EXECUTIVE SUMMARY

BACKGROUND

This research, funded through the Water Research Commission, seeks to address issues regarding water quality arising from land cover type change and urban sprawl in a predominantly agricultural catchment in Cape Town. The Kuils River and Eerste River are two important rivers that run through the eastern part of the Cape Metropolitan Area (CMA). The Kuils River joins the Eerste River near Macassar forming a tributary to it. The Eerste River finally ends in False Bay. The Eerste-Kuils River estuary is one of the eleven estuaries draining into the False Bay located approximately 36 km south east of Cape Town. The two rivers form a bigger catchment with an area of 660 km^2. A portion of this bigger catchment falls within the boundary of the CMA and the rest falls in Stellenbosch municipality. Although these catchments form part of urban developments, significant portions of the Eerste-Kuils River catchment have agricultural lands; hence it has both urban and agricultural source of nonpoint source (NPS) pollutants. Typical techniques for determining the extent and magnitude of NPS pollution problems include long term surface water monitoring studies and computer based simulation modelling (hydrologic models). Due to the long time and high expenses associated with surface water monitoring techniques, computer simulation techniques (use of models) have been relied upon to provide needed information for the development and implementation of NPS management guidelines.

OBJECTIVES AND AIMS

This research, '*A Comprehensive Investigation of the Kuils-Eerste River Catchments Water Pollution and Development of a Catchment Sustainability Plan'***,** aimed to assess nonpoint source (NPS) pollution in the Kuils-Eerste River Catchment through hydrologic experiments and modelling using Geographic information System (GIS). The major objectives which supported the overall aim were:

- Conducting hydrologic experiments (setting up of runoff plots) at selected locations for measuring surface runoff;
- Estimation of surface runoff through GIS modelling using curve number method;
- Assessment of runoff water quality over different land use types through sampling and generation of a water quality database (event mean concentrations);
- Collation of existing data on stream flow measurements and water chemistry of stream flow and surface runoff water;
- Generation of a GIS based hydrologic model (catchment loading model) capable of estimating

i) surface runoff using the NRCS Curve number method,
ii) pollutant concentrations and loading rates in the runoff water, and
iii) accumulated pollutant loading in the stream or river;

- Use of the above investigation to develop a working document for adapting the catchment into a sustainable system; and,
- To publish this work by means of scientific reports, conference papers and journals.

METHODOLOGY

The project was divided into four stages, corresponding to the major tasks that were carried out in the preparation of the input data for the models that were used to assess NPS pollution on the basis of the land cover types in the catchment. The acquisition of the relevant information, technology and expertise regarding water quality monitoring made up the main tasks during the initial stages of the research. Part of the work was accomplished by conducting literature reviews and evaluating available modelling tools. Literature regarding water quality assessment and guidelines was also reviewed.

The second part was focused on obtaining data that could be used for the application of the selected model of NPS pollution assessments. Kuils-Eerste River catchment was identified as a suitable study area because of the conditions in this catchment which are unique and are likely to reflect the situation experienced in many urbanising catchments. Most catchments situated close to urban areas would have similar inputs, for example, effluents from wastewater treatment works and industrial plants as well as nonpoint source pollution, which can originate from informal settlements, agricultural areas and other types of land uses. Data on the water quality of the surface water in these types of catchments are usually very limited, as was the case for the Kuils-Eerste River catchment before the start of this study. Land cover data was important in the development of the project hence a land cover map was developed with 36 land classes for the whole catchment as input data. Efforts were also made to acquire other data sets like annual rainfall, soil types and a digital elevation model.

The third stage involved preparation of input data tables of water chemistry in the form of Event Mean Concentration (EMC) obtained from the hydrological monitoring and runoff water sampling exercises carried out during the storm events that were experienced during the data collection period. These had to be prepared in formats that would make it possible to be uploaded into the system to estimate runoff, infiltration and pollutant loads. The SCS Curve Number method was selected for the estimation of runoff for the whole catchment because of the ease of preparing the limited number of input data sets needed and eases in implementing the method in a GIS. The fourth study stage involved the application of GIS based hydrological models such as NSPECT and RINSPE to simulate runoff, NPS pollutant loads and surface water quality in the catchment on the basis of the land cover types and soil information. N-SPECT (Nonpoint- Source Pollution and Erosion Comparison Tool) is a freely available ArcGIS based model provided by the NOAA Coastal Services Center to investigate potential water quality impacts from development, other land uses, and climate change. N-SPECT was initially developed as a decision support tool for coastal watershed managers in Hawaii and has since been applied in coastal areas around the U.S., the Caribbean, Central America, and the South Pacific. This tool operates accurately in medium-to-large watersheds having moderate topographic relief and is capable of providing maps of surface water runoff volumes, pollutant loads, pollutant concentrations, and total sediment loads. This model estimates runoff using the Curve Number (CN) method and it had limitations of not producing runoff at all in certain areas of urban catchments receiving lesser annual rainfalls because it estimates initial abstraction as a constant value of 20% of the potential maximum retention value (in reality this not the case in urban catchments). Therefore the runoff estimated using the CN method implemented in this model is a very negligible amount. This limitation necessitated the adjustment of the runoff estimation by inputting more accurate values of initial losses, which was achieved by developing the distributed parameter model called RINSPE (Runoff, Infiltration and Non point Source Pollution Estimation) using ArcView GIS 3.2. The RINSPE was used to investigate non-point source pollution (NPS) problems in an urban river catchment.

RINPSE is an event-based or annual based model that can estimate runoff, infiltration and the pollutant loading from different land cover types within a catchment. Implementation of the RINSPE model within ArcView GIS 3.3 through Avenue programming facilitated better data analysis than conventional methods. It is a powerful, up-to-date tool that would be capable of monitoring and instantaneously visualizing the accumulation and loading of pollutants. RINSPE is a cell-based distributed parameter hydrologic model which requires several categories of information such as land use, topographical data in the form of a digital elevation model (DEM), event mean concentrations (EMC) of the pollutants to be investigated, soils data, annual or event based rainfall data, and is capable of generating both estimates of quantity and quality of runoff and infiltration from the catchment for a given storm event or annual rainfall. In this model, the extracted spatial and non-spatial data are generated too through the RINPSE model engine designed in ArcView GIS. The model reduces the time required to analyse the numerical output and enables users to identify critical areas of NPS pollution and furthermore, makes it possible to perform various "what if" scenarios to support the decision making processes such as Best Management Practices (BMP) for the catchment. The RINSPE model used to study pollutant concentrations and loadings easily generate large amounts of data for analysis even in a small catchment. Using the above-mentioned input data sets, the RINSPE and N-SPECT models were successfully applied to the Kuils-Eerste River catchment and to estimate NPS pollutant loads of chosen variables such as nitrate, chloride, total nitrogen, and total phosphorous and total suspended solids. The success with which surface water variables such as concentrations and loads of nitrate, chloride, nitrogen, phosphorous and suspended solids may be simulated in surface water using the above two models depends largely on the quality of input data available such as rainfall, runoff distribution and digital elevation model.

RESULTS AND DISCUSSION

The results reveal that the accumulated loads of pollutants from the catchment increased substantially for all the pollutants for a two year period. Annual loads for all the parameters under study increased. This could be explained by the possible increased mobilisation of pollutants by urban sprawl, which also increased surface runoff between these two years. Rainfall interpolation results revealed that there was an increase in precipitation for a two year period. This slight increase in total rainfall is the possible cause of this increase in accumulated pollutant loads. Increased rainfall meant increased mobilisation and transportation of pollutants due to impacting by rain drops and the occurrence of higher volumes of surface runoff. Above all, the results confirm that surface water pollution is increasing at high rates in the catchment. Runoff model simulations revealed that there was an increase in runoff discharge loads at the outh of the catchment for the study period. Changed land surfaces include compacted surfaces, channelized surfaces, constructions, which are some of the activities that increase the imperviousness of the surface thereby leading to more flows in the form of runoff and less underground recharge.The results obtained show a distribution pattern that indicates high volumes of runoff in the eastern part of the catchment and lower values to the western side of the catchment.

Comparatively speaking, runoff volume for the two modelled scenarios on the basis of rainfall distribution, shows marked differences with the first scenario based on the rainfall gauges in the catchment and within the proximity of the catchment boundary registered volumes that ranges between 0,086 m_3 to 135.3 m_3, against the second model results of a range between 0.1 m_3 to 268.4 m_3. The accumulated surface runoff distribution map also compares well to the one generated on the basis of the earlier rainfall distribution map though the values registered are different. The first model's results of total runoff volume using rainfall map of 2006 range from 0 m_3 to 112 million m_3 as compared to the second modelling results based on the radar estimates of long term average rainfall which indicates values that range between 0 m_3 and 194 million m_3. The estimated accumulated pollutant loads exiting from catchment (at the outlet point just before the estuary) using the long term average rainfall data are as follows: Nitrate 216.5 tons/Yr; Total Nitrogen 3551.61 tons /Yr; Total Phosphorus 190.7 tons /Yr; Chloride 6828.49 tons /Yr; Total Suspended Solids 18884.9 tons /Yr. One of the outputs of the analysis by N-SPECT is the pollutant concentration grid. This is a map layer showing the spatial distribution of pollutants in the catchment and compares the contribution of each land use/cover to the observed pollution. A spatial observation of the pollutant distribution maps does not reveal any changes in the spatial extent to which pollutants are generated between the periods of study. The spatial distribution of pollutants on maps alone may not be enough to adequately interpret the actual prevailing scenarios.

Statistical tables were used for better interpretation and conclusion of modelling results. There were no noticeable variations in the percentages of pollutants that emanated from the land use classes when the classes are compared. This means that the change in precipitation did not influence the potential to generate pollutants so long as the surface conditions remained. With any change in the land characteristics, one would expect a corresponding response in terms of the potential to release chemical substances. The results show that the following land use classes, vineyards, industrial areas and the medium density residential areas contribute mostly towards the pollution in the catchments' streams and rivers. The vineyards contributed more than 40% of the entire load from classes followed by the industries and then the residential areas and open barren lands.

SUSTAINABILITY PLAN

A sustainability guideline is offered that focuses on the main activities that the catchment authorities can adopt for implementation with the following objectives:

- Restore and maintain degraded systems and habitats,
- Support sustainable human communities,
- Sustain biodiversity,
- Preserve natural ecosystems,
- Focus funding on the most effective strategies, and
- Teach about connections between individual actions and clean water.

CONCLUSIONS

The main and secondary aims of the study were achieved. Estimates of runoff, infiltration and pollutant loads were determined and can be useful as a management tool in the case of highly contaminated catchments. For urbanised catchments the two models would be able to estimate the surface runoff on the basis of the precipitation and land cover type. Runoff estimation on the basis of the hydrological soil groups and land use types, and estimation of pollutant accumulation and loading rates using a DEM on the basis of the runoff volume generated, Event Mean Concentrations in runoff, are the key aspects of the two models in generating results. The models however are dependent on input data and the modelled catchment should be well characterised, in particular, reliable hydrological data should be available. Broad management guidelines with predetermined guidelines and/or objectives for the surface pollution developed should be implemented to ensure that the water will be fit for its intended uses on a sustained basis.

RECOMMENDATIONS FOR FUTURE RESEARCH

A need exists for the implementation of a surface water quality programme in the catchment using the approach that is outlined in this study. The participation of the affected community of Kuils-Eerste River catchment in such a management programme is crucial for its success and the study should also explore various ways of involving the community.