Reconstructing Sea Levels Prior to 1872 Through Venetian Art and Architecture

An Interactive Qualifying Project Report submitted to the Faculty of
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Executive Summary

The goal of this project involves using three sources of sea level indicators in order to reconstruct sea levels in Venice prior to 1872. Interconnecting many fields such as art, architecture, archeology, biology and climatology, not only did this IQP successfully reconstruct sea levels, but also opened the door to a fourth sea level indicator. In addition, for the first time two WPI project centers have been directly interconnected by sharing useful data. The WPI project center in London was involved with archiving many of the photographs used in the study from the Courtald Institute.

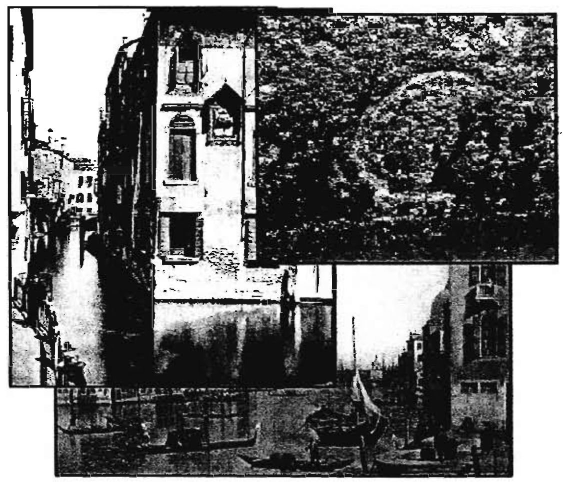

Figure 1 - Sea Level Indicators

Using accurate paintings from the mid 1700's created by Canaletto and Bellotto, the sea level was found to rise at a rate of .26 cm/year. This rate is 3 mm faster than the rate today (.23 cm/year). This suggests that sea level rise is not uniform. Theories suggest that in the past sea levels have changed by nearly 100 cm in only a century. There are many possible explanations for sea level rise, but at the top of the list is global warming. During the mid 1800's, the industrial revolution was the peak era for burning of fossil fuels, which in turn heated the earth and melted glacial ice. Since this time period, sea levels have been rising steadily without seizing. With a new understanding of rising sea levels from this project, further research is possible to compare climate correlations, and examine sea level trends.

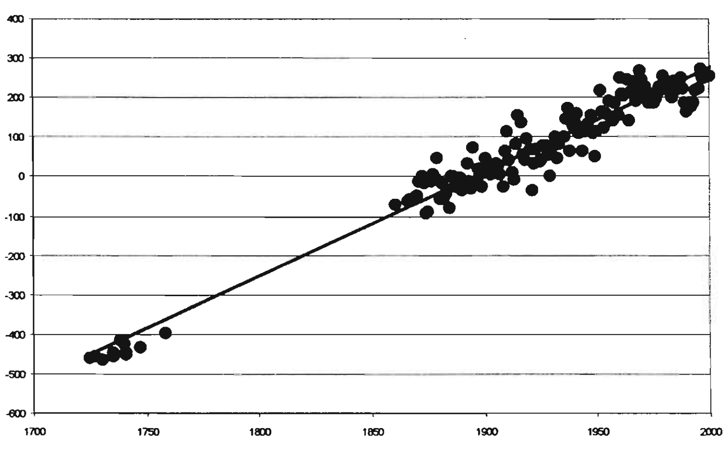

Figure 2 - Tidal Progression Line using all Sea Level Indicators

In order to understand how sea levels rose in the period right before tide gauges were installed, photographs from the mid to late 1800's were utilized. Using the same methodology developed for the paintings, 5 photographs depicting Venice in the mid to late

1800s were analyzed. Using the absolute heights found from the algae line in the photographs, a progression line from the known tidal data from 1872 to present day was extended down towards the 1800's. The absolute heights of the green line within the paintings were then put into the graph to extend the progression line further into the 1700's *(see Figure 1)*.

This project has also opened the door for future C-mark research, having documented nearly 150 C-marks throughout the sestieri of Costello and San Marco. These C-marks were originally thought to mark the *comune marino between 1700 and 1900*, however after analysis it was found that 90% of the C-marks collected had absolute heights which would indicate they were created after 1900. It is possible that these marks do not represent the *comune marino* at all. A theory behind the C marks states that they were carved during the time of construction of the building they were on and the line under the C is the level to where the workers at the time needed to dredge the canal to. If this were the case, C-marks would be very misleading as sea level indicators. Also, the workers could have moved the line under the C to make their job easier, skewing any possible results from C-marks. Further research and analysis is necessary to fully understand how C-marks can be used as valuable sea level indicators.

All of this information, including paintings, photos and C marks, has been put into searchable databases that include all on site measurements, results, maps, photos, materials, positioning, etc, for easy access for further future research.

Looking towards the future, there are other possible sources of sea level indicators. None of the sea level indicators used in this study date prior to 1700, leaving opportunity for more indicator sources. In order to accurately portray sea levels of the past to even the time before Christ, other sea level indicators need to be utilized. One source that was examined briefly in this study was the use of barnacles.

Figure 3 - Barnacle Excavation Site at Rialto

An excavation of the area under the Rialto market, in 2000, uncovered barnacles frozen in time on the canal wall *(see Figure 3, red square represents barnacles)*. The wall area was filled in 1398 and the distance from the zero line of 1897 to the barnacles at this site was measured to be –50 cm.

In order to use the barnacles as a sea level indicator, they need to be combined with the valuable green algae line. To do this, a measurement of the distance from the green line to the barnacles must be measured from different sites around the island. Once an average distance to the green line is determined from all sites, the number is added to the –50 cm distance to the barnacles from the green line at the excavation. The resulting number would be the location of the green line at the time of the excavation, 1398.

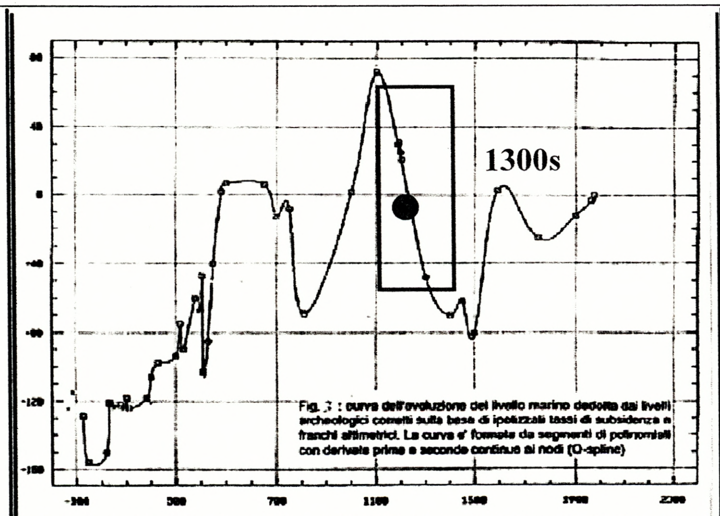

Fig. 1: curva dell'evoluzione del livello del mare in funzione del tempo

Figure 4 - Theoretical Sea Levels Over the Ages

To test this theory at one site, measurements were taken of barnacles located under the Rialto Bridge. These barnacles were found to be 25 cm below the green algae line. Adding this measurement to the –50 cm barnacle distance from the zero line, the green algae line in 1398 would be located at 25 cm below the algae line. The next step would be to graph this height to see if it falls on the sea level progression line in the 1300's. Unfortunately, only theoretical graphs of sea level prior to 1700 exist. One example is a graph created as entirely theoretical in nature *(see Figure 4)*. If this graph were used to place the barnacle measurement, then the –25 cm elevation of the green line would land almost perfectly on the sea level progression line *(see Figure 4, red dot)*. This could mean two things: The graph is an accurate representation of sea level progression over past centuries, and it also shows that barnacles can be used as a sea level indicator. Further analysis of barnacles and their distance to the green algae line will possibly result in a more accurate sea level progression line dating back to the time of Christ. It has been proven that biological sea level indicators (algae and barnacles) can be used to get accurate results and sea level progressions. This valuable information will eventually lead to reasons for increases and decreases in sea level progression, and also help to prevent further flooding in areas of high proximity to water, such as Venice.

Acknowledgements

First and foremost we would like to thank Prof. Fabio Carrera and Prof. H.J. Manzari for helping us mold an otherwise aimless project into something meaningful, with so much depth and potential; Dr. Dario Camuffo, and Emanuela Pagan from ISAC for their continuous suggestions, support and patience. We can only hope that we have replicated your research in a way you would be proud of; Ernesto Canal for his information on just about every aspect of our study; Davide Tagliapietra for his information on *comune marino* and barnacles; Marco from INSULA for his archeological know-how; and last but certainly not least we would like to thank Alberto Gallo for his time, driving us in his boat, where we were forced to smell hideous and awful smells and avoid canal rats first thing in the morning while searching for C-Marks.

Other people to thank include: Andrea and Davide from the VPC, the Kebab guy, bartenders at Fiddlers, Fabio the Gelato guy, Ca D'Oro Gelateria, Pizza Piu, Magnifico, , Hit Channel Radio Television, O-Zone, Anistasia, Jamilia, Kelis, and the one person at Billa who didn't care that we didn't have exact change… oh and Candy for eating all Dave's food.

AUTHORSHIP

All team members provided significant contributions towards the completion of this project over the entire course of this study. Team efforts include field work as well as authorship of the introduction and background of the final report including bibliographical content.

Individual contribution is as follows:

Nick Angelini was responsible for Microsoft Access databases for usable paintings, photographs, all C-Marks, and overall results as well as C-Mark data organization, including development of C-Mark website.

Laura Corsetto was responsible for development of validity testing methodology, author of the report section of the same title and the conclusions section, as well as results and analysis of validity testing, including error for data points in each sea level indicator result. In addition, Laura created Appendix B for the validity testing sites, and shared credit for the presentation slides.

David DeFusco was responsible for all MapInfo map locations for sea level indicators, creating results and analysis for each painting site, comparison to past research, and recommendations in the report. In addition, Dave created Appendix C and D for the painting sites, and shared credit for the presentation slides.

Michael Scarsella was responsible for the creation of the Canaletto and Bellotto painting spreadsheet, methodology section of the report, creating results and analysis for each photograph site, final sea level indicator analysis, Appendix C and D for the photograph sites, and shared credit for the presentation slides.

All discussions, conclusions, analyses and information databases contained within this report have been prepared as original works by this project team, unless otherwise cited or stated.

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1.0 Introduction

Worldwide, ocean levels have been affected by a gradual increase in average global temperature. Rising temperatures have caused glaciers on land in Antarctica, Iceland, and Greenland to melt and in turn, raise sea levels globally. According to a recent climate change study, the complete melting of Greenland's ice sheet would raise the oceans by seven meters.[1] These elevated levels would especially affect areas within close proximity to seawater, such as Venice, Italy.

Current trends predict that sea levels will rise 36 inches by the year 2100. Global warming appears to be the main contributing factor to these trends, but what researchers question is to what degree humans have influenced the rise in global temperature. Such events as the boom period of the Industrial Revolution, from 1860 to 1890, saw the beginning of fossil fuel consumption[2]. At approximately the same time, concern for the environment prompted researchers to begin documenting changes such as sea levels.

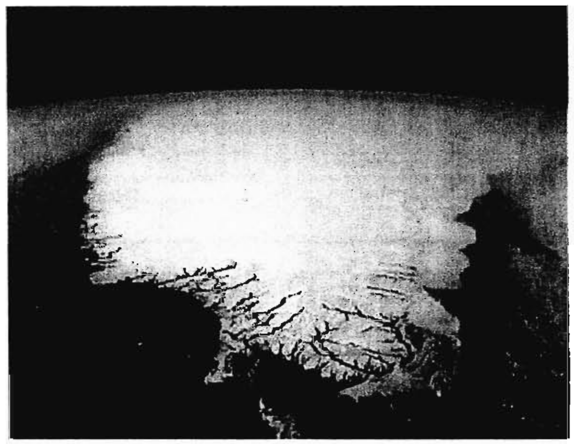

Figure 1 - Satellite View of Greenland

Venice, Italy began documenting sea levels with a tidal gage in 1872. Water levels are of particular interest to Venice because of its location in, and around the shallow lagoon fed by the Adriatic Sea. While this makes Venice extremely sensitive to water level variations, it also makes it an ideal location for examination of sea level changes. Extreme tidal fluctuations, such as high water of over 60 cm above normal have been increasing in frequency from roughly 80 days per year to 240 days per year[3]. (*see Figure 2*)

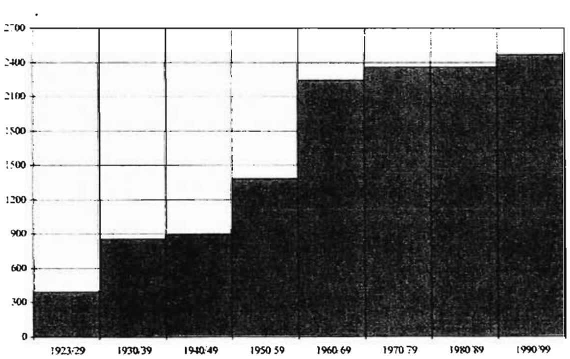

Figure 2 - Frequency of +60cm tides each decade

In addition to tidal fluxes affecting Venice, the threat of "sinking" has recently become a publicized risk. This sinking, known as ground subsidence, can be attributed to the weight of the city pushing down on the soft soil of the lagoon beneath it. Severe tidal fluxes, combined with ground

[1] Greenland Melt, National Geografic
[2] Columbia Encyclopedia 6th Ed. 2004.
[3] Centro Maree 2004

subsidence, cause frequent flooding, and are examples of what makes Venice so susceptible to deviations from normal tidal patterns.

In the period between 2000 and initiation of sea level recording in 1872, a 30 cm increase has been recorded.[4] (*see Figure 3*) This data is of particular interest to researchers at organizations such as the Italian National Research Counsel (Consiglio Nazionale delle Ricerche), or CNR, as they are associated with overseeing scientific and research activities in the country.[5]

Dario Camuffo, a climatologist working at ISAC, a division of CNR, in Padova, conducted a study in 2001 which used accurate landscape paintings by Canaletto and Bellotto which displayed water levels from the mid 18th century to reconstruct sea levels prior to 1872, before tide gages recorded data. By estimating water levels through the 18th century paintings, he was able to derive quantitative data when measured against present day identical views.

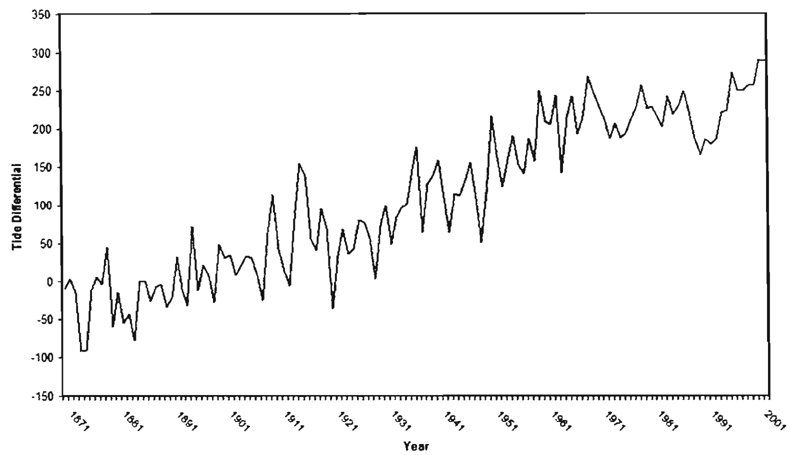

Figure 3 - Tide Gage Height(mm) vs Year

Camuffo's study has been considered ground-breaking because there was no apparent source of accurate data during the time prior to installation of tidal gages that would indicate the sea levels. Although Camuffo's study included 12 data points,[6] the possibility of expanding a more thorough investigation exists by obtaining more data points from new sources.

Using a similar approach to Camuffo, this study intends to examine 18th century paintings, 19th century photographs, and archeological sea level indicators to reconstruct what the sea levels were prior to 1872. It is important that sea levels prior to 1872 be documented in order to have a comprehensive dataset of tidal progression.

In addition, this study aims to verify Camuffo's results, include additional data points, and provide a more accurate reconstruction of sea levels in Venice prior to 1872. The paintings, photos and archeological data, will be cataloged into searchable databases for reference and documentation. Information from these databases will be formulated into a graph depicting a sea level progression line, which will be available for future research related to the rising sea level problem facing Venice.

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4 Camuffo, D. 1993.
5 CNR, 2004.
6 Camuffo and Sturaro, 2003.

2.0 Background

The Venetian painter Antonio Giovanni Canal "Canaletto" (1697-1768) (*see Figure 5)* and his nephew turned pupil, Bernardo Bellotto (1722-1780) created accurate reproductions of Venetian cityscapes. The tool behind Canaletto's accuracy is a lens system called a *camera obscura.* (*see Figure 4)* The camera obscura operates like a modern camera. The light beam penetrates through a lens, is reflected by mirror or a prism, and is projected onto a glass surface, where a sheet of paper, or canvas, was placed. Then, artists such as Canaletto drew in all the necessary details, obtaining a nearly 'photographic' image on canvas.[7]

Figure 5 - Antonio Giovanni Canal "Canaletto" (1697-1768)

The device first received the title *camera obscura* from a German scientist and astronomer, Johannes Kepler, in the early 17th century. As the device developed it was used in two ways; as the framework for the modern photographic camera, and as a precision drawing aid. Canaletto and Bellotto both used this device to paint their landscape views.[8] As a result of their accuracy, demand was high for the portraits they created. It became necessary for copies of each portrait to be reproduced in their shops, no longer in front of the original view, and often were altered at the artists' discretion. This study, similar to Dr. Camuffo's, will be utilizing the original painting of each view in an effort to obtain the most accurate source for data points.[9]

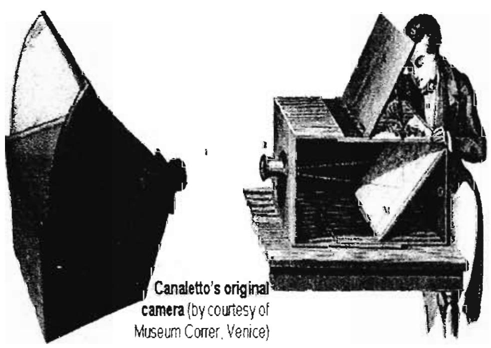

Figure 4 - Canaletto's Camera Obscura

The detail within the works of Canaletto and Bellotto was of such extreme detail, a valuable sea level indicator in the form of a green line of algae can be seen. This line, located on the canal walls, is created by an algae species called *Laminaria Alga.*[10] However, there are only two types of this alga that can grow on the canal walls, microflaura and microfauna. These two species are responsible for giving the algae its green color.[11]

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[7] Idem. Camuffo and Sturaro, 2003.
[8] Wilgus, Jack and Beverly, 2001.
[9] Ibid. Camuffo and Sturaro, 2003
[10] Camuffo, D, 2001.
[11] Wall Damage, 1992

Algae, which grow on structures found in marine environments, are a good biological indicator of the average high-tide level (AHTL). The algae belt is created by the frequent wetting of the bricks and stones on canal walls and wood on docks due to the tidal fluxes. The cumulative effect of the frequent submersions, as well as the water retained in the pores, constitutes the habitat favorable for seaweed.[12] Algae is an extremely good indicator of the AHTL because it is a gradual accumulation. Singular extreme events, such as rainfall, acqua alta or exceptional tides do not affect the algae belt because once the event has passed, the water left on the surface of the structure evaporates rapidly and does not allow for organism growth. The key to the formation of a distinct algae line depends not only on the moisture level, but also on the material which the algae resides. Porous materials such as wood, brick and mortar tend to support more prominent algae belts than materials less porous such as sandstone and marble.

Figure 6 - Algae line closeup in Canaletto's "PuntaDellaDogana" (1727)

The belt of algae seen in the paintings of Canaletto and Bellotto (*see Figure 6)* is found on all structures permanently affixed in the water (red line indicates approximate algae line). The accuracy of the algae belt as an indicator of the AHTL has come into question, and has subsequently proven to be quite precise in data collection.[13]

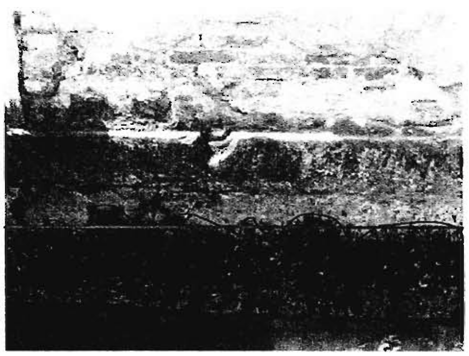

Figure 7 - Green algae line curve

However, there are outside factors that can affect how thick or high the algae belt will grow. Some of these factors include waves induced by wind or boat traffic, sun exposure, and the material on which the algae grow. In many areas of Venice, waves and splashing have caused the green line not to grow a straight line, but rather more of a sinusoidal curve (*see Figure 7).* The red line in the figure represents the actual green line, while the light green line represents the resultant average green line. In this case, in order to get an accurate reading of the height of the line, the average of the highest and lowest points on the line must be taken to find the actual position of the green line.

Figure 8 - C-mark

[12] Idem. Camuffo and Sturaro, 2003.
[13] Ibid. Camuffo and Sturaro, 2003.

In the past, the algae belt, called the *Comune Marino*, was periodically documented with engravings in the canal walls throughout Venice. Generally referred to as C-marks, due to the shape of the engraving on the canal wall (see *Figure 8*), these engravings can still be found on the foundations of buildings and canal walls. C-marks were etched on buildings at the top of the green line as archeological tools during the time of canal dredging.

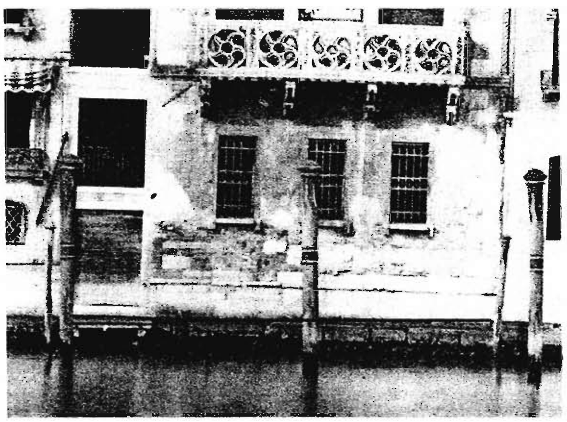

Figure 9- Early Photos in Venice showing Comune Marino (red line shows approximate level of algae)

Aside from the rare few which contain dates of engraving, it is difficult to say precisely when each carving was created, and no complete catalog of information is known to exist on the heights of these marks. In 1992, the WPI Venice Project Center began compiling a catalog of the locations of some engravings, which were discovered by a research team during an unrelated project, however this research remains in an incomplete state where it may be deemed useful for researchers.[14]

Photographs dating back to the nineteenth century are another good source that include the green algae line. Shortly after the invention of the camera in 1839,[15] the first photographs were taken. Photographs have an undisputed level of accuracy; therefore they are ideal for our purposes. These photographs (*see Figure 9*) will provide a secondary source from a later timeframe, showing an even more defined algae line than those found in the paintings of 18th century Venetian artists.

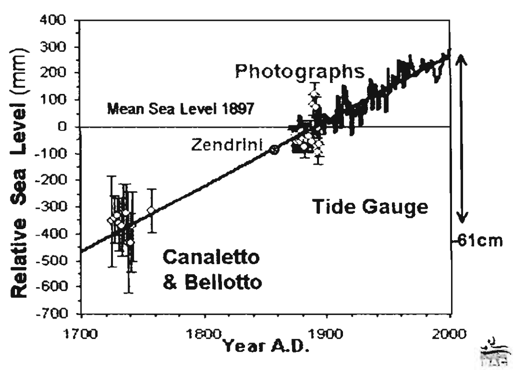

Figure 10– Camuffo's Data Coinciding with Tidal Data

An understanding of previous research is particularly important to the success of this study. Because similar methods have been used in the past, learning from, and hopefully improving upon these methods, is crucial. In his 2001 study, Dr. Camuffo used 12 different paintings, as well as tidal gage data, to derive a linear tidal progression[16] *(see Figure 10).* Taking generalized error into account, Camuffo's study showed that it is possible to reconstruct sea levels using the artistic indicators of the 18th century.

[14] Sewers and Wall Damage, 1992.
[15] Harry Ransom, 19 April 2004.
[16] ISAC, Camuffo, Dario Apr.26, 2004

This study intends to further explore illustrated sea level indicators, in addition to new photographic and archeological indicators, while examining the possibility of contributing threats to validity. All possible existence of error will be thoroughly examined, and aim to prove or disprove the possibility of artistic and archeological indicators acting as clues which may unlock unknown sea levels prior to 1872.

3.0 Methodology

Providing an accurate reconstruction of water levels in Venice involves considerable data collection in, and away from the field of work. Techniques of data collection for this project will not be completely innovative because of its similarity to Dario Camuffo's work, however new sources of data have created a need for a few unique methods of information collection.

For the purposes of this research, *sea level* indicators are identified as qualitative visual artifacts that directly or indirectly represent the water levels of Venice prior to 1872. The three indicators chosen for the purposes of this study include townscape paintings by Canaletto and Bellotto from the early to mid 1700s, black and white photographs from the mid 1800s, and engraved C-marks on canal walls dating from the 1700s to the 1900s.

All three sea level indicators contain information that can be quantitatively derived to show the water level of the representative timeframe through a unique biological indicator in the form of a line of algae (*see background*). This line, referred to as the *comune marino* (*see background*), appears as a green-brown line within the portraits of Canaletto and Bellotto, and as a definite dark line within the early Venetian black and white photographs. Representing the average high tide level (AHTL)[17] for the year of the portrait or photo, this line was also documented in over 200 locations within the canals of Venice with an etched "C" mark.[18]

To determine the undocumented sea levels predating 1872, our study involves deriving quantitative data from the differential between the AHTL of today and those displayed by sea level indicators of the time period under investigation. An analysis of this data aims to graphically represent a correlation between progression of time, and rising sea levels within Venice.· The relation between this rise in water level, and the rising global temperatures expects to be supported or disproved by comparison of known temperature changes versus the resulting water level increase rate from this study.

3.1 Reference levels

In order to create a differential between the water levels represented in the sea level indicators and today, a level for all measurements to be referenced from must be established. In Camuffo's study, sea levels of today are compared with relation to the derived water level from each painting under examination. This method of reported data can be described as a *relative* measurement format, because of its reference off of a previously known level.

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[17] Camuffo & Sturaro 2003 p.3
[18] Wall Damage 1992

This report intends to be accomplished within an *absolute* format, where measurements are referenced by their true elevations. As a result, all sea level indicators which predate the year 1897 will appear as negative numbers.

3.1.2 "Zero" Sea Level

When the tide gauge was installed in Venice to monitor the rising sea levels, there arose a need for a point of reference to avoid ambiguous measurement of levels. A level was derived which was referred to as the "zero line of 1897" as a result of two independent studies ranging from 1872 to 1907 (*see background*). This study is concerned with dates prior to 1897, where presumably the water levels were lower, hence the data derived in this study will be negative in value.

3.2 Collecting Relevant Sources

Having established that our three main sources of information will be derived from paintings, photographs, and C-markers, the collection of specific indicators must begin. Individual assessments are required for each source of data, to determine relevance.

3.2.1 Paintings and Photographs

Paintings and photographs are considered relevant for our purposes when they contain a clear view of the *comune marino*, or algae line on a canal wall. Attaining all relevant examples that fit this description requires a systematic search consisting of obtaining a complete list of works, with years of illustration for each artist, and as many early photographs, with dates, of Venice as possible. A catalog of factual information in a database with available images is produced to aid in proper selection of appropriate paintings and photographs as subjects in our data collection.

Ensuring that all possible paintings are reviewed for consideration as subjects requires a complete works list for the artist in question. Fortunately, when an artist has prepared a large number of works over an extended time period, it is of interest to collectors and historians to know how many of each work are in existence, and in what gallery they reside. When a list of this caliber is compiled it is known as the artist's *catalogue raisonné*[19]. This is the ultimate source for a complete works list for any artist under investigation, including the ones focused on in this study. Once the catalogues are accessed, documentation and analysis of relevance begins.

The next step involves organizing the now compiled list of paintings and photographs for analysis A spreadsheet for each of the artists is prepared (see *Figure 11*), listing each piece of work by

[19] W.G. Constable 1962

name, year of illustration, whether the work contains a water view, an image source, and a local link to the image.

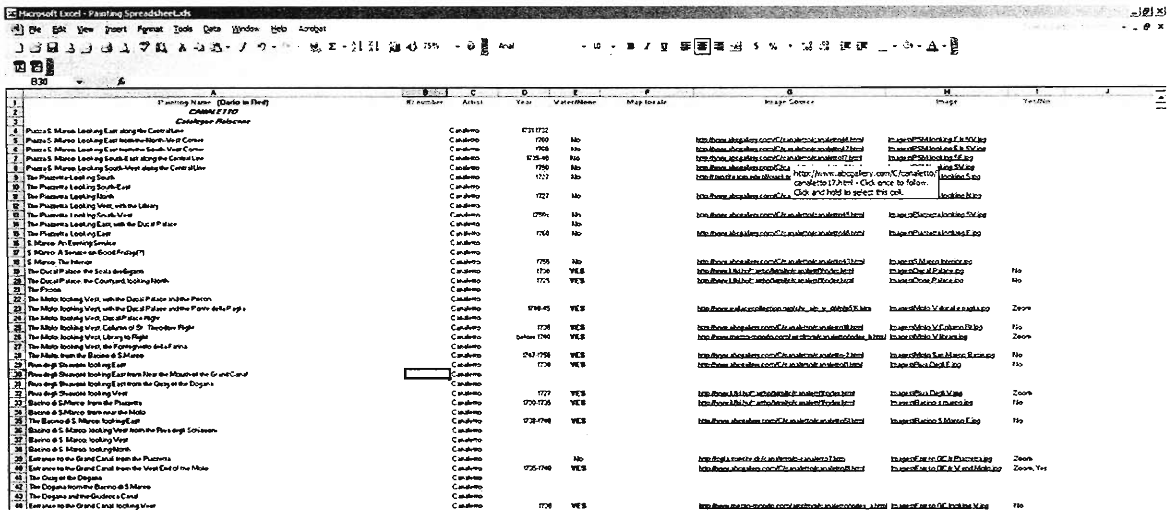


Figure 11 - Catalog of Paintings

The name of each piece of work, and the year of illustration are both available through the *catalogue raisonné*, however an image of the work is necessary to determine the next three groups of information. A thorough Internet and book search is the most efficient method to find pictures of each work. Each image is to be scanned or saved digitally and documented for sources, and finally made accessible via the spreadsheet. (See Appendix B) Each image then becomes the focus of initial review, and is given an appropriate designation as to whether it contains a water view or not. If the portrait contains a water view, it is then highlighted for further analysis.

Photographs from the time period under investigation are now of historical value and no reproductions are known to exist. In order to obtain as many relevant photographs as possible, they must first be digitally scanned, or found in digital media[20]. The digital media on which the photographs are located will be cataloged in a similar manner as paintings, and will be accessible for the same analysis.

The two primary sources of old photographs of Venice came from a local Venetian, as well as a Worcester Polytechnic Institute connection. In Venice, Luciano Filippi, published a book with an archive of some of the first photographs in Venice, called "Vecchie Immagini di Venezia". Luckily for the purposes of this study, each photograph was dated within this archive. The second source of photographs is from the Courtauld Museum in London, England, an associate of the WPI London Project Center. Previous projects at this facility dealt with organizing the archives for the Institute. The organization was utilized in the museum's online database to turn up some useful photographs for our study.

[20] Cortauld Institute May 5 2004

After preliminary reviews show that a painting or photograph has a view which contains water, it must then be further analyzed to see if it contains the important commune marino algae line indicator. If an image has been stored which is of good quality, little magnification is all that is necessary to determine whether there is a visible algae line.

3.2.2 C-Marks

The C-marks unlock a third source of information which may, or may not, provide some of the earliest data points for this study. C-Marks are considered for the purposes of this study, to be accurate representatives of the AHTL (*see background*) for the date which they represent. Few of the engravings within the canals contain documented dates, which are valuable indicators of sea levels for the given year. If a C-mark does not contain a date, it may be possible to derive the date by its AHTL line and where it fits into our derived progression line.

Each C-mark, dated or not, may be applicable to this study. Therefore, collecting data on C-mark locations will not be selective, and all sites will be investigated. The main source for locating the C-Marks around Venice is from data collected in a 1992 WPI IQP[21]. Locations were mapped using MapInfo G.I.S. software (see *Figure 12*), and were documented with corresponding photographs. The C-Marks were not a main focus of the study, and hence were given secondary consideration, and non traditional index codes. For the purposes of this study, the 1992 photographs were scanned digitally, catalogued by old index code, and given new index codes based on a system of island code, canal code, and sequential order within the canal they reside.

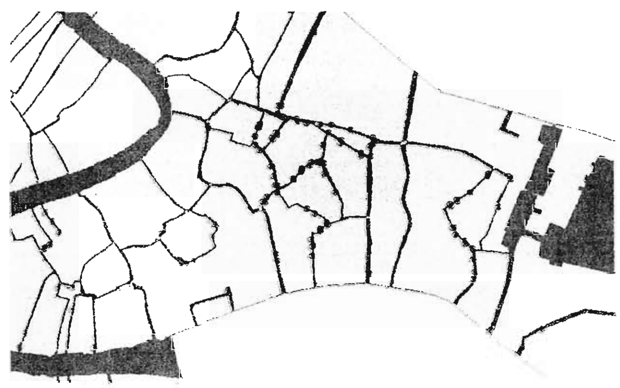


Figure 12 - Map of C-Mark Locations

[21] Wall Damage 1992

3.3 Preparation for Data Collection

Having obtained each relevant sea level indicator and cataloged them by their corresponding year, data collection procedures may commence. For the purposes of data collection, photographs and paintings are treated similarly while C-Marks will have a unique data collection procedure.

3.3.1 Preparation for Photograph and Painting Site Data Collection

Using Dr. Camuffo's work as a model,[22] painting and photographic sites are compared by way of on-site, and photometric analyses for the photographic and painting sources. A comparative analysis of the two will give a clear indicator for the water level differential between the image, and present day. In order to prepare for on-site visits, three important preparation procedures need to be accomplished: locations to be visited must be mapped, data collection sheets prepared and an initial walk-by visit must occur.

In order to map the location of the vantage point for each photo or painting, aerial maps of the city will be examined and cross-referenced within the views of the image for landmarks. If no recognizable landmarks are found, local residents will be questioned. Lastly, tools such as the *catalogue raisonné* are utilized because of the detailed description of the view within each portrait.

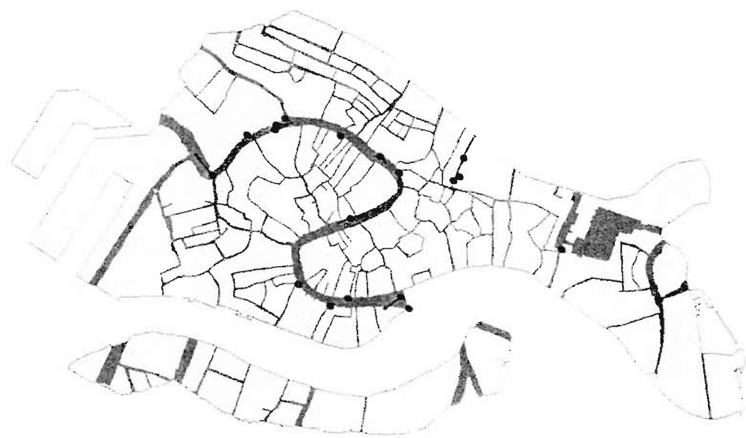


Figure 13 - Map of Painting Locations

After the vantage points of all sea level indicators are established, the locations are plotted on a MapInfo map for reference (See *Figure 13*), as well as for organizational purposes. Each location is designated by a unique index code on the map in the form of P### (starting at 001, and ascending upward) for paintings and F### for photos (*fotos* in Italian), rather than a descriptive name (*see Table 1*). The advantage to a symbolic representation over descriptive, is the time and space saved when referencing each individual indicator. The unique index code also avoids confusion when referencing paintings, due to the fact that there are more then one with duplicate titles, or identical views.

[22] ISAC, Camuffo, Dario, 26, Apr 2004.

P001a	Campo S. Giovanni and Paolo (Dario) (1741)	P010	Punta della Dogana
P001b	Campo S. Giovanni and Paolo (Dario) (1743/47)	P011	The Grand Canal and the Church of the Salute
P001c	SS. Giovanni e Paolo and the Scuola di S. Marco	P012	Entrance to the Grand Canal (Bellotto)
P002	Grand Canal: looking South-East from the Campo Sta Sofia to the Rialto Bridge	P013	The Arsenal, Venice (Bellotto)
P003a	Grand Canal: looking E, from the Camp di S. Vio	P014	The Grand Canal near S. Stae Church (Dario)
P003b	Grand Canal near the Campo San Vio looking towards the church of Santa Maria della Salute	P015	Il Rio dei Mendicanti è La Scuola de San Marco
P004	Grand Canal: from Sta Maria della Carità to the Bacino di S. Marco	P016	Grand Canal: looking East from the Palazzo Flangini to S. Marcuola
P005	Grand Canal: looking South-West from the Palazzo Grimani to the Palazzo Foscari (Dario)	P017	Canale di Sta Chiara: looking South-East along the Fondamenta della Croce
P006	Grand Canal: S. Geremia and the Entrance to the Cannaregio (Dario)	P018	Grand Canal: looking North-East from the Palazzo Balbi to the Rialto Bridge (Dario)
P007	Grand Canal: looking South-West from the Chiesa degli Scalzi to the Fondamenta della Croce, with S. Simeone Piccolo	P019	Entrance to the Grand Canal: looking East
P008	Rio dei Mendicanti: looking South	P020	The Grand Canal at S. Maria della Carità, looking S. Vio (Dario)
P009	Grand Canal: the rialto bridge from the north (Dario)	P021	The Grand Canal from Flangini Palace to Vendramin Calergi Palace (Dario)

Table 1 - Painting Index Code Table

Once each location is properly documented and mapped, two visits to the sites are necessary for analysis. The first visit to a site is relatively brief, and considered a preparation visit. Using the portrait or photograph as a cross reference to verify the location vantage point, landmarks are noted, as well as changes to the scenery. As much as 250 years have elapsed since the publication of most of these indicators, so it can be expected that the scenery has changed. Digital photographs of the current scenery are taken, as well as a general reproduction of the view expressed in the original photo or portrait. Important scenery changes are noted along the waterline. Any foundation, stairway, or cornerstone alteration since the year of illustration decreases the opportunity for a proper comparative analysis.

With digital photos completed, and important reference scenery documented, any tools necessary to do measurements should be noted. In some cases, a laser level may be necessary, or an extremely long measuring tape. Preparation is important for the second visit to the site, as it involves more detailed procedures, and adjustments may need to be made to visit during an appropriate time of day to avoid crowds or tidal issues.

3.3.2 Preparation for C-Mark Data Collection

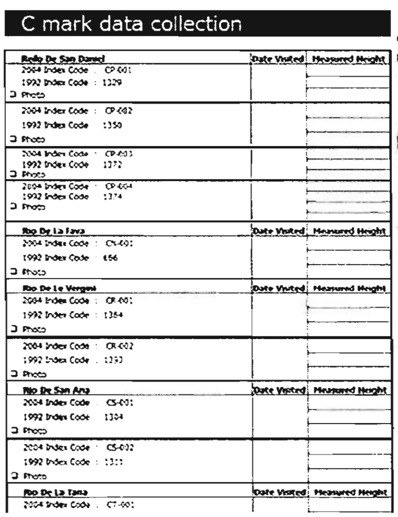
With C-Mark locations in hand, preparation for collecting C-mark data can begin. Initially, times and days to collect data are established, data collection routes created and mapped, and necessary tools are sought out, purchased, and inventoried.

3.3.2.1 Scheduling C-Mark Data Collection

Since C-marks can be up to 200 years old, their location may fall under the current water line, thus, significant planning must be done in order to coincide data collection times with low tides. A graphical representation of daily low tides, obtained from *Centro Maree* in Venice, aided in scheduling data collection days to match the most extreme low tides during the course of June and July. After speaking with residents, collection times were established as 2 hours prior to, and after low tide, in order to take advantage of maximum canal wall view.

3.3.2.2 C-Mark Mapping and Collection Sheets

Although data collection is limited to the sestieri (boroughs) of San Marco and Costello, a route was established to efficiently make use of boat access, and take advantage of the low tide timeframe. Given the 4 hour window for data collection, roughly 30 C-marks per day were collected. A map was created in MapInfo (*see Figure 14 left*) for the sestier, including location of the C-mark, and previous index number. A new index number was assigned to each C-mark for our records, organized by canal. A data sheet (*see Figure 14 right*) containing each new and old index number was created with fields to fill out with measurements, as well as photo documentation, and date of visit.


C mark data collection

Rio De San Daniel	Date Visited	Measured Height
2004 Index Code : CP-001 1992 Index Code : 1329 ❏ Photo		
2004 Index Code : CP-002 1992 Index Code : 1350 ❏ Photo		
2004 Index Code : CP-003 1992 Index Code : 1372 ❏ Photo		
2004 Index Code : CP-004 1992 Index Code : 1374 ❏ Photo		
Rio De La Fava	**Date Visited**	**Measured Height**
2004 Index Code : CV-001 1992 Index Code : 656 ❏ Photo		
Rio De Le Vergini	**Date Visited**	**Measured Height**
2004 Index Code : CR-001 1992 Index Code : 1364 ❏ Photo		
2004 Index Code : CR-002 1992 Index Code : 1393 ❏ Photo		
Rio De San Ana	**Date Visited**	**Measured Height**
2004 Index Code : CS-001 1992 Index Code : 1304 ❏ Photo		
2004 Index Code : CS-002 1992 Index Code : 1311 ❏ Photo		
Rio De La Tana	**Date Visited**	**Measured Height**
2004 Index Code : CT-001		

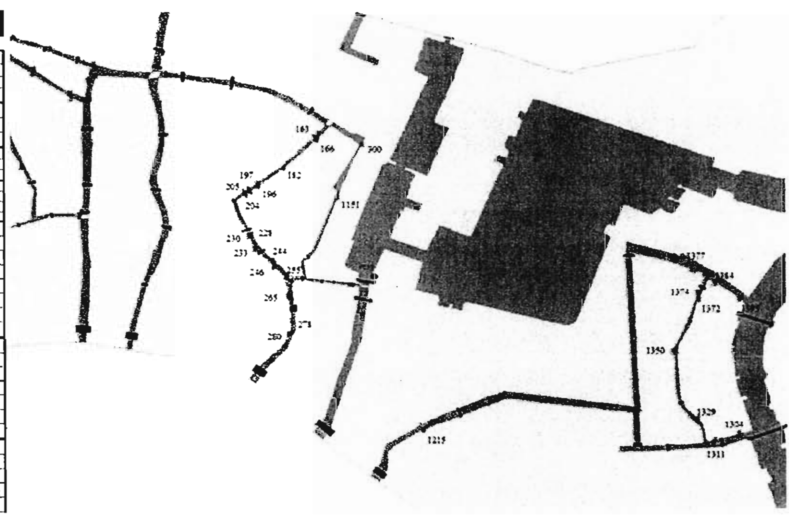


Figure 14 – C-Mark Collection Sheet (Left) and Accompanying Map (Right)

3.3.2.3 Tools for Collecting C-mark Data

Measuring the height of C-marks from a point of known elevation is a relatively easy task if the known elevation is directly above the area of interest, however in the canals of Venice, points of elevation are sometimes located on sidewalks up to 20-30 meters away. Thus, it becomes necessary for a *laser level* to be carried during data collection, as well as a *meter stick* to measure directly upward from the C-mark line. If the engraved line below the C is not visible, or covered in thick algae, it must be cleaned by way of a sturdy *bristled brush*. Lastly, a *digital camera* records a digital image of the C-mark showing the visible algae line and engraved line, with a *ruler* in the shot, and a small *whiteboard* with the new index number visible for record keeping and reference.

3.4 On-Site Data Collection

With site-specific information in hand, as well as preparatory information gathered, the data collection visit to each site can begin. Once again, painting and photograph data collection procedures are nearly identical, and can be treated as one, while the C-marks have a unique method, and will be addressed separately.

3.4.1 Painting and Photograph Data Collection

Tasks to be completed include a digital photo reproduction of the original view, measurements to reference markers, and documentation of data. Creating a digital reproduction can be accomplished by cross referencing the extreme left, right, top and bottom points in the original view, and recreating this with a digital camera (see *Figure 15*). In some cases, these views may need to be cropped vertically, or merged with several photos to achieve a wide-angle view not available to standard digital cameras.

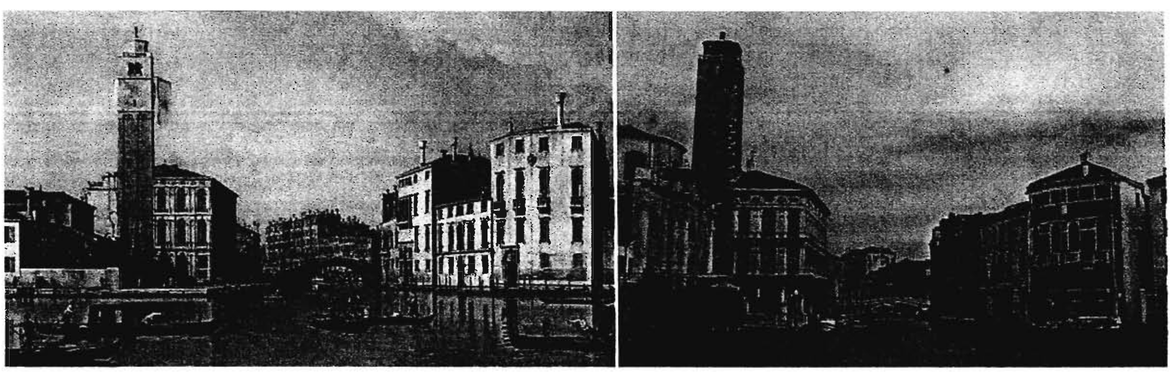


Figure 15 - Canaletto's 1735 "Grand Canal: Entrance to the Cannaregio" (left) and a Present-Day View (right)

The next step is arguably the most important, since each indicator would be useless without the measurements that accompany them. Reference points predetermined from the initial visit to each site were made in two of the three dimensions of space. The first of which is along the z-axis, which extends from the viewpoint to the vanishing point. In the case of the view shown in *Figure 16*, the z-axis measurements are made along the foundations from each vertical line, as shown in red.

X-axis measurements are made as shown in red in the vertical directions. A smaller metric measuring device such as a meter stick, or short measuring tape is sufficient for the vertical measurements. These vertical measurements are crucial, and should be measured and documented to the nearest centimeter or millimeter to ensure accuracy. This x-axis measurement will be a crucial element when deriving the vertical displacement of sea levels.

Figure 16 - Axial On-Site measurements

The final step while on-site is to record measurements on the *On-Site Data Form* (See Appendix C). A template was created for each site so vital information could be organized in a manner which would be consistent from site to site. This data form contains information regarding the original painting such as artist, year of illustration, a map of the vantage point, and an image. New information on the sheet includes: Index number, date of visit, digital image, on-site measurements, and comments regarding changes in the present-day view. All painting and photograph locations are documented on the on-site data form, and once completed, the photometric data derivation can begin.

3.4.2 C-Mark On-Site Data Collection

The preparatory phase of C-mark collection created maps of locations, and gathered the required tools to collect proper measurements at each site. An additional measure taken prior to embarking on each scheduled collection day is to take a laptop computer equipped with MapInfo GIS software, with elevation layers displayed. These elevations can then be cross referenced with objects in the canal that match with the documented elevations.

Upon arrival to a C-mark, the elevation map is brought up on the laptop with MapInfo, zooming in on the exact location. Good examples of locations are sidewalks on the same side of the canal, however not right on top of the C-Mark. The elevation of the sidewalk is noted on the C-mark collection sheet. Because this study is completed with data in absolute elevation terms, it is imperative to take all measurements as accurately as possible with relation to the elevation surrounding each C-mark.

One member of the group, equipped with a laser level, arrives at the point of known elevation, and levels the laser. The laser is then pointed toward the C-mark, and is aimed to a ruler which has been placed with the zero on the engraved line below the C, and numbers ascending upward. (see *Figure 17*)

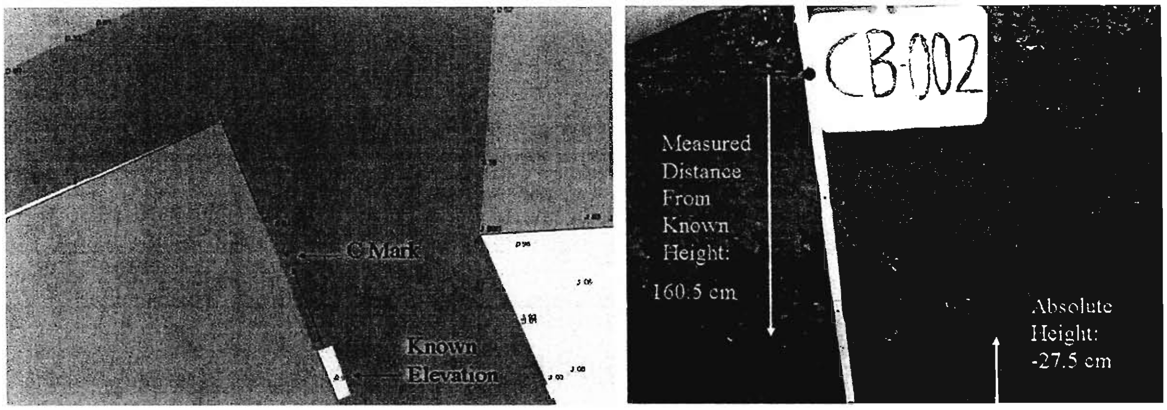


Figure 17 - C-Mark Elevations (Left) and Measurements (Right)

In the case of *Figure 16*, the point of known elevation is 133 cm above the zero line of 1897. By measuring how far below this elevation the engraved line under the C is, an absolute height above or below the zero line can be established. All measurements are recorded on the C-mark on-site data sheet (see appendix C) for reference and calculations.

All sites are visited by canal to ensure a thorough search. In some cases, new C-marks were found. These were accounted for, even though they were not previously documented. The new marks were mapped in the MapInfo C-mark layer for reference, as well as given an index number by its canal location. The new mark is then measured, just as any mark would be, and is given equal consideration toward the final results.

3.5 Off - Site Data Derivation

Once all on-site data has been collected for the three separate sea level indicators, quantitative results for the data must be derived. Photographs and paintings are, as expected, similar in methods of derivation, while the C-marks are unique and treated separately.

3.5.1 Photographs and Paintings

With on-site measurements recorded, off-site data derivation for each individual painting and photograph can begin. The data is derived by first creating a unique ratio of vertical and horizontal on-site measurements, and then applying them to the vertical green line measurement. While this method remains consistent for each photo and painting location, the results will be unique to each site. Following the data derivation, results will be represented in text, graph, and database forms for analysis.

The first step in deriving a measurement ratio is accomplished by looking at the original photographic or painting image and replicating each measurement that was taken on-site, directly on the image. By creating a ratio of the vertical and horizontal measurements, a photometric analysis will create a triangulation of measurements and yield a ratio, applicable to the true vertical displacement of algae in the year of the original image. In the case of *Figure 16*, hypothetical data would be compared as shown in Table 2.

Table 2 - Measurement Ratio Derivation

Measurement Axis	1754 (Original Image Measurements)	2004 (On-Site Measurements)	Resulting Ratio
Horizontal Z-Axis (1)	3.1 cm	15.8 m	509 : 1
Vertical X-Axis (2)	1.9 cm	9.8 m	515 :1
Vertical X-Axis (Algae)	.15 cm	.15 cm x 510 = **76.5 cm**	Apply 510 : 1 Ratio

Vertical Axis displacement = 76.5 cm

Because the measurements in the z-axis show a resulting ratio of roughly 500 : 1, this can be applied in the vertical direction to derive what the displacement of the algae level is in comparison to 2004.

As shown, in this hypothetical instance, the 76.5 cm increase is a relative number, and can be applied to our absolute measurement format by comparison to elevation points during on-site data.

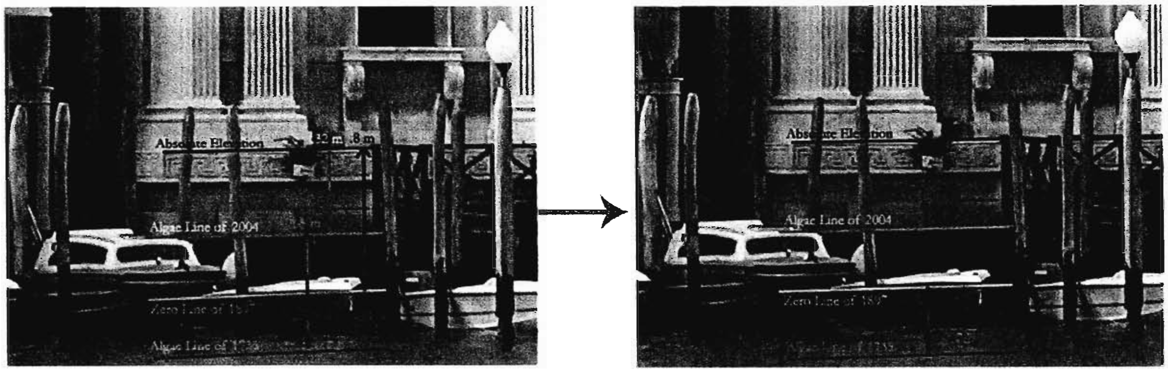


Figure 18 - Derivation of Algae Line elevation Part I (Left) & Part II (Right)

For example, if in the case of *Figure 16*, if the algae shift since the date of painting (1735) has increased by 76.5 cm, and on-site, the algae line was measured to be 32cm below the sidewalk, which has an elevation of .8 m above the zero line, the absolute elevation would be derived as shown in Figure 18.

Derivation of 1735 Algae Line Absolute Elevation

(Part I)
Absolute Elevation
- Algae Line of 2004
Algae line 2004 Abs. Elev.

(Part II)
Algae Line of 1735
- Algae line 2004 Abs. Elev.
= Absolute elevation of Algae Line of 1735

The technique of deriving a ratio for each individual sea-level indicator image is applied to all photo and painting selections. This complete data set is cataloged in a database by index number for each location, and includes each measurement ratio, resulting vertical sea level differential, and absolute elevation of the date of the original photograph or painting. This is more thorough, however similar to similar to that of Figure 19 which Camuffo prepared, using data from his own study[23].

Site	Date of painting	Observed algae displacement ΔCM_{obs} (cm)
1. Punta Dogana	1727	69±16
2. Fontego Tedeschi	1727	68±8
3. Balbi Palace	1730/31	67±6
4. Ca' Grande Palace	1732	70±9
5. Emo Palace –Cannaregio	1735	71±10
6. Giustinian-Lolin Palace	1735 (?)	66±10
7. Grimani Palace	1735	66±10
8. S. Stae Church	1740	77±18
9. S. Giovanni e Paolo	1741	77±10
10. Flangini Palace	1741	71±12
11. S. Sofia Church	1758	65±7
12. View of Grand Canal..., from the Campo Zobenigo	1730s (?)	73±10

D. Camu

Figure 19 - Sea Level Information from Paintings (D.Camuffo)

[23] ISAC, Camuffo, Dario Apr.26, 2004

3.6 C-Mark Dating and Cataloging

Collecting as much C-mark information as possible will serve two main purposes : to create a database of all known C-marks for the purposes of future research and reference, as well as to date the marks by placing their height within the tidal progression chart, and finding a corresponding year, resulting in the possibility for more data points.

Dr. Camuffo's study referenced three C-markers around the city with verified dates. Previous WPI research revealed over 100 engraved locations within the canal walls of Venice (see background), none of which revealed years of engraving. Since our study focuses on sea level indicators which have dates, it may seem that these would be of no obvious use. Conversely, we may be able to reverse-engineer a useful date for these C-marks by using the knowledge we apply to standard sea level indicators.

The scope of this study involves locating, and dating more then the three verified dated markers, and to employ them toward supporting our ultimate tide progression chart. By first obtaining the previously documented list of C-mark locations, this study will create a thorough Microsoft Access database, as well as Web GIS database of the C-marks, complete with maps, digital photos, and other helpful information to make the database as complete as possible.

If a standard painting or photograph can create an absolute sea level height by way of its corresponding year, this study proposes that a C-mark can be assigned a corresponding year by way of its absolute height. For example, if a C-mark is measured to have an absolute elevation of -24 cm, if we apply this height to the resulting progression line (see Figure 20, red line) we see the line dropped vertically to a corresponding year, which in this case, appears to fall approximately around 1797.

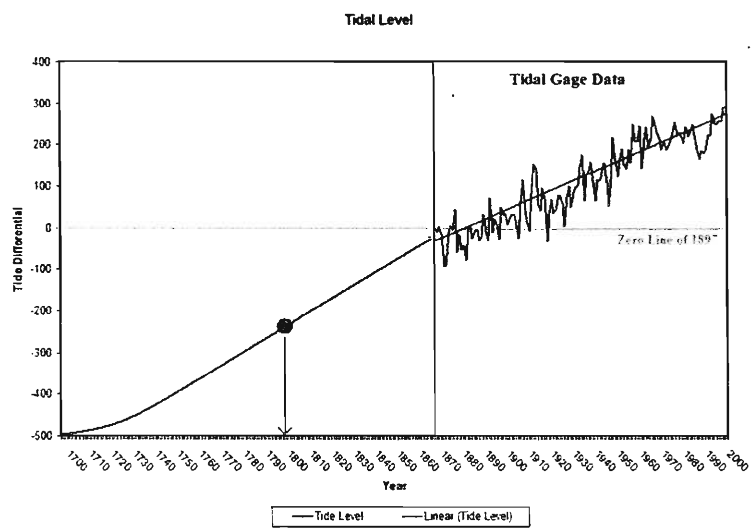


Figure 20– Dating C-marks by Absolute Height

This method of dating will be applied to as many C-marks as possible (see results), and will be included in the final Access database.

3.7 Testing Validity

All measurements in this study are referenced off of a naturally occurring, biological sea level indicator, the green algae line. This biological indicator is subject to a number of different variables which affect the way in which the organism proliferates, in turn affecting our measurements. The reliability of this study rests on the notion that all measurements in and around the green line are as accurate as possible. Hence, it is important to consider the possibility that the validity of measurements is threatened by many erroneous factors, which may culminate in one large margin of error for each statistical measurement.

Figure 21 - Algae Line

There appear to be three main environmental factors which affect the naturally occurring algae line in Venice; sun light exposure, canal wall material composition, and waves created naturally or by boat wake. This "biological error" must be accounted for in all resulting measurements by performing a number of bio-statistic analyses of the organism's reactions to different environmental variables.

In any test involving several variables, it is important to conduct experiments which isolate one variable at a time to determine their individual contribution. By eliminating the possibility of other influences, one variable may be examined. The same premise will be used for this study, where multiple factors may be affecting the growth height of the important algae line. Once enough data is present, a statistical analysis of each variable will be performed using unpaired t-tests[24]. An unpaired t-test take two sets of unrelated data, and compares them to each other to determine their statistical relevance.

A typical unpaired t-test which reveals a 5% relation or lower, is considered to instill a high level of confidence in the hypothesis being considered, whereas percentages yielding a higher value tend to disprove the hypothesis.

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[24] Shonat, Ross 2003

3.7.1 Sun Exposure

The first environmental condition which may affect validity of the algae line is the duration of sunlight exposure on the canal walls. The characteristic of sunlight affecting growth of plant organisms in different geographical directions is present not only in the marine environment, but on dry land as well. Lichen, a type of moss, tends to grow on the north facing side of vertical faces, where sun exposure is minimized. To what degree this trend affects algae is of interest in this examination of sun exposure. In order to analyze the effect of sunlight on algae, green lines existing on the same materials, in the same canal, with different sun exposures will be measured from a known elevation point at different positions. In order to achieve two completely different sun exposure levels, a canal must run roughly perpendicularly to the north south direction with one canal side facing north and the other side facing south (*see Figure 22*). Objects with southern exposure receive large amounts of sunlight during the course of the day, while objects with northern exposure tend to be shaded from sunlight. .

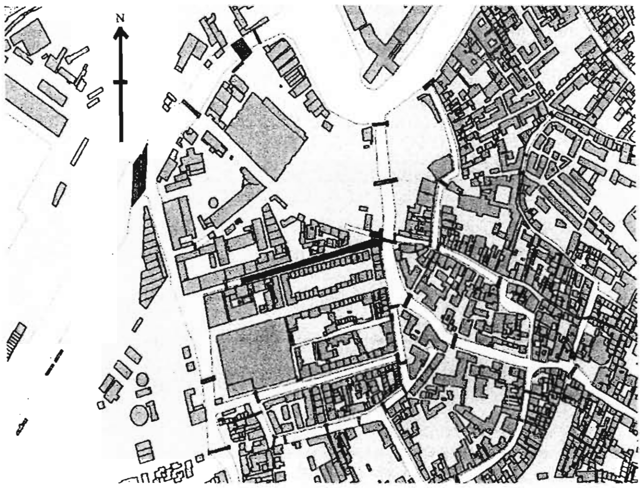

Figure 22 - Map of canal in red running roughly perpendicular to north south

In order to gather enough data about algae growth, 60 measurements will be taken in total, 30 from each side of the canal, of algae growing on the same type of building material from one known elevation point for both sides of the canal. This ensures that each measurement will be an average of the fluctuations in growth due solely to sunlight exposure.

3.7.2 Building Materials

The next variable to be examined is the canal wall material composition factor. Canal walls are commonly constructed with stone and brick. The algae grow on these materials, forming the green line used for all measurements in this study. Different materials in the green line however, may affect the rate at which algae grows. Because algae depend upon a moist environment in which to grow, one material may be more suitable to this then another, hence yielding a higher, or thicker green line. Brick, an inherently porous material, is hypothesized to be the more stimulating climate for algae.

The influence of building materials is tested in a manner that will isolate this variable from the other validity variables by using one side of a canal running east-west (to ensure that sun exposure is not a factor), or average wave height (to ensure wave height is not a factor) and measuring growth on two different types of materials. All measurements will be taken from areas of known elevation within the same canal. Thirty of the measurements will be on brick face and 30 on stone face, measuring from the current green line to the point of known elevation.

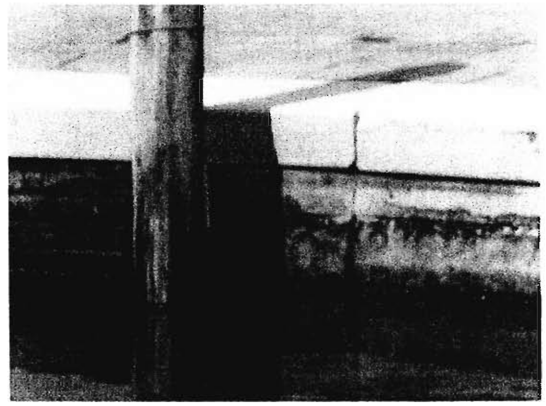

Figure 23 - Brick and Stone on a Canal Wall

3.7.3 Waves

The final variable is wave height contribution from wind as well as boat traffic. Algae tends to grow in areas of increased moisture. This leads to the conjecture that areas where waves increase the height of wet areas on canal walls, increase the height of the green algae line. Using data obtained from the *Centro Maree* in Venice, differing amounts of boat traffic will be analyzed by taking the data and determining what measurement sites are relevant to painting/photo sites in the area.

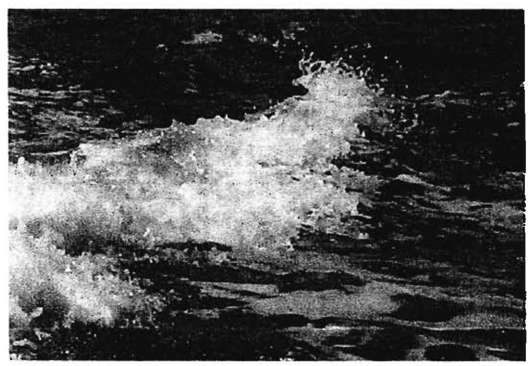

Figure 24 - Waves

The five stations (Celestia, S. Geremia, Palazzo Cavalli, Punta Salute, and Rio di Noale) are located within close proximity to the painting and photo site locations. The following table shows which painting/photo sites correspond with specific monitoring stations. Note: photo site F002 does not correspond with any station because the canal leading up to the Arsenale dead-ends at a Military zone.

Table 3 - Centro Maree Wake Information Table

	Altezza d'onda significativa medie mensili dei valori registrati nel periodo luglio - dicembre 2003					
Stazione	**lug-03**	**ago-03**	**set-03**	**ott-03**	**nov-03**	**dic-03**
Canale Giudecca	0.19	0.19	0.19	0.18	0.18	0.17
Sacca Misericordia	0.13	0.12	0.13	0.14	0.13	0.12
Murano	0.12	0.12	0.11	0.12	0.08	0.09
Punta Salute	0.12	0.12	0.11	0.11	0.1	0.11
Celestia	0.1	0.09	0.11	0.12	0.1	0.1
Rio Novo	0.09	0.08	0.09	0.09	0.1	0.1
S. Geremia	0.07	0.07	0.08	0.08	0.07	0.07
Palazzo Cavalli	0.06	0.06	0.06	0.06	0.06	0.05
Rio di Noale *(closed)*	0.03	0.04	0.05	0.05	0.05	0.05
Burano	0.05	0.05	0.03	0.03	0.03	0.02

Once the data is obtained from the *Centro Maree,* a statistical analysis will be performed on the data from each station for the duration of the 6 month sampling period. The analyzed data represents the average, top 1/3 height of all waves measured during that particular month at each station. These stations record measurements at a frequency of once every 50 minutes throughout the course of each 24 hour day. In the case of Rio di Noale, the monitoring station was still collecting data while the river was closed to boat traffic during 2003. While no painting or photo sites are located within the vicinity of this monitoring station, the data collected is representative of the waves caused solely by wind.

Table 4 - Sea Indicator and Proximity to Nearest Centro Maree Station

Centro Maree Station	**Painting/Photo Site Code**	**Average Wave Height (in m)**
Punta Salute	P003a	0.11 ± 0.01
	P003b	
	P011	
	P012	
	F001	
Celestia	P001a	0.1 ± 0.01
	P001b	
S. Geremia	P006	0.07 ± 0.005
	P007	
	P014	
	P016	
	F010	
Palazzo Cavalli	P005	0.06 ± 0.004
	P009	
	P018	
	F003	
Rio di Noale	*closed to traffic*	0.05 ± 0.01

The algae line will be sampled from locations with approximately the same absolute elevations and compared in order to determine what differences result from boat wakes; as well as how that difference relates to the average height of the wakes. This correlation was then used to determine the boat wake wave contribution using the data from the *Centro Maree* and applied to the appropriate painting and photo locations.

Once enough data is present, a statistical analysis of each variable will be performed using unpaired t-tests. An unpaired t-test takes two sets of data, and compares them to each other to determine their statistical relevance.

4.0 Results

4.1 Validity and Error Testing

4.1.1 Sun testing

The Sun Test was conducted on Rio d. San Barnaba, located in Dorsoduro, during a period of low tide. This rio runs East-West allowing for the canal wall of Campo San Barnaba to have northern exposure, while the wall of Fondamenta Alberti has southern exposure. Both sidewalks on this portion of the canal were at the same height with respect to each other and were constructed of the same brick material.

In total, 60 algae line measurements were taken from a 50 meter section of this canal; 30 from each side. The measurements were taken from the level of the sidewalk down to the green algae line and at intervals of roughly 50 cm along both sides, allowing for a good sampling of the heights of algae growth from both sides.

The hypothesis derived from onsite observations had been that algae tend to grow higher on materials with northern exposure (see section 3.7.1). Following data collection, a statistical analysis was performed on both sampling populations to determine if they were, in fact, statistically different. As seen in *Figure 25*, there appears a clear distance between the two sampling populations. The average distance the algae grew from the sidewalk, or sample mean, with northern exposure was 51 cm with a standard deviation from this mean of ± 4.5 cm. On the side with southern exposure, the sample mean was 60 cm with a standard deviation of ± 2.5 cm.

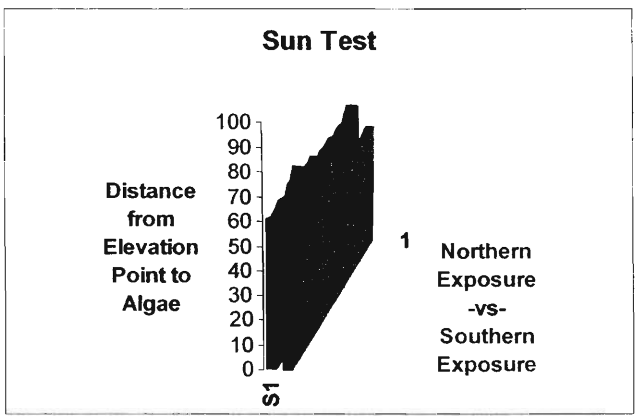

Figure 25 – Correlation between north, south exposure data

The hypothesis developed regarding the algae growth was then tested using an unpaired t-test, yielding a t value of 8.908. In regards to the hypothesis being wrong, this t value results in a probability of less than 0.001%. Thus, with 100% confidence, it can be stated that *algae grows higher on surfaces with northern exposure.* From this, the error to be applied to all other algae measurements, occurring from sun exposure, is the difference between the two sample means. This resulting error is ± **9 cm**.

4.1.2 Materials Testing

The Materials test was conducted on Rio dei Tolentini, located in Dorsoduro, during a period of low tide. This rio runs North-South with the canal wall being assessed having Eastern exposure, allowing for an average amount of sun exposure throughout the day. Algae lines on brick face and stone face were measured with the materials being on the same side of the canal allowing for equal sun exposure, and thus eliminating the possibility of the sun variable.

In total, 60 measurements were taken from a 50 meter section of canal; approximately 25 meters of brick face and approximately 25 meters of stone face. Thirty measurements were taken for each material, starting from the elevation point on the sidewalk down to the top of the green algae line.

The hypothesis developed for the effect of different materials based on on-site observations was that algae tends to grow higher on brick surfaces than on stone (see section 3.7.2). Following data collection, a statistical analysis was performed on both sampling populations to determine if they were, in fact, statistically different. As *Figure 26* shows, there appears to be a distinct difference between both sampling populations. The average distance (sample mean) from the elevation point to the top of the algae line on brick was 33 cm, with a standard deviation from this mean of ± 6.2 cm. The mean distance from the elevation point to algae growth on stone was 40 cm with a standard deviation of ± 5.5 cm.

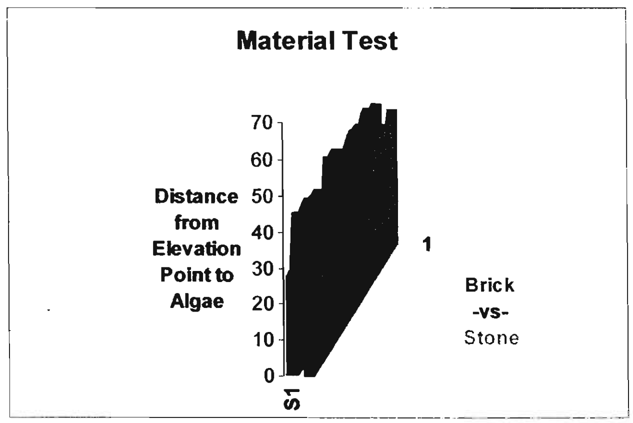

Figure 26 – Correlation between Brick and Stone data

With means and standard deviations of the data calculated, a statistical analysis was completed. Using an unpaired t-test, the hypothesis regarding material effect on algae growth was tested, yielding a t value of 4.848. This value translates to a probably of the hypothesis being incorrect of less than 0.001%. As a result, with 100% confidence, we can say that *the material in the canal does affect algae growth and that algae grow higher on brick surface than stone.* From this, the error resulting from material composition to be applied to our measurements is the difference between the two sample means. This resulting error is **± 7 cm**.

4.1.3 Wave Testing

The wave test was conducted using data obtained from 5 of the *Centro Maree's* wave height monitoring stations. In order to determine whether the height of waves frequenting an area truly has an effect on the height of the green algae line in the same area, two canals will be analyzed; the Grand Canal in front of the Palazzo Cavalli and the Arsenale canal. Each canal runs in the same direction (compass orientation) where the measurement area is concerned, is made up of the same building material, yet has greatly differing amounts of boat traffic using the waterway.

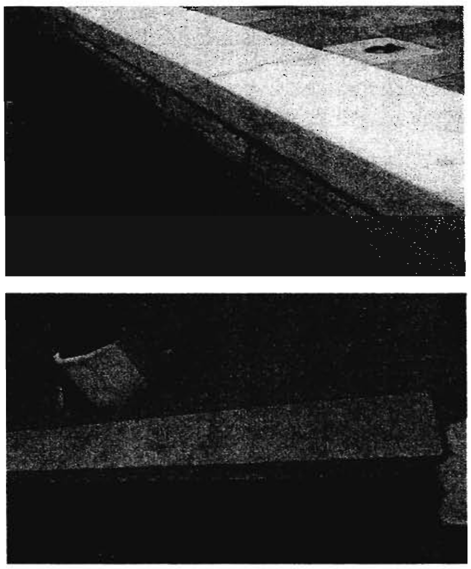

Figure 27 - Measurement sites Arsenale (top) and Grand Canal (bottom)

The canal wall of the Campo Arsenale sits at an average absolute elevation of 0.954 m and is constructed of stone (*see Figure 27, top*). The canal wall of Riva del Carbon sits at an average absolute elevation of 0.954 m, and is also constructed of stone (*see Figure 27, bottom*). The *Centro Maree* monitoring station Palazzo Cavalli is located next to the sidewalk of Riva del Carbon, and its boat wake wave height data will be assessed to determine the correlation between algae growth and wave height. The average wave height measured during a 6 month period in 2003 from this station is 0.06 ± 0.004 m.

In total, 30 measurements were taken from these two canal walls. Fifteen data points were collected from a 6 meter long area of canal (*see Figure 28, top*) between the Arsenale bridge and the left tower (AC). Fifteen measurements were also taken from an approximately 6 meter long section of sidewalk of Riva del Carbon (*see Figure 28, bottom*) to the left of Palazzo Farsetti Loredan (GC).

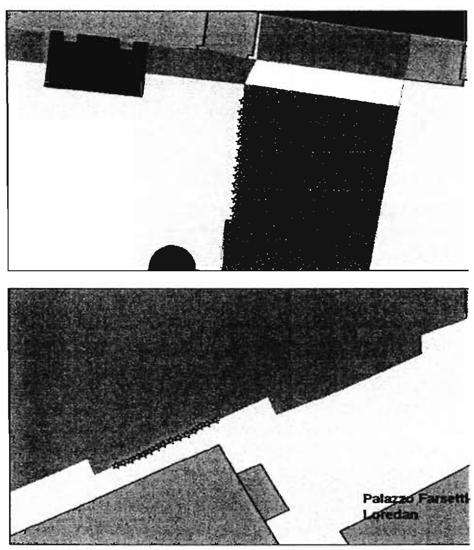

Figure 28 - Arsenale (top) and Riva del Carbon (bottom)

The sampling mean for the AC measurements is 46 cm with a standard deviation of ± 2.6 cm. The sampling mean for the GC measurements is 55 cm with a standard deviation of ± 2.3 cm. Using an unpaired t-test, these populations were then analyzed to determine their statistical difference and to test the hypothesis that areas with higher boat wake will have higher algae lines. The test yielded a critical t-value of 9.5584, which results in a probability of the hypothesis being wrong of less than 0.001%.

The correlation between boat wake wave height and the changes to the algae line must then be determined. The increase in algae line height due to boat wakes is the difference between the two sampling means; which is **9 cm** (*see Figure 29*).

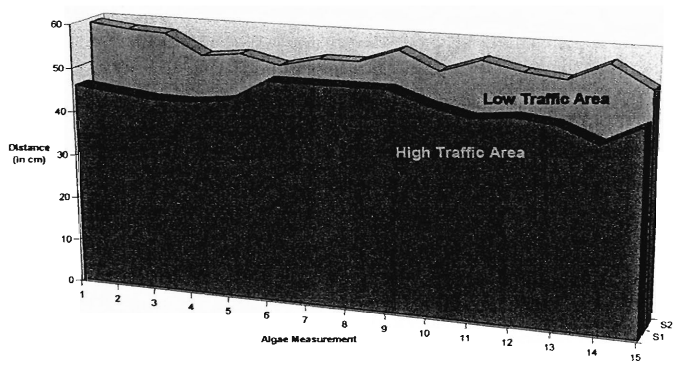

Figure 29 - Difference between the sampling means

Using the data from the Palazzo Cavalli *Centro Maree* monitoring station, located directly to the right of the measurement area on Riva del Carbon, the average shift in algae (9 cm) is divided by the average 1/3 highest wave measurement (6 cm). The resulting relationship shows that for every 1 cm of wave height the algae line is shifted approximately 1.5 cm higher. The following table illustrates the calculated algae shift, or error, associated with each painting/photo site.
The resulting error from waves will be applied to each site depending on which *Centro Maree* they correspond to.

Table 5 - Calculated algae line shifts from wave contribution

***Centro Maree* Station**	**Painting/Photo Site Code**	**Average Wave Height** (in m)	**Calculated Algae Shift** (in cm)
Punta Salute	P003a	0.11 ± 0.01	**± 16.5**
	P003b		
	P011		
	P012		
	F001		
Celestia	P001a	0.1 ± 0.01	**± 15**
	P001b		
S. Geremia	P006	0.07 ± 0.005	**± 10.5**
	P007		
	P014		
	P016		
	F010		
Palazzo Cavalli	P005	0.06 ± 0.004	**± 9**
	P009		
	P018		
	F003		
Rio di Noale	*closed to traffic*	0.05 ± 0.01	**± 7.5**

4.1.3 Human Error

While human error is generally unacceptable and usually preventable, it can and does occur despite even the most careful planning of experimentation techniques when in the field. Within this study, human error can occur in two different categories: on-site measurements and the painters, photographers or stone workers creating the sea level indicators being used.

In order to ensure that all derived values in this study are accurate, the possibility of human error must be considered. Depending on the specific dimensions of the objects being measured within the paintings and photos, the amount of error will also vary. To observe what effect even the slightest erroneous measurement may have, two different painting sites will be examined. For two painting sites, the changes caused by small increments in the measurements will be illustrated in the table below. For example, in site P001a, a difference of ± 1 cm difference in an on-site measurement results in a ± 0.40 cm difference in the calculated algae shift.

	Site Code	
	P001a	P014
Error Margin in Painting	**Effect on calculated measurements** (in cm)	
± 1 mm	± 21.5	± 16.27
± 5 mm	± 107.5	± 81.33
± 10 mm	± 215	± 162.67
Error Margin On-Site		
± 1 cm	± 0.40	± 1.07
± 5 cm	± 1.96	± 5.33
± 10 cm	± 3.93	± 10.67

Table 6 - Table of Human Error Data

These values were derived by taking the calculations used to determine the algae shift from the paintings, and changing the measured values by the above increments to observe the changes which occur in the final calculated algae measurements. The resulting effect would create a unique human error value for each painting.

4.2 Usable Paintings

The first objective at each painting site was to determine whether or not it was usable. There are many changes that can occur in a period of over two and a half centuries. Buildings can be re-designed, canal walls re-built, windows and doors relocated, bridges removed, etc. If many changes have occurred at a site, especially where the algae line is visible in the painting, then the site is deemed unusable. For the very reason that many of our original painting selections were deemed unusable, this section has been divided by usable, and unusable paintings.

The most important factor in yielding accurate results is the use of the scale formula. The scale formula is as follows:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

Where X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential. This formula puts the measurement into real terms, making the measurement appear to be taken from the same point of view as the painting or photo. Once the waterline differential is found, it is used to find the absolute elevation of the algae line in the painting. *(see appendix D for examples of how these formulas are used)*

4.2.1 P001 - San Giovanni e Paolo (Bellotto - 1741)

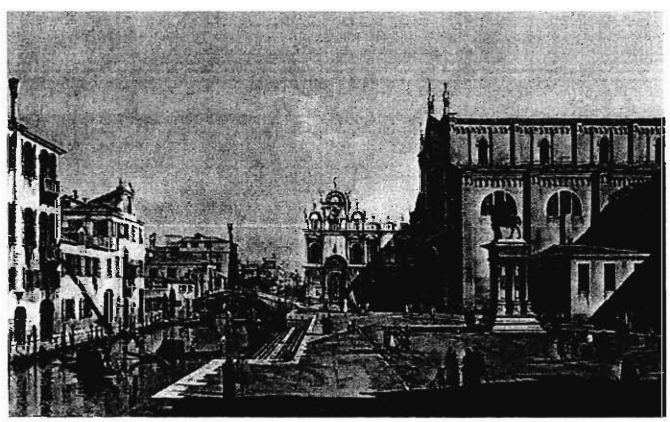

Figure 30 - P001a: Campo S. Giovanni e Paolo (Bellotto)

There are three total paintings of San Giovanni e Paolo, two have been deemed usable. The two usable paintings are index number P001a and P001b. Bellotto created P001a in 1741. The visible and usable algae line in the painting comes from the buildings on the left side of the Rio di Mendicanti. Actual measurements were taken from the area under the third archway from the left *(see* Figure 30, *red arrow).* The archway was used as a horizontal and vertical measurement reference. The final vertical measurement was taken from the sidewalk of the archway to the top of the green line *(see appendix D, P001a).* Using these measurements and the scale formula, a waterline differential of 74.75 cm was derived. This translates to a 74.75 cm rise in sea level since 1741. Yearly, this averages a rate of approximately 0.284 cm per year.

In order to put this result in absolute terms a measurement must be taken from a point of known elevation. In this case, the known elevation was at the sidewalk inside of the archway. A measurement was taken from this sidewalk down to the green algae line. In order to get an absolute elevation, a measurement taken from the known elevation is subtracted from the known elevation to get X. The waterline differential is then subtracted from X to get the absolute elevation of the green line in the painting. The known elevation of the sidewalk at this site was 89 cm, and the measured distance to the green line was 59.5 cm. X in this case equals 29.5 (89-59.5). When the waterline differential (74.75 cm) is subtracted from 29.5 the result is an absolute green line elevation of –45.25 *(see appendix D, P001a)*. The reason for a negative number in this case is because the zero line used as reference was established in 1897. Since all paintings used in this study were created prior to that time, all absolute elevations of algae lines for painting sites will be negative.

4.2.2 P001b - San Giovanni e Paolo (Bellotto - 1747)

Bellotto also created the painting with index number P001b. Although it is of the same view as P001a, it was painted 6 years later in 1747. The same archway used in P001a was used for measurements in P001b *(see Figure 31, red arrow)*. Using the scale formula in the same manner as in P001a, the waterline differential for P001b was found to be 72.97 cm. Applying the same absolute elevation formula, the absolute elevation was found to be –43.47 cm.

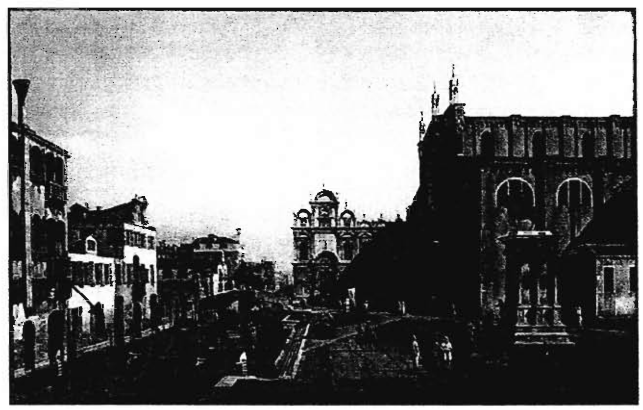

Figure 31 - P001b: Campo S. Giovanni e Paolo (Bellotto)

This painting was created six years after P001a. Theoretically, the difference in green line elevation should be 1.704 (6 years x .284 cm per year). The difference in green line elevation for these two sites is a 1.78 cm difference (45.25-43.47), accurate within .08 cm.

These results show that this site supports the methodology behind this study while simultaneously showing that the tidal levels appear to have been increasing, and maintaining a fairly constant rate.

4.2.3 P002 - Grand Canal: From S. Sofia to Rialto (Canaletto 1758)

Canaletto created this painting in 1758. The valuable green algae line is visible on the buildings on the left side in the painting. The building used for measurements was the second building in from the left, which today is the Foscari Palace hotel. Measurements used in the scale formula were off of the second window in from the left on the building *(see Figure 32, red arrow).* The green line directly under this window is where the green algae line was measured from. Using the scale formula, the waterline differential at this site was found to be 58.6 cm *(see appendix D, P002).* The absolute height of the algae line in the painting was calculated to be –39.6 cm. Having been created in 1758, this painting is the youngest of the study. It was created nearly 20 years after S. Giovanni e Paolo; therefore its absolute was expected to be above that of S. Giovanni e Paolo. Site P001a was found to have an absolute elevation of –45.25, which is a 5.65 cm difference from this site.

Figure 32 - P002: Grand Canal: From S. Sofia to Rialto (Canaletto)

Using the same .284 cm rise/year calculation that was found from S. Giovanni e Paolo, this site should be a 4.83 cm difference (.284 cm/yr x 17 yr) from S. Giovanni. Therefore the methodology still withstands within an error of less than one centimeter (5.65 - 4.82 = 0.83 cm).

4.2.4 P003(a) - Grand Canal: Looking East, from the Campo di S. Vio (Canaletto - 1725)

Canaletto created this painting from the Campo di S. Vio in 1725. The most visible green algae line is located on the buildings on the left side of the Grand Canal. The building used to take measurements from is the three-story building on the left *(see Figure 33, red arrow).* A vertical measurement was taken from the second window from the right. Then a measurement from the bottom of the window to the green line was taken. Using the scale formula the waterline differential was found to be 73.0 cm for this site. Taking a measurement of 75 cm from the known elevation of the sidewalk in front of this building (105 cm) to the green line, an

Figure 33 – Grand Canal: Looking East, from the Campo di S. Vio (Canaletto)

absolute elevation of the green line was found to be –46 cm *(see appendix D, P003a).* This painting is the oldest used in this study and has the lowest absolute elevation, putting it as the first data point on the tidal progression graph.

4.2.5 P005 Grand Canal: Looking South-West from the Palazzo Grimani to the Palazzo Foscari (Canaletto – 1735)

This painting site is located on the Grand Canal facing southwest from the Palazzo Grimani. The visible algae line can be seen on the buildings on the left side of the painting. The two first buildings from the left are those with the most visible algae line. The building with the orange tint color, first from the left, could not be measured from due to the construction of docks in front of the area where the algae line is visible. The next building from the left is the one that was used for measurement *(see Figure 34, red arrow).* The area measured was underneath the left-most window on the building. Using vertical measurements from the bottom of this window, a waterline differential of 58.6 cm was found from 1735 when Canaletto created this cityscape *(see appendix D, P005).*

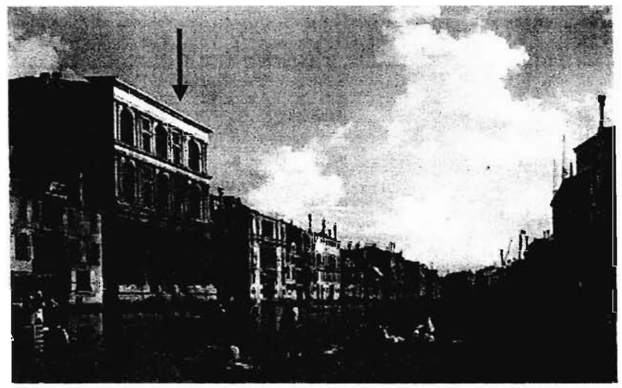

Figure 34 - Grand Canal: Looking South-West from the Palazzo Grimani to the Palazzo Foscari (Canaletto)

To get an absolute elevation, the sidewalk in-between the two buildings on the left was used. The distance of the green algae line to the known elevation of the sidewalk was added to the waterline differential and then subtracted from the known elevation to get an absolute height of –45.6 cm from the zero line of 1897. This painting's absolute height should be lower than that of S. Giovanni e Paolo, which was created 5 years later. P001a's absolute elevation is –45.25 cm, which is a difference of less than one centimeter when compared to this site's absolute height. Therefore, the absolute heights are agreeable with the progression trend.

4.2.6 P006 – Grand Canal: S. Geremia and the Entrance to the Cannaregio (Canaeletto - 1735)

Canaletto created this painting in 1735. There are two areas that a green algae line is visible in this view. The first is under the wall to the left of the painting. This area could not be used for measurement because the wall has been reconstructed and any windows on the building behind the wall could not be used for the scale formula due to their location. The location is unsuitable because this painting is vanishing point perspective and the results would be skewed if the measured areas were not right next to, or above one another.

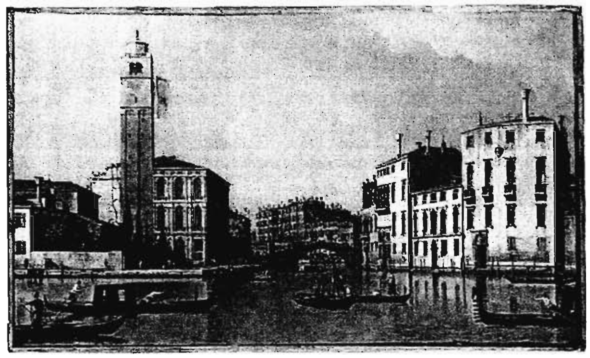

Figure 35 – Grand Canal: S. Geremia and the Entrance to the Cannaregio (Canaletto)

Due to the complications with measuring on the left side, measurements were taken off the bottom-right window on the building to the far right. Once a vertical and horizontal was taken from the window, the scale formula was applied and a waterline differential of 63.44 cm was found *(see appendix D, P006)*. The sidewalk to the right of this building was used to find the absolute elevation of the algae line in this painting to be –44.44 cm. This is within less than one centimeter of error than that of P005, which was also created in 1735. This reason this difference exists could be that the paintings were created at different times of the year and also any threats to validity or human error.

4.2.7 P007 – Grand Canal: Looking South-West from the Chiesa degli Scalzi to the Fondamenta della Croce, with S. Simone Piccolo (Canaletto – 1738)

Canaletto created this painting of the Grand Canal near the Scalzi church in 1738. The area used for measurements is to the left of the painting. The horizontal of the low wall in between the two buildings on the left was used in the scale formula *(seeFigure 36, red arrow)*. The vertical from the sidewalk to the algae line was also used to get a waterline differential of 71.29 cm for this site. The

Figure 36 - Grand Canal: Looking South-West from the Chiesa degli Scalzi to the Fondamenta della Croce, with S. Simone Piccolo (Canaletto)

known elevation of the sidewalk (.92 m) was then applied to find the absolute elevation of the green line in the painting to be –41.29 cm. A waterline differential of 71.29 is a .268 cm/year rise in sea level, which is a difference of only .02 cm from that of S. Giovanni e Paolo's yearly sea level rise.

4.2.8 P009 - Grand Canal: The Rialto Bridge from the North (Canaletto – 1727)

Canaletto created this cityscape in 1727. There are only two areas in this painting where the green algae line is visible. They are both located on the building to the left in the painting. The only accessible area where the algae is visible is under the railing on the right of the building *(see Figure 37, red arrow)*. The window to the far right on this building was used for a vertical and horizontal measurement. When the scale formula was applied a waterline differential of 71.5 cm was found. In order to put this into absolute terms, the known elevation of sidewalk with the railing to the right was used. The resulting absolute height of the green line in this painting is –45.5 cm, which is agreeable with the year it was created.

Figure 37 - Grand Canal: The Rialto Bridge from the North (Canaletto)

4.2.9 P0010 – Punta Della Dogana (Canaletto – 1727)

In addition to P009, Canaletto also created Punta Della Dogana in 1727. The punta still exists today, however there are some things that have changed. Most changes are not visible to the naked eye, but the level of the fondamenta on the punta has been raised by over 20 cm. However, measurements were still taken at this site. The height and width of a section of the near-most column was taken and scaled with a measurement from the fondamenta to the green algae line. Since the fondamenta has been raised, the changes needed to be made to the measurements *(see note in appendix D, P010)*. The resulting waterline differential was found to be 69.5 cm. Using the known elevation of the punta, the absolute elevation of the green line was found to be –37.5 cm. However, these results are very skewed.

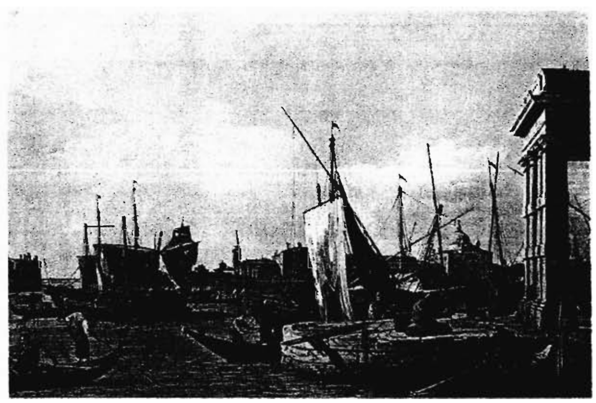

Figure 38 - Punta Della dogana (1727)

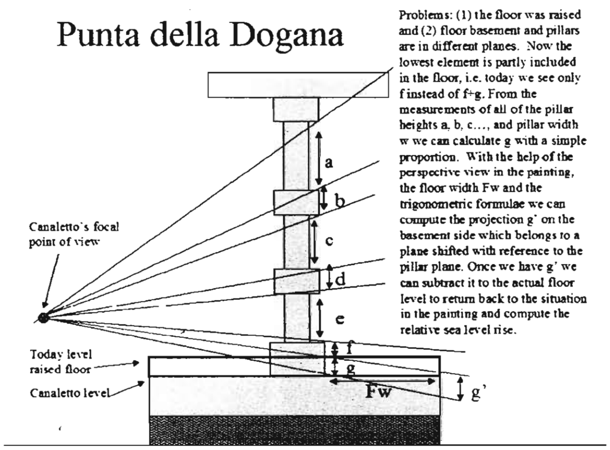

Figure 39 - Punta Dogana Explaination

Figure 39 shows how the punta has been raised since the days of Canaletto. It is still possible to get a relative waterline differential, but it is difficult to get an accurate absolute elevation of the green line because the punta has been raised and reconstructed more than once. This is why the absolute elevation of –37.5 is not correct. The painting is dated in 1727, which would mean it should have an absolute height lower than almost all of the other paintings, which it does not. Therefore, this painting will not be included in the trend line because it is not accurate enough.

4.2.10 P011 – The Grand Canal and the Church of the Salute (Canaletto – 1730)

Canaletto created this painting in 1730. There is a visible algae line along the steps in front of the church of the Salute *(see Figure 40, red arrow).*

Figure 40 - The Grand Canal and the Church of the Salute (1730)

The measurements needed for the scale formula were taken off the church of the Salute under to windows to the left. The main vertical measurement that was put into the scale formula was taken from the top of the stairs to the bottom of the stairs. Then a measurement was taken from the bottom of the stairs, which is also the sidewalk in front, to the green algae line. A waterline differential of 72.57 was then determined from the scale formula. In order to find the absolute height of the algae line in this painting the known elevation of the sidewalk in front of the church was used. The resulting absolute height was found to be –48.57 cm *(see appendix D, P011).*

4.2.11 P012 – Entrance to the Grand Canal (Bellotto – 1741)

Figure 41 - Entrance to the Grand Canal (1741)

Bellotto created this painting in 1741 looking south towards the Entrance to the Grand Canal. One area that the green algae line is visible is located on the convent to the right of the painting. However, the convent no longer exists so that algae line could not be used. The usable algae line is located on the building to the left of the painting, just underneath the dock. The door on the first floor of this building still exists today as it was in the painting and it was used for measurements. Using a vertical on the door, and a vertical from the sidewalk at the bottom of the door to the algae line, the waterline differential for this site was found to be 70.25 cm *(see appendix D, P012).* Using the known elevation of the sidewalk, the absolute height of the algae line in this painting was found to be –44.75 cm.

4.2.12 P014 – Grand Canal: Near S. Stae Church (Bellotto 1740)

Figure 42 - P014: Grand Canal: Near S Stae Church

Site P014 is located near San Stae church on the Grand Canal. Bellotto painted this cityscape in 1740. The visible algae line in this painting is located on the red building on the right side of the painting. The building has not changed since the time of the painting so it can be used for measurement. The object measured was the window on the bottom-left of the building *(see Figure 42, red arrow).* A vertical and horizontal measurement was taken of the window and the distance from the bottom of the window to the green line. Using the scale formula, the waterline differential for this site was found to be 77.27 cm. In order to get the absolute elevation of the green line, the known elevation of the sidewalk next to the building was used. The absolute elevation was found to be –42.27 cm for this site *(see appendix D, P014).* This elevation is slightly lower than that of P001a (S. Giovanni e Paolo), which appears to make it accurate because it dates prior to that of P001a (1741).

4.3 Unusable Paintings

Three paintings have been deemed unusable. A painting is deemed unusable due to changes at the site locations since the date of the original painting which would impede accurate measurements. In most paintings the valuable green algae line is only visible in small areas. If these small areas have been reconstructed, or removed, then it is impossible to make any accurate measurements.

4.3.1 P004 - GC: From Sta. Maria della Carita to the Bacino di San Marco (Canaletto – early 1730s)

Canaletto created this painting in the early 1730's. There are a large number of changes in the present that occur from this painting. The spires on the church are gone and the bell tower is completely removed. The visible algae line in the painting is on the wall of the sidewalk foremost in the painting. This area has been completely covered up and extended out and the bridge is gone on the right. Measurements were taken at this site regardless, but there were not feasible results that could be formulated because too much has been altered in the painting.

Figure 43 - P004: From Sta. Maria della Carita to the Bacino di San Marco

4.3.2 P008 - Rio di Mendicanti and the Scuola di S. Marco (Canaletto 1723)

Canaletto painted this painting from the north end of the Rio di Mendicanti. The view includes what is the hospital today and two bridges across the Rio. However, too many aspects of this painting have changed today to take accurate measurements. First of all, the first bridge seen in the painting *(see Figure 44, red arrow)* no longer exists.

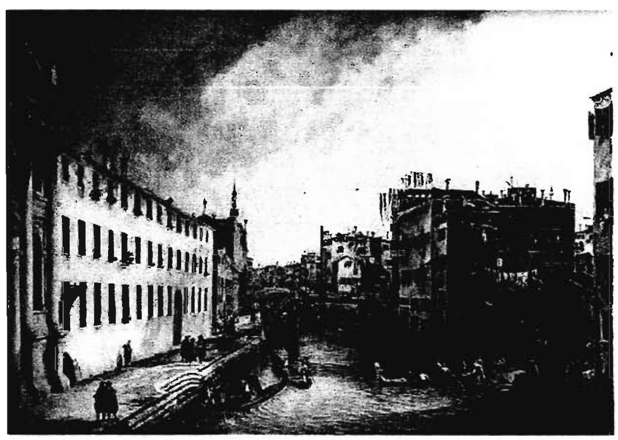

Figure 44 - P008: Rio di Mendicanti and the Scuola di S. Marco

Also, to the right of the archway on the long building on the left there are four windows, however today there are only two windows and they have arches at the top. The only algae line in the painting is along the sidewalk, which today has been raised due to rising water levels. As a result, there is no place to take an accurate measurement from, and no accurate algae line to measure to.

Figure 45 - Rio di Mendicanti Present-Day view

4.3.3 P013 - The Arsenale (Bellotto 1748)

Bellotto created this painting in 1748. It displays a visible algae line along the canal in the center of the painting. However, today the entire wall that the algae line is on in the painting has been altered. Also, the building directly above the wall in the painting no longer exists. This makes it impossible to get any accurate measurements from this site. If the algae line extended further to the left onto the tower, measurements could be taken. However, the algae line is not visible on the tower in the painting, and what is visible is not reliable. For these reasons, this site is considered to be unusable.

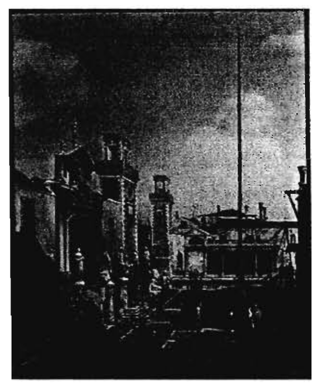

Figure 46 - P013: The Arsenale

4.3.4 P015 - Il Rio Dei Mendicanti e La Scuola Di San Marco (Bellotto 1740)

Bellotto created this painting in 1740. It is similar to that of the paintings of S. Giovanni e Paolo, except that the point of view is from further south. The only visible algae line is on the canal wall on the right side of the Rio. Unfortunately, today that wall has changed completely. It has been built up higher than it is in the painting, and also new brick has been put over the wall. Measurements taken off the algae line on the new brick would be skewed because the new brick is at an angle down towards the canal. Because the original wall in the painting by Bellotto does not coincide with the wall at present day, the results would be considered unreliable, hence deeming the painting site unusable.

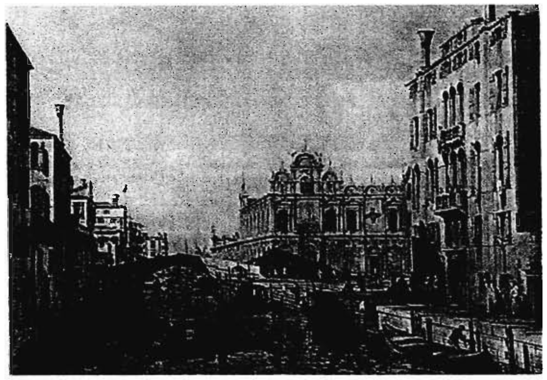

Figure 47 - P015: Il Rio Dei Mendicanti e La Scuola Di San Marco

4.3.5 P016 – Grand Canal: Looking East from the Palazzo Flangini to S. Marcuola (Canaletto – Unknown)

It would appear that this painting would be usable, but after further analysis it was deemed unusable for a few reasons. First of all, the date that Canaletto created this painting is unknown. Without the date of the painting, it would be impossible to put the results on the tidal progression line. Even if the painting was dated, there still exist other factors to why it cannot be used. The first building on the left now has a wave blocker on the bottom of it (see Figure 48, red arrow). This blocker is simply a large piece of stone placed right above the water line. Not only does this prevent waves, but also algae growth. Therefore, there is no algae line on this building and it cannot be measured from. The only other building in the painting with an

Figure 48 - Grand Canal: Looking East from the Palazzo Flangini to S. Marcuola (Unknown)

Figure 49 - Present Day View

algae line is to the right of this building. The second building cant be used because it has completely changed from the time of the painting to today (*see Figure 49, green box*). Unfortunately these are the only two areas in the painting that the green algae line is visible, so it has been deemed unusable.

4.3.6 P017 - Canale di Sta Chiara: looking South-East along the Fondamenta della Croce (Canaletto – Unknown)

Canaletto created this painting of the area near what are now Piazza le Roma and Ferrovia. The main problem with this painting is that the date of its creation is unknown. It would be impossible to put this painting on the tidal progression line without a known date. Also, all the buildings on the right side of the Grand Canal in the painting are gone and the train station is now in their place. This means the only algae line left to use would be that on the wall to the left. However, the line in the painting is very faint and there it is also possible that the wall has been reconstructed or raised since the creation of the painting. With all of these factors, especially that the painting is not dated, it is not possible to achieve accurate results.

Figure 50 - Canale di Sta Chiara: Looking South-East along the Fondamenta della Croce (unknown)

4.3.7 P018 - Grand Canal: looking North-East from the Palazzo Balbi to the Rialto Bridge (Canaletto – 1731)

Canaletto created this painting from the Palazzo Balbi in 1731. There is no on site data form for this painting site because the painting was deemed unusable before data collection started. The reason it is not usable is because there is no area where the algae line is clear enough to get an accurate measurement. The first building on the left casts a shadow over the algae line, so it is hard to tell where the algae line ends and the water begins. The buildings to the right also have an algae line, but they are also in shadow, so it is impossible to tell if there actually is an algae line, or it is just where the

Figure 51 - Grand Canal: Looking North-East from the Palazzo Balbi to the Rialto Bridge (1731)

actual water level is located. It would be impossible to get accurate results if the most crucial measurement for the scale formula is not available. With all of these factors in consideration, this painting was considered unusable.

4.4 Photograph Results

The first objective with each photograph was to determine whether or not it was usable. A photo is deemed reliable and usable when it fits a certain necessary criteria. For the purposes of this study, the photographs must have been taken prior to 1897, and must have a visible algae line. Even if a photo agrees with these two qualifications, it can still be eliminated from the study because of changes to the scenery today which were depicted in the photo. Many changes can occur over a century of time such as buildings re-designed, canal walls re-built, windows and doors relocated, bridges removed, etc. If many changes have occurred at a site, especially where the algae line is visible in the painting, then the site is deemed unusable. For the very reason that many of our original painting selections were deemed unusable, this section has been divided into usable, and unusable paintings.

The most important factor in yielding accurate results is the use of the scale formula. The scale formula is as follows:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

Where X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential. This formula puts the measurement into real terms, making the measurement appear to be taken from the same point of view as the painting or photo. Once the waterline differential is found, it is used to calculate the absolute elevation of the algae line in the photograph. *(see appendix D for examples of how these formulas are used)*

4.4.1 Unusable Photographs

Each photograph collected from the aforementioned archives had been collected without knowledge of their corresponding dates. Dates are of utmost importance for this study because we are focusing on pre-1900 data. The original 16 photographs were collected on the assumption that they dated before 1900, and the visual indication that they showed the *comune marino*. After contacting a representative from each archive, dates were associated with each photograph, and those which dated later then 1900 were dismissed, with the exception of one, which was 1901, and was kept for purposes of overlapping tidal gage data with photograph data.

Those 5 photos affected by the date cutoff are shown in gray within *Table 7*.

Table 7 - Photographs with Corresponding Years

Index #	Name	Year
F001	The Salute	1860
F002	The Arsenale	1866
F003	Palazzo Manin	1867
F004	Façade - Palazzo Franchetti	1870
F005	Façade - Palazzo Foscari	1870
F006	Façade - Palazzo Vendramin	1870
F007	Façade - Palazzo Contari-Fason	1870
F008	Façade - Palazzo Pesaro	1870
F009	Church of San Sebastiano	1978
F010	Façade - Ca D'Oro	1870
F011	Ca D'Oro	1978
F012	Gate – Arsenale	1978
F013	Façade - Palazzo Rezzonico	1901
F014	Façade - Palazzo Corner-Mocenigo	1978
F015	Front - Palazzo Ducale	1925
F016	Canal - City of Venice	1900

Although the remaining photographs conform to the date range under examination, on-site inspections yielded reasoning to dismiss them from this study. Such reasoning is due to changes in the waterline since the original date of the photograph, construction impeding accurate measurements, lack of access to the building or algae line for proper measurements, and extreme changes such as buildings that are no longer existent. Those photographs affected by these problems are shown in green in Table 7.

The remaining photographs were deemed reliable, and fit the necessary criteria for this study. Those not dismissed are shown on a map in *Figure* 52. All 5 of the remaining photographs are described in more detail in the following sections.

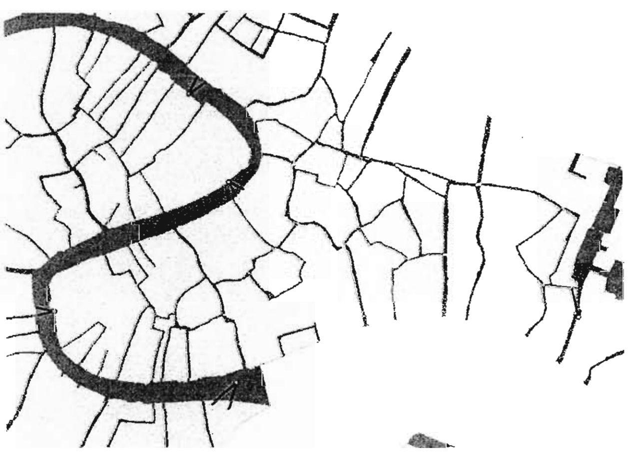

Figure 52 - Map of Usable Photograph Locations

4.4.2 F001 - The Salute (1860)

The first photograph, given index number F001, is of the Salute, located in Sestier Dorsoduro. This photo was found in the Archivio Filippi[25], and represents the earliest photograph in this study, from 1860. The visible and usable algae line in the painting comes from the front of the Salute. On-site measurements were taken from the area under just to the left of the front façade, facing the direction of the camera. *(see Figure 53, red arrow).* The column on the far right of that face was used as a horizontal reference, while the distance from the column to the sidewalk with a known elevation was used for a vertical reference. The final vertical measurement was taken from the sidewalk of known elevation to the top of the green line (*see appendix D, F001).* Using these measurements and the scale formula, a waterline differential of 33.9 cm was derived. This translates to a 33.9 cm rise in sea level since 1860. Yearly, this averages a rate of approximately 0.252 cm per year. This numerical rate of increase is similar to the .23 cm per year generally accepted by researchers.

Figure 53 - F001 The Salute (1860)

In order to put this result in absolute terms a measurement must be taken from a point of known elevation. From this elevation point, algae height can be derived in the photograph. When a ratio is established, which in this case was 218:1(*see appendix D, F001*, the measured height of the algae to the elevation point in the photo can be brought into large-scale terms by multiplying by the ratio. This interprets into the measurement that the algae line in 1860 was 147.9 cm below the current sidewalk elevation point. As a result of knowing this, we can obtain an absolute elevation for that measurement by subtracting from the known elevation point. In this case, we get **-6.9 cm**. The reason for a negative number in this case is because the zero line, which all elevations are referenced off of was established in 1897. Since most photographs used in this study were taken prior to that time, most absolute elevations of algae lines for photographs sites will be negative.

[25] Filippi, 1991 p 95

4.4.3 F002 - The Arsenale (1866)

The second usable photograph, given index number F002, is of the Salute, located in Sestier Castello. This photo was found in the Archivio Filippi, and is reported as being taken in 1866[26]. The visible and usable algae line in the painting comes from the left side canal wall. On-site measurements were taken on the left side of the canal, toward the towers. (*see Appendix C F002*). The towers, which still stand today, were used as a horizontal reference, while the window on the Arsenale entrance was used for a vertical reference. The final vertical measurement was taken from the sidewalk of known elevation to the top of the green line (*see appendix D, F002).* Using these measurements and the scale formula, a waterline differential of 32.05 cm was derived. This translates to a 32.05 cm rise in sea level since 1866. Yearly, this averages a rate of approximately 0.23 cm per year. This numerical rate of increase is identical to, and supports the .23 cm per year generally accepted by researchers.

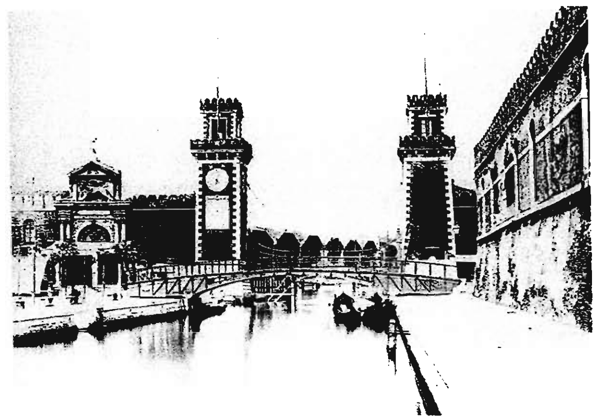

Figure 54 - F002 The Arsenale (1866)

In order to put this result in absolute terms a measurement must be taken from a point of known elevation. From this elevation point, algae height can be derived in the photograph. When a ratio is established, which in this case was 345.5 : 1 (*see appendix D, F002*, the measured height of the algae to the elevation point in the photo can be brought into large-scale terms by multiplying by the ratio. This interprets into the measurement that the algae line in 1866 was 100.05 cm below the current sidewalk elevation point. As a result of knowing this, we can obtain an absolute elevation for that measurement by subtracting from the known elevation point. In this case, we get **-6.05 cm**. The reason for a negative number in this case is because the zero line, which all elevations are referenced off of was established in 1897. Since most photographs used in this study were taken prior to that time, most absolute elevations of algae lines for photographs sites will be negative.

[26] Filippi 1991, p.161

4.4.4 F003 – Palazzo Manin (1867)

Figure 55 - Palazzo Manin (1867)

The third usable photograph, given index number F003, is of Palazzo Manin, located in Sestier San Marco. This photo was found in the Archivio Filippi, and is reported as being taken in 1867[27]. The visible and usable algae line in the painting comes from the Grand Canal wall left to right.

On-site measurements were taken on the right side of the photo on the left side of Palazzo Manin. (*see Appendix C F003*). The column on the far left of the palazzo was used as both a horizontal reference and a vertical reference. The final vertical measurement was taken from the sidewalk of known elevation to the top of the green line (*see appendix D, F003).* Using these measurements and the scale formula, a waterline differential of 31.57 cm was derived. This translates to a 31.57 cm rise in sea level since 1867. Yearly, this averages a rate of approximately 0.23 cm per year. This numerical rate of increase is identical to, and supports the .23 cm per year generally accepted by researchers.

In order to put this result in absolute terms a measurement must be taken from a point of known elevation. From this elevation point, algae height can be derived in the photograph. When a ratio is established, which in this case was 179.5 : 1 (*see appendix D, F003*), the measured height of the algae to the elevation point in the photo can be brought into large-scale terms by multiplying by the ratio. This interprets into the measurement that the algae line in 1867 was 82.57 cm below the current sidewalk elevation point. As a result of knowing this, we can obtain an absolute elevation for that measurement by subtracting from the known elevation point. In this case, we get **-5.57 cm**. The reason for a negative number in this case is because the zero line, which all elevations are referenced off of was established in 1897. Since most photographs used in this study were taken prior to that time, most absolute elevations of algae lines for photographs sites will be negative.

[27] Filippi 1991, p.32

4.4.5 F010 – Façade Ca D'Oro (1870)

The Fourth usable photograph, given index number F010, is of Palazzo Manin, located in Sestier San Marco. This photo was found in the Courtauld Institute Art and Architecture archive, and is reported as being taken in 1870[28]. The visible and usable algae line in the painting comes from the Grand Canal wall left to right.

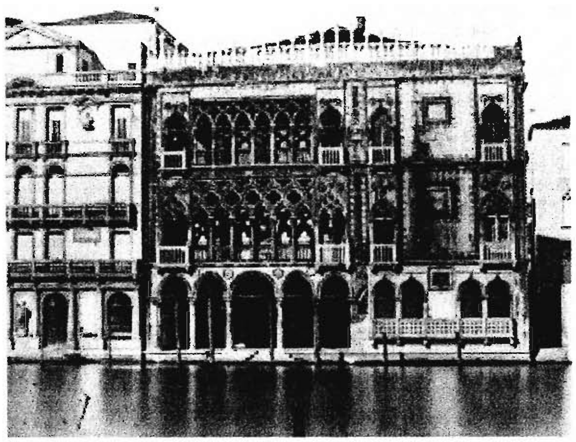

Figure 56 – Façade Ca D'Oro (1870)

On-site measurements were taken on the middle section of the photo on the second floor of Ca D'Oro. (*see Appendix C F010*). The window next to the second floor arcade was used for a horizontal reference while the same floor columns on the arcade were used for a vertical reference. The final vertical measurement was taken from the sidewalk of known elevation to the top of the green line on the right side of the palace (*see appendix D, F010).* Using these measurements and the scale formula, a waterline differential of 31.7 cm was derived. This translates to a 31.7 cm rise in sea level since 1870. Yearly, this averages a rate of approximately 0.236 cm per year. This numerical rate of increase is similar to, the .23 cm per year generally accepted by researchers.

In order to put this result in absolute terms a measurement must be taken from a point of known elevation. From this elevation point, algae height can be derived in the photograph. When a ratio is established, which in this case was 183.5 : 1 (*see appendix D, F010*), the measured height of the algae to the elevation point in the photo can be brought into large-scale terms by multiplying by the ratio. This interprets into the measurement that the algae line in 1870 was 135.7 cm below the current sidewalk elevation point. As a result of knowing this, we can obtain an absolute elevation for that measurement by subtracting from the known elevation point. In this case, we get **-4.7 cm**. The reason for a negative number in this case is because the zero line, which all elevations are referenced off of was established in 1897. Since most photographs used in this study were taken prior to that time, most absolute elevations of algae lines for photographs sites will be negative.

[28] Courtauld Institute, July 18

4.4.6 F013 – Façade Palazzo Rezzonico (1901)

The fourth usable photograph, given index number F013, is of Palazzo Rezzonico, located in Sestier San Marco. This photo was found in the Courtauld Institute Art and Architecture archive, and is reported as being taken in 1901[29]. This is the only photograph to apply later then the zero line of 1897. The visible and usable algae line in the painting comes from the Grand Canal wall left to right.

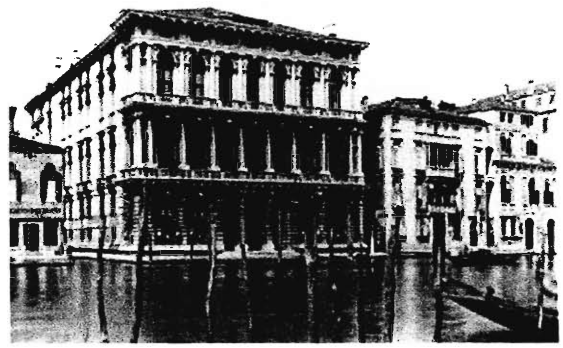

Figure 57 – Façade Palazzo Rezzonico (1901)

On-site measurements were taken on the middle section of the photo on the first floor of Palazzo Rezzonico. (*see Appendix C F013*). The distance between the left most columns was used for a horizontal reference while the distance from the ledge below the window, up to the window used for a vertical reference. The final vertical measurement was taken from the ledge of known elevation to the top of the green line on the left side of the palace (*see appendix D, F013).* Using these measurements and the scale formula, a waterline differential of 24.21 cm was derived. This translates to a 24.21 cm rise in sea level since 1901. Yearly, this averages a rate of approximately 0.235 cm per year. This numerical rate of increase is similar to, the .23 cm per year generally accepted by researchers.

In order to put this result in absolute terms a measurement must be taken from a point of known elevation. From this elevation point, algae height can be derived in the photograph. When a ratio is established, which in this case was 131.5 : 1 (*see appendix D, F013*), the measured height of the algae to the elevation point in the photo can be brought into large-scale terms by multiplying by the ratio. This interprets into the measurement that the algae line in 1910 was 105.2 cm below the current sidewalk elevation point. As a result of knowing this, we can obtain an absolute elevation for that measurement by subtracting from the known elevation point. In this case, we get **.8 cm**. The reason for a positive number in this case is because the zero line, which all elevations are referenced off of was established in 1897. Since this is the only photograph used in this study which was taken after that time, it is the only absolute elevation for photographs which is positive.

[29] Courtauld Institute, July 18

4.5 C-Mark Results

The third sea level indicator, C–Marks, account for over one hundred data points in our results. Each engraved site was given careful examination, and as much relevant data on each location was collected in order to fully catalog these important sea level indicators for future reference, as well as aid in proper dating procedure in our final analysis. The following sections will describe the relevant data collected, as well as go into detail on results obtained within each of the datum collected.

4.5.1 Collected Information

All C-marks sites within the San Marco and Castello Sestieri were visited, cataloged, and finally entered within a Microsoft Access database (*see Figure 58*). This database contains information and photographs relevant to each individual C-Mark. The list of associated data is as follows: digital photograph scanned from originals from 1992[30], new 2004 digital photo, index code from 1992, index code from 2004, photo of zoomed in mapped location, absolute height of each engraved line, material on which the engraving resides, direction the engraving faces and building height above each C-mark.

ID	Date Visited	Canal Name	1992 Index Code	1992 Photos	2004 Index Code	MapInfo Map	2004 Photos	Material	Direction	Building Height (m)	2004 Calculat
1		Rio Dei Mendicanti									
2	7/3/2004		890	C marker Photos (1992)\890	CA-001	MapInfo Map	2004 Photo	Sandstone	South East	Not Available	25.5
3	7/3/2004		896	C marker Photos (1992)\896	CA-002	MapInfo Map	2004 Photo	Granite	South East	Not Available	27
4	7/3/2004		897	C marker Photos (1992)\897	CA-003	MapInfo Map	2004 Photo	Sandstone	North West	14.59	39.5
5	7/3/2004		946	C marker Photos (1992)\946	CA-004	MapInfo Map	2004 Photo	Sandstone	North West	Not on building	50.5
6		Rio Dei San Giovanni Laterano									
7	7/3/2004		396	C marker Photos (1992)\396	CB-001	MapInfo Map	2004 Photo	Sandstone	South	Not Available	34.5
8	7/3/2004		403	C marker Photos (1992)\403	CB-002	MapInfo Map	2004 Photo	Sandstone	South West	Not Available	-27.5
9	7/3/2004		416	C marker Photos (1992)\416	CB-003	MapInfo Map	2004 Photo	Sandstone	South West	Not Available	37
10	7/3/2004		423	C marker Photos (1992)\423	CB-004	MapInfo Map	2004 Photo	Sandstone	North East	Not Available	50.5
11		Rio Del Piombo									
12	7/3/2004		618	NEG	CC-001	MapInfo Map	2004 Photo	Sandstone	North West	16.96	8
13	7/3/2004		619	C marker Photos (1992)\619	CC-002	MapInfo Map	2004 Photo	Sandstone	South East	12.8	13
14	7/3/2004		633	C marker Photos (1992)\633	CC-003	MapInfo Map	2004 Photo	Sandstone	North West	13	-5
15	7/3/2004		634	C marker Photos (1992)\634	CC-004	MapInfo Map	2004 Photo	Sandstone	South East	12.26	-33
16	7/3/2004		639	NEG	CC-005	MapInfo Map	2004 Photo	Sandstone	South East	12.72	13.5
17	7/3/2004		641	C marker Photos (1992)\641	CC-006	MapInfo Map	2004 Photo	Sandstone	North West	17.07	17
18	7/10/2004		679	NEG	CC-007	MapInfo Map			South	16.05	30.5
19		Rio Del Pestrin									
20	7/10/2004		873	C marker Photos (1992)\873	CD-001	MapInfo Map	2004 Photo	Sandstone	South East	Not Available	18
21	7/10/2004		876	NEG	CD-002	MapInfo Map	2004 Photo	Sandstone	North West	Not Available	17
22	7/10/2004		881	NEG	CD-003	MapInfo Map	2004 Photo	Sandstone	South East	15.12	20
23	7/10/2004		882	NEG	CD-004	MapInfo Map	2004 Photo	Sandstone	North West	Not Available	0.5
24	7/3/2004		771	C marker Photos (1992)\771	CD-005	MapInfo Map	2004 Photo	Sandstone	North	Not Available	25.5
25	7/3/2004		773	C marker Photos (1992)\773	CD-006	MapInfo Map	2004 Photo	Sandstone	South	13	10.5
26	7/3/2004		783	C marker Photos (1992)\783	CD-007	MapInfo Map	2004 Photo	Sandstone	North	Not Available	48.5
27		Rio Del Mondo Novo									
28	7/3/2004		2	C marker Photos (1992)\2.jp	CE-001	MapInfo Map	2004 Photo	Sandstone	North East	10.98	-11.5
29	7/3/2004		10	C marker Photos (1992)\10.j	CE-002	MapInfo Map	2004 Photo	Sandstone	North East	10.76	19
30	7/3/2004		28	C marker Photos (1992)\28.j	CE-003	MapInfo Map	2004 Photo	Sandstone	North East	10.78	-23
31	7/3/2004		34	C marker Photos (1992)\34.j	CE-004	MapInfo Map	2004 Photo	Sandstone	East	14.36	11.5
32	7/10/2004		41	C marker Photos (1992)\41.j	CE-005	MapInfo Map	2004 Photo	Sandstone	North East	Not on building	
33	7/3/2004		42	C marker Photos (1992)\42.j	CE-006	MapInfo Map	2004 Photo	Sandstone	West		14.5
34	7/3/2004		52	C marker Photos (1992)\52.j	CE-007	MapInfo Map	2004 Photo	Sandstone	South East	14.27	24
35	7/3/2004		57	C marker Photos (1992)\57.j	CE-008	MapInfo Map	2004 Photo	Sandstone	North West	16	24.7
36	7/3/2004		58	C marker Photos (1992)\58.j	CE-009	MapInfo Map	2004 Photo	Granite	South East	Not Available	26.5
37		Rio De Santa Maria Formosa									
38	7/3/2004		974	C marker Photos (1992)\974	CF-001	MapInfo Map	2004 Photo	Sandstone	North West	Not Available	37
39	7/3/2004		975	C marker Photos (1992)\975	CF-002	MapInfo Map	2004 Photo	Sandstone	South East	Not on building	28
40			981	C marker Photos (1992)\981	CF-003	MapInfo Map	2004 Photo	Sandstone	North West	16.9	—
41	7/3/2004		982	C marker Photos (1992)\982	CF-004	MapInfo Map	2004 Photo	Sandstone	North West	16.9	4
42	7/3/2004		983	NEG	CF-005	MapInfo Map	2004 Photo	Sandstone	South East	16.85	20
43	7/3/2004		990	C marker Photos (1992)\990	CF-006	MapInfo Map	2004 Photo	Sandstone	North West	16.36	30
44	7/3/2004		991	C marker Photos (1992)\991	CF-007	MapInfo Map	2004 Photo	Granite	South East	14.12	29
45	7/3/2004		997	C marker Photos (1992)\997	CF-008	MapInfo Map	2004 Photo	Sandstone	North West	16.36	37
46		Rio De La Tetta									
47	7/3/2004		437	C marker Photos (1992)\437	CG-001	MapInfo Map	2004 Photo	Sandstone	South West	Not Available	21
48	7/3/2004		445	C marker Photos (1992)\445	CG-002	MapInfo Map	2004 Photo	Sandstone	North West	Not Available	83.5
49	7/3/2004		448	C marker Photos (1992)\448	CG-003	MapInfo Map	2004 Photo	Sandstone	South West	Not Available	55.5
50	7/3/2004		466	C marker Photos (1992)\466	CG-004	MapInfo Map	2004 Photo	Sandstone	South West	Not Available	48.5

Figure 58 - Access Database of C-marks

[30] Wall Damage, 1992

In addition to this information collected, MapInfo maps reflecting the locations of each C-Mark have been verified or moved to more precise areas when necessary. A total of 15 previously undocumented C-Marks have been added to complete mapped locations and databases more thoroughly.

4.5.2 Engraving Material

The canal walls of Venice are comprised of mostly sandstone, brick, and granite. Because these are hard materials, they were ideal for the carving of C-Marks. With data collected regarding the material on which the engravings were carved, the resulting graph (*see Figure 59*) shows that 94% of the engravings were on sandstone, and the remaining 6% were all on granite. Brick proved not to be a factor within the results, as none of the engraved C-Marks appeared on brick.

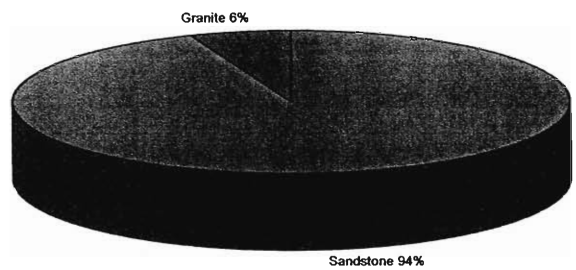

Figure 59 - Percentage of Engraving Material

4.5.3 Directions of Engravings

Another piece of information collected at each engraving location is the direction which the C-Mark faces. This also interprets into the direction the canal wall faces, which is taken into consideration in the error and validity section of this report (*see section 4.1*).

A more in-depth analysis of C-Mark engraving directions can be found in section 5.3.2.

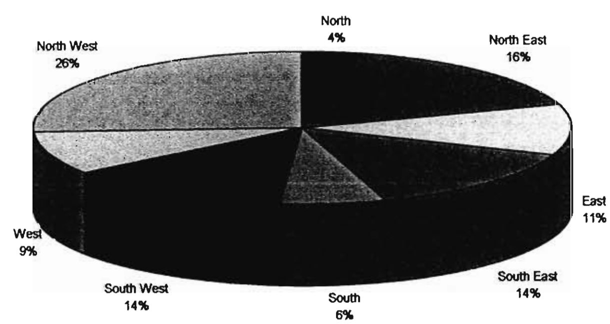

Figure 60 - Percentage of Directions Engravings Face

4.5.4 Building Height and Subsidence

Bearing in mind that the absolute height of each sea level indicator is of utmost importance for this study, and the fact that an attempt will be made to assign a date to each engraving, it is important to look at factors that may skew any accurate outcomes. Subsidence is a problem which effects Venice more then normal locations because of the soft marshy terrain beneath it. When heavy buildings are placed upon the soft terrain, sinking occurs, especially over a long period of time.

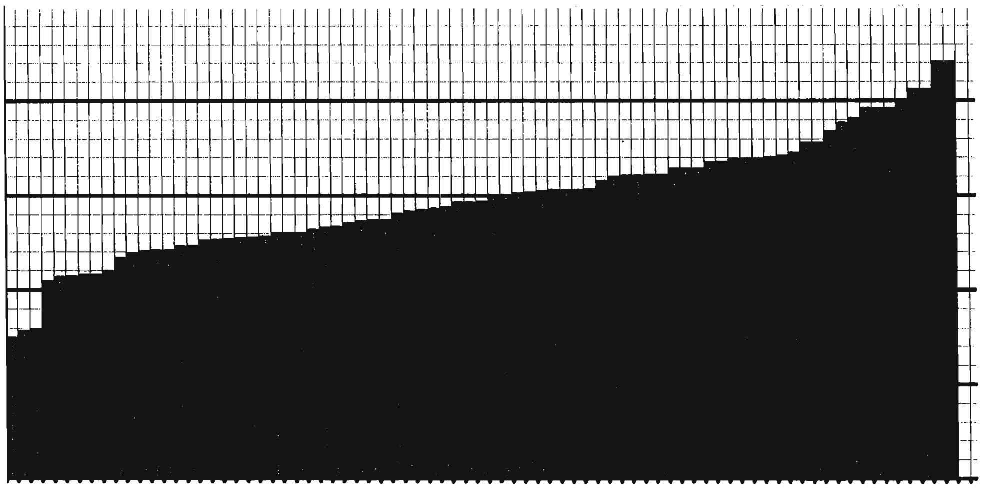

Figure 61 - Distribution of Building Heights on which C-Marks are located

Figure 61 shows the distribution from low to high of the building heights on which C-Marks are located. This does not take into account a situation where a C-Mark is below a sidewalk, bridge, or any other situation that does not specifically incorporate a building. Since the engravings are permanently affixed to the side of the buildings, the subsidence would have a direct effect on the absolute elevation of the C-Mark. Therefore, it is important to factor in this possible effect when attempting to date the C-Marks by their absolute elevation of today.

4.5.5 Frequency of Absolute Heights

Among all of the information collected for each C-Mark, the most important with relation to this study involves the absolute height of the engraved line below the "C". Because the engraved line represents the average high tide level on the top of the green line, the C-Mark is, in essence, an indicator of the sea level for the year of each engraving. By plotting the absolute height of each C-Mark on a bar graph in ascending order (see *Figure 62*), the possibility exists to create an approximate timeframe which C-Marks were engraved, or even specifically date each individual C-Mark (*see analysis section 5.4*)

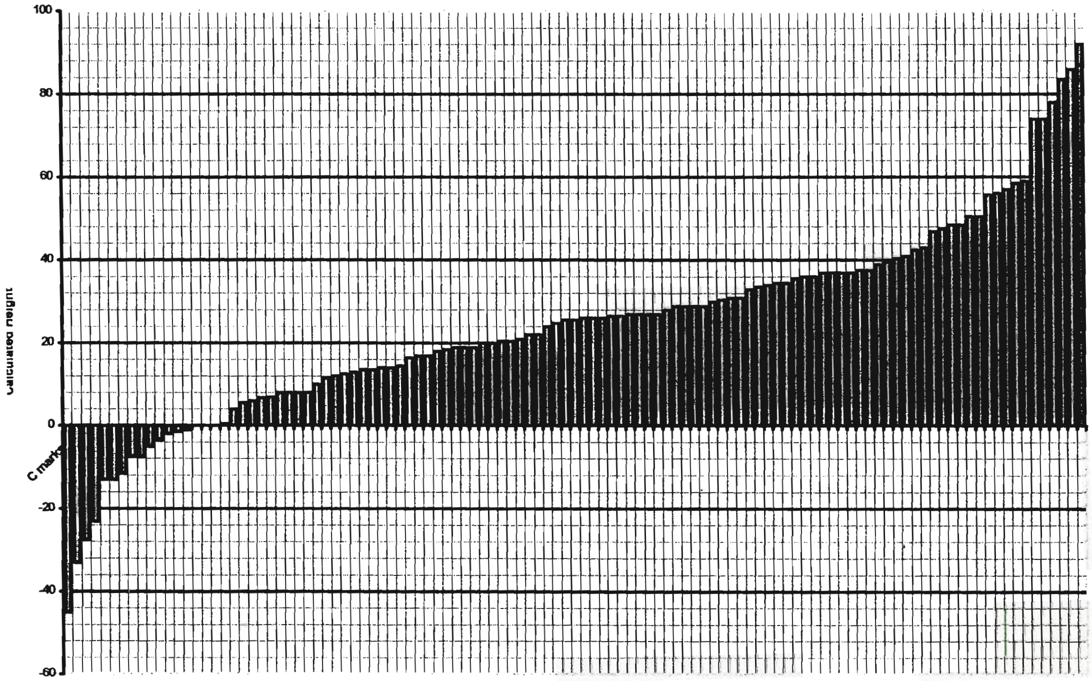

Figure 62 - C-mark Distribution Graph

5.0 Analysis

The following analysis section is organized to first analyze each sea level indicator separately, indicating what trend they appear to show amongst similar sea-level indicators, and lastly the culmination of all sea-level indicators, and the overall trend they prove.

Two additional tasks will utilize the resulting trend line from all sea level indicators:

- Assign a date to each C-Mark by correlating absolute height, to the corresponding year on the trend line
- Compare the trend line to global warming data to search for any correlation

5.1 Painting Analysis

After all painting results were formulated, a graphical analysis must be formed to fully understand tidal progression trends. There are three main areas of importance to analyze: Waterline differential, absolute elevation of algae line in paintings, and the yearly tidal growth rate of each painting. The following is a table of all painting results.

Table 8 - Painting Results Table

Index #	[illegible]	Algae line Differential (cm)	Absolute Elevation of Algae (cm)	[illegible]
P001a	1741	74.75	-45.25	0.2842
P001b	1747	72.97	-43.47	0.2839
P002	1758	58.60	-39.6	0.2382
P003	1725	73.00	-46	0.2616
P005	1735	58.60	-45.6	0.2178
P006	1735	63.44	-44.44	0.2358
P007	1738	71.29	-41.29	0.2680
P009	1727	71.50	-42.5	0.2581
P011	1730	72.57	-48.57	0.2649
P012	1741	70.25	-44.75	0.2671
P014	1740	77.27	-42.27	0.2927
			Sea Level Growth Rate Average: (cm/year)	0.2611

5.1.1 Algae line Differential

The algae line differential, sometimes referred to as the waterline differential, is crucial because it displays how much the sea level has changed since the date of the painting. An accurate algae line differential is also important because all other results are derived using it, such as the absolute elevation and tidal growth rate. Graphically, these algae line differentials should decrease as the year increases. *Figure 63* shows all painting algae line differentials compared to the date of the painting and also their trend line. The trend line is of decreasing decent as it should be.

This decreasing trend line proves that sea levels were indeed rising during the time span of the paintings. In some cases there is a larger differential from year to year than others. This proves that the rise in sea level is not uniform when observed at over a year or so. When the trend line is observed over the entire time span (approx. 1725-1760), it appears to be uniform. This shows that the sea level could spike up or down from year to year depending on outside conditions, such as weather.

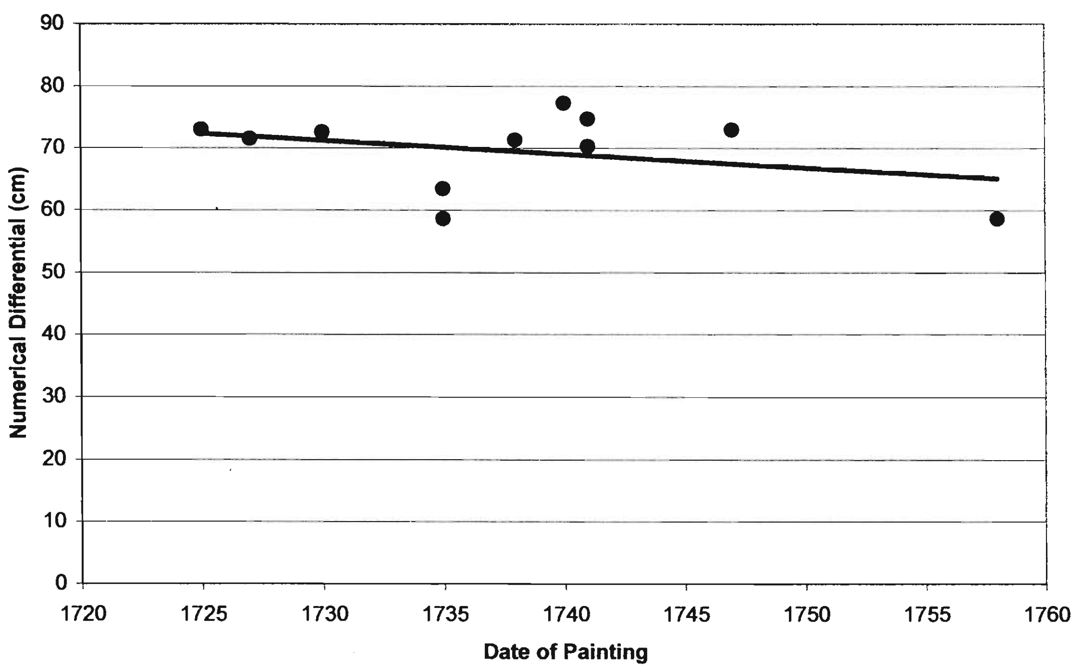

Figure 63 - Algae Differential Vs Painting Year

5.1.2 Absolute Elevation of Algae Line

The absolute elevation of the green algae line in the paintings is crucial for placement on the overall tidal progression graph of this study. This is the actual trend line and data points that will be placed on the overall graph to create the final tidal progression line. Graphically, this trend should increase as the date of the painting increases. This graph *(see Figure 64)* displays how far below the zero line of 1897 the absolute elevation of the algae line in the paintings is located.

The trend line in the absolute elevation graph is increasing, as it should be. In addition to the algae line differential progression trend decreasing, the increase of the absolute height of the algae line also shows that sea levels have been steadily rising. Similar to the algae line differential data points, the absolute elevation data points also appear to spike up or down from year to year, however still keeping an overall uniform positive progression. Once again, these spikes could be due to outside factors that affect sea level over a short period of time. However, the most important fact is that the sea levels are rising over time in a uniform progression.

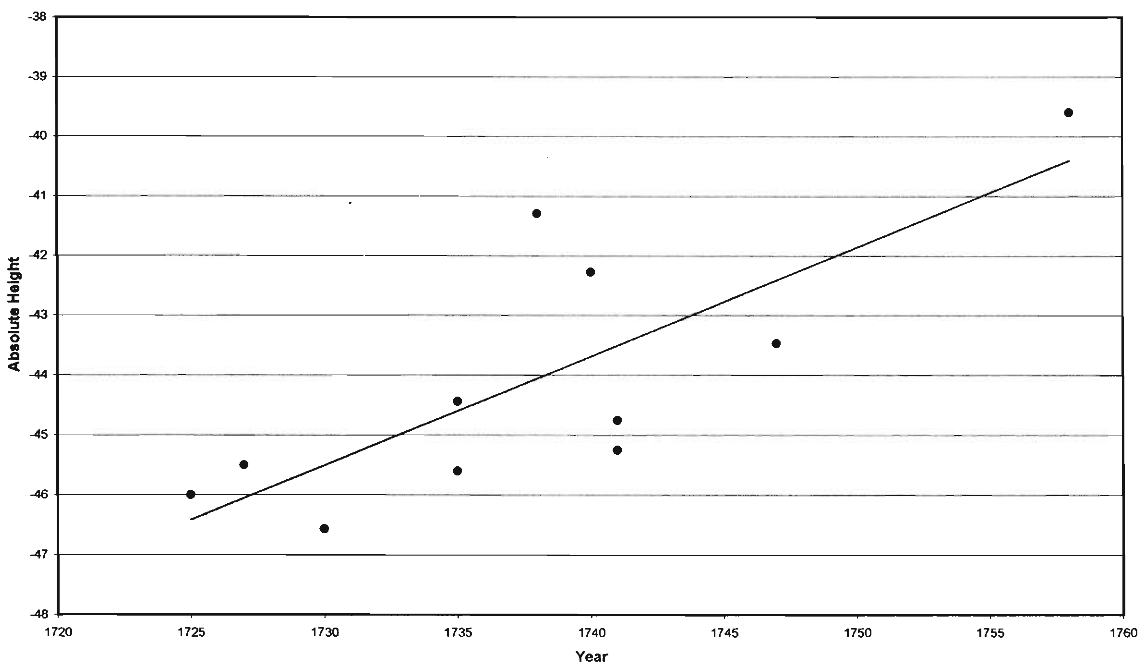

Figure 64 - Absolute Elevation of Algae Vs Painting Year

5.1.3 Sea Level Growth Rate

The scientifically agreed upon value of sea level rise is .23 cm/year. However, this value is an average and may, in reality, spike from year to year, or over a certain time span. In order to fully understand how fast sea levels are rising in Venice, the tidal growth rate must be found. *Figure 65* displays the painting growth rates in cm/year. To obtain these growth rates the painting date was divided by the algae line differential.

The average of all painting growth rates is 0.2611 cm/year. This displays that over the time span of the paintings (1725 to 1760), the sea level rose approximately 26 mm a year, which is 3 mm/year faster than the tidal growth rate today. One explanation for the faster sea level rise is that sea level increase is not precisely uniform over all of time. This could mean that outside effects, such as weather and global warming, could alter the speed of sea level increase over a shorter time span.

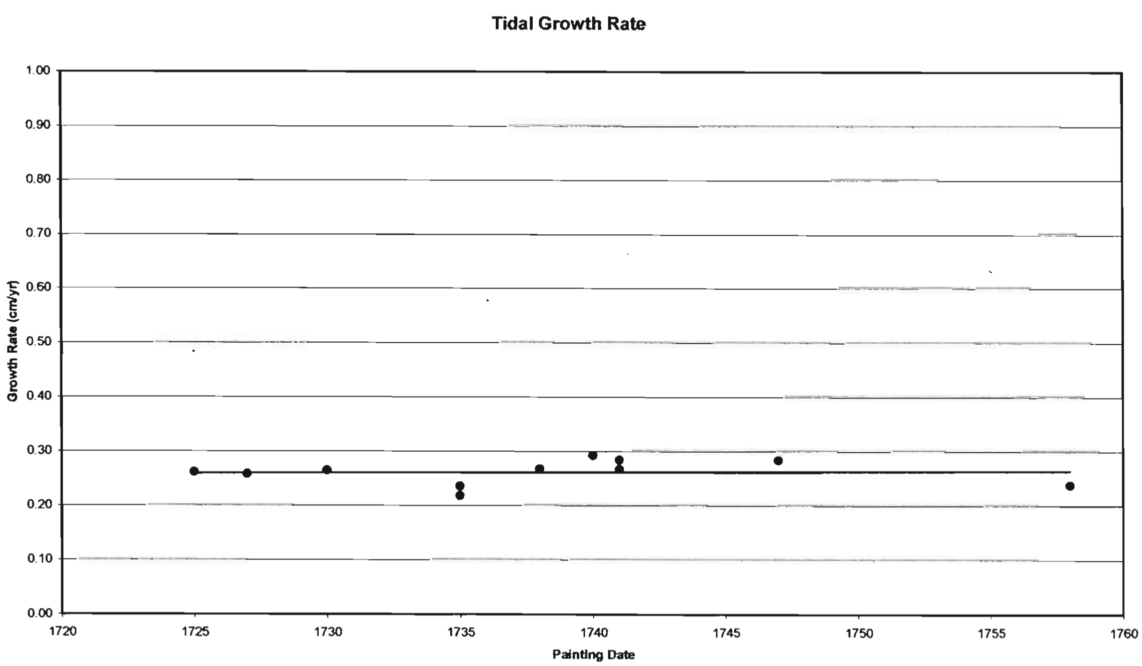

Figure 65 - Sea Level Growth Rate Vs. Painting Year

5.1.4 Correlation of Painting and Tidal Data

The best way to see if sea level rise is uniform is to compare the trend lines of short time periods to each other. For example, the comparison of the painting tidal progression line to the tidal progression line of known tidal data after 1872 *(see*

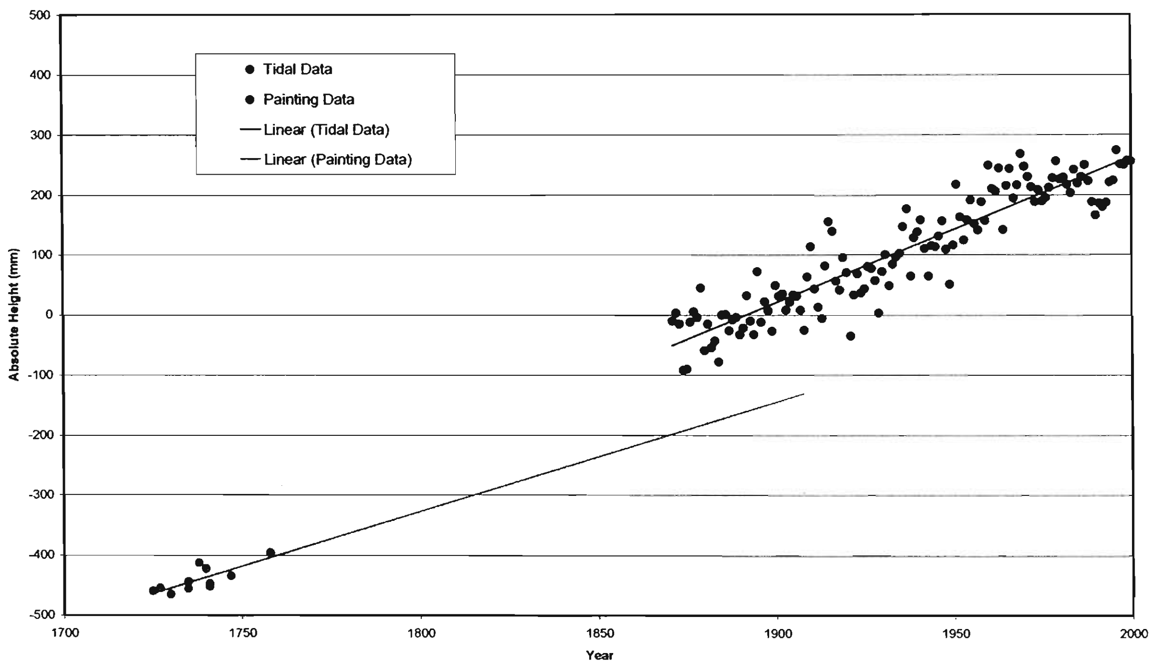

Figure **66***)*. These two progression lines, when put separately on the same graph, do not line up perfectly with each other. This means that the tidal progression over the entire time span of 1700 to present day is not linear. It is possible to obtain a progression line of every data point, paintings and know tidal, but this progression line will be an average that does not display the precise accuracy that the smaller progression lines display *(see*

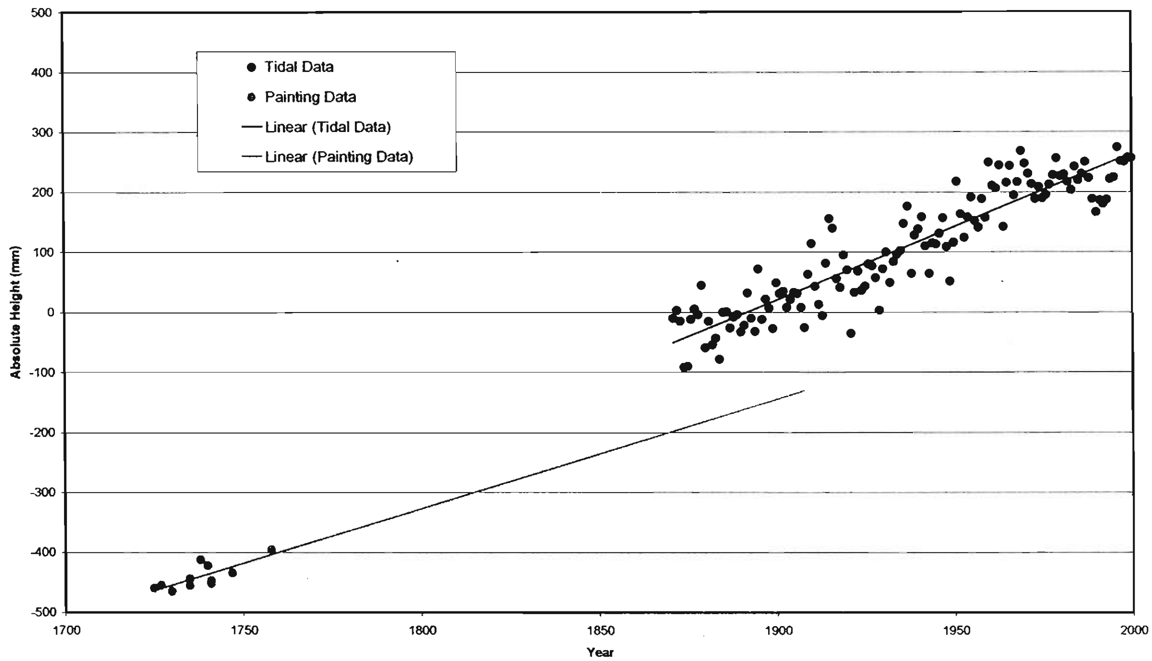

Figure **66***).*

Directly comparing painting data points to known tidal data shows that the progression line would curve somewhere around the mid to late 1800's *(see Figure 68).* The red area in Figure 68 is where the sea level would have to rise at a more rapid rate in order to progress to where the tidal data begins. This theory is very possible because this is the time period of the industrial revolution. Many scientists agree that the burning of fossil fuels began to heat the Earth, causing global warming and glacier melting. This in turn would lead to a faster rate of sea level rise per year.

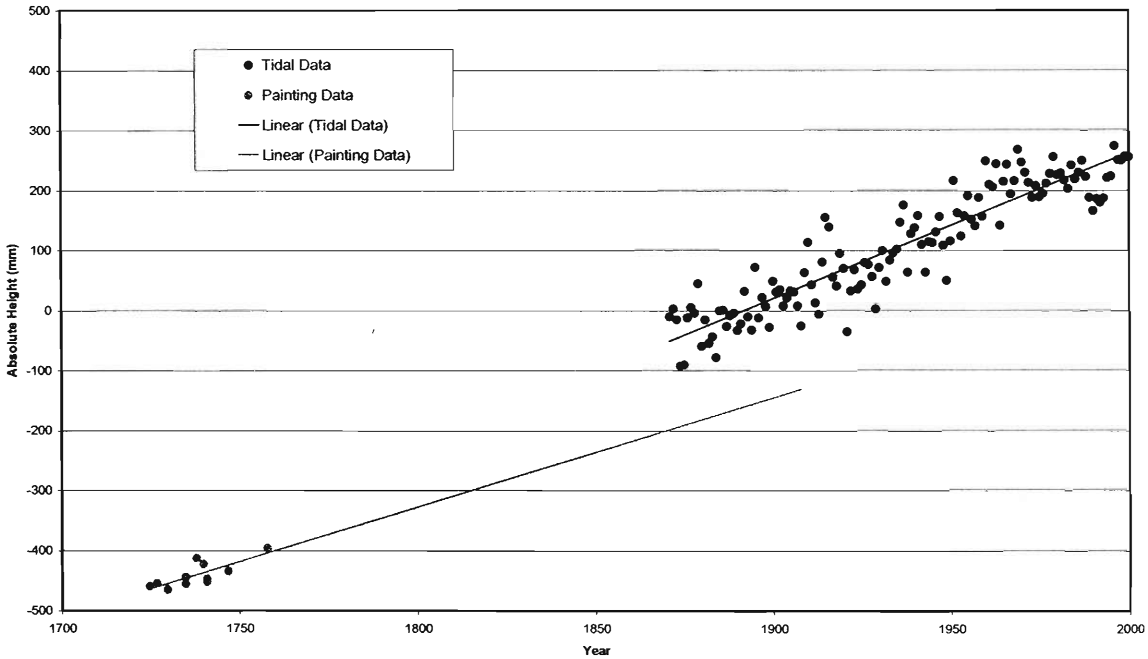

Figure 66 - Absolute Height Vs Painting Year and Linear Progressions

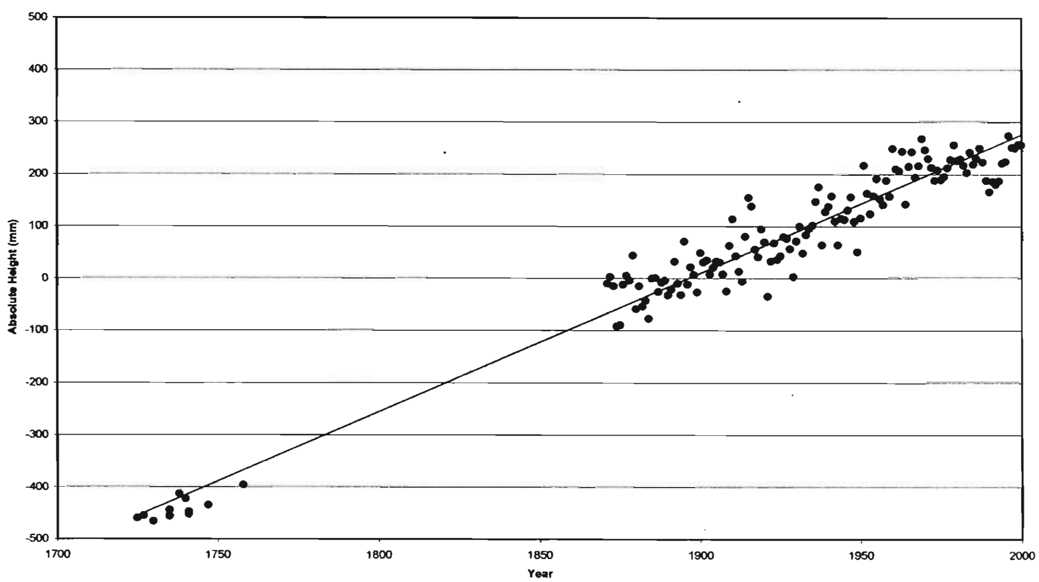

Figure 67 – Absolute Height Vs Painting Year with Linear Progression Line

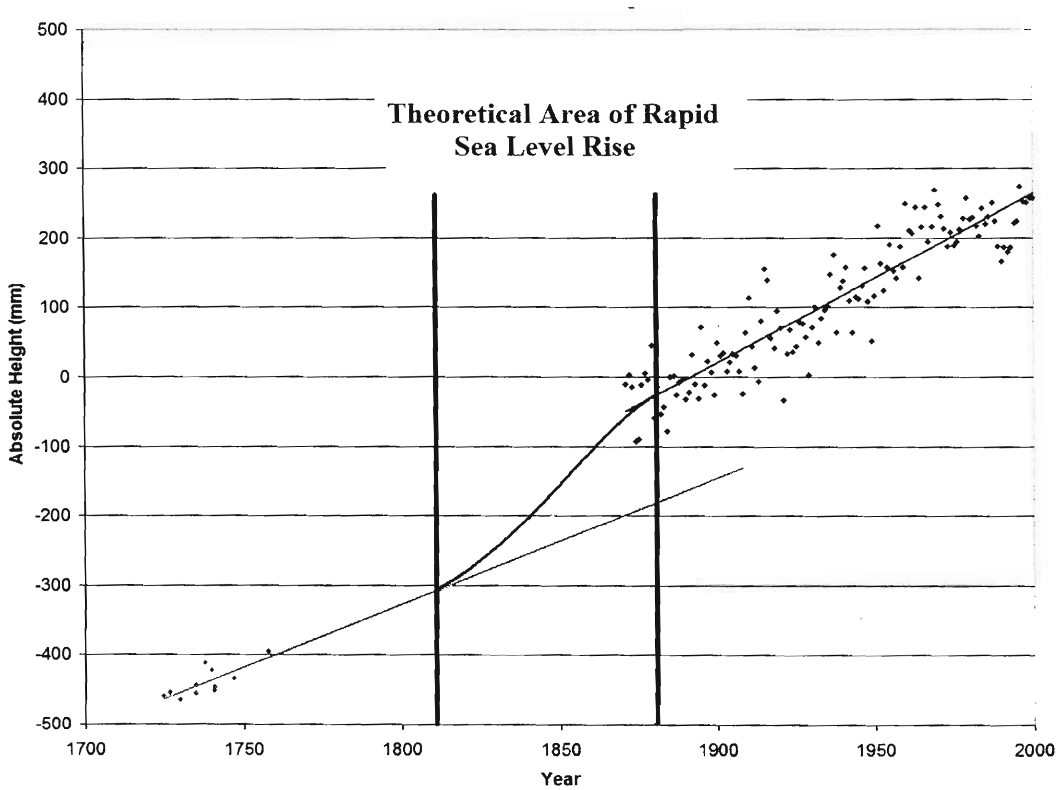

Figure 68 - Theoretical Sea Level Rise

5.2 Photograph Analysis

With results collected for each usable photograph, a statistical and graphical analysis is necessary in order to derive a proper trend line. The five data points of interest correlate in three important ways for this investigation: algae differential; absolute algae level height; and tidal level growth rate. Each of these results can be found in *Table 9*.

Table 9 - Photograph Results

Index #	Photo Location	Year	Algae Differential (cm)	Absolute Algae (cm)	Tidal Level Growth Rate (cm/year)
F001	The Salute	1860	33.9	-6.9	0.252
F002	The Arsenale	1866	32.05	-6.05	0.230
F003	Palazzo Manin	1867	31.57	-5.57	0.230
F010	Façade - Ca D'Oro	1870	31.7	-4.7	0.236
F013	Façade - Palazzo Rezzonico	1901	24.21	0.92	0.235

5.2.1 Algae Height Differential

The first set of results for the data involves the algae differential. This set of data represents how much the algae level has changed from the year of the photograph, up to 2004. Graphically, this should result in a decreasing trend, where the closer the year approaches to 2004, the differential is expected to decrease. Statistically, this can be analyzed to see what the tidal level growth rate average is since the year of the photograph.

The resulting graph, when plotting algae differential height versus photograph year, is shown in *Figure 69*. As expected, there appears to be an indicated decreasing trend. When the linear progression line is inserted (*Figure 69 red line*), the relationship is proven to be substantially evident, as all points are located almost directly on the progression line.

This trend supports the idea not only that sea levels were increasing during the period of 1860-1901, but appeared to be doing so at a steady rate. The rate of tidal level growth can be calculated using the formula below.

$$\text{Rate of Tidal Level Increase} = \frac{\text{Algae Height Differential}}{2004 - \text{Photograph Year}}$$

The results from this analysis are explained and represented graphically in analysis section *5.2.3 Tidal Level Growth Rate*.

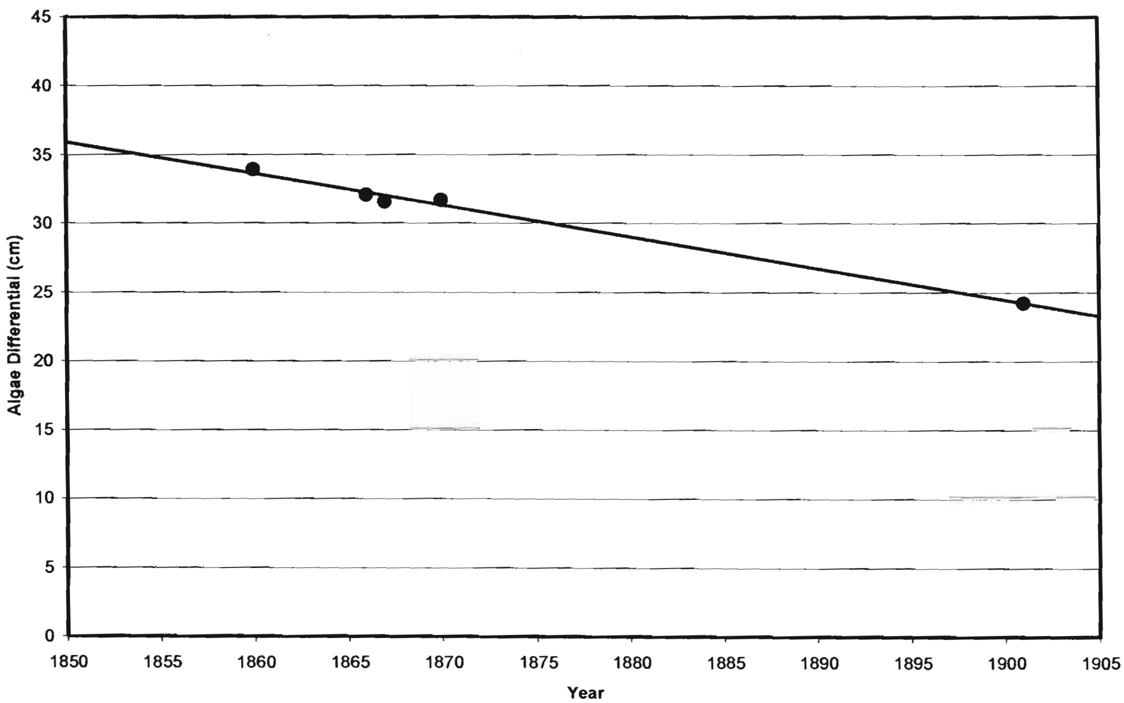

Figure 69 - Algae Height Differential Vs Photograph Year

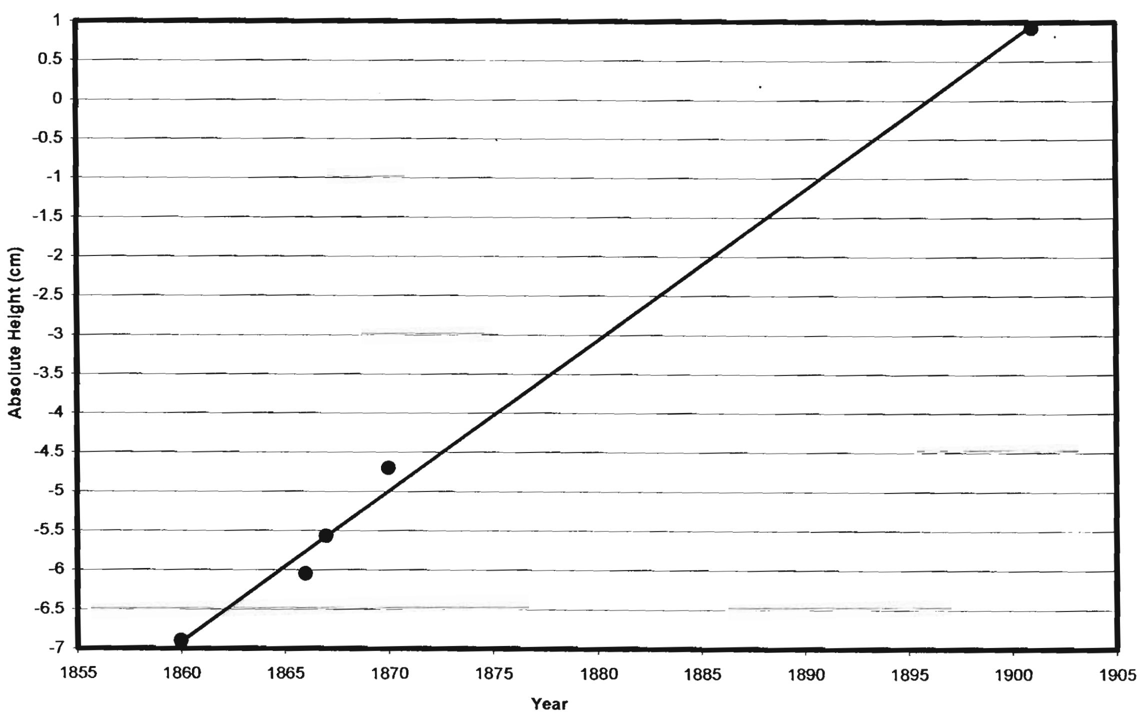

Figure 70 - Absolute Height Vs Photograph Year

5.2.2 Absolute Algae Height

The second set of results for the data involves the absolute elevation of the algae height. This set of data is the most important for this study, since it is the number which will be inserted into the final overall graph with all sea level indicators to build a finalized progression line. Literally, this set of data represents how far above or below the zero line each photograph's respective algae line lies. Graphically, this should result in an increasing trend, where the closer the year approaches to 2004, the height is expected to increase. Absolute heights for this data set are expected to be negative prior to the 1897 zero line year, since there appears to be a decreasing differential trend, as shown in *section 5.2.1*.

The resulting graph, when plotting absolute algae level height versus photograph year, is shown in *Figure 70*. As expected, there appears to be an indicated increasing trend. When the linear progression line is inserted (*Figure 70 red line*), the relationship is proven to be substantially evident, as all points are located almost directly on the progression line.

This trend supports the idea not only that sea levels were increasing during the period of 1860-1901, but appeared to be doing so at a steady rate. In order to verify this, statistically, the absolute elevations can be divided by the absolute value of the photographic year minus 1897, to find the resulting average sea level rate.

$$\text{Rate of Tidal Level Increase} = \frac{\text{Absolute Algae Height Level}}{|(\text{Photographic Year} - 1897)|}$$

As shown in *Table 10*, the tidal increase rate, when analyzed between the date of the photograph and the 1897 zero line year, shows that the rate varies between .17 cm/year and .23 cm/year. The generally accepted scientific value for sea level increase is .23 cm/year, and appears to be supported by the results shown in this study.

Table 10 - Tidal Increase Rate from Photo Year to 1897

Index #	Photo Year	Tidal Increase Rate (cm/yr)
F001	1860	.186
F002	1866	.195
F003	1867	.186
F010	1870	.170
F013	1901	.230

5.2.3 Tidal Level Growth Rate

Reference has been made several times to the scientifically accepted value of annual tidal level growth; 0.23 cm/year. This numerical value appears to be supported by the data range spanning from 1860 – 1897 (*see section 5.2.2*). By expanding this data set to 1860 – 2004, a larger range can be used for verification of the scientifically accepted value. The idea behind this concept is to take the algae height differential between the date of each photograph and 2004, and divide this number by the number of years separating the photograph and 2004, an average growth rate per year can be derived (*see formula in section 5.2.1*).

When the tidal level growth rate is graphed versus the photographic year, a linear result should result, where each tidal level growth rate is consistently similar to the scientifically accepted value of 0.23 cm/year.

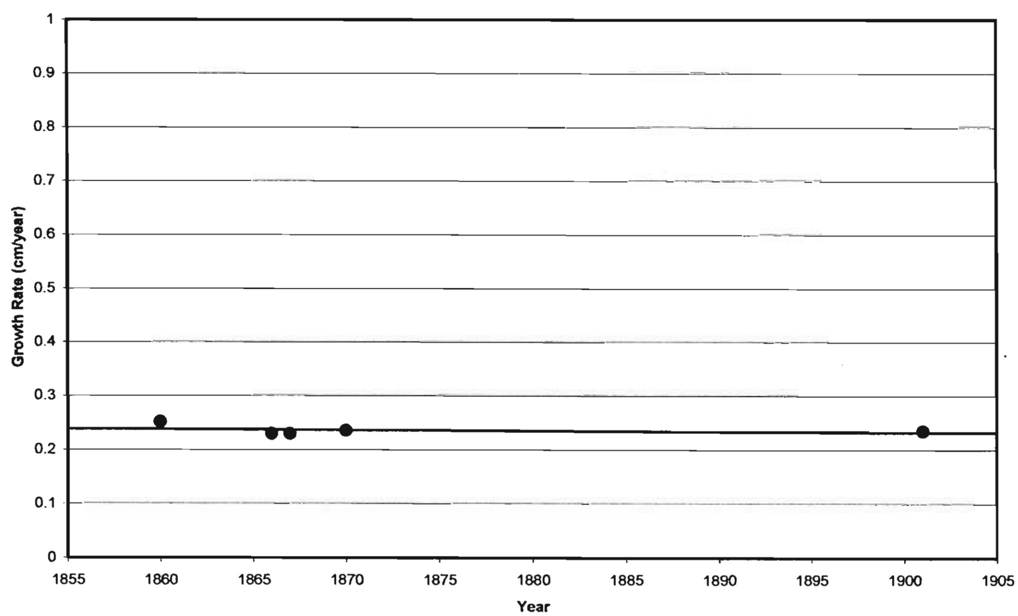

Figure 71 - Annual Growth Rate Vs Photographic Year

Figure 45 shows the 5 data points plotted on the appropriate graph. As shown by the linear progression line (*Figure 71, red line*), the points appear to be mostly linear in a horizontal direction. The values of the 5 points, as seen in *Table 9*, show a mean value of .2366 cm/year, indicating a correlation and support of the scientifically accepted value of sea level rise.

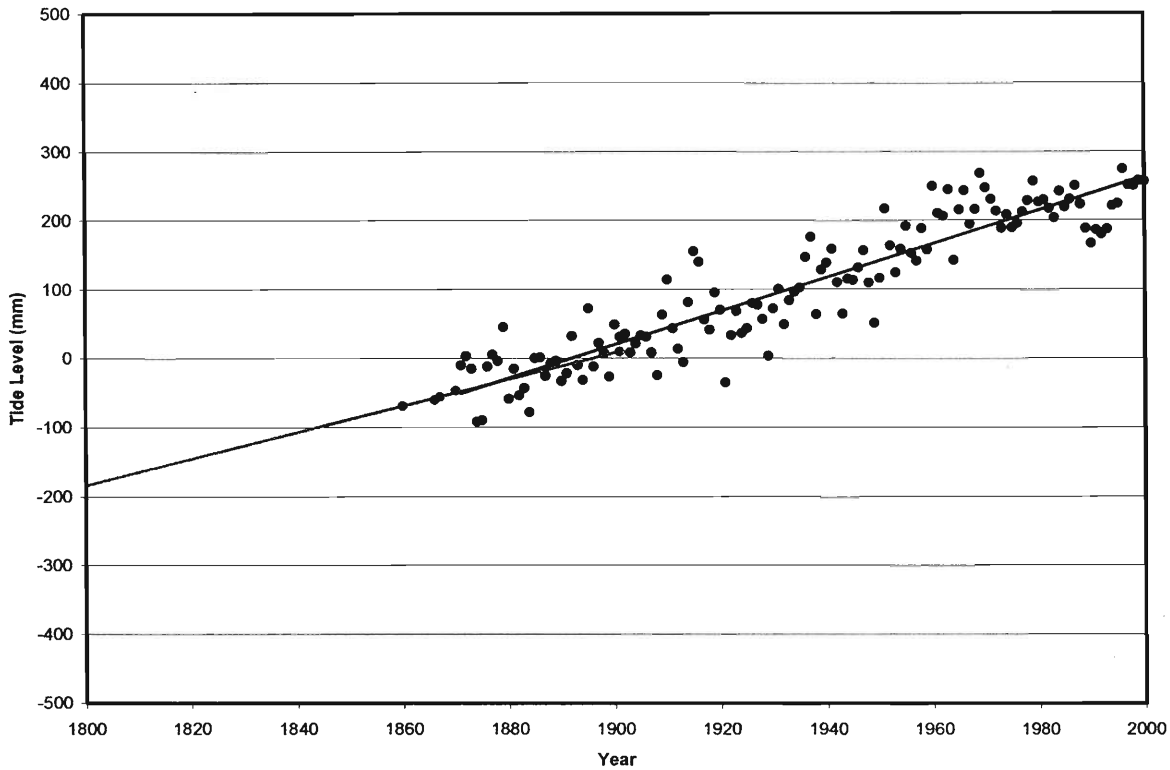

Figure 73 – Tide Gage Data and Photo Data Vs. Year

Although it appears as though the two separate data sets show different linear progression line equations, interest lies in showing exactly how much the two sets of data differ. By automatically calculating the slopes within Microsoft Excel, the true equations of the lines can be derived, and the slopes can be numerically quantified (*See Table 11*).

Table 11 - Tide Gage Slope & Photographic Data Slope

	Tidal Gage Data	Photographic Data
Slope of Linear Progression Line	2.4322 mm/yr	1.9189 mm/yr

The difference in the two data set slopes indicates that at some point in time where they overlap, there was an increase in sea level rise rate. This change, while not obviously significant, translates to an increase of .5133 mm/yr which translates to 5.1 cm over a 100 year period, and 10.2 cm over a 200 year period, assuming both slopes remained identical.

With evidence of sea level rates increasing right around the turn of the 20th century, a need grows for understanding what was responsible for this change. An analysis of climate change versus sea level change can be found in section *5.5 Correlating Climate Change and Sea Level.*

5.3 Final Sea Level Indicator Analysis

Having completed a correlation between the sea level indicators and tide gage data in a separate, segregated analysis, the culminating analysis with all sea level indicators can be developed and analyzed. As with previous analyses, the final sea level progression will be developed by first looking at data points and trends they appear to dictate, followed by progression trends indicated by all sea level indicators, finally resulting in an overall correlation among all three sea level indicators.

5.3.1 Plotting All Sea Level Indicator Data

With data points previously examined in a small scale, among only the years which each indicator surrounded, all points can now be viewed as a whole, along the entire span of time under investigation. Data sets will be treated separately for this portion of the analysis, and will merely be presented on the same plot for purposes of hypothesizing correlation.

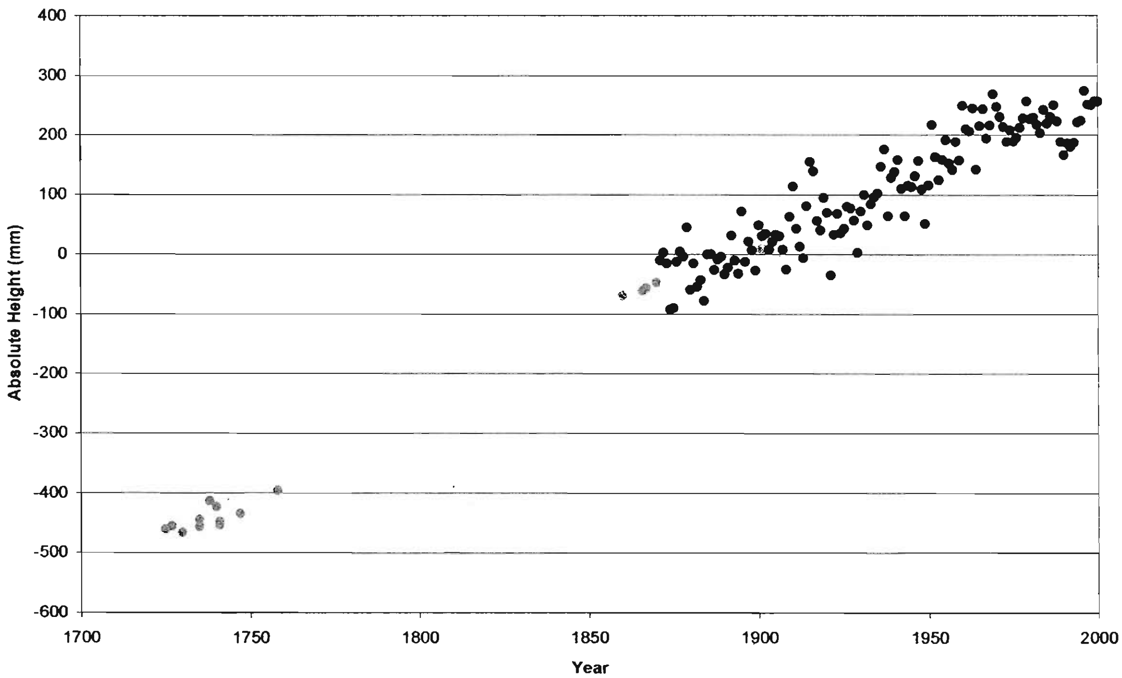

Figure 74 - Absolute Height vs Year of All Sea Level Indicators

Figure 74 shows the plot of all data from the sea level indicators with paintings in pink, photographs in green, and tide gage data displayed in blue. At first glance, the three sets of data appear very linearly correlated, and appear to adhere to a common slope. The analysis which follows, compares each data set separately, and then finally altogether in order to prove or disprove correlation among the sets of data.

5.3.2 Sea Level Indicator Data Trends

Simply plotting data points on a graph can show an overall trend that appears to be associated among them. Since we are dealing with three separate sets of data however, rather then one, trends must be analyzed separately to see any overlapping trends. If each data set in this study shows a separate trend in sea level increase rate, then the overlapping trends may give clues as to timeframes which spike, or level off the rate.

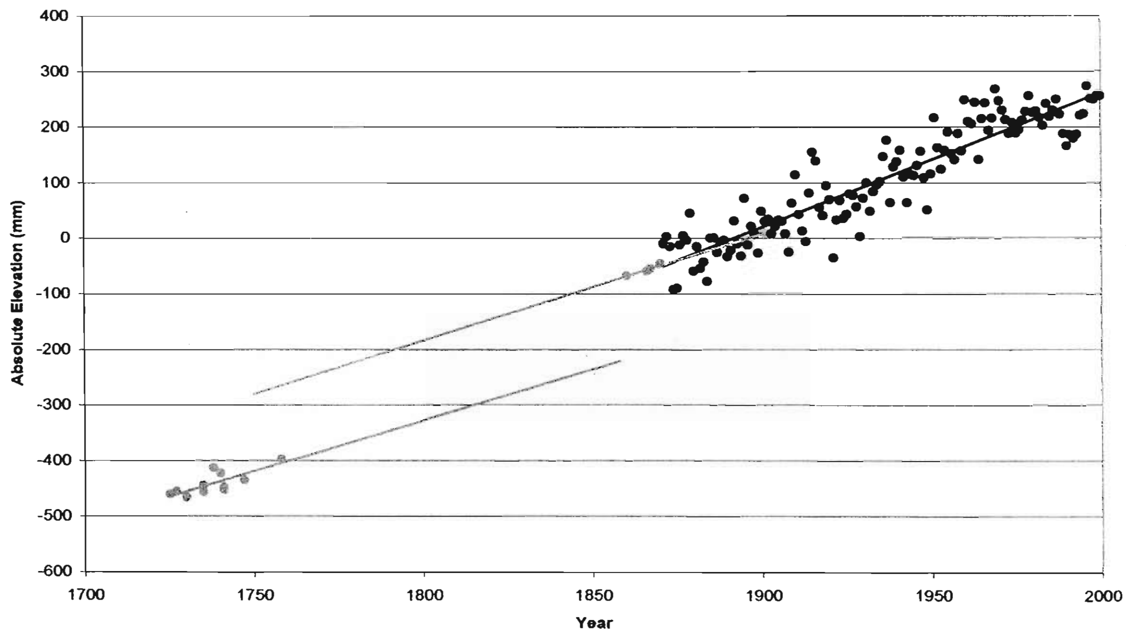

Figure 75 - Absolute Height vs Year of Sea Level Indicator with Progression Lines

Figure 75 shows the respective linear progression line for each data set in matching color for ease of viewing. As discussed previously, the correlation with the photograph data (green) and the tidal data (blue) show that shortly prior to the beginning of the 1900s there was a spike in sea level increase rate.

The next correlation which had not been previously touched upon, deals with the painting data (pink) and the photograph data (green). At first glance, the two progression lines appear to be running parallel to each other. Derivation of the slope of each line shows in *Table 12* that the slopes

Table 12 - Painting Data Slope & Photographic Data Slope

	Painting Data	Photographic Data
Slope of Linear Progression Line	1.8212 mm/yr	1.9189 mm/yr

are not identical. The painting data, the earlier of the two data sets, appears to be a slightly less severely increasing slope then that of the later timeframe data from the photographs.

5.3.3 Average Sea Level Increase Rate

Searching for correlations among several sets of data can prove useful for many statistical analyses, however in this study, the final result will be an equal contribution of all sea level indicators leading toward an ultimate progression trend. The first trend to be examined will be the average sea level increase rate. This trend is the result of an average of all sea level indicators, and is completely linear.

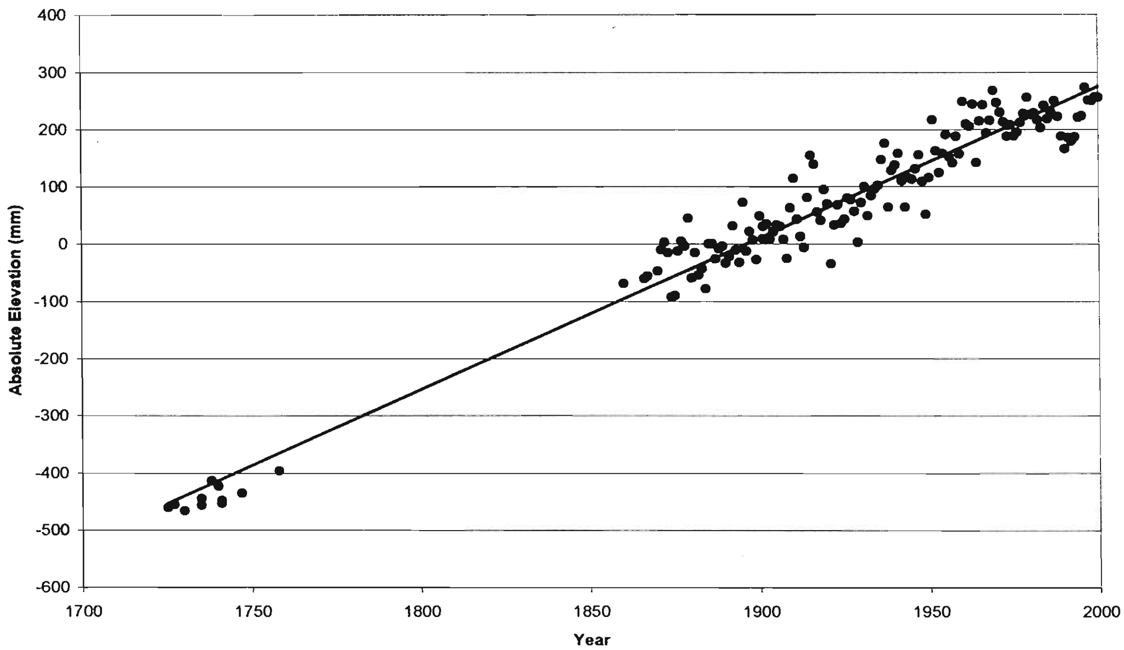

Figure 76 - Average Sea Level Increase Rate (Linear Progression)

Figure 76 shows the linear progression of all the sea level indicator points in red. This average shows what was expected to occur when the data points were plotted originally in separate data sets. Ideally, this average sea level rate correlates with the scientifically accepted rate of increase which is .23 cm/year. Analyzing the slope of the line through Microsoft Excel, the resulting average sea level increase rate is **.26 cm/yr** (See *Table 13*).

Table 13 - Average Sea Level Increase Rate Statistics

Slope Sea Level Increase Rate	Accepted Value	% Error
.26 cm/yr	.23 cm/yr	13.04 %

The percentage of error in an experiment can be quantified by the percentage error equation seen below. The resulting error can bee seen in *Table 13*. A 13% error is considered to be within the range of acceptance for the data in this data range.

$$\% \text{ Error} = \frac{\text{Accepted - Experimental}}{\text{Accepted}} \times 100$$

After viewing the resulting average sea level increase rate, noting its similarities to the scientifically accepted value, and statistically comparing the two values, evidence supports the idea that the sea level indicators used in this study are showing trends that would indicate their accuracy.

5.3.4 Final Sea Level Increase Rate Curve

Expectations leading up to the final graph, show that the datum all appear to point to a linear trend from the earliest sea level indicators of the early 1700s up to the beginning tidal gage data recording in 1872. All options for curves or linear relationships among the data points and sets have been explored up to this point, indicating a few possible trends. The end result however, after creating a polynomial progression trend for all data weighing equally, shows a curved result shown in *Figure 77.*

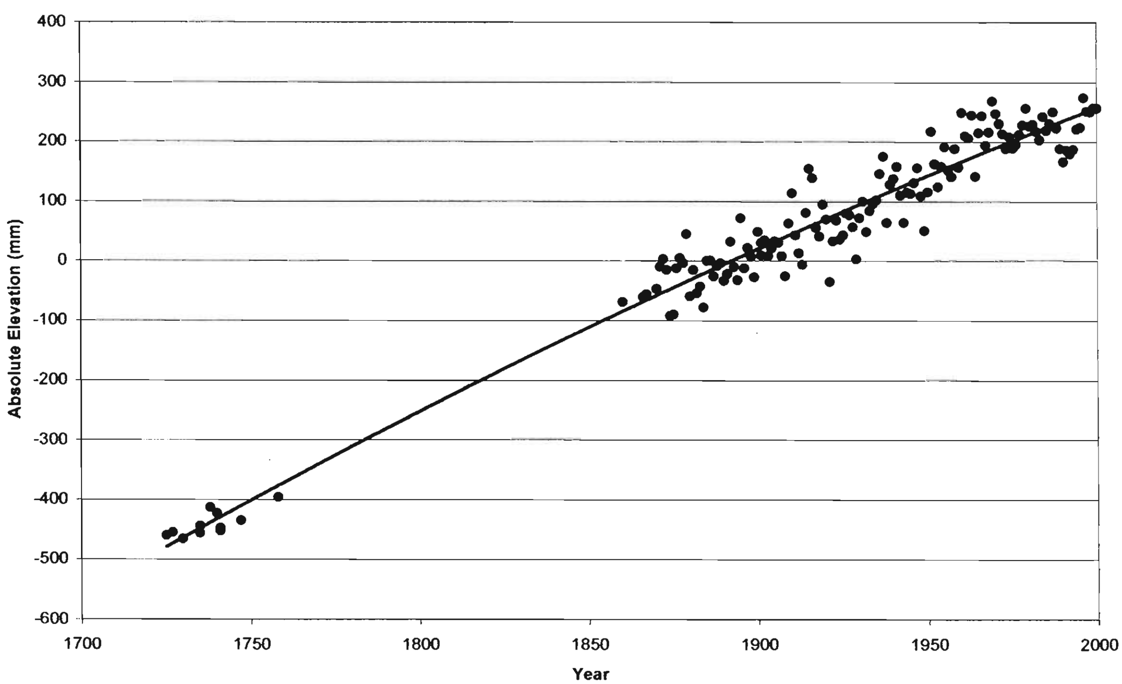

Figure 77 - Final Sea Level Increase Rate Graph

5.3.5 Error In Results

Given that the painting/photo sites are located scattered throughout the city, different factors will affect the measurements taken at each site differently. Each site has been evaluated for certain criteria determining which error will have the largest contribution to the algae line measurement (*see Figure 78, Figure 79*). The criteria are as follows: compass orientation regarding sun exposure, Moto Ondoso contribution from the nearest *centro maree* monitoring station, and material composition of the canal wall.

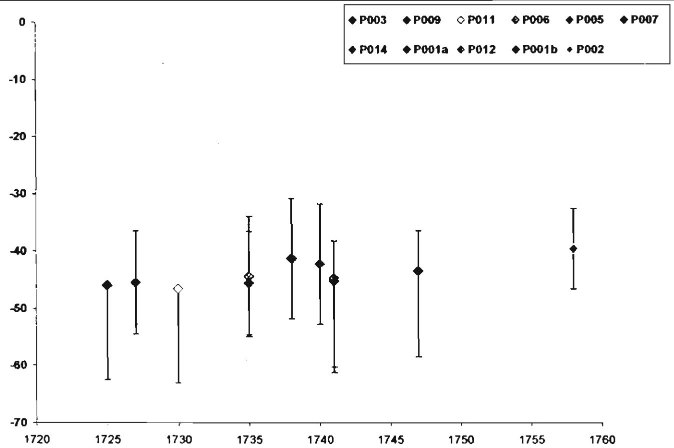

Figure 78 – Painting Results With Applied Error

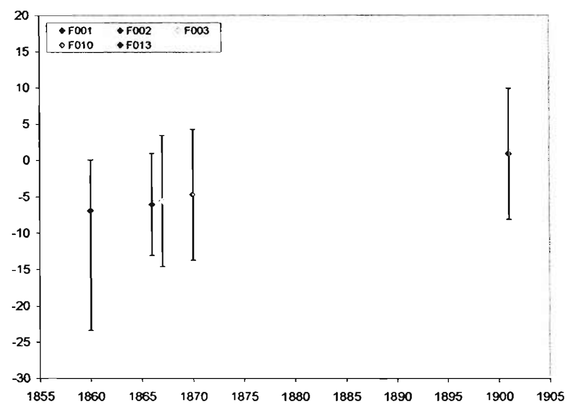

Figure 79 – Photo Results With Applied Error

P001a & b

These two paintings are located at the same site on Rio del Mendicanti at Campo Giovanni è Paolo in Castello. This rio runs North-South, so the need to compensate for the effects of the extremes of sun exposure is not necessary. The algae measurements were taken from brick face, eliminating the need to compensate for the algae possibly being higher due to material composition. This rio has a high amount of boat traffic, as well as direct exposure to the northern lagoon. It is located near the Celestia monitoring station for the *centro maree*. In order to compensate for the effects of Moto Ondoso, a –15 cm error bar was applied to both painting measurements.

P002

This site is located on the Grand Canal, just north of the Ponte di Rialto. In this case, it is subject to all three error factors, so the largest contributing error possible to the site will be used. This is in the form of the Moto Ondoso data from the monitoring station Palazzo Cavalli. An error bar of ± 9 cm is then applied to the value.

P003

This site is located at the Academia on the Grand Canal. The measurements were conducted on stone face, and nearby the *centro maree* station Punta Salute. The measurements were taken off of the stone canal wall, so the possibility of higher measurements had they been taken off brick. Also, the measurement was taken off the wall in a very high traffic area of the Grand Canal, therefore the measurement must be normalized for the possibility that the measured value is much higher than what it should be. Therefore, a + 7 cm and -16.5 cm error bar is applied.

P005

This site is located on the Grand Canal, facing south, near Palazzo Cavalli. The measurement was taken off of a stone surface with southern exposure, as well as in an area of high traffic. In order to compensate for this, an error bar of ± 9 cm was applied to the measurement; the positive component had the measurement been on a surface with northern exposure, and the negative component to eliminate the effect of Moto Ondoso in the area.

P006

This site is located at the entrance to Cannaregio on the Grand Canal. It faces South, and is located directly next to the S. Geremia monitoring station. The error applied to this painting is + 9 cm and -10.5 cm in order to eliminate the effects of sun exposure and Moto Ondoso.

P007

This painting site is on the Grand Canal between P.le Roma and the entrance to Cannaregio. The site faces south, and is located in an area of high traffic. To compensate for the over-exposure to sun, + 9 cm was added as well as -10.5 cm to account for the Moto Ondoso effect measured from the S. Geremia station.

P009

This site is located just north of the Ponte di Rialto in an area of moderate traffic. The measurements were taken off of a stone surface, near-by to the Palazzo Cavalli monitoring station. The error bar associated with this site is + 7 cm to account for the effect of the stone surface and -9 cm for the Moto Ondoso contribution.

P011

This site is located near the Salute church. It faces north, and is in an area of high boat traffic. Because both factors contribute to take away from the measured value, the higher error associated with the Moto Ondoso measurements from the Punta Salute monitoring station will be considered; the resulting error bar is -16.5 cm.

P012

This site is also located in the mouth of the Grand Canal, near Salute. The sight faces south, and measurements were taken off of a stone foundation in an area of high traffic. In order to compensate for these effects, + 9 cm was added for the over-exposure to sun and -16.5 cm to account for the measured Moto Ondoso.

P014

This site is located on the Grand Canal at San Stae church, facing North, in an area of moderate traffic. Because the measurements were taken on stone, + 7 cm must be added to accommodate for the algae line being lower than it could be. Also, -10.5 cm must be added to account for the Moto Ondoso contribution measured by the S. Geremia Station.

F001

This photo site is located at the mouth of the Grand Canal, facing north. The measurements were taken from a stone surface in an area of high traffic. To compensate for these two factors, + 7 cm was added to eliminate the effect of the stone and -16.5 was added to account for the Moto Ondoso measured at Punta Salute.

F002

This site is located in the canal leading up to the Arsenale. It is in an area of extremely low traffic with average sun exposure, and on a stone surface. The only factor needed to be accounted for is the material composition, so + 7 cm was added.

F003

The site is located in the Grand Canal, facing north, in an area of moderate boat traffic. Also, it is in the vicinity of the Palazzo Cavalli monitoring station and the measurements were taken off of a stone surface. The error resulting from these contributing factors is + 7 cm to account for the stone material, and -9 cm to account for the Moto Ondoso contribution.

F010

This site is located on the Grand Canal, facing south, near Ca d'Oro. To account for the moderate boat traffic and the over-exposure to sun, and error bar of ± 9 cm was added.

F013

This site is located just south of the Ponte di Rialto, in an area of moderate traffic. The measurements were taken on a stone surface with North-West exposure. To accommodate for the under-exposure to sun and effects of Moto Ondoso, an error bar of ± 9 cm was added.

5.4 C-Mark Analysis

5.4.1 Canal Wall Material

The durability of certain materials within the Venetian canals is limited by its ability to avoid corrosion and chipping by boat traffic. For this reason, most of the materials which line the canal walls are non-porous stone, such as granite. Other materials, such as brick, which appears below sidewalks or building foundations, and wood, which is used for pilings or boat docks, are much more porous and susceptible to salt erosion or chipping.

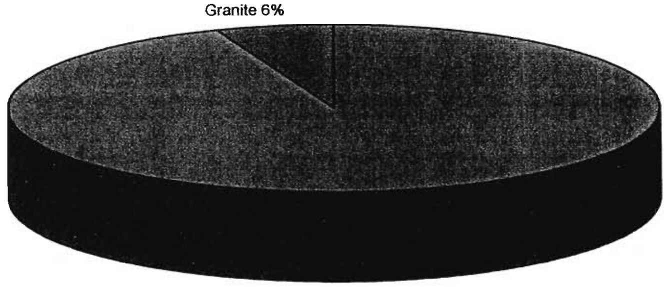

Figure 80 - Percentage of Engraving Material

Even though the canal walls of Venice are comprised of 3 major materials (granite, sandstone and brick), the longevity of C-Mark engravings appears to be associated with 2 possible scenarios: brick was not a common medium during the timeframe of engravings, or brick has not endured the test of time, and has either been covered with a new material, or has eroded away the valuable sea level indicator engraving.

5.4.2 Direction C-Marks Face

Sun exposure, as seen in the sun exposure test, can affect the growth of algae at a rate of ±9 cm depending upon a northern or southern exposure. Since northerly facing algae grows higher, interest lies in the number of northerly and southerly facing engravings.

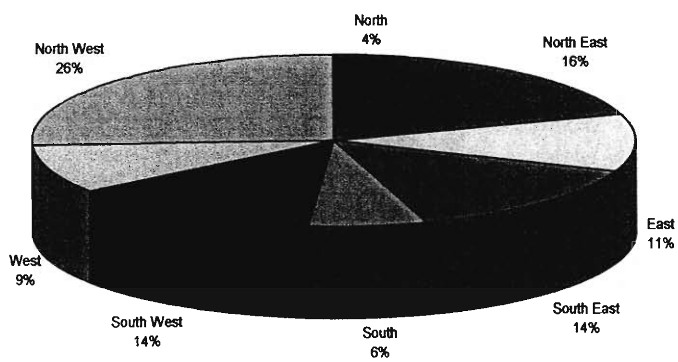

Figure 81 - Percentage of Directions Engravings Face

Of all the C-Marks collected, 46% face in a direction considered to be northerly, while only 34% account for a southerly direction. Knowing that the northerly direction yields a lower algae line then the southerly direction, why would engravings tend to be on the northerly facing canal walls? An assumption can be made from knowledge of what the purpose was behind the C-Marks. While dredging canals, construction workers would place the C and its accompanying engraved line at the top of the algae line to act as a "mark" for them to hit with the water level, to know when they completed their job. If the mark could be placed at a position that was still considered the top of the green line, while actually being higher then normal, the canal would not require as much dredging, and the workers would hit their mark sooner then if the mark was lower.

5.4.3 Absolute Height

Theoretically, each absolute height represents a different date, where the lower the number, the earlier the date will be. If an absolute height is zero, it should correlate with a height that is exactly that of the zero line of 1897, and would be given a height of zero (see *Figure 82*).The data displayed in the distribution graph of absolute C-Mark heights substantially varies, naturally, establishing a wide range of heights. Each height, or bar in the graph represents a different absolute height and different date along the timeline.

Due to known threats of validity few outliers are present. For example, the scientifically accepted value of annual sea level to rise is 0.23 cm per year. Taking this into consideration, and assuming that the oldest C-Mark is roughly 250 years old, we can conclude that it is impossible for a C-Mark to exceed 57.5cm in height. Therefore when looking at our graph, we are able to eliminate all data exceeding this 57.5 cm mark.

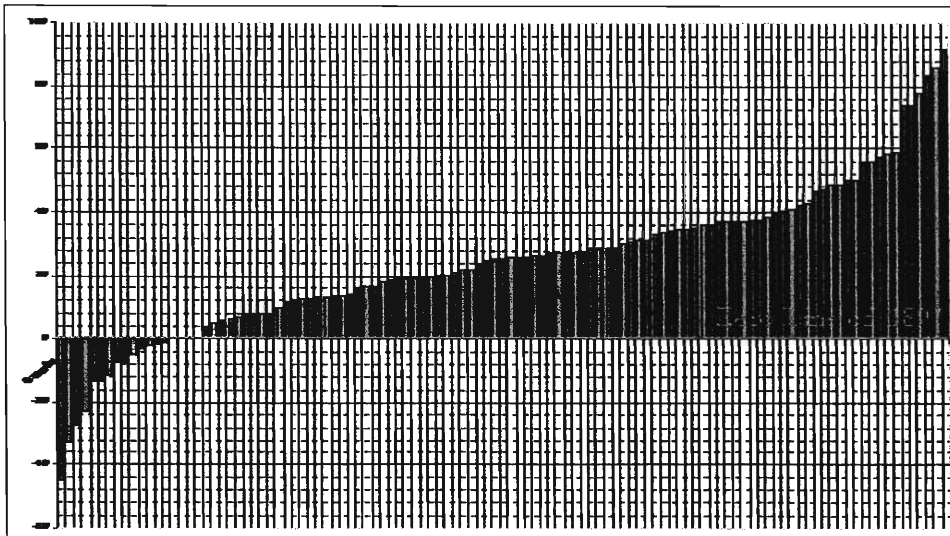

Figure 82 - Absolute Height of C-Marks and Their Relation to 1897

5.4.4 Dating C-Marks by Absolute Height

Knowing that each C-Mark corresponds to an absolute height, the possibility exists to assign a date to each of the absolute heights, and therefore to the C-Mark itself. The necessary components to derive a date for a C-Mark are: absolute heights, and the formula of the linear progression line for all known sea level indicators. Since the linear progression line was created in an Excel spreadsheet, an equation is easily derived, which is $y = 2.649x - 5022.3$. What this means is that for each height "y" entered into the formula, a corresponding x can be calculated by changing the formula around and entering into Excel as $x = (y + 5022.3) / 2.649$. The resulting x value is the engraving year of the C-mark, rounded off to the nearest year (*see Figure 83*).

1992 Index Code	2004 Index Code	2004 Calculated Height	Approximate Date
890	PANA-MEND00	255	1992
896	PANA-MEND01	270	1998
403	ZANI-LATE10	-275	1792
618	BORG-PIOM10	80	1926
619	MARI-PIOM10	130	1945
633	BORG-PIOM11	-50	1877
634	MARI-PIOM11	-330	1771
639	MARI-PIOM12	135	1947
641	BORG-PIOM12	170	1960
873	BORG-PEST21	180	1964
876	FORM-PEST21	170	1960
881	BORG-PEST20	200	1971
882	FORM-PEST20	5	1898
771	FORM-PEST10	255	1992
773	ZANI-PEST10	185	1966
2	FAVA-MOND10	-115	1853
10	FAVA-MOND00	190	1968
28	FAVA-MOND22	-230	1809
34	FAVA-MOND21	115	1939
42	FAVA-MOND20	145	1951
52	FAVA-MOND31	240	1987
57	FILI-MOND30	247	1989
58	FAVA-MOND30	265	1996
975	FORM-FORM00	280	2002
982	QUER-FORM02	40	1911
983	FORM-FORM01	200	1971
990	QUER-FORM03	300	2009
991	FORM-FORM02	290	2005
437	LATE-TETT00	210	1975
445	SEVE-TETT20	835	2211
448	LATE-TETT20	555	2105
392	LORE-LORE00	-75	1868
163	BRAG-SCUD12	270	1998
166	TERN-SCUD13	80	1926
196	TERN-SCUD11	220	1979
205	BRAG-SCUD10	55	1917
228	TERN-SCUD22	205	1973
230	BRAG-SCUD22	-130	1847

Figure 83 - Assigning Dates to C-Marks

In formulating years of engraving for each C-Mark, we have discovered a total of twelve that pre-date our zero-line of 1897. The earliest of which, dated at approximately 1726 was derived from our absolute C-Mark height of –45. On the other hand, some skewed results may be due to building subsidence, reconstruction, or even canal maintenance. Some C-Marks may have even been relocated without documentation. For example, when digging in canals, workers may have moved the C-Mark higher than it actually was causing the sea level to appear lower, therefore seeming as though the canal has been dug deeper, faster. This would result in a C-Mark date to be much later than it really is. Also, a C-Mark carved on the wall of a high building may in fact result in an inaccurate measurement due to ground subsidence. In this case, the C-mark date would be much earlier. As shown in our table, the dates range quite significantly from the early 18th century, to the early 21st century. These dates are an approximation based on our tidal progression line formulated from our sea level indicators.

5.5 Comparison to Previous Research

It is important to compare the research done in this study with that of previous research. In this case, the source of previous research comes from Dr. Dario Camuffo. In 2001, Camuffo lead a study using some of the same accurate paintings used in this study to reconstruct sea levels. The data that is directly comparable is that of the waterline differentials at each site. Table 14 is a comparison of waterline differentials from 2001 to 2004.

Table 14 - Comparison to Previous Research

	Date of Creation (Yr)	2004 Differential (cm)	Camuffo's 2001 Differential (cm)	2001 to 2004 Differential Difference	2004 Differential Increase (cm/yr)
P003	1725	73.00	70	3.00	0.75
P009	1727	71.50	68	3.50	0.88
P005	1735	58.60	58	0.60	0.15
P006	1735	63.44	63	0.44	0.11
P014	1740	77.27	77	0.27	0.07
P001	1741	74.75	69	5.75	1.44
P002	1758	58.60	57	1.60	0.40
				Average of Differentials 2001 to 2004 (cm)	Average of Differential Increase (cm/yr)
				2.17	0.54

The area in green is the waterline differentials from this study and the area in purple is the waterline differentials from Camuffo's study. In order to see how much the sea level has risen over a short period of time (2001-2004), the two different waterline differentials need to be compared.

First of all, the 2001 differential was subtracted from the 2004 differential to yield the total distance that the sea level has risen since 2001 *(see Table 14, orange area).* The average of these numbers was then found to be 2.17 cm. This is how much the sea level has risen since 2001. The reason that this number is so high is because Camuffo's error has not been applied to these numbers and it most cases the error Camuffo attached was ± 10 cm. Next, the difference in waterline differentials was divided by the number of years since the study in 2001, which is 4 (2001, 2002, 2003, 2004). This resulted in the waterline differential increase per year *(see Table 14, blue area).* The average of the differential increases was then found to be .54 cm/yr.

The two waterline differentials were then plotted on a graph to show differences in increase. *Figure 84* displays Camuffo's 2001 differentials as compared to the differentials of 2004. It can be concluded that it is possible to use the same methodology to reconstruct sea levels using paintings, for the difference is waterline differentials from 2001-2004 was never above an error of ± 1 cm.

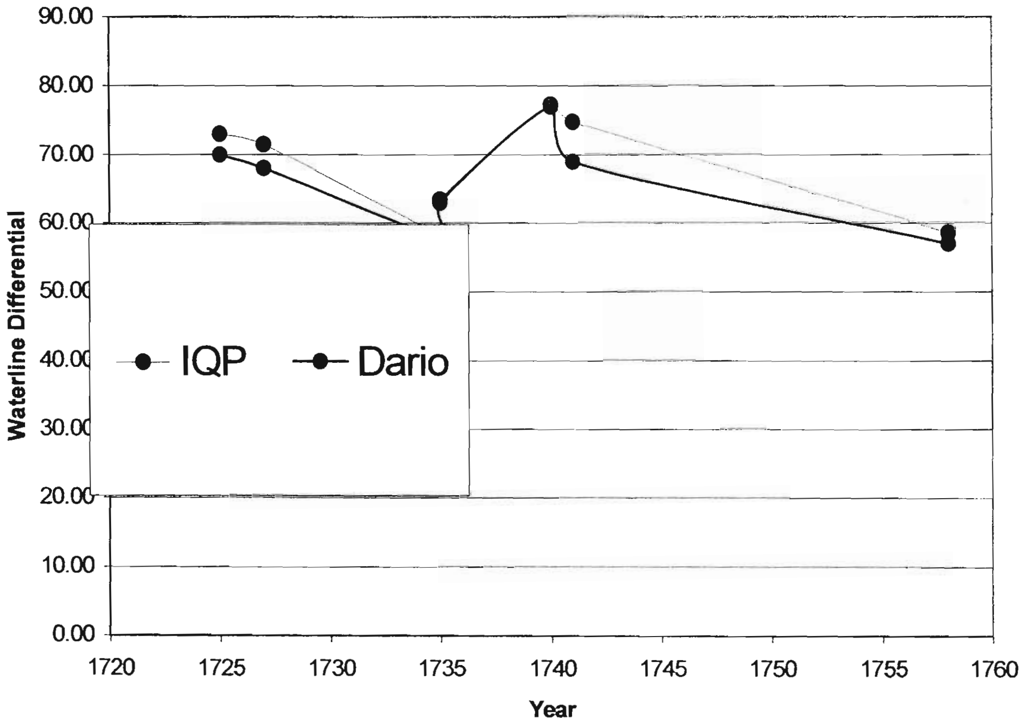

Figure 84 - Comparison to Previous Research

6.0 Conclusions

After the completion of this study, a few conclusions may be drawn about the use of the *comune marino* (green algae line) to indicate sea levels in both present day as well as through various kinds of artistic and archeological sea level indicators in the past. Firstly, the use of *il comune marino* to indicate the average high tide level was extremely valuable for this study. In both of the sea level indicators used to derive the absolute sea level heights, the algae line was the only indicator of sea level reliable enough as well as consistently present in all instances.

A few problems were found with the use of the green line. Given that algae are a biological organism, it is affected by several environmental factors. Duration of sun exposure, the material on which the algae grows, and the amount of Moto Ondoso in the area all effect the height to which the top of the green line grows. These factors all contributed a range of error to every calculated measurement derived from the sea level indicators. The two sources of error found to predominantly affect this study were due to a lack of sun exposure in areas of very high boat traffic. Despite the presence of this error, an analysis of the calculated results of this study was compared with the analyses of comparable studies show a similarity between the derived sea levels during the same periods of time and this one.

The next conclusion which can be drawn stems from the results of the data which were analyzed through the use of the past sea level indicators. The tidal fluctuation theory *(See Figure 85)* depicts the theoretical natural tidal cycle from 2000 A.D. back to 100 B.C.. Looking at the graph during the time period of this study and overlaying this study's derived data on top, the progression lines have a clear correlation. There is a section of this study's data set between the painting years and the photo years which shows a slight increase in the rate at which the tides were rising. This increase in rate occurred between the late 1700's – late 1800's; around the time of the Industrial Revolution. While this study does not show that humans are solely responsible for the rising sea levels, it does show that the actions of humans can effect the global environment, namely natural tidal fluctuation cycles.

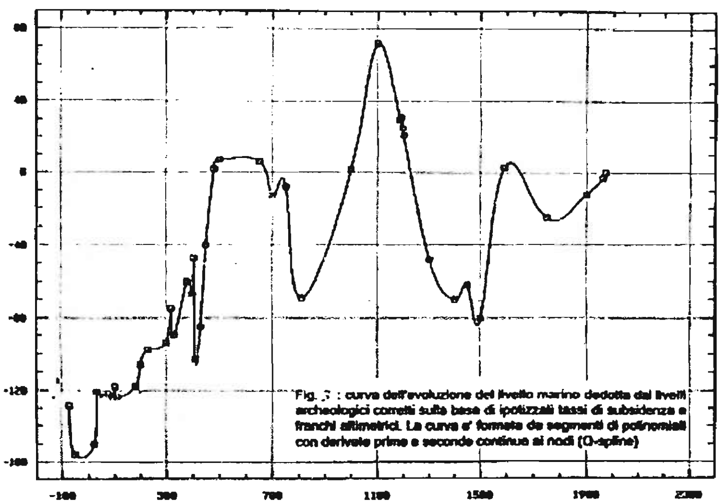

Figure 85 - Theoretical Tidal Fluctuation Graph

Also, because both natural and human-influenced events throughout the world can have such a significant impact on sea levels, the data is most useful when looked at over short periods of time (by the decade) instead of over periods of centuries. Short, yet significant changes in tidal levels become averaged out when look at over long periods of time and data sets. Therefore, it is the feeling that these tidal progressions will be most helpful when looked at over short periods of time when comparing these trends to world-wide events of both natural and human origin.

Originally it was hypothesized that the stone engravings in the canal wall, called C-marks, were created to mark the top of the *comune marino* during periods of construction or renovation pre-dating Canaletto's paintings in the early 1700's. Based on the information collected during this study, it is the conclusion that the data disputes this theory. Overall, 90% of the C-marks that have been dated using the methodology discussed in *section 5.4.4* fall above the zero line of 1897. Due to this fact, this study shows that either the C-marks were dated later than 1900 or they were not used to mark the top of the *comune marino*. Finally for this reason, the team has concluded that the C-marks are not of any use as a sea level indicator for this study, and most likely cannot be dated using the derived tidal progression line.

7.0 Recommendations

This study has proven the existence of valid sea level indicators found in art and architecture, and has opened the door to the possibility for other sources of indicators. For example, one more indicator may exist within the city of Venice. Similar to the algae, the barnacles can be considered biological indicators of sea level, given that they grow in Venice because of its semi-aquatic environment. Barnacles are aquatic organisms that grow in the intertidal zone; or the range between high and low tides. This organism is a bivalve and, like clams, has a soft body surrounded by six hard plates which it closes during periods of exposure to air. Once a barnacle has cemented itself to a hard surface, it remains in that spot for the rest of its life[32]. This characteristic makes them ideal for use as a sea level indicator because even when the barnacle dies, its shell remains in that exact place unless scraped off.

An excavation in 2000 in the area under the Rialto market turned up areas of interest with respect to barnacles. The original canal wall lining the Grand Canal was filled in with dirt and stone in 1398, freezing the wall in time exactly how it existed. On this wall there exists a line of barnacles that were cemented in place and "frozen in time" *(see Figure 86, red line).*

Figure 86 - Excavation at Rialto Pesceria

The barnacles at this excavation site were measured to be approximately 50 cm below the zero line of 1897. Theoretically, it is possible to measure how far from the green algae line barnacles

[32] Barnacles 1-2

grow today and apply that number to the barnacles at this excavation site. This would display the location of the green algae line at the time the wall was filled in. For example, if the barnacles are located at –50 cm, and the barnacles today are 25 cm below the green algae line, then the algae of the time the wall was filled in would be –75 cm. Therefore, this data point would be graphed verses the year the wall was filled in 1398. Then the tidal progression line from the graph in the results of this project could be extended further down to the 1300's.

Example measurements to verify this sea level indicator were taken from an area where barnacles grow under the Rialto Bridge. At this site, the barnacles *(see Figure 87, red circle)* were found to be located 25 cm below the green algae line. On-site observations showed that barnacles tend to grow near bridges, or in areas of elevated shade. All barnacle sites that were visited showed the location of the barnacles to be under, or in, the green algae line. *Figure 87* shows the barnacle line (red) underneath the green line (green).

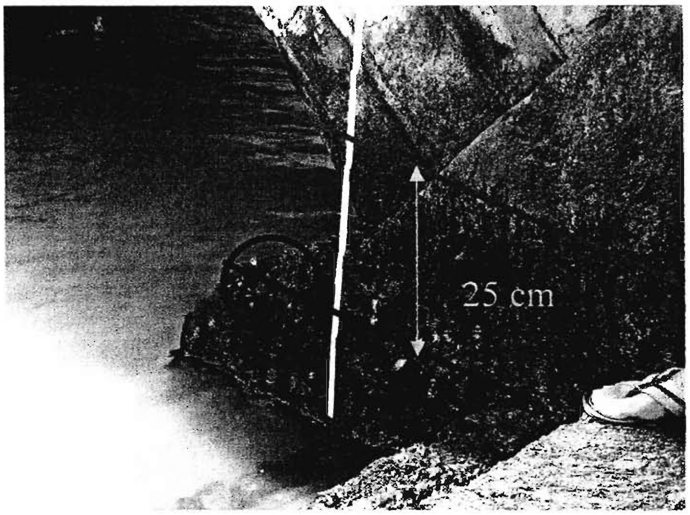

Figure 87 - Barnacle Relation to Green Line

The accuracy of using the barnacle line as a sea level indicator is relatively uncertain. Usually, barnacles grow in clusters and it is difficult to measure to one point fixed point within the cluster. In some areas, the cluster of barnacles is over 10 cm thick *(see Figure 88)*. Further biological research would be necessary to fully understand where to measure to on the barnacle line.

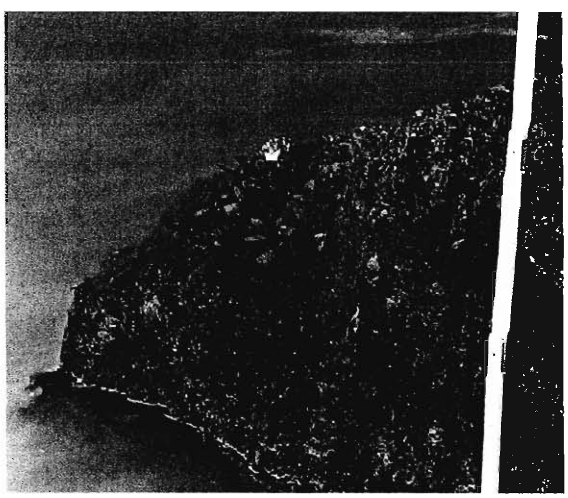

Figure 88 - Barnacle belt thickness

There are three different areas that the barnacles could grow in that would prove or disprove validity of barnacles as sea level indicators. The three scenarios involve the location of the growth: above the green line, within the green line, or below the green line. If the barnacles grow above the green line, then the green line in the excavation would be lower than the barnacles. This would mean that sea level was much lower than it is today in the late 1300's. For example, if the barnacles were found to grow an average of 30 cm above the green line, this would mean that the sea level in 1398 was approximately 80 cm below the zero line.

The second scenario involves the barnacles growing in the algae line. This would indicate that the sea level in 1398 would be approximately 50 cm below the zero line. This comes from the measurement of the excavated barnacles to the zero line, which is –50 cm. Lastly, the barnacles could be found to grow under the green algae line. If this were the case, then the sea level would actually be higher than –50 cm in 1398 *(see Figure 89 for all scenarios).*

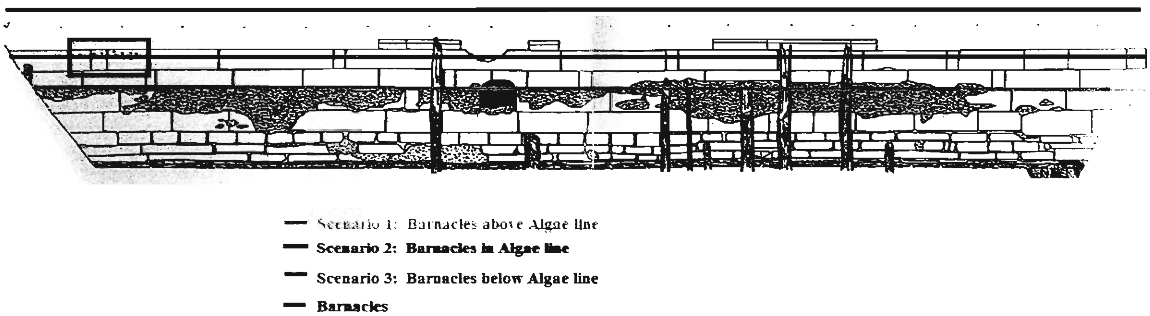

Figure 89 - Barnacle Growth Scenarios

It may sound line scenario 3, the barnacles growing below the algae line, is impossible because the sea level in 1398 should be lower than it is today. However, this is extremely inaccurate because it has been proven that sea level has not risen uniformly over centuries, not only by this study, but also by others. *Figure 90* is a widely accepted graph of sea level progression trends since before the time of Christ. The red box displays the timeframe around the 1300's. The tidal progression seems to spike around 1100, putting the sea level at a height equivalent to that of today. Therefore, it is very possible for the green line to be above where the barnacles grow.

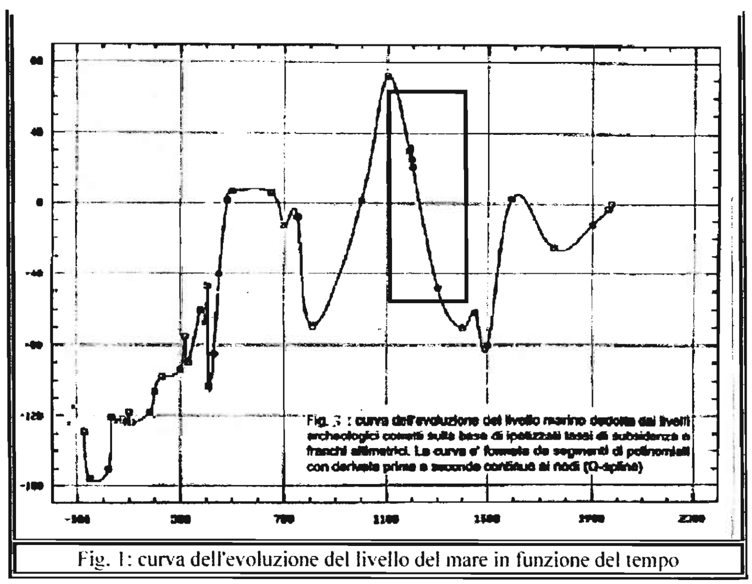

Figure 90 - Evolution of Sea Levels since B.C.

The measurements taken of barnacles under the Rialto Bridge were found to be 25 cm below the green algae line *(see Figure 87).* Theoretically, in order to put the sea level of 1398 in absolute terms the 25 cm must be added to the –50-centimeter measurement to the barnacles from the excavation. The resulting absolute elevation of the green line in 1398 would be –25 cm. Looking at the graph above, it is possible that this estimation could be correct, however more experiments with barnacle locations would need to be performed in order to get accurate results.

The idea of using barnacles as a sea level indicator is mainly theoretical for now, however the ground has been broken and it appears as though it may be possible to use the barnacles to find the location of the green algae line. Further analysis of new sea level indicators such as this could lead to a more precise sea level trend line dating much further back in time, with much greater certainty, then ever imagined.

In regard to the C-marks, further investigations should be completed to determine what their specific purpose was; possibly in conjunction with archeologists and the city records. Also, C-marks located in other sestieri should be measured and catalogued, as this study was focused mainly on the sestieri of Castello and San Marco. Once all the data from every C-mark in the city has been collected, a more accurate analysis can be completed. This may lead to a better idea of their purpose, as well as possibility of dating them.

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Appendix A – Annotated Bibliography

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http://www.usatoday.com/news/world/2002-11-21-venic-sinking_x.htm.
Summary: This source provides some insight into the project itself and also looks at what other researchers are doing to address the problem
Search: "Venice paintings measure"

Baetjer, Katharine and Links, J.G. Canaletto. The Metropolitan Museum of Art, New York. Copyright 1989
Summary: This book gives background information on Canaletto and also includes his paintings and drawings. A short biography on Canaletto in included also. It goes on to dicuss Canaletto's painting techniques and accuracy. It also has a large number of paintings and drawings that were done by Canaletto which include explanations of each.
Source: Gordon Library Catalog

Camuffo, Dario & Sturaro, Giovanni "Use of proxy-documentary and instrumental data to assess the risk factors leading to sea flooding in Venice" *Global and Planetary Change* Volume 40, Issues 1-2, January 2004, Pages 93-103 Dario
Summary: Factors associated with the sea level rise in Venice. Not specifically related to the paintings or project work on that subject, but another study he did involving other factors.
Search: Science Direct Journal Database search for "Dario Camuffo"

Camufffo, Dario "Canaletto" Sea level changes in Venice Archaeometry based on Canaletto's paintings. CNR ISAC, http://www.isac.cnr.it/~microcl/climatologia/canaletto.htm
Summary: Dario Camuffo's work. Thorough methodology, background information, and results on his own website. Also gives bibliography of his own publications.
Search: Google search for "Dario Camuffo cnr"

Camuffo, Dario "Canaletto's paintings open a new window on the relative sea-level rise in Venice" *Journal of Cultural Heritage* Volume 2 Issue 4 (Oct.-Dec.2001) pp 277-281

Summary:

Search: Science Direct database for "Dario Camuffo"

Constable, W.G. "Canaletto: Giovani Antonio Canal, 1697-1768" Oxford University Press, London, 1962. pp. 185-329 (Volume II).

Summary: Catalogue Raisonne: All known Canaletto paintings up to publishing date. Also gives description of what each painting is and where the painter was standing when he did it.

Search: Worldcat Database. "Canaletto Catalogue Raisonne" Worcester Art Museum

Johnson, Bruce "Canaletto's pictures prove that Venice was sinking 300 years ago" Daily Telegraph London, England 11/20/02

http://www.telegraph.co.uk/news/main.jhtml?xml=%2Fnews%2F2002%2F11%2F20%2Fwcanal20.xml

Summary: Complete article from above reference. This is taken from the telegraph in the UK. Tells of Dario Camuffo's findings.

Links, J.G. Canaletto. Phaidon Press Limited, 1982.

Summary: This source includes most, if not all of Canaletto's paintings. It also gives a little description of what each painting is and around where the painter was standing when he did it.

http://www.worcesterart.org/Collection/art_research.html Art Hist. Resources on the Web

http://witcombe.sbc.edu/ARTHLinks.html 18th Century

http://witcombe.sbc.edu/ARTH18thcentury.html#18century 18th Century Art, Canaletto

http://gallery.euroweb.hu/html/c/canalett/index.html

- paintings before 1735 http://gallery.euroweb.hu/html/c/canalett/1/index.html
- paintings after 1735 http://gallery.euroweb.hu/html/c/canalett/2/index.html

• http://witcombe.sbc.edu/ARTH18thcentury.html#18century Bernardo Bellotto

- http://gallery.euroweb.hu/html/b/bellotto/index.html

Appendix B – Validity Testing Database

Appendix B

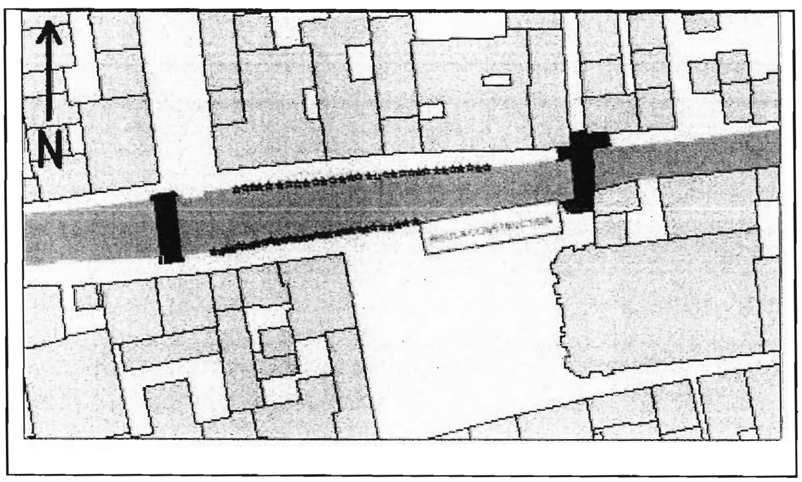
Validity Test Site Form

CODE: N/A **LOCATION:** Rio di San Barnaba

Site Information

Date Visited: 7/14/2004
Known Site Elevation: N/A
Length of Measurement Area: 50 meters
Number of Measurements Taken: 30/side

Measurement Focus Area – MapInfo Map



Appendix B

Raw Data:

Kind of Test	Southern Exposure	Northern Exposure
Sun Test		
	in cm	in cm
Rio d. San Barnaba	*(on brick)*	*(on brick)*
	59	50
	61	49.5
	59	48
	56	49
	57	51
	57	50.5
	56	50.5
	57	47
	58	50
	57.5	49.5
	57.5	51.5
	58	50.5
	57	51
	58.5	50
	61	43
	59.5	54
	60	64
	60	58.5
	60.5	54
	65	55
	67	51
	63	43.5
	63	51.5
	59.5	54.5
	60.5	50
	61.5	53.5
	60	55.5
	58.5	55
	60	44
	61	41

Statistics Formulas:

Sample mean (or average):

$$\bar{x} = \sum_{i=1}^{N} x_i / N$$

Sample standard deviation (SD):

$$SD = \sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2 \Big/ (N-1)}$$

t-test equation (for statistical differences between two groups):

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(SD_1^2 / n\right) + \left(SD_2^2 / n\right)}}$$

Reportable Results:

sampling mean (S.E.): 59.6 cm
standard deviation: ± 4.5 cm

sampling mean (N.E.): 51.2 cm
standard deviation: ± 2.5 cm

t value: 8.908

Appendix B

Validity Test Site Form

CODE: N/A **LOCATION:** Rio di Tolentini

Site Information

Date Visited: 7/15/2004
Known Site Elevation: N/A
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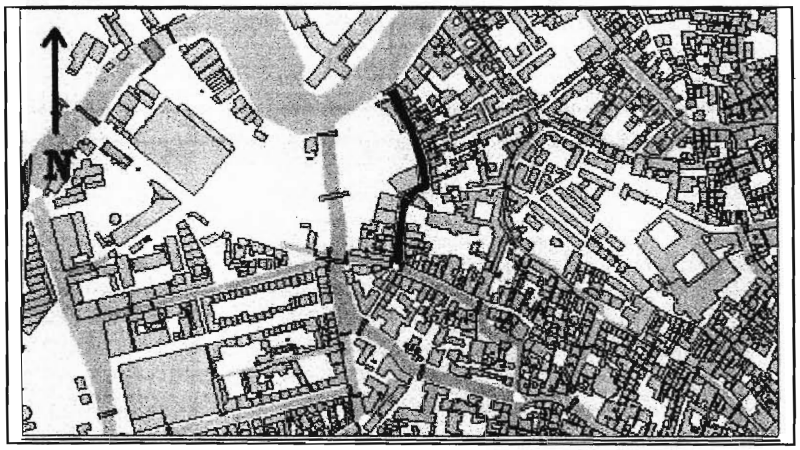
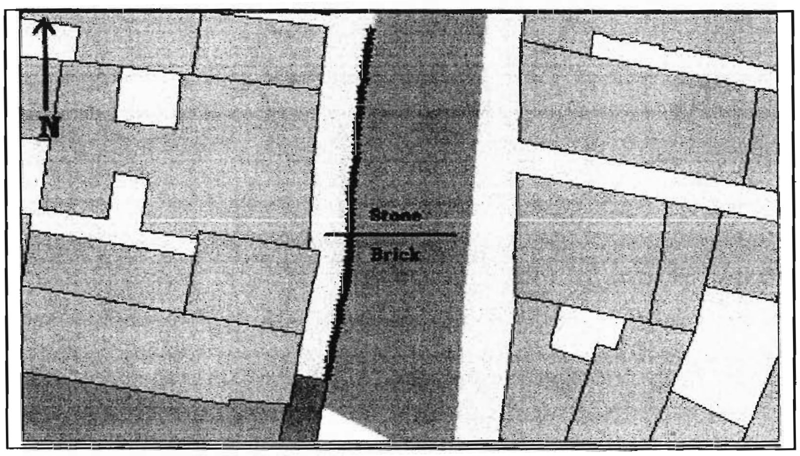
Number of Measurements Taken: 30/material

Measurement Focus Area – MapInfo Map





Appendix B

Raw Data:

Material Test	eastern exposure	
	in cm	in cm
Rio dei Tolentini	*(on stone)*	*(on brick)*
	42	40.5
	42	34
	43	37.5
	44	39.5
	43.5	40
	41	40
	43	39
	42.5	40.5
	43.5	40.5
	43	39.5
	40.5	38.5
	40	26
	41	40
	28.5	40
	45	26
	45	25.5
	44	25.5
	46.5	26.5
	30	32.5
	28	32
	41	32.5
	40.5	26
	41	27
	42	26.5
	42	26
	40.5	25.5
	42	32
	43	25.5
	28.5	26
	27.5	32.5

Statistics Formulas:

Sample mean (or average):

$$\bar{x} = \sum_{i=1}^{N} x_i / N$$

Sample standard deviation (SD):

$$SD = \sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2 \Big/ (N-1)}$$

t-test equation (for statistical differences between two groups):

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(SD_1^2 / n\right) + \left(SD_2^2 / n\right)}}$$

Reportable Results:

sampling mean (B): 32.8 cm
standard deviation: ± 6.2 cm

sampling mean (S): 40.1 cm
standard deviation: ± 5.5 cm

t value: 4.848

Appendix B

Validity Test Site Form

CODE: N/A **LOCATION:** Grand Canal & Arsenale

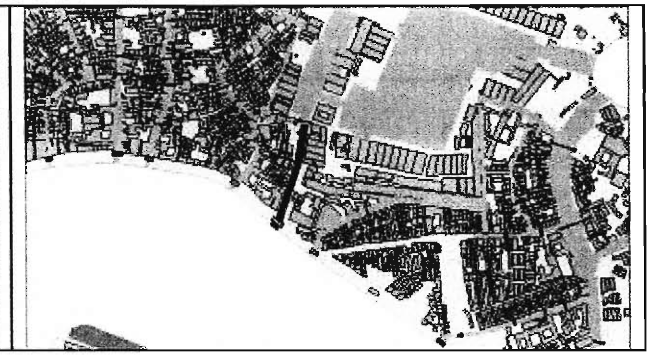
Site Information

Date Visited: 7/25/2004
Known Site Elevation: 0.945 m
Length of Measurement Area: 6 meters @ each site
Number of Measurements Taken: 15/site

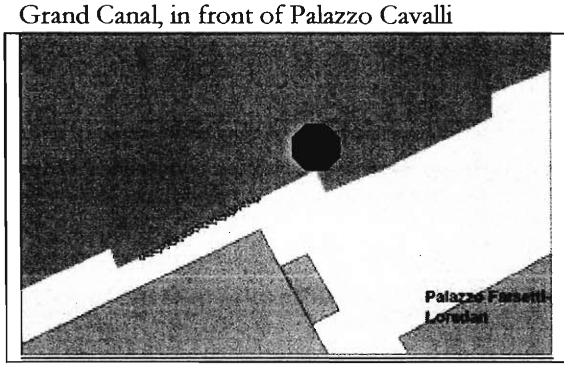
Measurement Focus Area – MapInfo Map

Grand Canal

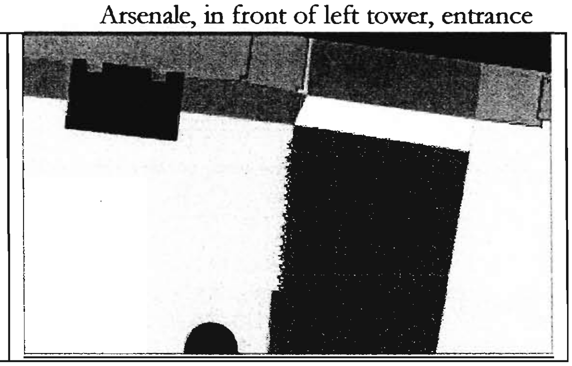
Arsenale



Grand Canal, in front of Palazzo Cavalli



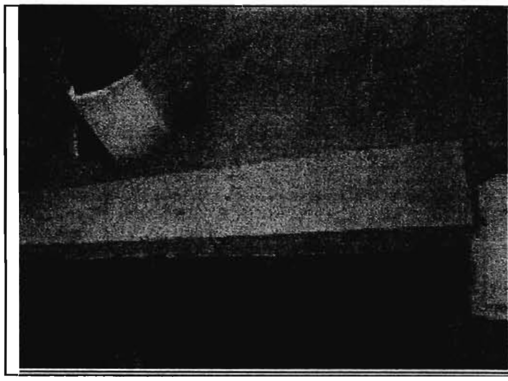
Arsenale, in front of left tower, entrance



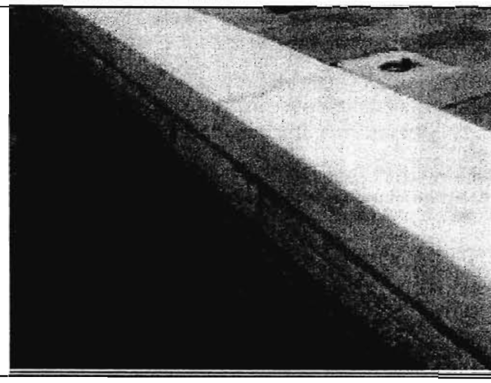
Appendix B

On-site Photos

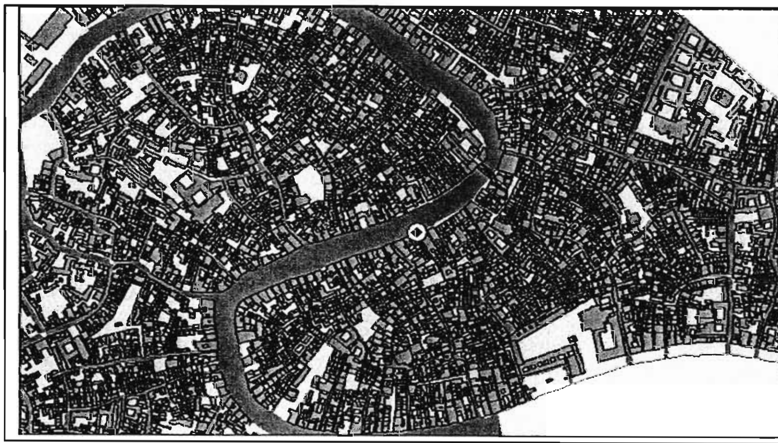
Grand Canal measurement site



Arsenale measurement site



Nearest *Centro Maree* Station:



Raw Data:

Wave Test	on stone in cm	on stone in cm	
Arsenale Canal	59	46	Grand Canal
	58	45	
	57.5	44	
	53	44	
	54	45	
	52	50	
	54	50	
	54	50	
	57	50	
	53	47	
	56	45	
	54	46	
	53	45	
	57	41.5	
	52	46	

Appendix B

Statistics Formulas:

Sample mean (or average):

$$\bar{x} = \sum_{i=1}^{N} x_i / N$$

Sample standard deviation (SD):

$$SD = \sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2 \Big/ (N-1)}$$

t-test equation (for statistical differences between two groups):

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(\frac{SD_1^2}{n}\right) + \left(\frac{SD_2^2}{n}\right)}}$$

Reportable Results:

sampling mean (AC): 54.9 cm
standard deviation: ± 2.3 cm

sampling mean (GC): 46.3 cm
standard deviation: ± 2.6 cm

t-value: 9.558

Appendix C – On-Site Data Forms

Appendix C

Site Information Form

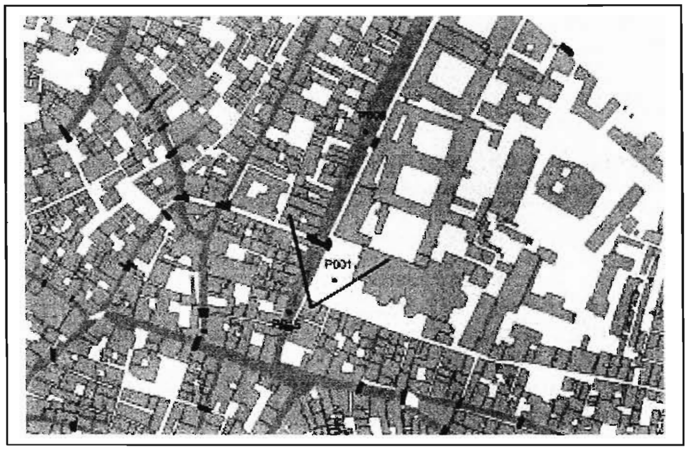
Site Code: P001a

Date: 06/08/04

Site Location by Name:
San Giovanni e Paolo

Artist: Bellotto

Year: 1741



Location Map

Photos:

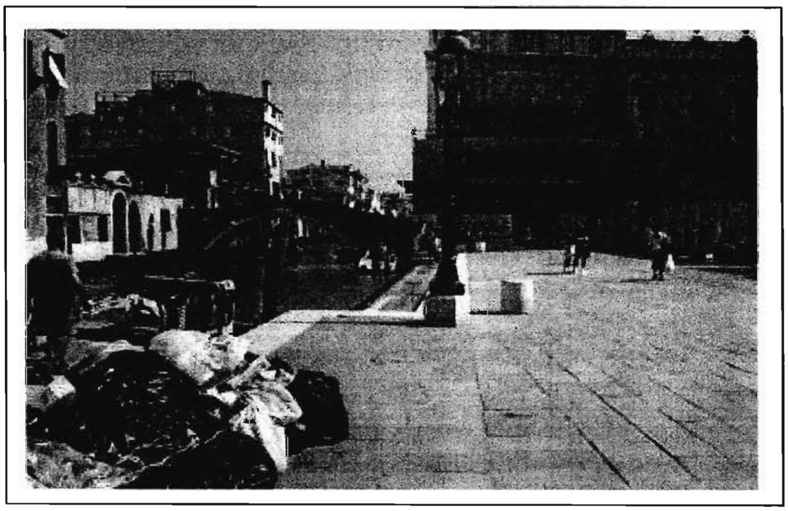


Figure 1 – On-Site Photo

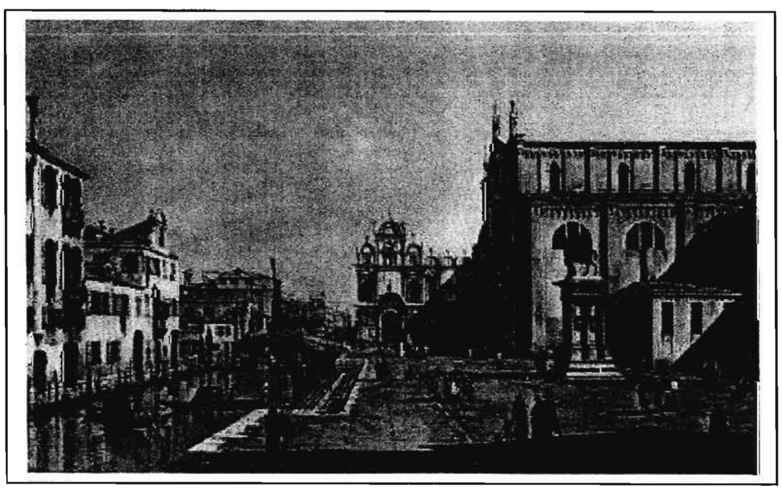


Figure 2 – Bellotto Painting

Appendix C

a) 3rd building from left, canal side, added a porch/ story on roof
b) Lamp posts added on either side of steps to canal
c) 3rd step of top set filled in, landing made wider and higher
d) Building address 6825 Cannaregio was not present at time of painting
e) Stone carvings added to bridge
f) Stone wall adjacent to building 6825 was not present
g) Cobblestone piazza was redone
h) Decorative stonework removed from around the top step
i) Madonna and Child art on bridge added

Measurement Information:

Vertical Axis Measurements

Measurement information taken off of high archway on the 3rd building from the left, canal side.

A. Height of arch .... 301 cm

B. Brick to top of black................ 12.0 cm

C. Brick to top of green line........... 43.5 cm

Horizontal Measurements

D. Measurements made from wall of buildings on canal side, to opposite side of bridge.
Length of Bridge......................... 15.67 m

Appendix C

Site Information Form

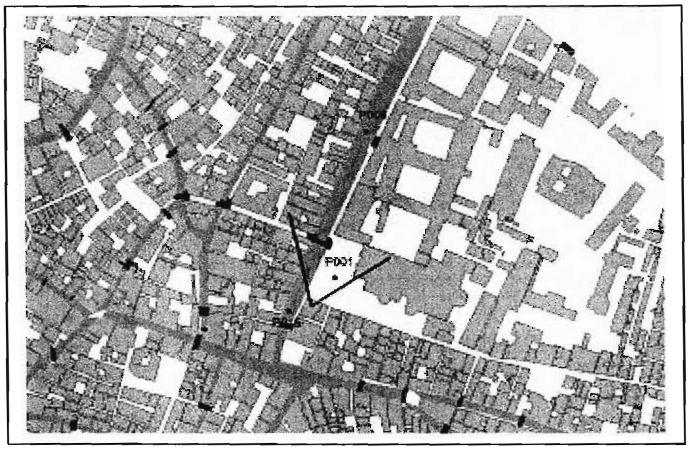
Site Code: P001b

Date: 06/08/04

Site Location by Name:
San Giovanni e Paolo

Artist: Bellotto

Year: 1743/1747



Location Map

Photos:

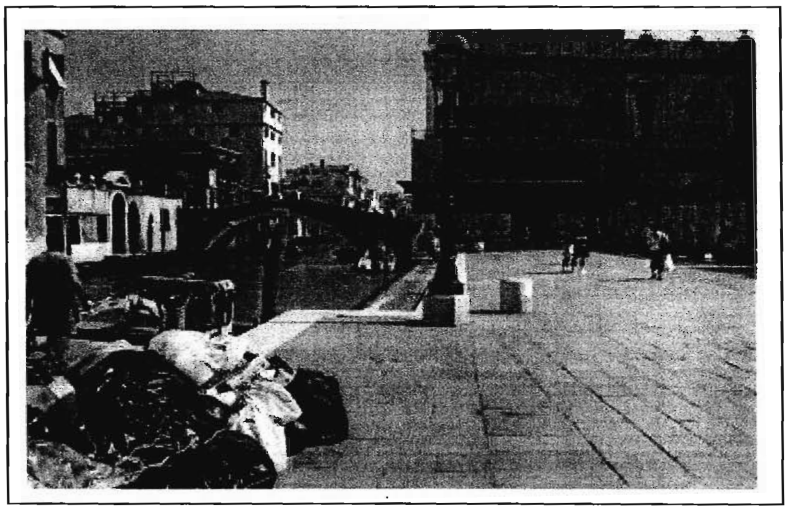


Figure 1 – On-Site Photo

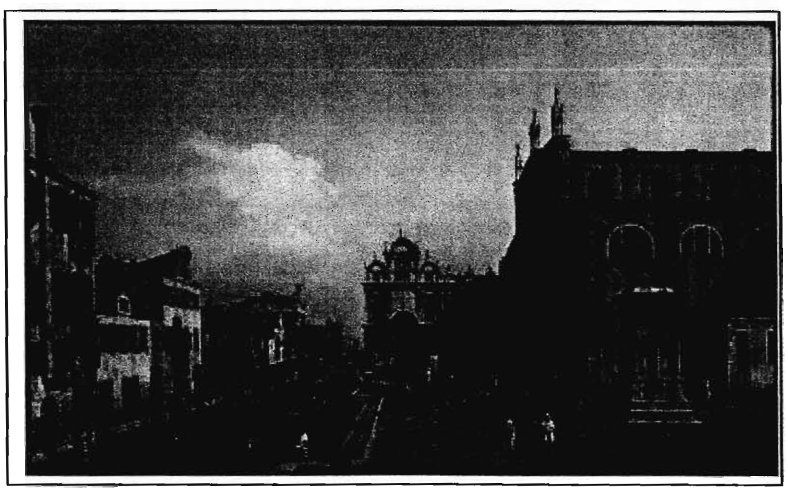


Figure 2 – Bellotto Painting

Appendix C

Comments:

a) 3rd building from left, canal side, added a porch/ story on roof
b) Lamp posts added on either side of steps to canal
c) 3rd step of top set filled in, landing made wider and higher
d) Building address 6825 Cannaregio was not present at time of painting
e) Stone carvings added to bridge
f) Stone wall adjacent to building 6825 was not present
g) Cobblestone piazza was redone
h) Decorative stonework removed from around the top step
i) Madonna and Child art on bridge added

Measurement Information:

Vertical Axis Measurements

Measurement information taken off of high archway on the 3rd building from the left, canal side.

A. Height of arch .... 301 cm

B. Brick to top of black................ 12.0 cm

C. Brick to top of green line........... 43.5 cm

Horizontal Measurements

D. Measurements made from wall of buildings on canal side, to opposite side of bridge.
Length of Bridge...................... 15.67 m

Appendix C

Site Information Form

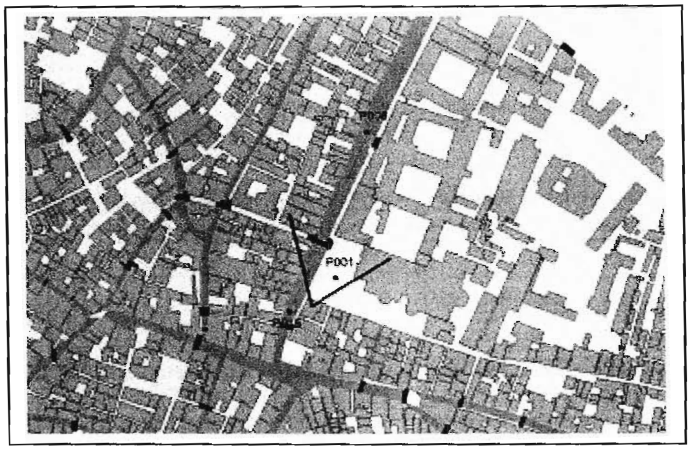
Site Code: P001c

Date: 06/08/04

Site Location by Name:
SS. Giovanni e Paolo and
The Scuola S. Marco

Artist: Canaletto

Year: 1725



Location Map

Photos:

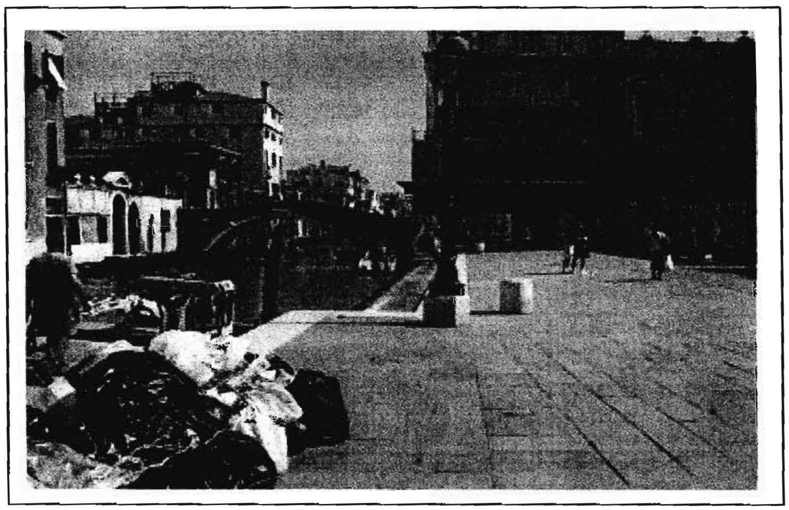


Figure 1 – On-Site Photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

a) 3rd building from left, canal side, added a porch/ story on roof
b) Lamp posts added on either side of steps to canal
c) 3rd step of top set filled in, landing made wider and higher
d) Building address 6825 Cannaregio was not present at time of painting
e) Stone carvings added to bridge
f) Stone wall adjacent to building 6825 was not present
g) Cobblestone piazza was redone
h) Decorative stonework removed from around the top step
i) Madonna and Child art on bridge added

Measurement Information:

Vertical Axis Measurements

Measurement information taken off of high archway on the 3rd building from the left, canal side.

A. Height of arch .... 301 cm

B. Brick to top of black................ 12.0 cm

C. Brick to top of green line........... 43.5 cm

Horizontal Measurements

D. Measurements made from wall of buildings on canal side, to opposite side of bridge.
Length of Bridge..................... 15.67 m

Appendix C

Site Information Form

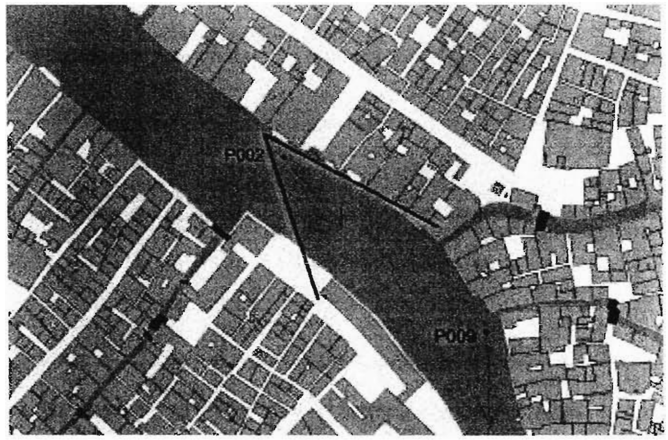
Site Code: P002

Date: 06/09/04

Site Location by Name:
Grand Canal looking Southeast From the Campo Sta Sofia to the Rialto Bridge

Artist: Canaletto

Year: 1758



Location Map

Photos:

Figure 1 – On-Site Photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

Measurement Information:

Vertical Axis Measurements

A. 1st door on side of building #2........................ 114.0 cm

B. Vertical on second window in from left.............170.0 cm

C. Algae line to inside of window frame bottom.......160.0 cm

Horizontal Axis Measurements

D. Width of 2nd window in from left..........…..........110.0 cm

Appendix C

Site Information Form

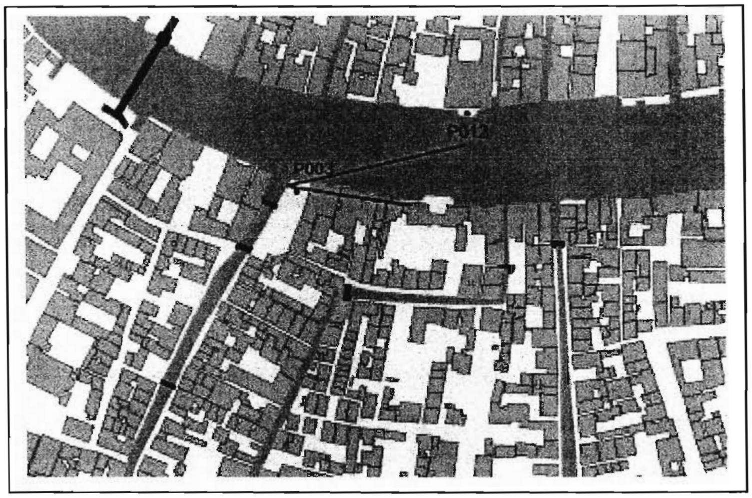
Site Code: P003a

Date: 06/09/04

Site Location by Name:
Grand Canal Looking East
From the Campo San Vio

Artist: Canaletto

Year: 1725



Location Map

Photos:

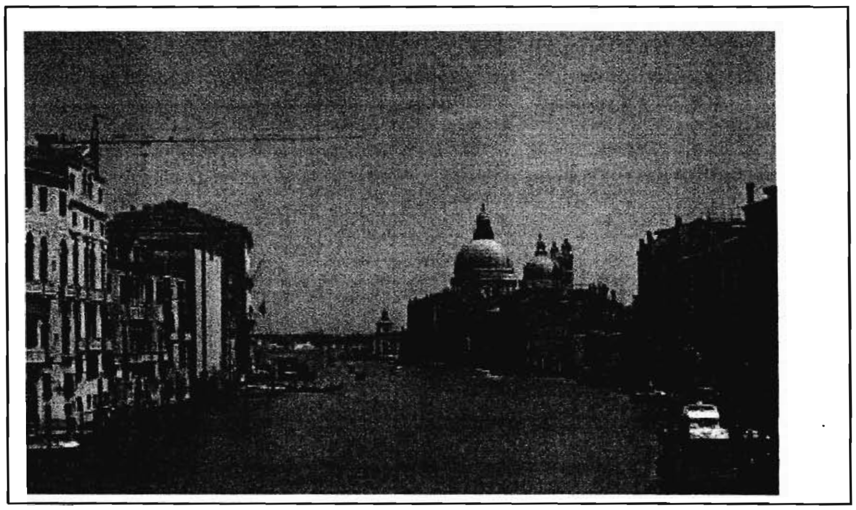


Figure 1-On Site Photo

Figure 2 –
Canaletto Painting

Appendix C

Comments:

a) Measurements used were taken from 3-story building on left.

Measurement Information:

Vertical Axis Measurements

A. 1st door on side of building on right........................ 335.5 cm

B. Vertical of window on building to the left..................115 cm

C. Bottom of window to green line.............................111 cm

D. Known elevation to green line................................75 cm

Appendix C

Site Information Form

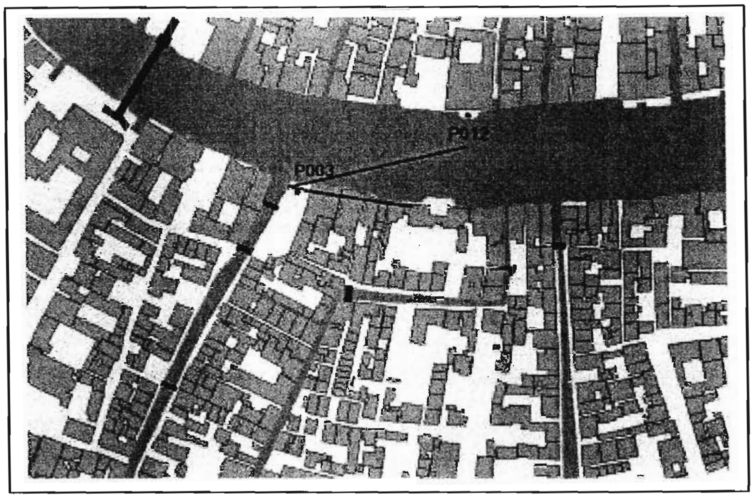
Site Code: P003b

Date: 06/09/04

Site Location by Name:
Grand Canal near the Campo San Vio looking towards the church of Santa Maria della Salute

Artist: Canaletto

Year: 1730



Photos:

Location Map

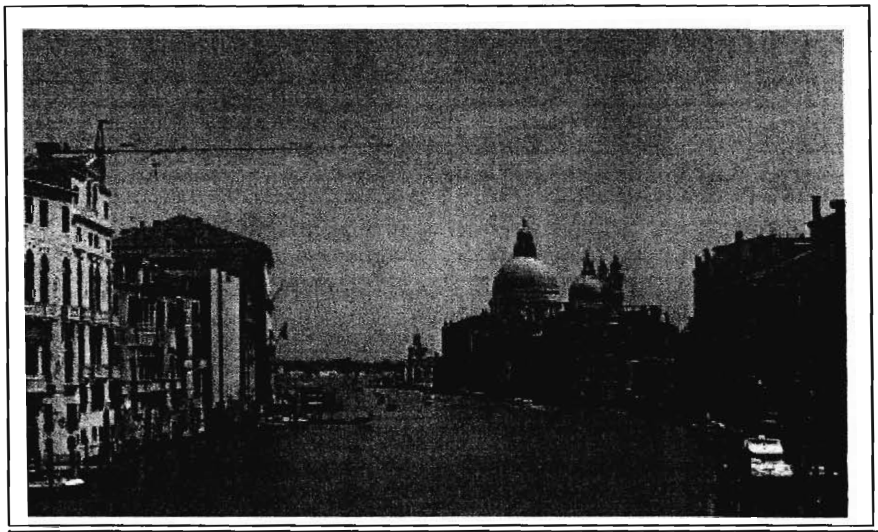


Figure 1 – On-Site Photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

*For results, Painting P003a will be used because it was created at an earlier date and will be more useful.

Measurement Information:

Vertical Axis Measurements

1st door on side of building #2........................ 114.0 cm

Horizontal Axis Measurements

Appendix C

Site Information Form

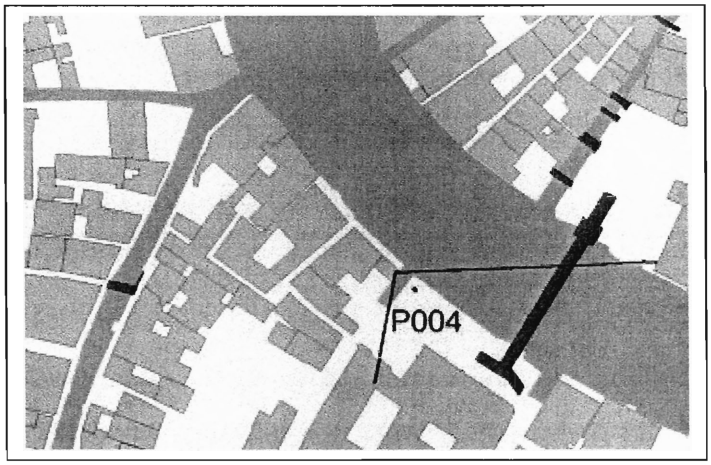
Site Code: P004

Date: 06/23/04

Site Location by Name:
Grand Canal: from Sta Maria della Carita to the Bacino di San Marco

Artist: Canaletto

Year: early 1730's



Location Map

Photos:

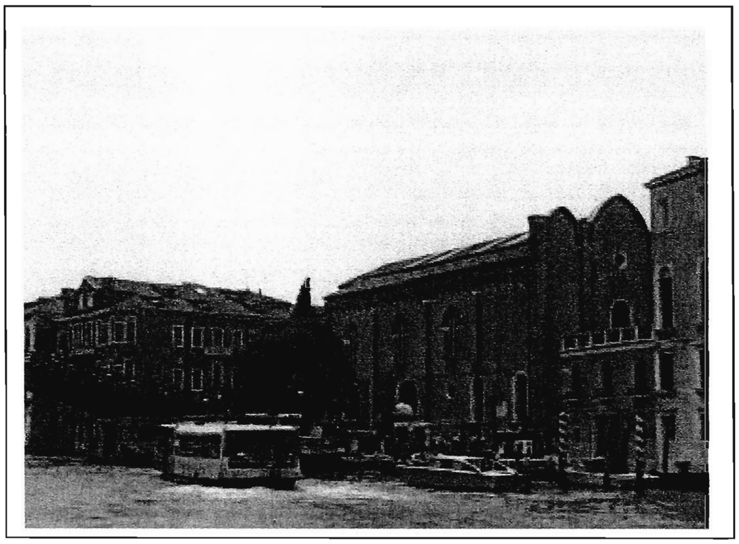


Figure 1 – On-Site Photo

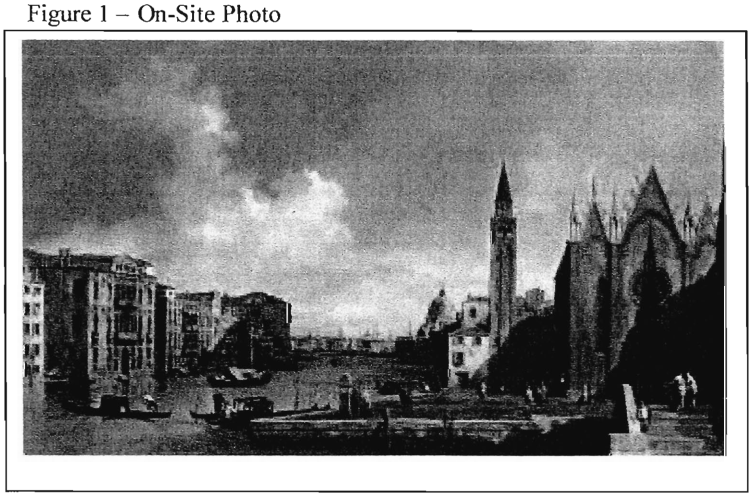


Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Façade of church changed. Window placement and size has changed. Original configuration still visible in newer bricks.
b) Wall with algae grown is of different construction then original. Piazza has been increased in size, and changed in shape. (See Figure 1 for site sketch)
c) Stairway leading to canal in front of Church has been built, not visible in painting.

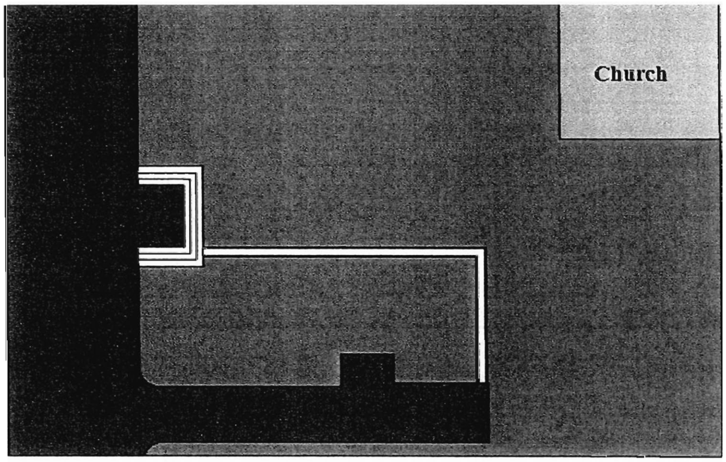


Figure 1 - p004 Site Sketch

Site p004 showed piazza changes since the date of painting. Although the same sidewalk appears to be a valuable algae line indicator, a number of assumptions were taken into account under 2 possible conditions.

Assumptions (Condition #1):

a) White line on sidewalk (shown in sketch) is original end of sidewalk.
b) Height of sidewalk is same as original height

Distance from stairs to end of white line..................... 15.67 m
Distance from beginning of stairs to white line ....3.33 m
Total distance of White line (Sidewalk in painting)..... ....**19.00 m**
*This distance serves as the horizontal measurement for this site.

Assumptions (Condition #2)

a) White line on sidewalk (shown in sketch) is original end of sidewalk.
b) Height of sidewalk has changed by the height of 1 layer of stone

Height of top layer of stone.................................... 30 cm

Appendix C

Measurement Information:
Condition #1
Vertical Axis Measurements

A. Height of top layer of stone................................ 244.0 cm

B. Green line of algae to sidewalk.............................. 83.0 cm

C. Black line of algae to sidewalk.............................. 35.0 cm

Horizontal Axis Measurements

D. Distance along Sidewalk: Center to right side of painting.........19.0 m

Condition #2
Vertical Axis Measurements

A. Height of top layer of stone................................ 244.0 cm

B. Green line of algae to sidewalk.............................. 83.0 cm

C. Black line of algae to sidewalk.............................. 35.0 cm

Horizontal Axis Measurements

D. Distance along sidewalk: center to right side of painting.......... 19.0 m

Elevation Reading on sidewalk .... 0.97 m

Appendix C

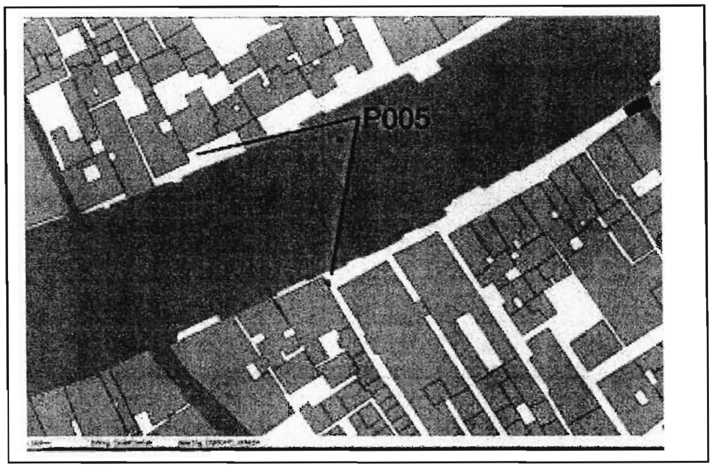
Site Information Form

Site Code: P005

Date: 06/23/04

Site Location by Name:
Grand Canal: looking southwest
From the Palazzo Grimani to the
Palazo Foscari
Artist: Canaletto

Year: 1735



Location Map

Photos:

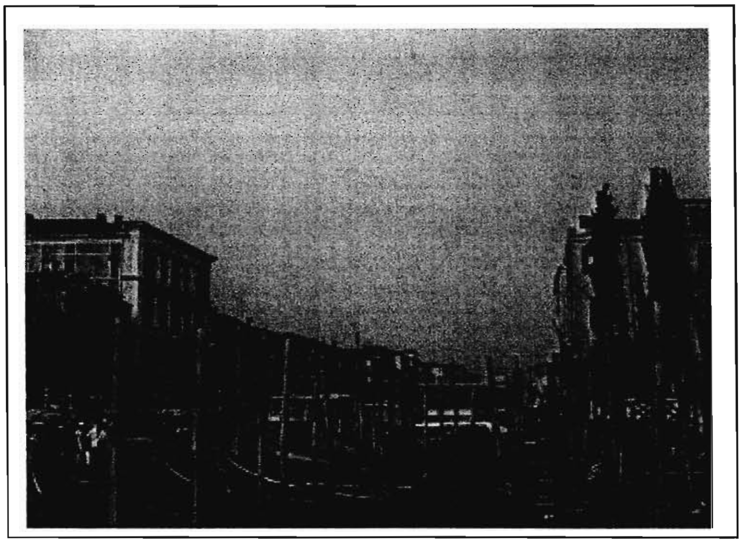


Figure 1 – On-Site Photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Many docks impeding view of algae line on large white palace.
b) Pink building in left side of painting has altered 1st floor, and added 4th story.

Measurement Information:

Vertical Axis Measurements

A. Bottom of window to beginning of foundation (Large white building).... 164.0 cm

B. Top of foundation to green line .... 171.0 cm

C. Top of foundation to black line .... 152.5 cm

D. Known elevation to green algae line

Horizontal Axis Measurements

No Horizontal measurements deemed reliable. Vanishing point in painting yields diminishing measurements at inconsistent rate. Vertical axis measurements only for this site.

Elevation Reading on sidewalk .... 0.97 m

Appendix C

Site Information Form

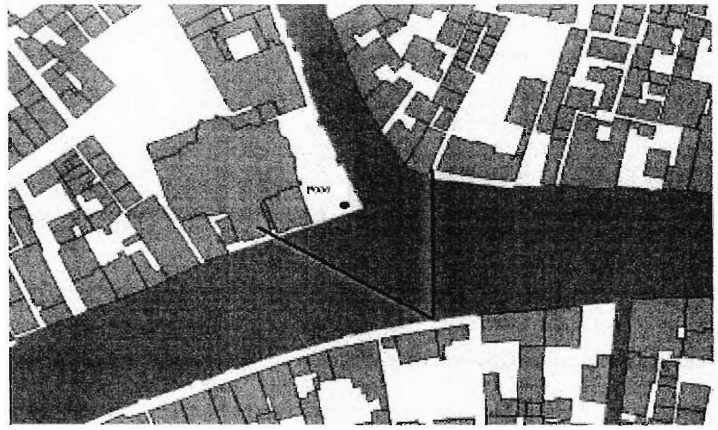
Site Code: P006

Date: 06/21/04

Site Location by Name:
Grand Canal: Entrance
To Cannaregio

Artist: Canaletto

Year: 1735



Location Map

Photos:

Figure 1 – On-Site Photo

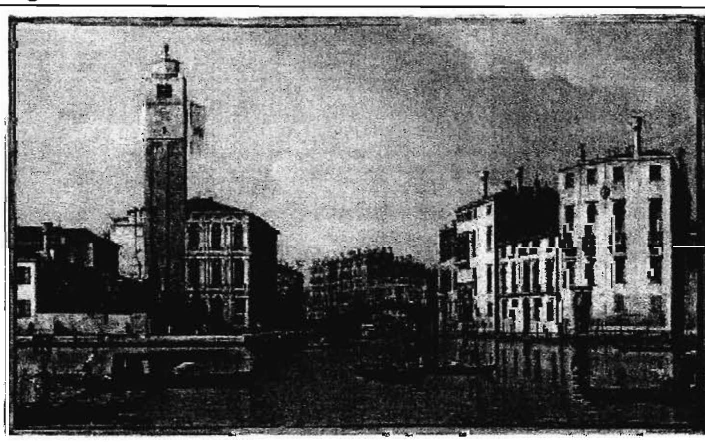


Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Police gazebo added with wooden dock in front
b) Tan building, far right, now is red
c) Statue added to end of sidewalk on left, 1740

Measurement Information:

Vertical Axis Measurements

A. Window on red building vertical..............................101.0 cm

B. Bottom of measurement A to dark green line .... 161.0 cm

C. Sidewalk to green line... 92.0 cm

Horizontal Axis Measurements

D. Width of window inside frame .... 112.5 cm

Appendix C

Site Information Form

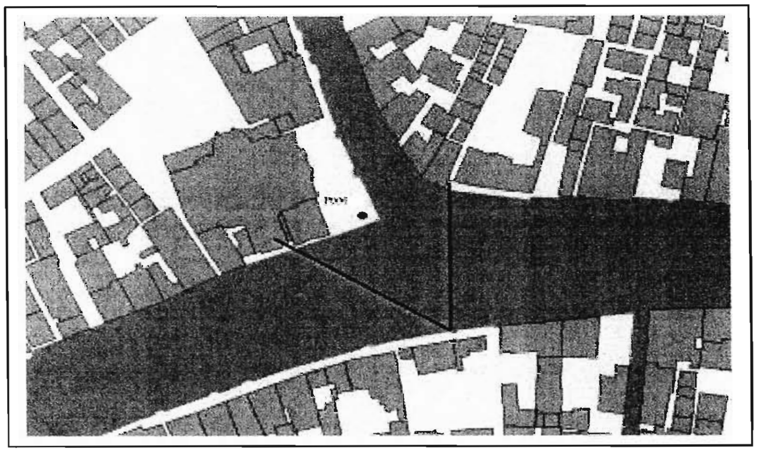
Site Code: <u>P007</u>

Date: <u>06/30/04</u>

Site Location by Name:
<u>Grand Canal: SW from chiesa Degli Scalzi</u>

Artist: Canaletto

Year: 1738



Photos:

Location Map

Figure 1 – On-Site Photo

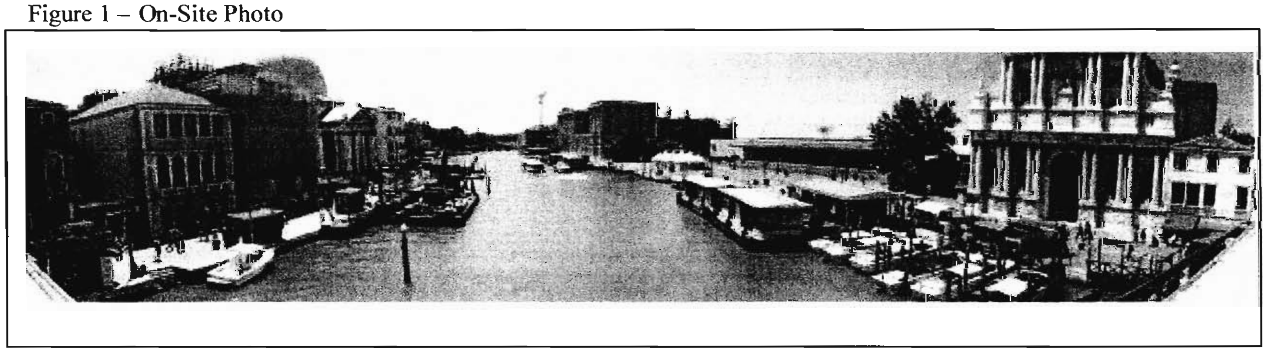


Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Scalzi bridge added over Grand Canal
b) Canal wall blocked off by construction barriers and equipment directly in front of church
c) Ferrovia boat stops added in front of train station.

Measurement Information:

Vertical Axis Measurements

A. Height of low building to left.................................380.0 cm

B. Bottom of measurement A to green line .... 60.0 cm

Horizontal Axis Measurements

C. Width of low building to left....................................720.0 cm

D. Width of column, pink building on left.......................39.5 cm

Appendix C

Site Information Form

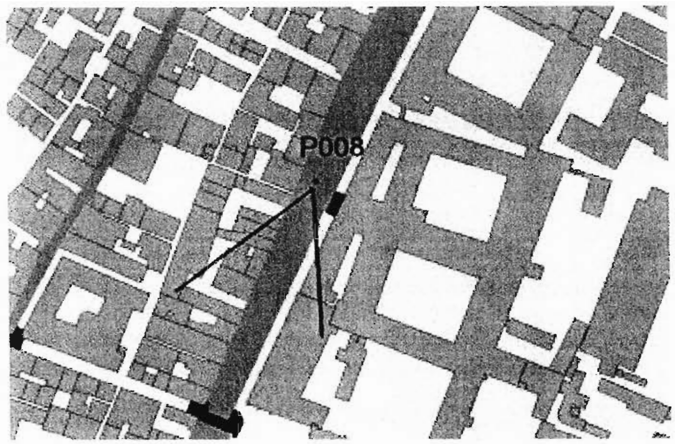
Site Code: P008

Date: 07/06/04

Site Location by Name:
Rio dei Mendicanti:
Looking South

Artist: Canaletto

Year: 1723



Location Map

Photos:

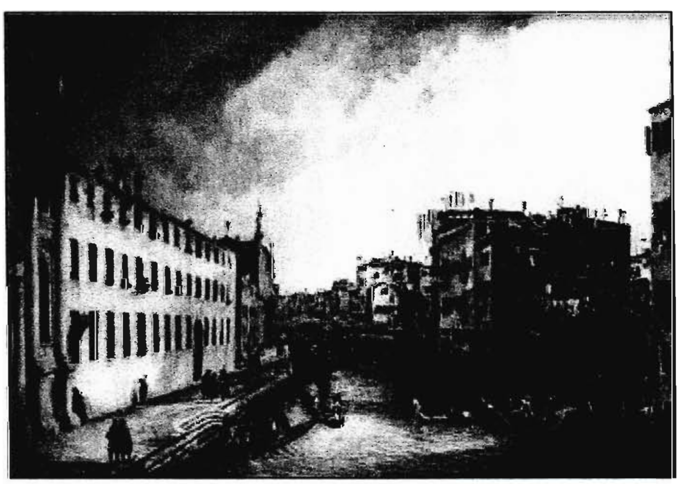


Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Near bridge has been removed
b) Canal wall on left re-done
c) Buildings on right have changed, all windows

Measurement Information:

No measurements were taken because too much at this site has changed to get accurate results.

Appendix C

Site Information Form

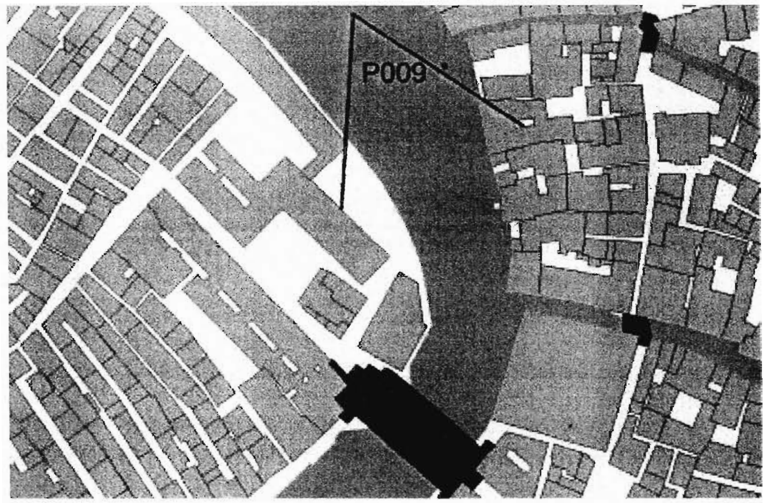
Site Code: P009

Date: 07/6/04

Site Location by Name:
Rialto bridge from the North

Artist: Canaletto

Year: 1727



Location Map

Photos:

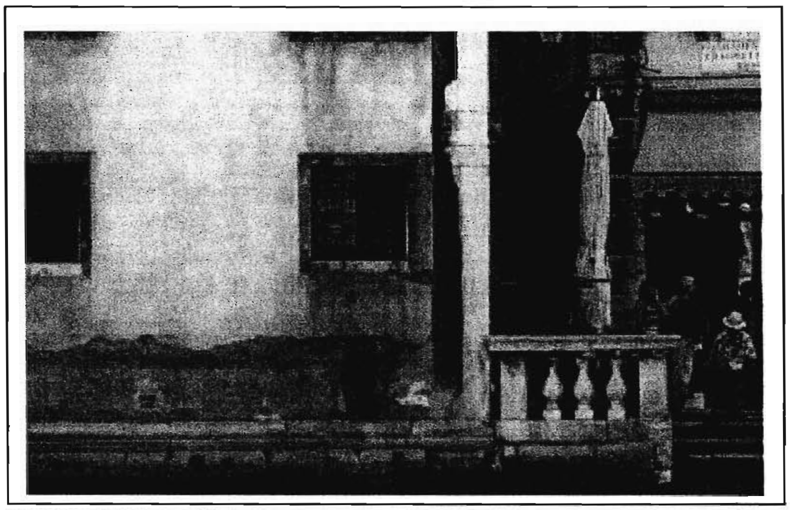


Figure 1 – On-Site Photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Nothing has changed from the painting to today.

Measurement Information:

Vertical Axis Measurements

Measurement taken from right side of building on left with railing to the right.

A. Height of space on railings... 69 cm

B. Green line to bottom of railing.. 66 cm

C. Black line to bottom of railing..38 cm

D. Height of window to far right on building...........................105 cm

E. Bottom of window to algae line...226 cm

Horizontal Measurements

F. Width of window.. 104 cm

G. Width of railing...210 cm

Appendix C

Site Information Form

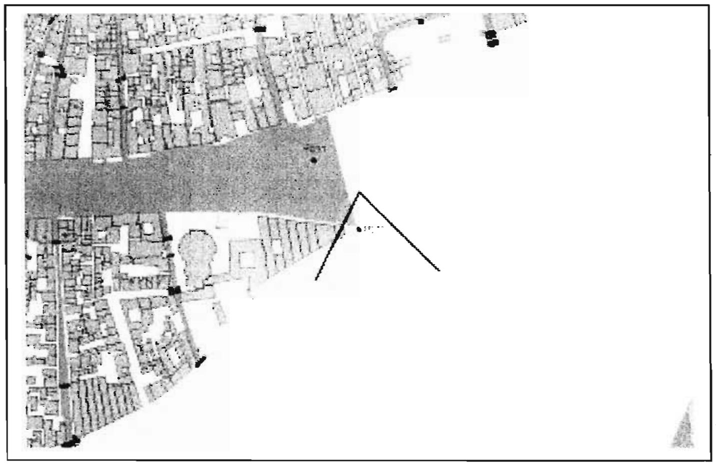
Site Code: P010

Date: 06/21/04

Site Location by Name:
Punta Della Dogana

Artist: Canaletto

Year: 1727



Location Map

Photos:

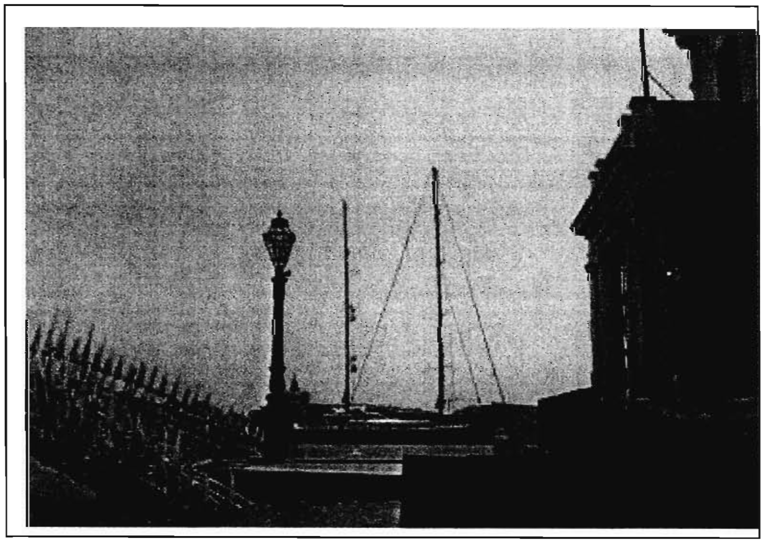


Figure 1 – On-Site Photo

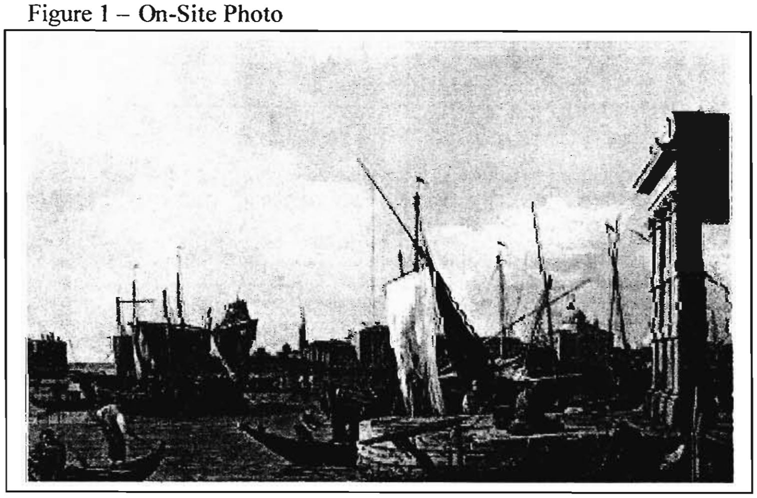


Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Boat dock in the way of San Stae Church canal wall and algae line. (Vaporetti stop S.Stae)
b) 3rd story built upon building to right of S. Stae

Measurement Information:

Vertical Axis Measurements

A. Building on right (tan), 1st floor
Left side window frame..244.0 cm

B. Bottom of measurement A to dark green line .... 183.0 cm

C. Bottom of measurement A to light green line .... 144.0 cm

Horizontal Axis Measurements

D. Width of window inside frame .... 114.5 cm

Appendix C

Site Information Form

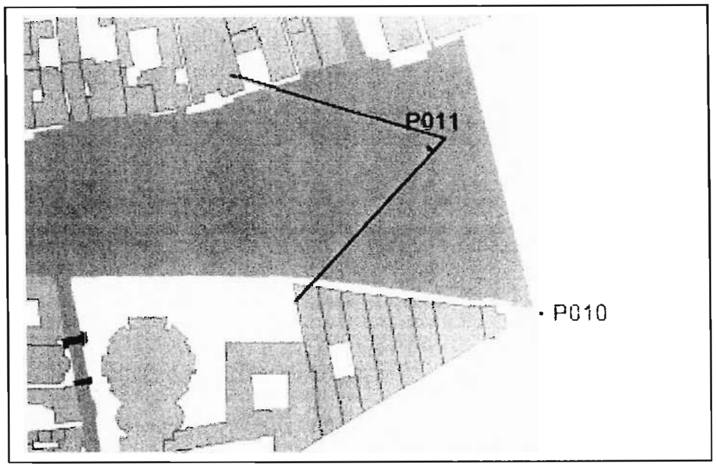
Site Code: P011

Date: 06/23/04

Site Location by Name:
The Grand Canal and the church
Of the Solute

Artist: Canaletto

Year: 1735



Location Map

Photos:

Figure 1 – On-Site Photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Nearside of Salute under construction, algae line impeded
b) Nearside of Salute impeded by "Salute" Vaporetti terminal.
c) Farside of Salute under construction. Far corner of waterline impeded.

Measurement Information:

Vertical Axis Measurements

A. Bottom of window to beginning of foundation (Large wht building)... 164.0 cm

B. Top of sidewalk to green line .... 117.0 cm

C. Top of sidewalk to black line .... 65.0 cm

Horizontal Axis Measurements

A. Width of cubic section of column on far left of Salute Façade ....147.5 cm

Elevation Reading on side walk .... 1.41 m

Appendix C

Site Information Form

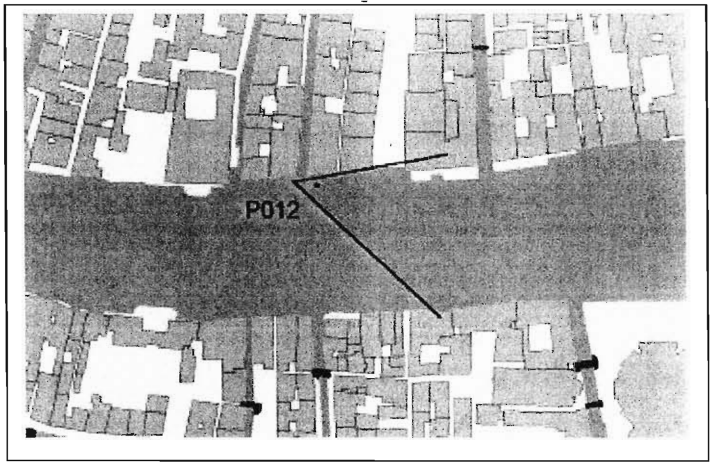
Site Code: P012

Date: 06/23/04

Site Location by Name:
Entrance to the Grand Canal

Artist: Bellotto

Year: 1740



Location Map

Photos:

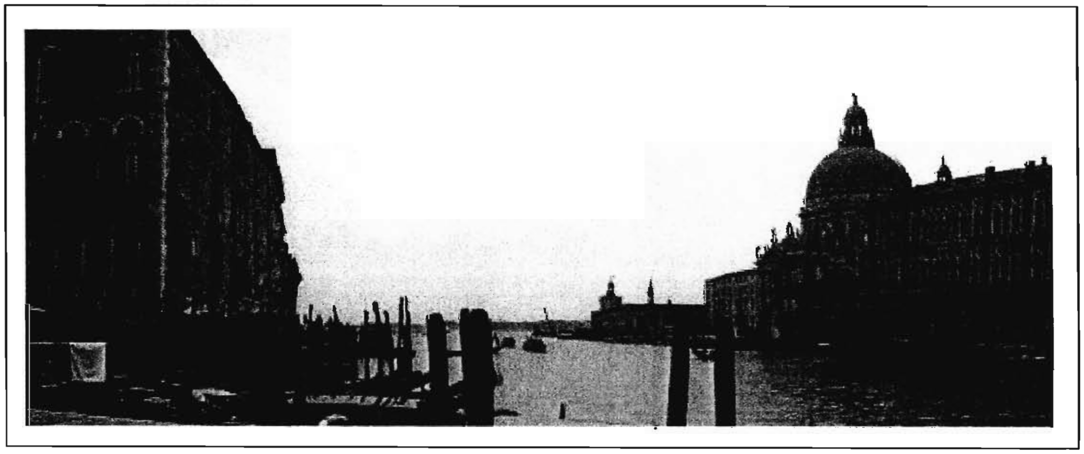


Figure 1 – On-Site Photo

Figure 2 – Bellotto Painting

Appendix C

Comments:

a) Half of convent on right side of Salute replaced by newer pink building
b) Docks added and outdoor dining added to Gritti Palace hotel (left side of painting)
c) 4th story added to Gritti Palace
d) Convent church is no longer visible in skyline

Measurement Information:

Vertical Axis Measurements

A. Left side building: Door from sidewalk to top of door, bottom of frame..245.5 cm

B. Foundation of building on left to green line.................................. 52.5 cm

C. Foundation of building on left to black line .... 17.5 cm

Horizontal Axis Measurements

A. Left side building: Door width, not including frame........................ 130.0 cm

Elevation Reading on sidewalk .... 0.98 m

Appendix C

Site Information Form

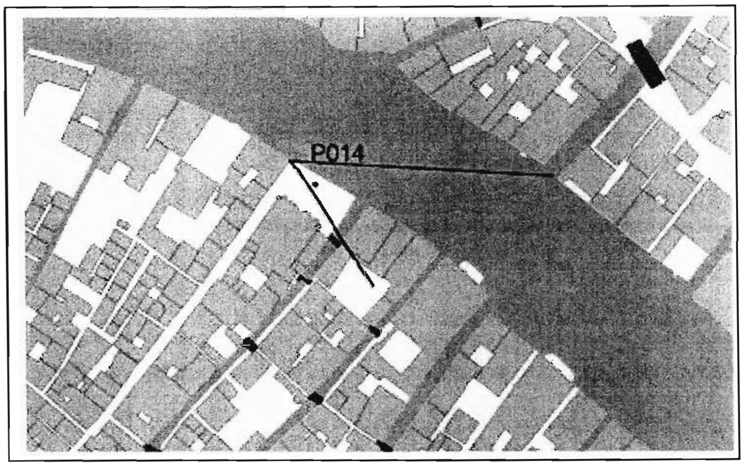
Site Code: P014

Date: 06/11/04

Site Location by Name: Grand Canal Near San Stae Church

Artist: Bellotto

Year: 1740



Photos:

Location Map

Figure 1 – On-Site Photo

Figure 2 – Bellotto Painting

Appendix C

Comments:

a) Boat dock in the way of San Stae Church canal wall and algae line. (Vaporetti stop S.Stae)
b) 3rd story built upon building to right of S. Stae

Measurement Information:

Vertical Axis Measurements

A. Building on right (tan), 1st floor
Left side window frame..244.0 cm

B. Bottom of measurement A to dark green line .... 183.0 cm

C. Bottom of measurement A to light green line .... 144.0 cm

Horizontal Axis Measurements

D. Width of window inside frame .... 114.5 cm

Appendix C

Site Information Form

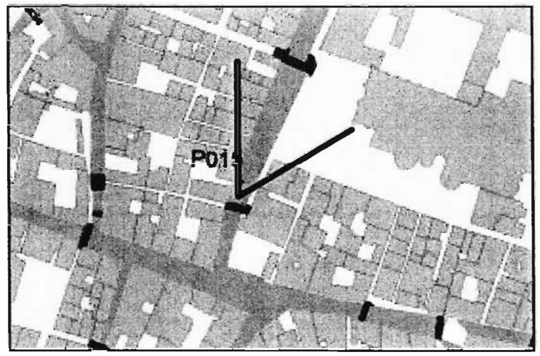
Site Code: P015

Date: 07/06/04

Site Location by Name:
Rio dei Mendicanti:
Looking South

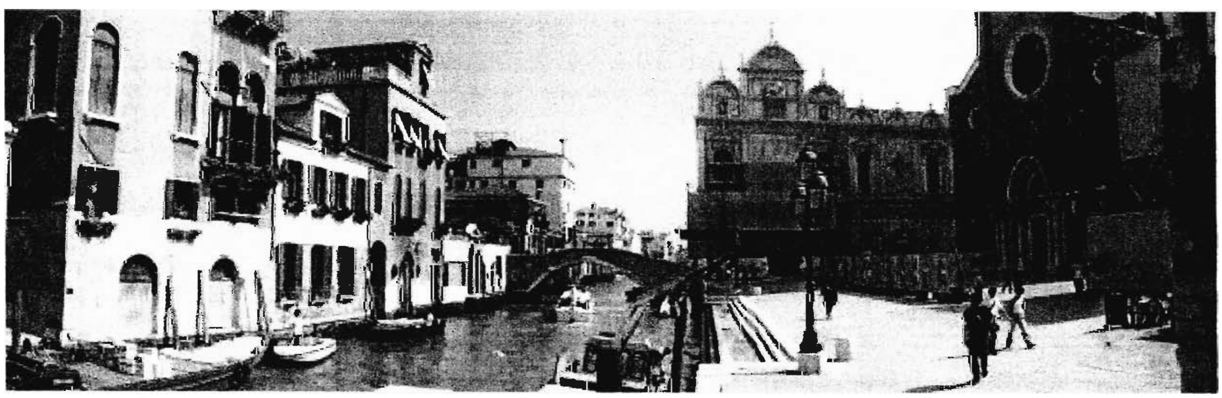
Artist: Bellotto

Year: 1740



Location Map

Photos:
Figure 1: On site



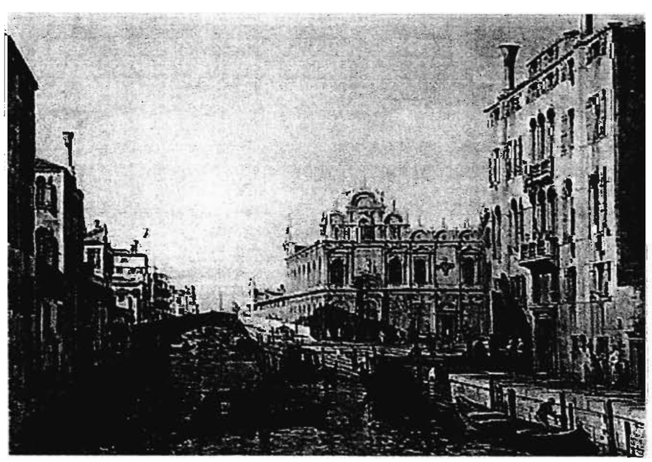


Figure 2 – Bellotto Painting

Appendix C

Comments:

a) Canal wall to right has been completely reconstructed and built over the previously existing wall where the green algae line was visible in the painting.

Measurement Information:

No measurements were taken because too much at this site has changed to get accurate results.

Appendix C

Site Information Form

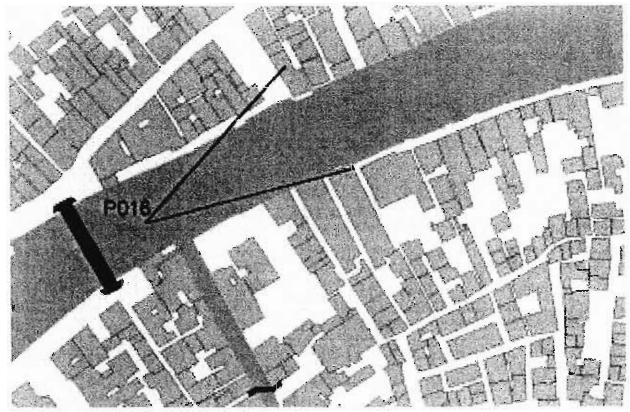
Site Code: P016

Date: 06/30/04

Site Location by Name:
Grand Canal to S. Marcuola

Artist: Canaletto

Year: unknown



Location Map

Photos:

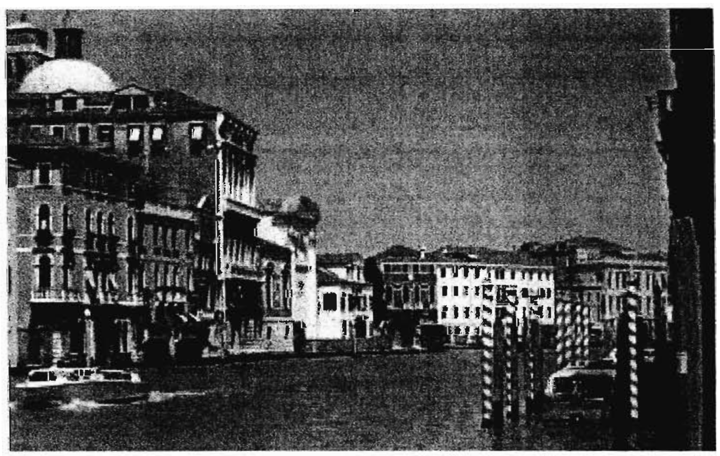


Figure 1 – On site photo

Figure 2 – Canaletto Painting

Appendix C

Comments:

a) Could not take measurements off building on left due to algae blocker
b) Building to the right of first building has changed completely and it cannot be used.

**No measurements could be taken at this site, it is deemed unusable.*

Appendix C

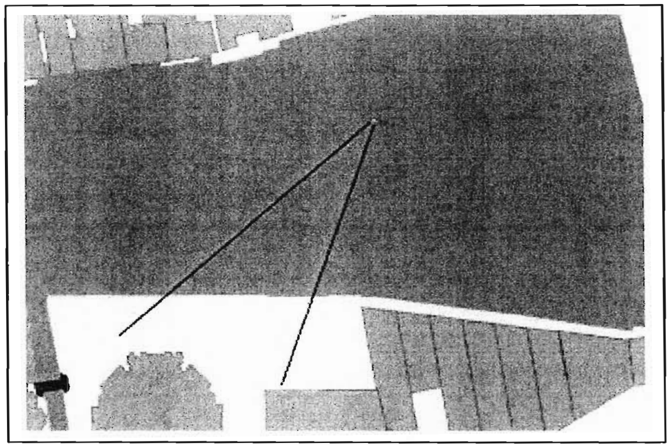
Site Information Form

Site Code: F001

Date: 07/20/04

Site Location by Name:
Salute

Year: 1860



Photos:

Location Map

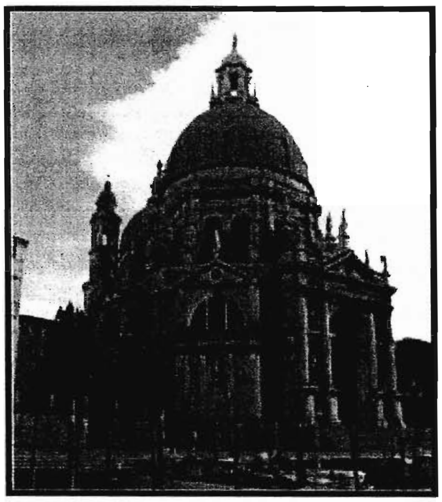


Figure 1 – Present Day Photograph

Figure 2 – Original Photograph

Appendix C

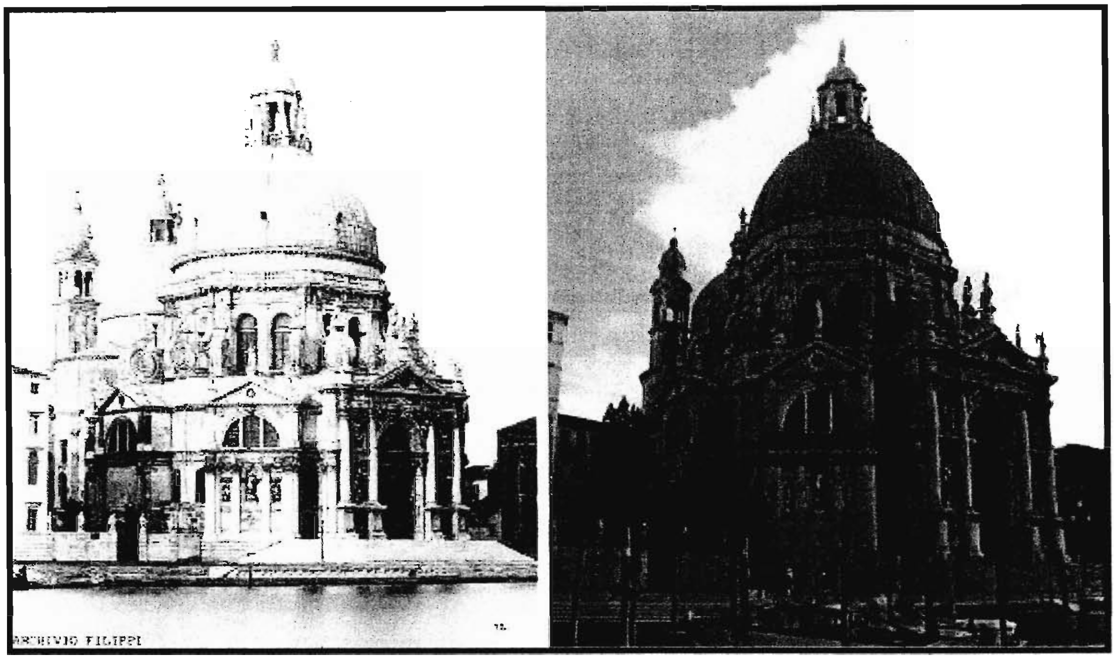


Figure 3 – Side-by-side of original photo and new photo.

Comments:

a) Nearside of Salute under construction, algae line impeded.
b) Nearside of Salute impeded by "Salute" Vaporetti terminal
c) Farside of Salute under construction. Far corner of waterline impeded
d) Many boatdocks on front of salute impeding wave traffic, increased boat parking

Measurement Information:

Vertical Axis Measurements

A. Bottom of column to sidewalk level..164.0 cm

B. Top of sidewalk to green line...104.0 cm

C. Top of sidewalk to black line..65.0 cm

Horizontal Axis Measurements

D. Width of cubic section of column on far left of Salute Façade............147.5 cm

Elevation Point on sidewalk.................................141.0 cm

Appendix C

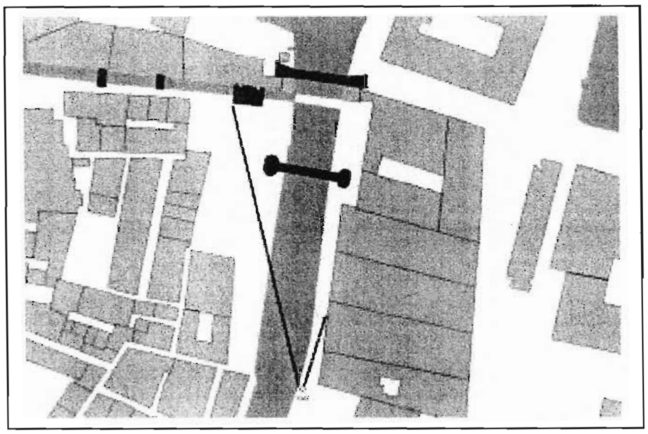
Site Information Form

Site Code: F002

Date: 07/16/04

Site Location by Name:
Palazzo Manin

Year: 1866



Photos:

Location Map

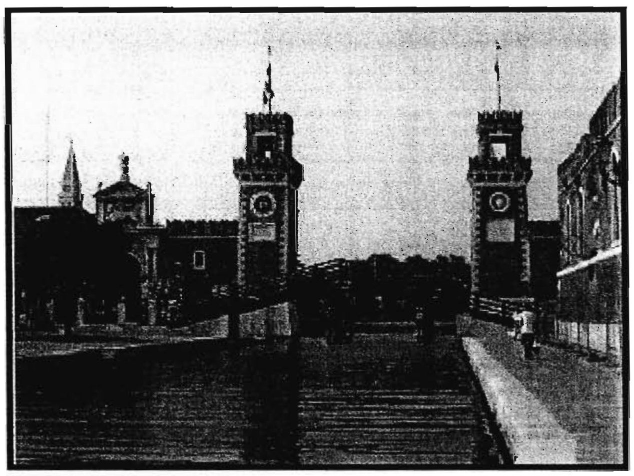


Figure 1 – Present Day Photograph

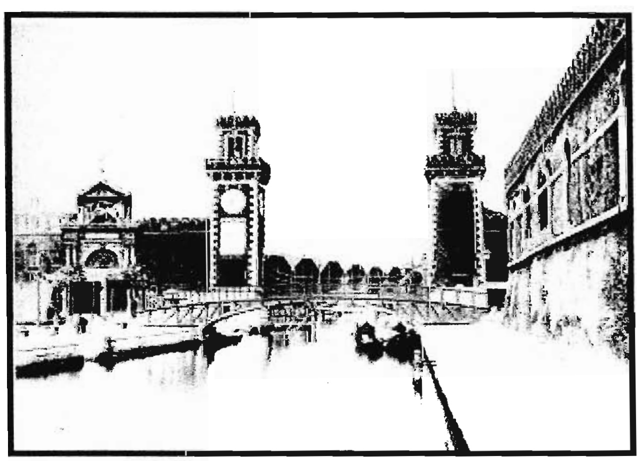


Figure 2 – Original Photograph

Appendix C

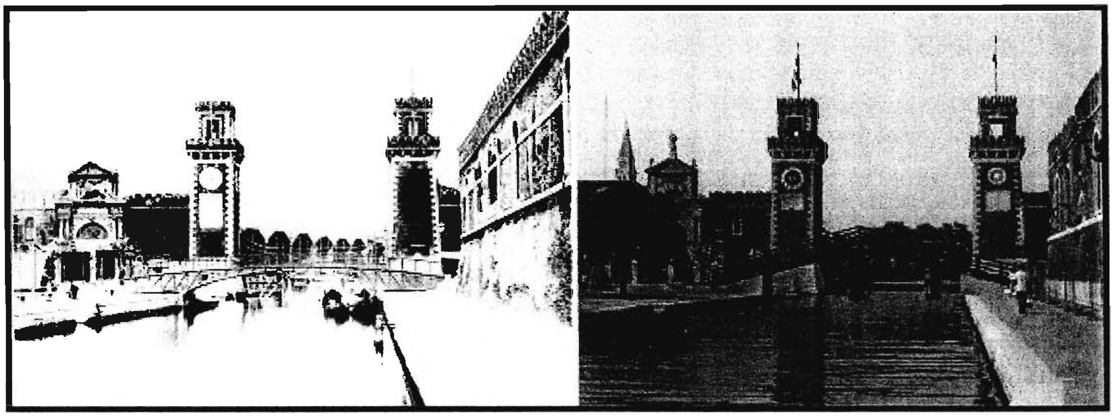


Figure 3 – Side-by-side of original photo and new photo.

Comments:

a) Bridge has changed
b) Canal wall on right side has been redone with new materials
c) Façade of Arsenale Building on left side has been redone
d) Missing white décor on right tower

Measurement Information:

Vertical Axis Measurements

A. Window, lower left of left tower..................................312.0 cm

B. Sidewalk elevation point to green line..........................70.0 cm

Horizontal Axis Measurements

D. Right tower, base length...................................... 552 cm

Elevation Point (Sidewalk on left side of Palazzo)............. 94.0 cm

Appendix C

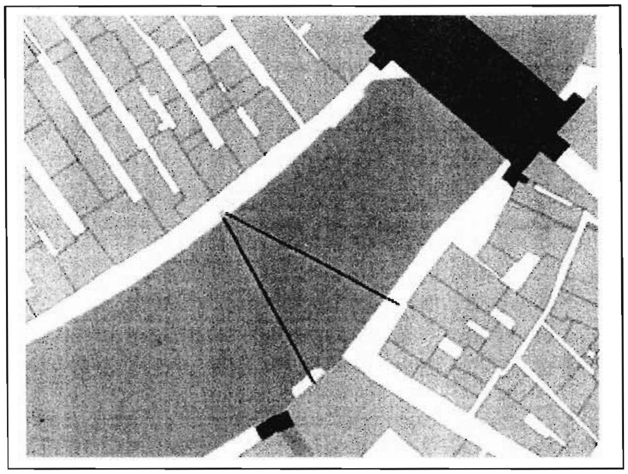
Site Information Form

Site Code: F003

Date: 07/16/04

Site Location by Name:
Palazzo Manin

Year: 1867



Location Map

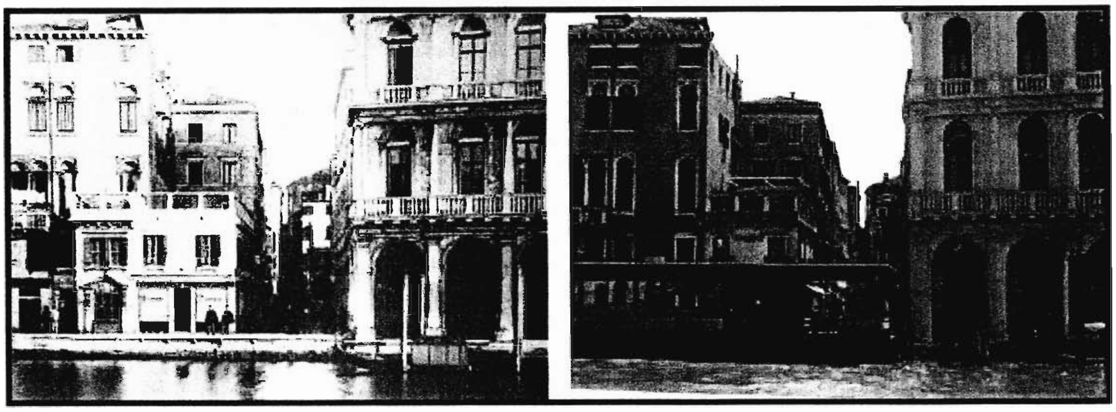
Photos:

Figure 1 – Present Day Photograph

Figure 2 – Original Photograph

Figure 3 – Side-by-side of original photo and new photo.

Appendix C



Comments:

a) Building on left side of Palazzo has changed
b) New Façade on first floor of building on left side
c) Rialto Boat stop in front of photo area
d) Boat dock in front of Palazzo Manin

Measurement Information:

Vertical Axis Measurements

A. Left arch height of vertical column to base of arch.........311.0 cm

B. Sidewalk elevation point to green line...........................51.0 cm

Horizontal Axis Measurements

D. Left arch column width.. 100.0 cm

Elevation Point (Sidewalk on left side of Palazzo).............77.0 cm

Appendix C

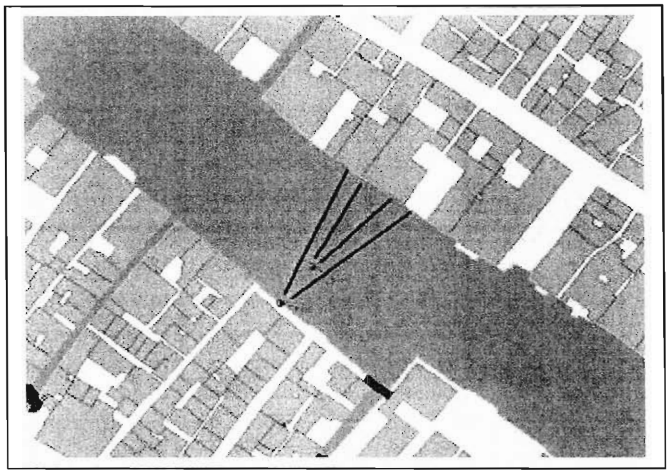
Site Information Form

Site Code: F010

Date: 07/13/04

Site Location by Name:
Façade – Ca D'Oro

Year: 1870



Location Map

Photos:

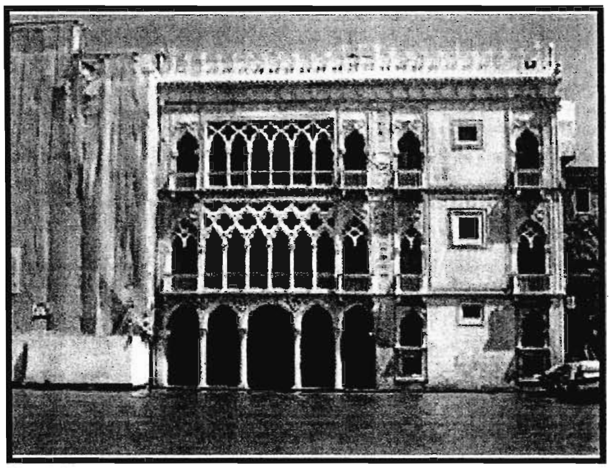


Figure 1 – Present Day Photograph

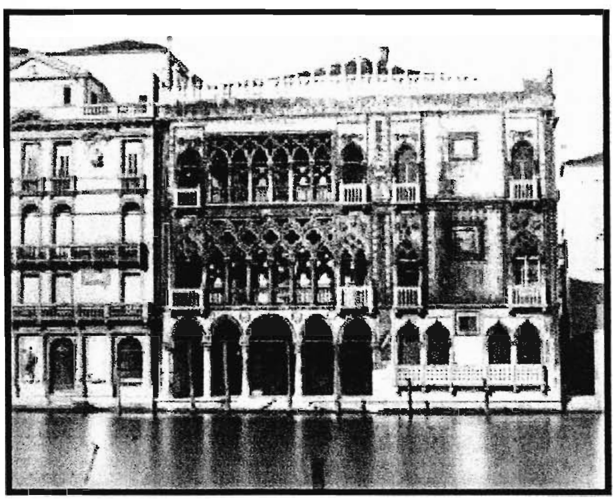


Figure 2 – Original Photograph

Appendix C

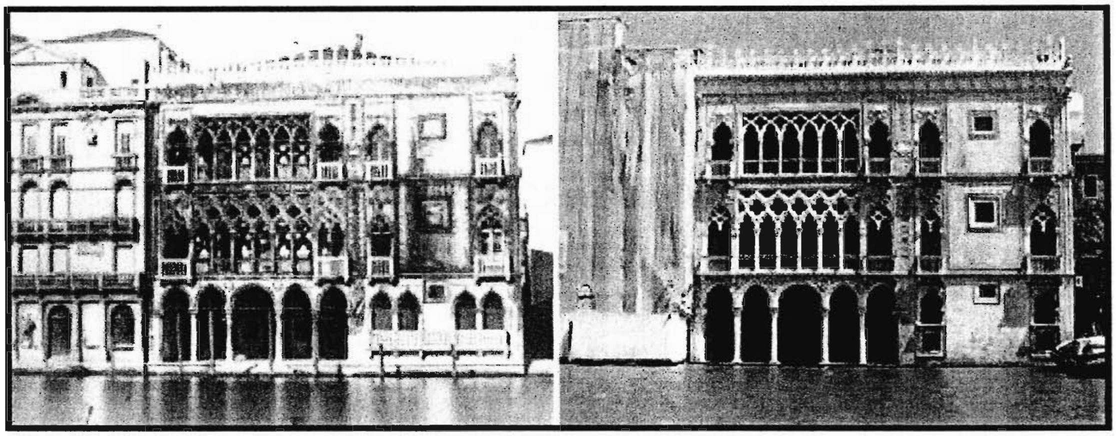


Figure 3 – Side-by-side of original photo and new photo.

Comments:

a) First floor, right side, changed since date of photograph.
b) Reliable algae line in middle, not on right side where changed.
c) Construction on left side of building at time of inspection
d) No sidewalk access to façade for measurements
e) Measurements taken inside of building

Measurement Information:

Vertical Axis Measurements

A. 2nd floor arcade column height................................181.0 cm

B. Elevation point to green line...................................104.0 cm

Horizontal Axis Measurements

D. 2nd floor window to right of arcade columns................ 205.0 cm

Elevation Point...131.0 cm

Appendix C

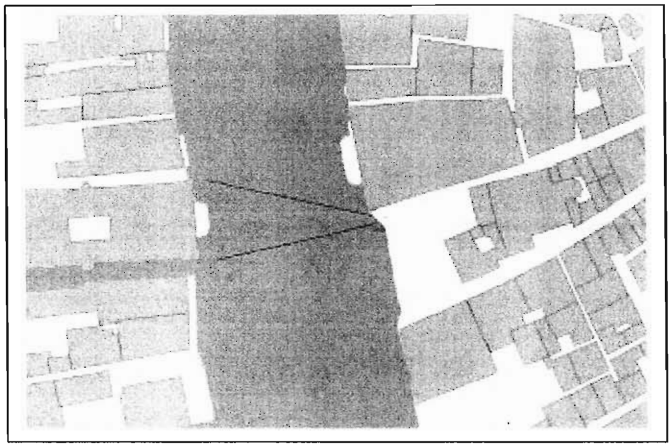
Site Information Form

Site Code: F013

Date: 07/20/04

Site Location by Name:
Palazzo Rezzonico

Year: 1901



Location Map

Photos:

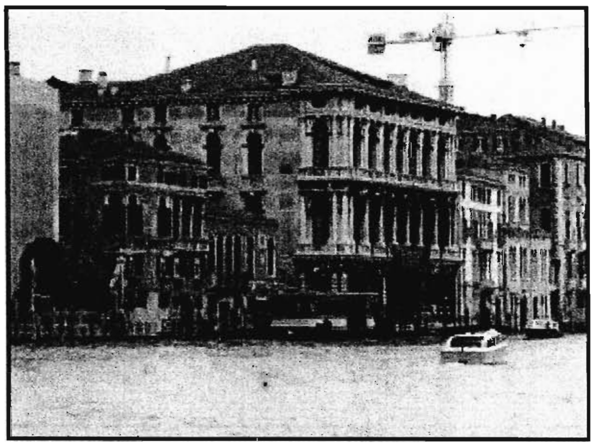


Figure 1 – Present Day Photograph

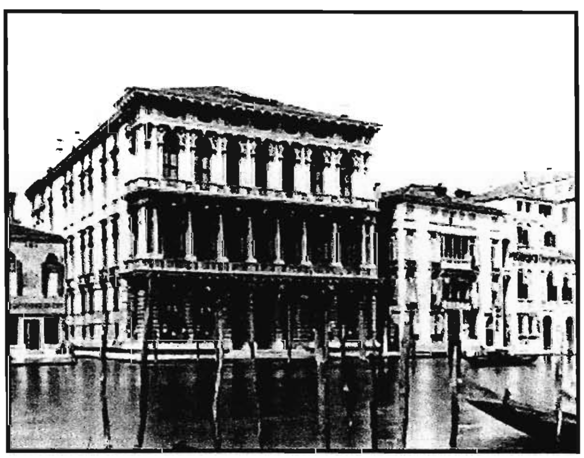


Figure 2 – Original Photograph

Appendix C

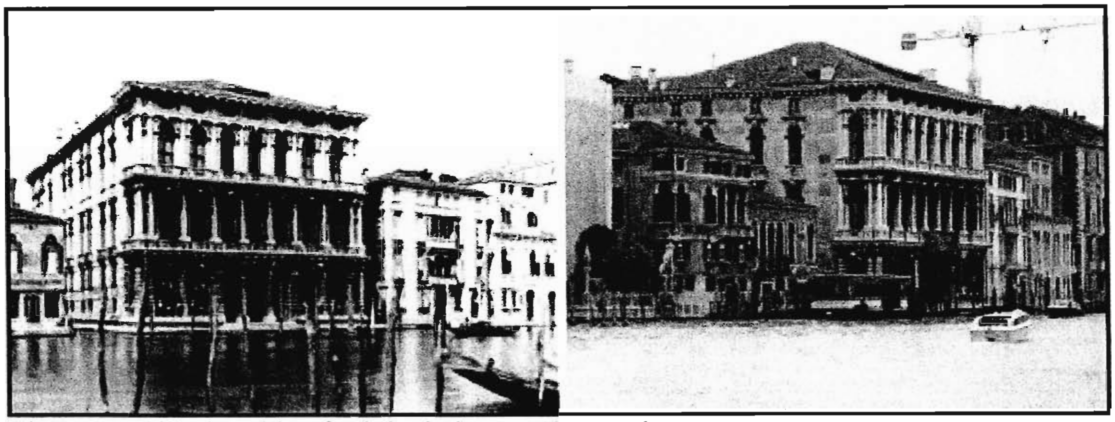


Figure 3 – Side-by-side of original photo and new photo.

Comments:

a) Wooden bridge on left front of Palazzo constructed
b) Dock on front of Palazzo
c) Ca Rezzonico Vaporetti stop to left of Palace

Measurement Information:

Vertical Axis Measurements

A. Ledge to first floor window.....................................170.0 cm

B. Top of ledge to green line.......................................70.0 cm

Horizontal Axis Measurements

D. Leftmost column to next column on right................... 340.0 cm

Elevation Point...106.0 cm

Appendix D – Results Forms

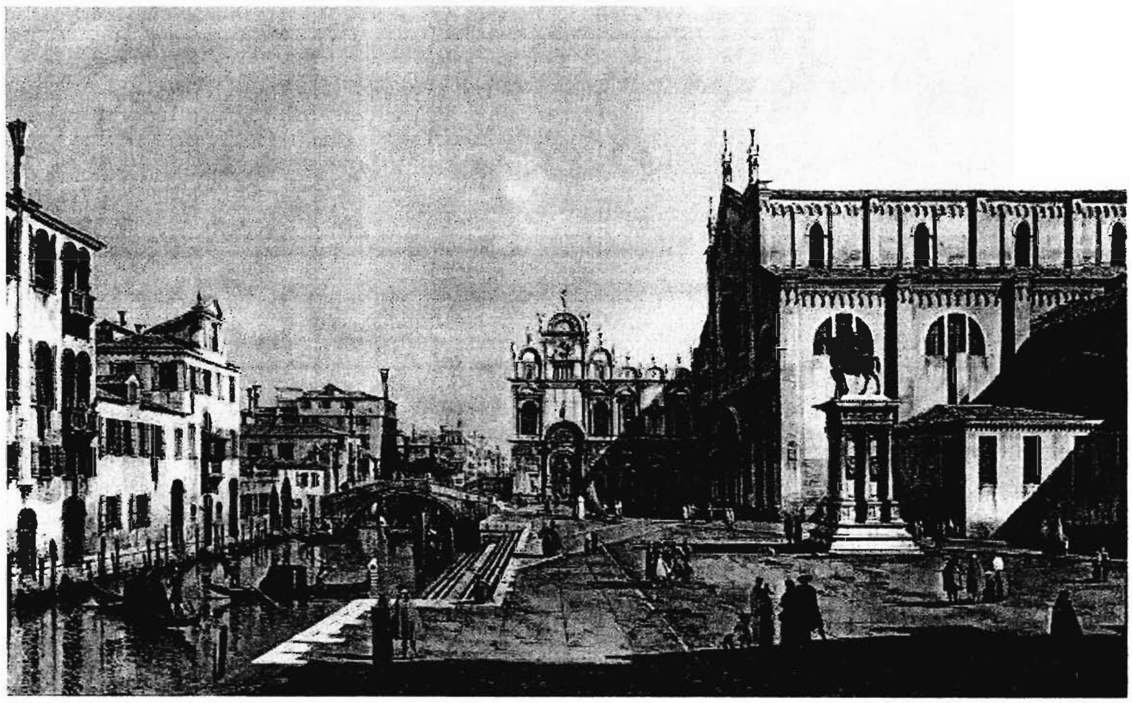
Appendix D

Results

CODE: ___P001a___ **LOCATION:** _S. Giovani e Paolo__

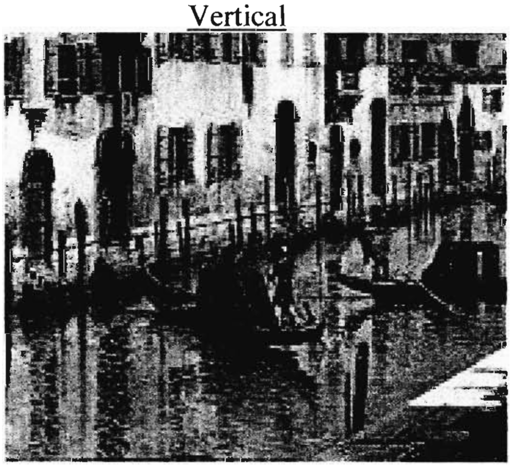
Original Painting Information

Artist: Bellotto
Year: 1741
Title: Campo San Giovanni e Paolo

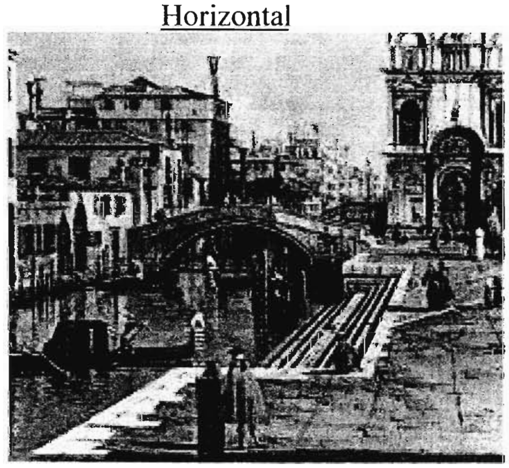


On-Site Measurement focus areas

Vertical



Horizontal



Appendix D

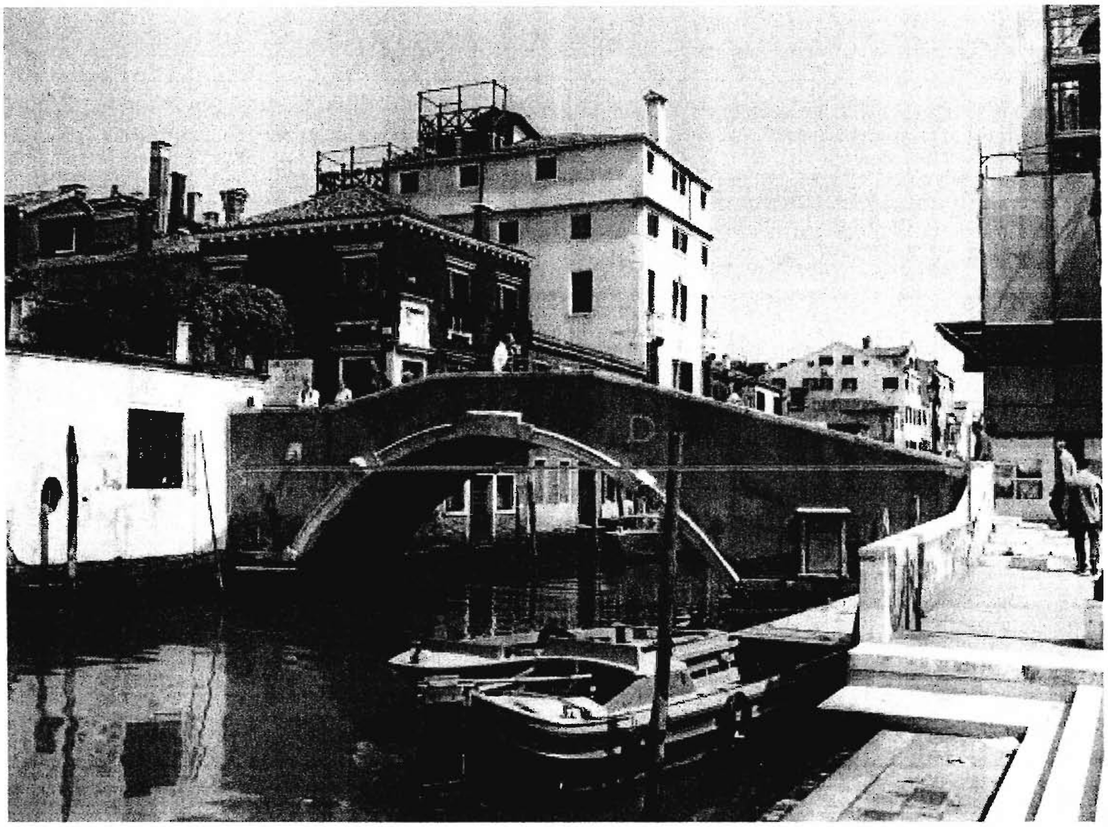
Results Methodology

Figure 1
Drawing of measured objects

Key:

Section	Description	Value
A	Vertical Height of Archway	301.0 cm
B	Distance from top of black line to brickwork	12.0 cm
C	Distance from top of green line to brickwork	43.5 cm

Appendix D



Section	Description	Value
D	Horizontal Length of Bridge	1567

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.

Measurements taken:

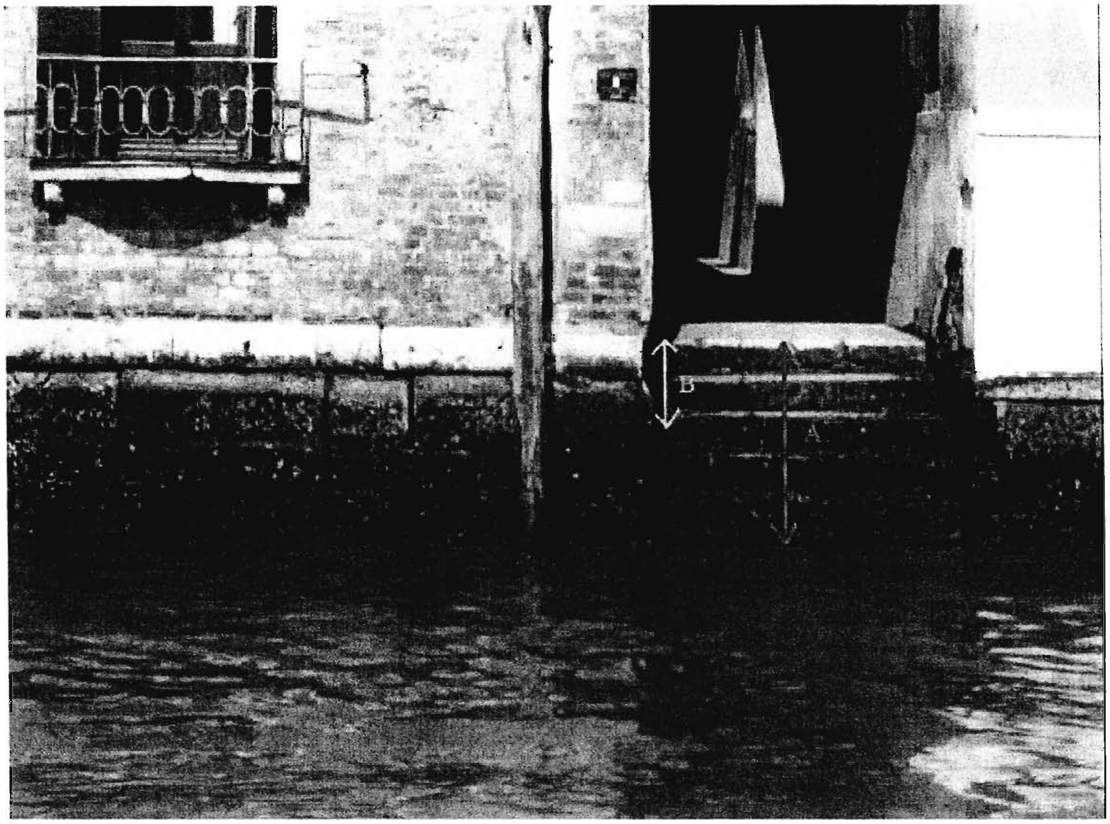
$$\frac{1.4}{301} = \frac{.55}{X}$$ (Scale Formula)

X= 118.25 cm

118.25 – 43.5 = 74.75cm
Resulting waterline differential for this site: **0.7475 m**

Appendix D

Absolute height



A is the know elevation of the sidewalk from the zero line established in 1897.
B is the distance measured from the sidewalk to the green line.

A= 89 cm
B=59.5 cm

To get the absolute waterline differential B is subtracted from A to get X, and then the relative waterline differential is subtracted from X.

89-59.5 = 29.5 – 74.75 = -45.25

Absolute waterline differential for this site: **-0.4525 m**

Appendix D

Results

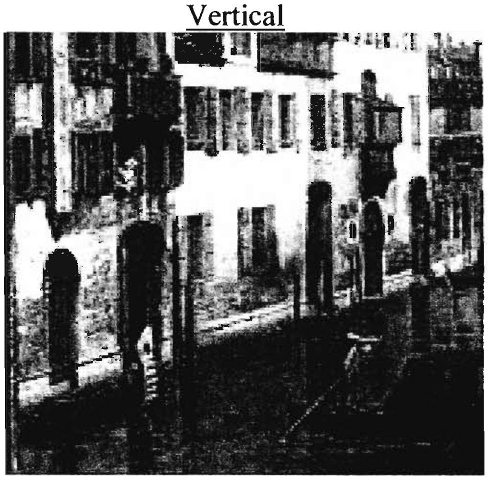
CODE: P001b **LOCATION:** S. Giovani e Paolo

Original Painting Information

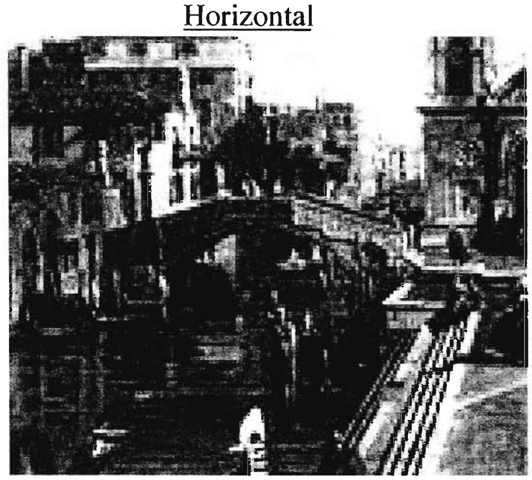
Artist: Bellotto
Year: 1743/1747
Title: Campo San Giovanni e Paolo

On-Site Measurement focus areas

Vertical



Horizontal



Appendix D

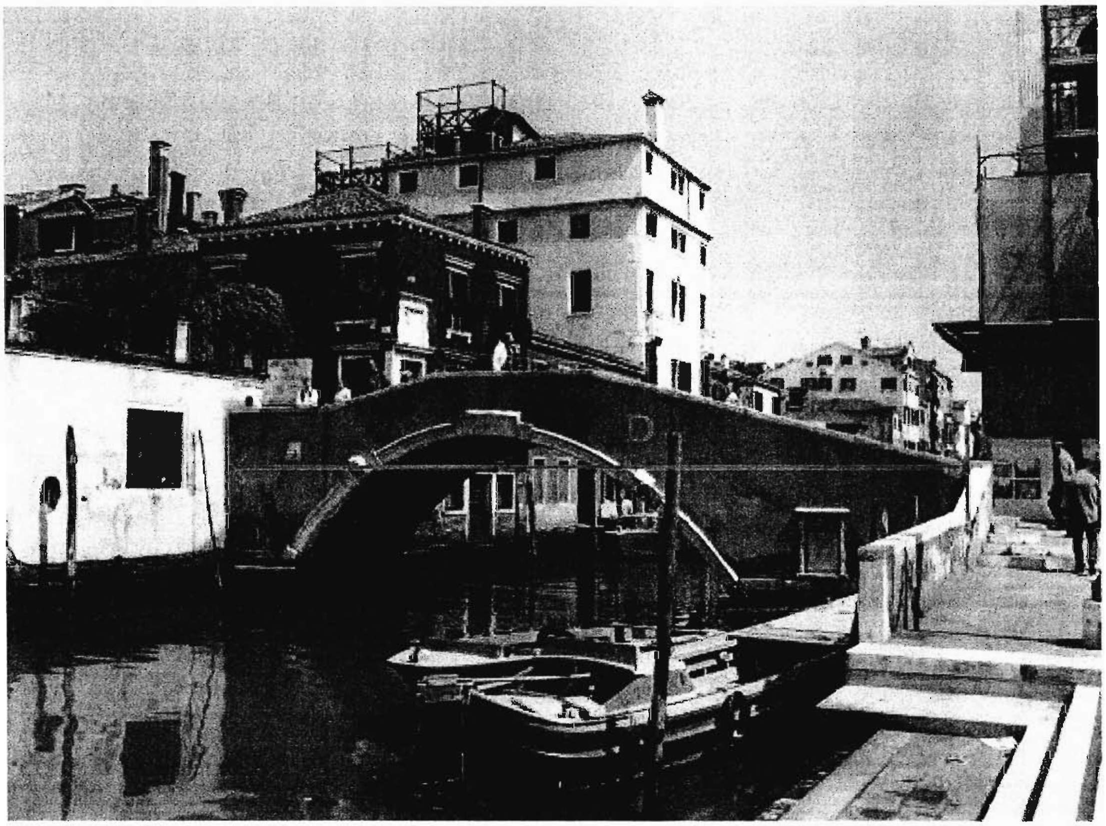
Results Methodology

Figure 1
Drawing of measured objects

Key:

Section	Description	Value
A	Vertical Height of Archway	301.0 cm
B	Distance from top of black line to brickwork	12.0 cm
C	Distance from top of green line to brickwork	43.5 cm

Appendix D



Section	Description	Value
D	Horizontal Length of Bridge	

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.

Measurements taken:

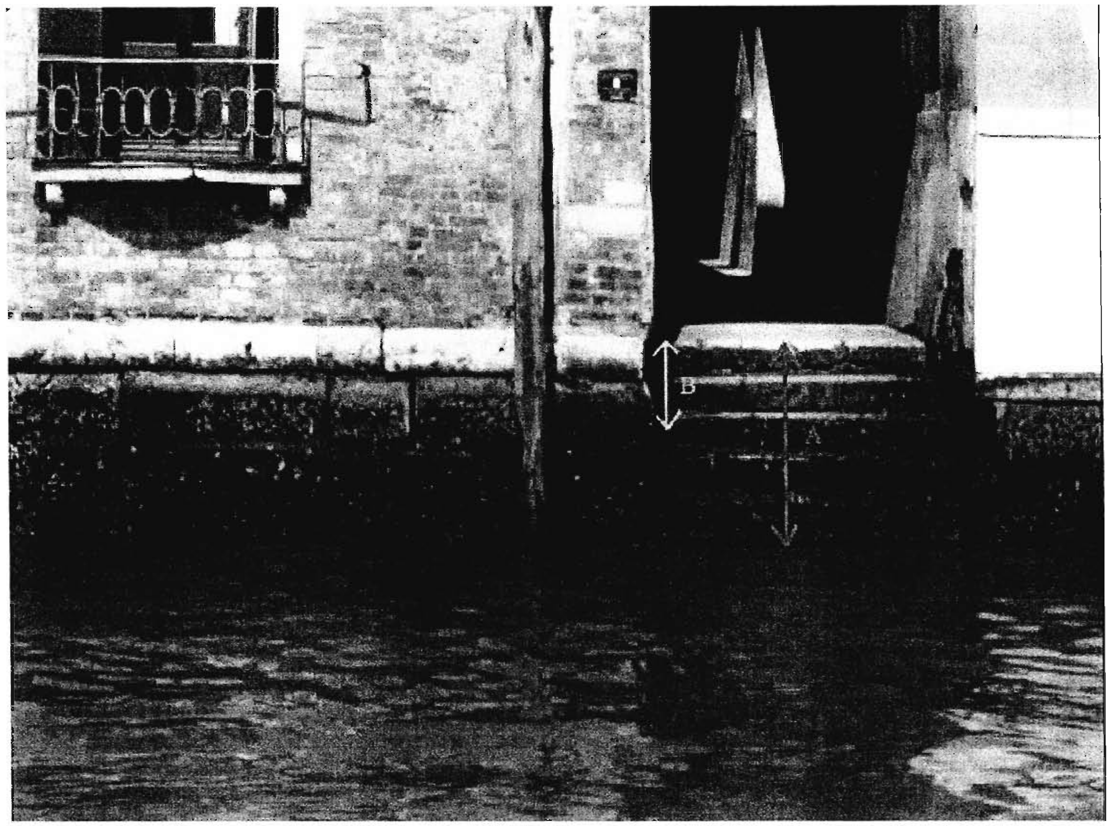
$$\frac{1.65}{301} = \frac{.4}{X}$$

X= 72.97

Resulting waterline differential for this site: .7297 m

Appendix D

Absolute height



A is the know elevation of the sidewalk from the zero line established in 1897.
B is the distance measured from the sidewalk to the green line.

A= 89 cm
B=59.5 cm

To get the absolute waterline differential B is subtracted from A to get X, and then the relative waterline differential is subtracted from X.

89-59.5 = 29.5 – 72.97 = -43.47

Absolute waterline differential for this site: **-0.4347 m**

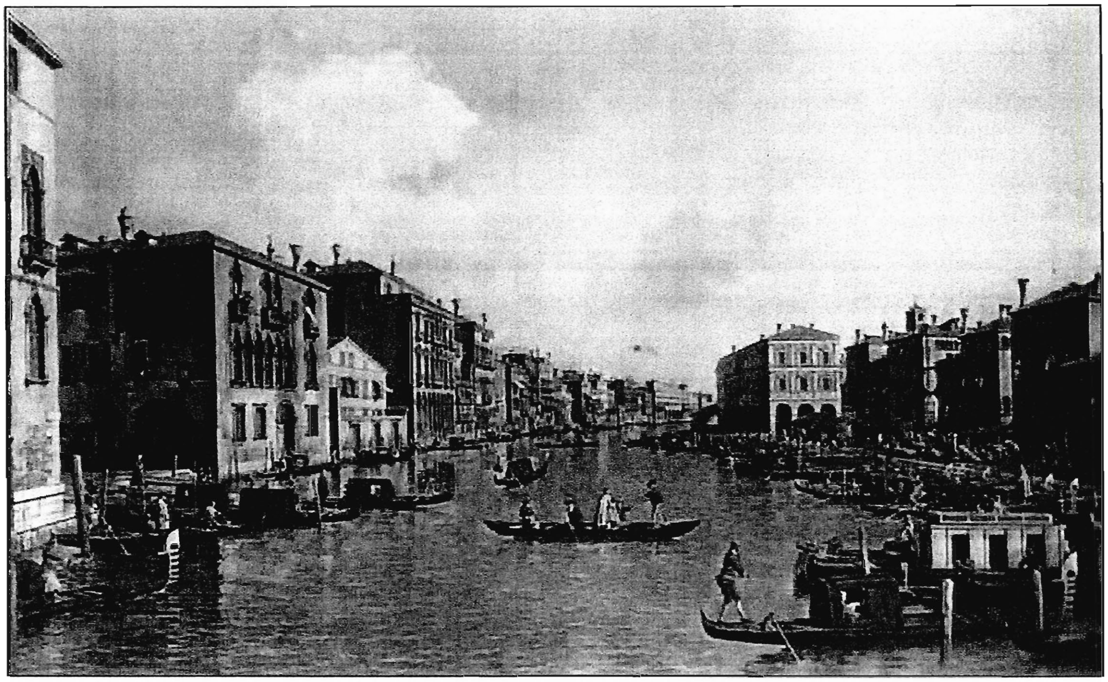
Appendix D

Results

CODE: P002 **LOCATION:** Grand Canal from S. Sofia

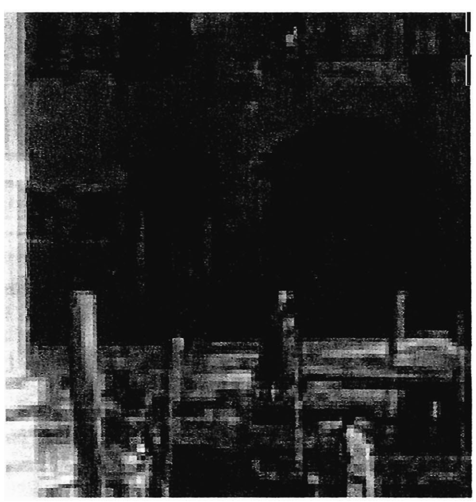
Original Painting Information

Artist: Canaletto
Year: 1758
Title: Grand Canal from S. Sofia to Rialto



On-Site Measurement focus areas

Vertical and Horizontal



Appendix D

Results Methodology

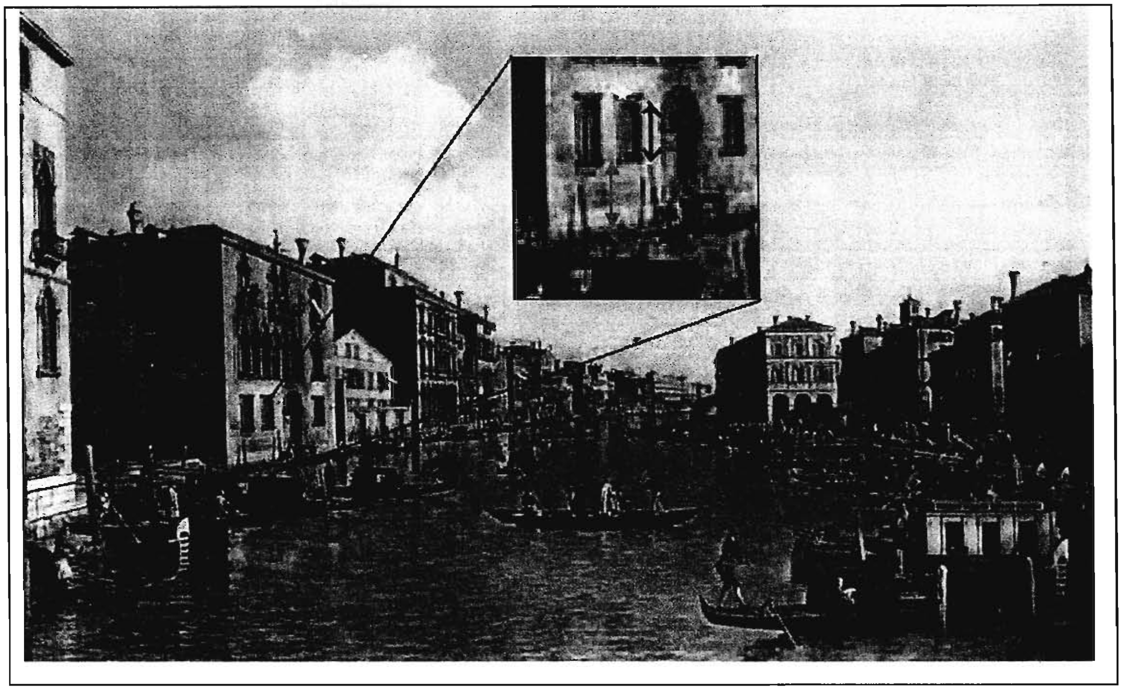


Figure 1
Drawing of measured objects

Key:

Section	Description	Value
Red line	Vertical Height of Window	170 cm
Green line	Distance from bottom of window to green line	160 cm
Yellow line	Horizontal length of window	110 cm

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.
Measurements taken:

$$\frac{.7}{170} = \frac{.9}{X}$$

X= 218.6 X-160 cm = 58.6
Resulting waterline differential for this site: **58.6 cm**

Appendix D

Absolute height

A is the know elevation of the sidewalk from the zero line established in 1897.
B is the distance measured from the sidewalk to the green line.

A= 99 cm
B=80 cm

To get the absolute waterline differential B is subtracted from A to get X, and then the relative waterline differential is subtracted from X.

99-80= 19 – 58.6 = -39.6

Absolute waterline differential for this site: **-0.396 m**

Appendix D

Results

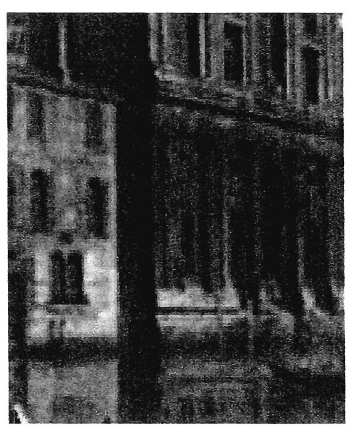
CODE: P005 **LOCATION:** G.C. from Palazzo Grimani

Original Painting Information

Artist: Canaletto
Year: 1735
Title: Grand Canal: Looking south-west from Palazzo Grimani to Palzzo Foscari

On-Site Measurement focus areas

Vertical and Horizontal



Appendix D

Results Methodology

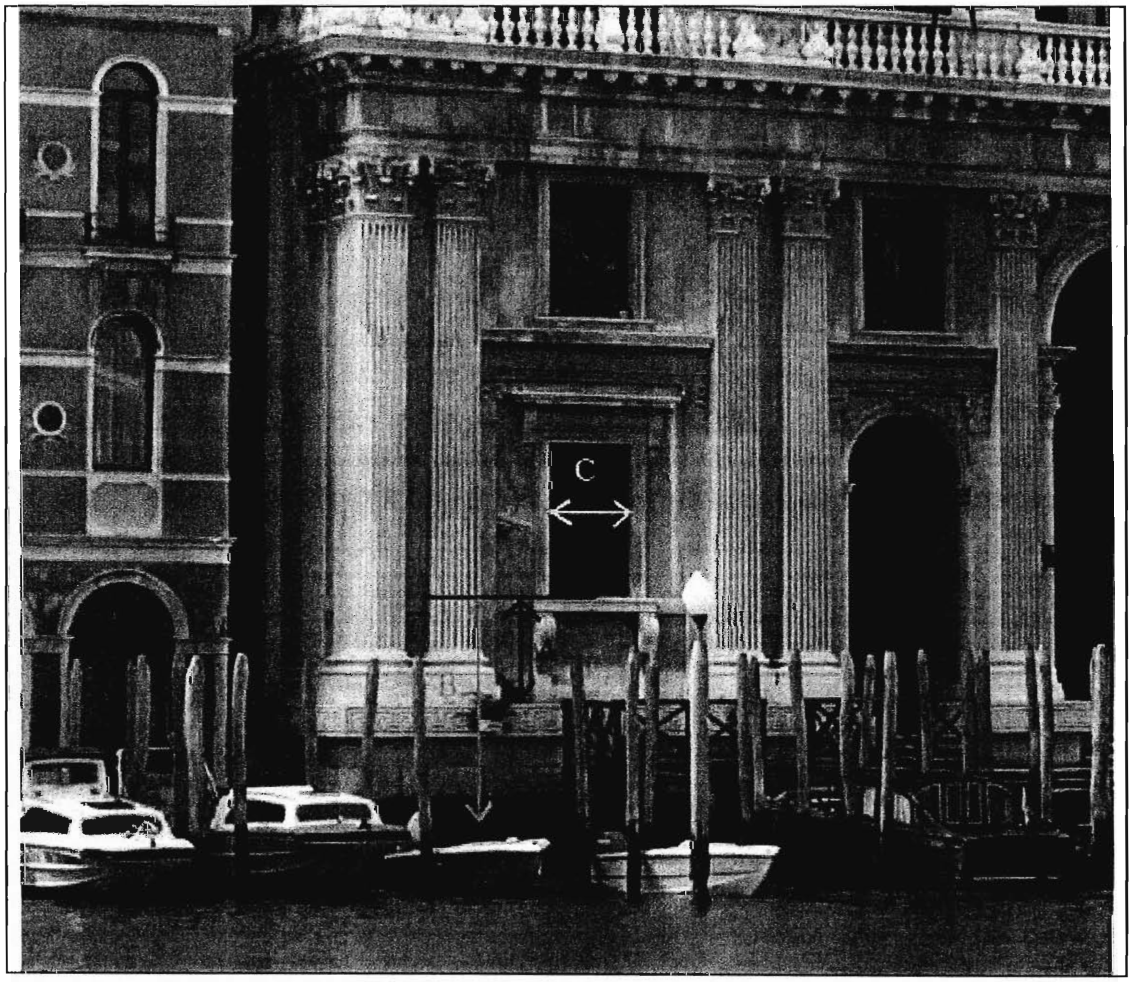


Figure 1
Drawing of measured objects

Key:

Section	Description	Value
A	Vertical Height bottom of window to top foundation	164 cm
B	Distance from bottom of window to green line	171 cm
C	Horizontal length of window	145 cm

Appendix D

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.
Measurements taken:

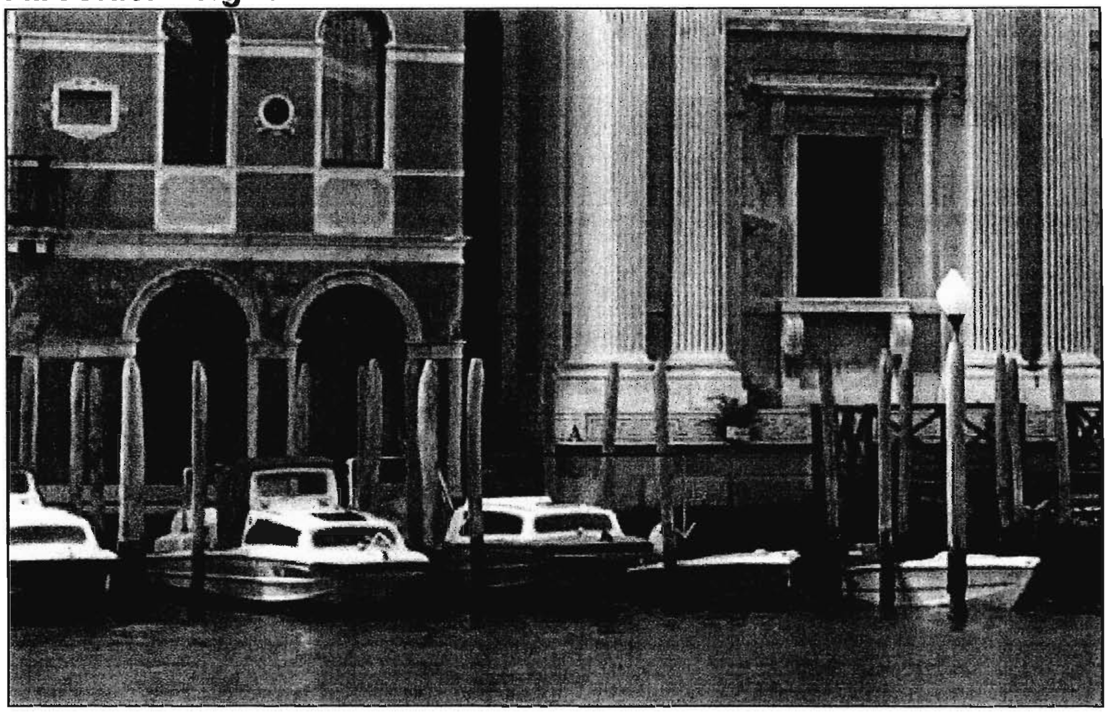
$$\frac{.5}{164} = \frac{.7}{X}$$

X= 229.6 X-171 cm = 58.6

Resulting waterline differential for this site: **58.6 cm**

Appendix D

Absolute height



A is the know elevation of the sidewalk from the zero line established in 1897.
B is the distance measured from the sidewalk to the green line.

A=142 cm
B=129 cm

To get the absolute waterline differential B is subtracted from A to get X, and then the relative waterline differential is subtracted from X.

142-129 =13– 58.6= -45.6

Absolute waterline differential for this site: **-0.456 m**

Appendix D

Results

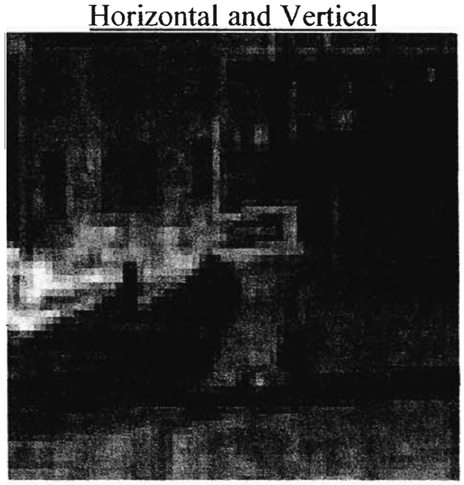
CODE: P009 **LOCATION:** Rialto Bridge from the North

Original Painting Information

Artist: Canaletto
Year: 1727
Title: Grand Canal: Rialto Bridge from the North

On-Site Measurement Focus Area

Horizontal and Vertical



Appendix D

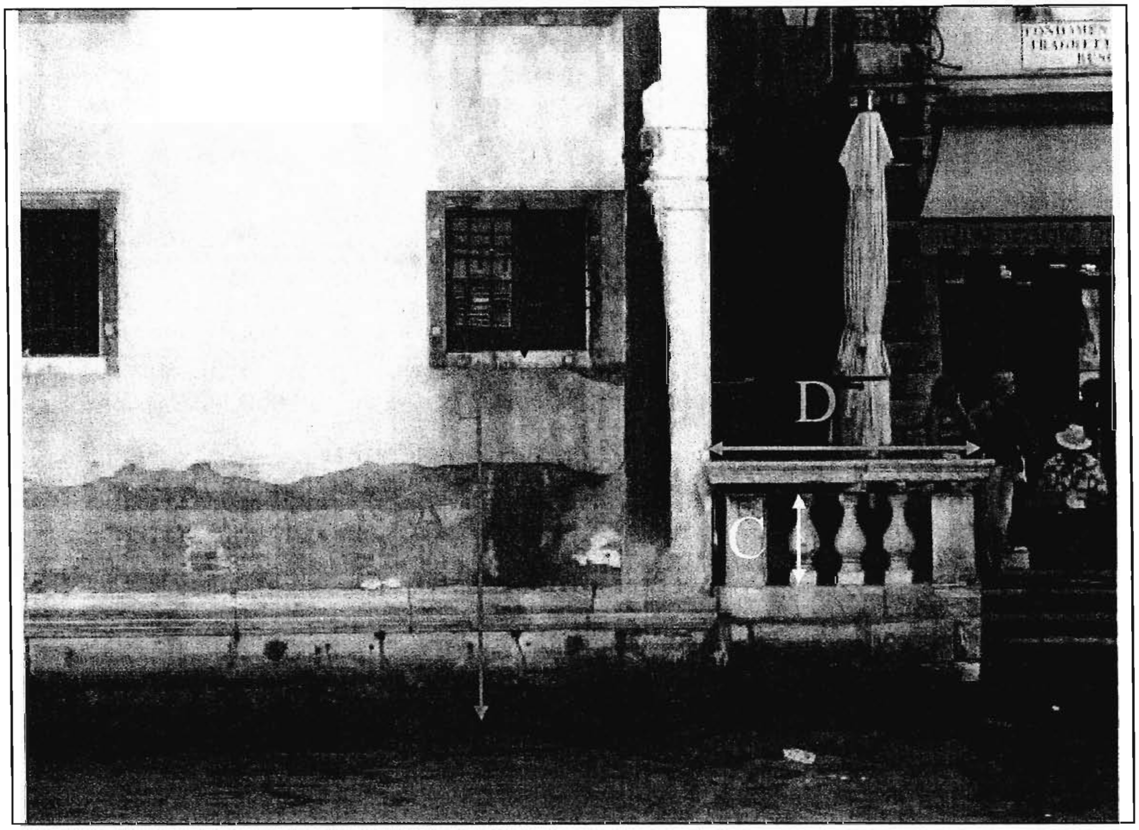


Figure 1 - Drawing of measured objects

Key:

Section	Description	Value
A	Bottom of window to green line	226.0 cm
B	Vertical of window	105.0 cm
C	Vertical of railing space	69.0 cm
D	Horizontal length of railing	210 cm

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.

Appendix D

Measurements taken:

$$\frac{.35}{105} = \frac{.85}{X} \quad \text{(Scale Formula)}$$

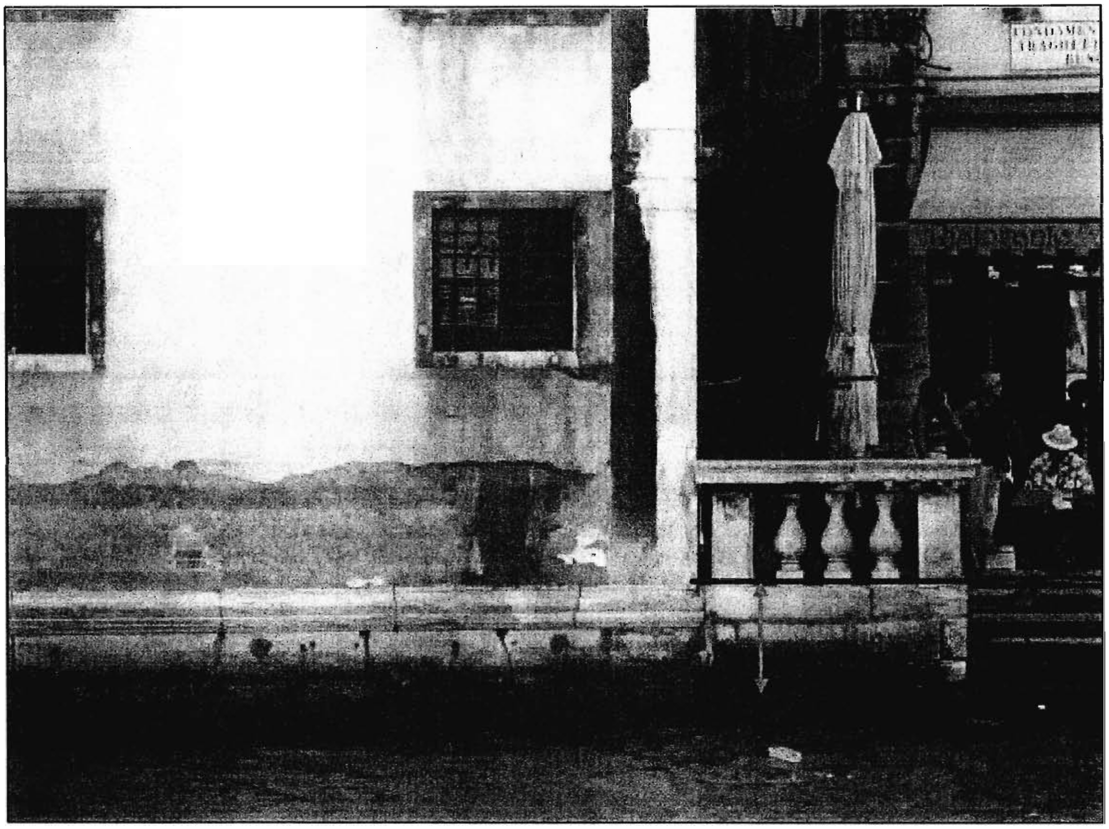
X= 297.5 cm

297.5 – 226 = 71.5 cm

Resulting waterline differential for this site: **71.5 cm**

Appendix D

Absolute Elevation



The red line represents the known elevation, which is 1.25 m.

The green line is the measurement taken from the known elevation to the green algae line, which is 96 cm.

To get absolute elevation:

125-71.5-96= -42.5cm

The absolute waterline height for this site: -42.5 cm

Appendix D

Results

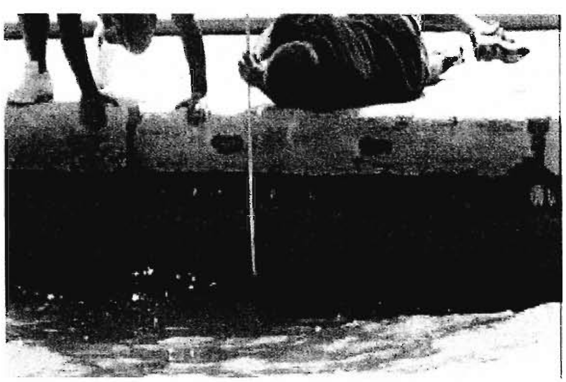
CODE: P010 **LOCATION:** Punta Della Dogana

Original Painting Information

Artist: Canaletto
Year: 1727
Title: Punta Della Dogana

On-Site Measurement focus areas

Vertical



Horizontal

Appendix D

Results Methodology

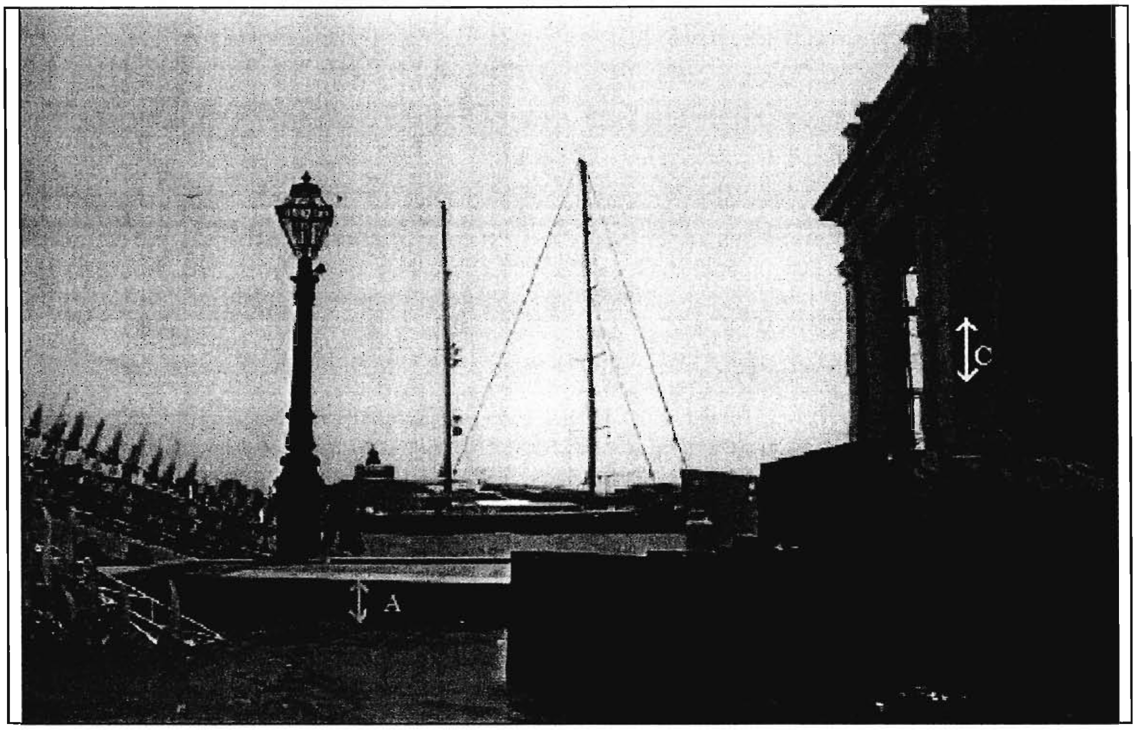


Figure 1
Drawing of measured objects

Key:

Section	Description	Value
A	Vertical Height to green line	69.0 cm
B	Horizontal width of column	80.0 cm
C	Vertical Height of column section	113.5 cm

Appendix D

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.

Measurements taken:

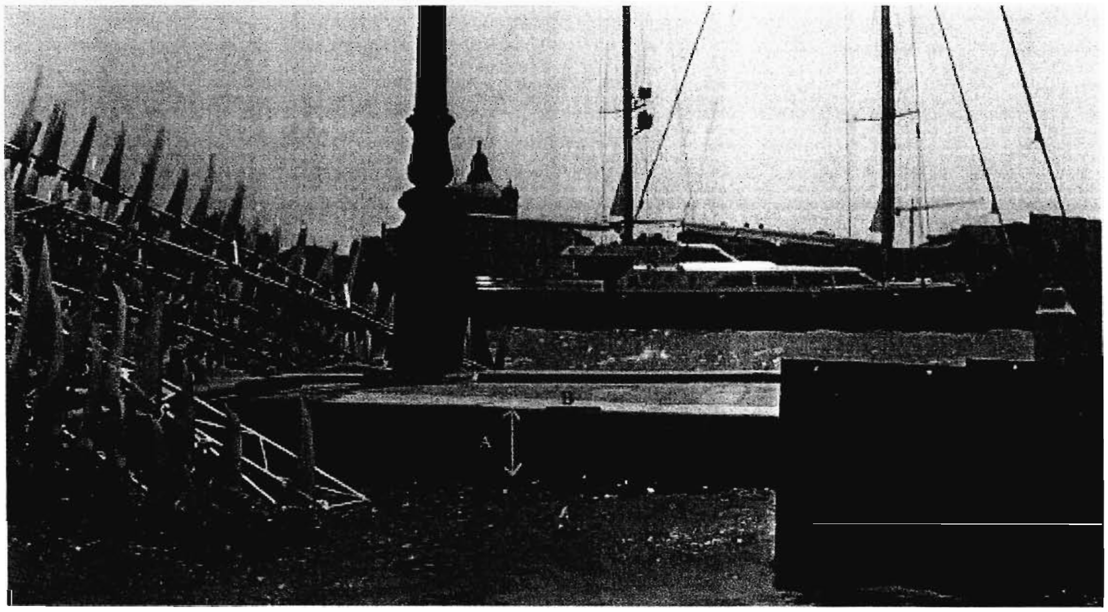
$$\frac{1.1}{80} = \frac{1.8}{X} \quad \text{(Scale Formula)}$$

X= 130.9 cm

130.9 – 69.0 = 61.9cm
Resulting waterline differential for this site: **0.619 m**

Appendix D

Absolute Waterline Differential



B is the level of know elevation from the zero line.
A is the distance from the known elevation to the green line.

A= 69 cm
B= 126 cm

To get the absolute waterline differential A is subtracted from B.

126-69= 57

The absolute waterline differential for this site is: **.570 m**

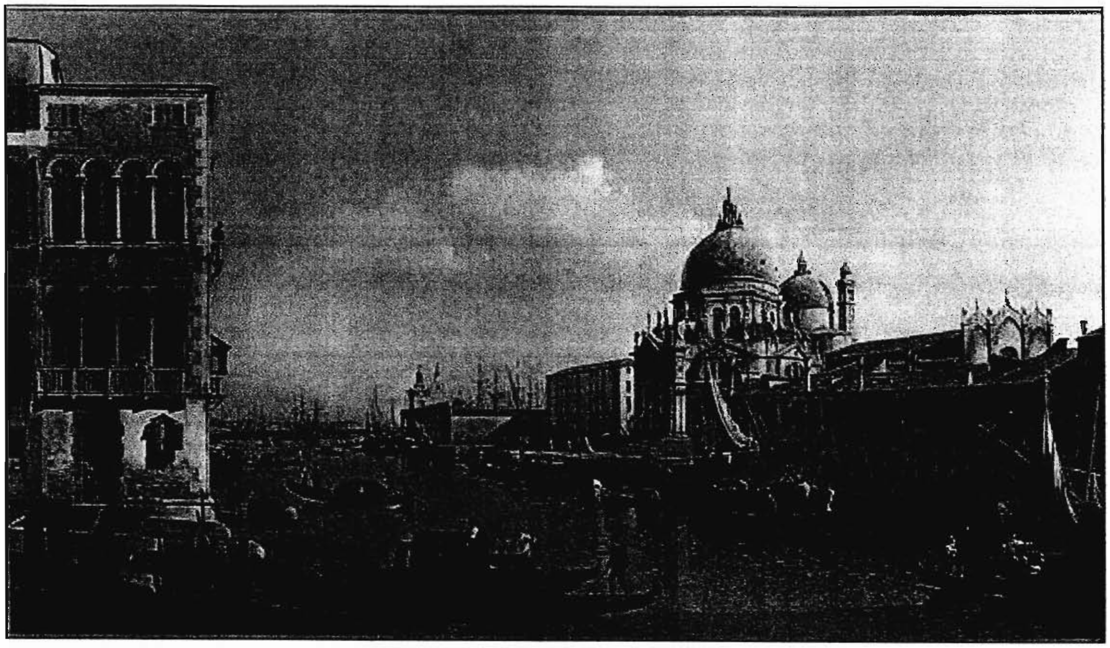
Appendix D

Results

CODE: ___P0012___ **LOCATION:** Entrance to the Grand Canal

Original Painting Information

Artist: Bellotto
Year: 1741
Title: Campo San Giovanni e Paolo



Appendix D

Results Methodology

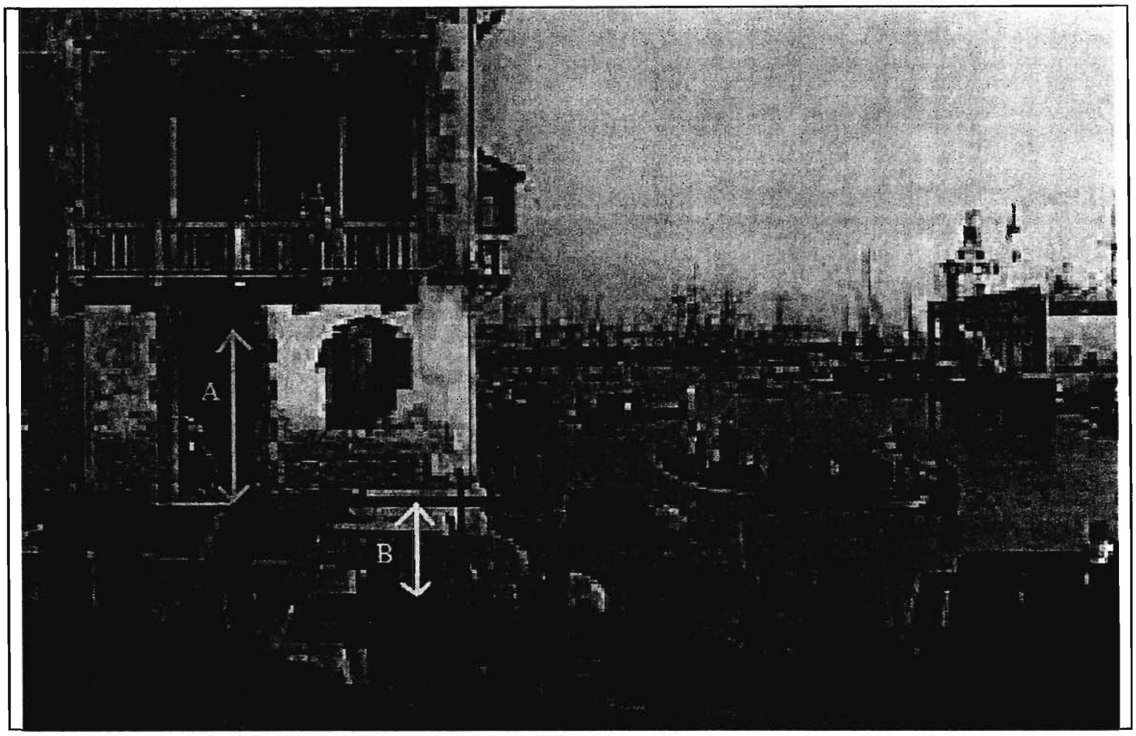


Figure 1
Drawing of measured objects

Key:

Section	Description	Value
A	Vertical Height of Doorway	245.5 cm
B	Distance from top of green line to bottom of door	52.5 cm

Appendix D

Scale formula:

$$\frac{\text{Measurement of object in painting}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in painting}}{X}$$

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.

Measurements taken:

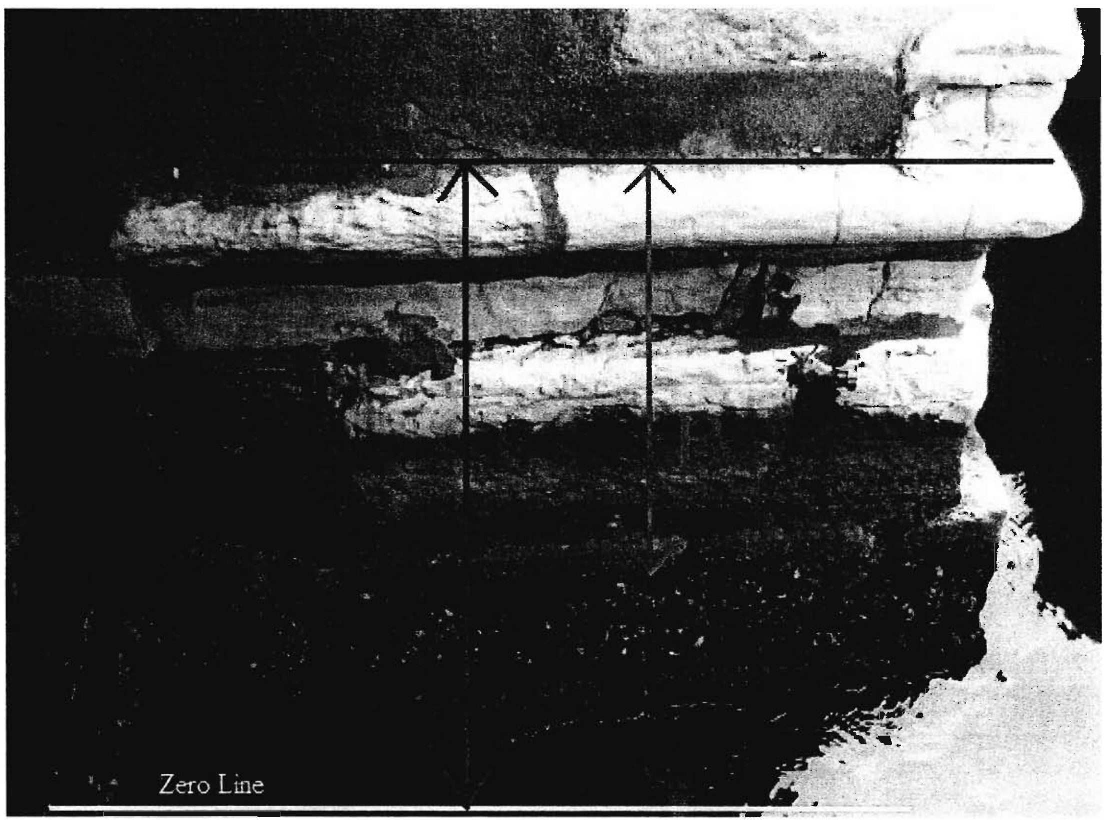
$$\frac{2.2}{245.5} = \frac{1.1}{X} \quad \text{(Scale Formula)}$$

X= 122.75 cm

122.75 – 52.5 = 70.25 cm
Resulting waterline differential for this site: **70.25 cm**

Appendix D

Absolute height



A is the know elevation to the sidewalk on left (not visible) from the zero line.
B is the distance measured from the sidewalk to the green line.

A= 98 cm
B= 52.5 cm

Appendix D

To get the absolute waterline differential B is subtracted from A to get X, and then the waterline differential found above is subtracted from X.

98-72.5 = X
X= 25.5

25.5-70.25 = -44.75
Absolute waterline differential for this site: **-.4475 m**

Appendix D

Results

CODE: P014 **LOCATION:** Grand Canal Near San Stae Church

Original Painting Information

Artist: Bellotto
Year: 1740
Title: The Grand Canal Near San Stae Church

On-Site Measurement Focus Area

Horizontal and Vertical

Appendix D

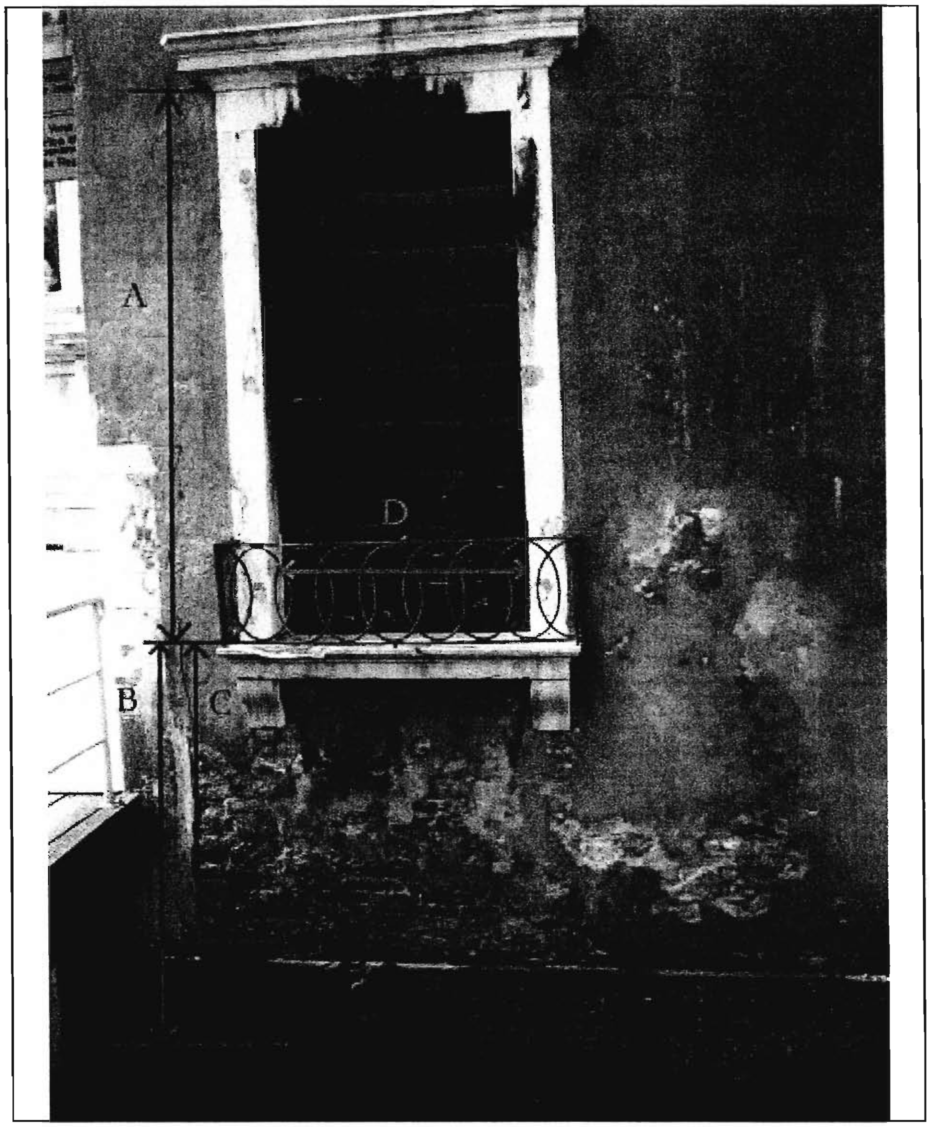


Figure 1 - Drawing of measured objects

Key:

Section	Description	Value
A	Left side window frame	244.0 cm
B	Bottom measurement A to dark green line	183.0 cm
C	Bottom measurement A to light green line	144.0 cm
D	Width of inside window frame	114.5 cm

Scale formula:

<u>Measurement of object in painting</u> = <u>Measured algae line in painting</u>

Appendix D

Measurement of object today X

X is the water level in the painting and the measured algae is subtracted from X in order to get a waterline differential.

Measurements taken:

$$\frac{1.5}{244} = \frac{1.6}{X} \quad \text{(Scale Formula)}$$

1.5 X = 390.4

X= 260.266 cm

390.4 – 260.266 = 77.266 cm

Resulting waterline differential for this site: 0.7727 m

Appendix D

Absolute Elevation

The red line represents the known elevation, which is 1.55 m.

The green line is the measurement taken from the known elevation to the green algae line, which is 119 cm.

To get absolute elevation:

155-77.27-118= -41.27cm

The absolute waterline height for this site: -42.27 cm

Appendix D

Results

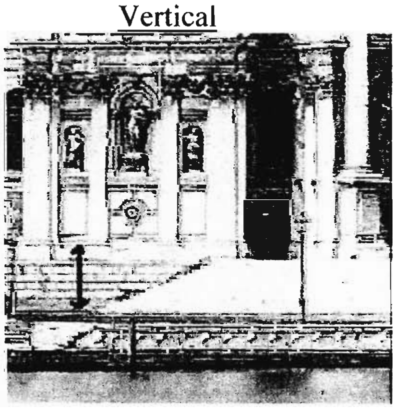
CODE: ___F001____ **LOCATION:** _The Salute__

Original Photograph Information

Year: 1860
Title: The Salute

On-Site Measurement focus areas

Vertical



Horizontal

Appendix D

Results Methodology

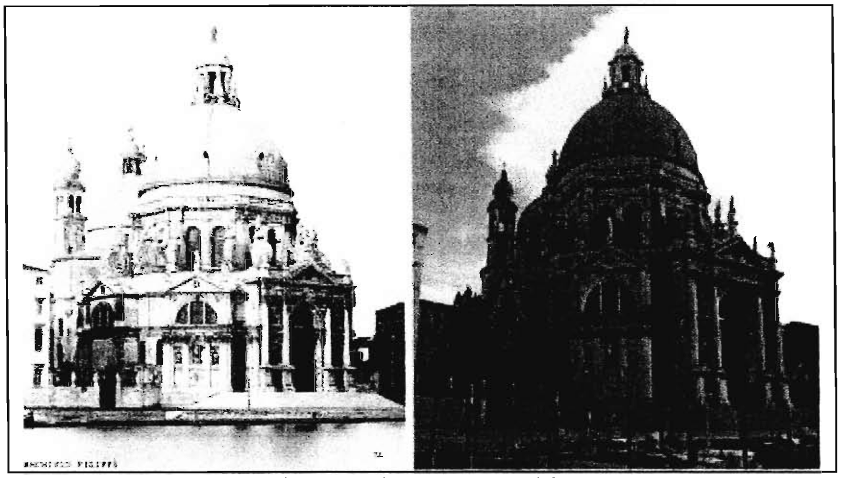


Figure 1 - Side-by-side Photographic Comparison

Key:

Description	On-SiteValue	Photo Value	Ratio
Vertical Bottom of column to sidewalk level	164 cm	.75 cm	219 : 1
Vertical Sidewalk elevation point to green line	104.0 cm	.678 (1860)	Unknown
Horizontal Width of cubic section column, left facade	147.5 cm	.68 cm	217 : 1
		Resulting Average Ratio	218 : 1

Description	Value
Elevation Point on sidewalk on left of Palazzo	141 cm

Scale formula:

$$\frac{\text{Measurement of object in Photograph}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in photograph}}{X}$$

Green Line from Sidewalk 1860: Algae line photo value x Resulting Average Ratio
.678 cm x 218 = **147.9 cm**

Absolute Elevation 1860: Absolute elevation – Vertical to algae in photograph
141 cm – 147.9 cm = **- 6.9 cm**
Absolute Elevation of Algae in 2004: Absolute elevation – Vertical to algae on-site
141.0 cm – 114.0 cm = **27 cm**
Algae Line Differential from 1860 – 2004 = 27 – (-6.9) = **33.9 cm**

Analysis: 6.9 cm from 1860 – 1897 (37 yrs) = **.186 cm / yr**
Analysis: 33.9 cm from 1870 – 2004 (134 yrs) = .252 cm/yr

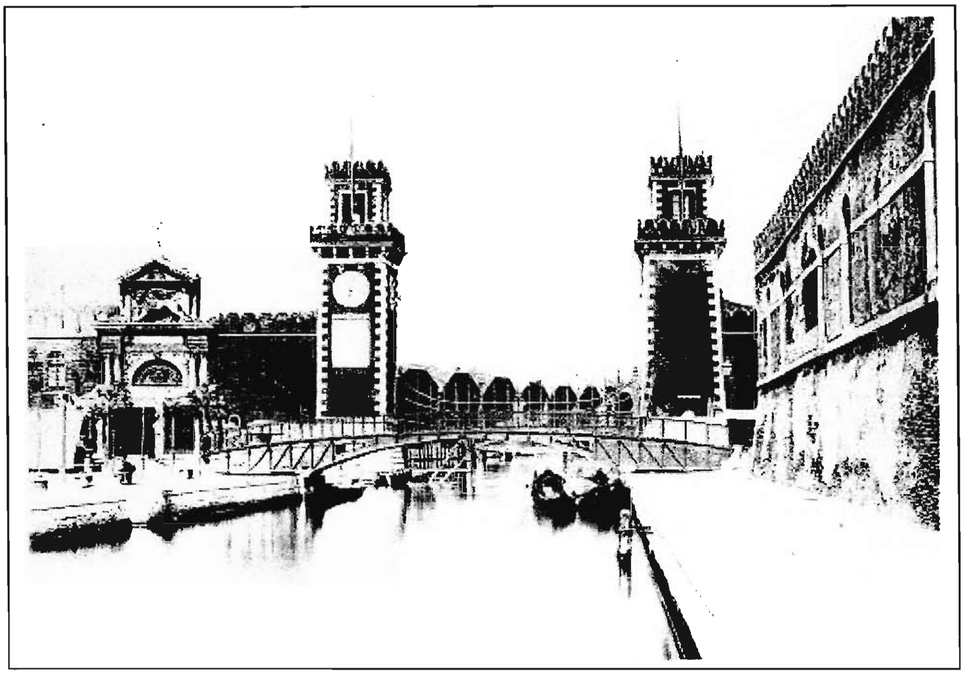
Appendix D

Results

CODE: F002 **LOCATION:** The Arsenale

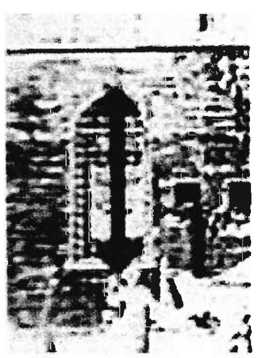
Original Photograph Information

Year: 1866
Title: The Arsenale

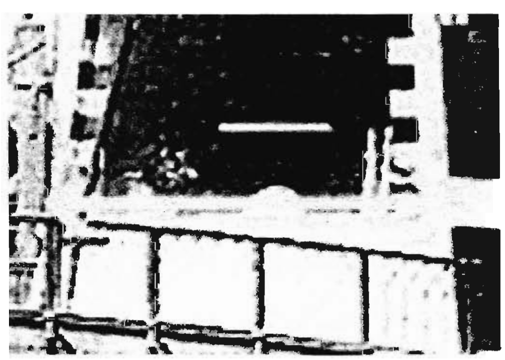


On-Site Measurement focus areas

Vertical



Horizontal



Appendix D

Results Methodology

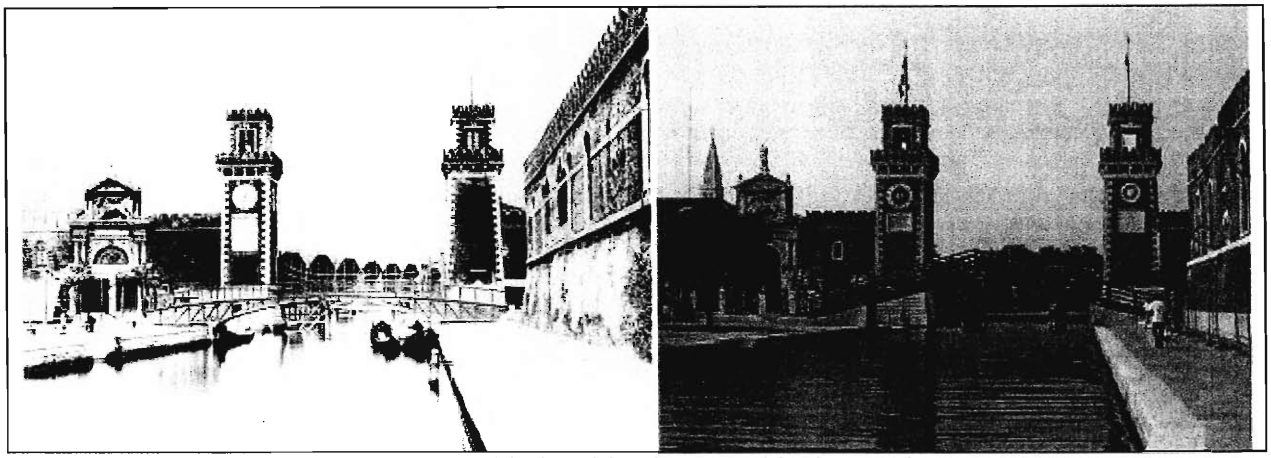


Figure 1 - Side-by-side Photographic Comparison

Key:

Description	On-SiteValue	Photo Value	Ratio
Vertical height of window	312.0 cm	.90 cm	346 : 1
Vertical Sidewalk elevation point to green line	70.0 cm	.29 cm (1866)	Unknown
Horizontal length of right tower base length	552 cm	1.6 cm	345 : 1
		Resulting Average Ratio	345.5 : 1

Description	Value
Elevation Point on sidewalk on left of Palazzo	94.0 cm

Scale formula:

$$\frac{\text{Measurement of object in Photograph}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in photograph}}{X}$$

Green Line from Sidewalk 1866: Algae line photo value x Resulting Average Ratio
.29 cm x 345 = **100.05 cm**

Absolute Elevation 1866: Absolute elevation – Vertical to algae in photograph
94 cm – 100.05cm = **- 6.05 cm**
Absolute Elevation of Algae in 2004: Absolute elevation – Vertical to algae on-site
94.0 cm – 68.0 cm = **26 cm**
Algae Line Differential from 1866 – 2004 = 26 – (-6.05) = **32.05 cm**

Analysis: 6.05cm from 1866 – 1897 (31 yrs) = .195 cm / yr
Analysis: 32.05 cm from 1866 – 2004 (138 yrs) = **.23 cm/yr**

Appendix D

Results

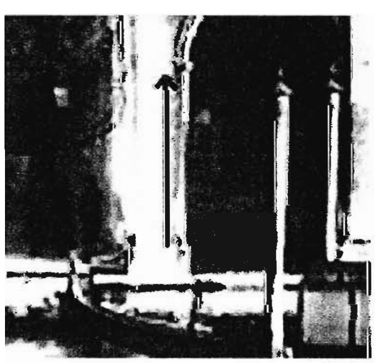
CODE: F003 **LOCATION:** Palazzo Manin

Original Photograph Information

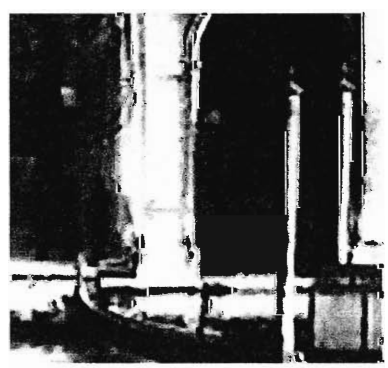
Year: 1867
Title: Palazzo Manin

On-Site Measurement focus areas

Vertical



Horizontal



Results Methodology

Appendix D

Figure 1 - Side-by-side Photographic Comparison

Key:

Description	On-SiteValue	Photo Value	Ratio
Vertical Left arch column height to arch base	311 cm	1.75 cm	178 : 1
Vertical Sidewalk elevation point to green line	51.0 cm	.46 cm (1867)	Unknown
Horizontal Left arch column width	100 cm	.55 cm	181 : 1
		Resulting Average Ratio	179.5 : 1

Description	Value
Elevation Point on sidewalk on left of Palazzo	77.0 cm

Scale formula:

$$\frac{\text{Measurement of object in Photograph}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in photograph}}{X}$$

Green Line from Sidewalk 1867: Algae line photo value x Resulting Average Ratio
.46 cm x 179.5 = **82.57 cm**

Absolute Elevation 1867: Absolute elevation – Vertical to algae in photograph
77 cm – 82.57 cm = **- 5.57 cm**
Absolute Elevation of Algae in 2004: Absolute elevation – Vertical to algae on-site
77.0 cm – 51.0 cm = **26 cm**
Algae Line Differential from 1867 – 2004 = 26 – (-5.57) = **31.57 cm**

Analysis: 5.57cm from 1867 – 1897 (30 yrs) = **.186 cm / yr**
Analysis: 31.57 cm from 1867 – 2004 (137 yrs) = .23 cm/yr

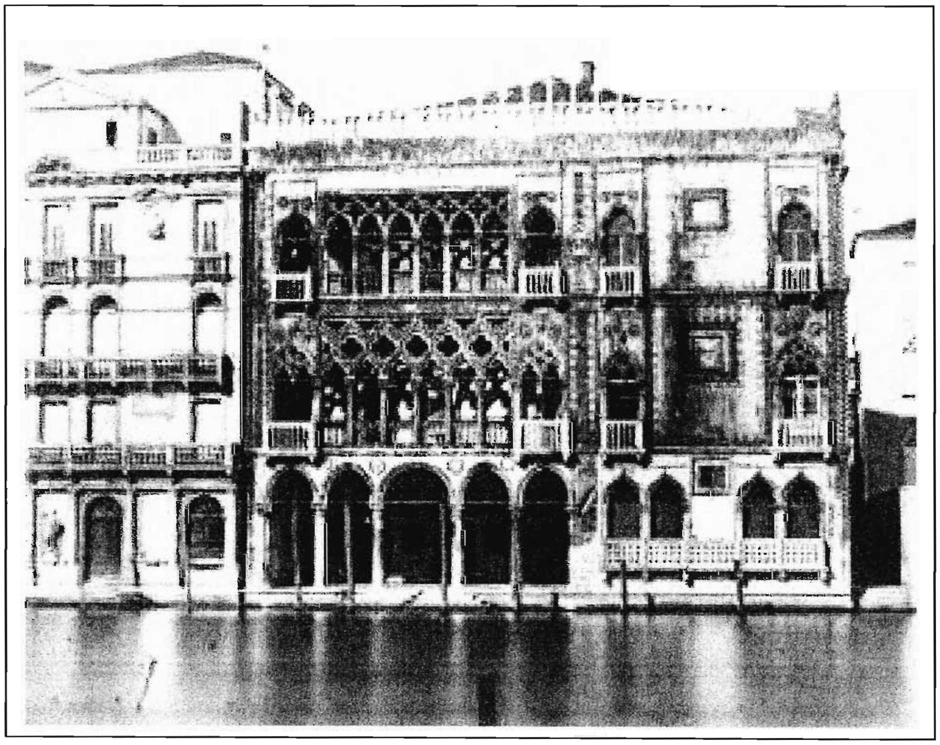
Appendix D

Results

CODE: F010 **LOCATION:** Ca D'Oro

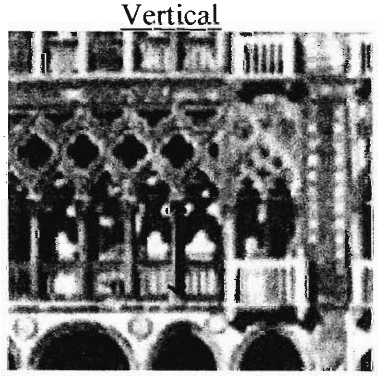
Original Photograph Information

Year: 1870
Title: Façade Ca D'Oro

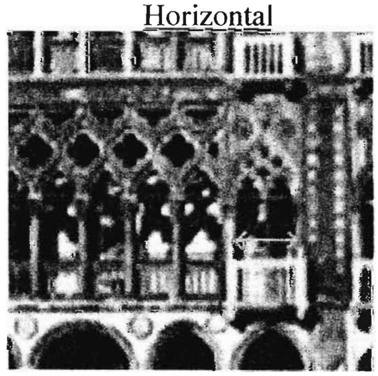


On-Site Measurement focus areas

Vertical



Horizontal



Appendix D

Results Methodology

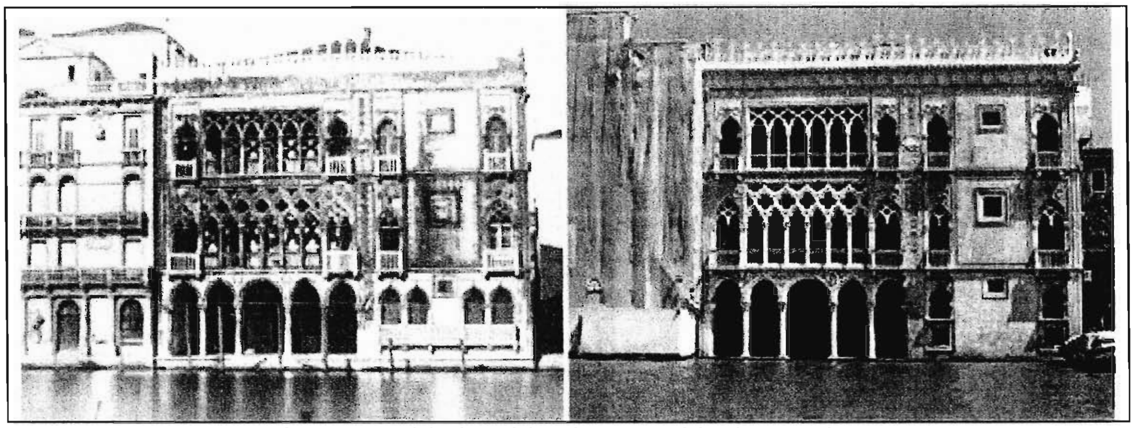


Figure 1 - Side-by-side Photographic Comparison

Key:

Description	On-SiteValue	Photo Value	Ratio
Vertical 2nd floor arcade column height	181 cm	1.0 cm	181 : 1
Vertical Sidewalk elevation point to green line	104.0 cm	.74 (1870)	Unknown
Horizontal 2nd floor window to right of arcade columns	205 cm	1.1 cm	186 : 1
		Resulting Average Ratio	183.5 : 1

Description	Value
Elevation Point on sidewalk on left of Palazzo	131 cm

Scale formula:

$$\frac{\text{Measurement of object in Photograph}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in photograph}}{X}$$

Green Line from Sidewalk 1870: Algae line photo value x Resulting Average Ratio
.74 cm x 183.5 = **135.7 cm**

Absolute Elevation 1870: Absolute elevation – Vertical to algae in photograph
131 cm – 135.7 cm = **- 4.7 cm**
Absolute Elevation of Algae in 2004: Absolute elevation – Vertical to algae on-site
131.0 cm – 104.0 cm = **27 cm**
Algae Line Differential from 1870 – 2004 = 27 – (-4.7) = **31.7 cm**

Analysis: 4.7 cm from 1870 – 1897 (27 yrs) = **.17 cm / yr**
Analysis: 31.7 cm from 1870 – 2004 (134 yrs) = .236 cm/yr

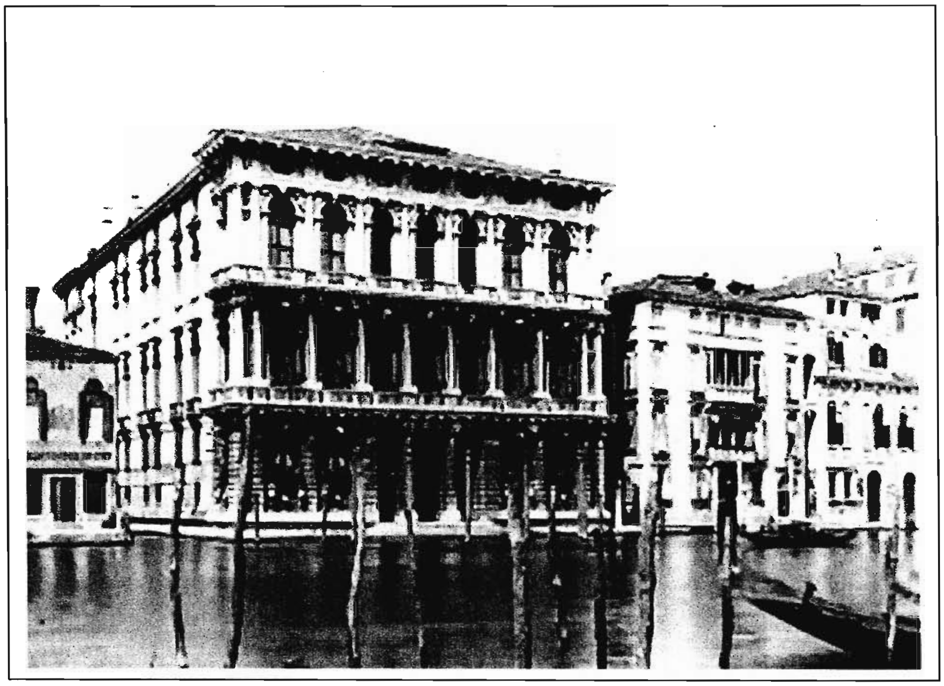
Appendix D

Results

CODE: F013 **LOCATION:** Palazzo Rezzonico

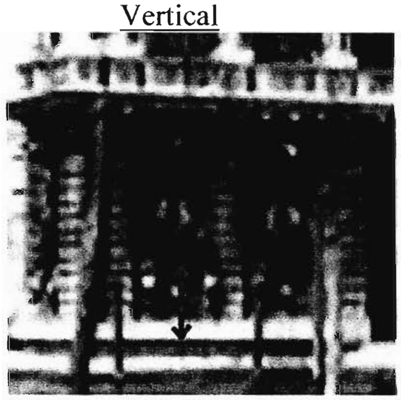
Original Photograph Information

Year: 1901
Title: Palazzo Rezzonico

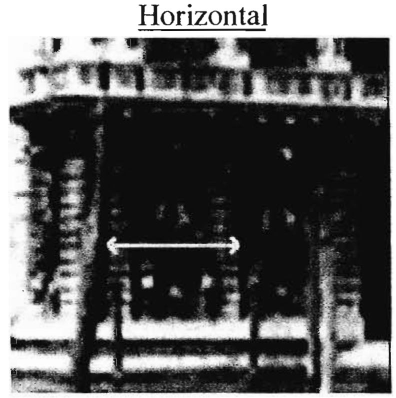


On-Site Measurement focus areas

Vertical



Horizontal



Appendix D

Results Methodology

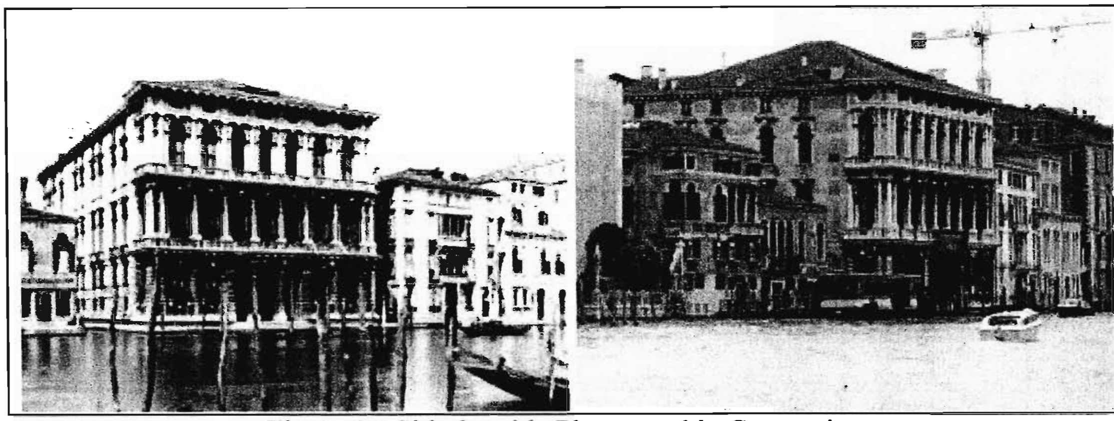


Figure 1 - Side-by-side Photographic Comparison

Key:

Description	On-SiteValue	Photo Value	Ratio
Vertical Ledge to first floor window	170 cm	1.29 cm	131.7 : 1
Vertical Top of ledge to green line	70.0 cm	(1901)	Unknown
Horizontal Leftmost column to next column on right	340 cm	2.59 cm	131.3 : 1
		Resulting Average Ratio	131.5 : 1

Description	Value
Elevation Point on sidewalk on left of Palazzo	106 cm

Scale formula:

$$\frac{\text{Measurement of object in Photograph}}{\text{Measurement of object today}} = \frac{\text{Measured algae line in photograph}}{X}$$

Green Line from Sidewalk 1901: Algae line photo value x Resulting Average Ratio
.8 cm x 131.5 ratio = **105.2 cm**

Absolute Elevation 1901: Absolute elevation – Vertical to algae in photograph
106 cm – 105.2cm = **.8 cm**
Absolute Elevation of Algae in 2004: Absolute elevation – Vertical to algae on-site
106.0 cm – 80.99 cm = **25.01 cm**
Algae Line Differential from 1901 – 2004 = 25.01 - .8 = **24.21 cm**

Analysis: .92 cm from 1897 - 1901 (4 yrs) = **.23 cm / yr**
Analysis: 24.21 cm from 1901 – 2004 (103 yrs) = .235 cm / yr

C Markers2

Date Visited	Canal Name	1982 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
7/3/2004	NEW	0	FILI-MOND31		North West	Sandstone	2036	37
7/3/2004	NEW	0	FORM-MOND2		West	Sandstone	1847	-13
7/3/2004	NEW	0	FAVA-MOND2		North East	Sandstone	1883	-3.5
7/7/2004	NEW	0	ZACC-VIN01		North West	Sandstone	1979	22
7/10/2004	NEW	0	ANZO-MICH00		South West	Sandstone	1968	19
7/10/2004	NEW	0	ANZO-MICH01		South West	Sandstone	2005	29
7/10/2004	NEW	0	ANZO-MICH03		South West	Sandstone	1858	-1
7/10/2004	NEW	0	ANZO-CORN0		North East	Sandstone	1998	27
7/10/2004	NEW	0	GARZ-CORN0		South West	Sandstone	2005	29
7/10/2004	NEW	0	ANZO-VERO00		South	Sandstone	1998	27
7/10/2004	NEW	0	DUCA-DUCA0	Not Available	North West	Sandstone	1994	26
7/10/2004	NEW	0	ANZO-MICH05		South West	Sandstone	2175	74
7/10/2004	NEW	0	ANZO-MICH06		North East		1896	0
7/10/2004	NEW	0	FAVA-MOND2					
7/10/2004	NEW	0	STEF-DUCA00	20	South East	Sandstone	1994	26
7/10/2004	Rio De San Anzolo	89	ANZO-ANZO00	13	South West	Sandstone	1968	19
	Rio Dei Mendicanti							

Date Visited	Canal Name	1982 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
7/3/2004		890	PANA-MEND0	Not Available	South East	Sandstone	1992	25.5
7/3/2004		896	PANA-MEND0	Not Available	South East	Granite	1998	27
7/3/2004		897	ZANI-MEND00	14.59	North West	Sandstone	2045	39.5
7/3/2004		946	ZANI-MEND01	Not on building	North West	Sandstone	2087	50.5
	Rio Dei San Giovanni							
7/3/2004		396	ZANI-LATE00	Not Available	South	Sandstone	2026	34.5
7/3/2004		403	ZANI-LATE10	Not Available	South West	Sandstone	1792	-27.5
7/3/2004		416	ZANI-LATE11	Not Available	South West	Sandstone	2036	37
7/3/2004		423	LATE-LATE10	Not Available	North East	Sandstone	2087	50.5
	Rio Del Piombo							
7/3/2004		618	BORG-PIOM10	16.96	North West	Sandstone	1926	8
7/3/2004		619	MARI-PIOM10	12.8	South East	Sandstone	1945	13
7/3/2004		633	BORG-PIOM11	13	North West	Sandstone	1877	-5
7/3/2004		634	MARI-PIOM11	12.26	South East	Sandstone	1771	-33
7/3/2004		639	MARI-PIOM12	12.72	South East	Sandstone	1947	13.5
7/3/2004		641	BORG-PIOM12	17.07	North West	Sandstone	1960	17
7/10/2004		679	MARI-PIOM20	16.05	South		2011	30.5
	Rio Del Pestrin							
7/10/2004		873	BORG-PEST21	Not Available	South East	Sandstone	1964	18

Date Visited	Canal Name	1892 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
7/10/2004		876	FORM-PEST21	Not Available	North West	Sandstone	1960	17
7/10/2004		881	BORG-PEST20	15.12	South East	Sandstone	1971	20
7/10/2004		882	FORM-PEST20	Not Available	North West	Sandstone	1898	0.5
7/3/2004		771	FORM-PEST10	Not Available	North	Sandstone	1992	25.5
7/3/2004		773	ZANI-PEST10	13	South	Sandstone	1966	18.5
7/3/2004		783	FORM-PEST11	Not Available	North	Sandstone	2079	48.5
	Rio Del Mondo Novo							
7/3/2004		2	FAVA-MOND1	10.98	North East	Sandstone	1853	-11.5
7/3/2004		10	FAVA-MOND0	10.76	North East	Sandstone	1968	19
7/3/2004		28	FAVA-MOND2	10.76	North East	Sandstone	1809	-23
7/3/2004		34	FAVA-MOND2	14.36	East	Sandstone	1939	11.5
7/10/2004		41	FORM-MOND2	Not on building	North East	Sandstone		Not Available
7/3/2004		42	FAVA-MOND2	Not Available	West	Sandstone	1951	14.5
7/3/2004		52	FAVA-MOND3	14.27	South East	Sandstone	1987	24
7/3/2004		57	FILI-MOND30	16	North West	Sandstone	1989	24.7
7/3/2004		58	FAVA-MOND3	Not Available	South East	Granite	1996	26.5
	Rio De Santa Maria F							
7/3/2004		974	QUER-FORM0	Not Available	North West	Sandstone	2036	37
7/3/2004		975	FORM-FORM0	Not on building	South East	Sandstone	2002	28

Date Visited	Canal Name	1992 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
		981	QUER-FORM0	16.9	North West	Sandstone		-----------------
7/3/2004		982	QUER-FORM0	16.9	Norht West	Sandstone	1911	4
7/3/2004		983	FORM-FORM0	16.85	South East	Sandstone	1971	20
7/3/2004		990	QUER-FORM0	16.36	North West	Sandstone	2009	30
7/3/2004		991	FORM-FORM0	14.12	South East	Granite	2005	29
7/3/2004		997	QUER-FORM0	16.36	North West	Sandstone	2036	37
	Rio De La Tetta							
7/3/2004		437	LATE-TETT00	Not Available	South West	Sandstone	1975	21
7/3/2004		445	SEVE-TETT20	Not Available	North West	Sandstone	2211	83.5
7/3/2004		448	LATE-TETT20	Not Available	South West	Sandstone	2105	55.5
7/3/2004		466	LATE-TETT21	Not Available	South West	Sandstone	2079	48.5
7/3/2004		468	SEVE-TETT21	Not Available	North East	Sandstone	2149	6.7
	Rio De San Lorenzo							
7/3/2004		392	LORE-LORE00	13.3	South West	Sandstone	1868	-7.5
7/3/2004		475	LATE-LORE00	Not on building	East	Sandstone	2020	33
7/3/2004		482	LORE-LORE01	Not on building	West	Sandstone	2030	35.5
	Rio De Greci							
		561	LORE-GREC00	-------------	West			-----------------
	Rio De Scudi e de la S							

Date Visited	Canal Name	1982 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
6/24/2004		163	BRAG-SCUD1	13.25	South East	Sandstone	1998	27
6/24/2004		166	TERN-SCUD13	12.28	North West	Sandstone	1926	8
6/24/2004		182	TERN-SCUD12	13.5	North West	Sandstone	2058	43
6/24/2004		196	TERN-SCUD11	12.68	North West	Sandstone	1979	22
6/24/2004		197	BRAG-SCUD1	14	South East	Sandstone		------------
6/24/2004		204	TERN-SCUD10	Not Available	North West	Sandstone	2037	37.5
6/24/2004		205	BRAG-SCUD1	Not Available	South East	Sandstone	1917	5.5
6/24/2004		228	TERN-SCUD22	Not on building	South West	Sandstone	1973	20.5
6/24/2004		230	BRAG-SCUD2	Not Available	North East	Sandstone	1847	-13
6/24/2004		233	BRAG-SCUD2	11.67	North East	Sandstone	2221	86
6/24/2004		244	TERN-SCUD21	15.97	South West	Sandstone	2026	34.5
6/24/2004		246	BRAG-SCUD2	12.01	North East	Sandstone	2037	37.5
6/24/2004		255	TERN-SCUD20	12.06	South West	Sandstone	1996	26.5
	Rio De le Gorne							
6/24/2004		300	VIGN-GORN00	11.9	North West	Sandstone	2190	78
6/24/2004		1151	VIGN-GORN01	Not on building	North West	Sandstone	2243	92
	Rio De San Severo							
7/3/2004		794	FORM-SEVE10	Not Available	North West	Sandstone	2043	39
7/10/2004		815	QUER-SEVE00	16.36	North East	Sandstone	2117	58.5

Date Visited	Canal Name	1992 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
7/10/2004		816	SEVE-SEVE20	Not on building	West	Granite	1926	8
7/10/2004		1002	QUER-SEVE20	10.46	East	Sandstone	2119	59
7/10/2004		1007	QUER-SEVE21	17.76	North East	Sandstone	2032	36
	Rio De San Zaninovo							
7/10/2004		1038	FILI-ZANI00	14.64	North East	Sandstone	2075	47.5
7/10/2004		1057	FILI-ZANI01	7.91	North East	Sandstone	2111	57
7/10/2004		1066	QUER-ZANI00	14.95	South	Kinda Granite	1973	20.5
7/10/2004		1092	FILI-ZANI02	Not on building	North East	Sandstone	1888	-2
	Rio Del Vin							
7/10/2004		582	ZACC-VIN04	14.19	North	Sandstone	1949	14
7/10/2004		589	FILI-VIN03	15.23	South East	Sandstone	1994	26
7/10/2004		591	ZACC-VIN03	19.57	North Wes1t	Sandstone	2022	33.5
7/10/2004		594	ZACC-VIN02	19.57	North West	Sandstone	2013	31
7/10/2004		1021	FILI-VIN02	19.05	East	Sandstone		NO LINE
7/10/2004		1025	ZACC-VIN00	12.07	West	Sandstone	1994	26
7/10/2004		1027	FILI-VIN01	18.36	East	Sandstone	2051	41
7/10/2004		1033	FILI-VIN00	Not Available	East	Sandstone		NO LINE
	Rio De La Fava							
7/10/2004		686	MARI-FAVA10	16.05	West	Sandstone		

Date Visited	Canal Name	1982 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
	Rio De La Canonica o							
7/10/2004		629	FILI-CANO01	10.66	West			lost
7/10/2004		631	FILI-CANO00	12.75	West			lost
	Reilo De San Daniel							
6/24/2004		1329	RUGA-DANI00	10.69	South West	Sandstone	1949	14
6/24/2004		1350	DANI-DANI00	Not Available	East	Sandstone	1941	12
6/24/2004		1372	RUGA-DANI01	7.43	North West	Sandstone	2049	40.5
6/24/2004		1374	DANI-DANI01	Not on building	East	Sandstone		???
	Rio De San Gerolamo							
7/10/2004		1377	DANI-VERG10	Not Available	North East			
	Rio De Le Vergini							
6/24/2004		1384	RUGA-VERG2	7.79	North East	Sandstone	2024	34
6/24/2004		1393	RUGA-VERG2	Not Available	North East	Sandstone	1934	10
	Rio De San Ana							
6/24/2004		1304	RUGA-ANA10	Not Available	South	Sandstone	2073	47
6/24/2004		1311	RUGA-ANA11	12.63	South	Sandstone	1958	16.5
	Rio De La Tana							
6/24/2004		1215	ANA-TANA20	Not Available	North West	Sandstone	1943	12.5
	Rio De La Ca Di Dio							

Date Visited	Canal Name	1992 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
6/24/2004		265	BRAG-DIO02	19.55	East	Sandstone	2107	56
6/24/2004		278	BRAG-DIO01	17.74	East	Sandstone	1947	13.5
6/24/2004		280	BRAG-DIO00	Not on building	South East	Sandstone	2013	31
	Unknown							
	No Location	1083	CV-001					
	Undocumented Marke							
	Rio De Ca Michiel							
7/10/2004		801	ANZO-MICH04	Not on building	South West	Sandstone	2175	74
7/10/2004		805	ANZO-MICH02	15.28	West		1726	-45
7/10/2004		827	ANZO-MICH07	Not on building	South West	Sandstone	1896	0
7/10/2004		829	ANZO-MICH08	12.58	North West	Sandstone	1890	-1.5
	Rio De Ca Corner							
		164	ANZO-CORN0	15.26	North West			
7/10/2004		165	ANZO-CORN0	15.26	North West	Sandstone		
7/10/2004		167	GARZ-CORN0	16	South East	Sandstone	2032	36
7/10/2004		170	ANZO-CORN0	22	North West			
7/10/2004		173	ANZO-CORN0	22	North West	Sandstone	1926	8
	Rio Del Duca o De Sa							

Date Visited	Canal Name	1982 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
7/10/2004		328	DUCA-DUCA0	Not Available	North West	Sandstone	1896	0
	Rio Del Santissamo							
7/10/2004		404	STEF-SANT00	15.2	East	Sandstone	1868	-7.5
7/10/2004		405	MAUR-SANT00	16.74	West	Sandstone	1919	6
7/10/2004		419	MAUR-SANT01	14.6	West	Sandstone	1922	7
	Rio De San Maurizio e							
		360	MAUR-MAUR0	Not Available	East			
	Rio Menuo o De La V							
7/10/2004		86	DUOD-VERO2	16.7	North	Granite	2056	42.5
	Rio De S.M. Zobenigo							
7/10/2004		12	DUOD-ZOBE0	13.57	East	Granite		no line
	Rio de l'Alboro o de le							
7/10/2004		42	ZOBE-ALBO00	18.8	West	Sandstone	2005	29
	Rio de La Veste							
		111	MOIS-VEST30	15.74	North West			
		116	MOIS-VEST31	17.2	North			
	Rio Dei Scoacamini							
		748	LUCA-SCOA20	20.58	South East			

Date Visited	Canal Name	1992 Index Code	2004 Index Code	Building Height	Direction	Material	Approximate Date	2004 Calculated Height
		754	LUCA-SCOA21	20.58	East			
	Rio De Le Procuratie							
		734	MARC-PROC0	Not Available	North West			
		740	GALL-PROC00	15.1	South East			
	Rio Dei Ferali							
		688	GALL-FERA20	15	South West			
		691	GALL-FERA21	13.66	North East			
		693	GALL-FERA22	13.66	North East			
		700	GALL-FERA23	13.13	East			
	Rio De La Luna o Dei							
		646	MARC-ZECA00		South			
		647	MARC-ZECA01		South			

Paintings DB

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
Piazza S. Marco: Looking East along the Central Line	Canaletto	1731-173			
Piazza S. Marco: Looking East from the North-West Corner	Canaletto	1760	No		
Piazza S. Marco: Looking East from the South-West Corner	Canaletto	1760	No		
Piazza S. Marco: Looking South-East along the Central Line	Canaletto	1735-40	No		
Piazza S. Marco: Looking South-West along the Central Line	Canaletto	1750	No		
The Piazzetta: Looking South	Canaletto	1727	No		
The Piazzetta: Looking South-East	Canaletto				
The Piazzetta: Looking North	Canaletto	1727	No		
The Piazzetta: Looking West, with the Library	Canaletto				
The Piazzetta: Looking South-West	Canaletto	1750s	No		
The Piazzetta: Looking East, with the Ducal Palace	Canaletto		No		
The Piazzetta: Looking East	Canaletto	1760	No		
S. Marco: An Evening Service	Canaletto				
S. Marco: A Service on Good Friday (?)	Canaletto				
S. Marco: The Interior	Canaletto	1755	No		
The Ducal Palace: the Scala dei Giganti	Canaletto	1730	YES	No	
The Ducal Palace: the Courtyard, looking North	Canaletto	1725	YES	No	
The Prison	Canaletto				

Painting Name (Dario In Red)	Artist	Year	Water/None	Yes/No	Code
The Molo: looking West, with the Ducal Palace and the Prison	Canaletto				
The Molo: looking West, with the Ducal Palace and the Ponte della Paglia	Canaletto	1740-45	YES	Zoom	
The Molo: looking West, Ducal Palace Right	Canaletto				
The Molo: looking West, Column of St . Theodore Right	Canaletto	1730	YES	No	
The Molo: looking West, Library to Right	Canaletto	before 17	YES	Zoom	
The Molo: looking West, the Fonteghetto della Farina	Canaletto				
The Molo: from the Bacino di S.Marco	Canaletto	1747-175	YES	No	
Riva degli Shiavoni: looking East	Canaletto	1730	YES	No	
Riva degli Shiavoni: looking East from Near the Mouth of the Grand Canal	Canaletto				
Riva degli Shiavoni: looking East from the Quay of the Dogana	Canaletto				
Riva degli Shiavoni: looking West	Canaletto	1727	YES	Zoom	
Bacino di S.Marco: from the Piazzetta	Canaletto	1730-173	YES	No	
Bacino di S.Marco: from near the Molo	Canaletto				
The Bacino di S. Marco: looking East	Canaletto	1738-174	YES	No	
Bacino di S. Marco: looking West from the Riva degli Schiavoni	Canaletto				
Bacino di S. Marco: looking West	Canaletto				
Bacino di S. Marco: looking North	Canaletto				
Entrance to the Grand Canal: from the Piazzetta	Canaletto		No	Zoom	
Entrance to the Grand Canal: from the West End of the Molo	Canaletto	1735-174	YES	Zoom,	
The Quay of the Dogana	Canaletto				

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
The Dogana from the Bacino di S.Marco	Canaletto				
The Dogana and the Giudecca Canal	Canaletto				
Entrance to the Grand Canal: looking West	Canaletto	1730	YES	No	
Entrance to the Grand Canal: looking East	Canaletto	1744	YES	Zoom,	P009
Grand Canal: the Salute and Dogana from the Campo Sta Maria Zobenigo	Canaletto				
Grand Canal: the Salute and the Dogana, from near the Palazzo Corner	Canaletto				
Grand Canal: looking East, from the Camp di S. Vio (Dario)	Canaletto	1725	YES	Yes	P003a
Grand Canal: from Sta Maria della Carita to the Bacino di S. Marco	Canaletto	early 1730	YES	Yes	P004
Grand Canal: looking Sout-East, from the Campo della Carita to the Palazzo Venier	Canaletto				
Grand Canal: 'The Stonemason's Yard'; Sta Maria della Carita from across the Grand	Canaletto	1728	YES	No	
Grand Canal: looking North from the Palazzo Contarini dagli Scrigni to the Palazzo R	Canaletto				
Grand Canal: looking North from the Palazzo Rezzonico to the Palazzo Balbi	Canaletto				
Grand Canal: looking South from the Palazzi Foscari and Moro-Lin to Sta Maria della	Canaletto	Unknown	YES	Find Ne	
Grand Canal: looking South from the Palazzo Foscari	Canaletto				
Grand Canal: looking North-East from the Palazzo Corner-Spinelli to the Rialto Bridg	Canaletto	1725	YES	YES	
Grand Canal: looking North-East from the Palazzo Balbi to the Rialto Bridge (Dario)	Canaletto	Unknown	YES		
Grand Canal: looking South-West from the Palazzo Coccina-Tiepolo to the Palazzo F	Canaletto				
Grand Canal: looking South-West from the Palazzo Grimani to the Palazzo Foscari (	Canaletto	1735	YES	YES	P005
Grand Canal: the Rialto Bridge from the South	Canaletto	1727	Yes	No	
Grand Canal: the Rialto Bridge, from the Fondamenta del Vin	Canaletto				

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
Grand Canal: looking North from near the Rialto Bridge	Canaletto				
Grand Canal: the Rialto Bridge from the North	Canaletto				
Grand Canal: looking South from the Ca da Mosto to the Rialto Bridge	Canaletto				
Grand Canal: looking South-East from the Palazzo Michiel dalle Colonne to the Fond	Canaletto				
Grand Canal: looking South-East from the Campo Sta Sofia to the Rialto Bridge (Dari	Canaletto	1758	YES	YES	P002a
Grand Canal: looking North-west from the Campo Sta Sofia to S. Marcuola	Canaletto	1756	YES	YES	P002b
Grand Canal: looking South-East from the Palazzo Pesaro to the Fondaco dei Tedes	Canaletto				
Grand Canal: looking South-East from the Palazzo Vendramin-Calergi to the Palazoz	Canaletto				
Grand Canal: looking South-East from the Palazzo Vendramin-Calergi to the Palazzo	Canaletto				
Grand Canal: looking North-West from the Palazzo Vendramin-Calergi to S. Geremia	Canaletto				
Grand Canal: S. Geremia and the Entrance to the Cannaregio (Dario)	Canaletto	1735	YES	YES	P006
Grand Canal: looking East from the Palazzo Bembo to the Palazzo Vendramin-Caler	Canaletto	After 1730	YES	No	P018
Grand Canal: looking East from the Palazzo Flangini to S. Marcuola	Canaletto	Unknown	YES	Zoom,	P016
Grand Canal: looking South-West from the Chiesa degli Scalzi to the Fondamenta de	Canaletto	1738	YES	YES	P007
Grand Canal: looking North-East from the Chiesa degli Scalzi to the Cannaregio	Canaletto				
Grand Canal: looking North-East from Sta Croce to S. Geremia	Canaletto				
Grand Canal: Sta Lucia and the Church of the Scalzi	Canaletto				
Canale di Sta Chiara: looking South-East along the Fondamenta della Croce	Canaletto	Unknown	YES	Zoom,	P017
Canale di Sta Chiara: looking North-West from the Fondamenta dlla Croce to the Lag	Canaletto				
The Arsenal: the Water Entrance	Canaletto	1732	YES	No	

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
The Arsenal and the Campo di Arsenale	Canaletto				
Campo S. Angelo	Canaletto				
Campo S. Geremia	Canaletto				
Campo S. Gesuiti	Canaletto				
Campo Sta Margherita	Canaletto				
Campo Sta Maria Formosa	Canaletto	1730	No	No	
Campo S. Polo	Canaletto				
Campo di Rialto	Canaletto	1758-176	No	No	
Campo S. Salvatore	Canaletto				
Campo S. Stefano (now Francesco Morosini)	Canaletto				
Campo S. Stefano (now Francesco Morosini)	Canaletto				
The Cannaregio	Canaletto				
The Cannaregio: looking South	Canaletto				
The Cannaregio: Bridge of Three Arches	Canaletto				
Rio dei Mendicanti: looking South	Canaletto	1723	YES	YES	P008
Rio di Mendicanti and the Scuola di S. Marco	Canaletto				
Rio di Mendicanti	Canaletto				
SS. Apostoli: Church and Campo	Canaletto	1735-174	No	No	
S. Francesco della Vigna: Church and Campo	Canaletto				
S. Giamoco di Rialto	Canaletto				

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
S. Giorgio Maggiore: from the Entrance to the Grand Canal	Canaletto				
S. Giorgio Maggiore: from the Canale di Giudecca	Canaletto				
S. Giorgio Maggiore: from the Bacino di S. Marco	Canaletto				
S. Giorgio Maggiore: from the Bacino di S. Marco, looking East	Canaletto				
S. Giorgio Maggiore	Canaletto				
SS. Giovanni e Paolo and the Scuola di S. Marco	Canaletto	1725	YES	Zoom,	
SS. Giovanni e Paolo and the Monument to Bartolommeo Colleoni	Canaletto				
The Monument to Colleoni and the Church of SS. Giovanni e Paolo	Canaletto				
Sta Maria Della Salute	Canaletto	1730	YES	Maybe	
Sta Maria Zobenigo	Canaletto				
S. Nicolo di Castello	Canaletto				
Il Redentore	Canaletto				
S. Salvatore	Canaletto				
S. Simeone Piccolo	Canaletto				
The Fondamenta Nuove and Sta Maria del Pianto	Canaletto				
On the Fondamenta Nuove, looking West	Canaletto				
Palazzo Corner della Ca Grande	Canaletto				
Palazzo Grimani	Canaletto				
Palazzo Pesaro	Canaletto				
Palazzo Vendramin-Calergi	Canaletto				

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
Scuola di S. Rocco	Canaletto	1735	No	No	
Scuola di S.Teodoro	Canaletto				
Twelve Ducal Ceremonies and Festivals	Canaletto				
OTHER SOURCES					
The Grand Canal from Campo S. Vio towards the Bacino	Canaletto	1730	YES	No	
A Regatta on the Grand Canal	Canaletto	1732	YES	No	
Reception of the French Ambassador in Venice	Canaletto	1740's	YES	Maybe	
Campo S. Rocco	Canaletto	1730	No	No	
Grand Canal near the Campo San Vio looking towards the church of Santa Maria dell	Canaletto	1730	YES	Zoom,	P003b
The Grand Canal at S. Maria della Carita, looking S. Vio (Dario)	Canaletto				P020
Grand Canal: the rialto bridge from the north (Dario)	Canaletto	1727	YES	YES	P009
Punta della Dogana (Dario)	Canaletto	1727	YES	YES	P010
The Grand Canal and the Church of the Solute	Canaletto	1730	YES	Maybe	P011
Piazza San Marco: Looking North	Canaletto	1727	No	No	
The Basin of San Marco on Ascension Day	Canaletto	1732	YES	No	
The Feast Day of St. Roch	Canaletto	1735	No	No	
Bacino di S. Marco from S. Giorgio Maggiore	Canaletto	1735-44	YES	No	

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
Bacino di S. Marco from the Canale della Giudecca	Canaletto	1735-174	YES	No	
The reception of the French Ambassador in Venice	Canaletto	1740s	YES	No	
The Vigilia di S. Pietro	Canaletto	1756	YES	No	
The Vigilia di S. Marta	Canaletto	1756	YES	No	
Capriccio: the Horses of San Marco in the Piazzetta	Canaletto	1743	No	No	
Capriccio: the Grand Canal, with an Imaginiary Rialto Bridge and Other Buildings	Canaletto	1740s	YES		
BELLOTTO					
Entrance to the Grand Canal	Bellotto	1740	YES	Maybe	P012
The Grand Canal near S. Stae Church (Dario)	Bellotto	1740	YES	YES	P014
Campo S. Giovanni and Paolo (Dario)	Bellotto	1741	YES	YES	P001a
Campo S. Giovanni and Paolo (Dario)	Bellotto	1743/47	YES	YES	P001b
Campo S. Giovanni and Paolo (Dario) (DETAIL)	Bellotto	Same	YES	Skip	
The Grand Canal from Flangini Palace to Vendramin Calergi Palace (Dario)	Bellotto				P021
The Arsenal, Venice	Bellotto	1748	YES	Zoom,	P013
The Piazzetta	Bellotto	1748	No	No	
Piazza San Marco	Bellotto	1740	No	No	
IL RIO DEI MENDICANTI E LA SCUOLA DI SAN MARCO	Bellotto	1740	YES	YES	P015
Capriccio: Architectural	Bellotto	1765	YES	FAKE	

Painting Name (Dario in Red)	Artist	Year	Water/None	Yes/No	Code
GUARDI					
The Rialto Bridge with the Riva del Vin	Guardi	1785	YES	No	

Photographs

Index Number	Name	Year	Tidal Growth Rate	Algae Differential (cm)	Absolute Algae (cm)
F001	The Salute	1860	0.252	33.9	-6.9
F002	The Arsenale	1866	0.23	32.05	-6.05
F003	Palazzo Manin	1867	0.23	31.57	-5.57
F010	Façade - Ca D'Oro	1870	0.236	31.7	-4.7
F013	Façade - Palazzo Rezzonico	1901-1909	0.235	24.21	0.8

Research

Site Code	Site Name	Date Visited	Absolute Height (cm)	Green Line Differential (in cm)
P001a	Campo S. Giovanni and Paolo (Dario) (1741)	6/8/2004	-45.25	74.2
P001b	Campo S. Giovanni and Paolo (Dario) (1743/47)	6/8/2004	-43.47	72.97
P001c	SS. Giovanni e Paolo and the Scuola di S. Marco	6/22/2004		
P002	Grand Canal: looking South-East from the Campo Sta Sofia to the Rialto Bridge (Dario)	6/9/2004	-39.6	58.6
P003a	Grand Canal: looking East, from the Camp di S. Vio (Dario)	6/9/2004		73
P003b	Grand Canal near the Campo San Vio looking towards the church of Santa Maria della Salute	6/9/2004		
P004	Grand Canal: from Sta Maria della Carita to the Bacino di S. Marco	6/23/2004		
P005	Grand Canal: looking South-West from the Palazzo Grimani to the Palazzo Foscari (Dario)	6/23/2004	-45.6	58.6
P006	Grand Canal: S. Geremia and the Entrance to the Cannaregio (Dario)	6/21/2004	-44.44	63.44
P007	Grand Canal: looking South-West from the Chiesa degli Scalzi to the Fondamenta della Croce,	6/30/2004	-41.29	71.29
P008	Rio dei Mendicanti: looking South	7/6/2004		
P009	Grand Canal: the rialto bridge from the north (Dario)	7/6/2004	-42.5	71.5
P010	Punta della Dogana	6/21/2004		61.9
P011	The Grand Canal and the Church of the Solute	6/23/2004	-48.57	72.57
P012	Entrance to the Grand Canal (Bellotto)	6/23/2004	-44.75	70.25
P013	The Arsenal, Venice (Bellotto)			
P014	The Grand Canal near S. Stae Church (Dario)	6/11/2004	-42.27	77.266
P015	Il Rio dei Mendicanti è La Scuola de San Marco	7/6/2004		
P016	Grand Canal: looking East from the Palazzo Flangini to S. Marcuola	6/30/2004		
P017	Canale di Sta Chiara: looking South-East along the Fondamenta della Croce	6/11/2004		
P018	Grand Canal: looking North-East from the Palazzo Balbi to the Rialto Bridge (Dario)	7/6/2004		