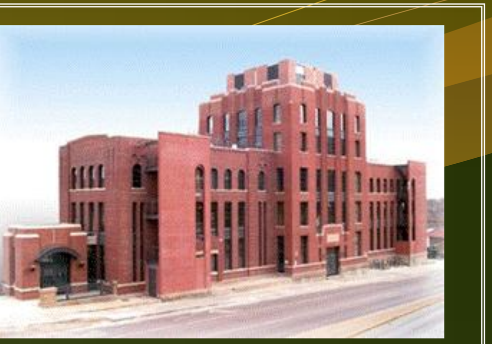
The efficiency of grassed waterways in reducing sediment yield within an agricultural watershed



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Problem Statement

It is estimated that 90% of U.S. cropland is losing fertile soil above the sustainable rate. In Iowa, one-half of the fertile topsoil has been lost during the last century of farming. In addition, 60% of Iowa soils are over-fertilized which drastically lowers water quality. In response to soil degradation and decreasing water quality, Best Management Practices (BMPs) have been widely adopted by Iowan agricultural producers to increase retention of runoff volume, as well as reduce sediment delivery and Non-Point Source (NPS) pollution. Common BMPs in the croplands of southeast Iowa are Grassed WaterWays (GWWs) which have been found to effectively reduce runoff/sediment conveyance and gully formation by slowing water flow and increasing infiltration rates.

Construction of the GWWs in eastern Iowa

Objective

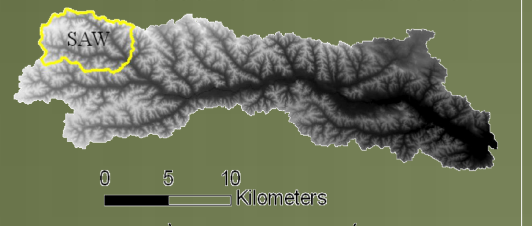
This research investigates the storm-event based efficiency of GWWs in reducing sediment yield (SY) within an agricultural Iowa watershed. The efficiency of the GWWs was examined by utilizing the Water Erosion Prediction Project (WEPP), which was calibrated for single storm events.

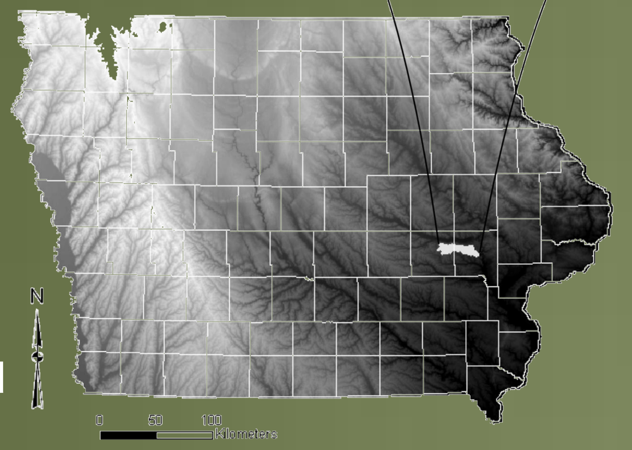
Site Description

This study focuses in the headwaters of the Clear Creek Watershed (CCW) within the 26 km^2 South Amana sub-Watershed (SAW), located in eastern Iowa, with the following characteristics:

- Average gradient of 4%
- Soil texture is silty clay loam
- Average annual precipitation of ~ 900 mm/yr
- Corn and soybean cover ~ 80% of the watershed

Clear Creek Watershed





The SAW within the CCW in Iowa

The SAW and the GWWs indicated by the red, dendrite shape features

GWW characteristics in the SAW

- Planted to bromegrass (*Bromus wildenowii*)
- Grass cover is uncut
- Shaped into a parabolic channel
- Width of 11.5 m and depth of 0.35 m
- Length of 250 m for drainage areas less than 30 acres
- Average slope of 2%

Methodology

The efficiency of GWWs at reducing NPS pollution was examined at a single event scale, since the majority of sediment and contaminants are transported during high-magnitude storm events. Potential factors affecting the efficiency of a GWW include:

(1) GWW dimensions (e.g., length)
(2) Gradient of the contributing hillslopes
(3) Magnitude of the events (e.g., peak runoff rate Q_{peak})
(4) Prevailing soil conditions
(5) Condition of the grass cover (i.e., cut or unmanaged)

I. Field Measurements

Field measurements from May to November 2007 and from June to October 2008 were performed to support the calibration/validation of WEPP:

(1) A dual-tipping bucket rain gauge, located near the center of the SAW, provided real-time precipitation measurements through a cellular modem.
(2) Continuous stage measurements at 15-minute intervals were collected with a Global Water WL16 pressure transducer at the SAW outlet .
(3) Flow velocity measurements were performed at the SAW outlet using an Acoustic Doppler Velocimeter (Flowtracker) by Sontek to produce a stage-discharge rating curve.
(4) An automated Sigma 900 MAX Portable Sampler by Hach was deployed at the SAW outlet to collect suspended sediment samples .

II. Model Calibration/Validation

- The WEPP model was employed to generate event-based runoff and soil erosion rates in the SAW for evaluating GWWs for 8 storm events (4 events for calibration and 4 events for validation).
- Model calibration was performed by adjusting individual key parameters within their expected physical ranges until the modeled runoff, sediment yield (SY), and Sediment Delivery Ratios (SDRs) at the SAW outlet approached the measured values during the event.
- Runoff was primarily controlled by the hydraulic conductivity, whereas upland erosion and SY by interrill and rill erodibility, critical hydraulic shear stress and Manning's coefficient.

Event	Date	Rainfall	Runoff	Water Discharge	Susp. Sed. Load
---	---	(mm)	(mm)	(m^3)	(ton)
1*	6/22/07	74	55	1,421,000	2600
2a	8/19/07	24	2	50,800	10
4	7/7/08	51	5	136,000	100
5*	7/12/08	13	2	56,200	40
6a*	7/17/08	43	16	416,500	550
6b	7/19/08	30	16	422,800	1450
6c*	7/21/08	19	13	330,500	1050
8	9/12/08	62	30	790,600	2200

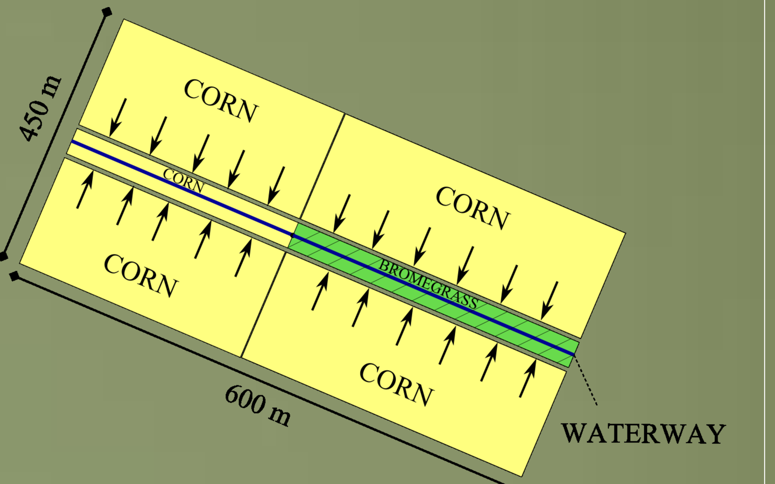
* Calibrated events

III. Model Simulations

Model simulations consisted of two components:

(i) Overall assessment of the effect that GWW length has on reducing runoff and SYs within a representative test hillslope, by altering the GWW length between 100 m - 600 m and planting corn the remaining length.
(ii) Examine the effects of the gradient of the contributing hillslope area on GWW efficiency by changing the hillslope gradient between 0.5 – 6.0%.

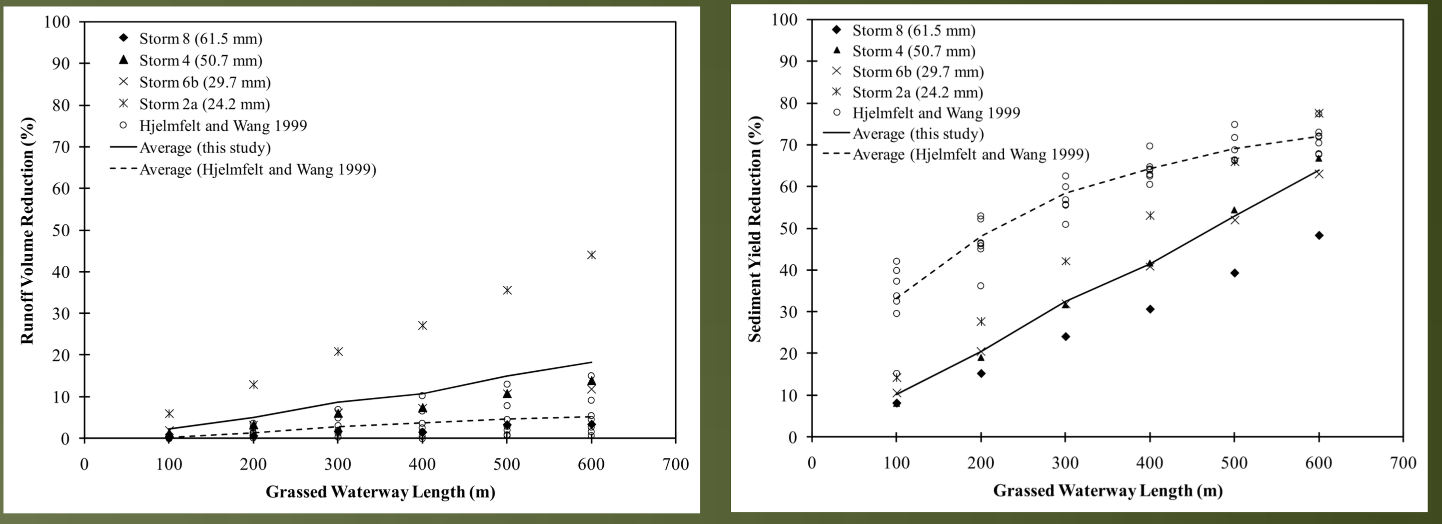
The representative hillslope runs were compared with the modeling study performed by Hjelmfelt & Wang (1999) (H&W) who evaluated GWW length for a field in Goodwater Creek, Missouri.



The representative hillslope used in the simulations

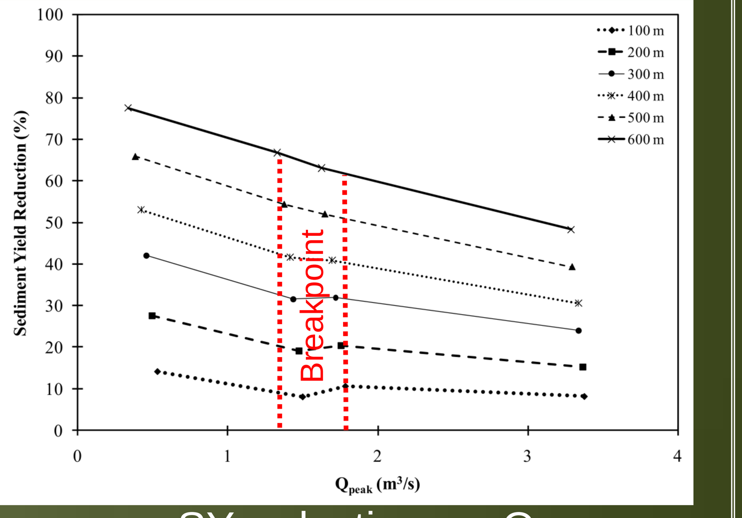
Results

- ✓ Reductions in runoff volume and sediment yield from the contributing hills increased as the length of the GWW increased.
- ✓ Reduction in runoff volume increased about 20 times and the reduction in SY improved 2 times in the H&W study, while in the present study the reduction in runoff volume increased about 9 times and resulted to an increased reduction in SY of almost 6 times.
- ✓ Differences between the results on the two studies are attributed to:
  (1) The recorded differences in the peak runoff discharges (Q_{peak}) between the two study sites and the variability amongst their values.
  (2) Performance of existing transport capacity formulas when nearly saturated conditions exist (H&W study) vs. well drained soils (SAW).

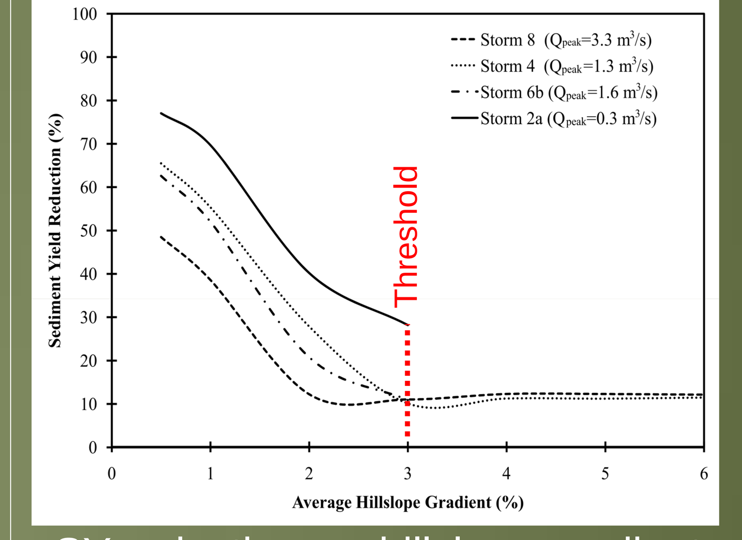


Runoff (left) and SY (right) reduction as a function of the GWW length for the H&W (1999) and the present study

(→) GWW efficiency is governed by the hydrology, expressed as Q_{peak}. There is a **breakpoint** in the slope of the trendlines: for Q_{peak} > 1.8 m^3/s the rate of sediment yield reduction decreases until a GWW length of 500 m. The maximum GWW length of 600 m provided, on average, the highest reduction of runoff volume (~ 18%) and SY (~ 65%).



SY reduction vs. Q_{peak}



SY reduction vs. hillslope gradient

(←) A **threshold** value for the average hillslope gradient of ~3% was observed beyond which the GWW efficiency was independent of the steepness of the surrounding topography (i.e., GWWs remained ineffective). For the low magnitude events, as the gradient of the hillslope increased, the depth of runoff decreased to a point where the transport capacity equations used in WEPP produced erroneous results.

Acknowledgments

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