NutrientNet: An Internet-Based Approach to Teaching Market-Based Policy for Environmental Management

(forthcoming in Journal of Economic Education)

To N. Nguyen and Richard T. Woodward¹

¹ To N. Nguyen is a graduate student and Richard T. Woodward is an associate professor in the Department of Agricultural Economics at Texas A&M University, College Station, Texas. This work was supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 2003-38411-13493. Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture. The website discussed in this paper was developed by a team that included Gedas Mitkus, lead programmer, a team from the World Resources Institute including Mindy Selman, Siet Meijer, Jenny Guiling, Suzie Greenhalgh and Jonathan St. John, and Marty Matlock for the University of Arkansas.

Contact author: Richard T. Woodward, Department of Agricultural Economics, Texas A&M University, 2124 TAMU, College Station, TX 77843. Email: r-woodward@tamu.edu  Fax: (979)845-4261
Abstract

NutrientNet is an Internet-based environment in which a class can simulate a market-based approach for improving water quality. In NutrientNet, each student receives a role as either a point source or a nonpoint source polluter and then the participants are allowed to trade water quality credits to cost-effectively reduce pollution in a watershed. The authors provide an overview of the content and structure of this website. They focus on the features that make NutrientNet an effective teaching tool for instructors and a rich learning environment for students.

Keywords: market-based approach, nutrient trading, water quality, web-based teaching

JEL codes: Q28, A22
The water pollution problems receiving the most regulatory attention today are associated with excessive nutrient loadings, most often from agriculture and other nonpoint sources. The implementation of total maximum daily load (TMDL) programs has been widespread in watershed-based management plans. In the mean time, policymakers are increasingly turning away from “command and control” type policies in favor of market-based (MB) approaches. This altered environmental and regulatory landscape necessitates preparing for future environmental managers.

To improve the education of students for the environmental problems and solutions of the futures a group of researchers at the World Resources Institute, Texas A&M, and the University of Arkansas has developed a new web-based educational package, NutrientNet, which can be used at no cost at the website at http://edu.nutrientnet.org (Figure 1). NutrientNet allows classes to participate in a simulated market for nutrient trading and a set of teaching tools and supplementary instructional materials that facilitate a one-session to two-week segment on MB approaches to water quality problems.

The use of simulated markets to teach MB approaches has increasingly been tried for students in environmental management. However, almost all of them are in-classroom games (Nugent 1997; Anderson and Stafford 2000; Ando and Harrington 2006). NutrientNet is an online resource that creates an in-depth and realistic environment for trading, teaches students about physical properties of water pollution, includes interactive self-assessment exercises, and automatically generates summary data that can be used to emphasize the characteristics of an
MB pollution control mechanism. In this rich learning environment, the NutrientNet software handles the major tasks of organizing the game and recording the transaction data generated, which allows the instructor and the students more time for discussing and analyzing the effects of trading. The environmental setting also can be used as a case study. In NutrientNet, we set up the profiles of sources of pollution, site characteristics and costs, from real-world data of Michigan’s Kalamazoo basin. We acknowledge that the real-world setting together with comprehensive information and presentation of NutrientNet may require students in general or introductory economic classes to be more carefully introduced to the water quality issues and terminology so that they can enjoy and take full advantage of the exercises in NutrientNet. For this reason, an Internet-accessible supplementary guide (Nguyen et al. 2006) is available to fill the gap in background for those students who are not familiar with the water quality issue and/or the economic principles behind MB environmental policies.

We show the key features of the NutrientNet package that provides supportive teaching tools for instructors and a rich learning environment for students. In doing so, we first review the MB approach to water quality improvement in practice and the trading process in the NutrientNet simulated market. Then we focus on the teaching tools and the learning utilities provided with the package. Next, we make a comparison between the two types of simulated market, classroom-based game and web-based market in NutrientNet. Finally, we briefly discuss keys for an effective use of NutrientNet.

THE TRADING PROCESS IN NUTRIENTNET
In this section, we briefly discuss how water quality trading works in practice and then focus our discussion on the trading process and available utilities in NutrientNet that enables participants to trade water quality credits.

**How Water Quality Trading Works in Practice**

In practice, the usual approach is for the pollution control authority to mandate a limit, called a cap, on the total pollution discharge within an impaired watershed or basin. Where a U.S. Environmental Protection Agency required Total Maximum Daily Load has been completed, this should define the total maximum daily load for each relevant pollutant and establish the initial allocation of the cap to the various point source polluters in the watershed. Examples of point source polluters include industrial plants and waste water treatment plants. Polluters generate credits if they reduce pollutant emissions below their mandated loading level and become potential suppliers of credits. Those who seek to discharge in excess of their allowed loadings are potential buyers for credits. The credits are transferable so that point source polluters can either buy or sell them.

In the case of nutrient pollution, nonpoint sources such as farmers are currently the major cause of water pollution and their participation in the solution of water quality problem becomes essential (U.S. Environmental Protection Agency, Office of Water 2002). The current discharges from agricultural lands are usually taken as the allowed loading and farmers can receive credits for implementing best management practices (BMP) to reduce the discharge below the current levels. In fact, farmers can often reduce discharge at a much lower marginal cost than point sources (Faeth 2000) and this makes them potential suppliers of credits.
A trading program creates a market for water quality credits and offers point source polluters the flexibility to either reduce pollution internally or finance comparable reductions that are undertaken by others, mainly nonpoint sources. In such a program, a source reduces pollution only if it can do so at a lower cost than other sources and so this approach in theory will be cost efficient as it obtains the environmental goal.

**The Simulated Trading Process in NutrientNet**

NutrientNet is a simulated setting in which students will act as polluters some of whom have an obligation to reduce their pollution load and all of whom can sell or buy nutrient reduction credits. An instructor will create a market with students playing the roles of point sources polluters (PSs), wastewater treatment plants, or nonpoint source polluters (NPSs), farmers. These roles are automatically assigned. A trading session can be organized in a lab for the entire class or students can be allowed to access the site occasionally over a period of days or weeks, interacting with each other through automatically generated e-mail messages.

The main activities of students in the NutrientNet trading process are illustrated in Figure 2. The two types of agents, PSs and NPSs, have their own incentives to participate in the market, minimizing compliance costs and maximizing profits respectively. The information arrows represent the availability of information on the prices of credits bought and sold in the market and participants can access the information at any time. After making decisions on how many credits to buy or sell and at what price, they can act in their interests by making use of three market activities available in NutrientNet: placing an offer to buy or sell credits, bargaining, and accepting offers. The bargaining is enabled through email contacts. All transactions are recorded
on the students’ balance sheets, allowing them to track their current credits and money in their account (Figure 3). We will discuss the NutrientNet trading process in more detail below.

**INSERT FIGURE 2**

**INSERT FIGURE 3**

The site provides students with abundant information about physical characteristics of their site, their costs to reduce pollution, the offers to buy or sell credits in the market and the prices paid for credits during the period. Using this information, they can evaluate the prices at which they would buy or sell credits, and then compare that to the market offers currently available in the market. Unlike most pedagogical trading games, in NutrientNet students are faced with “real-world” conditions in which they must make discrete choices as to what practices they might implement. A change in abatement practices will not result in one more unit of reduction, but a change of hundreds or thousands of pounds. This obviously makes the student’s choices more difficult, but it also adds an important element of realism. The available information gives the students ideas to make choices to implement pollution reduction practices and/or to buy or sell credits with the abundant information; students still need to carry out some simple analysis on their own. Figure 4 presents a portion of the Market page where the students can find prices and amounts of credits that are currently offered to sell or buy. The information on physical and geographical characteristics of a student’s plant or farm and on reduction costs of alternative waste water treatments (WWTs) or best management practices (BMPs) are linked to the MyNutrientNet page. An example of a student’s farm characteristics is shown in Figure 5.
For the simulated trading process to work effectively the students should be encouraged to optimize the benefits for their roles. It is usually helpful to use grading as an incentive. Students taking the role of a PS will be awarded based on their savings from compliance costs and those taking the role of a NPS will be awarded based on the profits that they make in the trading market. The grading issue will be discussed in the conclusion.

**LEARNING ECONOMICS OF MB APPROACH**

In theory and practice, the economic justification for an MB approach as against the command-and-control type is in terms of cost efficiency of environmental policy. The exchange mechanism of MB approach allows the equalization of marginal cost of pollutant reduction hence total reduction of pollution for the least cost. For an MB approach to prove beneficial there should be heterogeneity in marginal cost of abatement across the polluters. Because a key lesson intended for students using the NutrientNet exercise is the cost efficiency of an MB approach, we create appropriate cost profiles of PSs and NPSs to assign to participants and shows them results from the trading session for their learning. We discuss these two points below.
Cost Profiles of PSs and NPSs in NutrientNet

The nutrient reduction cost profiles of PSs and NPSs in NutrientNet are created from GIS-based data of Michigan’s Kalamazoo basin that was used in the World Resources Institute parent site, http://nutrientnet.org. The nutrient loading, reductions, and costs of agricultural practices are estimated using the Revised Universal Soil Loss Equation (RUSLE) model (U.S. Department of Agriculture-Agricultural Research Service 2007). In developing the educational version of NutrientNet, a number of characteristics of each source were altered to create more heterogeneity in the marginal costs of reduction among market participants. For PSs, changes were made in nutrient concentration (ppm), water flow, and/or discharge limit across PSs. For NPSs the field areas, current crop, previous crop, and/or nutrient content were changed from their original values.

Figure 6 shows the demand and supply functions for PS and NPS participants. The left panel shows the supply and demand curves for a single NPS and single PS polluter. As shown the cost functions are step functions and for this NPS it is optimal to supply about 5 lbs. if the price is greater than about 50¢ and less than $10. The PS, would sell credits if the price is greater than $6 and would buy about 7000 credits if the price is less than $6. Note that cost estimates are different for each particular treatment practice and they are available for NutrientNet participants to compare for making a choice (Figure 5).

The right panel of Figure 6 provides an example of aggregate supply and demand curves for a market with 16 NPSs and 14 PSs. This hypothetical market has an optimal clearing at price of $5.3 and quantity of around 56,000 pounds of nutrient reduction. As discussed below, the optimal solution is presented together with actual trading results, allowing for students to see how well their market performed relative to the theoretical optimum.
Cost Efficiency of Nutrient Trading: Post-Trade Analysis

The key lesson of a NutrientNet exercise for students is the cost efficiency of credit trading. In order to help them learn this lesson, a summary page reports the results from a trading session including the load distribution over the watershed and cost efficiency of an MB policy. Table 1 contains the summary page report for analysis of alternative policies including the actual trading session in which they participate. As seen from this figure, the first three rows of the table correspond to the three alternative policies: no trading in which PSs can comply only by reducing discharges, PS only trading in which PSs can comply to the cap by reducing discharges and/or buying credits from other PSs, and PS and NPS trading (optimal) in which PSs can choose reducing discharges and/or buying credits from other PSs and NPSs and the trading is hypothetically optimal. The last row corresponds to the actual trading session.

The table shows estimates of total quantity and total cost of nutrient reduction for each of the four alternative solutions. Further it also gives shares of PS and NPS in total amount of reduction as well as unit costs of reduction for the alternatives. The aim is to provide students a picture of the extent of the benefit of the trading session relative to the optimal solution and other limited trading policy. The example given in Table 1 reports in the last row the results from a trading session. In this case the redaction unit cost is greater than that of the optimal solution and less than the other two solutions, which partially or completely limiting trading of reduction credits. In the meantime, the resulted quantity of reduction in the trading session exceeds the
other counterpart numbers. The estimates in this table show students the benefits of trading as expected in theory of an MB approach in terms of cost efficiency.

INSERT TABLE 1

In order for the trading in NutrientNet to take place and achieve economic educational goals, which is at the core of NutrientNet, the package offers a suite of tools and utilities to support the teaching and learning about the MB approach. In the next two sections we discuss in details those two aspects of the NutrientNet package.

SUPPORTIVE TEACHING TOOLS

We discuss the supplementary documents for instructor to supports the teaching of the MB approach and the use of the NutrientNet website. In the following section we discuss features covering NutrientNet that are favorable for the productive learning of economics students.

In NutrientNet, the teaching tools provided for an instructor can be categorized into instructional materials and online utilities to assist an instructor in a trading session. The instructional materials include a guide to the MB approaches to water quality improvement and a Microsoft PowerPoint file on how to use NutrientNet in lectures. In addition to these two files, NutrientNet also has a Microsoft Word file that contains a sample classroom assignment for participants. All of these materials are accessible from the Teaching Tools page accessible from
the NutrientNet home page (see Figure 1). Exhibit 1 introduces in brief the contents of these materials.

**INSERT EXHIBIT 1 ABOUT HERE**

In addition to supplementary documents, an instructor is also provided various online aids and utilities to create and monitor activities of the market participants and evaluate student performance. All of these are accessed from the instructor home page. An instructor will do all of the tasks from his homepage as shown in Figure 7.

All that an instructor needs in order to create a NutrientNet market is a list of participants’ email addresses. After pasting the list into a page in the site, the instructor only needs to complete a simple procedure to enter necessary details for the trading session such as time period. The rest of process is done automatically by the program, including sending emails to all students to inform them that a market session has started for their participation.

As for measuring student understanding about the water pollution issue and the MB approach, the instructor can use available standard quizzes or create custom quizzes for use with support from a utility installed in NutrientNet. Currently, there are two standard quizzes available from NutrientNet including “Water Quality,” testing knowledge about water pollution problems, and “Water Quality Economics,” about the economics of the MB approaches to water quality. In assigning a quiz, the instructor can choose either to have it graded, in which case a percentage score is given for each student, or nongraded, in which case students are not allowed to move on to the next question until they have given the correct answer. All data on student participation and performance can be accessed either as an html printout or downloaded as a comma-separated value (csv) file, which can be read by Excel.
A particularly useful utility built into NutrientNet is the ability to impersonate a participant and access his or her NutrientNet page. This capability enables an instructor to have updated information on participation of students. Impersonating can also be used to help individual students understand the site or, if the instructor has access to the internet in the classroom, to show the entire class how to use of the site or interactively explore the economics of nutrient trading.

NUTRIENTNET LEARNING ENVIRONMENT

Basically, NutrientNet is an application of the problem-based learning methodology (Gallaher 1997) in which students learn in a group working to solve complex, real-world problems under the mentoring of the instructor. We believe that this approach together with the set of teaching tools and learning utilities developed in NutrientNet promotes student learning. In this section we show the NutrientNet learning environment features and how they make student learning easy, fun, and realistic.

Web-Based Trading Market

The web technology provides new opportunities for improving active learning techniques. In NutrientNet, students learn mostly from the process of evaluating their situation, making and responding to offers, and completing assigned exercises. Throughout a trading
session, students make several choices about treatment practices and trading credits based on their own estimations. For example, unlike most pollution trading exercises, marginal costs of abatement are not simply handed to the student; these must be calculated in order to evaluate each trade. They can easily navigate through their site to get information about their fields or plants and the market and the options available to them. Online trading combined with various web-based presentations of data and information in NutrientNet make student learning easy, fun, and active in which students work mostly independently in searching, analyzing, and making choices (Simkins 1999).

**Graphical Presentation of Most Economic and Environmental Effects**

One of the features of NutrientNet that distinguishes it from many other trading exercises is the in depth presentation of data for use while a market is active and for post-trading analysis. Because all data are captured electronically by the web site, various tables, charts, and graphs are instantly available. For example, the site provides graphical presentations of time-series of market prices and the distribution of nutrient loading in the watershed and tables with the costs of alternative treatment practices (Figure 8) and economic analysis of trading. Such data visualization is a very useful tool supporting the students in analysis of the economic and environmental effects, which can be led by the instructor or guided through an assignment.

INSERT FIGURE 8
Real World Setting of a Watershed and Realistic Choices

As mentioned earlier the watershed used for setting up the profiles of point sources and nonpoint sources in NutrientNet is Michigan’s Kalamazoo basin (Figure 10). As a PS or a NPS, the students have choices of treatment practices of which nutrient loading, reductions, and costs are estimated using real-world GIS-based data. Students participating in NutrientNet will be presented a setting close to the real world water quality problem so that they get a feeling of real problems occurring in the practice. The practice over decades and in many disciplines has shown that real-world problem solving encourages the active student learning (Stanford University CTL 2001).

The realism of NutrientNet gives students a much clearer sense that market-based approaches are possible, not just at a theoretical level, but actually can be implemented in real policy settings. Further, the cost-minimizing outcome is typically not achieved exactly. Tradable credits programs can reduce costs, but the markets are not perfectly efficient and students who participate in a NutrientNet exercise realize this. Further, a widespread concern with transferable credits markets is that they can lead to “hot spots” in which the pollution is concentrated in a small area. The graphical presentation of the final pollution load in NutrientNet facilitates discussion of this issue (Figure 8).

Of course this realism has its costs, sometimes distracting from the specific pedagogical goals on which the instructor might be focused. On the other hand, the realism provides new
information to the students about water pollution and watershed management that enrich the overall learning objectives of the class.

**Interactions between Instructor and Participants and Among Participants**

Good undergraduate education encourages contacts between students and faculty and develops reciprocity and cooperation among students (Chickering and Gamson 1987). Such communication and cooperation are promoted in NutrientNet through site-generated emails that allow communication back and forth among market participants, (see Figure 10). Although markets are frequently considered to be competitive rather than cooperative environments, as Adam Smith taught us long ago, in fact cooperation arises through the self-interested actions of individuals. This is consistent with Alan Randall’s (1999) argument that many environmental problems can be attributed to what he calls “isolation paradoxes, in which individual action fails but everyone would be better off with coordinated action than with no action at all” (p. 30). Markets, Randall argued, represent one way to overcome this isolation paradox. As interactions improve, so does their economic performance and the environmental outcomes in the simulated watershed.

The competitive yet interactive approach to solving problems in NutrientNet is, therefore, a way to foment cooperation. Although a market can be implemented in a computer lab, this is not necessary; trading can take place outside class and take place over several days or longer. Communication between students is facilitated by emails that are generated by the site informing
students of counter-offers or when a bid is accepted. The site also provides easy ways to get assistance from the instructor and a way for the instructor to give feedback to select students or the complete class.

**Online Quizzes for Instant Feedback, or for Grading Purposes**

In addition to written assignments, online quizzes incorporated into NutrientNet can be used to help students self-check what they have learned about water quality problems and economics of the MB approach, (see Figure 11). Instructors can use standardized quizzes or design customized quizzes, including true-false, multiple-choice, and open-ended questions. If the instructor desires, the results of multiple-choice quizzes can be carried out instantly and shown to students. Even for open-ended quizzes, the teacher can check and grade them easily and quickly via the web site. In addition, the instructor can set up deadline for the online quizzes they want to use and so the students are required to finish the task on time.

**INSERT FIGURE 11**

**Role Changes**

As in many classroom exercises, there are several advantages to using multiple rounds of trading in a class. First, there is simply the need for students to become accustomed to the web site. Secondly, in NutrientNet an instructor can choose a different scenario for each round in a multi-period trading exercise. In that way, the students can be assigned different roles as PSs and NPSs. Such changes in roles taken will give the students opportunities to understand different issues and economic incentives face by PSs and NPSs in the MB mechanism. In addition,
multiple rounds can be used to explore different program designs. For example, the fine for being out of compliance can be lowered, bringing home the lesson about effect of low fines affect environmental compliance and prices in a tradable rights program. Other variations include considering the impact of different trading ratios between point and nonpoint sources or setting the fine at zero to discuss the ethics of compliance.

Overall, the NutrientNet environment is a fun, realistic, and friendly educational environment for students to learn about the application of MB-based policy in environmental quality management. Next we compare NutrientNet with other classroom games that we mentioned earlier in terms of how well they facilitate the instructor and the students in teaching and learning MB-based approach in environmental management.

**NUTRIENTNET VERSUS CLASSROOM GAMES**

By taking advantage of computer and world-wide-web technology, NutrientNet has gone a long way toward resolving the tradeoff between a simple and tractable game and a rich and realistic learning environment. This tradeoff between realism and tractability in classroom games is discussed in Ando and Harrington (2006) and is a common concern for instructors. Programming and computers can make it possible to add realism without making the exercise too complicated for both the student and the instructor.

In a typical pollution trading game the instructor is required to work as the organizer and the regulator of market. As the regulator of the market the instructor needs to do a variety of tasks such as creating and imposing limits, allocating initial credits/permits, calling out the prices, recording offers to sell or buy, or recognizing that market clearing depends on the game
rule design. In NutrientNet the web site carries out almost all of these tasks. At most, the instructor just works as the organizer of the market. He is only required to set up the market and choose some characteristics for the market as he wants to have following a simple step-by-step guide that can be downloaded from the site.

In a classroom game, students are given some materials such as firms’ marginal abatement cost curve or information needed to derive costs of treatment alternatives. These students are then required to calculate the optimal credits or permits they want to buy or sell given prices on the market. In addition, the students are usually required to keep records of all transactions they have made. For post-trading analysis, a manual compilation of transactions is needed to give summaries for industry trading results. In NutrientNet, routine calculations and record keeping are carried out by the web site, whereas the process of determining the relevant marginal costs falls to the students. For example, a student’s credit and cash balances are always available on the balance sheet on the student home page (Figure 13). Released from these requirements to carry out the simple calculations, students can focus on trading and analyzing the data, which are mostly summarized and visualized for ease of understanding.

In addition to the ability to create a rich learning environment while not sacrificing the ease of use for the instructor and the students, the computer-based market allows flexibility in many aspects. Aware of the limits on faculty time, NutrientNet was designed to minimize faculty workload. The instructor can easily scale the exercise for a class of virtually any size, multiple rounds of trading can be carried out, and it is even possible to combine groups from different classes or even different campuses. All of these pose difficulties for classroom games (Ando and Harrington 2006).
CONCLUSION

NutrientNet was developed to be an educational tool to support the teaching of the MB approach for environmental improvement. The core of the application is a simulated market for trading nutrient reduction credits between PS or NPS polluters. Even though the website brings students a rich learning environment that encourages active learning, there are two important things should be concerned by teachers to make use of the site.

First, the instructor should equip students with a minimum background in the environmental pollution issue and the economics of the MB approach in resolving the pollution problem including the benefits that PSs and NPSs can earn from water quality trading. It is this knowledge that will guide students to work out their strategies in their roles as PS and NPS polluters. The teaching tools of NutrientNet, particularly the guide, include supplementary materials that can help achieve this task, but instructor guidance would significantly help.

Second, the MB approach to environmental management achieves pollution reduction goals through the use of economic incentives for polluters. Similarly, in NutrientNet incentives need to be created for the participants to work out best solution for themselves. Based on our experience in numerous classes, the NutrientNet exercise will not work if students are not given a tangible incentive to participate and try to “win” in each round of trading. Ideally, participants’ incentives should be tied to their performance in terms of monetary savings or profits in the trading. NutrientNet provides the statistics necessary for this evaluation. On the other hand, extremely strict grading based on performance is probably not recommended, because as in most games that are fun, NutrientNet involves a degree of luck. Although such luck may make it inappropriate for grading of great consequence, it makes the use of the site a lot more fun.
REFERENCES


FIGURE 1: Homepage of NutrientNet at http://edu.nutrientnet.org/.
FIGURE 2: The trading process in NutrientNet.
My NutrientNet Home

<table>
<thead>
<tr>
<th>BALANCES</th>
<th>Loading: 24,904 lbs</th>
<th>Credits: 11,041</th>
<th>Cash: 14,550.53</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>Field</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Field #3</td>
<td>![Details icon]</td>
</tr>
</tbody>
</table>

Notes:  
1. To view or modify farming field details click on its name or Details icon.

<table>
<thead>
<tr>
<th>Date</th>
<th>Loading</th>
<th>Credits</th>
<th>Cash</th>
<th>Transaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 14 23:42</td>
<td>52,987</td>
<td>0</td>
<td>0.000</td>
<td>New farming field</td>
</tr>
<tr>
<td>Oct 15 19:49</td>
<td>0</td>
<td>-1,000</td>
<td>10,000.00</td>
<td>Sale of credits</td>
</tr>
</tbody>
</table>

FIGURE 3: The balance sheet of a NPS.
Market

Use this form to view market offers and buy or sell credits.

<table>
<thead>
<tr>
<th>Actions</th>
<th>Offer type</th>
<th>Credits</th>
<th>Price</th>
<th>Placed (ET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept</td>
<td>wanted</td>
<td>1,000</td>
<td>$10.00</td>
<td>10/15/07 00:27</td>
</tr>
<tr>
<td>Accept</td>
<td>wanted</td>
<td>2,000</td>
<td>$6.00</td>
<td>10/15/07 00:33</td>
</tr>
<tr>
<td>Accept</td>
<td>for sale</td>
<td>5,000</td>
<td>$11.00</td>
<td>10/15/07 00:48</td>
</tr>
</tbody>
</table>

FIGURE 4: The NutrientNet market.
**Field name:** Field #2

Field area: 8,000 acres
Tillage: Fall plow
Filter strip: None
Baseline load: 98,794 lbs.

### Selected best management practices
- [ ] Conservation tillage
- [x] Constructed wetland
- [ ] Sediment basin
- [ ] Filter strip
  - Hay

<table>
<thead>
<tr>
<th>Summary of best management practices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load &amp; reductions</strong></td>
</tr>
<tr>
<td>BMP</td>
</tr>
<tr>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Constructed wetland</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Credits &amp; costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMP</td>
</tr>
<tr>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Constructed wetland</td>
</tr>
</tbody>
</table>

**FIGURE 5:** Characteristics of a field and best management practices.
FIGURE 6: Example of supply and demand for nutrient reduction

(negative quantities indicate prices at which all market participants would prefer to supply credits)
FIGURE 7: The homepage for an instructor.
FIGURE 8: Charts for loading distribution
FIGURE 9: A geographical location in the Kalamazoo basin.
Offer details:

This offer is to **BUY** credits

Credit amount: 2,000 @ $6.00  
Total price: $12,000.00  
Market: To_Market  
Period: Period_01  
Offer posted: 10/15/07 00:33 (ET)  
Remarks: I don't need 3000. Will you sell me 2000 instead?

You counter with an offer to **SELL** credits

Credit amount: 2000  
Credit price ($)  
Remarks: If you pay $9, I'll sell you 2000. Accept and we'll close the deal  
(optional, max 70 characters)

[Counter offer][Go back]

**FIGURE 10:** Student interaction.
True or False: If discharges exceed the environment’s absorptive capacity, then it leads to pollution, a degradation in environmental quality.

○ True
○ False
○ Sometimes true some times false
○ Impossible to tell
○ none of the above

FIGURE 11: Online quiz
## TABLE 1: Trading Market Efficiency Analysis

<table>
<thead>
<tr>
<th>Policy options</th>
<th>Pollution reduction (lbs)</th>
<th>Total cost</th>
<th>Cost of reduction ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>PS</td>
<td>NPS</td>
</tr>
<tr>
<td>No trading</td>
<td>121,357</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>PS only trading</td>
<td>103,115</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>PS and NPS trading (optimal)</td>
<td>126,561</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Your trading results</td>
<td>163,874</td>
<td>30</td>
<td>70</td>
</tr>
</tbody>
</table>
EXHIBIT 1. Supplementary instructional materials available on NutrientNet site

A Guide to Market-Based Approaches to Water Quality

This 25-page guide (Nguyen et al. 2006) was written to introduce students to water quality problems, how these problems have been addressed in the United States, and the potential for using water quality markets. The guide also discusses economics of the market-based approach in comparison to a command-and-control policy. However the discussion about economics assumes no prior understanding of economics or water quality problems. The guide is in PDF format and can be accessed at the website’s main page.

PowerPoint Presentation

This PowerPoint presentation can be used to explain to participants the overall flow of NutrientNet. The presentation provides step-by-step instructions on how to use NutrientNet. In the first few slides key concepts of point source and nonpoint source are introduced together with role playing in NutrientNet. Next the slides show participants the basic steps to log-in and access to their homepage called My NutrientNet. These slides use true images from the NutrientNet website so that students can follow the procedure easily on their personal computer or in a lab. Then students are presented whatever information is available about their site, such as field characteristics, initial loading and credits, alternative treatment practices, and financial balance. Students are also instructed what they are allowed and advised to follow in a sample trading session. Finally, post-trade analysis using graphs and numbers will help students to analyze costs and environmental effects of alternative environmental policies.

NutrientNet Assignment

This document contains questions that can be used and modified to provide a classroom exercise that will walk students through the NutrientNet experience and help them to think about the decisions that are made. It also provides an easy way to generate a quantifiable measure of student performance and understanding.