Team First: The Perfect Wave

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The assignment that led to this image was simply to create and capture a unique flow phenomenon with a team of three other people. My team decided we wanted to image a breaking wave and to do so, we decided to use a Flume. The exact details of our flow set up are discussed below but in short, a flume is a narrow channel through which water is pumped and which obstructions can be placed inside in order to observe how the flow of water is affected. The flume that we ended up using featured transparent sides so the intent with the image was to capture a side-view of a wave as it broke and curled over, imaging both what was going on underwater, as well as above the water. We had to play with a number of set-ups before successfully creating a wave but were ultimately successful in consistently creating a breaking wave and then capturing a well-timed picture of said wave.

As mentioned above, the team used a flume to create our crashing wave effect. We were initially unsuccessful in replicating ocean like conditions, such as a shore line and water pulse, to create our breaking wave and so had to resort to forcing a surge of water to curl back on itself. In order to accomplish this, we placed a dam at the far end of the flume which allowed only a small trickle of water through. We then placed a second, removable dam upstream of the first which blocked all flow when it was in place. One team member (Chet Roe) was responsible for operating this dam and held it in place until roughly ten inches of water built up behind it. Once the proper amount of water had built up, the upstream dam was rapidly removed causing a surge of water to flow down the flume and collide with the permanent dam. The splash from this impact created a wave-like effect, which we captured in the image above. The diagram below shows our set-up in greater detail.

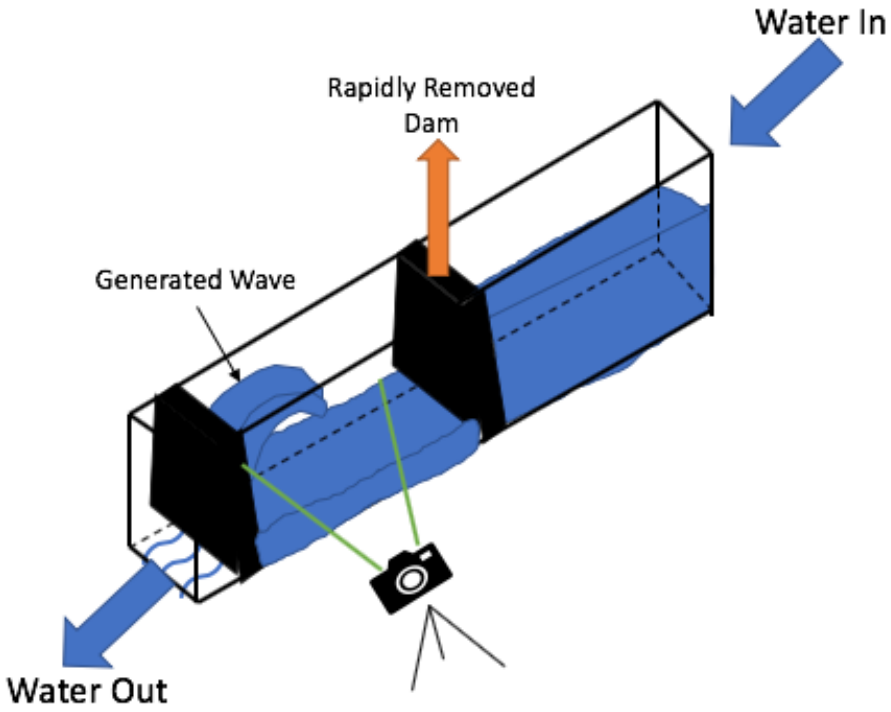

Figure 1: Diagram of Flow Apparatus

While the wave captured in this image was not created naturally, or even by a mechanism that simulated natural wave creation, the best shot we have at analyzing the physics is to compare it to an oceanic wave. In a scholarly article titled “Breaking and Dissipation of Ocean Surface Waves” the author, Alexander Babanin, mentions that there are three individual events in a wave breaking; breaking onset, breaking in progress, and residual breaking. Since the breaking wave was not caused by oceanic mechanisms and the image was taken before any residual breaking could occur, we will focus on the breaking in progress. In this article Babanin describes how the continued breaking of a wave is driven primarily by gravity and the inertia of the water. In an oceanic wave “Instability is a key word in the breaking process” (Babanin, 2011) and the wave essentially continues to grow as it travels until it becomes unstable and crashes. One common mechanism for this is when a deep water wave enters shallower water, it is pushed up out of the water by the ocean floor until it reaches a height where it is unstable (Babanin, 2011). In the case of our image it is not the ocean floor that pushes the wave up out of the water, but rather the static plate that we placed in the flow path. As teammate Chet Roe describes, “As the water hits the wall, it has nowhere to go other than up or down, in this case, because we are flowing along the bottom, creating a 90 degree elbow, the water can only go up. The force of the water hitting the wall has an equal and opposite force of the wall pushing back on the water. As the water moves up, it is also experiencing a force to the left, making some of it move back in the direction it came from. At some point, it’s upwards velocity stops and reverses due to gravity, making it fall back down again. Thus, it hits the wall, is forced upwards and backwards, then falls back down with gravity. This is what creates the circular motion and classic wave curled shape.”

In order to capture this image, no advanced visualization techniques were needed. While my other teammates used a drop of red food coloring to add color and contrast to the image, simply framing the flow against a white background was enough to distinguish great detail in the wave. The white background we used was an opaque diffusion sheet which could be positioned anywhere along the flume and by positioning it behind the area where the wave was crashing, we were able to create a clean background for the image that offered good contrast. The lighting used for this image was a combination of the overhead lights and two long LED bulbs which were placed directly behind the diffusion sheet. These LED lights were ultimately what made the background such a pure white and created such a stark contrast with the edges of the flow. The flash on the camera was left off in order to avoid reflections in the glass sides of the flume.

My teammate, Hana Kieger, describes our photographic technique as the following, “For our photographic intent, we wanted to have the clearest image possible where we could focus just on the flow. For this reason, the field of view is quite restricted. The height of the field of view is roughly 11cm and the width was roughly 17cm. The distance from the lens to the wall of the flume was roughly 12 inches. The focal length was 85mm. As Ibrahim mentioned, we used a Nikon D80 camera (digital) which yielded a final image with the resolution of 3872×2592. The exposure was 1/2000 sec, the aperture was f/5.6, and the ISO was 1250.”

Post processing for this image was relatively involved as there was a lot of cleaning up that needed to be done. A large part of this was editing out the many small water droplets that had collected on the sides of the flume during our repeated trials. The image was also cropped to make the subject the focus of the image and then some extraneous framing from the flume was also edited out. I then used contrast and exposure adjustments to brighten the background and increase the contrast between the wave and its surroundings bringing out much of the wave's detail in this process. The last set of adjustments I made were aimed at bringing out the metallic color of the wave. I noticed that there were some interesting textures and silvery colors in the original image and so I decided to amplify these aspects in order to give the flow a "flash frozen liquid metal" appearance. This was accomplished by upping the vibrance of the image and then playing with levels until the metallic color was brought out. The original image is included below for reference.

Figure 2: Unedited Image

For me, I really like the way this image really captures the stillness under the water, the developing turbulent layer right underneath the surface of the water, and finally the chaotic turbulence of the crashing wave far above the water. I also am quite fond of the way that the air water interface causes excess diffraction of light which really accentuates some of the flow patterns occurring in the wave. The only thing I was unhappy with in this image was our inability to replicate an oceanic wave. I think developing the image further a small motor could be used to create pulses in the flume, which, if paired with an artificial "beach" would have a much better chance of recreating an oceanic wave.

References

Babanin, Alexander. *Breaking and dissipation of ocean surface waves*. Cambridge University Press, 2011.