The Condamine Valley groundwater monitoring network, southeast Queensland

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The Upper Condamine Valley has been selected for the first stage of an ambient water-quality monitoring network for Queensland. This important agricultural region in the headwaters of the Murray-Darling River System is heavily reliant on groundwater and has a number of established and potential water-quality problems. The network will record the normal variation of a large number of parameters on a broad regional scale and determine long-term trends. It will give early warning of incipient deterioration (or improvement) in water quality and serve water users, catchment managers, or those undertaking more intensive studies. An assessment of existing water-quality data was carried out to select monitoring stations. The Water Resources Commission database contains thousands of analyses collected since the 1940s. However, only values for conductivity and the major ions (excluding nitrate) are considered reliable, and the data are unevenly distributed spatially and temporally, making assessment difficult. Cluster analyses were used to outline natural variation and unstable or problem areas. Environmental information and published reports were also used. Information from the network will be accessible to the public, and available either as raw data, statistical appraisals, or comprehensive water-quality reports.

Objectives

The water-quality monitoring network for the catchment of the Upper Condamine River, as described in this paper and in a full report (McNeil & others, 1991) is part of an ambient water-quality network which the Water Resources Commission is designing for Queensland. The methodology used forms the basis for similar networks throughout the State.

The objectives are to describe the present state of the waters together with any possible changes at a regional scale. It should warn of incipient major problems in time for action to be taken, provide an inventory for water use planning and also feedback for basin-wide land and water management. It is not intended that the network be detailed enough to delineate individual pollution sites, for example, but it should give the regional and historical background needed to plan efficiently more intensive investigations and remedial projects.

The Condamine catchment was selected as the prototype for a statewide monitoring network for several reasons: it is (a) an economically important agricultural area; (b) one of the State's most intensively measured regions; (c) fairly typical of many areas of Queensland; and (d) several water-quality problems have been noted in the district. In addition, the Condamine Valley is a headwaters catchment of the Murray-Darling River System, the largest drainage basin in Australia.

Description of the catchment

The network covers the region upstream of the township of Dalby (Fig. 1), covering about 13 500 km². It is an important agricultural region with heavy use of water for irrigation. During 1986–87 approximately 29 000 ha were irrigated, with 43% of that area relying on groundwater according to the Australian Bureau of Census and Statistics for 1986–87.

The groundwater resources have been severely depleted in parts of this catchment, either seasonally or permanently, as a result of excessive use. As a result, the region was proclaimed an area of sub-artesian supply in 1956 and was then subject to the provisions of the (then) Water Act. All bores other than those used for domestic purposes must be licensed, and metering of bores was introduced in 1979 to obtain an accurate assessment of groundwater use.

Leslie Dam, the principal water supply for Warwick, supplements the groundwater for irrigation in the Condamine Groundwater Management Area (CGMA). Several supplementary weirs also provide water supplies, and improve recharge.

Water-quality problems

This is an area with a number of known and potential water-quality problems, most of which are non-point source. The most serious potential problem arises from the fact that the aquifer system on which the CGMA depends is being seriously overdrawn. This system is subartesian, but large in areal extent and with multiple water beds, some at depths of up to 100 m. The overburden is thick and extremely clayey, so that recharge is very slow from the only major source the Condamine River. The surface waters of the upper tributaries, on which this recharge depends, are of good quality but, as described below, appear to show rising trends in salinity. In addition, the sandstones along the borders of the valley are a known source of saline water, which could intrude into the main irrigation area as water levels fall in the long term.

Additional water-quality problems include sporadic nitrate levels of up to 400 mg/L in basaltic aquifers on the northeast side of valley. Although septic tanks are widespread and some geological units may discharge nitrate, many of the high readings may be related to cattle feedlots, piggeries, and poultry farms, many of which are situated on the boulder-strewn and vesicular basaltic outcrops surrounding Toowoomba. Because the soils here are often thin and the rocks heavily fractured, effluent can have an easy passage to the aquifers. Thus, groundwater contamination can occur, unless appropriate protection is taken. These intensive animal husbandry establishments are increasing both in size and number. Seventy properties where either new feedlots or extensions to existing feedlots were proposed, were inspected by Commission officers between 1988 and 1991.

Another problem is the high salinity level associated with
Oakey Creek. This major tributary contains intensive rural and urban settlement, and includes the largest city of the region, Toowoomba. Effluent from a number of industries as well as secondary treated sewage from this city are discharged into Gowrie Creek. Water-quality problems in Gowrie Creek were brought to the attention of the then Water Quality Council in 1980. Data collected in the current study show that the quality of water in this creek is usually unsuitable for drinking, as it exhibits a high proportion of sodium and chloride ions which is unusual for this part of the State. Examination of salinity distributions in the shallow groundwater (<50 m) indicates that supplies from the Gowrie Creek alluvium are not excessively saline compared with those from other creeks in the area, and that, although nitrate levels tend to be a little above background levels (10 mg/L to 45 mg/L as NO₃⁻), much higher values are common around the basalts to the east.

Other possible adverse influences on water-quality include land clearing, with associated increases in turbidity, salinity and nutrients, and a dramatic increase since the 1960s in the use of fertilisers.

Iron bacteria are widespread in the groundwater, requiring an estimated quarter of a million dollars a year in rehabilitation and maintenance of affected bores. The most-affected areas are the basalts around Toowoomba, the sandstones around Pittsworth, and the alluvium along Farm Creek, a tributary in the southeastern headwaters. The problem is exacerbated when oxygen enters the system, caused by the present low water levels owing to overuse of bores.

Available data, their quality and their assessment

Historically, the Water Resources Commission had no systematic plan for the sampling of groundwater. The present bank of chemical analyses in the Commission data base has been collected ad hoc since the 1950s, normally by staff already in the field doing hydrographic, advisory or investigative work. An unfortunate side-effect of this indirect approach was that collection, preservation, transport and storage of samples were not up to the standards specified by modern laboratories. For example, only a one-litre sample container was normally filled, no preservation was carried out, and several weeks sometimes passed before delivery to the laboratory. In some comparative tests carried out recently, typically 80% of the iron was lost from unacidified samples. Past values for iron, manganese and pH are thus probably useless. Other parameters, such as pesticides, which are coming into public prominence now, were not measured.

While the areal distribution of the 6700 samples collected is quite comprehensive, the temporal distribution has in many cases been less than ideal. Many bores have been sampled only once or twice. This does not provide the information required for most statistical tests aimed at predicting trends.
Processing of past data

Because of the high costs of carrying out major programs of both sampling and analysis, as well as, the need to identify long-term trends, a set of programs was designed in SYSTAT to process the very large volume of irregularly accumulated water-quality data.

The basic method employed was cluster analysis: it is a robust, multivariate procedure which detects natural groupings in data; is capable of using all of the data whilst making few assumptions about its structure, and avoids loss of integrity of individual samples. It is also not dependent on the data being collected regularly in space or time. However, it is necessary to make a careful choice of the parameters selected for clustering. The reason is that if some parameters are closely correlated or interdependent, the results will be biased. Similarly, the parameters must be weighted in such a way that those usually contributing the greatest bulk of the sample do not overwhelm the effect of significant changes in lower-volume parameters. The variables used in the suite of programs are automatically specified in subroutines, and include the percent equivalents of the major ions. These are always available in past analyses, are reasonably reliable, and experience has shown that they form a very good basis for classifying the natural waters in Queensland.

Most cluster analysis programs have difficulty in handling more than one or two hundred samples at once, so that an entire basin cannot be grouped in one run. To overcome this, the region was divided into subareas of similar geological environment. The samples for each subarea were then sorted into batches, clustered and reclustered into ‘subgroups’ representative of their subarea. Each subgroup was then represented by a single hypothetical average sample, and these were clustered to form “super-groups” representative of the entire basin. The groups and supergroups were represented on triangular diagrams and on Box and Whisker plots (Fig. 2). The vertical axes represent meq/L and indicate the relationships of all the major ions to each other within the group.

The effectiveness of the method in highlighting natural variations is demonstrated in an area in the southeastern headwaters of the Condamine. The terrain is basaltic, with steep dissected uplands, mostly forested. There are narrow stretches of alluvium on the lower courses of the creeks. The annual rainfall is high at around 1350 mm. As verified by aerial photography and Landsat satellite imagery, there has been substantial clearing of the forests overlying the basalts. This mostly took place prior to 1980, but has continued until the present, despite some regrowth. Rising conductivity trends have been observed in the surface water on which recharge depends.

Figures 3 and 4 show the areal distribution of groundwater groups for the periods 1978–81 and 1986-88, respectively. Inspection shows that the relatively saline and high magnesium and chloride Group C is replacing the low-salinity Group J from the basalts and the more-sodic Group B on the alluvium.

These results, in conjunction with increases in surface water salinity and rising water levels in some bores, provided enough evidence to indicate that the deforestation of the basalts for agricultural purposes is increasing the salinity and particularly the magnesium content of the natural waters of the region, despite the fact that some tree regrowth has occurred.

Once the general salinity pattern of the catchment was known, transects were plotted, showing the variation of several parameters with depth along selected paths across the valley. These were used to pick sites for monitoring bores which were usually placed within a zone where the water quality was still typical of the aquifer, but close to an area where at least one important parameter was rising with time or distance either down-valley or across the valley.

Sampling methods and bore construction techniques

Existing water-level measuring bores are to be used as monitoring stations whenever possible, but in some cases new bores are to be constructed, usually in areas where sensitive parameters (such as organics) may be present. These will be based as much as practicable on USEPA standards. Piezometers will be established in each water-bed, and stainless steel or other suitable casing will be used below the waterline. Bore construction will involve a minimum of disturbance or contamination to the waterbed.

Sampling will be carried out by trained hydrographers, using either a bladder pump, a Grundfoss pump, or an inertial (WaTerra) pump. All necessary steps will be taken to ensure quality control of the sample. Guidelines on methods for groundwater sampling, sample preservation, and transport and delivery have been prepared by an inter-departmental technical working group (Rayment & Poplawski, 1992). Two training workshops based on these
Design of groundwater monitoring network

Groundwater monitoring bores were selected on two levels, as primary and secondary stations.

Ten primary stations were selected at the following locations:

- One site located at the upstream beginning of the main Condamine alluvium, and one at the downstream-end near Dalby for overall trends.
- Two sites in the alluvium of the CGMA to detect any change in the general health of the aquifer: one at the upstream-end and the other in the most productive area.
- Two sites on the basalts in areas known to have nitrate problems.
- One site in the Oakey Creek catchment and at the upstream-end of the irrigation area downstream of Gowrie Creek.
- Two sites within the southeastern headwaters in the area of rising trends demonstrated by the cluster analysis.
- One on the drier western side of the valley, because little is known of the groundwater here and it may be a potential source of contamination.

Four bores are to be newly constructed, but otherwise existing facilities are suitable.

More than 100 water-level measuring bores are designated as secondary stations, and field measurements of conductivity and other parameters listed below be made at two yearly intervals, when these bores are being flushed and backwashed.

An initial set of parameters was selected, which is typical of many modern networks designed for regional monitoring rather than for specific or intensive investigations. From this list, appropriate parameters and sampling intervals for primary bores, as described below, were selected for the region.

Parameters to be sampled in the field every two years and after rises in water level:

- conductivity
- pH
- temperature
- dissolved oxygen
- redox potential
- total dissolved solids
- alkalinity
- colour
- suspended solids
- major ions
- fluoride
- total organic carbon
- boron
- iron
- manganese
- heavy metals
- nutrients
- bacteria
- pesticides

guidelines have been held for field staff.

It is proposed to rely heavily on field (probe) measurements for some parameters, using freshly discharged water. Field measurements are practical, reliable, and cost effective, particularly for remote areas.
Samples are to be collected for the following parameters at selected stations, usually once only for background values:

- aluminium
- cyanide
- arsenic
- gross alpha radiation
- total volatile solids
- gross beta radiation
- methylene blue active (detergents)

Sampling every two years provides sufficient regularity to detect statistically significant trends in this basin, because of both its large size and slow hydrological processes. However, extra sampling is recommended after major water-level fluctuations, as investigations indicate that in Queensland the recharge and flow regime have a greater bearing on water-quality than seasonal effects.

Conclusion

The Queensland Water Resources Commission in the past, like most similar data-collecting organisations, has been “data-rich but information-deficient” in many aspects of water quality. The network outlined in this paper is designed to redress this situation, and is based on statistical analysis of the past data in conjunction with an environmental assessment.

Information acquired will be accessible to the public, and available either as raw data, statistical appraisals, or comprehensive water-quality reports, according to the needs of researchers, managers, or general clients. The network will be reviewed after five years of operation.

Acknowledgement

George Gates, Department of Water Resources, New South Wales, for refereeing this paper.

References
