

RESEARCH PROJECT TITLE: Improving Tillage Systems for Minimizing Erosion

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INTERIM REPORT

PROJECT OBJECTIVES:

1. Investigate the difference in infiltration and runoff generation mechanisms under different tillage systems.
2. Study the impact of major field factors on rill/gully formation under different tillage systems.

KEY WORDS: conservation tillage, infiltration, surface runoff, soil erodibility

STATEMENT OF PROBLEM: Soil erosion and sediment delivery to streams are among the major concerns of producers, government agencies, and environmental communities due to the loss of productive soil and the potential environmental impacts. In the Northwest Wheat and Range Region producers generally following one of three different types of management techniques: conventional tillage, conservation tillage, or direct seed. The effectiveness of these techniques at minimizing erosion has varied widely. There is a need to better understand how the effectiveness of these management practices at minimizing erosion varies with the local climate, soil types, and topography. With a better understanding of the physical processes controlling runoff generation and erodibility we can develop tools which will assist managers in the selection of optimal management practices that are better suited for the particular climate zone, soil type, and topography.

ZONE OF INTEREST: high precipitation zone

ABSTRACT OF RESEARCH FINDINGS: Despite an unusually dry winter we have feel we have made progress in developing a better understanding of the key processes leading to the generation of surface runoff across different landscapes in the Northwest Wheat and Range Region. Although there was essentially no runoff in any of our runoff plots, our well measurements identified subsurface perching and even areas of surface saturation at the direct-seed, conservation tillage and conventional tillage sites. Subsurface perched water tables developed on somewhat discontinuous buried argillic horizons. At two of the sites shallow restrictive layers on top of “clay knobs” lead to surface saturation. The direct-seed site did not have a clay knob however, an argillic horizon at the midslope position lead to the development of a perched water table. We observed frozen soil at each site however these soils thawed before any rain or melt event occurred. The conservation tillage site indicated that a perched water table may develop on shallow plow pans. We see these subsurface restrictive layers as being a key factor in understanding the generation of runoff especially as land mangers use conservation tillage techniques that improve infiltration and increase surface cover.

RESULTS AND INTERPRETATION: As described in the revised proposal the project was divided in two major tasks corresponding to two project objectives listed above. Task 1 consisted of investigating the infiltration and runoff generating processes in a conventional tilled site, a conservation tillage site, and a direct seed site. Task 2 included the investigation of major factors controlling seasonal changes in soil erodibility at each site. In this report we will first describe the location of each site and the climate variability for this first year of study, and then we will describe the results by each task.

- Research Sites

All three research sites used in this investigation were located in the high precipitation zone of the Northwest Wheat and Range Region (see Figure 1). The conservation tillage site had the highest elevation and received slightly more precipitation than the other two sites. All three sites have a silt loam topsoil and within each site some argillic soil horizons were observed within 1.5 m of the soil surface. The effect of these horizons on runoff generation is discussed.

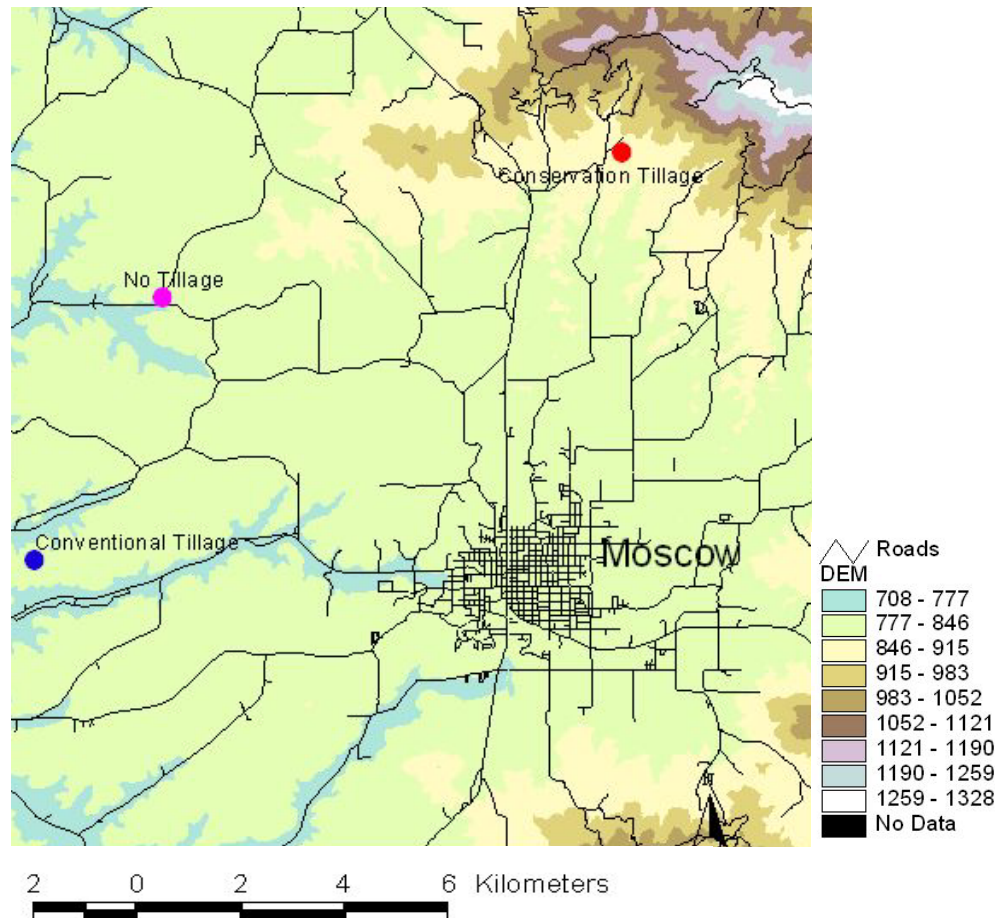


Figure 1. The 10 m digital elevation model in meters, roads, and location of each study site.

- Climate for the 2004-2005 Water Year

The climate for the 2005 winter was unusually dry and warm and greatly limited our field studies. Figures 2 and 3 show minimum and maximum daily temperature, cumulative

precipitation, 30 year average cumulative precipitation and snow depth for the 2005 winter. Pullman and Moscow weather stations recorded only 10 mm of precipitation between 1/18/2005 and 3/18/2005. Normally Moscow and Pullman receive 137 mm and 122 mm of total precipitation during the months of January and February. Mean daily air temperatures reached highs of 11.1 C (51 F) and 11.7 C (52 F) at Moscow and Pullman, respectively. On March 12, 2005 Moscow and Pullman recorded high temperatures of 20.6 C (69 F) and 20.0 C (68 F), respectively. The warm, dry weather during this time dried the soils enough so that some landowners began preparing their land for seeding during the end of February. Since the focus of our study was to monitor runoff and erosion on existing fields we were forced to remove all our instrumentation during the first week in March at each of the sites.

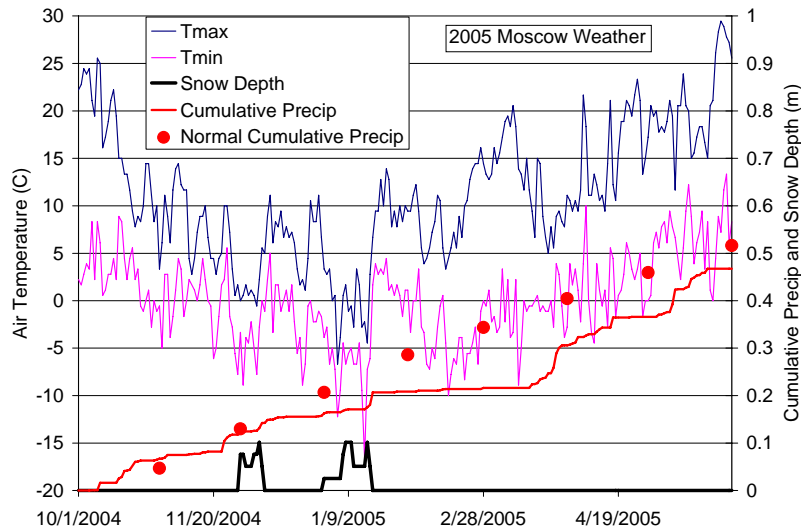


Figure 2. Minimum and maximum daily air temperature, cumulative precipitation, normal cumulative precipitation (30 year average), and snow depth recorded at Moscow, ID for 2005.

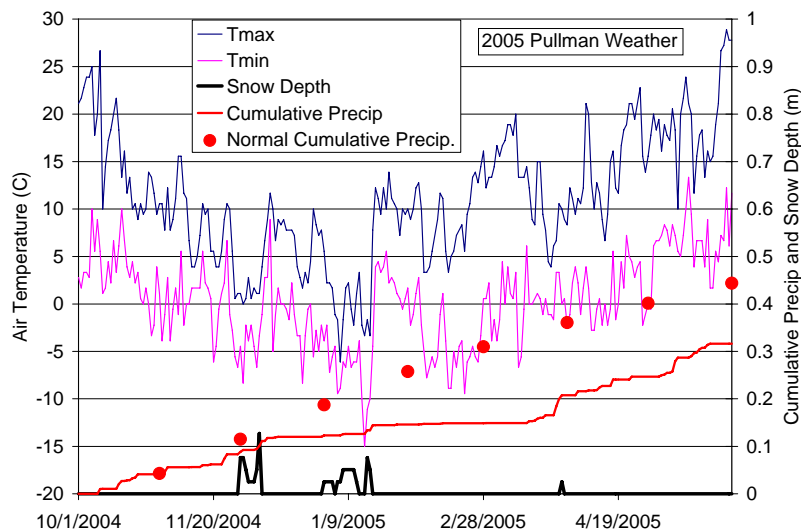


Figure 3. Minimum and maximum daily air temperature, cumulative precipitation, normal cumulative precipitation (30 year average), and snow depth recorded at Pullman, WA for 2005.

Objective 1. Investigate the difference in infiltration and runoff generation mechanisms under different tillage systems.

As described in the proposal at each research site we identified three slope positions which were instrumented to determine the fundamental process causing surface runoff for different events. The possible runoff producing processes included saturation-excess runoff (i.e. runoff which occurs because the soil can not store any more water) due to a restrictive argillic horizon, saturation-excess runoff due to a restrictive plow pan, runoff which occurs on frozen soil, and runoff which occurs because the rainfall intensity exceeds the infiltration capacity of the soil. The upper two positions included 1.8 m x 5.5 m (6 ft x 18.2 ft; ¼ of a standard USLE plot) where runoff rates were measured with tipping bucket flow gages. After flow measurement all runoff water drained to a secondary basin to settle silts and clays which would then be manually weighed after each event to estimate total sediment load. Both a deep and shallow monitoring well was installed by each plot. The deep well was installed down to an argillic horizon or to approximately 1.5 m if no argillic horizon was found. The shallow well was installed above the plow depth. Each well was instrumented with a pressure sensor to record perched water depth every hour. Two thermocouples were installed beside each plot at 5 cm and 15 cm to monitor hourly changes in soil temperature to indicate the presence of a frozen soil layer. Frost tubes were installed at each hillslope location as a secondary measure to monitor soil freezing. No runoff plots were installed at lower slope positions since these location were usually flat and influenced mostly by the rising and falling water table in the flood plain. In order to better understand the variability in the perched water at each site additional monitoring wells were installed between each of the hillslope positions.

Task 1.1. Tillage system characterization

One of the most interesting aspects of the study was the observed variability in the argillic horizon and its influence on the development of perched water. A map showing the variability of the argillic horizon was already developed for the direct seed site. This map was confirmed for the hillslope used in this study through manual augering. At the conservation and conventional tillage sites a cat mounted giddings probe was used to extract soil cores down to a depth of 2 m. Approximately 40 soil cores were extracted from each site. The thickness and depth of each soil horizon was recorded and soil samples were saved from unique soil horizons for texture analysis. Although we noticed general trends between topographic position and soil horization, there were some exceptional soil features, particularly at the direct seed site, which appear more or less random. In general for the conservation and conventional tillage sites the depth to a restricting layer (i.e. argillic horizon, fragipan, or clay pan) is shallowest on tops of the ridges (i.e. the clay knobs) and deepest at toe slopes. With the exception of the ridge tops, the soil layer immediately above the argillic horizons are all much whiter E-horizons which have less clay. The physical process which leads to the development of these E-horizons is somewhat unclear however they usually indicate the presence of seasonal perched water tables and perhaps significant subsurface lateral flow (Personal communication, P.A. McDaniel) which seem to be confirmed by this study, see below. Although it is beyond the scope of this project to investigate in great detail the implications of these E-horizons, we do see this as potentially being an indicator which managers could use to describe the hydrology of a particular landscape. The distribution of each soil layer will be included in the results section for each site below.

Task 1.2. Measurements of major field parameters for runoff generation

The equipment was installed beginning in late November and all sites were completely functional by the beginning of January. At the land manager's request at each site, all equipment was removed during the first week of March to allow for spring tillage. Only one major snow melt event took place on January 18, 2005. No surface runoff was measured at any of the sites during this event. Although the soils froze before the January 18th event, the soil had thawed by the time any significant rain or snowmelt took place. Despite the lack of runoff at the plot sites, the instrumentation revealed temporal perched water patterns indicating the potential for saturation-excess runoff. The data collected at each of these sites is described below.

Direct Seed Site

A 120 m west facing hillslope was selected for the direct seed site, see Figure 4. The farm manager broke the hillslope into three strips. The upper and lower strips had 30 cm high standing grain stubble, and a lentil crop had been harvested in the midslope strip leaving little standing residue. Figure 5 shows a cross-sectional profile of the hillslope, the depth of the well, the depth to an argillic horizon, and the maximum water table depth reached at each well location. Thirteen wells were installed along the hillslope. The top three locations did not have an identifiable argillic horizon, however a distinct argillic horizon was present below the upper and midslope runoff plots. Like the top of the hill, no argillic horizon was present immediately downslope of the lower runoff plot, but it was found again in the four lower well locations. As seen in Figure 5, the water table never reached the soil surface except at the lowest well location. A tile line runs on the contour at the base of the hillslope, however, we are unsure at this time exactly where it is located. As seen in Figure 6 there was essentially only one major recharge event recorded at the base of the hillslope. Figure 7 shows that a perched water table developed above the midslope argillic horizon (Wells 8, 9, and 10) and that the perched water depth increased with slope length. Before reaching well 7, however, this saturated layer had either drained vertically because of the absence of a restricting argillic horizon or perhaps it was drained by the tile line. Soil temperature readings indicate that both the upper and lower plots were frozen for parts of the winter. No runoff due to frozen soil was observed (see Figure 8).



Figure 4. Photographs of the direct seed site.

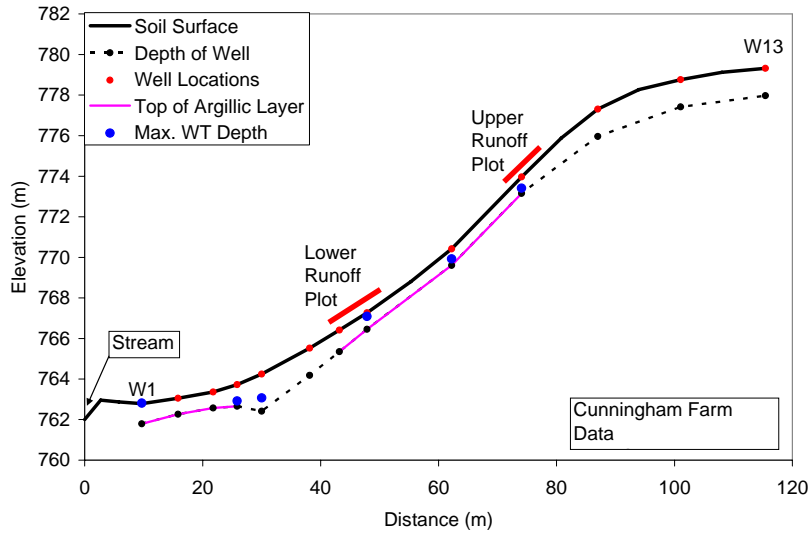


Figure 5. Hillslope profile, with well locations, depth of the well, depth to the top of the argillic horizon, and the maximum water table depth observed during the winter of 2005.

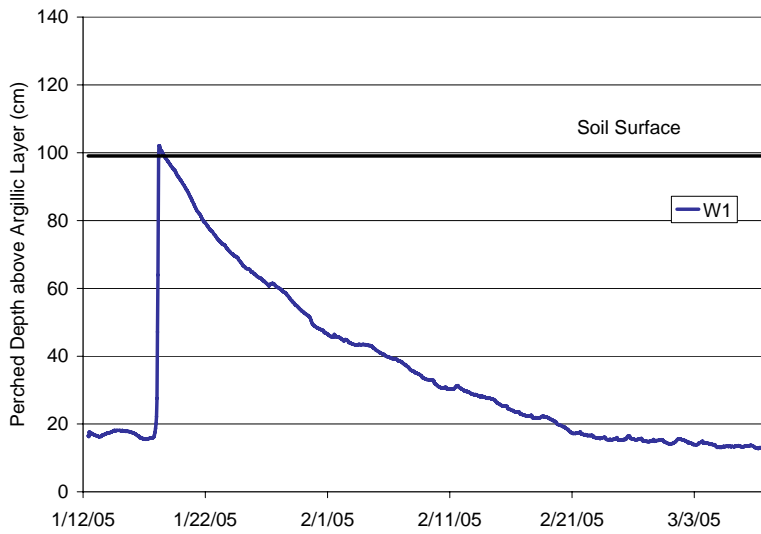


Figure 6 Perched water depth readings at well 1 (W1).

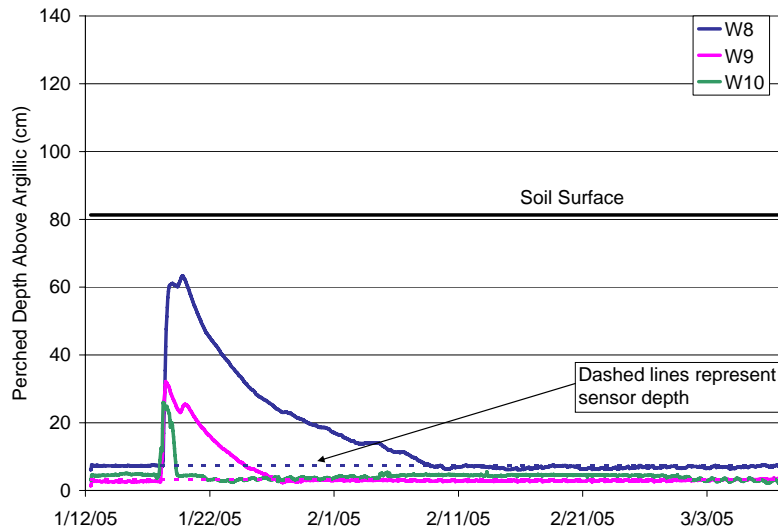


Figure 7 Perched water depth readings at wells 8, 9, and 10 (W8, W9, W10).

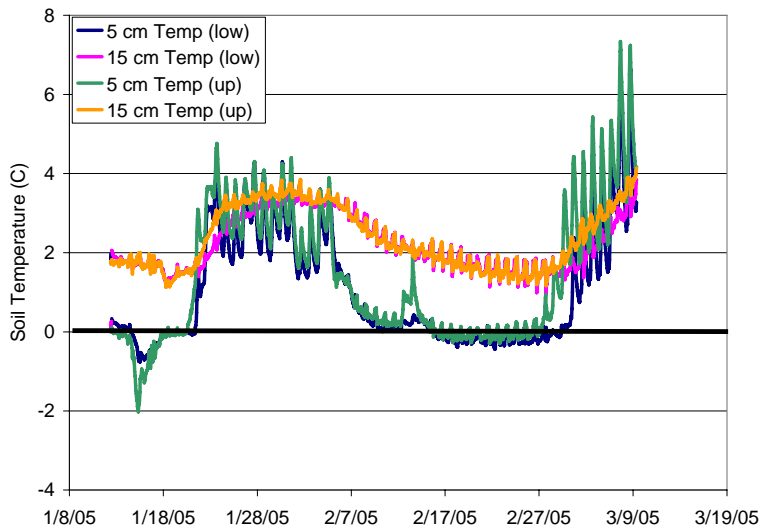


Figure 8 Soil temperature readings at the lower and upper runoff plot locations.

Conventional Tillage Site

At the conventional tillage site a northwest facing hillslope was used for runoff plots. A second transect of seven wells was installed on another north facing slope, where typically a large snow drift develops, to investigate the influence of snow drifting on runoff and subsurface saturation. Figure 9 shows pictures of both slopes. One advantage of the north facing slope was that four of the wells (W13-W16 on Figure 10) were located outside farmed areas on mid and upper slopes. These four well did not need to be removed in February. An argillic horizon was not identified within the top 2 m of the soil surface at W14 and W15 (Figure 10). These two monitoring wells, however, both had very persistent water tables which did not completely drain until the beginning of June. It is somewhat surprising to find a persistent perched water table on such a steep slope with a perennial grass land cover. This fall, we will be drilling deeper at W14 and W15 to see if the restricting layer is located deeper than 2 m or if there is a sand layer which

supplies the water to these positions. It is interesting to point out that the perched layer at the downslope well (W15) did not develop until the end of March whereas the perched layer at the upper well (W14) developed in January. Despite the persistent water table at W14 and W15, the water table never saturated the entire soil profile causing runoff. Runoff occurred twice at the upper well location (W13) (Figure 12). As we observed at other sites, clay knobs tend to have shallow soils with a relatively small capacity to store water. These clay knobs are more likely to saturate and cause runoff which can lead to excessive erosion downslope. Like the direct seed site no runoff occurred at the conventional tillage site.

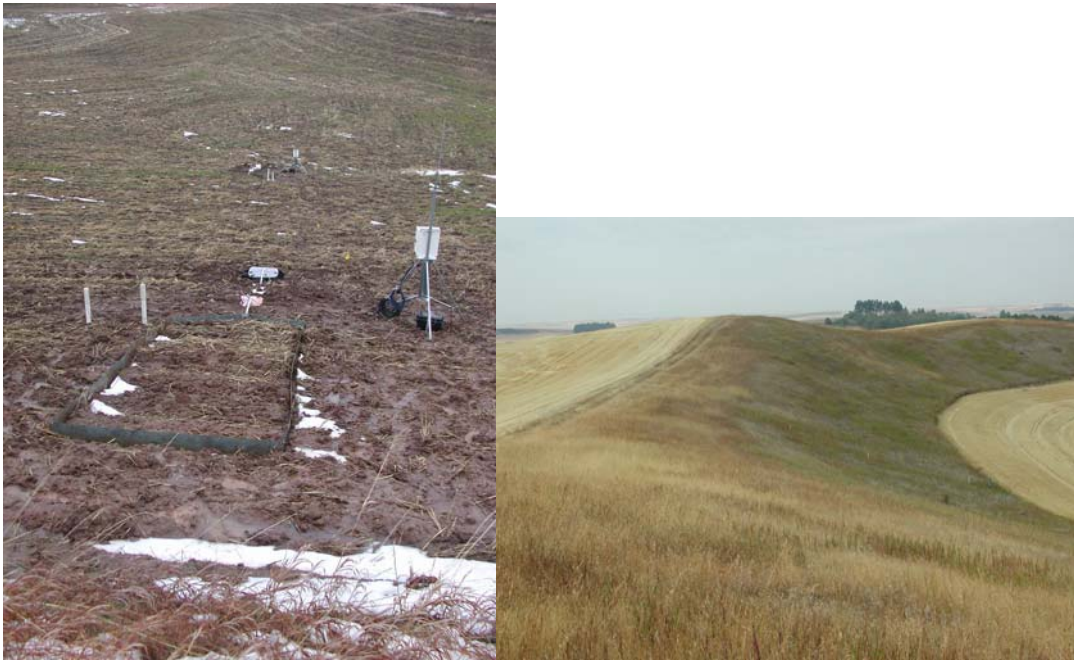


Figure 9. Runoff plots in the conventional tillage site on left. North facing hillslope at the conventional tillage site.

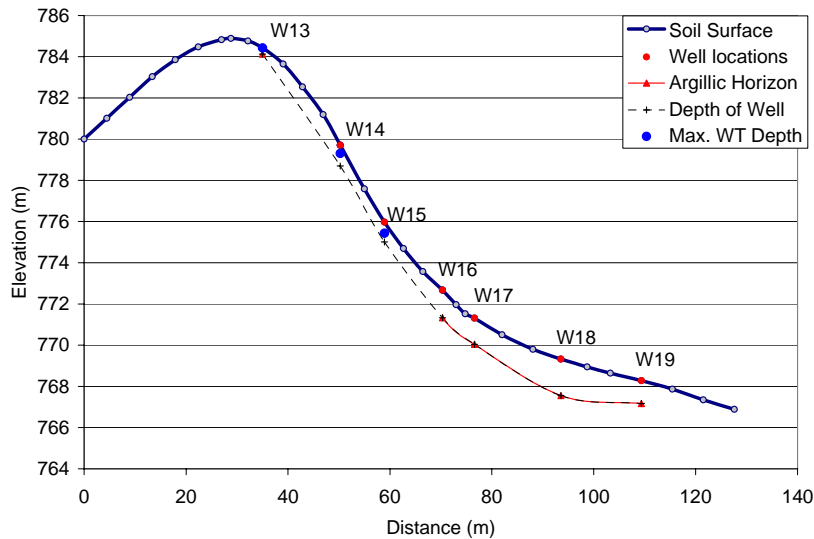


Figure 10. A hillslope profile of the north facing hillslope at the conventional tillage site.

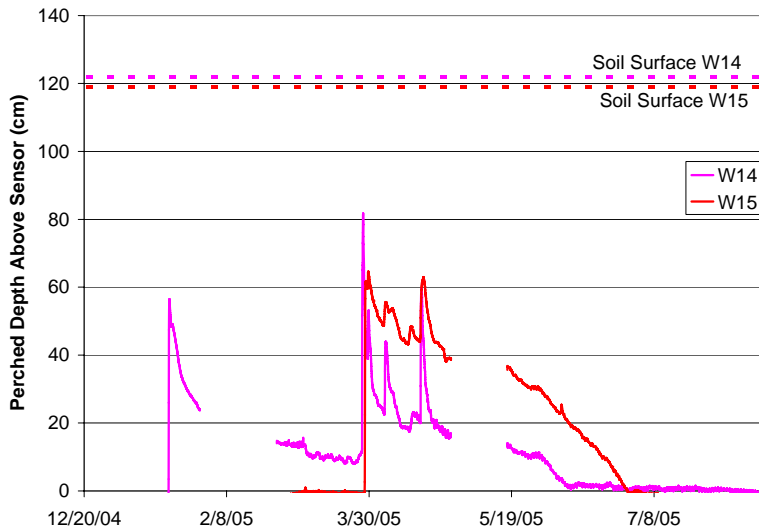


Figure 11. Perched water depth measured at wells 14 and wells 15. Notice that the perched water depth didn't form at the lower well (W15) until later in March. No perched water tables were measured in wells 16 through 19.

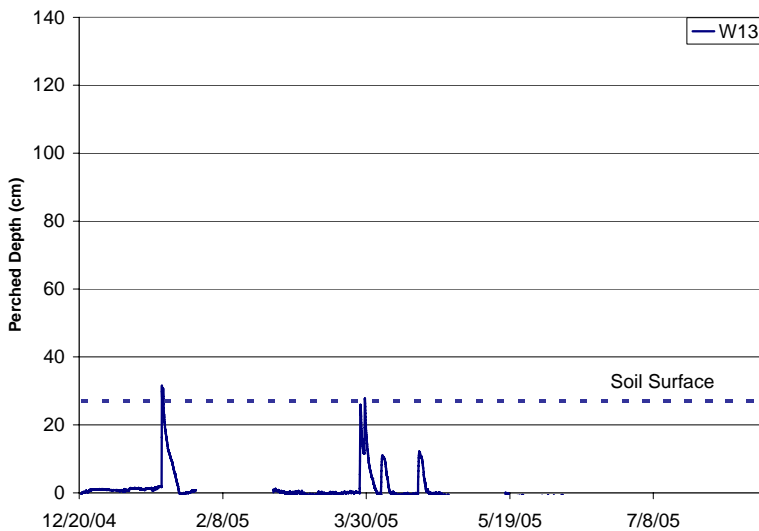


Figure 12. Perched water depth readings at well 13. Notice two different periods of surface saturation at this “clay knob” location.

Conservation Tillage Site

The conservation tillage sites were installed on a northeast facing hillslope which typically has a persistent snow drift. A small snow drift formed in the upper plot before the January 18th storm but it was not enough to result in runoff from the hillslope plot. An argillic horizon was found at each of the well locations and ranged in depth from 0.30 m at the upper ridge to 0.88 m at the lower toe slopes. Figure 14 shows a picture of the upper runoff plot and the lower toe slope position. As seen in Figure 15, we observed a perched water layer at the two lowest wells (W4 and W5) however the perched layer remained well below the soil surface. Interestingly, we

observed perching in each of the shallow wells indicating that a plow pan in these soils could be acting as a restricting layer, see Figure 15.

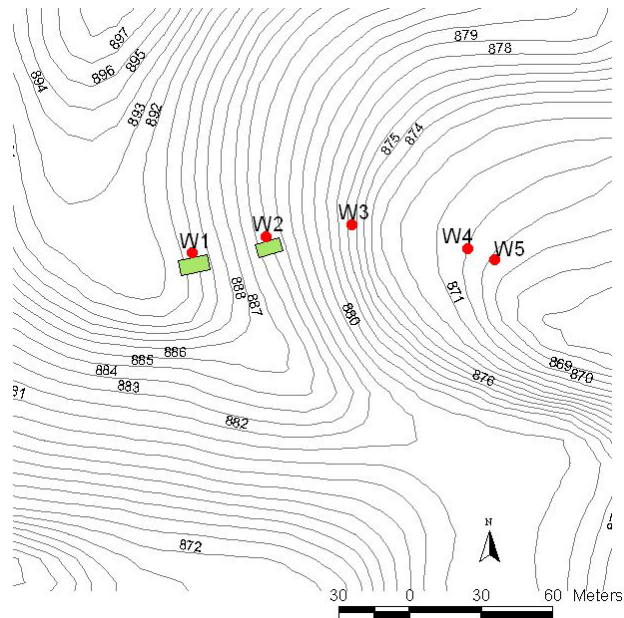
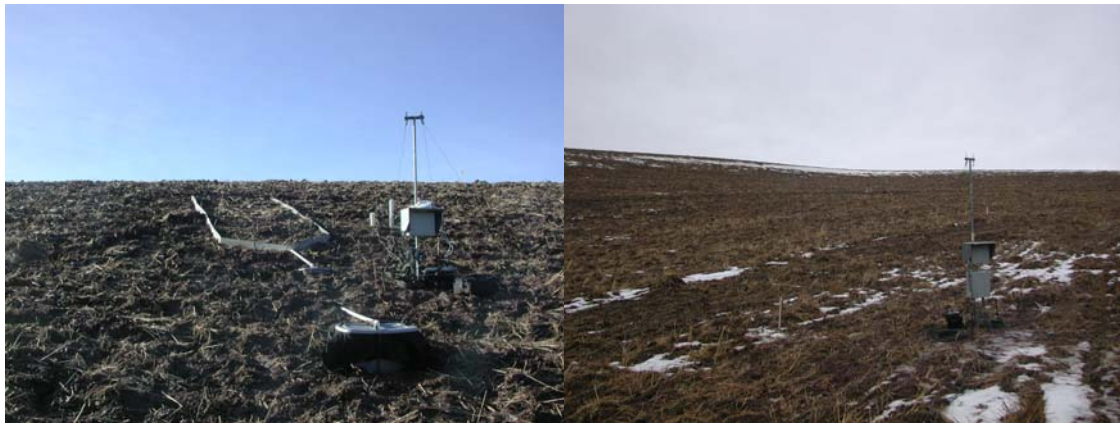


Figure 13. Contour map showing the location of runoff plots and wells at the conservation tillage site.



Figures 14. Upper runoff plot installed at the conservation tillage site on left. Lower site at the conservation tillage site.

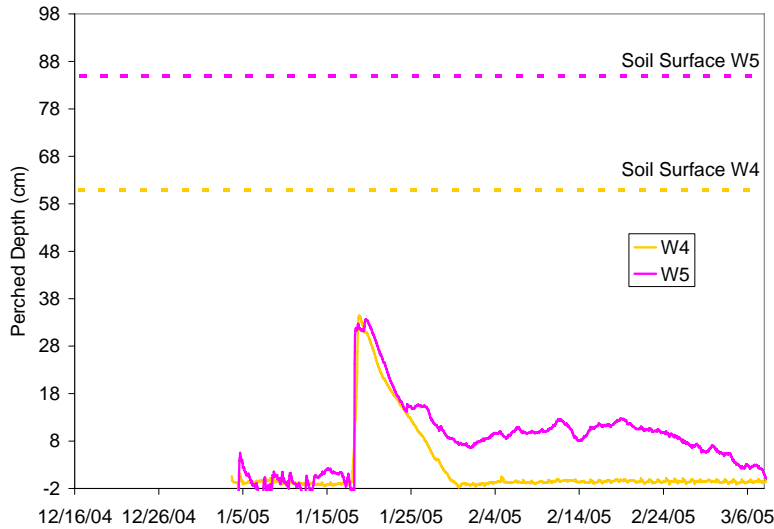


Figure 15. Perched water depth measured at wells 4 and 5 at the conservation tillage site. No other deep wells registered any perched water at this site.

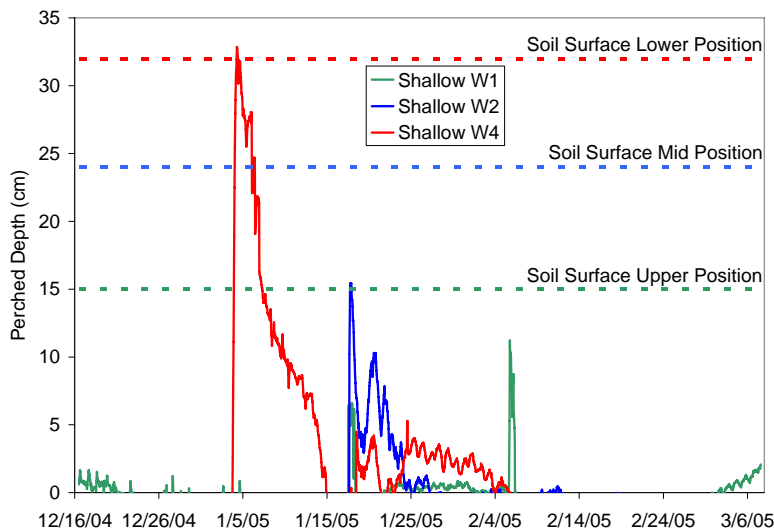


Figure 16. Perched water depth measured in the shallow wells at the conservation tillage site. Well 4 indicates surface saturation at the lowest position due perching on the plow pan.

Task 1.3. Watershed scale runoff generation

We simulated the hydrology of the watershed for the conservation tillage site using our GIS-based hydrology model (SMR) as proposed. Results from the SMR simulations are not meaningful at this time given the limited runoff observed at each site. We will be improving the model runs based on data from Tasks 1.1 & 1.2, especially knowing the locations and depths of restrictive layers. To this effect, we initiated a method to derive evaporative fluxes from satellite images using a technique developed by Dr. Rick Allen in Kimberly, Idaho.

Objective 2. Study the impact of major field factors on rill/gully formation under different tillage systems.

Task 2.1.

The objective was to observe major field parameters affecting rill formation and development. Major field parameters that were pre-identified were overland flow, slope, percent residue, antecedent soil moisture content, roughness, and bulk density.

The field areas of observation in the conventional till site and the direct seed site were determined in the first week of January 2005. For every event in these fields, the pre-identified parameters were then observed until the first week of March when the enclosing T-posts and baling wires were removed to give way to spring tillage. In both farms, no overland flow or rill erosion were observed. The other parameters were not measured, since, except for the antecedent soil moisture content, they were to be measured if erosion occurred.

Task 2.2.

The objective was to determine, among others, the effect of freeze and thaw on the erodibility of the farm soils in a laboratory with a flume. The laboratory flume at the Palouse Conservation Field Station (PCFS) is still under construction. This task will be completed when the flume is ready.

Task 2.3.

The objective was to inventory (in time) rill and gully erosion in three topographical locations on a field which has convex, concave, and straight slopes. Observations for this task were scheduled along with the observations for Task 2.1. No inventory, however, was done since there was no runoff and thereby also no rill erosion. Activities related to this task will continue during this season.

An Improved Data Gathering Technique.

The research team is considering installing a runoff measurement system at the outlet of the conventional tillage site. The flume maybe able to measure the drainage area's runoff and sediment yield. These data can be used to answer one objective of Task 2.3, which is to know the effect of land use on erosion. The data can also indirectly answer the questions of Task 2.1, which is relating rill and gully formation to some major soil parameters. The major parameters though will instead be related to the total sediment yield of the drainage area. These data would be useful at the ultimate goal of building a GIS map of soil erodibility.