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## Pipe distribution systems for surface irrigation

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### 1. INTRODUCTION

This paper is based on research work carried out by the Water Engineering and Development Centre (WEDC) of Loughborough University of Technology in collaboration with the Bangladesh Agricultural Research Institute (BARI), into buried pipe distribution systems for surface irrigation. The work is being funded by the Overseas Development Administration of the UK (ODA).

Conventional surface irrigation schemes use branching networks of open channels, comprising main and secondary canals to convey the water and tertiary and quaternary canals to distribute the water to fields. A little known alternative to the tertiary canal is the buried pipe distribution system, ending in outlets from which irrigators distribute water to their fields for surface irrigation. Although low pressure pipelines are also used for conveyance, of interest here are pipe systems for irrigation distribution. They are low pressure pipe systems, that is with operating pressures not greater than 10 m and usually less than 6 m. Some medium pressure systems (with pipe working pressures greater than 10 m) are included where they supply surface irrigation schemes and have low outlet pressures.

### 2. DESCRIPTION OF A TYPICAL BURIED PIPE DISTRIBUTION SYSTEM

A typical pipe system receives water from a canal, reservoir or pump and distributes this over a command area of 10 to 100 ha via a loop or branch layout of low pressure pipes serving a number of outlets. Each outlet supplies water to a quaternary distribution system which comprises either earth channels or surface pipes or hoses. The pipeline is buried and the only above ground structures are outlets and associated outlet distribution structures, air vents, surge risers and structures at the inlet directing the water into the pipeline.

Although asbestos cement pipe has been used in some instances, pipe systems are generally constructed using either rigid plain wall uPVC or nonreinforced concrete pipe. Nonreinforced concrete pipe systems are significantly cheaper in cost, and can be made reliably by a range of methods, including low cost spinning technology (given adequate attention to the composition of the concrete mix and curing of the finished pipe). However the quality of pipeline installation and the choice of the jointing system are critical to the final performance of the pipe system. Extensive experience in the USA (Pimley et al, 1990 and Wegley, 1987) and more limited experience in India and Sri Lanka (Merriam, 1985, 1990) suggest

that tongue and groove pipe with a mortar seal appears to offer the most reliable low cost concrete pipe and joint option. Depending on the prevailing tariffs, taxes and raw material prices, uPVC pipe systems can be from 1.5 to 2 times the cost of an equivalent nonreinforced concrete pipe scheme (Bentum et al, 1991). Nevertheless uPVC pipe systems are easier to install successfully and achieve higher distribution efficiencies compared to concrete pipe equivalents.

Thin walled externally corrugated (smooth bore) uPVC pipe is a relatively new product offering considerable capital and installation cost savings over rigid plain walled uPVC pipe, particularly for pipe sizes greater than 300 mm diameter. They make the extension of the pipe distribution system beyond the tertiary level an attractive possibility. (A wide range of alternative pipe profiles are currently available and under development, and evaluation of their extensive potential for low pressure irrigation is required.) In some systems the pipe is constructed by first extruding a uPVC profile with "T" shaped configuration. Coiled rolls of this profile can be transported to site, where using portable winding equipment the profile is spirally wound to form pipes of the required diameter. The edges of the profile are mechanically fastened (locked) and glued to achieve the water tight joint.

Typical pipe diameters for low pressure pipe systems range from as small as 150 mm for uPVC pipe up to 400 mm for the larger concrete pipes. Low pressure pipe systems with larger diameter pipes exist but tend to be at secondary level rather than tertiary level.

### 3. CLASSIFICATION OF BURIED PIPE SYSTEMS

Low pressure buried pipe systems come in many forms but can be usefully categorised on the basis of pressure control (closed, semi-closed, and open), and the origin of the supply pressure (gravity, pumped, or mixed).

Where the pipeline consists of two or more hydraulically unconnected pipe sections with discontinuous hydraulic grade lines, so that water overflows from the one higher in elevation to the lower, the system is known as open. Where these simple overflow stands are replaced with float valves, which in effect hydraulically connect the pipe sections, the systems are called semi-closed. The most common situation however is where the system comprises one interconnected pipe network, with no need for the dissipation of excess head and these are called closed systems.

The choice between a loop or branching pipe layout (as shown in figure 1) will be influenced by a number of factors including the pipe material to be used and the

arrangement of the land to be irrigated.

#### 4. BURIED PIPE SYSTEMS IN AFRICA

Although the great majority of buried pipe systems built to date are to be found in the USA and south and southeast Asia, low pressure pipe systems distributing water at the tertiary level are also to be found, albeit less widely, in Africa.

The earliest use of low pressure pipe in Africa, is in the orchard irrigation systems associated with the citrus estates of southern Africa, built in the 1950's and 60's and which are still in use in a number of countries today including Swaziland, Zimbabwe and South Africa. Though many of these early systems were converted in the 1960's to medium pressure sprinkler systems to reduce the cost of labour, rising energy costs are resulting in a reversal of this trend recently, in some instances. These pipe systems used hand rammed nonreinforced concrete pipe up to 300 mm in diameter and 0.6 m length, with installation methods and system designs based on pioneering work carried out in California years earlier (Coles, 1990).

More recent interest has centred on evaluating the practicality of replacing the traditional mesqas (tertiary open channels) in Egypt with pipeline systems, (EWUP-Fort Collins Staff Team, 1983) and using pipe distribution systems as part of smallholder development programmes to generate cash income by irrigation of vegetables, in countries such as Kenya, Mali, Niger and Zimbabwe (Carter, 1989).

The main features of some of the pipe systems identified are summarised in table 1.

#### 5. OPPORTUNITIES FOR PIPE SYSTEM USE IN AFRICA

The successful use of buried pipe systems depends on careful selection of the type of system best suited to the prevailing physical, social and economic conditions. Selection and design must include the way

in which the system is to be operated and controlled, as well as its suitability for the topography and water source available. Some of the benefits of buried pipe systems which make them attractive in the African context are discussed below.

In general pipe systems are particularly attractive, where soils are coarse in texture such that high seepage losses would result from earth channels, where the command area is undulating and much of it would be out of command with an open channel system, and/or where the water supply is valuable and limited. Wherever lining of open channels is being considered, buried pipe systems may be recommended instead, because of their lower cost (see section 7), higher transit efficiencies and advantages in terms of providing a more flexible irrigation supply with a minimum of disruption during construction, and environmental benefits of eliminating the habitats of snails and mosquitoes and reducing water logging.

##### Improved Distribution Efficiency

One of more important benefits is the higher distribution efficiency possible particularly where pumping is necessary, or where the water resource is limited.

Well built concrete pipe systems have 10 to 25 % of the losses typically measured on lined channel systems and a fraction of the losses of earth channel systems. Lined channel systems are also more susceptible to damage and in many instances after only several years their performance deteriorates so that their distribution efficiencies are similar to those of earth channels (Goldsmith and Makin, 1989).

Situations in Africa where pipe systems may be attractive for this reason will include:

Areas where irrigation requires pump lift from a river or canal.

Areas irrigated from a reservoir, where higher distribution efficiencies can enable an increase

**Figure 1. Buried pipe system layout with a loop system on the left side and a branching system on the right.**



in the irrigable command area and/or intensity of irrigated crop production, without a change to the storage. It may be feasible with a pipe system to irrigate land which was previously out of command under an open channel system.

#### Ease of Construction

Buried pipe systems can be installed more quickly than open channel systems, partly because of the reduced labour involved in construction but also because of the less intensive site surveying requirements, and the reduction in delays due to disagreements on alignment and land acquisition. This can be important for minimising the delay between allocation of funding and the receipt of the first income from the development by the beneficiaries.

#### Flexibility

The transit time for water to reach an outlet is very much less for a buried pipe system than for an open channel, giving farmers greater flexibility of supply, especially where pipe systems are built with sufficient capacity, and designed to allow operational choice. This can enable more varied cropping patterns and improved water management practices to be adopted. Currently pipe systems in Africa reflect this emphasis on flexibility and improved management given their predominant use in the irrigation of higher value crops for income generation.

#### Land Saving

Buried pipe systems can reduce the land area taken by the distribution system by 0.5 to 2 % of the total command area (Bentum et al, 1991). For earth channel distribution systems this can be a very significant cost particularly where the land is valuable in terms of the crop that can be grown. In most countries in Africa land saved will not have a great value, with the exception of densely settled areas of high fertility, for example in some parts of Egypt.

#### Health and Environment

Although little specific information has been found on the environmental and health impact of buried pipe distribution systems, reduced water losses and elimination of suitable habitats for disease vectors will have a positive impact, compared to open channels. In the African situation this may be important in influencing the incidence of diseases such as schistosomiasis and malaria, particularly where the whole distribution system is piped, and irrigation is a recent introduction to the area.

Where irrigation systems are also used for domestic water supply the reduced opportunity for contamination of the water supply once in the pipe system, will result in a measurable improvement in water quality and therefore a reduction in the incidence of water borne ill-health. Improved distribution efficiencies lead to reduced environmental degradation due to waterlogging.

### 6. DESIGN AND CONSTRUCTION ISSUES

A wide range of specifications and construction practices are in use on low pressure pipe systems and designers admit to significant knowledge gaps. However opportunities exist through the sharing of information on proven aspects of the technology to reduce the cost and improve the quality and performance of the buried pipe systems currently being constructed.

Specific issues relating to the design, construction and installation of buried pipe distribution systems in an African context include:

The need for provision of an adequate sand trap at the inlet to the pipe system where river water with high suspended solids loads is the irrigation water source.

**Table 1. Summary of Pipe Systems Identified in Africa**

SI No	Location	Project	Operating Period (yrs)	Command Area (ha)	Pipe Material and size	Crops grown	Max operat pressure (m)	Pipe Length (m/ha)
1.	Algiers Algeria	Mitidja Plain	40-50	+20000	RC 0.1-0.5 m	orchard/veg	5-40	
2.	Tanta Govern Egypt	Munifiya L/P Pipeline Project	1	6x53	uPVC 0.3-0.4 m	cereals/veg	3-4	19-57
3.	Giza Govern. Egypt	El Hammami Pipeline Project	2	266	AC 0.5-0.6 m	cereals/veg	6	16
4.	Rift Valley Kenya	Amaya Project Samburu Dist.	5	20	uPVC 100-280 mm	cereal/veg	5	190
5.	Rift Valley Kenya	Lari Wendani Proj Nakuru Dist.	2	38	uPVC 140 mm	cereal/veg	5	183
6.	Lake Victoria	Nyanduzi	7	5.6	uPVC	vegetables	5	
7.	Nord Niamey Niger	FAC/BRGM	2-3	5x5	uPVC	vegetables	3-4	
8.	southern Africa	Citrus estates	30-40	vary	non RC 100-250 mm	citrus fruit	1.8	?

Note: RC = reinforced concrete; non RC = nonreinforced concrete; AC = asbestos cement

The existence of high water tables in many existing surface irrigation schemes, for example the delta and Nile margins in Egypt, make provision of dewatering and avoidance of pipe flotation necessary during pipe installation.

Because many materials including pipe, resin and cement need to be imported and often transported long distances, careful consideration needs to be made of locally available resources as part of system and pipe material selection.

## 7. PIPE SYSTEM COST

Buried pipe systems built in a range of situations and countries in all reported cases cost less than lined channel alternatives. The cost of pipe systems, ranges from 10% less than low cost ferrocement lining built in Thailand, to half the cost of brick lining systems as built in Bangladesh (Bentum et al, 1991). Similar savings could be expected for African situations.

Although earth channel systems are considered low cost, when the land take and required water control structures are included, system costs range from 30 to 50 % of comparable nonreinforced concrete pipe systems. When the higher distribution efficiency of pipe systems is taken into account so that the cost of the water supply (reservoir, tubewell or secondary canal) is spread over a larger area than pipe systems are comparable in cost per hectare to earth channel systems (Bentum et al, 1991).

The main components of the maintenance cost of buried pipe systems are repairs to leaking joints and above ground structures. Careful specification, design and construction of the pipe system can avoid most of these problems. Concrete pipe systems have the advantage that repairs are inexpensive and can generally be performed by the irrigators with a minimum of training. In common with any other infrastructural investment, effective maintenance of buried pipe systems will depend on the existence of effective community organisation and commitment.

## 8. CONCLUSIONS

Buried pipe distribution systems have not been widely used in Africa to date, but merit consideration in any of the following circumstances:

- where open channels would require lining (for example because of sandy soil)
- in undulating topography
- where water is to be pumped from the source
- where water is limited or has a high value
- where environmental problems could be reduced by the use of a buried pipe system

The main constraints on wider implementation of buried pipe distribution systems are lack of knowledge and experience of suitable design and construction methods. WEDC hopes to reduce these through the current research project and short training courses.

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