THE WORLD BANK

Building Resilience in Pacific Atoll Island Countries

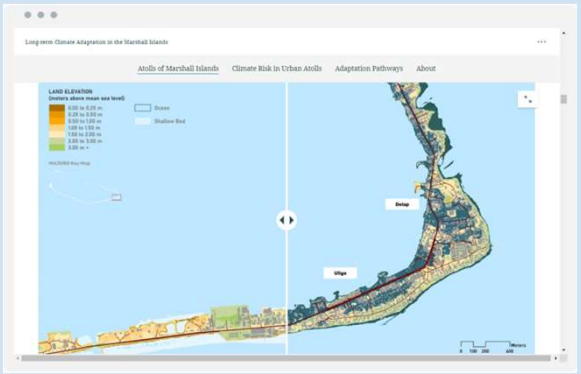
Adapting to Rising Sea Levels in the Marshall Islands

Artessa Saldivar-Sali
Senior Municipal Engineer
World Bank

1

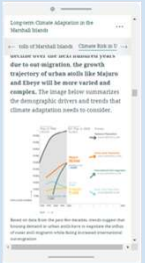
Overview of *Adapting to Rising Sea Levels in the Marshall Islands*

https://www.youtube.com/watch?v=iHPUDwfKy4k



Three chapters with the following objectives:

1. **'Ad jolet jen Anij': Atolls of the Republic of Marshall Islands** introduces the context of RMI and an overview of SLR impacts
2. **Climate Risk in the Urban Atolls of Majuro and Ebeye** highlights the significance of urban atolls and the hazards faced by communities under various SLR scenarios
3. **Adaptation Pathways: Building a Resilient Future** summarizes the adaptation pathways available to RMI's urban atolls and their resilience to different SLR intervals



2

TARGET AUDIENCE	GUIDING QUESTIONS
Global (COP26/Donors) 	How does SLR impact RMI's urban atolls? What are RMI's viable pathways under various climate scenarios?
GoRMI Decision-Makers (Cabinet) 	What are effective adaptation pathways? How do pathways address SLR impact on housing and potential land loss?
Local Community 	What SLR impacts do urban neighborhoods face? What adaptation options do communities have?

3

1. POSITIONING RMI

4

Back then we would experience flooding every few years. Now we experience flooding every year.

We have lived here for 40 years, but if things get worse we will consider moving back to Namo atoll.

Hones Nenam, 71
showing the level of water from the last king tide that flooded his home

5

4
Atoll Nations

are at the forefront of this planetary threat.

As low-lying nations with entire cities and villages built along the coast, residents of atoll nations have adapted their cultures and livelihoods around the ocean.

The way of life across four atoll countries are threatened by sea level rise and other impacts of climate change.

By the end of this century, these atolls may be significantly or entirely submerged.

1. REPUBLIC OF MARSHALL ISLANDS
2. Kiribati
3. Tuvalu
4. Maldives (Indian Ocean)

6

14
Pacific Island Countries

and atoll nations are collectively working on long-term adaptation plans to respond to the impact of sea level rise.

REPUBLIC OF MARSHALL ISLANDS
Kiribati
Tuvalu
Cook Islands
Fiji Islands
Federated States of Micronesia
Nauru
Palau
Papua New Guinea
Solomon Islands Tonga
Samoa
Timor-Leste
Vanuatu

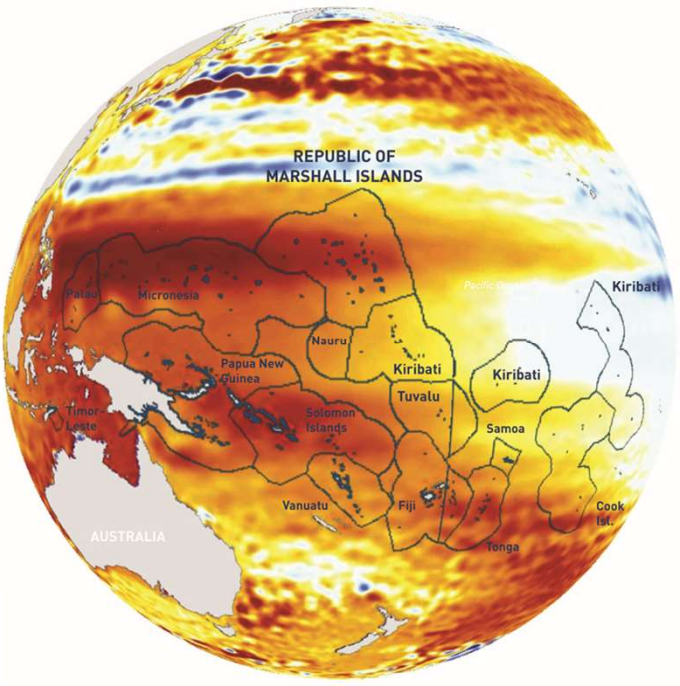
7

Accelerated
Sea Level Rise

As low-lying atolls in the Pacific, the Marshall Islands will be one of the first to face sea level rise as an existential threat.

Satellite observations from the last two decades have shown sea level rising faster in the Northern Pacific ocean.

Between 1993-2012, sea level rise rates around the Pacific Islands were about
three times greater
than the global mean value.

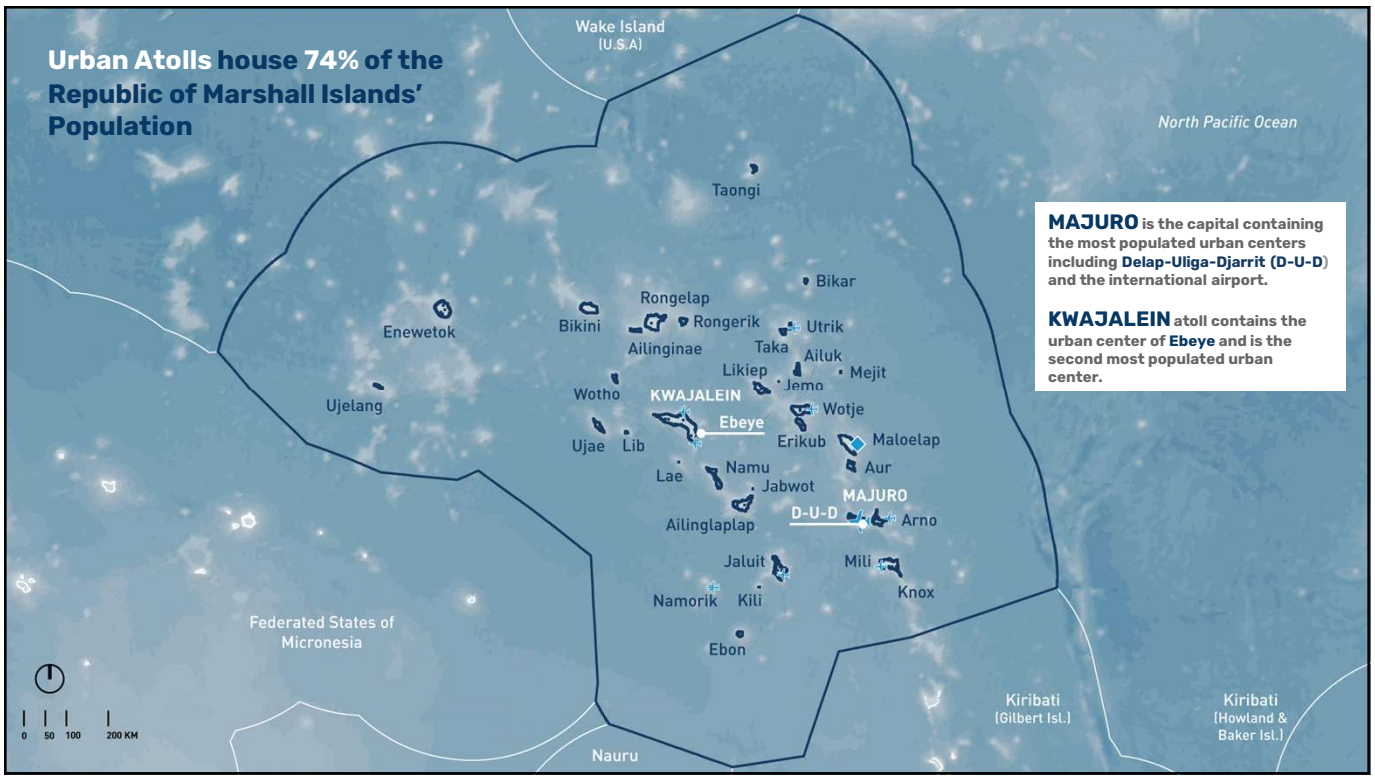


22-YEAR SEA SURFACE HEIGHT CHANGE (1992-2014)

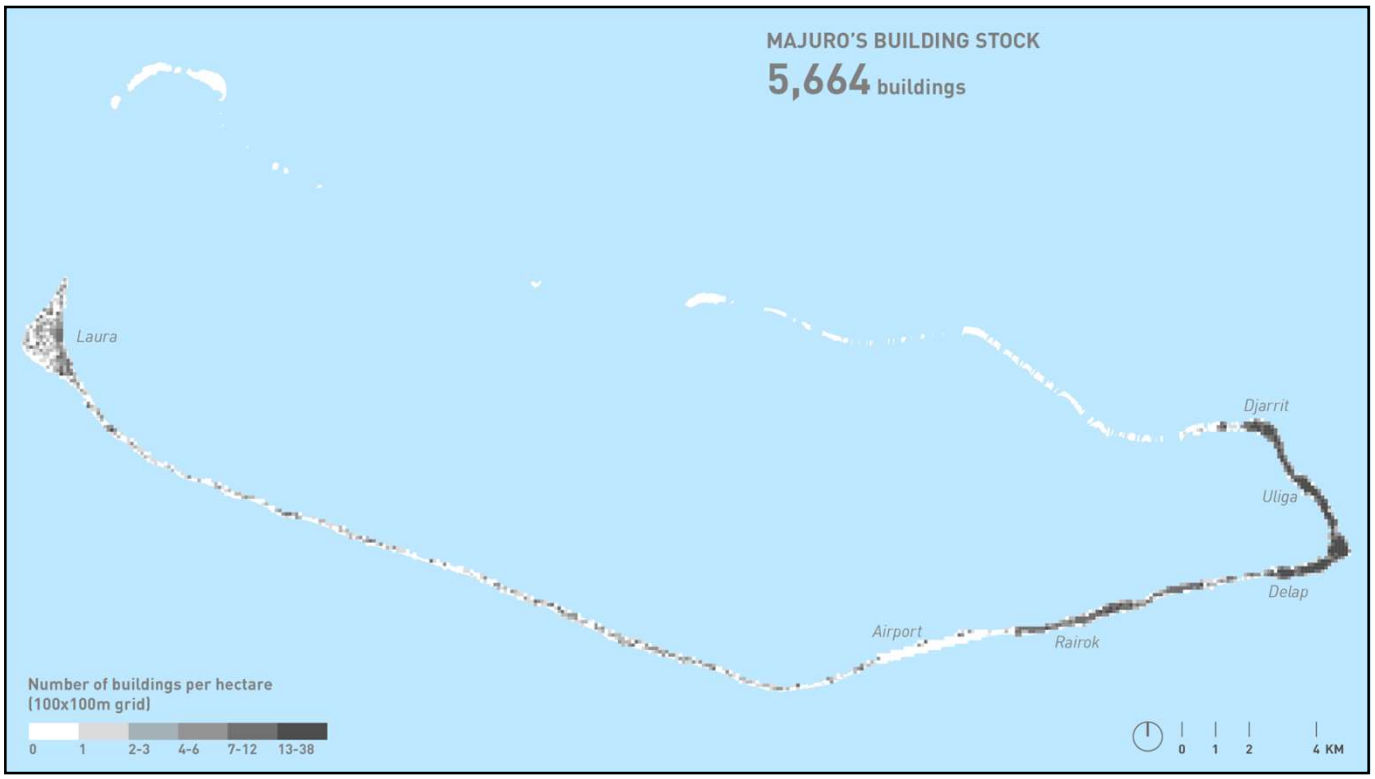
-7.0cm 0 +7.0cm

Source: NASA Scientific Visualization Studio

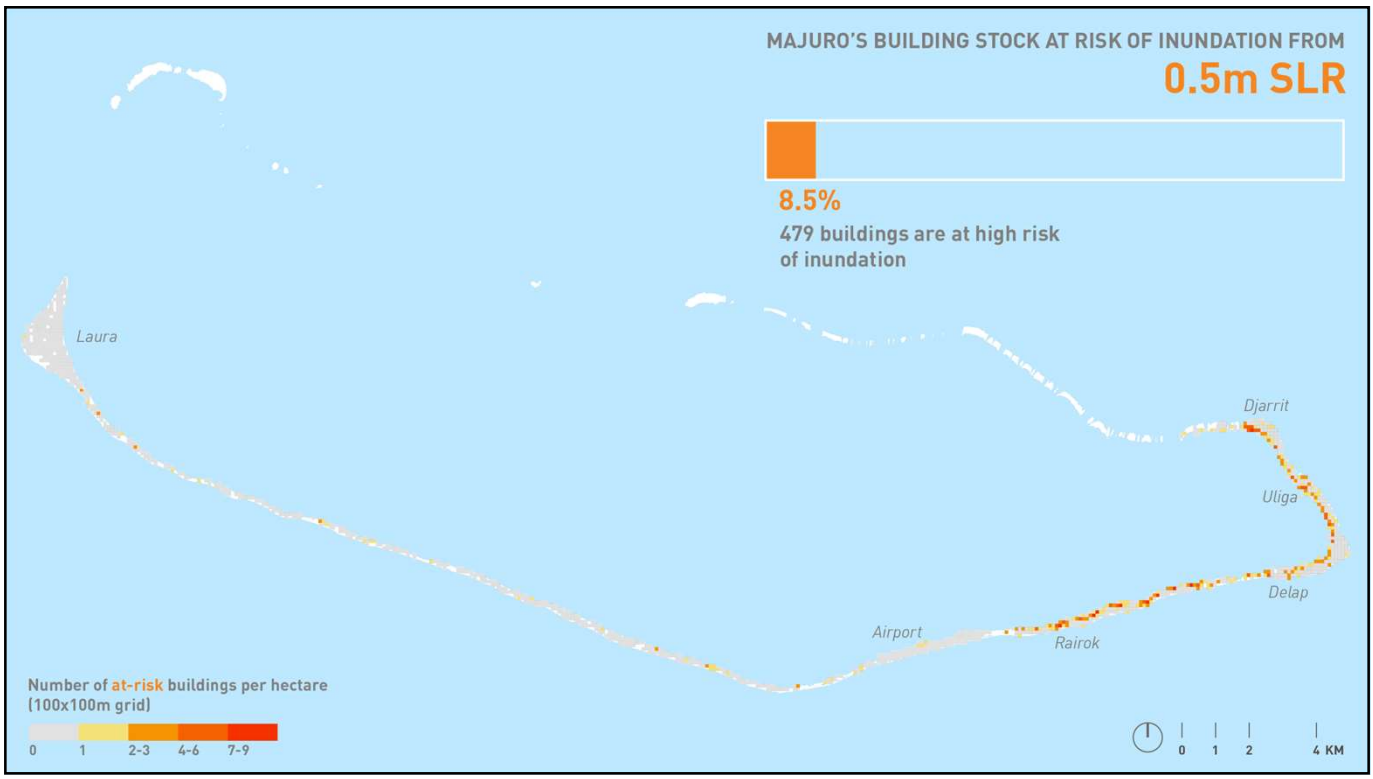
8


Urban Atolls house 74% of the Republic of Marshall Islands' Population
Wake Island (U.S.A)
North Pacific Ocean
Taongi
Bikar
Rongelap
Enewetok
Bikini
Rongerik
Utrik
Ailinginae
Taka
Ailuk
Likiep
Mejit
Jemo
Wotho
KWAJALEIN
Ujelang
Wotje
Ebeye
Erikub
Maloelap
Ujae
Lib
Aur
Lae
Namu
Jabwot
MAJURO
D-U-D
Arno
Ailinglaplap
Jaluit
Mili
Knox
Namorik
Kili
Federated States of Micronesia
Ebon
Kiribati (Gilbert Isl.)
Kiribati (Howland & Baker Isl.)
Nauru
0 50 100 200 KM
MAJURO is the capital containing the most populated urban centers including Delap-Uliga-Djarrit (D-U-D) and the international airport.
KWAJALEIN atoll contains the urban center of Ebeye and is the second most populated urban center.

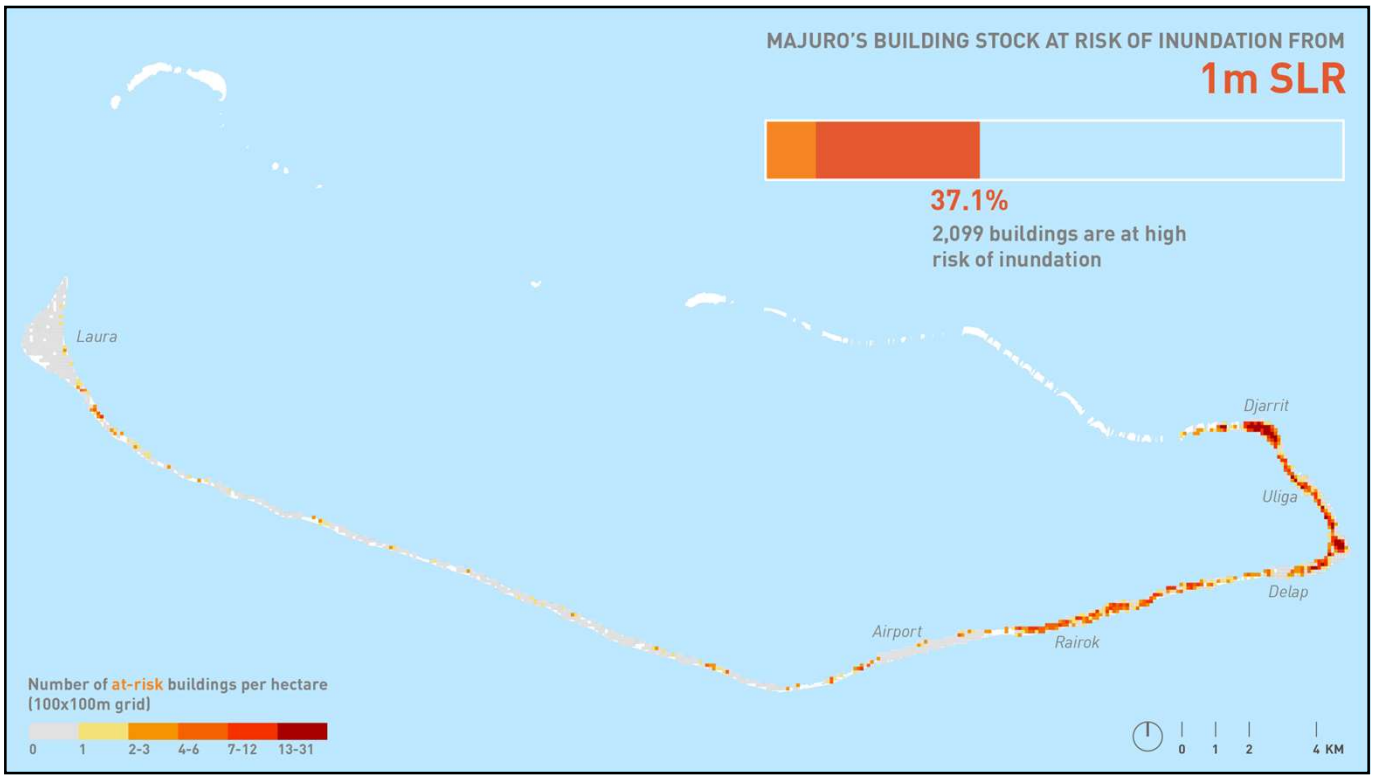
9


MAJURO'S BUILDING STOCK
5,664 buildings
Laura
Djarrit
Uliga
Delap
Airport
Rairok
Number of buildings per hectare (100x100m grid)
0 1 2-3 4-6 7-12 13-38
0 1 2 4 KM

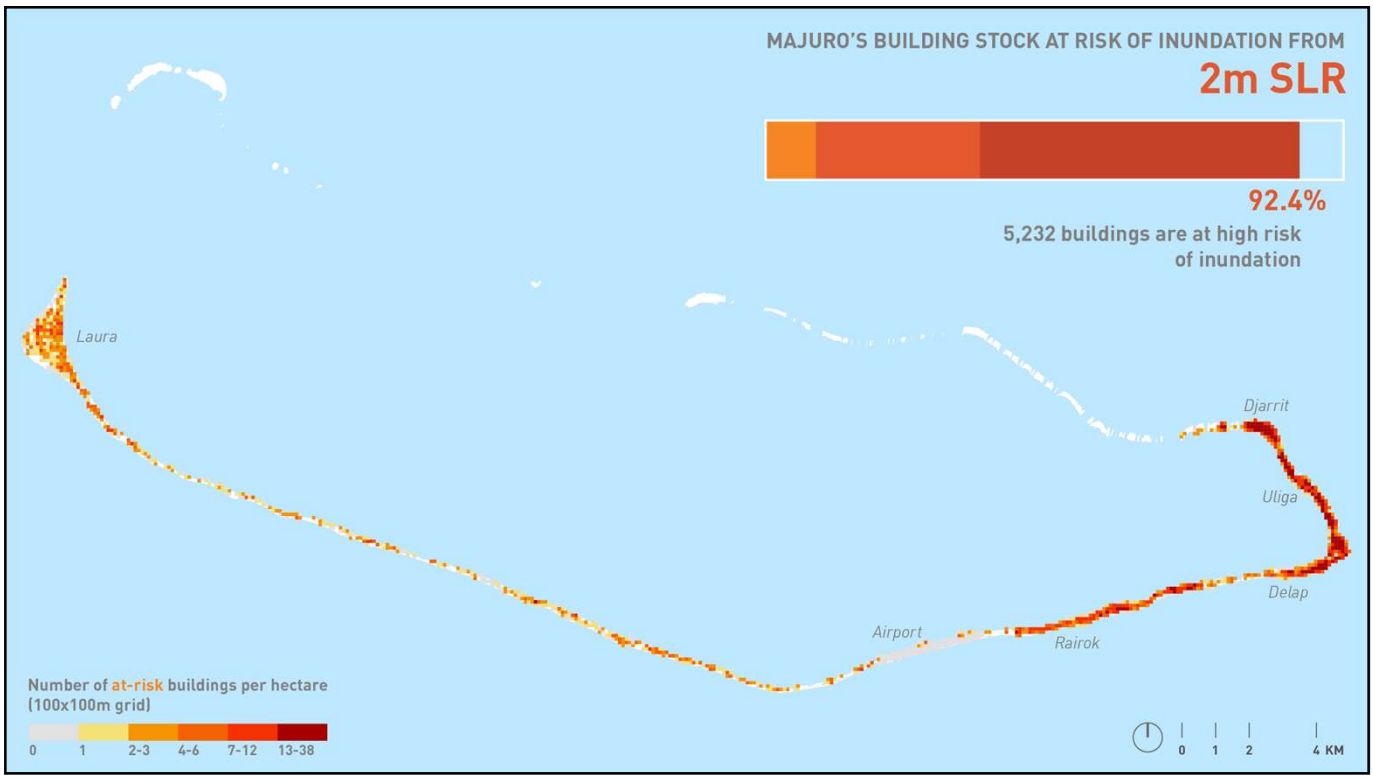
10


MAJURO'S BUILDING STOCK AT RISK OF INUNDATION FROM
0.5m SLR
8.5%
479 buildings are at high risk of inundation
Laura
Djarrit
Uliga
Delap
Airport
Rairok
Number of at-risk buildings per hectare (100x100m grid)
0 1 2-3 4-6 7-9
0 1 2 4 KM

11


MAJURO'S BUILDING STOCK AT RISK OF INUNDATION FROM
1m SLR
37.1%
2,099 buildings are at high risk of inundation
Laura
Djarrit
Uliga
Delap
Airport
Rairok
Number of at-risk buildings per hectare (100x100m grid)
0 1 2-3 4-6 7-12 13-31
0 1 2 4 KM

12

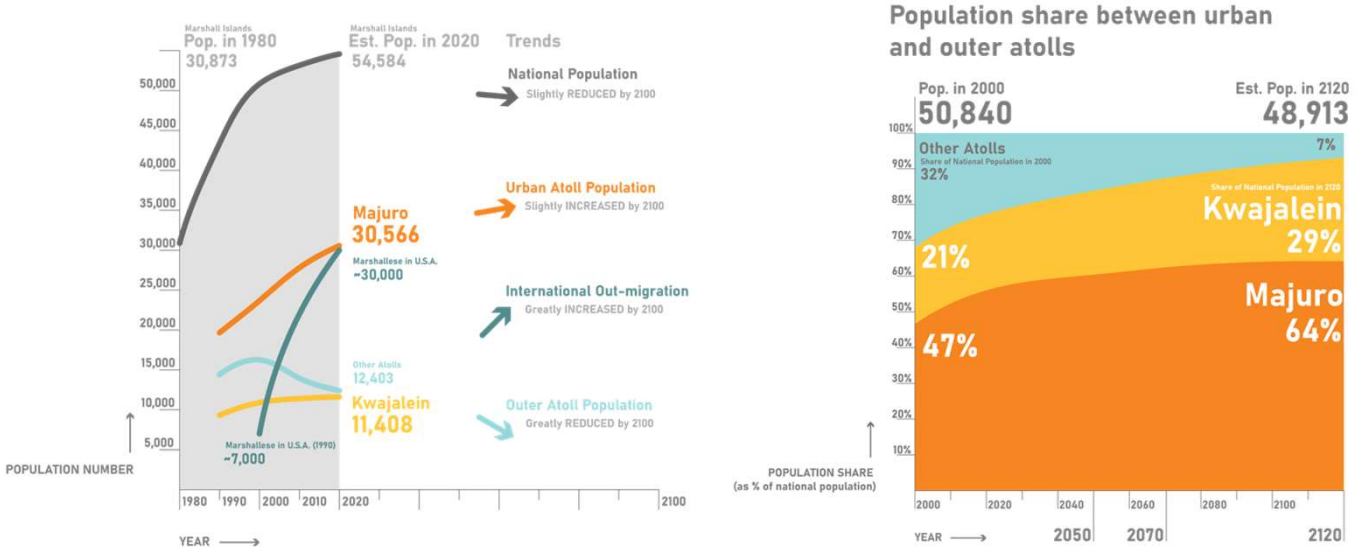


13

2.UNDERSTANDING URBAN ATOLLS AND SLR

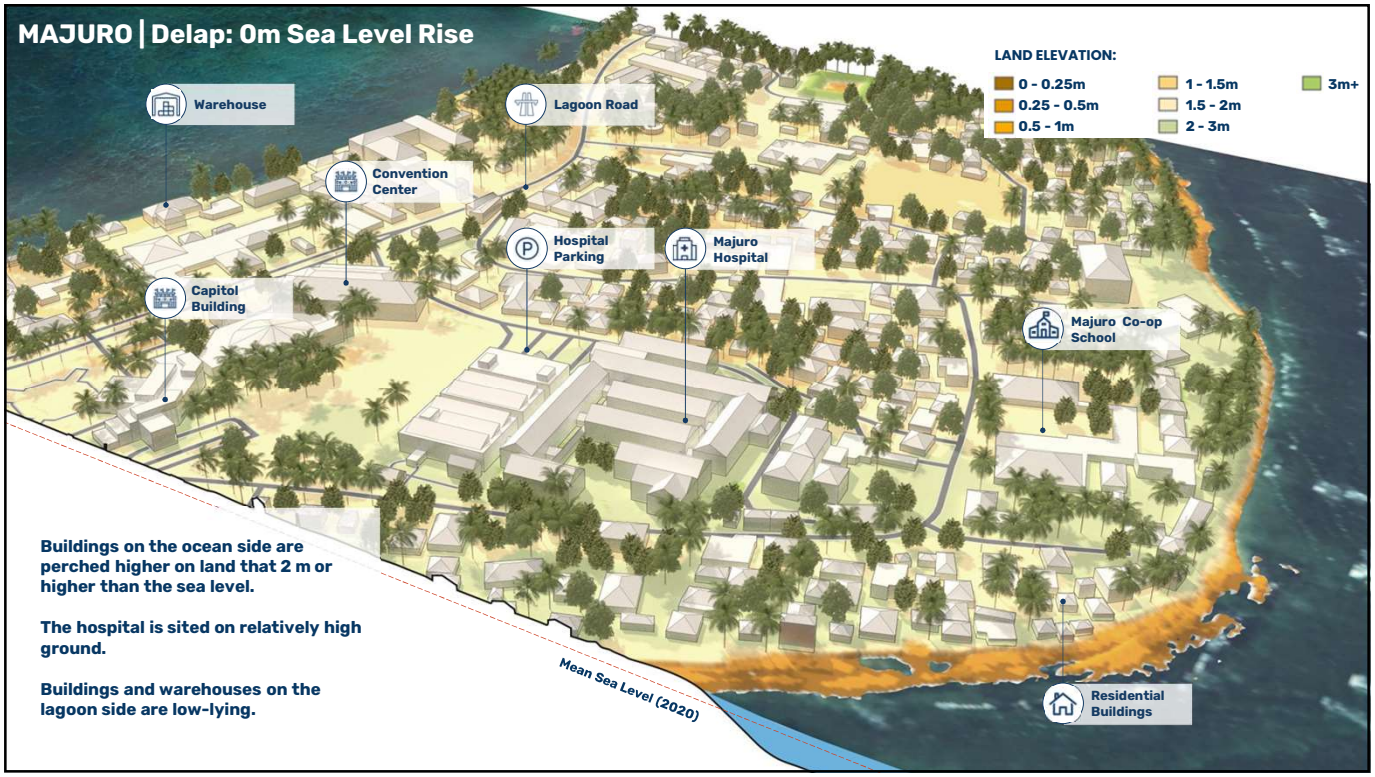
14

Urban atolls house 76% of RMI's population today
Demographic trends and environmental drivers will greatly increase the urban share of the population by 2120

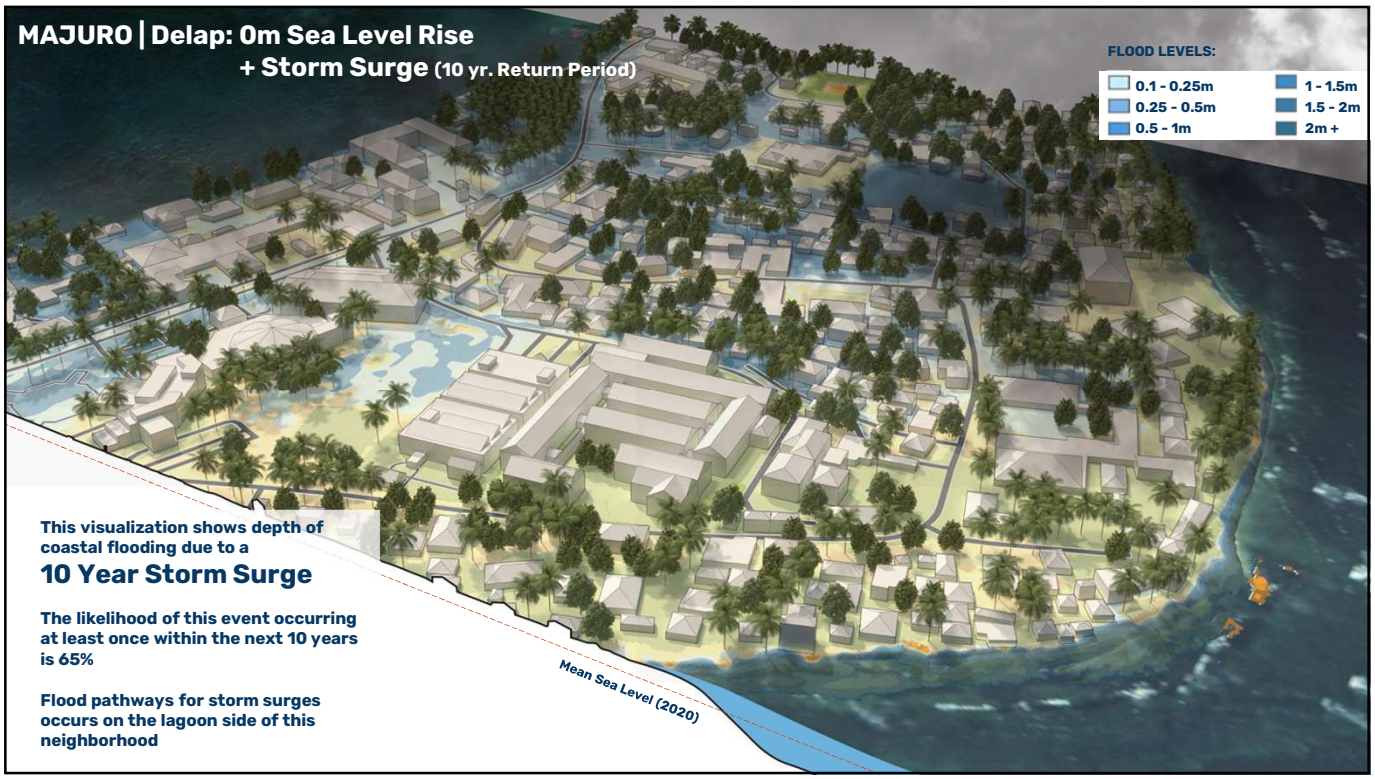


15

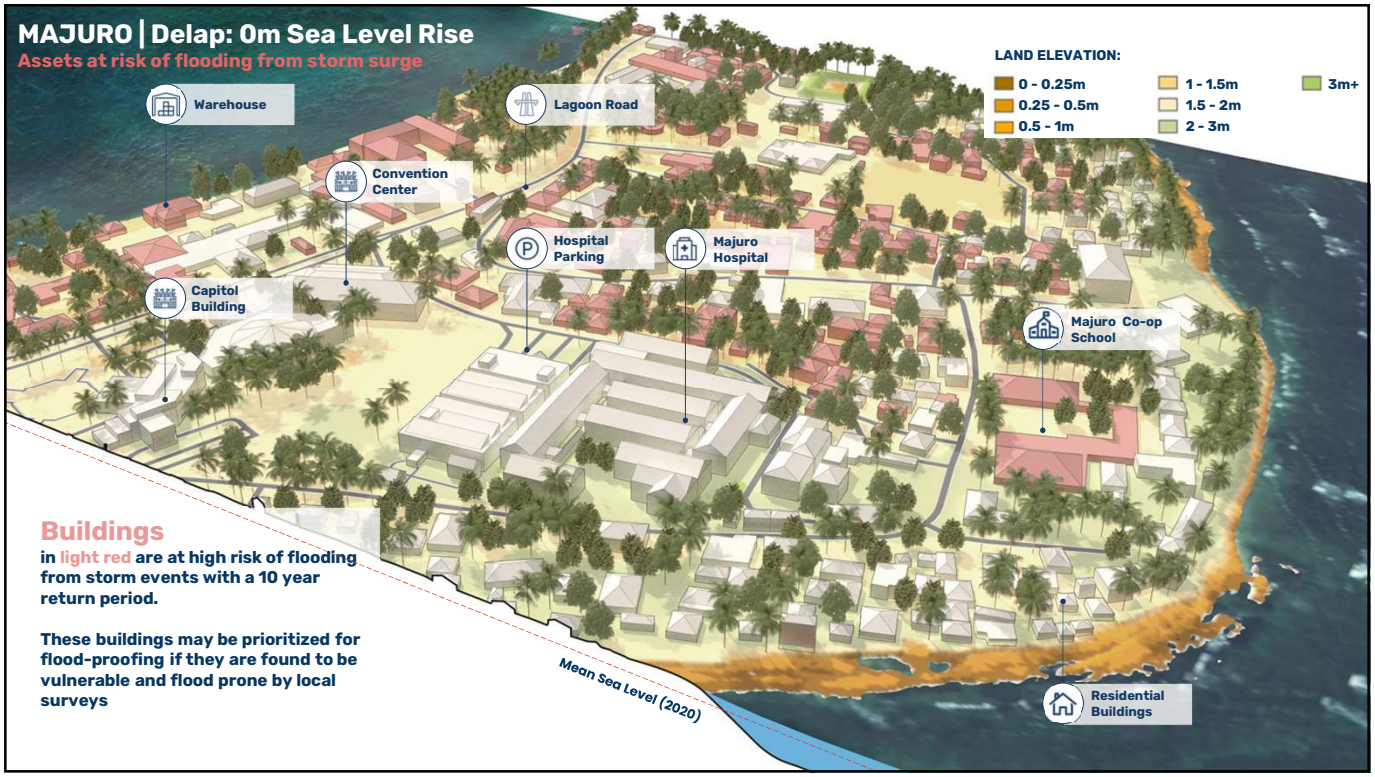
16


MAJURO | Delap: 0m Sea Level Rise
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
Warehouse
Lagoon Road
Convention Center
Hospital Parking
Majuro Hospital
Capitol Building
Majuro Co-op School
Residential Buildings
Mean Sea Level (2020)
Buildings on the ocean side are perched higher on land that 2 m or higher than the sea level.
The hospital is sited on relatively high ground.
Buildings and warehouses on the lagoon side are low-lying.

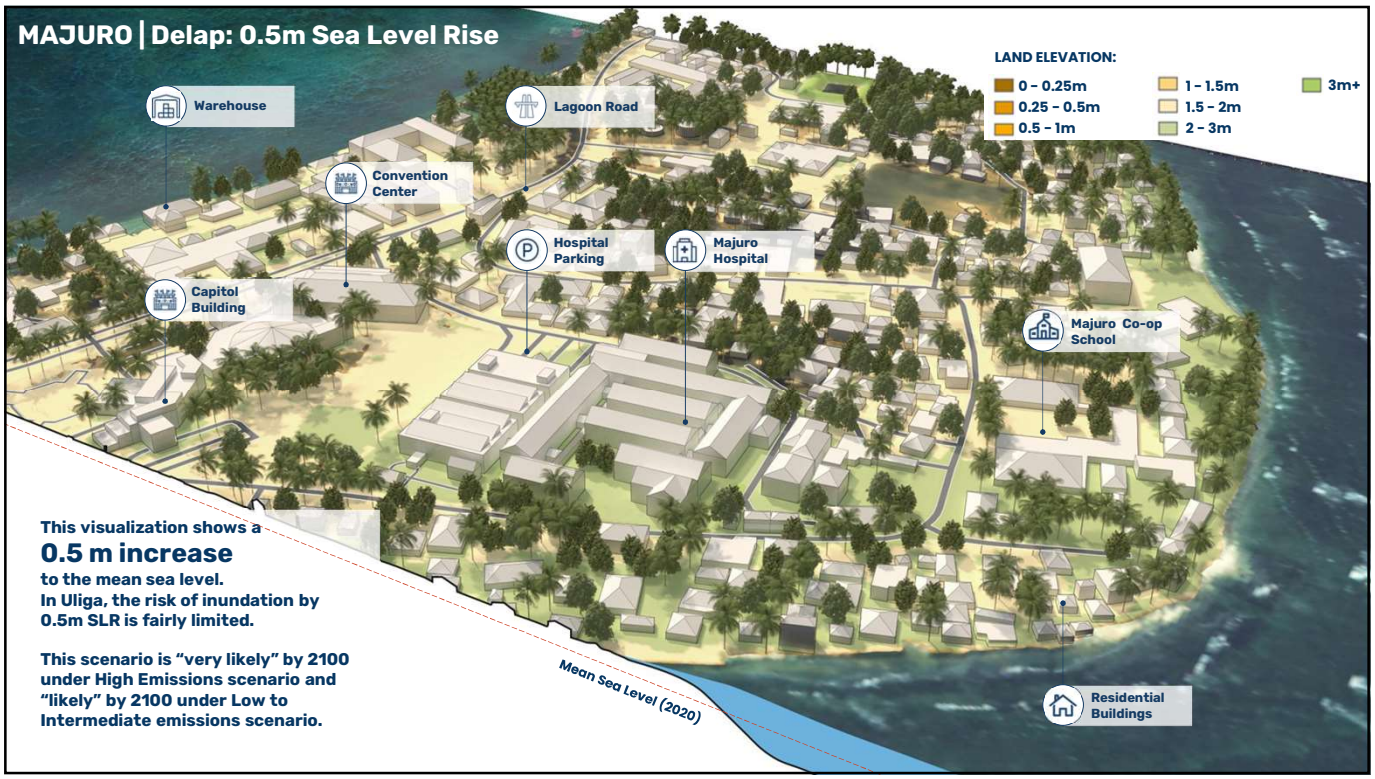
17


MAJURO | Delap: 0m Sea Level Rise
+ Storm Surge (10 yr. Return Period)
FLOOD LEVELS:
0.1 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2m +
Mean Sea Level (2020)
This visualization shows depth of coastal flooding due to a
10 Year Storm Surge
The likelihood of this event occurring at least once within the next 10 years is 65%
Flood pathways for storm surges occurs on the lagoon side of this neighborhood

18


MAJURO | Delap: 0m Sea Level Rise
Assets at risk of flooding from storm surge
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
Warehouse
Lagoon Road
Convention Center
Hospital Parking
Majuro Hospital
Capitol Building
Majuro Co-op School
Residential Buildings
Mean Sea Level (2020)
Buildings
in light red are at high risk of flooding from storm events with a 10 year return period.
These buildings may be prioritized for flood-proofing if they are found to be vulnerable and flood prone by local surveys

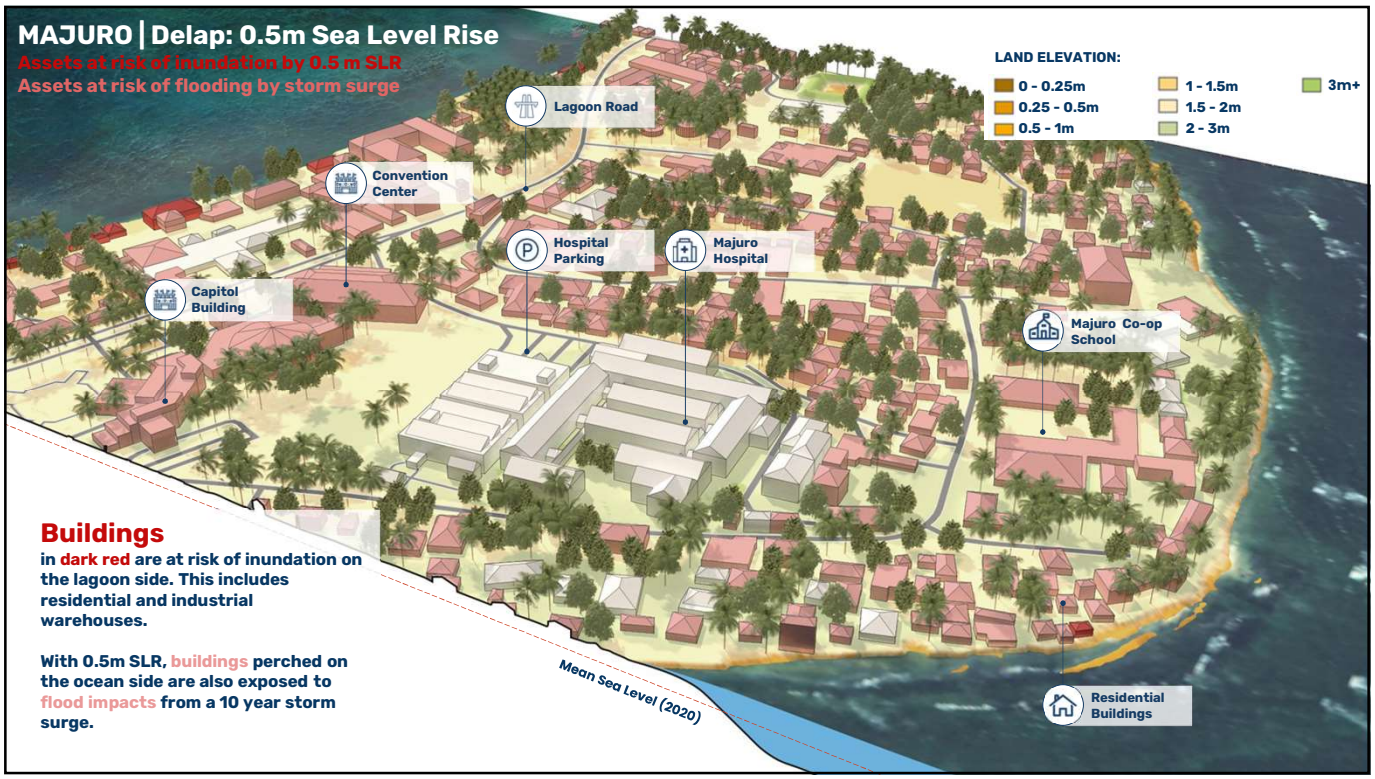
19


MAJURO | Delap: 0.5m Sea Level Rise
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
Warehouse
Lagoon Road
Convention Center
Hospital Parking
Majuro Hospital
Capitol Building
Majuro Co-op School
Residential Buildings
Mean Sea Level (2020)
This visualization shows a
0.5 m increase
to the mean sea level.
In Uliga, the risk of inundation by 0.5m SLR is fairly limited.
This scenario is "very likely" by 2100 under High Emissions scenario and "likely" by 2100 under Low to Intermediate emissions scenario.

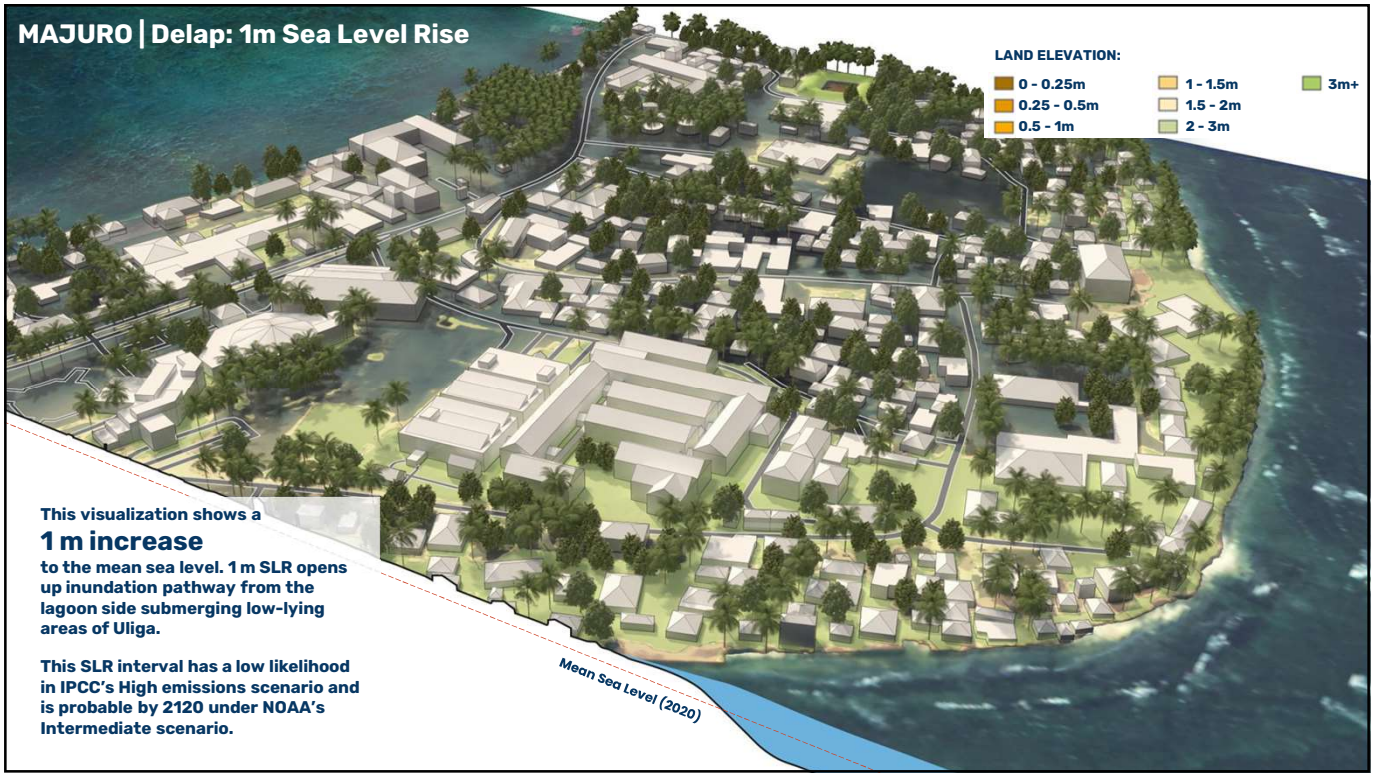
20


MAJURO | Delap: 0.5m Sea Level Rise
+ Storm Surge (10 yr. Return Period)
FLOOD LEVELS:
0.1 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2m +
This visualization shows depth of coastal flooding due to a
10 Year Storm Surge
with a sea level rise of 0.5 m.
Storm surges in this scenario flood a larger area of Uliga and opens up flood pathways from the ocean side as well. Nuisance flooding becomes much more common.
Mean Sea Level (2020)

21


MAJURO | Delap: 0.5m Sea Level Rise
Assets at risk of inundation by 0.5 m SLR
Assets at risk of flooding by storm surge
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
Lagoon Road
Convention Center
Hospital Parking
Majuro Hospital
Capitol Building
Majuro Co-op School
Residential Buildings
Buildings
in dark red are at risk of inundation on the lagoon side. This includes residential and industrial warehouses.
With 0.5m SLR, buildings perched on the ocean side are also exposed to flood impacts from a 10 year storm surge.
Mean Sea Level (2020)

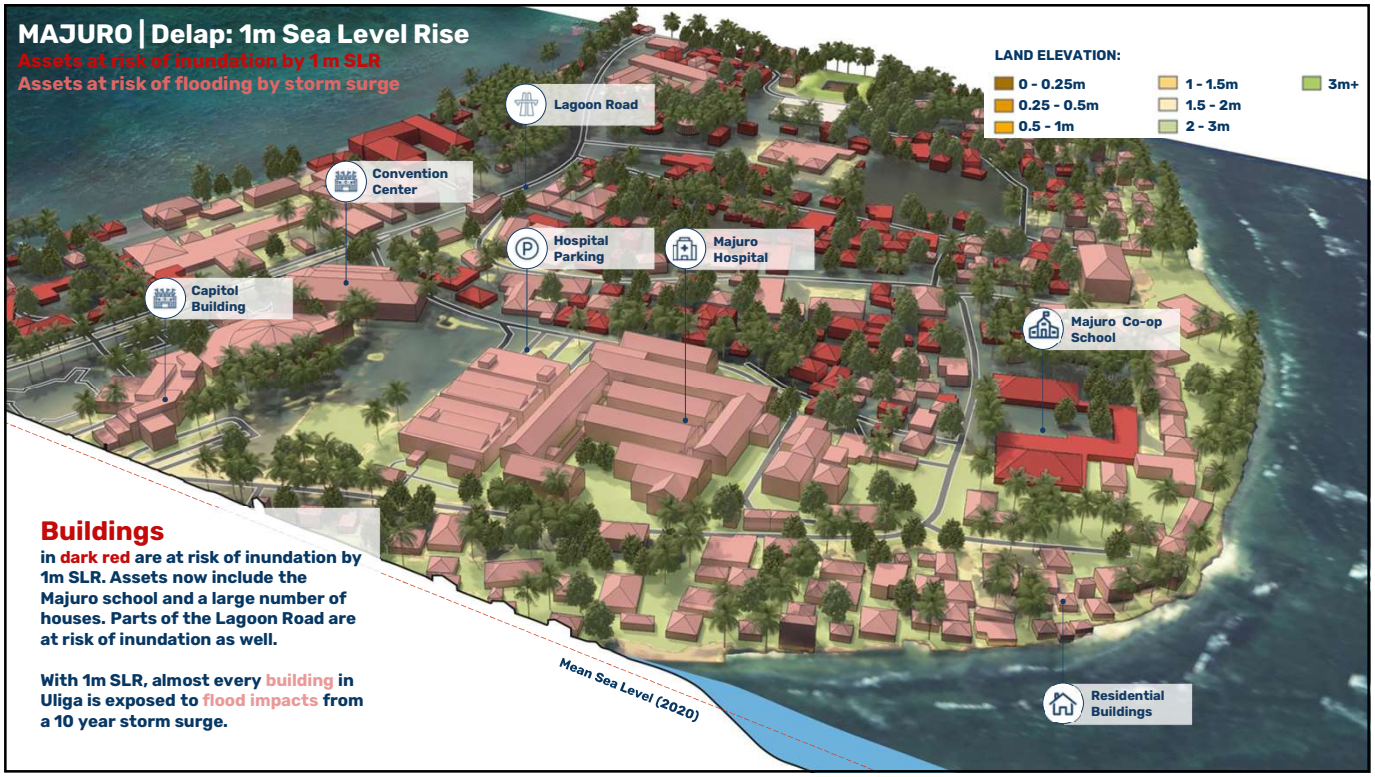
22


MAJURO | Delap: 1m Sea Level Rise
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
This visualization shows a
1 m increase
to the mean sea level. 1 m SLR opens up inundation pathway from the lagoon side submerging low-lying areas of Uliga.
This SLR interval has a low likelihood in IPCC's High emissions scenario and is probable by 2120 under NOAA's Intermediate scenario.
Mean Sea Level (2020)

23


MAJURO | Delap: 1m Sea Level Rise
+ Storm Surge (10 yr. Return Period)
FLOOD LEVELS:
0.1 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2m +
This visualization shows depth of coastal flooding due to a
10 Year Storm Surge
with a sea level rise of 1 m.
Storm surges in this scenario may end up flooding almost the entire neighborhood with more than 0.5m of water.
Mean Sea Level (2020)

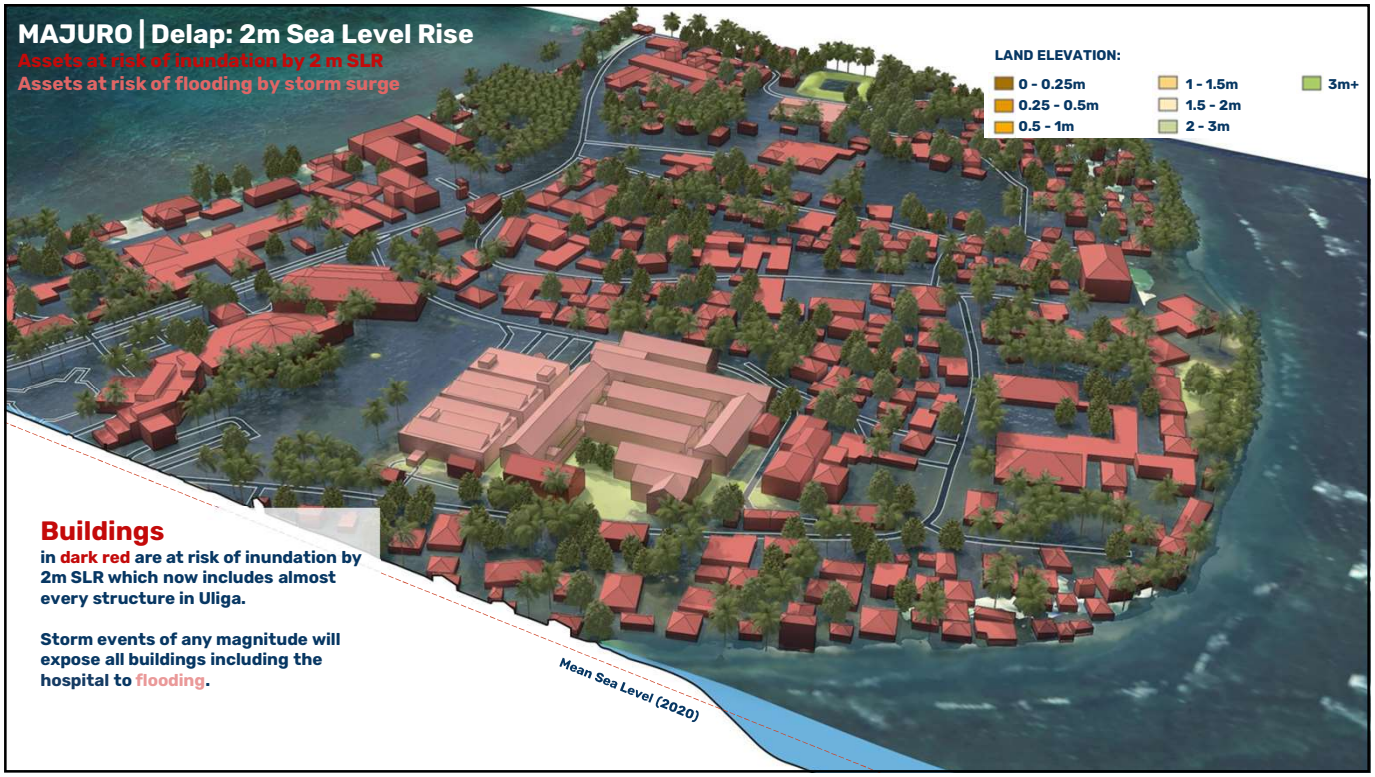
24


MAJURO | Delap: 1m Sea Level Rise
Assets at risk of inundation by 1 m SLR
Assets at risk of flooding by storm surge
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
Lagoon Road
Convention Center
Hospital Parking
Majuro Hospital
Capitol Building
Majuro Co-op School
Residential Buildings
Mean Sea Level (2020)
Buildings
in dark red are at risk of inundation by 1m SLR. Assets now include the Majuro school and a large number of houses. Parts of the Lagoon Road are at risk of inundation as well.
With 1m SLR, almost every building in Uliga is exposed to flood impacts from a 10 year storm surge.

25


MAJURO | Delap: 2m Sea Level Rise
LAND ELEVATION:
0 - 0.25m
0.25 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 3m
3m+
Warehouse
Lagoon Road
Convention Center
Hospital Parking
Majuro Hospital
Majuro Co-op School
Residential Buildings
Mean Sea Level (2020)
This visualization shows a
2 m increase
to the mean sea level. A 2 m SLR potentially inundates all of Uliga barring the hospital, reservoir, and some parts of the ocean side.
This scenario is physically plausible by 2120 under extreme climate conditions and should be considered for planning purposes.

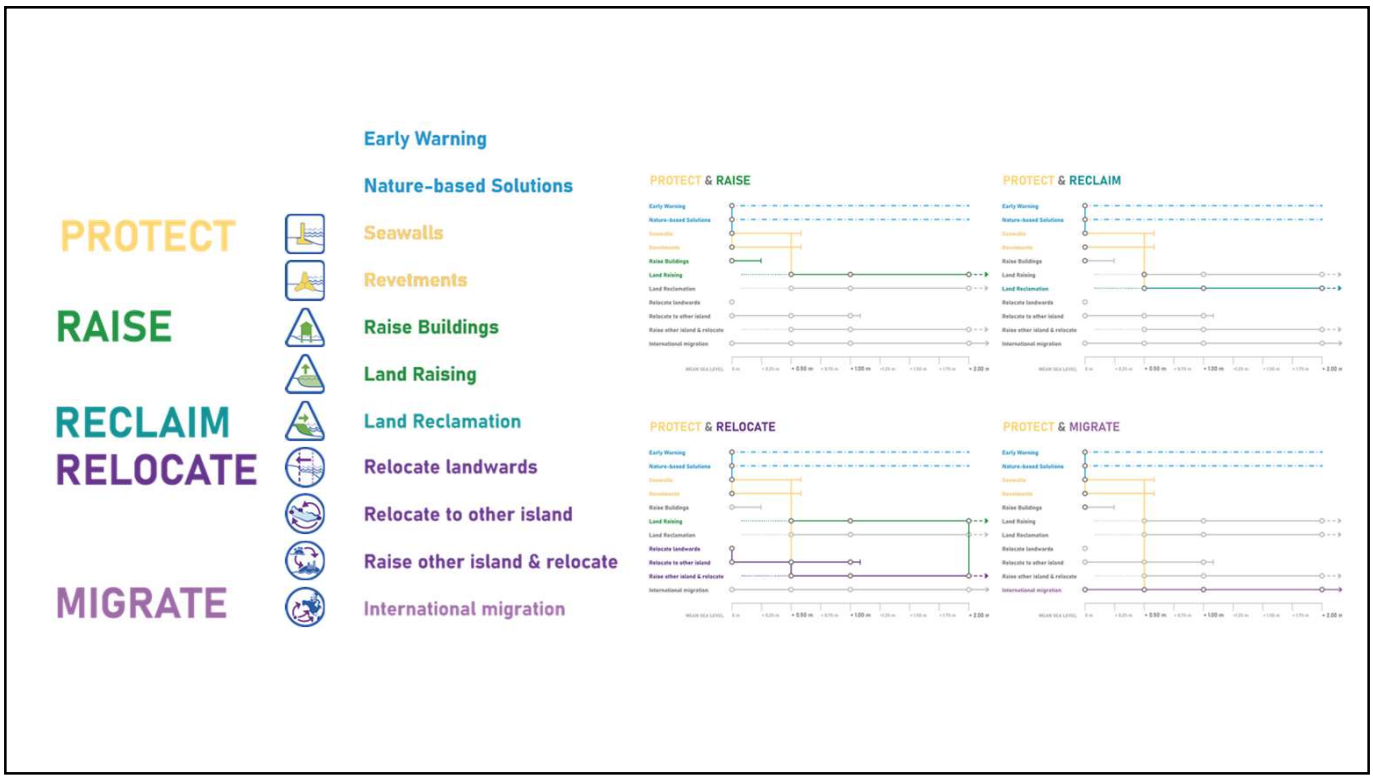
26



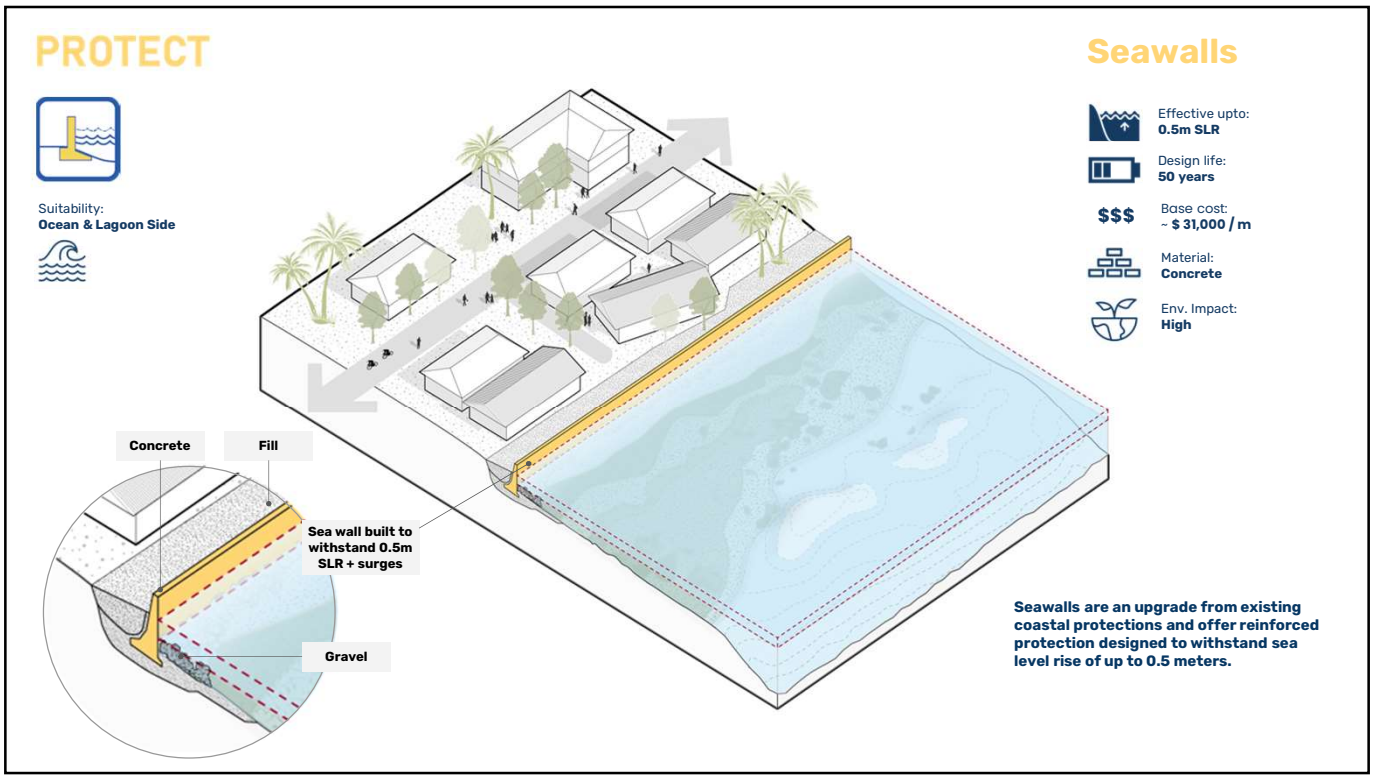
27

3.EXPLORING ADAPTATION PATHWAYS

28


PROTECT
RAISE
RECLAIM
RELOCATE
MIGRATE
Early Warning
Nature-based Solutions
Seawalls
Revetments
Raise Buildings
Land Raising
Land Reclamation
Relocate landwards
Relocate to other island
Raise other island & relocate
International migration
PROTECT & RAISE
PROTECT & RECLAIM
PROTECT & RELOCATE
PROTECT & MIGRATE

29


PROTECT
Seawalls
Suitability:
Ocean & Lagoon Side
Effective upto:
0.5m SLR
Design life:
50 years
$$$
Base cost:
~ $ 31,000 / m
Material:
Concrete
Env. Impact:
High
Concrete
Fill
Sea wall built to withstand 0.5m SLR + surges
Gravel
Seawalls are an upgrade from existing coastal protections and offer reinforced protection designed to withstand sea level rise of up to 0.5 meters.

30

PROTECT

Revetments

Suitability:
Lagoon Side Preferable

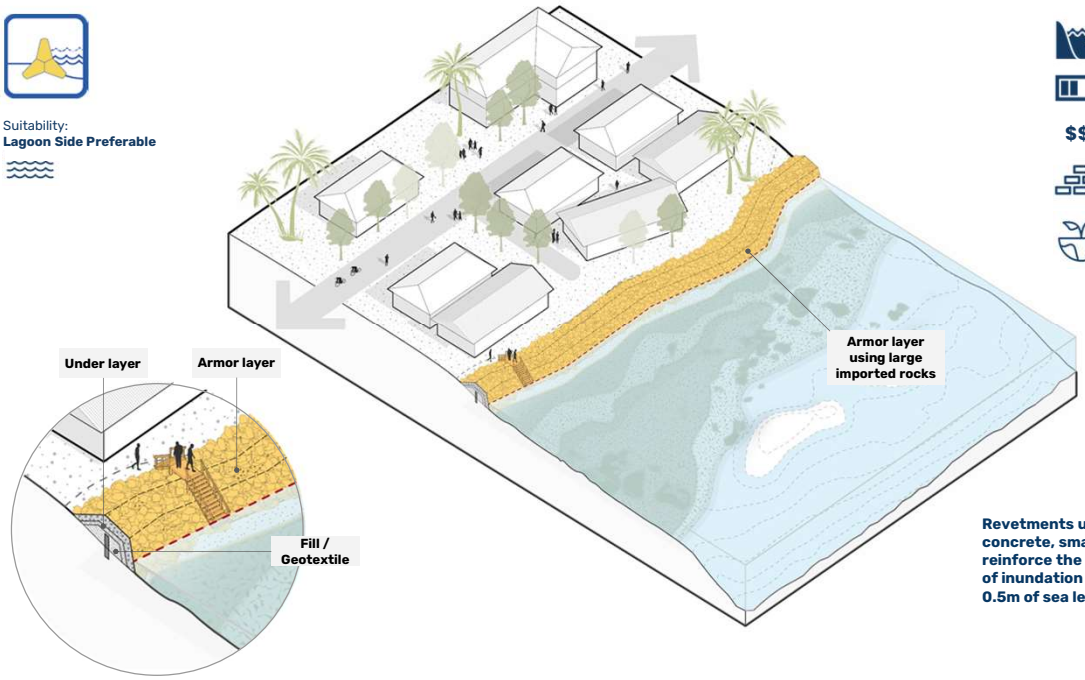
Effective upto:
0.5m SLR

Design life:
50 years

$$$ Base cost:
~ $ 23-30,000 / m

Material:
Aggregate, concrete

Env. Impact:
Medium



Revetments use various layers of concrete, small aggregates and rocks to reinforce the coast and reduce the risk of inundation and flooding for up to 0.5m of sea level rise

31

PROTECT

Revetments

Suitability:
Lagoon Side Preferable

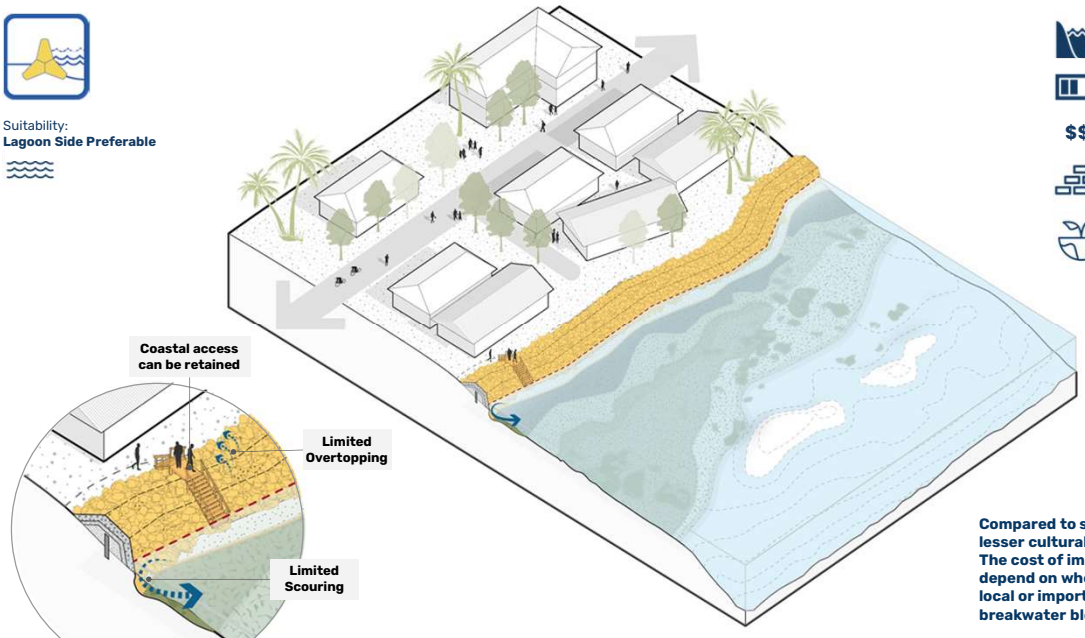
Effective upto:
0.5m SLR

Design life:
50 years

$$$ Base cost:
~ $ 23-30,000 / m

Material:
Aggregate, concrete

Env. Impact:
Medium



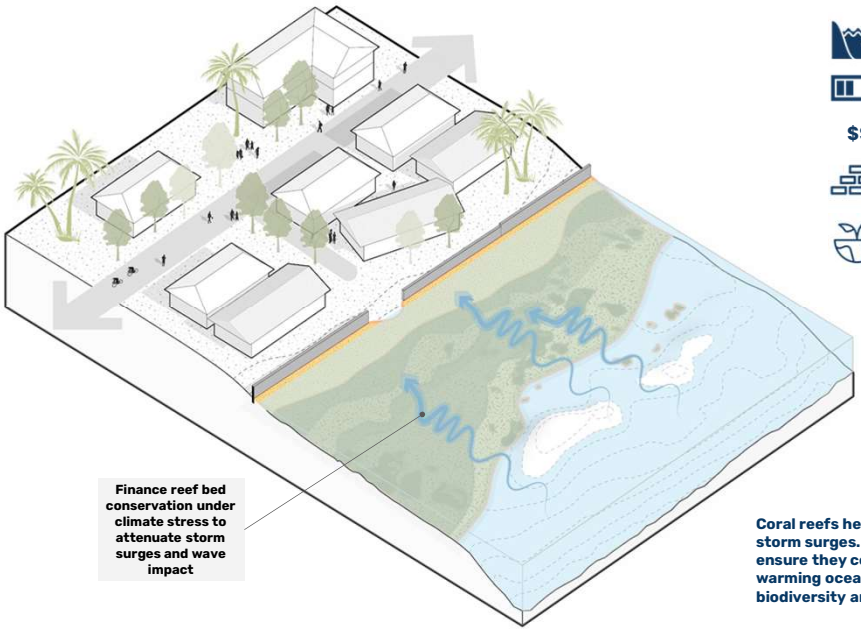
Compared to seawalls, revetments have lesser cultural or environmental impact. The cost of implementing revetments depend on whether the outer layer uses local or imported rocks, or concrete breakwater blocks.

32

PROTECT

Nature-based Solutions

Suitability:
Lagoon Side Preferable



Effective upto:
N/A

Design life:
Varies

$$ Base cost:
Varies

Material:
Natural / Hybrid

Env. Impact:
Positive

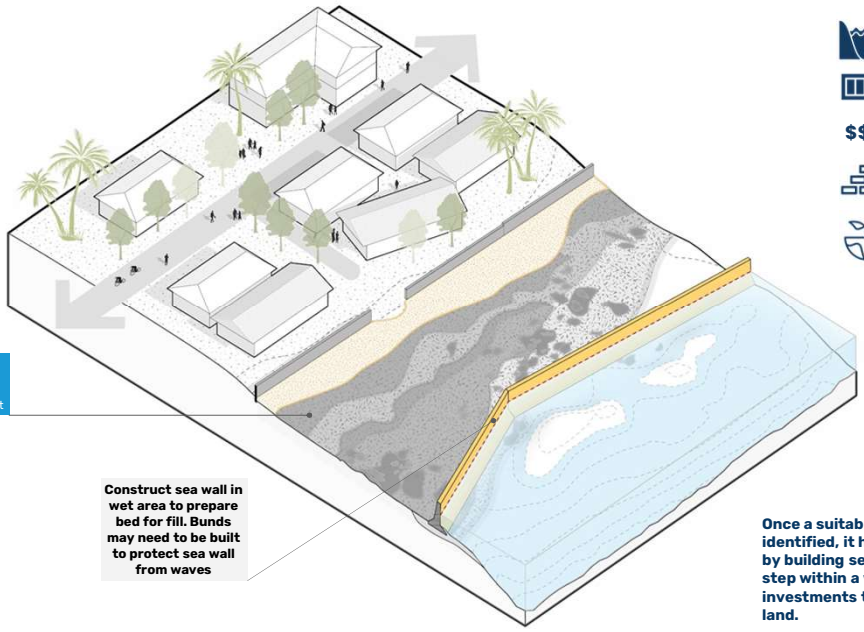
Coral reefs help limit the impact of storm surges. Reef conservation can ensure they continue to function within warming oceans while benefiting biodiversity and local livelihoods.

33

RECLAIM

Land Reclamation

Suitability:
Lagoon Side Preferable



Effective upto:
No Limits

Design life:
100 years

$$$$ Base cost:
~ $ 31,000 / m + 2,000 / m²

Material:
Aggregate, concrete

Env. Impact:
Very High

Once a suitable shallow bed site is identified, it has to be prepared for fill by building sea walls. This construction step within a wet area requires more investments than building sea walls on land.

34

RECLAIM

Suitability:
Lagoon Side Preferable

Land Reclamation

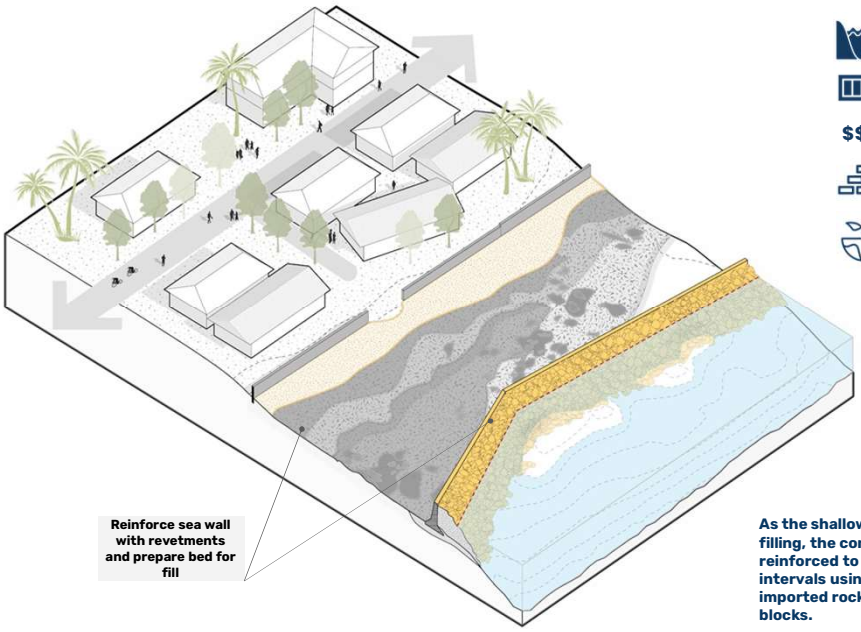
Effective upto:
No Limits

Design life:
100 years

$$$$ Base cost:
~ $ 31,000 / m + 2,000 / m²

Material:
Aggregate, concrete

Env. Impact:
Very High



Reinforce sea wall with revetments and prepare bed for fill

As the shallow bed is prepared for land filling, the constructed seawall must be reinforced to withstand future SLR intervals using revetments (local rocks, imported rocks, or precast concrete blocks.

35

RECLAIM

Suitability:
Lagoon Side Preferable

Land Reclamation

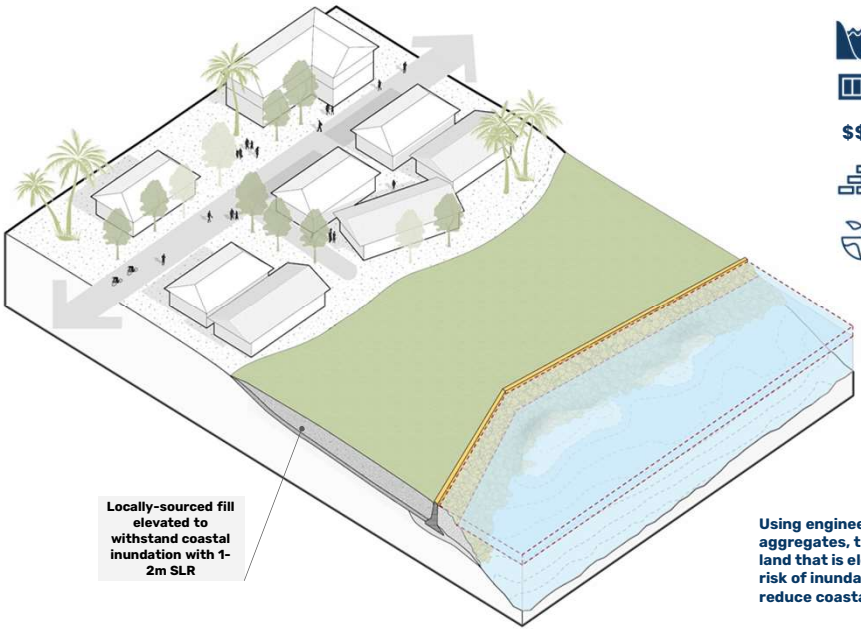
Effective upto:
No Limits

Design life:
100 years

$$$$ Base cost:
~ $ 31,000 / m + 2,000 / m²

Material:
Aggregate, concrete

Env. Impact:
Very High



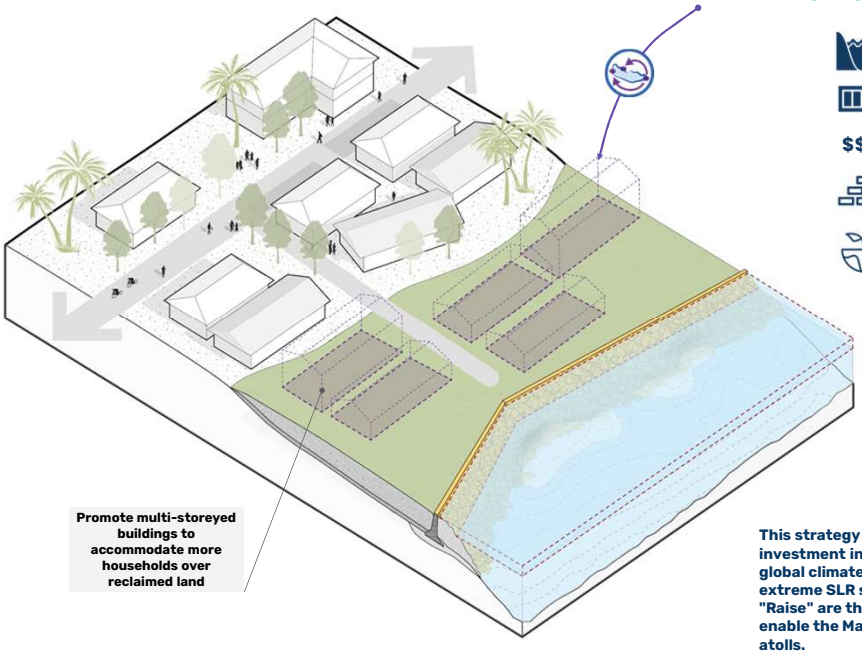
Locally-sourced fill elevated to withstand coastal inundation with 1-2m SLR

Using engineered soil and imported aggregates, the bed is filled to create land that is elevated to eliminate the risk of inundation from extreme SLR and reduce coastal flooding risk.

36

RECLAIM

Suitability:
Lagoon Side Preferable



Land Reclamation

Effective upto:
No Limits

Design life:
100 years

$$$$ Base cost:
~ $ 31,000 / m + 2,000 / m²

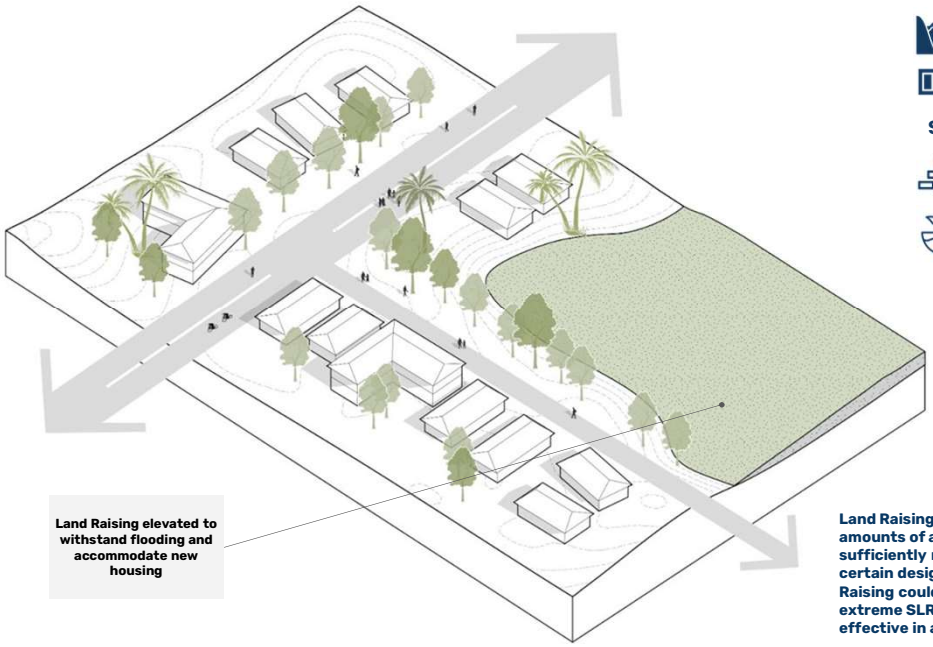
Material:
Aggregate, concrete

Env. Impact:
Very High

This strategy would be an over-investment in a 100 year timeframe if global climate targets are met. In an extreme SLR scenario, "Reclaim" with "Raise" are the only pathways that enable the Marshallese stay on in the atolls.

37

RAISE



Land Raising

Effective upto:
No Limits

Design life:
100 years

$$$ Base cost:
~ $ 800 / m²

Material:
Aggregate, Fill

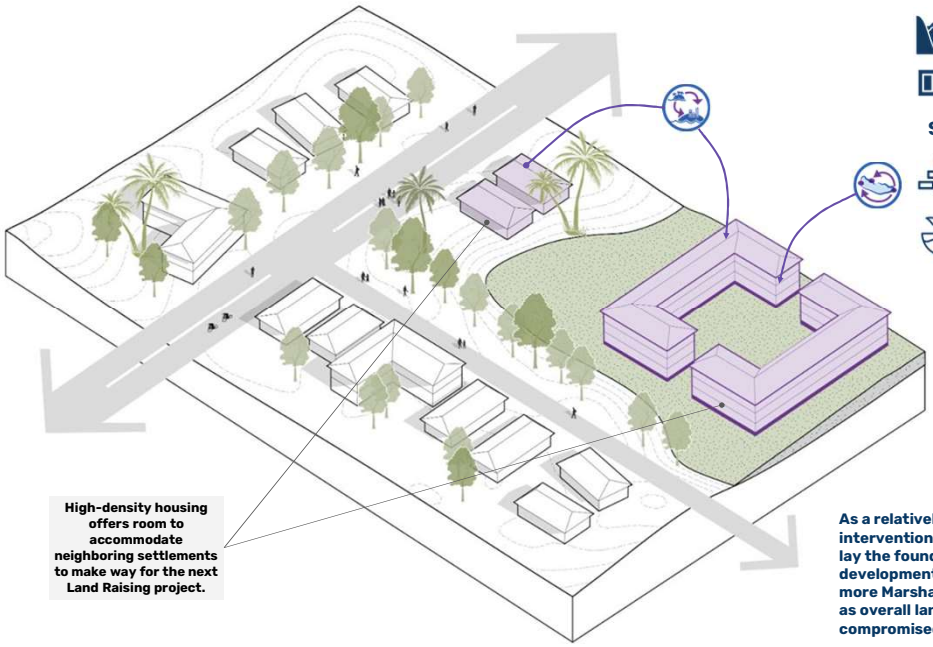
Env. Impact:
Very High

Land Raising requires bringing large amounts of aggregate and fill to sufficiently raise an area above a certain design flood elevation. Land Raising could make areas resilient to extreme SLR and is theoretically effective in all scenarios.

38

RAISE

Land Raising



Effective upto: **No Limits**

Design life: **100 years**

$$$ Base cost: **~ $ 800 / m²**

Material: **Aggregate, Fill**

Env. Impact: **Very High**

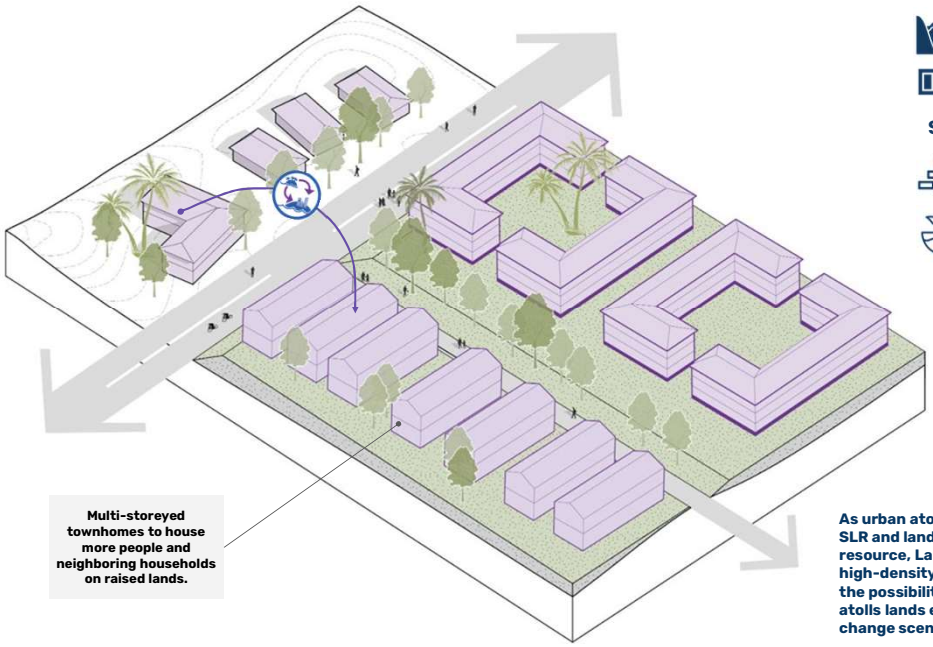
High-density housing offers room to accommodate neighboring settlements to make way for the next Land Raising project.

As a relatively costly and complex intervention, Land Raising should ideally lay the foundation for high-density developments that can accommodate more Marshallese within elevated lands as overall land availability is compromised by SLR.

39

RAISE

Land Raising



Effective upto: **No Limits**

Design life: **100 years**

$$$ Base cost: **~ $ 800 / m²**

Material: **Aggregate, Fill**

Env. Impact: **Very High**

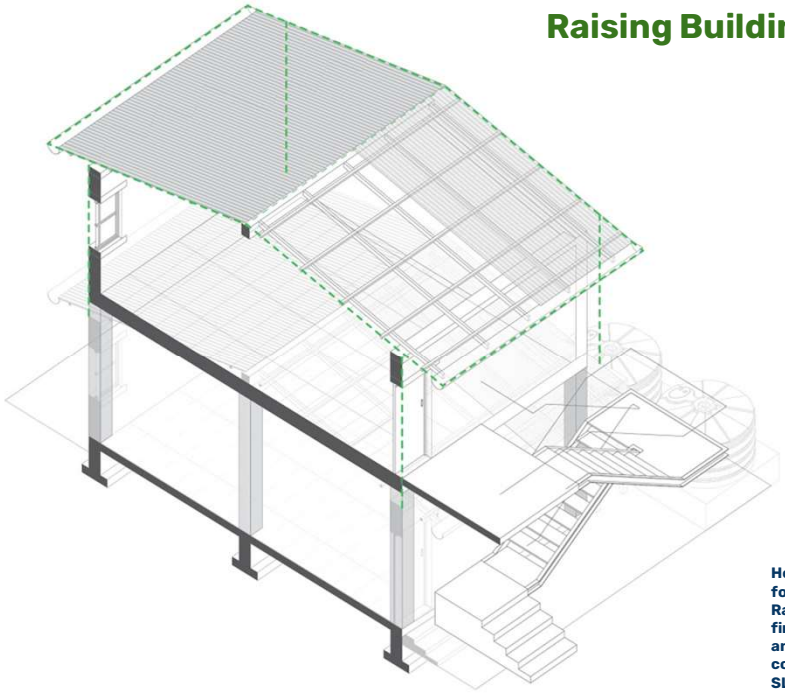
Multi-storeyed townhomes to house more people and neighboring households on raised lands.

As urban atolls face higher intervals of SLR and land becomes a scarce resource, Land Raising accompanied by high-density housing offers Marshallese the possibility to continue living on atolls lands even under extreme climate change scenarios.

40

RAISE

Raising Buildings (Concrete)



Effective upto:
Upto 0.25m

Design life:
50 years

$ Base cost:
~ $ 130 / m²

Material:
Concrete, Rebar, Brick

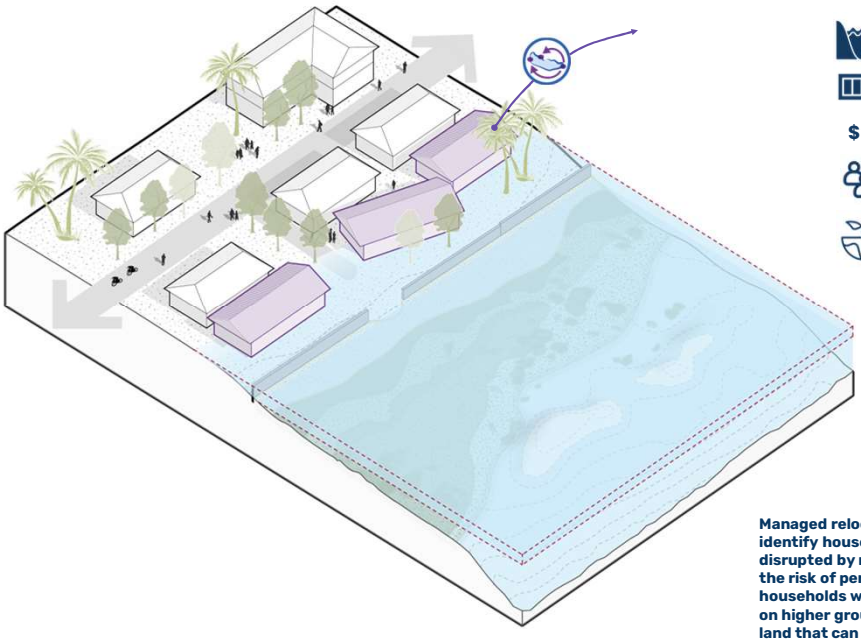
Env. Impact:
Low

Houses with a strong concrete foundation are good candidates for Raising. With adequate planning and financing concrete homes could support an entirely new level. The lower levels could be retrofitted to withstand low SLR scenarios or opened up as residents move to the upper level.

41

MIGRATE

Migration within RMI



Effective upto:
Relative

Design life:
N/A

$$$ Base cost:
~ $ 150,000 / person

Social Impact:
Very High

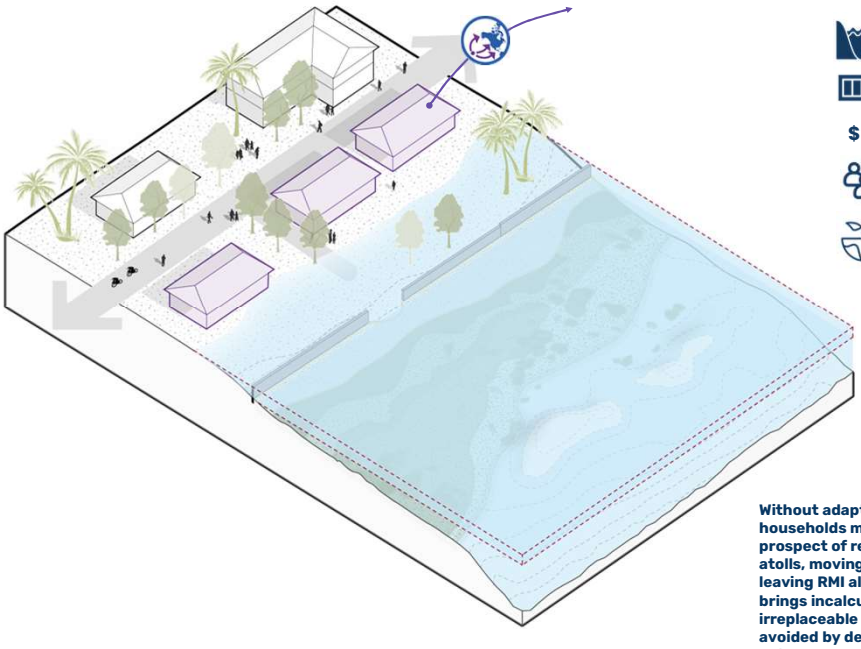
Env. Impact:
N/A

Managed relocation with RMI would identify households that are greatly disrupted by nuisance flooding or face the risk of permanent inundation. These households would be moved to houses on higher ground, reclaimed or raised land that can withstand current and future SLR scenarios.

42

MIGRATE

Migration / Out-migration



Effective upto:
Relative

Design life:
N/A

$$$
Base cost:
~ $ 70-150,000 / person

Social Impact:
Very High

Env. Impact:
N/A

Without adaptation, many more households may have to face the prospect of relocating within their atolls, moving to another atolls, or leaving RMI altogether. This pathway brings incalculable social costs and irreplaceable cultural loss and can be avoided by deploying other pathways in a timely manner.

43

Thank you

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Artessa Saldivar-Sali (asaldivarsali@worldbank.org)
Senior Municipal Engineer
World Bank

44