Domestic water supply options in Gezira irrigation scheme

EIMAN FADUL and BOB REED

The Gezira irrigation scheme in Sudan is one of the largest in Africa and contains over 1,200 unregistered and illegal villages that are home to immigrant agricultural workers. The majority have no source of clean domestic water supply, frequently relying on nearby irrigation water for all their needs. Over 50 per cent of the population are infected with schistosomiasis and other water-borne diseases. This paper examines the problems in one such village, Taweel, and suggests options for improving the supply.

After discussing the physical and institutional environment governing water supply, the paper reviews the status of other water supply schemes in the area. It shows that many are in a poor condition because of lack of funding, insufficient staff and poor consideration of operation and maintenance. A review of possible water supply options suggests three possible solutions: a pipeline from a borehole in a nearby village; simple treatment of the irrigation water flowing through the village; and the construction of an infiltration gallery in a nearby main irrigation canal. The paper concludes that there is insufficient information available to make a final decision on the best option but the proposals can form the foundation for further data collection and stakeholder consultation.

Keywords: water supply, infiltration gallery, domestic water treatment, schistosomiasis control, Gezira irrigation scheme, sustainability

> The Gezira in Sudan is one of the largest irrigated agricultural schemes in Africa under one management

The Gezira Irrigation Scheme in Sudan is one of the largest irrigated agricultural schemes in Africa under one management (2.2 million ha). The scheme lies in the central part of Sudan, located in the triangle between the Blue Nile and White Nile south of Khartoum. The area is irrigated by gravity through a dense canal network (over 18,000 km) from the Sennar Dam, 250 km to the south of Khartoum on the Blue Nile (Babiker et al., 1985) (Figure 1)

There are more than 1,200 unregistered villages in the area, inhabited by agricultural workers who immigrated from Western Sudan or neighbouring countries. The majority of them have no adequate

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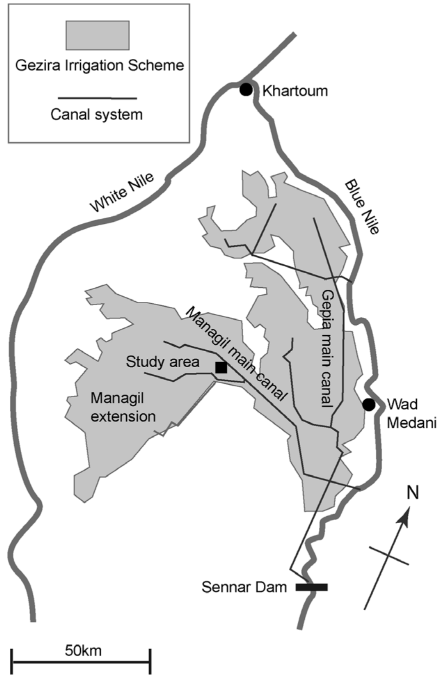


Figure 1 Gezira Irrigation Scheme and location of study area

There is a need to find an appropriate alternative water supply which fits the local circumstances

source of water supply. In most cases the situation is exacerbated by the fact that their settlements are considered illegal (Babiker et al., 1985). These villages are highly infected by schistosomiasis (exceeds 50 per cent in the scheme area) owing to the use of infected water from irrigation canals for domestic water supply and daily activities. There is a need to find an appropriate alternative water supply which fits the local circumstances.

This paper discusses the water supply problems for one such village (Taweel) with the aim of suggesting options for safe, reliable drinking water using appropriate technologies which are easy to operate and maintain by the village community.

Institutional structure

There are many institutions involved in the construction, operation and maintenance of water supplies in the Gezira scheme:

- The Ministry of Irrigation and Water Resources (MOIWR) is responsible for all water affairs, and balances the water demand from the various users throughout the country. This includes

Many institutions are involved in the construction, operation and maintenance of water supplies in the Gezira

control of water abstraction, operation and maintenance of irrigation structures and drinking water facilities, among others.

- The National Water Corporation (NWC) is the main body responsible for water supply in the country. It provides the engineers, technicians, funding for construction and monitoring of water services. After construction, the water system is handed to the rural councils.
- Rural councils are responsible for the management, operation and maintenance of the water services in all but the largest of towns. They are poorly funded and have limited technical staff. They generally control their systems using three government officials: a clerk, guard and operator. The NWC instructs them on how to run the water service with respect to opening hours and water prices. Community involvement is limited and is left to the initiative of the clerk. This lack of local institutionalized involvement has led to schemes that are not effective at responding to local conditions. Some council have become aware of this problem and have started involving the community in the management of water services.
- The Water and Environmental Sanitation programme (WES) is a programme supported by UNICEF and implemented jointly with the Government of Sudan and other collaborating agencies. It gives priority to the adoption of affordable, simple, appropriate and low cost technology options and uses the provision of safe drinking water as a lever to promote environmental sanitation and personal hygiene. WES facilitates the creation of new sources for community water supply, the rehabilitation of the old/defunct water sources and the establishment of community-based operation and maintenance systems.
- NGOs such as Qatar Charitable and Al Sugya Charitable Organization provide drinking water in the rural areas of Sudan.

Water resources

The Gezira irrigation scheme is constructed on a generally flat plain covered by clays. The area is semi-arid, characterized by hot dry summers (April–October) and cold dry winters (November–March). The regional geology consists of three formations:

- basement complex where groundwater is hardly found;
- Nubian rock formations which directly overlay the basement complex and cover most of Gezira state; they are a major aquifer; and
- the Gezira formation, which is composed of unconsolidated gravel, sand, silt and clay and represents the uppermost part of the geologic succession; this is also a good aquifer.

Water resources in the scheme are surface water, groundwater and rainwater

Water resources in the scheme are surface water, groundwater and rainwater. The geological structure is the determining factor for the type of supply used (WHO, 2004). Most drinking water in Gezira comes from the Gezira formation using a network of boreholes and shallow wells (Omer, 1983).

The other common source is surface water from the irrigation scheme. This is fed from the Sennar dam on the Blue Nile River. The dam has a capacity of 0.6 km^3 mainly for the purpose of flood control and to provide storage for irrigation water for the whole year. The Blue Nile River has high turbidity during the rainy season but its water quality is considered chemically fit for human and animal consumption; however, bacteriologically it is unsafe and must be treated (Hassan, 2007).

Haffirs store water from surface runoff during the rainy season

There are no springs or natural surface water resources within the scheme area; however, rainwater harvesting is popular. The mean annual rainfall varies from 200 mm/year in the north to 400 mm/year in the south mainly during June and September (Babiker et al., 1985). Large earthen reservoirs (locally called *haffirs*) are constructed to store water from surface runoff during the rainy season. The *haffirs* can be natural or man made and are mainly found in areas underlined by the basement complex. *Haffirs* are usually contaminated and a source of Guinea worm disease.

Current water treatment

The technologies used for water treatment in the Gezira scheme depend on the community size. Rapid gravity pressure filters are found in towns, with operation and maintenance being run by well-trained technical staff. Funding is through a household monthly tariff, supported by NWC.

Haffir and shallow infiltration well used to abstract water

Pressure filter in towns in Gezira scheme

Slow sand filters are found in large villages and run by the rural councils. However, they lack the funds for operation and maintenance. As a result, some of the systems are no longer working.

Non-functioning slow sand filter

Water from boreholes, *haffirs* and handpumps is usually untreated

Water supplied from boreholes, *haffirs* (for larger villages), and handpumps (for small communities) is usually untreated. Boreholes and *haffirs* are usually constructed by NWC whereas handpumps are usually constructed by WES or NGOs and run by the communities themselves.

There are a large number of broken water supplies in the area. The main reasons for failure are:

- The water supply institutions have been unable to meet the commitments necessary to keep the installed facilities functioning: shortage of fuel, spare parts, technicians or the funds necessary to maintain and run the services. A large number of slow sand filters are not functioning for these reasons.
- Water charges (tariffs) are so low that they do not cover the cost of operation and maintenance.
- There is a lack of understanding of the social and economic realities of life at the local level on the part of planners.
- There is 'top-down', purely central government-initiated implementation with no consultation at local level.
- There is limited community involvement in the planning, operation and maintenance of the water services.

A comparison of different water supplies and their construction cost is shown in Table 1.

Problem statement

Taweel village is located in the Gezira scheme, Managil Extension, between latitudes 14° 20.6′ and 14° 21.1′N and longitudes 33° 0.1′ and 33° 0.39′ E. The village is constructed along either side of a canal. It is approximately 850 m long and 50 m wide. The village is surrounded by agricultural land and there is little room for expansion. People have constructed a few small local bridges across the canal to cross from one side to the other.

The village has a population of approximately 1,500 in 240 families. They were originally immigrants from Western Sudan who settled in the area 15–20 years ago. The community lacks any physical amenities and has no security of tenure. The men are agricultural workers who share their profits with the farm owners who provide the land and equipment. The average monthly income is approximately US$100 per family. Women also help in the field, as well as doing domestic work.

The village is organized such that decisions are made by the council of elders and a community committee. The council of elders are responsible for solving conflicts and social problems whereas the

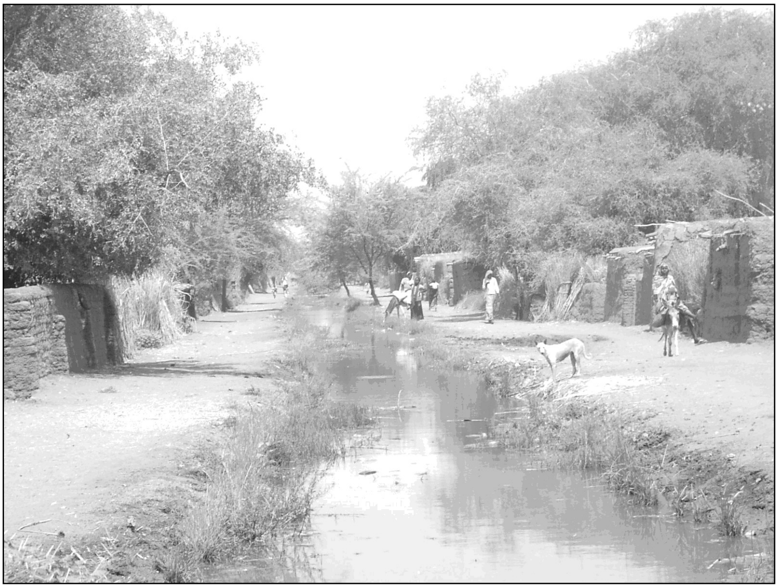
Table 1 Comparison of different water supply systems

Water source	*Benefit*	*Limitation*	*Construction cost*
Handpump on shallow borehole	Low cost Easy to operate and maintain Suitable for small communities and especially illegal settlements in Gezira scheme	Not appropriate in areas where the groundwater is absent Often cease operating because of seasonal variations in the groundwater The supply is vulnerable to surface contamination	US$3,500
Deep borehole	Efficient, reliable Water quality is good	Insufficient fuel supply due to poor funding affects regularity of power supply High initial cost (usually provided by the NWC)	$68,000
Haffir	Provides pre-sedimentation prior to filtration Large storage capacity	A slight slope near an episodic runoff channel to direct the runoff into the *haffir* Requires large area and earthworks Source of contamination and disease transmission if unprotected Uneconomical for small communities	$58,000
Local irrigation canal: direct abstraction	Accessible Free to use	Source of contamination and disease transmission Smaller canals unreliable as canal dries out for part of year	–
Irrigation canal – slow sand filter – house/yard tap	Relatively simple system using local materials Good water quality, quantity and convenience No need to use chemicals Low running costs Easy maintenance	Treatment plant requires large area and volume High initial cost (provided by the NWC) Requires regular power supply Unsuitable for high turbidity water Can be a source of contamination if not well maintained and protected	$105,000
Irrigation canal – rapid gravity filter – house/yard tap	Good water quality, quantity and convenience Suitable for large communities	High initial and running cost Technical supervision essential Uses chemicals and high power	$155,000

Source: MOIWR (2007)

community committee is responsible for representing the needs and rights of the village to the rural council.

The main water supply for the village is the irrigation canal which divides the village. This supply is very convenient as it is accessible to all families and close to their homes. However, it is unreliable: between April and May the canal is dried for maintenance purposes. During this period the women have to fetch water from the main canal 3 km away, a two way journey of around 2 hours. They carry jerry cans filled with water on their heads or use donkeys to carry the water. The raw water from the canal is used for drinking, cooking, bathing, watering animals and irrigating the fields. People have no objection to using the source even though their animals are watered just a few metres upstream of collection points. They believe that running water is clean.



Taweel village and the irrigation canal

Diseases such as typhoid, giardiasis, dysentery and schistosomiasis are common

The average per capita water consumption is 12 l/d. However this rate is substantially reduced during the times when the canal is dry to 5 l/d. These figures can be compared with the government's National Program of Action (NPA) for child survival and development which recommends a minimum of 20 litres of safe water per capita per day within one kilometre of the user's dwelling (Al Awad et al., 1985).

The health situation in the village has drawn the attention of many researchers. Diseases such as typhoid, giardiasis, dysentery and schistosomiasis are common (Henri et al., 2002). More than 70 per cent of the population in the village are infected by schistosomiasis mainly because of the use of the polluted irrigation canal water for their domestic water needs (Henri et al., 2002).

Taweel village water sources

The main reason for upgrading the water supply is to reduce the incidence of schistosomiasis

The main reason for upgrading the water supply to the village is to reduce the incidence of schistosomiasis. However, the existing supply (the canal in the village) is very convenient for most of the year and provides as much water as is required. This means that any new supply must be at least as convenient and provide at least as much water as is already taken from the canal. A summary of the possible supply options follows.

Rainwater

Household rainwater catchment is not practised in the area because of inappropriate roof design and low rainfall. Large-scale rainwater catchment in a *haffir* is also not possible because there is not enough land available to construct it. In any case, the level of service provided by a *haffir* would be lower than that currently provided by the canal so the community would be unlikely to accept it.

Groundwater

WES has made attempts to obtain groundwater in the village but has been unsuccessful as the water was found to contain high total dissolved solids, chlorides and sulphates. No attempt has been made to drill deep boreholes as the village is not large enough to justify the expense. A village 5 km away already has a deep borehole and it may be possible to use this as a source for Taweel village.

Surface water

The canal running through the village is an obvious source but would need to be treated. Unfortunately it is unreliable as it is closed for maintenance for two months each year. A large storage reservoir was considered to hold sufficient water for the dry period but, as with the *haffir*, there is insufficient land.

Approximately 3 km from the village is a larger irrigation canal that operates for the whole year. This could be a possible source.

Water supply options

A full evaluation of the options for serving the village led to the shortlisting of three. These options are not mutually exclusive and elements from each could be combined in other ways depending on the demands and capabilities of the community and institutions. Table 2 summarizes the options.

Option 1: Pipeline to nearby borehole

> The community could contribute by providing the manpower for construction

It may be possible to lay a pipeline from the borehole in the nearby village to Taweel. The pipeline would serve a series of community taps spread around the village. Estimates of construction and operating costs are shown in Table 2. The community could contribute towards construction costs by providing the manpower for construction, and institutional support would be provided by NWC. The local rural council could provide community training, scheme monitoring, technical advice and major repair inputs. Water committees in the two villages would share any maintenance and operation costs related to the pump.

The benefits of this option are that no further treatment is required, implementation could be rapid and the scheme is technically simple.

Success would depend on the borehole having sufficient yield for the two villages, the willingness of the other community to share their water and a well-managed tariff collection and scheme management system.

Option 2: Improving quality of water from the irrigation canal in the village

When water is stored for a day in safe conditions, more than 50 per cent of most bacteria die

This option is a short-term measure to provide a safe drinking water supply from an unsafe, polluted water source. The method proposed is the three pot system. The technique relies on the fact that when water is stored for a day in safe conditions, more than 50 per cent of most bacteria die and the suspended solids and some of the pathogens will settle to the bottom of the container (WHO, 2005). This technique can be expanded to a larger scale of containers to increase the flow rate for domestic use rather than drinking purposes only. A tap can easily be installed 15 cm above the bottom of the container to allow space for suspended solids settlement and to withdraw water without disturbing the sediment. Three drums are needed and every day new water is brought to the house and one drum is filled. Figure 2 illustrates the process.

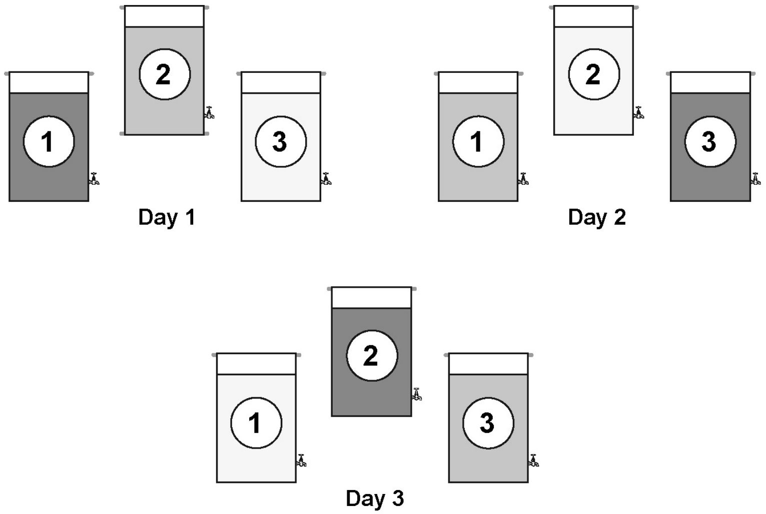
The cercariae, which act as intermediate hosts in the life-cycle of schistosomiasis, attack people who come in contact with a contaminated water source. Since they are relatively short lived (up to 48 hours), storage and settlement for at least 48 hours will eliminate them. Longer periods of storage will lead to better water quality (Ooemen et al., 1999).

Operation and maintenance of the three-pot system is one of the important aspects in this option. Time of filling and withdrawing is a key element in the success of this procedure; the time elapse between filling a drum and using it is 48 hours minimum to eliminate the cercariae. Community education and training is a very important issue.

The community should be trained to limit the contact with irrigation water

The drum containers (100 or 200 litre) are locally available so the initial cost for this option is relatively low (estimated as $28,800 for the whole village) and there is negligible cost for operation and maintenance.

Health benefits can be maximized if the community is made fully aware of the causes and effect of schistosomiasis and trained to limit their contact with irrigation water.



Day 1: Drum 1: Fill with water; Drum 2: Store water; Drum 3: Use water and clean drum
Day 2: Drum 1: Store water; Drum 2: Use water and clean drum; Drum 3: Fill with water
Day 3: Drum 1: Use water and clean drum; Drum 2: Fill with water; Drum 3: Store water

Figure 2 Storage and settlement procedure

Option 3: Infiltration gallery on the main irrigation canal

The water quality in the main canal 3 km from the village is similar to that of the village canal; however it has the advantage of running all year round. Treating the water using a slow or rapid sand filtration system is not an option because the construction and operational costs would be too high for the population size.

Filtration galleries are one of the oldest means of water treatment

A simpler alternative is to use an infiltration gallery. Infiltration galleries (IFG) are one of the oldest means of water treatment; people have long known that water quality can be improved by filtration through soils. In the UK the Romans dug collection tunnels under streams in the chalk regions of the south east (Helm, 1998). Infiltration galleries are widely found on islands in the Pacific such as the Republic of the Marshall Islands, Tarawa, Kiribati and Cook Islands. IFGs are also found in the Cocos Islands in the Indian Ocean as well as in Barbados in the Caribbean (UNEP, 1998). In Uganda an IFG was installed in a small river to provide water for a school. In India, they were used to filter highly turbid river water. In Wad Kowli, East Sudan, a 130 m long 100 mm perforated PVC pipe was installed in the bed of the Atbara River to provide water for 30,000 refugees (Helm, 1998). Although no reference has been found to IFGs being used below irrigation canals, there is no reason why they should not be considered.

The system consists of a series of perforated pipes laid in a bed of gravel below the bed of the canal. The perforated pipes are connected to a collector tank at the side of the canal from where the water is pumped to an overhead tank to gravity feed a series of communal tap stands in the village (Figure 3). Water filters through the sand in the bed of the canal into the gravel bed and hence into the perforated pipes. The canal bed acts as a filter, removing silt and much of the bacteria. If well designed it should also remove the cercariae of the schistosome.

The canal bed acts as a filter, removing silt and much of the bacteria

Although the water in the main canal has a high sediment load during the rainy season, the design of the canal allows for self-cleaning. During the 80 years of operation the canal has maintained stable dimensions and longitudinal bed slope (Younis, 2001). The infiltration pipes are laid below the canal bed so will not affect the hydraulic characteristics of the channel. The high flow rate will also continuously scour the canal bed, ensuring it does not become blocked by silt being drawn down towards the pipes.

Assuming the MOIWR gave approval for such a scheme it would still require the canal to be drained during the construction period. Sustainability would also be dependent on an efficient tariff collection system in the village to pay for fuel for the water pump, salaries for the attendants and general operation and maintenance.

Selection

Selection of the most appropriate water supply is not based purely on technical factors. Affordability, sustainability and acceptability must

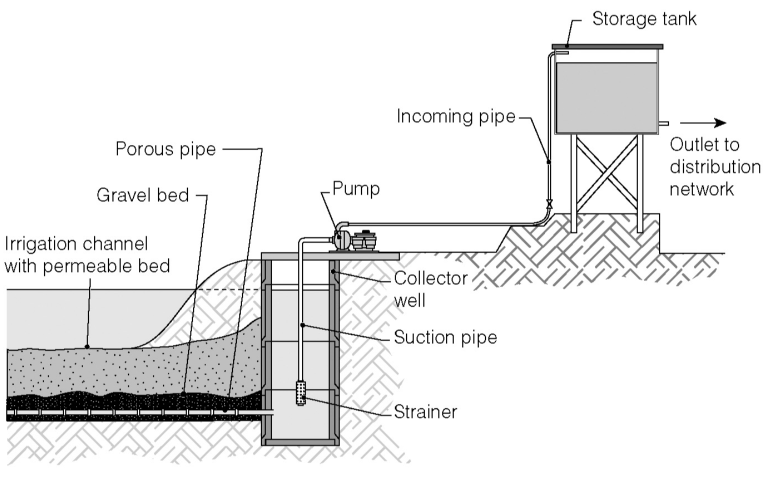


Figure 3 Sketch of the infiltration gallery layout

Affordability, sustainability and acceptability must be considered

also be considered (IRC, 2001). Affordability means that the stakeholders responsible for the construction, operation and maintenance of the scheme have the financial resources to be able to meet their responsibilities. Evidence from previous schemes suggests that, while the funding of construction has been considered, funding for operation and maintenance has not. Acceptability means that the water supplied is of appropriate quality, quantity and accessibility to meet the demands of the user community. This is particularly important in this case because of the convenience of the supply being replaced. It also means that the water must be from a source that will not give rise to conflicts with neighbouring communities. Sustainability means that systems and practices are in place to ensure the continued operation of the scheme. This is not only to ensure the generation of sufficient funds for operation and maintenance but also the provision of technical and managerial support and a ready supply of spare parts. Table 2 suggests criteria for selection of appropriate options.

Table 2 Criteria for technology selection

Option	*Affordability*			*Acceptability*	*Technical appropriateness*	*Benefits*
	Initial cost	*Yearly O&M cost*	*Yearly household tariff*			
Sharing borehole with a neighbouring village	$44,000	$5,280	$22	Likely to give rise to conflicts with neighbouring community Equitable access to the improved supply	Over-extraction may occur Depends largely on technical and institutional support for major maintenance	Increasing the quantity of available safe water Improving access to water Productive activities
Improving traditional source	$28,800	–	–	Not reliable source Time and efforts to collect water are not reduced Health risks during water collection	Short term solution No technical support is required	The cheapest option to implement Drums are locally available Changing hygiene behaviour
Infiltration gallery at main canal	$46,150	$7,656	$32	Sufficient water with good quality Reliable source Equitable access to the improved supply	Flexibility with future demand Use of local material Community involvement in the construction No environmental hazards	Sufficient water quantity 35 litre per capita per day Improving access to water Productive activities Training of community members to do regular inspection

Source: IRC (2001), WHO (2005), Helm (1998)

Next steps

The next step is to collect additional data to check that the proposed options are realistic and likely to work. They must also be costed and the requirements for making them sustainable itemized. The options can then be presented to the village community and other stakeholders for consideration.

NWC, WES, the Ministry of Health and the local rural council are also stakeholders and must be involved in the consultation. Responsibilities for funding, implementation, operation and maintenance must be clearly laid out and agreed by all parties.

Caretakers and mechanics will also require training

Once the decision has been made on which option to select, the community will require training in scheme management such as simple budgeting, financing and personnel management. Technician staff such as caretakers and mechanics will also require training (IRC, 1991).

Significant changes in social and working practices will be needed to isolate the community from the canal water

It cannot be assumed that the village will want an improved water supply. It may be necessary to undertake an extended period of community mobilization before they appreciate the benefits of a new supply. It must also be accepted that improving the water supply alone will do little to reduce the incidence of schistosomiasis in the village. Significant changes in social and working practices will be needed to isolate the community from the canal water. This will require extensive investments in time and money from health and community development specialists.

Conclusions

- Finding an affordable, safe and sustainable domestic water supply for a community that has ready access to a polluted but accepted source poses particular difficulties. Poor communities are more likely to choose a source that is convenient and plentiful but contaminated, over one that is clean but inconvenient and restricted.
- Safe, convenient and plentiful water supply options for Taweel village are very limited. Three options are suggested but all have their limitations and further work is required to establish the best solution.
- Providing a safe water supply for the village will not, on its own, significantly reduce the incidence of schistosomiasis in the village. Intense education together with changes in working practice will be needed to minimize people's contact with infected water.
- There is insufficient information available to select the best water supply option for Taweel village. The data presented will form the

foundation for further research and detailed consultation with the community, government and other stakeholders.

- An essential part of any new scheme will be building the capacity of the local community to better operate and maintain the water points and the network system through the provision of long-term technical advisory services, goods, works and training.
- Institutional support, community management, sustainable financing mechanisms and participatory approaches to planning and decision making are key elements in the sustainability of the proposal. The failure of old rural water supply schemes has been largely due to the water supply authorities' focus on technical aspects and failure to appreciate the other aspects necessary for sustainable supplies.
- The other principal cause of failure of previous schemes is the lack of consideration of operation and maintenance during project development.

Focusing on technical aspects alone results in failure

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