H53B-1024. FLUVIAL EROSION MEASUREMENTS OF STREAMBANK USING PHOTO-ELECTRONIC EROSION PINS (PEEP)

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Background

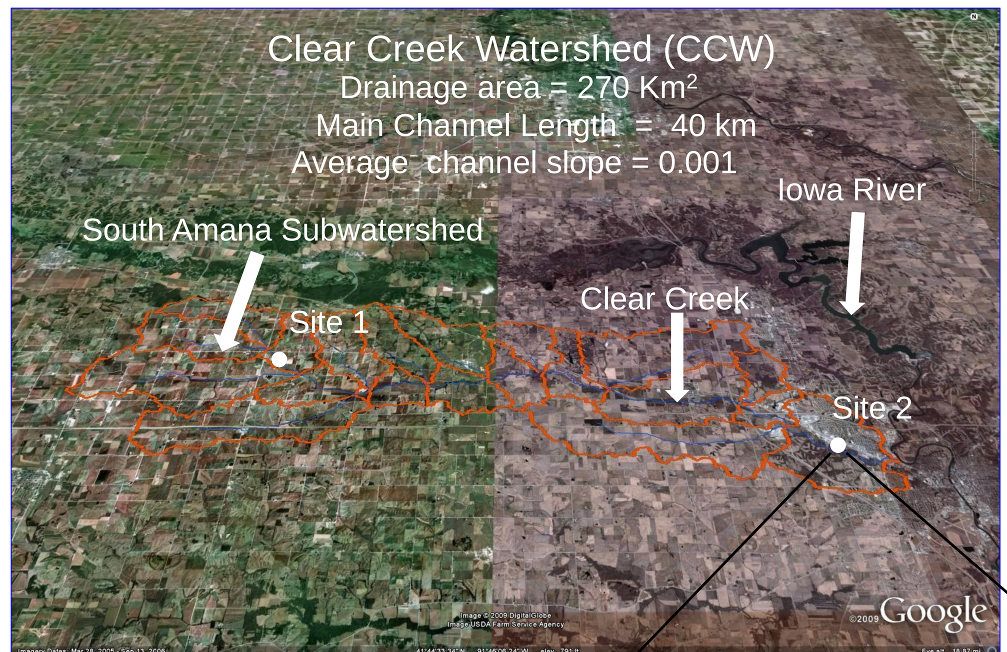
Cohesive streambank erosion is characterized by two main mechanisms, mass failure due to gravity and fluvial entrainment of individual particles (Thorne, 1980). Mass failure is defined as a process, when blocks of bank material collapse, triggered by the collective action of gravity and fluid forces (e.g., Millar and Quick, 1998; Duan, 2005) and mainly occurs during and right after the recession of high flow events. Fluvial entrainment refers to a continuous process that commences when the hydraulic forces exceed the resistance forces (Millar and Quick, 1998; Papanicolaou et al., 2007). For non-cohesive soils the resistance force is dependent on the submerged weight and friction angle (angle of repose) and for cohesive soils is function of the cohesion strength (Papanicolaou et al., 2007; Thorne and Tovey, 1981). Fluvial erosion, comparatively to mass failure results to less erosion on an event scale and for this reason has received much less attention compared to mass failure.

In this study, relative importance of fluvial erosion (compared to mass failure) was determined in two reaches from different locations of the Clear Creek Watershed (CCW). One site was selected at the second order stream and another site was located at the fourth order stream. Each of them was characterized by different flow condition and land-use.

Main Goal

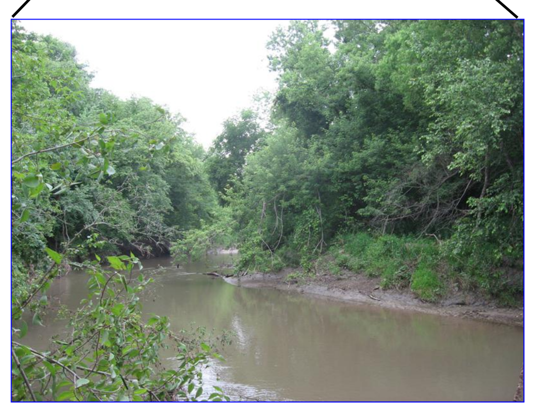
1. To identify the dominant erosion mechanism (mass failure or fluvial entrainment) affecting two stream reaches of different stream order, flow condition, and land-use.
2. To evaluate the performance of PEEP in monitoring bank erosion by direct comparison with the result of topographical survey and manual measurement.

Study Location: Clear Creek Watershed, Iowa, USA



Study was conducted at two different locations :
Site 1: located at headwater reach at South Amana Subwatershed.
Site 2: located close to the confluence of Clear Creek and Iowa River.

The CCW is characterized by cold winters and hot summers with wet springs.
Average temperature = 9°C
Maximum temperature = 31°C (July)
Low temperature = – 26°C (January).
Mean annual rainfall = 889 mm.
Snowfall water equivalent (SWE)= 76.2 mm/yr
High intensity thunderstorms are common from April to September with a peak in June.
Soil Type varies from sandy loam to clay loam.



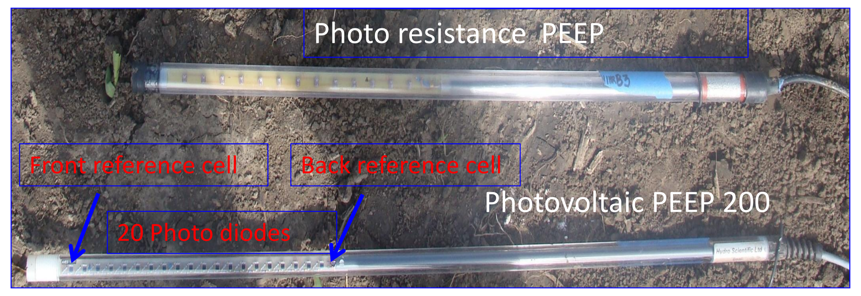
Site 2: Camp Cardinal, close to the confluence of Clear Creek and Iowa River. a fourth order stream flowing through an urban environment. Flow is less flashy than that of site 1 and the sustained high flows facilitate fluvial erosion. Silty loam is the dominant soil texture in this area. The average bank height was 5.8 m and the average bank angle was 47°. The mean annual flow is 7.2107 m³/ yr and the sediment discharge is 7.8 tons.

Site 1: South Amana, a 76-m headwater reach, a second order stream. The reach drains a 26-km² land that consist 80% agricultural area (corn and soybean) and 20% grassland. The dominant soil texture within this catchment is silty-clay loam and is highly erodible. The mean annual stream flow discharge is 5.9106 m³ / yr with an annual sediment discharge is 5.1 tons (Abaci and Papanicolaou, 2009).

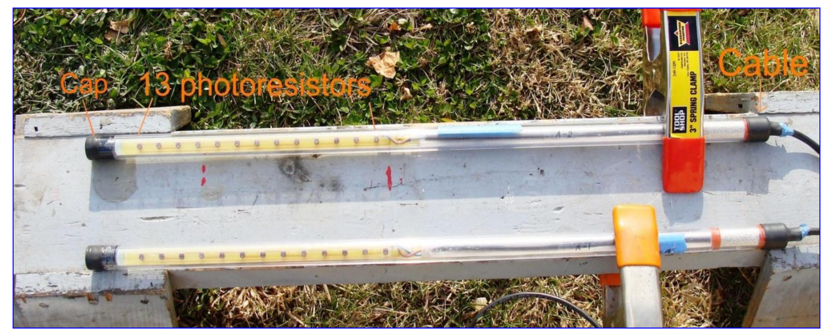
Photo Electronic Erosion Pins (PEEP)

- The PEEP is an optoelectronic device consisting of an array of photovoltaic cells (photodiodes) or photo-resistance cells connected in series and enclosed within a transparent acrylic tube.
- The PEEP , inserted into the streambank, allows monitoring of streambank erosion continuously at high resolution time intervals, thereby time, magnitude, and frequency of specific erosion events at the site can be clearly identified.
- Two type of PEEP : 1. Photo resistance PEEP
  2. Photovoltaic PEEP

Spesifications	Photovdtaic PEEP		Photo-Resistance PEEP
Models	PEEP 110	PEEP 200	-
Number of photodiodes or photo-resistors in series	12, including reference cells.	20, including reference cells.	13
Reference cells	2	2	0
Number of thermistors	0	2	0
Tube length (cm)	50	66	
Total sensor length (cm)	56	72	
Active length (cm)	11	20	22
Tube external diameter (mm)	16	16	18
Reference cell output(mV)	0-100	0-225	0



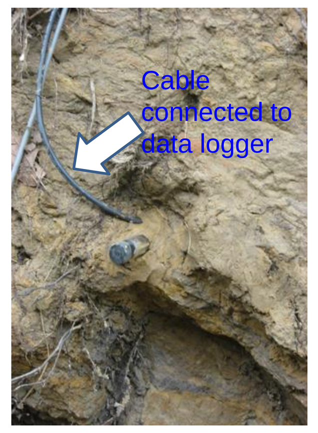
An array of photovoltaic cells or photodiodes constitutes a photovoltaic PEEPs. Photodiode is a type of photo detector capable of converting light into voltage at the atomic level. It outputs an analogue millivolt signal directly proporsional to the intensity of incident light striking the PEEPs.



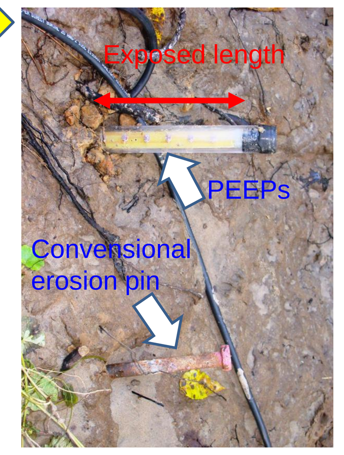
A photo-resistance PEEPs consists of an array of 13 photo-resistors. If the light falling on the device increases, the resistance decreases, thereby allowing higher electricity to pass through the conduction band. The resulted voltage is proportional to the intensity of incident light that strike the PEEPs.

Principles of Operation

An installation hole was drilled using a soil auger to provide a room for inserting a PEEPs into the bank.



As an initial condition , a PEEPs was fully inserted into the bank , except that only a front reference diode was exposed to the light.



As the bank was eroded, the exposed length increase, more intensive incident light was received by PEEPs

The received incident light was converted to Milivolt signal by photodiodes in the PEEPs.

The signal was sent continuously trough a cable to data loggers.

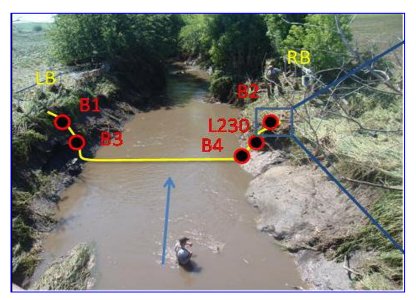
Data logger records magnitude of milivolt signal continuously at a certain time interval. The magnitude of signal was proportional to the exposed length of the PEEPs .

Field Works

Site 1

Drilling a hole for a PEEPs

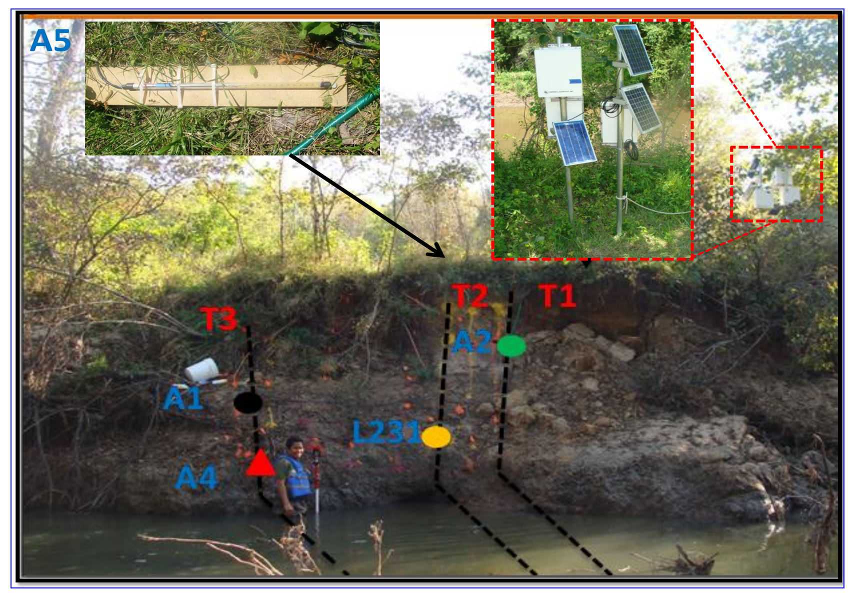
Inserting a PEEPs into the streambank



Left, condition at site 1 before flood event. Right, survey conducted at site 1 on June 23rd, 2009 (after flood event).

Survey before flood event (May 23th, 2009) at site 1.

Site 2



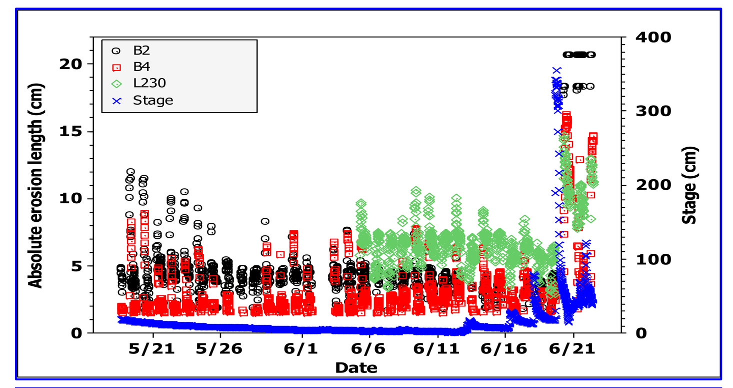
Survey after flood event (September 9th, 2009)

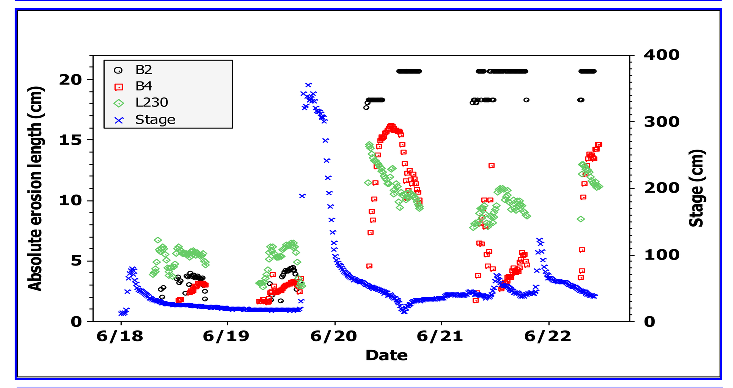
Callibrating the PEEPs at the floodplain.

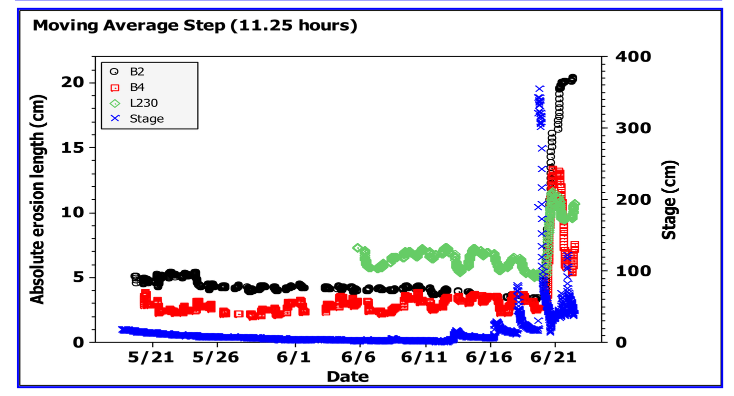
Callibrating the PEEPs in the bank.

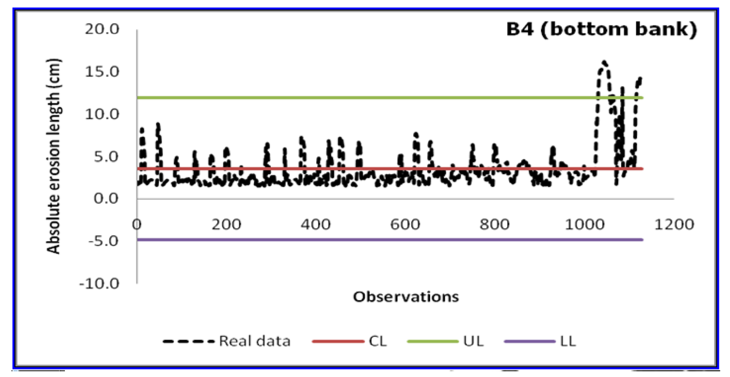
RESULT

Site 1







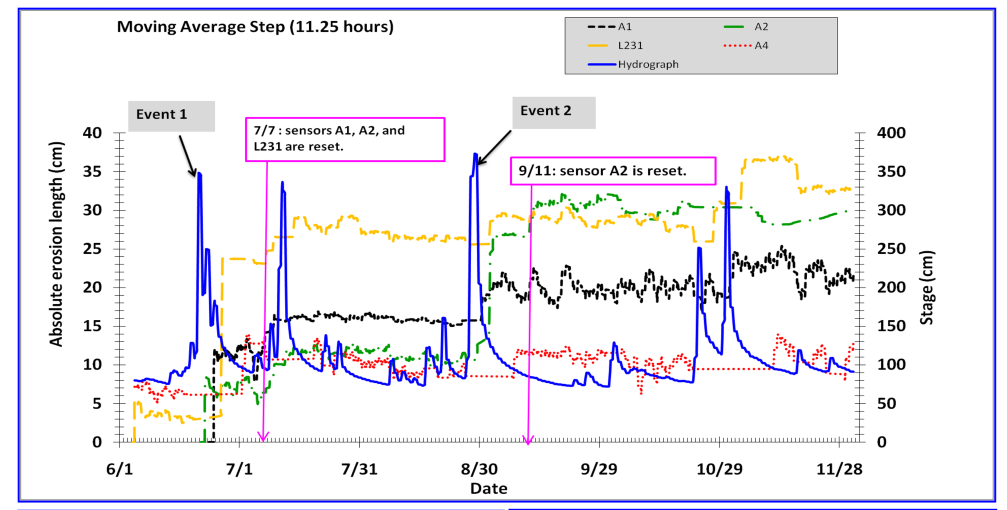


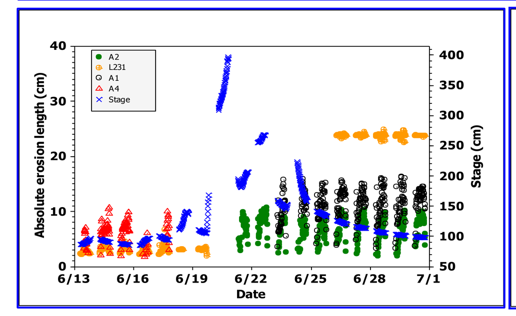
The Shewhart chart effectively detect the critical erosion event and the dominant trend of the data.

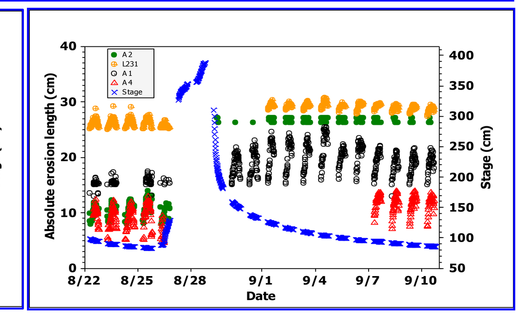
Erosion length (cm) after the June 19th event at site 1			
Observation Point	Survey	PEEP Sensor: Automated	PEEP Sensor: Manual measurement with tape
PEEP B2	17.4	20.3	27.9
PEEP L230	-	11.8	8.9
PEEP B4	12.7	11.9	9.5
PEEP B1	58.7	-	-
PEEP B3	Deposition	-	-

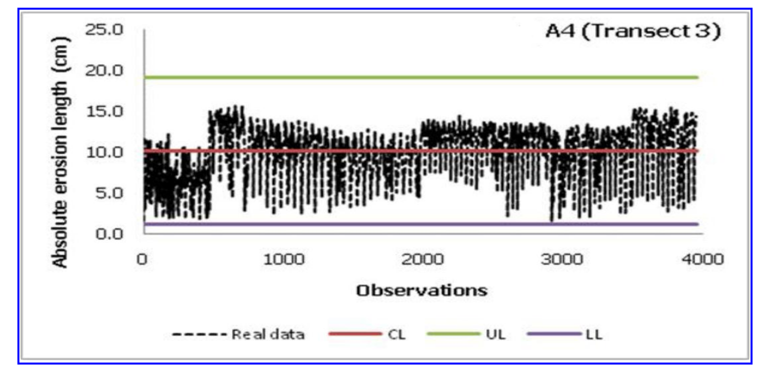
Survey on bank cross section was conducted on May 28th and June 23rd

Site 2









Erosion length (cm) after the August 27th event at site 2			
Observation Point	Survey	PEEP SENSOR: Automated	PEEP SENSOR: Manual measurement with tape
PEEP A2	23.9	23.7	20.5
PEEP L231	4.3	5.7	6.2
PEEP A1	8.7	10.6	12.0
PEEP A4	16.6	11.6	11.5

Bank cross section survey was conducted at July 30th and September 30th

Data analysis of site 2 reveals :

- **By referring to the Shewhart chart , fluvial erosion was the dominant erosion processes at site 2.**
- **The maximum error between manual and automated measurements of the exposed length of the PEEPs was less than 20%.**
- **The error between the channel survey and the automated PEEP measurements was less than 30%.**

Data analysis of site 1 reveals :

- **Bank erosion dominates at the top and mid section before June 19, 2009.**
- **Mass failure was dominant process at the top after June, 2009.**
- **Mass failure was the dominant erosion processes at Site 1.**
- **Maximum bank retreat was observed roughly 21 hours after the occurrence of the hygrograph's peak.**
- **The maximum error between manual and automated measurements of the exposed length of the PEEPs was less than 27%.**
- **The maximum error between the channel survey and the automated PEEP measurements was less than 14%.**

Conclusion

1. The erosion process at site 1 located in the headwaters (first order streams) of clear creek is dominantly characterized by mass failure mechanism.
2. Continuous fluvial erosion is more prevalence at site 2 located at the mouth of the Clear Creek Watershed (fourth order stream).
3. The statistical analysis confirms the above findings.
4. PEEP sensors are overall in good agreement with the traditional bank erosion methods.