Mary Rahjes
Get Wet
MCEN 5151: Flow Visualization
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I. Introduction

The purpose of this first assignment is to help get us comfortable taking pictures of different flow phenomenon. I chose to take pictures at Boulder Creek, focusing on the different small waterfalls that can be found all along the creek. These small waterfalls attracted my attention because of the change in flow from laminar to turbulent as the water crashed over the different sized rocks. While my experience with photography is quite limited, I feel that I was able to aptly capture the flow phenomenon with my chosen picture. My final image shows the water of the creek becoming turbulent as it crashes upon a partially submerged rock at the bottom of a short waterfall.

II. Photograph Setup

To capture the picture, I went to Boulder Creek and found a number of waterfalls that seemed to be appropriate for photographing. After trying a number of different locations, I found that the best pictures were taken from the South side of the creek. I also tried to take pictures from further down the bank, instead of directly perpendicular to the creek flow, so that I could capture the full effect of the water as it ran through the waterfall. Figure 1 depicts the exact setup for capturing the image. For most of the pictures I took, I tried to get out into the water a bit by sitting on rocks near the edge of the creek. This meant I had more flexibility with the scope of the picture, allowing me to utilize the zoom function of my camera as well as manually getting closer to the objects of interest.

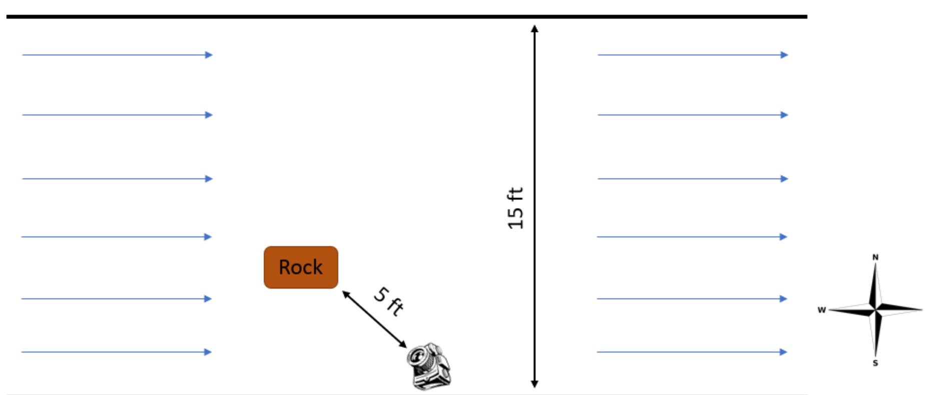

Figure 1: Diagram of photograph setup

III. Fluid Dynamics

The flow phenomenon captured in this picture can be described using the Reynolds number. The Reynolds number is a dimensionless parameter that conceptualizes the turbulence of a flow by dividing the inertial forces by the viscous forces acting on a fluid at a given time [1]. Equation 1, which can be found below, shows how one can find the Reynolds number. In the equation, *Re* is the Reynolds number, *u* is the fluid velocity, *L* is the characteristic length, and *v* is the kinematic viscosity of the fluid.

$$Re = \frac{uL}{v} \qquad (1)$$

Using this equation, it is possible to find the Reynolds number, and therefore prove that the area of flow in the picture is in fact turbulent. Although I was unable to measure every variable myself, it is possible to use educated estimations in order to demonstrate the flow phenomenon. To calculate the Reynolds number, I will use an estimated fluid velocity of $u = 0.3\ \frac{m}{s}$, an estimated characteristic length of $L = 0.05\ m$, and the kinematic viscosity of water at 15°C of $v = 1.1386 \times 10^{-6}\ \frac{m^2}{s}$. With these, it can be calculated that the Reynolds number is:

$$Re = \frac{(0.3)(0.05)}{1.1386\times10^{-6}} = 13{,}174$$

Turbulent water is characterized by a Reynolds number greater than 2900, so it can be shown that the water in the picture is definitely turbulent [1].

The presence of the rocks in question, as well as the resulting turbulence, can cause numerous effects on the creek around it. One of these effects is flow deceleration, which can be found upstream as well as downstream from the rock, and is related to the distance between the rocks in the flows path [2]. Due to the water having to redirect its path as it comes across an obstacle, there are areas within the flow where the velocity becomes zero or even negative as the fluid is pushed off the obstacle and away into a direction that leads it back downstream. This means that not only is the water going downstream slowed down, but the water upstream is also slowed down due to the buildup of fluid around the obstacle.

IV. Visualization Technique

The photograph was taken at Boulder Creek, so no additional materials were used in order to capture the fluid flow. The only tool used to enhance the visibility of the water was strategic placement of the camera in order to maximize use of natural light and shading from the trees overhead.

V. Photographic Technique

This picture was taken using a Nikon D3500, with an aperture range of f/3.5-5.6 and a focal length range of 18-55mm. The camera was set to an aperture of f/5.6, an ISO of 640, shutter speed of $^{1}/_{250}$ of a second, and a focal length of 55 mm.

In terms of image manipulation, I did my best to only enhance what was already in the image. This included cropping the image down from its original size, and adjusting the lightness, contrast, and saturation. Figure 2 and Figure 3 below show the difference between the original image and the final image.

Figure 2: Original Image

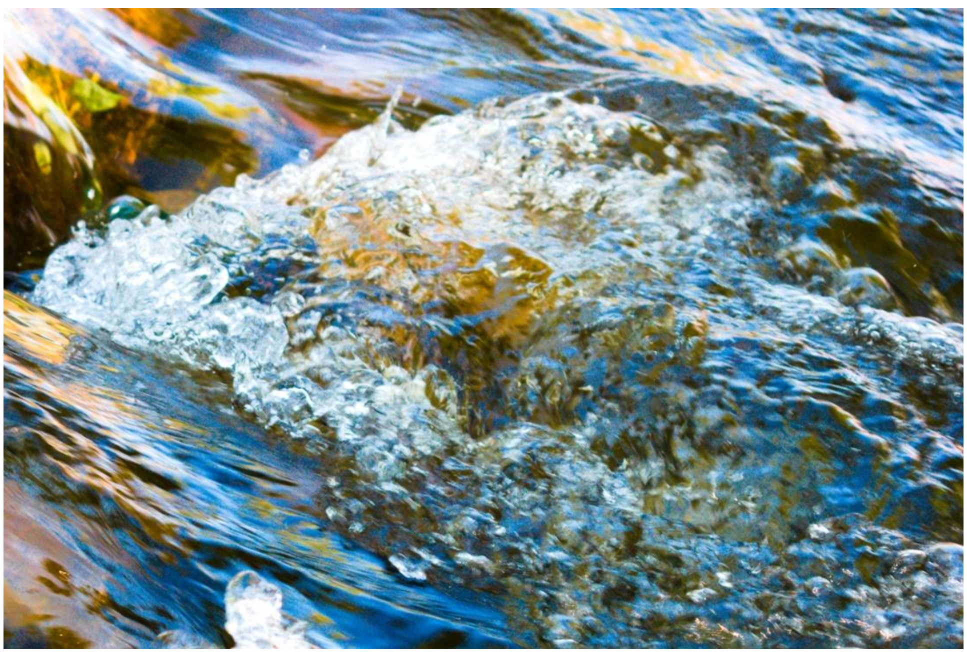

Figure 3: Final Image

VI. Results

Even though I had no photography experience before this, I was happy with the quality of the image I was able to capture, and the flow phenomenon I was able to showcase. In the future, however, I would like to try taking the picture with a different camera setup. A faster shutter speed may help the bubbles look more defined. Moving closer to the area of focus, instead of zooming in the camera or cropping the image down in post processing, may allow more flexibility in how I frame the photo or what elements I include. I also think that taking pictures of this same spot at different times of the day may be interesting due to the changing natural light that falls through the leaves of the trees and hits the water. Overall though I am pleased with my final image and my ability to capture turbulent flow so clearly.

VII. References

[1] Gerhart, Philip M., et al. *Munson, Young, and Okiishi's Fundamentals of Fluid Mechanics*. 8th ed., John Wiley & Sons, Inc. 2016.

[2] Fang, H. W., et al. "Influence of Boulder Concentration on Turbulence and Sediment Transport in Open-Channel Flow Over Submerged Boulders." *Journal of Geophysical Research: Earth Surface*, vol. 122, no. 12, 16 Nov. 2017, pp. 2392–2410., doi:10.1002/2017jf004221.