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Examining the Benefits and Drawbacks of the Sand Dam Construction in Cadadley Riverbed

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Abstract:- In dry land areas like Somaliland shortage of water is very common. People have to travel for long distances to find water, and after it rains, most of the water is lost to evaporation or surface run off. The challenge in arid and semi-arid climates is how to harvest rainwater; most of villages in Somaliland need how to harvest rainwater and running water through their dry valleys.

This study aimed to evaluate the positive and negative impact of existing water infrastructure (sand dams) in dry rivers in Cadadley district and to compare these with appraisal of sites yet to be developed that can be constructed sand dams in Cadadley region Somaliland.

This study employs a method known as probing, which involves hammering a rod into the middle of the riverbed until it makes contact with the floor beneath the sand, producing a dull sound. The level of the sand is then marked on the rod, which is subsequently pulled straight up without any twisting. The crucial factor in determining the location for constructing a sand storage dam is the depth of the basement or impermeable layer relative to the riverbed surface. Ideally, the dam should be built where the impermeable layer is closest to the riverbed surface.

The result shows that sand dam need reconstruction because of short of their spill ways and there is poor choice location.

Keywords:- *Sand Dam; Probing; Dry River; Cadadley; Somaliland*

I. INTRODUCTION

Sand Dams are a fantastic water resource solution in drylands. However, they are not appropriate everywhere. Successfully building sand dams is not an easy task, but it is based on a small number of very simple principles and rules.

Indeed, the construction of a robust and effective sand dam does not necessarily require formal engineering qualifications. Sand dams, technically categorized as rectangular weir overflow gravity dams, are typically built using steel-reinforced rubble stone masonry. It's important to note that the design and construction of sand dams often deviate from the guidelines outlined in technical and engineering manuals, as experience has shown that practical knowledge and adaptation play significant roles in their successful implementation. [1]

A groundwater dam is a structure that obstructs the natural flow of groundwater and stores water below the ground surface. There are basically two types of groundwater dams: i) sub-surface dams and ii) sand-storage dams. A sub-surface dam is constructed below ground level and arrests the flow in a natural aquifer, whereas a sand-storage dam impounds water in sediments caused to accumulate by the dam itself [2]

Fig 1: Locations of Groundwater Dams Around the World (Hanson & Nilsson 1986)

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II. TYPES OF DAMS

A. Subsurface Dams

The principle of a sub-surface dam is relatively simple: a trench is dug across the valley, reaching down to bedrock or their impervious, solid, impervious layer, at a suitable location. In the trench an impermeable wall or barrier is constructed, and the trench is refilled with excavated material.

A subsurface reservoir created in this manner effectively stores water during the wet season, and the stored water can be utilized as a valuable water resource throughout the dry season. This ensures a more sustainable water supply for various purposes, such as agriculture, livestock, and domestic use, even when surface water is scarce [2]. An underground dam is a facility that stores ground water in the pores of strata to enable sustainable use. These dams have many advantages, e.g., unlike a surface dam, land is not submerged to store water and there is no danger of breaching due to natural or manmade disasters [3].

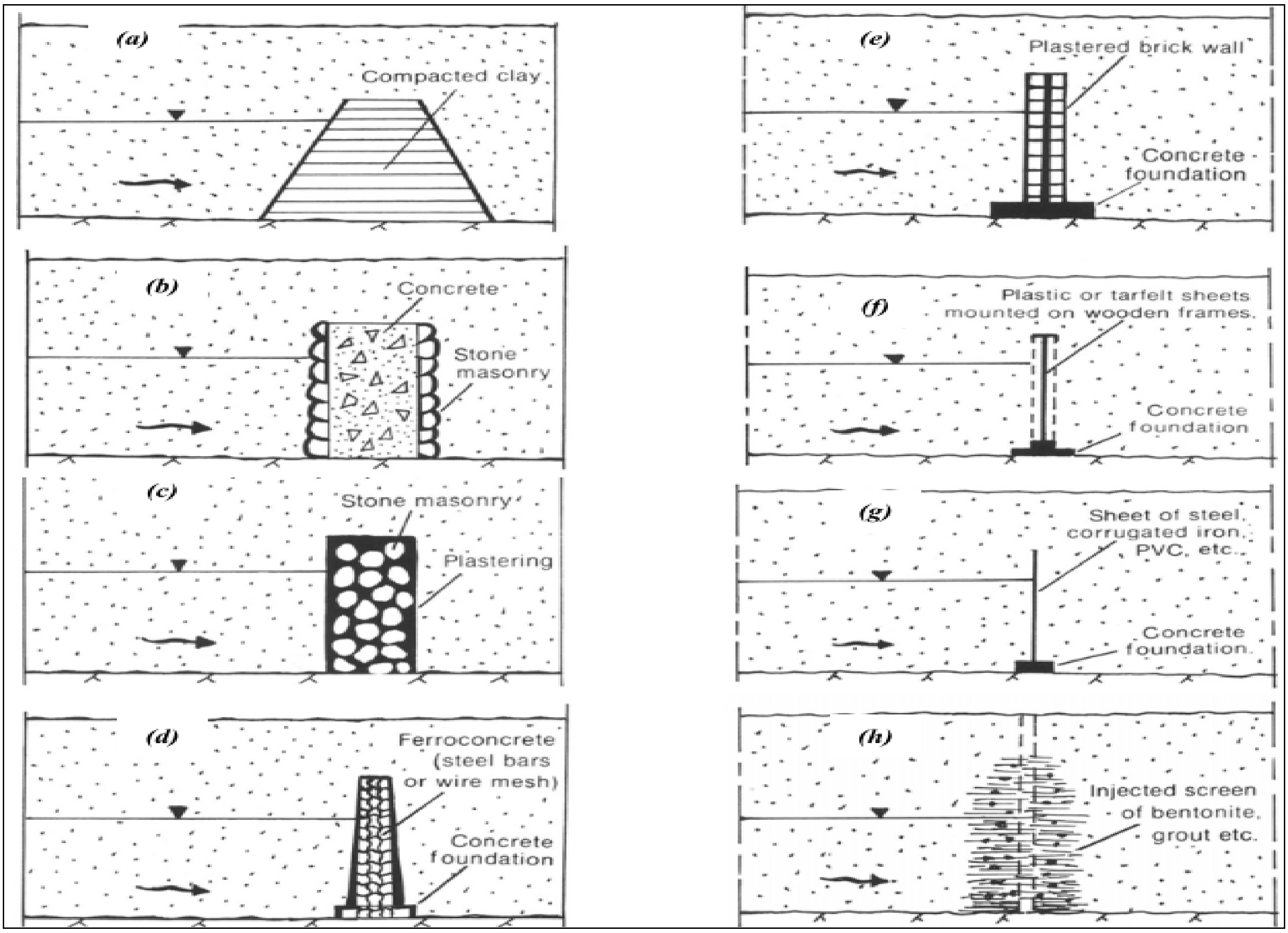

Fig 2: Sub-Surface Dam Types: a) Clay Dike,.b) Concrete Dam, c) Stone Masonry Dam, d) Reinforced Concrete Dam, e) Plastered Brick Wall, f) Plastic or Tarred-Felt Sheets, g) Corrugated Iron, Steel, or PVC Sheet, h) Injection Screen (Hanson and Nilsson, 1986, Nilsson, 1988)

B. Sand- Storage Dams

The fundamental concept behind a sand-storage dam is as follows: a weir of appropriate dimensions is built across the stream bed. When heavy rains occur, sand carried by the flow is deposited behind the weir, gradually filling up the reservoir with sand. This artificial aquifer replenishes each year during the rainy season, and the stored water is utilized during the dry season (Wipplinger, 1958). Various types of sand-storage dams exist, including concrete dams, stone masonry dams, gabion dams with clay cover or clay core, as well as stone-fill concrete and stone dams.[2].

A sand storage dam, also referred to as a sand dam, is a small dam built on and within the riverbed of a seasonal sand river. The functioning of a sand dam depends on the deposition of coarse sand upstream of the structure, thereby enhancing the natural storage capacity of the riverbed aquifer. During the wet season, the aquifer becomes replenished with water, thanks to both surface runoff and groundwater recharge occurring within the catchment area.. [4].

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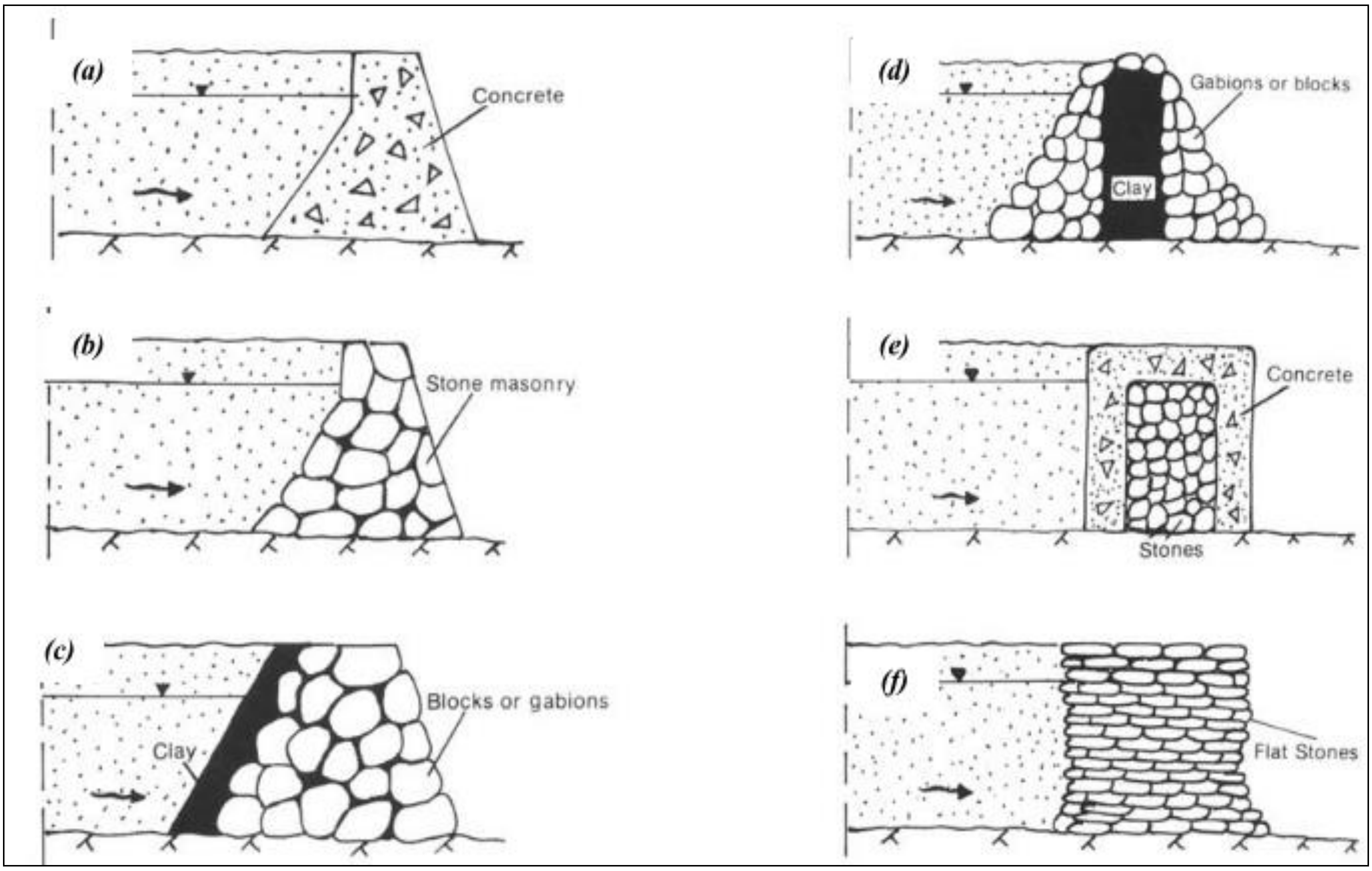

Fig 3: Types of Sand-Storage Dams: a) Concrete Sand-Storage Dam, b) Stone Masonry Sand-Storage Dam, c) Gabion Sand-Storage Dam with Clay Cover, d) Gabion Sand-Storage Dam with Clay Core, e) Stone-Fill Concrete Sand- Storage Dam, f) Stone Sand-Storage Dam (Nilsson, 1988)

III. LITERATURE

The most comprehensive information about groundwater dams is given in Nilsson (1988), which consists of the most detailed concept including literature review. As it is mentioned in Nilsson (1988); there are several groundwater dams in the world including Europe, Africa, Asia and America[5].

Africa is a continent where groundwater dams are extensively utilized. In northwestern Africa, particularly in Morocco and Algeria, several large sub-surface dams are in operation. Additionally, in East Africa, groundwater dams are commonly employed for water supply purposes. Examples include sand storage dams in the Machakos Region of Kenya and sub-surface dams near Dodoma, Tanzania (Nilsson, 1988).

The history of subsurface dams in East Africa traces back to Dodoma in Tanganyika (now Tanzania) around 1905. While people and animals have been accessing water from dry riverbeds since ancient times, the hydrogeological explanation for this phenomenon wasn't known until a century ago. The explanation lies in the presence of naturally formed dykes, known as subsurface dams, located beneath the surface of the sand. These dams effectively obstruct the downward flow of water within the voids between sand particles in riverbeds, making water accessible in otherwise dry riverbeds. [6].

After 1990, a new civil engineering technology emerged, known as the mixed-in-place slurry-wall method. This innovation enabled the construction of subsurface dams capable of storing 1 million cubic meters or more of groundwater. These large-scale subsurface dams are often referred to as mega-subsurface dams.[3].

By 1995, in five southern provinces of China, a total of 52 underground dams had been built within the karst region. These dams collectively possessed a storage capacity of 40 million cubic meters, sufficient to irrigate approximately 8,900 square kilometers of fields. Subsequently, at least five additional subsurface dams were constructed in the river basin using methods such as grouting and the clay-wall technique, wherein a cut-off wall is established using clay.[3]

In Hargeysa, the capital of Somaliland, an aged survey report dating back to 1954 recounts the involvement of Engineer S.R. Chetwynd Archer, a Chartered Civil Engineer from Tanganyika. Archer was summoned to Hargeysa with the task of designing a water supply system intended to serve 40,000 people, utilizing water from a subsurface dam. [6].

Fig 4: Person Stands on the Remains of Subsurface Dam [6]

IV. SITUATIONAL ANALYSIS

This study aimed to evaluate the positive and negative impact of existing water infrastructure (sand dams) in dry rivers and to compare these with appraisal of sites yet to be developed that can be constructed sand and subsurface dams in Cadaadley region Somaliland. where 1 sand dams have been built along the riverbed also the Somaliland Development Fund through the Ministry of Water is also working building Subsurface dams or sand dams in the area.

Somaliland, located in the Horn of Africa, is acknowledged as one of the most drought-prone regions in the area. The drinking water situation in Somaliland poses significant challenges, particularly in rural areas where women and children are compelled to cover extensive distances in search of water for both household and livestock use.

Traditionally, these areas were mostly occupied by nomads (or pastoralists), who mi- grate with livestock in search of water and grazing pastures. Today, more and more settlements in Somaliland are located close to a major water source, and towns are becoming increasingly more agricultural.

In these regions, surface water sources are often inaccessible due to their dependence on seasonal climatic fluctuations, which can result in conventional surface water storage tanks being either partially filled or completely empty. Additionally, the water scarcity problem in Somaliland worsens in many regions, mainly due to the extremely low annual rainfall. As a result, increasing groundwater resources becomes vital solution to meet the country's water supply demands.[7].

A. Geology of the Cadadley

Between Cadadlay and Dhubatothe lies an east-west belt characterized by granitized psammitic gneisses containing intrusions of granitic material. However, this belt is intersected by a north-south zone consisting of hornblende schist, dolerites, and some metamorphosed calcareous bands intermixed with granulites and psammitic gneisses. This zone is likely associated with faulting in the Argan through Da-ar Budhuq, although further field investigations are necessary for confirmation.

While aerial photographs suggest extensive faulting across the area, drainage patterns are predominantly influenced by jointing. The basement system was uniformly eroded to a peneplain and subsequently overlaid by Cretaceous sediments. Typically, these sediments comprise 10 to 50 feet of maroon reddish to pale greenish clays and silts in the lower 50 feet, often with at least 10 feet of conglomerate or sandstone beneath them.

A second layer of clay and silt clay is frequently observed approximately 160 feet above the base of the Cretaceous period, composed of Nubian sandstones. These clays, mentioned earlier, were initially identified in Liedod north of Hargeisa by a researcher in 1939 and subsequently labeled as the Hedod clays by Dr. Mason in 1953.

V. MATERIAL AND METHODS

This research employed a probing technique. The proximity of the impermeable layer beneath the riverbed surface is crucial for identifying the optimal location for constructing a sand storage dam. Ideally, the dam should be situated where the impermeable layer lies closest to the riverbed surface. Upstream areas of this location should feature deeper basements, thereby leading to a more extensive sand dam aquifer.

To measure the depth of sand in the riverbed, an iron rod with a diameter of 16 mm (5/8") can be employed. Notches should be carved into the probing rods at intervals of every 25 cm to facilitate the collection of sand samples upon retrieval. Additionally, a hammer is required to drive the rod into the riverbed, and a tripod ladder is recommended for handling long probing rods during this process. The procedure for conducting these measurements is outlined below:

Strike the probing rod vertically into the center of the riverbed until it contacts the floor beneath the sand, producing a muted sound. Indicate the sand level on the rod, then carefully withdraw the rod in a straight upward motion without rotating it.

Fig 5: Measuring Cadadley Riverbed by using Iron Rod(2m) to Identify Depth of Impermeable Layer in the Riverbed.

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Figure 6 is an example of a longitudinal profile. It shows the points at which the sand is deepest (here: 4.0 m deep between 55 and 60 metres) and where natural subsurface dykes (of solid bedrock or impermeable soil) are located (for example at 40, 70 and 85 metres). The locations with deep sand are the potential reservoir of a sand dam and the natural dykes are potential locations for a sand dam. After making a longitudinal profile of the selected riverbed section, the point where the sand is the deepest and therefore the largest reservoir can be selected. In figure 6 this is at 60 meters [4]

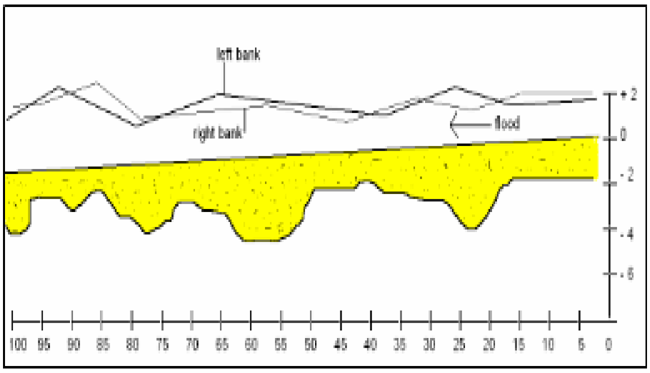

Fig 6: Example of a Longitudinal Profile of a River Section [4]

With knowledge of both the longitudinal and cross-sectional profiles, it becomes possible to calculate the reservoir capacity. Figure 7 illustrates an example of a cross-section where the sand reaches its maximum depth. It is imperative to take measurements at regular intervals, typically every 1 or 2 meters across the riverbed, to comprehensively assess the riverbed morphology. [4].

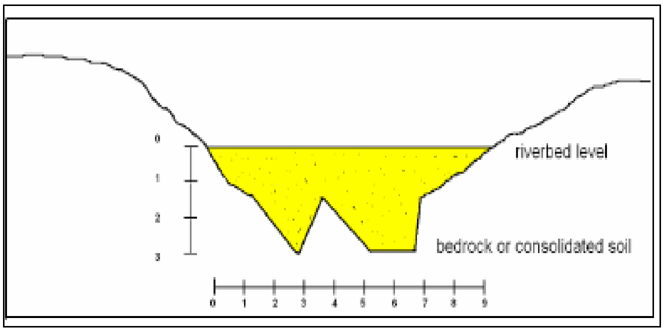

Fig 7: Example of Cross Profile and Probing Results [4]

A. Tools Needed

- Probing rods made of 16 mm (5/8”) iron rods for measuring depths of sand.
- A circular leveling tool made of a transparent hosepipe for measuring the gradients of riverbeds.
- Two long tape measures, one hanging down vertically from the horizontal one, to measure width and depth of riverbeds.
- A tripod ladder for hammering long probing rods into the sand.
- A mason hammers.
- A 20 liters jerrycan with water.
- The Probing Data Sheets [4]

Table 1: Example of Data Sheet of Probing

Example of a Data Sheet:

Measurement nr.	*Distance between measurements (m)*	*Width of riverbed (m)*	*Depth to water (m from surface)*	*Depth of the sand (m from surface)*	*Type of sand*	*Type of bedrock or soil under the sand*	*Height of the riverbank (m)*		*Items seen on the riverbanks*
							Left	Right	
1	0	20.8	-	0.5	Medium	Clay	1.5	1.9	Acacia tree
2	20	24.2	-	0.6	Fine	Clay	1.0	1.6	
3	20	28.2	-	0.7	Medium	Clay	1.4	1.84	Waterhole
4	20	25.5	0.30	1.25	Medium	Rock	1.3	1.7	
5	20	19.5	-	0.8	Coarse	Rock	1.4	1.65	Fig tree
6	20	21.3	-	0.7	Coarse	Clay	1.4	1.7	
7	20	18.6	0.8	1	Medium	Clay	1.97	1.55	
8	20	17	1.2	1.3	Coarse	Clay	1.3	1.64	Rock

B. Soil Sample Test Cadadley

This is the soil sample of Cadadley riverbed; it collected three different areas; it was collected the coarsest sand to know percentage of saturation and percentage of extraction by using these two formula:

- Saturation: Water input *100 / sand volume
- Water Extraction: Water output *100 / sand volume

Assessing the saturation capacity of the sand. Lower saturation capacity may indicate that the sand can absorb more water, which could be beneficial for water retention in the dam a higher volume of sand. A greater sand volume means there is more material available for building the dam.

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Table 2: Soil Sample Test Cadadley

Sand volume (liters)	Water input volume (Liters)	Water output Volume (Liter)	Saturation Capacity (%)	Extraction Capacity (%)
9 L	1.5L	1L	16.6%	11.1%
9 L	2L	0.45L	22.2%	5%
9 L	1.5L	0.6L	16.6%	6.6%
9 L	1.5L	1L	16.6%	11.1%

C. Probing in Cadadley

In Cadadley it has be evaluated one site which is constructed sand dams by companies AL HAYAT Dam, This site point was used probing method to evaluate the positive and negative impact of existing water infrastructure (sand dams) in dry rivers and to compare these with appraisal of sites yet to be developed that can be constructed sand and subsurface dams in Cadaadley district.

VI. RESULT

After investigation, here is the outcome and debate of the Cadadley riverbed. The results of sand dam is displayed in the tables below, along with recommendations. Areas like the kind of instruction, sand volume, water extraction test, truthing the surrounds, spill way design, and amount of runoff water from the dam were examined in the sand dam.

Table 3: Type Infrastructure of Sand Dam

Type Infrastructure	Sand Dam
Location	*Cadaadley*
Organization	*Al Hayaad (2012)*
GPS	*N9.766985 E44.679375*
Main Problems	*No wells / No Farms / Expensive / Bolders*

Table 4: Volume of Sand of Sand Dam

Volume of Sand	Sand Dam
Max width (m)	*75*
Max Depth sand (m)	*3*
Max throw back (m)	*310*
Sand volume Hudson (m3)	*11625*
Volume of Extractable water (m3)	*979,41*
Corrected for 1/6 rule (40%) (m3)	*979,41*
	1371,17

Table 5: Water Extraction Tests of Sand Dam

Water Extraction Tests	Sand Dam
Average extraction from 4 samples: (11%, 5%,	8%
6.6%, 11.1%)	

Table 6: Truthing Surroundings of Sand Dam

Truthing surroundings	Sand Dam
Leakages	Yes (see Picture 1)
North wall secured	Yes
South wall Secured	Yes
Boulders present	Yes
Material	Mason Stones and Cement
Visible floods at banks of dam	Not sure
	All of the points probed had water, the highest
Ground water level presence	groundwater level was slightly over 2m from the
	impermeable rock layer. However, this togga
	had just recharged (2 weeks prior to probing, it

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	had rained for 2 days)
Deepest point for a well	GPS N9.767154 E 44.681043 (Probe 11)
Cost Benefit Analysis	N/A
Estimate cost of cement (USD) per 1m3	195
Length of dam (m)	40
Width of dam (m)	0.8
Height of dam (m)	2
Volume cement needed (m3)	64
Total cost of cement (USD)	12,480
Cost benefit analysis (Cost for 1m3 of water) USD	12.74

Table 7: Spillway Design of Sand Dam

Spillway Design	**Its Height (1,50m), and should have been Twice**
	as long, or twice as high on either side.
Flood Discharge Factor (F)	350
Rainfall Intensity Factor (R)	0,20
Topographical Factors T=(a+b+c)	0,80
(a) Vegetation	0,25
(b) Soil type	0,40
(c) Slope	0,15
Average Slope	11%
Slope a	12,56
Slope b	10,05
Gradient over whole watershed	11,45
Spillway calculation meters length (m)	56,00
Spillway calculation (height)	?
Actual Spillway (length) (m)	32,00
Actual Spillway height (m)	1,5
Conclusion Spillway	Spillway for this dam is too short in comparison
	to other dams.
Volume of runoff water from the dam	
volume of run off from watershed (km3)	0,402
volume of run off from watershed (m3)	402000000
Percentage of run-off water captured by dam	0,024%
Cost of 1m3 of water (USD) for this dam	20,42
Cost of 1m3 of water (USD) for this dam (correcred)	14,59

Fig 8(i): AL HAYAT Dam Sideview

Fig 8(ii): AL HAYAT Dam front view

Fig 8: Alhayad Dam

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VII. CONCLUSION

The Sand Dam has annual run off 300 million m3 of water in the watershed area of 67km2, the sand dam is able to harvest on 979 m3. (0.024%). With a cost of roughly $20,000 and 979m3 (979,000 liters) of water, this means that 1m3 (1000 litters) cost $20.43. This is 6.8 times the competitive price, which prices 1m3 of water at $3.00 (Erik Petersen). Or if we take the corrected measurements for 1/6 rule ($14.59 per 1m3), as well as the average cost of water across 6 villages in Somaliland ($5 for 1m3), then the price of water from this dam is still 3.5 times high-er than the competitive price.

- Benefits: The dam is ideal for temporary hand dug wells (2-3m deep) after flooding as ground-water level can be as high as 2.25m, or 30cm from the surface at certain locations. The well re-lives pressure off public wells in the town.

RECOMMENDATIONS

In ALHAYAT Sand Dam there are no wells upstream of the sand dam. There are also no Farms located upstream of the dam. This suggests that the dam was not built in a favorable lo-cation for members of the community who are not sinking wells. Secondly depth of sand is shallow 3m. Judging by Downstream, there are many boulders present, so prob-ably lots of underground seepage. There are no underground dikes to prevent gravity pulling water downstream in a sand-river. The waterholes will therefore dry up a few weeks after flooding.

It is recommended to construct a subsurface of soil which will stop water seeping downstream, thereby creating a larger reservoir.

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