MCEN 5151-002 Flow Visualization

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Team Third Project Report

# The Making of "Clash"

Figure I: "Clash" Final Image

## (I) Project Background

The image shown in Figure I above was taken for the Team Third project; part of the Flow Visualization curriculum at the University of Colorado Boulder. The goal of the project was to create a thoughtful controlled flow scenario which actively and accurately demonstrates a flow phenomenon with artistic aesthetic in mind. This image is meant to support an investigation on white-water turbulent rapids and the physics behind the "mound" of water in the center. Unlike other project images I have taken, this captures an entirely natural phenomenon with a water volume and mass flux not possible to recreate in a lab setting. As can be seen, the water in the image is hitting a rock wall with enough momentum to both splatter and take in a large amount of air, leading to a drastic change in color. The following sections go into detail on some of the physics behind this flow as well as how this image was created.

(II) Image Flow

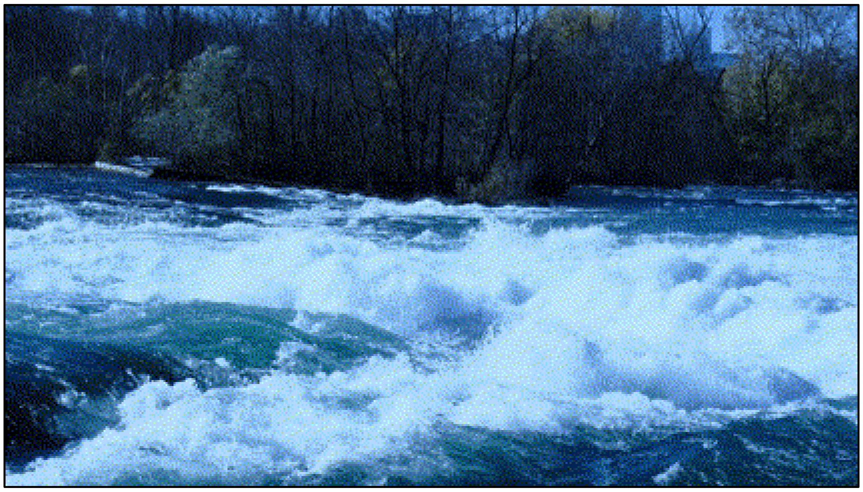

Figure II: Flow Visual

The image itself was captured upstream of Niagara Falls, NY at the location shown in Figure III with the flow profile shown in Figure II above. The 16:9 image captures a physical area of approximately 12' x 6.75' to capture as much of the flow as possible without distracting from the water in focus. This particular location is known for having some of the highest natural flow rates in the world at a rate of about 3,160 tons of water per second (*Niagara Falls Facts*, n.d.). This translates to the water in the image moving at approximately 25mph evenly across a 525ft wide stretch of river as can be seen in Figure II (*Niagara Falls Facts | Geology Facts & Figures*, n.d.).

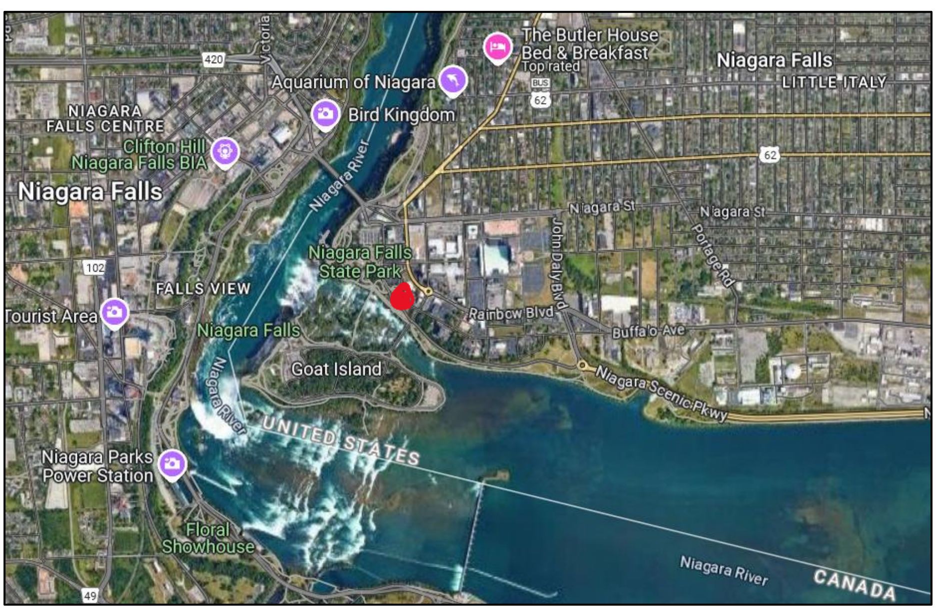


Figure III: Picture Location (43°04'53.2"N 79°03'39.7"W)

(III) Flow Physics

It is safe to say that the flow shown in the image is turbulent, given high speeds and high flow volume which lacks repeatability when interacting with the riverbed below. That said, we can confirm this assumption by calculating the Reynolds Number of the flow:

$$Re = \frac{UD}{v} = \frac{\frac{11.18m}{s} * 3.66m}{0.000001002m^2/s} = 40{,}827{,}125$$

The velocity was derived from the above 25mph estimate, with the characteristic length being the approximate length of the flow caught on camera (12ft). This calculation confirms the flow is turbulent and shows that inertial forces have complete dominance over the movement seen. Figure IV below attempts to visualize this effect via an estimated cross-section of the flow:

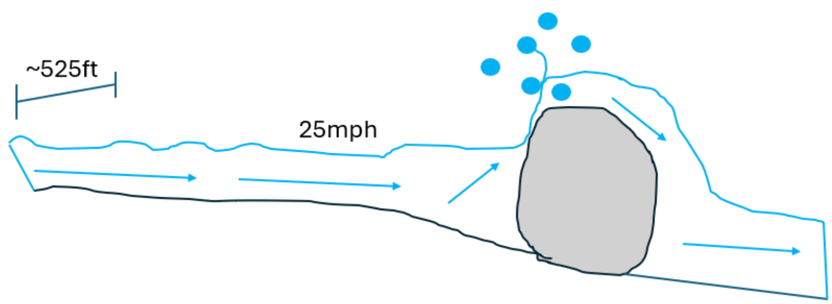


Figure IV: Flow Diagram

The formation of droplets upon hitting a rock (and/or protruded area of ground) combined with the dominance of inertial forces is in practice a horizontal application of the Rayleigh-Plateau instability (Barker et al., 2023). Given the reduction in surface area created by the protrusion and the high speed at which the water is traveling, the Rayleigh-Plateau instability predicts the formation of droplets. The formation of droplets allows the water to take in air, which changes the refractive properties of the water and turns it white as can be seen in the image. This intake of oxygen can be significant, especially given the turbidity of the rapids seen. A 2012 study suggests that even mild rapids can increase the oxygen saturation of a river by upwards of 20% (Hall Jr. et al., 2012). All of these factors contribute to the motion phenomena of the rapids.

(IV) Visualization Techniques

Given the flow is entirely natural, there were minimal controls on the visualization process beyond ensuring adequate weather and environmental conditions. Given the rapidity of the water and consistency of the riverbed, the water is sufficiently opaque to help in visualizing the flow. The weather (and lighting) allowed for a high shutter speed and tight aperture to assist with clarity. The image was taken at 10:36am on a clear and sunny day, the day after a small rain shower (which likely increased the flow rate).

## (V) Photographic Techniques

The image captures an area of approximately 12' x 6.75' provided by the camera approximately 5' from the ground and 10' from the subject. The image was taken on a Fujifilm XT30 II digital mirrorless camera with f/20 for heightened sharpness. The unedited image is 6240x3512 and the edited image was cropped to be 5637x3173. The image was taken using a 1/250 shutter speed with an ISO of 200 on an XC15-45mm interchangeable lens at 34.3mm focal length. This shutter speed was chosen for high clarity, and luckily due to plenty of natural lighting could be combined with a tight aperture and low ISO for a bright and clear image. A dynamic range of 100% was used for exaggerated coloring as well as a red and blue white balance (built in setting) to naturalize the lighting. In post-processing, using Adobe Lightroom, the contrast was decreased, and the lighting was adjusted to make the image more colorful.

Unedited Image

Edited Image

Figure V: Unedited vs Edited Image

## (VI) Conclusion

I believe the image provides a great insight into some of the flow physics found in a river and is fascinating to look at in detail. I enjoy the image both from a flow perspective and from an aesthetic perspective, though I believe it could be improved with some added elements such as rain or a horizon to add something else to look at. To develop this idea further I think it would be great to have a better understanding of what the riverbed looks like. Though I do not have the tools to do so, I believe it would give renewed insight into what is influencing the flow in the image.

**Bibliography:**

*Niagara Falls Facts | Niagara Falls State Park USA. (n.d.). Retrieved November 21, 2024, from https://www.niagarafallsstatepark.com/niagara-falls-state-park/amazing-niagara-facts*

*Niagara Falls Facts | Geology Facts & Figures*. (n.d.). Retrieved November 21, 2024, from https://www.niagaraparks.com/visit-niagara-parks/plan-your-visit/niagara-falls-geology-facts-figures/

Barker, B., Bell, J. B., & Garcia, A. L. (2023). Fluctuating hydrodynamics and the Rayleigh–Plateau instability. *Proceedings of the National Academy of Sciences*, *120*(30), e2306088120. https://doi.org/10.1073/pnas.2306088120

Hall Jr., R. O., Kennedy, T. A., & Rosi-Marshall, E. J. (2012). Air–water oxygen exchange in a large whitewater river. *Limnology and Oceanography: Fluids and Environments*, *2*(1), 1–11. https://doi.org/10.1215/21573689-1572535