3.9 Isotope

3.9.1 Environmental Radioisotope Determination and the “Age “of the Groundwater

As explained above, it is essential at any particular point to know how long it took the groundwater to reach that point, calculated from the time it was recharged. The ^{14}C ages in the unconfined aquifer system are shown in Fig. 3.9-1a. Overall, the ages are high, despite the fact that the aquifer system can be recharged virtually everywhere in the basin. Nevertheless, it is important to note that younger water occurs in the northwestern part of the basin in or near the Kalkrand basalt. Younger water (< 2000 a) also occurs along the lower reaches of the Nossob River, which confirms recharge from the riverbed during periods of flood. Younger water (< 5000 a) of good quality also occurs along the lower reaches of the Auob River at borehole WW39854 (J8K), confirming the importance of floodwater recharge in the basin.

On the other hand, groundwater in the Auob Aquifer is generally old, even close to the northern and western edge of the basin (see Fig.3.9-1b). The pattern is relatively consistent but in the centre of the area (mainly in an elongated zone along the Nossob River, and extending towards borehole WW39850 (J6A)) the ages are very high. These high ages are inconsistent as far as the relative distance to any potential recharge area is concerned. Also in the Nossob Aquifer the ages are very high, already in the northeastern part of the basin (see Fig.3.9-1c). The younger age at borehole WW39856 (J8N) is considered to be incorrect as it is a very low yielding borehole and the sample may have become contaminated during the extended sampling process.

Considering the high ^{14}C ages, very low tritium values can be expected both in the unconfined aquifer (see Fig.3.9-2a) and in the confined Auob Aquifer (see Fig.3.9-2b). Nevertheless, it is important confirmation that natural recharge is a very slow process. The trace of tritium in a few boreholes in the unconfined aquifer and also in one borehole in the Auob Aquifer could indicate that younger water may be blended into the aquifer and that a mixture of very old and younger water is abstracted in places. It may possibly also confirm that the ^{14}C ages could be overestimated due to chemical reactions.

3.9.2 Stable Environmental Isotope Results

Both the deuterium and ^{18}O stable isotope results (in ‰) are negative numbers as these waters are depleted in these isotopes. However, the programme that was used for plotting the values could not handle negative data and the results were multiplied by –1 before plotting. When multiplied by –1, the deuterium values in the unconfined aquifer system decrease from the northwest to the southeast (see Fig.3.9-3a). This agrees with the direction of the topographic gradient. However, the difference in elevation is only 350 to 400 m, which will allow a maximum increase of 10 ‰ due to the altitude effect. The difference is somewhat greater and, therefore, the water was possibly also subjected to evaporation. The low values along the lower Nossob are conspicuous as they are lower than expected for that area and must be related to the recharge processes, which will be discussed further below. The large number of data points is due to the parallel IAEA project under which two-thirds of the stable isotope analyses (^{2}H and ^{18}O) were carried out.

Except for the extreme south, deuterium values in the Auob Aquifer do not vary significantly over the basin (see Fig.3.9-3b). This would indicate that once the groundwater has reached the aquifer, no evaporation or other process can significantly affect the stable isotope concentrations. Only mixing with water from another source can change the stable isotope composition. The higher values in the far south agree with the values in the unconfined aquifer system, indicating that the two aquifers are in hydraulic contact. Fig.3.9-3c shows a similar consistent pattern for the Nossob Aquifer. The extremely high value (-20 ‰) at borehole WW36986 on the Weissrand contrasts with the nearby borehole WW39853 (J7N) with a more realistic value of –50 ‰.

Initially it would seem that the ^{18}O distribution in the unconfined aquifer system differs from that of deuterium, but it seems to be largely related to the choice of contour intervals (see Fig.3.9-4a). Also in this case the values increase in a southeasterly direction along with the topographic gradient and the groundwater flow direction. In the unconfined aquifer system evaporation or evapotranspiration is possible over most of the basin. In this case the low values (up to –9.0 ‰) along the lower reaches of the Nossob River are also clearly evident. In the Auob Aquifer the values in the southwestern half of the basin are consistently above –7.0 ‰ while they are smaller than –7.0 ‰ in the northeastern half of the basin (see Fig.3.9-4b). In the extreme south, the values are comparable with those of the unconfined aquifer system.

In the Nossob Aquifer (see Fig.3.9-4c) the same two boreholes, WW36986 and WW39853 (J7N), with high deuterium values, also have anomalously high $d^{18}O$ values.

In Fig. 3.9-5a all the available stable isotope data points are plotted together. The graph also shows the meteoric water line and a linear regression line for the Kalahari groundwater. The main feature is that most of the points plot along a linear regression line with a slope of approximately 5, which agrees with a typical evaporation line. Thus virtually all the groundwater in the basin has been subjected to evaporation. The isotope data for the unconfined aquifer system of the Kalahari, basalt (Kalkrand Formation) and the Rietmond Formation are plotted separately in Fig.3.9-5b. This clearly shows the distribution of the points along the evaporation line. Two of the boreholes along the lower reaches of the Nossob River with low values for both variables can clearly be seen in the lower left-hand corner of the graph. These waters are close to the meteoric water line and have, therefore, not been subjected to evaporation or evapotranspiration. This is of significance, as it would indicate that the floodwater soaked away quickly before the water had a chance to evaporate at the surface. The outliers at the higher end of the scale have already been identified on the maps.

The graph for the Auob Aquifer (Fig.3.9-5c) shows that the deviation from the meteoric water line is generally less for the Auob groundwater, except for a few outliers, which have already been identified on the maps. Most of the Nossob groundwater also plots in this part of the graph (see Fig.3.9-5d).

The nitrogen isotope ratio ($^{15}N/^{14}N$), expressed as $d^{15}N$ ‰, has been determined for fifty samples in the unconfined aquifer system and the Auob Aquifer in areas where nitrate occurs. The results were plotted on maps for providing an overview of the situation (see Fig.3.9-6a and 3.9-6b). Generally, a $d^{15}N$ value of +5 to +8 ‰ indicates that the nitrate is from a natural soil/plant origin, while a $d^{15}N$ value higher than +10 ‰ may indicate nitrogen from an animal source or on-site sanitation. Although most of the isotopic ratios are low, some of them are high enough to indicate a potential pollution source. These values confirm observations in the field where boreholes, particularly shallow ones, are often inadequately protected against pollution from the surface at stock-watering points. In other cases on-site sanitation has not been properly designed and septic tanks and their french drains are too close to the boreholes. In the case of the unconfined aquifer system, a total of eight boreholes sampled for ^{15}N showed potential signs of pollution, while at four of these it could be more likely. Two, or potentially three of the boreholes sampled in the Auob Aquifer may be affected. The identified boreholes should be inspected for further follow-up actions.

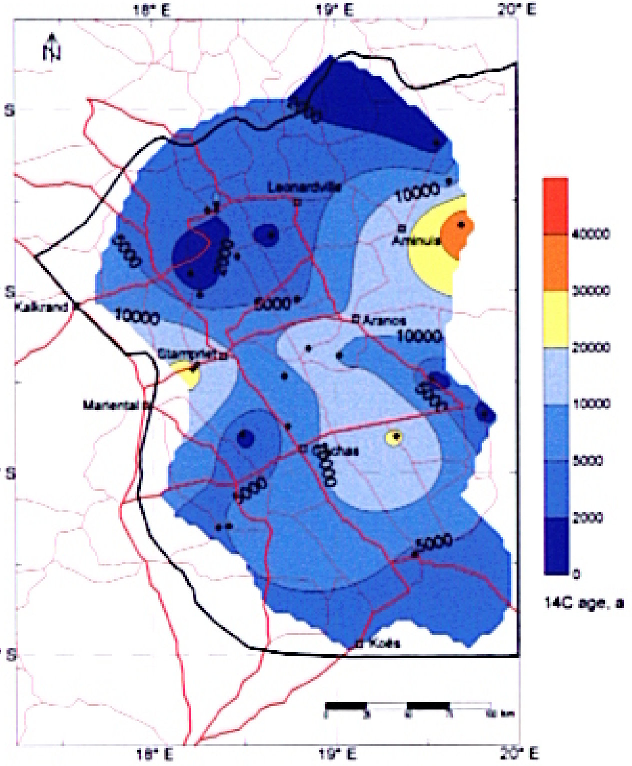

Fig.3.9-1a Carbon-14 groundwater age in the unconfined aquifer system (Kalahari, basalt & Rietmond)

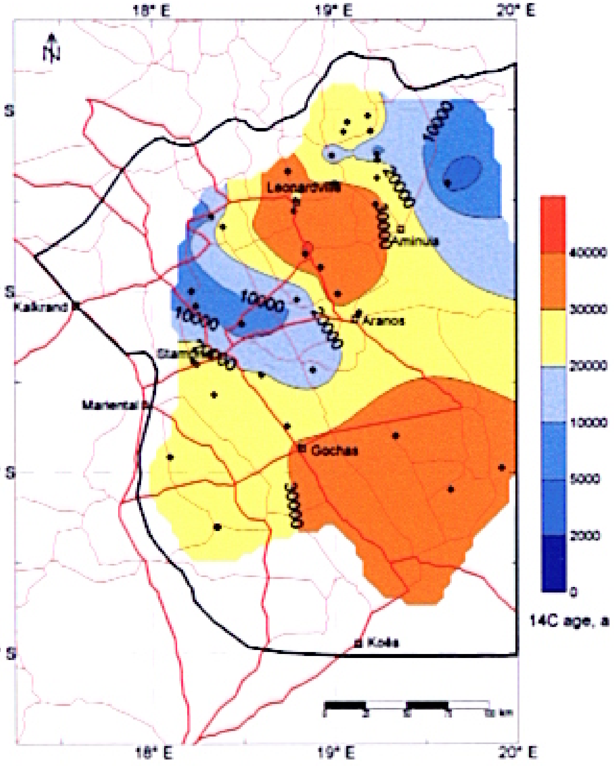

Fig.3.9-1b Carbon -14 groundwater age in the Auob aquifer

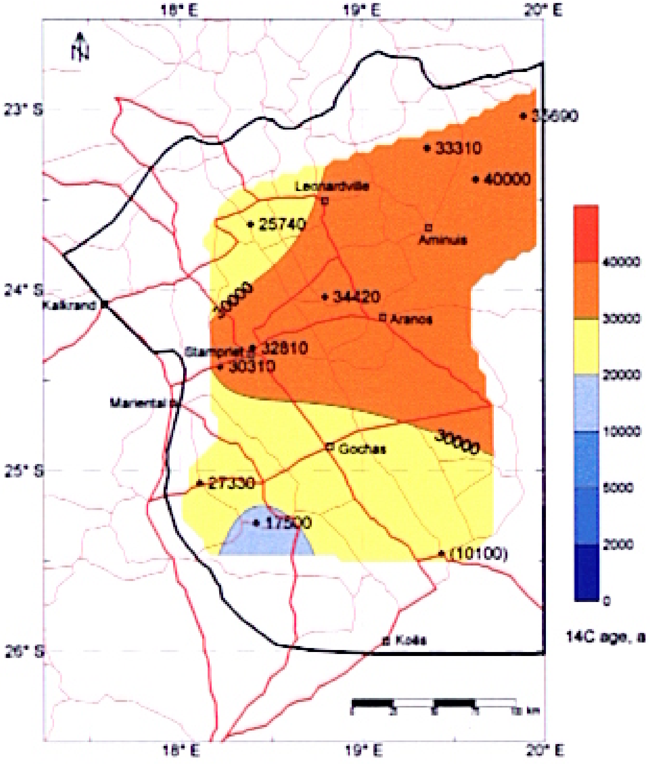

Fig.3.9-1c Carbon-14 groundwater age in the Nossob aquifer

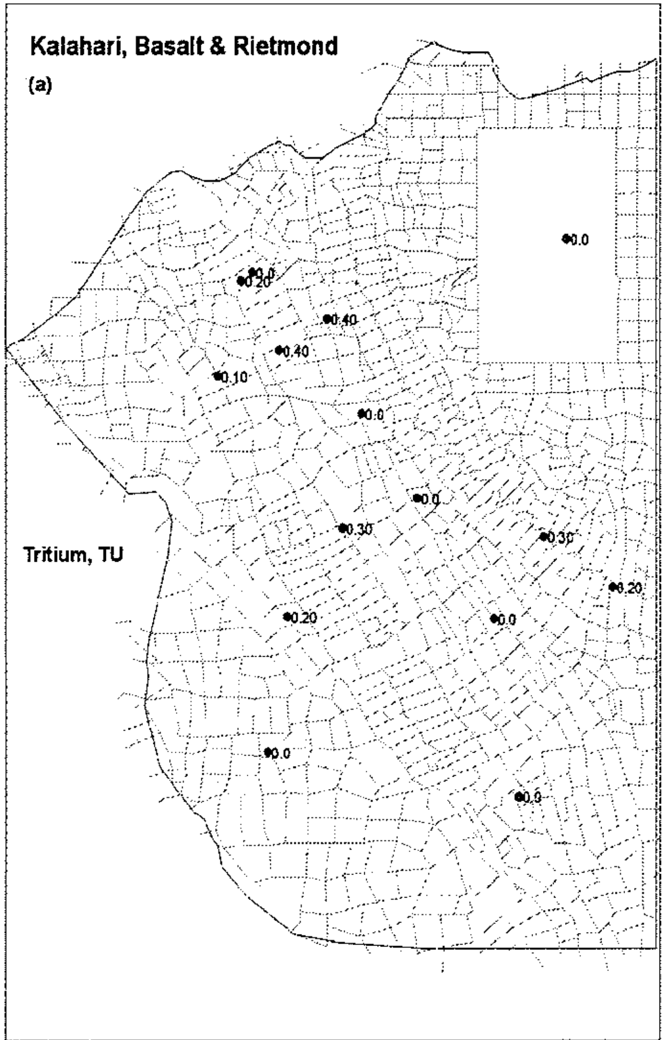

Fig.3.9-2a Tritium concentrations in the unconfined aquifer system (Kalahari, basalt & Rietmond)

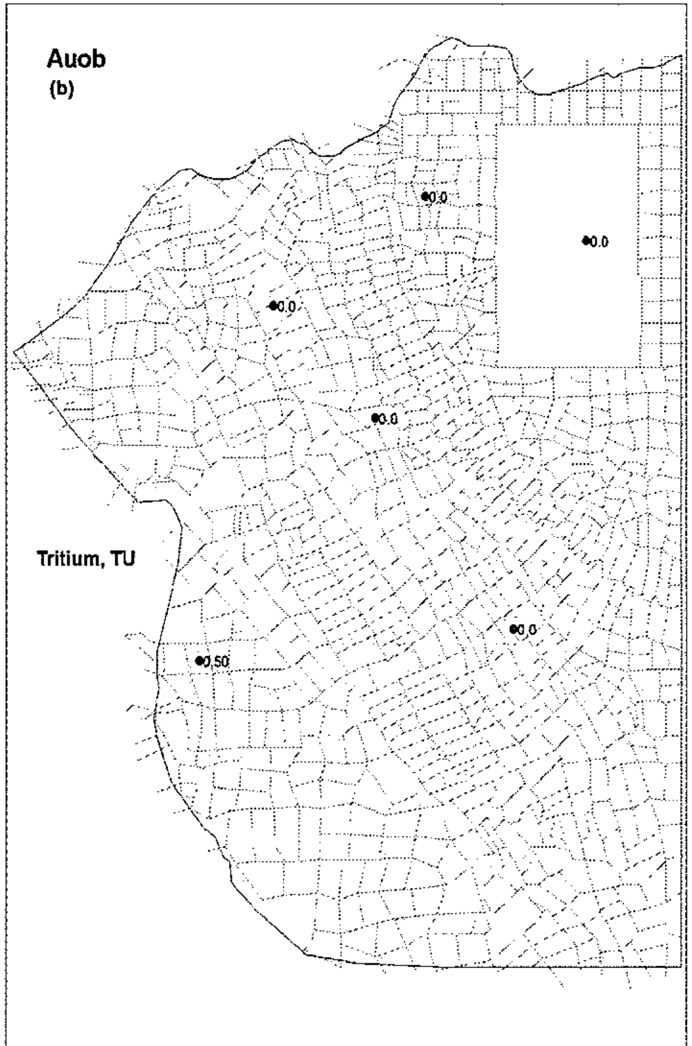

Fig.3.9-2b Tritium concentrations in the Auob aquifer