Return to the City of Water

Quantifying Change in the Venetian Canals

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Abstract

This project addressed the rumors spreading through the city of Venice, Italy regarding an alteration in the canal system. Residents have reported a change of flow and a movement of the watershed that influences the Venetian canals. Development and projects such as MOSE have exacerbated these concerns. This project addressed these rumors by analyzing the change of the canal system through hydrodynamics and tide delay studies.

Acknowledgements

Team Rii would like to thank…

…The Istituzione Centro Previsioni e Segnalazioni Maree for taking the time out of their busy schedules to give us a tour of their facility, to provide us with daily tide forecasts through personal email and to provide us with the details that we needed to complete this project.

...UNESCO and Insula for providing us with data and information from their past studies that were crucial to our project

...And lastly to our advisors Professor Fabio Carrera and Professor James CoCola for without their guidance we would not have been able to complete this project in such a sucessful manner.

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Executive Summary

The canals of Venice are an integral part of daily life in the "City of Water." The canals serve a dual purpose as aquatic transportation routes and sewage disposal outlets. People that live so close to the water have a greater need for knowledge about how the water acts day to day. This project, through the analysis of hydrodynamics and tide delay, aimed to aid in the understandings of the workings of the Venetian canals and any how the y change over time.

Multiple institutions, such as UNESCO, Insulaa S.pA. and the *Instituzione Centro Previsionmi e Segnalazioni Maree (Centro Maree)*, have been founded in Venice to observe the canals and collect data about their behavior. The *Centro Maree* has been forecasting tidal levels in Venice for over 30 years, using a series of statistical and astronomical models. UNESCO and Insula have also been conducted more specific studies of the canals and the areas of hydrodynamics, sedimentation, boat traffic and infrastructure damage and how they all factor into one another since the 1990s. This information, which is gathered through studies, is useful for planning maintenance and preservation.

Worcester Polytechnic Institute students have been working through the Venice Project Center since the 1980s to study various aspects of Venice. In 1990 the first study on tides and hydrodynamics of the canals was completed, setting a standard that was expanded over a course of nine years (1990-1999). Many of these standards have been adopted by collaborative institutions like UNESCO and Insula, S.p.A .

The hydrodynamics database assembled by WPI and its Venetian collaborators was last revisited in 1999. Since then, there has been great speculation, both in colloquial and scientific circles, about change in the hydrodynamics of the canals. The objectives of this project were to revisit the hydrodynamics research from the 90's and analyze the results for potential changes, to measure tidal delay in the inner canals, and to set a standard for making canal research accessible for future studies through the wiki based website *Venipedia.*

Studying Changes in Hydrodynamics over Time

The hydrodynamic portion of this project consisted of measuring 52 canal segments that were previously measured in between 1990 and 1999. The methodology established by the hydrodynamics projects in the 90's was used for consistency.

Figure 0.1: Maps depicting past area of study (left) and 2010 area of study (right)

Velocities (speed and direction) of the flow of canal segments were measured and compared to the speeds recorded in 1999. This comparison was conducted for both in-coming and out-going tides.

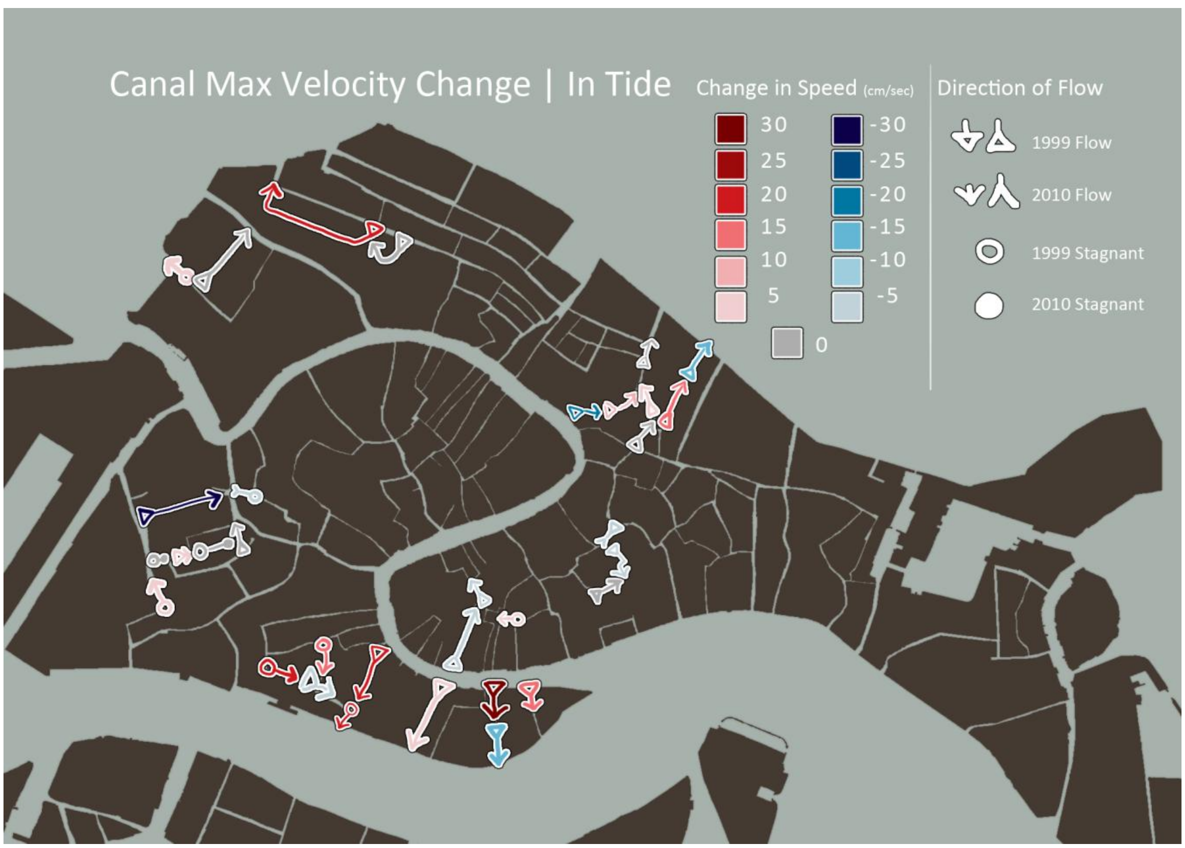

Figure 0.2: Map depicting canal velocity change between the 90's and 2010 at the incoming tide

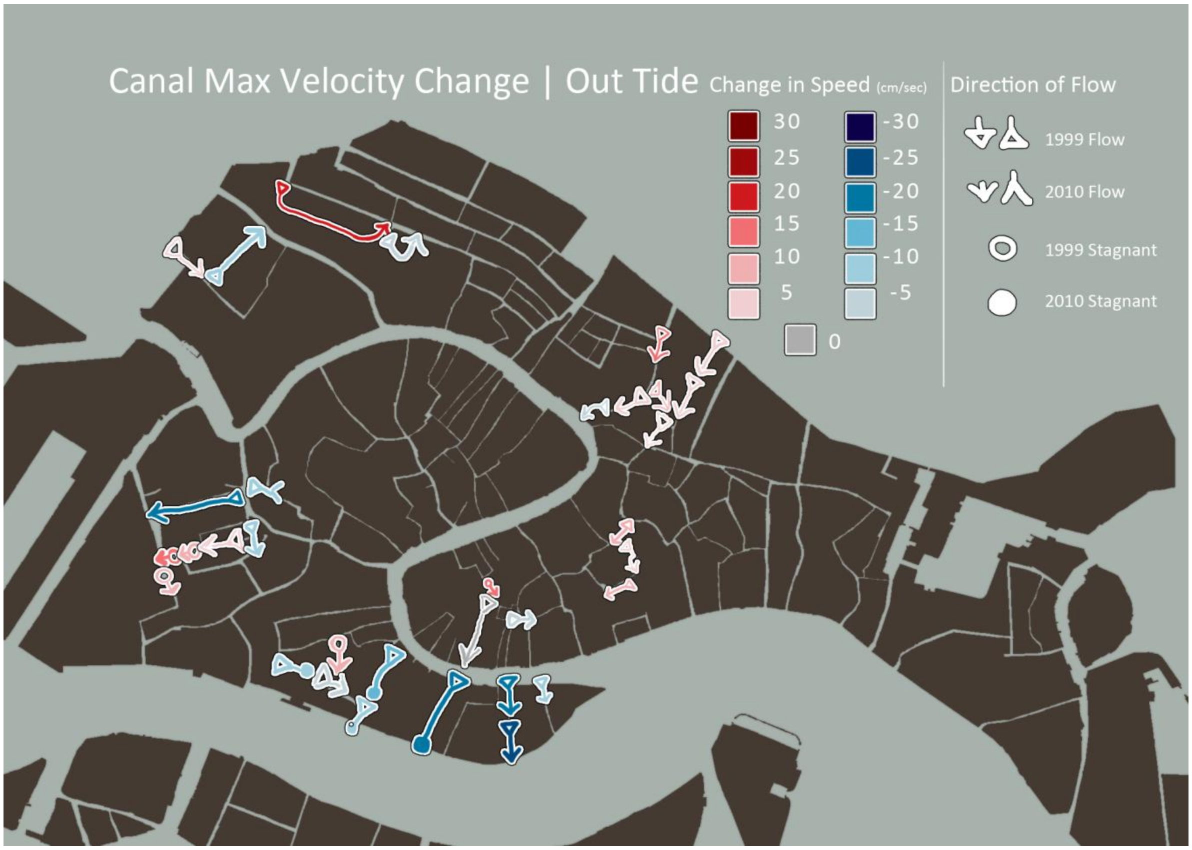

Figure 0.3: Map depicting canal velocity change between the 90's and 2010 at the incoming tide

The recorded changes in speeds, from 1999 to 2010, for in-tide and out-tide were normally distributed. The majority of the canal segments have not changed direction of flow between 1999 and 2010 (66.7%). However, the primary location for drastic change in speed was in Dorsoduro (in-tide became incredibly faster while out-tide slowed down drastically). The primary location for drastic changes in flow direction was in Santa Croce (in-tide changed from north following and stagnant to south flowing; and out-tide south flowing to north flowing); and Dorsoduro (in-tide changed from stagnant to south flowing, out-tide south flowing to stagnant). These changes provide evidence towards the idea that the watershed has changed in a way that more water is entering the south end of the *Canale Grande* during in-tide, but cannot leave through the north end due to another flow that surrounds the island. If this is the case the speeds and directions have changed due to the fact that at in-tide the water that is built up at the north end of the canal has nowhere to go except into the tributaries of Santa Croce and Dorsoduro. Then in the out-tide the water can leave the south end of the *Canale Grande* freely, resulting in less need for water to travel through the same Santa Croce and Dorsoduro tributaries

Identify Tide Delay

Tide delay measurements were spread out across Venice and a total of 59 canal segments were measured. 37 of these measurements occurred at high tide and 22 occurred at low tide. The data collected consisted of observing when the water level reached its most extreme points in the tide cycles (low tide and high tide). Then to determine when the time difference of the tide arrival at the measured canals, the recorded time of extreme was compared to the time of the extreme at the tide gauge stations surround Venice, Punta della Salute and Misericordia.

0.4 Area of study for Tide Delay

As water enters and exits Venice, there are patterns of water distribution that seem to directly correlate to the tide delay, these patterns are illustrated below. During the low tide, the water seems to exit mostly through the southern end of the *Canale Grande*. As the outer canals empty out, water gets dragged from the center of the island. During the high tide, water possibly originating from the Malamocco Inlet enters through the northern Grand Canal. Then, water enters from the southern end of the Grand Canal originating from the Lido Inlet. When the waters meet near the Santa Croce/San Polo border, the water builds up, creating a watershed.

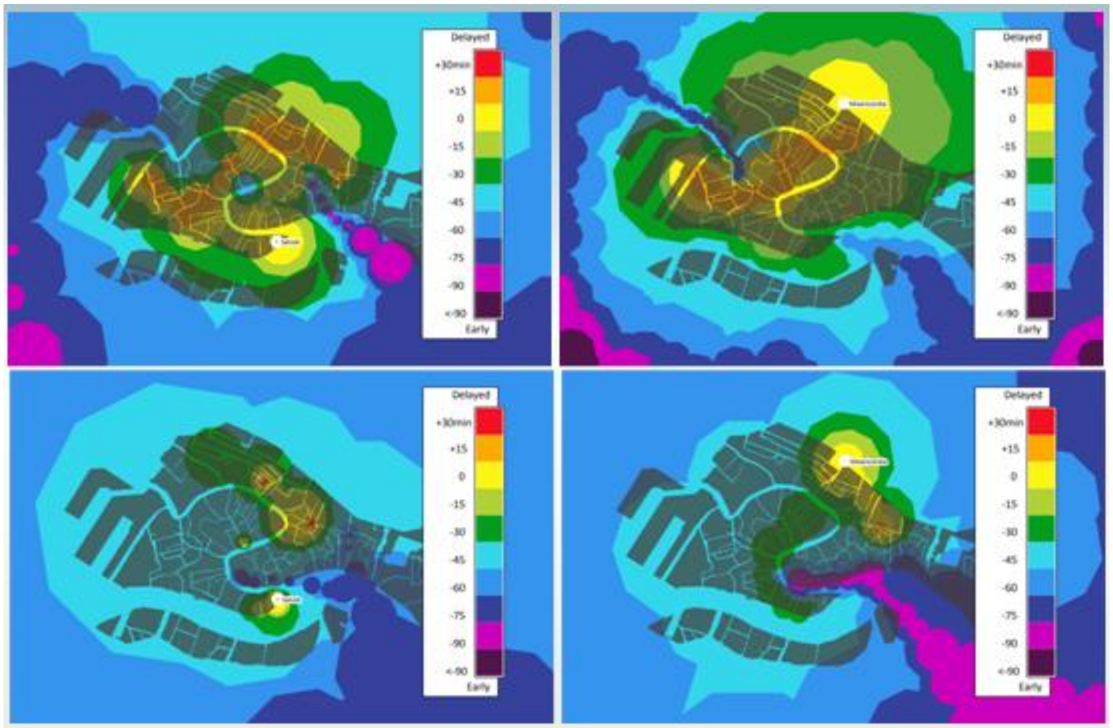

Figure 0.5: Four tide delay maps in respect to high tide (top) and low tide (bottom) and Salute (left) and Misericordia (right)

Setting a Standard for Sustainable Canal Data

The third objective was to share the data in an accessible way. This was done by creating a series of maps and articles that are hosted on Venipedia, an online wiki about Venice developed by WPI students. Each canal has an article that details its morphology, location, history, and previous study results. This method of data storage may be used as the VPC standard for cataloging canal data for future projects.

Recommendations

Although much was achieved in the time span of this project, there is opportunity to expand the study. For hydrodynamics, future IQP groups should plan to study the following canal segments: those in the Giudecca; those which connect to the lagoon directly in northern Cannaregio; and those which connect to the *Canale Grande* in southern Cannaregio, and northern San Polo. Seeing how these canals have changed can provide more support for the change in the watershed. In terms of tide delay, the watershed can be further studied in Western Venice. Finding where the source of the in-coming water into the *Canale Grande* is recommended to help make sense of any emerging patterns. As far as the sharing of all this information is concerned, future groups should follow a standard for making the data easily maintainable, so that the canals database can continue to evolve.

1. Introduction

Life on earth is made possible due to the abundance of water. For this reason, civilizations have been established around oceans, seas, lakes, and lagoons. An aquatic-side city requires knowledge about the behavior of its neighboring water system in order to for many facets of urban planning. When water behaves in expected or extreme manners, it can result in the loss of human life, homes, and resources. Recently the horrors of the 2004 tsunami in Indonesia left 11 countries devastated. With a death told of 150,000 it has been referred to as the deadliest tsunami in history.[1] Then in 2005, the tragedy of Hurricane Katrina struck the Gulf Coast of the United States where 1836 died, 275,000 homes were destroyed, and over $110 billion in damage have been estimated[2]. Lastly, in June of 2010, China's south-east Jiangxi providence was hit by a massive flood due to an unusually extreme storm-season, where over 800,000 were left homeless, and approximately 150 people lost their lives[3]. Even though it has been up to five years since these natural disasters occurred, the recovery process is still in the beginning stages[4]. Understanding water bodies and the elements that influence them is the best way to prevent disasters from occurring. This will ultimately save lives and the money of those involved. Gathering hydrodynamic information for accurate forecasting and for reactive and proactive urban maintenance is incredibly useful for the longevity of any civilization by the sea.

Venice is the City of Water, where the "roads" are a complex system of canals. Venetians use these canals to travel from one place to another when they do not travel by foot. They are also used to dispose of sewage and other domestic wastes. These canals are a way of Venetian life and no one could imagine living without them. However, living so close to the water poses a number of problems for the locals as unique as the lifestyle is itself. High water levels due to tides from the Adriatic and meteorological factors result in flooding of the city. This flooding can be minor, like *acque alte* where boots must be worn for a few hours, to severe, such as the Great Flood of 1966 that destroyed irreplaceable artwork around the city and left 5,000 homeless.[5] This flooding from the canals can result in damages to everything from personal and domestic goods to commercial goods to infrastructure. It also leaves people 'stranded' in parts of the island for hours when they cannot access other parts due to flooding, while others simply return home with soaking wet shoes and pants. It can also, in rare cases, pose a risk to human health. The solutions to these problems require an accurate tide forecasting system to be in effect with a thorough understanding of the workings of the hydrodynamics of the canals.[6].

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[1] *National Geographic* – The Deadliest Tsunami in History?
[2] HurricaneKatrinaRelief.com
[3] *The Guardian United Kingdom News* – China Devastated by Floods
[4] *Fox News* – Katrina Five Years Later: Slow Recovery in 9th Ward
[5] *The Telegraph* – Venice's Great Flood in 1966 Destroyed Art and Homes
[6] Theory and Application of Wave Propagation and Scattering in Random Media

The *Instituzione Centro Previsioni e Segnalazioni Maree* has been forecasting the tide levels for the city of Venice for over 30 years. Their goal is 'to guarantee maximum information on tides and an efficient and immediate alerting service in case of exceptionally high tides'.[7] This is achieved through statistical modeling of all meteorological and astronomical data from both the Adriatic Sea and the Venetian Lagoon. The tide center focuses almost all of its efforts and energy on the waters surrounding the island, not the waters of the inner canals. This inner canal data could be useful for even more accurate predictions of tide levels and corresponding times in specific parts of this city.

In the 1990s WPI began studying the inner canals of Venice. Over the course of 10 years students have analyzed over 130 of the 180 canals. In 1999 a WPI project group conducted a final study on some of the Northern canals of the island, and compiled all the data collected over that decade into one database[8]. This database dates back to before the turn of the century, and since then no new hydrodynamics data has been collected. Since then, there has been speculation in Venice that the canals have begun to flow differently. This inquisition as to the change of the canals provides a validation for revisiting hydrodynamic measurements.

The aim of this project was to quantify changes in the flow of the canals. This was done in part by first measuring the hydrodynamics of canal segments that have been previously studied. This projects data was then analyzed against the existing database in order to visualize any patterns of change. Secondly, this project explored the timing of the tides. This was accomplished through measurements of the tide delay across a wide range of canal segments. The behavior of the tidal delay was then correlated with the hydrodynamic information. Thirdly, this project's data was complied with the existing database and stored in an online catalog, so that the database can be updated over time.

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[7] Citta' di Venezia - Instituzione Centro Previsioni e Segnalazioni Maree

[8] *Hydrodynamics of the Inner Canals of Venice*. (E'99)

2. Background

Venice is a cityscape woven together by waterways. Over 170 canals create the framework for the city's landmasses and transportation routes. This array of waterworks act as the arteries of Venice. They serve to connect, transport, cleanse and supply the city with the essentials of urban life.

2.1 Venetian Lagoon

The Venetian Lagoon is estimated to be about 6,000 years old. This lagoon, the largest of the Adriatic Sea, was created by the silting of three rivers: the Piasve and Sile to the north of the Lagoon and the Brenta to the south. The three rivers carried eroded soil into the Adriatic Sea where it slowly accumulated and created two types of islands. One, *barene*, are low-lying islands capable of supporting some types of grassy vegetation. The other type, *velme*, are sandbars which are only exposed to the air by low tides. *Velme* are incapable of having any sort of vegetation. These islands eventually became *lidi*, or long thin islands that lie just above sea level. The islands kept growing which resulted in closing off the waters surrounding the river mouths from the Adriatic.[9]

Figure 2.1 Venetian Lagoon and its inlets to the Adriatic Sea

The Lagoon is connected to the Adriatic by three inlets. The Northern Lagoon is fed by the Lido Inlet, which is the widest with a width of 900 meters. The Central Lagoon is fed by the Malamocco Inlet, which is the deepest with a depth of 20 meters. The Southern Lagoon is fed by the Chioggia inlet which is the smallest with a maximum depth of 8 meters and a width of 400 meters. The flows in these inlets are tidally driven, which means water passes through them due to the tide coming into the lagoon from the Adriatic.[10]

2.2 The Inner Canals of Venice

There are 182 canals in Venice which separate the city into six regions known as *sestieri*. The six *sestieri*, along with the area of *Dorsoduro,* known as the *Giudecca,* can be seen in fig 2-2. Natural canals can be found at the boundaries of the *sestieri*. The canals separate the city into 120 islands that make up Venice proper.

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[9] Long-term variations on sea level and tidal regime in the lagoon of Venice
[10] Temporal variations of water flow between the Venetian Lagoon and the open sea

Figure 2.2: Map of Sestieri

In the days before modern septic systems, Venice's canals acted as an urban sewage marvel. The waterways carry salt water from the surrounding Venetian Lagoon, which is fed by the Adriatic Sea. The movement of the tides flushes away the waste that is deposited into the canals. This sewage system has endured over the years and is still the main method of sewage removal from Venetian homes. However, over time, there is a build-up of sediment from sewage and sea debris at the bottom of the canals[11].

2.2.2 Dredging the Canals

Sedimentation is the accumulation of solids at the bottom of the canals. These solids are composed of sewage waste, masonry debris, and sea deposits[12]. When sediment builds up on the canal floors, the flow through them is directly affected.

Over time sediment builds up in the canals. As a result, the canals need to be dredged periodically in order to maintain safe water conditions and insure the ability of boats to navigate the waterways. There are two main types of dredging: deep-water dredging and dry-bottom dredging. Depending on the situation either one or both of these types of dredging can be used to dredge a particular canal.[13]

Figure 2.3: A boat being used for deep-water dredging

[11] *Quantification of sediment sources in the city of Venice, Italy* (E'99)
[12] Ibid
[13] Insula Website: "Canal Excavation"

2.2.3 The Canals and Transport

The canals are used as waterways for daily boat traffic. Even though gondolas and other row boats are still in use, most of the traffic is from motorized boats. The use of motor vehicles in the canals adds a layer of anthropogenic phenomena to the state of the canals.

2.3 Tides and the Venetian Canals

The island of Venice is completely surrounded by a body of water known as the Venetian Lagoon. This lagoon is fed by the Adriatic Sea. The tides of the Adriatic Sea directly control the water level and tides of the Lagoon as well as the canals. There are two factors that influence these tides, these are astronomical and metrological.

2.3.1 The Tides and Astronomical Factors

The word tide is a generic term used to describe the visible influence of the moon and the sun on the world's waters. Along the surface of the earth there is an inward gravitational force and this pulls the water in the direction of the planet. The moon and the sun have an inverse influence on the waters. Their gravitational pull is 'superimposed' to that of the earth's resulting in the drawing out of the water directly beneath the body.[14]

The lunar cycle is approximately 29 days with four phases. There is the full and new moon, known as *sizigia* in Italy. And there is the waning and half waxing, *qadrantura*. Sizigia is when the moon is directly above or directly opposite the fixed point of reference on earth. Quadrantura is directly in the middle of the two sizigia occurrences. Sizigia result in the most extreme tides due to the waters of the oceans 'heaping' (two horizontal flows of water coming together at one destination). Likewise quadrantura results in the least extreme tides due to the compensating maximum withdrawal of water from the regions around the earth that are between the areas of water being pulled.[15]

[14] Our Restless Tides ('98)
[15] Our Restless Tide ('98)

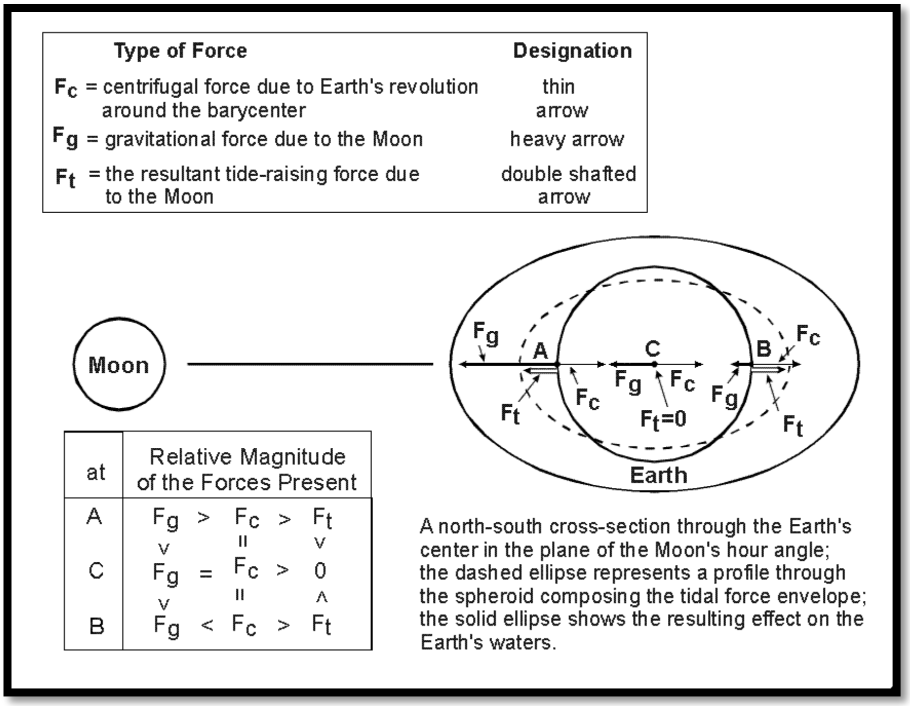

Figure 2.4: The effect of lunar forces on the surface waters of earth

The sun also plays a role in the tidal fluctuations of earth, but to a much lesser degree than the moon. This is because the moon is much closer to the earth than the sun, thus the sun has a much smaller gravitational effect. The most extreme influence of the sun is at noon and midnight, just like the moon. The least extreme influence of the sun is at 6 and 18 hours, for the same compensating reason as with the moon.[16]

2.3.2 Meteorological Factors Affecting Tides

Major winds can also influence the tide. There are two winds in particular that manipulate the Venetian Lagoon the most. The first is known as the Bora which comes from the Swiss Alps to the Appenines of Italy to the Balkans. It is a cold, winter wind that blows northeast to southwest at speeds up to 100 knots. The second major wind is the Sirocco which is opposite of the Bora. It is formed in Libya and Egypt. It is hot and can occur year round. It blows southeast to northeast over the Mediterranean Sea carrying excess moisture resulting in rain and fog.[17]

[16] Ibid
[17] MEDEX Winds ('99)

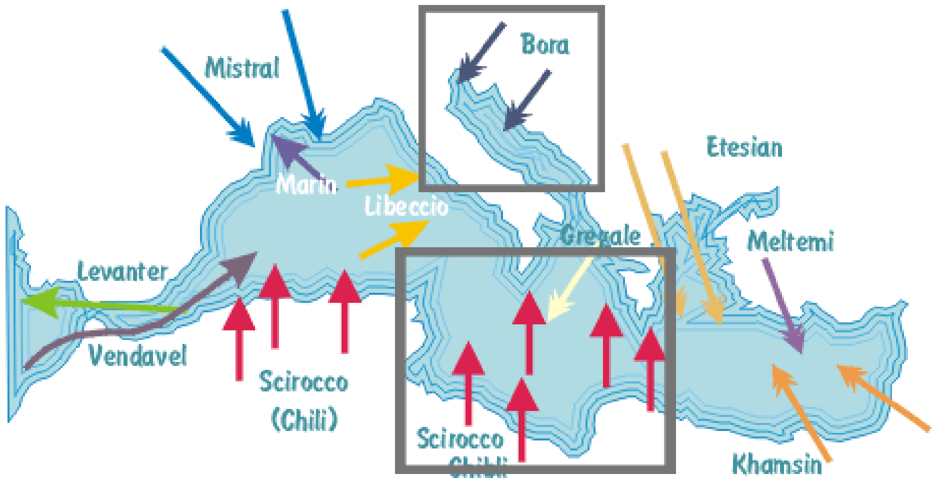

Figure 2.5: The winds that affect the Venetian Lagoon and tides

When a wind of great force and magnitude blows in the same direction as the tide, the tide will accelerate as it flows in that direction. This results in a higher and more pronounced tide When the winds blow in the opposite direction than that of the flow, the tide is much lower and less extreme.[18]

The barometric pressure also has a small role in the workings and alterations of the tides. When there is a high barometric pressure the height of the tide decreases. When there is a low barometric pressure the height of the tide increases.[19]

2.3.3 Tide Forecasting for the Venetian Canals

Tide forecasting is crucial to the daily lives of Venetians. It is important to have an idea of how high the tides will be in the coming months, and more importantly in the coming days so Venetians (and tourists) can prepare for high waters. The island of Venice has had a warning siren for unusually high tides since the 1970s; at the time there was only one siren which was located on the bell tower of San Marco. In 1979 Venice experienced highly damaging floods and from this the city decided that a better forecasting and warning program had to be implemented. From this the *Instituzione Centro Previsioni e Segnalazioni Maree* was created with the following goal: "to guarantee maximum information on tide and an efficient and immediate alerting service in case of exceptionally high tide".[20]

[18] MEDEX Winds ('99)
[19] Ibid

[20] Citta' di Venezia - Instituzione Centro Previsioni e Segnalazioni Maree

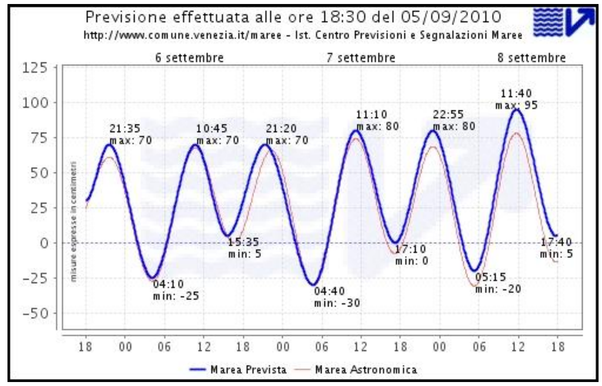

Figure 2.6: A chart showing the difference between high tide and low tide

The *Instituzione* carries ou two forms of tide forecasting: long-term and short-term. Long-term tide forecasting focuses on the study of lunar and solar cycles, as well as permanent morphological factors.[21]

Short-term tide forecasting is much more accurate than long-term tide forecasting. Current weather and conditions of the Mediterranean and Adriatic Seas factor in with the lunar and solar cycles to make tide forecasting into an almost exact science.[5] The *Instituzione* has a number of data collecting platforms (several in the Venetian Lagoon, and one 7 miles into the Adriatic) that collect wind velocity, wave height and barometric pressure which then are factored together with the lunar cycle and 20 models(about half statistical and half deterministic) are drawn up by computer programs to predict the tides for up to 6 days ahead of time. Scientists at the *Instituzione* then overlay the models and statistically average out the errors to develop a forecast and inform the public of the predicted tides to come. The models that prove to be the most accurate are analyzed in an attempt to imporve future modeling forecasts.[22]

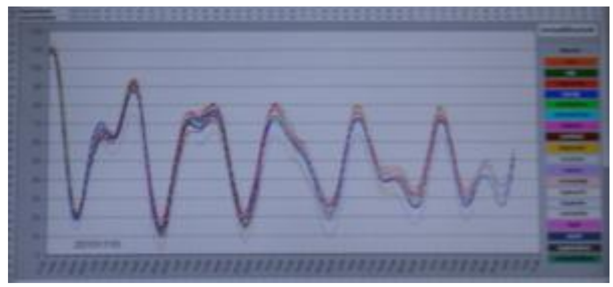

Figure 2.7: The statistical model of all meteorological and astronomical data in Centro Maree

The *Instituzione* will warn the city if the tide is predicted to rise about 110 centimeters (this is known as *Acque Alte* or high waters), the warning will occur 3 hours before the predicted high tide is forecasted to arrive. The warning is a series of sirens, the old air raid sirens along the coast and islands in the lagoon, and more

[21] Ibid
[22] Ibid

specialized newer sirens within the central portions of the main island. These newer sirens within the

Figure 2.8: The warning station at Centro Maree

city replaced the older air raid sirens; the new alert sirens have the ability to ring at various different tones: one for each level of Acque Alte (110cm, 120cm, 130cm, 140cm, or higher). The new sirens also have speakers, so that forecasters at the center can relay voice messages directly to the city if necessary.[23]

2.3.4 Tide Measurement

Tides are measured by 52 meteorological and tide gauge stations scattered within the Lagoon. They are located in waterholes, in harbor inlets, and along the coastline from the Po River dealta to Trieste. Stations may have a floating tool that gauges and records the tide level electronically every ten minutes. Some have the ability to read the atmospheric pressure, rain, wind direction and wind speed.[24]

The tide level measurements refer to the Zero Tide Level at Punta della Salute. This level is identified by a boundary stone placed on the bank along the Canal della Giudecca, which has been used to record tide heights in Venice since 1872. This point of reference is close to the tidal gauge station, and this level matched the Mean Seal Level in 1897.[15]

[23] Citta' di Venezia - Instituzione Centro Previsioni e Segnalazioni Maree
[24] Long-term variations on sea level and tidal regime in the lagoon of Venice

2.3.5 Tide Delay

Over the past 100 years, the tide delay in the Venetian Lagoon has become less significant. The following graphic compares the tide delay from 1900-1950 to today's tide delay.

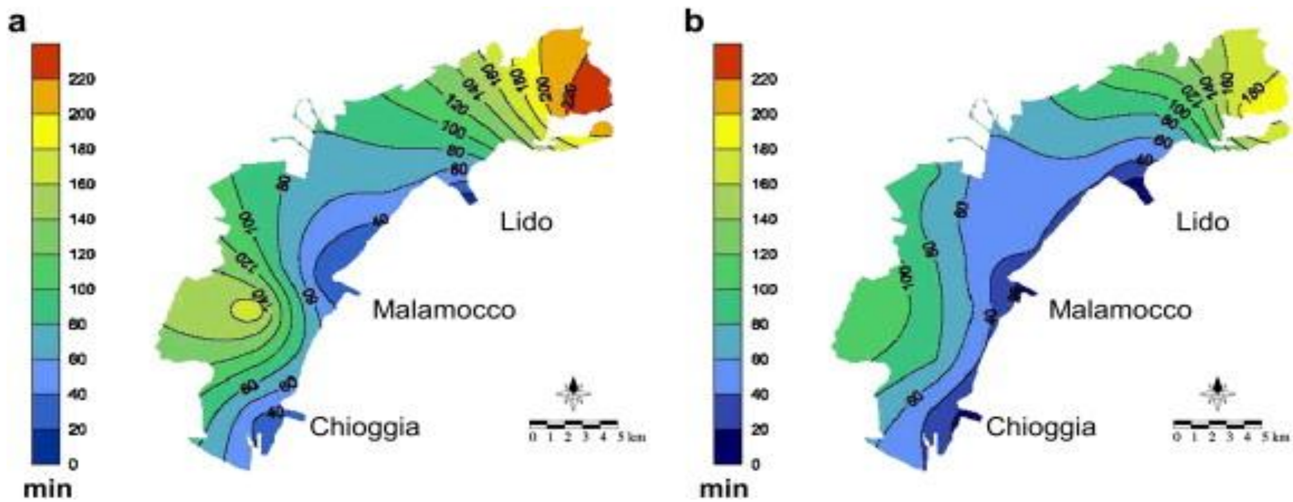

Figure2.9: An illustration of the change of tide delay times from the early 1900's to today

The current tide propagation delay is not as significant as the one from the first half of the 1900's. The 220 minute and 200 minute isopleths have disappeared completely. Also, there is no longer a delay in the outlets, unlike in the early 1900s. The tidal wave damping power in the lagoon is stronger than the harbor inlets. Due to the change in the tide delay times, it's concluded that this damping capacity has dropped significantly.

2.3.6 Tidal Wave Propagation

Tidal wave propagation is the phenomenon of the tidal waves being spread throughout the lagoon from the inlets to the Adriatic Sea. In Venice, this process is slowed down by the shape of the canals and low depths. Also, different atmospheric conditions can change the tide such as air pressure, wind, and the free oscillations of the Adriatic Sea. Under poor weather conditions, the Lagoon will behave as if it were a single basin by exchanging volumes of water between the three basins.[25]

2.4 Hydrodynamics of the Venetian Canals

The ebb and flow of the Venetian canals are influenced by several variables including: the tides, the long term change in water levels, the physical form of the canal system, and the friction. The canals were formed

[25] Theory and Application of Wave Propagation and Scattering tin Random Media

naturally before the city did then were later urbanized. Natural and anthropogenic factors can be quantified to understand their impact on the state of the canals. Knowing the velocity, volume, depth, and quality of the water in the canals is crucial in order to understand how to maintain them.

2.4.1 The Canals and Subsidence

Subsidence is the gradual sinking of landforms to a lower level as a result of earth movements, or in this case human interference. The change of the land masses around a body of water can alter the hydrodynamic flow. The natural rate of subsidence in Venice is 1.27 centimeters per year. In the 1920's, this rate accelerated to 5.08 centimeters per year. The main cause for this drastic change was Venice entering its industrial period, and more specifically when water began being pumped from the subsoil. Soon after, laws were passed forbidding water removal from below Venice's surface, which brought Venice closer to its original rate of subsidence.[26]

2.4.2 The Canals and Climate Change

Eustatism, or the worldwide changes in sea level, is mostly caused by climate change, plate tectonics, and human interference. Climate change is leading to the melting of glaciers, which adds a lot of water to the oceans.[27] The movement of ocean floors constantly adds to the already thick oceanic plates, which causes the sea level to rise even more.[28] Venice's sinking naturally caused the sea level to rise in relation to the shore. The global sea level is expected to increase another 15 centimeters by 2050, and 34 centimeters by 2100.[29]

2.4.3 Mean Sea Level Trends

This figure covers over 130 years of data collection. In 1872, the global MSL was 150 centimeters below Punta Della Salute, so that was used as the starting reference point. A chart of this type was also made for other Adriatic towns where tide gauge systems are located, and they saw very similar oscillations.

The blue line in the graph refers to the mean of the 11 year period that precedes that point. The graph shows a sharp increase in this moving average between 1930 and 1960. This change was due to high subsidence processes such as taking water from the subsoil.

[26] Lane, Fredrick. Venice: A Maritime Republic
[27] Church, J.A., Gregory, J.M., Huybrechts, P., Kuhn, M., Lambeck, K., Nhuan, M.T., Qin, D., Woodworth, P.L. Changes in Sea Level
[28] K C Macdonald. Mid-Ocean Ridges: Fine Scale Tectonic, Volcanic and Hydrothermal Processes Within the Plate Boundary Zone
[29] U.S. Environmental Protection Agency

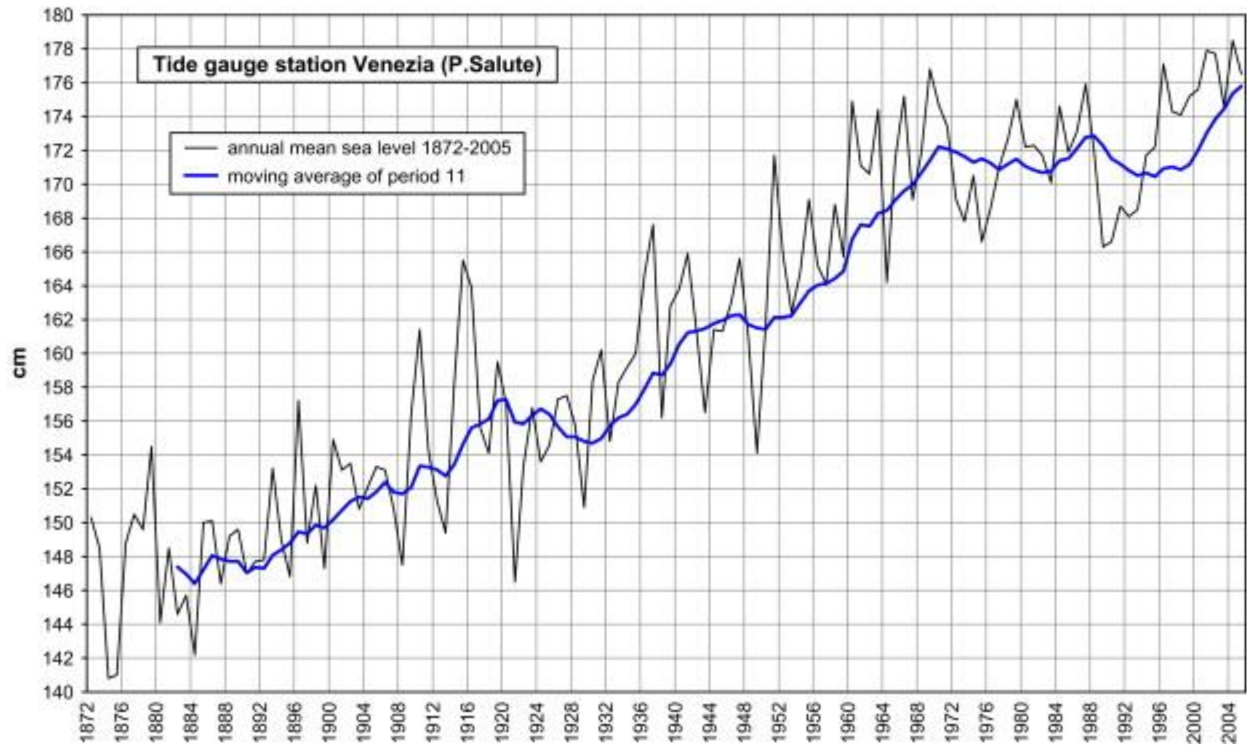

Figure 2.10: Chart of the Mean Sea Level annual mean values in Venice

2.4.4 Friction's Effect on the Flow

It is important to understand how the canals themselves influence the flow of adjacent canals. Friction between the canal wall and the water results in the water along the wall to move slightly slower than the water in the direct center of the canal[30].

2.4.5 Canal Intersections and Segments

Each intersection of two canals results in the alteration of the flow in both canals. When obtaining data, the canals must be broken into segments that take into account these intersections. This portrays an accurate representation of the hydrodynamics. A segment ends, and a new one begins at every intersection of canals.

2.4.6 The Hydrodynamic Influence of Rii Tera

Rii tera are canals that have been filled in with rock, gravel and dirt. Rii tera tombati are canals that have been completely filled in, and rii tera con volti are canals that have been covered over. The rii tera tombati have no flowing water within them, so they have no affect on the adjacent canal's flows. When a rii tera tombati intersects another canal that is flowing with water, the two segments are treated as one. The rii tera con volti is treated like any other canal, as it still has a flow of water through it.[31]

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[30] *Hydrodynamics of the Inner Canals of Venice*. (E'99)

[31] Ibid

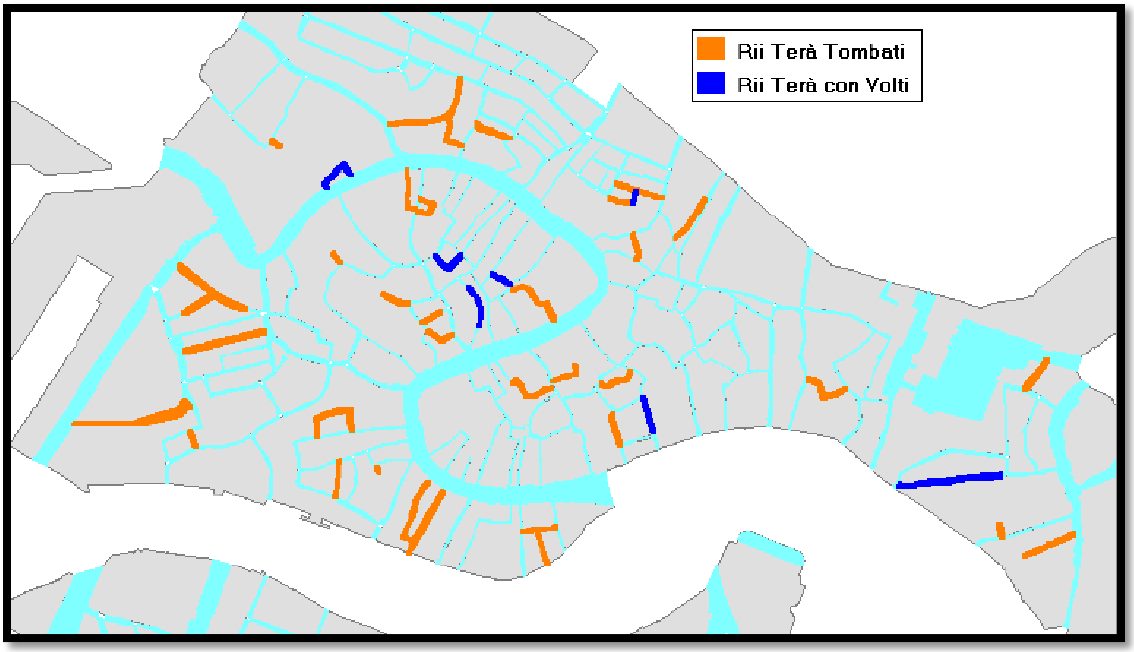


Figure 2.11: Rii tera tomabti (orange) and rii tera con volti (blue) locations

2.5 The Lagoon Watersheds

There have been many rumors circulating amongst the Venetians for some time regarding changes in the flows of the canals, primarily in the northern sestiere of Cannaregio. These rumors come down to one main idea about a change in the watershed of the Venetian lagoon. Supporters of the idea, such as Umberto Sartori, believe that the original flow of the water entering the lagoon has changed in the course of 50 years due to various governmental interventions towards the 'sinking' of Venice, the most recent example being the MOSE project. They say that the flows that once used to buffer the island and its canals from those damaging flows from the South (See in Figure <<__>> 1968 green arrows) have not been redirected. They no longer buffer the island from those damaging flows, but instead flow directly through the island themselves. This they claim results in faster currents and more aggressive tides that are rapidly damaging infrastructure that comes into contact with the canals.[32]

[32] Umberto Sartori - Report on flood-tide in the Lagoon of Venice, 2009

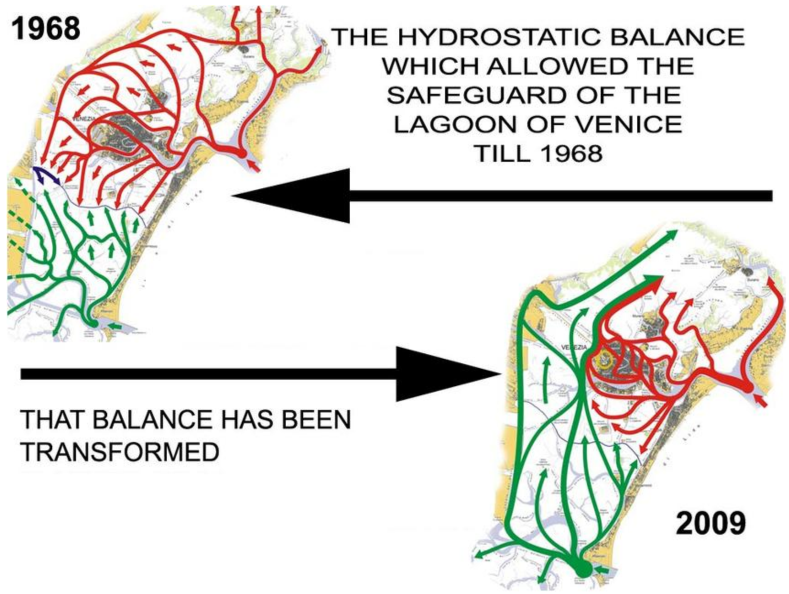


Figure 2.12: Artist depiction of watershed change rumors

2.6 Past WPI Hydrodynamic Studies

In the year 1990 the first WPI project was completed focusing on the study of the hydrodynamics of the inner Venetian canals. The last one, until this study, was completed in the summer of 1999.

The first project team from WPI to study the flow characteristics of the canals completed their project, A *Hygienic, Dynamic, and Static Study of the Canals of Venice,* in January and February of 1990. Their project focused on four canals in the Venetian sestiere of Dorsoduro (the southernmost region of the island. They were the first WPI group to devise a method for collecting measurements. This projects group's results were later ruled inaccurate, as they used a cork as the flotation portion of their device. This resulted in the device flowing with the surface water instead of the central flow of the canal and made their results highly susceptible to the effects of wind and boat traffic.[33]

The Study of Tide Flows, Mud Buildup, Boat Traffic, and Structural Damage on the Cannaregio Canal Subsystem was the second project team from WPI to address the topic of hydrodynamics in the canals. This project was completed in the March and April of 1991 and focused on the sestiere of Cannaregio (the northernmost region of the island). They covered a much larger area of canals than the 1990 group did, and created the first reliable flow measuring device. They were the first project team to map hydrodynamics results using MapInfo, and they helped rework the canal segment naming system devised in the 1980s.[34]

[33] *Hydrodynamics of the Inner Venetian Canals* (E'99)
[34] Ibid

This WPI project, *A Static and Dynamics Study of the Canals of Venice, Italy*, completed in the months of January and February of 1992 focused their area of study in the sestiere of Santa Croce (east-central region) and San Polo (centermost region). They used the same methods developed by the 1991 group, and also mapped their info onto MapInfo.[35]

The project team, *A Topological and Hydro-Dynamics Study of the Canals in the San Marco,* of WPI studied the velocity flows of the canal segments in the sestiere of San Marco (west-central region). They completed this study in March and April of 1992 and were the first group to take into account the effect of meteorological factors on the tides and how that would impact their results.[36]

A Topological/Hydro-Dynamics Study and Geographical Information System of the Canals in the Castello Area was completed in May and June of 1992 and focused on the sestiere of Castello (east most region). They used the same methods as in the previous projects.[37]

The WPI, *Hydrodynamics of the Inner Venetian Canals*, project was completed in the months of May and June in 1999. This project compiled all past hydrodynamics data collected by WPI, UNESCO and Insula into one database. They also collected their own hydrodynamics data in the sestiere of Cannaregio (northernmost region) to add to this database. This was the final WPI project of its kind for over a decade.[38]

[35] Ibid
[36] Ibid
[37] Ibid
[38] Ibid

3. Methodology

The aim of this project is to assist the city of Venice in understanding how the workings of the canals have changed over time, and how they influence the tides entering and leaving the city. The following objectives were identified:

1) To quantify changes over time in the hydrodynamics of the canals

2) To analyze the timing of the tides

3) To set a standard for presenting canal data accessibility

This study focused on measuring hydrodynamics and tide delays. Approximately five to fifteen canals from each section of Venice were picked to be studied. This study was conducted between October 24, 2010 and December 17, 2010. Since the maximum flow velocities in the canals occur during the new and full moons, hydrodynamic testing occurred during those times (Appendix C). Tide delays also were studied during the new and full moon (Appendix I). This allowed for the most noticeable change of rising and falling tides so that accurate times for tide peak could be recorded.

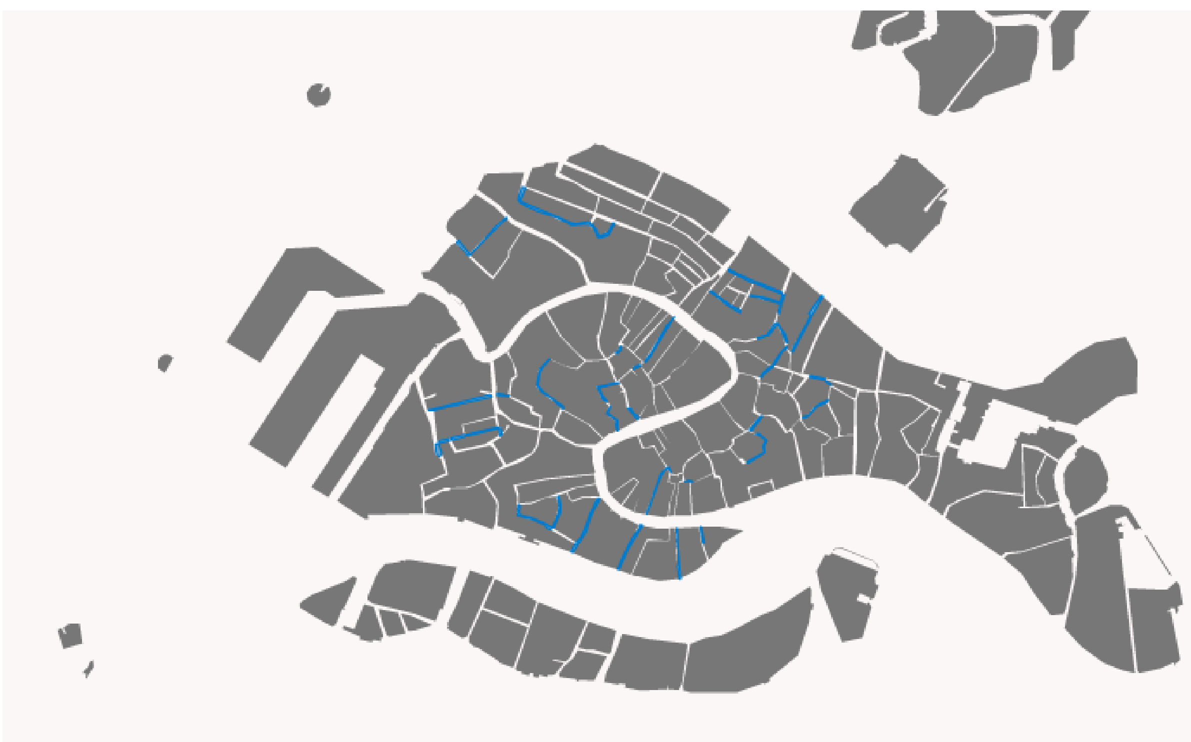


Figure 3.1: Area of hydrodynamics study

Figure 3.2: Area of tide delay study

3.1 Area of Study Selection

In order to compare the present hydrodynamics of the Venetian canals to the past hydrodynamics of the canals, measurements taken by previous WPI students were repeated as best as possible. A representative set of canals spread out over the entire city were chosen that had been previously measured for hydrodynamics. Visual surveys of potential canals were performed to insure that the canal segments had adequate access points, such as sidewalks for wide bridges, for measurements to be performed.

Figure 3.3: An ideally accessible canal for hydrodynamics testing

A preliminary assessment of the state of the canals was also recorded during the surveying process. By using these criteria to select canals, measurements taken were compared to past studies (Appendix F) and any potential trends over time were analyzed.

3.2 Hydrodynamics: Measuring Flow Velocities

In 1999, a group of WPI students studied the hydrodynamics of the inner canals by measuring the maximum flow velocity of various canals and compiled previous hydrodynamic data (Appendix E). The procedures used to obtain their data were followed as closely as possible to produce data that could be most effectively compared to past measurements.

3.2.1 Scheduling of Measurements

In order to determine the maximum possible velocity of the canals, measurements were taken while the tidal flows were at their maximum. This occurs in between high and low tide during the full and new moon phases (Appendix C). The 1999 group determined that taking measurements approximately one hour before the predicted maximum velocity would insure that the fastest flow would not be missed. Depending on the amount of time required to test all of the canals and the window of opportunity allowed by the lunar calendar, the period for taking measurements could be extended from twenty-four hours to forty-eight hours as necessary.

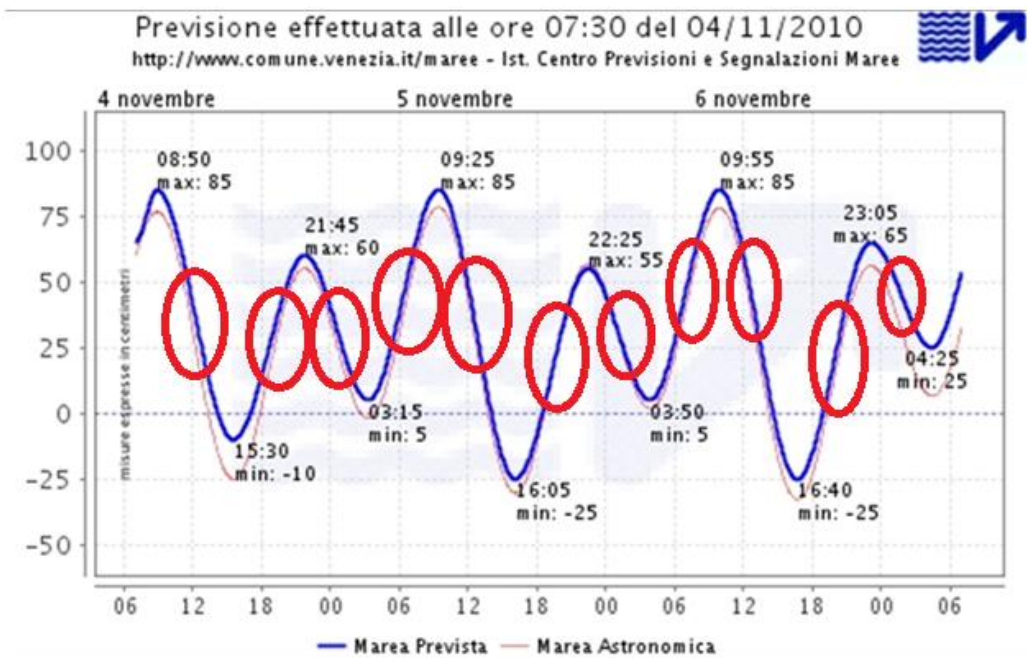


Figure 3.4: Tide chart depicting the forecast for the day before, day of and day after the new moon and ideal hydrodynamics testing times

3.2.2 Measurement Tool

The device that was used is a replication of a device used by the 1999 project team. It consisted of a plastic soda bottle, two aluminum blades, and a lead weight. The bottle was used to provide buoyancy and was painted fluorescent to make it easily visible at night. It was small enough to be minimally affected by the wind along the surface of the canal. The bottle was attached by fishing line to two interlocking perpendicular aluminum blades. A small weight was attached to the blades to keep the device perpendicular to the surface of the water.

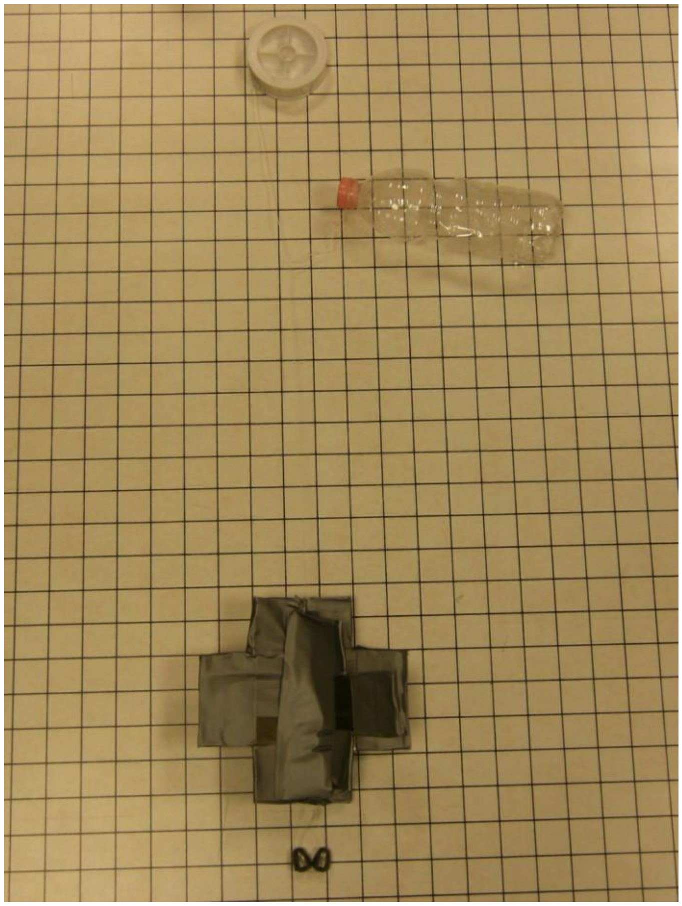


Figure 3.5: Hydrodynamic Device

The previous project team assumed that the average canal depth was 1.5 meters. In order to have the device move in the canal at one third of the assumed canal depth, twine was used to attach the bottle to the blade so that there was a distance of 0.5 meters between the two objects. This allowed the blades to sink to one-third of the canal depth (Appendix B).

3.2.3 General Procedure

The flow velocity was measured by determining the amount of time required for a flotation device (see section 4.2.2) to move between two predetermined points. The direction of tidal flow was determined by throwing the device into the section of canal to be measured. After the direction of the flow was established, a start point was selected. This could be a landmark along the canal, such as a pole. Then the end point was chosen approximately 10 meters from the start point. Whenever possible, start and end points used from previous hydrodynamic testing were selected (Appendix G).

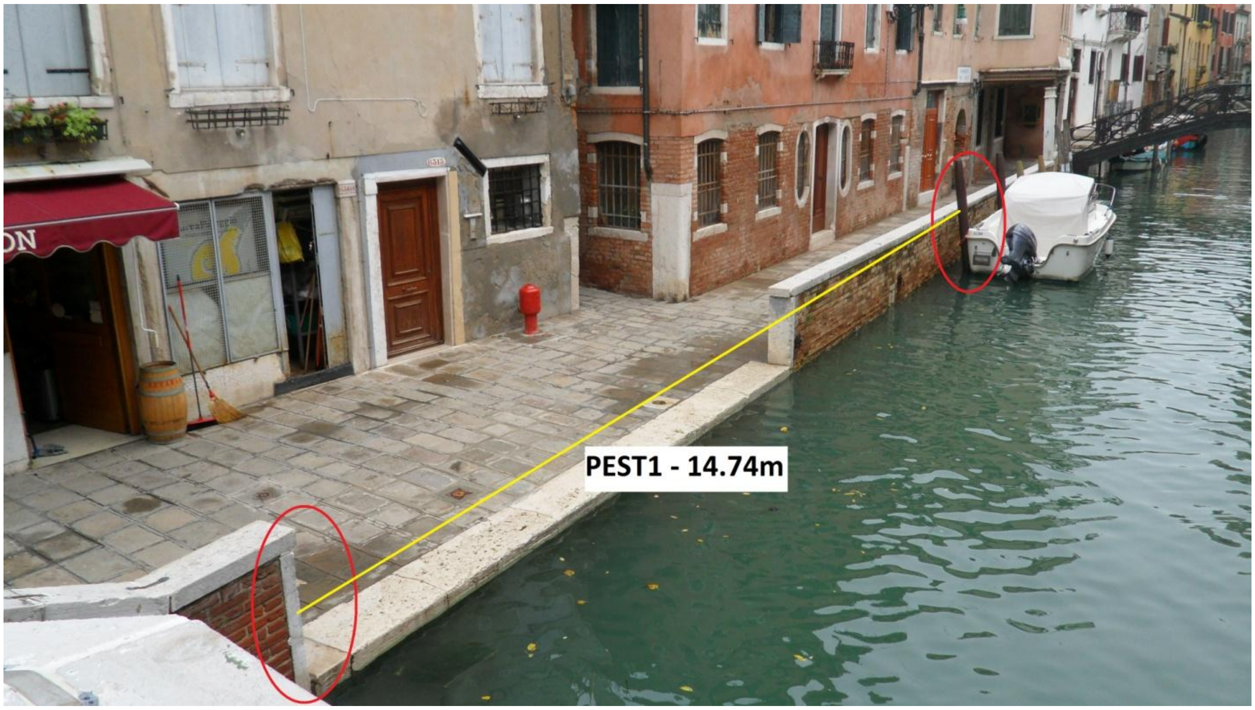


Figure 3.6: Example of start and end points for hydrodynamics testing

After establishing the direction of flow and selecting the start and end points, the flotation device was thrown into the canal before the starting point to allow the device to reach the velocity of the water.

Figure 3.7 Hydrodynamics testing – Device moving with the current of the canal

In order to record the time it took for the flotation device to travel the predetermined distance, a stopwatch was started when the device passes the start point and was stopped after the device passes the end point. The test was performed three times to ensure that the results were precise and consistent.

Figure 3.8: Hydrodynamics testing – Throwing the device into the canal

The maximum flow in open channels occurs in the center and at one-third the depth from the surface. Measurements were taken by throwing the flotation device as close to the center as possible to obtain the maximum flow of the water.

3.2.3 Data Collection

The following table was used to record the data in the field (Appendix D):

Table 1: Hydrodynamics Field Data

Date	Time of Day	Canal Segment	Hydrodynamics								
			Distance (m)	Time (s)			Velocity (m/s)			Average	
				Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Time	Velocity

3.3 Measuring Tide Delays

In partnership with Centro Maree, this part of the project is aimed to further the understanding of the tide delays in different parts of the city. A tide delay is defined as the time it takes a high or low tide to reach a canal, after the *Punta della Salute* tide gauge station records its high or low tide.

3.3.1 Scheduling of Measurements

The difference in water level between high and low tide is the most drastic during the new and full moon. By taking measurements during this time period, it was the easiest to indentify the point where the water level changes direction. During each moon phase, either new or full, canals from each of the six sestieri were measured for tide delay (Appendix I).

Measurements were taken on the day of the new or full moon as well as the day before and the day after. On each day of testing measurements were taken at high tide, low tide, and the subsequent high tide. At each tide four canal segments were examined. Two different sestieri were measured on each tide so that canal segments from each of the six sestieri could be measured on each day of testing.

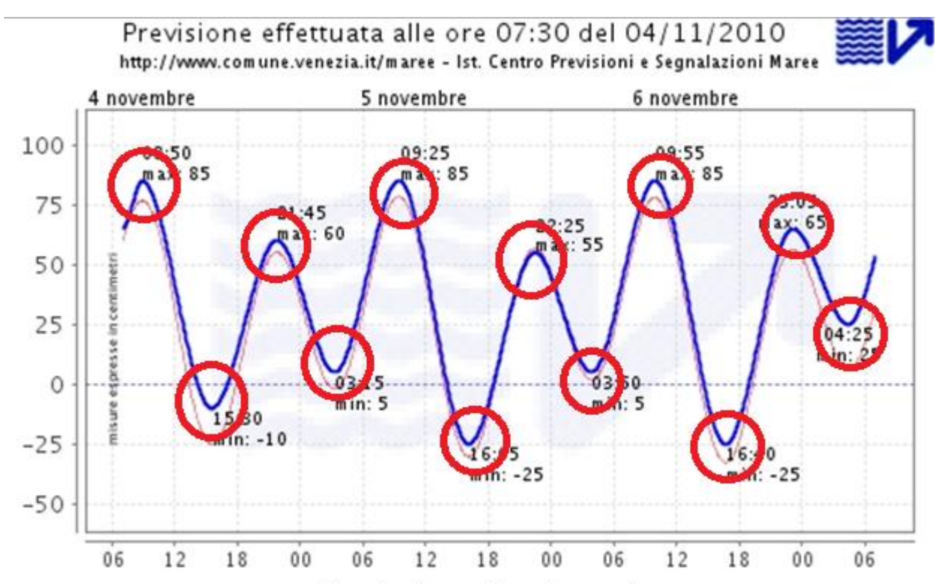


Figure 3.9: Tide chart depicting the forecast for the day before, day of and day after the new moon and ideal tide delay testing times

3.3.2 Measurement Tool

Tide delay measurements were performed using a device to determine the height of the water. The device consisted of a plumb-bob and a piece of wood. The plumb-b was built by attaching a small weight to the end of a thin piece of rope. The piece of wood had a hole near one of the ends. The plumb-bob was strung through the hole. The piece of wood provided a level surface for measurements to be taken. The plumb-bob insured that the rope was completely vertical so that the distance measured would not be skewed.

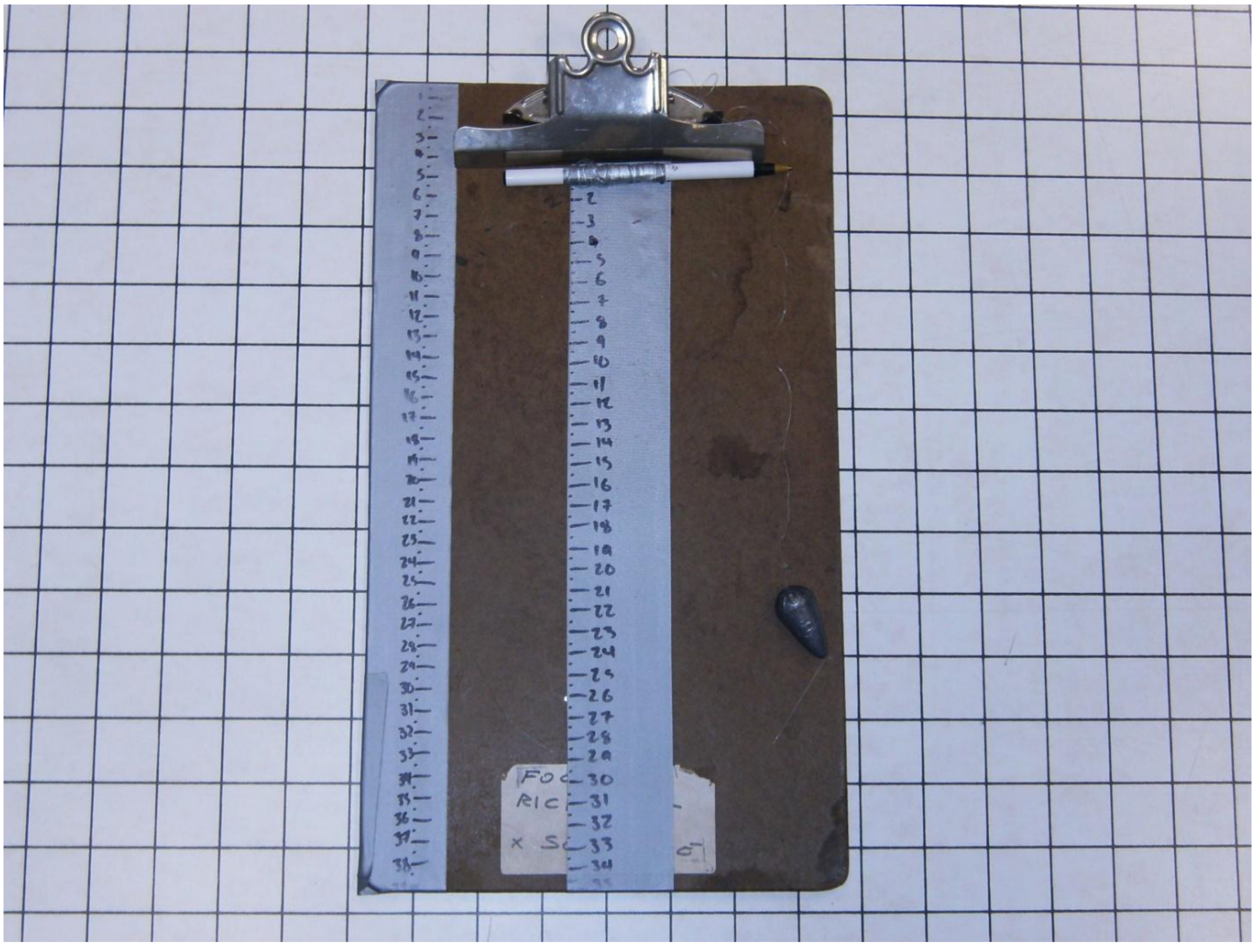


Figure 3.10: The tide delay testing device – "plumb-bob"

By lowering the plumb-bob to the surface of the water and pulling the line back up through the hole in the wood, the distance from the sidewalk to the water could be calculated. In total, four devices were constructed so that measurements could be taken simultaneously at four different canal segments (Appendix H).

3.3.3 General Procedure

The tide delay was measured by recording the time a particular canal segment reached either high or low tide and calculating the difference between that measured time and the predicted time. Predicted times for high and low tide were provided by the Instituzione Centro Previsioni e Segnalazioni Maree, which is Venice's tide forecasting station.

To measure the time of a high or low tide the canal segment was observed prior to the predicted tide. A device was used (see section 4.3.2) to measure the distance from a known point of elevation, such as a sidewalk, to the water. If the distance from the sidewalk to the water changed then the tide had not been reached. When the measured distance stops changes the tide has been reached. When the tide has been reached the time and measured distance are recorded. After the tide has been reached the change in the measured distance should reverse. For example, if the distance was decreasing, after the tide it would start decreasing. The measured distance was then used to calculate the water level by subtracting the value from the known elevation the distance was measured from.

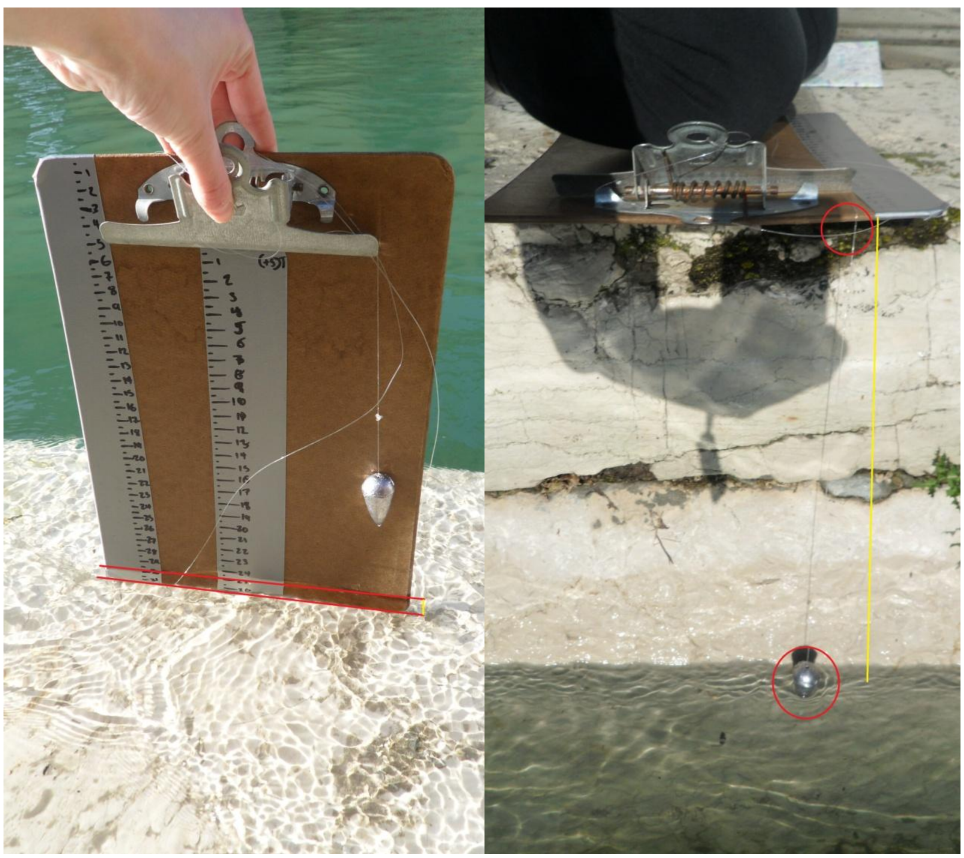


Figure 3.11: Measuring the tide delay above the sidewalk (left) and below the sidewalk (right)

3.3.4 Data Collection

When measuring a canal segment, the date and tide (high or low) was recorded. The time of the tide and the distance to the water was also recorded. The exact location that the measurement was taken was observed and located on a map in order to find the known elevation (Appendix J).

Table 2: Tide delay field form

Canal Segment - Sestiere - Date – High/Low Tide		
#	Time	Length of string (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		

3.4 Venipedia: Maintaining Canal Data

As part of this project, existing canal data and the collected data, were uploaded online is such a way as to set an example of an accessible data standard. The key criteria for creating accessible data were: to present the data in an easily viewable way, to allow the data to be edited and expanded, and to organize the information semantically.

The data was presented in the body of Venipedia articles in the forms: text, table, kml maps, and images. All the files, as well as the raw data are accessible through direct links. Moreover the files can be updated with newer file versions directly on Venipedia. The data becomes accessible through internal and external links. Whenever a canal was named in an online map, the hyperlink to the canal Venipedia article was provided. Likewise, the Venipedia article links to other canal pages and canal data as well as to project maps internally in the site and externally on the web. This creates a series of linked data spaces on the internet that increase the accessibility of the canal data.

4. Results

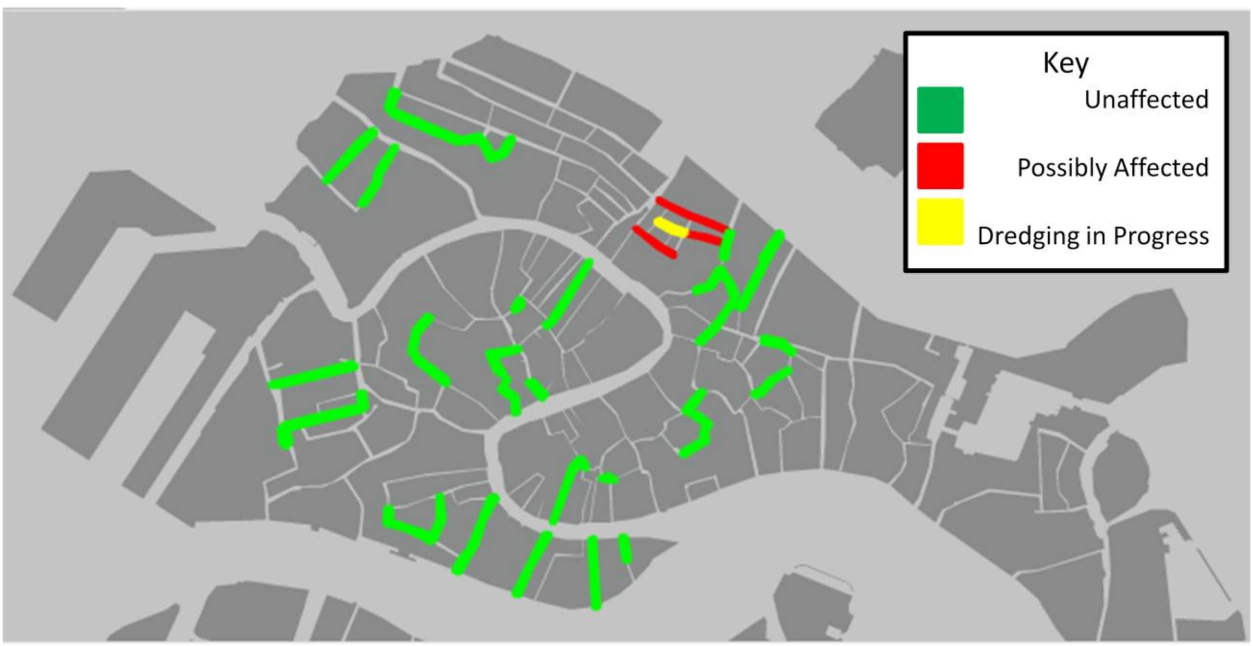
This chapter contains the results of data collected for hydrodynamics and tide delay (Appendix F and K).

4.1 Hydrodynamic Data

This section contains data collected from hydrodynamic testing (Appendix F).

4.1.1 Canal Segments Measured

A total of 52 canal segments were measured for maximum velocities during both the incoming and outgoing tides. During the course of testing a canal in Cannaregio, Rio de San Andrea, was undergoing dredging. As a result, 7 of the measured canal segments had flows that were possibly affected by the nearby dredging and could not be used in velocity comparisons. The remaining 45 canal segments were unaffected (see figure 4.1). All canal segments were tested during both incoming and outgoing tides.



4.1: Map showing 2010 area of hydrodynamics study split up by influence of dredging

4.1.2 Directional Changes with Respect to Tides

For each canal segment tested, the directions of flow for both incoming and outgoing tides were recorded. Canal segments could behave in one of four ways: flow in different directions during incoming versus outgoing tides, flow in the same directions, be stagnant for both tides, or be stagnant for one tide and flow during the other.

Of the 45 canal segments studied, 30 flowed in opposite directions during incoming and outgoing tides (66.7%), 8 flowed in the same directions (17.8%), 7 were stagnant during one half of the tide cycle and moving for the other (15.5%), and 0 canal segments were stagnant for both incoming and outgoing tides. As the tides change from incoming to outgoing water tends to change directions. This case is seen for the majority of the canals.

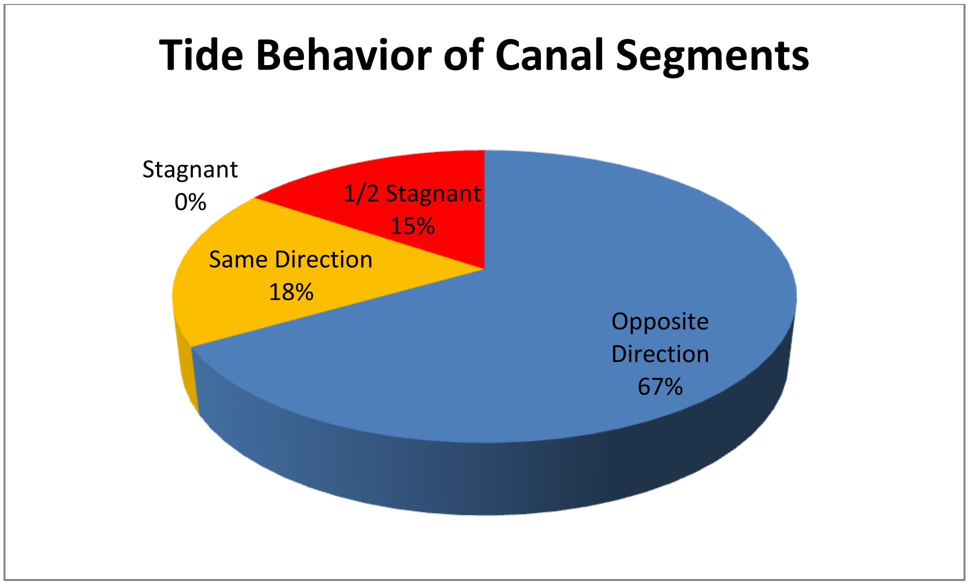


Figure 4.2: Directional behavior of canal segments during changes in tides

4.1.3. Maximum Velocities

For each of the canal segments measured, the maximum flow velocity was determined for both incoming and outgoing tides. Prior WPI studies separated canal speeds into four general categories: stagnant, lazy, mid-ranged, and fast. Stagnant segments had speeds ranging from 0 centimeters per second (cm/s) to 1 cm/s. Lazy segments had speeds ranging from above 1 cm/s to 10 cm/s. Mid-ranged segments had speeds ranging from above 10 cm/s to 20 cm/s. Fast segments had a speed greater than 20 cm/s. The speeds for each canal segment during incoming and outgoing tides, broken down by categories, can be seen in figure 4.3 below.

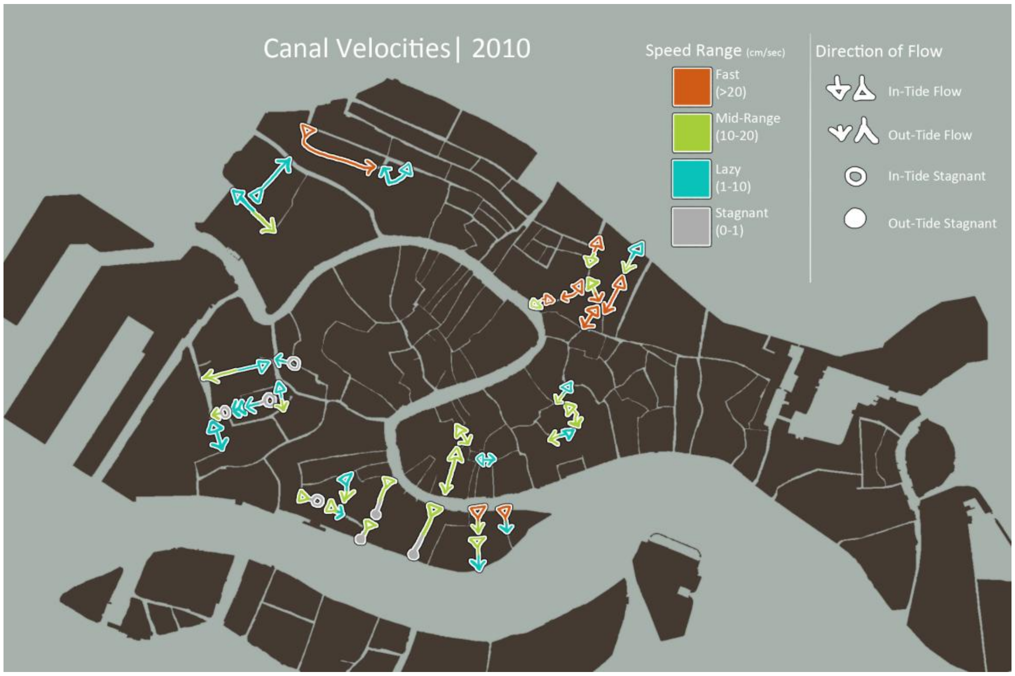


Figure 4.3: Map depicting 2010 velocities and directions for both incoming and outgoing tides

4.1.3.1. Incoming Tide

During the incoming tide, 3 of the segments were stagnant (6.7%). 15 of the segments were lazy (33.3%), 15 of the segments were mid-ranged (33.3%), and 12 of the segments were fast (26.3%). Figure 4.4 shows the distributions of speeds for canal segments during the incoming tide. The gray represents stagnant canal segments, the blue represents lazy canal segments, the green represents mid-ranged canal segments, and the red represents fast canal segments. The canal segments are evenly distributed around 14 cm/s with a few canal segments with much faster speeds. The canal segment with the fastest speed was FORN1 in Dorsoduro, which was also flowing in a southern direction when most of the other canal segments (73.3%) were flowing north.

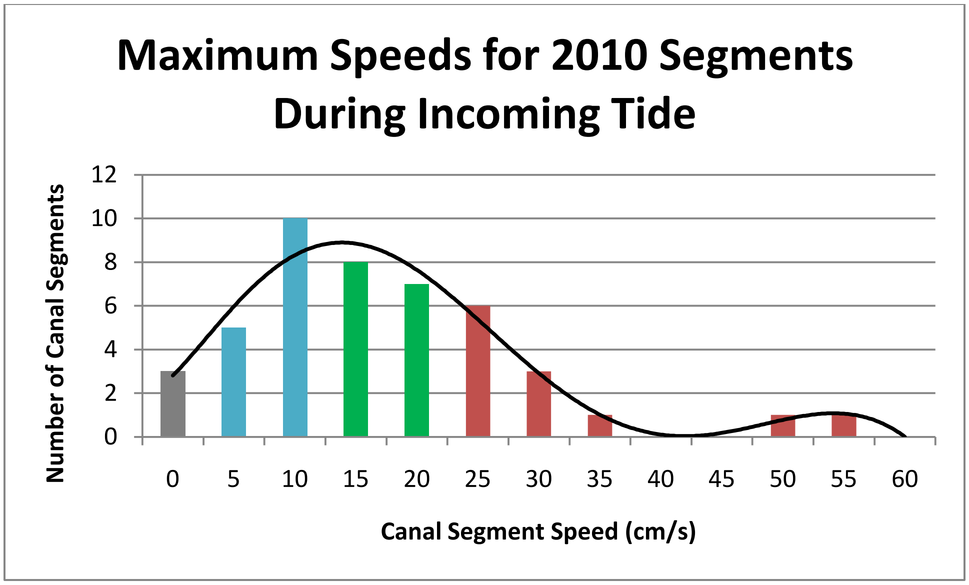


Figure 4.4: Speeds Distribution for Canal Segments during Incoming Tide

4.1.3.2. Outgoing Tide

During the outgoing tide, 4 of the segments were stagnant (8.9%). 14 of the segments were lazy (31.1%), 18 of the segments were mid-ranged (40%), and 9 of the segments were fast (20%). Figure 4.5 shows the distribution of canal segments speeds during the outgoing tide.

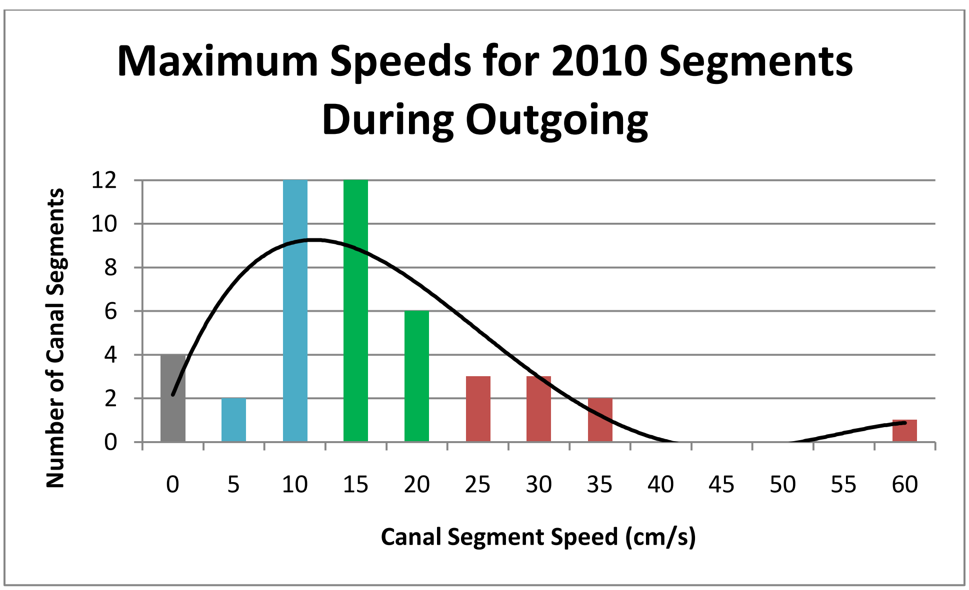


Figure 4.5: Speed Distribution of Canal Segments Unaffected by Dredging during Outgoing Tide

4.2 Tide Delay Data

This section contains data collected during tide delay measurements (Appendix K).

4.2.1 Canal Segments Measured

59 of segments were measured for tide delay. Of the segments measured, 37 were measured for high tides and 22 segments were measured for low tide.

4.6 **Area of Tide Delay Study**

4.2.2 Canal Segment Tide Delays vs. Punta della Salute Real-time Data

Of the canal segments measured for their high tides, 3 segments had times that matched the high tide at Punta della Salute (8.1%). 16 segments had high tide occur at a time later than Punta della Salute (43.2%). 18 segments had high tide occur at a time earlier than Punta della Salute (27.2%). The average delay for these segments was -16.54 minutes with a standard deviation of 35.67 minutes. There was a wide range of data, from -150 minutes to 17 minutes. When the times with delays between -60 minutes and -150 minutes are excluded, the standard deviation is 17.75 minutes.

Figure 4.7: Map of low tide delay times with respect to the Punta della Salute low tide time

For canal segments measured for their low tides, no segments occurred at the same time as Punta della Salute. 4 segments occurred at a time later than the predicted time (18.2%). The remaining 18 segments had low tide occur at a time earlier than Punta della Salute (81.8%). The average delay for these segments was -17.36 minutes with a standard deviation of 22.27 minutes. This set of data did not have any outliers.

4.8 Map of low tide delay times with respect to the Punta della Salute low tide tim

4.2.3 Canal Segment Tide Delays vs. Misericordia Real-time Data

Of the canal segments measured for their high tides, 3 segments had times that matched the high tide at Misericordia (8.1%). 29 segments had high tide occur at a time later than Misericordia (78.4%). 5 segments had high tide occur at a time earlier than Misericordia (13.5%). The average delay for these segments was -26.35 minutes with a standard deviation of 35.67 minutes. There was a wide range of data, from -135 minutes to 10 minutes. When the times with delays between -60 minutes and -135 minutes are excluded, the standard deviation is 15.15 minutes.

Figure 4.9: Map of high tide delay times with respect to the Misericordia high tide time

For canal segments measured for their low tides, no segments occurred at the same time as Misericordia. 3 segments (13.6%) occurred at a time later than the predicted time. The remaining 19 segments (86.4%) had low tide occur at a time earlier than Misericordia. The average delay for these segments was -30.55 minutes with a standard deviation of 25.33 minutes. When the 5 outliers, between -64 and -74 minutes, are excluded, the standard deviation is 21.34 minutes.

4.10 Map of low tide delay times with respect to the Misericordia low tide time

4.3 Sustainable Data Results

The result of this project's set standard on accessible canal data included various formats and edit to the Venipedia site. The infobox template for canals was set; it includes the basic information of each canal: name, map location, image, canal segments, canal intersections, length, depth, area, and orientation of flow.

Rio de la Panada

View of Panada canal segment

Sestiere	Cannaregio
Length	438.5 m
Area	3186.6 m²
Segments	PANA1, PANA2, PANA3
Intersections	WIDM, MIRA
Flow Direction	N/S

4.11 Basic Canal Infobox on Venipedia

The formatting for canal articles was set so that each article will contain the following: a history and description of the canal, stats about the canal segments, a table of studied data (velocity, dredging schedule, damage, sewer outlets, tide delay), a photo gallery, and an interactive map. These articles will detail the information collected for this project as well as provide a depository for future collected data about each Venetian canal.

5. Analysis

This chapter contains the analysis of the results obtained from hydrodynamic and tide delay data.

5.1 Hydrodynamics

Hydrodynamic measurements taken by prior WPI students were repeated for 52 of the canals segments using the same methodology. Canals that were possibly affected by dredging in 1999 and 2010 could not be used to make an adequate comparison of any potential changes in the canal hydrodynamics. A total of 33 canal segments that were measured in this study were not currently affected by dredging and were not affected in prior WPI studies. These canal segments were used to compare past and present hydrodynamic measurements.

5.1.1 Effect of Dredging on Canals

Some of the canal segments tested by past WPI projects were near canals that were undergoing dry-bottom dredging. These canals segments could have been possibly affected by the dredging. 12 of the canal segments possibly affected by dredging in 1999 were repeated in this study and were not currently near canals being dredged.

Figure 5.1 shows the canals that were dredged in 1999 and the direction the canal segments possibly affected by dredging flowed during the incoming tide. Most canal segments flowed north during the incoming tide, which is typical canal behavior. Three canal segments (PEST1, TETT1, and FORM) flowed south during the incoming tide.

Figure 5.1: 1999 Incoming Tide Flow Directions of Canal Segments Possibly Affected by Dredging in 1999

Two of the three canal segments flowing south during the incoming tide in 1999, PEST1 and TETT1, changed directions in 2010 and flowed north while FORM continued to flow south in 2010 (Figure 5.2). The dredging of a nearby canal could have caused PEST1 and TETT1 to change the direction they would normally flow during the incoming tide and flow in the opposite direction then it normally should. One canal segment, ORIO1, flowed north in 1999 and changed direction to flow south in 2010. This segment could have also been affected by dredging. However, it changed to flow in the direction that is uncommon among canals during the incoming tide and could be the result of some other hydrodynamic phenomenon.

Figure 5.2: 2010 Incoming Tide Flow Directions of Canal Segments Possibly Affected by Dredging in 1999

The velocities of these canal segments could have also been influenced by being near to a canal undergoing dredging. Table 3 shows the velocities of the canal segments that were possibly affected by dredging in 1999. Both the 1999 velocities and the 2010 velocities are shown. A positive number represents a canal flowing north and a negative number represents a canal flowing south. Some of the canal segments that do not change direction between years also do not have a significantly different speed (FRAR1, STIN, MUNE, and FORM). Other canal segments, such as TOMA, experienced increases of over 10 cm/s. Many canal segments, such as LIO, had decreases in speed greater than 10 cm/s. The dredging of a canal could have drastically changed the behavior of several of the canals nearby both in terms of direction of flow and speed.

Table 3: Velocities of canal segments possibly affected by dredging in 1999 during incoming tides

Canal Seg.	1999 Possibly Affected Incoming Velocity (cm/s)	2010 Comparison Incoming Velocity (cm/s)
2TOR2	30.8	20.83
DOMI	21.8	14.56
FRAR1	10.23	8.63
ORIO1	5.8	-11.11
POLO4	10.86	20.29
STIN	1.15	5.88
TOMA	1.15	20.99
MUNE	14.19	15.25
FORM	-10.07	-10.77
LIO	27	7.22
PEST1	-0.8	29.12
TETT1	-7.29	13.5

Figure 5.3 shows the direction of flow for canal segments that were possibly affected by dredging in 1999 during the outgoing tide. The majority of the segments flowed south with only two segments (ORIO1 and FORM) flowing north. Another two segments (PEST1 and TETT1) had no measurable flow during the outgoing tide.

Figure 5.3: 1999 Outgoing Tide Flow Directions of Canal Segments Possibly Affected by Dredging in 1999

In 2010, FORM continued to flow north during the outgoing tide (Figure 5.4). The other segment that flowed north during the outgoing tide in 1999, ORIO1, flowed south in 2010. In 1999 ORIO1 flowed north for the both incoming and outgoing tides and in 2010 it flowed south for both the incoming and outgoing tides. This could be a result of being near a canal in the process of dredging or some other influence that changed its direction. Both of the canals that did not flow during the outgoing tide in 1999 (PEST1 and

TETT1) flowed south in 2010. This change from stagnant to dynamic is most likely the result of the nearby dredging prevent water from moving through those segments during the outgoing tide.

Figure 5.4: 2010 Outgoing Tide Flow Directions of Canal Segments Possibly Affected by Dredging in 1999

The table below shows the outgoing velocities for 1999 and 2010 for canal segments possibly affected by dredging in 1999. Several of the canal segments (FRAR1, STIN, MUNE, and FORM) do not experience great increases or decreases in their velocities. This is also true for their velocities during the incoming tide and were most likely unaffected by the dredging of the nearby canal. The two canals that were not moving during the outgoing tide in 1999 not only moved in 2010 but also had fast velocities. Some canals, such as LIO, had substantial decrease in velocity of over 10 cm/s. This decrease matched the decrease during the incoming tide.

Table 4: Velocities of canal segments possibly affected by dredging in 1999 during outgoing tide

Canal Seg.	1999 Possibly Affected Outgoing Velocity (cm/s)	2010 Comparison Outgoing Velocity (cm/s)
2TOR2	-32.9	-26.53
DOMI	-16.8	-13.82
FRAR1	-8.96	-11.88
ORIO1	6.18	-9.85
POLO4	-3.06	12.32
STIN	-7.02	-11.1
TOMA	-7.02	-22.41
MUNE	-16.4	-16.24
FORM	2.13	6.67
LIO	-30	-3.01
PEST1	0.01	-58.79
TETT1	0.01	-23.08

The dredging of canals can have widespread and dramatic changes in the hydrodynamics of the surrounding canals. Canals can change which direction they are flowing for incoming and outgoing tides. Dredging can also make canals not flow for at least half of the tide cycle. Their speeds can also greatly increase or decrease. However, many canal segments that appear close enough to a canal being dredged to be affected experience no effects and retain their hydrodynamic behavior during the dredging process.

5.1.2.1 Comparisons of Flow Velocities of Outgoing Tides

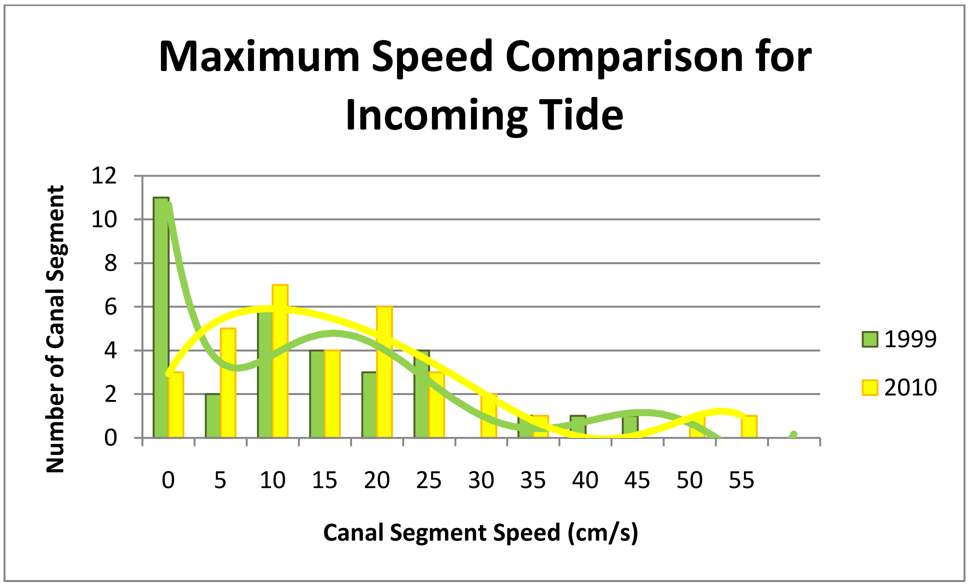


Figure 5.5: Graph depicting the maximum velocities for incoming tides

The changes in speeds, from 1999 to 2010, for in-tide, appear to be normally distributed. Segment BURC, displayed in the map below in the second darkest blue, had the highest decrease in speed, -21.25 cm/sec. Two segments decreased in speed by an average of 6.015 cm/sec, five segments by an average 2.398 cm/sec. Seven segments had an absolute speed change of less than 1 cm/sec. Five segments increased by an average of 2.998 cm/sec, one segment by 7.53 cm/s, four segments by an average of 11.765 cm/sec, four segments by an average of 17.659 cm/sec. Segment BATE1, below in the darkest red, saw the highest speed increase, 29.5 cm/sec. The majority of the canal segments (66.7%) have not changed direction of flow between 1999 and 2010.

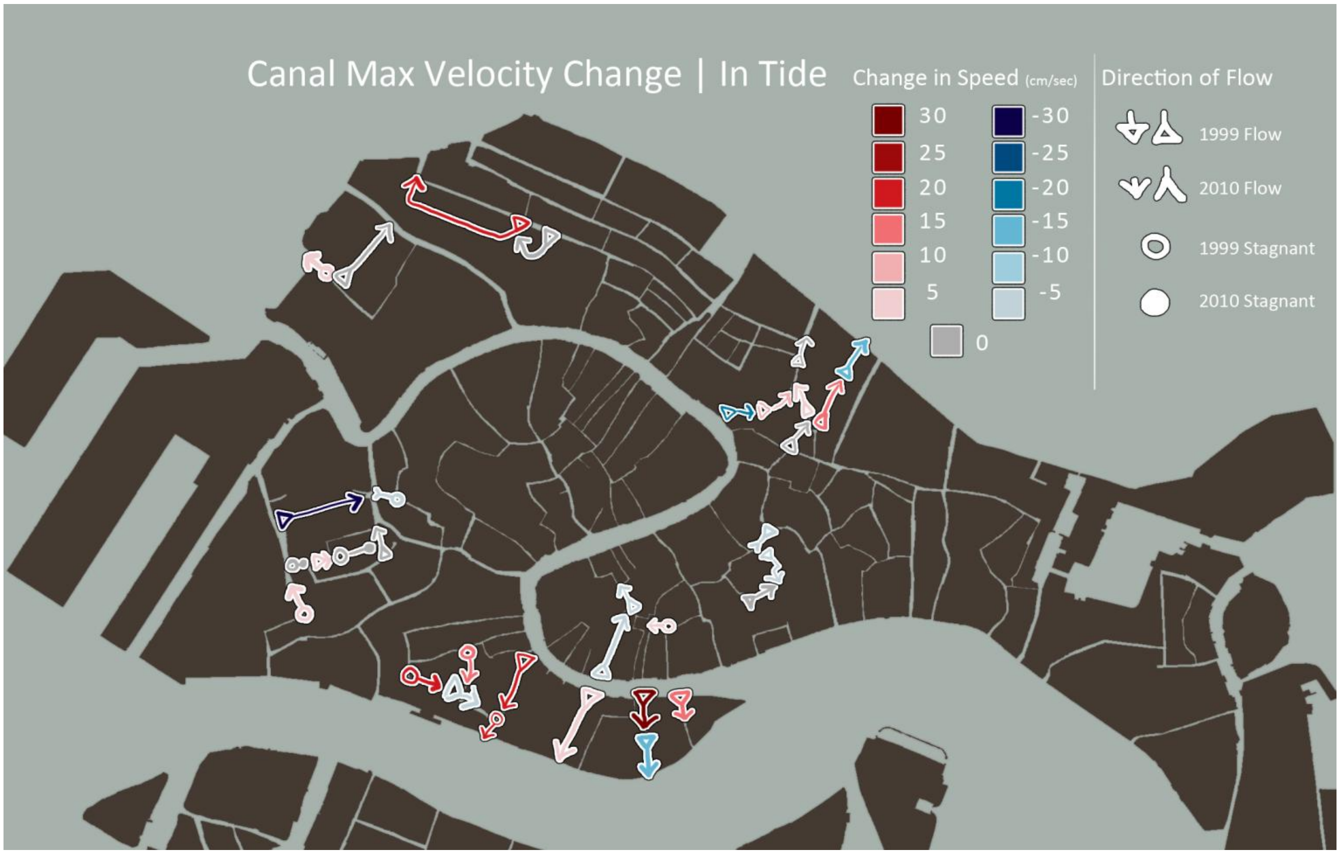


Figure 5.6: Map depicting the direction of flow and change in flow velocity for incoming tides between 1999 and 2010

The most amounts of changed canals seem to be in the Dorsoduro area. This could possibly be because of the change in the watershed that has been rumored to have occurred. The rumor suggest that the flows that entered the lagoon from the northern Adriatic used to surround the island and buffer it from the more aggressive flows entering from the southern Adriatic are now no longer surrounding the island but actually flowing directly through it, while allowing the southern flows to interact with it Figure 5.7. In other words, the flows depicted in green in Figure 5.7 now flow around to the north-western part of the island, where during the incoming tide they 'cork up' the north end of the *Canale Grande*. This results in the *Canale Grande* filling up completely at the beginning of the incoming tide. As water keeps coming into the *Canale Grande*, the tributaries in Dorsoduro start to flow as the water in the *Canale Grande* has nowhere else to go since the northern end is 'corked'. This is possibly why the velocities have increased in speed in this area in the past decade.

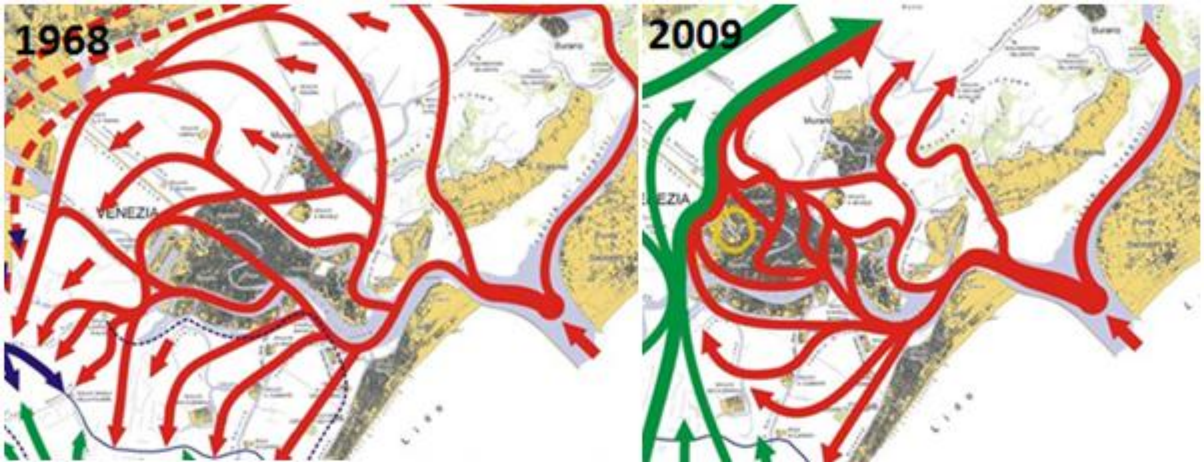


Figure 5.7: Image depicting the rumors of the watershed change between 1968 and 2009

5.1.2.2 Comparisons of Flow Velocities of Outgoing Tides

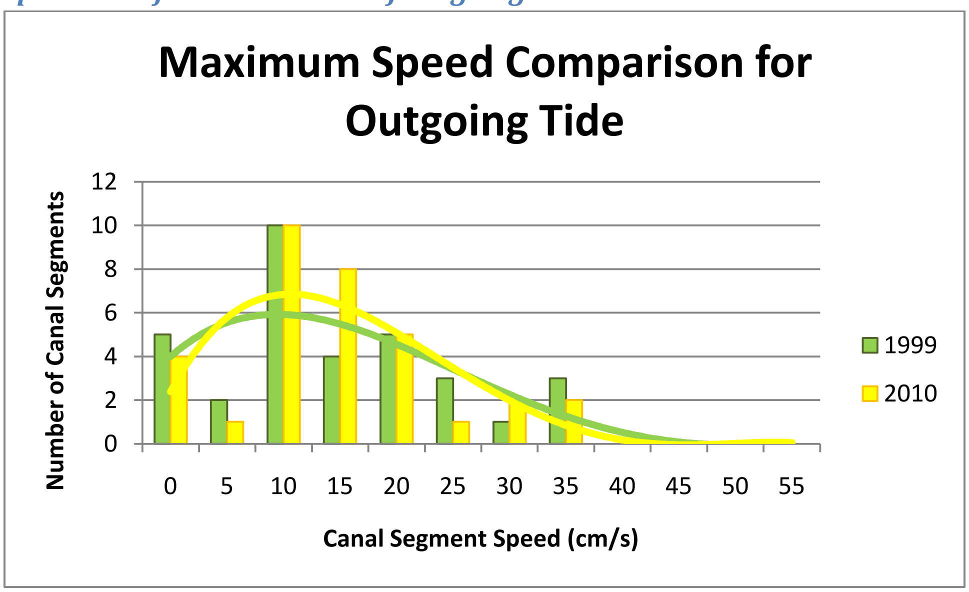


Figure 5.8: Graph depicting the maximum velocities for outgoing tides

The changes in speeds, from 1999 to 2010, for outgoing-tide, appear to be normally distributed. Segment FORN2, displayed in the map below in the second darkest blue, had the highest decrease in speed, 21.51 cm/sec. Four segments decreased by an average of 16.588 cm/sec, six segments by an average of 2.53. One segment had an absolute change in speed of 0.93 cm/sec. Six segments increased by an average2.161 cm/sec, six by an average 7.225 cm/sec, two segments by an average 12.995 cm/sec. The segment BATE1 had the highest increase of 15.3cm/sec and can be seen below in the third darkest red. Most of the canal segments (66.7%) have not changed direction of flow between 1999 and 2010.

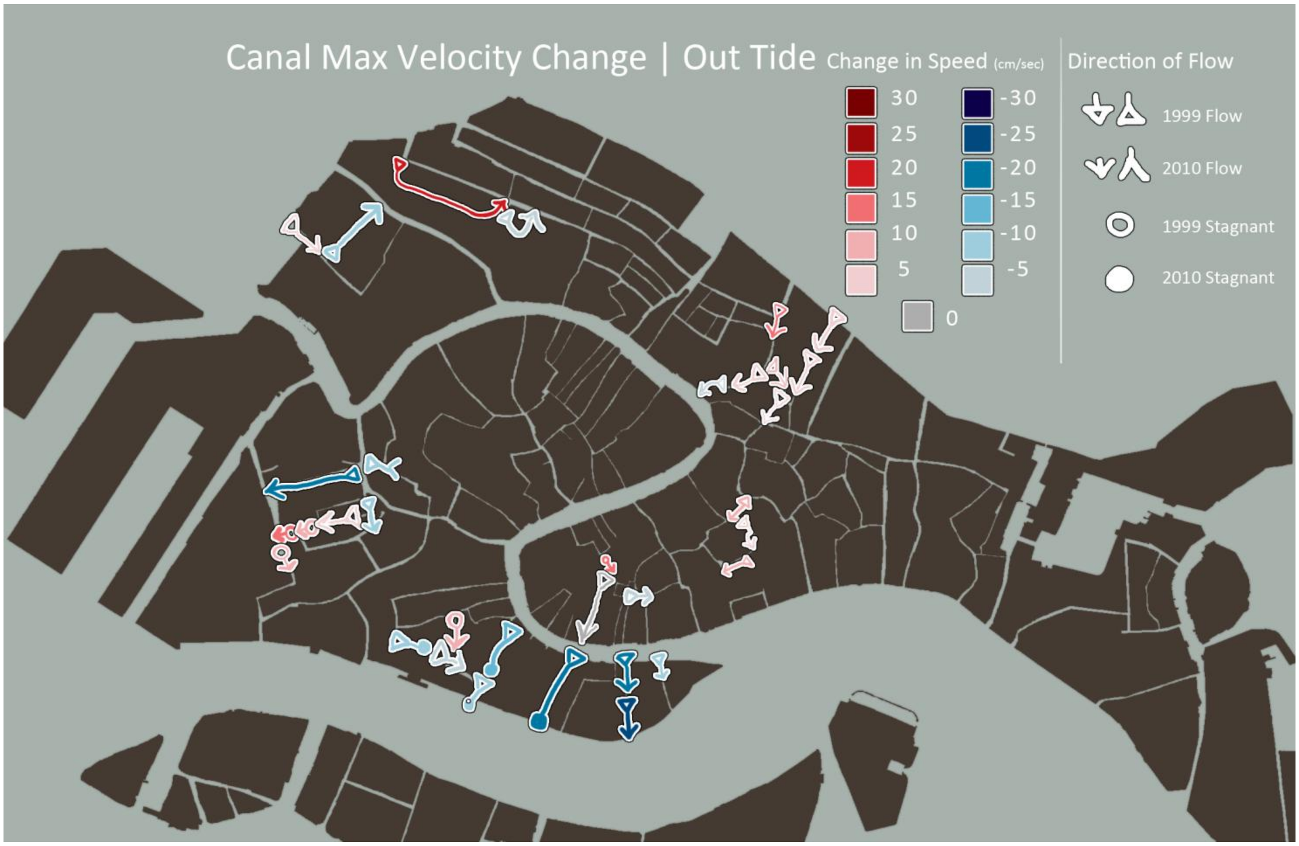


Figure 5.9: Map depicting the direction of flow and change in flow velocity for outgoing tides between 1999 and 2010

Like with the incoming tide, Dorsoduro experienced the most changes in speed during the outgoing tide as well. This is once again correlated back to the rumor regarding the watershed as an explanation for this observation. When the tide begins to move outwards, the *Canale Grande* moves in a southward direction again, and all the water in it empties through the south end. This would mean the water does not need to leave through the tributaries of Dorsoduro. It is also possible that by the time the tide moves outwards the *Canale della Giudecca* has reached the same 'height' as the southern end of the *Canale Grande* (as a result of the water leaving through the tributaries during the incoming tide) and this would result in there being no flow in Dorsoduro between the *Canale Grande* and the *Canale della Giudecca*.

This would explain why the flows in this area dramatically decreased in speed over the past ten year.

5.1.3. Flow Direction Comparisons

The following sections discuss the changes in flow direction between 1999 and 2010 and the possible reasons for these changes to have occurred.

5.1.3.1 Comparison of Flow Direction of Incoming Tides

Figure 5.10: Map depicting the direction of flow of 1999 incoming tides

Figure 5.11: Map depicting the direction of the flow of 2010 incoming tides

Figures 5.10 and 5.11 show the comparison of 1999 and 2010 directions for the incoming tide. From these figures it is easy to see that the changes over the decade have occurred primarily in the eastern-southern sestiere of Santa Croce and Dorsoduro. The segments that experienced changes in Dorsoduro were entirely stagnant in 1999 and in present day all were moving in a southern direction. The segments in Santa Croce in 1999 were primarily north flowing and stagnant, but upon returning to them in 2010 they were primarily south flowing and different segments stagnant. This, like the change in flow velocities, provides support for the rumors suggested by Umberto Sartori.[39] When the green flows from the south of the lagoon (depicted Figure 5.7) 'cork' up the north end of the *Canale Grande* during the incoming tide, the *Canale Grande* continues to fill with incoming water that has no escape through that north end. So this water flows through the tributaries in the Santa Croce and Dorsoduro region and out into the *Canale della Giudecca*. This could explain why these canal segments have changed flow direction in the past decade.

[39] Umberto Sartori - Report on flood-tide in the Lagoon of Venice, 2009

5.1.3.2 Comparison of Flow Direction of Outgoing Tides

Figure 5.12: Map depicting the direction of flow of 1999 outgoing tides

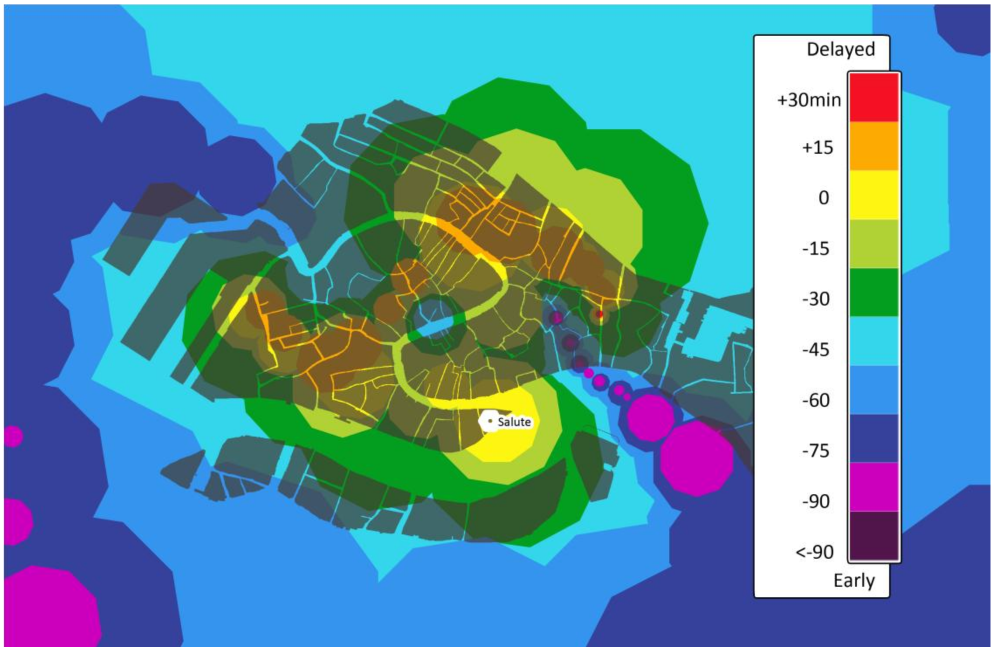
Figure 5.13: Map depicting the direction of flow of 2010 outgoing tides

Figures 5.12 and 5.13 show the comparison of 1999 and 2010 directions for the outgoing tide. These figures illustrate that the changes over the decade have occurred primarily in the eastern-southern sestiere of Santa Croce and Dorsoduro. The segments in Santa Croce in 1999 were primarily south flowing and stagnant, but upon returning to them in 2010 they were almost entirely north flowing and different segments stagnant. The segments that experienced changes in Dorsoduro were south flowing in 1999 and in present day almost all were stagnant. In both cases this could be the similar trend witnessed with the incoming tides. When the tide begins to move outwards again, the *Canale Grande* moves in a southward direction. This would mean the water does not need to leave through the tributaries of Santa Croce or Dorsoduro. It is also possible that by the time the tide moves outwards the *Canale della Giudecca* has reached the same height as the southern end of the *Canale Grande* (as a result of the water leaving through the tributaries during the incoming tide) and this would result in there being no flow in Dorsoduro between the *Canale Grande* and the *Canale della Giudecca*.

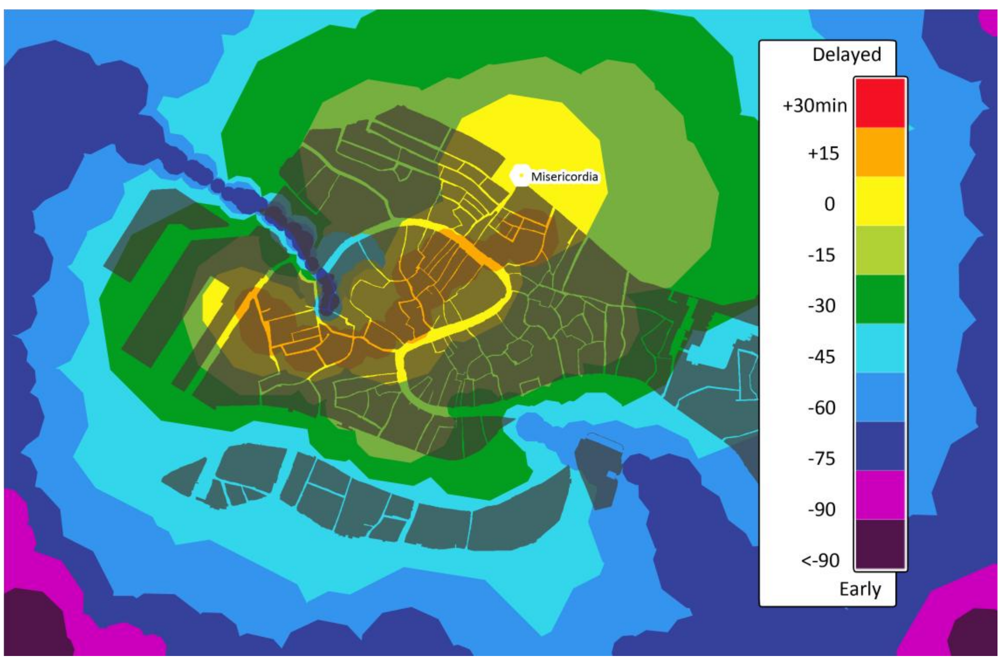
5.2 Tide Delay

This section analyzes the results for tide delay studies, which compliment the results from hydrodynamic studies as proof of the new watershed location.

5.2.2 Delays at High Tide



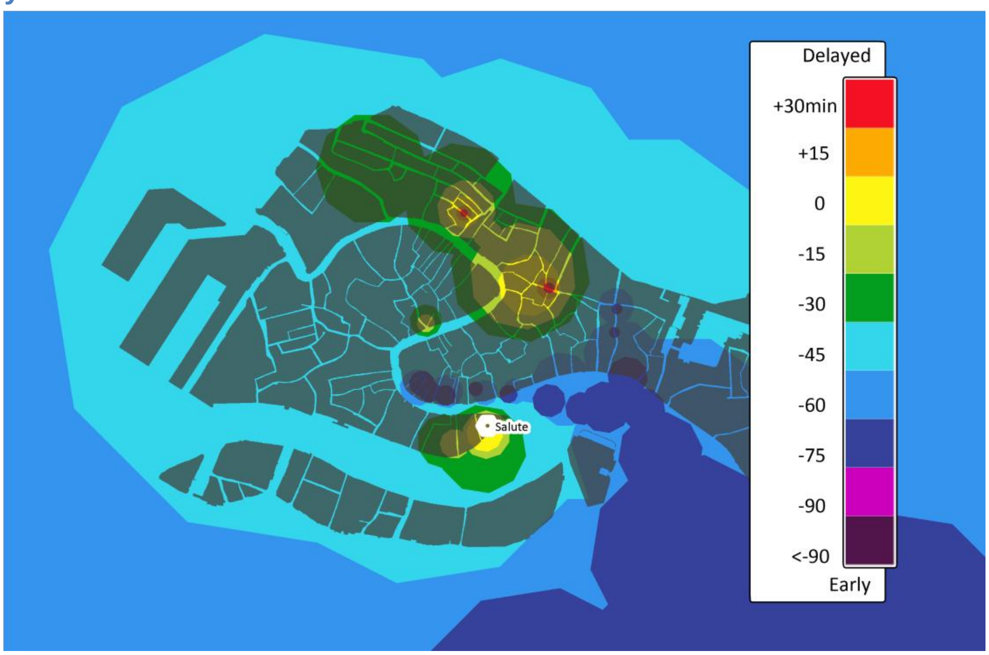
5.14 High tide delays with respect to Punta della Salute



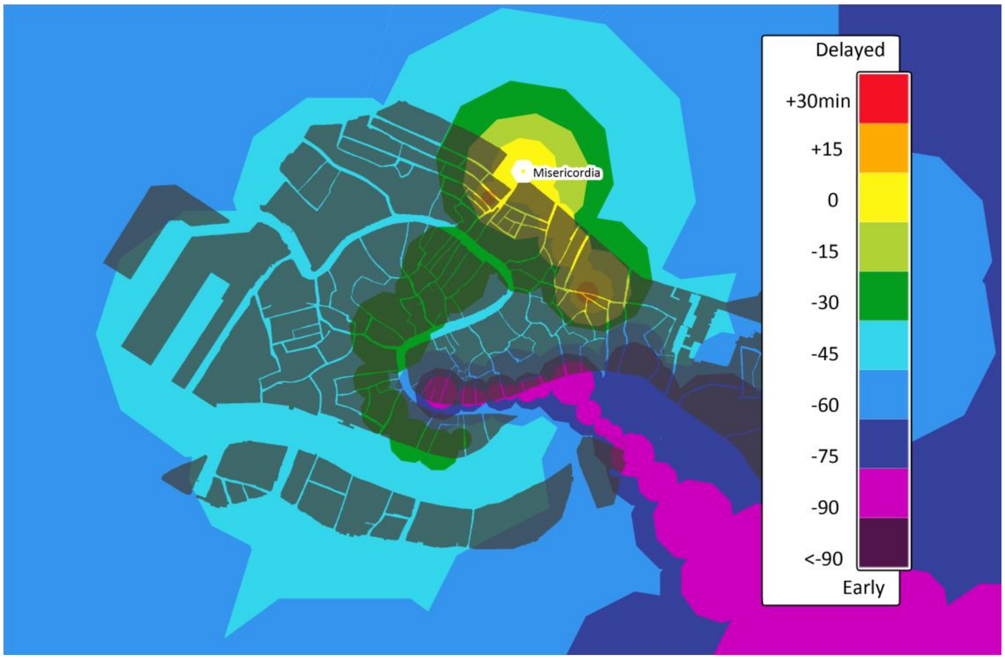
5.15 High tide delays with respect to Misericordia

As depicted in the above maps, water enters Venice though the two ends of the *Canale Grande*. First, water comes from the northern end of the *Canale Grande.* This water enters Venice about 45 minutes before the southern end of the canal, providing evidence that Venice is now getting water from two different sources. When the water makes it way into Venice through the Lido Inlet and the southern end of the *Canale Grande*, the water meets somewhere in the middle, ideally in the middle of the watershed. Then, the water level of the *Canale Grande* rises to a level higher than the surrounding canal networks. This water is then distributed to nearby canals which make up the watershed line, since it's where the water builds up. The border between the 0 minute delay and the canals that reached high tide 15 minutes earlier than Misericordia shows where the water starts to be rejected from the island. Basically, there is too much water in central Venice approaching high tide that water naturally starts flowing toward the lower water level, which is the lagoon in this case.

5.2.3 Delays at Low Tide



5.16 Low tide delay with respect to Punta della Salute



5.17 Low tide delays with respect to Misericordia

During the outgoing tide, as the waters are approaching low tide, the pressure is released from the northern end of the *Canale Grande* which causes an immediate rush of water out of the southern end of the *Canale Grande*. This is depicted by the dark blue in the map of Punta della Salute, and by the pink in the map of Misericordia. Further studies will be needed to see if water is also exiting through the northern end of the *Canale Grande*, just like how the water enters Venice.

5.2.4 Watershed Patterns in Data

When Venice is filling up with water, during the incoming tide, it is receiving this water from two locations: the northern end of the *Canale Grande* and the southern end of the *Canale Grande* in the *Canale della Giudecca*. The water from the northern end of the *Canale Grande* is reaching Venice quicker than the other source. This leads to a possibility of having two different water sources for the island of Venice: the Lido and the Malamocco Inlets from the Adriatic Sea. Venice has always been known to get its water solely from the Lido Inlet, since it is much closer than the Malamocco Inlet. There are numerous reasons why this might be happening.

One reason the Malamocco Inlet is reaching Venice before the Lido Inlet is because the waters from the Malamocco Inlet are transporting water faster than in the past, and the Lido Inlet is transporting waters slower than in the past. The *Canale Pitroli* is bringing up water very quickly to the west of Venice through the increase in cargo boats traveling that route, from the Malamocco to the western Venice Lagoon. The MOSE tidal gate project might be effecting the Lido Inlet with the island that is now directly in the middle of the opening, possibly restricting the water flow.

There is a commonality in all four of the tide delay maps. There is a clear pattern as a diagonal from eastern Dorsoduro to eastern Cannaregio which might be the current home to the watershed. When the water builds up in the *Canale Grande,* after high tide it is possible, though not proven through this study, that the water might be forced through the northern end of the *Canale Grande* as well as the southern end. Since the "cork" is water coming from the Malamocco Inlet, in order for the cork to be removed, this water must leave Venice. It seems that the water will want to leave the island in the same way it enters it, but more data and studies are necessary to confirm or deny this.

6. Recommendations

Much of the collected information from this project is in the form of recommendations for future studies that may follow.

6.1 Lessons Learned in the Field

One of the most helpful preparations for hydrodynamics testing was what was referred to as 'surveying' or 'observing' the canals before the time of testing. Much was accomplished during these outings that saved valuable time and energy for the actual days of testing. By going out ahead of time the group was able to identify which canals were still accessible for hydrodynamics testing and which were not. Identifying any difficulties in those canals that were accessible (such as constant boat traffic or docked boats) allowed for the group to prepare for difficulties at time of testing. The points of reference for start and end points from the 1999 study were identified at these times, and if they no longer existed new points were identified, distances measured and pictures taken. By being familiar with the location of the canal, and how to get to it also allowed for valuable time to be saved at time of testing especially for those tests done after dark.

For the executing of hydrodynamics testing, it is important to be prepared for every worst possible circumstance imaginable when it comes to the device (Section 3.2.2, Appendix B). For every device being used in the field, there should be that many back-up devices for the extreme case that the entire device is dropped into a canal and cannot be retrieved. Along the same lines, for every device that is being used in the field, there should be an extra blade carried along with that device in the extreme case that an emergency replacement of the blade is necessary. Extra duct tape should be also brought along to attach this new blade, or to fix the original along with extra fishing weights if those are to fall off with the original blade. Lastly, it is a good idea to have a long stick, such a broomstick, on hand in case the fishing line gets caught on the anchor or motor of a docked boat. Using the stick to unhook the fishing line is a much better idea than climbing onto someone's boat, which can get you in trouble.

For tide delay testing it is important that the fishing line that makes up the plum-bob (Section 3.3.2, Appendix H) is attached to something (such as the clip-board) so that if the line slips from the tester's hand it will not disappear into the canal. Securing the fishing line down to a larger object will ensure that testing will not have to end early due to the plum-bob disappearing into the canal being tested.

On a more social note, be sure to be able to communicate to the locals who do not speak English what you are doing. To many people who are unfamiliar with the methodology it appears that the hydro testers are just teenage kids throwing plastic bottles into the canals, and tide delay testing can appear as loitering. These do not go over well with many. Simply being able to explain that you are students studying the flow of the canal, or measuring the tide will save a lot of time and inconveniences (Gondolier's destroying your device with their ores) and make the entire experience much more enjoyable for all parties involved.

The final recommendation from experiences in the field should go without saying, but will be mentioned. If testing is to occur in the fall/winter months such as this project did be prepared for the cold and wet weather that you will be testing in. Rain boots, long underwear, rain coats, hats and waterproof gloves are an absolute must. Being prepared for the elements will make testing all the more pleasant which results in more accurate results.

6.2 The Future of Hydrodynamics Studies

Because hydrodynamics testing could only be done approximately three days every two weeks, only nine days were dedicated to hydrodynamics testing in a seven week period of study (Section 3.2.4, Appendix C). Within these nine days of testing, only a short two to three hour period within each outgoing and incoming tide can be hydro tested, ensuring that the most accurate maximum flows are obtained. Assuming that each canal segment takes approximately 15 minutes to test at a time, and then taking into account hindrances from boats, poor weather and getting lost allows for a very small number of canal segments to actually be hydro tested in a given day. Even when a group of four students split into two pairs for hydro testing, the area covered was not as big as hoped. On the best day nine segments per pair were analyzed. 52 total canal segments were tested for hydrodynamics by the end of the third testing cycle (Appendix D).

This leave opportunities for future study of the canal segments in the area of hydrodynamics for comparisons to the joint WPI, UNESCO and Insula studies compiled in 1999[40]. The 1999 IQP that this project was modeled after accounted for the hydrodynamics for 170 canal segments (Appendix E). In this study, 52 of these 170 segments were revisited in order to compare in the area of hydrodynamics. This leaves 118 of the segments compiled in the 1999 report untested over a decade later. It is highly recommended that IQPs about hydrodynamics of the inner Venetian canals continue over the next few years. These groups are encouraged to test and analyze the hydrodynamics of those remaining segments. If this happens, all 170 segments could be revisited within 3 years of each other, which would result in a fair comparison of the hydrodynamics of the canals. These tests should be done in the near future, due to the implications the MOSE project might create. The groups testing after MOSE is fully operating will not be able to test with extreme high tides, as was done in previous studies.

[40] *Hydrodynamics of the Inner Venetian Canals* (E'99)

6.1 Suggested canals for future studies for hydrodynamics

Figure 6.1 depicts the canal segments (in pink) that this project group feels would be the best area of study for the next group of students who study the hydrodynamics of the canals. These canal segments were chosen for a number of reasons, but the main reason being that the future results obtained from the study of these segments will hopefully be able to shed more light on the workings of the Venetian watershed and provide any more hints, or possible solid evidence toward the rumors previously addressed in this report. The study of these canal segments will be able to identify some of the hydrodynamic trends of the *Canale Grande*, and were picked for this purpose. Those selected in northern Cannaregio are to determine any possible trends with the watershed and to address rumors specific for Cannaregio and its flows. The canal segments in the Giudecca were chosen to identify any possible changes that have occurred in the *Canale della Giudecca*, which could explain some of the phenomenon witnessed in Dorsoduro during this study. With this the hope is that next year's study on the canals can provide more concrete support or negate the rumors about the watershed.

These 170 canal segments that were analyzed throughout the 1990s and are now being revisited today only make up approximately half of the totally canal segments in the entirety of the canal system. There are 367 total canal segments throughout all of Venice, and because only 170 have been tested for hydrodynamics this leaves 197 canal segments that have never been tested for hydrodynamics. Many of these canal segments have not been tested because they are not ideal for the methods used in this project. In this case a new methodology can be created to resolve this issue. It is suggested to expand the knowledge of the canals and how they are changing by analyzing as many of these unaccounted canal segments as possible. This is an ideal project for an ambitious IQP group, or perhaps for a Civil Engineering or Fluid Mechanics MQP. If more of these canal segments that have never been tested for hydrodynamics before can be tested in the near future, a benchmark can be set for future comparisons, like with this project and the 1990 data. This would allow for a more thorough and broad observation and analysis on how the canal hydrodynamics have changed over the course of the past ten years, and for years to come.

6.3 The Future of Tide Delay Studies

Tide delay testing could only be done approximately three days every two weeks, so in a seven week period of study only nine days were able to be dedicated to collecting data on the tide delay (Section 3.3.4, Appendix I). In the case of this project, the study of tide delay was not added to the methodology until the 4th week in, after the first new moon had already passed. This resulted in only having two testing cycles left to work with, thus only six days to collect tide delay data. With four students in the group, and tide delay being tested at the morning high tide, afternoon low tide, and the night high tide this allowed for 12 canals segments to be tested and data recorded on a completely successful day, 36 in a weekend and 72 in the total time allotted for testing. In the case of this project a total of 60 canal segments were analyzed in the end for tide delay (Appendix K).

With 362 total canal segments within the boundaries of Venice, it is impossible for 60 to give a fair representation of the canal system as a whole. For this reason, future groups should continue the analysis of the tide delay throughout the remaining 362 canal segments that were not analyzed in this project. An ambitious IQP group of four students could get a maximum of 108 canal segments tested for tide delay in a seven week term following the methodology laid out in this project. In a few years, all canal segments could be accounted for, and a much more accurate and complete graphic could be made to represent the tide delay that the island is undergoing. If future IQP groups, or perhaps MQP groups, could study how various meteorological factors influence the tide delay and obtain concrete data to support it.

Further-more, if a more complete collection of data can be obtained the opportunity for a model to be made will present itself. This model could represent the data and how the tide changes depending on the moon, the winds, and other factors. This could possibly be part of an MQP in the field of Computer Science and Programming.

6.4 The Future of Canal Data

This project's recommendations for the future are that students and Venipedia users will follow and improve the standards for sharing information accessibly. For canals specifically future groups or individuals should populate all the articles for every canal in Venice. These articles should be expanded with colloquial information as well as with useful data. This way the information gathered about the canals can be expanded, shared, and easily accessed.

6.5 Expanding the Area of Study

This project was initially set to cover the topics of hydrodynamics, sedimentation accumulation, boat traffic, and infrastructure damage. When the issue of time presented itself, all four areas of studies did not seem feasible to complete in a seven week period.

6.4.1 Sedimentation Accumulation

Sedimentation testing has proven to be extremely time consuming. The methodology is a tedious and multi-step process which includes testing the depth of a canal at every square meter. An ideal canal to test for sedimentation accumulation would be a short and narrow one, which are hard to come by. A boat is needed to do all these tests, unless there is a canal that has sidewalks on both sides and is narrow enough to reach the middle of the canal from the sidewalk.

The device that was made for testing consisted of two PVC pipes connected with epoxy. On the bottom, a plastic potting base was attached perpendicular to the pipe to create a flat surface. A bare pipe end would have pierced the sediment on the bottom of the canal, and thus the wrong readings would have been obtained. A few layers of duct tape were put on creating a smooth, cone-like surface. That would create the least amount of resistance when pulling the device out of the water. Also, a small anchor was put in the cavity inside the duct tape to assist in weighing the device down. Otherwise, it popped up when pushed down to test the canal. A map layer of sedimentation volumes taken from the 1999 sedimentation IQP[41] was made for this project on Google Maps (Appendix L).

6.4.2 Boat Traffic

Boat traffic testing is very time consuming as well. When UNESCO conducted boat counts, they hired about 100 people to conduct counts at various intersections for 12 hour shifts. With a project group of four students also trying to complete other aspects of a project, it was determined boat traffic counts were not feasible. However, the data UNESCO collected through boat counts was able to be compiled into several layers on Google Map (Appendix L). If a group were to look into this area of study in the future, it is recommended that they look into different intersections that UNESCO may have not been able to get to. If

[41] *Quantifying Sedimentation in the Venetian Canals* (E'99)

a future group does the same areas as UNESCO, they should map the data they collect and compare it to the data UNESCO collected.

6.4.3 Infrastructure Damage

A lot of problems were encountered in this area of study. First, repeating the past project was difficult. They obtained a boat from UNESCO to use for their data collection, which was not the case for this project. Since the group did not have access to a boat, the idea to do a strictly visual rating system to differentiate between different degrees of damage was suggested. However, since the exact areas of damage could not be measured without a boat, a rubric needed to be made explaining the criteria for each degree of damage. This was much more subjective than stating the exact size of the area of damage. If someone were to repeat this project, they should plan to get a boat, possibly sponsored by UNESCO, so they are able to measure the exact area of the damage.

For this project, every canal that was tested for hydrodynamics was previously observed. During the surveys group members took note of the damage along the walls and other canal infrastructure. It was noticed that the visible damage was not nearly as substantial as the past project group dealt with. However, this could be due to the fact that Insula has been maintaining the canal walls and fixing the areas of damage that were previously studied. It was decided in the 4^{th} week that due to the 'lack' of infrastructure damage this portion of the project should be dropped.

WORKS CITED

Christine L. Biscotti, Andrea M. Emery, Maxwell Pistilli and Joseph A. Zsofka. 1999. *Hydrodynamics of the Inner Canals of Venice*. WPI Interactive Qualifying Project.

Città Di Venezia Centro Previsioni e Segnalacioni – *Tide Center - City of Venice - Città Di Venezia - Il Portale Ufficiale Della Città*. Web. 15 Sept. 2010. http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/EN/IDPagina/1644.

Church, JA, JM Gregory, P. Huybrechts, M. Kuhn, K. Lambeck, MT Nhuan, D. Qin, and PL Woodworth. 2001. Changes in sea level. *Climate Change* 200 : 639-94.

Davis, Robert, and Garry Marvin. 2004. *Venice, the tourist maze: A cultural critique of the world's most touristed city*. Berkeley and Los Angeles, California: University of California Press.

Ferla, M, M Cordella, L Michielli, and A Rusconi. "Long-term variations on sea level and tidal regime in the lagoon of Venice." *Estuarine, Coastal and Shelf Science* 75.1-2 (2007): 214-222. Web. 18 Nov 2010. <http://au4sb9ax7m.scholar.serialssolutions.com/?sid=google&auinit=M&aulast=Ferla&atitle=Long-term+variations+on+sea+level+and+tidal+regime+in+the+lagoon+of+Venice&title=Estuarine,+coastal+and+shelf+science&volume=75&issue=1-2&date=2007&spage=214&issn=0272-7714>.

Gačić, Miroslav, Isaac Mancero Mosquera, Vedrana Kovačević, Andrea Mazzoldi, and Vanessa Cardin. "Temporal variations of water flow between the Venetian lagoon and the open sea ." *Journal of Marine Systems* 51.1-4 (2004): 33-47. Web. 18 Nov 2010. <http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VF5-4D9D9J1-1&_user=74021&_coverDate=11%2F01%2F2004&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1546050924&_rerunOrigin=google&_acct=C000005878&_version=1&_urlVersion=0&_userid=74021&md5=c6af8045a1270d073ce7c65156a0f25c&searchtype=a>.

Gallagher, Tracy. "Katrina Five Years Later: Slow Recovery in 9th Ward." *Fox News* 26 Aug 2010: n. pag. Web. 1 Dec 2010. <http://liveshots.blogs.foxnews.com/2010/08/26/katrina-five-years-later-recovery-slow-in-9th-ward/>.

Insula - canal excavation. in Insula - A Future for Venice [database online]. 2008 [cited September 25 2010]. Available from http://www.insula.it/scavorii_en.asp?show=2&subsection=10.

Insula - the ancient venetian sewer system. 2008 [cited September 20 2010]. Available from http://www.insula.it/resource/pdf/gatoli_eng.pdf.

Ishimaru, A. "Theory and application of wave propagation and scattering in random media." *Proceedings of the IEEE* 65.7 (2005): 1030-1061. Web. 18 Nov 2010. <http://au4sb9ax7m.scholar.serialssolutions.com/?sid=google&auinit=A&aulast=Ishimaru&atitle=Theory+and+application+of+wave+propagation+and+scattering+in+random+media&title=Proceedings+of+the+IEEE&volume=65&issue=7&date=2005&spage=1030&issn=0018-9219>.

Jocelyn Bessey, Enrico Cafaro, Victoria Klun, James McElroy, Jr., Jennifer Shaw. 1993. *Venice Canal Studies*. WPI Interactive Qualifying Project.

Kurpis, Brian. "Frequently Asked Questions." *HurricaneKatrinaRelief.com*. HurricanKatrinaRelief.com, 2005-2009. Web. 1 Dec 2010. <http://www.hurricanekatrinarelief.com/about_us.html>

Lane, Frederic Chapin. 1973. *Venice, a maritime republic*. Baltimore: Johns Hopkins University Press.

Macdonald, K. C. 1982. Mid-ocean ridges: Fine scale tectonic, volcanic and hydrothermal processes within the plate boundary zone. *Annual Review of Earth and Planetary Sciences* 10 : 155.

MEDEX winds. in Naval Research Laboratory [database online]. 1999 [cited September 8 2010]. Available from http://www.nrlmry.navy.mil/~medex/tutorial/medex/winds/wind_all.html.

Our restless tides. Center for Operational Oceanographic Product and Services [database online]. 1998 [cited September 8 2010]. Available from http://www.co-ops.nos.noaa.gov/restles1.html.

Ozbas, Halil I., James William Horstick, Matthew John Crawford, Alexander Peter Borrelli, Fabio Carrera, and Stephen J. Weininger. 1999. *Quantification of sediment sources in the city of venice, italy*. WPI Interactive Qualifying Project.

Re, I., and P. Endangerment. 2006. United states environmental protection agency.

Sartori, Umberto. "Report on flood-tide in the Lagoon of Venice, 2009." *Venice Observer*. 2009. Web. 11 Dec 2010. <http://venicexplorer.net/observer/images/maree-venezia-2009/index.php?hlangs=en>.

"The Deadliest Tsunami in History?." National Geographic 07 Jan 2005: n. pag. Web. 1 Dec 2010. <http://news.nationalgeographic.com/news/2004/12/1227_041226_tsunami.html>

"Venice's Great Flood in 1966 destroyed art and homes ." *Telegraph* 01 Dec 2008: n. pag. Web. 1 Dec 2010. <http://www.telegraph.co.uk/news/worldnews/europe/italy/3540719/Venices-Great-Flood-in-1966-destroyed-art-and-homes.html>.

Ward, Alan. "Weighing Earth's Water from Space." Earth Observatory. NASA, 23 Dec 2003. Web. 1 Dec 2010. <http://earthobservatory.nasa.gov/Features/WeighingWater/>

Watts, Jonathan. "China devastated by floods." Guardian (2010): n. pag. Web. 7 Dec 2010. <http://www.guardian.co.uk/world/2010/jun/20/china-devastated-floods>.

APPENDIX A – LITERATURE REVIEW

3.1 Sources Reviewed Primarily for Background Topics Regarding Tides

Centro Previsioni e Segnalacioni Maree - *Città Di Venezia - Home - City of Venice - Città Di Venezia - Il Portale Ufficiale Della Città*. Web. 15 Sept. 2010. <http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/EN/IDPagina/1644.>.

This website contains information on long-term and short-term tide forecasting, along with what the tides are expected to be like while we are in Venice. Many graphs and explanations are included, which provided a clearer understanding of the subject. This source also contains regulations and rules that the City of Venice follows. The source also provided information about what Venetians do in preparation for Acque Alte.

Climate Change 2001: The Scientific Basis - Church, J. A., J. M. Gregory, P. Huybrechts, M. Kuhn, K. Lambeck, M. T. Nhuan, D. Qin, and P. L. Woodworth. *UNEP/GRID-Arendal - Home*. Web. 15 Sept. 2010. <http://www.grida.no/climate/ipcc_tar/wg1/408.htm>

This chapter assesses the current knowledge regarding the global and regional rates of change of sea level in relation to climate change. However, because of the slow response to past conditions of the oceans and ice sheets and the consequent land movements, changes in sea level prior to the historical record are considered.

Fine Scale Tectonic, Volcanic and Hydrothermal Processes Within the Plate Boundary Zone – Macdonald, Ken C. *Annual Reviews*, Inc. Web. 15 Sept. 2010. <http://www.annualreviews.org/doi/pdf/10.1146/annurev.ea.10.050182.001103>

This article focuses primarily on plate tectonics and how they function. It also contains information about mid-ocean ridges and the movement of plates.

Long-term variations on sea level and tidal regime in the lagoon of Venice – Ferla, M, M Cordella, L Michielli, and A Rusconi. *Estuarine, Coastal and Shelf Science* 75.1-2 (2007): 214-222. Web. 18 Nov 2010. <http://au4sb9ax7m.scholar.serialssolutions.com/?sid=google&auinit=M&aulast=Ferla&atitle=Long-term+variations+on+sea+level+and+tidal+regime+in+the+lagoon+of+Venice&title=Estuarine,+coastal+and+shelf+science&volume=75&issue=1-2&date=2007&spage=214&issn=0272-7714>.

This article is an analysis of data collected from the real-time tidal gauge system in the Venice lagoon and specifically the Northern Lagoon. It investigates the possibility of subsidence and eustatism affecting the tide delay, as well as the change in Mean Sea Level.

MEDEX Winds - Naval Research laboratory, Internet, World Wide Web, http://www.nrlmry.navy.mil/~medex/tutorial/medex/winds/wind_all.html, 1999.

This online tutorial provided information regarding the two influential winds in the Mediterranean which have major impacts on the Venetian canals – The Bora and Sirocco. It explains the sources of the winds and how they alter the Adriatic Sea, the Venetian lagoon and the canals.

Our Restless Tides - Center for Operational Oceanographic Product and Services, Internet. World Wide Web, <http://www.co-ops.nos.noaa.gov/restles1.html> February, 1998.

This online written lesson provided information on lunar cycles, solar cycles and the gravitational impact on tides. It was also helpful in identifying tidal inequalities and explained how tides are predicted based on the position of the celestial bodies.

Temporal Variations of Water Flow Between the Venetian Lagoon and the Open Sea – Gačić, Miroslav, Isaac Mancero Mosquera, Vedrana Kovačević, Andrea Mazzoldi, and Vanessa Cardin. *Journal of Marine Systems* 51.1-4 (2004): 33-47. Web. 18 Nov 2010. <http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VF5-4D9D9J1-1&_user=74021&_coverDate=11%2F01%2F2004&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1546050924&_rerunOrigin=google&_acct=C000005878&_version=1&_urlVersion=0&_userid=74021&md5=c6af8045a1270d073ce7c65156a0f25c&searchtype=a>.

This article discusses the tide variance and the effect is has on the islands in the lagoon. It also analyzes the different flows through the three Venice Lagoon inlets: the Malmocco, Lido, and Chioggia inlets. The trends of the difference in tidal flows throughout the past century are also analyzed.

Theory and Application of Wave Propagation and Scattering in Random Media - Ishimaru, A. *Proceedings of the IEEE* 65.7 (2005): 1030-1061. Web. 18 Nov 2010. <http://au4sb9ax7m.scholar.serialssolutions.com/?sid=google&auinit=A&aulast=Ishimaru&atitle=Theory+and+application+of+wave+propagation+and+scattering+in+random+media&title=Proceedings+of+the+IEEE&volume=65&issue=7&date=2005&spage=1030&issn=0018-9219>.

This report discusses the change in the study of wave propagation due to changes in the atmosphere, the ocean, and biological media who's characteristics are randomly varying in time and space. It introduces the idea of waves being distributed randomly and continuous waves. Also, they give reasons as to why some tides are more intense than others and how they fluctuated throughout the lunar cycle.

U.S. Environmental Protection Agency: Web. 15 Sept. 2010. <http://www.epa.gov/>.

This source contains predications made by EPA regarding the future changes in the natural sea level. It also shows how the rate of the rising sea level is changing.

Venice: A Maritime Republic - Lane, Frederic. Baltimore: Johns Hopkins UP, 1973.

This article contains an in depth exploration of Venice's problem with subsidence. It discussed various theories for the sinking of the land as well as the historical context of the issue.

Sources Reviewed Primarily for Background Topics Regarding Canal and Lagoon History and Information

Canal Excavation - *Insula: A Future for Venice*. 2008. Insula spa. Web. 25 Sep 2010. <http://www.insula.it/scavorii_en.asp?show=2&subsection=10>

This part of the Insula Webpage provided information on canal excavation and the reason why it is a necessary part of maintenance in Venice. It also describes two types of dredging that Insula performs: deep-water dredging and dry-bottom dredging.

Quantification of Sediment Sources in the Canals of the City of Venice, Italy - Borrelli, A., Crawford, M., Horstick, J., Ozbas, H.. 1999. WPI Interactive Qualifying Project.

This IQP provided information about the Venetian sewer system and the composition of the canal walls and how sedimentation buildup in the canals influences other canal aspects such as sedimentation.

The Ancient Venetian Sewer System. - Insula: A Future for Venice. Insula spa. 2008. Web. 25 Sep 2010. <http://www.insula.it/resource/pdf/gatoli_eng.pdf>

This part of the Insula Webpage provided information about the history and construction of the Venetian sewage system.

Venice Canal Studies – Jocelyn Bessey, Enrico Cafaro, Victoria Klun, James McElroy, Jr., Jennifer Shaw. 1993. WPI Interactive Qualifying Project.

This Interactive Qualifying Project written by students that previously studied at the Venice Project Center was a useful resource for background on the Venice Lagoon.

Venice the Tourist Maze: A Cultural Critique of the World's Most Touristed City - Davis, Robert and Marvin, Garry, 2004.

This book provided information about the history of Venice and addresses many of the issues that Venice faces. It also provided information on the current state of the canals and what is being done to protect them. In describing the history of the Venice, the book also discusses the Venetian sewer system from past to present.

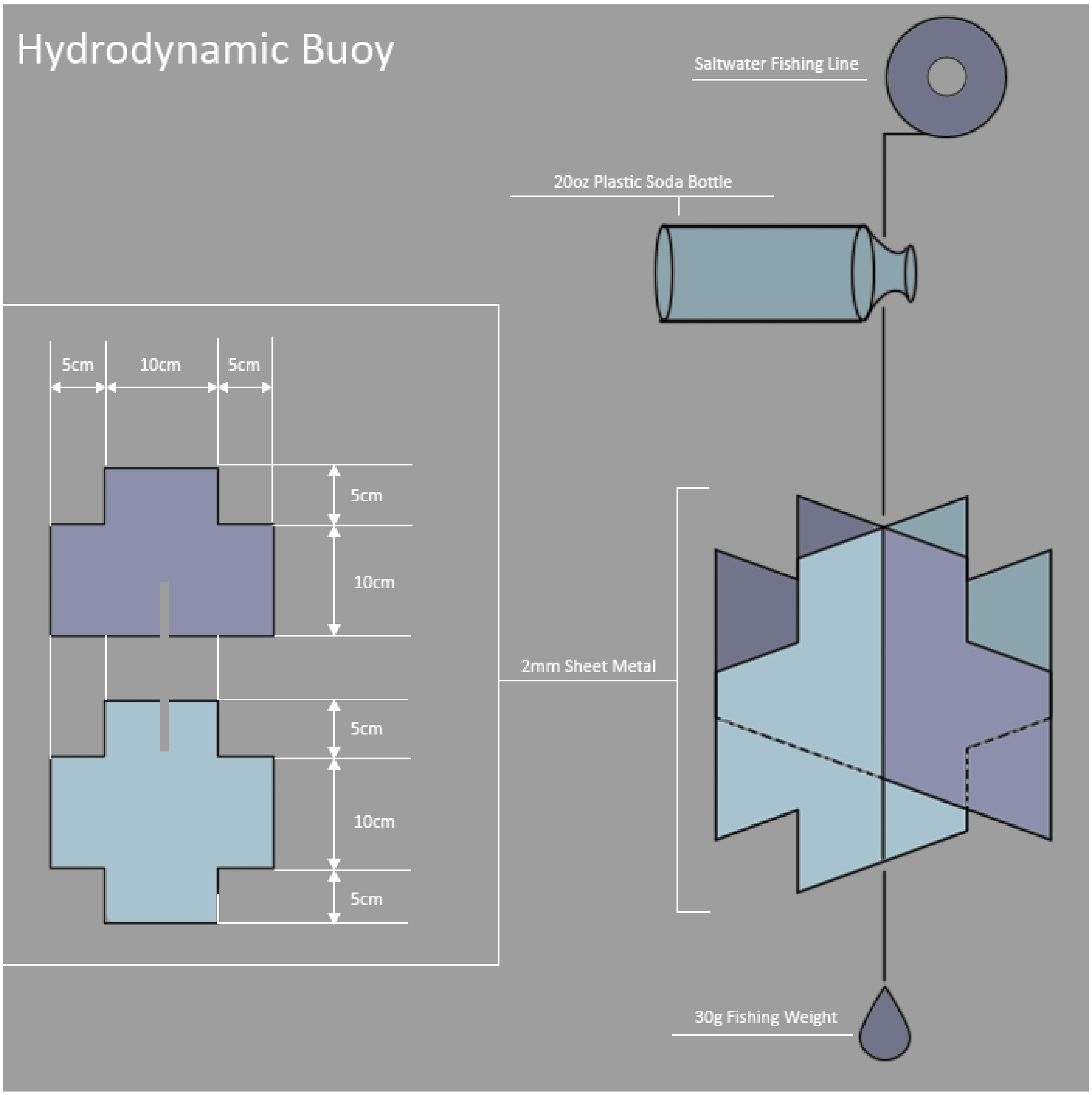
Sources Reviewed Primarily for Methodology

Hydrodynamics of the Inner Canals of Venice – Biscotti, Christine, Emery, Adrea, Pistilli, Maxwell and Zsofka, Joseph. 1999. WPI Interactive Qualifying Project.

This past WPI IQP served as a guideline to help determine what should be included in the background, literature review and methodology. The report described the basic hydrodynamic behavior of the canals in 1999 and provided a benchmark to compare to the present day hydrodynamics of the canals. It outlined our hydrodynamics methodology entirely and a basis for results comparison.

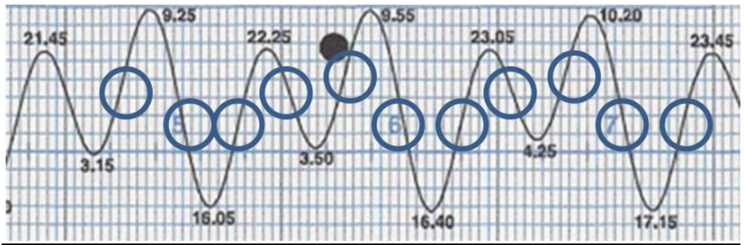
APPENDIX B – HYDRODYNAMICS DEVICE

HYDRODYNAMICS DEVICE



APPENDIX C – SCHEDULE FOR HYDRODYNAMICS TESTING

November 4th – 6th 2010 – NEW MOON



<u>November 4th – Thursday (Day before new moon)</u>

Cannaregio

High Tide (8:50) – Low Tide (15:30) – Tide going OUT

PANA2 OUT – Tested at 12:35, tide level ~23 cm, flowing in the direction of North to South

Average Velocity = 0.31 m/s = 31 cm/s

MIRA OUT – Tested at 12:45, tide level ~17 cm, flowing in the direction of East to West

Average Velocity = 0.25 m/s = 25 cm/s

WIDM1 OUT – Tested at 12:55, tide level ~15 cm, flowing in the direction of North to South

Average Velocity = 0.24 m/s = 24 cm/s

PANA1 OUT – Tested at 13:05, tide level ~12 cm, flowing in the direction of North to South

Average Velocity = 0.096 m/s = 9.6 cm/s

Low Tide (15:30) – High Tide (21:45) – Tide going IN

PANA2 IN – Tested at 18:15, tide level ~23 cm, flowing in the direction of South to North

Average Velocity = 0.31m/s = 31 cm/s

MIRA IN – Tested at 18:05, tide level ~17 cm, flowing in the direction of West to East

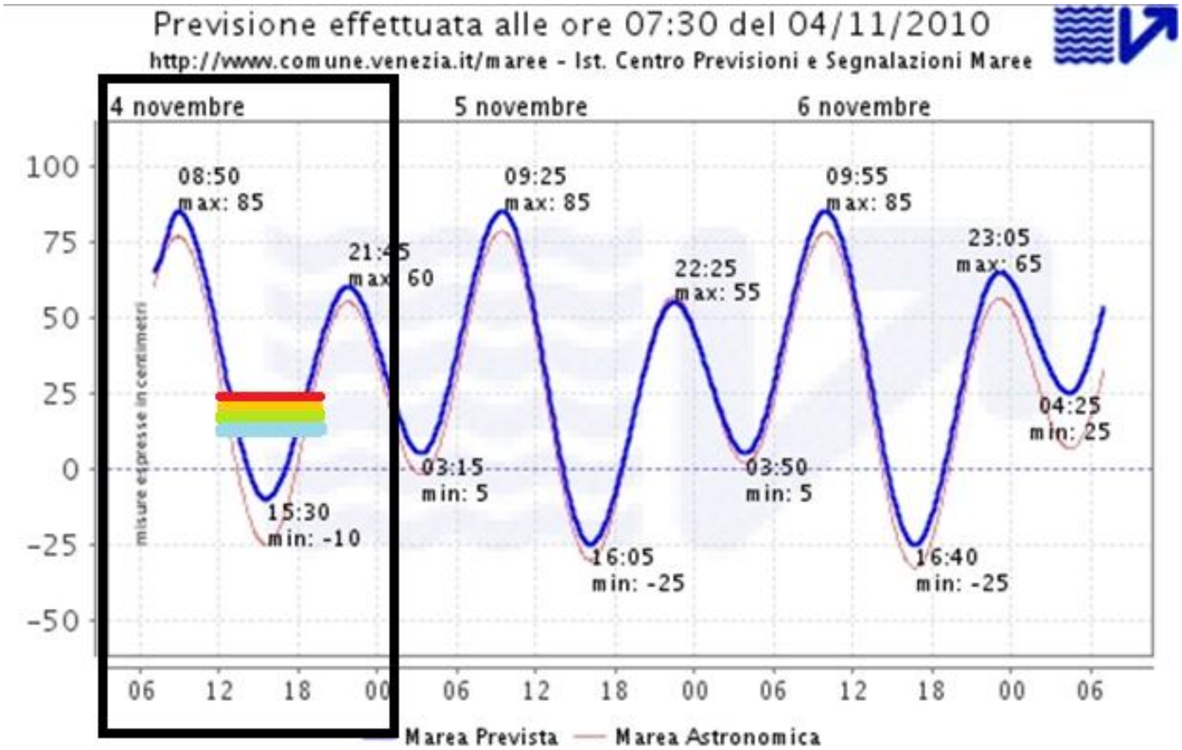
Average Velocity = 0.24 m/s = 24 cm/s

WIDM1 IN – Tested at 17:55, tide level ~15 cm, flowing in the direction of South to North

Average Velocity = 0.15 m/s = 15 cm/s

PANA1 IN – Tested at 17:43, tide level ~12 cm, flowing in the direction of South to North

Average Velocity = 0.076 m/s = 7.6 cm/s



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<u>November 5th – Friday (New Moon)</u>

Cannaregio

High Tide (9:25) – Low Tide (16:05) – Tide going OUT

APOS3 OUT – Tested at 12:30, tide level ~47 cm, flowing in the direction of North to South

Average Velocity = 0.16 m/s = 16 cm/s

APOS1 OUT – Tested at 12:45, tide level ~44 cm, flowing in the direction of North to South

Average Velocity = 0.29 m/s = 29 cm/s

GOZZ OUT – Tested at 13:00, tide level ~40 cm, flowing in the direction of West to East

Average Velocity = 0.18 m/s = 18 cm/s

GESU2 OUT – Tested at 13:16, tide level ~37 cm, flowing in the direction of North to South

Average Velocity = 0.17 m/s = 17 cm/s

CATE3 OUT – Tested at 13:30, tide level ~34 cm, flowing in the direction of West to East

Average Velocity = 0.083 m/s = 8.3 cm/s

Low Tide (16:05PM) – Low Tide (22:25) – Tide going IN

APOS3 IN – Tested at 19:50, tide level ~47 cm, flowing in the direction of South to North

Average Velocity = 0.29 m/s = 29 cm/s

APOS1 IN – Tested at 19:35, tide level ~44 cm, flowing in the direction of South to North

Average Velocity = 0.47 m/s = 47 cm/s

GOZZ IN – Tested at 19:25, tide level ~40 cm, flowing in the direction of South to North

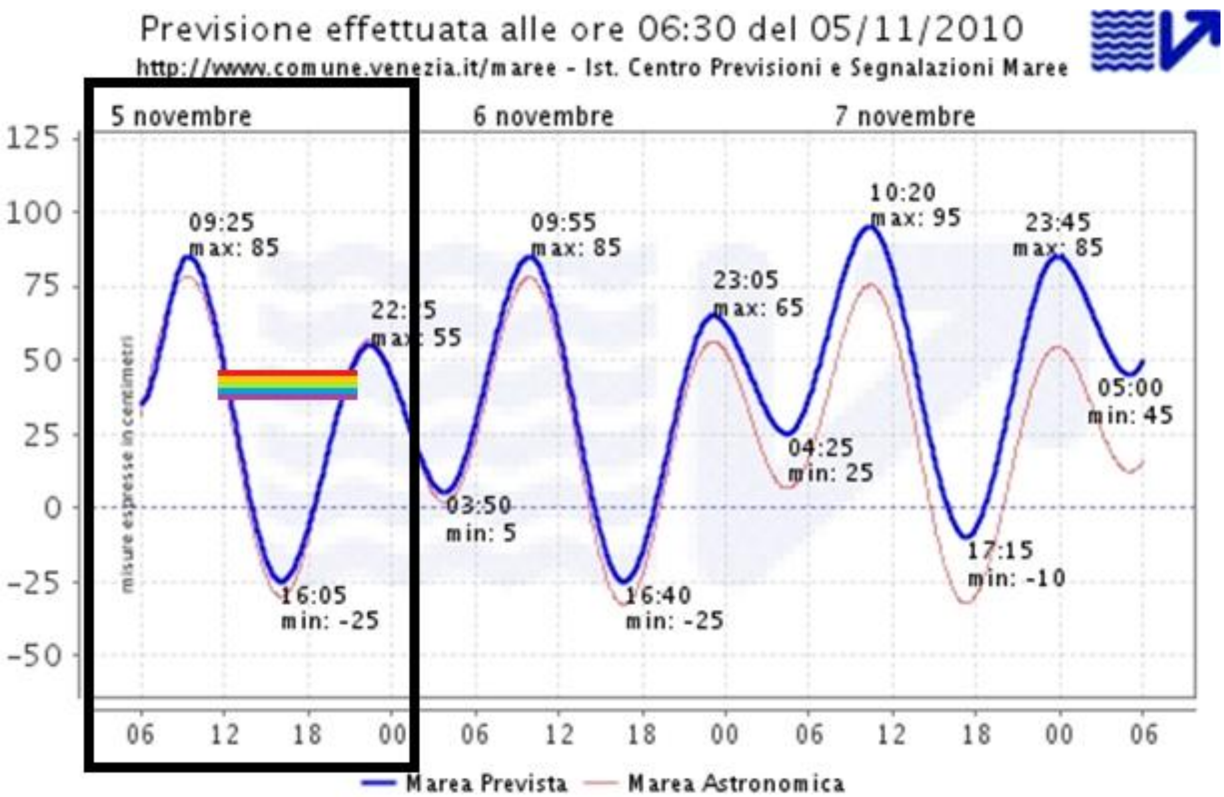
Average Velocity = 0.08 m/s = 8 cm/s

GESU2 IN – Tested at 19:15, tide level ~37 cm, flowing in the direction of South to North

Average Velocity = 0.2 m/s = 20 cm/s

CATE3 IN – Tested at 19:00, tide level ~34 cm, flowing in the direction of East to West

Average Velocity = 0.086 m/s = 8.6 cm/s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<u>November 6th – Saturday (Day after new moon)</u>

San Marco

High Tide (9:55) – Low Tide (16:40) – Tide going OUT

VEST2 OUT – Tested at 12:18, tide level ~48 cm, flowing in the direction of West to East

Average Velocity = 0.08 m/s = 8 cm/s

ANZO2 OUT – Tested at 12:43, tide level ~43 cm, flowing in the direction of West to East

Average Velocity = 0.15 m/s = 15 cm/s

SANT OUT – Tested at 13:15, tide level ~38 cm, flowing in the direction of North to South

Average Velocity = 0.18 m/s = 18 cm/s

PROC OUT – Tested at 13:45, tide level ~34 cm, flowing in the direction of East to West

Average Velocity = 0.11 m/s = 11 cm/s

FERA2 OUT – Tested at 14:13, tide level ~30 cm, flowing in the direction of West to East

Average Velocity = 0.11 m/s = 11 cm/s

BARE1 OUT – Tested at 14:30, tide level ~27 cm, flowing in the direction of North to South

Average Velocity = 0.13 m/s = 13 cm/s

Low Tide (16:40) – Low Tide (23:05) – Tide going IN

VEST2 IN – Tested at 20:22, tide level ~48 cm, flowing in the direction of East to West

Average Velocity = 0.08 m/s = 8 cm/s

ANZO2 IN – Tested at 20:10, tide level ~43 cm, flowing in the direction of East to West

Average Velocity = 0.13 m/s = 13 cm/s

SANT IN – Tested at 19:53, tide level ~38 cm, flowing in the direction of North to South

Average Velocity = 0.16 m/s = 16 cm/s

PROC IN – Tested at 19:36, tide level ~34 cm, flowing in the direction of West to East

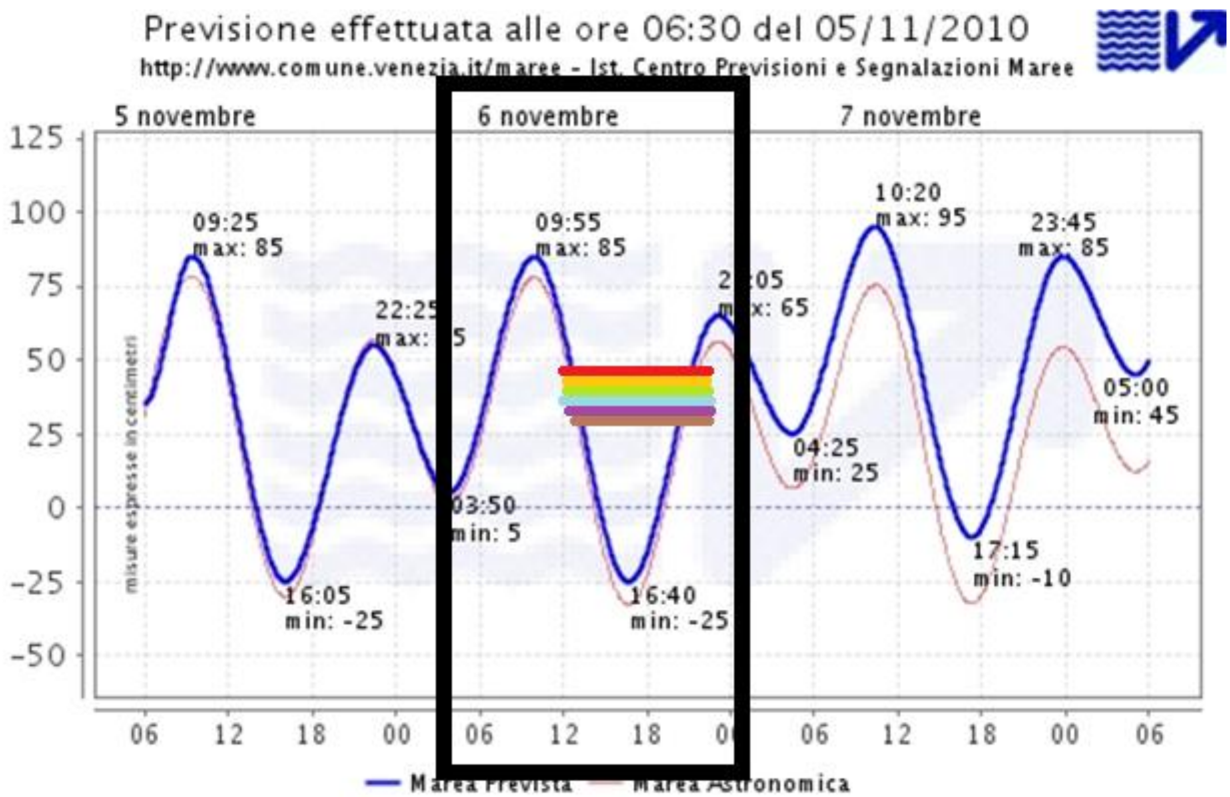
Average Velocity = 0.07 m/s = 7 cm/s

FERA2 IN – Tested at 19:22, tide level ~30 cm, flowing in the direction of East to West

Average Velocity = 0.08 m/s = 8 cm/s

BARE1 IN – Tested at 19:00, tide level ~27 cm, flowing in the direction of South to North

Average Velocity = 0.07 m/s = 7 cm/s



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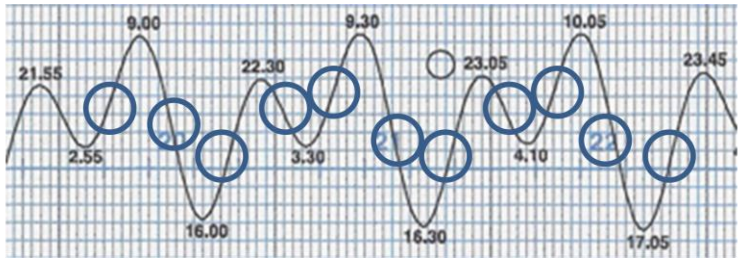
November 20th-22nd 2010 – FULL MOON



<u>November 20th – Saturday (Day before full moon)</u>

San Polo

High Tide (9:30AM) – Low Tide (16:00) – Tide going OUT

DOMI OUT – Tested at 11:44, tide level ~70 cm, flowing in the direction of North to South

Average Velocity = 0.13 m/s = 13 cm/s

2TOR2 OUT – Tested at 12:00, tide level ~65 cm, flowing in the direction of East to West

Average Velocity = 0.26 m/s = 26 cm/s

ORIO1 OUT– Tested at 12:09, tide level ~62 cm, flowing in the direction of North/East to South/West

Average Velocity = 0.09 m/s = 9 cm/s

STIN OUT – Tested at 12:35, tide level ~52 cm, flowing in the direction of East to West

Average Velocity = 0.11 m/s = 11 cm/s

FRAR1 OUT – Tested at 12:46, tide level ~49 cm, flowing in the direction of North to South

Average Velocity = 0.118 m/s = 11.8 cm/s

Low Tide (16:00) – High Tide (22:30) – Tide going IN

FRAR1 IN – Tested at 19:47, tide level ~49 cm, flowing in the direction of South to North

Average Velocity = 0.083 m/s = 8.3 cm/s

STIN IN – Tested at 20:30, tide level ~52 cm, flowing in the direction of West to East

Average Velocity = 0.053 m/s = 5.3 cm/s

ORIO1 IN – Tested at 20:53, tide level ~62 cm, flowing in the direction of North/East to South/West

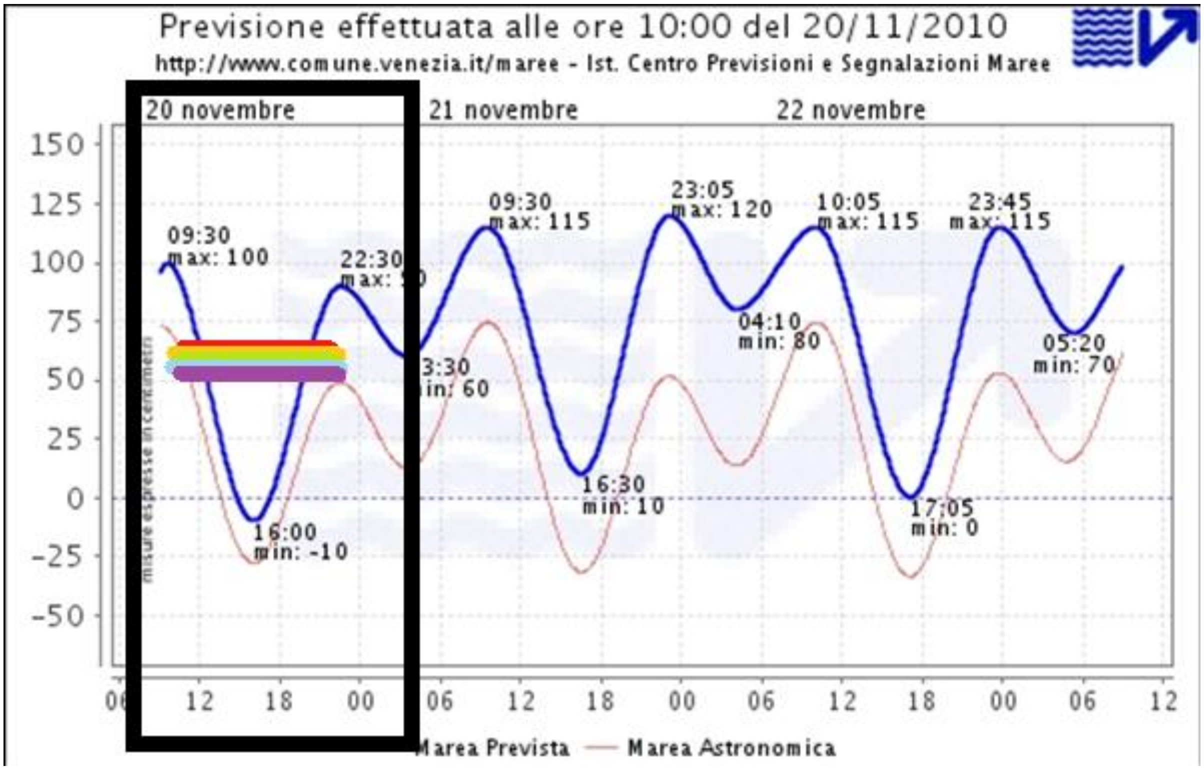
Average Velocity = 0.11 m/s = 11 cm/s

2TOR2 IN – Tested at 21:15, tide level ~65 cm, flowing in the direction of West to East

Average Velocity = 0.2 m/s = 20 cm/s

DOMI IN – Tested at 21:40, tide level ~70 cm, flowing in the direction of South to North

Average Velocity = 0.14 m/s = 14 cm/s



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November 21st – Sunday (Day of full moon)

Castello

High Tide (9:30AM) – Low Tide (16:30) – Tide going OUT

LIO OUT – Tested at 12:32, tide level ~70 cm, flowing in the direction of North to South

Average Velocity = 0.028 m/s = 2.8 cm/s

TETT1 OUT – Tested at 13:15, tide level ~67 cm, flowing in the direction of West to East

Average Velocity = 0.226 m/s = 22.6 cm/s

PEST1 OUT – Tested at 13:28, tide level ~63 cm, flowing in the direction of West to East

Average Velocity = 0.58 m/s = 58 cm/s

FORM OUT – Tested at 13:35, tide level ~60 cm, flowing in the direction of South/West to North/East

Average Velocity = 0.066 m/s = 6.6 cm/s

Low Tide (16:30AM) – High Tide (23:45) – Tide going IN

FORM IN – Tested at 19:30, tide level ~60 cm, flowing in the direction of North/East-South/West

Average Velocity = 0.106 m/s = 10.6 cm/s

PEST1 IN – Tested at 19:45, tide level ~63 cm, flowing in the direction of East to West

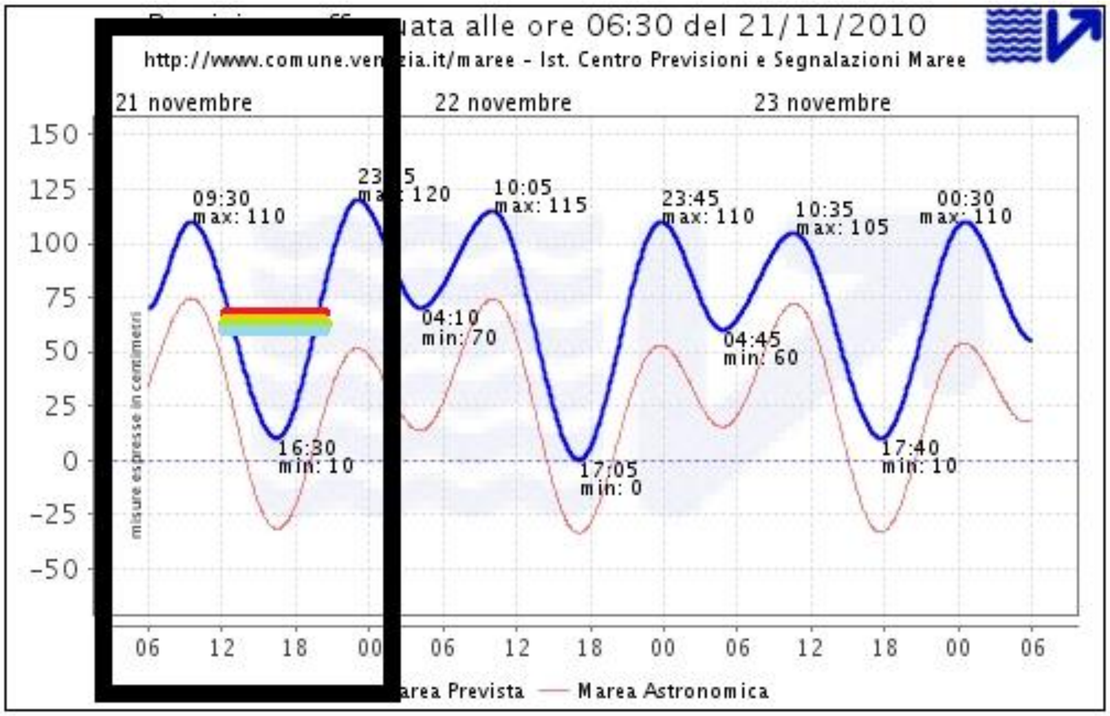
Average Velocity = 0.286 m/s = 28.6 cm/s

TETT1 IN – Tested at 20:00, tide level ~67 cm, flowing in the direction of East to West

Average Velocity = 0.13 m/s = 13 cm/s

LIO IN – Tested at 2-:15, tide level ~70 cm, flowing in the direction of South to North

Average Velocity = 0.07 m/s = 7.0 cm/s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November 22nd – Monday (Day after full moon)

San Polo

High Tide (10:05) – Low Tide (17:05) – Tide going OUT

TOMA OUT – Tested at 13:00, tide level ~70 cm, flowing in the direction of West to East

Average Velocity = 0.216 m/s = 21.6 cm/s

POLO4 OUT – Tested at 13:20, tide level ~67 cm, flowing in the direction of South to North

Average Velocity = 0.12 m/s = 12.0 cm/s

Device Broke

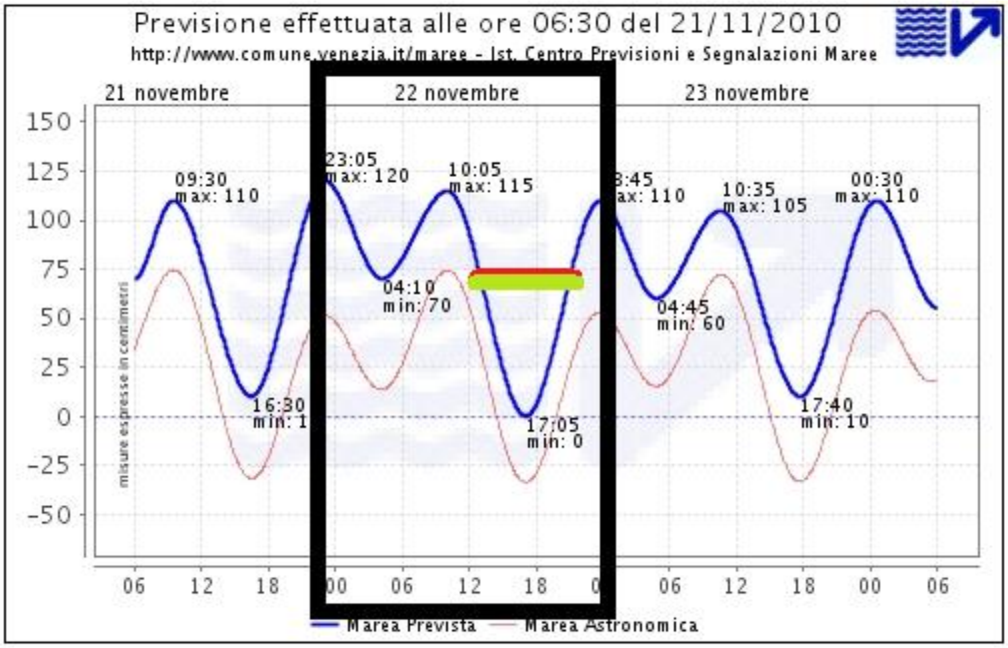
Low Tide (17:05) – Low Tide (23:45) – Tide going IN

POLO4 IN – Tested at 21:55, tide level ~67 cm, flowing in the direction of South to North

Average Velocity = 0.197 m/s = 19.7 cm/s

TOMA IN – Tested at 22:22, tide level ~70 cm, flowing in the direction of East to West

Average Velocity = 0.20 m/s = 20.0 cm/s



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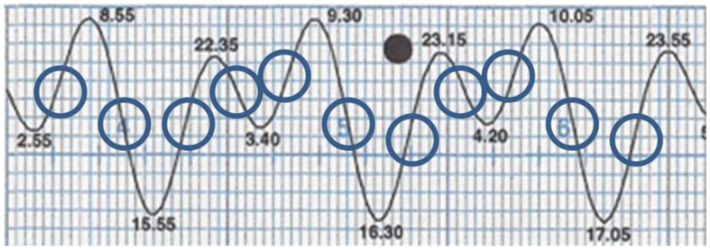
December 4th-6th 2010 – NEW MOON



December 4th – Saturday (Day before new moon)

Cannaregio Group 1

High Tide (8:55) – Low Tide (15:55) – Tide going OUT

CATE2 OUT – Tested at 11:35, tide level ~65 cm, flowing in the direction of West to East

Average Velocity = 0.16 m/s = 16 cm/s

CAT1 OUT – Tested at 11:45, tide level ~63 cm, flowing in the direction of West to East

Average Velocity = 0.24 m/s = 24 cm/s

PRIU3 OUT – Tested at 11:55, tide level ~60 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

PRIU2 OUT – Tested at 12:00, tide level ~60 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

PRIU1 OUT – Tested at 12:05, tide level ~60 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

Low Tide (15:55) – High Tide (22:30) – Tide going IN

PRIU1 IN – Tested at 19:12, tide level ~60 cm, flowing in the direction of West to East

Average Velocity = 0.035 m/s = 3.5 cm/s

PRIU2 IN – Tested at 19:20, tide level ~60 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

PRIU3 IN – Tested at 19:30, tide level ~60 cm, not flowing

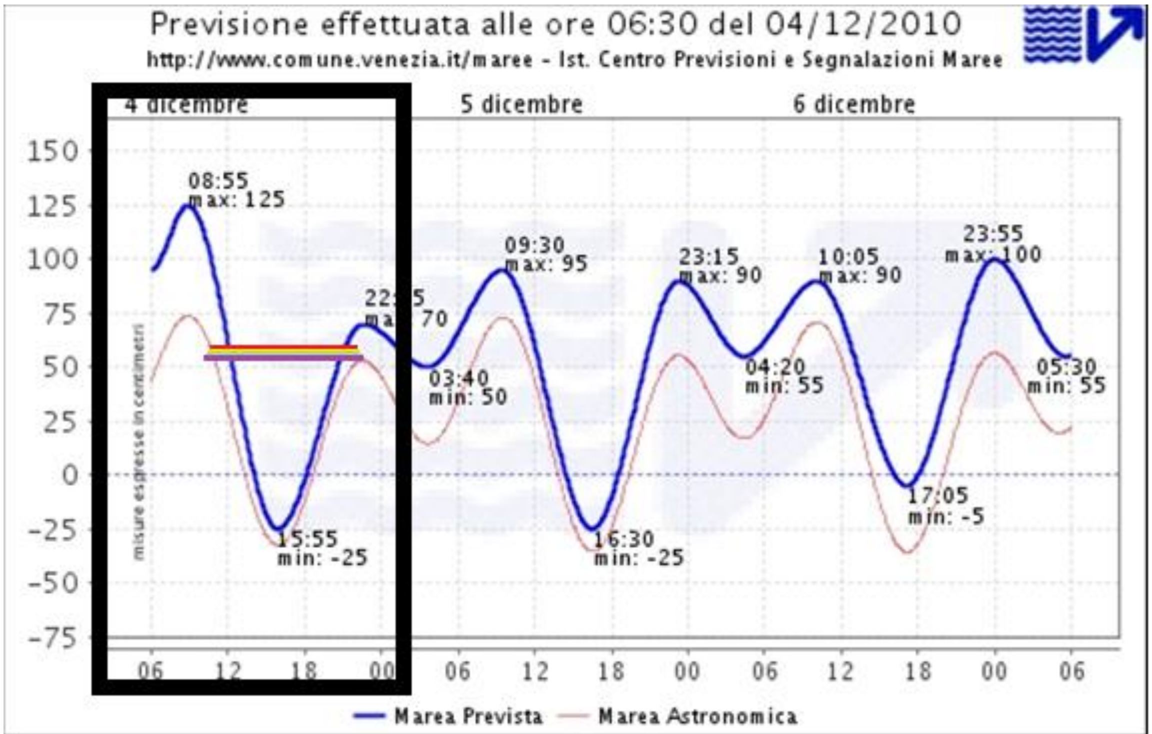
Average Velocity = 0 m/s = 0 cm/s

CATE1 IN – Tested at 19:37, tide level ~63 cm, flowing in the direction of East to West

Average Velocity = 0.115 m/s = 11.5 cm/s

CATE2 IN – Tested at 19:45, tide level ~65 cm, flowing in the direction of East to West

Average Velocity = 0.086 m/s = 8.6 cm/s


Previsione effettuata alle ore 06:30 del 04/12/2010
http://www.comune.venezia.it/maree - Ist. Centro Previsioni e Segnalazioni Maree
4 dicembre
5 dicembre
6 dicembre
150
125
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75
50
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-50
-75
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max: 125
15:55
min: -25
03:40
min: 50
09:30
max: 95
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min: -25
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max: 90
04:20
min: 55
10:05
max: 90
17:05
min: -5
23:55
max: 100
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Marea Prevista
Marea Astronomica

December 4th – Saturday (Day before new moon)

Cannaregio Group 2

High Tide (8:55) – Low Tide (15:55) – Tide going OUT

CREA3 OUT – Tested at 12:05, tide level ~50 cm, flowing in the direction of NorthWest to SouthEast

Average Velocity = 0.113 m/s = 11.3 cm/s

GIOB OUT – Tested at 12:30, tide level ~48 cm, flowing in the direction of South to North

Average Velocity = 0.063 m/s = 6.3 cm/s

BATE1 OUT – Tested at 14:22, tide level ~35 cm, flowing in the direction of NorthWest to SouthEast

Average Velocity = 0.33 m/s = 33 cm/s

GHET OUT – Tested at 14:37, tide level ~33 cm, flowing in the direction of South to North

Average Velocity = 0.086 m/s = 8.6 cm/s

Low Tide (15:55) – High Tide (22:30) – Tide going IN

GHET IN – Tested at 19:04, tide level ~33 cm, flowing in the direction of North to South

Average Velocity = 0.048 m/s = 4.8 cm/s

BATE1 IN – Tested at 19:28, tide level ~35 cm, flowing in the direction of SouthEast to NorthWest

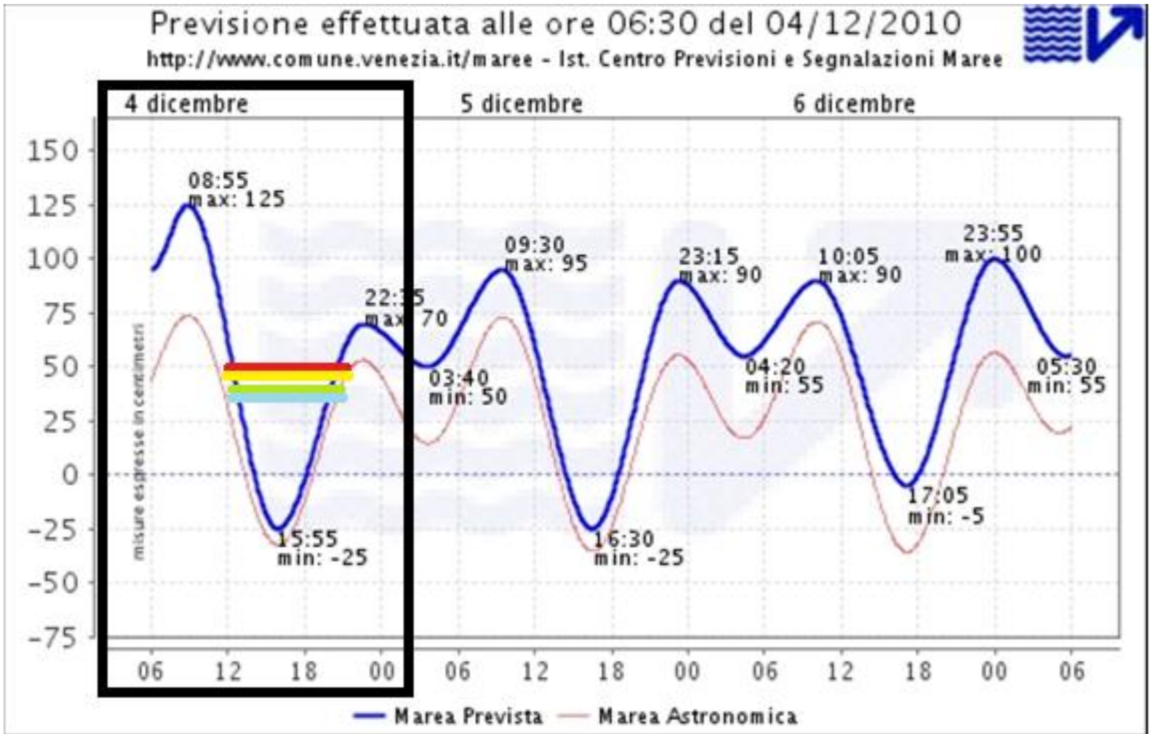
Average Velocity = 0.243 m/s = 24.3 cm/s

GIOB IN – Tested at 19:39, tide level ~48 cm, flowing in the direction of South to North

Average Velocity = 0.069 m/s = 6.9 cm/s

CREA3 IN – Tested at 20:13, tide level ~50 cm, flowing in the direction of SouthEast to NorthWest

Average Velocity = 0.039 m/s = 3.9 cm/s


Previsione effettuata alle ore 06:30 del 04/12/2010
http://www.comune.venezia.it/maree - Ist. Centro Previsioni e Segnalazioni Maree
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10:05
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23:55
max: 100
03:40
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04:20
min: 55
05:30
min: 55
15:55
min: -25
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misure espresse in centimetri
Marea Prevista
Marea Astronomica

<u>December 5th – Sunday (Day of new moon)</u>

Dorsoduro

High Tide (9:30) – Low Tide (16:30) – Tide going OUT

SALU1 OUT – Tested at 11:41, tide level ~67 cm, flowing in the direction of North to South

Average Velocity = 0.055 m/s = 5.5 cm/s

FORN1 OUT – Tested at 11:50, tide level ~65 cm, flowing in the direction of North to South

Average Velocity = 0.15 m/s = 15.0 cm/s

FORN2 OUT – Tested at 12:00, tide level ~63 cm, flowing in the direction of North to South

Average Velocity = 0.088 m/s = 8.8 cm/s

VIO OUT – Tested at 12:15, tide level ~60 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

TROV3 OUT – Tested at 12:25, tide level ~57 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

TROV2 OUT – Tested at 12:26, tide level ~55 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

OGNI1 OUT – Tested at 12:40, tide level ~54 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

OGNI2 OUT – Tested at 12:45, tide level ~52 cm, flowing in the direction of West to East

Average Velocity = 0.053 m/s = 5.3 cm/s

ROMI1 OUT – Tested at 13:00, tide level ~50 cm, flowing in the direction of North to South

Average Velocity = 0.059 m/s = 5.9 cm/s

Low Tide (16:30) – High Tide (23:15) – Tide going IN

ROMI1 IN – Tested at 19:35, tide level ~50 cm, flowing in the direction of North to South

Average Velocity = 0.115 m/s = 11.5 cm/s

OGNI2 IN – Tested at 19:38, tide level ~52 cm, flowing in the direction of West to East

Average Velocity = 0.113 m/s = 11.3 cm/s

OGNI1 IN – Tested at 19:44, tide level ~54 cm, flowing in the direction of West to East

Average Velocity = 0.155 m/s = 15.5 cm/s

TROV2 IN – Tested at 20:01, tide level ~55 cm, flowing in the direction of North to South

Average Velocity = 0.19 m/s = 19.0 cm/s

TROV3 IN – Tested at 20:07, tide level ~57 cm, flowing in the direction of North to South

Average Velocity = 0.17 m/s = 17.0 cm/s

VIO IN – Tested at 20:21, tide level ~60 cm, flowing in the direction of North to South

Average Velocity = 0.13 m/s = 13.0 cm/s

FORN2 IN – Tested at 20:33, tide level ~63 cm, flowing in the direction of North to South

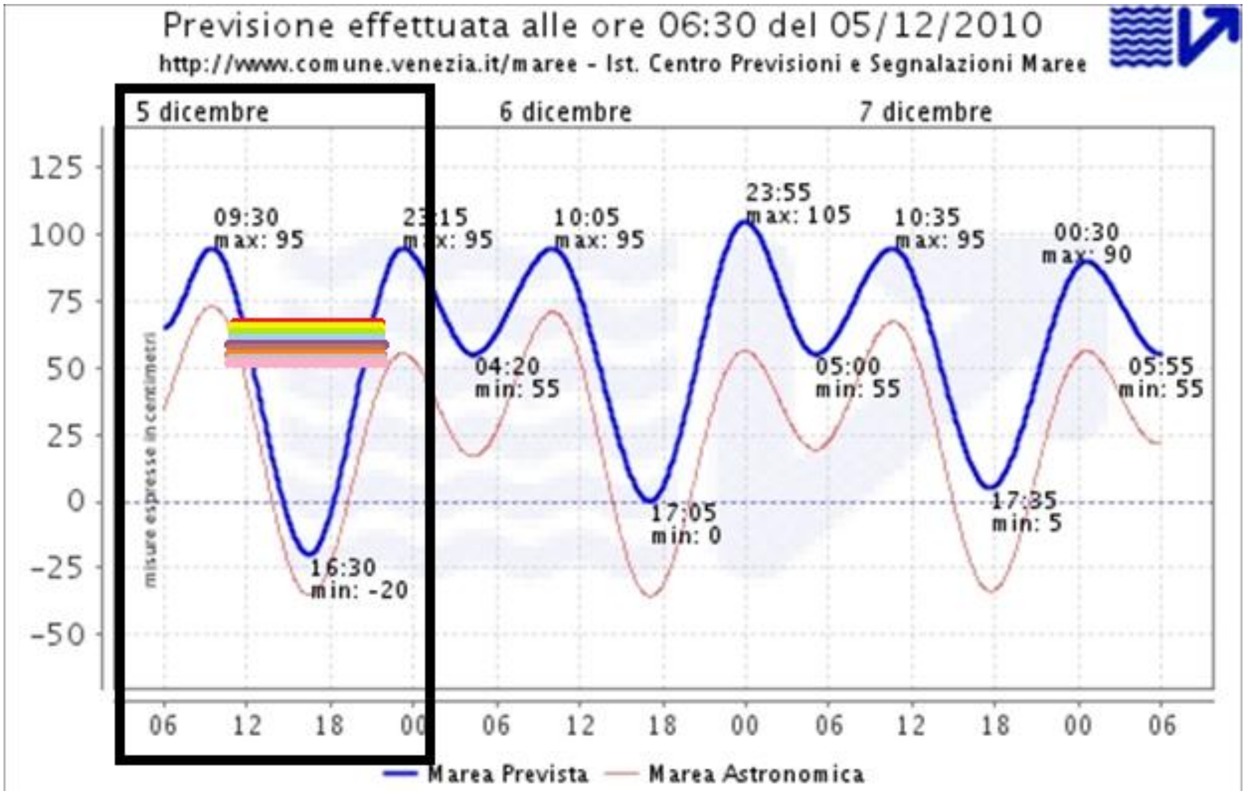
Average Velocity = 0.16m/s = 16.0 cm/s

FORN1 IN – Tested at 20:39, tide level ~65 cm, flowing in the direction of North to South

Average Velocity = 0.51 m/s = 51.0 cm/s

SALU1 IN – Tested at 20:53, tide level ~67 cm, flowing in the direction of North to South

Average Velocity = 0.27 m/s = 27.0 cm/s


Previsione effettuata alle ore 06:30 del 05/12/2010
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16:30 min: -20
04:20 min: 55
10:05 max: 95
17:05 min: 0
23:55 max: 105
05:00 min: 55
10:35 max: 95
17:35 min: 5
00:30 max: 90
05:55 min: 55
Marea Prevista
Marea Astronomica

December 5th – Sunday (Day of new moon)

Santa Croce

High Tide (9:30) – Low Tide (16:30) – Tide going OUT

MUNE OUT – Tested at 11:38, tide level ~67 cm, flowing in the direction of North to South

Average Velocity = 0.156 m/s = 15.6 cm/s

MAGA OUT – Tested at 11:53, tide level ~65 cm, flowing in the direction of East to West

Average Velocity = 0.038 m/s = 3.8 cm/s

BURC OUT – Tested at 12:12, tide level ~62 cm, flowing in the direction of North to South

Average Velocity = 0.14 m/s = 14.0 cm/s

MAGG3 OUT – Tested at 12:35, tide level ~58 cm, flowing in the direction of North to South

Average Velocity = 0.115 m/s = 11.5 cm/s

TERE1 OUT – Tested at 12:48, tide level ~55 cm, flowing in the direction of North to South

Average Velocity = 0.062 m/s = 6.2 cm/s

MAGG2 OUT – Tested at 12:53, tide level ~53 cm, flowing in the direction of North to South

Average Velocity = 0.094 m/s = 9.4 cm/s

MAGG1 OUT – Tested at 13:10, tide level ~49 cm, flowing in the direction of North to South

Average Velocity = 0.067 m/s = 6.7 cm/s

TREP3 OUT – Tested at 13:34, tide level ~47 cm, flowing in the direction of North to South

Average Velocity = 0.15 m/s = 15.0 cm/s

Low Tide (16:30) – High Tide (23:15) – Tide going IN

TREP3 IN – Tested at 19:06, tide level ~47 cm, flowing in the direction of South to North

Average Velocity = 0.029 m/s = 2.9 cm/s

MAGG1 IN – Tested at 19:27, tide level ~49 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

MAGG2 IN – Tested at 19:34, tide level ~53 cm, flowing in the direction of South to North

Average Velocity = 0.017 m/s = 1.7 cm/s

TERE1 IN – Tested at 19:41, tide level ~55 cm, flowing in the direction of South to North

Average Velocity = 0.025 m/s = 2.5 cm/s

MAGG3 IN – Tested at 19:57, tide level ~58 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

BURC IN – Tested at 20:11, tide level ~62 cm, flowing in the direction of South to North

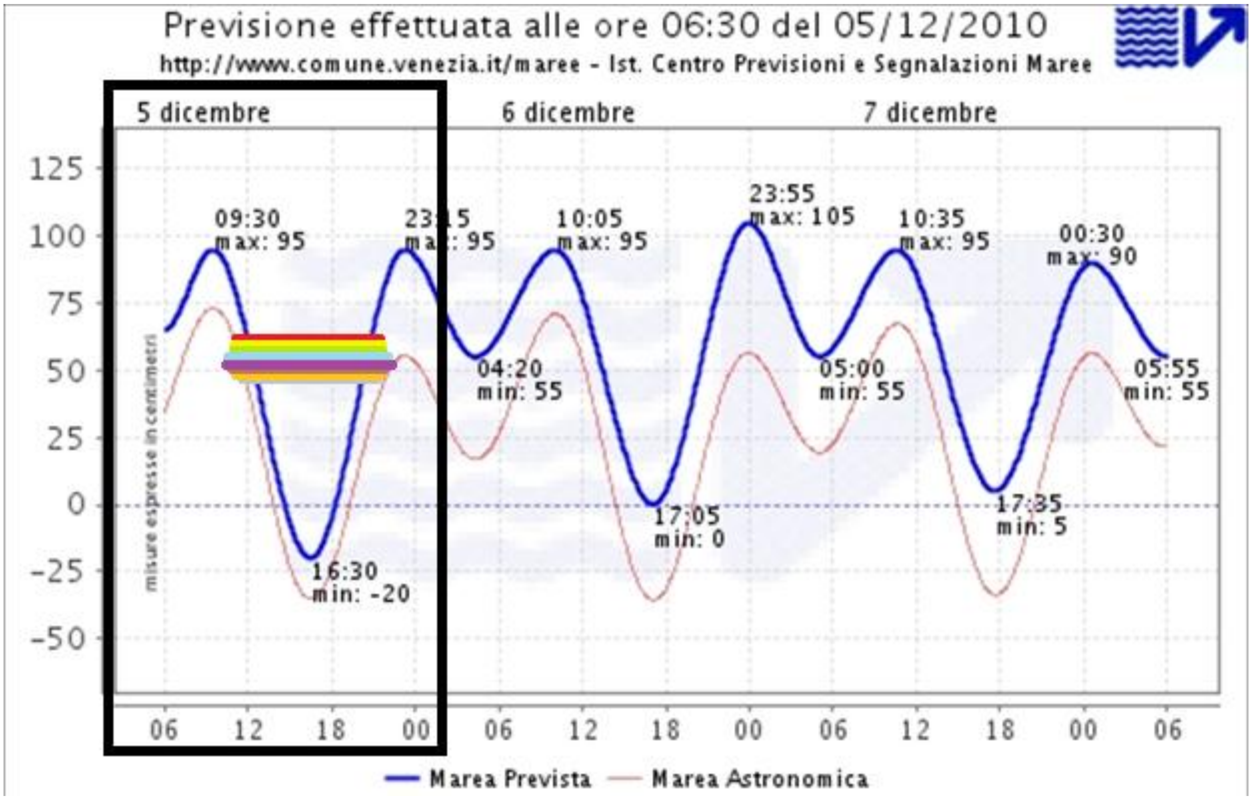
Average Velocity = 0.092 m/s = 9.2 cm/s

MAGA IN – Tested at 20:21, tide level ~65 cm, not flowing

Average Velocity = 0 m/s = 0 cm/s

MUNE IN – Tested at 20:34, tide level ~67 cm, flowing in the direction of South to North

Average Velocity = 0.146 m/s = 14.6 cm/s



Previsione effettuata alle ore 06:30 del 05/12/2010
http://www.comune.venezia.it/maree - Ist. Centro Previsioni e Segnalazioni Maree
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Marea Astronomica

APPENDIX D – HYDRODYNAMICS FIELD FORMS

Hydrodynamics Field Form

Date	Time of Day	Canal Segment	Distance (m)	Time (s)			Velocity (m/s)			Average	
				Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Time	Velocity
04/11/2010	13:05	**PANA 1 Out (N-S)**	5.23	56.9	49.2	46.6	0.09	0.1	0.1	50.9	0.096
04/11/2010	17:43	**PANA 1 IN (S-N)**	5.23	74.2	55.4	68.8	0.07	0.09	0.07	66.1	0.07
04/11/2010	12:35	**PANA 2 Out (N-S)**	8	24.0	28.1	24.2	0.33	0.28	0.33	25.4	0.31
04/11/2010	18:15	**PANA 2 IN (S-N)**	8	26.0	22.7	26.4	0.33	0.28	0.33	25.0	0.31
04/11/2010	12:45	**MIRA Out (E-W)**	7.04	29.9	26.1	27.7	0.23	0.27	0.25	27.9	0.25
04/11/2010	18:05	**MIRA In (W-E)**	7.04	27.2	27.9	31,8	0.26	0.25	0.22	28.9	0.24
04/11/2010	12:52	**WIDM 1 Out (N-S)**	8.73	38.0	35.4	34.4	0.23	0.25	0.25	35.9	0.24
04/11/2010	17:55	**WIDM 1 In (S-N)**	8.73	57.5	57.2	58.2	0.15	0.15	0.15	57.6	0.15
05/11/2010	12:30	**APOS 3 Out (N-S)**	5.47	30.6	29.6	36	0.17	0.18	0.15	32.06	0.16
05/11/2010	19:50	**APOS 3 In (S-N)**	5.47	17.4	18	19.9	0.31	0.3	0.27	18.4	0.29
05/11/2010	12:45	**APOS 1 Out (N-S)**	4.36	16.9	13	/	0.25	0.33	/	14.95	0.29
05/11/2010	19:35	**APOS 1 In (S-N)**	4.36	8.5	9	9.9	0.51	0.48	0.44	9.13	0.47
05/11/2010	13:00	**GOZZ Out (W-E)**	10.13	59.3	54.7	55.4	0.17	0.19	0.18	56.5	0.18
05/11/2010	19:25	**GOZZ In (E-W)**	10.13	101	138	128.9	0.1	0.07	0.08	122.6	0.08
05/11/2010	13:16	**GESU 2 Out (N-S)**	4.24	27.7	24	20	0.15	0.17	0.2	24.9	0.17
05/11/2010	19:15	**GESU 2 In (S-N)**	4.24	20.6	21.8	18.6	0.2	0.19	0.22	20.6	0..20
05/11/2010	13:30	**CATE 3 Out (W-E)**	4.47	55.7	55.3	45.2	0.08	0.08	0.09	52	0.083
05/11/2010	19:00	**CATE 3 In (E-W)**	4.47	41.8	50	59	0.1	0.08	0.08	50.2	0.086
06/11/2010	12:18	**VEST 2 Out (W-E)**	4.39	55.4	60	56.7	0.08	0.07	0.08	57.4	0.08
06/11/2010	20:22	**VEST 2 In (E-W)**	4.39	58.1	57.3	59.2	0.08	0.08	0.08	58.2	0.08
06/11/2010	12:43	**ANZO 2 Out (W-E)**	4.52	35.8	34.6	24.2	0.13	0.13	0.19	31.53	0.15
06/11/2010	20:10	**ANZO 2 In (E-W)**	4.52	36.4	35	33.5	0.12	0.13	0.13	35	0.13
06/11/2010	13:15	**SANT Out (N-S)**	4.64	29.5	28	21.6	0.16	0.17	0.21	26.4	0.18
06/11/2010	19:53	**SANT In (N-S)**	4.64	29.3	29.2	30	0.16	0.16	0.15	29.5	0.16

06/11/2010	13:45	**PROC Out (E-W)**	5.06	45.1	43.8	52.8	0.11	0.12	0.10	47.3	0.11
06/11/2010	19:36	**PROC In (W-E)**	5.06	73.1	72	80.1	0.07	0.07	0.06	75.1	0.07
06/11/2010	14:13	**FERA 2 Out (W-E)**	4.43	40.1	40.2	40.4	0.11	0.11	0.11	40.2	0.11
06/11/2010	19:22	**FERA 2 In (E-W)**	4.43	48.3	55.8	56.7	0.09	0.08	0.08	53.6	0.08
06/11/2010	14:30	**BARE 1 Out (N-S)**	7.8	66	57.2	58.1	0.12	0.14	0.13	60.43	0.13
06/11/2010	19:00	**BARE 1 In (S-N)**	7.8	111.1	101.3	117.2	0.07	0.08	0.07	109.8	0.07
20/11/2010	11:44	**DOMI OUT (N-S)**	7.12	51.8	48.3	54.9	0.13	0.14	0.12	51.6	0.13
20/11/2010	21:40	**DOMI IN (S-N)**	7.12	48.9	/	/	0.14	/	/	48.9	0.14
20/11/2010	12:00	**2TOR2 OUT (E-W)**	9.18	34.9	35.7	33.3	0.26	0.26	0.27	34.6	0.26
20/11/2010	21:15	**2TOR2 IN (W-E)**	9.18	43.4	45.4	43.5	0.21	0.20	0.21	44.1	0.20
20/11/2010	12:09	**ORIO1 OUT (NE-SW)**	12.8	131.1	128.8	/	0.09	0.09	/	129.9	0.09
20/11/2010	20:53	**ORIO1 IN (NE-SW)**	12.8	125.1	115.2	106.8	0.10	0.11	0.12	115.7	0.11
20/11/2010	12:35	**STIN OUT (E-W)**	8.32	65	86	76.9	0.128	0.097	0.108	75.9	0.11
20/11/2010	20:30	**STIN IN (W-E)**	8.32	145.5	129.5	151.5	0.05	0.06	0.05	142.16	0.053
20/11/2010	12:46	**FRAR1 OUT (N-S)**	8.45	70	72.3	/	0.12	0.116	/	71.15	0.118
20/11/2010	19:47	**FRAR1 IN (S-N)**	8.45	99.5	101.4	93.1	0.08	0.08	0.09	96.7	0.083
21/11/2010	12:32	**LIO OUT (N-S)**	5.03	148	179.7	176.9	0.03	0.027	0.028	504.6	0.028
21/11/2010	20:15	**LIO IN (S-N)**	5.03	71.1	68.2	/	0.07	0.07	/	69.65	0.07
21/11/2010	13:15	**TETT1 OUT (W-E)**	4.73	20.3	20.4	20.8	0.23	0.23	0.22	20.5	0.226
21/11/2010	20:00	**TETT1 IN (E-W)**	4.73	36.2	34.4	34.6	0.13	0.13	0.13	35.06	0.13
21/11/2010	13:28	**PEST1 OUT (W-E)**	14.14	25.4	24.8	22.2	0.55	0.57	0.63	24.13	0.58
21/11/2010	19:45	**PEST1 IN (E-W)**	14.14	48.5	49.1	48.1	0.29	0.28	0.29	48.56	0.286
21/11/2010	13:35	**FORM OUT (SW-NE)**	10.6	162.9	157.6	156.7	0.065	0.067	0.067	159.06	0.066
21/11/2010	19:30	**FORM IN (NE-SW)**	10.6	97.6	100.3	97.5	0.11	0.10	0.11	98.46	0.106
22/11/2010	13:00	**TOMA OUT (W-E)**	6.6	29.4	28.7	30.3	0.22	0.22	0.21	29.5	0.216
22/11/2010	22:22	**TOMA IN (E-W)**	6.6	30.16	30.4	34.08	0.21	0.21	0.19	31.54	0.20
22/11/2010	13:20	**POLO4 OUT (S-N)**	4.57	37.1	/	/	0.12	/	/	37.1	0.12

22/11/2010	21:55	**POLO4 IN (S-N)**	4.57	22.6	22.0	23.0	0.20	0.20	0.19	22.5	0.196
04/12/2010	11:35	**CATE2 OUT (W-E)**	8.26	48.8	50	/	0.16	0.16	/	49.4	0.16
04/12/2010	19:45	**CATE2 IN (E-W)**	8.26	98.3	96.8	91.9	0.084	0.085	0.089	95.6	0.086
04/12/2010	11:45	**CATE1 OUT (W-E)**	10.6	43.5	42.3	44.3	0.24	0.25	0.23	43.36	0.24
04/12/2010	19:37	**CATE1 IN (E-W)**	10.6	95.4	91.0	84.8	0.11	0.11	0.125	90.4	0.115
04/12/2010	12:00	**PRIU3 OUT (NA)**	8.9	NA	NA	NA	0	0	0	NA	0
04/12/2010	19:30	**PRIU3 IN (NA)**	8.9	NA	NA	NA	0	0	0	NA	0
04/12/2010	12:03	**PRIU2 OUT (NA)**	10.4	NA	NA	NA	0	0	0	NA	0
04/12/2010	19:20	**PRIU2 IN (NA)**	10.4	NA	NA	NA	0	0	0	NA	0
04/12/2010	12:05	**PRIU1 OUT (NA)**	2.9	NA	NA	NA	0	0	0	NA	0
04/12/2010	19:12	**PRIU1 IN (W-E)**	2.9	81.5	80.5	85.0	0.035	0.036	0.034	82.3	0.035
04/12/2010	12:05	**CREA OUT (NW-SE)**	7.1	57.4	55.0	65.2	0.12	0.12	0.10	59.2	0.113
04/12/2010	20:13	**CREA IN (SE-NW)**	7.1	181.2	187.2	169.8	0.039	0.037	0.041	179.4	0.039
04/12/2010	12:30	**GIOB OUT (S-N)**	6.45	100.7	103.7	98.2	0.064	0.062	0.065	100.86	0.063
04/12/2010	19:39	**GIOB IN (S-N)**	6.45	99.0	90.2	89.3	0.065	0.071	0.072	92.8	0.069
04/12/2010	14:22	**BATE1 OUT (NW-SE)**	4.4	12.8	13.7	12.6	0.34	0.32	0.34	13.0	0.33
04/12/2010	19:28	**BATE1 IN (SE-NW)**	4.4	16.7	19.6	17.2	0.26	0.22	0.25	17.8	0.243
04/12/2010	14:37	**GHET OUT (S-N)**	3.69	42.8	43.7	35.6	0.08	0.08	0.10	40.7	0.086
04/12/2010	19:04	**GHET IN (N-S)**	3.69	76.5	73.2	75.4	0.048	0.05	0.048	75.03	0.048
05/12/2010	11:41	**SALU1 OUT (N-S)**	6.5	114.3	104.7	98.9	0.05	0.06	0.065	105.96	0.055
05/12/2010	20:53	**SALU1 IN (N-S)**	6.5	23.8	22.8	22.7	0.27	0.28	0.28	23.1	0.27
05/12/2010	11:50	**FORN1 OUT (N-S)**	10	60.7	65.1	70.9	0.16	0.15	0.14	65.5	0.15
05/12/2010	20:39	**FORN1 IN (N-S)**	10	20.8	19.2	18.4	0.48	0.52	0.54	19.4	0.51
05/12/2010	12:00	**FORN2 OUT (N-S)**	7.2	86.4	73.7	/	0.08	0.097	/	80.05	0.088
05/12/2010	20:33	**FORN2 IN (N-S)**	7.2	54.5	41.1	40.0	0.13	0.17	0.18	45.2	0.16
05/12/2010	12:15	**VIO OUT (NA)**	10	NA	NA	NA	0	0	0	NA	0
05/12/2010	10:21	**VIO IN (N-S)**	10	70.0	81.1	/	0.14	0.12	/	75.55	0.13

05/12/2010	12:25	**TROV3 OUT (NA)**	7.53	NA	NA	NA	0	0	0	NA	0
05/12/2010	20:07	**TROV3 IN (N-S)**	7.53	42.2	45.0	41.2	0.17	0.16	0.18	42.8	0.17
05/12/2010	12:26	**TROV2 OUT (NA)**	7.86	NA	NA	NA	0	0	0	NA	0
05/12/2010	20:01	**TROV2 IN (N-S)**	7.86	39.8	39.7	38.8	0.19	0.19	0.2	39.4	0.19
05/12/2010	12:40	**OGNI1 OUT (NA)**	7.53	NA	NA	NA	0	0	0	NA	0
05/12/2010	19:44	**OGNI1 IN (W-E)**	7.53	46.2	47.1	/	0.16	0.15	/	46.6	0.155
05/12/2010	12:45	**OGNI2 OUT (W-E)**	6.01	95.0	100.3	103.6	0.06	0.05	0.05	99.6	0.053
05/12/2010	19:38	**OGNI2 IN (W-E)**	6.01	57.1	56.8	44.3	0.105	0.105	0.13	52.7	0.113
05/12/2010	13:00	**ROMI1 OUT (N-S)**	2.52	43.0	44.2	40.0	0.058	0.057	0.063	42.4	0.059
05/12/2010	17:35	**ROMI1 IN (N-S)**	2.52	23.5	21.9	20.1	0.107	0.115	0.125	21.8	0.115
05/12/2010	11:38	**MUNE OUT (N-S)**	10.5	63.8	68.3	62.2	0.16	0.15	0.16	64.76	0.156
05/12/2010	20:34	**MUNE IN (S-N)**	10.5	71.4	72.5	63.4	0.14	0.14	0.16	69.1	0.146
05/12/2010	11:53	**MAGA OUT (E-W)**	9.4	232.0	286.9	216.9	0.040	0.032	0.043	245.2	0.038
05/12/2010	20:21	**MAGA IN (NA)**	9.4	NA	NA	NA	0	0	0	NA	0
05/12/2010	12:12	**BURC OUT (N-S)**	10.0*	77.8	81.6	55.4	0.12	0.12	0.18	71.6	0.14
05/12/2010	20:11	**BURC IN (S-N)**	3.8*	40.3	41.4	41.2	0.094	0.091	0.092	40.9	0.092
05/12/2010	12:35	**MAGG3 OUT (N-S)**	7.55	64.4	68.7	67.3	0.11	0.10	0.11	66.8	0.115
05/12/2010	19:57	**MAGG3 IN (NA)**	7.55	NA	NA	NA	0	0	0	NA	0
05/12/2010	12:48	**TERE1 OUT (N-S)**	3.2	47.5	53.8	48.3	0.067	0.059	0.062	49.8	0.062
05/12/2010	19:41	**TERE1 IN (S-N)**	3.2	120.7	142.7	108.3	0.026	0.022	0.029	123.9	0.025
05/12/2010	12:53	**MAGG2 OUT (N-S)**	5.5	65.7	51.7	58.4	0.083	0.106	0.094	58.6	0.094
05/12/2010	19:34	**MAGG2 IN (S-N)**	5.5	297.3	303.8	306.9	0.018	0.018	0.017	302.6	0.017
05/12/2010	13:10	**MAGG1 OUT (N-S)**	9.1	131.4	129.2	141.7	0.069	0.07	0.064	134.1	0.067
05/12/2010	19:27	**MAGG1 IN (NA)**	9.1	NA	NA	NA	0	0	0	NA	0
05/12/2010	13:34	**TREP3 OUT (N-S)**	5.8*	35.0	34.8	43.8	0.16	0.16	0.13	37.86	0.15
05/12/2010	19:06	**TREP3 IN (S-N)**	3.8*	122.3	131.8	126.1	0.031	0.028	0.03	126.7	0.029

APPENDIX E – PAST HYDRODYNAMICS RESULTS & DATA

Canal Segment	Canal	Length (m)	Area (m^2)	Max Velocity in (cm/s)	Max Velocity out (cm/s)
2TOR2	Rio de le Do Torre	49.3	292	30.8	-32.9
ACQU1	Rio de l'Acqua Dolce	65.3	538	0.1	-6.37
ACQU2	Rio de l'Acqua Dolce	41	448	2.41	-0.1
ACQU3	Rio de l'Acqua Dolce	53.5	602	2.41	-0.1
ANDR1	Ri di S. Andrea	37.3	310	0.01	-0.01
ANDR2	Ri di S. Andrea	37.3	310	0.01	-0.01
ANZO2	Rio de S. Anzolo	34.2	177	15.47	-0.1
APON2	Ri di S. Aponal	35.1	199	-1.48	-0.01
APOS1	Rio dei Ss. Apostoli	50.6	460	40	-25
APOS2	Rio dei Ss. Apostoli	50.2	449	40	-25
APOS3	Rio dei Ss. Apostoli	133.6	1114	45	-20
AVOG	Rio de l'Avogaria	185.8	1646	-0.1	4.41
BARE1	Rio dei Bareteri	96.4	684	-10	3.76
BARN1	Rio de S. Barnaba	201.1	1397	-6.03	4.23
BARN2	Rio de S. Barnaba	132.2	1014	-6.03	4.23
BATE1	Rio del Batelo	472.6	4540	7.813	-18.5
BIAG2	Rio de S. Biagio	188.1	2699	-4.9	20.8
BOTE	Rio de le Bote	60.7	503	-2.96	3.18
BRAZ	Rio Brazzo	72.5	578	-8.36	-4.14
BRIA	Rio Briati	130.3	1658	10.41	-13.1
BURC	Rio de le Burchiele	49.3	292	30.8	-32.9
CARM	Rio dei Carmini	124.5	1521	6.25	-12.5
CASS2	Rio de S. Cassian	62.6	309	-21.4	21.4
CATE1	Rio de S. Caterina	52.6	447	18.33	-7.44
CATE2	Rio de S. Caterina	93.3	986	0.01	-15
CATE3	Rio de S. Caterina	151.7	1657	0.01	-8.38
CAZZ	Rio de la Cazziole e de Ca'Rizzi	229	1544	0.01	0.01
CONV	Rio de le Converitite	258.9	3388	5.2	-6.5
CREA1	Rio de la Crea	266.9	1496	-10.36	24.58
CREA2	Rio de la Crea	94.4	1125	0.01	-9.45
CROC	Rio de la Croce	255	2458	-10.9	3.2
DOMI	Rio de S. Maria Mater Domini	283	1606	21.8	-16.8
ERBE	Rielo de le Erbe	91.5	402	-3.48	1.6
EUFE1	Rio de S. Eufemia	129.6	1113	-21.28	24.2
EUFE2	Rio de S. Eufemia	228.2	2056	-21.5	11.18
FERA1	Rio dei Ferali	35.5	180	10.23	-8.96
FERA2	Rio dei Ferali	136.4	668	10.23	-8.96
FORM	Rio de S.M. Formosa	164.6	1042	-10.07	2.13

FORN1	Rio de Is Fornasa	104.3	489	-22	-30.56
FORN2	Rio de Is Fornasa	168.6	1469	-22	-30.56
FOSC2	Rio de. S. Fosca	138.7	1471	14.33	-5.93
FRAR1	Rio dei Frari	87.6	747	1.15	-7.02
FRAR2	Rio dei Frari	34.3	249	1.15	-7.02
GESU1	Rio dei Gesuiti	128.4	2330	12.68	0.01
GESU2	Rio dei Gesuiti	44	456	19.95	-6.49
GHET	Rio del Ghettio Novo	196.3	1687	-5.18	12.35
GIAR2	Rio dei Giardini	68.7	2020	24.04	27.02
GIAR3	Rio dei Giardini	359.2	6397	24.04	27.02
GIOB	Rio dei Giobbe	274.4	1648	6.17	13.47
GOZZ	Rio del Gozzi	163.5	1171	15.63	-6.93
GRIM1	Rio Grimani	37.6	184	23.19	-17.32
GRIM2	Rio Grimani	42.2	277	17.5	-19.19
GRIS1	Rio de S. Giovanni Grisostomo	141.3	645	-12.5	0.01
GRIS2	Rio de S. Giovanni Grisostomo	77.9	442	-12.5	0.01
LIO	Rio de S. Lio	89.3	676	27	-30
LUST	Rio dei Lustraferi	76.3	436	36.16	-16.33
MADA2	Rio de la Madalena	203.6	1231	23.6	-25.8
MAGA	Rio del Magazen	63.9	504	-2.59	-9.7
MAGG1	Rio de S. Maria Maggior	169.6	1439	0.01	0.01
MAGG2	Rio de S. Maria Maggior	74.6	880	0.01	0.01
MAGG3	Rio de S. Maria Maggior	57.3	723	0.01	0.01
MALP1	Rio del Malpaga	153.4	1026	-7.98	4.54
MALP2	Rio del Malpaga	50.4	416	-9.33	5
MALP3	Rio del Malpaga	52.5	339	-9.25	7.93
MALP4	Rio del Malpaga	150	1148	-9.25	7.93
MARC1	Rio de S. Marcuola	39.5	200	37.13	-19.92
MARC2	Rio de S. Marcuola	97.8	628	37.13	-19.92
MARC3	Rio de S. Marcuola	46.4	319	37.13	-19.92
MARG	Rio de S. Margherita	279.1	3117	-4.44	-27.7
MIRA	Rio de S. Miarcoli	18.3	609	23.63	-24.04
MOND3	Rio del Mondo Novo	72.4	520	0.01	-9.59
MORO	Rio de Ca'Moro	80.8	1732	6.77	-8.04
MUNE	Rio de le Muneghete	349.6	22052	14.19	-16.41
MUTI	Rio dei Muti	75.9	631	11.04	-5.52
NICO1	Rio de S. Nicolo dei Mendicoli	172.7	1464	6.27	-17.39
NOAL3	Rio de Noal	45.2	631	43.33	-28.88
NOVO4	Rio Novo	236.3	3522	19.86	-20.7

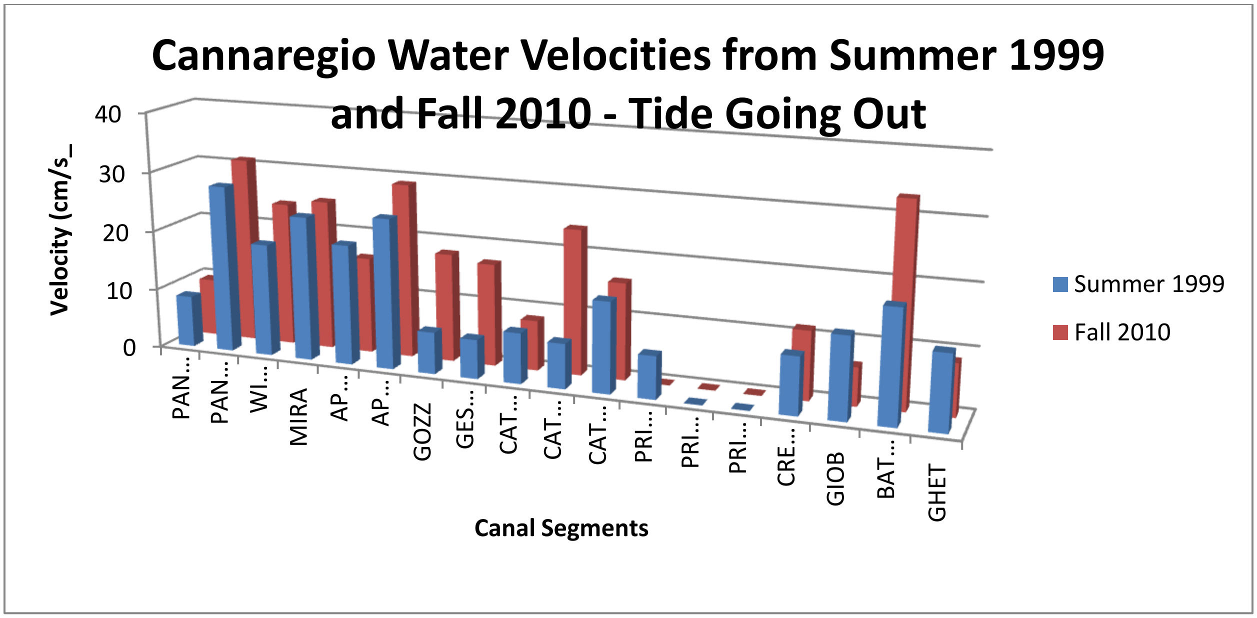
OGNI1	Rio dei Ognisanti	193.8	1636	0.1	-8.27
OGNI2	Rio dei Ognisanti	49	596	0.01	-8.27
ORIO1	Rio de S. Giacomo dell'Orio	51.6	395	5.8	6.18
ORSE	Rio e Bacino Orseolo	120.1	1140	0.01	0.01
PALA	Rio de la Palada	158.6	2541	0.01	3.13
PANA1	Rio de la Panada	119.7	1400	14.3	-8.66
PANA2	Rio de la Panada	222.5	1142	21.84	-27.99
PANA3	Rio de la Panada	85	565	14.94	-25.84
PEST1	Rio del Pestrin	79.7	763	0.01	-0.8
PEST2	Rio del Pestrin	120.6	901	24.25	-19.4
PIER3	Rio di S. Pietro di Castello	104.1	5169	7.9	7.9
POLO3	Rio de S. Polo	90.5	990	10.86	-3.06
POLO4	Rio de S. Polo	76	882	10.86	-3.06
PRIU1	Rio Priuli	49.2	379	11.15	7.06
PRIU2	Rio Priuli	83.7	745	0.01	0.01
PRIU3	Rio Priuli	47.8	547	0.01	0.01
PROC	Rio de le Procuratie	105.2	578	7.23	-4.03
PROV2	Rio de S. Provolo de l'Osmarin	35.4	144	14.48	-10.5
RACH1		69.5	291	9.7	0.01
RAFF1	Rio de l'Anzolo Rafael	211.9	1852	0.01	-4.45
RAFF2	Rio de l'Anzolo Rafael	113.4	1320	0.01	-4.45
ROMI	Rio de le Romite	176.9	1254	0.01	0.01
SALU1	Rio de la Salute	89.9	649	-14.48	-13.55
SALU2	Rio de la Salute	95.9	649	-14.48	-13.55
SALV	Rio de S. Salvador	216.5	1072	10.86	-13.03
SANT	Rio del Santissimo	275.3	1596	17.84	-17
SCOA1	Rio dei Scoacamini	99.6	631	16.3	-15.4
SCOA2	Rio dei Scoacamini	25.6	208	16.3	-15.4
SEBA	Rio de Sebastian e S. Basegio	257	2765	24.59	-14.92
SENS4	Rio de la Sensa	82.7	844	37.03	-16.39
SERV2	Rio dei Servi	137.2	1478	25.88	-14.44
STIN	Rio de S. Stin	111.9	935	1.15	-7.02
TENT1	Rio del Tentor	49.3	548	7.17	-12.53
TENT3	Rio del Tentor	249.8	3109	0.01	0.01
TERE1	Rio de le Terese	64.7	1429	0.01	-5.08
TERE2	Rio de le Terese	153	1942	0.01	-11.77
TETT1	Rio de la Tetta	39.9	264	0.01	-7.29
TOLA1	Rio de la Toletta	67.7	371	0.01	0.01

TOLA2	Rio de la Toletta	123.6	575	0.01	0.01
TOMA	Rio de S. Toma'	165.2	844	1.15	-7.02
TRAP	Rio del Trapolin	175.5	1281	7.73	1.57
TRAS	Rio dei Trasti	74.9	484	-11.6	-11.6
TREP3	Rio dei Tre Ponti	36.7	477	3.97	-21.16
TROV2	Rio de S. Trovaso	261.9	2493	0.01	-14.08
TROV3	Rio de S. Trovaso	48.7	709	0.01	-8.06
TRTE	Rio de le Torete	87.4	440	10.32	0.01
VERG2	Rio de le Vergini	71.2	863	16.03	-14.09
VEST2	Rio de le Veste	35.5	374	0.01	-9.81
VIN	Rio del Vin	232.2	1351	24.6	-24.28
VIO	Rio de S. Vio	267.6	2354	-9.09	-18.51
WIDM1	Rio Widman	114.9	782	12.75	-18.79
WIDM2	Rio Widman	22.3	157	12.75	-18.79
ZECA		69.5	558	5.77	6
ZIRA1	Rio de Sant'Andrea se la Zirada	57.7	404	0.01	-5.47

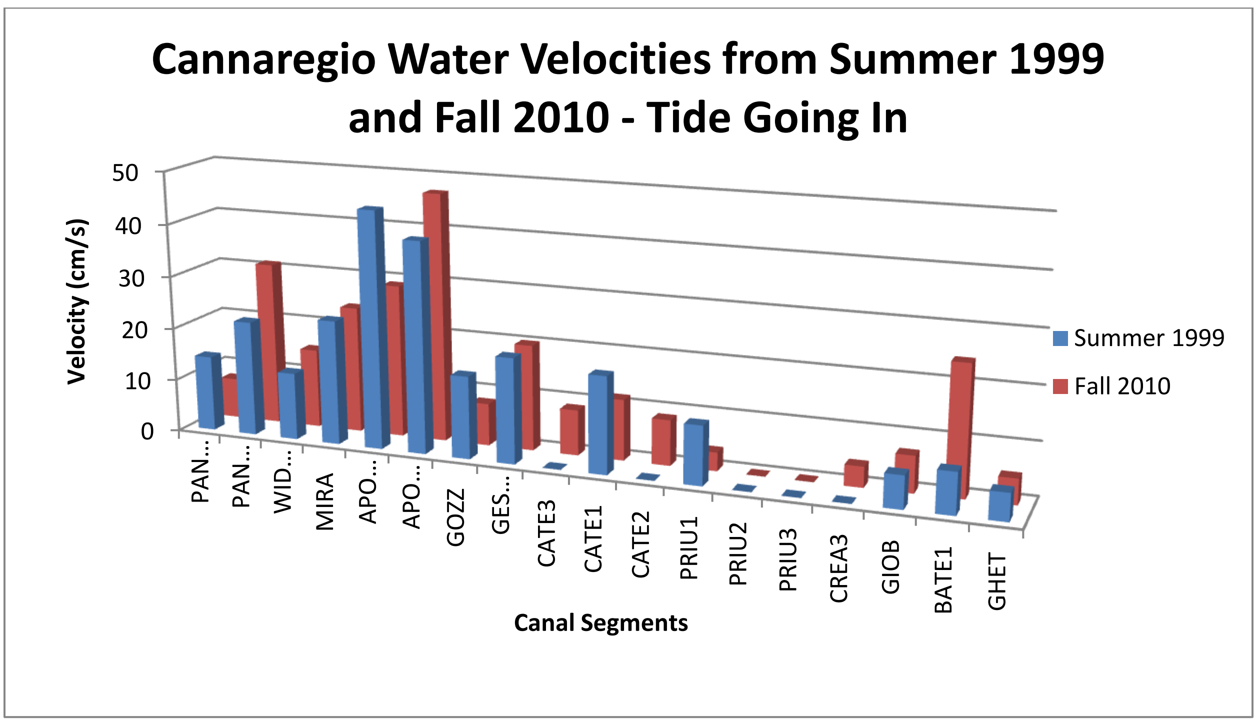
APPENDIX F – HYDRODYANIMCS COMPARISONS BETWEEN SUMMER 1999 & FALL 2010

Cannaregio

Canal Seg.	1999 Out Velocity (cm/s)	2010 Out Velocity (cm/s)	1999 In Velocity (cm/s)	2010 In Velocity (cm/s)	Comments
PANA1	-8.6	-9.6	14.3	7.6	Open to lagoon so accurate data is hard to obtain due to lagoon activities influencing canal segment
PANA2	-27.99	-31	21.84	31	
WIDM1	-18.79	-24	12.75	15	
MIRA	-24.04	-25	23.63	24	
APOS3	-20	-16	45	29	Very hard to measure – Possibly related to slower than expected flow?
APOS1	-25	-29	40	47	
GOZZ	-6.93	-18	15.63	8	
GESU2	-6.49	-17	19.95	20	
CATE3	-8.38	-8.3	0.01	8.6	
CATE1	-7.44	-24	18.33	11.5	
CATE2	-15	-16	0.01	8.6	
PRIU1	7.06	0	11.15	3.5	Dredging on adjacent canals
PRIU2	0.01	0	0.01	0	Dredging on adjacent canals
PRIU3	0.01	0	0.01	0	Dredging on adjacent canals
CREA3	-9.45	-11.3	0.01	3.9	
GIOB	13.47	6.3	6.17	6.9	
BATE1	-18.5	-33	7.813	24.3	
GHET	12.35	8.6	-5.18	-4.8	



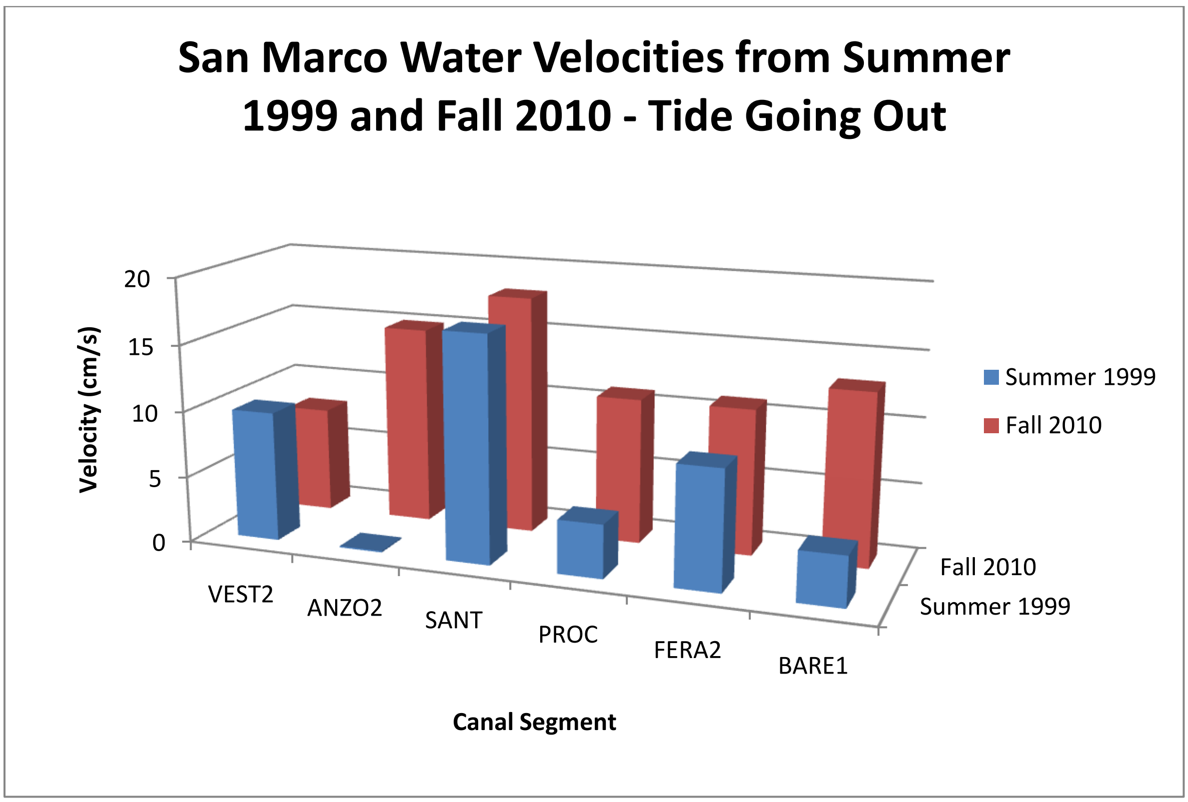
Cannaregio Water Velocities from Summer 1999 and Fall 2010 - Tide Going Out
Velocity (cm/s_
40
30
20
10
0
PAN…
PAN…
WI…
MIRA
AP…
AP…
GOZZ
GES…
CAT…
CAT…
CAT…
PRI…
PRI…
PRI…
CRE…
GIOB
BAT…
GHET
Canal Segments
Summer 1999
Fall 2010

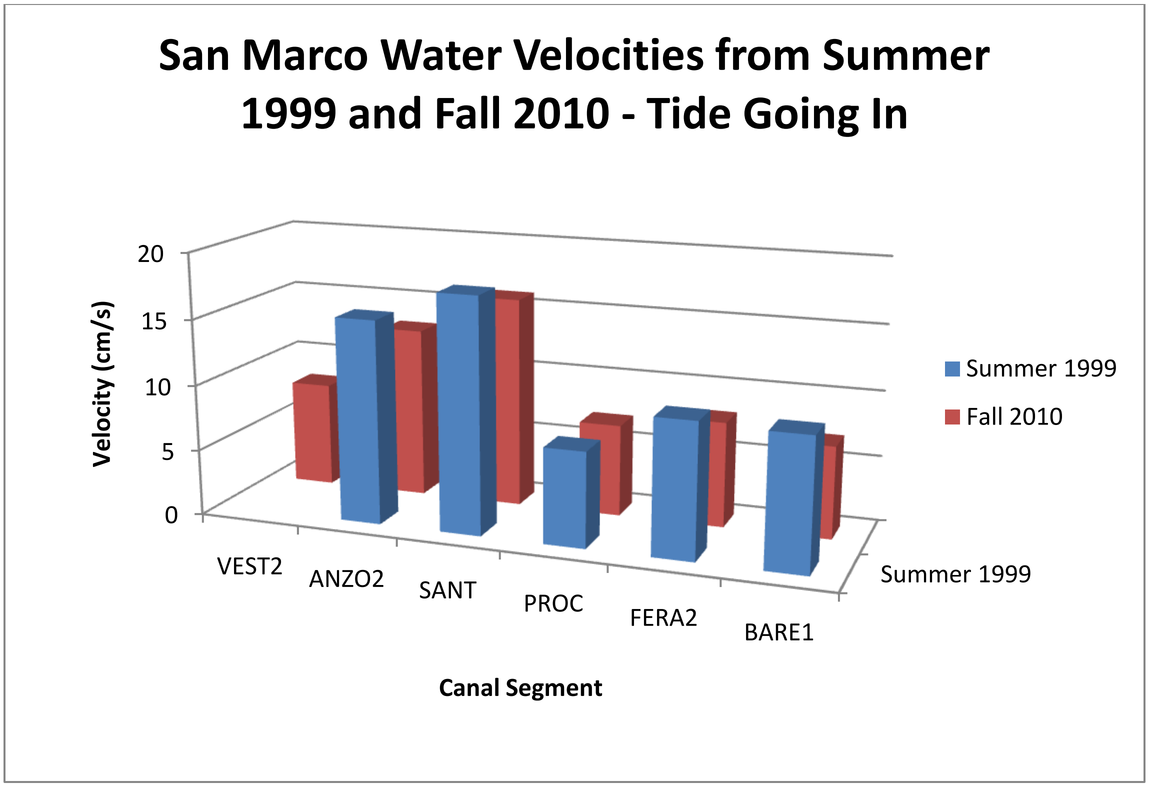


Cannaregio Water Velocities from Summer 1999 and Fall 2010 - Tide Going In
Velocity (cm/s)
50
40
30
20
10
0
PAN…
PAN…
WID…
MIRA
APO…
APO…
GOZZ
GES…
CATE3
CATE1
CATE2
PRIU1
PRIU2
PRIU3
CREA3
GIOB
BATE1
GHET
Canal Segments
Summer 1999
Fall 2010

San Marco

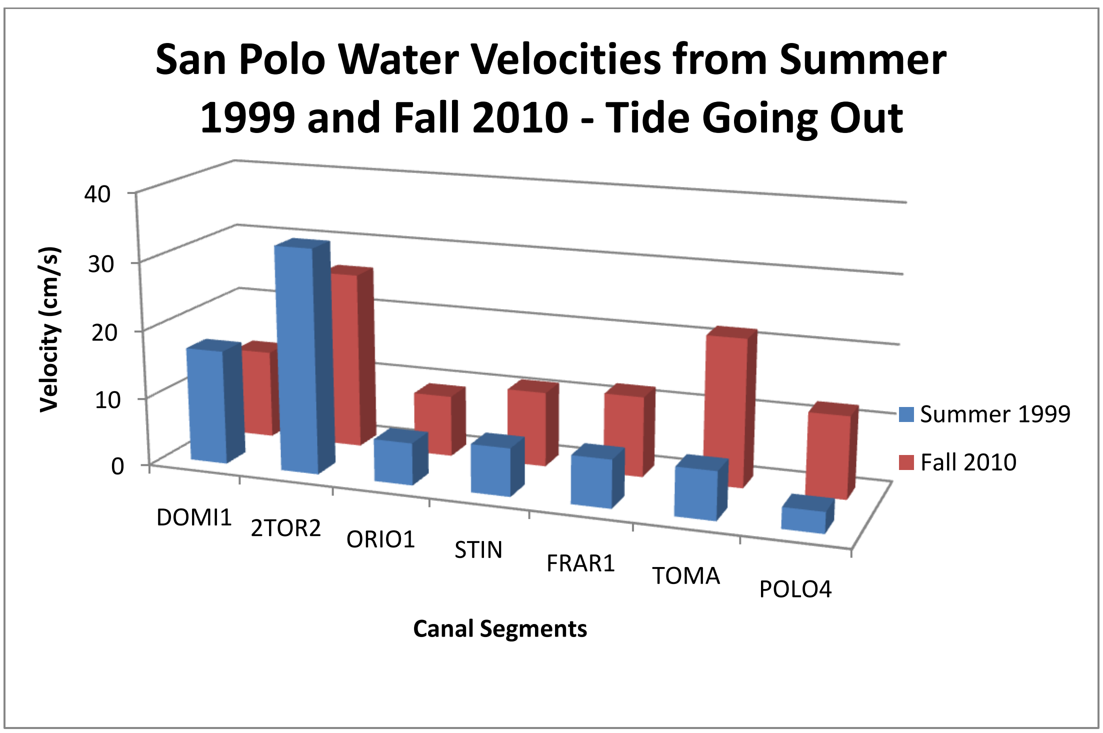
Canal Seg.	1999 Out Velocity (cm/s)	2010 Out Velocity (cm/s)	1999 In Velocity (cm/s)	2010 In Velocity (cm/s)	Comments
VEST2	-9.81	-8	0.01	8	
ANZO2	-0.1	-15	15.47	13	
SANT	-17	-18	17.84	16	
PROC	-4.03	-11	7.23	7	
FERA2	-8.96	-11	10.23	8	
BARE1	3.76	13	-10	-7	

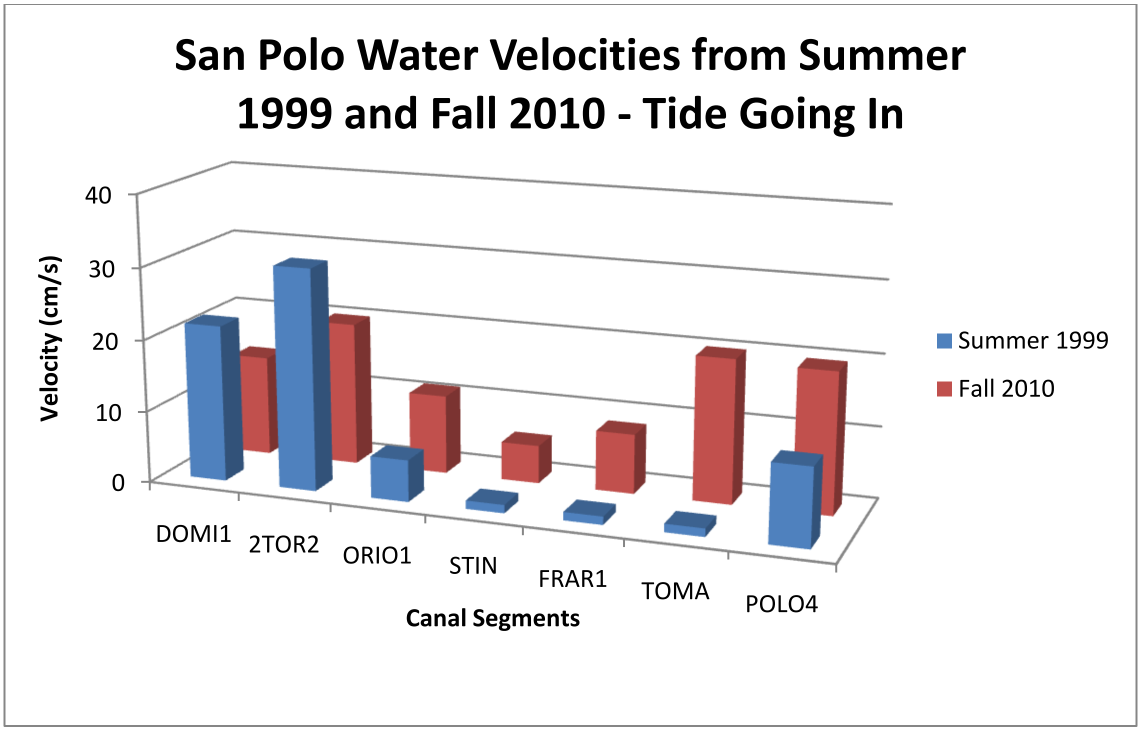



San Marco Water Velocities from Summer 1999 and Fall 2010 - Tide Going In
Velocity (cm/s)
20
15
10
5
0
VEST2
ANZO2
SANT
PROC
FERA2
BARE1
Summer 1999
Canal Segment
Summer 1999
Fall 2010

San Polo

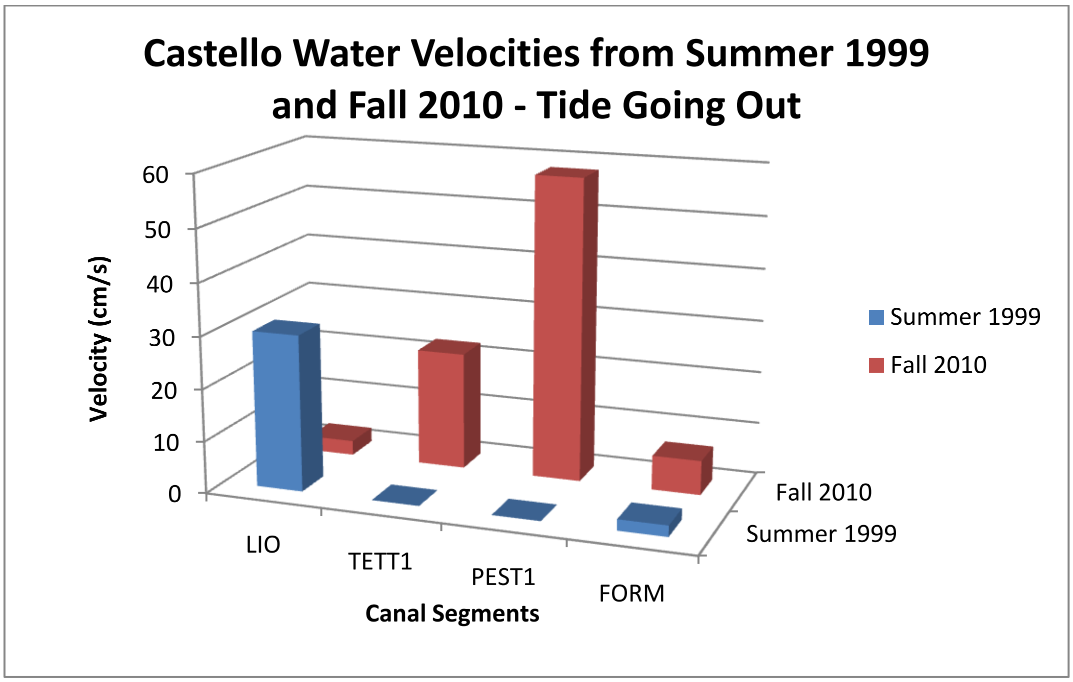
Canal Seg.	1999 Out Velocity (cm/s)	2010 Out Velocity (cm/s)	1999 In Velocity (cm/s)	2010 In Velocity (cm/s)	Comments
DOMI1	-16.8	-13	21.8	14	
2TOR2	-32.9	-26	30.8	20	
ORIO1	6.18	9	5.8	11	Somewhat windy along surface of water
STIN	-7.02	-11	1.15	5.3	
FRAR1	-7.02	-11.8	1.15	8.3	Somewhat windy along surface of water
TOMA	-7.02	-21.6	1.15	20	
POLO4	-3.06	-12	10.86	-19.6	

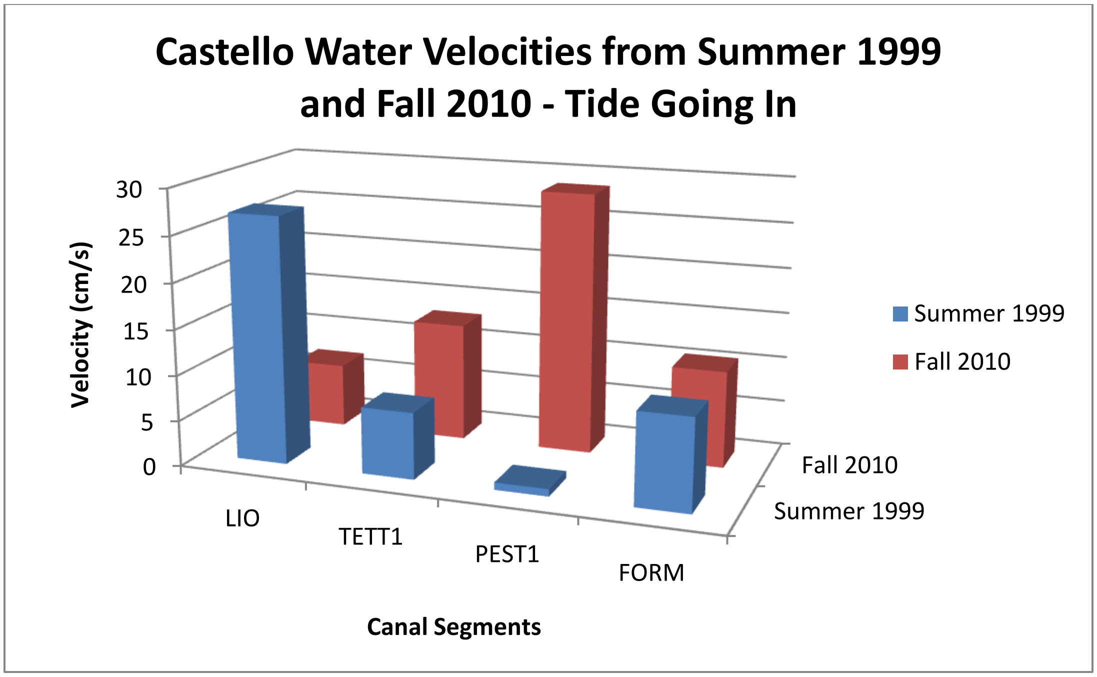



San Polo Water Velocities from Summer 1999 and Fall 2010 - Tide Going In
Velocity (cm/s)
40
30
20
10
0
DOMI1
2TOR2
ORIO1
STIN
FRAR1
TOMA
POLO4
Canal Segments
Summer 1999
Fall 2010

Castello

Canal Seg.	1999 Out Velocity (cm/s)	2010 Out Velocity (cm/s)	1999 In Velocity (cm/s)	2010 In Velocity (cm/s)	Comments
LIO	-30	-2.8	27	7	Rainy and windy day
TETT1	0.01	22.6	-7.29	-13	Rainy and windy day
PEST1	0.01	58	-0.8	-28.6	Rainy and windy day
FORM	2.13	6.6	-10.07	-10.6	Rainy and windy day

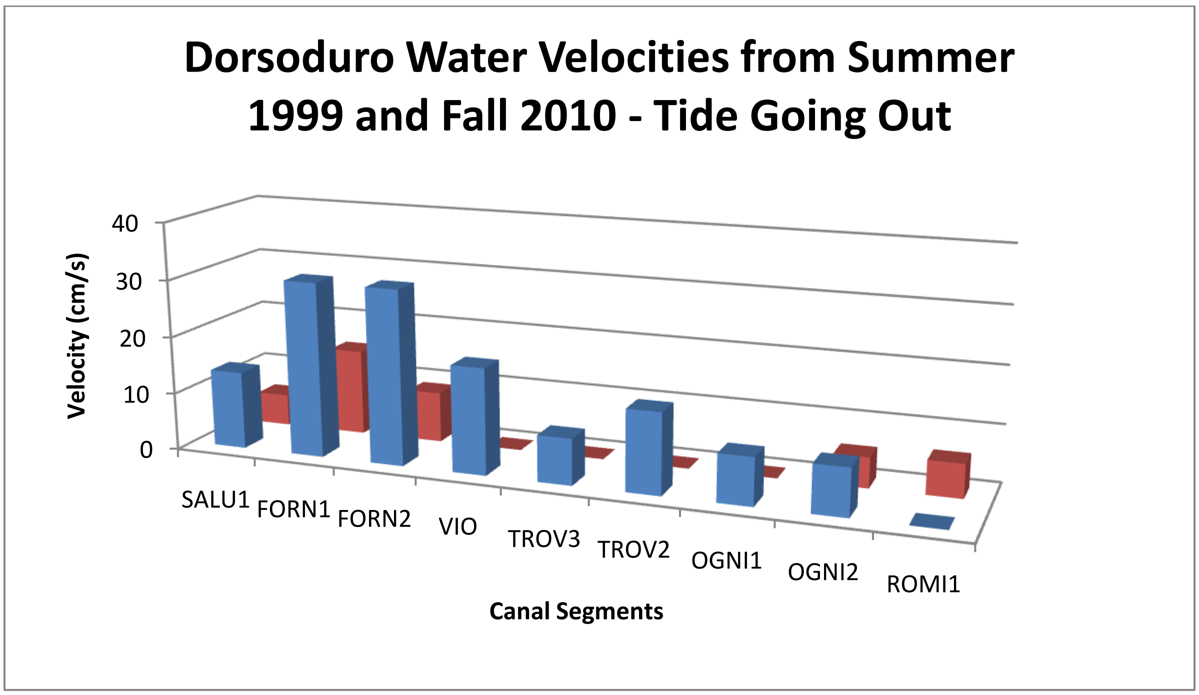


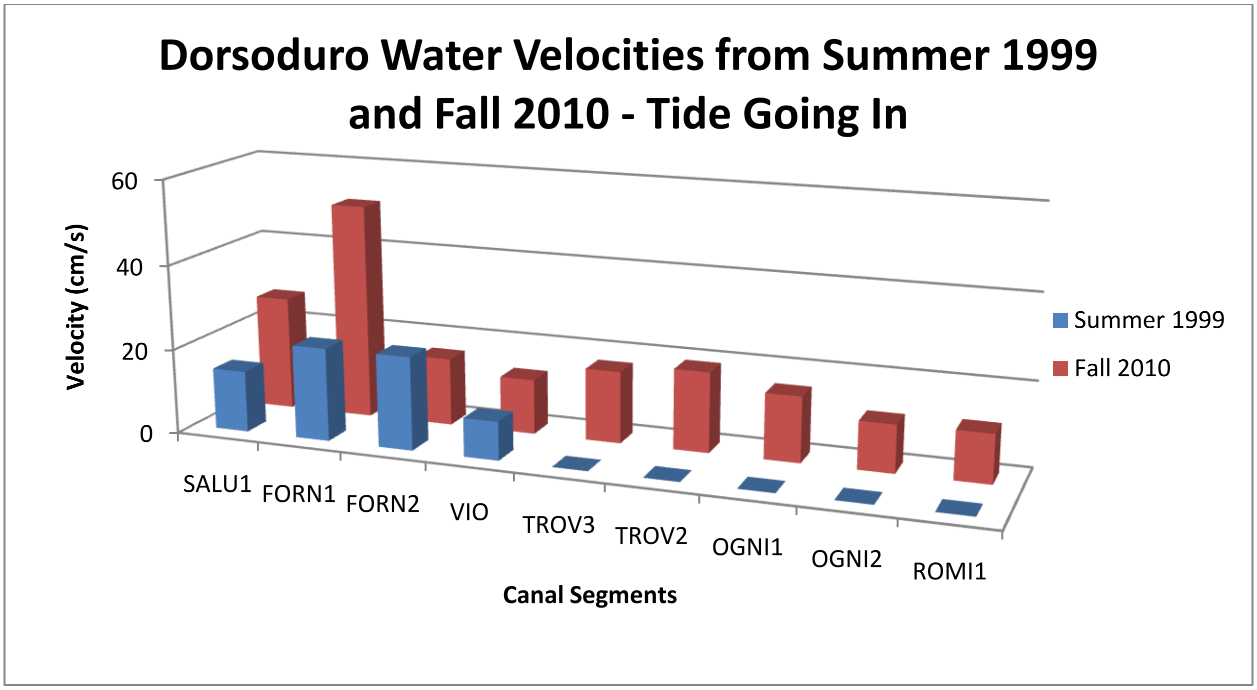


Castello Water Velocities from Summer 1999 and Fall 2010 - Tide Going In
Velocity (cm/s)
30
25
20
15
10
5
0
LIO
TETT1
PEST1
FORM
Canal Segments
Fall 2010
Summer 1999
Summer 1999
Fall 2010

Dorsoduro

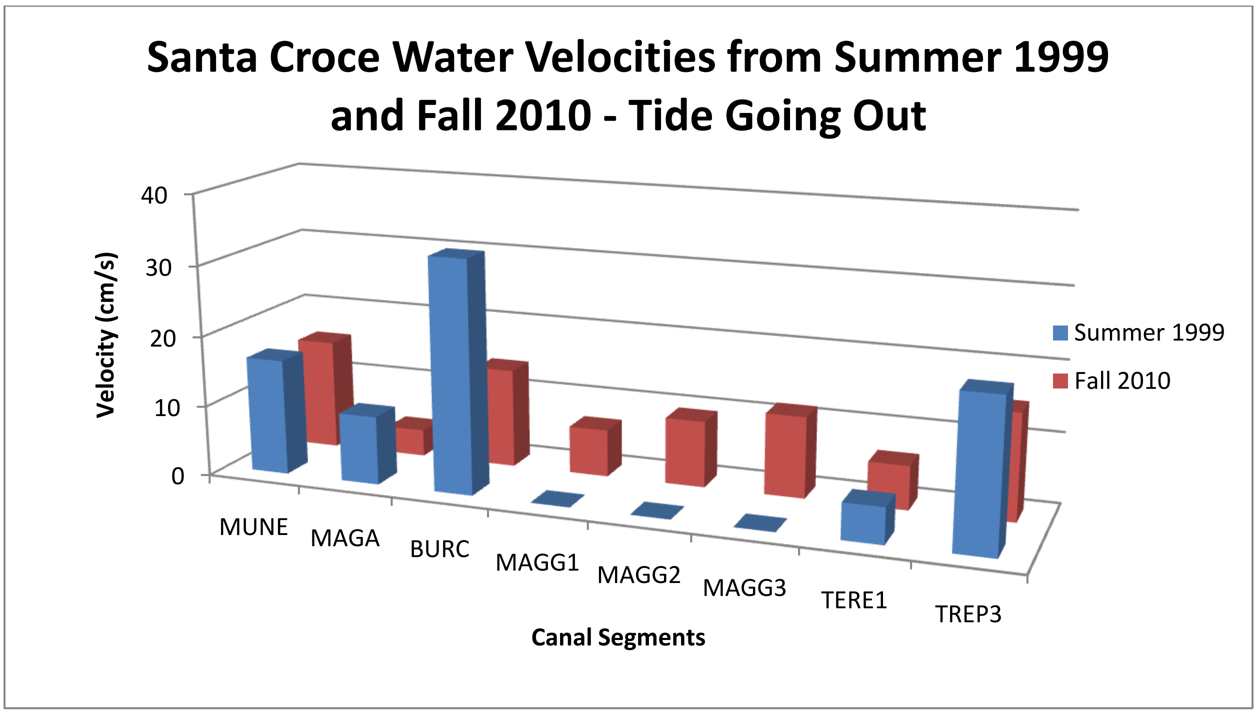
Canal Seg.	1999 Out Velocity (cm/s)	2010 Out Velocity (cm/s)	1999 In Velocity (cm/s)	2010 In Velocity (cm/s)	Comments
SALU1	-13.55	-5.5	-14.48	-27.0	
FORN1	-30.56	-15.0	-22	-51.0	
FORN2	-30.56	-8.8	-22	-16.0	
VIO	-18.51	0	-9.09	-13.0	
TROV3	-8.06	0	0.01	-17.0	
TROV2	-14.08	0	0.01	-19.0	
OGNI1	-8.27	0	0.01	-15.5	
OGNI2	-8.27	-5.3	0.01	-11.3	
ROMI1	0.01	-5.9	0.01	-11.5	

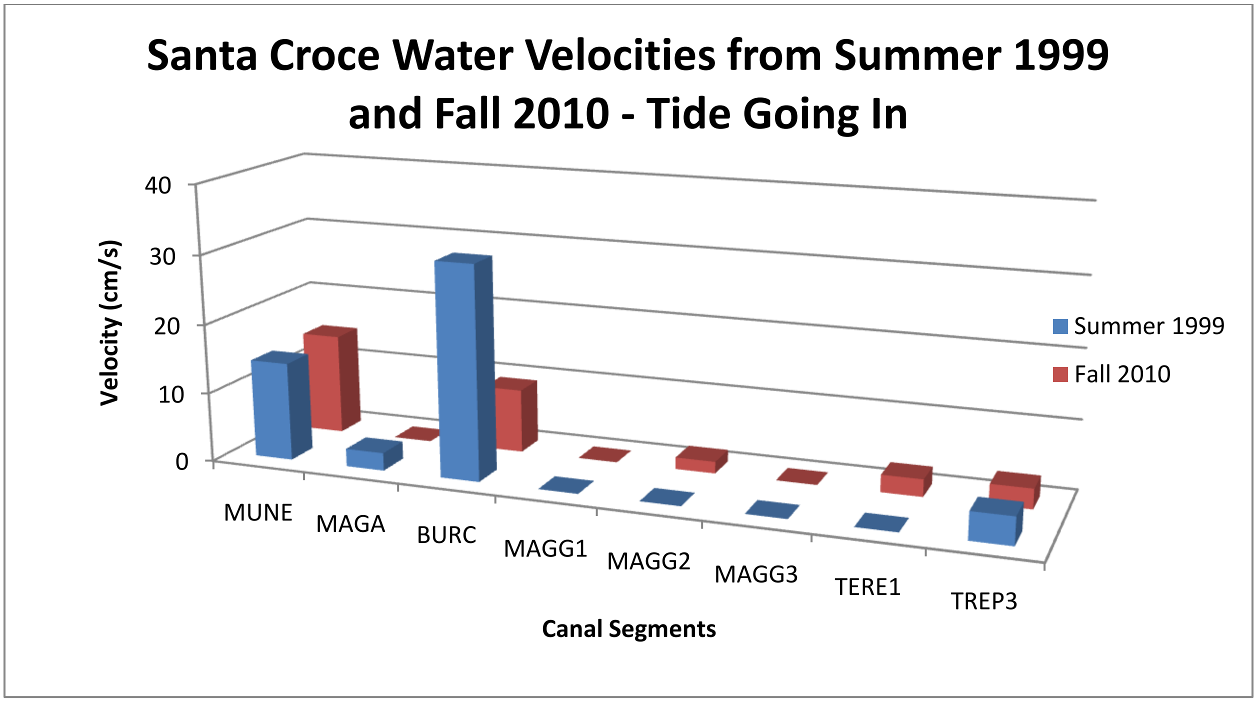



Dorsoduro Water Velocities from Summer 1999 and Fall 2010 - Tide Going In
Velocity (cm/s)
0
20
40
60
SALU1
FORN1
FORN2
VIO
TROV3
TROV2
OGNI1
OGNI2
ROMI1
Canal Segments
Summer 1999
Fall 2010

Santa Croce

Canal Seg.	1999 Out Velocity (cm/s)	2010 Out Velocity (cm/s)	1999 In Velocity (cm/s)	2010 In Velocity (cm/s)	Comments
MUNE	-16.4	-15.6	14.19	14.6	
MAGA	-9.7	3.8	-2.56	0	
BURC	-32.9	-14.0	30.8	9.2	
MAGG1	0.01	-6.7	0.01	0	
MAGG2	0.01	-9.4	0.01	1.7	
MAGG3	0.01	-11.5	0.01	0	
TERE1	-5.08	-6.2	0.01	2.5	
TREP3	-21.16	-15.0	3.97	2.9	



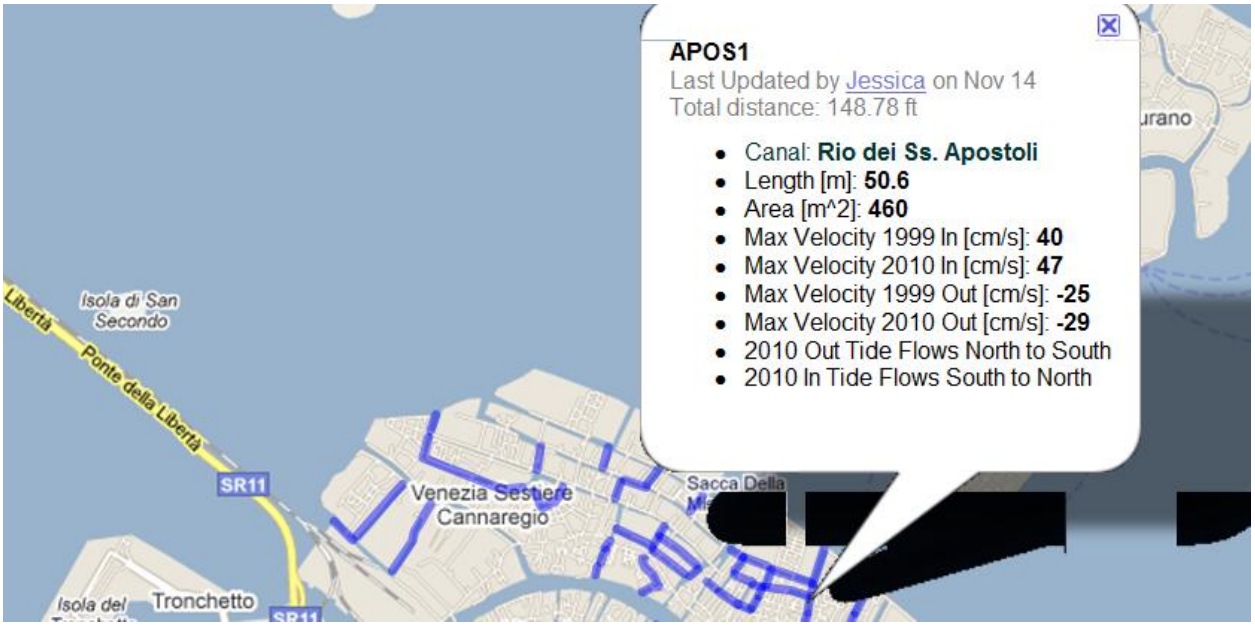


Santa Croce Water Velocities from Summer 1999 and Fall 2010 - Tide Going In
Velocity (cm/s)
40
30
20
10
0
MUNE
MAGA
BURC
MAGG1
MAGG2
MAGG3
TERE1
TREP3
Canal Segments
Summer 1999
Fall 2010

APPENDIX G – HYDROYNAMICS DATABASE

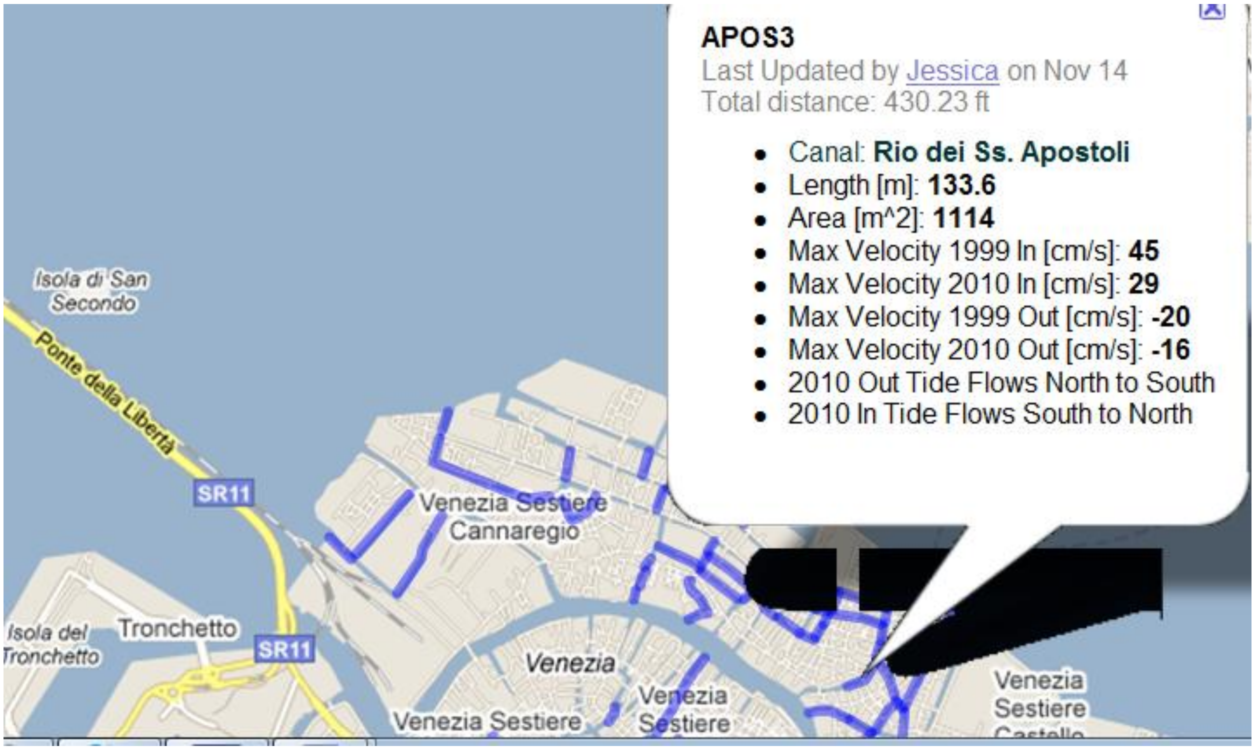
CANNAREGIO

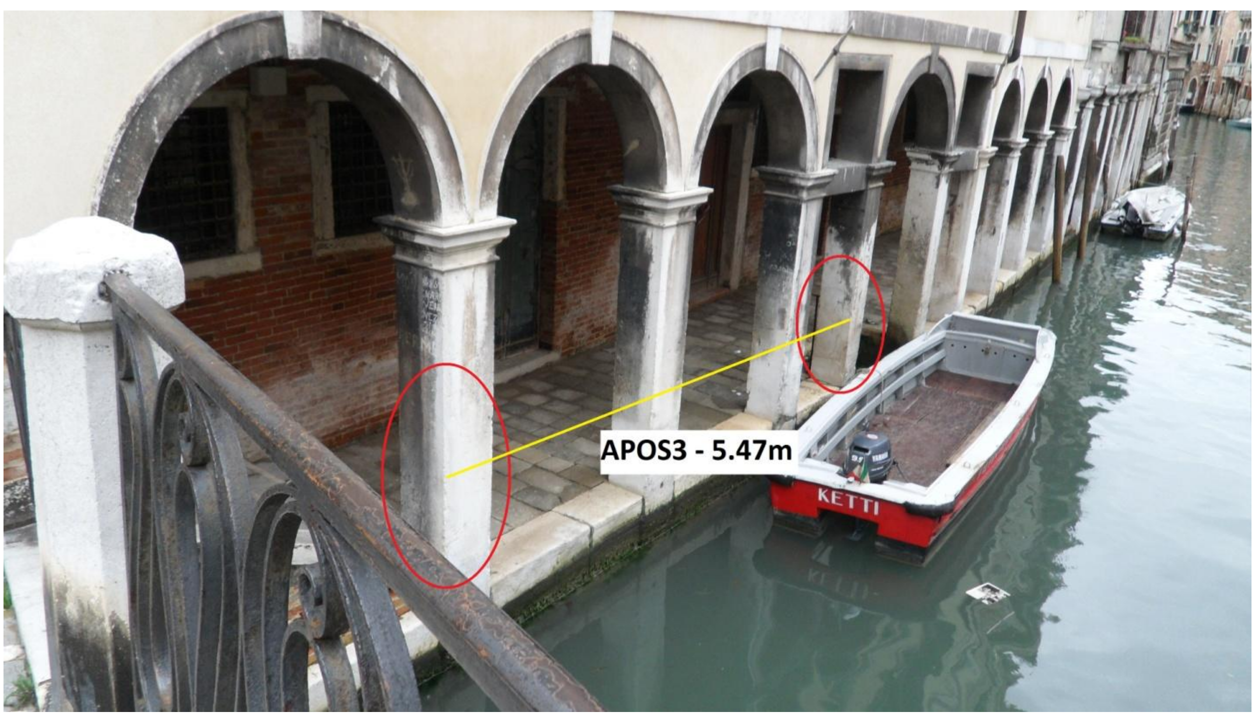
APOS1


APOS1
Last Updated by Jessica on Nov 14
Total distance: 148.78 ft
Canal: Rio dei Ss. Apostoli
Length [m]: 50.6
Area [m^2]: 460
Max Velocity 1999 In [cm/s]: 40
Max Velocity 2010 In [cm/s]: 47
Max Velocity 1999 Out [cm/s]: -25
Max Velocity 2010 Out [cm/s]: -29
2010 Out Tide Flows North to South
2010 In Tide Flows South to North
Isola di San Secondo
Ponte della Libertà
SR11
Venezia Sestiere Cannaregio
Sacca Della
Tronchetto

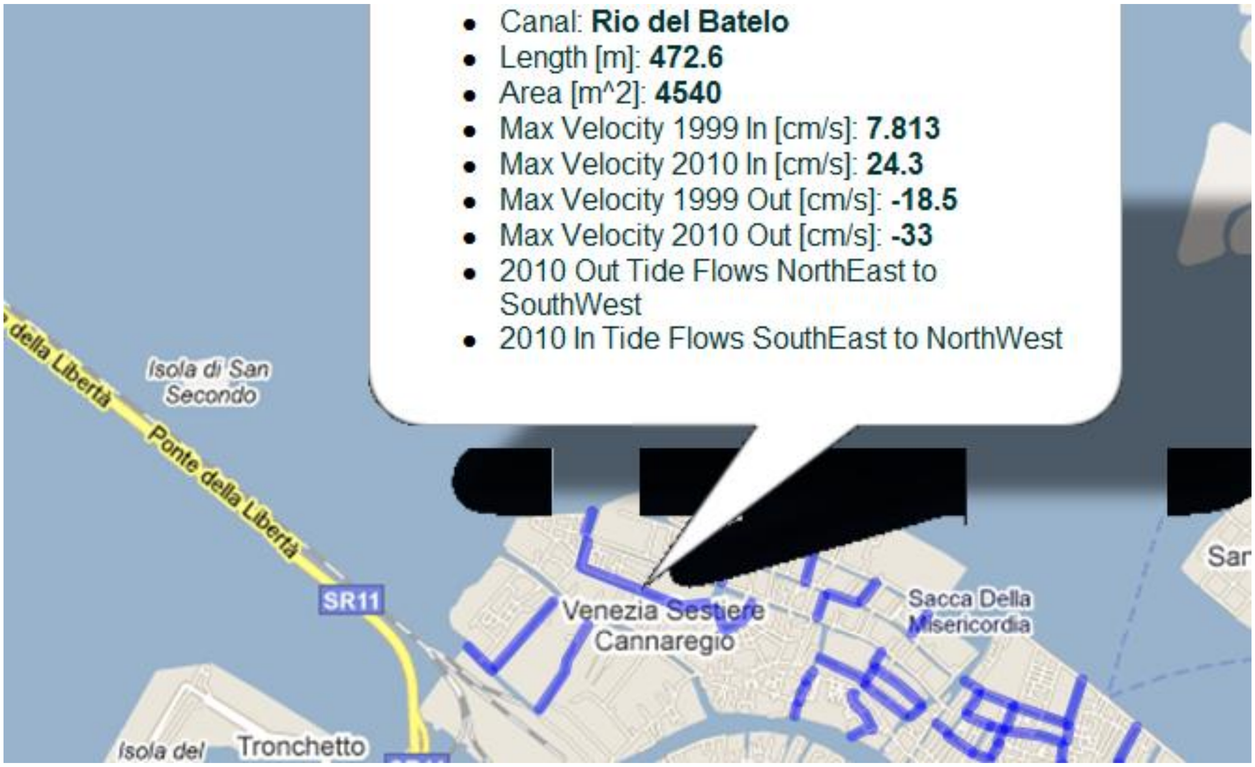

APOS1 - 4.36m

APOS3


APOS3
Last Updated by Jessica on Nov 14
Total distance: 430.23 ft
Canal: Rio dei Ss. Apostoli
Length [m]: 133.6
Area [m^2]: 1114
Max Velocity 1999 In [cm/s]: 45
Max Velocity 2010 In [cm/s]: 29
Max Velocity 1999 Out [cm/s]: -20
Max Velocity 2010 Out [cm/s]: -16
2010 Out Tide Flows North to South
2010 In Tide Flows South to North
Isola di San Secondo
Ponte della Libertà
SR11
Venezia Sestiere Cannaregio
Isola del Tronchetto
Tronchetto
SR11
Venezia
Venezia Sestiere
Venezia Sestiere
Venezia Sestiere


APOS3 - 5.47m
KETTI

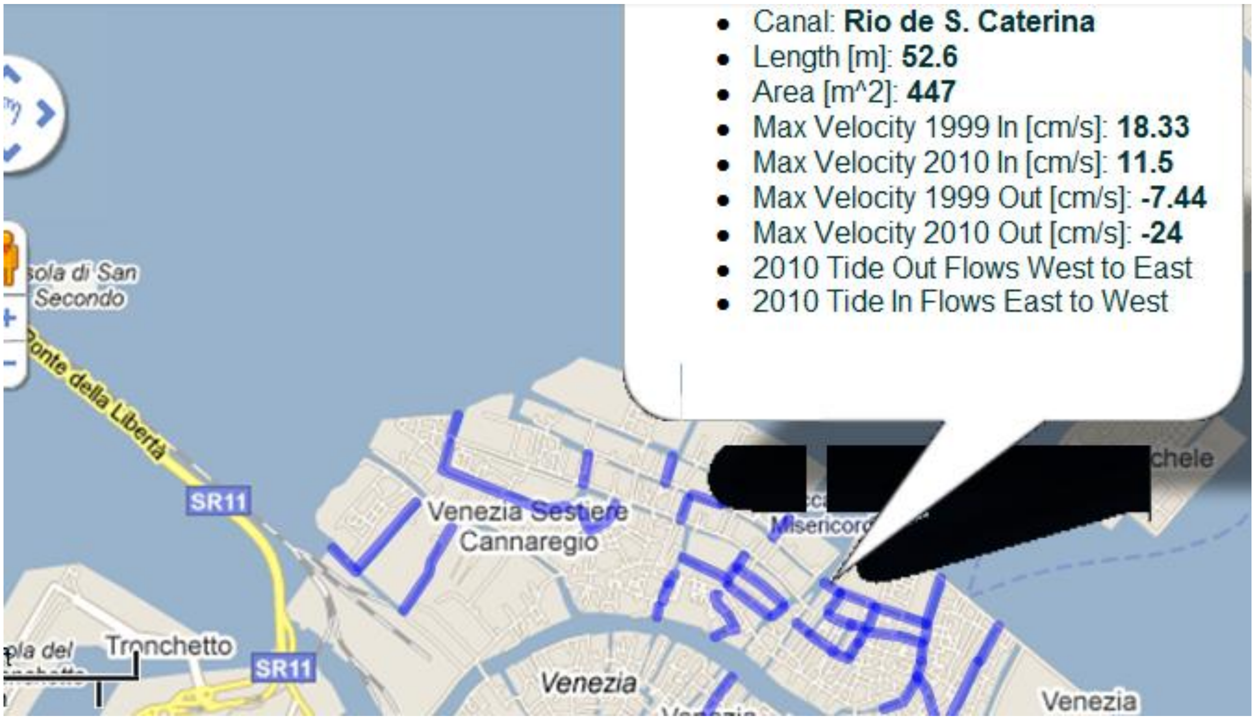
BATE1



Canal: Rio del Batelo
Length [m]: 472.6
Area [m^2]: 4540
Max Velocity 1999 In [cm/s]: 7.813
Max Velocity 2010 In [cm/s]: 24.3
Max Velocity 1999 Out [cm/s]: -18.5
Max Velocity 2010 Out [cm/s]: -33
2010 Out Tide Flows NorthEast to SouthWest
2010 In Tide Flows SouthEast to NorthWest
Isola di San Secondo
Ponte della Libertà
della Libertà
SR11
Venezia Sestiere Cannaregio
Sacca Della Misericordia
Isola del
Tronchetto

BATE1 - 4.4m

CATE1

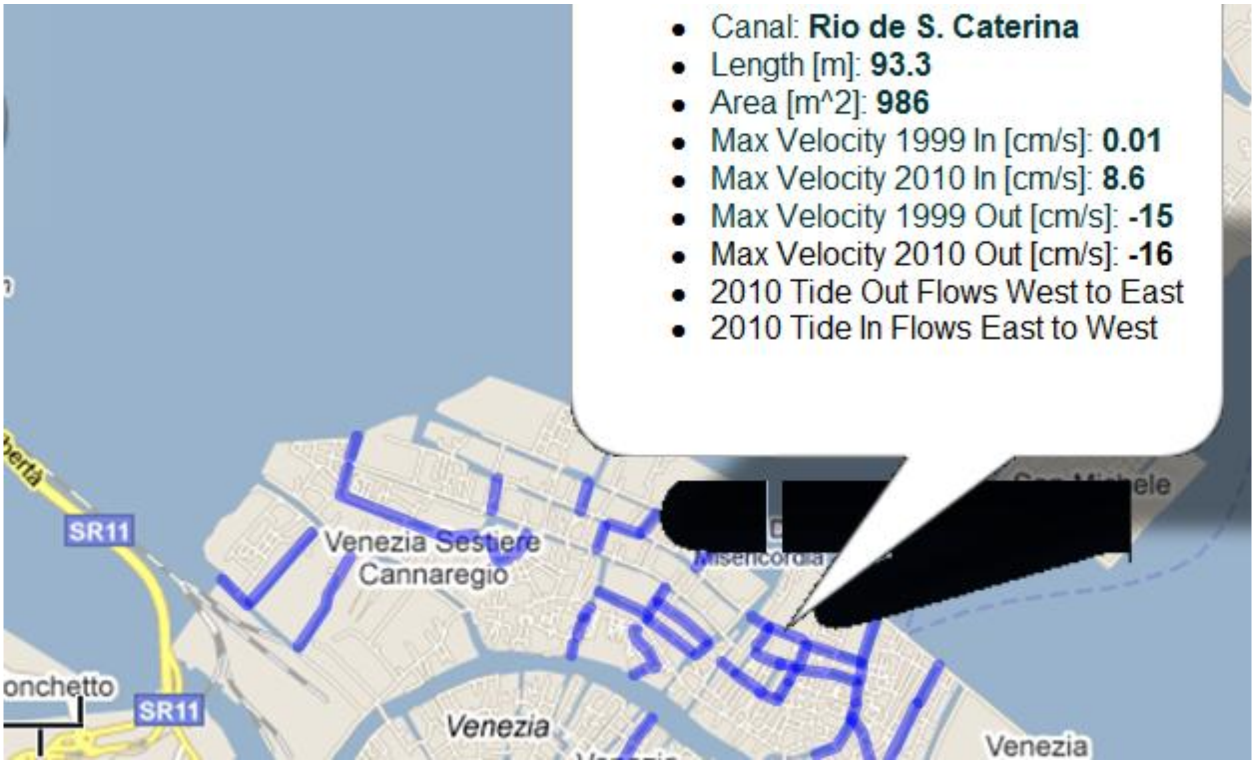


- Canal: **Rio de S. Caterina**
- Length [m]: **52.6**
- Area [m^2]: **447**
- Max Velocity 1999 In [cm/s]: **18.33**
- Max Velocity 2010 In [cm/s]: **11.5**
- Max Velocity 1999 Out [cm/s]: **-7.44**
- Max Velocity 2010 Out [cm/s]: **-24**
- 2010 Tide Out Flows West to East
- 2010 Tide In Flows East to West

Secondo
Ponte della Libertà
SR11
Venezia Sestiere
Cannaregio
[redacted]
Tronchetto
SR11
Venezia
Venezia

CATE1 - 10m

CATE2

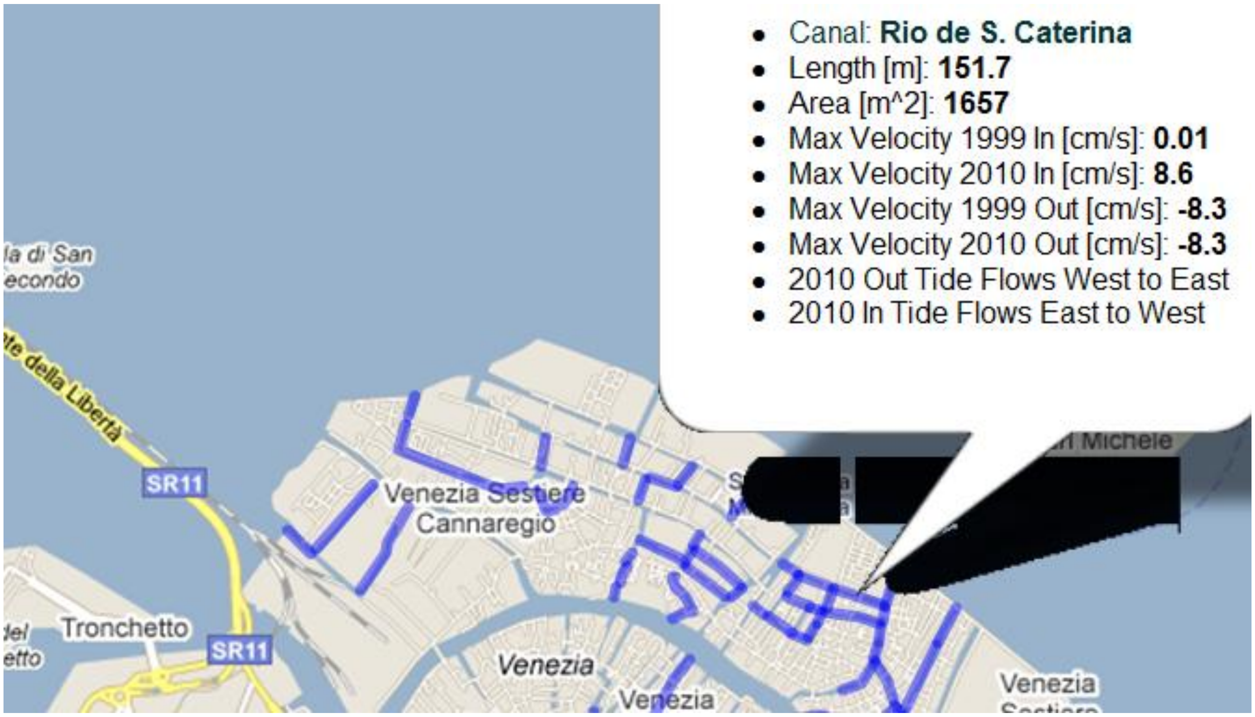


- Canal: **Rio de S. Caterina**
- Length [m]: **93.3**
- Area [m^2]: **986**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **8.6**
- Max Velocity 1999 Out [cm/s]: **-15**
- Max Velocity 2010 Out [cm/s]: **-16**
- 2010 Tide Out Flows West to East
- 2010 Tide In Flows East to West

[redacted]
SR11
SR11
Venezia Sestiere
Cannaregio
onchetto
Venezia
Venezia

CATE2 - 8.26m

CATE3

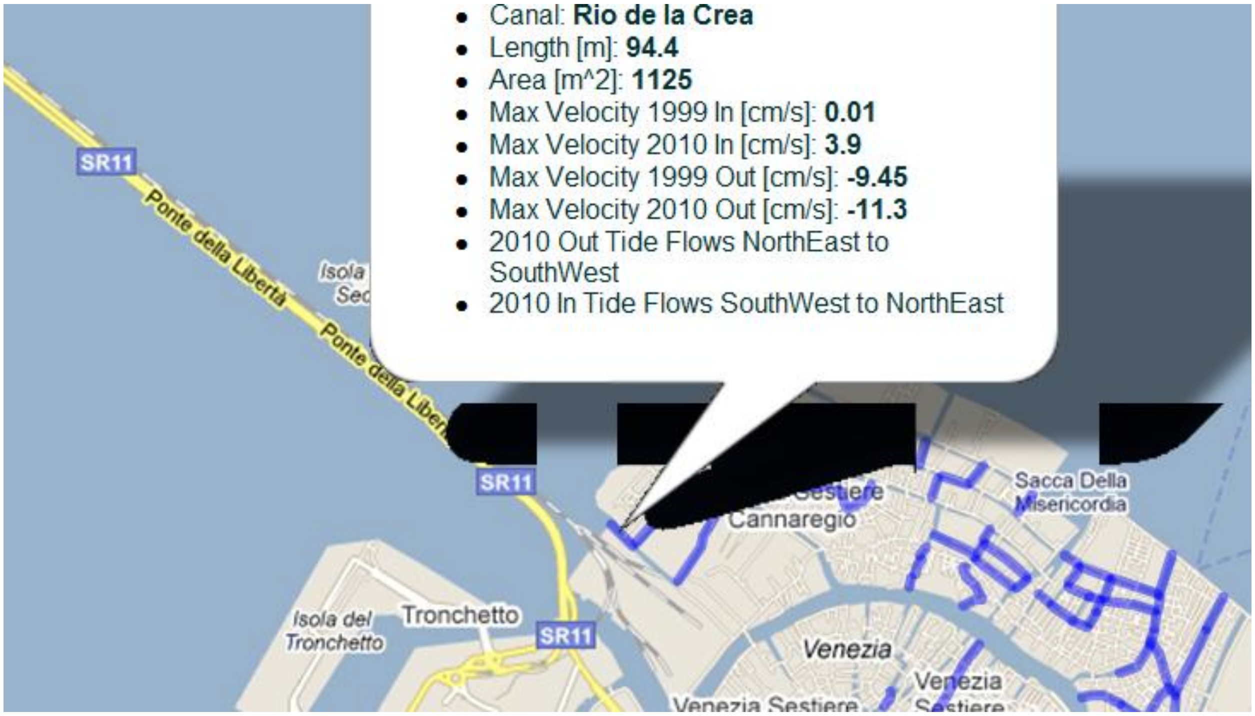


- Canal: **Rio de S. Caterina**
- Length [m]: **151.7**
- Area [m^2]: **1657**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **8.6**
- Max Velocity 1999 Out [cm/s]: **-8.3**
- Max Velocity 2010 Out [cm/s]: **-8.3**
- 2010 Out Tide Flows West to East
- 2010 In Tide Flows East to West

Venezia Sestiere Cannaregio
Tronchetto
SR11
SR11
Venezia
Venezia
Venezia

CATE3 - 4.47m

CREA3

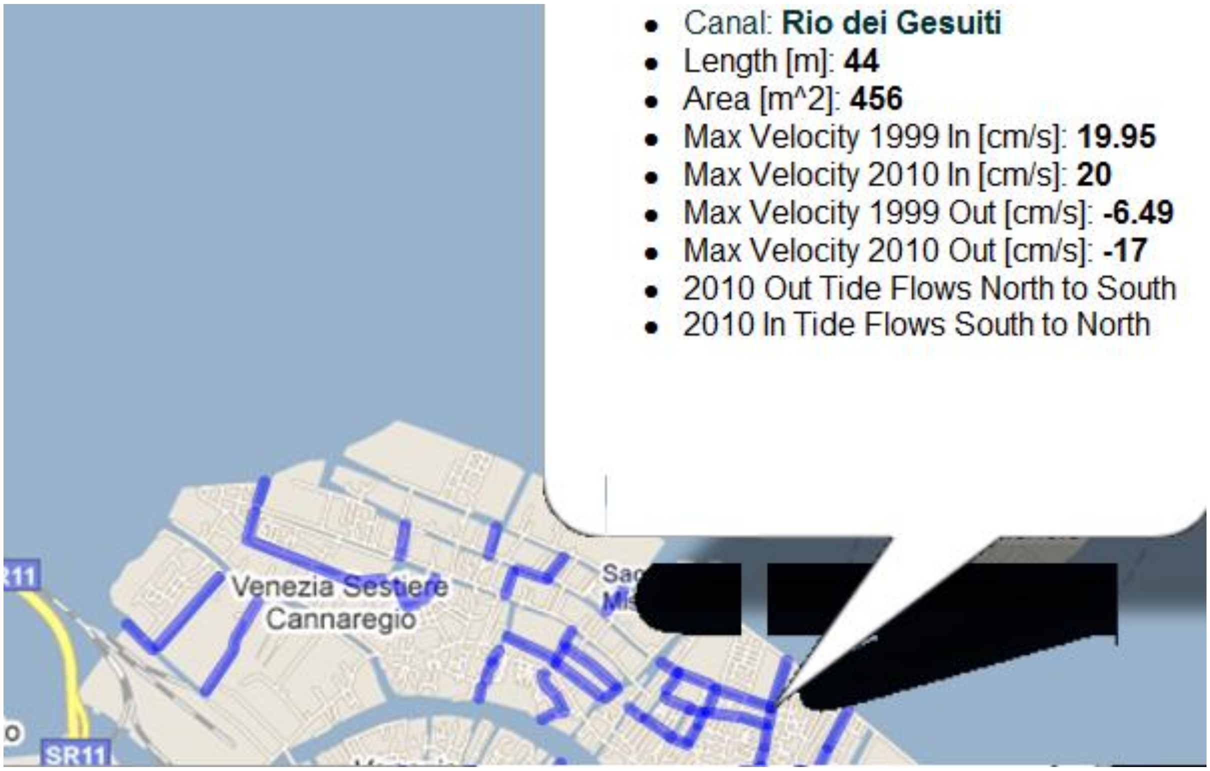


- Canal: **Rio de la Crea**
- Length [m]: **94.4**
- Area [m^2]: **1125**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **3.9**
- Max Velocity 1999 Out [cm/s]: **-9.45**
- Max Velocity 2010 Out [cm/s]: **-11.3**
- 2010 Out Tide Flows NorthEast to SouthWest
- 2010 In Tide Flows SouthWest to NorthEast

SR11
Ponte della Libertà
Ponte della Liber
SR11
Cannaregio
Sacca Della
Misericordia
Isola del
Tronchetto
Tronchetto
SR11
Venezia
Venezia

CREA3 - 7.1m

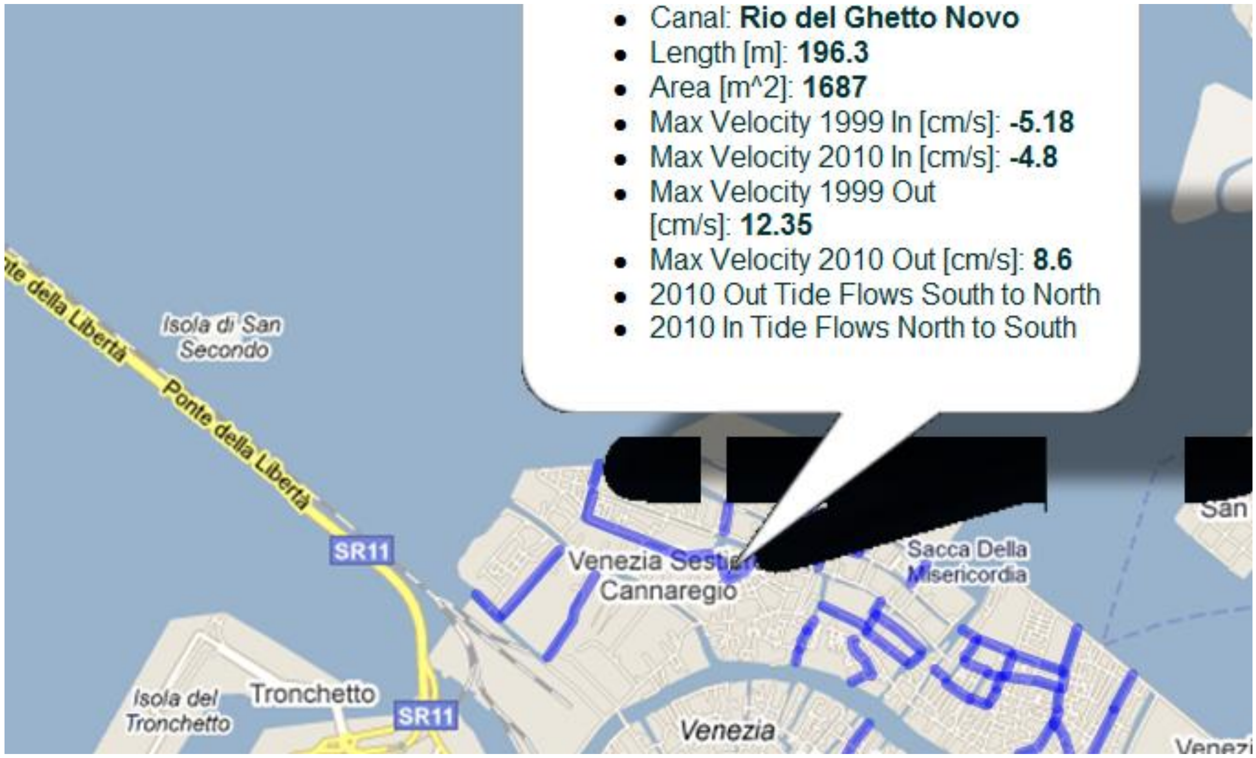
GESU2



Canal: Rio dei Gesuiti
Length [m]: 44
Area [m^2]: 456
Max Velocity 1999 In [cm/s]: 19.95
Max Velocity 2010 In [cm/s]: 20
Max Velocity 1999 Out [cm/s]: -6.49
Max Velocity 2010 Out [cm/s]: -17
2010 Out Tide Flows North to South
2010 In Tide Flows South to North
Venezia Sestiere Cannaregio
SR11
[redacted]

GESU2 - 4.24m

GHET


Canal: **Rio del Ghetto Novo**
Length [m]: **196.3**
Area [m^2]: **1687**
Max Velocity 1999 In [cm/s]: **-5.18**
Max Velocity 2010 In [cm/s]: **-4.8**
Max Velocity 1999 Out [cm/s]: **12.35**
Max Velocity 2010 Out [cm/s]: **8.6**
2010 Out Tide Flows South to North
2010 In Tide Flows North to South
Isola di San Secondo
Ponte della Libertà
SR11
Cannaregio
Sacca Della Misericordia
Isola del Tronchetto
Tronchetto
Venezia

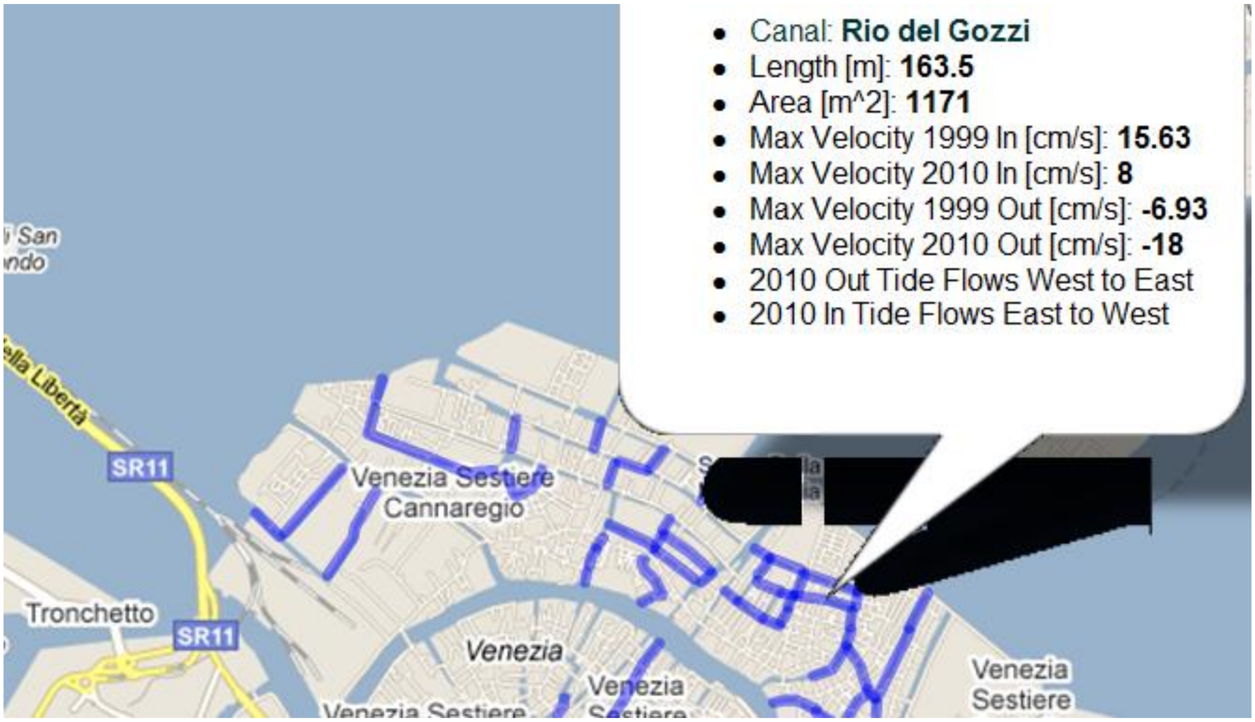

GHET - 3.69m

GIOB

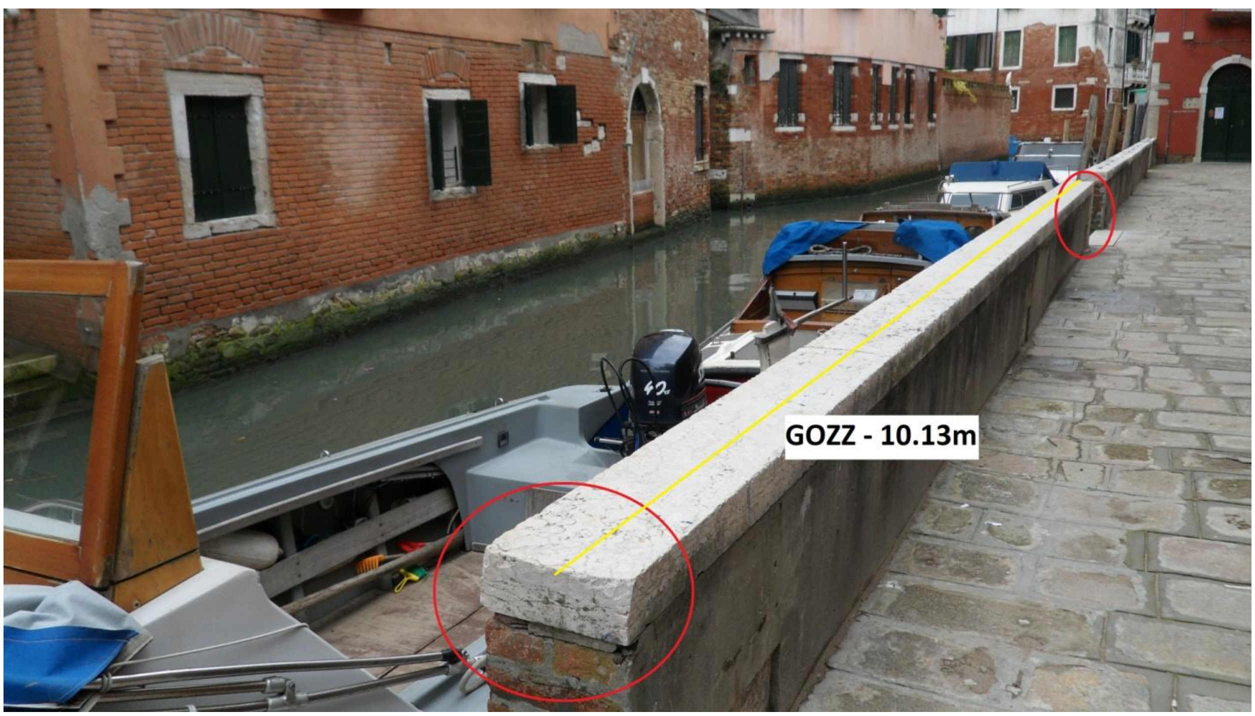
Canal: Rio dei Giobbe
Length [m]: 274.4
Area [m^2]: 1648
V Max 1999 In [cm/s]: 6.17
V Max 2010 In [cm/s]: 6.9
V Max 1999 Out[cm/s]: 13.47
V Max 2010 Out [cm/s]: 6.3
2010 Out and In Tides Flow North
San Giuliano
SR11
Ponte della Libertà
Murano
San Michele
SR11
Isola del Tronchetto
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere Castello
Arsenale
Darsena Grande
Bacino Stazione Marittima
Venezia

GIOB - 6.45m

GOZZ

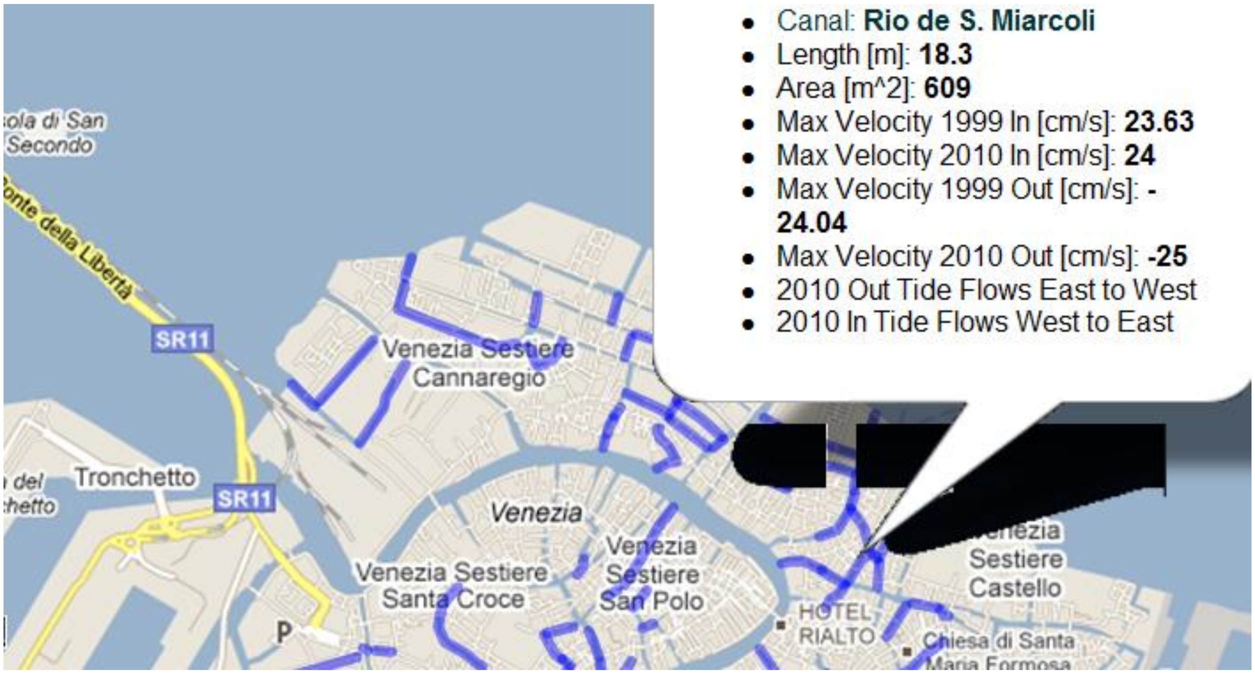


- Canal: **Rio del Gozzi**
- Length [m]: **163.5**
- Area [m^2]: **1171**
- Max Velocity 1999 In [cm/s]: **15.63**
- Max Velocity 2010 In [cm/s]: **8**
- Max Velocity 1999 Out [cm/s]: **-6.93**
- Max Velocity 2010 Out [cm/s]: **-18**
- 2010 Out Tide Flows West to East
- 2010 In Tide Flows East to West
[redacted]
SR11
Venezia Sestiere
Cannaregio
Tronchetto
SR11
Venezia
Venezia
Sestiere



GOZZ - 10.13m

MIRA



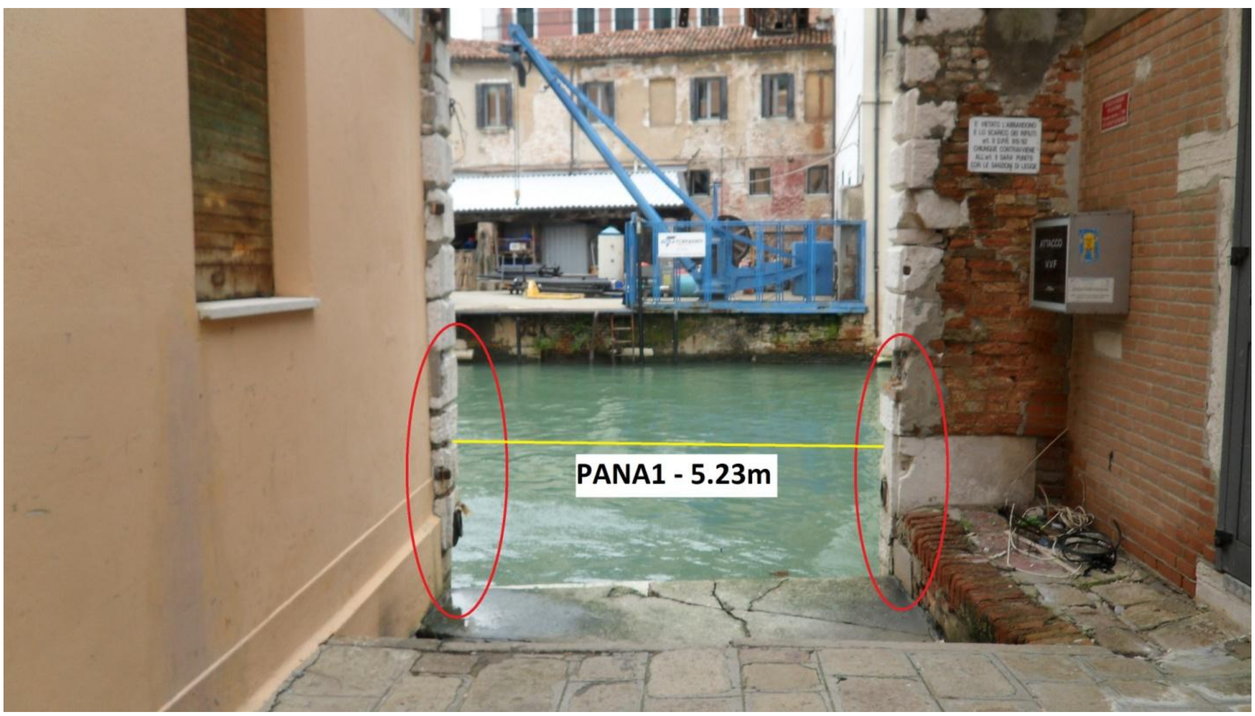
- Canal: **Rio de S. Miarcoli**
- Length [m]: **18.3**
- Area [m^2]: **609**
- Max Velocity 1999 In [cm/s]: **23.63**
- Max Velocity 2010 In [cm/s]: **24**
- Max Velocity 1999 Out [cm/s]: **-24.04**
- Max Velocity 2010 Out [cm/s]: **-25**
- 2010 Out Tide Flows East to West
- 2010 In Tide Flows West to East
SR11
SR11
Venezia Sestiere Cannaregio
Tronchetto
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
Sestiere Castello
HOTEL RIALTO
Chiesa di Santa

MIRA - 7.04m

PANA1

- Canal: Rio de la Panada
- Length [m]: **119.7**
- Area [m^2]: **1400**
- Max Velocity 1999 In [cm/s]: **14.3**
- Max Velocity 2010 In [cm/s]: **7.6**
- Max Velocity 1999 Out [cm/s]: **-8.66**
- Max Velocity 2010 Out [cm/s]: **-9.63**
- 2010 Out Tide Flows North to South
- 2010 In Tide Flows South to North

SR11
Venezia Sestiere Cannaregio
Sacca Della
[redacted]
SR11
Venezia



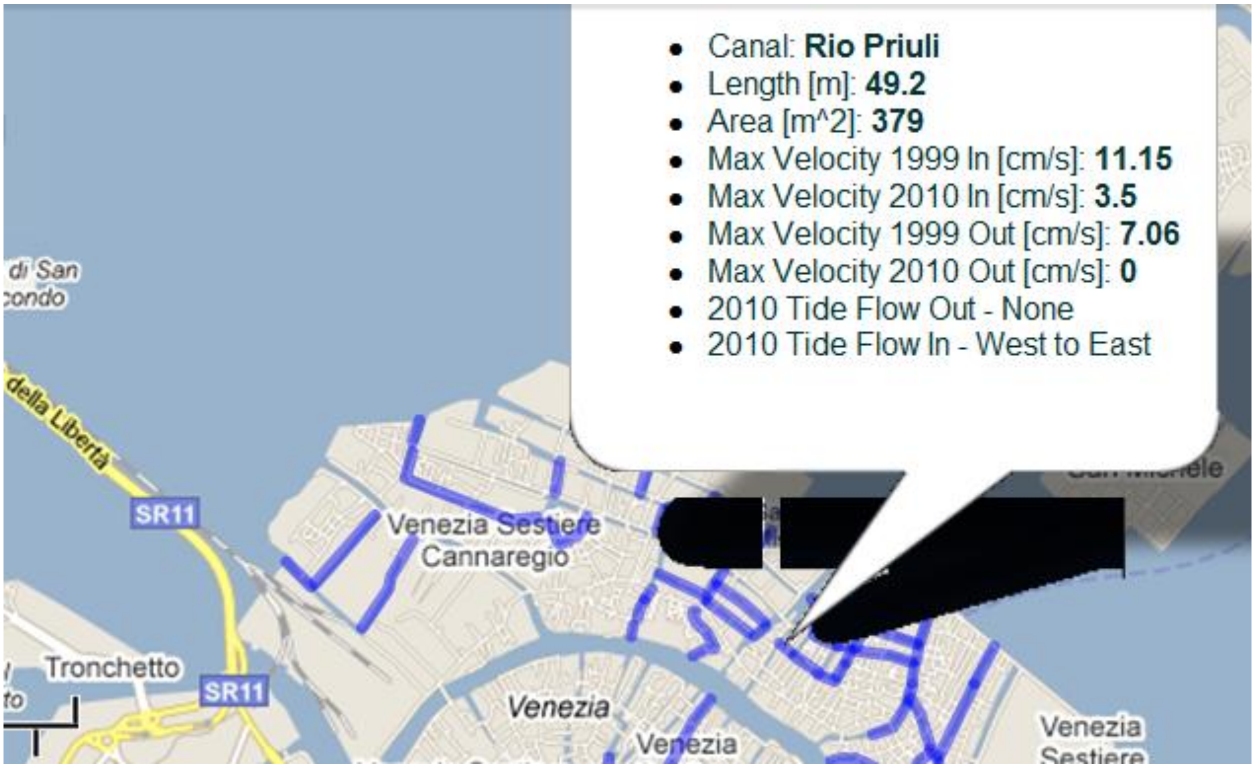
PANA1 - 5.23m

PANA2

Canal: Rio de la Panada
Length [m]: 222.5
Area [m^2]: 1142
Max Velocity 1999 In [cm/s]: 21.84
Max Velocity 2010 In [cm/s]: 31
Max Velocity 1999 Out [cm/s]: -27.99
Max Velocity 2010 Out [cm/s]: -31
2010 Out Tide Flows North to South
2010 In Tide Flows South to North
SR11
Venezia Sestiere Cannaregio
SR11
Venezia
Venezia
Venezia Sestiere

PANA2 - 8m

PRIU1

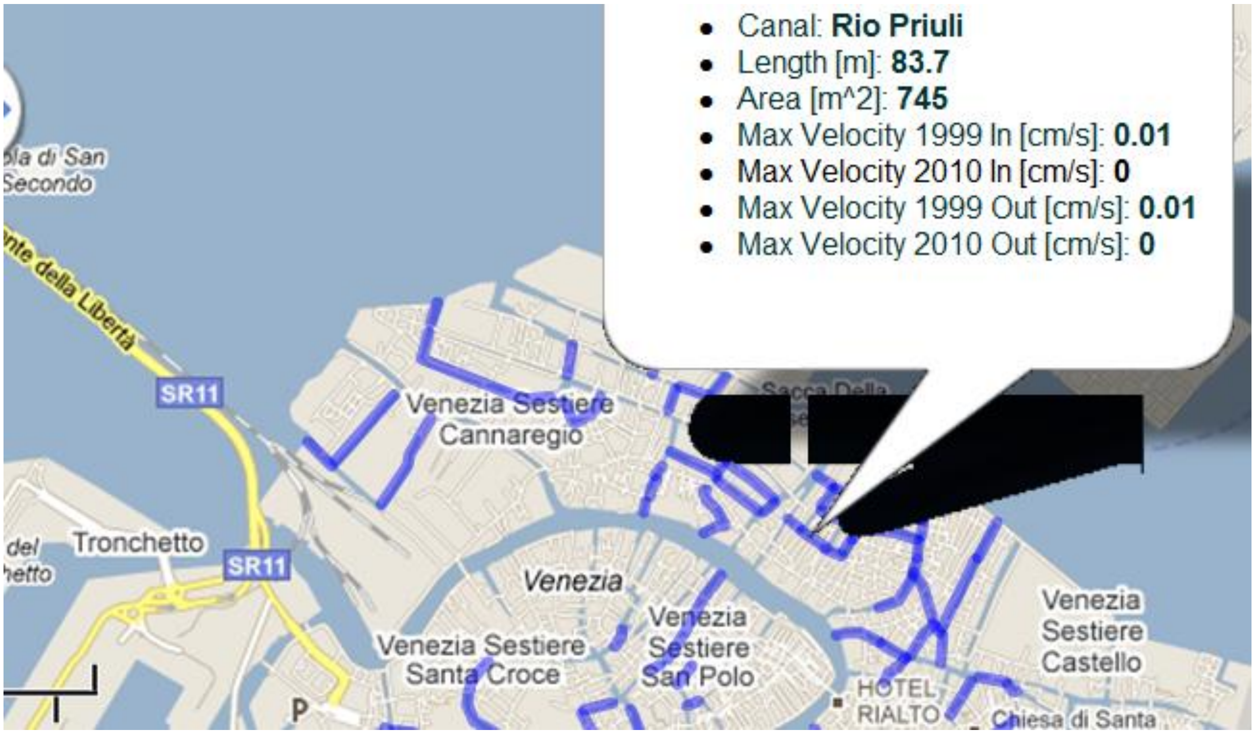


- Canal: **Rio Priuli**
- Length [m]: **49.2**
- Area [m^2]: **379**
- Max Velocity 1999 In [cm/s]: **11.15**
- Max Velocity 2010 In [cm/s]: **3.5**
- Max Velocity 1999 Out [cm/s]: **7.06**
- Max Velocity 2010 Out [cm/s]: **0**
- 2010 Tide Flow Out - None
- 2010 Tide Flow In - West to East

[redacted]
di San
condo
della Libertà
SR11
Venezia Sestiere
Cannaregio
Tronchetto
SR11
Venezia
Venezia
Venezia
Sestiere

PONTE
PRIULI
PRIU1 - 2.9m

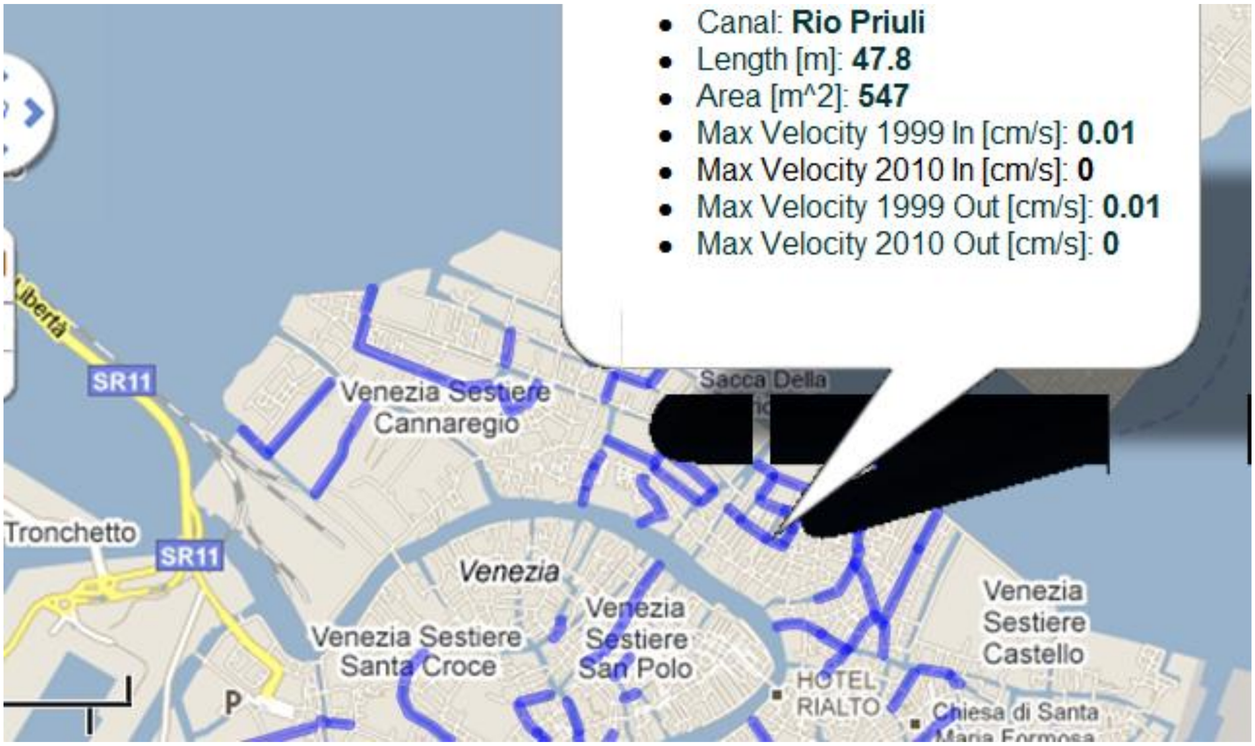
PRIU2



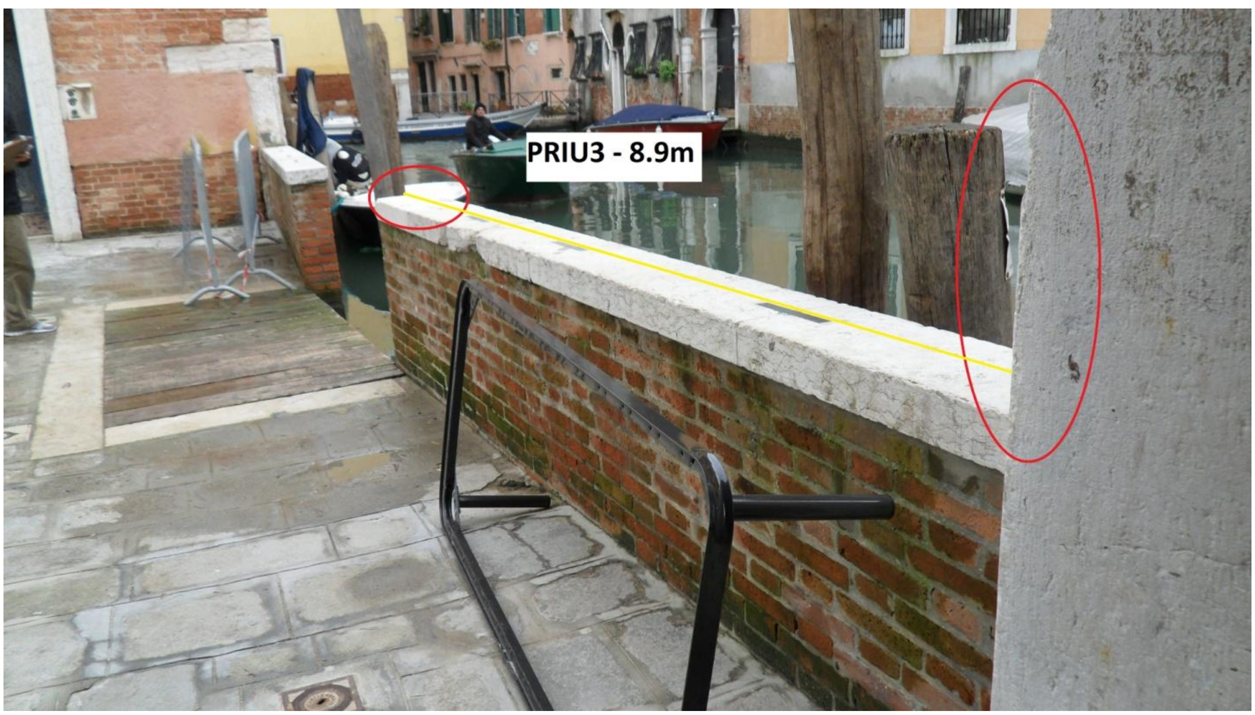
Canal: **Rio Priuli**
Length [m]: **83.7**
Area [m^2]: **745**
Max Velocity 1999 In [cm/s]: **0.01**
Max Velocity 2010 In [cm/s]: **0**
Max Velocity 1999 Out [cm/s]: **0.01**
Max Velocity 2010 Out [cm/s]: **0**
[redacted]
Venezia Sestiere Cannaregio
SR11
Tronchetto
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
Venezia Sestiere Castello
HOTEL RIALTO

PRIU2 - 10.4m

PRIU3

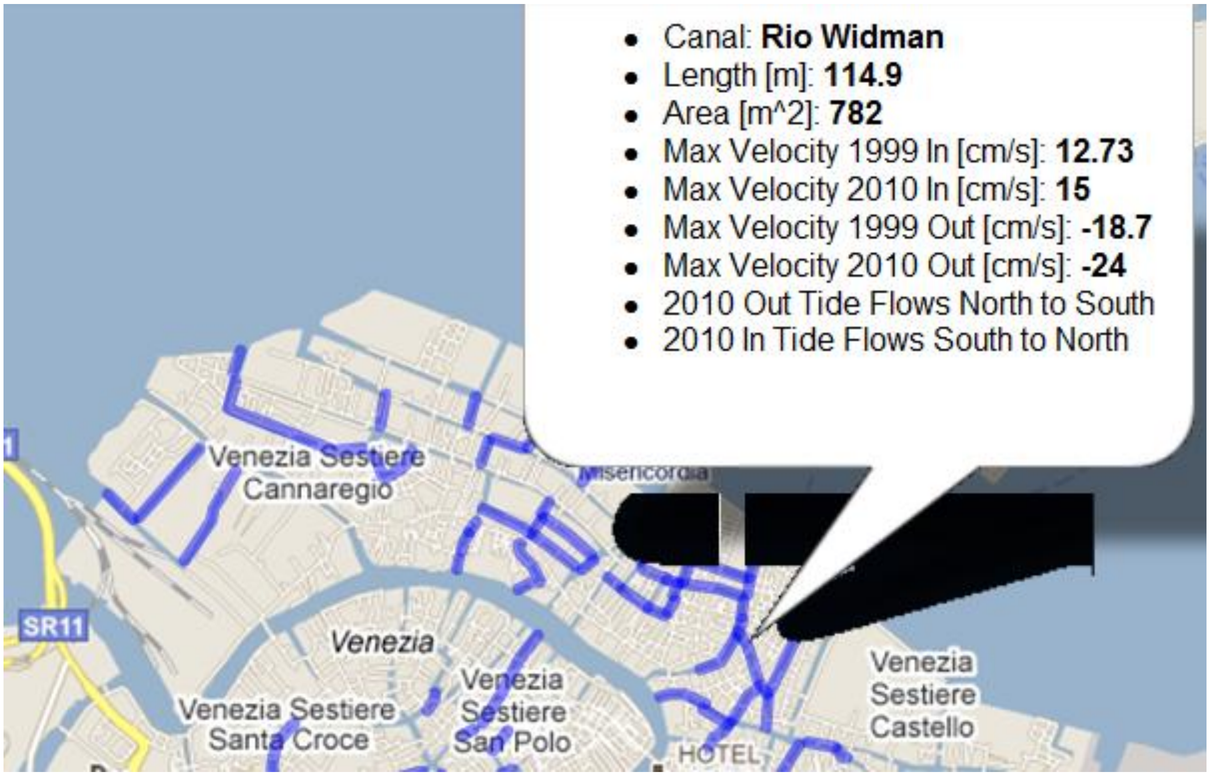


- Canal: **Rio Priuli**
- Length [m]: **47.8**
- Area [m^2]: **547**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **0**
- Max Velocity 1999 Out [cm/s]: **0.01**
- Max Velocity 2010 Out [cm/s]: **0**
SR11
Venezia Sestiere Cannaregio
Sacca Della
[redacted]
Tronchetto
SR11
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
Venezia Sestiere Castello
HOTEL RIALTO
Chiesa di Santa Maria Formosa



PRIU3 - 8.9m

WIDM1

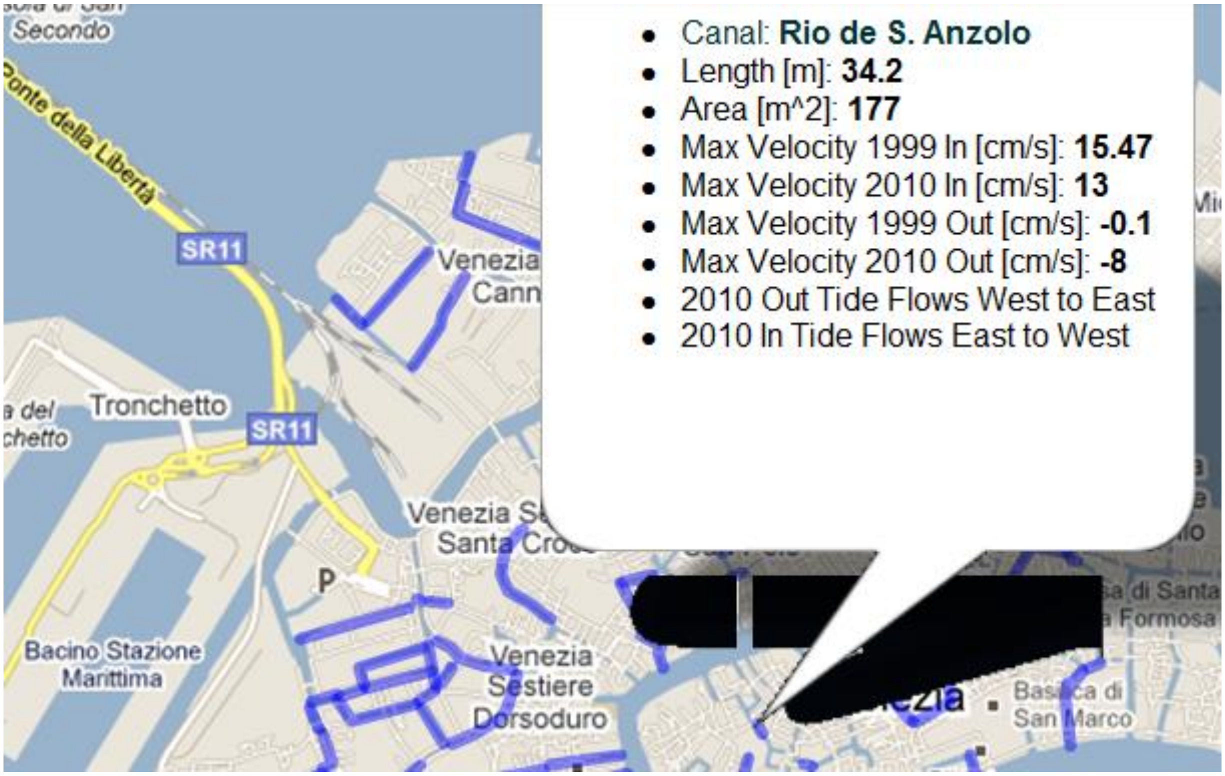


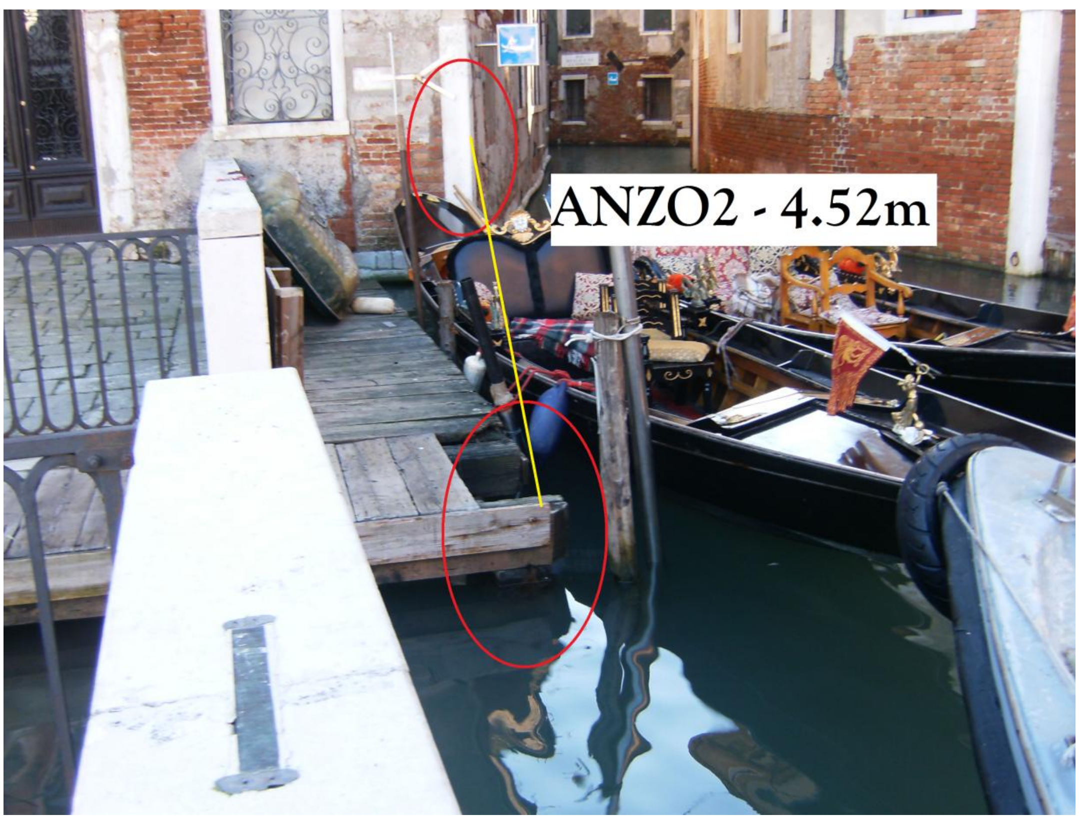
Canal: **Rio Widman**
Length [m]: **114.9**
Area [m^2]: **782**
Max Velocity 1999 In [cm/s]: **12.73**
Max Velocity 2010 In [cm/s]: **15**
Max Velocity 1999 Out [cm/s]: **-18.7**
Max Velocity 2010 Out [cm/s]: **-24**
2010 Out Tide Flows North to South
2010 In Tide Flows South to North
Venezia Sestiere Cannaregio
Misericordia
[redacted]
SR11
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
Venezia Sestiere Castello
HOTEL

WIDM1 - 8.73m

SAN MARCO

ANZO2


Secondo
Ponte della Libertà
SR11
Tronchetto
SR11
Bacino Stazione Marittima
Venezia Sestiere Dorsoduro
- Canal: **Rio de S. Anzolo**
- Length [m]: **34.2**
- Area [m^2]: **177**
- Max Velocity 1999 In [cm/s]: **15.47**
- Max Velocity 2010 In [cm/s]: **13**
- Max Velocity 1999 Out [cm/s]: **-0.1**
- Max Velocity 2010 Out [cm/s]: **-8**
- 2010 Out Tide Flows West to East
- 2010 In Tide Flows East to West


ANZO2 - 4.52m

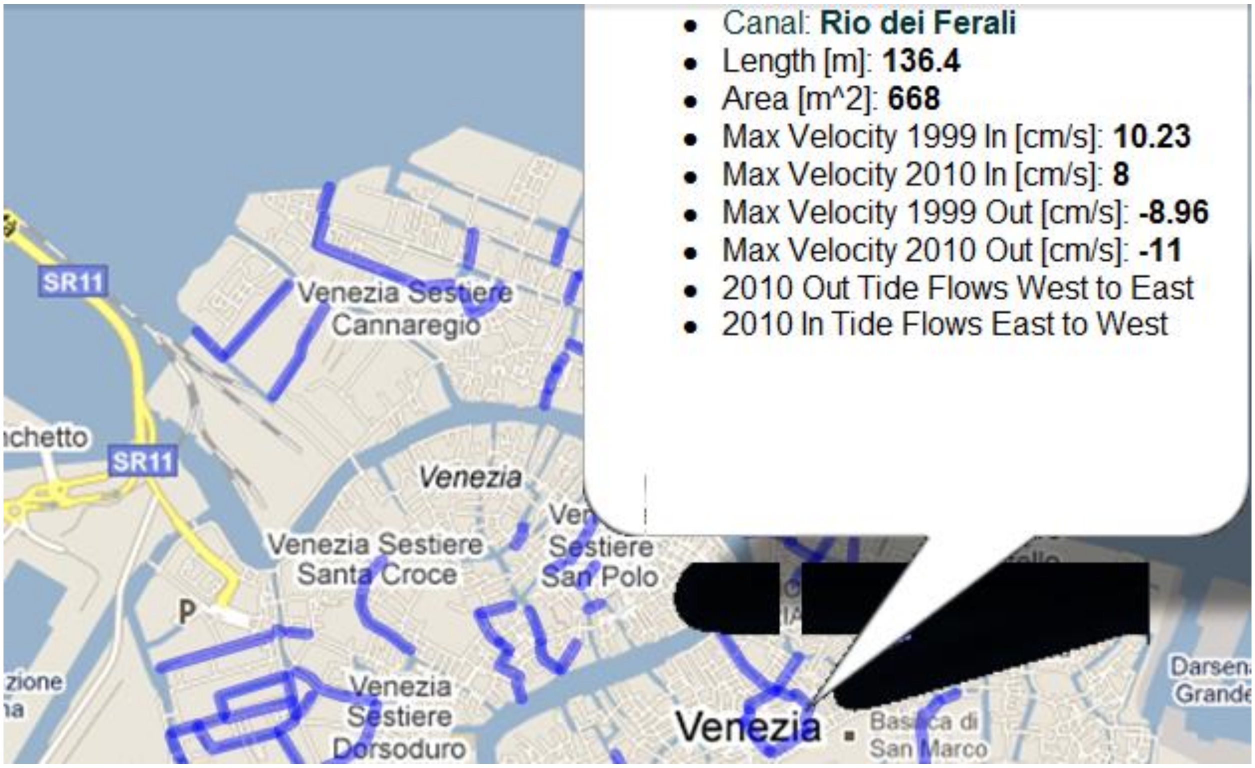
BARE1

- Canal: **Rio dei Bareteri**
- Length [m]: **96.4**
- Area [m^2]: **684**
- Max Velocity 1999 In [cm/s]: **-10**
- Max Velocity 2010 In [cm/s]: **-7**
- Max Velocity 1999 Out [cm/s]: **3.76**
- Max Velocity 2010 Out [cm/s]: **13**
- 2010 Out Tide Flows North to South
- 2010 In Tide Flows South to North

SR11
Venezia Sestiere Cannaregio
SR11
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
P
Venezia

BARE1 - 7.6m

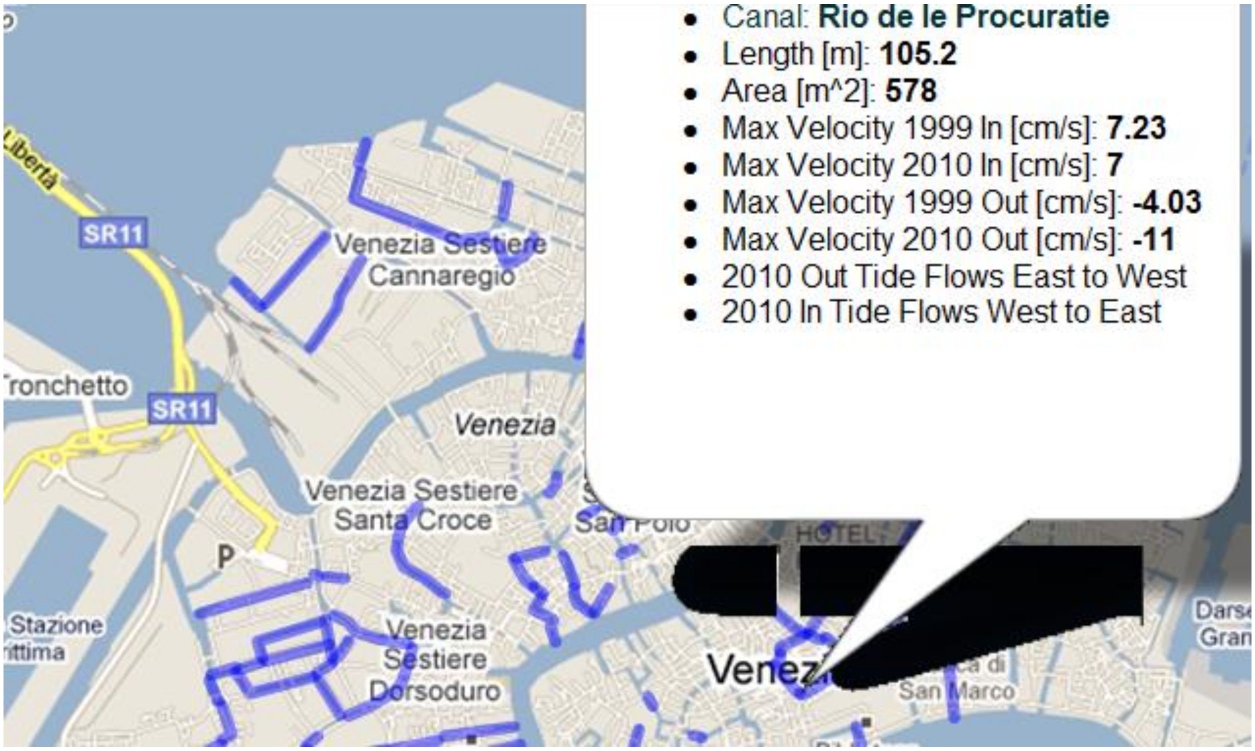
FERA2

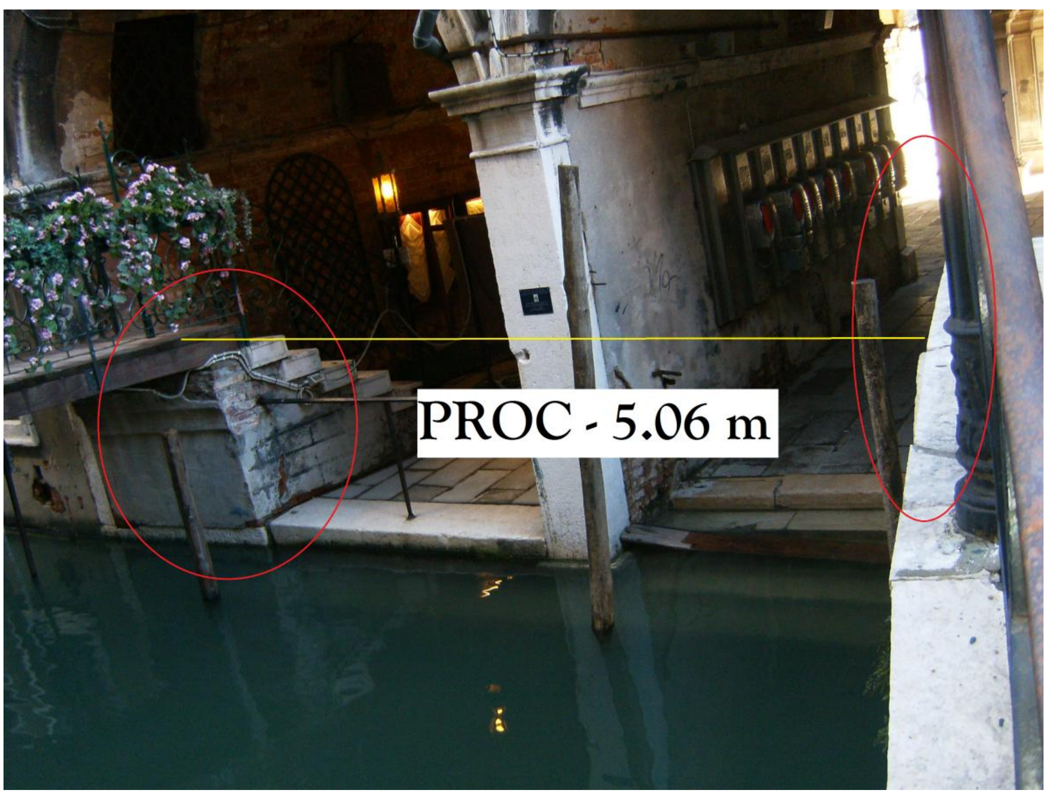


Canal: **Rio dei Ferali**
Length [m]: **136.4**
Area [m^2]: **668**
Max Velocity 1999 In [cm/s]: **10.23**
Max Velocity 2010 In [cm/s]: **8**
Max Velocity 1999 Out [cm/s]: **-8.96**
Max Velocity 2010 Out [cm/s]: **-11**
2010 Out Tide Flows West to East
2010 In Tide Flows East to West
SR11
Venezia Sestiere Cannaregio
SR11
Venezia
Venezia Sestiere Santa Croce
Sestiere San Polo
[redacted]
Venezia Sestiere Dorsoduro
Venezia
Basilica di San Marco

FERA2 - 4.43m

PROC


Canal: **Rio de le Procuratie**
Length [m]: **105.2**
Area [m^2]: **578**
Max Velocity 1999 In [cm/s]: **7.23**
Max Velocity 2010 In [cm/s]: **7**
Max Velocity 1999 Out [cm/s]: **-4.03**
Max Velocity 2010 Out [cm/s]: **-11**
2010 Out Tide Flows East to West
2010 In Tide Flows West to East
SR11
Venezia Sestiere Cannaregio
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere Dorsoduro
P
[redacted]
San Marco

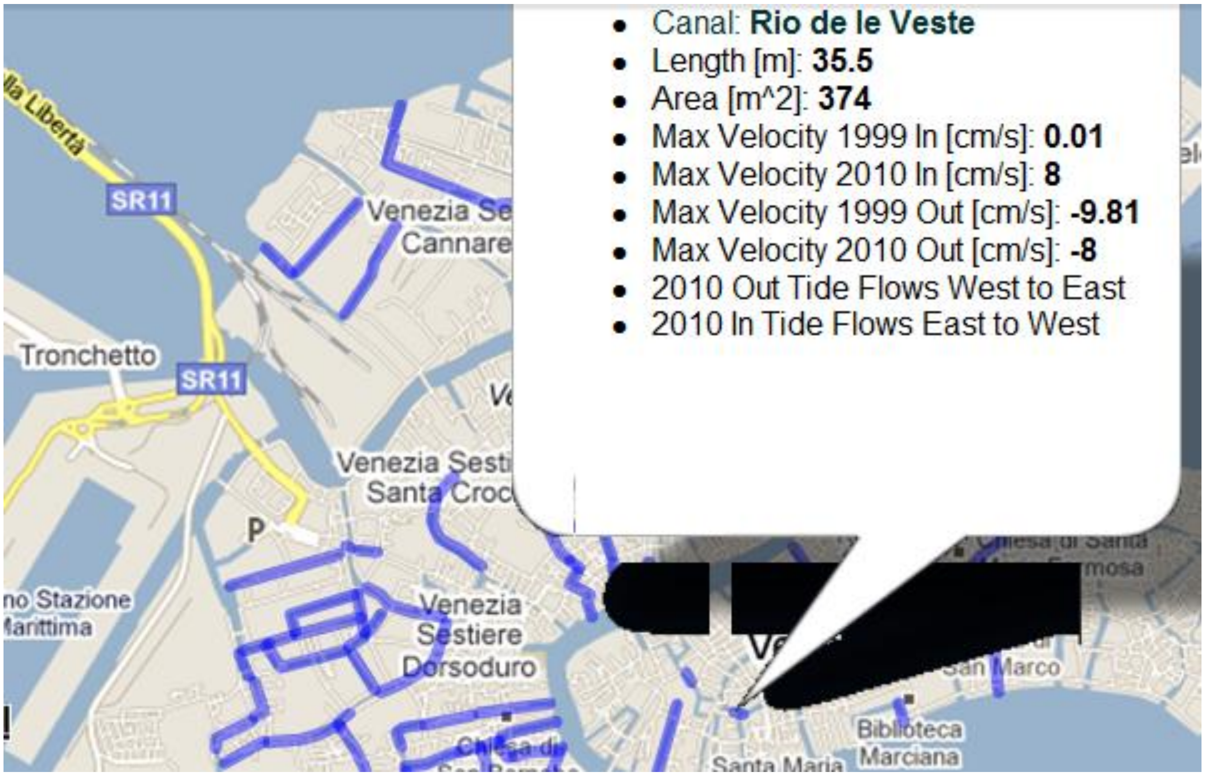

PROC - 5.06 m

SANT

- Canal: **Rio del Santissimo**
- Length [m]: **275.3**
- Area [m^2]: **1596**
- V Max 1999 In [cm/s]: **17.84**
- V Max 2010 In [cm/s]: **16**
- V Max 1999 Out [cm/s]: **-17**
- V Max 2010 Out [cm/s]: **-18**
- 2010 Out Tide Flows South
- 2010 In Tide Flows North
SR11
SR11
Isola del Tronchetto
Tronchetto
Bacino Stazione Marittima
Venezia Sestiere Dorsoduro
Chiesa di San Barnaba
Santa Maria della Salute
Biblioteca Marciana
Sacca

SANT - 4.64m

VEST2

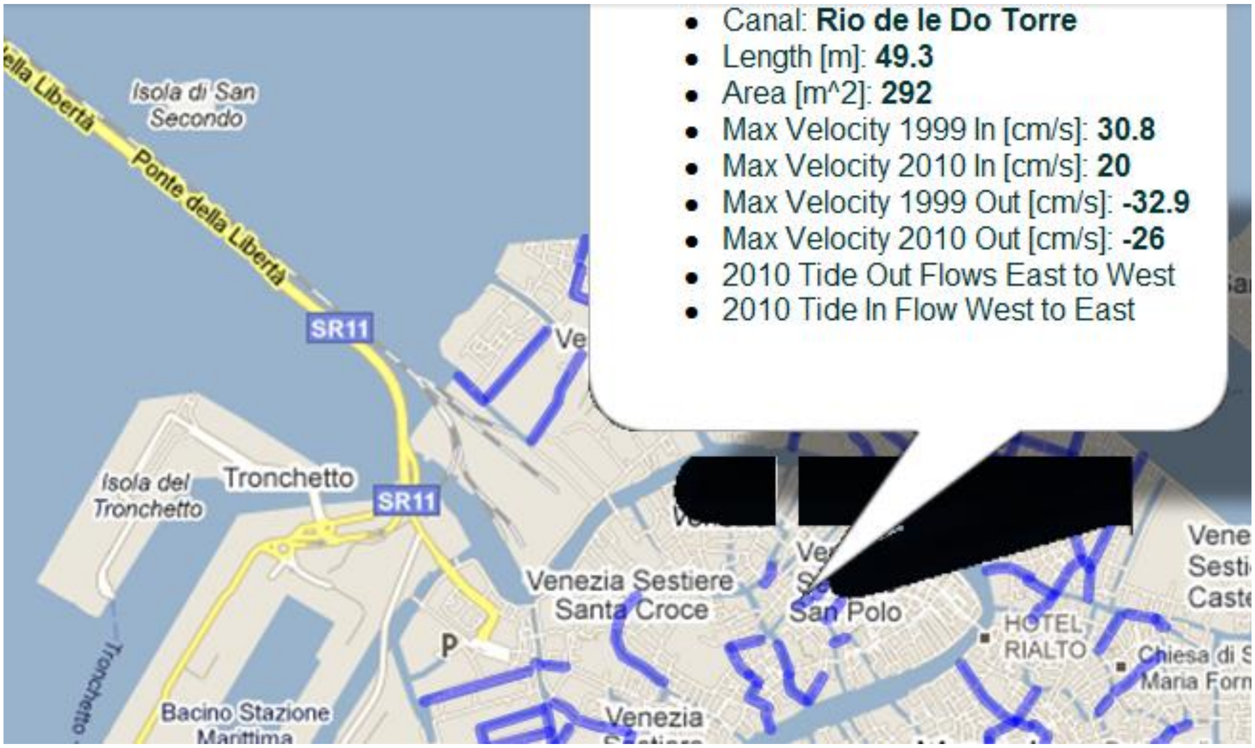


Canal: **Rio de le Veste**
Length [m]: **35.5**
Area [m^2]: **374**
Max Velocity 1999 In [cm/s]: **0.01**
Max Velocity 2010 In [cm/s]: **8**
Max Velocity 1999 Out [cm/s]: **-9.81**
Max Velocity 2010 Out [cm/s]: **-8**
2010 Out Tide Flows West to East
2010 In Tide Flows East to West
Tronchetto
SR11
SR11
Venezia Sestiere Dorsoduro
Biblioteca Marciana

VEST2 - 4.39m

SAN POLO

2TOR2



Canal: **Rio de le Do Torre**
Length [m]: **49.3**
Area [m^2]: **292**
Max Velocity 1999 In [cm/s]: **30.8**
Max Velocity 2010 In [cm/s]: **20**
Max Velocity 1999 Out [cm/s]: **-32.9**
Max Velocity 2010 Out [cm/s]: **-26**
2010 Tide Out Flows East to West
2010 Tide In Flow West to East
Isola di San Secondo
Ponte della Libertà
SR11
Tronchetto
Isola del Tronchetto
SR11
[redacted]
Venezia Sestiere Santa Croce
San Polo
HOTEL RIALTO
Bacino Stazione

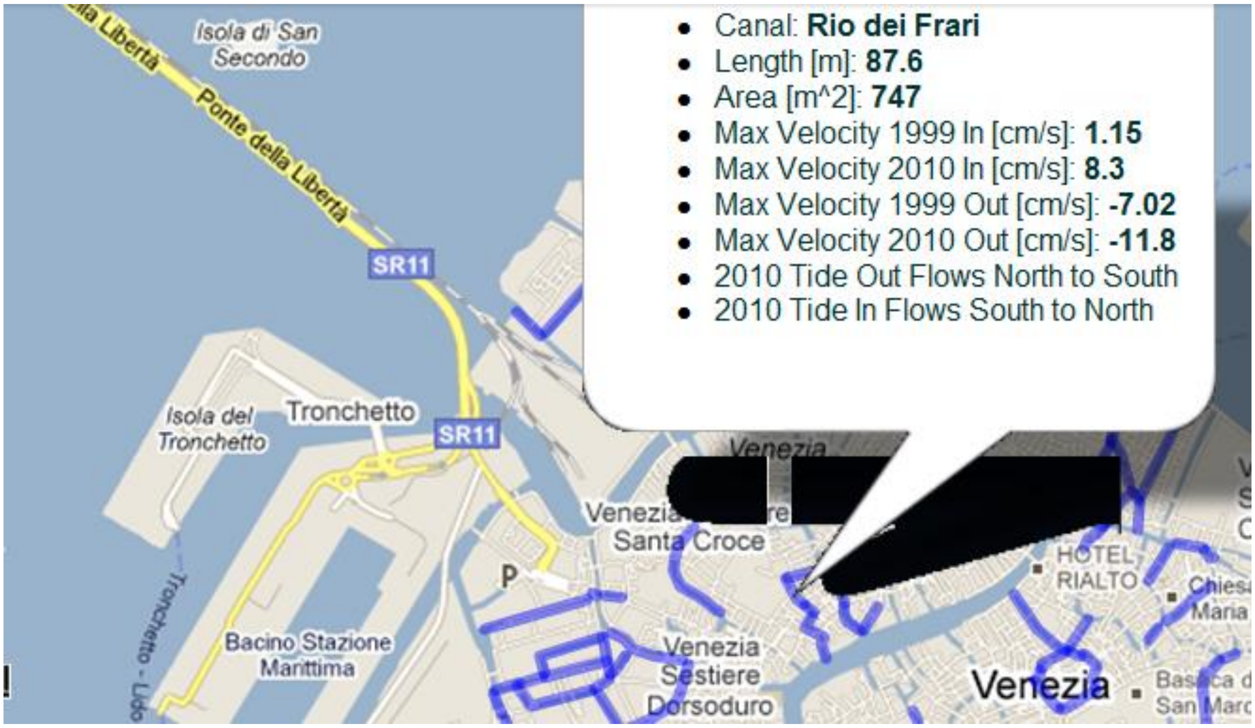
2TOR2 - 9.18m

DOMI1

Canal: **Rio de S. Maria Mater Domini**
Length [m]: **283**
Area [m^2]: **1606**
Max Velocity 1999 In [cm/s]: **21.8**
Max Velocity 2010 In [cm/s]: 14
Max Velocity 1999 Out [cm/s]: **-16.8**
Max Velocity 2010 Out [cm/s]: -13
2010 Out Tide Flows North to South
2010 In Tide Flows South to North
Isola di San Secondo
Ponte della Libertà
SR11
Tronchetto
SR11
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
Venezia Sestiere Castello
HOTEL RIALTO
Chiesa di Santa Maria Formosa

DOMI - 7.12 m

FRAR1

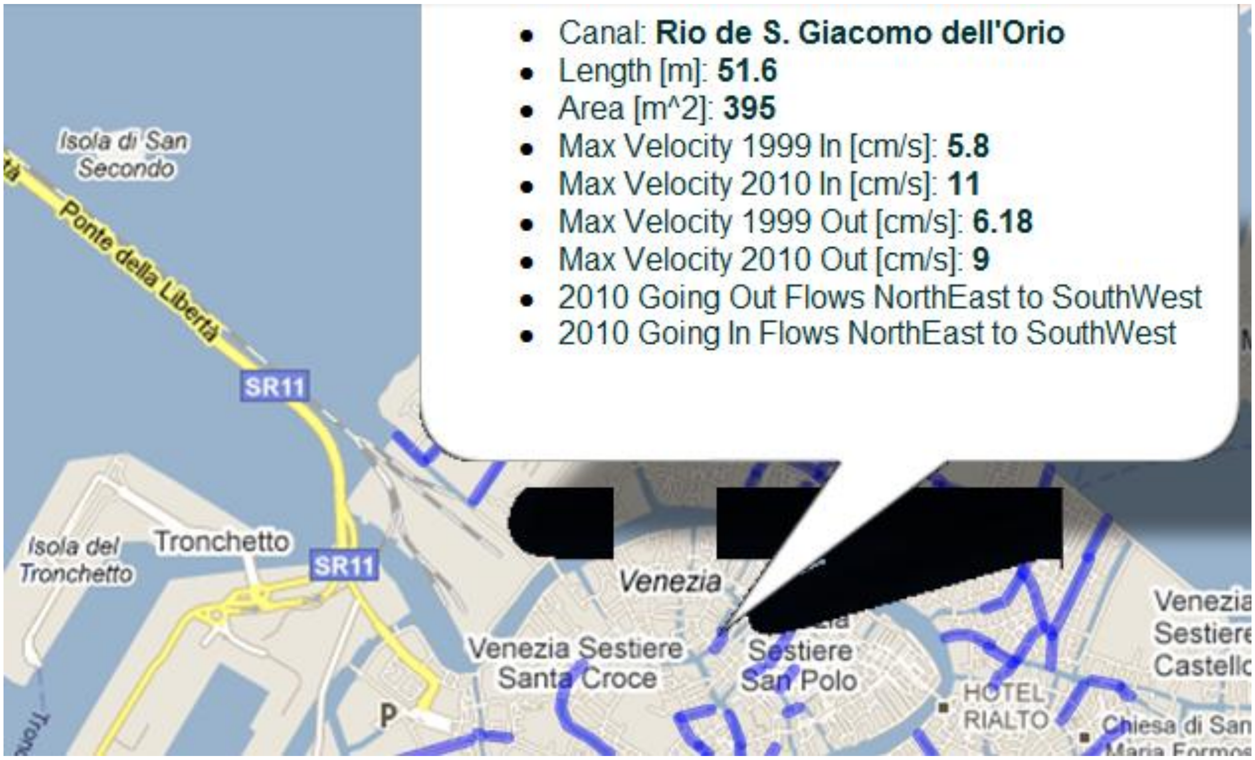


- Canal: **Rio dei Frari**
- Length [m]: **87.6**
- Area [m^2]: **747**
- Max Velocity 1999 In [cm/s]: **1.15**
- Max Velocity 2010 In [cm/s]: **8.3**
- Max Velocity 1999 Out [cm/s]: **-7.02**
- Max Velocity 2010 Out [cm/s]: **-11.8**
- 2010 Tide Out Flows North to South
- 2010 Tide In Flows South to North

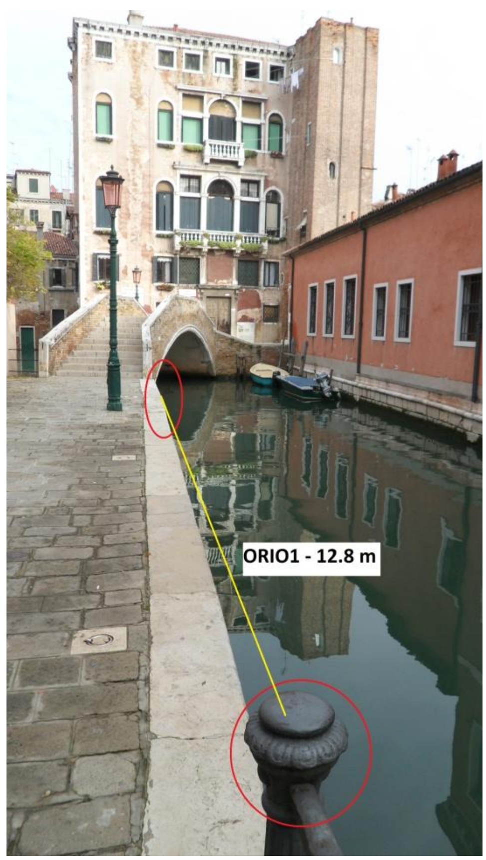
Isola di San Secondo
Ponte della Libertà
SR11
SR11
Isola del Tronchetto
Tronchetto
Tronchetto - Lido
Bacino Stazione Marittima
Santa Croce
HOTEL RIALTO
Venezia Sestiere Dorsoduro
Venezia

FRAR1 - 8.45 m

ORIO1

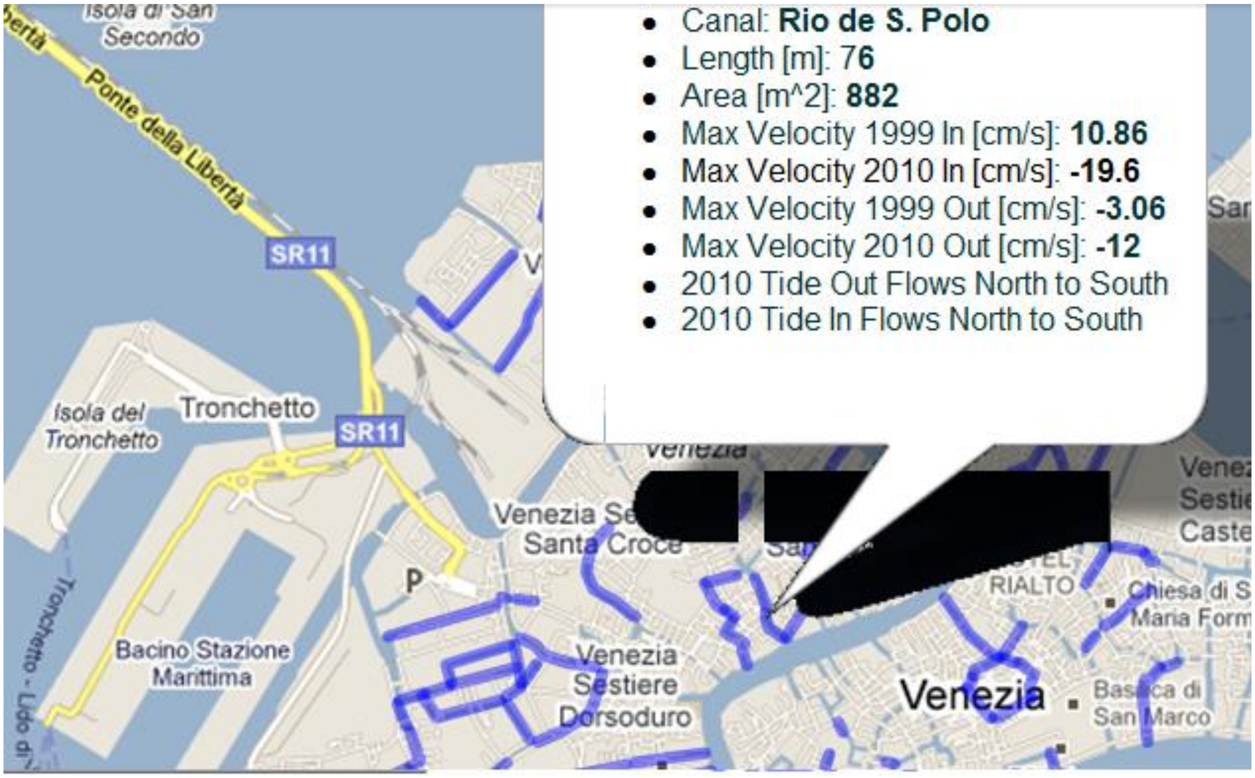


Canal: **Rio de S. Giacomo dell'Orio**
Length [m]: **51.6**
Area [m^2]: **395**
Max Velocity 1999 In [cm/s]: **5.8**
Max Velocity 2010 In [cm/s]: **11**
Max Velocity 1999 Out [cm/s]: **6.18**
Max Velocity 2010 Out [cm/s]: **9**
2010 Going Out Flows NorthEast to SouthWest
2010 Going In Flows NorthEast to SouthWest
Isola di San Secondo
Ponte della Libertà
SR11
Isola del Tronchetto
Tronchetto
SR11
Venezia
Venezia Sestiere Santa Croce
Sestiere San Polo
HOTEL RIALTO

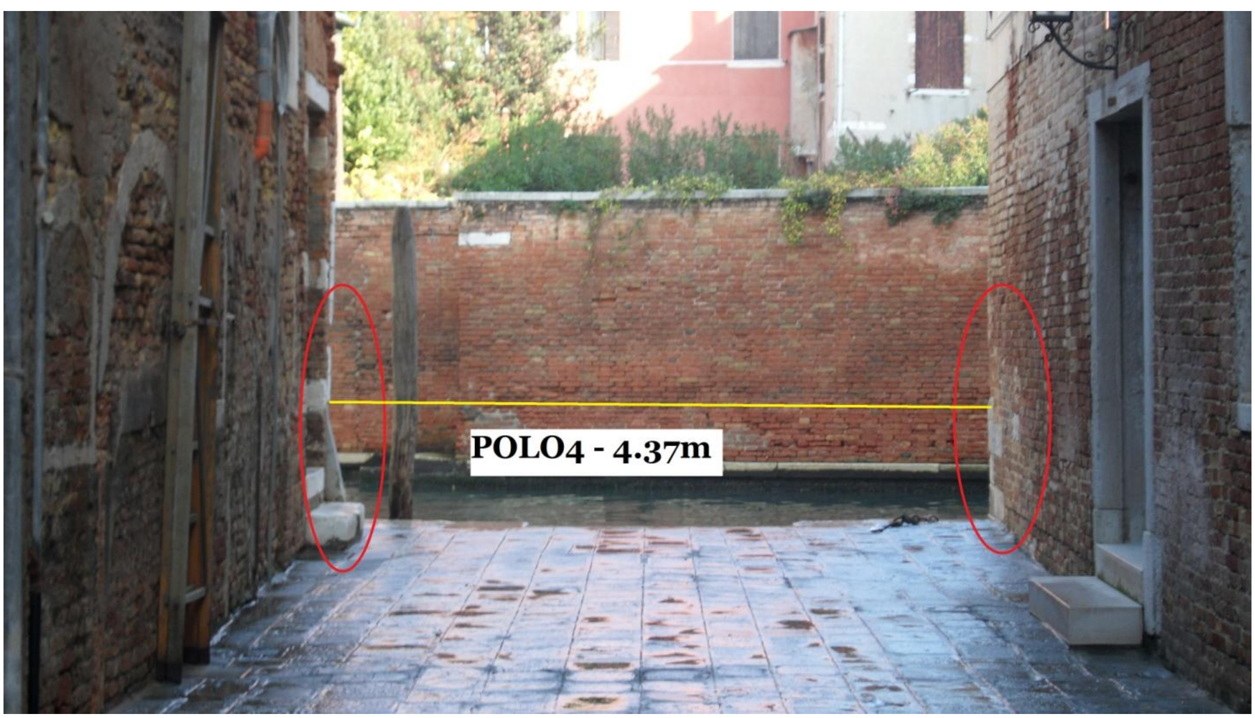


ORIO1 - 12.8 m

POLO4

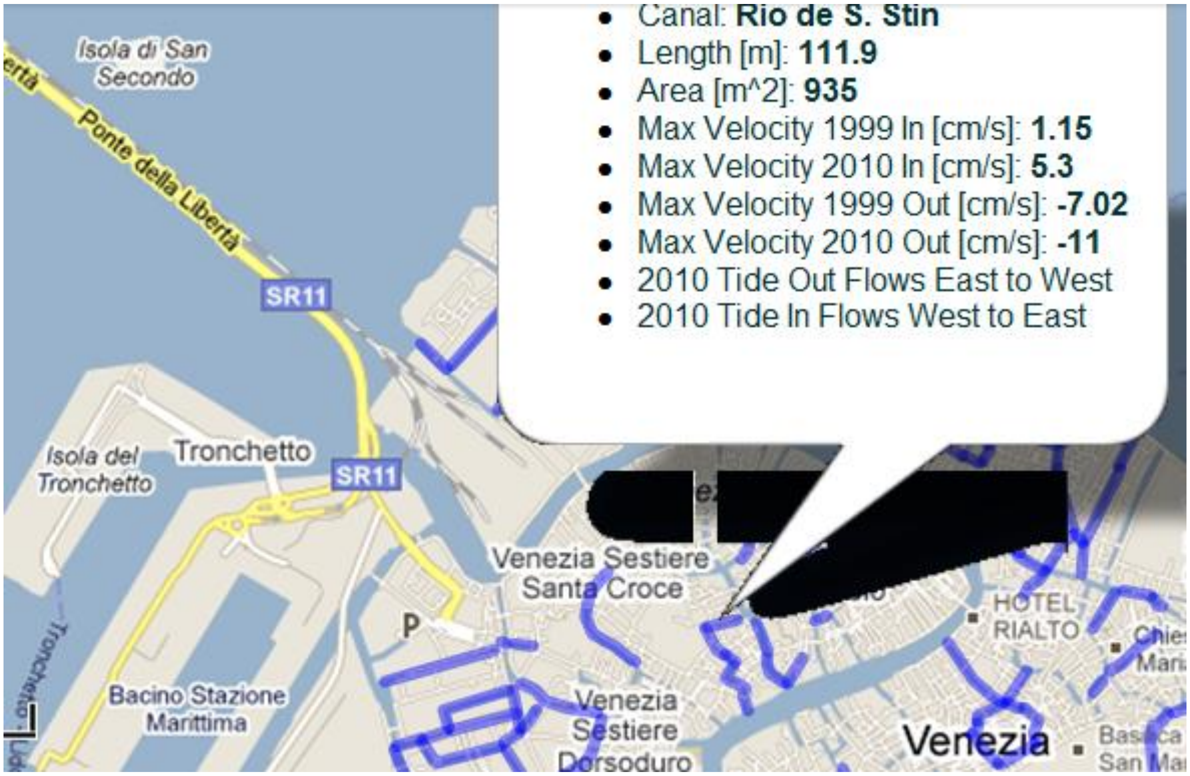


Canal: Rio de S. Polo
Length [m]: 76
Area [m^2]: 882
Max Velocity 1999 In [cm/s]: 10.86
Max Velocity 2010 In [cm/s]: -19.6
Max Velocity 1999 Out [cm/s]: -3.06
Max Velocity 2010 Out [cm/s]: -12
2010 Tide Out Flows North to South
2010 Tide In Flows North to South
Ponte della Libertà
SR11
SR11
Isola del Tronchetto
Tronchetto
Bacino Stazione Marittima
[redacted]
RIALTO
Venezia Sestiere Dorsoduro
Venezia



POLO4 - 4.37m

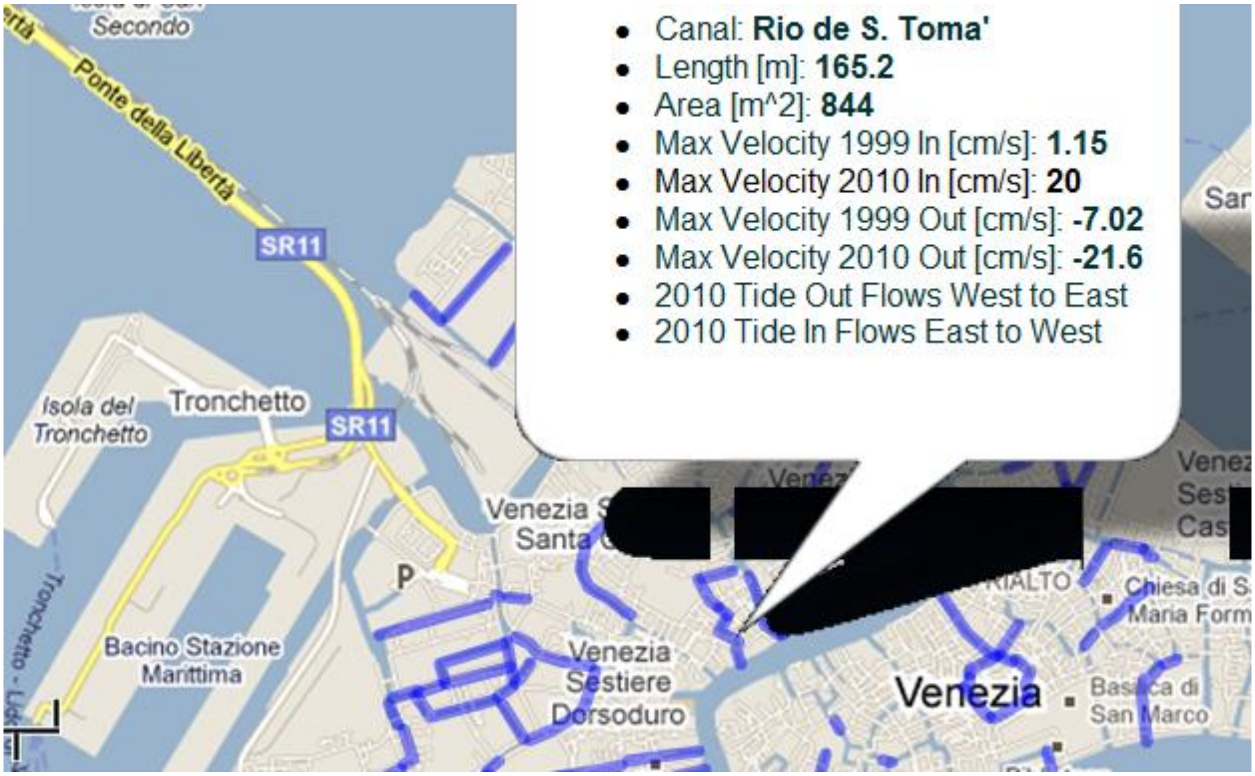
STIN



Canal: **Rio de S. Stin**
Length [m]: **111.9**
Area [m^2]: **935**
Max Velocity 1999 In [cm/s]: **1.15**
Max Velocity 2010 In [cm/s]: **5.3**
Max Velocity 1999 Out [cm/s]: **-7.02**
Max Velocity 2010 Out [cm/s]: **-11**
2010 Tide Out Flows East to West
2010 Tide In Flows West to East
Isola di San Secondo
Ponte della Libertà
SR11
Isola del Tronchetto
Tronchetto
SR11
[redacted]
Venezia Sestiere Santa Croce
P
HOTEL RIALTO
Bacino Stazione Marittima
Venezia Sestiere Dorsoduro
Venezia

STIN - 8.32 m

TOMA



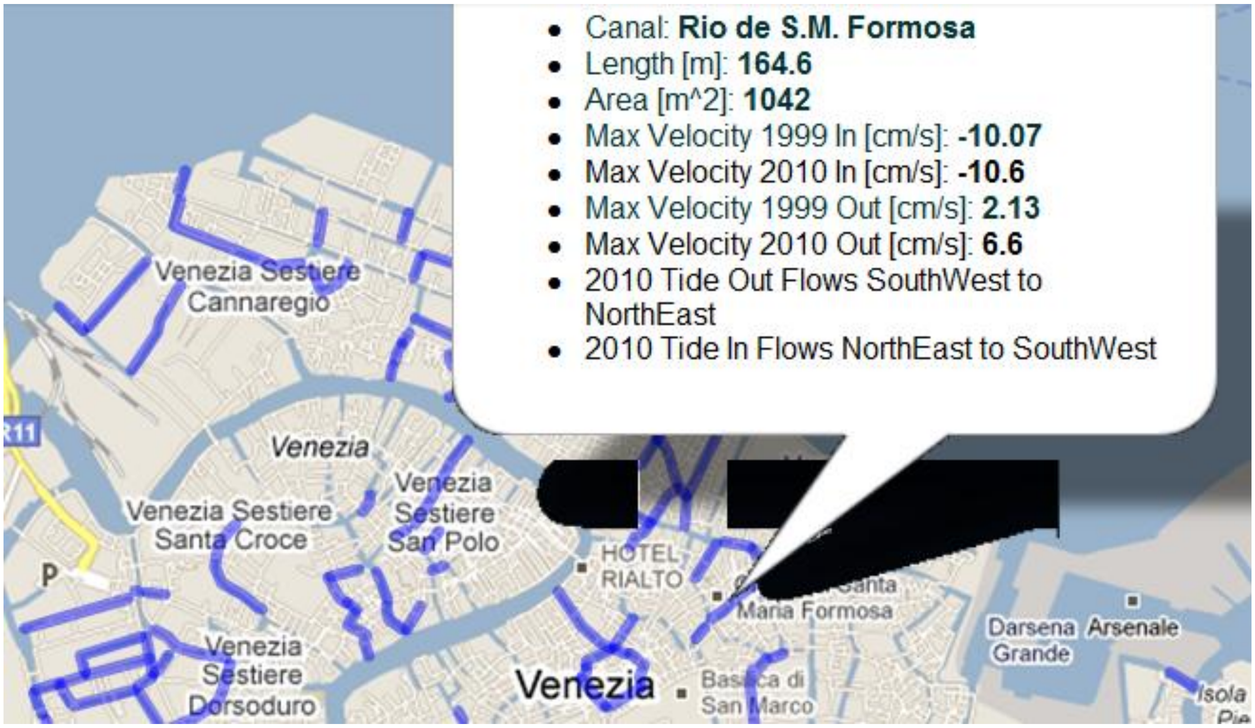
- Canal: **Rio de S. Toma'**
- Length [m]: **165.2**
- Area [m^2]: **844**
- Max Velocity 1999 In [cm/s]: **1.15**
- Max Velocity 2010 In [cm/s]: **20**
- Max Velocity 1999 Out [cm/s]: **-7.02**
- Max Velocity 2010 Out [cm/s]: **-21.6**
- 2010 Tide Out Flows West to East
- 2010 Tide In Flows East to West

Secondo
Ponte della Libertà
SR11
Isola del Tronchetto
Tronchetto
SR11
[redacted]
Bacino Stazione Marittima
Venezia Sestiere Dorsoduro
RIALTO
Venezia
Basilica di San Marco

TOMA - 6.6 m

CASTELLO

FORM



- Canal: **Rio de S.M. Formosa**
- Length [m]: **164.6**
- Area [m^2]: **1042**
- Max Velocity 1999 In [cm/s]: **-10.07**
- Max Velocity 2010 In [cm/s]: **-10.6**
- Max Velocity 1999 Out [cm/s]: **2.13**
- Max Velocity 2010 Out [cm/s]: **6.6**
- 2010 Tide Out Flows SouthWest to NorthEast
- 2010 Tide In Flows NorthEast to SouthWest

Venezia Sestiere Cannaregio
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
HOTEL RIALTO
Maria Formosa
Darsena Grande
Arsenale
Venezia Sestiere Dorsoduro
Venezia
San Marco

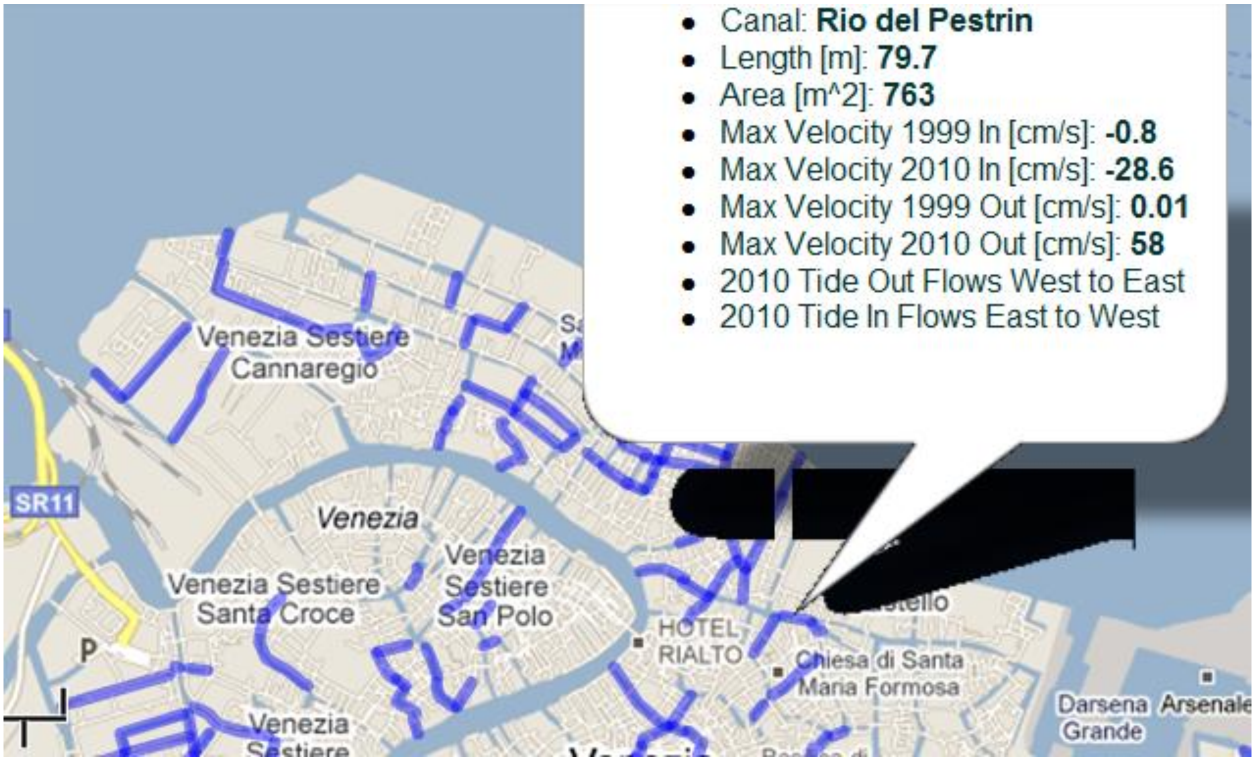
FORM - 10.6 m

LIO

- Canal: **Rio de S. Lio**
- Length [m]: **89.3**
- Area [m^2]: **676**
- Max Velocity 1999 In [cm/s]: **27**
- Max Velocity 2010 In [cm/s]: **7**
- Max Velocity 1999 Out [cm/s]: **-30**
- Max Velocity 2010 Out [cm/s]: **-2.8**
- 2010 Tide Out Flows North to South
- 2010 Tide In Flows South to North
SR11
SR11
Venezia Sestiere Cannaregio
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
Castello
HOTEL RIALTO
Chiesa di Santa Maria Formosa
Darsena Grande
Venezia

LIO - 5.03m

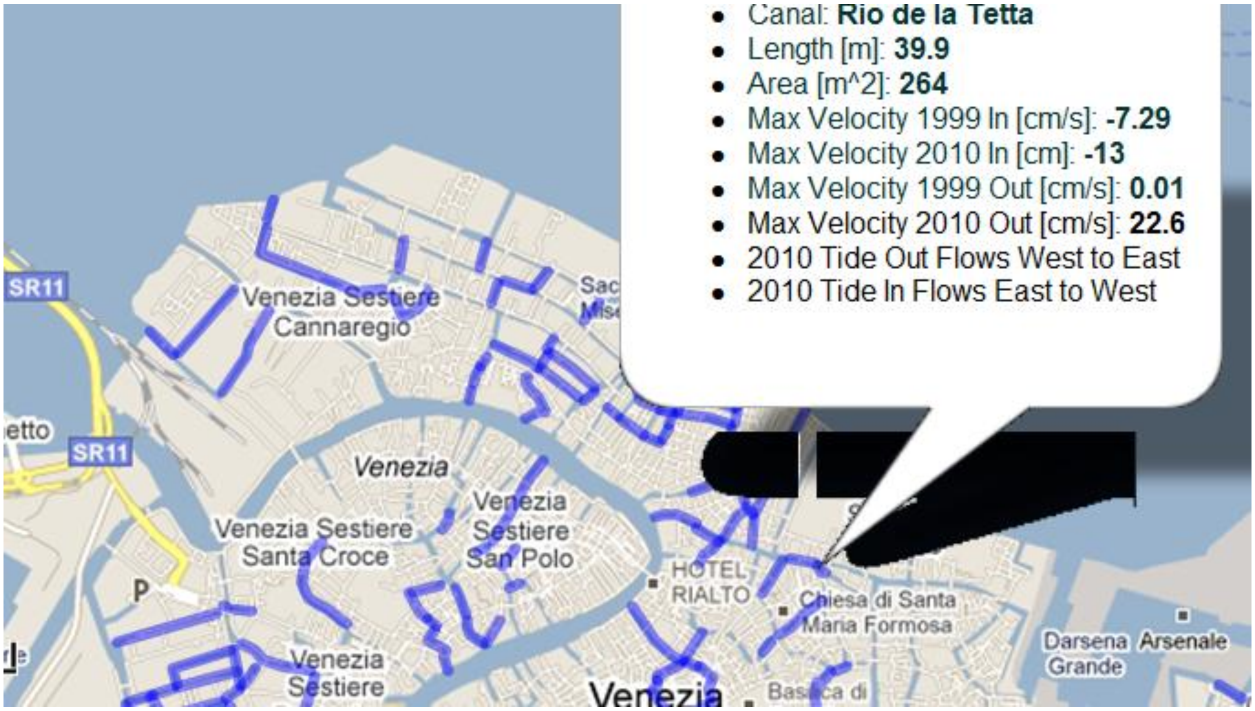
PEST1



Canal: **Rio del Pestrin**
Length [m]: **79.7**
Area [m^2]: **763**
Max Velocity 1999 In [cm/s]: **-0.8**
Max Velocity 2010 In [cm/s]: **-28.6**
Max Velocity 1999 Out [cm/s]: **0.01**
Max Velocity 2010 Out [cm/s]: **58**
2010 Tide Out Flows West to East
2010 Tide In Flows East to West
Venezia Sestiere Cannaregio
SR11
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
HOTEL RIALTO
Chiesa di Santa Maria Formosa
Darsena Grande
Arsenale
P
[redacted]

PEST1 - 14.74m

TETT1

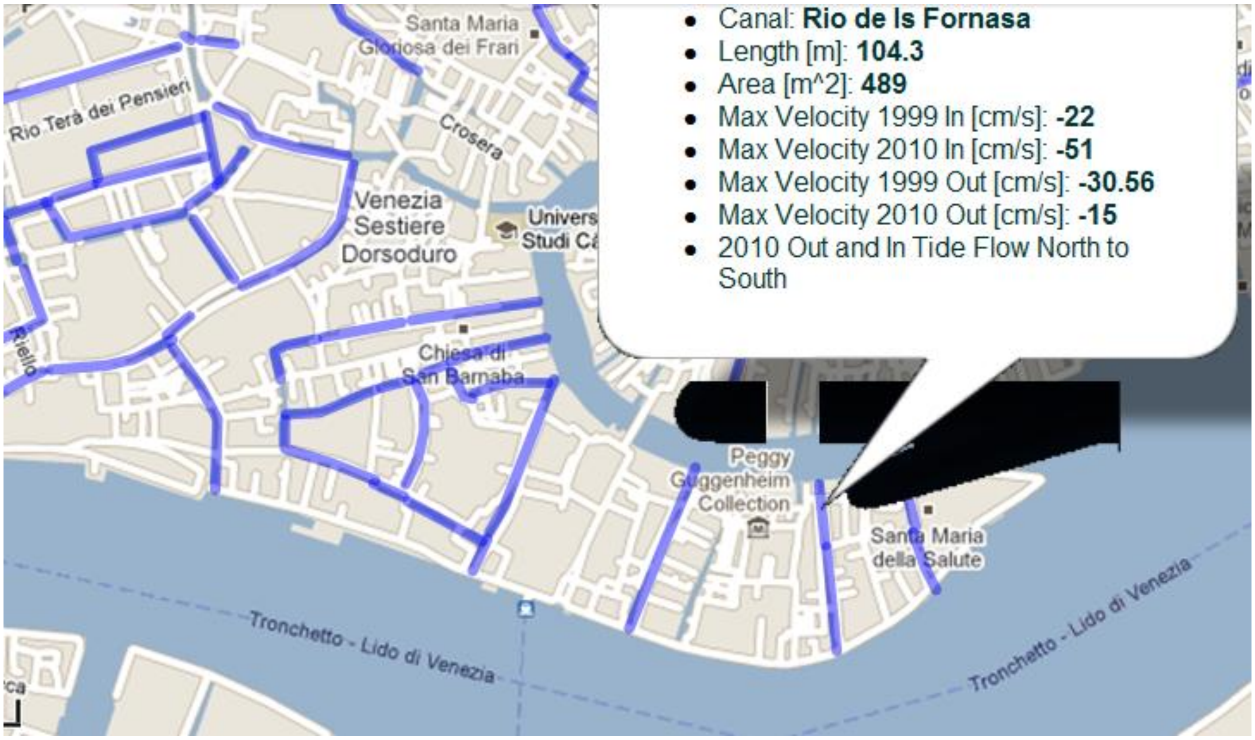


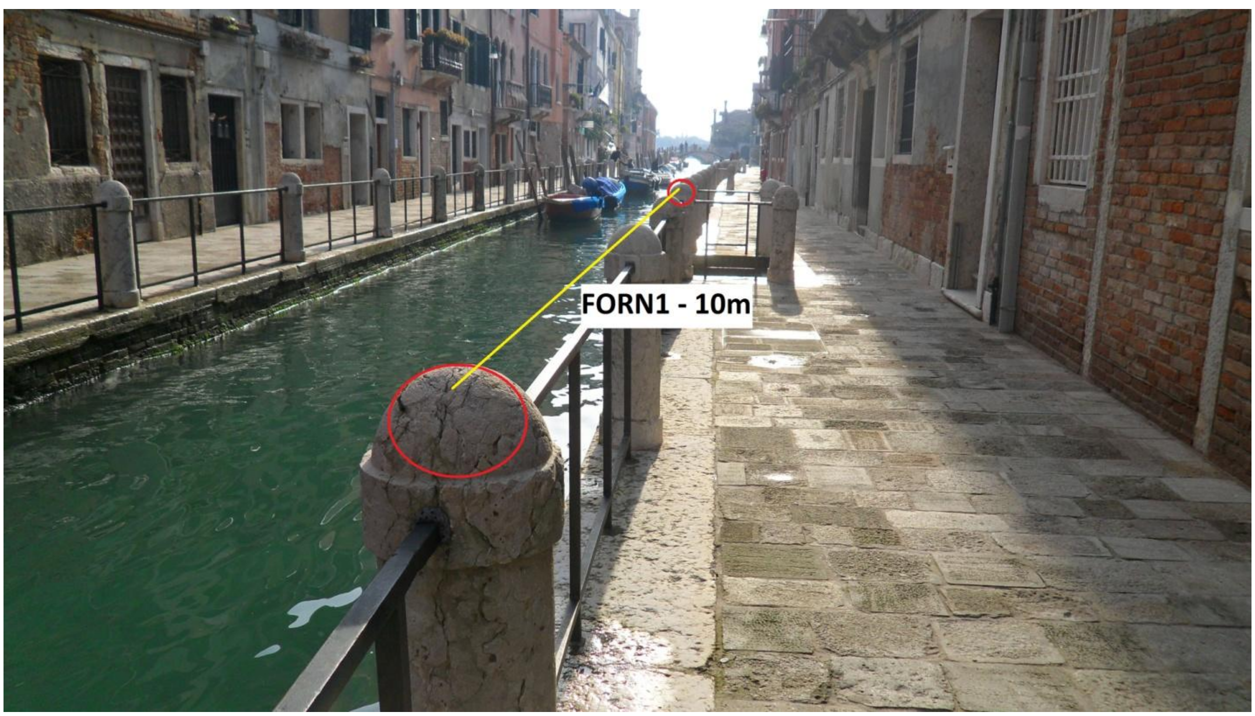
Canal: **Rio de la Tetta**
Length [m]: **39.9**
Area [m^2]: **264**
Max Velocity 1999 In [cm/s]: **-7.29**
Max Velocity 2010 In [cm]: **-13**
Max Velocity 1999 Out [cm/s]: **0.01**
Max Velocity 2010 Out [cm/s]: **22.6**
2010 Tide Out Flows West to East
2010 Tide In Flows East to West
SR11
Venezia Sestiere Cannaregio
SR11
Venezia
Venezia Sestiere Santa Croce
Venezia Sestiere San Polo
HOTEL RIALTO
Chiesa di Santa Maria Formosa
Darsena Grande
Arsenale
Venezia

TETT1 - 4.73m

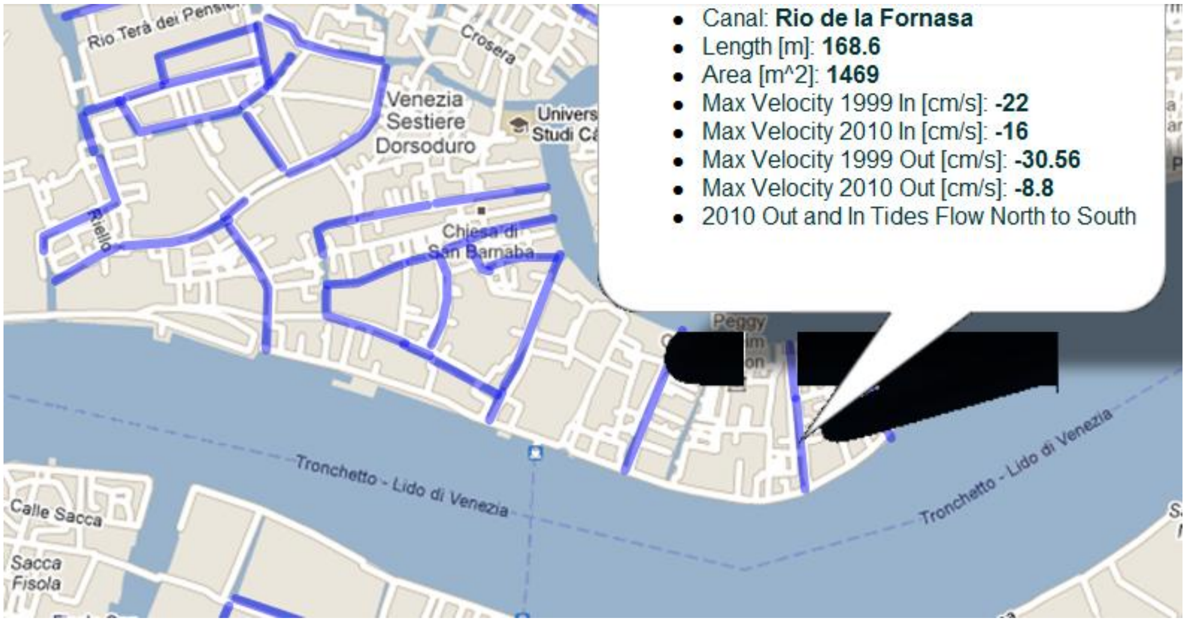
DORSODURO

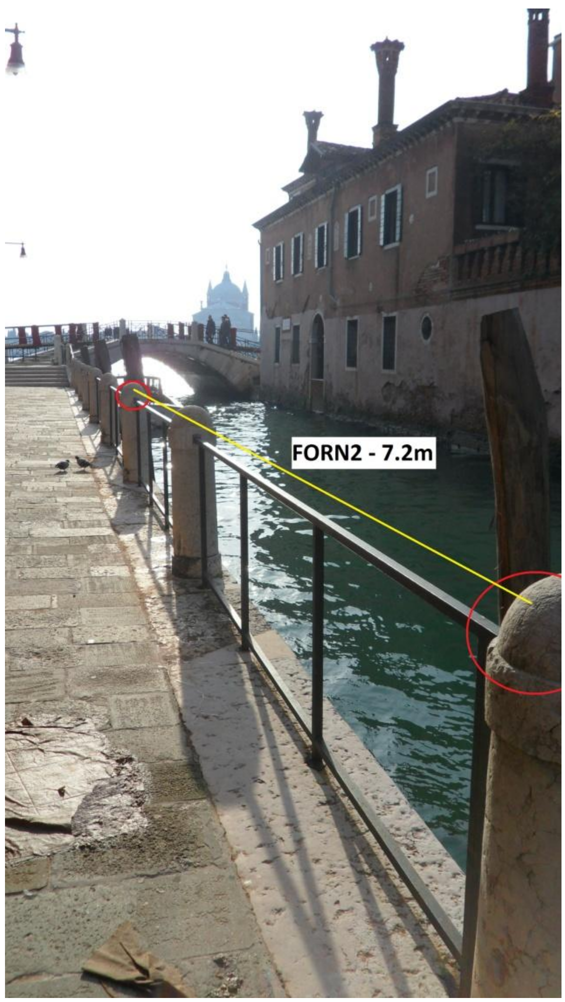
FORN1


Canal: **Rio de Is Fornasa**
Length [m]: **104.3**
Area [m^2]: **489**
Max Velocity 1999 In [cm/s]: **-22**
Max Velocity 2010 In [cm/s]: **-51**
Max Velocity 1999 Out [cm/s]: **-30.56**
Max Velocity 2010 Out [cm/s]: **-15**
2010 Out and In Tide Flow North to South
Santa Maria Gloriosa dei Frari
Rio Terà dei Pensieri
Crosera
Venezia Sestiere Dorsoduro
Chiesa di San Barnaba
Peggy Guggenheim Collection
Santa Maria della Salute
Tronchetto - Lido di Venezia
Tronchetto - Lido di Venezia

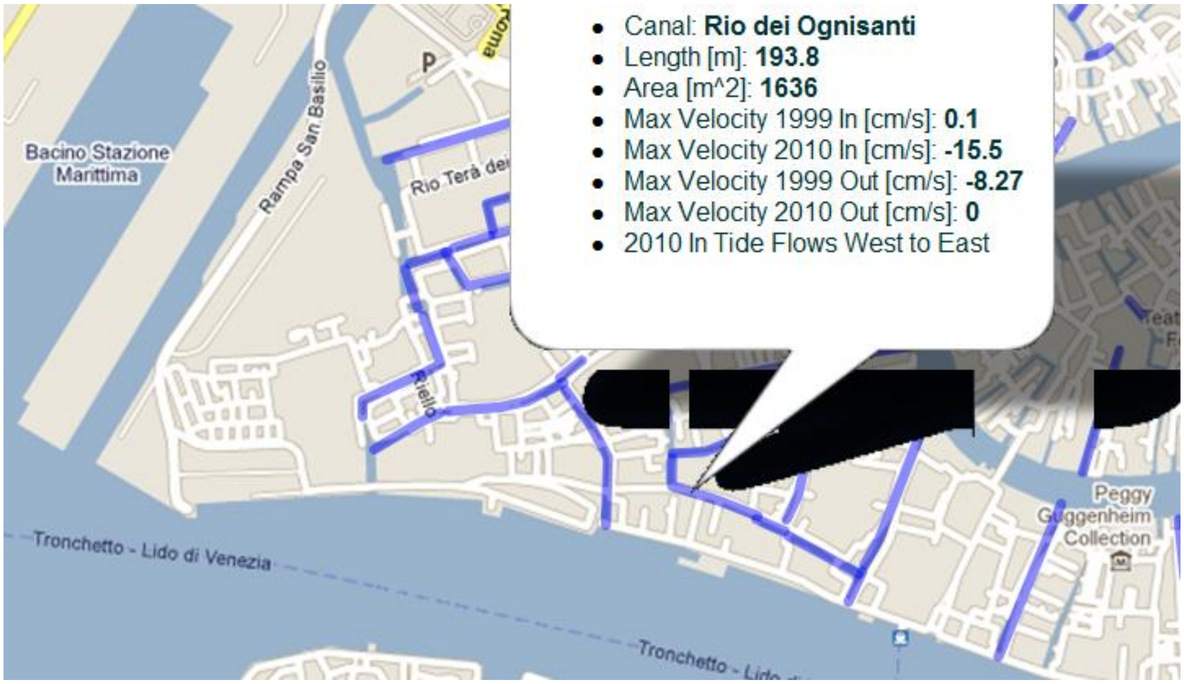

FORN1 - 10m

FORN2

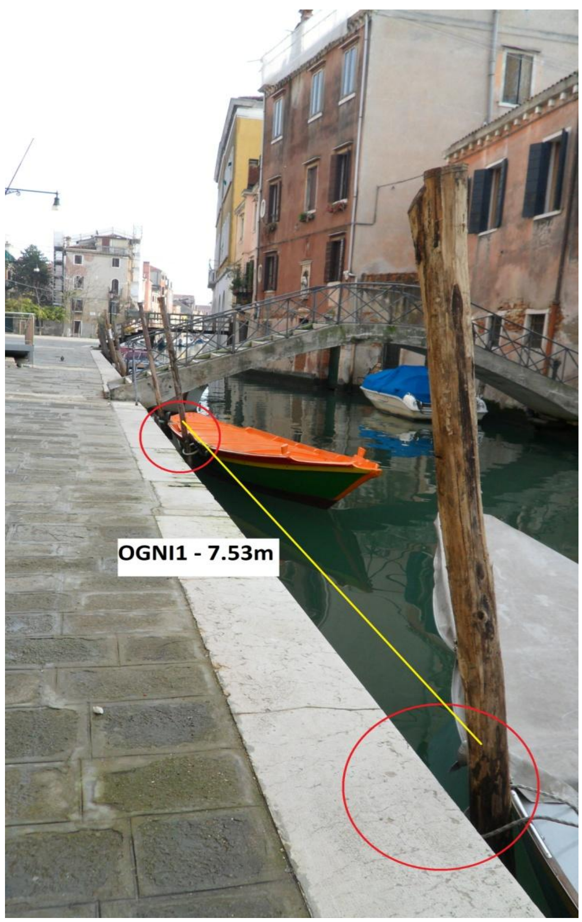

• Canal: **Rio de la Fornasa**
• Length [m]: **168.6**
• Area [m^2]: **1469**
• Max Velocity 1999 In [cm/s]: **-22**
• Max Velocity 2010 In [cm/s]: **-16**
• Max Velocity 1999 Out [cm/s]: **-30.56**
• Max Velocity 2010 Out [cm/s]: **-8.8**
• 2010 Out and In Tides Flow North to South
Rio Terà dei Pensieri
Crosera
Venezia
Sestiere
Dorsoduro
Riello
Chiesa di
San Barnaba
[redacted]
Tronchetto - Lido di Venezia
Tronchetto - Lido di Venezia
Calle Sacca
Sacca
Fisola


FORN2 - 7.2m

OGNI1

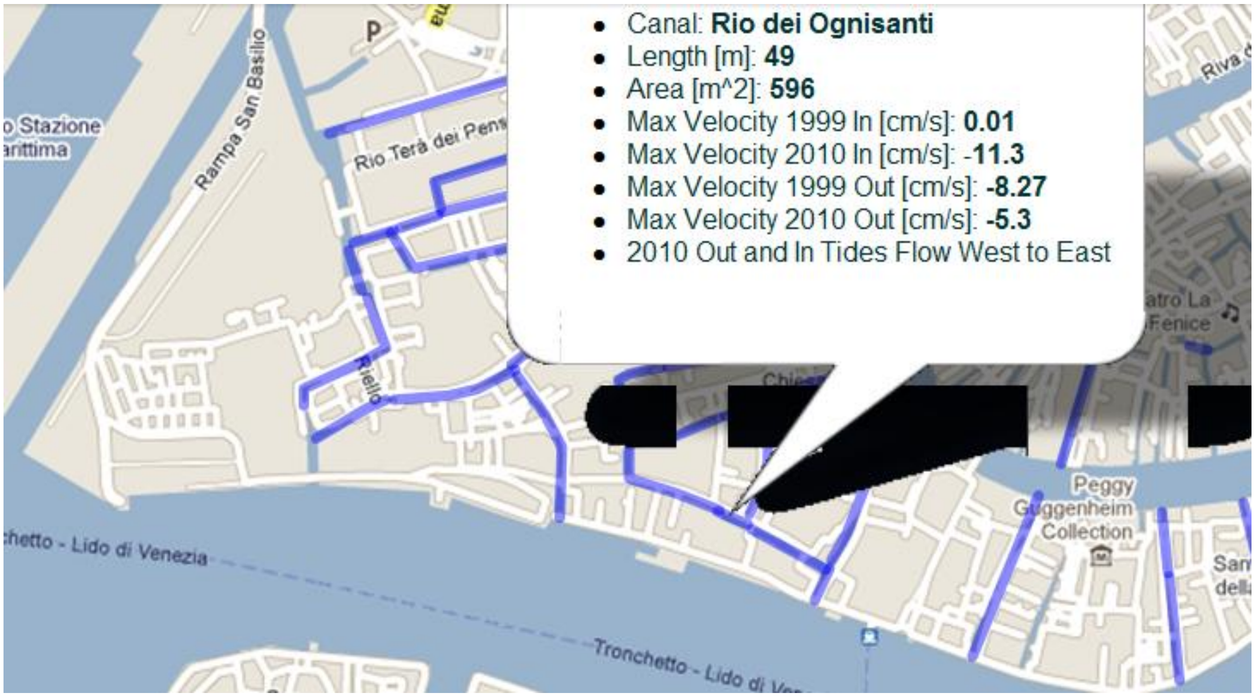


Canal: **Rio dei Ognisanti**
Length [m]: **193.8**
Area [m^2]: **1636**
Max Velocity 1999 In [cm/s]: **0.1**
Max Velocity 2010 In [cm/s]: **-15.5**
Max Velocity 1999 Out [cm/s]: **-8.27**
Max Velocity 2010 Out [cm/s]: **0**
2010 In Tide Flows West to East
Bacino Stazione Marittima
Rampa San Basilio
Rio Terà dei
Riello
Tronchetto - Lido di Venezia
Peggy Guggenheim Collection

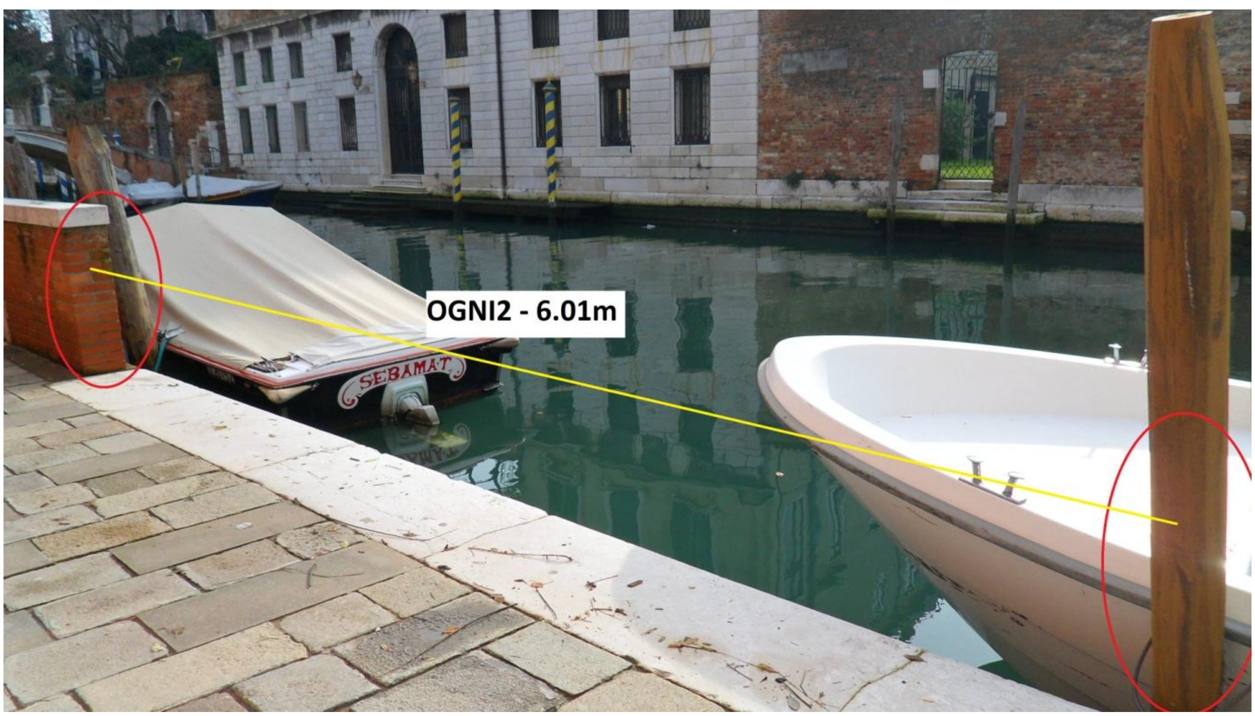


OGNI1 - 7.53m

OGNI2

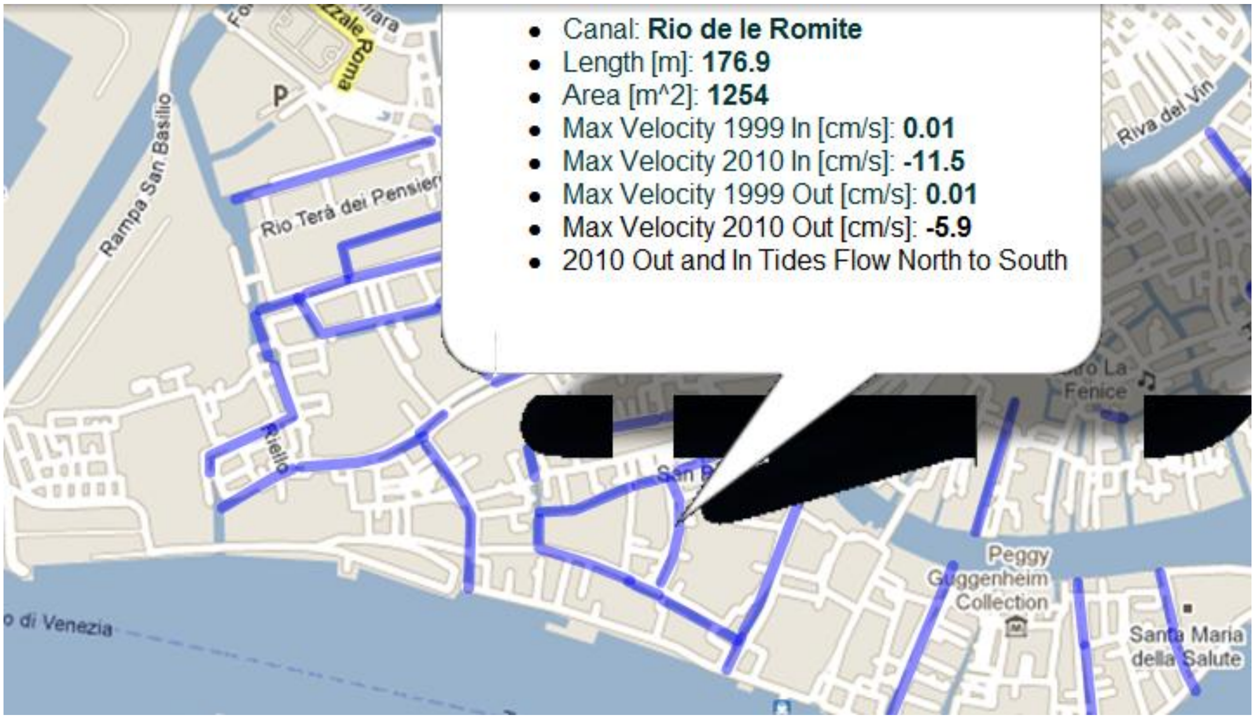


Canal: **Rio dei Ognisanti**
Length [m]: **49**
Area [m^2]: **596**
Max Velocity 1999 In [cm/s]: **0.01**
Max Velocity 2010 In [cm/s]: -**11.3**
Max Velocity 1999 Out [cm/s]: **-8.27**
Max Velocity 2010 Out [cm/s]: **-5.3**
2010 Out and In Tides Flow West to East
Rampa San Basilio
Rio Terà dei Pens
Riello
Peggy Guggenheim Collection
Tronchetto - Lido di Venezia



OGNI2 - 6.01m
SEBAMAT

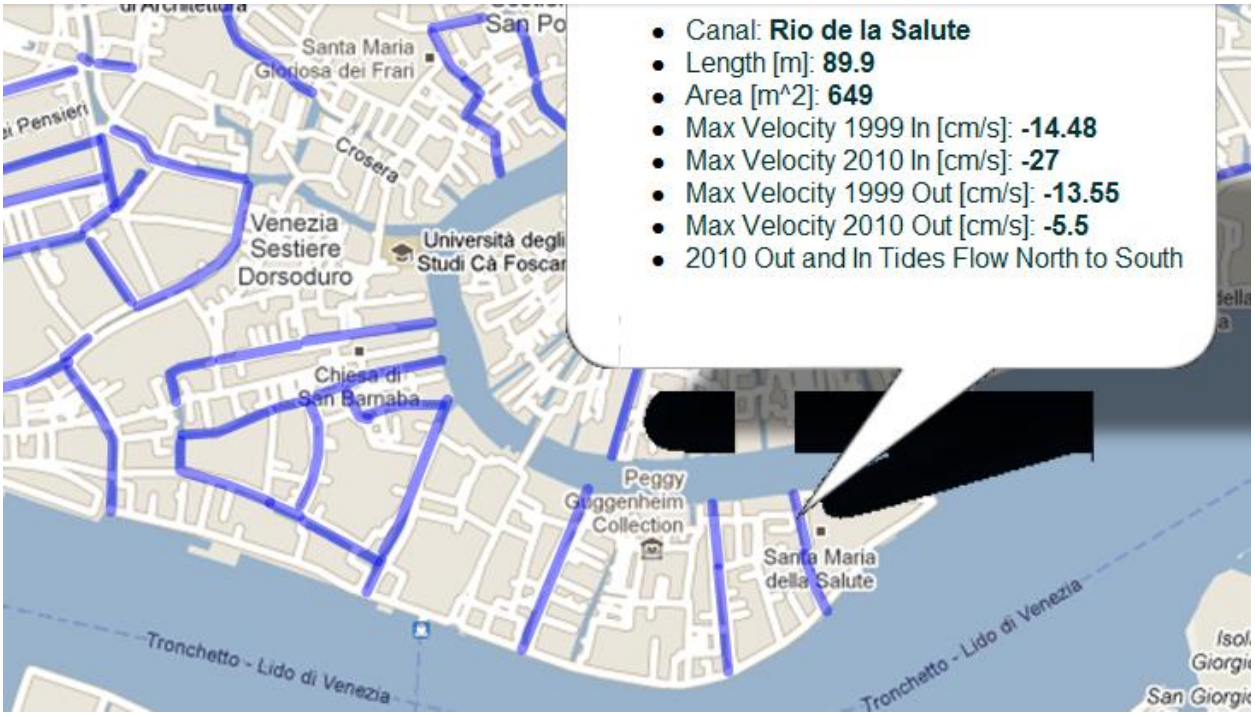
ROMI1



Canal: **Rio de le Romite**
Length [m]: **176.9**
Area [m^2]: **1254**
Max Velocity 1999 In [cm/s]: **0.01**
Max Velocity 2010 In [cm/s]: **-11.5**
Max Velocity 1999 Out [cm/s]: **0.01**
Max Velocity 2010 Out [cm/s]: **-5.9**
2010 Out and In Tides Flow North to South
Rampa San Basilio
Rio Terà dei Pensieri
Riello
Riva del Vin
Peggy Guggenheim Collection
Santa Maria della Salute

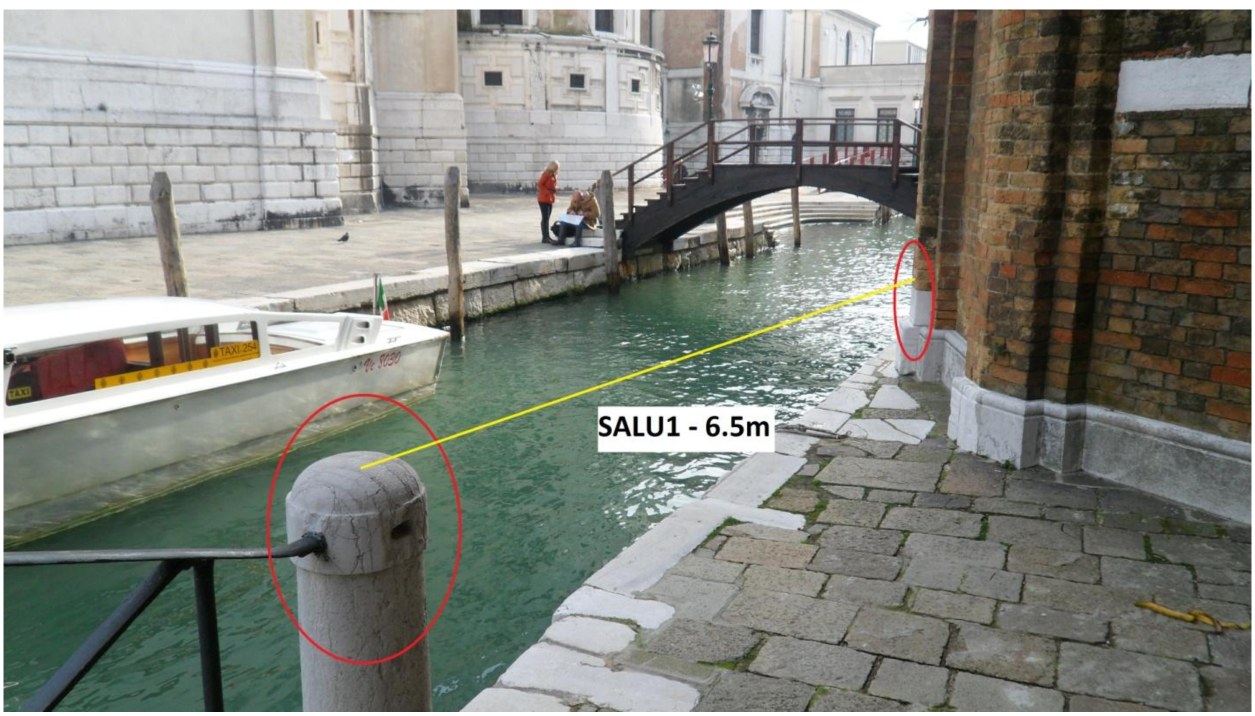
ROMI1 - 2.52m

SALU1



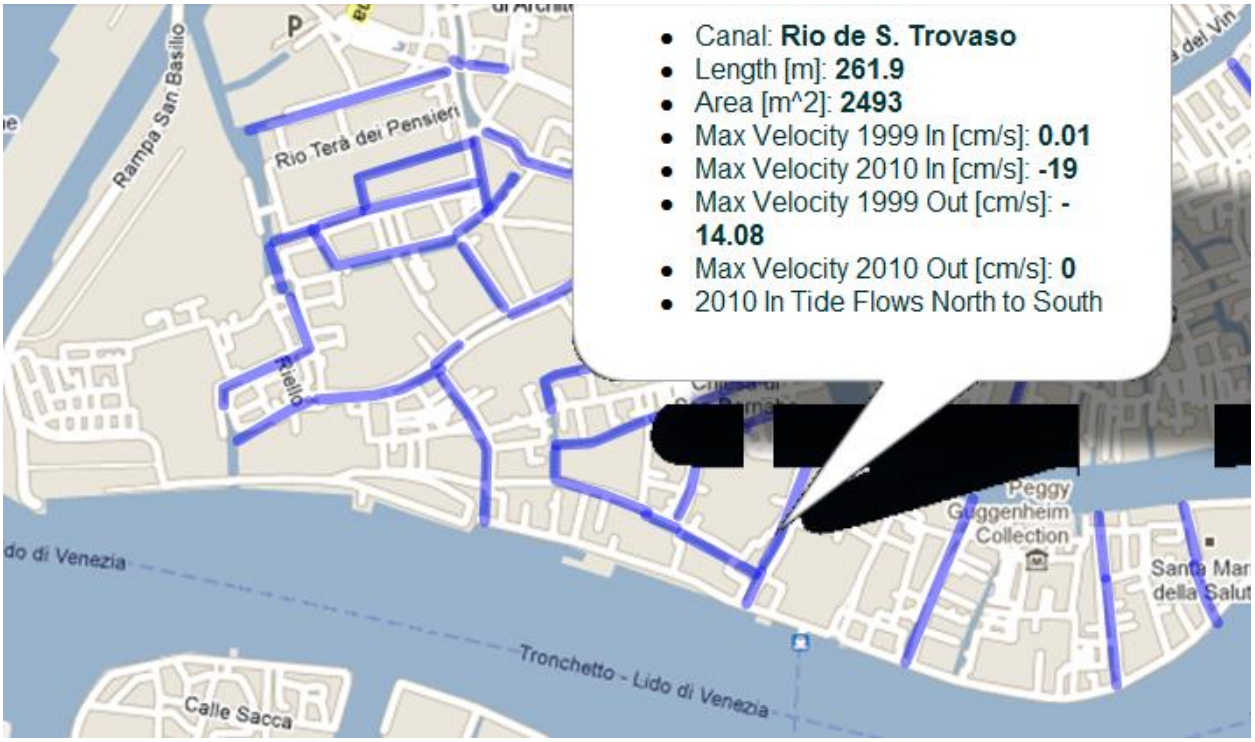
- Canal: **Rio de la Salute**
- Length [m]: **89.9**
- Area [m^2]: **649**
- Max Velocity 1999 In [cm/s]: **-14.48**
- Max Velocity 2010 In [cm/s]: **-27**
- Max Velocity 1999 Out [cm/s]: **-13.55**
- Max Velocity 2010 Out [cm/s]: **-5.5**
- 2010 Out and In Tides Flow North to South

Santa Maria Gloriosa dei Frari
Crosera
Venezia Sestiere Dorsoduro
Chiesa di San Barnaba
Peggy Guggenheim Collection
Santa Maria della Salute
Tronchetto - Lido di Venezia
Tronchetto - Lido di Venezia



SALU1 - 6.5m

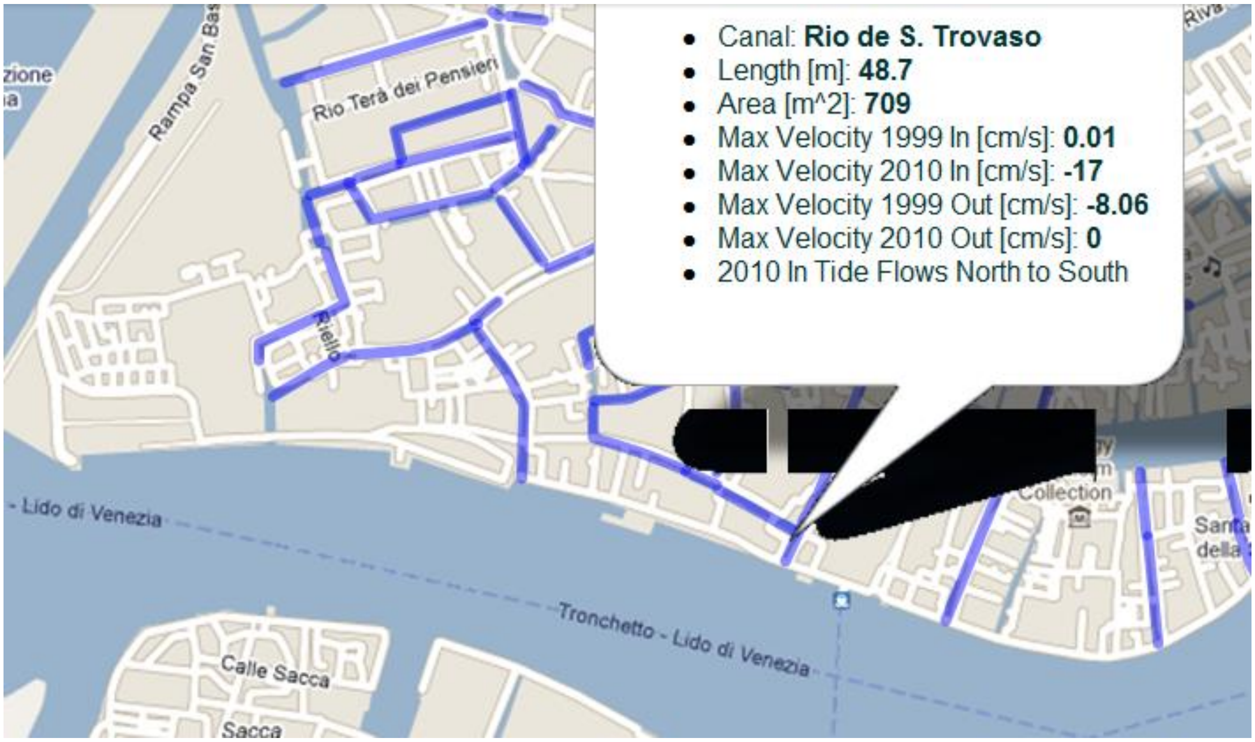
TROV2



- Canal: **Rio de S. Trovaso**
- Length [m]: **261.9**
- Area [m^2]: **2493**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **-19**
- Max Velocity 1999 Out [cm/s]: **-14.08**
- Max Velocity 2010 Out [cm/s]: **0**
- 2010 In Tide Flows North to South
Rampa San Basilio
Rio Terà dei Pensieri
Riello
[redacted]
Peggy Guggenheim Collection
Tronchetto - Lido di Venezia
Calle Sacca

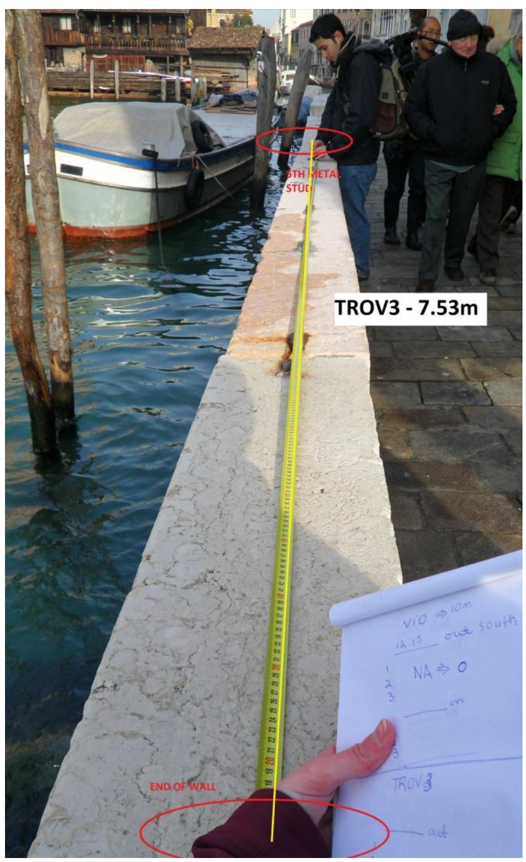
TROV2 - 7.86m

TROV3



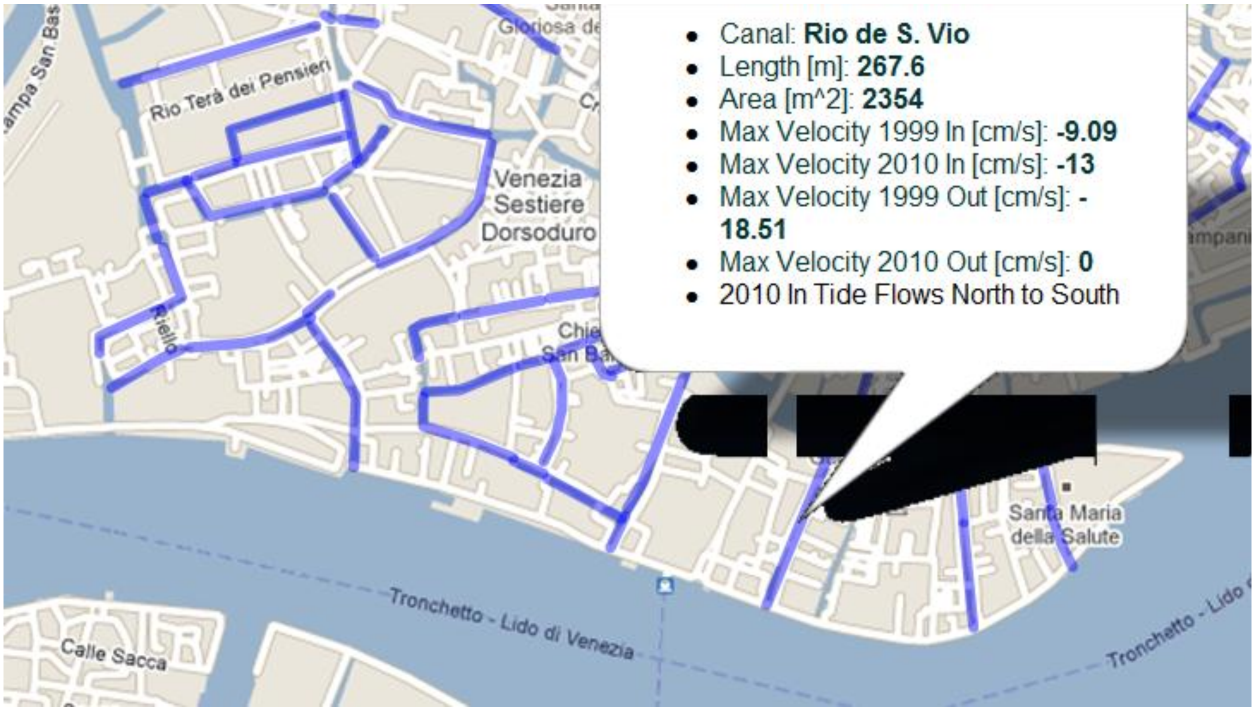
- Canal: **Rio de S. Trovaso**
- Length [m]: **48.7**
- Area [m^2]: **709**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **-17**
- Max Velocity 1999 Out [cm/s]: **-8.06**
- Max Velocity 2010 Out [cm/s]: **0**
- 2010 In Tide Flows North to South

Rampa San Bas
Rio Terà dei Pensieri
Lido di Venezia
Tronchetto - Lido di Venezia
Calle Sacca
Sacca
Collection

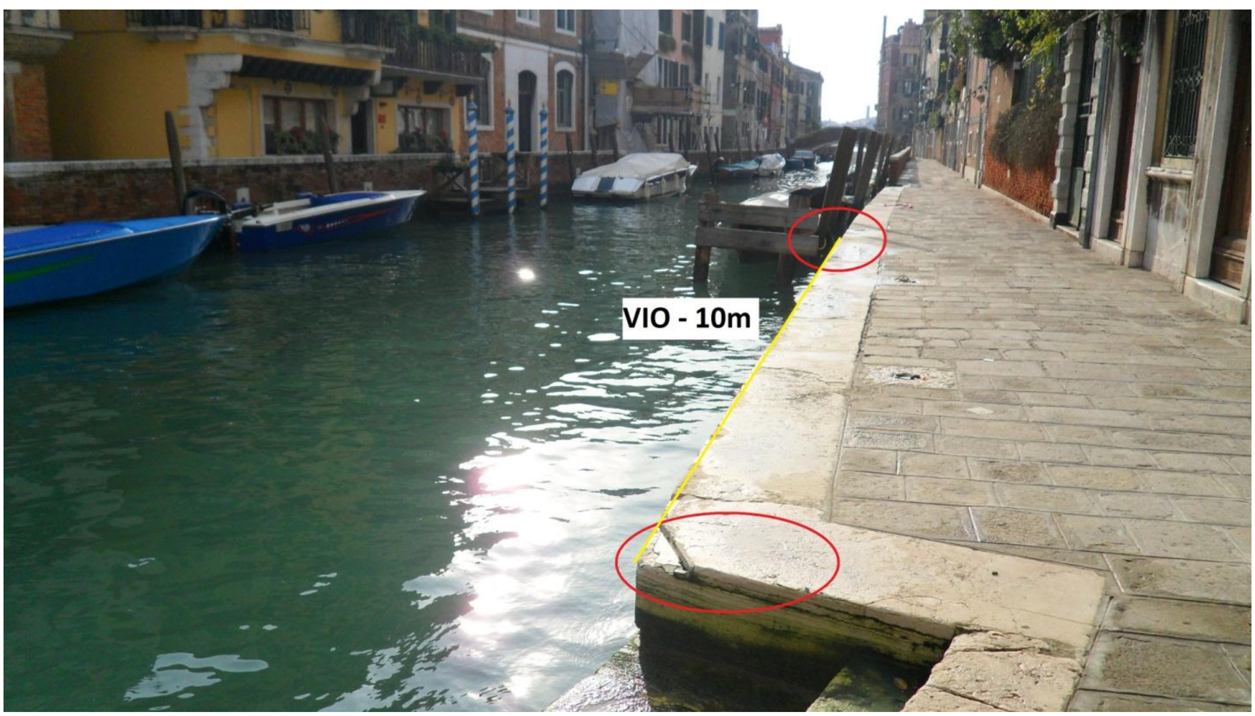


5TH METAL STUD
TROV3 - 7.53m
END OF WALL

VIO



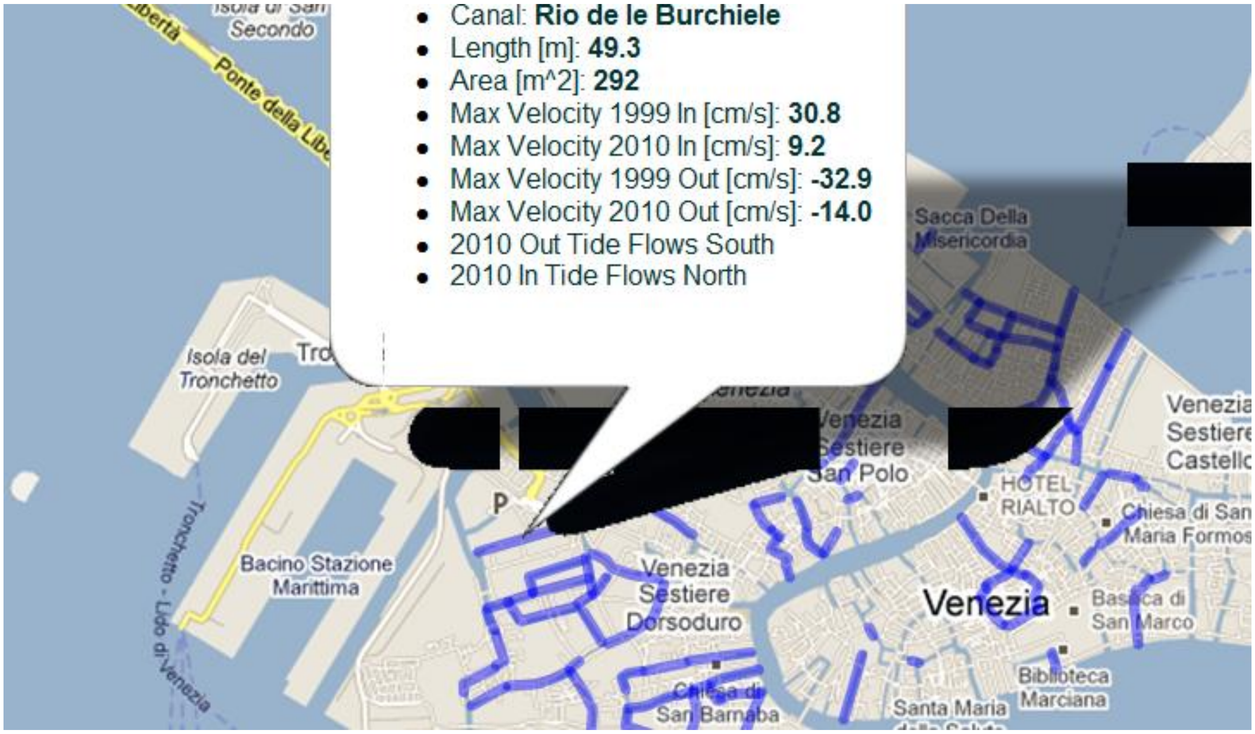
Canal: **Rio de S. Vio**
Length [m]: **267.6**
Area [m^2]: **2354**
Max Velocity 1999 In [cm/s]: **-9.09**
Max Velocity 2010 In [cm/s]: **-13**
Max Velocity 1999 Out [cm/s]: **-18.51**
Max Velocity 2010 Out [cm/s]: **0**
2010 In Tide Flows North to South
Rio Terà dei Pensieri
Venezia Sestiere Dorsoduro
Santa Maria della Salute
Calle Sacca
Tronchetto - Lido di Venezia
Tronchetto - Lido



VIO - 10m

SANTA CROCE

BURC

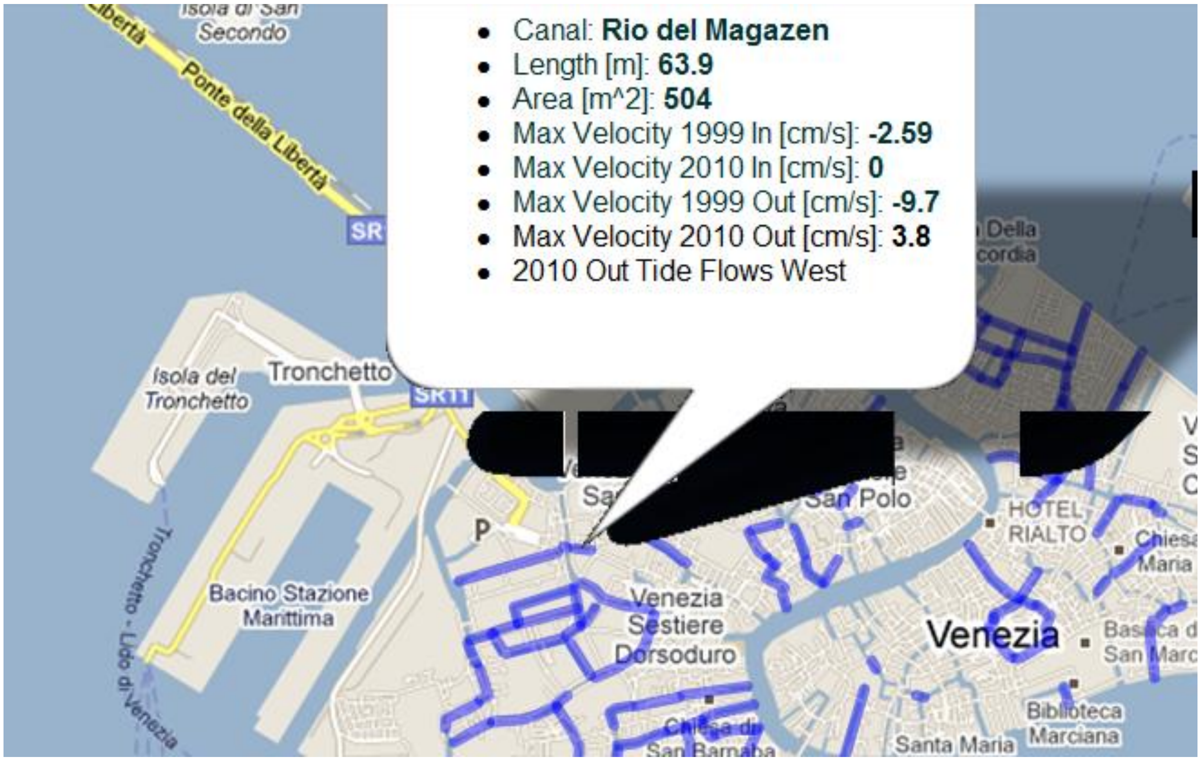


- Canal: **Rio de le Burchiele**
- Length [m]: **49.3**
- Area [m^2]: **292**
- Max Velocity 1999 In [cm/s]: **30.8**
- Max Velocity 2010 In [cm/s]: **9.2**
- Max Velocity 1999 Out [cm/s]: **-32.9**
- Max Velocity 2010 Out [cm/s]: **-14.0**
- 2010 Out Tide Flows South
- 2010 In Tide Flows North

[redacted]
Secondo
Ponte della Libertà
Sacca Della Misericordia
Isola del Tronchetto
Venezia Sestiere San Polo
Venezia Sestiere Castello
HOTEL RIALTO
Chiesa di Santa Maria Formosa
Bacino Stazione Marittima
Tronchetto - Lido di Venezia
Venezia Sestiere Dorsoduro
Venezia
Basilica di San Marco
Biblioteca Marciana
Chiesa di San Barnaba
Santa Maria

BURC - 10.0m

MAGA

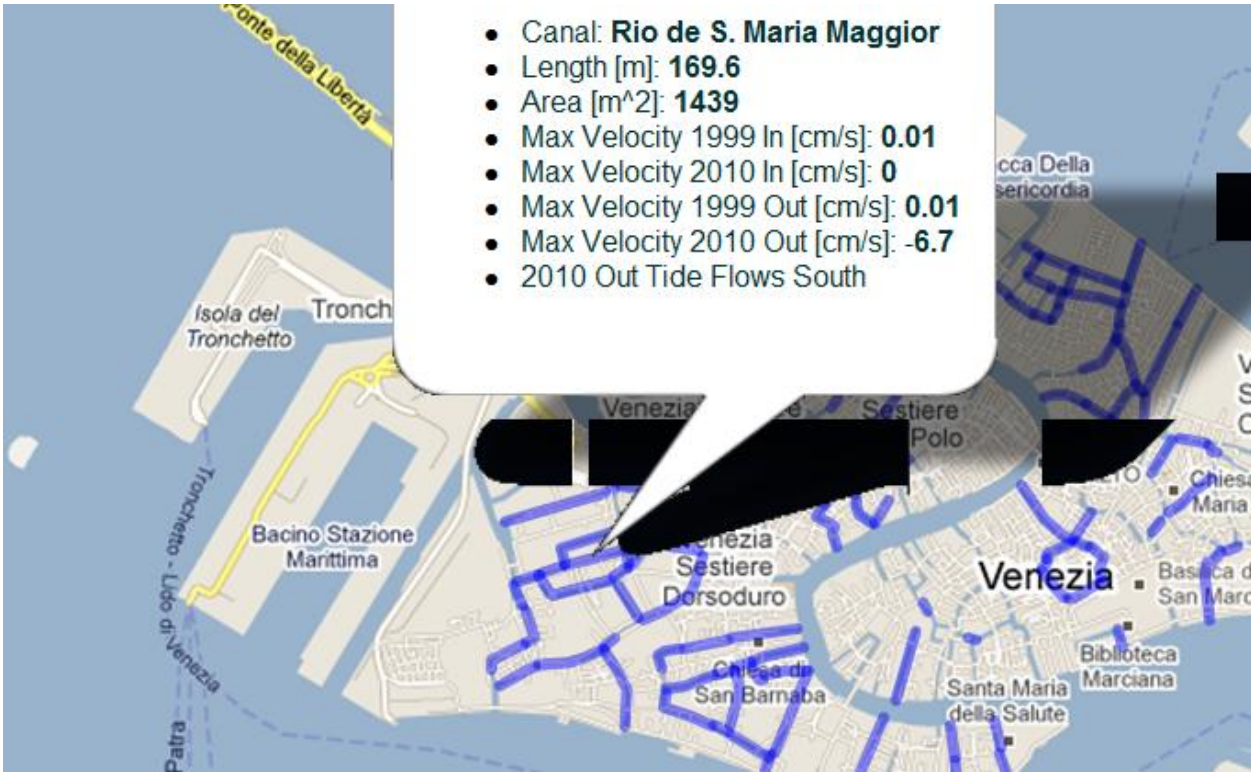


- Canal: **Rio del Magazen**
- Length [m]: **63.9**
- Area [m^2]: **504**
- Max Velocity 1999 In [cm/s]: **-2.59**
- Max Velocity 2010 In [cm/s]: **0**
- Max Velocity 1999 Out [cm/s]: **-9.7**
- Max Velocity 2010 Out [cm/s]: **3.8**
- 2010 Out Tide Flows West

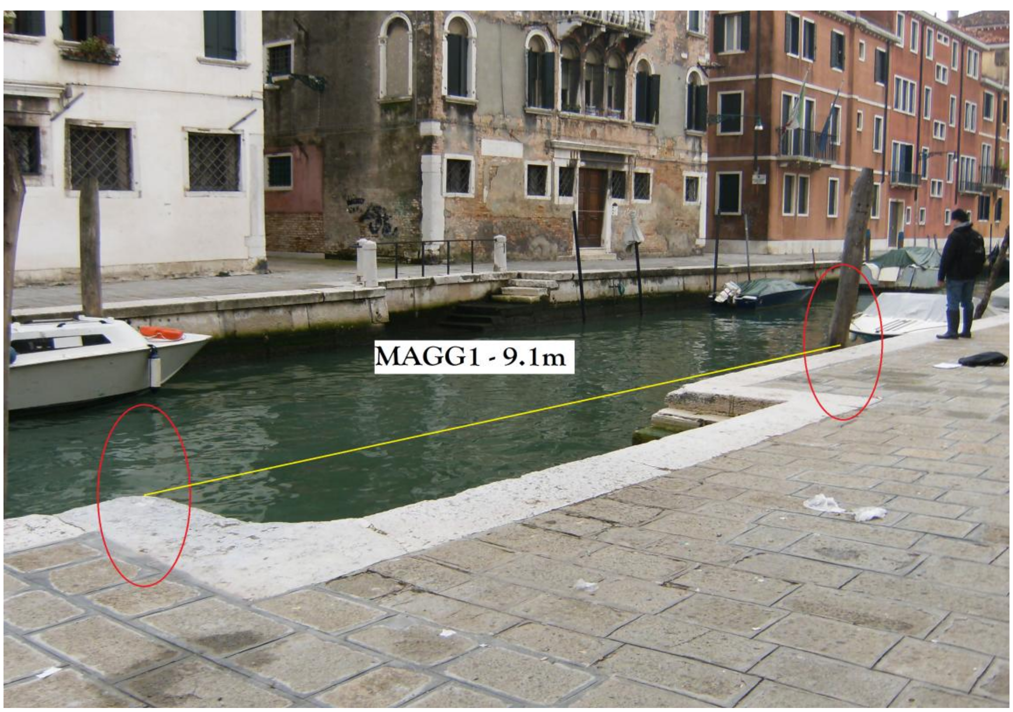
Isola di San Secondo
Ponte della Libertà
SR
Isola del Tronchetto
Tronchetto
SR11
P
Tronchetto - Lido di Venezia
Bacino Stazione Marittima
Venezia Sestiere Dorsoduro
San Polo
HOTEL RIALTO
Venezia
Chiesa di San Barnaba
Biblioteca Marciana
Santa Maria

MAGA - 9.4m

MAGG1

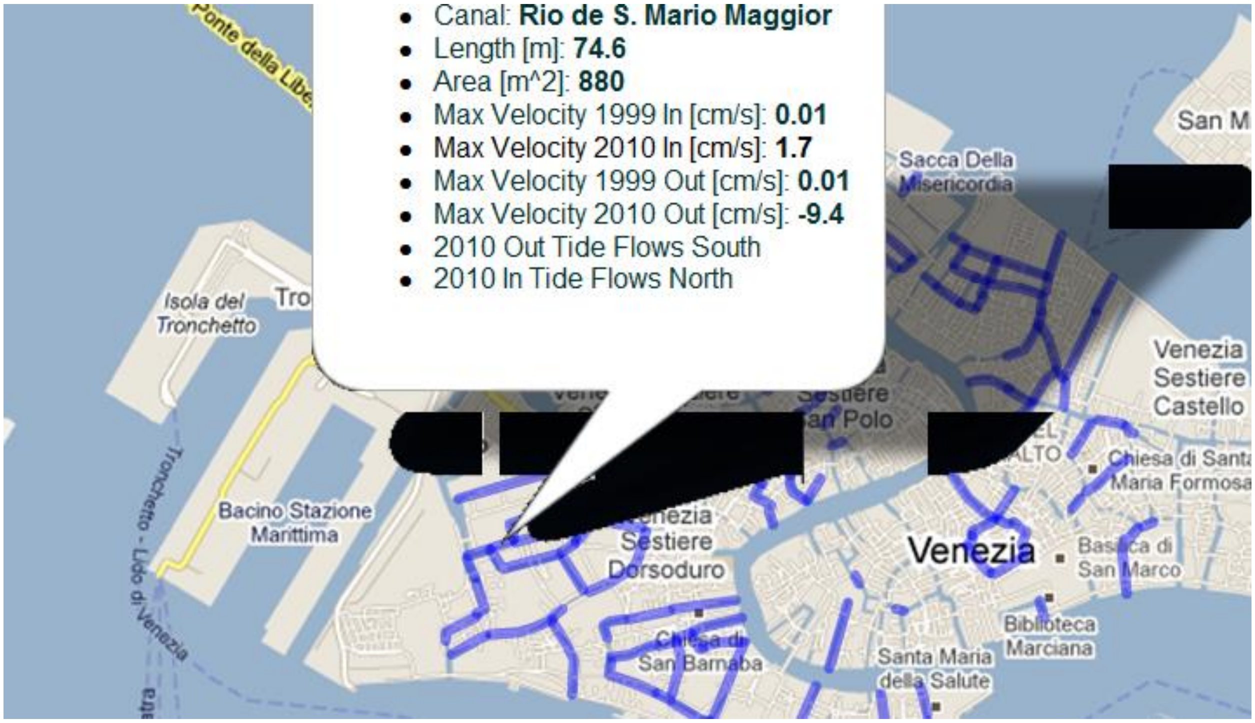


- Canal: **Rio de S. Maria Maggior**
- Length [m]: **169.6**
- Area [m^2]: **1439**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **0**
- Max Velocity 1999 Out [cm/s]: **0.01**
- Max Velocity 2010 Out [cm/s]: -**6.7**
- 2010 Out Tide Flows South
Ponte della Libertà
Isola del Tronchetto
Bacino Stazione Marittima
Tronchetto - Lido di Venezia
Sestiere Dorsoduro
Chiesa di San Barnaba
Venezia
Santa Maria della Salute
Biblioteca Marciana



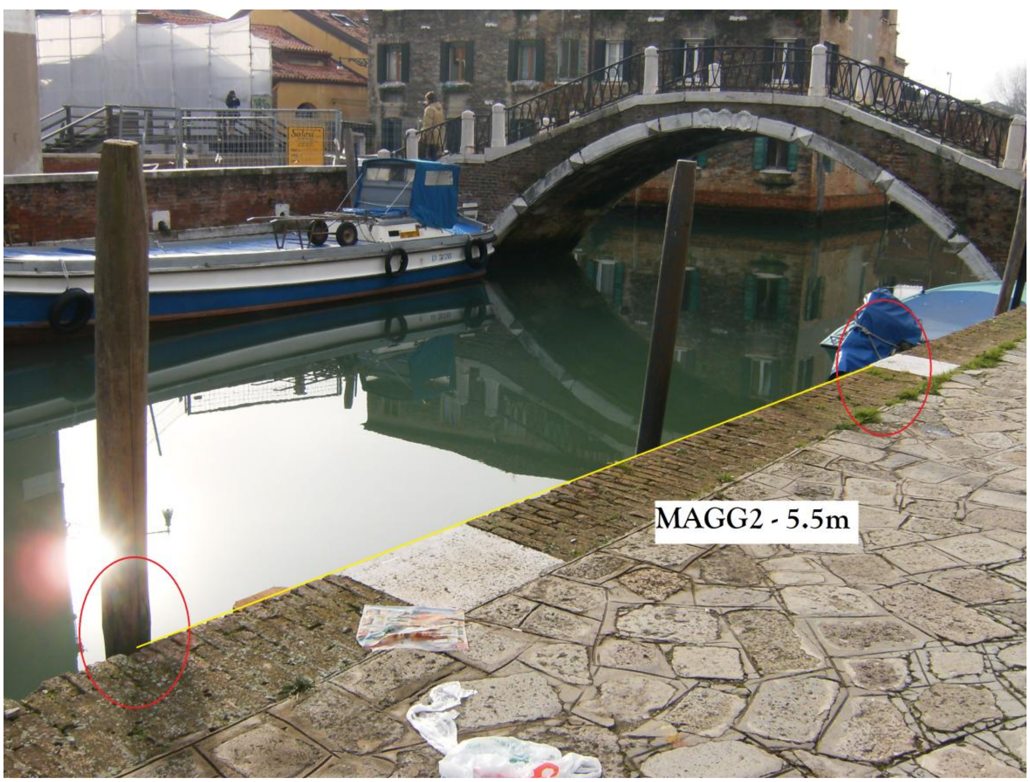
MAGG1 - 9.1m

MAGG2



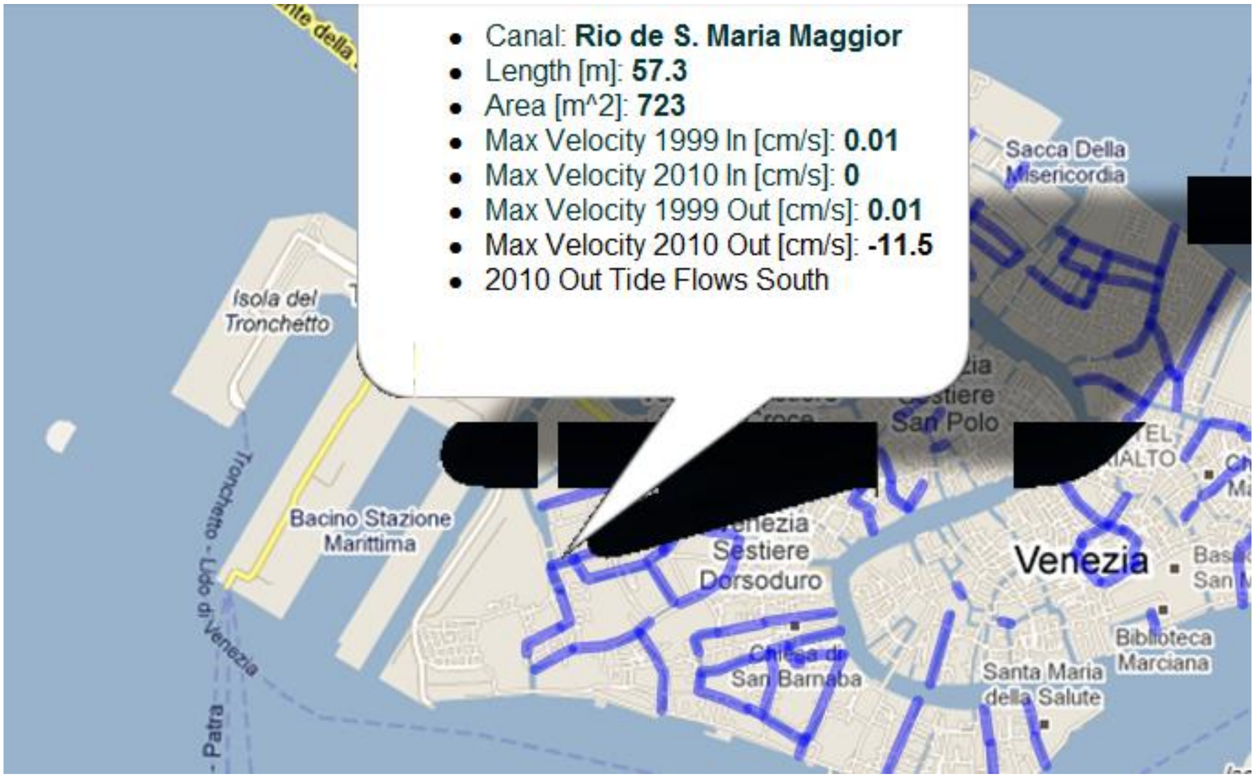
- Canal: **Rio de S. Mario Maggior**
- Length [m]: **74.6**
- Area [m^2]: **880**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **1.7**
- Max Velocity 1999 Out [cm/s]: **0.01**
- Max Velocity 2010 Out [cm/s]: **-9.4**
- 2010 Out Tide Flows South
- 2010 In Tide Flows North

[redacted]
Sacca Della Misericordia
Isola del Tronchetto
Bacino Stazione Marittima
Tronchetto - Lido di Venezia
Venezia Sestiere Castello
Venezia
Biblioteca Marciana
Santa Maria della Salute
Chiesa di San Barnaba



MAGG2 - 5.5m

MAGG3



- Canal: **Rio de S. Maria Maggior**
- Length [m]: **57.3**
- Area [m^2]: **723**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **0**
- Max Velocity 1999 Out [cm/s]: **0.01**
- Max Velocity 2010 Out [cm/s]: **-11.5**
- 2010 Out Tide Flows South
Sacca Della Misericordia
Isola del Tronchetto
Bacino Stazione Marittima
Tronchetto - Lido di Venezia
Venezia
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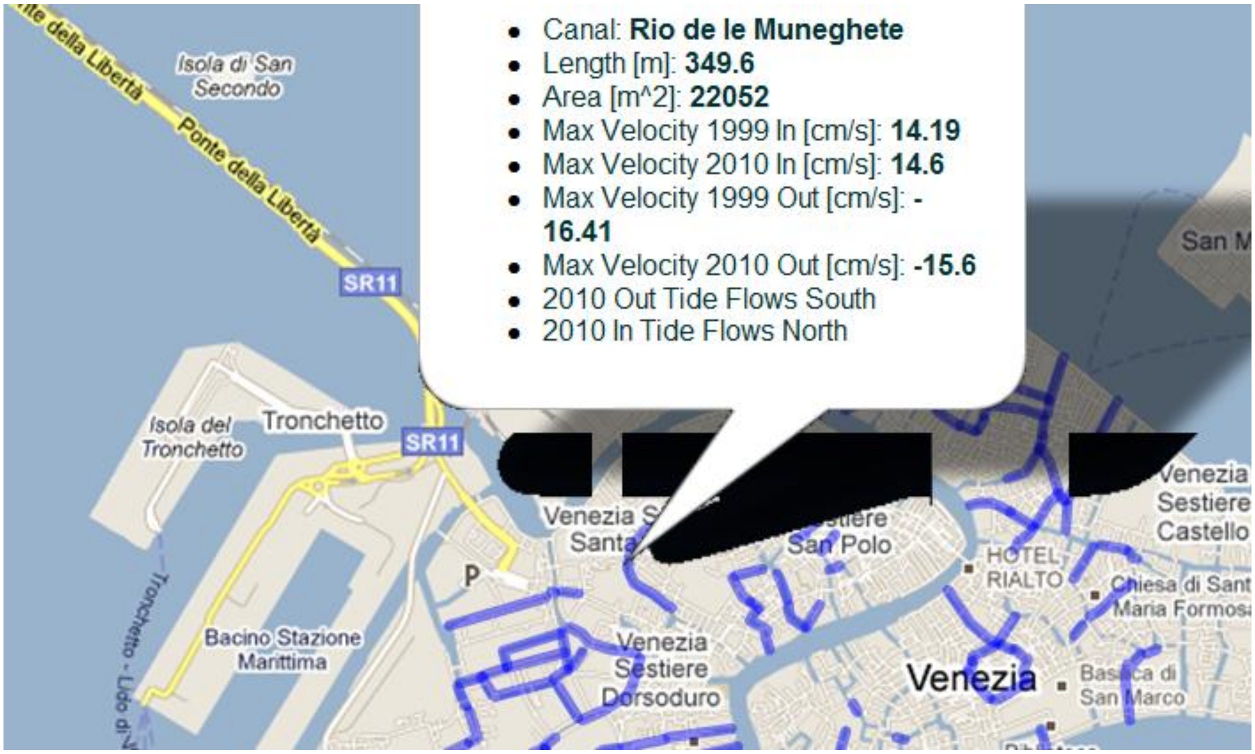
Santa Maria della Salute
Biblioteca Marciana

MAGG3 - 7.55m

MUNE

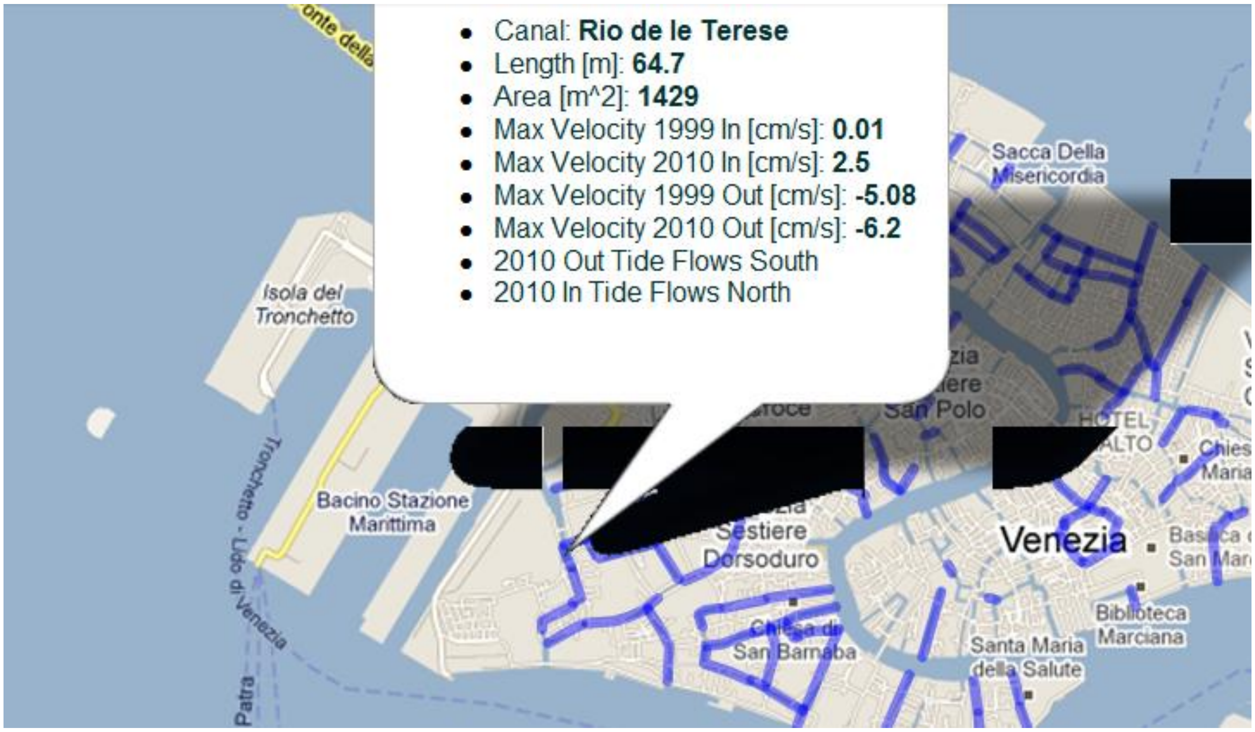


- Canal: **Rio de le Muneghete**
- Length [m]: **349.6**
- Area [m^2]: **22052**
- Max Velocity 1999 In [cm/s]: **14.19**
- Max Velocity 2010 In [cm/s]: **14.6**
- Max Velocity 1999 Out [cm/s]: **-16.41**
- Max Velocity 2010 Out [cm/s]: **-15.6**
- 2010 Out Tide Flows South
- 2010 In Tide Flows North

Isola di San Secondo
Ponte della Libertà
SR11
Isola del Tronchetto
Tronchetto
Bacino Stazione Marittima
P
Venezia Sestiere Dorsoduro
Sestiere San Polo
HOTEL RIALTO
Venezia Sestiere Castello
Chiesa di Santa Maria Formosa
Venezia
San Marco

MUNE - 10.5m

TERE1



- Canal: **Rio de le Terese**
- Length [m]: **64.7**
- Area [m^2]: **1429**
- Max Velocity 1999 In [cm/s]: **0.01**
- Max Velocity 2010 In [cm/s]: **2.5**
- Max Velocity 1999 Out [cm/s]: **-5.08**
- Max Velocity 2010 Out [cm/s]: **-6.2**
- 2010 Out Tide Flows South
- 2010 In Tide Flows North

Sacca Della Misericordia
Isola del Tronchetto
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San Polo
Sestiere Dorsoduro
Venezia
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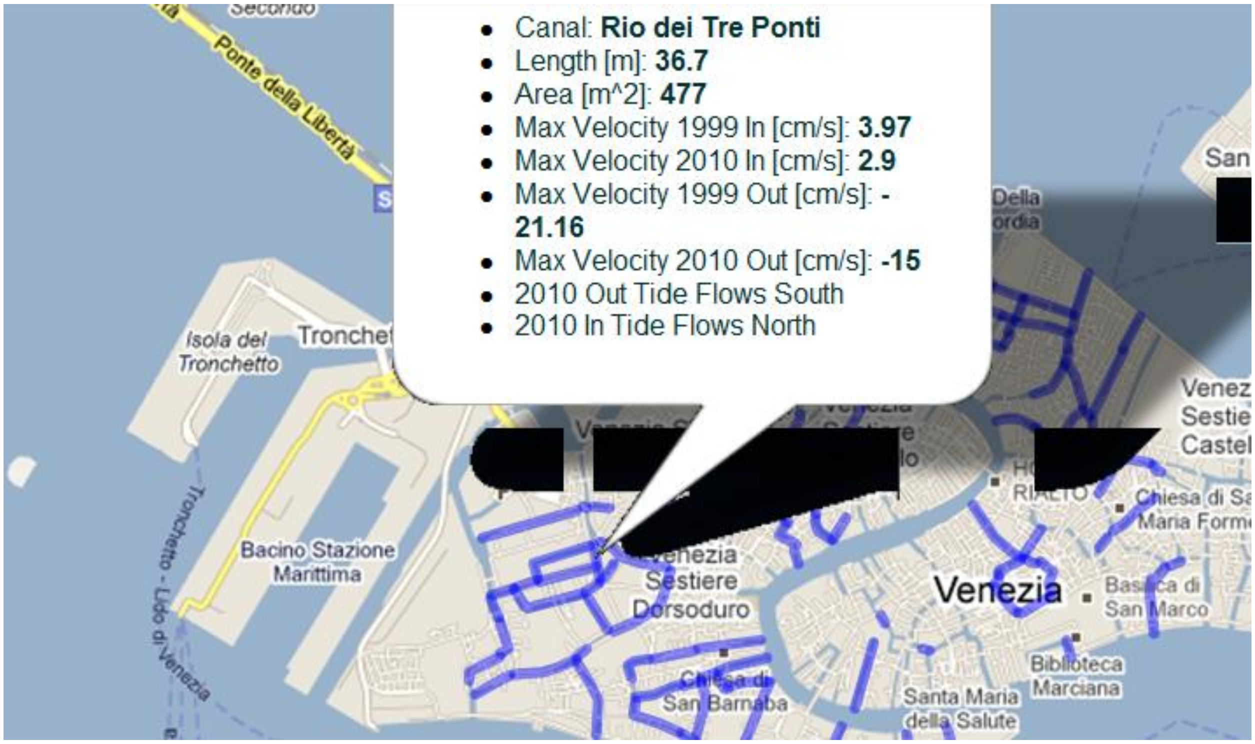
Santa Maria della Salute
Biblioteca Marciana

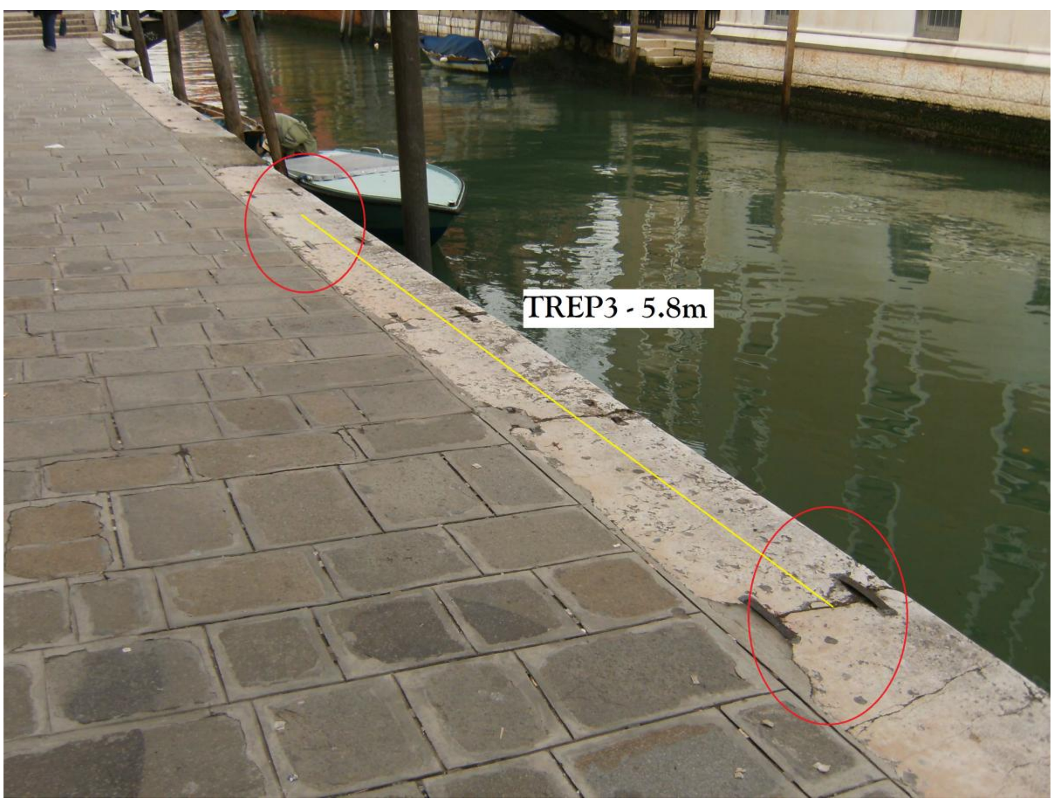
TERE1 - 3.2m

TREP3



- Canal: **Rio dei Tre Ponti**
- Length [m]: **36.7**
- Area [m^2]: **477**
- Max Velocity 1999 In [cm/s]: **3.97**
- Max Velocity 2010 In [cm/s]: **2.9**
- Max Velocity 1999 Out [cm/s]: **-21.16**
- Max Velocity 2010 Out [cm/s]: **-15**
- 2010 Out Tide Flows South
- 2010 In Tide Flows North

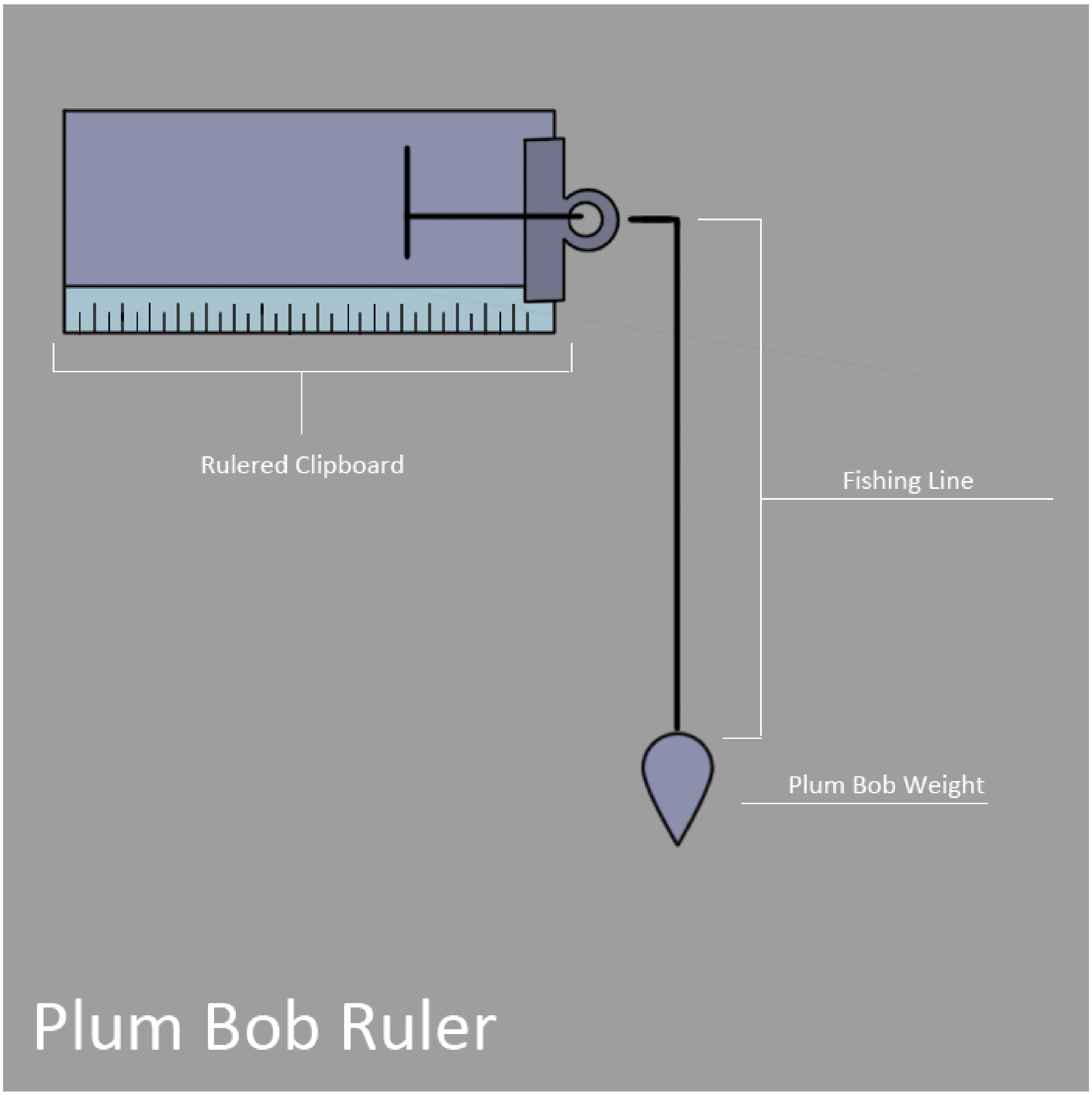
[redacted]
Ponte della Libertà
Isola del Tronchetto
Tronchetto - Lido di Venezia
Bacino Stazione Marittima
Venezia Sestiere Dorsoduro
Chiesa di San Barnaba
Venezia
Basilica di San Marco
Biblioteca Marciana
Santa Maria della Salute



TREP3 - 5.8m

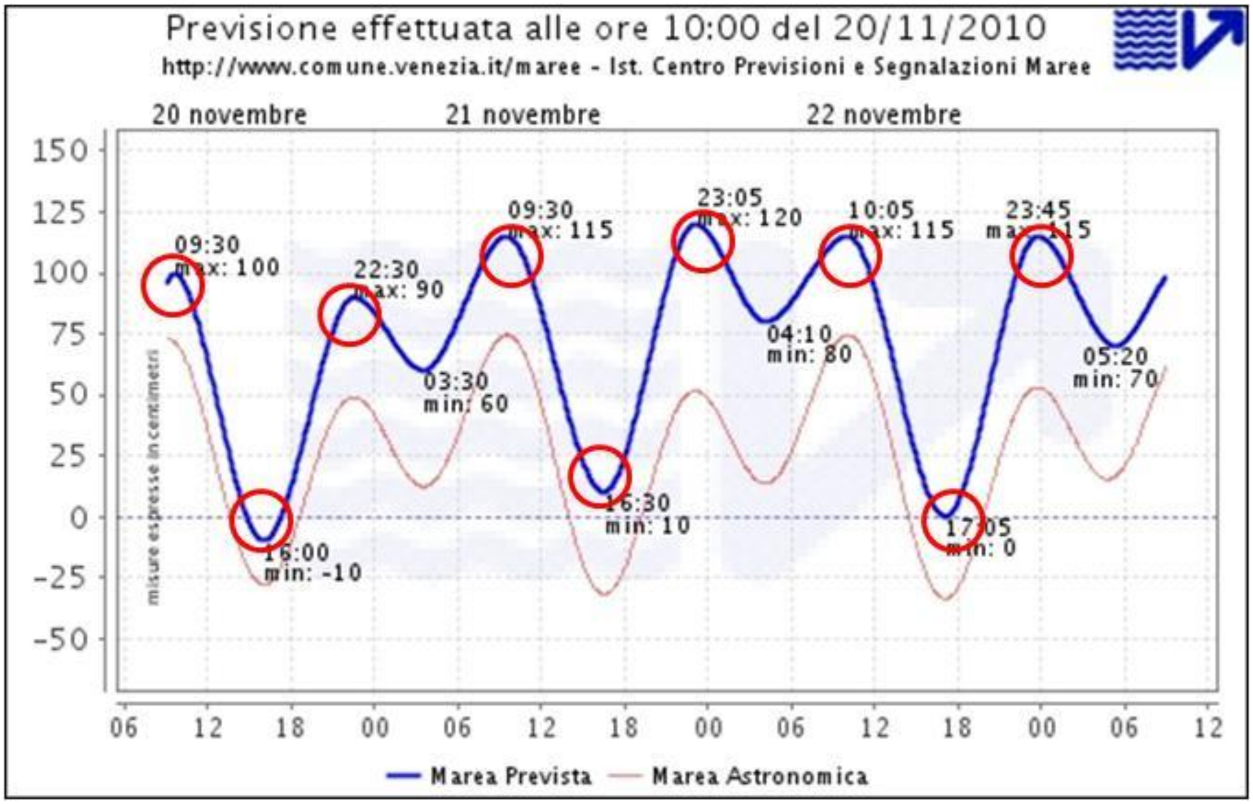
APPENDIX H - TIDE DELAY DEVICE

Tide Delay Device



APPENDIX I - SCHEDULE FOR TIDE DELAY TESTING

November 20th-22nd 2010 – FULL MOON



<u>November 20th – Saturday (Day before full moon)</u>

High Tide Forecasted at 9:30

<u>Cannaregio</u> – PANA2, GOZZ

<u>San Polo</u> – DOMI, ORIO

Low Tide Forecasted at 16:00

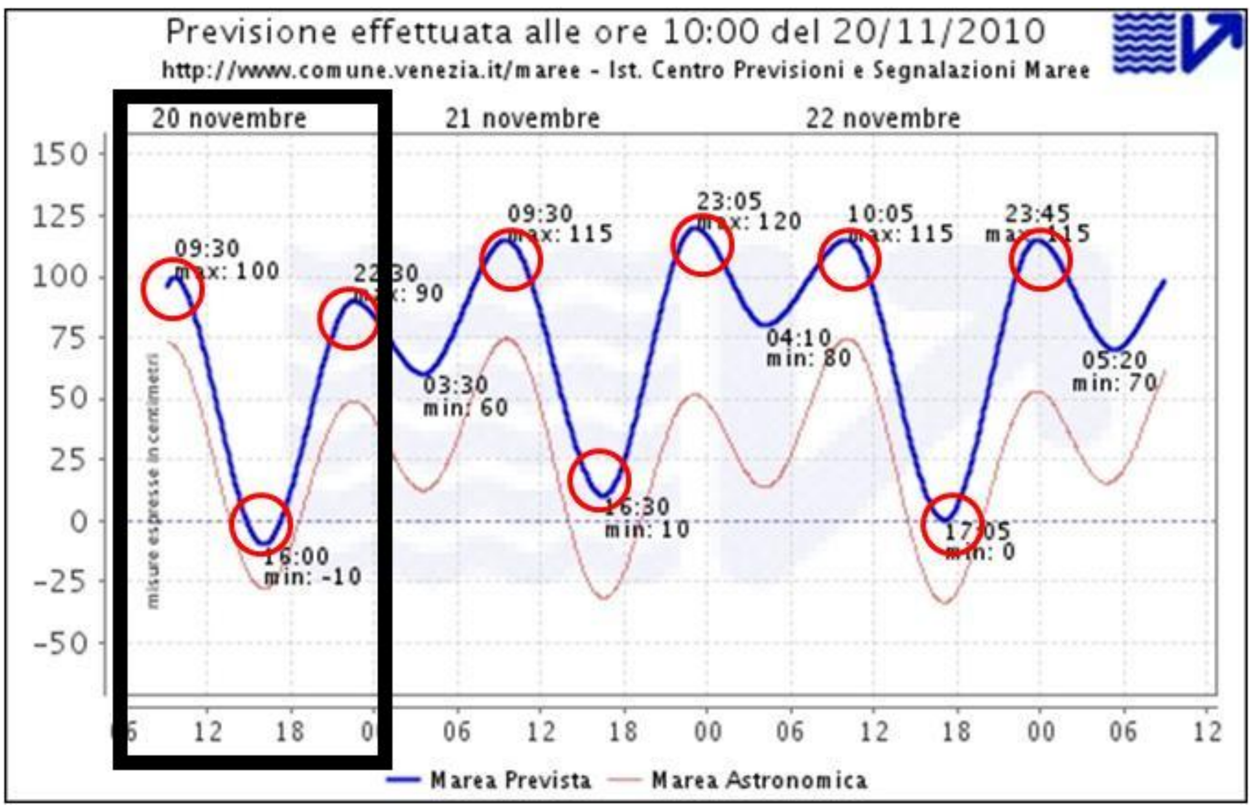
<u>Castello</u> – VIN, FORM

<u>San Marco</u> – SALVE, BARE1

High Tide Forecasted at 22:30

<u>Santa Croce</u> – MAGA, BURC

<u>Dorsoduro</u> – ROMI, TOLA1



November 21^st – Sunday (Day of full moon)

High Tide Forecasted at 9:30

Santa Croce – NOVO4, MUNE

Dorsoduro – VIO, FORN1

Low Tide Forecasted at 16:30

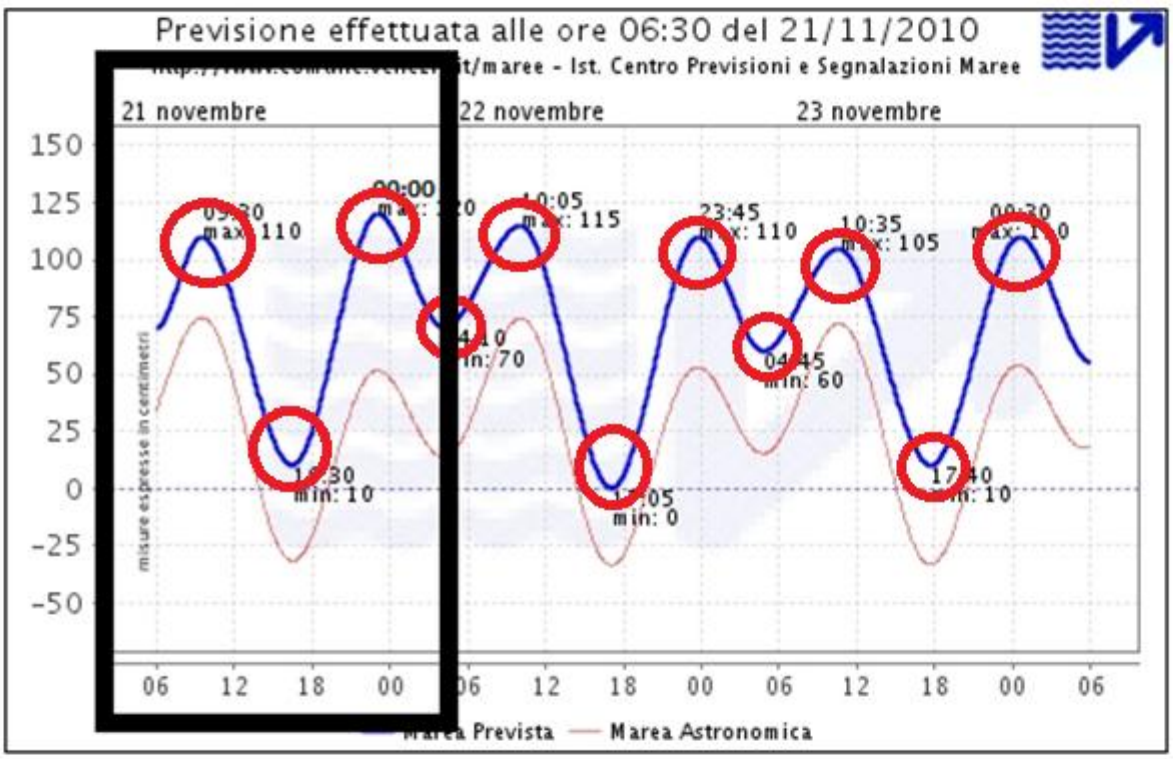
San Polo – SEVE2, APON2

San Polo – TOMA, POLO4

High Tide Forecasted at 00:00

Castello – PEST2, MOND3

San Marco – FERA2, ORSE



November 22nd – Monday (Day after full moon)

High Tide Forecasted at 10:05

Dorsoduro – BRIA, MAGG1

Santa Croce – ZIRA1, TOLE

Low Tide Forecasted at 17:05

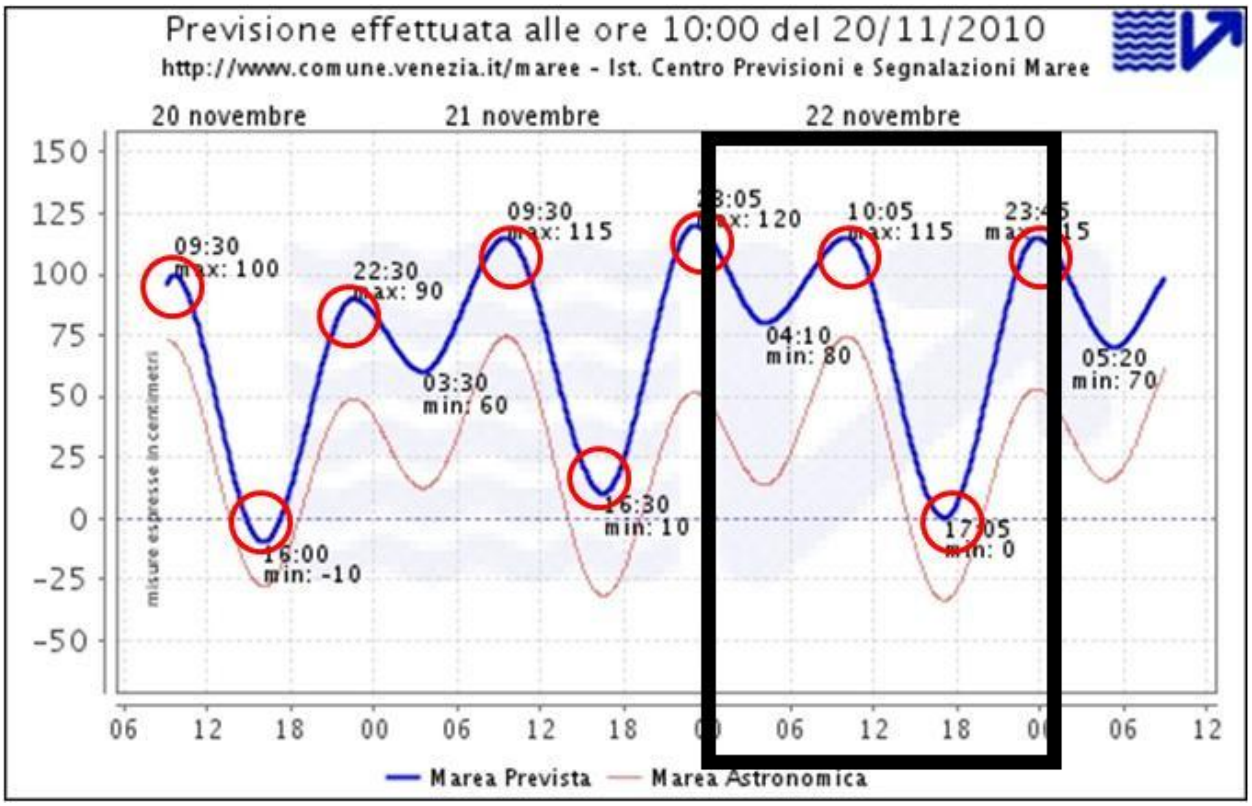
Castello – PROV2, PEST1

Cannaregio – MARC2, FOSC2

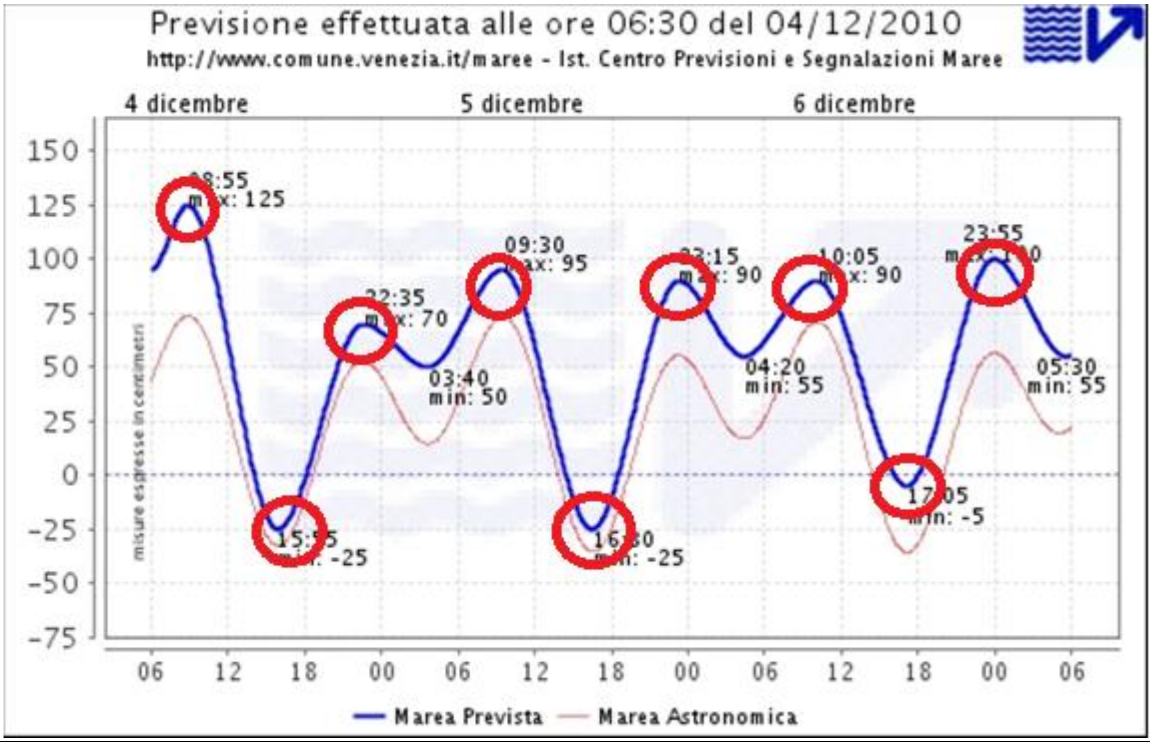
High Tide Forecasted at 23:45

San Polo – 2TOR2, CASS2

Cannaregio – CATE3, MIRA



December 4^{th}-6^{th} 2010 – NEW MOON



December 4th – Saturday (Day before new moon)

High Tide Forecasted at 8:55

San Polo – CASS1, MELO

Cannaregio – MADA2, MISE

Low Tide Forecasted at 15:55

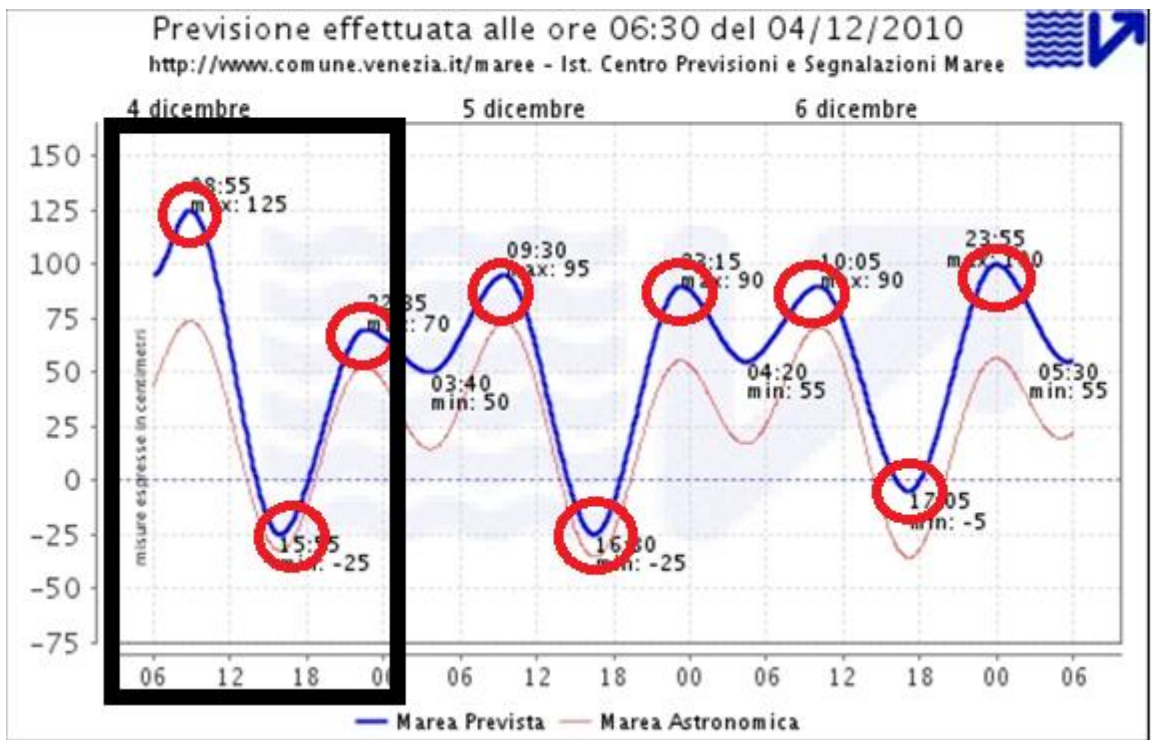
San Marco – DUCA, MAUR

Castello – TETT2, LATE1

High Tide Forecasted at 22:35

Santa Croce – MARN, DEGO4

Castello – MOND2, ZANI



December 5th – Sunday (Day of new moon)

High Tide Forecasted at 9:30

Santa Croce – GAFF, TREP3

Dorsoduro – BARN1, BARN2

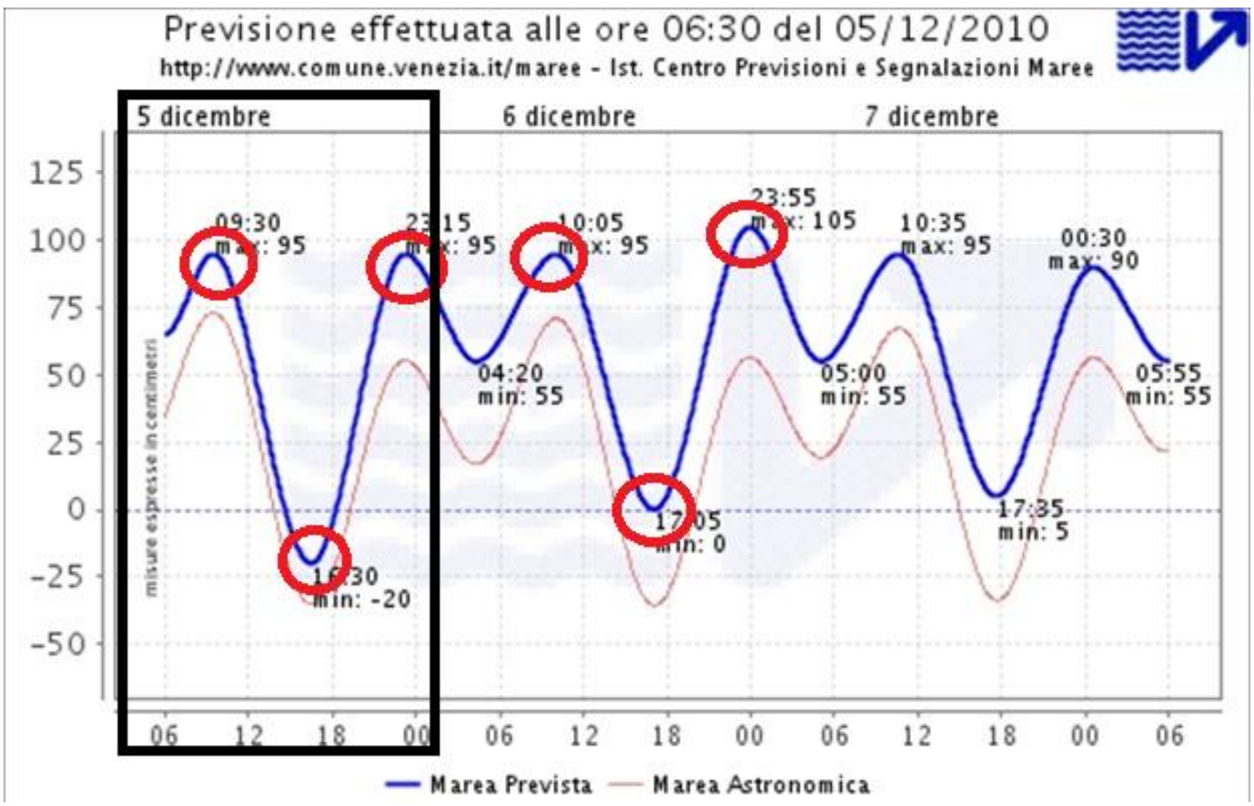
Low Tide Forecasted at 16:30

Cannaregio – TRAP, FELI2

San Polo – ERBE, MELO

High Tide Forecasted at 23:15

San Marco – CORN, GARZ



December 6th – Monday (Day after new moon)

High Tide Forecasted at 10:05

San Marco – CANO, ZULI

Castello – VIGN, GIUS

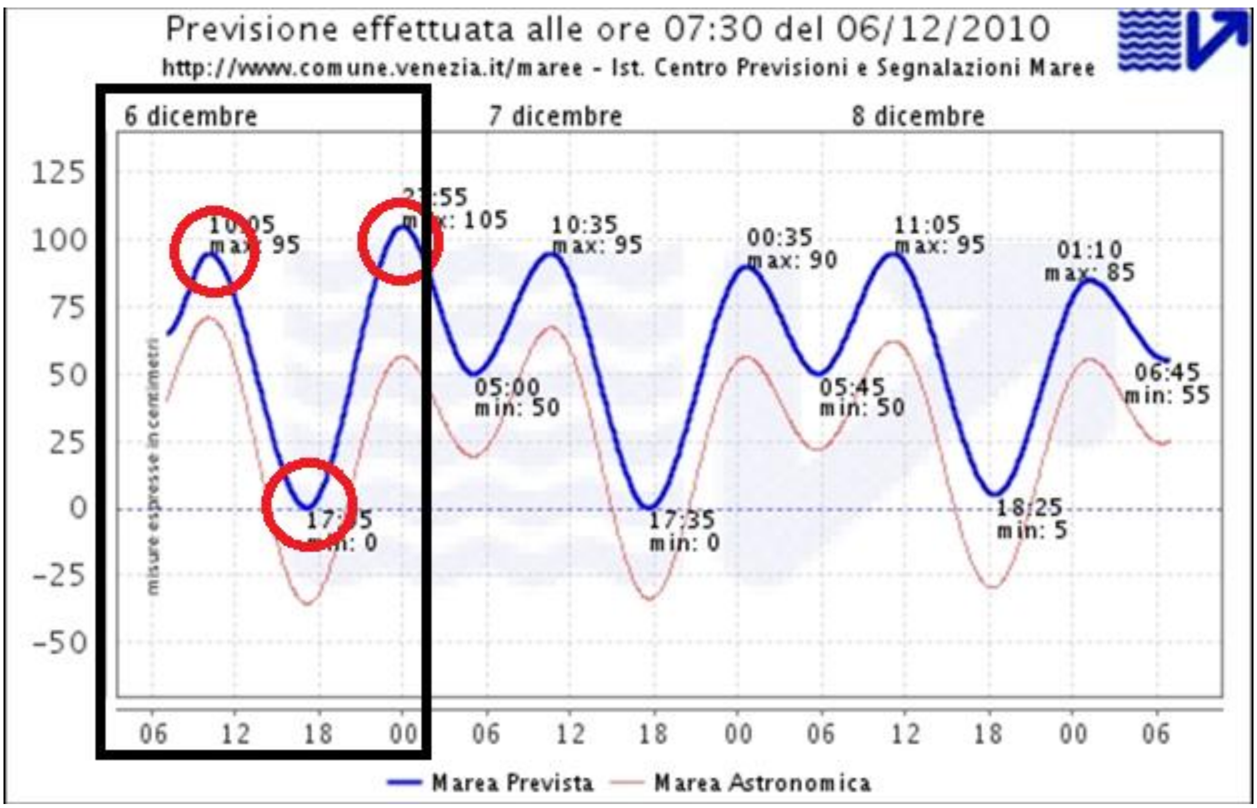
Low Tide Forecasted at 17:05

~~Dorsoduro – MARG, CAFO2~~

Dorsoduro – TORE, SALU1

High Tide Forecasted at 23:55

Cannaregio – APOS4, APOS3



APPENDIX J - FIELD FORMS FOR TIDE DELAY

GOZZ - Cannaregio - November 20th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	9:06	-16
2	9:12	-14
3	9:20	-13
4	9:25	-13
5	9:30	-11
6	9:35	-13
7	9:40	-15
8	9:45	-15
9	9:50	-16

ORIO - San Polo - November 20th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	9:17	-35
2	9:20	-33
3	9:21	-33
4	9:27	-31
5	9:28	-31
6	9:30	-30.5
7	9:32	-32
8	9:34	-33
9	9:35	-32.5
10	9:38	-32
11	9:42	-33
12	9:44	-32
13	9:46	-32
14	9:48	-33
15	9:50	-33
16	9:53	-33

BARE1 - San Marco - November 20th 2010 - Low Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	15:25	-89
2	15:35	-91
3	15:40	-93
4	15:45	-95

5	15:52	-96
6	15:57	-97
7	16:00	-97
8	16:04	-98
9	16:06	-96
10	16:10	-93

SALVE - San Marco - November 20th 2010 - Low Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	15:35	-149.4
2	15:42	-149.4
3	15:45	-148.9
4	15:48	-138.2
5	15:53	-147.7
6	15:55	-147.8
7	15:57	-147.9
8	15:59	-147.1
9	16:00	-145.5
10	16:03	-145.7
11	16:08	-145.7
12	16:15	-146.2
13	16:17	-146.9

FORM - Castello - November 20th 2010 - Low Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	15:22	-145
2	15:30	-146
3	15:36	-147
4	15:44	-147.5
5	15:52	-148.5
6	16:00	-150
7	16:08	-149.5
8	16:11	-150
9	16:17	-151
10	16:23	-149.5

11	16:29	-149

VIN- Castello - November 20th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	15:27	-85.5
2	15:30	-84.5
3	15:34	-88
4	15:36	-88
5	15:38	-87.5
6	15:40	-87
7	15:42	-87
8	15:48	-87
9	15:51	-87
10	15:56	-86.5
11	15:58	-86
12	16:00	-86
13	16:05	-86

BURC - Santa Croce - November 20th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	22:14	-35
2	22:18	-35.5
3	22:23	-35
4	22:27	-34.5
5	22:29	-34
6	22:31	-33.5

MAGA - Santa Croce - November 20th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	22:12	-57
2	22:17	-51
3	22:21	-51
4	22:25	-51
5	22:27	-49
6	22:30	-49
7	22:33	-47
8	22:36	-46
9	22:40	-51

APON2 - San Polo - November 20th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	22:10	3.5
2	22:15	3
3	22:20	3
4	22:24	3.5
5	22:25	3.7
6	22:26	4
7	22:28	4.2
8	22:30	4.4
9	22:32	4.5
10	22:34	5
11	22:37	5.2
12	22:39	5.5
13	22:42	5.2
14	22:43	5

FORN1 - Dorsoduro - November 21st 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:10	-11
2	9:15	-7
3	9:20	-3
4	9:25	-1
5	9:27	0
6	9:30	2
7	9:33	0
8	9:35	-4
9	0:00	-5

VIO - Dorsoduro - November 21st 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:08	-18
2	9:11	-17
3	9:14	-16
4	9:17	-15.5
5	9:20	-15
6	9:24	-14.5

7	9:27	-14.5
8	9:31	-15
9	9:34	-16
10	9:37	-17
11	9:40	-18

MUNE - Santa Croce - November 21st 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	9:23	-46
2	9:27	-46
3	9:28	-47
4	9:30	-46
5	9:31	-45.5
6	9:33	-45.5
7	9:34	-45.5
8	9:35	-45.5
9	9:38	-45.7
10	9:40	-45.7
11	9:43	-46
12	9:47	-46

NOVO4- Santa Croce - November 21st 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	9:26	-34.5
2	9:29	-34.5
3	9:30	-32
4	9:31	-31.5
5	9:32	-30
6	9:34	-28
7	9:36	-28
8	9:37	-28
9	9:40	-33
10	9:41	-32
11	9:45	-33.5
12	9:47	-34

MAGG – San Polo - November 21st 2010 - Low Tide

#	Time	Distance from Sidewalk (cm)
1	16:13	-105.5
2	16:15	-105.5
3	16:18	-106
4	16:20	-106
5	16:23	-106.5
6	16:25	-107
7	16:28	-107
8	16:30	-107.5
9	16:33	-108
10	16:35	-107
11	16:38	-106.5

POLO4 - San Polo - November 21st 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:12	-87
2	16:17	-89
3	16:22	-91
4	16:25	-91
5	16:27	-92
6	16:30	-94
7	16:34	-91
8	16:38	-91

TRTE - Cannaregio - November 21st 2010 -Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:14	-103
2	16:15	-104
3	16:16	-103
4	16:17	-102
5	16:22	-104
6	16:25	-105
7	16:28	-104
8	16:35	-104

BATE1- Cannaregio - November 21st 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)

1	16:17	-78
2	16:20	-78.5
3	16:22	-79
4	16:24	-82
5	16:26	-80
6	16:28	-80
7	16:30	-79
8	16:32	-79
9	16:35	-78
10	16:40	-78

FERA2 - San Marco - November 21st 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	23:45	-19
2	23:49	-20
3	23:52	-20
4	23:55	-20
5	0:00	-22
6	0:03	-21
7	0:05	-21
8	0:08	-20

ORSE - San Marco - November 21st 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	23:54	4
2	23:55	5
3	0:00	5
4	0:10	4.5
5	0:12	4

LORE - Castello - November 21st 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	23:40	7
2	23:43	7.5
3	23:45	8
4	23:48	8
5	23:50	8.5
6	23:53	8.5

7	23:55	8
8	23:58	8.5
9	0:00	8.5
10	0:03	8.5
11	0:05	8.5
12	0:08	8.5
13	0:10	8.5
14	0:13	8.5
15	0:15	9
16	0:18	8.5
17	0:20	8
18	0:23	7.5
19	0:25	7

SEVE2- Castello - November 21st 2010 - High Tide

#	Time	Distance from Sidewalk (cm)
1	23:42	20.5
2	23:43	20.5
3	23:44	20.75
4	23:45	20.75
5	23:46	20.8
6	23:47	20.8
7	23:48	20.8
8	23:49	20.9
9	23:50	21
10	23:51	21.5
11	23:52	21.5
12	23:53	21.5
13	23:54	21.5
14	23:55	21.5
15	23:56	21.5
16	23:57	21.5
17	23:58	21.5
18	23:59	21.5
19	0:00	21.5
20	0:01	21.5
21	0:02	21.5
22	0:03	21.5
23	0:04	21.5

24	0:05	21.5
25	0:06	21.5
26	0:07	21.5
27	0:08	21.5
28	0:09	21.5
29	0:10	21.5
27	0:11	21.5
28	0:12	21.5
29	0:13	21.5
30	0:14	21.5
31	0:15	21.5
32	0:16	21.5
33	0:17	21.75
34	0:18	22
35	0:19	22
36	0:20	22
37	0:21	22
38	0:22	22
39	0:23	21.5
40	0:24	21.5
41	0:25	21.5
42	0:26	21.5
43	0:27	21
44	0:28	21
45	0:29	20.75
46	0:30	20.75
47	0:31	20.75

BRIA - Dorsoduro - November 22nd 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	9:50	-17
2	9:55	-16.5
3	10:00	-15.5
4	10:05	-15
5	10:10	-15
6	10:15	-14
7	10:20	-15
8	10:25	-15.5

ZIRA2- Dorsoduro - November 22nd 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:40	9.5
2	9:41	10
3	9:42	9.5
4	9:43	9.5
5	9:44	9
6	9:46	9
7	9:47	9
8	9:48	8.5
9	9:49	8.5
10	9:50	8.5
11	9:51	7.5
12	9:52	7.5
13	9:53	7.5
14	9:54	7.5
15	9:55	7.5
16	9:56	7.5
17	9:57	7
18	9:58	7
19	9:59	6.5
20	10:00	6.5
21	10:01	7
22	10:02	7
23	10:03	7
24	10:04	7
25	10:05	6.5
26	10:06	6.5
27	10:07	7
28	10:08	6.5
29	10:09	7
30	10:10	7
31	10:11	7
32	10:12	7.5
33	10:13	7
34	10:14	7
35	10:15	7.5
36	10:16	8
37	10:17	8.5
38	10:18	8.5

39	10:19	9
40	10:20	9
41	10:21	9
42	10:22	9
43	10:23	9
44	10:24	8.5
45	10:25	9
46	10:26	9
47	10:27	9
48	10:28	8.5
49	10:31	8.5
50	10:32	8
51	10:33	7.5
52	10:34	7
53	10:35	7
54	10:36	6.5
55	10:37	6
56	10:38	6

TOLE - Santa Croce - November 22nd 2010 - High Tide

#	Time	Distance from Sidewalk (cm)
1	9:40	4.5
2	9:42	5
3	9:44	3.5
4	9:47	2.8
5	9:50	2
6	10:07	2
7	10:16	4
8	10:25	4
9	10:30	2.5

FOSC2 - Cannaregio - November 22nd 2010 - Low Tide

#	Time	Distance from Sidewalk (cm)
1	16:45	-85
2	16:50	-86
3	16:53	-86
4	16:57	-88

5	17:00	-88
6	17:03	-88
7	17:05	-89
8	17:08	-87
9	17:11	-84

MARC1 -Cannaregio- November 22nd 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:45	-112
2	16:46	-112
3	16:47	-112
4	16:48	-111.5
5	16:49	-111.5
6	16:50	-112
7	16:51	-112
8	16:52	-112
9	16:53	-112
10	16:54	-112
11	16:55	-112.5
12	16:56	-112.5
13	16:57	-112.5
14	16:58	-112.5
15	16:59	-113
16	17:00	-114
17	17:01	-114
18	17:02	-114
19	17:03	-116
20	17:05	-116
21	17:06	-117

PEST1 - Castello - November 22nd 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:54	-94
2	16:55	-93.5
3	16:57	-94
4	17:00	-93.5
5	17:04	-92
6	17:05	-98.5

7	17:07	-96.5
8	17:09	-94

PROV2 - Castello - November 22nd 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:43	-115
2	16:45	-115
3	16:48	-115.5
4	16:50	-115.5
5	16:53	-115.5
6	16:55	-115.5
7	16:58	-116
8	17:00	-116
9	17:03	-116.5
10	17:05	-116
11	17:08	-115.5
12	17:10	-115.5
13	17:13	-115

CASS2 - San Polo - November 22nd 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	23:34	5.5
2	23:35	6
3	23:36	6
4	23:37	6
5	23:38	6.1
6	23:39	6
7	23:40	6
8	23:41	6.5
9	23:42	6.5
10	23:43	6.5
11	23:44	6.5
12	23:45	6
13	23:46	5.7
14	23:47	5.7
15	23:48	5.5
16	23:49	5.5
17	23:50	5.2

18	23:51	5
19	23:52	4.8
20	23:53	5.5
21	23:54	5

CATE3 - Cannaregio - November 22nd 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	23:30	1
2	23:35	3
3	23:40	4
4	23:43	4
5	23:45	5
6	23:47	4
7	23:50	4
8	23:53	3

MIRA - Canneregio - November 22st 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	23:30	-31
2	23:33	-30
3	23:35	-29.5
4	23:38	-30
5	23:40	-30
6	23:43	-30.5
7	23:45	-30.5
8	23:48	-31
8	23:48	-31

MADA2- Cannaregio - December 4th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	8:30	-2.5
2	8:31	-2
3	8:32	-2
4	8:33	-2
5	8:34	-3
6	8:35	-3
7	8:36	-3

8	8:37	-2.5
9	8:38	-2.5
10	8:39	-2.5
11	8:40	-2.5
12	8:41	-3
13	8:42	-3.5
14	8:43	-3
15	8:44	-3
16	8:45	-3
17	8:46	-3
18	8:47	-2.5
19	8:48	-2.5
20	8:49	-2
21	8:50	-2.5
22	8:51	-2
23	8:52	-2
24	8:53	-2
25	8:54	-2
26	8:55	-2
27	8:56	-2
28	8:57	-2
29	8:58	-2
30	8:59	-2
31	9:00	-2
32	9:01	-2
33	9:02	-2
34	9:03	-1.5
45	9:04	-1.5
36	9:05	-1.5
37	9:06	-2
38	9:07	-2
39	9:08	-2.5
40	9:09	-3

MISE - Cannaregio - December 4th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	8:25	24
2	8:30	26
3	8:35	26

4	8:40	26
5	8:45	26
6	8:50	27
7	8:53	27.5
8	8:55	28
9	8:58	27
10	9:02	27
11	9:05	26

MELO - San Polo - December 4th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	8:30	10.5
2	8:35	11
3	8:40	11
4	8:45	11.5
5	8:50	11.5
6	8:55	12
7	9:00	12.5
8	9:05	12
9	9:10	11

CASS1 - San Polo -December 4th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	8:30	12
2	8:33	12
3	8:35	12
4	8:40	12
5	8:45	11.8
6	8:46	12.3
7	8:49	12.5
8	8:51	12.7
9	8:53	13
10	8:55	13.2
11	8:58	13.5
12	9:00	13.3
13	9:05	13.3
14	9:07	13
15	9:10	12.5

16	9:15	12

MAUR- San Marco - December 4th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	15:33	-114
2	15:34	-114
3	15:35	-114
4	15:36	-114
5	15:37	-114.5
6	15:38	-114.5
7	15:39	-115
8	15:40	-115
9	15:41	-115
10	15:42	-115.5
11	15:43	-115.5
12	15:44	-115.5
13	15:45	-115.5
14	15:46	-116
15	15:47	-116
16	15:48	-116
17	15:49	-116
18	15:50	-117
19	15:51	-118
20	15:52	-118
21	15:53	-118
22	15:54	-119
23	15:55	-119
24	15:56	-120
25	15:57	-120
26	15:58	-120
27	15:59	-120
28	16:00	-119.5
29	16:01	-119.5
30	16:02	-119.5
31	16:03	-119.5
32	16:04	-119.5
33	16:05	-119.5
34	16:06	-119.5

45	16:07	-119.5
36	16:08	-119.5
37	16:09	-119.5
38	16:10	-119.5
39	16:11	-119.5
40	16:12	-119
41	16:13	-119

DUCA - San Marco - December 4th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	15:30	-161
2	15:35	-161
3	15:40	-163
4	15:45	-163
5	15:50	-164
6	15:53	-164.5
7	15:55	-165
8	16:00	-164
9	16:05	-163.5

LATE1 - Castello - December 4th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	15:34	-101.5
2	15:38	-101.5
3	15:40	-101.5
4	15:42	-102
5	15:44	-102.5
6	15:46	-103
7	15:48	-103
8	15:50	-104
9	15:52	-104.5
10	15:54	-105
11	15:56	-105
12	15:58	-105.5
13	16:00	-106
14	16:02	-106
15	16:04	-106

16	16:06	-106
17	16:08	-106.5
18	16:10	-107
19	16:12	-108
20	16:14	-107
21	16:16	-106.5
22	16:18	-106

TETT2 - Castello - December 4th 2010 - Low Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	15:46	-153.9
2	15:48	-153.7
3	15:51	-154.3
4	15:52	-152.9
5	15:54	-152.9
6	15:55	-152.4
7	15:59	-153.1
8	16:06	-150.9
9	16:08	-150.4
10	16:10	-149.9
11	16:16	-148.4
12	16:19	148.9
13	16:25	-148.9
14	16:27	-146.9

ZANE - Castello - December 4th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	22:15	-51
2	22:20	-51
3	22:25	-51
4	22:30	-50
5	22:33	-50
6	22:35	-49
7	22:38	-48
8	22:40	-49
9	22:45	-50

MOND2- Castello- December 4th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	22:20	-53
2	22:21	-53
3	22:22	-53
4	22:23	-53
5	22:24	-53
6	22:25	-53
7	22:26	-51
8	22:27	-51
9	22:28	-51
10	22:29	-49
11	22:30	-49
12	22:31	-43
13	22:32	-43
14	22:33	-43
15	22:34	-42.5
16	22:35	-42
17	22:36	-42
18	22:37	-42.5
19	22:38	-42
20	22:39	-42
21	22:40	-42
22	22:41	-42
23	22:42	-42
24	22:43	-43
25	22:44	-43
26	22:45	-43

ZUAN - Santa Croce - December 4th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	22:20	-70
2	22:22	-70
3	22:24	-69
4	22:26	-69
5	22:28	-69

6	22:30	-69
7	22:32	-69
8	22:34	-68.5
9	22:36	-69
10	22:38	-69
11	22:40	-69.5
12	22:42	-69.5

MARN - Santa Croce - December 4th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	22:22	-45
2	22:24	-44.5
3	22:25	-44.5
4	22:29	-42.5
5	22:30	-42.5
6	22:32	-43.5
7	22:35	-43.8
8	22:36	-43.5
9	22:40	-44
10	22:42	-42
11	22:43	-42.5
12	22:44	-41
13	22:46	-41.5
14	22:50	-42
15	22:51	-43
16	22:52	-44

BARN2 - Dorsoduro - December 5th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	9:10	-7
2	9:15	-6
3	9:20	-5
4	9:25	-4
5	9:28	-4
6	9:30	-3
7	9:35	-4
8	9:40	-5

BARN1- Dorsoduro- December 5th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:18	8
2	9:19	7.5
3	9:20	7
4	9:21	7
5	9:22	6.5
6	9:23	7
7	9:24	7
8	9:25	7.5
9	9:26	8
10	9:27	8.5
11	9:28	7.5
12	9:29	7.5
13	9:30	7
14	9:31	7
15	9:32	7
16	9:33	7.5
17	9:34	7
18	9:35	6.5
19	9:36	6
20	9:37	6
22	9:38	5.5
23	9:39	5.5
24	9:40	5.5

GAFF - Santa Croce - December 5th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:16	-10
2	9:18	-9.5
3	9:20	-9
4	9:22	-8
5	9:24	-7
6	9:26	-8
7	9:28	-8.25
8	9:30	-8

9	9:32	-9
10	9:34	-9
11	9:36	-9.5

TREP3 - Santa Croce -December 5th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:21	-45
2	9:23	-44
3	9:25	-43
4	9:29	-44.5
5	9:30	-45
6	9:32	-45.6
7	9:35	-45
8	9:40	-46

MELO - San Polo - December 5th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:15	-115
2	16:20	-117
3	16:25	-118
4	16:28	-118
5	16:30	-119
6	16:34	-117
7	16:38	-117
8	16:40	-116

ERBE- San Polo- December 5th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:20	-124
2	16:21	-124
3	16:22	-124
4	16:23	-124
5	16:24	-124
6	16:25	-124
7	16:26	-124

8	16:27	-125
9	16:28	-125
10	16:29	-125
11	16:30	-125
12	16:31	-125
13	16:32	-125
14	16:33	-125.5
15	16:34	-125.5
16	16:35	-125.5
17	16:36	-125.5
18	16:37	-125
19	16:38	-125
20	16:39	-125
21	16:40	-124

FELI2 - Cannaregio - December 5th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:10	-93
2	16:15	-93
3	16:20	-93.5
4	16:22	-93.5
5	16:24	-93.5
6	16:26	-94
7	16:28	-94
8	16:30	-94
9	16:32	-94.5
10	16:34	-94
11	16:36	-94
12	16:38	-93.5
13	16:40	-93.5

TRAP - Cannaregio - December 5th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:20	-148
2	16:22	-148
3	16:24	-149
4	16:25	-150

5	16:26	-150
6	16:28	-150
7	16:29	-149.5
8	16:30	-149
9	16:31	-151
10	16:32	-150
11	16:33	-149
12	16:35	-149.5
13	16:36	-150
14	16:38	-151
15	16:40	-152
16	16:41	-151.5
17	16:44	-151
18	16:45	-151
19	16:49	-150
20	16:55	-149

GARZ - San Marco - December 5th 2010 - High Tide		
#	**Time**	**Distance from Sidewalk (cm)**
1	23:00	-35.5
2	23:02	-35.5
3	23:04	-34.5
4	23:06	-34
5	23:08	-33.5
6	23:10	-33.5
7	23:12	-33
8	23:14	-33
9	23:16	-32.5
10	23:18	-32
11	23:20	-32.5
12	23:22	-32.5
13	23:24	-32
14	23:26	-31.5
15	23:28	-32
16	23:30	-31
17	23:32	-31.5
18	23:34	-30
19	23:36	-30.5

20	23:38	-31
21	23:40	-31.5

CORN - San Marco - December 5th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	22:06	-34
2	22:08	-32
3	22:10	-32
4	22:12	-32
5	22:14	-33.5
6	22:16	-34
7	22:20	-31.5
8	22:22	-33
9	22:24	-33
10	22:26	-32
11	22:30	-31
12	22:32	-32.5
13	22:38	30
14	22:40	29

ZULI - San Marco - December 6th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:50	-1
2	9:55	0
3	10:00	1
4	10:05	2
5	10:07	1
6	10:10	1
7	10:15	-1

CANO- San Marco- December 6th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:54	2
2	9:55	2
3	9:56	2

4	9:57	2.5
5	9:58	2.5
6	9:59	3
7	10:00	3
8	10:01	3.5
9	10:02	3.5
10	10:03	4
11	10:04	4
12	10:05	4
13	10:06	3.5
14	10:07	3.5
15	10:08	3

VIGN - Castello - December 6th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	9:52	-35.5
2	9:54	-35.5
3	9:56	-35
4	9:58	-35
5	10:00	-35
6	10:02	-35
7	10:04	-34.5
8	10:05	-34.5
9	10:06	-34
10	10:08	-34.5
11	10:10	-35
12	10:12	-35

SALU1 - Dorsoduro -December 6th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:57	-122.1
2	17:00	-121
3	17:04	-121
4	17:05	-120.6
5	17:07	-120.8
6	17:10	-122
7	17:12	-122.5

TORE- Dorsoduro- December 6th 2010 - Low Tide		
#	Time	Distance from Sidewalk (cm)
1	16:55	-110
2	16:56	-11
3	16:57	-112
4	16:58	-112.5
5	16:59	-112.5
6	17:00	-113
7	17:01	-113
8	17:02	-113.5
9	17:03	-113.5
10	17:04	-113
11	17:05	-113
12	17:06	-113
13	17:07	-113.5
14	17:08	-113.5
15	17:09	-113.5
16	17:10	-113.5
18	17:11	-113.5
19	17:12	-114
20	17:13	-114
21	17:14	-114.5
22	17:15	-115

APOS3 - Cannaregio - December 6th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	23:41	-16
2	23:45	-14
3	23:50	-13
4	23:53	-13
5	23:55	-12
6	23:59	-12
7	0:04	-10
8	0:10	-12
9	0:13	-13

APOS4 - Cannaregio - December 6th 2010 - High Tide		
#	Time	Distance from Sidewalk (cm)
1	23:43	13.5
2	23:45	14
3	23:47	14
4	23:49	14.5
5	23:51	15
6	23:53	14.5
7	23:55	14.5
8	23:57	14.5
9	23:58	15
10	23:59	14.5
11	0:00	15
12	0:01	15
13	0:02	15
14	0:03	15
15	0:04	15
16	0:05	15
17	0:06	15
18	0:07	14.5
19	0:08	14.5
20	0:09	14.5
21	0:10	14
22	0:11	14
23	0:12	13

APPENDIX K – TIDE DELAY TABLE OF RESULTS

Segment	Date	Tide Type	Actual Time at Salute/Misericordia	Actual Time Recorded at Segment	Delay ?
GOZZ	20/11/10	High	9:20	9:30	10
ORIO	20/11/10	High	9:20	9:30	10
BARE1	20/11/10	Low	16:25	16:04	-11
SALVE	20/11/10	Low	16:25	16:00	-25
FORM	20/11/10	Low	16:25	16:17	-8
VIN	20/11/10	Low	16:25	15:36	-49
BURC	20/11/10	High	23:15	22:18	3
MAGA	20/11/10	High	23:15	22:36	-39
APON2	20/11/10	High	23:15	22:39	-36
FORN1	21/11/10	High	9:50	9:30	-20
VIO	21/11/10	High	9:50	9:24	-26
MUNE	21/11/10	High	9:50	9:34	-16
NOVO4	21/11/10	High	9:50	9:37	-13
MAGG	21/11/10	Low	16:45	16:33	-12
POLO4	21/11/10	Low	16:45	16:30	-15
TRTE	21/11/10	Low	16:45	16:25	-20
BATE1	21/11/10	Low	16:45	16:24	-21
FERA2	21/11/10	High	0:05	0:00	-5
ORSE	21/11/10	High	0:05	0:00	-5
LORE	21/11/10	High	0:05	0:15	10
SEVE2	21/11/10	High	0:05	0:22	17
BRIA	22/11/10	High	10:15	10:15	0
ZIRA2	22/11/10	High	10:15	10:27	12
TOLE	22/11/10	High	10:15	9:42	-33
FOSC2	22/11/10	Low	16:40	17:05	25
MARC	22/11/10	Low	16:40	16:49	9
PEST1	22/11/10	Low	16:40	17:05	25
PROV2	22/11/10	Low	16:40	17:03	23
CASS2	22/11/10	High	23:35	23:43	8
CATE3	22/11/10	High	23:35	23:45	10
MIRA	22/11/10	High	23:35	23:35	0
MADA2	4/12/2010	High	8:55	9:05	10
MISE	4/12/2010	High	8:55	8:55	0
MELO	4/12/2010	High	8:55	9:00	5
CASS1	4/12/2010	High	8:55	8:58	3
MAUR	4/12/2010	Low	16:45	16:11	-34
DUCA	4/12/2010	Low	16:45	15:55	-50
LATE1	4/12/2010	Low	16:45	16:12	-33
TETT2	4/12/2010	Low	16:45	15:51	-54
ZANE	4/12/2010	High	23:55	22:38	-77

MOND2	4/12/2010	High	23:55	22:42	-73
ZUAN	4/12/2010	High	23:55	22:34	-81
MARN	4/12/2010	High	23:55	22:44	-71
BARN2	5/12/2010	High	9:15	9:30	15
BARN1	5/12/2010	High	9:15	9:27	12
GAFF	5/12/2010	High	9:15	9:24	9
TREP3	5/12/2010	High	9:15	9:25	10
MELO	5/12/2010	Low	17:00	16:30	-30
ERBE	5/12/2010	Low	17:00	16:36	-24
FELI2	5/12/2010	Low	17:00	16:32	-28
TRAP	5/12/2010	Low	17:00	16:40	-20
GARZ	5/12/2010	High	0:15	23:34	-41
CORN	5/12/2010	High	0:15	22:30	-105
ZULI	6/12/2010	High	10:30	10:05	-25
CANO	6/12/2010	High	10:30	10:05	-25
VIGN	6/12/2010	High	10:30	10:06	-24
SALU1	6/12/2010	Low	17:20	17:05	-15
TORE	6/12/2010	Low	17:20	17:05	-15
APOS3	6/12/2010	High	0:00	0:04	4
APOS4	6/12/2010	High	0:00	0:06	6

APPENDIX L – DELIEVERABLES: OTHER MAPS

Sedimentation Related Maps

Sedimentation Volumes in Canal Segments

From *Quantifying Sediment in the Venetian Canals – WPI IQP – E'99*

http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=110440766011273321622.00049460b340bf002b07d&ll=45.438454,12.355757&spn=0.022645,0.060854&z=14

Boat Traffic Related Maps

Rules and Regulations of the Inner Canals of Venice

From UNESCO Report – The Evolution of Venetian Boat Traffic – 2000

http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=110440766011273321622.000493fb7eea6321cc4b7&ll=45.438032,12.337904&spn=0.022645,0.093555&z=14

Total Daily Passengers at a Single Point

From UNESCO Report – Il Traffico Acqueo nei Canali Interni di Venezia - 1999

http://maps.google.com/maps/ms?ie=UTF8&hl=en&dirflg=w&doflg=ptk&oe=UTF8&msa=0&msid=115780869215059366243.000493fbf35b05f40c4c3&ll=45.439297,12.354641&spn=0.022644,0.060854&z=14

Total Daily Boats at Selected Intersection

From UNESCO Report – Il Traffico Acqueo nei Canali Interni di Venezia - 1999

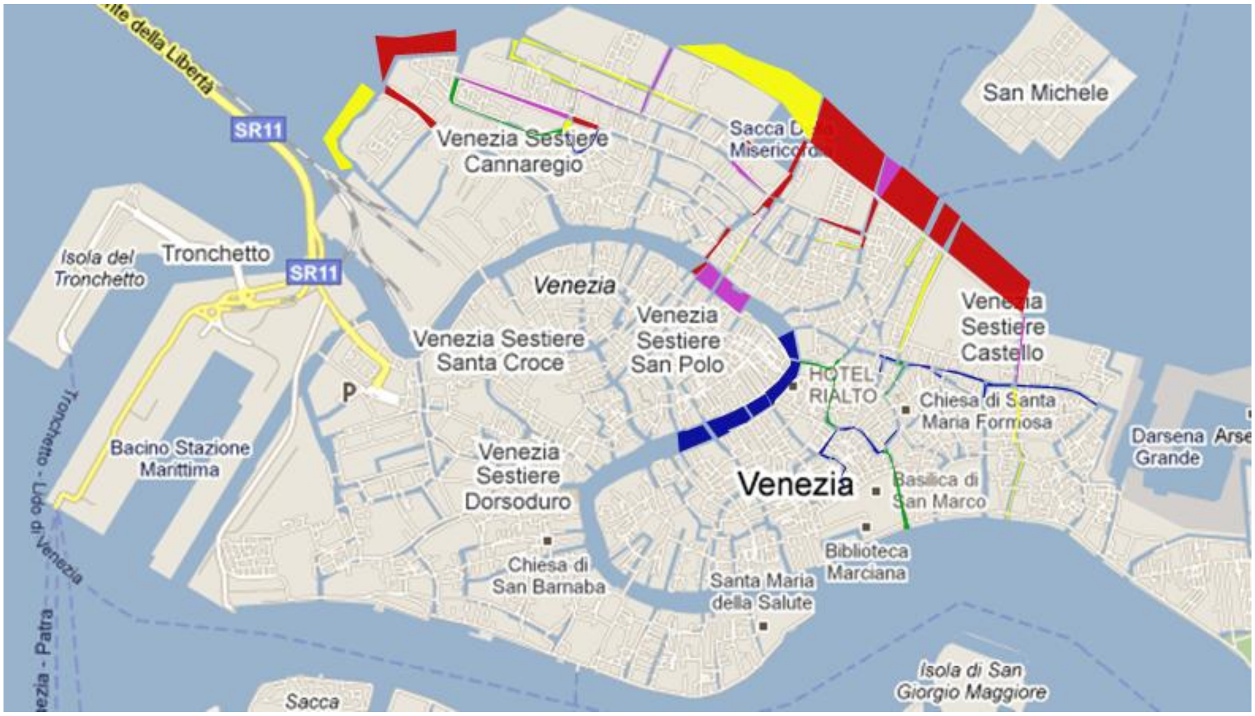
http://maps.google.com/maps/ms?ie=UTF8&hl=en&dirflg=w&doflg=ptk&oe=UTF8&msa=0&msid=115780869215059366243.000493fa654fbdce43d55&ll=45.438393,12.340136&spn=0.022645,0.093555&z=14

Most Frequent 'Links' From Lagoon to Central Venice

From UNESCO Report – The Evolution of Venetian Boat Traffic – 2000

http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=110440766011273321622.000493fa654e0c176a531&ll=45.437972,12.343826&spn=0.04529,0.187111&z=13

Distribution of Private Crafts in the Canals of Venice



From UNESCO Report – Il Traffico Acqueo nei Canali Interni di Venezia - 1999

http://maps.google.com/maps/ms?ie=UTF8&hl=en&oe=UTF8&msa=0&msid=103140249760910180705.000493fa6ca0132c5c24f&ll=45.438514,12.352839&spn=0.022645,0.060854&z=14

Total Daily Passengers at Select Canal Segments

From UNESCO Report – Il Traffico Acqueo nei Canali Interni di Venezia - 1999

http://maps.google.com/maps/ms?ie=UTF8&hl=en&oe=UTF8&msa=0&msid=101570310457053562333.000493fa660d9614d57d8&ll=45.437129,12.337818&spn=0.022645,0.093555&z=14

APPENDIX M – CALENDAR

SEPTEMBER 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 PQP – And so it begins	2 Group Meeting 1PM – Split up Background	3 Start Individual Background Research	4 Research
5 Research	6 Group Meeting 1PM – Present Initial Research	7 Research	8 PQP – Discuss Focus	9 Research	10 Group Meeting 1PM	11 Research
12 Research	13 Group Meeting 1PM – Wrote Introduction	14 Research	15 PQP – Discuss Introduction	16 Start Individual Background Write Up & Methodology	17 Group Meeting 1PM – Edit Intro	18 Write Background Sections and Methodology
19 Write Background Sections and Methodology	20 Group Meeting 1PM – Discuss Background and Meth Progress	21 Write Background Sections and Methodology	22 PQP – Discuss Intro again	23 Combine Background Sections & Methodology	24 Group Meeting 1PM – Edit Intro	25 Edit Background and Methodology
26 Edit Background and Methodology	27 Group Meeting 1PM – Go Over Background and Meth Edits	28 Individual Work on Lit Reviews and Graphics	29 PQP – Discuss Background	30 Edit Background Sections Individually & Lit Reviews		

OCTOBER 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 Group Meeting 1PM – Edit Methodology	2 Edit Background Sections & Lit Reviews POWERPOINT
3 Edit Background Sections & Lit Reviews POWERPOINT	4 Group Meeting 1PM – Review Background POWER POINT	5 Combine Intro, Background, Meth and Lit Reviews	6 PQP – Discuss Deliverable POWERPOINT	7 Create Appendix Edit Refworks POWERPOINT	8 Group Meeting 1PM - Proposal	9 Create Appendix Edit Proposal POWER POINT
10 Create Appendix Edit Proposal POWER POINT	11 Group Meeting 1PM – Update Proposal POWERPOINT	12 FINALIZED PROPOSAL POWER POINT	13 PQP DELIVERABLE POWERPOINT	14 Final Presentation Proposal Due	15 Fall Break	16 Fall Break
17 Fall Break	18 Fall Break	19 Fall Break	20 Fall Break	21 Fall Break	22 Fall Break	23 Depart for Venice
24 Arrive in Venice	25 Orientation Get de-jetlagged	26 First IQP Meeting Discussed first "plan of attack"	27 Observed/document canals that will be tested on new moon	28 IQP Meeting - Built Hydro Device and tested it	29 Sort through UNESCO boat reports	30 Sort through UNESCO boat reports
31 Sort through UNESCO boat reports						

NOVEMBER 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1 Map data from UNESCO boat reports	2 IQP Meeting – Discuss data and where to analyze	3 Scheduled Hydro testing and worked on presentation	4 New Moon – Hydrodynamics Testing	5 1st Presentation New Moon – Hydro Testing and	6 New Moon – Hydrodynamics Testing/Observing
7 Analyze UNESCO sedimentation reports – Make Map of Data	8 Write Report and Observing Canals and WIKI meetings	9 Create canal wiki template for future IQPs - Build Sed. device	10 Visit Tide Center Demo for Ships Worked on website	11 Observed Canals Worked on Report/ Worked on Website	12 2nd Presentation Observed Canals	13 Worked on Website/Worked on Report
14 Worked on Website/Worked on Report	15 IQP Meeting to discuss data and scope of project. Fix Report.	16 Fix report – Remove sed. and damage and add tide delay	17 Fix report – Remove sed. and damage and add tide delay	18 Fix report – Remove sed. and damage and add tide delay	19 3rd Presentation Work on report/website	20 Full Moon – Hydro and tide delay testing
21 Full Moon – Hydro and tide delay testing	22 Full Moon – Hydro and tide delay testing	23 Meeting with Jim regarding writing. Work on report. Work on website.	24 Thanksgiving Break – Work on report/website	25 Thanksgiving Break – Work on report/website	26 Thanksgiving Break – Work on report/website	27 Thanksgiving Break – Work on report/website
28 Work on report. Work on website.	29 Work on report. Work on website.	30 Observe canals for hydro testing Work on report and website				

DECEMBER 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 Observe canals for hydro testing Work on report and website	2 Observe canals for hydro testing Work on report and website	3 4th Presentation Work on report and website. Prep for testing and build devices	4 New Moon – Hydro and tide delay testing
5 New Moon – Hydro and tide delay testing	6 Work on report – Results, analysis, exec. summary, appendix	7 Discuss results with advisors - Work on report and presentation	8 5th Presentation Work on report and website	9 Work on report, website, and presentation	10 Work on report, website, and presentation	11 **Finish report and website!**
12 **Finish report and website!**	13 **6th Presentation Finish report and website!**	14 **Finish report and website!**	15 **Finish report and website! Dress Rehearsal**	16 **Final Presentation at UNESCO**	17 **Final touches on report and website!**	18 Depart for US. **Final report and website done!**
19 Arrive in US. **Final Report and website due!**	20	21	22	23	24	25
26	27	28	29	30	31	

APPENDIX N - BUDGET

Hydrodynamics Device:

- **Fishing Line $2.00**
- **Soda Cans for Metal $4.00**
- **Plastic Bottle for Buoyancy $1.50**
- **30g Fishing Weight $2.00**
- **Tape Measure $8.00**

Tide Delay Devices:

- **Rope $5**
- **Weights $10**

$45 was also spent on the sedimentation device - This topic was dropped from our project in the 4th week in Venice