1. INTRODUCTION

Water is characterised by both its quantity (availability) and its quality (for example, its salinity). The significance of an integrated management of water quantity and quality is stated in Principle 15 of the South African National Water Act of 1998 as “Water quality and quantity are interdependent and shall be managed in an integrated manner, which is consistent with broader environmental management approaches” (Pegram *et al.*, 1998). In arid and semi-arid areas it may seem that water quantity is the primary concern. However, quantity and quality issues are so interwoven that attempting to address one without the other is an exercise in futility (Seelig *et al.*, 2001).

Salinity, as a result of natural and anthropogenic solute inputs, is causing serious water quality problems in many parts of the world, such as the Breede and Fish-Sundays River systems in South Africa (Jonker, 1995), the Murray Darling Basin in Australia (Blackmorea *et al.*, 1999) and the eastern and western lowlands of Eritrea. Salinity causes loss of yield and degradation of agricultural lands. History relates that ancient civilizations based on irrigated agriculture in river valleys (e.g. Mesopotamia) collapsed, as they did not provide drainage systems for leaching of the accumulated salt (Aswathanarayana, 2001). Salinity is also reported to cause road and wall damage in many parts of Australia (Blackmorea *et al.*, 1999). Furthermore, salinity also limits domestic and industrial water uses. It has a direct influence on the industrial and domestic water users through corrosion of water reticulation systems such as water delivery pipes.

Salinity is related to the total dissolved solid (TDS) concentration of water (Walling and Webb, 1986). According to Michael (1997a), the main soluble constituents in water are calcium, magnesium, sodium and, sometimes, potassium as cations and chloride, sulphate, bicarbonate and carbonate as anions. The standard method of measuring salinity is the use of electrical conductance (EC), sometimes referred to as specific conductance (Seelig *et al.*, 2001). Salinity is expressed in various units which include, millimho per centimetre (mmho/cm), deci-siemens per metre (ds/m), moles per cubic metre of solution (mol/m^3), grams per cubic metre of solution (g/m^3) and milliequivalents per litre of solution (meq/l). The fate and transport of salts in the soil is described mathematically with hydrosalinity models (Moolman, 1993).

Studies dealing with hydrosalinity are essential for assessing the effects of land and water uses on salinisation. Research focused on soil salinity has been carried out internationally for more than a century (Shouse *et al.*, 1997). Similarly, the development and application of computer operated mathematical models to simulate the movement of pollutants, and thus to anticipate environmental problems, has been the subject of extensive research by government agencies, universities and private companies for many years (Jayatilaka and Connel, 1995). Models dealing with salt loading in streams and across impoundments are of global interest because such models can provide a wide range of support for salinity management: from helping to understand the cause-effect relation between various sources and salinity impacts, to design of control measures and subsequent assessment of their effectiveness. However, knowledge about the main sources and controlling factors is important for the development of hydrosalinity models.

Salinity is affected by a combination of several soil-water-salt-plant factors. Therefore, in order to accurately estimate the magnitude of the hazard posed by salinity, it is important to identify and understand the processes that control salt movement from the soil surface through the root zone to the groundwater and streamflow. Knowing these processes makes it possible to develop optimum management schemes for environmental control for the purpose of preventing groundwater, streamflows and farm land salinisation (Bresler, 1981). For the above reasons, an extensive literature review was undertaken (Chapters 2 and 3) to assess the governing processes in hydrosalinity, to examine how these processes interact with various factors to influence water salinisation and to explore some modelling techniques employed to describe these processes.

The main aim of this research was to develop and evaluate a catchment hydrosalinity module that could provide information for use in planning, design and management of water and land uses through modelling surface and subsurface salinisation, including reservoir and streamflow. In general, the module makes two basic assumptions, *viz.* salt is a conservative substance, and reservoirs and flow in streams are completely mixed systems. The *ACRU* agrohydrological modelling system (Schulze, 1995a), with its physically-conceptually based structure and its multi-purpose capability as a lumped or distributed model, was found to be a suitable model within which the hydrosalinity module could be developed for its intended uses. The hydrosalinity module was developed in the object oriented version of the model, *viz. ACRU2000*. It inherits the basic structure and objects of the model. The new module was designed with the help of Rational Rose Software and is encoded with Java object-oriented programming language. The specific objectives of this project were:

a. to develop a catchment hydrosalinity module within the *ACRU* agrohydrological modelling system to:
    i. simulate TDS concentration and salt loading of surface and subsurface flows from a number of land use categories including irrigated, non-irrigated and impervious areas and, to
    ii. simulate reservoir storage as well as outflow salinity and salt loading;

    in order for predictions from the module to assist catchment planners to:
    - assess effects of climatic and hydrologic variability on future TDS concentration and salt loading
    - assess effects of future land use changes on future salinity levels and salt loading
    - assess the effects of water resources developments on future salinity levels and salt loading and to
    - analyse how operating policies or water allocation such as reservoir releases designed to dilute high TDS concentration at downstream reaches, may need to change to mitigate effects of exceeding salinity standards, especially in critical low flow periods; and furthermore
b. to test the hydrosalinity module both for its underlying codes and through comparison of simulated streamflow TDS concentration against the available observed values.

As part of the development and evaluation of the new module, a sensitivity analysis is undertaken to assess model response to changes in the main hydrosalinity input parameters. A case study is also carried out for the Upper Mkomazi Catchment to illustrate some potential applications of the module. This dissertation documents the development and evaluation of the hydrosalinity module (Chapters 5, 6 and 7). Some important points that need further explanation are discussed and general conclusions are presented in Chapter 8. Further research to enhance the performance of the hydrosalinity module is recommended in Chapter 9.