

# The Evolution of Venice Through Mapping Technology: A Venice Project Center Collaboration with the *Atlante della Laguna*

An Interdisciplinary Qualifying Project  
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***Worcester Polytechnic Institute***  
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## I. ABSTRACT

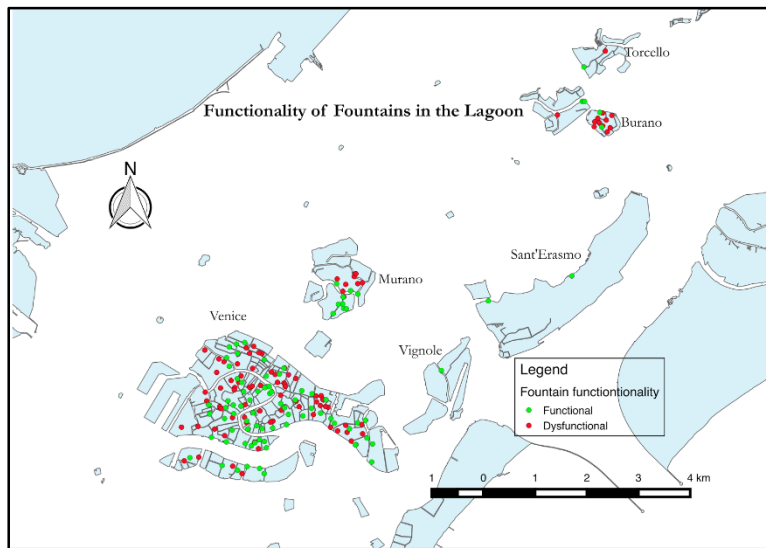
The City of Venice is famous for its unique structure and culture, but those same features create unique management challenges. To help address these challenges, the city informs its decisions with the *Atlante della laguna* (Atlas of the Lagoon), an online collection of data that can be overlaid on maps of the Venetian Lagoon. We established a collaboration between WPI's Venice Project Center (VPC) and the Atlas to contribute the VPC's expansive collection of data. We also provided the first three contributions: a survey of public drinking fountains in Venice and the lagoon, a visualization of the evolution of Venice from 1000 to 1300, and a tool to navigate historical maps of Venice. Our work will directly help the City of Venice and pave the way for future contributions from the VPC to the Atlas.

## II. EXECUTIVE SUMMARY

We worked closely with the *Atlante della Laguna* (Atlas of the Lagoon, or “Atlas”), an expansive online catalog of maps overlaid with data about Venice and the surrounding lagoon. The City of Venice uses the Atlas to make informed decisions and the Atlas is always looking for more data to incorporate into its repository. One ideal source of data is WPI’s Venice Project Center (VPC). The VPC has collected numerous datasets in the past 25 years about every aspect of Venice, many of which contain information that is not available through the Atlas. The VPC is interested in publicizing this data by contributing it to websites like the Atlas.

We established a collaboration between the Venice Project Center and the *Atlante della laguna* in order to publicize the VPC’s data and expand the Atlas’s catalog. We set up a connection between the VPC’s website and the Atlas that will make sharing our datasets easy while allowing us to maintain the VPC’s control of the data. We also selected three datasets from the VPC, updated and expanded their results, and contributed those results to the Atlas.

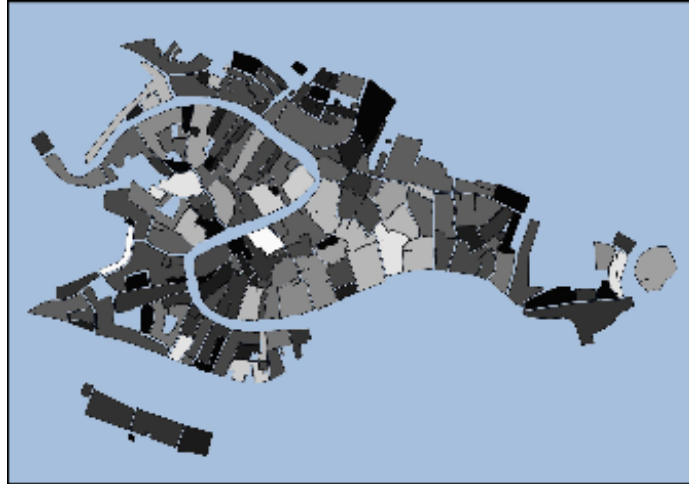
For the first dataset, we collected information about the location, condition, and functionality of public fountains in Venice. We reviewed and updated data that was collected in 2004 by *Public Art Preservation in Venice: Non-Public Wellheads and Fountains*, and expanded the dataset with additional fountains in Venice and on the other islands in the Venetian Lagoon. We assessed 181 fountains in the Lagoon, 89 of which were



functional. We analyzed this information to create recommendations about which nonfunctional fountains to prioritize when conducting fountain repairs. Our analysis also revealed that the fountains, most of which flow continuously, waste approximately 141,000,000 L/yr of water. We recommend that the City of Venice invest in installing push buttons on these fountains to prevent them from flowing while they are not being used, which will save the city €141,000 worth of water annually.

While collecting this data we also developed the software to power the connection between the Venice Project Center and the Atlas. We extended the VPC’s data management system to allow users to publish any dataset to the Atlas. To test our connection, we used the fountains data we had collected, which is now visible in the *Atlante della laguna* website.

For the second dataset, we showed the historical evolution of Venice's islands based on information from ancient manuscripts contained in the book *Venezia romanica*. We first used *Venezia romanica* to find locations of ancient canals that were filled in to create streets. Using these locations we broke apart the 125 islands of modern Venice and found that 177 smaller islands had existed in 1300. We used the manuscripts to find the date of earliest mention for each island. With this information we created a visualization of the evolution of Venice using maps of the city in 25-year increments. We also added the data to the VPC's collection, and from there used the publishing feature we created to contribute it to the Atlas.



Our third and final contribution was a collection of historical maps of Venice, presented in a new web application called the Historical Map Explorer. It displays high-resolution scans of six maps of Venice, created between 1500 and 1847, with an easy-to-use interface. It also contains hundreds of annotations that highlight historically important structures in Venice. Those annotations are cross-referenced across maps so users can follow a structure throughout the years and easily view every map that contains it. Unlike our other two contributions, the Historical Map Explorer is a website rather than a dataset, so the Atlas embedded a



link from their website directly to the Historical Map Explorer rather than using our new publishing feature.

These three contributions from the Venice Project Center to the Atlas are the beginning of a collaboration that we hope will last for many years to come. We hope each of the three datasets will be useful to the users of the Atlas and we are excited to see what will come of this collaboration in the future.

### III. ACKNOWLEDGEMENTS

The Venice Atlas team would like to extend their thanks and gratitude towards all groups and individuals outside this paper's authors for assisting us in various tasks that made the completion of this project possible. This gratitude further extends to those who assisted in the construction and editing of this paper.

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**Professor Michael Aghajanian** - Thanks to Advisor Aghajanian for overseeing and helping us in terms of general guidance for our preparation, presentation, and report especially his invaluable comments and suggestions.

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#### **IV. AUTHORSHIP**

The creation of this paper was a group effort with all members contributing to its construction as well as its editing and finalization for submission. Each member of the group wrote an equal portion of this paper.

# TABLE OF CONTENTS

LIST OF FIGURES.....	9
LIST OF TABLES .....	10
INTRODUCTION.....	11
BACKGROUND.....	12
The Atlas of the Lagoon .....	12
The Venice Project Center.....	13
Chapter 1: Cataloguing and Contributing the Fountain Data to the Atlas of the Lagoon .....	14
1.1. BACKGROUND.....	14
1.2. METHODOLOGY.....	16
1.2.1. Finding Fountain Locations .....	16
1.2.2. Conducting the Field Survey .....	16
1.2.3. Cataloging Fountains On Other Islands In The Lagoon .....	16
1.2.4. Adding Datasets to the Atlas.....	16
1.3. RESULTS AND ANALYSIS.....	17
1.3.1. Fountain Data in Venice .....	17
1.3.2. Fountain Data from the Lagoon Islands.....	20
1.4. CONCLUSIONS AND RECOMMENDATIONS .....	22
1.4.1. Recommendation on Fountains in Venice.....	22
1.4.2. Recommendation on Tourist Density Analysis.....	22
1.4.3. Recommendation on Further Search for Fountains.....	22
1.4.4 Recommendations on Continuing the Atlas Collaboration .....	23
Chapter 2: Mapping the Evolution of Venice Through Ancient Manuscripts .....	24
2.1. BACKGROUND.....	24
2.2. METHODOLOGY .....	25
2.2.1. Creating the ‘Proto-Islands’ .....	25
2.2.2. Dating Each Proto-Island.....	25
2.2.3 Adding More Detail to the Evolution Map .....	26
2.3. RESULTS AND ANALYSIS.....	26
2.4. CONCLUSIONS AND RECOMMENDATIONS .....	27
2.4.1. Recommendations for Future Groups .....	27
Chapter 3: Making Historical Maps of Venice Available Online .....	29
3.1. BACKGROUND.....	29
3.1.1 The Historical Map Explorer .....	29

3.2. METHODOLOGY .....	31
3.2.1 Modifying the Explorer Web Application .....	31
3.2.2 Selecting New Maps to Include in the Explorer .....	31
3.2.3 Adding Maps and Shape Information Using the Explorer .....	32
3.2.4 Making the Explorer Available through the Atlas .....	32
3.3. RESULTS AND ANALYSIS.....	32
3.4. CONCLUSIONS AND RECOMMENDATIONS .....	33
3.4.1 Built-In Map Tiling .....	33
3.4.2 Connect Features with Other VPC Data .....	33
3.4.3 Allow Deep Linking.....	33
3.4.4 Complete Annotation Catalog .....	33
3.4.5 Expand Catalog .....	33
BIBLIOGRAPHY .....	34
APPENDIX A: Cataloging Fountains .....	35
APPENDIX B: More Details on Mapping of the Evolution of Venice Through Ancient Manuscripts .....	38
APPENDIX C: Historical Map Explorer.....	44



## LIST OF FIGURES

Figure 1. Atlas Website navigation menu translated to English.....	12
Figure 2. View of Atlas interface.....	12
Figure 3. A functional fountain (Type C - Alto).....	14
Figure 4. Graffiti on a Venetian fountain.....	15
Figure 5. Aqua Veritas logo.....	15
Figure 6. 100%pubblica logo.....	15
Figure 7. Fountain assessments (i.e. flowrate and height).....	16
Figure 8. The steps involved in moving data from Firebase to <i>Atlante Della Laguna</i> , with indications of what was in place before the project began.....	17
Figure 9. This section of the Console allows users to publish to the Atlas.....	17
Figure 10. Number of Fountains assessed in 2004 and 2014.....	18
Figure 11. Population density versus fountain functionality.....	19
Figure 12. Population density versus flowrate range.....	19
Figure 13. Population density versus fountain condition.....	20
Figure 14. Degree of damage of fountains.....	20
Figure 15. Fountain functionality in Venice and some islands in the lagoon.....	21
Figure 16. A fountain with push button.....	22
Figure 17. Scan of Map of San Polo from <i>Venezia romanica</i> (Dorigo 2003) .....	24
Figure 18. Venice today compared to proto-islands.....	25
Figure 19. The manuscripts provide the earliest date of mention for each structure.....	26
Figure 20. A map of each structure on one island drawn in detail.....	26
Figure 21. Final evolution map based on manuscript data. Light grey islands are older, black is the newest. ....	27
Figure 22. The Historical Map Explorer, displaying Jacopo de'Barbari's famous map of Venice.....	29
Figure 23. The Historical Map Explorer displaying the Rialto Bridge in fine detail.....	30
Figure 24. The Historical Map Explorer with the annotation for the Basilica of San Marco visible and selected, displaying the list of other maps it appears on.....	30
Figure 25. The new map selection dropdown in the Historical Map Explorer.....	31
Figure 26. The new "additional maps" section of the Feature Info bubble in the Explorer.....	31
Figure 27. An example of a historical map in which only Venice's coastline is visible (Giovanni Merlo, 1656. Obtained from Venepedia). ....	32

## LIST OF TABLES

Table 1. Fountain Assessment in Venice.....	18
Table 2. Fountain assessment on the Lagoon islands.....	21

## INTRODUCTION

Venice is one of the most historically important and architecturally fascinating cities in the world. It is a symbol of man's ability to conquer the landscape not only by constructing a city on the sea, but by turning it into an economic powerhouse that gave birth to its own unique culture. It houses hundreds of churches, bell towers, intricate wellheads, and many other works of art. In addition to its historical importance, Venice is a living city with a unique structure which creates numerous management challenges. Overcoming these challenges requires a profound understanding of how the city came to be and how it will evolve. Meaningful data about every aspect of Venice helps to achieve this understanding.

The City of Venice addresses these challenges with a project called the *Atlante della laguna* (Atlas of the Lagoon, or "Atlas"). It provides a central repository of publicly available information about Venice and the surrounding lagoon through online map overlays. The Atlas has a broad set of environmental and historical data such as geology, habitats, environmental impacts, and the morphological history of the lagoon, and it is always looking for more data to add to its expansive catalog.

The Venice Project Center (VPC) has been collecting and publishing data on many subjects in Venice, such as information on the condition and locations of Venice's public fountains, since 1988. Our project has begun the process of making the VPC's data available through the Atlas's website. The first dataset we contributed to the Atlas was the fountain data in Venice and the Venetian Lagoon. It serves as a contribution to the Atlas, but also as the first test case for our connection between the VPC and the Atlas. In developing this connection we established the technical infrastructure, policies, and procedures to provide the Atlas with access to VPC data while maintaining the VPC's control of the data.

Our second and third datasets focused on the historical evolution of Venice, information that also helps the City of Venice make policy decisions but is currently lacking in the Atlas. For the second, we used ancient manuscript references to find the dates of earliest mention for each island in Venice between 1000 and 1300. For the third, we added previously unavailable historical maps to the Historical Map Explorer, a tool that provides an online view of maps of Venice such as the famous de'Barbari map.

This project contains three specific deliverables. The first is a map overlay that gives locations and conditions of fountains in Venice that can be displayed on the Atlas website. The second is a map that shows how the islands of Venice evolved from 1000 to 1300 with the references linked to each islands. The final deliverable is an updated and expanded Historical Map Explorer that will display a wide range of historical maps.

# BACKGROUND

All aspects of our project involved working closely with the *Atlante della Laguna* and the Venice Project Center. Each of the three sections of the project requires additional background which we will discuss in each section's chapter.

## The Atlas of the Lagoon

The City of Venice, in partnership with several other organizations, created the *Atlante della laguna* to organize and display the numerous and varied datasets that have been collected about Venice (*Atlante Della Laguna*, a). The Atlas displays this data overlaid on a customizable map of Venice and the Venetian Lagoon.

This map-based visualization allows its users to better understand how the datasets relate to the geography of the lagoon and to each other. Figure 1 shows the many categories of information contained in the Atlas. Each category contains several subjects, which each contain multiple layers of data that can be displayed on the map. For example, within the History category is The Morphological Evolution of the Venetian Lagoon, a dataset that displays the changes in the shape of the lagoon since 1811. Clicking on that dataset opens the Atlas map with seven different layers, as shown in the sidebar in Figure 2, each of which displays a map of Venice from a different year between 1811 and 2003. This visualization allows users to see the morphological evolution of the city using a familiar frame of reference.

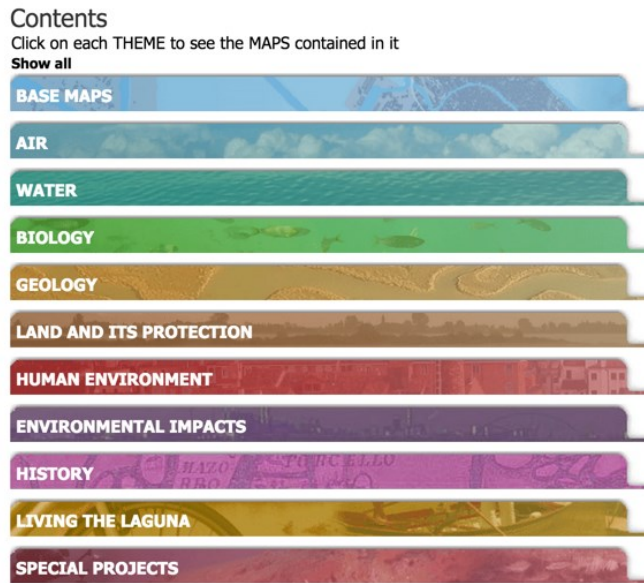


Figure 1. Atlas Website navigation menu translated to English

The Atlas is used by the Venetian

Government and other organizations in Venice to inform decisions that affect the lagoon (F. Carrera, personal communication, October 14, 2014). Because the Atlas contains such a diverse collection of data and uses the map format as a powerful visualization tool, it is capable of displaying correlations and other relationships that would otherwise be unnoticeable. Understanding these relationships can help city officials predict the effect of

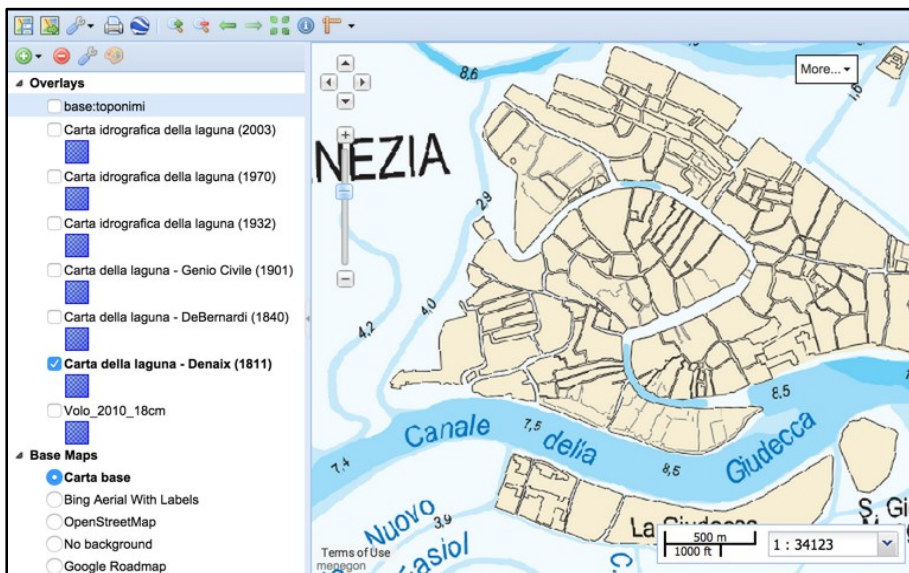


Figure 2. View of Atlas interface

their decisions on the ecology of the lagoon and the citizens of Venice. By contributing to the Atlas we have helped the various organizations achieve this goal.

### **The Venice Project Center**

In 1988, Worcester Polytechnic Institute (WPI) established the Venice Project Center (VPC), a permanent office that organizes and oversees WPI student projects in Venice. Over the past 25 years, hundreds of WPI students have conducted projects dedicated to improving the quality of Venetian life and preserving the historical elements of the city (F. Carrera, personal communication, October 14, 2014). In the process, the VPC has gathered data about a wide range of subjects relevant to those two goals, including catalogs of public art, studies of acid rain, and analysis of the impacts of tourism (Carrera, n.d.). Many of these datasets have been made public on the VPC website, [veniceprojectcenter.org](http://veniceprojectcenter.org), and on Venipedia, a wiki-based website that provides accurate and detailed information about Venice and the surrounding lagoon. Many of the VPC's datasets are suitable for inclusion into the Atlas and contain information that the Atlas does not currently have. Though the information was already publicly accessible, making it available on the Atlas website has presented it to a broader audience.

# Chapter 1: Cataloguing and Contributing the Fountain Data to the Atlas of the Lagoon

## 1.1. BACKGROUND

This was the first time that the Venice Project Center (VPC) directly contributed its data to the Atlas of the Lagoon. This allowed the VPC to further publicize its wealth of data that it had been collecting since 1988 through the Atlas. The dataset that was most suitable to serve as a test connection between the Atlas



Figure 3. A functional fountain (Type C - Alto)

and the VPC was the catalog of fountains in the Venetian lagoon. The detail of this technical connection will be described in section 1.2.4.

Not only did it serve a technical purpose, but it also serves as a permanent contribution to the Atlas for public use. This data can be used to perform various analyses like the ones we will illustrate in this report.

The fountain data was suitable because of nature of the subject, completeness, and usefulness. The subject matter is relatively stable. Fountains are not built, destroyed, or restored frequently, so most of the information about them remains accurate many years after it was first collected.

The team that originally collected the data in 2004, *Public Art Preservation in Venice: Non-Public Wellheads and Fountains* (Kelly et al., 2004), recorded over 45 data elements of each fountain, and created an algorithm to consistently quantify the condition of the fountains. The algorithm used information from a book, *Stone Decay and Conservation* (Amoroso et al., 1983), to rate the degree and types of damage that affected each fountain. This technique was used to

thoroughly assess the fountains and wellheads in the city of Venice, only skipping those that were inaccessible to the research team. After our team reassessed some of the fountains, we concluded that the algorithm should be fine-tuned to deliver a more accurate assessment. For instance, the original algorithm valued grime at 20% of overall damage, but rust and missing pieces were valued only 15%. Since rust and missing pieces cause more damage to these public arts, we re-evaluated the weight of grime to 15%, rust to 20%, and missing pieces to 25%. This new algorithm was only applied to the fountains that we added to the dataset. In order to differentiate the new and old data, we compiled all of the new data in a different folder with timestamps and uploaded it to the CK Console, a server that stored and ran all of the VPC's data, all at once. This new data included the fountains in Venice that the *Public Art Preservation in Venice* team did not capture and the ones on the Lagoon islands. It is important to note that we did not change any of the original data except updating the flowrate and condition. We only changed the algorithm that we used for the new records in the dataset. We also did not change the data elements that were collected by the original team.

To understand the different categories and weights included in the algorithm, we needed to understand the types of damage that could occur to these artifacts. The types of damage can be grouped into three categories: vandalism, accidental damage, and natural damage. Vandalism is when someone purposefully damages a fountain, including breaking or spray painting it. However, not all damage caused by people is vandalism. Sometimes people cause accidental damage to public art by coming in contact with it or sitting and leaning on it. The last form of destruction is natural destruction. Natural destruction can come in many





Figure 4. Graffiti on a Venetian fountain

forms, such as water damage, pollution damage, rust, moss, and algae. The fountains we studied are mostly susceptible to damage caused by rust and algae. When left uncared for, metals rust over time. Rust is caused by the oxidation of iron in the presence of air and water. Venice's location in relation to the water exacerbates this process. Its location also increases the rate of algae growth. Although algae is not as destructive as rust, it is still a problem that could be prevented. The information we recorded regarding the damage levels of fountains will help restoration efforts. Although there are many fountains in the city, unfortunately, some people are hesitant about the quality of the water coming from the fountains. Italians are particularly skeptical about the quality of tap water, as a result, they are the world's largest bottled water consumer. However, according to the website of Aqua Veritas, a water company operating in Venice, drinking water that comes from the taps and public fountains, at least in Venice and the surrounding islands, is strictly and carefully controlled and entirely safe to drink. In fact, Veritas regularly tests over 10,000 samples and analyzes over 200,000 parameters through the company laboratory. Checks are carried out at various stages of the water cycle, from the source to the distribution network, with continuous monitoring carried out by an electronic system with centralized control. To

confirm the water quality for consumers, Veritas is certified by ISO 9001/2008, while the Veritas laboratory is accredited to the European standard UNI CEI EN ISO / IEC 17025 accreditation certificate with n.0211 issued by ACCREDIA (Riccardo Seccarelo, 2009).

The fountain data that we recorded can also make an important contribution to an ongoing effort by the city of Venice to reduce the use of disposable water bottles. There have been promotions to encourage refilling reusable water bottles from the fountains instead of using disposable



Figure 5. Aqua Veritas logo

bottles (Rosenthal, 2009). 100%Pubblica

was an organization that executed a campaign back in 2008 to reduce the waste of plastic water bottles in Venice by handing out free water bottles and maps of fountains in the city (100%pubblica, 2008).

The scope of the *Public Art Preservation in Venice* team focused exclusively on the city of Venice. The scope of the Atlas, however, is the entire Venetian Lagoon. We addressed this problem by surveying the fountains on the inhabited islands in the Lagoon (Murano, Burano, Mazzorbo, Torcello, Sant'Erasmus, and Vignole). This approach expanded the data while maintaining consistency in format between the City fountains' data and the data from the rest of the Lagoon.



Figure 6. 100% pubblica logo

## 1.2. METHODOLOGY

Completing this section of the project required validation of the data previously recorded in the VPC database, collection of data for fountains in Venice that had not yet been recorded and data for the fountains on the islands of the lagoon that had not yet been researched, publishing the information to the VPC database, and developing a connection to share this information with the Atlas.

### 1.2.1. Finding Fountain Locations

All of the fountains that were assessed by the previous IQP team had the exact address and coordinates so we were able to easily pinpoint them on the map. In addition, 100%Pubblica was another source of fountain data. Unfortunately, there was no evidence that this organization was still active since their campaign in 2008, and they provided only one fountain map on their site with very poor resolution. However, we were able to estimate the location of the fountains on their map and some of these fountains were not documented by the previous IQP team. We also received fountain data from Aqua Veritas. This data was mainly used to later identify the fountain locations that we might have missed.

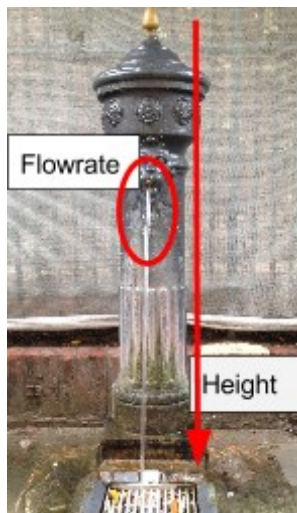


Figure 7. Fountain assessments (i.e. flowrate and height)

### 1.2.2. Conducting the Field Survey

With good information about the fountains we were able to find the previous recorded ones. We conducted the field survey to verify and update the condition of each fountain. Occasionally, we came across some that were not recorded. We recorded them to a new spreadsheet as well by using the same assessment criteria. A detailed description of some of the more important fields of the new table is included in the Appendix A. After we assessed all the fountains in the city, we updated the data in the CK Console.

We took a number of measurements such as fountain height, spout height, and base perimeter. Flow rate was also an important criteria. To determine the flow rate, we took a one liter container and timed how long it took to fill (seconds/liter). We then converted this to liters/minute.

### 1.2.3. Cataloging Fountains On Other Islands In The Lagoon

After finishing the fountains in the city, we moved on to those on the other islands of the lagoon. We used the same process to catalog them as the fountains in the city. The only source of information about the fountains on these islands came from Aqua Veritas. However, there were only street names provided these islands so it was quite challenging to pinpoint their exact location on a map. Therefore, we sometimes needed to consult other maps and explore the locations on our own. We only considered inhabited islands that were included in Aqua Veritas' datasheet. These islands were Murano, Burano, Torcello, Sant'Erasmus, Vignole, Lido, Pellestrina and San Francesco.

### 1.2.4. Adding Datasets to the Atlas

The final step in the fountain data collection was to make our data available through the Atlas. We set up a connection to allow the Atlas system to access the Venice Project Center database. This avoided data duplication and eliminated issues with keeping multiple copies up to date. The solution involved extending the CK Console, the software that is used to manage the VPC database. We enabled communication between the Console and Geoserver, the software that manages the Atlas's online maps. Figure 8 shows the steps each



dataset goes through to be made available on the *Atlante della laguna* website.

### Flow of Data from VPC to Atlas

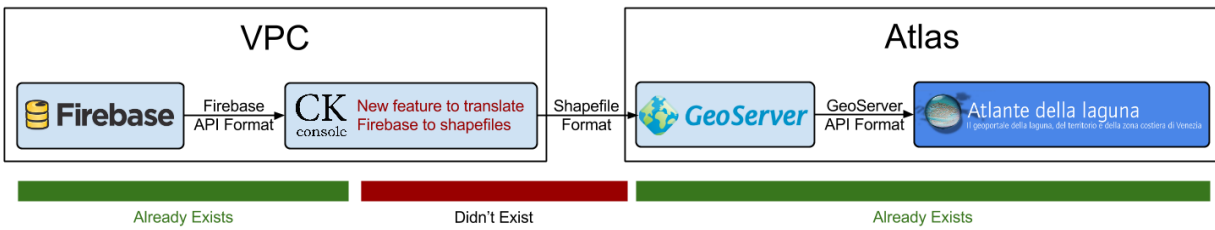


Figure 8. The steps involved in moving data from the VPC's database to *Atlante della laguna*, with indications of what was in place before the project began.

Once this feature was in place we used it to send the fountain data to the Atlas. We also provided them with a long-form description of the dataset to include in their catalog.

We added a feature to the CK Console to enable export to the Atlas. When the user starts the export, they can choose the layer's name and description as shown in the Atlas and upload a style for the layer. If the layer was created from a shapefile, they can choose whether to upload those shapes to the Atlas or to upload points generated from the record's latitude and longitude, which is what the Console does for layers without shapefile data. After the user clicks Update, the Console converts the data into a format compatible with the Atlas's Geoserver, then sends the data to the Atlas. Subsequent updates of the Geoserver data replace the data that was sent earlier. The user can also delete datasets from the same location. This method of interaction allows for easy publishing while maintaining the VPC's ownership of the data.

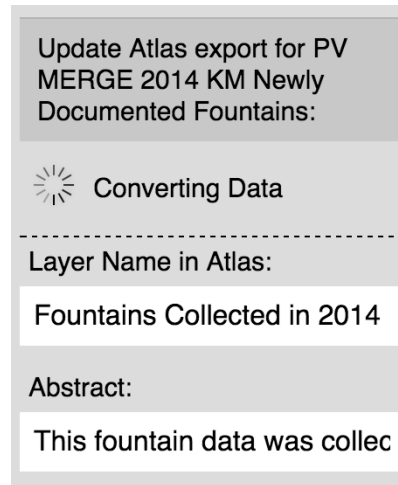


Figure 9. This section of the Console allows users to publish to the Atlas

## 1.3. RESULTS AND ANALYSIS

### 1.3.1. Fountain Data in Venice

Using the data collected by the *Public Art Preservation in Venice* team, 100%Pubblica's fountain map, and Aqua Veritas' data, we were able to locate and reassess all of the 109 fountains that were previously documented. In addition, our team found 33 more fountains in Venice that were not documented. In total, we found 142 fountains in the City of Venice. Some of these fountains were not recorded by either 100%Pubblica or Veritas. Figure 10 below shows the number of fountains that were assessed in 2004 and 2014.

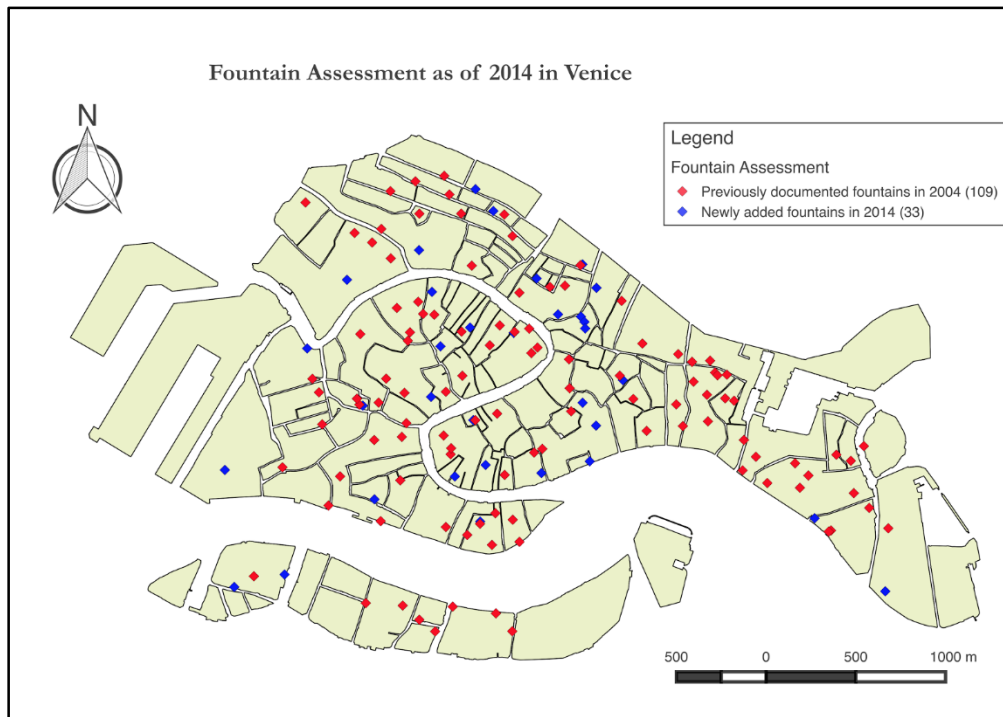


Figure 10. Number of Fountains assessed in 2004 and 2014

Below is a table of all fountains that our team assessed in the City of Venice.

Table 1. Fountain Assessment in Venice

<b>Sestiere</b>	<b>Number of assessed fountains</b>	<b>Number of functional fountains</b>
Cannaregio	31	10
Castello	35	17
San Marco	18	11
Santa Croce	13	4
Dorsoduro	32	18
San Polo	13	11
<i>Total</i>	<i>142</i>	<i>71</i>

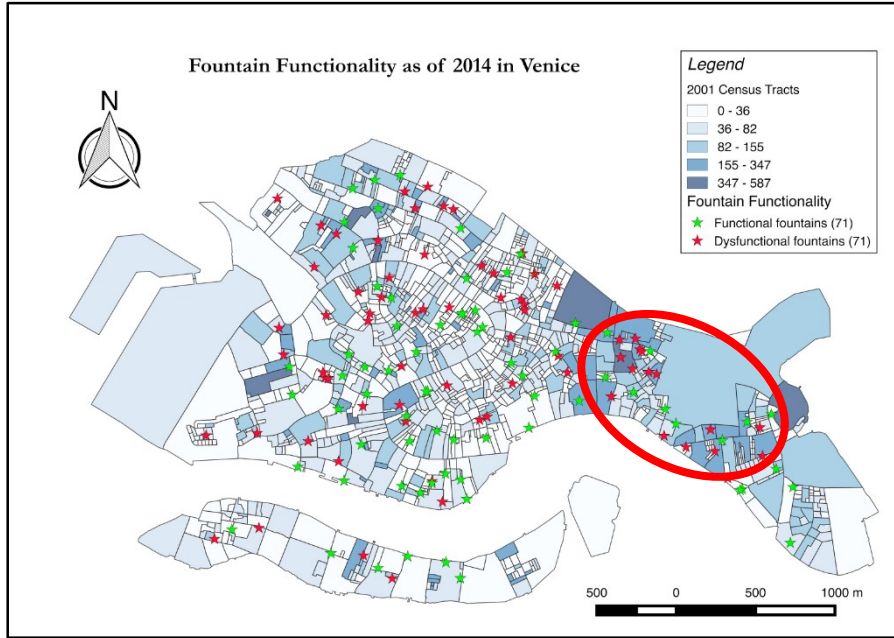


Figure 11. Population density versus fountain functionality

There are many nonfunctional fountains in a high density area as seen in the oval in Figure 11. Public fountains should be operational in highly populous areas. This data helps us understand and visualize the state of these fountains and hopefully will serve to get them repaired.

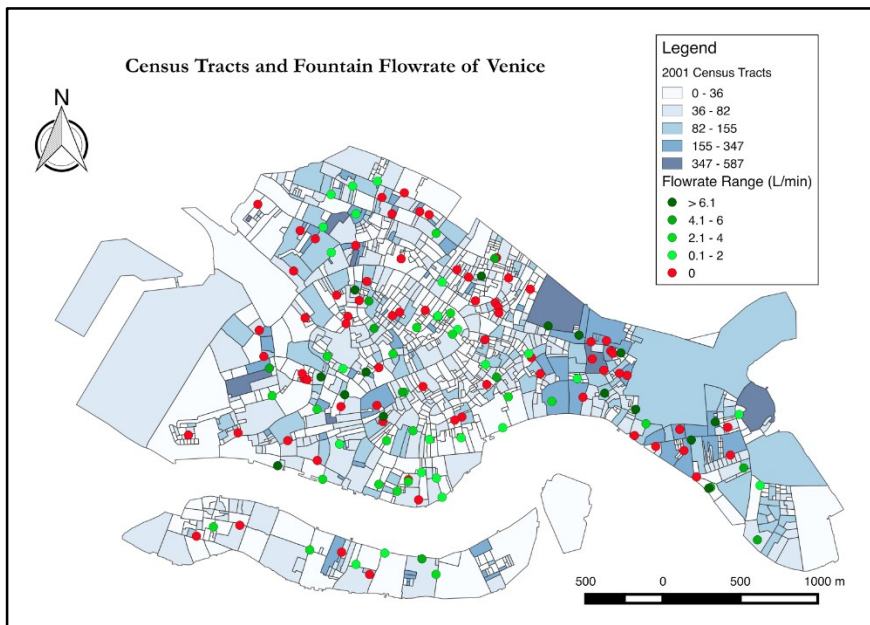


Figure 12. Population density versus flowrate range

produced about 269 liters of water per minute. This could be extrapolated to about 387,000L/day or 141,000,000L/year - the equivalent of filling 56 Olympic-sized swimming pools. This is also equivalent to the average water consumption of about 1,000 Italians for a whole year. With this much water wasted annually,

Figure 11 depicts the 2001 census tracts and the fountain functionality in Venice. The different colors in the map represent the population density. The darker the color, the higher the population density. The green markers represent the 71 functional fountains, whereas the red markers represent the 71 nonfunctional fountains. The figure illustrates the juxtaposition of the population density and the fountain functionality.

There are many nonfunctional fountains in a

Figure 12 delves a little bit deeper than the illustration above. It represents the same census tracts and the different flow rates of functional fountains. The vast majority of fountains in Venice run continuously, leaving only a few fountains that had a push button to operate. For the purpose of this analysis, we assumed that all fountains ran continuously just to make the calculations easier. From the data we collected and uploaded into the CK Console, we calculated that all of the working fountains in the city

based on the price of water on Veritas' website, Venice wastes about €141,000/year (Riccardo Seccarello, 2009)

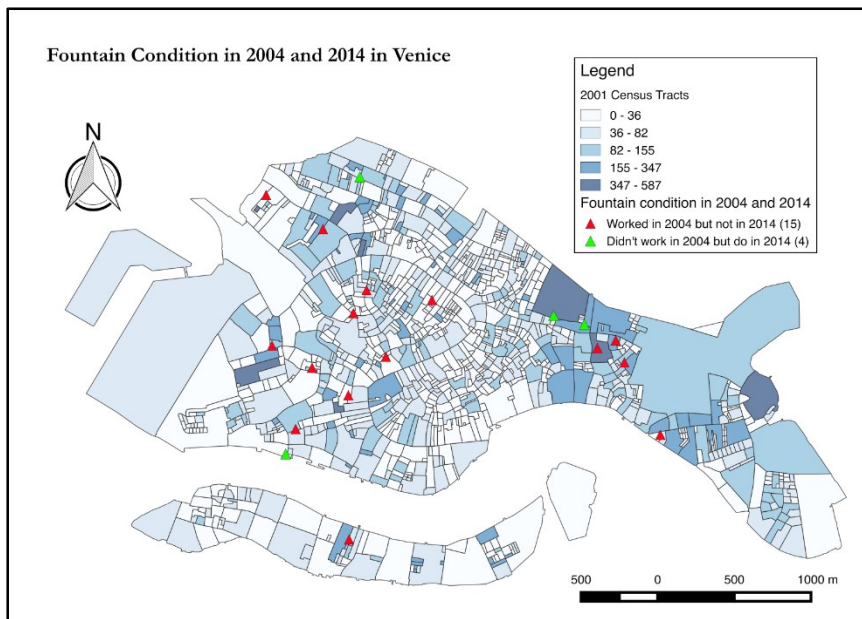


Figure 13. Population density versus fountain condition

Figure 13 is an illustration of fountain conditions that were assessed in 2004 and 2014. It is not a good sign that in 10 years, there are 15 fountains that stopped working in relatively populous areas, whereas only four fountains were repaired. If left unchecked, fewer and fewer fountains will be available to the public and these public works of art will no longer serve any practical purpose.

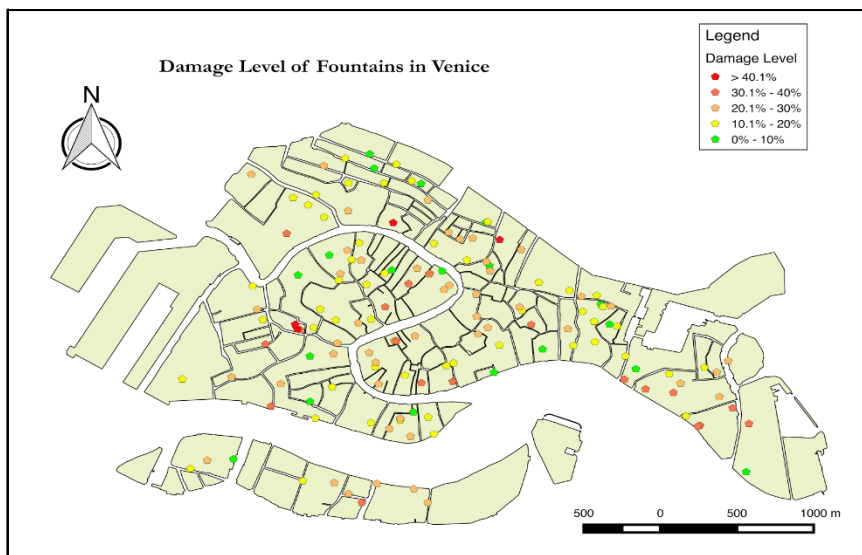


Figure 14. Degree of damage of fountains

Figure 14 analyzed the degree of damage of each fountain in the City of Venice. Thankfully, after our assessment, none of the fountains were damaged more than 50%.

### 1.3.2. Fountain Data from the Lagoon Islands

We assessed fountains on Burano, Mazzorbo, Murano, Vignole, Sant'Erasmus and Torcello. Some of the fountains on these islands were removed because they were not working anymore. To prove it, we asked the locals who lived near where the fountains were, and they confirmed that the fountains were indeed removed because they no longer worked. Usually, they were replaced with flower pots and sometimes covered with a cobble stone floor. We also found a few fountains that were not indicated by Veritas because

they were installed after Veritas produced their fountain datasheet. For instance, we found two fountains in a public park in Mazzorbo, Burano. Below is a table of fountains on each island we explored.

Table 2. Fountain assessment on the Lagoon islands

Island	Number of assessed fountains	Number of functional fountain
Murano	19	10
Burano & Mazzorbo	15	4
Torcello	2	1
Sant'Erasmus	2	2
Vignole	1	1
<i>Total</i>	<i>39</i>	<i>18</i>

Figure 15 is an infographic of all the fountains we assessed in the Venetian Lagoon. The data represents all functional and non-functional fountains. An interesting fact on the island of Burano is that only four out of 15 fountains on the island were functional in such a populous area. We also found that five fountains were removed in Burano due to their dysfunctionality.

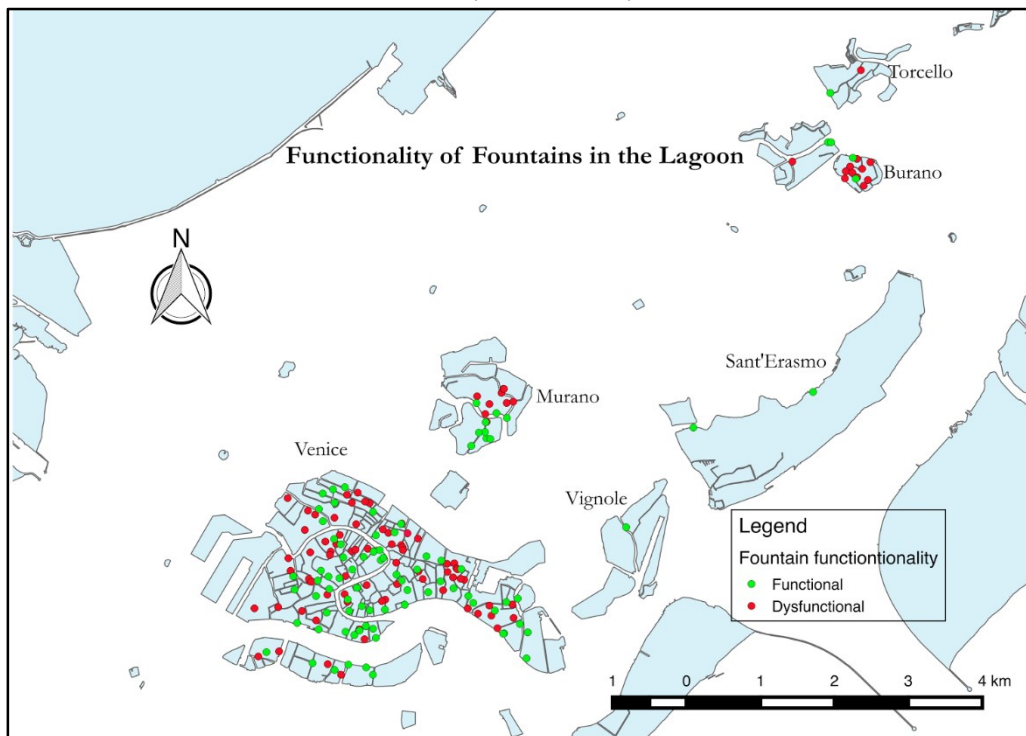


Figure 15. Fountain functionality in Venice and some islands in the lagoon



## 1.4. CONCLUSIONS AND RECOMMENDATIONS

We found 182 fountains in total in Venice, Torcello, Murano, Burano, Mazzorbo, Vignole, and Sant’Erasmus. By having this result published to the Venice Project Center and directly contributed to *Atlante della Laguna*, we hope this data will better serve the public. For instance, any agency like 100%Pubblica could use this data to publish the location of all fountains in the City on a map so that tourists could easily find them, which means that they could refill their water bottles and help reduce the amount of plastic bottle waste.

### 1.4.1. Recommendation on Fountains in Venice

Another integral motive of this fountain assessment was to find out whether they still worked to serve the public. As seen in Section 1.3, only half of the fountains in Venice are functional. Many of the non-functional fountains are located in very populous areas such as Castello, which are contrary to the purpose of having public fountains that are supposed to provide drinking water. This result proved that the City’s effort to encourage the public to use water fountains was quite ineffective because many of these nonfunctional fountains were left to rust at least in the past ten years. Since there was already a public drinking water system in place, why didn’t the City put a little more effort to make them all work and reduce the waste of plastic water bottles in the process? They could shut them all down and no future work would be needed to repair these public arts and, at the same time, no more water would be wasted. However, we strongly believe that no one would want to see these art pieces crumble to rust and become a part of ancient history. Therefore, we would like to recommend to at least repair and get the non-functional fountains. Another suggestion is to add a push button on each fountain. Most of these fountains keep running continuously, which wastes water and money.



Figure 16. A fountain with push button

### 1.4.2. Recommendation on Tourist Density Analysis

One of the more important aspects of this project that we recommend for future work is to analyze the tourist density versus fountain functionality especially in the City of Venice. Our project analyses involved only the census tracts available in 2001 from The National Institute for Statistics, the main supplier of statistical information in Italy (ISTAT, 2014). Thus, the statistical analyses involving tourists would be a useful project to undertake because this kind of information would help us to better understand the importance of having functional fountains in popular tourist destinations like San Marco square. Additionally, the result would aid the City of Venice to not only better visualize and control waste management, but also to hopefully install or repair dysfunctional fountains where most people would use them.

### 1.4.3. Recommendation on Further Search for Fountains

Our team did a thorough job in terms of locating and assessing the fountain of Venice. However, we believe that possibly there are fountains out there that neither the *Public Art Preservation in Venice* team, 100%Pubblica, Aqua Veritas, nor our team could find. We cross-referenced our result with Veritas’ datasheet to make sure that we covered all the fountains that Veritas operated. Even though we discovered 33 more fountains in Venice, we still could not identify a few fountains that Veritas indicated. This may have been because their locations were imprecise, preventing us from locating the fountain or from correlating the Veritas record with a fountain we had previously recorded. We recommend that future researchers work to reconcile our list with the Veritas list and add the fountains located on the islands of San Francesco, Lido and Pellestrina.

#### 1.4.4 Recommendations on Continuing the Atlas Collaboration

Our purpose in collecting fountain data was to provide a test case for our connection to the Atlas, which was very successful. The next step is to include more datasets, evaluated on the same criteria the fountains dataset was chosen. Another possible way to choose the next datasets to include is using a system of criteria devised by *VPC Open Data: Providing Greater Access to Venice's Data Resources*, a concurrent VPC project, to select data for inclusion on Venice's Open Data website. Another, more ambitious continuation of this project might involve augmenting the export-to-Atlas feature we developed for the CK Console to share with other websites in the same way.

## Chapter 2: Mapping the Evolution of Venice Through Ancient Manuscripts

### 2.1. BACKGROUND

The Atlas has a large amount of information spread across many categories such as water, biology, and geology. Most of their information is up to date and modern. However, in addition to modern-day information, the Atlas contains several maps that show how the city has changed over time. These maps have been gathered and used for many different purposes based on their age (*Atlante Della Laguna*, b). For instance, the Atlas contains a historic map from 1809 created by Captain Augusto Napoleonic Dénaix for the purpose of showing the topographical make-up of the city. The Atlas is now using this map to show how the shape of the city has changed since then. The Atlas has collected several other maps that also show how the city has

changed from the late 1600s to the modern day, but does not have any that show what the city looked like before this period.

To get a view of the city before the 1600s we delved deeper into the history of Venice. Exploring primary sources from earlier in Venetian history helped us show what the city looked like long ago. Past Venice project groups from WPI, such as *Venice Through the Canals of Time: Mapping the Physical Evolution of the City* (Weis et al., 2013), created an interactive map of Venice as it was in 1100 and 1300. Their primary source was Wladimiro Dorigo's *Venezia romanica* (2003). Dorigo used historical manuscripts from 1000 to 1300 to compile detailed maps of the city during those years. In his maps, he shows each structure that can be proven to have existed in this time period. As well as the maps, he provides a compiled list of manuscripts that state the date of earliest mention for each structure. By using this information, we were able to find the oldest mentioned structure for each island and date the islands. With this we also made a visual representation that shows the islands appear based on the dates they were first proven to exist. Making this map available through the Atlas has allowed a larger audience to view its information.

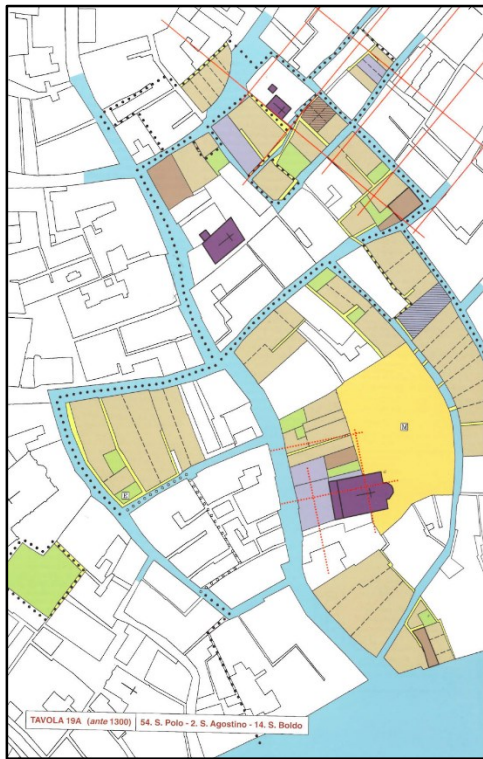


Figure 17. Scan of map of San Polo from Venezia Romanica (Dorigo 2003)



## 2.2. METHODOLOGY

Creating the map showing the evolution of Venice required two main steps. The first step was to break up Venice into smaller ‘proto-islands’, and the second was to provide dates for these islands. We also wanted to depict one island in detail by adding each structure to the map and linking the data to each structure as an example for future groups.

### 2.2.1. Creating the ‘Proto-Islands’

To show how Venice grew, we compared the maps from *Venezia romanica* (Dorigo, 2003) to a map of modern day Venice. We accomplished this by using Quantum Geographical Information System (QGIS), a widely-used mapping program. We overlapped Dorigo’s maps with a modern QGIS map that just shows the islands that make up Venice. We found all the ancient canals that, according to Dorigo, have been filled in to create larger islands and added these to the QGIS map. We also used information from the VPC on other filled-in canals not mentioned in the book. These filled-in canals are known because they are currently streets that start with the name Rio Terá. This prefix was given to streets that were once canals. By adding these to the map, we were able to break apart the modern islands into the smaller islands they used to be. These ‘proto-islands’ allowed us to date smaller pieces of land which was more precise than assigning dates to larger modern islands.



Figure 18. Venice today compared to proto-islands

### 2.2.2. Dating Each Proto-Island

We assigned dates to each proto-island using the date of the oldest structure on each, which we found in *Venezia romanica* (Dorigo, 2003). We assumed that if a structure existed on an island, that whole island existed unless specifically stated otherwise. The information for each structure found in the book, such as date of earliest mention, type of structure, and reference number from the Venetian archives was then linked to the appropriate proto-island in the map.

Once the proto-islands were all dated we were able to group them by date in increments of 25 years. Once the GIS map was completed, we made it available to the Atlas using the same technology discussed in Section 1.2.3. A flow chart of these processes as well as a more detailed explanation can be found in Appendix B.

### 2.2.3 Adding More Detail to the Evolution Map

Once we finished the map that showed the evolution of Venice, the next logical step was to add the details specified by Dorigo. These include structures, such as churches and roads, as well as the information provided for each. To do this for the entire map would take more time than we had. Rather than doing the entire map we focused on adding the structures to one island, and then creating a detailed procedure so others could do the same. This procedure can be found in Appendix B.

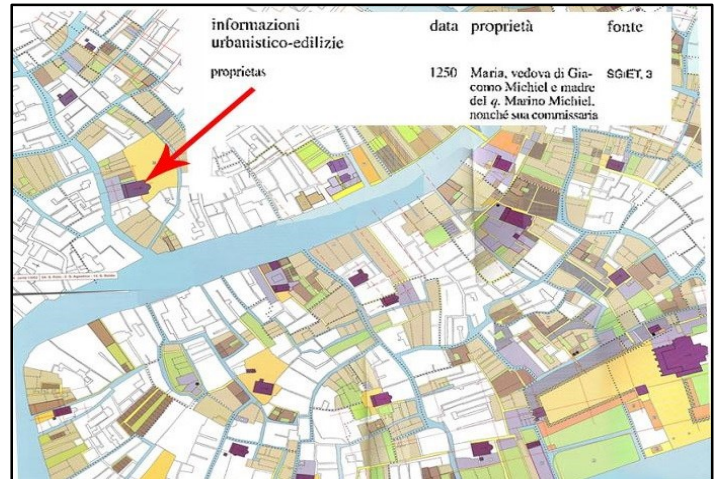


Figure 19. The manuscripts provide the earliest date of mention for each structure

## 2.3. RESULTS AND ANALYSIS

A modern map of Venice shows that there are 125 islands that make up the City today. Using Wladimiro Dorigo's *Venezia romanica* (2003) as a reference, we were able to break apart these modern islands to create smaller proto-islands. Our breakdown shows that there were 177 islands that made up Venice in 1300. There are fewer islands now as a result of filling in canals, transforming two or more islands into one. In its current state, the evolution map we created can serve many uses. It is not perfect and has some issues. These issues are one of the multiple ways future groups could improve or build off of our project.

Some islands not having references was one of our prominent issues. *Venezia romantica* sometimes showed that there was an island, but it did not have the references to prove it. When faced with this situation we used deductive reasoning to provide dates for them. We looked at the surrounding islands to see what dates they had and chose one of the references from those islands if it made sense.

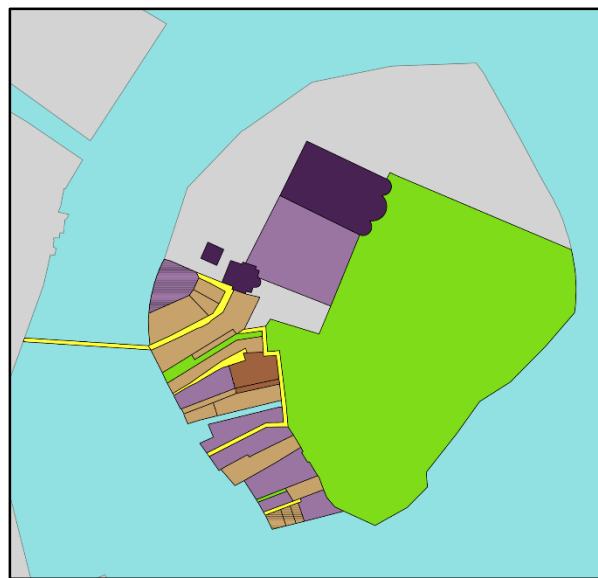


Figure 20. A map of each structure on one island drawn in detail

Another problem is that we only had one main source, *Venezia romanica*. This was mainly a problem when we looked at our finished evolution. We noticed that, according to the manuscripts, there were no islands that existed before 1013, but this is obviously not true. This was because our map was based purely off

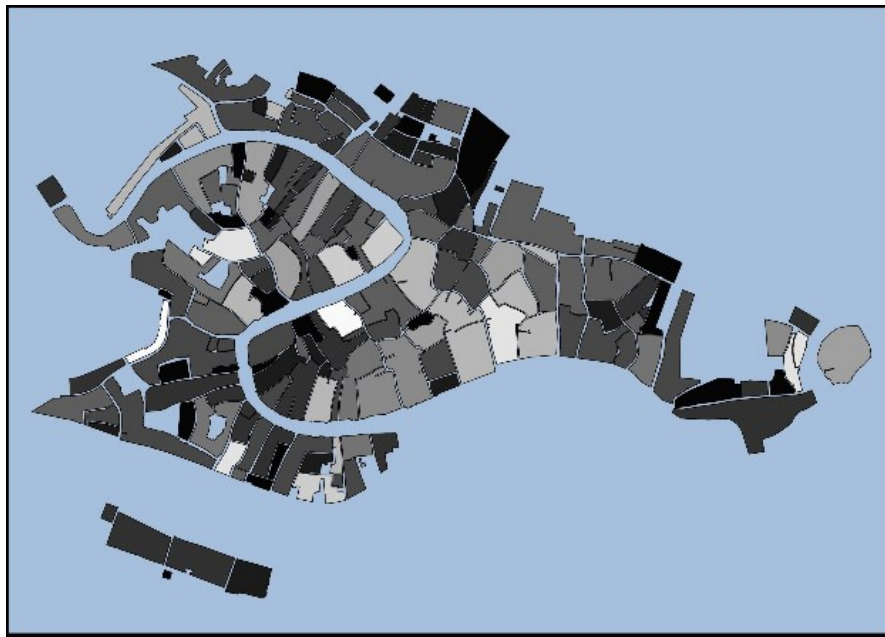


Figure 21. Final evolution map based on manuscript data. Light grey islands are older, black is the newest.

ancient manuscripts and it was not common for people to keep documents in the early time periods. Because of this our map cannot show the accurate dates for the older islands. This was less of a problem for any islands that were formed around or after 1200 because around this time the manuscripts began specifically stating when they created new islands by filling in marshland. Even though the evolution is not completely accurate, the breakdown of the proto-islands will still serve as a helpful building block for future groups.

## 2.4. CONCLUSIONS AND RECOMMENDATIONS

The map we created showing the dates for each island is more than something interesting to look at. It is possibly the only digital map of its kind for Venice. This means that it will be useful to future researchers and the City of Venice. By showing what islands are the oldest, researchers and archaeologists can get a better idea on where to search for possible artifacts. This is especially true in cases where a newer island is surrounded by older islands. When this happens, it means researchers are likely to find something that provides an earlier date for the newer island.

Being on the Atlas means it will be used as a decision making tool for the City of Venice. By using this map, they can create an archeological risk map. This type of map shows locations where people should not be allowed to build new or bigger buildings. If an island is likely to be a good location for archeological research, the city won't want businesses to build there.

### 2.4.1. Recommendations for Future Groups

There are three main ways future project groups could both improve and build off of our results. The first is working yet again with *Venezia romanica* to make a map similar to ours, but for a different time period. The book has information for the years 1300-1360. We initially planned on doing this time period in addition to 1000-1300, but found it was too time-consuming to do both. A group that wants to do this would be doing a similar process as we did, but they could build off of our existing map.

The second addresses our problem of using a single source. Because we exclusively used *Venezia romanica* as our source of information, there may be more data future groups could include on our map. They could use other sources to find structures that are older than the ones we found. Looking into church records would be helpful for this because churches are often some of the oldest documented buildings.

Our final recommendation is to continue our work on adding detail to the map by adding each individual structure. This might not be best for a future IQP group, but could be done by someone who is studying history or working in GIS. They could create a slider that shows each building appearing based on the date of earliest mention.

## Chapter 3: Making Historical Maps of Venice Available Online

### 3.1. BACKGROUND

Though the maps created by Wladimiro Dorigo are impressively detailed, they only cover a limited time period. For information about the evolution of Venice in the intervening time period we turned to historical maps. The Venice Project Center (VPC) has a collection of hand-drawn maps created between 1500 and 1800 that can help provide information about the centuries in between Dorigo's work and the data already contained in the Atlas (F. Carrera, personal communication, October 7, 2014). Unfortunately, these maps are hand-drawn and most do not show an overhead view of the city. This makes them incompatible with the strict coordinate system and overhead view of standard map software, including the Atlas.

#### 3.1.1 The Historical Map Explorer

The solution to this problem is the Historical Map Explorer, an online historical map viewer. It was originally created by *Venice through the Canals of Time*, a previous WPI project team, and was then called the de'Barbari Explorer (Weis et al., 2013).

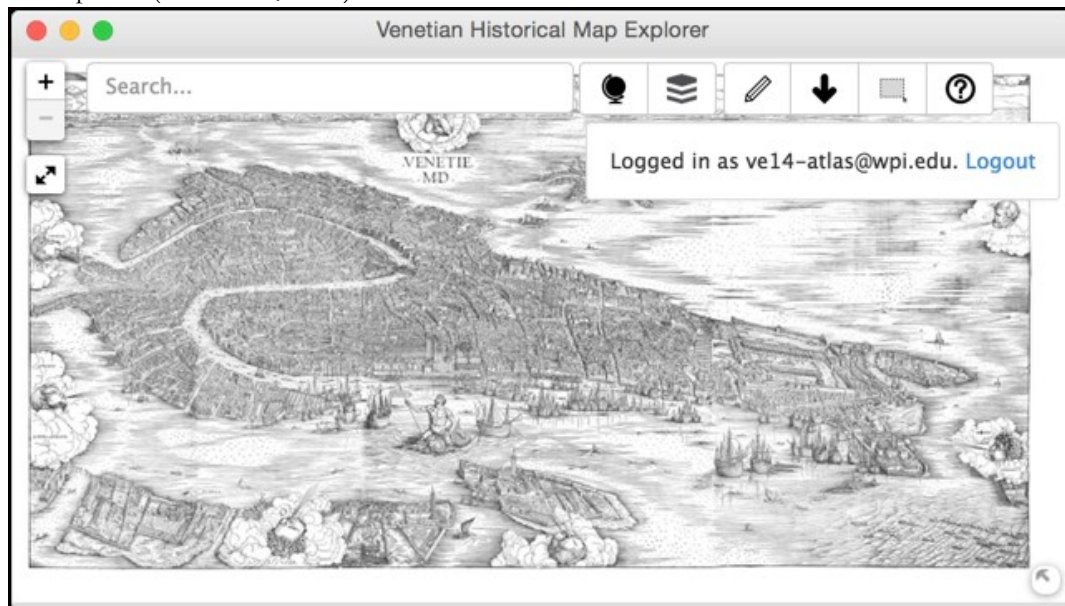


Figure 22. The Historical Map Explorer, displaying Jacopo de'Barbari's famous map of Venice

The Explorer was designed to accommodate skewed and distorted historical maps — specifically, the famous de'Barbari map. Like other tools, including the Atlas, it allows the user to view the entire map or zoom in and see the fine details.





Figure 23. The Historical Map Explorer displaying the Rialto Bridge in fine detail

The Explorer also displays annotations that highlight historically relevant buildings on the map. These annotations show which buildings were present when the map was created, and also give viewers a point of reference in a map that may otherwise be difficult to read because of its unfamiliar perspective.

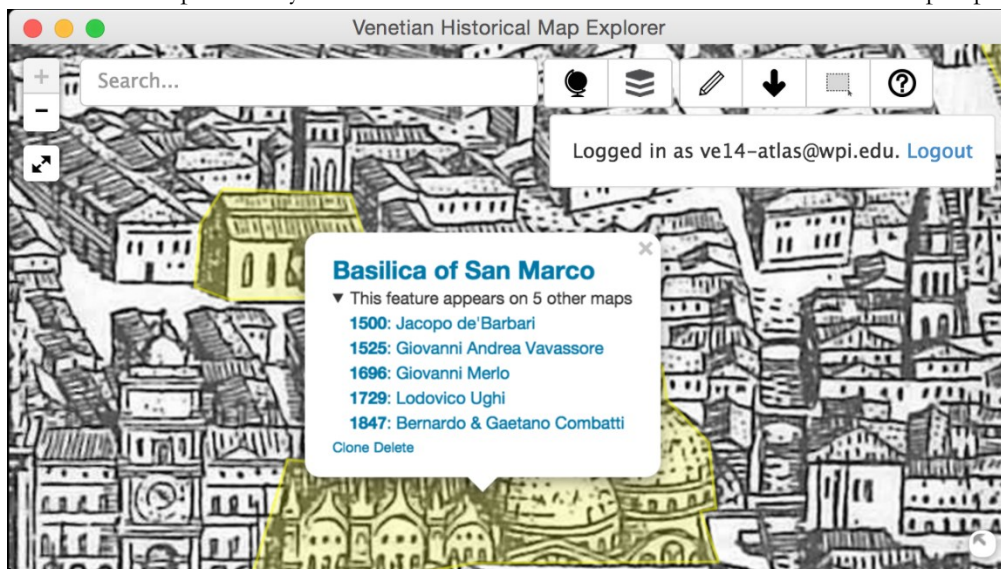


Figure 24. The Historical Map Explorer with the annotation for the Basilica of San Marco visible and selected, displaying the list of other maps it appears on

The Historical Map Explorer is the third and final section of our project. We will make a selection of historical maps more accessible by adding them to the Explorer, including the same highlights that were previously shown on the de'Barbari map.

## 3.2. METHODOLOGY

Adding additional historical maps to the Historical Map Explorer involved changing the code, selecting new maps, and using the Explorer interface to add new maps and shape information to the database. Once the new functionality was complete we made the Explorer available through a link from the Atlas website.

### 3.2.1 Modifying the Explorer Web Application

Our first step in modifying the Explorer was to reorganize the code into smaller, independent modules to make future development simpler (see Appendix C for details). We then reorganized the database, adding a section to hold map data and separating features' data from their location and shape on the map. We incorporated user interface elements related to the inclusion of multiple maps: a map selection drop-down next to the existing layer selection drop-down (see Figure 25) and a form that logged-in users can use to add new maps. We also updated the existing interface for creating new features to also support adding an existing feature to a new map. Finally, we included enhancements to the existing bubble that displayed the name and Venipedia link of the selected feature, adding an indicator of which maps the feature appeared on and allowing the user to click on a map label to be taken to the same feature on the map they clicked (see Figure 26).

We also created a command-line tool to convert a high-resolution source image into the map tiles that the Explorer uses to display the maps. Various third-party tools existed to do this, but we found that it was faster and easier to create our own tool than to research the existing tools and learn how to use them. Details about this tool and instructions for its use can be found in Appendix C.



Figure 25. The new map selection dropdown in the Historical Map Explorer

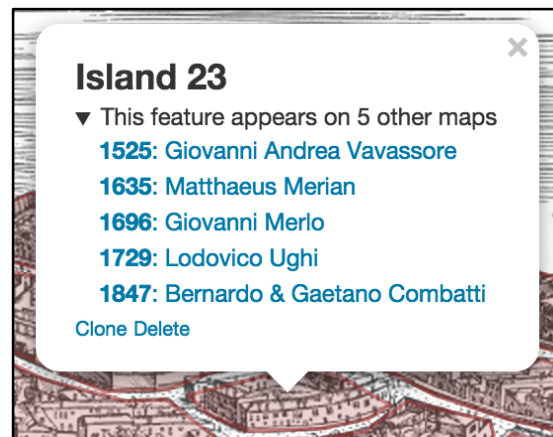


Figure 26. The new “additional maps” section of the Feature Info bubble in the Explorer

### 3.2.2 Selecting New Maps to Include in the Explorer

To choose which maps we put on the Historical Map Explorer we consulted *Piante e vedute prospettiche de Venezia*, a compilation of historical maps of Venice (Cassini, 1971). We chose maps based on the level of resolution we could obtain and the amount of Venice that was visible in the map. The second criterion was particularly important because many maps of Venice were drawn from a side view, rather than the modern tradition of top-down views, and so they only showed the buildings on the nearest coastline (see Figure 27). While taking these criteria into account, we also chose maps spread apart in time to give the most

comprehensive view of how Venice had changed over the years. For information on the maps we chose, see Appendix C.



Figure 27. An example of a historical map in which only Venice's coastline is visible (Giovanni Merlo, 1656. Obtained from Venepedia)

### **3.2.3 Adding Maps and Shape Information Using the Explorer**

After the code changes were in place and the new maps were selected, we used the custom tiling tool described in Section 3.2.1 to convert the source images to tiles. This process generates many files totaling several gigabytes and so was done on an external server with high bandwidth to allow fast upload to the VPC's servers. When the tiles were in place we added each map to the Historical Map Explorer using the newly-added map creation form described in Section 3.2.1.

Once each map had been added to the Historical Map Explorer, we used the Explorer's tools to add annotations on the new maps for the features that were already annotated in the de'Barbari map. Because of the large number of annotations, we were not able to replicate every feature across all five new maps. We chose to focus on the Islands and Churches layers, as we decided those would be the most representative of the power of the Historical Map Explorer.

### **3.2.4 Making the Explorer Available through the Atlas**

The Historical Map Explorer was the first resource included in the Atlas that exists outside the Atlas's own online map viewer, so we had to decide how best to include this type of resource. After discussing it with our sponsors, some of the administrators of the Atlas, we decided to include a link to the Explorer alongside the other history-related datasets in the Atlas.

## **3.3. RESULTS AND ANALYSIS**

The new Historical Map Explorer allows users to see historical maps, many of which were not previously available online, in an easy-to-use online viewer. These maps, which span from the 1500's to the 1800's, can be used to see how Venice and its structures have evolved since that time period. To help that research, and to help users find their bearings in unfamiliar maps, the Explorer provides annotations of different types of historically important structures on each of the maps. These annotations are cross-referenced, and clicking on an annotation shows which other maps that annotation is present on with the option to show the structure on those other maps. The Historical Map Explorer, like the Evolution of Venice Map, will help researchers get a better picture of Venice's past as well as being interesting to Venetians and visitors who are interested in the history of the city.



## **3.4. CONCLUSIONS AND RECOMMENDATIONS**

Of the sections of our project, the Historical Map Explorer is the one with the greatest potential for technological enhancement. During our planning and execution many ideas presented themselves that were infeasible to include in our project.

### **3.4.1 Built-In Map Tiling**

The Historical Map Explorer contains three types of data; maps, layers, and features. Users can contribute all three types of data, but the only one that requires the user to do work outside the Explorer is maps. This currently involves running a command-line script on a source image and uploading the resulting map tiles to a server before adding the map to the Explorer. Because the process is already mostly controlled by the command-line script, automating it would be fairly simple. However, it would require substantial user interface consideration. The creation of a map would involve a lengthy upload process of a very large source file, during which the user must not exit their browser, followed by an even longer conversion process, during which the user may exit their browser but then would need to return to the map creation. The current system of simple text forms would not support such interaction.

### **3.4.2 Connect Features with Other VPC Data**

The Historical Map Explorer was built on the de'Barbari Explorer, which was created in isolation from the rest of the VPC's data. As a result it lacks the ability to integrate the large collection of data the VPC has gathered over the past 25 years. The layers in the Historical Map Explorer are parallel with the entries in many of the datasets in the VPC's collection, so the correlation of data between the Explorer and the rest of the VPC's collection would not be technically complex. However, these datasets are broad and inconsistent in their structure so the nature of the connection would have to be correspondingly versatile in both technical implementation and user interface.

### **3.4.3 Allow Deep Linking**

In web development, "deep linking" refers to the ability to create a link to a web application in a specific state. In the case of the Historical Map Explorer, this might mean a link that loads a particular map with a certain set of layers enabled and perhaps even with a specific feature selected. Links such as these could be useful to users to share an interesting feature in a certain map or to websites such as the Atlas to allow website integration. Members of the Atlas have suggested that this feature could allow users who are looking at a certain feature in the Atlas's modern-day view to follow a link to view the same feature in the past.

### **3.4.4 Complete Annotation Catalog**

Due to the size of the task and time constraints imposed by the other sections of the project, we were not able to add all of the features to all of the maps. This task could be completed by one or more future IQP teams, interns, or volunteers.

### **3.4.5 Expand Catalog**

The catalog of historical maps we established spans four centuries, a larger span of information than was available anywhere before, but it has the capacity to include even more. Once the catalog of annotations of current maps is complete we recommend including even more historical maps to expand the catalog backwards or forwards in time or to fill in the years in between the maps we have already included.

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### Chapter 1: Cataloguing and Contributing the Fountain Data to the Atlas of the Lagoon

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## APPENDIX A: Cataloging Fountains

### Fountain Types



Type A - Delfini



Type B - Puglia



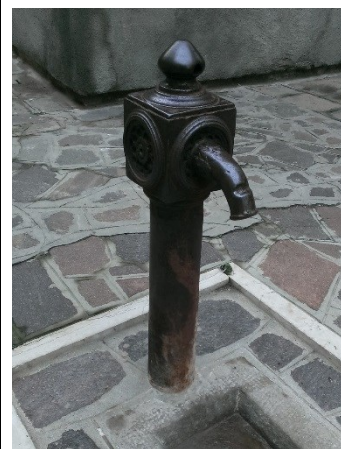
Type C - Alto



Type D - Ott. Basso



Type E - San Marco



Type F - Cylindro



Well - Pozzo



Type G - Tubo



Type H - Neri

### Fountain Damage Condition Rating

Field	Weight
Algae	10%
Graffiti	15%
Grime	15%
Missing Pieces	25%
Rust	20%
Surface Damage	15%

### Algorithm

**Condition Rating** = (Algae×0.1) + (Graffiti×0.15) + (Grime×0.15) + (Missing Pieces×0.25) + (Rust×0.2) + (Surface Damage×0.15)

### Sestiere/Island Abbreviation for Data Entry

Sestiere/Island	Abbreviation
Cannaregio	CN
San Polo	SP
Castello	CS
Dorsoduro	DD
San Marco	SM
Santa Croce	SC
Murano	MN
Sant'Erasmus	SE
Vignole	VL
Burano & Mazzorbo	BN
Torcello	TL

## Data Table and Description

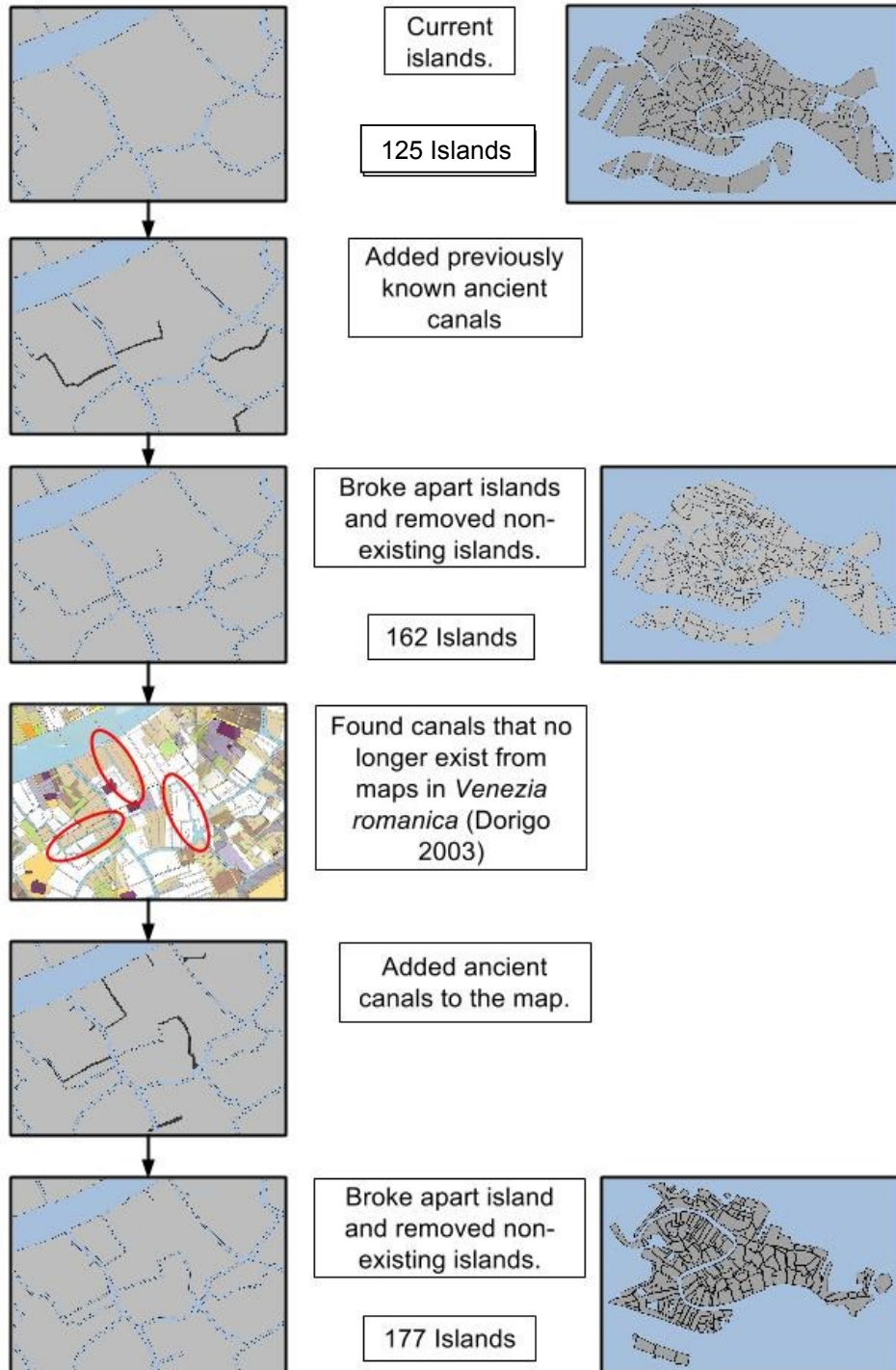
<b>Damage Assessment</b>	
Algae	Percentage of the fountain's surface area covered with algae.
Graffiti	Percentage of the fountain's surface area covered with graffiti.
Grime	Percentage of the fountain's surface area covered with dirt and/or residue. Ranked as (high = 100%), (medium = 50%), (low = 1%).
Missing Pieces	Percentage of the fountain's deterioration - pieces lost. Ranked as (high = 100%), (medium = 50%), (low = 0%).
Rust	Percentage of the fountain's surface area covered with rust.
Surface Damage	Percentage of the fountain's surface area that contained chalking, flaking and peeling.

<b>Important Measurements in data fields</b>	
Faucet Height	Distance from lowest part of the drain to the mouth of the spout.
Faucet Length	Total length of the spout.
Flow Rate	Flow rate of fountain determined in liter per minute.
Height	Total height from lowest part of the drain to the top of the fountain.
Surface Area	Total surface area of the fountain, usually the multiplication of height and base perimeter. For simplification, assumed either square or circular base shape.
Subtype	The different types of fountains that could be found in this appendix. EX: Puglia, Tubo, Neri etc.
Material	The material that the fountains were made out of, usually metal and some stone.
Visibility	How clear/visible the fountains were from the general public. EX: a fountain on a main street could be considered as 'high,' whereas a fountain in a little square behind buildings could be considered as 'low'. Ranked from 'high,' 'medium,' and 'low.'

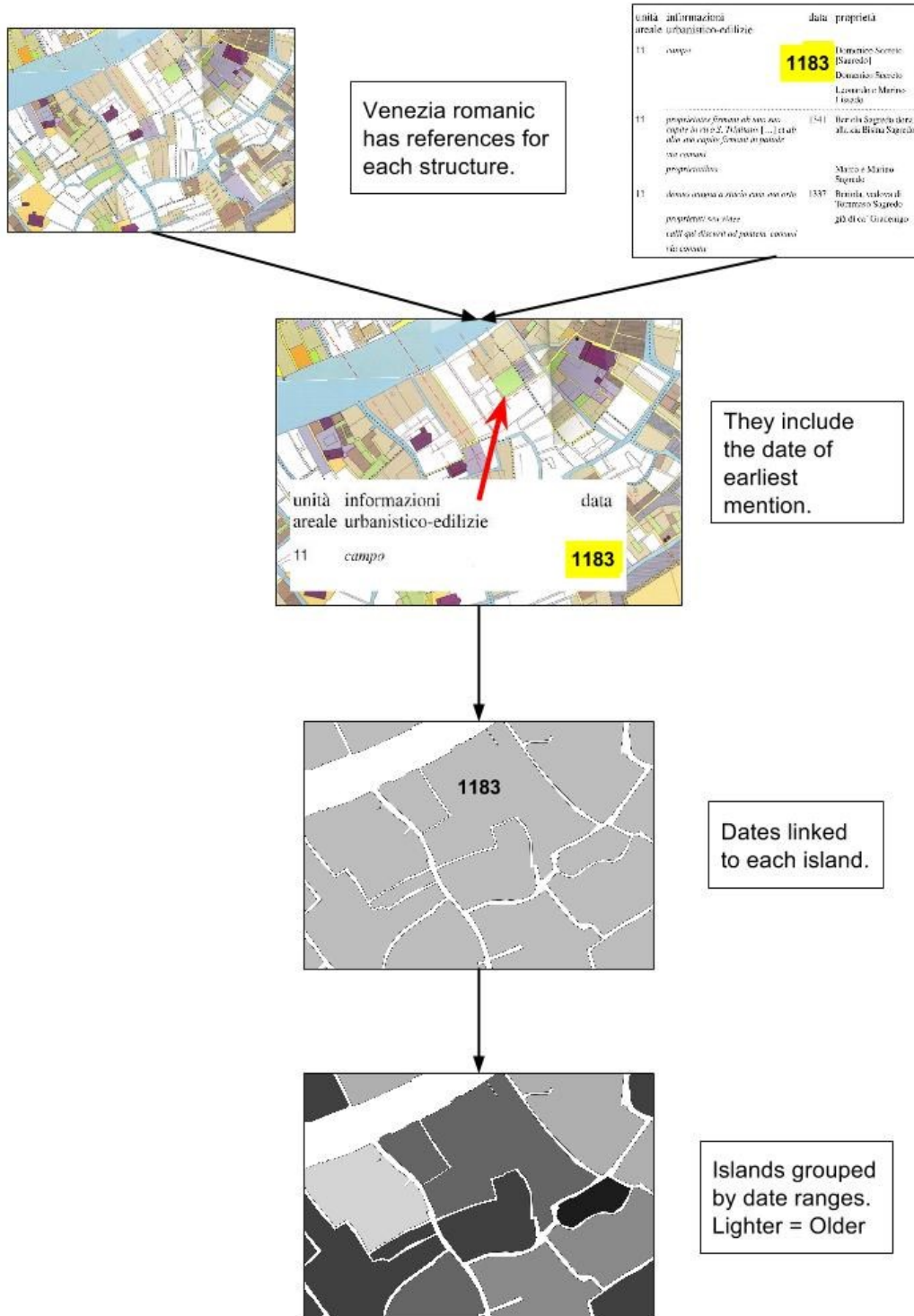


# APPENDIX B: More Details on Mapping of the Evolution of Venice Through Ancient Manuscripts

## How to create proto-islands



## How to date proto-islands



## How to Create and Date Proto-Islands

### Layers to Use:

- 1000
- 1300
- Proto-Islands 1000-1300
- All the Parish Layers
- Parish Total
- Rii Tera
- Streets by Name
- Buildings
- All georeferenced Dorigo scans.

### Creating Proto-Islands:

1. Make sure all files are in the same coordinate system. Most should be in EPSG:3857 - WGS 84 / Pseudo Mercator. If not refer to the VPC's guide on how to convert coordinate systems.
2. Create a base layer by combining the 1000 and 1300 layers in a new layer or copy the shapes in Proto-Islands 1000-1300 to a new layer.
3. If the parish you are working on is already scanned and georeferenced properly skip to step 16.
4. Use the parish layers to locate the parish you will be working in and disable all other layers.
5. Open print composer and add new map. The larger the map is the easier it will be when going into Photoshop and other future steps.
6. Adjust map so it shows the entire parish and export map as an image.
7. Open this image in Photoshop and lock it. Changing the colors to black first is helpful, but not required.
8. Open the scan of the parish into the same canvas and line up the two images as best as possible by rotating and resizing the scan.
9. Turn off all layers besides the now properly sized scan and save it as a .TIF file.
10. Open Georeferencer in QGIS and open raster. Choose the correctly sized scan.
11. Add points to the raster and the base layer. Need at least 3, but the more the better.
12. Change the settings and make sure they are set to the following:
  - a. Transformation type: Linear
  - b. Resampling method: Linear
  - c. Compression: NONE
  - d. Create world file unchecked. Can check if wanted.
  - e. Output raster: Find a place to save the georeferenced scan and name it
  - f. Target SRS: EPSG:3857 (Unless working in a different projection.)
  - g. Generate pdf map: Blank
  - h. Generate prf report: Blank
  - i. Set Target Resolution unchecked
  - j. Use 0 for transparency when needed checked
  - k. Load in QGIS when done checked
13. Start Georeferencing
14. If the new raster layer does not appear or appears far away from where it should be, make sure everything is in the same CRS. All layers and the project itself.
15. Several raster layers can be used at the same time. If one scan overlaps and blocks information from another you can make the white parts transparent.
  - a. Open properties and go to transparencies tab.
  - b. Add new transparency with Red, Blue, and Green all set to 255 and transparency set to 100.
16. Create a layer for drawing ancient canals.
17. Compare scans to base layer to find ancient canals.
18. Use Streets and Buildings as guides to draw the unrecorded ancient canals. It helps to have snapping turned on. Make sure to save edits to the layer and the project every few minutes.



19. Some places you can use logic to assume there were canals. These are places where a confirmed canal goes halfway into an island then abruptly stops. Unless Dorigo states it was surrounding by buildings then there you can add a possible canals from there. The filled in canals typically became streets, so use them as guides.
20. Once all canals are added, use the difference tool to remove the ancient canals from the islands. Vector > Geoprocessing Tools > Difference. Input should be the base layer, difference layer should be the canals. Make sure add result to canvas is check off.
21. Clean up any issues/slivers by either manually editing nodes, doing a similar procedure as the canals, but just with polygons over the slivers, or the remove slivers tool.
22. If there are any islands that are made of multiple polygons overlapping make them into one polygon.
  - a. Turn editing on
  - b. Select the polygons
  - c. Edit > Merge Selected Features
23. If all pieces are good then make each island register as a separate polygon. Vector > Geometry Tools > Multipart to singleparts. Make sure add result to canvas is check off.

#### Dating Proto-Islands:

1. Give each island a unique ID in GIS.
2. Using *Venezia romanica* (Dorigo 2003), find the oldest structure for each island.
3. Type the information for the reference along with the ID for the island it's located on into an excel sheet.
4. Load the excel sheet into GIS. You might have to save it as a CSV file first.
5. Right click your Proto-Islands layer, open properties, and go to the Joins tab.
6. Add a join between the layer and the excel sheet.
  - a. Join layer: Your excel sheet
  - b. Join field: id
  - c. Target field: id
7. Right click the layer and open its attribute table.
8. Make the data permanently attached to the shapefiles.
  - a. Turn on table editing.
  - b. Add a new column, set the correct type, and set the width (max number of characters). Ex: Date, type integer. Do not use date as type, that requires YYYY-MM-DD
  - c. Just below the edit buttons, there is a drop-down button. Find your new column in this.
  - d. In the drop down menu to the right of the sigma find the field from the excel sheet that matches your new column and double click it. Sometimes QGIS requires you to put quotation marks around the field name. Ex: "sheet1\_date".
  - e. Click Update All
  - f. Delete the old column and save edits.
9. Repeat step 8 for each field.

#### Grouping islands by date:

1. Right click Proto-Island, open properties, and go to the style tab.
2. Click the first drop-down menu to changed Single Symbol to Graduated.
3. Choose Date as the Column.
4. Choose a number of classes, color ramps, and mode. Play around with these to get it to look like how you want.
5. Click classify and OK.

### **Creating Detailed Map**

#### Creating Each Structure:

1. Make sure all files are in the same coordinate system. Most should be in EPSG:3857 - WGS 84 / Pseudo Mercator. If not refer to the VPC's guide on how to convert coordinate systems.
2. Use the Proto-Islands from the time period you are working in as a base layer
3. If the parish you are working on is already scanned and georeferenced properly skip to step 15.
4. Use the parish layers to locate the parish you will be working in and disable all other layers.
5. Open print composer and add new map. The larger the map is the easier it will be when going into Photoshop and other future steps.
6. Adjust map so it shows the entire parish and export map as an image.
7. Open this image in Photoshop and lock it. Changing the colors to black first is helpful, but not required.
8. Open the scan of the parish into the same canvas and line up the two images as best as possible by rotating and resizing the scan.
9. Turn off all layers besides the now properly sized scan and save it as a .TIF file.
10. Open Georeferencer in QGIS and open raster. Choose the correctly sized scan.
11. Add points to the raster and the base layer. Need at least 3, but the more the better.
12. Change the settings and make sure they are set to the following:
  - a. Transformation type: Linear
  - b. Resampling method: Linear
  - c. Compression: NONE
  - d. Create world file unchecked. Can check if wanted.
  - e. Output raster: Find a place to save the georeferenced scan and name it
  - f. Target SRS: EPSG:3857 (Unless working in a different projection.)
  - g. Generate pdf map: Blank
  - h. Generate prf report: Blank
  - i. Set Target Resolution unchecked
  - j. Use 0 for transparency when needed checked
  - k. Load in QGIS when done checked
13. Start Georeferencing
14. If the new raster layer does not appear or appears far away from where it should be, make sure everything is in the same CRS. All layers and the project itself.
15. Add the Ancient Structures layer for the time period you are working in onto the map and turn on editing. If one does not yet exist, create a new layer.
16. Turn snapping on for your base layer.
17. If the scan is georeferenced properly, you should be able to simply create a new feature and trace the shape of each individual building. If not, you may have to use the Streets by Name and buildings layers as a guide.

#### Dating Each Structure:

1. Give each structure a unique ID in GIS.
2. Using *Venezia romanica* (Dorigo 2003), find the manuscript reference for each structure.
3. Type the information for the reference along with the ID for the associated structure into an excel sheet.
4. Load the excel sheet into GIS. You might have to save it as a CSV file first.
5. Right click your Ancient Structure layer, open properties, and go to the Joins tab.
6. Add a join between the layer and the excel sheet.
  - a. Join layer: Your excel sheet
  - b. Join field: id
  - c. Target field: id
7. Right click the layer and open its attribute table.
8. Make the data permanently attached to the shapefiles.
  - a. Turn on table editing.

- b. (If using a new shapefile) Add a new column, set the correct type, and set the width (max number of characters). Ex: Date, type integer. Do not use date as type, that requires YYYY-MM-DD
  - c. Just below the edit buttons, there is a drop-down button. Find the correct (new) column in this.
  - d. In the drop down menu to the right of the sigma find the field from the excel sheet that matches your (new) column and double click it. Sometimes QGIS requires you to put quotation marks around the field name. Ex: "sheet1\_date".
  - e. Click Update All
  - f. Delete the old column (from the spreadsheet you joined) and save edits.
9. Repeat step 8 for each field.

## APPENDIX C: Historical Map Explorer

### Explorer Code Organization

When we started work on the Historical Map Explorer its code was well-organized internally but was all in one file. Since we would be adding more components in addition to working with the existing components, we decided to break them into separate files. Here is a short explanation of each file:

- **DataService.js:** Defines a DataService object, which provides access to the data stored in Firebase. It provides direct access to the Firebase API (off the 'fb' property), stores a local cache of features, and contains utilities for searching or manipulating data.
- **Downloader.js:** Contains functions related to the downloading of maps.
- **FirebaseAuth.js:** Defines an object that controls Firebase authentication.
- **init.js:** Used during development only to load the rest of the source.
- **LayerManager.js:** Manages the showing and hiding of layers, including feature popups and refreshing the layers when the user switches between maps.
- **main.js:** The main entry point of the code. Instantiates objects with the various constructors, sets up relationships between them in the code, and adds nearly all the event listeners used in the application.
- **MapManager.js:** Manages the loading and switching of maps.
- **PolyDrawer.js:** This file may be slightly misnamed, as it not only manages the polygon drawing that is part of adding a new feature but also displays the feature naming screen and saves the feature to the database.
- **RectDrawer.js:** Handles drawing rectangles on the screen as part of downloading maps.

Once we split up the files, rather than including them individually in the HTML and managing dependencies manually, we decided to use **require.js** (<http://requirejs.org/>), a Javascript library to manage module-based apps and resolve dependencies automatically. During development an **init.js** file provided the configuration for **require.js**. Once the Historical Map Explorer was ready for deployment we used **r.js**, a tool provided with **require.js**, to combine all the scripts into one compressed file for efficient delivery to users.

## Tile Generator Tool

Part of the process of adding a map to the Historical Map Explorer is to transform the map's high-resolution source image into many 256x256-pixel tiles. These tiles must be generated for a variety of zoom levels, starting with the most zoomed-in. To create each zoom level the image is resized to half its original size, then tiles are generated again. This process repeats until the entire map fits in one or two tiles.

When it came time to generate tiles in our project, we researched various tools, but we were unable to find one to our liking. Instead, we wrote a script in node.js (a server-side Javascript platform) to generate the images using the well-known image manipulation library Imagemagick. The script has two advantages over proprietary software. First, it is capable of batch processing a number of image files, which is especially convenient because the process of generating the tiles is a long one. Second, it can run on any server. This allowed us to upload the script and the source images to a server outside Venice, then perform the conversion there. We could then upload the tiles to the VPC's server using our outside server, which had a much faster internet connection. Even after compression, the tiles generated by the tool make up a very large collection of files, so performing this upload on a fast internet connection saved us substantial time.

To use the tool, first ensure you have node.js and Imagemagick installed. Download the tool from the Historical Map Explorer Github: <https://github.com/veniceprojectcenter/historical-map-explorer>. Run `npm install` to install the required node modules. Then, use the tool by running `node generate_tiles.js file1.tif file2.tif` from the `generate_tiles` directory, where `file1.tif`, `file2.tif`, etc. are the paths the source image files. The tool will display its progress and will create directories named after the input images with the final tiles.

The tool is built using Promises, a Javascript design pattern, with the `when.js` library. Despite the use of promises, operations occur synchronously to avoid overloading the user's computer with too many concurrent Imagemagick processes. The Promises pattern should allow the tool to be easily expanded in the future, including potentially being incorporated into the Historical Map Explorer.

## New Maps in the Historical Map Explorer

Our source for the new maps in the Historical Map Explorer was *Piante e vedute prospettiche di Venezia*, a book dedicated to the maps of Venice. In addition to the year and author of each map we recorded its description, original size, type (bird's-eye, orthographic, or panoramic), and page in that book.

Year	Description	Author	Original size	Type	Page No.
1525	Pianta prospettica della città intagliata in legno da Giovanni Andrea Vavassore detto Vadagnino	Giovanni Andrea Vavassore	mm. 371x527	Bird's-eye	48
1635	Pianta prospettica della città eincisa da Matthaeus Merian e pubblicata per la prima volta nel "Teatrum Europaeum"	Matthaeus Merian	mm. 305x715	Bird's-eye	97
1696	Pianta prospettica della città incisa da Giovanni Merlo	Giovanni Merlo	mm. 780x1597	Bird's-eye	116
1729	Pianta topografica della città disegnata da Lodovico Ughi e pubblicata a Venezia nel 1728 da Giuseppe Baroni e ristampata nel 1739 ca. da Lodovico Ferlanetto	Lodovico Ughi	mm. 1475x2635	Orthographic	138
1847	Pianta prospettica della città disegnata da Bernardo e Gaetano Combatti nel 1847 e aggiornata a tutto il 1855	Bernardo e Gaetano Combatti	mm. 1275x1460	Bird's-eye	196