FEASIBILITY MAPPING OF GROUND WATER YIELD CHARACTERISTICS USING WEIGHT OF EVIDENCE TECHNIQUE: A CASE STUDY

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ABSTRACT:

In this study, weight of evidence(WOE) technique based on the bayesian method was applied to estimate the groundwater yield characteristics in the Pocheon area in Kyungki-do. The ground water preservation depends on many hydrogeologic factors that include hydrologic data, landuse data, topographic data, geological map and other natural materials, even with man-made things. All these data can be digitally collected and managed by GIS database. In the applied technique of WOE, The prior probabilities were estimated as the factors that affect the yield on lineament, geology, drainage pattern or river system density, landuse and soil. We calculated the value of the Weight W+, W- of each factor and estimated the contrast value of it. Results by the ground water yield characteristic calculations were presented in the form of posterior probability map to the consideration of in-situ samples. It is concluded that this technique is regarded as one of the effective technique for the feasibility mapping related to detection of groundwater bearing zones and its spatial pattern.

KEY WORDS: Weight of evidence , Groundwater yield characteristics, Hydrogeologic factors, GIS

1. . INTRODUCTION

The Ground water is a hidden, but important resource. Over developing of the ground water resource might give rise to serious disasters such as drying up, ground subsidence and seawater invasion since the amount of ground water resource is not limitless. Once ground water disaster happened, it can not only be usable any more but also recovery takes a long time. Therefore, reasonable procedure and method for getting the feasibility mapping of ground water is indispensable for proper usage and systematic control of water resources.
The feasibility mapping of ground water on Pocheon area in Kyongki-do carried out with a statistical research. Bayesian, modified weight of evidence modelling statistical analytical method, is developed for a non-spatial application in medical diagnosis (Raines GL, Bonham-Carter GF, Kemp LD, 2000). This method has been used for spatial estimation system such as Integration of geological database for Gold Exploration in Nova Scotia (Bonham-Carter, 1998) and A predictive GIS model for mapping potential gold and base metal mineralization in Takab area, Iran (Asadi and Hale, 2001). The groundwater preservation depends on many hydrogeologic factors that include topographic data, land use data and geological map and other natural materials, even with man-made things. All these data can be digitally collected and managed by GIS database. And finally the map of ground water yield characteristics is made out.

2. TOPOGRAPHY AND GEOLOGY

The Pocheon area is located in the end of northern Kyongki-do, lying within the coordinates of 37° 36' 00"N~38° 11' 00"N, 127° 05' 00"E~127° 27' 00"E . In general, geography is related with geology and structure. The study area has mostly N40~45E trending faults. These faults are associated with Pocheon fault zone which has mainly two north eastern trending faults. Additionally study area has minor N22~45W trending faults came from main faults. Eastern and western part of study area is covered with steep hilly to mountainous terrain. Around these steep area, there is plain low land composed of granite. The Pocheon area is composed of Pre-Cambrian meta sedimentary rocks, Mesozoic igneous rocks, Cretaceous sedimentary rocks and volcanic rocks and Quaternary basalt.

Meta sedimentary rocks consist of biotite gneiss, granite gneiss, porphyroblastic gneiss, quartzite, limestone, quarts-mica schist. Igneous rocks consist of diorite, gabbro, coarse grained biotite granite, fine grained biotite granite and mica granite generated from Jurassic Daebo orogeny. Northern part of study area is characterized with unconformity of Cretaceous sedimentary rocks, volcanic rocks and Quaternary basalt. Sedimentary rocks mainly composed of conglomerate and sandstone with shale and mudstone interbedded are dominant in the Sinhung-li and Gososung-li, Chansu-myun (Fig. 1).

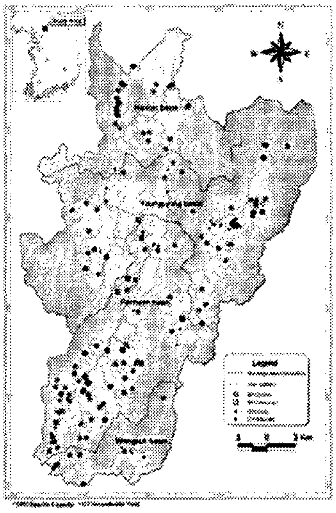

Fig. 1. Location of the study area.

3. METHODS

3.1 Bayesian Analysis

Weight of evidence methodology combines spatial data from diverse sources to describe and analyze interactions, provide support for decision makers, and make predictive models. This method is based on the application of Bayes' Rule of probability, with an assumption of conditional independence. Probability is the measurement of uncertainty and subjective uncertainty to the probability of occurrence of an event is expressed as a value between 0 and 1. Measurement would be determined by current knowledge or information of the event. Therefore, if a new information is obtained, its probability would be corrected and Bayes' Rule provides with the method to make corrections in the probability with such new information is obtained. One of the main concepts in the Bayes' Rule is the idea of prior and posterior probability. Prior probability is the initial probability that is determined prior to consider various spatial data; this prior probability may be corrected with use of additional information related to specific event and this corrected probability is posterior probability. That is, prior probability is obtained by analyzer's intuition or subject experience of the past and prior probability may be corrected to form posterior probability according to additional information. Therefore, Bayes' Rule is the one used in obtaining conditional probability of each model when measurement value is set up to each model that has prior probability and the such conditional probability of each model is called posterior probability. (Bonham-Carter, 1994.)

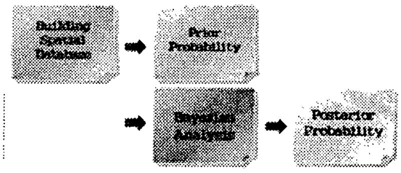

Fig. 2. Bayesian analysis process.

The GIS-based groundwater yield characteristics mapping process can be broken down into four main steps.

1) Building a spatial digital database
2) The estimation of a prior probability: the probability of groundwater yield characteristics in a unit area, given no further information
3) Calculating weights and generalize for each evidential theme
4) Combining the evidential theme to predict groundwater yield characteristics

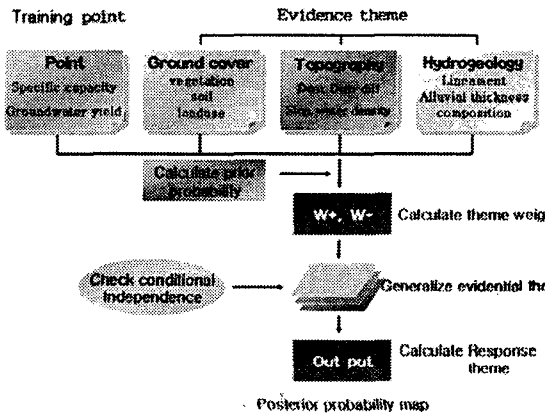

Fig. 3. Flow chart for identification of groundwater yield characteristics.

3.2 Input maps

Each data was set up as the spatial database with use of Arcview program

Table1. Data layer of study area

Data name	Data Type	Scale
Groundwater yield	Point	1:50,000
Vegetation map	Grid	20m × 20m
Soil map	Polygon	1:50,000
Landcover map	Polygon	1:50,000
Slope map	Grid	20m × 20m
Drainage density map	Grid	20m × 20m
DEM	Grid	20m × 20m
Lineament density map	Grid	20m × 20m
Hydrologic unit map	Polygon	1:50,000
Alluvial layer map	Grid	20m × 20m

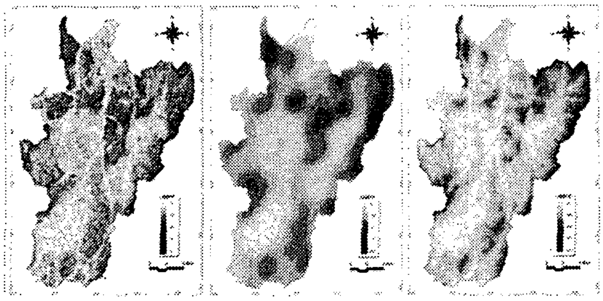

Fig. 4. (a) Slope map, (b) Digital Elevation map, (c) DEM-diff map.

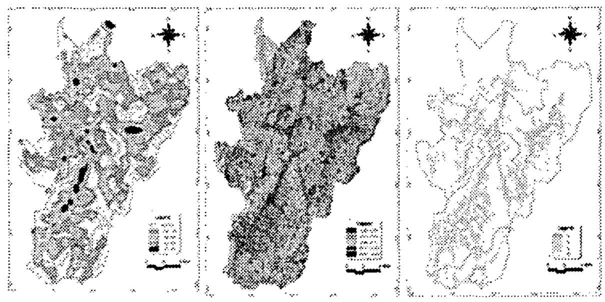

Fig. 5. (a) River system, (b) Vegetation map, (c) Soil map.

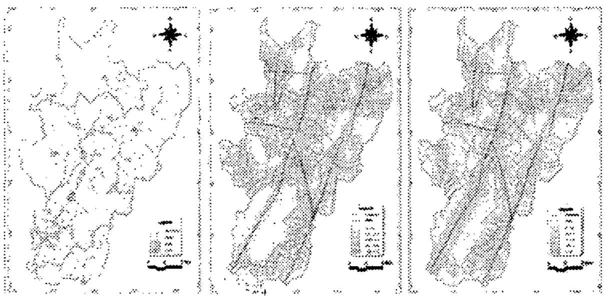

Fig.6.(a) Landuse map, (b) Lineament density, (c) Lineament (continuity) Density.

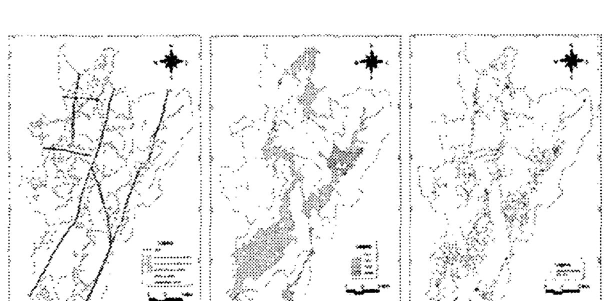

Fig. 7. (a) Hydrogeologic unit, (b) Alluvium component, (c) Alluvium Thickness.

4. CONCLUSIONS AND REMARKS

In this study, to perform groundwater yield characteristic analysis, database was set up with use of Arcview GIS program using spatial data of various elements related to topography, land cover and geology of Pocheon area in Kyungki-do, and groundwater yield characteristics map was drawn with use of weight of evidence method of Bayesian analysis (Fig. 8).

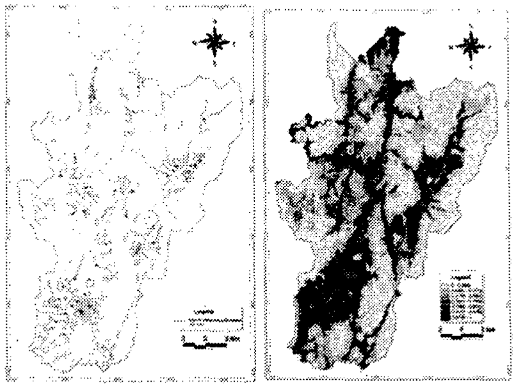

Fig. 8. (a) Alluvium weathering thickness, (b) Map of a posterior probability of a groundwater yield characteristic

In addition, aquifer capacity was quantitatively classified with application of groundwater yield of well corresponding to drawn groundwater yield characteristic map. Contribution of soil and landuse characteristics of vadose zone to groundwater recharge was considered through assessment of landcover elements. SCS soil classification was corrected and applied in the soil elements among landcover elements in consideration of permeability and run-off. It was found that groundwater yield characteristic was high in Group A and Group B. Contribution to recharge rate was high with elevating density of vegetation and was high when vegetation was not less than 20%. Landuse was high in agricultural area. The elements of average digital elevation, slope, altitude difference and river system density of the area corresponding to 20mX 20m lattice were considered as topographic elements. High topographic altitude and high slope increase run-off are disadvantageous in groundwater recharge. It was high when topographic altitude was not higher than 250m, slope was not higher than 9°, and altitude difference was not larger than 150m. Run-off is increased with elevating river system density but is also contributable in recharge. It was high when river system density was not less than 2. In terms of geology element, assessment was made with use of the elements related to lineament and hydrogeologic unit influencing on rock aquifer and, in case of area with developed alluvium, assessment was made with use of the thickness and constituents of alluvium influencing alluvium aquifer. Unconsolidated sediment was high among hydrogeologic units and yield probability is high with elevating lineament density and continuity. When lineament density was not lower then 0.8, lineament in consideration continuity is high in case of not lower than 0.4. Groundwater yield probabilities of constituents of alluvium were similarly high; gravel showed high probability; yield characteristic is increased with increasing thickness of alluvium and weathering and was high when thickness of alluvium was not less than 20m and weathering thickness was not less than 16m (Table 2).

Table 2. Weight of evidence analysis of recognition criteria domain

	CLASS	Area(sq.km)	Points	W+	S(W+)	W-	S(W-)	C	S(C)	stud(C)
Vegetation (%)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Soil	A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	D	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Landuse	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	agriculture	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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DEM (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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DEM-difference (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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slope (°)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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River system density	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	CLASS	Area(sq.km)	Points	W+	S(W+)	W-	S(W-)	C	S(C)	stud(C)
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thickness (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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weathering thickness (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Hydrogeologic unit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible] density	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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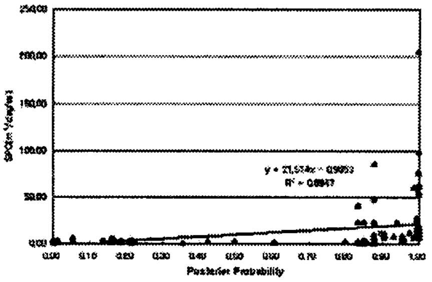

Fig. 9. Relationship between posterior yield (rock) and SPC.

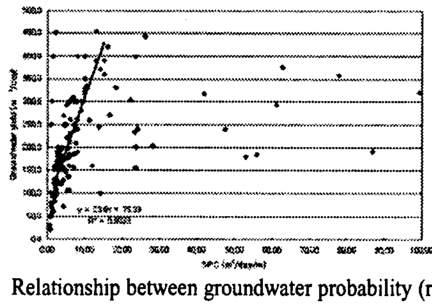
Fig. 10. Relationship between groundwater probability (rock) and SPC.

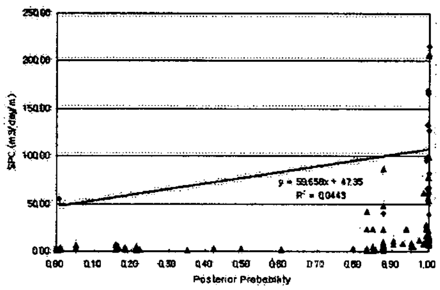

Fig. 11. Relationship between posterior yield (alluvium) and SPC.

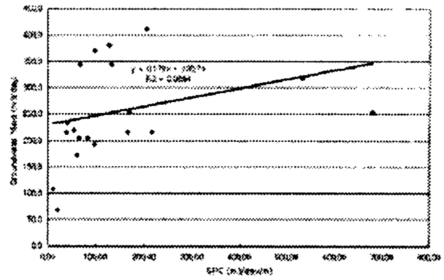
Fig. 12. Relationship between groundwater probability (alluvium) and SPC.

The result of yield characteristic analysis was tested with use of correlation between the result of groundwater yield characteristic analysis and well yield data, and the significance of such result was quantitatively expressed with use of yield data. For this, well yield data form 43 places of alluvium aquifer and 197 places of rock aquifer were used. In case of rock aquifer, expected groundwater yield is 150m^3/day, 250m^3/day, 350m^3/day, 450m^3/day and 550m^3/day at not higher than 0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8 and at not lower than 0.8 of groundwater yield probability, respectively (Fig. 9, Fig. 10) and, in case of alluvium aquifer, 240m^3/day of constant groundwater yield is expected at overall groundwater yield probabilities (Fig. 11, Fig. 12). Predictive groundwater yield obtained with this result of yield characteristic analysis is a statistical quantity by the element influencing on groundwater yield characteristics and well yield data; the result may be changed by distribution and reliability of well yield data and the quantity may changed with correction of assessment elements or addition/removal of data. In future, to test the assumption of conditional independence that is the basic assumption in Bayesian analysis used in this study, pairwise test and overall test should be performed and review on uncertainty of expected values (weight distribution and missing data) are required.

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