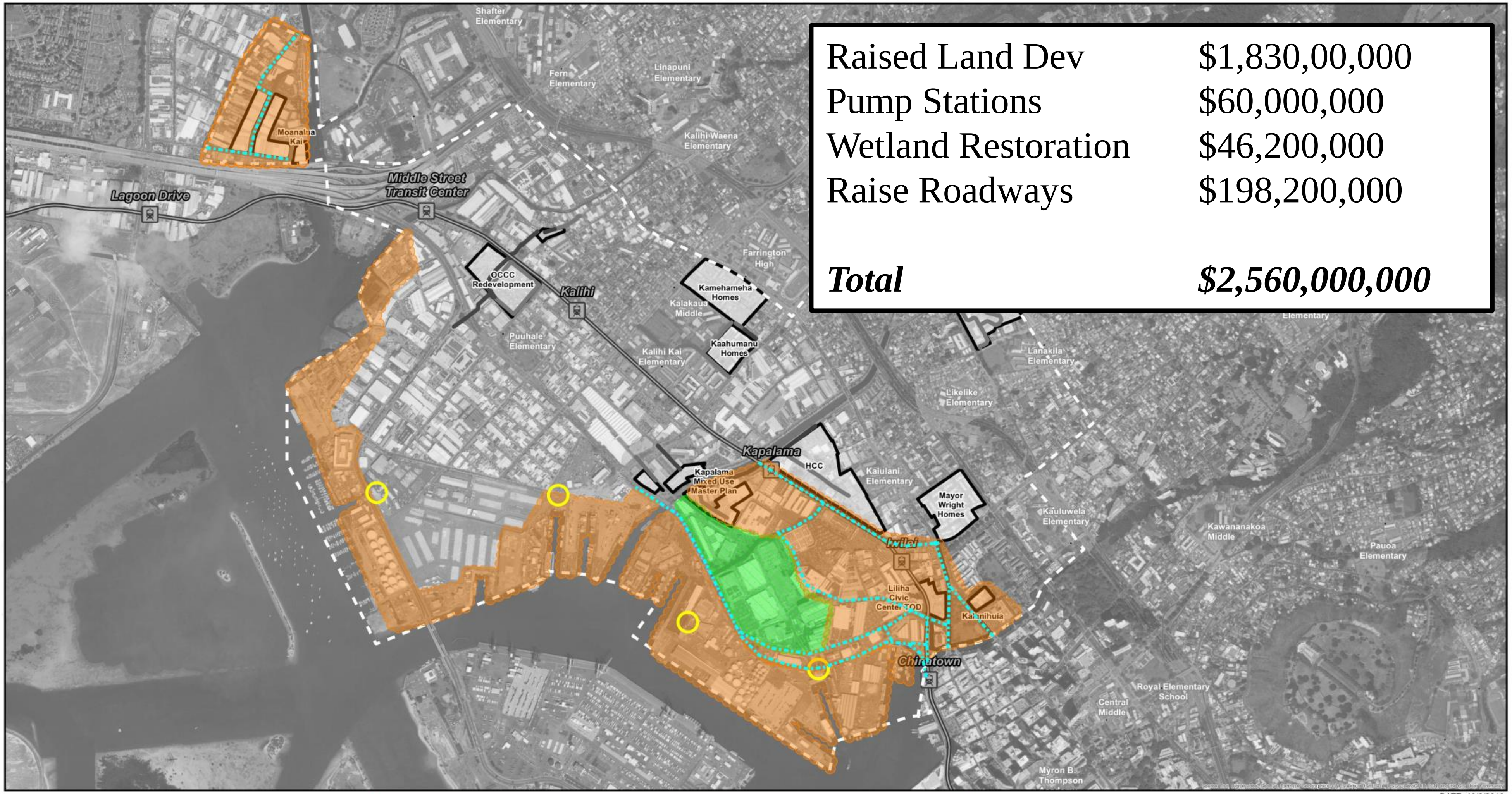

Raised Land Dev	$1,830,00,000
Pump Stations	$60,000,000
Wetland Restoration	$46,200,000
Raise Roadways	$198,200,000
Total	***$2,560,000,000***

DATE: 10/2/2019

Legend

- Future Rail Stations
- Future Rail Line
- State TOD Projects
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades

- Upgraded Port Seawall
- Future Pump Stations
- Elevated Roadway
- Future Raised Development Area
- Future Restored Wetland Area

Option 2

RAISE AND RESTORE

Infrastructure concept – for demonstration purposes only

Baseline Infrastructure Cost ~$1,579,100,000

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DATE: 10/2/2019

Legend

- Future Rail Stations
- Future Rail Line
- State TOD Projects
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades

- Future Raised Development Area
- Tidal Barrier
- Future Pump Stations

Option 3
BARRIERS AND BULKHEADS

Infrastructure concept – for demonstration purposes only

Baseline Infrastructure Cost ~$1,579,100,000

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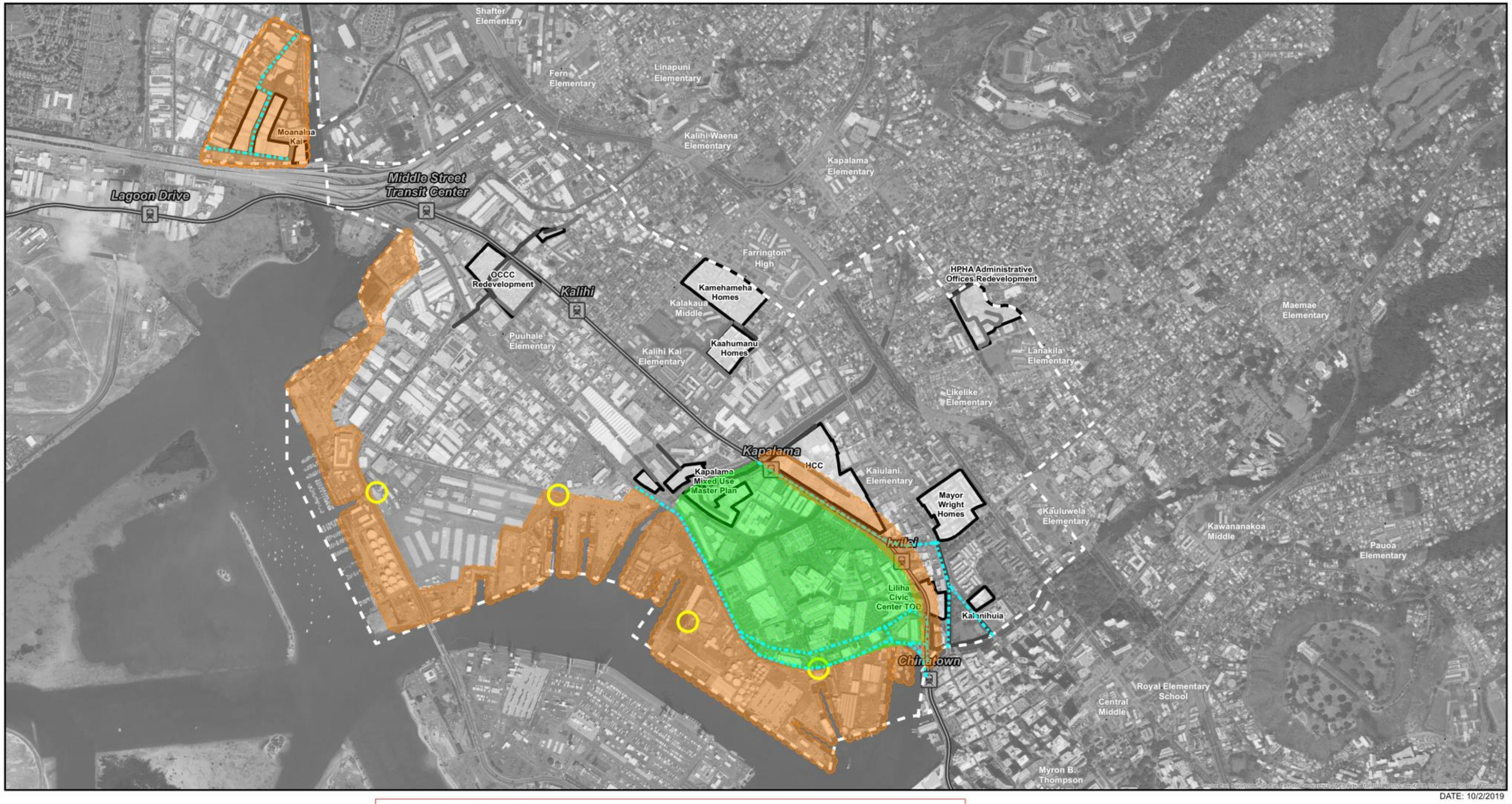

Legend

- Future Rail Stations
- Future Rail Line
- State TOD Projects
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades

- Upgraded Port Seawall
- Future Pump Stations
- Elevated Roadway
- Future Raised Development Area
- Future Restored Wetland Area

Option 4
RETREAT AND RESTORE

Infrastructure concept – for demonstration purposes only

Baseline Infrastructure Cost ~$1,579,100,000

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Flexible Adaptation Pathways – Objective and Options

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers and Bulkheads)

Option 4
(Retreat and Restore)

Objective: Ensure adequate infrastructure capacity and *flood protection* for TOD area investments through 2100

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Flexible Adaptation Pathways - Triggers, Timing, and Thresholds

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers and Bulkheads)

Option 4
(Retreat and Restore)

<u>Objective</u>: Ensure adequate infrastructure capacity and *flood protection* for TOD area investments through 2100

Sea level rise (feet)	1	2	3	4	5	6
Gradual climate change	2020	2040	2060	2080	2100	2120
Rapid climate change	2020	2035	2050	2065	2090	2105

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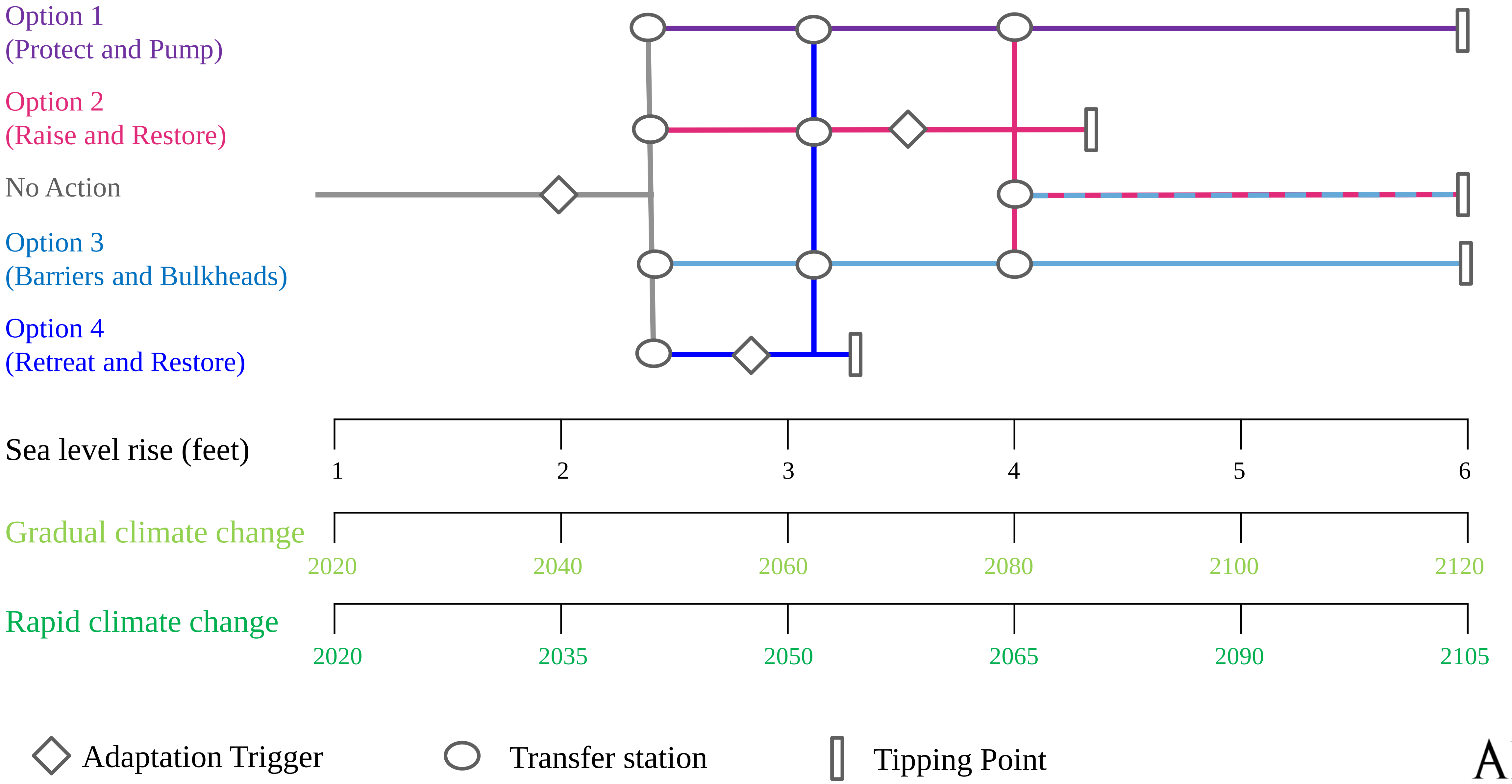
Flexible Adaptation Pathway - Map



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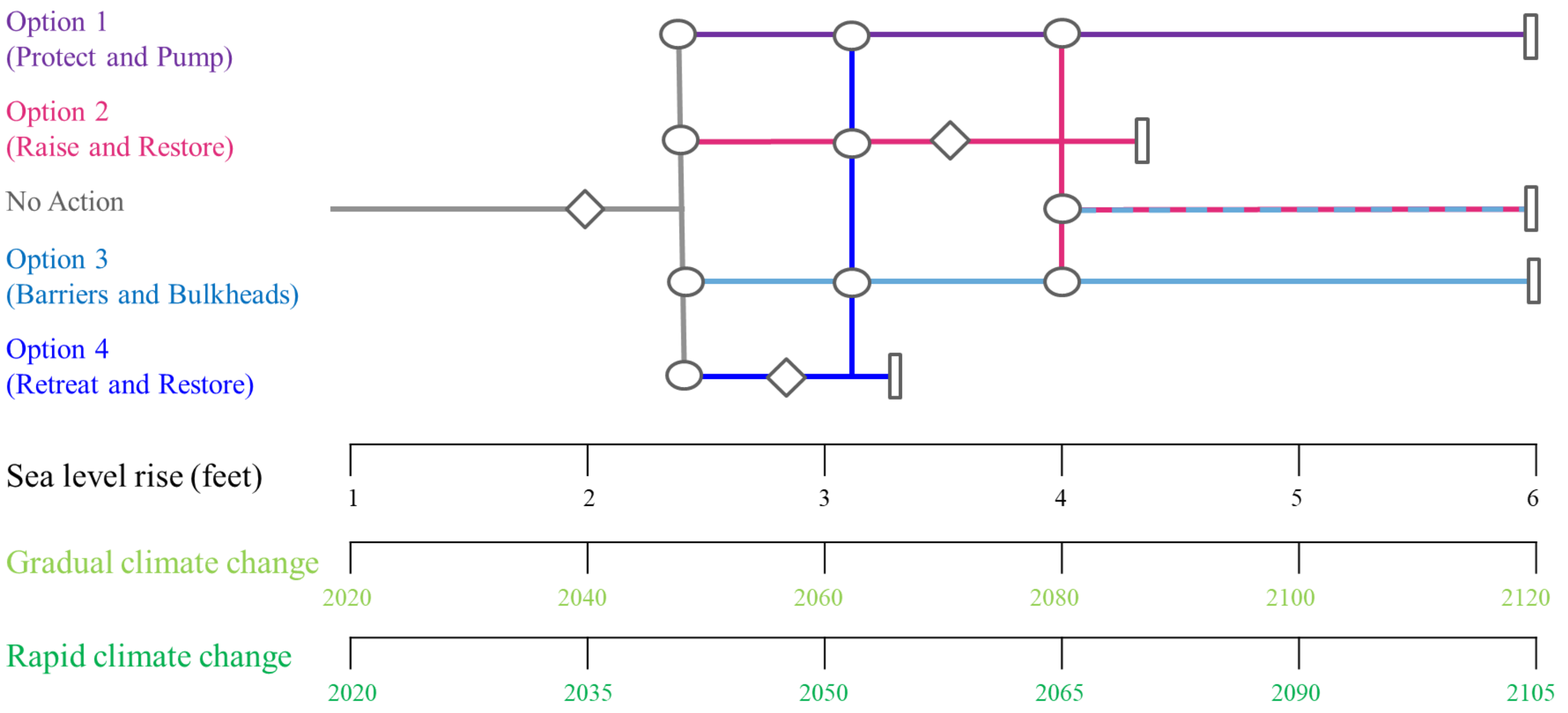
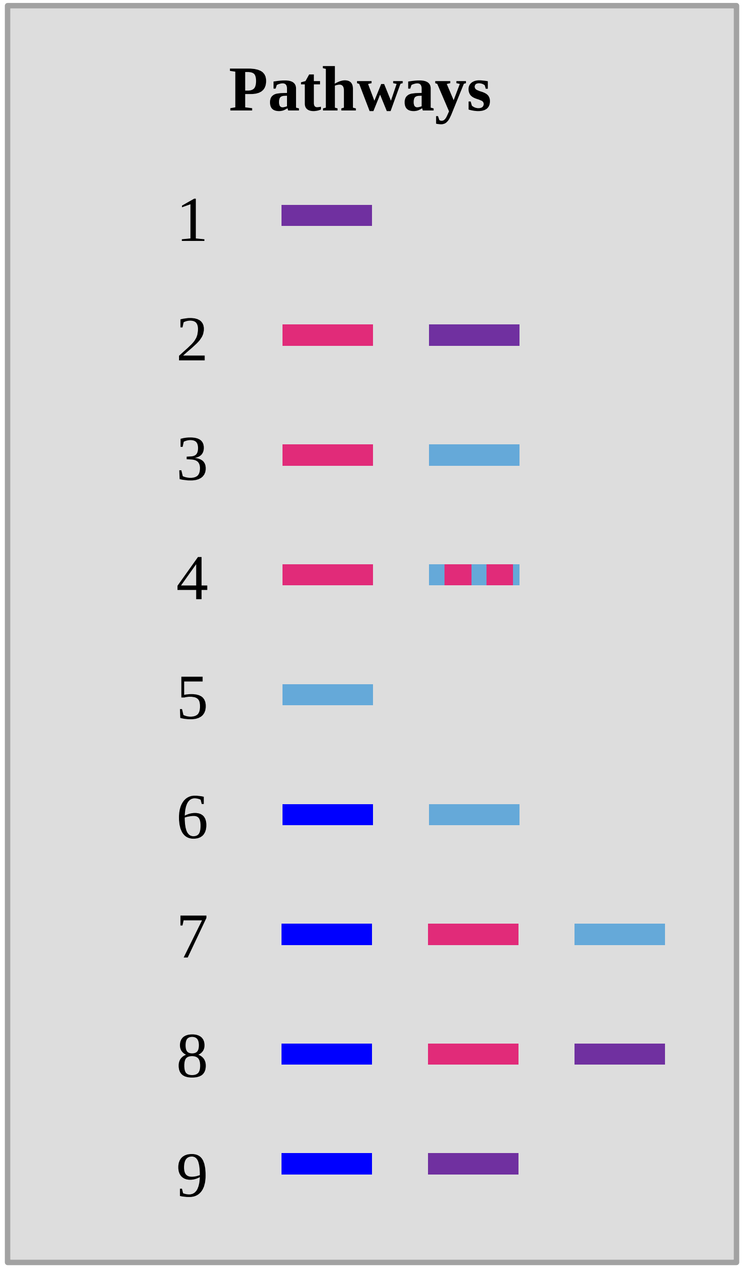
Flexible Adaptation Pathways





Adaptation Trigger

Transfer station

Tipping Point

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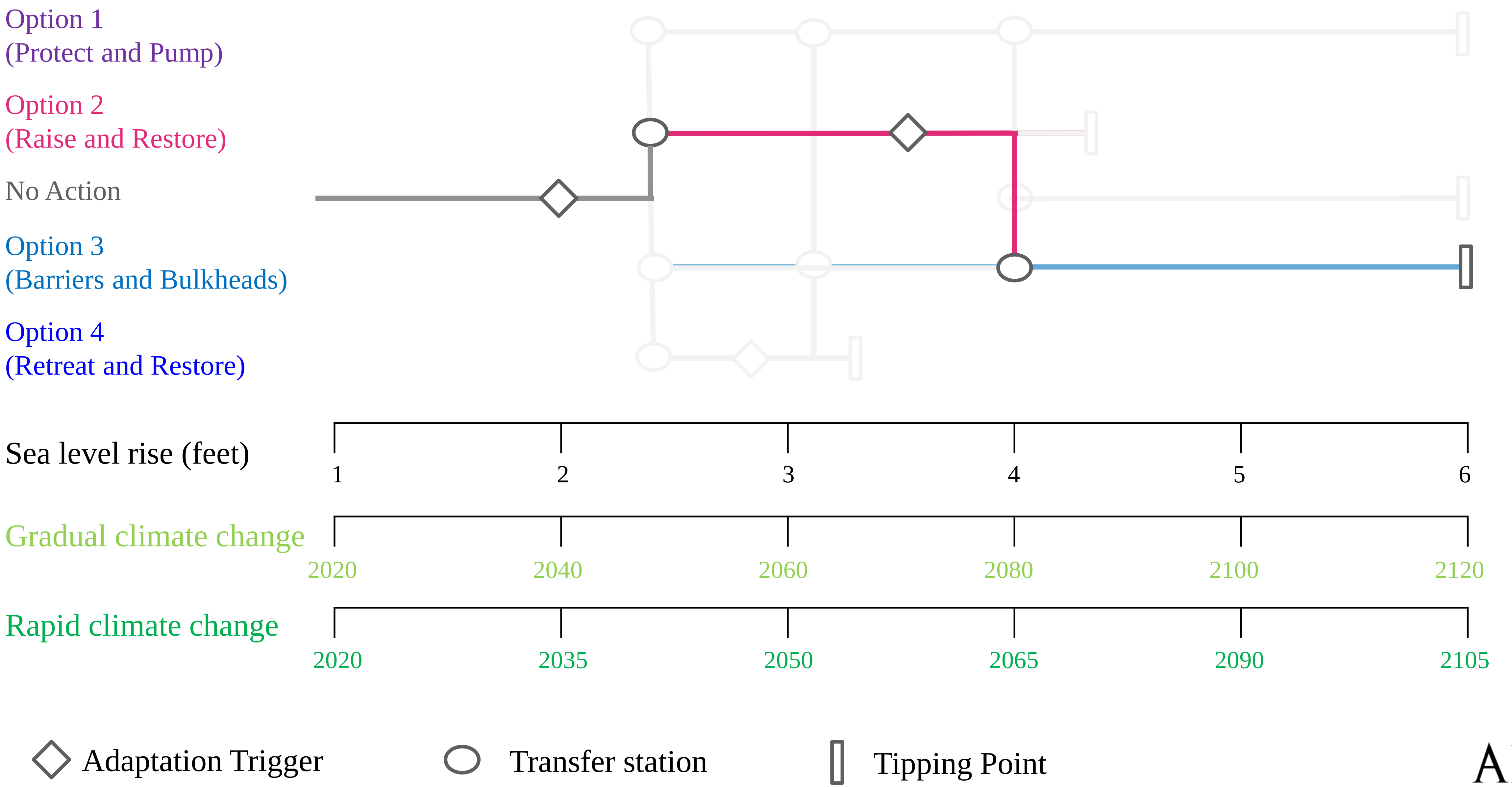
Flexible Adaptation Pathways – Evaluate (Near-Term)

Pathways	Costs	Benefits	Net Present Value
1	- - - -	+ + +	$
2	- - - - -	+ + + +	$ $ $
3	- - -	+ + + + +	$ $ $ $ $
4	- - - -	+ + + + +	$ $ $ $
5	- - -	+ + +	$
6	- - - -	+ +	$ $ $
7	- - - - -	+ + +	$ $
8	- - - - - -	+ + + +	$
9	- - - - -	+ +	$

Flexible Adaptation Pathways - Selection

Pathways	Costs	Benefits	Net Present Value
1	- - - -	+ + +	$
2	- - - - -	+ + + +	$ $ $
3	- - -	+ + + + +	$ $ $ $ $
4	- - - -	+ + + + +	$ $ $ $
5	- - -	+ + +	$
6	- - - -	+ +	$ $ $
7	- - - - -	+ + +	$ $
8	- - - - - -	+ + + +	$
9	- - - - -	+ +	$

Flexible Adaptation Pathway – Hypothetical



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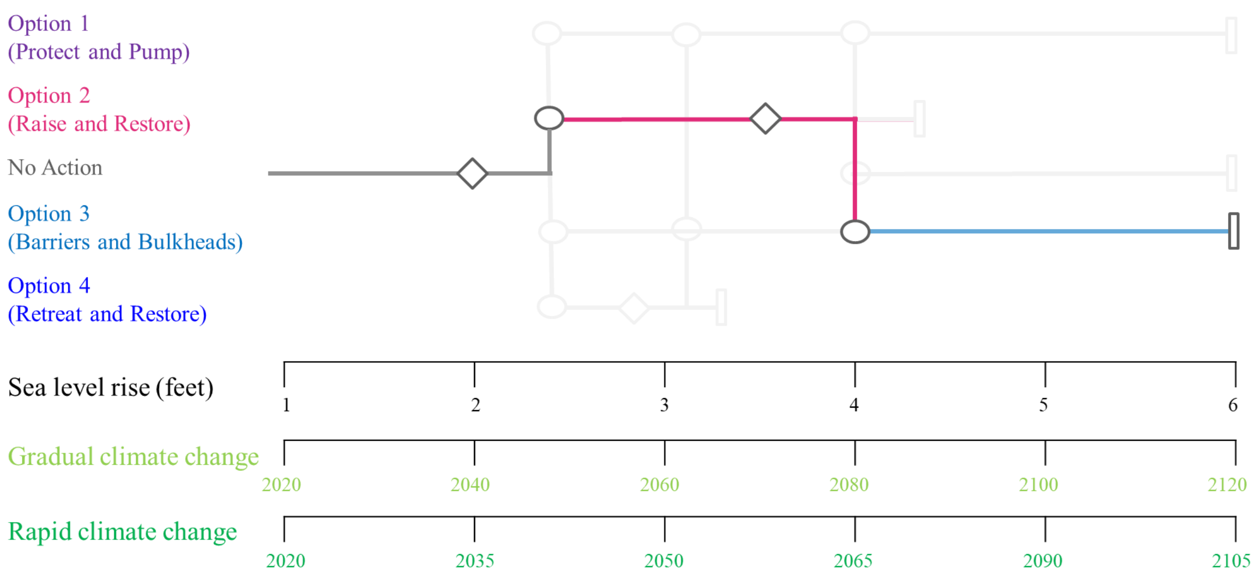
Flexible Adaptation Pathway



Core Findings (Hypothetical)

- Port and waterfront parcels require protection in all scenarios (no-regrets solution)
- Raising parcels is ineffective as a standalone solution (eventual transfer essential)
- Implementing seawalls or tide barriers too early could be economically inefficient
- Restoration combined with protection leads to co-benefits and high NPV
- Upfront costs of hard infrastructure can be deferred but only temporarily
- Early commitment to protection or retreat focused options promote path-dependence

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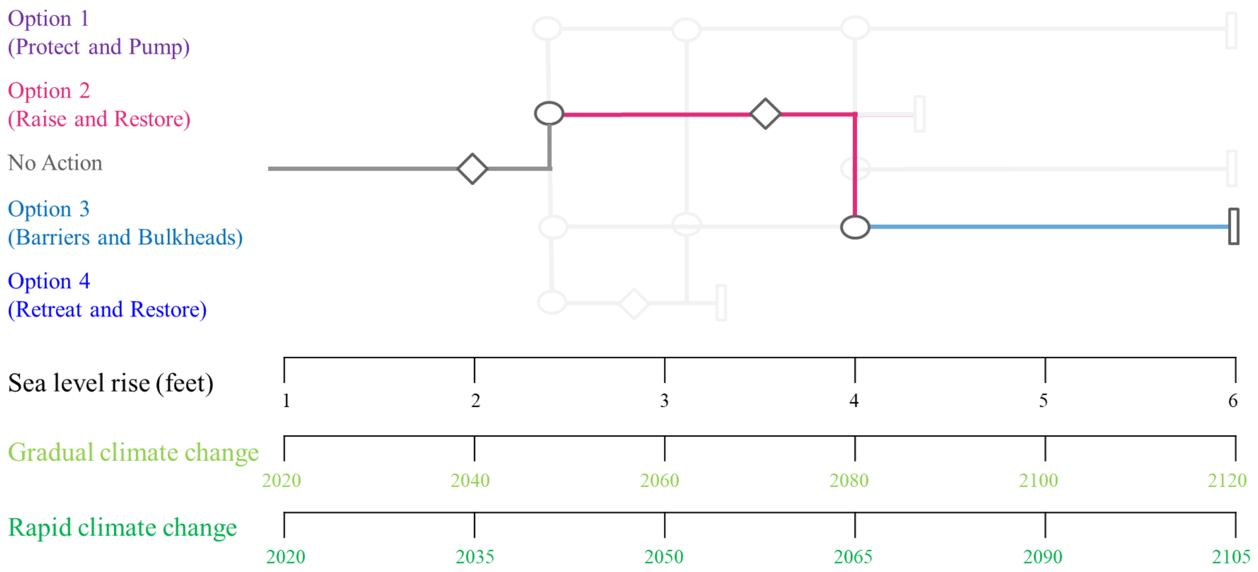
Flexible Adaptation Pathway



Trigger	Action (Hypothetical)
SLR 1ft *2020-2030*	• Initiate comprehensive flexible adaptation pathways study
SLR 2ft *2030-2040*	• Raise all waterfront parcels • Restore lower Iwilei wetland
SLR 3ft *2040-2060*	• Install pump stations
SLR 4ft *2060-2080*	• Construct tidal barriers • Reinforce waterfront bulkheads
SLR 5ft *2070-2100*	• Monitoring
SLR 6ft *2080-2120*	• Evaluate future plans

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Flexible Adaptation Pathways - Benefits

- Providing flexibility to adapt infrastructure planning to uncertain climate change outcomes
- Avoiding lock-in decisions and identifies near-term ‘no regret’ options
- Clearly outlining future decision (trigger) points for investment
- Presenting approachable framework for cost-benefit analysis
- Mapping out achievable pathways towards successful future outcomes

‘Real’ Recommendations for Implementation (2020-2030)

- Conduct demonstration study focusing on large scale flood infrastructure needs
- Develop initial suite of ‘real options’ - fitted with flexibility to adapt to future change
- Flood *risk* study required for cost-benefit analysis of ‘real options’
- Map out realistic timing, thresholds, tipping points for decisions
- Pre-work for various adaptation pathways include may include technical studies for groundwater, coastal flooding, and sea level rise

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Extreme Heat

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The Washington Post
Democracy Dies in Darkness

Capital Weather Gang • Analysis

Inside Hawaii's wild summer of broken high-temperature records

Honolulu set 29 record highs. Lihue tied or broke record highs 20 days in a row.


The sun sets behind telescopes at the summit of Mauna Kea on the Big Island on July 14. (Caleb Jones/AP)

By **Matthew Cappucci** and **Ryan Saunders**
September 26, 2019 at 1:13 p.m. PDT

Tying or breaking a record high temperature is impressive. Doing it several d
do it 20 days in a row? That's unheard of.

But not this year in Hawaii. The Aloha State just wrapped up probabl
left and right and over and over again. It's yet another location fe

Honolulu has seen 45 days with record highs so far this year,
equivalent of more than two record highs every week. Begi
days.

But even more impressive have been the nighttime
degrees. This year has featured 19 such nights.
lows has helped 2019 claim the top spot for
and third place in the process, while tyin

Honolulu also hit 95 degrees on the final day
in more than a century of bookkeeping, as well as

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Hawaii's Heat Wave Is Breaking Record Highs

BY EVIE CARRICK | JUNE 21, 2019


PHOTO: GETTY IMAGES

Part of what makes Hawaii so great is its warm, temperate weather — daytime temperatures typically average between 78 to 85 degrees. However, this spring has been off the charts — literally. In May and June, a Hawaiian heat wave has led to record-high temperatures across the state.

This week, the weather service recorded a high of 91 degrees in Honolulu, which broke the 1995 record of 90 degrees for the date, the Associated Press reported. In Kahului, a high of 92 degrees tied a record set in 1969.

Each of the seven days prior also saw temperature ties and record highs. And

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Challenge

- Infrastructure is ***capital-intensive*** and ***long-lived***

- ***Uncertainty*** in how the future may unfold due ***climate*** and ***socio-economic*** conditions

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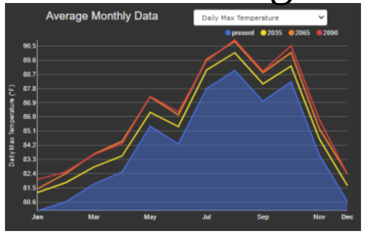
Planning for uncertainty in how much and how fast the heat will rise…

+1 F
(August)

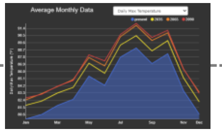
time and rate of change

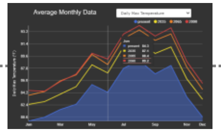
+8 F
(August)

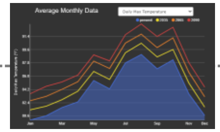
Low warming

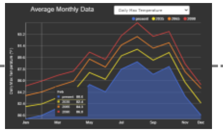


RCP4.5 10% percentile

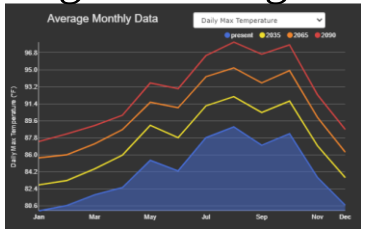








High warming



RCP8.5 95% percentile

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Planning for uncertainty in how much and how fast the heat will rise…

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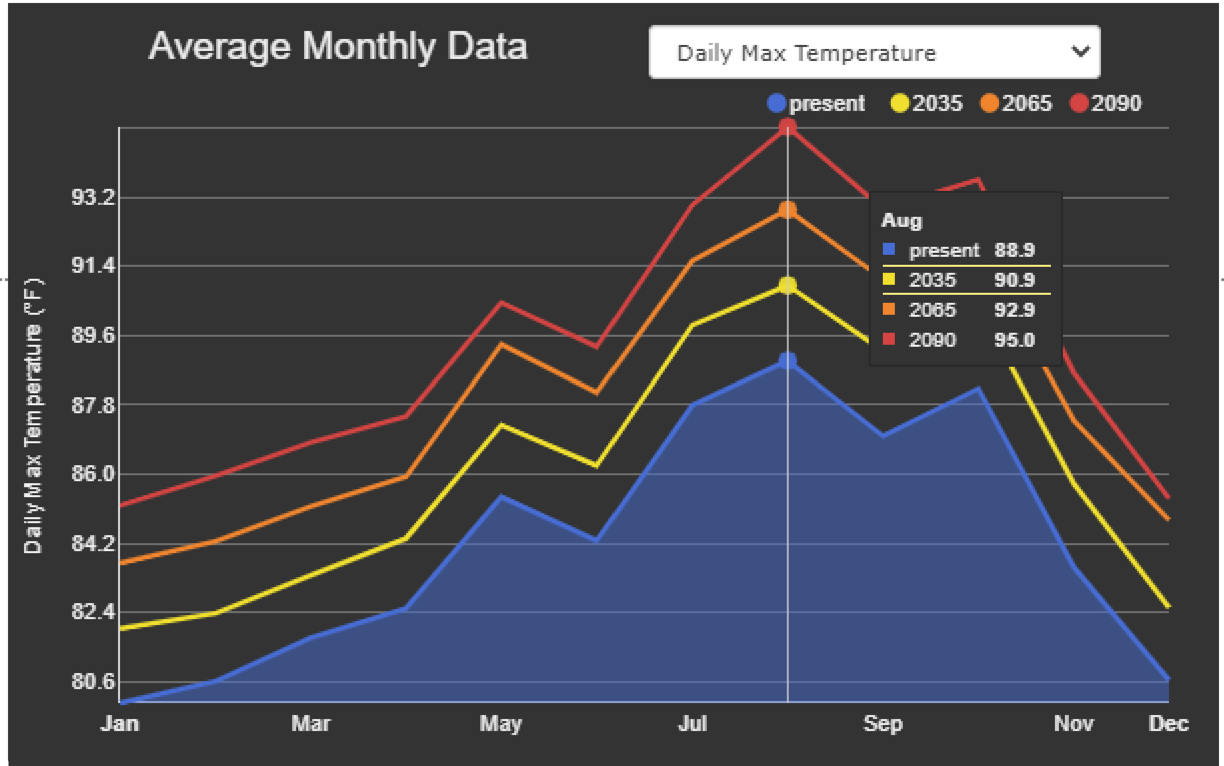
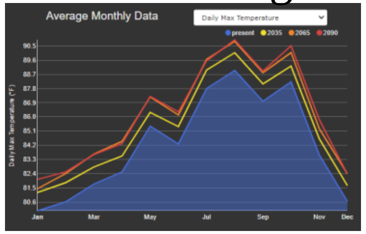


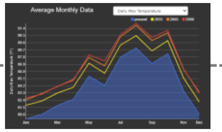
Source: WeatherShift.com, Honolulu, HI

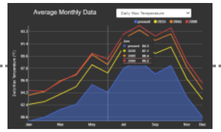
+8 F
(August)

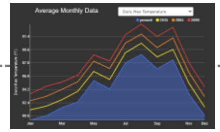
Low warming

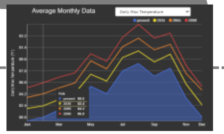


RCP4.5 10% percentile

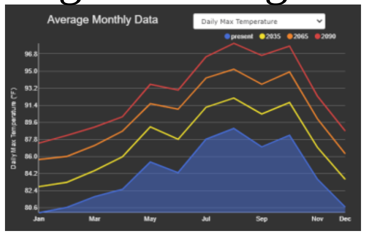








High warming



RCP8.5 95% percentile

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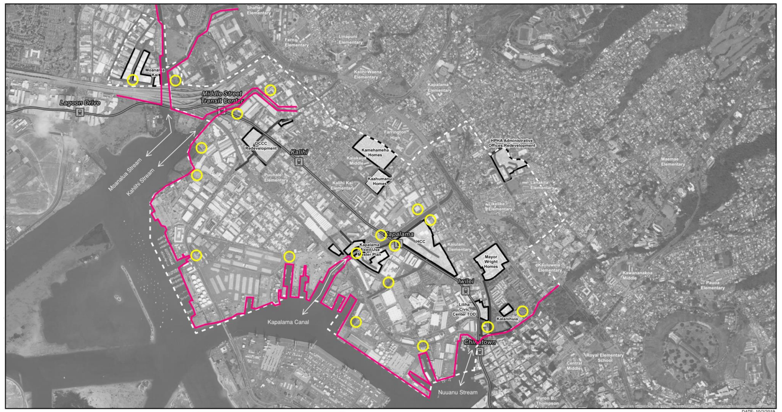
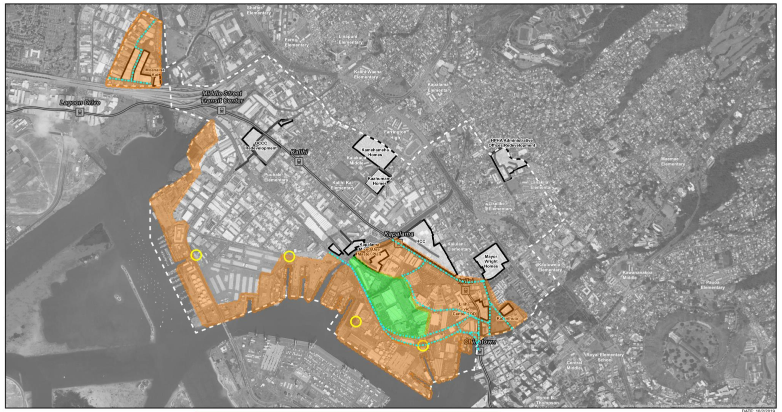
Just as there are SLR options,



Legend
- Future Rail Stations
- Future Rail Line
- State TOD Projects
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades
- Upgraded Seawall
- Future Pump Stations

Option 1
PROTECT AND PUMP



Legend
- Future Rail Stations
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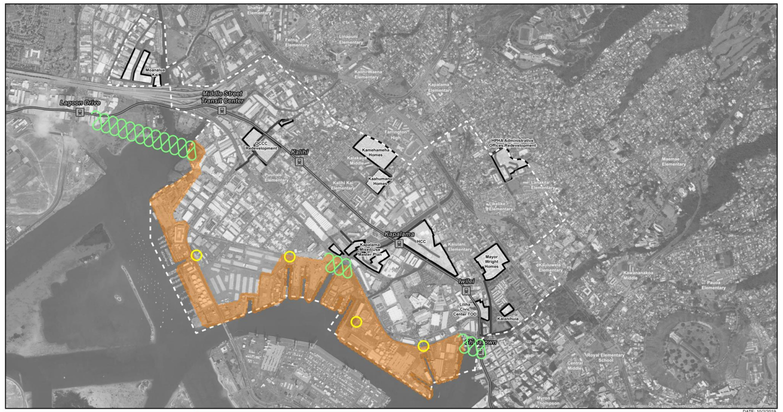
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades
- Upgraded Port Seawall
- Future Pump Stations
- Elevated Roadway
- Future Raised Development Area
- Future Restored Wetland Area

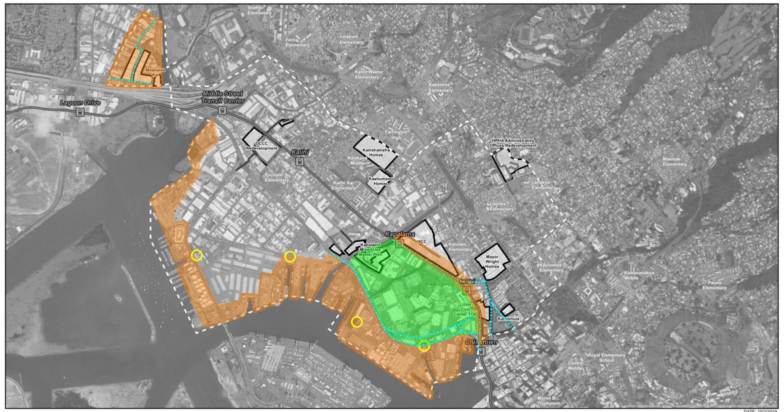
Option 2
RAISE AND RESTORE



Legend
- Future Rail Stations
- Future Rail Line
- State TOD Projects
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades
- Future Raised Development Area
- Tidal Barrier
- Future Pump Stations

Option 3
BARRIERS AND BULKHEADS



Legend
- Future Rail Stations
- Future Rail Line
- State TOD Projects
- New Sewer Lines
- Upgraded Sewer Lines
- New Water Lines
- Upgraded Water Lines

Long-Term Upgrades
- Upgraded Port Seawall
- Future Pump Stations
- Elevated Roadway
- Future Raised Development Area
- Future Restored Wetland Area

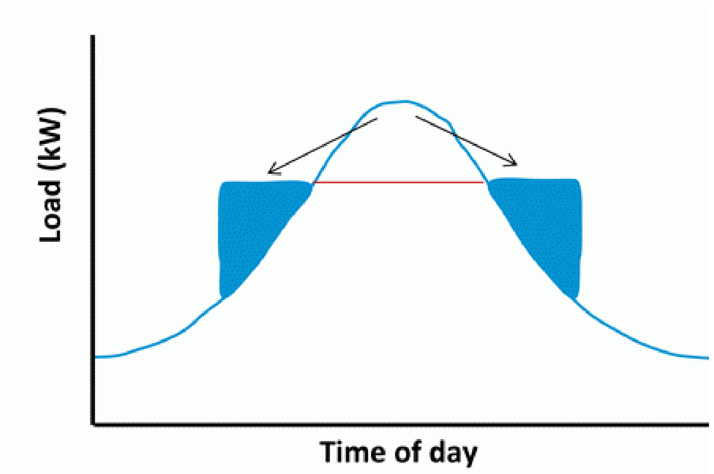
Option 4
RETREAT AND RESTORE

there are heat mitigation options.

Decentralized Air Conditioning

Passive Design

District Cooling



Load Shifting

FAP options aligned to an objective

Option 1
(Decentralized AC)

Option 2
(Passive Design)

No Action

Option 3
(District Cooling)

Option 4
(Load Shifting)

Objective: Ensure adequate infrastructure capacity and *extreme heat protection* through 2100

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with triggers, timing, and thresholds

Option 1
(Decentralized AC)

Option 2
(Passive Design)

No Action

Option 3
(District Cooling)

Option 4
(Load Shifting)

<u>Objective</u>: Ensure adequate infrastructure capacity and *extreme heat protection* through 2100

Temperature Rise (F)	1	2.5	4	5.5	7	8.5
Gradual climate change	2020	2040	2060	2080	2100	2120
Rapid climate change	2020	2030	2040	2050	2060	2070

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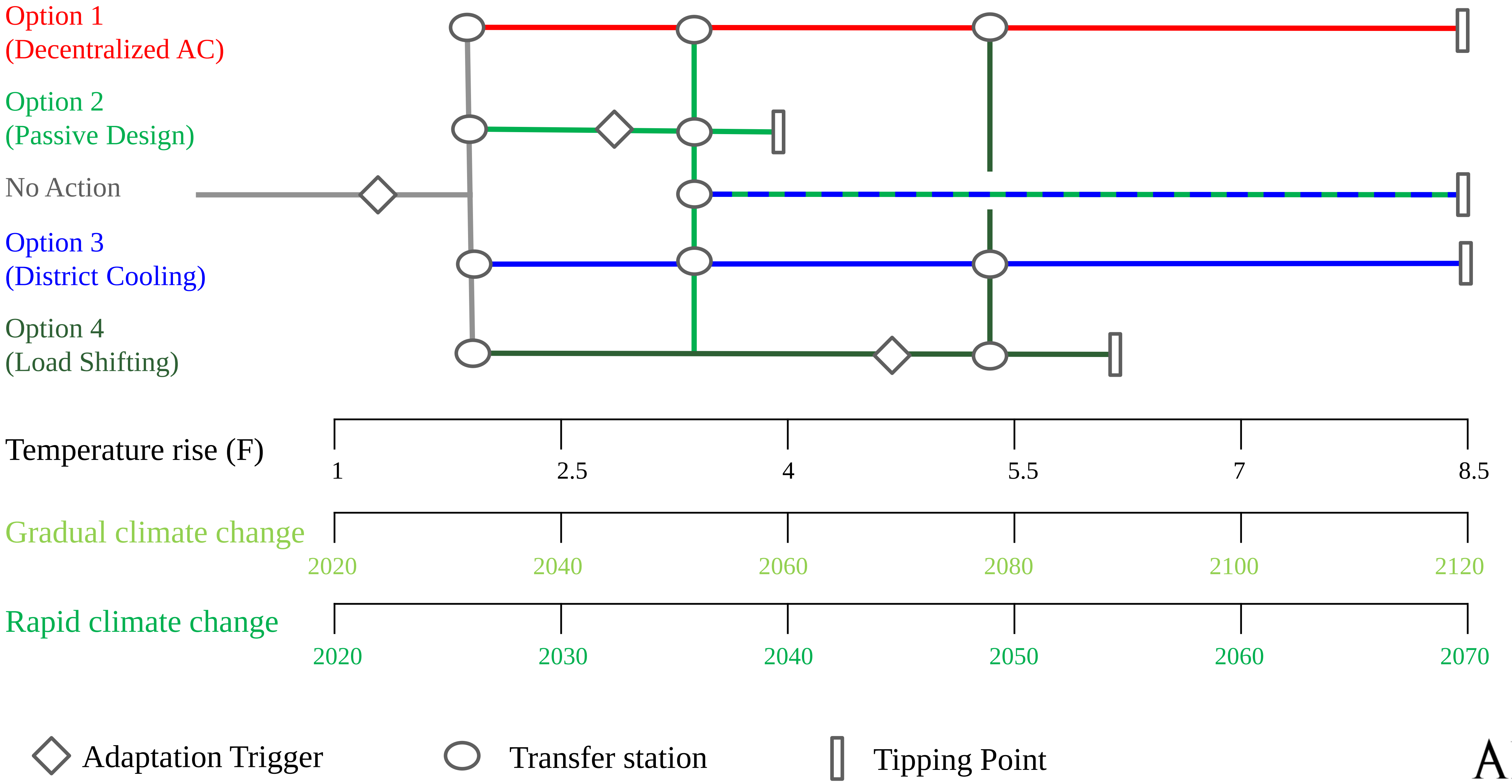
and a FAP Map enabling decisions over time



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Flexible Adaptation Pathways – Evaluated

Pathways	Costs	Benefits	Net Present Value
1	- - - - - -	+ +	$
2	- - - - - -	+ + + +	$ $ $
3	- - - -	+ + + + +	$ $ $ $
4	- - -	+ + + + +	$ $ $ $ $
5	- - - -	+ + + +	$ $
6	- - - -	+ + + +	$ $ $
7	- - -	+ + + +	$ $ $ $
8	- - - - - -	+ + + +	$ $ $ $
9	- - - -	+ +	$ $

Flexible Adaptation Pathways – Prioritized

Pathways	Costs	Benefits	Net Present Value
1	- - - - -	+ +	$
2	- - - - -	+ + + +	$ $ $
3	- - - -	+ + + + +	$ $ $ $
4	- - -	+ + + + +	$ $ $ $ $
5	- - - -	+ + + +	$ $
6	- - - -	+ + + +	$ $ $
7	- - -	+ + + +	$ $ $ $
8	- - - - -	+ + + +	$ $ $ $
9	- - - -	+ +	$ $

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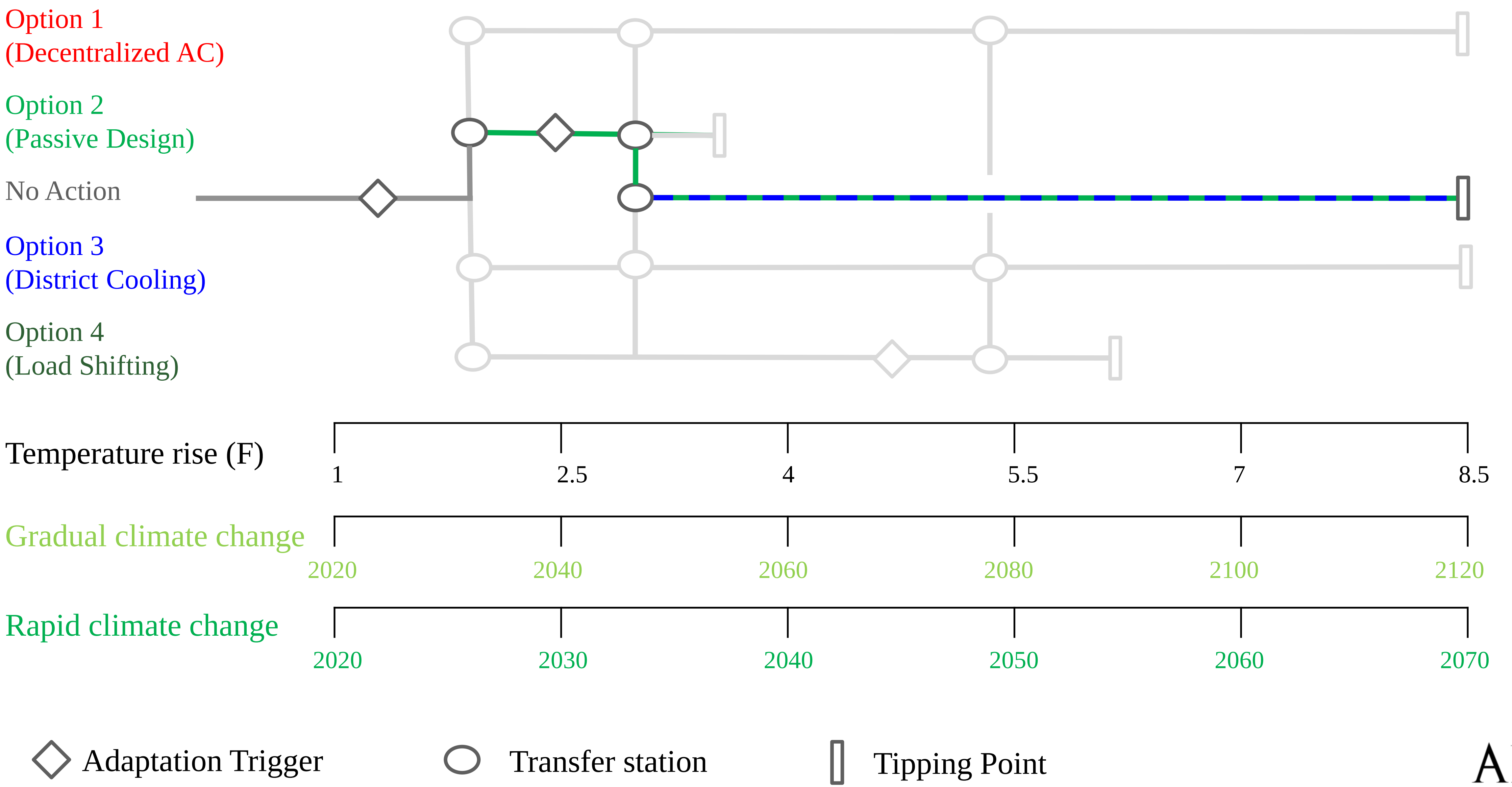
Flexible Adaptation Pathway – Selected (Hypothetical)



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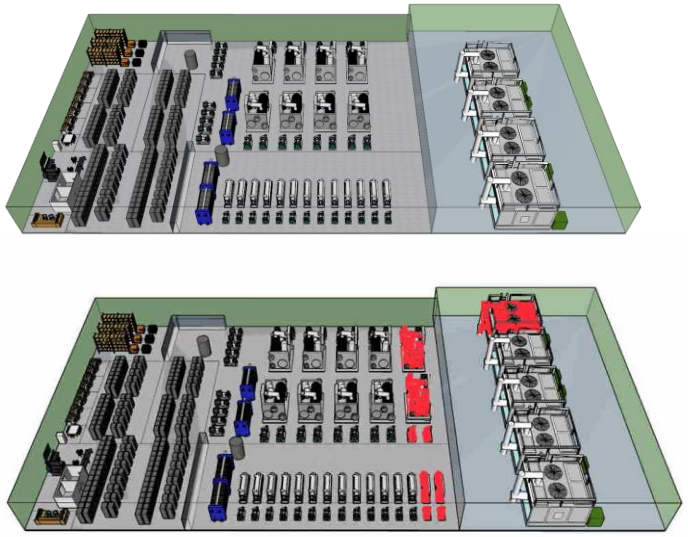
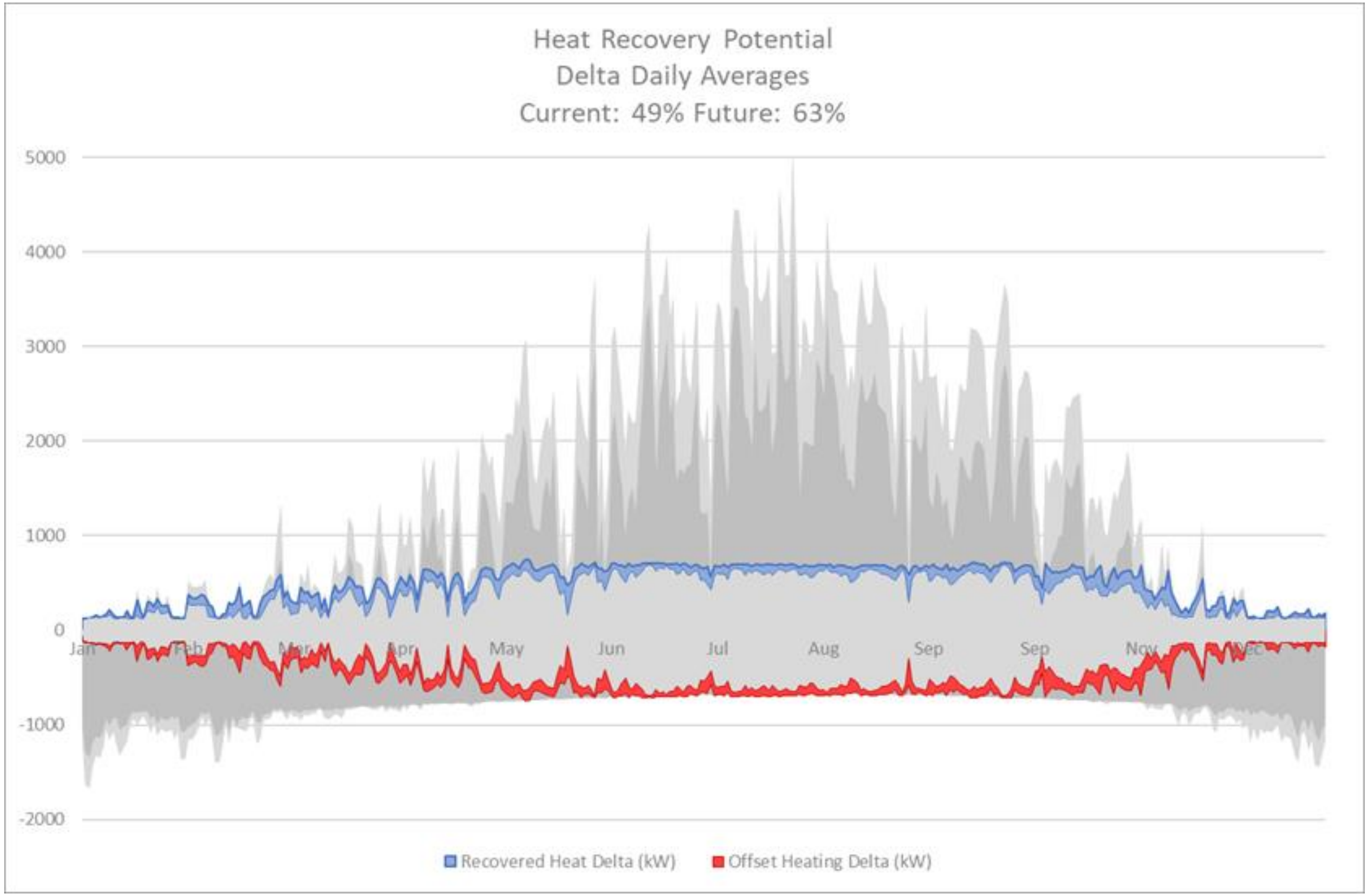
Enabling “No-Regret” Climate Safe Solutions



Modular Expansion Potential

Community Beneficial



Community Scale Heat Sharing: Over time the system is optimized to perform ever better

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Flexible Adaptation Pathways

An approach to Coastal Flooding and Extreme Heat

State Climate Change Commission Meeting – 28 October 2020

Through the Lens of Iwilei-Kapalama and Heat Wave of 2019

Jack Hogan, PE
Jack-W.Hogan@arup.com

Cole Roberts, PE
Cole.Roberts@arup.com

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