The Permissible Yield in Mae Sai multilayered Aquifers System

Arlai, P.[1], Sitisak Manyu[2], Kriangsak Pirarai[2], Arun Lukjan[1] and Monthon Yongprawat[1]

Abstract— *Chaingrai is an important province in the north of Thailand which is located at the golden triangle delta. Nowadays, Chaingrai is the trade hub among the southern part of Republic of China, Burma, Loas P.D.R and Thailand. Consequently, the economy of Chaingrai tendency grows up. From these mentioned consequences, Chaingrai will be developed more infrastructures for serving the economic growth in the future, i.e., water resources. Groundwater is a premier water resource existing in Chaingrai and may be more extracted to support for this economic growth in the future. Therefore Department of Groundwater Resources which is the key authorized department for groundwater resources management investigates the hydrogeology and groundwater resources of the aquifers in Chaingrai province. This article only focuses to determine the permissible yield of Mae Sai multilayered aquifers system which is an aquifer system in Chaingrai province. As the permissible yield is a crucial parameter to manage groundwater resources in a basin. The permissible yield is calculated by a fully 3-D groundwater model and its yield values are expressed sub-districtwise in Mae Sai aquifers area. The result shows the total permissible yield of Mae Sai multilayered Aquifers System is 109,305 CMD.*

Keywords— **a fully 3-D Groundwater flow Model, Permissible Yield, Mae Sai multilayered Aquifers System.**

1. INTRODUCTION

Chaingrai is a northern border province of Thailand and located at the golden triangle delta. Presently, Chaingrai is the regional trade center among the southern part of Republic of China, Burma, Loas P.D.R and Thailand through Mae Khong river. Consequently, the economy of Chaingrai tendency grows up. As these matters of facts, Chaingrai will be developed more infrastructures for serving the economic growth in the future and one of critical infrastructures is water resources. Groundwater is an available abundant water resource in Chaingrai and potentially withdrawal to support for this economic growth in the future. Up-to-date, there is yet no any groun dwater investigation in the province. Thus Department of Groundwater Resources which is the key department which plays major role for groundwater resources management in Thailand investigates the hydrogeology groundwater resources of the aquifers in Chaingrai province in order to well-plan for sustainable groundwater resources management in Chaingrai.

The permissible yield is an important parameter to manage the groundwater resources. Since permissible yield informs the policy maker how many available groundwater rate can be still extracted under the permissible yield constraints. With this information, a policy maker can use it whether to permit the request of groundwater development in the area or not.

The article investigates the permissible yield sub-districtwise in the Mae Sai basin, Chaingrai province. The geological investigation discloses that the Mae Sai basin is a mulitilayed aquifers system, thus the fully 3-D groundwater model-MODFLOW-2000 is set up under the hydrogeological conditions of Mae Sai basin. The 3-D groundwater model is calibrated in both steady state- and transient calibration. Then the permissible yield concept is applied into the groundwater model. The next, the zone budget module is embedded into the groundwater model in order to calculate the permissible yield sub-districtwise in the Mae Sai basin.

2. Study area and model implementation

Study Area:

Mae Sai Basin is located in the Mae Sai-, Chaing San- and Mae Jan district (Amphoe in Thai) which is the northernmost district of Chaingrai in the northern Thailand. The westernmost part of the basin contains several hills. The northern basin is flat area, while the high terrace areas where the natural recharge exists presents in the southeast and west of basin. The basin's altitude varies from +140 to +1450 m. (MSL) (Fig.1). The geological investigation of Department of Groundwater Resources (DGR, 2009) discloses that Mae Sai basin comprises of 4 aquifer layers which are intervened by 4 thin aquitard layers (Fig.2).

Model Implementation:

Since Mae Sai Basin is composed of 4 aquifer layers which are intervened by 4 thin aquitard layers, thus the conceptual model is elaborately set up following the all available hydrological conditions. The next a fully 3-D of FD of groundwater model which is comprised of top unconfined- and 7 confined aquifer layers is established

Dr.-Ing.Phatcharasak Arlai is a lecturer at Program of Civil and Environmental Engineering and the head of Research Unit for sustainable Water Resources and environmental Management, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, 85 Malaiman Rd., Muang, Nakhon Pathom, 73000, Thailand, e-mail: arlai_p@mail2.npru.ac.th , Tel. and Fax. 0066-(0)34-261065.

Mr.Sitisak Munyu, Senior Hydrogeologist, Department of Groundwater Resources, Bangkok, Thailand

Dr.Kriangsak Pirarai, Senior Hydrogeologist, Deparment of Groundwater Resources, Bangkok, Thailand

Mr.Arun Lukjan-Research Assistant and Mr.Monthon-M.Eng student at Research Unit for sustainable Water Resources and environmental Management, Faculty of Science and Technology, Nakhon Pathom Rajabhat University.

to synchronize with the conceptual model (Fig.3). Aftermath, the grid spacing of groundwater model is optimized to determine the optimal grid spacing (Fig.4).

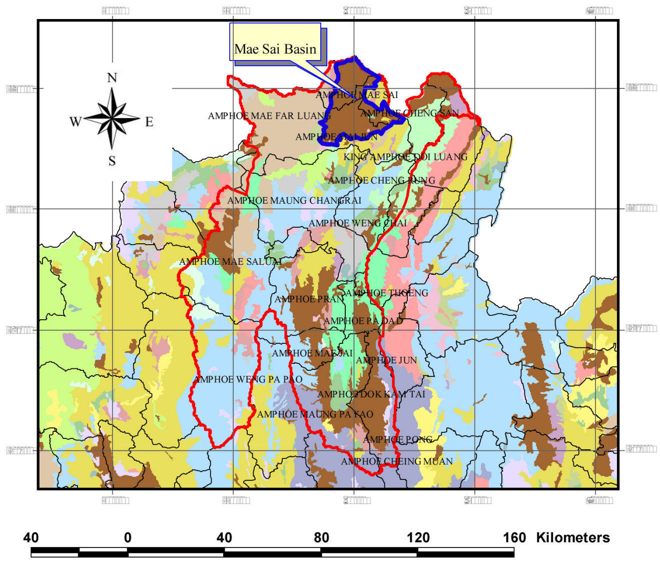

Fig.1. The Hydrogeological map of Mae Sai basin

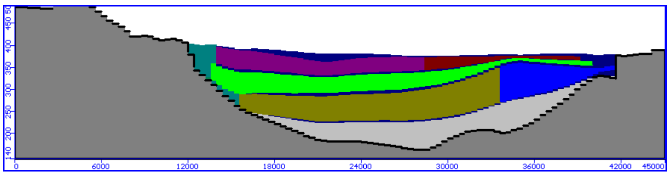

Fig.2. A cross-section of Mae Sai multilayered aquifers system

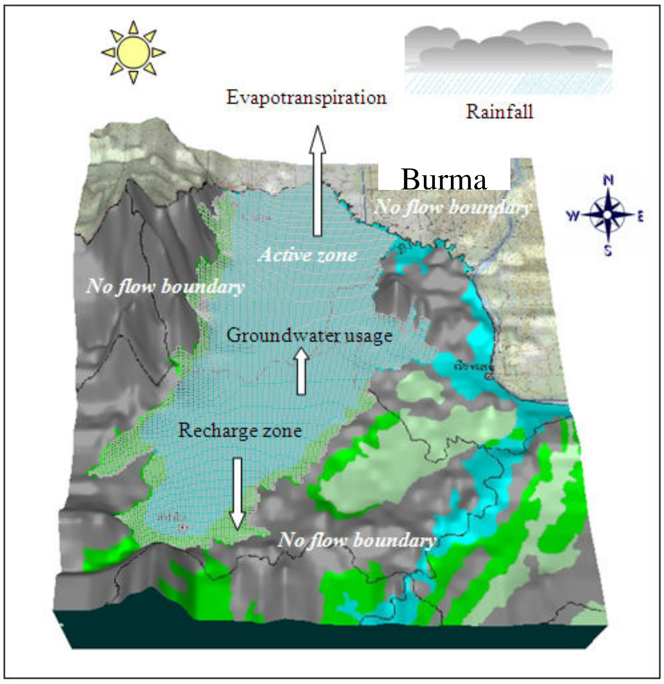

Fig.3 FD Grid of Mae Sai multilayered aquifers system

The optimal grid spacing curve unveils that the grid spacing at 400 m is optimal size as this grid spacing size firstly turns out the minimum error. Therefore the grid size of 400x400 m^2 is selected to discretize the finite difference grid of Mae Sai model.

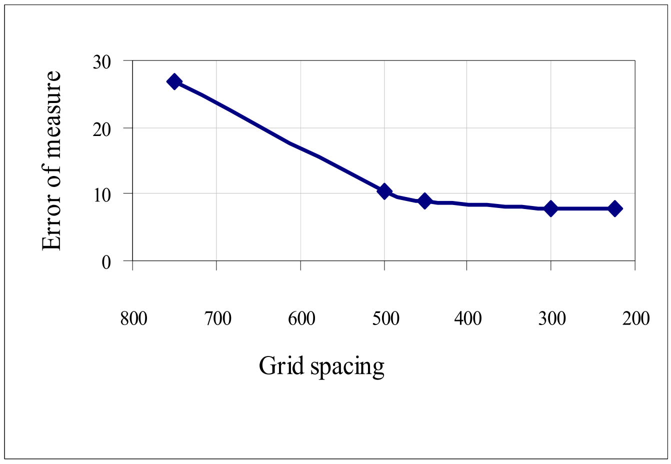

Fig.4 Optimal grid spacing curve: Error versus Grid Spacing

Different boundary conditions are ornately applied to the model as follows: the no flow boundary is applied at the impermeable area (Fig.3), recharge module is applied at the high terrace area, the middle of basin, river module is applied along the Mae Nam Kam river and general head boundary where the active cells of model connecting with the Mae Khong river (Fig.5). Finally, the existing pump is input into the groundwater model.

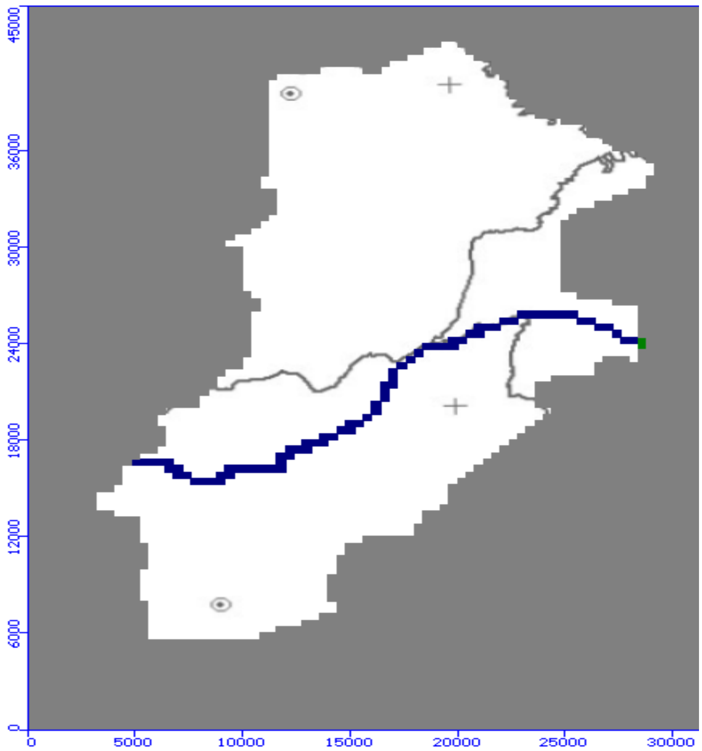

Fig.5 The river module applied at the top layer of Mae Sai groundwater model: the blue is Mae Kam river channel, the white is active cells, the gray is inactive cells and the brown is the general head boundary

Groundwater Model Calibration:

The groundwater model calibration is induced thereafter implementing groundwater model in order to make sure that the model can reasonably mimic the groundwater system. Since the groundwater level has been not yet measured in the study area before, the Department of Groundwater Resources then pays full attempt to develop the monitoring wells and measure the Piezometric head as much as possible (Fig.6). The Piezometric head are measured from January to June, 2009. The steady state – and transient calibration are done with these measured water table and Piezometric head.

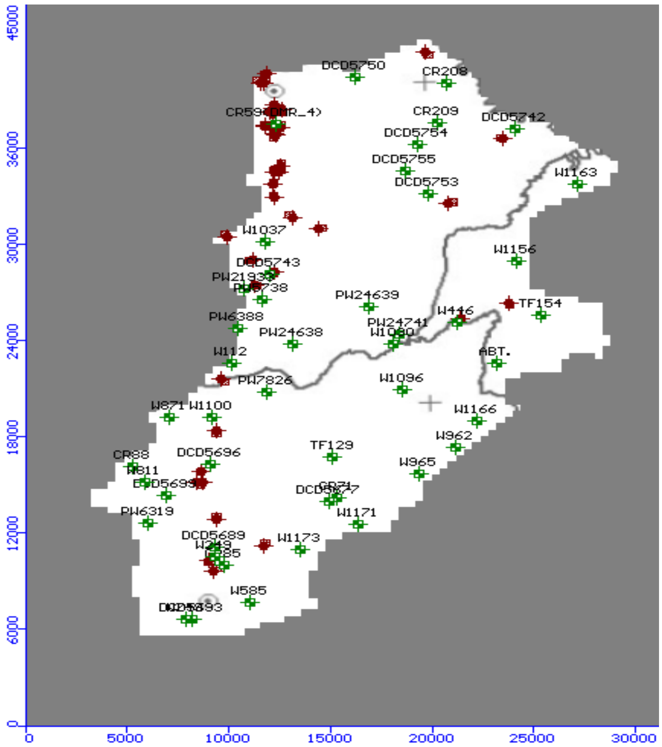

Fig. 6 The locations of monitoring wells and pumping wells

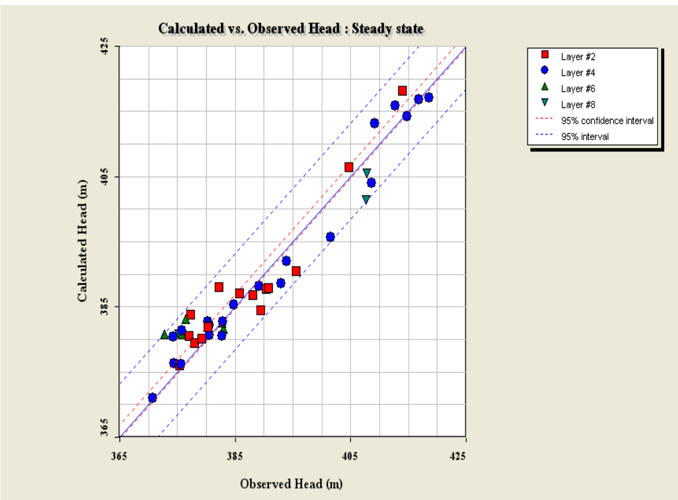

Fig.7 Scattered plot of observed head versus calculated head in steady state calibration

The steady state calibration is induced to calibrate the set of hydraulic conductivity and recharge. The error evaluation measures are assessed in both quantitative and qualitative aspects (Anderson and Woessner, 2002). The quantitative assessment is shown in the scattered plot between observed head versus calculated head (Fig.7). The scattered plot shows that the parameters are well-calibrated, as all correlated points are relied on the band of 95% confident limit. In the other hand, the qualitative assessment is evaluated by spatial plot between observed- and calculated head (Fig.8), it discloses that the spatial distribution of observed- and calculated head reasonably conform to each other. This means that the set of calibrated parameters are well-calibrated in the quantitative view point.

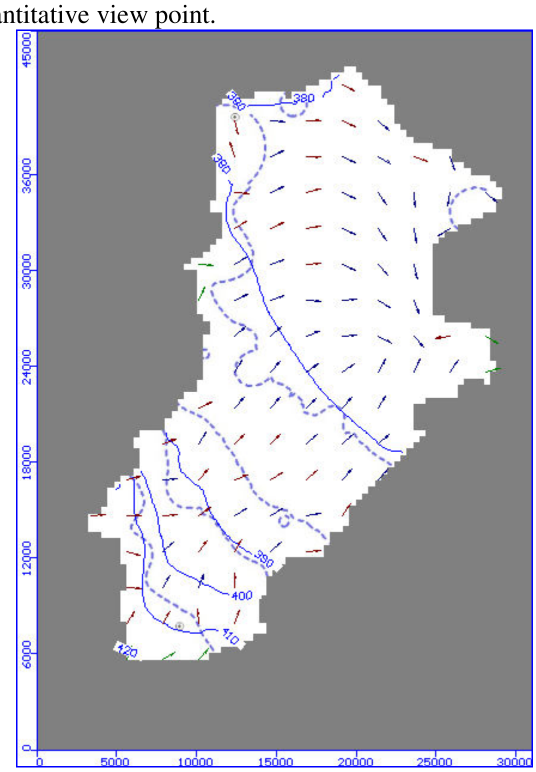

Fig.8 An example of spatial distribution of observed- and calculated Piezometric head in layer 2.

The transient calibration aims to calibrate the storage and recharge parameter. The quantitative assessment is induced to evaluate the calibration result by comparing between observed- and calculated Piezometric head (Fig.9). The result shows is reasonably calibrated, as it expresses an acceptable conforming between these data.

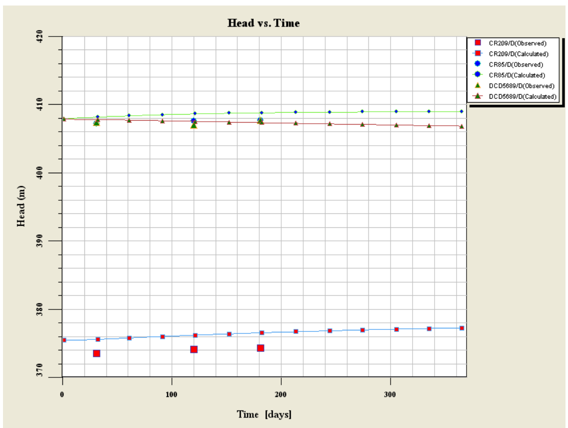

Fig.9 Transient plot between observed- and calculated Piezometric head

3. Permissible Yield

Each aquifer system has a unique definition of permissible yield. Therefore, it firstly needs to define the definition of permissible yield of the Mae Sai multilayered aquifers system. For Mae sai aquifers system, the Department of Groundwater Resources defines the permissible yield as "the total pumping rate which induces the average piezometric head in each layer equal to -20 meter from the land surface in the next 20 years minus the existing pump rate". The main aim of this study is to report the permissible yield sub-districtwise in the study area.

The next, the permissible yield concept will be introduced into the groundwater model. By that, every active cell of groundwater model will be specified to present a groundwater pumping well, because, with this specified pumping distribution, it can calculate the maximum permissible yield for that active cell. Furthermore, the pumping rate in active cells are divided into 2 zones (Fig.10), namely, the 1st zone is the area where the aquifer thickness is not greater than 50 meters (or area of Mae Sai basin flank) and the 2nd zone is the area where aquifer thickness is greater than 50 meters (or middle area of Mae Sai basin), as the cross-section of Mae Sai aquifers system forms about a curve as shown in Fig.2, consequently, if apply a same pumping rate in two zones, it turns out much different piezometric heads in these two zones. Therefore, it needs to divide the study area into these two pumping zones. The next, all pumping wells in the same zone are equal. The pumping in each active cell is calculated from the averaged value of currently total pumping rate in the zone. Thus the pumping rates are specified as 1.2 and 0.34 CMD for the 1st and 2nd pumping zone, respectively.

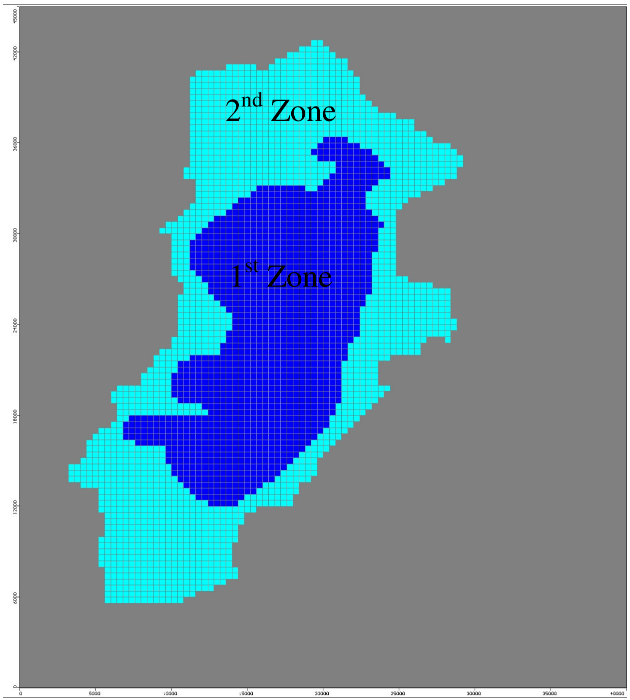

Fig.10 Two zones of pumping well distribution of Mae Sai multilayered aquifers system

Several ten times of groundwater model simulation, it finally, turns out the total permissible yield of 109,305 CMD for Mae Sai basin. The next, the Zone Budget module is embedded into the groundwater model to calculate the yield sub-districtwise. Aftermath, the zone budget results are reported sub-districtwise as shown in Table1.

Table 1 Permissible Yield in Every Sub-district in Mae Sai Basin

No	Sub-district	District	Permissible Yield (CMD)
1	Wiang Pan Kam	Mae Sai	775
2	Mae Sai	Mae Sai	4,174
3	Koa Chang	Mae Sai	4,601
4	Pong Pha	Mae Sai	17,606
5	Sri Muang Chum	Mae Sai	19,342
6	Pong Ngam	Mae Sai	10,319
7	Ban Dai	Mae Sai	15,340
8	Huai Krai	Mae Sai	5,564
9	Sri Don Muang	Chaing San	8,692
10	Pasak	Chaing San	472
11	Mae Rai	Mae Jan	1,862
12	Mae Kam	Mae Jan	3,019
13	Sri Kam	Mae Jan	884
14	Pasang	Mae Jan	594
15	Patung	Mae Jan	508
16	Mae Jan	Mae Jan	459
17	San Sai	Mae Jan	2,586
18	Jan Jar Tai	Mae Jan	9,204
19	Jan Jar	Mae Jan	3,304
Total			**109,305**

4. Summary

Mae Sai aquifers system is conceptualized to the conceptual model which comprises of 8 modeled layers, i.e., top unconfined aquifer- and 7 confined aquifer layers. Fully 3-D of FD of groundwater model is set up following the conceptual model. The permissible yield concept is applied to the model. Then it turns out the permissible yield of 109,305 CMD for Mae Sai Basin. This permissible is finally reported sub-districtwise so that a policy maker can use them for a sustainable groundwater resources management.

ACKNOWLEDGMENT

We cordially express my special thanks to Department of Groundwater Resources, Thailand for supporting data and research fund for the project.

REFERENCES

[1] Anderson, M.P and Woessner W.W., (2002), Applied Groundwater Modeling: Simulation of Flow and Advective Transport: Elsevier.

[2] Department of Groundwater Resources (2009), Groundwater Resources Assessment in Kok river basin.