CHANGES IN STREAM FLOW WITHIN A LINEAR CHANNEL

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In this study, I ask if there is significant change in water velocity within one channelized drainage ditch when the surface type and/or cross sectional area of that ditch changes. Answering this question will be accomplished by attaining the water velocity along the banks and in the middle of the ditch, to provide data on how the surface of the ditch and its general construction allows water to flow through it. The ditch studied is man-made, linear, shallow in slope, and contains equal lengths of altering surfaces such as smoothed concrete, riprap, gabions, and natural vegetation. Water velocity was seen to increase most closely correlated with the width and/or area of the channel, however an increase in stream flow suggests velocity measurements were altered by water being added between sections of channel. This particular ditch is a tributary of Woodcock Creek, and is located within a residential neighborhood near midtown Mobile, AL. Cross sections of the channel will also be taken to provide data on changes in velocity due to the change in shape of the ditch.

Keyword: water velocity, water flow, gabions, riprap, drainage ditch, ditch construction, channelized stream, runoff, discharge, stream flow.

Introduction

As the population of Mobile has increased, the city has become more urbanized, causing an increase in runoff water collected by paved streets, parking lots, sidewalks, and other impermeable surfaces. In order to prevent flooding, Mobile has had to channelize and armor many of the drainage ditches that run throughout the city and its suburbs. Currently, the city maintains several different types of drainage ditches within the Dog River Watershed (DRW). Many of these ditches, although still lined with natural vegetation, have been widened and deepened to allow a higher volume of water to pass through in time of heavy precipitation. Other ditches have been channelized and armored with materials such as riprap, gabions, or smoothed concrete walls and/or floors. A study by Ashley Turton (2009) shows that Mobile's ditches are comprised of 51.9% natural vegetation, 27.5% concrete reinforced, 13% riprap, and only 6.8% gabion reinforced. Because each type of drainage ditch is constructed in a different fashion, water reacts to each channel differently.

The materials used along the banks and floor, the slope of the walls, as well as the total area of the channel all play a role in how the water flows through it. Over the years many streams or drainage systems were constructed by straightening, widening, and armoring channels with smoothed concrete throughout Mobile and the DRW. These massive drainage canals are designed to move vast amounts of water at a high velocity. However, in areas with little to no slope and low water levels, these wide channels can collect sediment if water velocity decreases within them. Figure 1 shows the general layout of these different channels. Channels located along the side of roadways and urban landscapes are often covered in loose rocks known as riprap. Riprap is generally used for small triangular channels or larger trapezoidal channels, and is a cheaper alternative to constructing solid concrete structures or gabions (Froehlich, 2012). Gabions offer a relatively inexpensive option for controlling erosion, and also provide several benefits to a stream when used properly. Gabion walls and weirs are extremely permeable and allow sediments and organic matter to pass through them (Mohamed, 2010). According to Mohamed, a biochemical reaction naturally occurs between the gabion stones which assist in purifying the water as it passes through the stones (2010). Another benefit to using gabions is that they are a flexible structure that is able to deform, rather than break or crack like solid concrete (MGS, 2005).

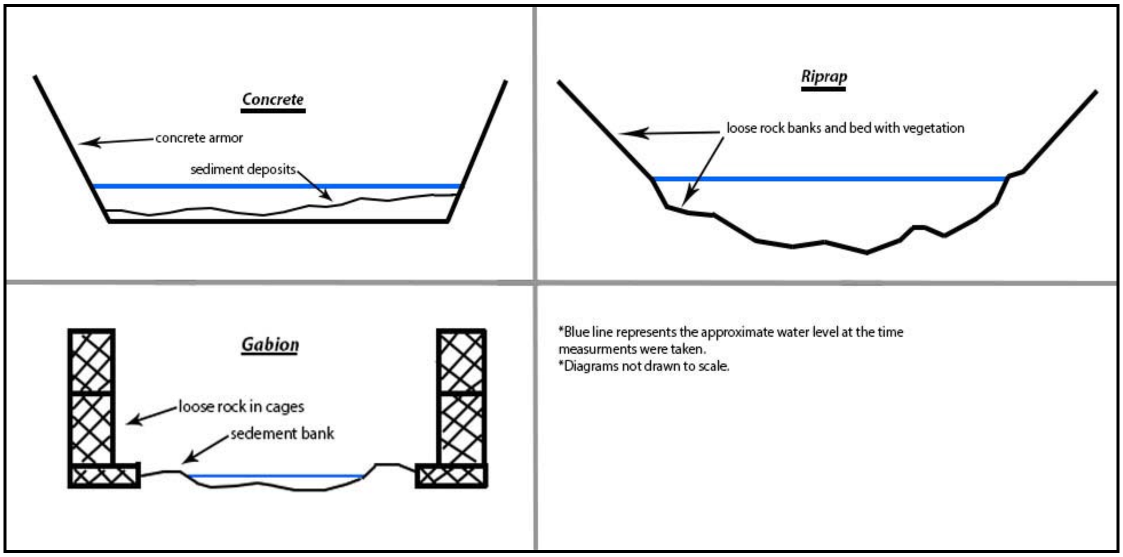

Figure 1. Cross section diagrams of concrete, riprap, and gabion channels.

It is important to note the behavior of water within these different types of channels, to gain understanding on which is truly the best type of ditch to implement in a specific location. Also, the way water is transferred from one type of ditch to another could possibly have negative effects on the channel or its immediate surroundings. These negative effects may include problems with erosion, sediment deposition, and flooding. The stream or river degradation may occur for several different reasons, including an increase in water discharge (Galay, 1983). Slope is able to contribute to degradation both upstream and downstream, and many times any change in one independent variable will affect another (Galay, 1983).

Research question

Is there significant change in water velocity or discharge within one channelized drainage ditch when the surface type and/or cross sectional area of that ditch changes?

Methods

Several parameters must be taken into consideration for accurate testing. Following the instruction for measuring stream flow by the EPA (2012), the cross sectional area of the stream, velocity, and discharge rate were calculated for each section of the drainage ditch in the study. First, the cross section of each channel was taken by placing a string at water level and taking depth measurements in one foot increments across the channel. Water velocity was measured in the middle of each channel, as well as the outer banks of the channel. An orange was used as a flotation device and timed as it floated down each type of ditch for fifty feet. By dividing fifty feet by the number of seconds it took to travel it, you are given the velocity of the stream in feet per second, or FPS. The discharge or flow rate of each channel was found by using the formula Q(flow rate)=A(area)*V(velocity). Measurements used in data were collected approximately 2 hours after an 8-10 hour rain event.

The channel being used for this project is a small tributary of Woodcock Branch. This channel flows from east to west, is linear in its flow, and has minimal change in slope from one end to the other. It is located north of Airport Boulevard, within a residential neighborhood off of Old Government Road. It joins with Woodcock Branch north of the confluence of Woodcock and Eslava Creek (Fig. 2).

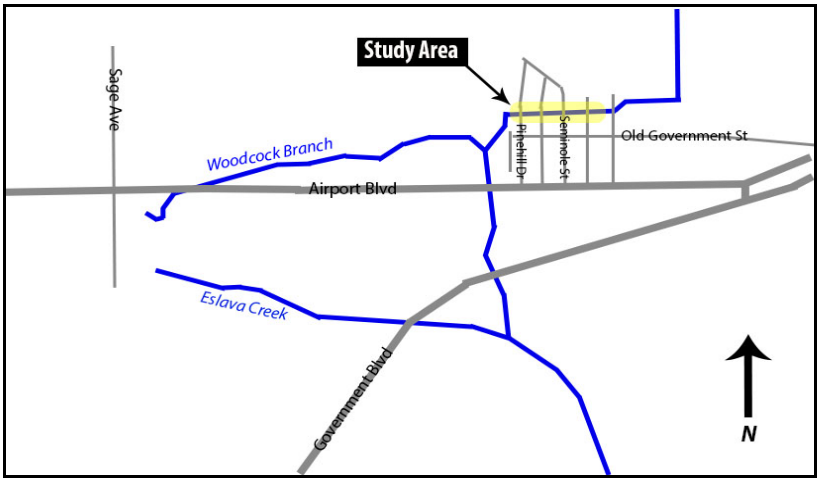

Figure 2. Map of study area

Results

The first section of the ditch that was assessed was constructed with smoothed concrete, and farthest upstream, or east, of the study area. Each of the banks and the floor of the channel were concrete. Other than cracks that have occurred over time from unknown causes, this section of the drainage ditch is completely impermeable. A large amount of sediment has collected throughout this section, mostly located along the northern bank. Although this was not part of my study, I believe the difference in sediment deposits from one side to the other is due to the type of trees located along the sides of the channel. The Northern bank contained a higher number of leaf-shedding trees, such as Chinese tallow trees locally known as popcorn trees. The southern bank was less vegetated above the channel, and did not seem to contribute leave or any other debris. The total width of the concrete channel at water level was 30ft 5in, and had an average depth of 8.52in. The cross sectional area of this section contained 21.29ft^2 of water. Water velocity was measured at .08fps. By multiplying the area by velocity it was found that stream flow was 1.7 cubic feet per second.

Water continues downstream from the smoothed concrete channel and transitions to a well vegetated section armored with riprap. These rocks lined each bank, and had a wide variety of plants growing from the top of the ditch down to the water line. The floor of the channel had some large rocks like those located along the banks, but was predominately covered by smaller stones or the natural stream bed. The total width of ditch at water level was 15ft 1.5in, which is less than half of the width of the ditch several feet upstream (Fig. 3). Due to this section being drastically narrower than the concrete channel upstream from it, the average depth increased to 21.67in. Along with the increase in depth, both the velocity and cross sectional area experienced an increase. Water velocity measured was .11fps and cross sectional area at 27.08ft^2. The total stream flow, or discharge, for this section was 2.98 cubic feet per second.

Figure 3. Transition from concrete to riprap channel

After flowing through two sections of vegetated riprap channels, the water flow experiences another change when it is greeted by a gabion channel. Although gabions are usually terraced, this channel was constructed with vertical walls two baskets high. The lowest (and third) basket was wider than the two above it but only half as tall, and served as a foundation for the walls above. The floor of this section seemed to be closer to natural than constructed. Each bank had several feet of soil and vegetation between the gabion walls and the water, which allowed for the water to meander and flow in a more natural fashion than in the previous types of channels (Fig. 4). Although the total width of the channel from one gabion wall to the other was 34ft 6in, the width of the stream at water level was only 21ft 1in. The cross sectional area of the stream was 11.79ft^2, which is nearly half the area of the concrete section, and almost one third the area of the riprap section. Average depth for this section was 6.74in. The gabion section decreased in area, but velocity and discharge increased substantially. Velocity was recorded at .28fps, and this section of the channel discharged water at a rate of 3.3 cubic feet per second.

Figure 4. Gabbion channel

Conclusions

In comparing the velocity and discharge of each stream, there is a steady increase in both variables the further downstream the water flowed. However, velocity in the center of each section differed from the velocity of water along the bank (Table 1). Although the concrete channel had the slowest velocity in the center, the water velocity increased closer to the bank, or wall. Attempts at taking measurements of velocity along the banks of the riprap and gabion ditches were all unsuccessful due to the orange getting trapped in vegetation, extremely slow water in small inlets along the bank, shallow areas, or soft sediments. Each failed attempt of bank velocity was considered as incomplete data and recorded as DNF, or did not finish, after 15 minutes had passed without movement.

Table 1. Table displaying colelcted data

Ditch Type	Cross Sectional Area (sq. ft.)	Water Velocity (fps)	Discharge (cubic fps)	Width (at water level)	Average Depth
Concrete	21.29	0.08	1.70	30 ft 5 in	8.52 in
Riprap	27.08	0.11	2.98	15 ft 1.5 in	21.67 in
Gabion	11.79	0.28	3.30	21 ft 1 in	6.74 in

One factor that was not foreseen in the study was the increase of water, or discharge. Because there is an increase in discharge, this tells us that the channel is steadily gaining water as it flows downstream. It is important to note that the increase is experienced within the two channels that are built with permeable materials. Just as these materials allow water to escape the channel and become ground water, it also allows water to flow into the channel from the ground. This suggests that water is being added from an increase of runoff water or base flow, however further studies will need to be completed to decipher this question.

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