International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:6, No:10, 2012

The Water Quantity and Quality for Conjunctive Use in Saline Soil Problem Area

P. Mekpruksawong, S. Chuenchooklin and T. Ichikawa

***Abstract*—**The aim of research project is to evaluate quantity and quality for conjunctive use of groundwater and surface water in lower in the Lower Nam Kam area, Thailand, even though there have been hints of saline soil and water. The mathematical model named WUSMO and MIKE Basin were applied for the calculation of crop water utilization. Results of the study showed that, in irrigation command area, water consumption rely on various sources; rain water 21.56%, irrigation water 78.29%, groundwater and some small surface storage 0.15%. Meanwhile, for non-irrigation command area, water consumption depends on the Nam Kam and Nambang stream 42%, rain water 36.75% and groundwater and some small surface storage 19.18%. Samples of surface water and groundwater were collected for 2 seasons. The criterion was determined for the assessment of suitable water for irrigation. It was found that this area has very limited sources of suitable water for irrigation.

***Keywords*—**Conjunctive use, Groundwater, Surface water, Saline soil.

I. Introduction

THE Nam Kam River, a tributary of the Makong River, is located in Northeast, Thailand as show in Fig. 1. The study area covers about 900 Km^2 of the Lower Nam Kam Basin. The annual rainfall is 1,600 mm. while annual pan evaporation 1,788 mm. and may cause the natural move upward of salt to ground surface. The high seasonal variation of runoff and insufficient water storage often causes water scarcity problem in this area. Both surface and groundwater are used for the cultivation in this area and may cause the distribution of salinity if there is inappropriate using. For the sustainable conjunctive use of surface and groundwater, the assessment of water quality in each season and quantity are need for the management of salinity distribution

II. Study Area

The majority of the water available in the Lower Nam Kam Basin is provided by surface runoff from the Nam Kam River and its main tributary the Lam Nam Bang. The maximum monthly runoff occurs in September at the rate of 393.69 million cubic meters (MCM) and the minimum in February at 9.93 MCM. Surface water resource in this area is limited during the dry season. Water suitable for drinking is confined to relatively shallow aquifers [1]. According to the previous study, the area has salt rock slopes of 5-10 degrees to the north and the formation exists at the 90-200 m depth from the ground surface. As for the water quality, the salinity of water retained in sand, silt, clay and sandstone varies according to their location and depth. The contact surface of fresh, brackish and saline water is at 30-40 m below the ground surface of the Lower Nam Kam Basin [2]. However, in comparison with most areas in the northeastern region, the areas show a relatively good potential for irrigation development because of the suitability for irrigation of its soil as well as high runoff in the wet season. The Lower Nam Kam Regulator was constructed during 2005 to 2009 at the downstream of flood area that occurs in the wet season by The Royal Irrigation Department (RID), Thailand. The purpose of this project is to keep river runoff of wet season for the cultivation in both wet and dry season. The reservoir area covers about 29.9 km^2 of flood area when the gate is operated at normal level. This regulator is located on the Nam Kam River just 1.7 km upstream from its confluence with the Mekong River [3].

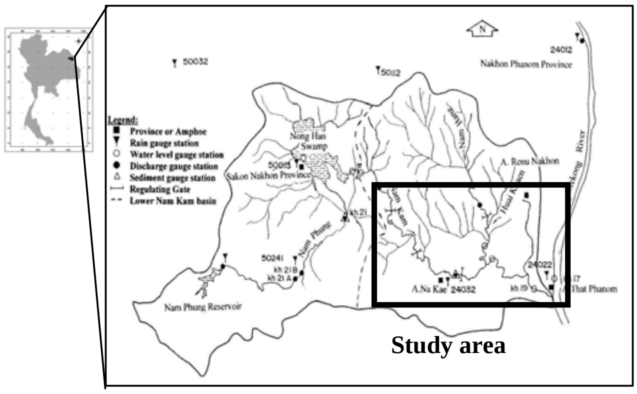


Fig. 1 Location of the lower Nam Kam River Basin

The geologic map shown in Fig. 2 can concluded that this area is characterized by floodplains and undulating terrain. The floodplain consists of the Quaternary unconsolidated sediments. These sediments can be divided into 5 sub-units, namely high terrace (Qth), middle terrace (Qtm), lower terrace (Qtl), valley plain (Qfv), and flood plain (Qff) deposits. The undulating terrain consists of consolidated sediments of the Phu Pan, Kok Kruat, Maha Sarakham Formation, and Phu Tok Formation. The Maha Sarakham Formation was formed in the upper part Cretaceous and is composed of thick to very thick mudstone, shale, siltstone interbedded with rock salt layers. The formation is exposed at areas of making salt along the Nam Kam River from Ban Dong Khun Kram to Ban Kang Pho.

P. Mekpruksawong, is with The Office of Project Management, Royal Irrigation Department, Bangkok, 10300 THAILAND (phone: 66-81922-7034; fax: 66-2243-1044; e-mail: phatta05@yahoo.com).
S. Chuenchooklin, is with the Faculty of Engineering, Naresuan University, Phitsanulok, 65000 THAILAND (e-mail: sombatc@nu.ac.th).
T. ICHIKAWA, is with the Tokai University, 9-1-1 Toroku, Kumamoto 862-8652, JAPAN, (e-mail: tichi@ktmail.tokai-u.jp).

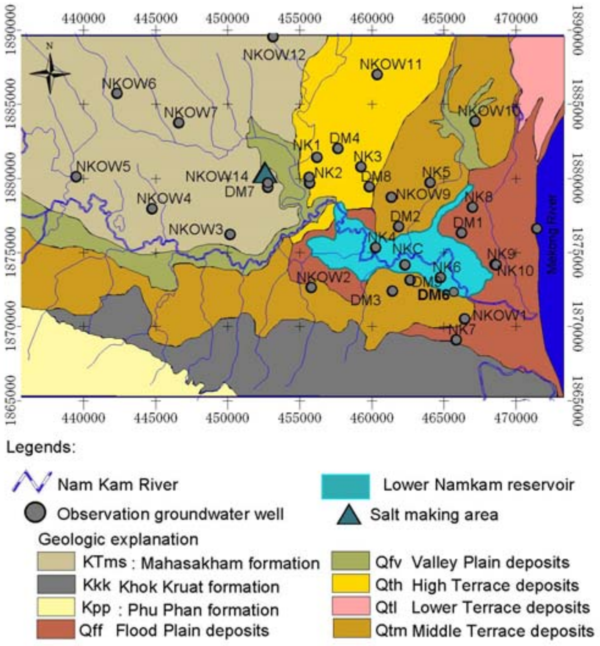


Fig. 2 Geologic map of Lower Nam Kam River Basin

Hence, the Quaternary unconsolidated sediments are underlain by the Maha sarakam Formation with rock salt. Based on the existing seismic data re-interpreted by Chiang Mai University [4] and the boring log data, it is possible that the rock salt layer is distributed at the depth between 115-290 m with the thickness of 50 to 250 m in the area.

III. GROUNDWATER LEVEL CHANGE

Fig. 3 shows the daily GWL change at observation sites in Fig. 2. The GWLs at points DM1, DM2, DM4 and DM8 represent the piezometric head of confined aquifers (depth over 80 m), and GWLs at another 6 points (points DM6, NK2, NK3, NK8, NK9, and KNOW 14) represent shallow GWLs (depth less than 80 m). GWL of confined aquifers does not change with time while GWL of shallow aquifers changes drastically. GWL of shallow aquifers reach to bottom in the end of May

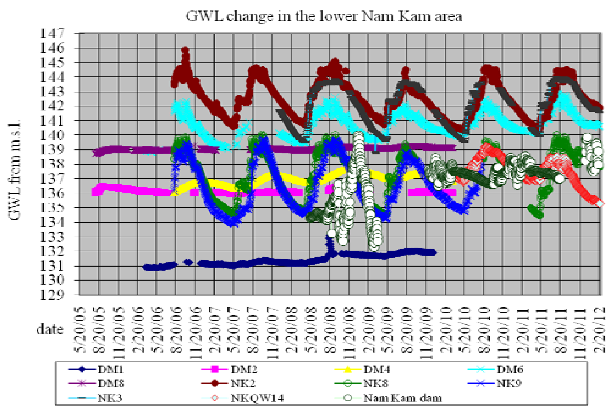


Fig. 3 Groundwater level change from 2005 to 2012

and peak in the beginning of October as shown in Fig. 3. This behavior means that there are high infiltration periods in the wet season (June to September) and pumping of GW just after the wet season. Thus, if the piezometric head of GW in confined aquifer becomes higher than the shallow GWL, GW that may have high salt concentration will rise up to near ground surface [5].

IV. WATER DEMAND ANALYSIS

This area has conjunctive use of surface water and groundwater for irrigation**.** In irrigation project area, farmer uses irrigation water first because no pay for water charges. If it is not enough to, they will use the water from pond and groundwater respectively. In non irrigation system area, farmer use water, sorting is stream water, pond water and groundwater respectively. The outline of water demand calculation in order to find amount of water uses in each type in irrigation and non-irrigation area shows in Fig. 4. The mathematical model WUSMO (Water Use Study Model) was applied for the calculation of crop water requirement and effective rainfall utilization. The crop water requirement from WUSMO was input to the Mike basin, a mathematical model for the calculation of water balance in streams and reservoirs. The simulation result of the Mike basin model shows the quantity of water getting from irrigation systems, from steam and water shortage. From field observation, this water shortage has meant as well as water that farmer take from pond and groundwater well for their crop.

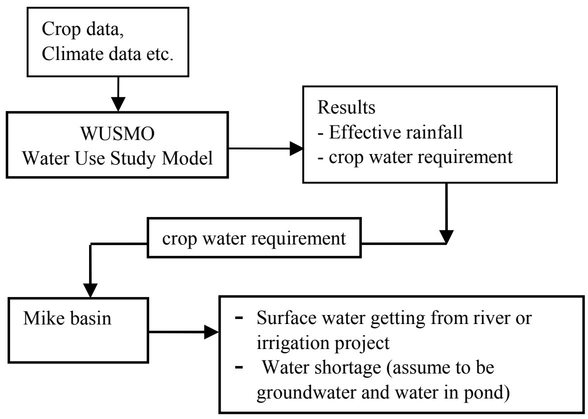


Fig. 4 Outline of water demand calculation

A. Water balance in Paddy field

The WUSMO has principal of computation based on water balance in paddy field as shown in Fig. 5 and expressed in equation (1).

$$W_{irr} = \frac{ET_c + W_{lp} + W_{se} - R_e}{Irr.Rff.} \quad (1)$$

Where W_{irr} = Irrigation water requirement

ET_c = Crop water requirement

W_{lp} = water needed for land preparation of paddy fields

W_{se} = Water seeps from paddy field

R_e = Effective rainfall

$I_{rr.}Eff.$ = Irrigation efficiency

The basics data used for calculation consist of crop area, crop calendar, evapotranspiration, rainfall and crop coefficient. Calculation based on monthly basis from April 2008 to April 2009 with the following assumptions;

- Land preparation for paddy = 200 mm./season
- Water seeps from paddy field = 3.0 mm/day
- Irrigation efficiency = 50% for irrigation project area and 100% for non-irrigation area because famer get water from nearby water sources, save and less loss.

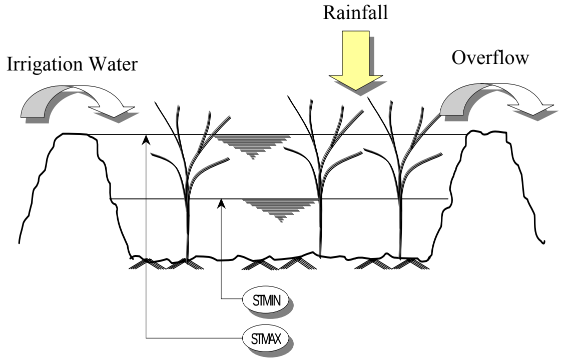


Fig. 5 Water level condition of effective rainfall calculation model

Effective rainfall depends on the farm’s bund and water supply behavior. Effective rainfall fills to paddy field, depending on amount of rainfall, R_n and water level before rain that divided into 3 levels as shown in Fig. 5 and with condition in Table I as following

TABLE I
EFFECTIVE RAINFALL CONDITION

Case	Effective Rainfall, R_e	Condition
STn-1>STMAX	0	
STMIN<STn-1<STMAX	STMAX-STn-1 Rn	Rn>(STMAX-STn-1) Rn<(STMAX-STn-1)

Note: STn-1 = water level in paddy field before rain.

- Minimum water level in paddy field (STMIN) = 45 mm.
- Water level after usual supply water (STO) = 90 mm.
- Maximum water level in paddy field (STMAX) = 120 mm.

B. Water Balance in River System

The Mike Basin program, developed by DHI (Danish hydraulic Institute) is a tool for water balance calculation of river system with the principle equation.

$$S_i = S_{i-1} + I_i - Q_i - E_i \quad (2)$$

Where S_i = reservoir storage at the end of time i
S_{i-1} = reservoir storage at the end of time i-1
I_i = inflow to reservoir at period i
Q_i = outflow to reservoir at period i
E_i = net loss from evaporation seepage and rainfall at period i

Schematic Diagram of the Nam Kam Basin for modeling shows in Fig. 6. The water use for agriculture from the model is summarized below.

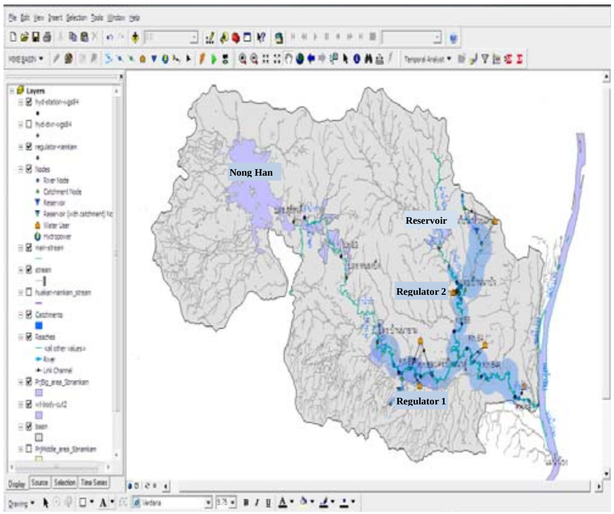


Fig. 6 Schematic diagram of the Nam Kam River system

Irrigation area: The total irrigation area is approximately 136.48 Km^2 with total water demand 184.18 MCM/year. This amount of water comprise of effective rainfall 39.72 MCM /year (21.56%), water from irrigation project 144.19 MCM /year (78.29%), and groundwater or other source approximately 0.27 MCM /year (0.15%).

Non-irrigation area: The total non-irrigation area is 557.69 Km^2 with total water demand 405.40 MCM /year. This amount of water comprises of effective rainfall 148.97 MCM /year (36.75%). From interview to farmer and field observation, the Nam Kam River and its main tributary cannot deliver water to non-irrigation area further than 500 m from the bank because lack of irrigation system. These steam water is approximately 178.66 MCM/year (44.07%). Groundwater or other source is approximately 77.77 MCM /year (19.18%).

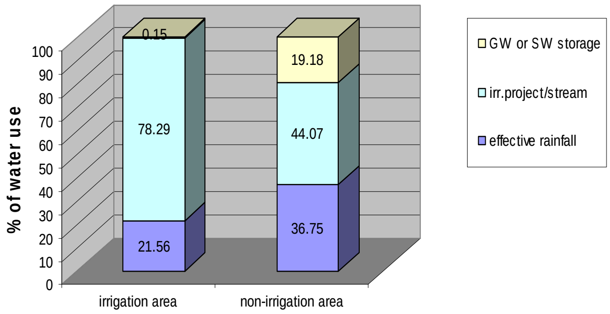


Fig. 7 Percentage of water use for agriculture in irrigation and non-irrigation area

V. Analysis of Water Quality for Irrigation

The surface water and groundwater samples are collected in the wet and dry seasons. The sampling points shows in Fig.8. The 60 samples in each season (25 surface water samples and 35 groundwater samples) are analyzed in laboratory for 13 parameters, i.e. pH (at 25^{o}C), Conductivity, Total Dissolved Solids, Nitrate, Calcium, Magnesium, Iron, Sodium, Potassium, Bicarbonate, Carbonate, Chloride and Sulfate. The assessment criteria of the suitability of water for irrigation consider from these characteristics

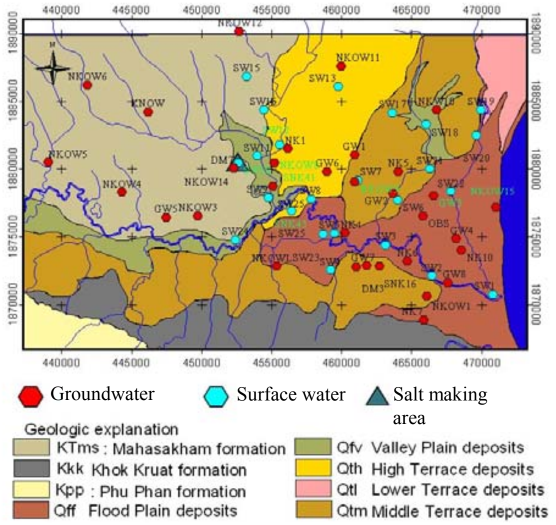


Fig. 8 Sampling point for water quality testing

Salinity: Salts in soil or water reduce water availability to the crop to such an extent that yield is affected.

Water infiltration rate: Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters to soil. Such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation to the next. The two most common water quality factors which influence the normal infiltration rate are the salinity of the water (total quantity of salts in the water) and its sodium content relative to the calcium and magnesium content. High salinity water will increase infiltration. Low salinity water or water with high sodium to calcium ratio will decrease infiltration. Both factors may operate at the same time.

Ion toxicity: Calcium, Magnesium, sodium, Carbonate, Bicarbonate, Chloride, Sulfate, Nitrate or Potassium from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields.

Miscellaneous: Excessive nutrients reduce yield or quality; unsightly deposits on fruit or foliage reduce marketability; excessive corrosion of equipment increases maintenance and repairs.

Water quality problems though often complex, generally occur in the four general categories previously discuss. Each may affect the crop and soil singly or in combination of two or more [6]. This research observes the Residual sodium carbonate (RSC), Electrical conductivity (EC_w), Sodium adsorption ratio (SAR) and toxic to evaluate water quality. The irrigation water quality criteria of each parameter show in Table II-Table VI [7].

TABLE II
EVALUATE USING RSC AND SCORE

RSC (meq/L)	< 1.25	1.25 – 2.5	> 2.5
Degree of Restriction on Use	None	Can be used but need to monitor soil salinity and a good management	Not suitable
Score	2	0	- 2

TABLE III
EVALUATE USING EC_W AND SCORE

Degree of Restriction on Use	EC (mS/m)	Score
Excellent: Can be used for all crop	≤ 25	2
Good: Can be used if there is sufficient water for leaching. No need the measure for salinity accumulation control. Suitable for sensitive crop.	25 – 75	1
Permissible: Cannot be used for poor drainage capacity soil. Need measure for salinity control. Suitable for moderate sensible crop.	75 – 200	0
Doubtful: May be used in a special case, such as good infiltration and drainage capacity soil. Sufficient water for leaching and suitable for tolerant crop.	200 - 300	-1
Unsuitable: Cannot be used for all crop	≥ 300	- 2

TABLE IV
EVALUATE USING SAR AND SCORE

Degree of Restriction on Use	SAR	Score
Very low: Can be used for all crop	< 1	2
Low: Can be used but need to be careful for tolerant crop.	1– 9	1
Medium: Need gypsum and leaching for quality improvement.	10 – 17	0
High: Unsuitable for longtime using. (Chronic effect)	18 - 25	-1
Very high: Cannot be used for all crop	≥ 26	- 2

TABLE V
EVALUATE USING TOXICITY AND SCORE

Ions	Unit	Recommended range	Values in study area[1]	
			Wet season	Dry season
Calcium (Ca^{2+})	meq/L	0 - 20	0.409 – 4.337	< 0.1 – 1,275
			0.79 – 6,230	0.1 – 16,227
Magnesium (Mg^{2+})	meq/L	0 - 5	0.02 - 1.06	< 0.001 – 247
			0.06 – 2,113	0.0 – 964
Sodium (Na^{+})	meq/L	0 - 40	0.37 - 39	0.9 – 39,829
			1.17 – 35,850	1.4 – 28,759
Carbonate (CO_3^{2-})	meq/L	0 - 0.1	2.1 – 8.4	0
			2.40 - 105	0.0 - 0.0
Bicarbonate (HCO_3^-)	meq/L	0 - 10	8.5 – 34	0.0 – 280
			9.80 - 427	0.0 – 632
Chloride (Cl^-)	meq/L	0 - 30	2.5 - 70	1.0 – 39,824
			3 – 118,463	1.7 – 145,670
Sulfate (SO_4^{2-})	meq/L	0 - 20	0 – 10.85	0.1 – 260
			0 – 1,084	0.0 – 129
Nitrate (NO_3^-)	mg/L	0 - 10	0 – 0.20	< 0.14 - 0.80
			0 – 4.41	0 – 4.41
Potassium (K^+)	mg/L	0 - 2	1.20 – 3.26	1.5 – 11
			0.60 – 16,080	0.0 – 4,810
	Score	1	If in recommended value	
	Score	-1	If out of recommended value	

Note: [1] Upper row = surface water; Lower row = groundwater

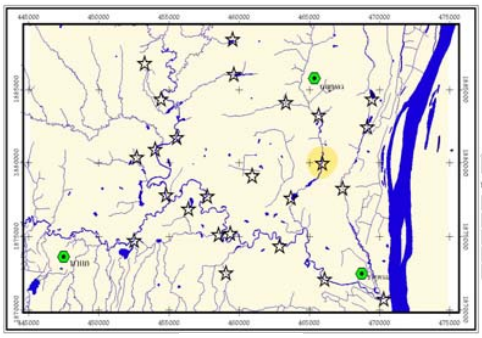
TABLE VI
EVALUATE USING IRON (FE^{2+}) AND SCORE

Value	< 5 mg/L	5 < X <20 mg/L	> 20 mg/L
Degree of Restriction on Use	Not influence to crop if soil has good drainage	Influence to crop if continue use for long period	Influence to crop if continue use for short period
Score	1	-1	-1

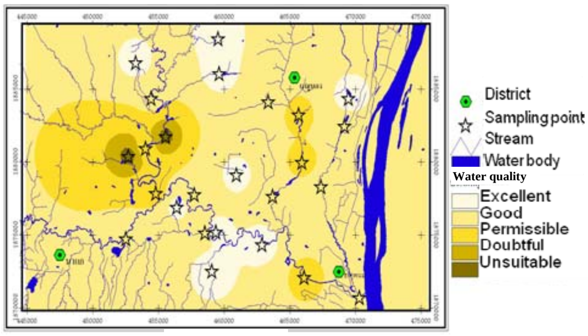
The laboratory testing results found that all water types in study area had RSC over 2.5 meq./L in all season which is not suitable for irrigation. This may promote soil problems i.e., compact soil which is inhospitable for crops.

The distribution of EC_w, SAR of surface water and groundwater in wet and dry season presents in Fig. 9.- Fig. 14. The EC_w of surface water in wet season does not be problem for crop use, while dry season, many points are not suitable for crop use particularly along the Nam Bang stream. Shallow groundwater has worst quality than surface water but mostly lie on usable for crop. The deep groundwater quality at all 4 points is not suitable for crop both in wet and dry season. The SAR of surface water in wet season has high value near the Mekong River and extends cover most of area in the dry season particularly near salt making area at the Nam Bang stream. The SAR of shallow groundwater has medium to very high value in dry season more than in wet season. The deep groundwater at 3 point show very high value both in wet and dry season while 1 points change from low SAR in wet season to high SAR in dry season.

The toxic substances for plant from Table V show that this area has highest value of toxicity over the recommended value except nitrate. Groundwater has more high toxicity than surface water. The concentration of Fe^{2+} of surface and groundwater in Fig. 15- Fig. 17 shows that most of water has value in the recommendation, but groundwater have more points that out of recommendation value than surface water.

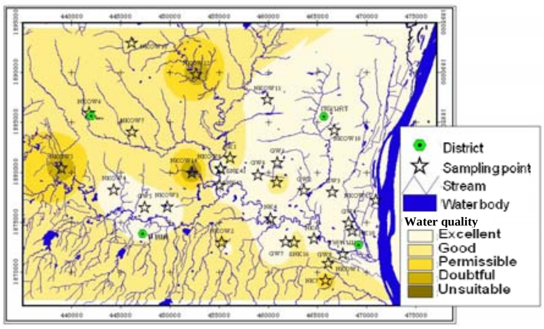


Wet season

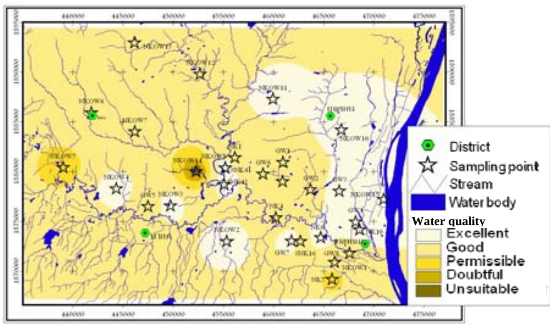


Dry season

Fig. 9 Surface water quality assessment evaluate using EC_w

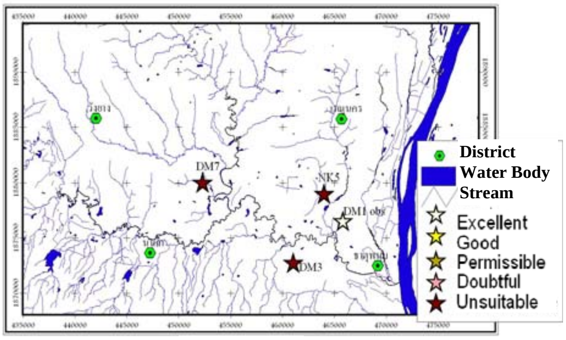


Wet season

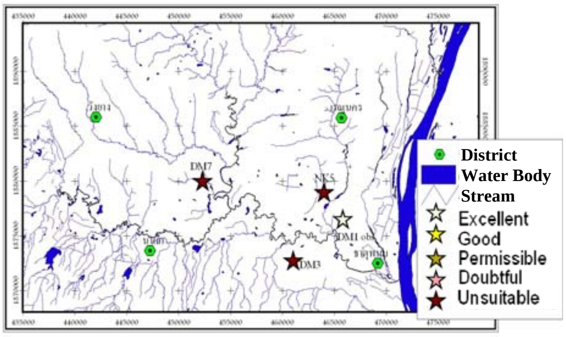


Dry season

Fig. 10 Shallow groundwater water quality assessment evaluate using EC_w

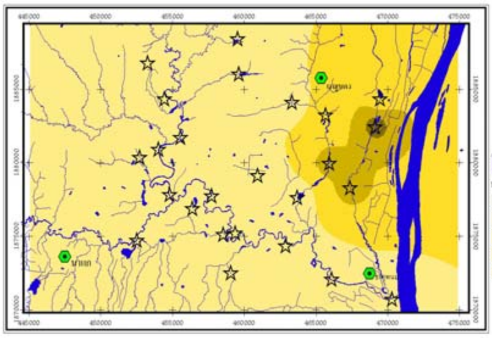


Wet season

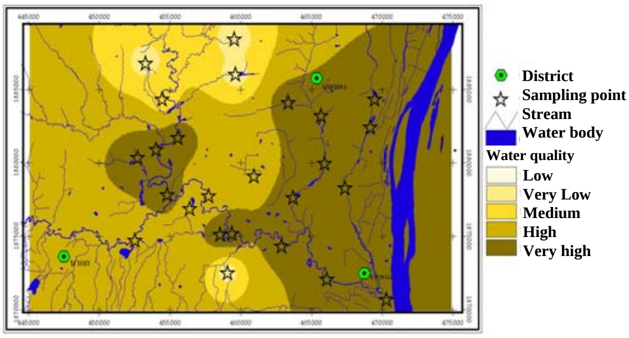


Dry season

Fig. 11 Deep Groundwater quality assessment evaluate using EC_w

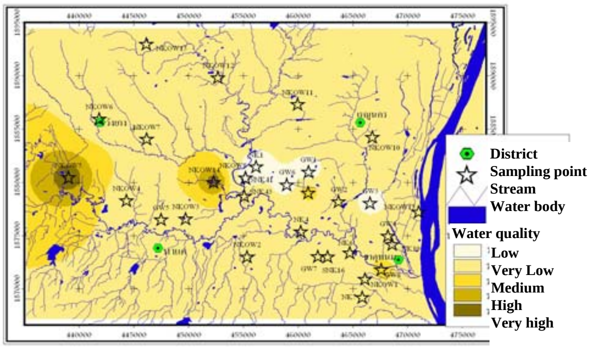


Wet season

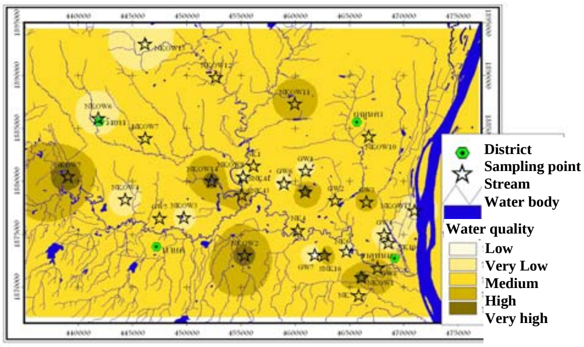


Dry season

Fig. 12 Surface water quality assessment evaluate using SAR

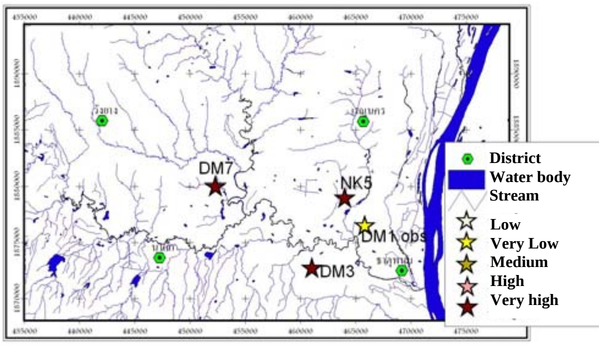


Wet season

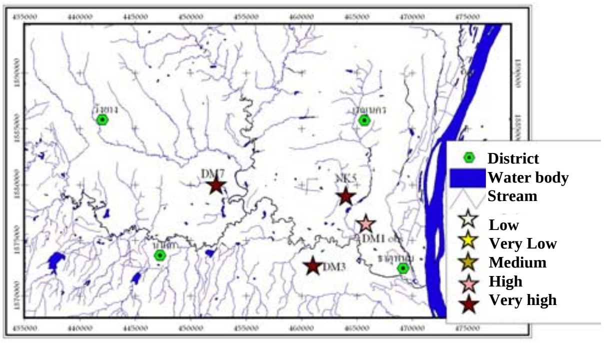


Dry season

Fig. 13 Shallow groundwater water quality assessment evaluate using SAR

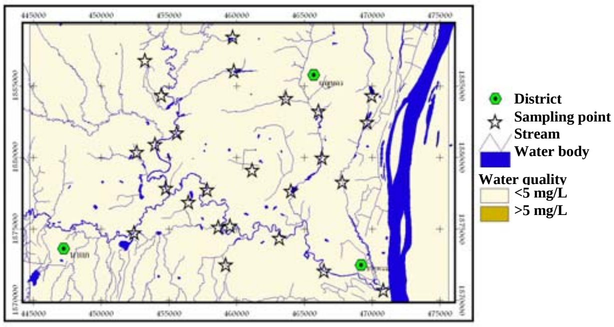


Wet season

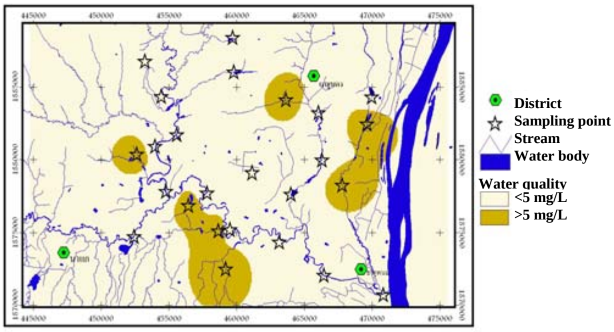


Dry season

Fig. 14 Deep groundwater water quality assessment evaluate using SAR

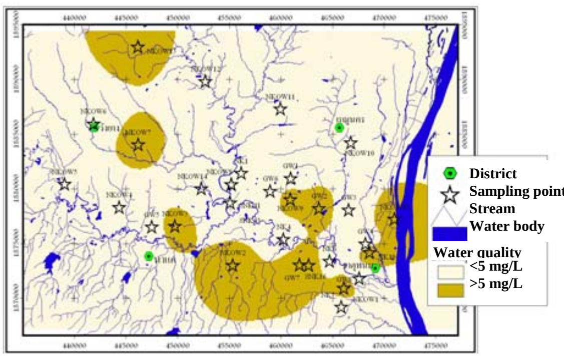


Wet season

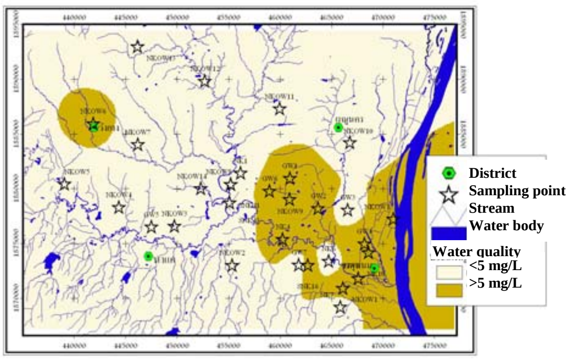


Dry season

Fig. 15 Total iron of surface water in wet and dry season

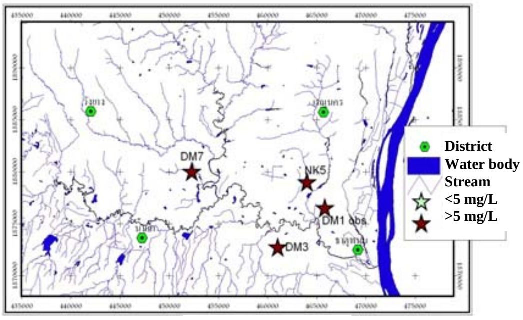


Wet season

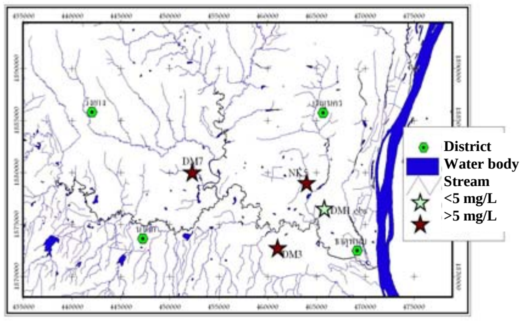


Dry season

Fig. 16 Total iron of shallow groundwater in wet and dry season



Wet season



Dry season

Fig. 17 Total iron of deep groundwater in wet and dry season

To evaluate water quality by combine all parameters, we set up the criteria to evaluate suitability of water in 2 main steps;

Step 1: Evaluate using EC_w and SAR together as show in Table VII. If value is in moderate or none restrict of use (quality score ≥ 0), then consider next step

Step 2: Consider parameters of EC_w, SAR, Toxicity and RSC and give quality score of each one as show in Table II-VI.

The summation score of step 1and step 2 was used to evaluate the suitability of water for irrigation that are classified into 3 levels, suitable, fair and unsuitable depends on the score as following;

TABLE VII
EVALUATE USING EC_W AND SAR TOGETHER AND SCORE

Potential Irrigation Problem				**Units**	**(Degree of Restriction on Use)**		
					(None)	**(Slight to Moderate)**	**(Severe)**
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*							
SAR	= 0 – 3	**and EC_w**	=	mS/m	> 70	70 – 20	< 20
	= 3 – 6		=	mS/m	> 120	120 – 30	< 30
	= 6 – 12		=	mS/m	> 190	190 – 50	< 50
	= 12 – 20		=	mS/m	> 290	290 – 130	< 130
	= 20 – 40		=	mS/m	> 500	500 – 290	< 290
Score					2	0	-2

Suitable: EC_w:SAR score ≥ 2 and total score of EC_w, SAR, Toxicity and RSC > 2

Fair: EC_w: 2 < SAR score ≥ 0 and total score of EC_w, SAR, Toxicity and RSC > 2

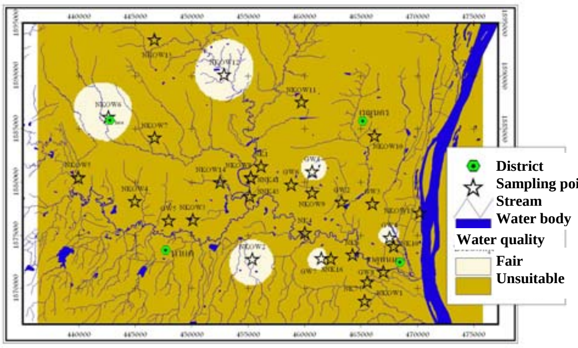
Unsuitable: EC_w : SAR score < 0 (not pass step 1) or total score of EC_w, SAR, Toxicity and RSC ≤ 2 (not pass step 2)

The results of water quality classification using criteria as mention can be concluded as the following.

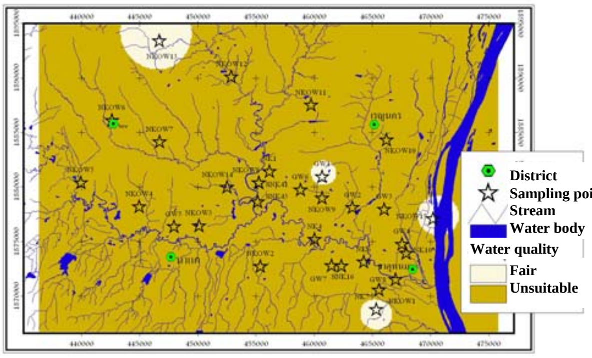
Surface water: when evaluate water quality using EC_w and SAR together (EC:SAR), all sampling points have severe condition to use (Step 1 with score -2) at all point and all season. Then, surface water is classified as unsuitable quality level for crop using.

Shallow groundwater: Fig. 18 shows the distribution of shallow groundwater quality classification level in wet and dry season. From 31 sampling points, only 6 points in wet season and 4 points in dry season have quality classification level of fair for crop using while remaining points have level of unsuitable for crop using. Then, most of shallow groundwater sampling points are unsuitable using for crop.

Deep Groundwater: All sampling points have quality classification as unsuitable level for crop using in all season as well as surface water.



Wet season



Dry season

Fig. 18 The assessment of suitability of shallow groundwater

VI. Conclusion

The aim of research project is to evaluate quantity and quality for conjunctive use of groundwater and surface water in the Lower Nam Kam area, Thailand, even though there have been hints of saline soil and water. The mathematical model named WUSMO and MIKE Basin were applied for the calculation of crop water utilization. As the results, the authors get the following results.

Cultivation area in the Lower Nam Kam basin is approximately 694.16 Km^2. The total water demand is estimated to 589 MCM/year with comprise of effective rainfall 32.0%, irrigation water 24.5 %, the Nam Kam and Nam Bang River 30.3% and groundwater or other source 13.2%. The area has conjunctive use of surface water and groundwater because of the water scarcity problem. However, the quality of surface water, shallow and deep groundwater are examined in wet and dry season, the results show that surface water's quality in this study area has so limitation for crop utilization and causes decrease infiltration capacity of soil due to a high salinity water and high sodium to calcium ratio. The groundwater, as well as surface water, is inappropriate to use anywhere and anytime. Then, this area need to have the water development program in order to control and manage water quality for the sustainable conjunctive use of surface water and groundwater.

Acknowledgment

The authors wish to thank the Royal Irrigation Department and Tokai University for supporting data and equipment in this research. National Research Council of Thailand is highly appreciated to the main contribution of research fund.

References

[1] Royal Irrigation Department, Thailand. "Lower Nam Kam Basin, report on proposed development strategy"*, by GITEC Consult GMBH, (1982).*

[2] Khon Kaen University. "Environmental Impact Study of the Lower Nam Kam Irrigation Project Report", (2001).

[3] Royal Irrigation Department, Thailand. "The feasibility and environmental impact study of Lower Nam Kam irrigation project", *by Asdecon coperation Com., (1995).*

[4] Royal Irrigation Department, Thailand. "The environment mitigation and rehabilitation for salt rock geology and hydrogeology of Lower Nam Kam irrigation project", *by Chiang Mai University, (2006).*

[5] P. Mekpruksawong et.al. "An analysis of groundwater condition in a saline groundwater area, Thailand" in 2008 Proc. HYDROCHANGE Conf.,Japan pp.401-408

[6] Ayers, R.S. and D.W. Westcot. "Water quality for agriculture" *FAO Irrigation and Drainage paper 29. FAO,* Rome 1976, pp. 3-4.

[7] P. Jirawan, "Water Quality for Irrigation" (Book style). Royal Irrigation Department, Thailand, pp. 123–135.