Study of Salt Contamination Using Hydrogeological Model in the Lower Nam Kam Irrigation Project, Nakorn Panom Province, Thailand

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Abstract

The salt contamination in the Lower Nam Kham Irrigation Project area possibly causes from geologic and hydrogeologic characteristics, and effecting to the soil and groundwater. The study area is underlain by the two aquifer units; the Quaternary and the Phu Tok aquifer which is the upper aquifer and fresh water, and the Mahasarakham aquifer with rock salt which is the lower aquifer and salt water. These aquifers are separated by the clay confining layer and the salt contamination caused by the salt groundwater flowing through fracture cut upward from the Mahasarakham aquifer to the Quaternary and the Phu Tok aquifer. The hydrogeological model is used to study the salt contamination and the purpose of this model is also to simulate the groundwater flow system. Furthermore, the model leads to the better understanding of the groundwater flow system, pattern and direction of groundwater flow, and piezometric head of groundwater. Additionally, the results obtained from this hydrogeological model study can be applied for planning, operating and maintenance of the irrigation project area.

Keywords: Hydrogeological model, Groundwater flow, Salt contamination

1. Introduction

The Lower Nam Kam Irrigation project has been established for the water resource management project in Nakorn Panom province located in north eastern part of Thailand. The salt contamination in this area is one of the serious problems caused by geologic and hydrogeologic characteristics and effecting to the soil and groundwater of the area. The data obtained from this project will be used to plan for reservoir construction and an irrigation conveyance system for fresh water storage. The fresh water storage is overlain by a salt layer containing two categories of groundwater sources, namely; a shallow fresh groundwater (Quaternary and the Phu Tok aquifer) underlain by impervious strata, and a deep saline groundwater in the confined aquifer (Mahasarakham aquifer). The salt contamination caused by salt groundwater flows through fractures cut upward from the Mahasarakham aquifer to the Quaternary and the Phu Tok aquifer. In dry season, the large abstraction of shallow groundwater in the study area is the cause of the shallow groundwater potentometric level becoming lower than the deep groundwater potentometric level. It is indicated that reversal of groundwater piezometric level causes upconing of salt water. The objective of this study is to establish the hydrogeological model that will describe and predict groundwater flows and salinity spreading related to land salinisation in the Nam Kam irrigation scheme.

2. Study Area

The Lower Nam kam Irrigation project is located in the north eastern part of Thailand. The project area covers Tat Panom district, Renu Nokorn district and Na Kae district, Nakorn Panom province (Figure 1). The water in Nam Kam River derived from Nog Han Reservoir which is the main source of surface water supply for the area. The river flows from west to east of the area and joint with Kong River at Tat Panom district, Nakorn Panom province.

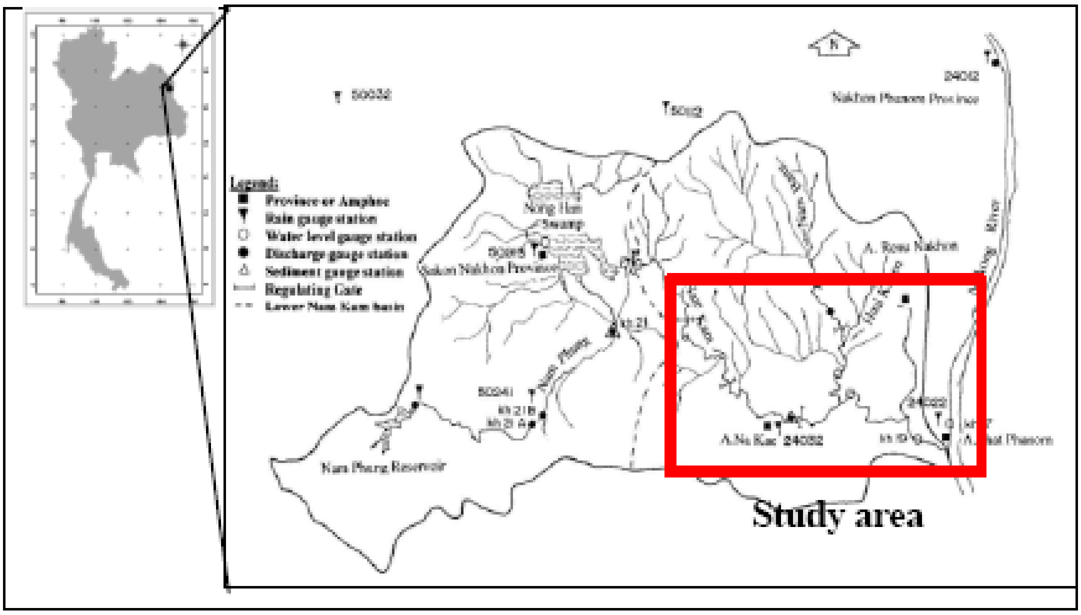

Figure 1 Topographic map of the study area.

3. Geologic and Hydrogeologic Setting

The study area is mainly covered by unconsolidated sediments and is underlain by consolidated rocks. The unconsolidated sediments are mostly various Quaternary deposits such as clayey sand, silt and very fine sand, thickness about 20 meters. The unconsolidated to semi-consolidated sediments are also included Phu Tok formation which is consisted of coarse to very coarse sand and gravel, thickness about 20 meters. The consolidated rocks are Mahasarakam formation and Khok Krout formation. The Mahasarakam formation consists of mudstone in the upper part and mudstone, siltstone, sandstone interbedded with rock salt in the lower part. The Kok Krout formation consists of fine-grained sandstone. The geologic map of the study area and geologic cross section along east-west line and north-south line are showed in Figure 2, 3 and 4, respectively.

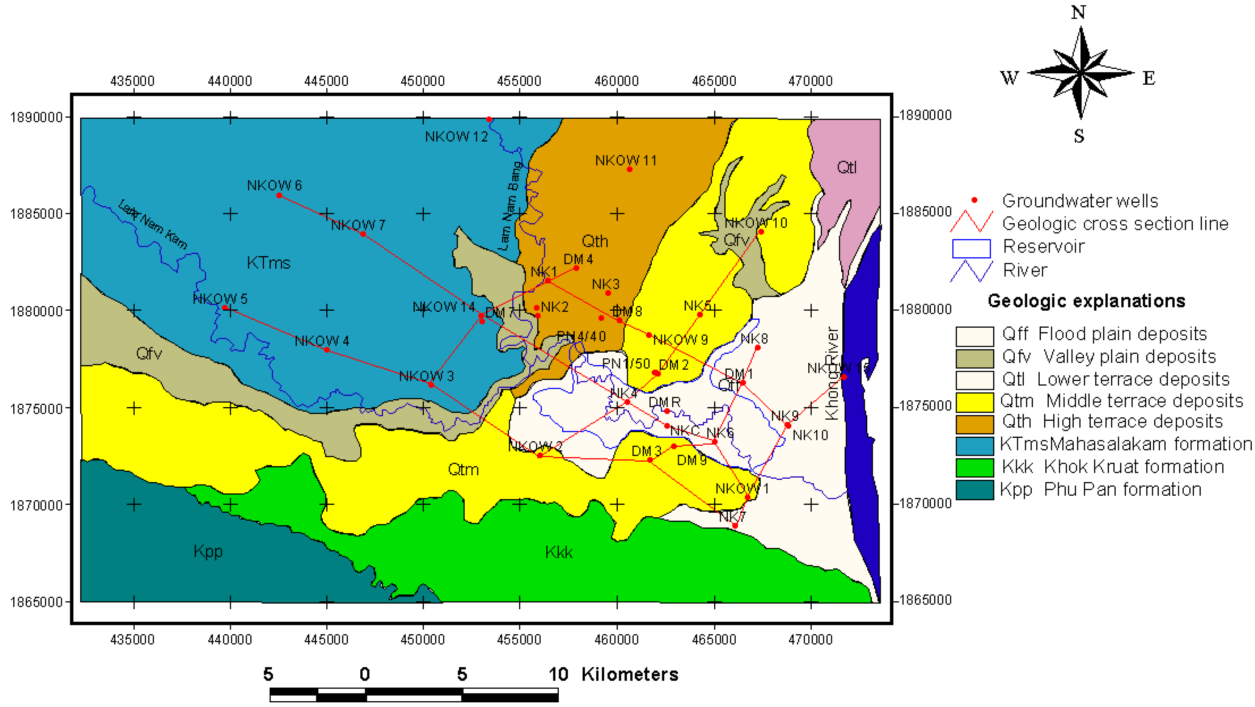

Figure 2 Geologic map of the study area.

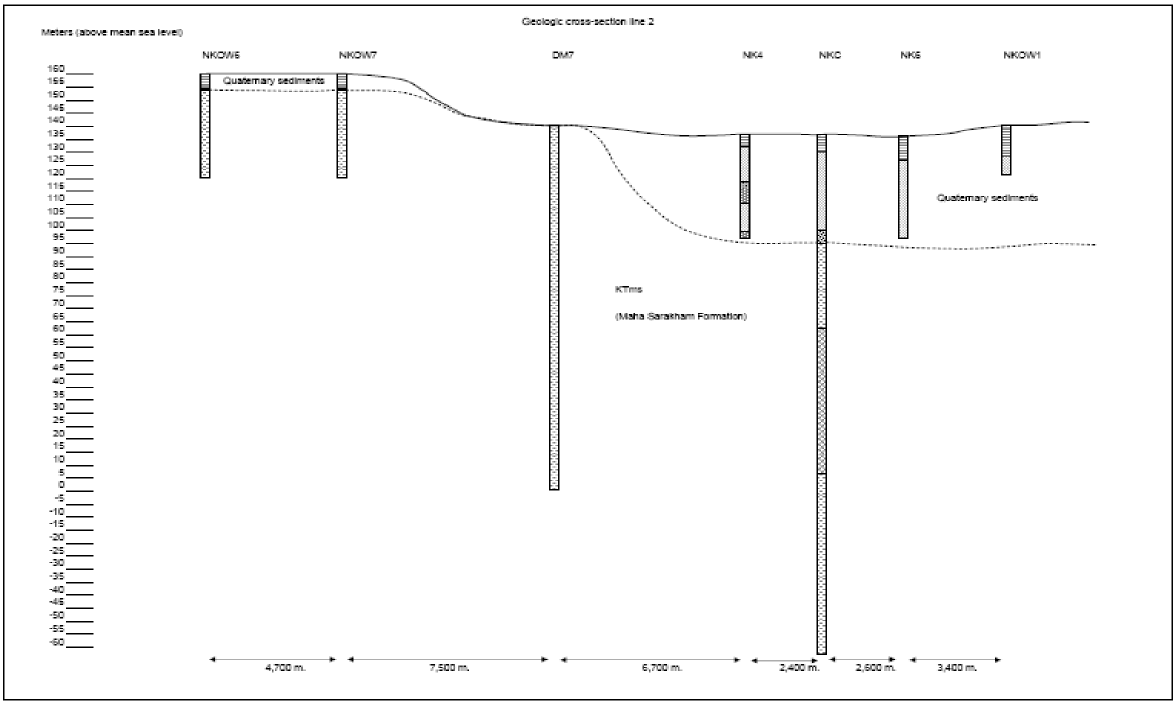

Figure 3 Geologic cross section along line east-west (line 2)

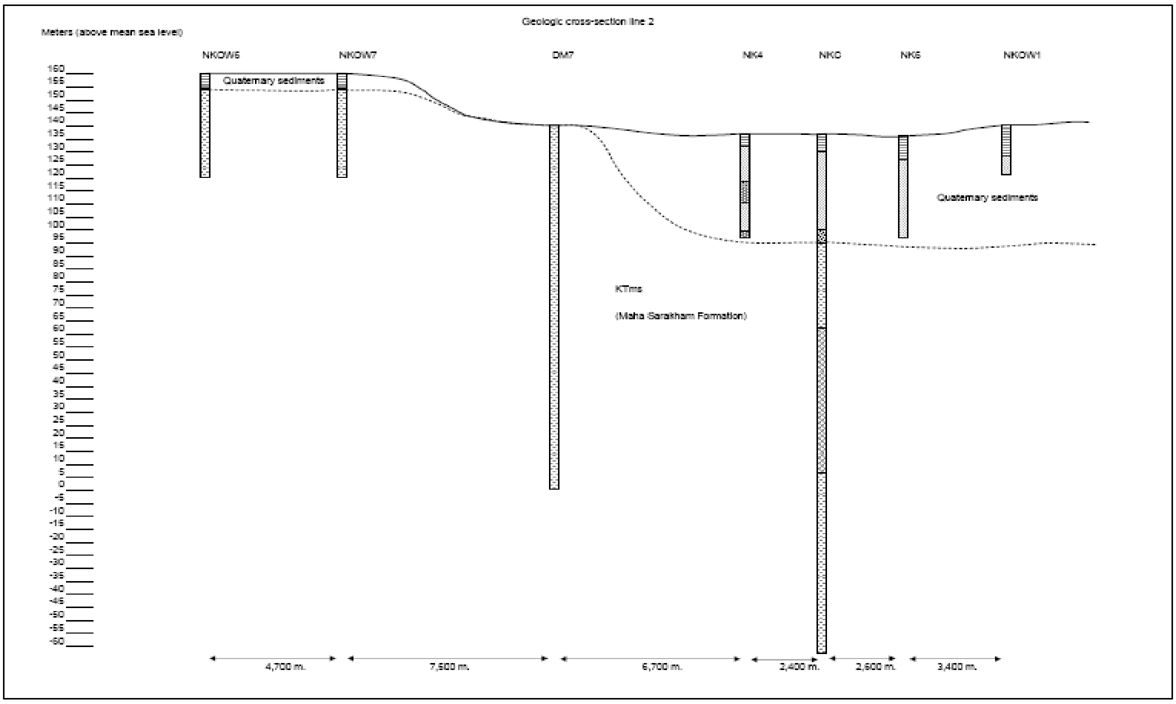

Figure 4 Geologic cross section along line northt-south (line 5)

The aquifer system in the study area can be divided into two aquifer units on the basis of differences in lithologic characteristics and hydraulic properties of aquifer. These aquifer units are the shallow fresh groundwater (Quaternary and the Phu Tok aquifer) which is underlain by a deep saline groundwater in the confined aquifer (Mahasarakham aquifer). The shallow fresh groundwater is the productive aquifer of the study area and thickness is about 40 meters. The deep saline groundwater generally has low potential for being productive aquifer and the salt contamination occurred in the area is also caused by the salt groundwater from this aquifer. Table 1 shows the summary of the aquifer systems of the study area.

Table 1 Summary of the aquifer systems of the study area.

Aquifer system	Average depth (m)	Transmissivity (m^2/d)	Storage coefficient (Unitless)
Quaternary aquifer	20	3.19-21.33	0.006-0.10
Phu Tok aquifer	20	17.3-81.7	0.251-0.261
Mahasarakham aquifer	> 200	0.048	4.41×10^{-5}

4. Methodology

The groundwater in this area is occurred in unconsolidated sediments of Quaternary and Phu Tok aquifer, and fractured rock system of Mahasarakham aquifer. This study assumes that the groundwater in fractured rock system of Mahasarakham aquifer is equivalent porous media (EPM). It means that the groundwater can be occurred in both pore and fracture. The MODFLOW created by the United States Geological Survey is chosen as a code for simulations and used as a finite difference technique (Waterloo Hydrogeologic Inc., 2006). The method divides the flow field into a discrete set of blocks or cells. It assumes that hydrogeologic properties within each block are homogeneous and uniform. The model output includes simulations of hydraulic head, distributions, flow rate and water balances (Anderson and Woessner, 1992 , Mercer and Faust, 1980, and Zheng, 1996) . This study is also included the solute transport model for salt contamination study. Designation and construction of a groundwater flow model and solute transport model are the process of transforming the conceptual model into mathematical model form leading to hydraulic head and flux simulations. The required result is an interactive model with features to represent the hydrogeologic framework, hydraulic properties, hydraulic process, and boundary conditions. The three-dimensional numerical model covers approximately 330 square kilometers. The lateral extent of the model corresponds to natural physical and hydrologic boundary. The model area and, model layers and grids of the study area are shown in Figure 6 and 7, respectively. The model consists of three layers. The first layer represents the Quaternary and Phu Tok unconsolidated aquifer, the second layer represents the fractured rock of Mahasarakham aquifer, and the third layer represents the Khok Krout impermeable rock. The uniform mesh size is of 250 × 250 meters which is large enough to reflect the density of input data and desired output detail. The approach modeling for the hydrogeological model include three major steps ; 1) developing a model for steady state simulations, 2) developing a model for transient state simulations, and 3) assembling data sets and running the model to predict scenarios.

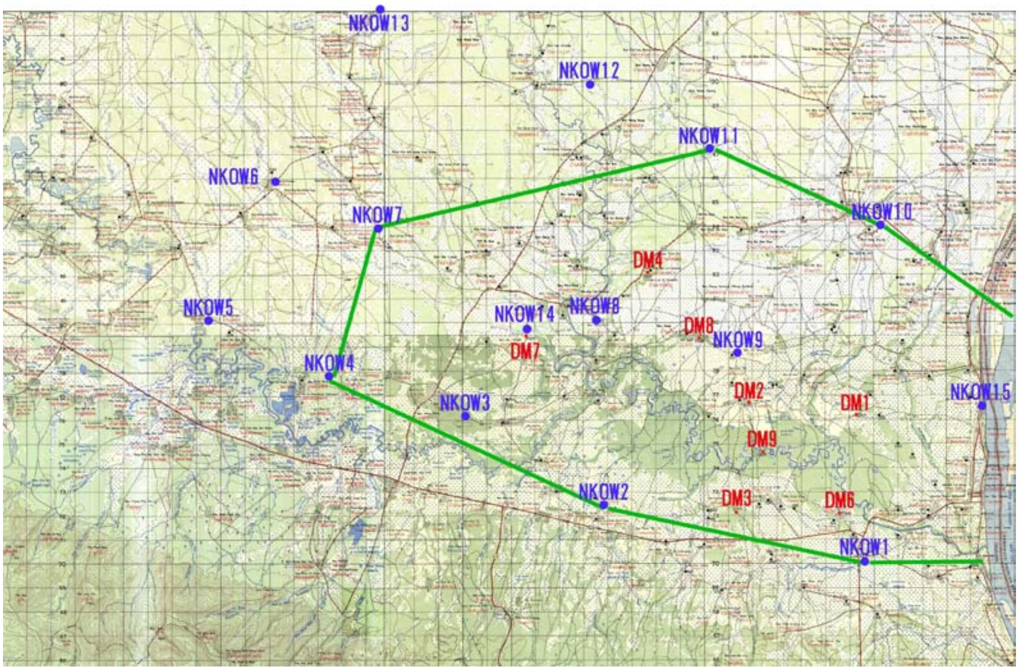

Figure 6 Model area

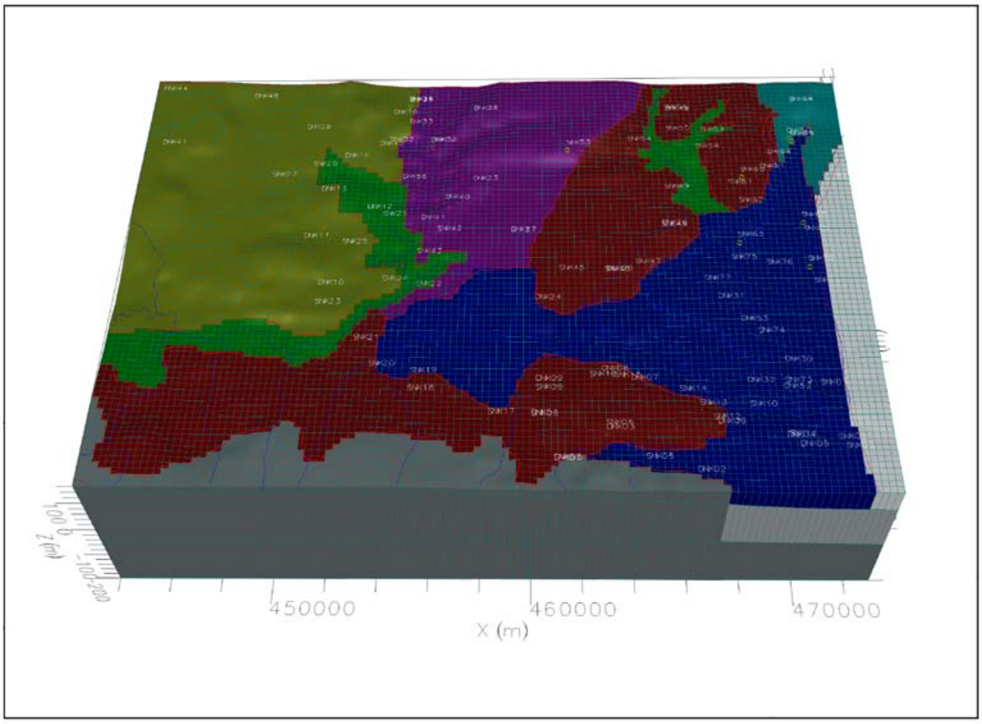

Figure 7 Model layers and grids.

5. Results and conclusions

The flow and solute transport model simulation was set to calibrate the groundwater conditions in January, 2008, using that month's complete data set. The data of groundwater heads from 97 observation wells was used as calibration target (Figure 8). The mathematical calibration was done by comparison between measured head and simulation head. The mathematical and graphical scatter diagram comparing simulated heads and observed head of the steady state model is shown in Figure 9. The contour of the piezometric head and the groundwater flow direction is exhibited in Figure 10 while Figure 11 shows groundwater flow system along line east-west which crosses the area containing salt groundwater (Ban Pra Song) and Figure 12 shows the three dimensions of the piezometric head of the study area

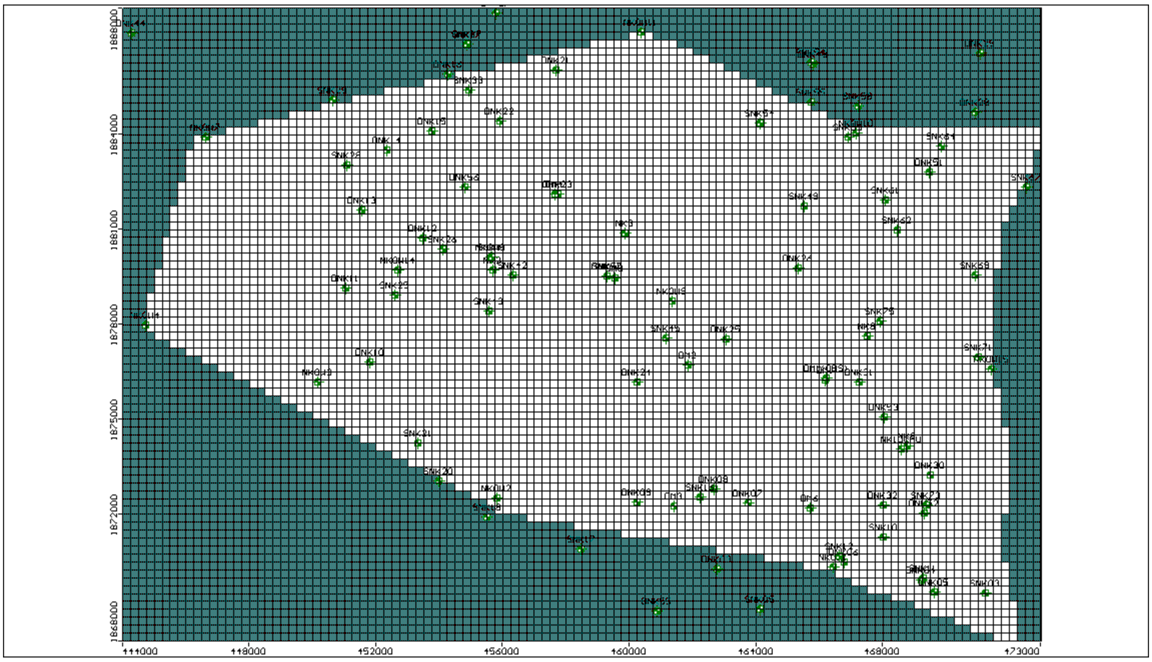

Figure 8 Location of groundwater observation wells.

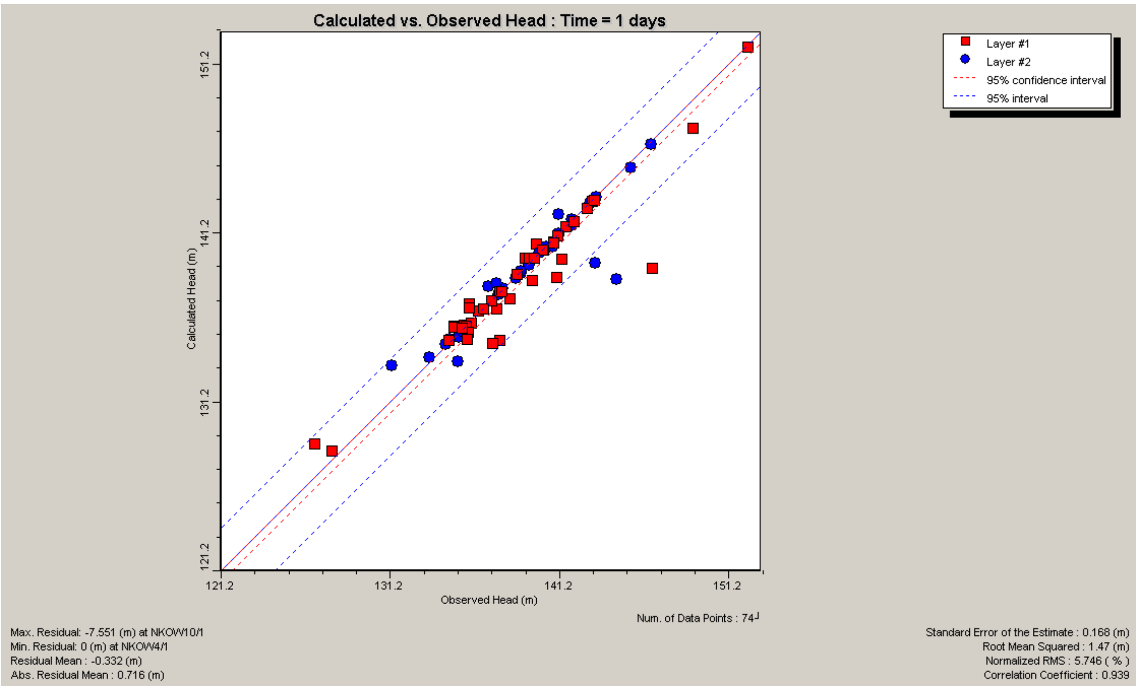

Figure 9 Mathematical and graphical scatter diagram comparing simulated heads and observed head of the steady state model.

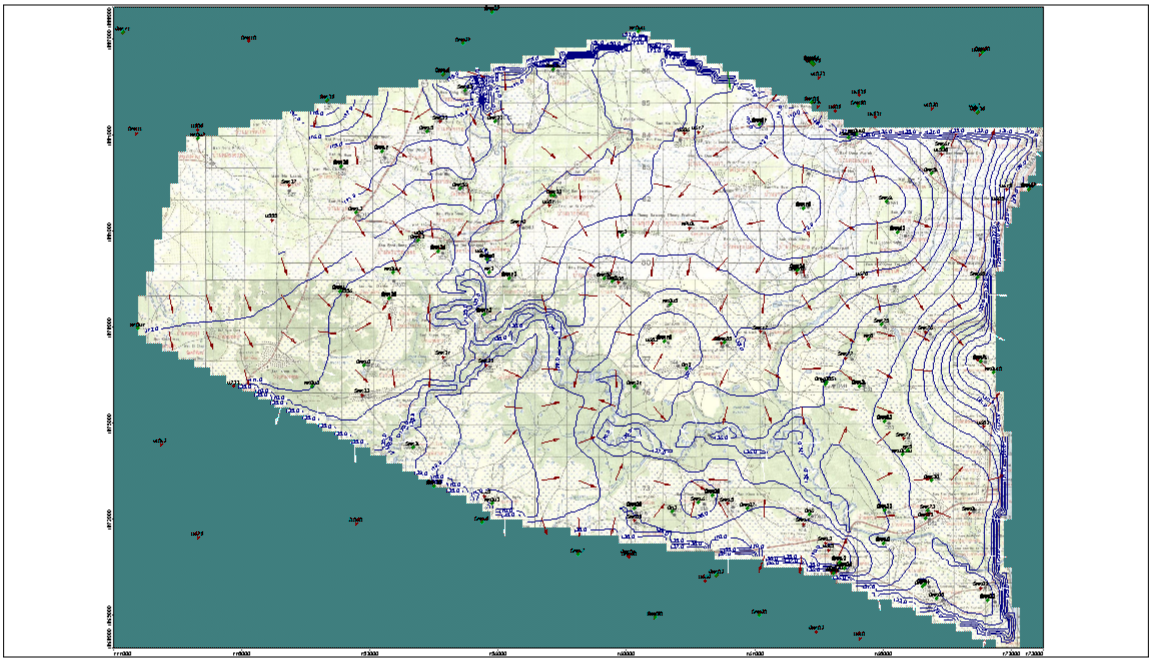

Figure 10 Piezometric head and groundwater flow direction from model simulation.

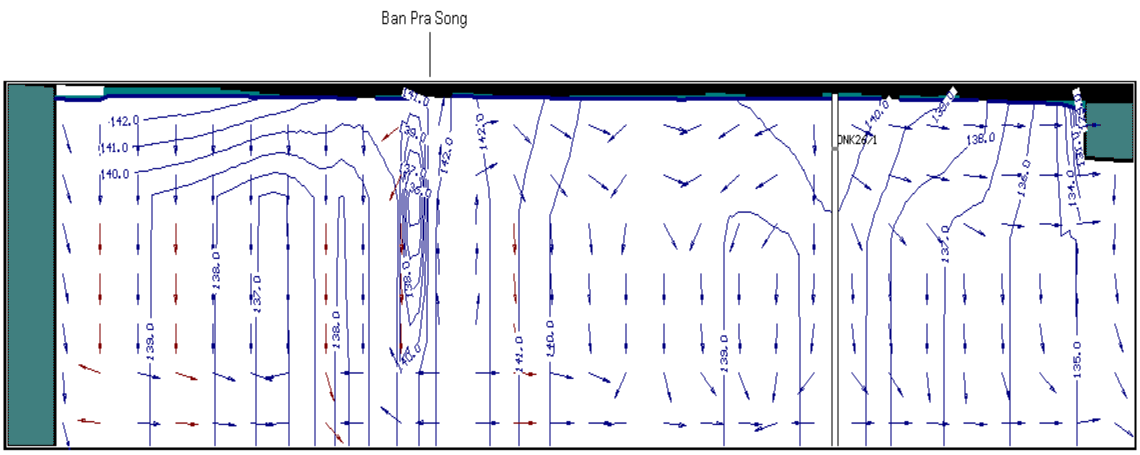

Figure 11 Groundwater flow system shows the infiltration process occurring in the area.

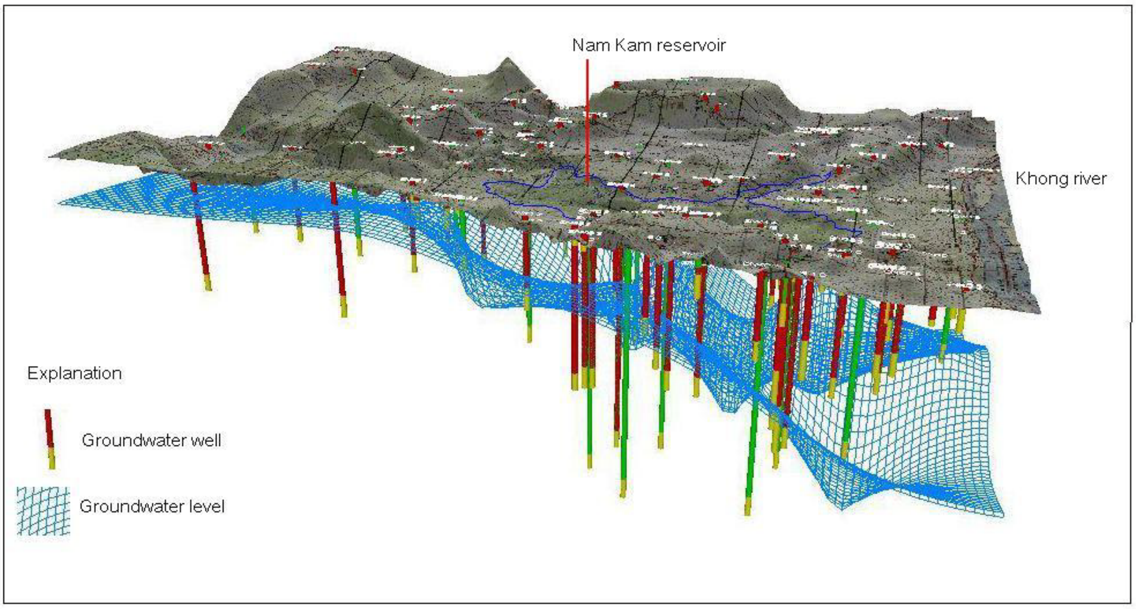

Figure 12 Three dimensions of the piezometric head of the study area**.**

The flow systems from the model simulation results show the infiltration process occurring in the recharge area in the western part of the study area. The water flows through fractures downward Mahasarakham aquifer with rock salt layer which is the lower aquifer while salt water flows upward to the Quaternary and the Phu Tok aquifer at the Ban Pra Song area. Therefore, it can be concluded that this process is the cause of the salt contamination in this study area. The solute transport model reveals the area affected from salt contamination (Figures 13). All the results obtained from this study lead to a better understanding of the hydrogeology in the study area and can be also applied for planning, operating and maintenance in the irrigation project area.

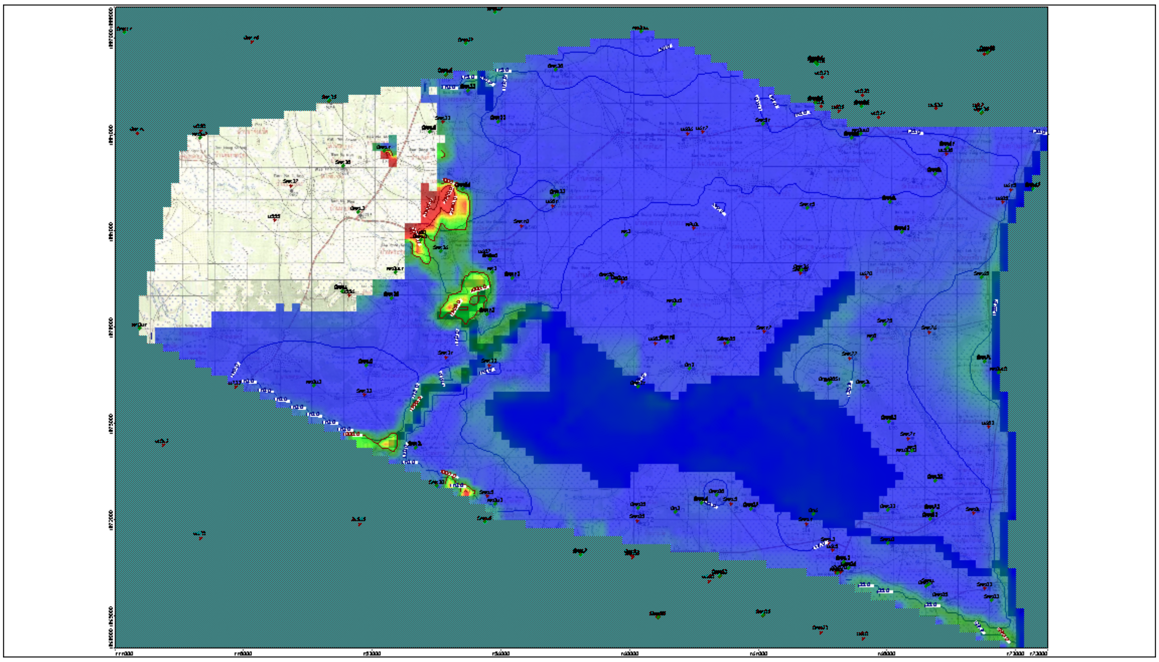

Figure 13 The model simulation of the area that salt groundwater effects to soil (red and yellow colors are the salt contamination area).

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