Capacity building Activities

DAY #2

Develop climate-sensitive approach to prioritize climate-resilient actions

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suez

Capacity Building Program Journey

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	DAY 1	DAY 2	DAY 3	DAY 4
Objectives	Sensitization to Climate Change & Understanding Climate Risk in Homa Bay	Develop a climate sensitive diagnosis and action prioritization in a data-scarce context	Streamline climate change in urban development – a step by step approach	Apply methodological approaches to urban infrastructures
Focus area	Climate Fresk HB CRA	**HB CRA** **Urban drainage**	Project cycle NbS	Climate resilient checklist

Agenda of Day #2

CRA Approach

Objectives of today

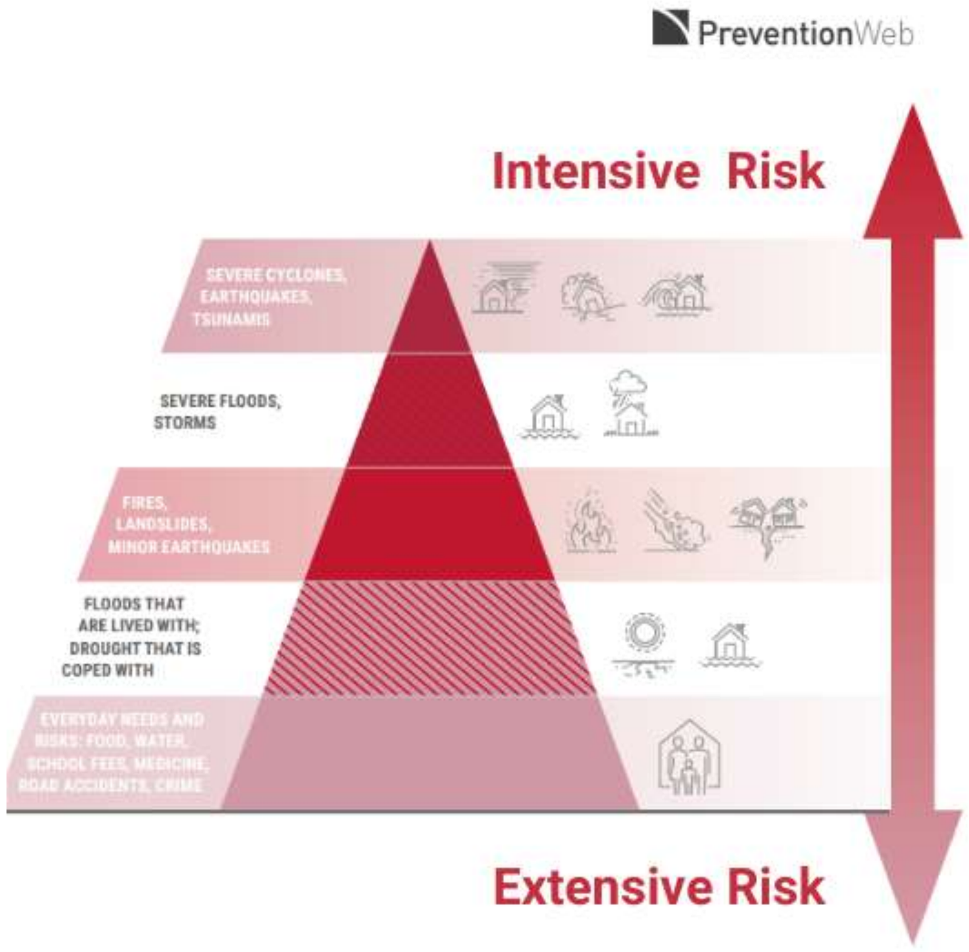
We have done a quite extensive CRA focused on 3 neighbourhood.

Beyond this one shot assignment, how can you pursue and engage into climate sensitive actions?

CRA Approach

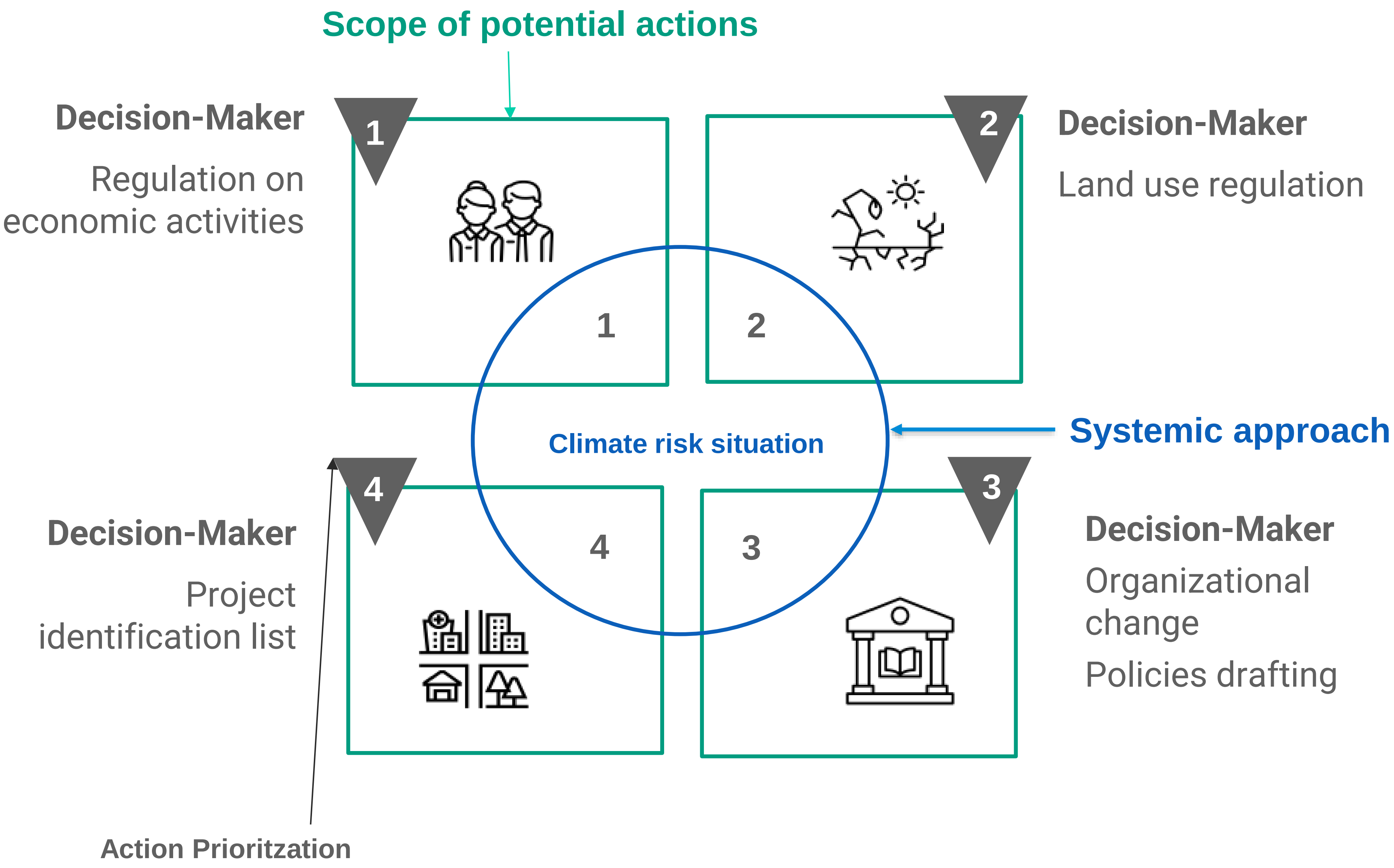
One starting point, multiple expectations:

A variety of measures to be developed!
Impact modelling that will help:
- determine intensive and extensive risk and impact
Extensive risk => Land use issue
Intensive risk => Disaster preparedness
- The who's doing what regarding these impacts



Source: UNDRR

From impact chain to action identification



CRA Approach

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Scoping of possible adaptive actions: CRA

For technical experts
How to produce evidence-based knowledge to inform planning in a data-scarce environment?

For decision-makers and institutional actors
In a context of limited institutional resources, how to target key elements of a climate risk assessment systemic approach to drive decision-making process and potential procurement?

Agenda – Morning session

1. Introduction *(9:00-9:15)*
2. Hands-on the RCRA methodology *(9:15-10:30)*
3. *Coffee Break* *(10:30-10:45)*
4. Tools in practice *(10:45-12:00)*

Lunch Break *(12:00-13:00)*

Agenda – Afternoon session

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1 Session Introduction *(13:00-13:15)*

2 Sectoral focus #1 Water *(13:15-14:45)*

3 *Coffee Break* *(14:45-15:00)*

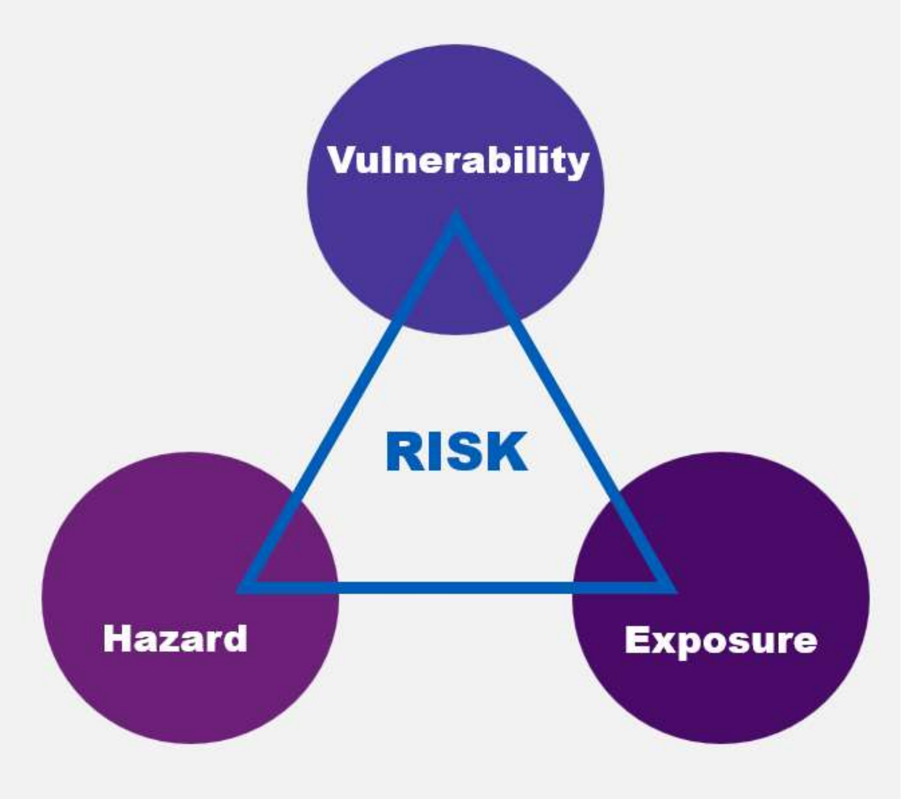
4 Quiz and closing of the day *(15:00-15:30)*

5 Closing of the day *(15:30)*

Climate Risk Assessment Approach

Definitions / Reminder

Vulnerability: propensity or predisposition to suffer the negative effects of climatic hazards. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.



Hazard: the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, health impacts, property and infrastructure damage, or degradation of livelihoods and ecosystems.

Exposure: Presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings in a given area to a hazard.

Hazard assessment

Hazards assessment

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#1 | Determine relevant climate hazards

#2 | Select relevant hazard indicators

#3 | Analyze historical trends and events

#4 | Analyze future projections across different scenarios

Disaster inventory for Homa Bay:

Year	Disaster Type	Origin
2004	Riverine flood	Heavy rains
2009-10	Riverine flood	Heavy rain
2012	Riverine flood	Torrential rain
2015	Flash flood	Torrential rain
2015	Riverine flood	Heavy rains
2019	Flash flood	Heavy rainfall and overflowing rivers
2020	Flood	Prolonged rains
2021	Flood	"Long Rains" season
2023	Flood	Heavy rains

Source: EM-DAT and Department of Disaster Management and Special Programs

Hazards assessment

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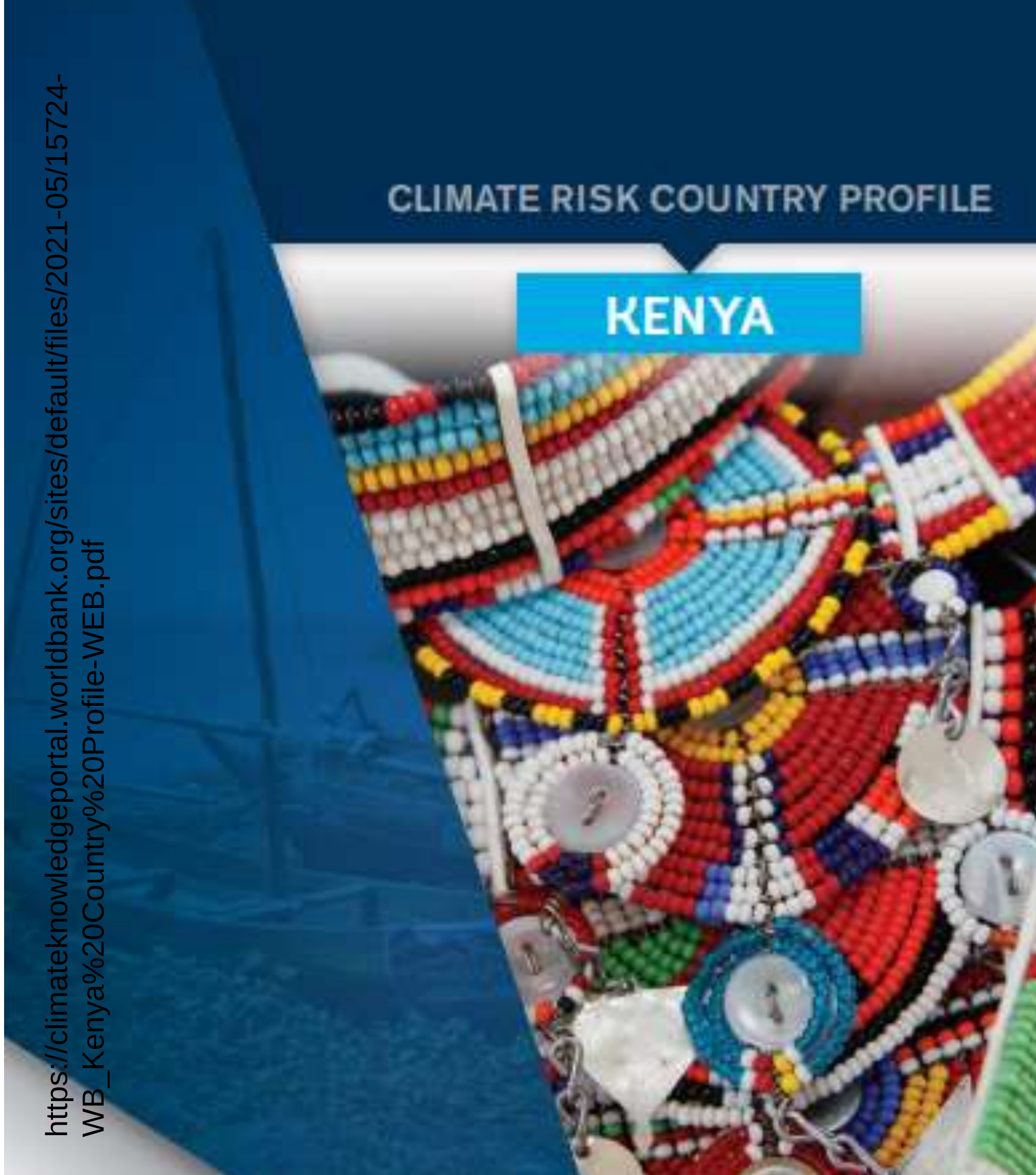

https://climateknowledgeportal.worldbank.org/sites/default/files/2021-05/15724-WB_Kenya%20Country%20Profile-WEB.pdf

Hazards assessment

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Examples of hazard indicators that can be found in global database:

Increasing temperatures:
- Annual seasonal monthly average (air) temperature

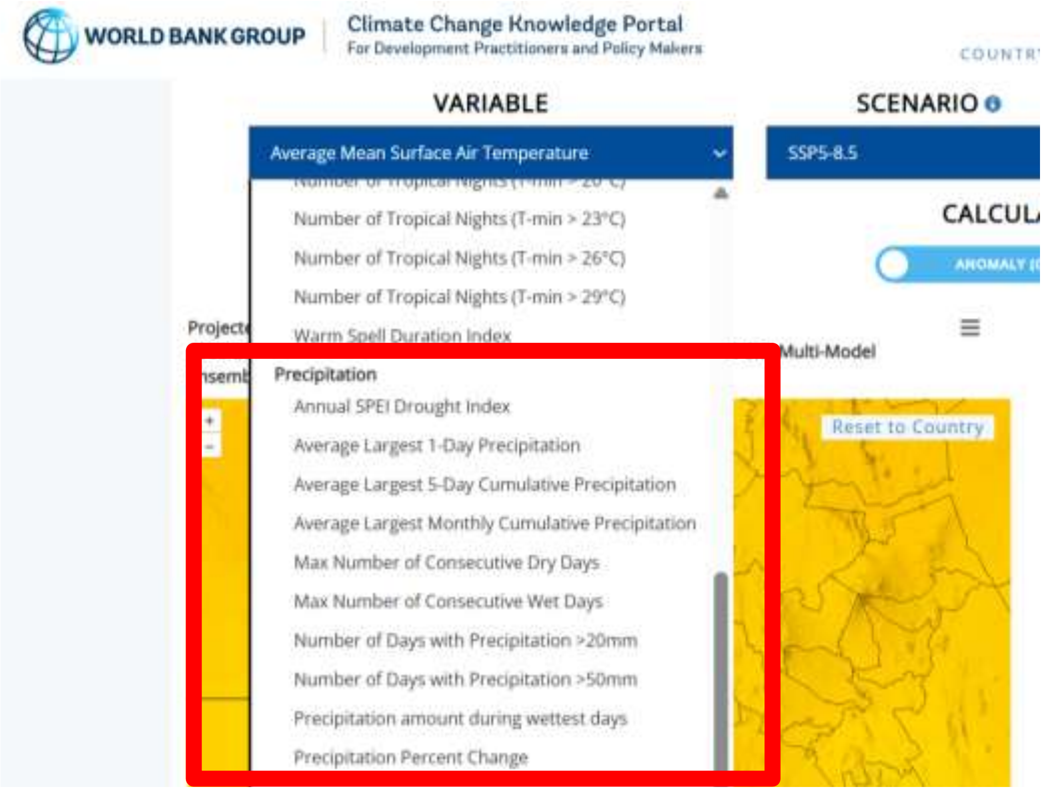
Heat waves:
- Heat wave frequency (avg. number of heat waves per year)
- Heat wave intensity (avg. temperature above local threshold during heat wave)
- Heat wave duration (avg. length of individual heat waves – no. days)

Sea level rise:
- Absolute sea level change (cm)
- Relative sea level change (incl. local land movement) (cm)

River floods:
- No. of days with precipitation > 100mm
- Flooding magnitude (peak discharge)
- Flooding frequency (avg. no. of flood days per year)

Hazards assessment

BUT these indicators depends of the database, the climate models, etc.



Hazards assessment

#1 | Determine relevant climate hazards

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But usually we are using the following indicators:

Increasing temperatures:

- Mean temperature / Average Mean Surface Air Temperature

Heat waves:

- Number of Hot Days (Tmax > 35°C) / Days with TX above 35°C

Flood:

- Precipitation / Total precipitation

Hazards assessment

GLOBAL CENTER ON ADAPTATION

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Key questions:

- What are **key historical trends** in the city? (looking back over 30 years is ideal)
- What **major historical climate events** have occurred for each relevant hazard?
- What were **the impacts**? (e.g. loss of lives and/or livelihoods, direct and indirect economic losses)
- What **sectors and groups of people were most affected**, including women, poor communities, children, the elderly, etc.?
- How have these **hazards changed over time**? (More/less frequent? More/less intense? Longer/shorter duration?)

Hazards assessment

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Database	Characteristics	Indicators	Scale	Provider
ERA-5	Historical data Combines model data with observations from across the world Going back to 1940 until today	Various indicators under temperature and precipitation	City scale (closest point in the grid)	Copernicus, ECMWF
World Bank CC Knowledge Portal	Historical data (ERA-5) and future projected data Uses CMIP6 ensemble models (global climate models)	Various indicators under temperature and precipitation, relative humidity and growing season length	County scale	World Bank
IPCC Atlas	Historical data, future projected data and paleoclimate CMIP5 global, CMIP6 global and CORDEX	Various indicators under temperature, precipitation, wind, snowfall, ocean	City scale (closest point in the grid)	IPCC

Hazards assessment / Done in Homa Bay

#1 | Determine relevant climate hazards

#2 | Select relevant hazard indicators

#3 | Analyze historical trends and events

#4 | Analyze future projections across different scenarios

- **Historical**
  - Measures from Kenya Meteorological Department
  - Field observations
  - International databases in open access (e.g. ERA-5)
- Projected change
  - Climate projections from KMD
  - Climate change/Climate risks reports
  - International databases in open access (e.g. IPCC Atlas, WB Knowledge Portal)
- Impact modelling
  - Hydrological and hydraulic study

Hazards assessment / Results for Homa Bay

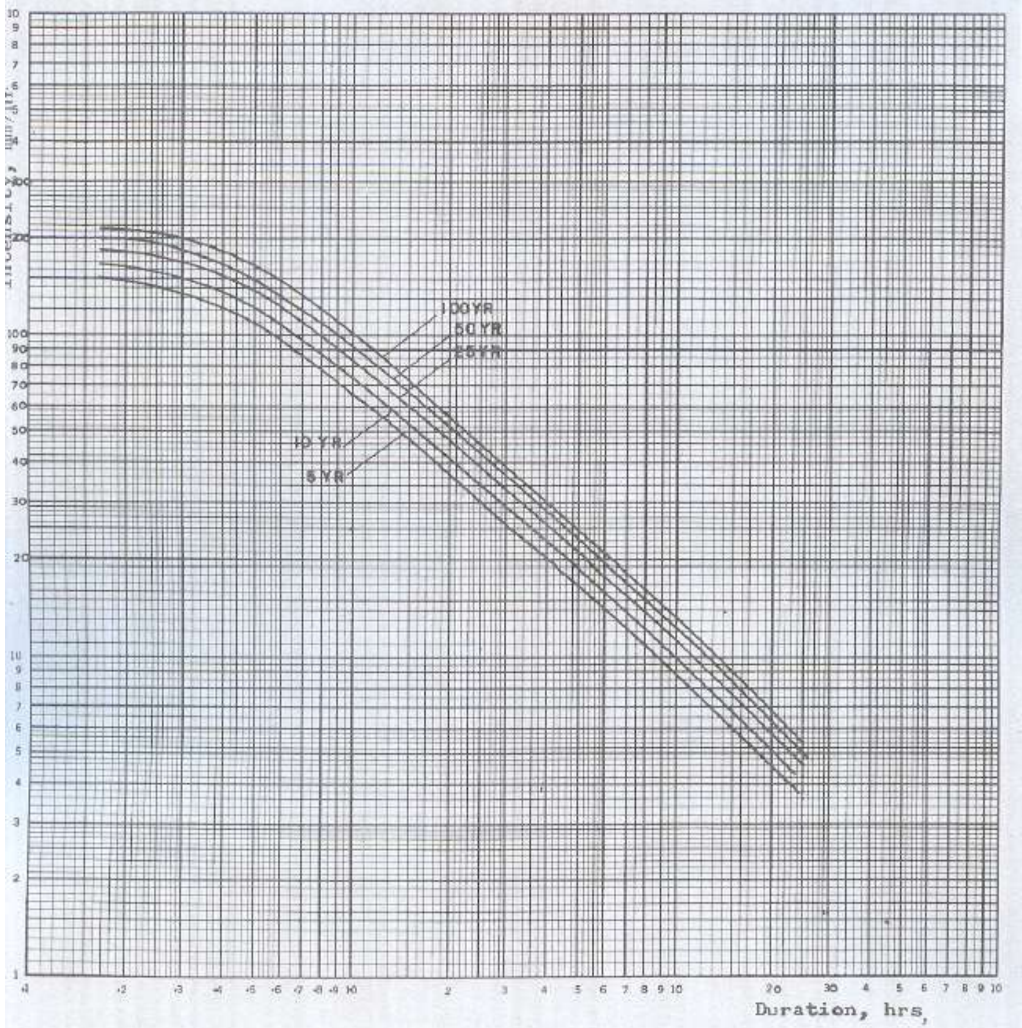
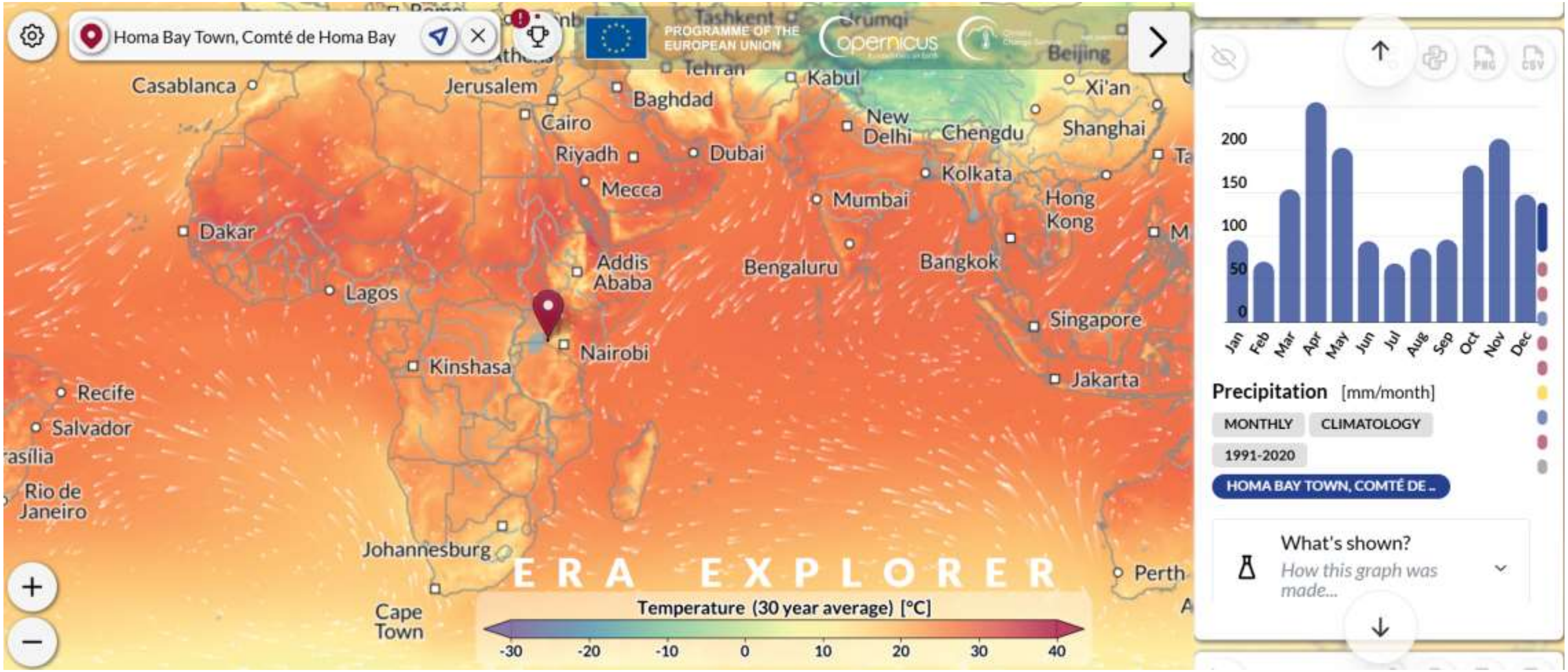


FIGURE A-8. Rainfall Intensity - Duration - Frequency Relationships for Kisumu.

- 72 -

Hazards assessment / ERA-5



Hazards assessment / World Bank Climate Change Knowledge Portal

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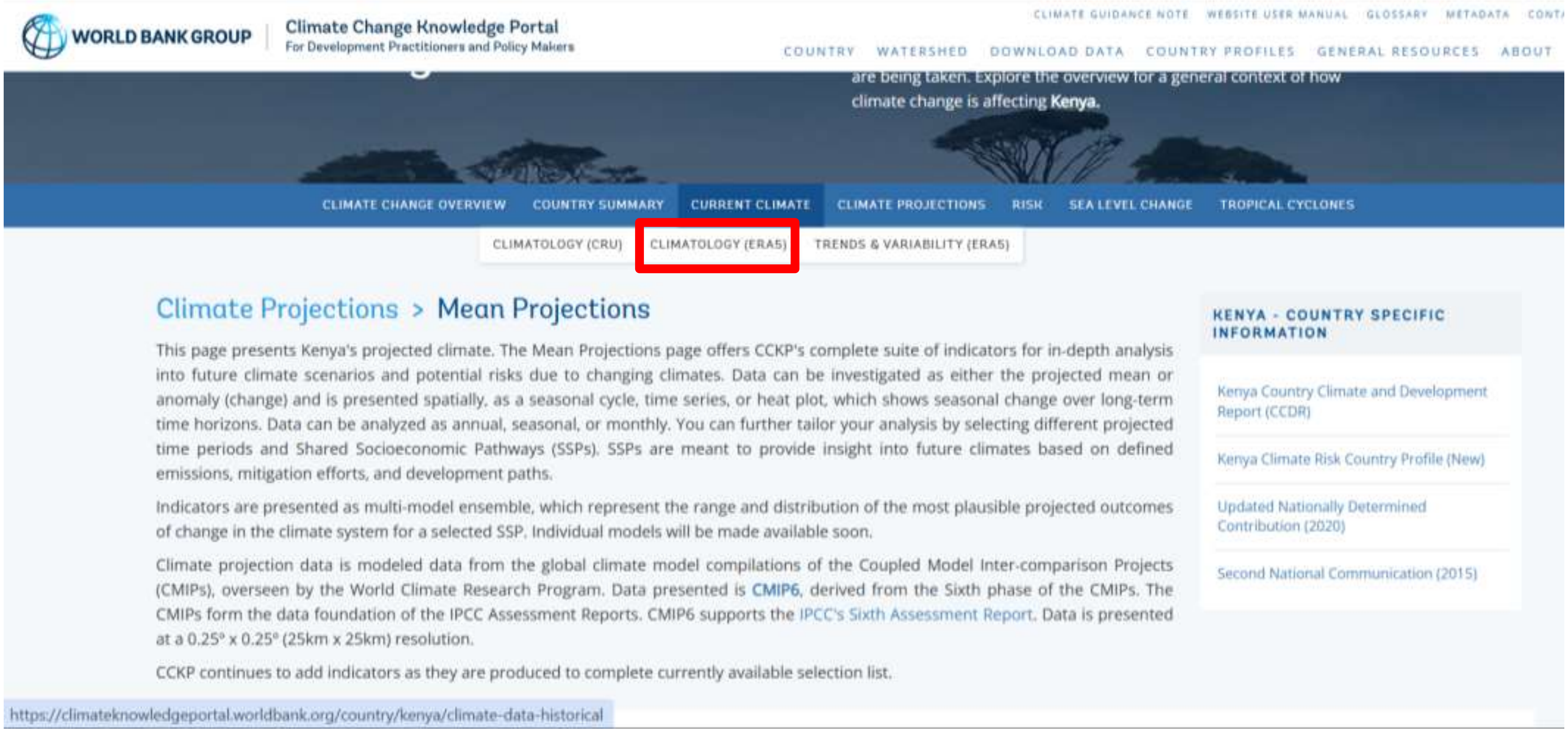

WORLD BANK GROUP | Climate Change Knowledge Portal
For Development Practitioners and Policy Makers

CLIMATE GUIDANCE NOTE | WEBSITE USER MANUAL | GLOSSARY | METADATA | CONTA

COUNTRY | WATERSHED | DOWNLOAD DATA | COUNTRY PROFILES | GENERAL RESOURCES | ABOUT

are being taken. Explore the overview for a general context of how climate change is affecting **Kenya**.

CLIMATE CHANGE OVERVIEW | COUNTRY SUMMARY | CURRENT CLIMATE | CLIMATE PROJECTIONS | RISK | SEA LEVEL CHANGE | TROPICAL CYCLONES

CLIMATOLOGY (CRU) | CLIMATOLOGY (ERA5) | TRENDS & VARIABILITY (ERA5)

Climate Projections > Mean Projections

This page presents Kenya's projected climate. The Mean Projections page offers CCKP's complete suite of indicators for in-depth analysis into future climate scenarios and potential risks due to changing climates. Data can be investigated as either the projected mean or anomaly (change) and is presented spatially, as a seasonal cycle, time series, or heat plot, which shows seasonal change over long-term time horizons. Data can be analyzed as annual, seasonal, or monthly. You can further tailor your analysis by selecting different projected time periods and Shared Socioeconomic Pathways (SSPs). SSPs are meant to provide insight into future climates based on defined emissions, mitigation efforts, and development paths.

Indicators are presented as multi-model ensemble, which represent the range and distribution of the most plausible projected outcomes of change in the climate system for a selected SSP. Individual models will be made available soon.

Climate projection data is modeled data from the global climate model compilations of the Coupled Model Inter-comparison Projects (CMIPs), overseen by the World Climate Research Program. Data presented is CMIP6, derived from the Sixth phase of the CMIPs. The CMIPs form the data foundation of the IPCC Assessment Reports. CMIP6 supports the IPCC's Sixth Assessment Report. Data is presented at a 0.25° x 0.25° (25km x 25km) resolution.

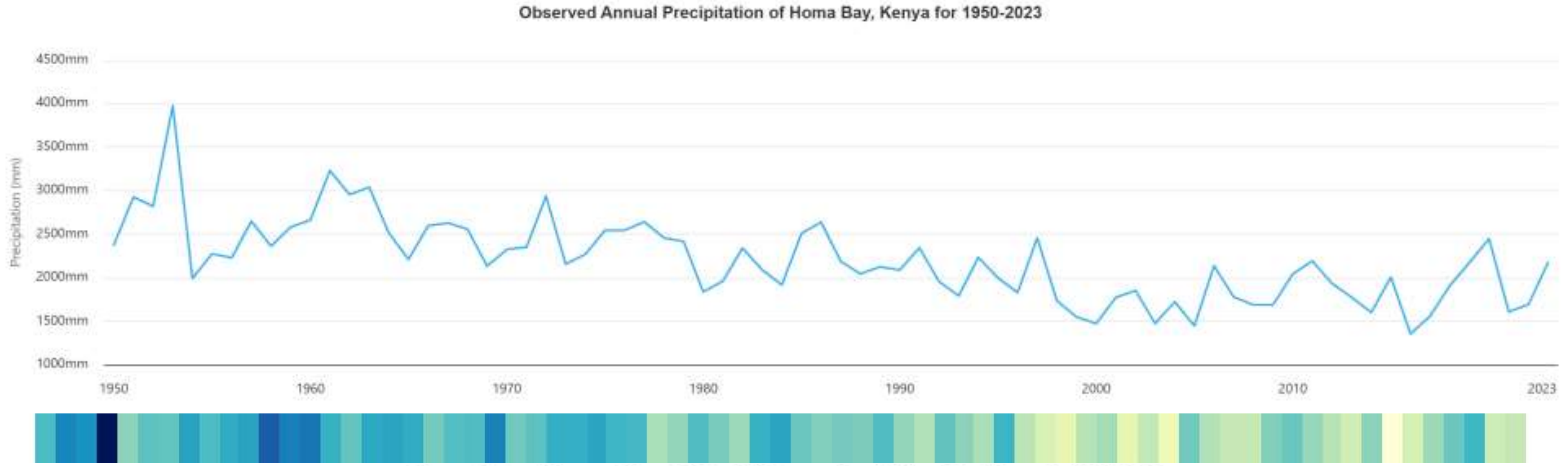
CCKP continues to add indicators as they are produced to complete currently available selection list.

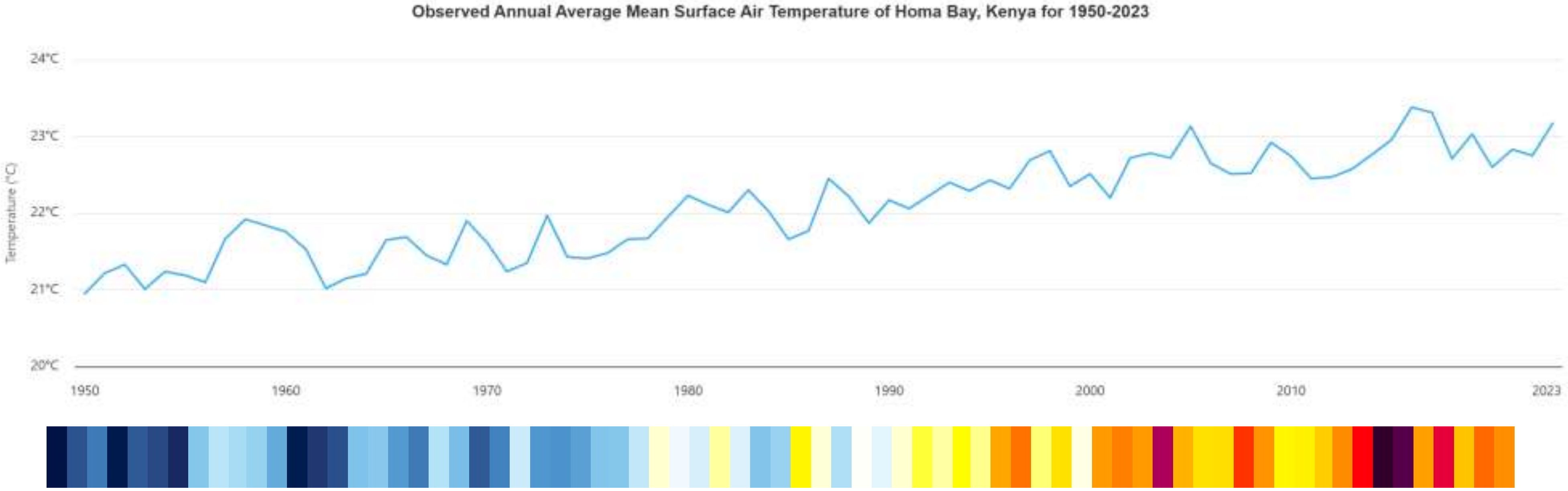
KENYA - COUNTRY SPECIFIC INFORMATION

- Kenya Country Climate and Development Report (CCDR)
- Kenya Climate Risk Country Profile (New)
- Updated Nationally Determined Contribution (2020)
- Second National Communication (2015)

https://climateknowledgeportal.worldbank.org/country/kenya/climate-data-historical

Hazards assessment / Results for Homa Bay





Hazards assessment

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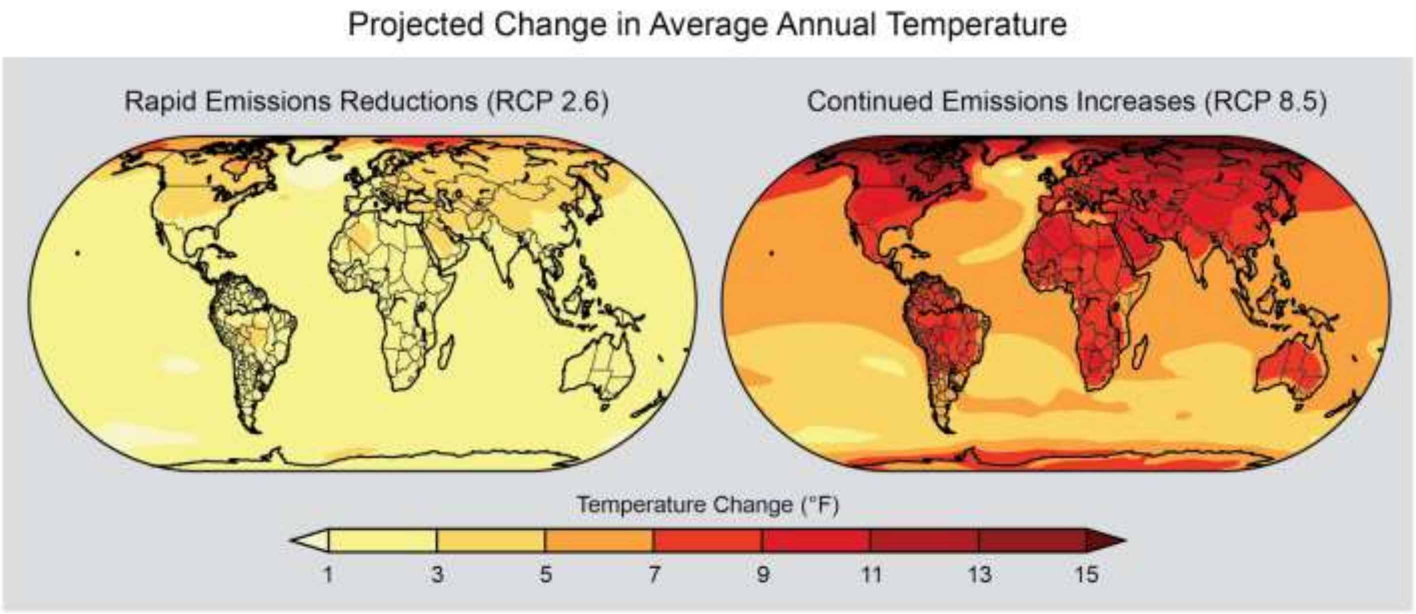


Hazards assessment / IPCC scenarios

IPCC AR5 Report (2014)

RCP 2.6: Emissions stabilise before 2050

RCP 4.5: Emissions stabilise at a low level by the end of the century

RCP 6.0: Emissions stabilise at a medium level by the end of the century

RCP 8.5: Emissions continue to increase at the current rate

IPCC AR6 Report (2021)

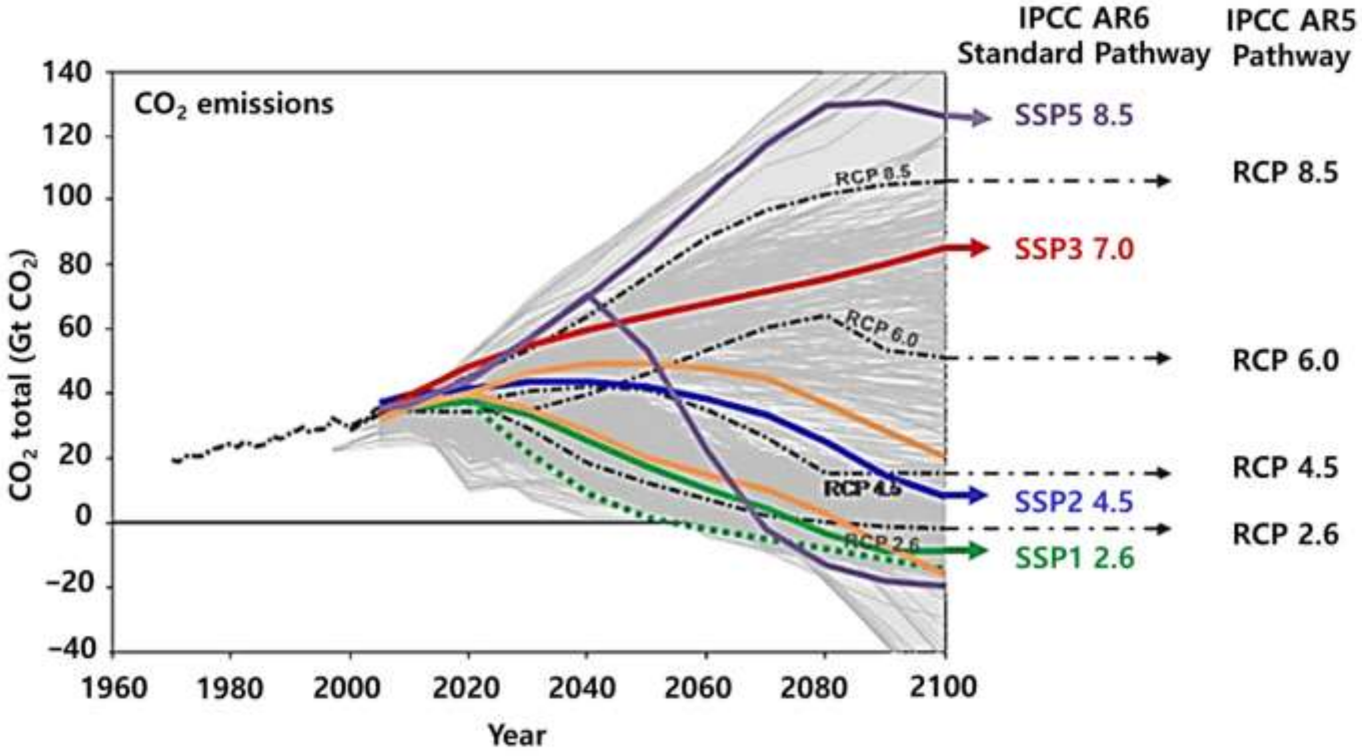
SSP1-1.9 : Very low greenhouse gas emissions

SSP1-2.6 : Low greenhouse gas emissions

SSP2-4.5 : Intermediate greenhouse gas emissions

SSP3-7.00 : High greenhouse gas emissions

SSP5-8.5: Very high greenhouse gas emissions



Riahi et al., 2017.

Hazards assessment / Climate models

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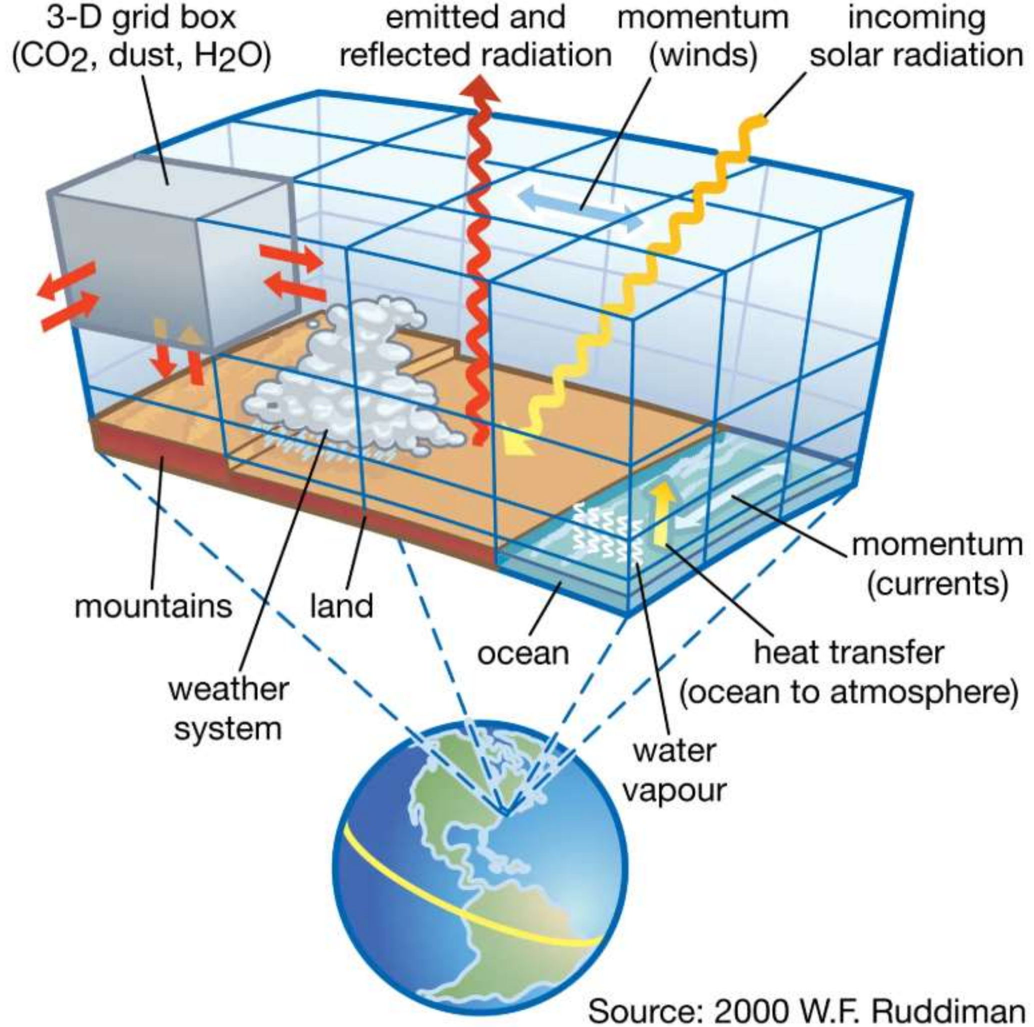
Results are based from **aggregated models** and not from a single model

Two types of models available with different resolution:

- Global (CMIP6 / CMIP5 models) 100 to 250 km
- and regional (CORDEX Africa RCM) 50 km

Concept diagram of climate modeling



Source: 2000 W.F. Ruddiman

Hazards assessment / Done in Homa Bay

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Hazards assessment

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Database	Characteristics	Indicators	Scale	Provider
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Climate Information Portal	Future projected data Can use CMIP6 global, CMIP5 global and CORDEX	Various indicators under temperature, precipitation, soil moisture, water discharge, water runoff and aridity	City scale (closest point in the grid)	WMO, WCRP, GCF, SMHI
IPCC Atlas	Historical data, future projected data and paleoclimate CMIP5 global, CMIP6 global and CORDEX	Various indicators under temperature, precipitation, wind, snowfall, ocean	City scale (closest point in the grid)	IPCC

Hazards assessment / Done in Homa Bay

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#4 | Analyze future projections across different scenarios

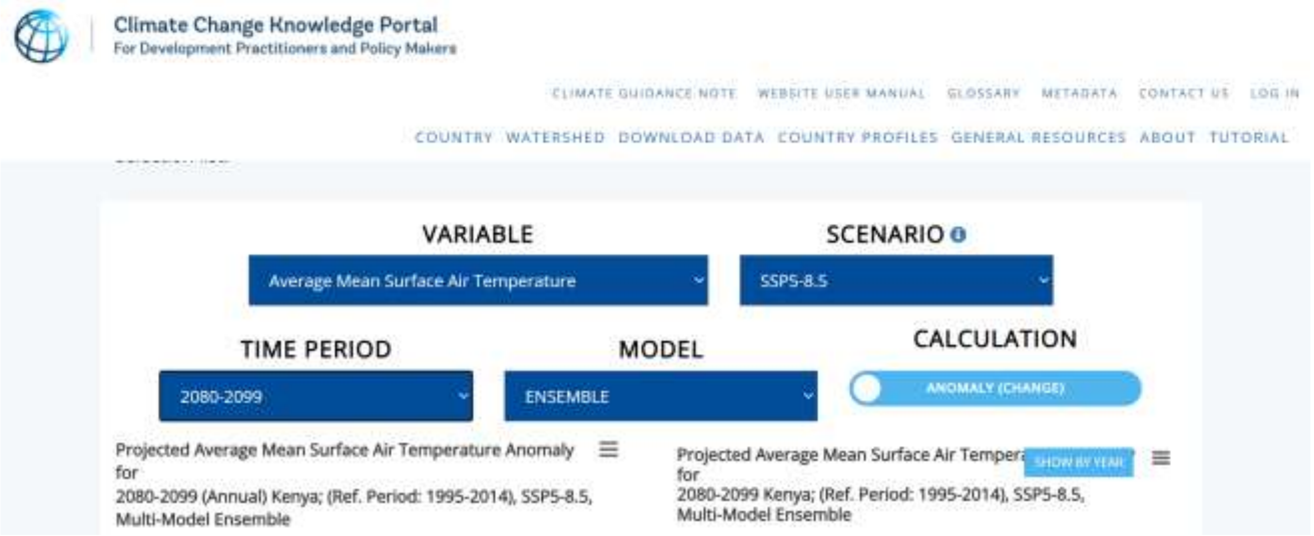
1 Choose your database

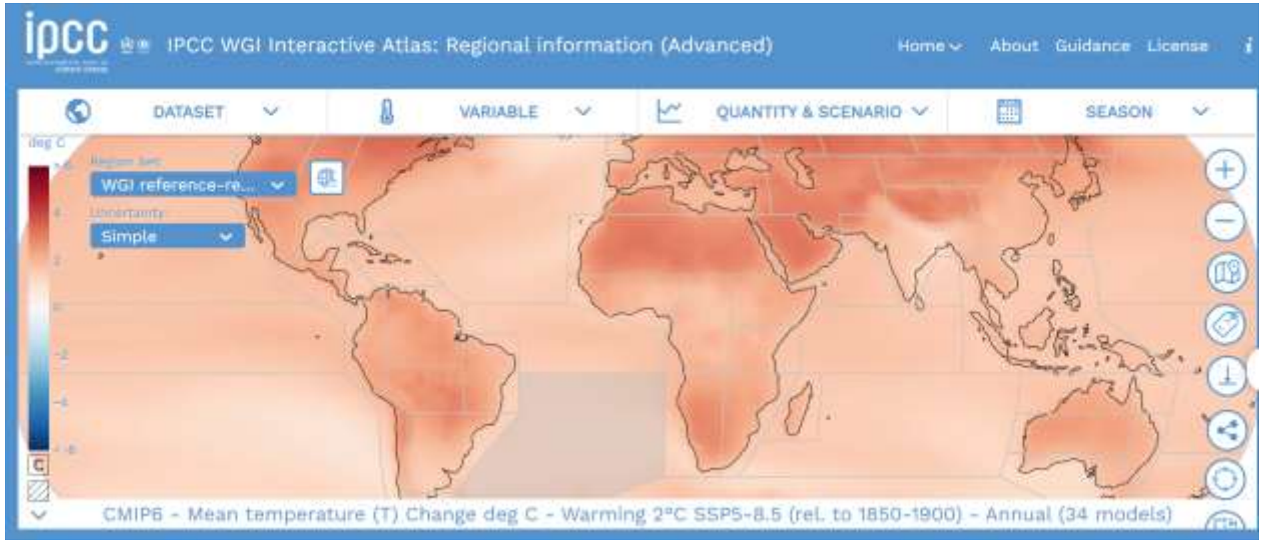
2 Select your parameter

3 Select your scenario

4 Select your time horizon

5 Select your models





Results for Homa Bay

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Scenarios	Average temperature (°C)	Average rainfall (mm/day)	Heavy precipitation (Nb days >20mm)	Heatwave (days)	Number of days above 35°C (days)
RCP 4.5	Short-term: +1°C Medium-term: +1.6°C	Short-term: -1.5% Medium-term: --1.2%	Short-term: +0.9 days Medium-term: +1.2 days	Short-term: +38.5 days Medium-term: +72.3 days	Short-term: +1.5 days Medium-term: +4.1 days
RCP 8.5	Short-term: +1.1°C Medium-term: +2°C	Short-term: +2.2% Medium-term: +2.3%	Short-term: +0.6 days Medium-term: +1.3 days	Short-term: +37.8 days Medium-term: +97.8 days	Short-term: +4.5 days Medium-term: +13.3 days

Key takeaway: clear warming trend whichever scenario is chosen, but no distinct trend for annual rainfall, going from less to more rain depending on the projections. However heavy precipitation intensifies slightly.

Exposure assessment

What can be exposed?
Land use mapping

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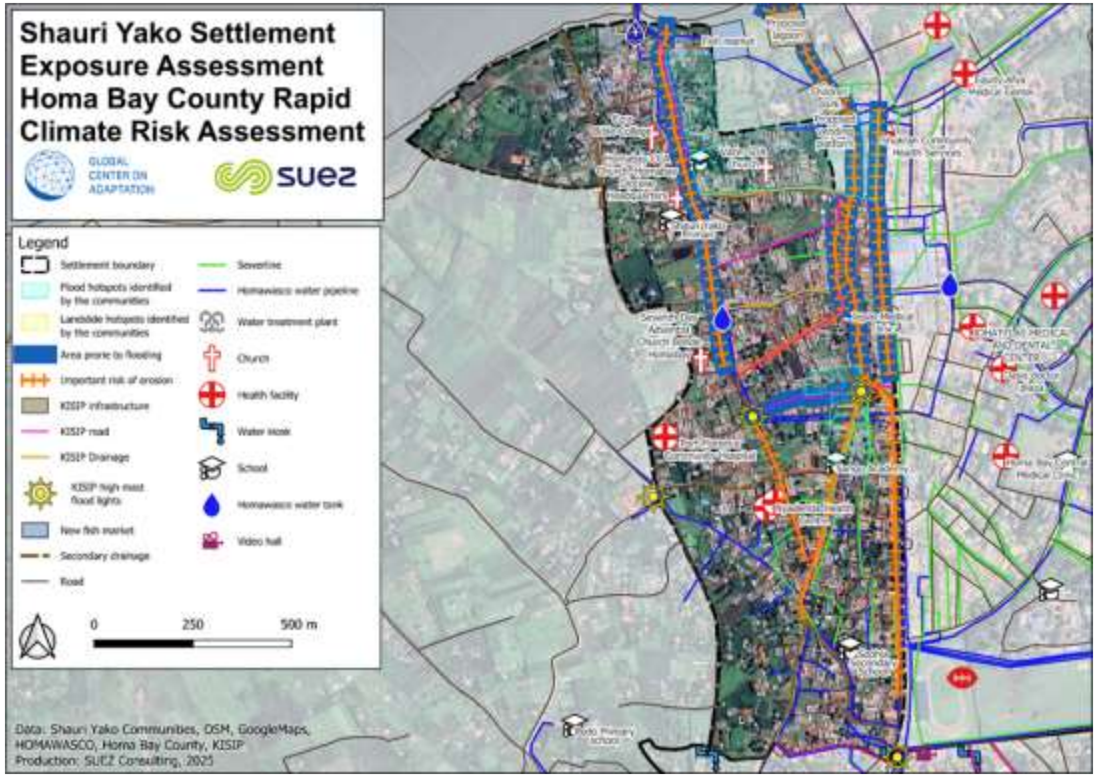
ECOSYSTEMS

BUILT ENVIRONMENT



INTANGIBLE ASSETS

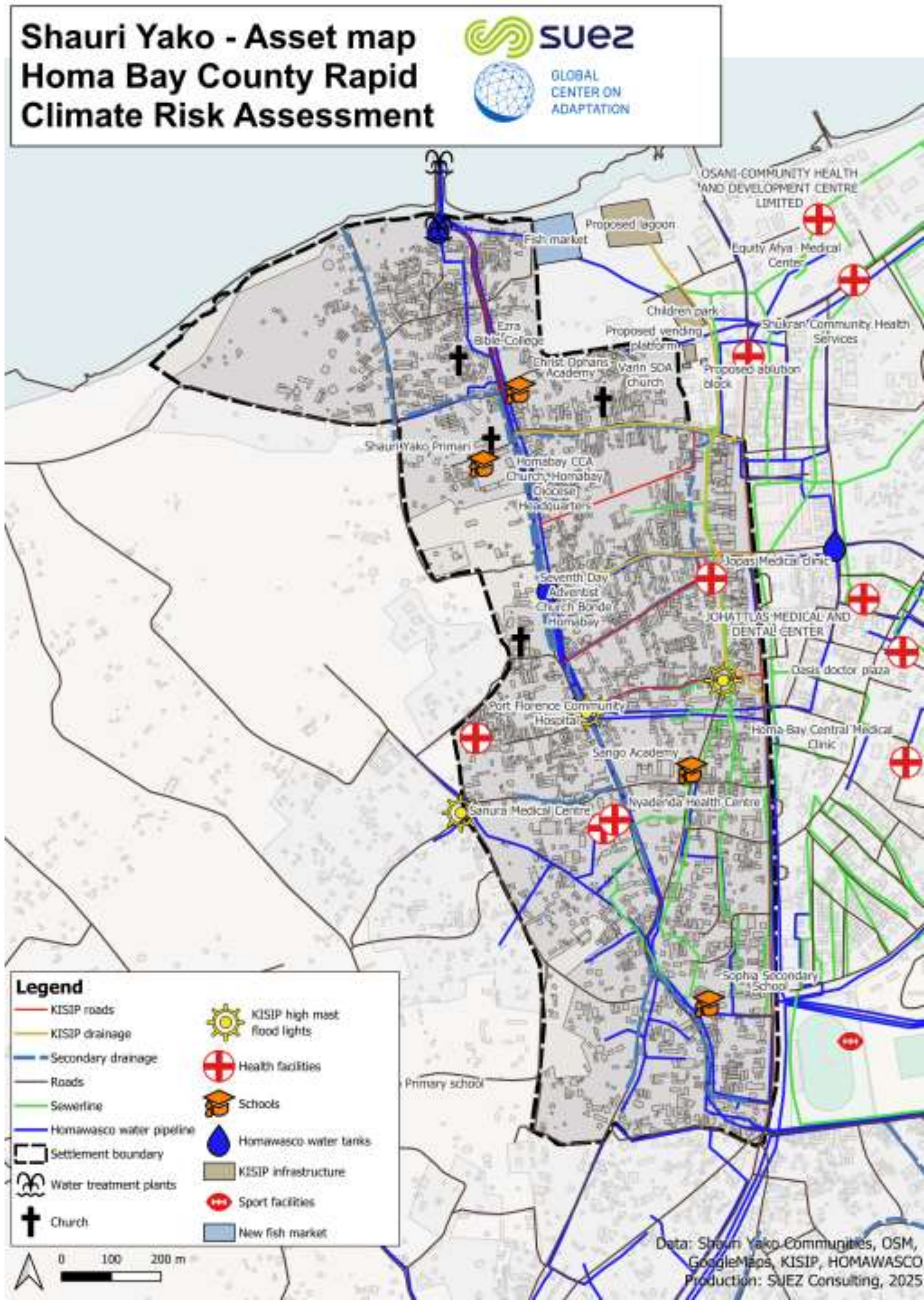
HUMAN BEINGS

Results for Homa Bay

Map database
- OpenStreetMap
- GoogleEarth/ Google Maps
- ESRI (world land cover)

Assets
- Data (and GIS files) from stakeholders (e.g. Homawasco, County)
- International database (e.g. Google maps, UNEP Geodata)
- Field observations, settlement mapping

Hazards
- Hazard maps



Vulnerability assessment

What types of vulnerability?

Social vulnerabilities: who lives in the three settlements, in terms of age, gender, ethnies, social rank, etc., and how these socio-demographic characteristics influence their capacity to adapt.

Economic vulnerabilities: What is the share of the economic activities that are climate sensitive and what is the level of livelihood so people can better prepare against hazards.

Geophysical vulnerabilities: how hydrology, topography and the natural environment make the area more vulnerable.

Infrastructure vulnerabilities: looking at all types of infrastructure (water, sanitation, communication, energy, health, education, etc.).

Institutional vulnerabilities: how the institutional set-up act as an obstacle for action or a lever.

How can we measure vulnerability?

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Secondary data
- Literature
- Existing reports (national, local, from funders, NGOs)
- Databases (e.g. KNBS)

Field data
- Focus groups (community validation workshops)
- Semi-structured interviews
- Multi-stakeholder workshops
- Household surveys, settlement profiling
- Street surveys

Focus on the gender issue

Why gender matters?
- Unequal impacts
- Limited adaptive capacity
- Women’s perspective and knowledge

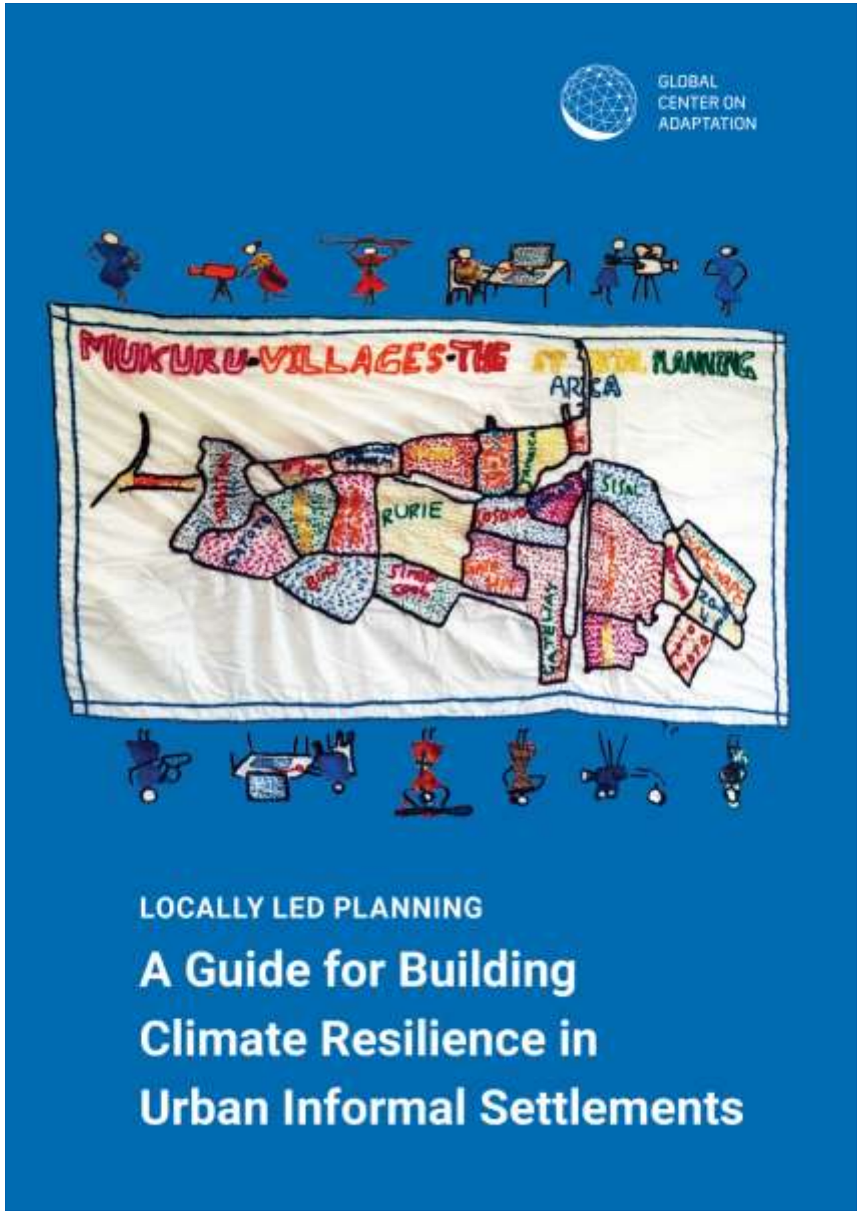
How we integrated the gender issues in a project:
- A gender expert
- 3 Women groups in each informal settlements
- Disaggregated data - high percentage of female-headed households in all three settlements (33.4% in Shauri Yako, 37% in Sofia and Makongeni)

Gender sensitive actions:
- Microfinance
- Tenure security for women, particularly female-headed households: Who is doing it? How to implement?

How to engage local communities and take into account their perspectives?

Collecting local perspectives / feedback

Mukuru guide



Collecting local perspectives / feedback

Climate Action Plan for Brazzaville

Objective: Undertake GHG emissions and climate risk assessment at the whole scale of Brazzaville district (Congo Republic) and develop a climate action plan for the district.

Client: French Development Agency / Brazzaville Municipality

Implementer: Suez Consulting

Major hazards: flooding, erosion, built-up of sand and urban heat

Street Survey

This approach, while less comprehensive than full settlement profiling, offers an effective alternative for engaging a broad and dispersed population. It relies on a carefully designed questionnaire adapted to time constraints, with data collected using KoboToolbox. The rollout is supported by students, providing a practical and scalable method for gathering community input.

Street survey box
Source: SUEZ Consulting

Collecting local perspectives / feedback

Climate adaptation in local development plans in Guinea

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CVCA methodology

Widely tested worldwide

Easy tool to implement

Provides a framework for analysing vulnerability and adaptive capacity to climate change **at community level**

Combine community knowledge and scientific data to improve understanding of the local impacts of climate change and design appropriate adaptation pathways

Field guide #	Name of tool	Purpose of tool
1	Hazard Map	The Hazard Map provides an introduction to the community, its surroundings and the hazards that affect it. It identifies key livelihood strategies, the resources they require and where they are practised.
2	Historical Timeline	The Historical Timeline provides an overview of important events in the community. It enables analysis of hazard trends and changes based on community perceptions.
3	Seasonal Calendar	The Seasonal Calendar identifies important livelihood activities throughout the year and provides a basis for discussing seasonal changes observed by communities.
4	Daily Clock	The Daily Clock explores gender differences in daily tasks, providing insights into gender-specific roles and responsibilities.
5	Household Decision-Making Pile Sorting	The Pile Sorting exercise explores gender differences in decision-making power in the household. It promotes discussion on the value of joint decision-making.
6	Impact Chains	Impact Chains facilitate assessment of direct and indirect impacts of hazards on livelihoods, providing a basis for discussing how people are currently responding to the impacts.
7	Vulnerability Matrix	The Vulnerability Matrix identifies priority livelihood assets and hazards, both climate-related and other. It also assesses the degree of impact that the hazards have on the livelihood assets.
8	Venn Diagram	The Venn Diagram identifies the institutions that interact with the community members and the services that they provide.
9	Adaptation Pathways	Adaptation Pathways identify options for adaptation and resilience building and assess the opportunities and barriers to putting them in place.

Collecting local perspectives / feedback

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Climate adaptation in
local development plans in Guinea

CVCA methodology

Conduct CVCA methodology to inform local development plans in Guinea.

Client: French Development Agency

Implementer: Suez Consulting

Major hazards: flooding, erosion, built-up of sand and urban heat

Priorization of climate adaptation option

Impact scoring

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A scoring is useful to anchor potential action on identified risks… but there isn't a single approach to establish a scoring system!

Risk score	Vulnerability				
Exposure		4	3	2	1
	4	16	12	8	4
	3	12	9	6	3
	2	8	6	4	2
	1	4	3	2	1

Quantitative impacts requires proxy or data collection (e.g. value of assets exposed, carbon sequestration potential, impact on sector GDP for service interruption, number of households exposed) and cannot be run on all vulnerability / exposure elements

Qualitative scoring has been conducted in Homa Bay where Sofia reaches a lower impact scoring compared to Makongeni and Shauri Yako.

Iterative process to select actions

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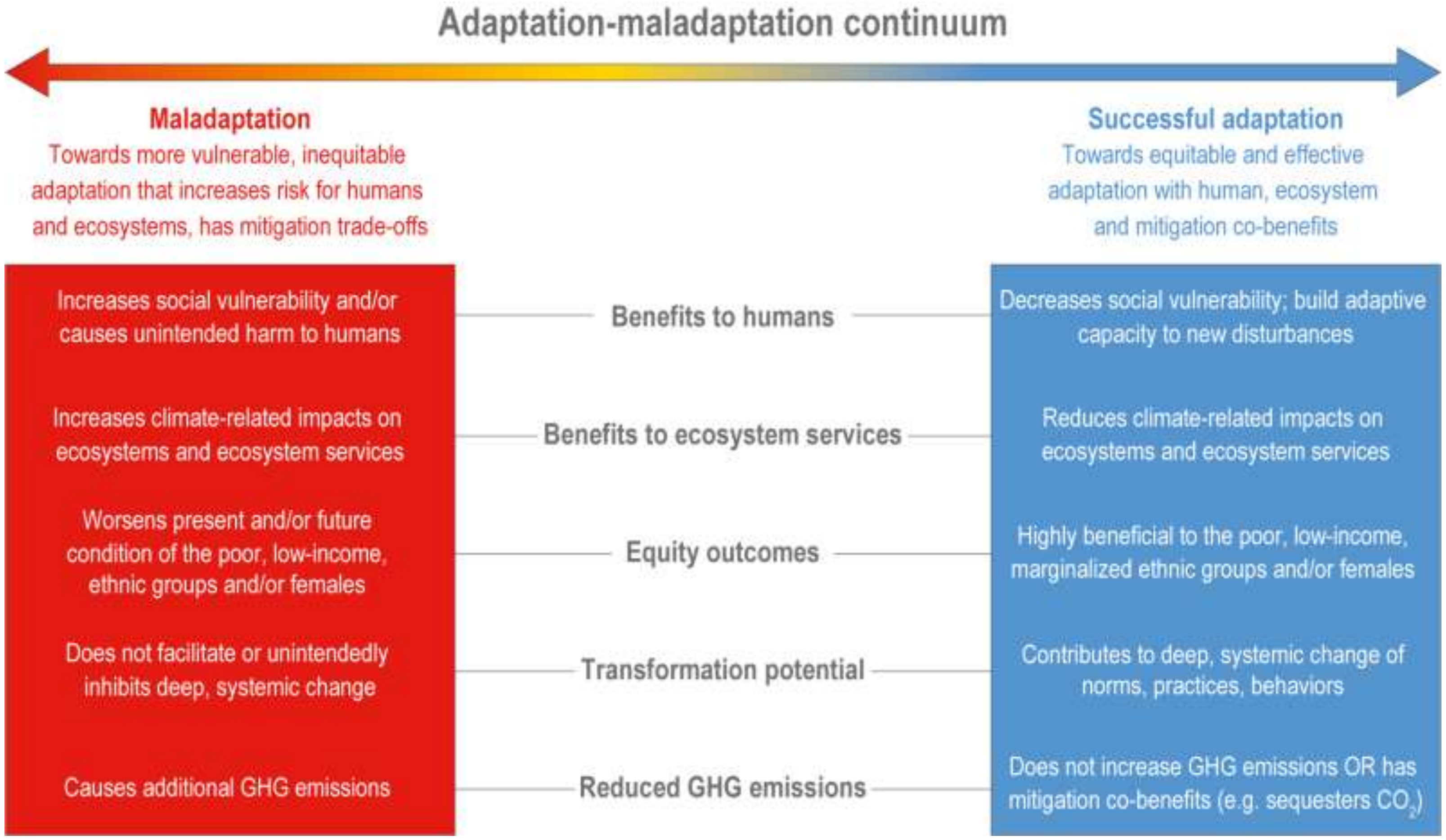
Agree on criteria for selecting the actions (risks addressed, benefits, cost, fitness with potential investments and **potential project lead……**) and discuss these criteria and the actions

Nature-based Solutions (NbS) Inventory - Long List											Benefits	Costs		Feasibility			Grant eligibility	
Project Name	City/ Town	NBS Family	NBS Type	Scale	NBS case category	Urban context	Climate context	Intentional / Unintentional	Cost/Budget (USD)	Funders	Reported benefits	Implementation costs	Maintenance costs	Operational feasibility	Institutional feasibility	Public acceptability	KUSP II UDG eligibility	Number of WB ESS supported
Nairobi Arboretum	Nairobi	Open Green Spaces	Urban Park	Neighbourhood	Green infrastructure	CBD	Subtropical highland	Unintentional			31	0	0	0	0	3	3	5
Kaya Tembo Sacred Forest	Mombasa	Urban Forests	Habitat conservation	Plot	Green infrastructure	Peri-urban	Tropical dry savannah	Unintentional	Udisclosed	Local Digo community	30	0	0	0	0	0	0	5
Bangladesh Mangrove Restoration Project	Mombasa	Mangrove forests	Mangrove restoration and rehabilitation	Catchment	Green infrastructure	Urban Formal	Tropical dry savannah	Unintentional			28	0	0	1	1	3	0	5
Wote Green Park Project	Wote	Open Green Spaces	Urban park	Neighbourhood	Green infrastructure	Urban Formal	Tropical dry savannah	Unintentional	636,350	World Bank (KUSP1)	26	2	2	2	2	2	3	5
Manguo Swamp Catchment Protection	Limuru	Natural Inland Wetlands	Wetland restoration and rehabilitation	Catchment	Green infrastructure	Urban Formal	Subtropical highland	Unintentional	171,400		25	3	0	0	0	0	0	2
John N. Michuki Memorial Conservation Park	Nairobi	River and Stream Renaturation	River rehabilitation and clean-up	Neighbourhood	Green infrastructure	Urban Formal	Subtropical highland	Intentional	Undisclosed		25	0	0	0	0	1	3	4
Uhuru Park	Nairobi	Open Green Spaces	Urban park	Neighbourhood	Green infrastructure	CBD	Subtropical highland	Unintentional	2,100,000		23	1	1	0	0	0	3	4
Ondiri Wetland Conservation	Kikuyu	Natural Inland Wetlands	Wetland restoration and rehabilitation	Catchment	Green infrastructure	Urban Formal	Subtropical highland	Unintentional	9,000		21	3	0	0	0	3	0	3
Upper Tana-Nairobi Water Fund (UTNWF)	Nairobi	River and Stream Renaturation	Bank and bed renaturation	Catchment	Policy/ Programmatic	Peri-urban	Subtropical highland	Intentional	1,350,000		21	0	0	0	0	2	0	3
Eldoret Arboretum	Eldoret	Open Green Spaces	Urban park	Neighbourhood	Green infrastructure	CBD	Subtropical highland	Unintentional	703,600	World Bank (KUSP1)	20	2	0	2	2	3	3	4
Living Smiles, Kuku County	Kuku County	Terraces and Slopes	Living Smiles	Plot	Green infrastructure	Rural	Hot semi-arid	Intentional	130,000	Private donors	19	3	2	2	3	0	3	4
Nandi Park	Eldoret	Open Green Spaces	Urban park	Neighbourhood	Green infrastructure	CBD	Subtropical highland	Unintentional	Undisclosed	Consortium of Uasin Gishu County Government, Embassy of Sweden, Civil Society Urban Development Programme and other local urban fora	18	1	0	0	0	3	3	5
Kayole Estate Transformation Program	Nairobi	Open Green Spaces	Natural playgrounds	Neighbourhood	Green infrastructure	Urban Formal	Subtropical highland	Unintentional	Undisclosed		17	0	0	2	0	0	3	4
St. John's Community School	Nairobi	Bioretention Areas	Rain gardens	Plot	Green infrastructure	Urban Informal	Subtropical highland	Intentional	85,000	SwedBio	16	1	2	3	3	3	0	3
Kenyatta Ave & Moi Street	Nakuru	Green Corridors	Integrated road with planters	Street	Hybrid infrastructure	CBD	Warm-summer Mediterranean	Unintentional	625,850	World Bank (KUSP1)	16	2	0	0	0	2	3	4
Bridge International Academy kwa Reuben	Nairobi	Bioretention Areas	Filter strips	Plot	Green infrastructure	Urban Informal	Subtropical highland	Intentional	Undisclosed	SwedBio	16	0	0	1	3	0	0	4
Oginga Odinga Street Tree Canopy	Nakuru	Green Corridors	Street tree canopies	Street	Green infrastructure	CBD	Warm-summer Mediterranean	Unintentional	Undisclosed - KII awaited	KURA	16	0	0	0	0	3	3	4
The Nairobi Dam Trust Initiative	Nairobi	Bioretention Areas	Retention ponds	Catchment	Green infrastructure	Urban Formal	Subtropical highland	Unintentional	600,000		15	0	0	0	0	0	3	1

Maladaptation screening process

Maladaptation refers to management choices and actions that increase vulnerability to climate change rather than reducing it.



Maladaptation screening process

Maladaptation refers to management choices and actions that increase vulnerability to climate change rather than reducing it.

Avoiding environmental maladaptation

1. Avoid degradation that causes negative effects in situ
2. Avoid displacing pressures onto other environments (neighbouring areas or areas that are connected ecologically or socio-economically)
3. Support the protective role of ecosystems against current and future climate-related hazards
4. Integrate uncertainties concerning climate change impacts and the reaction of ecosystems
5. Set the primary purpose as being to promote adaptation to climate-related changes rather than reduce greenhouse gas emissions

Avoid sociocultural maladaptation

1. Integrate local social characteristics and cultural values about risk and the environmental dynamics
2. Integrate and develop local skills and knowledge related to climate-related hazards and the environment
3. Call on new skills that the community is capable of acquiring

Avoid economic maladaptation

1. Promote the reduction of socio-economic inequalities
2. Support the relative diversification of economic and/or subsistence activities
3. Integrate any potential changes in economic and subsistence activities resulting from climate change

Magnan, A. (2014) Avoiding maladaptation to climate change: towards guiding principles, S.A.P.I.EN.S, 7.1, 2014

Coffee break *(10.30-10.45)*

Tools in pratice

Procure & supervise a CRA

Case of Nakuru Municipality

Context: Nakuru municipality wants to launch a similar CRA study than Homa Bay, but they want to procure it directly and seeking advice from you how the best way to conduct it.

Key objectives: what would be the most important points to stress at each step of the procurement process?

Step 01 | Prepare – what are the key data and existing sources?

Step 02 | Draft ToRs – objectives, tasks…?

Step 03 | Select CRA team – criteria for selection?

Step 04 | Supervise CRA – means to supervise?

Step 05 | Communication – sharing the results?

Step 06 | M&E – indicators to follow?

Let's take 60 minutes to:

→ Hazard assessment to get a baseline for the CRA and complete what needs to be done in Step 01

→ Elaborate what is needed from step 02

→ Share our thoughts collectively

Procure & supervise a CRA

Case of Nakuru Municipality

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Step 01 | Prepare – what are the key data and existing sources?

Step 02 | Draft ToRs – objectives, tasks…?

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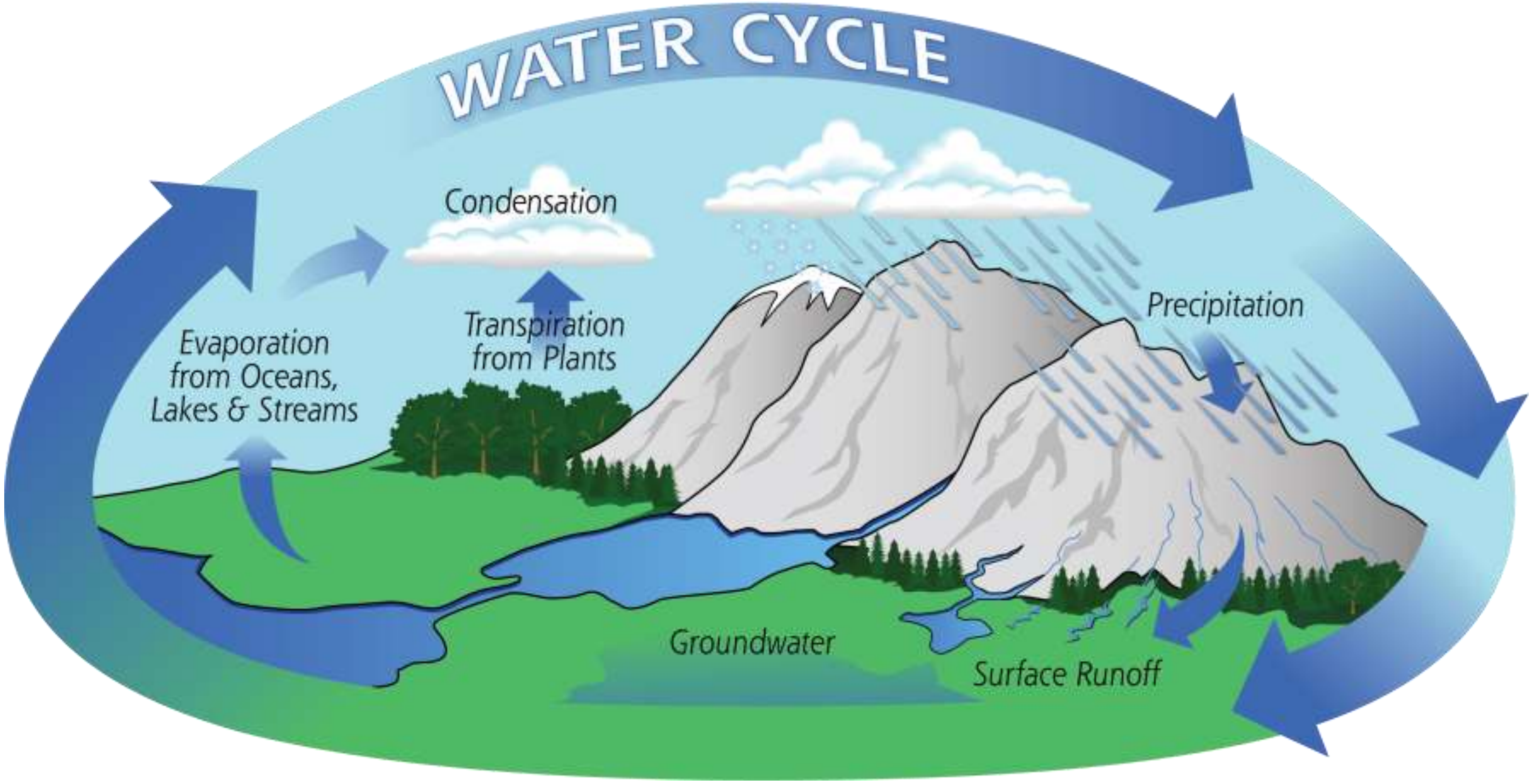
Step 05 | Communication – sharing the results?

Step 06 | M&E – indicators to follow?

Sectoral focus #1 Water: Basics about hydrology and sectoral focus (13:15 - 14:45)

The water cycle – the simple diagram

- Evaporation
- Transpiration
- Condensation
- Precipitation
- Runoff
- Infiltration
- Subsurface flow



credit: nasa.org

The water cycle - the complex diagram

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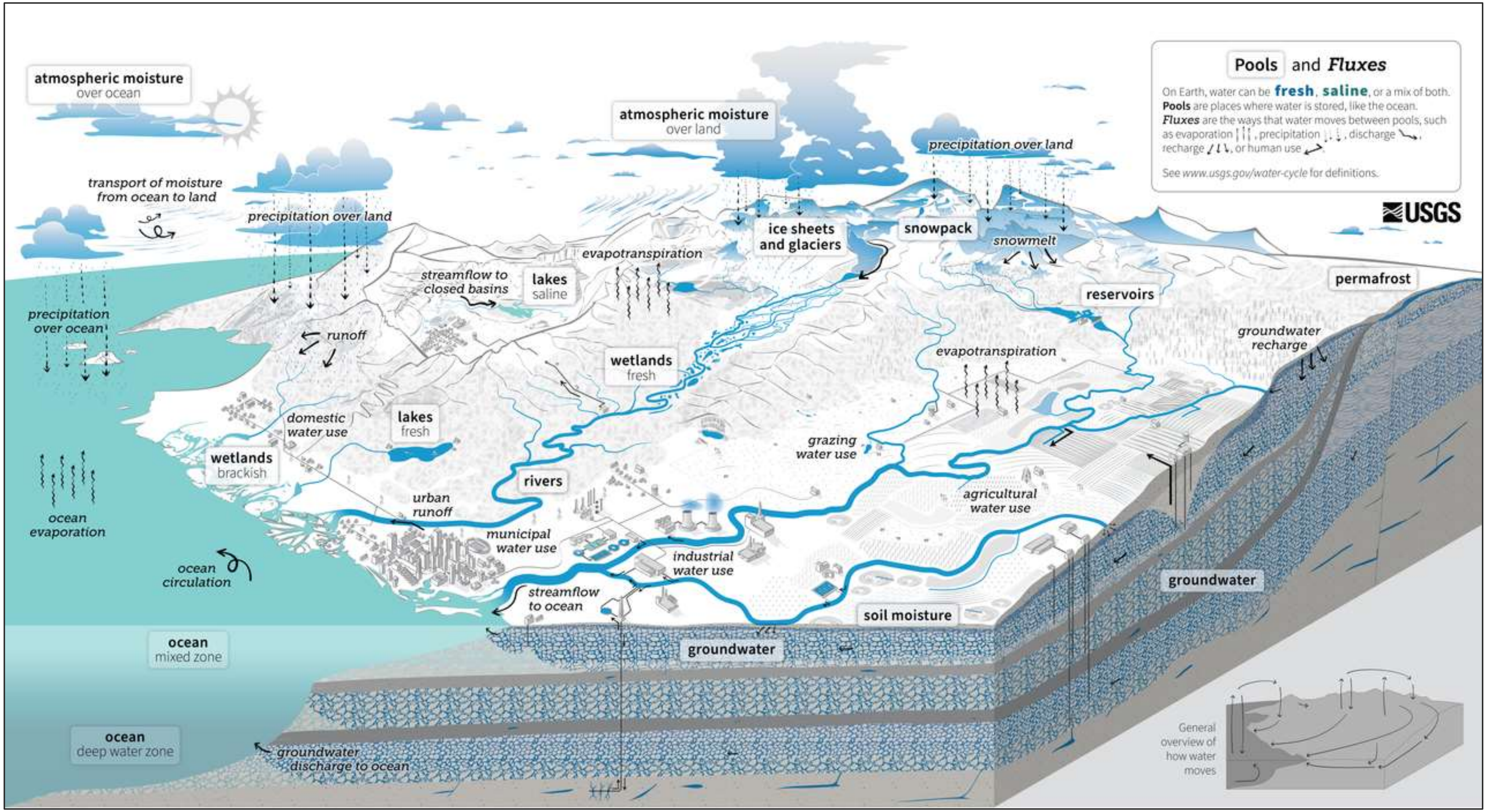


credit: USGS

Hydrology science

- **Hydrology** is the study of all these phenomenon and how they interact between each other

- Simple assumptions are used to simplify these complex phenomenon

- Why do we study it?
  - A natural resource
  - Can cause hazard

- One application example:
  - Rainfall runoff response, or how to convert precipitation into surface runoff

credit: USGS

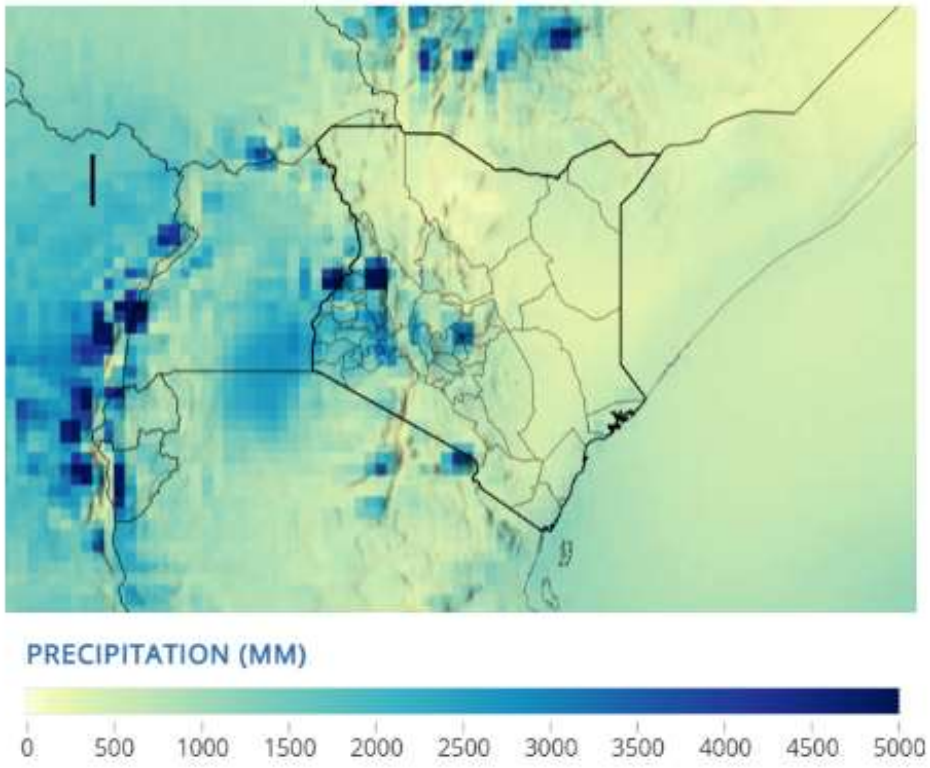
Precipitation

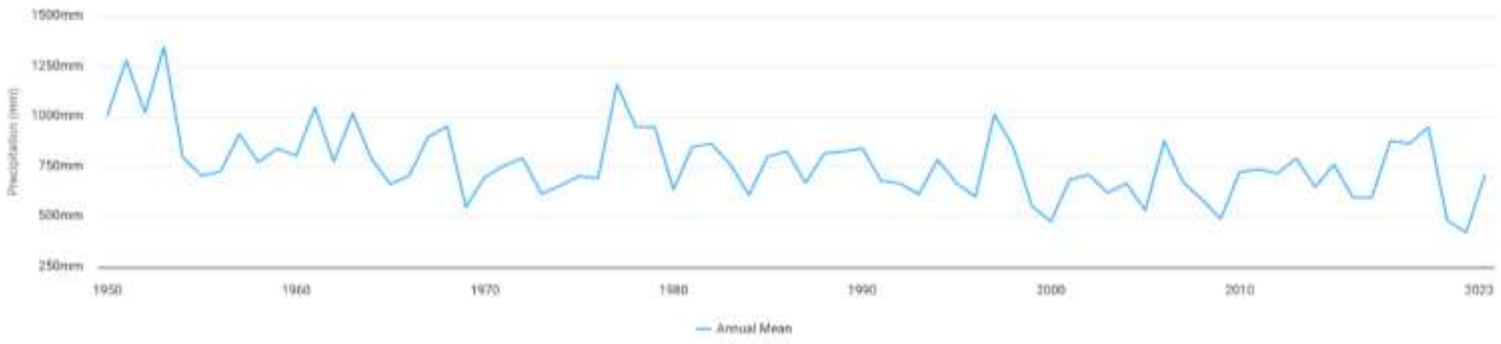
- When atmospheric moisture is too heavy to remain suspended in clouds (mostly rainfall)

- Precipitation is variable **in space**
  - Highlands and areas close to waterbodies receive more precipitation

- Precipitation is variable **in time**
  - Seasonal variability (dry / rainy seasons)
  - Interannual variability (El Niño, IOD, …)

Observed Climatology of precipitation 1991-2020 Kenya (credit: World Bank, Knowledge portal-ERA5)





Observed annual precipitation of Kenya for 1950-2023 (credit: World Bank, Knowledge portal-ERA5)

Precipitation estimation

- Rainfall is estimated via ground measures (rain gauges). It can be completed by satellite estimates
- In Kenya, there are 23 rainfall stations, Kisumu is the closer from Homa Bay, and is operating since 1903
- When sufficient data are available, statistics can be done to calculate the average precipitation, but also the probability of more extreme event (storm or drought)

Automatic rain gauge (credit: Météo-France)

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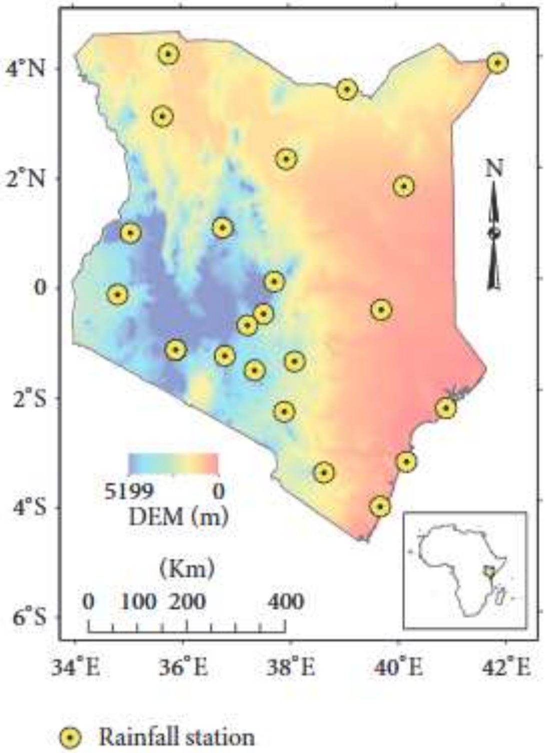
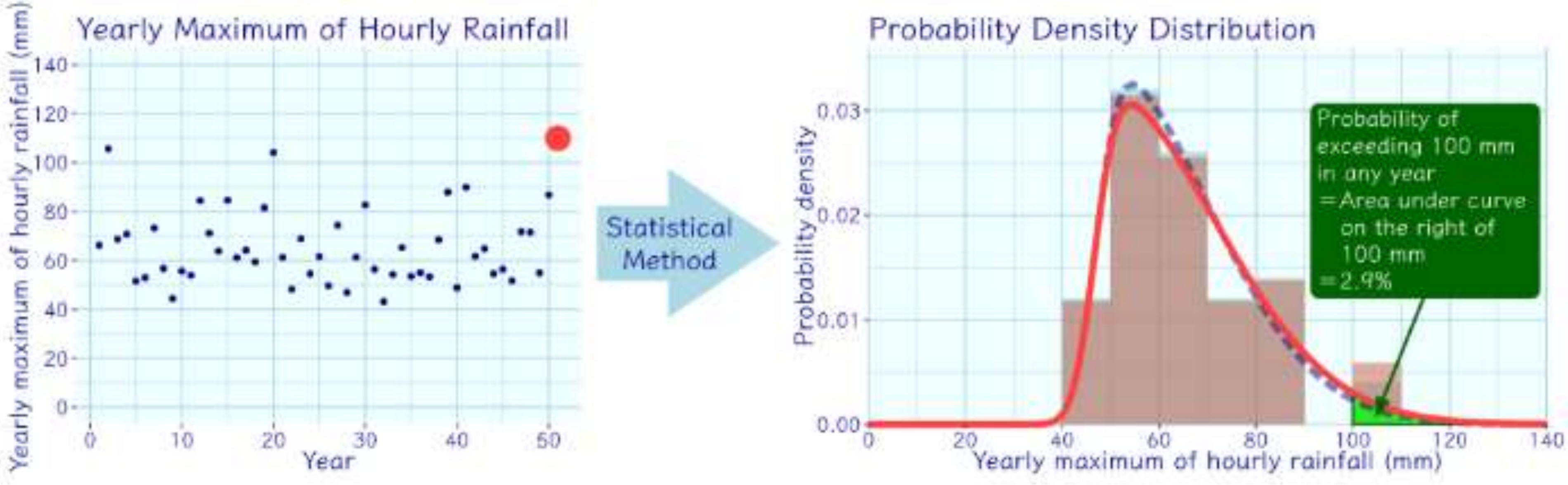
Rainfall station in Kenya (credit: Onyutha, 2016)



Precipitation – return period

- Estimation of very rare to extreme events
- Return period is the probability of a certain size event occurring in a single year
- A 10-year return period event has a 10% chance of happening every year

- 5 or 10-year → drainage infrastructure
- 100-year → floor levels in flood prone areas
- 1000-year or bigger → dam safety design



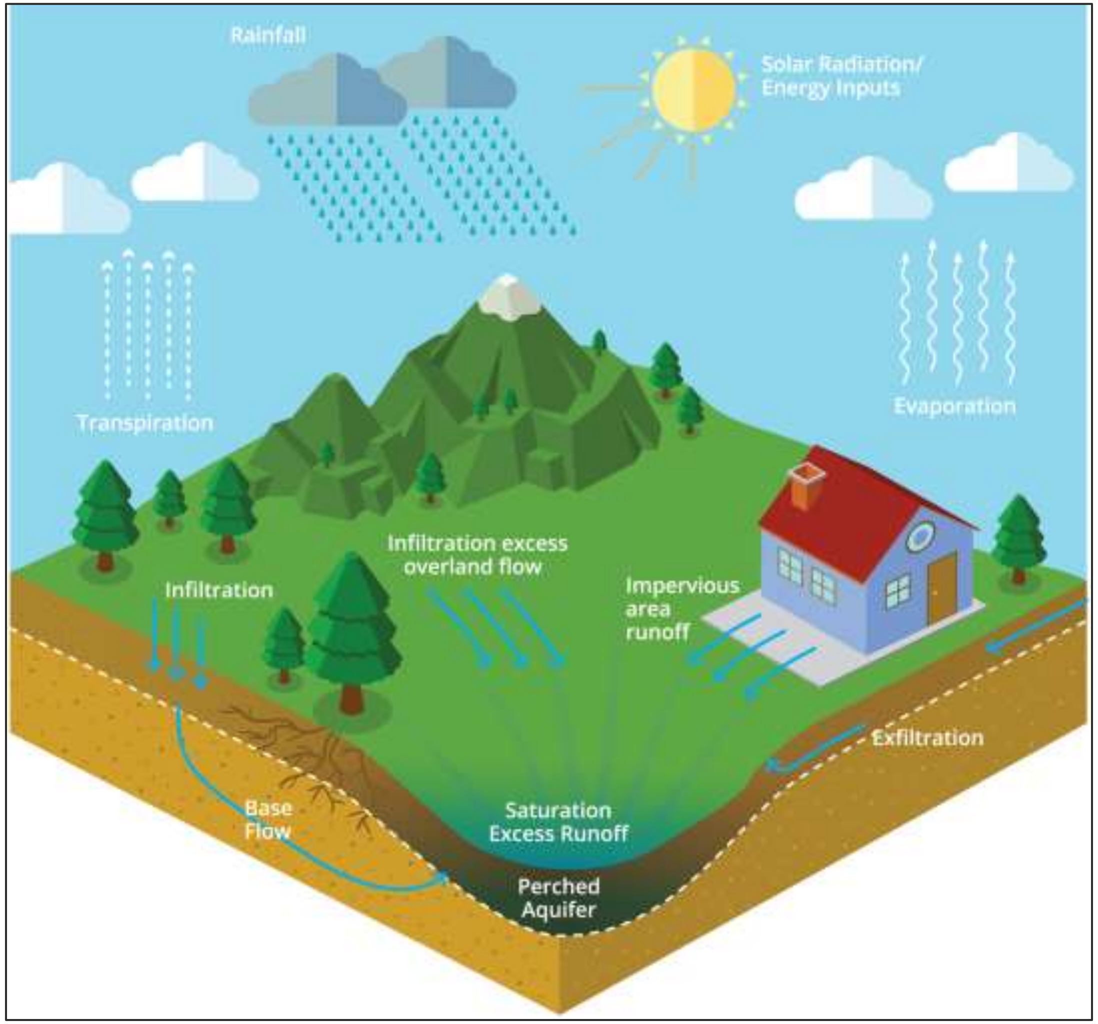
Statistical method to assess return period (credit: Hong Kong Observatory)

Runoff generation

- Runoff occurs when soil and vegetation can’t absorb all the water from precipitation

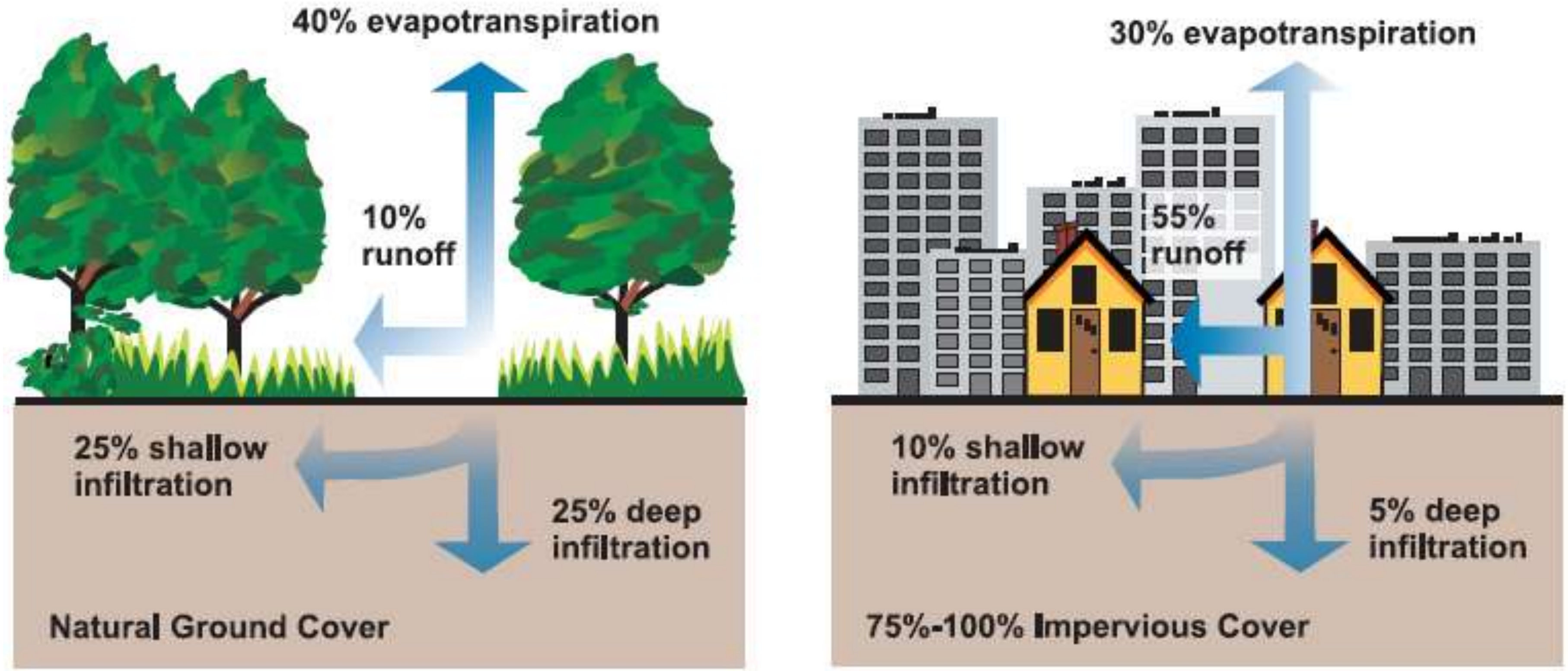
- Runoff discharge depends on basin characteristics:
  - Land Cover
  - Type of vegetation
  - Slope
  - Urbanization
  - Soil moisture
  - Catchment size and shape
  - …

Runoff generation (credit: ARR2019)



Pervious / Impervious area

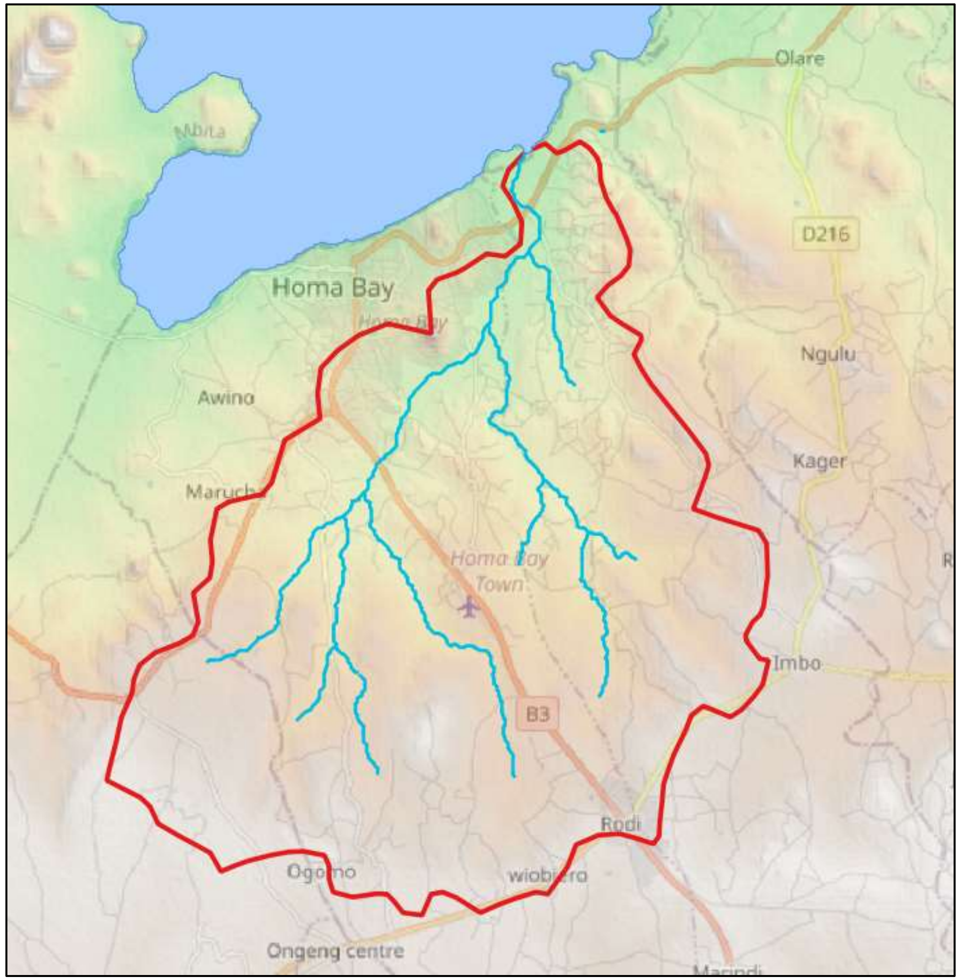
Runoff in pervious vs impervious area (credit: U.S. Environmental Protection Agency)



- Impervious areas increase flood risk and reduce available water resources

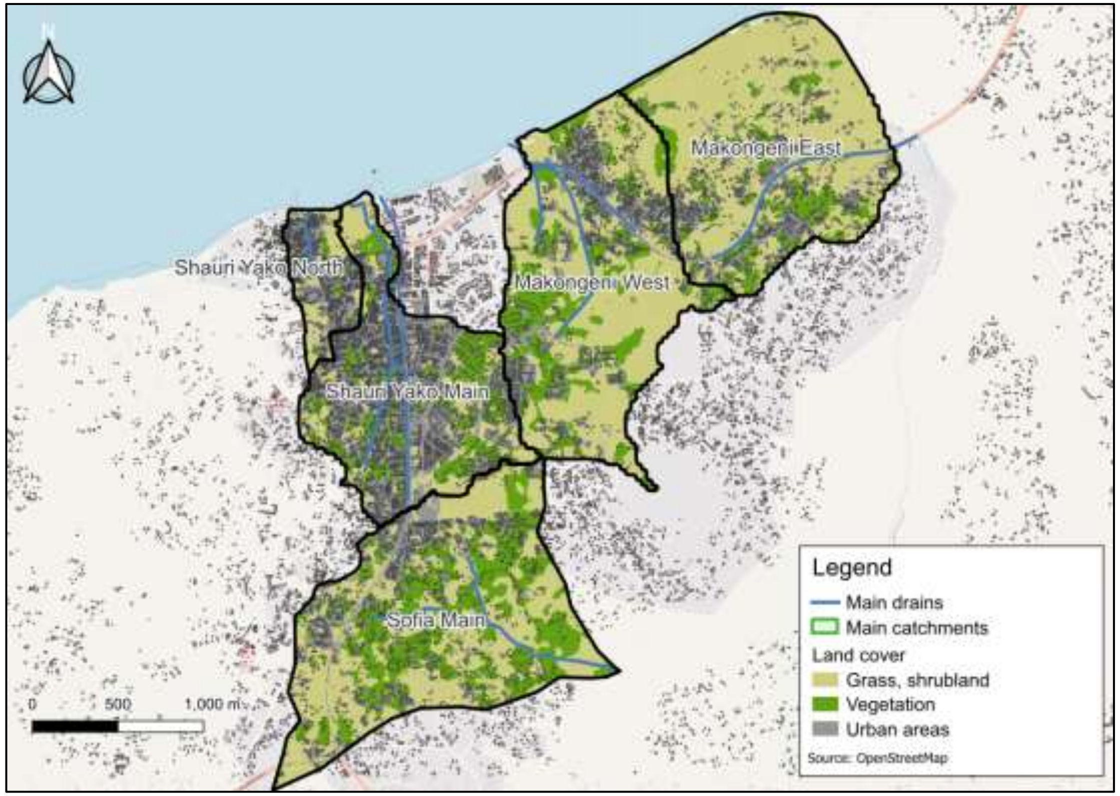
Catchment delineation

- A catchment or drainage basin is an area of land in which all flowing surface water converges to a single point (river mouth, lake or ocean)
- Catchment delineation is based on available topography
- For urban areas, stormwater drainage can influence catchment delineation



Rang'wena river catchment (source topography: NASA)

Catchment characteristics



Land Cover of the Shauri Yako, Sofi and Makongeni (credit: Homa Bay RCRA report)

- Catchment response is very sensitive to land cover. Land cover is usually estimated via existing database but can also be estimated via satellite imagery

Hydrologic modelling

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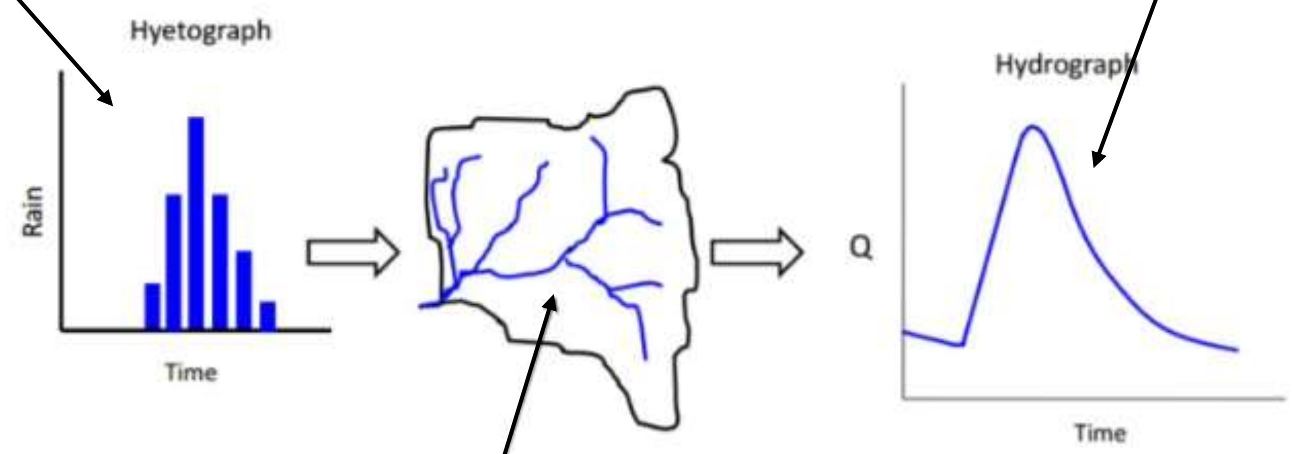
Rainfall data is used as input. Rainfall data can be past events recorded on rainfall gauge or statistically determined extreme events

Model output is the discharge (or hydrograph if variable in time)



Hydrological model uses catchment characteristics to convert rainfall to surface runoff

- **Model results must be compared with real data to validate the model**

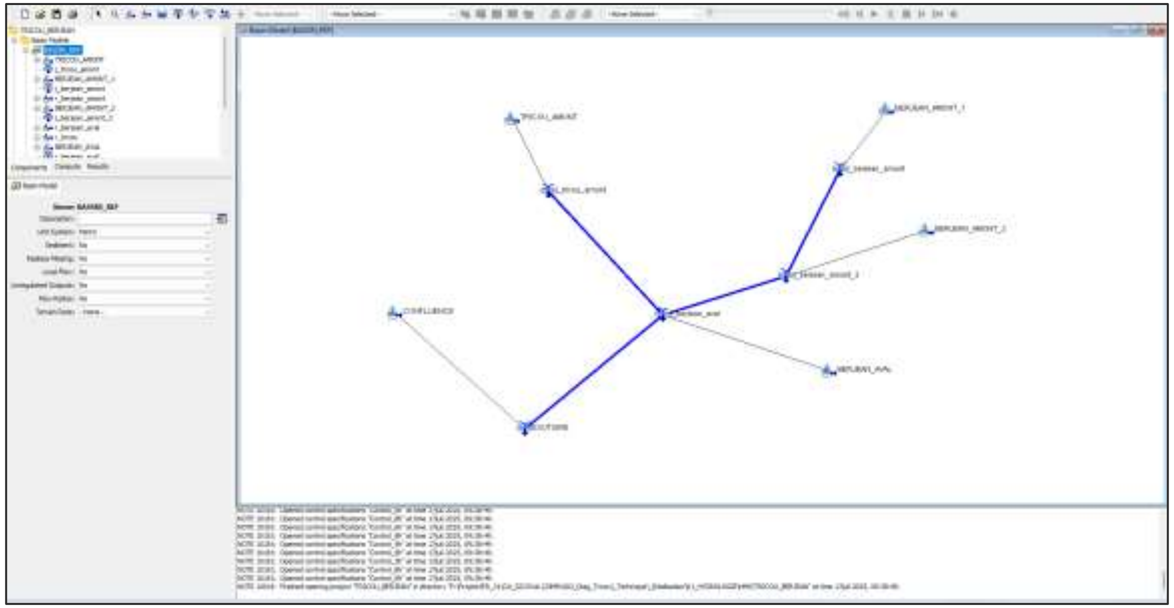
Hydrologic models

- Empirical method:
  - Regional Analysis Methods

- Pre-parameterized models:
  - Rational equation $Q = C * I * A$
  - SCS method

- Software (Runoff- Routing Model)
  - HEC-HMS (free)
  - SWMM (paid license)
  - MIKE SHE (paid license)

Screenshot of an HEC-HMS model (credit: SUEZ Consulting)



Hydrology / hydraulic

- Both water related sciences

- Hydrology: science of the water cycle
  - Precipitation
  - Evaporation
  - Infiltration
  - …

- Hydraulic: science of water movement
  - Storm drains,
  - Rivers,
  - Water distribution,
  - …

credit: USGS

Hydraulic modelling

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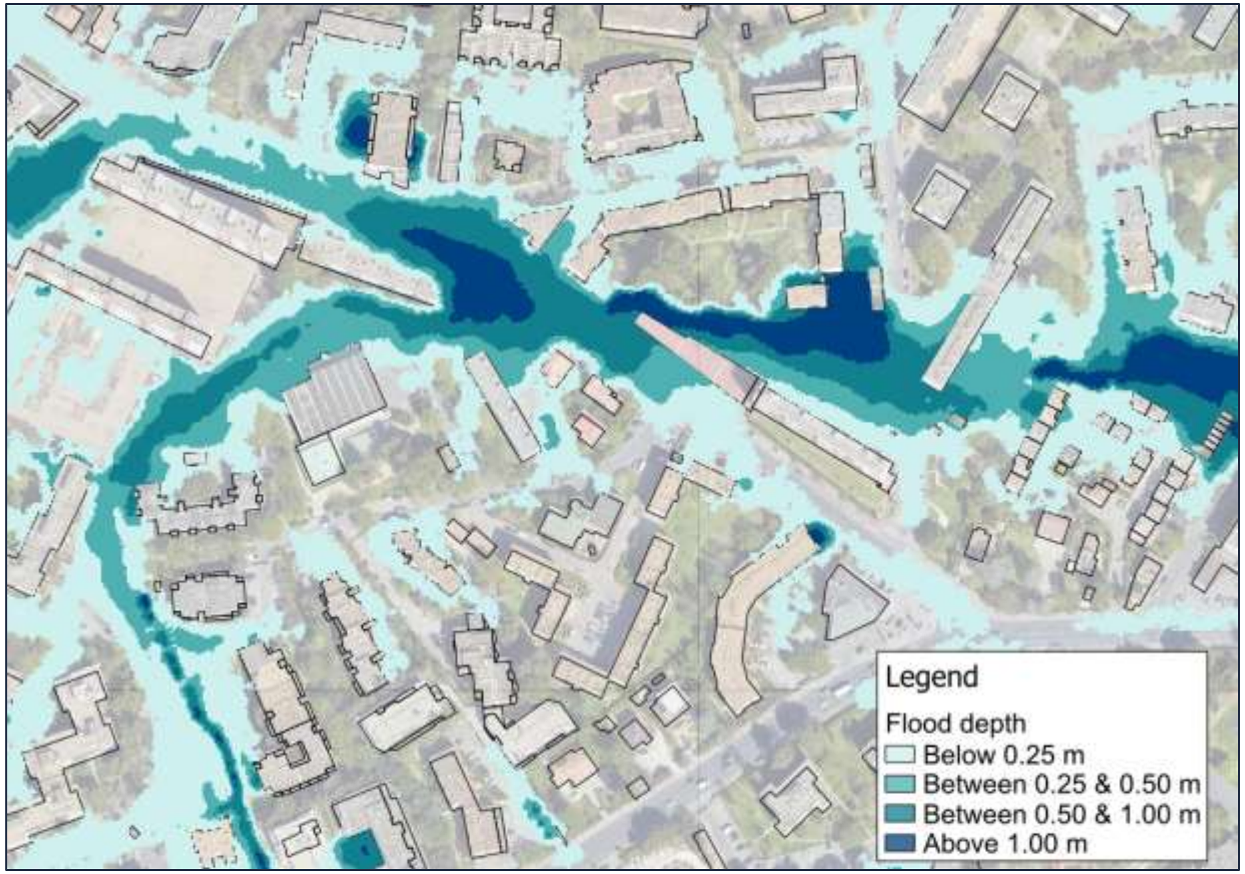
- Use the hydrologic model output (discharge)
- Need detailed topography
- Calculate the water depth and velocity
- Used for flood mapping

Flood maps made by hydraulic model (credit: SUEZ Consulting)

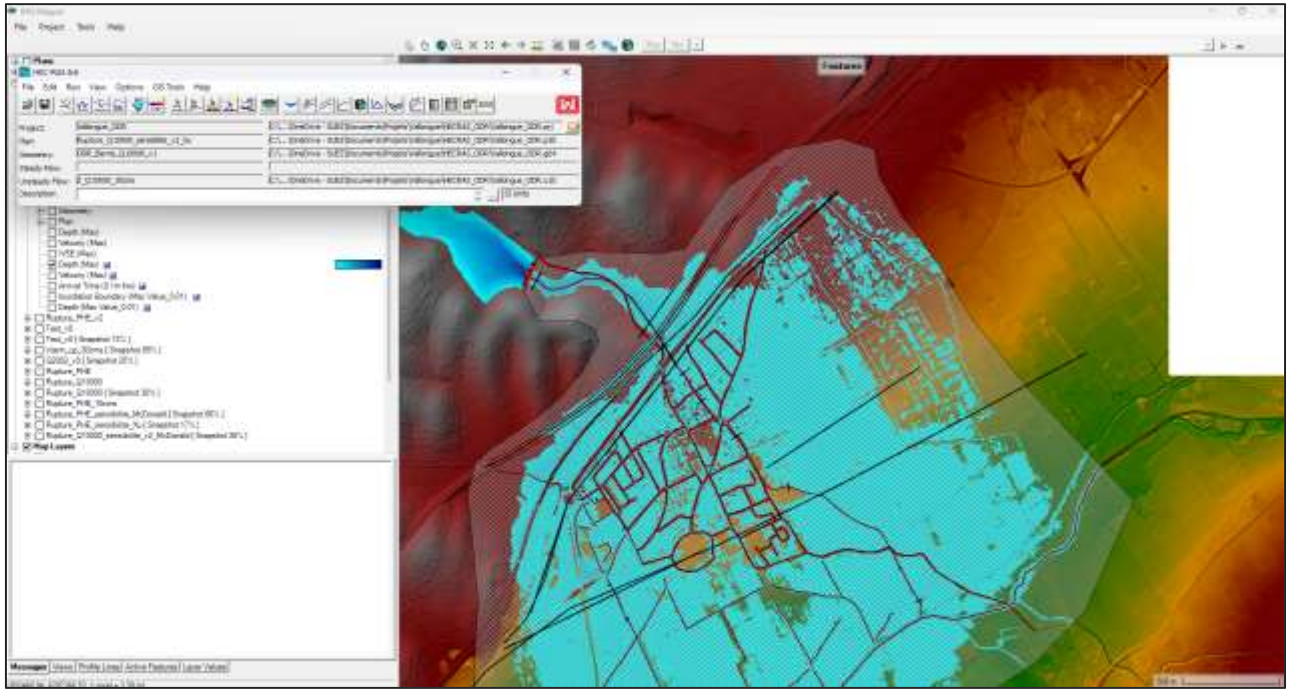


Hydraulic models

- Strickler formula: $V = K_s {R_h}^{2/3} i^{1/2}$

- Software
  - HEC-RAS (free)
  - MIKE+ (paid license)
  - TUFLOW (paid license)
  - PCSWMM (paid license)
  - Info Works (paid license)
  - …

Screenshot of an HEC-RAS model (credit: SUEZ Consulting)



Hydrologic/Hydraulics application

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- Multiple application
  - Designing drainage system
  - Predicting floods
  - Designing Flood protection
  - Hydropower
  - Urban drinking water and sewer systems
  - Designing irrigation schemes
  - Assessing project and infrastructures impacts on water resources
  - Determining the water balance of a region
  - …

Hydrologic application – Drainage design

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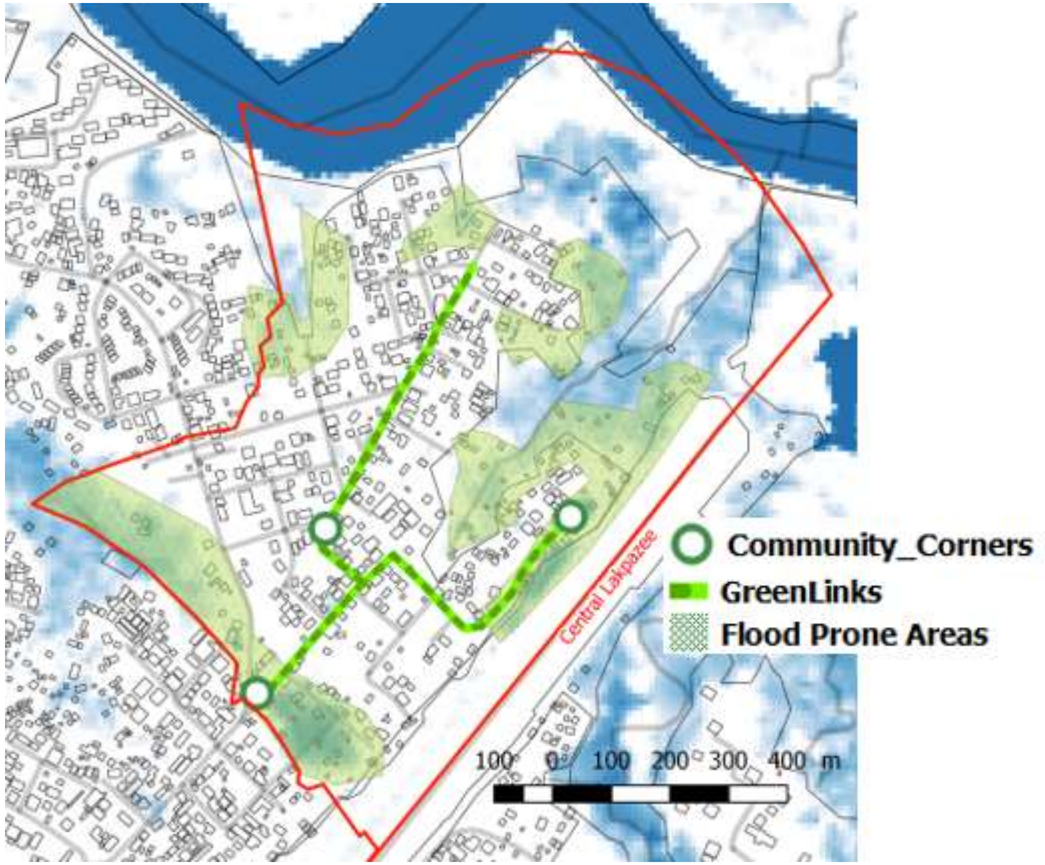
- Divide your urban area in small catchments
- Based on the catchment characteristics, estimate your discharge on every catchment outlet
- Size your drainage network accordingly
- Drainage network are usually sized for 1 in 5 years or 1 in 10 years extreme events

Shauri Yako and Sofia settlements divided into subcatchments (credit: Homa Bay RCRA report)

Hydrologic application – Include flood risk in future project and infrastructure



Example of flood prone area in Lakpazee project Liberia (source : SUEZ Consulting

- Define flood prone areas based on hydrological and hydraulic modelling
- Design your infrastructure accordingly to avoid any future inconvenience

Hydrologic application – Assess climate change impact on available water

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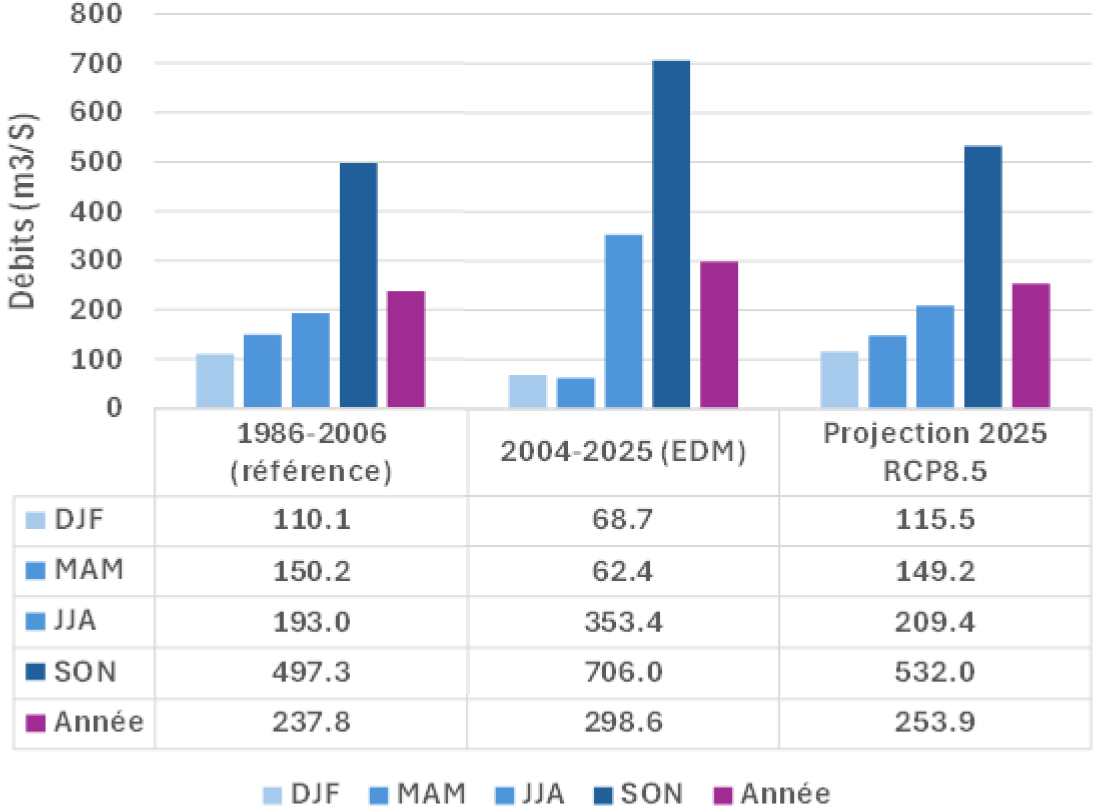

	1986-2006 (référence)	2004-2025 (EDM)	Projection 2025 RCP8.5
DJF	110.1	68.7	115.5
MAM	150.2	62.4	149.2
JJA	193.0	353.4	209.4
SON	497.3	706.0	532.0
Année	237.8	298.6	253.9

Climate change impact on inflow for a hydroelectric dam (credit: SUEZ Consulting)

- Assess climate change impact on hydropower reservoir water level (or freshwater storage)
- Define a long-term strategy to anticipate future drought and adjust consumption accordingly

To sum up

- **A complex series of processes**
  - evaporation,
  - precipitation,
  - runoff, …
- **that can be simplified using a few assumptions to determine**
  - water balance,
  - rainfall-runoff response,
- **With many applications**
  - flood protection,
  - Irrigation,
  - water supply,
  - hydropower, …

Hydrology data in Homa Bay (RCRA experience) Precipitation

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Kenya Meteorological département (paid service)

https://meteo.go.ke/

- ➔ Closest station Kisumu
- ➔ Rainfall records
- ➔ Frequency analysis and return periods
- ➔ Intensity-duration-frequency (IDF) curves
- ➔ Standard Precipitation Index (SPI)

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KENYA METEOROLOGICAL DEPARTMENT

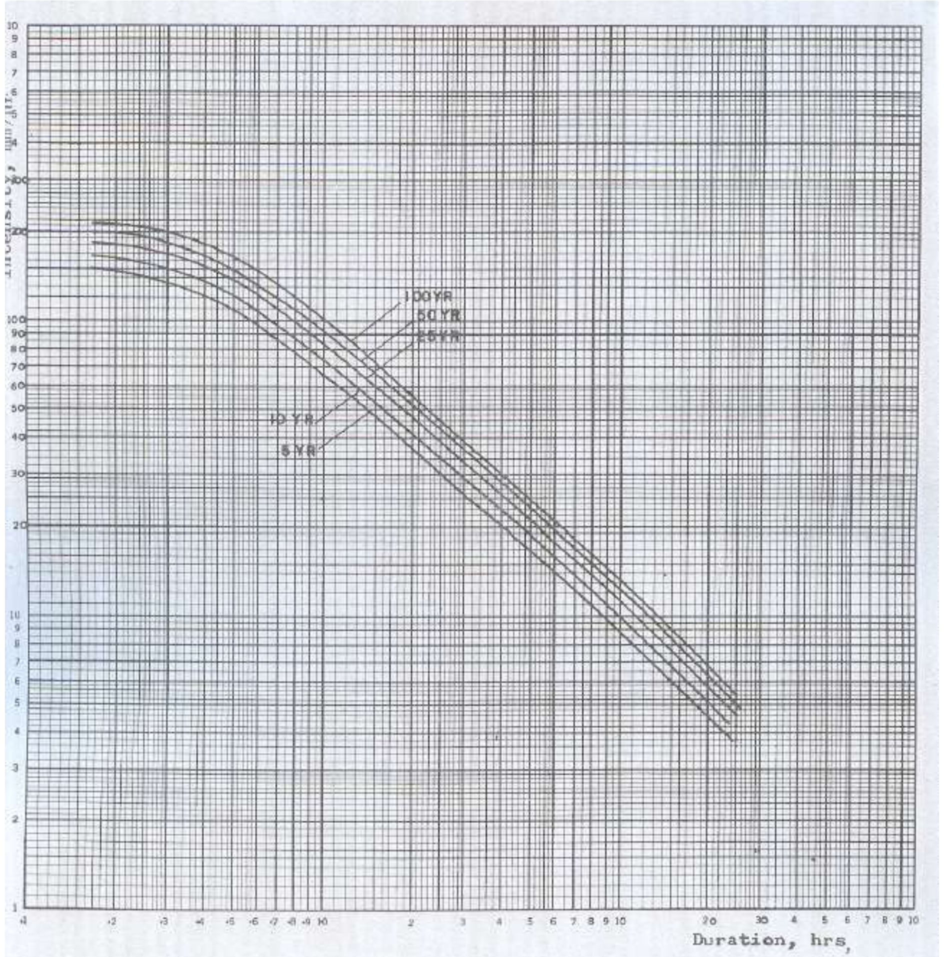


FIGURE A-8. Rainfall Intensity - Duration - Frequency Relationships for Kisumu.

- 72 -

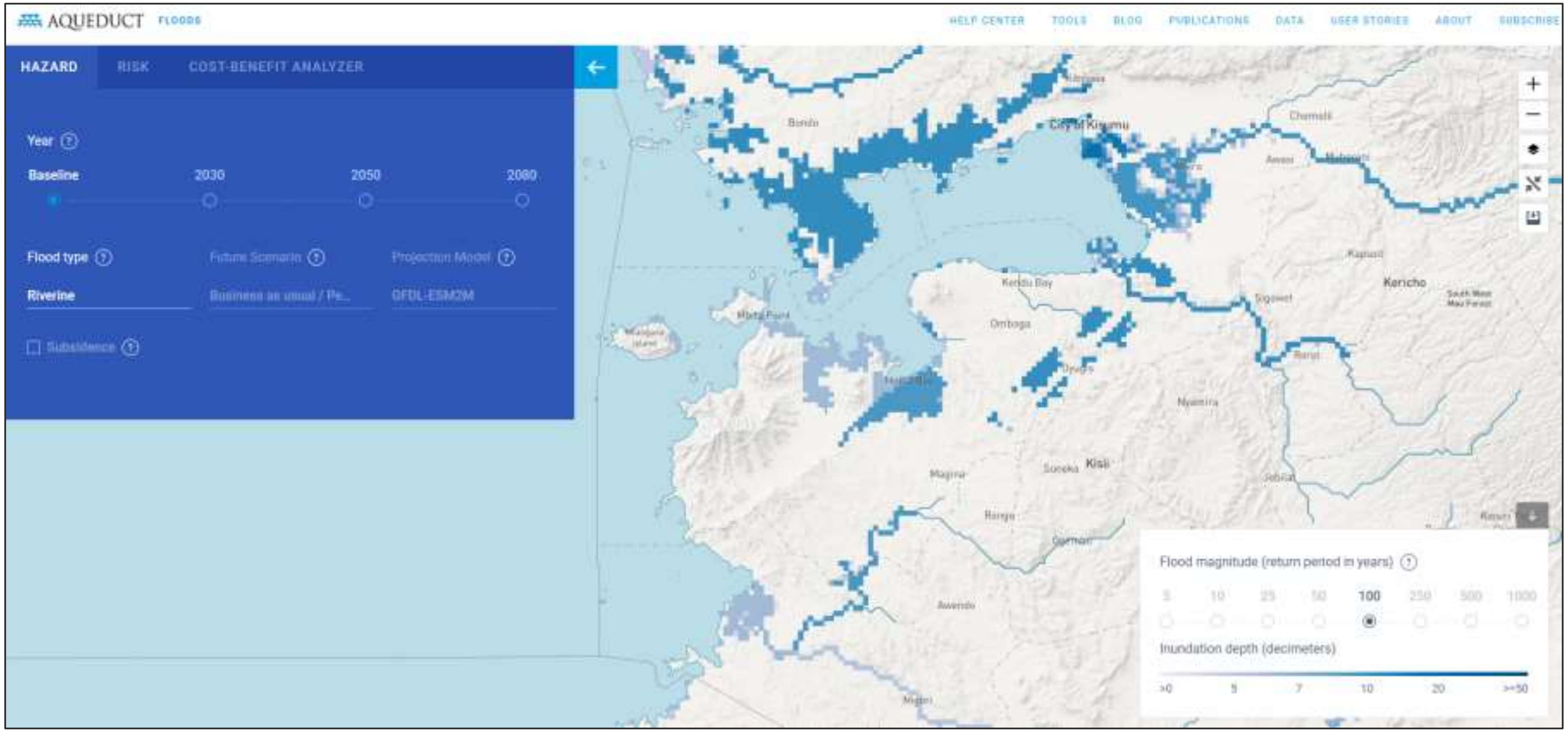
Hydrology data in Homa Bay (RCRA experience) Flood

Aqueduct floods (open data)

https://www.wri.org/applications/aqueduct/floods/

- Gridded data (1 km x 1 km)
- Downscaling of a global hydrology model

- Riverine / Coastal flood
- Climate change impact



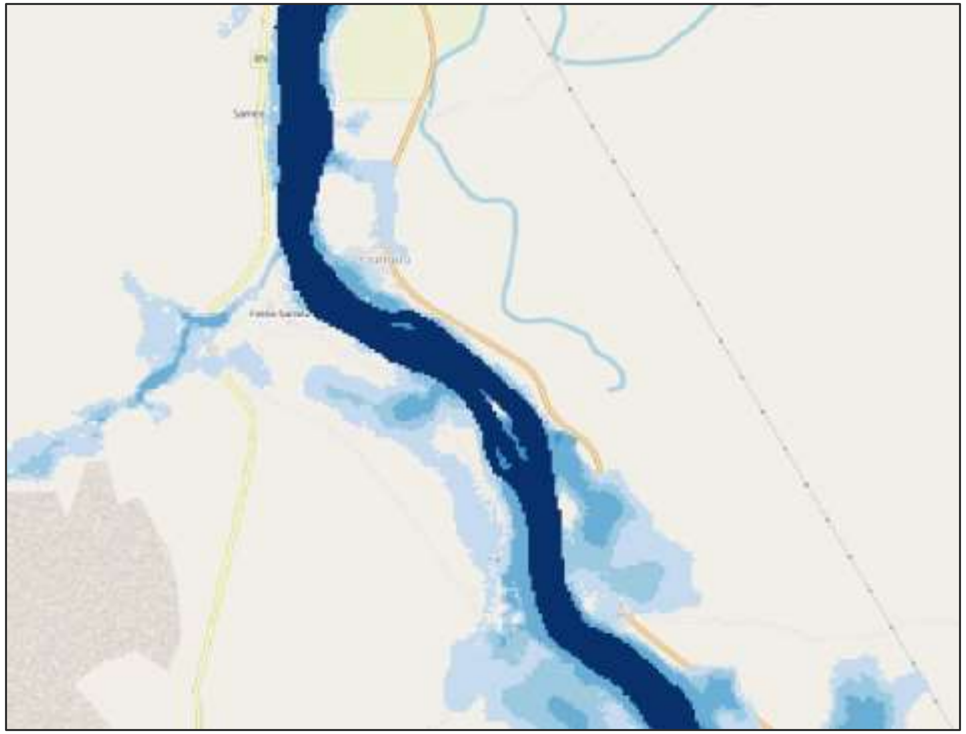
Hydrology data in Homa Bay (RCRA experience) Flood

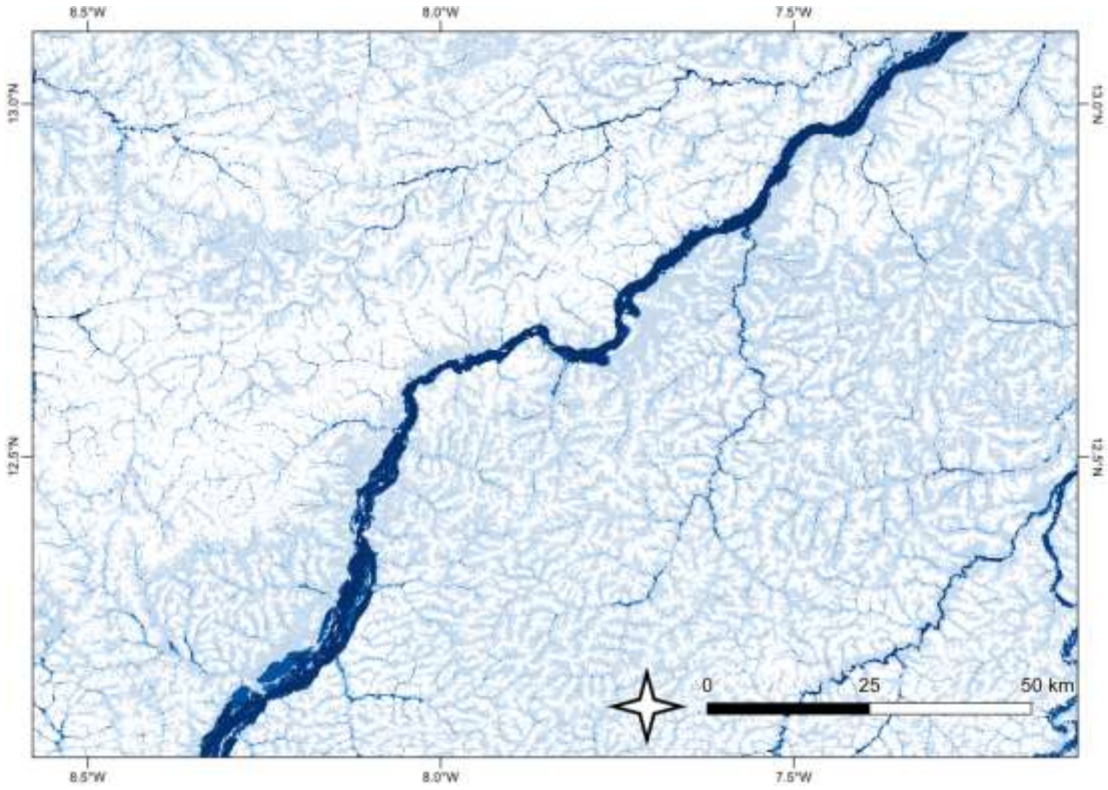
FATHOM (paid service)

https://www.fathom.global/

- Worldwide Gridded data (30 m x 30 m)
- Global hydrological and hydraulic model

- Ideal to assess potential flooded areas
- Pluvial / Riverine / Coastal flood
- Climate change impact





Hydrology data in Homa Bay (RCRA experience) Water balance

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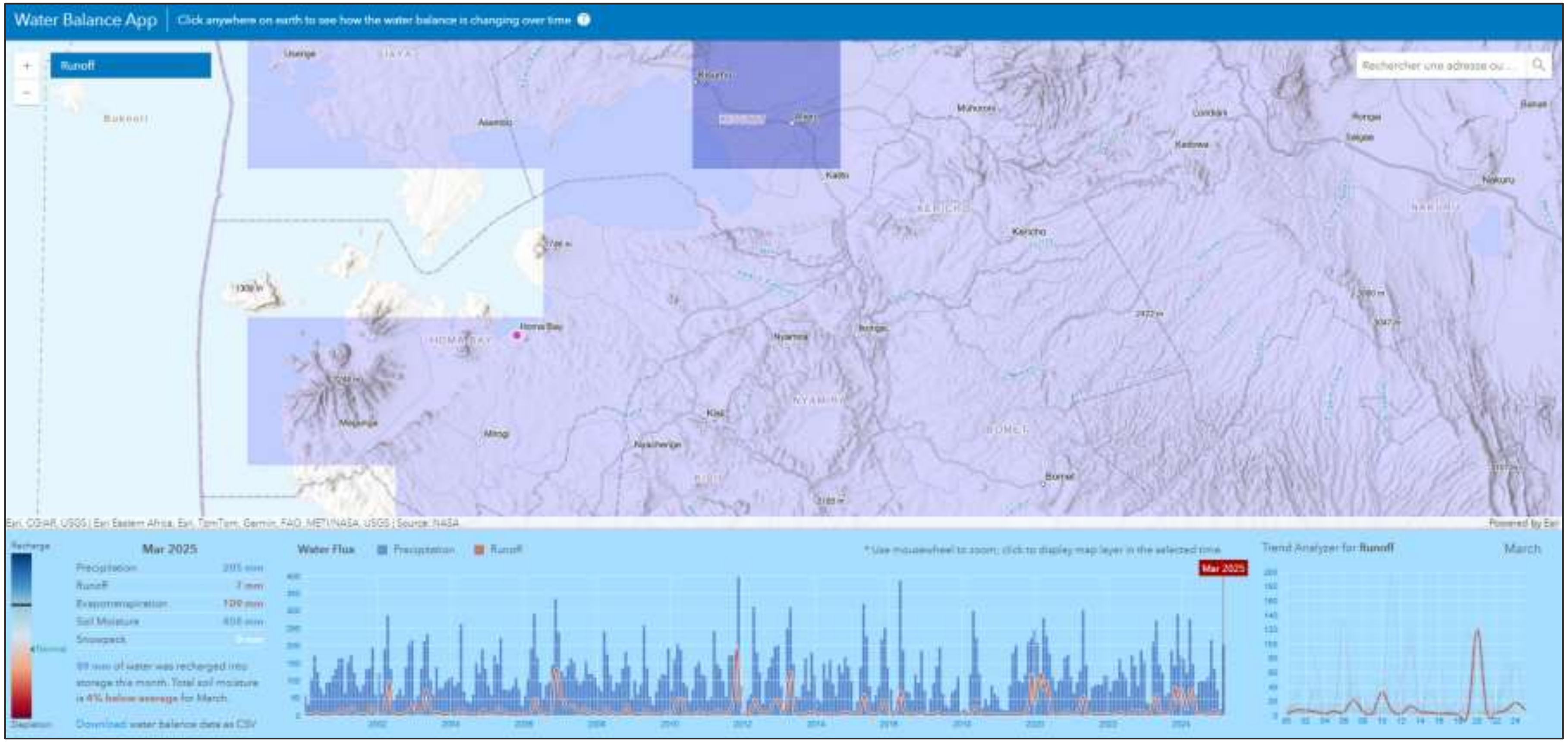
ESRI living atlas (open data)

https://livingatlas.arcgis.com/waterbalance/

- Online atlas
- Water balance over the past 20 years (01-2000)
- Soil moisture, precipitation, runoff, transpiration
- Based on NASA's Global Land Data Assimilation System (GLDAS-2.1) that estimates T°c, rain, etc… based on weather observation



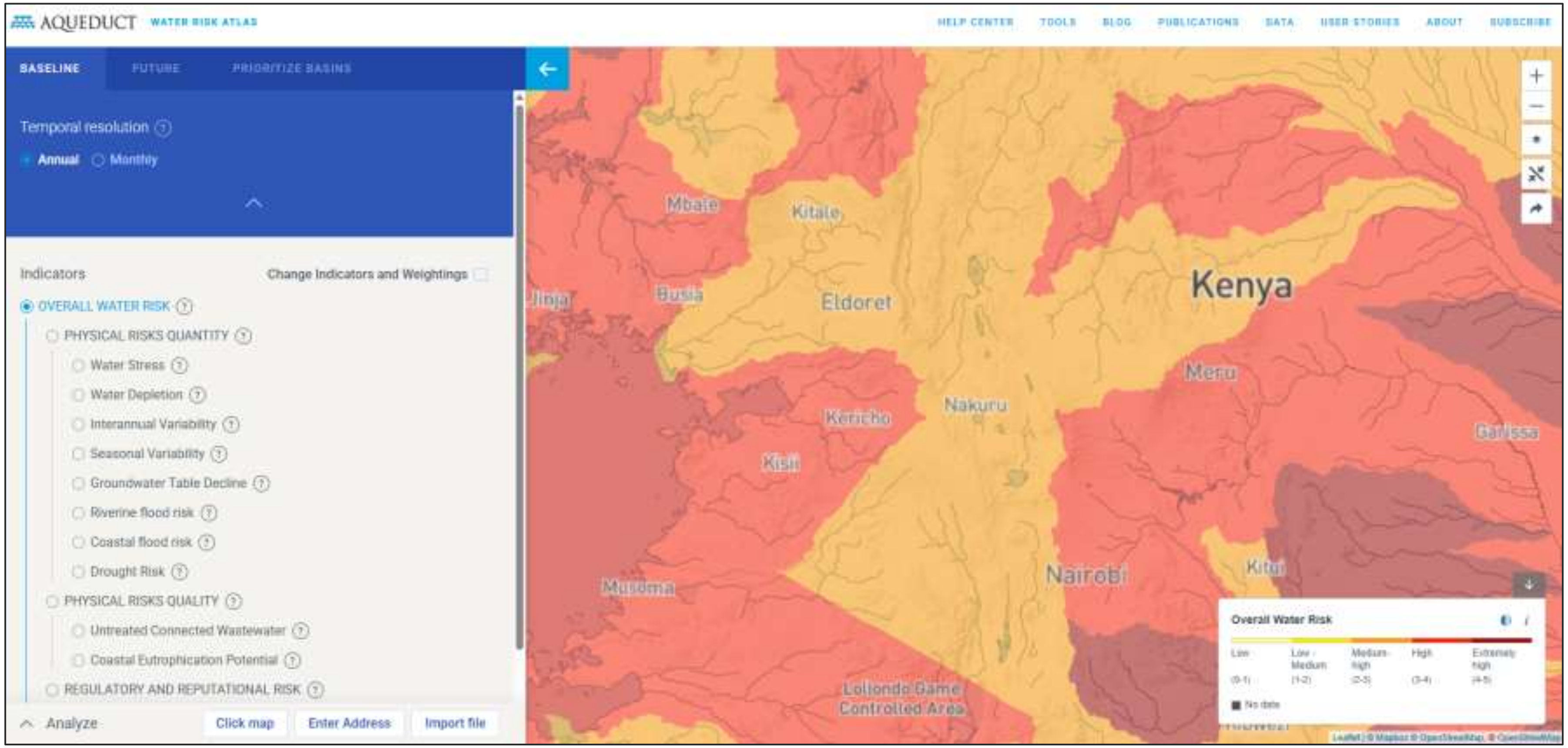
Hydrology data in Homa Bay (RCRA experience) Water balance

Aqueduct Water Risk Atlas (open data)

https://www.wri.org/applications/aqueduct/water-risk-atlas

- Online atlas
- Basin scale analysis

- Water risks indicator based on multiple hydrological model analysis
- Annual and monthly data
- Climate change impact



Hydrology data in Homa Bay (RCRA experience) Topography

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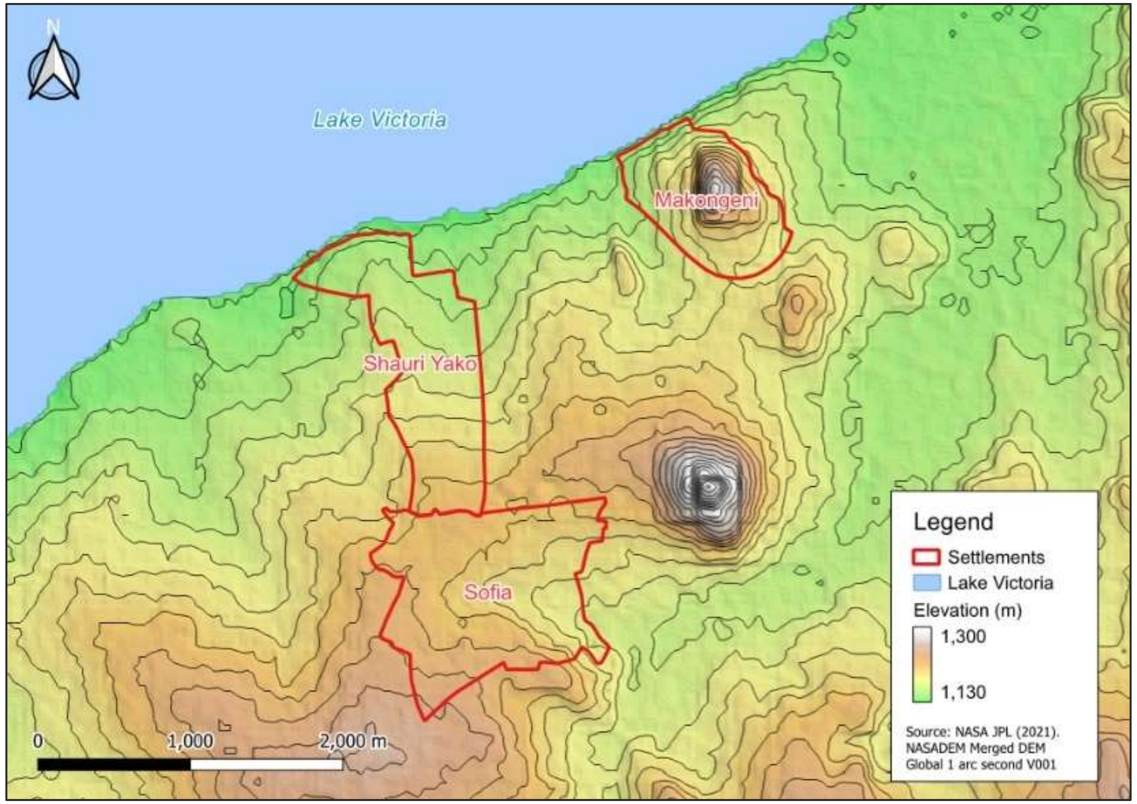
SRTM Data (open data)

https://www.eorc.jaxa.jp/ALOS/en/aw3d30/data/index.html

- NASA Project
- Shuttle Radar Topography Mission, project ALOS Global Digital Surface Model "AW3D30"

- Global topography data
- 30-meter resolution
- Satellites image analysis
- Can be used for catchment delineation



Hydrology data in Homa Bay (RCRA experience) Land cover

ESA World Cover Project (open data)

https://esa-worldcover.org/en

- Global land cover map
- 10-meter resolution
- Satellites image analysis
- Divided into 11 categories

Overview of available tools

Data source	Domain	Geographical coverage	Link
Kenya Meteorological département	Precipitation	Kenya	https://meteo.go.ke/
Global Precipitation Climatology Center	Precipitation	Worldwide	https://opendata.dwd.de/climate_environment/GPCC/html/gpcc_normals_v2022_doi_download.html
Aqueduct floods	Flooding	Worldwide	https://www.wri.org/applications/aqueduct/floods/
FATHOM	Flooding	Worldwide	https://www.fathom.global/
ESRI living atlas	Water balance	Worldwide	https://livingatlas.arcgis.com/waterbalance/
Aqueduct Water Risk Atlas	Water balance	Worldwide	https://www.wri.org/applications/aqueduct/water-risk-atlas
World Bank CC Knowledge Portal	Water balance	Worldwide	https://climateknowledgeportal.worldbank.org/country/kenya
SRTM	Topography	Worldwide	https://www.eorc.jaxa.jp/ALOS/en/aw3d30/data/index.html
ESA World Cover Project	Land cover	Worldwide	https://esa-worldcover.org/en

Hazards assessment / Done in Homa Bay

#1 | Determine relevant climate hazards

#2 | Select relevant hazard indicators

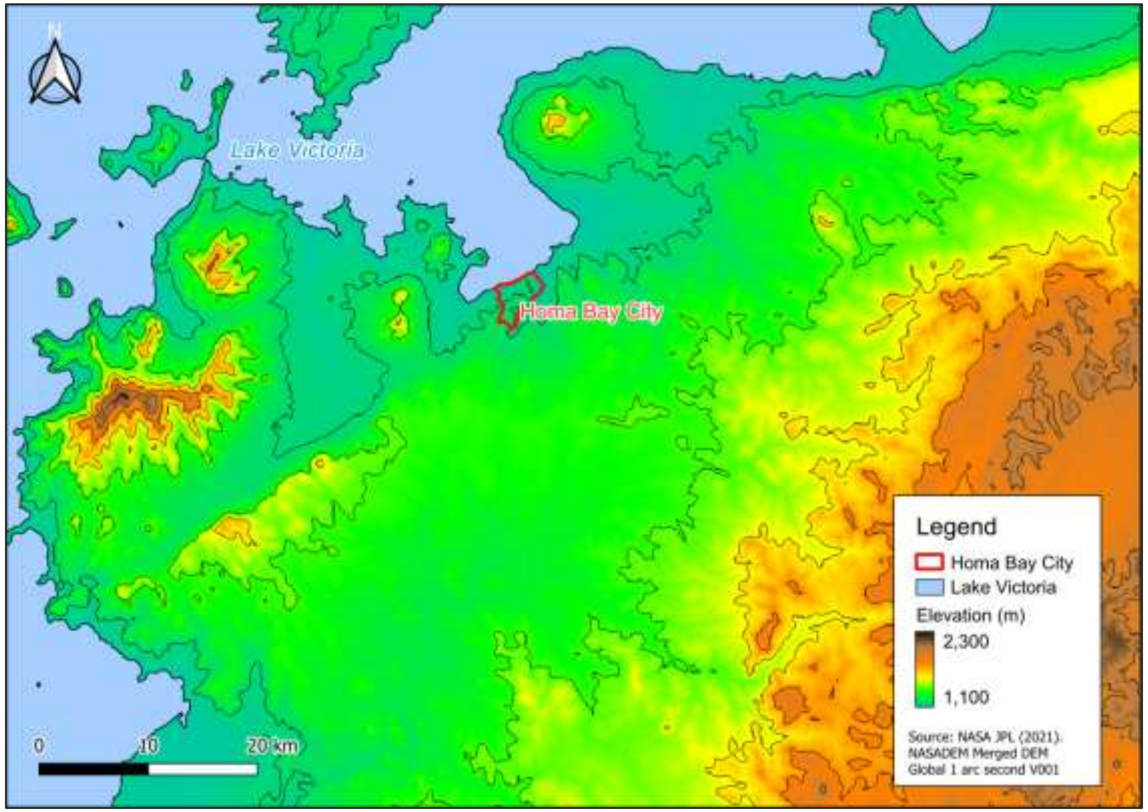
#3 | Analyze historical trends and events

#4 | Analyze future projections across different scenarios

- Historical
  - Measures from Kenya Meteorological Department
  - Field observations
  - International databases in open access (e.g. ERA-5)
- Projected change
  - Climate projections from KMD
  - Climate change/Climate risks reports
  - International databases in open access (e.g. IPCC Atlas, WB Knowledge Portal)
- Impact modelling
  - Hydrological and hydraulic study

Hydrologic modelling – Homa Bay case Climate

- Inland equatorial climate modified by altitude and Lake Victoria
- Elevation between 1,100 m and 1,300 m
- Average yearly rainfall ≈ 1 200 mm
- Divided into 4 distinct seasons
  - JF – Hot dry season – 100/150 mm
  - MAM – Long rainy season – 450/550 mm
  - JJAS – Cold dry season – 250/350 mm
  - OND – Short rainy season – 300/400 mm



Location and elevation of the Homa Bay City(credit: Homa Bay RCRA report)

Hydrologic modelling – Homa Bay case
Rainfall

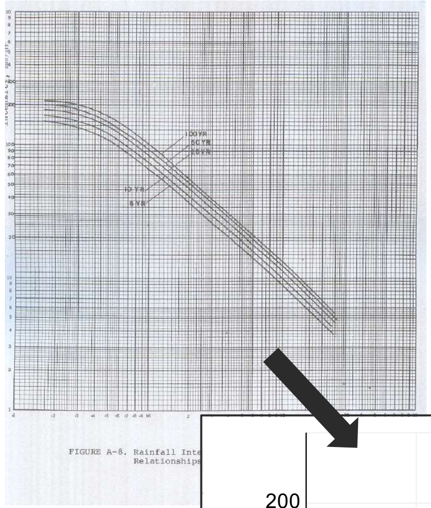
- Kisumu Airport meteorological station (55 km northeast of Homa Bay)

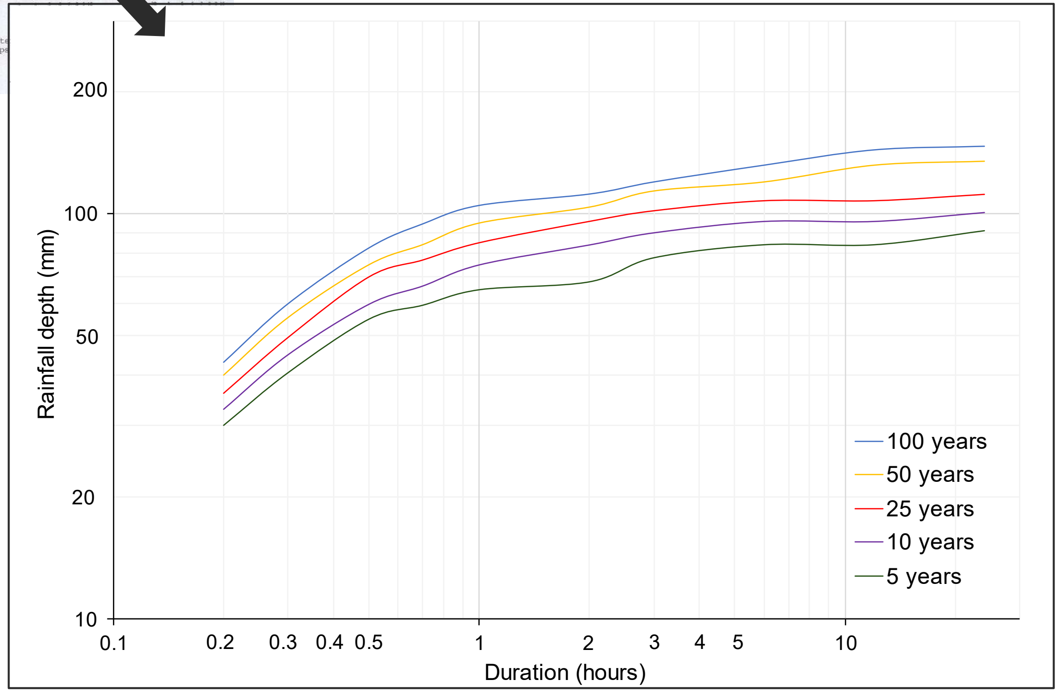
- Intensity-Frequency-Duration (IFD) curves

- For a 1 in 10 years event ➔ 75 mm in 1 hr
- For a 1 in 100 years event ➔ 105 mm in 1 hr

but

- For a 1 in 10 years event ➔ 96 mm in 6 hr
- For a 1 in 100 years event ➔ 132 mm in 6 hr

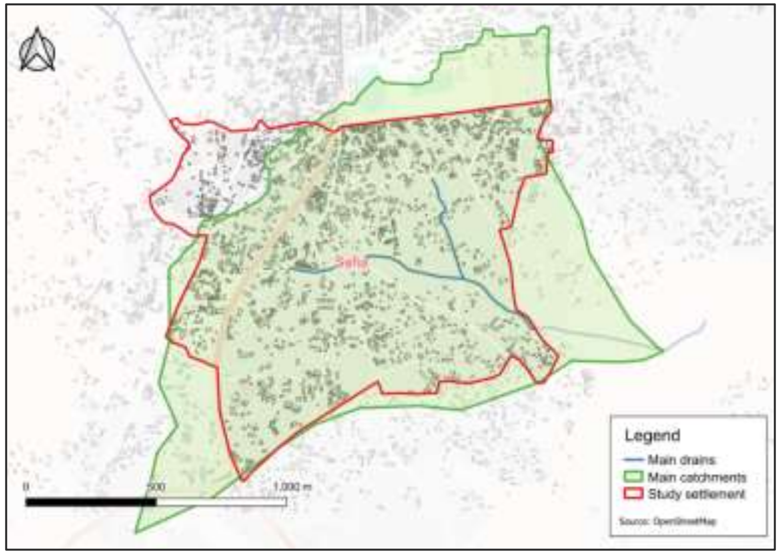


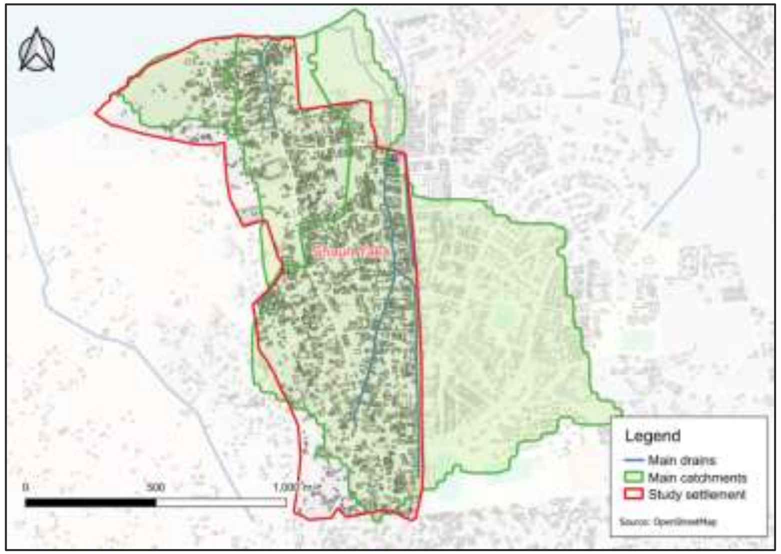


Intensity Frequency Duration (IFD) curves (credit: Homa Bay RCRA report)

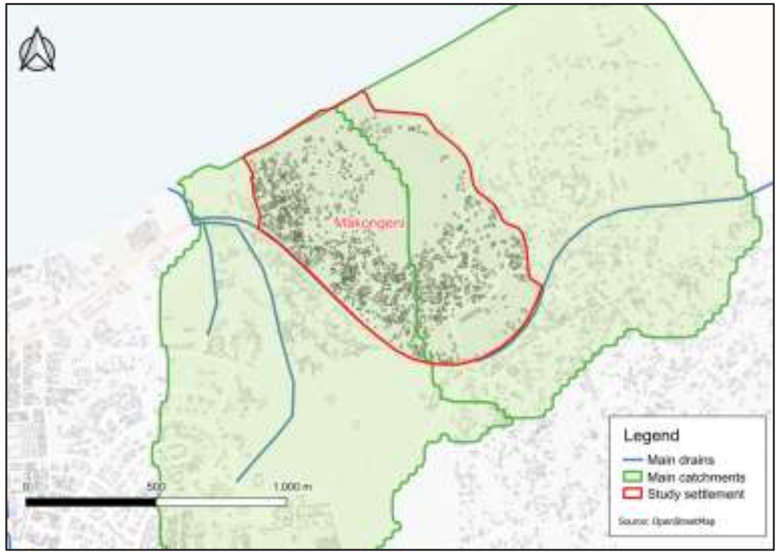
Hydrologic modelling – Homa Bay case
Catchment

- 3 settlements located on catchment head
- Shauri Yako and Makongeni catchments draining to Lake Victoria
- Sofia catchment draining to Rang’wena river



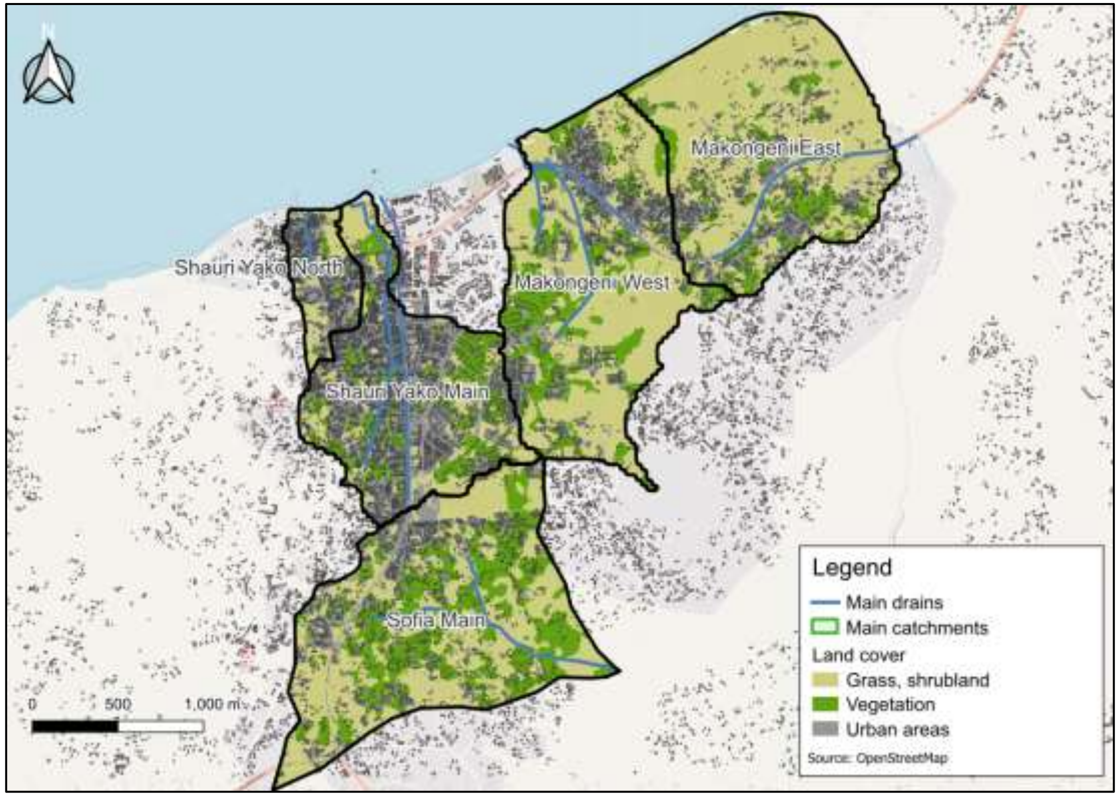


- 3 small catchments: between 1 & 2 km²
- Very steep (6 to 10%)
- Quick rainfall response, particularly vulnerable to flash flood



Catchment delineation for the 3 studied settlement

Hydrologic modelling – Homa Bay case
Land cover



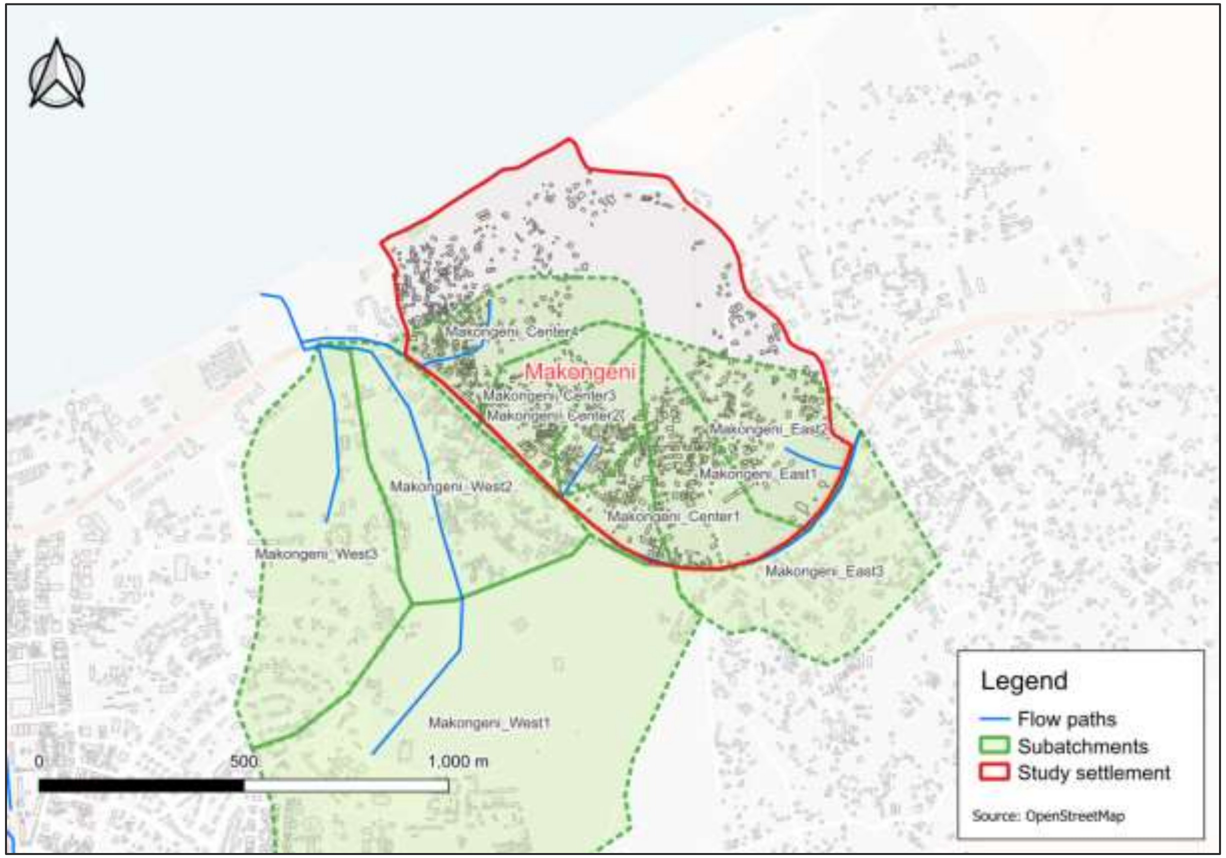
Land Cover of the Shauri Yako, Sofi and Makongeni (credit: Homa Bay RCRA report)

- Divided into 3 categories :
  - Urban area
  - Grass / Shrubland
  - Vegetation (bush, tress)

Name	Area (km²)	% Urban area	% Grass, shrubland	% Bush, trees
Makongeni East	1.71	15%	16%	69%
Makongeni West	1.82	19%	26%	54%
Shauri Yako Main	1.29	55%	25%	20%
Shauri Yako North	0.28	62%	8%	29%
Sofia Main	1.94	15%	37%	48%

Hydrologic modelling – Homa Bay case Makongeni

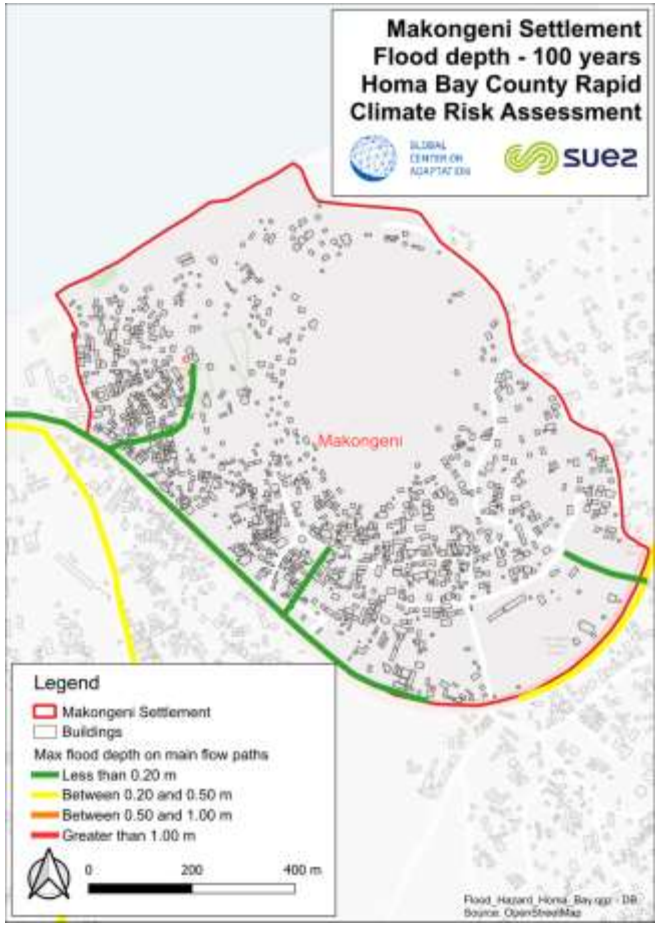
- Located on the slopes of Abuor Hills
- C19 road perpendicular to drainage path
- Lack of proper drainage in the valley bottom at the time of the modelling (Makongeni primary school)

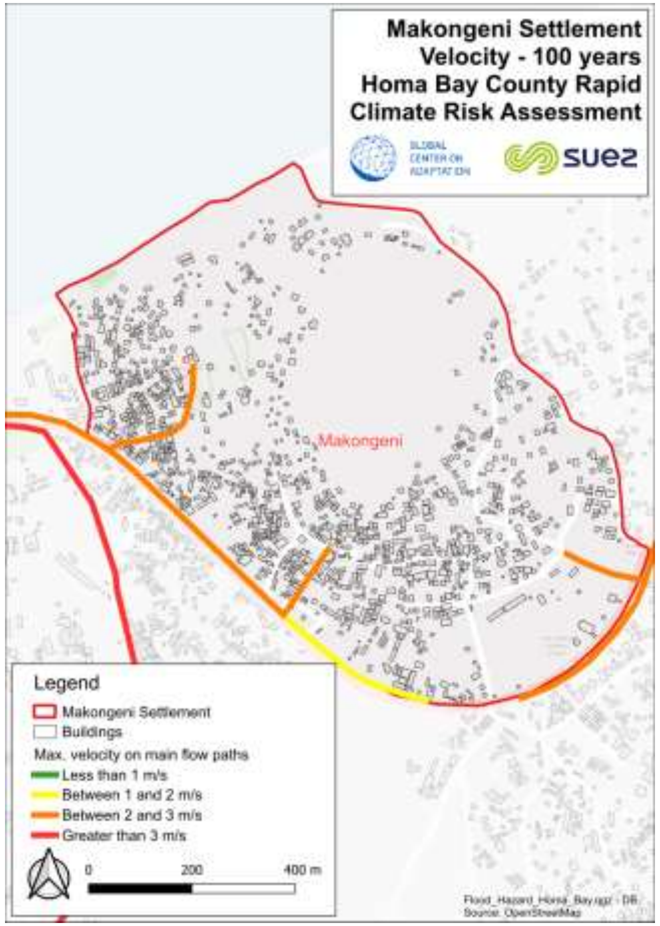


Hydrologic modelling – Homa Bay case
Hydrologic model results - Makongeni

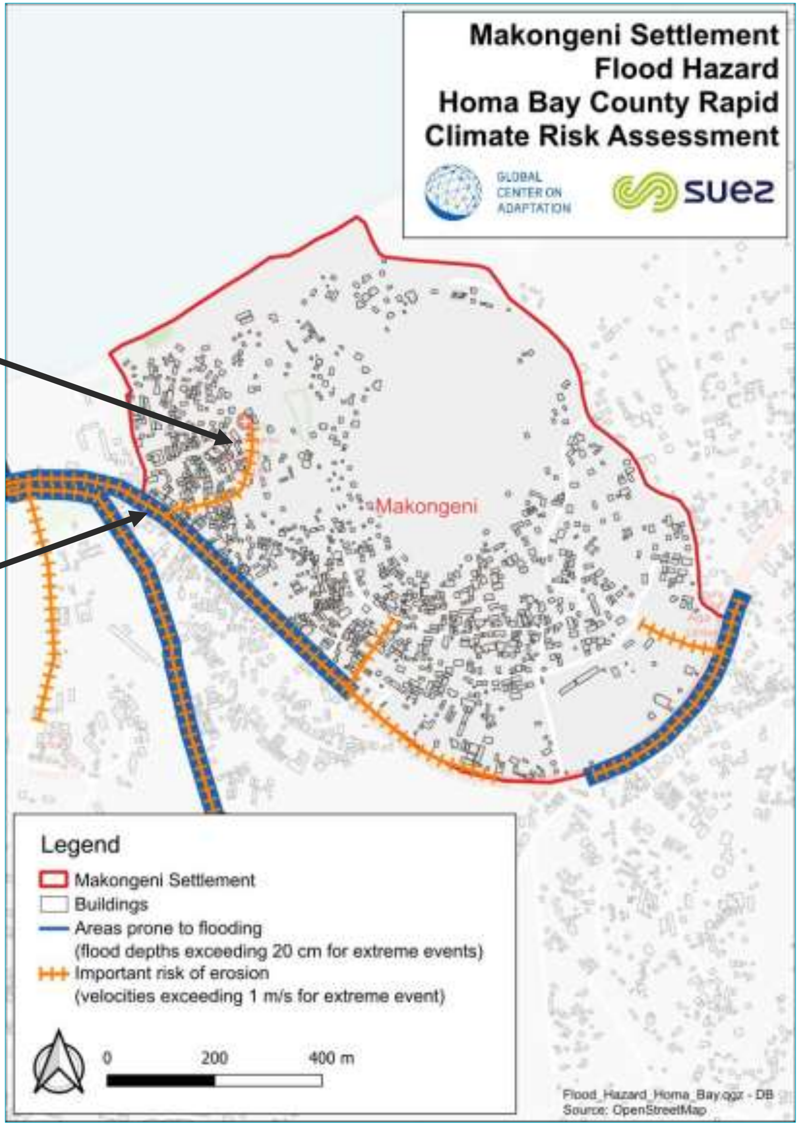
GLOBAL CENTER ON ADAPTATION

- Significant flood depths on the C19 road and in the valley bottom
- Important velocities along erosion path





Hydrologic modelling – Homa Bay case
Flood affected areas - Makongeni



- Slope + low infiltration + lack of proper drainage path

➔ Important erosion (not only for extreme events)

Hydrologic modelling – Homa Bay case
Flood affected areas - Makongeni

- Consistent with Community Validation Workshops

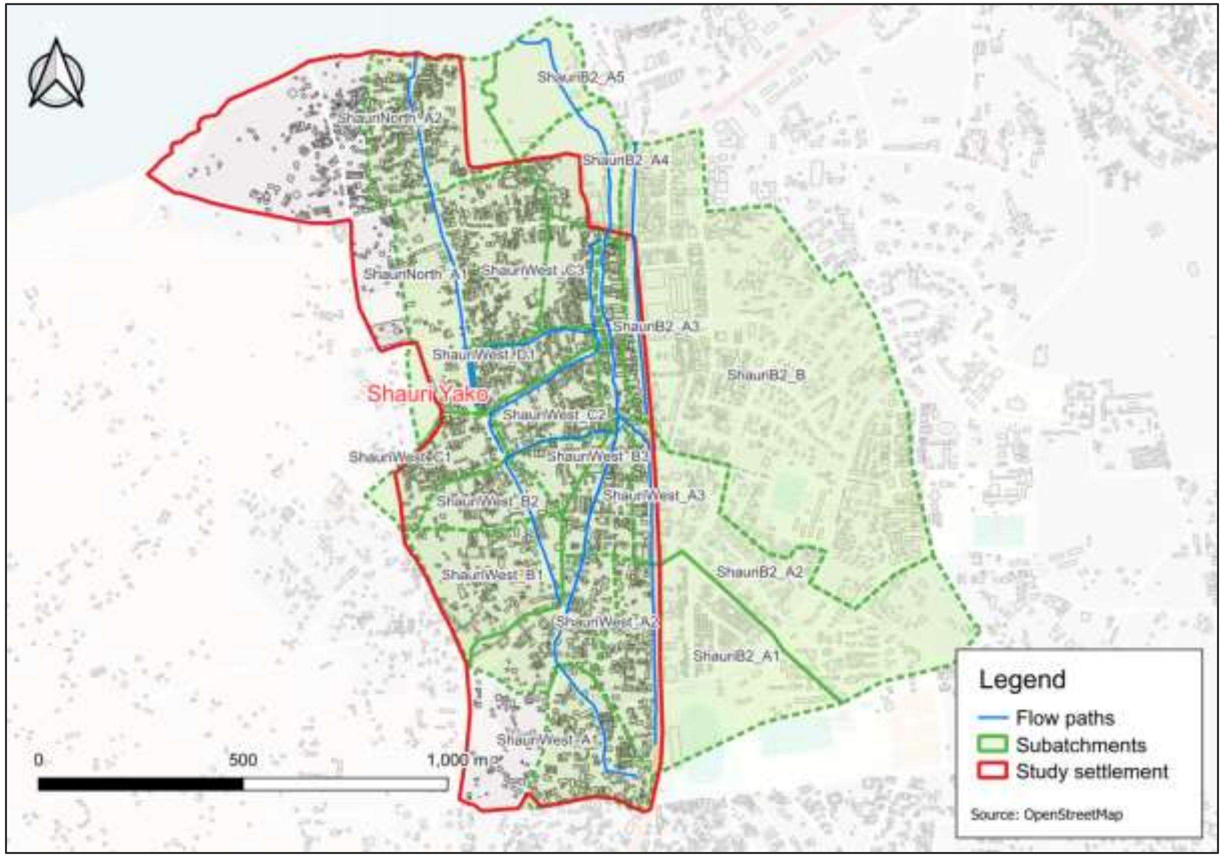
Hydrologic modelling – Homa Bay case
Flood affected areas - Makongeni

GLOBAL CENTER ON ADAPTATION

- New drainage works at Makongeni primary school
- Concrete / Rocks

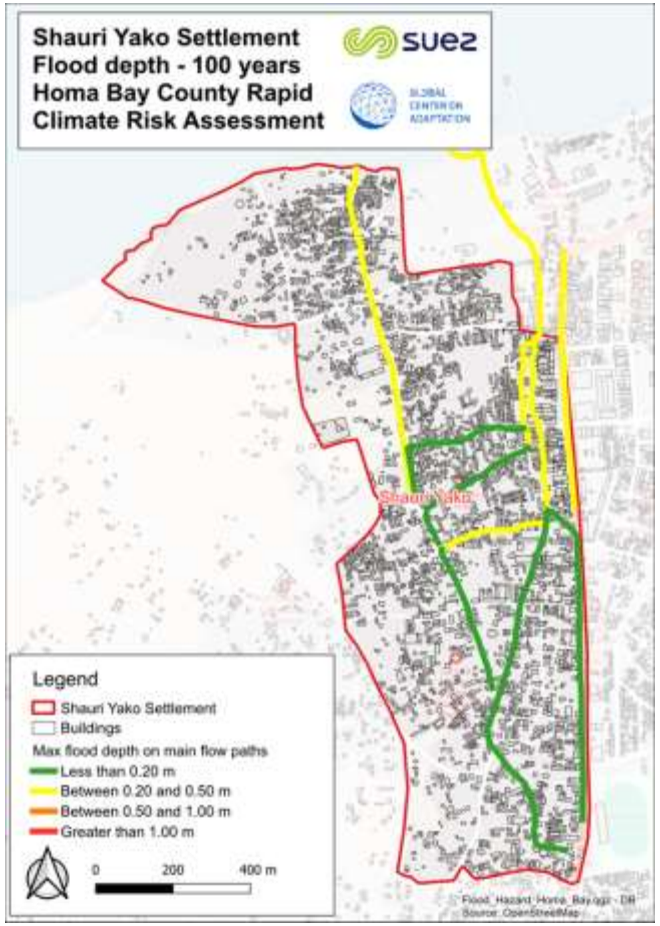
Hydrologic modelling – Homa Bay case Shauri Yako

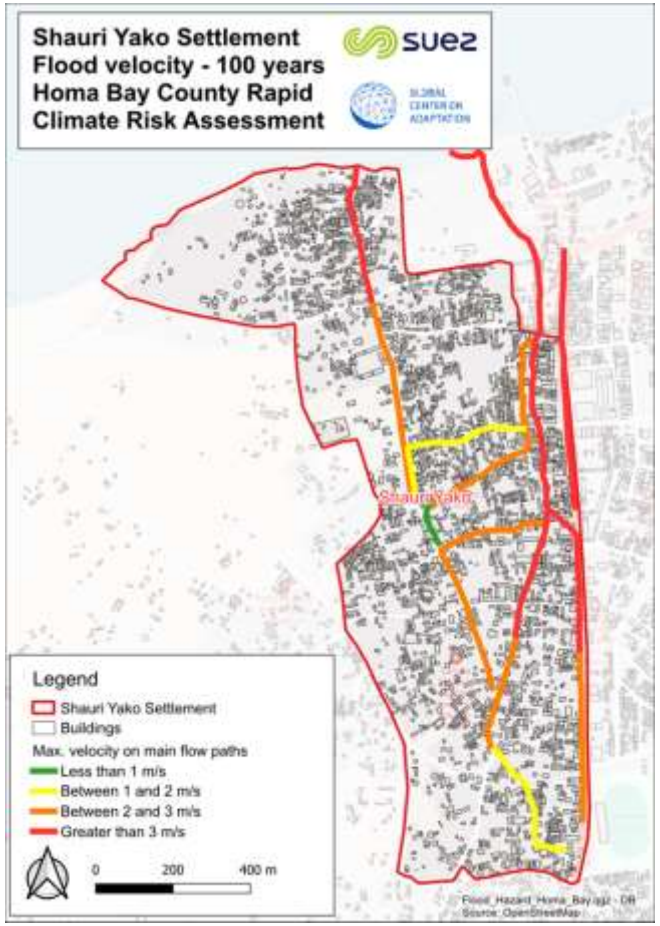
- Steep slopes and lack of drainage in the upper catchment
- Two drainage swale in the lower catchment, near the market, close to buildings



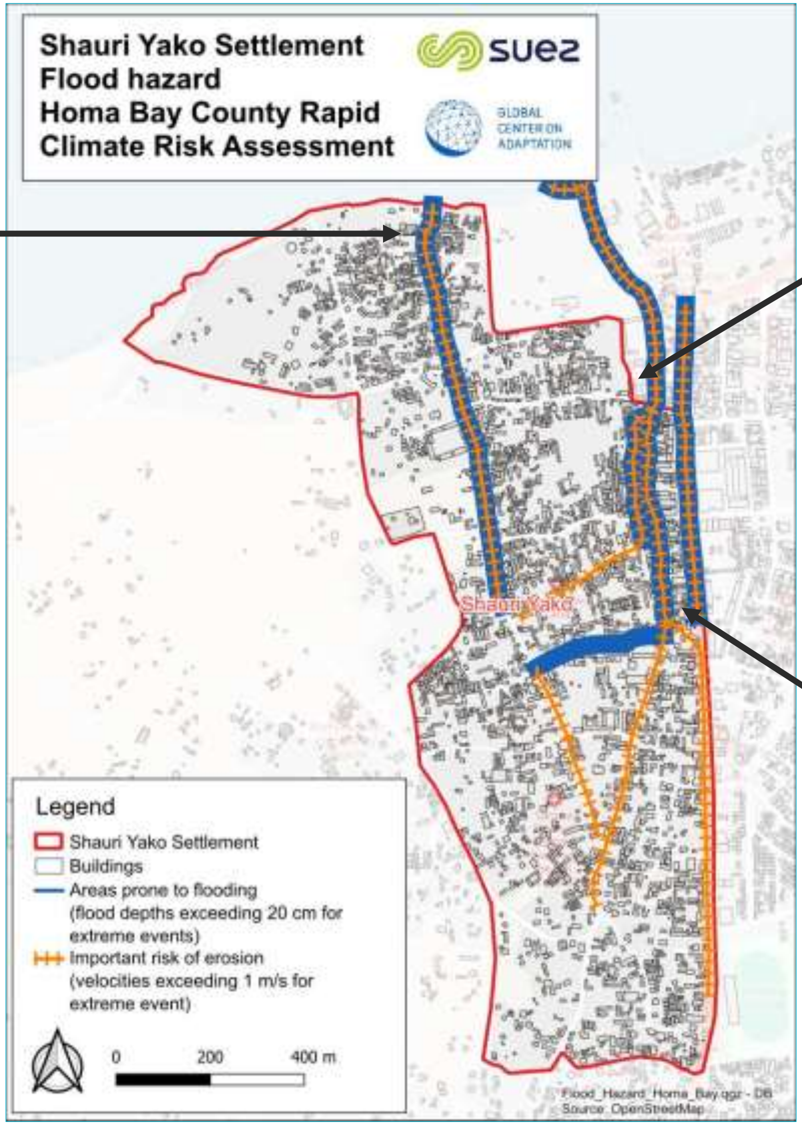
Hydrologic modelling – Homa Bay case
Hydrologic model results - Shauri Yako

- Significative depths north of the settlements (market)
- Important velocities along roads and in the two drainage swales





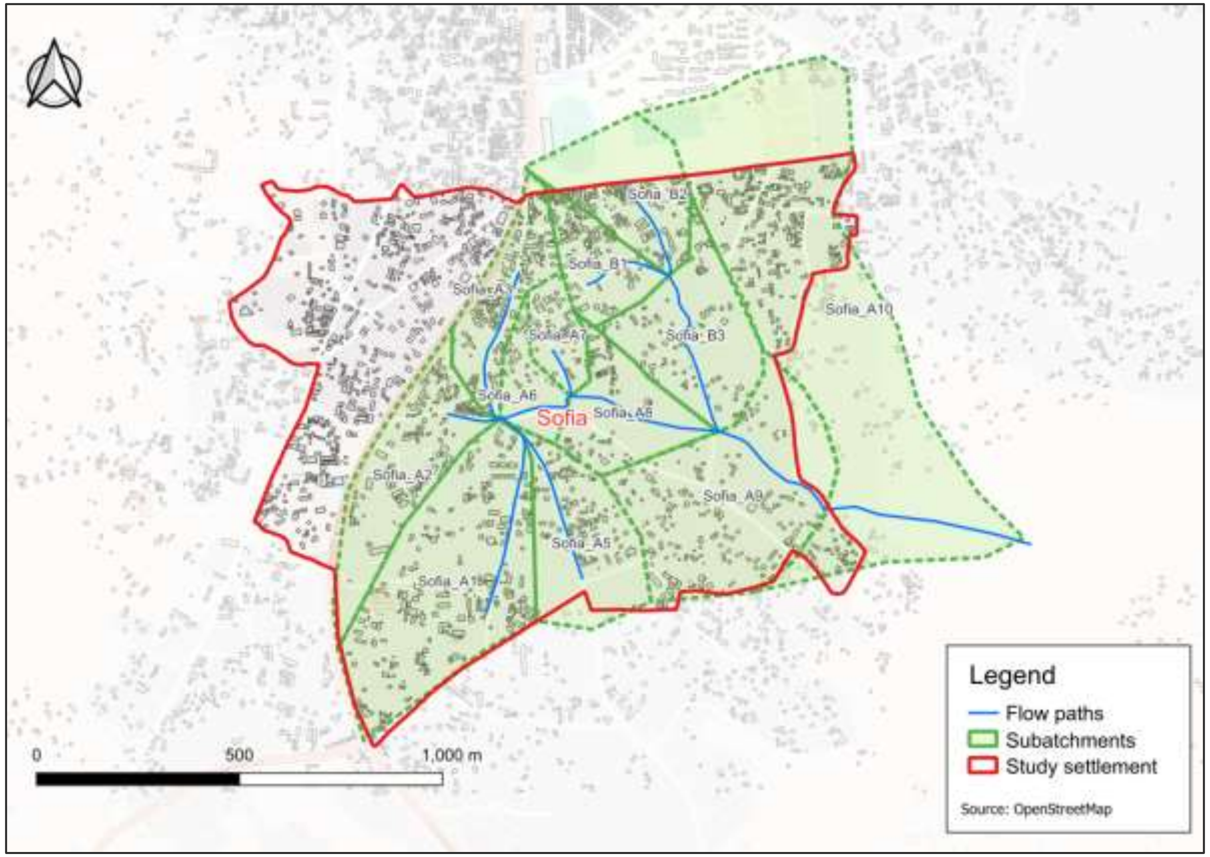
Hydrologic modelling – Homa Bay case
Flood affected areas - Shauri Yako



- Important erosion
- Drainage swale location creates an important flood risk, worsened by possible culvert blockage
- Consistent with Community Validation Workshops

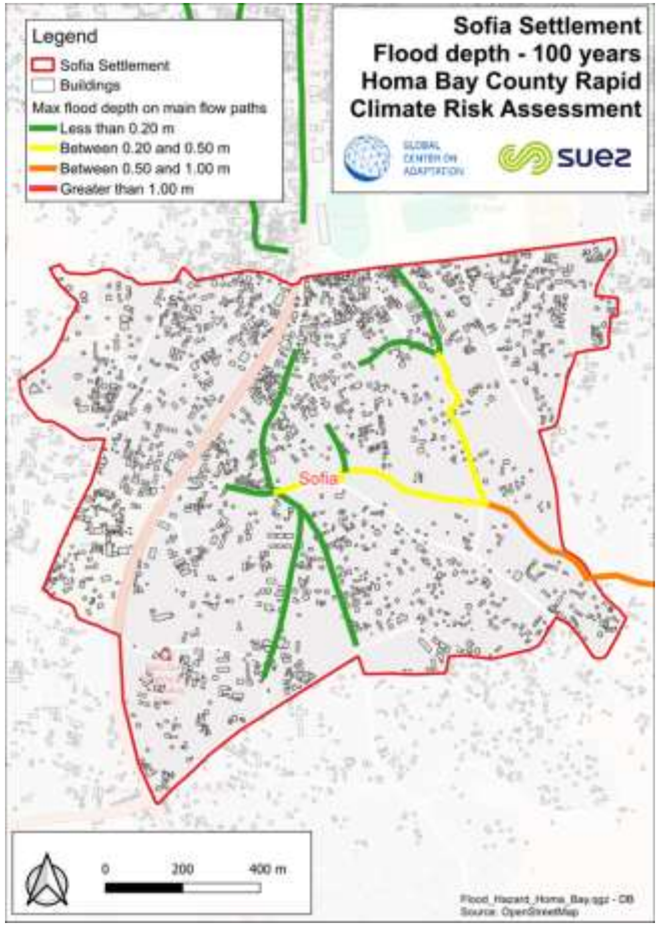
Hydrologic modelling – Homa Bay case Sofia

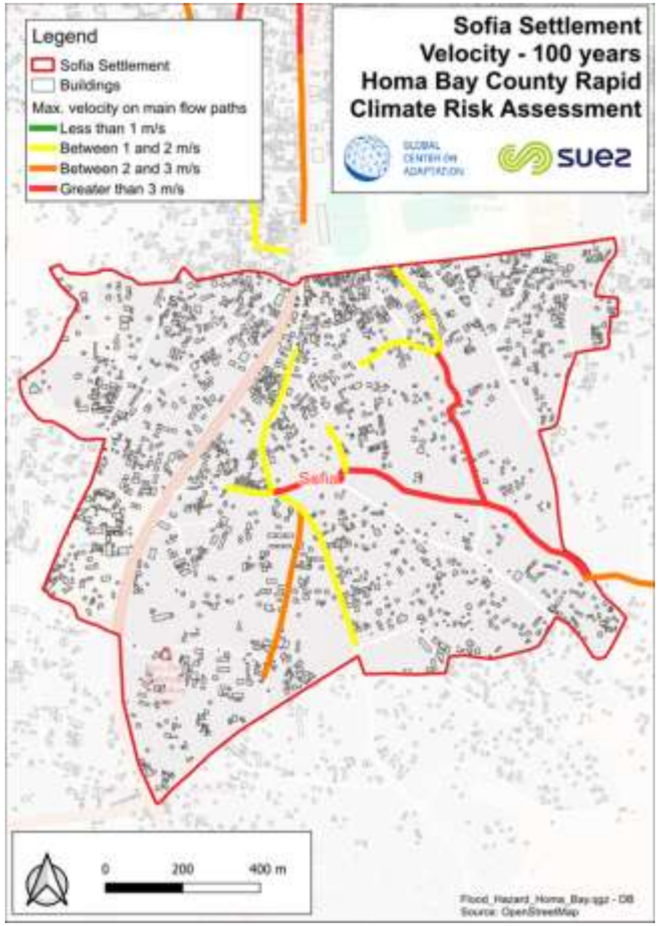
- Steep slopes and lack of drainage in the upper catchment
- Draining to Rang’wena river downstream, where flooding occurs occasionally



Hydrologic modelling – Homa Bay case
Hydrologic model results - Sofia

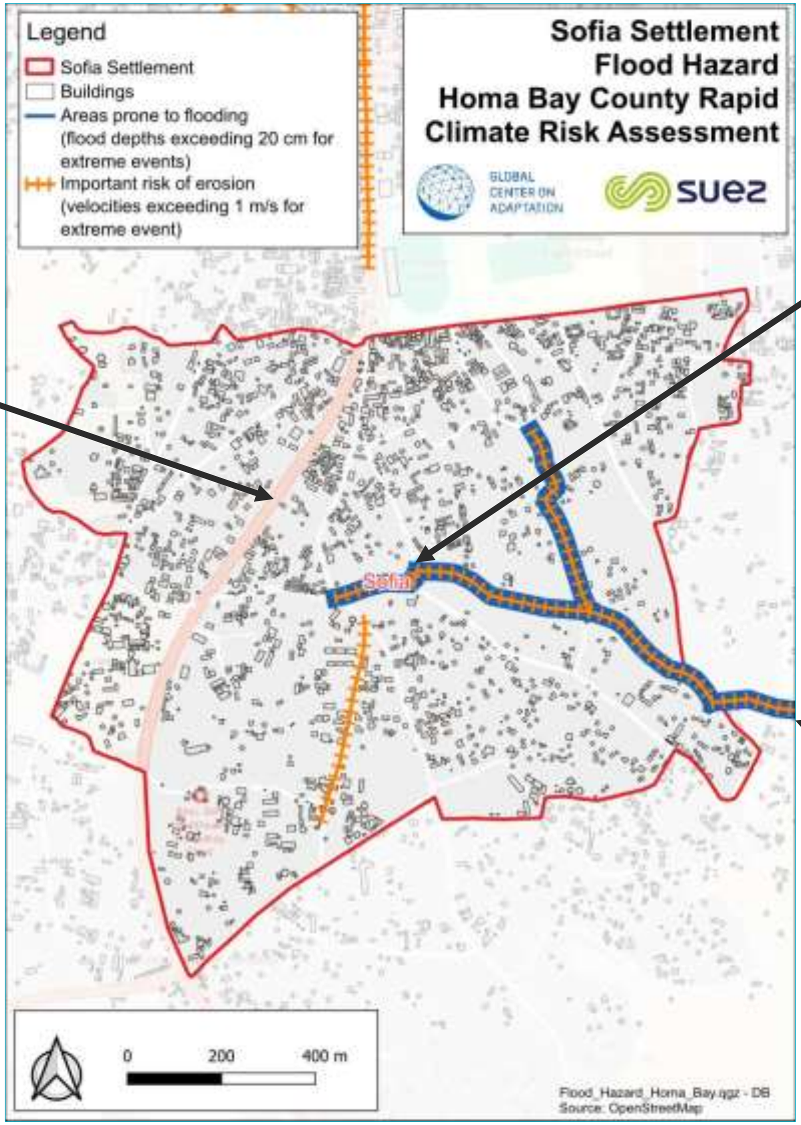
- Significative depths and velocity on the lower catchment
- Important velocities along main roads



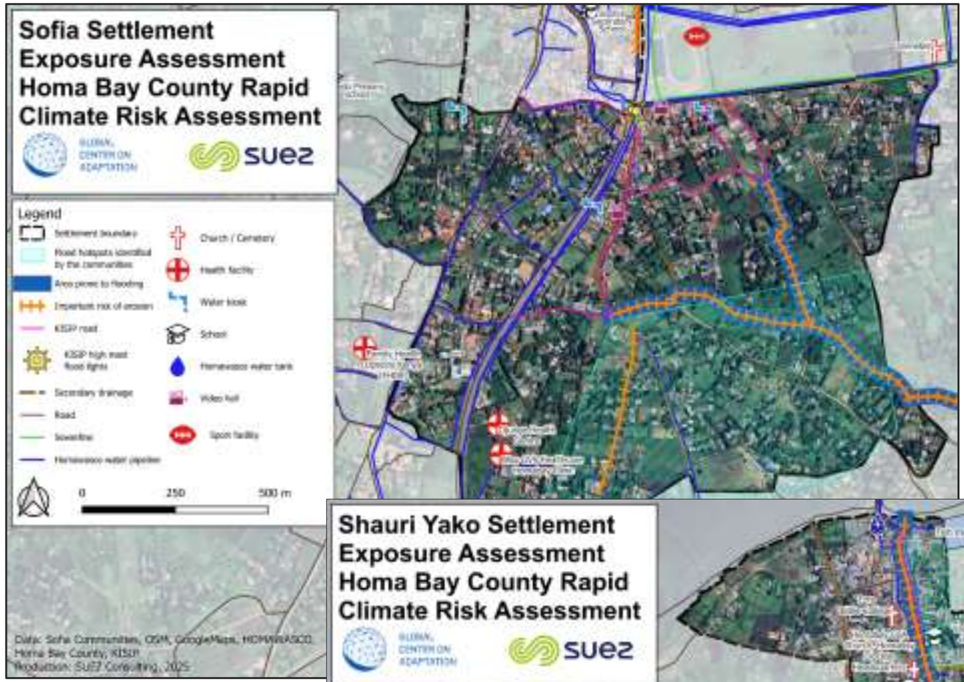


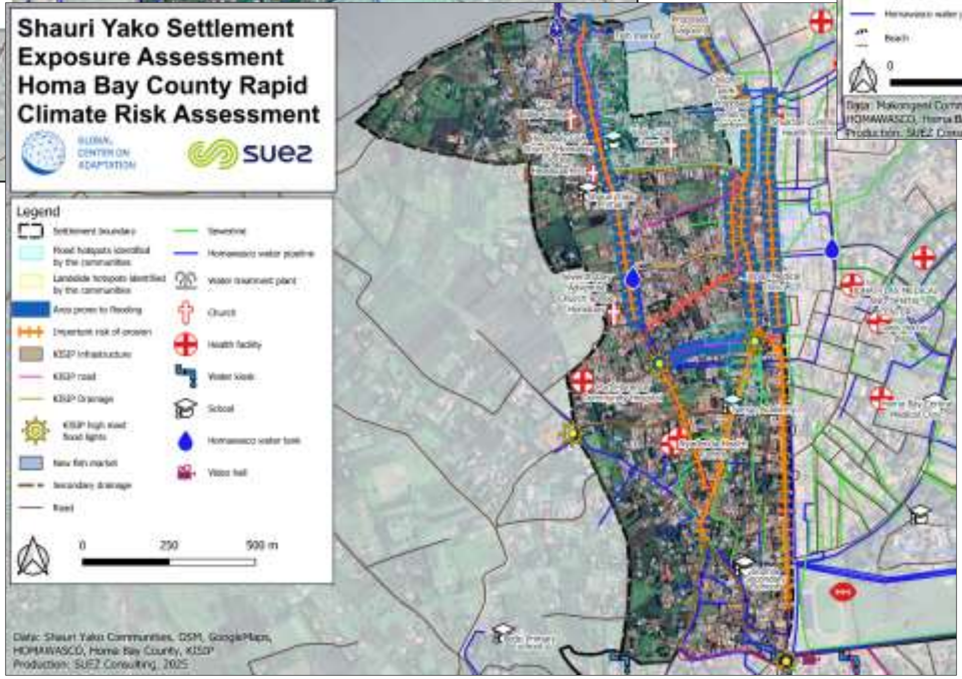
Hydrologic modelling – Homa Bay case
Flood affected areas - Sofia

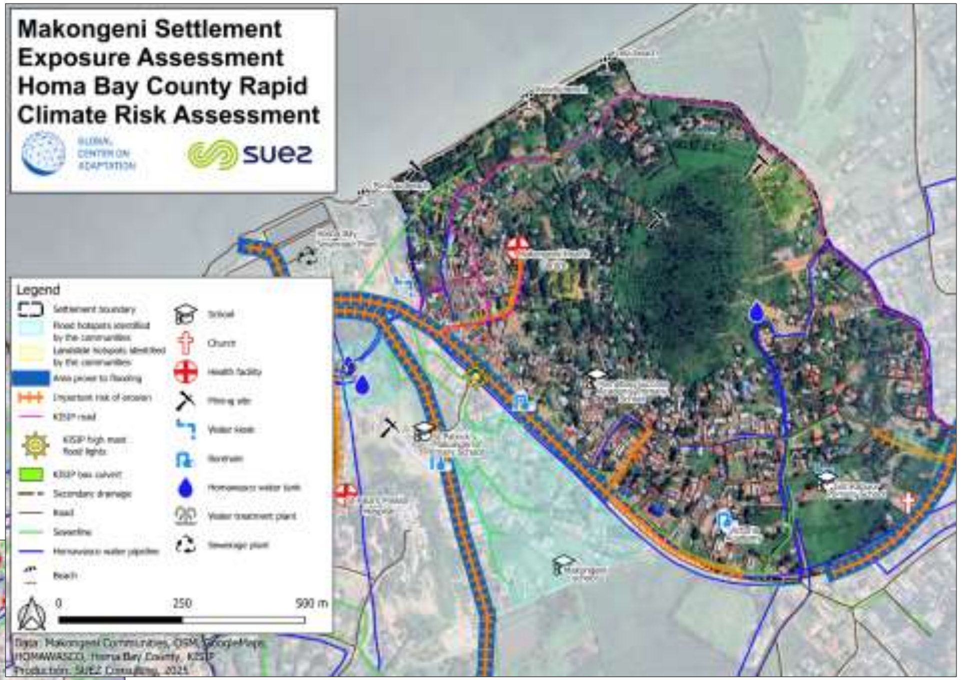
- Drainage structure on the head of catchment
- Consistent with Community Validation Workshops



Hydrologic modelling – Homa Bay case
Integration in exposure maps







- Cross reference with critical urban infrastructure, social facilities and houses to define exposure (yesterdays presentation)

Conclusion

GLOBAL CENTER ON ADAPTATION

- **1st step: gathering data**
  - Topography
  - Land Cover
  - Rainfall data

- **2nd step: catchment delineation and calculate the discharge**
  - Hydrological modelling

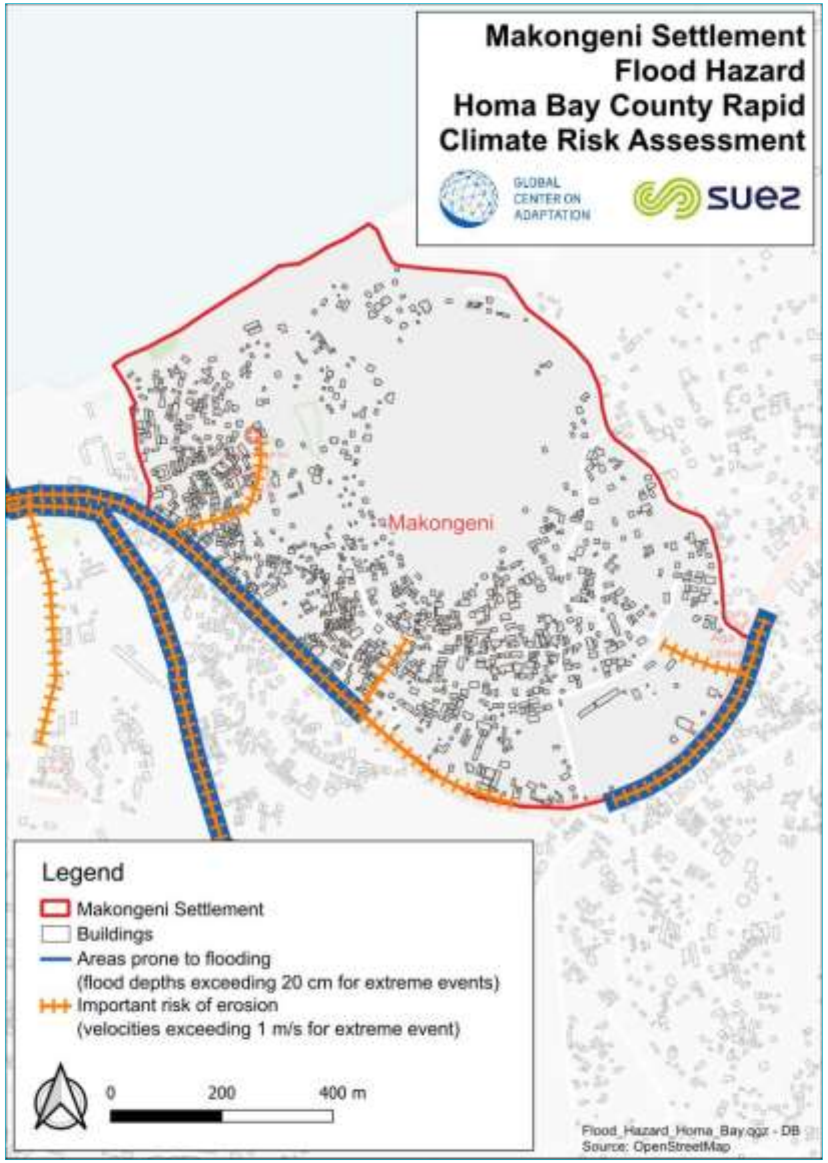
- **3rd step: estimate flood prone areas and erosion prone paths**
  - Hydraulics equation
  - Compare results with field observations

- **4th step: Cross reference results with systems and assets to assess the exposure**
  - Exposure maps and exposure scorings

What's next

- Drainage solutions depends on
    - Flood risk
    - Velocities and flood depths
    - Available areas
    - Close to roads, houses, …

- Drainage nature-based solutions & / or grey drainage



Thank you for listening!

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