An Assessment of the Trickle Feed System as a Tool for Implementing the Free Basic Water Policy

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Water Research Commission

AN ASSESSMENT OF THE TRICKLE FEED SYSTEM AS A TOOL FOR IMPLEMENTING THE FREE BASIC WATER POLICY

Report to the Water Research Commission

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Executive Summary

Background and Motivation

In 1994 the Department of Water Affairs and Forestry (DWAF) embarked on a new White Paper policy of water supply and sanitation. This involved the provision of basic water supply to approximately 14 million people with inadequate service. Since then billions of rands have been committed to this initiative, which has included the construction of hundreds of water schemes in rural communities throughout the country. An important principle of the policy was that the service provided by these schemes was to be managed at the local level. This included the responsibility of ensuring schemes were sustainable, including adequate cost recovery for operation and maintenance.

However, the national rate of unsustainable rural community water supply schemes has been unacceptably high. This has manifested in a significantly low rate of cost recovery. Reasons for low cost recovery include:

- Culture of non payment in areas where previous schemes were subsidised.
- Low reliability of schemes.
- Inappropriate level of service.
- Demand levels lower than design supply.
- Poverty.

In October 2000 the South African government announced a policy of supplying free basic water to all.

This consisted of providing 6000 litres per month free of charge to each household. Implementation of this policy since then has been the responsibility of local governments with facilitation from the National Department of Water Affairs and Forestry (DWAF). Funding of its implementation was to be sourced from cross subsidisation within local government areas and allocation of a nationally raised 'equitable share' to local governments.

Free basic water is presently available to 59% of South Africa's population. However, more than 50% of these people are in the larger urban centres and delivery in rural areas has remained problematic. This has been due to:

- Lack of high income sectors to cross subsidise poorer sectors.
- Rural schemes have higher water wastage and losses as a percentage of total supply.
- Many rural schemes are too capitally intensive relative to existing institutional capacity.
- Lack of existing infrastructure.

Debate generated over implementation of the Free Basic Water Policy in rural communities has formulated some suggestions for its facilitation. These include:

- Implementation of basic level of service schemes which cost less to operate and maintain than funds available to local government.
- Ensure automatic control of consumption.
- Create a better understanding of consumers by Water Service Authorities.
- Provide institutional support to local government authorities.

The Trickle Feed System is a new application of technology which incorporates the first two suggestions listed above. The Trickle Feed System involves delivering a set quantity of water each day to a storage tank at each consumer's household. This allows for the application of a monthly pre-paid stepped tariff with a free basic level of service with minimal administration.

Aims and Objectives

This research project has been undertaken to assist role-players to make informed decisions with respect to the implementation of the Trickle Feed System to provide a free basic water supply of a high level of service to rural communities. This research was initially undertaken for the research project '**A Cost Recovery Analysis of the Trickle Feed Rural Community Water Supply System'** (WRC Project No: K5/1272.) The Free Basic Water Policy was announced six months after this research project commenced. The scope of the research was then expanded to include research on the use of trickle feed system to support the implementation of the free basic water. This additional research was funded under a consultancy, K8/445- '*Guidelines for using the trickle feed water supply system for the implementation of the free basic water policy'.*

The specific research objectives included the following:

- Assessment of the cost recovery efficiency of the Trickle Feed System in application for rural community water supply.
- Assessment of the Trickle Feed System as an effective tool for the implementation of the Free Basic Water Policy in rural communities.
- Identification of variables which affect the implementation of the Free Basic Water Policy in rural communities.
- To provide assessment methodologies for the variables identified for future application.
- Provide clear guidelines to role-players for utilising the Trickle Feed System.
- Building capacity in previously disadvantaged individuals and organisations through direct training and participation in this research project.

Methodology

The focus of this research is on the potential application of the Trickle Feed System. It is a new technology to community water supply application in South Africa and has not yet been tested adequately. Several other similar technologies are also available and are utilised, with research and development reports undertaken. Detailed analyses of these technologies are beyond the scope of this research.

A literature review was undertaken to put rural community water supply and cost recovery in South Africa into context. This included a review of cost recovery strategies available and identification of constraints to their implementation.

Evaluation and monitoring of five case studies (operating and not operating) was undertaken. This included capture of operation and maintenance data (if available), liaison with role-players and visits to projects. Analysis also included testing and development of various components of the technology. These case studies were:

- Tubaste Water Project, former homeland of Lebowa, Limpopo Province.
- Newtown Low Cost Housing Development, Edendale, Pietermaritzburg.
- Mseleni Water Project, Northern KwaZulu Natal.
- Kransdraai Water Project, Southern KwaZulu Natal.
- Nondayana Water Project, Northern KwaZulu Natal.

This research report includes guidelines for role-players for the appropriate transfer of this new technology. These guidelines include a description and characteristics of the technology and case studies. The guidelines were presented at two workshops to generate comments from attendees including representatives from national and local government, NGOs and the private sector.

Capacity Building

Building capacity in previously disadvantaged individuals and organisations was a significant component of monitoring and evaluation undertaken in this research project. Training and supervision was undertaken for roles such as social and institutional evaluation, meter reading, maintenance log and financial recording. A significant objective of this research project is to facilitate the appropriate transfer of this technology and benefit previously disadvantaged communities through the provision of sustainable water supply.

Description of Trickle Feed System

Trickle Feed Systems are low pressure reticulated piped networks which deliver water to household storage tanks at a constant rate. The constant flow rate is maintained by a trickle feed box installed in each household tank. The trickle feed box is a small plastic container with a volume of approximately 5 litres. Flow into the household tank first enters the trickle feed box and is controlled by a float valve. An orifice of a determined diameter controls flow out of the trickle feed box into the household tank. The water level in the trickle feed box is kept constant by the float valve, which results in a constant flow or ‘trickle’ through the orifice.

The Trickle Feed System technology is charaterised by a constant ‘trickle’ flow to distributed household storage’s independent of consumption patterns. This eliminates peak flows in the reticulation, which allows for low-pressure reticulation and reduced pipe sizes. Benefits of utilising this technology include:

- Low cost ‘higher level of service’ to consumers.
- Increased health and hygiene.
- Simple administration requirements.
- Low maintenance.
- Low losses.
- Equitable distribution.
- Increased supply security.

Constraints of the Trickle Feed System include:

- Limited daily flow.
- Reduced tolerance to contaminants.
- Potential for tampering and illegal connections.

There are several options for household tanks in a Trickle Feed System. These include *in situ* concrete tanks and plastic tanks. Concrete tanks are cheaper and labour intensive to construct. However, plastic tanks are quick to install and are not restricted in location of installation.

Compatibility of the Trickle Feed System to the Implementation of Free Basic Water

The National Department of Water Affairs and Forestry has been promoting the implementation of the Free Basic Water Policy since 2001. Implementation by local authorities, particularly in rural areas, has been constrained due to lack of adequate funds. The Trickle Feed System offers an alternative to decision-makers which has the capacity to operate within this constraint. This is due to low operation and maintenance costs, simple administration and reduced losses in a low-pressure system. However, installation of a Trickle Feed System must be an improvement in level of service to ensure community acceptance.

Conclusions and Recommendations

The Trickle Feed System is a new technology for application to community water supply in South Africa. It has not yet been adequately tested, particularly in the implementation of the Free Basic Water Policy in rural communities. However, several urban and rural case studies investigated in this research project indicate that the trickle feed system is successful in the delivery of a consistent, high level of service.

Development of free basic water strategies is facilitated by lower costs of implementation, operation and maintenance. These strategies are also facilitated by simple and adaptable systems which deliver equitable and consistent supply to consumers. These variables have been evident in the trickle feed system case studies investigated.

However, community acceptance of trickle feed systems may not be positive if it is perceived as a decrease in level of service. This was a significant factor indicated in several case studies, particularly where community expectations are affected by existing or adjacent water supply services.

It is strongly recommended that further research is undertaken to develop the Trickle Feed System as an option for rural community water supply. Areas of further research include:

- Operation and maintenance costs.
- Household tank options.
- Consumer acceptance.
- Free Basic Water Strategies.

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1.0 Introduction

In 1994 the national Department of Water Affairs and Forestry (DWAF) embarked on a new White Paper policy of water supply and sanitation. This included the provision of basic water supply to approximately 14 million people with inadequate service. Since then billions of rands have been committed to this initiative, which has included the construction of hundreds of water schemes in rural communities throughout the country. An important principle of the policy was that the service provided by these schemes was to be managed at the local level. This included the responsibility of ensuring schemes were sustainable, including adequate cost recovery for operation and maintenance.

However, the national rate of unstainable rural community water supply schemes has been unacceptably high. This has manifested in a significantly low rate of cost recovery. Reasons for low cost recovery have included:

- Culture of non payment in areas where previous schemes were subsidised.
- Low reliability of schemes.
- Inappropriate level of service.
- Demand levels lower than design supply.
- Poverty.

Since 1997 many cost recovery strategies have been researched and implemented in rural water supply in South Africa. These include flat rates, block rates, prepaid meters, coupon systems and water kiosks. However, most of these strategies have had limited success and cost recovery remains problematic.

In October 2000 the South African government announced a policy of supplying free basic water to all. This consisted of providing 6000 litres per month free of charge to each household. Implementation of this policy since then has been the responsibility of local governments with facilitation from DWAF. Funding of its implementation was to be sourced from cross subsidisation within local government areas and allocation of a nationally raised 'equitable share' to local governments.

At initiation of the Free Basic Water Policy, approximately 10% of local authorities were already delivering a level of water supply service compatible with this policy. Delivery of this level of service has since expanded to 59% of South Africa's population. However, more than 50% of these people are in the larger urban centres and delivery in rural areas has remained problematic (DWAF, 2002). This has been due to many factors (DWAF, 2002; Still, 2001a; Rall, 2001) including:

- Lack of high income sectors to cross subsidise poorer sectors.
- Rural schemes have higher water wastage and losses as a percentage of total supply.
- Many rural schemes are too capitally intensive relative to existing institutional capacity.
- Lack of existing infrastructure.

Debate generated over implementation of the Free Basic Water Policy in rural communities has formulated some suggestions for its facilitation (Still, 2001a). These include:

- Implementation of basic level of service schemes which cost less to operate and maintain than funds available to local government.
- Ensure automatic control of consumption.
- Create a better understanding of consumers by Water Service Authorities.
- Provide institutional support to local government authorities.

The Trickle Feed System is a new application of a technology which incorporates the first two suggestions listed above. This research project investigates the potential application of the Trickle Feed System to assist in the implementation of the Free Basic Water Policy in rural communities. The Trickle Feed System involves delivering a set quantity of water each day to a storage tank at each household. This allows for the application of a monthly pre-paid stepped tariff with a free basic level of service with minimal administration.

This research project has been undertaken to assist role-players to make informed decisions with respect to the implementation of the Trickle Feed System to provide a free basic water supply of a high level of service to rural communities. This research was first undertaken for the research project **A Cost Recovery Analysis of the Trickle Feed Rural Community Water Supply System** (WRC Project No: K5/1272.) The Free Basic Water Policy was announced six months after this research project commenced. The scope of the research was then expended to include new objectives relative to this new policy. Objectives of this research project include;

- Assessment of the cost recovery efficiency of the Trickle Feed System in application for rural community water supply.
- Assessment of the Trickle Feed System as an effective tool for the implementation of the Free Basic Water Policy in rural communities.
- Identification of variables which affect the implementation of the Free Basic Water Policy in rural communities.
- To provide assessment methodologies for the variables identified for future application.
- Provide clear guidelines to role-players for utilising the Trickle Feed System.
- Building capacity in previously disadvantaged individuals and organisations through direct training and participation in this research project.

2.0 Literature Review

2.1 Rural Community Water Supply

2.1.1 Community Water Supply in the International Context

The supply of potable water to developing communities is a continuing challenge throughout the world. Between 1981 and 1990 a major initiative was undertaken by the United Nations to provide safe water to undeveloped communities. The International Drinking Water Supply and Sanitation Decade supplied approximately 1600 million people with safe water. However, the WHO (1997) estimated that in 1994 approximately 1.1 billion people, or 25% of the developing world's population, did not have access to potable water. This figure climbs to 43% in Africa as a whole and is even more significant in rural areas where the percentage of "unserved" is highest and delivery the slowest (Still, 2001b). Approximately 56% of Africa's rural population was unserved in 1990 (WHO, 2000a) and by 2000 this figure had only decreased by 3% to 53%.

By 2000, the WHO (2000a) estimated that 1.1 billion people still did not have access to safe drinking water. Population increases have helped to offset any increases in the provision of services. It may seem that we are no closer to reducing the large number of unserved communities. Many lessons have been learned during this critical time characterised by large population increases that correspond with an increase in demand for services. In a review of the International Drinking Water Supply and Sanitation decade (Middleton, 1998), it appears that much has been learned regarding "how to" provide adequate water and sanitation services to the worlds developing population. These include:

- Sustainability is critical.
- Sustainable systems fit the needs of the people who are going to use them.
- Systems should be upgradable.
- Water supply and sanitation development should be balanced.
- Planning and implementing balanced water supply and sanitation is difficult.
- Affordability needs to guide development choices.
- Subsidies are unreliable; if they are essential, they should be carefully targeted.
- The public sector has not made enough use of the capacity of the private sector.
- Privatisation needs strong, honest regulation.
- The role of the government should move from that of provider to that of facilitator and regulator.
- Full use should be made of community capabilities.
- Public education is essential.

2.1.2 Community Water Supply in South Africa

With the change in political dispensation in 1994, there was a change in water resource management and supply policy in South Africa. Providing access to adequate potable water for 12 million people and proper sanitation for 21 million became a higher priority over a previous focus on formal sector bulk supply. A framework to ensure this was outlined in the Water Supply and Sanitation Policy White Paper (DWAF, 1994). Principles in this policy document included:

- Water resource development is to be demand driven and community based.
- Basic service provision is a human right.
- "Some for All", rather than "All for Some".
- Equitable regional allocation of development resources.
- Water has economic value.
- The user pays.
- Integrated development.
- Environmental integrity.

These policies were implemented in the Reconstruction and Development Programme (RDP) in an attempt to provide basic service provision to all South Africans before 2001 (DWAF, 1994). This basic level of service included the supply of 25 litres per person per day of potable water within 200 metres distance with 98% reliability. Although the initial capital costs of basic level of service water supply infrastructure were to be subsidised by National Government through the Department of Water Affairs and Forestry, on going operation and maintenance costs were to be recovered on the local and regional level.

In 1998 the National Water Act was promulgated to govern the provision of water services in South Africa (RSA, 1998). The main objective of the National Water Act is to provide for the management of the nation's water resources to ensure sustainable use of water for the benefit of all users. The Act seeks to provide for the protection, use, development, conservation, management and control of all water resources in South Africa.

The Water Services Act complements the National Water Act as it aims to provide a developmental framework for water service provision by defining roles and responsibilities (RSA, 1997). This includes an envisaged management structure consisting of Water Services Authorities (WSA), Water Services Providers (WSP) and Water Boards. WSAs will include municipalities and will have the duty "to progressively ensure efficient, affordable, economical and sustainable access to water resources". This function will be fulfilled through the establishment of a WSP to provide water to consumers under WSA management. A WSP may be a local water committee or may be undertaken internally by the WSA. A Water Board will have the function to provide water services to other water service institutions within its service area.

Since the beginning of implementation of the RDP in 1994, it has been estimated that 5.3 million people have been served to the minimum RDP standards (Still, 2001b). Approximately R4.22 billion has been expended on new RDP projects and R900 million per year in now required to operate and maintain all projects. However, it estimated that there are still 7 million unserved people in South Africa. In order to serve those people to RDP minimum standards within the present community water supply paradigm, it has been estimated that a further expenditure of R16 billion will be required as these people are generally in the more remote and difficult communities to serve. This inequity was highlighted by the Cholera epidemic which took place between 2000 and 2001 where more than 10 000 people were infected (mostly in KwaZulu Natal) resulting in over 200 deaths (National Disaster Management Committee, 2001).

Further commitment was undertaken by the South African government in October 2000 with the announcement of a policy of supplying free basic water to all (DWAF, 2001a). This consists of a target of 6kl per month free of charge to each household. This is to be implemented by local authorities with funding from internal cross subsidisation and the national equitable share (see Section 5.4.2)

2.2 Sustainability of Rural Community Water Supply

2.2.1 Costs of Water Supply

Water in its natural form can be considered a free resource. However, there are many costs involved in supplying potable water to the end user. The sustainability of a water scheme is directly dependant on the development and implementation of a successful strategy to maintain the cost at low levels and recovering these costs. Poor cost recovery has been identified as the most significant constraint to the sustainability of water supply schemes in Africa (DWAF, 1997). This is also the case in rural community water supply in South Africa where the national average for cost recovery is estimated to be only 10% (Sussens, H. – pers. comm.). This has found to be highly variable ranging from 94% in areas managed by a formal water board (Bellars, J – pers. comm.) to 1% in remote areas with little institutional support (Still, D. – pers. comm.).

Since 1998 cost recovery has received significant attention in South Africa in order to improve sustainability of water supply schemes. DWAF introduced a period of mentorship support to operate, train and transfer (oTT) completed schemes as an important component of project implementation. The South African government addressed the issue even further in (DWAF, 2001a) with the announcement of the provision of free basic water supply to all. This is an effort to subsidise the cost recovery deficit, which is particularly experienced in the provision of basic water supply.

Costs can be categorised into Initial Capital Costs and Operation and Maintenance (O&M) Costs. Initial Capital Costs include all costs required to plan, design and construct a water supply scheme which is capable of providing sustainable potable water to end users. Government policy is that these costs are fully subsidised for the provision of a basic (RDP) level of service (DWAF, 1994). These costs include:

- Feasibility and planning.
- Design.
- Construction of abstraction works, storage, treatment works, reticulation and dispensing units.
- Construction supervision.
- Social facilitation and training.
- Initial mentorship and transfer.
- Implementing Agent and DWAF management overheads.

O&M Costs include all on going costs required to maintain a reliable supply of potable water to the end users. These costs include:

- Power for operation of pumps.
- Chemicals for water treatment.
- Maintenance of assets.
- Depreciation of assets.
- Replacement of assets when required.
- Administration costs.
- Support and mentorship costs.
- Catchment management costs.

Government policy was that these costs must be recovered on the local or regional level through tariffs levied for water use. However, the recent Free Basic Water Policy determines that these costs will be subsidised to a basic level of service (see Section 5.4). Up to 80% of O&M Costs are fixed and are not dependant on the quantity of water delivered (Hazelton, 2001). These include regular maintenance and administration costs such as meter reading, bookkeeping, billing and staff wages.

2.2.2 Cost Recovery

Several cost recovery options are available and have been utilised in rural community water supply projects (DWAF, 1997). These include:

i. Flat Rate Tariff

This system involves the levy of a flat tariff to each household per month irrespective of consumption. This system has been utilised on many water schemes previously due to its simplicity of implementation. However, as consumption is not related to the tariff, problems can arise with wastage and inequitable supply. This system relies on a community environment in which payment of tariffs and equitable consumption is voluntary, as typical of a small scheme with low maintenance. It is not suitable for larger and more complicated schemes as collection and administration of the tariff becomes difficult.

ii. Standpipe Committee System

This system involves a number of metered standpipes managed by a central committee. Each standpipe delivers to a determined number of households, which make up a single standpipe committee. The central committee bills each standpipe committee depending on consumption and members of each standpipe committee pay a pro rata portion of this bill. This is essentially an upgraded flat rate tariff system, which reduces wastage and consumption inequity. It is also more adaptable for larger schemes as the administration can be decentralised. This system has been introduced into a number of small to medium rural community water supply schemes with success. However, it depends on a large degree of transparency and willingness to pay in the community.

iii. Attended Access Point System

This system involves metered public standpipes managed by bailiffs. Each bailiff is responsible for operation and some maintenance of the standpipe, and collection of payment for dispensed water. Payment can be in cash or pre-purchased coupons. As consumption is directly managed, wastage and inequitable use can be reduced (Lima RDF, 2000). However, disadvantages include:

- High operation costs to manage bailiffs.
- Potential theft of cash or coupons.
- The use of coupons requires external retail agents for distribution requiring administration.
- Opening hours are limited.

iv. Unattended Mechanically Operated System

This system involves a number of public standpipes, which mechanically dispense water by coin or coupon operation. This system shares the benefits of the Attended Access Point System with reduced operational costs and theft risk. However, the dispensing units are more expensive and must be reliable and tamper proof.

v. Unattended Electronically Operated System

This system involves water connections (public and private) which are electronically operated to dispense water by using user cards or tags. These cards are electronically ensigned for determined quantities dependant on sale value and are linked to a central computer system, which also monitors consumption at the connections. This system affords a more efficient management of larger schemes including cost recovery. However, the initial cost of the system is expensive and requires a high level of capacity to operate. The technology is also relatively new and has experienced development problems in practical application.

vi. Manually Operated Access Point Storage System

This system involves a network of distributed storages at access points where water is dispensed. The tanks are filled each day manually by a bailiff thereby determining a maximum consumption, which can be prepaid. This system allows for higher level of service (household connection) with reasonable control over equitable consumption, cost recovery and wastage. Distributed storage also allows for use of smaller diameter reticulation with corresponding initial capital cost savings. Due to the costs to manage the bailiffs, this system is more viable in the peri-urban environment with higher population densities.

vii. Automatically Operated Access Point Storage System

This system incorporates automatic regulation of flow in the distributed storage system. This allows for prepaid cost recovery with low administration and management requirements. This system has recently become the focus in the development of several technologies including the Trickle Feed System.

viii. Conventional Metering and Billing System

This is the cost recovery system utilised in most developed urban communities with single household connections. It incorporates a full pressure system with metered connections, which is managed by a delegated authority. Costs to operate and maintain this system are high which makes it not viable for utilisation in rural communities due to low water usage.

2.2.3 Constraints to Cost Recovery

Successful cost recovery is regarded as an essential component in sustainable water supply provision (DWAF, 1998). If cost recovery is inadequate, international research (DWAF, 1997; Dreyer, 1997) and experience has shown that:

- Wealthier users are more subsidised than poorer users.
- More public funds are required to operate and maintain water schemes.
- Non -economically viable schemes fail.

Constraints which affect cost recovery can be categorised into technical, social and institutional variables.

Technical Variables

The quantity and quality of the water service that is provided has a direct relationship on the willingness to pay for that service by users. This includes variables such as:

- Reliability - willingness to pay will be reduced if a service is unreliable due to technical inefficiency.
- Level of Service – the level of service (communal standpipes, household connections etc) provided will determine the costs of supply and the consumer's willingness to pay.
- Consumption Levels – the level of consumption will directly determine the cost recovered assuming that there is payment for that service.
- Appropriateness – technology that is not appropriate to the application results in increased O&M costs and less reliability.
- Existing infrastructure – O&M costs of water schemes are directly related to the proximity to existing infrastructure such as electricity, roads and transport.

Social Variables

Ability and willingness to pay within a community will directly affect the level of cost recovery in a water supply scheme. Ability to pay is directly related to the soci-economic environment and can be relatively easily assessed. Willingness to pay is related to complex variables which are characteristic for each community. These variables include:

- Culture of social responsibility to paying for public services.
- Cultural perceptions of value of water.
- Level of community involvement in implementation, operation and maintenance of water scheme.
- Political stability.

Variables such as demographics of community settlement affect the costs of O&M. This is clearly demonstrated in water supply to rural communities in KwaZulu Natal, which are typically dispersed along the tops of ridges.

Institutional Variables

The efficiency of cost recovery is dependent on the capacity of the institutional structure, which has the responsibility to implement, operate and maintain water supply schemes. Effective implementation of a water scheme is an important component in ensuring sustainability of O&M. This requires an implementation structure with appropriate personnel and resources, which is often lacking in rural community water supply.

Efficient operation and maintenance requires a structure which is operational on the community level, yet has adequate capacity. Challenges these structures face in ensuring efficient cost recovery include:

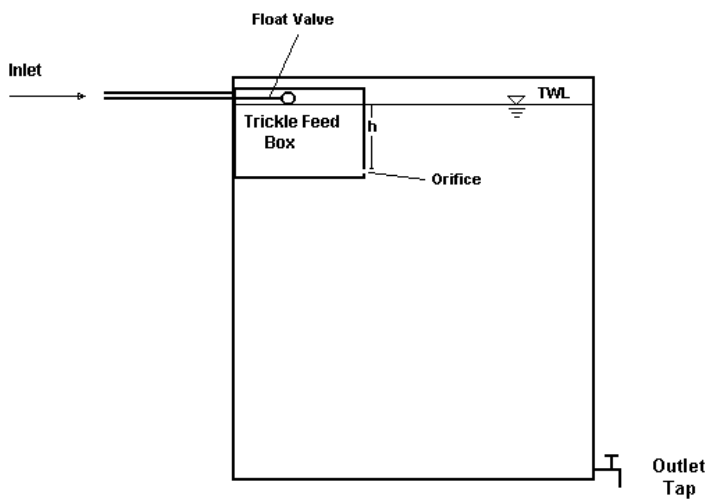
- Lack of defined punitive procedures for non payment.
- Inadequate financial and administration management capacity.
- Complex communication and authority structures in recipient communities.

3.0 Trickle Feed Water Supply Systems

3.1 Description of the Technology

Trickle Feed Systems are low pressure reticulated piped networks which deliver water to household storage tanks at a constant rate. The constant flow rate is maintained by a trickle feed box installed in each household tank (see Figure 1). The trickle feed box is a small plastic container with a volume of approximately 5 litres. Flow into the household tank first enters the trickle feed box and is controlled by a float valve. Flow out of the trickle feed box into the household tank is controlled by an orifice of a determined diameter. The water level in the trickle feed box is kept constant by the float valve, which results in a constant flow or 'trickle' through the orifice.

Figure 1 – Household Tank with Trickle Feed Box



Flow through the orifice is determined principally by the diameter of the orifice as detailed in Appendix A. Therefore, it is very important to size the orifice correctly for a chosen constant flow. To deliver a flow of 6000 litres per household tank per month an orifice of 2.5mm diameter is optimal.

3.2 Characteristics of the Technology

The Trickle Feed System technology is characterised by a constant 'trickle' flow to distributed household storages independent of consumption patterns. This eliminates peak flows in the reticulation, which allows for low pressure reticulation and reduced pipe sizes. Benefits of utilising this technology include:

- Low cost 'higher level of service' to consumers – household connections can be provided at low cost due to reduced reticulation pipe sizes and bulk storage required.
- Increased health and hygiene benefits – international research has shown that a higher level of service induces an in increase in consumption (Tipping, 2001) which can result in an increase in community health and hygiene.
- Simple administration requirements – supply to consumers is controlled automatically and any cost recovery can be a pre-paid fixed monthly tariff. No meter reading is required.
- Options for household storage – several options exist for household tanks including the low cost 'Nondayana' concrete tank, prefabricated plastic tanks and roof tanks which allow for low pressure internal plumbing (see Section 3.3).
- Low maintenance – technology is appropriate to community level O&M.
- Low losses – losses and wastage are minimised due to low pressure and flow. Losses at access points (eg – leaking taps) are limited to the set flow at that point and do not affect the entire system.
- Equitable distribution – supply to consumers is relatively unaffected by inlet pressure which results in equitable delivery to all consumers in the reticulation network.
- Increased supply security – storage at the household level provides additional security and continuity in the event of supply failure and reduces the size of bulk storage required.
- Retrofitting to existing systems – existing communal standpipe systems can be retrofitted to increase the level of service without upgrading of reticulation.
- Upgrade possible – the level of service of consumers can be upgraded by increasing flow into the tank (extra orifice) or installing another household tank. Careful design of the system can ensure that upgrading of reticulation capacity will not be necessary.

Constraints of the Trickle Feed System include:

- Limited daily flow – daily flow to each household is automatically limited and is difficult to adjust for events when increased supply is required. E.g. this does not allow for periodic increased demands at special events such as weddings and funerals.
- Community acceptance – it is important that this technology is adequately discussed with and accepted by the recipient community. To receive community acceptance, the technology must be accepted as an increase in the level of service provision rather than a punitive cost recovery mechanism.
- Reduced tolerance to suspended matter – the trickle feed box includes a fine mesh inlet to the ball valve and a medium sized orifice. These present constraints to suspended matter and possible blockage of flow. Adequate flushing of construction debris in pipes during commissioning is required before installation of the trickle feed box. Blockage or restriction of the orifice is also possible in 'hard' water conditions (high content of calcium carbonate), yet no realisation of this has yet occurred in operating projects. Various adaptations to the trickle feed box to solve this potential problem have been formulated, including the installation of nylon string through the orifice with free weights attached at each end of the string (Still, D. – pers. comm.).

- Potential for tampering and illegal connections – this is a well recognised constraint to the implementation of the Trickle Feed System. Tampering includes adjustment or removal of the float valve and increasing the orifice size in the trickle feed box. Illegal connections typically include bypassing the household tank for unregulated supply. The household tank can be constructed to minimise points of illegal access. However, the most significant prevention is obtained through adequate community liaison and education.

3.3 Options for Household Tanks

Household tanks need to be sized to provide adequate storage for daily supply (approximately 200 litres). Various options are available and have been utilised in existing projects.

'Nondayana' Concrete Household Tank

A concrete tank initially developed by Glover Development Engineers has been extensively utilised and continuously developed in the Nondayana project. These tanks are constructed *in situ* utilising a hessian form filled with any easily available and suitable material (eg. – leaves, grass clippings etc). The exterior is first plastered and the fill material removed when the plaster is dry. Then, the interior is also plastered. The final tank is shown in Figure 2 and an illustrated sequence of construction of this tank is shown in Appendix B.

Figure 2 – 'Nondyana' Concrete Household Tank

One of the most significant benefits of this tank option is its low cost (see Table 1 for total cost and breakdown). Cost of installation of this tank option is the lowest of all options available (Lenehan, 2002). Installation is labour intensive, optimising local economic empowerment. The tanks are robust with maintenance requirements within the capacity of community level O&M. Other benefits include:

- The inlet pipe is totally encased in plaster reducing potential points for tampering.
- The lid is sealed in place by a thin plaster layer which can be easily removed for maintenance but is difficult to tamper with unnoticed. By painting a distinctive paint mark over the tank and lid tampering can be easily identified.

- Stored water is not exposed to heating from the sun.

Table 1 – Costs of Construction for 'Nondayana' Concrete Household Tank

Item	**Cost (R)**
1.5 x pockets of cement @ R30/pkt	45.00
3 x wheelbarrows of plaster sand @ R8.5/wheelbarrow	25.50
2m of hessian @ R5/m	10.00
1 x tap @ R35/each	35.00
1 x GI nipple @ R2/each	2.00
2 x GI socket @ R2/each	4.00
1 x 1.2m steel fence dropper	8.00
Assorted wire	10.00
1 x plastic float valve	35.00
1 x 16mm x ½" female elbow	9.00
1 x plastic box (approximate dimensions 140 x 130 x 200mm)	8.00
20m of 16mm HDPE pipe @ R1.8/m	36.00
2 x labourers x 2 days @ R35/day	140.00
TOTAL	**367.50**

These tanks are only suitable for outdoor installation on a low stand. It is not viable to install concrete tanks inside houses, on elevated stands or on roofs.

Construction of these tanks requires a high level of supervision and training to ensure adequate quality control, particularly when utilising community labour. Construction components which require specific attention include:

- The level of the outlet tap must be high enough to ensure a 25 litre container can fit easily for filling.
- Assembly and installation of the trickle feed box in the tank must be adequate enough to ensure proper operation.
- The outlet tap can come loose from the tank, particularly soon after installation if consumers try to use the tank before the tap installation is set. This can be rectified by including steel reinforcement in the plaster in tank installation and undertaking community education of the tank construction process to reduce premature use.
- Adequate drainage works are required below the outlet tap to ensure health and hygiene benefits are maximised.

Plastic Household Tank Units

Several plastic tank options are available supplied pre-fitted with a trickle feed box. These tanks are relatively quick and easy to install, and are not as restricted in location of installation. This allows for several options of installation and corresponding levels of service. An upright tank can be installed outside the house on a stand. The upright tank can also be installed inside the house on a stand to allow for limited internal plumbing. A horizontal tank can also be installed on or in the house roof for increased pressure and internal plumbing (see Figure 3).

These tanks are more expensive than the concrete tank option (see Table 2 for total cost and breakdown). Other disadvantages include:

- Reduced labour intensive installation with less local economic empowerment.
- Stored water in tanks installed outside is exposed to heating from the sun. This can be rectified by painting tanks in appropriate colours and paints.
- Increased potential for tampering and illegal connections due to exposed inlet pipes and fittings.

Figure 3 – Options for Installation of Plastic Household Tanks

Table 2 – Costs of Construction for Plastic Household Tank

Item	Cost (R)
0.5 x pockets of cement @ R30/pkt	15.00
1 x wheelbarrows of plaster sand @ R8.5/wheelbarrow	8.50
Plastic tank unit (cheaper bulk prices available)	470.00
1 x tap @ R35/each	35.00
1 x 16mm x ½" female elbow	9.00
Assorted wire	5.00
20m of 16mm HDPE pipe @ R1.8/m	36.00
2 x labourers x 0.5 days @ R35/day	35.00
TOTAL	**613.50**

3.4 Related Technologies

Several other household tank 'constrained flow' technologies are utilised or are being presently developed to supply free basic water to communities. These include:

- Durban Yard Tank System – this system has been operational since 1998 and has been highly successful in the supplying consumers in peri-urban communities with free basic water. Initially this system was operated by a manual bailiff who operated a manifold daily to deliver 200 litres to a number of consumers. This has now been upgraded to include an Electronic Bailiff Unit which operates automatically (Bailey, 2002).
- LW Household Tank System– this system is presently being developed (Miller, J. – pers. comm.) and consists of a hydraulic control system to constrain flow into the household tank.
- Watertight Constrained Flow Valve System – this system is also still in development and consists of a lockable valve which can be set to constrain inflow into a household tank to determined volumes (Keth, D. – pers. comm.).

More detailed analyses of these technologies are beyond the scope of this research. However, studies relevant to these technologies are presently being undertaken, including:

- DWAF Yard Tank Pilot Monitoring Program – a program to monitor and evaluate a number of yard tank projects employing various technologies particularly with respect to the supply of free basic water (Sussens, H. – pers. comm.).
- Review of technologies for Controlling Water Consumption – a recently completed technical review providing guidelines to local government on the range of technologies available to control water consumption (DWAF, 2002).

3.5 Case Studies

Trickle Feed Systems have been utilised for domestic water supply schemes in developed countries such as the UK and New Zealand. These schemes typically consist of communities with limited water resources and widely distributed consumers. Although literature documenting these schemes is limited, many of them have been operating sustainably for more than 30 years (Abrams, R. – pers. comm.). Trickle Feed Systems have also been applied successfully in rural community water supply in South America since the early 1970's (Solsona, 1991) and more recently in the South Pacific island country of Kiribati (The Republic of Kiribati, 2001).

Application in South Africa has been limited to only a few projects. However, significant interest has recently been shown in this technology as potentially viable for the implementation of the Free Basic Water Policy. DWAF has recently commenced a programme of implementing a number of yard tank pilot projects which include assessment of the practical implementation and O&M requirements of the Trickle Feed System (Sussens, H. – pers. comm.).

Tubaste Water Project, former homeland of Lebowa, Limpopo Province

In 1992, the CSIR proposed the implementation of a Trickle Feed System utilising elevated plastic tanks installed inside consumer houses. Extensive liaison was undertaken with the recipient community, traditional structures and the Lebowa Government, from which it was assumed that this was the preferred option. Implementation commenced and approximately 20 tanks were installed before significant objections were raised by the youth of the community. These objections were based on expectations for a conventional high pressure level of service. Unfortunately, these issues were not resolved and vandalism occurred resulting in termination of implementation (Painting, E. – pers. comm.).

Newtown Low Cost Housing Development, Edendale, Pietermaritzburg

As part of the Business Partners for Development Project, a pilot scheme was implemented in Newtown in 2000. This project incorporated a Trickle Feed System for water supply in a new low cost housing development (Business Partners for Development, 2001).

Newtown is a densely populated settlement developed on a relatively steep slope on the outskirts of Edendale, Pietermaritzburg. The mean household income of the community is less than R1000 per month with 80% of residents living below the poverty line.

The pilot project involved the installation of various models of the 200 litre plastic tank. These included yard installation on a stand, installation inside houses on a stand and installation on house roofs. Objectives of implementation of this system were to ensure equitable supply of a limited source in a hilly area and allow for a simple pre-paid cost recovery strategy.

The scheme is still operational and supplying consistently to most consumers (Dedekind, J. – pers. comm.). However, several problems have arisen during operation, including:

- Water in the tanks becomes hot due to exposure to the sun.
- Vandalism and tampering has become a significant problem, particularly by consumers by-passing the tanks to increase supply (see Figure 4). In some areas, incidence of tampering is as high as 80%.
- Drainage at most outside tank installations is inadequate resulting in health hazards and rising damp in some houses.
- Absence of cost recovery due to customer dissatisfaction and lack of institutional structures.

Cost recovery is no longer an issue as Msunduzi Municipality has incorporated O&M of this scheme as part of its adopted free basic water policy. However, customer dissatisfaction has significantly threatened the viability of this scheme as well as implementation of this in other communities. Recently, several consumers have rejected the trickle feed option, citing concerns of poisoning and witchcraft interference to the outside tanks (Dedekind, J. – pers. comm.).

Figure 4 – Typical Bypass of Household Tank

Mseleni Water Project, Northern KwaZulu Natal

The Mseleni Water Project is an existing water scheme in the Umkhanyakude District Municipality in northern KwaZulu Natal. Construction of this project first took place in 1990 as an extension of the Mseleni Hospital water supply to the surrounding rural community. It has been progressively upgraded since then in an effort to serve the entire community of 17000 people (Fischlock, 2002). However, only 10000 people presently benefit from the scheme and supply is not consistent, particularly to consumers at the end of reticulation mains. This is due to a limited supply released from the hospital, insufficient capacity of the reticulation pipes, unregulated supply to some consumers and flat terrain of the supply area. Cost recovery has also been poor due to lack of institutional capacity and willingness to pay for a substandard service.

Approval was granted in October 2001 for an upgrade of the system to enable it to serve the rest of the community, ensure a more reliable supply, reduce losses and improve cost recovery. In order to improve equity of supply and management of the scheme, approximately 700 plastic trickle feed tanks are to be installed outside households. Supply to these tanks is automatically controlled by a float valve and orifice in the trickle feed box inside the household tank. The orifice has been sized to a diameter of 2.5mm to provide a daily flow of approximately 300l per day. The outlet tap is installed separate from the tank to reduce movement stress on the tank outlet. The cost per household tank unit including installation is approximately R675.

Construction commenced in March 2002 but progress has been slow principally due to problems of community acceptance. Previously some consumers had unregulated supply and had typically defaulted on tariff payments. The installation of the trickle feed household tank has been interpreted as a punitive measure and decrease in level of service.

A high degree of tampering with installed household tanks has been recorded. This includes:

- Removal of tank lids and tampering with the internal float valve in order to receive full supply pressure. This has been recorded at 45% of tank installations.
- Bypassing of household tanks to receive full supply pressure. This has been recorded at 2 of the 30 tank installations.

Technical problems which have been encountered include:

- Some taps have been incorrectly located at a level higher than the bottom of the household tank resulting in wasted storage.
- Air locks have been experienced in some of the meters on the outlet of the household tank, which is blocking flow to the outlet tap. Rectification of this problem is now being developed.
- Manufacturing imperfections in the trickle feed box (particularly in drilling the orifice) have resulted in sub-design flow.
- Debris in one main pipe is blocking the sieve in the float valve, which may be due to the insufficient scouring and chlorination resulting in algal growth.
- Tank stands were initially constructed using old tyres filled with sand. These stands were not stable and resulted in movement and damage to the outlet pipes. The stands are now constructed with concrete blocks, which provide improved stability.
- Water quality in the tanks which have had lids removed has decreased due to ingress of material and insects. All tanks have also experienced internal algae growth.

Kransdraai Water Project, Southern KwaZulu Natal

The Kransdraai Water Project is located in the Southern Drakensberg. It was initially constructed in 1998 to supply 750 consumers with communal standpipes and some metered household connections with an electronic pre-paid cost recovery system (Laubscher, W. – pers. comm.). Plastic tanks with trickle feed boxes were installed inside houses in early 2002 due to:

- Malfunctioning of the electronic metering system due to freezing of the water.
- Community demand for a higher level of service.
- Requirement to provide equitable and free basic level of water with a limited source.

The option of a constrained flow valve system was investigated. However, this option was found to involve a 40% higher capital cost.

The new project has now been operating for six months with very little maintenance requirements. O&M costs (excluding electricity costs for pumping) have averaged R3750 per month. Although the scheme is designed to supply the basic level of 6kl per household per month, consumers are only utilising approximately 1.5kl per month. Operation and maintenance was funded over the first six months of operation as part of implementation mentorship. No free basic water strategy has yet been developed for this project by the local authority and funding will now be from cost recovery. Cost recovery will be a monthly flat rate to consuming households.

Nondayana Water Project, Northern KwaZulu Natal

The Nondayana Water Project is located 45km north of Ulundi in northern KwaZulu Natal. It supplies an estimated 2000 consumers in 204 households (Lenehan, 2002). Previously, water supply consisted of three handpumps on boreholes. However, the handpumps are not operational for significant periods of time due to lack of maintenance. The water is also high in salts, resulting in utilisation by only 35% of the community. The rest of the community has been collecting water from rivers and unprotected springs.

The original Business Plan outlined a standard RDP full pressure reticulation system with public standpipe level of service. However, before construction commenced the community expressed a strong demand for a higher level of service. This was investigated resulting in a recommendation to adopt a Trickle Feed System.

Construction of all major components of the scheme has been completed excluding the installation of the main river abstraction pumps. Supply is presently dependent on flow from a spring. The scheme has been operational since February 2002, but is dependent on the supply from the spring, which is not adequate for the entire scheme. Flow from the spring varies between 300 and 1000l/hr depending on the time of the year and blockage of the intake with silt after storm events (Lenehan, 2002). Installation of a hydram pump on the spring inflow is also outstanding. This hyrdram will supply 8 households upstream of the main treatment and storage works.

To ensure equitable distribution of supply to all consumers with the present limited source, the Project Steering Committee (PSC) has adopted a strategy of alternating supply between each of the two gravity mains. In this mode of operation, the PSC and community have decided to delay implementation of cost recovery from consumers until full supply can be delivered. No free basic water strategy has been implemented by the local authority in this project and O&M costs are presently funded from community contributions to an O&M fund accumulated during project implementation.

4.0 Methodology and Results

4.1 Pilot Project Identification and Description

The Nondayana Water Project was selected for pilot analysis of the Trickle Feed System in a rural community. It is the only project in a rural community in which the Trickle Feed System has been operational with comprehensive monitoring and evaluation undertaken. This included project analysis undertaken in the preliminary stages of implementation (Tipping, 2001) and monitoring and evaluation undertaken as part of this research project (see Section 4.3).

The construction of the Nondayana Water Project was funded by Mvula Trust from the DWAF RDP Programme. The project operates in the area of Nondayana, consisting of the communities Damba, Magagadolo, Ndwaleni and Ntambonde. It is situated approximately 2.3km south of the town of Ceza and 45km north of Ulundi within the Mahlabatini District of Zululand District Municipality in the province of KwaZulu Natal. The central co-ordinates of the project area are 28°01'S and 31°24'E. The estimated number of beneficiaries of the project is 2000 living in 204 households.

The main source has been identified as the Vungu River which was found to produce a sustainable yield. Water is to be pumped in two stages from the river to the main treatment and storage works through 1.1km of 50mm diameter main. A secondary source was also identified, but now operates as the main source. This source consists of gravity flow from a protected spring to the main treatment and storage works. The main treatment will consist of an upflow roughing filter and two slow sand filters with inline chlorination. From the main storage, water will gravitate by means of 20km of reticulation pipelines to 196 households. A further 8 households upstream from the main storage will be supplied by pumping to a small slow sand filter/storage above these households and gravity reticulation. Pumping will be by hyrdram on the spring source inflow to the upflow roughing filter.

The original Business Plan was prepared and approved in 1997 and outlined a standard RDP full pressure reticulation system with public standpipe level of service. Construction was stalled throughout 1998 and 1999 due to lack of available funds and the first disbursement to the project was made in September 2000. During this time the community expressed a strong demand for a higher level of service that was proposed in the Business Plan. The Project Agent at that time, Glover Development Engineers, undertook a further planning report to investigate the feasibility of increasing the level of service within the budget allocated in 1997. This report recommended the adoption of a low pressure reticulation system with small storages distributed at each consuming household. Inside each household tank would be a ‘trickle feed box’ which would ensure constant flow to all consumers. Major reasons for this were that the trickle feed system is low flow and pressure requiring smaller diameter reticulation pipes. The cost of main storage was also reduced, as distributed storage would be provided with the household tanks. This proposal was then approved by the community, the Nondyana Water Committee and Mvula Trust and construction commenced in November 2000.

Construction of all major components of the scheme has been completed excluding the installation of the pumps at the Vungu River and the hydram pump. The scheme has been operational since February 2002, but is dependent on the supply from the spring, which is not adequate for the entire scheme. Due to an approximate 40% increase in pipe and fitting prices between formulation of the project budget in the Business Plan and implementation, funds available in the approved budget were inadequate. A Variation Order application was submitted and approved in August 2002. Outstanding works are presently being undertaken.

In order to ensure equitable distribution of supply to all consumers with the present limited source, the Project Steering Committee (PSC) has adopted a strategy of alternating supply between each of the two gravity mains. In this mode of operation, the PSC and community have decided to delay implementation of cost recovery from consumers until full supply can be delivered. Operation and maintenance (O&M) costs are presently funded from community contributions to an O&M fund accumulated during project implementation.

4.2 Community Baseline Survey

A community baseline survey was undertaken from 10 May to 18 May 2001 in order to assess the variables that would affect cost recovery and the operation of a Trickle Feed System. This survey was based on the Household Livelihood Security Assessment Methodology developed by CARE (Drinkwater & Rusinow, 1999). This approach involves assessment of household livelihoods in a community in order to identify what variables are significant to the development and evaluation of interventions. Livelihood embodies three fundamental attributes: the possession of human capabilities (education, skills, health, and psychological orientation); access to tangible assets; and the existence of economic activities.

The community baseline survey undertaken involved a survey of 33% of the households in the Nondayana community (67 of a total of 204 households). At each household an adult was asked to respond to a set questionnaire. The questionnaire utilised was designed to investigate livelihood variables which are significant to the implementation, operation and maintenance of a Trickle Feed System. Areas investigated included:

- Household capabilities – age range, education, health, etc.
- Household assets – resources available.
- Household economic capacity – employment, income, spending patterns etc.
- Water supply – sources, usage patterns, perceptions of the Trickle Feed System and cost recovery.

Results of this survey have been summarised in Appendix D.

Significant results of this survey are summarised in Table 3.

Table 3 - Summary of Significant Results from Community Baseline Survey

Variable	**Result**
Standard of education	62% educated to Grade 6 6% educated to Grade 12 4% tertiary educated
Employment	28% have some form of employment 27% are unemployed 45% other (student, pensioner etc.)
Cost recovery	94% willing to pay tariff 23% supported cross subsidisation within Nondayana 72% supported cross subsidisation from outside Nondayana 42% supported disconnection of defaulters
Community acceptance of the Trickle Feed System	88% had knowledge and understanding of the technology 94% believed it would be hygienic 97% believed it would be easily accessible 86% believed it provide sufficient water 91% believed it would be easy to use 59% believed it would be cheap

4.3 Monitoring and Evaluation Programme

Comprehensive monitoring and evaluation of the Nondayana project was undertaken during implementation (November 2000 to March 2002) and for the first six months of operation (February 2002 to August 2002). This included costs (initial capital and O&M), flows (supply, consumption and losses), maintenance requirements and household tank operation.

4.3.1 Financial

Detailed financial analysis of the project was undertaken before implementation to investigate the feasibility of a trickle feed system in Nondayana (Tipping, 2001). This analysis showed that the capital costs of construction would be slightly less than the original RDP design in this application, as shown in Table 4.

Table 4 – Cost Comparisons for System Options as Applied for Nondayana

System Type	**Costs (R)**				
	Pipes & Fittings	**Main Storage**	**Supply Points**	**Prepayment Extras**	**Total**
Conventional Stand tap	179 500	65 000	10 800	0	255 300
Mechanical Prepayment Stand tap	179 500	65 000	77 040	14 400	335 940
Electronic Prepayment Stand tap	179 500	65 000	27 900	40 000	312 400
Trickle Feed (Concrete Tanks)	151 700	38 000	36 000	0	225 700
Trickle Feed (Plastic Tanks)	151 700	38 000	63 000	0	252 700
Conventional Metered Yard Connections	585 500	65 000	64 800	0	715 300
Electronic Prepayment Yard Connections	558 500	65 000	132 300	40 000	795 800

Cost analysis of the project after construction (see Table 5) shows that the cost of the implemented trickle feed system was less than a conventional communal standpipe system in this application. The costs of pipes and fittings for the trickle feed system compared to a communal standpipe system were less than estimated due to the significant increase in pipe costs that have realised since 2000. These price increases were proportionally higher for the larger pipe diameters utilised in a communal standpipe system.

Table 5 – Cost Analysis of Implemented Trickle Feed System at Nondayana Compared to a Communal Standpipe System

System Type	**Costs (R)**			
	Pipes & Fittings	**Main Storage**	**Supply Points**	**Total**
Hypothetical Communal Standpipe System	225 000	65 000	20 000	310 000
Implemented Trickle Feed System	190 000	38 000	76 000	304 000

The project is currently operating as a gravity system with a protected spring source until the electric river abstraction pump is installed. Therefore, the only costs presently incurred for O&M of the system are salaries for staff and on going maintenance. Staff presently required to operate this project are two part time technical maintenance officers and one part time bookkeeper. Maintenance requirements since operation commenced in February 2002 have been minimal. Total O&M costs have averaged R2000 per month. Power cost for operation of the electric river pumps has been calculated to be R500 per month. Therefore, O&M costs for the project operating to original design can be expected to be approximately R2500 per month.

However, O&M costs involve more than just staff wages, maintenance and power costs (see Section 2.2.1). Comprehensive analysis of the total costs involved in O&M has been undertaken by Mvula Trust (2002) in the development of a rural water supply cost and tariff model. This model incorporates a wide range of costs in a spreadsheet model to calculate sustainable O&M costs of water supply projects in three demand scenarios (low, medium and high). Costs incorporated in the model include:

- Asset replacement costs.
- Overhead costs.
- Production costs.
- Repair and maintenance costs.
- Support and mentorship costs.

This model was applied to the Nondayana project in order to estimate realistic O&M costs. This was applied to the present project operation scenario with installation of the river pumps in October 2002. Total O&M costs were calculated to range between R6620 and R7122 per month (see Table 6), which is significantly higher than the basic estimate of R2500. However, it can not be expected that a Water Service Provider (PSC on this project) be responsible for total cost (eg. asset replacement and support and mentorship costs). These costs are shared between the Water Service Provider and the Water Service Authority in Table 6 to represent a realistic institutional management scenario. Cost to the Water Service Provider would then range between R2956 and R3458 per month.

Table 6 - O&M Cost for Nondayana Calculated by Rural Water Supply Cost and Tariff Model (Mvula Trust, 2002)

Cost Component	**Cost**	**Cost met by:**	
		Water Service Provider (PSC)	**Water Service Authority (Local government)**
Asset Replacement	R1219	R305	R914
Overhead	R2000	R2000	R0
Production Low demand Medium demand High demand	 R251 R502 R753	 R251 R502 R753	 R0 R0 R0
Repair and Maintenance	R400	R400	R0
Support and mentorship	R2750	R0	R2750
Total Costs			
Low demand Total cost Cost/Kl Average cost/household	 R6620 R3.89 R32.45	 R2956 R1.74 R14.49	 R3664 R2.14 R17.96
Medium demand Total cost Cost/Kl Average cost/household	 R6871 R2.02 R33.68	 R3207 R0.94 R15.72	 R3664 R1.08 R17.96
High demand Total cost Cost/Kl Average cost/household	 R7122 R1.39 R34.91	 R3458 R0.68 R16.95	 R3664 R0.72 R17.96

4.3.2 Maintenance

Monitoring of maintenance was undertaken by maintaining a record of maintenance events during the first six months of operation and conducting a survey of household tanks after one month of operation (March 2002) and five months after operation (July 2002).

Maintenance on the reticulation system has been minimal with significant maintenance only required on the Ntambone/Ndwaleni gravity main. This included repair of an improperly installed fitting and intervention to tampering with a break pressure tank. This tampering involved removal of the float control valve by local residents to receive more water.

Maintenance of the household tanks is summarised in Table 7.

Table 7 - Realised Maintenance Requirements for Household Tanks in Nondayana

Maintenance Requirements	**Percent of Household Tanks Affected**	
	After 1 month of operation	**After 5 months of operation**
Nothing required	77	65
Fix leaking taps	16	20
Maintenance of trickle feed box	7	17
Seal leaking cracks in concrete tank	0	1.5

The leaking taps have been due to faulty taps delivered by the supplier and inadequate securing of the tap in the concrete tank structure. Negotiations for rectifying the faulty taps are still ongoing. The design of securement of the taps in the tank has now been improved to include reinforcement (see Appendix B).

Maintenance to the trickle feed box has centred on the plastic valve utilised in the trickle feed box mechanism. The valves have a low tolerance to suspended solids in the water supply. These valves also have small components which can break and render the complete mechanism useless. However, frequency of total trickle feed box failure is still low (3%) which may be due to (Lenehan, 2002):

- Extensive flushing of the reticulation system of construction debris etc during commissioning before installation of the trickle feed mechanisms.
- Relatively good quality of inflow supply.
- Short period of operation.

The presence of small cracks in some concrete tanks has become apparent after five months of operation. The incidence of this fault is still low (1.5%).

During the construction process it was noted that insufficient attention was given to drainage and position of the tap to ensure adequate height for 25l containers at the household tanks. It was perceived that this could lead to environmental health risks. However, only 5% of the household tanks are experiencing drainage problems as consumers are careful to reduce wastage due to the limited supply available (Lenehan, 2002).

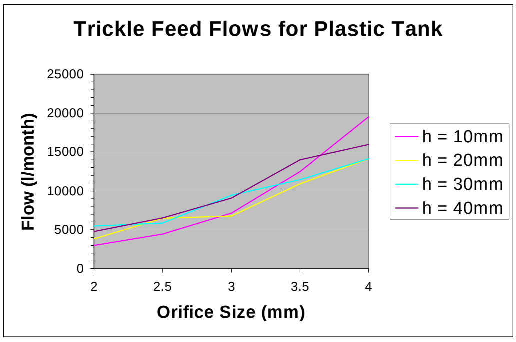
No incidences of tampering or illegal connections have yet been recorded at the household tanks.

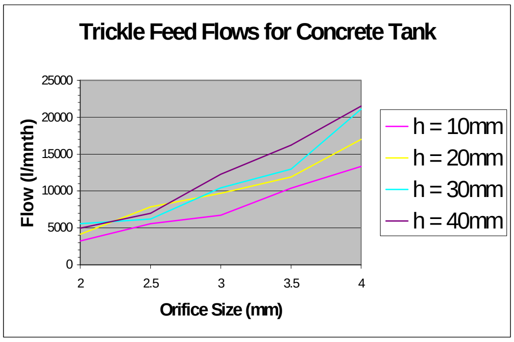
4.3.3 System Flows

Flows in the trickle feed system have been monitored by:

- Measuring spring inflow to the main storage and treatment works for four months (24 April – 21 August 2002).
- Meter readings on the two gravity mains for four months (24 April – 21 August 2002).
- Water use records at one household in each of the four communities of Damba, Magagadolo, Ndwaleni and Ntambonde for a period of one month (16 May to 19 June 2002).
- Meter readings at one household in each of the four communities of Damba, Magagadolo, Ndwaleni and Ntambonde for a period of three months (1 June to 21 August 2002).

Figure 5: Flows in household tanks





Graphs showing spring inflow and flow in the two gravity mains for the four month period, including water usage estimated from water use records over two months, are shown in Figure 5 above.

Meters were installed at one household in each community on the 1 June 2002 in order to determine household usage patterns more accurately. However, results from meter readings were not adequate to estimate usage patterns as intended. Meter reading in rural water projects is typically inadequate and usage patterns must be estimated from available data (Mvula Trust, 2002). A summary of deducted usage patterns from this data is shown in Table 8 below.

Table 8 – Summary of Water Usage Patterns for the Nondayana Water Project

Supply Area	**Supply to area from gravity main meter readings from 22/6 to 21/8 (m^3)**	**Estimated usage in area from household meter readings from 22/6 to 21/8 (m^3)**	**Estimated household usage per day (over 2 month period) (l)**	**Losses (%)**
Ntambonde/Ndwaleni	645	264	54	59
Damba/Magagadolo	677	538	76	21

Estimated household usage includes periods of non supply and does not indicate average use every day. As part of the household survey undertaken in July 2002 households were asked to estimate the number of 25 litre containers they filled during days of supply and average number of days they were supplied each week. These results are summarised in Table 9.

Table 9 - Summary of Reported Household Consumption

Community	**Average Consumption During Supply**		**Average Days per Month Supply Available**
	25l containers per day	**Litres per day**	
Ntambonde	4	100	1
Ndwaleni	4	100	3
Damba	4	100	8
Magagadolo	4	100	8

4.3.4 Technical

Technical evaluation of the household tank utilised in the trickle feed system was undertaken to assess the sustainability of this component of the system. This evaluation included:

- Surveys of tanks in operation in the Nondayana project (see Section 4.3.2).
- Development of solutions to problems encountered in the tank surveys.
- Controlled operation testing of tanks.

The development of solutions to tank problems involved constructing tank prototypes and testing. This was most significant in addressing the issue of leaking tap connections (see Section 4.3.2).

Controlled operation testing was undertaken to assess the flow characteristics in the tanks, particularly for different orifice and head above orifice (h) conditions. Results obtained for the 'Nondayana' concrete tank and the plastic tank are shown in Figure 5 above.

5.0 Evaluation of the Trickle Feed System

5.1 Technical Analysis

The sustainability of a water supply technology is dependent on the reliability and continuity of the service it provides (WHO, 2000). Technical reliability is evaluated by functioning time of the scheme measured as functioning days per month or year. Continuity is evaluated by the mean hours per day of supply in that functioning time. Flow patterns in the Nondayana scheme (see Section 4.3) indicate very low reliability. However, this is through deliberate management of the limited source and can not be attributed to the Trickle Feed System. When water has been supplied to respective communities, continuity is high. This has been facilitated by technical characteristics of the Trickle Feed System, such as:

- Consumer supply is independent of pressure.
- Supply security afforded by distributed household storages.
- Low maintenance requirements (see Section 3.3.2).
- Low losses – losses in the Damba/Magagadolo service areas were estimated at 21% which is significantly lower than average losses reported by Mvula Trust (2002) as 60%, with a range between 20% to 90%. Losses in the Ntambonde/Ndwaleni supply area were estimated at 59%, which is due to gravity main problems discussed in Section 4.3.3.

Low tolerance to suspended matter in the water has been experienced at both Mseleni and Nondayana projects, particularly in the commissioning stage. This has been rectified at both projects by extensive flushing of the reticulation system before installing the trickle feed boxes.

Sustainable operation of the trickle feed box is still not possible to ascertain due to the short period of analysis. Variables which require long term monitoring and evaluation include operation of the float valve, frequency of blockage in the float valve and blockage of the orifice. Trickle feed boxes requiring maintenance in the Nondayana project has risen from 3% after one month of operation to 12% after five months of operation (see Section 4.3.2). However, only 3% of the trickle feed boxes have experienced complete failure after five months of operation. Operation of the trickle feed boxes in the Newtown and Kransdraai projects have not yet experienced any significant technical problems.

5.2 Financial Analysis

Cost recovery efficiency is also dependent on the level of service provided and associated costs. Financial analysis in Section 4.3.1 indicates that the initial capital cost of implementation of a Trickle Feed System in Nondayana was cheaper than implementing a communal standpipe system. This however can not be assumed to be the case in all applications. Feasibility studies of potential application of Trickle Feed Systems in other northern KwaZulu Natal communities have shown the extra initial capital cost above the communal standpipe option to range from 10-12% (Ferreira, J. – pers. Comm.)

Realised O&M costs for supply of water in Nondayana have been R4.59/kl including the high losses in the Ntambonde/Ndwaleni supply area. This compares well with the mean cost per kilolitre of R4.96 in KwaZulu-Natal rural water supply projects (Mvula Trust, 2002), with a standard deviation R3.58. Modelling of supply costs in the Nondayana project, assuming design level of service (including electrical pumping), 40% losses and inclusion of all costs (asset replacement, support and mentorship etc.) as shown in Section 4.3.1, calculates the O&M cost of operation to be as low as R2.02/kl for high consumer demand.

5.3 Social Analysis

Community acceptance of a project is a significant variable in determining the cost recovery efficiency. This is related to the community's ability and willingness to pay. Efficient operation of the Nondayana project, despite the limited flow, can be attributed to the high degree of community acceptance (see Section 4.2). This is due to the poor level of water supply service which existed before project operation (see Section 3.1), and extensive community liaison undertaken before and during implementation.

Lack of community acceptance has significantly contributed to problems experienced in application of the Trickle Feed System in Tubaste, Newtown and Mseleni (see Section 2.3.5). This has principally due to existing higher levels of service in or near the recipient community and/or poor community liaison. This has resulted in rejection of the technology as an option, non payment of tariffs, tampering and vandalism.

5.4 Compatibility of the Trickle Feed System with the Implementation of the Free Basic Water Policy

5.4.1 The Free Basic Water Policy

In February 2001, the Minister of Water Affairs and Forestry announced a policy of provision of 6000l of water supply per household per month free of charge. This policy was initiated for several reasons. These include:

- The poorest 40% of the population (of which 75% are rural) have experienced an approximate 21% decrease in income over the last 8 years (Whiteford & van Seventer, 1999). Hence, the delivery of free basic municipal services has become an important initiative by the Government to alleviate poverty.
- The previous policy of water supply of charging a tariff to cover O&M costs has resulted in significantly lower water usage; particularly in rural areas. As a result, health benefits anticipated from the implementation of water supply services have been seriously compromised. The significance of optimising health benefits was highlighted during the cholera outbreaks experienced in the summers of 2000/2001 and 2001/2002. The sustainability of water schemes has also been compromised due to the lack of adequate external financial subsidisation.
- The new Constitution adopted by South Africa in 1996 contains a *bill of rights* which guarantees everyone the right to sufficient food and water. Terms and conditions under which service providers were to guarantee sufficient water supply were clarified in the 1997 Water Services Act which indicated that persons unable to pay for services were entitled to free basic water.

International experience of implementing subsidised water supply policies for indigent households shows difficulty in targeting relevant consumers and high administration requirements (Gomez-Lobo & Contreras, 2000). However, South Africa's self-targeting subsidy requires no means testing or high administration and is potentially viable (DWAF, 2002).

5.4.2 Implementation of the Free Basic Water Policy

Although the free basic water policy was initiated by the National Government, implementation is the responsibility of local government. Funding of implementation is anticipated to come from two sources:

- Cross subsidisation within local government areas from higher consumers, taxes and levies.
- Allocation of an 'equitable share' of nationally raised revenue to local government as required in the 1996 Constitution.

The potential for cross subsidisation in a local government area is dependant on the ratio between wealthy and poor consumers, the distribution of consumption in the supply are (i.e. the ration of large to small consumers) and the ration between industrial and residential consumers (DWAF, 2002). Therefore, cross subsidisation is lowest for rural local government areas with a high proportion of low income households.

The equitable share grant is principally to ensure that low income households in all municipalities receive access to basic municipal services (DPLG, 2000). It is based on the number of households in a local government area with a household expenditure less than R1 100 a month. The grant therefore favours municipalities with the highest level of poor households and most limited potential for cross subsidisation.

Implementation was planned to be undertaken in a phased approach from July 2001 (DWAF, 2002) with ultimate incorporation into a Water Services Development Plan in each area over a 5 year period. Presently, 191 of a total of 262 local government authorities in South Africa are implementing a free basic water policy. It was recognised that some municipalities would not have the capacity to implement a policy in the short term and until that time cost recovery for O&M should still take place.

Approximately 60% of South Africa's population is now served with free basic water supply. However, 50% of these people are in six Metro Municipalities with high institutional capacity and significant potential for cross subsidisation (DWAF, 2002). The total population of these Metros (12.6 million) will receive the free basic service in 2002. However, the 102 local authorities with a population of 14.6 million and average household income of less than R1200 per month have insignificant potential for cross subsidisation and have previously received inadequate equitable share allocations (Hazelton, 2001).

Application of the free basic water policy in rural communities is anticipated to be difficult (DWAF, 2002; Rall, 2001;Still, 2001a) due to:

- The lack of high income sectors which can afford to cross subsidise poorer sectors.
- Rural schemes have higher water wastage and losses as a percentage of total supply.
- Many existing rural schemes are too capitally intensive relative to existing institutional capacity.
- Lack of existing infrastructure.

District Municipalities have taken the responsibility for implementation of free basic policy in the rural areas in KwaZulu Natal. Implementation has been difficult. Rural District Municipalities such as Zululand and Umkhanyakude have previously been constrained due to lack of cross subsidisation potential, inadequate ‘equitable share’ and limited capacity. In the interim most District Municipalities have formulated first phase policies for implementation of free basic water. Zululand District Municipality has adopted an initial policy of supplying 5 litres per person per day (1200 litres per household per month) free within a distance of 800m by drilling boreholes. This includes installing and maintaining handpumps and protecting springs. Most other District Municipalities are adopting similar policies (Davis, 2002 – pers. comm.). Ugu District Municipality, which has reasonable capacity and infrastructure, has adopted a policy of reducing rural bulk tariffs to match urban tariffs through cross subsidisation.

DWAF has assumed the responsibility of facilitating local authorities in implementation of free basic water. This has included research, communication and promotion of allocation of available funds local government. DWAF’s communication strategy in 2002 included a Local Government Information Kit which will include the revised free basic water implementation strategy and guidelines, rural specific guidelines, improved financial models, pilot study summaries, guidelines on water supply control devices, a prepaid meter study report and water services regulations guidelines. Most importantly, the allocation of equitable share will increase significantly over the next three years.

5.4.3 Utilising the Trickle Feed System to the Implement Free Basic Water Policy

Sustainable implementation of free basic water is dependant on the O&M costs of water schemes to be within the constraints of funding available to local government. The Trickle Feed System offers an alternative to decision makers, which has the capacity to operate sustainably within this constraint. This is due to:

- Low operation and maintenance requirements – technical components of a trickle feed system require operation and maintenance which is within the capacity of local skills in the rural environment.
- Simple to administer – supply to consumers is set automatically and no meter reading is required to effect cost recovery if required.
- Reduced losses in a low pressure system – a low pressure system results in lower losses and a maintenance schedule with less frequency and significance of events.

Application of the trickle feed system as part of a free basic water policy is possible in environments in which this is an increase in level of service. Increase in level of service will stimulate willingness to pay for or value this new service. This is important to ensure community acceptance of a technology application.

Successful implementation of a Trickle Feed System is also dependant on:

- Extensive community liaison and education to ensure acceptance by consumers and minimise tampering and illegal connections. This should be standard practice in all water supply service installation and supply and is required as per the Water Services Act (RSA, 1997).
- Reticulated water must be kept clean of suspended matter to ensure sustainable operation of the trickle feed box.

Implementation of a tariff structure for consumption above the basic level of service can be achieved by adopting a fixed monthly tariff for predetermined extra consumption. Cost recovery of this tariff can be achieved with pre-paid flat rate requiring minimal administration. This creates potential for cross-subsidisation within a community and reduction of project operation and maintenance deficit.

Trickle Feed Systems require the construction of a tank at each household. This typically requires an up front payment (R50 per household at Nondayana) to subsidise this component of capital construction. Credit options for consumers who can not afford this up front payment are available (Venter-Hilderbrand, 2000) and include:

- Retail Loan Option
- Savings Investment (Stokvels) Option
- Savings ('pure' Stokvels) Option
- Institutional Loans
- Cross Subsidisation

6.0 Conclusions and Recommendations

The Trickle Feed System is a new technology in application in community water supply in South Africa. It has not yet been adequately tested, particularly in the implementation of the Free Basic Water Policy in rural communities. Operational trickle feed systems in rural communities so far only includes two projects in South Africa, both since February 2002. In neither of these projects has a free basic water strategy been implemented by their respective local government authorities.

However, several urban and rural case studies investigated in this research project indicate that the Trickle Feed System is successful in delivery of a reliable and consistent high level of service. Variables outlined in Section 3.0 which affect the effectiveness of the Trickle Feed System in implementation of Free Basic Water Policy were highlighted in investigation of the case studies. These included:

- Low cost higher level of service – implementation of a level of service higher than communal standpipe delivery is low cost, and can be cheaper as demonstrated in Nondayana Water Project.
- Simple administration – staff requirements to operate, maintain and administer the projects are minimal.
- Options to consumers – several options for household tanks have been utilised in various projects which provides more options for application of free basic water strategies.
- Low maintenance – several projects have been operating with minimal resources available for maintenance.
- Equitable supply and low losses – operation and consumption histories of both Nondayana and Kraansdraai projects indicate that equitable supply is achieved with minimal losses.
- Increased supply security – the supply security provided by distributed storage has been significant in ensuring equitable supply against a limited source at the Nondayana project.

Development of free basic water strategies are facilitated by lower costs of implementation, operation and maintenance. The are also facilitated by simple and adaptable systems which deliver equitable and consistent supply to consumers. These variables have been evident in the case studies investigated with trickle feed systems.

However, community acceptance of Trickle Feed Systems may not be positive if it is perceived as a decrease in level of service. This was a significant factor indicated in several case studies, particularly where community expectations are affected by existing or adjacent water supply services.

It is strongly recommended that further research is undertaken to develop the Trickle Feed System as an option for rural community water supply. Although present research indicates high potential utilising this technology for implementing free basic water strategies, operation of schemes has not been long enough to properly assess some variables and no free basic water strategy has yet been implemented with this technology. Areas of further research include:

- Operation and maintenance costs – although O&M costs have been low, longer operation periods will indicate if these costs stay low.
- Household tank options – further research is required on the household tank options including the internal trickle feed mechanisms to ensure sustainable operation.
- Consumer acceptance – variables which affect consumer and community acceptance need investigation to ensure appropriate application.
- Free Basic Water Strategies – the development of strategy options for trickle feed projects and implementation with local authorities is required.

7.0 References

Abrams, R *Personal Communication.* rabrams@paradise.net.nz.

Bailey, R 2002 *Application of the Durban Tank in a Rural Water Supply System*. eThekwini Water Services, Durban.

Bellars, J *Personal Communication* Umgeni Water. jane.laatz@umgeni.co.za.

Business Partners for Development 2001 *Report to the Steering Committee: KwaZulu Natal Pilot Project.*

Dedekind, J *Personal Communication.* dedekindj@pmbcc.gov.za.

Dreyer, L. 1997 *The Dynamics of Community Non-Compliance with Basic Water Supply Projects.* Water Research Commission Report No. TT 93/98, Pretoria.

Drinkwater, M. & Rusinow, T. 1999. *Presentation of CARE's Livelihood Approach for NRAC '99*. www.care.org.

Department of Water Affairs and Forestry 1994 *Water Supply and Sanitation Policy – White Paper.* DWAF, Pretoria.

Department of Water Affairs and Forestry 1997 *Implementing Prepayment Water Metering Systems.* DWAF, Pretoria.

Department of Water Affairs and Forestry 1998 *Understanding the Cost Recovery Challenge: A Study of Ten Rural Communities.* DWAF, Pretoria.

Department of Water Affairs and Forestry 2000 *Site Evaluation of Four Electronic Prepayment Water Metering Cost Recovery Systems.* DWAF, Pretoria.

Department of Water Affairs and Forestry 2001a *Free Basic Water: Press Releases.* DWAF, Pretoria.

Department of Water Affairs and Forestry 2001b *Fee Basic Water Provision – Key Issues for Local Authorities.* DWAF, Pretoria.

Department of Water Affairs and Forestry 2002 *Information Kit for Free Basic Water Implementation in South Africa.* DWAF, Pretoria.

Department of Water Affairs and Forestry 2003 *Fee Basic Water* – www.dwaf.gov.za

Ferreira, J. *Personal Communication*. AquAmanzi Developments (Pty) Ltd. aqualdy@futurenet.co.za

Hazelton, D. 2001 *Implementing SA's Free Basic Amount of Free Water Policy.* 6th Annual Water Africa Conference.

Keth, D *Personal Communication* Watertite Conservation (Pty) Ltd. watertit@iafica.com.

Laubscher, W *Personal Communication* AquAmanzi. laubscherw@jgi.co.za.

Lenehan, A 2002 *First Progress Report for the Nondayana Yard Tank Pilot Project*. Report to DWAF I & OS Directorate, Pretoria.

Lima Rural Development Foundation 2000 *Assessment of the Attended Coupon-operated Access-point Cost recovery System for Community Water Supply Schemes*. Water Research Commission Report No. TT 150/01, Pretoria.

Middleton, R. 1998 *World of Water: Beyond the International Drinking Water Supply and Sanitation Decade.* Lewis Publishers.

Miller, J *Personal Communication* LW Tank Systems CC lwts@lantic.net

Milton, J., Chetty, Y. 1998 *Overview of the New Water Legislation of the Republic of South Africa.*

Mvula Trust 2002. *A Rural Water Supply Cost and Tariff Model*. Water Research Commission Report.
Unpublished.

National Disaster Management Committee 2001 *Cholera.* sandmc.pwv.gov.za/ndmc/cholera.

Painting, E. *Personal Communication* evanrp@icon.co.za.

Republic of South Africa 1997 *Water Services Act No. 108 of 1997.* Cape Town.

Republic of South Africa 1998 *National Water Act No. 36 in 1998.* Cape Town.

Rall, M 2001 *Free Basic Water – Tapping its Development Potential in Rural Areas.* Email 18 October, 2001.

Still, D. 2001a *Free Basic Water in Rural Areas: Is it Feasible? A Perspective From KwaZulu Natal.* SAICE Congress 3 July, 2001

Still, D. 2001b *Rural Water Supply in South Africa.* DWAF Appropriate Technology Conference 22/23 November 2001.

Still, D *Personal Communication* Partners in Development. pidpmb@iafica.com

Solsona, F. 1991 *Water Metering and an Alternative System for Water metering in Developing Countries.* Division of Water Technology, CSIR. Pretoria.

Sussens, H. *Personal Communication* Department of Water Affairs and Forestry. sussensh@dwaf.pwv.gov.za

The Republic of Kiribati 2001 *Draft Report on the Implementation of Pilot Study – Kiribati SAPHE Project Water Supply Constant Flow System*. Kiribati.

Tipping, J. 2001 *An Overview of 'Trickle-Feed' Distributed Storage for Rural Water Supply in South Africa*. www.gde.co.za/tfreport.html

World Health Organisation 1997 *Conquering Suffering, Enriching Humanity.* Report of the Director General.

World Health Organisation 2000a *Global Water and Sanitation Assessment 2000 Report.* www.who.int/water_sanitation_health/Globalassessment/Global2.html

World Health Organisation 2000b *Tools for Assessing the O&M Status of Water Supply and Sanitation in Developing Countries.* WHO, Geneva.

Appendix A

Hydraulic Characteristics of the Trickle Feed System

Flow through the orifice is determined by the equation:

$$Q = Kd^2h^{1/2}$$

where:

Q = flow through the orifice.

K = coefficient dependant on velocity and constriction of flow through the orifice.

d = diameter of orifice.

h = head of water above the orifice.

Therefore, the constant flow (Q) is more dependant on the size of the orifice (d) than the height of the water above the orifice (h). It is very important to size the orifice correctly for a chosen constant flow. Results from empirical testing of the trickle feed box utilised in the Nondayana Project for flows from set orifice diameters are shown in Figure 1.

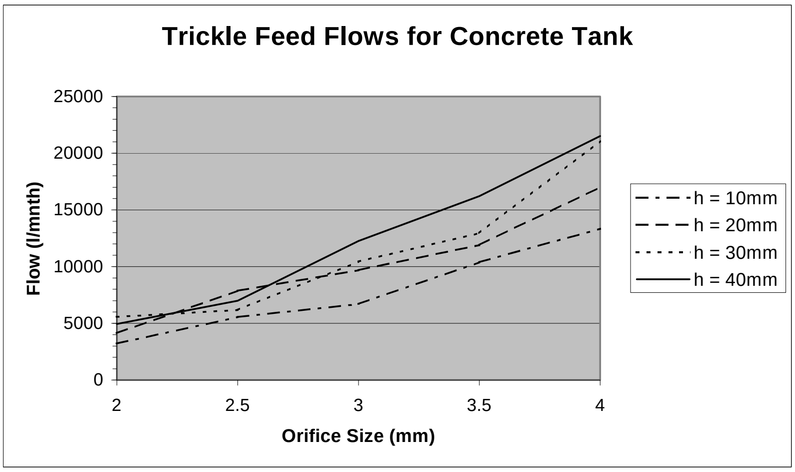


Figure 1 – Trickle Feed Flows for 'Nondyana' Concrete Household Tank

Q is also significantly dependant on the coefficient K, which is highly dependant on the physical characteristics of the orifice. These include:

- Shape of the orifice.
- Thickness of the wall in which the orifice is located.
- Angle at which the orifice is drilled and any imperfections from drilling.
- Proximity of the orifice to other physical constraints to flow dynamics, such as the side wall of the trickle feed box, the float valve, another orifice or debris in the trickle feed box.

Therefore, flows for determined diameters will be slightly different for each model of trickle feed box utilised.

Q is theoretically independent of the inlet pressure to the trickle feed box due to the control of the float valve. However, experimental results have shown that there is an approximate 1% increase in Q for a 100% increase in inlet pressure (Solsona, 1991). This is due to an onflow after closure of the float valve, which increases with inlet pressure.

Appendix B
Construction of the 'Nondayana' Concrete Household Tank

The hessian is first sewn into bags
for the stand and tank.

The hessian bags are filled and shaped.

A cement slurry is applied to
ensure binding of the plaster.

Plaster is applied to the outside.

A second layer of plaster is applied.

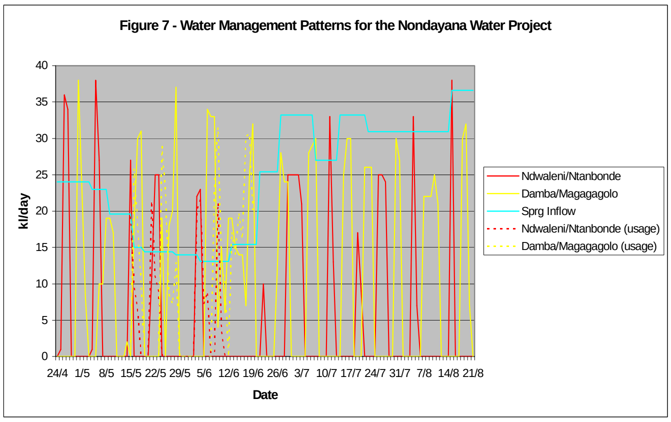
Reinforcement of the tank outlet tap.

The trickle feed box in the tank.

A completed prototype with access for testing.

A tank at Nondayana. (Note plaster seal on lid and encased inlet pipe)

APPENDIX C: Water Management Patterns for the Nondayana Water Projects



Appendix D

Summary of Results from Community Baseline Survey

QUESTIONS	ANSWERS	PERCENTAGE
How long have you lived in Nondayana?	0 - 5 years	
	6 - 10 years	14%
	11 - 20 years	27%
	Always	47%
Where did you live before?	Farm	6%
	Village	94%
Standard of Education	Grade 1	0%
	Grade 2	2%
	Grade 3	12%
	Grade 4	8%
	Grade 5	16%
	Grade 6	16%
	Grade 7	3%
	Grade 8	9%
	Grade 9	9%
	Grade 10	9%
	Grade 11	6%
	Grade 12	6%
	Technikon	4%
	Univeristy	0%
Which is your drinking water source?	Handpumps	15%
	River	27%
	Spring	58%
Which is your clothing washing source?	Handpumps	8%
	River	55%
	Spring	35%
	Rainwater	2%
Which is your cooking water source?	Public tap water	14%
	River	28%
	Spring	58%
Which is your bathing water source?	Public tap water	11%
	River	34%
	Spring	55%
Do you pay for water?	Yes	37%
	No	63%

QUESTIONS	ANSWERS	PERCENTAGE
How long does it take for you to fetch water?	0 - 30 minutes	32%
	30 - 60 minutes	43%

	60 minutes +	25%
How many 25 l containers are used daily?	1	12%
	2 - 3	48%
	4 - 6	35%
	more than 6	5%
How far away is your water source located?	0 - 100 m	21%
	100 m - 250 m	50%
	more than 250 m	29%
Which illness is most common in your home?	Cholera	28%
	Diarrhoea	16%
	T.B.	10%
	Other	46%
Has anyone suffered from Cholera in the last month?	Yes	46%
	No	44%
	No Response	10%
How many people live in your home?	0 - 5	20%
	6 - 10	42%
	11 - 15	31%
	16 +	7%
What is your work status?	Self Employed	4%
	Employed Full Time	8%
	Employed Part Time	11%
	Casual Work	5%
	Unemployed	27%
	Retired / Pensioner	30%
	Student	2%
	Disabled	2%
	Housewife	11%
Do you use the Handpump?	Yes	35%
	No	65%
How do you feel about the Handpump?	Very Satisfied	18%
	Satisfied	24%
	Unsatisfied	27%
	Very Dissatisfied	31%
Have you Heard about the Trickle Feed system?	Yes	88%
	No	12%
Have you signed a Trickle Feed installation contract?	Yes	63%
	No	37%

QUESTIONS	ANSWERS	PERCENTAGE
Do you know how the Trickle Feed System works?	Yes	49%
	No	51%
Are you prepared to pay a regular tariff for household water?	Yes	94%
	No	6%

How much would you be prepared to pay for a monthly tariff?	0 - R5-00 R5-00 - R10-00	30% 70%
Do you think that some families will not be able to afford this tariff?	Yes No	91% 9%
Shoud these families get a Trickle Feed system?	Yes No Don't Know	35% 35% 30%
Should these families get a Trickle Feed system that is subsidised within the community?	Yes No Don't Know	23% 47% 30%
Should these families get a Trickle Feed system subsidised by the government?	Yes No Don't Know	72% 8% 20%
Should families who do not pay the tariff, have their water switched off?	Yes No Don't Know	42% 33% 25%
Should families who do not pay the tariff, be given a warning?	Yes No Don't Know	68% 20% 12%
Should families who do not pay the tariff, be fined?	Yes No Don't Know	17% 60% 23%
Should families who do not pay, have no consequences?	Yes No Don't Know	20% 62% 18%
Do you think the Trickle Feed system will be hygienic?	Yes No Don't Know	94% 2% 4%
Do you think the Trickle Feed system will be safe?	Yes No Don't Know	92% 0% 8%
Do you think the Trickle Feed system will be easily accessable?	Yes No	97% 3%
Do you think the Trickle Feed system will provide sufficient water?	Yes No Don't Know	86% 3% 11%

QUESTIONS	ANSWERS	PERCENTAGE
Do you think the Trickle Feed system will be easy to use?	Yes No Don't Know	91% 0% 9%
Do you think the Trickle Feed system will be cheap?	Yes No Don't Know	59% 23% 18%
Do you think the Trickle Feed system will be	Yes	26%

expensive?	No	59%
	Don't Know	15%
Do you think Trickle Feed tanks will be insecure?	Yes	29%
	No	51%
	Don't Know	20%