GET WET REPORT

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Figure 1: River Water Flowing in the Boulder Creek

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UNIVERSITY OF COLORADO - BOULDER

MCEN 4151: Flow Visualization

In our initial assignment, Get Wet, students were asked to choose a single fluid phenomenon of our choice and capture its effect using whatever photographic technique we like. Due to the shear amount of fluid phenomena and equally vast photographic techniques in our world, the scope of this assignment was incalculably large and provided students an opportunity to pursue both their academic and artistic interests. Personally, I have always found nature to be an excellent place to visualize flow, thus prompting me to go to the Boulder Creek with my camera. Even though it is winter in Colorado, I knew the creek would still be flowing due to the abnormally warm temperatures in recent weeks. My goal was to observe and capture the organized chaos of water flowing over the many obstacles found in the creek in order to further understand why rivers flow the way they do.

Naturally, creeks exhibit both turbulent and laminar flow of water, and do so inside smaller spaces, creating the perfect place to capture flow phenomena. To put in perspective, my flow image captures the creek as if you, an observer, were standing four or five feet away from the center of the creek and spanning roughly two feet across. In essence, if you were standing on the creek side, you would have to focus your sight on this specific rock, but not wade into the water at all. As seen in Figure 1 on the title page, the laminar flow is smooth and clear to the eye while the rapids create a turbulent flow, seen in the bottom right quadrant of the image. The difference between laminar and turbulent flow, mathematically, is the Reynold's number. If the fluid flow has a Reynold's number below 2,000, the flow is defined as laminar and smooth. Characteristics of laminar flow include long streamlines of low pressure, high velocity fluid. These streamlines are captured in Figure 1 where the light is refracted and "shines" off of the creek. These lines are seen on the left half side of the image and are wavy in appearance. The transition from laminar to turbulent flow is difficult to see in this image, but occurs at the base of the "waterfall" as soon as the free-falling water reaches the creek's continuation. This turbulent flow means that the water increased its Reynold's number to above 4,000, which happens due to the increased velocity vector attributed to gravity, which occurs after the water flows off of the rock.

In mathematical terms, rivers and creeks can be typically studied as quasi-one-dimensional flows, meaning you only need one variable to analyze the variance of the flow over time. This makes the flow analysis exponentially simpler. However, in my image of the creek flow, there is clearly an additional dimension needed to fully understand the flow phenomena. The creek acts one-dimensional until flowing off the rock. At this point, gravity provides a downward force to the water creating a velocity vector similar to a projectile. As you can see, the initial velocity propels the water forward, away from the rock face, where it is then affected by gravity pulling it downwards. In doing more research, river or creek flow behavior can be characterized by more than just the Reynold's number. According to Fowler, river flow can also be defined by something called the *Froude number*, defined below (Fowler, 3):

$$Fr = \frac{u}{(gd)^{1/2}} = \frac{Q}{g^{1/2}A^{5/4}}$$

This equation states that water flow in a river is directly proportional to the channel discharge, Q [m^3 /s], and indirectly proportional to the channel depth. Essentially, a *Froude number* < 1 corresponds to a *tranquil* flow and a *Froude number* > 1 turns out to be a *rapid* flow. So what does all this mean for our image taken at the Boulder Creek? Well, the left half of the image shows a tranquil river flow, *Fr* < 1. The left half of the creek flow also has a smaller channel discharge, or mass flow, than the rapid more turbulent water to the right side of the image. As the water falls off of the water, the creek picks up speed due to the increased gravitational force and increases the *Froude number*, creating the rapid flow.

To capture the image, a lot of variables had to be taken into account. For instance, on this particular day of the image, the sky was completely overcast and emitted very bright white light. With this said, I had to adjust many settings on my camera, including the aperture. Fortunately, I have the option on my camera for snowy days where there is a lot of natural light available. This allowed my camera to absorb the appropriate amount of light and produce an image with adequate lighting. The "snowy day" setting on my camera was not the only feature I used to capture this image. Due to the speed of the creek flow, I also had to adjust my shutter speed to reduce the blur. I chose to use a shutter speed of 1/125 seconds, or 0.08 seconds. This setting was sufficient enough to eliminate blur from my focal point and take a clear picture. Additionally, to capture as clear of an image as I did, I chose to perch right up next to the creek and zoom in as little as possible in order to maintain my high resolution. Furthermore, to reduce the amount of zoom needed for this image, I chose to lay prone on the creek and stretch my body out as far as possible, simply to create the best image possible.

Works Cited:

Fowler, A. (2016). *Mathematical Geoscience.* S.1.: Springer London LTD. Retrieved February 16, 2018, from http://www3.ul.ie/fowlera/courses/geo/chap4.pdf