# Role of clay layers in rainfall-runoff processes in a serpentinite headwater catchment

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# Introduction

Rainfall-runoff processes in a headwater catchment have been explained as follows:

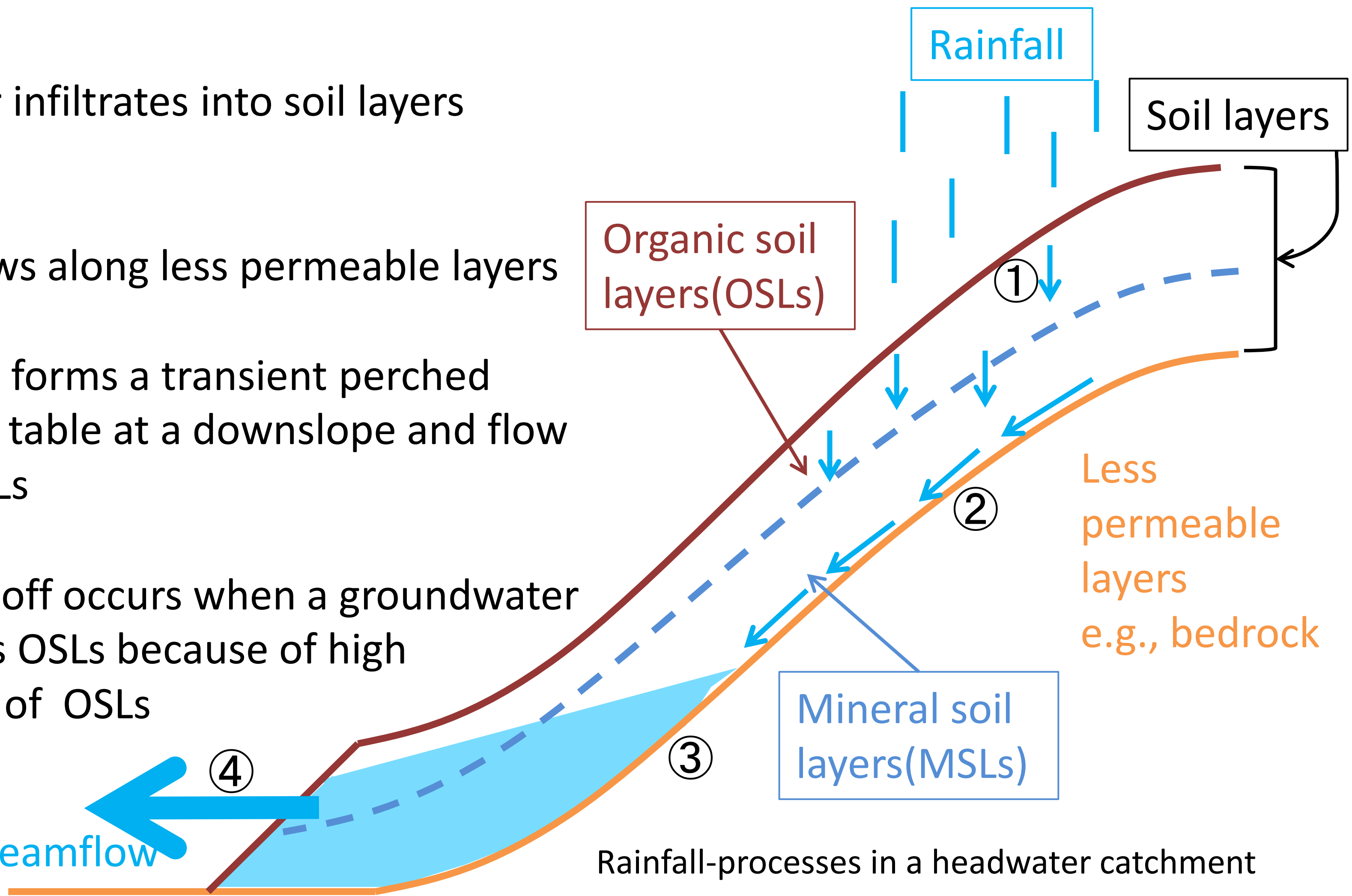
## Wet periods

① Rainwater infiltrates into soil layers vertically

② Water flows along less permeable layers

③ The water forms a transient perched groundwater table at a downslope and flow out from MSLs

④ Storm runoff occurs when a groundwater table reaches OSLs because of high permeability of OSLs




Rainfall-processes in a headwater catchment

# Introduction

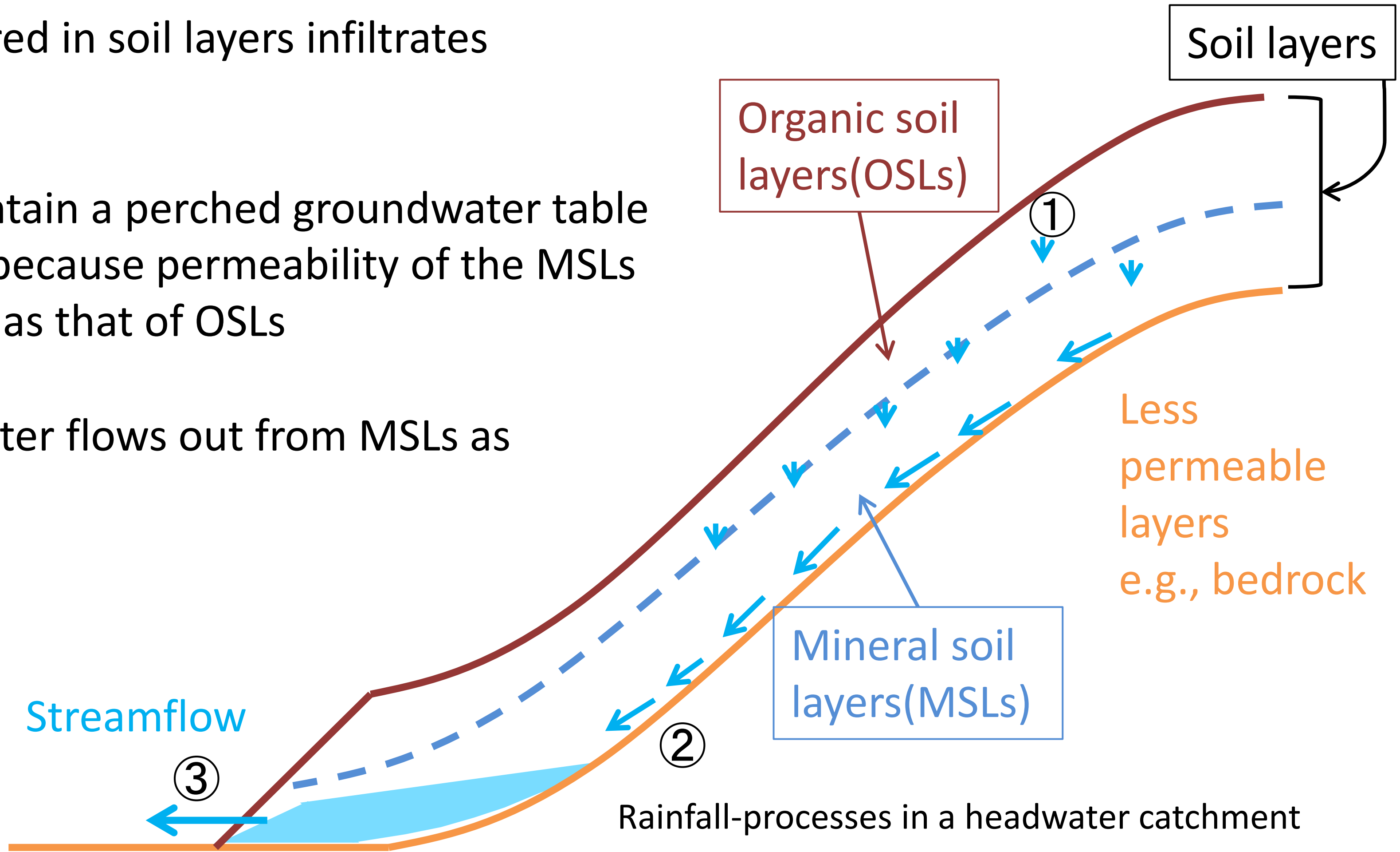
Rainfall-runoff processes in a headwater catchment have been explained as follows:

Dry periods

① Water stored in soil layers infiltrates vertically

② MSLs maintain a perched groundwater table after rainfall because permeability of the MSLs is not as high as that of OSLs

③ Groundwater flows out from MSLs as streamflow




Rainfall-processes in a headwater catchment

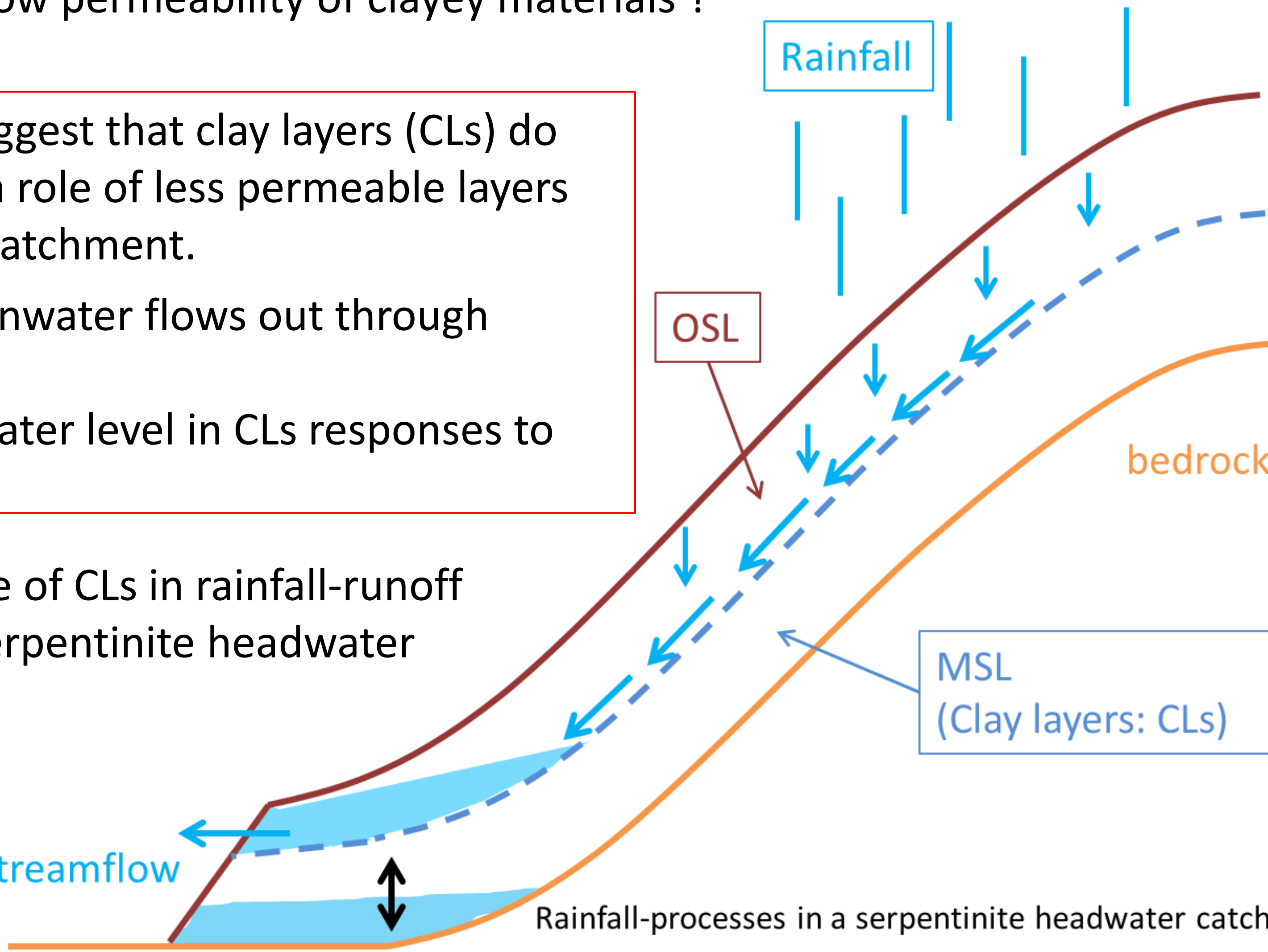
# Introduction

In a catchment where mineral soils are characterized by clayey materials (e.g., mudstone, slate, and serpentine catchment), MSLs function substantially as less permeable layers because of low permeability of clayey materials ?

Some studies suggest that clay layers (CLs) do not simply play a role of less permeable layers in a serpentine catchment.

- ✓ Most of rainwater flows out through OSLs
- ✓ A groundwater level in CLs responses to rainfall

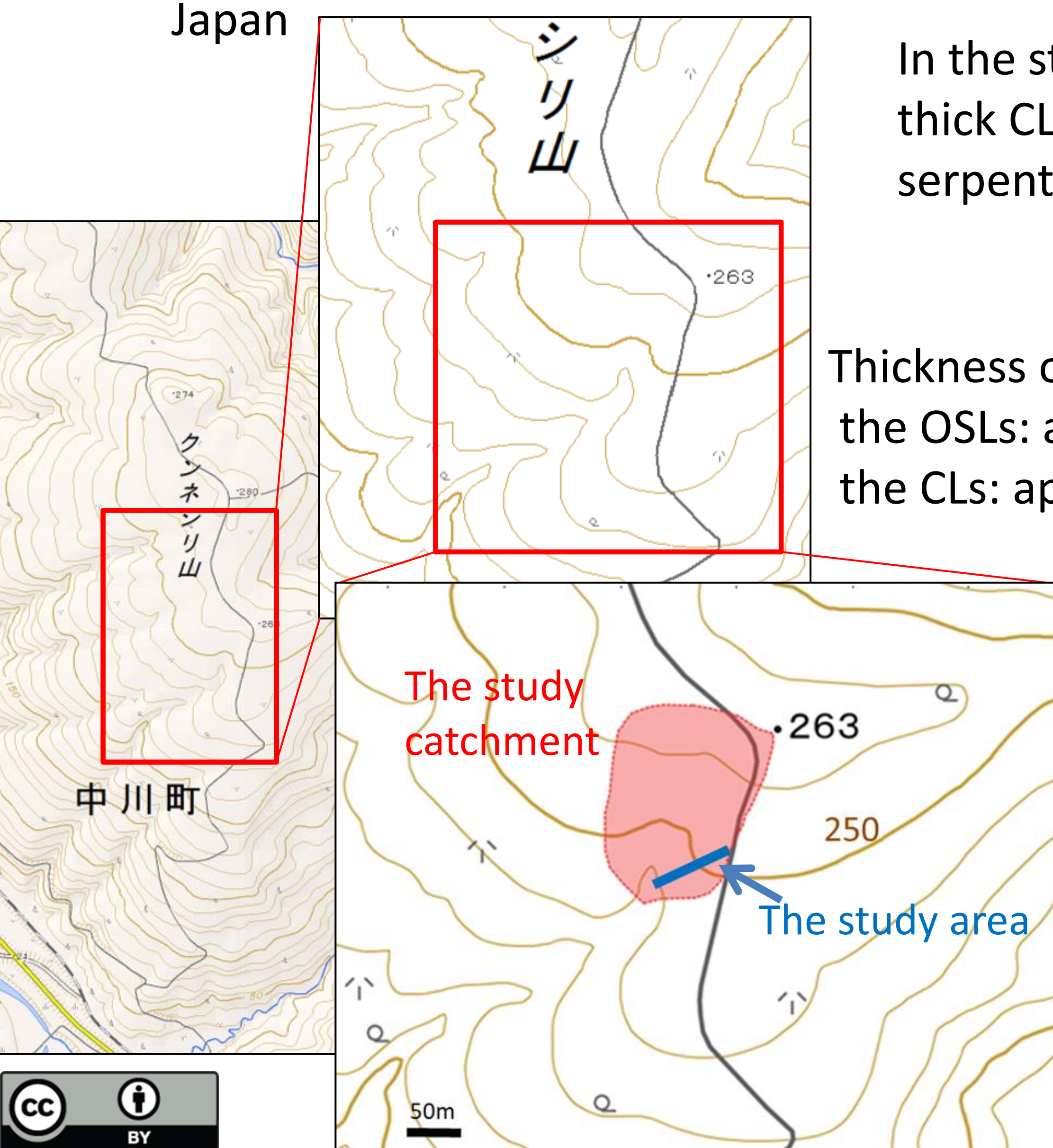
We discuss a role of CLs in rainfall-runoff processes in a serpentinite headwater catchment.




Rainfall-processes in a serpentinite headwater catchment

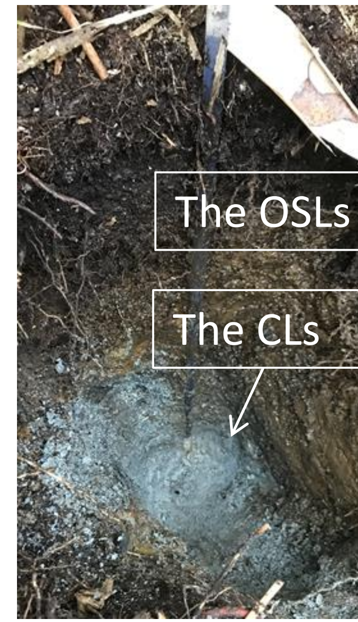
# Study catchment and study area

- A serpentinite headwater catchment (2.12 ha) in Hokkaido, Northern Japan




In the study catchment, MSLs consisting of thick CLs produced by weathering of the serpentinite bedrock underlies OSLs.

Thickness of
the OSLs: approximately 0.4m
the CLs: approximately 1.5m



The OSLs and the CLs

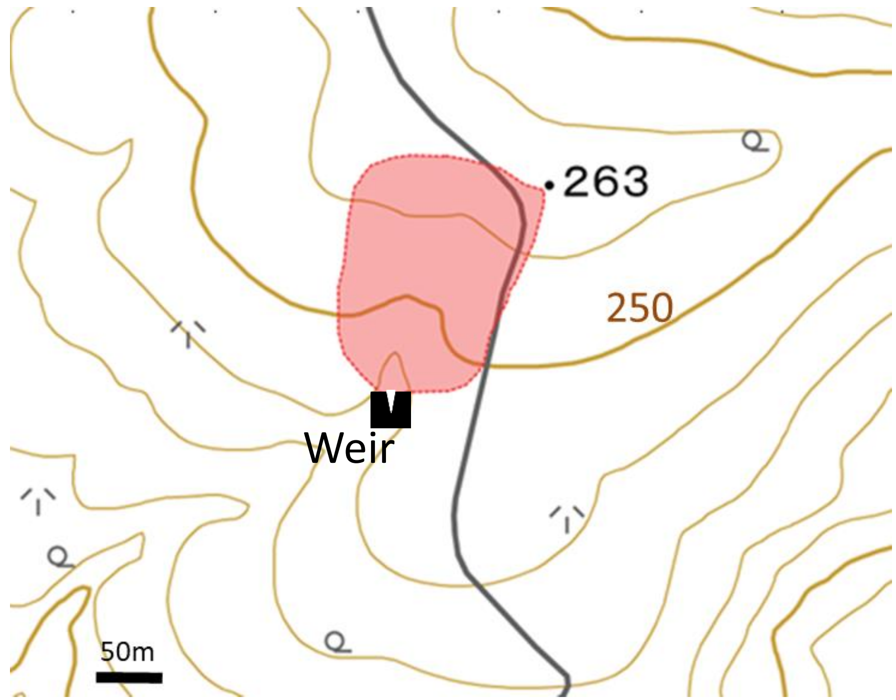
A study area where a spring was observed was set for detailed observations referred later.

# Methods（Study catchment set up）

- Streamflow discharge and temperature

The rate of streamflow discharge and water temperature was measured at 60-min intervals from 15 May 2019 to 2 November 2019, using a V notch weir and a water level gauge with a thermo recorder.


The weir



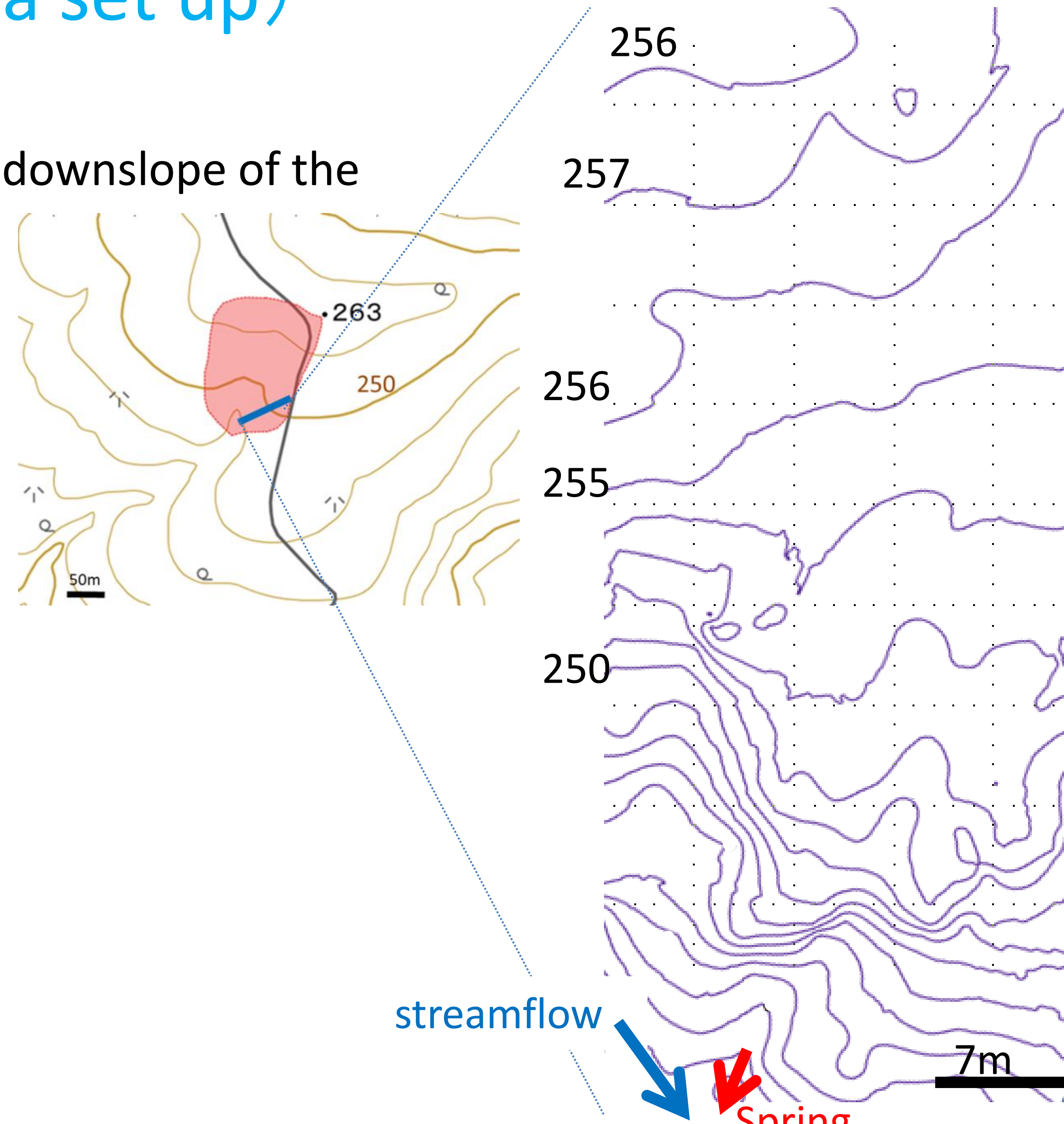

Weir location for the study catchment

# Methods（Study area set up）

- The study area

The spring was observed at a downslope of the study area.

Vegetation of study area consists of dense bamboo grass




Topographic map of the study area

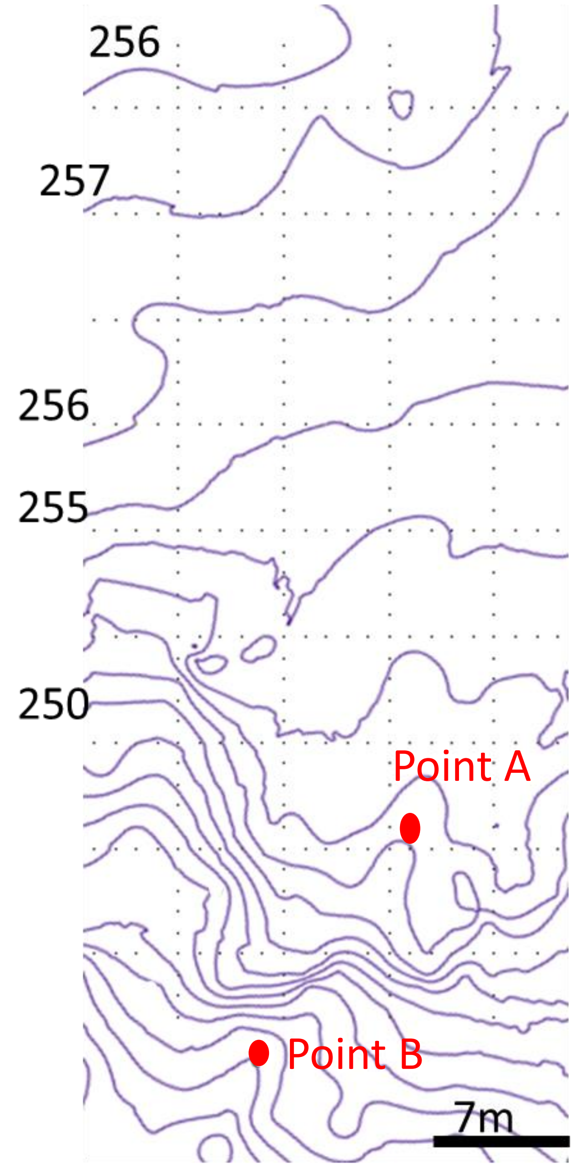
# Methods（Study area set up）

- Temporal variation of a groundwater level and temperature within each layer

Two observation wells (for the OSLs and for the CLs) were manually excavated at each point (Point A and Point B).

The observation wells for the OSLs and the CLs were excavated to CLs surface and bedrock surface, respectively.

We installed a water level gauge with a thermo recorders at the bottom of each observation well and monitored the groundwater levels and groundwater temperatures at 60-min intervals.



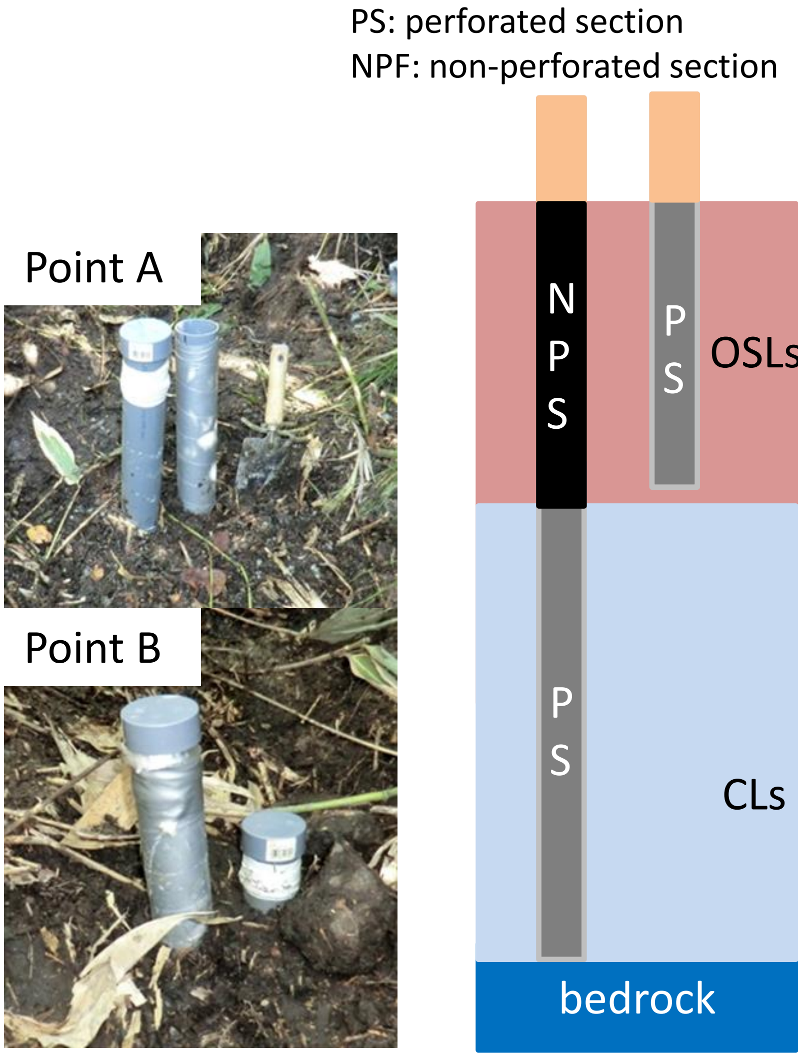

Wells location for the study area

# Methods（Study area set up）

- The observation wells

**Point A**
For OSLs（right）
Perforated section： 41cm
For CLs（left）
Non-Perforated section ： 60cm
Perforated section： 149cm

**Point B**
For OSLs（right）
Perforated section ： 38.5cm
For CLs（left）
Non-Perforated section ：43cm
Perforated section ：121cm



The observation wells

# Methods（Study area set up）

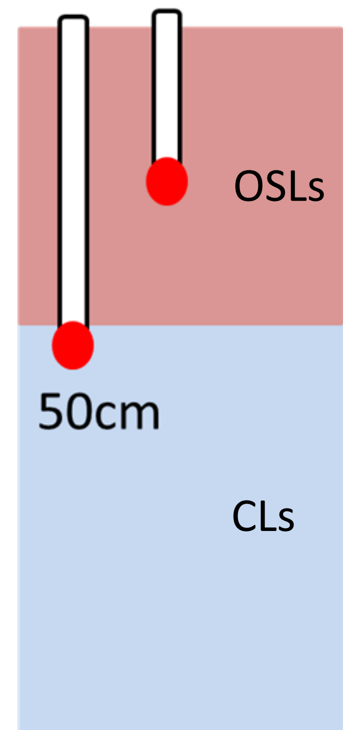
- Pressure head and groundwater flux

Temporal variation in pressure head ψ was measured at 60-min intervals from 15 May 2019 to 2 November 2019, using tensiometers installed at two depths (30cm and 50cm) at the ridge of the study area.

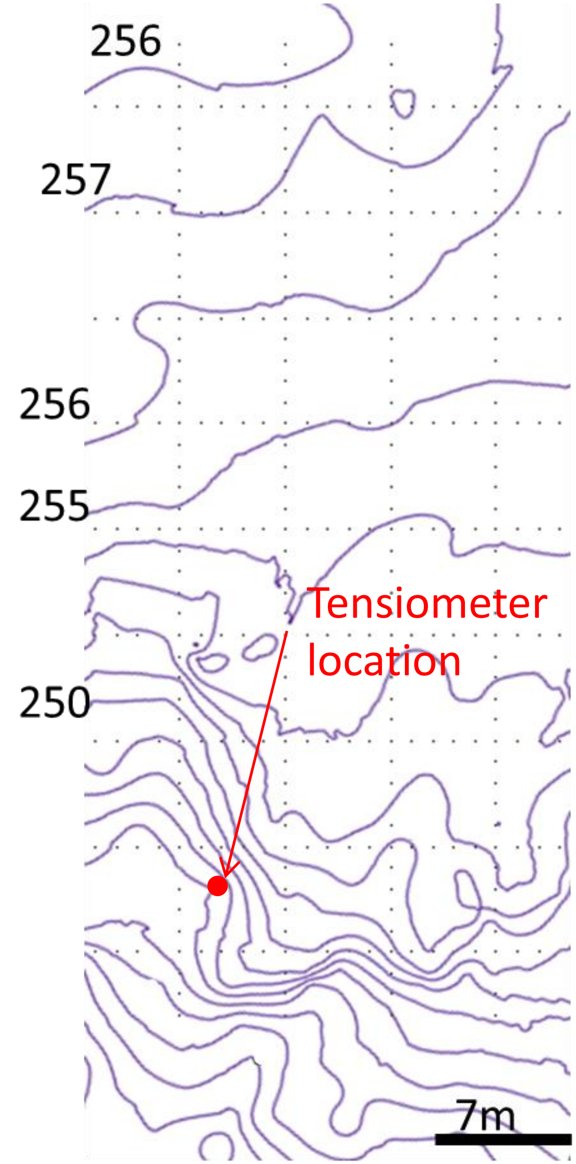
Then, we calculated groundwater flux between OSLs and CLs by using measured ψ values.

$$q = -K \frac{d(\psi + L)}{ds}$$

q: the flux rate
K : the hydraulic conductivity
L : the depth of the tensiometers
s: the distance in the direction of flow



The depth of the tensiometers



Tensiometer location for study area

# Methods（Study area set up）

- The electric conductivity（EC）

The streamflow,  the OSLs, the CLs

Samples collected from the weir and well.

Rainwater

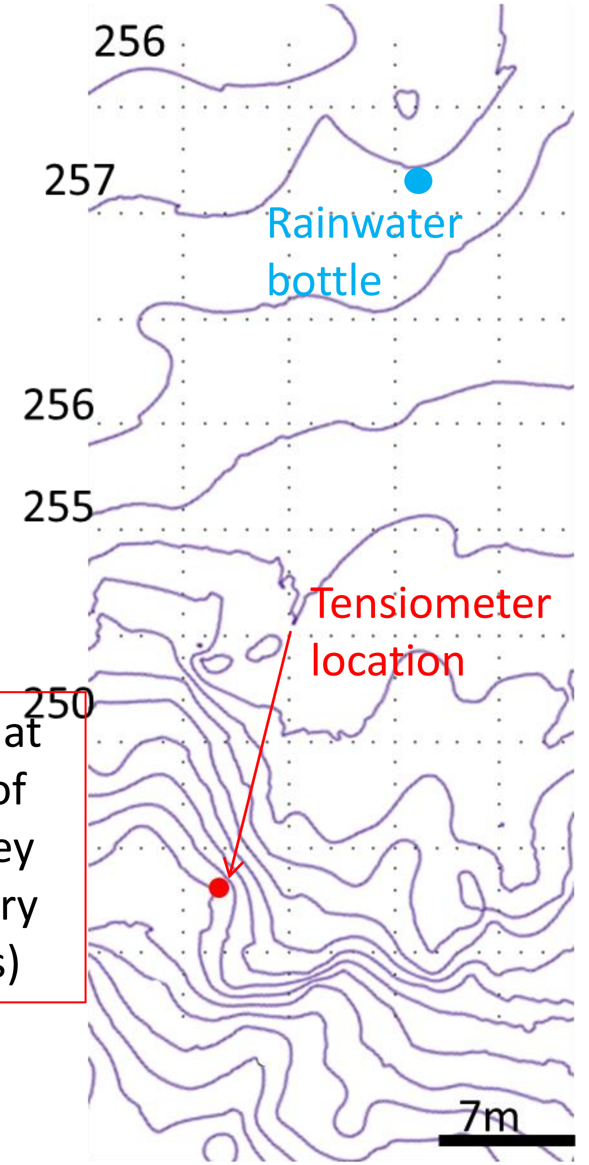
Samples collected a plastic bottle equipped with a mesh-covered funnel with a diameter of 21 cm.

Soil water（unsaturated water stored in the OSLs）

Samples collected by applying suction pressure to the OSLs at the tensiometer location.

Collected at the time of field survey (once every 4-5 weeks)

Temporal variation of the streamflow EC was measured at 60-min intervals from 28 September 2019 to 2 November 2019.




The tensiometer and rainwater bottle location

# Methods（Hydrograph separation and Laboratory tests）

- Hydrograph separation

The groundwater component of the CLs was separated from the hydrograph.

The equation used are

$$Q = Qs + Qc$$

$$C\ (Qs + Qc) = Cs\ Qs + Cc\ Qc$$

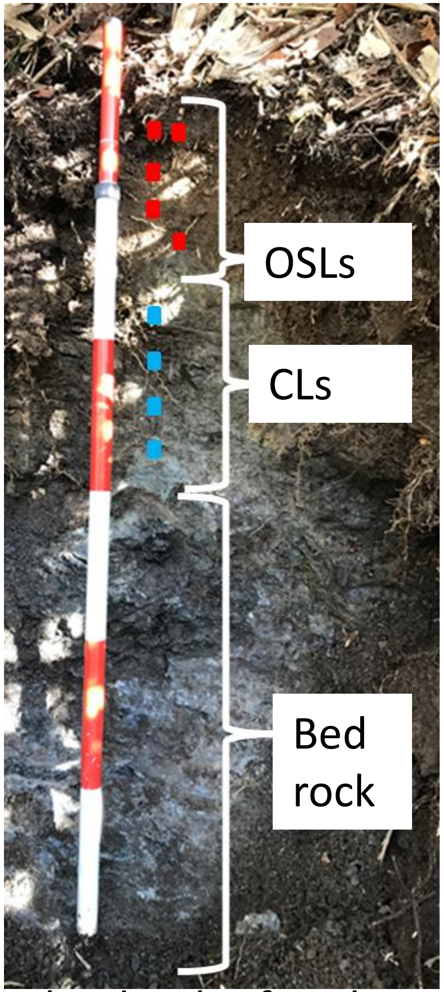
Q, C : Discharge and EC of streamflow

Qs, Cs : Discharge and EC of soil water

Qc, Cc: Discharge and EC of groundwater within CLs

It is possible that the EC values of the soil water and groundwater within the CLs are affected by rainwater.

Therefore, we examined the relationship between the ψ value of 30 cm and the EC values of the soil water and groundwater within the CLs to assesses the effect of rainwater.




The depth of each sample collected

- Laboratory test

The water retention curve and the saturated hydraulic conductivity (Ks) were measured using 5 OSLs samples and 4 CLs samples taken from a trench near the study area.

# Result（Laboratory tests）

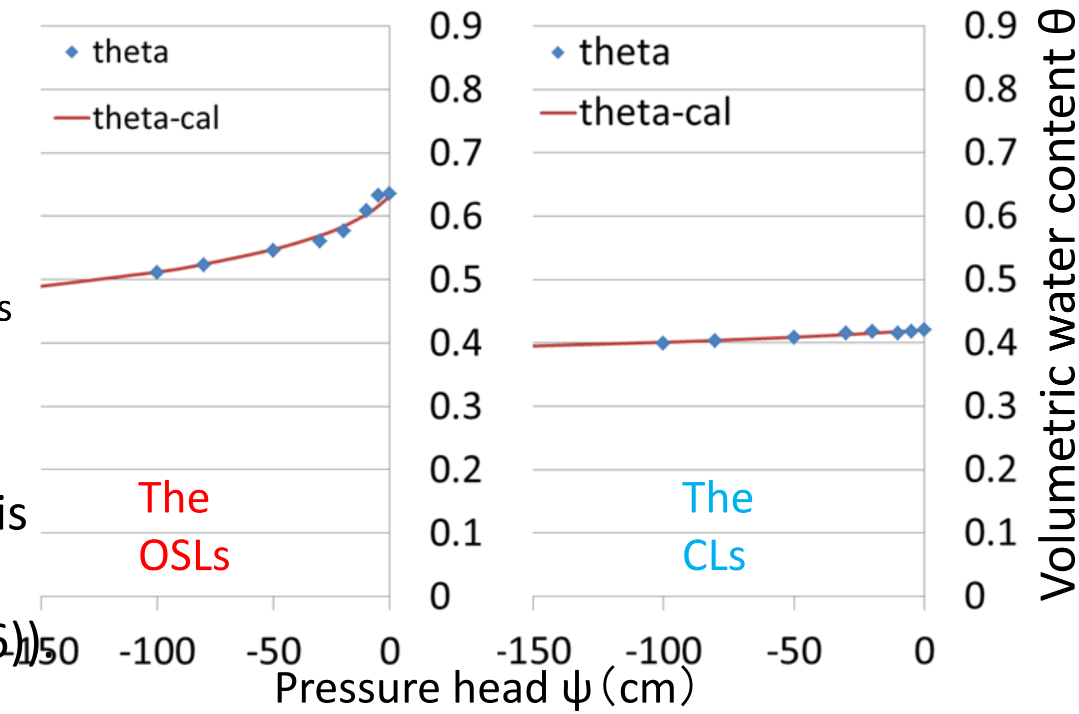
- The Ks

The OSLs：$8.89 \times 10^{-2}$cm/sec
The CLs：$7.00 \times 10^{-4}$cm/sec

※Geometric mean of measured values

- The water retention curve

θ is measured value, and θcal is obtained by fitting the lognormal model (Kosugi(1996)).

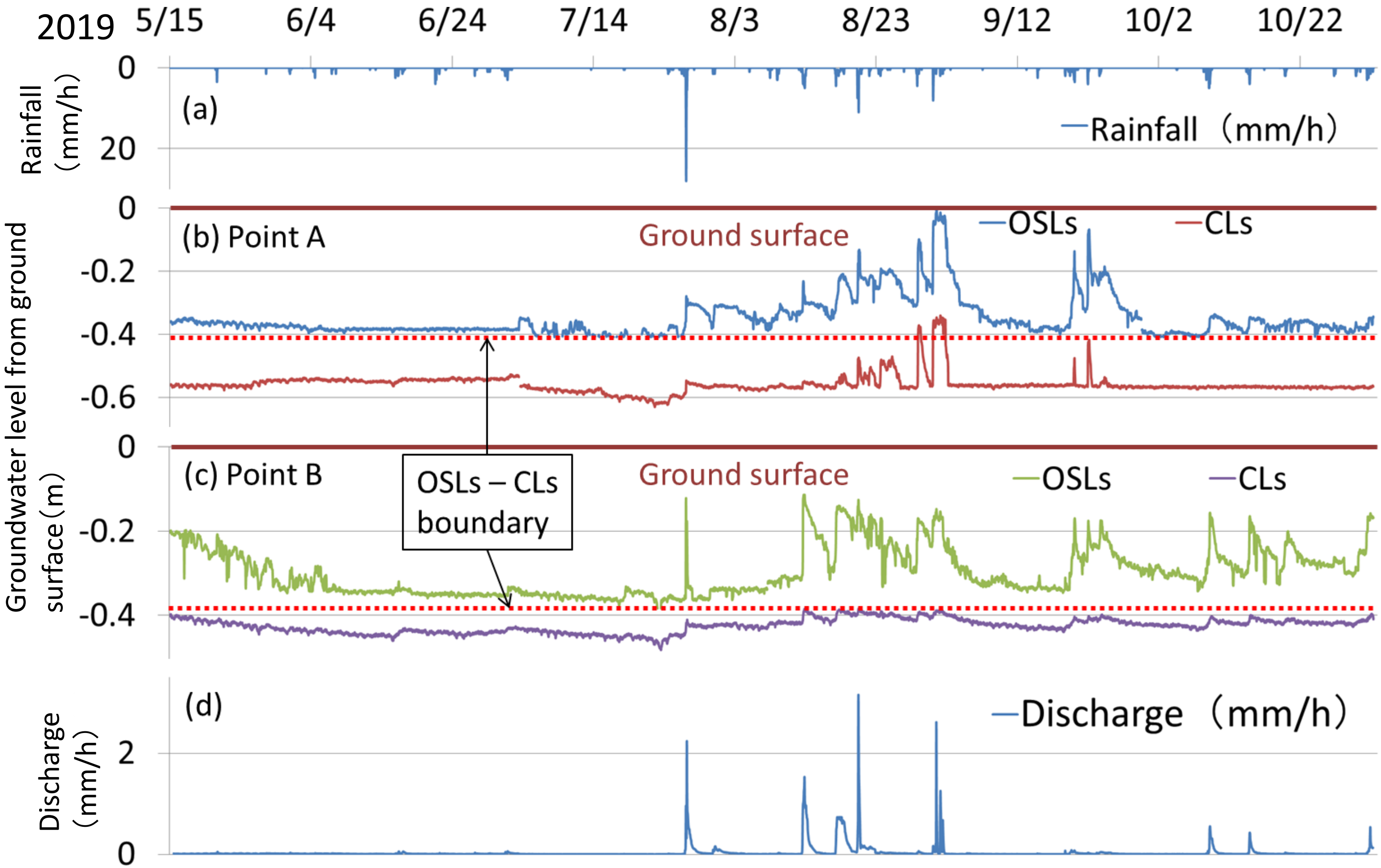



The water retention curve (left: The OSLs, right: The CLs)

This result of the laboratory tests shows that the OSLs have high permeability and low water-holding capacity and the CLs have low permeability and high water-holding capacity.

# Result（Groundwater level・Discharge）

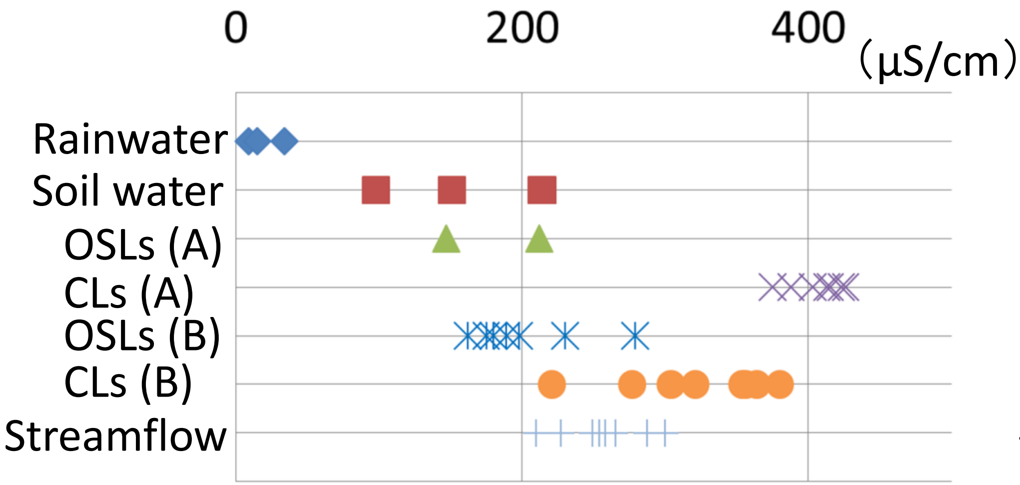




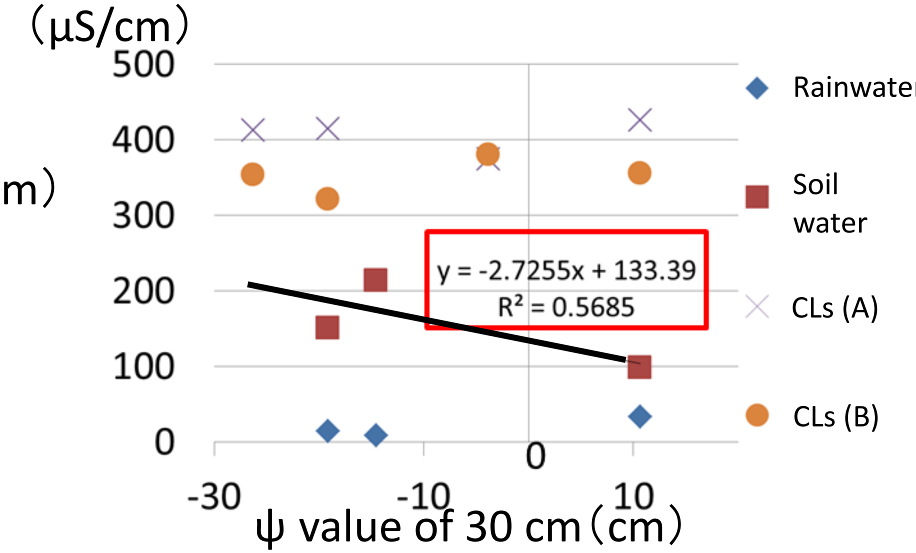

(a) Rainfall, (b) Groundwater level in Point A wells, (c) Groundwater level in Point B wells, and (d) Rate of streamflow discharge

The groundwater levels within the OSLs persist during dry periods in spite of the hydraulic characteristics of the OSLs: high permeability and low water-holding capacity.

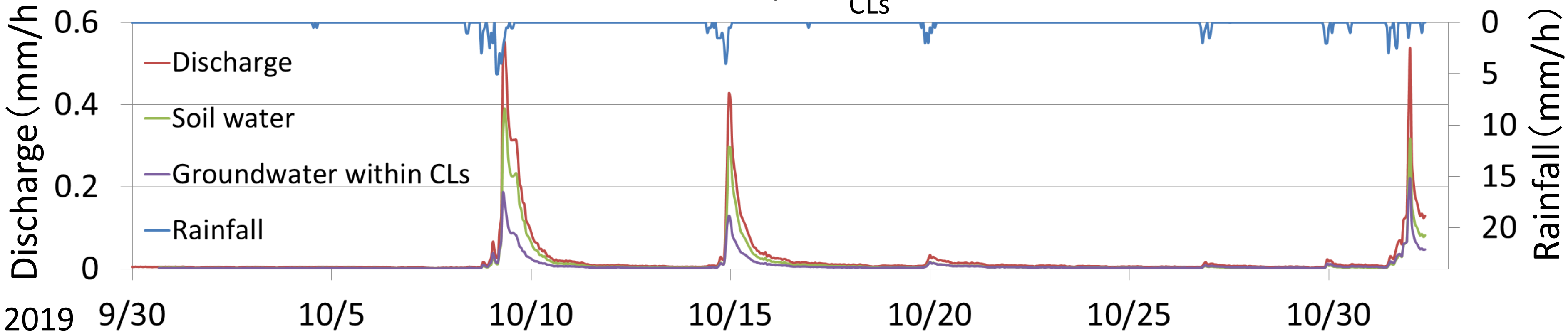
## Result（EC and Hydrograph separation ）




EC values Collected at the time of field survey




The relationship between the ψ value of 30 cm and the EC values of the soil water and groundwater within the CLs

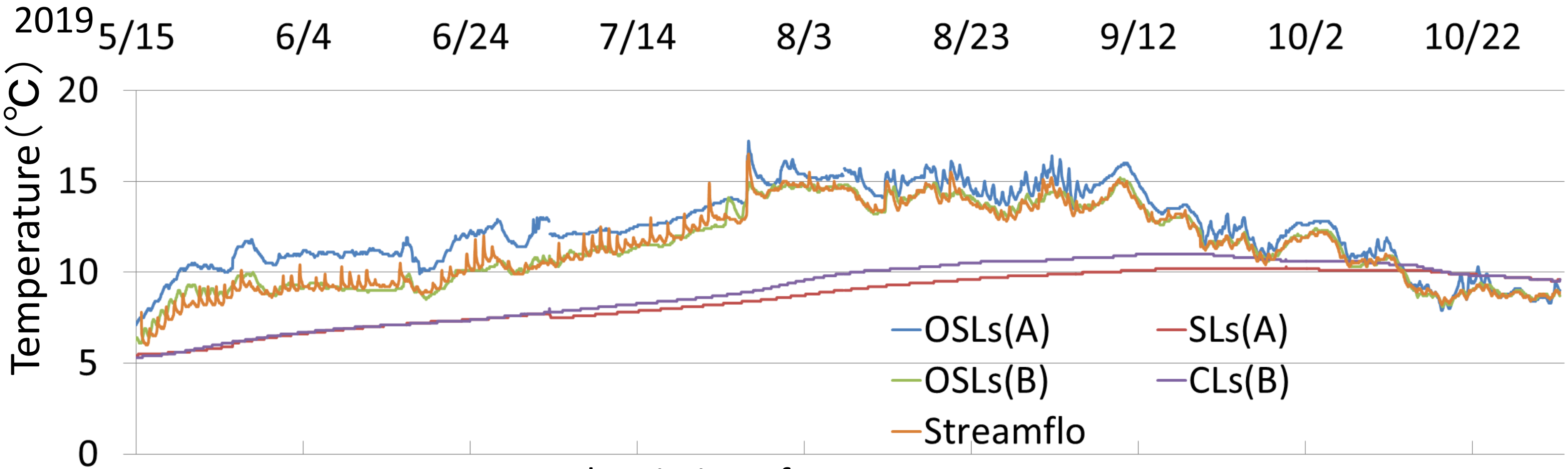



Observed streamflow, calculated the soil water component and groundwater within the CLs component

- Contribution of water emerging from the CLs to the total streamflow ranged from 31 to 76% in dry to wet periods.

→ This result shows that the soil water and the groundwater within the CLs are mixed and flow out as the streamflow.

# Result（Water temperature）



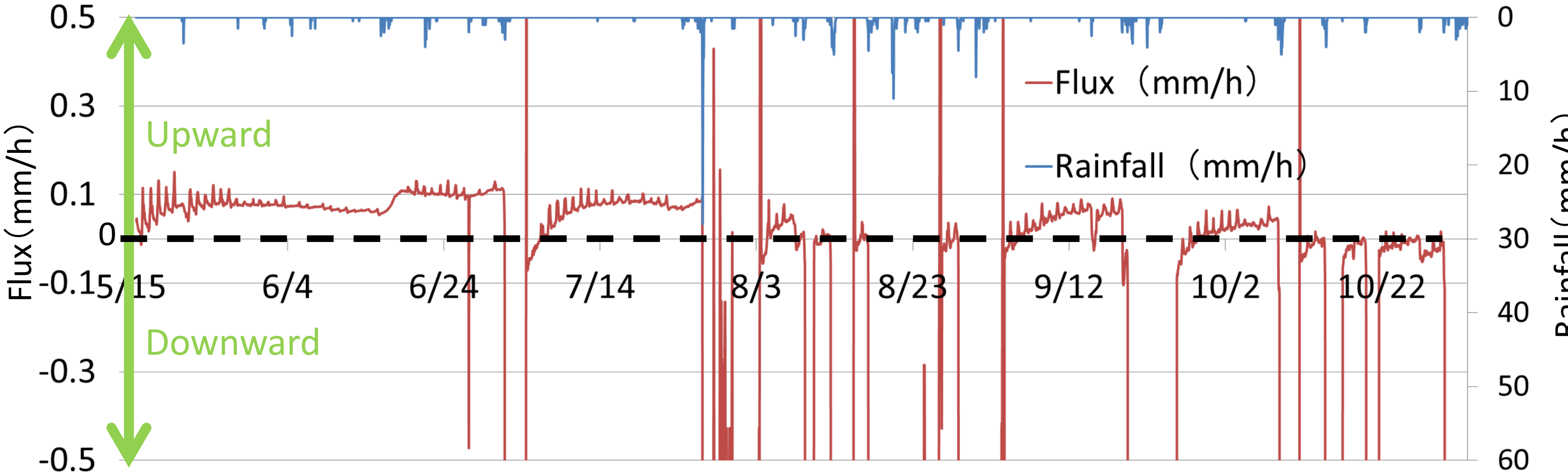

Temporal variation of water temperature

Temperature of the streamflow was similar to that of the OSLs at Point B with or without rain.

→ This result indicates that the groundwater within the OSLs is a main component of streamflow even during dry periods.

→ How does the groundwater within the CLs affect on the groundwater within the OSLs during dry periods ?

# Result（Groundwater flux）




Temporal variation of flux and rainfall

- Upward flux (from the CLs into the OSLs) occurred during dry periods and low flow periods.

→ As the CLs sustains almost saturated condition even if the OSLs was dry conditions, OSLs draw water up from CLs.

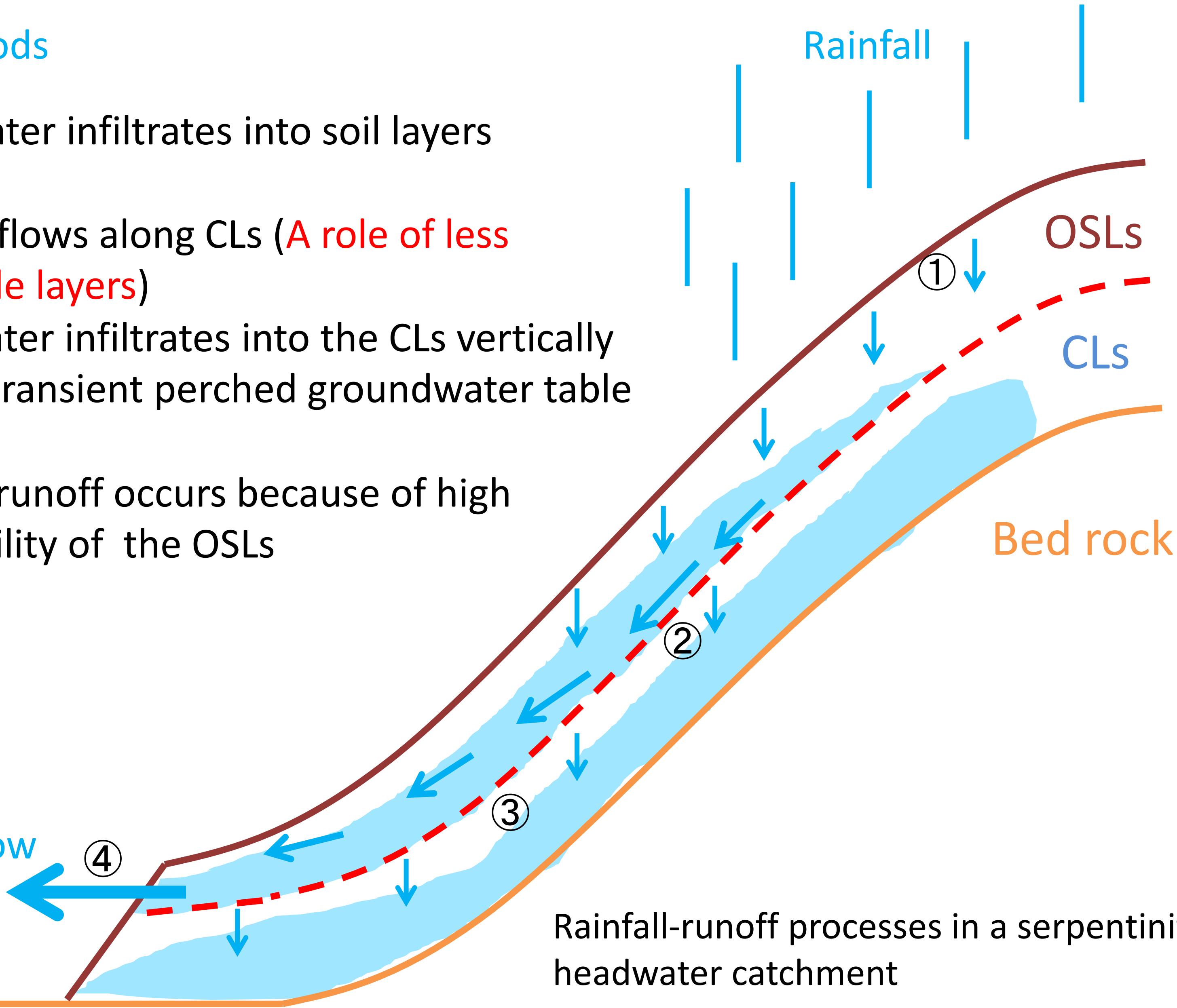
- Occurrence of the upward flux in a headwater catchment that resulted from dry conditions of OSLs is reported (e.g., Tsujimura 1993, Tsurita et al. 2009).

→ While upward flux was observed 57 days of a year in these previous studies, in this study, the upward flux was observed 102 days of the observation period (171 days) because of high water-holding capacity of the CLs.

# Discussion

## Wet periods

①Rainwater infiltrates into soil layers vertically
②Water flows along CLs (A role of less permeable layers)
③The water infiltrates into the CLs vertically where a transient perched groundwater table is formed
④Storm runoff occurs because of high permeability of the OSLs

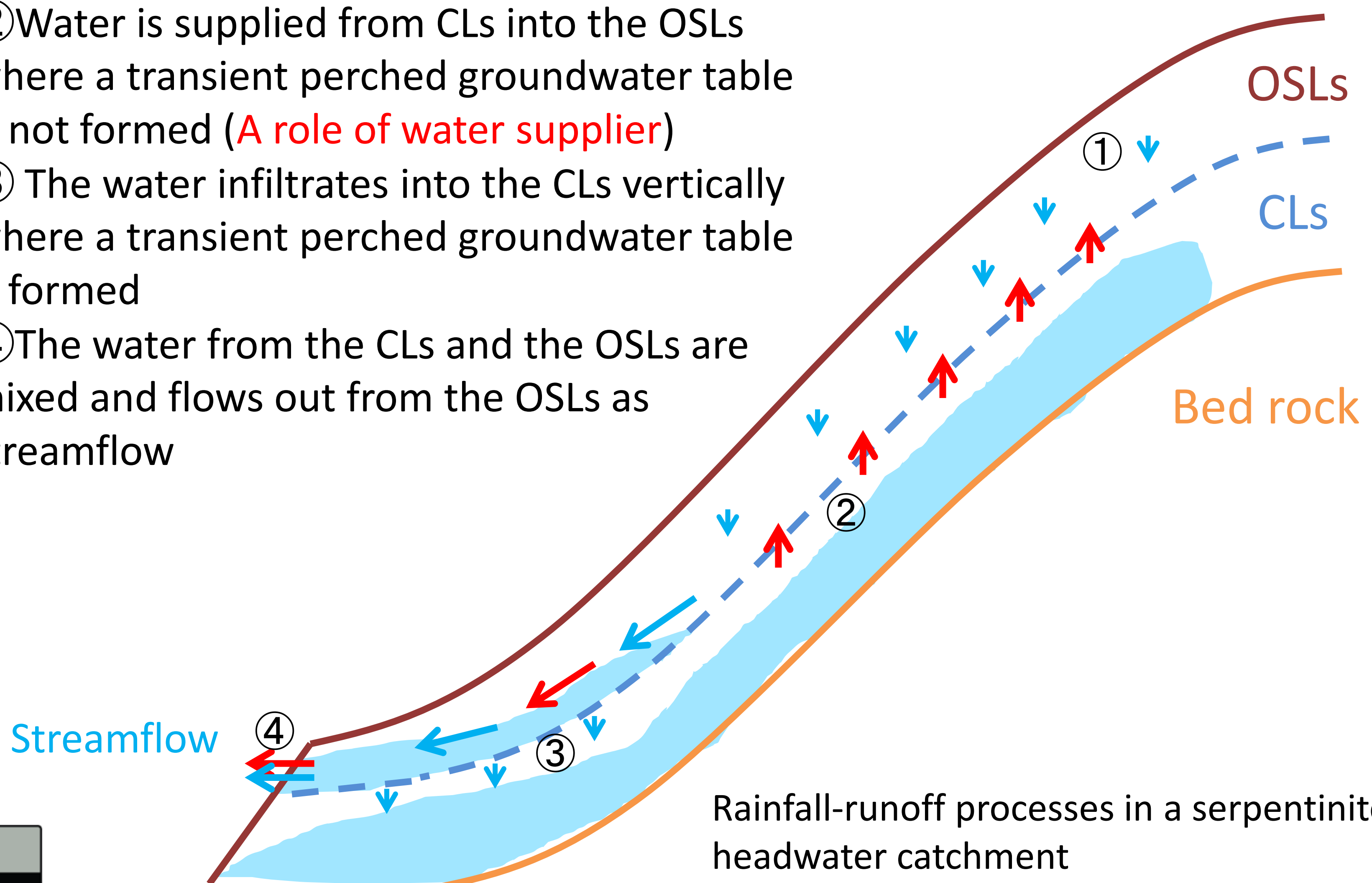



Rainfall-runoff processes in a serpentinite headwater catchment

# Discussion

Dry periods

①Water stored in OSLs infiltrates vertically
②Water is supplied from CLs into the OSLs where a transient perched groundwater table is not formed (A role of water supplier)
③ The water infiltrates into the CLs vertically where a transient perched groundwater table is formed
④The water from the CLs and the OSLs are mixed and flows out from the OSLs as streamflow




Rainfall-runoff processes in a serpentinite headwater catchment

# Conclusion

- Two roles of CLs in rainfall-runoff processes in a serpentinite headwater catchment
  - The roll of less  permeable layers
    - → In study catchment, streamflow constantly consists of groundwater within OSLs because of low permeability of CLs.
  - The roll of water supplier
    - → Water stored in the CLs is supplied to the OSLs as upward flux where the OSLs became dry condition and composes the streamflow in dry periods.
- It is considered that such a role of CLs gives a headwater catchment the property that the catchment becomes difficult to dry even though most of rainwater flows out through OSLs.