7.5 Water Strategy

The primary goals for Tanjung Ringgit's water strategy are to:

- Reduce consumption of potable water
- Maximize rainwater use and define other suitable resources for potable water
  - To be in combination with desalination of salt water and groundwater methods
- Manage stormwater to reduce erosion and control flooding events
- Integration with the sanitation strategy

The focus of the water concept is the reduction of the consumption of drinkable water while maximizing the efficient use / re-use of on-site water sources.
All water that comes into the system – rainwater, wastewater, desalinated water – shall be reapplied for a secondary and perhaps tertiary use. Stormwater quantity and quality management is a crucial element that works to protect and revitalize the eroded, damaged landscape.

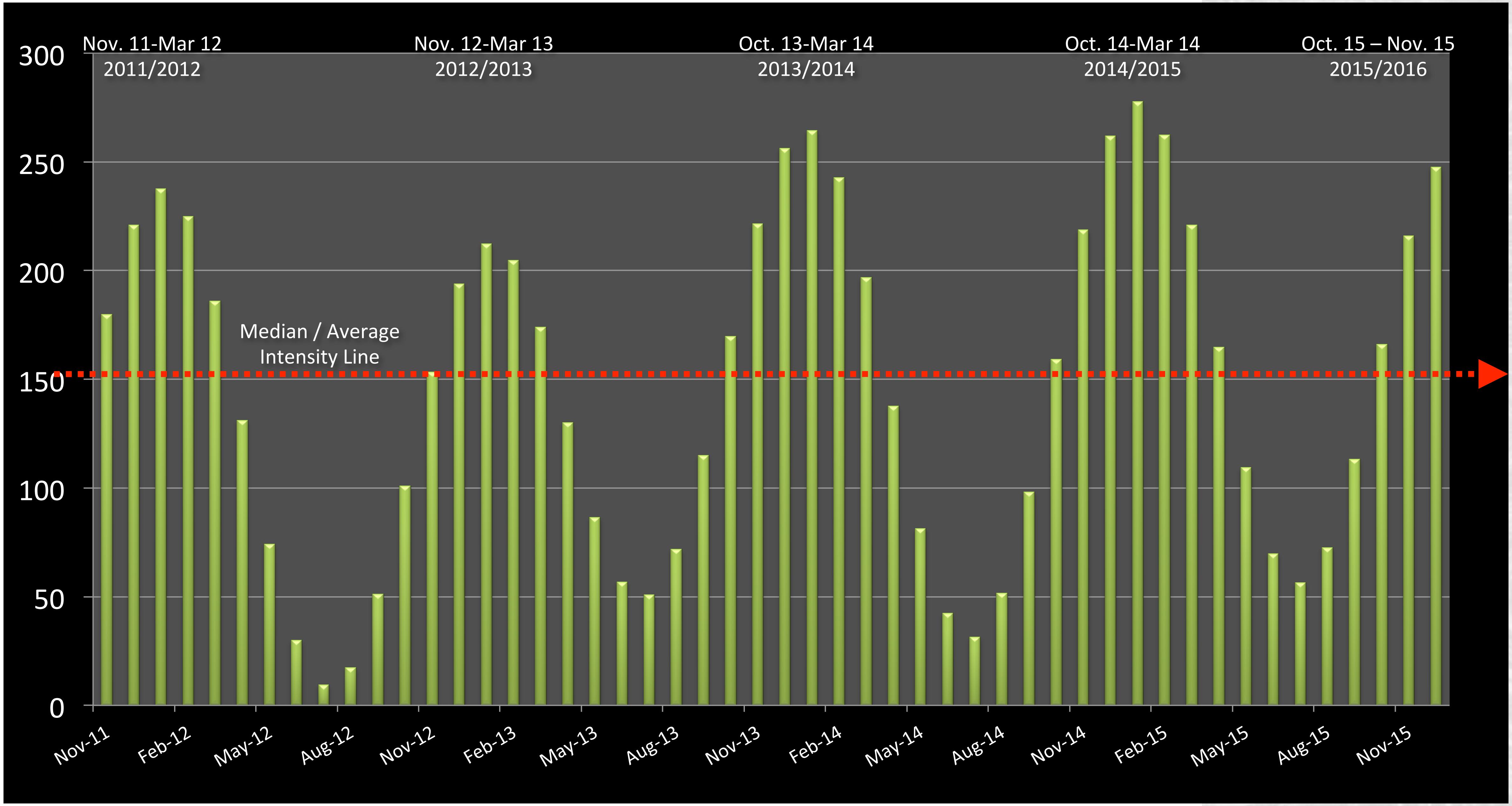
The water strategy is comprehensive design solution that requires specialist knowledge of low-tech yet cutting edge, integrated, and contextually appropriate solutions.

Current Situations: Primary Issues

EXISTING PROBLEMS

Current and Predicted Rainfall: 2011-2015

- Rainfall intensity has continued to increase each year (note periods between November to March) suggesting best times to collect excess rainwater for storage and further application
- Assumptions made for calculations have been baesd on a dry year 1.000 mm rainfall at 80% harvesting efficiency over a 365 day period



Source: Putrawan Habibi, environmental expert for Lombok / Tanjung Ringgit site and surroundings 2012

Goal 1: Reduce Consumption of Potable Water

REDUCED CONSUMPTION

METHODS AND SUGGESTIONS:

Raise awareness as to the importance of the need to reduce potable water consumption

- Educating locals as well as visitors of the environmental, economical, and long-term benefits of sustainable consumption

Reduce reliance on technical systems and introduce low-tech water saving and treatment systems

- Although the Tanjung Ringgit site should develop cutting-edge techniques and apply water-saving technical systems, *low-tech* solutions can also be viable and manageable over the long-term
- Low-tech solutions (such as collection of rainwater in cleansing biotopes or management of stormwater in street adjacent bioswales instead of conventional piping) are also innovative, cost-effective, and can be conveniently applied in the region
- Reduces mechanical maintenance and relies on employment of local workers for service

Utilize all available water resources and maximize efficiency

- Consider alternative means of obtaining water for potable needs
- Apply reused water for non-potable needs
- Use water-efficient ratings within buildings

REDUCED CONSUMPTION

Water Schematic: Resource Treatment Storage Application

RESOURCE	TREATMENT	STORAGE	APPLICATION
1. Rainwater (From Building Rooftops)	Screen	Tank storage below or adjacent to house / cisterns	Drinking Water (Potable)
2A. Rainwater (From Surface Flow)	Cleansing Biotope Terraces	Tank storage below or adjacent to house / cisterns	
2B. Existing Fresh Groundwater Wells	Natural Soil Filtration	Wells	
3A. Salt Water (Ocean)	Desalination	Tank storage below or adjacent to house / cisterns	
3B. Groundwater	Desalination	Tank storage below or adjacent to house / cisterns	
Greywater (After Household Use)	Cleansing Biotope Terraces	Cisterns/Terraces	For Households: Irrigation Public Facilities: Service Water
Rainwater (Conveyed Along Surface/Roads)	Bioswales (Ditches)	None; to be conveyed	Infiltration *Optional: Irrigation*
Blackwater (Wastewater)	Treatment dependent on site location	Tank; Transport to Terra Preta Farm	

Note: *Greywater from larger buildings (hotels, hostels, clubhouses) applied firstly as building service water*

Goal 1: Reduce Consumption of Potable Water

THE MAIN DRINKING WATER SOURCE IS RAINWATER:

THE WATER STRATEGY IS AN INTERCONNECTED SYSTEM:
Water is applied in the following ways:

- Drinking Water
- Irrigation / Service Water
- Infiltration

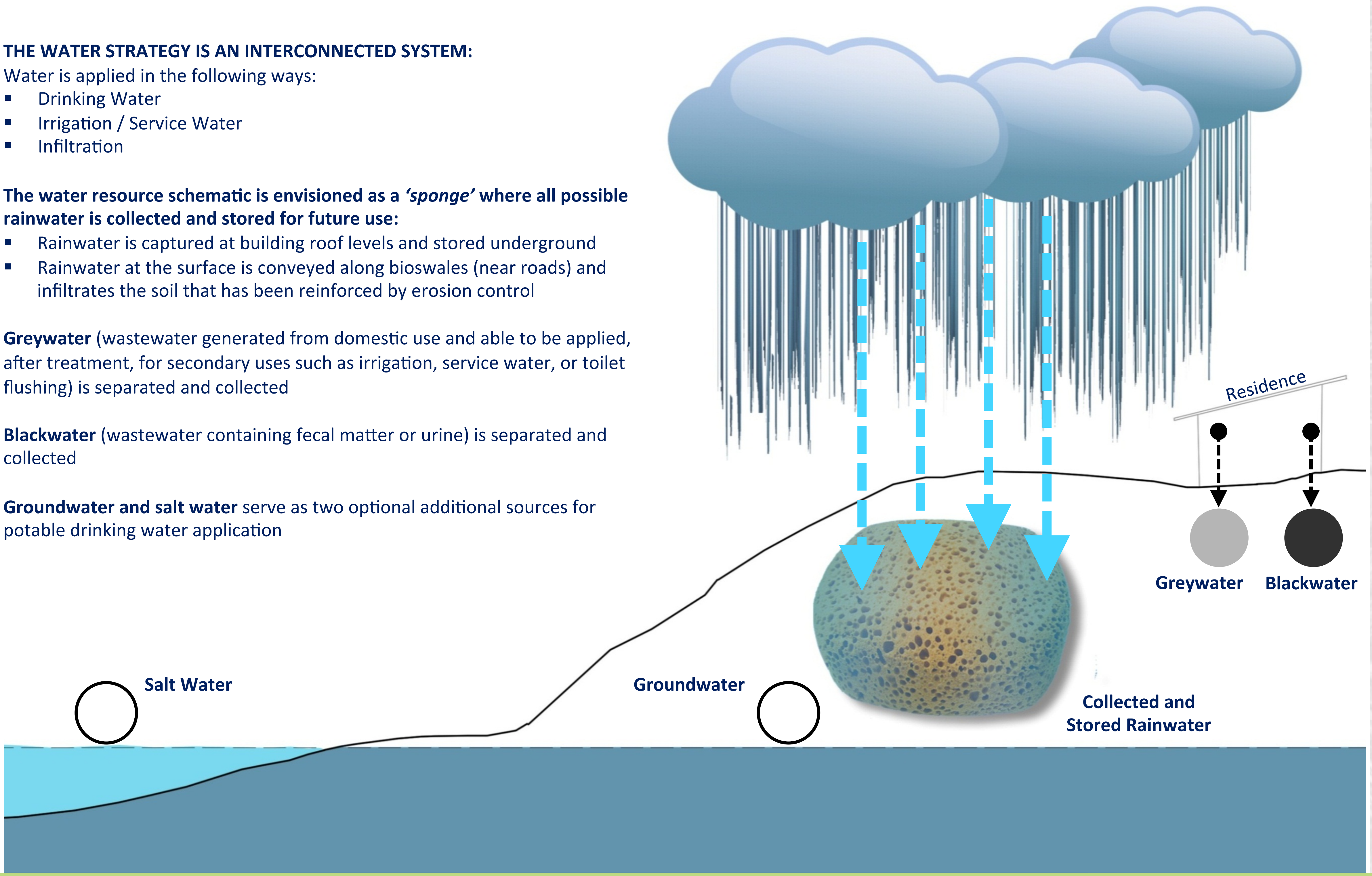
The water resource schematic is envisioned as a *'sponge'* where all possible rainwater is collected and stored for future use:

- Rainwater is captured at building roof levels and stored underground
- Rainwater at the surface is conveyed along bioswales (near roads) and infiltrates the soil that has been reinforced by erosion control

Greywater (wastewater generated from domestic use and able to be applied, after treatment, for secondary uses such as irrigation, service water, or toilet flushing) is separated and collected

Blackwater (wastewater containing fecal matter or urine) is separated and collected

Groundwater and salt water serve as two optional additional sources for potable drinking water application



Goal 1: Reduce Consumption of Potable Water

APPLICATION OF WATER RESOURCES:

The 'sponge' that has collected extra rainwater water drains out

- Rainwater from roofs is applied as potable drinking water

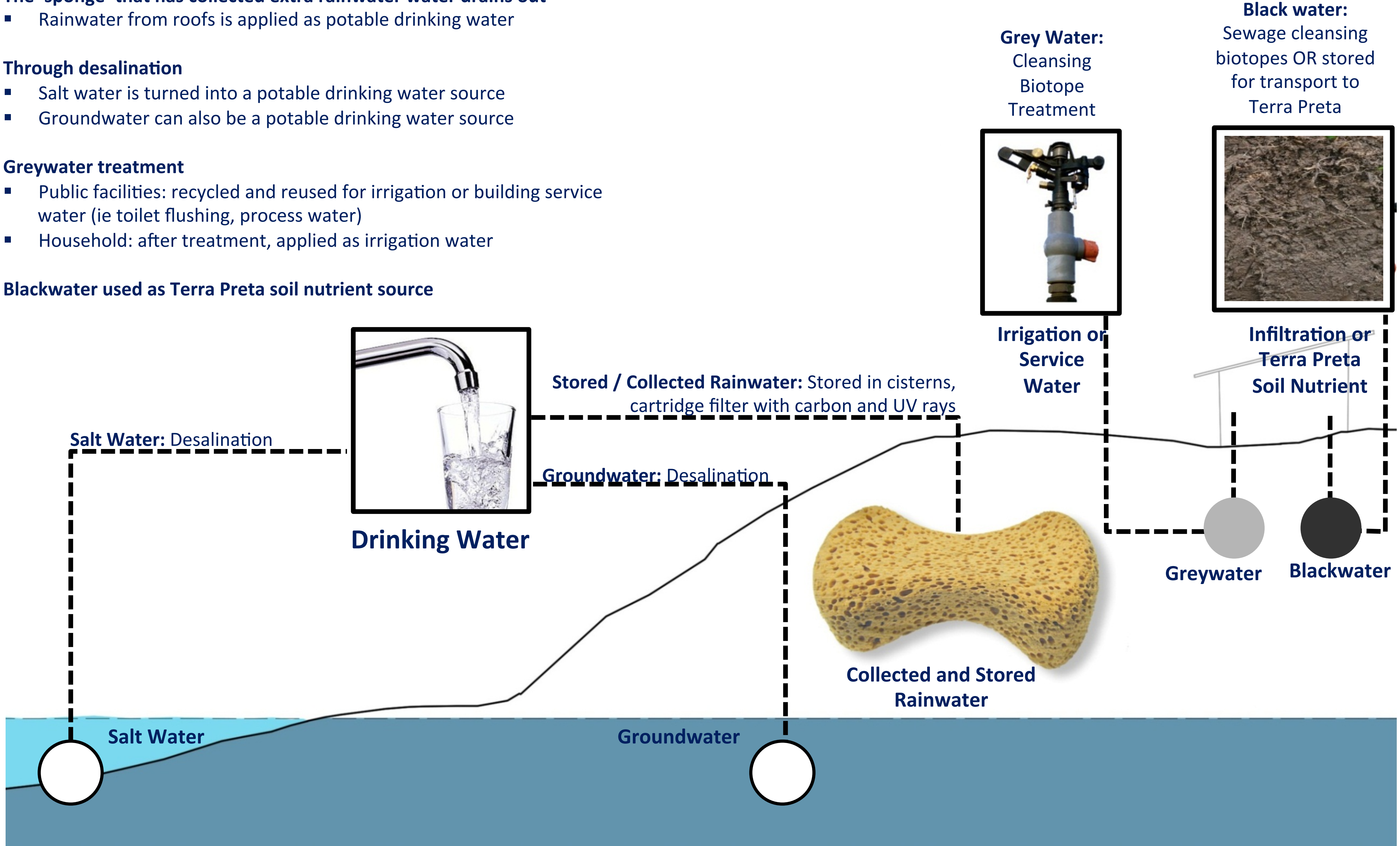
Through desalination

- Salt water is turned into a potable drinking water source
- Groundwater can also be a potable drinking water source

Greywater treatment

- Public facilities: recycled and reused for irrigation or building service water (ie toilet flushing, process water)
- Household: after treatment, applied as irrigation water

Blackwater used as Terra Preta soil nutrient source



Goal 1: Reduce Consumption of Potable Water

REDUCED CONSUMPTION

CALCULATION OF WATER DEMAND: BASED ON TOURIST DEMAND RATES:

The following table provides the calculation of the demand at 68, 100, 120, 150 and 200 lcd for visitor/tourist water in combination with estimated amounts of public facility and staff water demand

Note: areas where additional demand must be assumed

- We have assumed 100 lcd as an acceptable average for a water demand rate
- Staff use estimated at 15 liters-person-day
- For semi-public areas such as bars, restaurants, spas, terra preta plant:
  - Assumed at 20% of water demand at base rate of 100 liters/capita/day.

Total Tourist Demand (m^3/year)	Public Facilities (m^3/year)	Staff (m^3/year)	Total Demand (m^3/year)
190.000	40.000	60.000	290.000

Water demand rate: at rate of 100 liters per capita per day

To be revised due to final boundary!

PHASED WATER DEMAND FROM 2013-2022

Phase	Guests	Water demand (guests)	Water demand (staff)	Spa and Public Buildings	Total demand (rounded)	Primary Water Source: Harvested from Roofs	Additional volume: satisfy demand
	Number	m^3 / year	m^3 / year	m^3 / year	m^3 / year	m^3 / year	m^3 / year
Beds 2013-2015	1.200	43.800	13.140	8.760	70.000	40.000	30.000
Beds 2016-2018	3.600	131.400	39.420	26.280	200.000	120.000	80.000
Beds 2019-2022	5.600	204.400	61.320	40.880	310.000	180.000	130.000

To be revised due to final boundary!

ADDITIONAL POTABLE WATER SUPPLY SUMMARY

Option 2A: Harvested Rainwater (area required)	Opt. 2A Surface Area: (length x width)	Opt. 2A: Storage volume	Option 2B-2C: Desalination	Opt. 2B-2C: Energy demand (at assumed 4 kWh / day)	Emergency Only: number truck trips / day	Emergency Only: cost purchase trucked water	Emergency Only: cost purchase trucked water
hectares	m^2	m^3	m^3 / year	kWh / year	trips / day	Rp million/year	Euro/year
3.75	194	7.800	30.000	120.000	27	Rp 840	€ 70.000
10.00	316	20.800	80.000	320.000	73	Rp 2.240	€ 190.000
16.25	403	33.800	130.000	520.000	119	Rp 3.640	€ 310.000

Goal 1: Reduce Consumption of Potable Water

CALCULATION OF WATER DEMAND, BASED ON TYPE OF WATER DEVICE:

The following table provides the calculation of the demand at 68, 100, 120, 150 and 200 lcd

At the moment it is difficult to forecast the water demand per guest so assumptions shall be preliminary made

Being an eco-resort and given the scarcity of water it is logical to assume that water consumption must be minimized

- Guests should be informed of the water demand and consumption issues
- ***65 liters per capita per day (lcd)*** is sufficient for any guest with a dry toilet and centralized laundry facilities *(minimum)*

For special cases requiring more than 65 liters a day:

- Suggest options where guests can be charged a fee (ie 200%- 1.000% multiplied by the excess amount)
- Another option is to provide a percentage-based financial incentive to guests who reduce water consumption (under 65 lcd)

In order to provide an acceptable water demand standard, calculations have been based on an average of 100 lcd

Water Use	Minimum	100 lcd guests
Shower	45	45
Wash basin	5	5
Toilet flush	0	35
Laundry (by hand)	2	2
Laundry (by machine)	0	0
Food preparation	2	2
Drinking	4	4
Other	7	7
Total	**65**	**100**

Calculation of water demand at various levels of daily water consumption

Goal 1: Reduce Consumption of Potable Water

REDUCED CONSUMPTION

TECHNICAL SOLUTIONS FOR REDUCING CONSUMPTION:

For installation consider water efficient brands with quality tested fittings

Technical water saving solutions

- Water saving taps, adding air, reducing tap diameter, reducing pressure
- Water saving showers
- Add meters as visual reminder of amount used or saved
- Water cascading: direct water from hand wash basins and showers to the grey water reservoir and use stored water for flushing of toilets

Toilet systems

- Installation of dry toilets such as urine separating toilets or composting toilet to reduce use of conventional flushing toilets
- Installation of dual flush toilets for units that have water flushed toilets

Description	Volume	Unit
Roof area for one villa	125	m^2
Water demand	100 (assumed amount)	liters per guest per day
Occupancy level	4	guests per villa
Water demand per villa	100	m^3
Average rainfall rate	1.585	mm (liters/m^2/year)
Rainfall rate, dry year	1.000	mm (liters/m^2/year)
Collection efficiency	80%	percentage
Collected water per year	100	m^2
Additional source required	-	m^2
Additional source %	0%	consumption

***Testing:** water needs for Ocean Bay Villas development example*

Combine water efficient taps with meter readouts

Eco-Shower filters, cleans, and recycles water

Separated toilet-sink system example

Goal 2: Maximize Rainwater Use and Alternative Resources

METHODS AND SUGGESTIONS:

The primary drinking source is treated rainwater

- Source can last approximately for nine months during ‘rainy season’
- Secondary supply collection continues throughout year
- Tertiary supply as back-up resource

Secondary potable water options include harvesting rainwater in designated areas and drawing from existing fresh groundwater resources

Tertiary potable water options include desalinized and treated saline sea water or brackish groundwater; emergency option only is to transport water in by vehicle

Stormwater management system

- Reduce stormwater quantity and velocity at point of contact to limit erosion, mudding, and flooding problems and improve landscape condition
- Catch at building roofs, send to underground tanks, filter prior to potable use
- Catch rainwater from surfaces and direct to terraces for treatment
- Harvested rainwater can serve as multi-functional water features

Maximize efficiency of other water sources applied for non-potable needs

- Greywater (used potable water) treated and used as irrigation source
- Blackwater (sewage water) treated at point-of contact; transported to Terra Preta areas for infiltration in order to create fertile soil resource

Potable Water Schematic

RESOURCE	TREATMENT	STORAGE	APPLICATION
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Note: *Greywater from larger buildings (hotels, hostels, clubhouses) applied firstly as building service water*

Goal 2: Maximize Rainwater Use and Alternative Resources

OBTAINING DRINKING WATER, PROCESS AND CONCEPT:

Condition: No potable water pipe mains envisioned to be built for the Tanjung Ringgit site

Solution: The drinking water solution shall be supplied by a mixed system based upon collected rainwater from building rooftops; rainwater harvesting in designated areas; water drawn from existing fresh groundwater wells; saline salt water and brackish groundwater desalination; and as an emergency option, transported on-site potable water

Primary Process: Rainwater collected from roofs; peak amount achieved in March; storage tank empties out around October; need secondary and possibly tertiary source due to lowered supply during these periods

Secondary Process A: Rainwater harvested within specifically designated areas, treated in low-tech procedure

- Requires using excess land as specific collection area; reduced mechanical construction; may require mechanical filter

Secondary Process B: Conduct groundwater surveys and determine fresh groundwater well locations as existing source

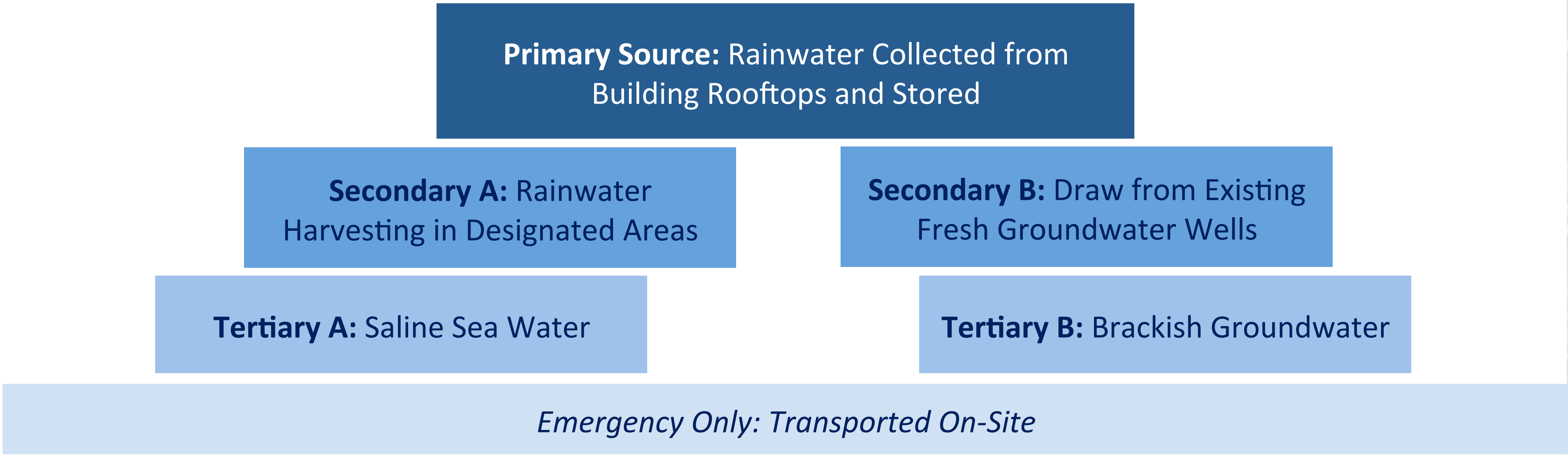
Tertiary Process A: Saline salt water treated, stored, and applied when primary supply is low

- Requires construction and long-term maintenance of facilities, energy source, output area

Tertiary Process B: Brackish groundwater treated, stored, and applied when primary supply is low

- Combine with saline salt water treatment facilities to consolidate large construction facilities and maintenance needs

Emergency Only: Potable water transported on-site only used in extreme shortage cases



Potable water pyramid scheme

Goal 2: Maximize Rainwater Use and Alternative Resources

CHARACTERISTICS OF USING RAINWATER AS A POTABLE WATER SOURCE:

- Offers independence from piped, trucked, and bottled water
- Requires special equipment and considerations
  - Roofing should be slanted and non-harmful surface material (ie no asphalt shingles)
  - Metal, ceramic, or slate roofs are better choices
  - Easy to integrate with photovoltaic panels – natural slope, non-harmful material type
  - Needs to be able to discard or filter first flush contaminants
  - Within the building shell / covered protected area, a shallow well pump and line pressure tank capable of maintaining average water pressure of 40-60 psi
  - The tank should be non-corrosive, with a filter system in place
  - Would also require a UV filter
- Suitable for individual homes and small communities
- Purification by means of multi-stage and multi-media filtration
- Eliminates contaminants present in rooftop-rainwater, like bacteria, organic and inorganic pollutants, and heavy metals like lead, copper, zinc, and cadmium
- Slow upward flow through specific filters (ex RainPC MKII filter) secures even water distribution through its filter elements
- Operates at low gravity pressure as well as pump pressure up to 6 bar
- Water flow at rate of four liters / minute
- Longer service life
  - Cartridge lasts to 35.000 liters
  - Pre- and multi-stage/multi-media filters can last to 10.000 liters, dependent on pollution rate
  - Easy to install, operate, maintain, and replace filter elements

Tank kept under house; filter prior to system entrance

Polyethylene tank material safe for potable water

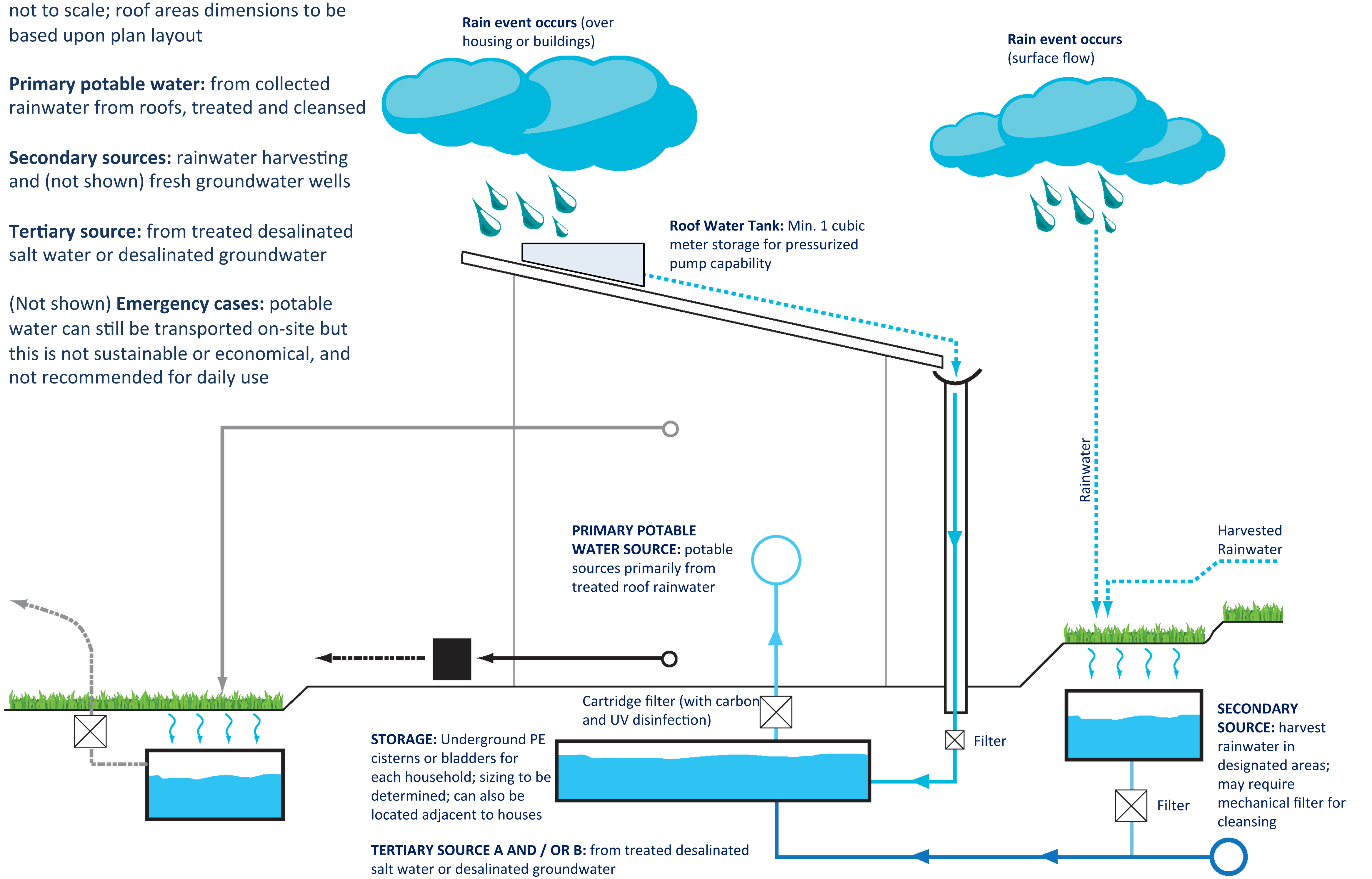
LEED Platinum Eco-Office collecting water from PV array

Storage can also occur aboveground in cisterns

Reduce concrete encasement and place in 'bladders'

Goal 2: Maximize Rainwater Use and Alternative Resources

- **Note:** Graphic shown representatively and not to scale; roof areas dimensions to be based upon plan layout
- **Primary potable water:** from collected rainwater from roofs, treated and cleansed
- **Secondary sources:** rainwater harvesting and (not shown) fresh groundwater wells
- **Tertiary source:** from treated desalinated salt water or desalinated groundwater
- (Not shown) **Emergency cases:** potable water can still be transported on-site but this is not sustainable or economical, and not recommended for daily use



Goal 2: Maximize Rainwater Use and Alternative Resources

PRIMARY SUPPLY: SATISFYING ADDITIONAL SUPPLY:

- Calculations reveal that the approximate 200.000 square meters of roof area can catch (at 80% assumed efficiency) **160.000 cubic meters rainwater volume per year**
- If the average demand is assumed at 100 liters per day, the **total demand required is 290.000 cubic meters**
- **130.000 cubic meters** *minimum* must still be satisfied
  - **Secondary sources:** harvested rainwater or drawn from fresh groundwater wells
  - **Tertiary sources:** desalinated saline sea water or desalinated groundwater
  - *Emergency source: water transported in on-site (rare cases)*

RAINWATER COLLECTION VOLUME: FROM ROOFS

Approximate Roof Area	**200.000**	**m²**
Rainfall, Dry Year	**1.000**	**mm/year (liters/m²/ year)**
Harvesting Efficiency (Assumed)	**80%**	
Rain Water Harvested	**160.000**	**m³/year**

To be revised due to final boundary!

160 000 *cubic meters of water can be harvested from the residential roofs*

CALCULATING ADDITIONAL SUPPLY: BASED ON GUEST DEMANDS

Average demand guests (liter per capita per day)	**Total demand** (m³ / year)	**Harvested rainwater units** (m³ / year)	**Additional supply** (m³ / year)
100	290.000	160.000	130.000

To be revised due to final boundary!

At 100 lcd demand, the ***290.000*** *cubic meter demand needed minus the* ***160.000*** *rainwater supply still requires* ***130.000*** *cubic meters of potable water*

Goal 2: Maximize Rainwater Use and Alternative Resources

SECONDARY POTABLE WATER: HARVESTED RAINWATER:

Concept: There is plenty of space available on site for collection of rainwater at surface level

- Specify public areas within the first phase of development to be used as multi-functional rainwater harvesting as well as community space for infiltration of water
- If no space is available, suggests need to increase surface area of roofs

Process: Water shall be drawn out from well point located adjacent to rainwater harvesting specific area

- Extra facilities such as constructed wetlands or cleansing biotope terraces can be integrated into the landscape while reducing amount of used sellable property
- Technology exists to take caught greywater and purify to standards above potable water standards

Rainwater harvesting locations to be appropriately located in next steps

To be revised due to final boundary!

Average demand guests (liters per guest per day)	**Additional supply** (m^3 / year)	**Additional collection area at zero purchase** (hectares, ha)	**Length x Width Area** (m^2)	**Storage Capacity** (m^2)	**Costs to Build** (€)	**Cost of Water** (€)	**Time to Recuperate Investment** (years)
100	130.000	10.40	320	50.000	2.2 Million	340.000	6.5

Costs and time to recuperate investment*:At 100 lcd at extra 130 000 demand rate collecting 50 000 cubic meters*

Technical rainwater harvesting in 'rigola' system

Create enclosed areas for harvesting

Wells located near water features to draw water out

Constant recirculation in rainwater harvesting areas

Water can collect in roofs or direct into biotopes

Goal 2: Maximize Rainwater Use and Alternative Resources

TERTIARY POTABLE WATER: DESALINATED SALINE SEA WATER:

Two sources for desalination exist: saline sea water and brackish groundwater

- For brackish groundwater to be used, client should conduct a groundwater survey prior to start of project to determine logical locations for placement of groundwater desalination plant

Background: Collected rainwater supply at half capacity around June

Process: desalinated water can be collected a few days prior to increased demand

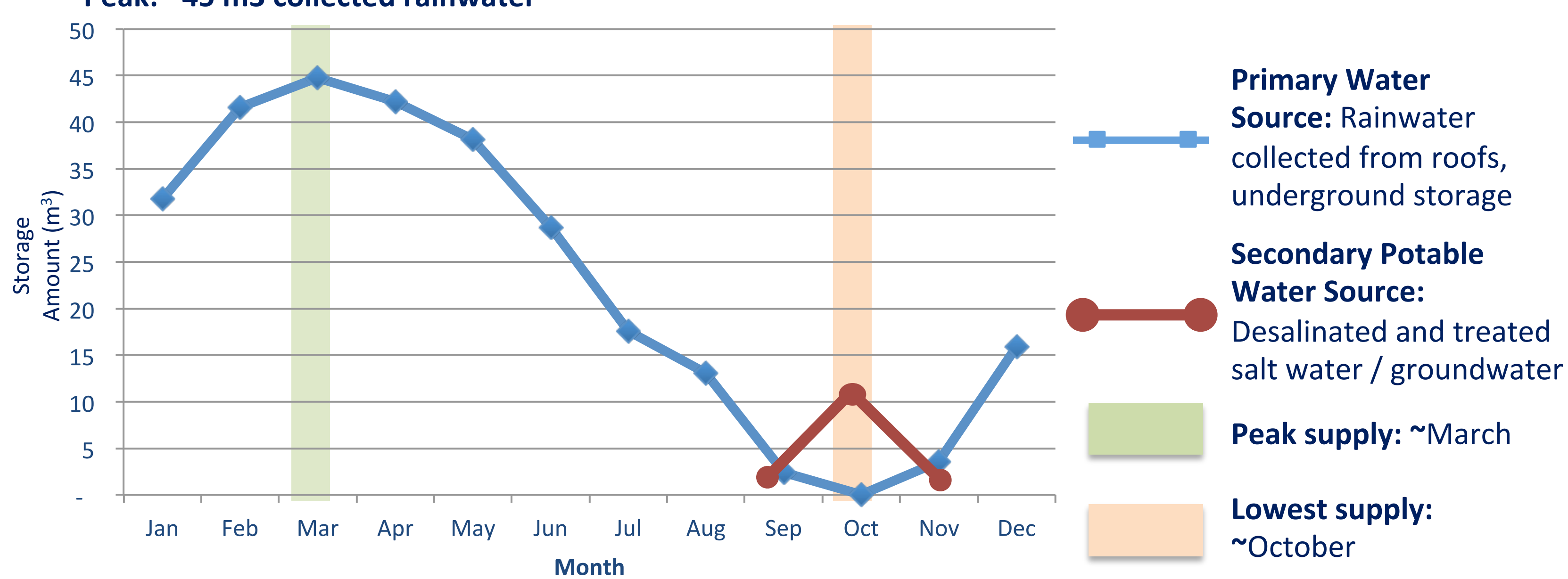
- Desalinated water in combination with harvested rainwater as primary potable water source

Required calculations: actual production level of desalination treatment system, costs, energy needs, how to satisfy energy demand needs (preliminary calculations have been provided)

Decentralized desalination plants locations: *Two primary first phase plants*

- One mixed salt water / groundwater desalination plant at Terra Preta Camp
- Two phase two plants have been further suggested if necessary

Peak: ~45 m3 collected rainwater



Exemplary storage tank: *calculated volume for single household*

Note the compact, efficient layout of desal site

Unit capable of approximately 80 m^3 desal water / day

Wells are better collection points (reduced direct contact)

Goal 2: Maximize Rainwater Use and Alternative Resources

POTABLE WATER

TERTIARY POTABLE WATER, A SUSTAINABLE APPROACH TO DESALINATION:

Background: majority of Indonesian systems use energy and waste intensive reverse osmosis system

Innovative technology: equipment exists that reduces energy consumption, limits space used for desalination (fairly new yet tested technology found in primarily in southeast Asia and soon in Middle East countries)

- Brackish and salt water desalination levels tested above World Health Organization potable drinking water standards
- Facility sizing: approximately 10 m^2 required for every 80 m^3 desalinated water *(small sizing)*
- Energy needs: 4 kilowatt hours energy need for every 80 m^3 desalinated water *(energy efficient)*
- Waste level: approximately less than 10% the volume of water to be treated *(low waste output)*
- Sustainable energy and construction: in combination with solar energy supply, a salt-nickel battery storage system can power the units; the *food grade* piping is designed to be easily constructed, transported, and later deconstructed
- Location and Setup: can be decentralized; shallow wells needed adjacent to system as source point for water extract into system thereby reducing amount of entering pollutants/sediments and typical maintenance resulting from direct contact to salt water
- Cost estimates: at ~400 m^3 water demand at rate of 6.850 Rp (0.5 Euros) = *~70 Euros / day*
  - Yearly rate approximately at *80.000 Euros*
  - Must figure in additional cost of supplemental Technology Access Fee which is calculated at around 1.000 Rp per cubic meter of desalinated salt water (extra 10.000 – 20.000)
  - Cost of system purchase varies: dependent on choice (figure 20.000 / unit as estimate)
  - Final cost could range from 100.000 – 150.000 for system
    - Also the storage area for the facilities plus staff training and maintenance are not included in the preliminary cost estimate

Disadvantages

- Machinery will be separated in enclosed areas, hiding visitors from the process
- If not paired with other techniques, mechanical failure leaves one without water source
- Relatively new technology has not had significant testing periods
  - Suggest test reach areas for implementation of new technology prior to commencement

Average demand tourists (liters per capita per day)	**Additional water supply** (m^3/year)	**Energy requirement** (kWh / year)
100	130.000	390.000

Conventional desalination: *The extra supply needed to satisfy potable water shows that a high energy requirement is needed (ex for 130.000 cubic meter extra supply, 390.000 kilowatt hours per year will be consumed)*

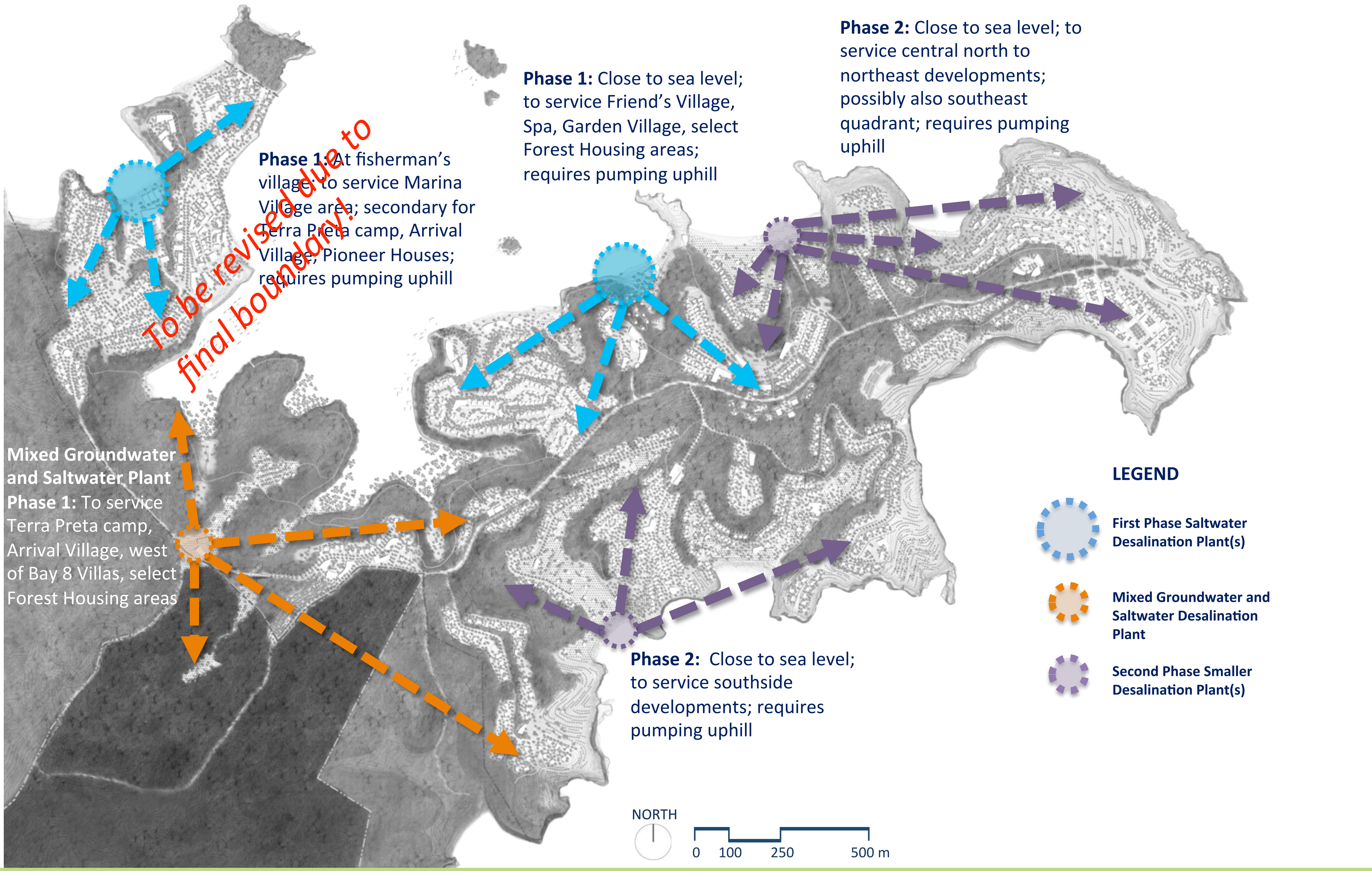
To be revised due to final boundary!

Average demand tourists (liters per capita per day)	**Additional water supply** (m^3/year)	**Energy requirement** (kWh / year)
100	130.000	6.500

Starfish sustainable desalination: *reduced energy needs of system decrease requirements by 600%*

Goal 2: Maximize Rainwater Use and Alternative Resources

DECENTRALIZED DESALINATION POINTS



Goal 2: Maximize Rainwater Use and Alternative Resources

EMERGENCY POTABLE WATER OPTION, TRANSPORTED ON-SITE:

- In extreme emergency cases only, such as severe weather conditions where potable water is no longer possible, transported water costs, volume and supply, and demand have been calculated

Average demand tourists (liters per capita per day)	Additional supply (m^3/year)	Number of trucks per day
68	70.000	60
100	130.000	120
120	170.000	160
150	230.000	210
200	330.000	300

To be revised due to final boundary!

Demand calculations to satisfy complete unsatisfied supply at a 100 lcd rate (would suggest, if selected, to mix systems and not rely on just one system)

Average demand tourists (liters per capita per day)	Additional supply (m^3/year)	Cost purchase water (millions Rp. / year)	Cost purchase water (Euro / year)
68	70.000	Rp2.000	€170.000
100	130.000	Rp4.000	€340.000
120	170.000	Rp5.000	€430.000
150	230.000	Rp6.000	€520.000
200	330.000	Rp9.000	€780.000

To be revised due to final boundary!

Approximate costs for additional water needs when trucked water to be used

Aboveground storage tanks for transported water

Tanker example for water distribution / supply

If brought to central supply, water could be carried in

Goal 3: Create a Holistic Sanitation Strategy

METHODS AND SUGGESTIONS:

Collect all household / building grey- and blackwater
- Cleanse and treat greywater in cleansing biotope terraces
- Send blackwater to separate tank storage or to waste sanitation terrace for initial cleansing; later to be transported to Terra Preta area

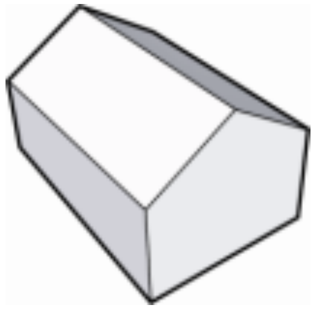
Apply the wastewater and reuse in further process
- Household greywater serves firstly as irrigation water, secondly service water
- Building greywater serves firstly as service water, secondly as irrigation water
- Household and building blackwater to be infiltrated within Terra Preta area for fertile soil creation

Using innovative, more sustainable purification techniques, building greywater and blackwater has proven a viable source for both potable drinking and non-potable service-related applications

Toilet sanitation are to be mixed based upon need
- Three systems proposed (centralized; water based independent, and dry system independent)

Goal 4: Manage Stormwater

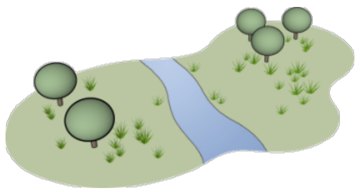
SURFACE STORMWATER STRATEGY:



Building

BUILDING:

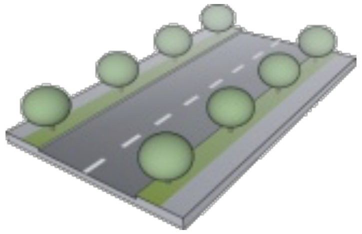
- Along terraces: collect upstream; store when possible or convey downstream
- Between developments: retain or detain in water features that function as pond or lake, with a recirculation system in place to keep water healthy
- Buildings: all rainwater on surface conveyed and used as potable water source



Open spaces and soft areas

OPEN SPACES AND SOFT AREAS:

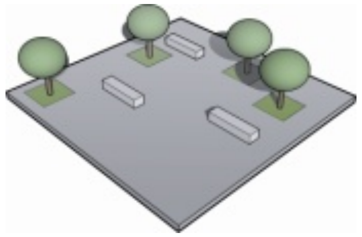
- Prior to area to be reforested: water conveyed along surface; not intended to be stored but rather to infiltrate into ground and assist in soil remediation of the reforestation strategy



Roads and streets

ROADS AND STREETS:

- Conduct, convey, and treat along planted bioswales (ditches) on sides of roads – refer to Transport
- Strategy presentation; overflow into landscape



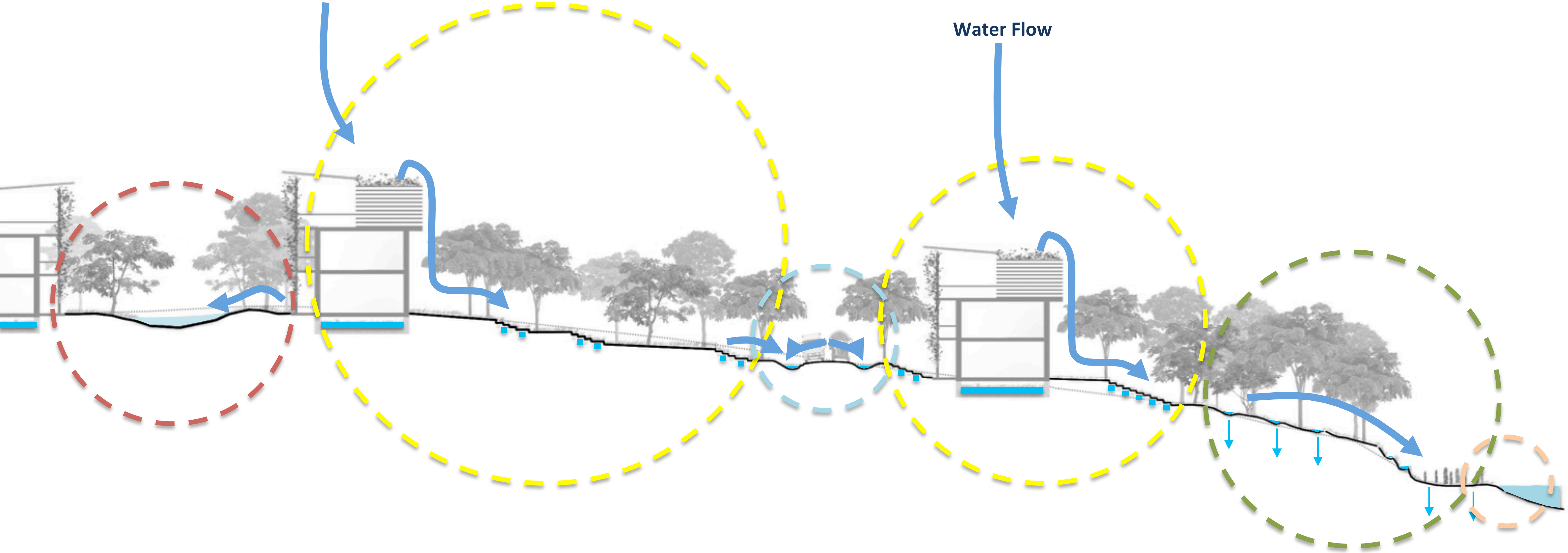
Plazas and terraces

PLAZAS AND TERRACES:

- Convey to closest water terrace for treatment or storage; overflow first to landscape; if necessary
- Reduced overflow to ocean after treatment; use permeable paving when possible; convey on the surface

Goal 4: Manage Stormwater

SURFACE STORMWATER STRATEGY

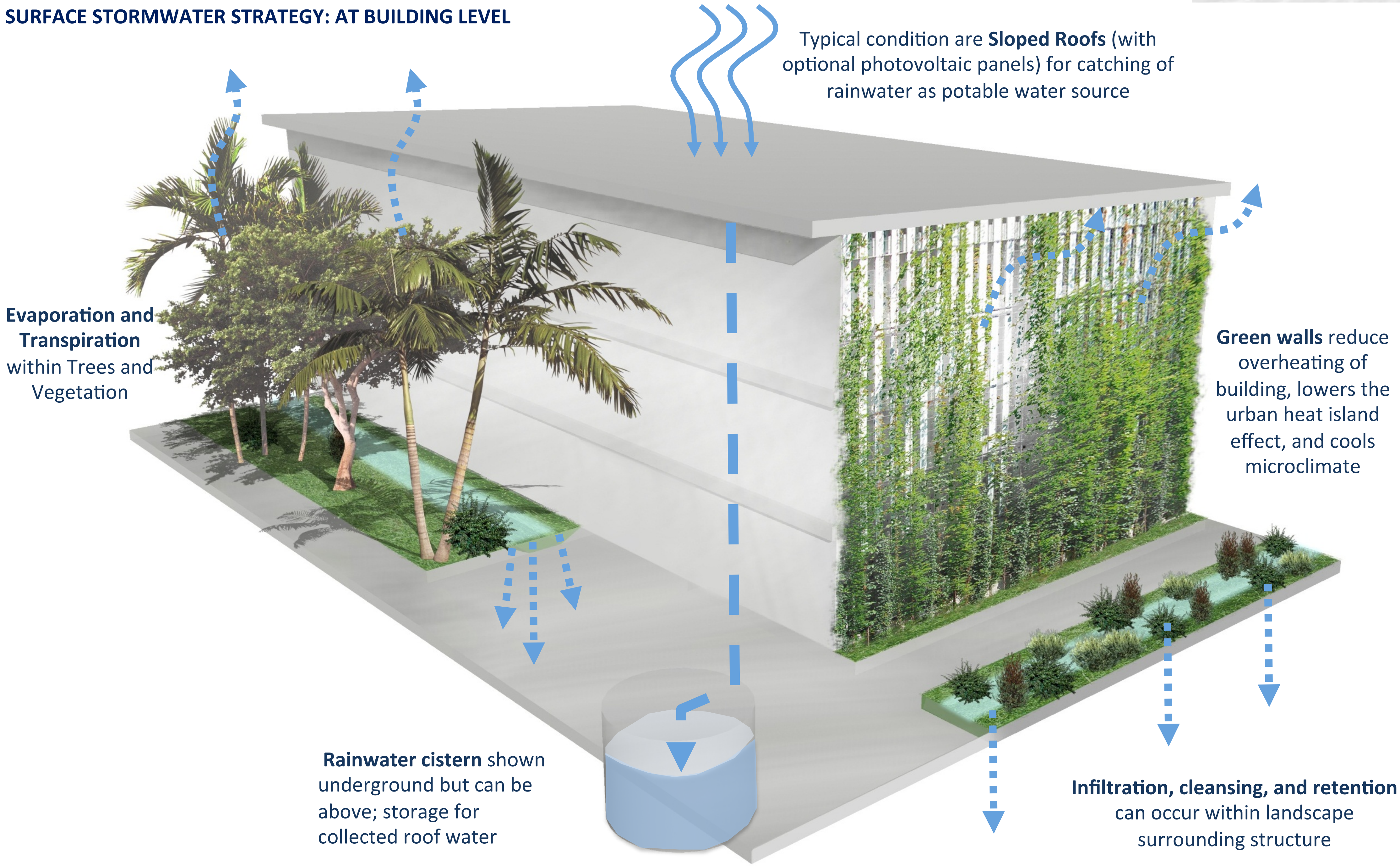


RETENTION:	COLLECTION:	CONVEYANCE:	COLLECTION:	INFILTRATION AL:	OVERFLOW:
caught rainwater distributed ponds; treated and cleansed within constantly circulating system	upstream at point-of-contact; store roof rainwater under housing; can store, treat, and clean water within terraces	direct off streets and roads into bioswales for treatment and redirection downstream	at building and terrace point-of-contact; store roof rainwater under housing; can store, treat, and clean water within terraces	within forest area, water into irrigation canals for beginning of reforestation and revegetation **Infiltration B:** Within gullies / valleys, water infiltrates into fertile productive soil	minimized and controlled emergency flow into ocean with primary overflow first into landscape

Schematic stormwater management applied over Lombok Tanjung Ringgit site (not shown to scale)

Goal 4: Manage Stormwater

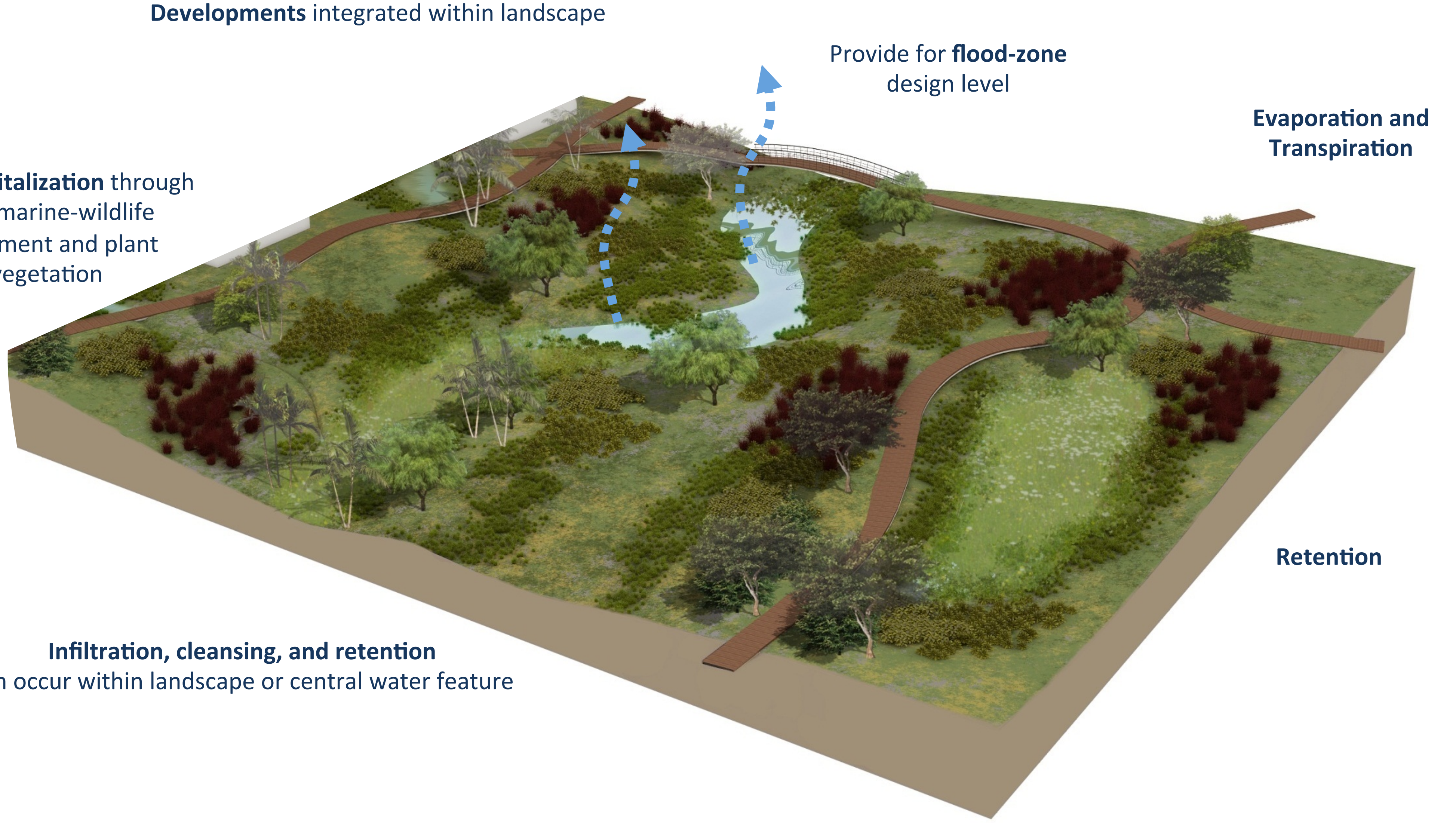
SURFACE STORMWATER STRATEGY: AT BUILDING LEVEL



Schematic stormwater management applied over Lombok Tanjung Ringgit site (not shown to scale)

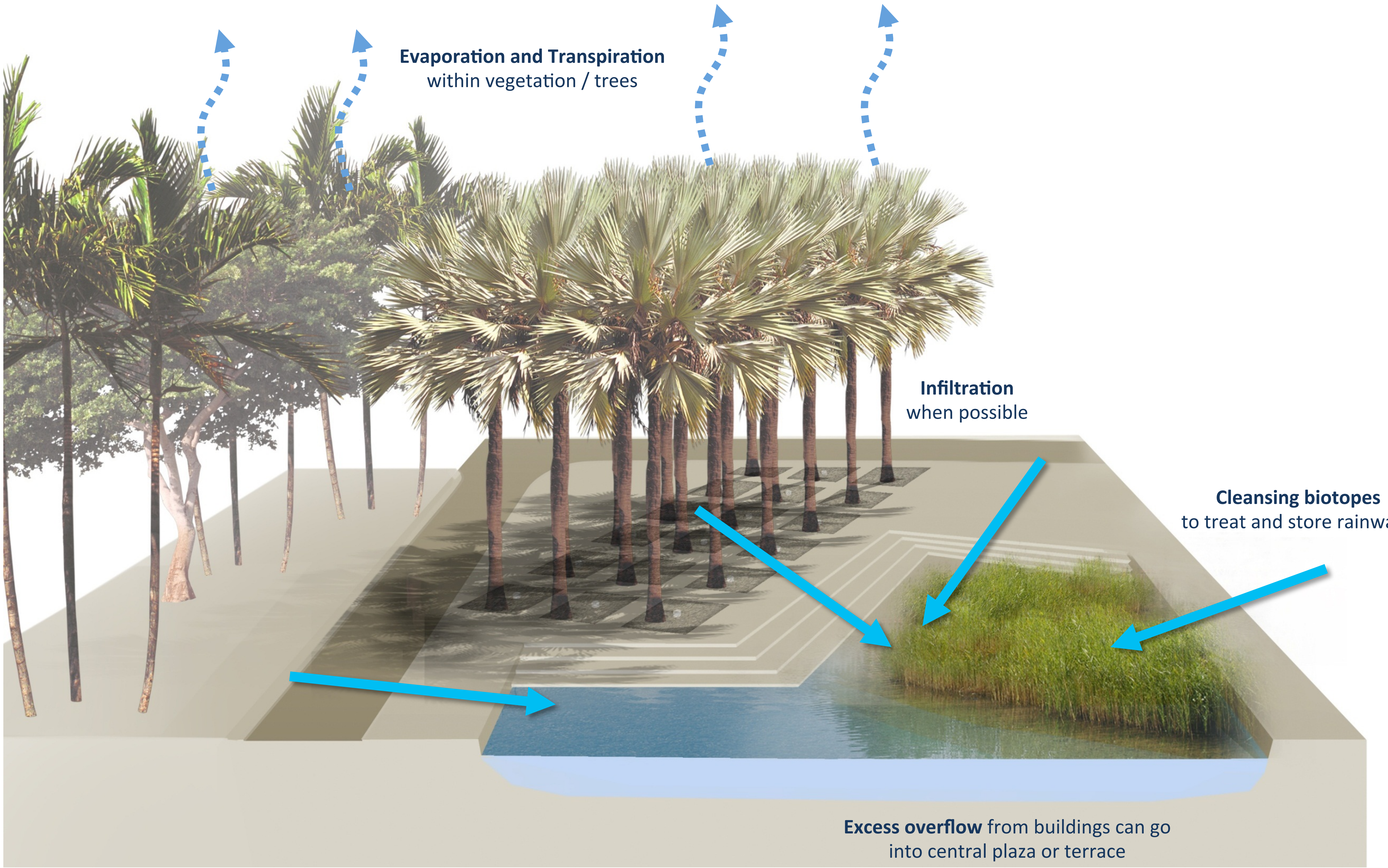
Goal 4: Manage Stormwater

SURFACE STORMWATER STRATEGY: OPEN SPACES AND PARKS



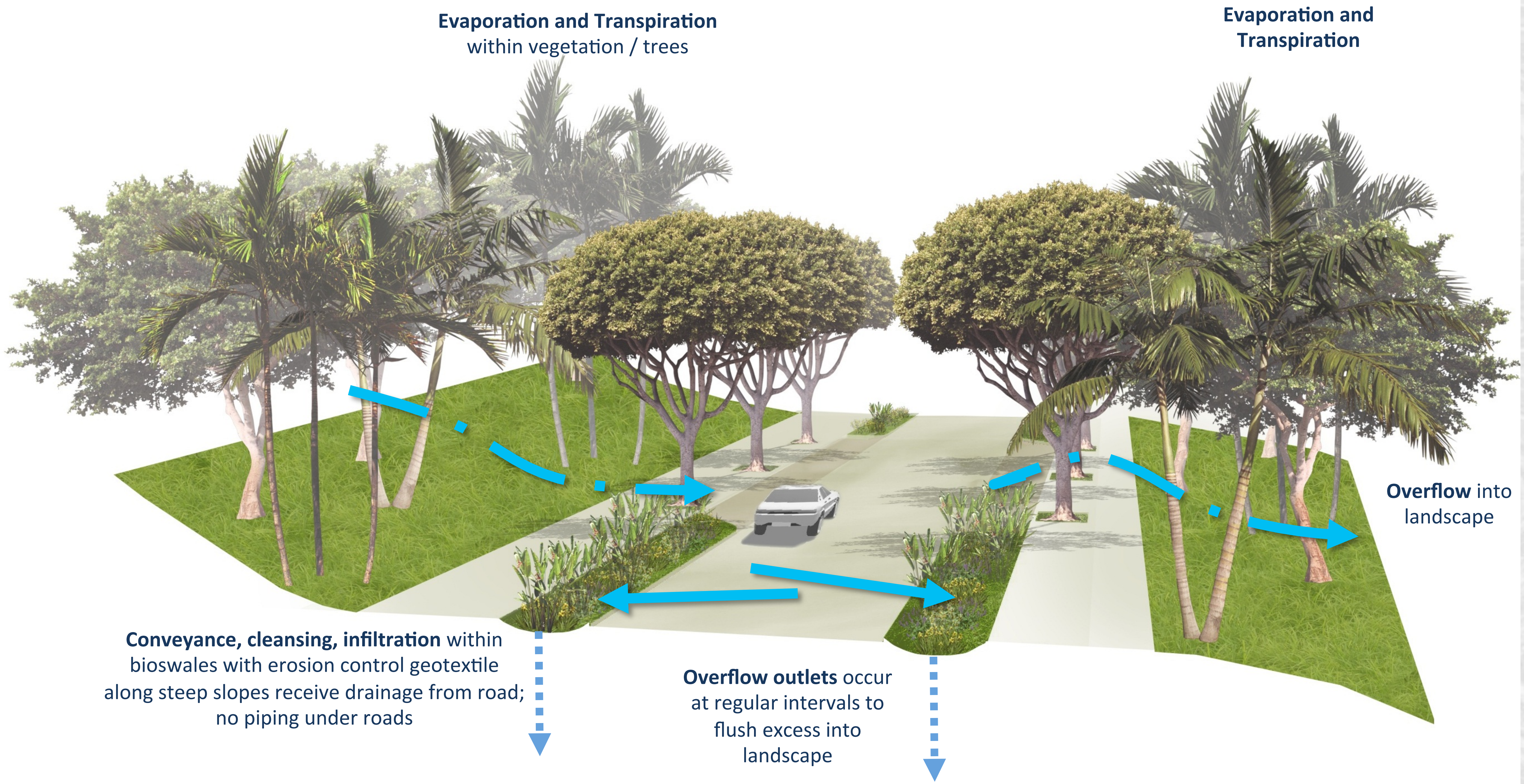
Goal 4: Manage Stormwater

SURFACE STORMWATER STRATEGY: PLAZAS AND TERRACES



Goal 4: Manage Stormwater

SURFACE STORMWATER STRATEGY: STREETS AND ROADS

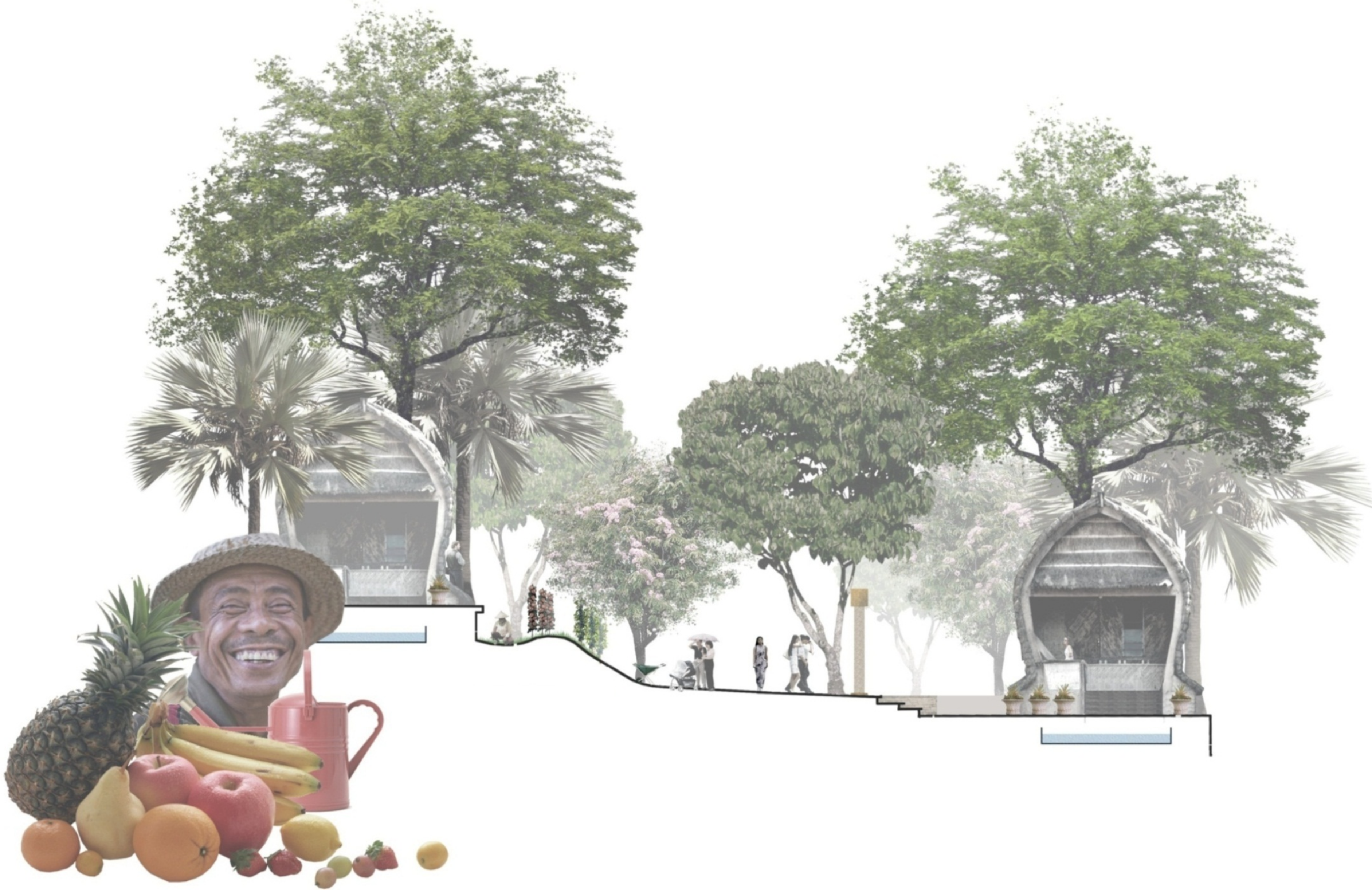


Goal 4: Manage Stormwater

CATCHING STORMWATER WITHIN DEVELOPMENTS:

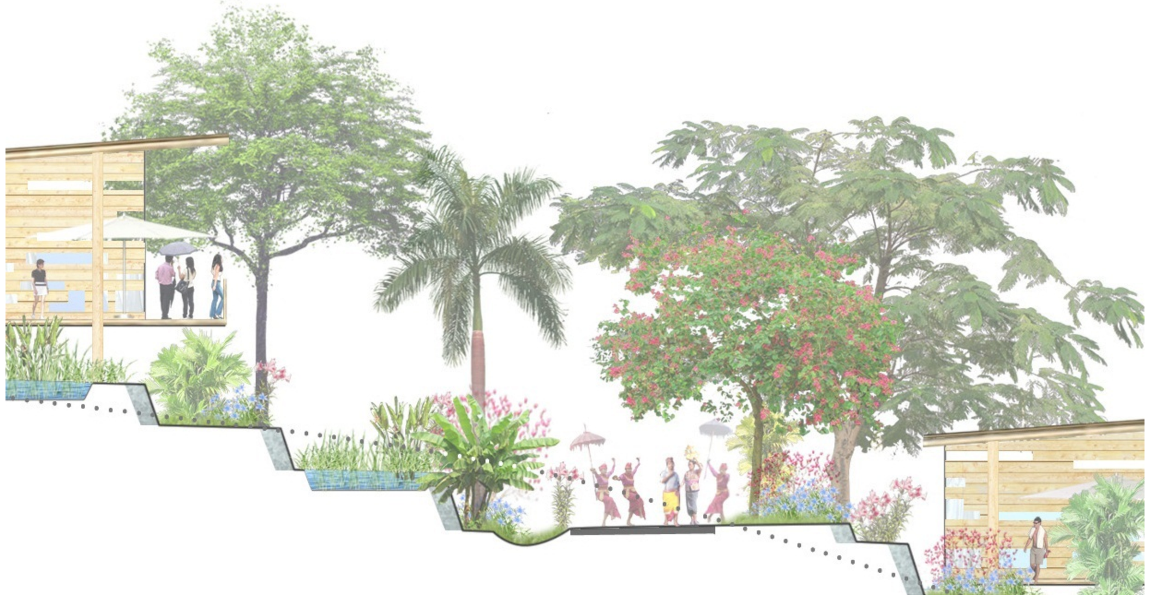
In the public space between the residential developments a combination of strategies influence the stormwater strategy

- For potable water collection, water from roofs flow into storage tanks
- For secondary water collection, rainwater harvesting can occur in terraces
- Steep slopes shall be erosion protected with geotextiles or bioengineering techniques, dependent on slope



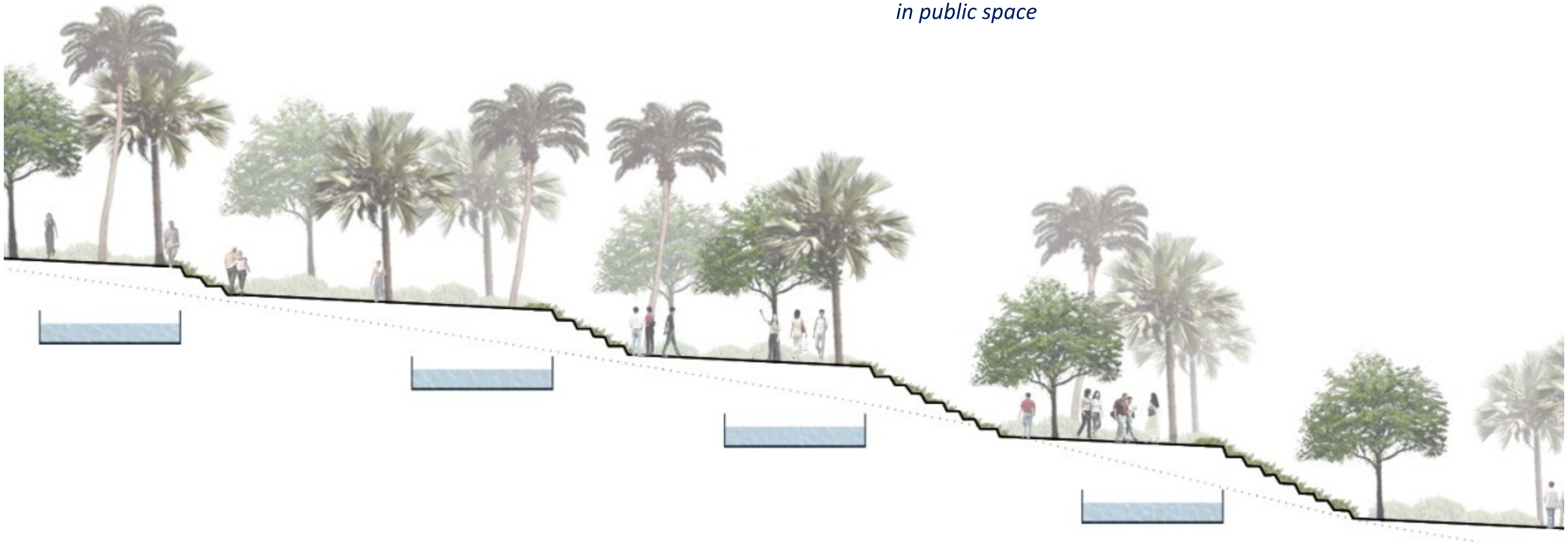
Goal 4: Manage Stormwater

VISUALIZING STORMWATER: SECTIONS



In cleansing biotopes along steep slopes

In retention ponds / natural swimming 'pools' between development plots in public space



Underground storage within terraces, along promenade

FLOODING AND EROSION CONTROL

TECHNIQUES:

- **In combination with controlling stormwater quantity and improving quality upstream at first point-of-contact, flood and erosion control requires a structured management plan prior to construction**
- **General rule is to first consider softscape maneuvers for erosion control**
  - Erosion control mats, geogrid or geotextiles, and careful grading prior to construction
- **Several techniques exist to stabilize slopes, dependent on the percentage of slope**
  - Up to 1:5: No additional slope stabilization necessary
  - From 20% (1:5) up to 33% (1:3): Geogrid or geotextile mat prior to seeding
  - Higher than 33% (1:3): each case to be determined individually
- **Slope stabilization also to occur along terraces as well (hardscape manuevers)**
  - Primarily terraces a reused as cleansing biotopes for greywater
  - However, when integrated in landscape they provide a method to deal with steep slope conditions
  - Wall construction should be limited but when necessary, integrate local materials and building methods specific to the region
- **Mangrove conditions –see Reforestation and Planting Strategy for further details**
  - Must protect mangroves that exist within bays in northern coves
  - Freshwater is vital for success of mangroves
  - Creating dams is to be prohibited as this does not manage stormwater but instead causes long term damage due to the unnatural patterns that result
  - Upstream control vital for success
- **In extreme slope conditions, consider bioengineering techniques**
  - Brush mattress
  - Live fascine
  - Gabion Brush layer
  - Geotextile wrapped soil lifts
  - Reedrolls
  - Rip rap cuttings

Geogrid material used for slope stabilization

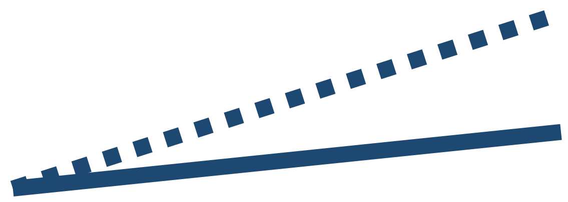
Revegetated geogrid over extreme slope condition

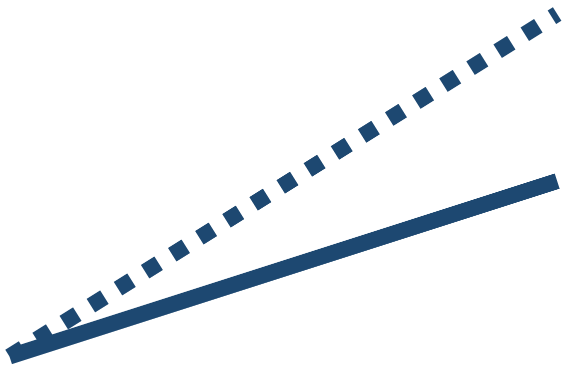
Erosion control mats over steep slopes

Goal 4: Manage Stormwater

FLOODING AND EROSION CONTROL

GUIDELINES FOR EROSION CONTROL ALONG SLOPES





TYPE A

- Up to 1:5 slopes: No additional slope stabilization necessary
- Vegetation shall provide the majority of slope stabilization needs
- Small structural walls can still be implemented here for terrace effect

TYPE B

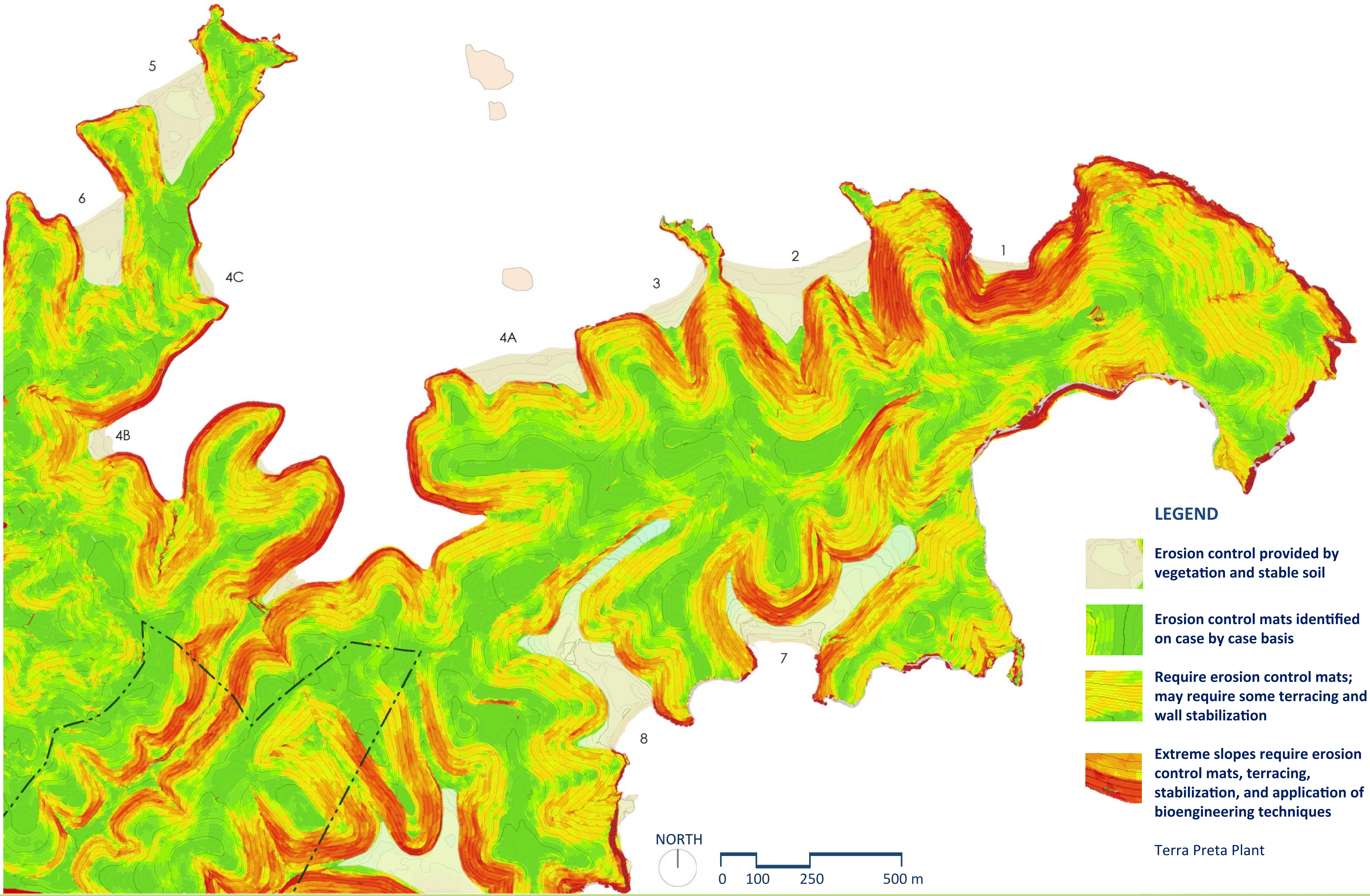
- From 20% (1:5) up to 33% (1:3) slopes: Geogrid or geotextile mat prior to seeding
- Could implement some bio-engineering techniques
- Structural retaining walls could provide majority of terracing support for conditions

TYPE C

- Higher than 33% (1:3): each case to be determined individually
- Bio-engineering techniques and larger terraced retaining walls beneficial for structural support
- Keep slopes under 50% (1:2) conditions
- Planted steel gabions can provide another retaining wall effect

FLOODING AND EROSION CONTROL

Erosion Control Assessment



Goal 4: Manage Stormwater

FLOODING AND EROSION CONTROL

Successful bioengineering techniques implemented along riverbank

Testing site prior to implementation (Feb 2009)

Improvement shown in short period (March-April 2009)

Continued greening (May 2009)

FLOODING AND EROSION CONTROL


TA 6. Brush mattress with Live fascine

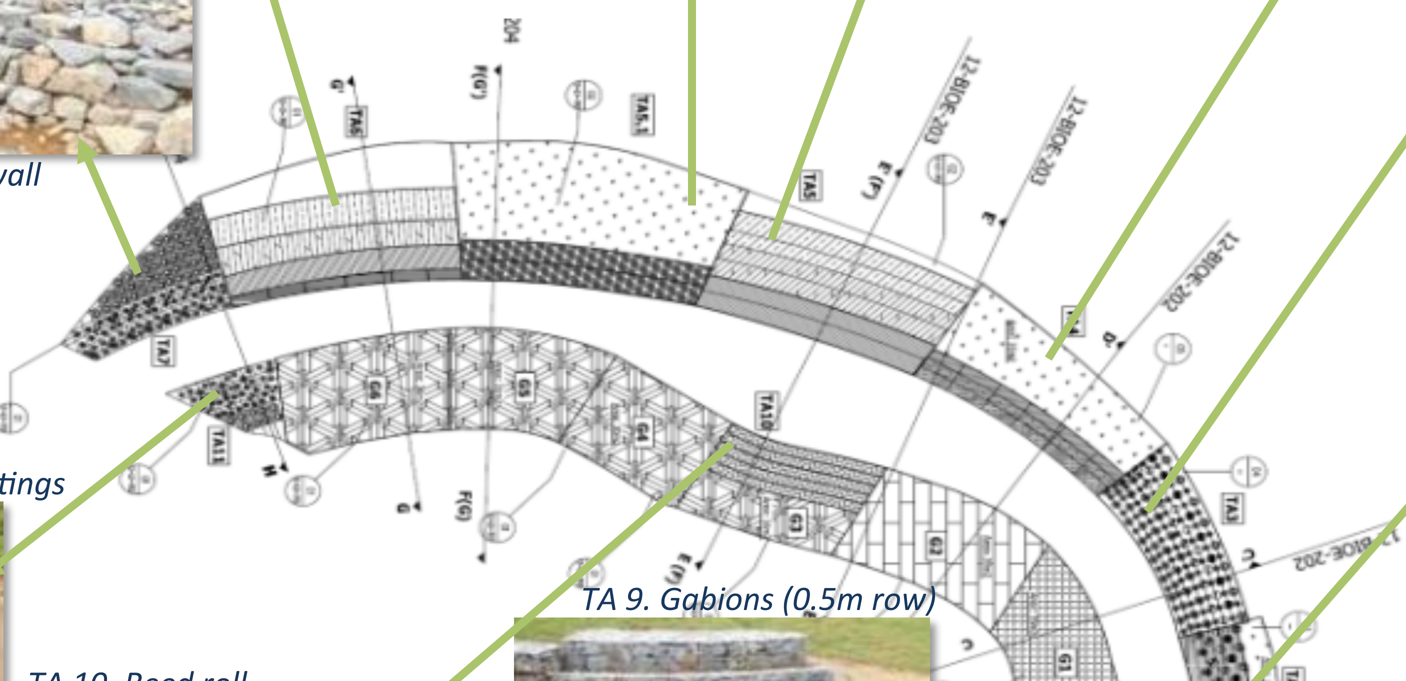

TA 5.1. Shrubs planting in geotextile


TA 5. Geotextile-wrapped soil lifts


TA 4. Multiple fascines with geotextile


TA 7. Rip rap with Stone wall


TA 3. Rip rap with cuttings




TA 2. Log cribwall with brush layers

TA 11. Stone wall with cuttings


TA 10. Reed roll


TA 9. Gabions (0.5m row)



TA 1 and 8. Gabions with brush layers

The bioengineering treatments implemented in Bishan Park, Singapore: *in Feb-March 2009*