



# Water Sector Programme Yemen

## Component 5: Support to Local Actors in Water Scarce Regions for Sustainable Management of Water Resources on Community Level

### Evaluation of the Water Resources Management Situation in Selected Districts of Amran Governorate

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## LIST OF ABBREVIATIONS

BGR	German Geological Survey
GAREWS	General Authority for Rural Water Supply Projects
GTZ	German Technical Co-operation
NWRA	National Water Resources Authority
RWSSP	Rural Water Supply and Sanitation Project
SFD	Social Fund for Development
UNDP	United Nations Development Program
WUA	Water Users Association

# 1 DESCRIPTION OF THE AREA

## 1.1 Size and Location

The area of this study includes four of the northern districts of Amran Governorate, which are, from west to east: Sawdah, Khamer, Kharef and Theibin. This area overlaps with that included in the DHV/UNDP (1993) report and World Bank (1996), both of which were limited to a 30 km long area occupying the central southern part of the current study, which is referred to as the Qaa' Al Bawn and its' subsidiary valley Qaa' Al Hamidah. This study includes part of the northern catchment surrounding Qaa' Al Bawn, and parts of the adjacent catchments to the west and north.

## 1.2 Rainfall

Figure 2 shows the average monthly rainfall from data in Table 2. Rainfall occurs mainly in March-April and in July-August and is related to the advance and retreat of the Inter-Tropical Convergence Zone. Storm events are typically short, intense and localized. Annual rainfall totals vary significantly from year to year and from location to location.

Table 1: Annual Rainfall Data for the meteorological and rainfall stations in the Amran Basin (from NWRA / BGR, 2007)

Name (availability from - to)	UTM-E	UTM-N	ALT	Average Rainfall (mm/a)	Max (mm/a)	Min (mm/a)
Bawn (1979-1987)	394600	1742700	2200	250	No data	No data
Al-Jannat (1976-1981)	386700	1734250	2250	241	No data	No data
Raydah (1976-1982; 2005-2006)	397100	1748600	2190	252	No data	No data
Shibam (1975-1991)	381700	1715787	2600	337	508	189
Hamedah (2006)	389433	1750331	2219	211	211	211
<b>Mean annual rainfall</b>				258		

Table 2: Average Monthly Rainfall for the meteorological and rainfall stations in the Amran Basin (from NWRA / BGR, 2007)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Bawn	7.0	13.0	39.0	31.0	36.0	2.0	38.0	55.0	6.0	10.0	5.0	8.0
Al-Jannat	4.0	1.4	26.4	34.0	24.8	11.8	17.7	78.9	16.5	20.4	4.8	0.0
Raydah	3.5	1.5	21.5	35.3	43.2	4.0	39.1	87.7	13.2	0.0	2.2	0.4
Shibam	3.7	9.5	36.8	82.5	46.2	25.9	70.7	101.0	11.2	7.5	5.0	5.0

It was intended that detailed daily rainfall data for the study area would be obtained prior to preparing this report, and that the data would have been

analyzed and key observations discussed within the report. However, data has not become available at the time of writing.

In the absence of detailed rainfall records for northern Amran, it is intended that rainfall is measured by the project for a period of 12 months to provide detailed local information. Up to twenty rain gauges and a meteorological station are planned to be installed by the project in the project area. This will permit the evaluation of actual rainfall, estimation of Potential Evapotranspiration and provide basic data that could be used in subsequent water balance estimates.

The planned detailed long-term monitoring should clarify the amount of rainfall available for the project area and provide valuable data regarding losses from evaporation from open storage such as cisterns and dams as well as likely 'losses' from crops.

The average annual rainfall for the recording stations noted in Table 1, which are mainly located in the southern part of the governorate is 258mm. The total amount of rainfall generally decreases with a decrease in altitude and from south to north. The definition of an arid climate is usually taken as less than 250mm per annum, which would include most, if not all, of the project area.

### **1.3 Geology**

The geology of the Amran basin comprises a faulted basin filled with Quaternary alluvium. The mountains forming the western and northern edges of the Qaa' comprise Jurassic limestones overlain at the far western edge of the basin by sandstones, while those to the east and south comprise Quaternary basalts and volcanics. Well logs show the alluvium of the Qaa' is 'interbedded' in places with layers of basalt which may be extensions of laccoliths in the limestones or may be subsurface continuations of the lava flows observed at the surface along the southern and eastern edge of the Qaa'. The thickness of the basalt along the eastern and southern edges of the Qaa' may not be great as in places limestone can be seen beneath the basalt.

### **1.4 Surface Water**

Surface water occurs locally as both permanently flowing streams (ghayl) and as ephemeral streams that only flow a few times a year during heavy rains (sayl). Ghayl are quite rare in the project area, and where they do occur they are locally important for domestic water supply and irrigation. One such valley in the Amran Basin that is fed by ghayl descends from beneath Thulaa' village (Photo 1). Ephemeral sayl flows occur in almost all valley locations several times during the two rainy seasons.

The land surfaces in the study area are designated into runoff and run-on areas. Water rights to flows from the runoff areas are specifically attached to fields in the run-on areas except in the largest valley catchments. Structures are built on the runoff areas to catch the rains as a 'sayl' and direct it onto specific fields. The hill on the left of Photo 2 has lines that descend the hill towards the fields in the valley. These lines comprise small 'grips' or furrows that guide the water to the field. In valleys with larger catchments channels are often constructed to divert the sayl to fields adjacent to the valley floor with local management practices.

## 1.5 Groundwater

The rainfall distribution results in the valleys feeding from the south and west of the Qaa' contributing to it more water than those from the opposite side. North of the Qaa' valleys to the west of the catchment divide that flow the Red Sea tend to have higher rainfall than those that drain to the eastern deserts.

Water arrives at the Qaa', in order of decreasing importance, via groundwater flow in the alluvial sediments of the peripheral valleys, via surface flows from the same valleys (referred to as 'sayl') and via direct rainfall on the Qaa'. The water is stored in the subsurface sediments of the Qaa' and, prior to the onset of significant groundwater abstraction, flowed in a northerly direction, finally exiting from the study area towards Al Jawf.

The most significant groundwater resources in the catchment surrounding the Qaa' are the valleys that feed into it. Where sediments accumulate in these valleys, there is potential for subsurface storage of groundwater. The larger the catchment of any individual valley, the larger the potential supply of water for storage to it becomes. The larger the volume of the alluvial sediments in the valley, the greater the potential groundwater storage capacity becomes. This is because, generally speaking, the intergranular space for storing water in loose sediment of coarse silt / fine sand size or greater is more than in the storage space in joints and fissures of a consolidated rock.

In a limestone such as that occurring in the Amran valley there is the potential for large subsurface caverns to develop through dissolution by groundwater which could therefore increase the storage capacity of the limestone. However there is no evidence of such cavern development in the Amran Limestone. It should also be pointed out that the occurrence of deep, wide sediment-filled valleys is limited, both in the catchment surrounding the Qaa' even more so in the watersheds beyond, that make up the greater part of the study area.

## 1.6 Wells

BGR made an inventory of the wells in the Amran basin in 2002. The inventory states that a total of 2565 wells are located within the Amran Basin. Of these, 1850 wells are located in Qaa' al Bawn and 715 are located outside of the Qaa'. Most of these wells are sited in valley locations where alluvial sediments have accumulated, as described above.

Approximately 50% of the wells in the BGR inventory are now non-operational, 25% of which are recorded as being non-operational because they have gone dry. The main reason wells have gone dry in the Qaa' is declining groundwater levels resulting from increased abstraction. This decline is of the order of 4m per year over the past 15 years.

## 2 SECTORAL WATER USE

### 2.1 Agricultural Sector

Different types of farming have been developed to suit the variations in rainfall distribution, geology and topography in the area. The runoff areas described above are usually designated as grazing areas whilst the run-on areas are used for growing crops such as sorghum following the rainy season(s).

More permanent water supplies, such as ghayl, are typically used for cultivation of more permanent plants such as qat and fruit trees. Access to wells also permits cultivation of crops outside the rainy season(s) such as winter wheat and barley as well as qat and fruit.

It is estimated that well over 90% of the available surface and subsurface water is used for agriculture. However, it should be pointed out that because of the low rainfall in this arid highland area, and the absence of alluvial deposits providing a significant aquifer, the quantity of water available for agriculture is still very limited.

### 2.2 Domestic Sector

To appreciate the water resources management situation in Amran outside of Qaa' al Bawn it is important to understand that at least 10 times as much water is used for agriculture as that used for domestic purposes. Even so, the economic returns on that water in terms of agricultural production are meager outside the Qaa' because the amount of water available to agriculture is not sufficient to irrigate any significant proportion of the land. This is the stark reality that it takes 1m<sup>3</sup> of water to produce 1kg of grain or to provide 50 people with domestic water for a day.

The main sources of domestic water supplies are, in order of decreasing importance:

- Cisterns
- Pumped village supply schemes from wells
- Tankers
- Dams

#### 2.2.1 Cisterns

The traditional solution to domestic water supply needs in villages is the construction of cisterns (Photo 5). Water is directed by dug channels from hillsides to a collecting cistern. Before reaching the cistern water is directed through a stilling pit constructed to facilitate the deposition of sediment carried in the water. This reduces the amount of sedimentation in the cistern itself. Maintenance is simple, and includes cleaning out the stilling pit and less frequent cleaning out of the cistern itself. Evaporation occurs whenever there is water in the cistern reducing supply and village boys commonly swim in the cistern resulting in various public health risks.

There is potential for the cleaning and restoration of existing cisterns and also for the siting and construction of new ones, though these evaporation and health issues should also be addressed.

Although some of the domestic water needs are met by the tanker supplies as discussed above, most people in the villages and countryside depend on women to carry water from the nearest well (Photo 3). The wells from which they collect are typically owned by farmers and are used primarily for irrigation. The women are allowed to fill up reused plastic containers from a standpipe / tap at the wellhead. In many cases the standpipe is from the cooling water bypass from the wellhead with potential lubricant and fuel contamination.

Although this situation is alleviated where there are village domestic water supply schemes the absence or failure of schemes results in a continued dependence on water being hand carried from wells. Due to the scarce groundwater resources of this area the distance to the nearest well is often quite significant. Large quantities are carried on women's heads or by donkey, typically 10 to 20 litres, and wheel barrows are used in addition where the terrain allows. There is no requirement for increased public awareness of the need for careful use of this water.

### **2.2.2 Pumped supply schemes from wells**

One perceived solution to the need for domestic water supply in rural areas is the provision of pumped village supply schemes. These generally require a drilled and partially cased well, a pump and motor, a rising main with valves and meters, a storage tank and if possible a network to house connections with or (usually) without meters.

Domestic supply schemes in villages generally do not include sanitation provision except unlined cess pits (bayaara, Photo 4), which are sometimes shared. House sewers sometimes lead directly to the nearest street or wadi. The result is an immediate public health hazard and a potential longer term problem of pollution of groundwater resources as the effluent seeps into the water table. Many villages have no pumped village supply schemes.

### **2.2.3 Tankered Water**

Large quantities of water are also transferred to homes from groundwater via wells and then tankers to be used for various purposes. A survey of water tankers was conducted during January 2008 as part of Component Four of the overall GTZ project. Although the survey was carried out in the districts which share the Qaa' al Bawn, some of the project districts extend beyond the Qaa', as did the survey (e.g. Theibin and Kharef). The survey gave an indicator of the quantities of water being transferred from different locations and for different uses. The survey was conducted amongst well owners who supplied tankers as well as the tanker drivers. The average price of water delivered more than 2km from the well is around 500 to 600YER/m<sup>3</sup>.

Figure 2 shows the quantity of water delivered from well to tanker by districts in Qaa' al Bawn and Figure 3 the distance the water is delivered. The quantity of water transferred from Qaa' al Bawn to the districts in the project area is shown in Table 3. The quantity delivered according to sectoral use for the Amran Basin as

a whole is shown in Table 4. The significant proportion of water being moved by distances of more than 2 or 3 km generally indicated that the water was leaving the Qaa'. Because of the relatively steep climbs involved these transfers were generally made by the more powerful tankers such as Isuzu trucks.

Table 3. The quantity of water transferred by tanker from Qaa' al Bawn between the districts in the project area.

From	To	Quantity (m <sup>3</sup> /day)
Rayda	Xamr	204
Rayda	Xaarif	69
Xaarif	Thibiin	10

Table 4. The amount of water being transferred by tanker for various uses (well owner estimates):

Use	Domestic	Qat	Other Agriculture	Other
m <sup>3</sup> /day	2,009	2,311	189	18
% use	44.4	51.0	4.2	0.4

The total transfer by tanker from the Amran Basin is estimated at around 6,000 m<sup>3</sup>/day. The largest proportion (around 51%) is for irrigating qat and the second largest is for domestic use (around 44%). The remainder is used for other agricultural products. The proportion transferred for domestic purposes is equivalent to the supply for around 150,000 people. This assumes they are supplied at a rate of 20litres/capita/day, which is fairly typical in rural areas in Yemen (World Bank; 1996).

The total population of the districts that make up the Amran basin (not just the project area) is 472,000, so at 20 lcd this equates to 32% of the population being supplied by tanker with water for domestic use. However, much of Amran City is supplied by the Amran supply scheme and people in the Qaa' can obtain water from their own wells. So the proportion of people in the rural sector dependent on water tankers for the supply of water for domestic use is likely to be higher, probably around 50%. The amount of water transferred by tanker for domestic use in the Amran Basin relative to the amount abstracted from wells for irrigation indicates that around 50% of the population uses only 1% of the total abstraction from the basin.

#### 2.2.4 Dams

Dams are probably the largest public capital investment in water infrastructure in the Amran area and are certainly the largest in terms of water quantity provided in the rural area. However the record of water storage in dams in the area indicates that very little water is actually stored for the dry season (Photo 6). Siting of dams, quality of construction, significant silting and high evaporation from their large surface area all contribute to the ineffectiveness of dams. Where water does become available by collection in a dam, unless the water rights of downstream users whose flow is impacted by the dam were addressed prior to construction there is potential for conflict and equity problems.

## **2.3 Municipal and Industrial Sectors**

There is no water used in the municipal sector outside of Qaa' al Bawn and practically none in the industrial sector.

## **3 GOVERNMENT AND DONOR ACTIVITIES IN WATER SECTOR**

### **3.1 Actors**

Several government agencies operate in the water sector in rural areas that are based in the Amran Governorate. Some of these are part-funded by foreign donors. These agencies include:

- The Governorate
- GAREWS
- RWSS
- SFD
- NWRA
- Public Works Project
- Ministry of Agriculture and Irrigation

Donors include:

- World Bank
- UNDP
- Dutch Aid
- GTZ

The main government representation at the local level is the Local Council, for which there is one in each of the four districts within the study area.

The main activities carried out by the agencies include the construction of village public domestic water supply schemes (mainly GAREWS). Due to the failure of many such schemes in the past, but not necessarily those by GAREWS, due to administrative and other problems (see below), the Rural Water Supply and Sanitation project (RWSS) have been involved in trying to establish the sustainability of new projects by ensuring that effective project administration is implemented. The rehabilitation of cisterns and in some cases the construction of new ones has been a major part of the work of the Social Fund for Development (SFD).

Dams have also been constructed in the rural areas of the Amran governorate by government agencies, particularly the Ministry of Agriculture and Irrigation. They have also developed detailed designs for several dams, but are waiting funding for them. The Ministry of Public Works is also active in the governorate in major construction works. Government road construction has led to easier access for tankers to wells and villages. NWRA have been involved in the process of issuing drilling permits.

The Agriculture and Irrigation office have also been involved in setting up model farms using modern irrigation methods, increasing public awareness regarding these methods and providing subsidies to farmers implementing those methods.

Some of the causes of failed projects have been related to lack of coordination between the implementing and receiving organizations. However more recently there have been significant attempts to address this situation. In particular a Water Management Committee has been established at Governorate level with a Technical sub-committee and an Information sub-committee. The committee has

developed a five year plan with prioritized projects which is also broken down into yearly aims.

The governor has intervened in the water sector directly on several occasions. Once was the unsuccessful order for the termination of pumping from a well adjacent to an Amran public supply well. In early April 2008 the cessation of water transfers by large tankers (which typically supply qat) was also ordered.

Despite these progressive administrative developments the water resources management issues described in the next section continue to prevail.

## **4 WATER RESOURCES MANAGEMENT ISSUES**

In a recent survey of Local Councils and government agencies working in the area, carried out for component four of the GTZ project, the two main issues affecting water resources management in Amran were identified as;

- illegal drilling and,
- failed village domestic supply schemes

### **4.1 Illegal Drilling**

Illegal drilling is particularly a problem in Qaa' al Bawn, where many wells are located in very close proximity. Interference effects of wells drilled too close to one another can result in individual wells becoming dry due to abstraction from deeper nearby wells. In the more mountainous parts that comprise most of the study area this issue is less important because there are fewer wells.

### **4.2 Failed Village Water Supply Projects**

The second main issue mentioned by Local Councils was that of failed village domestic water supply schemes. There were many reasons for the failure of the schemes which included:

- Wells that ran dry
- Schemes seized by individuals who turned them to their own use
- Pump and motor failure / lack of adequate operation and maintenance
- Schemes that were not finished
- Schemes that were never planned to be completed
- Schemes that have been recorded as implemented at the Governorate, but in fact have not been in the field

Most of the causes of project failure could have been overcome at the planning stage if adequate administrative measures had been included to ensure project sustainability. The only exception was in the case of wells running dry, a problem which could have been determined at the field investigation stage and the problem possibly rectified.

The adequate administrative measures to ensure sustainability mentioned above include:

- Local Council involvement at the project planning stage and during implementation rather than the projects being set up by agencies with particular individuals
- Local council budgets earmarked to cover involvement in project implementation
- Financial transparency concerning all persons involved in each stage of a project from donor to recipient
- Clear division of responsibility during all stages of the project and clear ownership, handover and signoff of projects by all involved

- Thorough commissioning of projects including the issuing of equipment guarantees and the deferment of contractor final payments until after commissioning and in some cases until a trial period is completed
- Project administration to ensure self-financing of a project, at least after implementation (for operation and maintenance) if not covering capital costs as well
- Setting up of a water-user association (WUA) as the ultimate benefactor responsible for the scheme
- Adequate provision for WUA/public complaints regarding unprofessional workmanship, lack of financial transparency to be heard, investigated and if necessary penalized

### **4.3 Other Measures**

Due to the unsustainability demonstrated in the donor and government initiatives in rural domestic water supply projects to date, it is unlikely that any significant changes will occur in the long term in the way water resources are mismanaged at present. However, if the underlying causes of unsustainability listed above were to be seriously addressed, that situation could change. In the meantime, there are some other less important measures that could contribute to improving the situation in this sector. These are improving or modernizing irrigation methods in the agricultural sector reuse of grey water in domestic settings and household rainwater harvesting.

#### **4.3.1 Modern Irrigation**

There are often mentioned amongst government agencies in the Amran governorate and local councils regarding the supposed benefits that could be reaped if modern irrigation techniques were to be introduced. However, a few factors should be noted regarding their efficacy.

- The savings in water by using drip irrigation as opposed to flooding the field have been questioned (Perry, C; in preparation).
- Any savings in water used in an area where there is an abundance of land that is not irrigated, such as occurs in the districts under consideration, is likely to be used in irrigating that land.
- A private well owner is more likely to use his water for his purposes rather than sell it to the domestic sector. However, this latter point would be worth investigating further.

#### **4.3.2 Greywater reuse**

Several methods of greywater reuse have been investigated in Yemen. One which was carried out under the World Bank was the reuse of water from mosques which had been used for wuduu' (washing before prayers) was reused for irrigation. The project found that it was much more likely to be successful if the mosque owned the garden being irrigated (miqshaama) and if any other costs involved, such as pumping, had been agreed between the mosque and the operator of the garden.

The reuse of water from sanitation schemes for municipal gardens/road verges is being undertaken in Amran. However, the applicability of this system in the rural areas is limited, where the cost of wastewater treatment for small communities or transport or reuse water from a central scheme is likely to be prohibitive.

Another possibility for reusing greywater is from individual households (washing that has not used soap) for cultivating vegetables in small gardens. This has been tried in Yemen and been found to be relatively successful.

### 4.3.3 Household Rainwater harvesting

There are some schemes to capture rainwater from house rooftops and store it for use in irrigating household gardens or for domestic purposes. The SFD has been involved in developing these small schemes.

## 4.4 Two Bigger Sector Issues

There are two larger, overarching issues that are generally not addressed by water resources management deliberations in Yemen. They are diesel prices and population growth.

### 4.4.1 Diesel Prices

Low diesel prices due to government subsidization continue to provide an effective subsidy for irrigation. The energy costs of pumping typically limit the depth from which water can be lifted relative to the value of the use to which the water is subsequently put. Where global diesel prices prevail 300 metres is a typical maximum economic pumping height/depth for irrigation. In Yemen this economic signal is not apparent and this constraint to irrigation is not felt and wells in excess of 500 metres are drilled and used for irrigation purposes. As a result water is not forced to higher value uses such as the domestic sector.

### 4.4.2 Population Growth

Yemen's national population growth rate is estimated at 3.46% in the World Factbook (CIA, 2007) while the national capital Sana'a has an estimated growth rate of 7% (World Bank, 2003).

Table 5 Population statistics for the districts in the study area from the censuses of 1994 and 2004 and % population increase that this represents

District	Population 1994	Population 2004	% annual growth
Sawdah	31,009	32,169	0.4
Kharef	40,406	45,977	1.3
Theibin	26,474	30,799	1.5
Khamer	69,110	73,225	0.57
<b>Total</b>	<b>166,999</b>	<b>182,170</b>	<b>0.88</b>

The average growth of these four districts of 0.88% is less than half the rate for the governorate as a whole. This may reflect the relative poverty of these districts but is more likely due to population movement to cities where jobs are perceived as more available. It is noted that the two districts outside the Qaa' are show a much smaller annual growth in population than those with a portion in the Qaa'.

The population growth rate is the most powerful driver of water demand in the domestic sector; however, as a factor in water resources management, it usually remains unaddressed.

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## ANNEXES

# ANNEX 1

## Figures

Figure 1 Average Monthly Rainfall from the four stations referred to Table 2

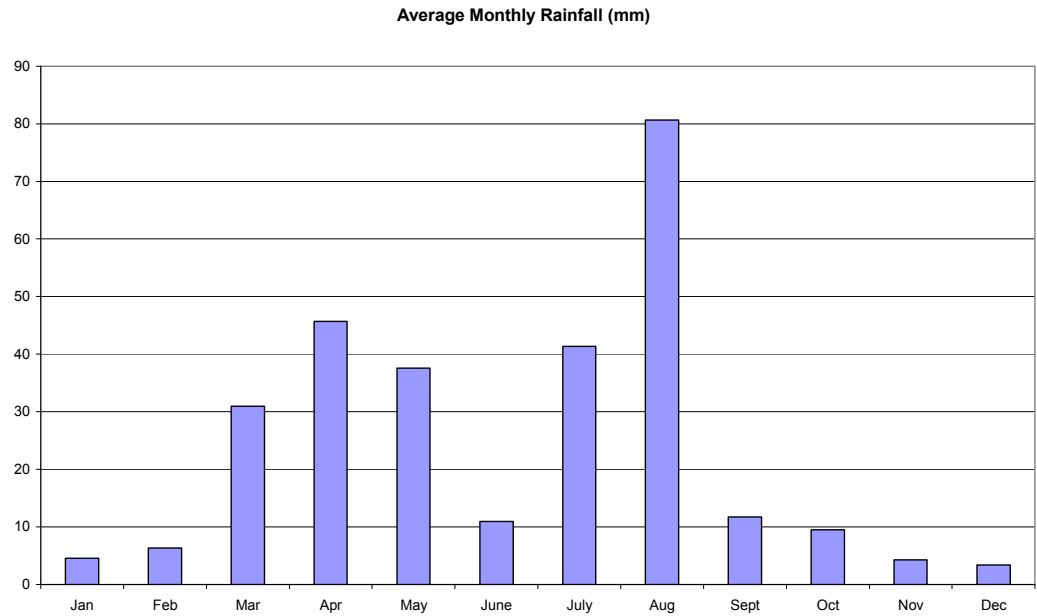


Figure 2 Quantity of water supplied by tankers for domestic use and for irrigating qat by district in the Amran Basin

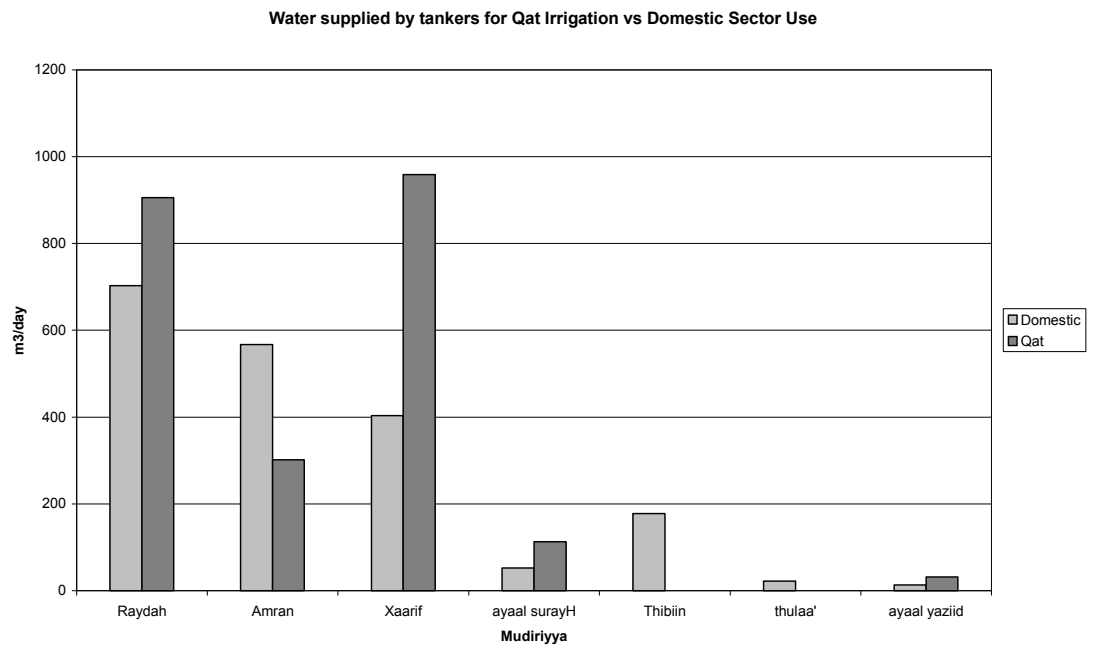
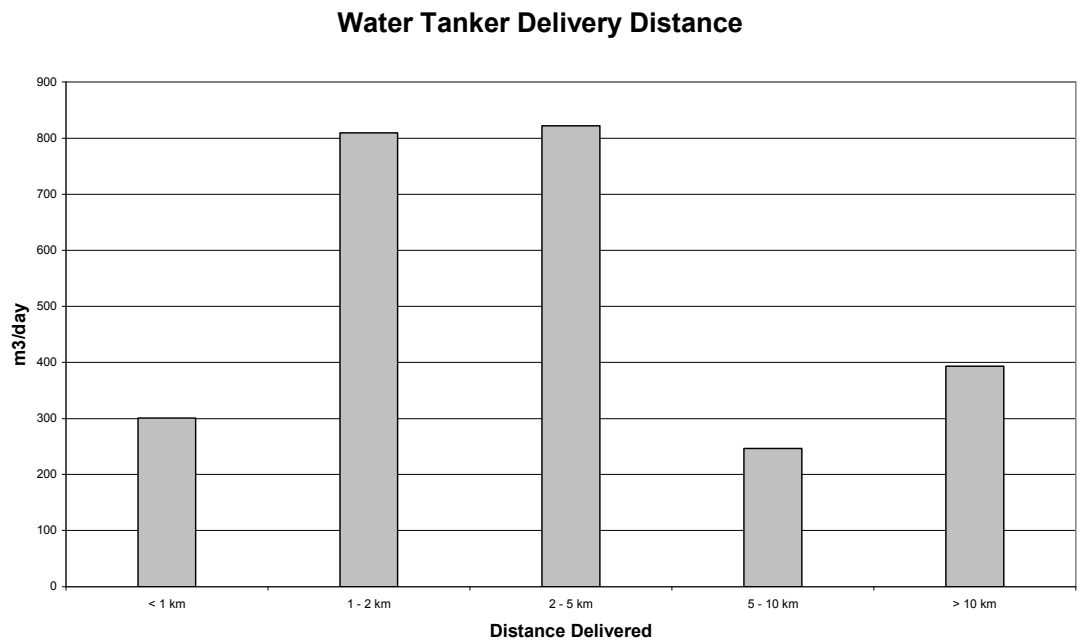


Figure 3 Distance water is delivered by tanker in the Amran Basin



## ANNEX 2

### Photos



Photo 1 A valley that is fed by ghayl, descending from beneath Thulaa' village



Photo 2 The hill on the left has lines that descend the hill towards the fields in the valley. These lines comprise small furrows that guide the water to the field.



Photo 3 Most people in the villages and countryside depend on women to carry water from the nearest well.



Photo 4 Cistern and approach channel, Theibin.



Photo 5 Cess pit (bayaara) being excavated next to the house. It will be unlined, but covered when finished



Photo 6 Dam without any water with two women in the distance carrying water to the village from a well 2km away.