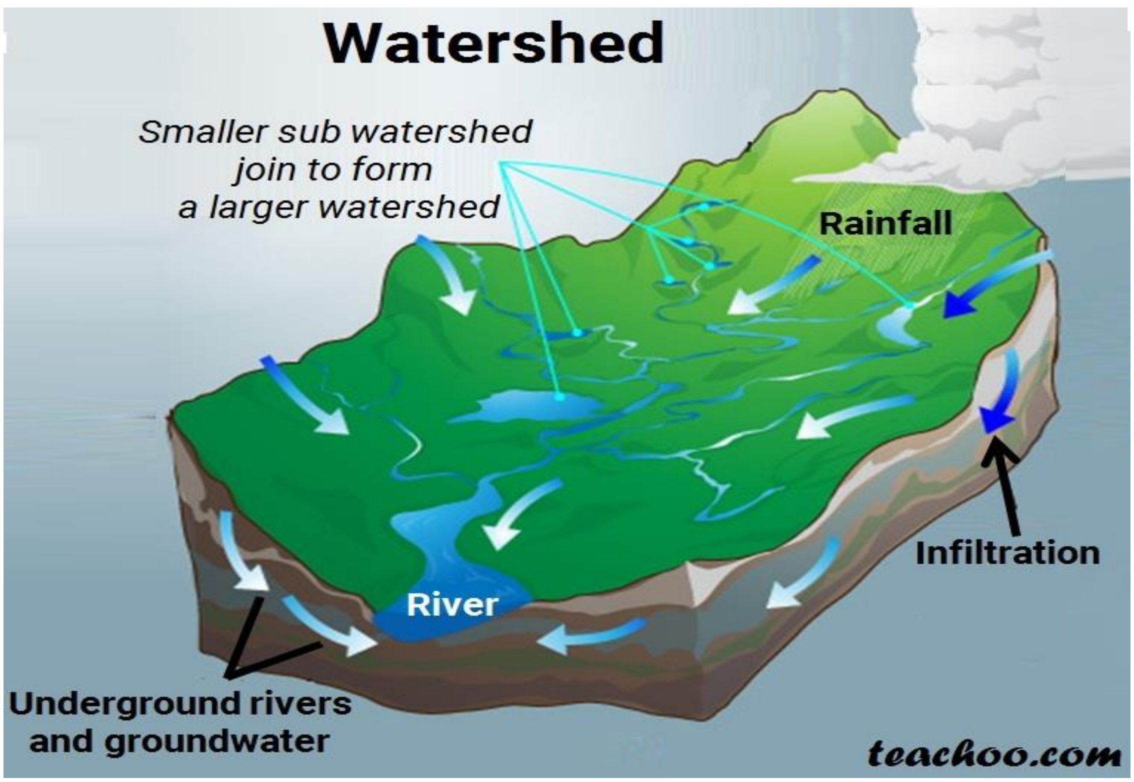
Project Proposal

For

Augmentation/Increased Production Capacity of Amoud/Dhamoug Aquifer through Construction of Forced Recharge & Watershed Management Schemes



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I. Acknowledgement:

The depletion of the ground water aquifer of Amoud/dhamoug is an existing reality and was first explored by SHABA top management and HE Mousa Bihi Abdi the president of Somaliland Republic who has declared to his council of ministries that Borama town expansion and available water Resources have gap and if immediate interventions are not taken place in time Borama town will face water shortage.

The words from the new Minister for the MOWRD during his first speech showed his awareness to the depletion to the water sources of the eastern aquifer showed his commitment to consider Borama aquifer recharge improvement as first priority for his new administration.

The contribution active role the regional coordinator for the MOWRD for Awdal region Eng. Awliyo is unforgettable.

Finally, it’s worthwhile to mention the encouragement from the Chairman of SHABA who was always giving encouragement and support to the technical team.

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III List of abbreviation and acronyms

ADB	African Development Bank
AWF	African Water Facilities
AWP	Annual Work Plan
BOD	Board Of Directors
BWD	Borama Water Board
BGL	Below Ground Level
CUM	Cubic Metre
DWl	Dynamic Water Level
GA	General Assembly
HH	House Hold
Lcd	Litre Per Capita Per Day
Lpd	Litre Per Person Per Day
M cum	*Million Metre Cubic*
MoNP&D	Ministry Of National Planning & Development
MoWRD	Ministry Of Water Resources Development
PPP	Public Private Partnership
SHABA	Shirkadaa Adeegyada Bulshada Awdal
SWL	Static Water Level
PESS	Population Estimation Survey
TS	Terra Solidli
UNICEF	United Nations International Children's Emergency Fund
RCC	Reinforced Concrete Cement
VES	Vertical Electrical Sounding
Berked	Under Ground Water Harvesting Storage
CLTS	Community Led Total Sanitation

CBM	Community Based Management
CHAST	Children Hygiene and Sanitation Training
DNH	Do No Harm
EIA	Environmental Impact Assessment
ES	Environmental And Social
ESMP	Environmental And Social Management Plan
ESS	Environmental And Social Management Screening
GIFT	Governance, Institutional Functionality Tool Kit.
MOHD	Ministry Of Heath
MOWRD	Ministry Of Water Resource Development
MoERD	Ministry Of Environment and Rural Development
O&M	Operations and Management (Maintenance)
NERAD	National Environmental Research and Disaster Preparedness Authority

PPPFRA	Public Private Partnership for Rural Areas
PHAST	Participatory Hygiene and Sanitation Transformation
SWALIM	Somali Water and Land Information Management
WIDRP	Water Infrastructure Development for Resilience In Somaliland Program
PIU	Project Implementing Unit

IV Proposal summary:

Project title	**Augmentation/increased production capacity of Amoud/Dhamoug aquifer through construction of forced recharge & watershed management schemes**
Project Location	**Amoud/Dhamoug water catchment**
Proposing organization	**SHABA**
Funding organizations	**UNICEF/MoWRD**
Project objectives	**To improve the living conditions of the Borama population through the provision of sufficient water supplies by increasing the production capacity of the Amoud and Dhammug aquifers.**
Project actors	**UNICEF, SHABA and MOWRD**
Project outputs or activities	• **Two dried up boreholes revitalized through forced recharge /artificial** • **Three earth dams constructed to recharge dried boreholes** • **6 surface/subsurface dams Constructed** • **Gullies repaired using gabion baskets** • **Soil bund and water conservation schemes Constructed**
Number and description of target beneficiaries	**300,000 (50,000 HH) people predominantly Women, children and elderly people living in Borama including IDP and urban poor.**
Project funds	**Total project budget 100% 799,160 USD** **MOWRD Contribution 37.54% 300,000 USD** **UNICEF Contribution 62.56% 499,160 USD**
Project duration	**6 Months**

1.1 Introduction

Over the past three years, SHABA was struggling to cover the huge gap between the supply and the demand of Borama town, eight production boreholes drilled by the Chinese in the eastern aquifer dried up with in very short period due to their shallow depth (less than 80m bgl). Several hydrological studies carried out by Terra Solidali (an international organization) revealed the depletion of the aquifer. TS & SHAAC geophysical company carrying out further comprehensive hydrological study of the area and had discovered another aquifer in Amoud which is adjacent the previous aquifer, they recommended the possibilities of drilling deeper boreholes, the PPP company with the assistance of the Somaliland government and WASH partners succeeded to drill another 8 deeper BH with maximum production of 5,200 CUM/day.

Borama town is expanding very fast during the last three decades, urbanization of the town started recently as huge business centers, tourism hotels, light industries and recreation centers started. this resulted enormous increase to the town population as well as the demand for enough water supply. The town used to get water from Dhamoug aquifer for the past century which was discovered by the British colony when the town population was very small, the aquifer is confined, there were 8 boreholes drilled by Chinese which used to supply the town but due to the fast-growing town population the water table of the aquifer due to over pumping and climate related issues which finally resulted dry up of eight production boreholes.

Ministry of Water Resources development and SHABA organized comprehensive hydrological study to discover alternative ground water resource which could be used for the growing demand for water at present time and the future. The study revealed that the present aquifer of Amoud/dhamoug started drastic drop down of the water table (8m/year) and alarmed to search for alternative aquifer, as a result of that nearly 12 boreholes dried up and cannot function as production wells for the town water supply. During the past half-decade nearly 8 production boreholes were drilled and despite their depth which are deeper than the dried-up boreholes still the phenomena of the water table drop down is active and exists.

The Ministry of water resources development and SHABA are now engaged in watershed management initiatives to manage well the received annual rainfall of the Amoud/dhamoug aquifer areas so that runoff water is taped to recharge the aquifer and reverse the down ward movement of the static and dynamic water levels of the bore wells

1.2 Background.

Borama town locates in mountainous area and the amount of the annual rainfall is quite enough compared to the rest of the country. Unfortunately like the other places of the country the valuable water from the rains ends into the sea taking away all the fertile soil and not allowing to infiltrate into the ground water. The over pumping and the slow recharge to the aquifer created imbalance of the resource and as a result of that nearly 12 production wells dried up and are not functional. The ministry of water resources development and SHABA drilled new deeper boreholes in Amoud aquifer which are now in use for the town water supply. However, the drop down of the aquifer is very active with a rate of 8M/year, this shows that the depletion of the aquifer is still active.

The town water supply used to depend on spring during the British Colony up to the independence but the water table dropped down and the major water sources for the town water supply were hand dug wells. During 1987 Chinese company drilled 8 boreholes and it was connected to the town water supply. All the Chinese drilled boreholes dried up due to the drop down of the water table and other 12 new boreholes were drilled in Dhamoug and Amoud aquifers.

The average annual rainfall of the area is more than 540mm/year which is quite enough compared to the other towns of the country, most of these amount ends into the sea without being exploited for different use or even recharging the ground water. The population of Borama town is growing very fast and the demand for water is increasing as well. SHABA has tried to cover that gap between the supply and coverage but the demand is always higher. Ground water resources are finite and limited, if the active phenomena of over pumping and lack of adequate ground water recharge from the rains are not put into consideration the new drilled boreholes will have the same phenomena and will get depleted.

The table below shows the number of boreholes that supply the town including the dried up.

1.3 Drilled boreholes in Amoud/Dhamoug Aquifer

SN	BH No.	Coordinate	Coordinate	Altitude	Depth	Water table	Remarks
1	BH 1	9.951205	43.2164024	1393	73.8m	33m	**Dried up**
2	BH 2	9.950991	43.2173041	1396	73.6m	33m	**Dried up**
3	BH 3	9.9503733	43.2160026	1400	40.8	33m	**Dried up**
4	BH4		43.2196924	1395	64.24	33m	**Dried up**
5	BH 5	9.95005453	43.219327	1395	55.94m	33m	**Dried up**
6	BH 6	9.9463285	43.2242718	1393	123m	33m	**Dried up**
7	BH 7	9.9473975	43.2244034	1395	115m	33m	**Dried up**
8	BH 8	9.9510332	43.2197488	1391m	60.2m	33m	**Dried up**
10	BH NO.8 (replacement	N 09.5020	E 43.22879	1385 M	190M	71.1M	**functioning**
11	BH NO.7 (Daahir rayaale)	N 09.94648	E 043.22342	1394 M	120M	85M	**Dried up**
12	BHNo.12(Beerta Qaasim)	N 09.94159	E 043.24771	1416M	120M	91M	**Dried up**
13	BH No. 13 (Dambaska)	N 09.92771	E 043.24475	1430M	116M	104M	**Dried up**
14	BH19 (Jamacada Amoud)	N 09.94905	E 043.22172	1385M	210M	91M	**functioning**
15	BH 20 (Beerta Aareeye)	N09.942218	E 043.23695	1390M	210M	89M	**functioning**
16	BH 21 (Ina Garnoog)	N 09.94846	E043.23320	1376M	230M	70M	**functioning**
17	BH23ceelka Madaxwaynaha	N09.94486	43.23114	1378m	160M	81M	**functioning**
18	BH24 SHABA	N09.94486	43.23114	1378m	160M	81M	**functioning**
19	BH25ceelka Madaxwaynaha	N9.94481	43.23114	1377m	220m		**Ongoing**
20	Ceelka UNICEF	N9.93870	43.18387	1470m	222M	105M	**Functioning**
21	BH14						**Dried up**
22	BH16						**Dried up**

2.1 Situation Analysis.

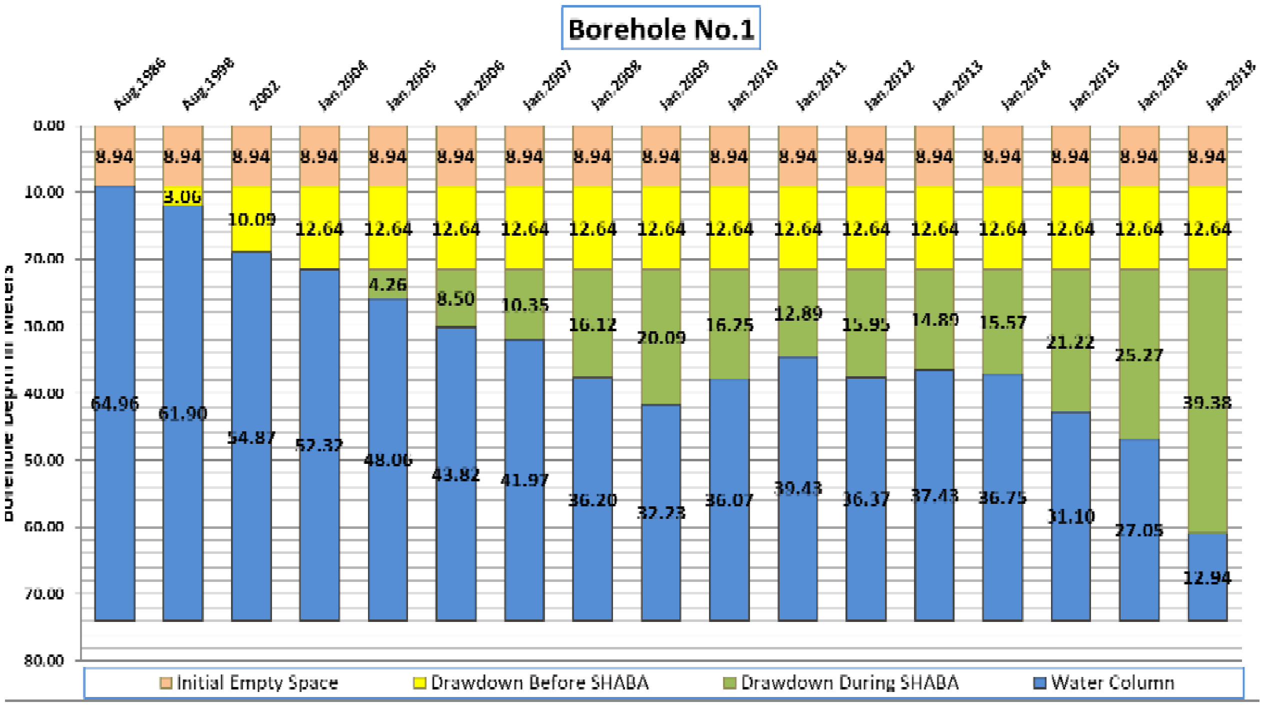
The occurrence of ground water resources and its potentiality or available quantities directly depend on several factors including the precipitation, aquifer characteristics, degree of exploitation and level of conservation. The precipitation and the subsequent recharge are a major influencing and crucial factor to the unremitting replenishment of underground aquifers. However, other properties such perviousness, penetrability etc. of the hosting and overlaying formation is also an important feature for aquifer constant amelioration as those sternly govern its recharge process. Any positive or negative transformation that ensues to those factors will directly affect to the ground water resources. In simple words, ground water resource is finite which could deplete if the equilibrium between the recharge and aquifer safe yield capacity is not balanced.

The process of the natural ground water replenishment in Dhammug and Amoud aquifers occurs very slow. The two main seasonal streams namely Dhamuug and Amoud had significant erosion during the last decade. The riverbeds are occupied by very thin layer of sand deposits in few areas and are excavated in nude crystalline rocks which exposes the basement in other sector. That indicates that water is running only during the rainy seasons and can only stay not more than one day. In that case the storage factor along the riverbeds in nearly zero. The crystalline basement has very little infiltration because of its low permeability so that the runoff supersedes its infiltration whereas there is also the evapotranspiration, those are on the ration of 2:80:18 respectively. Therefore, there is a very high surface runoff water and underground path, through geological fissures and fractures, that drains out of the basin.

considering the above negative hydraulic balance, it could be easily noted that situation of the Dhammug and Amoud streams contribution to the aquifer potentiality is negligible. Therefore, the capacity of present aquifer is very limited with respect to the aquifer storage and area. Before the occurrence of those recent changes in governing factors, the Dhamoug /Amoud aquifer was spring during 1970 where the town water supply was used to collect from spring box which means that the water table was at ground level. Later a protected shallow well with potential production was sunk to supply the water to town while the drilling of the boreholes started only during 1987 just before the start of the civil wars and the water table of the first drilled boreholes where only few meters below the ground level which was when the Chinese government drilled the first eight boreholes and from that time the water table is going deeper each year.

The water table continuous drop down was aggravated by to the over pumping to cover the huge demand for water of the town. During the start of SHABA management, before two decades the water table was very shallow (40-60m while it's now up to nearly 90-100m) with an average annual drop down of 8m/year.
There is gap between the present production and the town water demand, the international minimum standard of drinking water for urban is 40Lts per person per day. present population estimate is nearly 300,000 person and the required water supply for that number is 12,000,000 liters per day. Studies carried out by SHABA revealed that the rate of the water table drop down estimate is 8m/year, the aquifer area is limited, and the exploitation is much higher than its capacity as there are no still alternative another aquifer operating/developed so far.

If the drop down continuous without recovery measures, there is a likelihood of arisen depletion that could lead into the collapse of the aquifer which is irreversible phenomena. This is a factual indication that the situation of Borama water supply is in alarming needs immediate intervention.



Sample of dried up boreholes

2.2 Problem analysis.

Borama town is currently facing a very critical water scarcity situation. Due to the limited production of the water supply system, there is a notable huge gap between the daily supply and demand. The absence of sufficient rainfall replaced by sporadic rains caused by the prevailing climate change, which contribute minimal water capillary and percolation quantities. Because of the gradual topographic and geomorphological changes happening in the aquifers hosting terrains, significant number of gullies formed and invigorated the process of erosion by which completely swept the sand deposition and exposed the nude rock. The inexistence of parallelly contra-versant factors of reducing the ongoing erosion process such as land bunding, subsurface dams, sand dams etc. had been an aggravating factor.

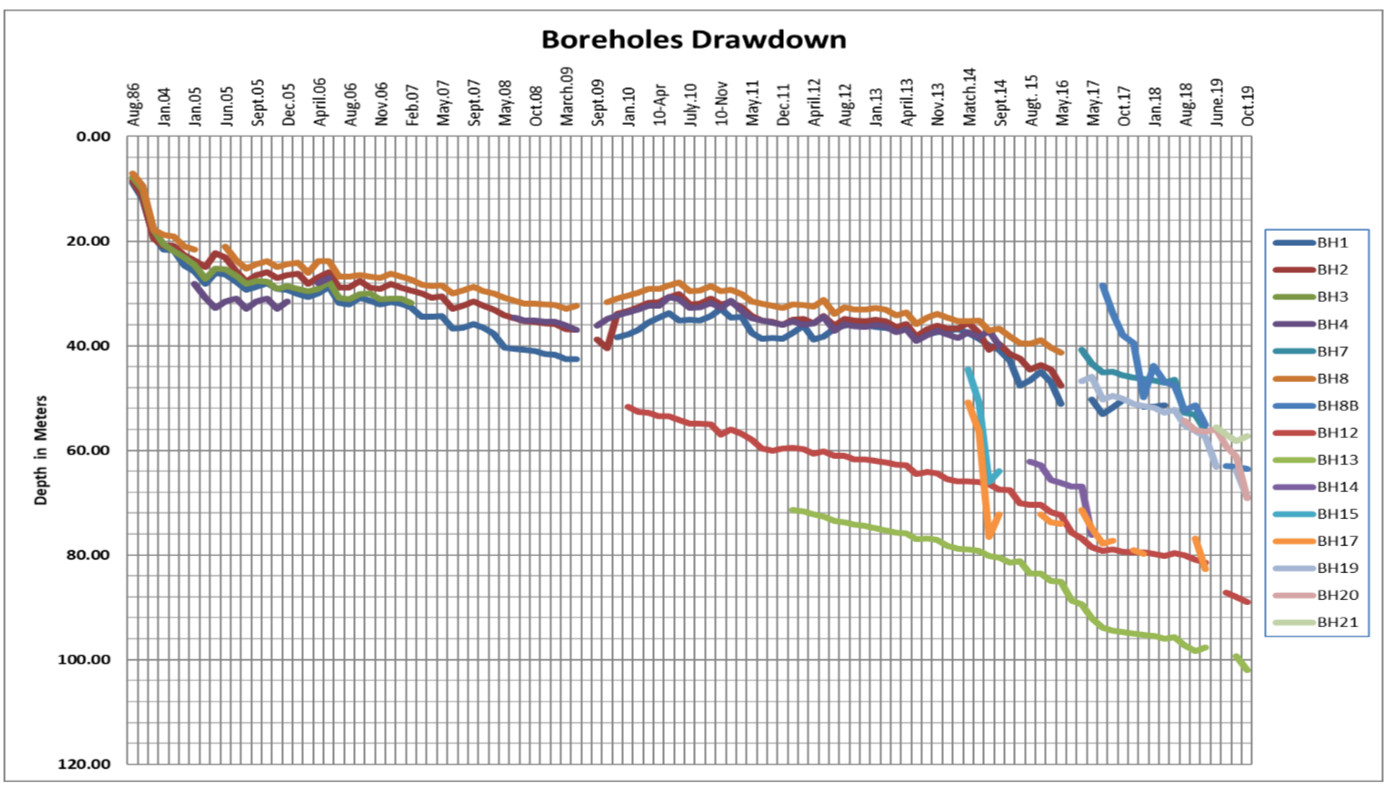
On the other hand, there has been a considerable increase of Borama town population during the recent decades. That notable increase was apart from the normal birth rate additive, was caused by increased urbanization due to the movement from rural to town centers of rural communities.

Facilitated by frequent droughts. Above that, the population growth was also contributed extensively by internal displacement and refugees. That population increase had wedged to the water supply situation of Borama as it augmented the water supply demand. The town population growth is among the fastest in the country, the town growth from the point of the view of the access to water is estimated by 12% as nearly 1300 new households get connections from the town water system.

All the above-mentioned negative factors ascribed in, one way or the other, to the present imbalance equilibrium of the water supply and demand. However, due to the continuous pumping from the Dhammug and Amoud aquifers and the lack of compensatory or replenishment processes there has been limited recovery in the borewells and as a result there has been significant dropdown of the water table and caused the depletion or drying up/abandonment of 12 borewells.

The effects of those adverse problems facing the Borama water supply included a paramount water shortage that caused the application of water supply rationing for the different town sectors. That is a clear indication of a failure for the continued supply of water to the people and as well the declined provision of adequate water supply for the community.

The emerging dropdown of the water table, the progressively happening aquifer capacity decline and the limitation of water supply all contribute to a serious alarm of an upcoming drastic water supply scarcity for the town which will eventually impact on the living conditions and health standards of Borama population.



The graph shows the drop down of the ground water in Amoud/Dhamoug aquifers

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Ground water resources are finite and limited, if the active phenomena of over pumping and lack of adequate ground water recharge from the rains are not put into consideration the new drilled boreholes will have the same phenomena and will get depleted

The table below shows the number of boreholes that supply the town including the dried up.

3.1 Project over all objectives.

Goals: Increased production capacities and enhancing of depleting water table through implementation of watershed management and artificial recharge schemes in the eastern aquifer of Borama town.

Augmentation/increased production capacity of Amoud/Dhamoug aquifer through construction of forced recharge & watershed management schemes.

Specific objectives

The overall objective of this proposal is to improve the living conditions of the Borama population through the provision of sufficient water supplies by increasing the production capacity of the Amoud and Dhammug aquifers.

3.2 **Project outcome**:

Outcome 1
Increase the awareness and attention of all stakeholders to mobilize necessary resources for the continued potentiality of the existing aquifers, that also pertains to enhance the implementation and sustainability of the existing aquifers.

Outcome 2
Proper exploitation of ground and rainfall water by means of water shed management schemes for imprisonment of the surface runoff water for the augmentation of the aquifer storage capacity.

Outcome 3
Limitation and/or reduction of the prevailing climate change related effects to the ground water storage.

Outcome 4
Provision of clean and adequate water supply to reduce the occurrence of communicable diseases and decrease the mortality and morbidity rates.

3.3Project outputs

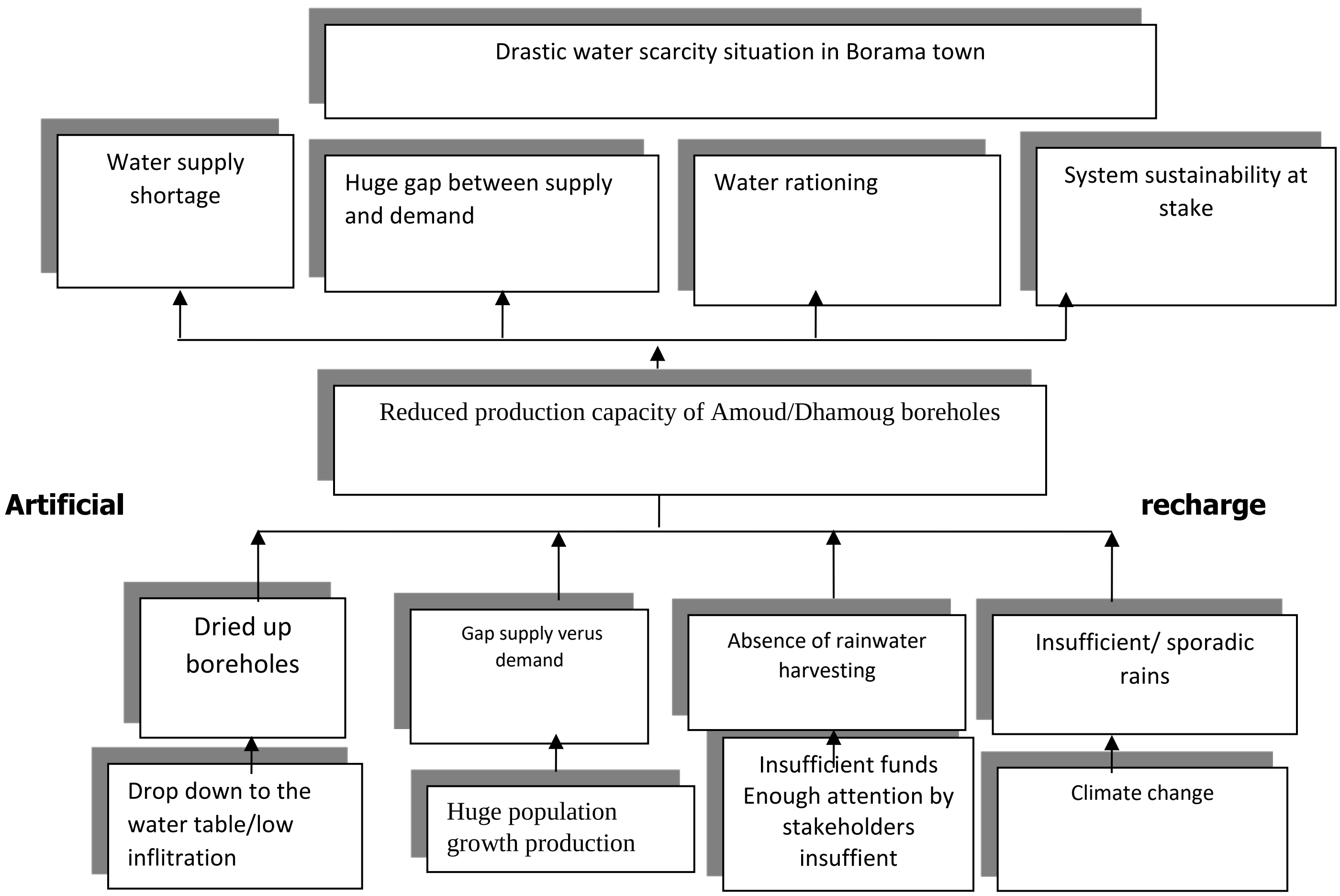
Output 1	Three earth dams constructed to recharge 3 dried up boreholes (B12, BH13 and BH4)
Output 2	Six Subsurface /sand dams constructed through for ground water recharge Enhancement
Output 3	2KM bad land protected with soil bunds through construction of soil bunds, runoff diversions and other relative watershed management techniques.
Output 4	one thousand indigenous trees replanted in the Amoud/Dhamoug aquifer watershed to Increase/support runoff water infiltration/recharge of the aquifer.

3.4 Project activities

- Establishment of project implementation unit
- Selection of qualified engineers
- Prepare project implement documents (tender documents)
- Community mobilization/sensitization
- Selection of implementation partner through int/national competitive bid
- Monitoring of project activates
- Evaluation of project out puts against the project goals/ outcomes
- Capacity building to the user communities/MOWRD and SHABA staff
- Establishment of sustainable management bodies/WASH committees/WU Associations

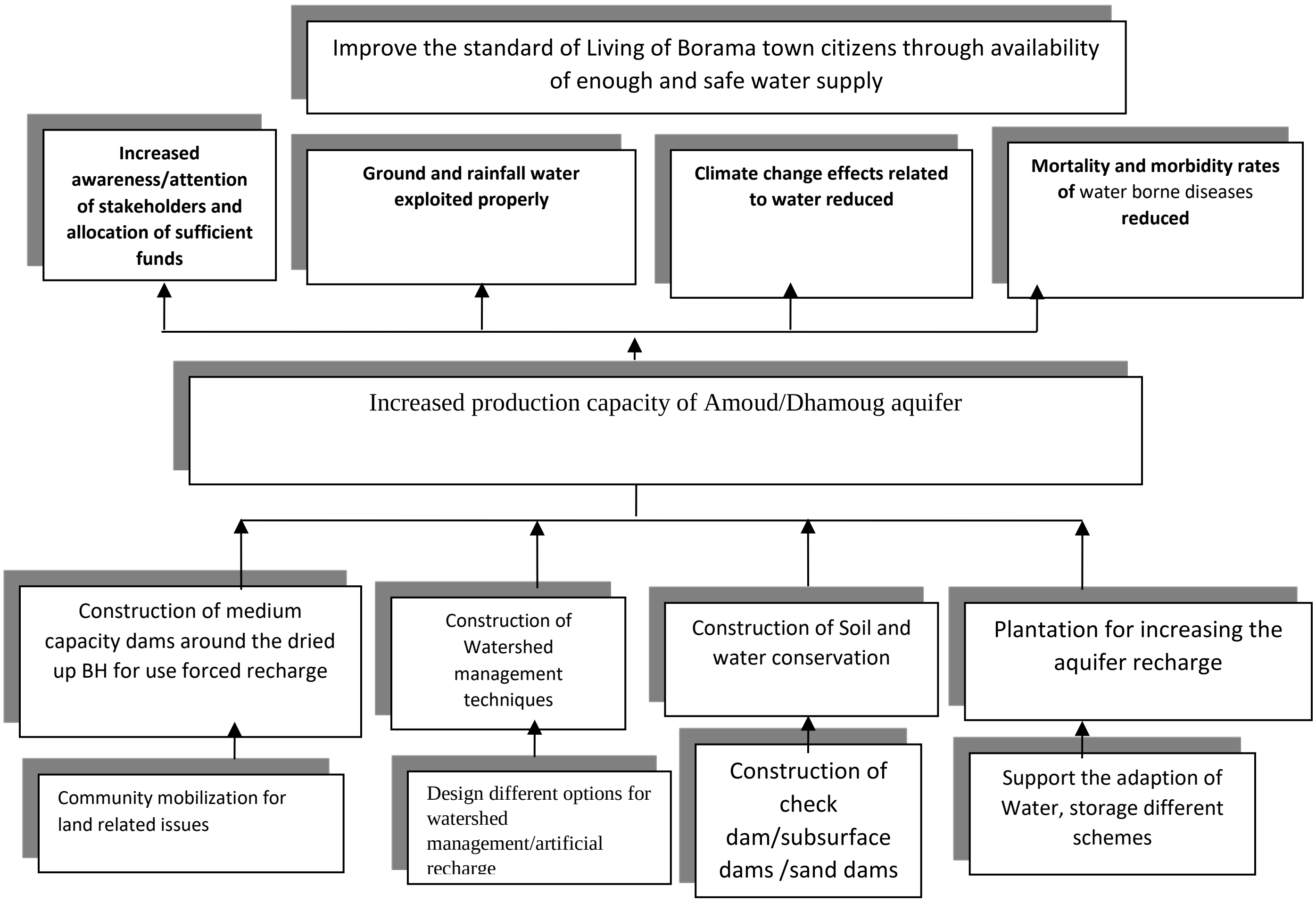
Annex 1

4,1 Problem Tree



Annex 2

5.1 Objective tree



Annex 3.

Log frame

project name	Augmentation/increased production capacity of Amoud/ Dhamoug aquifer through construction of forced recharge & watershed management schemes				
IMPACT	**Impact Indicator 1**	**Baseline (2011)**	**Milestone**	**Target (M24)**	**Assumptions**
Improve the standard of Living of Borama town citizens through enriching the eastern aquifer using modern technology of surface water storage to the ground water	Percentage of households get water supply on regular basis	250,000HH getting 15/per/day	250,000HH getting 30/per/day	6 months	Normal rainfall pattern, availability of funds
OUTCOME 1	Outcome Indicator 1	**Baseline (M0)**	**Milestone**	**Target (M24)**	**Assumptions**
Enhanced production capacity of dried up /depleting boreholes through forcing runoff water harvested from the rains	daily production	0 production	800 CUM/day	6 months	Normal rainfall pattern, availability of funds
OUTCOME 2	Outcome Indicator 1	**Baseline (M0)**	**Milestone**	**Target (M24)**	**Assumptions**
Enhanced ground water table level through proper watershed management of the catchment area	% of water table meter	105	88	6 months	Normal rainfall pattern, availability of funds
OUTCOME 3	Outcome Indicator 1	**Baseline (M0)**	**Milestone**	**Target (M24)**	**Assumptions**
Improved Soil and water conservation of the Amoud/Dhamoug dry rivers	% of recharge	5%	25%	12 Months	Normal rainfall pattern, availability of funds

Project Budget

Goals: **Increased production capacities and enhancing of depleting water table through implementation of watershed management and artificial recharge schemes in the eastern aquifer of Borama town**					
Outcome 1 Dried up boreholes (4, 12 &13) revitalized and reconnected to the water supply system					
SN	**Description**	**Unit**	**No. Unit**	**Unit Cost**	**Total Amount**
Output 1 construction of forced recharge scheme for 3 dried up boreholes B12, BH13 and BH4					
	Activities for output 1				
1	Hire qualified expert for implementation of forced recharge schemes	months	6	$1,200	$7,200.00
2	Prepare designs BOQs and tender documents for three earth dams(100Mx80Mx6M) for using forced recharge for two dried up the boreholes (4,12 and 13)	Units	3	$1,200	$3,600.00
3	Implementation of designed activities according to the design	Dams	3	$158,400	$475,200.00
4	Capacity building train SHABA and ministry staff	LS	1	$2,500	$2,500.00
	Subtotal 1				**$488,500.00**
Output 2 construction of 4 subsurface /sand dams for groundwater recharge enhancement					
	Activities for Outcome 2				
1	Hire qualified expert for implementation of subsurface/sand dams in Amoud/Dhamoug aquifers	months	6	$1,200	$7,200.00
2	Prepare designs BOQs (35mx3mx2m) and tender documents for 6 subsurface/dams in Amoud/Dhamoug dry rivers	Units	6	$1,200	$7,200.00
3	Implementation of designed activities	Units	6	$33,000	$198,000.00
4	Capacity building train SHABA and ministry staff	LS	1	$2,700	$2,700.00
subtotal 2					**$215,100.00**
Output 3 Construction of gully protection and soil bunds					
	Activities for Output 3				
1	Hire qualified expert for implementation of soil bunds, gully protection and reforestation schemes in Amoud/Dhamoug aquifers	months	6	$1,200	$7,200.00
2	Prepare designs BOQs& for 2KM soil bunds (50MX1MX1M, 15 Units of gully protection and plantation of 15,000 indigenous trees in Amoud/Dhamoug catchment areas	Units	4	$1,200	$4,800.00
3	Implementation of designed activities	m	2000	$4	$8,000.00
4	Training SHABA and ministry staff	LS	1	$560	$560.00
5	Construction of Gully protection using gabion baskets 2mX1mX1m	units	120	$500	$60,000.00
6	plantation of shady trees	units	1,000	$15	$15,000.00
Subtotal 3					**$95,560.00**
Grand total					**$799,160.00**
Ministry of Water Resources Contribution					**$300,000.00**
UNICEF Contribution					**$499,160.00**

6 .1 Importance of Water Harvesting

Rainwater harvesting, in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques. Rainwater harvesting has been practiced for more than 4,000 years, owing to the temporal and spatial variability of rainfall. It is an important water source in many areas with significant rainfall but lacking any kind of conventional, centralised supply system. It is also a good option in areas where good quality fresh surface water or ground water is lacking. Water harvesting enables efficient collection and storage of rainwater, makes it accessible and substitute for poor quality water. There are a number of ways by which water harvesting can benefit a community.

- Improvement in the quality of ground water,
- Rise in the water levels in wells and bore wells that are drying up,
- Mitigation of the effects of drought and attainment of drought proofing,
- An ideal solution in areas having inadequate water resources,
- Reduction in the soil erosion as the surface runoff is reduced,
- Decrease in the choking of storm water drains and flooding of roads and
- Saving of energy to lift ground water.

6.2 Types of Water Harvesting

Rainwater Harvesting: Rainwater harvesting is defined as the method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Three types of water harvesting are covered by rainwater harvesting.

- Water collected from rooftops, courtyards and similar compacted or treated surfaces is used for domestic purpose or garden crops.
- Micro-catchment water harvesting is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a tree, a bush or with annual crops.
- Macro-catchment water harvesting, also called harvesting from external catchments is the case where runoff from hill-slope catchments is conveyed to the cropping area located at foothill on flat terrain.

Flood Water Harvesting: Floodwater harvesting can be defined as the collection and storage of creek flow for irrigation use. Floodwater harvesting, also known as ‘large catchment water harvesting' or 'Spate Irrigation', may be classified into following two forms:

- In case of 'flood water harvesting within stream bed', the water flow is dammed and as a result, inundates the valley bottom of the flood plain. The water is forced to infiltrate and the wetted area can be used for agriculture or pasture improvement.
- In case of 'flood water diversion', the wadi water is forced to leave its natural course and conveyed to nearby cropping fields.

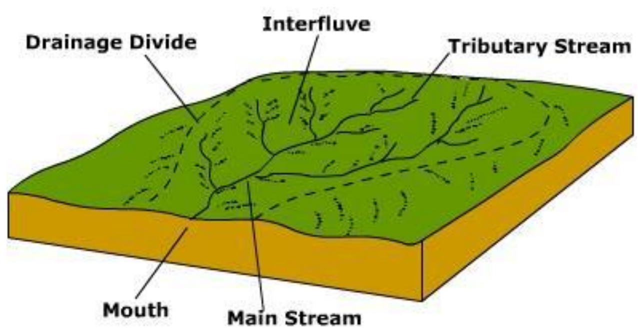
Groundwater Harvesting: Groundwater harvesting is a rather new term and employed to cover traditional as well as unconventional ways of ground water extraction. Qanat systems, underground dams and special types of wells are a few examples of the groundwater harvesting techniques. Groundwater dams like 'Subsurface Dams' and 'Sand Storage Dams' are other fine examples of groundwater harvesting. They obstruct the flow of ephemeral streams in a river bed; the water is stored in the sediment below ground surface and can be used for aquifer recharge.

6.3 Water Harvesting Technique

This includes runoff harvesting, flood water harvesting and groundwater harvesting.

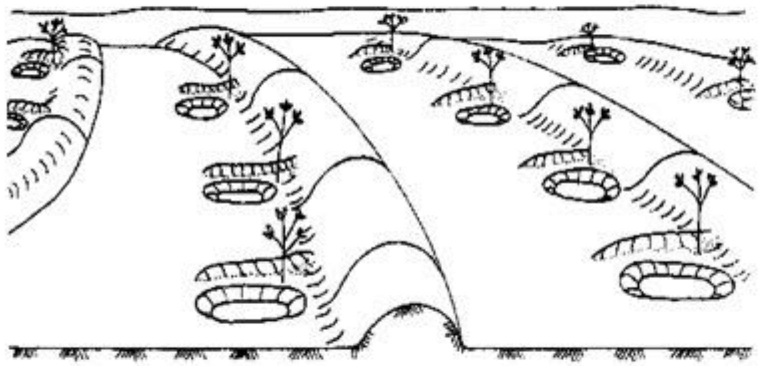
Runoff Harvesting

Runoff harvesting for short and long term is done by constructing structures as given below.



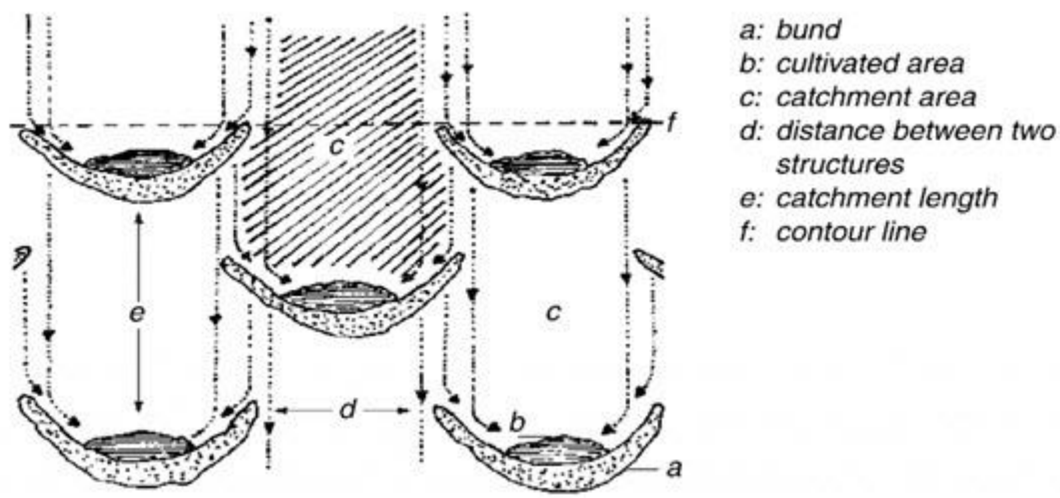
Term Runoff Harvesting Techniques

Contour Bunds: This method involves the construction of bunds on the contour of the catchment area These bunds hold the flowing surface runoff in the area located between two adjacent bunds. The height of contour bund generally ranges from 0.30 to 1.0 m and length from 10 to a few 100 meters. The side slope of the bund should be as per the requirement. The height of the bund determines the storage capacity of its upstream area.



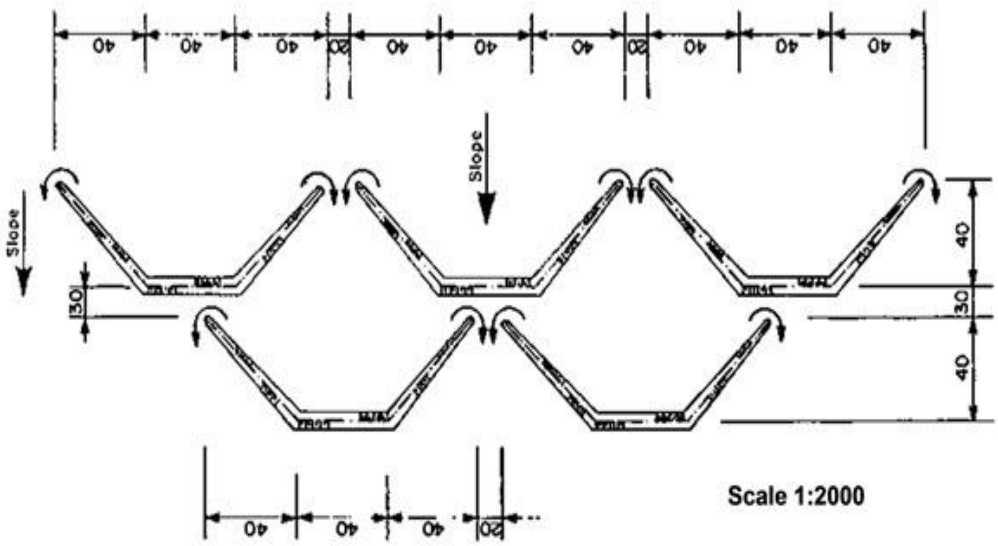
Contour Bunds.

Semi-circular Hoop: This type of structure consists of an earthen impartment constructed in the shape of a semicircle. The tips of the semi-circular hoop are furnished on the contour. The water contributed from the area is collected within the hoop to a maximum depth equal to the height of the embankment. Excess water is discharged from the point around the tips to the next lower hoop. The rows of semi-circular hoops are arranged in a staggered form so that the over flowing water from the upper row can be easily interrupted by the lower row. The height of hoop is kept from 0.1 to 0.5 m and radius varies from 5 to 30 m. Such type of structure is mostly used for irrigation of grasses, fodder, shrubs, trees etc.



Layout of Semi-Circular Hoop

Trapezoidal Bunds: Such bunds also consist of an earthen embankment, constructed in the shape of trapezoids. The tips of the bund wings are placed on the contour. The runoff water yielded from the watershed is collected into the covered area. The excess water overflows around the tips. In this system of water harvesting the rows of bunds are also arranged in staggered form to intercept the overflow of water from the adjacent upstream areas. The layout of the trapezoidal bunds is the same as the semi-circular hoops, but they unusually cover a larger area (Fig. 28.3). Trapezoidal bund technique is suitable for the areas where the rainfall intensity is too high and causes large surface flow to damage the contour bunds. This technique of water harvesting is widely used for irrigating crops, grasses, shrubs, trees etc.



Layout of Trapezoidal Bund.

Graded Bunds: Graded bunds also referred as off contour bunds. They consist of earthen or stone embankments and are constructed on a land with a slope range of 0.5 to 2%. The design and construction of graded bunds are different from the contour bunds. They are used as an option where rainfall intensity and soils are such that the runoff water discharged from the field can be easily intercepted. The excess intercepted or harvested water is diverted to the next field though a channel ranges. The height of the graded bund ranges from 0.3 to 0.6 m. The downstream bunds consist of wings to intercept the overflowing water from the upstream bunds. Due to this, the configuration of the graded bund looks like an open-ended trapezoidal bund. That is why sometimes it is also known as modified trapezoidal bund. This type of bunds for water harvesting is generally used for irrigating the crops.

Rock Catchment: The rock catchments are the exposed rock surfaces, used for collecting the runoff water in a part as depressed area. The water harvesting under this method can be explained as: when rainfall occurs on the exposed rock surface, runoff takes place very rapidly because there is very little loss. The runoff so formed is drained towards the lowest point called storage tank and the harvested water is stored there. The area of rock catchment may vary from a 100 m^2 to few 1000 m^2; accordingly, the dimensions of the storage tank should also be designed. The water collected in the tank can be used for domestic use or irrigation purposes.

Ground Catchment: In this method, a large area of ground is used as catchment for runoff yield. The runoff is diverted into a storage tank where it is stored. The ground is cleared from vegetation and compacted very well. The channels are as well compacted to reduce the seepage or percolation loss and sometimes they are also covered with gravel. Ground catchments are also called roaded catchments. This process is also called runoff inducement. Ground catchments have also been traditionally used since last 4000 years in the Negev (a desert in southern Israel) where annul crops and some drought tolerant species like pistachio dependent on such harvested water are grown.

Long Term Runoff Harvesting Techniques

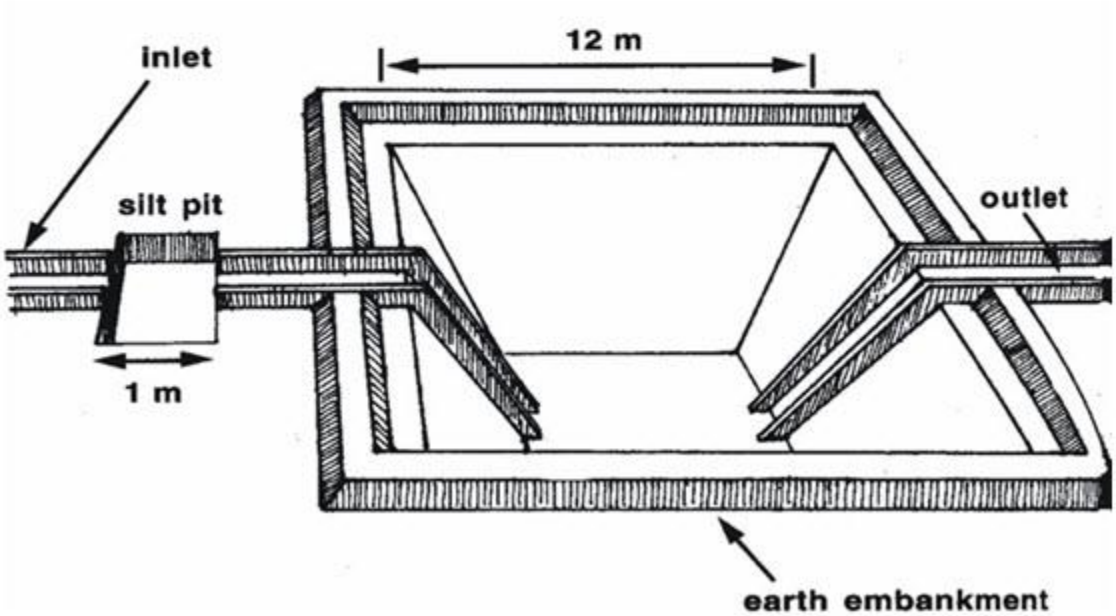
The long-term runoff harvesting is done for building a large water storage for the purpose of irrigation, fish farming, electricity generation etc. It is done by constructing reservoirs and big ponds in the area. The design criteria of these constructions are given below.

- Watershed should contribute a sufficient amount of runoff.
- There should be suitable collection site, where water can be safely stored.
- Appropriate techniques should be used for minimizing various types of water losses such as seepage and evaporation during storage and its subsequent use in the watershed.
- There should also be some suitable methods for efficient utilization of the harvested water for maximizing crop yield per unit volume of available water.

The most common long-term runoff harvesting structures are:

- Dugout Ponds
- Embankment Type Reservoirs

Dugout Ponds: The dugout ponds are constructed by excavating the soil from the ground surface. These ponds may be fed by ground water or surface runoff or by both. Construction of these ponds is limited to those areas which have land slope less than 4% and where water table lies within 1.5-2 meters depth from the ground surface (Fig. 28.4). Dugout ponds involve more construction cost; therefore, these are generally recommended when embankment type ponds are not economically feasible. The dugout ponds can also be recommended where maximum utilization of the harvested runoff water is possible for increasing the production of some important crops. This type of ponds requires brick lining with cement plastering to ensure maximum storage by reducing the seepage loss.



Embankment Type Reservoir: These types of reservoirs are constructed by forming a dam or embankment on the valley or depression of the catchment area. The runoff water is collected into this reservoir and is used as per requirement. The storage capacity of the reservoir is determined on the basis of water requirement for various demands and available surface runoff from the catchment. In a situation when heavy uses of water are expected, then the storage capacity of the reservoir must be kept sufficient so that it can fulfil the demand for more than one year.

Embankment type reservoirs are again classified as given below according to the purpose for which they are meant.

Irrigation Dam: The irrigation dams are mainly meant to store the surface water for irrigating the crops. The capacity is decided based on the amount of input water available and output water desired. These dams have the provisions of gated pipe spillway for taking out the water from the reservoir. Spillway is located at the bottom of the dam leaving some minimum dead storage below it.

Silt Detention Dam: The basic purpose of silt detention dam is to detain the silt load coming along with the runoff water from the catchment area and simultaneously to harvest water. The silt laden water is stored in the depressed part of the catchment where the silt deposition takes place and comparatively silt free water is diverted for use. Such dams are located at the lower reaches of the catchment where water enters the valley and finally released into the streams. In this type of dam, provision of outlet is made for taking out the water for irrigation purposes. For better result a series of such dams can be constructed along the slope of the catchment.

High Level Pond: Such dams are located at the head of the valley to form the shape of a water tank or pond. The stored water in the pond is used to irrigate the area lying downstream. Usually, for better result a series of ponds can be constructed in such a way that the command area of the tank located upstream forms the catchment area for the downstream tank. Thus, all but the uppermost tanks are facilitated with the collection of runoff and excess irrigation water from the adjacent higher catchment area.

Farm Pond: Farm ponds are constructed for multi-purpose objectives, such as for irrigation, live-stock, water supply to the cattle feed, fish production etc. The pond should have adequate capacity to meet all the requirements. The location of farm pond should be such that all requirements are easily and conveniently met.

Water Harvesting Pond: The farm ponds can be considered as water harvesting ponds. They may be dugout or embankment type. Their capacity depends upon the size of catchment area. Runoff yield from the catchment is diverted into these ponds, where it is properly stored. Measures against seepage and evaporation losses from these ponds should also be.

Percolation Dam: These dams are generally constructed at the valley head, without the provision of checking the percolation loss. Thus, a large portion of the runoff is stored in the soil. The growing crops on downstream side of the dam, receive the percolated water for their growth.

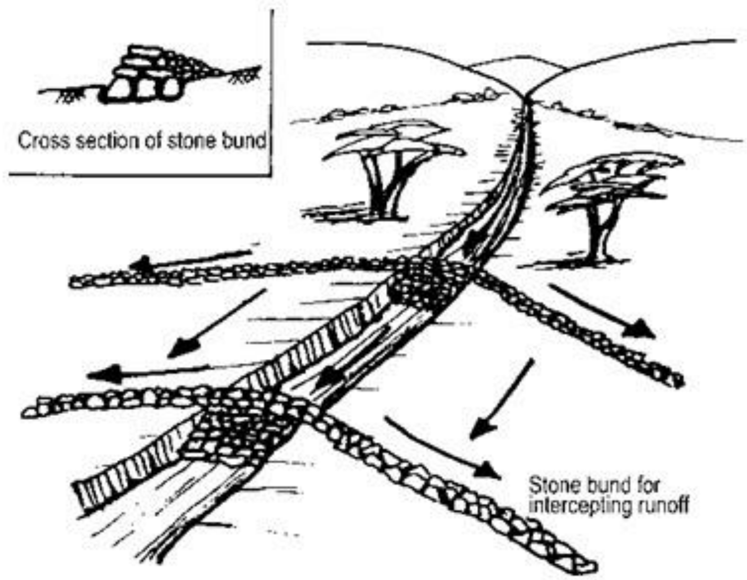
Flood Water Harvesting

To harvest flood water, wide valleys are reshaped and formed into a series of broad level terraces and the flood water is allowed to enter into them. The flood water is spread on these terraces where some amount of it is absorbed by the soil which is used later on by the crops grown in the area. Therefore, it is often referred to as "Water Spreading" and sometimes "Spate Irrigation". The main characteristics of water spreading are:

- Turbulent channel flow is harvested either (a) by diversion or (b) by spreading within the channel bed/valley floor.
- Runoff is stored in soil profile.
- It has usually a long catchment (may be several km)
- The ratio between catchment to cultivated area lies above 10:1.
- It has provision for overflow of excess water.

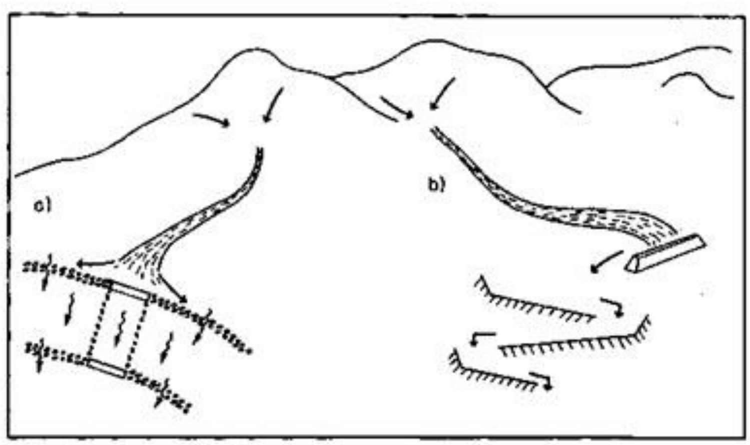
The typical examples of flood water harvesting through water spreading are given below.

Permeable Rock Dams (for Crops) These are long low rock dams across valleys slowing and spreading floodwater as well as healing gullies (Fig. 28.5). These are suitable for a situation where gently sloping valleys are likely to transform into gullies and better water spreading is required.



Permeable Rock Dams.

Water Spreading Bunds (for Crops and Rangeland): In this method, runoff water is diverted to the area covered by graded bund by constructing diversion structures such as diversion drains. They lead to the basin through channels, where crops are irrigated by flooding. Earthen bunds are set at a gradient, with a "dogleg" shape and helps in spreading diverted floodwater (Fig. 28.6). These are constructed in arid areas where water is diverted from watercourse onto crop or fodder block.

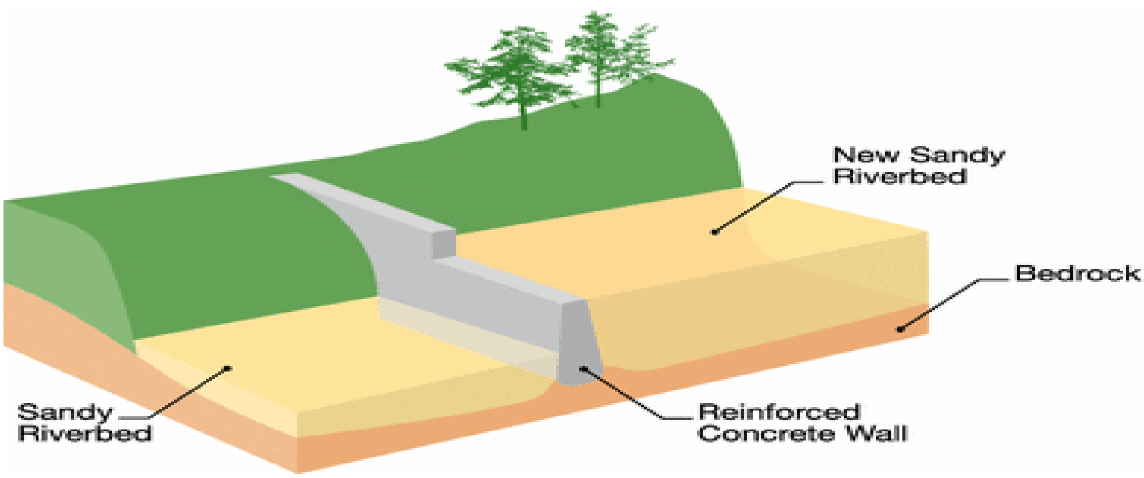


Flood Control Reservoir: The reservoirs constructed at suitable sites for controlling the flood are known as flood control reservoirs. They are well equipped with self-operating mechanical outlets for letting out the harvested water into the stream or canal below the reservoir as per requirement.

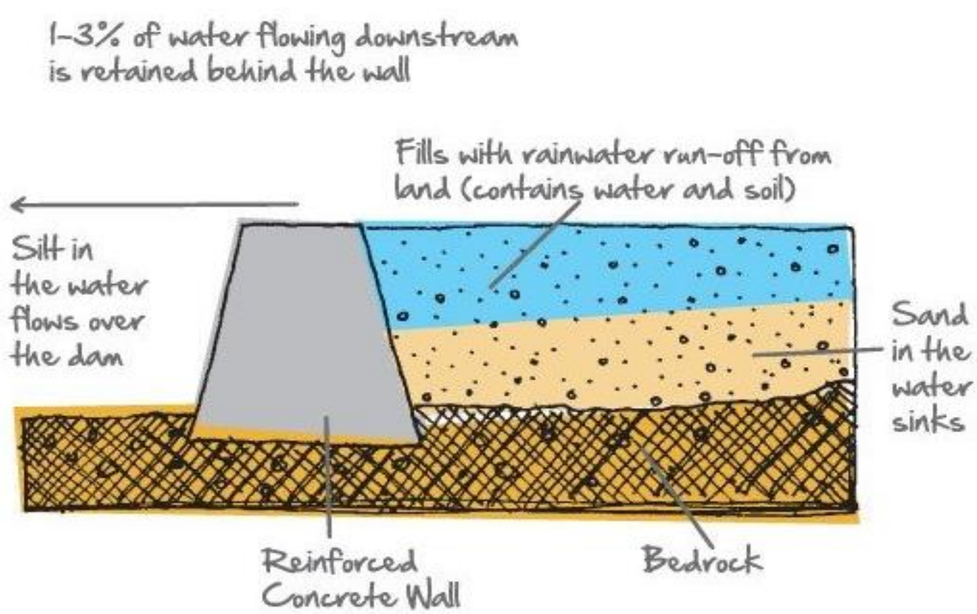
Groundwater Harvesting

Runoff vs. Flood Water Harvesting

- Water harvesting techniques which harvest runoff from roofs or ground surfaces fall under the term rainwater harvesting while all systems which collect discharges from watercourses are grouped under the term flood water harvesting.
- Runoff harvesting increases water availability for on-site vegetation while flood waters harvesting provide a valuable source of water to local and downstream water users and play an important role in replenishing floodplains, rivers, wetlands and groundwater.
- Runoff harvesting reduces water flow velocity, as well as erosion rate and controls siltation problem while in flood water harvesting**,** floodwater enters into the fields through the inundation canals, carrying not only rich silt but also fish which can swim through the canals into the lakes and tanks to feed on the larva of mosquitoes.



Sand dam



Annex 4.

Budget Earth dam

Construction of earth Dam for found water recharge in Amoud					
SN	**Activity description**	**Unit**	**No.0f Units**	**Unit Price**	**Total amount**
1	Mobilization/De-mobilization	Unit	2	1,300	$2,600.00
2	Excavation of earth dam 60mX60mX4m	M^3	14,400	4.5	$64,800.00
3	Soil compacting and hardening of the bottom and banks	M^2	6,400	2.7	$17,280.00
4	Provide and lay durable plastic sheet (High Density Polyethylene) 1mm thick, Provide and supply durable plastic sheet (High Density Polyethylene) 1mm thick	M^2	13,225	2	$26,450.00
5	Construction of intake and draw-off structures. The intake structure includes construction of two raw water inlet with steel grating covers and excavation and installation of two number 6 bar PVC conveyance pipe lines 60m length running parallel. The draw-off structure consists of an aqueduct of 1m x1m.	LS	1	3,200	$3,200.00
6	Provide centrifugal Pumps with diesel powered engine with capacity 10 cubic meters per Hour at 100m head with 2" hose 100m length,	set	1	4,200	$4,200.00
7	Excavation of silt trap 30mx30mx1m	M^3	900	2.6	$2,340.00
8	Construction of fence and gates according to detailed given. (Fence of galvanized GI chain link G16 height 2m) supported with angle 5 stand 2.5m above ground and 0.5m underground, placed in 4m intervals.	M^2	720	17.2	$12,384.00
9	Construction of elevated water tank	Unit	1	12,435	$12,435.00
10	Construction of rural kiosks	Unit	1	3,711.00	$3,711.00
11	Construction of animal trough	Unit	2	4,500	$9,000.00
	Budget for one earth dam				**$158,400.00**
	Budget for 3 earth dams 158,400x3				**$475,200**

Annex. 5

Sub-surface

Construction of Subsurface Dam in Amoud					
SN	**Activity Description**	**Unit**	**QTY**	**Unit cost**	**Total amount**
1	Community and resources mobilization/demobilization	trip	2	780	$1,560.00
2	Excavation of trench 45mX2mX1m	M^3	90	40	$3,600.00
3	Casting of lean concrete foundation	M^3	90	80	$7,200.00
4	Construction RCC concrete wall 25mX2mX3m	M^3	150	250	$37,500.00
5	Construction of sand dam wings/shoulders 6mX2mX3m	M^3	36	200	$7,200.00
	Budget for one submersible/sand dam				**$57,060.00**
	Total for 6 submersible/sand dam				**$342,360.00**