

# Leakage Reduction Through Pressure Management In Khayelitsha: Western Cape, South Africa

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## EXECUTIVE SUMMARY

Khayelitsha is one of the largest townships in South Africa and is located approximately 20 km from Cape Town on the Cape Flats (a large flat sandy area at or near sea level). There are approximately 43 000 serviced sites with both internal water supply and water borne sewage while there are a further 27 000 low-cost housing units which are supplied from communal standpipes supporting a population of approximately 450 000.

At the beginning of the new millennium, the water supplied to Khayelitsha was measured to be almost 22 million m<sup>3</sup>/a. The level of leakage was estimated from the night-time water use to be almost three-quarters of the water supplied to the area. The Minimum Night Flow (MNF) was measured to be in excess of 1 600 m<sup>3</sup>/hr which is sufficient to fill an Olympic sized swimming pool every hour.

The main source of the leakage was identified as the household plumbing fittings which have been badly damaged through constant exposure to a relatively high pressure of 80m. Such leakage results in very high water consumption in most properties and high levels of non-payment since the customers cannot afford to pay for new taps and toilet fittings let alone the high water bills.

The Khayelitsha Pressure Management Project was therefore proposed in 2001 to improve the level of service to the Khayelitsha community by reducing the excessive water pressure and pressure fluctuations in the reticulation system.

Following the construction and commissioning of the pressure management installation, the average daily flow was reduced from 2 500 m<sup>3</sup>/hr to 1500 m<sup>3</sup>/hr representing an annual saving of 9 million m<sup>3</sup>/yr or approximately 40% of the original water use. The Minimum Night Flow was reduced from 1 600 m<sup>3</sup>/hr to 750 m<sup>3</sup>/hr.

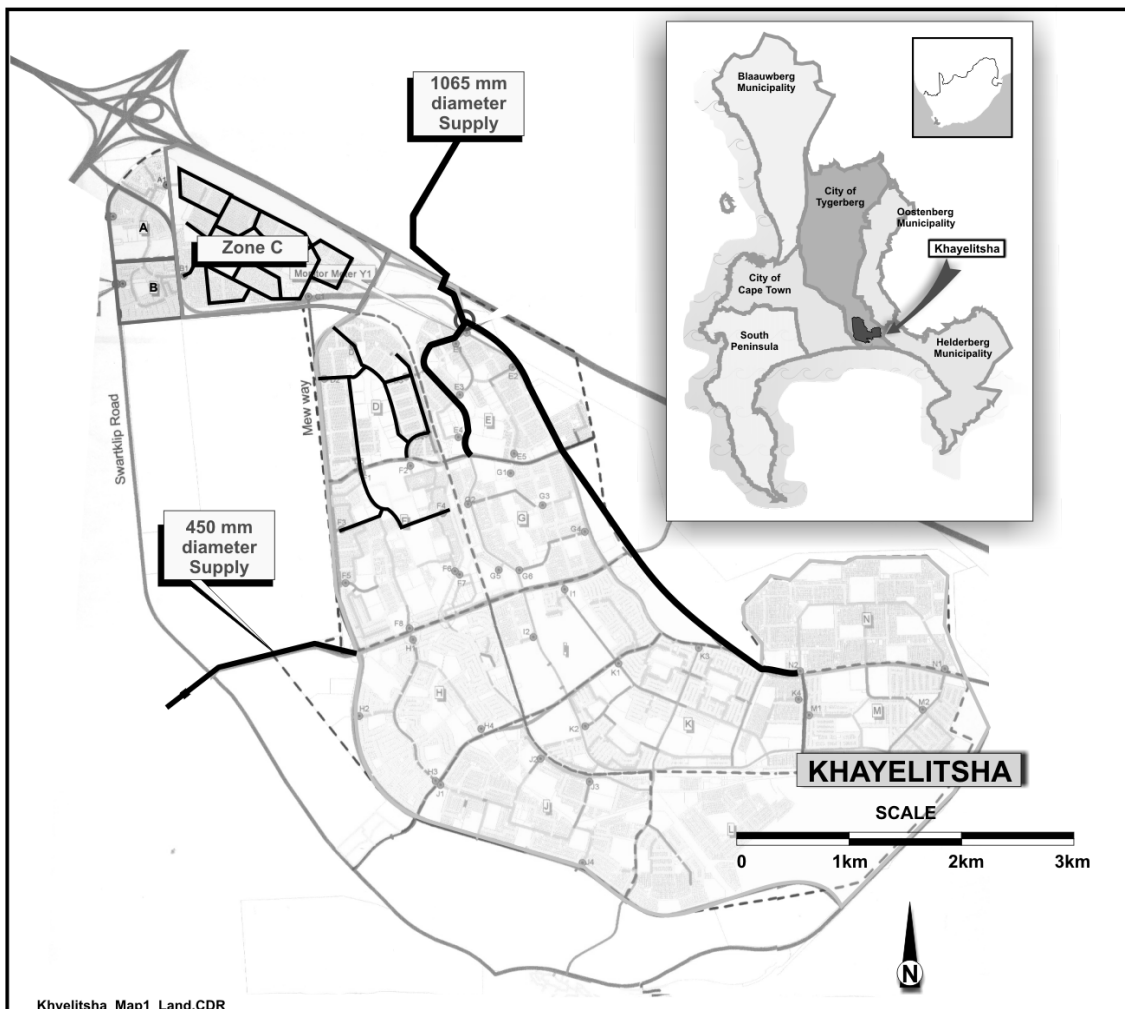
The approach used in the Khayelitsha installation is both simple and innovative and the savings achieved have exceeded both the Client's and the Project Teams' most optimistic expectations. Local labour was used throughout the project and the community support was a key factor in the successful implementation of the project.

From the Client's perspective, the Khayelitsha project shows not only Technical Excellence but also a true regard for the community and the environment. The project itself will save in excess of 9 million m<sup>3</sup>/year representing a financial saving of more than US\$3 million per year at current 2002 water rates – i.e. a 2 month pay-back.

## INTRODUCTION

Khayelitsha is one of the largest townships in South Africa and is located approximately 20 km from Cape Town on the Cape Flats. The area, which was previously a nature reserve, covers approximately 24 km<sup>2</sup> and now provides housing to approximately 450 000 people. There are approximately 43 000 serviced sites with both internal water supply and water borne sewage while there are a further 27 000 low-cost housing units which are supplied from communal standpipes. The area has been expanding continuously since the early 80's when the first settlements were established. The basic water distribution infrastructure is therefore relatively new and is considered to be in generally good condition.

Khayelitsha is supplied with potable water from Blackheath Reservoir situated at an elevation of 110 m through two large water mains supplying the area at an average pressure of approximately 80 m (8 Bar). A 1065 mm main supplies water from the north while a second 450 mm diameter pipe supplies the area from the west as can be seen in **Figure 1**.



**Figure 1: Location Map for Khayelitsha**

As the Khayelitsha township has grown, so too has the overall water consumption as well as the leakage from the system. At the beginning of the new millennium, the water supplied to Khayelitsha was measured to be almost 22 million m<sup>3</sup>/a. The levels of leakage

and/or wastage in an area can be estimated from the analysis of the Minimum Night Flow (MNF) which normally occurs between the hours of 2 am and 3 am in the morning when most of the population are asleep. In the case of Khayelitsha, the MNF was measured to be in excess of 1 600 m<sup>3</sup>/hr which is sufficient to fill an Olympic sized swimming pool every hour. From the analysis of the minimum night flows as well as the night-time sewage flows, it was established that most of the water supplied to the area was being returned to the sewer system through household leakage.

The Khayelitsha Pressure Management Project was therefore proposed in 2001 to improve the level of service to the Khayelitsha community by reducing the excessive water pressure and pressure fluctuations in the reticulation system. The high pressures and associated fluctuations over the past 20 years have caused serious damage to the internal plumbing fittings with the result that household leakage accounted for more than 80% of the non-revenue water supplied to the area. By reducing the pressure, it is possible to reduce such leakage and at the same time provide a better level of service to the consumers.

The City of Cape Town Administration fully supported the proposal and endorsed the findings of the Project Team. They agreed to proceed immediately with a small-scale pilot project in Zone C of Khayelitsha (see **Figure 1**) which was commissioned in January 2001 at minimal cost. The pilot installation was a great success and clearly demonstrated the benefits that can be achieved through pressure management in Khayelitsha. The savings through leakage reduction from the Pilot Project were estimated in March 2001 to provide a payback of less than 6 months. As a result of these findings, the City of Cape Town Administration quickly approved the commissioning of a full-scale project which commenced in June 2001 and was completed in February 2002.

## **SCOPE OF THE PROJECT**

In order to reduce wastage of water in an area it is first necessary to establish exactly where the main problems lie to ensure that the actions taken are appropriate and effective. In the case of Khayelitsha, the leakage problem was not due to burst pipes in the distribution system but rather to poor internal plumbing fittings which were leaking continuously. This conclusion was reached from the analysis of the minimum night flows into the area as well as the sewage return flows from the area. It should be noted that the City of Cape Town Administration is one of the few progressive water suppliers which has a policy of logging and monitoring both the inflows and sewage return flows in selected areas.

Having identified the key source of the leakage, the next step was to identify the most appropriate course of action to reduce the leakage permanently. In many other areas with similar leakage problems, the solution adopted by Consultants on behalf of the water supplier often involves retrofitting of plumbing fittings within the properties as the first action. While this course of action is appropriate in certain situations, care must be taken to address the underlying cause of the problem and not simply the overlying symptom. In many cases, the internal plumbing fittings are leaking not just because they are of poor quality but rather because the system pressures are excessive. If the system pressures are too high, even high quality fittings will start to leak after a few years. In such situations, the positive effects of retrofitting will be short-lived and the leakage levels will quickly return to the pre-retrofitting levels – usually within a year or two. The solution to this problem is to address the overall pressure problem after which the plumbing fittings can be replaced with confidence. It is interesting to note that retrofitting is one of the most costly Water Demand Management measures to implement and, to date, there are few (if any)

clear case studies demonstrating the long-term benefits in any water supply system in South Africa.

In order to implement pressure management, it is normally a reasonably simple procedure to install a standard pressure reducing valve. In the case of Khayelitsha, however, the situation was neither straightforward nor simple due to the size of the two supply pipes into the area. The Project Team decided that the most practical approach would be to cut into the two water mains and commission two installations, each with several sections of small diameter pipe and the appropriate sized PRV's. In this regard it was decided to install three 300mm diameter sections in the 1065 mm diameter main and two 200 mm diameter sections in the 450 mm diameter main as shown in **Figures 2** and **3**. It was also decided to introduce advanced pressure control which involves the commissioning of specially imported electronic controllers which are used to manipulate the pressure into the area during off peak periods. Through the use of such controllers, it is possible to achieve savings which are significantly larger than those normally obtained through the PRV's on their own.

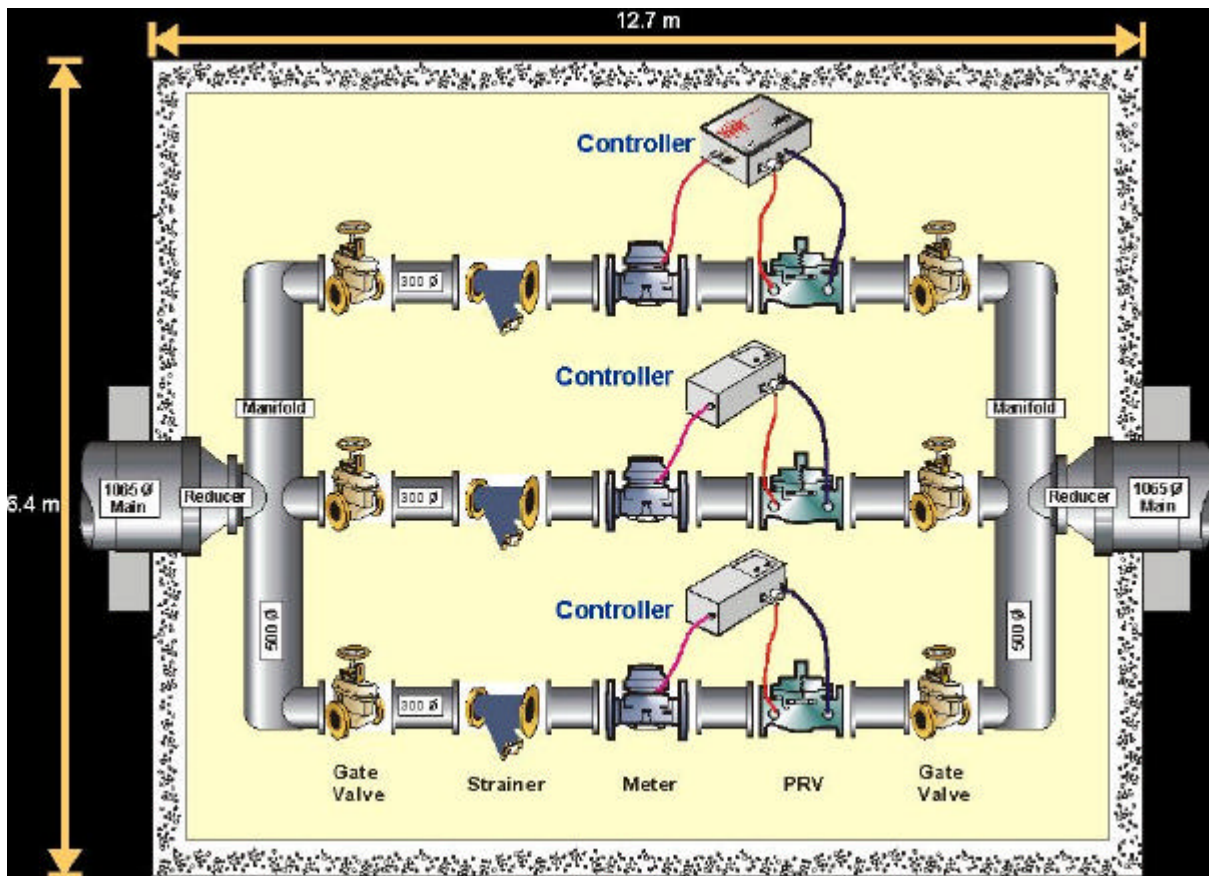


Figure 2: Schematic Layout of the 1065 mm diameter Installation

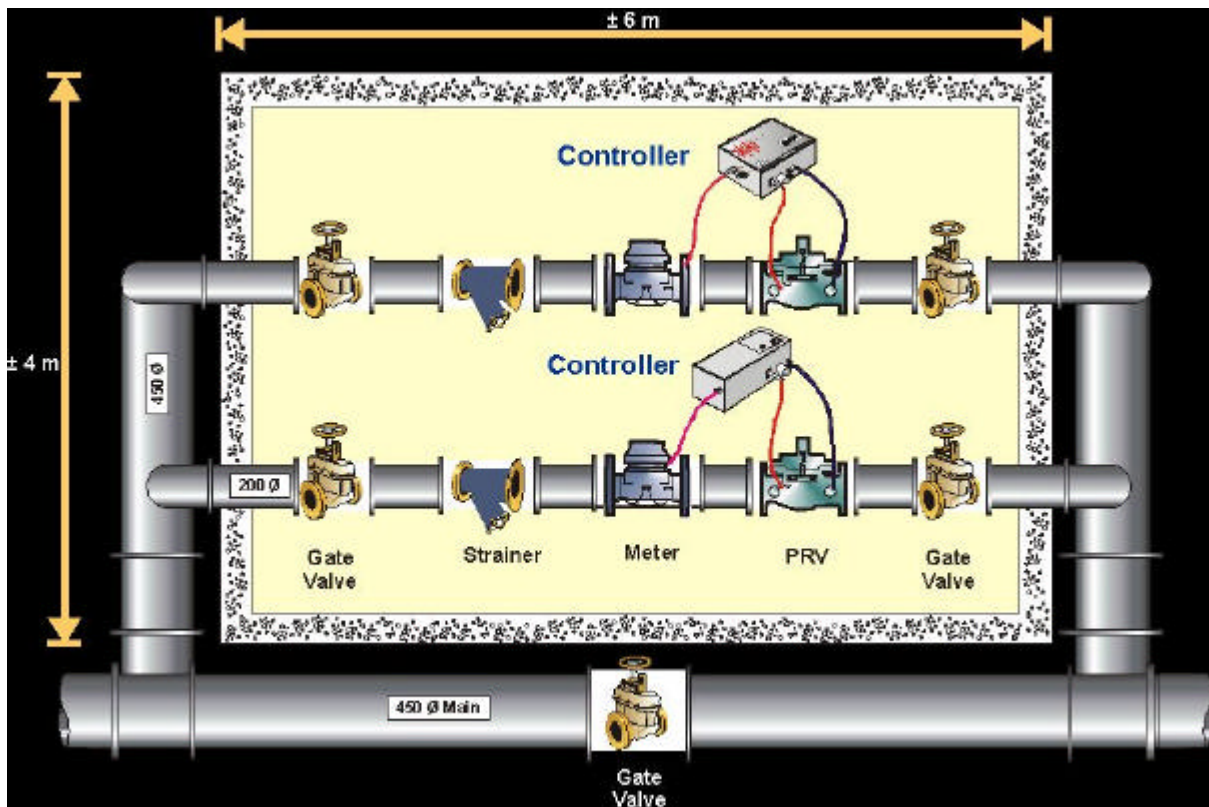


Figure 3: Schematic Layout of the 450 mm diameter Installation

## PROJECT IMPLEMENTATION

Having agreed on the approach and the conceptual design for the two PRV installations, the most difficult stage of the project was the construction of the chambers and the installation of the mechanical equipment. Most of the problems encountered were anticipated to a large degree although the following did cause some problems:

- Shortly after the start of the project (July and August 2001), the area was hit by severe storms resulting in the wettest two months since records began back in the 1870's. This problem was further aggravated by the sandy soil which had to be fully dewatered before any excavations could take place.
- The Client was unable to stem the flow of water in the pipelines due to leakage at the upstream valves with the result that the pipeline could not be drained. This in turn caused serious problems for the mechanical contractor who had to weld on new pipe flanges after cutting into the pipes. It was only through world-class welders working under the most atrocious conditions that it was at all possible to commission the installation.

As a result of these problems and others, several major on-the-spot design changes had to be implemented which involved quick action by both the Structural Engineer as well as the overall Project Manager. Despite the problems, the water supply to Khayelitsha was maintained (albeit at a lower level of service) throughout the cut-in period and no serious complaints were received from the consumers.

Some details of the 1065 mm diameter installation are shown in **Figures 4 and 5** from which the size and complexity of the project can be seen.



**Figure 4: Excavating and De-watering the Site for the 1065 mm Chamber**



**Figure 5: Internal View of a Portion of the 1065 mm diameter Chamber**

**Figure 4** shows the problems encountered with the high water table and wet conditions during construction which necessitated the use of a de-watering system since the bottom of the chamber is more than 6m below ground level. A blank flange plate can also be

seen which indicates the location of the water main. **Figure 5** shows some of the pipe details inside the chamber including the valves, meters, strainers and controllers.

## RESULTS FROM THE PROJECT

When motivating the project to the Client, the Project Team took great care not to over-emphasise the likely savings and not to create unrealistic expectations on the part of the Client. A one-year pay-back was indicated to the Client with the proviso that the savings could be higher depending on the level to which the pressures can be lowered. Despite many rounds of network analysis etc, the true situation can only be established through actual implementation and it is therefore very difficult to make accurate predictions for a project of this nature.

Another key issue addressed during this project was the accurate auditing of the savings in such a manner that there can be no doubt in the minds of either the Project Team or the Client. Such auditing is often overlooked as an unnecessary luxury with the result that many Water Demand Management projects cannot be judged properly since claims of large savings made by the Consultant are often not shared by the Client. In the case of the Khayelitsha project, the savings were monitored by the Client and there is no doubt that the figures quoted in this paper are factual.

The baseline from which the savings have been calculated is the level of leakage at April 2000 levels when the project was first identified by the Project Team and presented to the Client. The water supply situation in April 2000 had an average flow of 2500 m<sup>3</sup>/hr (representing an annual water demand of 22 million m<sup>3</sup>/a of which approximately 75 % was wastage) with a Minimum Night Flow of 1 600 m<sup>3</sup>/hr.

The first phase of pressure management involved the installation of the new pipes and pressure reducing valves (PRV) with the pressure reduced under fixed outlet pressure control: i.e. the pressure reduced throughout the whole day using standard PRV pressure reduction without any additional reduction from the controllers. The savings achieved for this condition are depicted in **Figure 6** from which it can be seen that the average daily flow was reduced to 1 800 m<sup>3</sup>/hr with a Minimum Night Flow of 1 200 m<sup>3</sup>/hr. The annual reduction in demand was estimated to be in the order of 6 million m<sup>3</sup>/yr.

The second phase of the pressure control involved using the electronic controllers to provide further pressure reduction during periods of low demand. This form of pressure control is termed Advanced Pressure Control and requires considerable experience and care to ensure that it is implemented properly. The results from this stage of the project are shown in **Figure 7** from which it can be seen that the Minimum Night Flow was lowered by an additional 450 m<sup>3</sup>/hr to 750 m<sup>3</sup>/hr with the average daily flow dropping by a further 300 m<sup>3</sup>/hr to 1 500 m<sup>3</sup>/hr. The total annual savings achieved through the use of the Time-Modulated Pressure Control are estimated to be in the order of 9 million m<sup>3</sup>/yr or 40% of the water originally supplied to the area.

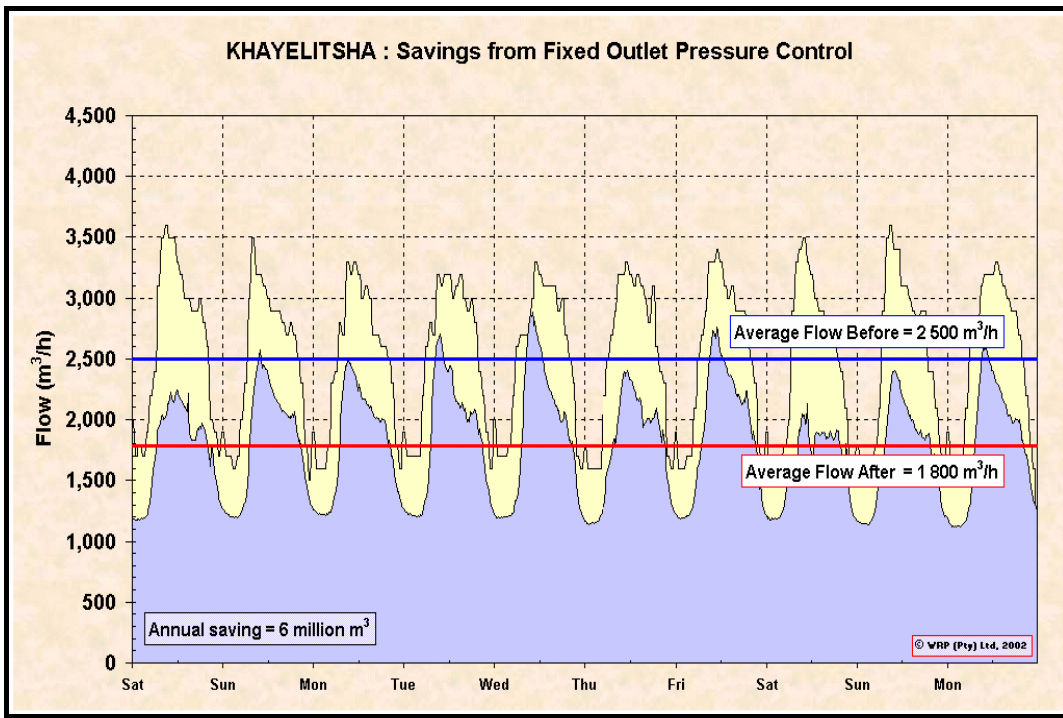


Figure 6: Inflow to Khayelitsha from Fixed Outlet Pressure Control

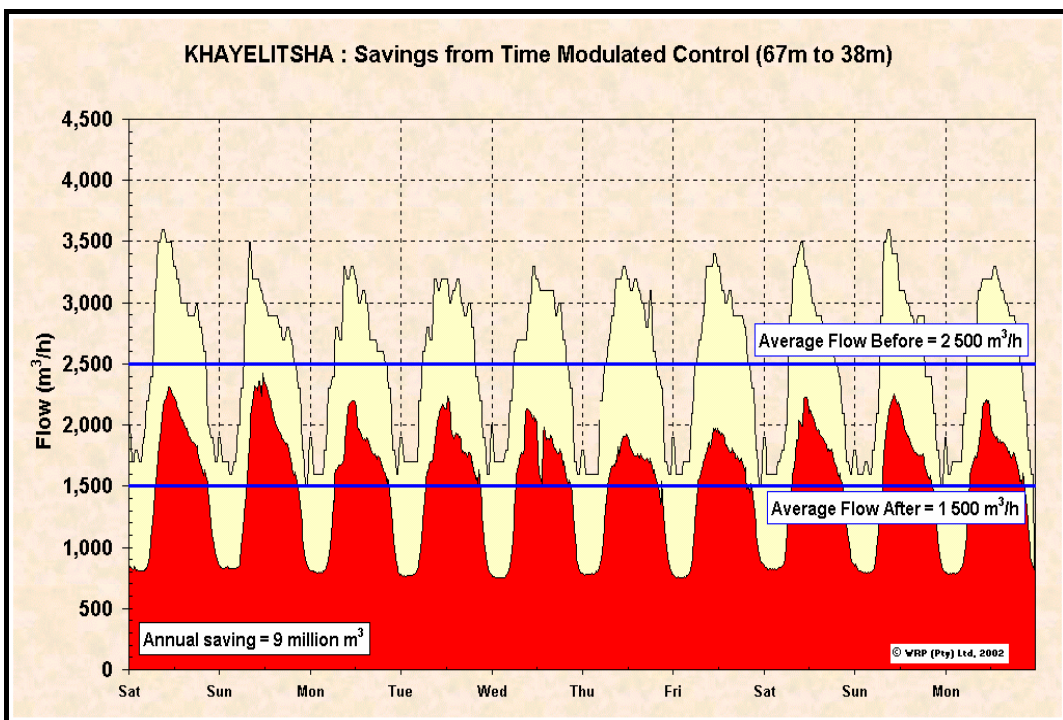


Figure 7: Savings achieved from the Fixed Outlet Pressure Control

It is important to note that at no time during the pressure management activities, was the pressure at any point in the system lowered below the minimum level experienced during normal peak demand periods.



## LOCAL COMMUNITY INVOLVEMENT

One of the main problems often experienced with a project of this nature is the possible negative reaction from the local community resulting in theft and/or vandalism of the installation. This is particularly relevant in projects influencing the water supply to communities. If the actions being undertaken are perceived to have a negative influence on the overall level of service to the community, the project is destined for failure no-matter how much effort is spent trying to remedy the situation. This potential problem was taken very seriously by the Project Team and Client from the inception of the project. The community was involved at each stage of the construction and was continually informed of progress and possible water shortages through continuous liaison with the Community Liaison Officer. All labour used on the project was sourced locally whenever possible and organised through the local labour forum to avoid any complaints of favoritism or nepotism (see **Figure 8**). It was through such measures that the project was constructed and commissioned within the confines of a low-cost housing area without one incidence of vandalism or theft.

Another interesting feature of this project is the overall design and appearance of the chamber. Engineers are not renowned for their flair and imagination when it comes to the design of concrete valve chambers and a concrete “shoe-box” is often favoured without windows or any weak points where entrance can be gained. In the case of this project, however, considerable effort was taken to provide a valve chamber that was both economical from a cost perspective but also aesthetic in as much as a simple box design can be. An Architect was approached for assistance and the end result is clearly evident from the completed chamber as shown in **Figures 9**.



Figure 8: Local Community painting the 1065 mm diameter Chamber



Figure 9: Completed Chamber in Khayelitsha

## CONCLUSIONS

The Khayelitsha Pressure Management project was initiated directly as a result of various submissions made to Council by the Project Team who provided sufficient motivation and evidence to support the investment of almost US\$ 0.3 million into the project. Without the enthusiastic support of the WRP team and Council staff from the City of Cape Town, it is unlikely that the project would have been approved by the politicians or accountants within Council.

Although there are already several advanced pressure control installations in South Africa, this project is by far the largest and most significant to be undertaken in the country. It is the first time in South Africa that an attempt has been made to reduce the pressure over such a large area ( $24 \text{ km}^2$ ) from a single installation and the actual savings achieved are amongst the highest in the world from such an installation.

The approach used in the Khayelitsha installation is both simple and innovative and the savings achieved have exceeded both the Client's and the Project Teams' most optimistic expectations. Despite the fact that the installation is situated within a squatter/informal area, there was no theft, vandalism or intimidation of any form. This can be attributed to the close liaison between the Council, Project Team and the Local Community who are all working together with a common goal of reducing wastage.

From the Client's perspective, the Khayelitsha project shows not only Technical Excellence but also a true regard for the community and the environment. The project itself will save in excess of 9 million  $\text{m}^3/\text{a}$  representing a financial saving of more than US\$2.7 million per year at current 2002 water rates – i.e. a 2 month pay-back. To place these figures in perspective, the proposed Berg River Scheme (recently approved to augment water supplies to Cape Town) and associated transfer works are estimated at 2002 prices to cost approximately US\$200 million. This new scheme will provide a safe yield of almost 80 million  $\text{m}^3/\text{a}$ . The Khayelitsha installation is already saving 11% of the yield from the Berg River Scheme at less than 0.2% of the cost. As a result of the savings already achieved, the proposed US\$3.6 million extension to the Zandvleit Sewage Treatment

Works has recently (July 2002) been postponed for at least two years and possibly indefinitely.

## **ACKNOWLEDGEMENTS**

The project described in this submission is a true team effort involving many organisations and individuals. While it is not possible to mention everyone who played a role in the successful completion of the project, it is considered appropriate by the Project Team to mention a few individuals without whom the project could not have taken place. The authors would therefore like to thank the following:

**Councilors from the former City of Tygerberg and present City of Cape Town** (in particular **Alderman Sitonga**: formerly Mayor of Tygerberg) for their support of the project at a political level and providing the Project Team with the opportunity of developing such a prestigious installation.

**Mr Charles Chapman**, former Water demand Management Manager for the City of Cape Town who actively supported the project from its inception.

**Mr Anic Smit** from the City of Cape Town who together with the authors recognised the potential for reducing wastage in Khayelitsha and actively motivated for a major pressure management project in the area. This project is considered to be the first main step towards the long-term goal of providing a more sustainable water supply to all Khayelitsha residents.

**Mr Tertius de Jager** and **Mr Larry Cronje**; (also from the City of Cape Town but based in Khayelitsha), for their continued support and enthusiasm throughout the project. As the Client's representative in Khayelitsha, their active involvement in the project contributed greatly to its success. They are also one of the very few teams in South Africa to monitor both flows into their supply area as well as sewage return flows out of the area

**Mrs Portia Mabece**, the community liaison officer for Khayelitsha, who worked continuously throughout the project to maintain communication and good relations between the community and the Project Team.

**Mr Hannes Botha** the architect who provided his special "touch" to the appearance of the chamber at no cost to the project. His efforts transformed an ordinary concrete valve chamber into a building that the local community is proud to own.