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
Objectives

- Describe Flexible Adaptation Pathways
- Demonstrate appropriateness for infrastructure intensive planning projects in Hawaii
- Highlight key benefits and recommendations for implementation
**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 UScipl, as well as existing residents with park-and-ride facilities and a bus transit service. The UH-West Oahu 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.

**WAIANA / 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 Hawaii in conjunction with new TOD, which may include housing, hotels, offices, retail, entertainment, and sports-related uses. There are also plans underway to extend the Pearl Harbor Historic Trail to this station area to improve regional bicycle access.

**HIALAWA / AIEA - PEARL CITY**
With its existing resources and destinations, the Aiea-Pearl City area serves as a keystone to the island's TOD plans. With TOD, Pearl City Community College could become more than just a daytime campus, and Pearlridge and Pearl Highlands Station areas could become flexible 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 living in the area.

**KALIHI**
While the Kalihi Station area will likely remain stable following the introdution of rail transit, the Middle Street and Kapilama Station areas have great potential for transformation with projects underway such as the State's modernization of OCCC and the revitalization of Kapilama Canal. The Kapilama/Waikiki 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 ongoing development and ongoing 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 Waikiki Station area will see significant shifts from existing industrial/commercial uses to more residential and mixed-use opportunities. The redevelopment of Mayor Wright Houses, 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. The 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 Waikiki and the University of Hawaii at Manoa.

**CIVIC CENTER / KAKAKO**
The neighborhood around the Civic Center and Kapalama Business District is under the jurisdiction of the Hawaii Community Development Authority (HCDA). TOD in this area is planned as high-rise mixed-use development to support Oahu'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
Challenge

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

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

- *Uncertainty* in how the future may unfold due *climate* and *socio-economic* conditions
Infrastructure Needs Assessment - Existing

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<th>Plans Outlined</th>
<th>Costs Estimated</th>
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Work in Progress:
- East Kapolei
- Halawa Stadium
- Iwilei Kapalama
(Proposed) Large scale flood infrastructure needs considered for TOD areas

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

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Tidal flooding – 4ft SLR
Iwilei-Kapalama District

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

- 6.0 ft of SLR
- 3.2 ft of SLR
- 2 ft of SLR

HIGH SCENARIO
INTERMEDIATE SCENARIO

Downstream Water Level
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

(Dessai and Hulme, 2007; Dessai and Van der Sluijs, 2007; Hallegatte et al., 2012).
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).
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)
Objective: Ensure adequate infrastructure capacity and *flood protection* for TOD area investments *through 2100*
Infrastructure concept – for demonstration purposes only

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

Seawall $427,950,000
Pump Stations $270,000,000
Total $837,540,000
Infrastructure concept – for demonstration purposes only

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

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<td>Pump Stations</td>
<td>$60,000,000</td>
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<td>Raise Roadways</td>
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<td><strong>Total</strong></td>
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Infrastructure concept – for demonstration purposes only

*Baseline Infrastructure Cost ~$1,579,100,000*
Infrastructure concept – for demonstration purposes only

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

**Objective**: Ensure adequate infrastructure capacity and flood protection for TOD area investments through 2100
Flexible Adaptation Pathway - Map

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers andBulkheads)

Option 4
(Retreat and Restore)

Sea level rise (feet)

Gradual climate change

Rapid climate change

Adaptation Trigger
Transfer station
Tipping Point
Flexible Adaptation Pathways

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers and Bulkheads)

Option 4
(Retreat and Restore)

Sea level rise (feet)

Gradual climate change

Rapid climate change
### Flexible Adaptation Pathways – Evaluate (Near-Term)

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Flexible Adaptation Pathway – Hypothetical

Option 1
(Protect and Pump)

Option 2
(Raise and Restore)

No Action

Option 3
(Barriers and Bulkheads)

Option 4
(Retreat and Restore)

Sea level rise (feet)

Gradual climate change

Rapid climate change

Adaptation Trigger

Transfer station

Tipping Point
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
## Flexible Adaptation Pathway

<table>
<thead>
<tr>
<th>Trigger</th>
<th>Action (Hypothetical)</th>
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<tr>
<td>SLR 1ft 2020-2030</td>
<td>• Initiate comprehensive flexible adaptation pathways study</td>
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</tbody>
</table>
| 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 |

**Option 1** (Protect and Pump)  
**Option 2** (Raise and Restore)  
**No Action**  
**Option 3** (Barriers and Bulkheads)  
**Option 4** (Retreat and Restore)  
**Sea level rise (feet):** 1, 2, 3, 4, 5, 6  
**Gradual climate change:** 2020, 2040, 2060, 2080, 2090, 2100  
**Rapid climate change:** 2020, 2035, 2050, 2065, 2090, 2105
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
Extreme Heat
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.

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 days in a row? That’s unheard of.

But not this year in Hawaii. The Aloha State just wrapped up probably the most extreme heat wave to hit the state in over 100 years.

Honolulu has seen 45 days with record highs so far this year, equivalent of more than two record highs every week. By comparison, the previous record was 27 days with record highs in 2015.

But even more impressive have been the nighttime temperatures. This year has featured 19 such nights, more than any other year in records. Lihue has also had a record-breaking summer. The city saw record highs for 20 days in a row, and nightly temperatures typically average between 78 to 85 degrees. However, this spring has been off the charts — literally. In May, which is normally the warmest month of the year in Hawaii, it was the only one that wasn’t.

This week, the weather service recorded a high of 91 degrees in Honolulu, which broke the 1933 record of 89 degrees for the date, tied a record set in 1969. Lihue also hit 91 degrees on the first day of July, more than a century of record-setting, as well as the 2015 record of 91 degrees.

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.

Hawaii’s Heat Wave Is Breaking Record Highs

By JON MARKOFF
June 25, 2019

The Associated Press
Challenge

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

• *Uncertainty* in how the future may unfold due *climate* and *socio-economic* conditions
Planning for uncertainty in how much and how fast the heat will rise...

+1 F (August)

Low warming

RCP4.5 10% percentile

Time and rate of change

High warming

RCP8.5 95% percentile

+8 F (August)
Planning for uncertainty in how much and how fast the heat will rise…

+1 F (August)

+8 F (August)

Low warming
RCP4.5 10% percentile

High warming
RCP8.5 95% percentile

Source: WeatherShift.com, Honolulu, HI
Just as there are SLR options,
there are heat mitigation options.
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
with triggers, timing, and thresholds

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

Option 1
(Decentralized AC)

Option 2
(Passive Design)

No Action

Option 3
(District Cooling)

Option 4
(Load Shifting)

**Temperature Rise (F)**

- **Gradual climate change**
  - 2020: 1
  - 2040: 2.5
  - 2060: 4
  - 2080: 5.5
  - 2100: 7
  - 2120: 8.5

- **Rapid climate change**
  - 2020: 1
  - 2030: 2.5
  - 2040: 4
  - 2050: 5.5
  - 2060: 7
  - 2070: 8.5
and a FAP Map enabling decisions over time

Option 1
(Decentralized AC)

Option 2
(Passive Design)

No Action

Option 3
(District Cooling)

Option 4
(Load Shifting)

Temperature rise (F)

Gradual climate change

Rapid climate change

Adaptation Trigger

Transfer station

Tipping Point
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## Flexible Adaptation Pathways – Prioritized

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Flexible Adaptation Pathway – Selected (Hypothetical)

Option 1
(Decentralized AC)

Option 2
(Passive Design)

No Action

Option 3
(District Cooling)

Option 4
(Load Shifting)

Temperature rise (F)

Gradual climate change

Rapid climate change

Adaptation Trigger
Transfer station
Tipping Point
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
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

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