A WEB ENABLED TOOL FOR GREEN ENGINEERING EDUCATION

Vinod Lohani[1], Binaya Regmi[2], Randy Dymond[3] and David Kibler[4]

Abstract *¾ The paper discusses potential of a prototype Problem Solving Environment (PSE) to explore environmental consequences of land development activities in a classroom setting. A PSE is a computer system that provides web-enabled access to scientific models. Our PSE encapsulates models for evaluating hydrologic, economic, and fish health response to watershed development activities. The study was undertaken as a part of a multidisciplinary research project, supported by USEPA during 1997-2001, at Virginia Tech, USA. The test watershed for this prototype application is the Back Creek watershed (57 sq. miles) in southwest Virginia, USA. The paper presents examples of how the PSE software can be useful in classroom settings to undertake hands on exercises related to green engineering. A brief demonstration of the PSE software was made to engineering students from freshman to graduate levels in fall 01 semester and summary of students' observations are presented. Also, live demonstration of the software can be arranged subject to availability of Internet facilities.*

Index Terms ¾ Green Engineering, Land Development, PSE.

INTRODUCTION

The paper discusses the current status of development and test application results of a Problem Solving Environment (PSE) software demonstration in a classroom setting. A PSE is a computer system that provides all the computational facilities necessary to solve a target class of problems. It seeks to combine discipline specific software tools into integrated systems for decision-making and problem solving [1]. The development work of the PSE software, hereafter called L2W (Landscapes to Waterscapes) PSE, was carried out as a part of a multidisciplinary research project: *From Landscapes to Waterscapes: Integrating Framework for Urbanizing Watersheds*, supported by USEPA during 1997-2001, at Virginia Tech. The major goal of the project was to develop procedures for integrated assessment of the hydrologic, ecological, and economic consequences of alternate land development scenarios that occur during the urbanizing process. The PSE work represents the integration component of the project. The Green Engineering Program in the College of Engineering, Virginia Tech, partially supported the work involving incorporation of the PSE into selected engineering courses. Three courses, from freshman to graduate levels, have been considered for test demonstration of the PSE software. Analysis of students' responses and future direction of activities are also discussed.

DESCRIPTION OF THE L2W PSE

L2W PSE is a prototype web-enabled system and allows a user to input land use changes within a watershed and run simulations of hydrology, economics and fish health to evaluate multi-disciplinary effects of land development. L2W PSE has the potential to be used in a classroom setting to investigate environmental issues related with land development with hands-on examples. It can demonstrate the effects of *what-if* scenarios of new development in a watershed and help frame further questions, which will lead to better models and eventually to tested applications for routine use. The simple and intuitive user interface and the canned format of input of L2W PSE allow users from all backgrounds to use the system without specialized knowledge of the underlying hardware and software, or the modeling techniques. The study area used for this prototype application is the Back Creek watershed (57 sq. miles), a sub-watershed of the Upper Roanoke River Basin, in southwest Virginia, USA. L2W PSE encapsulates models from hydrology, economics, and fisheries into an integrated system for evaluating the responses owing to land development activity. HSPF (Hydrological Simulation Program FORTRAN) is used for simulating hydrologic responses to land use change. The models/procedures that evaluate economic and ecological responses are developed using field data collected in and around Back Creek watershed [2]-[4]. These models can run either independently or jointly to evaluate effects of land development. GIS data and techniques are used to provide a common database to these models/procedures.

The architecture of the web-enabled PSE system is based on the state of the art Client/ Server technology. Communication on the Internet takes place between *server processes* – programs that operate continuously awaiting requests for service, and *client processes* – programs that initiate requests for service when needed [5]. The user interface of the PSE consists of a gridded map of Back Creek watershed along with four icons that define the type

[1] Vinod Lohani, Assistant Professor, Department of Engineering Fundamentals, Virginia Tech, Blacksburg, VA 24061, vlohani@vt.edu
[2] Binaya Regmi, Graduate Research Assistant, Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA 24061, bregmi@vt.edu
[3] Randy Dymond, Associate Professor, Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA 24061, dymond@vt.edu
[4] David Kibler, Professor, Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA 24061, kiblerdf@vt.edu

of land development patterns (namely, low density, medium density cluster, medium density conventional, and high density) (see Figure 0). The map interface is loaded to the client viewer (browsers) when ArcIMS Map Server gets request from the client. A user can access the PSE web site at: http://webl2w.cee.vt.edu. To access the user interface the user has to choose the 'software' option on the opening page of the web site. A new land development scenario is created by first choosing the desired development pattern and then clicking on grids that are available for development. The developable grids are defined based on examination of land slope, extent of flood plains, preserved lands like state parks, and pre-existing development condition. It may be noted that that each grid square represents 9 ha of developable land. The green colored grids on figure 0 show an example land development scenario with medium density cluster development pattern in headwater region of the watershed. Upon creation of the new development scenario the user submits the same for evaluation by clicking on 'submit' button. Java script and ASP is used to compile the new scenario and to send the request to run the server models. The server models, written in Visual Basic using ActiveX technology, in turn run the simulations. Perl script is used to access HSPF simulation from the server model. The outputs of the hydrology model are a form showing the original and changed land use distribution for the watershed, and a tabular display in Crystal Reports of the hydrologic effects including changes in annual runoff volume, storm peaks, and ground water recharge due to land development. The economic model produces a Microsoft Excel spreadsheet that shows changes in land values, tax revenues, and government expenditures. Finally, the fisheries model outputs a form that shows the habitat quality at pre-selected locations for sustaining healthy fish populations. Further details on individual models and development of the PSE software are given in [6].

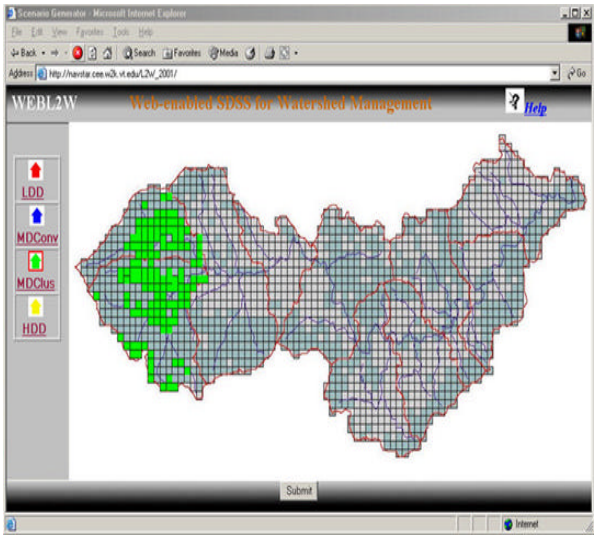

FIGURE. 0
L2W PSE USER INTERFACE

OVERVIEW OF ENGINEERING COURSES

Introduction to Engineering EF 1015

EF1015 is the first engineering course taken by all students in the College of Engineering in their freshman year at Virginia Tech. The course, taught by the faculty in the Engineering Fundamentals department, focuses on developing engineering problem solving skills. Students are assigned textbook problems to fit empirical functions including the linear, exponential, and power functions. MATLAB (matrix laboratory), a mathematical software, is used to develop logical thinking and algorithm development skills.

Hydrology CEE 4304

Hydrology is a senior/masters-level elective course in surface water hydrology in the Civil and Environmental Engineering (CEE) department. The course focuses on quantifying each of the main components of the hydrologic cycle essential to hydraulic design, such as rainfall, infiltration, evaporation, surface runoff and stream flow. The usual enrollment is between 30-40 students, who come from several departments across campus, including civil and environmental engineering, biological systems engineering, mining engineering, and crop/soil environmental science.

GIS Applications in Civil and Environmental Engineering CEE 5204

This course introduces geographic information systems (GIS) and covers the basics of cartography and mapping, coordinate systems, databases, spatial analysis and integration of various digital data and processes into computer based results. Students in the class have been predominantly from CEE department, but students from several other disciplines including geography, crop soil and environmental science, urban affairs and planning, and biological systems engineering have taken the course. This course is taught each fall semester and has a typical enrollment of 32 students.

Green Engineering Contents

Introduction to Engineering EF 1015

One of the topics covered in this course deals with 'engineering approximations.' Freshman students are assigned an 'approximation problem' with an objective to expose them early on with the fact that engineers are often required to make an approximation to an answer using basic understanding of the problem coupled with relevant assumptions. In order to cover some 'green' issues that freshman students can easily relate to, a problem involving approximation of environmental effects of urbanization in Back Creek watershed was assigned to about 100 freshmen taught by the first author in fall 01. Students were provided with the area of Back Creek watershed and were asked to: i)

estimate excess volume of water on an annual basis after urbanization of the watershed and ii) discuss possible environmental effects of the development. The relevant engineering terms like 'watershed', 'runoff', 'runoff coefficient' etc. were appropriately explained in the problem statement and also during in-class discussion. Students searched annual rainfall data for the Back Creek watershed in Virginia in the Internet and assumed values of runoff coefficient. Some students also reported looking at USGS flow records for Back Creek gaging site at Dundee to solve the problem. A typical procedure used for computing excess runoff volume involved computing volume of water before and after development using annual rainfall of about 42 inches and an assumed runoff coefficient. Some students used runoff coefficient of 0.2 for pre-development and 0.45 for urbanized conditions. On an average, students reported about 1100 million-cusec volume of excess runoff due to urbanization of the 57 sq. mi. watershed. Some common environmental effects reported include increase in total runoff volume and increase in uniform volume flow rate in the river. These increases could lead to increased erosion, disturbance of wildlife, and an increased risk of flooding [7].

Another topic that is emphasized in the course is the graphical analysis of empirical data. In order to cover some additional 'green' issues two problems, based on data generated as part of L2W research project, were assigned that required them to relate the cause and effect variables empirically. The first problem involved relating extent of 'new impervious area added' with 'increased runoff volume' in Back Creek watershed. The second one involved relating 'population density' with the 'road density network' in and around Roanoke region in Virginia. The students used the graphical and MATLAB techniques and reported linear relationship of following form between the new impervious area and increase in runoff volume that agrees with other research studies in this regard:

$$R = 4.0 \times 10^{-3} A + 0.46 \qquad (1)$$

where: R = % increase in runoff volume and A = new impervious area added in acres. Also, majority of students reported a power function relationship of the following form to relate the population density with the road density network:

$$D = 0.45P^{0.44} \qquad (2)$$

where: D= road density in miles / sq. mile and P = population density in persons per sq. mi. It may be mentioned that the authors have used a relationship similar to equation 2 in a research paper [8].

Above 'green engineering' related exercises are expected to give some exposure of urbanization related environmental impacts to students. An in-class demonstration of the PSE capabilities was then given to students. Their response is discussed in next section.

Hydrology CEE 4304

The twenty students in CEE 4304, taught by the fourth author, were given a presentation on L2W PSE and its application to the Back Creek watershed. They were then asked to read the L2W tutorial and go to the web address where the PSE is located. The assignment was to examine the hydrology and the fishery habitat impacts of total build-out at high-density residential, making two separate runs of the L2W PSE. Analysis of students' response is given in next section.

GIS Applications in Civil and Environmental Engineering CEE 5204

Near the end of this course, taught by the third author, L2W PSE software was used as an example to illustrate how the spatial data, the user interface, and the architecture of the model is critical to the decision making process. Students' response is discussed in next section.

ANALYSIS OF SURVEY RESPONSE

The students in above three classes were given a presentation, from 30-50 minute duration, about the potential of the web enabled PSE during the last 2 weeks in fall `01 term. While the details covered in these presentations varied slightly from class to class, the following general issues were discussed in all three classes:

- Need for multi-disciplinary efforts to analyze environmental effects of urbanization
- Definitions of decision support system and PSE
- Introduction to client-server architecture
- Brief description of hydrology/economics/fish model
- Different types of land development patterns
- Data collections and processing efforts
- Flow charts of different modeling systems
- User interface of the PSE
- Example land development scenarios creations and interpretation of results

After the presentation, all students were given 11 survey questions (see Table 1) and were asked to respond using following options: strongly agree, agree, neutral, and disagree. These questions were designed to observe student responses under three broader categories as below:

1. Introduction to technology: Questions 1, 6, 7, and 11 fall under this category.
2. Environmental awareness: Questions 2, 3, and 10 fall under this category.
3. Research interest and appreciation of course contents: Questions 4, 5, 8, and 9 fall under this category.

Altogether about 140 students participated in the survey. A brief analysis of the responses is presented in the following section.

TABLE I
SURVEY QUESTIONS

Question#	Question
1	The presentation helped me understand the term 'computer model' better.
2	The presentation is interesting and educational in assessing environmental effects of land development.
3	A multi-disciplinary approach (like engineering, economics, biology) may provide a better solution to environmental problems associated with land development.
4	I can better relate some or most of the present course to real world applications after this demonstration.
5	I can better appreciate importance of employing proper procedures for data collection and processing after this demonstration.
6	The web-based nature of this PSE/DSS technology should make it very useful for public at large.
7	This demonstration helped me understand client –server technology.
8	I would be interested in finding more detailed information about the PSE/DSS.
9	I would be interested in knowing how accurate the model results are.
10	It would be useful if I had access to the web PSE/DSS so that I can develop some scenarios of development to check their environmental impacts.
11	I think it is easy to use the PSE/DSS and interpret the output.

Introduction to Engineering

Altogether 102 students (taught by the first author) participated in the survey. *Fig. 1* shows bar chart of response from freshman engineering students. This chart shows a very low level of "disagreement" with several questions yielding to zero disagreement responses. On all 'introduction to technology' related questions (i.e. #s 1, 6, 7, and 11) on an average about 75% students had agreed or strongly agreed on this role of the PSE software. The questions that tested 'environmental awareness' aspects of the software (i.e. 2, 3, and 10), more that 80% students responded in a positive manner. Interestingly, on questions 2 and 3 there were no disagreements at all which indicates good potential of the software in imparting environmental education. In the third category of questions i.e. 'Research Interest and Appreciation of Course Contents' (i.e. #s 4, 5, 8, and 9), again on an average about 75% students responded in positive sense implying that the software was able to show 'real world' applications of the course contents and generated interest among majority of participants. It is interesting to note that on question # 3 (i.e. a multi-disciplinary approach like engineering, economics, biology may provide a better solution to environmental problems associated with land development) there was no disagreement at all, which can be considered as a significant role of PSE technology in imparting multi-disciplinary facets of environmental problems. The largest percentage of 'neutral' or 'disagree' response was recorded for question #8 which is understandable from the academic standing of these students.

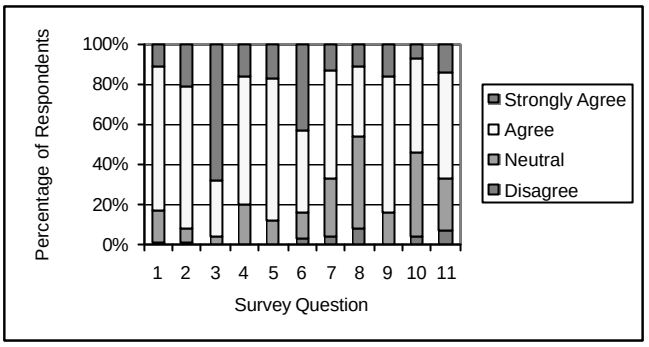

FIGURE. 1
SURVEY RESPONSE OF FRESHMAN ENGINEERING STUDENTS

Hydrology

Fig. 2 shows the bar chart of responses from 10 senior students in the Hydrology class. There was a high level of "agreement" on all questions, especially questions 3 (need for a multi-discipline approach in assessing watershed impacts) and 9 (curiosity about the accuracy of L2W results). Only question 8 (interest level in additional information about the L2W PSE) received a "disagree" response from a single student. Questions 4 (improved understanding of the present course and how it relates to real world) and 6 (web-based PSE is very useful for general public) received significant "neutral" responses. One possible interpretation of this outcome is that the instructor needs to do a better job of explaining the hydrologic operations embedded in the L2W PSE. There will always be a danger that students see PSE software as the proverbial black box and use it indiscriminately without understanding fundamental processes in hydrology and fishery science. We must guard against this.

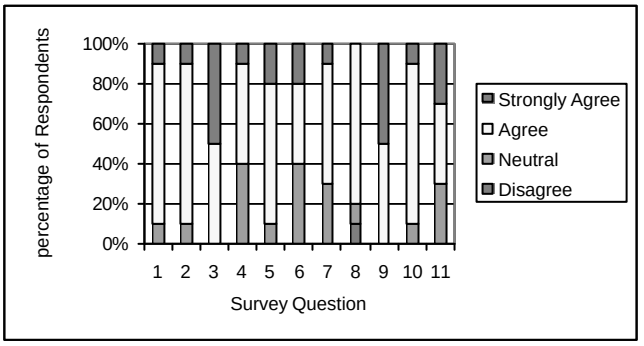

FIGURE. 2
SURVEY RESPONSE OF SENIOR CIVIL ENGINEERING STUDENTS

Fig. 3 shows bar chart of response from a group of 21 graduate students. The questions that appeared to be answered most positively by the older students were #2, 3, 7, 8, and 9, indicating that the presentation was interesting, that interdisciplinary methods are most useful in environmental issues, that they learned about new technology, would like to learn more about the system, but wonder about it's accuracy. Apparently questions 1, 4, and 5 did not strike the older students as relevant to their level of education.

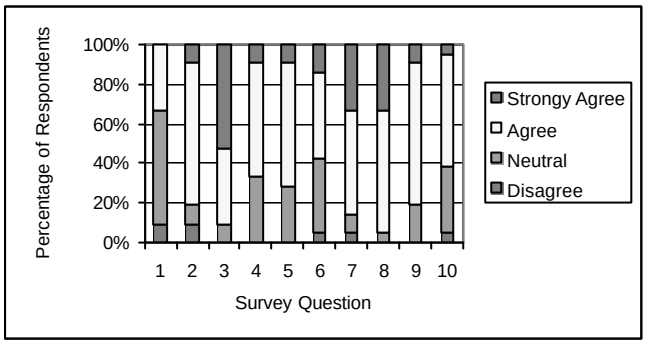

FIGURE. 3
SURVEY RESPONSE OF CIVIL ENGINEERING GRADUATE STUDENTS

CONCLUSION AND FUTURE WORK

The PSE development work is in progress at the time of this writing. Efforts are curently on to incorporate the PSE technology into five courses at Virginia Tech (three engineering courses as presented here and one senior level course from agricultural and applied economics department and another graduate course from fisheries and wildlife sciences department). Preliminary analysis of students' responses show that PSE technology has a good potential to impart environment education in a classroom setting. The web-enabled nature of the PSE makes its use possible not only at Virginia Tech but also all over the world. In the meantime, hydrology and fish related work have been extended to cover other research issues outside PSE and will be incorporated into the PSE as more funding becomes available.

ACKNOWLEDGEMENTS

This study has been supported by USEPA, under Grant # R825760–01–0, and by internal grants from Virginia Tech including the ASPIRES and REACHOUT programs. The authors also appreciate the financial support received under the Green Engineering Program of the College of Engineering at Virginia Tech.

REFERENCES

[1] Gallopoulos, E., Houstis, E., Rice, J., R., " Computer as Thinker/Doer: Problem-Solving Environment for Computational Science", *IEEE Computational Science and Engineering*, Vol. 1(2), 1994, pp. 11-23.

[2] Bicknell, B., R., Imhoff, J., C., J. L. Kittle, J.. L., Donigian Jr., A., S., Johanson, R., C., *Hydrological Simulation Program- FORTRAN, User's Manual for version 11.0,* National Exposure Research Laboratory, Research Triangle Park, USEPA, NC 27711, 1997.

[3] Kaltsas, I, *Spatial Econometrics Revisited: A Case Study of Land Values in Roanoke County*, Ph.D. Thesis, Department of Agricultural and Applied Economics, Virginia Tech, 2000.

[4] Stancil, V., F., *Effects of Watershed and Habitat Conditions on Stream Fishes in the Upper River Roanoke Watershed, Virginia*, Master's Thesis, Virginia Tech, 2000.

[5] Wright, J., R., Gavilan, G., Zhang, Y., Redinbo, K., "Emerging Technologies for Developing Distributed Database Systems", *Proceedings of Minnesota Water Conference*, ASCE, Minneapolis, 2000.

[6] Dymond, R., L., Regmi, B., Lohani, V., K., Dietz, R., "An Interdisciplinary Web-enabled SDSS for Watershed Management." *Unpublished manuscript*, Dept. of Civil and Environment Engineering, Virginia Tech, 2002.

[7] Homework papers, *EF 1015 course, Fall 01*, Virginia Tech, Blacksburg, VA, Instructor: Vinod Lohani.

[8] Bosch, D., Lohani, V., K., Dymond, R., Kibler, D., F., and Stephenson, K., "Hydro-Economics of Residential Development: A Virginia Case Study", *Paper accepted for the Journal of Water Resources Planning and management*, ASCE (to appear).