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Adoption of Soil and Water Protection Practices Among Land Owner-Operators in Three Midwest Watersheds

--Working Paper*--

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Adoption of Soil and Water Protection Practices Among Land Owner-Operators in Three Midwest Watersheds

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Introduction

Erosion of agricultural crop land remains a significant socio-environmental issue within the United States (US) primarily due to the adverse impacts of soil displacement on water quality. While soil erosion can create adverse on-site problems, a large proportion of the negative environmental consequences of soil erosion is associated with off-site damages (Halcrow, et al., 1982; Napier, et al, 1983). Some of the most commonly recognized on-site costs associated with soil erosion of agricultural land are loss of soil fertility, loss of chemical fertilizers, loss of resale value of crop land, loss of aesthetic value of land, and loss of wildlife habitat. Some of the most important off-site costs of soil erosion of crop land are sedimentation of streams and lakes, disruption of transportation systems, costs associated with making water potable, loss of recreation use of water resources, loss of wildlife habitat, loss of aesthetic value of water resources, and threats to human and animal health (Napier and Sommers, 1994; Napier, et al., 1983; Page, 1987).

The major difference between on-site and off-site damages caused by soil erosion is that on-site costs adversely affect owners of eroding land, while off-site costs primarily affect populations that do not own eroding farm land. Land owner-operators are usually concerned about on-site damages and will take corrective action to reduce erosion, if soil loss begins to adversely affect agricultural productivity of land resources and reduce farm income. Unfortunately, land owner-operators frequently ignore environmental degradation caused by soil erosion because they recognize that on-site damages are relatively inconsequential and that the economic costs associated with controlling erosion are quite high. Land owner-operators also know that costs associated with monitoring erosion at the farm level are extremely high which prevents government agencies from forcing land owners to internalize the off-site costs associated with agricultural pollution.

Given the high costs of monitoring nonpoint pollution and the reluctance of land owner-operators to assume the costs of implementing soil and water conservation production systems at the farm level, many farmers continue to employ production systems that contribute to environmental degradation. Without more extensive adoption of conservation production systems by farmers in the US, it is highly unlikely that national water quality goals will be achieved.

While public policies and intervention programs are needed to motivate land-owner operators to adopt and to continue use of conservation production systems at the farm level, such initiatives cannot be effectively implemented without knowing what factors contribute to adoption and/or rejection of such production systems. Unfortunately, existing research does not provide adequate evidence to establish public policies or to implement effective intervention programs. It is clear, however, that failure to adopt conservation production systems at the farm level cannot be attributed to the lack of technological solutions. Technologies and techniques have been in existence for many years to resolve practically any erosion problem (Lal and Stewart, 1995; El-Swaify, et al., 1985). The major barriers to adoption of conservation production systems at the farm level are socioeconomic in nature (Halcrow, et al., 1982, Lovejoy and Napier, 1986; Napier, et al., 1983). Until the socioeconomic barriers are identified and eliminated, little advancement will be made in further reduction of agricultural pollution in the US.

Research conducted since the early 1980s (Halcrow, et al, 1982; Lovejoy and Napier, 1986; Napier, et al, 1999_a; Napier, et al., 2000; Swanson and Clearfield, 1994) strongly suggest that new theoretical perspectives need to be examined because traditional models have been shown to be inadequate for predicting conservation adoption behaviors at the farm level. Existing research basically demonstrates that many variables commonly thought to affect conservation adoption behaviors at the farm level are not useful for predicting adoption behaviors across broad geographic regions. Some of the factors shown not to be good predictors of conservation adoption behaviors at the farm level are as follows: access to various types of information/education programs, characteristics of the farm enterprise, characteristics of the primary farm operator, awareness of environmental degradation, favorable attitudes toward conservation, possession of pro-environmental ethics, attitudes toward the environment, and access to government subsidies (Halcrow, et al, 1982; Lovejoy and Napier, 1986; Napier and Johnson, 1998; Napier, et al., 1999_a; Napier, et al., 1999_b ; Swanson and Clearfield, 1994).

While economic incentives can motivate land owner-operators to adopt conservation production systems, economic subsidies used to encourage adoption often must equal or exceed social and economic costs associated with adoption (Napier, et al., 1994; Napier, et al., 1999_a). Most existing subsidy programs offered by government conservation agencies do not provide sufficient economic incentives to adequately off-set the costs associated with adoption of conservation production systems. When subsidies are sufficiently high to facilitate adoption of conservation production systems, the subsidies must be maintained over time or rejection will occur when they are withdrawn. Rejection of conservation production systems after subsidies have been terminated nearly always results in loss of conservation investments because most land owner-operators will employ previously used production systems that degrade soil and water resources.

While many socio-economic variables have been assessed in the context of adoption of conservation production systems at the farm level, perceived impacts of adopting conservation production systems on the farm enterprise and the relative importance placed on factors used to make farm-level production decisions have not been examined. The purpose of this paper is to present the findings of a study designed to examine how such factors influence adoption of conservation production systems at the farm level in three Midwest watersheds. Study findings are discussed in the context of conservation programs within the three watersheds.

A Vested Interests Perspective

The theoretical perspective used to guide the investigation was developed from utilitarian components of social learning (Bandura, 1971) and social exchange (Ekeh, 1974) theories. The theoretical perspective was termed the "vested interests" model. The theoretical model basically posits that human beings are reward seeking and punishment avoiding creatures who attempt to achieve net benefits in every social situation. While individuals may not aspire to maximize profits in every decision-making situation, they always seek to balance costs and benefits in a manner that will produce net benefits for themselves. The model argues that many types of costs and benefits are considered in the decision-making process. Social, psychosocial, economic, and environmental benefits and costs of alternative action options are considered.

The vested interests model asserts that human beings evaluate people, places, and things in the context of potential benefits to be derived from contact with them. The model suggests that human beings evaluate things positively that will produce net benefits and will define negatively those things that will result in net losses. The outcomes of these assessments affect actions taken.
Action options that are perceived positively will have a higher probability of being implemented favorably than action options perceived negatively.

Land owner-operators are constantly assessing alternative action options and making decisions about adoption of agricultural production systems in the context of the outcomes of their evaluations. The vested interests model suggests that farmers will make production decisions in terms of the assessments of benefits and costs associated with alternative action options and that land owner-operators will adopt production systems that will generate the best combination of benefits achievable under constraints of ability to act factors.

Many factors affect the outcomes of the adoption decision-making process. Farmers who perceive that adoption of conservation production systems will result in a decrease in farm output and/or an increase in farm production costs will tend not to adopt such production systems because costs will be increased with no corresponding increase in benefits. Farmers who place higher levels of importance on access to economic and technical assistance when making decisions about adoption of new agricultural production systems will have a higher probability of adopting conservation production systems because economic subsidies and technical assistance are often offered to cooperating land owners to reduce some of the costs associated with adoption. Land owner-operators who place greater importance on costs of new production systems, risks associated with trying an alternative production system, and on demonstrated profitability of alternative production systems when making adoption decisions will have a lower probability of adopting conservation production systems because such systems are usually not profitable in the near-term and often not in the long-term (Batte, 1995; Mueller, et al., 1985; Putman and Alt, 1987). If profits are not expected, farmers will tend to be very reluctant to adopt. Farmers who place higher importance on the threat of agricultural pollution and government regulations governing agriculture when making adoption decisions will have a higher probability of adopting conservation production systems because such systems can reduce agricultural pollution and are more consistent with government regulations designed to protect environmental quality (Halcrow, et al., 1982; Swanson and Clearfield, 1994). Land owner-operators who place higher importance on access to information/education programs when making adoption decisions will have a higher probability of adopting conservation production systems because they will be more aware of the many non-economic benefits associated with adoption.

Research Methodologies

Descriptions of Study Watersheds: Data to examine the merits of the theoretical perspective used to guide the study were collected from 1,011 primary farm operators within three Midwest watersheds. A watershed was selected from each of three states to represent different types of production agricultural systems within different geographical regions of the Midwest. The data were collected in the fall of 1998 and the winter of 1999.

Ohio respondents were operating farms in a watershed located in the central part of the state close to the western suburbs of Columbus. Iowa respondents were operating farms in a watershed in northeast part of the state located west and south of Dubuque. Minnesota respondents were farming land in a watershed in the southeastern part of the state located west and south of Minneapolis.

The study watersheds were purposely selected to provide diversity in terms of agricultural specialization, topography of the land, and the distribution of population throughout the watershed. The watersheds ranged in size from approximately 350,000 acres for the Ohio watershed to over 1.4 million acres for the Minnesota watershed. The topography of the watersheds ranged from flat to gently rolling in Ohio to gently rolling to quite steep slopes in Iowa. The topography of the Minnesota watershed was flat in the flood plain with steep slopes rising to a plateau where the land became flat. The Ohio watershed is being rapidly invaded by suburbs, while the Iowa and Minnesota watersheds have been immune from suburbanization due to the distance to the nearest large city.

Farm operations within the three watersheds were quite different. Farmers within the Ohio watershed specialized in the production of grain, while Iowa and Minnesota farmers produced both feed grains and animals for market. Minnesota respondents were active in the production of dairy products.

Data Collection Techniques: Data were collected using a structured questionnaire that requested information about agricultural production systems in use at the time of the study. The questionnaire also requested information about perceived profitability of conservation production systems and the importance placed on a number of factors farmers commonly consider when making decisions about adoption of agricultural production systems.

The data were collected using a drop-off-pick-up-later technique that consisted of trained field-staff persons selecting every other occupied residence within specified sampling areas within the watersheds.[1] Field-staff persons contacted respondents at the farmer's home and explained the purpose of the study. Questionnaires were left in the possession of primary farm operators who agreed to participate in the study. Field staff persons arranged a convenient time to collect completed questionnaires. When questionnaires were retrieved, field-staff persons answered all inquiries made about the study instruments to ensure that respondents were correctly interpreting the questions.

The sample distribution was monitored throughout the data collection phase of the project using detailed county maps. Each field-staff person was asked to note the approximate location of each respondent on a map of their sampling area to provide a visual distribution of the study sample. Inspection of the maps provided by each field-staff person revealed that respondents were widely distributed over each sampling area.

A total of 105 primary farm operators in the Ohio watershed, 355 primary farm operators in the Iowa watershed, and 551 primary farm operators in the Minnesota watershed completed questionnaires. The response rate for each watershed was about 80 percent. Given the large sample size, the broad distribution of the sample throughout the study watersheds, the high response rate, and the sampling technique used to select the sample, it is argued that the samples are representative of the farm populations within the three watersheds.

Measurement of Study Variables: Agricultural production systems used at the time of the study were measured using 18 production practices that could be employed on Midwest farms. Primary farm operators were asked to indicate how often **each** farm production practice was used on his/her farm. The production practices evaluated were as follows: fall tillage, fall application of fertilizer, soil testing, no till, chisel plowing with 1/3 ground surface covered with crop residue at planting time (conservation tillage), ridge tillage, deep (moldboard) plowing, winter application of manure, banded (in furrow) application of fertilizer, side dressing of fertilizer during growing season, banded (in furrow) application of herbicides, mechanical weed control, use of nitrification inhibitor, crop rotation, contour planting, buffer strips, integrated pest management, and precision farming.

Possible responses to each of the agricultural production practices were as follows: never use, once every 5 years, once every four years, once every three years, every other year, use every year. Weighting values for the responses ranged from 0 for **Never Use** to 5 for **Use Every Year** for all of the agricultural practices except fall tillage, fall application of fertilizer, deep plowing, and winter application of manure whose weighting values were reversed. This method of weighting the responses resulted in higher values representing greater use of conservation production systems.

A composite index was calculated from the responses to the 18 production practices in use at the time of the study. Weights assigned to responses to the various production practices were multiplied by values to reflect environmental impacts of each production practice.[2] Fall tillage, deep plowing, and winter application of manure were defined as being the worst types of farm production practices assessed in terms of contributing to environmental degradation. Conversely, no till and chisel plowing with 1/3 ground cover with crop residue at planting time were defined as being the most environmentally benign of the practices assessed. Original weights assigned to responses to these five agricultural practices were multiplied by 2 to give greater emphasis to adoption of these practices (see Table 2). Since the responses had been initially weighted to reflect positive or negative environmental impacts, multiplying by 2 resulted in doubling scores (both positive and negative) for these five practices. The computed values for all of the production practices were summed to form a composite index termed **conservation production index**. The range of possible scores was theoretically 0 to 115, however, farmers tend to specialize in production practices which would preclude farmers from adopting both no till and chisel plowing with 1/3 ground cover at planting time. The index score for each respondent was used as the dependent variable for regression modeling.

The independent variables selected to represent various components of the vested interests model are as follows: perceived changes in production costs, perceived changes in output, required subsidy to adopt, and the importance of 8 factors used to make agricultural production adoption decisions. The independent variables were measured as follows:

"Perceived changes in production costs" was measured by asking respondents to indicate how farm production costs would change if his/her farm was operated in a manner to protect water from being polluted by agricultural chemicals and to prevent soil erosion beyond replacement levels. The possible responses ranged from **Large Decrease** (weighted -3) to **Large Increase** (weighted 3).

"Perceived changes in output" was measured by asking respondents to indicate how farm output would change if his/her farm was operated in a manner to protect water from being polluted by agricultural chemicals and to prevent soil erosion beyond replacement levels. The possible responses ranged from **Large Decrease** (weighted -3) to **Large Increase** (weighted 3).

"Required subsidy to adopt" was measured by asking respondents to indicate how many dollars per acre would have to be received to adopt conservation tillage systems. The value entered by each respondent was used for the statistical analysis.

Eight factors commonly used by farmers to make adoption decisions about new agricultural production systems were assessed by asking respondents to indicate the importance placed on "Access to government subsidy programs," "Access to technical assistance," "Cost of new production systems," "Level of risk associated with trying new production systems," "Access to information/education programs," "Concern for agricultural pollution," Demonstrated profitability of production practice," and "Government regulations." The possible responses ranged from **Not At All Important** (weighted 0) to **Extremely Important** (weighted 3).

Statistical Analysis: Descriptive and multivariate statistics were used to analyze the study data. Descriptive statistics were used to examine general trends within the study responses, while

stepwise regression analysis was employed to assess the relationships among the predictive variables when all were considered simultaneously.

Missing data for the 18 production practices assessed in the study were assigned the weighting value for "never use." It was assumed that respondents who did not elect to provide information about specific practices did so because they never use the practice. Missing data for the independent variables were attributed the variable mean which has been shown to be the most efficient means of salvaging observations when the number of observations is large, the correlations are relatively low, and the number of missing cases is small (Donner, 1982). All of these conditions were satisfied with the data set.

Study Findings

Descriptive findings are presented in Tables 1 through 5. Characteristics of the study samples are presented in Table 1 and show that respondents in the Minnesota watershed were slightly younger, slightly better educated, and had been engaged in farming their own land fewer years than farm operators in the Ohio and the Iowa watersheds. Primary farm operators in the Ohio watershed reported farming more acres of land than farmers in the Iowa and Minnesota watersheds. Ohio land owner-operators reported owning more land and renting more land for farming purposes than did farmers in the Iowa and Minnesota watersheds. Iowa respondents reported the lowest percentage of farm income derived from grain, however, they reported the highest percentage of farm income derived from animal production. Minnesota farmers reported the highest level of debt.

Farmers in the Ohio watershed reported the lowest percentage of farm labor contributed by the primary farm operator, even though study findings revealed that primary farm operators in all of the study watersheds contributed a large majority of farm labor. A much larger percentage of land owner-operators in the Ohio watershed reported receiving government financial assistance than farmers in the other watersheds, even though the greatest percentage of farmers in all of the watersheds did not receive financial assistance from the government. Minnesota farmers reported receiving very little financial support and little technical assistance from government sources. A majority of primary farm operators in the Ohio and the Minnesota watersheds reported that they believe their children will operate their farms in the future. A majority of land owner-operators in the Iowa watershed did not expect their farms to be operated by their children in the future.

Respondents in the Ohio watershed indicated that they were operating farms much closer to a city of 50,000 or more than land owner-operators in the other watersheds. This is one of the major reasons that farm land within the Ohio watershed is being rapidly converted to nonagricultural uses (Napier and Johnson, 1998).

Gross farm incomes in the study watersheds indicate that land owner-operators are generating extensive revenues. Approximately 16.2 percent of the Ohio farmers reported gross farm income exceeding $360,000 during the 1997 crop year, while the percentage of farmers in the Iowa and Minnesota watersheds reporting such levels of gross farm income was 7.3 percent and 4.7 percent respectively. One of the reasons for this level of income is that Ohio farmers report cultivating over 826.4 acres of land.

(Table 1 about here)

Findings for the various production practices assessed in the study are presented in Table 2 and show that fall tillage was being used extensively in all watersheds. Fall application of fertilizers was being used by a minority of farm operators in all watersheds with the highest use in the Ohio watershed. Soil testing was one of the most widely used conservation practices assessed and was commonly used in all three watersheds. No till was used extensively in Ohio but not in the other watersheds. Chisel plowing with 1/3 ground cover at planting time was used frequently in the Minnesota watershed and less so in the other two watersheds. Moldboard plowing was used extensively in Minnesota but not in the other watersheds.

Winter application of manure was frequently practiced in the Minnesota and Iowa watersheds and less so in the Ohio watershed. Banded application of fertilizer was seldom used in the Minnesota watershed, however, a significant minority of farmers in the Ohio and the Iowa watersheds used this production practice. Side dressing of fertilizer during the growing season was not used very often in the Iowa and Minnesota watersheds, however, a significant minority of farmers in the Ohio watershed used this practice. Banded application of herbicides was not used extensively in any of the study watersheds. Mechanical weed control was practiced extensively in the Iowa and Minnesota watersheds but not in the Ohio watershed. Crop rotation was used frequently in all watersheds. Use of ridge tillage, nitrification inhibitors, buffer strips, integrated pest management, and precision farming were not used very often in any of the watersheds assessed in the study.

(Table 2 about here)

Findings for perceptions about how production costs would change if the respondent's farm was operated in a manner to protect water from pollution by farm chemicals and to prevent soil loss beyond replacement level are presented in Table 3. These findings show that primary farm operators in all three watersheds believed that production costs would slightly increase. The

greatest increase was expected by Ohio farmers. The lowest expected loss was reported by Minnesota farmers.

(Table 3 about here)

Findings for perceptions about how farm output would change if the respondent's farm was operated in a manner to protect water from pollution by farm chemicals and to prevent soil loss beyond replacement level are presented in Table 4. The findings show that farmers in all three watersheds expected farm output to slightly decrease if farms were operated in a manner to protect soil and water resources.

(Table 4 about here)

Findings for the importance placed on the eight factors frequently used to make decisions about the adoption of new farm technologies at the farm level are presented in Table 5. These findings show that most of the factors posited to be extremely important to primary farm operators when they are engaged in making decisions about the adoption of new farm production systems are not as important as commonly thought among farmers in the study watersheds. Access to information/education programs were perceived to be of slight importance in all of the study watersheds and of least importance in the Minnesota watershed. All of the other factors assessed were shown to be slightly important or of significant importance. No factor assessed was reported to be extremely important in the decision making process when evaluated in terms of the mean scores. The highest ranked factor was demonstrated profitability which received a mean ranking of 3.3 among Ohio farmers, 3.2 among Iowa farmers and 2.7 among Minnesota farmers. A value of over 3 indicates that farmers in the Ohio and Iowa watersheds placed significant importance on demonstrated profitability when making adoption decisions about new agricultural production systems. The mean value for Minnesota farmers was 2.7 which indicated a level of importance between slight and significant.

(Table 5 about here)

Multiple regression analysis was used to assess the merits of the theoretical perspective used to guide the investigation. The variance in the **conservation production index** was regressed against the selected independent variables and the findings are presented in standardized regression coefficient form. All coefficients presented are significant at the 0.05 level.

Ohio regression findings:

$Y = 0.344X_1 + 0.283X_2$

Where Y = Conservation Production Index

X_1 = Access to information/education programs

X_2 = Level of risk associated with trying new production systems

Adjusted coefficient of determination (R^2) = 0.190

Iowa regression findings:

$Y = 0.273X_1 + 0.173X_2$

Where Y = Conservation Production Index Score

X_1 = Access to government subsidy

X_2 = Access to information/education programs

Adjusted coefficient of determination (R^2) = 0.110

Minnesota regression findings:

$$Y = 0.168X_1$$

Where Y = Conservation Production Index Score

X_1 = Demonstrated profitability of production practice

Adjusted coefficient of determination (R^2) = 0.024

Conclusions

Study findings basically repudiate the theoretical model used to predict adoption of conservation production systems within the Minnesota watershed and only slightly support the theoretical model within the Ohio and Iowa watersheds. The findings also demonstrated that multiple factors purported to affect adoption of new agricultural production systems at the farm level were not as useful as commonly thought in the decision making process relative to adoption of conservation production systems at the farm level. These findings strongly suggest that use of such factors to develop intervention programs within all three watersheds will result in only minor changes in conservation adoption behaviors of land owner operators.

Failure of the 8 criteria variables to explain adoption of conservation technologies and techniques in this study is very surprising because many adoption studies have reported these factors to be very important in the decision making process regarding adoption of new farm technologies and techniques (Napier, et al, 1999_b ; Rogers, 1995). Study findings strongly suggest that the criteria used to make adoption decisions about conservation production systems within the study watersheds are quite different from those used to make decisions about other types of farm technologies and techniques that could be integrated within the farm production systems presently in use within the watersheds. The failure of the criteria variables used in this study to predict adoption behaviors may be due to the fact that most conservation production practices are not profitable in the near- or in the long-term, while other farm technologies and techniques are nearly always more profitable than what presently exist. Diffusion-type variables, such as those used in this study, may only be effective predictors when the innovation being diffused is more profitable than what is presently in use.

Footnotes

1. Systematic random sampling was abandoned in the Ohio watershed because it became apparent after several weeks of data collection that it would be extremely difficult to locate 105 primary farm operators using the sampling approach initially employed. Most land owners within the watershed rent their crop land to large-scale producers to receive lower taxes associated with agricultural use until they sell the land for development purposes. Given the problems of locating farmers, anyone located within the sampling area who was engaged in production agriculture for a living was included in the study sample.

2. A panel of knowledgeable people were used to determine what practices should be defined as being the most environmentally benign and what practices should be classified as being abusive of the environment. The weights used to compute the composite index were determined using the same approach.

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Table 1: Characteristics of Study Respondents: Ohio (n=105), Iowa (n=355), and Minnesota (n=551)

	Ohio	Iowa	Minnesota
Age			
Mean	48.6 yrs	49.1 yrs	46.2 yrs
S.D.	11.9	11.8	11.1
Education			
Mean	12.7 yrs	12.8 yrs	13.0 yrs
S.D.	2.1	2.4	1.6
Years Farming			
Mean	23.8 yrs	24.9 yrs	21.3 yrs
S.D.	13.4	12.5	12.5
Acres Usually Cultivated			
Mean	826.4 ac	378.7 ac	421.1 ac
S.D.	896.1	470.4	493.9
Acres Owned			
Mean	283.3 ac	265.6 ac	233.7 ac
S.D.	461.1	248.6	187.3
Acres Rented			
Mean	498.8 ac	189.1 ac	316.7 ac
S.D.	610.1	265.2	623.2
Days Usually Worked Off Farm			
Mean	50.8 days	55.6 days	95.2 days
S.D.	94.4	95.8	104.0
Source of Farm Income			
Grain	68.6%	45.0%	62.1%
Animals	16.0%	39.9%	26.3%
Debt-to-Asset Ratio			
0-10	32.4%	20.5%	12.0%
11-20	12.4%	12.9%	9.4%
21-30	9.5%	14.0%	14.9%
31-40	7.6%	9.6%	16.2%
41-50	4.8%	10.4%	11.4%
51-60	6.7%	5.9%	7.8%
61-70	2.9%	1.1%	4.5%
71-80	1.9%	2.2%	4.0%
81-90	1.0%	0.3%	1.1%
91-100	0.0%	0.3%	0.0%
Missing	21.0%	22.8%	18.7%

Table 1: (continued)

	Ohio	Iowa	Minnesota
Percent Labor by Primary Farm Operator			
Mean	68.1%	76.4%	78.9%
S.D	27.0	21.6	20.9
Received Government Economic Support			
Yes	21.0%	15.7%	5.8%
No	79.0%	84.3%	94.2%
Received Technical Assistance			
Yes	27.6%	28.4%	8.7%
No	72.4%	71.6%	91.3%
Distance to City of 50,000 or Higher Population			
Mean	21.6 miles	49.9 miles	45.3 miles
S.D.	9.8	22.6	22.5
Farm Will be Operated by My Children in the Future			
Yes	55.2%	40.7%	52.1%
No	44.8%	59.3%	47.9%
Gross Farm Income			
< 59,999	21.9%	19.7%	8.6%
60,000-119,999	18.1%	23.6%	12.7%
120,000-179,999	12.4%	12.6%	22.5%
180,000-239,999	8.7%	13.2%	27.4%
240,000-299,999	4.8%	5.1%	10.4%
300,000-359,999	2.9%	2.8%	2.4%
360,000 >	16.2%	7.3%	4.7%
Missing	15.2%	15.7%	11.4%

Table 2: Use of Agricultural Production Practices at the Farm Level: Ohio (n=105), Iowa (n=355), and Minnesota (n=551)

	Frequency of Use								
	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Fall Tillage *									
Ohio	19 (18.1)	7 (6.7)	4 (3.8)	14 (13.3)	22 (21.0)	36 (34.3)	3 (2.9)	1.8	1.9
Iowa	80 (22.5)	22 (6.2)	17 (4.8)	41 (11.5)	52 (14.6)	115 (32.3)	28 (8.1)	2.1	1.9
Minn.	49 (8.9)	5 (0.9)	0 (0.0)	5 (0.9)	30 (5.4)	454 (82.4)	8 (1.5)	0.6	1.5
Fall Application of Fertilizer*									
Ohio	25 (23.8)	3 (2.9)	3 (2.9)	14 (13.3)	15 (14.3)	37 (35.2)	8 (7.6)	1.9	2.0
Iowa	174 (48.9)	12 (3.4)	13 (3.7)	35 (9.8)	37 (10.4)	48 (13.5)	36 (10.4)	3.3	1.9
Minn.	202 (36.7)	49 (8.9)	19 (3.4)	53 (9.6)	74 (13.4)	133 (24.1)	21 (3.8)	2.7	2.1

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
<u>Soil Testing</u>**									
Ohio	9 (8.6)	8 (7.6)	4 (3.8)	34 (32.4)	24 (22.9)	21 (20.0)	5 (4.8)	3.2	1.5
Iowa	8 (2.2)	32 (9.0)	41 (11.5)	164 (46.1)	45 (12.6)	30 (8.4)	35 (10.1)	2.9	1.1
Minn.	62 (11.3)	28 (5.1)	31 (5.6)	177 (32.1)	102 (18.5)	132 (24.0)	19 (3.4)	3.2	1.5
<u>No-Till</u>**									
Ohio	20 (19.0)	2 (1.9)	1 (1.0)	6 (5.7)	15 (14.3)	53 (50.5)	8 (7.6)	3.6	1.9
Iowa	201 (56.5)	16 (4.5)	3 (0.8)	23 (6.5)	24 (6.7)	42 (11.8)	46 (13.2)	1.3	1.8
Minn.	451 (81.9)	30 (5.4)	11 (2.0)	12 (2.2)	4 (0.7)	14 (2.5)	29 (5.3)	0.3	1.0

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Chisel Plowing with 1/3 Ground Surface Covered with Residue at Planting**									
Ohio	26 (24.8)	7 (6.7)	4 (3.8)	13 (12.4)	20 (19.0)	30 (28.6)	5 (4.8)	2.8	2.0
Iowa	88 (24.7)	16 (4.5)	12 (3.4)	39 (11.0)	56 (15.7)	112 (31.5)	32 (9.3)	2.9	2.0
Minn.	127 (23.0)	10 (1.8)	7 (1.3)	23 (4.2)	81 (14.7)	285 (51.7)	18 (3.3)	3.5	2.0
Ridge Tillage**									
Ohio	103 (98.1)	2 (1.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.2	0.1
Iowa	340 (95.8)	2 (0.6)	3 (0.8)	4 (1.1)	2 (0.6)	4 (1.1)	0 (0.0)	0.1	0.7
Minn.	524 (95.1)	5 (0.9)	2 (0.4)	1 (0.2)	1 (0.2)	18 (3.3)	0 (0.0)	0.2	0.9

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Deep (Moldboard) Plowing*									
Ohio	49 (46.7)	12 (11.4)	1 (1.0)	3 (2.9)	8 (7.6)	23 (21.9)	9 (8.6)	3.2	2.1
Iowa	155 (43.5)	56 (15.7)	20 (5.6)	48 (13.5)	18 (5.1)	21 (5.9)	37 (10.7)	3.4	1.7
Minn.	135 (24.5)	22 (4.0)	4 (0.7)	25 (4.5)	49 (8.9)	295 (53.5)	21 (3.8)	1.6	2.1
Winter Application of Manure*									
Ohio	56 (53.3)	4 (3.8)	3 (2.9)	2 (1.9)	1 (1.0)	32 (30.5)	7 (6.7)	3.2	2.2
Iowa	65 (18.3)	4 (1.1)	5 (1.4)	9 (2.5)	17 (4.8)	226 (63.5)	29 (8.4)	1.4	2.1
Minn.	200 (36.3)	10 (1.8)	4 (0.7)	21 (3.8)	40 (7.3)	254 (46.1)	22 (4.0)	2.1	2.3

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Banded (in furrow) Application of Fertilizer**									
Ohio	41 (39.0)	8 (7.6)	3 (2.9)	1 (1.0)	3 (2.9)	42 (40.0)	7 (6.7)	2.6	2.3
Iowa	134 (37.6)	9 (2.5)	6 (1.7)	15 (4.2)	12 (3.4)	143 (40.2)	36 (10.4)	2.6	2.2
Minn.	405 (73.5)	47 (8.5)	4 (0.7)	5 (0.9)	20 (3.6)	70 (12.7)	0 (0.0)	0.9	1.8
Side-Dressing of Fertilizer During Growing Season**									
Ohio	36 (34.3)	4 (3.8)	3 (2.9)	8 (7.6)	7 (6.7)	41 (39.0)	6 (5.7)	2.7	2.2
Iowa	160 (44.9)	12 (3.4)	13 (3.7)	33 (9.3)	23 (6.5)	76 (21.3)	38 (11.0)	1.9	2.0
Minn.	340 (61.7)	21 (3.8)	7 (1.3)	6 (1.1)	32 (5.8)	116 (21.1)	29 (5.3)	1.5	2.1

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Banded Application of Herbicides**									
Ohio	71 (67.6)	1 (1.0)	1 (1.0)	4 (3.8)	1 (1.0)	17 (16.2)	10 (9.5)	1.1	1.9
Iowa	208 (58.4)	6 (1.7)	2 (0.6)	18 (5.1)	21 (5.9)	58 (16.3)	42 (12.1)	1.4	1.9
Minn.	290 (52.6)	15 (2.7)	37 (6.7)	7 (1.3)	38 (6.9)	164 (29.8)	0 (0.0)	2.0	2.3
Mechanical Weed Control**									
Ohio	47 (44.8)	5 (4.8)	14 (13.3)	8 (7.6)	3 (2.9)	28 (26.7)	0 (0.0)	2.0	2.1
Iowa	24 (6.7)	3 (0.8)	6 (1.7)	13 (3.7)	32 (9.0)	244 (68.5)	33 (9.6)	4.4	1.4
Minn.	77 (14.0)	0 (0.0)	1 (0.2)	11 (2.0)	34 (6.2)	404 (73.3)	24 (4.4)	4.2	1.7

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
<u>Use of Nitrification Inhibitor</u>**									
Ohio	60 (57.1)	2 (1.9)	3 (2.9)	5 (4.8)	6 (5.7)	17 (16.2)	12 (11.4)	1.4	1.9
Iowa	224 (62.9)	7 (2.0)	5 (1.4)	29 (8.1)	10 (2.8)	26 (7.3)	54 (15.4)	0.9	1.5
Minn.	353 (64.1)	10 (1.8)	11 (2.0)	29 (5.3)	42 (7.6)	63 (11.4)	43 (7.8)	1.2	1.8
<u>Crop Rotation</u>**									
Ohio	2 (1.9)	0 (0.0)	2 (1.9)	6 (5.7)	12 (11.4)	75 (71.4)	8 (7.6)	4.6	0.9
Iowa	10 (3.1)	5 (1.4)	14 (3.9)	81 (22.8)	90 (25.3)	155 (43.5)	0 (0.0)	4.0	1.2
Minn.	57 (10.3)	4 (0.7)	4 (0.7)	17 (3.1)	66 (12.0)	403 (73.1)	0 (0.0)	4.3	1.6

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Contour Planting**									
Ohio	85 (81.0)	0 (0.0)	1 (1.0)	0 (0.0)	2 (1.9)	7 (6.7)	10 (9.5)	0.5	1.4
Iowa	109 (30.6)	6 (1.7)	3 (0.8)	11 (3.1)	9 (2.5)	175 (49.2)	42 (12.1)	3.1	2.2
Minn.	454 (82.4)	0 (0.0)	3 (0.5)	2 (0.4)	5 (0.9)	52 (9.4)	35 (6.4)	0.6	1.5
Buffer Strips**									
Ohio	65 (61.9)	3 (2.9)	2 (1.9)	0 (0.0)	1 (1.0)	21 (20.0)	13 (12.4)	1.3	2.0
Iowa	162 (45.5)	16 (4.5)	11 (3.1)	13 (3.7)	7 (2.0)	99 (27.8)	47 (13.5)	1.9	2.1
Minn.	440 (79.9)	2 (0.4)	2 (0.4)	5 (0.9)	6 (1.1)	60 (10.9)	0 (0.0)	0.7	1.6

	Never Use	Once Every 5 Yrs.	Once Every 4 Yrs.	Once Every 3 Yrs.	Every Other Year	Use Every Year	MD	X	SD
Integrated Pest Management**									
Ohio	73 (69.5)	14 (13.3)	4 (3.8)	2 (1.9)	0 (0.0)	12 (11.4)	0 (0.0)	0.8	1.6
Iowa	218 (61.2)	11 (3.1)	8 (2.2)	8 (2.2)	8 (2.2)	54 (15.2)	48 (13.8)	1.2	1.8
Minn.	420 (76.2)	5 (0.9)	4 (0.7)	3 (0.5)	6 (1.1)	77 (14.0)	36 (6.5)	0.8	1.8
Precision Farming**									
Ohio	90 (85.7)	2 (1.9)	1 (1.0)	0 (0.0)	1 (1.0)	11 (10.5)	0 (0.0)	0.6	1.6
Iowa	297 (83.7)	5 (1.4)	4 (1.1)	7 (2.0)	5 (1.4)	37 (10.4)	0 (0.0)	0.7	1.6
Minn.	422 (76.6)	37 (6.7)	3 (0.50)	2 (0.4)	5 (0.9)	82 (14.9)	0 (0.0)	0.9	1.8

*Weighted 5 through 0 with “never use” receiving a value of 5 and “use every year” a value of 0.
**Weighted 0 through 5 with “never use” receiving a value of 0 and “use every year” receiving a value of 5.

Ohio conservation production index score: mean = 50.0 Standard deviation: 13.1
Iowa conservation production index score: mean = 48.9 Standard deviation: 13.1
Minnesota conservation production index score mean = 38.5 Standard deviation: 13.0

Table 3: Perceptions of How Production Costs Would Change If Farm Operated in an Manner to Protect Water Quality and Soil Fertility: Ohio (n=105), Iowa (n=355), and Minnesota (n=551)

State	Possible Responses									
	Large Decrease -3	**Moderate Decrease -2**	**Slight Decrease -1**	**NO Change 0**	**Slight Increase 1**	**Moderate Increase 2**	**Large Increase 3**	**M.D.**	**$\bar{X}$**	**S.D.**
Ohio	2 (1.9)	3 (2.9)	9 (8.6)	32 (30.5)	20 (19.0)	33 (31.4)	6 (5.7)	0 (0.0)	0.8	1.3
Iowa	4 (1.1)	13 (3.7)	41 (11.5)	105 (29.6)	108 (30.4)	63 (17.7)	21 (5.9)	0 (0.0)	0.6	1.2
Minnesota	10 (1.8)	33 (6.0)	62 (11.3)	190 (34.5)	141 (25.6)	91 (16.5)	24 (4.4)	0 (0.0)	0.4	1.3

$\bar{X}$=Mean
M.D.=Missing data
S.D.=Standard deviation

Table 4: Perceptions of Land Owner-Operators About How Farm Output Would Change If Farm Was Operated in a Manner to Protect Water Quality and Soil Fertility: Ohio (n=105), Iowa (n=355), Minnesota (n=551)

	Possible Responses									
State	**Large Decrease -3**	**Moderate Decrease -2**	**Slight Decrease -1**	**NO Change 0**	**Slight Increase 1**	**Moderate Increase 2**	**Large Increase 3**	**M.D.**	**$\bar{X}$**	**S.D.**
Ohio	4 (3.8)	12 (11.4)	26 (24.8)	46 (43.8)	14 (13.3)	1 (1.0)	2 (1.9)	0 (0.0)	-0.4	1.1
Iowa	12 (3.4)	52 (14.6)	105 (29.6)	128 (36.1)	32 (9.0)	18 (5.1)	8 (2.3)	0 (0.0)	-0.4	1.2
Minnesota	20 (3.6)	62 (11.3)	115 (20.9)	230 (41.8)	71 (12.9)	44 (8.0)	9 (1.6)	0 (0.0)	-0.2	1.3

$\bar{X}$= Mean
M.D.= Missing data
S.D.= Standard deviation

Table 5: Importance Placed on Factors Affecting Experimentation With New Agricultural Production Systems: Ohio (n=105), Iowa (n=355), and Minnesota (n=551)

	Possible Responses						
Factor Affecting Decision	**Not at All Important 0**	**Of Little Importance 1**	**Of Slight Importance 2**	**Of Significant Importance 3**	**Extremely Important 4**	**Mean**	**S.D.**
1. Access to government subsidy programs							
Ohio	19 (18.1)	8 (7.6)	26 (24.8)	27 (25.7)	25 (23.8)	2.4	1.4
Iowa	42 (11.9)	53 (14.9)	101 (28.5)	79 (22.3)	80 (22.5)	2.4	1.2
Minnesota	74 (13.4)	101 (18.3)	173 (31.4)	156 (28.3)	47 (8.5)	2.0	1.1
2. Access to technical assistance							
Ohio	14 (13.3)	7 (6.7)	24 (22.9)	41 (39.0)	19 (18.1)	2.6	1.1
Iowa	45 (12.7)	32 (9.0)	126 (35.5)	113 (31.8)	39 (11.0)	2.3	1.0
Minnesota	61 (11.1)	76 (13.8)	172 (31.2)	182 (33.0)	60 (10.9)	2.3	1.1

Table 5: continued

3.Cost of new production systems							
Ohio	12 (11.4)	4 (3.8)	13 (12.4)	30 (28.6)	46 (43.8)	3.0	1.2
Iowa	53 (14.9)	19 (5.4)	31 (8.7)	143 (40.3)	109 (30.7)	2.9	1.2
Minnesota	68 (12.3)	58 (10.5)	128 (23.2)	169 (30.7)	128 (23.2)	2.5	1.2
4. Level of risk associated with trying new production system							
Ohio	11 (10.5)	3 (2.9)	15 (14.3)	40 (38.1)	36 (34.3)	3.0	1.1
Iowa	43 (12.1)	22 (6.2)	67 (18.9)	130 (36.6)	93 (26.2)	2.8	1.1
Minnesota	77 (14.0)	66 (12.0)	135 (24.5)	181 (32.8)	92 (16.7)	2.3	1.2

Table 5: continued

5. Access to information/ education programs							
Ohio	15 (14.3)	6 (5.7)	34 (32.4)	37 (35.2)	13 (12.4)	2.4	1.0
Iowa	44 (12.4)	31 (8.7)	118 (33.2)	129 (36.3)	33 (9.3)	2.4	1.0
Minnesota	85 (15.4)	131 (23.8)	166 (30.1)	128 (23.2)	41 (7.4)	1.9	1.1
6. Concern for agricultural pollution							
Ohio	9 (8.6)	3 (2.9)	17 (16.2)	53 (50.5)	23 (21.9)	2.9	0.9
Iowa	29 (8.2)	15 (4.2)	78 (22.0)	149 (42.0)	84 (23.7)	2.9	0.9
Minnesota	54 (9.8)	100 (18.1)	148 (26.9)	179 (32.5)	70 (12.7)	2.3	1.1

Table 5: continued

7. Demonstrated profitability							
Ohio	10 (9.5)	3 (2.9)	10 (9.5)	34 (32.4)	48 (45.7)	3.3	0.9
Iowa	36 (10.2)	6 (1.7)	33 (9.3)	141 (39.7)	139 (39.2)	3.2	0.8
Minnesota	57 (10.3)	54 (9.8)	92 (16.7)	204 (37.0)	144 (26.1)	2.7	1.2
8. Government regulations							
Ohio	15 (14.3)	7 (6.7)	21 (20.0)	36 (34.3)	26 (24.8)	2.6	1.2
Iowa	46 (13.0)	13 (3.7)	71 (20.0)	152 (42.8)	73 (20.6)	2.8	1.0
Minnesota	78 (14.2)	154 (27.9)	116 (21.1)	134 (24.3)	69 (12.5)	2.0	1.2

A National Water Pollution Control Assessment Model

--Working Paper*--

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A National Water Pollution Control Assessment Model

Timothy Bondelid, Research Triangle Institute
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I. Introduction

A. Good Morning, my name is Charles Griffiths and I am an economist in the Office of Policy at the US EPA.

B. Today I will present some work being conducted on a national water pollution control assessment model

C. I think that it is important that I emphasize my role in this project

1. This is a work-in-progress that has been going on for a number of years
2. I only began working on this project about one year ago and I have primarily worked on sensitivity analysis and goodness of fit
3. The primary water quality modeler is Tim Bondelid
4. George Van Houtven has done most of the economic work up until this point

D. My apologies to my discussant for the length of the paper

E. I will not be able to cover everything

1. I will outline the fundamentals of the model
2. I will illustrate the type of model results obtained
3. I will discuss the work done on sensitivity analysis and goodness-of-fit for the model.

II. The purpose of this research

A. To build a national-level water quality model. It is a major undertaking simply to wire together all of the river systems in the country

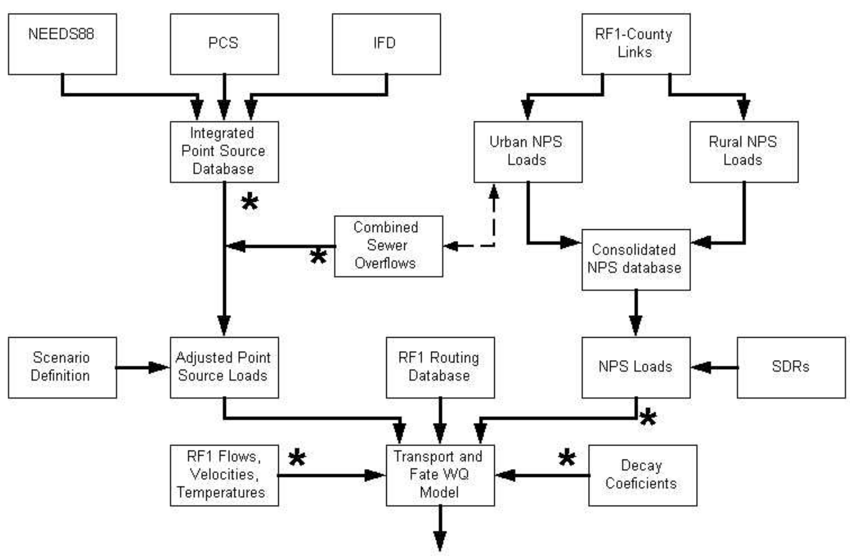
B. To evaluate the effect of water pollution control policies on water quality.

C. To measure the economic benefits associated with water pollution control policies

III. Overview of the Model

A. The National Water Pollution Control Assessment Model, which goes by the unwieldy acronym NWPCAM, can be described as:

1. national-level model of conventional pollutants in the major inland rivers and streams, larger lakes and reservoirs, and some estuarine waters in the lower 48 states.
2. This is done using the EPA's Reach File 1 framework, which covers 320,000 miles of rivers, lakes, reservoirs, and estuaries.
3. The model predicts ambient concentrations of 5 day biological oxygen demand (BOD), dissolved oxygen (DO), total suspended solids (TSS), and fecal coliform along all river reaches.
4. The model controls for loadings from both point and non-point sources, using stream flow and stream velocity data and a first-order decay equation to model pollutant fate.
5. The system includes most waters affected by major industrial, municipal, and CSO point sources.
6. These modeled pollutants form the basis for linking water quality to the Resources for the Future water quality ladder. This ladder is the basis for assigning four categories of beneficial use support (swimming, fishing, boating, and no use support) for each element in the NWPCAM.
7. These use support categories can then be used to measure the economic benefits to persons living near improved waters.

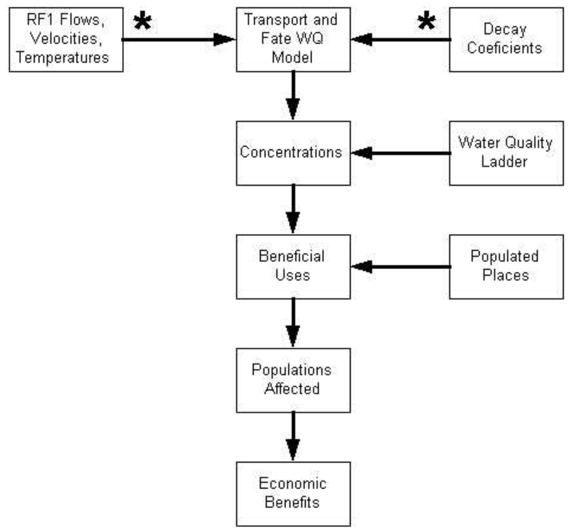


III. Overview of the model, cont'd.

B. Schematic of the model components and processes

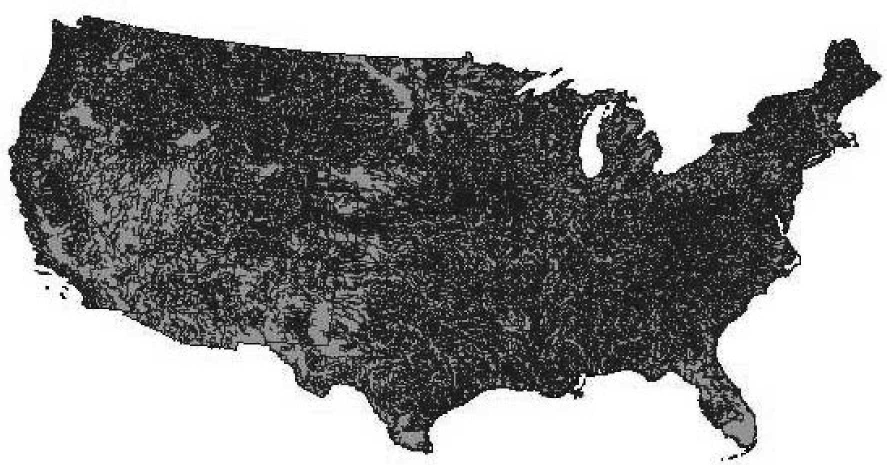
1. The central component of the NWPCAM is the RF1 routing model. To this routing framework is added the point source loads from municipal sources, industrial sources, and combined sewer overflows; non-point sources; stream flow, velocities, and temperatures; and pollutant decay coefficients. This allows the fate and transport modeling of pollutant concentrations for each sub-reach.

2. The upper left portion shows the construction of the point sources from the 1988 NEEDS survey, the Permit Compliance System, and the Industrial Facilities Discharger database, and data on combined sewer overflows
3. The upper right portion shows the construction of non-point source loadings from both urban and rural areas. The Sediment Delivery Ratio (SDR) is a coefficient that represents the reduction of pollutant loading as it goes from the field-level discharge to the waterways.



4. The pollutant concentrations are then compared to a water quality ladder to determine the beneficial use of each river reach.
5. The number of households proximate to those reaches can then be used to measure the economic benefit of improvements in water quality.
6. Areas of the model that have been checked for sensitivity have been marked with an *.

The RF1 System

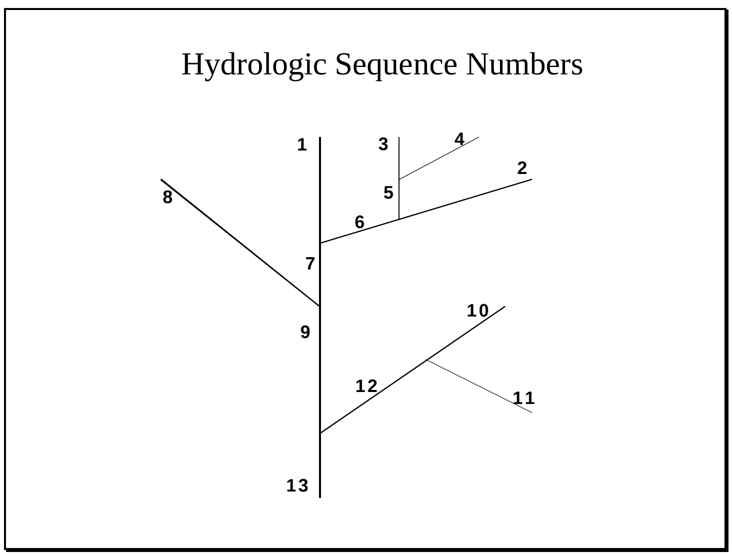


IV. Reach Files

A. The EPA Reach Files are a series of hydrologic databases created expressly to perform hydrologic modeling and to provide a unique identifier for each surface water feature. This unique identifier is called the “reach code.”

B. Reach File version 1, or RF1, contains approximately 632,000 miles of rivers, streams, and larger lakes.

C. RF1 is presently being superceded by RF3 that covers 3.6 million stream miles and includes intermittent, or non-perennial, streams. The reason that the NWPCAM continues to be modeled using RF1 is because crucial data such as stream flow and velocity is not available for RF3.



D. The key to the RF1 routing system is the Hydrologic Sequence Numbers

1. This is a stylized schematic of a river system.
2. Each river reach is an uninterrupted stretch of water, ending at a branch point, and is given a unique hydrologic sequence number.
3. The sequence numbering in the schematic is designed to allow the computer to quickly and efficiently model downstream flow.

E. The RF1 system contains approximate 68.000 reaches, with the average reach about 10 miles long. Since the entire effect of a pollutant discharge could occur in a 10 mile stretch, the NWPCAM is broken into 1-mile or shorter increments call computational elements. The expanded system includes approximately 655,000 computational elements.

NWPCAM Loadings Circa 1990s

All	Count	BOD, ton/yr	TSS, ton/yr
Municipal	14,063	874,262	929,262
Major	2,606	731,952	5,699,736
Minor	47,994	1,119,557	1,639,758
In NWPCAM			
Municipal	9,890	524,005	576,557
Major	2,261	664,056	3,569,373
Minor	24,854	386,760	926,955
On Coast			
Municipal	365	232,716	218,856
Major	194	55,664	838,869
Minor	1319	183,319	119,172
On Great Lakes			
Municipal	96	16,194	17,922
Major	54	2,954	608,593
Minor	135	1,066	20,713
Other Loads			
CSOs	505[a]	1,308,500	4,805,500
Rural NPS	43,097[b]	1,572,500	60,355,500
Urban NPS	16,399[b]	274,500	4,007,000

V. Pollutant loadings

A. Point source loadings data for municipal wastewater treatment plants and major industrial dischargers comes from the 1988 NEEDS survey and the Permit Compliance System.

B. Point source loadings from minor industrial dischargers comes from the Industrial Facilities Discharger database.

C. The table shows that the NWPCAM captures about 70% of the municipal dischargers, almost 90% of the major industrial dischargers, and half of the minor industrial dischargers.

D. Non-point source loadings are estimate by county for rural and non-rural areas, with the final load reaching the river reach dependent upon the watershed specific sediment delivery ratio.

E. These pollutant loadings are calculated for circa 1990 levels, which is the model "baseline."

F. These pollutant loadings can be adjusted for specific scenarios. Of particular interest is the hypothetical scenario of water quality in the absence of the Clean Water Act. This scenario can be modeled by changing the baseline loadings from their current national average, defined as 82% effective removal of influents, to the 1972 level of 62% effectiveness.

First-order Decay

$$\frac{dc}{dt} = K * c,$$

where

dc/dt = instantaneous change in concentration

K = decay rate (/d)

c = pollutant concentration (mg/L)

$$C_t = C_0 * e^{(Kt)}$$

where

C_0 = concentration at time zero

C_t = concentration at time t

VI. Hydrologic Modeling

A. The fate of BOD, TSS, and fecal coliform is assumed to be driven by a simple, but widely used first-order decay process. The instantaneous change in the pollutant concentration is a function of the pollutant concentration times the decay rate.

B. The closed-form solution of this equation specifies that the concentration at time t is a product of the concentration at time zero and an exponential decay.

C. The trick to this modeling approach is to pick the correct value for k. Using other studies as a guide, the decay coefficient for BOD and fecal coliform are -0.2 and -0.8 respectively.

D. The decay coefficient for TSS is a function of the "settling velocity," set at a default value of -0.3.

E. Dissolved oxygen is modeled differently, as a more complicated interaction of oxygen demand from organic materials, the sediment oxygen demand, reaeration from the atmosphere, and the saturation concentration of DO.

NWPCAM Water Quality Ladder

Beneficial Use	Fecal Coliforms (MPN/100 mL)	Dissolved Oxygen (mg/L) / (% sat.)	5-day BOD (mg/L)	Total Suspended Solids (mg/L)
Drinking	**0**	**7.0 / 90**	**0**	**5**
Swimming	**200**	**6.5 / 83**	**1.5**	**10**
Game Fishing	**1000**	**5.0 / 64**	**3.0**	**50**
Rough Fishing	**1000**	**4.0 / 51**	**3.0**	**50**
Boating	**2000**	**3.5 / 45**	**4.0**	**100**

VII. Economic Benefits

A. Use support is calculated using a modified version of the RFF water quality ladder.

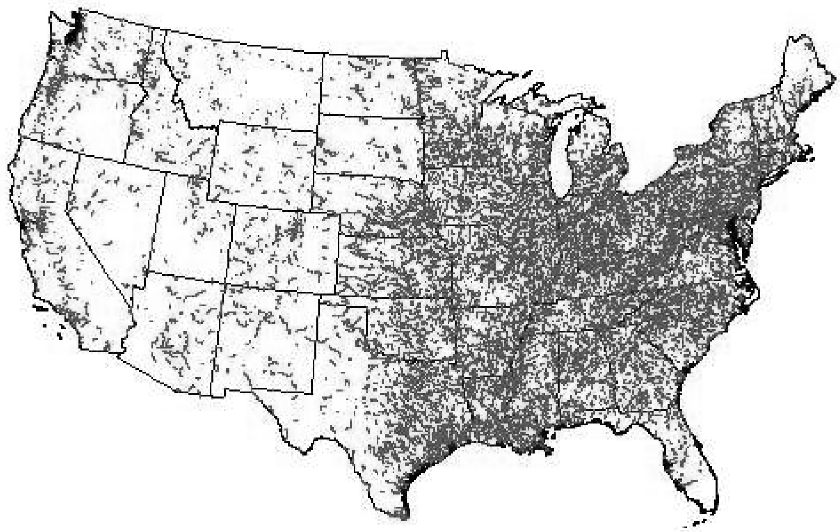
1. The original water quality ladder used DO, BOD, fecal coliform, pH, an dturbidity to distinguish five beneficial use categories: drinking, swimming, game fishing, rough fishing, and boating.
2. pH is not modeled so it is not included in the water quality ladder used in the NWPCAM.
3. Turbidity was converted to TSS using standard conversion techniques.
4. Drinking water was dropped as a category.
5. Game fishing and rough fishing were collapsed into one fishing category.

B. Use support is determined for each computational element based upon the most limiting factor among the four pollutants.

C. If any criteria is in exceedence for boating, the element is classified as having "no use support."

D. Economic benefits are determined by using the Carson-Mitchell household's willingness to pay values for populations proximate to RF1 waters experiencing changes.

Reaches at or downstream of point sources



VIII. Assessing the results

A. The NWPCAM provides two types of outputs

1. The number of miles meeting the designated uses defined in the water quality ladder.
2. A database containing the use support and pollutant concentrations for each of the 655,000 computational elements.

B. One of the tasks of assessing these results is defining what constitutes an improvement from one scenario to the next. Since the ultimate goal is to provide estimates of economic benefits, we use the change in the number of miles meeting various designated uses, but we should recognize that this is a discreet metric to assess changes in pollutant concentrations that occur on a continuous scale. A policy scenario that decreases pollutant loads from point sources creates improvements, although perhaps infinitesimally, in every reach downstream of those point sources. However, if these changes are not sufficient to move a reach from one beneficial use category to the next, then that reach is considered to have had no improvement using the water quality ladder.

C. Another task is to define the base from which to assess this change.

1. If our goal is to simulate improvements from point sources, then we must limit our analysis to reaches affected by these sources.
2. Of the 632,552 stream miles, only 288,034 are downstream of a point source.
3. Additionally 91,353 miles are already suitable for swimming, so no improvement can be made, leaving 196,681 of improvable miles.

Miles of Use Support Under “No Control” and “Zero Discharge” Scenarios for Reaches that are at or Downstream of Any Point Sources

“No Control” Scenario	“Zero Discharge”		
	Swimming (Miles)	Fishing (Miles)	Boating (Miles)
Swimming	91,353		
Fishing	14,446	81,428	
Boating	3,706	7,856	14,853
No Support	15,203	15,990	5,614

D. Even the 196,681 miles of improvable waters is not the correct base from which to assess changes since some downstream reaches may not improve because of non-point source pollution.

E. to find the base of improvable reaches, it is necessary to compare the scenario without the Clean Water Act, that is using the 1972 level of influent removal, with the scenario of zero discharge.

1. This table shows the reaches that improved if there were no point source pollution at all.
2. The main diagonal shows the miles that did not change in use support. For example, 814,000 miles that were fishable but not swimmable at 1972 removal levels remained fishable but not swimmable with 100% effective point source influent removal.
3. 62,815 miles improved in use support with zero point source discharge.

F. It is to these 63,000 miles that we should compare the effectiveness of using the 1990 effectiveness of 82% influent removal.

Sensitivity Analysis

Variable Changed	Degree of Change	Swimmable	Fishable	Boatable	No Use Support
		(Miles)	(Miles)	(Miles)	(Miles)
Baseline		238,627	424,712	475,894	156,658
Flow	+25%	258,267	443,217	490,666	141,885
Flow	-25%	214,517	399,813	453,868	178,684
Vel	+25%	233,822	417,225	469,291	163,261
Vel	-25%	245,776	435,508	484,480	148,072
Ybar	+25%	230,629	416,343	471,865	160,687
Ybar	-25%	251,973	434,724	479,962	152,590
P.S.	+25%	236,389	421,575	472,792	159,759
P.S.	-25%	241,458	428,534	478,927	153,625
NPS	+25%	218,968	403,960	459,655	172,897
NPS	-25%	267,243	449,685	494,129	138,423
CSO	+25%	238,383	424,071	475,291	157,260
CSO	-25%	238,886	425,436	476,541	156,010
SOD	+25%	238,627	424,712	475,894	156,658
SOD	-25%	238,627	424,712	475,894	156,658
KTSS	+25%	248,380	432,656	479,214	153,338
KTSS	-25%	228,993	413,657	470,403	162,149
KBOD	+25%	239,553	428,516	480,621	151,931
KBOD	-25%	237,527	419,848	469,418	163,133
KFC	+25%	238,688	424,712	475,895	156,657
KFC	-25%	238,510	424,712	475,894	156,658
AllUse	+25%	340,296	495,597	526,051	106,500
AllUse	-25%	179,420	340,963	405,946	226,606

IX. Sensitivity Analysis

A. The purpose of sensitivity analysis is to

1. Provide a range to bracket the baseline values
2. Determine which variables had the most significant effect
3. Test the model for hypersensitivity

B. Miles of use support

1. This table shows the effect of changing various parameters up or down 25%.
2. The first row shows the number of miles in each use support category under the baseline. Notice that the numbers do not sum to the total 632,000 miles. This is because the 238,627 miles that are swimmable are also fishable, and the fishable and swimmable miles are also boatable. Therefore, the 476,000 boatable miles include the swimmable and fishable miles as well. Note that the boatable miles plus the no use support miles do add to the required 632,552 miles.
3. Each of the other rows represent the model runs with one parameter increased or decreased by 25%. The last two rows show the model results if all of the above parameters were increased or decreased by 25%.

Sensitivity Analysis - Percent Change from Baseline Runs

Variable Changed	Degree of Change	Swimmable	Fishable	Boatable	No Use Support
Baseline		0.00%	0.00%	0.00%	0.00%
Flow	+25%	8.23%	4.36%	3.10%	-9.43%
Flow	-25%	-10.10%	-5.86%	-4.63%	14.06%
Vel	+25%	-2.01%	-1.76%	-1.39%	4.22%
Vel	-25%	3.00%	2.54%	1.80%	-5.48%
Ybar	+25%	-3.35%	-1.97%	-0.85%	2.57%
Ybar	-25%	5.59%	2.36%	0.85%	-2.60%
P.S.	+25%	-0.94%	-0.74%	-0.65%	1.98%
P.S.	-25%	1.19%	0.90%	0.64%	-1.94%
NPS	+25%	-8.24%	-4.89%	-3.41%	10.37%
NPS	-25%	11.99%	5.88%	3.83%	-11.64%
CSO	+25%	-0.10%	-0.15%	-0.13%	0.38%
CSO	-25%	0.11%	0.17%	0.14%	-0.41%
SOD	+25%	0.00%	0.00%	0.00%	0.00%
SOD	-25%	0.00%	0.00%	0.00%	0.00%
KTSS	+25%	4.09%	1.87%	0.70%	-2.12%
KTSS	-25%	-4.04%	-2.60%	-1.15%	3.51%
KBOD	+25%	0.39%	0.90%	0.99%	-3.02%
KBOD	-25%	-0.46%	-1.15%	-1.36%	4.13%
KFC	+25%	0.03%	0.00%	0.00%	0.00%
KFC	-25%	-0.05%	0.00%	0.00%	0.00%
AllUse	+25%	42.61%	16.69%	10.54%	-32.02%
AllUse	-25%	-24.81%	-19.72%	-14.70%	44.65%

C. Percentage change from the baseline

1. The total number of miles is hard to read, so this table shows the percentage of miles changed from the baseline.
2. The parameters that have the largest impact are the flow variable and the non-point source contribution.
    a. The flow variable is calculated from reaches with USGS gauging stations and estimated for other reaches, so it can be checked.
    b. The sensitivity of the non-point source contribution suggests that more attention needs to be paid to this variable.
3. Parameters with moderate impact on the results are the velocity, Ybar (i.e., the average stream depth), and the decay factor for TSS.
4. Note that the effect of point source loadings does not have a significant impact on the use support designation. This is result must be viewed with caution since we are now using all of the river reaches in the model once again. To get the correct effect of the point source loadings, we would have to use the correct base as described previously.

Two criteria for “goodness of fit” are used:

1. The difference between STORET and Model concentrations by reach:

$Delta_{Conc} = Conc_{STORET} - Conc_{Model}$

2. The difference between STORET and model use support estimates by reach:

$Delta_{Use} = Use_{STORET} - Use_{Model}$

X. Goodness of fit

A. To get a measure of how well the model is predicting, it is necessary to compare it to some known, true values. In this case, the only data that comes close to meeting this criterion is STORET data. This data contains true water quality measures, but it is reported to the EPA by the states and is not checked for correctness nor consistency of methods. It is far from the random sample that we would desire for measuring the predictive capacity of the model. Nevertheless, it is the best data available and so we will treat it as our truth.

B. We use two criteria for goodness of fit.

1. The most obvious is the difference between the STORET concentration levels and those predicted by the model.

2. Since this model ultimately is to be used to measure beneficial uses, we also measure the difference between the STORET and the model estimates of use support.

NWPCAM Results Compared to STORET for DO

Statistic	Concentration (mg/l) STORET	Model	Delta	Use Support (0, 1, 2, 3) STORET	Model	Delta
N	3,455	3,455	3,455	3,455	3,455	3,455
Mean	7.72	8.46	-0.74	2.75	2.95	-0.20
Std. Dev.	1.59	1.16	1.63	0.60	0.32	0.67
Skewness	-0.63	-1.97	0.22	-2.76	-7.58	-1.11
Kurtosis	2.16	12.75	4.36	7.80	60.5	7.81
90%	9.55	10.21	0.90	3	3	0
75%	8.75	8.92	0.17	3	3	0
Median	7.85	8.42	-0.67	3	3	0
25%	6.90	7.95	-1.63	3	3	0
10%	5.80	7.62	-2.60	2	3	-1

C. DO

1. Note that a negative number implies that the model is over predicting.
2. The model over predicts for DO concentrations, but not by much.
3. We now have to question what is the proper measure of central tendency. Mean is traditional, but it is affected by outliers. Given the degree to which the model spikes after a point source, the median may be a better guide.
4. The model over predicts concentrations using the median as well.
5. The model is very close in predicting use support.

NWPCAM Results Compared to STORET for BOD5

Statistic	Concentration (mg/l) STORET	Model	Delta	Use Support (0, 1, 2, 3) STORET	Model	Delta
N	2,159	2,159	2,159	2,159	2,159	2,159
Mean	1.91	6.84	-4.92	2.3	2.3	0.0
Std. Dev.	1.49	39.5	39.4	0.9	1.1	1.2
Skewness	4.32	9.62	-9.6	-1.3	-1.3	0.2
Kurtosis	37.27	98.42	99.2	0.9	0.2	0.9
90%	3.6	5.57	1.95	3	3	2
75%	2.3	2.3	1.0	3	3	0
Median	1.45	1.0	0.3	3	3	0
25%	1.0	0.5	-0.6	2	2	-1
10%	0.9	0.4	-3.5	1	0	-1

D. BOD

1. The model substantially over predicts using the mean.
2. The model only slightly under predicts using the median values.

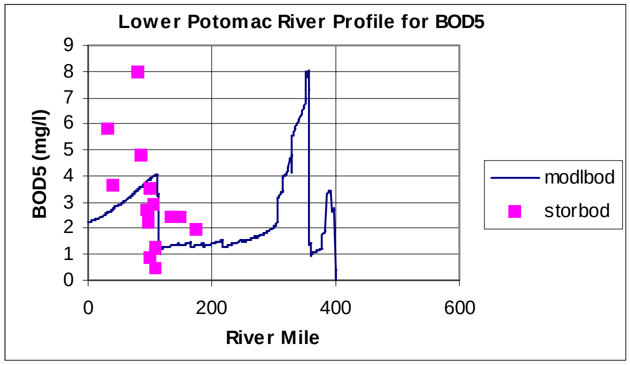
3. Use support estimates in this model are right on.

NWPCAM Results Compared to STORET for TSS

Statistic	Concentration (mg/l) STORET	Model	Delta	Use Support (0, 1, 2, 3) STORET	Model	Delta
N	392	392	392	392	392	392
Mean	445	43	402	1.8	2.2	-0.3
Std. Dev.	5,817	138	5,819	1.1	0.7	1.2
Skewness	19.1	9.3	19.1	-0.6	-1.0	-0.1
Kurtosis	373	112	373	-1.1	0.3	0.3
90%	219	80	165	3	3	1
75%	75	31	42	3	3	0
Median	20	13	2	2	2	0
25%	6	4	-5	1	2	-1
10%	2	1	-38	0	1	-2

E. TSS
1. The model grossly under predicts using the mean
2. The model under predicts using the median
3. The model is fairly close in its predictions of use support
4. This suggests that more effort may be needed with the modeling of TSS.

F. The results for fecal coliform are not reported because of a lack of STORET data.
G. The model may need additional development in its estimates of concentrations, but appears to be a good predictor of use support.



XI. Case Studies

A. A more traditional method of check the predictive capability of a model is the profile plot, where the pollutant concentrations for a stretch of water are plotted on the same graph as the STORET values.

B. Lower Potomac River

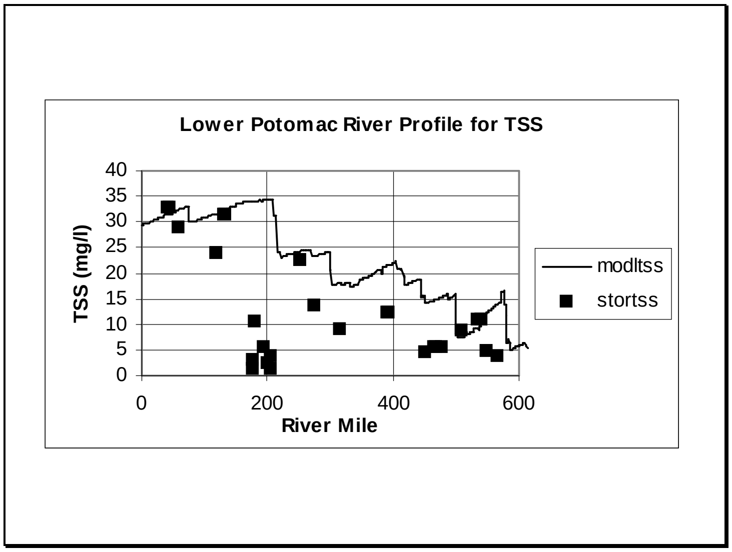
1. BOD

a. The plot is read upstream, with river mile 0 corresponding to the Chesapeake Bay, Washington, D.C. around mile 100, and Cumberland Maryland around mile 350.

b. STORET values are clustered around D.C.

c. The model captures the rise in BOD around D.C., but misses closer to the Chesapeake Bay.

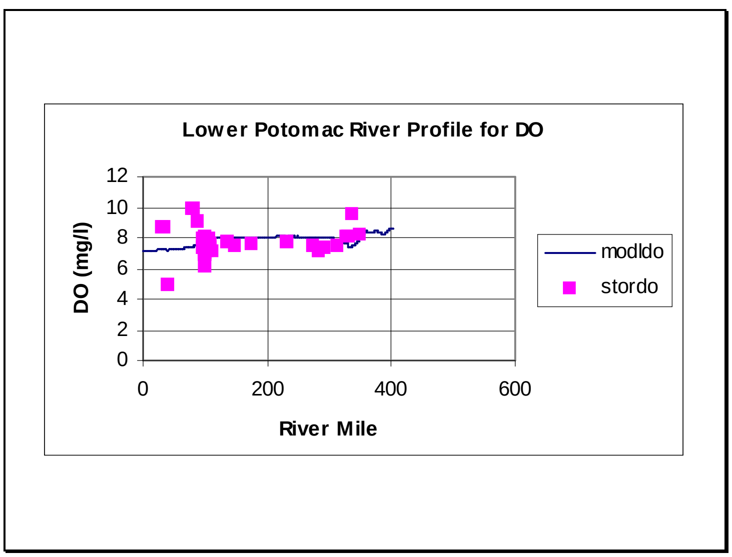
d. Additional estuarine modeling may be necessary.



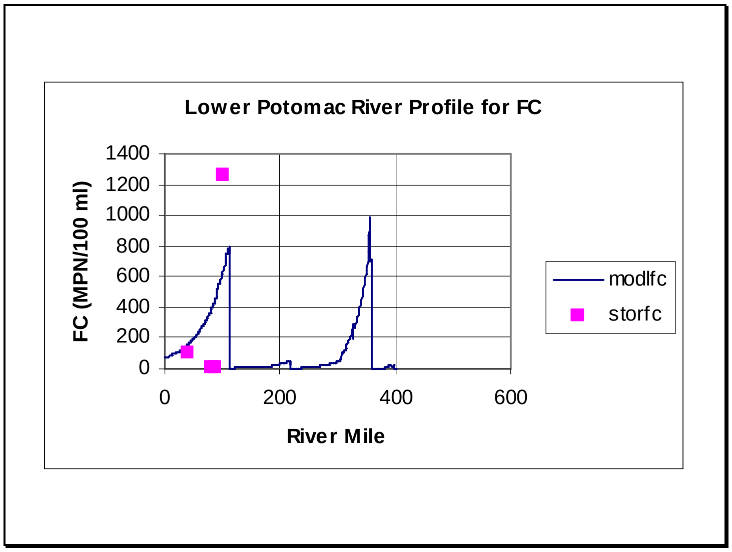
2. TSS

a. The model slightly over predicts TSS.

b. The cluster of low values around mile 200 are troublesome and may represent a misclassification of STORET values.



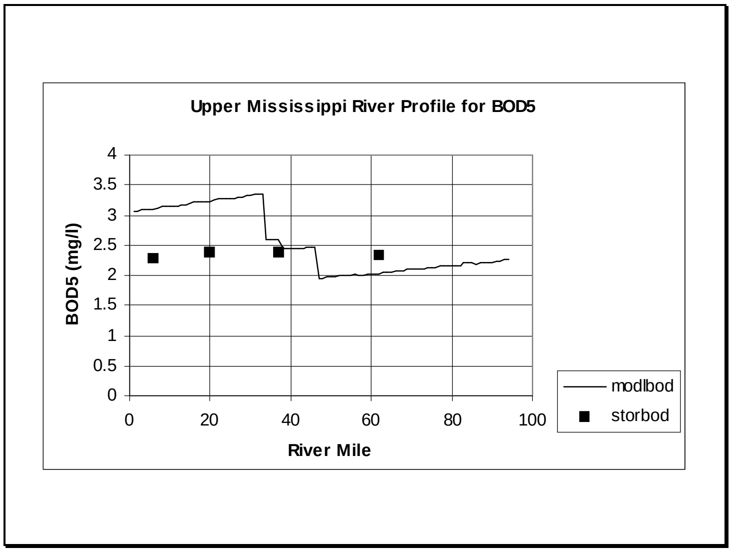
3. DO - The model predicts well for DO



4. Fecal Coliform

a. The model catches the spike around Washington, D.C.

b. Notice the absence of data on fecal coliform and the non-random nature of the data, clustered around D.C.

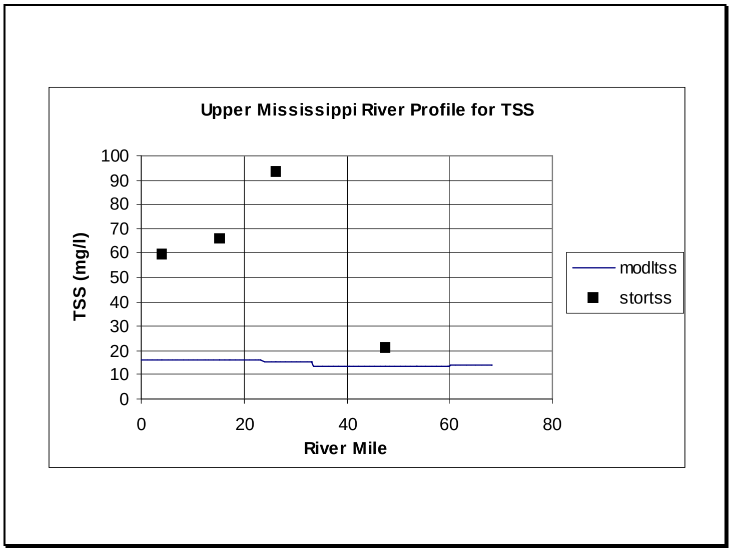


C. Upper Mississippi

1. BOD

a. The Wisconsin border is mile 0, at the confluence with the S. Clair River. Minneapolis-St. Paul is around Mile 30.

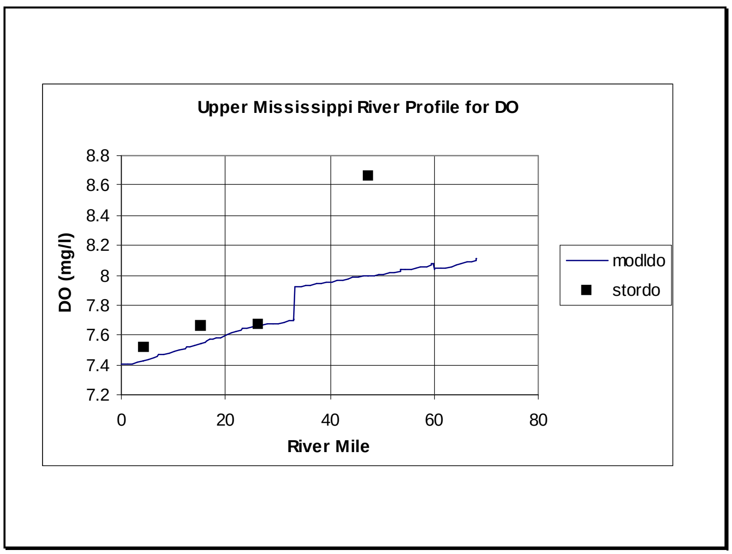
b. The model comes close to the STORET values.



2. TSS

a. The model substantially under predicts TSS, particularly around Minneapolis-St. Paul.

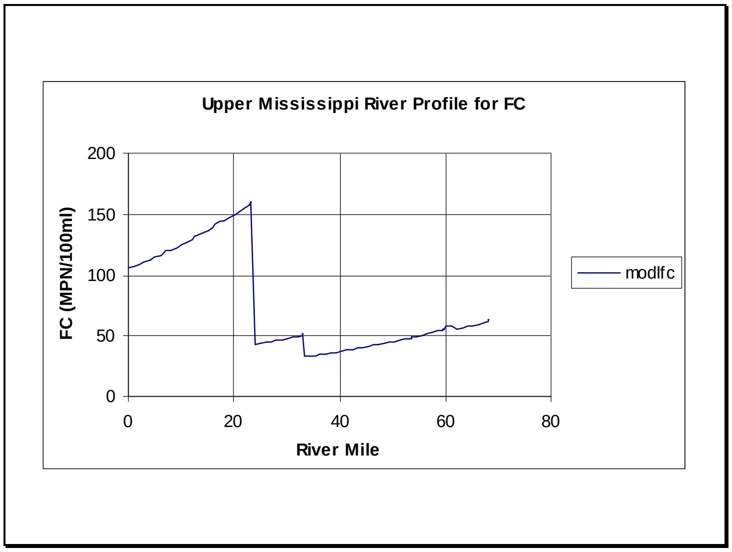
b. This may be due to non-point source loadings from the sediment runoff from the flat landscape. Additional non-point source modeling effort may be necessary.



3. DO

a. The model does well with DO

b. The difference between the model and the one missed point in only 0.6 mg/L.



4. Fecal Coliform - There are no STORET point for fecal coliform for this stretch of river

XII. Conclusions

A. From a modeling perspective, this exercise has been a success. The entire river reach system has been wired together in a reasonable fashion that allows national-level modeling.

B. The model's predictive ability is good

1. The model does not appear to be hypersensitive to any of the parameters
2. The model may need additional effort to more closely model pollutant concentrations
3. The model does well in predictive use support and may be used to predict changes in use support due to policy recommendations

C. Extensions

1. There is a version of the model that includes toxics.
2. Nutrients should be added to the model soon, which will include additional modeling of non-point sources.
3. The model will hopefully be linked to estuarine and coastline models to get a more complete measure of the benefits associated with changes in water quality.

Water Marketing & Instream Flow Enhancement in the Yakima River Basin

--Working Paper*--

PRESENTED BY:
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U.S. Bureau of Reclamation

- This is a working paper developed for the US Environmental Protection Agency Office of Economy and Environment, Office of Research and Development, and Region 10's workshop, "Economic Research and Policy Concerning Water Use and Watershed Management," held on April 21-22, 1999, at the Crowne Plaza Hotel in Seattle, Washington.

Note*: This paper was not presented at the workshop, as Ms. Yerxa was unable to attend due to illness.*

WATER MARKETING AND INSTREAM FLOW ENHANCEMENT IN THE YAKIMA RIVER BASIN

Introduction

The people of the Yakima Basin are highly dependent upon water from the Yakima River and its tributaries to meet a multitude of economic, environmental and social needs. The state allowed the water of the Yakima River and its tributaries to be over appropriated by the turn of the century. Present rights to water actually exceed the supply during most years. The Yakima Basin is the scene of intense competing demands; there are conflicting water needs for irrigation (both Indian and non-Indian), instream fisheries (both resident and anadromous), recreation, municipal and industrial, and to a smaller extent hydroelectric power.

The inhabitants of the Yakima River Basin, as in other arid regions, are aware of the importance of scarce water. Faced with evidence of shortages of supply to meet growing demand, the typical response has been to: commission a comprehensive study of resources; project the demand on an unconstrained scenario; consider the various supply-augmentation options (ie. build more reservoirs); recommend that which meets projected demand at the least cost (often not including external costs such as degradation to the environment); and implement the scheme through public agencies and at subsidized prices. Water management in the Yakima Basin has followed this traditional supply-side approach. The supply-led approach to water provision, coupled with under-pricing water, guarantees a long-term water problem. However, in the Yakima Basin a promising shift toward emphasizing more careful management of water and related resources is currently underway.

Endangered Species Act & Clean Water Act

Anadromous fish populations in the Yakima River and its tributaries, as well as other areas in the Columbia River system, have been seriously depleted from the historic levels (pre-1900s) when an estimated 600,000 to as many as 900,000 adult salmon and steelhead returned to the Yakima Basin each year. In the Yakima Basin, bull trout and steelhead are listed under the Endangered Species Act (ESA) and spring chinook are proposed to be listed under the ESA. There are also violations of section 303D of the Clean Water Act (CWA) in a number of reaches of the Yakima River and its tributaries. The lack of instream flows is one of the criteria used to determine violations of the CWA in the Yakima River Basin.

The Yakima River Basin Water Enhancement Project

In 1994, Congress passed the Yakima River Basin Water Enhancement Project (YRBWEP), Title XII of Public Law 103-434, in an effort to protect, mitigate and enhance anadromous fish and wildlife and to improve the reliability of water supply for irrigation. The major focus of this legislation is a voluntary Yakima River Basin Conservation Program (Basin Conservation Program). Title XII, Congress directed the

Secretary of Interior, acting through the Bureau of Reclamation (Reclamation), to facilitate water and water right transfers, water banking, dry-year lease options, the sale of lease of water, and other innovative allocation tools to address a host of problems encountered by Yakima River Basin anadromous fish in various life cycles and at various times throughout the year. Sections 1203 and 1205 of Title XII authorizes Reclamation to purchase or lease water, land, or water rights from anyone willing to limit or forego water use on a temporary or permanent basis for the benefit of anadromous fish and wildlife. Title XII authorizes up to $10 million (indexed to $12 million) and provides authority to use funds from the Basin Conservation Program appropriation of $67.5 million to acquire water and land.

Pilot Water Acquisition Program

As a forerunner to the full-scale water acquisition program authorized under Title XII, the Upper Columbia Area Office (UCAO) of Reclamation, in cooperation with the Environmental Defense Fund (EDF), developed and implemented a two-year Yakima Basin Pilot Water Acquisition Program. The pilot program was designed to address the legal, institutional, and public acceptability aspects of acquiring water and transferring to instream flow purposes. The pilot program began in FY 1995 and extended through FY 1996. The pilot program assisted in assuring the viability of the water and land acquisition program authorized under Title XII.

The pilot program was framed around a report written in 1994 by EDF (Zach Willey and Adam Diamant) titled, *Restoring The Yakima River's Environment: Water Marketing & Instream Flow Enhancement in Washington's Yakima River Basin*. The report states that economic value of water leases can be approached from a number of perspectives, but it suggests that Reclamation consider utilizing individually negotiated and auctioning lease solicitation options because these approaches are inherently tailored to the accommodation of the variable individual circumstances faced by potential lessors in the Yakima Basin. During the pilot program the EDF provided Reclamation with economic evaluations for water leases based on income approach.

In 1996, Reclamation leased water rights appurtenant to approximately 460 acres of land irrigated from the Teanaway River, a tributary in the upper Yakima Basin. These lands produced predominately timothy hay with a lesser amount of oat production, and were temporarily fallowed during the period of the lease. As a result of the water leases, approximately 2500
acre-feet of water rights were left in the Teanaway River to enhance instream flows. Reclamation paid between $23 to $40 an acre-foot to lease these water rights. Reclamation sought and received a change in purpose of use from an irrigation water right to an instream flow water right; this was the first time in the state that an irrigation water right was transferred and protected as an instream flow right.

Water and Land Acquisition Program

In FY 1997, Reclamation implemented the Yakima River Basin Water and Land Acquisition Program (Acquisition Program) authorized under Title XII. The main objective of the Acquisition Program is to obtain water or land with appurtenant water rights, through leasing, purchase, or other arrangements (ie. conservation easements), to provide for enhanced instream flows, flushing flows, and other instream uses and to conserve, protect and restore essential habitat for anadromous fish in the Yakima River and its tributaries.

Reclamation executed five water lease contracts in both 1997 and 1998 on two tributaries to the Yakima River. A total of approximately 1100 acres of irrigated farm land, producing predominately timothy hay, was temporarily fallowed. The associated irrigation water rights of approximately 6,000 acre-feet were transferred and protected as an instream flow. Reclamation paid approximately $23 to $35 an acre-foot for these natural flow water rights.

Reclamation is currently considering a number of water rights and /or lands with water rights for permanent acquisition in the Yakima Basin. Several of these acquisitions are likely to be completed by the end of the current fiscal year, while others are in various stages of the acquisition process. Reclamation will be looking for opportunities to partner with Bonneville Power Administration, Yakama Indian Nation, The Nature Conservancy (Conservancy), or others to acquire water rights and/or lands with appurtenant water rights.

The Nature Conservancy
Reclamation's UCAO entered into a cooperative agreement with the Conservancy in September of 1998. The Conservancy has expertise in the area of land and resource valuation and protection, and is experienced in accomplishing complex land conservation transactions. The Conservancy is providing valuable assistance in development and implementation of the Acquisition Program and is furnishing the land appraisals for the Acquisition Program.

Underlying Science
In the Columbia River Basin over $3 billion dollars has been spent in anadromous fish restoration, with little success. In 1994, the Northwest Power Planning Council (Council) and the Bonneville Power Administration funded a review of underlying science for salmon and steelhead recovery efforts in the Columbia River Basin. The Council's objective was to provide to the region a clear and authoritative analysis conducted by impartial experts. The Council asked that a group of independent scientists (Independent Scientific Group) develop a conceptual foundation for salmon and steelhead recovery efforts. In 1996, the Independent Scientific Group submitted a report, *Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem*, to the Council. The "normative river" conceptual foundation proposed in this report provides the scientific foundation for policy development and has been incorporated into the Acquisition Program.

A Biological study funded by the Basin Conservation Program and the Acquisition Program is on-going in the Yakima River Basin, under the direction of Dr. Jack Stanford (co-author of *Return to the River*), Director of the Flathead Biological Station, University of Montana. The study is directly relevant to the Acquisition Program because it will provide recommendations for actions needed to maintain or restore the environmental integrity of the most sensitive areas of the river basin in priority order. The study will also provide a protocol and baseline for long-term monitoring of the ecological integrity of acquired floodplains, riparian, and wetlands, thought to be critical to the recovery of salmon and steelhead runs in the Yakima Basin. Dr. Stanford provided Reclamation with a list of "critical river reaches" in the Yakima Basin where acquisition and restoration efforts (possibly water conservation) should be focused. The listing and prioritization of critical river reaches will aid Reclamation in prioritizing proposals, with an eye toward funding those proposals that provide the greatest net benefits, which obviously will include biological benefits.

Umatilla River Basin Water and Land Acquisition Program

A water and land acquisition program for the Umatilla River Basin is authorized under Section 209 of the Umatilla Basin Project Act of 1988, Public Law 100-557. This legislation authorizes $1 million to acquire from willing parties land, water rights, or interests therein for the benefit of fishery resources. Reclamation is working cooperatively with the Conservancy to purchase water rights and land with appurtenant water rights in the Umatilla River Basin. Additional funding for this program is under consideration for inclusion in Phase III of the Umatilla Basin Project Act.

Issues

Over the past almost 100 years, Reclamation programs have evolved from those with an emphasis on irrigation and power development to a much broader range of water resource management. Reclamation must enhance the transition of water from irrigation to other uses, but the internal mechanisms to do so are not necessarily in place. The implementation of the Yakima and Umatilla acquisition programs have been impeded due the following issues:

Economic evaluation of water rights

The traditional way that Reclamation values water rights does not provide an avenue for a willing seller/lessor market based acquisition program. This has been the number one problem in implementing the acquisition programs in the Yakima and Umatilla Basins. We will continue to utilize individuals or entities with expertise in this field.

Land appraisals

Reclamation's history and process of land acquisition by condemnation does not allow us to be competitive in the market. The Conservancy is working with us to provide land appraisals for the Acquisition Program.

Requirements for water acquisition

The requirements followed by Reclamation in acquiring land are not conducive to water acquisition. Reclamation's Denver office has been contacted regarding this issue and agree that the requirements for water acquisition should not follow the same requirements for land acquisition. They will look into this issue but they do not have a set policy.

Discussion of Napier and Tucker paper and of Bondelid, Griffiths and Van Houtven paper --Summarization

by Dr. Scott Farrow, Carnegie Mellon University

Napier and Tucker paper:

Dr. Farrow opened his remarks by emphasizing the need to consider the economic issues raised by the papers. With respect to the Napier and Tucker paper, Dr. Farrow commented on the importance of the question being asked by the authors, i.e., the factors determining the adoption by farmers of conservation practices. Dr. Farrow also complimented the data collection efforts of Mr. Napier's and Mr. Tucker's team, and noted that the data was clearly intended to provide a sense of the importance of perceptions of farmers regarding the costs and benefits of adopting conservation practices. However, the project seemed to be focused upon soliciting the willingness of farmers to accept a subsidy to adopt a conservation practice, and the authors neglected to discuss a very extensive economic literature on contingent valuation. In particular, the literature on survey design, survey instrument choice and the framing of questions was particularly important to address.

Dr. Farrow expressed concern with the choice of the authors' dependent variable, an index of conservation behavior for a farmer which is a rough measure of the conservation value of the way in which the farmer farms the land. The index is a sum, over the various different possible conservation practices, of a product of two variables: a discrete variable representing the frequency with which the farmer employs the conservation practice, with five different values ranging from "never" to "once a year" to "more than once a year," and a variable representing the conservation value of the practice, the values of which were obtained from expert elicitation. Here again, a large literature on expert elicitation should have been discussed, particularly on multi-attribute utility functions. Also, it is not clear exactly what is being measured by this dependent variable. Is it the social cost of the way a farmer practices farming? The authors are correct in stating that the literature on the social costs of nonpoint source pollution is very weak, but there has been some work done in this area by Marc Ribaudo and others that the authors did not reference.

With respect to the regression analysis, Dr. Farrow suggested that the authors might wish to use frequency of conservation practice as a dependent variable, and attempt to ascertain the determinants of frequency. The authors could still used their discrete frequency variable if they employed an ordered probit model, and could still use the same explanatory variables. The authors could even use the expert perceptions of social cost as an explanatory variable to see if the social costliness of a farming practice influences a farmer's decision to adopt a practice. Finally, the authors should have also discussed the economic literature on diffusion of technological change in agriculture (Griliches, Mansfield, and others more recent), and distinguished their paper from this literature. In sum, Dr. Farrow concluded that more economics could have been utilized in this paper, and that some economic literatures need to be discussed.

Bondelid, Griffiths and Van Houtven paper:

Dr. Farrow remarked that the question being asked by the authors, the benefits of water quality improvement, is a highly worthwhile question. Dr. Farrow also noted that this is an interdisciplinary question and expressed hope that this paper will be presented by the authors in a variety of professional audiences.

Dr. Farrow noted that the authors have combined a very large and complex water quality model with a larger economic analysis. However, in a paper that Dr. Farrow had co-authored earlier[1] using a similar economic model (that was less data-informed than the present paper) he had used EPA-mandated state water quality reports for his water quality data, and used contingent valuation data to measure benefits. The conclusion of Dr. Farrow's paper was that better information linking expected water quality improvements with benefits is necessary to plan efficient programs. Dr. Farrow noted that the present paper is a very large improvement on the water quality aspect of the analysis.

The paper suggests two types of policy questions, which Dr. Farrow labeled a "Gore Question" and a "Thompson Question." The Gore Question pertains to environmental efficacy: "is the environment getting better or worse?" It is thus important to ask, "what can the model utilized by the authors (the National Water Pollution Control Assessment Model, or "NWPCAM") tell us about the answer to this question?" The model is aimed at quantifying the economic benefits of the Clean Water Act, and hence utilizes two scenarios – one with the Clean Water Act and one without. This is an important question, but can it also answer the Gore Question? The current model utilizes stream-miles improved in a category as a unit of analysis, but is it the best index? Dr. Farrow proposed an index of water quality whereby:

- p_i^0 = the quality level or economic value of water quality at a baseline level for a stream segment *i*
- $p_i(Q)$ = the value of water quality level Q for stream segment *i*
- q_i^0 = a quantity measure of the importance of stream segment *i*, which can either be binary or a weighting measure of the population using stream segment *i*.
- n is all of the stream segments in the U.S.

$$\sum_{i=1}^{n} \frac{p_i(Q) q_i^0}{p_i^0 q_i^0}$$

While this is a standard index form, slightly more complex forms such as Fisher's Ideal Index may be used or issues of pollution aggregation may be addressed more directly. Dr. Farrow noted that the water quality ladder used by the authors is compressed from that originally used by Mitchell and Carson.[2] Mitchell and Carson's water quality ladder

1 Lyon, R.M. and S. Farrow. (1995) "An economic analysis of Clean Water Act issues." Water Resources Research 31(1)213-223.

2 Mitchell, R.C. and R.T. Carson. (1989) Using Surveys to Value Public Goods: The Contingent Valuation Method. p. 345. Resources for the Future, Washington, D.C.

included levels cleaner than "suitable for swimming" and dirtier than "suitable for boating." While this is not likely to be a serious problem, Dr. Farrow expressed curiosity regarding this decision.

Mr Farrow also noted that in his earlier paper he utilized state reports that are required to be filed with the EPA under section 305(b) of the Clean Water Act, which can be viewed as characterizing waters in the same terms as the Mitchell and Carson water quality ladder. Analyzing data at this level is useful for answering the Gore Question on a state basis, and might well be even more useful for a watershed-level analysis.

The economic question, which Dr. Farrow called the "Thompson Question," pertains to the efficiency of water quality regulation: "do the benefits of water quality regulation outweigh the costs?" While it is clear that the model will eventually be able to produce benefit estimates, Dr. Farrow noted that it is not clear that it will produce estimates of cost (little economic information is included in the paper), which is an important piece of information.

There are other economic questions raised by the paper. First, the authors might wish to expand upon the earlier Mitchell and Carson study,[3] which was completed almost sixteen years ago. Given the advances in contingent valuation, a better data set might be used. Second, the local attribution of population is very important in this model, since willingness to pay assumes a representative consumer. Attribution is important not only from a sampling point of view, but in considering the substitution effects for a given population. The fact that a stream reach is within a population boundary does not mean that the willingness to pay to improve that stream reach should be considered in isolation of other stream reaches. Third, discounting is omitted from the model. Fourth, it might be useful to use this study to compare contingent valuation with alternative methods of measuring benefits. Fifth, Dr. Farrow raised an aggregation issue that is characteristic of studies that hypothesize very large changes in environmental quality. He referred to a study that found that Americans were willing to pay, in the aggregate, 20% of Gross Domestic Product for the air quality benefits achieved by the Clean Air Act. If the willingness to pay estimates for this study are similarly large, critics might question the validity of the estimates.

Dr. Farrow lauded the efforts that the authors undertook to validate their data, although he suggested that the water quality inventory could also be tied back to the Clean Water Act section 305(b) state reports. Also, the authors might wish to consider disaggregating their analysis, perhaps down to the state or watershed levels, when attempting to ascertain the expected water quality benefits.

Dr. Farrow suggested some extensions. Including cost estimates might be extremely useful, and may serve to inform policymakers about the possibility of water quality trading. This may be especially useful in the context of looming deadlines for total

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3 Mitchell, R.C. and R.T. Carson. (1984) An Experiment in Determining Willingness to Pay for National Water Quality Improvements, Draft Report to U.S. Environmental Protection Agency. Resources for the Future, Washington, D.C.

maximum daily load regulations, which require states to establish the total pollutant load that may be introduced into a stream in order for the stream to meet water quality standards. The authors could also extend their work by introducing uncertainty into their model, as to whether water quality levels could actually be achieved by prescribed policies. Finally, households are not the only beneficiaries of water quality improvements; given the industrial uses of water, the industrial benefits of clean water should not be overlooked.

Dr. Farrow offered four conclusions of his discussion of the Bondelid, Griffiths and Van Houtven paper. First, the authors should not oversell the national coverage of their estimates. Second, the authors could expand their use of economics. Third, the authors should consider exposing the inner workings of their model to critique, in the hopes that some helpful suggestions might be made. Fourth, this paper is a large step forward, although much more can be done as the model evolves.

Note: *Ms. Yerxa was unable to attend the conference due to illness, so these comments were not formally presented by Dr. O'Neil.*

Discussion of Yerxa paper

by Bill O'Neil, US EPA Office of Economy and Environment

General

The premise for the new program managed by Bureau of Reclamation is that water is not being allocated efficiently under traditional water rights allocation systems.

Water is in effect subsidized for irrigation users and no market mechanisms exist to reallocate water to more highly valued uses.

In addition, the services provided by water left in the stream are "public goods" (available to everyone) like aquatic habitat support. These kinds of goods cannot be allocated efficiently by market systems, so it is appropriate for the government to determine the correct allocation of water between withdrawal and in stream uses.

The solution to this problem is to allow a government agency, Reclamation, to use public money to buy or lease water to remain in the stream for provision of public goods.

In theory this program is justified and represents a movement in the direction of greater efficiency in water use. But I would like to learn more about the details of the program.

In order to begin a discussion of the paper I would like to ask a few questions and suggest some possible topics for further work.

Price and Value of Water

This writer suggests that water has been provided at a subsidized price. This is a frequent allegation in the west and probably true since trades of water for use away from the original owner's land has generally been prohibited.

The Environmental Defense Fund used an "income approach" to determine the price at which Reclamation buys or leases water from owners. Could you explain what the income approach is?

I would expect that owners would have to be paid a price at least equal to the marginal value of water in the current use. That is the value added to farming by use of water for irrigation for example.

An additional level of efficiency could be attained if Reclamation paid a price equal to what would occur in a free market. That would be the value of the marginal product of water in its most valuable use, which might not be irrigation. Instead it might be equal the price urban consumers might be will to pay for water in residential or commercial use. Were these things considered by EDF?

Instream Value

Finally in deciding whether the water provides it the greatest value by leaving it in the stream we should attempt to estimate the value of the services provided by the aquatic habitat that will be supported by instream flows.

These services include the contribution to maintaining stocks of fish for commercial fishing and recreational activities. The Bureau might consider undertaking some investigation into the value of these services to illustrate the importance of instream flow and the willingness to pay by users of instream flow services. An example of this kind of work was included in the morning session yesterday in the analysis of management of the Snake River. Benefits transfer techniques were used to estimate recreation values as well as commercial fishing values for restoration of the salmon fishery in the Snake and Columbia River systems.

In summary, we need to know whether the \$23 to \$40 per acre foot “price’ is above or below the opportunity cost to owners or other prospective purchasers for withdrawal uses of water. And we need to know whether the value to society of instream flows is above or below the stated range and the opportunity cost of withdrawn water. Only then can we begin to determine the efficient allocation of water between instream and withdrawal uses.

WTP and Actual Payments

To the extent that service from the instream flows would actually be used by local residents, it might be appropriate to ask whether there was a willingness to actually contribute money to a fund to augment the budget available to Reclamation for purchasing and leasing water rights. Could a fund be established? Would local recreation associations agree to help raise money? Would the tourism industry participate in fund raising activities? It may be that an achieving an efficient and biologically appropriate level of instream flows takes more money that the political budget process has allowed. Local beneficiaries might be willing to make up the difference.

Water Supply and the Annual Flow Cycle

Is the shortage problem a continuous problem or is it primarily a problem of flow variation and storage? If shortages are temporary then possibly building impoundments is part of the answer. But if demand exceeds supply even after aggregating flows over a whole year or multiyear cycle then we have a more serious problem of rationing. In the latter case it becomes even more important to determine the demand and value of instream flows so the systems can be managed to provide for the public goods of aquatic habitat.

Alternative Solutions

In addition to using price or estimated values as tools for allocating water, it might be useful to investigate methods for extending the use of a given quantity of water.

More efficient irrigation methods to reduce water per unit of crop yield. These might include drip style irrigation, improve return flow systems, better timing in irrigation applications, adoption of crop types that use less water.

Water recycling could also be examined to determine whether water could be treated after residential or commercial use to the point where it was of good enough quality to be recycled for another use. For example wastewater can be treated and reused for irrigation of non-food crops thus reducing the need for new withdrawals from the rivers.

All these types of water saving activities will be investigated by the private sector when they are required to pay a price which is closer to market value including the value of instream services that must be "purchased" or protected by government for provision of public goods.

Question and Answer Period for Session II

Ted Napier, Ohio State University, first offered a response to some of the comments made by Scott Farrow, Carnegie Mellon University, in his discussion. Some of Mr. Farrow's comments were addressed in other papers. Mr. Napier replied that perhaps more thought could have been given to the title which may have misdirected the reader. An important point raised by Mr. Farrow pertains to the measurement difficulty of the dependent variable; however, the study was not intended to predict adoption of specific types of conservation practices (no-till, conservation tillage, ridge tillage, etc.), because it would be impossible to do so for many of the practices.

Mr. Napier emphasized that the importance of the study is to look at the whole package of conservation practices adopted by farmers, and not falling back upon using one conservation practice (say, no-till, for example) as an indicator of whether the farmer was practicing conservation. It is thus important to deal with the numerous complex activities that a farmer may engage in by developing a multi-attribute indicator. If the inquiry were limited to no-till, for example, the Ohio sample would have appeared to be extremely conservation-minded, and the Minnesota sample would have appeared to be indifferent to conservation. However, if conservation tillage were the practice, then the conservation rankings between the Ohio sample and the Minnesota sample would have been reversed. Finally, it is important to acknowledge the environmental problems associated with some individual conservation practices, which is one reason Mr. Napier used the expert-derived indices of the conservation value of each practice.

With respect to the contingent valuation literature, Mr. Napier noted Mr. Farrow's concerns about omitting a literature review, and replied that he has some concerns regarding the methodology. Mr. Napier closed by noting the importance of taking policy actions very soon, otherwise severe regulatory approaches will become necessary.

Charles Griffiths, US EPA Office of Economy and Environment, also expressed appreciation for Mr. Farrow's comments. Mr. Griffiths noted that many of the suggestions that Mr. Farrow made are already being discussed at EPA, such as updating the Mitchell and Carson data set4 and also using the state reports required to be filed under section 305(b) of the Clean Water Act, which EPA is attempting to develop into a more extensive reporting requirement. Laura Palmer, US EPA Office of Water, remarked that states have several different reporting methods from which they may choose, but over a three- or five-year period, states are in fact required to survey each individual site at least once. Mr. Palmer noted that there is now a push to make reporting more consistent.

Linda Fernandez, University of California at Santa Barbara, asked Mr. Farrow and Mr. Griffiths how they might speculate as to how those locality-specific estimates of water quality that Mr. Farrow suggested might be integrated into the model. Mr. Griffiths

4 Mitchell, R.C. and R.T. Carson. (1984) An Experiment in Determining Willingness to Pay for National Water Quality Improvements, Draft Report to U.S. Environmental Protection Agency. Resources for the Future, Washington, D.C.

replied that there are two ways to achieve this: one is to do a national survey and try to elicit more local rather than national responses, and the other is to perform a recreational analysis and a national travel-cost model. Ms. Fernandez noted that the emphasis still appears to be on the national level, not on the local level. Mr. Griffiths replied that this was due to the national scope of the policies which he is required to evaluate at EPA. Ms. Fernandez asked if the model could accept as input localized results from more local or regional analyses. Mr. Griffiths replied that the model could do this.

Edna Loehman, Purdue University, stated that she was involved in the benefits assessment of the Clean Air Act, and expressed concern that the benefits may not exceed the costs, and that this may be due to ignoring some of the different categories of benefits. For example, clean water provides benefits in terms of drinking water and in terms of a balanced pH. In areas where mercury poisoning is a problem, "clean" water may have other properties that are harmful to human health and wildlife. Mr. Griffiths agreed that there are some categories of benefits that are omitted, and some that may never be included in a benefits analysis. Mr. Farrow commented that EPA eventually came through with very positive figures for benefits as compared with costs, but further remarked that in a scientific inquiry, no estimates should be suppressed. Rather, estimates that are flawed should be criticized openly rather than discarded.

Gary Ellis, US Army Corps of Engineers, Walla Walla District, asked what the definition of "nonpoint source pollution" is. Mr. Napier responded that nonpoint source pollution pertains to nonspecific sources of pollution, whereas point sources are specific, identifiable sources of pollution. Ms. Palmer added that examples of point source pollution include storm sewers, or an industrial plant with a single emissions pipe, while an example of nonpoint sources pollution might be agricultural runoff, or runoff from a road that is not collected in a collection pipe but is instead directly deposited into a water body.

Mr. Ellis also asked a question regarding whether there were any contingent valuation questions valuing the benefits of a wetland. Mr. Napier replied that he only knew of one such paper, which calculated benefits by calculating the cost of mitigation, but Ms. Fernandez replied that she had a review paper titled "Economics of Wetlands," published by the American Petroleum Institute in 1991.

Mitchell Mathis, Center for Global Studies, asked Mr. Napier for some conclusions from his study as to what is most effective in inducing farmers to adopt conservation practices. Mr. Napier replied that direct subsidies typically work best, as farmers almost always have a bid price at which they will undertake conservation practices. "Mickey Mouse" subsidies such as technical assistance and information provision do not work very well. Thus, the USDA Conservation Reserve Program, in which farmland can be retired for conservation purposes, has been much more effective. Mr. Napier compares this with policies in Europe, which tend to be more of a command-and-control nature, which would not work as well here, not because of a monitoring issue, but a political acceptability issue.

John Tanaka, Oregon State University, asked Mr. Griffiths how EPA anticipates using the National Water Pollution Control Assessment Model (NWPCAM) to design regulations, given that the unit of analysis is a stream-mile. Mr. Griffiths responded that Mr. Tanaka was correct in noting that EPA could be in a position of imposing non-national standards upon different regulated parties, but Mr. Griffiths did not feel he was in a position to comment upon how these varying standards would be formulated or executed since these are functions beyond his office's powers. Mr. Farrow added, however, that the present push for water-quality-based regulation is one way that such location-specific information obtained from the model might be used to aid in regulation.

Mr. Mathis asked Mr. Griffiths if there was a potential for web-based customizable watershed-based analysis, to which Mr. Griffiths replied that the EPA Office of Water already has a Geographic Information Systems-based system called BASINS, which can ordered on a compact disc, which contains watershed-level data. Mr. Griffiths also pointed out that EPA is headed toward setting up a website with all of the information from NWPCAM and other watershed information.

Note: the remainder of this question and answer period was devoted to questions for speakers from session one.

Mr. Farrow asked Audrey Perino, Bonneville Power Administration, about some of the ecological irreversibilities inherent in the Snake River study, as opposed to the economic irreversibilities discussed by Ms. Perino. Ms. Perino stated that she is not certain if the economic irreversibilities are truly irreversible. The breaching of the dam will be accomplished by removing the earthen portion of the dam, which will not destroy the power-generation facilities of the dam. There is nevertheless an option value of the time and effort required to decommission the dam. Phil Benge, US Army Corps of Engineers added that the Drawdown Regional Effects Workgroup did build in an irreversibility into their analysis.

Mr. Tanaka asked Ms. Perino how much integration is incorporated into their economic analysis. For example, how would dam breaches on the Snake River affect the Columbia River system? How would transportation networks be affected? Ms. Perino stated that this was largely in the domain of the social impact team or the regional effects team. Gary Ellis, US Army Corps of Engineers, Walla Walla District, stated that it was assumed that there are a fixed number of trucks carrying agricultural and other products, and that a dam breach would raise the rental price of those trucks. Ms. Perino pointed out that regionally speaking, integration issues needed to be better addressed. At present, integration of the Columbia River system has not been accomplished in the Snake River study. The Snake River, however, is unique in that if salmon are to be saved, there are not many options available; on the Columbia River, there are many options. Policymakers may ultimately consider decommissioning dams on the Columbia River as well, such as the John Day dam, or the McNary dam. On the lower Columbia, however, there are better power generation facilities, and decommissioning these dams would be very costly. Biologists are advocating the decommissioning of the John Day dam.

Mr. Napier asked Mr. Benge if the Corps attempted to estimate the nonmarket value of a recreational experience. Bill O'Neil, US EPA Office of Economy and Environment, stated that it was indeed possible to measure the value of hiking and boating experiences, for example, by use of travel-cost analysis, and that this and that this was part of the analysis. Ms. Perino also emphasized that there are numerous political factors that will determine how recreational values might be used even if they are monetized. Mr. O'Neil concurred and noted that one senator was adamant about both maintaining the dams *and* saving the salmon (an almost impossible alternative).

Ms. Perino remarked that the Bonneville Power Administration is concerned that the dams may be decommissioned and that the salmon still might not be saved despite the free-flowing rivers, due to other obstacles that the salmon must face. Tony Prato, University of Missouri, pointed out that the same problem exists with respect to global warming. Mr. Prato also posed the question of whether salmon can be saved elsewhere. Ms. Perino replied that the Snake River dams became an issue because of the listing in 1990 of four Snake River-specific species as endangered species. Now, people are beginning to realize that habitat protection is a broader problem, and cannot be solved by Snake River measures alone. There is now a push for more holistic analysis, which has been labeled "Four-H" analysis, looking at issues of hydropower, habitat protection, harvesting (agriculture) and hatcheries. The problem, Ms. Perino posed, is money, which will almost certainly come from the hydroelectric industry. This may be one reason that the focus on habitat restoration has always been on the dams.

Tony Bynum, Yakama Nation, asked: (1) whether the salmon problem might become moot since the Corps is being sued over water quality standards set by the state of Washington; (2) whether the cost-benefit analysis captures the subsidies that are provided for construction and operation of the dams; (3) whether subsidies provided for the generation of hydroelectric power may be affecting the industry for alternative energy sources; and (4) whether the lost hydropower might be recovered by increasing capacity at other dam sites. With respect to Mr. Bynum's fourth question regarding increasing capacity at other dam sites, Ms. Perino responded that it is more appropriate to phrase the question in terms of the least-cost alternative for increasing Bonneville's ability to meet demand, whether it be increasing capacity or adopting conservation measures. Assuming the region will grow in the near future, it may be necessary to increase capacity at the other sites just to keep up with increased demand. Mr. Bynum remarked in response that it is necessary to balance the costs of increasing capacity with the very large costs of losing species. Mr. Prato pointed out that the subsidies provided to dam operation distorts prices. The result is cheap water, cheap power, cheap grazing and cheap access to federal timber lands, all forms of federal subsidies that if accounted for, would make issues of energy conservation and salmon protection moot. Ms. Perino agreed, but pointed out that gasoline prices are subsidized, also, indicating that many other energy prices are distorted. Mr. Prato cited a report produced by World Watch that estimated the subsidy for gasoline amounts to $5 per gallon.

Mr. Bynum returned to the point of considering conservation instead of capacity increases, and reiterated that it seemed incongruous for DREW to consider relatively inefficient means of providing power, when conservation measures are available and cheap. Ms. Perino replied that DREW was in fact looking at conservation measures very closely, but also considering the capacity-increasing measures that Mr. Bynum referred to. Ms. Perino expressed skepticism that conservation measures can be cost-effective and that consumers would be willing to conserve when power is so cheap in the Pacific Northwest (5 cents per kilowatt-hour).

Mr. Bynum inquired about the problem of sedimentation behind dams, and whether the cost of removing the sediment and the effect on power generation have been considered. Ms. Perino replied that she did not know if these costs were being considered by DREW.

Mr. Tanaka noted that the scenarios that were used by Mr. Ellis's social impact analysis team in their community focus groups were based upon preliminary data, and asked Mr. Ellis how much reliability could be placed upon the findings of the final report. Mr. Ellis stated that preliminary data was close enough to the more recent data to be able to elicit meaningful responses from the community focus group participants.

Note: Ms. Yerxa was absent, but the following discussion concerned her paper.

Edna Loehman asked if Mr. O'Neil might provide some of his planned remarks to the third paper in the session, "Water Marketing and Instream Flow Enhancement in the Yakima River Basin," which was not presented. Mr. O'Neil summarized the paper briefly, noting that it pertained generally to a program whereby the Bureau of Reclamation now has some funding to purchase water rights for the purpose of restoring instream habitat. Ms. Yerxa's paper was to address whether this program would work well, but there was little data in the paper. Maureen Sevigny, Oregon Institute of Technology, noted that in the Klamath Basin's water rights purchase program, only two farmers actually came forward as willing sellers, which was a disappointment. Mr. Bynum added that in the Yakima Basin, rate-setting is problematic because potential sellers are waiting for a better price, leading to a widespread holdout problem. Issues are also raised by leasing alternatives, and outright purchase of the property. Mr. O'Neil noted that the only data in Ms. Yerxa's paper to help the Bureau of Reclamation set set water prices was a study by the Environmental Defense Fund, which estimated water prices by calculating the income generated by using the water for irrigation, and arrived at a range of \$23 to \$40 per acre foot. Mr. Bynum stated that he thought the figure was to lease the water for a year. Mr. O'Neil agreed that there are many questions regarding the Bureau of Reclamation program that need to be answered. Mr. Ellis remarked that if the price of water is high enough, it might be cheaper to buy the land, to which Mr. Bynum responded that it already is cheaper to buy the land. Mr. O'Neil cautioned, however, that the market price of water is not necessarily bounded on the upper end by the price of the land, since the market price for water may involve transportation to urban areas for residential use, which entails transportation costs.