

Chalk catchment transit time: unresolved issues

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THE QUESTION

MTT (Mean Transit Time) is the average residence time of water from rainfall to river outflow at the foot of the catchment

MTT includes runoff and baseflow

MTT is therefore a function of storage and flow pathways and has groundwater quality as well as resource aspects

The Chalk is an important water-supply aquifer in northwest Europe – so what is the MTT of a typical Chalk catchment?

BACKGROUND

The MTT of a catchment without significant surface flow is normally taken to be the sum of mean residence time in the unsaturated zone and mean residence time in the saturated zone. However, the Chalk is a multi-porosity limestone aquifer, with a microporous matrix. This means that the movement of water through the Chalk can occur in complex ways, making the prediction of MTT far from straightforward.

Although the Chalk is a regionally-important aquifer, no study of catchment MTT has yet been published.

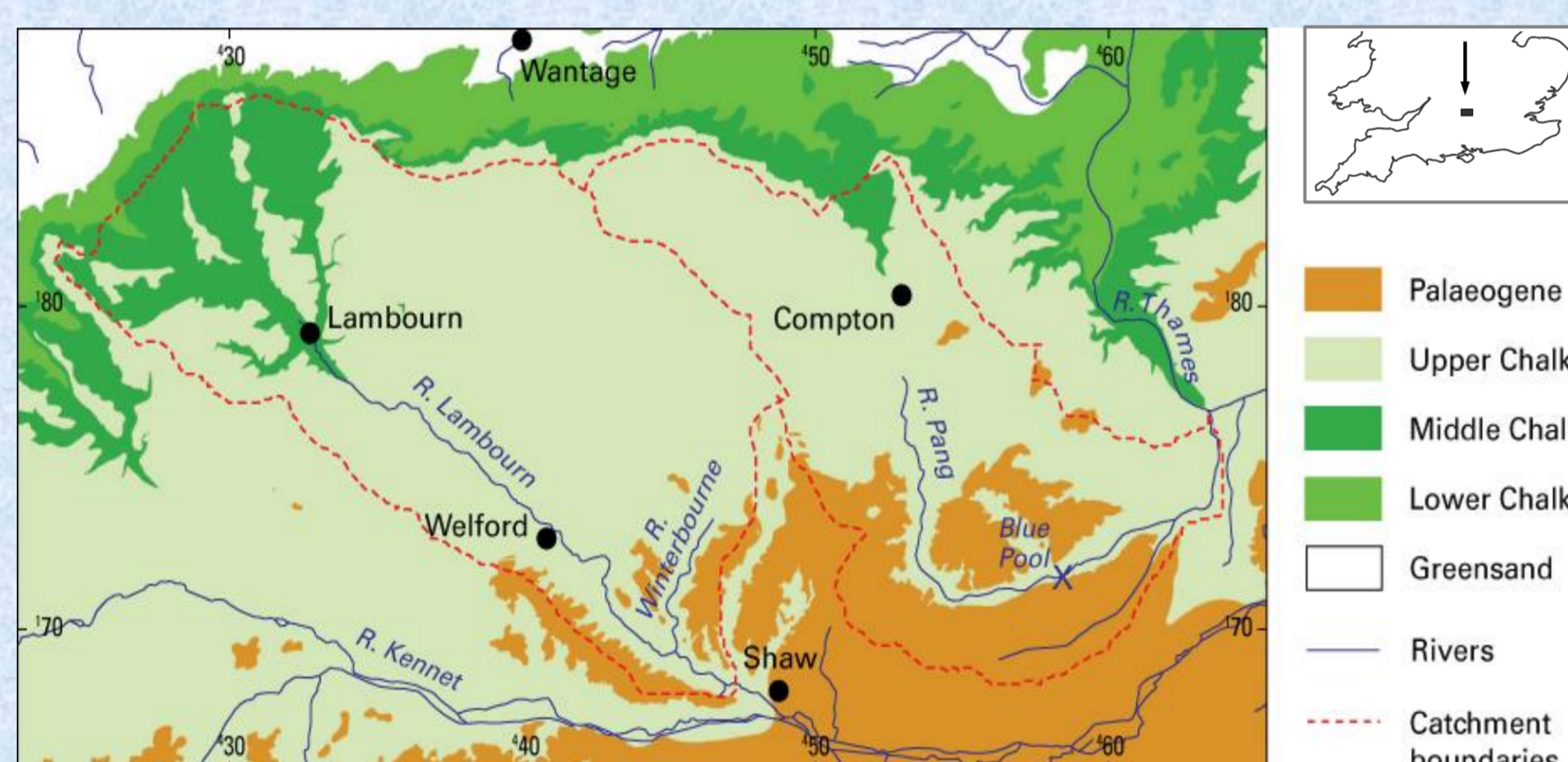


Figure 1. Catchment of the River Lambourn

The present study is based on the catchment of the River Lambourn in Berkshire, UK (Fig. 1), with an area of 235 km². Interfluvial areas rarely rise above 200 m asl (above sea level), whereas river elevation at the foot of the catchment is ~50 m asl. Mean annual precipitation is 731 mm. The thickness of the Chalk unsaturated zone reaches a maximum of over 100 m at the water divide at the top of the escarpment on the northern flank of the catchment (see Figure 2).

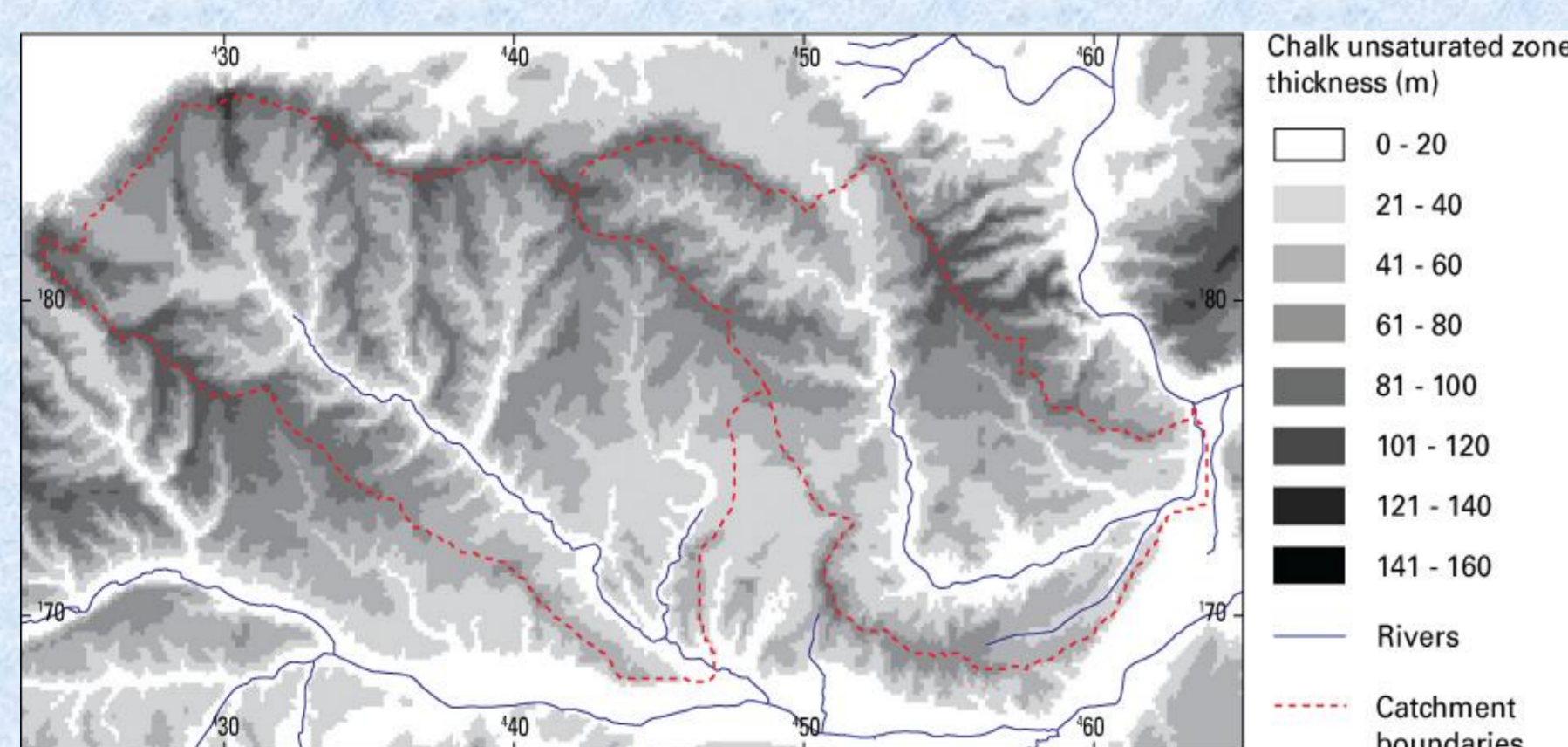


Figure 2. Unsaturated zone thickness in the Lambourn catchment

EVIDENCE

Age in the unsaturated (vadose) zone

From a tritium profile (Fig. 3), an infiltration rate of <1m/yr was inferred, subsequently confirmed by studies of other environmental tracers. Calculation of the ³H mass balance suggested a 15% loss to faster 'bypass flow'.

Mean USZ thickness in the Lambourn catchment has been calculated to be 53 m. Therefore, based on the various infiltration rate studies, MRT in the unsaturated zone is 50–60 years.

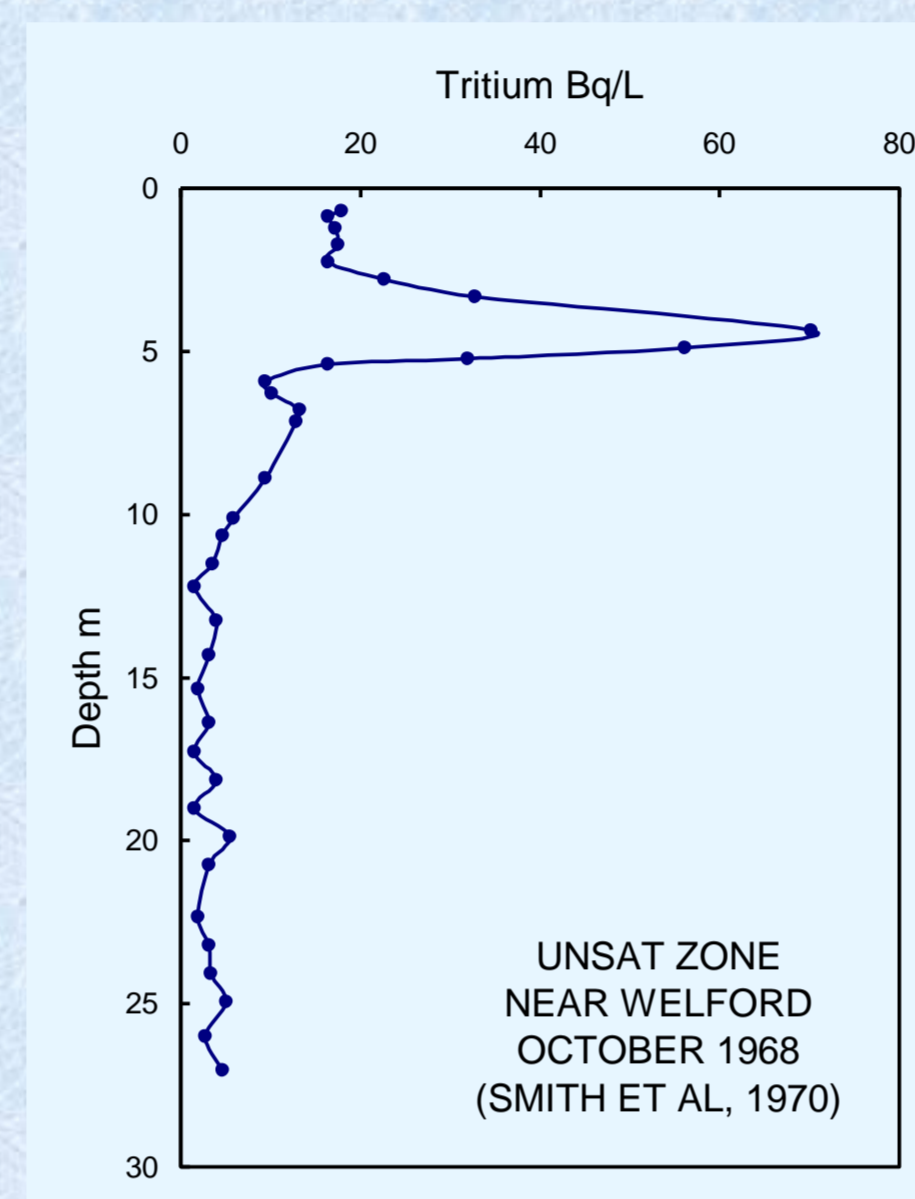


Figure 3. Tritium profile in the Chalk unsaturated zone of the Lambourn catchment

Age in the saturated zone

Groundwater residence time based on SF₆ measurements has been determined for waters from springs and boreholes in the catchment (Fig. 4). A narrow age range of 11–17 yr was found, consistent with a simple sectional model of groundwater flow.

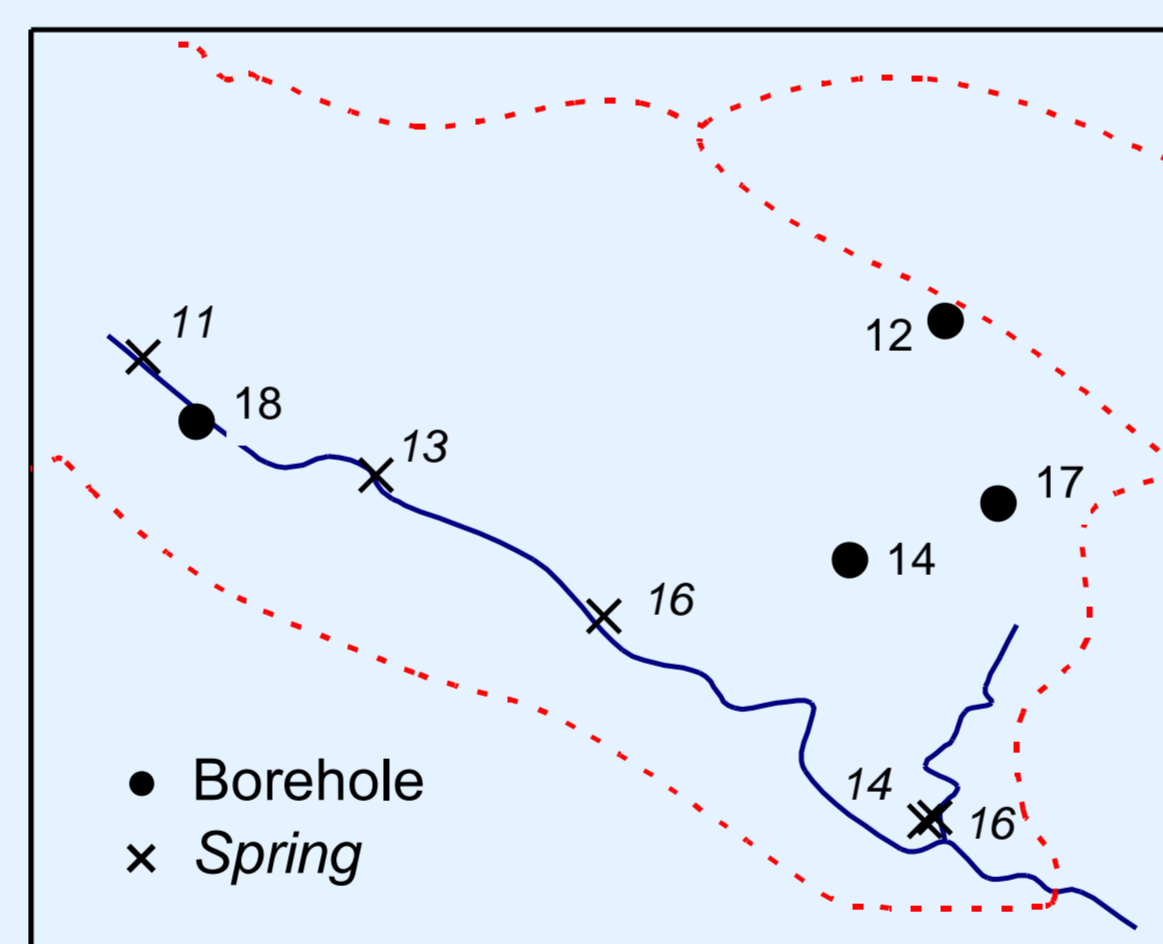


Figure 4. Map of SF₆ ages (yr) for springs and BHs

Age of the river water

Tritium activities in the Lambourn were measured from the late 1960s until the 1980s, (albeit with some gaps). A simple linear model fitted to the data (Fig. 5) indicates an apparent MTT of ~15 years. This would be rather long compared to non-Chalk catchments of similar size.

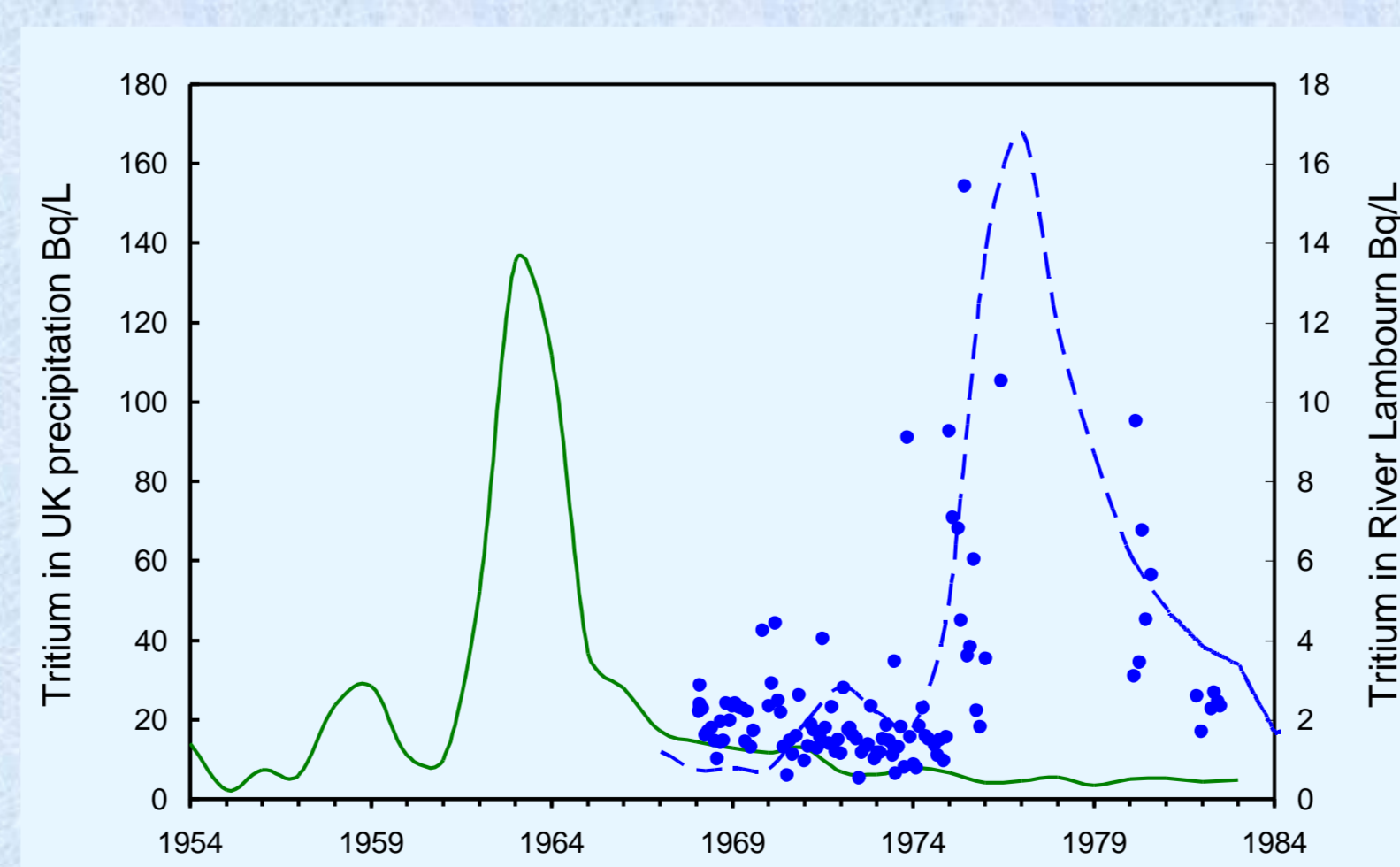


Figure 5. Tritium activity in rainfall and the river

DISCUSSION

On the one hand an apparent mean residence time of 50–60 years in the unsaturated zone plus 10–20 yr in the saturated zone, giving a combined age of 60–80 yr in total.

On the other hand, the tritium evidence from the river appears to give an MTT of ~15 yr. The river has a very high baseflow index (95%) so is almost entirely groundwater fed. Why are the transit time figures not in better agreement?

Three possibilities can be considered:

1. *Big difference between surface and groundwater catchments?* While the groundwater catchment may be smaller than the surface catchment due to some drainage to the neighbouring River Thames catchment, the difference is minor at most.
2. *Baseflow index wrong?* Baseflow measurement is a robust technique and a high value for the Lambourn is confirmed by highly-damped stable isotope values.
3. *Bypass flow greater than supposed?* It is possible that the river ³H peak simply represents bypass flow, in which case it would have to be much larger than the conventional 15% estimate (Fig. 6). This is not supported by other Chalk studies.

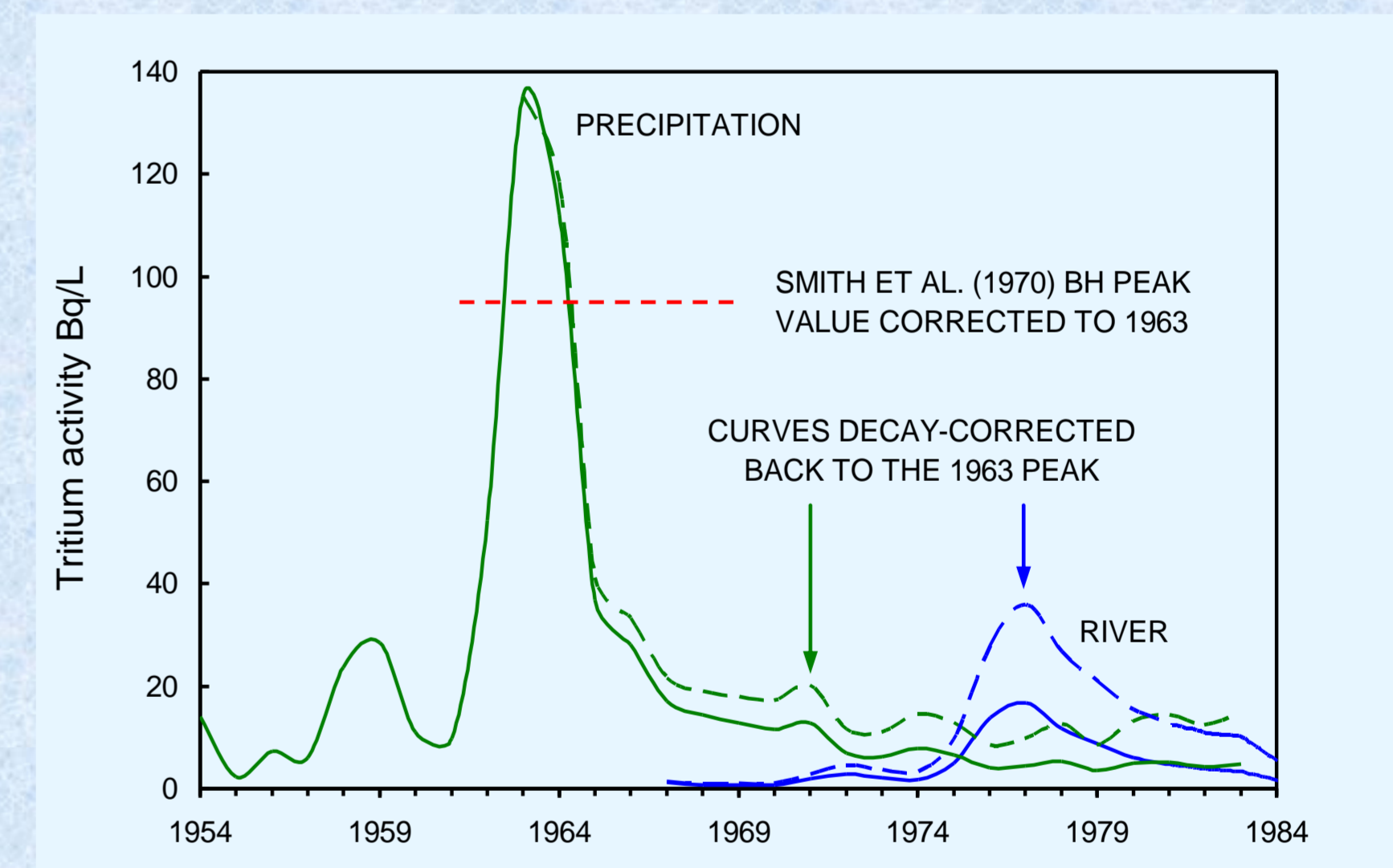


Figure 6. River tritium in proportion to rainfall ³H

CONCLUSIONS

- On the one hand, a tritium-based catchment MTT of 1–2 decades comparable with a variety of catchments worldwide
- On the other hand, a lot of evidence that most recharge travels slowly through the unsaturated zone, and is delayed for a further 10–20 yr in the saturated zone, implying an MTT of many decades
- The absence of similar data from comparable Chalk catchments makes these opposing scenarios difficult to resolve