Estimation of barometric responses of groundwater levels at observation stations of the Geological Survey of Japan, AIST

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Aim of This Research

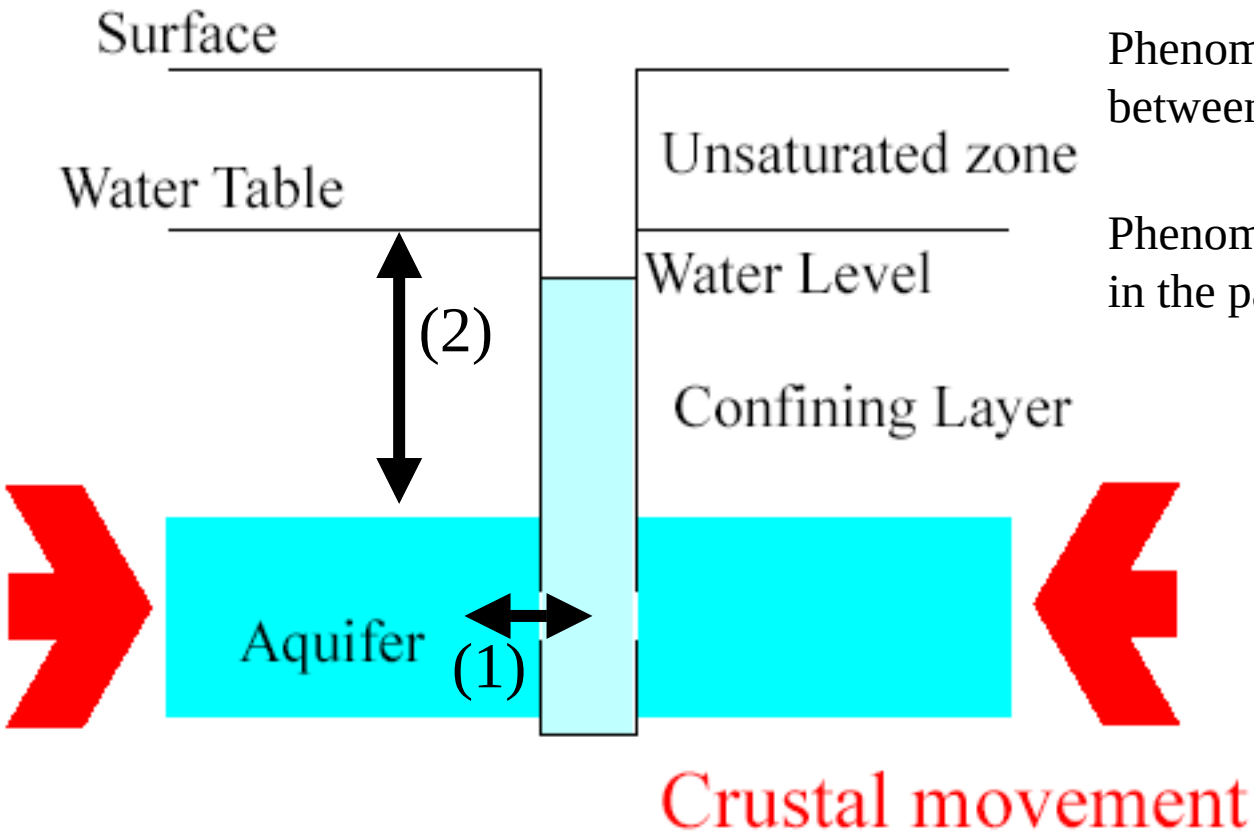
AIST has been measuring the groundwater levels of wells in order to detect crustal movements.

To exactly evaluate detection capability of the crustal movements, it needs to understand the hydraulic characteristics of the well and stratum.

This research tried to understand the hydraulic characteristics of the well and stratum, using the barometric responses of the groundwater levels.

Scheme of Crustal Strain Response

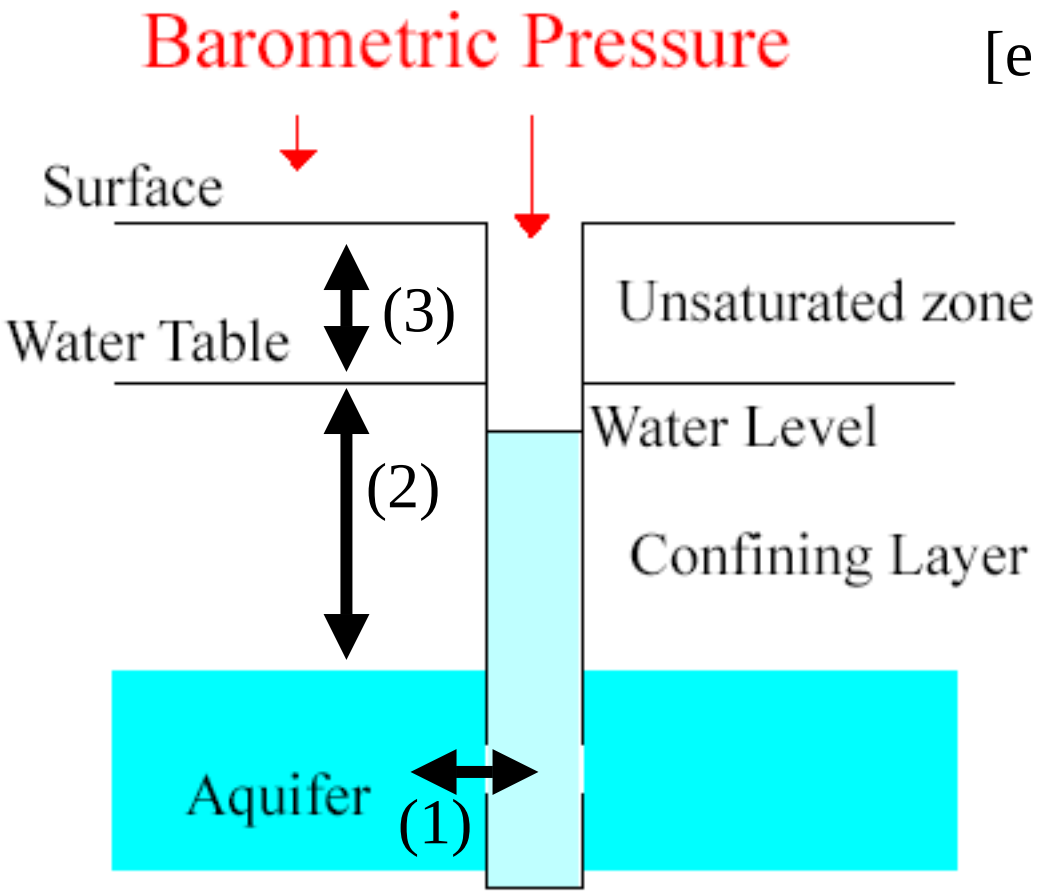
[e.g., Hsieh et al.(1987), Rojstaczer(1988)]



Phenomenon(1): Groundwater flow between the well and the aquifer

Phenomenon(2): Groundwater flow in the partial confining layer

Scheme of Barometric Response



[e.g., Rojstaczer(1988)]

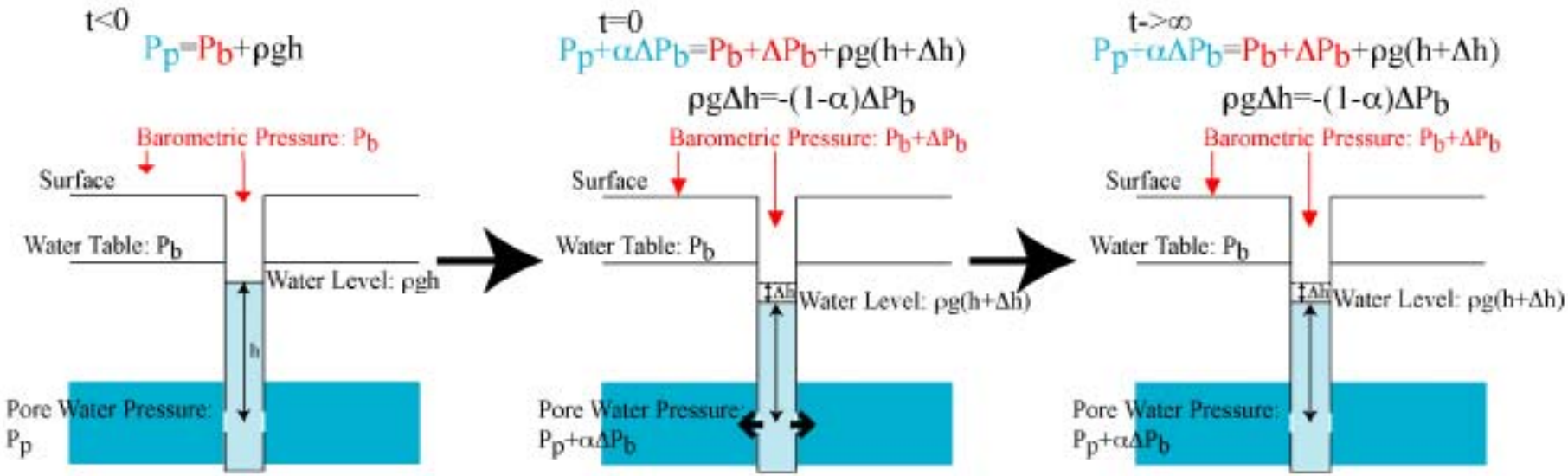
Phenomenon(1): Groundwater flow between the well and the aquifer

Phenomenon(2): Groundwater flow in the partial confining layer

Phenomenon(3): Air flow in the unsaturated zone

Scheme of Static Response

Response for step change of barometric pressure

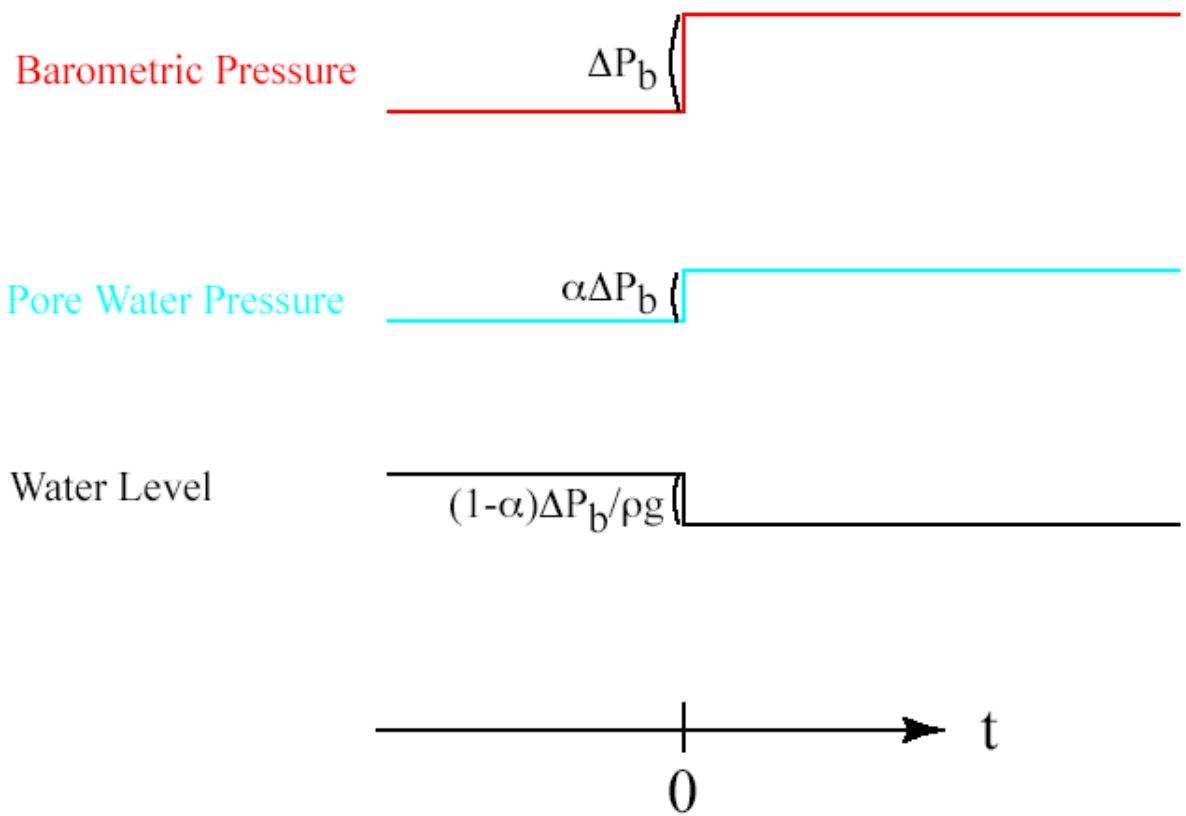


Ideal conditions for static response situation of barometric response

1. Very high permeability between the well and the aquifer
   or No wellbore storage
2. Perfect confining layer

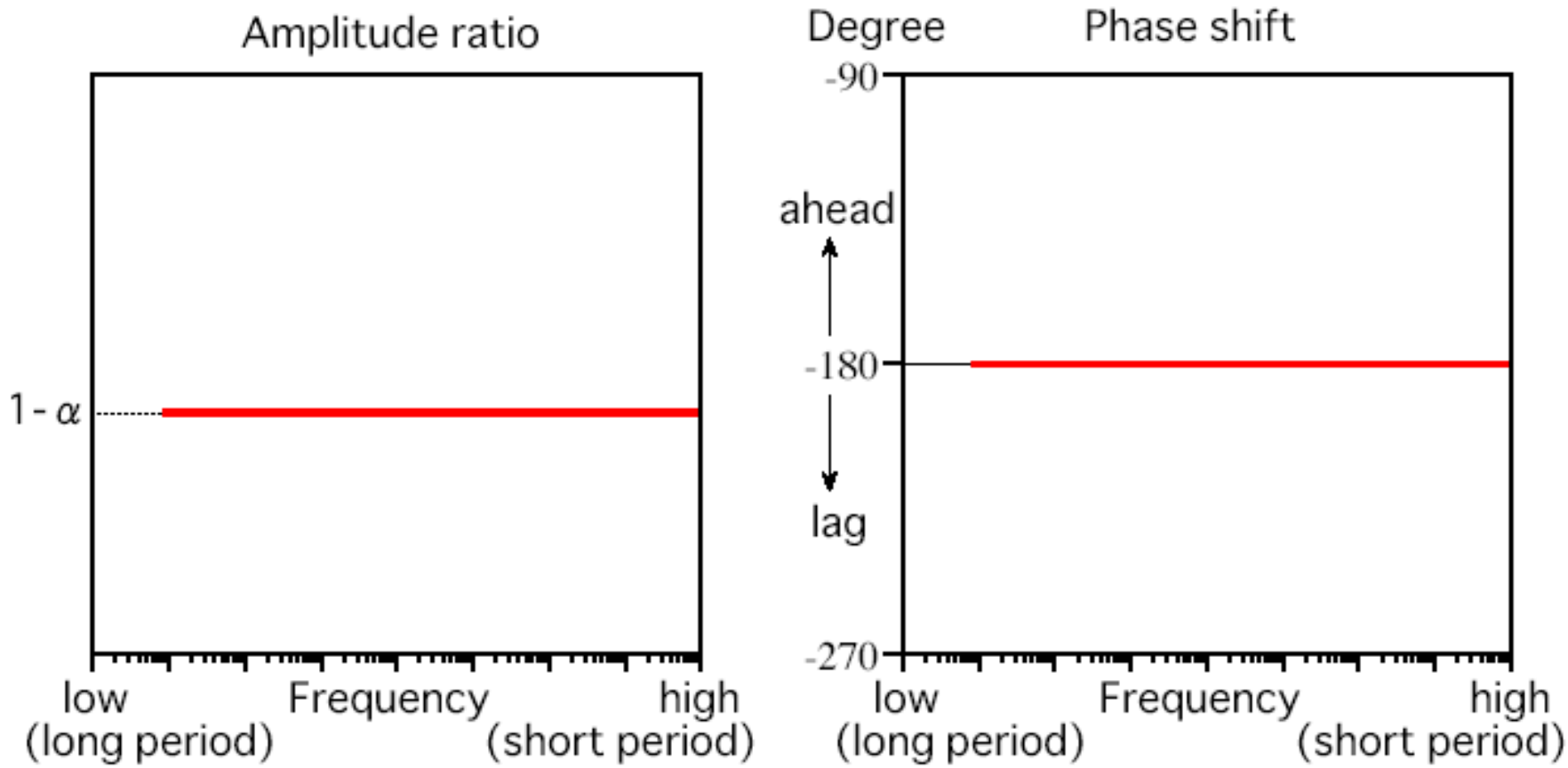
Static Response

Response for step change of barometric pressure in time domain



Static Response of water level

Response for step change of barometric pressure in frequency domain



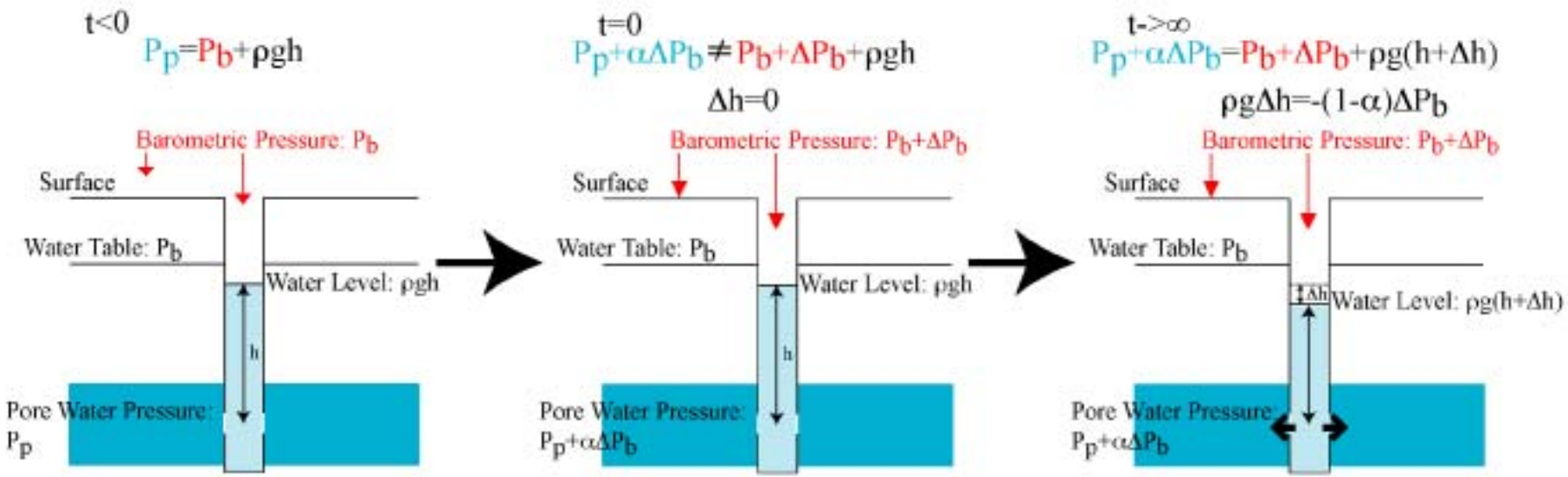
Characteristics of Static Response

- Amplitude ratio of water level change to barometric pressure change is constant at whole frequency range.

- Phase shift of water level change to barometric pressure change is in opposite phase at whole frequency range.

Scheme of Phenomenon(1)

Response for step change of barometric pressure

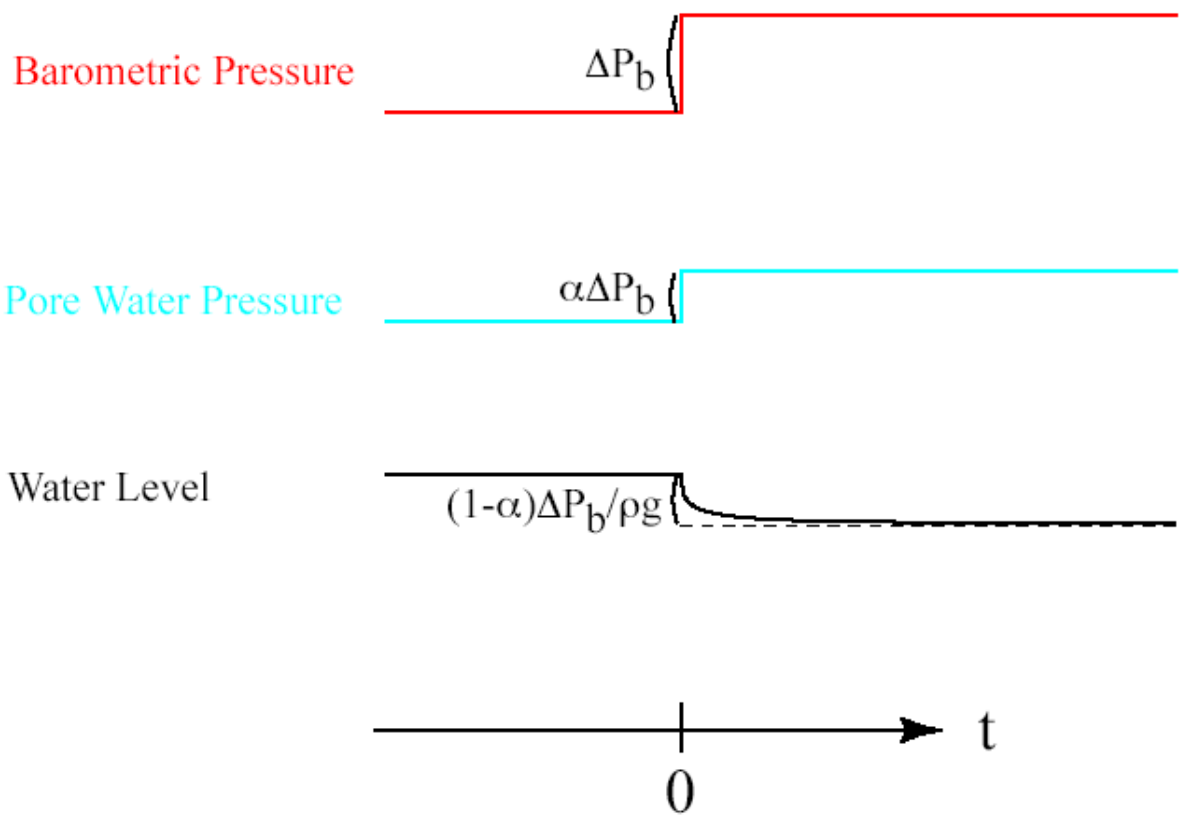


Conditions for phenomenon(1)

1. Low permeability between the well and the aquifer
   or Large wellbore storage
2. Perfect confining layer

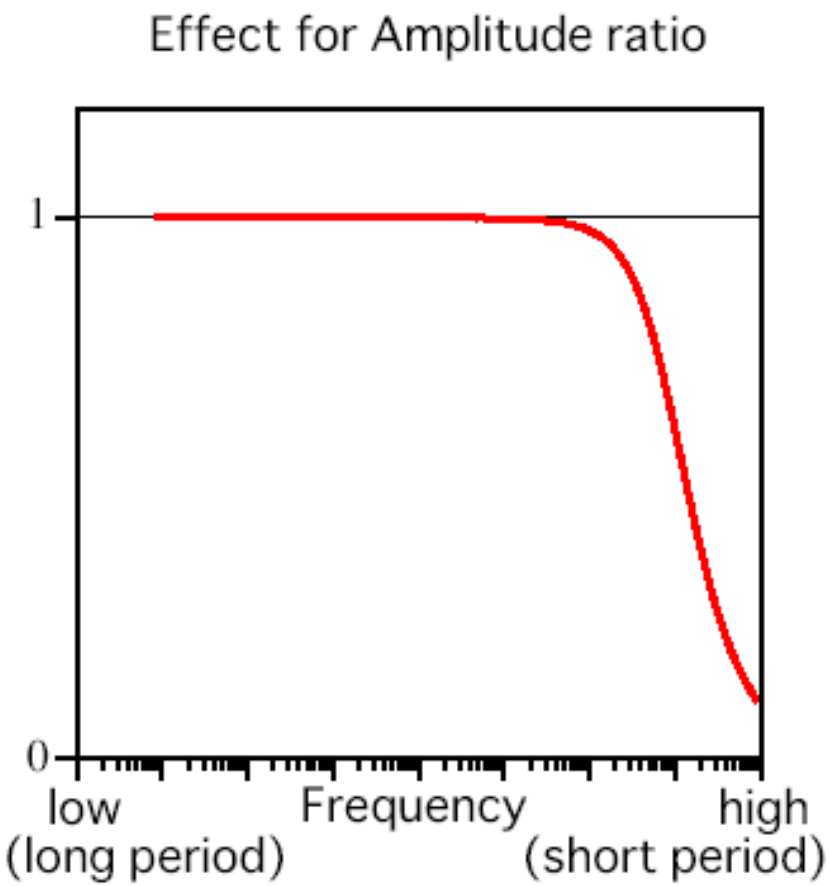
Effect of Phenomenon(1)

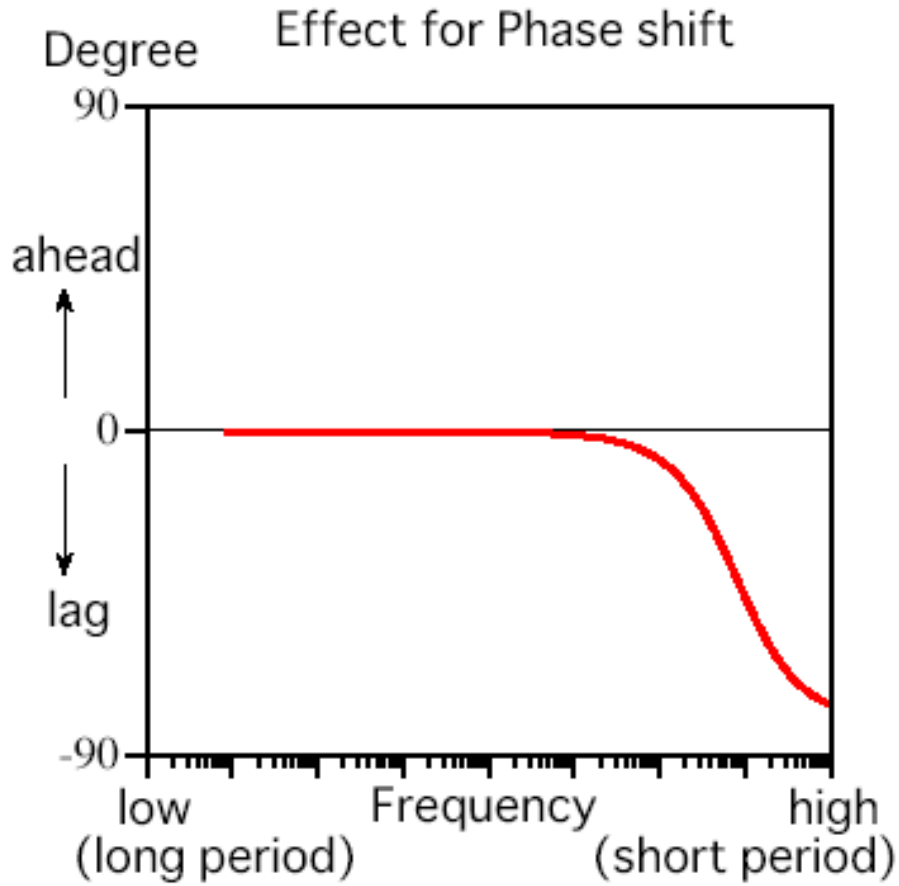
Response for step change of barometric pressure in time domain



Effect of Phenomenon(1) to water level

Response for step change of barometric pressure in frequency domain





Characteristics of Effect of Phenomenon(1)

• Phenomenon(1) is strongly related to the permeability between the well and the aquifer.

• The lower the permeability is, the larger the effect is.

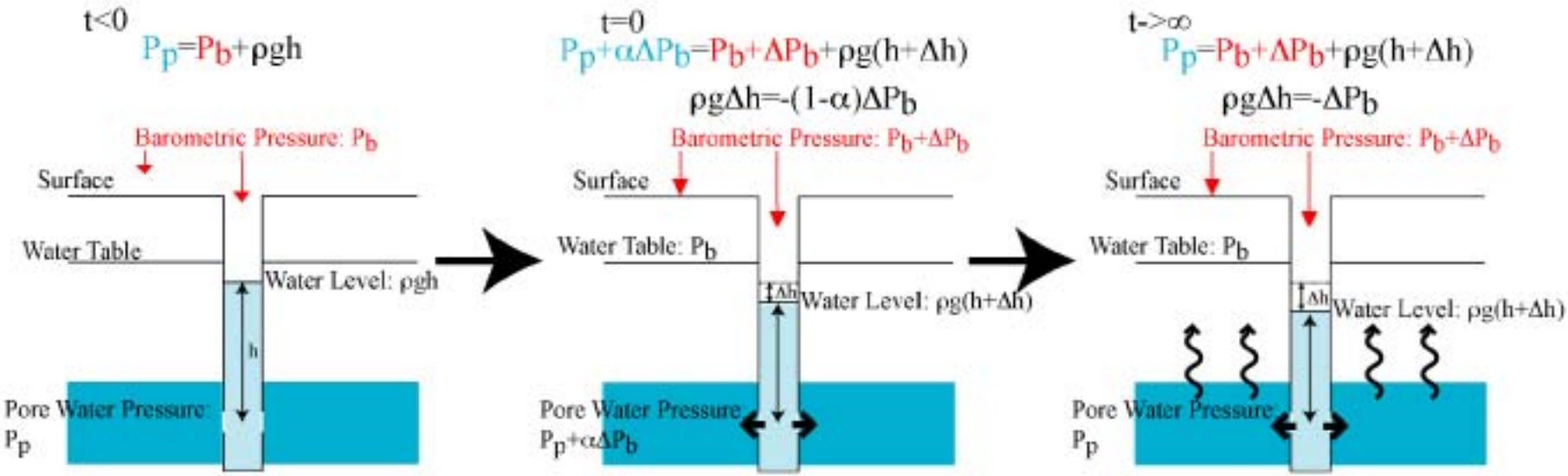
• The effect is characterized as decrease of amplitude ratio and lag of phase shift.

• The effect is not noticeable at low frequency range.

• The higher the frequency is, the larger the effect is.

Scheme of Phenomenon(2)

Response for step change of barometric pressure

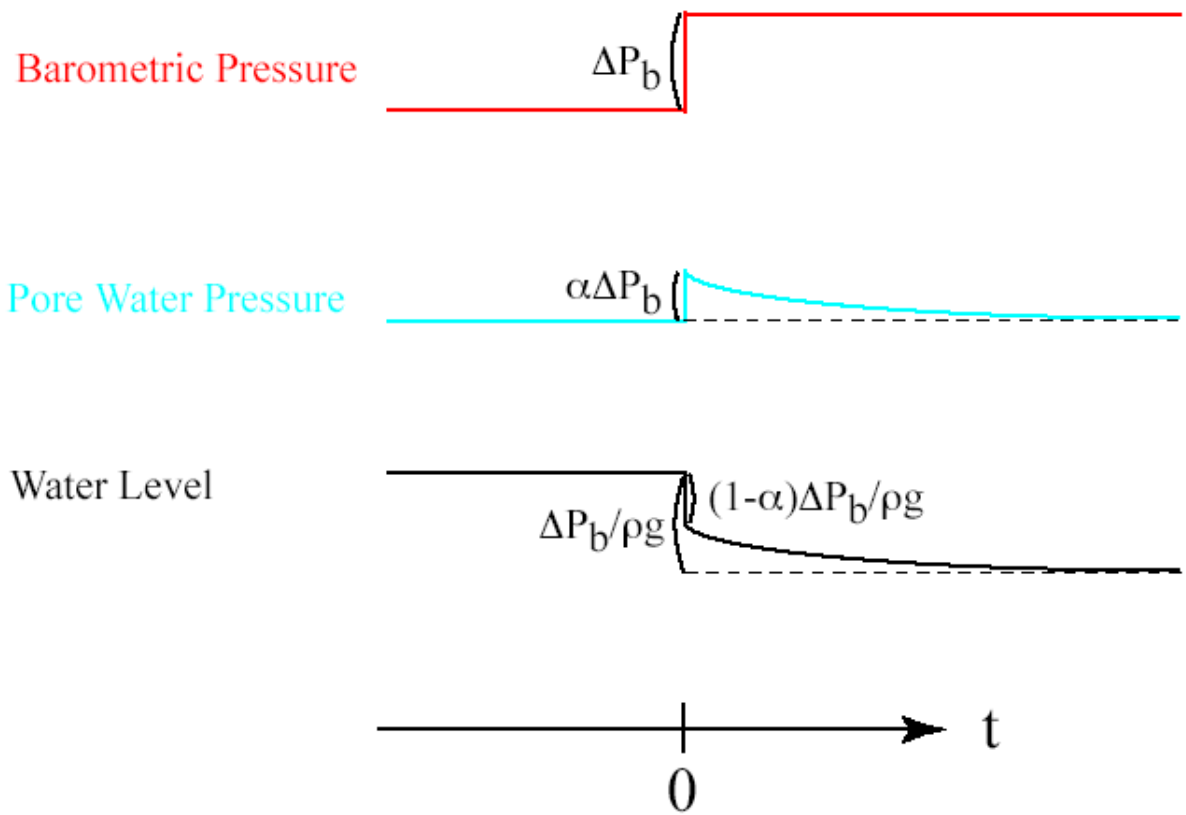


Conditions for phenomenon(2)

1. Very high permeability between the well and the aquifer or No wellbore storage
2. Partial confining layer

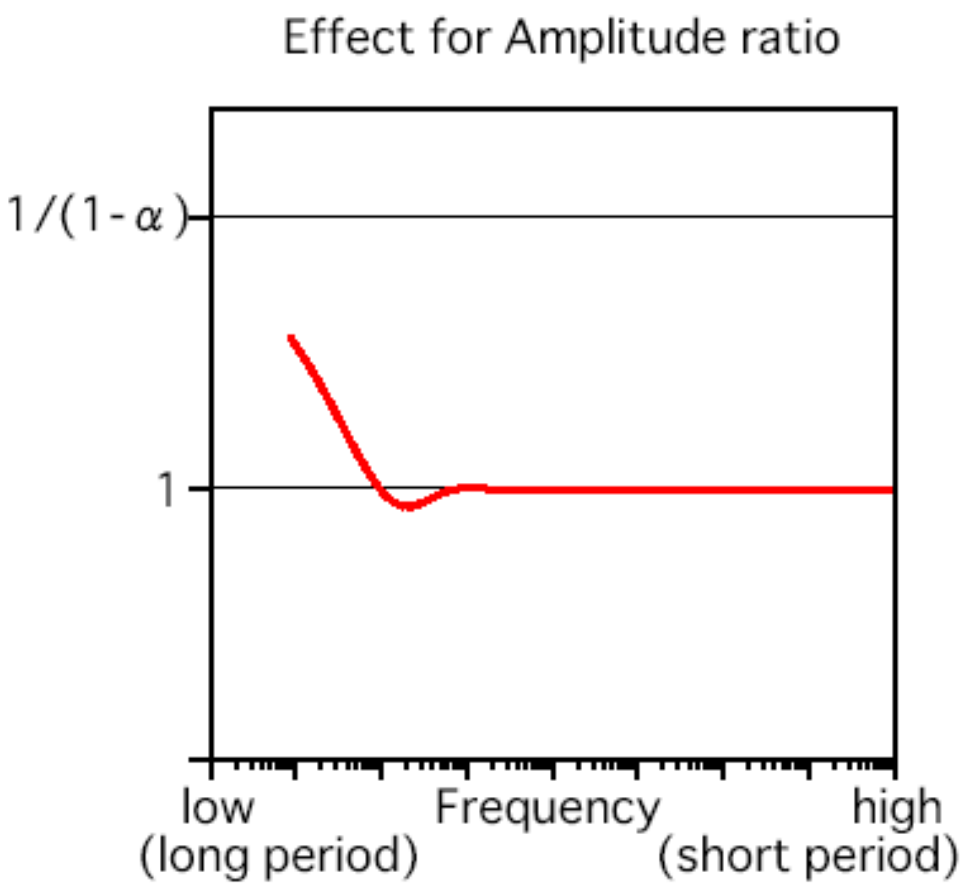
Effect of Phenomenon(2)

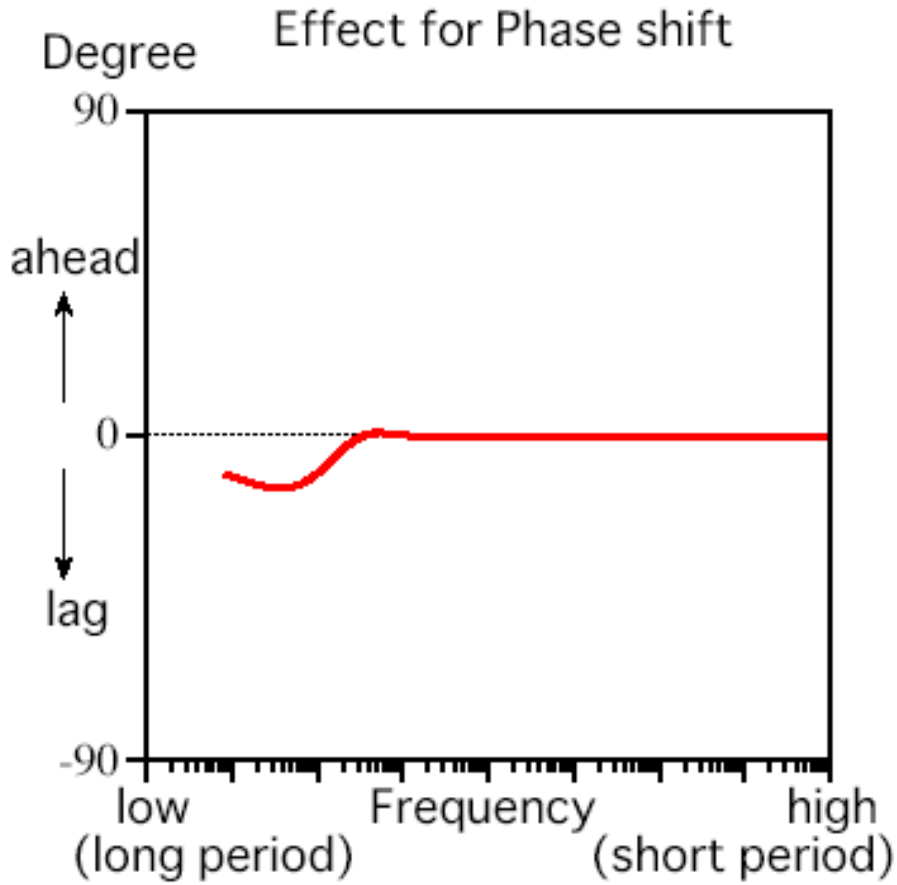
Response for step change of barometric pressure in time domain



Effect of Phenomenon(2) to water level

Response for step change of barometric pressure in frequency domain





Characteristics of Effect of Phenomenon(2)

• Phenomenon(2) is strongly related to the permeability of the confining layer.

• The higher the permeability is, the larger the effect is.

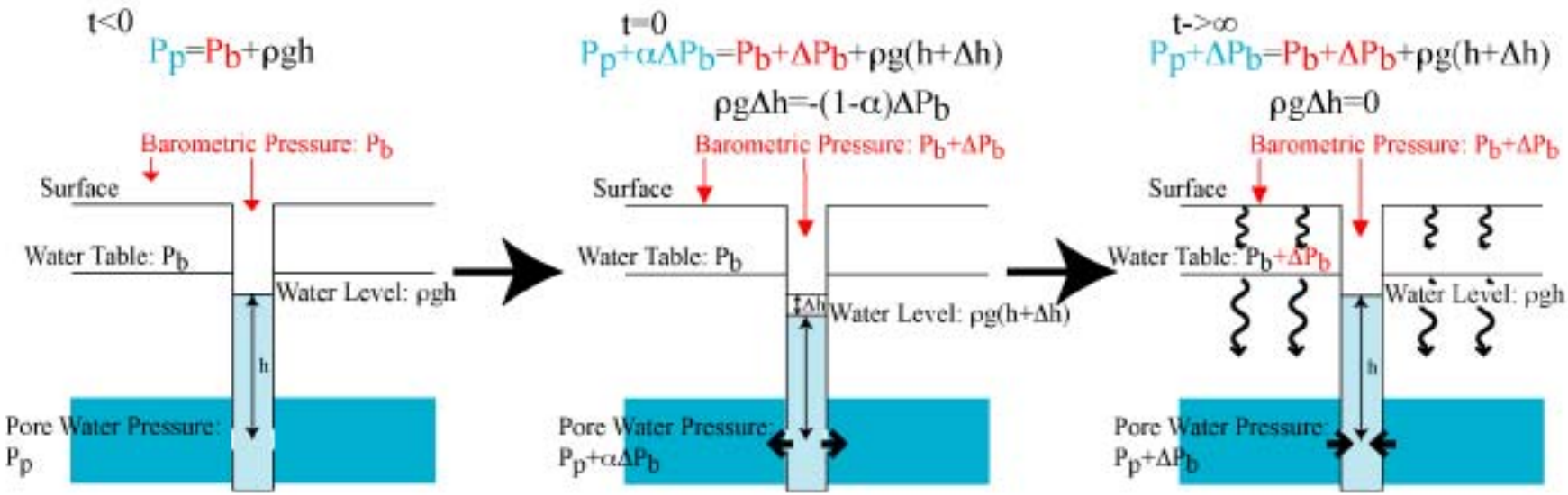
• The effect is characterized as increase of amplitude ratio and lag of phase shift.

• The effect is not noticeable at high frequency range.

• The lower the frequency is, the larger the effect is.

Scheme of Phenomenon(3)

Response for step change of barometric pressure

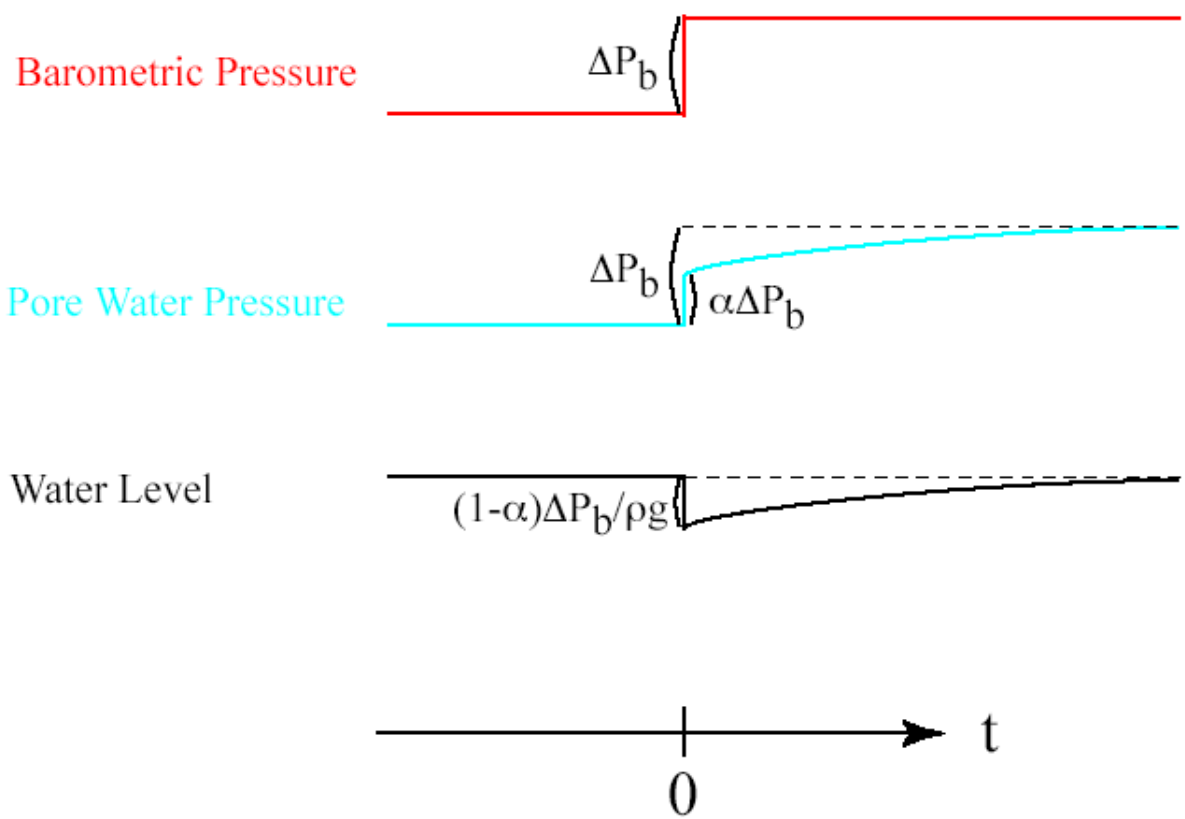


Conditions for phenomenon(3)

1. Very high permeability between the well and the aquifer or No wellbore storage
2. Partial confining layer

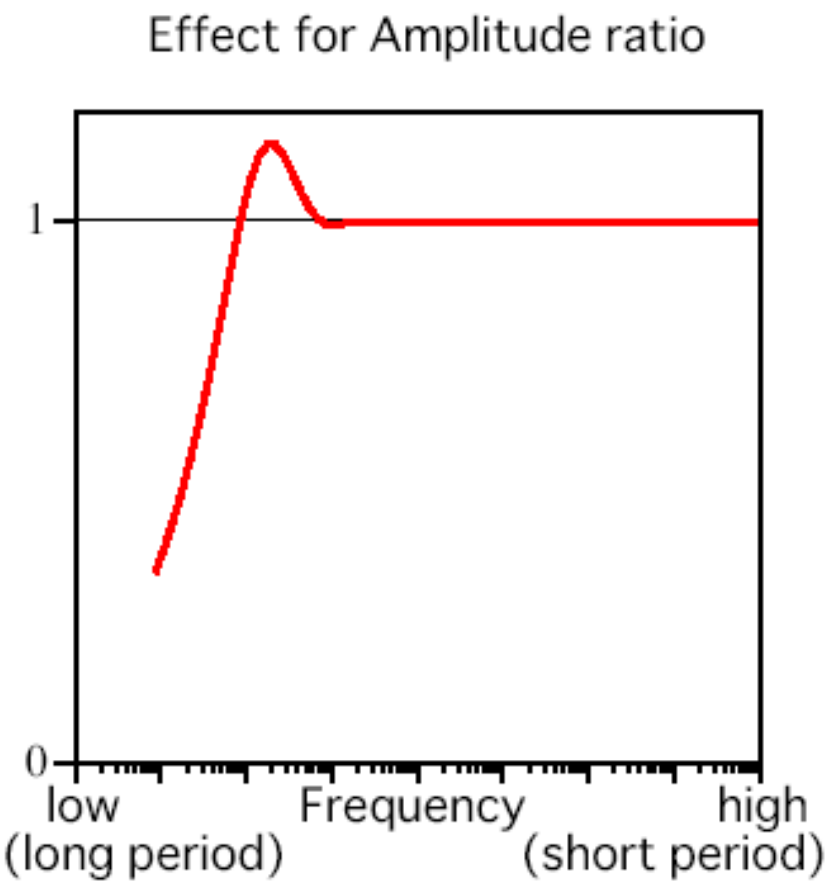
Effect of Phenomenon(3)

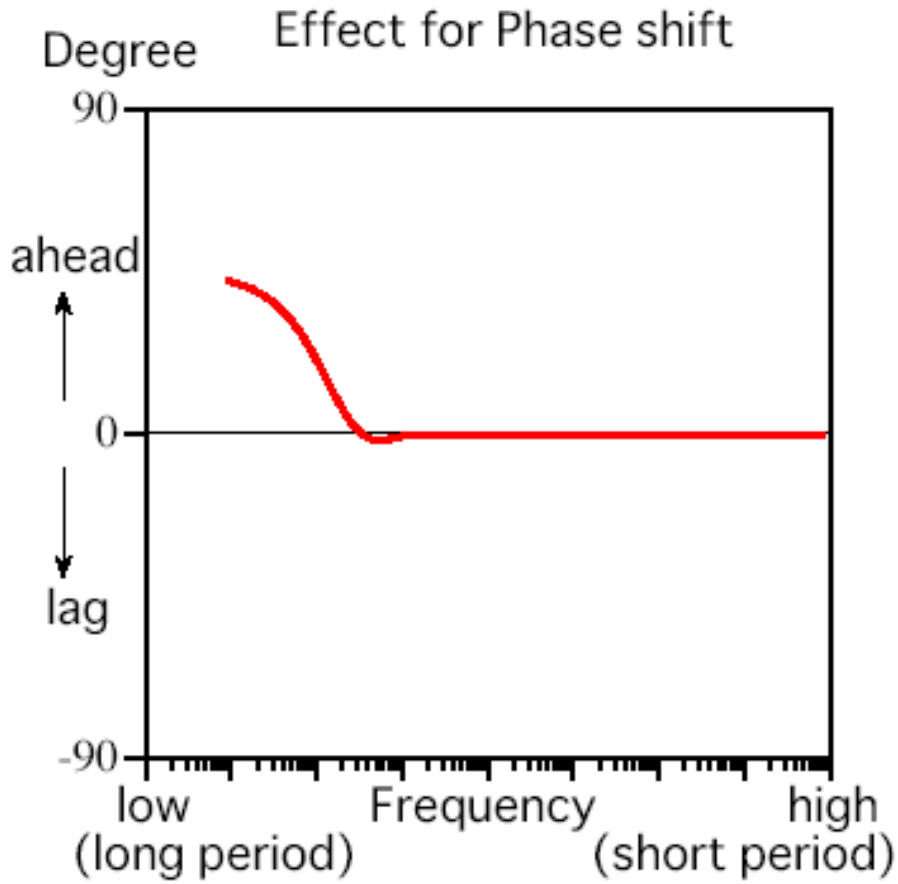
Response for step change of barometric pressure in time domain



Effect of Phenomenon(3) to water level

Response for step change of barometric pressure in frequency domain





Characteristics of Effect of Phenomenon(3)

• Phenomenon(3) is strongly related to the air diffusivity of the unsaturated zone.

• The higher the diffusivity is, the larger the effect is.

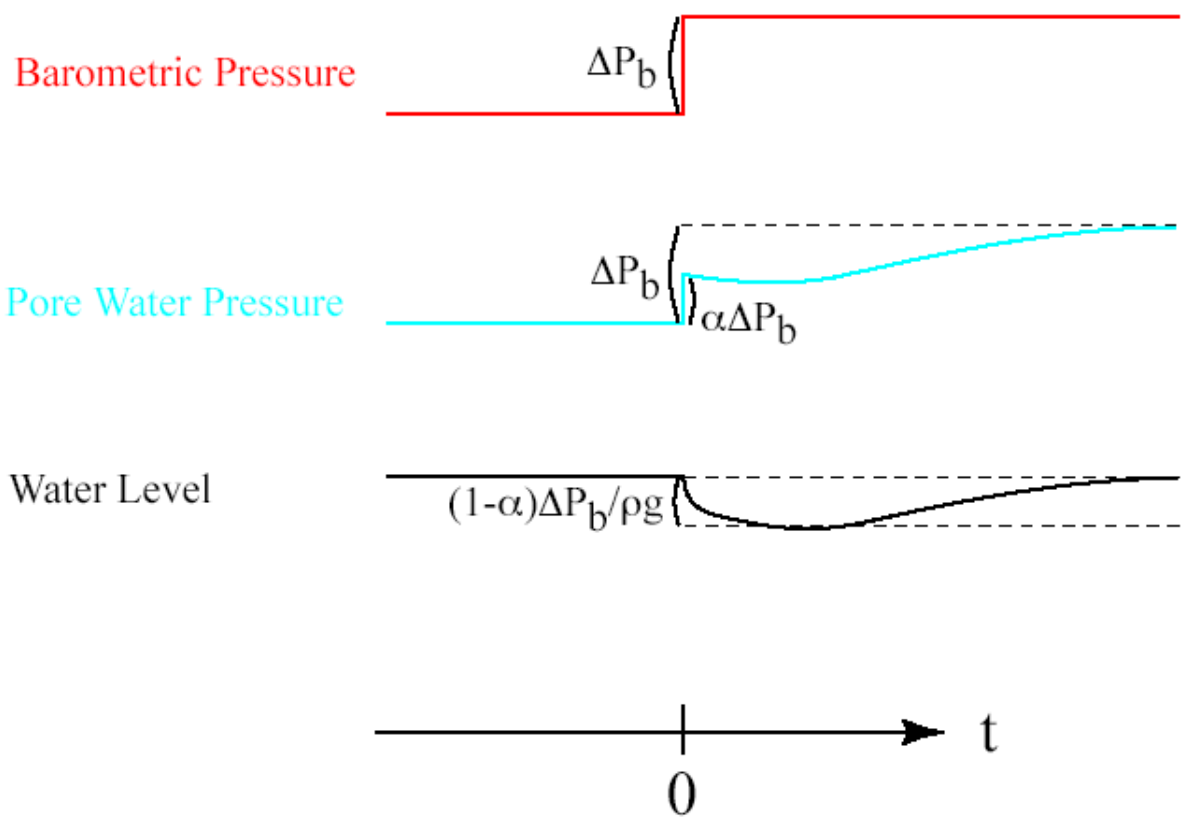
• The effect is characterized as decrease of amplitude ratio and ahead of phase shift.

• The effect is not noticeable at high frequency range.

• The lower the frequency is, the larger the effect is.

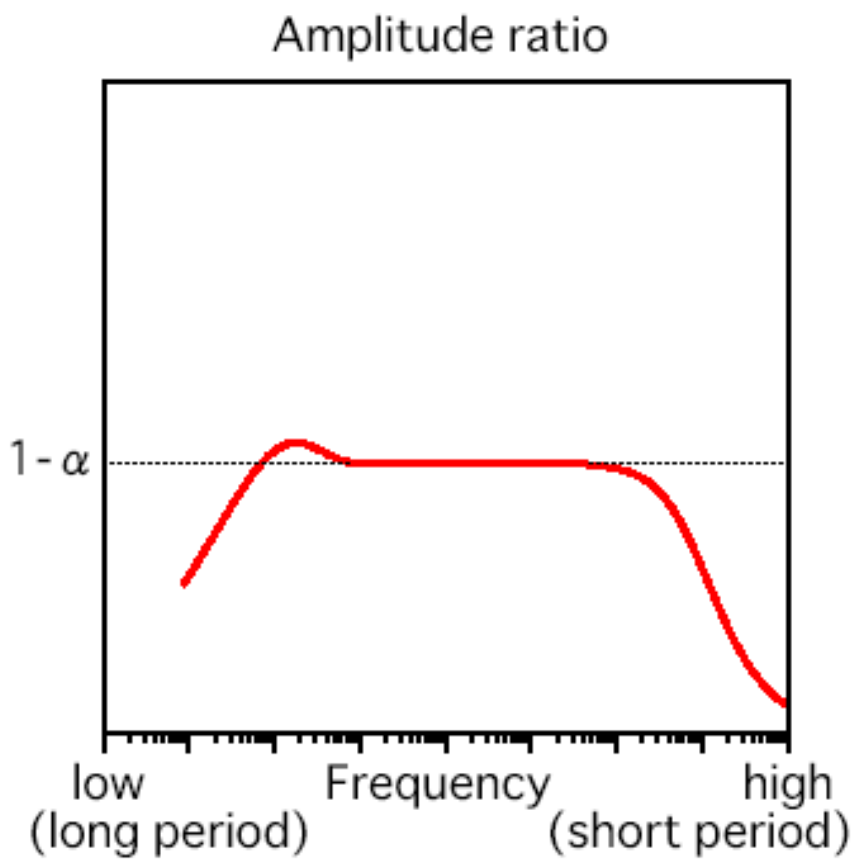
General Barometric Response

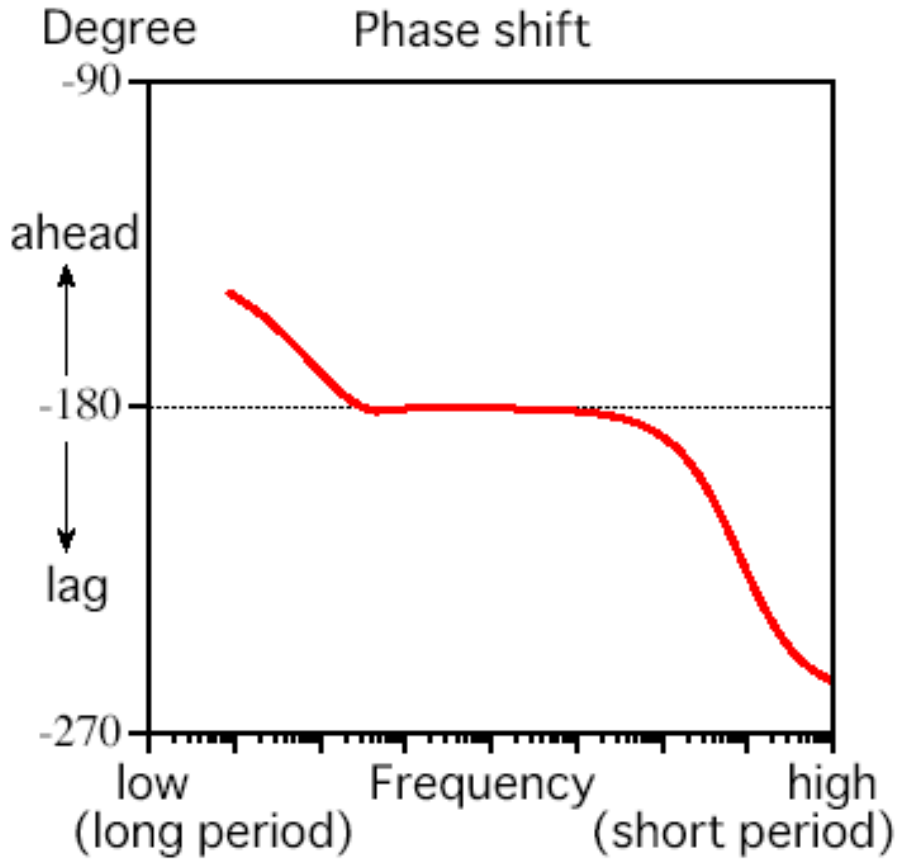
Response for step change of barometric pressure in time domain



General Barometric Response of water level

Response for step change of barometric pressure in frequency domain





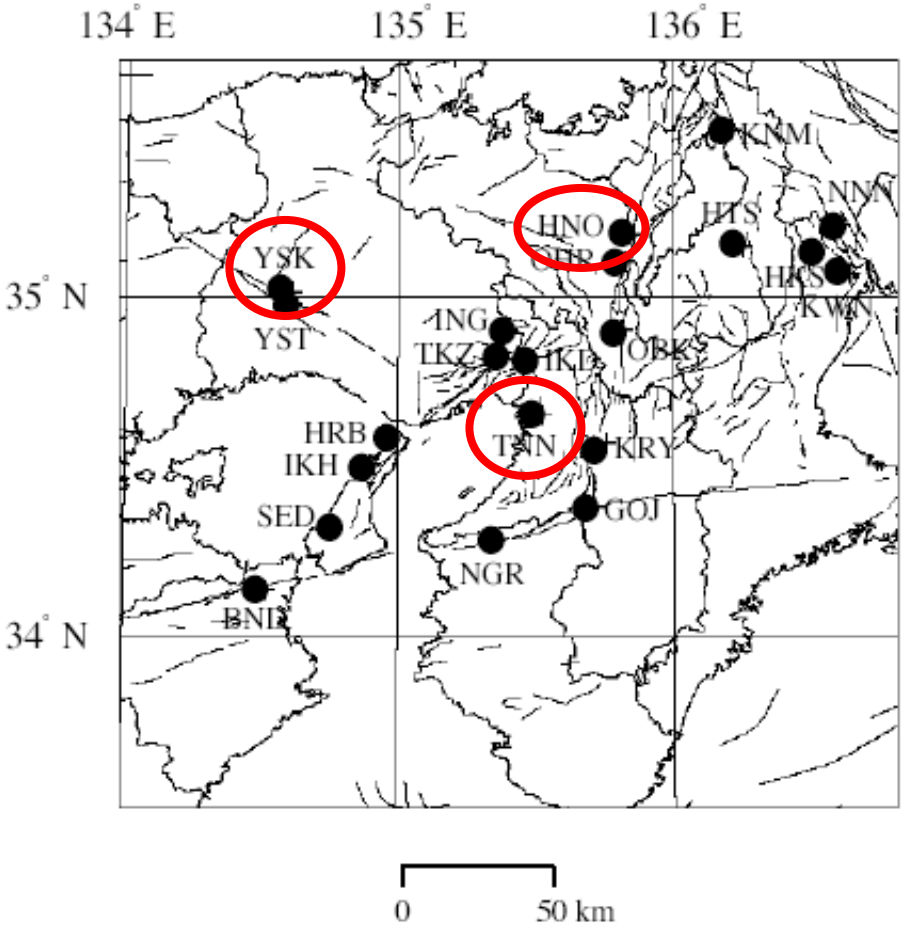
Analysis of observation data

• The barometric response of the groundwater level was estimated using the calculation of the transfer function of the well-aquifer system with input (the barometric pressure) and output (the groundwater level).

• If need be, the rainfall response of the groundwater level was corrected using the Matumoto's (1992) method.

• Using the tidal response and the barometric response, the paramters of the hydraulic characteristics of the well-aquifer system tried to be presumed.

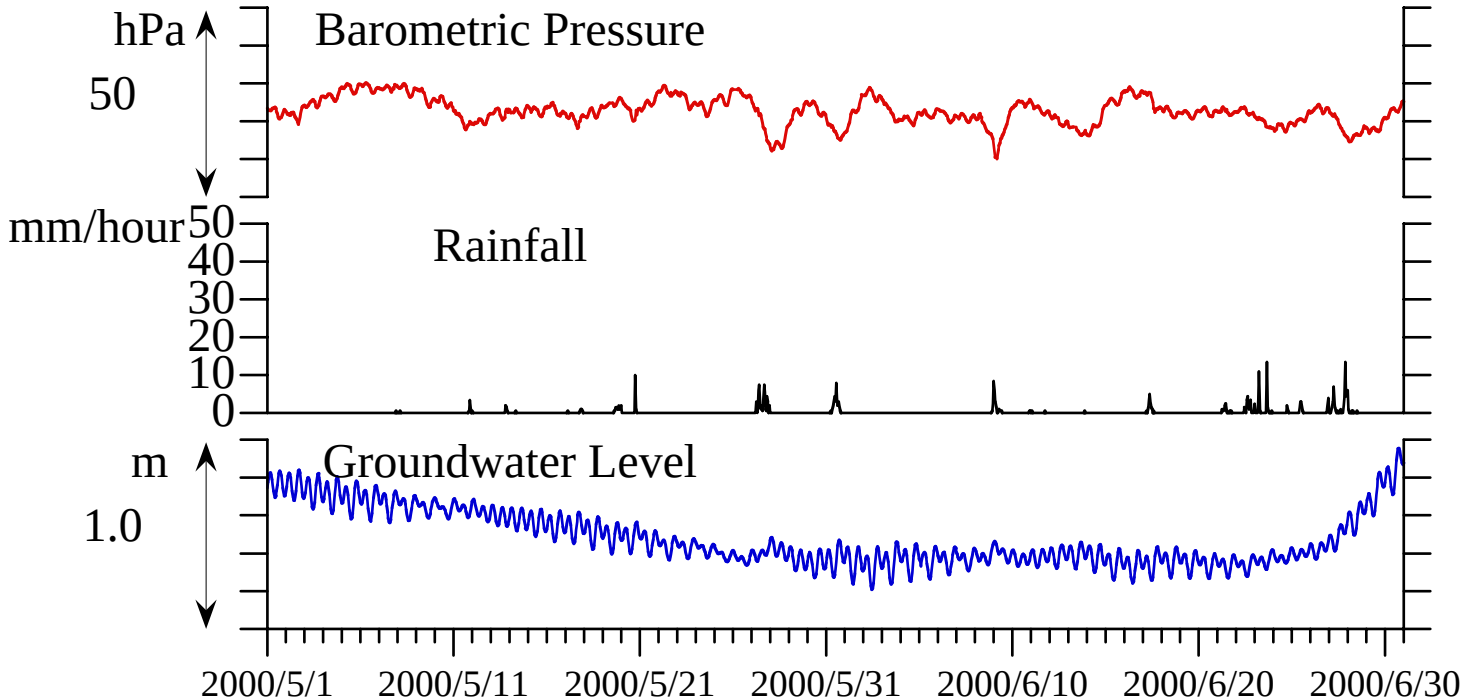
Observation stations in and around the Kinki district



26 wells at 21 observation stations

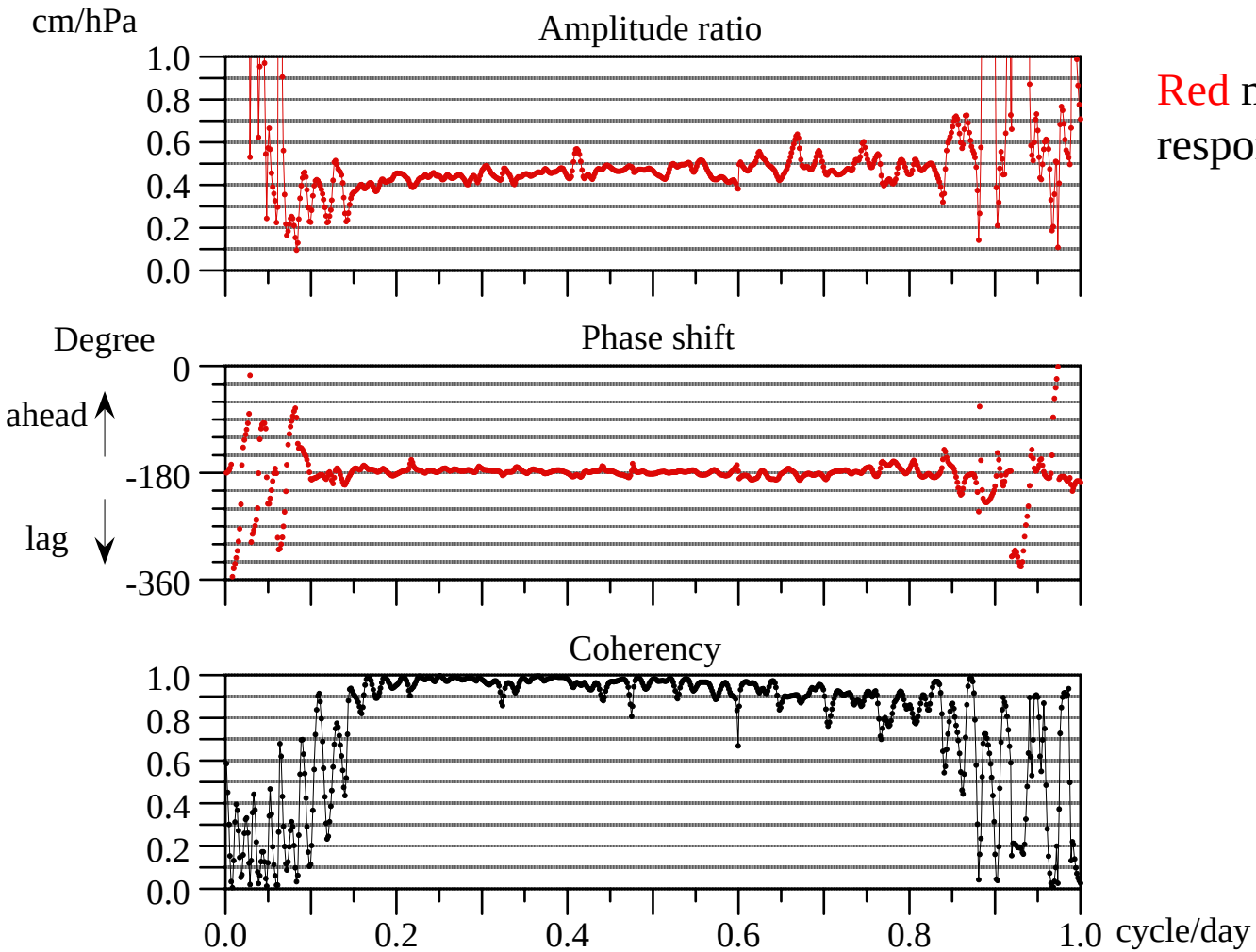
In this report, the results of 3 wells (red ellipses) are shown after this slide.

Result of Well at YSK Station



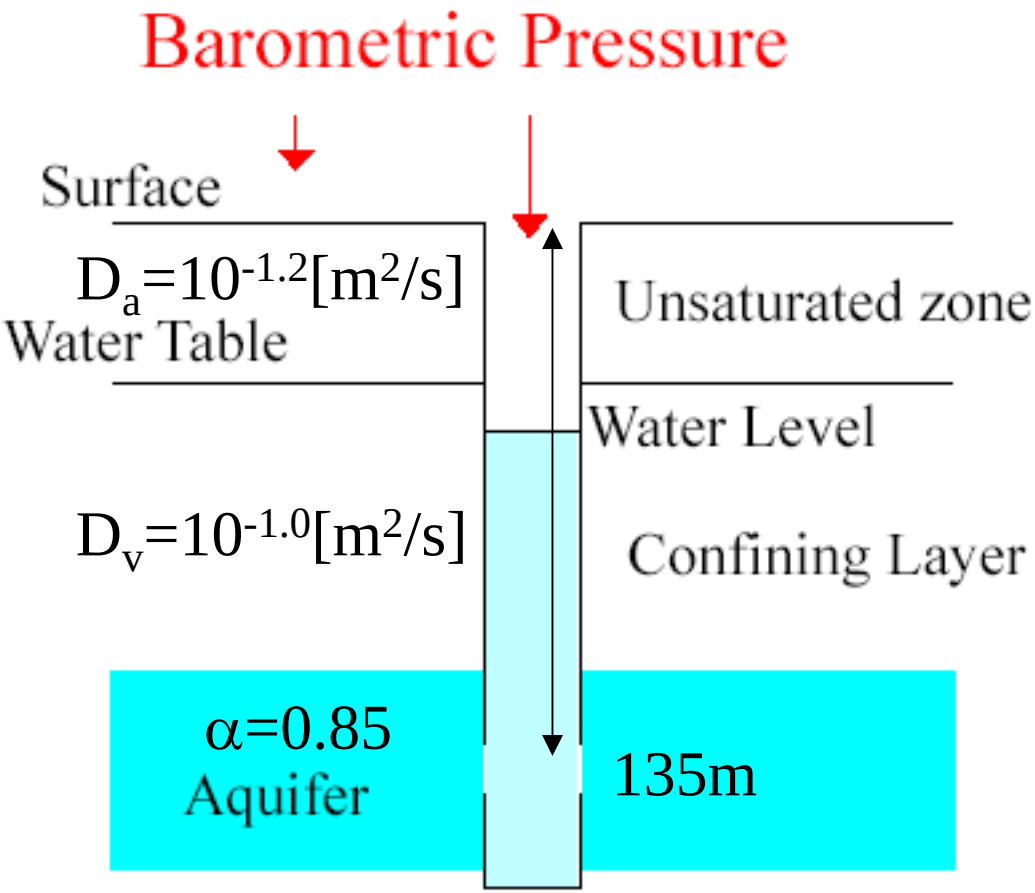
Groundwater level responded to the tide, the barometric pressure and the long-term rainfall.

Barometric Response of Well at YSK Station



Red means the calculated response.

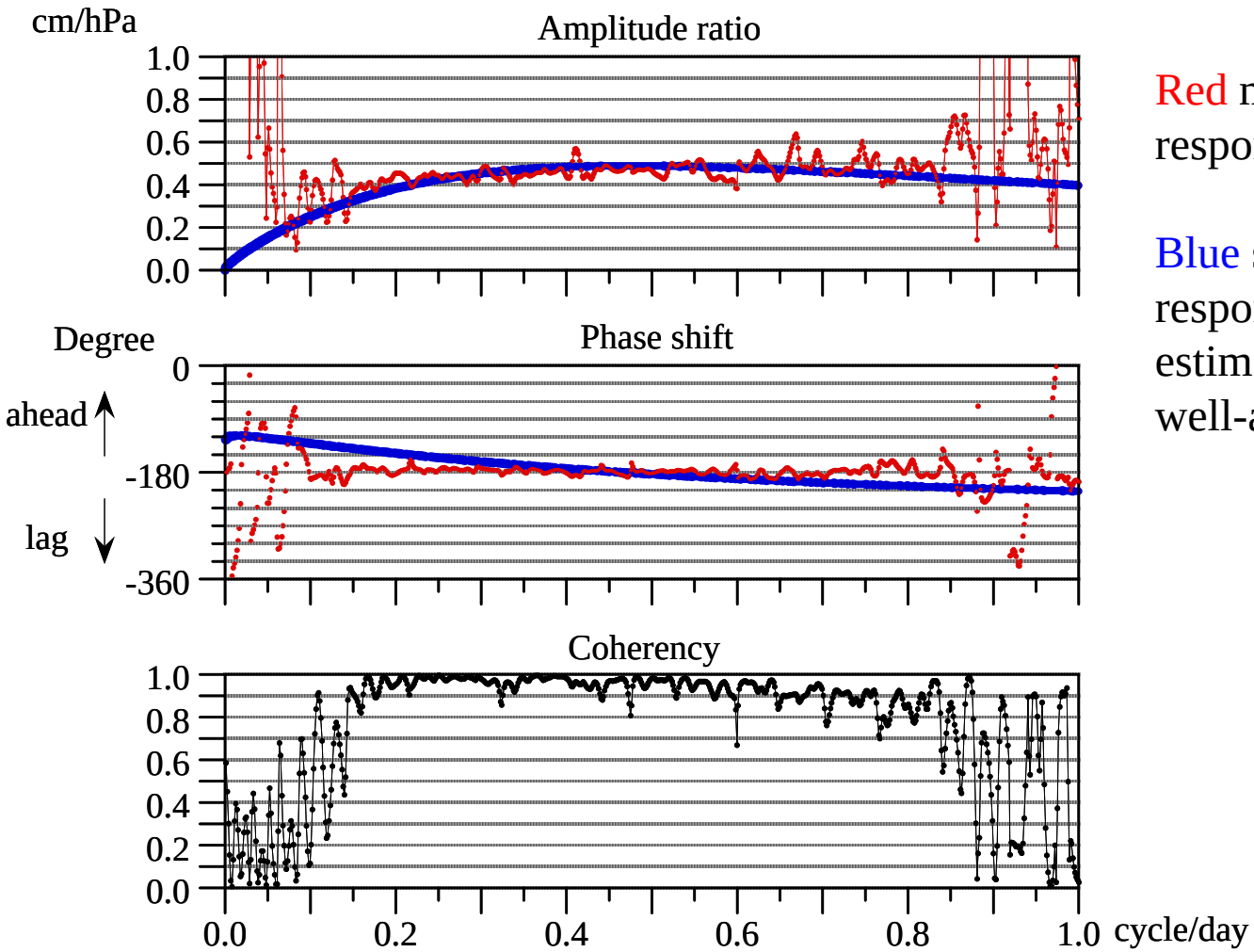
Model of Well at YSK Station



The borehole is sealed.
There is no wellbore storage.

Strain sensitivity of the aquifer is $40.0[mm/10^{-8}strain]$.

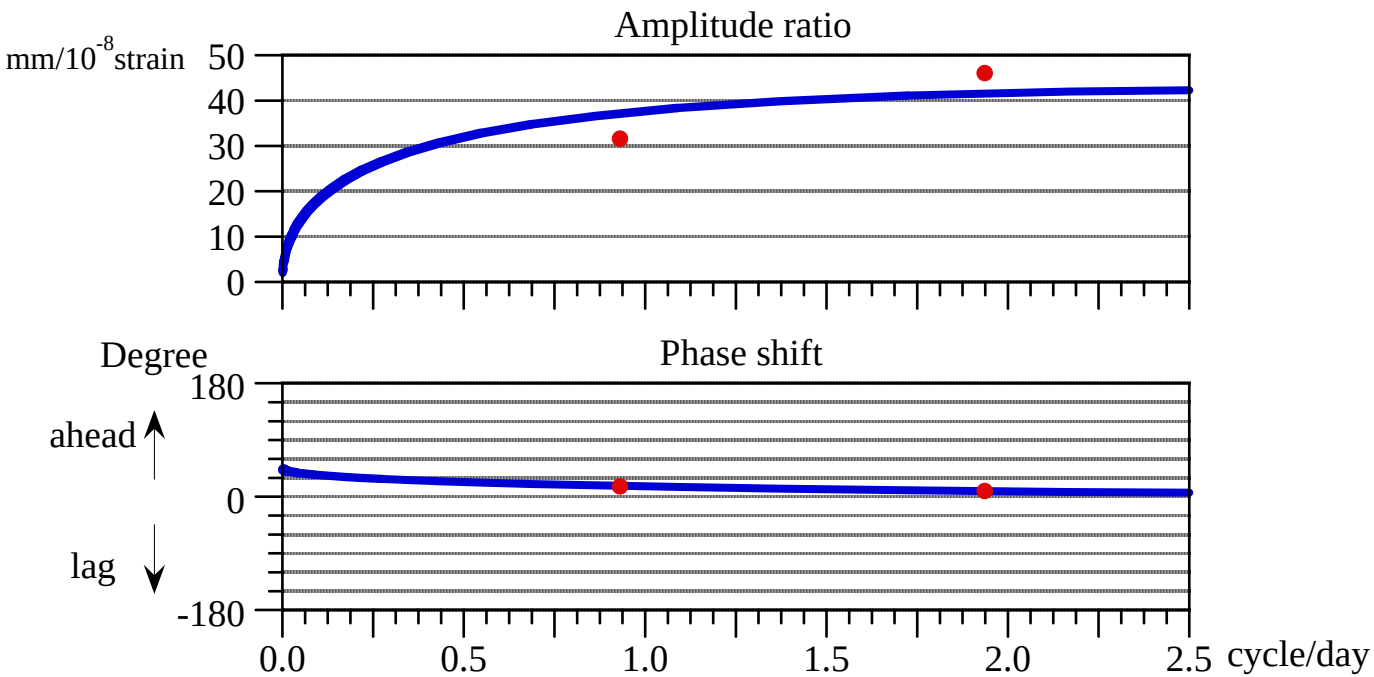
Barometric Response of Well at YSK Station



Red means the calculated response.

Blue shows the predicted response based on the estimated parameters of well-aquifer system.

Strain Sensitivity of Well at YSK Station

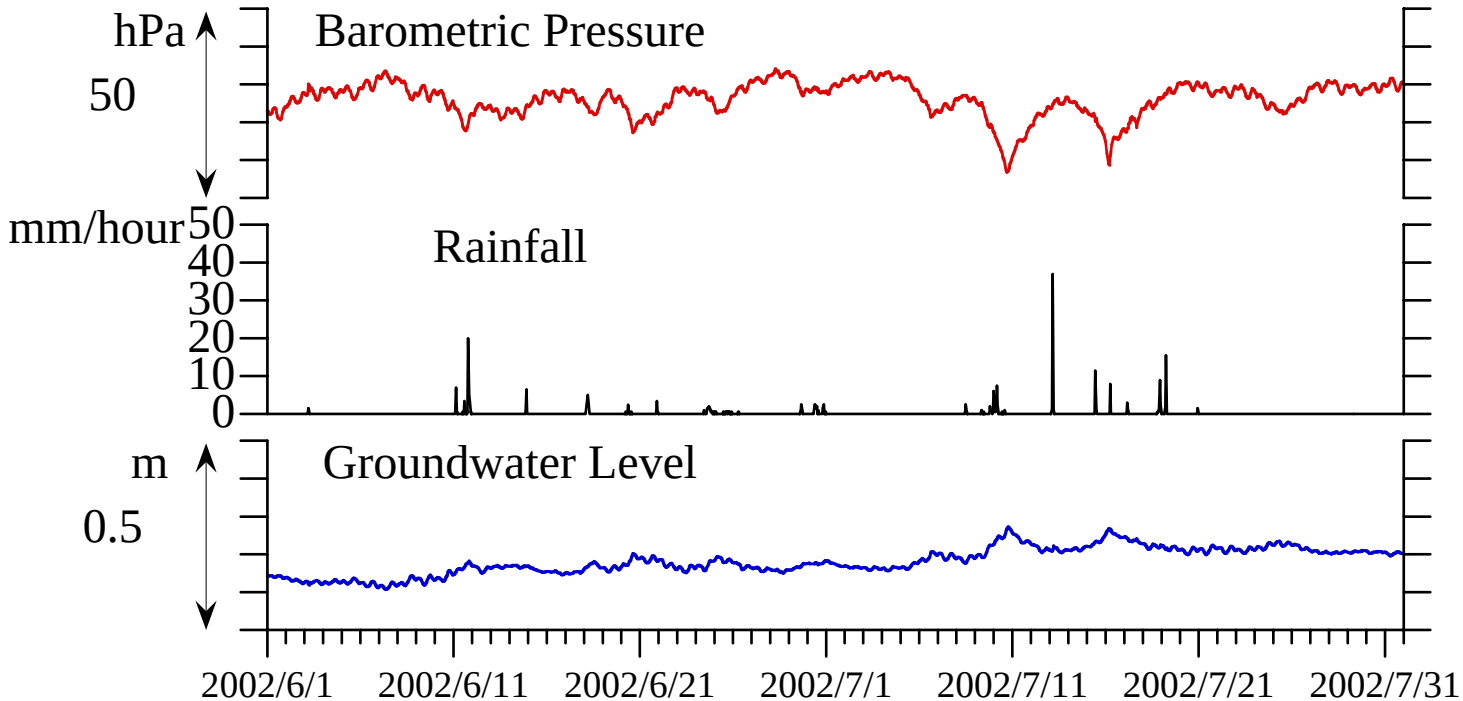


Characteristics of Well at YSK Station

- At low frequency, amplitude ratio of the barometric response decreases.

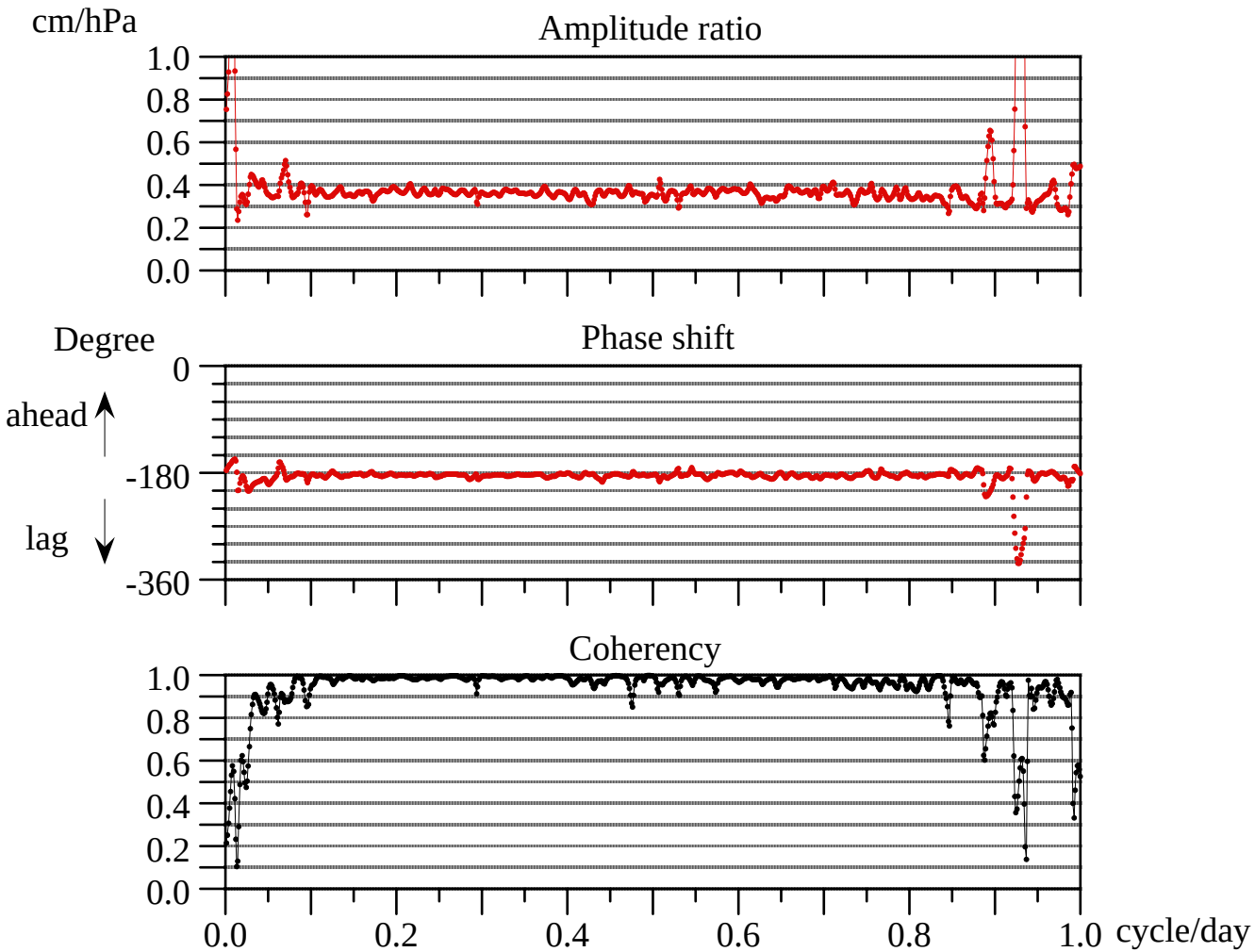
- This fact means the leakage from the aquifer due to the partial confining layer.

Result of Well at TNN Station

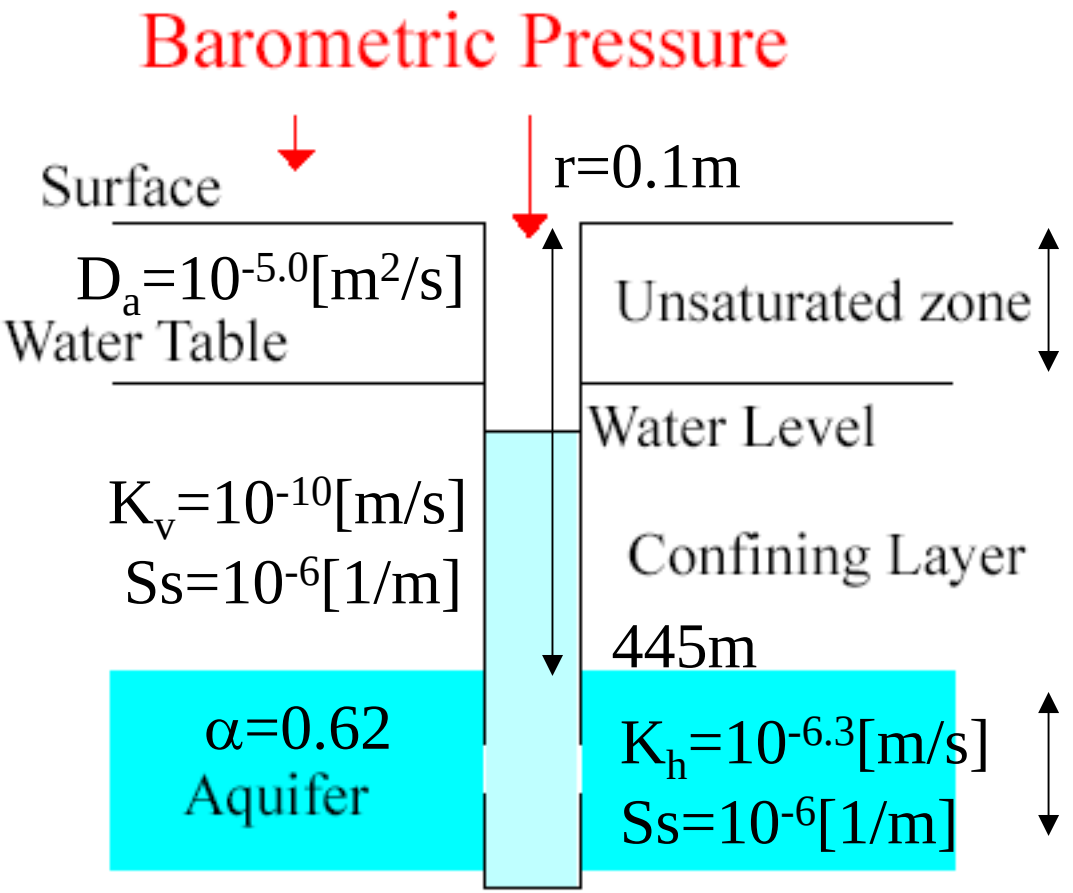


Groundwater level responded to the tide and the barometric pressure and did not respond to the rainfall in the short-term.

Barometric Response of Well at TNN Station

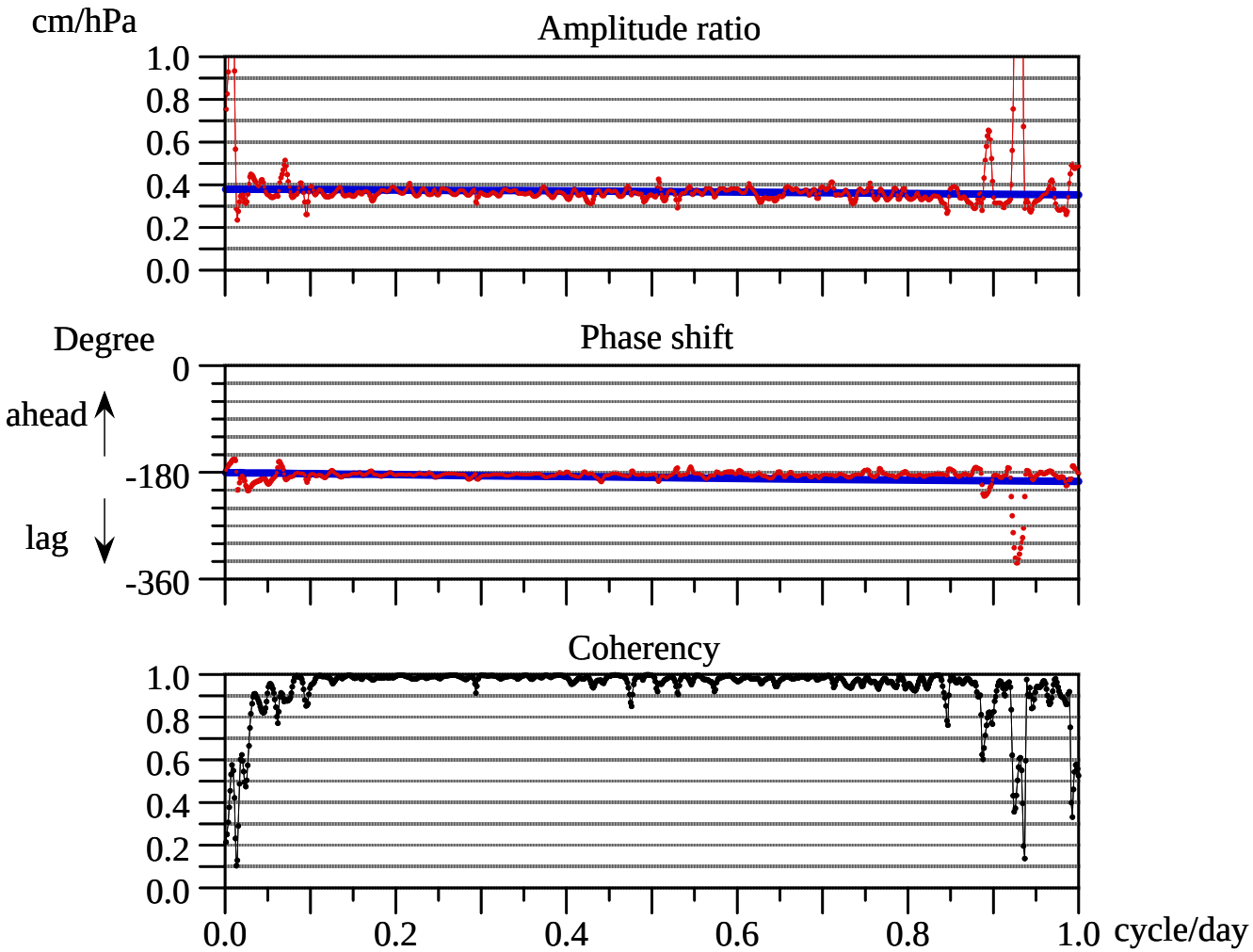


Model of Well at TNN Station

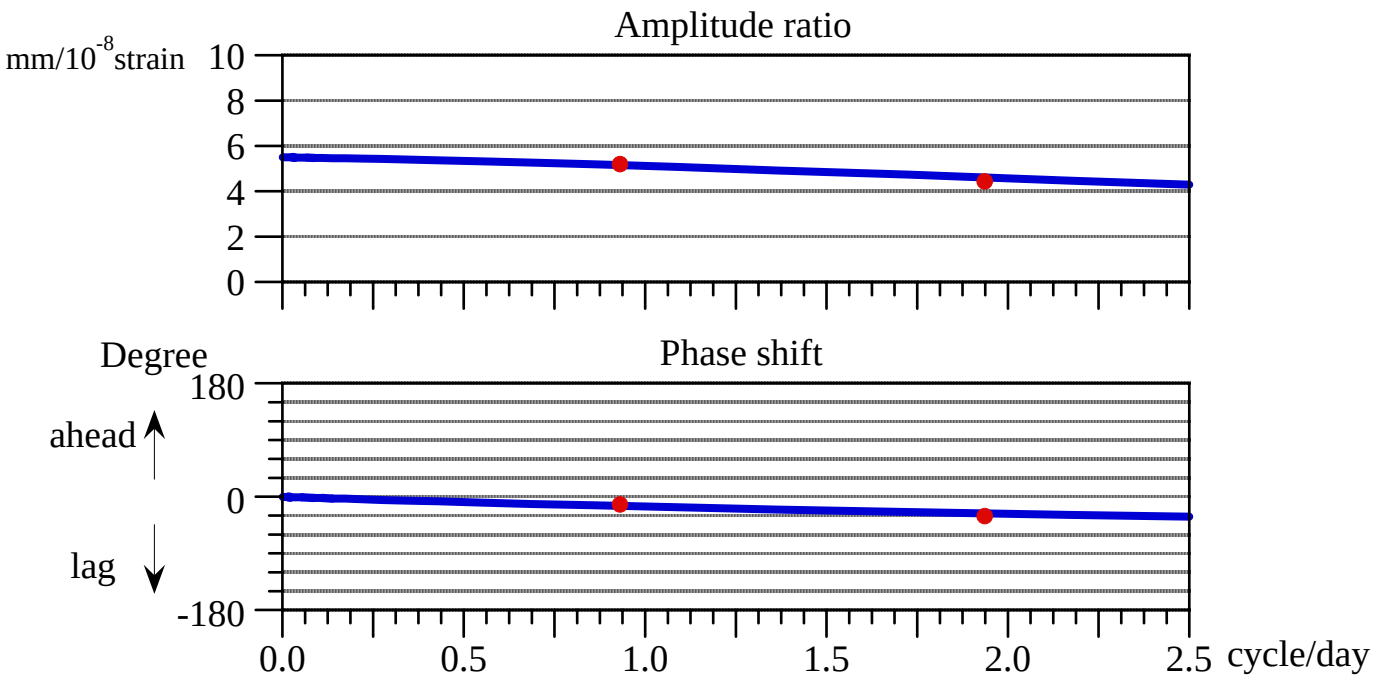


Strain sensitivity of the aquifer is $5.5[mm/10^{-8}strain]$.

Barometric Response of Well at TNN Station



Strain Sensitivity of Well at TNN Station



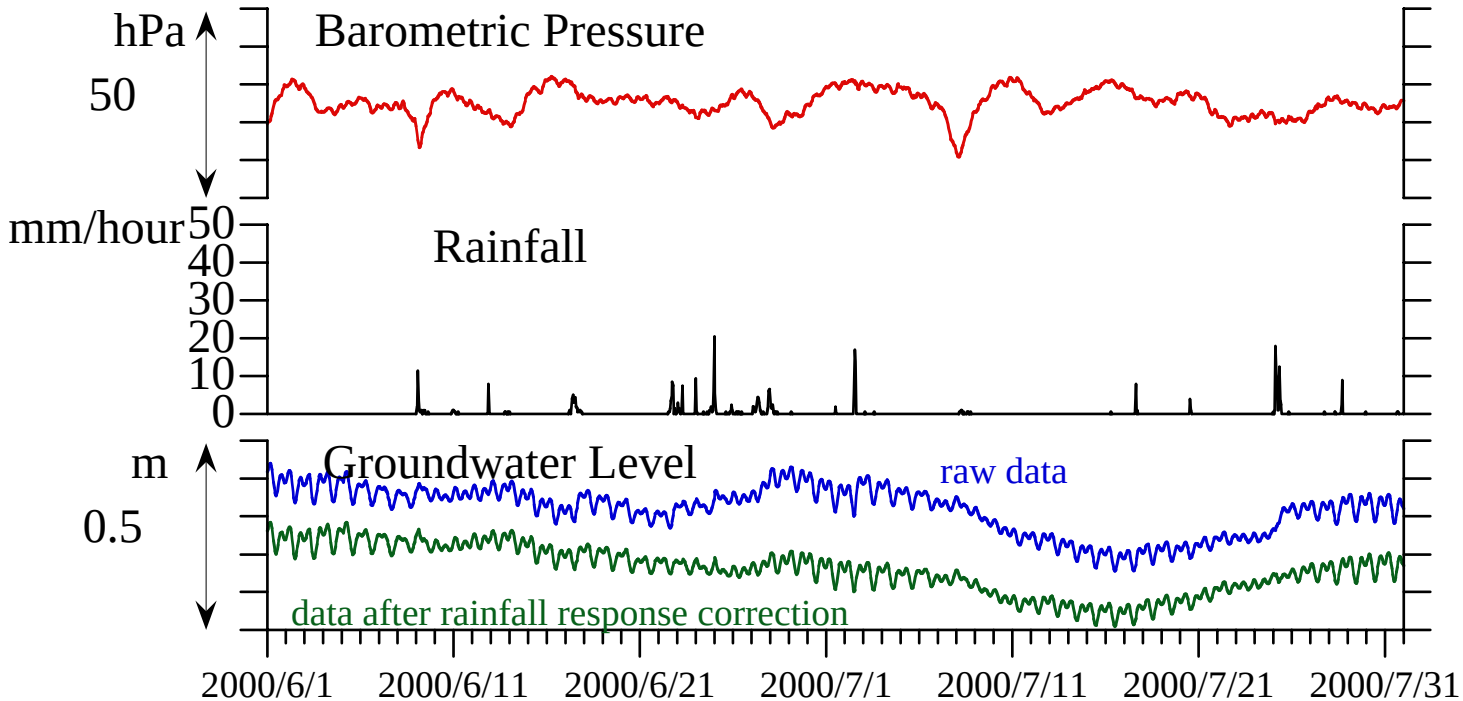
Characteristics of Well at TNN Station

- Amplitude ratio of the barometric response is roughly flat.

- This fact means little leakage from the aquifer due to the good confining layer.

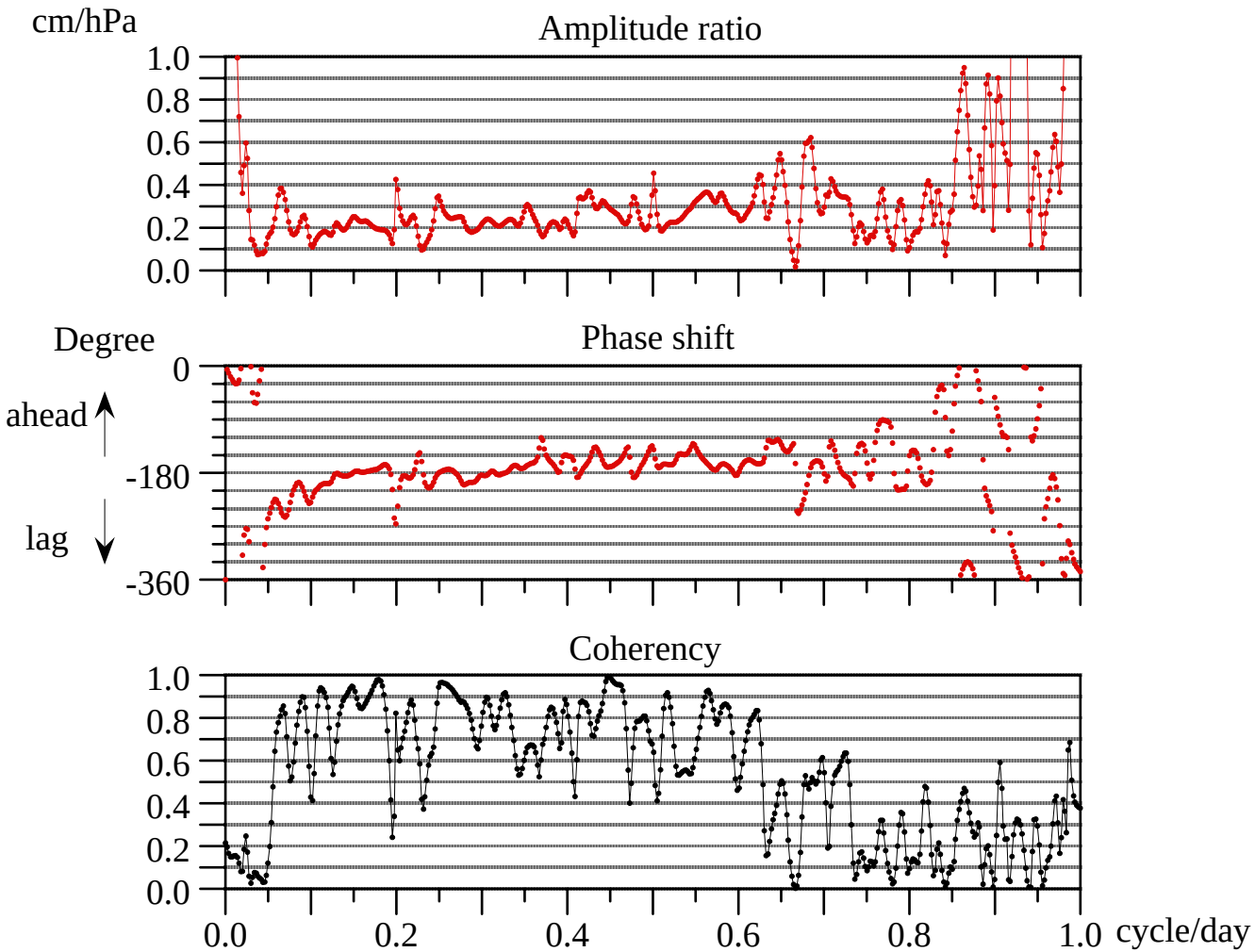
- The wellbore storage slightly affects.

Result of Well at HNO Station

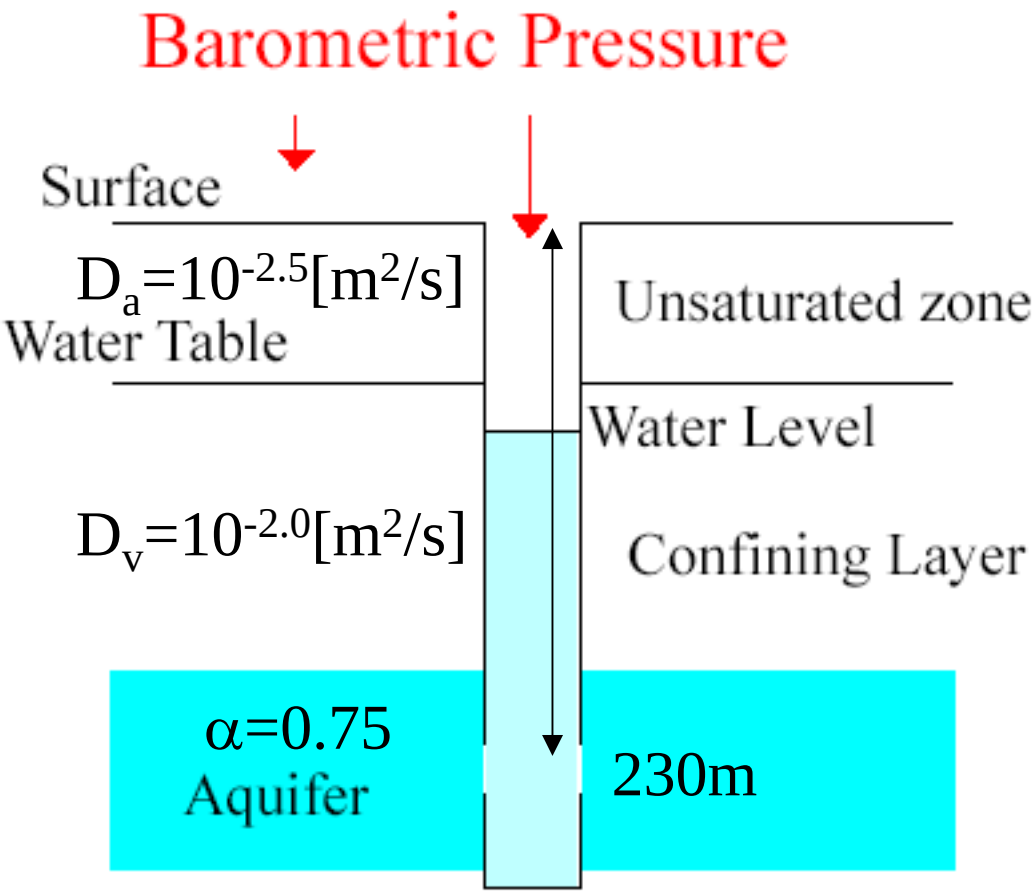


Groundwater level responded to the tide, the barometric pressure and the rainfall.

Barometric Response of Well at HNO Station



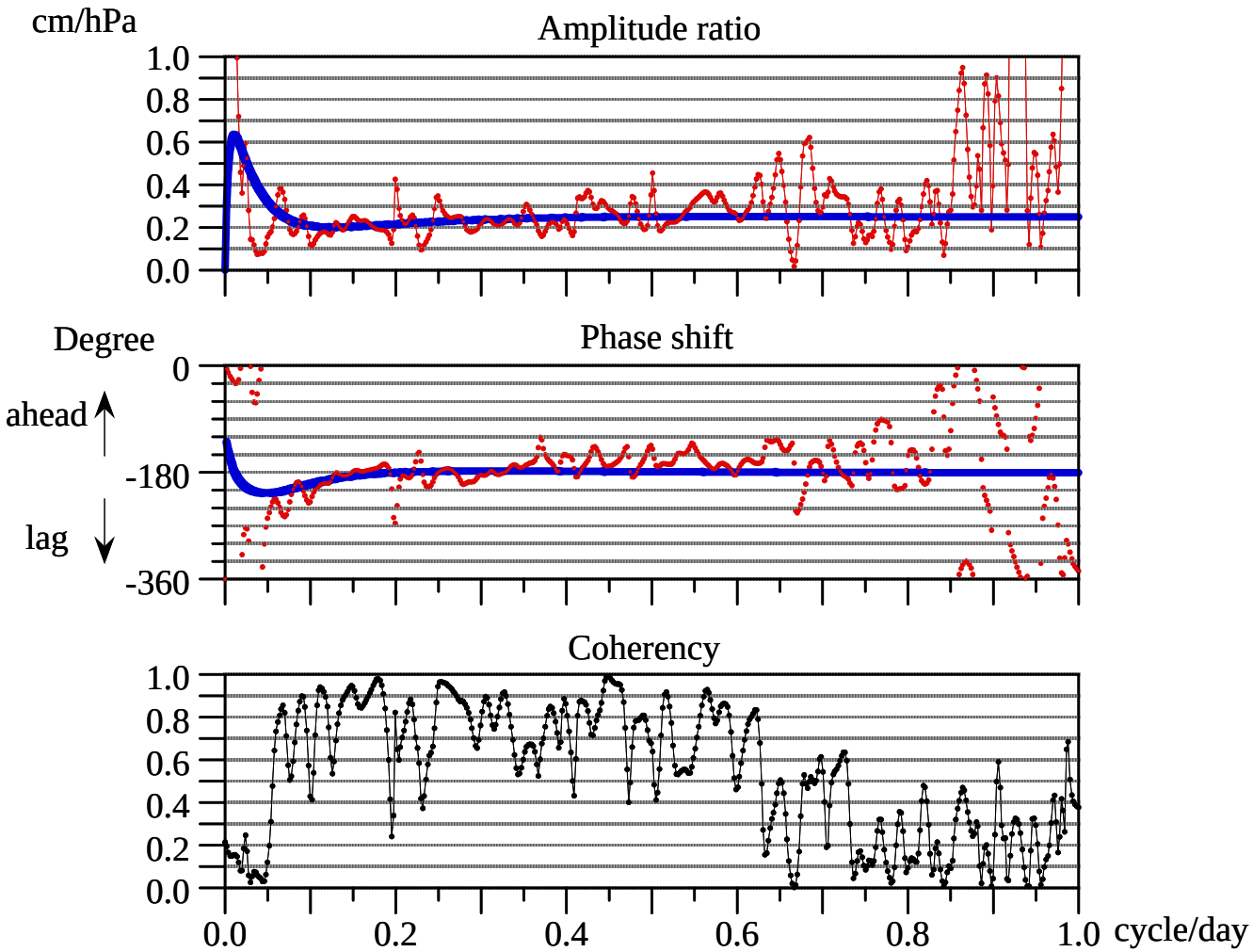
Model of Well at HNO Station



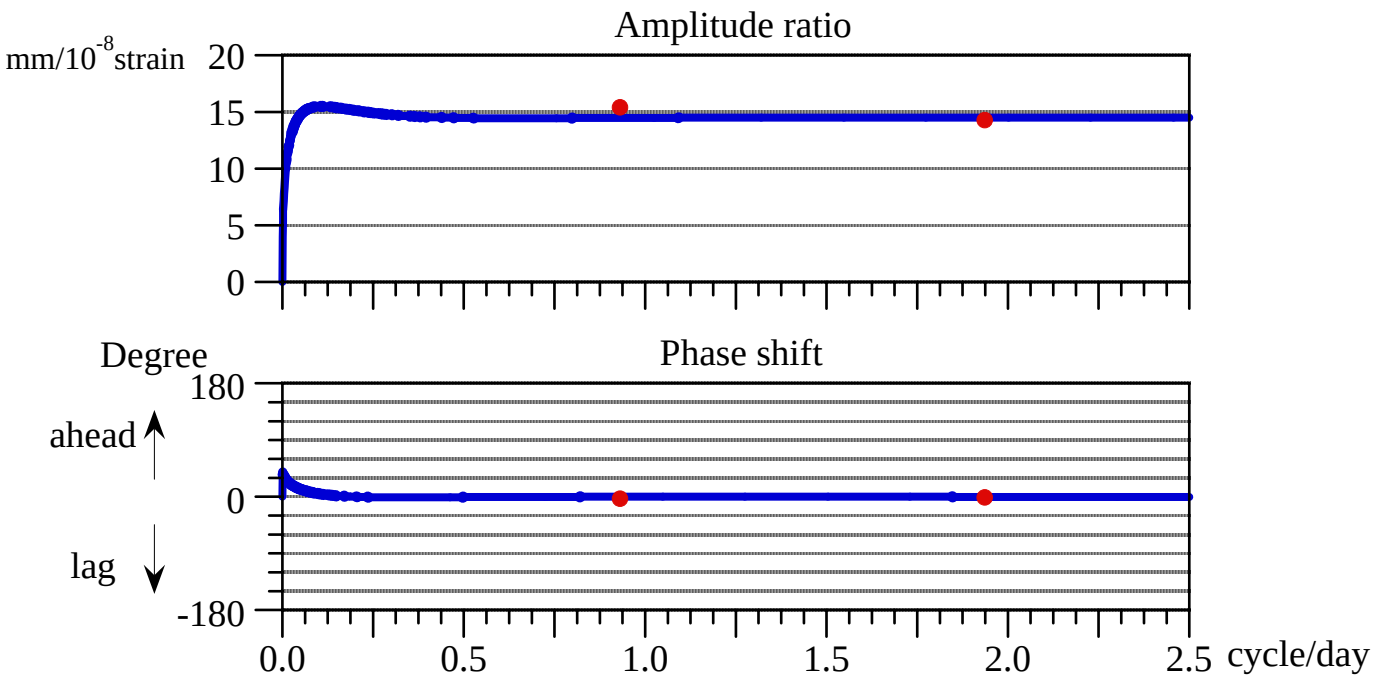
The borehole is sealed.
There is no wellbore storage.

Strain sensitivity of the aquifer is $14.5[mm/10^{-8}strain]$.

Barometric Response of Well at HNO Station



Strain Sensitivity of Well at HNO Station



Characteristics of Well at HNO Station

- The rainfall response of the groundwater level was not enough corrected.

- At low frequency, amplitude ratio of the barometric response slightly decreases.