Enhancing the Roles of Groundwater in the Context of the Sustainable Development Goals via Aquifer Vulnerability Assessment

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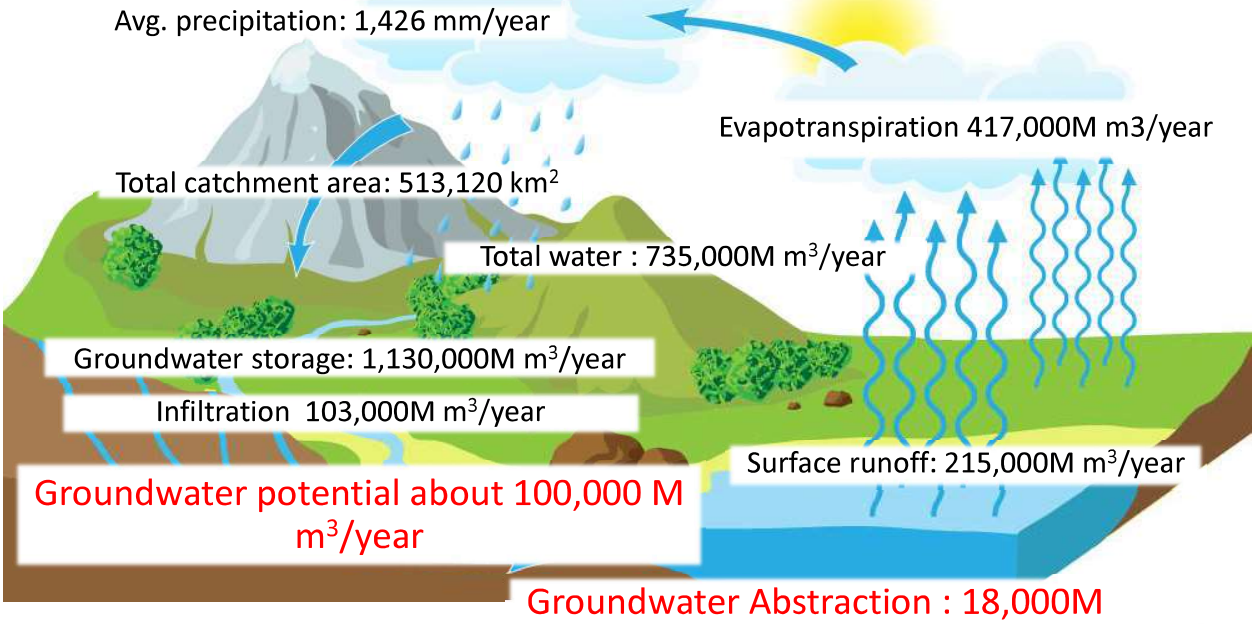
Presentation Outline

- Introduction/Research Problem Statement
- Materials and Methodology
- Results and Discussion
- Research Summary

Introduction: Thailand's water cycle

Source : 1. Department of Groundwater Resources
2. วจี รามณรงค์และสมชัย วงศ์สวัสดิ์, 2542



National Water Management Strategy

1. Water for Consumption
2. Water for Sustainable
3. Flood and Drought Mitigation
4. Water Quality
5. Water for Ecosystem
6. Water Management

Source : Office of the National Water Resources

Problem Statements and Research Objectives

Importance of Groundwater

- Water Supply, Sanitation, and Hygiene
- Food Security
- Sustainability, Ecosystems, and Climate Change

Research Objectives

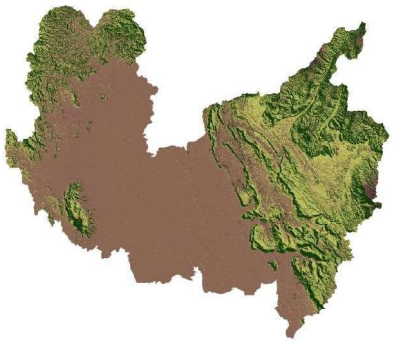
- To Compile Generic Global and Sparse Localized Hydrogeo-Spatial Datasets for DRASTIC Index Inputs
- To Perform Groundwater Vulnerability Assessment using DRASTIC Index model in Representative Study Areas
- To Validate DRASTIC Vulnerability Map with in-situ Contamination Measurements

Study Area

1. Pitsanulok/Sukhothai

2. Suphanburi

Source : Perry-Castañeda Library



3.Chanchoengsao

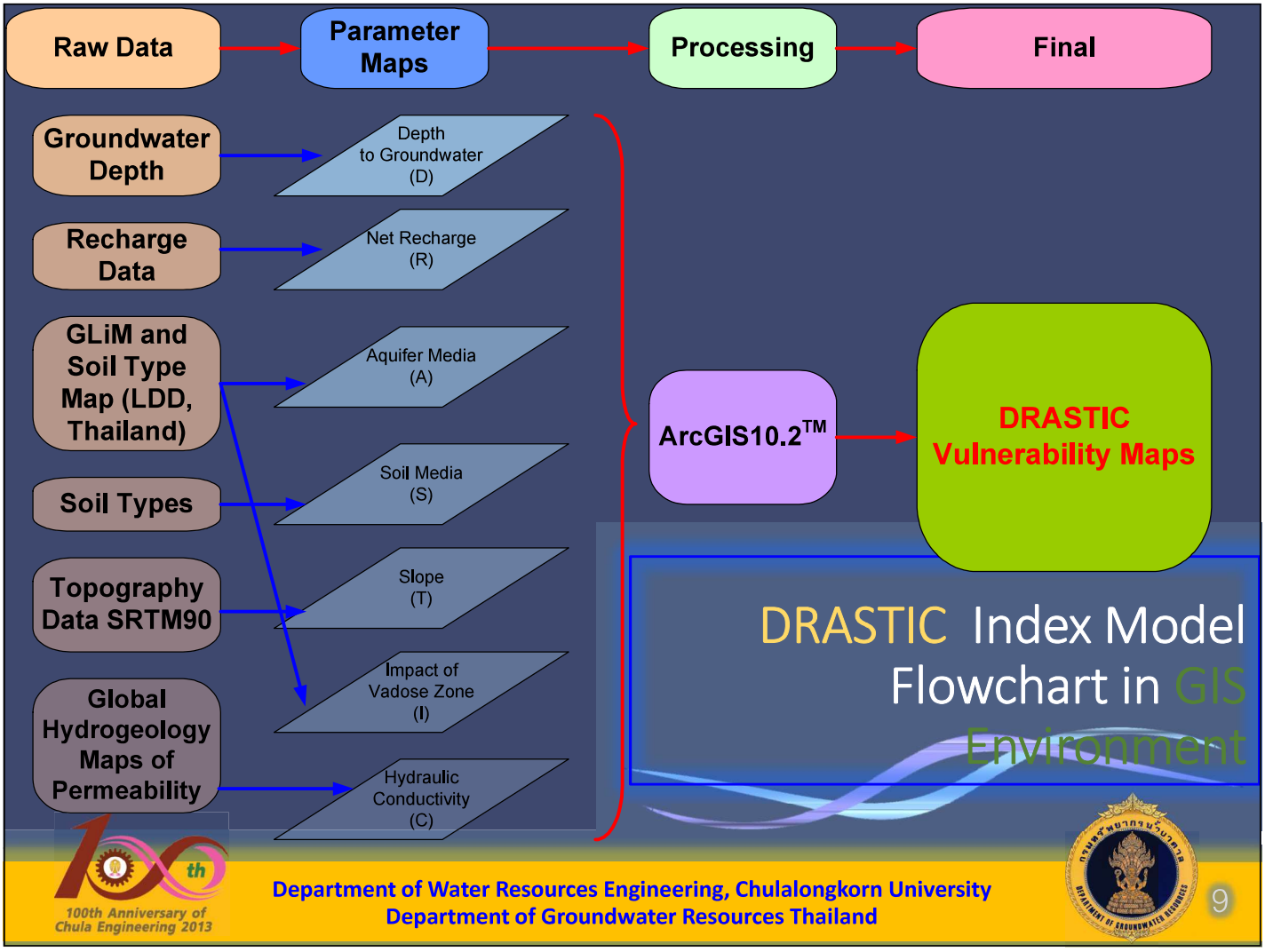
Low — High

Groundwater Vulnerability Assessment
DRASTIC (Aller et al. 1987)

DRASTIC Vulnerability Map

The DRASTIC vulnerability index equation:

$$D_i = D_w D_{r,i} + R_w R_{r,i} + A_w A_{r,i} + S_w S_{r,i} + T_w T_{r,i} + I_w I_{r,i} + C_w C_{r,i}$$



Rate and Weight of DRASTIC Indexes

D R A S T I C

Rate and Weight of 7 DRASTIC Parameters *(Modified from Aller et al. 1987)*

Depth to Groundwater (m)		Net Recharge (mm)		Topography (%)		Hydraulic Conductivity (m/d)		Soil Media	
Interval	Rating	Interval	Rating	Interval	Rating	Interval	Rating	Soil Classes	Rating
0-7	10	0-45	1	0-2	10	0.0 - 5.00	1	Clay	1
7-25	8	45-123	3	2-4	9	5.01 – 15.00	2	Clay Loam	3
25-50	5	123-224	6	4-8	8	15.01 – 35.00	3	Loam	5
50-100	3	224-355	8	8-12	5	35.01 – 75.00	4	Loamy Sand	7
100-250	2	>355	9	12-18	3	75.01 – 155.00	6	Sandy Clay	2
> 250	1			> 18	1	155.01 – 315.00	8	Sandy Clay Loam	4
								Sandy Loam	6
						> 315.01	10	Silty Clay Loam	3
								Sand	9
Weight = 5		Weight = 4		Weight = 1		Weight = 3		Weight = 2	

100th Anniversary of Chula Engineering 2013
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Department of Groundwater Resources Thailand
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Rate and Weight of DRASTIC Indexes

Rate and Weights (*A*=3 and *I*=5) of Aquifer Media (*A*) and Impact of Vadose Zone (*I*) *(Modified from Aller et al. 1987)*

Lithology Classes[32]	Hydrolithology Classes[33]	Bedrock Materials	*A* and *I* Ratings
Unconsolidated Sediments	Unconsolidated		8
	c.g. unconsolidate	Alluvial Deposits, Dune Sands	
	f.g. unconsolidate	Loess (Aeolian Sediment), Organic Sediment	
Siliciclastic Sediments	Siliciclastic Sedimentary	Limestone, Sandstone	6
	c.g. siliciclastic sedimentary	Dolomite, Siltstone, Salt	
	f.g. sedimentary	Conglomerate, Shale	
Mixed Sedimentary Rocks	Carbonate	Karst Limestone	10
Carbonate Sedimentary Rocks			
Evaporites			
Acid Volcanic Rocks	Volcanic	Permeable Basalt	9
Intermediate Volcanic Rocks			
Acid Plutonic Rocks	Crystalline	Igneous/Metamorphic Rocks	A(3) and I(4)
Intermediate Plutonic Rocks			
Basic Plutonic Rocks			
Metamorphic Rocks			
Water Bodies	*Other Rock*	-	8

Global and Local Geo-Spatial Data Assimilation for DRASTIC Inputs

Raw Data	Sources	Format	Resolution/Scale	Date	Output
Groundwater Depths	DGR	Shapefile	1 km	2008	Depth of Water (***D***)
Recharge Data	DGR	Point Measurement	-	2008	Recharge (***R***)
	University of Frankfurt	Shapefile	0.5° × 0.5°		
GLiM	Hamburg University	Geodatabase	1: 3,750,000	2012	Aquifer Media (***A***) and Impact of Vadose Zone (***I***)
Aquifer Media	DGR	Shapefile	1 km × 1 km	2009	
Soil Data	LDD	Shapefile	1 km × 1 km	2009	Soil Type (***S***)
	ISRIC, World Soil Information	Raster	1 km × 1 km	2014	
SRTM90	UCL/Elle-Geometrucs (Belgium) and CGIAR/CSI	Raster	90 m × 90 m	2000	Topography (***T***) or Slope (%)

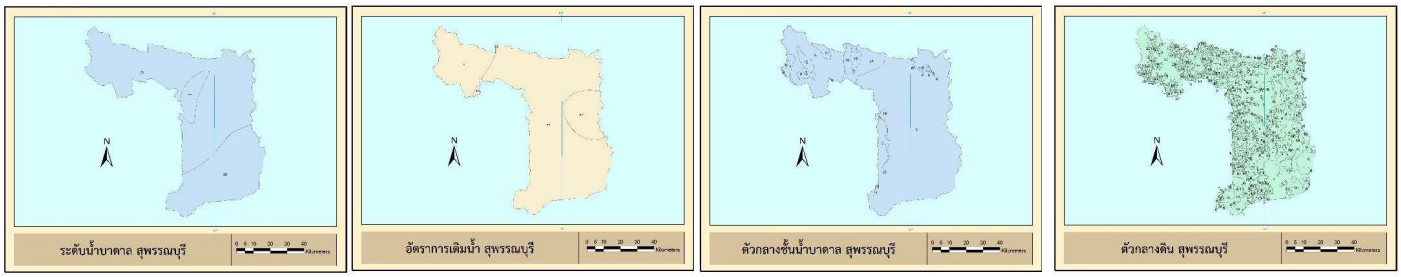
Data Sources for DRASTIC 7-Layer Generation

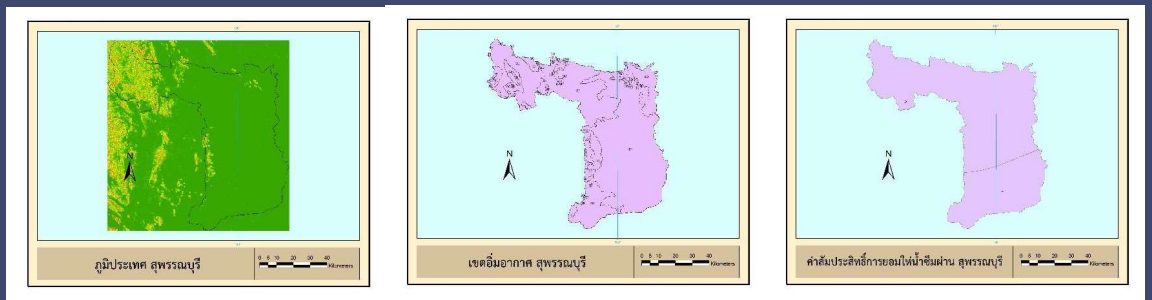
Vulnerability Classification by DRASTIC

DRASTIC vulnerability classification

DRASTIC Index	Vulnerability Class
> 176	Very High
146-175	High
115-145	Moderate
84-114	Low
< 84	Very Low

Results and Discussion
DRASTIC Map in the Suphanburi





Results and Discussion
DRASTIC Map in Chachoengsao

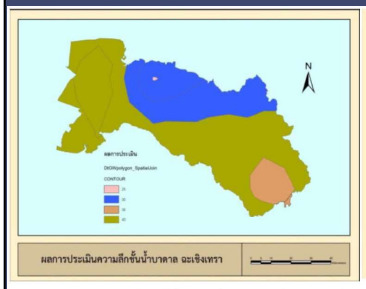


Fig. 1: DRASTIC Rating of the Depth to Groundwater (***D***) in Chachoengsao Province of Thailand

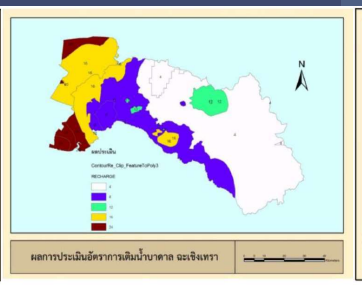


Fig. 2: DRASTIC Rating of the Recharge (***R***) in Chachoengsao Province of Thailand

Fig. 3: DRASTIC Rating of the Aquifer Media (***A***) in Chachoengsao Province of Thailand

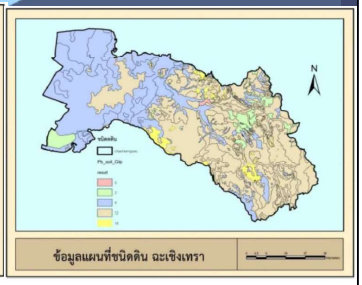


Fig. 4: DRASTIC Rating of the Soil Type (***S***) in Chachoengsao Province of Thailand

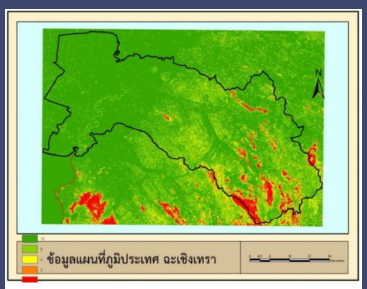


Fig. 5: DRASTIC Rating of the Topography/Slope (***S***) in Chachoengsao Province of Thailand

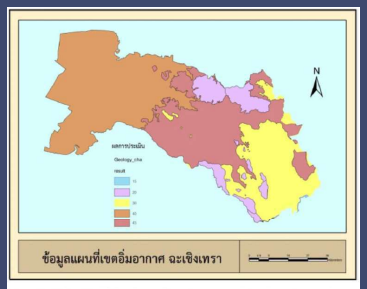


Fig. 6: DRASTIC Rating of the Impact of Vadose Zone (***I***) in Chachoengsao Province of Thailand

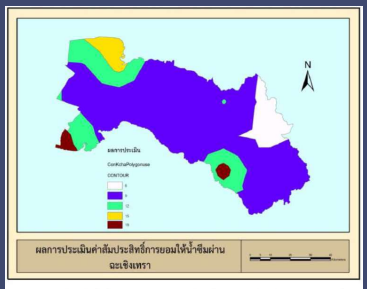
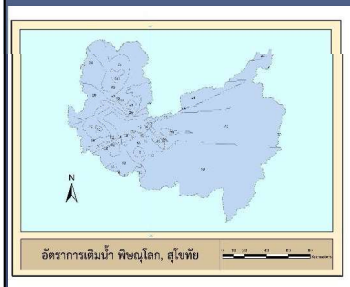
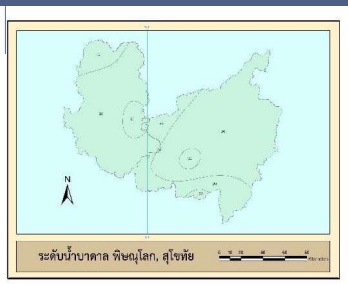
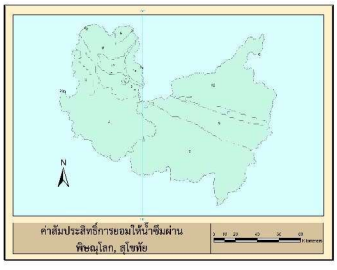


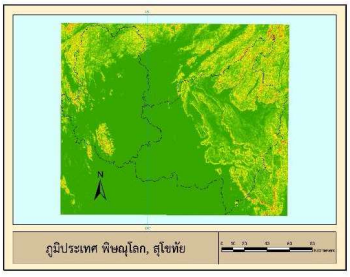
Fig. 7: DRASTIC Rating of the Hydraulic Conductivity (***C***) in Chachoengsao Province of Thailand

Results and Discussion
DRASTIC Map in the Sukhothai & Pitsanulok

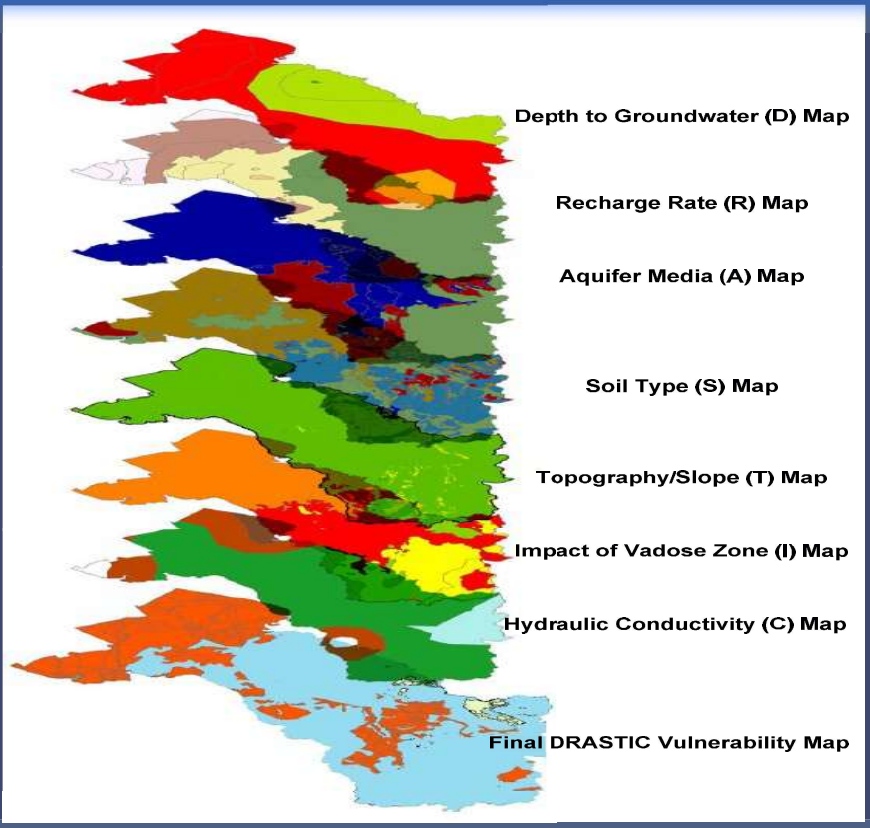




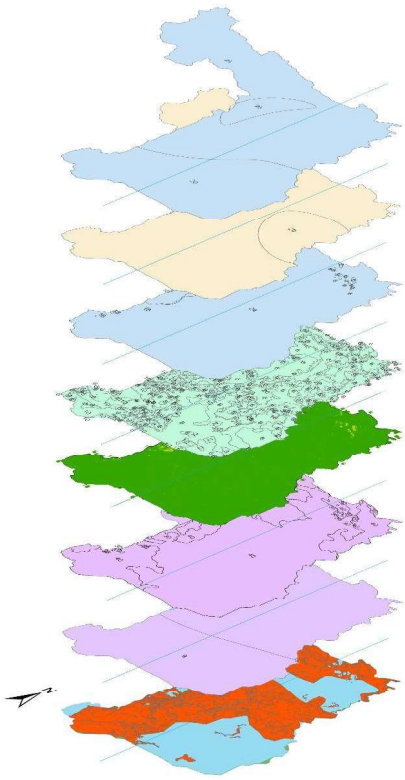




Groundwater Vulnerability Map of Study Area



Groundwater Vulnerability Map of Suphanburi



Depth to Groundwater (D) Map

Net Recharge (R) Map

Aquifer Media (A) Map

Soil Type (S) Map

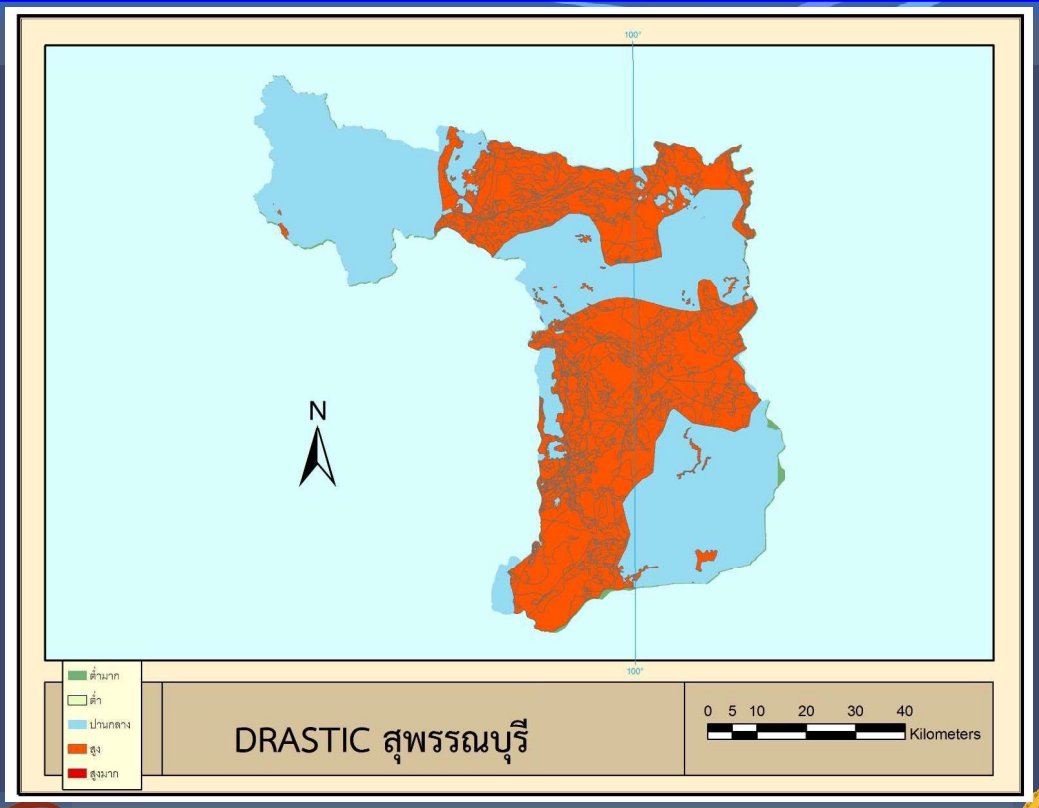
Topography (T) Map

Impact of vadose Zone (I) Map

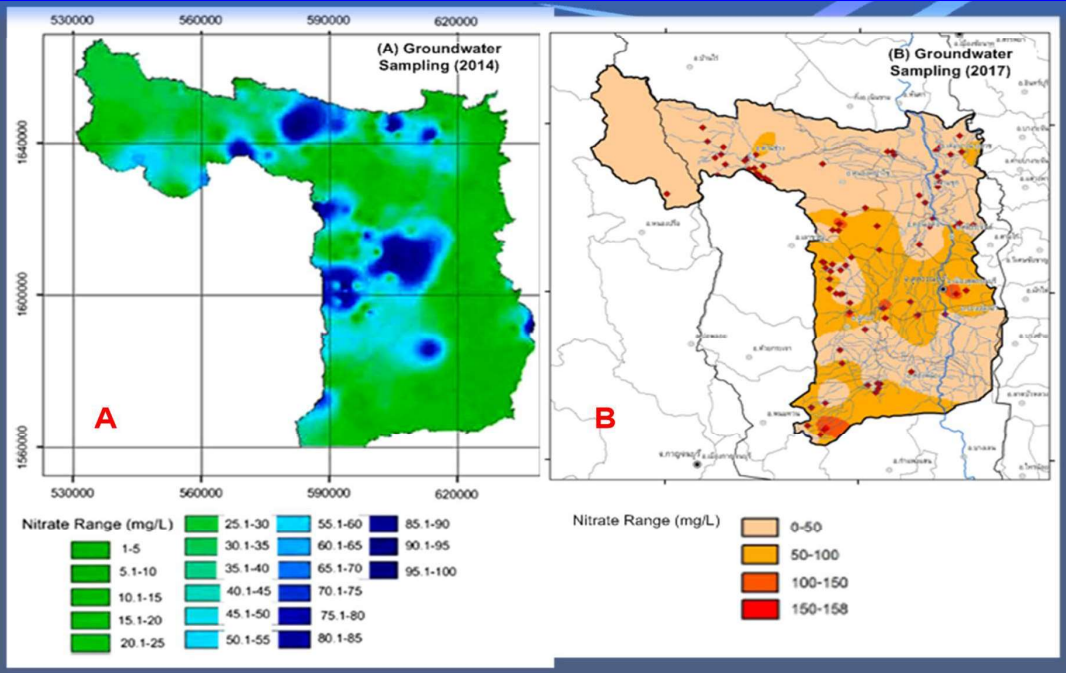
Hydraulic Conductivity (C) Map

Final DRASTIC Vulnerability Map

Groundwater Vulnerability Map Suphanburi



DRASTIC Vulnerability Map Validation



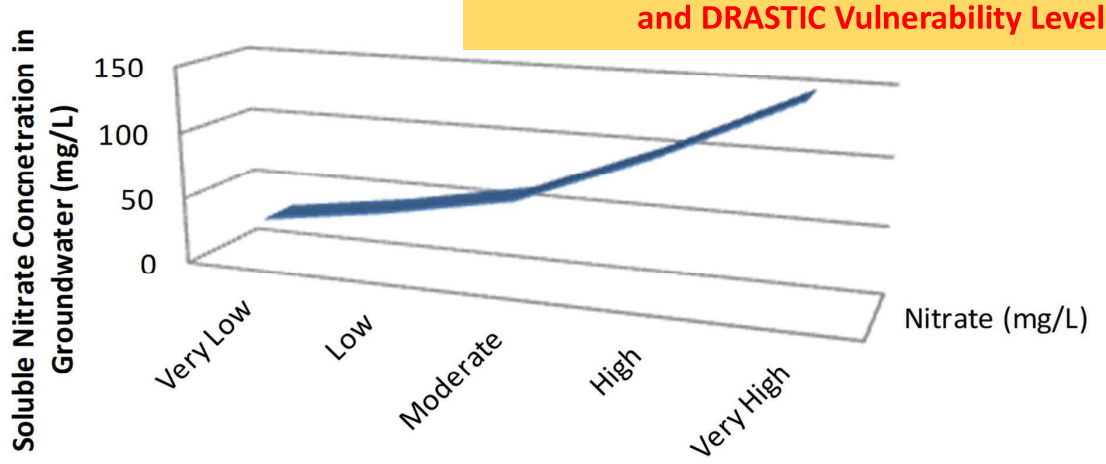
Extent of the Spatial Soluble Nitrate Contamination in Groundwater in Suphanburi Province:

(A) Data from Groundwater Sampling in 2014

(B) Data from Recent Groundwater Sampling in 2017

DRASTIC Vulnerability Map Validation

Correlation between Maximum Nitrate Concentration and DRASTIC Vulnerability Level with $R^2 = 0.89$



	Very Low	Low	Moderate	High	Very High
Nitrate (mg/L)	31	45	63	102	148

Research Summary 1 – DRASTIC Model Development And Improvement

- Intrinsic vulnerability of representative areas in Thailand can be achieved with modified empirical DRASTIC index model in GIS environment
- 7 DRASTIC parameters were identified even in limited hydrogeological observations by compiling available generic global datasets with sparse local observations
- DRASTIC Index varied between 66 and 213 and classified from very low→ low → moderate → high → very high Vulnerability degrees
- DRASTIC in GIS environment showed strong capacity for handling large amounts of geo-spatial data

Research Summary 2 – Long-Term Monitoring of Nitrate Contamination

- Long-Term monitoring of nitrate contamination in groundwater indicated that there were NO_3^- hotspot (and > 45 mg/L) in many areas of Suphanburi From 2014-2017
- From 2014 – 2017:
  - Some NO_3^- hotspot were disappeared
  - New NO_3^- hotspot were discovered
  - Extent of aqueous NO_3^- plume indicated the great mobility of NO_3^- and transport behavior could be simulated using MODFLOW and MT3D

Research Summary 3 – DRASTIC Vulnerability validation

- High/low nitrate concentrations from ***in-situ*** observations coincided with high/low intrinsic vulnerability from DRASTIC.
- DRASTIC vulnerability map can serve as a general guideline for sustainable groundwater use through policy recommendation and implementation related to proper monitoring, management, and governance of groundwater resources.
- And… hopefully… SDGs can be achieved.

Q&A