A Tale of Two Rivers: *The Water Cycle & River Catchment Hydrology*

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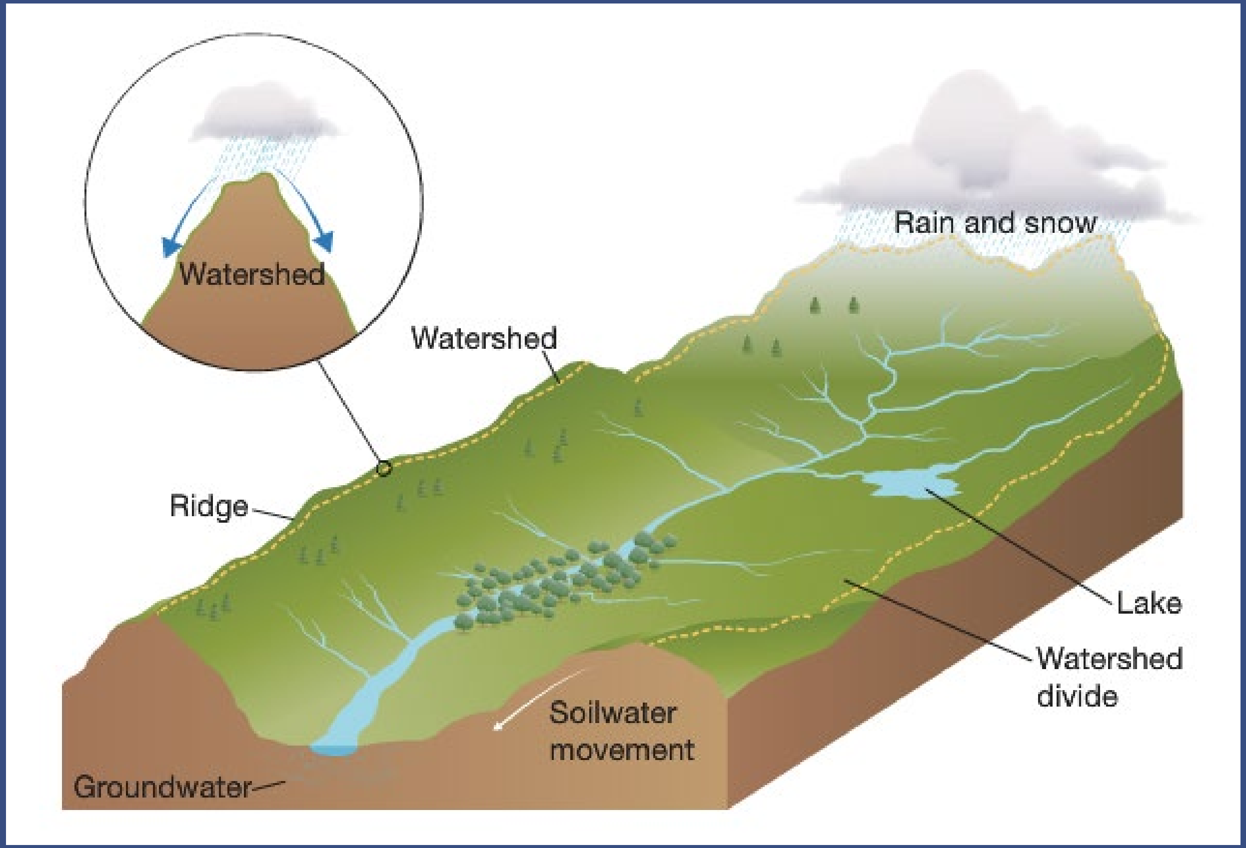
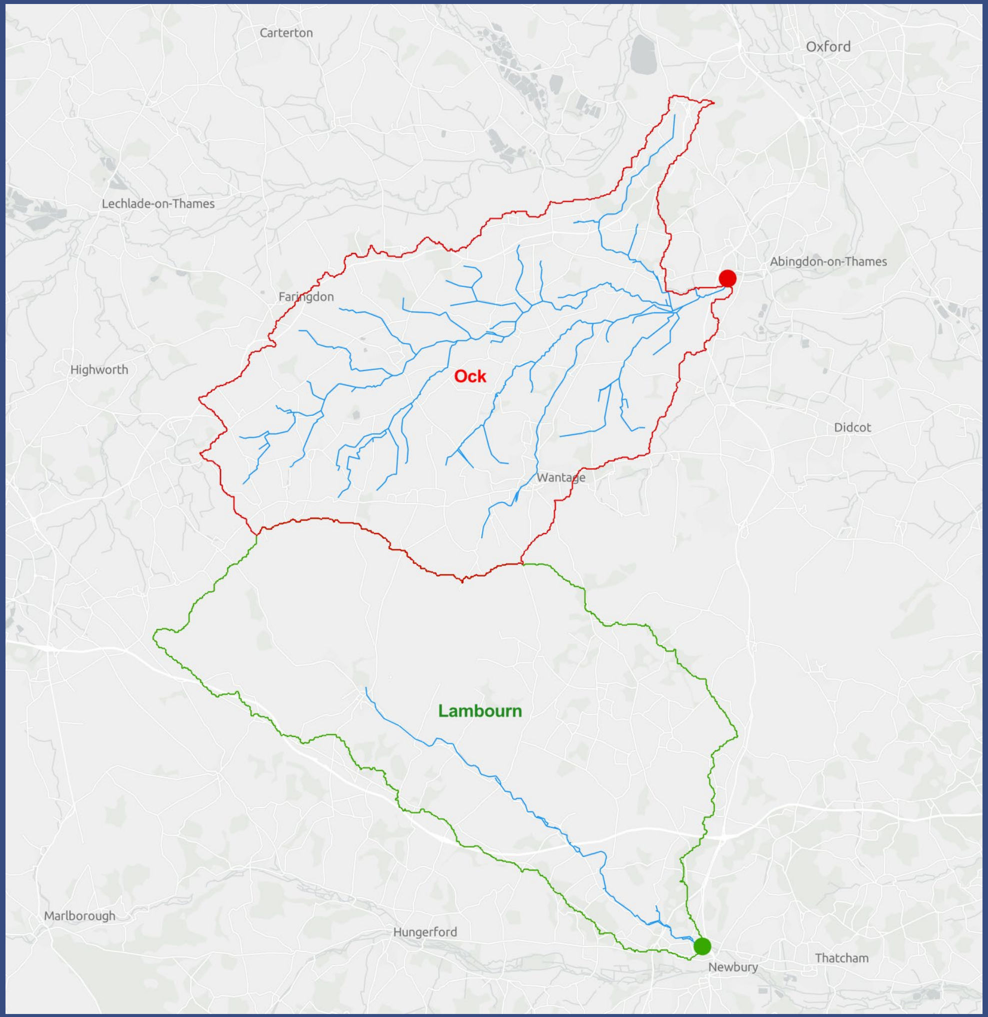
River Catchments

- A catchment is an area of land where water collects when it rains, often bounded by hills.
- As the water flows over the landscape it finds its way into streams and down into the soil, eventually feeding the river.



http://sncyear7geography.weebly.com/catchment.html

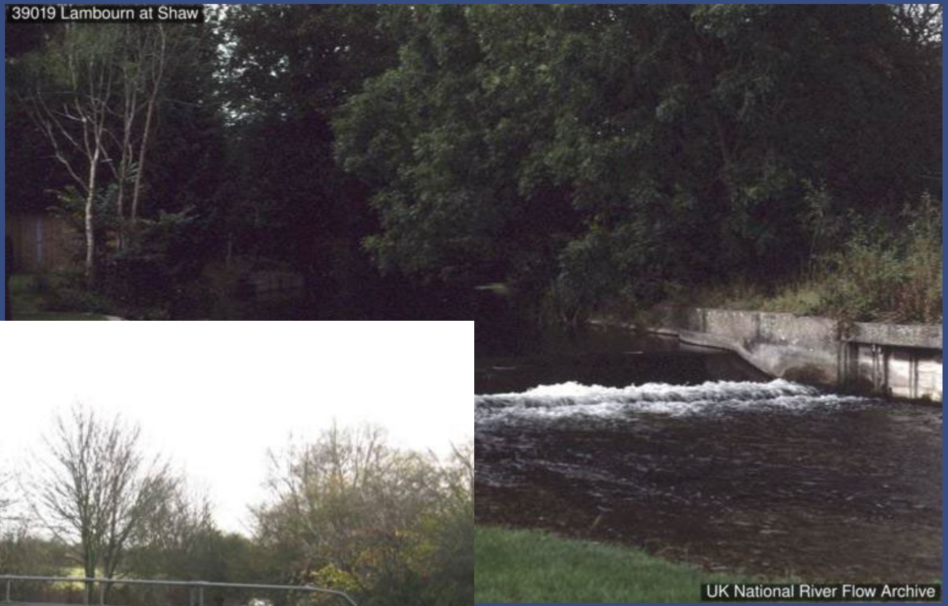
Our Study Catchments



- The **Ock** and **Lambourn** are two catchments located in southern/central England, not far west of the cities of Oxford and Reading.
- Flows in the catchments are measured by flow gauges positioned at the catchment outlets.

Monitoring River Discharge

- The **discharge** of a river is the volume of water that streams past a point in the river's course every second.
- The volume is estimated in cubic meters (m^3), and it is every second, so the units of discharge are **cubic meters a second (m^3/s)**



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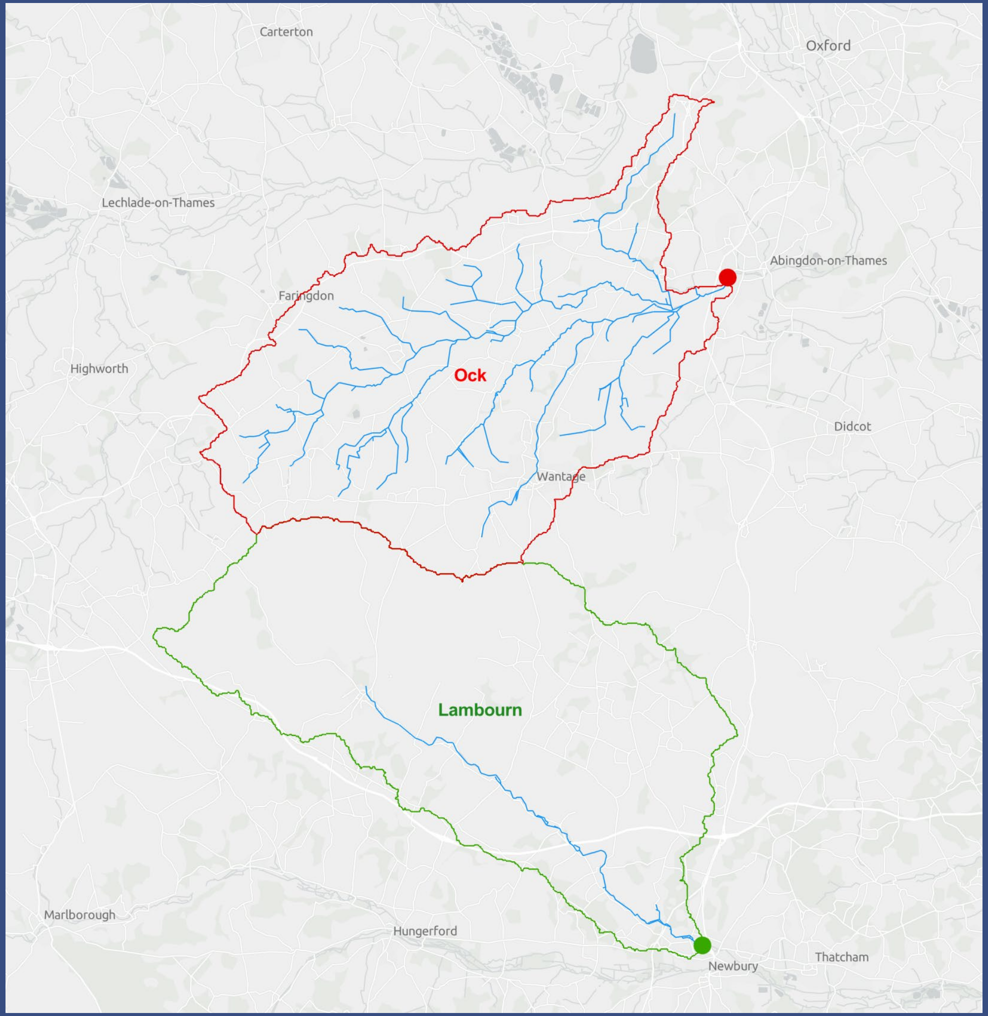
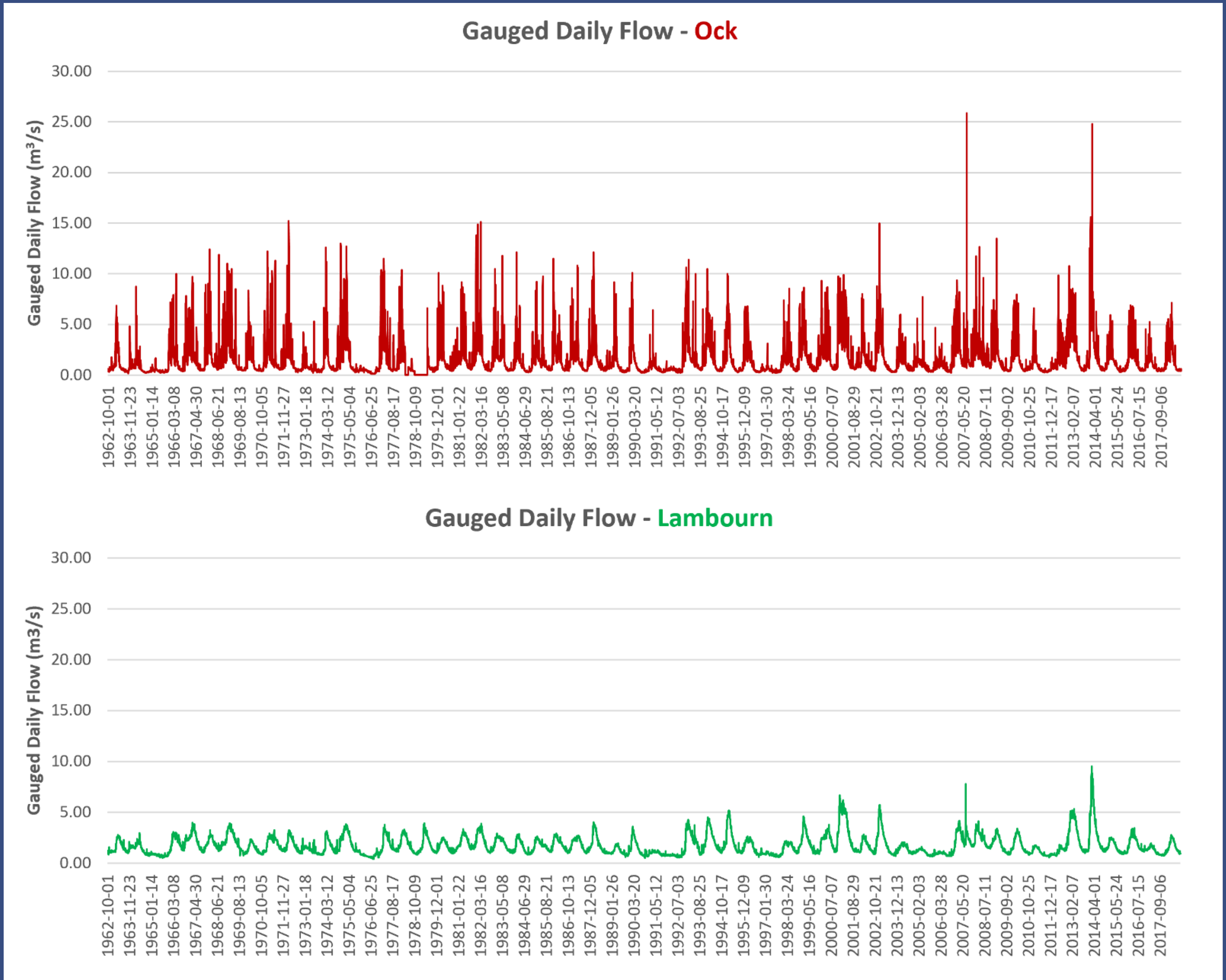


- The Ock and Lambourn catchments are neighbours and partially share a watershed boundary.
- Given their close proximity to one another, one might expect the two catchments to be quite similar.
- However….



Data from the NRFA

Hydrographs

	Minimum Flow	Maximum Flow	Mean Flow	Range
Ock	0.111 m^3/s	25.89 m^3/s	1.576 m^3/s	25.779 m^3/s
Lambourn	0.411 m^3/s	9.529 m^3/s	1.75 m^3/s	9.118 m^3/s

- The gauged daily flows of the Ock are more variable and have a greater range (25m^3/s) compared to the flows measured in the neighbouring Lambourn catchment (9m^3/s).

- The Ock has a maximum flow of just over 25m^3/s, whereas the Lambourn rarely peaks above 5m^3/s (maximum is 9.5m^3/s).

- So the Ock is a ___________ catchment.

- Whereas the Lambourn is a ___________ catchment.

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- The Ock has a maximum flow of just over 25m^3/s, whereas the Lambourn rarely peaks above 5m^3/s (maximum is 9.5m^3/s).

- So the Ock is a **FLASHY** catchment.

- Whereas the Lambourn is a **NON-FLASHY** catchment.

So why do these neighbouring catchments have such drastically different flow regimes?

In this lecture we will work through the hydrology of these two catchments and try to answer this question….

So…

What factors do you know about which might influence a catchments hydrology?

Catchment Hydrology

- Global and regional **climate systems**.
- The intensity and frequency of **precipitation** over the catchment.
- The different **landcover** components of the catchment (for example forest, grassland, urban surfaces and agriculture) which will influence interception and evapotranspiration processes.
- The **topography** of the catchment (is the catchment high elevation, or steeply sloped?).
- The characteristics of the catchments **soils** (are they permeable/not permeable, are they shallow/deep, and what condition are they in, e.g. have they been compacted by agriculture?).
- The characteristics of the catchments **geology** (is the bedrock permeable or not permeable?).
- The **presence of lakes and reservoirs** in the catchment (which store water for long periods of time).
- **Human modification** of the catchment (for example channelization or flood plain development).

Catchment Hydrology

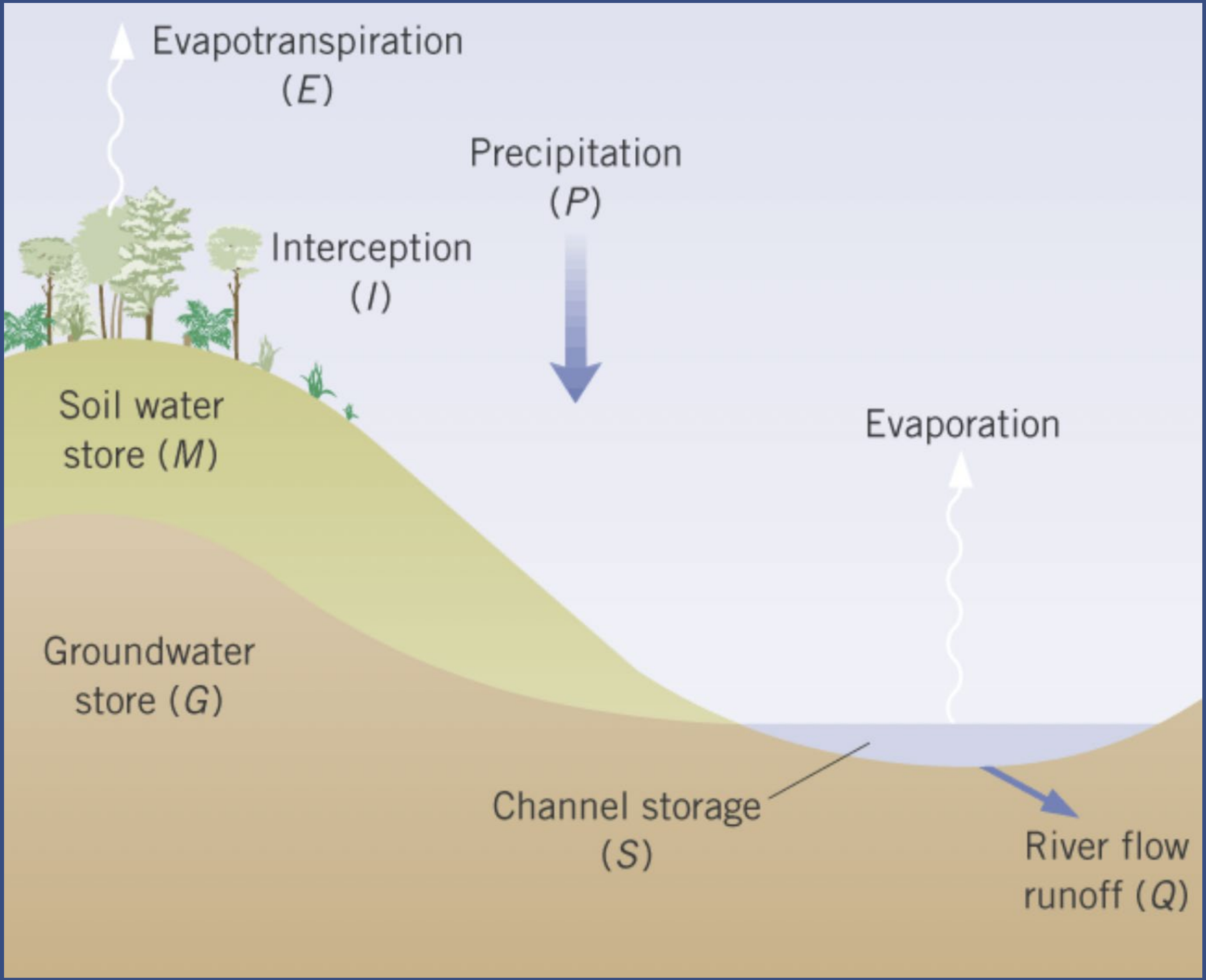


Image from Holden, 2012

Precipitation

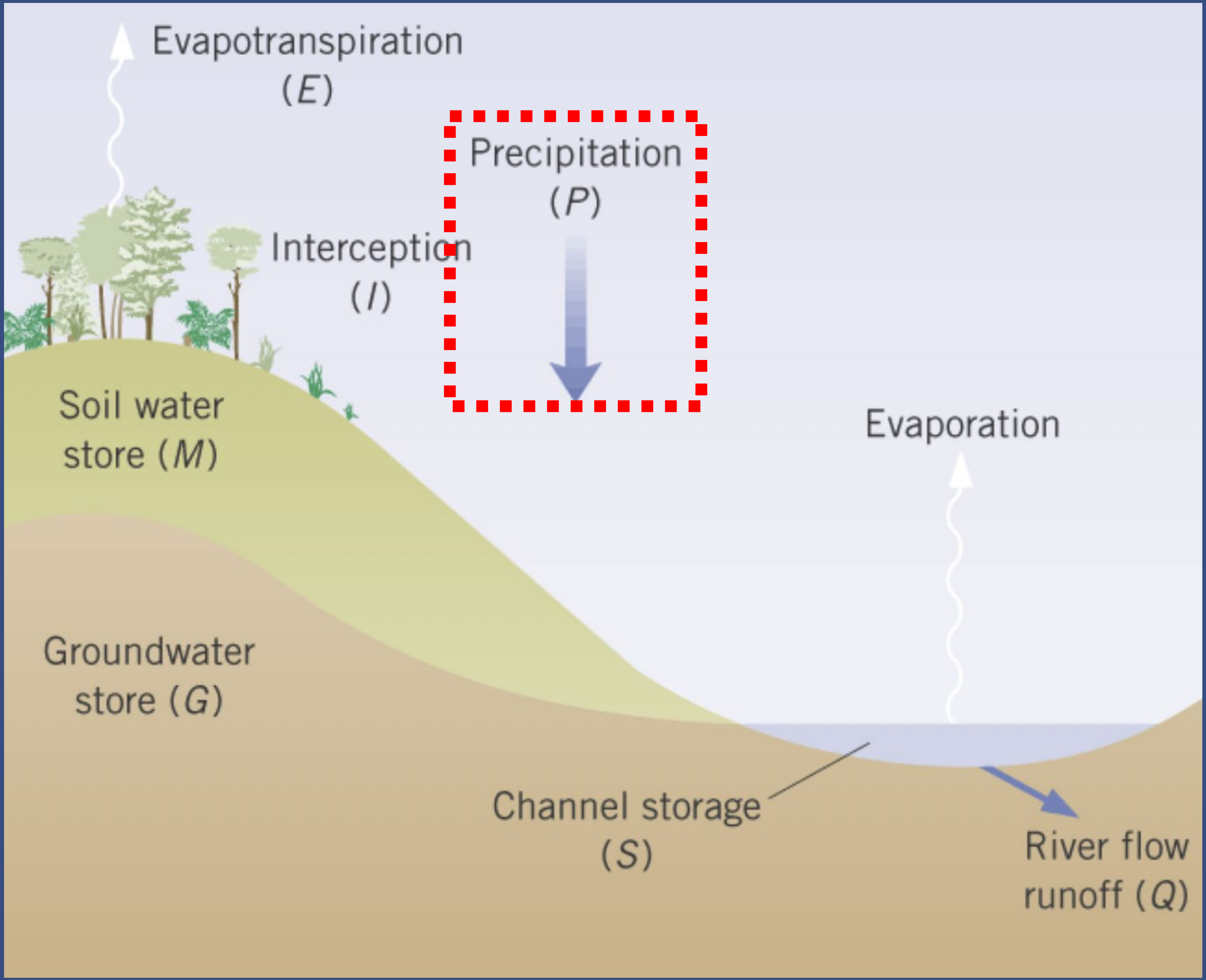


Image from Holden, 2012

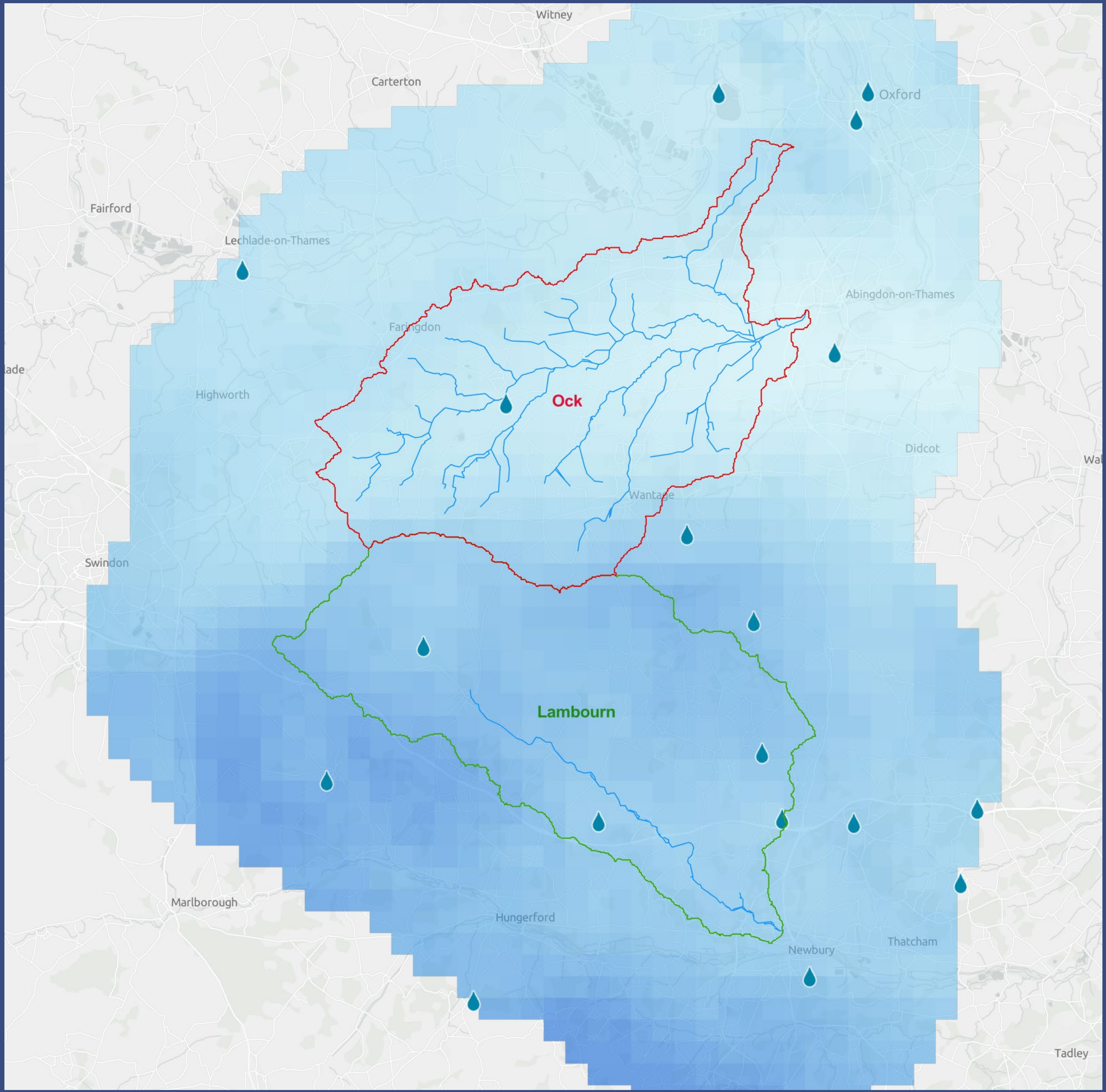
Precipitation

- Precipitation is the total atmospheric input of water or water equivalent mass (snow/ice).
- The greater the intensity of water delivery to the catchment, the more likely a catchment is to be flashy as there is more water moving through the catchment.
- The type and frequency of the precipitation also influences the hydrological response

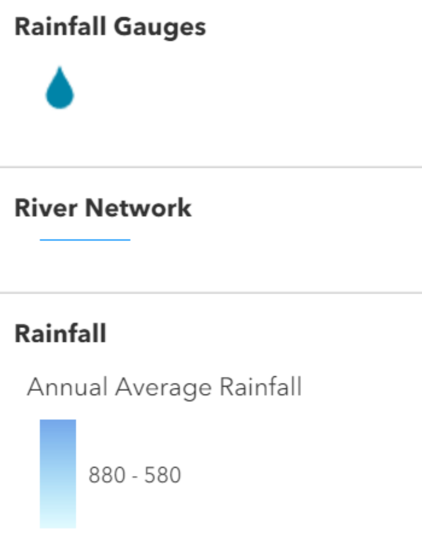
Measuring Precipitation

- Precipitation is measured using **rain gauges**.
- Across Great Britain the Met Office has a dense network of monitoring stations (data from these stations is stored in the MIDAS database).
- Precipitation measurements from these stations are used as inputs into **rainfall models** to create (through a process called spatial interpolation) a continuous surface of rainfall.

Comparing Precipitation

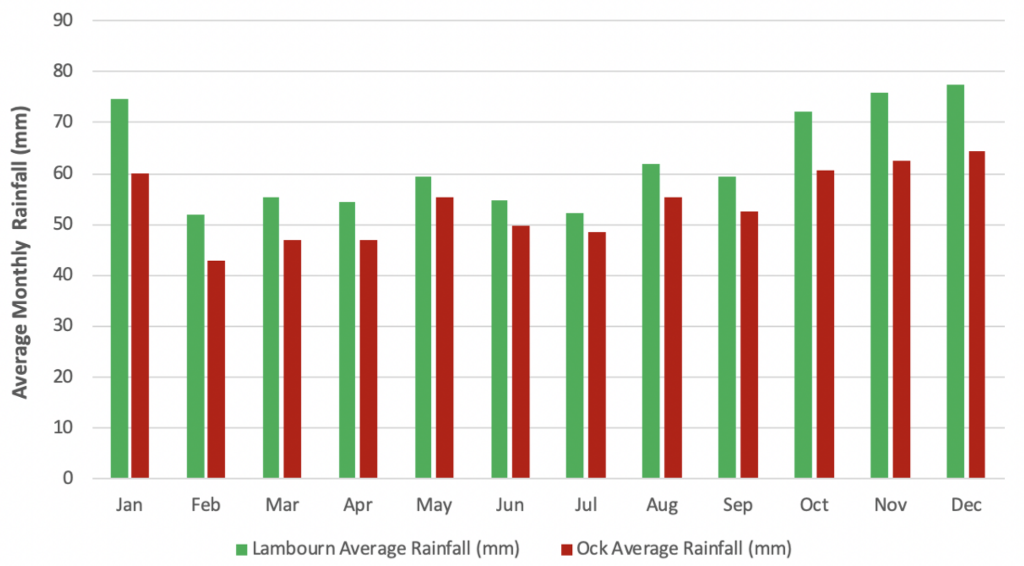


Precipitation data from CEH GEAR (Tanguy et al (2016)



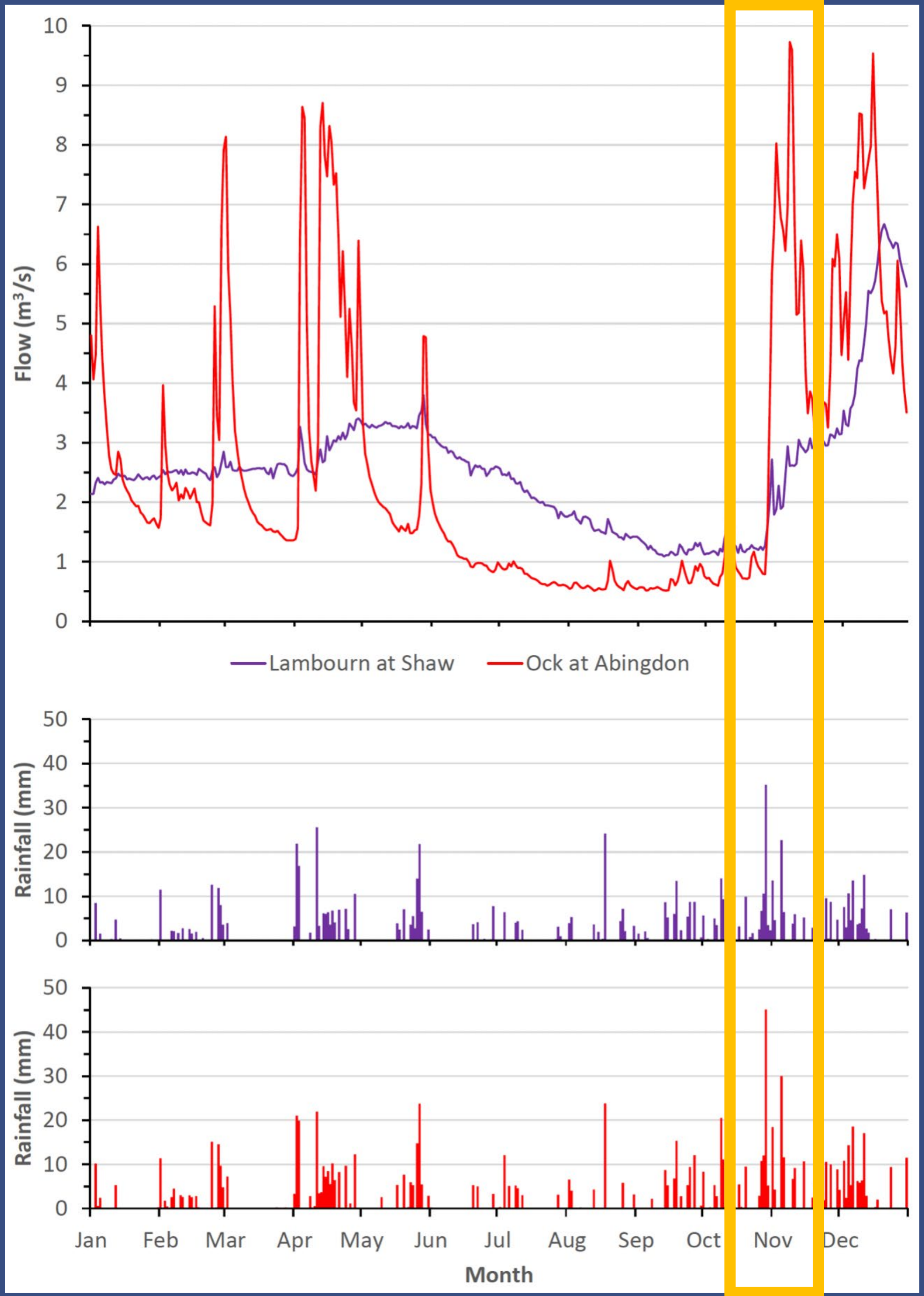
Comparing Precipitation

	Lambourn Average Rainfall (mm)	Ock Average Rainfall (mm)
Jan	74.52	60
Feb	52.02	42.77
Mar	55.29	46.94
Apr	54.37	47
May	59.29	55.3
Jun	54.85	49.88
Jul	52.3	48.47
Aug	61.95	55.4
Sep	59.53	52.63
Oct	72.07	60.52
Nov	75.75	62.62
Dec	77.61	64.32
Annual Average Rainfall (mm)	**Lambourn = 749.55**	**Ock = 645.85**



- The two catchments have similar rainfall inputs. However the **Lambourn catchment in the south generally receives moderately more rainfall than the Ock.**
- Its annual average rainfall is 749mm compared to 647mm in the Ock.
- Both catchments have higher average monthly rainfall in the winter (>60mm) than the summer (<60mm).

Rainfall-Flow Response



- The first graph on top shows discharge (m^3/s).
- The bottom graphs show precipitation (mm).

- The precipitation graphs look very similar across the year.
- However the hydrographs look very different.

- The Ock responds much more rapidly!

- Therefore the differences in flows cannot be explained by looking at rainfall.

- Given the slightly higher rainfall in the Lambourn there must be some other factors which influence the rainfall-streamflow response and reduce the flows to be lower than those measured in the Ock.

Figure from Davie and Quinn (2019)

Evapotranspiration

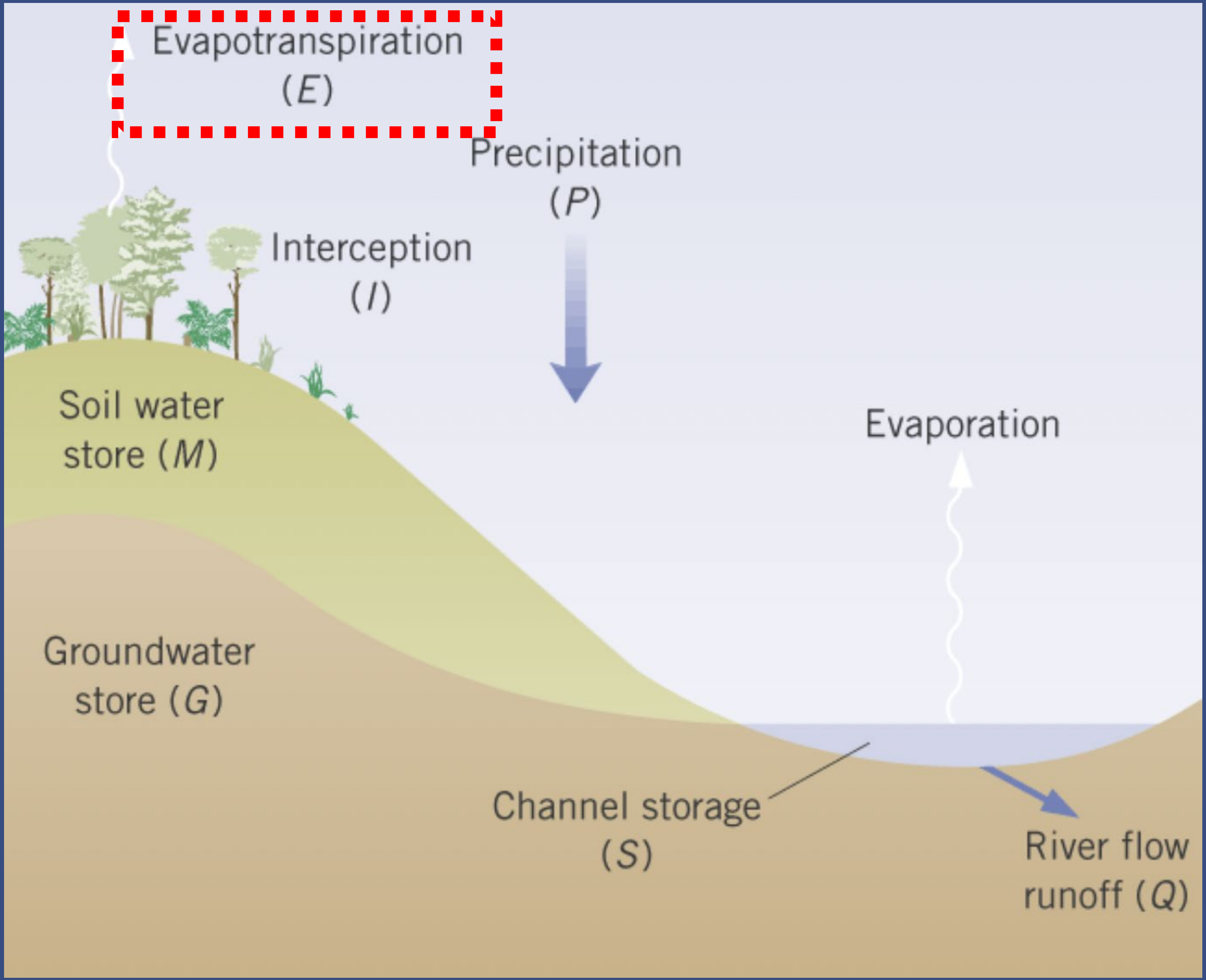
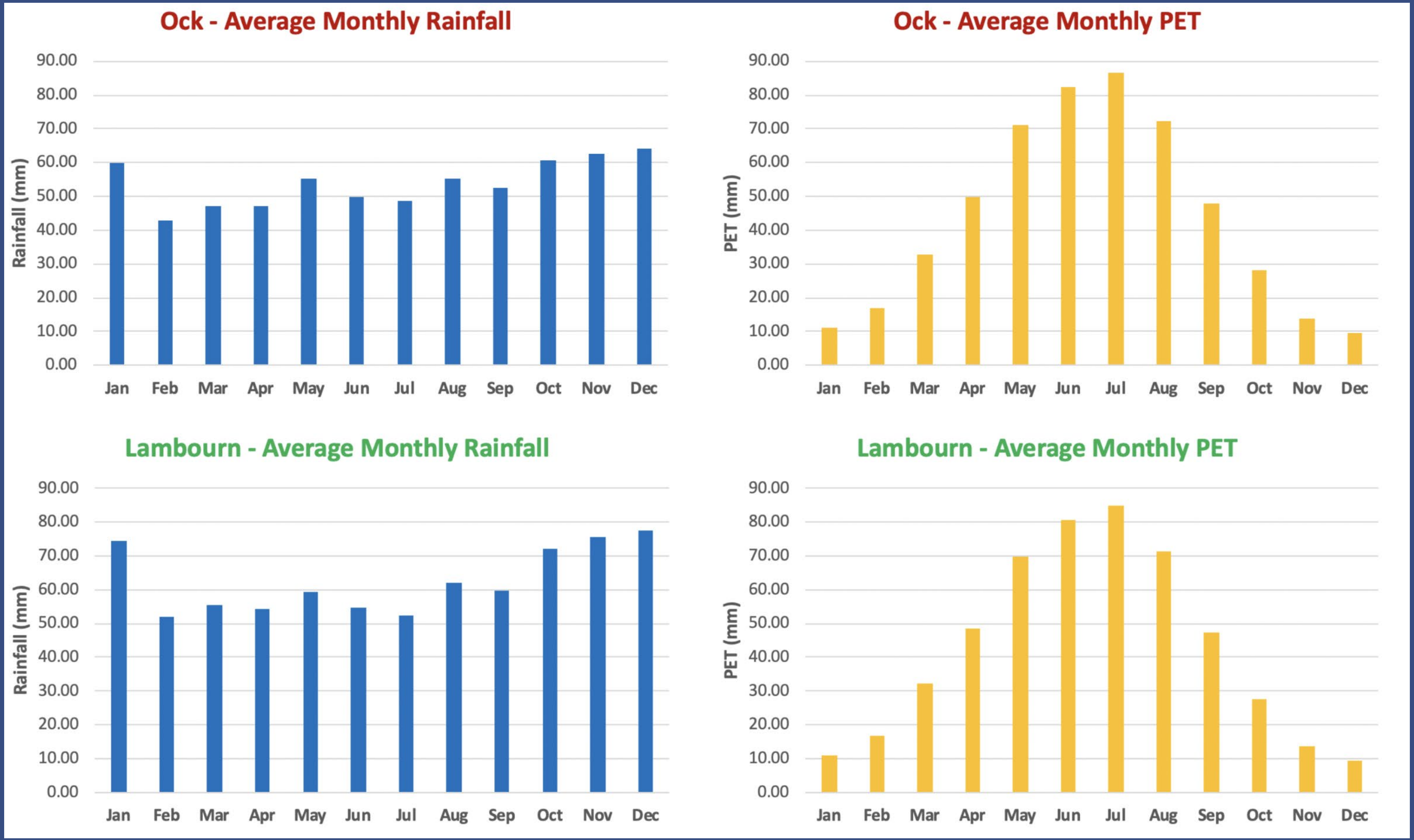


Image from Holden, 2012

Evapotranspiration

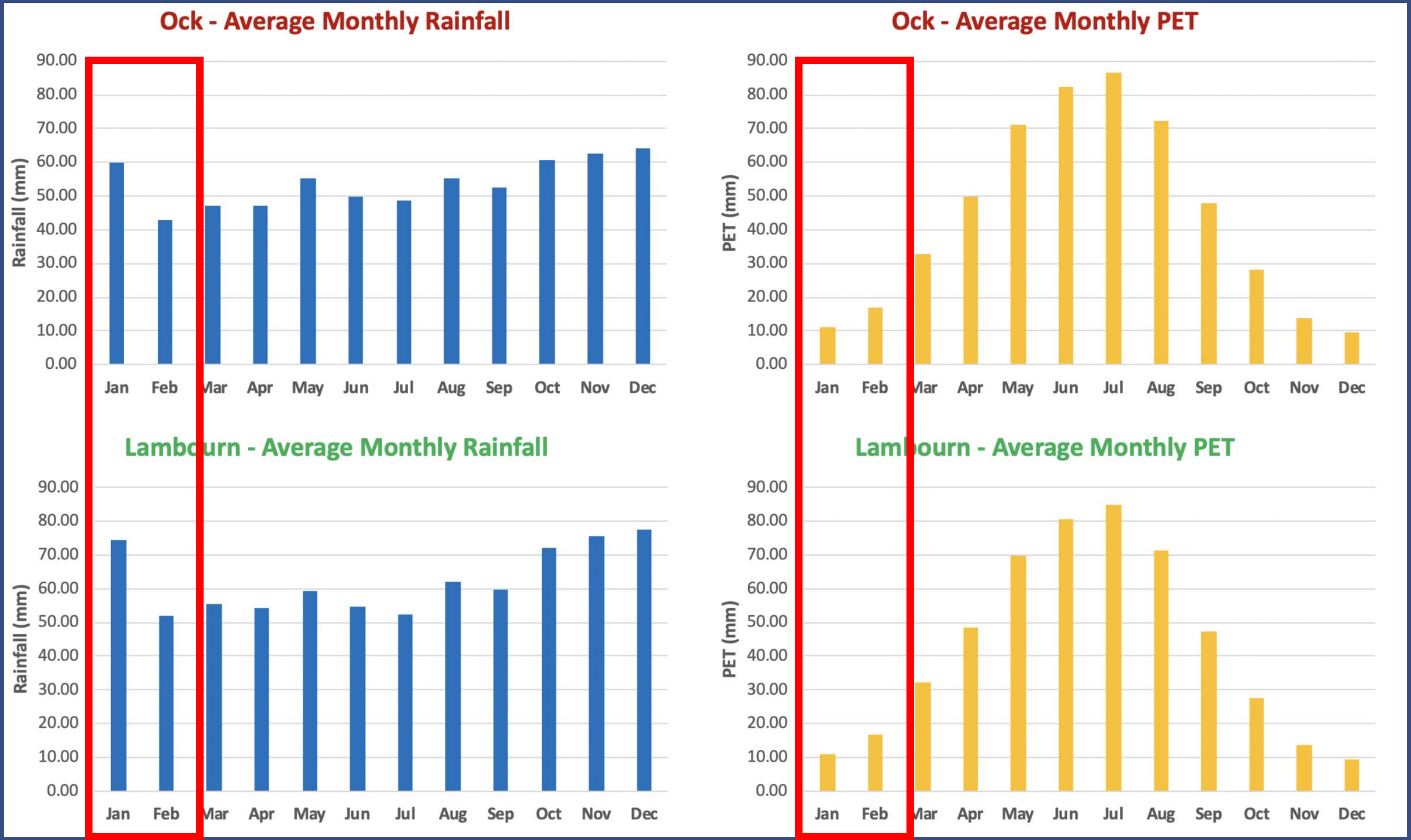
- **Evapotranspiration is the loss of water from the catchment system to the atmosphere.**
- Catchments with high rates of evapotranspiration will see less of its rainfall input transferred to streamflow.
- Evapotranspiration is influenced by a number of factors including solar radiation, wind speed, humidity, turbulence, plant cover/land cover and the bio-physical properties of the vegetation.

Comparing Evapotranspiration



PET data from CEH (Tanguy et al., 2017)

Comparing Evapotranspiration



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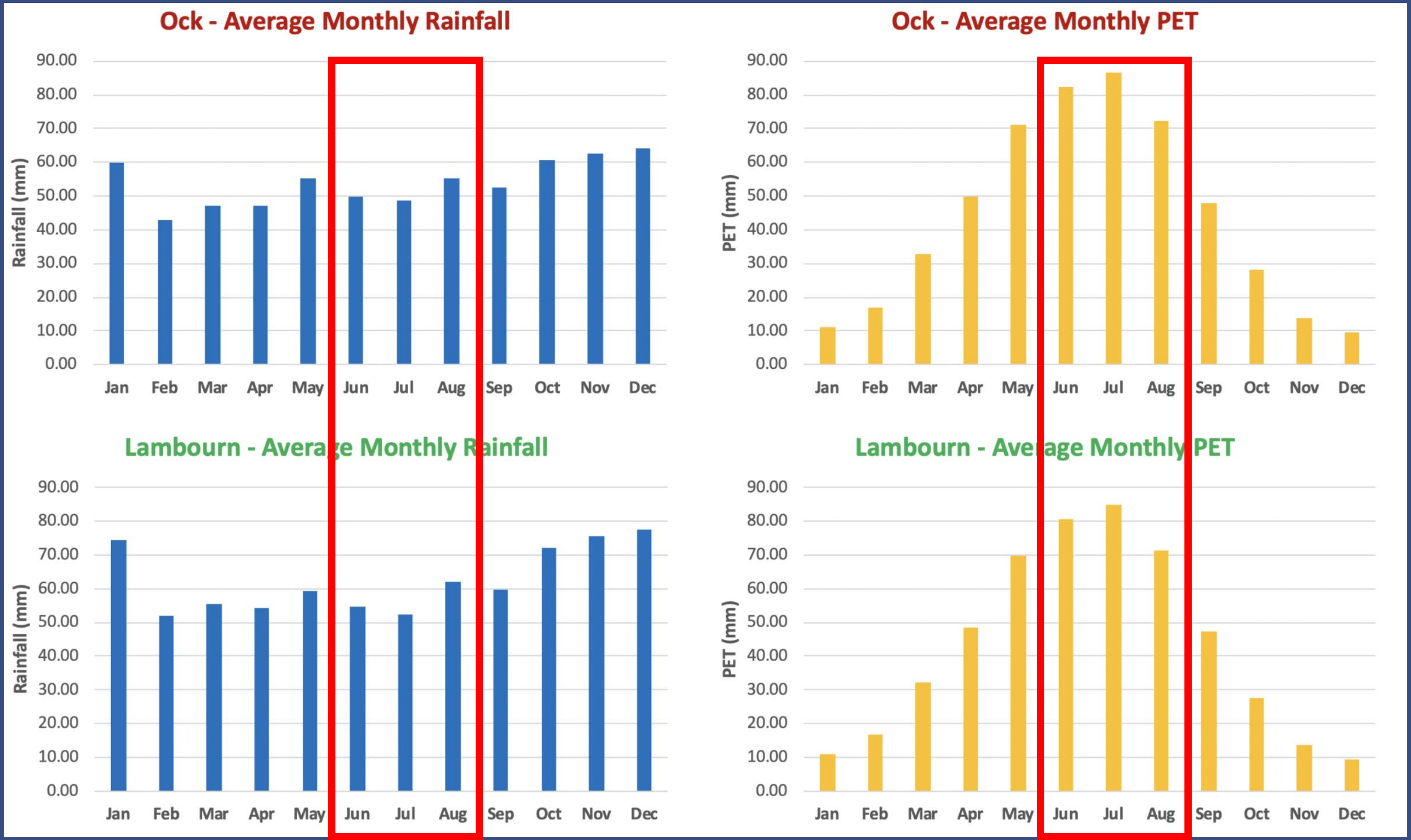
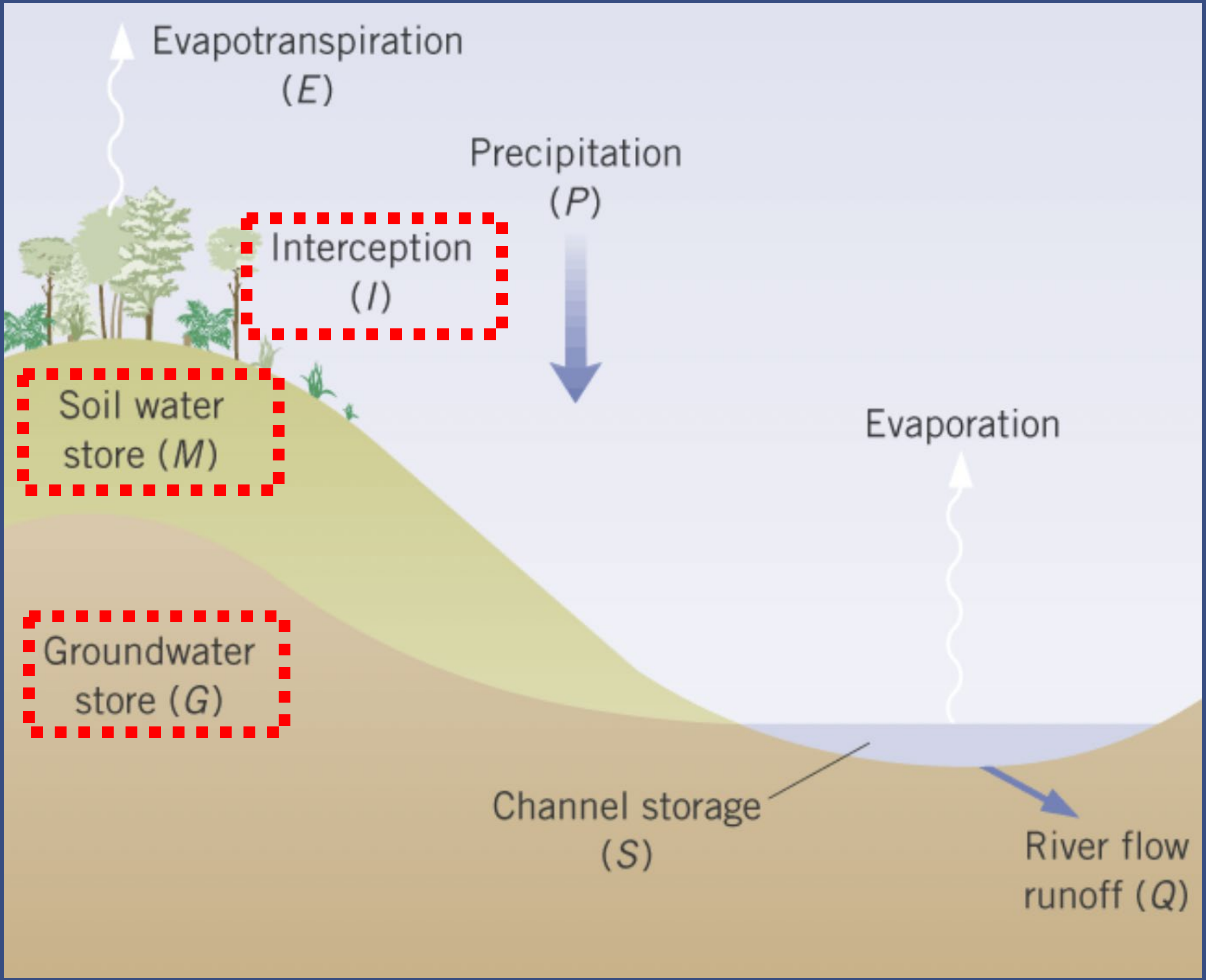
Comparing Evapotranspiration



PET data from CEH (Tanguy et al., 2017)

Catchment Properties



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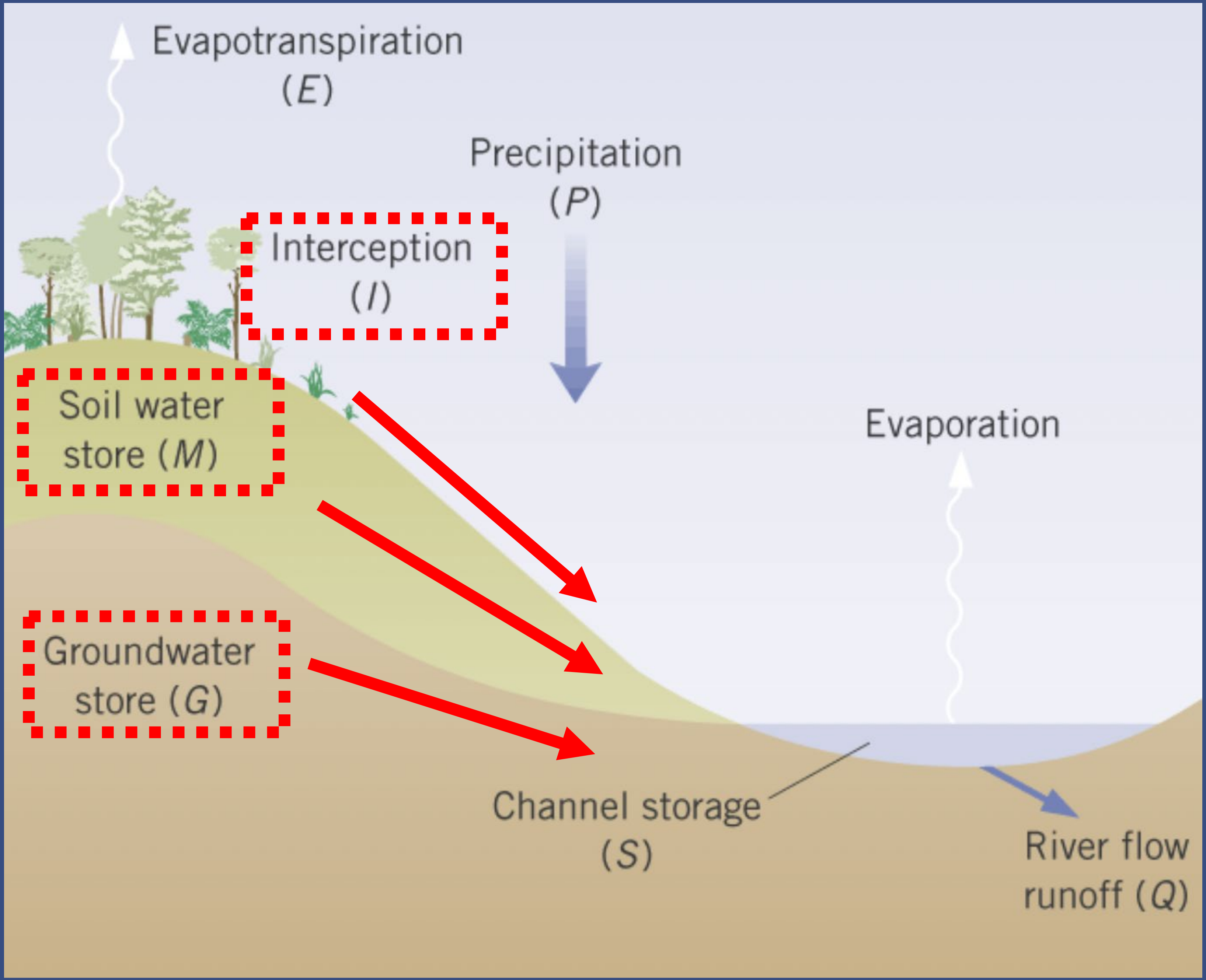
Catchment Properties



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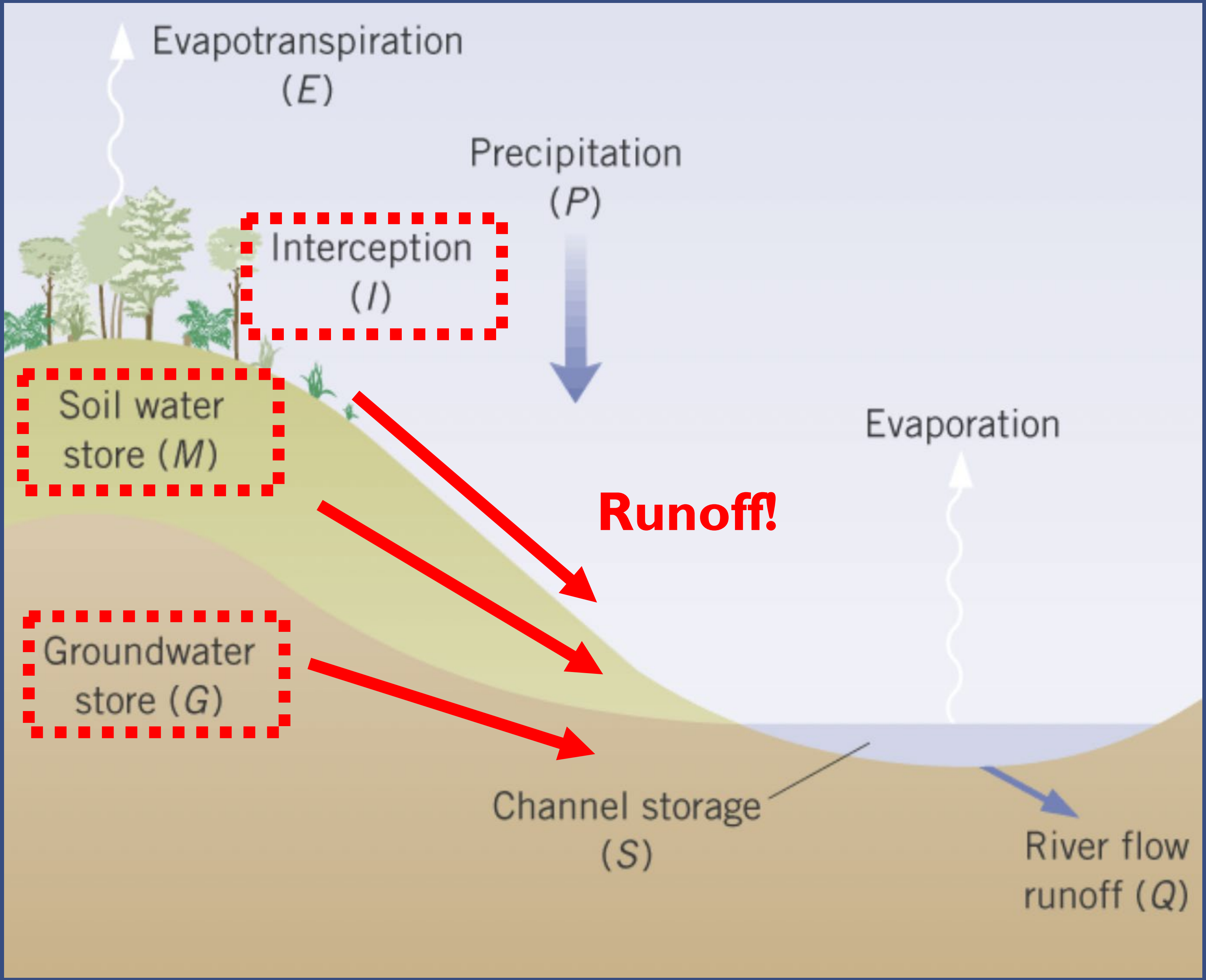
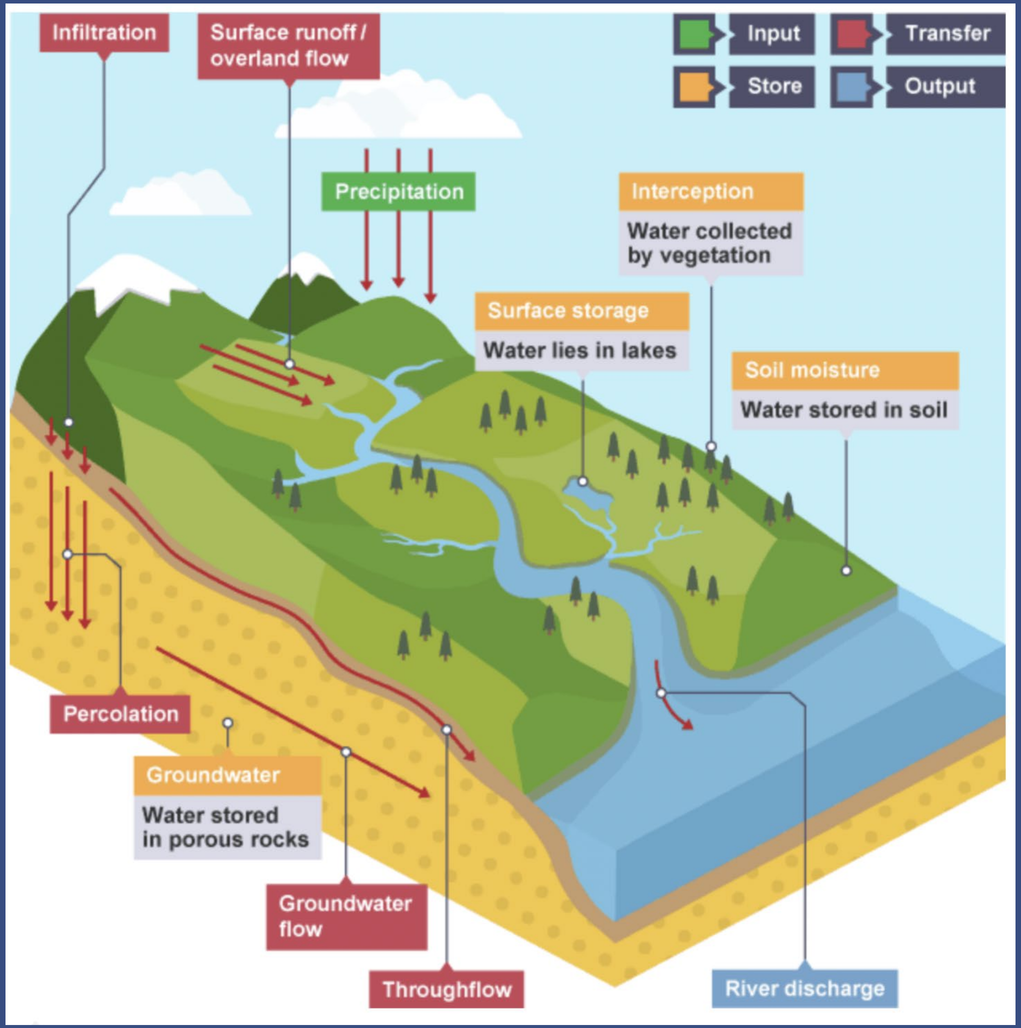


Image from Holden, 2012

Landcover and Runoff

- The landcover of the catchment is a significant factor affecting **runoff** – the transfer of precipitation to streamflow.

- Runoff can happen via 3 principal mechanisms:
  - **Overland Flow**
  - **Throughflow**
  - **Groundwater Flow**



Landcover and Runoff

- A highly vegetated rural catchment will have lots of vegetation on the surface.
- This will slow any overland flow giving it an opportunity to infiltrate into the soils, and move slowly to the channel as throughflow and (if the geology is suitable) groundwater flow.
- **Therefore vegetation slows down the runoff rate in the catchment**.

- Whereas a highly **urbanised catchment** with lots of man-made impervious surfaces does not allow for infiltration and will **increase** the rate of overland flow.

Landcover and Runoff

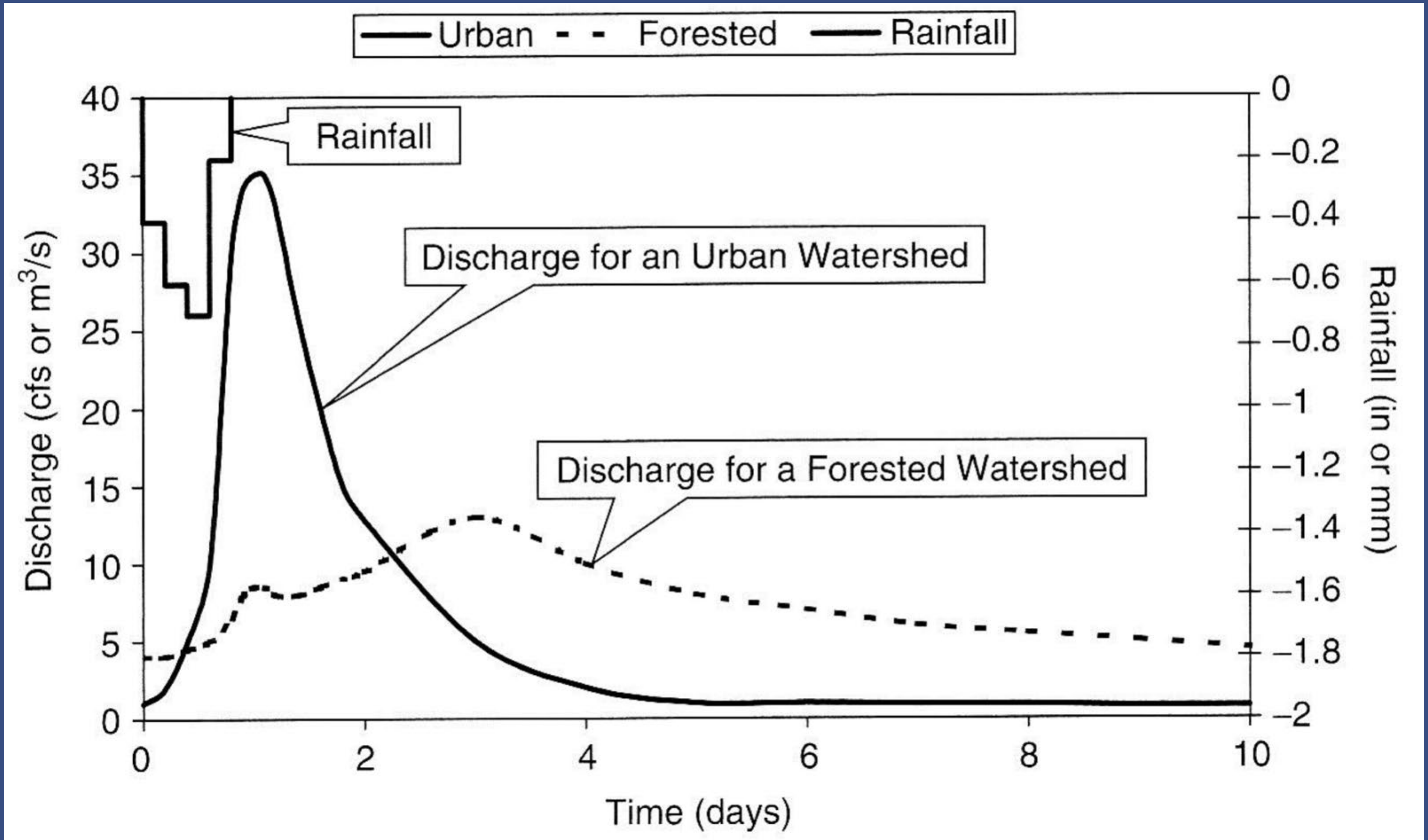
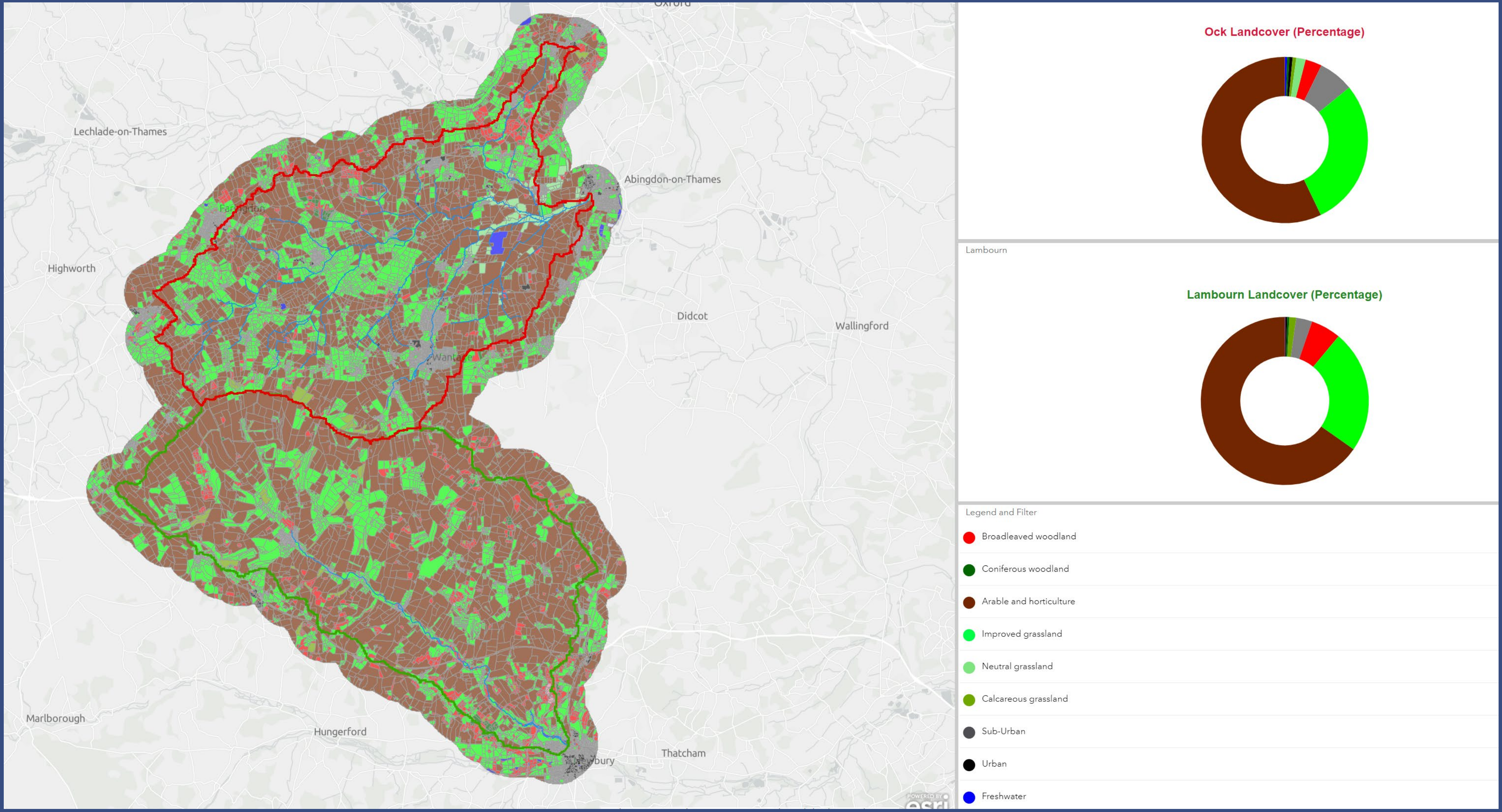


Image from Ward and Timble, 2004

Comparing Landcover



Landcover Data from CEH (2021)

Comparing Landcover

- The catchments generally have similar landcover patterns. Both are largely covered by **arable land** and improved **grassland.**
- Both have similar woodland cover as well. Neither catchment is particularly urbanised.
- The Ock has slightly more urban cover compared to the Lambourn (7.5% compared to 3.4%), however this is unlikely to be a big enough difference to significantly alter runoff processes and lead to the observed differences in streamflow.

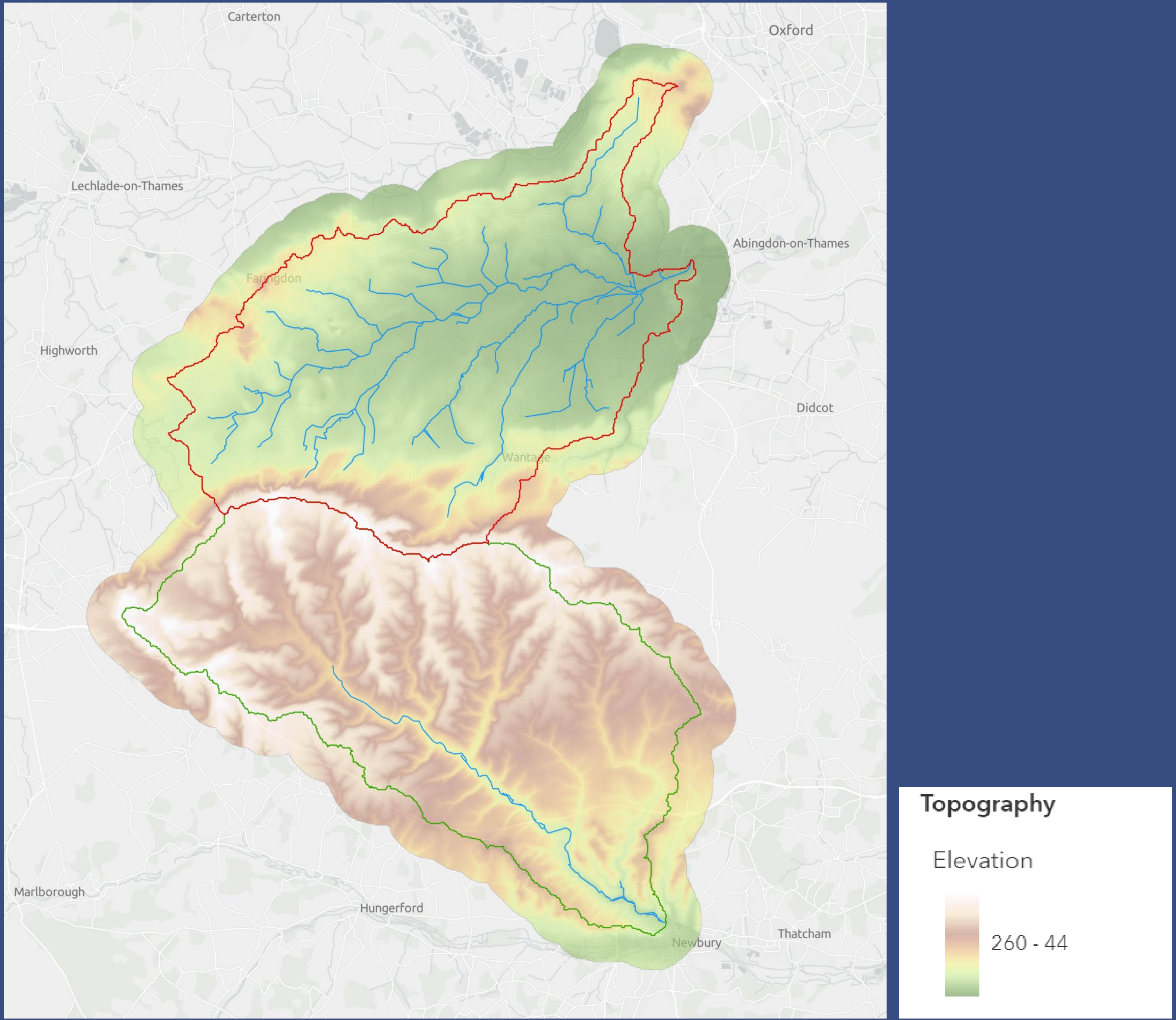
Topography and Runoff

- The topography and terrain of river catchments can also influence runoff processes. **Catchments with high elevation and steep slopes will typically have quicker runoff rates.**

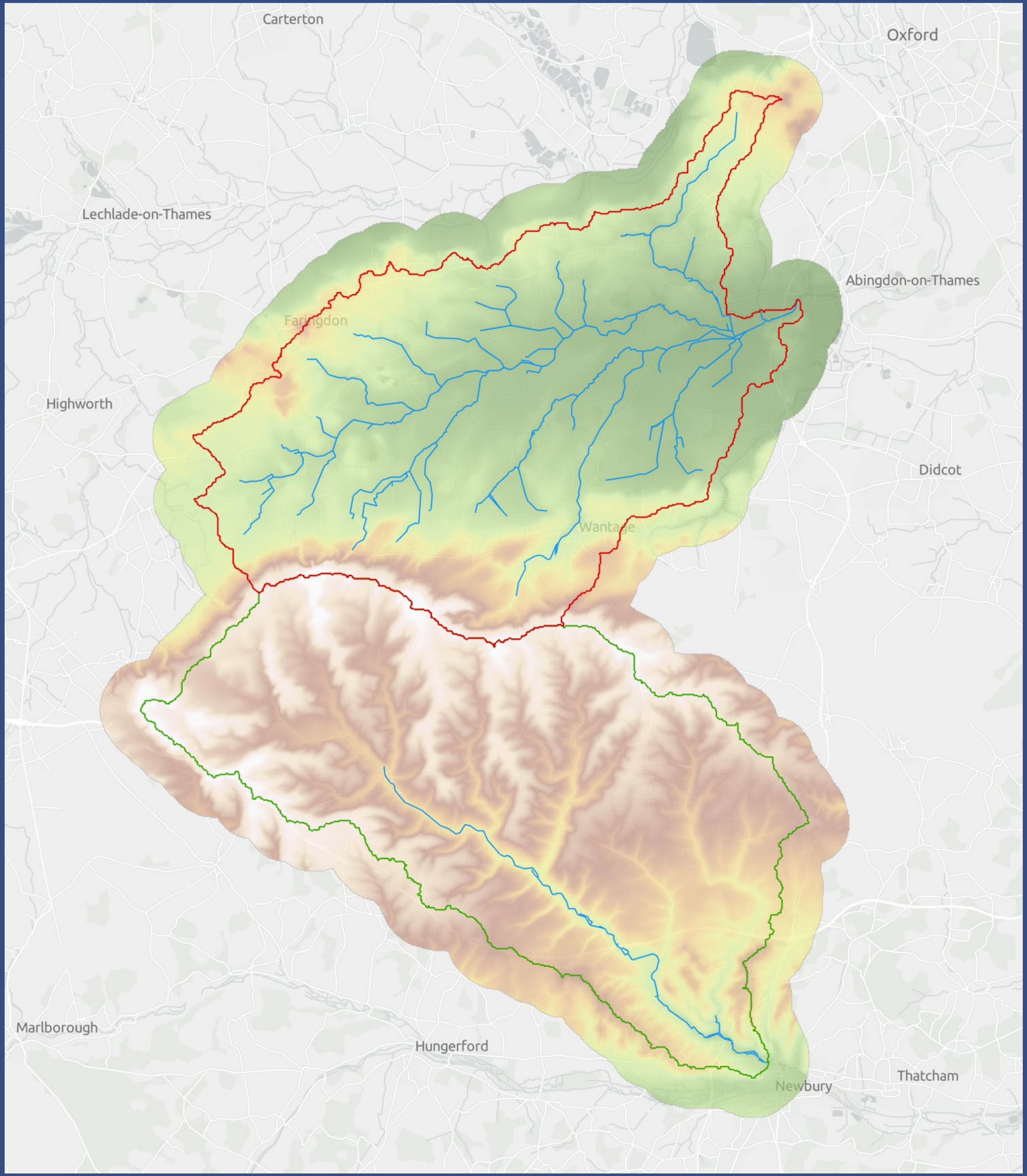
- Surface runoff is common as gravity moves the surface water down the hillslope before high rates of infiltration can take place.

- In contrast **catchments with large flat areas allow water to pond on the surface allowing for infiltration** (and subsequently throughflow and potentially groundwater flow) to take place.

Comparing Topography



Comparing Topography



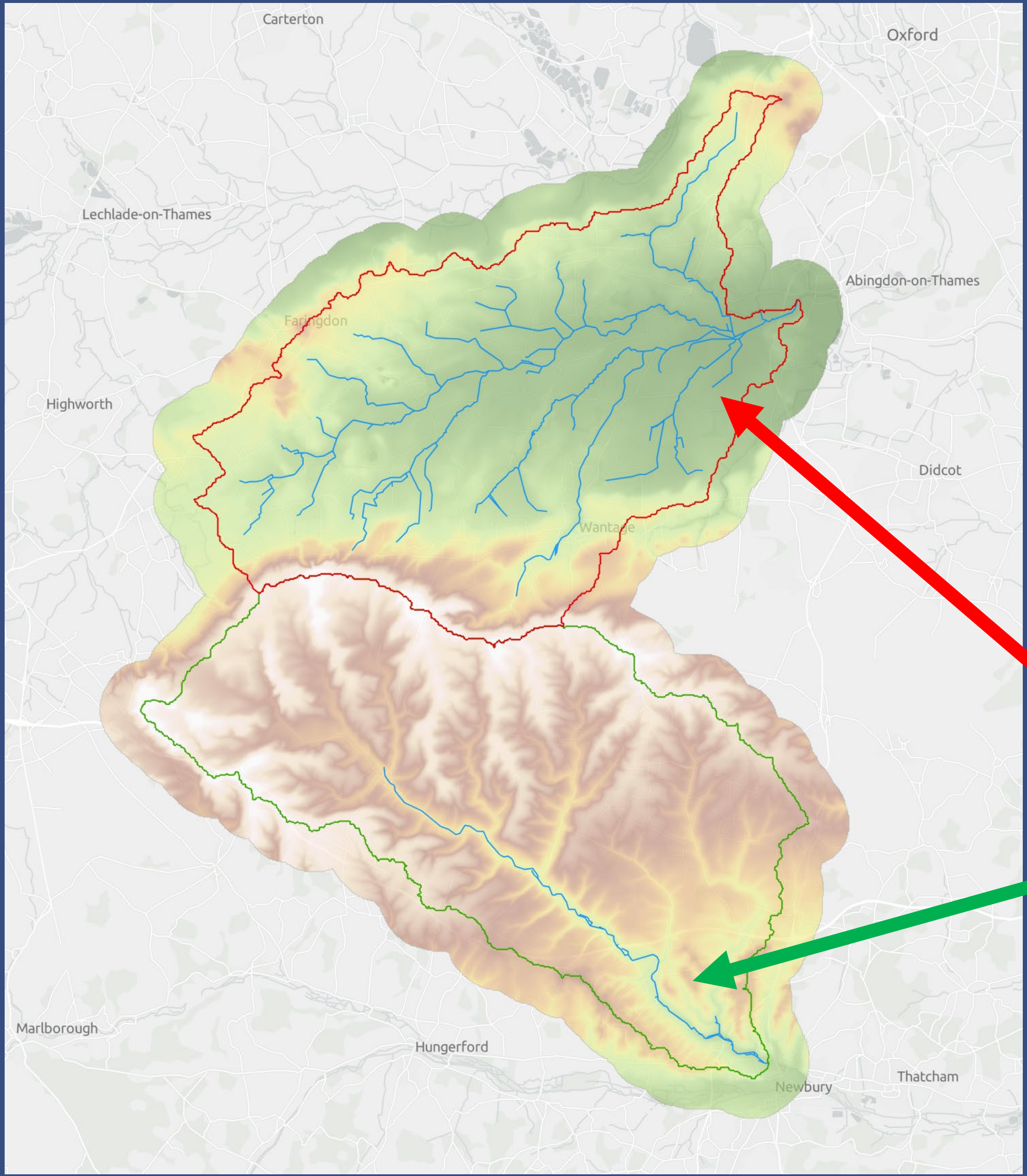
- The Ock has larger flatter areas, and yet however has flashier and more variable flows than the Lambourn.

- So the differences in slope cannot fully explain the differences in flows between the two catchments.

- **What else can you see?**

- **What is different about the two catchments on this map?**

Comparing Topography



- The Ock has larger flatter areas, and yet however has flashier and more variable flows than the Lambourn.
- So the differences in slope cannot fully explain the differences in flows between the two catchments.
- The river networks in the Ock and Lambourn have very different geometry and levels of complexity.
- The **Ock** has a much more detailed river network, with multiple tributaries.
- Whereas the **Lambourn** is comprised of largely a single river network.
- **But this is not linked with topography?**

- Precipitation
- Evapotranspiration
- Landcover
- Topography

- ~~Precipitation~~
- ~~Evapotranspiration~~
- ~~Landcover~~
- ~~Topography~~
- River Network??

- ~~Precipitation~~
- ~~Evapotranspiration~~
- ~~Landcover~~
- ~~Topography~~
- River Network??

So……????

What final factor have we not yet explored?

Geology

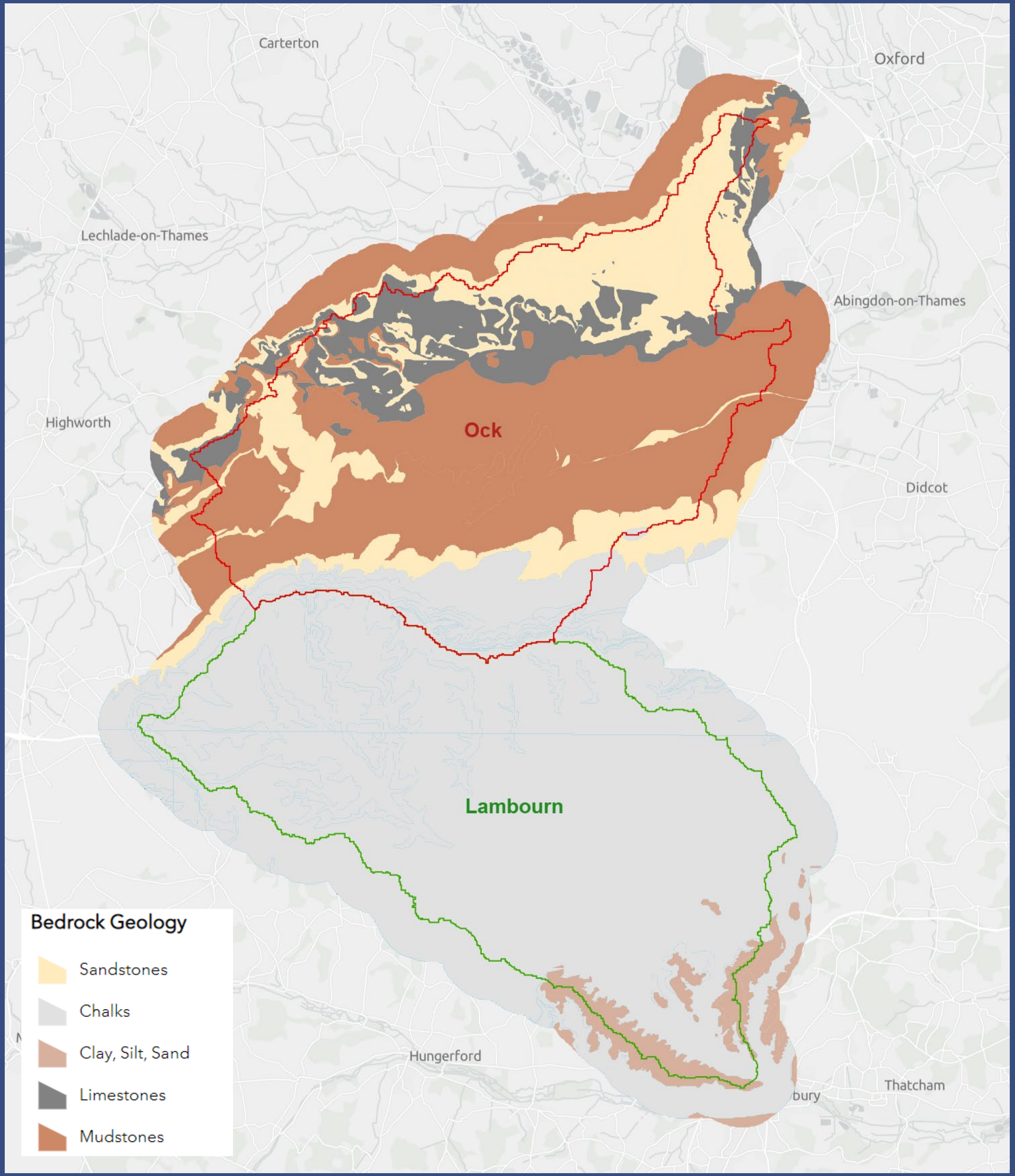
- Catchments with **highly permeable bedrock geologies**, such as limestone, will have high percolation and groundwater flow rates, allowing for water to be stored in the rocks.
- These catchments tend to **not be flashy**.

- Whereas catchments which are underlain by **low permeability rocks** will see the opposite in terms of percolation and groundwater flow.
- Very little water will be held back in the rocks and therefore water will move quickly to the river channel (they are **flashy catchments**).

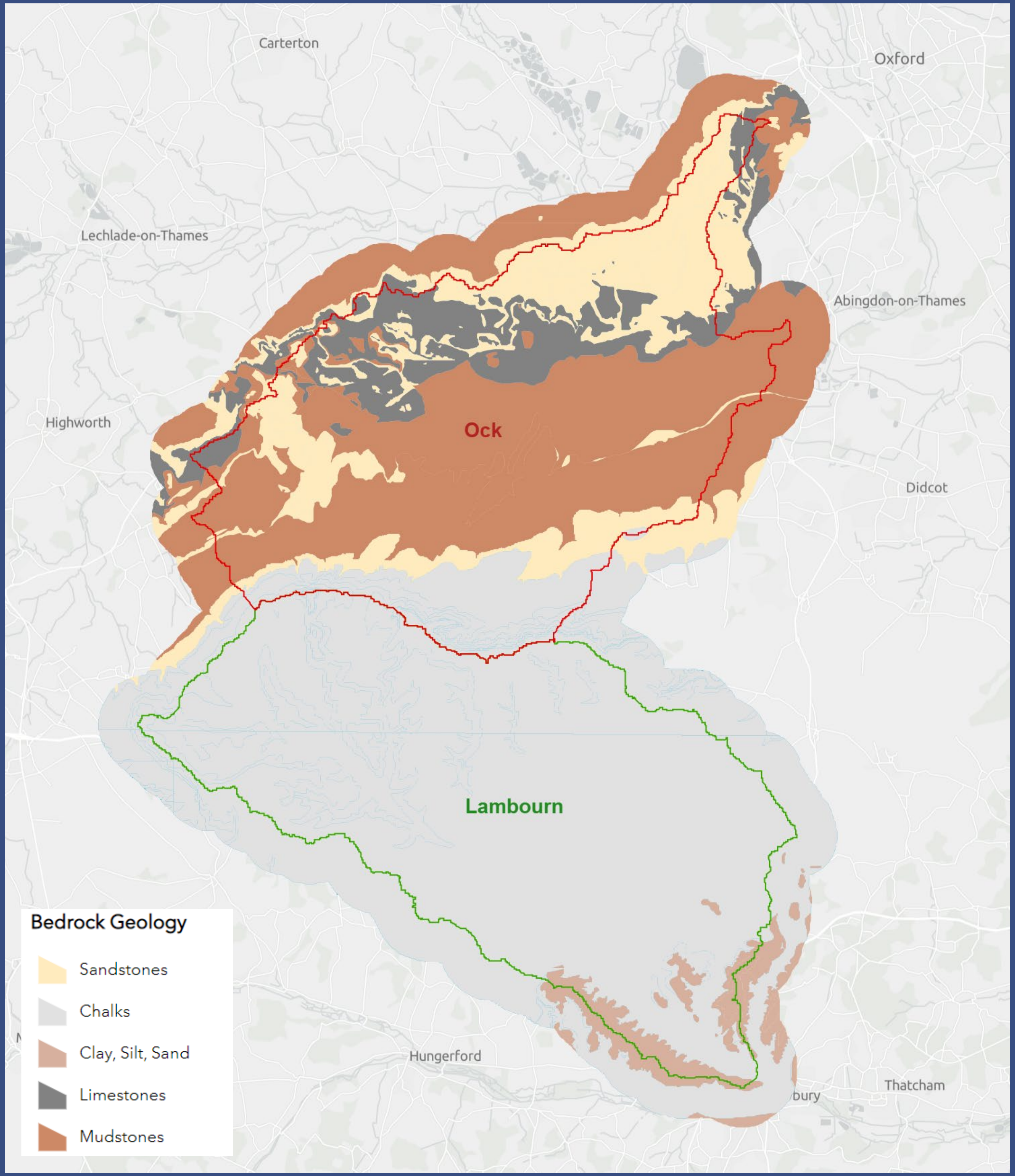
Geology & River Networks

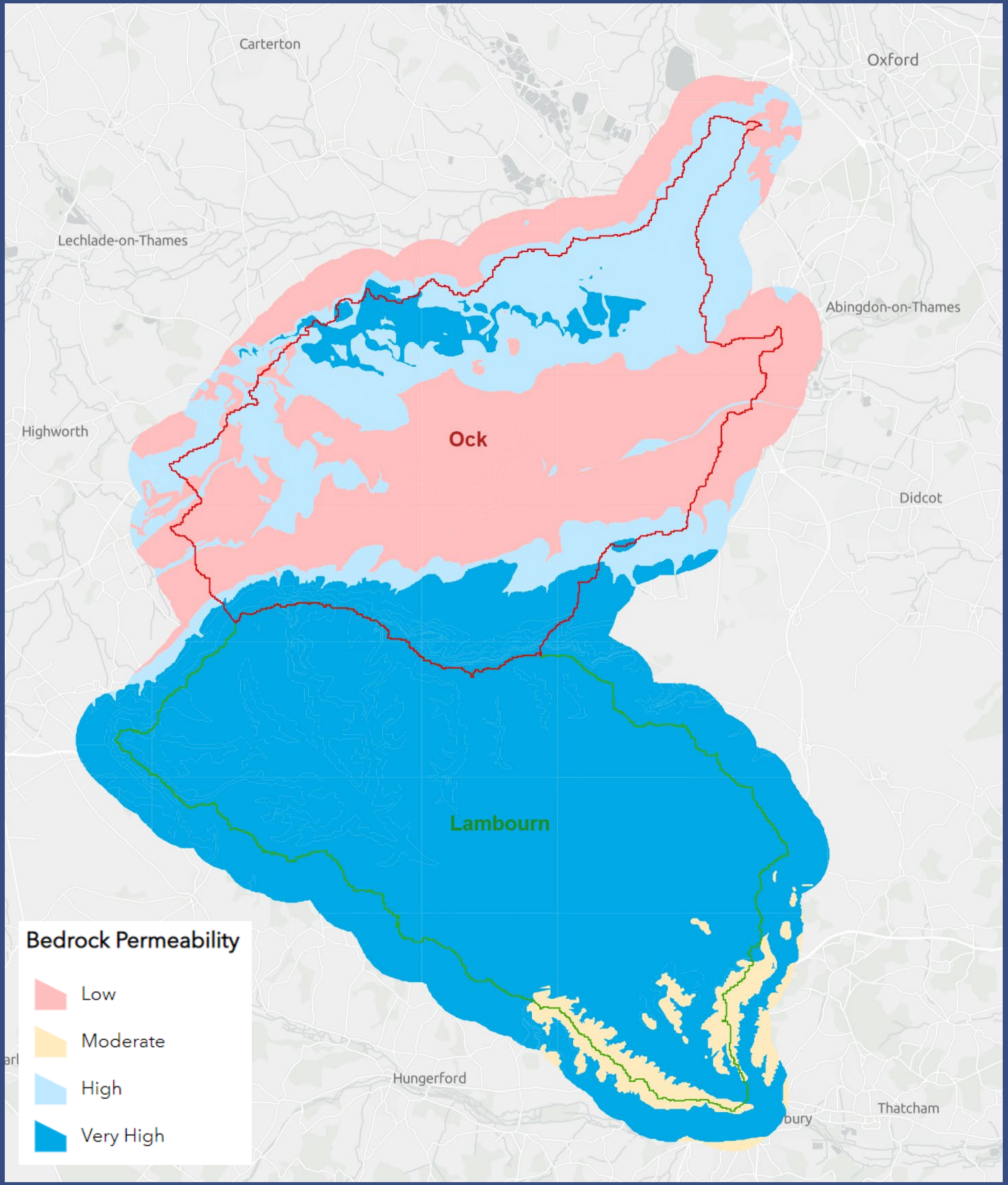
- Differences in bedrock permeability will also have an influence on the river drainage network geometry.
- Highly permeable geologies have weakly developed drainage networks, sometimes comprised of only a single channel, because there is much less surface runoff.
- Whereas catchments with low permeability rocks tend to have very developed river networks as there is more surface runoff.

Comparing Geology



Comparing Geology





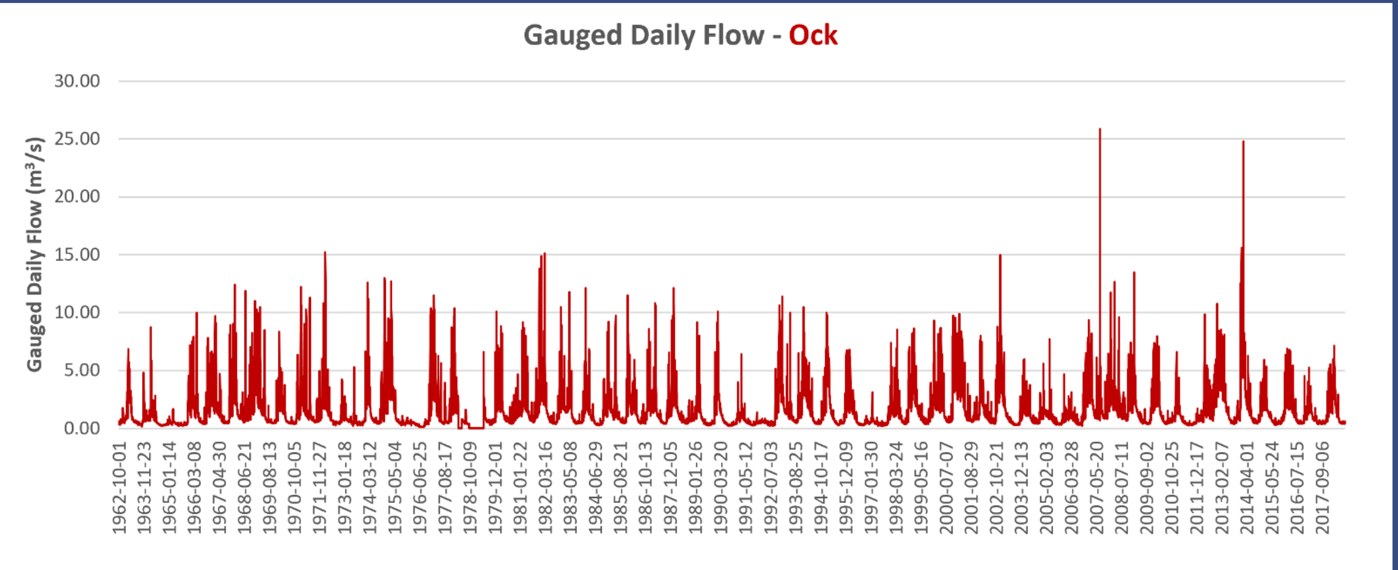
Comparing Geology

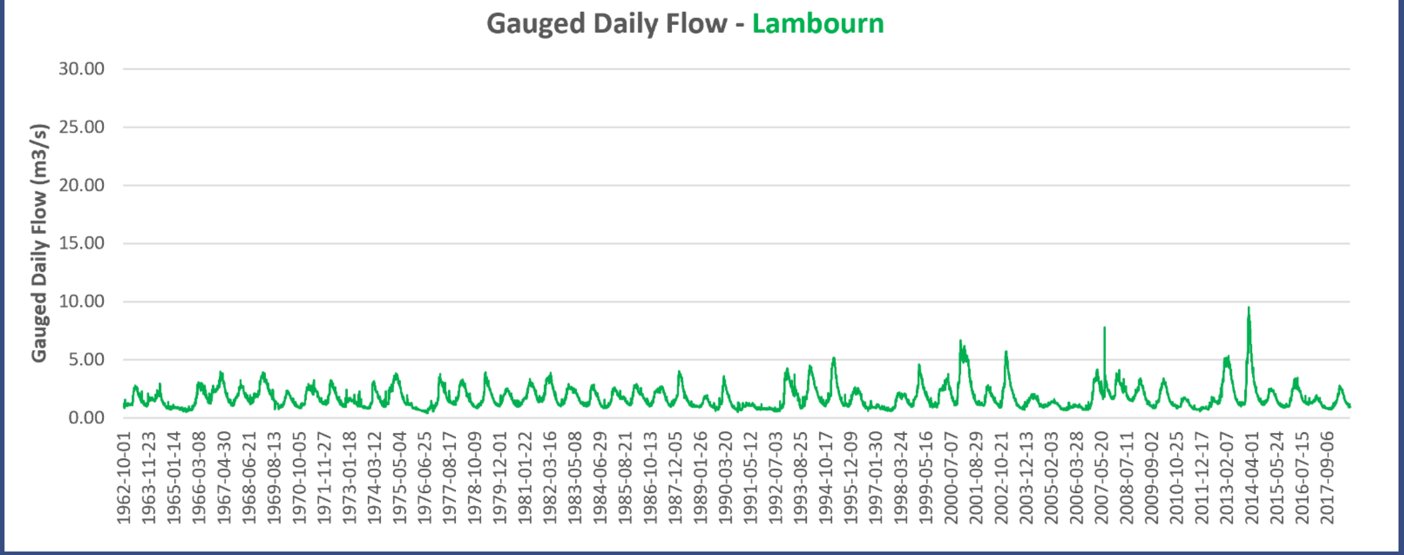
- The two catchments have very different geological characteristics:

- The **Ock** catchment is underlain by varied rock types, however is dominated by mudstones with some sandstone and limestone features.
- These rocks have **low permeability.**

- The **Lambourn** however is largely underlain by chalk.
- Chalk has **high permeability.**

Bringing it Together…





Data from the NRFA

- The flows in the **Ock** catchment are higher and more variable than the **Lambourn**. **This reflects the permeability of the two catchments geologies.**

- **The Lambourn is underlain by chalk which is highly permeable.**
- This allows for a larger volume of water to be stored in the catchment system, and it will **move slowly through the catchment to the river channel**.

- The **Ock catchment is underlain by low permeability bedrock**, and therefore only a small proportion of runoff will occur as groundwater flow.
- This means that **water is transferred from rainfall to streamflow quicker** and more efficiently, leading to higher and more variable streamflow.

So…

Why do the flows in these two neighboring catchments differ so much?

GEOLOGY – BEDROCK PERMEABILITY!

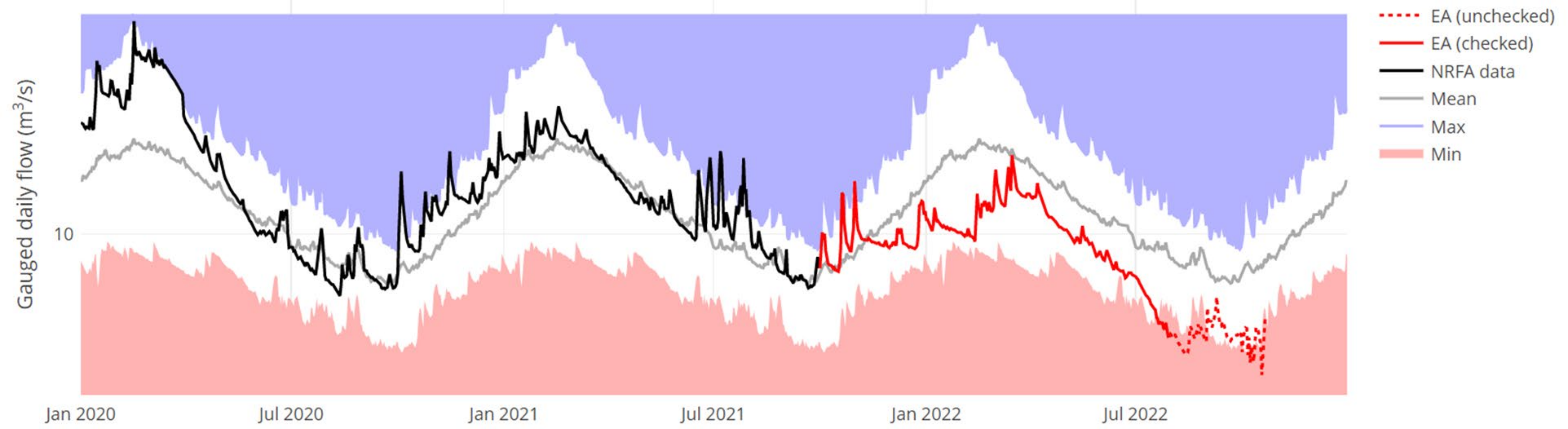
Why is Understanding Hydrology Important?

- Our drinking water comes from a combination of rivers, reservoirs and groundwater aquifers

- Having an understanding of the factors which influence the discharge of rivers is vital for effective water management.

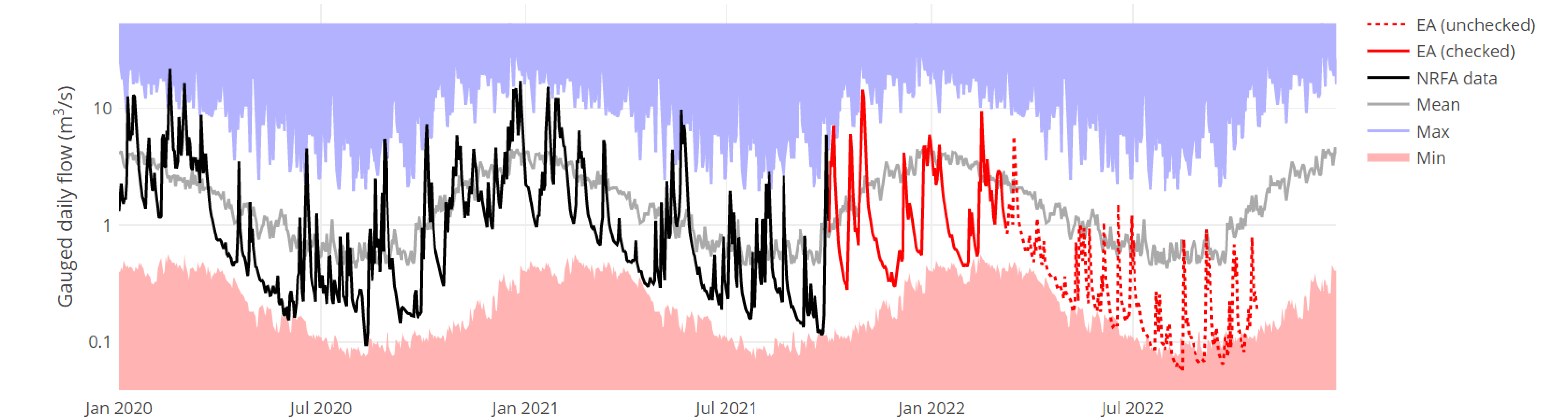
- We need to know how much water is likely going to be available for human consumption.

Low Flows – River Test



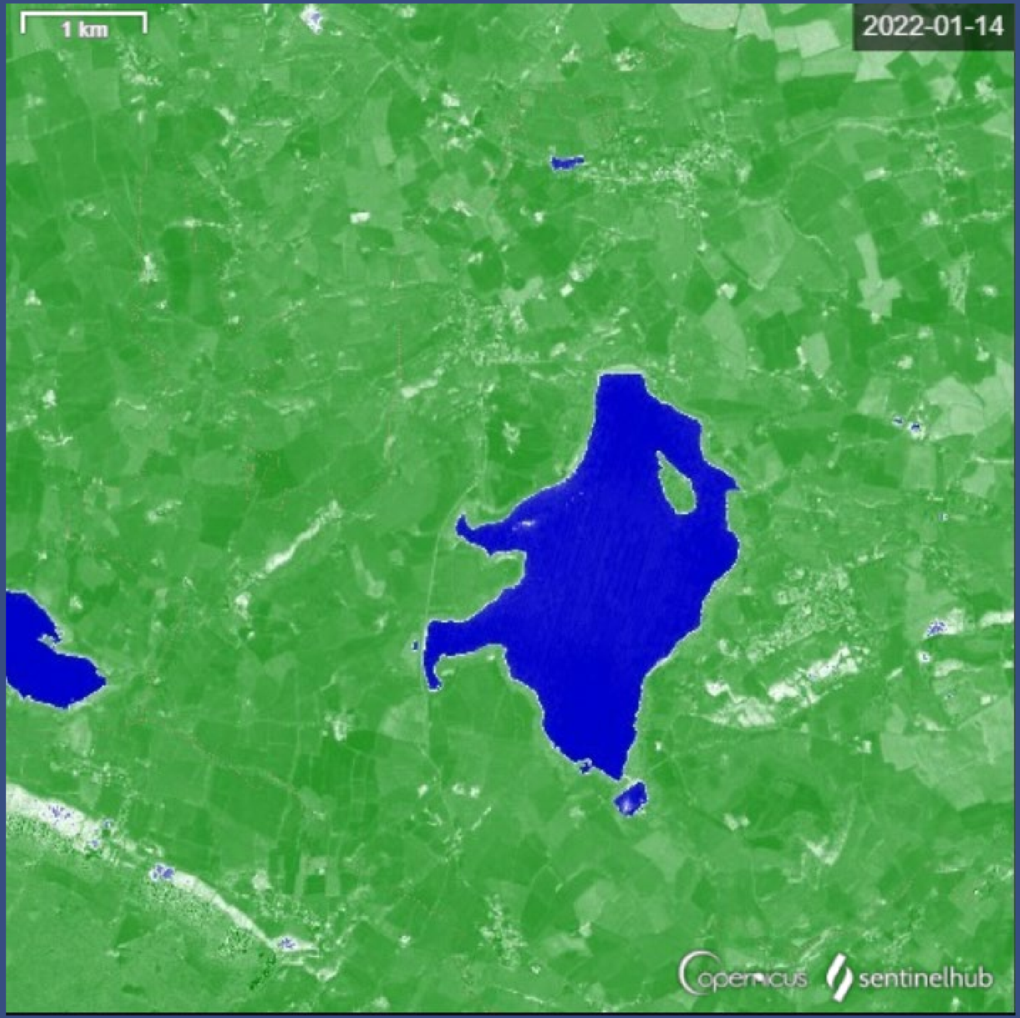
Source: CEH NRFA

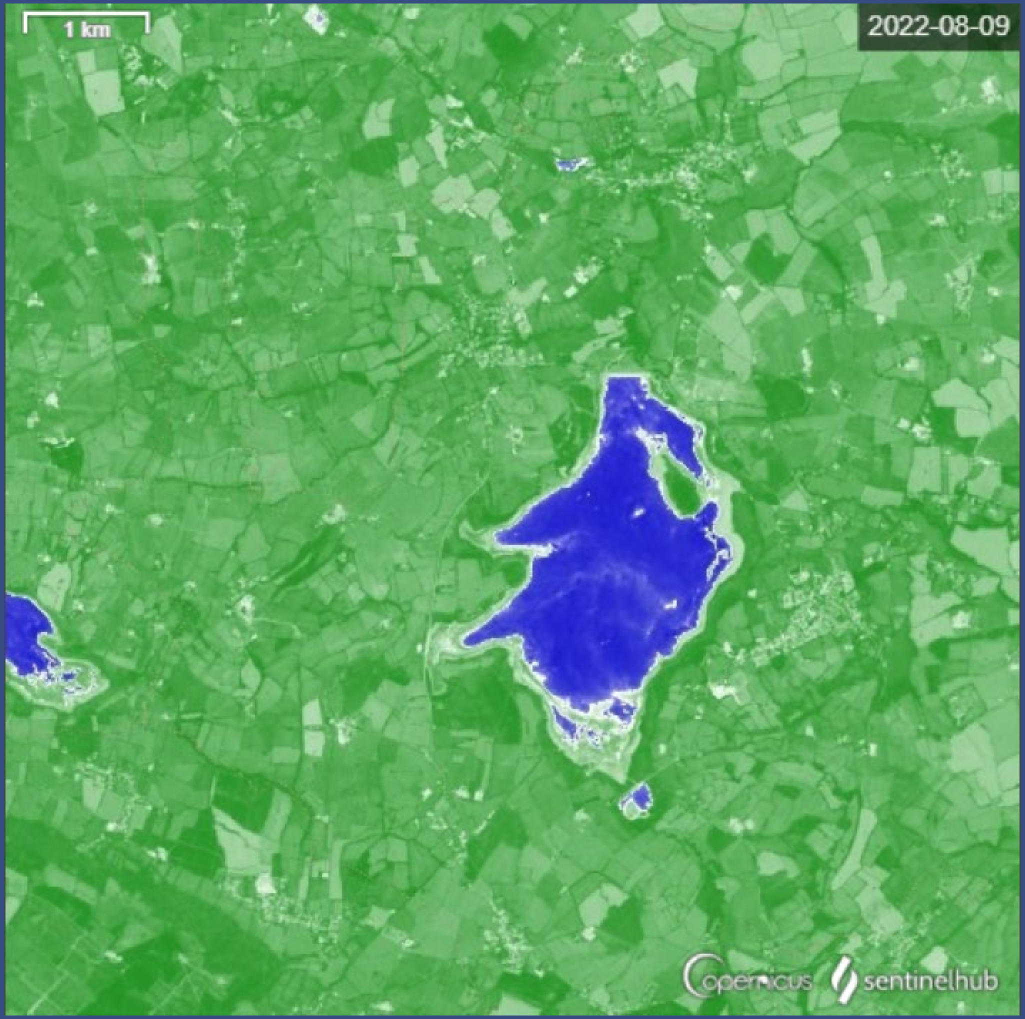
Low Flows – River Frome



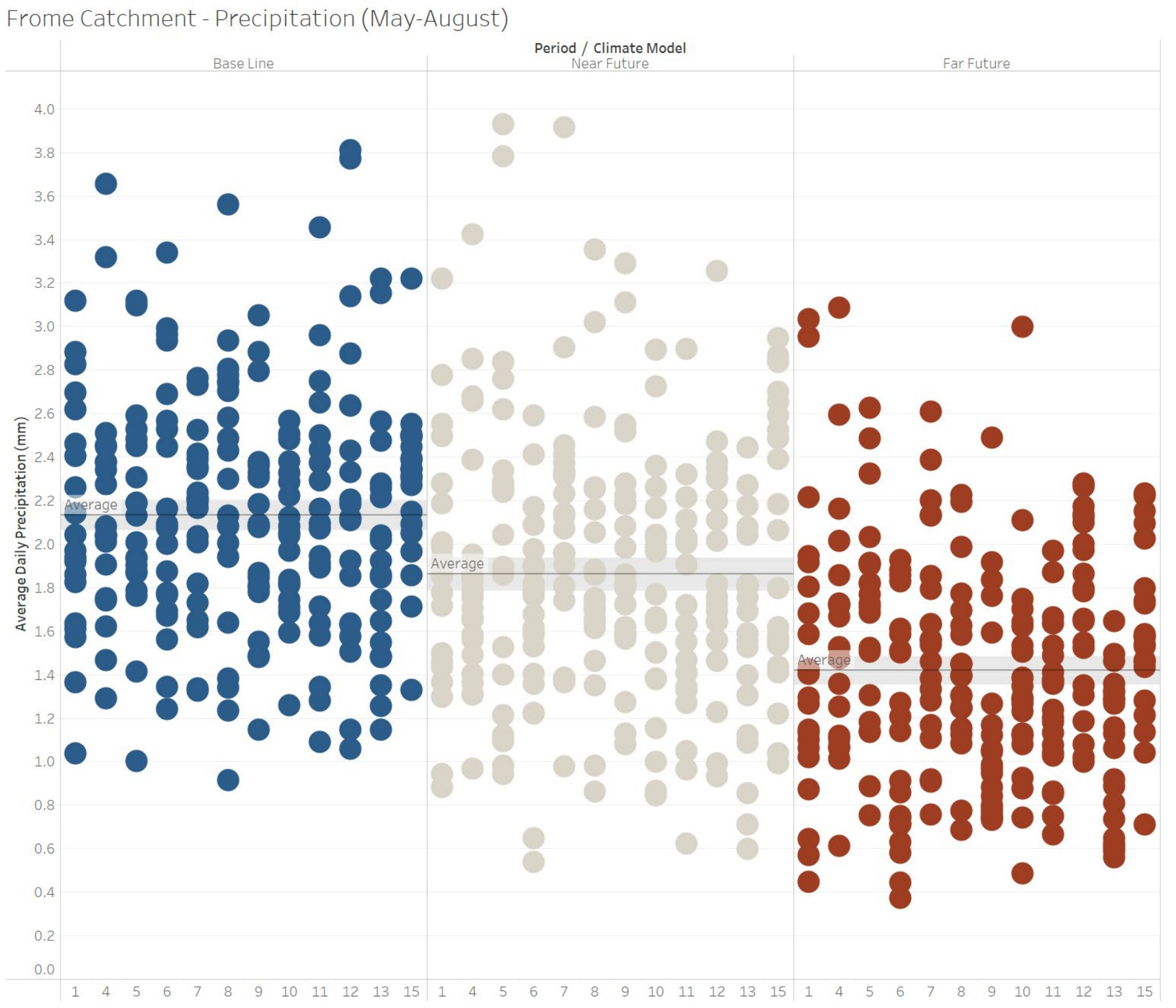
Source: CEH NRFA

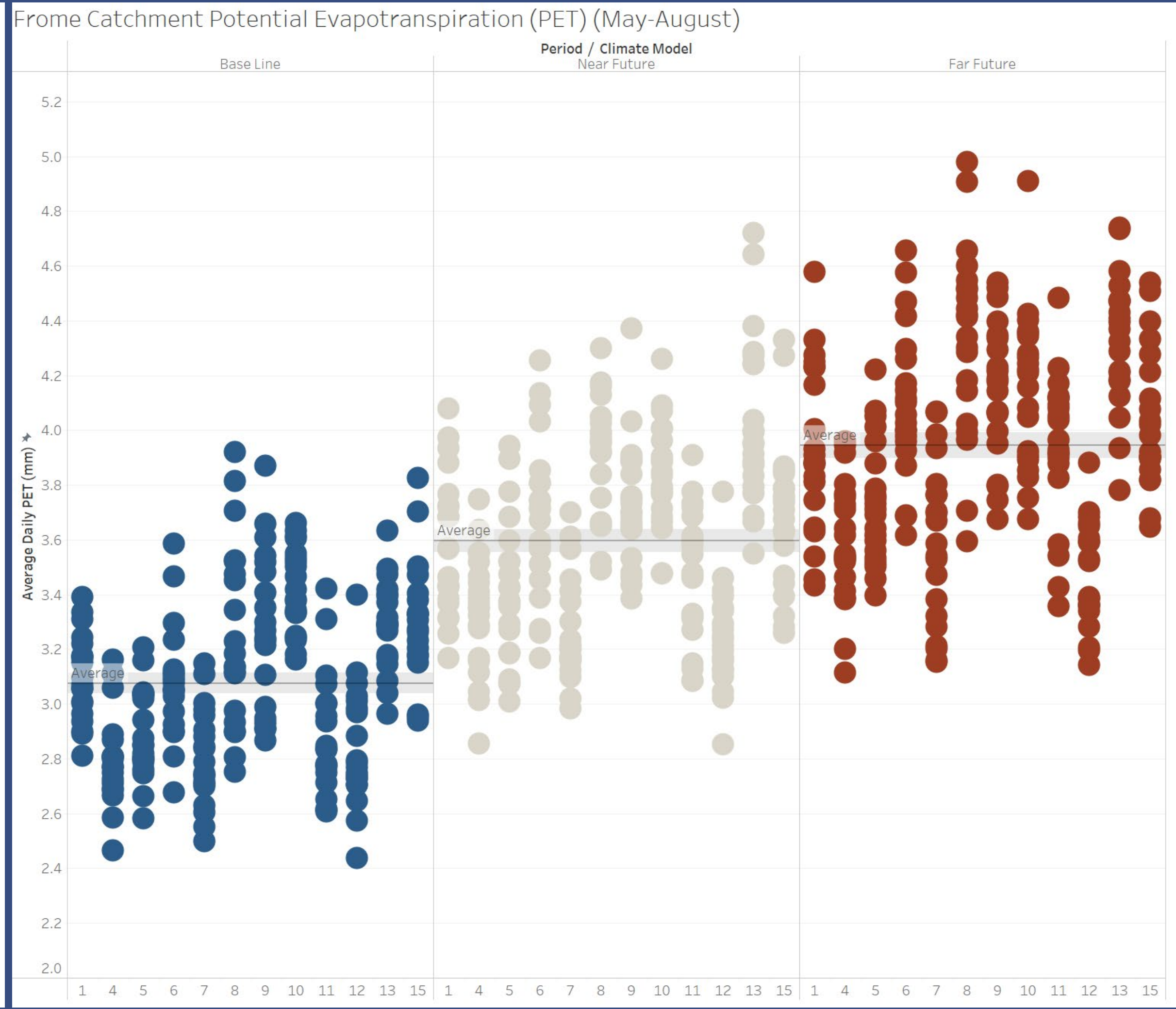
Low Flows – Chew Reservoir





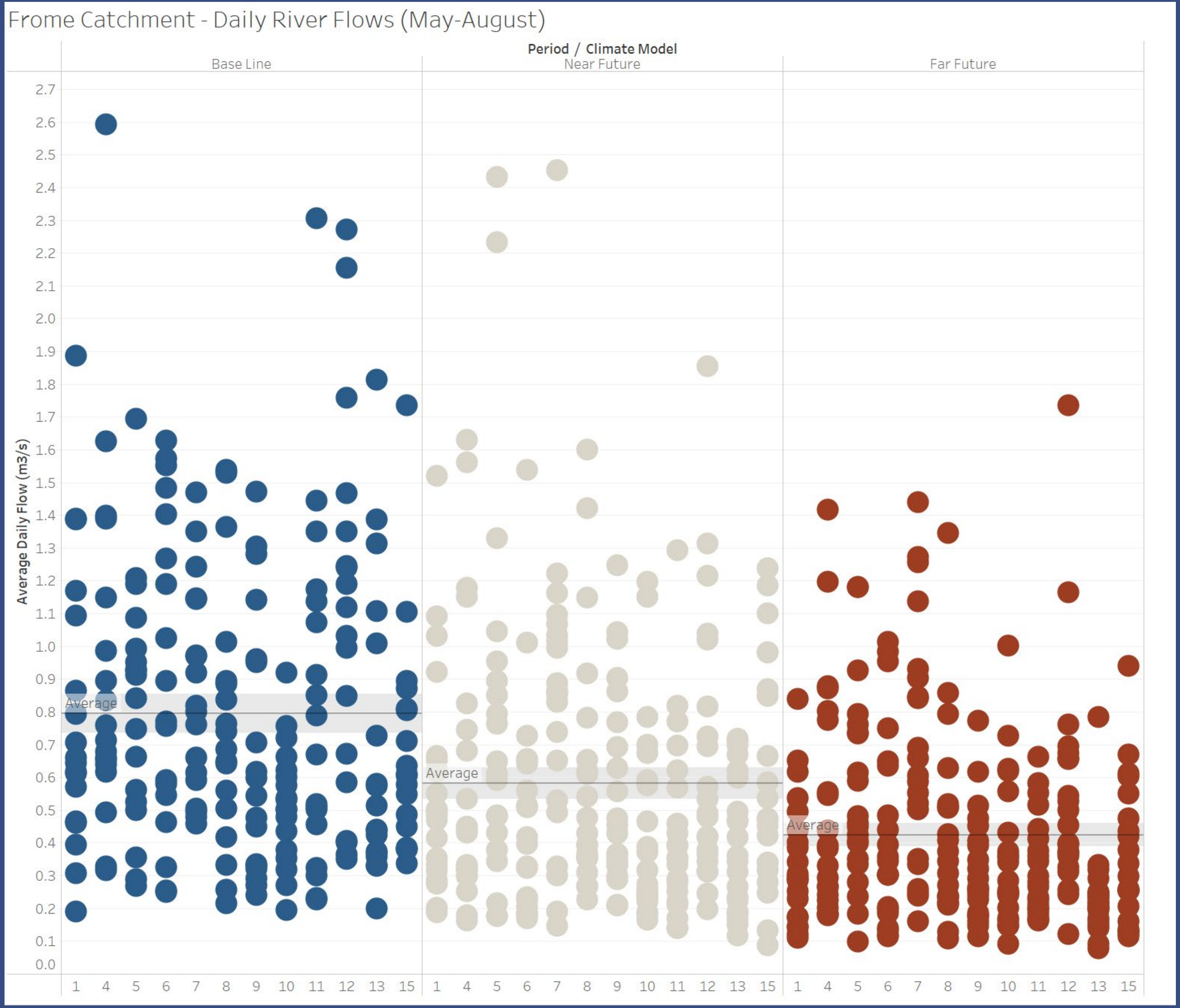
Climate Change!





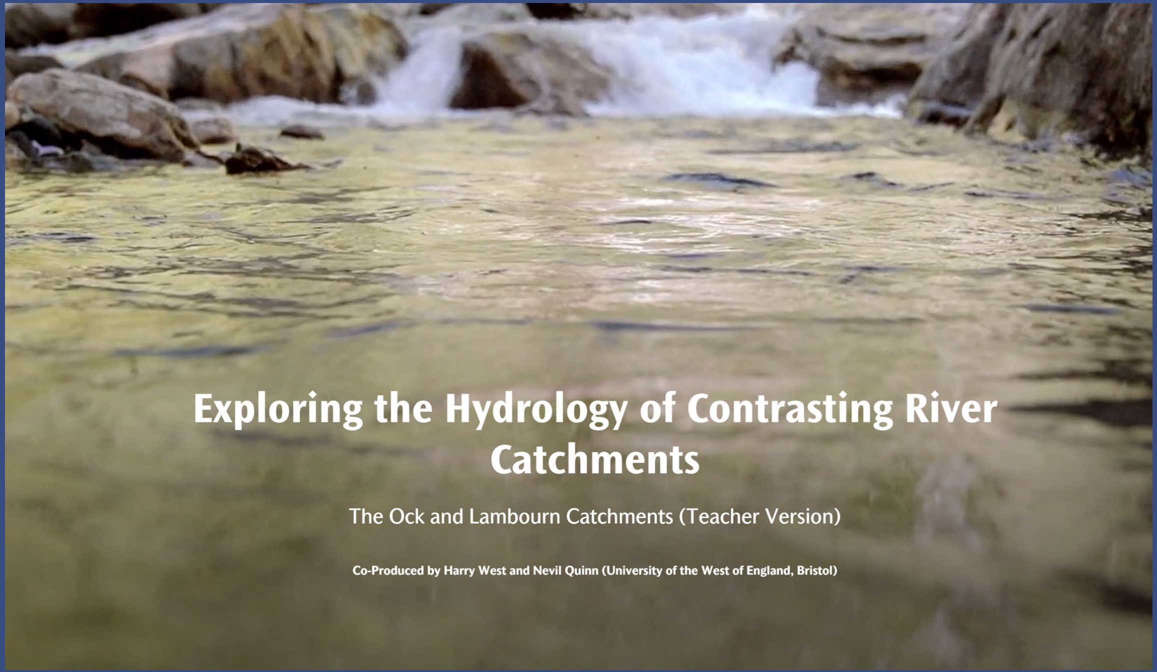
Data from the CEH EFlag Dataset (based on UKCP18)

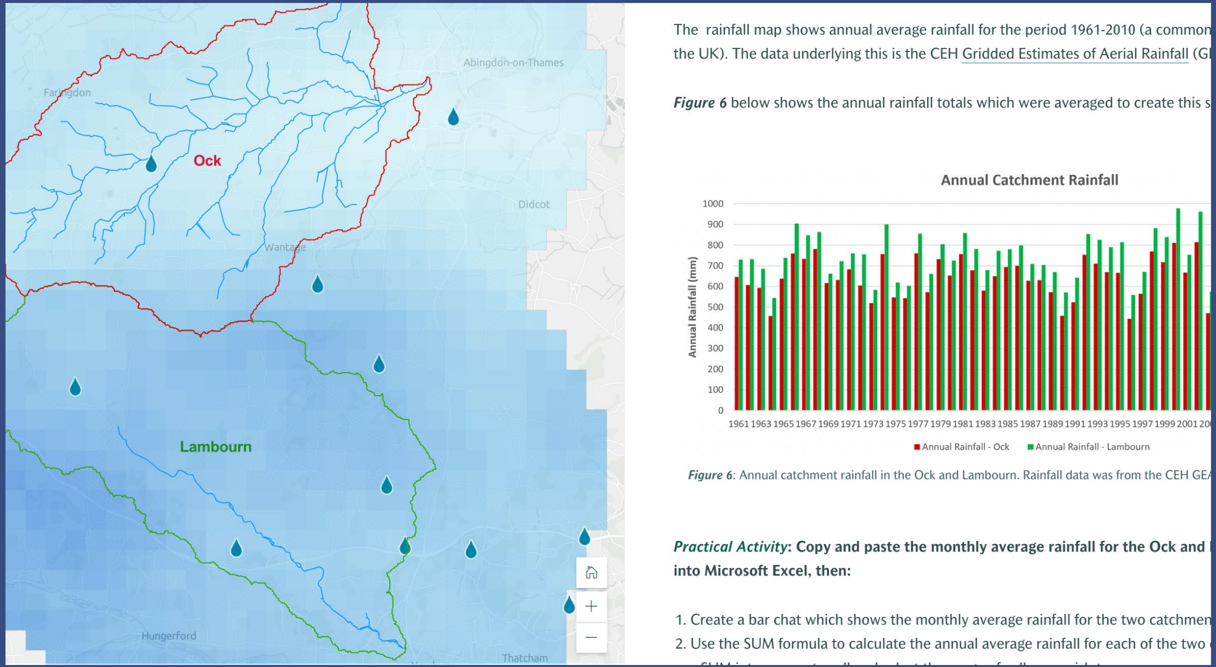
Climate Change!



Data from the CEH EFlag Dataset (based on UKCP18)

Explore the Ock & Lambourn for Yourself





https://www.geographysouthwest.co.uk/secondary/16-plus-articles/exploring-the-hydrology-of-contrasting-river-basins/

geography southwest

Thank you!

Any Questions?

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