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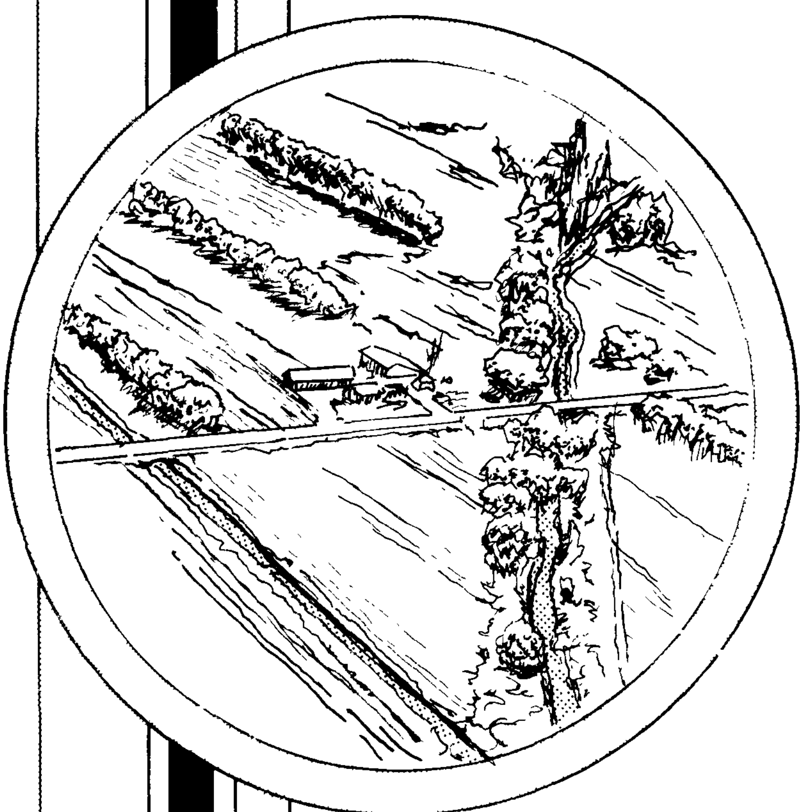
# Executive Summary Agricultural Land Use Water Interaction: Problem Abatement, Project Monitoring, and Monitoring Strategies



## Review Notice

Executive Summary

# Agricultural Land Use Water Quality Interaction: Problem Abatement, Project Monitoring, and Monitoring Strategies

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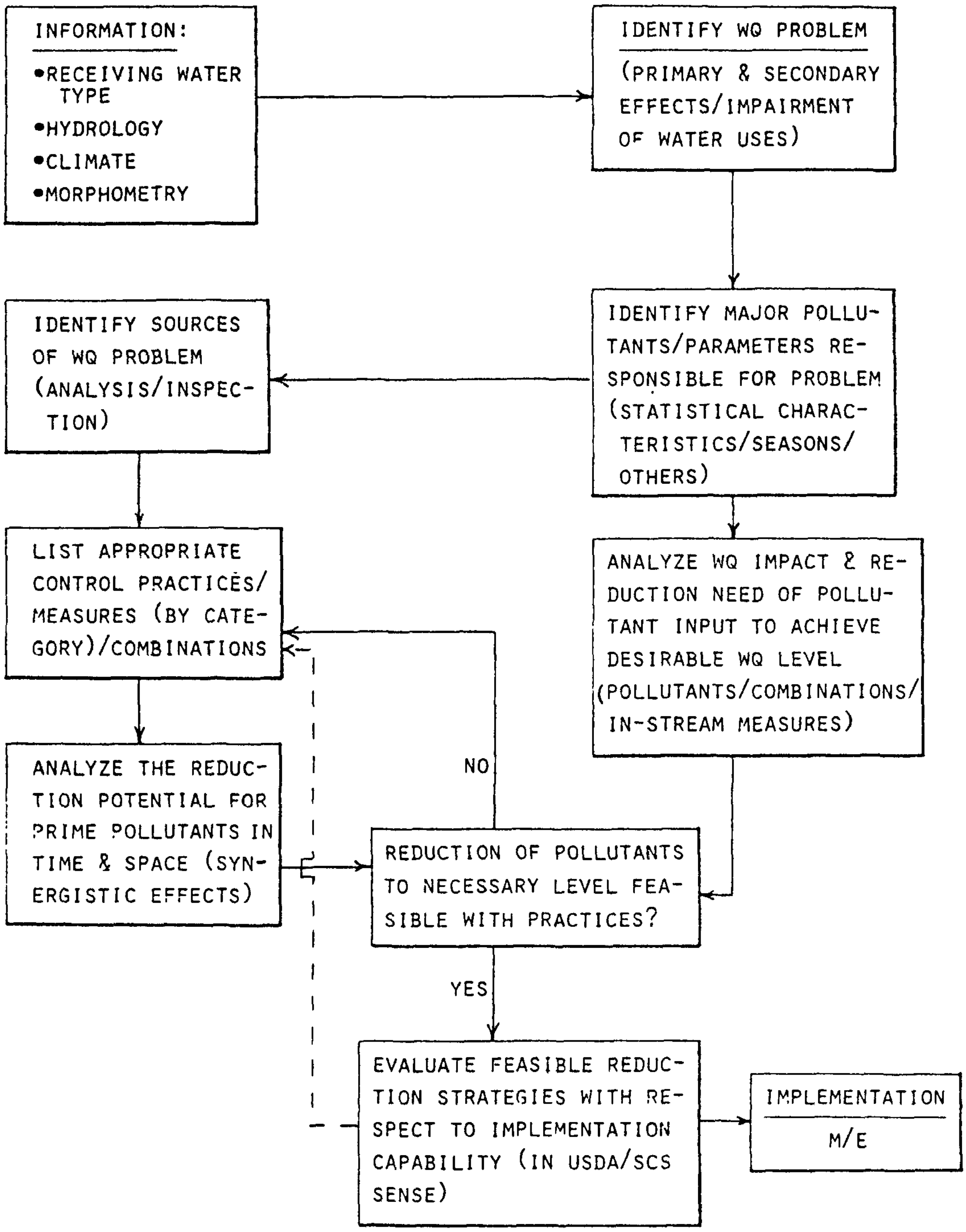
This report, of May 1980, for the U.S. EPA Water Planning Division's Rural NPS Section (under Purchase Order W-5571-NASX) addressed the following three tasks:

- General categorization of agriculturally related NPS pollution problems interfacing with various receiving waters, and outlining of potential remedies through modification of practices and introduction of new practices and/or practice combinations.
- Discussion of the requirements, method, and limitations of individual project monitoring.
- Consideration of the process/strategy of selecting projects for detailed monitoring/evaluation (M/E) across the United States under the Rural Clean Waters Program.

The basic idea underlying this report is that potential remedial actions on the land must be geared to existing water quality (WQ) problems. Thus only those agricultural land uses and practices that appear to cause WQ problems should be modified, and the degree of modification or the introduction of new practices must be determined by needed water quality improvements. This necessitates a "2-track" system for technical evaluation (Figure 1). First, after the water quality problem and its indicators have been described, the sources of the problem must be detected and the potential modifications of the pollutant load through practices/measures analyzed. Second, the desirable water quality must be identified and the reduction in pollutant input necessary to achieve the water quality goal computed (including possible instream measures). Third, the two tracks must be compared in order to determine which practices/measures are capable of reducing the input load such that the water quality goals are met. The implementability of the measures must finally be determined in socio-economic and institutional terms. This scheme requires the identification of cause-effect relationships for each project, the analysis of the pathways of pollutants, and the gearing up of M/E efforts, after preliminary analysis, to the particular water quality problem and its land/water setting.

FIGURE 1. TECHNICAL PROJECT EVALUATION



Given this approach to solving agricultural pollution problems and to monitoring the effectiveness of abatement measures, it is desirable to have a clear idea of three things: the likelihood of encountering water quality problems due to agricultural activities under certain conditions; how to set up the monitoring of problems of individual projects; and how to select projects across the United States. To obtain this general information, variables/parameters of the land/water interface were selected, including basic agricultural land uses, receiving waters, water quality problems and their indicators, and potential practices/measures to improve water quality. The following land uses were chosen:

Cropland*

- nonirrigated
- irrigated

Orchard/Vineyard

Grazing Land (including range, improved range, and pasture)

Animal Holding

Homestead

The following receiving water types were selected:

- Lake/Reservoir
- Small Stream
- River
- Bays (Great Lakes)
- Groundwater

The following water quality problems and their indicators were investigated:

- Sedimentation
- Eutrophication
- Salinity
- Pesticides
- Pathogens
- BOD/Organic Material Loading
- Nitrates

In this characterization "broad" water quality impacts described by combinations of various parameters (such as eutrophication) were combined with "specific" single parameter impacts (such as nitrate). This lumping together is not a problem as long as the pathway of pollutants is indicated and resulting problems are described. Secondary impacts such as on fishing, recreation, etc., were omitted here, since they are related to water uses that were not explicitly addressed in this report.

Five categories of practices/measures that influence water quality were distinguished:

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*In contrast to USGS classification, pastureland is not included in cropland; it is assumed, however, that hayland is included, possibly as part of a rotation.

1) Modification of land use activities without any additional structures and/or addition of nonstructural conservation/control practices;

2) Management strategies;

3) On-site structures attached to or associated with ongoing land use activities;

4) Off-site structures capturing and/or modifying runoff and washoff;

5) Streambank and instream control measures.

Practices/measures for all land use activities could be fit into this scheme. Thus examples of the first control area are chisel plowing (instead of moldboard plowing); of the second area, timing and application of fertilizer and pesticides; of the third area, grassed waterways and terraces; of the fourth area, sedimentation basins, ponds, and grassed strips; and of the fifth area, fencing against animals and copper sulfate application against algal bloom.

A broad identification was made, in sequential steps, of the water quality impact of agricultural activities. These steps were:

1) The description of the pollutants resulting from certain land use activities (Table 1);

2) A review of those pollutants that cause water quality problems (Table 2);

3) The integration of the above two steps into a simplified matrix of potential pollution problems in the different receiving water types resulting from agricultural activities (Table 3).

Since it is well-known that local factors influence the degree of severity of pollution problems, the impact of local soil types, structures, erodibility, and physiographic and climatic conditions was presented, as were examples that clarify the significance of these factors. One example: assume an agricultural land use affects a lake in all four water quality problem areas: sedimentation, eutrophication, pesticides, and $NO_3$. Given the particular interrelationships among sediment, eutrophication, and $NO_3$-N, it is known that erosion control alone might only reduce the sedimentation problem without improving the other water quality parameters. For example, if eutrophication is phosphorus (P)-limited, erosion control is helpful; if it is light-limited, a reduction in the fertilizer application rate is probably needed, in addition to some erosion control measures. $NO_3$ problems can most likely only be eliminated by reduced fertilizer application. Drainage characteristics notwithstanding, $NO_3$ might end up in the reservoir via interflow, a situation not helped by phasing input, since accumulation of pollutants is a problem in this receiving water type. Thus reducing runoff via soil and water conservation practices (SWCP) does not help. Depending on the type of pesticide, SWCP might have some impacts, but most likely, different management schemes would have to be applied to mitigate the problem. Therefore, reducing nutrient and pesticide application rates and timing their application must be added to erosion control practices. This shows that parameters such as sand, silt, clay, distribution of soil/sediment, adsorption

TABLE 1. POTENTIAL GENERATION OF POLLUTANTS FROM VARIOUS (BASELINE) LAND USE ACTIVITIES

| | Run-off | Perco-lation | Runoff | | | | | | | Percolation | | | | | Sediment/Soil* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sed. | N | P | BOD | Patho-gens | Pesti-cides | Salt | N | P | Patho-gens | Pest. | Salt | N | P | Pest. |
| Cropland | | | | | | | | | | | | | | | | | |
| • non-irrigated | X | X | X | X | X | | | X | | X | | | (X) | | (X) | X | X |
| • irrigated | X† | X | X | (X) | (X) | | | X | X | X | | | (X) | X | (X) | X | X |
| Pasture/Range | X | X | X | X | | (X) | (X) | (X) | | | | | | | (X) | (X) | |
| Orchard/Vineyard | X | (X) | X | (X) | | | | X | | | | | (X) | | (X) | (X) | |
| Animal Holding | X | X | (X) | X | X | X | X | | | X | (X) | (X) | | (X) | | X | |
| Homestead | X | (X) | (X) | | | X | (X) | | | X | (X) | X | | | | | |

*Implies also erosion of soils with high natural contents of nitrogen and phosphorus

†In case of irrigated agriculture, the runoff is not based on precipitation, but on irrigation water.

Note: (X) indicates lesser importance.

TABLE 2. POTENTIAL IMPACT OF INDIVIDUAL POLLUTANTS FROM AGRICULTURAL ACTIVITIES ON RECEIVING WATERS

| Impacted Receiving Water | Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sediment | P | N | BOD | Pesticides | Pathogens | Salt | Remarks |
| Lake/Reservoir | X | X | X | X | X | X | (X) | largely cumulative impact |
| Small Stream | X | (X) | X | X | X | X | X | largely transient impacts |
| River | (X) | | | (X) | (X) | (X) | (X) | largely transient impacts |
| Great Lakes (Bay) | (X) | | | (X) | (X) | (X) | | |
| Groundwater | | | X | (X) | X | (X)? | X | slow transition; also cumulative |

Note: (X) indicates the impact is not great.
? indicates the situation is largely unknown.

TABLE 3. AGRICULTURAL LAND USE/WATER QUALITY IMPACTS

| Land Use Activity | Receiving Water | | | | | | Problems |
|---|---|---|---|---|---|---|---|
| | Lake/Reservoir | | Small Stream | River | Bay | Groundwater | |
| | large | small | | | | | |
| Cropland | | | | | | | |
| nonirrigated | X | X | X | (X) | | | Sedimentation |
| | X | X | (X) | | | | Eutrophication (incl. hypol. DO-D) |
| | X | X | X | X | (X) | X? | Pesticide |
| | (X) | X | (X) | | | X | Nitrate |
| irrigated | X | X | X | (X) | | | Sedimentation |
| | X | X | X | (X) | | X | Salinity |
| | X | X | (X) | | | | Eutrophication (incl. hypol. DO-D) |
| | X | X | X | X | (X) | X? | Pesticide |
| | (X) | X | (X) | | | X | Nitrate |
| Orchard/Vineyards | | (X) | | | | | Eutrophication |
| | X | X | X | X | (X) | X? | Pesticide |
| | | | | | | X | Nitrate |
| Pastureland/Range | | (X) | | | | | Eutrophication |
| | | (X) | (X) | | | | Pathogens |
| | | (X) | (X) | | | | BOD |
| | (X) | X | X | | | | Sedimentation |
| Animal Holding | (X) | X | X | (X) | | | BOD |
| | (X) | X | X | (X) | | | Eutrophication |
| | (X) | X | X | (X) | | | Pathogens |
| | | (X) | (X) | | | X | Nitrate |
| Homestead | | (X) | (X) | | | | BOD |
| | | (X) | (X) | | | | Pathogens |
| | | (X) | (X) | | | | Eutrophication |

Note: (X) indicates the impacts are not great.
? indicates the situation is largely unknown.

capacity, trapping of P and nitrogen (N) in the reservoir, excessivity of N over P with respect to algae requirements, turbidity, snowmelt, potential enrichment of soil, and ratio of particulate P to dissolved P all play an important role in designing the overall abatement strategy. As can be seen, an awareness and understanding of the pathways of pollutants is essential.

Project monitoring can cover all the parameters of interest only if pathways of these parameters are known. This makes necessary a sound analytical investigation of the land/water interface prior to any monitoring. Too often, without such an investigation, the wrong parameters have been monitored or the right parameters at the wrong location and/or frequency. Thus, five basic questions have to be answered in setting up a monitoring and evaluation program for an individual project:

1) What are the types of samples to be taken and measurements to be made (constituents, flow, etc.);
2) What are the locations of sampling stations;
3) What is the frequency and duration of sampling at the stations; and
4) What are the methods to be used in sampling and measurement (i.e., equipment, etc.).
5) How are the data to be presented and stored for later analysis.

Generally these five characteristics of sampling programs cannot be considered independently. However, it is unnecessary that the same characteristics be considered for each station.

Therefore, the following steps should be taken in order to set up the most effective monitoring program:

1) Define the critical stretches of the receiving water;
2) Describe the apparent water quality problem in quantitative terms as much as possible;
3) State clearly which are the likely parameters that have to be controlled and in which season they are of concern;
4) State clearly what the critical land areas are that determine water quality impact and describe those individual water quality parameters that are influenced by the critical areas;
5) Assess qualitatively the effects that various BMPs might have on runoff and edge-of-stream load (and on water quality);
6) Attempt an analysis (possibly with regional data) of the impacts of various practices and practice combinations on the pollutant loads, the load distribution, and on the receiving water's quality. On the basis of this analysis, identify the critical parameters to be monitored.
7) Based on the problem's temporal and geographic characteristics, the parameters of concern, and the BMP's anticipated effects, lay out the monitoring network (including flow measurements). Since not all the areas are similar and not all areas are treated with the same practices,

receiving water loads (i.e., flows and concentrations) must be measured at various points. (This is particularly important in the case of lakes/reservoirs in order to derive a pollutant budget.)

8) Be prepared to monitor water quality and flow in creeks (draining to critical water quality stretches) during storm events occurring shortly after applications of fertilizer and pesticides (this generally requires automatic sampling equipment).

9) Determine the frequency of sampling in 1) creeks/drains to the receiving water; and 2) the receiving water's critical stretch. Generally, the frequency of monitoring has to be higher in the upstream portions of the basin than in the downstream portions. Further, frequency depends on the information needed for characterizing a pollution problem in a receiving water. Simply stated, when the pollution problem is of a cumulative nature (like eutrophication in lakes/reservoirs), the critical water quality area can be monitored relatively infrequently. However, the drainage into the major receiving water has to be monitored on a regular basis in order to establish the input patterns. (See also the March draft of NPS Task Force Guidance Document on Monitoring.)

10) Determine the appropriate length of time for a watershed to be monitored. This varies according to the nature of the pollution problem, the nature of the control of management strategy, and the length of monitoring chosen for other watersheds providing information to the program. Longer periods of monitoring reduce the variance of an estimate at a single site, leading to a tradeoff between parameter accuracy and monitoring duration. While long-term monitoring of projects may be required to reduce variance, a greater diversity of projects is desirable so that existing information might be more easily transferred to some sites that have not been monitored at all or only very infrequently.

11) Given the analytical framework for the analysis and the need for constant reassessment of the monitoring scheme and the value of the generated data, the data have to be processed and stored in such a way that they are easily accessible and transformable. All raw data should be kept on file. After initial collection, simple statistical manipulation can be performed and simple relationships plotted. Thus various initial questions about project performance and modeling assumptions can be addressed along with the monitoring performance.

12) Establish a quality assurance program.

It is essential to the success of every M/E project that the data generated are constantly analyzed and the new information fed back for improvement of the program. It is thus necessary to integrate firmly the land/water quality analysis with monitoring and evaluation of the water quality and the performance of the practices. This implies that the monitoring system must be continually adjusted to the results of the monitoring and analysis; it also means that the practices/measures must be adjusted as well. It is obvious that, in many cases, conventional measures do not meet established needs; they must be augmented by management measures, such as application of fertilizer/pesticides and their timing, in order to yield the desired water quality results.

To facilitate selection of potential projects across the United States for M/E, some characteristics/criteria were presented that were considered helpful in comparing these potential projects. Given the fact that potential projects should be identified on the basis of their water quality problems, the following steps are envisioned in the selection process:

1) Determine the areas that exhibit agriculturally based water quality problems, and define a project.
2) Characterize these projects according to important M/E criteria.
3) Weight the M/E criteria for final choice of projects.

Step 1 can be performed more or less along the lines of the current EPA/USDA identification process. Potential projects can be summarized for each region in a simple matrix (such as Table 3) where the entries would be the number of the particular land use/water quality problems in each region. The land use/water quality combinations that cause the most significant deterioration of water quality are considered for implementation. If there is an obvious tradeoff between a "large number" of specific problems (land use/water quality combinations) and infrequent but severely impacting land use/water quality problems, the choice must be made between the "large number" (possibly representing a typical problem) and the individual severe problem. If there is no obvious tradeoff, additional criteria are used, such as typical hydrology, ease of problem identification and isolation, and local capacity.

In step 2 the characterization of the projects chosen in terms of criteria that are important for M/E project selection should proceed in two ways:

1) A determination should be made based on federal perspective whether or not a project is typical.
2) On the basis of technical details, implementation potential, and institutional capabilities, a ranking should be made of the projects not categorized under 1).

Various tools, especially the recent RCA studies, are available for 1) above. For 2) some characteristics/criteria are defined that were tested for their suitability to characterize potential M/E projects (Table 4). Not all of these characteristics/criteria would carry the same weight (see below).

For step 3 the ranking of the projects should be based on these characteristics/criteria, all of which can be viewed as purely descriptive, but most of which guide comparisons in the review process. Thus the weighting should not be static, but should reflect the information gained in conducting M/E projects. In this way, statements can be made about each characteristic/criterion, reflecting, more or less, the current state of knowledge.

1) In selecting projects across the United States, all areas should ideally be covered; however, it is desirable initially to focus on areas that have cold, as well as warm, seasons.

TABLE 4. PROJECT CHARACTERISTICS

1. U.S. Location
   - North/South//East/West (i.e., separation into dry and humid areas and those impacted by snowfall)

2. Water Quality Problem (general)

3. Major Land Use (acres if available)
   - cropland (type of crop)
   - feedlots (covered under RCWP)
   - animal holdings (except feedlots)
   - range/pasture
   - mix (population centers and others)

4. Irrigation/Nonirrigation

5. Point Source Influence
   - point source
   - nonsewered/septic tanks
   - purely nonpoint source agricultural problem

6. Type of Pollution Problem (as defined by review of land)
   - erosion and associated nutrients
   - erosion and associated nutrients and pesticides
   - heavy pesticide use

7. Receiving Water (including hydrologic characteristics)
   - lake/reservoir
   - small stream
   - river
   - bay (Great Lakes)
   - groundwater

8. Drainage/Land Characteristics
   - flat, delta type
   - unclear drainage to critical water quality areas
   - clear-cut drainage
   - slope

TABLE 4. (CONTINUED)

9. Project Area (acres)/Watershed

10. Population in Project Area

11. Critical Area (acres
    - ratio of critical area to project area

12. Number of Farms (in critical land area)
    - large ( > 200)
    - medium (100-200)
    - small ( < 100)

    (these are not absolute limits, but reflect the 13 projects currently considered)

13. Number of Animal Facilities (in critical land area)

14. Water Use
    - drinking water supply
    - recreation (contact/noncontact)
    - fisheries and wildlife
    - agricultural and industrial water supply

15. Specific Water Quality Problems
    - coliform
    - pesticides
    - eutrophication (P-, N-, light-limited)
    - nitrate
    - sedimentation
    - salinity

16. Parameters Previously Monitored

17. Preliminary Analysis in Application (including pathway of pollutants)

18. Protective/Preventive Practices (suggested)

19. Suggested M/E plan in Project Application

20. Inclusion in 208 plan?

2) *A general description of the water quality problem allows a first* indication of the extent to which it can be quantitatively described.

3) It is necessary to isolate as much as possible individual, largely homogeneous land uses in order to draw any inferences for a potential project.

4) The choice of irrigated or nonirrigated land use is largely a matter of agency preference.

5) Any point source or septic tank influence should be minimized because its impact cannot be easily isolated and abstracted from concentration/load estimates, especially in lake/reservoir receiving water systems.

6) Overall *analysis and evaluation are facilitated if one specific* pollution problem can be identified. Different problem types need different remedies in terms of practices/measures, but the more individual practices are eventually combined in a so-called "Best Management Practice" (BMP), the lesser the likelihood that the effectiveness of individual practices can be identified. Thus since combinations of practices are very unique to a specific problem, the fewer problems involved the better and, hence, the fewer practices combined, the more useful the results.

7) Given the current state-of-the-art of identifying and evaluating receiving water pollution phenomena, it must be emphasized that if the receiving water is not a lake/reservoir, it will be difficult to measure and identify water quality impacts. There is, however, at least one caveat to this suggestion: if this receiving water's pollution problem has been present for a long time, it cannot be cleared up quickly, because of the lake/reservoir's "memory" (e.g., nutrients in sediments). This makes it rather unlikely that any changes in water quality can be identified as a result of practice changes in a period of about 5 years.

8) In order to effectively perform M/E, there should be only one drainage area and clear-cut drainage patterns.

9 and 11) The smaller the project's critical area with respect to the total project basin/watershed, the more difficult it is to identify clearly any distinct impacts; also, the smaller the ratio of receiving water surface area to watershed area, the lesser the likelihood that changes due to isolated land practices can be extracted from water quality data. Furthermore, the type of analysis applied is somewhat influenced by this configuration; in impoundments with extremely short hydraulic residence times, seasonal variations of loadings may become of overriding importance.

10) Since permanent and temporary population may contribute to pollution (see 5 above), it is advisable to have as small a population as possible in the project area (including the impacted receiving water area).

12) The smaller the number of farms the better, since diversified ownership of the lands under investigation makes it more difficult to monitor the agreed-upon practices. This is especially true if measures other than structures have to be used.

13) Since a large number of animal holding facilities makes identification of the problem area difficult, it is desirable to have a relatively small, observable number of facilities in the area.

14) Definite water use characterization of the critical water quality stretch is important, since it implies standards for respective water quality parameters that would have been set by the state having jurisdiction over the problem area. Such standards would provide for clearly identifiable thresholds to be reached in the receiving water improvement.

15) Some of the specific water quality problems occur mostly in combination, such as eutrophication, sedimentation, and $NO_3$. This influences the set of practices to be applied (and monitored) and the monitoring requirements (space and time) in the receiving water. Since each pollution problem is characterized by a unique setting, individual practices and combinations of practices must be analyzed in terms of individual pollutants and their behavior in the specific setting. The more interplay there is between problems, the more difficult analysis and monitoring become and thus the more careful their set-up must be.

16) Historical data can give some clue about past water quality trends, e.g., the time period a eutrophication problem has prevailed. But the data base is generally inadequate to draw any conclusions about the land use activities that caused the problem. This means that baseline data are valuable but not essential to the choice of M/E projects.

17-20) The more analysis performed prior to any monitoring exercise the better. The relative level of required analysis depends on the pollutant/practice/receiving water combination for each area (see 15).

On the basis of the above discussion, it is felt that the following factors are most important in selecting M/E projects at this time:

- ease of identifying the water quality problem and its cause;
- eutrophication problems in lakes/reservoirs or in other relatively stagnant water bodies generated in a clearly identifiable upstream area, with focus on those eutrophication problems whose history is only relatively short;
- the potential for reducing the "reason for the water quality problem" to one land use type (e.g., cropland versus animal holding) and thus the avoidance of "mixed land uses";
- avoiding areas where uncontrollable septic tank influences are possible;
- given the interest in tradeoffs of point source vs. nonpoint source, isolation of a project in which correction of both problems can be monitored (it would be helpful to have historical data on the point source effluent);

• avoiding areas with more than one drainage pattern.

Finally, since the utilization of the data is important, their handling and storage should be comparable to the EPA (STORET) and USGS systems. In this way the new data can be fit with other data sources to perform local and regional analysis of the type needed to initially assess the water quality problems of certain areas. (See discussion of individual project monitoring.)



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