Investigation of Groundwater-Streamflow interactions in the Bega alluvial aquifer using Tritium and Stable Isotope ratios.

DAVID J. M. STONE[1], MEREDITH THOMAS[2] and GREG RUSSELL[3]

1. Environment Division, Australian Nuclear Science and Technology Organisation,
2. School of Geosciences, The University of Wollongong
3. NSW Department of Land and Water Conservation, Sydney, South Coast Region

SUMMARY

An isotope hydrology study of the Bega Valley groundwater system has been made. The investigation which focussed on environmental tritium and stable isotope ratios confirms that that the resource is sustainable at the current usage rate.

INTRODUCTION

The sustainability of Groundwater extraction from the alluvial flats that extend along the Bega and Brogo rivers on the far south coast of NSW has been investigated using stable isotopes of water and tritium. Extraction from these aquifers industrial, agricultural and domestic purposes is high and the aquifer is regarded to be at moderate risk of depletion and degradation. An improved understanding of how the groundwater system interacts with surface water will allow this resource to be managed and sustainably utilised.

Of the two major rivers in the Bega valley, a catchment of about 1955 km^2, the Bemboka River flows east to where it is joined by the Brogo River flowing from the north (Fig 7). From the confluence, where the town of Bega is located, the Bega River flows east to the coast 20 km away. A small dam, with a capacity of 9900 megalitres in the upper Brogo catchment, regulates the flow of the Brogo River.

METHODS

Groundwater and streamflow samples were collected from sites, including transects across the alluvium, in both valleys upstream of the confluence and downstream to the tidal limit in April and July, 2000. Streamflow was sampled using a plastic bailer while groundwaters were withdrawn with the use of a Grundfos MP1 environmental sampling pump. They were analysed for stable isotopes ($^2H/H$, $^{18}O/^{16}O$) ratios, tritium (^3H), and major and minor chemical species. Rainwaters were collected and analysed for stable isotopes only.

Ion Chromatography was used for the analysis of the anions while either ICP-MS or ICP-AES was used for cations. The tritium analysis was carried out by standard procedures of electrolytic concentration and liquid scintillation counting (Calf, Seatonbury, and Smith, 1975). Analysis of the water samples for deuterium was conducted by CSIRO, Isotope Analysis laboratory using the zinc reduction method and a VG Isogas mass spectrometer (error; ± 0.8 per mil). The determination of oxygen-18 was conducted at the University of Wollongong using the CO_2 gas equilibration method, purified using a Micromass Multiprep Unit and measured on a Micromass Prism III (error; ± 0.1 per mil).

RESULTS

Nearly all samples had low Total Dissolved Solids and EC, and analysis of major ions revealed low concentrations in general, most groundwaters only slightly more salty than the streamflow samples. In addition Piper diagrams (Fig 1) revealed that with the exception of a groundwater samples approaching the tidal limit (bores 75049, and 39012) and several groundwaters at moderate distances from the Brogo River (39003, 39004), all the samples cluster in a tight group, typical of meteoric water. These samples, and particularly those near the

confluence of the rivers all show a linear relationship between total ions TDI and each major ion in composition diagrams (Fig 2), indicating the aquifer and streams are a well mixed system of two end members, possibly rainfall and evaporated rainfall.

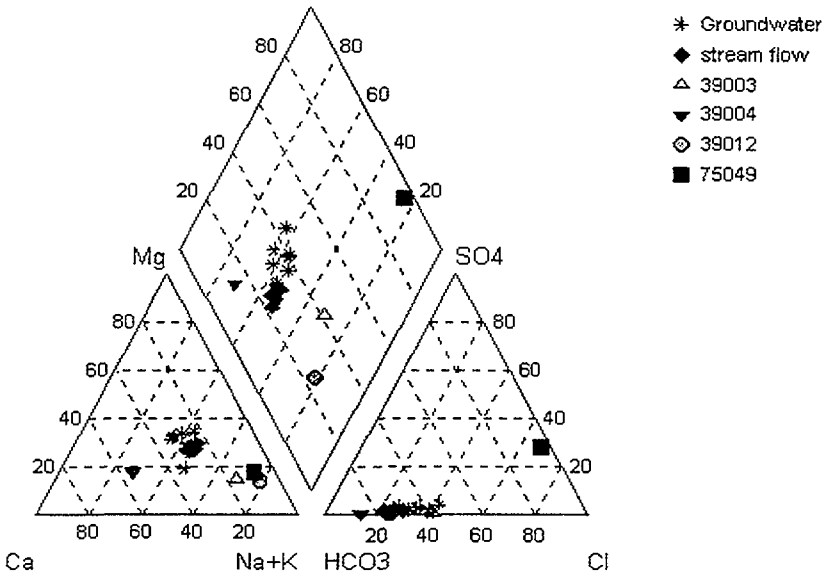

Figure 1: A piper plot of the analysis of water samples collected in April 2000

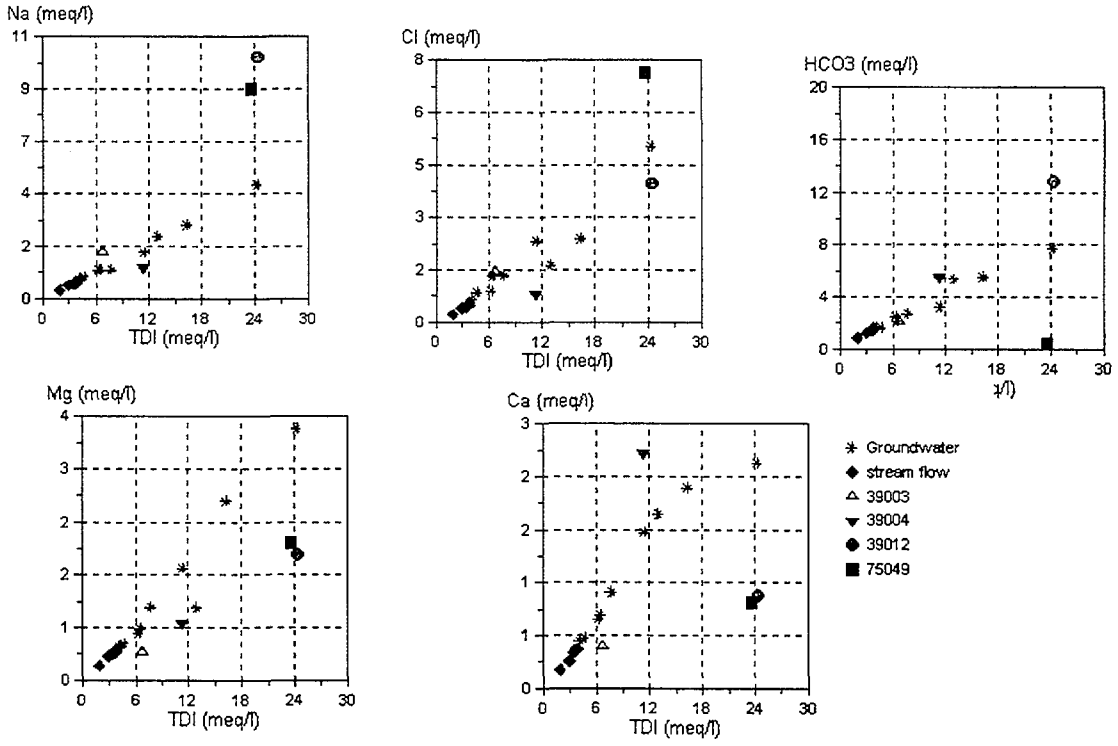

Figure 2: Composition diagrams of the concentrations of the major ions plotted against Total Dissolved Ions for samples in April 2000

Stable isotope analysis for April, when the aquifer waters averaged 18.5 C and streamflow 21.1 C, indicated that the waters were meteoric. All samples plot close to or above the global meteoric water line derived from the equation $\delta^2H = 8.13\ \delta^{18}O + 10.8$ (Craig, 1961a), with an O^{18} range from –4.5 to –6.0 per mil (Fig 3). The stream waters were more depleted than all but a few groundwaters, notably those downstream of the confluence. The isotopic difference between streamwater and groundwater, which can be taken as an indicator of temperature of recharge, was greatest in the upstream parts of the two rivers, while the difference was very small below the confluence. The samples taken in July, when the aquifer was 16.5 C and streamflow was 12.5 C, were consistently more depleted than those of April, (Fig 3). The strong correlation between temperature and stable isotopes in meteoric waters provides a seasonal signal that can be used to date groundwaters. The amplitude of seasonal variations in delta ^{18}O and ^{2}H is attenuated during groundwater recharge and preservation of seasonal variations implies short mean residence times.

The average shift in O^{18} was –0.16 per mil for groundwaters and –0.17 for stream samples, with one or two values nearly double the averages. Rainfall in this period was light and in the range –5 to –8 per mil. The shift in O^{18} is consistent with a temperature of recharge difference of 0.6 C, a value comparable with the difference in groundwater temperature. However the 2.0 C difference in groundwater temperature may be better explained by significant mixing of the substantially colder seasonal streamwater. This is supported by the trend toward convergence of the stream and groundwater isotopic values in samples taken progressively downstream.

Tritium activity in the samples collected in April range between 3.6 TU and 0.2 TU. These values need to be interpreted in light of the current long-term stability of tritium in precipitation over Southern Australia where rainfall in the period 1990 –2000 has been consistently in the range 3.0-3.5 TU, (Fig 4). Natural stratospheric input of tritium to the atmosphere is affected by latitude and altitude, and a considerable input of tritium into the atmosphere via thermonuclear weapons testing (Clark and Fritz, 1997) occurred between 1952 and 1963 resulting in dramatic increases in tritium levels. The peak in the concentrations occurring in 1963 (Fontes, 1980), when values of 10,000 tritium units were measured in North America. The distribution of tritium levels in precipitation averaged over the period from 1963 to 1968 for Australia indicate that the highest levels were found in the southeast over Victoria and reached 50 tritium units (Fontes, 1980), and had stabilised at about 4 TU by 1980, (Fig 5). Whereas it is not clear that tritium in Australian has ceased declining, it has stabilised at levels useful for the study of modern water age.

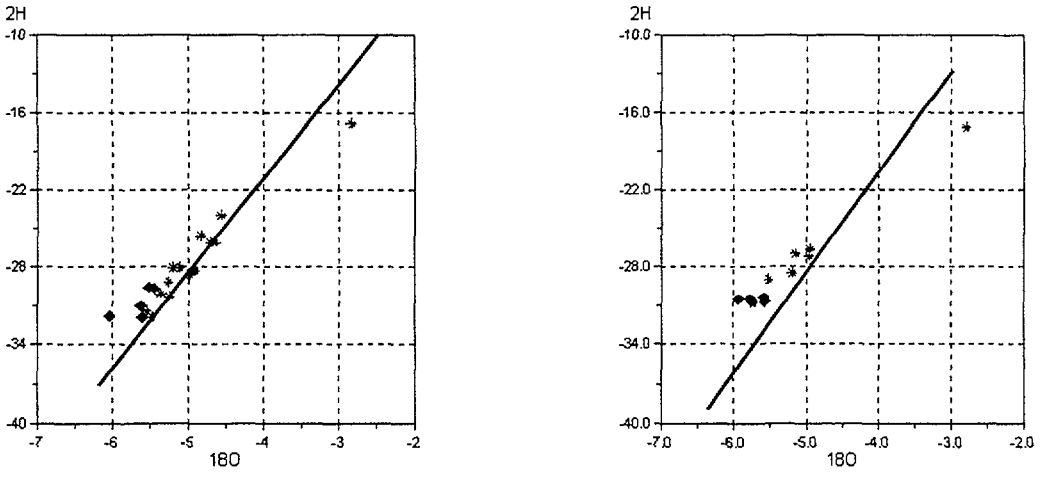

Figure 3. Delta ^{2}H v ^{18}O analysis for samples collected in April (left) and July (right) 2000; (streamflow; blue diamonds), vs global meteoric water line.precipitation has ceased declining, it has stabilised at levels useful for study of modern water age.

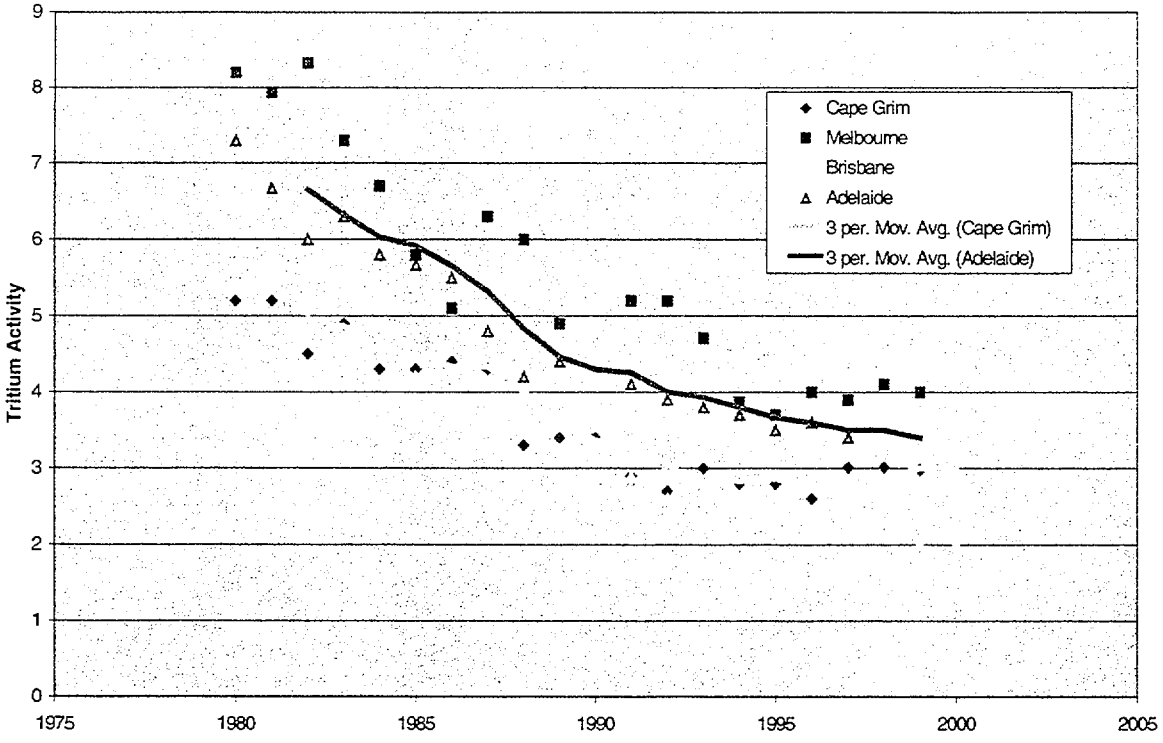

Figure 4. Tritium in Precipitation, selected stations in Southern Australia, 1979-2000.

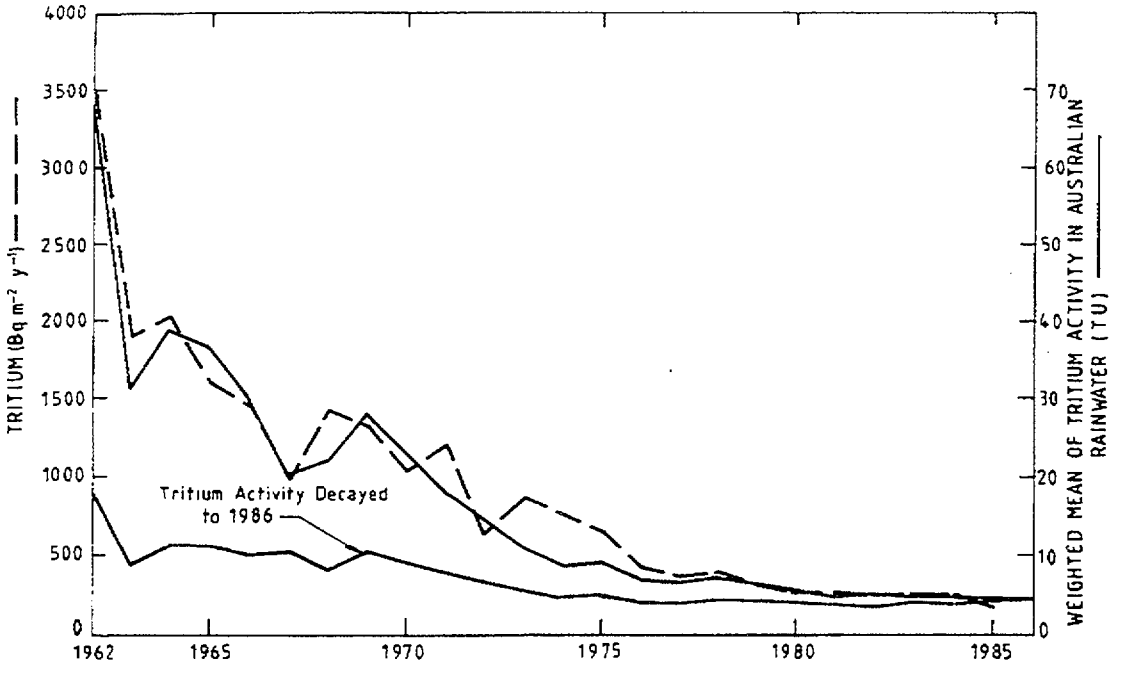

Figure 5. Weighted mean of Tritium activity in Australian Rainwater, 1962 -1985

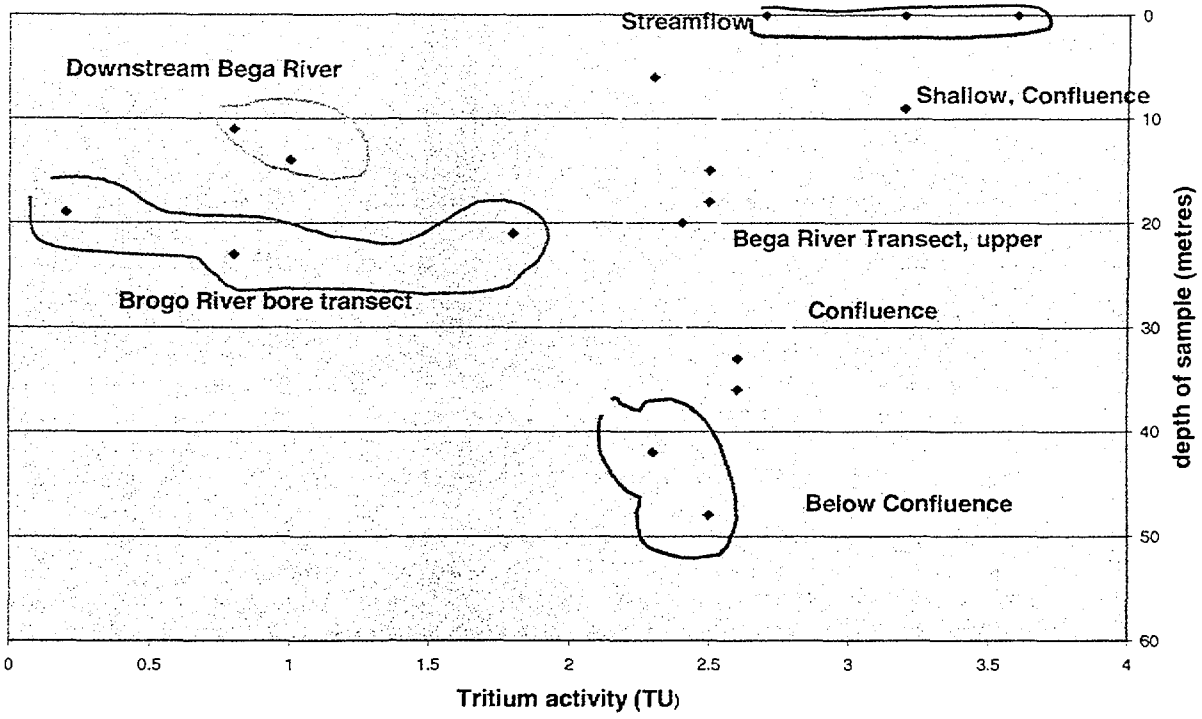

Figure 6. Plot of Tritium activity versus depth of sample in metres for groups of bores

Tritium in Groundwater reflects the conditions of recharge, and the history of water movement in the aquifer. The tritium activity of streams make apparent whether the stream is recharging groundwater or whether the groundwater is recharging the stream (Ferronsky and Polyakov, 1982). The stream samples varied from 3.6 TU in the Brogo river, whilst having a large dam on its upper reaches provides regulated streamflow which contains a substantial amount of surface water, to 2.7 TU in the unregulated Bega river, with a composite value of 3.2 TU found below the confluence. All the low EC groundwaters noted to cluster tightly on the basis of major ion composition had tritium activities in the range 2.3 to 3.2 TU, which would indicate mean residence times for the aquifer waters between 1-5 years. The other groundwaters had activity typically less than 1.0 TU indicating much older waters consistent with their exceptional major ion compositions. A plot of tritium activity versus borehole location and depth (Fig 6), indicates that the Brogo river is not recharging the adjacent alluvium since the tritium is much lower than in the streamwater. The Bega river however is recharging the adjacent alluvium, both above and below its confluence with the Brogo river, since tritium values are similar in stream and alluvium. This conclusion is supported by hydraulic data for the various transects.

CONCLUSION

In conclusion the isotopic evidence suggests that the groundwater in the alluvial aquifers of the Bega valley is generally well mixed and of low residence time. The groundwater is recharged from upstream sources in some areas with localised infiltration of surface runoff and stream flow. The groundwater is largely modern indicating a relatively constant and rapid recharge regime for this, probably streamflow-groundwater interaction. The current use of the Bega Valley groundwater system will not put the quantity of the groundwater at risk.

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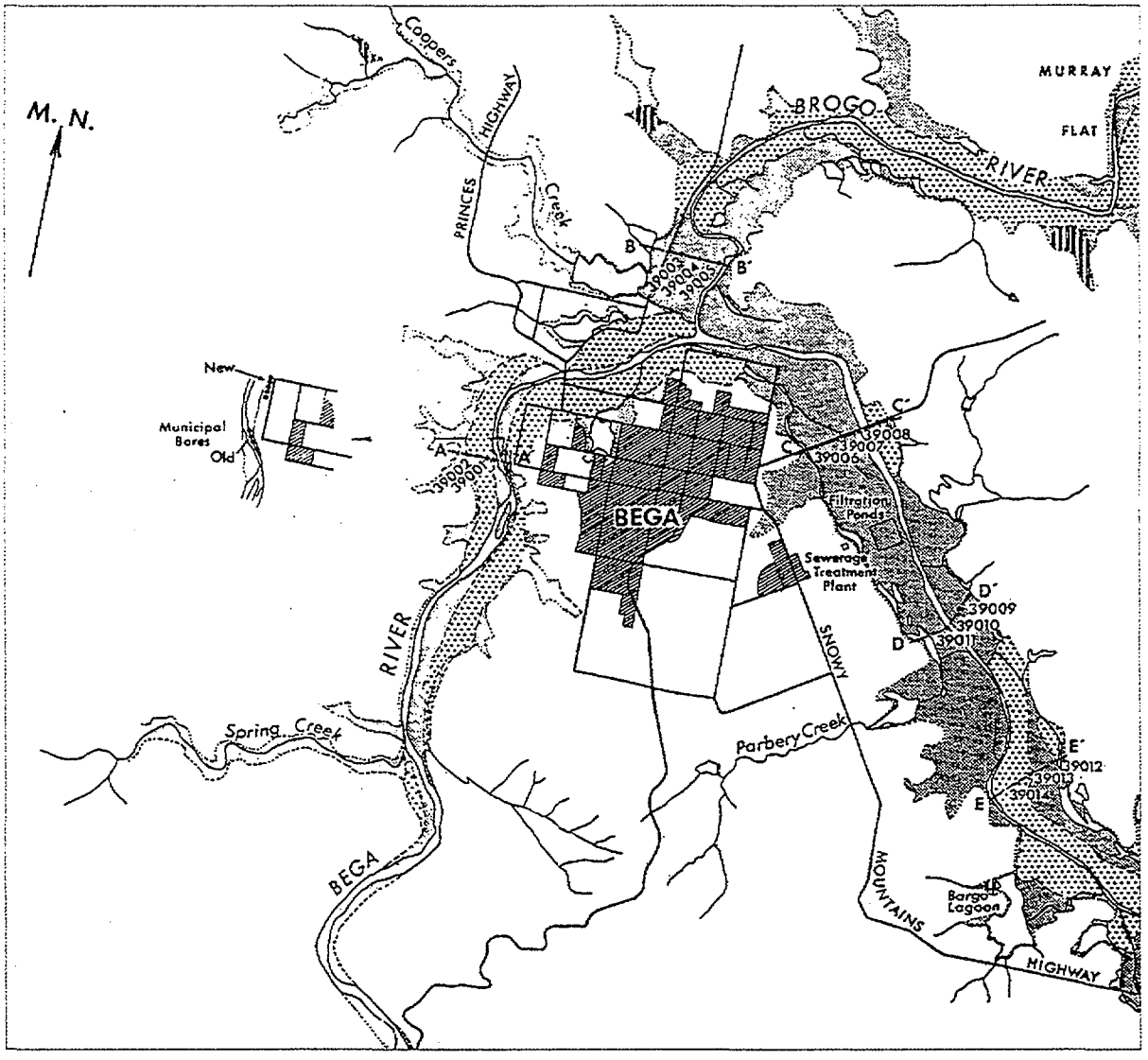

Figure 7. A plan of the Bega area showing the town, rivers, alluvial deposits and borehole locations.