Executive Summary

Due to its geographical location, Venice has always been subject to the ebb and flow of tides. Data collected from *il Istituzione Centro Previsioni e Segnalazioni Maree*, or *il Centro Maree*, shows that tide levels are rising each year. When the tide gets high enough to invade the pavement, this is referred to as *acqua alta* – high water. This phenomenon occurs at different water level heights throughout Venice, but *il Centro Maree* defines a high tide as *acqua alta* when the level surpasses 110 cm. According to *il Centro Maree*'s data from 1966-2009, "high water exceeds 110cm, on average about four times a year" (Bon, n.d.). By looking at their data, it is possible to see, as shown in **Figure 1**, that the frequency of *acqua alta* is increasing. *Acqua alta* is creating more inconveniences for pedestrians that wish to avoid floods. The Flood of 1966, which flooded about 90% of Venice, caused the city to actively begin taking measures toward flood protection. *Il Centro Maree* was founded as one of these preventative efforts. Today, this government agency gathers information on tides at *Punta Salute*. This location serves as a reference point for the tide level throughout Venice. There, they have a station housing a tide datalogger to measure tides. The information from *Punta Salute* allows *il Centro Maree* to come up with forecasts. Tide forecasts are represented in three parts: astronomical tide (moon and sun), meteorological tide (wind and barometric pressure) and predicted tide (sum of astronomical and meteorological). These parts are used to create a graph (see **Figure 2**) that displays the forecasted tide (*marea prevista*) as well as the astronomical tide (*marea astronomica*). The forecasts are updated every 24 hours and predict the tide trend for the next 72 hours. Knowing the current and future tides at any given moment is important, but more important is understanding the ins-and-outs of how tides work.

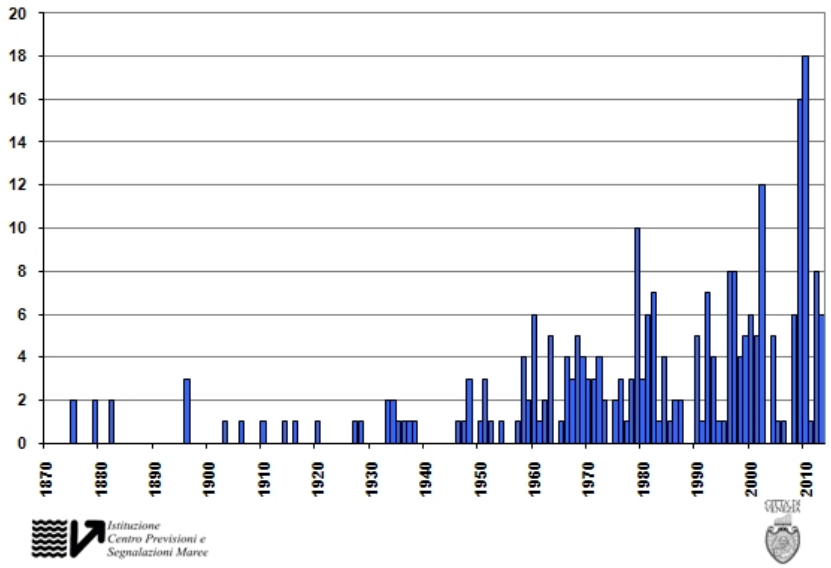

Figure 1. Graph showing the increasing frequency of acqua alta

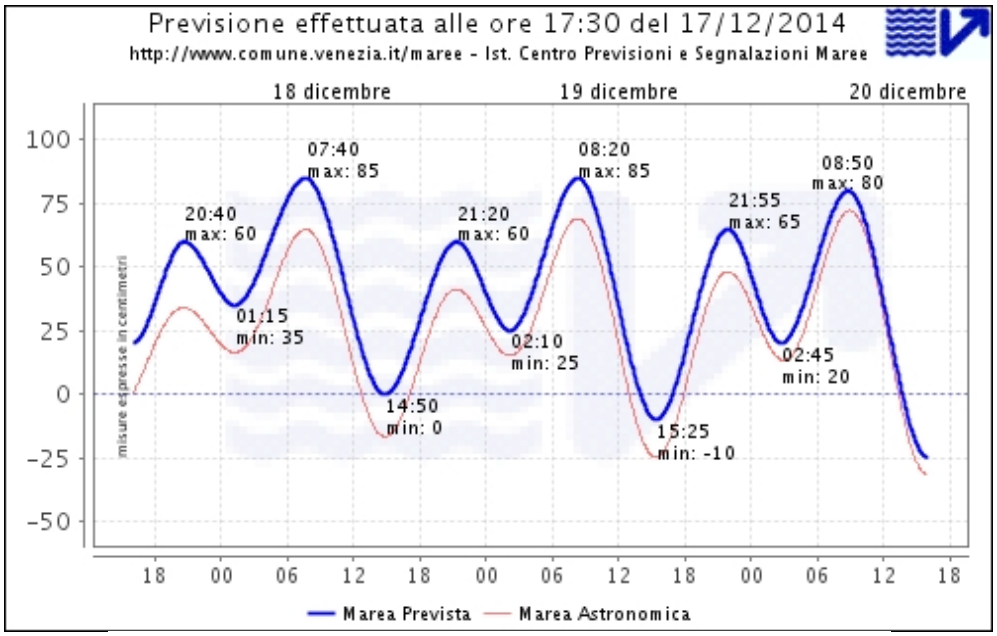

Figure 2. Graph showing the predicted and astronomical tides

In 1923, the *Consiglio Nazionale delle Ricerche* (CNR) was founded. In 1969, CNR established the Institute for the study of Dynamics and Large Masses (IDGM). IDGM would eventually be incorporated into the Institute of Marine Science (ISMAR) ("*Venice in Peril* – Scientific & Research"). ISMAR has dedicated much of its resources to studying *acqua alta*. Through these efforts, ISMAR was able to develop a Canal Hydrodynamics Model. Their model takes forecasts from *il Centro* Maree and produces the water levels in the inner canals of Venice.

Insula, SpA began taking preventative measures against floods by raising the pavements. Even though it changed how tides affected parts of Venice, raising pavements did not eradicate floods and still posed problems of its own. Insula also worked on mapping the city of Venice to determine the heights of pavements. They did this through their *Rilievo altimetrico, modellazione spaziale e scansione* (RAMSES) project. The pavement information can be used to determine whether or not an area floods by comparing elevations with current tide levels.

The idea of installing flood gates at the entrance to the Venetian Lagoon from the Adriatic Sea has been alive since the early 1980s. This idea became a reality in 2003 under the title "MOSE." MOSE aims to install flood gates at the three inlets from the Adriatic Sea to the Lagoon. When completed, the gates purpose will be to stop tides above 110cm from entering the Venetian Lagoon. Currently, completion of the gates is projected for the year 2017. The MOSE project is expected to stop floods from occurring in the majority of Venice, but will not solve the problem completely. Floods are a part of Venetian life that may never change. Instead of trying to stop nature there are those that stride toward making information about tides more accessible.

There are many applications that serve to inform pedestrians about *acqua alta* and floods. The majority of these applications uses either the current tide, tide forecast, or both from *il Centro Maree* and publish them. Some of these applications include elevation levels of popular areas along with the current tide. Others map out where they believe floods should be at that time based on comparisons between elevation levels and current tide levels. Displaying this information to pedestrians in a way that is easily accessible is important, but there is one major flaw with all of these applications. The only tide level they take into consideration is that at *Punta Salute*.

The goal of Piera Alta was to design a mobile web application that can route pedestrians around flooded areas. Users of our application can enter a start and end point, and the application will show them a path that will get them there without walking through flooded areas. What sets the Piera Alta application apart from others is that it combines information about current and future tides, tidal latencies, and mapping software. With this combination, our application allows pedestrians to get from point “A” to point “B” without getting their feet wet.

To achieve our design goal, we updated ISMAR’s Canal Hydrodynamics Model. The updated Model takes forecasts from *il Centro* Maree and runs them through a simulated Venetian canal system. The tide level in any canal at any given time is displayed in reference to Punta Salute. The 72-hour simulation, sent to us from ISMAR, is run through the Model. Updating the Model allowed us to see how the tides move through Venice, where the water enters, and where it leaves. By updating ISMAR’s Canal Hydrodynamics Model, we were able to visualize and understand the inner workings of Venetian tides. **Figure 3** provides a screenshot of one of the visuals created by the team. The full app can be accessed through the Venice Project Center website.

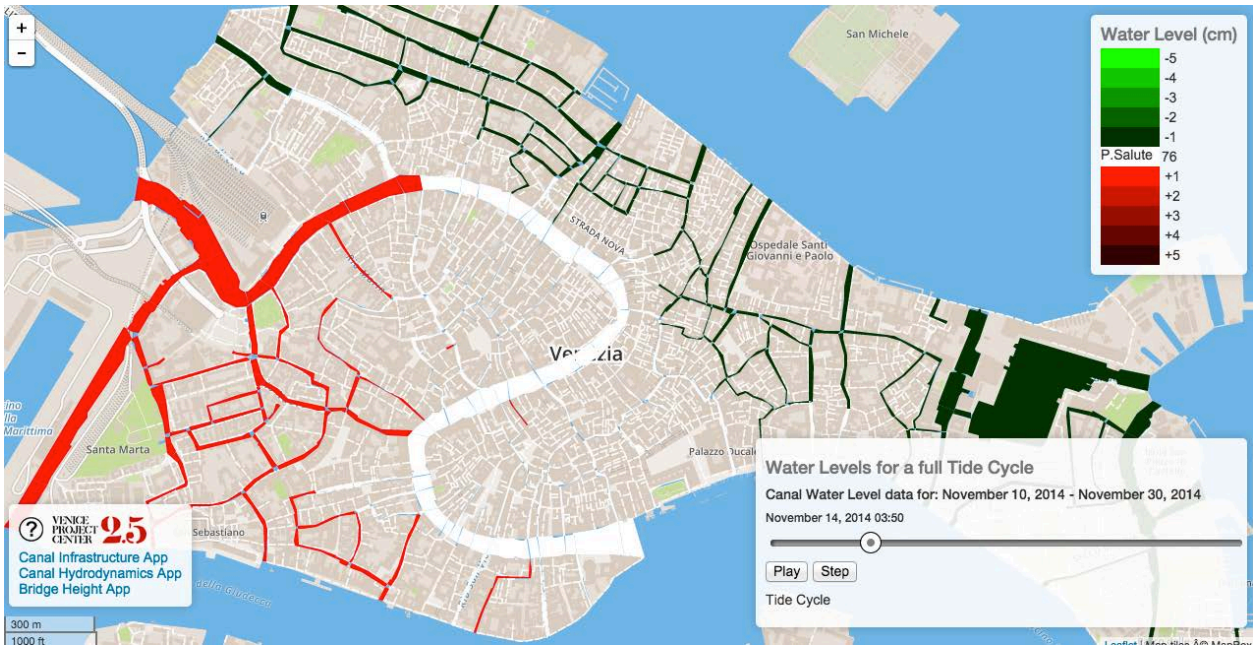

Figure 3. Water Level Delta App

To verify *il Centro Maree*’s forecasts and ISMAR’s model, Piera Alta used the Cleverpole along with a meter stick to measure the tide levels. Cleverpole is a tide sensor that was loaned out to us by Eraclit Venier, SpA. The sensor provided us with important information on tidal latency and time delays. The measuring stick served as a way to determine the elevation at which the sensor was installed by measuring between current tide levels (from *il Centro Maree*) and the pavement heights from Insula, SpA. With these devices, we were able to learn important behaviors of tides at five locations throughout Venice – two in *Castello*, one in *Cannaregio*, one in *Dorsoduro*, and one in *Santa Croce*. The tides were monitored during the full, new, and half-moons. **Figure 4** shows the output of the sensor for the *Santa Croce* region relative to *Punta Salute*’s tidal

behavior. These moon phases correspond to important parts of the tide cycle, and were our time windows for sensor installation.

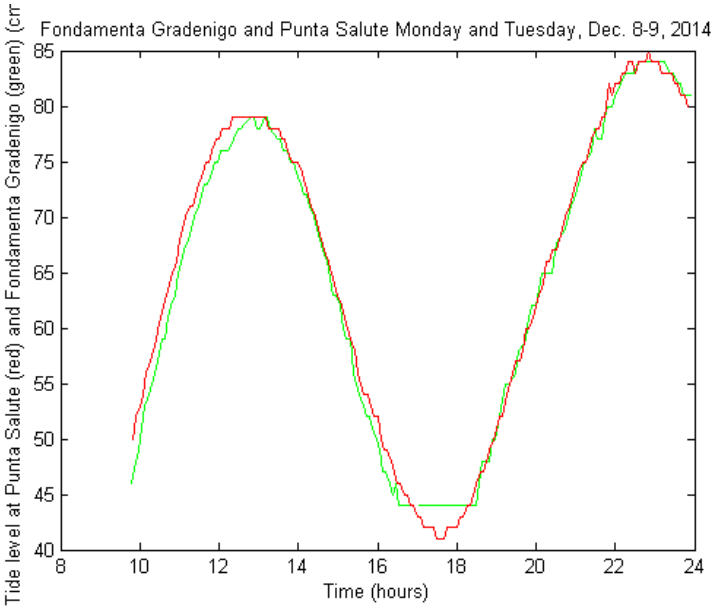

Figure 4. Sensor output (green) vs. Punta Salute *(red)*

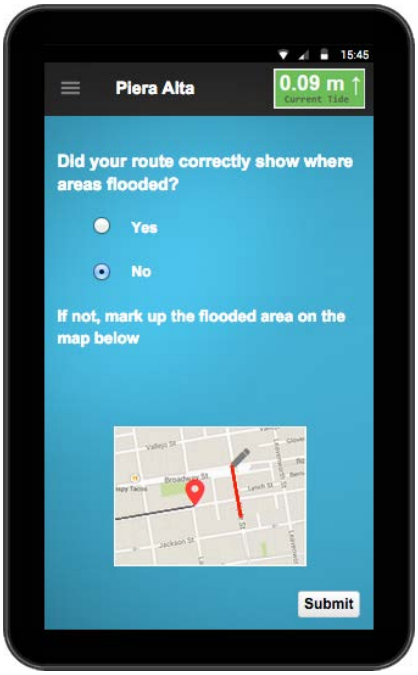

Figure 5. Flood report

With the information gained through tide monitoring, we were able to verify ISMAR's Canal Hydrodynamics Model and improve our app design. We discovered that the forecast outputs from *il Centro Maree* tend to not always be correct. Factors such as meteorological conditions and tide latency affect the actual tide level. The mobile app design accounts for these tide latencies. In addition to this, the app will feature a crowd-sourced feedback function that allows users to correct the flood status of streets. **Figure 5** shows the implementation of this feature.