การรวมระบบสารสนเทศทางภูมิศาสตร์กับแบบจำลองมลพิษแบบแพร่กระจาย จากแหล่งเกษตรกรรมเพื่อใช้ในการประเมินตะกอนที่ถูกพัดพาในลุ่มน้ำย่อยห้วยส้ม

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INTEGRATION OF GEOGRAPHIC INFORMATION SYSTEMS AND AGRICULTURAL NONPOINT-SOURCE POLLUTION MODEL TO ESTIMATE RUNOFF SEDIMENT OF HUAI SOM SUB-BASIN

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สุทธาสิณี กล่าวกิติกุล : การรวมระบบสารสนเทศทางภูมิศาสตร์กับแบบจำลองมลพิษแบบแพร่กระจายจากแหล่งเกษตรกรรมเพื่อใช้ในการประเมินตะกอนที่ถูกพัดพาในลุ่มน้ำย่อยห้วยส้ม (INTEGRATION OF GEOGRAPHIC INFORMATION SYSTEMS AND AGRICULTURAL NONPOINT-SOURCE POLLUTION MODEL TO ESTIMATE RUNOFF SEDIMENT OF HUAI SOM SUB-BASIN) อ. ที่ปรึกษา : ดร. ศุภิชัย ตั้งใจตรง, อ. ที่ปรึกษาร่วม : ผศ. ดร. ทวีวงศ์ ศรีบุรี ; 86 หน้า. ISBN 974-333-088-7.

การรวมระบบสารสนเทศทางภูมิศาสตร์ (GIS) กับ แบบจำลองภาวะมลพิษแบบแพร่กระจาย (AGNPS MODEL) เพื่อประเมินปริมาณตะกอนที่ถูกพัดพาในลุ่มน้ำห้วยส้ม จังหวัด เชียงใหม่ เครื่องมือที่ใช้ในการพัฒนาการรวมระบบสารสนเทศทางภูมิศาสตร์ และแบบจำลองภาวะมลพิษแบบแพร่กระจาย คือโปรแกรมระบบสารสนเทศทางภูมิศาสตร์ (pc-ARC/INFO), SURFER, IDRISI และ ID2AGS ทำการดิจิไทซ์ข้อมูลสารสนเทศได้แก่ ชนิดของดิน การใช้ที่ดิน ลักษณะภูมิประเทศ ความยาวของความลาดชัน และแม่น้ำ ข้อมูลที่ได้เป็นข้อมูลแบบเวคเตอร์ ต่อจากนั้นจะทำการแปลงแผนที่แสดงชั้นความสูงให้เป็นแบบจำลองชั้นความสูงของพื้นที่ แล้วนำข้อมูลแบบเวคเตอร์มาเปลี่ยนให้อยู่ในรูปแบบที่แบบจำลองต้องการ เปรียบเทียบผลที่ได้จากแบบจำลองกับผลที่ได้จากภาคสนาม พบว่าผลที่ได้จากแบบจำลองมีค่ามากกว่าจากภาคสนามมากเนื่องจากเหตุผลหลายประการเช่น โครงสร้างของดิน ความชันของพื้นที่ ความยาวของความลาดชัน และอื่นๆ นอกจากนี้ การศึกษานี้ได้ทำการทดสอบการเปลี่ยนแปลงของพารามิเตอร์นำเข้าที่มีผลต่อปริมาณตะกอนที่ถูกพัดพา พารามิเตอร์เหล่านี้ได้แก่ ค่าความขรุขระของแมนนิ่ง ค่าปัจจัยความคงทนต่อการชะล้างพังทลายของดิน ค่าปัจจัยการอนุรักษ์ดิน ค่าปัจจัยการจัดการพืชคลุมดิน และระยะเวลาที่ฝนตก ผลที่ได้พบว่า ถ้าลดค่าค่าความขรุขระของแมนนิ่ง ปริมาณตะกอนที่ถูกพัดพาจะเพิ่มขึ้น ส่วนค่าปัจจัยความคงทนต่อการชะล้างพังทลายของดิน ค่าปัจจัยการอนุรักษ์ดิน และค่าปัจจัยการจัดการพืชคลุมดิน ถ้าเพิ่มค่าของพารามิเตอร์เหล่านี้ ปริมาณตะกอนที่ถูกพัดพาจะเพิ่มขึ้น สำหรับปริมาณฝนตกต่อหนึ่งเหตุการณ์ที่เท่ากัน ถ้าเพิ่มระยะเวลาที่ฝนตก จะได้ปริมาณตะกอนที่ถูกพัดพาน้อยลง สรุปได้ว่าค่าปัจจัยการจัดการพืชคลุมดินมีผลต่อการเปลี่ยนแปลงปริมาณตะกอนที่ถูกพัดพามากที่สุด เพราะในแบบจำลองAGNPS มีพารามิเตอร์ที่ขึ้นอยู่กับ การใช้ที่ดิน 5 ตัว ได้แก่ ค่าคงที่ของสภาพผิวดิน ค่าความขรุขระของแมนนิ่ง ค่าปัจจัยการจัดการพืชคลุมดิน ค่าความโค้งของกราฟน้ำท่า

ภาควิชา ...สหสาขา...	ลายมือชื่อนิสิต ...สุทธาสิณี กล่าวกิติกุล...
สาขาวิชา ...วิทยาศาสตร์สภาวะแวดล้อม...	ลายมือชื่ออาจารย์ที่ปรึกษา ...[signature]...
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SUTTHASINI GLAWGITTIFUL : INTEGRATION OF GEOGRAPHIC INFORMATION SYSTEMS AND AGRICULTURAL NONPOINT-SOURCE POLLUTION MODEL TO ESTIMATE RUNOFF SEDIMENT OF HUAI SOM SUB-BASIN. THESIS ADVISOR : SUPICHAI TANGJAITRONG, Ph.D. THESIS CO-ADVISOR : ASSIST. PROF. THAVIVONGS SRIBURI, Ph.D. 86 pp. ISBN 974-333-088-7.

Integration of GIS and AGNPS have been done to predict the runoff sediment in Huai Som sub-basin, Chiangmai. The programs used in the integration of AGNPS and GIS were pc ARC/INFO, SURFER, IDRISI and ID2AGS. The spatial data of soil type, topographic, land cover and hydrography were digitized as vector data. Then the contour vectors were interpolated to create DEM (digital elevation model). After that, these maps were converted to grid maps with IDRISI tool. Finally, these databases were converted to form an array of model input data by ID2AGS. The output from the AGNPS model was compared to observed data. The result showed that the simulated data were higher than the observed data. The overestimate is the effect of several external and internal influences such as the structure of soil, slope gradient, slope length, etc. This study investigated the sensitivity analysis of model input parameters to runoff sediment. These parameters were Manning's roughness coefficient, Cropping factor (C-factor), Practice factor (P-factor), Soil erodibility factor (K-factor) and duration of rainfall. It found that the lower Manning's roughness coefficient value will increase runoff sediment; the higher C-factor, P-factor and K-factor value will increase the runoff sediment. For the storm duration, it is found that the increase in duration of rainfall, the decrease in runoff sediment. The results leads to a conclusion that the C-factor is the most sensitive to runoff sediment. Additionally, it found that other five parameters of the AGNPS model namely, the surface condition constant, Manning's roughness coefficient, cover and management factor, runoff curve number and COD which are based on the land use condition of the area, play significant roles in governing the model responses.

ภาควิชา สหสาขา ลายมือชื่อนิสิต สุทธาสินี กล่าวกิตติกูล

สาขาวิชา วิทยาศาสตร์สภาวะแวดล้อม ลายมือชื่ออาจารย์ที่ปรึกษา

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CHAPTER 1

INTRODUCTION

1.1 Background Information

The recent increasing use of agricultural non-point source water quality computer models necessitates the use of a consistent and comprehensive protocol for evaluating their effectiveness and utility in meeting specific modeling goals. The use of agricultural non-point source water quality models is often constrained by the excessive and time-consuming input data demands and the lack of computing efficiencies necessary for predicting the magnitude of agricultural non–point source pollution. Therefore, collecting, managing and manipulating this data into a suitable format is becoming increasingly challenging. Many environmental models require spatial data that is most easily stored and managed using a Geographic Information Systems (GIS). However, few models can be implemented within a GIS. In order to exploit these capabilities, a method of linking the model to a GIS is required. In effect this links scale models in the form of maps stored in the GIS to the mathematical environmental model.

Point source pollutants are associated with a point location such as a toxic waste spill site has received the greatest attention in the past. It is relatively easily controlled and identifiable. However, over recent years concern has shifted more to pollutants that are low in concentration, but ubiquitous in nature and referred to as non-point source (NPS) pollutants. The NPS pollutants are contaminated into surface and subsurface soil and water resources (e.g. sediment, fertilizers, pesticides, salts, and trace elements) that are diffused in nature and cannot be traced to a point location. They differ from the point sources due to their unidentifiable nature and the difficulty in control and management.

The magnitude and the extent of non-point source pollution can be evaluated long term on-site monitoring and simulation modeling. There are several non-point source pollution assessment models and agricultural non-point source (AGNPS) pollution model widely selected for the study is used single storm event based model. The AGNPS is intended to provide basic information on water quality to be used to classify non-point pollution problems in forest watersheds. The model provides outputs on hydrology, with estimation of both volume and peak runoff, and on sediment, with estimates of upland erosion, channel erosion, and sediment yield. Furthermore, the user will receive estimates of the pollutants nitrogen (N), phosphorus (P) and chemical oxygen demand (COD), in units of concentration and mass, contained in the runoff and the sediment. This information used to predict the NPS pollution for interested watershed, including water quality problem.

1.2 Rational of the study

Due to non-point source pollution is difficult to control and identify sources. Therefore, the most of useful tools that can be measured for non-point source pollution is mathematical models such as AGNPS model. The non-point source (NPS) pollution can be measured in real time or predicted with a model. The advantage of prediction is that it can be used to alter the occurrence of detrimental conditions before they manifest. This paper describes the design and implementation of an integrated non-point source pollution modeling system (AGNPS) including Geographic Information System (GIS) and a non-point source simulation. Then AGNPS model is investigated the ability to predict the condition in the Huai Som watershed is deteriorating due to erosion caused by the monsoon rain. If the present situation continues, the situation in this watershed become worse and ultimately it will affect the environment in the area.

1.3 Objective

1.3.1 To integrate GIS and AGNPS model for reducing the effort required in gathering model input data and predict quantitative levels of non-point pollutants to surface water.

1.3.2 To test the sensitivity of some parameters of the model that affects to runoff sediment.

1.3.3 To test the suitability of AGNPS model in soil erosion according to the environment of the study area.

1.4 Scope of the study

1.4.1 The area study is Huai Som basin Mae-Teang district, Chiangmai province. It covers an area of 407.7 rai.

1.4.2 The study emphasized on designing of a system for linking between GIS and AGNSP that is easy to provide the format of model input data.

1.4.3 The study applied AGNPS model to assess the soil erosion generated from the study area only.

1.4.4 Although the model for studying non-point source pollution requires extensive database. The study is limited to the selected basin and limitations of available input database.

1.4.5 The study identified the basin outlet using topographic maps and global positioning systems (GPS) in the field and collect runoff sediment at the outlet for model verification.

1.5 Anticipated Benefits

1.5.1 A GIS interface that facilitates input of the large amount of data required for running a watershed simulation and AGNPS model.

1.5.2 The linkage of GIS/AGNPS enhanced model flexibility for predicting non-point source pollution.

CHAPTER 2

LITERATURE REVIEW

Literature review is based on the five broad fields, non-point Source model, Soil Erosion, AGNPS model, GIS and Integration of GIS and non-point Source model.

2.1 Non-point source pollution models

Chester, et al. (1985) said that point source pollution entered the environment at discrete, and identifiable location. It could be measured directly or otherwise quantified. Major point sources of pollution include effluent from industrial or sewage treatment plant and from building or solid waste disposal site. non-point source pollution entered the environment from diffuse sources. These sources may be land based or airborned; for example storm washing fertilizer from crop land or forest. Pollution from non-point sources is relatively difficult to isolate and control. Point and non-point sources of pollution differ in the means and extent to which they are delivered to water bodies. Pollutants from land based point sources are usually delivered to water bodies in almost the same concentration. Non-point source pollutants follow the tortuous path resulting the partial deposition on land surfaces before delivery into the receiving water and hence its concentration always varies.

Apart from the above definition the non-point source pollution may be characterized (Novotny et al., 1981) as follows

1) The discharges of non-point source pollution enter into the surface water in a diffuse manner and at intermittent interval. Non-point source pollution is mostly related to meteorological events.

2) Pollution originates from an extensive area of land and follows a tortuous path before it reaches surface water.

3) Origin of non-point source pollution cannot be monitored and their exact source is difficult to trace.

4) Elimination or control of pollutants must be directed at specific sites.

5) Compliance monitoring for non-point source is carried out on land rather than in water.

6) Non-point source pollutants cannot be measured in terms of effluent limitations.

7) The extent of non-point source pollution is related to certain uncontrollable climatic events as well as geographic and geologic conditions, and may differ greatly from place to place and year to year.

8) Non-point source is derived from consecutive operations on extensive units of land, as in the case of agricultural operation. Point source are derived from repetitive operation over an extensive units of land as in the case of industrial activities.

2.2 Soil Erosion

Erosion is manifested by the deterioration of surface effected by exogenous forces, especially water, wind and man as significant anthropogenic factor (Holy, 1980).

Erosion by water is a process of detachment and transport of soil particles by raindrop impact and surface runoff. Detachment is the removal of soil particles from the soil mass, while transport is the movement of sediment, detached soil particles, to a location away from the point of detachment. Principal detaching agents are impacting raindrops and surface runoff while the principal transport agent is surface runoff.

2.2.1 Factors controlling erosion

Many factors affect the rate of erosion. The most important among these are the climate, land cover, soil type, and land slope. The climatic factors affection the soil erosion include the amount, intensity and duration of the rainfall. Because of the important role of raindrop impact, vegetation provides significant protection against erosion by absorbing the energy of the falling drops and generally reducing the drop sizes that reach the ground. In addition, a good land cover generally improves infiltration capacity through the addition of organic matter to the soil. Higher infiltration capacity means less overland flow and consequently less erosion.

2.2.2 Soil erosion estimation and prediction

Soil erosion can be estimated by three ways: field measurement of soil erosion; laboratory techniques and soil erosion models. Field measurement is the most accurate method, but it is laborious and expensive. Laboratory techniques are used to determine a factor that affects soil erosion to use it as an input to multivariate erosion models. Erosion models are generally developed for a specific location, but can be used for other areas with suitable modifications(Stocking, 1988). As early as the 1940s erosion models were developed to describe the relationship between various factors and soil erosion from agricultural fields.

Erosion prediction models have been progressed from data collection to compare practices, to simple empirical models, to complex empirical models and most recently toward process based models (McCool and Renard, 1990). Soil erosion models can be grouped into two categories: (1) Empirical models are basically statistical analysis of large data set to yield a mathematical expression which does not describe the process involved. The most commonly used empirical model for prediction of soil erosion is the Universal Soil Loss Equation (USLE). (2) Analytical models are process oriented and more accurate than empirical one, but complicated in nature requiring detail data example; WEPP, ANSWERS etc.

Harper (1988) reported that Universal Soil Loss Equation (USLE) has been used in Thailand over a decade for the slope up to 74 percent. Since the USLE was developed from empirical data gathered in the mid-west of United States of America where climate, slope, soil and agricultural practices differ from Northern Thailand, therefore, while applying this equation, user should modify the factors according to prevailing conditions in the field. Harper mentioned that "R" has to be improved for local areas, "SL" might not be appropriate for Northern Thailand, "C" must be replaced by onsite experiment, "K" may not be applicable to tropical soils, and "P" was based on data collected in USA.

2.2.3 Soil erosion studies in Northern Thailand

Soil erosion is Thailand's most severe natural resource problem. It was reported that nearly 17 million hectares of land had been suffering from severe soil erosion, particularly upland areas with slope gradient greater than five percent

(Department of Land Development, 1980). The severity of soil erosion is much worse in Northern Thailand where shifting cultivation and cultivation without proper conservation measures are widely practiced.

IBSRAM (1995) conducted and extensive research in Chiangmai province of Northern Thailand from 1989 to 1991 on soil erosion under different kinds of cropping practices in collaboration with Department of Land development (DLD) (1985). It is reported that soil erosion is maximum in areas where farmer plants crop in up and down slopes. Soil loss was considerable reduced when barriers like hedgerows, grass strips and hillside ditches were established across the slope. Slope steepness is not the only factor that affect the soil erosion process, but other soil properties, especially silt content also influence soil erosion rate to a great extent. (Table 1)

Table 1: Soil erosion rates of IBSRAM's sites in Northern Thailand

Land use	Slope (%)	Erosion rate (t/hectare/year)	Erosion rate (mm/year)
Up and down cultivation	18 – 40	58	4.46
Alley cropping	18 – 40	31	2.38
Grass strip	18 – 40	20	1.54
Hillside ditch	18 – 40	21	1.61
Agro-forestry	18 – 40	36	2.77

Source: IBSRAM, 1995

Maejo University of Chaingmai and Catholic University of Belgium conducted an extensive research in three provinces of Northern Thailand namely, Chiangmai, Chiangrai and Mae Hong Son under Soil Fertility Conservation Project (SFCP, 1992) starting from 1989. Runoff plots were used and concrete collection tanks were constructed down slope to collect soil erosion that took place in each runoff plot. The following soil erosion rates in Table 2 were found in different experimental sites.

Table 2: Soil erosion rates in MJU-KULeuven experimental sites in Northern Thailand.

Site	Slope (%)	Soil loss (t/hectare/year)	Soil loss (mm/hectare/year)
Doil Thung, Chiangrai	20-50	143	14.59
San Charoen, Chiangrai	30-47	90	9.00
Doi Yao, Chiangrai	43-55	86	8.60
Lao Che Guay, Chiangrai	34-45	76	7.60
Jabo, Mae Hong Son	30-40	50	5.81
Wawi, Chiangrai	50	40	4.00
Huai Luk, Chiangrai	50	40	4.00
Mae Sawan Noi, Mae Hong Son	27-35	5	0.54

Source: SFCP, 1992

Soil erosion rates from natural forest ranged from 0.02 t/hectare/year in hill deciduous forest to 8 t/hectare/year in sloping mixed deciduous forest (Tangtham, 1991). Converting forest on sloping land to cultivate upland agricultural crops such as rice corn, bean and sesame causes severe soil erosion ranging from 2 to 89 t/hectare/year (Naprakob, 1976; Hurni, 1982; Inthapand and Boonchi, 1990). And it is much higher than the tolerant limit of soil erosion of 12 t/hectare/year as suggested by the Department of Land Development. Application of agro-forestry systems such as growing of coffee in hill-evergreen forest or erosion control measures such as terracing, grass strips, hedgerows and contour bunds can limit soil erosion rates below the maximum permissible limit (Aneecksamphandt and Budee, 1987; Inthapand and Boonchi, 1990 and Aneecksamphandt, 1990).

2.3 AGNPS Model

Simulation models of non-point source pollution are therefore based on watershed hydrology i.e. precipitation, detachment of soil particles by rainfall, and early phase of overland flow. Thus modeling non-point pollution generally means modeling the most of the elements of hydrological cycle. Non-point simulation models are a part of a category of "loading model" which represent the imputes and movement of materials from the point of origin to water sources. These models interface with water quality and generally provides input concentrations and flow rates.

V.T. Chow (1972) has mentioned that there are basically two approaches to modeling non-point pollution. The first one is lumped parameter models, while the second one is distributed parameter model. The lumped parameter model treats the watershed or a significant portion of it as one unit. The various characteristics of the watershed are lumped together often with the empirical equation, the final form and magnitude of the parameters are simplified to represent the model unit as uniform system. The distributed parameter model involves dividing the watershed into smaller homogeneous units with uniform characteristics (soil, crop, slope. etc). Each area unit is modeled separately and the total output is obtained by summing all individual outputs from homogeneous units. Theoretically the lumped parameter model can provide the result at one location i.e. at watershed outlet, while the distributed parameter model can provide the result through out the system subunit. Distributed parameter model requires large computer spaces and extensive description of the system parameter. The model can be designated as continuous or event based. Discrete event modeling simulate the response of the watershed to a major rainfall or storm condition. The principal advantage of event based modeling over continuous simulation is that it requires relatively little meteorological data and can be operated with shorter computer run times. The principal disadvantage of the event based modeling is that it requires specifications of the design storm and antecedent moisture conditions, thereby assuming equivalence between the recurrence interval of the runoff. The principal advantage of continuous modeling is that it provides long time series of water and pollutant loading that can be analyzed statistically as to their frequency and occurrence.

AGNPS model is one of various computer based watershed analysis tool for evaluating agricultural non-point pollution sources affecting surface water table 3. The major computerized procedures of various modeling approaches are shown the Table 3.

Table 3: The major computerized procedures of various modeling approaches.

components Model	Excess rainfall	Overland flow	Routing stream flow	Eroded sediment quantity	Routing sediment
USLE	-	-	-	yes	yes
WRENS	yes	-	-	yes	yes
HYMO/SPNM	yes	yes	yes	yes	yes
SEDIMOT-II	yes	yes	yes	yes	yes
ARM/NPS	yes	yes	-	yes	yes
CREAMS	yes	yes	yes	yes	yes
AGNPS	yes	yes	yes	yes	yes

This model is a distributed parameter model developed by United States Department of Agriculture (USDA), US Agriculture Research Service (ARS) and Minnesota Pollution Control Agency (MPCA). It predicts soil erosion and nutrient transport / loading from agricultural watershed. Its distributed model design is achieved by subdividing a watershed to be simulated into a grid of square element areas, assumed to have uniform physical characteristics, and then applying three lumped parameter models to each element:

a) Erosion modeling is based on the USLE applied on a storm basis.

b) Its hydrology is based on the Soil Conservation Service Curve Number technique.

c) AGNPS uses another model named CREAMS to predict nutrient/pesticide and soil particle size generation, transport and interaction. Outflows from one element become inputs to adjacent ones. Thus, AGNPS integrates lumped model predictions for each element's behavior into a distributed watershed simulation.

The computations in AGNPS occur in three stages based on twenty items of information per cell. Initial calculations for all cells in the watershed are made in the first stage. These calculations include estimates for upland erosion, overland runoff volume, time until overland flow becomes concentrated, level of soluble pollutants leaving the watershed via overland runoff, sediment and runoff leaving impoundment-terrace systems, and pollutants coming from point source inputs such as feedlots.

The second stage calculates the runoff volume leaving the cells containing impoundment and the sediment yields for primary cells. A primary cell is one that no

other cell drains into. The sediment from these and other cells is broken down into five particle-size classes: clay, silt, small aggregates, large aggregates, and sand.
The sediment and nutrients are routed through the rest of the watershed in stage three. Calculations are made to establish the concentrated flow rates, to derive the channel transport capacity, and to calculate the actual sediment and nutrient flow rates. The Structure of sediment and nutrient losses model for AGNPS development is shown in Figure 1.

The model is written in C, FORTRAN and Pascal Languages and can be applies to the watershed sizes ranging from a few hectares to 20,000 hectares. Dividing the watershed, each watershed is divided into square, uniform units called cells. The size of these cells depends on the degree of detail desired in the analyses and on the size of the watershed. For watersheds up to 2,000 acres in size, the recommend is 10-acre cells, and for larger watersheds, 40-acre cells. But if a very detailed investigation is desired, It can determined larger or smaller than recommended cells.

2.3.1 Model input Data

The model-input data requires sources of watershed topography, soil, land use, channel, and point-source information. There are a total of 20 parameters for each of the AGNPS cells. (See appendix A)

2.3.2 Model Output Data

The model output data also includes three major parts: hydrology, soil erosion, and nutrient pollution. These data are organized in a tabular file, which can be viewed by the model output functions. (See appendix A)

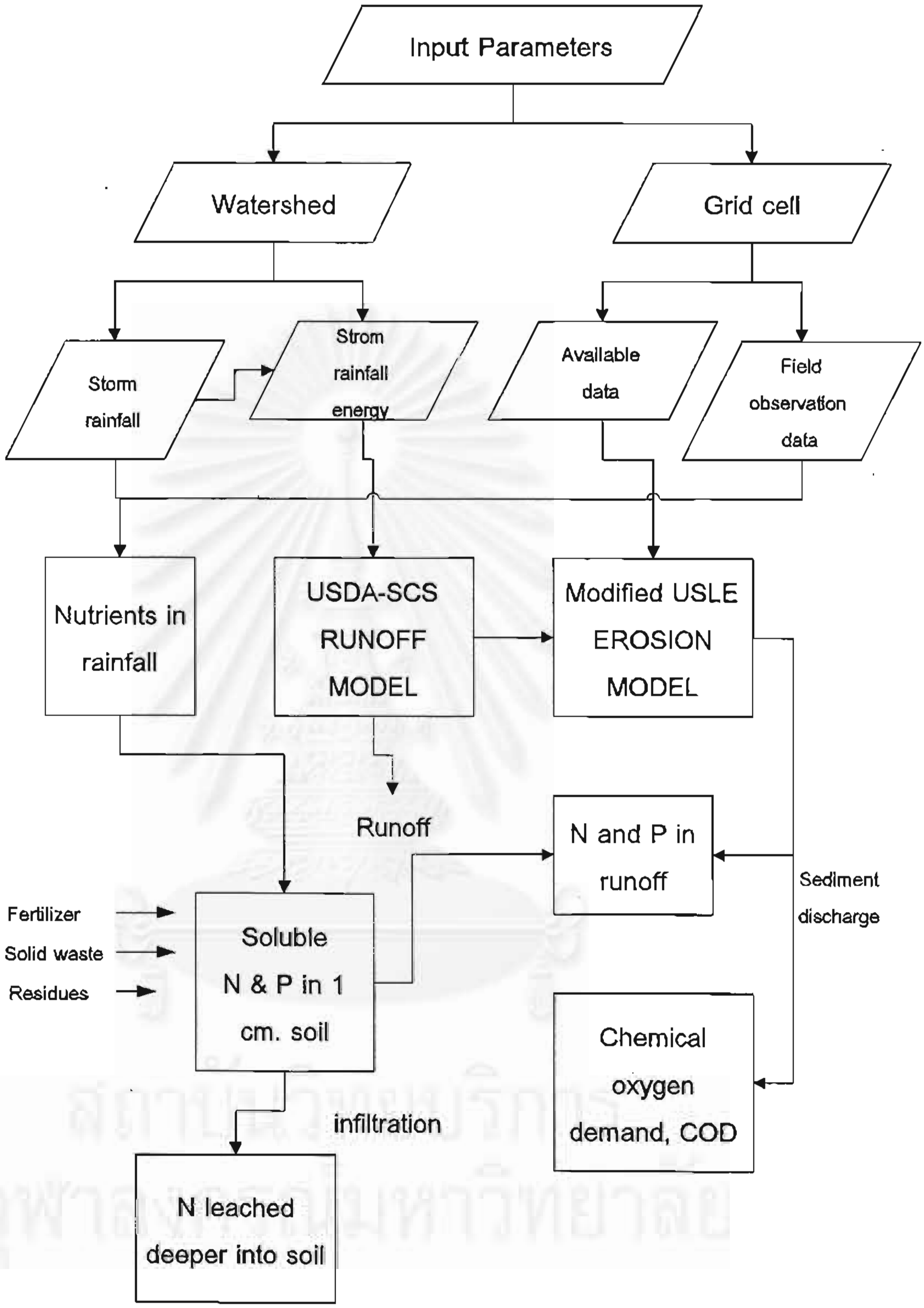


Figure 1: Structure of sediment and nutrient losses model for AGNPS development

2.3.3 The limitation of AGNPS model

a) AGNPS allows only 1,350 cell per simulation and not less than 30 cell.
b) In terms of discharges, AGNPS predicted no flow if a storm had a precipitation depth less than 25 mm.(1 inch) because AGNPS is designed to model erosion events not low flow events, the numerical accuracy achieved is acceptable.(Hudson, 1963)
c) AGNPS does not consider the thickness of soil surface layer.

2.3.4 Applications of AGNPS in Thailand

Kakkanopas (1988) used AGNPS model to estimate soil and water losses on storm precipitation for Nan watershed research station. Two sub-watersheds of Nan watershed were selected namely, Haui Liengtai and Huai Wangpo. Haui Liengtai is mix deciduous f›rest, dry dipterocap forest and dry evergreen forest. Huai Wangpo is forest plantation mixed dry dipterocarp forest, mix deciduous and dry evergreen forest. Results found that soil losses from Huai Liengtai sub-watershed during 1992 to 1995 was measured about 4801.81, 3389.35 and 5626.5 tons/acre, water losses was measured about 2.31, 1.53 and 1.50 inches/area respectively. While Wangpo sub-watershed found soil losses about 4936.19, 8488.25 and 7148.97 tons/acre and water losses was measured about 2.44, 1.55 and 1.59 inches/area. The rainfall-soil and water losses relationship of all sub-watersheds were high significantly in statistics.

2.4 Geographic Information System (GIS)

2.4.1 General

GIS are computer-based tools to capture, manipulate, process, and display spatial or geo-referenced data. They contain both geometry data (coordinates and topological information) and attribute data, that is, information describing the properties of geometrical objects such as points, lines, and areas.

Burrough (1986) defined GIS as "A powerful set of tools for collection, storing, retrieving at will transforming and displaying spatial data from the real world".

Arnoff (1989) defined GIS as "Any manual or computer based set of procedure used to store and manipulate geographically referenced data".

2.4.2 Uses of Geographic Information Systems

Since GIS are capable of combining large volumes of data from a variety of sources, they are a useful tool for many aspects of water quality investigations. They can:

- help determine location, spatial distribution and area affected by point source and non-point source pollution,
- be used to correlate land cover and topographical data with a variety of environmental variables including surface runoff, drainage, and drainage basin size,
- be used for assessing the combined effects of various anthropogenic and natural factors on water quality,
- be incorporated into water quality models.

2.4.3 Geographic Information System Structure

The two basic types of geographic data structures used in most GIS are *raster* and *vector*. The raster data structure is analogous to a grid placed over an image. Geographic features such as rivers, roads and boundaries are represented as lines or vectors.

Components of GIS: A GIS has five major components

a) Data Input: It collects and processes spatial data from a variety of sources, including digitized map information, coded aerial photographs, satellite and remote sensing images and geographically referenced data.

b) Data management: It allows a database to be used through a combination of hardware and software facilities and to relation to each other.

c) Data Manipulation and Analysis: It transforms the various data into a common form that permits subsequent spatial analysis. Tabular data, stored on computer systems for example, are converted first to a map scale common with other data, and then all data are analyzed together.

d) Data Retrieval: In the creation procedure of a database, access procedure is established retrieval of both spatial and non-spatial data. Efficient data retrieval are largely dependent upon the volume of data stored, the method of data encoding and file structure design. In general there are well-developed procedure for efficient retrieval of non-spatial data in GIS.

e) Data Display: The data reporting displays the database, the results of statistical computations, and produces hybrid maps. Outputs include tabular data, colour images, graphs and single or composite maps.

2.4.4 GIS Software (ARC/INFO)

The study used ARC/INFO version 3.4 D (ESRI, 1992) for managing the spatial data. The software is composed of two primary components. Arc for handling spatial information and INFO for handling non-spatial information. There are several GIS software available (e.g., GRASS/ILWIS) for watershed management, but ARC/INFO has been used to study the Huai Som creek basin.

Data input is done by digitization and involved the use of digitizing tablet which is an electronic device consisting of a tablet on which the map is placed and a hand held cursor to trace the feature being digitized. Digitizing is the process of converting the map projection into digital information.

ARC/INFO is made up of several parts or subsystems. Each system is designed to handle different GIS functions such as input, output, manipulation, analysis and data management. The basic components are ARC and Table.

A geographically referenced computerized model can account for every land parcel, and therefore allow researchers to locate critical non-point source pollution areas in a large watershed in much less time and with less error than any manual approach.

2.5 Integration of GIS and NON-POINT SOURCE model (Agricultural non-point source pollution)

Several recent developments have helped to provide a more suitable environment for integration of non-point source models with GIS software packages. In conjunction with GIS, the most used non-point source models are AGNPS (Agricultural Non-point Source Pollution; Young *et al.*, 1985) and ANSWERS (Agricultural Non-point Source Watershed Environmental Response Simulation), but several less known models are used also. In the case of erosion modeling, the USLE (Universal Soil Loss Equation) and its modifications are used (Wischmeier and Smith, 1978).

There are several software packages of GIS, these are ERDAS (Zeeuw *et al.*, 1991), GRASS (Brodeur, 1990; Engel, 1991), and ARC/INFO (Steenberghe, 1991; Vieux, 1991) appear to have been the most popular for supporting the modeling of non-point source. An important characteristic of GIS is that it is an integrating technology. GIS makes it possible to combine information themes of many fields, and undoubtedly has accelerated this trend. The model-GIS integration is the best beneficial because all the functions relate to data manipulation, display function, and conventional engineering modeling methods are connected together and interactively to integrate their powers. Integrating GIS technology with modeling capabilities provides a valuable approach to assist in identifying the critical areas and to rank the relative severity of area in the watershed.

Geographic information systems have been integrated with simulation models in several studies. Srinivasan and Engel (1991) developed an integration between GRASS GIS and ANSWERS to assist with inputing and interpreting model output. Hession et al. (1989) linked the Virginia GIS (VirGIS) with AGNPS model to evaluate the effectiveness of alternative cropland management strategies in reducing non-point source pollution to the Chesapeake Bay.

Tim et al. (1992) integrated water quality computer simulation modeling with geographic information system to delineate critical area of non-point source pollution at the watershed level. They used VirGIS model to estimate soil erosion, sediment yield, phosphorus loading from Nomini Creek watershed, 1,505 hectares, in Westmoreland country, Virginia. On the basis of selected output criteria as soil erosion rate, sediment yield and phosphorous loading, they zoned the watershed for non-point pollution potential by using the GIS . Panuska *et al.*(1991) have mentioned about the linkage of Agricultural Non-Point Source Pollution (AGNPS) model with terrain analysis Digital Elevation Model (DEM) to estimate the topographic attributes of a small watershed near Treynor, 82.8 acre, Iowa USA. This linkage of models helped in the analysis of the watershed much more accurately. He *et al* (1993) has mentioned about the integration of GIS, non-point source pollution model (AGNPS), Geographic Resource Analysis Support System (GRASS) and a hydrologic model (GRASS WATERWORKS) to evaluate the impact of agricultural run-off on water quality in the Cass river in a watershed of Saginaw bay, 841 square miles, USA. Tim U. S. and Jolly R. (1994) have described about integration of GIS hydrologic modeling in drainage study to develop a surface water management plan for Blue Grass watershed, 417-ha watershed located in southern Iowa, USA This linkage provided an effective mechanism for performing large area surface water and drainage management studies. Robinson K. J and Robert M. R. (1993) studied about integration of GIS and AGNPS as important tools for supporting the development of agricultural resource conservation and water quality management plans. Rosenthal *et al* (1995) linked GIS- hydrology model to aid in forming input files for the hydrologic model, SWAT (Soil and Water Assessment Tool).

In aspect of soil erosion, there are several researches, for example:

Young et al. (1989) have mentioned about the development of a non-point source pollution model in Minnesota, USA. The model was used for analysis of non-point source pollution in the watershed. They further stated that this model has been used effectively in identifying the problem area and to prioritized watershed in Garvin Brook watershed, 46,516 acres in USA, and management practices were recommended to reduce the erosion and pollution problem.

Lo, Chiang and Tsai (1993) tested the AGNPS model link with GIS for studied erosion process and measured sediment yields were obtained for the Tsengwen Reservoir watershed in Taiwan. They found that it was necessary to prescribe appropriate soil and water conservation practices to control the reservoir sedimentation problem in Taiwan. The model is also capable of identifying areas within the watershed with high erosion and sediment yield.

Integrating the GIS technology with modeling capabilities provides a valuable approach to assist in identifying the critical areas and to rank the relative severity. To select important process and parameters of watershed that contributes to water quality degradation require appropriate state wide data in a GIS format. Ranking model is then developed to use the data and to predict the relative potential for agricultural non-point source pollution. While the model is specifically tailored for agricultural pollution potential, the same approach can be used to incorporate other non agricultural uses.

CHAPTER 3

STUDY AREA

3.1 Topography (general information of the watershed)

Huai Som creek, a 161.20 acres catchment basin, is situated in the Northern region of Thailand in Chiangmai province (See Figure 2 and 3). Royal Forest Department is responsible to this area. The geographical location of the Huai Som watershed in the map is lies between 19° 05 ′ North to 19° 06′ North and 98° 59 ′ East to 99° 00 ′ East. The Huai Som creek is 1.58 kilometers long and it drains into the Mae Ping river. The topography of the Huai Som basin is dominated by mountains with an elevation of 320 to 417 meters above mean sea level with an average slope in the area of 10% and over 50% of the entire watershed area having a high slope complex.

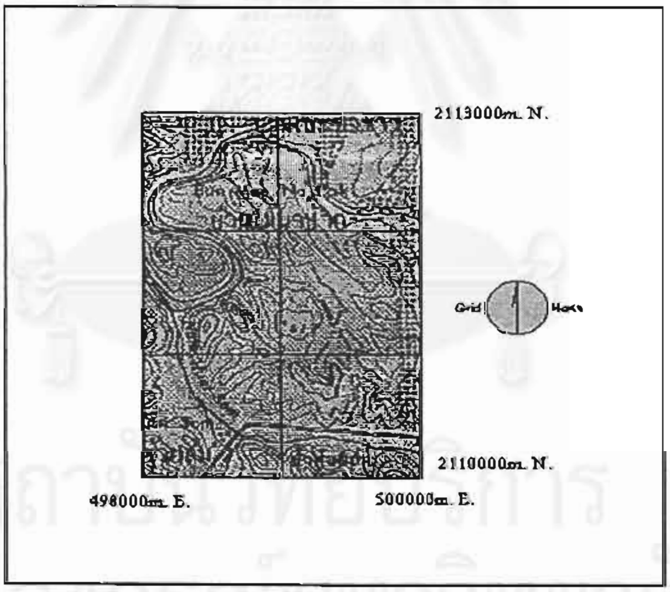


Figure 2: The study area in Huai Som basin.

Figure 3: Huai Som area in Chiangmai.

3.2 Climate

The climate of the northern Thailand region is governed by monsoons and characterized by three distinct seasons. The rainy season from mid-May to November when the region comes under the influence of the Southwest monsoon, cool dry season. From November to the end of February during which time the Northeast monsoon brings dry cool air from continental Asia and hot dry summer from the end of February until mid-May when the region comes under the influence of the southeast monsoons.

In this study, field survey was carried out on June and July 1999 (Table 3). During this period, the weathers are as following.

In June, the total rainfall recorded at Mae Teang Meteorological Observation station was 124 mm. The average temperature in the basin is 27.69 °C with a maximum of 32.21 °C and a minimum of 21.8 °C. The average relative humidity is about 74.10 % with an average wind velocity of 26.19 km/day.

In July, the total rainfall recorded at Mae Teang Meteorological Observation was 177.5 mm. The average temperature in the basin is 27.89 °C with a maximum of 32.40 °C and a minimum of 22.2 °C. The wind velocity has no record in this month.

Table 4: The precipitation of Mae Teang Meteorological Observation on June and July 1999.

Date	Rainfall intensity on June	Rainfall intensity on July	Date	Rainfall intensity on June	Rainfall intensity on July
1	-	-	17	-	8.5
2	-	-	18	-	7.4
3	35.6	0.5	19	-	0.3
4	5.4	-	20	0.7	0.4
5	-	16.2	21	-	5.7
6	-	0.5	22	8.2	5.0
7	-	-	23	8.0	-
8	-	-	24	16.2	-
9	2.6	-	25	3.8	1.3
10	16.8	9.1	26	-	4.1
11	0.2	2.3	27	-	18.5
12	1.7	-	28	-	9.2
13	16.8	7.5	29	-	51.7
14	0.5	5.0	30	-	10.8
15	7.5	0.9	31	-	8.6
16	-	4.6	Total	124.0	177.5

3.3 Land cover

The whole area of the basin is degraded dry dipterocarp forest. It has low species diversity. Its subtypes include the deciduous dipterocarp forest, deciduous dipterocarp forest with pine and scrub deciduous formations and low sandstone ridges in the Northeast plateau. The most common trees in this forest are Phluang (*Dipterocarpus tuberculatus Roxb.*), Hiang (*Dipterocarp us obtusifolius Teysm*), Teng (*Shorea obtusa Wall.*), Rang (*shore siamensis Miq.)* and Yang-Krand (and *Dipterocarpus intricatus Dyer.*) The dry dipterocarp forest also occurs extensively on the terrace formations of the Northern part of the central plain, In other physiographic regions, it is less wide spread, in the lower rainfall zones, It occurs mainly on leached terraces, gravelly lands of terraces and low hills of acidic rocks.

3.4 Soils

The topsoil layer is thick about 2-5 inches with pH 4.5-5.1. The color of soil is likely dark reddish brown and most of the area is stony soil. Soil investigations were carried out mainly on the basis of the soil map compiled by Department of Land Development; Ministry of Agriculture and Cooperative. The soil structure is made up of two series that is Tha Yang/Lat Ya Series Association and slope Complex.

Soils were classified according to national classification that was based on "Major soils of Southeast Asia" by R. Dudal and F.R. Moormon (1964) and USDA classification (1970). The following large groups of soil were found in the study area: Red Yellow Podsolic Soils and Reddish Brown Lateritic Soils.

The Red Yellow Podsolic soils are characterized as very dark grayish brown or dark brown over yellowish red or reddish yellow. Texture is sandy loam or loamy sand over gravelly or very gravelly clay loam or clay. Most of the soils have very deep (>150 cm.) profile. They are well drained with a moderate permeability and medium to rapid reaction ranges from very strongly acidic to slightly acidic (pH 5.5 – 6.5). Potassium (K) availability is medium to high while phosphorus is moderately low to very low. The Red Yellow Podsolic soils are equivalent to Paleustults in USDA classification.

The Reddish Brown Lateritic Soils are characterized as dark brown or dark reddish brown, over dark reddish brown, dark red or red, sandy loam or loam over clay loam to clay. Reaction ranges from very strongly acidic to slightly acidic (pH: 4.5 – 6.5). The reddish brown Lateristic soils have widely vary in soil profiles. In the lower slope they are thick (>150 cm) and uniform but on the steep slopes they are moderately deep (50 –100 cm) and stony and often have been eroded down as far as weathered rock. But the soils covered by forest or Scrubland, the structure is moderately fine and medium subangular blocky, moderately permeable, and medium to rapid runoff. Potassium (K) availability is very high, phosphorus availability ranges from low to very low and cation exchange capacity (CEC) varies from moderately high to high. The reddish brown Lateristic soils are equivalent to Orthoxic Palehulmults in USDA classification.

The other soil information is relatively with Huai Som basin are shown in Table 5.

Table 5: The information of soil in this study area.

Parameter		Huai Som upper slope					Huai Som middle slope				
Soil type (FAO)		RUDI-LUVIC ARENOSOL					RUDI-LUVIC ARENOSOL				
horizon name		Ah	EB	CB	CBt	Cm	Ah	EB	CB	CB	2 Cm
horizon depth (cm)		0-6	6-26	2 6 - 41	41-52	>52	0-6	6-22	22-50	50-81	>81
coarse (%)	sand	80.5	75.5	80.0	72.5		70.9	57.5	61.3	56.9	
	silt	14.5	20.5	16.0	16.5		24.7	35.9	33.3	28.6	
	clay	5.0	4.2	4.0	11.5		4.4	6.6	5.4	14.5	
pH (H_20)		5.1	5.0	4.7	4.7		4.8	4.5	4.5	4.5	
base saturation (%)		80.5	23.0	15.5	21.0		43.6	14.0	15.6	14.1	
organic content (%)		1.50	<1	<1	<1		4.55	<1	<1	<1	
Exchangeable cation											
Ca^{++}		3.5	0.2	0.1	0.1		2.99	0.19	0.25	0.37	
Mg^{++}		0.30	0.15	0.1	0.1		0.58	0.09	0.09	0.06	
Na^{+}		0.05	0.03	0.04	0.05		0.05	0.03	0.03	0.04	
K^{+}		0.15	0.1	0.15	0.1		0.24	0.1	0.09	0.13	
P available (ppm)		6.5	3.0	2.5	2.5		17.5	27.0	5.5	1.5	

Source: Subproject of the European Thai Forest Project.

CHAPTER 4

METHODOLOGY

The study can be divided into 4 steps.

4.1 Collection of secondary data.
4.2 Database preparation.
4.3 Running AGNPS model
4.4 Field study
4.5 Compare the model result with available observed data.

4.1 Collection of Secondary Data

The existing data related to this thesis study have been collected in the forms of maps, reports, books, and historical statistic records. Major data are as follows:

- Topographic map, on the scale of 1: 50,000: The Royal Thai Survey Department, Bangkok, Thailand, 1992.
- Land use map, scale 1: 15,000: classified from air photography, The Royal Thai Survey Department, Bangkok, Thailand, 1983.
- Soil map, scale 1: 250,000: surveyed, classified and mapped, The department of Land Development, 1976.
- Meteorological observation records on June and July 1999, by Mae Teang Meteorological Observation Station and Huai Som research Station.

These data were used as basic input data for the AGNPS model.

4.2 Preparation of Database using GIS, SURFER software and IDRISI

4.2.1 Performance of GIS software

ARC/INFO version 3.4D (ESRI, 1992) has been used in this study. The software, that is a vector based GIS software, consists of two sub systems, ARC which is a set of tools for managing geographic features such as points, lines and areas, and INFO which is a database management system for managing attributes associated with the geographic features by ARC.

Creation of database, the first step was input the spatial data from map and store in computer. The computer is a tool in capture, manipulate process and display spatial data. The required database was contour, stream, land use and soil. The contour and stream data received from topographic map. The land use data received from land use map. The soil data received from soil map. The following step were:

1) Digitization of Map

For digitization of a map, tic points are required. Tics are reference points that allow all coverage features to be registered to a common co-ordinate system. The tic points for a map was selected according to study area. For this study, four tic points were selected at the four corners of the study area. UTM of four tic points are given in Table 6.

Table 6: UTM Co-ordinate of Tic Points.

Tic Point	X Coordinate	Y Coordinate
1	498000	2113000
2	500000	2113000
3	500000	2110000
4	498000	2110000

The digitization of the tic points was very important before starting the digitization of a map. Because when digitizing or editing a coverage, tics are used to automatically transform digitizer coordinates into coverage coordinates. The Root Mean Square (RMS) error was kept less than 0.003, the maximum permissible limit for digitization. The ADS command of ARC/INFO was then used to digitize the maps.

2) Digitization of Coverages

Before starting digitization of a coverage, tic points were entered each time with the same RMS error limit as accepted criteria during the digitization of tic points. By doing so, the map is oriented to exact position. Different data layers having different RMS error results unwanted sliver polygons during the matching of the boundary of the same feature in overlay functions. The line digitized used in creation of the stream and contour coverage. The polygon used in creation of the land use, soil and boundary coverages.

3) Identification & Correction of Digitization Error

After digitization of a coverage, the next step was to display the map and correction of the error that occurred during the digitization. Chiefly, dangle error (dangling nodes) was found. They indicated that a polygon does not close properly (undershoot)) or an arcs has exceeded its intersection with another arc (overshoot).

The undershoot errors were removed by using the CLEAN with an assignment of proper fuzzy tolerance and dangle length. The fuzzy tolerance was defined as the minimum distance that separates all arc coordinates in a coverage. During use of CLEAN command, 2 or more arc coordinates within the fuzzy tolerance of each other are snapped together. Dangle length is the minimum length allowed for dangling arcs. Any dangling arc less than this length would be deleted during CLEAN. Remaining dangling arc were removed by using the command REMOVE ARCS of ADS

4) Adding User-ID to Coverage Features

The feature in the coverage was categorized into different GIS classes, which were then assigned User-Ids using ADS. User-Ids could be assigning by keyboard entry. If a polygon having more than one labels or polygons having no label. The label errors were displayed by two ways that are LABELERRORS and EDITPLOT. In this study use the LABELERRORS commands which list all the polygons having no label or having no label or having more than one label. This method was used to detect the label errors.

5) Building Arc/Polygon topology

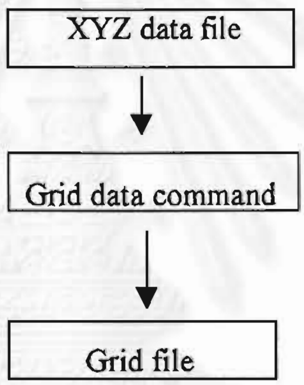
The next step after correction of errors was the creation of watershed boundary, land use, soil texture coverage using BUILD command. In order to ensure that the arcs were stored as an order series of X, Y coordinate which defined a line, all arcs in coverage were sequentially numbered, the polygon was created by a number of arc which comprise its border. Similarly the arc topology was created for the streams and contour coverage in order to ensure that all arcs in a map were sequentially numbered, all arcs had direction.

6) Convert GIS file to SURFER file

In this step, the data are derived from digitize map such as contour coverage, stream coverage, land use coverage and soil coverage. Then, to convert contour data into XYZ data file using UNGENERATE for compatible with SURFER software. The XYZ data file would be created

4.2.2 Performance of SURFER Software

The application of SURFER was to create a contour map from an XYZ data file. The data command from the Grid menu used an XYZ data file to produced a grid [.GRD] file. The grid file was then used by the Contour command to produce a contour map. The flow chart was displayed here



In this step, it would determinated boundary of contour map that is:
X direction: minimum = 498000 maximum = 500000
Y direction: minimum = 2110000 maximum = 2113000

Then set the size of grid was 40 by 40 meters. So it would automatically calculated the number of grid lines. The number of grid columns in the X direction was 51, and the number of grid lines in the Y direction is 76. In reason, this size was selected because it would provided the integer number of square cell. After that, choosing gridding method to interpolated grid node values. This study used Kriging method because it generates the best overall interpretation of most data sets and provides smooth contour map appearance. When gridding was complete the grid file was created.

4.2.3 Performance of IDRISI Software

IDRISI is a raster-based GIS and Image Processing software with very strong analytical capabilities. It consists of a rich suite of functions (modules) which can mostly be seen as basic tools.

1) Import all maps from SURFER to IDRISI software.

In order to calculate slope, slope length and aspect must imported contour data from SURFER and soil, stream, land use data GIS to IDRISI software using IMPORT command to get them into a format that was compatible with a specific IDRISI software. The result file was vector. Then, they must be converted to raster file using the RASTER/VECTOR conversion command. After that, the raster file with support IDRISI would be created.

2) Calculation Slope, aspect coverage

Creating a slope map by hand is very tedious. Essentially, it required that the spacing of contours be evaluated over the whole map. As is often the case, tasks that are tedious for humans to do are simple for computers. The SURFACE command was used in calculates both the slope and the aspect of surface cells from Digital Elevation Model (DEM). SURFACE made this calculation by comparing the heights of cells to those of their neighbors. From this information, the gradient of the slope can be determined of the middle cell, as well as the aspect of the slope. For this study chooses calculated aspect in degrees and slope in percents.

3) Creation of Slope length map

The slope length was measured from the point where surface flow originates, to the outlet channel or a point down slope where deposition begins. The slope length was taken from contour map by using ERODE.EXE (See in Appendix B) that was IDRISI module. This program is a DOS-based IDRISI module designed to calculate cumulative downhill slope length from a DEM . In the process, it was calculated and provided three intermediate files: maximum downhill slope angle, slope length, and outflow direction (flow direction or aspect).

4.2.4 IDRISI ~ AGNPS Link

The objective of linking IDRISI with AGNPS was to convert IDRISI data and some necessary data to the format of the input file of AGNPS model. The files from IDRISI which was contained in this study were catchment image, flow direction image, land cover image, slope length image, gradient image, soil image and stream image. The other necessary data which were contained in this conversion were watershed identification, description of the watershed, area of cells (acres), precipitation (inches, storm duration (hours). The AGNPS input file would be created in the correct format of create AGNPS input file within the interface.

The ID2AGS program which was developed by Visual Basic is modified to support this study. The source code of this program is shown in Appendix C. Figure 4 illustrates the user interface for IDRISI ~ AGNPS Link. The functions of the various elements were outlined below.

Set Environment: This selects the IDRISI environment file containing the correct path for the directory where the images are stored.

Image Text Boxes: A list of available files is shown when these are clicked on and the user selects to appropriate one.

Load Images: When all the images have been selected this load the values contained in the images into a multidimensional array.

Catchment Information Textboxes: Enter information pertaining to the whole catchment in a further set of textboxes.

Create AGNPS input file: Clicking on this button creates the AGNPS input file in the correct format.

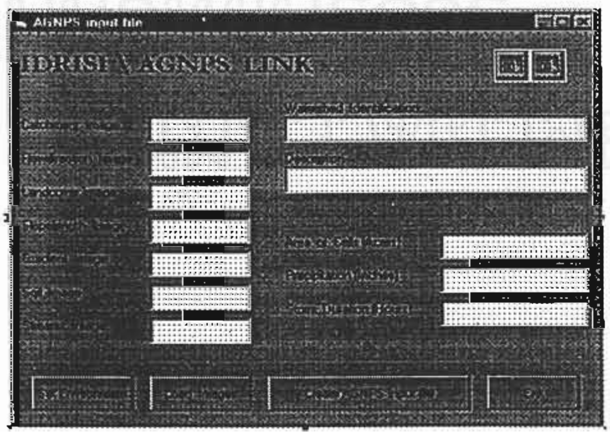


Figure 4: User interface for the IDRISI ~ AGNPS Link.

4.3 Running AGNPS model

4.3.1 Preparation of Input Image

The AGNPS model was used to predict soil erosion, sediment, nitrogen, phosphorus and COD loading for Huai Som watershed. The input data was stored and manipulated in IDRISI, the raster based GIS software, before conversion to an ASCII text file and input into the AGNPS model. The model required two sets of data i.e. watershed data as a whole and individual cell data. Watershed data consist of name of the watershed area of each cell (acre), number of cell, precipitation amount (inches). The individual cell data requires 20 inputs for each cell, these could be derived from just seven images, These were slope image, flow direction image, soil image, land use image, catchment image, stream image, slope length image.

The model has been developed for single storm events. Therefore, it is essential to input the amount of the rainfall and the energy intensity value of that particular storm as a basic information to the model. In the situations where the calculation of rain energy intensity values is not possible, the amount of rainfall, duration and the storm type can be selected as an option. There are three storm types that will enable in calculating the energy intensity values. The storm type I is for the least intensive rains and the type II is for the most intensive short duration rains. The storm type III is for the area like Gulf of Mexico and tropical maritime climates where specially in coastal areas get large amount of rainfall during 24-hour period. Therefore, the storm type I which is mostly suitable for the rainfall conditions in the study area and selected 24 hour rainfall events for the study area.

All the input images were converted to ASCII integer format that was required for the conversion program. Specification for the values that required for these images and the input variables derived from them are available in following below.

<u>Model Parameters for each cell</u>

1) *<u>Cell number</u>* : Each cell in the watershed was identified by a number. The cells were numbered consecutively from the cell in the northwest corner and proceeding from west to east southward. In the study area, total numbers of cells are 403.

2) *Receiving Cell Number* : The number of the cell into which the significant portion of the runoff drains. Drainage direction was determined by the cell topography. In this study, the receiving cell number has been determined by using the contour map and aspect map from IDRISI.

3) *Aspect (Flow direction)* : The flow direction was determined by cell topography or channel flow. Flow direction was a single digit in the range of 1-8 indicating the principal direction of drainage from the cell. Each value refers to a direction with 1 representing north and proceeding clockwise, 8 representing northwest. See Figure 5 below. In this study, it received from the step 4.2.3 of IDRISI.

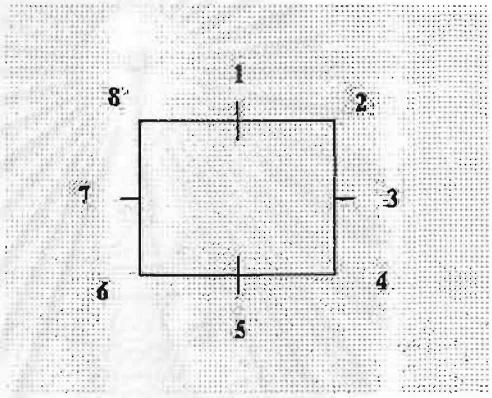


Figure 5: Flow direction

4) *SCS curve number* : The runoff curve number or hydrologic soil-cover complex number used in the SCS equation for estimating direct runoff from storm rainfall. The value of SCS curve number were obtained from Soil Conservation Department and have been used to run the model. The SCS curve number depends on the antecedent moisture condition, hydrologic soil type and existing land use patterns. The hydrologic soil group in the area was B. The antecedent moisture condition was condition II (average moisture) because the rainstorm have been occurred in this study area before getting sediment yield from field. The land use was taken from AGNPS user manual (AGNPS user manual, Murty, 1985). These values were given in Table 7.

5) *land slope (%)* : This is the percentage rise of each cell. The slope of each was calculated by the 4.2.3 of IDRISI step. If the cell was water enter a value of 0.

6) *Slope shape factor* : An identification number used to indicate the dominant slope shape of the cell (uniform = 1, convex = 2 or concave = 3). In this study, the slope shape factor was obtained from flow direction image and slope image. Most of the cells in this study area were concave slope. Calculating slope shape factor by observes

from flow direction. If receiving cell is higher slope than drainage cell, the slope shape factor would be convex. In contrast, receiving cell was lower slope than drainage cell, it would be concave. If the slope of receiving cell equal to drainage cell, it would be uniform.

7) Field slope length (feet) : Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the run-off enters a well defined channel that was part of drainage network. The calculating of slope length in this study were occurred in the 4.2.3 step. If the cell was water enter a value of 0.

8) *Manning's roughness coefficient for the channel* : Values of various roughness coefficient for different land use conditions at the time of the storm can be found in many soil and water conservation, and hydrology text books. The land use map has been used to determine the Manning's roughness coefficient in a cell depending upon the land condition in that particular cell. Note that this parameter had two input roughness value, one for overland conditions and one for the channel. The channel roughness value for this study is 0.99 (Foster *et al.*, 1980) and the forestland value was 0.4 (The Department of Land Development (DLD), 1976). See in Table 7.

Table 7: Different land use parameters.

Land Use	Curve number for hydrological soil group	Surface Condition Constant	Cropping factor	Manning Roughness coefficient	COD
Forest	55	0.59	0.001	0.4	65
Water	100	0.01	0	0.99	0

Source: Young et al (1987)

9) *Soil erodibility factor (K) for USLE* : This factor determines the soil's ability to withstand erosion. The high value showed the high potential for erosion and less value shows that high potential for erosion and less value showed that the soil was more resistance against erosion. The value varies according to the soil types. The soil map has been used to determine the soil erodibility factor of a cell, depending upon the soil texture in the cell. K values for different soils determined in study area are given in Table 8 and have been adapted as input value for the model.

Table 8: K- factor.

Soil texture	K- factor
Tha Yang and Lat Ya associate series (Ty / Ly)	0.33
Slope Complex (Sc)	0.25

Source: The Department of Land Development (Thailand)(1981)

10) *Cropping factor (C) for USLE* : AGNPS model use the USLE equation (Universal Soil Loss Equation) for the estimation of soil loss from watershed. C-factor determined the soil loss corresponding to existing land cover. C adjusted the soil loss estimate to suit these conditions. Values used were obtained from the department of land development (1981) is 0.001 for natural forest. The value for the water cell was 0.

11) *Practice factor (P) for USLE* : This is the support practice factor to represent the management practice used to control the soil erosion. A value of 1 was taken in the study to represent the worst case having no support practice and the water cell was 0.

12) *Surface condition constant* : It is a factor which adjust the time that requires the overland runoff to become channelized flow and this factor depends upon land use pattern. This value is 0.29 for forestland (Young et al., 1982).

13) *Chemical oxygen demand factor (COD)* : This factor determine the COD concentration in runoff, based on the land use in the cell. The COD of forested land is 65 mg/l (Timmons et al., 1977). COD of water cell was 0.

14) *Soil texture* : It is the major soil texture classification and is determined from the soil classification texture triangle. The texture classes and numbers to designate to each were shown in Table 9. The input value in each cell has been determined from the soil map.

Table 9: Input value of soil texture.

No.	Soil texture	Input value
1	Sand	1
2	Silt	2
3	Clay	3
4	Peat	4

The texture for this study has one type. It is sand that input value is one and the water cell is 0. When the soil texture is selected, the default vales for the nutrient characteristics will pop up. The default values for this study is selected. It is shown in Figure 6.

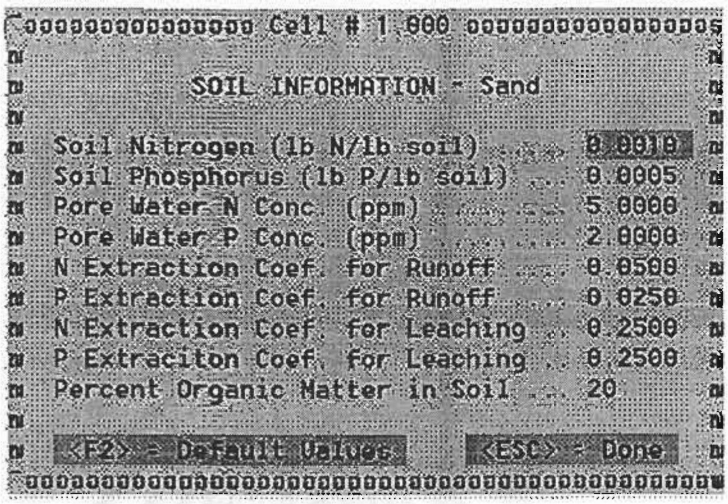


Figure 6: Default value of soil information.

15) *Fertilization level (zero, low, medium, high)* : In the study area the level of fertilization was zero because it is no use fertilization.

16) *Pesticide Indicator* : The value was zero for this study area.

17) *Point source indicator* : This parameter indicates existence of a point source input within a cell. There was no point source in the study area so the value was 0.

18) *Additional Erosion indicator* : It is a value estimating the amount of erosion (in tons) originating from a gully or other source occurring within the cell. This value is included in the total amount of sediment eroded in the cell. In the study watershed there was no prominent gully source so this factor was omitted in the study. (enter a value of 0.)

19) *Impoundment factor* : It indicates number of terrace in the cell and any other number indicates the number of impoundment in the terrace system with a maximum of 13. Since there was no impoundment terrace in the study area, 0 has been taken as an input value for impoundment factor.

20) *Channel indicator* : This factor indicating existence of a defined channel within a cell. The value of 0 denotes no defined channel and 1 for the channel in the cell. The stream map has been used to determine the channel in the study area. If the cell was

indicated that it is a non-water cell, the depth of flow was determined for each discharge assuming uniform flow. If the cell indicated that it is a water cell, the cell may act as a sediment trap. The hydraulic geometry for the cell determined the trap efficiency. The sediment trap width was equal to the water cell input width; the sediment trap depth was equal to the water cell input depth; and the sediment trap length was equal to the water cell length. The depth of flow established the settling time for each particle size class. The width & depth of flow determined the sediment transport capacity. That was all that is necessary to determine sediment deposition by particle size.

The AGNPS model parameters input values used in the study were given in Table 10.

Table 10: Parameter values used in the study.

Parameter	possible value	Value used in the study	Source
1. Cell number	Depend on the number of cell in watershed	1, 2, 3, ..., 403	-
2. Receiving cell	Depend on the flow direction	Depend on the flow direction	Contour map
3. Aspect	1-8	1-8	Contour map
4. SCS curve number	Depend on land use	0,55	-
5. land slope (%)	0,1-99	0-50	Contour map
6. Slope shape factor	1-3	1-3	Contour map
7. Field slope length	0,1-300	0-196	Contour map
8. Manning's roughness coefficient	0-0.99	0.4, 0.99	-
9. Soil erodibility factor (K) for USLE	0-1	0, 0.29, 0.33	-
10. Cropping factor (C) for USLE	0-1	0, 0.001	-
11. Practice factor (P) for USLE	0-1	0,1	-
12. Surface condition constant	0-1	0, 0.01, 0.59	-
13. Chemical oxygen demand factor	Depend on land use	55	-
14. Soil texture	0-4	0, 1	Soil map
15. Fertilization level	0-3	0	-
16. Pesticide Indicator	0,1	0	-
17. Point source indicator	0,1	0	-
18. Additional erosion	0,1	0	-
19. Impoundment factor	0,1-13	0,1	-
20. Channel indicator	0,1	0,1	Stream map

The model used these data in a variety of ways in order to generate the output from a study area. The use of these parameters by the model in the aspect of simulating the results were presented below.

- Runoff volume

The runoff is a portion of precipitation that flow overland surfaces toward larger bodies of water. Before runoff can occur, rainfall must satisfy the immediate demands of infiltration, evaporation, interception, surface storage, and surface detention or channel detention. Some are very minor losses. The runoff volume from each cell is determined using USDA (The United States Department of Agriculture), Soil Conservation service (1972). The equation used in this method is

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)}$$

Where: Q = runoff volume (inches)
P = rainfall intensity (inches)
S = retention factor (inches)

And the retention factor is defined as

$$S = \frac{1000 - 10}{CN}$$

CN = curve number

- Peak runoff rate

The equation used to determine the peak runoff rate was developed by Smith & Williams (1980) and is expressed as

$$Q_p = 3.79\,A^{0.7}\,CS^{0.16}\,(R_0 / 25.4)^{0.903A\ 0.017}LW^{-0.19}$$

Where
Q_p = peak flow rate (m^3/s)
A = drainage area (km^2)
CS = channel slope (m/km)
R_0 = runoff volume (mm)
LW = watershed length width ratio which calculated by L^2/A where L is the watershed length.

- Soil erosion

The Universal Soil Loss Equation (USLE) is used to predict upland erosion potential for a single storm event. (Wischmeir & Smith, 1978)

$$A = RKLSCP$$

Where A = soil loss in tons per acre

R = rainfall and runoff erosivity index

K = soil-erodibility factor

L = length of slope factor

S = degree of slope factor

C = cropping-management factor

P = conservation practice factor

- Sediment deposition

The method used for sediment routing involves equation for sediment transport and deposition described by Foster et al. (1981) and Lane (1982).

$$Q_s(x) = Q_s(o) + Q_{s1} * \frac{dx}{L_r} - \int_0^x D(x) * Wdx$$

Where $Q_s(x)$ = sediment discharge at the down stream end of the channel reach in pounds per second

Qs (o) = sediment discharge at the upstream end of the channel reach in pounds per second

Qs1 = lateral sediment inflow rate in pounds per second

x = down slope distance in feet

Lr = reach length in feet

D(x) = sediment deposition rate at a point x in pounds per square foot

W = channel width in feet

- Chemical transport model

This part of the model estimates the transportation of nitrogen, phosphorus and COD (chemical oxygen demand) throughout the watershed. Chemical transport calculations are divided into soluble and sediment adsorbs phase. Nutrient yield in sediment adsorb phase is calculated using total sediment yield from a cell as follows:

$$Nut_{sed} = (Nut_f)\, Q_s(x)\, E_{\&}$$

Where Nut_{sed} = nitrogen and phosphorus transported by sediment
Nut_f = N and P content in the field
$Q_s(x)$ = sediment yield
$E_{\&}$ = enrichment ratio

and $E_{\&}$ = $7.4\, Q_s(x)^{-0.2}\, T_f$
Tf = correction factor for soil texture; depends on the soil type, Clay = 1.15, Silt = 1, Sand = 0.8, Peat = 1.50

Soluble nutrient estimates consider the effect of nutrient level in rainfall, fertilization and leaching. Soluble nutrient contented in runoff are estimated as follows:

$$Nut_{sol} = C_{nut} * Nut_{ext} * Q$$

Where: Nutsol = concentration of soluble N and P at the soil surface during the runoff
Cnut = the mean concentration of soluble N and P at the soil surface during the runoff
Nutext = the extraction co-efficient of N and P for movement into runoff
Q = the total runoff

COD in the model is assumed soluble. Estimates of COD in runoff are based on calculated runoff volumes and average concentration of COD in that volume. The average concentrations are calculated from the estimates made from the COD values correspond to the land use conditions in a given cell. Soluble COD is assumed accumulate only after flow has become channelized, without any allowable losses.

4.3.2 Operation of the AGNPS Model

After the creation of the input file it was retrieved into the AGNPS model. The data checking facility was then used to check for errors. If no input errors were detected. A grid file was then created containing the cell layout of the watershed and the routing within the watershed. The model was run and began the calculations for generating output results. The output results can be displayed both grafix display and tabular output. The "Grafix Display" generated both input parameters and output results by display that watershed information in map format. The "Tabular Output" generated a report of AGNPS results in table form.

4.4 Field Study

The purpose of the field survey was to collect sediment at the outlet of Huai Som basin.

- *Material*

1) Bamboo (1.5 –2.0 inches in diameter and 4 feet long)
2) Plastic plate (Black thick plastic, 3 X 9 meters)
3) Small steel string, needles and Small thin sheet of bamboo tissue
4) Slant cover
5) Large steel trickle (one square inch hole)
6) Small nylon strain (32 hole per inch)
7) Plankton net (20 micron pore)
8) GPS

- *Procedure*

a) To select the area to set the sediment trap.

Selecting the outlet of Huai Som basin for setting the sediment trap by using GPS. In this study, the collecting sample is 3 storms.

b) To design sediment trap.

The sediment trap was consisted of three layers of filters, which separated the erosive mixture by sizes and weights of sediment. The collecting tools were installed at the outlet watershed to block the flow of stream. This sediment trap collected soil loss from surface runoff. Most of sediments could not pass through these three filters. Only water and fine clay were released by the end of the last filter. (See Figure 7-11)

c) To build sediment trapped structure

First, plastic plates were placed down on the ground and on both side of the tunnel to prevent water and sediment leaking hole.

After that the main structure was settle on. Bamboo sticks were deeply deposited into the ground and also along horizontal side to hold the structure from water pressure. Each piece of stick was connect with steel needles and small thin line of bamboo tissue. Then three layers of filter were install in.

d) Filter installation

First filter, which made of a strong steel filter was used for trapping large particle such as sticks, gravel and leaves in addition this first gate was constructed with the strongest structure to retard the speed of water flow and be tolerant to pressure.

When the mixture was trapped by the first filter, second layer which made of tiny hole nylon sheet would separated small gravels ,leaves and sand and to prevent damage in the last delicate filter.

The rest of mixture was classified by last layer. This layer was a fine pore to collector which reserve clay and fine sand. Actually, this filter was an instrument to collect microorganisms in water which was called "plankton net". And the rest of mixture were released though pores and the open-duck at the end of this plankton net. This last layer had a special installation to support pressure caused by the slow flow of water through this very limit filter pores. Plankton net was attached in zinc plate, which was put in the soil floor.

After all process were done, a slant was placed to cover the top of instrument in order to prevent leaves and small sticks falling from the top.

- *Analysis*

After collecting sediment yields from field. Drying them at 103 degree of Celsius for 24 hour. Then the dry sediment yields were weighted.

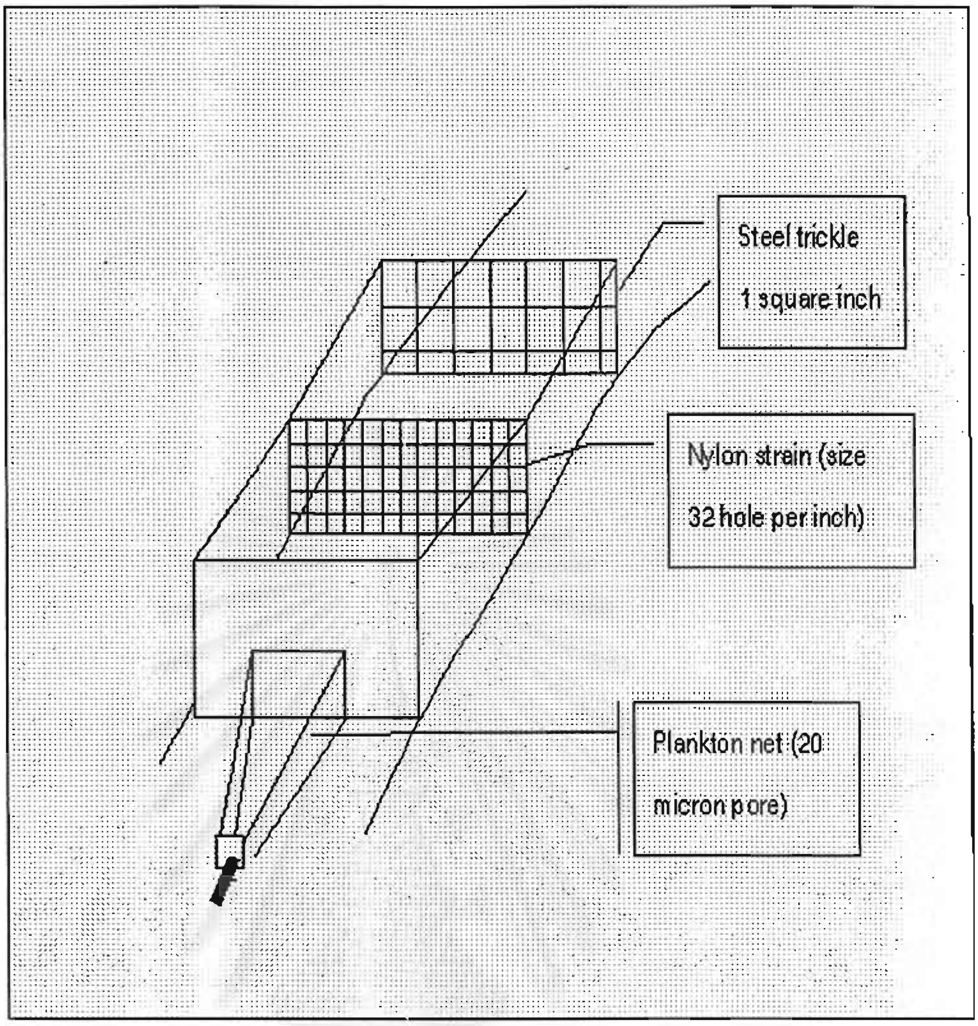


Figure 7: The outline of sediment trapped construction.

Figure 8: The first filter of sediment trapped.

Figure 9: The second filter of the sediment trapped.

Figure 10: The last filter of sediment trapped.

Figure 11: Sediment trapped.

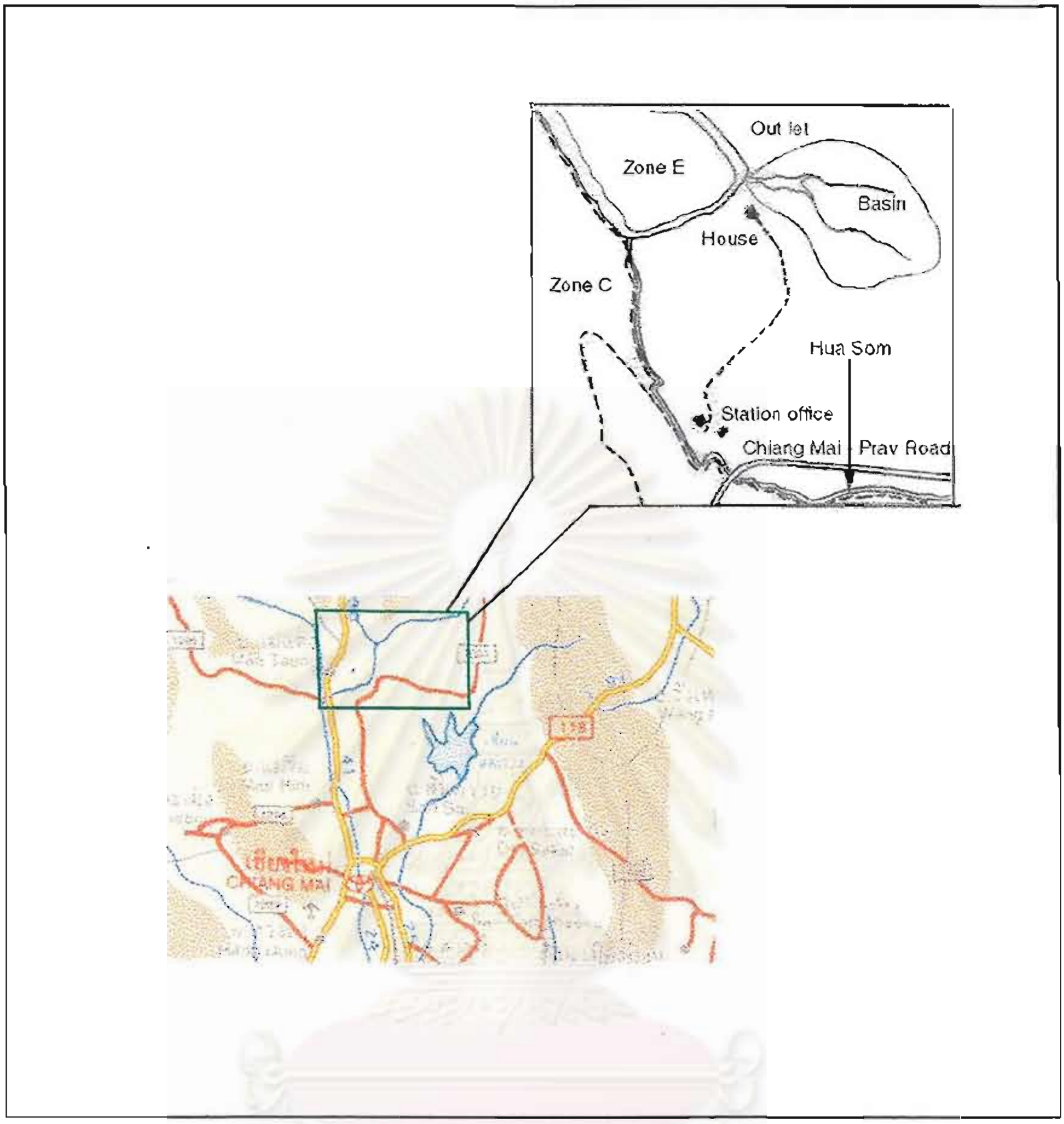


Figure 12: The study area with the outlet of the basin.

4.5 Compare the model result with available observed data.

AGNPS model was run for the different storm rainfall after the input of the watershed and the cell data. Each storm has its typical characteristics to generate runoff, which is given as the discharge at the outlet of the model. The model results of different storms generation discharge were compared with the observed discharge in the study area at the outlet of the watershed. The adjustment was done for the test out the sensitivity of sediment yield in discharge that was one of the model output parameter. The input parameters were tested in this study such as Manning's roughness coefficient, K-factor, C-factor, P-factor. For the range in values used for each input parameter was: Manning's roughness coefficient was 0.01-0.4, K-factor was 0.14-0.62, C-factor was 0.001-1 and P-factor was 0.01-1.

For the rainfall intensity, it must be higher than 25 mm. If the rainfall intensity is less than 25 mm, the model was not capable of producing any pollutant from the watershed. To get rainfall intensity from Huai Som Research station. Due to there was no recording gauges for the study area so it could not calculate energy intensity of rainfall.

Summary the methodology of this study in the Table 11 and Figure 13.

Table 11: Table of methodology.

INPUT	SOFTWARE	OUTPUT
TOPOGRAPHY MAP	GIS	CONTOUR MAP CREEK MAP
CONTOUR MAP	ARC2SURF	XYZ DATA FILE
XYZ DATA FILE	SURFER	DEM (FILE.GRD)
DEM (FILE.GRD)	IDRISI	GRADIENT IMAGE FLOWDIRECTION IMAGE CATCHMENT IMAGE STREAM IMAGE SOIL IMAGE LANDUSE IMAGE CONTOUR IMAGE
CONTOUR IMAGE (REAL ASCII)	IDRISI4	SLOPE LENGTH IMAGE
7 IMAGE(INTEGER ASCII)	ID2ADS	ASCII FILE (.DAT)
ASCII FILE (.DAT)	AGNPS MODEL	TABULAR AND GRAFIX OUTPUT

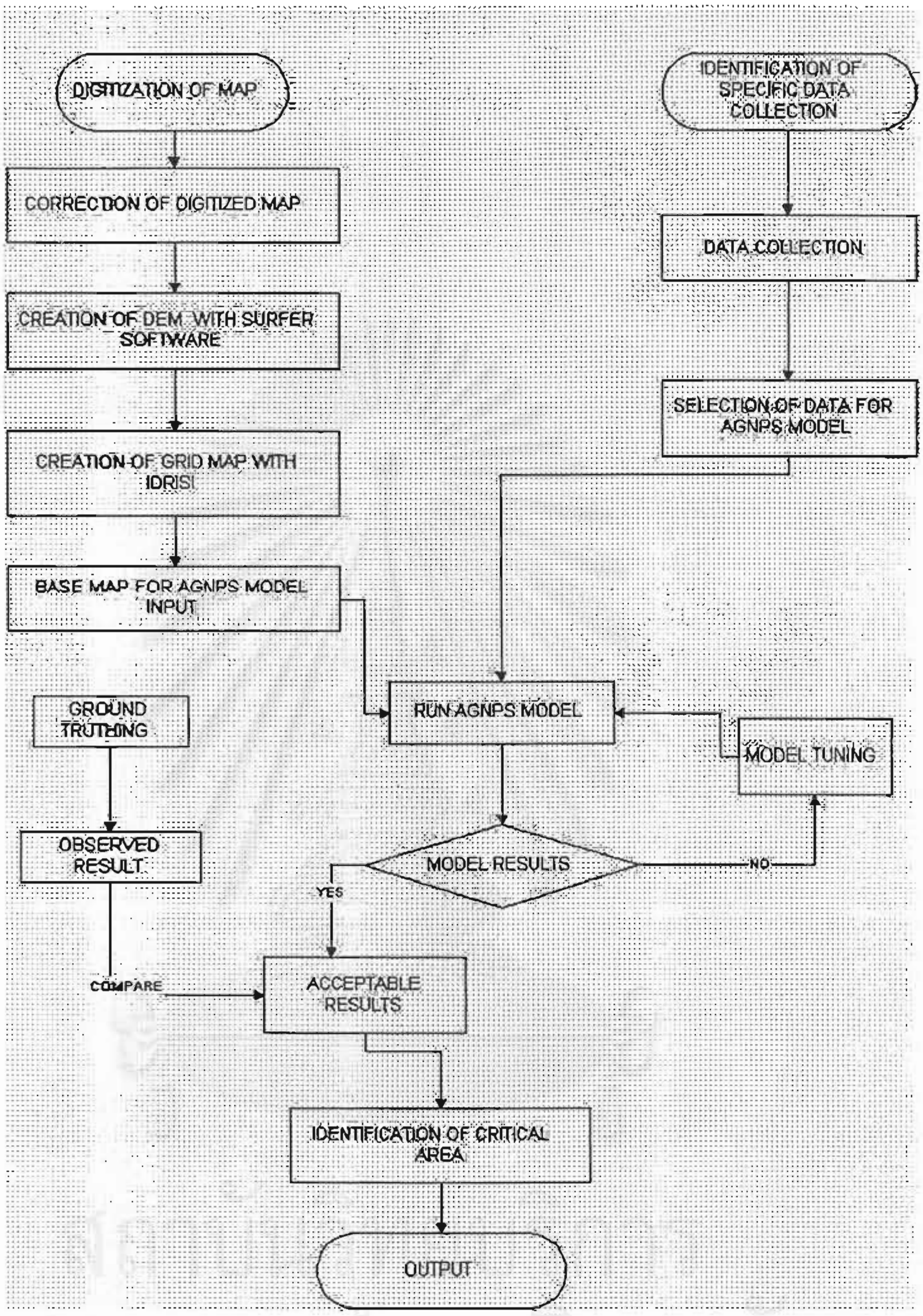


Figure 13: Conceptual Methodology

CHAPTER 5

RESULTS AND DISCUSSIONS

In this study, there are distinct of the results to 4 type

5.1 Results of the GIS, SURFER and IDRISI

The study has assembled the spatial data of soil type, topography, land cover, hydrography into GIS as vector data with the same resolution and coordinate system. The contour map has been converted to SURFER to create DEM (digital elevation model) file. After that, these maps were converted to grid maps. A grid size of 0.4 acres (40 by 40 meters) was used for data aggregation and for facilitating subdivision of grid cells in AGNPS to represent the analysis size in the study. The grid data of slope gradient, slope length, flow direction, stream, catchment and soil maps were created with IDRISI tool (Figure 14-17). Finally, linking of these databases with the AGNPS model were performed through ID2AGS which is the utility program developed in Visual Basic language with visual basic tool. This program is a set of commands that can produce a data file suitable for direct AGNPS input.

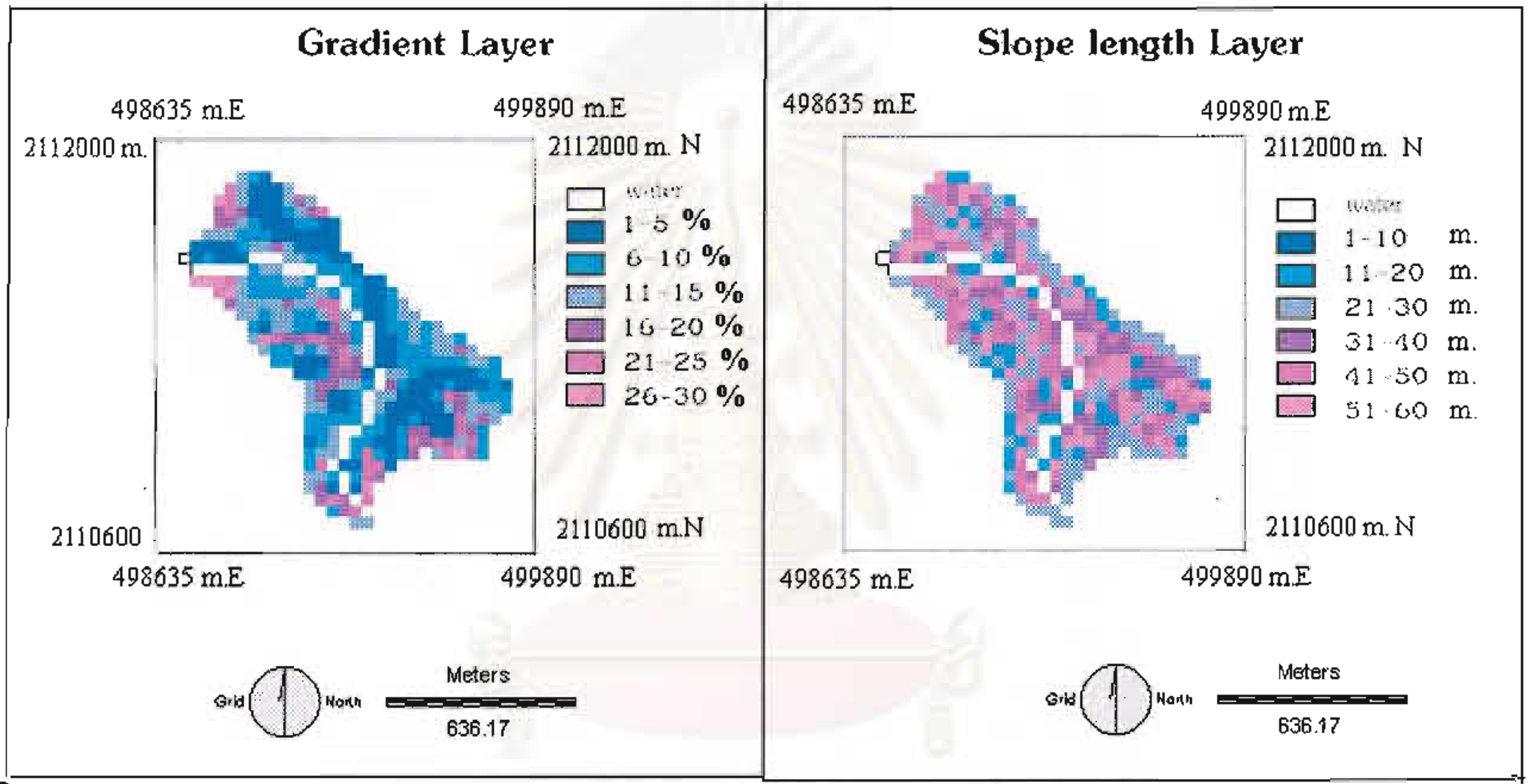


Figure 14: The image of gradient and slope length layer from IDRISI software.

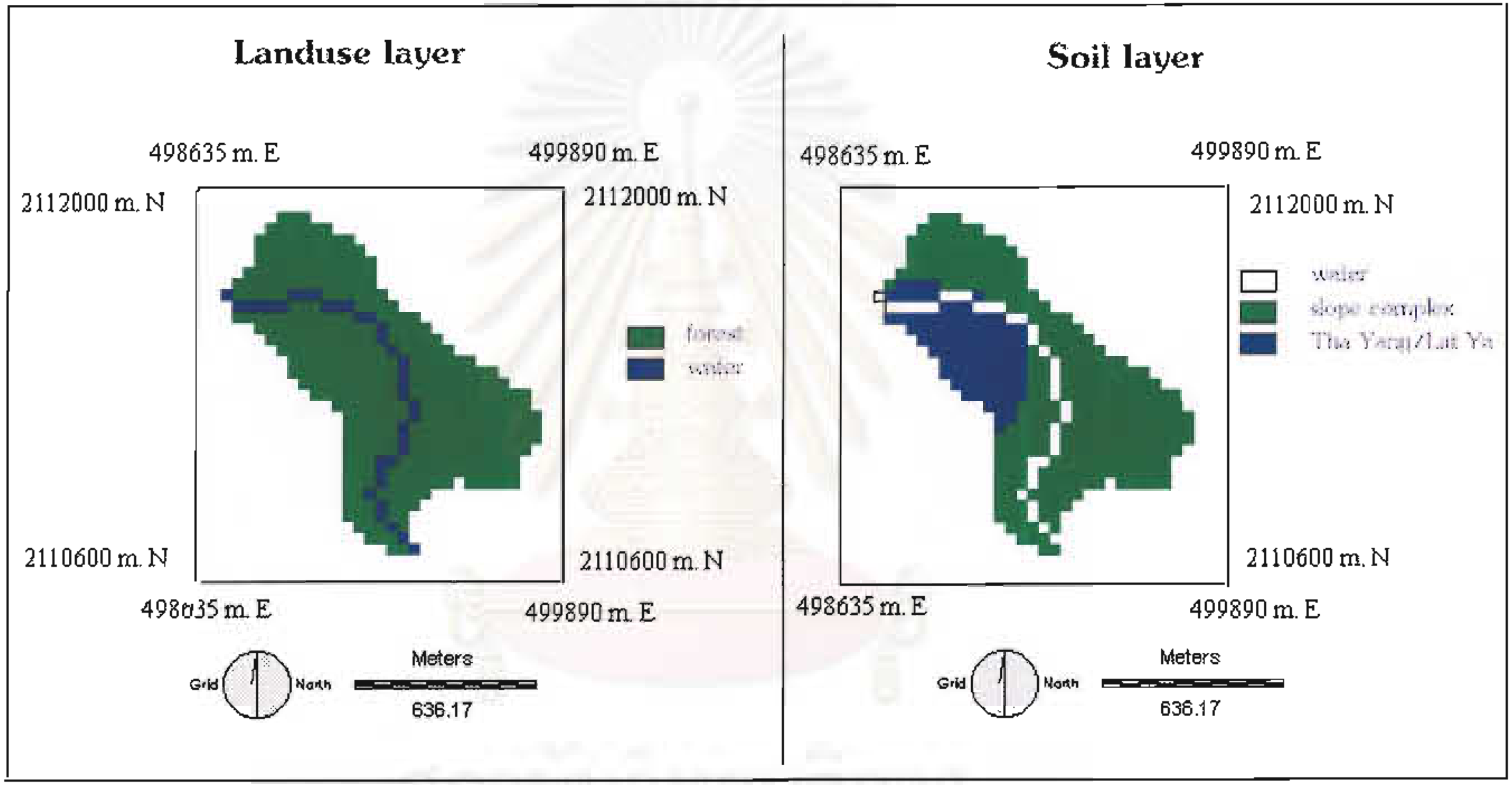


Figure 15: The image of the soil and land use layer from IDRISI software.

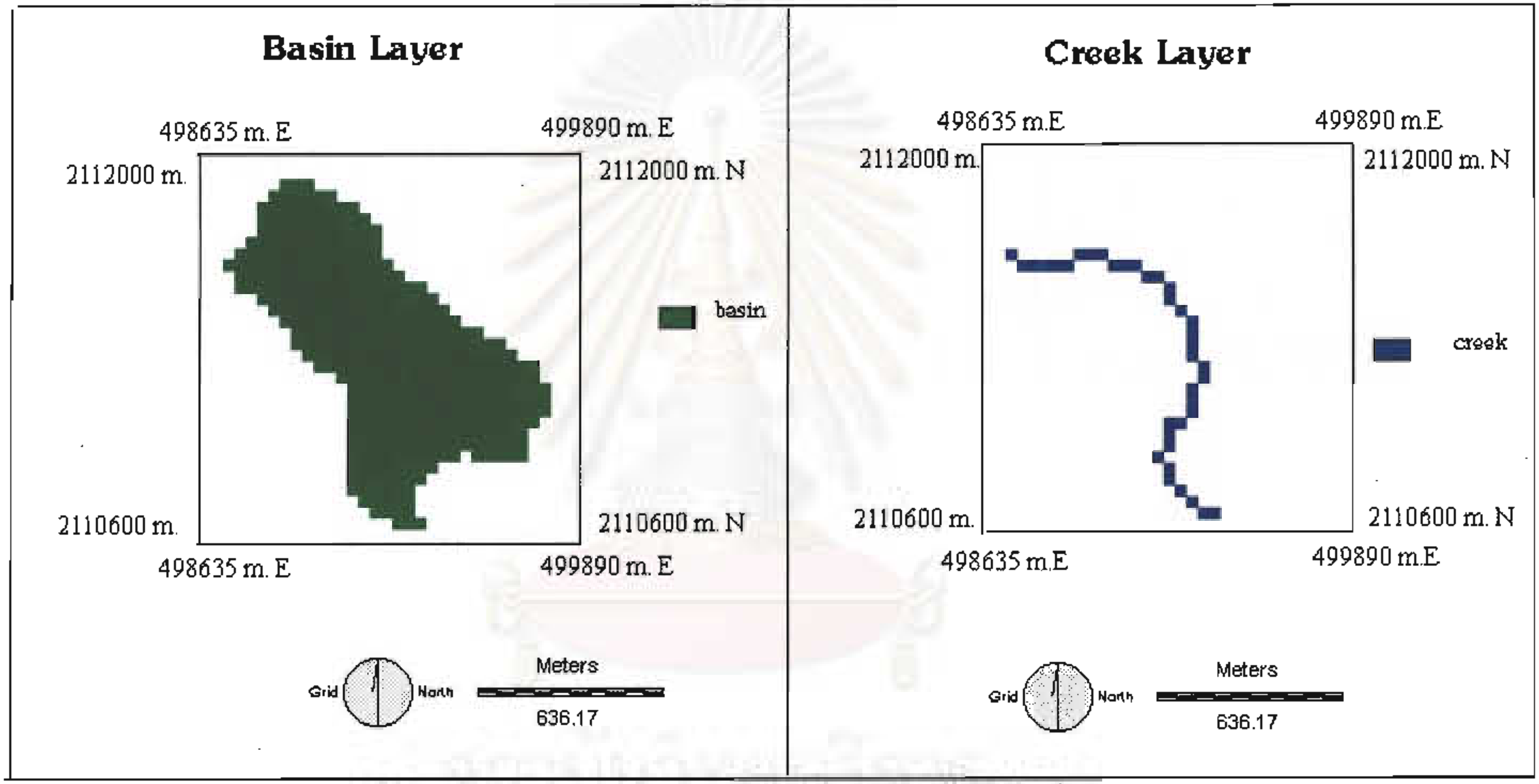


Figure 16: The image of basin and creek layer from IDRISI software.

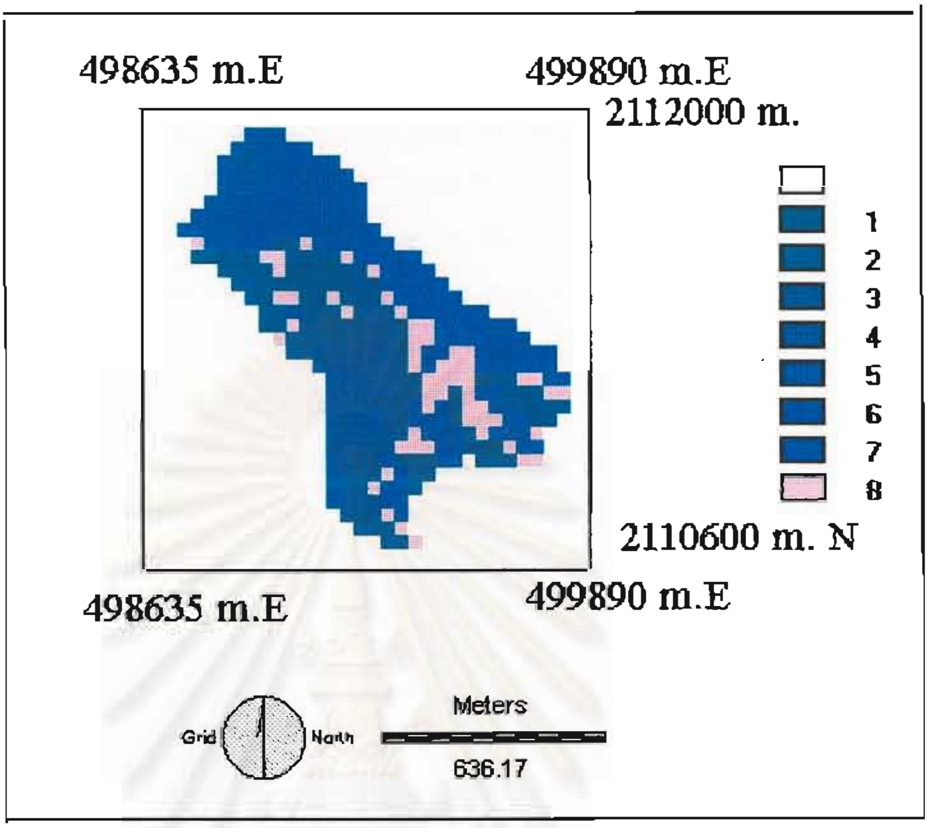


Figure 17: The image of flow direction from IDRISI software.

5.2 Evaluation of IDRISI ~ AGNPS Link

Integrating a non-point source pollution model with a GIS. These have been used to evaluate this system. The IDRISI~AGNPS Link (developed by Visual Basic) is easy to use. The program provides a user friendly "point and click" interface and the specific elements of this are arranged in a logical order which, it is hoped, provides an intuitive environment. However, there are stringent requirements for the format and dimensions of the image files that are imported from IDRISI. The production of these requires a good working knowledge of IDRISI and a clear understanding of the data required for the AGNPS model. One area where the IDRISI~AGNPS Link fails, is in the calculation of the energy intensity value. In order to obtain this value, precipitation must be deleted and re-entered within the AGNPS model so the energy intensity calculation is performed. Due to the scarcity of data available, some default parameters will be used for the AGNPS. Thus the inputs for some data are eliminated. Therefore this program is not a universal coupling of IDRISI and AGNPS.

5.3 Sensitivity of input parameter of the AGNPS model

The analysis of model sensitivity is very important step before starting any simulation process. This step is basically an adjustment of one or more variables of the model to investigate the influence of the variables to the output of the system. For this study, the input parameter that was used to adjust the sensitivity of the model results consists of four parameters; Manning's roughness coefficient, K-factor, C-factor, P-factor and duration of the rainfall.

Table 12: The sensitivity of Manning's roughness coefficient parameter to sediment yield.

Manning's roughness coefficient value	Sediment yield (tons)	Description for channelized flow	Source
0.01	1.34	Concrete	Neger, 1981
0.03	1.23	Rubble, short grass pasture	Neger, 1981
0.04	1.2	Mature row crop	Neger, 1981
0.1	1.13	Heavy stand of timber, a few down trees	Neger, 1981
0.2	0.89	Small grain (good, 14 inch rows)	AGNPS manual
0.25	0.88	Wheat Straw(4 tons/acre)	AGNPS manual
0.3	0.87	Grass (Very dense)	AGNPS manual
0.4	0.85	Forest land	AGNPS manual

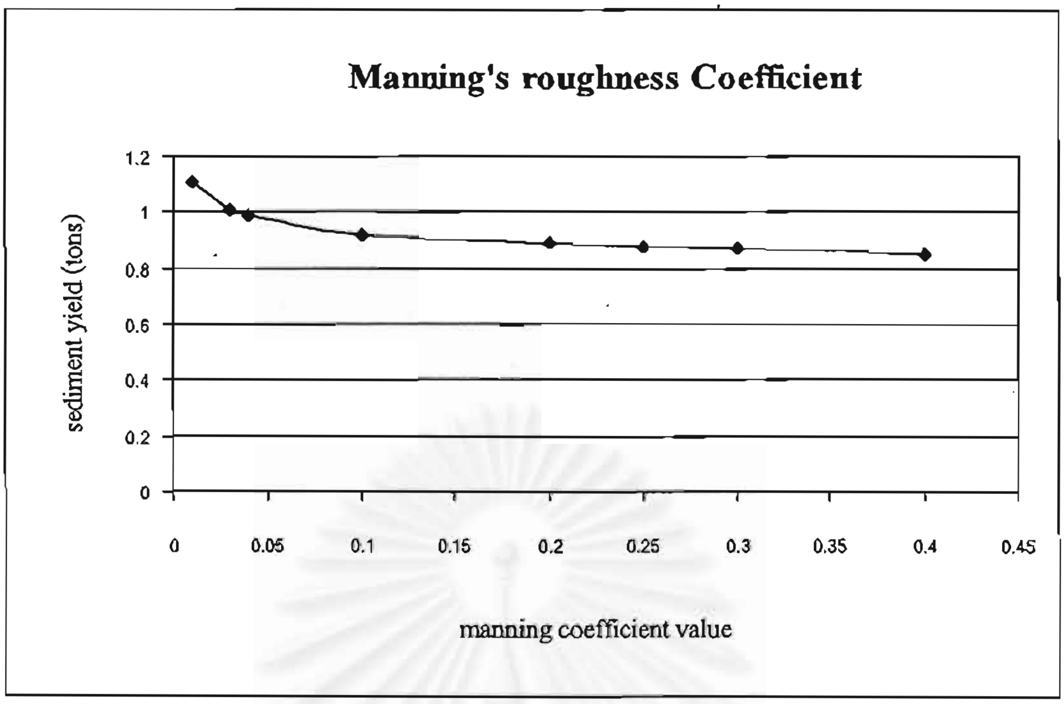


Figure 18: The sensitivity of Manning's roughness coefficient parameter to sediment yield

Manning's roughness coefficient:

The input parameters for this running model that are; rainfall intensity is 1.8 for 2 hours, C-factor is 0.064, COD is 65, K-factor are 0.33 for Tha Yang/Lat Ya association and 0.25 for slope complex. SCC is 0.59. For testing the sensitivity of Manning's roughness coefficient to the model the value has been varied from 0.01-0.4. For the water cell, the Manning's roughness coefficient is 0.99. The Manning's roughness coefficient is value of various roughness coefficients for different land use conditions at the time of the storm. From graph in Figure 18, it is seen that during the value 0-0.1it is conclude that the lower Manning's roughness coefficient value will increase sediment yield. It is shown that the erosion is higher than high value of Manning's roughness coefficient.

Table 13: The sensitivity of K-factor parameter to sediment yield

K-factor	Sediment yield(tons)	Soil series
0.14	0.78	Ban Chong (Bg)
0.22	0.85	Chiang Khan (Ch)
0.27	0.89	Mae Taeng (Mt)
0.3	0.91	Korat (Kt)
0.33	0.93	Lad Ya/Tha Yang association
0.36	0.95	Korat/Renu (Kt/Rn)
0.4	0.98	Hang Chat (Hc)
0.52	1.07	Mae Sai (Ms)
0.62	1.14	Lumpang (Lp)

Source: The department of land conservation, 1981

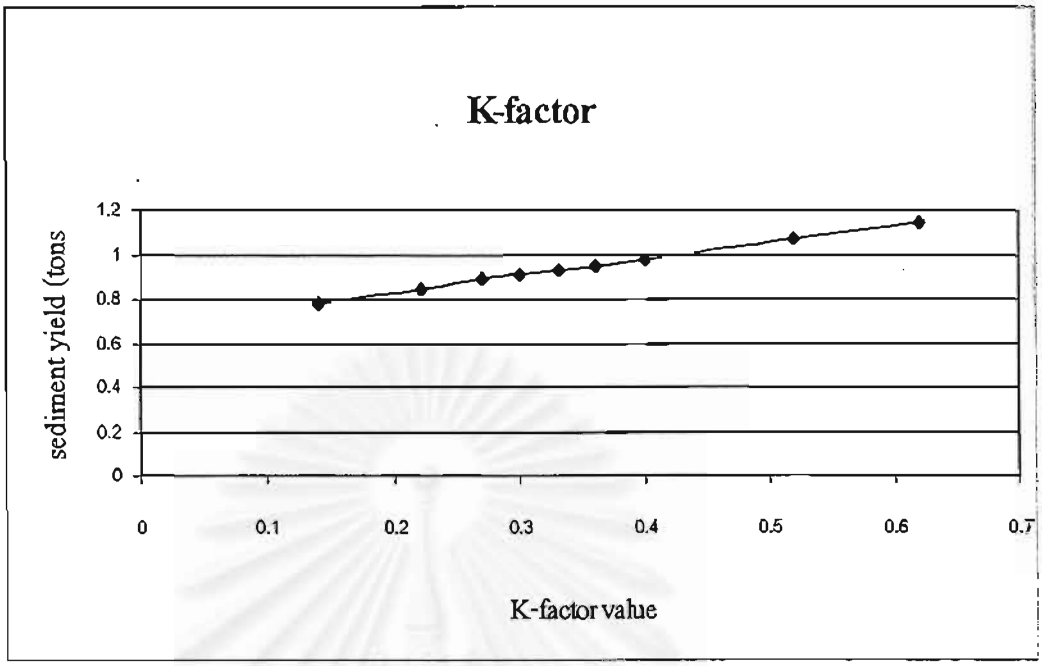


Figure 19: The sensitivity of K-factor parameter to sediment yield

K-factor:

The input parameters for this running model that are ; rainfall intensity is 1.8 for 2 hours, C-factor is 0.064, COD is 65, Manning's roughness coefficient is 0.4 for forest land and 0.99 for water. SCC is 0.59. For K-factor , it uses the variable value in 0.14-0.62 for different soil series. The K-factor for the slope complex is 0.25. The K-factor is a measure of the inherent erodibility of a given soil under the standard condition of the unit USLE plot maintained in continuous fallow. It is based on soil texture, organic-matter content, permeability, and other factors inherent to soil type. From graph in Figure 19, it is seen that the higher K-factor value will increase sediment yield. Consequently erosion is higher.

Table 14: The influence of C-factor parameter to sediment yield

C-factor	Sediment yield (tons)	condition	Source
0.001	0.07	Dense Forest	Watanasak, 1978
0.003	0.15	Hill evergreen forest	The department of land conservation, 1981
0.014	0.48	Mix deciduous with teak	The department of land conservation, 1981
0.02	0.57	Pasture	Watanasak, 1978
0.064	0.93	Mix deciduous dry forest	The department of land conservation, 1981
0.09	1.13	Prairie / Savanna grass	The department of land conservation, 1981
0.15	1.53	Wheat	Watanasak, 1978
0.3	2.14	Orchard	Watanasak, 1978
0.4	2.49	Coconut	Watanasak, 1978
0.5	2.83	Pineapple field	Watanasak, 1978
0.6	3.17	Potato	Watanasak, 1978
0.7	3.51	Rice field	Watanasak, 1978
0.8	3.84	Castor-oil plant	Watanasak, 1978
1	4.45	Active mining	Watanasak, 1978

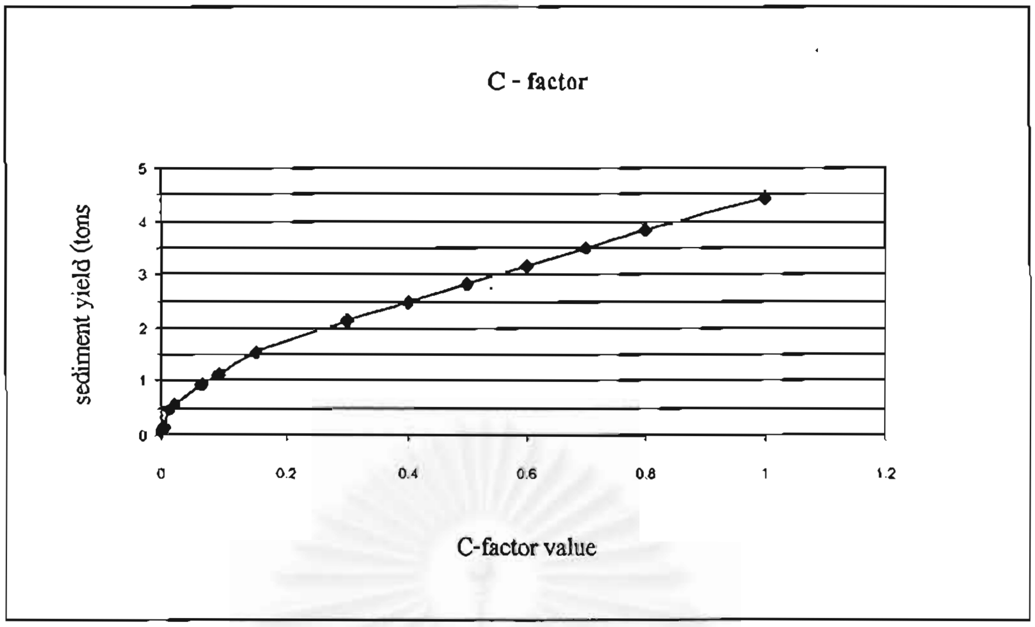


Figure 20: The influence of C-factor parameter to sediment yield

C-factor:

The input parameters for this running model that are ; rainfall intensity is 1.8 for 2 hours, K-factor are 0.33 for Tha Yang/Lat Ya association and 0.25 for slope complex. COD is 65, Manning's roughness coefficient is 0.4 for forest land and 0.99 for water. SCC is 0.59. P-factor is 1.00 because this study area has no conservative. For C-factor , Values for C in this running are 0.001-0.3 for different land cover. The C-factor is perhaps the most important USLE factor because it represents conditions that can be managed most easily to reduce erosion. Values for C can vary from near zero for a very well protected soil to 1.5 for a finely tilled, ridged surface that produces much runoff and leaves the soil highly susceptible to rill erosion. C-factor bases on cropping sequence, surface residue, surface roughness, and canopy cover, which are weighted by the percentage of erosive rainfall during the six crop stages. Lump these factors into table of soil loss ratios, by crop and tillage scheme. From graph in Figure 20, it is seen that the higher C-factor value will increase sediment yield. Consequently erosion is higher.

Table 15: The influence of P-factor parameter to sediment yield.

P-factor	Sediment yield (tons)	Conservation
0.01	0.06	Mulching
0.08	0.23	Contour plowing (slope 2-7%)
0.18	0.42	Terracing (slope 17-20%)
0.25	0.51	Contour and graded terrace(or bank) system (slope 2-7%)
0.3	0.56	Contour and graded terrace(or bank) system (slope 7.1-12%)
0.4	0.62	Crop rotation on terrace and graded waterways(slope 17-20%)
0.5	0.68	Contour strip cropping (slope 2-7%)
0.6	0.73	Contour strip cropping (slope 7.1-12%)
0.7	0.78	Contour cultivation or contouring (slope 13-16%)
0.8	0.83	Contour cultivation or contouring (slope 12.1-18%)
0.9	0.88	Contour cultivation or contouring (slope 18.1-24%)
1	0.93	No conservative

Source: The department of land conservation, 1981.

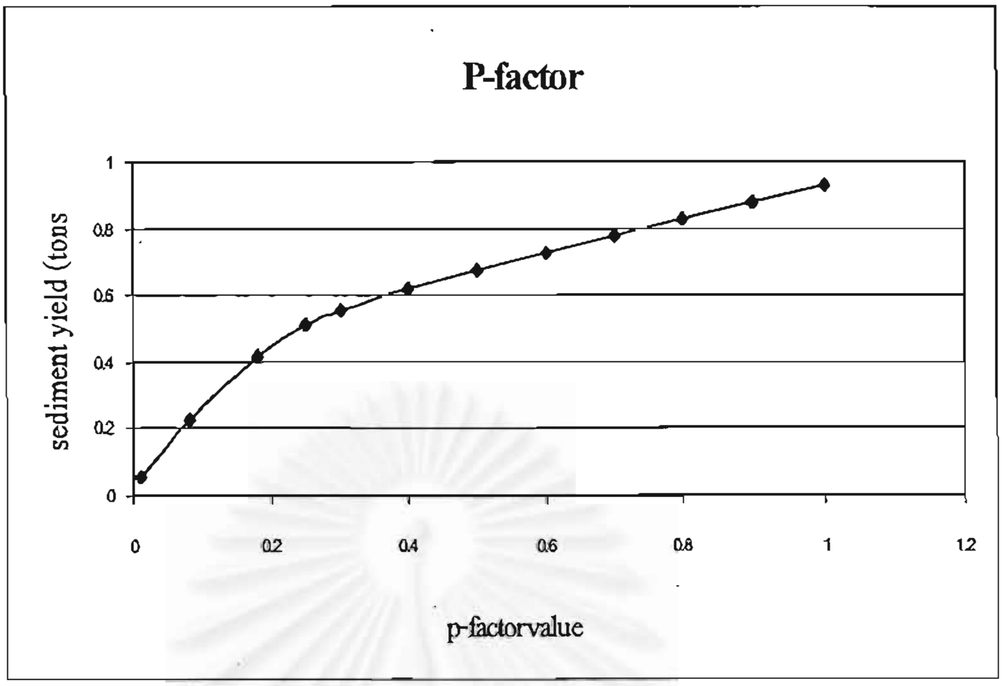


Figure 21: The influence of P-factor parameter to sediment yield

P-factor:

The input parameters for this running model that are ; rainfall intensity is 1.8 for 2 hours, K-factor are 0.33 for Tha Yang/Lat Ya association and 0.25 for slope complex. COD is 65, Manning's roughness coefficient is 0.4 for forest land and 0.99 for water. SCC is 0.59. C-factor is 0.064 for forestland. For P-factor represents how surface conditions affect flow paths and flow hydraulics. For example, with contouring, tillage marks are credited with directing runoff around the slope at much reduced grades. However, slight changes in grade can change runoff erosivity greatly. P-factor bases on installation of practices that slow runoff and thus reduce soil movement, P-factor value change according to slope ranges with some distinction for various ridge heights. From graph in Figure 21, it is seen that the higher C-factor value will increase sediment yield. Consequently erosion is higher.

From the above, the C-factor is the most sensitivity to sediment yield because there are five input parameters of the AGNPS model namely, the surface condition constant, overland Manning's roughness coefficient, cover and management factor, runoff curve number and Chemical Oxygen Demand (COD) factor which are based on the land use condition of the area.

5.4 Results from fields

A field survey was conducted on 24-25/6/1999 and 29/7/1999. The purpose of the field survey was to collecting sediment yield at the outlet of the basin. The results from field survey were shown in table 16.

Table 16: The results from field study.

No,	Date	Rainfall (in.)	Duration (hr)	Total Sediment Yield (grams)
1	24/6/1999	0.7	0.5	44.5
2	25/6/1999	0.9	0.5	114.8
3	29/7/1999	2.5	6.0	150.0

From 3 sediment yield samples and study area, it was found that the first sample (collected in 24/6/1999) had the rain amount of 0.7 inches, duration of 0.5 hr. and sediment yield of 44.5 grams. The second sample (collected in 25/6/1999) had the rain amount of 0.9 inches, duration of 0.5 hr. and sediment yield of 114.8 grams. The third sample that was collected in 29/7/1999 had the rain amount of 2.5 inches, duration of 6 hr. This was a heavy rain and sediment yield of 150.0 grams. These sediment sample are clay.

That was the rain on 24-25/6/1999 but it cannot be used as samples because the limitation of the model see explanation in chapter 2.

5.4 Results of AGNPS model

The results have two type of soil such as clay and sand. The weight of clay is 0.04 tons and the weight of sand is 0.01 tons.

Table 17: Results from the AGNPS model.

No.	Rainfall (in.)	Duration (hr)	Total Sediment Yield (tons)
1	0.7	0.5	-
2	0.9	0.5	-
3	2.5	6.0	0.04

From the rainfall intensity as measured from field, the model provided results as shown in Table 17. Table 17 is shown that the 3-strom events are used in this study but only one sample can be used to run model because of not enough amount of rain in 2 first sample. This is found to be a limitation of this model. It has come to the conclusion that the area is not critical in terms of soil erosion based on these measured sediment results.

The output results of AGNPS model can be displayed in two forms: the tabular output as shown in Table 18 and the graphic output as shown in Figure 22.

Table 18: Tabular output from AGNPS model.

WATERSHED SUMMARY	
Watershed identification	Huai Som
Drainage area of the watershed	161.20 acres
Area of each base cell	0.40 acres
Characteristic storm precipitation	2.48 inches
Strom energy-intensity value	23.96
VALUES AT THE WATERSHED OUTLET	
Cell number	65
Runoff volume	0.29 inches
Peak runoff rate	46.72 cfs
Total sediment yield	0.05 tons
Total nitrogen in sediment	0.07 lbs/acre
Total soluble nitrogen in runoff	0.01 lbs/acre
Soluble nitrogen concentration in runoff	0.15 ppm
Total phosphorus in sediment	0.04 lbs/acre
Total soluble phosphorus in runoff	0.00 lbs/acre
Soluble phosphorus concentration in runoff	0.00 ppm
Total soluble chemical oxygen demand	0.02 lbs/acre
Soluble chemical oxygen demand concentration in runoff	0.27 ppm

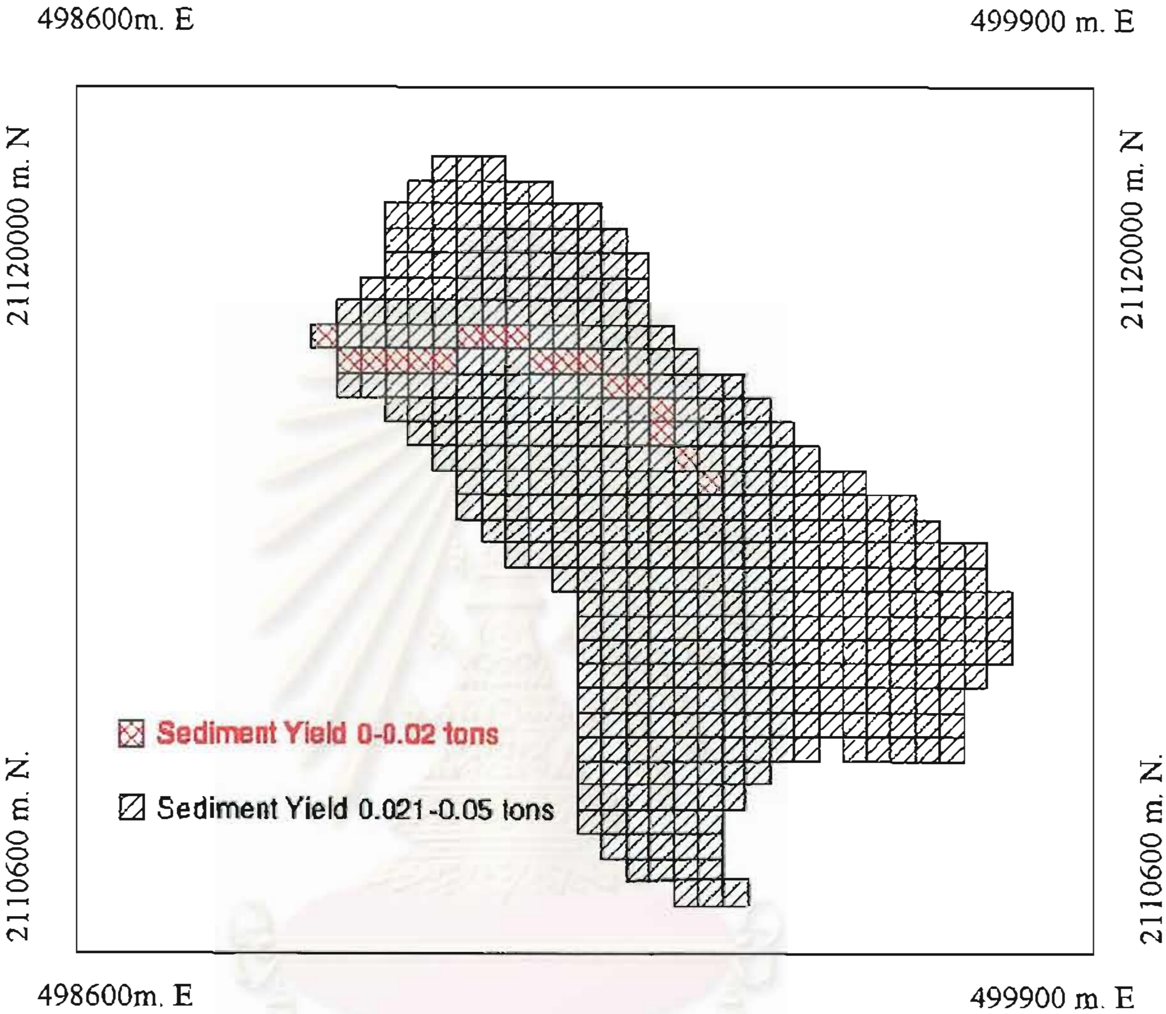


Figure 22: Sediment loading estimate by the AGNPS model.

5.6 Comparison of AGNPS output data with observed field data

Comparison of the results from model and field study with clay soil show that the sediment yield values from model are higher than the field values. For the given, the models overpredicted sediment yield by 266 times. See the result in Table 18.

Table 19: Comparison of AGNPS output data with observed field data.

Rainfall (in.)	Observed Data	AGNPS Output Data
2.48	150 grams	0.04 tons

The rainfall intensity which obtain from the standard gauges of the study area are used in running model for testing the sensitivity of rainfall duration to sediment yield. The results are shown in Table 19 and Figure 22. It is found that the increase duration of rainfall, the decrease sediment yield.

Table 20: The sensitivity of rainfall duration to sediment yield.

Rainfall intensity (inches)	3hr. duration	6hr. duration	9hr. duration	12 hr. duration
1.65	0	0	0	0
1.7	0.01	0.01	0.01	0
1.9	0.03	0.02	0.02	0.02
2.1	0.04	0.03	0.03	0.03
2.3	0.05	0.04	0.04	0.04
2.48	0.06	0.05	0.05	0.05
2.6	0.06	0.06	0.06	0.05
2.8	0.07	0.07	0.07	0.06
3	0.08	0.08	0.08	0.08
3.5	0.12	0.11	0.11	0.11
4	0.17	0.16	0.15	0.15
5	0.3	0.27	0.26	0.26

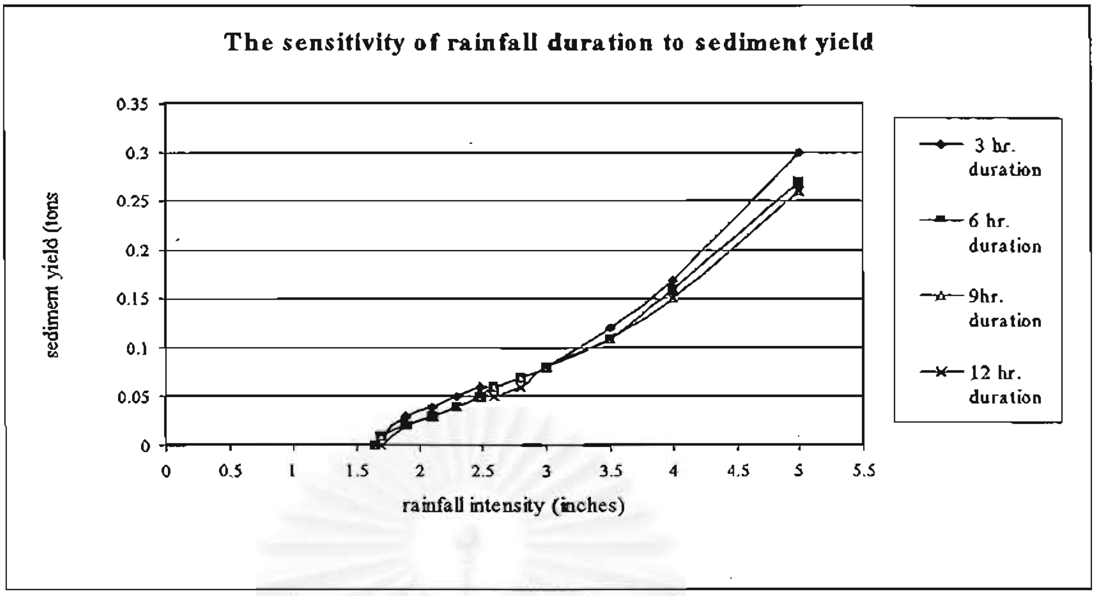


Figure 23: The sensitivity of rainfall duration to sediment yield.

The overpredicted of sediment yield from the model occur because of the following reasons:

- *The structure of soil*

The soil structure, which is determined by the arrangement of soil particles into aggregates, determines the content of non-capillary pores in the soil and the stability of the soil aggregates. In this study area, the topsoil is sandy loam and low amount of topsoil. Most of area is hardrock in the soil profile. Therefore the movement of soil particle is low. Consequently the sediment yield is low too.

- *The effect of slope gradient and slope length*

The erosion is conditional on surface runoff from slopes. With increasing slope gradient and slope length and with continuing rainfall water running off the slopes gain higher velocity and tangential stress and the action of its destructive force on the soil surface increases. The intensity of erosion processes usually decreases with a drop of the slope gradient until soil particles which have been detached and transported over the soil surface begin to sediment. In this study, the values of slope gradient and slope length are obtained from estimate from IDRISI software that it is not exactly value.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Based on the study of the Huai Som basin, the conclusions and recommendations are as follows:

6.1 Conclusions

1) The AGNPS model has been integrated with SURFER, IDRISI and GIS tools to predict non-point source pollution. The non-point source pollution of this study area was limited to sediment yield from erosion. The integrated system assists input procedure of AGNPS by gathering input data from GIS layers.

2) The model can answer numerous practical, problems but the results may not be exact since the techniques are approximated by describing real-world in a simplistic fashion.

3) The study found that C-factor is the most sensitivity to sediment yield. And the AGNPS model does not concern with the thickness of soil surface layer.

4) Comparison of the results from model with field study showed that the sediment yield from model is higher than the value from field study for 266 times. The overestimate is the effect of several external and internal influences such as structure of soil, slope gradient and slope length.

5) Since the database in the present study was inadequate, it could not evaluate whether the model is good or not.

6) The accuracy and reliability of the models are limited. Although some models represent the best available technology for analysis of environment systems, a common distortion are made by many factors, i.e.,

a) As has already been discussed the empirical nature of the USLE and its origins in North America limit its applicability to a tropical environment such as Thailand. The simplification of an extremely complex process, such as soil erosion, into one equestion is bound to cause inaccuracies. The limitations of the USLE are predicts soil lost at field level and should not be used to predict sediment levels in rivers at the drainage basin level. Sediment yield may differ from the results generated by the USLE due to downstream deposition (Morgan, 1986). Gully erosion which can produce large amounts of sediment is not modeled.

b) The assumption that each factor remained constant within each 404.7 rai grid cell is an obvious simplification of reality.

c) The map from which they were digitized was at a very small scale that could cause spatial inaccuracies. The vector map of this was interpolated to a DEM, which can cause further errors.

d) There may have been errors in the original soil survey and the information provided about each class was extremely general. This made the calculation of the K-factor values difficult. This factor is the least likely to be realistic.

e) Although the contours were digitized from a good quality map at a large scale errors are always inherent in the interpolation of these to a DEM. Unfortunately the calculation of the slope length was only approximate.

f) The spatial resolution was further to 40 m square which moves the distribution of the variables further from reality.

g) Many defaults of input parameters provided within the model were used. Although there is some provision for Tropical climates most of these were set using data from temperate areas and may thus, be inappropriate.

6.2 Recommendations

1. This study has been carried out with only one cell size of 40m x 40m. Varying the cell size to analyze the effect of grid size on soil loss should be carried out.
2. Different storm event with longer rain periods is necessary for investigating hydrological responds of the model.
3. Other non-point source model may be used to compare with AGNPS model result.
4. There are possibilities for further research on improving the integration of the GIS software or other software with the AGNPS model.
5. The future non-point source runoff modeling should incorporate ground water dynamics, the spatial and temporal variability of rainfall, and accumulation and wash-off of specific pollutants.
6. Model selection is an important part of the modeling process. To decide which model is appropriate for the problem on hand, the user must understand the model concepts, assumptions and limitations thoroughly to justify whether it will adequately treat the problem of concern.

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APPENDIX A

Appendix A: AGNPS Input/Output

Input data required:

The 7 basic input IDRISI layers

1. catchment
2. land use
3. gradient
4. stream
5. soils
6. channel slope
7. slope length factor

five pieces of data are required for the total watershed:

1. watershed identification/description
2. precipitation (inches)
3. erosion index (EI-value) for that storm/rainfall event
4. area of each cell (acres)
5. outlet cell number

An important implication of this set is that AGNPS does not accommodate non-uniform storms, i.e. it uses a lumped modeling approach for its rainfall.

For each watershed element, AGNPS requires the following 20 input data values (its distributed parameter information):

1. cell number
2. number of the cell into which it drains(receiving cell number)
3. aspect
4. SCS curve number
5. Average land slope (%)
6. Slope shape factor (uniform, convex or concave)
7. Average field slope length (feet)
8. Manning's roughness coefficient for the channel
9. Soil erodibility factor(K) for USLE

10. Cropping factor(C) for USLE
11. Practice factor (P) for USLE
12. Surface condition constant (factor based on land use)
13. Chemical oxygen demand factor
14. Soil texture
15. Fertilization level
16. Pesticide indicator
17. Point souce indicator
18. Additional erosion
19. Impoundment factor
20. Channel indicator

<u>AGNPS output data at the watershed outlet or for whole watershed</u>

Output values for the whole watershed

1. watershed description
2. area(acres)
3. area of each cell (acres)
4. characteristic storm precipitation (inches)
5. storm energy-intensity (EI) value

output values at the watershed outlet

<u>hydrology</u>

1. runoff volume (inches)
2. peak runoff rate(cfs)
3. fraction of runoff generated within the cell
4. sediment (by particle size and in total)
5. sediment yield (tons)
6. sediment concentration (ppm)
7. sediment particle size distribution
8. upland erosion (tons/acre)
9. channel erosion (tons/acre)
10. amount of deposition (%)
11. sediment generated within the cell (tons)
12. enrichment ratio

13. delivery ratio

<u>Nutrient</u>

1. nitrogen
2. sediment associated mass (lbs/acre)
3. concentration of soluble material (ppm)
4. mass of soluble material in runoff (lbs/acre)
5. phosphorous
6. concentration of soluble material (ppm)
7. chemical oxygen demand
8. concentration (ppm)
9. mass (lbs/acre)

APPENDIX B

Erode Users Manual (a DOS-based IDRISI module)

Name: erode.exe.

To be placed in the same subdirectory as the idrisi.env and idrisi.exe files.

Program Description:

This program (erode.exe) is a DOS-based IDRISI module designed to calculate cumulative downhill slope length from a DEM. In the process, it calculates and saves three intermediate files -- maximum downhill slope angle, slope length, and outflow direction (flow direction or aspect).

To Run: type "erode" at the DOS prompt while in the appropriate subdirectory.

The program will then ask for the following input and output filenames.

Inputs:

1. The name of the DEM file to be processed. This file must be in the subdirectory specified for data in the idrisi.env file. The DEM must be in REAL ASCII format. Erode will also query the resolution line of the DEM's filename.doc file, so be sure that this is correct. If the resolution is unknown, erode will crash.
2. Slope filename - The name of the output file to contain the slope angle data.
3. Slope Length filename - The name of the output file to contain the slope length data.
4. Cumulative slope length filename - The name of the output file to contain the cumulative slope length data.
5. Outflow filename. This represents the flow direction (or aspect) of each cell.

1. Cutoff Slope - A value that represents the change in slope required to reset the cumulative slope length value to zero. If the slope decreases by more than the specified amount then there will be deposition rather than erosion and the cumulative slope length will be reset to zero. The value given for the Cutoff Slope should be between 0 and 1. For example, if the cutoff slope is set to 0.5 (50%) and the slope angle changes along flow direction from 10 degrees to 4 degrees, the change is greater than 50%, so the cumulative slope length is set to zero. Again, this is done to simulate areas of deposition. See Hickey, Smith, and Jankowski (1994) for a longer discussion of the cutoff slope (full reference on web page).

Outputs:

The output files are placed in the same subdirectory as the idrisi.env and idrisi.exe files, NOT wherever all other data files are stored

1. Slope file - The code will calculate the maximum downhill slope angle from the DEM. The slope will, therefore, correspond exactly to the outflow direction (aspect) of the cell in question
2. Slope Length file - Contains the slope length for each cell. In other words, the distance from the center of one cell to the center of the next along flow direction.
3. Cumulative Slope Length file - Contains the maximum cumulative slope length for each cell. The sum of the slope lengths along flow direction -- reset in cases of deposition (see above description of cutoff slope) and, where there are converging flow paths, the longer cumulative slope length takes precedence.
4. Outflow file - Contains the flow direction (or aspect) for each cell. This output direction is the same as the direction of maximum downhill slope angle.

North = 1

NE = 2

E = 3

SE = 4

S = 5

SW = 6

W = 7

NW = 8

APPENDIX C

Source code for IDRISI ~ AGNPS Link

The below source code are a part of modified parameters in this case study.

```
Private Sub Command3_Click()
   Dim cell As Integer   'cell number
   Dim cellno As Integer  'total number of cells
   Dim recell As Integer  'recieving cell number
   Dim texture As Integer  'soil texture
   Dim cod As Integer   'chemical oxygen demand
   Dim Channel As Integer  'channel indicator
   Dim gradient As Integer 'slope in %age
   Dim SCS As Integer  'SCS Curve Number
   Dim c As Single 'C factor
   Dim k As Single  'K factor
   Dim SCC As Single  'Surface Condition Constant
   Dim manning As Single   'overland Mannings roughness coefficient
   Dim length As Single 'slope lenght in feet
   ReDim cellid(Rows&, Cols&, 1) As Integer 'grid of cellids
   Dim file As String
file = InputBox("Please enter a name for the AGNPS input file.Must be *.dat", "agnps input
file", "agnps.dat")
   Screen.MousePointer = 11
   Open file For Output As #1 'open to write file.
Print #1, "AGNPS SCS_TR55 format 5.00"
Print #1, Tab(7); 0; Tab(15); 0; Tab(23); 0; Tab(31); 0; Tab(39); 0; Tab(47); 0; Tab(55); 0;
Tab(63); 0
Print #1, Text1.Text 'Prints Entries in Textboxes
Print #1, Text2.Text
Print #1, Tab(11); Format$(Text3.Text, "000.00"); Tab(20); 'calculates and prints total no of
cells in catchment
      cellno = 0
For row% = 1 To Rows& Step 1
For col% = 1 To Cols& Step 1
If Int(Old_image_data(row%, col%, 1)) > 0 Then
```

```
cellno = cellno + 1
        Else
        End If
    Next col%
    Next row%
Print #1, Format(cellno, "00000"); Tab(28); Format(cellno, "00000"); Tab(39); 1; Tab(47); 1;
Tab(55); 1; Tab(59); Format(484, "000.00")
 Print #1, Tab(14); "III"; Tab(23); 0; Tab(29); Format(Text5.Text, "00.0"); Tab(35); Format
(Text4.Text, "000.00"); Tab(45); Format(0.8, "0.00")
'prints data from the array
 cell = 0
 For row% = 1 To Rows& Step 1 'creates new array of cellids
 For col% = 1 To Cols& Step 1
 If Int(Old_image_data(row%, col%, 1)) > 0 Then
 cell = cell + 1
  cellid(row%, col%, 1) = cell
        Else
   cellid(row%, col%, 1) = 0
        End If
    Next col%
    Next row%
 For row% = 1 To Rows& Step 1
  For col% = 1 To Cols& Step 1
    If Int(Old_image_data(row%, col%, 1)) > 0 Then 'prints data for cell within catchment
            Select Case Int(Old_image_data(row%, col%, 2)) 'calculates recieving cell
            Case 0
              recell = Int(cellid(row%, col%, 1))
            Case 1
              recell = Int(cellid((row% - 1), col%, 1))
            Case 2
              recell = Int(cellid((row% - 1), (col% + 1), 1))
            Case 3
              recell = Int(cellid(row%, (col% + 1), 1))
            Case 4
              recell = Int(cellid((row% + 1), (col% + 1), 1))
            Case 5
              recell = Int(cellid((row% + 1), col%, 1))
```

```
Case 6
   recell = Int(cellid((row% + 1), (col% - 1), 1))
Case 7
   recell = Int(cellid(row%, (col% - 1), 1))
Case 8
   recell = Int(cellid((row% - 1), (col% - 1), 1))
End Select
Select Case recell
Case 1
   recell = 403
Case Else
   recell = recell
End Select
Select Case Int(Old_image_data(row%, col%, 3)) 'calculates C factor,chemical
oxygen demand,and overland mannings value
Case 1
   c = 0.064
   cod = 65
   manning = 0.1
   SCC = 0.59
   p = 1
Case 2
   c = 0
   cod = 0
   manning = 0.99
   SCC = 0
   p = 0
End Select

Select Case Int(Old_image_data(row%, col%, 6)) 'calculates K factor.
Case 0
   k = 0
Case 1
   k = 0.33
Case 2
   k = 0.25
End Select
```

```
Select Case Int(Old_image_data(row%, col%, 6)) 'calculates Soil Texture
Case 0
  texture = 0
Case 1
  texture = 1
Case 2
  texture = 1
End Select
Select Case Int(Old_image_data(row%, col%, 7)) 'identifiies with channels
Case 2
  Channel = 0
Case 0
  Channel = 1
End Select
Select Case Int(Old_image_data(row%, col%, 4)) 'converts slopelength to feet
Case 0 To 91
  length = Int(Old_image_data(row%, col%, 4)) * 3.281
Case Is > 91
  length = 300
End Select
Select Case Int(Old_image_data(row%, col%, 5)) 'limits gradient(in %age) to 99
Case Is > 99
  gradient = 99
Case 0 To 99
  gradient = Int(Old_image_data(row%, col%, 5))
End Select
Select Case Int(Old_image_data(row%, col%, 6))
Case 1
  SCS = 55
Case 2
  SCS = 55
Case 0
  SCS = 100
End Select
```

APPENDIX D

Example of AGNPS Input File

```
AGNPS SCS-TR55 format 5.00
    0    0    0    0    0    0    0    0
Huai Som basin
creek
         0.40   403   403    1    1    1 484.00
          IA  23.96   6.0  2.48  0.80
    1   000    6   000    4  55.00  14.0    1
          190  0.400  0.33 0.0640  1.00  0.59   65
           1    0    0    0    0    0    1
Soil:   0.0010 0.0005  5.00  2.00
        0.050  0.025  0.250  0.250   20
Channel:  0.00 3.4250 0.3151  0.00 0.4537 0.2192
         0.00 153.000 0.6000  0.00  0.00
        0.040    1    0    0    0
           1    1    1    1    1
    2   000    6   000    5  55.00   9.0    1
           66  0.400  0.33 0.0640  1.00  0.59   65
           1    0    0    0    0    0    1
Soil:   0.0010 0.0005  5.00  2.00
        0.050  0.025  0.250  0.250   20
Channel:  0.00 3.4250 0.3151  0.00 0.4537 0.2192
         0.00 153.000 0.6000  0.00  0.00
        0.040    1    0    0    0
           1    1    1    1    1
```

APPENDIX E

Sample AGNPS Model Output

FEEDLOT

****

INITIAL

a

161.20 0.40 2.48 23.96 65 000 0.29 66.14 0.77

0.05 0.01 0.15 0.03 0.00 0.00 0.02 0.35

****

SEDIMENT

0.02	0.00	24	39	113.22	0.00	0.61
0.02	0.00	3	6	16.29	0.00	0.09
0.13	0.00	0	1	14.02	0.00	0.08
0.16	0.00	0	0	0.32	0.00	0.00
0.48	0.00	0	0	0.09	0.00	0.00
0.80	0.00	1	1	143.94	0.00	0.77

****

SOIL_LOSS

1 000 0.40 0.08 0.00 0.00 0.08 0.43 . 0.0

0.03	0.00	0.01	0.01	3
0.03	0.00	0.01	0.01	51
0.26	0.00	0.10	0.01	94
0.33	0.00	0.13	0.00	100
0.98	0.00	0.39	0.00	100
1.63	0.00	0.65	0.03	96

2 000 0.40 0.08 0.00 0.00 0.08 0.40 0.0

0.01	0.00	0.00	0.00	3
0.01	0.00	0.00	0.00	55
0.08	0.00	0.03	0.00	95
0.10	0.00	0.04	0.00	100
0.29	0.00	0.12	0.00	100
0.49	0.00	0.19	0.01	97

****

NUTRIENT

```
1 000 0.40    3.97  0.52    0.02  0.00   0.21
     1.98  0.26    0.00  0.00  0.01        1.16   0.29  16.25
2 000 0.40    1.51  0.19    0.02  0.00   0.21
     0.75  0.09    0.00  0.00  0.01        1.16   0.29  16.25
3 000 0.40    0.66  0.08    0.02  0.00   0.21
     0.33  0.04    0.00  0.00  0.01        1.16   0.29  16.25
4 000 0.40    7.78  1.13    0.02  0.00   0.21
     3.89  0.57    0.00  0.00  0.01        1.16   0.29  16.25
5 000 0.80    2.55  0.81    0.02  0.00   0.13
     1.28  0.40    0.00  0.00  0.01        1.16   0.18  10.16
```

****

PESTICIDE

0

BIOGRAPHY

Sutthasini Glawgitigul, born on February 23, 1973 in Bangkok graduated bachelor degree in Chemistry Science at Srinakarintharawirot Prasarnmitr University in 1995. Then I had worked at Science Tech Company in 1996. Next year, I entered a Master degree program at the Inter-departmental Science, Graduate School of Chulalongkorn University.