Catchment Scale
What this section will address

Plot scale

Hillslope scale

Catchment scale
This section

- What are the soil moisture-topographic relations at the watershed scale?
- How do hillslopes connect to the catchment?
- What are the time- and geographic source components of runoff
  - An Isotope Hydrology Primer
  - Hydrograph separation at the catchment scale
  - What is mean residence time and how can we calculate it?
Soil moisture
Wet: Strong topographic control

After Grayson et al., Water Resources Research (1997)
Soil Moisture
Dry: Weak topographic control

After Grayson et al., Water Resources Research (1997)
Terrain relationships

Tarrawarra May 1996 - Soil Moisture v. ln(a / tanβ)

R² = 0.52

Roger Grayson, pers. Com.
Threshold responses

- Runoff ratio
- Moisture content (%)

Satellite
Tarrawarra

Roger Grayson, pers. Com.
How catchment units sequence

Rising limb
Falling limb

Rising limb
Falling limb

McGlynn and McDonnell, 2003a WRR
Why this is important

- M15 Runoff
- Riparian runoff
- Hillslope runoff

Why this is important

McGlynn and McDonnell 2003b WRR
Could be other geomorphic reservoirs that are important.

Slumgullian Flow, CO

Rapid Bay Valley, Fleurieu Penin, Southern Australia
Another way of looking at this

(a) Topography

(b) Depth to the Water Table

Seibert et al, 2003 WRR
It’s not continuous

…steady state???

(a) Topography

(b) Depth to the Water Table
Or, looking at this geochemically
Southern Piedmont, USA

![Graph showing Na⁺ and SO₄²⁻ concentrations for February 2 Storm, Outcrop, and Riparian GW, with data from Burns et al. 1999, Burns et al. 2001, and Burns et al. 2003.](image)

Burns et al. 1999 *WRR*
Burns et al. 2001 *HP*
Burns et al. 2003 *Groundwater*
Discrete units that connect and disconnect

![Diagram showing Na+ and SO4^2- concentrations](image)

- **February 2 Storm**
  - Outcrop
  - Riparian GW
  - Hillslope

**SO4^2- Concentration (μeq/L)**

**Na+ Concentration (μeq/L)**

**Bedrock Depth**
From geographic source to time source

What we learn in Hydrology 101

Quick Flow, Assumed to be precipitation

Slow Flow—Assumed to be Groundwater/interflow

The reality

Data of Colin Neal

Kirchner, 2003 HP
“...streamflow responds promptly to rainfall inputs, but fluctuations in passive tracers are often strongly damped. This indicates that storm flow in these catchments is mostly ‘old’ water”
Subsurface Flow From Snowmelt Traced by Tritium

J. Martinec

Federal Institute for Snow and Avalanche Research, Weissfluhjoch, Davos, Switzerland

An explanation is offered of the apparent discrepancy between the small velocities of subsurface flow and the watershed response. Environmental tritium in the hydrological cycle provided evidence for a new insight into the runoff mechanism. By this concept the quick reaction of outflow to a massive groundwater recharge is brought to agreement with the long residence time of the infiltrated water.

Role of Subsurface Flow in the Runoff

The proportion of subsurface flow in the total discharge has been frequently underestimated in runoff models. If the output from a basin corresponds to the input in a snowmelt period or in a hydrological year, it seems difficult to consider the subsurface flow, traveling sometimes several years, as a major runoff component. However, a significant presence of subsurface flow in the snowmelt discharge can be recognized by environmental isotope techniques. From the balance equation

\[
\text{water stored hitherto in the subsurface reservoir. The strong proportion of the prevailing old subsurface water in the discharge as shown by Figure 1 is thus also explained.}
\]

The identification of runoff components by tritium was verified by detailed measurements on a snow lysimeter [Arnsen et al., 1973]. As shown in Figure 2, the meltwater intercepted upon leaving the snowpack had on the average 180 TU (TU = tritium unit, a concentration of 1 tritium atom per \(10^{18}\) hydrogen atoms), whereas the winter base flow in the adjacent basin had about 280 TU. The tritium concentration of the
Stable Isotopes: Hydrologic Tool

- **Element with different number of neutrons**
  - $^{16}\text{O}$ (Light Element)
  - $^{18}\text{O}$ (Heavy Element) 0.2%

- $\delta^{18}$
- A primer on this now

- Naturally available in all water (e.g., rainfall)

- $\text{H}_2^{18}\text{O} \leftarrow$ Part of water molecule (ideal tracer!)

- “Fingerprint” for water molecules

- $^{18}\text{O}$ temporal patterns in precipitation follow seasonal temperatures