# Monitoring Terrace Control of Water Pollution from Soil Erosion and Sediment in the Columbia Basin Counties of Oregon: October 1978 to April 1979



Special Report 595, July 1980
Agricultural Experiment Station
Oregon State University, Corvallis

# Contents




*Author:* Gerald O. George, agriculture engineer on an Interagency Personnel Act assignment from US Department of Agriculture Soil Conservation Service to Oregon State University Agriculture Experiment Station, Pendleton, Oregon.

# Monitoring Terrace Control of Water Pollution from Soil Erosion and Sediment in the Columbia Basin Counties of Oregon: October 1978 to April 1979

Gerald O. George

The basic objective of this study was to determine terrace effectiveness in reducing the amount of eroded materials that leaves a terraced field to become stream water pollution.

Secondary objectives were: (a) to quantify this sediment and relate it to gross intraterrace soil movement, and (b) to determine sediment production potential of frozen soils or possibly the most erosive soil condition, a partially frozen soil.

These objectives were based on the questions of: (a) just how effective are terraces in reducing sediment, or (b) is the terrace just a means of relocating the point of sediment discharge into a stream?

The fields and monitoring sites were laid out with the foregoing objectives and questions in mind. After erosion had occurred, it appeared that under the 1978-79 climatic conditions some management and tillage practices were more effective in erosion control than terraces, so rill meter measurements were made of two stubble mulch fields to verify and support observations.

## Equipment

The 1978-79 terrace monitoring project started with the water year in October 1978 and ended May 1, 1979. Recording and volumetric rain gauges, recording thermometers, recording flow meters, and sediment traps were installed on five ranches in the Columbia Basin dryland wheat area of Oregon shown in Figures 1 and 2. The recording rain gauge was a seven-day, tipping-bucket type that recorded precipitation in 0.01 inches per hour. The recording charts could be interpolated to 15-minute intervals. The tipping-bucket gauge was to establish precipitation intensities, and volume gauges were used as back-up for total period (day or week) precipitation.

The thermometer was a 3-level recording type. Temperatures were taken at 0-, 3-, and 6-inch depths so soil temperature could be determined at time of runoff and erosion. The flow meter was to determine amount of runoff flowing out of a terrace as a function of time during a rain storm.

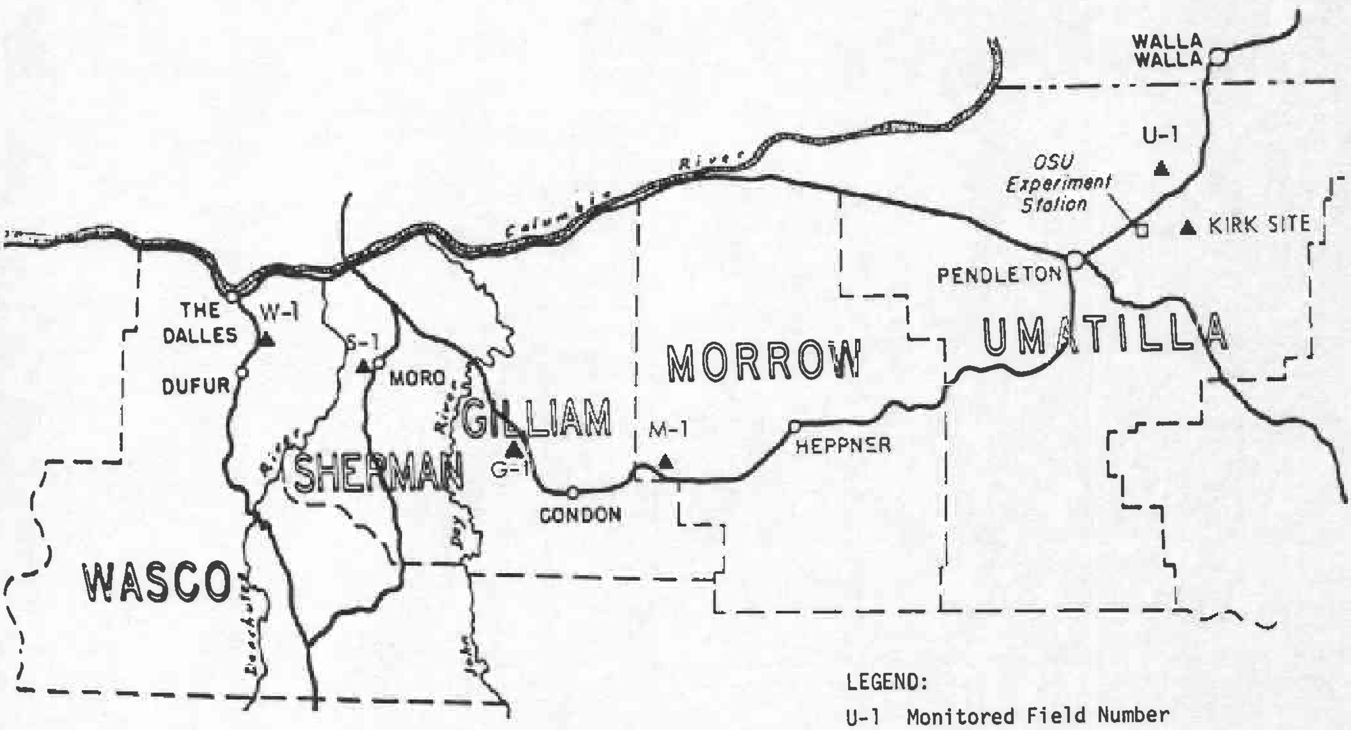


Figure 1. Map of the five counties in Oregon where erosion was monitored during 1978-79.

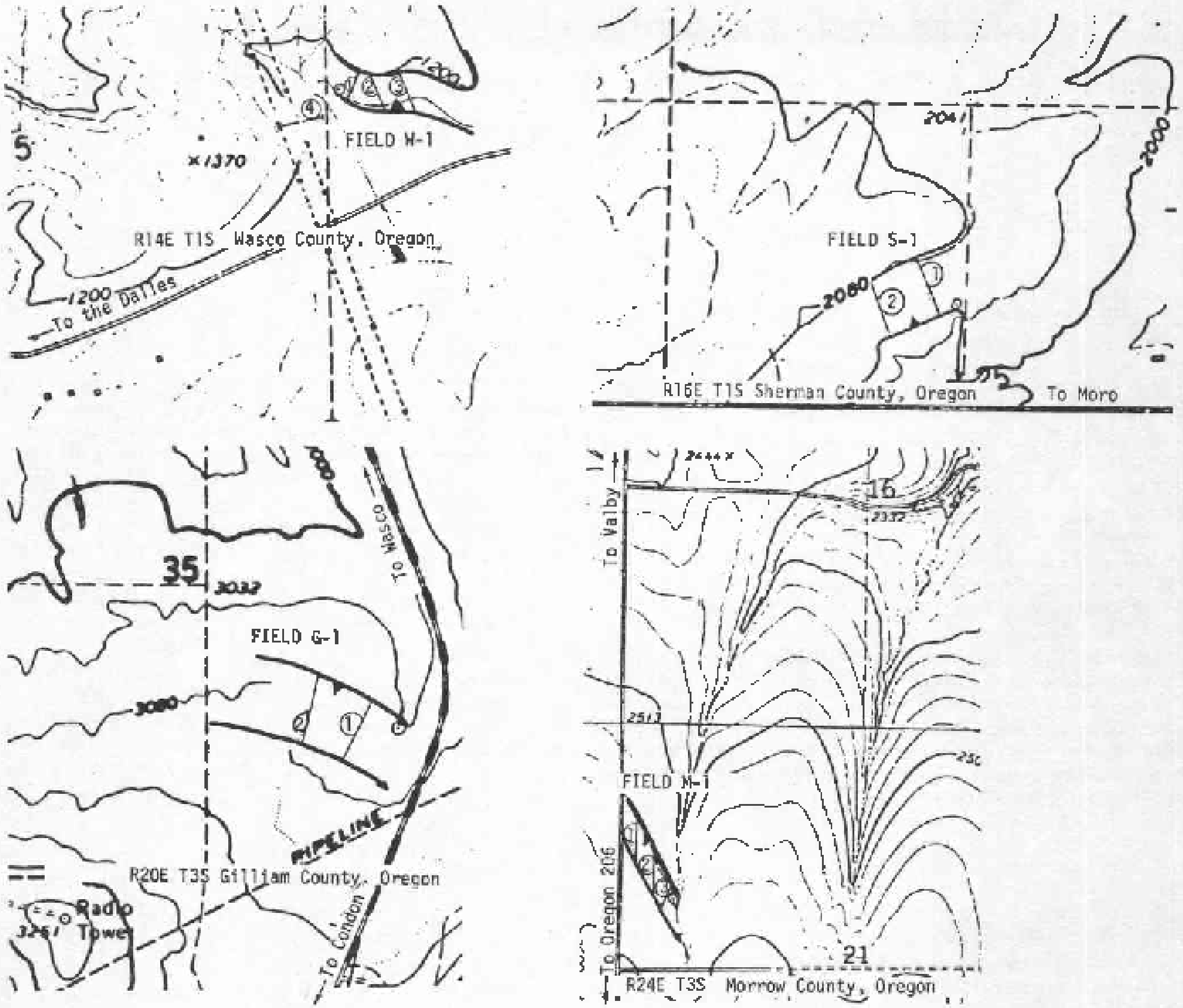


Figure 2. Map of field and site locations in five-county area.

A rill meter, designed by D. K. McCool (2)*, was used to measure intraterrace soil erosion for comparison with the sediment leaving the field, and also to compare with the USLE long-term prediction of upland erosion (1). The rill meter produces accurate results if before and after erosion measurements are made. If before and after erosion measurements cannot be made, operator judgment is required to determine extent of erosion. This can produce a wide variation between actual quantities and measured quantities if care is not exercised by the evaluator.

## Terrace Systems

Two types of terrace systems, level and graded, were monitored. The graded terraces had flow gradients from 0.6 percent in Morrow County to 1.5 percent in Sherman County. All terraces were designed to meet Oregon Soil Conservation Service terrace standards in effect at time of construction. They were designed by Soil Conservation Service technicians located in field offices in the respective counties.

The level terraces were in Wasco and Umatilla counties (Figure 2). They were constructed in the summer of 1978; it appeared they would be relatively easy to monitor and quantify for sediment because they were cut into subsoil. They were designed to handle a 10-year, 24-hour storm runoff, but when construction was completed they were almost twice as large as the design standard required by SCS at the time of layout and construction.

The graded terraces had been constructed at least 5 years before monitoring; they were designed using criteria and standards in force when installed. These terraces were old enough to be well established.

The terrace in Gilliam County was the only non-farmed-over terrace that was monitored. This terrace system was farmed from the top of the upslope terrace embankment into the bottom of the down-slope terrace. The up-slope face of the terrace embankment was grassed with natural native vegetation.

Landowners used conventional farming methods in all terrace systems; no attempt was made to contour farm, stubble mulch, or practice reduced tillage (Table 4). The Gilliam County graded terrace system was cross-slope farmed to the extent required to avoid double seeding or farming over the terrace.

* Numbers in parenthesis refer to "References Cited," page 7.

## Climate

Between October 1 and November 15, 1978, there was less than 0.25 inches of precipitation throughout the monitoring area. On November 11, the temperature dropped below freezing and cloudiness commenced, but on November 16 and 17 a warming trend with some precipitation began. From 3 inches to 6 inches of snow fell on November 19; daytime melting and night-time freezing persisted until November 30. From November 30 to December 4, the soil surface was bare of snow, but the top 3 inches of the winter wheat field soils were a quagmire during the afternoon and a frozen mass at night.

On December 4, it started raining on soil that was frozen to 6 inches, but the rain turned to snow before runoff occurred. From December 5 to 23, there was intermittent snow with freezing and thawing, but very limited or no runoff. The snow cover was essentially gone by December 23, but the soil was frozen to about 18 inches. On December 27, it started snowing once more; continued freezing temperatures and intermittent snowfall occurred throughout January.

The snow reached a maximum depth of 14 inches at the Pendleton monitoring field and 20 inches at The Dalles monitoring field. On February 5, when the major thaw started, there were 10 inches of snow cover remaining, and the soil was frozen to 12 inches.

On February 5, 1979, a rapid temperature rise initiated a general thaw; all the snow was gone by February 14. Between February 5 and 14, a general rainfall sum varying from 0.5 inches to 1.1 inches occurred. Maximum recorded 1-hour intensity was 0.15 inches and for 24 hours was 0.52 inches. The daily rainfalls for February 5 to 14 are shown in Table 1. The monthly recorded precipitation in the erosion monitoring fields is shown in Table 2a., and the 30-year mean precipitation is shown in Table 2b.

**Table 1. Daily rainfall from February 5 through 14, 1979, at five erosion monitoring fields in Oregon**

| | | Inches per day on indicated dates in February | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| County | Field[1] | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| Wasco | W-1 | .00 | .31 | .03 | .00 | .00 | .22 | .04 | .27 | .00 | .00 | .87 |
| Sherman | S-1 | .00 | .00 | .52 | .00 | .00 | .26 | .04 | .27 | .00 | .00 | 1.09 |
| Gilliam | G-1 | .00 | .03 | .16 | .00 | .03 | .08 | .08 | .13 | .00 | .00 | .51 |
| Morrow | M-1 | (Total vol. guage .47) | | | | | .01 | .01 | .01 | .00 | .00 | .50 |
| Umatilla | U-1 | .01 | .09 | .03 | .00 | .00 | .24 | .08 | .28 | .09 | .00 | .81 |

[1] See Figure 2 for field locations.

**Table 2a. Monthly precipitation, rainfall and snowfall, recorded at erosion monitoring fields in Oregon in 1978-79**

| | | Month | | | | | | |
|---|---|---|---|---|---|---|---|---|
| County | Field[1] | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May |
| Wasco | W-1 | .04 | .16 | .86 | 1.23 | .56 | .63 | .09 |
| Sherman | S-1 | .54 | .48 | .70 | 1.34 | .89 | 1.00 | .13 |
| Gilliam | G-1 | 3.08 | 1.20 | 1.11 | .87 | .88 | 1.69 | .83 |
| Morrow | M-1 | 1.28 | .74 | 1.03 | .85 | .82 | 2.26 | 1.17 |
| Umatilla | U-1 | .88 | .83 | .82 | 1.63 | 1.43 | 1.46 | .90 |

[1] See Figure 2 for field locations.

Table 2b. Mean monthly precipitation including rainfall and snowfall (30-year mean, 1931-1960)

| County | Field[1] | Month | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May |
| Wasco | W-1 | 1.60 | 1.67 | 2.06 | 1.41 | 1.19 | .63 | .82 |
| Sherman | S-1 | 1.62 | 1.64 | 1.79 | 1.25 | 1.08 | .76 | .84 |
| Gilliam | G-1 | 1.44 | 1.45 | 1.42 | 1.17 | 1.23 | .95 | 1.32 |
| Morrow | M-1 | 1.44 | 1.38 | 1.38 | 1.13 | 1.29 | 1.27 | 1.34 |
| Umatilla | U-1 | 1.40 | 1.19 | 1.43 | 1.18 | 1.20 | 1.09 | 1.12 |

[1] See Figure 2 for field locations.

## Soils (Table 3)

Bulk density samples taken in October 1978 in fields U-1 and G-1 indicated a mean bulk density of 75 and 85 pounds per cubic feet, respectively. In these same fields in April 1979, the mean bulk density was 112 pounds per cubic feet. All other fields were sampled in April 1978.

## Farm Management

Farm management practices on all fields were essentially the same during summer fallow: Moldboard plow, spring tooth harrow, rod weed, and seed. Different types of drills (Table 4) were used for seeding. In 1978, one or two additional weeding operations were carried out because of August and September rains (Table 4); moldboard plowing was the primary tillage in all cases.

## Observation

As equipment was installed during September and October 1978, residue and soil samples were taken. Measured residue ranged from 100 to 500 pounds per acre, and soil bulk density from 75 to 95 pounds per cubic feet. When walking across a seeded field in October 1978, a very fine soil mulch, about 3 inches deep, would boil out from under foot-like flour or ashes.

All fields were seeded by October 15, 1978; winter wheat had grown 2 to 3 inches tall when the hard freeze occurred on November 15. Experimental observations indicated severe frost injury and impaired tillering. In essence, little vegetative cover was present for erosion or sediment control in the monitored fields during the runoff monitoring season.

Table 3. Soils monitored and their erosion and hydrologic factors

| County | Field[1] | Soil type | Slope phase (%) | Soil loss tolerance (Tons/A) | Soil erodibility | | Hydrologic soil group | Watershed |
|---|---|---|---|---|---|---|---|---|
| | | | | | Surface | Sub-soil | | |
| Sherman & Umatilla | S-1 U-1 | Walla Walla silt loam, deep | 7–12 | 3–5 | 0.49 | 0.64 | B | Erskine & Wildhorse |
| Morrow | M-1 | Valby silt loam | 1–7 | 2 | 0.43 | 0.49 | C | Eightmile |
| Gilliam | G-1 | Condon silt loam | 2–7 | 2 | 0.32 | 0.43 | C | Ferry |
| Wasco | W-1 | Duart silt loam | 12–25 | 2 | 0.43 | 0.43 | C | Fifteen Mile |

[1] See Figure 2 for field.

Table 4. Tillage operations performed on fields monitored for soil erosion in 1978-79 winter

| County | Field[1] | Soil series | 1978[2] seeding date | Plow used | Number of operations | | | | Drill type |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Spring tooth harrow | | Rod weed | | |
| | | | | | Normal | 1978 | Normal | 1978 | |
| Wasco | W-1 | Duart | 9/25 | Mbd.[3] | 1 | 1 | 2 | 3 | Dbl. disc |
| Sherman | S-1 | Walla Walla deep | 9/26,30 | Mbd. | 1 | 2 | 2 | 2 | Deep fur. split pack. |
| Gilliam | G-1 | Condon | 10/6,7 | Mbd. | 1 | 2 | 2 | 3 | Dbl. disc |
| Morrow | M-1 | Valby | 10/3,4 | Mbd. | 2 | 3 | 2 | 2 | Shovel |
| Umatilla | U-1 | Walla Walla deep | 10/4,5 | Mbd.[3-4] | 1 | 2 | 2 | 2 | Dbl. disc |

[1] See Figure 2 for field locations.
[2] 9/25 indicates September 25.
[3] Coulters were used to achieve better straw burial.
[4] Mbd. is moldboard plow.

When the snow melt and rainfall occurred in November, there was no observable runoff, erosion, or sediment from the monitored sites. All the fields were quagmires about 3 inches deep (Figure 3). Subsequently, rainfall and snowfall periods did not produce any runoff until the general thaw occurred between February 5 and 14. During the first two days of the thaw, February 5 and 6, there was little or no erosion because the ground was still frozen to the surface and covered with snow. As the snow cover disappeared, the soil surface warmed and became a slurry quagmire over the frozen, deeper layers of soil. This slurry of soil and water became fluid enough to move; it accumulated in low areas, then ran over the top of snow that had not melted. This action continued for two to three days with rilling becoming more pronounced each day.

Since there was very little rainfall, and intensity was low, the erosion and rilling occurred from fluid soil movement after most of the snow was gone. Consequently, a large portion of the sediment was deposited above the flow lines in level terraces, ponds, and level areas in fields. It is possible that beneath the soil surface a large amount of water was flowing from higher to lower hill slope positions.

During runoff and immediately after it had subsided, the sediment traps (3 feet by 8 feet by 1 foot deep basins) were checked for the amount of silt trapped, and grab samples were taken. At one graded terrace site, the upper terrace overtopped and increased the outflow and sediment for the monitored site. At another site erosion at the structure entrance mixed an unknown amount of local sediment with the field sediment. In both instances, however, the traps were effective in removing the heavier sediments from the water. Field measurements were made (Table 4), but a relationship between the field erosion measurements and the trapped sediment could not be obtained.

Therefore, it was not possible to accurately determine how much of the soil movement in the field arrived at the terrace outlet to cause stream pollution. Grab samples were taken at each graded terrace outlet and used to estimate the amount of sediment at these points.

Measurements at the flow meters and computations of storage in the level terraces indicated that 95 percent of the total snowfall and rainfall from December 27 to February 14 ran off the intraterrace areas (Figures 3 and 4). There was no outflow from the level terraces, so their traps had no silt (Figure 5).

Rill measurements of soil movements were made in April after the erosion occurred. These are shown in Table 5.

Two winter wheat fields were measured that had excellent vegetative cover from incorporated stubble estimated at 1,000 pounds per acre (Figure 6). These fields did not have terraces. They had an average slope of 17 percent and an average soil loss of 9 tons per acre (Table 5). These averages are site selective because the sites were picked to locate and get a measurable condition. From observation of these 80-acre stubble-mulched fields, the overall field average was much less than the measured loss.

As stated earlier, a super saturated or quagmire soil condition was observed after the first heavy precipitation in November, and again during the February thaw. There was a number of factors that individually, or as a unit, contributed to this fluid soil surface condition.

During November, the soil was not frozen and the quagmire was about 3 inches deep. This was about the depth of the soil mulch left after rod weeding and seeding operations. It is possible with two or three rod weeding operations that a slightly impermeable pan is being created which may restrict water movement into the soil and encourage underground water flow downhill over the impermeable rod pan.

The summer advantage of the soil mulch to break soil capillary pores and reduce evaporation suddenly turns to a disadvantage because rainfall is not allowed to infiltrate below the soil mulch. Plow pans and genetic layers at greater soil depths may likewise inhibit internal drainage and encourage downhill flow on top of the layers after the soil is wetted deeper and precipitation in excess of 0.5 inch occurs per 24 hours and continues for two or more days.

There is the possibility that soil infiltration and permeability changes to lower rates as the weather cools in the fall. Cooler rainfall in the fall could cause reduced infiltration and permeability rates because of increased viscosity. Both conditions could be occurring simultaneously to contribute to the quagmire conditions in the top few inches of the soil.

During freezing and thawing, the soil mulch was observed to expand and heave. This soil mulch filled to saturation with water, froze, expanded and then thawed. If

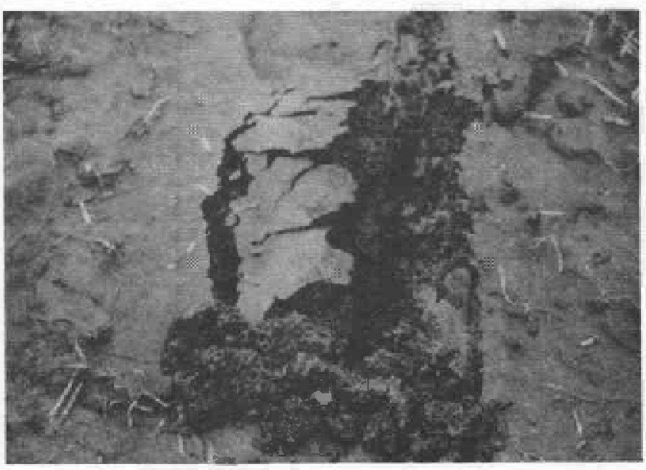

**Figure 3. Surface soil flows back into footprint on February 8, 1979.**

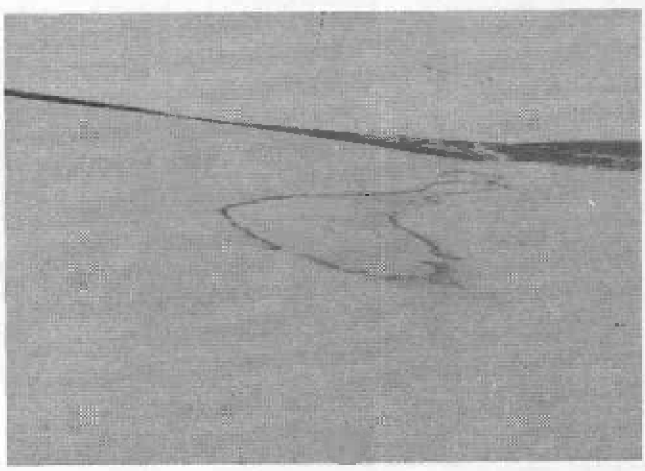

**Figure 4. Level terrace partially filled with runoff on February 8, 1979.**

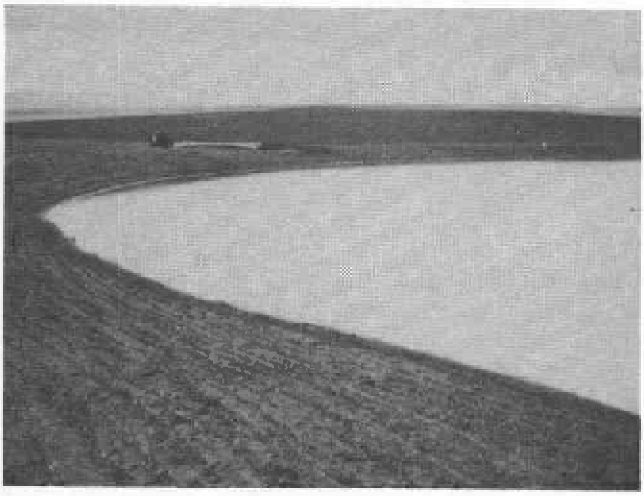

Figure 5. Terrace filled with snowmelt runoff on February 15, 1979.

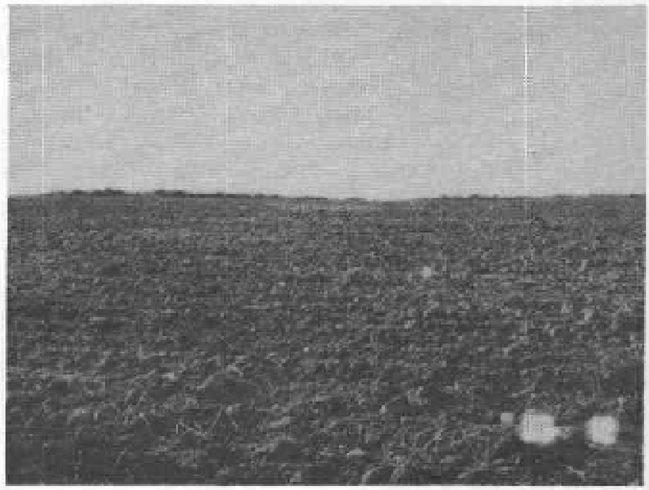

Figure 6. Field with stubble mulch that had less than 9 tons per acre erosion in February 1979.

**Table 5. Soil movement at erosion measuring sites as measured with the rill meter in the spring of 1979**

| County | Site | Soil series | Soil erodibility factor (K) surface | Soil erodibility factor (K) sub-soil | Aspect | Ave. slope (%) | Length (Ft.) | Soil moved (Ton/A) | Type of terrace | Amount[1] of soil leaving terrace outlet (Ton/A) | USLE[2] predicted erosion (Ton/A) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wasco | W-1 | Duart | 0.43 | 0.43 | SE | 15 | 199 | 10 | Level | None | 5.9 | |
| | W-2 | Duart | 0.43 | 0.43 | S | 12 | 307 | 12 | Level | None | 5.1 | |
| | W-3 | Duart | 0.43 | 0.43 | SW | 10 | 279 | 17 | Level | None | 3.9 | |
| | W-4 | Duart | 0.43 | 0.43 | E | 21 | 230 | 6 | None | All | 5.2 | Stubble mulch |
| Sherman | S-1 | Walla Walla, deep | 0.49 | 0.64 | S | 6 | 370 | 9 | Graded | 1.8 | 2.4 | Grab sample of soil leaving field |
| | S-2 | Walla Walla, deep | 0.49 | 0.64 | S | 6 | 455 | 10 | Graded | 2.0 | 2.0 | |
| Gilliam | G-1 | Condon | 0.32 | 0.43 | NE | 3 | 675 | 10 | Graded | 2.5 | 0.9 | " " |
| | G-2 | Condon | 0.32 | 0.43 | N | 4 | 585 | 25 | Graded | 6.3 | 1.1 | " " |
| Morrow | M-1 | Valby | 0.43 | 0.49 | NE | 4 | 478 | 10 | Graded | 2.0 | 1.4 | " " |
| | M-2 | Valby | 0.43 | 0.49 | N | 4 | 468 | 16 | Graded | 3.2 | 1.4 | " " |
| | M-3 | Valby | 0.43 | 0.49 | N | 6 | 474 | 17 | Graded | 3.4 | 2.3 | " " |
| Umatilla | U-1 | Walla Walla, deep | 0.49 | 0.64 | S | 5 | 601 | 13 | Level | None | 2.2 | |
| | U-2[8] | Walla Walla, deep | 0.49 | 0.64 | W | 10 | 234 | 30 | Level | None | 4.2 | |
| | U-3 | Walla Walla, deep | 0.49 | 0.64 | E | 6 | 370 | 27 | Level | None | 2.4 | |
| | U-4 | Walla Walla, deep | 0.49 | 0.64 | E | 12 | 166 | 12 | None | All | 2.6 | Stubble mulch |
| | U-6 | Walla Walla, deep | 0.49 | 0.64 | E | 8 | 578 | 34 | None | All | 4.0 | |
| | U-7[3] | Walla Walla, deep | 0.49 | 0.64 | E | 16 | 152 | 29 | None | All | 6.8 | |

[1] Special notes of all or none refer to disposition of the soil loss measured with the rill meter

[2] USLE equations and factors used to predict erosion in Column 10 are: $A = R\,K\,LS\,C\,P$

$P = 1$ $R = 15$
$C = 0.35$ normal tillage very little stubble; 0.19 for stubble mulch
$K =$ See Columns 4 and 5 for soil erodibility

For slopes less than 9% $LS = \frac{(1)^{0.3}}{(72.6)} \; \frac{(0.43 + 0.305 + 0.0435^{2})}{(6.613)}$ For slopes greater than 9% $LS = \frac{(1)^{0.3}}{(72.6)} \; \frac{(S)^{1.3}}{(9)}$

[3] U-3 and U-7 were over top of terrace 100 ft. south and parallel to U-6

runoff does not occur when the soil thaws, the soil will consolidate. Once consolidation occurs, there is a short period of time when the infiltration rate is reduced and runoff will occur at a rainfall intensity less than measured infiltration rates would indicate. As this runoff water flows in the down-slope direction, water increases in volume and velocity, dislodging soil particles and causing erosion.

If there is no time for consolidation of the soil before freezing, as that soil thaws, a minute amount of rainfall also will start erosion at the soil-air surface. This will visually appear different from a consolidated condition in that erosion from the unconsolidated frozen condition will start further up the slope. In February 1979 there was no opportunity for soil consolidation because the soil froze early in the winter and remained frozen until the thaw occurred. As the snow melted, early runoff had very little discoloration from sediment because the water was running over a frozen soil surface. As the melted snow water continued to flow, it thawed the soil and started the rill pattern. As the snow melted and exposed the soil surface, the soil melted and was super-saturated above the frozen layers below. This super-saturated soil then moved down-slope over the frozen layers as a mud slurry. The major erosion of the runoff season occurred under the above frozen conditions.

## Conclusion

The conclusions drawn from the 1978-79 erosion study are based on one group of rill meter measurements after erosion had occurred. Further monitoring needs to be done to verify and refine measurements and conclusions. Better sediment traps and evaluation methods must be developed so effectiveness and efficiency of recommended best management practices can be better evaluated. It was found that cropland soils frozen to the surface do not erode. Erosion occurs after the soil has started thawing. Thus, any treatment that would reduce soil freezing would indeed reduce erosion losses.

All monitored terraces had an impact on reducing water pollution from sediment as silt accumulations were observed in all terraces. Monitored level terraces were 100 percent effective in reducing stream pollution. Tillage practices have a definite impact in reducing sediment available for stream pollution.

In two instances where measurements were made, there was a soil bulk density change between October 1978 and April 1, 1979.

## References Cited


1. Billings, W. H., 1976, Universal Soil Loss equation—Oregon Agricultural Technical Note 29.
2. McCool, D. K., unpublished, Use of the Rill Meter to Measure Erosion.
3. Wischmeier, W. H., and D. D. Smith, 1979. Predicting rainfall erosion losses—A guide to conservation planning. Agricultural Handbook 537. U.S. Department of Agriculture, Washington, D.C.