Frozen Mountain Flow

Get Wet Report

MCEN 5151

9/11/2019

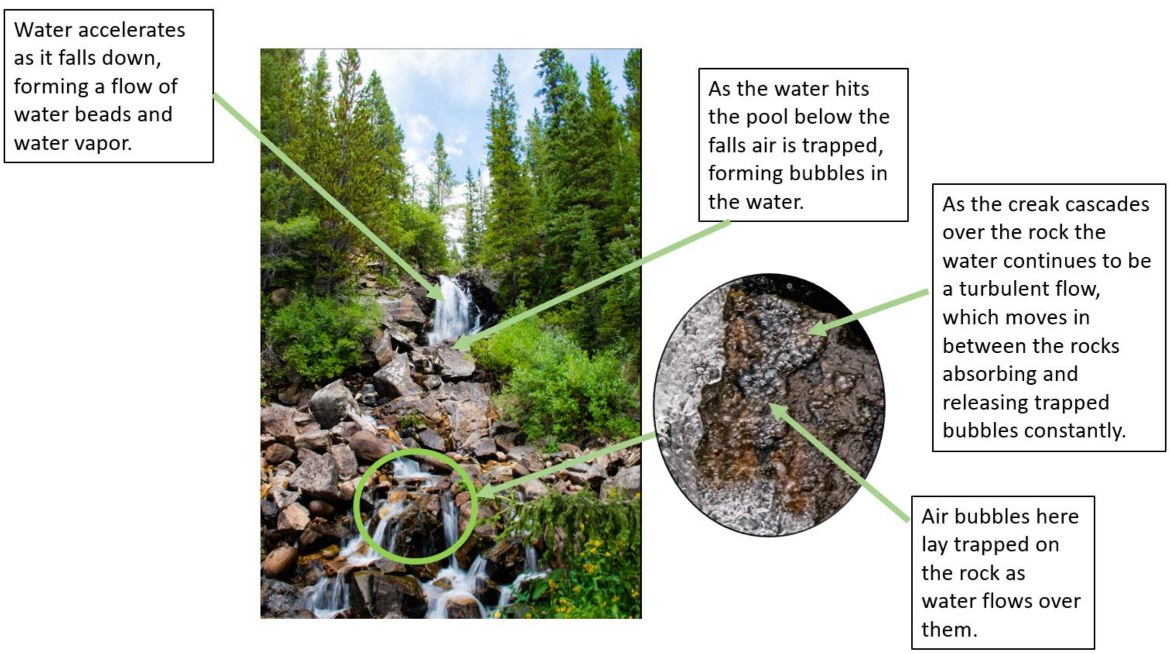
Aaron Zetley

Introduction:

In the image above, I worked to understand the natural flow of the creek at a singular instant. With both the interaction of the large falls not seen in the image and the smaller cascading movement over the granite rocks, I was curious to how the flow looked beyond the abilities of the "shutter speed" of the human eye. In essence, I wanted to freeze the chaotic movement of the water being forced down this creek into a singular moment. This enabled me to better understand the true makeup of the fluid and the gas trapped within the water and on surfaces of the rocks. This image created the opportunity to see the fluid phenomena of stream aeration, rapid gas exchange velocities, and turbulent water movement in a naturally cascading stream.

Fluid Mechanic Background:

This image shows the several dynamic fluid phenomena including aeration of a liquid, bubble formation, sheering of a turbulent fluid on a solid surface, and the interaction of bubbles within flowing turbulent stream. A diagram of the interaction of the water and the air is shown below.



According to a paper by the US geological survey (1) one of the major components of the reaeration (addition of oxygen and/or air into water) of streams is through mechanical aeration. The equation for rate of absorption of oxygen per unit time is described as so:

$$\frac{dc}{dt} = k_2(c_s - c) \text{ where the coefficient } k_2 = \frac{3.3v}{H^{1.33}} \quad (1)$$

In this case k_2 is the coefficient of reaeration, t is time, c is concentration, c_s is the concentration of the saturation of oxygen at a given temperature, v is the mean velocity of the water, and H is the depth of the water. In cases like the creak in submitted image, velocity of the fluid is high and the stream height low creating a scenario for the mechanical movement of the water that enables the formation more pockets of air to be trapped. The functions of reaeration is in essential to many environments and ecosystems and helps improve the quality and cleanliness of water by helping rid organic pollution and runoff. This is performed by the mixing of this oxygen with organic molecules within the water initiating the combustion reaction where oxygen functions as the "fuel" to destroy organic waste (1).

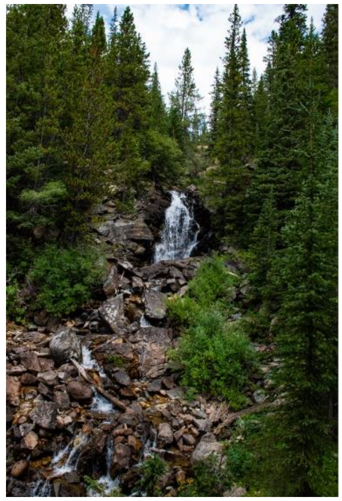
It was found in a paper conducted that the University of Koblenz-Landua in Germaney that rate of exchange of gas within a stream like in the submitted image above is directly related to the streams surface roughness. (2) The differences in gas exchange velocity was quantified experimentally by measuring oxygen levels in smooth rippled and rough flows and relating results to following equation:

$$k = \alpha\,(\varepsilon v)^{\frac{1}{4}}\,Sc^{-\frac{1}{2}}$$

In this equation the model relates the gas exchange rate to the near surface turbulence of the water. (2) In the equation above k is the gas exchange velocity, with α denoting the scaling factor. The symbol ε represents the dissipation rate of turbulent kinetic energy, v being the viscosity of water, and Sc the Schmidt number which is a ratio relating the kinematic viscosity of water and the molecular diffusivity of the gas. (2) In reality as the paper discuses no study has validated that the equation above fits water flows that contain mostly gravity fed turbulence which this image shows. Despite this, the equation help quantify the interaction and importance of turbulence, the water velocity, and surface roughness in the exchange rate of gas within a stream. If we assume this equation is valid, we see that the effective gas exchange rate is so high (lots of bubbles) in the submitted image as the surface roughness, velocity and turbulence are high in the stream.

Visual Technique

This image was taken during a 3 day backpacking trip in Indian Peaks Wilderness. Information on the path of this backpacking trip can be viewed here. After 5 to 6 miles of downhill backpacking from Pawnee Pass we arrived at this gorgeous waterfall and set of cascading streams slightly. Using my Nikon d5500 DSLR camera during a bright Sunny day I was able to capture the image with plenty of light for the shot. In my attempt to understand the physical makeup of the water as it flowed down past the large waterfall, I composed the image to capture the smaller cascading falls instead of the fifteen foot falls above. Below is an image of the area of the falls.



Photographic Technique:

The field of view of the image was taken within a square box of approximately 1.5 feet by 1.5 feet. The imaged was captured with a Nikon D5500 DSLR Camera (Digital) with a 18-140mm lens. The exposure time was 1/4000 sec with a f stop of f/9.0 and a focal length of 130mm. The image was taken around ten feet away from the image to avoid getting wet and the two insure sharpness in full field of view of the image. Even with full the daylight the image was shot at ISO 4000 due to enable the image sensor to capture enough light in such a short amount of time. No large edits were performed on the image other than slight changes in exposure, contrast, sharpness, and levels. These in actions were done in both lightroom and photoshop using the original Raw type file image to help sharpen the shapes of the bubbles in water and on the rocks. Lastly the image was cropped to focus in on the main elements of the image, the water and air bubbles with the water and over the rock on the right.

Self Reflection and Future Projects

I really loved this image for its ability to freeze a natural phenomenon un-seeable by the human eye into something attainable and understandable. I think the physics of aeration and bubble formation can be well seen in this image along with the variety of bubble shapes that form with the mixing of the water and the air as the fluid cascaded down the falls. One questions I have is I wonder how the temperature of the effected the mixing of the water and the air bubble. I am also fascinated by how this image although a capturing a fluid moving rapidly in this instant looks so similar to actual ice with air bubbles within it. I wonder the relationship between the formation of ice and turbulent flow like so and why it may seem to look similar. I would love to in the future take this image in a more controlled environment with even more light to possibly view this air and liquid mixing within even more sharpness and clarity. I would also like to try to uses a slow motion camera to record the phenomenon at an incredible fast rate to see the interaction of the air bubbles both in the fluid and on the rock beyond what the eye can see.

References:

1. Langbein, W B., and W. H. Durum. “The Aeration Capacity of Streams.” *The Aeration Capacity of Streams*, US Geological Survey Cirvular 542, 1967, pubs.usgs.gov/circ/1967/0542/report.pdf.
2. Noss, C. & Bodmer, Pascal & Koca, Kaan & Lorke, Andreas. (2018). Flow and Turbulence driven Water Surface Roughness and Gas Exchange Velocity in Streams. E3S Web of Conferences. 40. 05018. 10.1051/e3sconf/20184005018.