EXECUTIVE SUMMARY

BACKGROUND AND MOTIVATION

It has been indicated by DWAF that the Grootdraai catchment will soon experience severe water shortages as domestic, industrial and agricultural water use increases. It is, therefore, important to develop a systematic strategy or plan to reduce the amount of water used in the area, as well as the wastewater generated.

Pinch technology has been successfully applied in improving thermal efficiencies in the chemical and process industries over the last 15 years. This has been through the re-arrangement of heat sources and sinks to optimise the overall thermal efficiency of the process. By taking advantage of certain parallels between the principles of heat and mass transfer, the systematic design procedures of pinch technology have been extended to address the problems of water use and wastewater generation. The overall goal is to reduce the amounts of water used and wastewater generated, with no detrimental effects to the process. The options are the re-use of water in different operations; regeneration and re-use; or regeneration and recycling. Freshwater and wastewater flows are reduced in each case, and in the latter two cases the contaminant load of the wastewater is also reduced.

The application of pinch technology in the reduction of freshwater use and wastewater reduction has already been done on a number of plants and processes internationally as well as in South Africa. Some of these applications have been for industrial complexes where a number of plants were considered and an overall water use optimisation has been conducted.

Therefore the approach of applying pinch technology over a larger area may not necessarily be a novel one, the application of pinch for a multi-sectoral and multi-users application is.

OBJECTIVES

Following the submission of a research proposal to the Water Research Commission in 2000, the project titled "The Application of Pinch Technology in Water Resource Management to reduce water use and wastewater generation for an area" was approved.

The objectives of the project were as follows:

- Develop an inventory of water users and wastewater generators in the Highveld Ridge area
- Application of a water pinch technology model that optimises the water use and wastewater generation in the area.

PART I – OVERVIEW

WATER DEMAND MANAGEMENT AND PINCH TECHNOLOGY

Water scarcity has been identified as a driver of implementing new technologies for water use as well as re-use, recycling and regeneration options. However, there are other drivers for initiating water and wastewater saving initiatives. Hall (1997) identified the following water and wastewater reduction drivers:

- Economics
- Regulation and compliance
- Corporate waste reduction goals
- Regional water shortages/resource limitations
- Site infrastructure barriers

The increased awareness of dangers to the environment due to over extraction of water, the importance of environmental protection and tougher environmental legislation are further driving forces towards reductions in water consumption and wastewater generation.

The scarcity of good quality industrial water and the stricter discharge regulations have resulted in higher costs for fresh water and the treatment of wastewater respectively. This requires capital expenditure with little or no productive return and there is now considerable economic incentive to reduce both fresh water consumption and wastewater generation. This has impacted all types of industries including chemical processing, paper and pulp, manufacturing, petrochemical and electricity generation industries.

The prime objective of pinch technology is to achieve financial savings in the process industries by optimising the ways in which process utilities, namely energy and water, are applied for a wide variety of purposes. Pinch Technology does this by making an inventory of all producers and consumers of these utilities and then systematically designing an optimal scheme of utility exchange between these producers and consumers.

Pinch Technology provides a method to solve complex multi-stream energy and water integration problems. The technology has provided a rigorous means of analysing processes. It is based on sources and sinks, and the approach of reuse, recycle and regeneration, and combinations of these. The pinch approach not only sets targets but also recommends appropriate network design changes, which maximize the re-use of water/energy.

PART II

WATER PINCH AND CATCHMENT MODELLING

There are numerous activities that affect both the quantity and quality of water in a catchment. The activities meet their water requirements by drawing from the surface bodies and/or groundwater. The effluents generated through these activities are returned to the same system, creating a cycle of use with external inputs and outputs. The major inputs into a catchment are rainfall and inflow from other catchments. Inflow from other catchments can be in the form of surface bodies (e.g. rivers) and groundwater from an upstream catchment, as well as artificial mediums such as canals and pipelines. The major outputs from a catchment are evaporation, transpiration and outflow to other catchments. Outflows to other catchments can be in the form of surface bodies (i.e. rivers and streams) and groundwater to a downstream catchment, as well as artificial mediums such as canals and pipelines.

The increased demand from users and the increased number of users has decreased the availability of water and also the quality of the available water in the Grootdraai catchment. The water in an area has to be managed in such a way that it is not detrimental to the other users, especially downstream users. For a catchment, as mentioned previously, there is a limited supply. The abstraction of water and the release of effluent must be managed in a sustainable way.

The following measures are used to manage the limited water resources available in a catchment:

- The variation in the quantity of water that enters and leaves a catchment can be controlled with the building of reservoirs.
- Water use can be regulated by means of permitting, where a user is given the authority to draw a limited amount of water per unit time. These permits can also be applied to the release of effluent, where the volumes and quality of the water released is regulated.
- Close monitoring of the water quality at selected points.

The water pinch model developed by Mr. C. Brouckaert (referred to as the "model") from the University of Natal, Durban was used for this study. The decision was taken to use TDS only for the case study, with the focus on whether water pinch can successfully be applied to a catchment situation. It is important that the modelled situation closely resembles the actual situation in the catchment, while at the same time falling within the constraints of the model programmed in the MATLAB computer package.

The model follows a plant set-up, which is made up of different processes and operations, which have specific water requirements. The input requirements for the different users are in the form of a source, processes and sinks.

A comparison between water pinch and a catchment situation highlights the limitations with the application of pinch to a catchment situation. The limitations listed include the following factors:

- Distance and altitude difference between "processes"
- Limits and varied supply of the water source
- Limits posed by the sensitivities of the surrounding ecological environment
- The effects of groundwater and its movement
- The effects of evaporation and transpiration

In addition to the limitations listed above, the data available for representation of a catchment situation is limited. Comparing a typical production facility with a catchment under the listed model data requirements shows this:

- Sources – catchments have numerous sources that are highly variable, data indicating the fate of water that enters the catchment is scarce.
- Processes – catchments have numerous users with different types of water requirements, uses and releases. Data for water losses in non-industrial users is poorly known.
- Sinks – include evaporation and transpiration that varies from site to site depending on numerous factors and are poorly known.

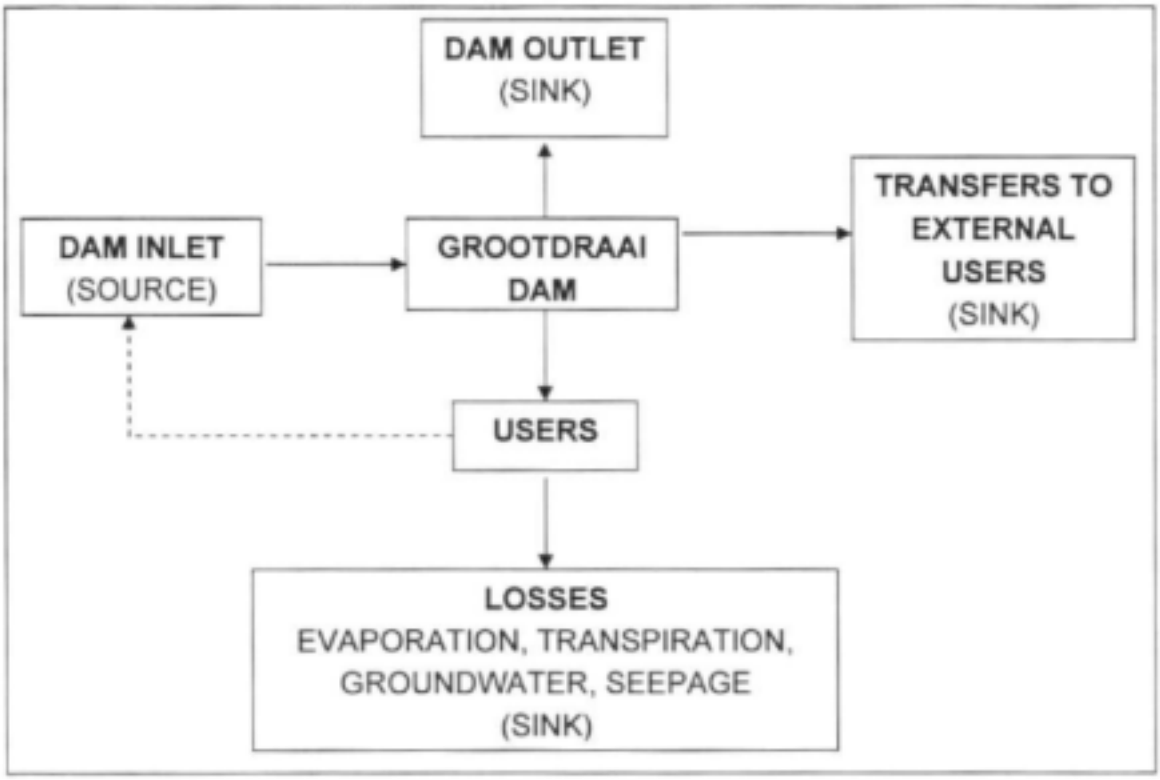
To model the catchment, a process of data gathering and identification of gaps in the data needs to be undertaken. The gaps can then be filled through water balances across the various systems in operation in the catchments as well as the catchment itself. The case study on the Grootdraai catchment shows a possible approach.

PART III

CASE STUDY- GROOTDRAAI CATCHMENT

The Grootdraai catchment is located in the Industrial Highveld, which forms part of Mpumalanga Province. The catchment has a surface area of 7924 km^2 and forms part of the Upper-Vaal reach. One major river, the Upper Vaal, drains the catchment, with no rivers or streams entering the catchment. All streams within the catchment drain into the Grootdraai dam, which is located at the western boundary.

The major users in the catchment draw their water from the Grootdraai dam. The water available for these uses is therefore dependent on the availability of water in the dam. The Grootdraai dam has a capacity of 364 million m^3. The diagram below gives a graphic representation of the water demand from the dam:



Information on the users drawing from the dam, with their current demand from the dam and releases back into the system, are provided in the table below:

Overview of water demand and return by the users

USER	DEMAND (m^3/year)	RETURN (m^3/year)
Irrigation	321 500	-
Tutuka Power Station	47 420 000	-
Matla Power Station	53 838 000	-
SASOL	91 250 000	4 015 000*
Ermelo Municipality	3 600 000	1 982 124
Bethal Municipality	5 420 250	3 011 250
Thuthukane Township	1 427 556	642 400
TOTAL	203 277 306	9 650 774

* Released outside the catchment

The application of the pinch model yielded results that showed that in principle all the waste water of the different users could be re-used, thereby reducing the demand on the dam by the total of the currently released waste waster. The inflow to the dam would also be reduced, as part of the waste water is currently released up-flow from the dam. Due to the limited availability of input information that was required for the model, it was not possible for the model to optimise the allocation of the waste water streams to the users. It appeared that the outcome of the model was effectively a random allocation to the users.

A spread sheet calculation was carried out, which showed that the waste water can indeed be allocated to the different users without infringing on the requirements of the users in terms of maximum allowed inlet TDS. All individual users could take a part or all of the total waste water. Without further constraints e.g. the cost to transport the waste water or additional costs for treatment by the user, there was no preference to allocate the waste water to a specific user. This result confirmed the outcome of the model.

The following conclusions were reached:

- The available information from the users (inlet and outlet quantities of water and requirements for inlet and outlet TDS) were not optimal input information for the model to optimise the allocation of the waste streams to different users and therefore the model output was closer to a random allocation.
- There are large differences between a catchment and a plant situation for which the model was designed, and in order to use a water pinch type model for a catchment, considerable changes to the current model would likely be required.

- The modelling as well as the spreadsheet calculation showed that in terms of TDS inlet requirements all waste water could be re-used by the main water users.
- The study catchment area may not be representative for other catchments for two reasons. In this particular catchment, only a small percentage of the inlet water is released as waste water, due to the presence of industries that evaporate most water as part of their processes. Also, another aspect of this type of industry is that most of the TDS in the inlet water is not returned to the surface water of the catchment, but becomes part of ash disposal sites.

As good water management is important for South Africa in general and more specifically in catchments such as the Grootdraaidam catchment, where water demand is likely to exceed water supply in the future, it is recommended to investigate the development of a model that can reliably simulate all the important aspects of a catchment and thereby help to reduce water use by optimising the allocation of waste water to different users. This model should be based upon the principles of water pinch, but would probably be substantially different from existing models.