Proposed Best Management Practices (BMP's) to be Applied in the Lower Boise River Effluent Trading Demonstration Project

by

David L. Carter, Ph.D, CPAgSSc

1. **Sediment Basins**
2. **Filter Strips**
3. **Underground Outlet**
4. **Straw in Furrows**
5. **Crop Sequencing**
6. **Polyacrylamide**
7. **Sprinkler Irrigation**
8. **Microirrigation**
9. **Tailwater Recovery System**

February 2002

1. Sediment Basins

1. Description and phosphorus removal mechanism.

Sediment basins are constructed basins, ponds, or small reservoirs to collect and store sediment and associated nutrients derived from irrigation erosion of farmed fields. These structures impede the flow rate of irrigation runoff water sufficiently to essentially eliminate turbulence and permit settling of suspended materials in accordance with Stokes Law (18). They may collect runoff water from one field, several fields, or a portion or whole watershed. The capacity of these basins must be sufficient for the resident time of inflow water to be at least two hours, and preferably longer, for them to be most effective (7).

As inflow water enters the basin, the flow rate slows, turbulence decreases and suspended sediment with adsorbed and integral phosphorus settles and deposits in the basin and is thereby removed from the water. The outflow water contains suspended materials too small in particle size to settle under particular ponding conditions, phosphorus associated with those materials and dissolved phosphorus. By this process, usually the greater portion of the phosphorus entering the basin is removed from the water because the greater portion of the phosphorus is associated with the suspended sediment. The phosphorus removal efficiency is generally highest when the suspended sediment concentration in the inflow waters exceeds 200 mg L^{-1}, but can be high even at concentrations below 100 mg L^{-1} (8, 17).

2. Application criteria. (See NRCS Practice Code 350.)

Sediment basins should be constructed to catch irrigation runoff from one or more low residue fields that will be surface irrigated for one or more irrigation seasons. The application of other erosion control practices to these fields may lessen the benefits of the sediment basins. Where several fields are included and the crop rotation is such that one or more fields meet the above criteria each irrigation season, the sediment basin will be effective each irrigation season. Where only one field is involved and different crops are grown during different growing seasons, the sediment basin will likely be most effective during low residue crop seasons, and have questionable effectiveness when permanent cover or close growing crops are grown. Typically, sediment basins will need to be cleaned after each season of use to reestablish effectiveness for the next irrigation season, except where close growing or permanent cover crops are grown on a single field with a single pond.

Sediment basin size for a particular application can best be estimated by using SISL (14) to estimate the amount of sediment expected to enter the basin during the irrigation season. All fields and crops must be considered. Estimating that every ton of sediment will occupy about one cubic yard will provide a volume necessary to contain the sediment. Then add to that a volume to hold about 50% of the maximum flow rate of water diverted to irrigate the fields draining into that basin for two hours. Where multiple fields are involved, it is unlikely that all will be simultaneously irrigated, but more than one might be irrigated at the same time. Then, I suggest adding an uncertainty factor of about 20%. Therefore, construct the basin so that its empty volume is 1.2 times the volume determined as outlined above.

3. Potential side effects and ancillary benefits.

Sediment basins have been used for many years (1, 2, 3, 4, 10, 11, 15, 16, 17). They are ponds that sometimes require fencing to keep animals and people out. The larger ones attract waterfowl which can complicate efforts to evaluate phosphorus removal effectiveness. Often weeds around the perimeter are not controlled and may be unsightly, although herbicide applications can control them. The sediment removed from basins is generally piled along one or both sides, and this can lead to both weed and unsightly problems. These basins and the area around them sometimes remove small areas of farmland from production.

Seepage into shallow groundwater and wetting adjacent soil for a few feet may be evident, but wetting soil for longer distances rarely occurs. In the case of large basins on perennial streams, provision for fish passage may be required. Also, on these main streams, provisions to bypass storm-caused flows may be needed. None of these possible negative side effects are considered very important when compared to potential benefits of sediment basins.

Sediment basins function to remove sediments and associated phosphorus and other nutrients, etc., from irrigation runoff water. They are an excellent education tool to demonstrate that large quantities of soil are being eroded from farmland. Efforts should to made to apply other BMP's that would eliminate the need for sediment basins by reducing or eliminating erosion losses of our precious soil.

4. Monitoring effectiveness.

There are two possible approaches to evaluating how effectively sediment basins remove phosphorus from irrigation runoff water. One approach is to measure the amount of phosphorus being trapped or removed from the runoff water. This can be accomplished by measuring water inflow and outflow, along with total phosphorus concentrations repeatedly during the irrigation season. These measurements need to be made at least biweekly for basins receiving water from multiple fields where water is passing through the basin all of the time (4, 11). Weekly samplings may improve the precision. These measurements would have to be made several times during each irrigation and for most irrigations for a single field basin. Water flow would also have to be measured at the same time or continuously recorded. Research results have shown that during an irrigation set samples of the first water entering the basin along with water flow measurement should be taken. Subsequent sampling times should be at approximately the following times after the previous sample: 15 min, 30 min, 1 hr, 1 hr, 1 hr, 2 hr, 2 hr, and then at 3 to 4 hr intervals until runoff ceases. Measurements described can be used to calculate phosphorus removal for the irrigation season, and at time intervals within the season.

An alternate method is to measure the newly constructed basin to determine its capacity or volume before irrigation runoff begins, then measure the capacity after the season to determine the volume of sediment collected. The trapped sediment can be grid sampled to determine bulk density and phosphorus concentration in the sediment. This approach, if done carefully, will give an accurate measure of the quantity of sediment associated phosphorus trapped during the season, but it will not provide a measure of the amount that was not trapped. When using this method, sampling must represent the many zones of trapped sediment in the basin, because there will be zones of coarser and finer sediments that will vary significantly in phosphorus concentration. Cross section sampling across the deposited sediment and along it should be done. Also, depth intervals of about 6 inches should be separated at each sampling point. No particular procedure has been established.

The preferred approach for this Lower Boise River Effluent Trading Demonstration Project is to calculate the phosphorus removal percentage based upon available research results. These calculations can be made quite accurately if basins are installed, operated, and maintained in accordance with NRCS Practice Code 350. Data are available to estimate the amount of soil that will be eroded under various field conditions (10, 14) and the sediment and phosphorus trapping efficiency of correctly designed, operated, and maintained sediment basins (1, 3, 4, 5, 6, 7, 8, 9, 10, 15, 17). The monitoring required is visual inspection to determine if the design, operational, and maintenance criteria are being satisfied. Contracts will likely dictate inspection times and criteria to assure that practice code requirements are being followed. Inspection before the first irrigation, about mid-season, and after the irrigation season should be adequate. This latter approach costs much less than actual monitoring by sampling, chemical analyses, and water flow measurement.

5. Design features.

The NRCS has developed design criteria for sediment basins documented as NRCS Practice Code 350. Their requirements apply to rectangular basins, but all basins are not rectangular. Actually, a fan-shaped basin is most efficient (3). Additionally, the initial capacity of a basin should be sufficient that the resident time of water up to the time of cleaning the basin is never less than two hours (7) This will assure that most sediments will settle and deposit in the basin according to Stokes law (18). These design features should be followed.

6. Installation requirements.

Install according to NRCS Practice Code 350, except that size must be sufficient for a minimum two-hour retention time for the entire season.

7. Operational and maintenance requirements.

Operate and maintain according to NRCS Practice Code 350, and additionally assure that resident time is a minimum of two hours.

8. Calculating phosphorus removal effectiveness.

The sediment removal efficiencies of sediment basins are well documented. The 10-year Rock Creek Rural Clean Water Program Project (17) evaluated sediment removal efficiencies of 131 basins over varying lengths of time up to 10 years depending upon the year of installation. These basins included three general types. One type was basins receiving runoff from one field. The second type was basins receiving runoff from two to six or seven fields and they were generally called farm size basins, even though runoff may come from lands with different owners. The third type was larger basins receiving runoff from multiple fields in a sub-watershed. In that study, they were called field, farm, and sub-basin sediment ponds. The range of sediment removal efficiency was 75% to 95% with an average of 87%. That is remarkable efficiency, particularly when there were upstream BMP's installed above some of these basins. Generally the field type basins had the highest sediment removal efficiencies and many of those were above 90%, with very few below 85%. Farm type were next highest in efficiencies and sub-watershed were lowest, but still many of the latter had efficiencies over 80%.

Sediment removal efficiencies of many other basins of all three types have been evaluated (17). Robbins and Carter (16) determined that the efficiency of a sub-watershed basin receiving runoff from multiple fields comprising 289 acres was 85% to near 98% when the sediment concentration exceeded 1,000 mg L^{-1} where erosion was extremely high. The efficiency was never below 65%, even when the sediment concentration in the inflow was very low. Carter (7) reported sediment removal efficiencies of six basins, two of each type, ranging in efficiency from 75% to 92%. Brown, Bondurant, and Brockway (4) monitored the sediment removal efficiency of a large sub-watershed basin for five years and reported results at five water inflow rate ranges. The efficiency increased sharply with sediment concentration up to 100 mg L^{-1}, then more gradually in a curvilinear pattern. The efficiency was above 70% most of the time. There was about a 10% difference over the range of inflow rates measured. Retention time for this basin was only 1.1 to 1.7 hrs, depending upon the flow rate. If the retention time had been greater, efficiency would have been higher. This basin was constructed by the Northside Canal Company in Jerome County to remove 50% of the sediment in the water passing through it. Performance was better than expected. Many more examples could be cited.

For the purposes of this effluent trading demonstration project, it is logical to assign sediment removal efficiencies of 80%, 75%, and 65% for field, farm, and sub-watershed basins, respectively. The variability in efficiencies among evaluated basins and seasonal variation suggest an uncertainty factor of 10% for all basins.

The phosphorus removal efficiencies will be lower than the sediment removal efficiencies, and will vary with sediment load. I suggest they not be used for calculating phosphorus credits for the effluent trading for this BMP. The fact that dissolved phosphorus will not be removed appreciably by sediment basins complicates the use of phosphorus removal percentages as sediment and its associated phosphorus concentrations change. I suggest calculating the quantity of sediment removed by the BMP in tons, and then multiplying that quantity by the amount of phosphorus that is associated with each ton of sediment. The same factor of two pounds of phosphorus per ton of sediment should be used for all basins. Sub-watershed basins receive a higher portion of finer sediments likely to be richer in phosphorus. However, the retention time is generally longer for these sub-watershed basins permitting more finer particles to settle.

This approach clearly quantifies an amount of phosphorus that would have been lost into the drain without the BMP.

9. Calculating phosphorus retained by the BMP.

The on-site phosphorus retention for sediment basins is totally dependent upon the sediment removed from irrigation runoff water by settling processes in these basins. The dissolved phosphorus in the runoff water will not be changed appreciably because there is little relationship between sediment load and dissolved phosphorus at the concentrations in these basins. Therefore, calculating the phosphorus retained on site involves calculating the amount of sediment deposited and the phosphorus concentration in that sediment. If we assume that each ton of sediment deposited contains two pounds of phosphorus (P) as proposed by David Ferguson (12, 13) in his analyses of published data, and predict the amount of sediment that will be eroded from fields as outlined in NRCS Agronomy Technical Note No. 32 (Rev. 2) (14), use the appropriate sediment removal efficiency and the uncertainty discount, the phosphorus retained on site in pounds can be calculated. This approach leads to the following:

$$P\ retained\ \ in\ pounds = SISL\ values\ for\ fields \times (sediment\ removal\ efficiency\ for\ basin\ type\ -\ uncertainty\ value\ for\ variability) \times 2\ pounds\ of\ P\ per\ ton\ of\ sediment$$

Example 1: Consider a 20-acre field of dry beans with an irrigation run length of 660 feet without a convex end from which all of the runoff water enters a sediment basin constructed to catch runoff water from that field only. Assume this crop followed small grain, the soil K factor was 0.43, conventional tillage was used, and that irrigation was by tubes without cutback.

$$SISL\ value = 12.1 \times 0.87 \times 0.85 \times 1.00 \times 0.9 \times 20 = 161\ tons$$

$$P\ retained = 161 \times (.80\ -.10) \times 2 = 225\ lbs\ of\ P$$

Example 2: Consider a farm sediment basin receiving runoff from four fields. Assume all fields are 20 acres with irrigation runs of 660 feet without convex ends, irrigated by siphon tubes without cutback, on slopes of 1.2% on fields A and B and 0.9% on fields C and D. All fields are the same soil with a soil K factor of 0.43. Field A is dry beans following alfalfa with conventional tillage. Field B is sugar beets following small grain with conventional tillage. Field C is in second year alfalfa. Field D is wheat following corn with conventional tillage.

$$Sediment\ entering\ pond = SISL(A)\ + SISL(B)\ + SISL(C)\ + SISL(D)$$

$$Sediment\ tons = 132.6\ + 132.6\ + 0\ + 13.2 = 278.4$$

This is a farm type pond, therefore

$$P\ retained = 278 \times (.75\ -.10) \times 2 = 361\ lbs$$

If all four fields are owned by the same farmer, that farmer should have all the credit for the phosphorus retained. If there is different ownership, the phosphorus retained would have to be allocated based upon the specific ownership of each field. If one farmer owns fields A and B and another farmer owns fields C and D, the allocation would be:

$$P\ retained\ to\ be\ credited\ to\ owner\ of\ A\ and\ B = (132.6 + 132.6) \times .65 \times 2 = 345\ lbs$$

$$P\ retained\ to\ be\ credited\ to\ owner\ of\ C\ and\ D = (0 + 13.2) \times .65 \times 2 = 17\ lbs$$

The following year, as crop rotations progress, new allocations based upon crops grown would have to be made.

Allocating the phosphorus retained for a sub-watershed sediment basin may be difficult. Often these basins will be along drains that flow all year and receive inflow from numerous sources. Using SISL to calculate sediment inflow may or may not be possible, and likely most often questionable. Another complicating factor is that all of the drain flow may not be diverted through the basin because of fish escapement requirements or other factors. If the application of SISL is questionable, it may be necessary to make measurements through each year.

Where SISL is applicable, the same approach as outlined for farm sediment basins can be applied. Admittedly, all of the sediment in the drain may not come from irrigated fields, but it is safe to assume that the portion that does come from those fields will be removed at the percentage suggested. Phosphorus retained can be allocated as discussed for farm sediment basins. The portion of the sediment from sources other than irrigation runoff would be very difficult to allocate. There would be merit in assigning the phosphorus retained to the organization that constructed and maintains the basin. This may be a canal company or some other entity. If a farmer does not participate in the construction and maintenance cost, that farmer should receive no phosphorus credits derived from the basin. However, some farmers may participate through an irrigation district or soil conservation district.

Should a decision to measure sediment and/or phosphorus removal efficiency be made, there are multiple approaches that can be applied. One approach would be to measure sediment concentrations in the inflow water using an Imhoff cone and make simultaneous water flow measurements. Those measurements, and the application of the suggested sediment removal efficiency for sub-watershed basins, could be used to calculate the amount of sediment trapped. Applying the two pounds of phosphorus per ton of sediment, the quantity of phosphorus removed could be calculated. Another approach would be to measure sediment loads in both inflow and outflow waters along with flow measurements to have a reasonably accurate measurement of the sediment trapped and apply the P concentration factor. A third approach would be to sample both inflow and outflow waters and measure both sediment and phosphorus concentrations along with water flow. This would be a costly monitoring program. Two or three years of measurement may reveal patterns that could be applied to future years. Needless to say, these large, sub-watershed sediment basins present a rather complicated problem when attempting to determine phosphorus credits. However, they can be an excellent means for removing a portion of the phosphorus from the drainage water. Also, although not documented, it may be possible to add lime, calcium chloride, or some other chemical to enhance phosphorus precipitation and increase sedimentation in these larger basins. Some research would be required to assess this possibility, and it appears that some of these drains on the Lower Boise tract would be excellent research sites.

Another approach that appropriately should be considered under this BMP is to allow a farmer, a group of farmers, or other organization to actually measure the phosphorus concentration in the sediment settled into sediment basins. This can be done after the basins are dewatered to permit grid sampling of the sediment. Samples can be analyzed for total phosphorus concentration. If the results show that the concentration exceeds the two pounds of phosphorus per ton of sediment used in the foregoing calculations, the new factor should be used for the particular sediment basins where such measurements are made. Those contemplating making such measurements should be aware that these sampling and chemical analyses processes are costly.

References.

1. Ballard, F. L. 1975. Analysis and design of settling basins for irrigation return flow. Unpublished Masters Thesis. U of I Grad. School.

2. Brockway, C. E., D. L. Carter, and C.W. Robison. 1981. Irrigation return flow study. Unpublished Final Report of a PL 92-500, Section 208 Water Quality Management Planning Grant from the Idaho Department of Health and Welfare, Division of Environment.

3. Bondurant, J. A., C. E. Brockway, and M. J. Brown. 1975. Some aspects of sedimentation pond design. Presented at the National Symposium on Urban Hydrology and Sediment Control, Univ. Kentucky, Lexington, KY. July 28-31, 1975.

4. Brown, M. J., J. A. Bondurant, and C. E. Brockway. 1981. Ponding surface drainage water for sediment and phosphorus removal. Trans. ASAE Vol. 24(6):1478-1481.

5. Carter, D. L. 1976a. Guidelines for sediment control in irrigation return flow. J. Environ. Qual. 5:119-124.

6. Carter D. L. 1976b. Control of sediments, nutrients, and absorbed biocides in surface irrigation return flows. EPA-600/2-76-237. Interagency Project No. EPA-IAG-D5-F648.

7. Carter, D. L. 1985. Controlling erosion and sediment loss on furrow-irrigated land. pp. 355-364. In: S. A. El-Swaify, et. al. (ed.) Soil erosion and conservation. Soil Conserv. Soc. Am., Ankeny, IA.

8. Carter, D. L. 1990. Soil erosion on irrigated lands. *Irrigation of Agricultural Crops* - Agronomy Monograph no. 30, pp. 1143-1171, ASA-CSSA-SSSA.

9. Carter, D. L., and J. A. Bondurant. 1977. Management guidelines for controlling sediments, nutrients, and absorbed biocides in irrigation return flows. pp. 16-19. In Anonymous (ed.) Irrigation return flow quality management. Proc. EPA Natl. Conf., Fort Collins, CO. 16-19 May 1977. USEPA, Ada, OK.

10. Carter, D. L., C. E. Brockway, and K. K. Tanji. 1993. Controlling erosion and sediment loss from furrow-irrigated cropland. J. Irrig. & Drain. Engr. 119(6):975-988. ASCE Paper No. 4142.

11. Carter, D. L., M. J. Brown, C. W. Robbins, and J. A. Bondurant. 1974. Phosphorus associated with sediments in irrigation and drainage waters from two large tracts in southern Idaho. J. Environ. Qual. 3:287-291.

12. Ferguson, D. F. 2000a. Estimating an agricultural surface irrigated Copeland sediment and phosphorus loss with average surface irrigation soil loss. Unpublished Technical Report, Idaho Soil Conservation Commission.

13. Ferguson, D. F. 2000b. Watershed scale and field-scale sediment basin phosphorus reduction effectiveness. Unpublished Technical Report, Idaho Soil Conservation Commission.

14. Natural Resources Conservation Service, USDA. Agronomy Technical Note No. 32 (Rev. 2). 2000. Predicting irrigation induced soil loss on surface irrigated cropland. Originally prepared by Floyd G. Bailey, State Conservation Agronomist, SCS, in association with Dr. David L. Carter, Supervisory Soil Scientist, ARS, in 1991. Revised Sept. 1994. Revision 2 by Clare Prestwick, Irrigation Engineer, NRCS, Idaho, in June, 2000.

15. Robbins, C. W., and C. E. Brockway. 1978. Irrigation water salt concentration influences on sediment removal by ponds. Soil Sci. Soc. Amer. J. 42:478-481.

16. Robbins, C. W., and D. L. Carter. 1975. Conservation of sediment in irrigation runoff. J. Soil and Water Conser. 30:134-135.

17. Rock Creek Rural Clean Water Program Final Report 1981-1991. 1991. A Ten Year Inter-agency Report of a Project Conducted in Twin Falls County, Idaho, under a Grant Administered by Idaho Department of Health and Welfare, Division of Environmental Quality.

18. Stokes, G. G. 1851. On the effect of internal friction of fluids on the motion of pendulums. Trans. Camb. Phil. Soc. 9:8-106.

2. Filter Strips

1. Description.

Filter strips are permanent cover or close growing crops along the lower ends of surface irrigated fields to slow flow velocity of furrow streams so that transported sediments settle out before reaching the tailwater ditch. Perennial, biennial, or annual crops may be used in these strips, but they must be seeded at a rate sufficient to establish dense plant cover. When installed and managed correctly, these filter strips provide effective sediment and associated phosphorus runoff control (1, 2, 3, 4, 5).

The most common filter strips are double or triple-seeded cereal crops across the extreme lower ends of furrow-irrigated fields. Strips are usually 10 to 20 feet wide. Seeding must be done so that plants are established before furrow irrigating for the season begins. Fall seeding or very early spring seeding will be required to meet this goal. Sometimes when alfalfa or grass crops are killed to grow row crops, the alfalfa or grass along the lower 10 to 20 feet of the field can be left alive to provide effective filter strips.

2. Application criteria.

This BMP is applied to surface-irrigated fields where row crops are to be grown and significant surface irrigation erosion is anticipated. They are commonly used when growing dry beans, sugarbeets, corn, or onions. Usually they are a single year BMP consisting of cereal crops, but they can be multiyear when consisting of alfalfa or perennial grass.

3. Potential side effects and ancillary benefits.

The application of filter strips to control sediment and phosphorus in runoff water is an easy BMP to apply. Also, the area covered by the strip can sometimes be harvested and provide some economic return. For example, a farmer can harvest wheat from a wheat filter strip at the same time he harvests wheat on fields of his farm. The per acre yield will likely be only about 60% to 70% of that from fields because tractor turning on the filter strips will reduce the harvestable plant population (3). Alfalfa or grass hay can be harvested from filter strips provided there is sufficient time between irrigating the row crops to allow hay curing when needed.

A potential negative effect of filter strips arises when they are not installed or managed correctly. In fact, it is not uncommon to see new tailwater ditches developed by sideflow of water at the upper edge of the filter strip. This can result in greater sediment loss from the field than if no filter strip had been planted. Many years of promoting filter strips as a conservation practice has demonstrated that inappropriate installation and management is common (5). The negative end result is that farmers who do not install and manage filter strips correctly believe they are practicing sediment loss control when they are not.

4. Monitoring.

Filter strips must be established with dense plant population and plants should be at least 3 to 6 inches in height before the first irrigation. They should be examined before the first irrigation of the field with follow-up examinations as necessary to assure that they have been installed correctly, that the irrigation furrows are pulled into these strips one-third to one-half the width of the strip and not all the way through it, and that the plants are sufficiently established to slow water velocity without being eroded out of place. If these requirements are not met, no phosphorus credits should be permitted. If these requirements are satisfied, the phosphorus retained by the BMP can be calculated based upon research results.

The sediment and phosphorus removal efficiencies of filter strips can be monitored by measuring stream flows and collecting and analyzing samples of both inflow and outflow waters over numerous time intervals. This is the method used to obtain and analyze the research data used for calculating the phosphorus credits for this BMP. The process is time consuming, costly, and requires special equipment and laboratory analyses. However, there may be situations where monitoring by measurement is preferred. The procedure to accomplish this monitoring by measurement follows.

At least 10 irrigation furrows are randomly selected for measurement before an irrigation begins. Furrow stream measuring flumes are placed in these furrows immediately upstream from where the furrow streams enter the filter strip. These flumes must be installed so that water samples can be collected by catching water as it drops from the downstream lip of the flume with a beaker or cup. This will generally require digging a small hole at that point in the furrow. Also, provisions will have to be made for the water below the flume to move away and allow sampling only that water falling from the flume. Flumes must be installed by competent, experienced technicians to assure accurate measurements.

If sediment concentration is to be measured by Imhoff cones, such cones need to be placed in stands nearby each furrow to be sampled. Experienced, competent technicians are required to accomplish these measurements. If the samples are to be taken to a laboratory for filtering and chemical analyses, containers should be prepared before the sampling begins. If simultaneous measurement of the amount of erosion occurring during the irrigation is desired, flumes should be placed, as described, in the head ends of these same furrows.

Flume readings should be made and one-liter water samples collected beginning a few seconds to a minute or two after the first water passes through the flume. Subsequent flow measurements should be made and samples collected at 15 min, 30 min, 1 hr, 1 hr, 1 hr, 2 hr, 2 hr, and then 3 or 4-hr intervals until runoff ceases. The flows for each time interval are the average of the readings at the beginning and the end of the time interval, and the sediment concentration is the average of the concentration at the beginning and the end of the interval. The total flow and sediment concentration for each measured furrow is obtained and averaged for all furrows measured. This average furrow flow and sediment load are multiplied by the number of furrows in the water set. The result is the amount of sediment entering the filter strip.

The quantity of water and sediment leaving the filter strip can be determined by measuring the water flow and sediment concentration in the tailwater ditch just downstream from the water set. This is done by the method described above, but a larger flume will be required. The results here represent the quantity of sediment leaving the filter strip. Using the inflow and outflow quantities, the sediment and phosphorus removal percentage or efficiency is calculated. If the Imhoff cone method is used, the 2 pounds of phosphorus per ton of sediment can be multiplied by the tons of sediment to provide the quantity of phosphorus retained or removed by the filter strip. If samples were chemically analyzed for phosphorus concentration, then the resulting phosphorus concentration in the sediment should be applied.

The described process can be applied at the upper ends of the selected furrows to measure the amount of water and sediment entering the furrow. The difference in the total amount of sediment entering the irrigation set area and the amount entering the filter strip represents the quantity of sediment eroded from the irrigation set area.

Often several water sets are required to irrigate a field. When that is the irrigation process, measurements from more than one water set should be made to increase the precision and accuracy of the evaluations.

The foregoing processes describe how to monitor by measuring for an irrigation. To obtain seasonal results, these measurements would have to be made for all irrigations. As mentioned before, these processes are time consuming, costly, and require trained technicians. The efforts of several workers are required. One person cannot do it alone.

5. Design features.

The design must be according to NRCS Practice Code 393.

6. Installation requirements.

Filter strips must be installed as specified by NRCS Practice Code 393.

7. Operation and maintenance requirements.

Operation and maintenance must be according to NRCS Practice Code 393.

8. BMP effectiveness.

When designed, installed, and operated according to NRCS Practice Code 393, research has demonstrated that filter strips remove 40% to 70% of the sediment in the runoff water reaching them. Most of them remove more than 50%. Hence a sediment removal efficiency of 55% as an average for this BMP is logical. However, there is considerable variation in their effectiveness with considerable risk of failure after the first two to four irrigations when erosion rates are high and the deposited sediment forms a water barrier ahead of the tailwater ditch, forcing sideflow channeling. Therefore, an uncertainty value of 15% is assigned to this BMP.

9. Calculating phosphorus retained by the BMP.

The mechanism involved to remove phosphorus from surface runoff water is that of removing sediment and preventing it from moving beyond the field toward the lower Boise River. The SISL model is applied to the field to calculate the amount of sediment that would leave the field if the BMP were not applied. Then the sediment removal efficiency and the uncertainty factors are applied to calculate the tons of sediment removed by the filter strip. That value is multiplied by the two pounds of phosphorus per ton of sediment factor to give pounds of phosphorus retained by applying the practice.

Example:

Assume a SISL value of 188 tons for a 20-acre field of dry beans.

$$\textit{Phosphorus retained} = 188 \times (0.55 - 0.15) \times 2 = 150 \textit{ lbs of phosphorus}$$

10. References.

1. Brockway, C. E., D. L. Carter, and C. W. Robison. 1981. Irrigation return flow study. Unpublished Final Report of a PL 92-500, Section 208 Water Quality Management Planning Grant from the Idaho Department of Health and Welfare, Division of Environment.

2. Carter, D. L. 1985. Controlling erosion and sediment loss on furrow irrigated land. pp. 355-364. In: S. A. El Swaify, et al. (ed.) Soil Erosion and Conservation. Soil Conservation Society of America, Ankeny, IA.

3. Carter, D. L. 1990. Soil erosion of irrigated lands. In: Irrigation of Agricultural Crops, Agron. Monograph No. 30:1143-1171, ASA-CSSA-SSSA.

4. Carter, D. L., C. E. Brockway, and K. K. Tanji. 1993. Controlling erosion and sediment loss from irrigated cropland. J. Irrig. and Drain. Engr. 119:975-988. ASCE Paper No. 4142.

5. Rock Creek Rural Clean Water Program Final Report 1981-1991. 1991. A Ten Year Interagency Report of a Project Conducted in Twin Falls County, Idaho, under a Grant Administered by Idaho Department of Health and Welfare, Division of Environmental Quality.

3. Underground Outlet

1. Description.

The underground outlet BMP is a conduit installed beneath the ground surface along the lower end of a field to collect runoff water and convey it to a suitable outlet such as a surface drain. Runoff water enters this conduit through inlet risers from the conduit to a specified elevation above the ground surface. When first installed, small earthen dams are placed just downstream from each of these riser inlets to stop water from flowing downslope along the end of the field so that the water enters the riser outlets. This process forms small sediment basins usually called minibasins. Often by the end of the first season, and nearly always by the end of the second season, these minibasins have completely filled with sediment. In some cases the elevation of the inlet riser tops can be raised by attaching extenders if sufficient slope remains after a season or two of use (1, 2, 3).

Disposing surface irrigation runoff water through these outlets can significantly reduce sediment and associated phosphorus loss from fields, particularly the first two irrigation seasons following installation. They are most effective when installed in place of the tailwater ditch where field slope increases into the tailwater ditch of the last 10 to 80 feet of the irrigation run. This is the typical convex end condition. However, they prevent erosion in any tailwater ditch. Therefore, this BMP is not limited to convex field end conditions. The underground outlet BMP will also effectively remove runoff water from field ends where low side-slope results in ponding of tailwater (1, 2, 3).

2. Application criteria.

Underground outlets can be used on any surface-irrigated field, except where side slope along the field end is not sufficient to permit 0.3% slope of the underground conduit to a satisfactory outlet, while still meeting the burial depth requirement. Sometimes if burial over a short distance is not deep enough, the buried conduit can be a weight bearing culvert type. Their sediment removal efficiency from surface runoff water will be highest on fields with convex shaped lower ends. Convex shaped lower ends have resulted from farmers keeping tailwater ditches deeper than the lower ends of irrigation furrows to prevent water ponding. After years of constructing and cleaning these ditches along the bottoms of fields, the shape of the lower ends of fields increases in slope because of headcutting erosion, first at immediate furrow end and later further up slope. The condition worsens with time, and over many years, thousands of tons of soil are lost from the lower ends of these fields (1, 2, 3).

The primary purpose of these underground outlets is to catch sediment from erosion further upslope and correct these convex or increasing slope conditions. Correctly installed underground outlet systems will form small sediment basins, sometimes called minibasins, in which sediment is trapped and removed from tailwater. As these minibasins fill with sediment, the slope at the field end is decreased, and this will continue until the field end becomes level. Then the runoff water does not collect and pond because it runs into risers from the underground conduit, serving as inlets, and is transported away. The water movement to these riser inlets is slow, and sediment settles out of the slow flowing water.

Furrow erosion is a dynamic process, and stream velocity increases rapidly with increasing slope. Recent observations have shown that severe erosion and sediment loss can occur even when using the polyacrylamide BMP when a severe convex field end is present.

The underground outlet BMP may be a good option for many farmers as they begin changing farming practices to apply other conservation BMP's. For example, a farmer may accrue significant phosphorus credits by installing this BMP during seasons of low residue cropping while adjusting to applying the polyacrylamide, crop sequencing, or other conservation tillage BMP's. Research data have shown that underground outlet systems often pay for themselves in 4 to 8 years from increased crop production resulting from greater harvested area (1, 2, 3). Adding the value of phosphorus credits could shorten that time to a year or two. After that, farmer net income will be higher.

3. Potential side effects and ancillary benefits.

Installing underground outlets provides several benefits. One is to reduce sediment and associated nutrient loss from fields. Another is to change the shape of field ends allowing equipment to transverse the area where once the tailwater ditch prevented crossing. The net result on many fields is to increase the production area on the field. It is not uncommon to find up to 5% of the field area out of production because of severe convex end conditions. Associated with that production area loss is nearly a 5% less net profit from the field. Still another benefit is that weed control at field ends is much easier when convex ends are not present. Weed problems are often unsightly on severe convex end areas. Special treatment is often necessary, and often not done, to control these weed problems. Where convex ends have been corrected, crop cover extends to the end of the field, weed problems are less severe, and access is better to treat those problems that do occur.

Access into and out of fields to field roads is usually unrestricted once the deep tailwater ditch has been filled with sediment. This results in time savings for tilling, seeding, and harvesting crops. It also lessens the hazard of damage to equipment that can occur when crossing deep ditches.

4. Monitoring.

When phosphorus credits will be calculated based upon previous research results from field applications, the only monitoring required is to ascertain by observation that the BMP has been installed and is in use during the irrigation season. Once an underground outlet system has been installed, it would be difficult not to use it. This calculation method is recommended.

The phosphorus credits for this BMP can be monitored by measuring stream flows and collecting and analyzing samples of both inflow and outflow waters over numerous time intervals. This is the method used to obtain and analyze the research data used for calculating phosphorus credits. The process is costly, time consuming, and requires special equipment and laboratory analyses. Should monitoring by measurement be preferred, the procedure to accomplish such monitoring follows.

A minimum of 10 irrigation furrows are randomly selected for measurement before an irrigation begins. Small furrow stream measuring flumes are placed in each selected furrow just above where the runoff water begins to pond before entering riser inlets. These flumes must be installed so that water samples can be collected by catching water from the downstream lip of the flume with a beaker or cup. This usually requires digging a small hole at that point in the furrow. Also provisions must be made for water below the flume to move away and allow sampling only the water falling from the flume. Flumes must be installed by competent, experienced technicians to assure accurate measurements.

There are two options for measuring sediment and phosphorus concentrations. One is to use Imhoff cones to estimate sediment concentration from which tons of sediment can be calculated. The tons of sediment is multiplied by the factor 2 pounds of phosphorus per ton of sediment. If this is the option to be used, Imhoff cones should be placed in nearby stands so that water samples can be quickly placed in them for timed sedimentation measurements. Qualified and experienced technicians will be required for this approach. The second option is to collect one-liter water samples and transport them to a laboratory where sediment and phosphorus concentrations can be measured. The phosphorus concentration in the sediment is required. Obtaining that value generally requires a total phosphorus measurement in the water sample containing the sediment and another phosphorus concentration in the filtrate from filtering out the sediment. There are alternative methods, but these need not be discussed at this time.

Flume readings should begin and one-liter water samples collected a few seconds to a minute or two after the first water passes through the flume. Subsequent flow measurements should be made and samples collected at 15 min, 30 min, 1 hr, 1 hr, 1 hr, 2 hr, 2 hr, and then at 3 to 4-hr intervals until water ceases to flow. The flow for each time interval is the average of the reading at the beginning and the end of the time interval, and the sediment concentration for the interval is the average of the concentration at the beginning and end of the interval. The total flow and sediment concentration for each measured furrow is obtained and averaged for all furrows measured. This average furrow flow and sediment load is multiplied by the number of furrows in the water set to give the amount of sediment entering the BMP.

The quantity of water and sediment leaving the field during the water-set irrigation must be measured at or near the outlet of the conduit transporting the water from the field. This is done as described for each furrow discussed previously, at the same time intervals, but a larger flume is required. The results obtained represent the quantity of sediment and associated phosphorus leaving the field that was not removed by the underground outlet BMP. Using the inflow and outflow quantities, the sediment and phosphorus removal percentage or efficiency can be calculated. If the Imhoff cone method was used, the tons of sediment removed is multiplied by the 2 pounds of phosphorus per ton of sediment to obtain the quantity of phosphorus retained by the BMP. If samples were chemically analyzed for phosphorus concentration, then the measured phosphorus concentration in the sediment should be used as the multiplier.

Often several irrigation water sets are required to irrigate a field. When that is the irrigation process, monitoring by measurement should be done for more than one irrigation water set to improve precision and accuracy of the evaluations.

The foregoing process describes how to monitor by measuring for an irrigation. To obtain seasonal results, these measurements would have to be made for all irrigations. As mentioned before, these processes are time consuming, costly, and require several trained and qualified technicians. One person cannot make all these measurements alone.

Should this monitoring by measuring approach be selected, a simultaneous measure of field erosion might be considered. This can be done by placing furrow stream measuring flumes at the head ends of the same furrows selected for runoff measurements. The process described for measuring runoff from the selected furrows is followed. The difference in the quantity of sediment leaving the furrows and the quantity entering represents the amount of erosion for field area in the irrigation set.

5. Design features.

Underground outlets should be designed according to NRCS Practice Code 620.

6. Installation requirements.

Install according to NRCS Practice Code 620.

7. Operation and maintenance requirements.

This BMP will be most effective before the convex end problem is corrected. After that, the sediment removal efficiency reduces, but can continue to be sufficiently high to retain significant amounts of phosphorus. Effectiveness will depend upon the application of other conservation BMP's.

Some farmers have chosen to remove some of the sediment from the minibasins and haul it back up to the upper end of the field. Doing this will again increase the sediment removal efficiency of these systems, much as would be the case for the sediment basin BMP when the basin is cleaned. However, such practices are not generally recommended because of negative impacts upon other ancillary benefits.

8. BMP effectiveness.

Research results indicate that the underground outlet BMP removes 80 to 95% of the sediment from surface-irrigation tailwater until the minibasins formed at installation are filled with sediment. After that, sediment removal efficiency decreases, but results indicated efficiencies from 51 to 83%. Results after minibasins are filled with sediment depends upon the general overall slope of the field, irrigation practices, and the application of other BMP's. The uncertainty factor increases after the minibasins are filled with sediment.

Research showed that minibasins on some fields filled the first irrigation season following installation. Most were filled after two irrigation seasons (1, 2, 3). For purposes of the effluent trading demonstration project, a reasonable sediment removal efficiency is 85% for the first two irrigation seasons with an uncertainty value of 15%, and 65% with an uncertainty value of 25% for subsequent years.

The phosphorus retained by this BMP depends upon the sediment removed from the irrigation runoff water. There would be little or no effect upon dissolved phosphorus. Therefore, the two pounds of phosphorus per ton of sediment would be applied.

9. Calculating phosphorus retained by the BMP.

Calculating the phosphorus retained by applying this BMP would be the same as for the sediment basin BMP except the uncertainty factor is higher. The sediment removal efficiency and uncertainty factor are applied, and the tons of sediment saved are multiplied by the two pounds of phosphorus per ton of sediment.

Illustration:

Assume 20-acre field SISL = 165 tons

For each the first and second season:

$$P\ retained = 165 \times (.85 - .15) \times 2 = 231\ lbs\ of\ phosphorus$$

For each subsequent season:

$$P\ retained = 165 \times (.65 - .25) \times 2 = 132\ lbs\ of\ phosphorus$$

References.

1. Carter, D. L. 1985. Controlling erosion and sediment loss on furrow irrigated land. pp. 355-364. In: Soil Erosion and Conservation, Soil Conservation Society of America, Ankeny, IA.

2. Carter, D. L. 1990. Soil erosion on irrigated land. Ch. 37. pp. 1143-1171. In: Irrigation of Agricultural Crops, Agronomy Monograph No. 30.

3. Carter, D. L. and R. D. Berg. 1983. A buried pipe system for controlling erosion and sediment loss on irrigated land. Soil Sci. Soc. Amer. J. 47:749-752.

4. Straw in Furrows to Reduce Surface Irrigation Erosion

1. Description.

Straw or other residues placed in irrigation furrows effectively reduce furrow irrigation erosion (1, 2, 3, 4, 5). Equipment is available to place straw from bales into furrows for this purpose. Application rates of about four pounds of straw per hundred feet of furrow are sufficient, although higher rates are acceptable. The straw needs to be in place for all irrigations to be most effective. After cultivating, it will likely be necessary to add more straw to the furrows before the next irrigation (3).

2. Application criteria.

This BMP is appropriately applied to fields growing low residue crops to reduce erosion and sediment and associated phosphorus runoff. The straw should be cut into 8 to 12-inch lengths. Short, chaff-like straw should be avoided. If pieces are cut too short, they will move with the irrigation water and the treatment will lose its effectiveness. Available application equipment places straw appropriately if the quality of the straw is good, meaning that it is not cut into pieces only an inch or two long. Some short pieces mixed with longer ones is satisfactory. Application rates will range from about 400 to 1,000 pounds per acre depending upon row spacing and machine settings. If cultivations are to follow, lower application rates of about 400 pounds are preferred to avoid cultivating problems.

3. Potential side effects and ancillary benefits.

The application of straw to irrigation furrows to reduce erosion requires commitment and timing to assure that the straw is in place at every irrigation. Application costs are considered reasonable and will likely be more than offset by selling phosphorus credits derived from the practice. The straw in the furrows reduces evaporation from the soil surface that may allow the irrigator to lengthen the time between irrigations about one day. This could result in one or two less irrigations during the season. This reduction in evaporation can also cause excess moisture, causing crop rot and diseases on fields with low slopes. It also increases infiltration, improving crop production on the steepest slopes along the field (2, 4).

4. Monitoring.

The monitoring needed is to observe that straw is in the furrows during every irrigation. Additional straw needs to be added after cultivations disturb the previous application. Perhaps a record of the amount of straw added would be helpful to assure a minimum of 400 pounds per acre.

Actual monitoring of the effectiveness of this BMP on a field would compromise its effectiveness. Placing small flumes in furrows and making flow and sediment concentration measurements as described for sediment basins, filter strips, and underground outlets BMP's could be done, but the effectiveness of the BMP on the field would be decreased because this evaluation would require that some furrows have no straw in them for comparison with those that have straw. The erosion and sediment loss from the non-straw furrows would reduce the amount of sediment and associated phosphorus retained by applying the BMP. Therefore this approach is not recommended. The effectiveness of the straw in furrows BMP is well documented (1, 2, 3, 4, 5).

5. Design features.

The only design feature is to assure that straw is fairly evenly distributed along the furrows, and that the straw includes a significant portion of stems 8 to 12 inches long. Straw should be free of weed seed.

6. Installation requirements.

The straw must be placed directly into the furrows so that it is in contact with both the bottom and sides of the furrow. The application rate should not be less than four pounds of straw per 100 ft of furrow, which is about equivalent to 400 to 1,000 pounds per acre. Higher rates will not provide greater erosion control benefit. Straw should be free of weed seed. Most pieces should be 8 to 12 inches in length.

7. Operation and maintenance requirements.

Straw must be in the furrows at the rate specified during each irrigation. This usually requires an application before the first irrigation, including any preplant irrigation, and after each cultivation. Furrow stream size may need to be slightly larger with straw than without it so that water reaches and supplies adequate water to the lower end of the field.

8. BMP effectiveness.

The application of straw to irrigation furrows slows the water flow velocity, thereby reducing the eroding energy forces that would be present without it. This significantly reduces erosion and sediment loss and increases infiltration. Phosphorus is retained by reducing sediment and associated phosphorus loss. Research results indicate an erosion reduction of 90% by applying the BMP. Variability in results suggests an uncertainty value of 20%.

9. Calculating phosphorus retained by the BMP.

The phosphorus retained is calculated by applying the SISL model to the field to calculate the sediment loss expected with traditional practices. The tons of sediment calculated is multiplied by the efficiency percentage minus the uncertainty factor and the two pounds of phosphorus per ton of sediment factor to give pounds of phosphorus retained.

Example:

Assume a SISL value of 230 tons for a 20-acre field of sugarbeets.

Phosphorus retained $= 230 \times (0.90 - 0.20) \times 2 = 322$ *pounds of phosphorus.*

References.

1. Aarstad, J. S., and D. E. Miller. 1981. Effects of small amounts of residue on furrow erosion. Soil Sci. Soc. Amer. J. 45:116-118.

2. Berg, Robert D. 1984. Straw residue to control furrow erosion on sloping, irrigated cropland. J. Soil and Water Conserv. 39:58-60.

3. Brown, M. J. 1985. Effect of grain straw and furrow irrigation stream size on soil erosion and infiltration. J. Soil and Water Conserv. 40:389-391.

4. Brown, M. J., and W. D. Kemper. 1987. Using straw in steep furrows to reduce soil erosion and increase dry bean yields. J. Soil and Water Conserv. 42:187-191.

5. Miller, D. D., and J. S. Aarstad. 1983. Residue management to reduce furrow erosion. J. Soil and Water Conserv. 38:366-370.

6. Shock, C. C., L. B. Jensen, J. H. Hobson, M. Seddigh, B. M. Shock, L. D. Saunders, and T. D. Stieber. 1999. Improving onion yield and market grade by mechanical straw application to irrigation furrows. Hort. Tech. 9:251-253.

5. Crop Sequencing to Control Surface Irrigation Erosion (Residue Management)

1. Description

This BMP involves more long-term sequential management elements than most other BMP's. In fact, it could become almost the entire farm management program. It includes direct seeding without tillage and the application of residue management BMP's. It reduces tillage by more than 90%. It reduces nitrogen fertilizer requirements and cost and reduces input production costs significantly. Research results (1, 2, 3, 4, 5) have shown that commitment to this management program will significantly increase farm profit while conserving soil, water, and fertilizer resources. This BMP is flexible and can be applied on a year-to-year basis if desired, but will provide the best benefits if applied over the entire crop rotation.

Most surface irrigation soil loss occurs when low residue crops are grown. Usually residues from previous crops are buried beneath the soil surface by moldboard plowing followed by excessive disking, roller harrowing, land planing, and other practices perceived necessary to produce successful low residue crops such as dry beans, sugarbeets, onions, and corn. Often such crops are grown following alfalfa or mint which are high residue crops that protect the soil from eroding. Changing the crop sequence to direct seed, corn, or cereal without tillage following high residue crops retains the protection of those high residue crops against soil loss, greatly reduces production costs, and provides yields as high as or higher than traditional practices. Additionally, corn and cereal are high nitrogen consuming crops, and research has shown that most of the needed nitrogen for these crops is provided following alfalfa as a result of nitrogen fixed by bacteria while the alfalfa was growing, being mineralized, and becoming available to the subsequent corn or cereal crop (1, 2, 3, 4, 5). Therefore, little or no nitrogen fertilizer is needed. When cereal or corn is grown later in the cropping sequence, as is the case traditionally, fertilizer nitrogen is required for a successful crop.

The concept involved in applying this crop sequencing BMP is to grow crops in the sequence that will minimize the number of tillage operations over the entire crop rotation, and to expose the soil to severe erosion the minimum number of seasons during the rotation. To apply the concept, generally the same crops can be grown, but in different order than traditionally followed. In some cases, there may be economic advantages to discontinuing a crop or two or adding a crop or two to the rotation.

Research has shown (1, 2, 3) that soil erosion and sediment and associated nutrient loss is significantly reduced by following this crop sequencing BMP. The phosphorus credits attained by applying this BMP may markedly increase net profits to participating farmers.

2. Application criteria.

This BMP is applicable to any field used to produce low residue crops one or more seasons of a crop rotation under surface irrigation. Generally farmers have several fields on which they rotate crops in a manner that provides the desired diversity. Usually alfalfa is in the crop mix, and it is usually grown successively for three years. Mint is also a multiyear, high residue crop grown in the lower Boise river project area.

3. Potential side effects and ancillary benefits.

Application of this BMP reduces tillage operations and costs and can lead to reduced needs for tillage equipment. It also reduces the need to apply nitrogen fertilizer where alfalfa is in the crop rotation for the two seasons following killing the alfalfa. Production costs are significantly reduced by fewer tillage operations and net profits significantly increased. The added benefit of producing phosphorus credits can add to net profits.

One negative side effect is the sociological aspect of breaking traditions and the fear that doing so will lead to crop failures. Many farmers have the perception that large, no-till equipment will be needed, but that is not the case. Only minor equipment modifications are sometimes needed, but often no changes are required (1, 2, 3). Weed control differs from that with traditional tillage. Weed problems need to be identified early and control measures taken. Generally annual weed problems are less severe than with traditional tillage, depending upon the control practices in the previous crop. Perennial weed problems can often be identified earlier in the direct seeded crops allowing earlier control practices.

4. Monitoring plan.

This BMP is best monitored by field observation of tillage and seeding practices. The farmer must be required to keep a record of all tillage and seeding practices including dates to show to a field inspector for the Lower Boise Effluent Trading Demonstration Project. Several inspections should be made. The first early in the season before any tillage or seeding is done to evaluate the fields to be treated by the BMP. The second should be after seeding. A third should be made after cultivation time for the crops involved to assure the BMP has not been abandoned by over-cultivating. A fourth should be made before harvest.

Monitoring by measuring effectiveness of this BMP on the fields where it is applied is not possible without splitting the field into traditional and treated portions. The research conducted to determine BMP effectiveness was done on many fields that were divided into traditional tillage and crop sequences with crop sequences and tillage practices applied to control surface irrigation erosion. Those results are well documented. Therefore, monitoring by making measurements on those fields where the BMP is applied is unnecessary and would compromise the BMP effectiveness.

5. Application features. (Also see NRCS Practice Codes 329A, 329B, 329C, 777, ID-450, and Tech. Note #32, Rev. 2.)

This BMP may not be applicable to all farms and fields. Certainly fields irrigated by sprinkler or microirrigation systems would not be eligible, and fields already in continuous high residue crops would show no benefit. The application would differ depending upon the traditional crop rotation. The fundamental application is that when a farmer planned to follow a high residue crop with a low residue crop and do so by plowing under residue, but instead of doing that, spray kills the high residue crop and directly seeds corn or cereal. He then would only clean the irrigation furrows and use them to irrigate the direct-seeded crop. Some tilling may be advisable for some corn crops. The next season, similar decision changes would likely be made.

For example, assume that a farmer traditionally grows alfalfa on his fields for three years and then plows it down and grows dry beans for two seasons, sugarbeets for one season, then cereal for a season, corn for a season, and then returns to alfalfa for three seasons. Using the SISL model, soil loss can be calculated for each season.

One application of this BMP would be to kill the alfalfa in the late fall or the early spring, and directly seed corn into the alfalfa residue. Furrows that had been used to irrigate the alfalfa would be cleaned and used to irrigate the corn. The corn would be harvested and then cereal would be directly seeded into the field, and again the same furrows would be cleaned and used to irrigate the cereal. The third year, dry beans would be grown without moldboard plowing but with disking only or without any tillage by directly seeding beans into the cereal residue. Dry beans would be grown the third year with minimum tillage and then sugarbeets would be grown with reduced tillage, and then corn with reduced tillage. Following corn, alfalfa would be seeded with peas or alone, but without extensive tillage.

There would be significant phosphorus credits accumulated the first, second, and third years after alfalfa. The fourth and fifth years, fewer credits would be accumulated. These credits could be increased by applying the polyacrylamide BMP.

Another example would be to assume the same traditional crop sequence. The BMP application would be no-till corn, then no-till cereal, then back to alfalfa. This change may provide the farmer with greater income than he is presently attaining because his input costs will be significantly lower, crop yields will likely be the same or higher than with the traditional rotation, and equipment needs will be significantly reduced. The phosphorus credits can be sold for profit to enhance net income. In this example, phosphorus credits will be high because erosion will be significantly reduced.

Still another example that could be applied when farmers do not wish to grow alfalfa most of the time would be to first follow alfalfa with corn, cereal, corn, cereal, and peas-alfalfa. Mint could fit into the cycle as desired as well.

There are many examples that could be provided. The important application criteria are to follow high residue crops with directly seeded crops as many seasons as possible, and then apply other residue management or polyacrylamide BMP's. Research has demonstrated in numerous field trials that this BMP can be successfully applied (1, 2, 3, 4, 5).

Farmers who do not grow corn and do not want to grow it can follow alfalfa or mint with directly seeded cereal. Also, should they prefer to grow cereal before corn, that can be done as well, but utilization of nitrogen from the alfalfa is not as efficient by cereal as by corn. Corn can be easily directly seeded into cereal stubble.

6. Installation requirements.

These requirements are covered under application criteria. Also see NRCS Practice Codes 329A, 329B, 329C, 777, and ID-450.

7. Operation and maintenance requirements.

The only requirements would be to follow the application criteria discussed. Field inspection and farmer records could verify that the crops scheduled to be grown were seeded in the prescribed manner.

8. BMP effectiveness.

The effectiveness of this BMP for reducing phosphorus loss from the land depends upon its effectiveness in preventing erosion and topsoil loss. Research has shown that changing the crop sequence in the rotation so that the number of tillage operations is minimized markedly reduces erosion and topsoil loss, significantly decreases crop production costs, and remarkably increases crop production net income before any consideration is given to the value of phosphorus credits (1, 2, 3). Adding the benefits of the value of phosphorus credits will enhance that income. The mechanism is that changing the crop sequence and reducing tillage can reduce surface irrigation erosion and topsoil loss up to 90% to 95% depending upon the particular crop sequence selected when applying the BMP. This high percentage reduction in topsoil loss represents savings of hundreds of pounds of phosphorus over the crop rotation cycle. A sediment loss reduction efficiency of 90% with an uncertainty factor of 10% is assigned for purposes of the effluent trading demonstration project.

Many different traditional cropping sequences exist in the study area, and many different new sequences are possible when applying the BMP. This permits considerable flexibility in applying the BMP.

Applying this BMP will have little if any effect upon dissolved phosphorus. The phosphorus savings results from saving topsoil and the two pounds of phosphorus per each ton of topsoil saved as compared to traditional crop sequences.

9. Calculating phosphorus retained by the BMP.

Applying this BMP reduces surface irrigation erosion and the loss of topsoil with its associated phosphorus. Therefore, the topsoil loss expected from surface irrigation erosion for the traditional crop sequence is calculated by the SISL model and compared to that calculated by the SISL model for the BMP crop sequence. This difference is then multiplied by (0.9 - 0.1) representing the assigned sediment removal efficiency and the uncertainty percentage. This can be done for any one year, or for the entire crop rotation by adding the yearly results. Some years' differences will be large and some years' differences will be small. It is recommended that farmers study the impacts over the entire crop rotation so they will better understand the potential impact of applying this BMP, and in some seasons, adding a second BMP.

To illustrate the overall significance of this BMP, two tables have been generated to compare an assumed traditional crop sequence with two different crop sequences that could be applied under the BMP. The first comparison includes the same crops at the same frequency, but grown in different sequence. The second comparison is the same traditional sequence compared to a BMP sequence where highly erosive crops are eliminated. These are only two illustrative examples of many possible. These tables may appear complicated, but farmers and technicians are encouraged to study them because of the concepts and understanding they convey in the phosphorus credits calculations and the potential value of these credits to farmers over both yearly and longer time periods.

The assumed data for these comparisons are as follows.

Field size = 20 acres

Slope = 1.4% with a moderate convex end

Irrigation method = siphon tubes without cutback

Soil erodibility, KA = 0.65

Traditional crop sequence = alfalfa, dry beans, dry beans, sugarbeets, cereal, corn, peas-alfalfa, alfalfa. This is an eight-year rotation, but calculations will be made for six seasons beginning with dry beans following alfalfa and ending with the peas-alfalfa. Little or no erosion is expected during the other two seasons when alfalfa is grown.

Tillage = traditional including moldboard plowing for the traditional crop sequence

First comparison BMP crop sequence = alfalfa, no-till corn, no-till cereal, reduced-till dry beans, reduced-till dry beans, reduced-till sugarbeets, peas-alfalfa, alfalfa. The seasons, beginning with no-till corn following alfalfa and ending with peas-alfalfa will be compared. Crops are the same as traditional but in different sequence.

Second comparison BMP crop sequence = alfalfa, no-till corn, no-till cereal, peas-alfalfa, alfalfa, alfalfa, no-till corn. The comparison will be made beginning with no-till corn and ending with no-till corn. Dry beans and sugarbeets are eliminated compared to the traditional sequence.

Tillage for BMP = tillage would vary from no-till to chisel plowing, but would exclude moldboard plowing. Generally only disking and roller-harrowing or similar operations would be included, and those only a minimum number of times between crops. Cleaning old irrigation furrows is not considered a tillage operation.

The calculations include applying the SISL model for the crop sequence involved, multiplying by 20 for the 20 acres, and then multiplying by 2 representing two pounds of phosphorus per ton of soil to give pounds of phosphorus saved for the 20 acres. The value of the phosphorus credits would depend upon the effluent trading established price per pound of phosphorus. Below is an example of the first year comparison.

Traditional crop sequence of dry beans following alfalfa:

$$SISL_T = 10.9 \times 0.65 \times 0.70 \times 1.0 \times 0.9 \times 20 = 89.27 \text{ tons}$$

Crop sequence BMP of no-till corn following alfalfa:

$$SISL_{BMP} = 10.9 \times 0.65 \times 0.7 \times 0.1 \times 0.9 \times 20 = 8.92 \text{ tons}$$

$$SISL_T - SISL_{BMP} = 80.35 \text{ tons}$$

$$\text{Phosphorus retained} = 64.3 \times 2 = 129 \text{ pounds of phosphorus}$$

$$\text{Sediment retained} = 80.35 \times (0.9 - 0.1) = 64.3$$

Assuming a seller's ratio at Mason Creek of 0.75 and prices of \$5, \$15, \$25, and \$50 per pound gives \$484, \$1,451, \$2,419, and \$4,838

The tables following the references are results of these types of calculations for each of the six seasons.

In addition to the value of the phosphorus credits derived from the BMP, farmers can expect to save about \$3,200 in nitrogen fertilizer cost and about \$8,400 in tillage operational costs when applying the BMP and growing the same crops as in the traditional sequence, over the entire crop rotation. When changing crops to eliminate low residue crops, the nitrogen fertilizer savings would be \$3,200 and the tillage operational cost savings would be about \$11,200. Crop yields will not usually differ significantly, and when they do, it is likely they will be higher when applying the BMP. Crop quality will be the same or higher when applying the BMP as when farming traditionally.

These calculations are for a 20-acre field. Values will be eight times greater for a 160-acre farm.

References.

1. Carter, D. L. Extensive unpublished data and observations of the author.

2. Carter, D. L., and R. D. Berg. 1991. Crop sequences and conservation tillage to control irrigation furrow erosion and increase farmer income. J. Soil and Water Cons. 46:39-142.

3. Carter, D. L., R. D. Berg, and B. J. Sanders. 1991. Producing no-till cereal or corn following alfalfa on furrow irrigated land. J. Prod. Agric. 4:174-179.

4. Meek, B. D., D. L. Carter, D. T. Westermann, and R. E. Peckenpaugh. 1994. Root-zone mineral nitrogen changes as affected by crop sequence and tillage. Soil Sci. Soc. Amer. J. 58:1464-1469.

5. Meek, B. D., D. L. Carter, D. T. Westermann, J. L. Wright, and R. E. Peckenpaugh. 1995. Nitrate leaching under furrow irrigation as affected by crop sequence and tillage. Soil Sci. Soc. Amer. J. 59:204-210.

Same Crop Comparison for 20 Acres

	Traditional Crop Sequence			BMP Crop Sequence [1/]							Value of Phosphorus Credits, $ per Pound		
Year	Crop	Previous Crop	SISL	Crop	Previous Crop	SISL	Topsoil Saved	Phosphorus Retained at Farm	Seller's Ratio	Phosphorus Credits Saleable	$5	$15	$25
			(tons)			(tons)	(tons)	(pounds)					
1	Dry beans	Alfalfa	89.27	No-till corn	Alfalfa	8.93	80.33	129	0.75	97	485	1,455	2,435
2	Dry beans	Dry beans	127.53	No-till cereal	No-till corn	3.50	124.03	198	0.75	148	740	2,220	3,700
3	Sugarbeets	Dry beans	177.84	Reduced-till dry beans	No-till cereal	33.48	144.36	230	0.75	172	860	2,580	4,300
4	Cereal	Sugarbeets	177.84	Reduced-till dry beans	Reduced-till [2/] dry beans	63.77	114.07	183	0.75	137	685	2,055	3,425
5	Corn	Cereal	95.64	Sugarbeets	Reduced-till [2/] dry beans	88.91	6.73	11	0.75	8	40	120	200
6	Peas-alfalfa	Corn	35.10	Peas-alfalfa	Sugarbeets	23.08	12.02	19	0.75	14	70	210	350
				Total phosphorus credits for the 6 years				770			2,880	8,640	14,410

Same Traditional Crops but No Low Residue Crops in BMP Sequence for 20 Acres

Year	Crop	Previous Crop	SISL	Crop	Previous Crop	SISL	Topsoil Saved	Phosphorus Retained at Farm	Seller's Ratio	Phosphorus Credits Saleable	$5	$15	$25
1	Dry beans	Alfalfa	89.27	No-till corn	Alfalfa	8.93	80.33	129	0.75	97	485	1,455	2,435
2	Dry beans	Dry beans	127.53	No-till cereal	No-till corn	3.50	124.03	198	0.75	148	740	2,220	3,700
3	Sugarbeets	Dry beans	177.84	Peas-alfalfa	No-till cereal	5.27	172.57	276	0.75	207	1,035	3,105	5,175
4	Cereal	Sugarbeets	177.84	Alfalfa	Peas-alfalfa	1.47	176.37	282	0.75	212	1,060	3,180	5,300
5	Corn	Cereal	95.64	Alfalfa	Alfalfa	1.47	94.17	151	0.75	113	565	1,695	2,825
6	Peas-alfalfa	Corn	35.10	Corn	Alfalfa	8.91	26.19	43	0.75	32	160	480	800
				Total phosphorus credits for the 6 years				1,079			4,045	12,135	20,235

1/ Nitrogen fertilizer costs will be reduced by about $3,200 by applying the BMP over the entire 6 year rotation when using the same crop comparison or the changed crop comparison. Applying the BMP will greatly reduce the number of tillage operations and associated costs. Research results (1, 2, 3) indicate a potential tillage operational cost savings of $8,400 when applying the BMP using the same crops and $11,200 when using different crops.

2/ Applying the polyacrylamide BMP these two seasons reduces topsoil loss about 95% and increases the phosphorus credits even more in comparison to traditional practices.

6. Polyacrylamide (PAM) to Control Surface Irrigation Erosion

1. Description

Various long chain, anionic polyacrylamides added to irrigation water or irrigation furrows reduce furrow erosion and sediment loss dramatically. These materials are readily available, and there are several application techniques that provide excellent erosion control. Applying PAM will reduce the loss of sediment and phosphorus associated with that sediment. This practice will not have a significant impact on dissolved phosphorus. Applying PAM does increase infiltration and thereby will reduce runoff to some extent, thus decreasing the quantity of dissolved phosphorus in surface runoff reaching the lower Boise river, but that effect is small enough to be within the margin of error in estimating surface runoff (1, 2, 3, 4, 5, 6, 7, 8, 9).

2. Application criteria.

Applying the polyacrylamide (PAM) BMP is recommended for intensive row crops where other BMP's to reduce erosion are modestly effective. The BMP can be applied to irrigation water for other crops, but cost effectiveness may be low. Integrating this BMP with the crop sequencing BMP will provide excellent erosion control for the entire crop rotation. This BMP would be applied to the row crops and intensive row crops in the rotation, and no-till and reduced-till practices would be applied to other crops. This is a one season practice, and polyacrylamide must be applied every irrigation as specified by NRCS Practice Code ID-450.

3. Potential side effects and ancillary benefits.

Applying the polyacrylamide BMP provides a method to control erosion and sediment loss without changing from traditional crop sequences or changing tillage practices (1, 3, 4, 5, 8, 9). Certainly phosphorus credits will accrue from applying this BMP. The value of the phosphorus credits would likely more than offset costs of applying the BMP. In addition, polyacrylamide improves the efficiency of other conservation practices. It reduces other sediment management costs and prevents pesticides, microbes, and weed seeds from moving to surface water.

The only negative side effects are those associated with polyacrylamide application techniques. When the irrigation water source is high in sediment concentration, head ditches may fill with sediment if the polyacrylamide is applied to the water head for the field. In cases such as these, the polyacrylamide may need to be applied to the furrow streams or the dry furrows before irrigation commences.

4. Monitoring plan.

The monitoring necessary is to observe the irrigation operation to assure that polyacrylamide is being applied every irrigation. In addition, periodic checks should be made for evidence of erosion or sediment in the tailwater ditch.

Monitoring the effectiveness of this BMP by measuring the sediment and phosphorus removal efficiencies cannot be done without compromising the effectiveness of the BMP to a field. Doing so would require leaving a number of untreated furrows for measurement, and these furrows would erode.

The sediment and phosphorus loss from them would be about 20 times greater than from PAM-treated furrows. Should measuring effectiveness of the BMP in place be desired, the method outlined for the filter strips and underground outlet BMP's is appropriate and should be applied to the inflow and outflow from at least 10 untreated and PAM treated furrows for each water set. Measurements in the tailwater ditch would not be needed.

Extensive research has been conducted on the application of PAM, and the addition of more field measurement of established application technology would add little new information and be of no value to the Lower Boise River Effluent Trading Demonstration Project.

5. Design features.

Polyacrylamides should be applied according to NRCS Practice Code ID-450.

6. Installation requirements.

According to NRCS Practice Code ID 450.

7. Operation and maintenance requirements.

According to NRCS Practice Code ID-450.

8. BMP effectiveness.

Extensive research and field demonstrations indicate that polyacrylamide applied according to NRCS Practice Code ID-450 will reduce irrigation furrow erosion by more than 95%. Variability in results is rather low, and an uncertainty factor of 10% should adequately assure that phosphorus credits will not be over estimated. The variability usually results when convex lower field ends are present, when application machinery does not function properly, or application techniques are not closely followed. There are continuing efforts to develop improved application methods.

9. Calculating phosphorus retained by the BMP.

The effect of polyacrylamide is to prevent surface irrigation erosion and sediment loss. Therefore, phosphorus retained is calculated based upon sediment saved, as compared to traditional practices. The SISL model is used to calculate the amount of sediment that would be lost from the field without the application of polyacrylamide, then the 95% reduction of that amount and the 10% uncertainty factor are applied to calculate the tons of sediment saved. That value is multiplied by the two pounds of phosphorus per ton of sediment to give pounds of phosphorus retained.

Example:

Assume a SISL value for 20 acre field = 190 tons of sediment

$$190 \times (.95 - .10) \times 2 = 323 \text{ lbs of phosphorus retained}$$

References.

1. Lentz, R. D., I. Shainberg, R. E. Sojka, and D. L. Carter. 1992. Preventing irrigation furrow erosion with small applications of polymers. Soil Sci. Soc. Amer. J. 56:1926-1932.

2. Lentz, R. D., and R. E. Sojka. 1996. Polyacrylamide application to control furrow irrigation-induced erosion. pp. 421-430. In: Erosion Control Technology---Bringing It Home. Proc. of Conf. XXVII, Seattle, WA, Feb. 27 to Mar. 1, 1996, International Erosion Control Association.

3. Lentz, R. D., and R. E. Sojka. 1994. Field results using polyacrylamide to manage furrow erosion and infiltration. Soil Sci. 158:274-282.

4. Lentz, R. D., R. E. Sojka, and C. W. Robbins. 1998. Reducing phosphorus losses from surface irrigated fields: Emerging polyacrylamide technology. J. Environ. Qual. 27:305-312.

5. Sojka, R. E., and R. D. Lentz. 1997. Reducing furrow irrigation erosion with polyacrylamide (PAM). J. Prod. Agric. 10:47-52.

6. Sojka, R. E., R. D. Lentz, and D. T. Westermann. 1998. Water and erosion management with multiple applications of polyacrylamide in furrow irrigation. Soil Sci. Soc. Amer. J. 62:1672-1680.

7. Sojka, R. E., R. D. Lentz, C. W. Ross, T. J. Trout, D. L. Bjorneberg, and J. K. Aase. 1998. Polyacrylamide effects on infiltration in irrigated agriculture. J. Soil and Water Cons. 53:325-331.

8. Sojka, R. E., R. D. Lentz, D. L. Bjorneberg, J. K. Aase, J. Entry, D. Morishita, C. W. Ross, and T. Trout. 1999. Polyacrylamide (PAM) - A Million Acre Progress Report. pp. 85-92. In: Proc. International Irrigation Show, Nov. 7-9, 1999, Orlando, FL, Irrigation Association.

9. Trout, T. J., R. E. Sojka, and R. D. Lentz. 1995. Polyacrylamide effect on furrow erosion and infiltration. Trans. ASAE 38:761-765.

7. Sprinkler Irrigation

1. Description.

Applying water by a system of pipes, nozzles, and pumps causing the water to reach the crop or ground in droplets varying from very fine to large drops is called sprinkler or spray irrigation. This practice has grown steadily over the past half century, and the associated technology has also grown and been continually updated so that very sophisticated systems are available today. Sprinkler irrigation is much more efficient than surface irrigation, and it can be used where surface area slope changes preclude surface irrigation methods. There is a wide variety of sprinkler systems available including center pivot, linear continual moving, wheel lines, hand move, solid set, and others. Correctly designed and operated sprinkler irrigation systems do not cause significant erosion, and there is no surface runoff water because all the water applied infiltrates into the soil.

2. Application criteria.

Sprinkler irrigation systems can be applied to most lands that are surface irrigated as well as to lands that cannot be successfully surface irrigated because of slope changes over short distances and slope steepness. Most crops can be successfully sprinkler irrigated, but there are a few exceptions where sprinkler application of water can damage and reduce crop quality. Some site specific conditions including soils, crop rotations, and tillage practices may preclude the use of sprinkler systems, but these are rare. In some locations safe discharge of overflow water during power outage events could cause serious problems. Wide application of sprinkler irrigation could impact downstream water supplies.

3. Potential side effects and ancillary benefits.

The initial investment for equipment to sprinkler irrigate a field or farm is significant and ranges widely. Sprinkler systems require pumps to develop pressure in the system to distribute the water. Therefore, electrical power or other fuel costs can be significant each season. In some areas, shortage of electrical power has slowed the expansion of sprinkler irrigation, at least temporarily.

One other disadvantage to sprinkler irrigation is that 5% or more of the water leaving nozzles or spray tips evaporates before it reaches the crop or ground. This percentage has been decreased by developing better sprinkler nozzles and spray heads, but it is still significant.

An important advantage of sprinkler irrigation is that most surface irrigation delivery ditches to fields can be eliminated when converting from surface to sprinkler irrigation. This results in time savings in farming practices because machinery turnarounds are much less frequent, and ingress and egress to fields are less restrictive than with surface irrigation.

Another advantage of sprinkler irrigation is that fertilizers and pesticides can be precisely and timely applied to growing crops, improving the effectiveness and efficiency of using such materials. This improves crop production efficiency and conserves resources.

Tillage practices are less restrictive under sprinkler irrigation than with surface irrigation. One challenge always present under surface irrigation is assuring that water reaches the lower end of the field early enough during the irrigation set that the lower end of the field receives adequate water to meet crop needs. The usual result is that the lower end of the field is underirrigated or the upper end is overirrigated or both. This challenge has caused farmers to over till to bury residue so that water flow is not restricted in furrows. This over tillage greatly increases erosion and sediment loss. This is not a factor under sprinkler irrigation. Heavy residues can be left on the soil surface without inhibiting irrigation.

4. Monitoring.

The only monitoring necessary is to observe to assure that the conversion to sprinkler has been made according to NRCS Practice Code 442. Periodic visual observation during irrigations should be made to assure there is no runoff. If runoff is found, some operational practices may need to be changed, such as effectively reducing the application rate.

5. Design features.

Sprinkler systems must be designed as required by NRCS Practice Code 442.

6. Installation requirements.

Sprinkler systems must be installed as specified by NRCS Practice Code 442.

7. Operation and maintenance.

Sprinkler systems must be operated and maintained according to NRCS Practice Code 442. Annual inspections should be made to assure that the standards are being met.

8. BMP effectiveness.

The application of this sprinkler irrigation BMP will remove phosphorus from surface runoff water by two mechanisms, and the results are additive for calculating phosphorus removed. The first mechanism is that applying the BMP essentially eliminates irrigation erosion and thereby the sediment and nutrients that would have left the fields under traditional surface irrigation and tillage practices will not leave. Phosphorus credits will result from this erosion preventing or reducing process.

The second mechanism is that the total phosphorus in 50% of the water diverted to irrigate the fields will not be permitted to pass across the fields and become drainage water as would occur under surface irrigation. Therefore, the quantity of phosphorus in 50% of the diverted water is retained. This quantity is added to that from the first mechanism to give total phosphorus retained.

There exists some uncertainty associated with the design and operation of sprinkler irrigation systems. Often these are associated with power outages and equipment malfunction. Such events can cause erosion and runoff. An uncertainty value of 10% is assigned to this BMP.

9. Calculating phosphorus retained by the BMP.

The phosphorus retained by applying this BMP would be the sum of the quantities resulting from the two phosphorus removal mechanisms. For the first mechanism, the SISL model is applied for the fields on the farm to calculate the quantity of sediment that would have been lost with traditional irrigation and cropping systems. The resulting tons of sediment is multiplied by the two pounds of phosphorus per ton of sediment factor to give pounds of phosphorus by the first mechanism.

Phosphorus retained from the second mechanism are calculated by multiplying the quantity of water diverted to irrigate the fields by the total phosphorus concentration in that water, and applying the 50% factor. The pounds of phosphorus by this mechanism are added to those of the first mechanism to give the total phosphorus retained for the fields involved. Then the uncertainty factor is applied to calculate phosphorus retained on-site.

Example:

Assume a 160-acre farm comprised of multiple fields in various crops in a usual rotation on each field, and that the entire farm is converted to sprinkler irrigation.

The calculation method is to apply the SISL model to each field to calculate the tons of sediment expected to leave each field under traditional surface irrigation. Add those amounts together to give a total for the farm. Then multiply those tons of sediment by the two pounds of phosphorus per ton of sediment to give the total pounds of phosphorus by the first mechanism. Then add to that amount the pounds of phosphorus in 50% of the water diverted to irrigate the farm. This value is obtained by multiplying the amount of water diverted by its average total phosphorus concentration. Multiply this result by (100 – .1) = 0.9 for the 10% uncertainty.

Assume:

SISL total for fields = 960 tons of sediment

$$960\ tons \times 2 = 1{,}920\ pounds\ of\ phosphorus\ retained$$

Add to that:

$$160\ acres \times 3.5\ ft\ per\ acre = 560\ acre\ feet\ of\ water$$

Assume a total phosphorus concentration of 0.250 mg L^{-1} or ppm.

One acre-ft of water weighs 2.72 million pounds, and there are 0.250 pounds of phosphorus in each acre foot of water.

Therefore:

$$2.72 \times 560 \times .50 \times 0.250 = 190 \textit{ pounds of phosphorus retained}$$

Phosphorus retained for the farm is:

$$1,920 + 190 = 2110 \textit{ pounds}$$

Applying the uncertainty factor of 10% gives:

Phosphorus retained on site for trading = 2,110 × 0.9 = 1,899 lbs

Note: The values of these phosphorus credits in the effluent trading program are not known at this writing, but let us assume three values and estimate the increased income to the farmer for applying the sprinkler irrigation BMP.

Assume a seller's ratio of 0.75 at Mason Creek.

Assume $ 5 per pound:	$ 5 × 1,899 × 0.75	=	$ 7,121
$10 per pound:	$10 × 1,899 × 0.75	=	$14,242
$20 per pound:	$20 × 1,899 × 0.75	=	$28,485

References.

1. Allen, R. G. 1992. Catch-3D sprinkler pattern analysis software; user's manual. Dept. of Biol. and Irrig. Engr., Utah State University, Logan, Utah.

2. ASAE. 1999. Planning, Design, Operation and Management of Low Energy Precision Application (LEPA) Irrigation Systems. Engineering Practice X531, 17 p., Am. Soc. of Agric. Engr., St. Joseph, MI 49085.

3. Bordovsky, J. P., and W. M. Lyle. 1996. LEPA irrigation of grain sorghum with varying water supplies. Trans. ASAE 39(6):2033-2038.

4. Buchleiter, G. W. 1992. Performance of LEPA equipment on center pivot machines. Appl. Engr. in Agric. 8(5):631-637.

5. Coelho, R. D., D. L. Martin, and F. H. Chaudrhy. 1996. Effect of LEPA irrigation on storage in implanted reservoirs. Trans. ASAE 39(4):1287-1298.

6. DeBoer, D. W., D. L. Beck, and A R. Bender. 1992. A field evaluation of low, medium and high pressure sprinklers. Trans. ASAE 35(4):1185-1189.

7. Duke, H. R., D. F. Heermann, and L. J. Dawson. 1992. Appropriate depths of application for scheduling center pivot irrigations. Trans. ASAE 35(5):1457-1464.

8. Fangmeier, D. D., W. F. Voltman, and S. Eftekharzadeh. 1990. Uniformity of LEPA irrigation systems with furrow drops. Trans. ASAE 33(6):1907-1912.

9. Heermann, D. F., and T. L. Spofford. 1998. Evaluating center pivot irrigation systems. ASAE Paper 98-2068. ASAE, St. Joseph, MI 49085-9659.

10. Heermann, D. F., G. W. Buchleiter, and K. M. Stahl. 1999. Effect of application pattern shape on center pivot irrigation uniformity. Irrig. Assoc. Tech. Conf. Proc., pp. 69-76.

11. Howell, T. A., A. D. Schneider, and D. A. Dusek. 1991. Corn and sorghum yield response to LEPA irrigation. ASAE Paper No. 91-2520, 26 p. ASAE, St. Joseph, MI 49085-9659.

12. Howell, T. A., A. Yazar, A. D. Schneider, D. A. Dusek, and K. S. Copeland. 1995. Yield and water use efficiency of corn in response to LEPA irrigation. Trans. ASAE 38(6):1737-1747.

13. Kincaid, D. C. 1994. Comparison of modified LEPA and low elevation spray system for center pivot irrigation. ASAE Paper No. 94-2099, 11 p. ASAE, St. Joseph, MI 49085-9659.

14. Kincaid, D. C., B. A. King, and D. W. DeBoer. 2000. Sprinkler packages and their configurations for center pivot irrigation. Proc. of Fourth National Irrigation Symposium. ASAE, St. Joseph, MI 49085-9659.

15. Kincaid, D. C., K. H. Solomon, and J. C. Oliphant. 1996. Drop size distributions for irrigation sprinklers. Trans. ASAE 39(3):839-845.

16. King, B. A., and D. C. Kincaid. 1997. Optimal performance from center pivot sprinkler systems. Bulletin 797, University of Idaho Coop. Ext. System, Agricultural Experiment Station, Moscow, ID.

17. Li, J., and H. Kawano. 1996. Sprinkler rotation nonuniformity and water distribution. Trans. ASAE 39(6):2027-2031.

18. Louie, Michael J., and John S. Selker. 2000. Sprinkler head maintenance effects on water application uniformity. J. Irrig. and Drain Engr. 126:142-148.

19. Louie, M. J., and J. S. Selker. 2000. Sprinkler head maintenance effects on water application uniformity. J. Irrig. and Drain. Engr. 126:141-148.

20. Lyle, W. M., and J. P. Bordovsky. 1991. LEPA low energy precision application. Irrig. J. 41(3):18-24.

21. Lyle, W. M., and J. P. Bordovsky. 1995. LEPA corn irrigation with limited water supplies. Trans. ASAE 38(2):455-462.

22. Martin, D. L., D. E. Eisenhauer, and M. Volkmer. 1997. Design of LEPA irrigation systems. ASAE Paper No. 97-2212, 18 p. ASAE, St. Joseph, MI 49085-9659.

23. Mitchell, J. P., S. Allaire-Leung, B. L. Sanden, and L. Wu. 2000. Sprinkler spacing effects on carrot yield and quality. J. Hort. Tech. 10(2) (accepted).

24. Nderitu, S. M., and D. J. Hills. 1993. Sprinkler uniformity as affected by riser characteristics. Appl. Engr. in Agric. 9(6):515-521.

25. New, L., and G. Fipps. 2000. Efficient center pivot irrigation. Texas Agr. Ext. Ser. Bull. B-6096, 20 p. Texas A & M Univ., College Station, TX.

26. Or, D., and R. J. Hanks. 1992. Soil water and crop yield spatial variability induced by irrigation and uniformity. Soil Sci. Soc. Amer. J. 56:226-233.

27. Reaves, R. E. 1999. Latest farm and ranch survey reveals pulse of irrigation. Irrigation Business and Technology 7(6):57. The Irrigation Association, Fairfax, VA.

28. Schneider, A. D. 1999. Efficiency of LEPA and spray irrigation. In: Proc. 1999 Intl. Water Resources Engr. Conf., 8 p. Seattle, WA, Aug. 8-12, 1999. Am. Soc. of Civil Engr.

29. Schneider, A. D., and T. A. Howell. 1995. Sprinkler application methods and irrigation system capacity. Trans. ASAE 38(6):1693-1697.

30. Schneider, A. D., and T. A. Howell. 1997. Methods, amounts, and timing of sprinkler irrigation for winter wheat. Trans. ASAE 40(1):137-142.

31. Seginer, I., and M. Kostrinsky. 1975. Wind, sprinkler patterns, and system design. J. Irrig. and Drain. Div., ASCE 101(4):251-264.

32. Seginer, I., D. Nir, and R. D. von Bernuth. 1991. Simulation of wind-distorted sprinkler patterns. J. Irrig. and Drainage Engr.117(2):285-306.

33. Spurgeon, W. E., and T. P. Makens. 1991. Irrigation management for LEPA systems. ASAE Paper No. 91-2519, 21 p. ASAE, St. Joseph, MI 49085-9659.

34. Spurgeon, W. E., A. M. Feyerherm, and H. L. Manges. 1995. In-canopy application mode and soil surface modification for corn. Appl. Engr. in Agric.11(4):517-522.

35. Wallach, R. 1990. Effective irrigation uniformity as related to root zone depth. Irrig. Sci. 11:15-21.

8. Microirrigation
(Trickle and Drip Irrigation)

1. Description.

Microirrigation is a system of tubes and emitters or porous tubes to apply irrigation water beneath growing crop plants or on or near the soil surface close to growing plants. Tubes can be plowed in beneath crop rows, or laid on the surface beside crop rows in about any kind of configuration desired. Equipment is available to do that. Usually water entering these systems must be filtered to remove materials that may clog emitters or porous tube openings. Systems can be permanently installed or taken out following the production of a high value crop such as onions. Micro-irrigation can be used on most crops, but costs for installation and removal may be too high for some crops or fields.

2. Application criteria.

Microirrigation systems can be applied to any land that can be surface irrigated as well as to lands that cannot be surface irrigated because of land surface slope changes. Most crops can be trickle irrigated, utilizing system designs that are crop specific.

3. Potential side effects and ancillary benefits.

The costs of microirrigation systems are significant and range widely. Pumps and electrical power or other fuels are needed, but pressures required are low so that operational costs are not as great as with sprinkler irrigation.

Where permanent microirrigation systems are applied, field delivery ditches can be eliminated. Surface residues do not limit microirrigation as they can surface irrigation. Tillage practices are, therefore, not as restrictive. Fertilizer and pesticides can be applied through microirrigation systems. Care must be taken to avoid salt accumulation in the root zone when the water source has significant salt concentration.

Water use efficiency is very high with properly designed, installed, and operated microirrigation systems. Values approaching 100% efficiency have been reported, and values above 95% are common.

As with sprinkler irrigation, power outages or pump malfunction can cause erosion and runoff events. Also, flush water from sand media filters may be bypassed and some runoff can occur.

4. Monitoring.

The only monitoring necessary is to assure that the conversion from surface to microirrigation has been made. Flush water from sand media filters should be monitored to assure no significant runoff occurs.

5. **Design features.**

Design of microirrigation systems is very important. These systems should be designed as specified in NRCS Practice Code 441.

6. **Installation requirements.**

Installation requirements will vary according to crop and the planned duration of the system. Systems must be installed as specified in NRCS Practice Code 441.

7. **Operation and Maintenance Requirements.**

Microirrigation systems must be operated according to NRCS Practice Code 441.

8. **BMP effectiveness.**

The application of this microirrigation BMP will remove phosphorus from surface runoff water by two mechanisms, and results are additive for calculating phosphorus credits. The first mechanism is that applying the BMP will eliminate erosion, and thereby the sediment and associated nutrients that would leave the fields in surface runoff under traditional surface irrigation will not leave. Phosphorus credits will accrue as a result of this erosion preventing process.

The second mechanism involves the phosphorus in the water diverted to irrigate the fields. When traditional irrigation is used, about 50% of the water applied runs off as surface drainage. When the microirrigation BMP is applied, there will be no runoff; therefore, the phosphorus in one half of the diverted water will be retained.

An uncertainty factor of 2% is suggested for this BMP because of the slight chance of power outage, pump failure, runoff from sand media filter backflush, and pipe breakage.

9. **Calculating phosphorus retained by the BMP.**

The phosphorus retained by applying the BMP would be the sum of the quantities resulting from the two phosphorus removal mechanisms. For the first mechanism, the amount is calculated by applying the SISL model for fields converted to microirrigation to determine the tons of sediment that would be lost with traditional irrigation, and multiplying that number by the two pounds of phosphorus per ton of sediment factor.

The phosphorus retained by the second mechanism is calculated by determining the quantity of phosphorus in the water diverted to irrigate the fields under the BMP, and multiplying that amount by the 50% factor. Water diversion to farms in the area averages about 3.5 acre feet per acre, and the total phosphorus concentration in that water is about 0.250 mg L^{-1} or ppm. The results for the two mechanisms are added together to give phosphorus retained for the farm or field. Note that each acre foot of water weighs 2.72 million pounds.

The phosphorus retained on-site for trading is calculated by applying the uncertainty factor of 2%.

Example:

Assume a 160-acre farm comprised of multiple fields in various crops in a usual rotation on each field. Further assume that half of the fields, comprising 80 acres, are irrigated with a microirrigation system, and that other fields are being farmed with traditional surface irrigation because they have dense cover crops on them.

The calculation method is to apply the SISL model to determine the quantity of sediment expected to leave each field in the 80 acres converted to microirrigation. Multiply that value by the two pounds of phosphorus per ton of sediment to give phosphorus credits by the first mechanism. Then add to that 50% of the phosphorus in the water diverted to irrigate those fields. This is accomplished by multiplying the amount of water diverted to the 80 acres by its total phosphorus concentration and applying the 50% factor. Then apply the uncertainty value of 2%.

Assume SISL total for the 80 acres under the BMP = 825 tons

$$825 \text{ tons} \times 2 = 1{,}650 \text{ pounds of phosphorus}$$

Add to that

$$80 \times 3.5 \times 2.72 \times 0.50 \times 0.250 = 95 \text{ pounds of phosphorus}$$

Note: One acre foot of water weighs 2.72 million pounds.

The total phosphorus retained for the 80 acres converted to the microirrigation BMP is

$$(1{,}650 + 95) \times .98 = 1{,}710 \text{ pounds of phosphorus}$$

Note: The values of phosphorus credits in the effluent trading program are not known at this writing, but with assumed values of \$5, \$10, or \$20 per pound and a seller's ratio of 0.75, the farmer could expect increased income for applying the microirrigation BMP and selling the phosphorus credits as follows.

$ 5 per pound: $ 5 × 1,710 pounds × 0.75 = $ 6,412
$10 per pound: $10 × 1,710 pounds × 0.75 = $12,825
$20 per pound: $20 × 1,710 pounds × 0.75 = $25,650

References.

1. ASAE Standards, 46th Ed. 1999. EP-458. Field evaluation of microirrigation systems. ASAE, St. Joseph, MI 49085-9659.

2. Ayars, J. E., C. J. Phene, R. A. Schoneman, B. Meso, F. Dale, and J. Penland. 1995. Impact of bed location on the operation of subsurface drip irrigation systems. pp. 141-146. In: Proc. 5th Int. Microirrigation Congress, Orlando, FL, 2-6 April 1995. ASAE, St. Joseph, MI 49085-9659.

3. Ayars, J. E., C. J. Phene, R. B. Hutmacher, K. R. Davis, R. A. Schoneman, S. S. Vail, and R. M. Mead. 1999. Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. Agric. Water Mgt. 42:1-27.

4. Boman, B. J. 1995. Effects of orifice size on microsprinkler clogging rates. Appl. Engr. Agr. 11(6):839-843.

5. Boman, B. J., R. C. Bullock, and M. L. Parsons. 1995a. Effectiveness of Teflon and Sevin sprays in controlling caterpillar damage to microsprinkler spaghetti tubing. Appl. Engr. Agr. 11(4):523-525.

6. Boman, B. J., R. C. Bullock, and M. L. Parsons. 1995b. Ant damage to microsprinkler pulsator assemblies. Appl. Engr. Agr. 11(6):835-837.

7. Bordovsky, J. P. 1998. Evaluation of high frequency cotton irrigation for planned soil water depletion with LEPA and drip systems. Final Report submitted to Cotton, Inc. Project 96-286.

8. Burt, C. M., S. Styles, R. E. Walker, and J. Parrish. 1999. Irrigation evaluation software. Irrigation Training and Research Center, Cal. Poly. San Luis Obispo, CA.

9. Caldwell, D. S., W. E. Spurgeon, and H. L. Manges. 1994. Frequency of irrigation for subsurface drip-irrigated corn. Trans. ASAE 37:1099-1103.

10. Camp, C. R. 1998. Subsurface drip irrigation: A review. Trans. ASAE 41(5):1353-1367.

11. Camp, C. R., P. J. Bauer, and P. G. Hunt, 1997. Subsurface drip irrigation lateral spacing and management for cotton in the southeastern Coastal Plain. Trans. ASAE 40:993-999.

12. Camp, C. R., E. J. Sadler, and W. J. Busscher. 1989. Subsurface and alternate-middle micro irrigation for the southeastern Coastal Plain. Trans. ASAE 32:451-456.

13. Camp, C. R., E. J. Sadler, and W. J. Busscher. 1997. A comparison of uniformity measures for drip irrigation systems. Trans. ASAE 40(4):1013-1020.

14. Camp, C. R., W. M. Thomas, and C. C. Green. 1993. Microirrigation scheduling and tube placement for cotton in the southeastern Coastal Plain. Trans. ASAE 36:1073-1078.

15. Camp, C. R., J. T. Garrett, E. J. Sadler, and W. J. Busscher. 1993. Microirrigation management for double-cropped vegetables in a humid area. Trans. ASAE 36:1639-1644.

16. Enciso, J. D. M., and B. Unruh. 1999. Effect of row pattern and spacing on water efficiency for drip irrigated cotton. ASAE Paper 99-250. ASAE, St. Joseph, MI 49085-9659.

17. Howell, T. A., A. D. Schneider, and S. R. Evett. 1997. Subsurface and surface microirrigation of corn - Southern High Plains. Trans. ASAE 40(3):635-641.

18. Lamm, F. R., H. L. Manges, L. R. Stone, A. H. Khan, and D. H. Rogers. 1995a. Water requirement of subsurface drip-irrigated corn in northwest Kansas. Trans. ASAE 38(2):441-448.

19. Lamm, F. R., W. E. Spurgeon, D. H. Rogers, and H. L. Manges. 1995b. Corn production using subsurface drip irrigation. pp. 388-394. In: Proc. 5th Int. Microirrigation Congress, Orlando, FL., 2-6 April 1995, ASAE, St. Joseph, MI 49085-9659.

20. Lamm, F. R., L. R. Stone, H. L. Manges, and D. M. O'Brien. 1997. Optimal lateral spacing for subsurface drip-irrigated corn. Trans. ASAE 40:1021-1027.

21. Manges, H. L., W. E. Spurgeon, Z. M. Huang, and D. J. Tomsicek. 1995. Subsurface dripline spacing and plant population for corn production. pp. 388-394. In: Proc. 5th Int. Microirrigation Congress, Orlando, FL, 2-6 April 1995. ASAE, St. Joseph, MI 49085-9659.

22. Nakayama, F. S., and D. A. Bucks. 1986. Trickle irrigation for crop production. Elsevier, Amsterdam.

23. O'Brien, D. M., D. H. Rogers, F. R. Lamm, and G. A. Clark. 1998. An economic comparison of subsurface drip and center pivot sprinkler irrigation systems. Appl. Engr. Agric. 14(4):391-398.

24. Oron, G., Y. DeMalach, Z. Hoffman, Y. Keren, H. Hartman, and N. Plazner. 1990. Wastewater disposal by sub-surface trickle irrigation. Water Sci. Tech. 23:2149-2158.

25. Phene, C. J., R. Yue, I-Pai Wu, J. E. Ayars, R. A. Schoneman, and B. Meso. 1992. Distribution uniformity of subsurface drip irrigation systems. ASAE Paper No. 92-2569, 14 p. ASAE, St. Joseph, MI 49085-9659.

26. Powell, N. L., and F. S. Wright. 1993. Grain yield of subsurface microirrigated corn as affected by irrigation line spacing. Agron. J. 85:1164-1170.

27. Spurgeon, W. E., H. L. Manges, and T. P. Makens. 1991. Drip line spacing and plant population for corn. ASAE Paper No. 91-2952. ASAE, St. Joseph, MI 49085-9659.

9. Tailwater Recovery Irrigation System

1. Description

Approximately 50% of the water applied to surface-irrigated fields runs off the surface and becomes tailwater. This tailwater transports sediments, nutrients, plant residue (including weed seed) towards the Boise river in the study area. The tailwater recovery irrigation system is comprised of collection facilities to retain and store runoff water, pipelines to pump the water to fields where it can be reused, low pressure pumps to move the water through these pipelines, and electrical power to run the pumps. All tailwater is recovered so that there is no surface runoff from the farm. This BMP will likely require cleaning sediments from the collection facilities and transporting it back to the fields. The extent of this activity will depend upon the application of BMP's that reduce erosion and sediment loss from the fields (1, 2, 3, 4).

Water is applied to fields, and runoff is collected and pumped to fields where it can be reused. The runoff is again collected and reused (1, 2, 4).

2. Application criteria.

This BMP can be applied to any surfaced-irrigated farm desired, almost without limitation. Application will require land for constructing collection facilities, the installation of NRCS practice code standard pipelines, pumps with sufficient capacity to pump the water to points of reuse, and electrical power or other fuel to operate the pumps. Sediment removal from the collection facilities will be required periodically. This may be annually.

3. Potential side effects and ancillary benefits.

The application of the tailwater recovery irrigation system BMP requires commitment to maintain collection facilities, pumps, and pipelines, and to the assurance that no runoff water will leave the farm during the irrigation season. Sediment removal from the collection facilities will likely be an ongoing activity until other practices are applied to eliminate or greatly reduce surface irrigation erosion.

Tailwater from one farm often becomes part of the irrigation source for farms downslope in the irrigation district. As with sprinkler and microirrigation systems, the tailwater recovery irrigation system may impact irrigation district operations, should sufficient numbers be installed. Also, because of power outages, pump failures, and other unforeseen events, 100% reuse may not occur and some runoff could result.

A positive benefit to this BMP is that the farmer can claim that he is not permitting his farm to contribute to surface water pollution, as is the case with sprinkler and drip irrigation systems as well. He can also claim a higher irrigation efficiency than with traditional surface irrigation (4).

4. **Monitoring.**

The only monitoring required is to observe the system operation and assure that surface runoff water is not leaving the farm. The phosphorus credits will be calculated based upon the amount of water diverted to the farm and its total phosphorus concentration and the application of the SISL model for the fields comprising the farm when farmed traditionally without the BMP.

5. **Design features.**

The design of the system must be according to NRCS Practice Code 447.

6. **Installation requirements.**

The system must be installed according to NRCS Practice Code 447.

7. **Operation and maintenance requirements.**

The operation and maintenance requirements must conform to NRCS Practice Code 447 requirements. These requirements will include sediment removal from the catchment ponds to assure adequate storage capacity to prevent overflow.

8. **BMP effectiveness.**

The application of this BMP will remove phosphorus from surface runoff waters by two mechanisms, and the results will be additive for calculating phosphorus credits. The first mechanism functions by preventing sediments and nutrients in surface runoff water from leaving the farm. Phosphorus credits will accrue from this mechanism.

Secondly, the total phosphorus in 50% of the water diverted to irrigate the farm will not be permitted to pass across the farm and become surface drainage water, as would be the situation if traditional irrigation was practiced. Phosphorus credits will accrue from this mechanism and will be additive to those credits accrued from the first mechanism.

An uncertainty factor of 5% is assigned because of possible problems in the day-to-day operations such as power outages, pump failure, or storm events adding to runoff, etc.

9. **Calculating phosphorus retained by the BMP.**

The phosphorus retained would include phosphorus saved by two mechanisms. For the first mechanism, the SISL model is applied for the fields on the farm to calculate the quantity of sediment that would be lost with traditional irrigation and cropping systems. The resulting tons of sediment is multiplied by the two pounds of phosphorus contained in each ton of soil to provide phosphorus saved by the first mechanism.

Phosphorus retained by the second mechanism is calculated by multiplying the quantity of water diverted to irrigate the farm by the total phosphorus concentration in that water and applying the 50% factor. The results are added to phosphorus saved by the first mechanism, and then the 5% uncertainty factor is applied.

<u>Example</u>:

Assume a 160-acre farm comprised of 8 x 20 acre fields.

The calculation method is to apply the SISL model to each field and add the results to give the total sediment expected to be lost from the farm without the BMP, and then apply the 2 lbs phosphorus per ton of sediment.

Assume: SISL total for the 8 fields = 800 tons of sediment

800 tons × 2 lbs = 1,600 lbs of phosphorus credits

Add to that:

160 acres × 3.5 acre ft per acre = 560 acre ft of water

Assume a total P concentration of 0.25 mg L^{-1} or ppm.

One acre-ft weighs 2.72 million lbs and there are 0.25 lbs of P in each million pounds of water. Therefore,

2.72 × 560 × 0.25 × 0.50 = 190 pounds of phosphorus

Total phosphorus retained for the 160-acre farm will be

(1,600 lbs + 190 lbs) × .95 = 1,700 pounds of phosphorus

Note: The value of a pound of phosphorus in the effluent trading program is not known at this writing, but assuming the following values and a seller's ratio of 0.75, the increase in income to the farmer applying the BMP to his farm could be:

Assume	\$ 5 per pound:	\$ 5 × 1,700 × 0.75 =	\$ 6,375
	\$10 per pound:	\$10 × 1,700 × 0.75 =	\$12,750
	\$20 per pound:	\$20 × 1,700 × 0.75 =	\$25,500

References.

1. Bondurant, J. A. 1970. Get double use out of irrigation water. Idaho Farmer 88:24-27.

2. Bondurant, J. A. 1969. Design of recirculating irrigation systems. Trans. ASAE 12:195-198, 201.

3. Bondurant, J. A., and L. S. Willardson. 1966. Recirculating farm irrigation systems. pp. 243-256. In Development of the total watershed. Proc. Am. Soc. Civ. Engr. Irrig. Drain. Specialty Conf., Oct 6-9, 1965. Billings, MT.

4. Trout, T. J. 1995. The case for irrigation tailwater reuse in southern Idaho. Proc. of Winter Commodity Schools 27:93-94.

An Example Table Illustrating Phosphorus Conservation Expected From Applying Various BMP's and Potential Dollar Value Benefits From Selling Phosphorus Credits at Five Prices

The following table has been generated to provide some examples of phosphorus credits that might be expected from applying one or more of the nine Best Management Practices (BMP's) developed for the Lower Boise River Effluent Trading Demonstration Project. The table shows potential income from those phosphorus credits based upon different trading values per pound of phosphorus credits. The table is based upon the following assumptions:

Farm size = 160 acres comprised of eight 20-acre fields or fractions thereof. For example, two 10-acre fields would comprise a 20-acre field, etc.

Crop rotation

Two fields, or 40 acres, in permanent cover crops such as alfalfa, mint, pasture, grass, etc.

Two fields, or 40 acres, in close growing crops such as cereal, peas, etc., with one field, or 20 acres, seeded to alfalfa with the close growing crop.

Two fields, or 40 acres, in row crops such as dry beans, corn, row peas, etc.

Two fields, or 40 acres, in intensive row crops such as sugarbeets, onions, etc.

Assume that row crops follow permanent cover crops, intensive row crops follow row crops, close growing crops follow intensive row crops, and permanent cover crops follow close growing crops.

Slope = all fields slope between 1% and 1.9%, and have moderate convex ends.

Tillage = all fields are traditionally tilled including moldboard plowing, except as applying a BMP changes this practice.

Irrigation = siphon tubes without cutback, and that irrigation lengths are about 660 feet.

Soil erodibility = K = 0.49. Therefore the adjustment factor is 1.0.

Applying the SISL model to the number of acres in each crop type according to the above rotation sequence and irrigation practices, gives the following yearly expected surface irrigation soil loss values:

Equation:

$$SISL = BSL \times KA \times PC \times CP \times IP$$

Applied to 40 acres of permanent cover crops

$$SISL = 0.9 \times 1.0 \times 0.75 \times 0.2 \times 0.9 \times 40 = 4.86 \text{ tons}$$

Applied to 40 acres of close growing crops

$$SISL = 4.0 \times 1.0 \times 1.0 \times 1.0 \times 0.9 \times 40 = 144 \text{ tons}$$

Applied to 40 acres of row crops

$$SISL = 10.9 \times 1.0 \times 0.7 \times 1.0 \times 0.9 \times 40 = 275.68 \text{ tons}$$

Applied to 40 acres of intensive row crops

$$SISL = 15.2 \times 1.0 \times 1.0 \times 1.0 \times 0.9 \times 40 = 547.20 \text{ tons}$$

Some examples of phosphorus credits and dollar values based upon different prices per pound of P in the trading program. The example is on a farm from which surface runoff enters Mason Creek.

Best Management Practice Applied	Phosphorus Retained at the Farm	Seller's Ratio (Mason Creek)	Phosphorus Credits Saleable	Value of Phosphorus Credits Based upon the Following Trading Value per Pound				
	pounds		pounds	$5	$10	$15	$20	$25
Sediment Basins								
All row crop and intensive row crop fields treated with field sediment basins	1,152	0.75	864	$4,320	$8,640	$12,960	$17,280	$21,600
All fields drain into one farm sediment basin	1,263	0.75	947	4,337	9,474	14,212	18,949	23,686
Filter Strips								
All row crop and intensive row crop fields treated with filter strips	658	0.75	494	2,469	4,937	7,406	9,875	12,343
Underground Outlet, first year, on all row crop and intensive row crop fields	1,152	0.75	864	4,320	8,640	12,960	17,280	21,600
Polyacrylamide applied to all row crop and intensive row crop fields	1,399	0.75	1,049	5,246	12,490	15,738	20,983	26,229
Crop Sequencing, same crops, different order								
No-till corn following alfalfa, 20 acres, and no-till cereal following corn on 20 acres [1/]	632	0.75	474	2,370	4740	7,110	9,480	11,850
Straw in Furrows of all row crops and intensive row crops	1,359	0.75	1,019	5,095	10,190	15,285	20,380	25,475
Sprinkler Irrigation, whole farm converted	2,092	0.75	1,569	7,845	16,560	23,535	31,380	39,225
Tailwater Recovery, applied to whole farm	2,208	0.75	1,656	8,280	16,560	23,535	31,380	39,225
Microirrigation, applied to all intensive row crops	1,165	0.75	874	3,496	8,740	13,110	17,480	21,850
Combining Crop Sequencing and Polyacrylamide Apply crop sequencing as above and apply polyacrylamide to intensive row crops	1,562	0.75	1,172	5,860	11,720	17,580	23,440	29,300
Combining Crop Sequencing and Microirrigation Combine the BMP's and apply each as above	1,797	0.75	1,348	6,740	13,480	20,220	26,960	33,700

[1/] Applying the Crop Sequencing BMP would have other financial benefits. If applied as in the table, about 10 tillage operations would be saved on the 40 acres changed. This would represent a savings of about $4,000. Also, about $1,260 could be saved in nitrogen fertilizer cost on the corn following alfalfa. The total of these two savings is about $5,260. This amount could be added to each of the last five columns. Also, savings from this BMP will increase as seasons progress, depending upon how it is applied.