

Relationship between groundwater, hydrology and water use in lower north region of Thailand

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Abstract Groundwater is an alternative water resource in addition to the widely used surface water. If the groundwater is used excessively more than the groundwater safe yield, it will cause the groundwater to decline continuously and increase the cost of groundwater pumping. This study was carried out to investigate the status of groundwater in the lower north region of Thailand covering three provinces such as Sukhothai, Phitsanulok and Phichit, located in Yom and Nan river basins. The provinces are important agricultural areas of rice production and often pump the groundwater for conjunctive use along with the surface water. The study was done to determine the trend of groundwater and the relationships between the groundwater levels and the related factors such as the river water levels and the water uses in the areas. It is found that the trend of groundwater levels was to decline on the average of 0.69m./year in Sukhothai, 0.37m./year in Phitsanulok and 0.46m./year in Phichit, indicating the excessive groundwater uses. The groundwater levels were found to be closely related to the rainfall amounts and Yom and Nan river water levels, showing the role of recharging the groundwater. Also, the groundwater levels were related to the groundwater uses. The water demands, water uses and water resources within the three provinces were studied. The total average annual water demand was 3,765 million cum., dividing into Sukhothai as 30.9%, Phitsanulok as 43.1% and Phichit 26%. The water demand was classified according to the different uses such as the agriculture as 75.4%, the ecology as 17%, the consumption as 7% and the industry as 0.6%. The water resources to meet the water demands were obtained from the effective rainfall as 43.6%, the surface water resource as 42.7% and the groundwater resource as 13.7%.

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I. INTRODUCTION

Groundwater is a natural water resource in addition to the surface water such as surface runoff, reservoirs, ponds including rainfall. In general, the surface water is used as the primary water resource while the groundwater is used as a supplementary one. The lower north region of Thailand covering three provinces such as Sukhothai, Phitsanulok and Phichit, located in Yom and Nan river basins is the location of important agricultural areas of rice production. The water uses are supplied from both surface water and groundwater. The surface water depends on the runoff in Yom and Nan rivers. However, about the availability of large storage reservoir in the upstream of the two river basins, there is only one large reservoir, namely Sirikit reservoir, in the Nan river basin but none in the Yom river basin. This causes the limitation of surface water frequently in the dry seasons. Tuantan studied and found that in the central plain basin covering the three provinces, the water deficit has occurred in the past (1979-2006) and expected to occur continuously in the near future(2015-2039) and far future(2075-2099) due to the excessive water demand and the impact of climate change [1]. Accordingly, there has

been often the withdrawal of groundwater particularly for rice cropping requiring a large amount of water. The withdrawal of groundwater may exceed the potential or safe groundwater yield, causing the groundwater to decline continuously for many years. From the study result by the Department of Groundwater Resources of Thailand [2], it was found that in the lower north region covering Sukhothai, Phitsanulok and Phichit provinces during the recent decade, the groundwater levels decline continuously on the average of 0.10 – 0.25 m./year, causing the groundwater levels in the critical areas to be the depth of more than 8 m. below the ground surface and then affecting the cost of pumping groundwater. Also, Tuantan and Athit found the trend of groundwater level decline in Sukhothai [3] and Phitsanulok[4]. Therefore, this study was carried out to investigate the trend of groundwater levels, the relationship between the groundwater levels and Yom and Nan river levels and the groundwater uses. The study result can be utilized to find the appropriate mitigation measures to alleviate and solve the problem of the groundwater decline in the future.

II. OBJECTIVES

The objectives of this study are to determine

- 1) the statistics and trend of groundwater levels
- 2) the relationship between the groundwater levels and Yom and Nan river levels
- 3) the relationship between the groundwater levels and the groundwater uses

III. STUDY AREA

The study area is located in the lower north region of Thailand covering three provinces such as Sukhothai, Phitsanulok and Phichit, located in Yom and Nan river basins as shown in Fig. 1. Figure 1 also shows the location of groundwater observation wells and Yom and Nan rivers.

IV. METHODOLOGY

- 1) The water uses were determined in four sections such as agriculture, ecology, industry and consumption.

- 2) The water resources were determined in three sources such as effective rainfall, surface water resource and groundwater resource.
- 3) The data were analyzed in monthly time scale during the years 2007 - 2014.
- 4) The statistical analysis was applied to determine the average, drawdown, recovery and trend of the groundwater levels.
- 5) The graphs of plotting the related parameters were developed to determine the relationships.
- 6) The groundwater level data were obtained from the observation wells of the Department of Groundwater Resources [5].
- 7) The Yom and Nan river level data were obtained from the Royal Irrigation Department [6].
- 8) The rainfall data were obtained from the Meteorological Department [7].
- 9) The agricultural cropping area data were obtained from the Department of Agricultural Extension [8].
- 10) The industrial water use data were obtained from the Hydro and Agro Informatics Institute [9].
- 11) The household water consumption data were obtained from the Provincial Waterworks Authority [10].

V. RESULT AND DISCUSSION

A. *Statistic and trend of groundwater levels*

Fig.2 shows the time series of groundwater levels, Yom and Nan river levels in Phitsanulok province. The groundwater levels varied with time throughout each year, increasing in the rainy seasons and decreasing in the dry seasons. In addition, the groundwater levels varied according to the Yom and Nan river levels. Table 1 shows the summary of groundwater depth below the ground surface in the year 2013, annual groundwater drawdown, annual groundwater recovery and the rate of groundwater level decline in the observation wells in Sukhothai, Phitsanulok and Phichit provinces during the years 2007-2014. It is found that

- a) The groundwater depth was maximum in Sukhothai as 18.27 m. while the groundwater depths in Phitsanulok and Phichit provinces were 9.90 m. and 12.17 m. respectively. This result indicates that Sukhothai encountered the most

cost of pumping groundwater while Phitsanulok had the most shallow groundwater depth due to gaining more water from the two rivers to supply surface water and recharge the groundwater.

- b) The groundwater drawdown was due to groundwater withdrawal while the groundwater recovery was due to groundwater recharge. The annual groundwater drawdown and recovery depths were maximum in Phichit, indicating the most vulnerability of groundwater due to the limitation of groundwater storage.
- c) The rate of groundwater level decline was maximum Sukhothai as 0.69m./year, indicating the groundwater use much exceeding the safe yield of groundwater storage.

B. Relationship between the groundwater levels and Yom and Nan river levels

Fig. 2 shows the variation of the monthly groundwater levels compared to Yom and Nan river levels in Phitsanulok province. It is found that the groundwater levels varied according to the Yom and Nan river levels in the dry and rainy seasons in each year. In addition, the groundwater levels were more affected by the Nan river levels than the Yom river levels due to the reason that the Nan river is larger and has more runoff than the Yom river.

C. Relationship between the groundwater levels, groundwater drawdown, and groundwater uses

1) Water demands

Table 2 shows the annual water demands for various water use sections in Sukhothai, Phitsanulok and Phichit provinces. Also, the water demands were determined in term of proportions as the percentage of the total water demand in each province and each water use section. It is found that

- a) The total average annual water demand was 3,765 million cum., dividing into Sukhothai as 30.9%, Phitsanulok as 43.1% and Phichit as 26%. The result shows that Phitsanulok had the most water demand, considerably more than those of Sukhothai and Phichit.
- b) The water demand was classified according to the different sections of water uses such as the agriculture as 75.4%, the ecology as

17%, the consumption as 7% and the industry as 0.6%. The result shows that the agriculture was the section requiring the most water demand as much as 3/4 of the total water demand, significantly much more than those of the other sections as summed up as 1/4 of the total water demand.

2) Water resources

Fig.3 shows the time series of annual water uses from rainfall, surface water and groundwater in Phitsanulok province. It is found that

- a) The water resources from the rainfall significantly affected the total water use in each year. The total water use varied according to the rainfall amount. The water use was large as occurred in the wet year 2011 and decreased as occurred in the dry year 2014.
- b) The rainfall and the surface water were the major and fundamental water resources for the water uses and significantly much more than the groundwater.
- c) The groundwater resource was used as the supplementary water to the rainfall and the surface water when the available surface water resource was insufficient.

3) Relationship between the groundwater level and groundwater use

Fig.2 shows the monthly groundwater levels while Fig.3 shows the annual groundwater uses in Phitsanulok province. It is found that the groundwater levels varied inversely with the groundwater uses such that the low groundwater levels occurred in the same years as the large groundwater uses. As occurred in the dry year 2013, the large groundwater use lowered the groundwater level significantly. Oppositely, as occurred in the wet year 2011, much less groundwater use little lowered the groundwater level. This result shows that the groundwater use affected the groundwater level.

4) *Relationship between the groundwater drawdown and groundwater use*

Fig.2 shows the monthly groundwater drawdown depths while Fig.3 shows the annual groundwater uses in Phitsanulok province. The groundwater drawdown depth is defined as the lowering depth of the groundwater level from maximum level to minimum level in each year cycle before changing to recover or increase. It is found that the groundwater drawdown depths varied along with the groundwater uses such that the more groundwater use, the more groundwater drawdown. The large groundwater drawdown depths occurred in the same years as the large groundwater uses, as occurred in the dry year 2013. Oppositely, as occurred in the wet year 2011, little groundwater use caused little groundwater drawdown. This result shows that the groundwater use affected the groundwater drawdown.

VI. CONCLUSION

- a) The groundwater levels in the three provinces had trends to decline continuously, causing the increase of depths of groundwater levels in the wells and the cost of pumping the groundwater for use.
- b) The groundwater levels varied according to the Yom and Nan river levels.
- c) The total average annual water demand was 3,765 million cum., dividing into Sukhothai as 30.9%, Phitsanulok as 43.1% and Phichit 26%. The water demand was classified according to the different uses such as the agriculture as 75.4%, the ecology as 17%, the consumption as 7% and the industry as 0.6%.
- d) The water resources to meet the water demands were obtained from the different sources such as the effective rainfall as 43.6%, the surface water resource as 42.7% and the groundwater resource as 13.7%.
- e) The groundwater levels varied inversely with the groundwater uses. The large groundwater uses caused the groundwater levels to decline. The continuous decline of groundwater levels indicated that the groundwater uses in the past exceeded the potential or safe yield of the groundwater resources in the areas.

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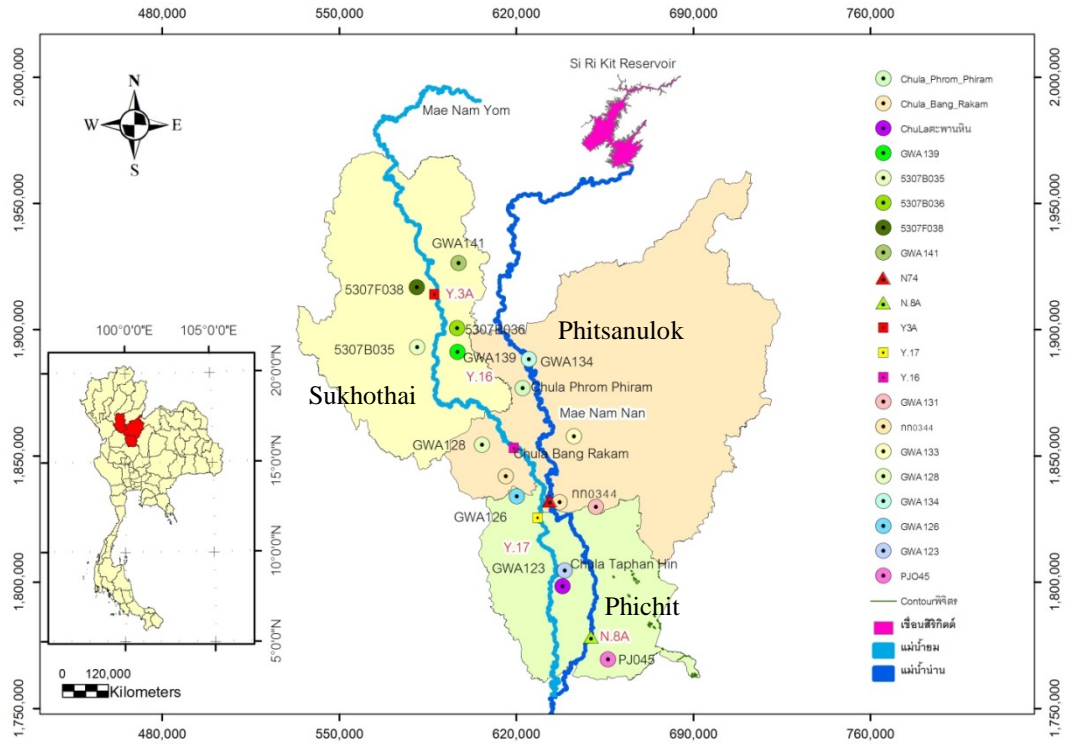


Fig 1. Map of three provinces, two rivers and groundwater observation wells

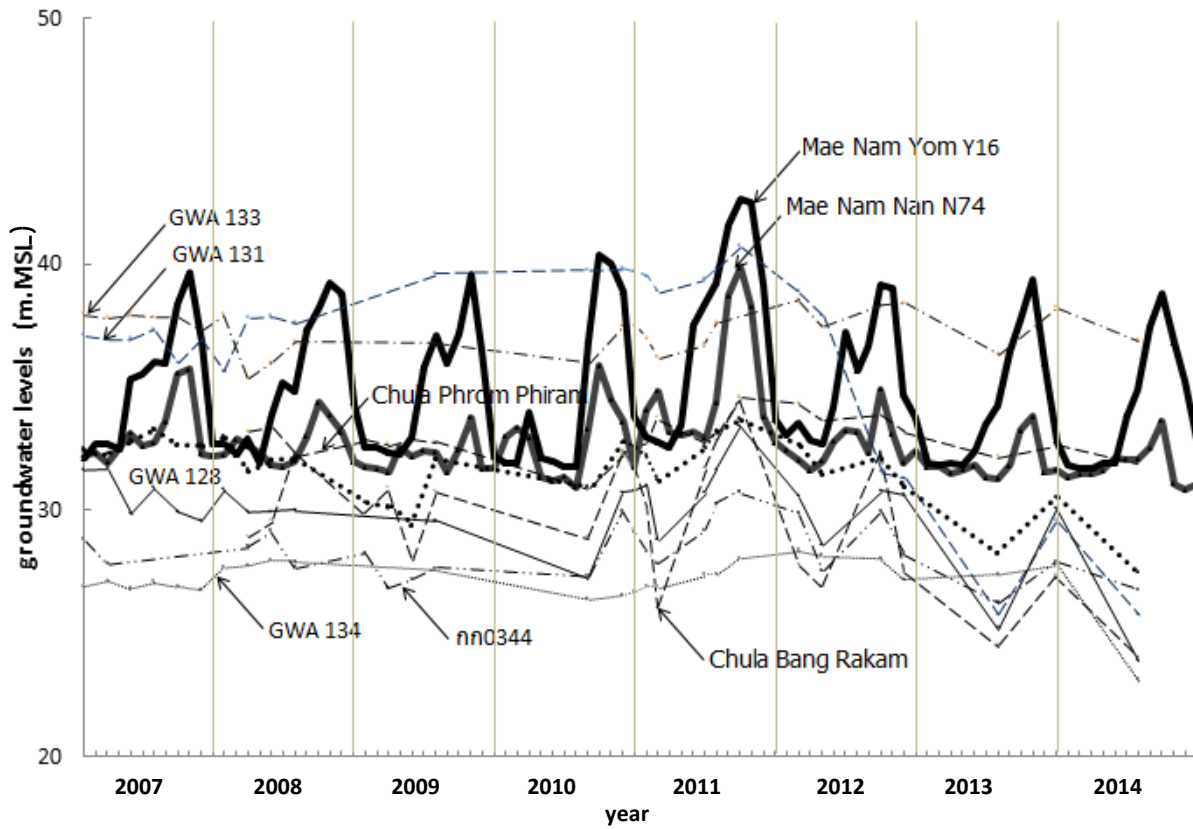


Fig 2. Time series of groundwater levels and river water levels in Phitsanulok province

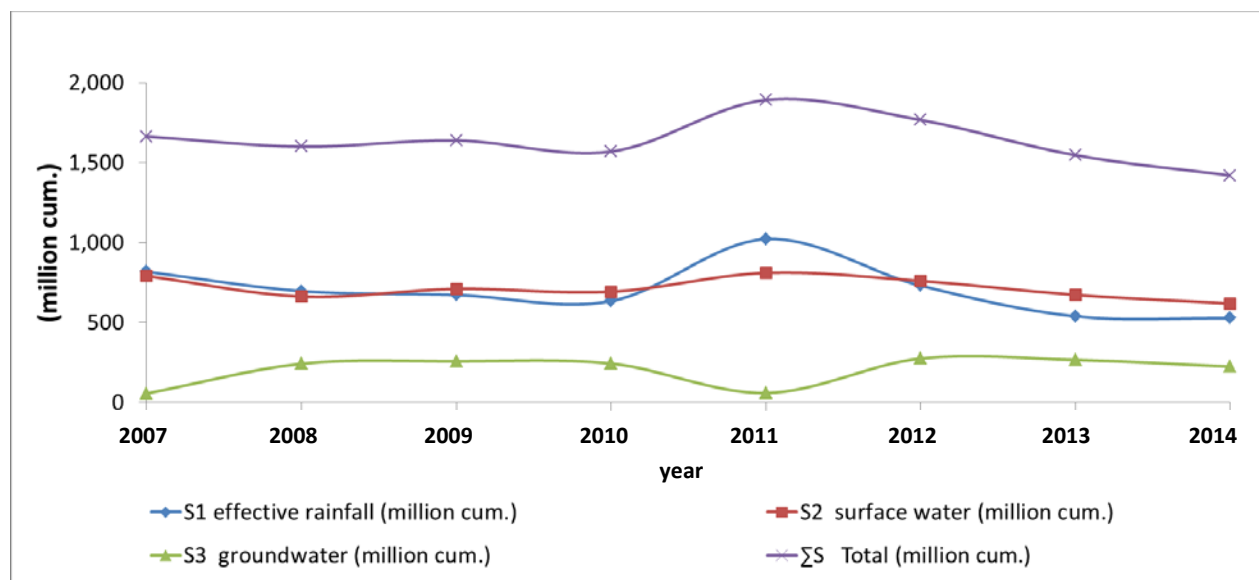


Fig 3. Time series of water uses from rainfall, surface water and groundwater in Phitsanulok province

TABLE 1 Groundwater depth, drawdown depth, recovery depth, rate of groundwater level decline

No	item	Sukhothai	Phitsanulok	Phichit
1	groundwater depth below ground surface in year 2013 (m)	18.27	9.90	12.17
2	annual groundwater drawdown (m/year)	2.95	2.64	3.37
3	annual groundwater recovery (m/year)	2.14	1.77	3.06
4	rate of groundwater level decline (m/year)	-0.69	-0.37	-0.46

TABLE 2 Annual water demands for water use sections in Sukhothai, Phitsanulok and Phichit

Section	agriculture (million cum.)	ecology (million cum.)	consumption (million cum.)	industry (million cum.)	Total (million cum.)
Province					
Sukhothai	869	198	85	11	1,163
Phitsanulok	1224	276	114	8	1,622
Phichit	743	167	66	4	980
Total	2836	641	265	23	3765
proportion(%)	75.4	17	7	0.6	100

TABLE 3 Annual water uses from rainfall, surface water and groundwater

Water source	effective rainfall (million cum.)	surface water (million cum.)	groundwater (million cum.)	Total (million cum.)	proportion(%)
Province					
Sukhothai	507	482	174	1,163	30.9
Phitsanulok	704	715	203	1,622	43.1
Phichit	430	412	138	980	26
Total	1641	1609	515	3765	100
proportion(%)	43.6	42.7	13.7	100	