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Water Buffer Management Retention, Recharge and Reuse of Al Sayla Water in Sana'a Basin

ادارة حجز المياه (تخزين، تغذية واعادة استخدام) لمياه السيلة في حوض صنعاء

Submitted by:

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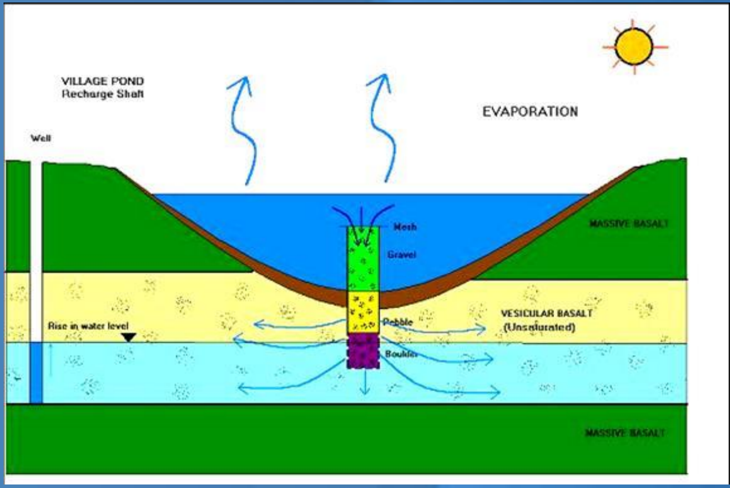

3R

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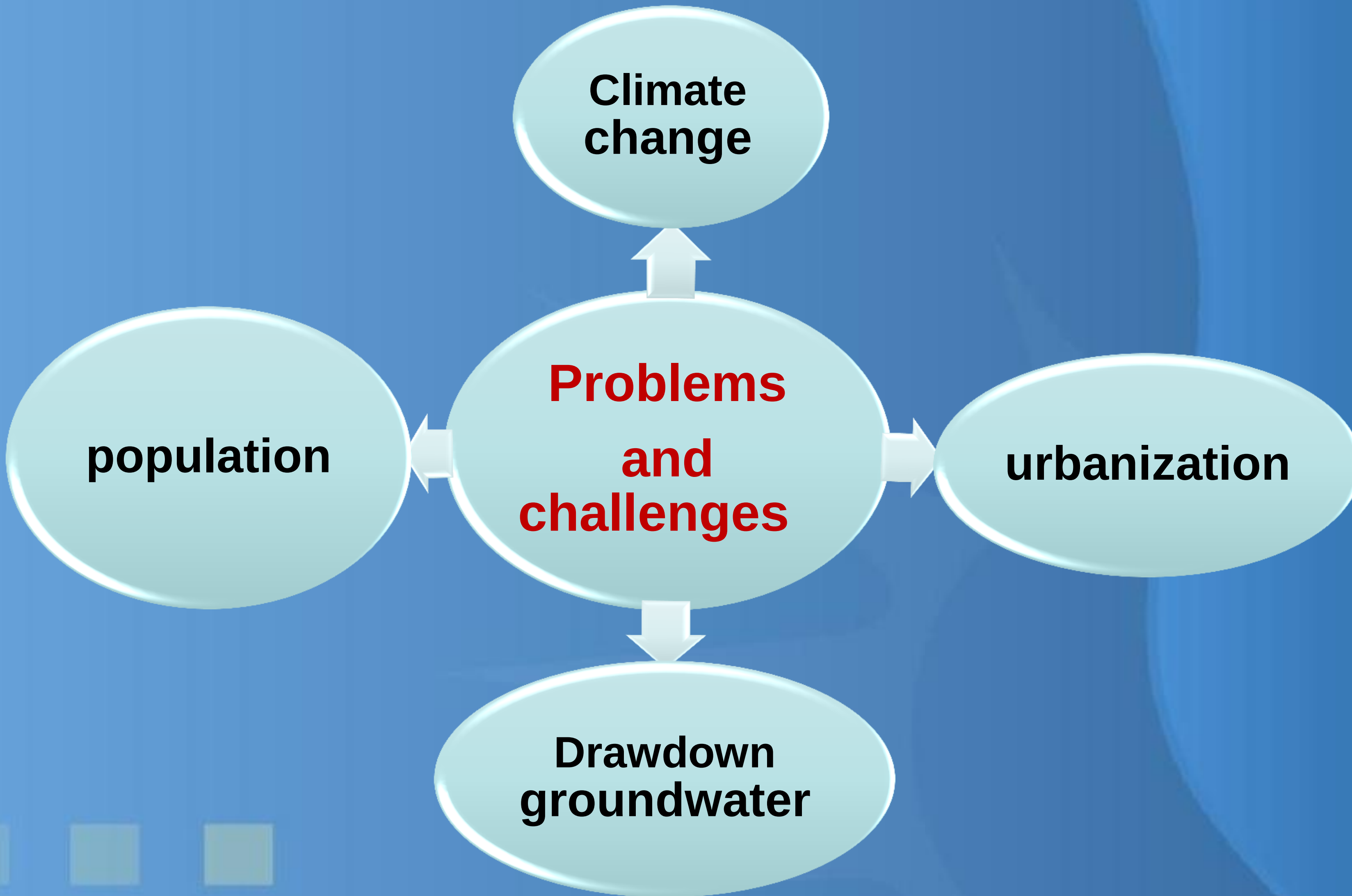


Research Objectives

Aim

To identified the rainwater Retention, Recharge and Reuse (3R) in integrated natural resources management in the Sana'a Basin (Wadi AlSaylah).

objective

- Support water resources managers (stakeholders) in implementing & identified appropriate 3R techniques to manage the scarce water of the Basin,
- Provide appropriate techniques through 3R along AlSylah which may be demonstrate a good example to stakeholders on water resources management.
- To test if 3R techniques will be a good alternative to the development of large surface water storage dams.

Study Area

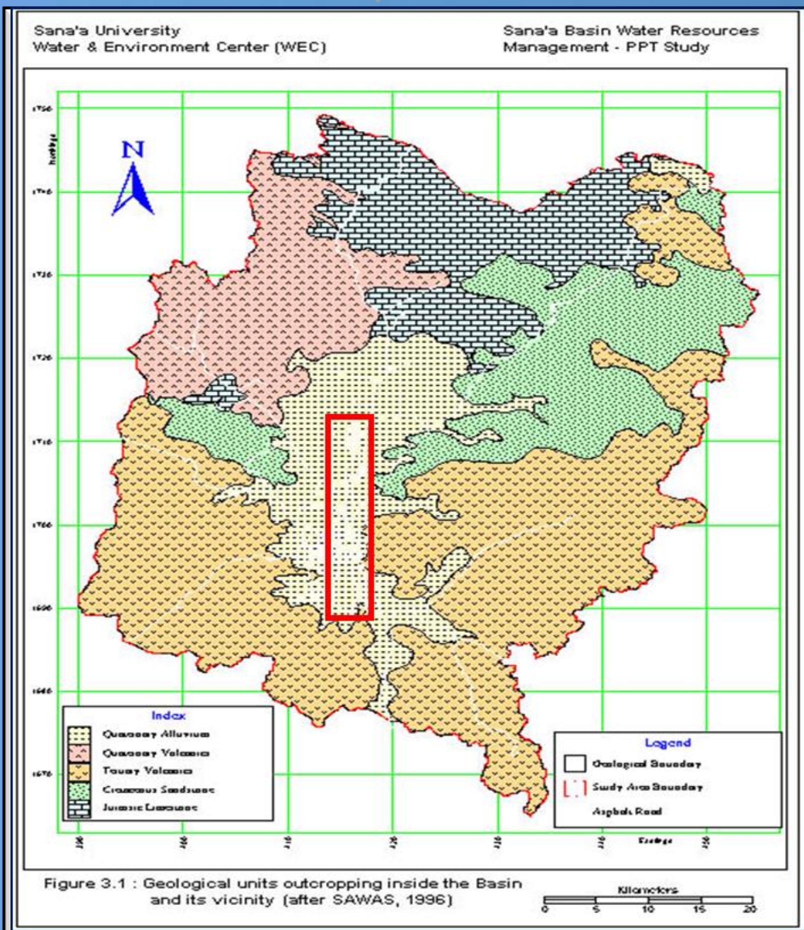
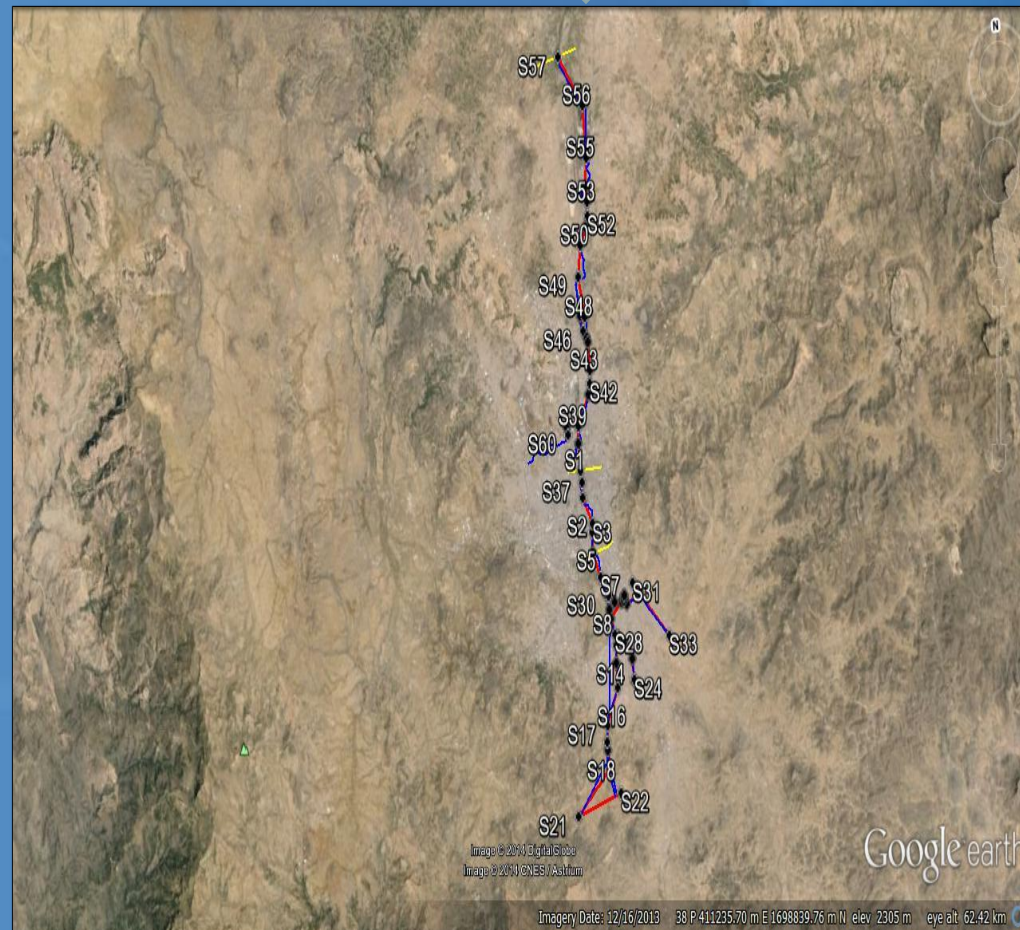
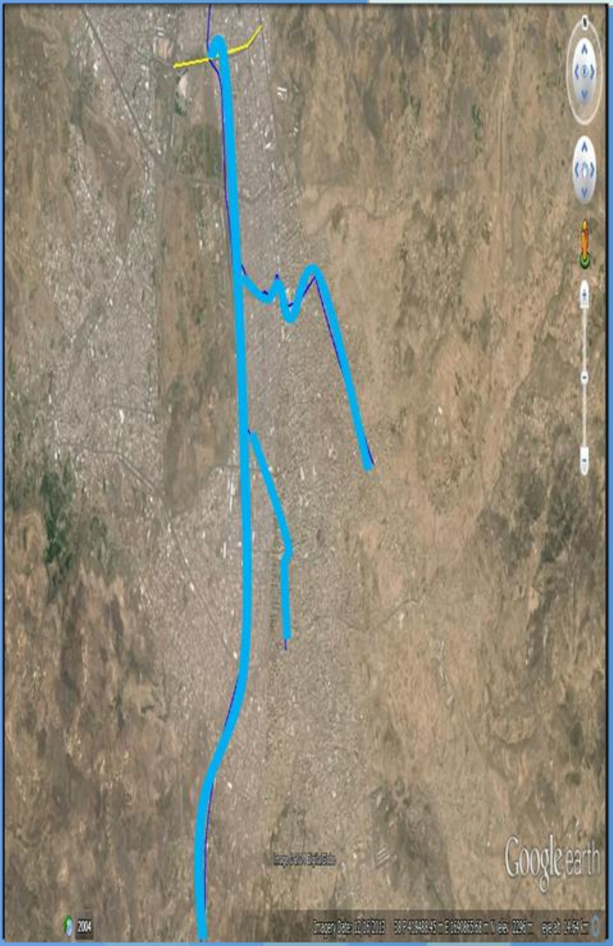


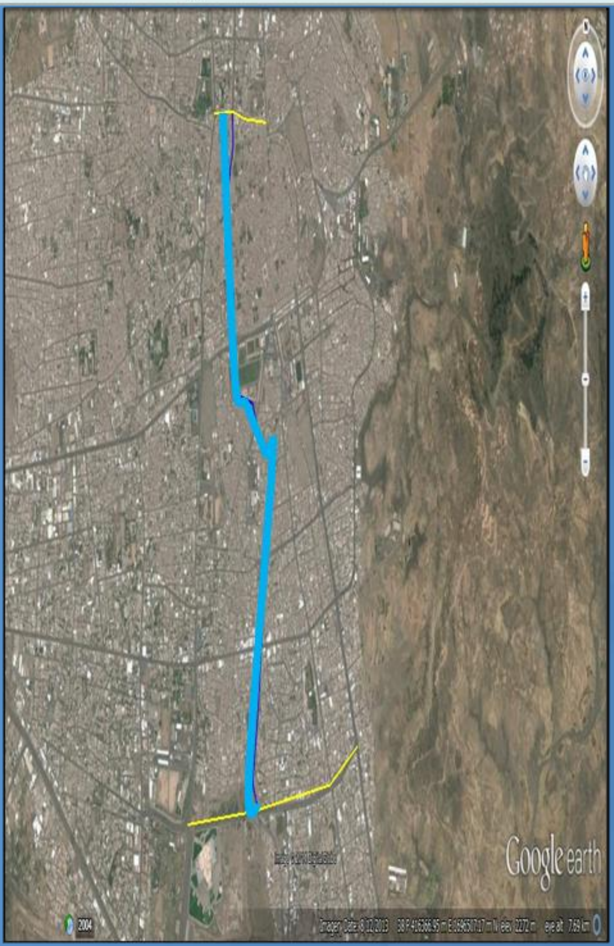
Figure 3.1 : Geological units outcropping inside the Basin and its vicinity (after SAWAS, 1996)



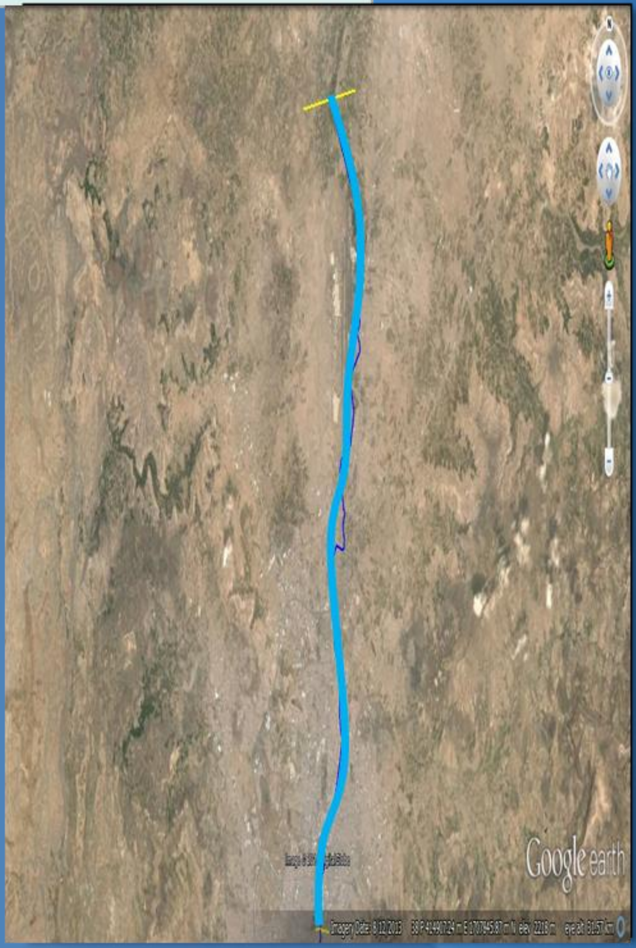
Study Area Division



Up-stream



Mid-stream



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Methodology

Review of all available data

Field surveys

Detailed analyses

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Suggested Structures

Up-stream
- Check Dams
- Diversion Dams
- Shaft Wells

Mid-Stream
- ponds
- Shaft Wells
- Trenches & pits

Down-stream
- Check Dams
- Diversion Dams
- Shaft Wells
- ponds

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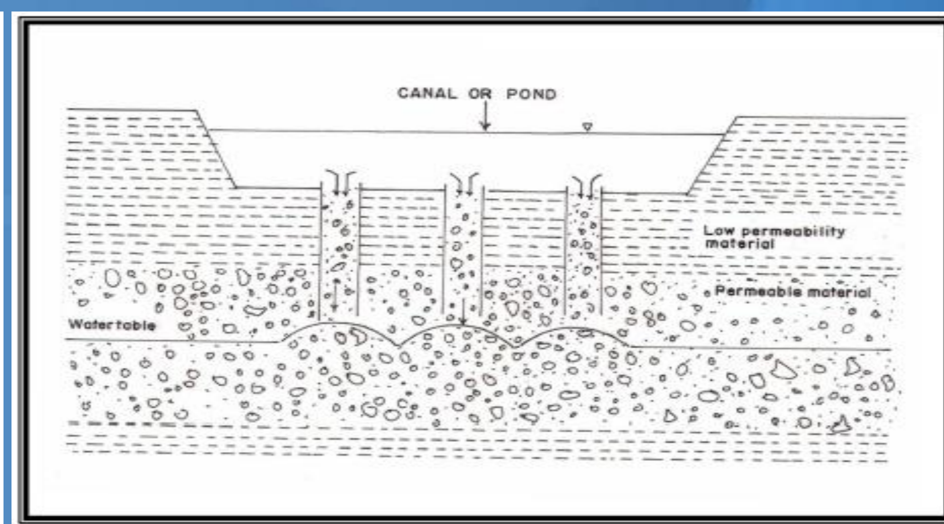
Suggested Structures



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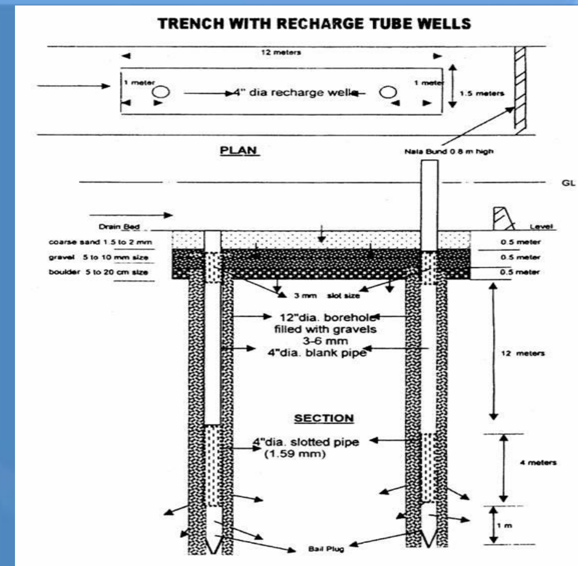
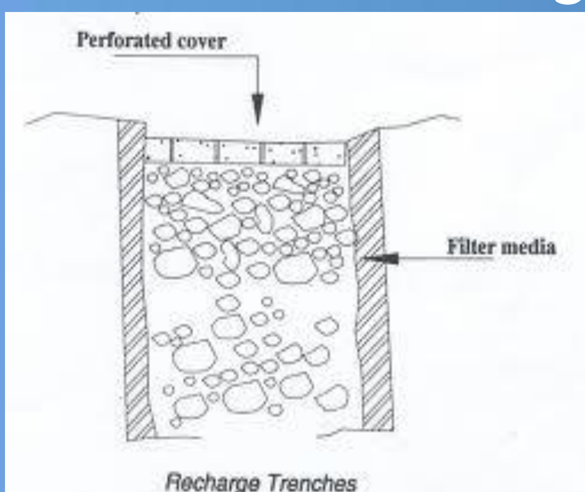
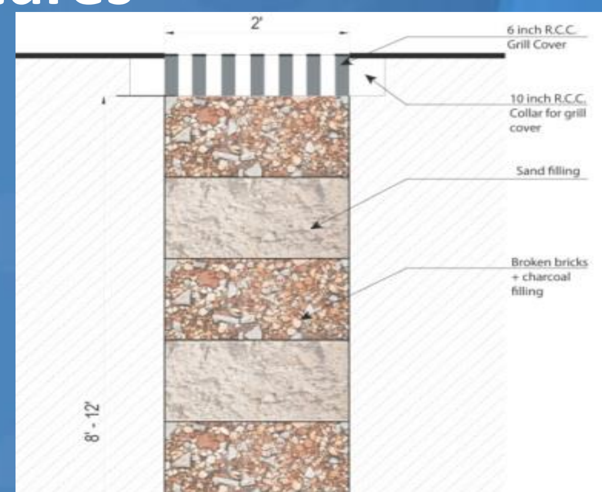


Suggested Structures





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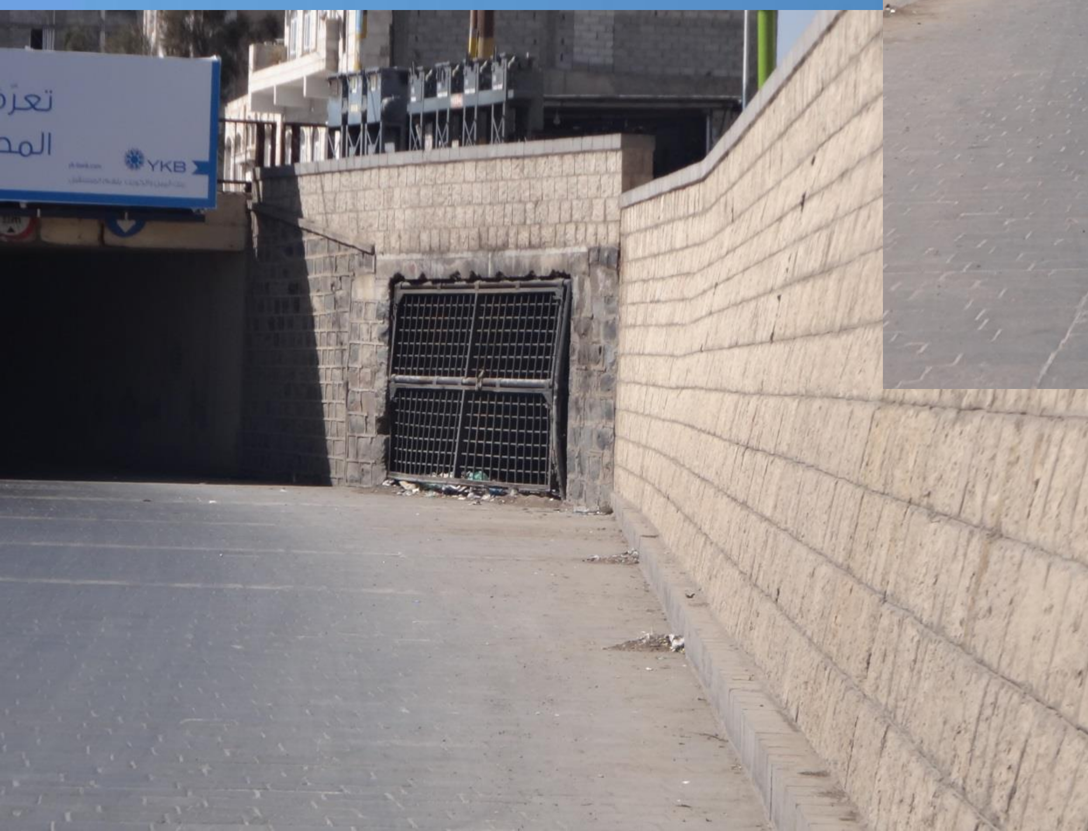
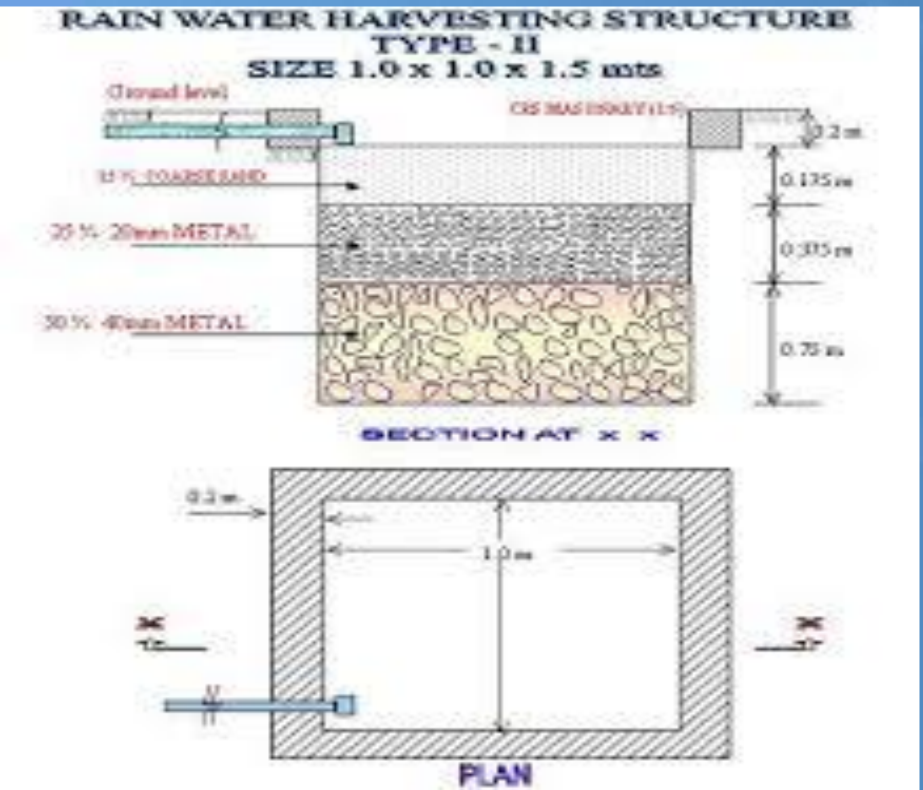
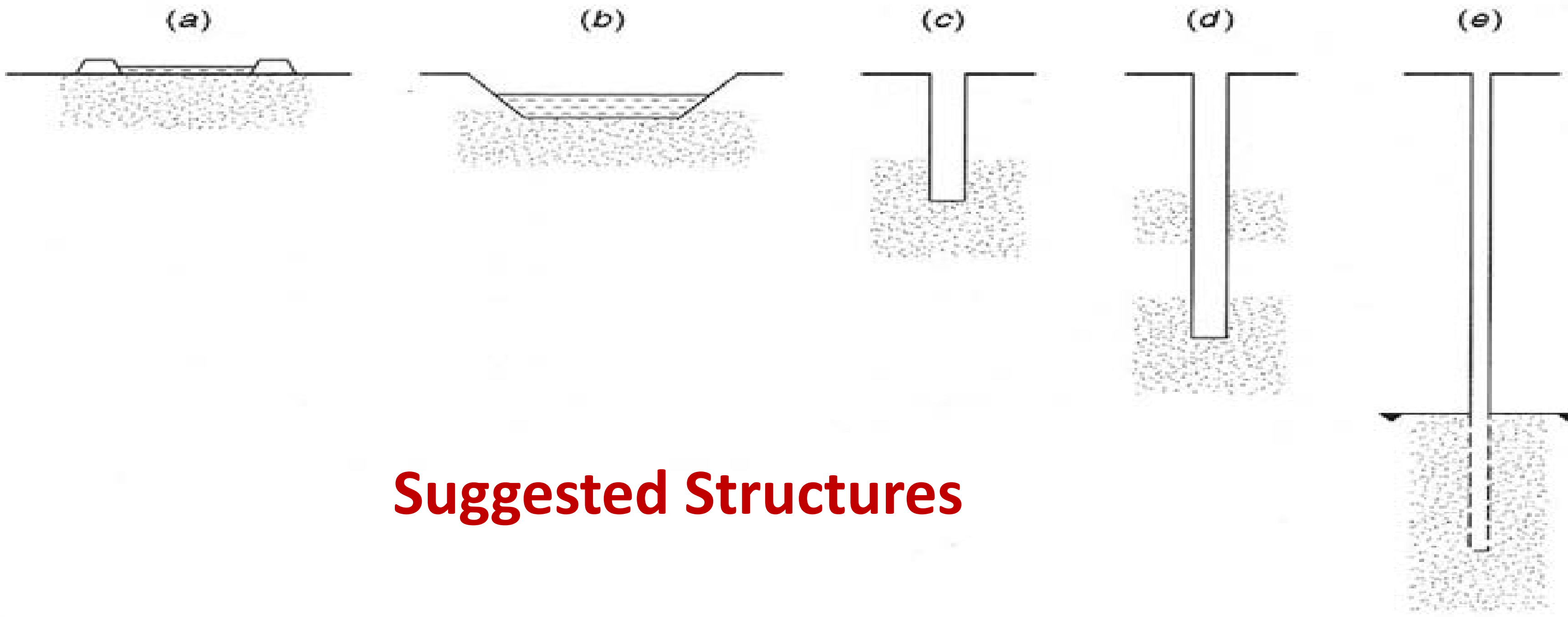


Suggested Structures
Pits





Suggested Structures

Recharge Systems for Increasingly Deep permeable materials: (a) Surface Basin, (b) Excavated Basin, (c)Trench, (d)Shaft or Vadose Zone Well (e)Aquifer Well

Upstream suggested structures				
At Entry of Wadi Hamil				
Type of Structures	Length	width/ radius	Depth	Description
Check Dams	15	8	3	Length of stream before the dam 1000 m, which can be reserved approximately 24000 m3 of water
Along channel of Wadi Artil				
Spreading Weir 1		6	1	irrigate 5 hectare.
Spreading Weir 2		15	1	irrigate 5 hectare.
Spreading Weir 3		10	1	irrigate 2 hectare.
Spreading Weir 4		15	1	irrigate 5 hectare.
Spreading Weir 5		30	1	Irrigate 10 hectare
Outlet of Wadi Artil (Algyle AlAswad)				
shaft Wells		1.5 – 2	3 – 5	- Rehabilitation the old shaft wells along the outlet of wadi Artil - Use these shaft for Recharge

Upstream suggested structures (cont.)				
Al-Hiwar Park				
Infiltration Pits		25 – 30	5 - 7	- Rehabilitation the pits to be used for shallow aquifer recharge and then pump the water for irrigation through hand dig wells
Dug Well (deep shaft well)		3	30	For water reuse in the irrigation of green areas of Al-Hiwar Park.
Dar Al-Reasah				
Infiltration Pit	180	80	15	
Dug wells(deep shaft wells)		1.5 – 2	25 - 30	For reuse in the irrigation the surrounding areas

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	Middle stream				
	Qubat Almahdi				
1	first diversion and conveyance system	69	1.03	4.318	Storm runoff (482,000 m3)
2	second diversion and conveyance system	7	0.85		Alsayla floods
3	reservoir to store water	25	25	20	the bottom of reservoir to be of gravel layer/sedimentation rate of .14m/year (222.5 m3/km2/yr)
4	channel to carry water to recharge pit and shafts	8	8"		
5	infiltration pit	10	10	10	filled with boulders
6	shaft 1		3	20	filled with boulders and gravel
	shaft 2		2	10	filled with boulders and gravel

	Middle stream (Con)

7	pipe channel to deliver water to dug well	84	8"		52 m to get water to the bottom of well to avoid air trap
8	existing dug well (as working dug well no need for further filtration)	2	2	70	no need for filtration, as it is working well
9	appropriate spill out structures and control of flow in pipes and manholes				

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Downstream suggested structures					
28	Faculty of Army (Al Rawdha)				
1	Pit	250	100	20	- The amount storage water in the pond about 5000m3. - it used for recharge the shallow aquifer
2	Shaft Wells		1.5 – 2	3 - 5	- For recharge
3	Dug wells(deep shaft wells)		1.5 – 2	25 -30	- For reuse in irrigation and other proposes
29	Near Airport Sana'a				
1	Pits	150	60	10	
2	Shaft Wells		1.5 – 2	3 - 5	- For recharge
3	Dug wells(deep shaft wells)		1.5 – 2	25 -30	- For reuse in irrigation and other proposes
30	Check Dams at downstream				
1	Alrodah MAI farm		1.5 - 2.5	25 - 30	For recharge & Reuse
2	Near by farms		1.5 – 3.0	25 - 30	For recharge & Reuse
3	Nearby the airport at the cross of sylah and bni alharth road		2.0 – 3.5	20 - 25	For recharge & Reuse

Analysis and Results

- **Reservoir - Deeper than normal infiltration basin to capture and store as much flood flow as possible (flashy floods) for subsequent use or infiltration and groundwater recharge**

- **Pilot testing (done through):**
  - ✓ **groundwater modeling is desirable for the simpler systems of basins, trenches, vadose-zone wells, and aquifer wells,**
  - ✓ **How these systems perform and how they should be designed and managed depends very much on local conditions of soil, hydrogeology, climate, and water quality.**

Analysis and Results :

1. Runoff estimation:

- SCS method used to estimate runoff of Al Syla and promising site for the period 2013-2022 using synthesized daily rainfall
- The generated daily flood/runoff figures were then used in daily simulation of water balance for each proposed structures along Wadi Al syla

2. Structure (Reservoir Operation) Simulation Model

- Determine the storage capacity i.e. dimensions of the structure;
- Work of reservoir between irrigation and recharge;
- Determine the yield that could be released from the reservoir to fulfill its purposes;
- estimate the average hydrological variables of the reservoir, e.g., precipitation, irrigation, evaporation, and infiltration.

Water Budget of Reservoir Subsurface Seepage (Qs):

$$Si = Si\text{-}1 + Qi + Pi - Qout - Ei - Ii - Ri$$

- Reservoir simulation results include day to day values of main items of the daily simulation
- It presents; the runoff, the inflows, groundwater recharge, evaporation losses; irrigation use; and the spilled away water.

Infiltration pit

Darcy's equation

- **Applying Darcy's equation to a soil after it has been flooded with water yields (Bouwer 1978, and references therein):**

$$Vi = K\frac{Hw+Lf-Hwe}{Lf}$$

Vi **is the infiltration rate,**
K **the hydraulic conductivity of wetted zone,**
Hw **the water depth above soil,**
Lf **the depth of wetting front,**
hwe **the capillary suction or negative pressure head at wetting front.**

Infiltration (Seepage) trenches

- **The recharge rate for seepage trenches is estimated to be about 20% of *Q* calculated with Equation for a vadose-zone well (shaft-dry well). i.e. 20% of the following**:

$$Q = \frac{2\pi K L_w^2}{Ln\left(\frac{2L_w}{r_w}\right) - 1}$$

1. Surface Infiltration

- Requires: permeable soil and sufficient land If not available, recharge to be achieved through vertical infiltration systems

2. Vadose-Zone Infiltration= shafts=dry wells, Trenches, ditches

3. Direct recharge Wells

Used where permeable soils and/or sufficient land area for surface infiltration are not available, vadose zones are not suitable for trenches or shafts, and aquifers are deep.

Using dry well is better than drilling new well, because the history shown that well is penetrating permeable layers and it is capable of accepting a gravity recharge well. (Best way to avoid clogging through dual recharge and pumping of well)

Groundwater modelling

The aquifer modelling study (MODFLOW) to understand groundwater resources availability and achieving realistic estimations of the impacts of water saving and aquifer recharge investments in the site.

The modeling process included the following:

- **Creating new model domain** (Gid Network, Grid Layers , Layer Type, Applied Model Units, Layer Thickness, Boundary Conditions)
- **Input Data** (Validation of the Input Data, Wells and Hydraulic Parameters (Flow Properties)
- **Steady State Calibration** (Time Steps, Input Pumped Water, Calibrated Conductivity values, Calculated Head Contour Map)
- **Transient Run** (Adaptive Time Stepping; Specific Yield (Sy); Recharge package;
- **Output of the Transient Calibration Run** (Groundwater Head)

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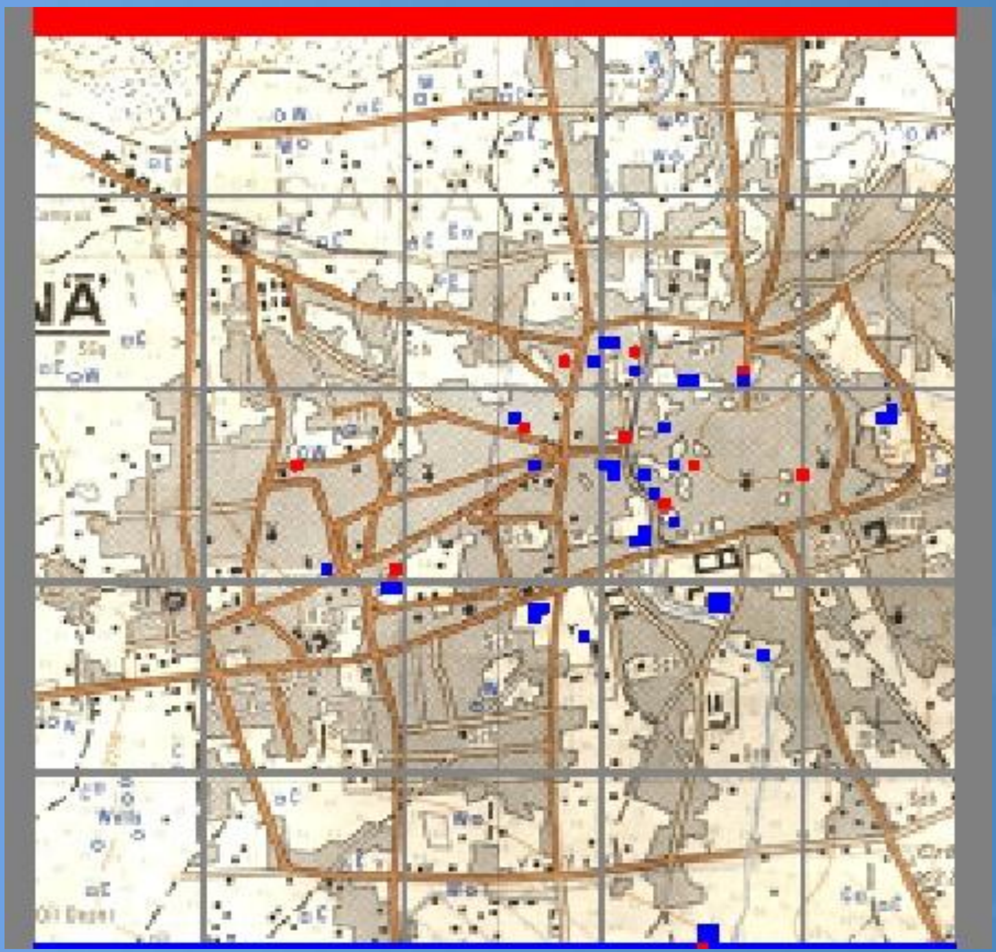
WL Raise due to recharge from proposed structures



الرقم	الاسم	المساحة خلية	الرقم	الاسم	المساحة خلية
1	المهدي	3	12	شكره	1
2	ابن حسين	1	13	فندق سام	1
3	الجوزاء	2	14	العرضي	4
4	الحرقان	2	15	الشرطة	1
5	عنقاد	3	16	الضباط	3
6	بروم	1	17	التحرير	1
7	القاسمي	1	18	شارب	2
8	قصر السلاح	3	19	العلفي	1
9	الشوشه	1	20	العصيمي	4
10	الباش	1	21	التوفيق	1
11	الجديد	1	22	السايلة	1

4. Buffer (3R) Management Techniques

- The quantity of available water, landscape and the local preferences play an important role in the selection of the techniques.

- For the present study, step wise approach is used, to assist in a selection of the most favorable 3R technique(s) and their implementation

  - ✓ Field visit to the project area (sites)
  - ✓ hydrological scan (availability of water source)
  - ✓ landscape, local preferences
  - ✓ list of possible 3R technique
  - ✓ numerical modeling (cost effectiveness- institutional aspects, environmental assessment and social benefit)
  - ✓ Select of 3R techniques
  - ✓ Design
  - ✓ Construction and operation

Application of 3R technique in Wadi Al Syla catchment:

- To illustrate the applicability of 3R technique in Wadi Alsylah catchment:
  - Qubat Al Mahdi site is select to be used, Where 9 civil structures are proposed for retention, recharge and reuse of flood water from Al Sayla and storm urban runoff from the city.
- The storm urban runoff is particularily important as it is more frequent than floods in Alsylah stream.
  - Records show that storm runoff occurs annually about 8 times, while the floods in Alsylah stream occurse 2-3 times a year.
  - For meqshama, i.e. agriculture purpose it would be more appropriate to use storm runoff than floods of Al syla.

Type and Dimensions of proposed 3R structures at promising sites

No	Site name/ proposed structures	Length M	width/radius m	Depth M	Remarks
	Middle stream				
	Qubat Almahdi				
1	First diversion and conveyance system	69	1.03	4.318	Storm runoff (482,000 m3)
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8	Existing dug well (as working dug well no need for further filtration)	2	2	70	no need for filtration, as it is working well
9	Appropriate spill out structures and control of flow in pipes and manholes				

Discussion

1. Cost Effectiveness

- ✓ proposed structure site was assessed in terms of US$/$m^3$ of water harvested from structures.
- ✓ The results were compared with the cost incurred on structure construction/rehabilitation to determine the recovery cost period.
- ✓ The value of captured/recharged water assessed as 250 YER ($ 1.1) for a cubic meter following the cost estimate of cubic meter of de-salineated water taken to Sana’a, TREC, (2006).
- ✓ The proposed structures include reservoir, check dams, pits, recharge basin, shafts, ..etc.

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Analysis & Selection of suitable structures for Qubat Al Mahdi site

No.	Proposed structures	Recharge from infiltration pit	Recharge from 2 shafts	Recharge from existing well	Recharge from irrigation field	total recharge	
		M^3	M^3	M^3	M^3	M^3	Remark
	From Storm runoff = 482,484 m3 while from Al Syla 2,451,497 m3						
1	2 diversion and conveyance systems: for irrigation field return				204927		OK

Analysis & Selection of suitable structures for Qubat Al Mahdi site

No.	Proposed structures	Recharge from infiltration pit M^3	Recharge from 2 shafts M^3	Recharge from existing well M^3	Recharge from irrigation field M^3	total Recharge M^3	Remark
2. Reservoir with Capacity of 9000 m^3 Cost= 41860 USD							
a	Using pit, 2 shafts and existing well	89230	139549	118973		347751	OK
B	Using pit and well	137716	0	183622		321338	X
C	Using pit alone	271133	0	0		271133	X
D	using pit and 2 shafts	129216	199000	0		328216	X
3. Reservoir Capacity of 12000 m^3 Cost= 55813 USD							
		111574	180145	148765		440485	X
		11157	18015	14877		44048	X
	TOTOAL RECHARGE AT SITE					552,678	

2. Institutional aspect

- ✓ it has been make clear to stakeholders that preventive maintenance of 3R structures is required and that implies a periodic action taken to forestall major repair or replacement of its components.

- ✓ It may be drying up and scarifying of recharge ponds, periodic pumping of recharge wells, or regular application of lubricants/ protective substances to the mechanical parts or replacement of minor parts that are subject to deterioration or repeated failure.

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3. Environmental Assessment and Social Benefit

- ✓ **The most significant factor in environmental and social terms is that the Sana'a Basin is suffering from rapid and severe depletion of groundwater as water from both aquifers is used for domestic, industrial and agricultural use.**

- ✓ **Rates of extraction far exceed both natural and artificial recharge (i.e through irrigation and wastewater return flow), its use is inefficient and water extraction is still not fully regulated (formally and informally) throughout the Basin.**

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Conclusion and Recommendations

3R techniques can be considered as main answers to droughts; water shortage, and water scarcity. Even without considering future climate conditions, an urgent need for more water security exists.

Water buffer management has a number of direct benefits, such as more production by securing soil moisture and water availability and easier access to drinking water

There is a good chance of profit and security that can emanate from proper application of Retention, Recharge, and Reuse measures in the Sana'a Basin.

3R can help further the development agenda by preventing undue suffering from wide climate swings or from water scarcity and degradation in general.

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Conclusion and Recommendations

The best way to utilize flood waters for artificial recharge is to capture and store these waters in deep basins or reservoirs that provide pre-sedimentation but are not expected to give high infiltration rates. Clear water is then taken out of these reservoirs and placed into infiltration basins that can be readily dried and cleaned to maintain high infiltration rates, and, hence, should be shallow.

The storm urban runoff is particularily important as it is more frequent than floods.

Records show that storm runoff occurs annually about 8 times, while for floods 2-3 times a year. So for meqshama, i.e. agriculture purpose it would be more appropriate to use storm runoff than floods of Al syla.

Conclusion and Recommendations

The assessment of costs and benefits for new 3R infrastructures can be based on simple field and modeling techniques for reservoir simulations.

To maximize benefits, the water buffer must be improved in large areas: basins, sub-basins, districts, and municipalities.

Implementing 3R at the basin level will make a real and self-sustaining change.

To create more secure buffers it is important to not only promote and explore 3R interventions but also to further develop the mechanism whereby are supported and sustained financially.

Indirect Benefits

- The control over of further depletion of ground water levels
- Sustained abstraction of ground water ensures long term irrigation, minimization of frequency of re-drilling of tube wells over time.
- Restoration of well irrigation in areas where wells have gone dry which increases in employment potential by using local labor either skilled or semi-skilled;
- Increase in per-capita income of the local people resulting in better living standards;
- People's participation in the development work enhances the benefits; environmental improvements helping in reduction of pollution hazards.

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Thank You for Your Attentions