EXPLORING SAN FRANCISCO'S TREASURES:

MASHING UP PUBLIC ART, SOCIAL MEDIA, AND VOLUNTEERED GEOGRAPHIC
INFORMATION TO CREATE A DYNAMIC GUIDE

by

Nancy Elizabeth Milholland

A Thesis Presented to the
FACULTY OF THE USC GRADUATE SCHOOL
UNIVERSITY OF SOUTHERN CALIFORNIA
In Partial Fulfillment of the
Requirements for the Degree
MASTER OF SCIENCE
(GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY)

May 2014

Acknowledgements

I wish to thank my committee chair, Edward Pultar and committee members Karen Kemp and

Jennifer Swift for their feedback and support in writing this thesis.

Mono Simeone and Rick Kos of the GIS Education Center for introduced me to GIS

through a variety of short courses. They enthusiastically supported my interest in GIS. Mono also

provided infrastructure for me to keep my application running post graduation.

Susan Sutton, my spouse, created legend graphics for different art types. She helped specify

requirements for building metadata. Most of all, she supported and encouraged my pursuit of a

degree in spatial science.

Some material in this thesis is based on the following:

Milholland, N. and E. Pultar. 2013. . The San Francisco Public Art Map Application: Using

VGI and Social Media to Complement Institutional Data Sources. In *MAPINTERACT '13*.

Orlando, USA: ACM.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AGOL	ArcGIS Online
API	Application Programming Interface
CCSF	Community College of San Francisco
CGI	Contributed Geographic Information
CRU	Create, Read, Update
CRUD	Create, Read, Update, Delete
CSS	Cascading Style Sheet
CSV	Comma Separated Variable
FIPS	Federal Information Processing Standard
FPA	Federal Art Program
GI	Geographic Information
GPS	Global Positioning System
HTML	Hypertext Markup Language
IDE	Integrated Development Environment
iOS	iPhone Operating System
JSON	JavaScript Object Notation
KDC	Knowledge Discovery in Cyberspace
KML	Keyhole Markup Language
KMZ	Keyhole Markup Language, Zipped
LBS	Location Based Services
MXD	Map Exchange Document
NEA	National Endowment for the Arts

NOAA	National Oceanic and Atmospheric Administration
PIM	Public Information Map
POI(s)	Point(s) of Interest
PWAP	Public Works of Art Program
R	Read
REST	Representational State Transfer
SDK	Software Development Kit
SFAC	San Francisco Arts Commission
SFMA	San Francisco Mural Arts
SFO	San Francisco Airport
SFOM	San Francisco Airport Museum
SFPAM	San Francisco Public Art Map
SFPC	San Francisco Planning Commission
SOD	Sudden Oak Death
UCSF	University of California San Francisco
URL	Uniform Resource Locator
USC	University of California San Francisco
VGI	Volunteered Geographic Information
WGS84	World Geodetic System 1984
WPA	Works Progress Administration
YBG	Yerba Buena Gardens

Abstract

The San Francisco Public Art Map (SFPAM) mashes up disparate sources of data to create a dynamic, comprehensive, and interactive map of public art and landmark buildings in the City of San Francisco. The San Francisco Arts Commission administers publicly funded art and is responsible for over 800 pieces but maps are incomplete or inaccurate. There are hundreds of other art pieces such as murals, street art, and art funded by private organizations not included in the San Francisco Arts Commission dataset. Existing applications focus on one type of art or a narrow selection of installations. No application combines institutional data sets, peer-reviewed volunteered geographic information, and social media to create a comprehensive view of publicly available art.

The SFPAM consists of a web client and ArcGIS Online maps. The web client uses JavaScript, Dojo, social media application programming interfaces, ArcGIS Server, ArcSDE , REST services, and Microsoft SQL Server technologies. Configuration and development to add functionality to Esri's Public Information Map 2.0 source code transformed a disaster map to an art map. The web application incorporates Stamen Design basemaps to provide a fresh look that complements the art content. ArcGIS Online maps enable users to contribute new art and buildings and view art data on mobile devices through the ArcGIS for Mobile or Collector applications.

There are three levels of curated data: institutional, administrative, and social. Institutional curation consists of datasets provided by institutions that administer or fund public art projects. The administrative level includes reviewed volunteered geographic information. Social curation consists of a dynamic layer of pictures and comments on public art through social media streams such as Flickr, Panoramio, Instagram, and YouTube. The application demonstrates a unique method of combining data sources to provide a public art map for visitors and residents of San Francisco.

Chapter 1: Introduction

The City of San Francisco is endowed with a rich variety of art in public spaces. The San Francisco Arts Commission (SFAC) alone curates over 800 pieces of public art. In addition to the SFAC holdings, there are colorful murals, landscaped parks, art monuments, street art of mysterious origin, and pieces curated by other organizations. There is no one place to learn about all the different art available in the city's built environments. Existing mobile and web applications that map art locations silo information by covering only certain categories of art such as publicly funded pieces, murals, or street art. No application currently uses social media as a source of art data.

The San Francisco Public Art Map (SFPAM) is a web and mobile application that aggregates location based publicly accessible art data in San Francisco. The project compiles art location information from disparate institutional sources. Volunteered Geographic Information (VGI) creates a dynamic layer of pictures and comments on public art through social media streams such as Flickr, YouTube, Instagram, and Panoramio. Residents or visitors in San Francisco locate and learn more about public art through accessing the application.

ArcGIS Server, ArcSDE , ArcGIS Online, and Microsoft SQL Server provide backend services. Esri's Public Information Map (PIM) provides a development starting point for the web application. The web application uses JavaScript, Dojo, and social media application programming interfaces (APIs) to create an interactive user guide. The iPhone Operating System (iOS) software development kit (SDK) 6.x, XCode 4.6, and ArcGIS Runtime SDK for iOS 10.1.1 furnished a development environment for exploring the creation of a 6.x native application for iPhone and iPad.

ArcGIS Online (AGOL) for Organizations, Esri ArcGIS for Mobile, and Esri Collector provide an

interface to update and add new data in the field, as well as a mobile client map option.

Chapter 2: Motivation

This chapter explores the value of public art, the ubiquity of mobile devices, and the potential

benefits of a mobile art application in sections 2.1 -2.4. Sections 2.5 - 2.7 investigate VGI, social

media, data quality, and the concept of curation. Section 2.8 describes several web and mobile

applications. Section 2.9 lists the research questions explored in the thesis.

2.1 Art in Every Day Life

Dog lovers walking their dogs at Fort Funston encounter two homages to canines installed

on the crumbling concrete wastewater outflow pipes by the ocean. One bas-relief sculpture depicts

running greyhounds. A second shows a mysterious dog buddha gazing out to sea. What is the story

behind these pieces? People see art taking public transportation, playing in parks, reading in libraries,

or performing any number of daily tasks that take them into San Francisco's built environment.

Artists may be well known, such as sculptor Andrew Goldsworthy, little known, or unknown. Over

300 colorful murals depicting daily life, politics, history, community, humor, hope, and culture greet

walkers in the Mission District. Whether sublime or tacky, subversive or bland, moving or

humorous, funded or unfunded, art is part of the fabric of the city of San Francisco.

2.2 Public Art

Cartiere (2008) states that the origin, definition, and purposes of public art are not clear. Did

public art originate with the cave paintings at Lascaux? Or did public art in the United States

officially originate in 1967 with a commission for a sculpture by Alexander Calder from the National

Endowment of the Arts's (NEA) new fund for public art (Miles 2009)? Others such as Cartiere

(2008) argue public art originated in the 1930's with either the Federal Art Program (FPA) of the

Works Progress Administration (WPA) or the Public Works of Art Program (PWAP).

Cartiere asks when the term *public art* became a dirty word, used primarily by administrators of funds for public art, and notes that many terms and kinds of art such as "permanent works, temporary works, political activism, service art, performance, earthworks, community projects, street furniture, monuments, memorials, plunk, and plop art," are used to describe public art works. An art installation may be as small as one's hand or encompass several acres.

Over time, several paradigms have defined public art (Knight 2008). Memorials commemorating loss or monuments celebrating heroes and victories comprise early state sanctioned art. Other paradigms include functional art, such as tables and chairs; art in the park such as Christo's *The Gates*; art as the agora or public place; and art as pilgrimage. An extreme example of art as pilgrimage is De Maria's *Lightning Field*, a work requiring a guide to find the site, an accident release form, and overnight stay with up to 5 other pilgrims in a small cabin cut off from cell coverage.

Miles (2008) wonders whether public art such as monuments, works created through public funding for urban redevelopment, and those commissioned by public agencies on behalf of the public are perpetuating a power dynamic and promoting an implicit set of values. He writes, " Public art in context of the cultural industries as perceived drivers of redevelopment reinvents the tradition of the public monument. Statues in public parks and squares seem inoffensive as they blend, covered in moss and pigeon shit into an urban landscape. But public monuments arose as one element in a spectrum of public institutions which includes the workhouse, the prison, and the museum." Monuments, statues, and sculptures also serve the common good as references for navigation or wayfinding due to their landmark saliency: characteristics that differentiate a landmark visually from the surrounding environment (Raubal and Winter 2002).

Hein (2006) notes that concurrent with the development of art by agencies on behalf of the public, various communities began discovering their own voice in the 1970s through creating murals on available wall space. The murals were generally funded by grassroots donations and created by local residents. Hein quotes Timothy Dresher, who talks of public art, "done for a general undefined population … and commissioned by official bodies" in contrast to community art "created by or with a group of people who will interact with the finished artwork." The Mission murals of San Francisco integrate common symbols of Hispanic residents such as the Virgin of Guadalupe with contemporary events, providing a voice for those communities.

Cartiere defines public art broadly as "art outside of museums and galleries" that meets one of the following criteria: publicly accessible or visible; of public interest to individuals or a community; maintained for or used by individuals or a community; or publicly funded. This broad definition of public art informs the San Francisco Public Art Map (SFPAM). Most individuals are interested in learning about the art they see in front of them or the art where they will be travelling; it is of little consequence which organization funded the project. Why should a user have to look at multiple applications or sources to find out about several pieces of art that are in close proximity? The SFPAM seeks to improve user access and experience by bringing art data for publicly funded art, art funded by other organizations, murals, and street art into one application.

2.3 Art and Experience

Using John Dewey's work describing types of experience, Hein (2006) classifies the encounter with art as a kind of consummatory event that adds zest to life. Subject and object are one, and there is a satisfying completeness. The encounter may be transformative or generative. Ideas are brought into focus and become private experience as a person engages the object. Art has the power to challenge ideas and transform people.

2.4 Mobile Devices

Mobile phones have expanded human capabilities through increased access to information as well as possibilities for people to connect with one another (Smith 2011). According to Lunden (2012), Nielsen reports that 50.4% of US consumers use smart phones. The market share for Android is 48.5% and iOS is 32%. Global Positioning Systems (GPS) chips provide low cost and efficient navigation and location services for mobile and smart phones (Hwang and Yu 2012). A mobile-friendly, web-based application bridges the gap between different operating systems and can be used by more devices than a native application, while a native application offers performance benefits and broader use of built-in device functionality. A public art application for mobile access expands human capabilities through publicizing and directing people to accessible public art. People can engage art on the streets directly instead of from their armchairs.

2.5 Crowd Sourcing, VGI, and Social Media

Howe (2006) coined the term *crowdsourcing* to refer to the ability of socially networked individuals to produce solutions equal or greater to that of experts or professionals in a fast, cost effective manner. Crowdsourcing can be used by any group for a variety of reasons in an asynchronous fashion, (Barbier et al. 2012). Crowd sourced data can also be clustered to create categories using metadata or hash tags.

Although Boulos et al. (2011) described user-contributed, geo-referenced material as the "Wikification of GIS by the masses" in 2005, other phrases are more commonly used. Goodchild (2007) documented the phenomenon of untrained citizens voluntarily contributing geographic information and remarked:

> They represent a dramatic innovation that will certainly have profound impacts on geographic information systems (GIS) and more generally on the discipline of geography and its relationship to the general public. I term this volunteered geographic information (VGI), a

special case of the more general Web phenomenon of user-generated content (Goodchild 2007,212).

Urban environments, such as San Francisco, contain large numbers of citizens using mobile location-based services (LBS). Thus, they also contain inherent resources for generating spatial data and information to complement traditional means of data mapping, (Mooney, Sun, and Yan 2011). Cuff (2008) writes that the rise of cell phones with GPS and other sensors in urban environments signals a shift from centralized, unattended sensors controlled by scientists to decentralized, distributed citizen sensing. A central authority may maintain the database and rules under which urban sensors contribute information. Cuff cites the Great Backyard Bird count as an example of urban sensing. Citizens are both consumers and producers of data, even if inconsistent or not fully intentional contributors. Dangermond (2011) notes that one critical requirement for using VGI is structuring data collection for analysis. Geographic information may be challenging to extract from VGI depending on the source and geospatial data format (Pultar et al. 2009).

Georeferenced social media generates VGI and crowdsources the earth's surface (Newsam 2010). Work has been done (Kennedy et al. 2007) to demonstrate that photo-sharing services with tagged and geolocated photos can be mined to discover locations and events. Chen et al. (2009) has developed a system using georeferenced images to generate maps with images of tourist locations.

Popular social media services include Twitter, Foursquare, Facebook, and YouTube. Flickr, a cloud based photo-sharing service, posts daily statistics of camera usage by upload total and users. While the all time camera brand on Flickr is Canon, statistics for June 5, 2013 (www.flickr.com/cameras), show that three iPhone cameras had the largest number of users as well as image uploads to the service with Canon DSLRs taking the next two spots. The three iPhones accounted for 635,591 uploads from 19,239 users. The Canon DSLRs accounted for 275,930

uploads from 8068 users. The Flickr statistics are an indicator of the growth and dominance of mobile devices for generating VGI.

The benefits and challenges of using VGI are summarized in Table 1 based on experience from the Oak Mapper environmental monitoring system (Connors, Lei, and Kelly 2012). Oak Mapper combines data from different sources: scientists working on mapping Sudden Oak Death (SOD); citizens who contribute information; and social media streams such as Twitter and Flickr that have hashtag references to SOD. The Oak Mapper project, while an environmental monitoring system, models a data acquisition and integration framework similar to the San Francisco Art Map: there are "official" entries, crowd sourced entries, and social media points. The current version of Oak Mapper enables users to submit data using an iPhone application that leverages the GPS of the device and turns a personal phone into a research instrument. Searching social media using a filter of "Sudden Oak Death" produces additional geolocated points.

Table 1 Benefits and Challenges Using VGI

Benefits	Challenges
Ability to leverage volunteers	Data credibility, quality, consistency
Increased scale of coverage	Metadata standards
More informed public	Unpredictability, bias and motivation
Active consensus building	Perceptions of surveillance
Community and social networking	Reinforced authority and differential empowerment
Massive data flows	Access and the digital divide
Increased cooperation	Technical challenges

Source: **(Connors, Lei, and Kelly .2012, 1274)**

2.6 Value of VGI

This section compares traditional geographic information production and VGI creation. Quality concerns, value, and benefits are discussed. Different components of VGI are identified as

well as types of research using crowd-sourced images. New metaphors for VGI are described and appropriated for the SFPAM.

2.6.1 Traditional Geographic Information (GI) and VGI

Flanagin and Metzger (2008) raise questions about VGI with regards to quality, accuracy, reliability, and value. VGI is difficult to assess from a quality perspective. There are a large number of contributors and a lack of gatekeepers, and data does not meet academic standards for quality. Feick and Roche (2013) note that traditional GI is usually constructed by one person and evaluated according to resolution, positional accuracy, currency, and professional reputation. As Chrisman (1984) has written, data quality is not just positional accuracy, but communicates information from the producer to the consumer so that the user can determine the fitness of use for a given purpose. Value is difficult to measure even with traditional GI. The utility of both GI and VGI depend on the fitness of use for the consumer's purpose and the consumer's perception of value.

Harvey (2013) states that distinctions should be drawn between VGI and contributed GI (CGI) when discussing crowd-sourced data. VGI has opt-in agreements to clarify data collection and reuse, whereas CGI has opt-out agreements that are vague, open-ended, and provide the user with limited controls. Mobile phone tracking data that can be resold is an example of CGI. Social media streams and peer-reviewed VGI used in the SFPAM contain data reuse agreements that users confirm when uploading data to the various sites.

Feick and Roche (2013) summarize ways VGI creation differs from traditional GI production: producers are not experts, but amateurs with a range of interests and abilities; distinction between producers and consumers is blurred as produsers participate in both roles Budathoki (2008); creation and use of data is loosely organized; and volunteers may lose interest in a project and stop participating.

Pultar et al. (2009) comment that an advantage of VGI is the creation of a dynamic GIS that makes use of changing geographic objects over time. A dynamic GIS leverages temporal geodata and provides better analysis, queries, and visualization. Data creation is driven by personal interest and motivation, resulting in data that would not have been created by government or commercial organizations (Goodchild 2008). Additional benefits of VGI include:

- Creation of rich datasets based on local and experiential knowledge Hall (2010).
- Fostering of a culture of participation where citizens can participate and control viewpoints Roche (2011).
- Building of technical skills and social networks.
- Potential to mobilize large numbers of contributors over short periods of time to construct data that is more responsive to changing needs than government or commercial organizations can provide (Feick and Roche, 2013, 19-20).

2.6.2 VGI Data Quality

As noted in Table 1, challenges to using VGI include data credibility, consistency, and quality, as well as producer unpredictability, bias, and motivation. These issues are particularly important when using VGI in a scientific study or in disaster and crises situations. Goodchild and Glennon (2010), are among those who have discussed strategies and concerns with regards to using VGI (Elwood, Goodchild, and Sui 2012; Flanagin and Metzger 2008; Barbier et al. 2012). Cuff , Hansen, and Kang (2008) question whether data quality concerns are as important when dealing with art and politics.

VGI for public art differs from disaster or crises mapping in several ways: data quality is not a time-sensitive matter of life and death; data has a long lifespan unless the point of interest (POI) is temporary; and data can be revised. A consumer of public art data is not monitoring how close a fire is to property and making a decision to evacuate. Public art data should be located and described verbally or through an image with enough accuracy for a consumer to locate the physical POI and

learn more about the piece. The POI should be relevant to public art. Strategies such as filtering and incremental improvement of data accuracy can improve data quality.

2.6.3 Components of VGI

One of the key contributions of both peer-reviewed VGI and social media VGI for the SFPAM is the inclusion of image content.) One way of making sense of VGI photo collections such as Flickr comes from clues extracted from user-assigned labels and tags (Kennedy et al. 2007). Tags are entered without reference to ontology or categorization and can be inaccurate, wrong, or ambiguous. The tag may not even describe the image content. Geotagged location information provides another clue to content. Computer vision analysis can be combined with geotags and label analyses to generate representative pictures of landmarks for an area such as San Francisco. However vision analysis is not always applicable or practical given the intended use for VGI.

Tsou and Leitner (2013) describe the emerging social media research framework for knowledge discovery in cyberspace (KDC). The three interdependent components are place, time, and messages. Place may be the GPS location, the interpretation of a place name, user context, or scale. Time may be a snapshot or a period of time. Messages consist of different kinds of content such as text, images, or video depending on the social media stream. Interpretation and analysis depends on context and medium.

Newsam (2010) divides work leveraging georeferenced crowd-sourced photographs into three categories: annotating novel images (such as Kennedy's work above), annotating geographic locations, and performing geographic discovery. Tsou and Leitner (2013) also distinguish between social media research as big and small data. VGI in the San Francisco Art Map falls into the category of geographic discovery and small data. The purpose of the map is to discover, integrate, and

visualize as many different locations of art as possible in the San Francisco extent for public use.

VGI data extraction and visualization is constrained both by location and by context. With a few

exceptions, art works, especially murals and street art, will have only one geotagged image. Most art

will not have an obvious or commonly used identifier such as "The Golden Gate Bridge." The

artist's name and the work's title may appear on a nearby plaque or embedded in the artwork. In the

case of murals and street art the identity of the artist and title may be a matter of local knowledge.

2.6.4 Different metaphors for VGI Value

Feick and Roche (2013) propose two metaphors to describe the VGI use and production.

The first is based on Debord's (1958) concept of 'dérive,' translated as drift. The second metaphor is

that of Lego building blocks.

Feick and Roche describe drift as wandering in an urban environment "without specific aims

other than to discover and become immersed in a narrative network of experiences and lives." They

draw an analogy to the VGI produser who:

> *Explores, uses and produces new VGI without necessarily having a predefined plan, timetable or*
> *schedule. Navigation in VGI processes allows produsers to encounter unexpected data sources,*
> *discover anticipated phenomenon and then increase the potential value of VGI as processes and as*
> *datasets (Feick and Roche 2013, 25).*

Further, Feick and Roche link value and creation of VGI to serendipity, a concept describing

"unexpected discoveries that are made randomly and through intelligence in a process that initially

targets a different object than those that are discovered."

While drift and serendipity may describe creativity in individual VGI contributions, the

second metaphor of VGI as Lego blocks addresses collaborative data usage as well as reuse. Very

different end products can be built from the same blocks, such a space ship, house, or truck. VGI

can be seen as data blocks that can be reused, extended, or mashed up to expand the value of the original data.

Both of these metaphors are helpful in describing the value of peer-reviewed VGI and social media for the SFPAM. There is a sense of both serendipity and drift as to the art works that have captured the interest and notice of the contributors. Like a Lego creation, the map uses multiple VGI sources, extends them through extraction of content into a common data model, and mashes them up into an art map. In addition, the map itself encourages wandering through data by clicking and exploring the features. Hopefully the map encourages viewers to engage in their own drifting discovery of San Francisco's art treasures.

2.7 Curation and Social Media

Liu (2011) has developed a model of socially distributed curation during crises. Curation is a process of choosing what is meaningful and is usually associated with institutions that employ curators to make decisions about what stories or objects to preserve. Liu argues that social media supports curation tasks such as collecting, organizing, storytelling, and preserving of memories in a way that allows others to reuse and redefine collective memories, whether experienced directly or indirectly. Social media shifts curation from an individual defining what is worth preserving to a social network of multiple people defining cultural heritage. While Liu focused on the role of social media as curator of crisis heritage, the SFPAM uses social media as curator of public art.

There are three levels of curation in the SFPAM: institutional, administrative, and social. Art data comes from institutions that fund and curate public art. Peer-reviewed VGI, administrative scraping of web sites, and local knowledge create additional layers. Social media creates a dynamic layer of pictures and comments on public art from contributors who unknowingly take on the role

of curator through posting and tagging images. Combining data from multiple curators creates a richer set of art data points.

2.8 Web and Mobile Art Applications

There are multiple applications available for web and mobile clients that document art locations. None are comprehensive in their coverage of publicly available art. Table 2 summarizes features of several applications and indicates if the application is targeted to web and/or mobile devices. The web applications are not specifically designed to be mobile friendly; organizations develop native applications for iOS or Android to address mobile users. The San Francisco Arts Commission has a public art map that was last updated in 2009. The map contains only a subset of the agency's holdings, is difficult to find from the main SFAC website, is not designed for mobile access, and does not have a VGI component or social media layer.

Table 2 Selected Art Applications and their Capabilities

Name	Description	Designed for Website/ Mobile	SF Art Locations	VGI	Social Media as VGI layer	Map
Art and Architecture – San Francisco	Photos and history of buildings and public art in San Francisco	Website	Art and building locations. 1800+ map points, but actual POIs is 622	Users can request that the author research and include a building or artwork	No	All points shown on map. Selecting a point brings up an image with url to article
Culture Now	Art, Architecture and History in the Public Realm. Public art locations, podcasts, videos, events, and tours.	Website/ Mobile. Map function doesn't work on iPhone	12	Users can submit form and images for consideration by admins.	No	All points shown on map. Search by artist, city, title, architect, city, or year
Fontly	Capture, map, and explore the world of vintage typography	Web, iOS	~200 examples of typography	Yes. All locations user submitted using the IOS application	No	All points shown based on map extent. Awkward navigation, interaction with pop ups, point clustering
SF Mural Arts	Online resource for	Website/ Mobile	750+ murals in San	Photos of existing murals.	No	All points shown on map

	murals in San Francisco. Murals listed by neighborhood.		Francisco			
San Francisco Arts Commission Public Arts Map	Dated and difficult to find Google map selection of SFAC public art	Website	~100 out of agency's 800+ pieces	No	No	All points shown on map

SF Mural Arts (www.sfmuralarts.com) has a beautiful web gallery of 750+ murals in San Francisco. The website documents basic information about murals such as the artist, pictures, date of creation, and location. The murals can be listed by neighborhood. However, while the website has a map of the murals, clicking on individual points generates mixed results. SF Mural Arts released an iOS application in December 2012 that allows a user to view locations of all the murals. Users can submit pictures of murals on the web for consideration or send an email from the mobile application suggesting new sites. Some murals are sponsored by SFAC, but the majority are commissioned locally. The application allows one to select favorite murals to create a tour.

Art and Architecture – San Francisco (www.artandarchitecture-sf.com) is a web site with pictures and history of buildings and public art organized by neighborhood. The author, Cindy Casey, has been posting pictures and history of art and buildings since 2011 in response to a *New York Times* article that detailed the neglect, loss, and mismanagement of San Francisco's public art Wright (2011). The website is a great resource for pictures and history, but difficult to navigate. The site grew organically over time and does not provide summary of locations included. The art and architecture covered reflects the author's interest; however users can send an email to the author requesting inclusion of a building or public art piece.

The site can be searched for an artist. All points are displayed on a simple Google map with popup windows containing a title, image, and hyperlink to the article on the image. There is no

clustering, and a user cannot navigate from an article on the web site to locate the POI on the map. While there are over 1800 markers, multiple markers are placed at the same location representing different photos of the same POI, as well as POIs that should be mapped at a slightly different latitude and longitude. Overlapping markers do not always link to the same web article. This makes it difficult to assess the number of buildings or public art pieces covered by the website. When multiple markers are placed at the identical latitude and longitude, only the last marker placed on the map is accessible.

Culture Now is a web and mobile application with a wealth of information on public art, architecture, history of art and architecture, guided tours through the application, and events. Most locations are events in the Northeastern U.S., although there are a few art pieces in San Francisco. All locations are mapped and can be searched for or filtered in a variety of ways. This application is one of the few that contains notable buildings. Users can submit a form and image for consideration by the application administrators.

Fontly is a mobile application that collects data and images of interesting typography. Users submit all records with no administrative review. A simple form collects information on what the sign says and asks the submitter to categorize the sign from a pull down list. Users can "like" a submission. Records are accessible as points on a map. A subset of records is available for recently submitted locations, favorites, and a user's submitted locations.

With the exception of Art and Architecture – San Francisco, which includes art based on the interests of the site curator, applications segregate public art data by agency or type of art. No single application provides a complete view of art in San Francisco. Some applications accept VGI contributions. No application uses unstructured social media art POIs as a resource for expanding art locations.

Geotagged social media, filtered by metadata such as "art" or "sfart" within the extent of San Francisco, provides several hundred photos and videos of unsolicited VGI data. Social media provides a citizen curated, dynamic, time-sensitive, and decentralized catalog of public art. The best publicly available source documenting murals and street art may be social media if the art is illegal, sponsored by a small organization, or sponsored by an individual for a residence. Social media entries are time-sensitive due to volume limitations placed on API data access.

The SFPAM breaks down barriers between categories of art or agency by aggregating art data from as many sources as possible and letting the consumer decide which art is interesting. Art locations come from organization datasets, peer-reviewed VGI, and unsolicited VGI. The map exists to make art information broadly available and enable the public to be both consumers and producers of art data.

2.9 Research Questions

This thesis investigates the following research questions:

1. How can a comprehensive, interactive, dynamic map of public art and architecture for San Francisco be built from disparate data sources?
2. What is a common, extensible data model for public art and architecture?
3. How can social media be used to provide information about San Francisco's public art?
4. How can institutional, peer-reviewed VGI, and social media data sources for San Francisco public art and architecture be evaluated for quality?

The Background chapter following looks more closely at 44 different art applications and evaluates their technology, datasets, functionality, VGI, and social media capabilities.

Chapter 3: Background and Review of Existing Applications

This chapter assesses the Esri Public Information Map and how it contributes to the San Francisco Public Art Application (SFPAM). Existing art applications are reviewed to determine their contribution to San Francisco art information, mobile accessibility, technology, datasets, VGI, and functionality. The final section describes the value of the SFPAM as an art application for San Francisco.

3.1 Esri Public Information Map

In 2010 Esri created a prototype web application for VGI using ArcGIS 10.0 and web services called the Public Information Map (PIM). The application, which is no longer available online, was used to support the Deepwater Horizon oil spill recovery by combining authoritative content from organizations such as the National Oceanic and Atmospheric Administration (NOAA), the disaster response feed from Ushahidi, and live data feeds from social media such as YouTube, Twitter, and Flickr. Users also posted content and links. The ArcGIS Server Development Team (2010) documented the following observations:

- The application provides potential ways for user generated and policed data gathering in regards to things users are passionate about.
- Social media results are unpredictable, and it is tricky to filter social media to include only relevant information.
- Use a generic search term such as "oil spill", use only georeferenced data, and limit the extent.
- Set up social media filters and enable community policing through allowing data to be flagged as inappropriate.
- If you allow people to add data, they will, and contributions may not be relevant.
- Time is important for incident data.
- This type of application has broader application than disaster response.

Esri has released several iterations of the PIM application and code base for public use.

The PIM observations translate well to the SFPAM application. Institutions, user contributions, and social media provide data. Georeferenced filtering by generic keywords such as "art" or "sfart" within the San Francisco extent provides rich social media results. Time is not critical for public art data, with the exception of events. The SFPAM application does not include art events.

The SFPAM application is an example of how the PIM has broader application than disaster response. The PIM was customized to become a web-based art map for San Francisco. Modifications to the PIM code included extent, filters, graphics, text, basemaps, layers, and social media streams. The PIM provides an attractive interface, includes basic navigation and search functionality, and is highly configurable and extensible by developers who download the code.

While the PIM provides an excellent framework for desktop browsers, the interface is not optimized for mobile phones or tablets. A mobile friendly web or native application requires additional development.

3.2 Review of Existing Art Applications

Section 3.2.1 introduces the existing applications and reviews their extent, POIs in San Francisco, client platforms, and mapping platform. Section 3.2.2 describes data sources for different art applications and use of VGI. Section 3.2.3 assesses basic mapping functionality for the applications. Section 3.2.4 looks at the limitations of current applications using the public art commission dataset in San Francisco.

3.2.1 Existing Art Application Description, Extent, and Technology

Research on art applications generated a list of forty-four programs for review. Table 3 lists the application name, brief description, extent, and the number of San Francisco locations mapped.

Appendix A.1 contains the web Uniform Resource Locators (URLs) for each application. Research includes art applications without San Francisco locations to understand the overall capabilities of art applications and assess the uniqueness of the SFPAM.

Twenty-three applications contained POIs of art located in San Francisco. The number of POIs in San Francisco ranged from five to over two thousand. Seventeen of the applications had a primary geographic focus on San Francisco. Art and Architecture – San Francisco, 1:AM, and SF Mural Arts contained the greatest number of San Francisco locations. Art and Architecture – San Francisco and Field Trip were the only applications to include more than one broad category of art. The remaining applications focused on street art, murals, typography, neon signs, or publicly funded art.

One application, Art Around SF was not implemented. *Street Art SF* contains no location data. Four Android applications failed to run (numbers 17, 19, 32, 43 in Table 3). The website (http://www.artmapper.org) for Public Art Locations no longer exists. 1:AM requires a user account and logon to browse entries.

Table 3 Art Application Description and Extent

Name (an "*" indicates the application does not work)	Description	Extent	#SF locations
1. Art and Architecture – San Francisco	Photos and history of buildings and public art in San Francisco	San Francisco and other cities where author has travelled	622
2. Art Around	Public art, galleries, museums, festivals	Primarily Washington, DC	0
3. Art Around SF*	Project cancelled	San Francisco	0
4. Art Basel Miami Beach	Miami Beach artists, galleries, and exhibitions	Miami Beach	0
5. Art Guide	Art and exhibitions in the U.K.	U.K.	0
6. ArtTrax Public Art	Public art in South Dublin County	Ireland	0
7. Belfast Public Art Guide	A guide to public art in Belfast.	Belfast, Northern Ireland	0
8. Belfast Murals Guide	A guide to murals in Belfast	Belfast, Northern Ireland	0
9. Bristol Street Art Map	Bristol street art	Bristol, UK	0
10. Culture Now: Museum without walls	Art Architecture and History. Public art locations, podcasts, Videos, events, and tours.	US. Partnerships with various public arts organizations.	12
11. Field Trip	Developed by Google. Contains art, architecture, food, culture, and historical information from many sources	Global	~100 for art
12. Fontly	Capture, map and share vintage typography. Web application is view only.	World	~200
13. Gone Tomorrow SF	Map and directions to street art	San Francisco Bay Area	~25
14. Graffiti Mapper	Map graffiti	United States	0

Name (an "*" indicates the application does not work)	Description	Extent	#SF locations
15. Hong Kong Art Guide	Art exhibitions and news in Hong Kong	Hong Kong	0
16. Laguna Beach Public Art Map	65+ Public art locations in Laguna Beach	Laguna Beach	0
17. ExperienceLA.com Public Art LA*	ExperienceLA.com Public Art and Historic Sites mobile application pilot project focuses on select art pieces and historic locations in Downtown L.A.	Los Angeles	0
18. Mural Locator	News, events, mural gallery, and map of murals around the world	World	~50
19. NYC Subway Art*	Graffiti and Street Art	New York City	0
20. PDX Art Trekker	475 public art pieces in Portland, OR	Portland, OR	0
21. Privately-Owned Public Open Space (POPOS) and Public Art	Public art located in POPOS in San Francisco. Buildings or new additions over 25,00 sq feet are required to spend 1% of construction cost on Public Art	San Francisco	39
22. Project Neon	New York Neon signs	New York City	0
23. Public Art Finder	Public Art Locations around San Francisco	San Francisco	~50
24. Public Art Fund	Brings free public art exhibitions to New York	New York City	0
25. Public Art Locations*	Geolocated tweets of public art to @PublicArtApp with pictures using yfrog,twitpic, and lockerz	San Francisco and Oakland	75
26. Public Art in Public Places	Public art in Southern California	Southern California	0
27. Public Art Omaha	Public art in Omaha, NB	Omaha, NB	0
28. Public Art PDX	Public art in Portland via iPhone application	Portland, OR	0
29. San Francisco Civic Art Finder	San Francisco Art Commission Public dataset	San Francisco	600+
30. San Francisco Landmarks Google Map	Landmarks and landmark districts as defined by article 10 of the San Francisco Planning Code. Does not include landmarks such as statues and monuments.	San Francisco	~300
31. San Francisco Mural Project	Google Map with pictures, description, title, location, and artist information	San Francisco and Oakland	~40
32. San Francisco Public Art – SF Art*	San Francisco Art Commission Public dataset	San Francisco	600+
33. SF Arts.Org	Art Events in San Francisco	San Francisco	5
34. SF Mural Arts	Online resource for murals in San Francisco. Murals listed by neighborhood	San Francisco	757+
35. SF Public Art	San Francisco Public Art Commission dataset mobile application	San Francisco	600+
36. SFAC Public Art	San Francisco Art Commission map of Public Art Projects. Last updated 2008, limited locations.	San Francisco and airport	~100
37. SF Street Art Map	Street art locations primarily in Haight Ashbury, San Francisco	San Francisco	~25
38. SF Street Art	600 photos documenting 250 sites in San Francisco	San Francisco, primarily SOMA, Mission, Tenderloin, and Nob Hill	250
39. Street Art SF	Street Art Photos and locations - no map available	US	Unknown
40. SF's Secret Spaces and Hidden Oases from SPUR	Includes POPOS	San Francisco	39
41. STQRY	Art, culture, and historic sites.	Global	65 SFAC artworks
42. The Living New Deal	New Deal public works projects in the US. More than public art and architecture. 322 projects for San Francisco some of which are art and architecture.	US	~90
43. Tram Art*	Art in the vicinity of Amsterdam's trains	Ansterdam	0
44. 1:AM Mobile Application	Archive of street art movement and community of street art enthusiasts.	Global	~2000

Appendix A.2 contains the client and mapping platform details for each application. Google Maps dominated as the mapping platform of choice for thirty-six applications. Mapbox, Mapquest, and Leaflet with Open Street Maps each provided the platform for one application. One application uses Apple Maps. Two applications did not contain maps. One application had an unknown mapping platform, as the program did not load.

The application client platforms consisted of web, iOS, Android, and Windows. Some applications had multiple clients. Table 4 shows how many applications supported each client type. Fifteen of the applications supported only web clients, with one designed as a mobile friendly site. Fourteen applications consisted of native clients only. Fourteen applications supported a mix of web and native client types. Only one application provided a Windows native client. Twenty-eight supported a web client. There were similar numbers of iOS and Android clients.

Table 4 Client Types Summary

Client Type	Number of Applications
Web only	15
Native client for mobile only	15
N/A	1
iOS	17
Android	18
Web	28
Windows	1

3.2.1.1 ArcGIS Online Art Maps

A search of ArcGIS Online (AGOL) content for "art" returns over 1300 results consisting of web maps, web application, and layers. The content uses AGOL templates such as the story map to create maps and applications. The maps for San Francisco do not provide comprehensive coverage of art. The SFPAM uses AGOL for two feature services and three web maps. AGOL provides a mobile solution and a means to edit or add features.

3.2.2 Public Art Content, VGI, and Social Media

Appendix A.3 contains an assessment of each application for public art commission content, VGI, and social media usage. This section summarizes the results.

Did the application intentionally include a public art commission dataset? Twenty-two of the applications included a full or partial public art commission dataset. Twelve of the applications used the San Francisco Arts Commission dataset.

Did the application include art events? Nine applications included information on art events, two of which contained San Francisco events. One, sfarts.org, focuses primarily on cultural events in San Francisco.

Did the application solicit user contributions of art locations? Thirteen of the applications solicit art locations from users, with ten including locations in San Francisco. For applications that allowed art submissions by users, nine (six for San Francisco) required administrative review before being added to a map. One reviewed submissions only if flagged by other users for inappropriate content.

What kind of community VGI such as comments, ratings, photos, likes, or flag for offensive could a user contribute? Sixteen applications allowed users to comment, rate, like, submit a photo, or flag entries. Seven applications had the capability for users to add comments or photos.

Did any application use social media as a data source for content? Only one application, Public Art Locations, requested that users post content to their map via Twitter address @PublicArtApp. This reflects a conscious choice of the user to post content to the application and the application consists only of Twitter data posted to the account. The application is no longer running. None of the applications use Flickr, YouTube, Instagram, or Panoramio as dynamic data

sources. None of the applications reuse social media data as a mashup or in a manner unforeseen by the original contributor.

Can the user share an art location or the web map with others using social media? Seventeen of the applications allow users to share a map location or art event using social media. The most common outlets are Twitter and Facebook.

3.2.3 Mapping Functionality

Appendix A.4 describes basic mapping functionality for each application. This section summarizes the results.

Is the application map or location focused? The map should be easy to find and display all features when filtering is off. Thirty applications were location and map focused; the remainder either had no map, a difficult to find or use map, or a map for a single selected entry.

Are basic navigation tools available such as panning and zooming? Almost every map provided basic navigation tools to pan and zoom, with six exceptions.

Is there any capability to search features by attribute? Twenty-nine applications provided a range of search options. Some applications provided filtering by prescribed choices, for example a pull-down list of neighborhoods. Some allowed users a free text-based search. Others searched for nearby, highly rated, or most recent entries. Three of the applications generated search results in a list that could not be displayed using a map.

Is there layer control to toggle data display? Surprisingly only four applications, Field Trip, Privately Owned Public Open Space (POPOS) and Public Art, SF's Secret Spaces and Hidden Oases from SPUR, and STQRY allowed the user to turn layers on an off.

Can a user choose a different basemap display? Twenty –one or less than half provided the user the ability to change the basemap display. Some maps allow the user to bring up Google Street View.

Are points displayed as clusters or is point selection buffered to choose overlapping points? Eight of the applications either buffered point selection or clustered densely populated locations.

Can the user access navigation tools to find a route to a location? Seventeen of the applications allow the user to generate navigation instructions to a location.

3.2.4 Limitations of Applications Using the SFAC Public Art Dataset

San Francisco Public Art-SF Art, San Francisco Public Art Finder, San Francisco Civic Art Finder, and San Francisco Public Art are mobile applications that use only the full SFAC dataset. San Francisco Public Art-SF Art does not run. The other three applications have imported the dataset into a mobile framework with little correction or restructuring of the data. San Francisco Public Art has linked images to several sites and corrected the locations of some art works.

Public Art Finder no longer returns data, as of 29 November 2013. Privately Owned Public Open Space (POPOS) and Public Art, Culture Now, SF Arts.Org, have fewer than 20 SFAC locations. SF Mural Arts focuses on murals in San Francisco. The SFAC Public Art map is outdated, spatially inaccurate, and covers a subset of the organization's collection.

Both STQRY and Field Trip, include a subset of the SFAC art locations. STQRY initially published twenty-six art locations. Eight of the locations were off by several blocks to a mile. STQRY has corrected the initial entries and expanded the offering to sixty-five entries as of 29 November 13. Entries include images and descriptions.

Field Trip contains over 150 SFAC art works. Most have associated images, a detailed description and Google has improved or changed the accuracy of many of the points. The data is

not accessible outside of the mobile application, so only visual inspection of data is possible. While Field Trip appears to contain the most spatially accurate subset of SFAC data points for any application, several still appear to be incorrectly located. Field Trip contains datasets from multiple sources covering topics such as architecture, historic places, lifestyle, offers, food, art, and museums. While the application doesn't narrowly focus on a particular type of art, the interface is complicated and sluggish. The user has to scroll through many dataset options to narrow what is shown.

3.3 Value of the SFPAM

The SFPAM provides a comprehensive local art map that broadly defines public art. The combination of datasets and the model of three curation levels are unique to the SFPAM among art applications. No art application uses social media as a dynamic data source. The SFPAM expands the functionality of the PIM by adding Instagram and Panoramio as social media layers. By changing the search parameters for social media, a user can add hundreds of additional results to the art map. Social media can capture art that is not part of an institutional dataset because the art is new, not sponsored or tracked by an institution, or illegal. By querying social media, users can also view art that may have been removed.

Stamen Design produces three beautiful basemaps called Watercolor, Toner, and Terrain. The SFPAM consumes Stamen Design web map tiles and provides them as basemap choices to users. Stamen Design basemaps are unique to the SFPAM as an art map. The SFPAM was also the first application using the Esri JavaScript API to incorporate Stamen Design web map tiles as a basemap choice. Users have the flexibility to change the look of the map and the results through layer controls, social media configuration, and basemap choice.

Outside of AGOL maps, the SFPAM is the only application built on Esri technology, as the majority of applications use Google maps. SFPAM leverages AGOL to provide a mobile solution with ArcGIS for Mobile and Collector. Through AGOL and the mobile applications, users can submit or edit art and building locations without modifying backend data. The architectural design of the SFPAM enables incremental improvements to data quality without impacting the user.

Chapter 4: Methodology

This chapter describes the methodology for developing the SFPAM. Section 4.1 documents the technology and system architecture used by the application for web and mobile. Use cases are found in Section 4.2. Section 4.3 details the application development process. Section 4.4 shows the data model and geodatabase schema implementation. Section 0 lists data sources and services. Application evaluation methods and requirements are discussed in Section 4.6.

4.1 Technology and System Architecture

The SFPAM consists of three client products: a web application, a proof of concept iOS native mobile application, and an ArcGIS Online (AGOL) for organizations map. The AGOL map is accessible through web browser, Esri ArcGIS mobile client, and Esri Collector. The AGOL map allows an authorized user "create, read, update and delete" (CRUD) permission depending on Representational State Transfer (REST) service configuration. Art data can be updated in the field using a mobile device or at a desktop using the AGOL web interface.

4.1.1 Backend Services

The SFPAM uses ArcGIS Server 10.1 and 10.2 to provide REST services and mapping functionality. There are two environments providing REST services. The test REST services environment consists of a Windows Server 2008 R2 SP1 virtual server, nmilholl.usc.edu. The server is hosted at the University of Southern California (USC). Services are created from ArcMap 10.1 Map Exchange Document (MXD) files using shapefiles and file geodatabase feature classes. Services are shared through the http://nmilholl.usc.edu:6080/ArcGIS/rest/services/ endpoint. These services are read-only. The test environment provides a quick way to share datasets as services to the SFPAM without requiring the data to conform to a data model. Currently the SFPAM web application consumes these read-only services.

The production environment consists of a Windows Server 2008 R2 SP1 virtual server. The database backend uses Microsoft SQL Server 2008 R2 with ArcSDE. Services are created from ArcMap 10.2 MXD files and a database connection to sfpubart. Services are shared using the http://maps2.ccsf.edu/arcgis/rest/services/SFPUBART endpoint. The production environment will provide services following the completion of this thesis so that the SFPAM remains publicly accessible.

4.1.1.1 Users and Permissions Configuration in the Production Environment

A Microsoft SQL Server 2008 geodatabase, sfpubart, was created on the production server database instance using ArcMap 10.2. The database currently is not versioned. In addition to the database owner, a database user gisManager was created with CRUD permissions. User gisManager was mapped to a user in the GIS Server Manager Identity Store and given Administrator permissions.

4.1.2 Web Application Architecture

Figure 1 shows the high-level architecture diagram for the web-based application. Three domain names were purchased to be the entry point for the web application front end: sfpublicart.com, sfpublicart.org, and sfpublicart.net. The domains are hosted in the cloud and resolve to the same location provided by the web hosting service. The webhosting x86_64 virtual server runs Linux kernel 2.6.32. The web application uses hypertext markup language (HTML), cascading style sheets (CSS), JavaScript, ArcGIS API for JavaScript 2.7, and the Dojo toolkit.

A client web browser accesses the application through www.sfpublicart.com, www.sfpublicart.org, or www.sfpublicart.net. The application has JavaScript configuration files that specify which mapping, feature, basemap, and social API services to load and display. Loading of data is asynchronous, so the user is able to view information on the map display while requests are

completing. The configuration files provide instructions to the application as to what data is initially loaded in the web browser and how the data should appear. Once the application has loaded, the user can interact with the application using the web browser. The user can change the layers displayed, the social media search terms, and the background basemap.

SF Public Art Map Web Architecture

maps2.ccsf.edu (Production)
Map and Feature REST Services, ArcGIS Server 10.2, ArcSDE, SQL Server

nmilholl.usc.edu (Test)
Map and Feature Services (REST, ArcGIS Server 10.1)

User client requests

Social Media Streams

sfpublicart.com
html, JavaScript Web Server

stamen.com
Stamen Design Map Tiles server

Open Streetmap Basemap

ESRI JavaScript libraries/API/
Basemap Services (different ESRI servers)

Figure 1 System architecture for web application

Maps2.ccsf.edu provides production map and feature REST services using a SQL Server backend database to store data. REST services for the web client are read-only, as feature editing is not currently supported by the SFPAM web application. Nmilholl.usc.edu provides REST services for testing data, services, and the application. This server allowed the SFPAM to go live while the backend production environment was under development. Stamen Design, Open Streetmap, and Esri provide basemap services. In addition Esri servers are accessed for JavaScript libraries. Social media APIs provide JavaScript Object Notation (JSON) data consumed by the application.

4.1.3 Mobile Application Architecture

The native mobile application for Apple iOS development environment uses Xcode 4.6 integrated development environment (IDE) and Esri's ArcGIS Runtime SDK for iOS, Version 10.1.1.The architecture for the native mobile application is shown in Figure 2. The architecture reflects a simpler scope of functionality, the pilot status of the application, and several technical challenges. Esri's SDK for runtime does not currently support map tile services for base maps from Stamen Design. Social media JSON services are not included due to both programming complexity and the time required to load data from services on a mobile device.

SF Public Art Mobile Application Architecture

maps2.ccsf.edu
Map and Feature REST Services,
ArcGIS Server 10.2,
ArcSDE, SQL Server

iOS 6.x
Native Application

ESRI Basemap and
ArcGIS Services

Open Streetmap
Basemap Service
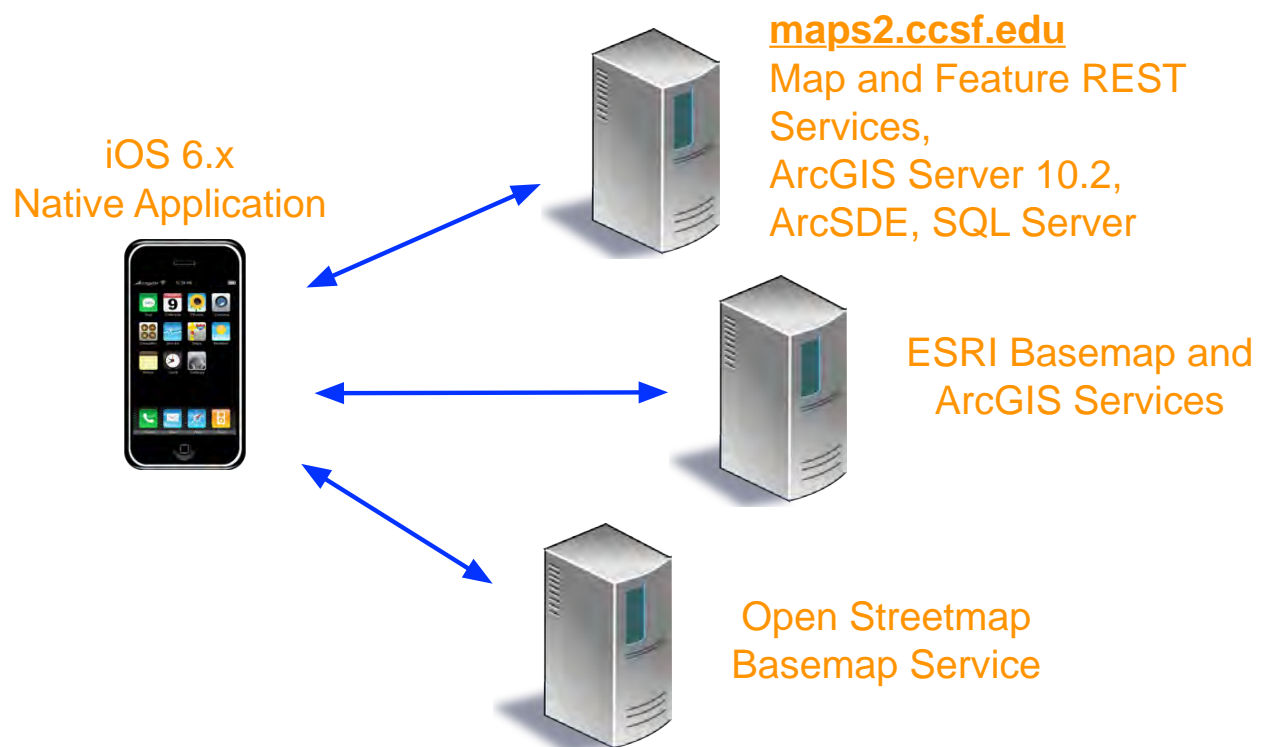
Figure 2 - Mobile application architecture

4.1.4 ArcGIS Online (AGOL) Architecture

Incorporating AGOL with the existing SFPAM architecture provides flexible and quickly configurable options for sharing data on multiple devices for editing. Maps created in AGOL for

Organizations can be shared as a web map and also as a feature service. By combining CRUD REST services using a backend database with an AGOL map configured for CRUD or create, read, update (CRU), editing of art POIs can be performed using different devices and interfaces. Esri ArcGIS for Mobile or Esri Collector for Mobile can be used to collect and update data in the field. The AGOL map can also be consumed by native mobile applications using the ArcGIS Runtime SDK. Desktop clients can access the map through a web browser or ARCGIS for Desktop. An AGOL web map can be shared as a feature service to hide the backend REST service from users. Empty feature services can be created, associated with a map template and used to allow contributions from users without changing data stored in the database. These contributions can be reviewed and incorporated into the feature set by an administrator.

Figure 3 shows the architecture for incorporating AGOL with the SFPAM environment. AGOL maps were created to consume maps2.ccsf.edu REST services. The maps were configured to enable editing via web and mobile clients using Esri native applications for iPhone to collect data, store photographs, and update existing data for art and building POIs.

SF Public Art ArcGIS Online (AGOL) Architecture

Mobile
1. ESRI ArcGIS mobile client (iPhone, iPad, Android)
2. ESRI Collector mobile client(iPhone, iPad, Android)
3. Other mobile native application that consumes AGOL map service

maps2.ccsf.edu (Production)
Map and Feature REST Services, ArcGIS Server 10.2, ArcSDE, SQL Server

ArcGIS Online Map and Service

Other external services

Desktop
1. Web client requests
2. ArcGIS for Desktop

Figure 3 ArcGIS Online (AGOL) architecture

4.2 Use Cases

This section describes the actors, actor permissions, the high-level use cases, and which use cases apply to which component of the SFPAM.

4.2.1 Actors

There are four actors in the SFPAM system: the Administrator, User, Power User, and Social Media stream. A description of the actors and their CRUD permissions for art and building POIs is shown in Table 5.

Table 5 Actors for SFPAM

Actor Name	Description	CRUD for POIs
Administrator	Application and data administrator with power to perform all tasks, upload data into system, configure web application, and configure AGOL. Has CRUD permission for data points. Reviews AGOL submitted data for inclusion in dataset. Has access to backend server and maps through ArcMap or AGOL.	CRUD
Power User	Same capabilities as the general user plus the ability to edit or add POIs to AGOL feature services through AGOL and Esri mobile applications	R for backend services, CRU for AGOL feature services

Actor Name	Description	CRUD for POIs
User	The general user who can navigate the SFPAM, change extent, display additional information, change visible layers or basemap, and change the search configuration for the social media streams.	R
Social Media	Provides on demand POIs that match search criteria in JSON format. Authenticates query using application key.	

4.2.2 High Level Use Cases

The high level use cases for the actors are shown in Figure 4. Users interact with the

application through navigation controls such as panning and zooming; locating an art POI on the

map; viewing detailed information about an art piece; sharing a map; and requesting navigation to an

art piece. Users control the display of information through configuring which layers are visible;

selecting a basemap for display; configuring which social media streams are visible; and adjusting a

social media stream's query volume or search term.

A Power User logs into AGOL, Collector, or ArcGIS mobile using an account created in

AGOL. The account has access to a map containing SFPAM REST services with read (R)

permission and AGOL feature services with CRU permission. The Power User can add new POIs

or update existing POIs in the AGOL feature service layers.

An Administrator adjusts filters on social media streams to include or exclude art related

posts. The Administrator also approves user-submitted art locations following review for accuracy

and content and adds them to the backend geodatabase. Social media authenticates the application

using an application key code, if required. Social media also posts JSON pages to the SFPAM

application based on the submitted search request.

SFPAM High Level Use Cases
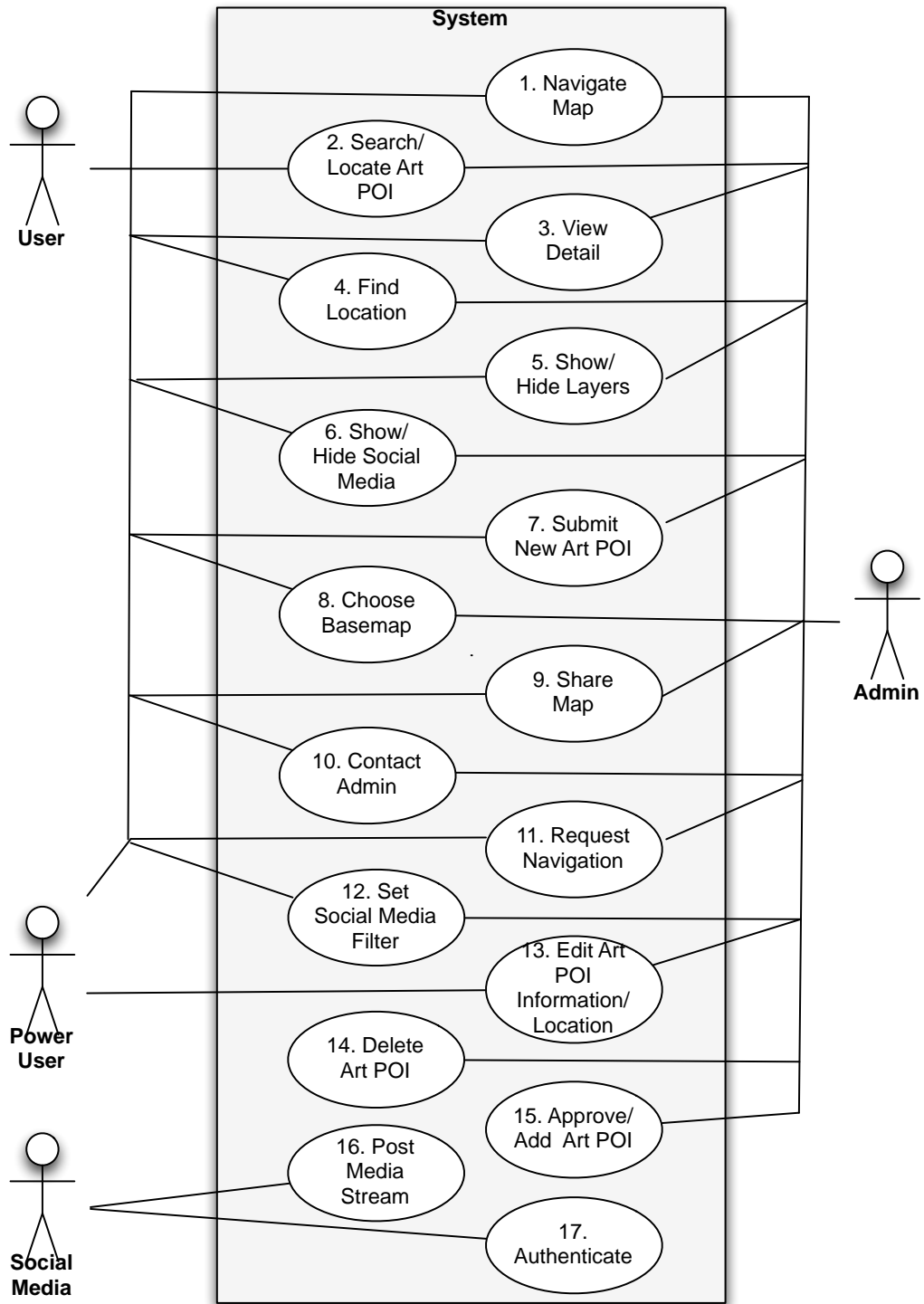
Figure 4 High-level use cases

Table 6 lists the use cases and the applicable actors. The table also shows which use case is implemented for each component of the SFPAM. Stretch use cases are also indicated. These are requirements that are desirable but may not be implemented in the current iteration of the SFPAM.

Table 6 Use Cases by Actor and SFPAM Component

Use Case Name and Number	Actors				SFPAM Component		
	User	Power User	Administrator via ArcMap, Source Code, AGOL, Collector, or ArcGIS Mobile	Social Media	Web	Mobile	AGOL, Collector, ArcGIS Mobile
1. Navigate Map	X	X	X		X	X	X
2. Search/Locate Art POI	X	X	X		X	X	X
3. View Detail	X	X	X		X	X	X
4. Find Location	X	X	X		X	X	X
5. Show/Hide Layers	X	X	X		X	X	X
6. Show/Hide Social Media Layer	X	X	X		X		
7. Submit New Art POI		X	X		S	S	X
8. Choose Basemap	X	X	X		X	X	X
9. Share Map	X		X		X		AGOL, ArcGIS for Mobile
10. Contact Administrator	X	X			X	S	X
11. Request Navigation	X	X	X			S	AGOL, Collector
12. Set Social Media Filter	X		X		X		
13. Edit Art POI Information/ Location		X	X				X
14. Delete Art POI			X				X
15. Approve/Add Art POI			X				X
16. Post Media Stream				X	X		
17. Authenticate Social Media				X	X		

The use cases drive the functional requirements for the SFPAM. Requirements are described in Section 4.6.1.

4.3 Development Process

The development process for the web, mobile, and AGOL components of the SFPAM are discussed in the sections following.

4.3.1 Web Application Development

Web application development, data preparation, and requirements development was done on a Macintosh running OS 10.8.4. Parallels 7.1 provided a Windows 7 environment for Windows-

only applications. Aptana Studio 3, QSEE, Dreamweaver, MS Office, ArcDesigner, Firebug, Firefox, Safari, and ArcMap client 10.1 and 10.2 were the primary development tools.

A Subversion source code repository in Subversion was created and linked to Aptana Studio 3. Major feature changes were checked into the repository following successful testing and deployment.

Three domains, sfpublicart.com, sfpublicart.org, and sfpublicart.net were purchased and associated with an existing hosted virtual server account, nmilholland.com. All resolve to an identical document directory under nmilholland.com. The SFPAM code base was uploaded to the document directory. Each URL was tested from a client to verify the web application was accessible and running.

Web application code changes were tested on the local client and debugged. Changes were then uploaded to the sfpublicart.com server. Affected server files were backed up, new files deployed, and functionality tested using a client to access the webserver. If significant functionality was being introduced, the production environment was cloned to a new directory, for example, sfpublicart.com/deployment/test. Deployment and testing was performed on the cloned directory prior to pushing changes to sfpublicart.com. Any minor file edits performed on the server were copied back to the client development environment for check-in.

An iterative spiral method of testing and development was employed throughout the development process. When new features were implemented, the application was tested to verify the application loaded, existing functionality did not break, and the feature functioned as expected. The firebug plug-in on Firefox was used to monitor errors and provide feedback on how to fix issues.

4.3.2 Data Service Development Process

Data came from from multiple sources. Specific details regarding data sources are found in Section 0. Data source formats included shapefile, comma separated variable (CSV), Keyhole Markup Language (KML), Keyhole Markup Language Zipped (KMZ), JSON, and text scraped from JavaScript or HTML files. One shapefile required projection to World Geodetic System 1984 (WGS84) Web Mercator Auxiliary Sphere. All other data sources required editing, formatting, or processing in order to create a feature set. Some KML/KMZ files needed to be accessed at their URL using Google Earth before they could be saved on the local client. One site limited KML/KMZ downloads to 20 POIs per page, necessitating development of a Model Builder script to process over 15 files. The Model Builder script is shown in Appendix B. Data was cleaned and transformed in Excel and ArcMap.

Some external images referenced in HTML popup fields could be loaded if the HTML was accessed from a client system. Once the HTML was loaded onto the sfpublicart.com web server, the client could no longer load the image due to the image host's disabling of hot linking. As a workaround, the thumbnail images were loaded into a client browser, scraped from the browser cache, and uploaded onto the sfpublicart.com website. Popup fields containing the harvested images were configured so that clicking on the image directs the user to the original image site.

Data layers were brought into geodatabase feature sets. Services created on nmilholl.usc.edu used file geodatabases and services created on maps2.ccsf.edu used data stored in the SQL Server sfpubart geodatabase. Once data was cleaned, an ArcMap MXD file was prepared for publishing as a REST service. The process for publishing production services from maps2.ccsf.edu was more complex due to additional security configuration required with database connections, database users,

local Windows security, and the Server Manager Identity store. The SFPAM web, AGOL, or mobile application was then configured to use the published service.

4.3.3 Infrastructure

The test virtual server nmilholl.usc.edu required minor port, firewall, and directory permission configuration changes to enable ArcGIS Server to publish services outside the firewall. The production server required installation of licenses for 10.1 Esri product suite, ArcGIS server 10.1, ArcGIS Web Adaptor, and Microsoft Software updates. A geodatabase was created in the existing SQL Server instance using ArcMap 10.1. The geodatabase was configured based on an interpretation of the data model described in Section 4.4.1. The resulting geodatabase schema is described in Section 4.4.2. Existing database users were given permissions in the database comparable to permissions in existing databases. The web adaptor was configured to allow access to Esri services to resolve to maps2.ccsf.edu instead of maps2.ccsf.edu:6080. New database connections by database user were created from ArcMap to the geodatabase. Database connections to MXD files were defined. A server connection from ArcMap to maps2.ccsf.edu was created and the geodatabase registered with ArcServer.

Data was exported from the test environment to the production environment. Fields were mapped to the data model, data imported into the geodatabase, and feature classes added to MXD files. New services were created and published for use with AGOL, mobile clients, and the web application.

Configuration of the production environment was challenging. IT changes, Microsoft updates, power outages, network port configuration changes, license expiration, and incorrect DNS server configuration were all system changes outside the control of the thesis project. The ArcGIS server files were corrupted during the power outage. This contributed to long periods where the

REST services were unavailable or the ArcGIS Server service was unable to start. In August of 2013, the ArcGIS environment was upgraded to 10.2, requiring additional configuration changes.

4.3.4 Web Feature Development

The Esri PIM is a complex multi-file code base with multiple configuration options for including REST services, configuring the display of REST services, defining REST service legends, including basemaps, and including social media streams. Untangling the code to determine how to change existing features or integrate new features proved challenging.

High-level use cases and nonfunctional requirements were defined to prioritize web development. One nonfunctional requirement was to rebrand the PIM as an art map. shows the visual difference between the PIM disaster map tracking earthquakes in Japan and the SFPAM, pictured using the Stamen Design Toner basemap. References to natural disasters, icons, Public Information Map, and REST services were removed from the code. Text and headings were rewritten to refer to the San Francisco Public Art Map.
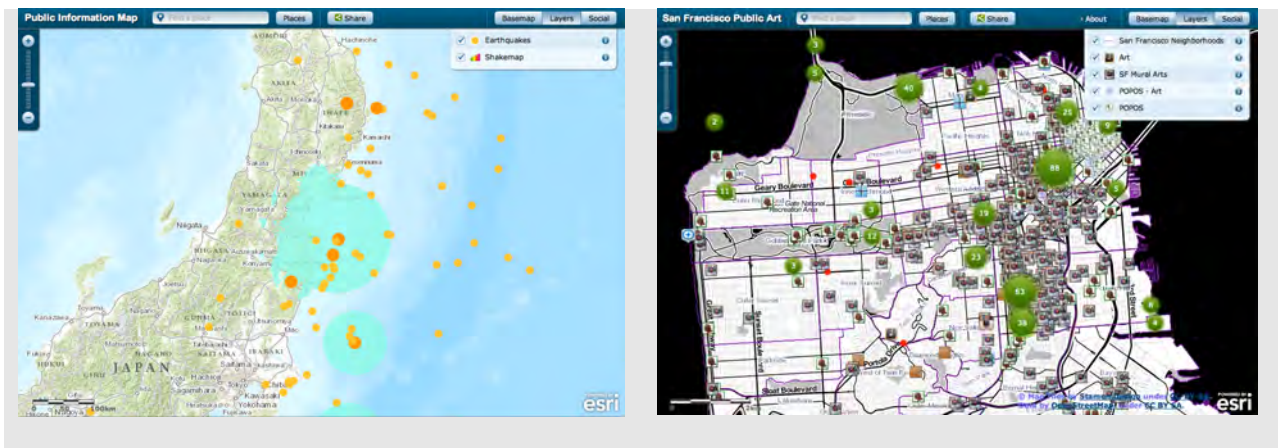
Figure 5 PIM disaster map and SFPAM

Code was developed to incorporate Stamen Design's Terrain, Toner, and Water Color basemaps as user configurable options. The visual textures of the Stamen basemaps provide a more appropriate look as backgrounds to a map highlighting art. The Stamen maps are web tile maps, a

case not handled by the existing code. A nonfunctional requirement for the SFPAM was that new features have functionality identical to similar features and code modifications maintain existing functionality. Adding tile maps required code modifications for the main display, basemap configuration, and the "Share" option. The "Share" option allows a user to share a URL containing the current map configuration or to embed HTML with the map configuration.

Bing basemaps were removed as options given a change in licensing. The Esri Gray basemap was added. Table 7 shows the files and integration required to configure basemaps and add web tile map capability. Appendix D contains code snippets illustrating code changes required to include Stamen Design basemaps.

Table 7 Basemap Integration

File Name	Basemap Integration: Description of Related Functionality
about.html	Contains text describing SFPAM application
basemaps.js	Configures which basemaps to include, their unique id, title, thumbnail image for legend, copyright text, whether basemap is from OpenStreetMap or Stamen Design, and service URL.
application.js	Contains text for social media sharing
embed.html	Calls embed.js, describes map contents
embed.js	Creates user interface for generating code to embed shareable map.
index.html	Contains text describing application
mapBasemaps.js	Gets list of basemaps, determines if initial basemap set by URL or from configuration, interprets type of basemap and creates appropriate layer type such as OpenStreetMapLayer, WebTileLayer, or ArcGisTiledMapServiceLayer. Also defines a WebTileLayer class that inherits from the Esri TiledMapServiceLayer.

As REST services became available, the JavaScript layers.js file was updated to incorporate the service, describe the layer, and define the legend. Multiple options for graphics rendering of feature services are available: simple, class breaks, and unique value. Appendix E provides an example of a REST service configured to use unique value rendering based on an attribute field. Map REST services do not require configuration as they inherit symbology from their service. Social media streams and APIs were assessed for inclusion. The PIM code included Flickr, Twitter, and YouTube. SmugMug and Picasa were investigated and rejected as sources. SmugMug contained

beautiful pictures of public art in San Francisco, but also many wedding photographs tagged as art. Picasa contained surprisingly few geotagged photos of art in San Francisco. Panoramio and Instagram social media feeds were added to the application using search tags of "art" and "sfart" respectively.

A new social media stream must be integrated into existing application functionality, even if those capabilities are not used in the SFPAM. Table 8 describes the files that must be edited or created to incorporate a new social media stream.

Table 8 Integrating a New Social Media API into the SFPAM

File Name	Social Media Integration: Description of Related Functionality
about.html	Contains text describing SFPAM application
embed.js	Creates user interface for generating code to embed shareable map.
index.html	Includes social media file such as instagram.js.
instagram.js, panoramio.js	Contains constructor and methods for adding the Instagram/Panoramio social media stream to SFPAM.
main.js	Global variables for layer names and parameters for sharing map.
social.js	Configures whether the social media stream is included at application launch. Defines title, description, legend graphics, initial search terms and values.
socialLayers.js	Updates which layers are on or off based on whether checkbox is checked; calls social media method to query API; manages layers; determines if social media should be displayed as cluster or heat map; updates social media layer; sets slider values for configuration popup; interprets social parameter settings if application has been shared and parameters for range, dates, and key words are in URL; and constructs the information/user configuration popup window for each social media stream.
tasks.js	Interprets current map settings and create a URL or HTML with parameters describing the settings in order to share the map. Interprets values from URL and change map configuration to match.
userinterface.js	Listens for user changes to configuration settings such as search term, date, or volume of information to return and request update of social media points.

Each new social media stream required a new JavaScript file to construct the social media object and its methods. APIs differ as to input parameters, output fields, use of extent as a parameter, and application key. Date and extent were not used to define the Instagram search due to the API definition. In contrast, Flickr uses start date, end date, and extent to frame a query to the API.

Instagram.js and panoramio.js were created to define options for constructing the json query such as the maximum number of json pages to return, extent, key word for search, and the API application key. The ArcGIS feature collection, geometry, fields, and popup window were also defined. Behavior for user browser interactions such as "onClick" was specified. Methods were coded to add layers, turn layers on and off, construct queries to the social media API, parse results, determine which results contain XY coordinates, correct results, define popup window content, and push results to a feature layer collection. The feature layer collection is added to an array for processing and display as a cluster or a heat map based on initial application configuration or runtime user choice.

4.3.5 Mobile Development

An Apple iOS Developer Program one-year license was acquired. With the license, provisioning profiles can be obtained to deploy applications to a developer's iOS devices for testing. The license also means a new application can be submitted to the App Store for distribution after approval by Apple. Xcode 4.6 IDE and Esri's ArcGIS Runtime SDK for iOS, Version 10.1.1 were downloaded to an Apple MacBook Pro Intel laptop running OSX 10.8.4. An iPhone 4s running 6.1.3 was used for testing applications in addition to the 6.1 simulators for iPhone and iPad. A first generation iPad and an iPad mini were also available for testing.

Mobile iOS client development was chosen because of the availability of devices for testing and the author's interest in the technology. While the Android platform dominates the mobile market globally and in the United States (phys.org 2013), the perception in San Francisco is that iPhones dominate the San Francisco Bay Area market, (Rosoff 2013). The primary users of the SFPAM should be in the San Francisco Bay Area.

Project iOS samples from Esri were downloaded and combined to consume REST services

and test implementation of functionality such as choosing a basemap, basic navigation controls, and

popup windows.

4.3.6 AGOL Development

AGOL extends the SFPAM by providing a way to collect art data and pictures using either

web or mobile devices. Table 9 describes the steps taken to create three AGOL maps for

consumption by web clients and mobile devices. An AGOL for organizations account with

Administrator or Publisher privileges is required to create the maps described in Table 9.

Table 9 AGOL Configuration Steps

AGOL Product	Administrator Steps	ArcSDE REST Service	SFPAM Client Role	AGOL Account Type
CRU(D) Web Map or Application	Create Map Add REST services Configure symbology, popups, and layers Create two empty feature service based on existing art and building REST feature services. Configure new feature services so that users can edit or delete only features they create. Share publicly as map or application	Read-only REST services	Power User	Any AGOL user. Map can also be shared outside of AGOL.
CRU(D) Map for Mobile	Copy CRU(D) Web map. Configure popups to display images using fields with links instead of HTML. Share publicly as map	Read-only REST services	Power User	Any AGOL user. Must have an account to use ArcGIS mobile client. Other applications can use ArcGIS map id to use map service.
CRU(D) Web Map or Application	Create Map Add REST services Configure symbology, popups, and layers Keep map as private to Administrator.	CRUD Rest Services (with password access if Delete enabled)	Admin	AGOL for Organization Publisher or Administrator

The first map was created using read-only REST services from the CCSF server with two

empty feature services: one feature service is based on the feature layer containing art, and the

second is based on the feature service containing buildings. This map also contains the art and building feature layers.

Access to edit the map is restricted to users with an ArcGIS account. These Power Users can add new art and buildings to the empty feature layers. The map is configured so that a user can only edit features the user created in the AGOL feature service. This allows a group of Power Users to add and edit new features for review by an administrator. The administrator can then import the features into the production geodatabase. The Power Users cannot edit or add features to the production geodatabase.

The group of Power Users can be restricted in the future to ArcGIS for Organization accounts that have been added to a group with CRUD permissions to the ArcGIS feature layers. Unfortunately, free ArcGIS accounts can't be added to ArcGIS for Organizations groups.

A second map was created for mobile use, identical to the first except that different fields were used to present image and image target links. Mobile applications do not interpret HTML text for rendering. All ArcGIS user accounts can consume the map using ArcGIS for mobile. Only ArcGIS for Organization accounts can use the Collector application. The AGOL map can also be consumed by native client applications for Android or iOS.

The third map consumes CRU REST services from the CCSF server. If the services have delete capability, they must be password protected. This map is only shared with the map publisher account. The SFPAM administrator can use this map to edit art and building features using a client other than ArcMap. Esri's ArcGIS for mobile or Collector for mobile can be used in the field to update a feature's location, add a picture, or update attributes, as well as add new features directly to the production database.

Each of the AGOL maps can be accessed using a web browser, Esri ArcGIS for mobile, Collector, or ArcMap.

4.4 Data Model and Geodatabase Schema

This section describes the data model and implementation as a geodatabase schema.

4.4.1 Data Model

The normalized conceptual data model for the SFPAM is shown in Figure 6. Attributes are documented in greater detail in Section 4.4.2 describing the geodatabase schema.

PUBLICART contains features and attributes describing art POIs. An entry may contain 1 to many entries in the ARTDATASOURCE table. The ARTDATASOURCE table contains metadata from the art POI's source of origin such as an organization's unique id for the piece. An agency may have multiple entries for a single art POI interest in the PUBLICART table, as there may be multiple panels, pieces, or simply duplicates. From a user's perspective, one entry is sufficient. From an SFPAM administrative perspective duplicate entries need to be tracked in case of future updates from an agency, as it is unknown which entry will be updated.

ARTTYPE describes art categories such as sculpture or mural. NEIGHBOHOOD provides names of city neighborhoods. ORGANIZATION specifies names of organizations providing data or responsible for managing art or buildings. PHOTO contains images of POIs. Since there can potentially be a many to many relationship between photos and art or building POIs, PUBLICARTPHOTO and BUILDINGPHOTO are used to normalize the joins.

ARTIST provides names and other descriptive information such as website for the primary creator of a POIs. ARTISTTYPE describes whether the person is an artist or architect. BUILDING contains architectural POIs such as historic landmarks, Privately Owned Public Open Space,

significant buildings, or other architectural features. OCCUPANCYTYPE describes building usage, such as commercial, while BUILDINGSTYLE categorizes a POI in terms of architectural history. SOCIALMEDIA contains references to images and attributes for social media postings describing art POIs. STATUS refers to the state that best describes social media entries and POIs, such as active or removed.

The data model design was influenced by a review of art datasets, assessment of common social media attributes, and in consultation with a professor who teaches a survey course in Bay Area architecture.
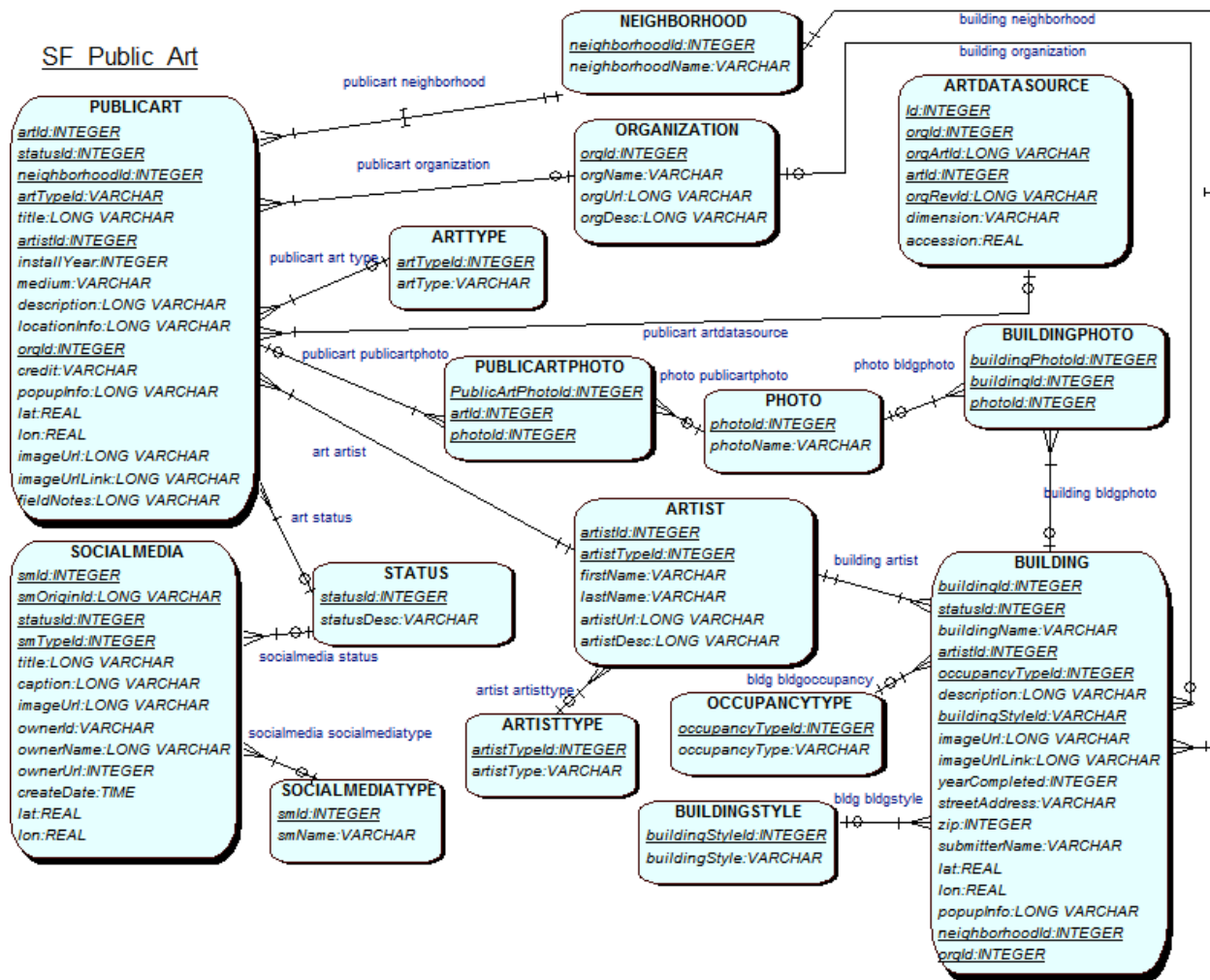
Figure 6 SFPAM conceptual data model

4.4.2 Geodatabase Schema

The conceptual data model was translated into an ArcMap geodatabase schema and instantiated in the sfpubart SQL Server database. Figure 7 shows the ArcDiagrammer visualization of the schema. PUBLICART became the SFPubArt84M point feature class. Buildings and ArtSource (ARTDATASOURCE) are also point feature classes. Neighborhoods became a polygon feature class and a domain. PHOTOS became two attachment tables, one related to Buildings and one related to SFPubArt84M. SOCIALMEDIA was dropped as a table as social media features are generated on demand at run time. Some companies also have legal restrictions on storing social media information in databases.
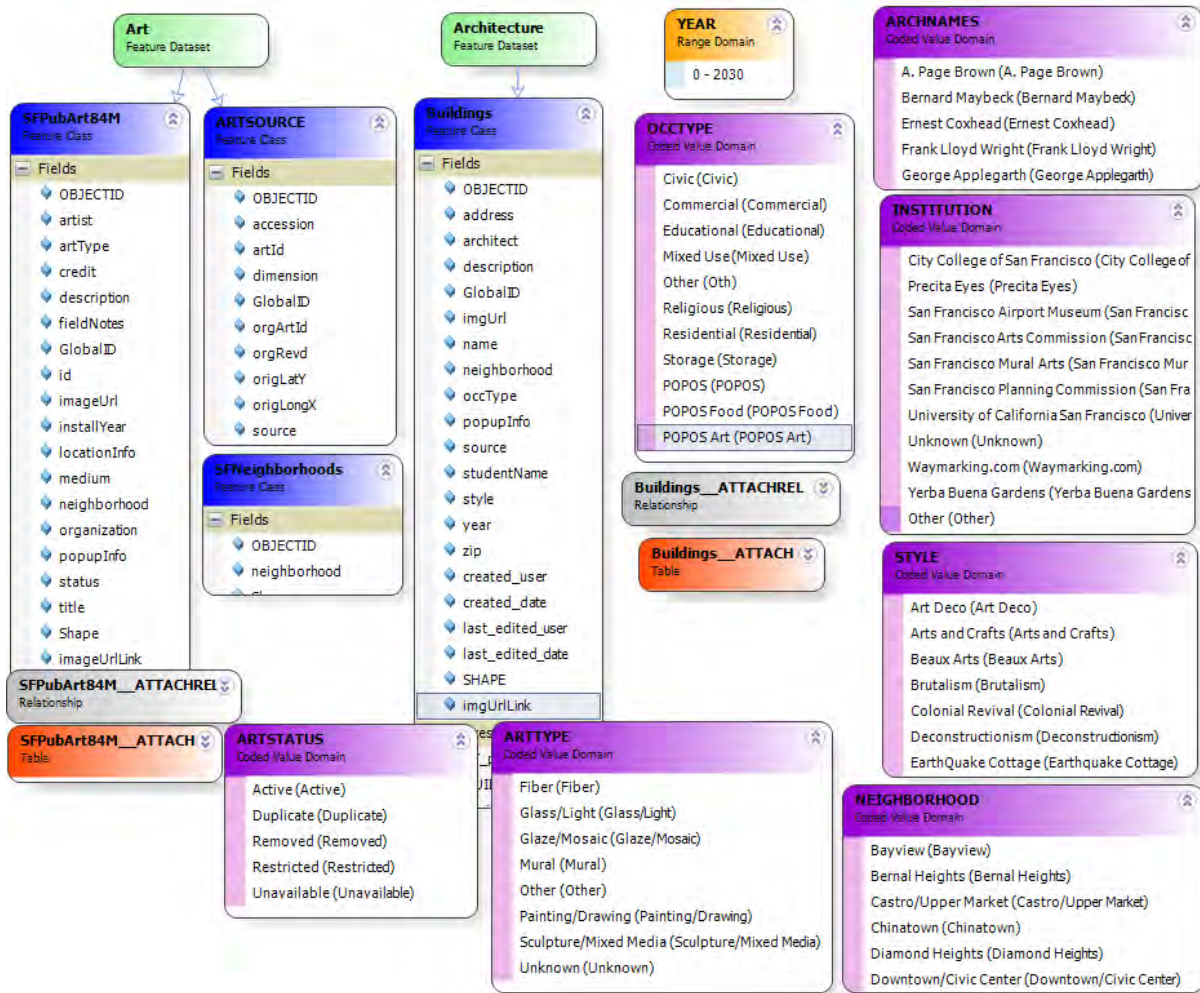
Figure 7 ArcDiagrammer Geodatabase Schema

The schema was simplified, as related tables can't be used in current versions of Collector and ArcGIS for Mobile. Remaining tables became domains, with the exception of ARTIST. Artist and architect names are not normalized due to the complexity of handling related tables. Since there are a large number of names, and the data is under review and revision, using a domain was not an option. As the data quality and mobile applications mature, the schema choice for artist names will be revisited.

Sections 4.4.2.1 to 0 describe the geodatabase feature classes, attributes, and domains in greater detail.

4.4.2.1 Public Art (SFPubArt84M) Table and Fields

The SFPAM displays art POIs stored in the SFPubArt84M table using REST services. The

attributes are described in Table 10.

Table 10 SFPUBART84M (Public Art) Feature Class Fields

Field Name	Description	Alias	Type
OBJECTID	System generated unique id	OBJECTID	Esri OID
artist	Name of artist in Last Name, First Name format.	Artist	String
artType	Simplified category of type of art	Art Type	ARTTYPE Coded Value Domain
credit	Credit for acquisition of POI	Credit	String
description	Description of art	Description	String
fieldNotes	Additional information or comments from user submitting or updating data.	Field Notes	String
id	Temporary field with original organization ID for art point. Field will be deleted after all duplicates identified and removed. Original information stored in ARTSOURCE feature class.	id org gen	String
imageUrl	URL to picture of art	Image URL String	String
imageUrlLink	Target URL for browser when image clicked.	imageUrlLink	String
installYear	Year art piece installed. Originally converted from ARTSOURCE.accession if provided.	Install Year	Integer
locationInfo	General location information about art piece.	Location Information	String
medium	Detailed information about art materials.	Medium	String
neighborhood	Neighborhood of art point	Neighborhood	NEIGHBORHOOD Coded Value Domain
organization	Organization that administers the art piece or provided the dataset.	Organization	INSTITUTION Coded Value Domain
popupInfo	HTML formatted information about art piece provided by an organization that may take the place of structured fields. Multiple images can be referenced.	Popup Info	String
GlobalID	System generated unique ID	GlobalID	GlobalID
status	Status of art piece. Active is default.	Status	STATUS Coded Value Domain

4.4.2.2 ARTSOURCE Table and Fields

The point feature class ARTSOURCE (Table 11) retains original information from datasets

such as an organization's ID for a POI, the revision ID, and the original XY coordinates. Entries

may have a many to one relationship with SFPubArt84M as duplicates are identified and removed

from the SFPubArt84M table. This table is not shared as a REST service.

Table 11 ARTSOURCE

Field Name	Description	Alias	Type
OBJECTID	System generated unique id	OBJECTID	Esri OID
accession	Real number representing year of acquisition.	Accession Date as Real	Double
artId	artId matches OBJECTID of related entry in SFPUBART84M. Many to 1 relationship given duplicate entries.	Art Id SFPAM	String
dimension	Text describing art piece dimensions.	Art Dimension	String
GlobalID	System generated unique ID	GlobalID	GlobalID
orgArtId	Art Id from source	Org Art Id	String
orgRevId	Revision ID from source	Org Revision Id	String
origLatY	Original latitude/Y coordinate	Original Latitude Y	String
origLongX	Original longitude/X coordinate	Original Longitude X	String
source	URL or other information describing original source for data	Source of Data	String

4.4.2.3 SFNeighborhoods Table and Fields

SFNeighborhoods (Table 12) is a polygon feature class that displays San Francisco

neighborhood boundaries and labels. The feature class is shared as a REST service. The feature class

was used to locate neighborhoods of POIs and fill in the SFPubArt84M .neighborhood attribute

field during initial data cleanup. The feature class was also used to provide most of the

NEIGHBORHOOD coded domain values. Neighborhoods outside of San Francisco are not

included.

Table 12 SFNeighborhoods

Field Name	Description	Alias	Type
OBJECTID	System generated unique id	OBJECTID	Esri OID
neighborhood	Name of San Francisco neighborhood	SF Neighborhood	String

4.4.2.4 Buildings Table and Fields

The Buildings table is a point feature class containing building, POPOS, and architectural

features of interest. Attributes are described in Table 13.

Table 13 Buildings

Field Name	Description	Alias	Type
OBJECTID	System generated unique id	OBJECTID	Esri OID
architect	Architect name. Default is "Unknown"	Architect Name	Coded Value

Field Name	Description	Alias	Type
address	Address of building or architectural feature	Street Address	String
description	Description of building or feature	Description	String
GlobalID	System generated unique ID	GlobalID	GlobalID
imageUrl	URL to picture building or feature	Url to picture of building	String
imgUrlLink	Target URL for browser when image clicked.	imgUrlLink	String
name	Name of building or feature	Building Name	String
neighborhood	Neighborhood of art point	Neighborhood	NEIGHBORHOOD Coded Value Domain
occType	Occupancy designation or type of Privately Owned Public Open Space. Default is "Res"	Occupancy Type	OCCTYPE Coded Value Domain
popupInfo	HTML formatted information about building or feature provided by an organization that may take the place of structured fields. Multiple images can be referenced.	Popup Info	String
source	Organization that provided the information.	source	INSTITUTION Coded Value Domain
studentName	Optional name of student submitting building or feature	Student Submitter Name	String
style	Style of building or feature. Default is "Other"	Building Style	String
year	Year building or feature completed. 0 for default or unknown	Year Completed	YEAR Range Value Domain
zip	Zip code where building or feature is located	Zip	String

4.4.2.5 Domain Values

The domain values are described in Table 14. The descriptive value and code are provided.

In several cases the full list of domain values is found in Appendix.

Table 14 Domains used in Geodatabase Schema

Domain Name	Description	Value and Code	Domain Type
ARCHNAMES	Names of prominent San Francisco Bay Area architects.	See F.1 for list of names.	Coded Value Domain
ARTSTATUS	Status of art POI	Active Duplicate Removed Restricted Unavailable	Coded Value Domain
ARTTYPE	Simplified art type or medium	Fiber Glass/Light Glaze/Mosaic Mural	Coded Value Domain

Domain Name	Description	Value and Code	Domain Type
		Painting/Drawing Sculpture/Mixed Media Other Unknown	
INSTITUTION	Institution managing art or providing information	City College of San Francisco Precita Eyes San Francisco Airport Museum San Francisco Arts Commission San Francisco Mural Arts San Francisco Planning Commission University of California San Francisco San Francisco Airport Museum Unknown Waymarking.com Yerba Buena Gardens Other	Coded Value Domain
NEIGHBORHOOD	Neighborhood name	See F.2 for list of neighborhoods	
OCCTYPE	Occupancy designation or type of Privately Owned Public Open Space	Civic (Civic) Commercial (Commercial) Educational (Educational) Mixed Use (Mixed Use) Other (Other) POPOS (POPOS) POPOS Art (POPOS Art) POPOS Food (POPOS Food) Religious (Religious) Storage (Storage)	Coded Value Domain
STYLE	Building/feature	See F.3 for list of building styles	Coded Value Domain
YEAR	Year building or feature completed or art acquired.	Value from 0-2030	Range Domain

4.5 Data and Services

This section describes the data sources, REST services, and basemaps that comprise the

SFPAM.

4.5.1 Institutional and Administratively Curated Data Sources

Multiple sites provided data for the SFPAM. Table 15 describes the organization, level of curation, data, and the number of POIs for the different data sources. A detailed discussion of data quality can be found in Chapter 6. The Appendix contains additional information. Appendix G.1 lists the URLs for each organization. Appendix G.2 provides a brief dataset description and URL to the dataset.

Table 15 Organization, Level of Curation, Description of Art Data, and POIs

Organization	Level of Curation	Description of Art Data	# POIs
Art and Architecture-SF	Administrative	Art and architectural features researched by the author. Site used for reference only	1960 image markers for 622 locations
City College of San Francisco (CCSF)	Institutional	CCSF Ocean Campus art	27
data.sfgov.org	Institutional	City of San Francisco open data portal containing neighborhood boundaries	N/A
Living New Deal	Administrative	New Deal art locations and projects used for reference only	~100, not all relevant to art or buildings
Precita Eyes	Institutional	Hard copy mural map and description of murals in the Mission neighborhood sponsored by Precita Eyes, a community based mural center. Used for reference.	~120
San Francisco Airport Museum (SFOM)	Institutional	Changing exhibitions of art at the San Francisco Airport sponsored by SFOM. These exhibitions are not part of SFAC's public art display at the airport.	19 locations with multiple art works
San Francisco Arts Commission (SFAC) and data.sfgov.org	Institutional	Subset of the 3,000 art objects from the San Francisco Civic Art Collection. The collection includes historic monuments, memorials, gifts, purchases and works commissioned through the City's Public Art Program. The SFAC administers the Civic Art Collection.	692
San Francisco Mural Arts (SFMA)	Administrative (VGI)	Collection of public San Francisco murals and documented by administrators or submitted by users (VGI) to the site	797
San Francisco Planning Commission (SFPC)	Institutional	San Francisco Planning Department datasets describing privately owned public open space and landmarks in San Francisco, many of which contain art work	108 POPOS 294 Landmarks
University of California San Francisco (UCSF)	Institutional	Commissioned works and sculptures at the Mission Bay Campus	13
Waymarking.com	Administrative (VGI)	Unique locations including art, statues, monuments, murals and landmarks contributed and peer reviewed by members (VGI).	318
Yerba Buena Gardens (YBG).	Institutional	Collection of public art and features at Yerba Buena Gardens.	7

Locations and attributes for SFOM, UCSF, and YBG POIs were extrapolated from map graphics, web descriptions, and site visits, as these organizations did not have georeferenced datasets online.

San Francisco Neighborhoods and CCSF datasets were in shapefile format using California State Plane Zone 3 Federal Information Processing Standard (FIPS) Zone 0403 projection. The remaining datasets were either Excel files with X, Y coordinates or KMZ files that mapped to the WGS84 Web Mercator Auxiliary Sphere projection. San Francisco Neighborhoods was converted to a feature class called SFNeighborhoods in the geodatabase. The feature class retains the California State Plane projection and is re-projected on the fly. The CCSF dataset attributes were transformed to match the SFPubArt84M table and missing information filled in where possible.

The SFAC Excel spreadsheet required scrubbing prior to import. XY fields were in a single column and needed to be split. Each item entry was reviewed and assigned an artType value. Data was imported into a shapefile and processed further. Neighborhoods were calculated for each entry. Points located far from San Francisco were moved to their correct location. The shapefile was imported into the SFPubArt84M table. Location correction and enhancement of data is an ongoing process facilitated through the use of mobile applications.

SFMA POIs were extracted from a JSON file. The name, image URL, SFMA id, and URL for additional information on the SFMA website was constructed. PopupInfo was created from the available fields. Initially a feature class was created and then the information was imported into the SFPubArt84M feature class.

A search of Waymarking.com for art related POIs resulted in resulted in over 15 KMZ files. The files were converted into geodatabase feature classes using the Model Builder script described in

Appendix B. The feature classes were combined in to one feature class and duplicate features removed. The POIs were categorized by art type. Fields mapping to SFPubArt84M were created and populated prior to importing to SFPubArt84M.

The SFPC provided three KMZ files for POPOS and historical landmarks. The KMZ files provided HTML descriptions of the POIs but no other attributes. Neighborhood was calculated for each entry. The features were converted from KMZ. POPOS, Food POOS, and Landmarks were appended into the Buildings feature class. The HTML information was inserted into the popupInfo field. Html data from KML files often needed editing to remove opening and closing brackets or fix idiosyncrasies. ArcMap often could not edit the text with field calculator. Importing or cutting and pasting ended up with truncated data. The field could only be corrected after import into an ArcSDE database.

Art POPOS were added to the SFPubArt84M as they contain information about artwork. The POPOS popupInfo fields needed to be split if there were multiple art pieces. The HTML was simplified as the original fields exceeded 4000 characters, the character limit for SQL Server. Art and Architecture-SF and Living New Deal provided detailed descriptions, images, and location information that improved data quality of other datasets. These two sites made it easier to locate pieces of art in the field when attributes from an SFAC entry were vague. The sites images for POIs were particularly helpful in providing visual cues. Precita Eyes provided additional information such as titles, locations, and artist names for a variety of murals.

PopupInfo fields required configuration in ArcMap to display correctly in the web application. The template can be found in Appendix C.

4.5.2 SFPAM Services

ArcMap map documents were used to create REST services to publish backend database features. Feature and map services were published as read-only for use with public maps. Definition queries created layers to differentiate feature sources, such as POPOS. Art and buildings feature and map services were created with CRU permission for administrative use in AGOL. The services, layers, permissions, description and feature class are shown in Table 16. These services were used by all the SFPAM client application components.

Table 16 Description of REST Services

Service	Layer ID	CRUD	Description	Feature Class
SFPUBART/Buildings Feature and map service	0	CRU	Everything in the Buildings table	Buildings
SFPUBART/BuildingsRO/Buildings Feature and map service layer	1	R	Everything in the Buildings table except POPOS	Buildings
SFPUBART/Neighborhood84MRO Feature and map service	0	R	Neighborhood boundaries and labels.	SFNeigborhoods
SFPUBART/SFPubArt84MgrR0/POPOSArt Feature and map service layer	3	R	Art POPOS POIs	SFPubArt84M
SFPUBART/SFPubArt84MgrR0/SFMuralArts Feature and map service layer	0	R	SFMA POIs	SFPubArt84M
SFPUBART/SFPubArt84Mgr Feature and map service	0	CRU	Everything in the SFPubArt84M table.	SFPubArt84M
SFPUBART/SFPubArt84MgrRO/SFPublicArt Feature and map service layer	1	R	Everything in the SFPubArt84M table except SFMA and Waymarking.com POIs	SFPubArt84M
SFPUBART/ BuildingsRO/POPOS Feature and map service layer	0	R	POPOS	Buildings
SFPUBART/SFPubArt84MgrR0/Waymarking Feature and map service layer	2	R	Waymarking.com POIs	SFPubArt84M

4.5.3 Social Media Services

The social media streams described in Table 17 were added as clustered points to the map. Flickr and Instagram required API keys in order to do searches. Twitter was dropped due to the OAUTH multiple hidden key requirements. The filters used for each API are listed, including the initial keyword. Results are filtered for valid coordinate values, but not extent, before being added to

the social media layer. The application tracks the id required to perform callback queries and an initial maximum page count of results is specified in the application configuration for each social media stream. Fields extracted from the return results of each point vary by API, but can generically be described as author, author's social media home page URL, date of the post, image URL, title, and description, comment or caption. Each social media stream is a feature layer service that can be toggled on or off by the user. The user can change the configuration of the search keyword and the volume of results. The volume of results changes either a time or page count variable used to construct the search for an API.

Table 17 Social Media Data Sources (last accessed 13 December 2013)

Social Media	Description	Security	Search	Generic Fields Extracted
Flickr	Photo stream service and API; www.flickr.com	API Key	Start date, end date, keyword of 'art', geotagged, extent, JSON page count	Author, author social media home page URL, date of post, and image URL, title, and description
Instagram	Photo stream service and API; www.instagram.com	API Key	Keyword of 'sfart' JSON Page count, recent	Author, author social media home page URL, date of post, and image URL, and first comment
Panoramio	Photo stream service and API; www.panoramio.com	N/A for search	Keyword of 'art' JSON page count, extent, order (recent), max number of results	Author, author social media home page URL, date of post, and image URL, and title
YouTube	Video stream service and API; www.youtube.com	N/A for search	Keyword of 'art' JSON page count, max results, radius from extent mid point, YouTube time variable	Author, author social media home page URL, date of post, and image URL, title, and description

4.5.4 Basemaps

Esri, Open Street Map, and Stamen Design provide basemap service layer choices for the SFPAM. Table 18 lists the basemap and corresponding URLs for accessing the services. Esri Light Gray and Satellite basemaps require both base and reference Map Servers. Open Street Map is referenced through a specific OpenStreetMapLayer API call. The three Stamen Design maps call

tiled map services. Users can configure which map to display. The Stamen Watercolor basemap

loads by default.

Table 18 Basemap Services (accessed 11 December 2013)

Basemap	URL for Service or Tiled Map Service
Esri Light Gray	http://services.arcgisonline.com/ArcGIS/rest/services/Canvas/World_Light_Gray_Base/MapServer http://services.arcgisonline.com/ArcGIS/rest/services/Canvas/World_Light_Gray_Reference/MapServer
Esri Satellite	http://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer http://services.arcgisonline.com/ArcGIS/rest/services/Reference/World_Boundaries_and_Places/MapServer
Esri Topographic	http://server.arcgisonline.com/ArcGIS/rest/services/World_Topo_Map/MapServer
Esri World Street Map	http://server.arcgisonline.com/ArcGIS/rest/services/World_Street_Map/MapServer
Open Street Map	esri.layers.OpenStreetMapLayer API call used to create layer, no URL required
Stamen Terrain	http://${0}.stamen.com/terrain/${1}/${2}/${3}.jpg
Stamen Toner	http://${0}.stamen.com/toner/${1}/${2}/${3}.png
Stamen Watercolor	http://${0}.stamen.com/watercolor/${1}/${2}/${3}.jpg

4.5.5 AGOL Services

Two AGOL feature services were created for Power Users to contribute new building or art

locations without impacting the backend database. The service names and URLs are described in

Table 19.

Table 19 AGOL Services

Service Name	URL
Add a New Building	https://ccsfgis.maps.arcgis.com/home/item.html?id=62a8363e4c1d4d679e22dc0baff89925
Add New Art Points	https://ccsfgis.maps.arcgis.com/home/item.html?id=5d296b9d6f60425a8e9b68f1bbd7d49d

4.6 Application Evaluation

The application was evaluated according to the functional requirements described in Table

20 and the non-functional requirements described in Table 21. Functional requirements were based

on the high-level use cases. The requirements were written at a high level so that users of the system

can verify them through use of the application, also known as User Acceptance Testing (UAT). The

requirements were verified using the web, AGOL, or Esri mobile applications. The pilot iOS

application was not be tested, but screen shots are provided.

4.6.1 Functional Requirements

The results of functional requirements testing are summarized in Section 5. Each

requirement in Table 20 was verified for the appropriate SFPAM component.

Table 20 Functional Requirements

Use Case	Requirement Number and Description	Web (W), AGOL (A), Esri Mobile (M)
1. Navigate Map	1.1 The system shall provide the capability to pan the map.	W, A, M
	1.2 The system shall provide the capability to zoom the map in and out.	W, A, M
2. Search/ Locate Art POI	2.1 The system shall provide the capability to display art and building POIs on the map that a user can locate using navigation controls.	W, A, M
	2.2 The system shall provide the capability to search the art database for POIs by title, artist/architect, or neighborhood; return a list of POIs matching the criteria; select a POI, and focus on the selected POI.	W (Stretch), A
3. View Detail	3.1 The system shall provide the capability to show detailed attribute information for a selected POI.	W, A, M
	3.2 The system shall provide the capability to view multiple records at a selected point.	W (Stretch), A, M
4. Find Location	4.1 The system shall provide the capability to enter a location by name or address, select a location, and focus on the selected location.	W, A, M
5. Show/Hide Layers	5.1 The system shall provide the capability for a user to select feature layers to display or to hide.	W, A, M
6. Show/Hide Social Media Layer	6.1 The system shall provide the capability for a user to select social media layers to display or hide. The social media layers choices shall be Flickr, Instagram, Panoramio, and Youtube.	W
7. Submit New Art POI	7.1 The system shall provide the capability for Power Users or administrators to submit new art or architecture POIs. The submitter will be able to geolocate the POI and enter attribute information for the POI.	A, M
8. Choose Basemap	8.1 The system shall provide the capability for users to choose a basemap to display as background. The basemap choices will be Esri Light Gray, Esri Satellite, Esri Topographic, Esri World Street Map, Open Street Map, Stamen Terrain, Stamen, Toner, and Stamen Watercolor.	W
9. Share Map	9.1 The system shall provide the capability for users to share the map as a URL, embedded html, or to Facebook and Twitter. The configuration of the map shall be captured. Depending on the client, configuration will include visible layers, social media search terms, extent, and basemap choice	W, A, M
10. Contact Administrator	10.1 The system shall provide the capability to contact the application administrator through email.	W, A, M
11. Request Navigation	11.1 The system shall provide the capability for the user to request navigation directions to or from a selected POI.	A, M
12. Set Social Media Filter	12.1 The system shall provide the capability for the user to set the search terms for social media queries. Flickr search parameters will be start data, end date, and keyword. Instagram, Panoramio, and YouTube parameters will be a keyword and a volume indicator.	W

Use Case	Requirement Number and Description	Web (W), AGOL (A), Esri Mobile (M)
13. Edit Art POI Information/ Location	13.1 The system shall provide the capability for Power Users and administrators to edit art or architecture POIs' location and attribute information.	A, M
	13.2 The system shall restrict edit capability for Power Users to features they have created.	A, M
14. Delete Art POI	14.1 The system shall provide the capability for Power Users to delete features they have created.	A, M
	14.2 The system shall provide the capability for administrators to delete features.	A, M
15. Approve/ Add Art POI	15.1 The system shall provide the capability for administrators to approve and add POIs.	A, M
16. Post Media Stream	16.1 The system shall provide the capability to post POIs and their attributes from a social media stream based on search filters. Author, author social media home page URL, date of post, and image URL attributes will be captured for Flickr, Instagram, Panoramio, and YouTube. Title will be captured for YouTube, Panoramio and Flickr. Either comment, caption or description information will be captured for Flickr, Instagram, and YouTube.	W
17. Authenticate Social Media	17.1 The system shall provide the capability for authentication with social media. Keys will be provided for Flickr and Instagram.	W

4.6.2 Non-functional Requirements

Non-functional requirements describe business rules and other desirable characteristics for system implementation. Table 21 lists the requirements and the component of the SFPAM that were used to test the requirement. Some requirements are specific to the backend system and the ArcMap MXD files used to create REST services. The results of non-functional testing are described in Section 5. Requirements 18.1-18.3 and 18.5-18.8 were verified on AGOL to show the geodatabase schema implementation, as well as on the backend system using ArcMap. Some requirements were verified on the backend system using ArcMap to test that the system captured information from the frontend applications.

Table 21 Non-functional Requirements

Descriptor	Requirement Number and Description	System (S), Web (W), AGOL (A), Esri Mobile (M)
18. Geodatabase Schema	18.1 The system will provide the capability to store art and architecture POIs as a geo-located point.	S, A
	18.2 The following attributes will be created for art POIs: artist	S, A

Descriptor	Requirement Number and Description	System (S), Web (W), AGOL (A), Esri Mobile (M)
	artType, credit , description, fieldNotes imageUrl, imageUrlLink, installYear, locationInfo, medium, neighborhood, organization, popupInfo, status.	
	18.3 The following attributes will be created for architecture POIs: architect, address, description, imageUrl, imageUrlLink, name, neighborhood, occType, popupInfo, source, studentName, style, year, and zip.	S, A
	18.4 The system will provide the capability to store images for POIs.	S, A, M
	19.5 The system will provide the capability to capture creator, create date, modifier, and last modified date.	S, A, M
	18.6 The system will provide the capability to preserve the original id, revision id, location, and dimension for art POIs.	S, A
	18.7 Each POI will have a unique id for the feature class and database.	S, A
	18.8 A geodatabase schema will be implemented based on the logical data model.	S, A
19. Preserve Functionality	19.1 The functionality of the original web application will be preserved.	W
	19.2. New functionality shall behave in a manner comparable to existing functionality. Stamen design basemaps, Esri Light Gray basemaps, Instagram, and Panoramio features will exhibit the same functionality as existing features.	W
20. Brand as Art Map	20.1 The PIM will be converted from a disaster map to an art map. References, layers, and imagery supporting a disaster map will be removed. The application will be renamed the San Francisco Public Art Map.	W
	20.2 The web application will be hosted at sfpublicart.com, sfpublicart.org, and sfpublicart,net.	W
	20.3 The application will support multiple layers of art or architecture features.	S, W, A, M
	20.4 Help information will be rewritten to refer to the SFPAM contents.	W
21. Display	21.1 The initial extent of the web application will be San Francisco	S, W, A, M
	22.2 The application will display neighborhood boundaries and names. Boundaries will be displayed at zoom levels below 1:250,000 and names will be displayed at zoom levels below 1:100,000.	S, W, A, M
	21.3 Art POIs will be symbolized by art type. Art POPOS are symbolized as Art POPOS.	S, W, A, M
	22.4 Building POIs will be symbolized by POPOS type or generic building.	S, W, A, M
	21.5 Social Media POIs will either be represented by a cluster marker or symbolized by social media type.	W
22. Security	22.1 Users shall have read-only access to map features.	W, A
	22.2 Power Users shall have CR access to an empty feature class and UD for features they have created.	A, M
	22.3 Administrators shall have shall CRUD access to map features.	S, A, M

Since the SFPAM used existing application code, performance and web standards testing

was not performed.

Chapter 5: Results

This section documents the application results for the SFPAM. The functional and nonfunctional requirements' testing results are summarized in 5.1 and 5.2. Additional details and screenshots supplement the testing summaries. Changes made as a result of initial requirements testing are described in 5.3. REST services are summarized in 5.4, SFPAM web application results shown in 5.5, and AGOL maps described in 5.6. The Esri mobile application implementation examples are found in 5.7 and a mobile iOS pilot application is found in 5.8. The section concludes with 5.9, a summary of functionality differences between the client applications.

5.1 Summary of Functional Requirements' Test Results

Table 22 summarizes the functional requirements' testing results. Each requirement was verified for the applicable client application. A "No" or "N/A" result indicates that the requirement was not tested for a particular client application. The test may not be applicable to the client; the functionality only needs to be demonstrated in one environment; or the functionality was not implemented in the client. A "Yes" result indicates the requirement was verified. The result is summarized in the "Result Description" column with the last date of verification. Testing occurred and concluded in August 2013. The final test results verified that the system functioned as expected.

Table 22 Functional Requirements' Test Results

Req #	Yes (Y)/ No (N)			Result Description	Verified Date
	Web	**AGOL**	**Esri Mobile**		
1.1	Y	Y	Y	The user can pan the map	8/22/13
1.2	Y	Y	Y	The user can use zoom controls for web interfaces and pinch controls for mobile to zoom in and out.	8/22/13
2.1	Y	Y	Y	The user can view art and building POIs in the San Francisco extent by using the zoom and pan controls to select points.	8/22/13

Req #	Yes (Y)/ No (N)			Result Description	Verified Date
	Web	**AGOL**	**Esri Mobile**		
2.2	N	Y	N	Using AGOL a user can filter on art or building fields to return a subset of results. The web and mobile system does not currently support the functionality to search the art database for POIs by title or artist/architect, return a list of POIs matching the criteria, select a POI, and focus on the selected POI.	8/22/13
3.1	Y	Y	Y	A user can view a popup window with attribute information for the feature by selecting and clicking on a POI.	8/22/13
3.2	N	Y	Y	A user can view multiple records by paging through popup windows when a location with multiple POIs is selected. Or by seeing a list of points selected. This capability is available for AGOL and the Esri Mobile applications. This functionality is not currently available for the SFPAM web application.	8/22/13
4.1	Y	Y	Y	A user can enter a name or address, select a location, and focus on the selected location.	8/22/13
5.1	Y	Y	Y	A user can turn feature layers on and off.	8/22/13
6.1	Y	N/A	N/A	The user can turn Flickr, Instagram, Panoramio, and YouTube social media layers on and off.	8/22/13
7.1	N/A	Y	Y	A Power User with an AGOL account can add new features to the art or building feature service via a Power User map. The feature services store new features in AGOL, not the back end database. The Power User map is accessible through AGOL and Esri mobile applications. A user with Administrator privileges can access an administrator's map through AGOL or Esri mobile applications. The administrators map allows the administrator to add new art or architecture POIs to the backend datasets.	8/22/13
8.1	Y	Y	N/A	A user of the web application can choose from the following basemaps: Esri Light Gray, Esri Satellite, Esri Topographic, Esri World Street Map, Open Street Map, Stamen Terrain, Stamen, Toner, and Stamen Watercolor. An AGOL user can choose from Esri provided basemaps. The Stamen Design 8/22/13 basemaps are available as layers that can be turned on or off to hide the Esri basemap. Mobile users can select from Esri provided basemaps. Mobile does not have the capability to use the Stamen Design web tile layers.	8/22/13
9.1	Y	Y	Y/N	Users can share the map as a URL, embedded HTML, or to Facebook and Twitter. The configuration of the map shall be captured including visible layers, social media search terms, extent, and basemap choice. Collector users cannot share a map.	8/22/13
10.1	Y	Y	Y	Users can contact the administrator via email. An email link is provided in the web application about.html. An email address is included in the details about the map for AGOL and Esri mobile applications.	8/22/13
11.1	N/A	Y	Y/N	The user can request navigation directions to or from a selected POI using the Esri Collector application.	8/22/13
12.1	Y	N/A	N/A	The user can set the search terms for social media queries. Flickr search parameters are start date, end date, and keyword. Instagram, Panoramio, and YouTube parameters are a keyword and a volume of information indicator.	8/22/13
13.1	N/A	Y	Y	Power Users and administrators can edit art or architecture POIs, location and attribute information. Collector users must have an ArcGIS for Organizations account.	8/22/13

Req #	Yes (Y)/ No (N)			Result Description	Verified Date
	Web	AGOL	Esri Mobile		
13.2	N/A	Y	Y	Power Users can only edit features they have created.	8/22/13
14.1	N/A	Y	Y	Power Users can only delete features they have created.	8/22/13
14.2	N/A	Y	Y	Administrators can delete features.	8/22/13
15.1	N/A	Y	Y	Administrators can evaluate POIs, and approve them by adding them to the backend datasets. Administrators can then delete them from the user populated feature sets.	8/25/13
16.1	Y	N/A	N/A	The system can post POIs and their attributes from a social media stream based on search filters. Author, author social media home page URL, date of post, and image URL attributes can be for Flickr, Instagram, Panoramio, and YouTube. Title will be captured for YouTube, Panoramio and Flickr. Comment, caption or description information can be captured for Flickr, Instagram, and YouTube.	8/22/13
17.1	Y	N/A	N/A	The system is able to authenticate with Flickr and Instagram.	8/22/13

5.2 Summary of Nonfunctional Test Results

Table 23 summarizes the nonfunctional requirements testing results. Each requirement was verified for the backend system or the applicable client application. "N/A" indicates that the requirement was not applicable for the particular client application or that the requirement only needed to be verified on one client to demonstrate a system capability provided by the backend. A "Yes" result indicates the requirement was verified. The result is summarized in the "Result Description" column, and a last verified date provided. Testing occurred and concluded in September 2013. The final test results verified that the system functioned as expected.

Table 23 Non functional Requirement Results

Req #		Yes (Y)/ No (N)			Result Description	Verified Date
	Sys.	Web	AGOL	Esri Mobile		
18.1	Y	N/A	Y	N/A	The system provides the capability to store art and architecture POIs as geolocated points.	9/23/13
18.2	Y	N/A	Y	N/A	The following attributes can be stored for art POIs: artist, artType, credit, description, fieldNotes imageUrl, imgUrlLink, installYear, locationInfo, medium, neighborhood, organization, popupInfo, status.	9/23/13
18.3	Y	N/A	Y	N/A	The following attributes can be stored for building POISs: architect, address, description, imageUrl, imageUrlLink, name, neighborhood, occType, popupInfo, source, studentName, style, year, and zip.	9/23/13
18.4	Y	N/A	Y	Y	Images can be stored in the system for POIs.	9/23/13
18.5	Y	N/A	Y	Y	The backend system captures and stores creator, create	9/23/13

Req #	Yes (Y)/ No (N)				Result Description	Verified Date
	Sys.	Web	AGOL	Esri Mobile		
					date, modifier, and last modified date for art and building features. AGOL hosted feature services store creator, create date, modifier, and last modified date for art and building features.	
18.6	Y	N/A	Y	N/A	The ARTSOURCE table preserves the original id, revision id, location, and dimension for art POIs.	9/23/13
18.7	Y	N/A	Y	N/A	Each POI has a unique id for the feature class and database in the form of a system generated GlobalID.	9/23/13
18.8	Y	N/A	Y	N/A	The geodatabase was implemented based on the logical data model.	9/23/13
19.1	N/A	Y	N/A	N/A	The functionality of the original application was preserved.	9/23/13
19.2	N/A	Y	N/A	N/A	New functionality behaves in a manner comparable to existing functionality. Stamen design basemaps, Esri Light Gray basemaps, Instagram, and Panoramio features exhibit the same functionality as existing features.	9/23/13
20.1	N/A	Y	N/A	N/A	The PIM was converted from a disaster map to an art map. References, layers, and imagery supporting a disaster map were removed. The application was renamed the San Francisco Public Art Map.	9/23/13
20.2	N/A	Y	N/A	N/A	The web application is hosted at sfpublicart.com, sfpublicart.org, and sfpublicart.net.	9/23/13
20.3	Y	Y	Y	Y	The application supports multiple layers of art or architecture features.	9/23/13
20.4	N/A	Y	N/A	N/A	Help information was rewritten to refer to the SFPAM contents.	9/23/13
21.1	Y	Y	Y	Y	The initial extent of the web application is San Francisco.	9/23/13
21.2	Y	Y	Y	Y	The application displays neighborhood boundaries and names. Boundaries are displayed at zoom levels below 1:250,000 and names are displayed at zoom levels below 1:100,000.	9/23/13
21.3	Y	Y	Y	Y	Art POIs are symbolized by art type. Art POPOS are symbolized as Art POPOS.	9/23/13
21.4	Y	Y	Y	Y	Building POIs are symbolized by POPOS type, as Landmark, or generic building.	9/23/13
21.5	N/A	Y	N/A	N/A	Social Media POIs are represented by a cluster marker or symbolized by social media type.	9/23/13
22.1	N/A	Y	Y	N/A	Users have read-only access to map features.	9/23/13
22.2	N/A	N/A	Y	Y	Power Users have CR access to an empty feature class and UD for features they have created.	9/23/13
22.3	Y	N/A	Y	Y	Administrators have create, read, update, and delete (CRUD) access to map features.	9/23/13

5.3 Changes Based on Initial Requirements Testing

As a result of preliminary requirements testing, several changes were incorporated into the

design and implementation of the SFPAM prior to final verification testing.

Coded value domains displayed differently depending on the client application. The domains were recoded so that the description matched the code value. The neighborhood domain was expanded to include values for areas such as Alcatraz and the San Francisco Airport (SFO).

The SFPAM web application and AGOL map popups interpret HTML code embedded in fields correctly for display, but mobile applications simply display the raw HTML code. In particular, HTML code did not display images on mobile devices. This led to several changes in order to correctly display images on mobile devices.

A field to complement the existing image URL field was created in the Building and SFPUBART84M tables. The new image URL link field provides the capability to store a different target location for the browser when an image is clicked.

A new AGOL map was created and configured specifically for mobile. The map uses image URL and image URL link fields to display images instead of referencing the popupInfo fields for building and art features.

Data was extracted from the popupInfo fields to populate image URL and image URL link fields in the backend database. Additional unstructured text was extracted from the popupInfo field. This populated blank fields to improve data quality and visibility for mobile devices. For example, landmark features contained image URL, address, date of construction, building name, and architect name embedded in the popupInfo field. While web applications could view this data in an easily readable formatted way, the mobile applications provided a long HTML string.

The popupInfo field in the Building and SFPUBART84M tables was configured to the SQL Server maximum value of 4000 characters to accommodate long HTML fields from multiple data sources. The HTML content was revised and reformatted for several hundred records as the content exceeded 4000 characters. Requirements testing revealed a bug in ArcMap, the ODBC driver, or

SQL Server as the system no longer accepted inserts to the Building and SFPUBART84M tables. The fields were dropped, recreated with a value less than the maximum character length, and repopulated.

Testing revealed a Flickr API bug with bounding boxes. Queries to the Flicker API that include a bounding box no longer return entries uploaded after August 6, 2013. There is no current workaround or date for a fix from Flickr. The SFPAM can be configured to use a hardcoded San Francisco geographic center as search term instead of the extent, but this removes flexibility from the application. No results will be returned if the user pans to a region outside of San Francisco.

Finally, testing AGOL maps with different combinations of AGOL accounts and group settings influenced the decision to make the two AGOL San Francisco Public Art and Architecture maps open to all types of AGOL accounts for read access of backend services and write access of the AGOL

5.4 REST Services Summary

Map and feature services described in Section 4.5.2 were created and published on the ArcGIS for Server production server. Two empty AGOL feature services were created and published for Power Users. Table 24 summarizes which services and their corresponding layers are consumed by application.

Table 24 Services Used by Each Application

Client Application	Buildings	BuildingsRO	Neighbor-hood84MRO	SFPubArt-84Mgr	SFPubArt-84MgrR0	AGOL Add Building/ Art Points
sfpublicart.com website		X	X		X	
AGOL mobile or web: SF ART Admin	X		X	X		X
AGOL mobile or web: San Francisco Public Art and Architecture		X	X		X	X
AGOL mobile or web: San Francisco Public Art and Architecture for Mobile		X	X		X	X

Mobile iOS native pilot application consumes backend services through the configuration of the AGOL San Francisco Public Art and Architecture for Mobile web map service.		X	X		X	

Client applications consuming the BuildingsRO and SFPubArt84MgrRO services were configured to access each layer within the service.

5.5 SFPAM Web Application Results

The web application sfpublicart.com is the primary user interface for the SFPAM. The entry point to the website is reviewed in Section 5.5.1. Popups are discussed in Section 5.5.2. Section 5.5.3 illustrates basemap, layer, and social media configuration. Searching for a location, managing bookmarks, sharing the map, and learning more about the map are described in Section 5.5.4.

5.5.1 Main Page

The website loads data asynchronously to shorten the length of time the page remains blank and eliminate load dependencies between data sources. As the application loads, displayed data volume and visual complexity increases. Figure 8 shows the website's main page for sfpublicart.com, sfpublicart.org, or sfpublicart.net.
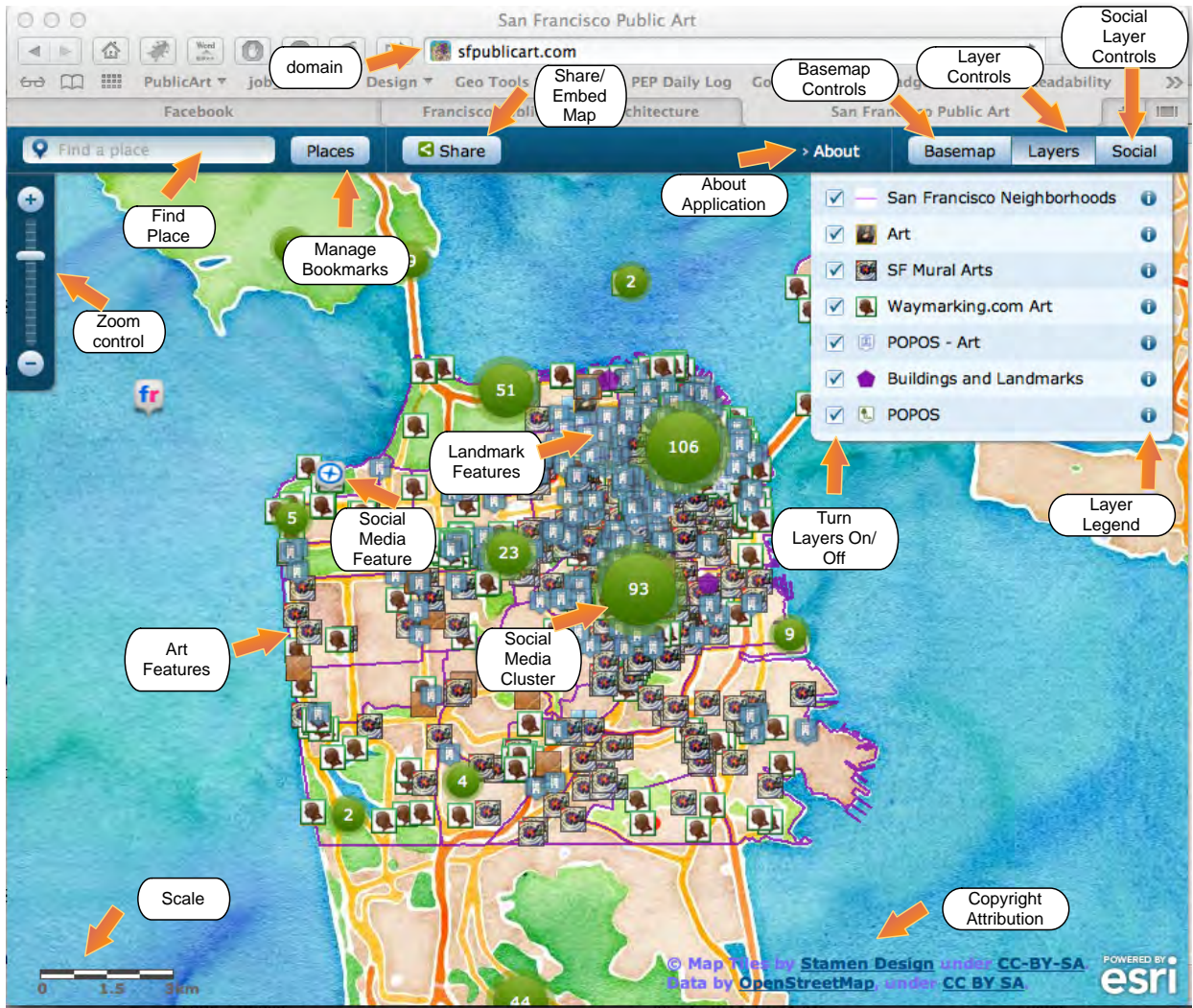
Figure 8 - The main page for sfpublicart.com

Callouts highlight the application's controls and features. All REST data layers and social media layers enabled for the application are loaded. The initial basemap is Stamen Design's Watercolor tiles. REST service data layers of art and buildings appear display as individual points. Social media data appears as circular clusters or single points depending on density.

The application provides basic navigation controls such as panning, by clicking and dragging, and zooming, by using the zoom toolbar. A scale is visible to the lower left of the web page. Copyright attribution for basemaps appears to the lower right. The top toolbar provides options to

locate a place, manage place bookmarks, share or embed the current configuration of the map, learn more about the map, and control layer selection.

5.5.2 Popups

The user can interact with the map and view detailed information through selecting art points or social media clusters to access popup details. Art and building locations appear as single points; social media data may appear as either a single point or a cluster. A cluster popup has navigation controls to page through different social media points. Popup windows have scrollbars enabled. **Figure 9** contains four examples of popup windows that demonstrate different ways the application can be configured to display POI attributes.
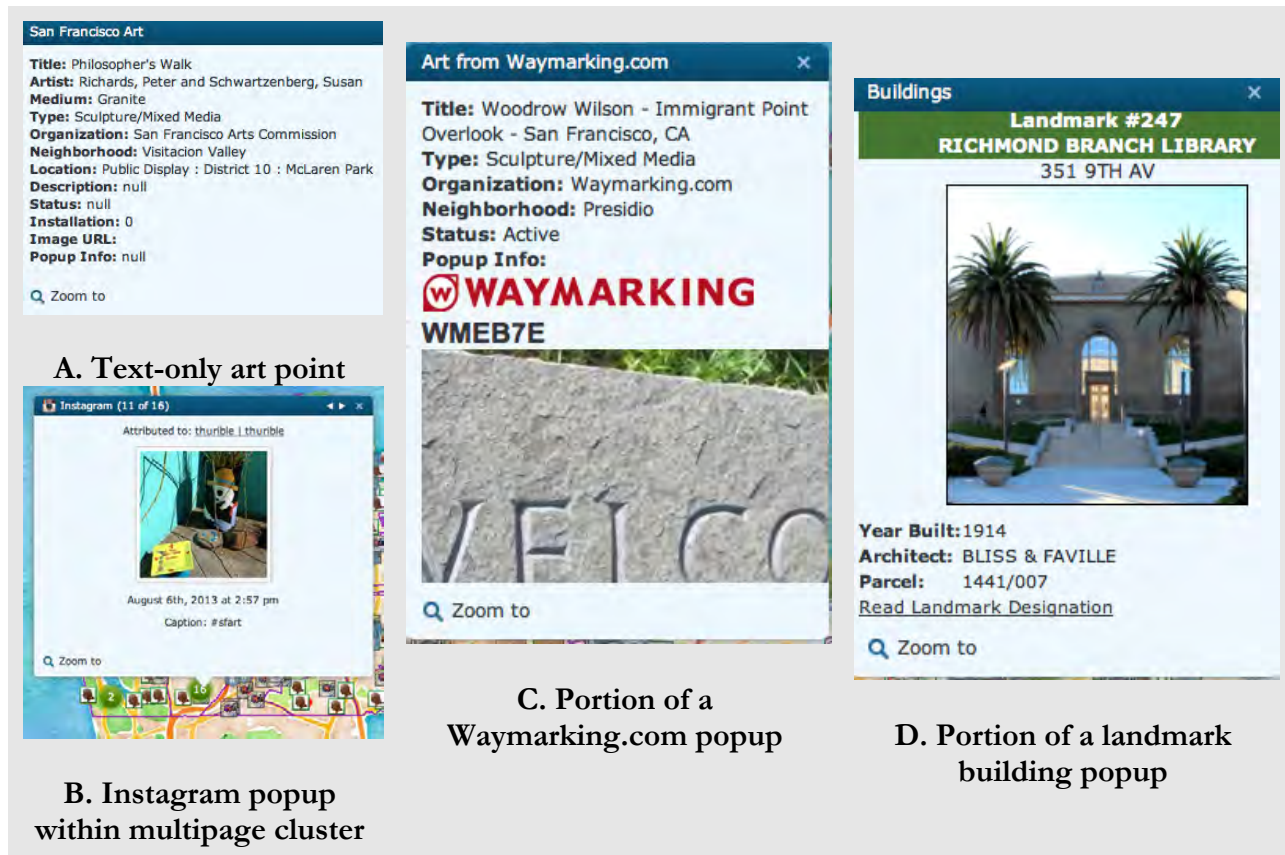

A. Text-only art point

B. Instagram popup within multipage cluster

C. Portion of a Waymarking.com popup

D. Portion of a landmark building popup

Figure 9 Sample popup windows

Figure 9A is a text only popup of a SFAC art location. A multipage popup of social media points showing an Instagram point is found in Figure 9B. Figure 9C displays the top portion of a popup from Waymarking.com data, while Figure 9D shows the bottom half of the popupinfo field from a landmark building location. Clicking on an embedded image in a popup opens a browser window to the image's original or parent website. Additional links may be embedded in the popupInfo field. Each popup window contains a link to zoom the map to the POIs location.

5.5.3 Layer Controls

The layer controls allow the user to change the basemap, turn layers on and off, and change the search parameters for social media. There are three segment tabs to the layer control; selecting a segment displays a control panel for the segment. Clicking a depressed tab hides the control panel.

The application loads with the Layers control panel displayed. The control panel lists the REST service layers portrayed on the map with a title and single legend icon. Additional legend and layer information is available by clicking the information icon to the right of the layer name. Figure 10 shows the expanded legend panes for the Art (A), Buildings (B.), and POPOS (C) layers. The Art and Waymarking.com layers include a transparency slider, and both layers are symbolized by art type. These examples illustrate different configuration options available to configure a legend.

A. Art layer legend

B. Building layer legend

C. POPOS layer legend
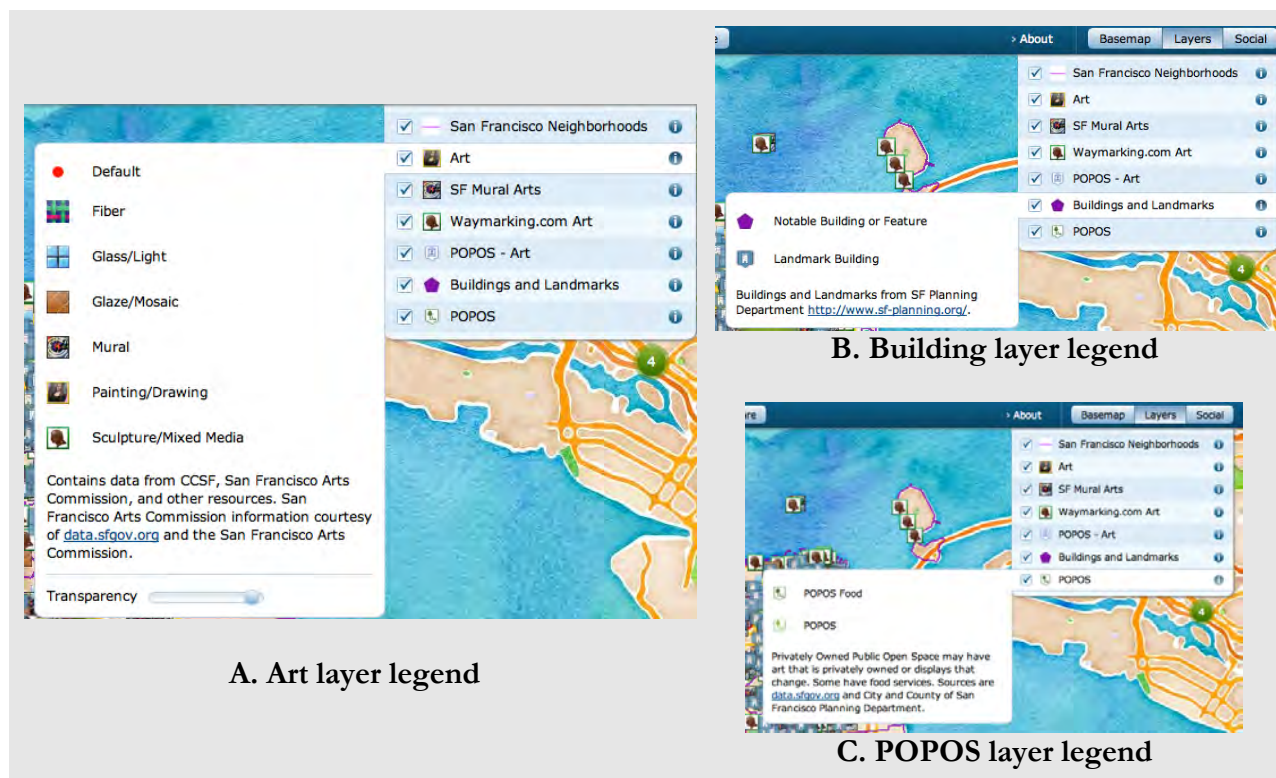
Figure 10 Legends for the art, building, and POPOS layers

Figure 11 contains images of the basemap and social media panes. The basemap pane shown in 11A provides the user with five background choices from Esri services and three from Stamen Design. The administrator can configure the map for different basemap options. A user can style the map using the basemap selector.

Both the social media layer selection pane and the settings pane are displayed in 11B. Social media layers can be turned on or off by clicking on the layer name or checkbox. Since social media points are dynamic, turning a layer on forces a new set of queries to get social media POIs for the map. Zooming and panning also triggers new queries. The number of geolocated entries returned for each social media search is displayed in parentheses, although not all may be visible on the map.

The user can change the search parameters for each social media stream using the settings pane. There are tabs for each social media layer. Selecting a tab displays modifiable search parameters. The search button must be clicked to implement the new filters.

A. Basemap choices   B. Social media search
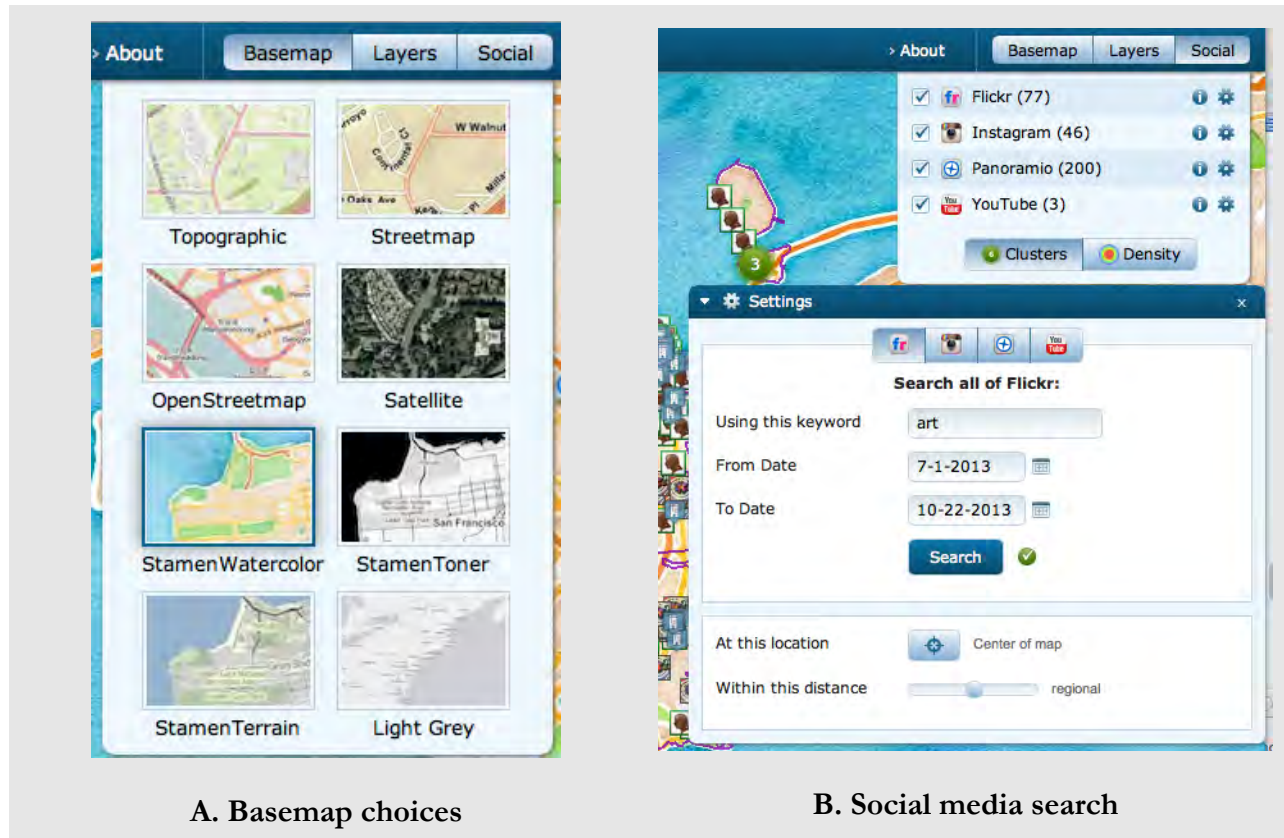
Figure 11 Basemap and social media configuration

Social media layers can also be displayed as a heatmap by toggling the "Density" tab. This disables access to popup displays for social media.

5.5.4 Additional Functionality

Additional map functions include "Find a place", "Places", "Share", and "About." The "Share" and "About" functions were modified to incorporate changes to the underlying application code.

The user can search for addresses and locations by entering text into the "Find a place" text box. A pull-down list of locations from the Esri geocode service appears as the user enters text; the user can select the desired location. The map zooms to a pin representing the location. Figure 12 shows the text "San Francisco City Hall" and resulting location pin. The pin disappears once the text box is cleared.
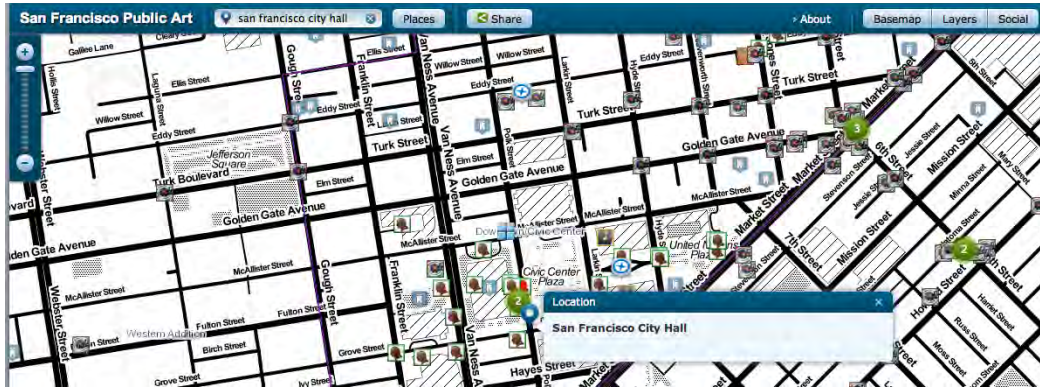
Figure 12 Find a place

The "Places" function shown in Figure 13 allows the user to bookmark by name the extent and layer configuration at the time of creation. Multiple bookmarks can be created. The bookmarks persist while the webpage is loaded in the browser.
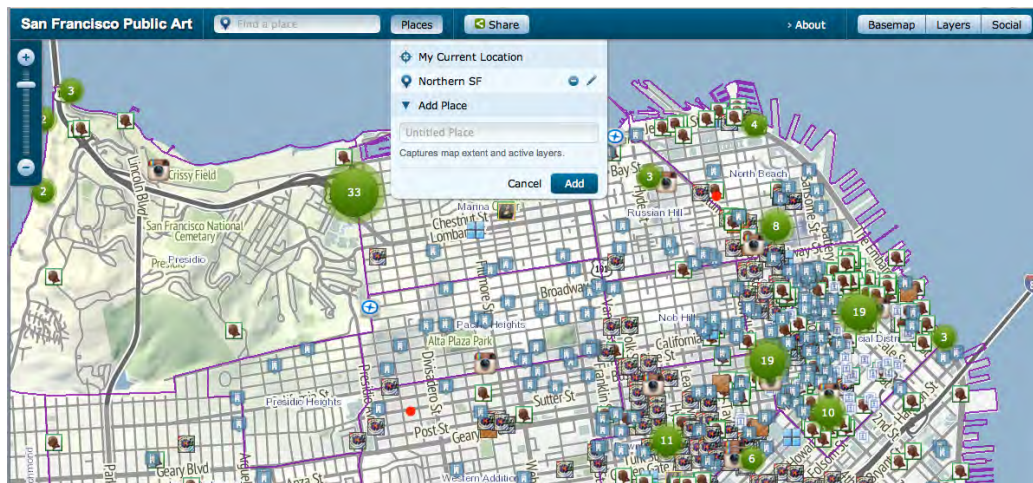
Figure 13 Places

The "Share" function provides the capability to share a map to Facebook or Twitter, as well as to embed the map in an HTML page. The current layer settings, map extent, basemap background, and social layer search terms will be saved as parameters to the shared link. Figure 14 shows the two sharing options. In Figure 14A, the user can select either Facebook or Twitter to share a link to the map on social media. Figure 14B shows the interface to generate HTML code to embed the map on a web page. The user can choose preconfigured map dimensions or generate a custom size. The resulting HTML code can be added to a webpage.

| A. Share map on Facebook or Twitter | B. Embed map in HTML |
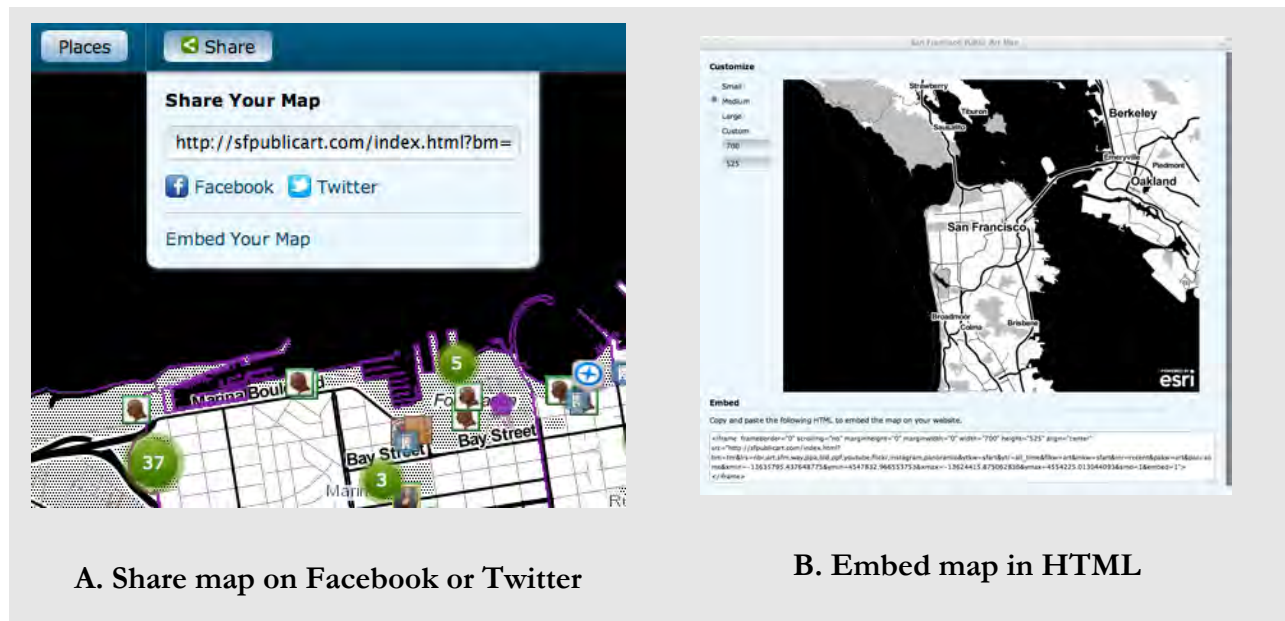
Figure 14 Share map options

Finally, clicking the "About" button brings up an information pane with more information about the map layers. Contact information for the map administrator is included as well as a link to the AGOL map where new features can be added.

5.6 AGOL Results

Three maps and two feature services were created in AGOL. The names, purpose, and links including the AGOL map service ID are listed in Table 25. The primary reasons for creating these maps and features services are to:

- Provide a means for Power Users with ArcGIS accounts to add new features without touching the backend data
- Enable users to access the art map using ArcGIS mobile clients
- Provide a means for the administrator to edit the backend database using web or mobile clients
- Provide a configured map service for use with the pilot native iOS application.

Because mapping services instead of features services are consumed, symbology is retained from the original MXD files used to generate the REST services.

**Table 25 AGOL map services**

Map or Feature Service Name	Description	AGOL Link including ID
Add a New Building	Feature service for new building features.	https://ccsfgis.maps.arcgis.com/home/item.html?id=62a8363e4c1d4d679e22dc0baff89925
Add New Art Points	Feature service for new art features.	https://ccsfgis.maps.arcgis.com/home/item.html?id=5d296b9d6f60425a8e9b68f1bbd7d49d
San Francisco Public Art and Architecture	Web map displaying existing art and buildings for Power Users to add new features to the AGOL feature services	https://ccsfgis.maps.arcgis.com/home/item.html?id=94d0872b64d849708e620735e861eb98
San Francisco Public Art and Architecture for Mobile	Web map for use with mobile devices. ArcGIS mobile clients can add new features to the AGOL feature services.	https://ccsfgis.maps.arcgis.com/home/item.html?id=173842bc350d4f379ebc184f0c1897eb
SF Art Admin	Administrator map with CRU permissions for editing the backend database. Can be used as web map or through ArcGIS mobile clients to edit in the field.	https://ccsfgis.maps.arcgis.com/home/item.html?id=707f6d7440c843db97356357e203b147

Figure 15 shows the AGOL *San Francisco Public Art and Architecture* web map. On the left side under "Contents," the layers from the backend REST services, feature services for adding art and buildings, and the Stamen Design base map layers are visible. A popup window displays a multi-page popup window for selected points.
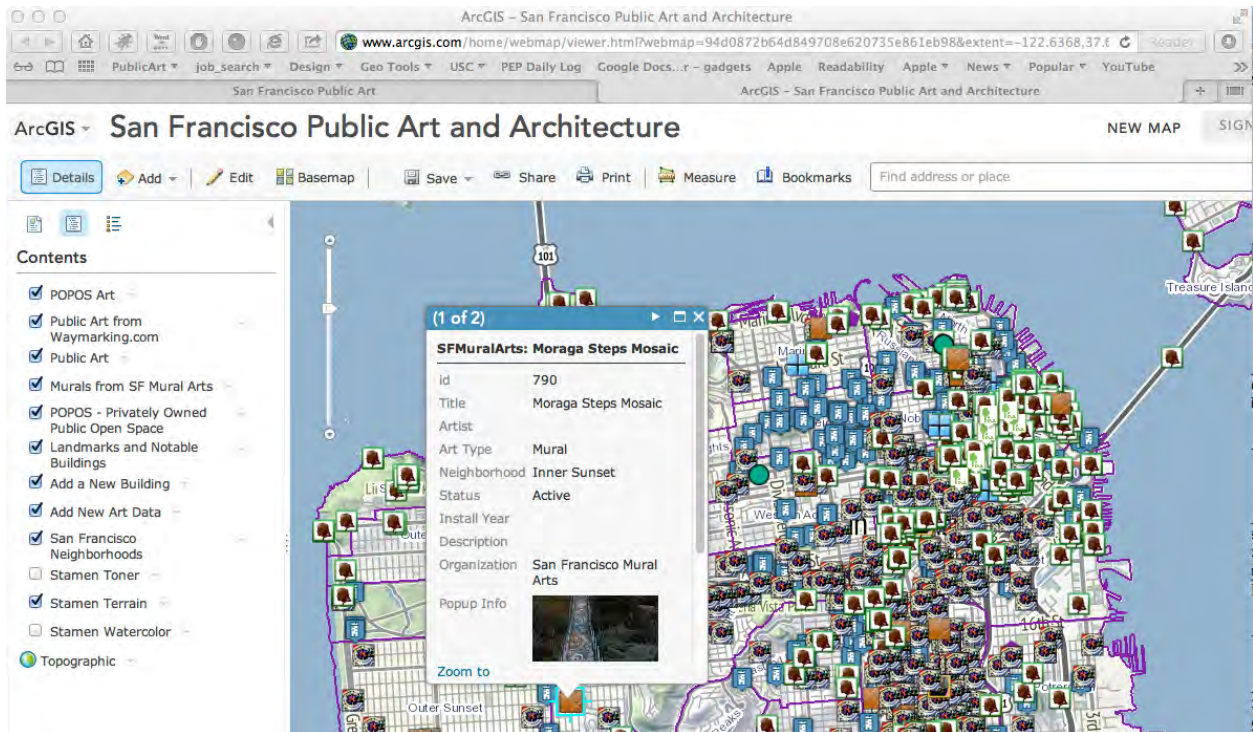
Figure 15 AGOL San Francisco Public Art and Architecture Map

A user can select the "Edit" button to add new features to the AGOL features services.

Figure 16 shows the "Add Features" pane with PUBLICART selected. A new feature point has been

added to the map and the editing window is open to add attribute information. A user can add

images through providing external web links or by uploading images. Dropdown windows display

values imported from the backend domains when the feature service was created using a backend

REST service as a model.
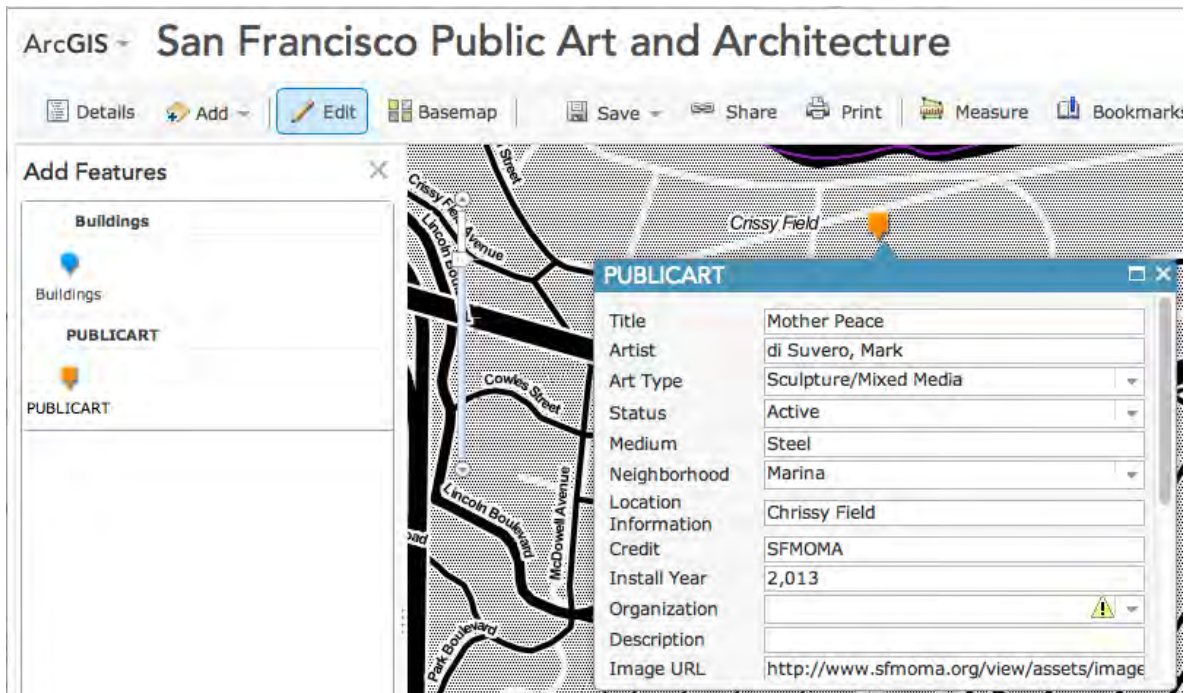
Figure 16 Adding new art features to the AGOL feature service

The AGOL *San Francisco Public Art and Architecture* and the *San Francisco Public Art and Architecture for Mobile* maps are configured so that users can edit or delete features they create but not features of other users.

Figure 17 show the AGOL SF Art Admin map in editing mode. The editing pane contains the AGOL feature services. The map has access to the Buildings feature service with CRU access to all Building table records and the SFPubArt84Mgr feature service with CRU access to all art features in the SFPubArt84M table. The editing popup for the selected feature is shown. Since the map is for administrators to edit backend data, the features within the Buildings and SFPubArt84Mgr service have not been broken into multiple layers. Both the position and attributes of features can be edited. Images can be uploaded or deleted from the associated attachment tables.
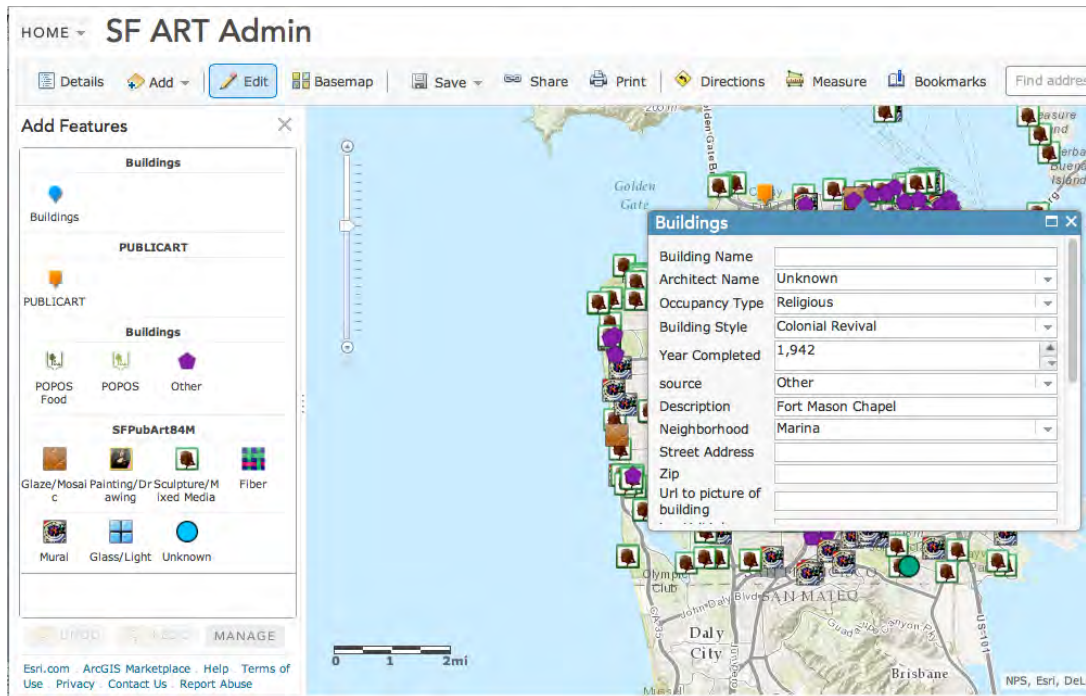
Figure 17 - AGOL SF Art Admin map in editing mode

The SF Art Admin map is not publicly shared, so it will not appear in searches of ArcGIS on web or mobile unless the user is the map owner.

5.7 Esri Mobile Application Results

The AGOL maps described in the previous section can be accessed in the ArcGIS for Mobile and Collector native applications. Only *San Francisco Public Art and Architecture for Mobile* is configured to display images using links properly. This section looks at some of the mapping functionality provided through the native applications. These examples demonstrate the interaction of the Esri mobile applications with the backend services of the SFPAM using web map configuration in AGOL. Images were captured on an iOS 4s phone. The symbology is consistent with the AGOL web maps and the backend REST services.

Figure 18 displays aspects of the basic interface for the ArcGIS for Mobile iOS application. 18A shows the results of a search for "SF Art" by the Administrative owner of the AGOL maps.

Other users will see similar results with SF ART Admin excluded. Selecting San Francisco Public Art and Architecture for Mobile brings the user to the basic map view (Figure 18B). The client provides basic functionality such as a legend view (Figure 18C) and layer controls (Figure 18D).

| A. Map search results | B. ArcGIS for Mobile map view | C. ArcGIS for Mobile legend | D, ArcGis for Mobile layer controls |
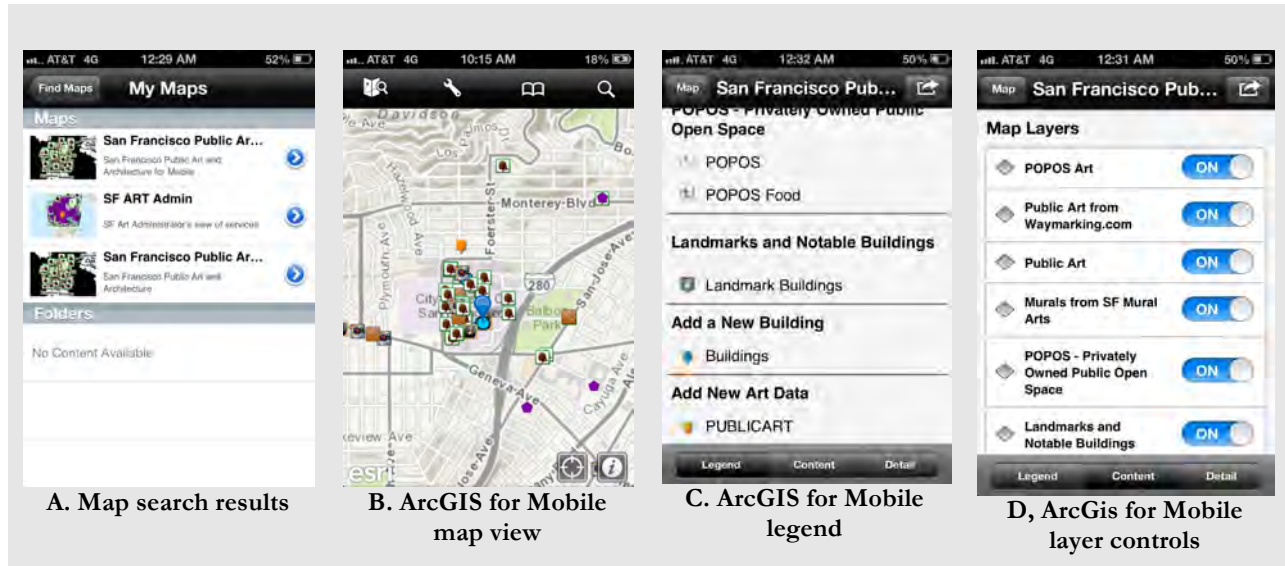
Figure 18 ArcGIS for Mobile basic functionality

Figure 19 consists of images from the Collector application. The basic map view is shown in Figure 19.A. A correctly displayed image in the popup window is found in Figure 19B. In Collector, a user can navigate between locations; the application contains routing functionality. Figure 19C shows the route generated between points and Figure 19D shows the route directions.

| A. Basic map view | B. Popup image display | C. Navigation route to a POI | D. Route directions |
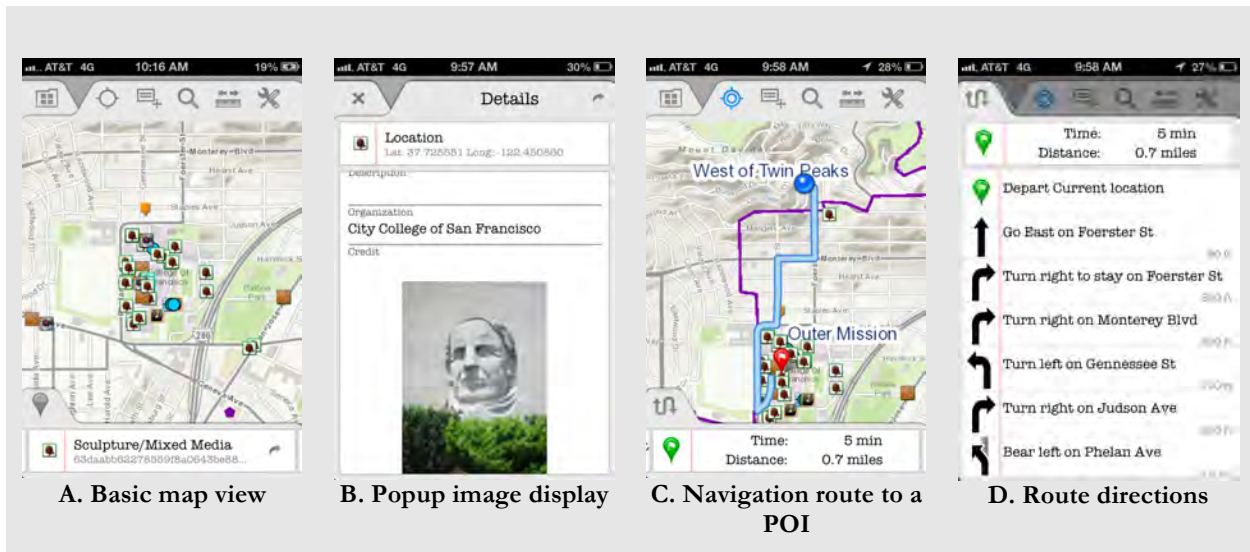
Figure 19 Collector map view, popup, and directions

Figure 20 shows different aspects of editing a point or adding a new feature. In ArcGIS for Mobile, if a point is selected and edit clicked in the popup pane, the attribute-editing form appears (Figure 20A). From the attribute-editing form, the point can be repositioned (Figure 20B). In Collector, selecting the new feature icon brings up a pane to select the feature class (Figure 20C). The attribute editing screen is shown in Figure 20D.

| A. Editing a POI in ArcGIS for Mobile | B. Adjusting a POI position during editing in ArcGIS for Mobile | C. Choosing which feature to add in Collector | D. Attribute editing screen for adding a new feature in Collector |
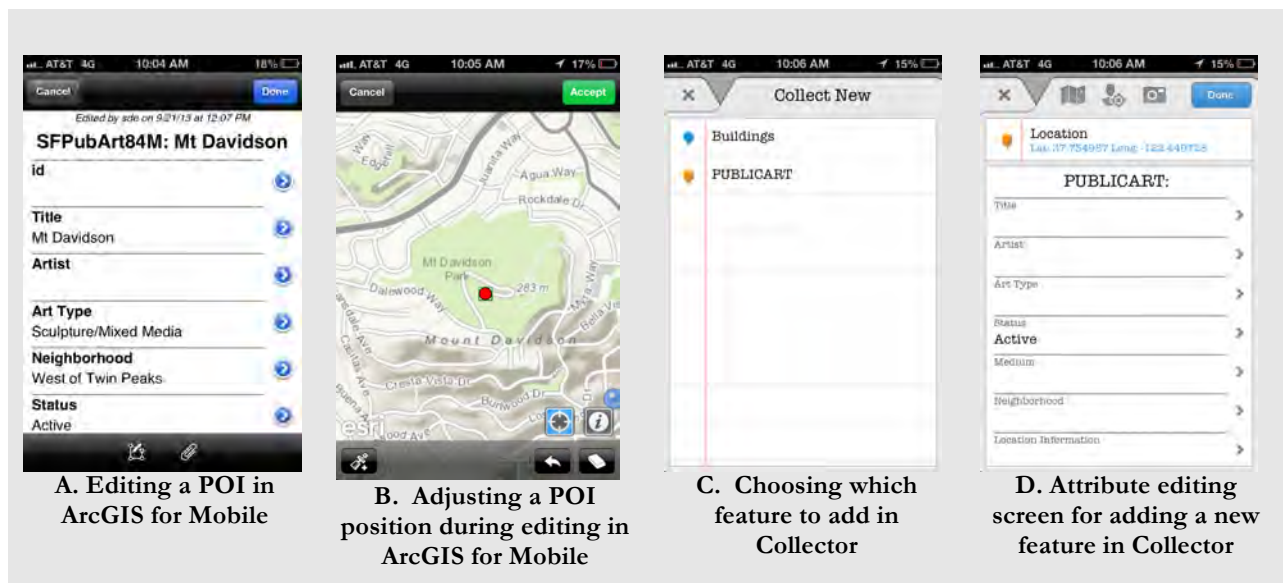
Figure 20 Editing using mobile applications

The Esri native client applications provide a mobile option for users to enjoy the art and building datasets, as well as to contribute additional data.

5.8 Mobile iOS Pilot Application Results

While the Esri native clients applications address mobile access to the SFPAM, this solution requires downloading an Esri application and an Esri user, developer, or organizational account for access. A less restrictive solution does not require a user account for accessing art data.

Using Esri iOS for mobile sample Xcode projects, a pilot native iOS program was developed. Figure 21 contains images captured in the iOS emulator for an iPhone 5 running 6.1 showing current functionality. The application consumes the AGOL *San Francisco Public Art and Architecture for Mobile* web map. The AGOL configuration is reflected in the layers displayed as well as attribute order and selection. Symbology is passed by the backend REST map services to AGOL and the native application.

The pilot application has pan and zoom functionality and a basemap picker. Point selection is buffered so that underlying points are selected (Figure 20A). Popup displays (Figure 20B) scroll and reflect the selection of multiple points through multi-page navigation (Figure 20C). The Esri gray basemap is visible in Figure 20A. The topographic basemap provides the background in Figure 20D.

A. Gray basemap and callout for selected points	B. Popup detail	C. Additional popup details and image	D. Topographic basemap selection
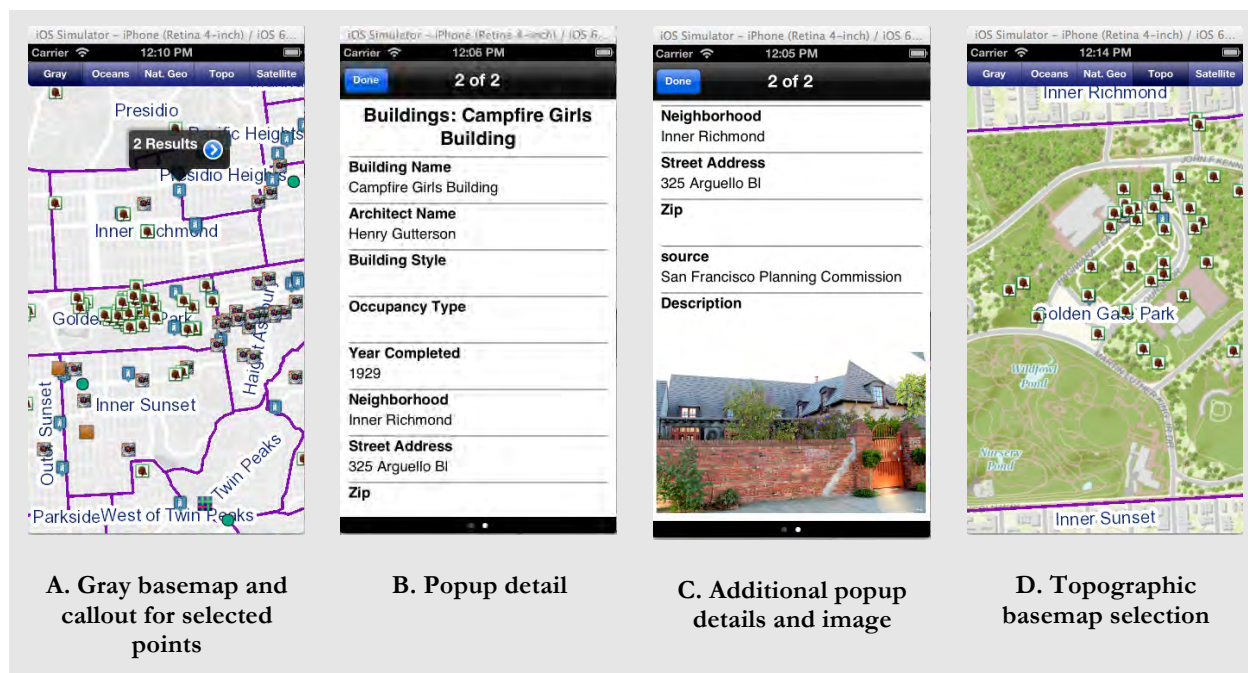
Figure 21 Native mobile application with popup display and basemap picker

Future development of the application could add a legend display and layer control. Additional functionality could add identify and zoom to current location, search art and building data for a term, and submit a new building or feature. The application could also be targeted for iPad displays. Android native client development would make the art data available to a large segment of the mobile market.

5.9 Summary of Functionality Differences Between Clients

Table 26 provides a summary of functionality across the different SFPAM clients. Web maps (SFPAM and AGOL) do not require an ArcGIS account, but mobile applications do. Only AGOL web maps and Collector can provide directions to a location. The SFPAM web client doesn't have feature-editing capability, but the other client interfaces have editing enabled for both AGOL feature services and backend services. Only the SFPAM web client displays social media, displayed as clustered points or a heat map.

AGOL provides filtering by attribute field. Web maps can display Stamen Design web tile layers, share the map configuration as a URL, render HTML fields for popup display, and post the map to social media such as Twitter or Facebook. AGOL and ArcGIS for mobile can select multiple points through buffering and display them in popups. The SFPAM client only has this functionality for social media layers. All clients except the SFPAM can upload images as attachments.

Table 26 Comparison of functionality differences between clients

Functionality	SFPAM web client	AGOL web maps	ArcGIS for Mobile	Collector for Mobile
ArcGIS user account required to use map	N	N	Y	N/A
ArcGIS for Organizations account required to use map	N	N (except for admin map)	Any ArcGIS account type	Y
Directions to selected location	N	Y	N	Y
Coded value domain value instead of code automatically displayed	N	In popups but not table view	N	N
Editing/ Display of AGOL feature services	N	Y	Y	Y
Editing of backend features	N	Y admin user only	Y admin user only	Y admin user only
Extent always resets to San Francisco	Y	N	N	N
Feature clustering or heat map	Y (Social media only)	N	N	N
Filtering by attributes	N	Y	N	N
HTML rendering in popups	Y	Y	N	N
Image uploading	N	Y	Y	Y
Multiple selection of points and display in popups	Y (Social media only)	Y	Y	N
Share map as URL or to social media	Y	Y	N	N
Social media layers	Y	N	N	N
Stamen Designs basemap layers	Y	Y (as layers, not basemaps)	N	N

Functionality differs across client types. Additional functionality can be added to the SFPAM client and the native pilot application through future work.

Chapter 6: Discussion

This chapter discusses the data used in the San Francisco Public Art Map (SFPAM). The first

section provides a detailed assessment of datasets representing the three levels of curated data as

well as a general assessment. The second section looks at future ways to improve data quality.

6.1 Data Assessment

This section assesses the data quality of the primary institutional datasets, a selection of

waymarking.com features, and a random selection of Instagram features. The SFAC dataset is

compared to control points from the Waymarking.com peer reviewed VGI. These control points are

also compared with GPS readings from an iPhone. The Instagram data is reviewed for content

quality. Finally all datasets are reviewed from a KDC perspective.

6.1.1 Institutional Datasets

The primary institutional datasets are provided by the SFAC and SFPC. While the SFAC

consists of publicly funded art and monuments, the SFPC datasets is made up of building

landmarks, POPOS, and POPOS art. Benefits of GI listed by Craglia and Nowak (2006) include

greater access to information, more transparent and accountable governance, improved

empowerment and participation, citizen goodwill, and quality of life. Including the SFAC and SFPC

datasets in the SFPAM makes information more visible. In addition, the public can verify whether

POPOS and POPOS art are conforming to government mandates regarding accessibility. New

buildings in downtown San Francisco are required to set aside a certain portion of the building

footprint for open space and art. Can the space and artwork be found and visited during stated

hours?

6.1.1.1 SFPC Datasets

The SFPC datasets were produced by a GIS administrator and consist of POIs associated with geocoded addresses. Information embedded in the original KML HTML was extracted to map unstructured content to fields such as name, architect or artist, completion date, address, and description. Field information was not consistently available across points. The geocoded addresses are generally adequate for finding landmarks and several of the POPOS. Some landmarks consist of more than one address, architect, and building completion date, so a choice needed to be made for the relevant field and other information noted elsewhere. Additional wayfinding instructions were required for some POPOS features as they are located within a building or on a rooftop and are not casually found. Art POIs were geocoded by address. If a POPOS contained multiple artworks, they were described and represented by a single point. The art POPOS would be better served by being mapped to actual locations as well as providing building address and location descriptions. This will be addressed in future data quality improvements. According to the KDC components, time is unspecified. Contents consist of unstructured HTML, which can be extracted into fields, and one or more images. Place is composed of an address, coordinates, additional directions, and images.

6.1.1.2 SFAC Dataset

The SFAC art collection has over 4000 items (Wright and Harmanci 2011), making the organization one of the largest administrators of public art in the country. Little money is available for management and maintenance of the collection, and the organization is uncertain of the actual inventory or details such as location for all the pieces. This confusion is reflected in the publicly available dataset. The SFAC dataset is the primary source of information for publicly funded art POIs, but the data is problematic. Neither detailed descriptions, nor image URLs are included in the

dataset. The dataset contains multiple entries for the same art POI. Most challenging is the spatial accuracy of the entries.

The City of San Francisco is divided politically into 11 districts. Based on the brief location description included in the SFAC dataset, a district was assigned to each art POI. Each POI's assigned district was compared to the actual district. 151 points, or 22 percent, were not located in their described district.

Figure 22 shows the distribution of collocated art POIs for the SFAC art dataset. There are 157 locations for 689 art pieces. Only 101 locations are associated with one art piece. Three locations account for over 300 pieces of art. One location containing 123 art works is a hospital campus with restricted access to all but a handful of pieces. The ninety-three San Francisco Airport art pieces were collocated despite the airport's consisting of multiple terminals. Art POIs are located in publicly accessible locations, private offices, and passenger-only locations past security. Ninety-two art pieces are collocated by SFAC's headquarters. A review of each art piece's assigned district reveals that most of the points belong in other districts.
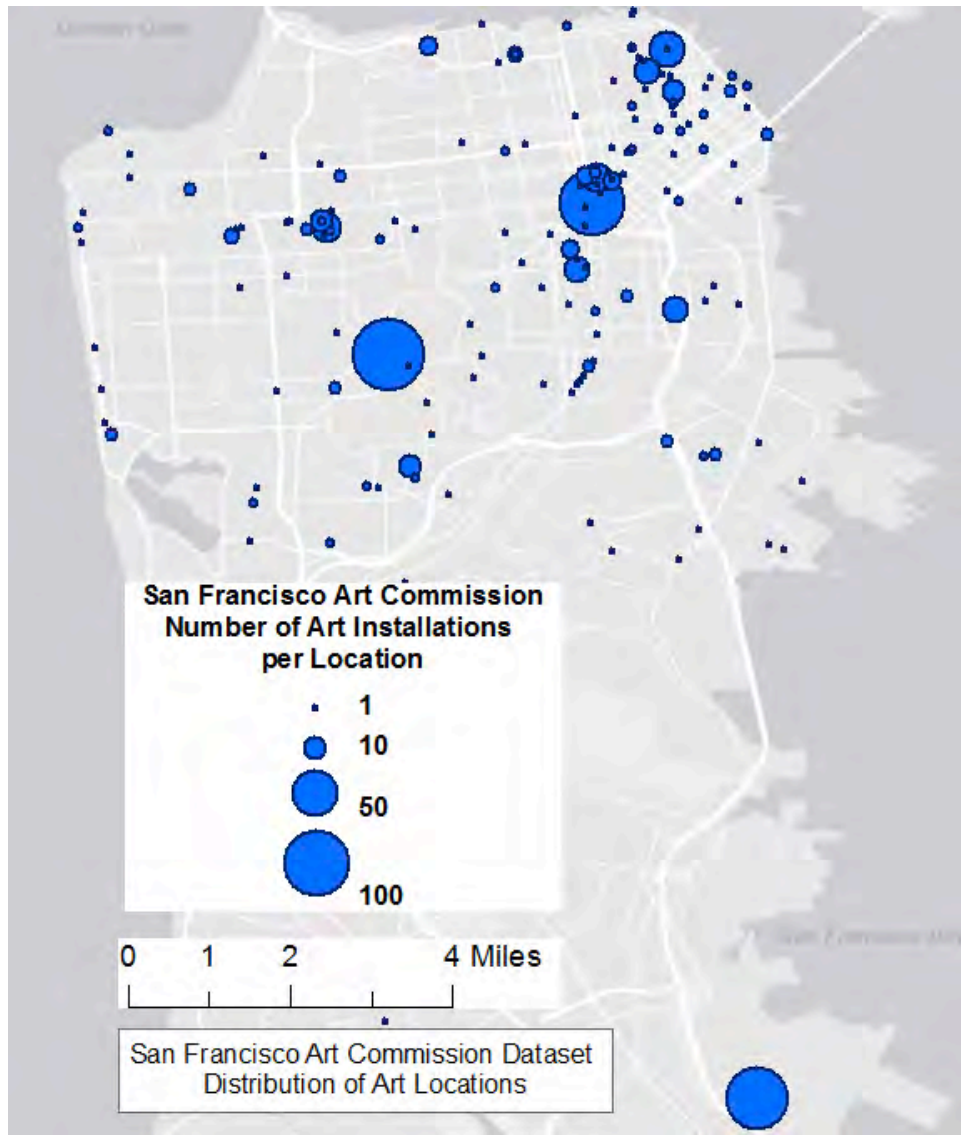
Figure 22 Distribution of SFAC art installations per location

The comparison of stated district with the actual placement of points as well as the high number of collocated points indicate there are positional accuracy problems with the SFAC dataset. It is unclear how the dataset creator derived point locations. The section following looks at a subset of points and compares them to VGI.

6.1.2 Peer Reviewed VGI as Control Points

Waymarking.com features represent landmarks of interest to members of Waymarking.com. A user submits a feature that has been geolocated using a GPS device and includes information such as an image, title, and other background information. The user also categorizes the submission. Another member of Waymarking.com reviews the submission for approval to the category. One drawback of this system is that multiple entries for the same landmark can be submitted by using different categories. A statue of a lion might show up in the database twice, once categorized as a lion statue and once categorized as a Smithsonian item, because two different people submitted entries to two different categories, each with a different reviewer. The SFPAM waymarking.com dataset was created by extracting KML files from the Waymarking website. Features were chosen for the dataset based on whether they represented public art such as monuments, sculptures, murals, street art, or other objects of interest. Multiple KML files were combined into a features set and fields extracted from the unstructured HTML text. Additional analysis of content provided additional field values. Duplicates were removed as part of the data mapping process.

A review of art features indicated an overlap between the SFAC dataset and the Waymarking.com dataset. A high-density area for public art POIs was selected to provide a sample set to compare positional accuracy of the public art dataset versus Waymarking.com peer reviewed VGI. The VGI points were also compared to locations captured by an iPhone to see how closely the points matched. This provides information on how well geolocated social media captured by phone potentially compares to GPS, as well as verifies whether the Waymarking.com VGI points were close to the actual landmarks.

6.1.2.1 Comparison of SFAC Sample Data Points Location to Waymarking.com VGI

A high-density area for public art POIs was selected to provide a sample set to compare

positional accuracy of the public art dataset versus Waymarking.com peer reviewed VGI. Twenty-

four GPS data points representing monuments and artwork in Golden Gate Park's Music

Concourse were mapped using VGI from Waymarking.com. The corresponding twenty-two data

points from the SFAC were identified and mapped. Figure 23 shows the overall location and

discrepancy of the two sets of data points, while Figure 24 shows the Music Concourse in greater

detail.
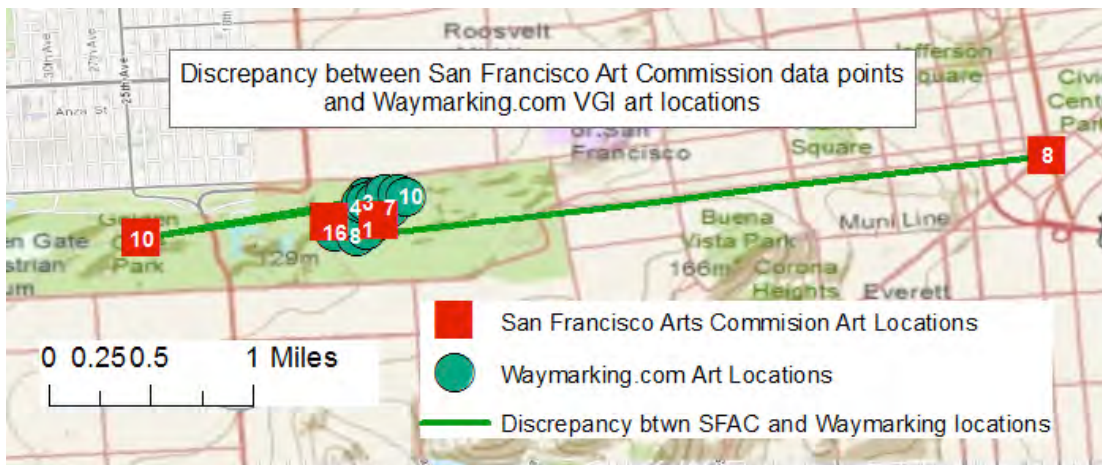
Figure 23 Discrepancy between SFAC data points and Waymarking.com VGI

Several things are immediately apparent: while there are twenty-two SFAC POIs, only four

are represented graphically, and several points are more than a mile from the Music Concourse.
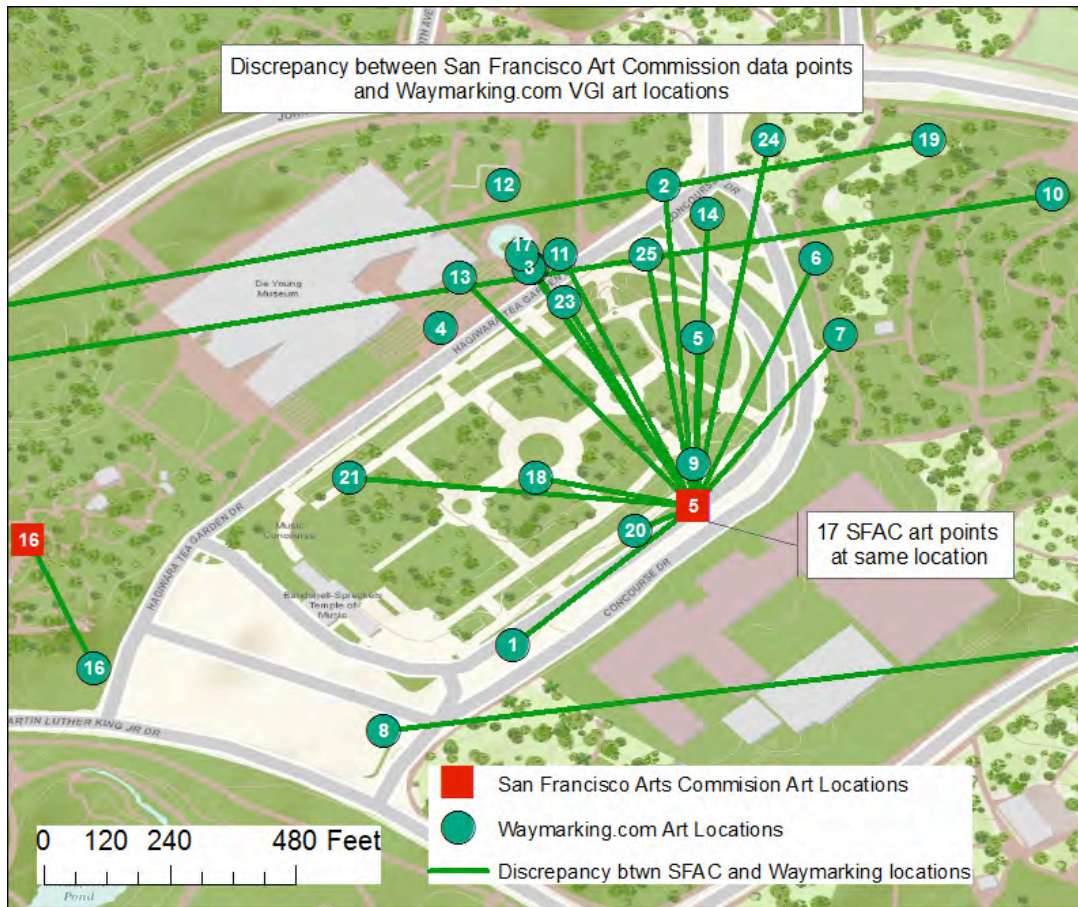
Figure 24 Music Concourse detailed view

Table 27 shows the calculated distance in feet between corresponding datasets for each applicable point. The average distance between corresponding points excluding the three points over a mile away was 456 feet. The closest SFAC point to a Waymarking.com point was 101 feet. Feature 8 was 2.7 miles away, while features 10 and 19 were one mile away. Seventeen of the SFAC points were located at the same coordinates as Feature 5.

Table 27 Distance between Waymarking.com, iPhone locations, and SFAC locations.

Marker ID	Name of Point of Interest	Discrepancy between Waymarking and SFAC Locations in Feet	Discrepancy between Waymarking and iPhone Locations in Feet
1	Beethoven	382	57
2	Cervantes Monument	613	27
3	Dor vase (La poeme de la vigne)	519	11
4	Drawn Stone - Andrew Goldsworthy	N/A	137
5	Francis Scott Key	320	14
6	General John Pershing	508	8

Marker ID	Name of Point of Interest	Discrepancy between Waymarking and SFAC Locations in Feet	Discrepancy between Waymarking and iPhone Locations in Feet
7	Goethe (1749-1832) and Schiller	396	11
8	Giuseppe Verdi	(2.7 miles) 14283	29
9	Hearst Fountain	N/A	13
10	John McLaren	(1 mile) 5521	N/A
11	Lion	521	10
12	Lion Watching	N/A	20
13	Navigators Sundial	563	42
14	Padre Junipero Serra	557	19
16	Pioneers From Japan Memorial	263	6
17	Pool of Enchantment	547	6
18	Rideout Fountain	246	33
19	Robert Burns	(1mile) 5358	N/A
20	Robert Emmet	101	8
21	Roman Gladiator	526	76
22	Sphinx	517	31
23	The Apple Cider Press	436	15
24	Thomas Starr King	708	18
25	U. S. Grant	486	15
	Average discrepancy in feet	**1589**	**28**
	Average discrepancy excluding #4 for iPhone and #s 8, 10, and 19 SFAC	**456**	**22**

6.1.2.2 Comparison of iPhone Data Collection to Waymarking.com VGI

Since mobile devices are commonly used to generate social media VGI, a mobile device was used to create data points for comparison with Waymarking.com's peer reviewed VGI. Twenty-two data points were captured in the Music Concourse using an iPhone 4s and the EveryTrail Pro application. Figure 25 shows the discrepancy iPhone data points and the Waymarking.com data points and Table 27 shows the distance. The furthest distance between corresponding points was 137 feet. Since the sculpture in question, feature 4, spans a distance greater than the discrepancy, the distance should be dropped from the average. The average discrepancy between iPhone coordinates and Waymarking.com coordinates, excluding feature 4, was twenty-two feet. Standing on the opposite side of a large statue could easily change the results by several feet.
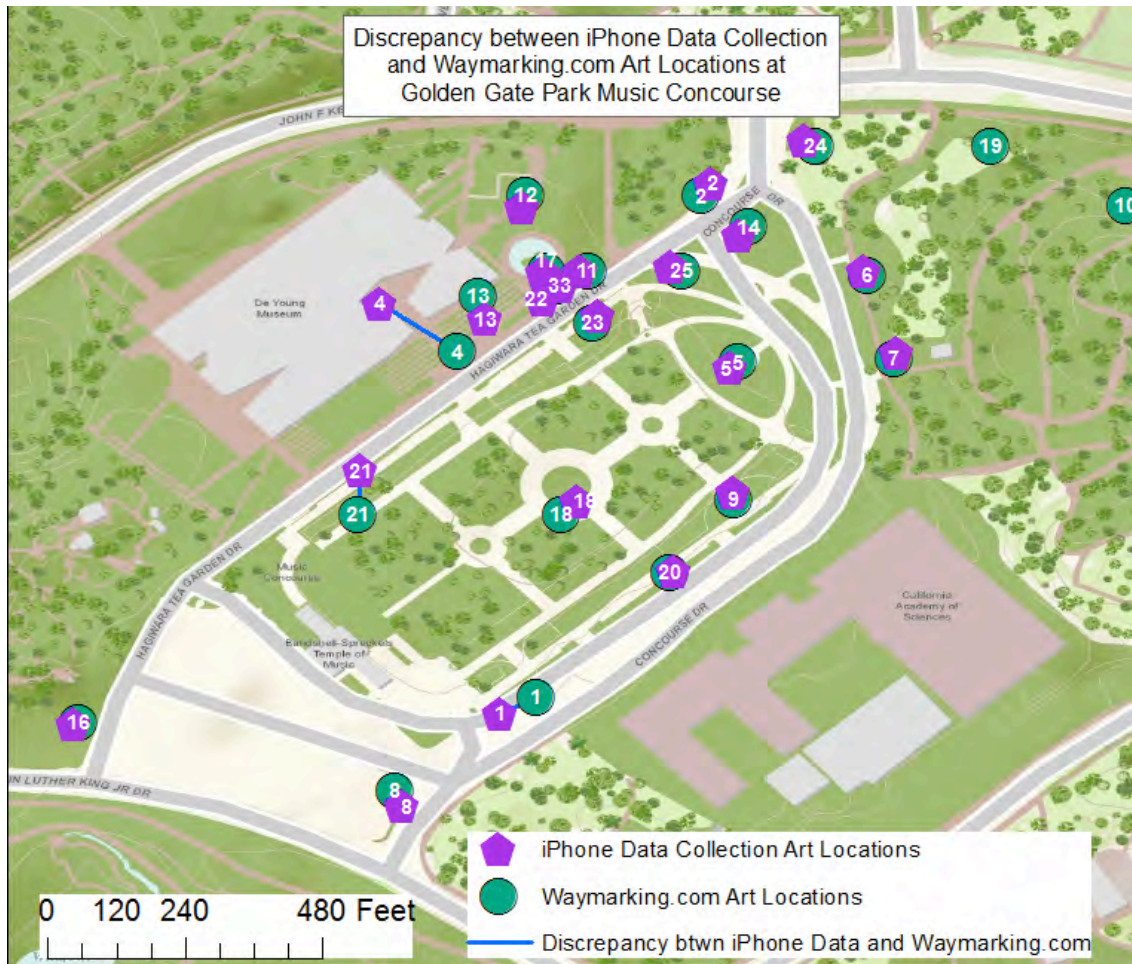
Figure 25 IPhone data collection vs. Waymarking.com VGI

6.1.3 Analysis of Instagram Sample Set for Relevant Content

The Instagram API does not provide the capability to search using a location bounding box and tag. The challenge for using this social media stream as a data source for public art was creating a search to return relevant art images located in San Francisco.

Using the tag "sfart" as shorthand for San Francisco art, 1614 geolocated images were retrieved from instagram.com on 10/3/2013. The images were mapped and 1582 of the images were within the greater San Francisco Bay Area. Only thirty-two images (2 percent) were located outside the area. 1052 (65 percent) of the images were located within the City of San Francisco. The tag

"sfart" returned relevant geographically tagged data despite the handicap of not being able to specify a bounding box as part of the search term.

The Instagram data was analyzed for appropriate content to answer the question, "How many images are of publicly accessible art, such as murals, street art, or publicly funded art?" A randomizing program, random.com, was used to generate a random ID list of 105 images representing a 10 percent sample set of the images within San Francisco. The images were reviewed and categorized as art, galleries, or personal. The art classification indicated an image was publicly accessible. Images classified as galleries comprised pictures from art galleries, museums, and fairs. These images may be time sensitive or require admission, but contain pictures of art. The remaining images consisted of pictures of people, food, personal artwork, or other content not relevant to publicly accessible art. Table 28 shows the results.

Table 28 Instagram Images by Category

Category	# of Images	% of Images
Art	67	64%
Galleries	24	23%
Personal	14	13%

Almost two thirds of the image content was of publicly accessible art, with an additional 23 percent being art related but restricted by time or venue. Only 13 percent of the sample content was not relevant for the purposes of documenting public art.

6.2 Summary of Primary Datasets using the KDC Framework

The primary datasets were evaluated using the KDC components of place, time, and content. Datasets with features and locations that were inferred from websites or PDFs, such as UCSF, were not included. Table 29 shows how the datasets map to each component. Place was assessed by evaluating whether the dataset features for art or buildings contained accurate

coordinates, additional text describing the place, or directions to the location. When assessing social

media, only features with coordinates were considered. A "Y" value indicates that the component

was always present for features; an "N" value indicates the component was never present; and "S"

indicates the component was sometimes included with features. Time represents the time and date

that the feature information was collected. Content was divided into title or name for a feature; the

inclusion of an image showing the feature; and the name of the artist or architect. Many of the

datasets have additional content, but these are minimum fields of primary interest. Images could also

be considered a component of place as images provided important waymarking clues.

Table 29 Dataset evaluation using KDC framework

Dataset Source	Curation Level	Place			Time	Content			Comments
		X,Y	Direc-tions	Accurate	Date Verified	Title/Name	Image	Artist	
City College of San Francisco	Inst	Y	Y	Y	N	Y	Y	Y	Contains additional content.
San Francisco Arts Commission	Inst.	Y	Y	S	N	Y	N	Y	Contains additional content.
Landmarks and Buildings (SFPC)	Inst.	Y	Y	Y	N	Y	Y	S	
POPOS and POPOS art (SFPC)	Inst.	Y	Y	S	N	Y	Y	S	Accurate when coordinates combined with location.
San Francisco Mural Arts	Admin (VGI)	Y	N	S	N	Y	Y	N	Artist names at source website
Waymarking.com	Admin (VGI)	Y	S	Y	Y	Y	Y	S	
Flickr	Social	Y	S	S	Y	S	Y	S	
Instagram	Social	Y	S	S	Y	S	Y	S	
Panoramio	Social	Y	S	S	Y	S	Y	S	
YouTube	Social	Y	S	S	Y	S	Y	S	

The assessment shows that no single dataset contains features with all components as

defined. The SFAC dataset is the only one with no images. The most spatially accurate datasets are

Waymarking.com and SFPC's landmarks and buildings. The POPOS datasets are accurate when coordinates, location, and images are combined to provide context as to where in a building art or open space is located. Only social media datasets provide a verification date for when the feature data was captured. Social media sometimes includes location information, feature names or titles, and artist names, but the details are unstructured.

6.2.1 Data Assessment Summary

Analysis of the SFAC institutional public art dataset reveals flaws with positional accuracy for many of the POIs. Useful data for engaging users and providing waymarking clues such as visual images or descriptions is missing. There are also many other publicly accessible art works within San Francisco.

The iPhone data capture simulates the geolocation accuracy possible for VGI images submitted to social media sites. The iPhone feature locations were within close visual range to the peer-reviewed VGI GPS locations for features. This suggests that art POIs from reviewed VGI as well as social media sources can provide more accurate location for features than the SFAC dataset. While VGI may not have the same attributes as an institutional dataset—such as title, artist, or medium—VGI can complement and supplement institutional datasets with images of art features and greater location accuracy. A review of the Instagram data images shows that search terms can be refined to return a high percentage of relevant images.

No single dataset meets the KDC components of place, time, and content for every feature. VGI improves the overall accuracy of the application and provides guidance for correcting institutional data. Mapping social media provides a dynamic set of art data points that change daily and provides a glimpse of which public art is actually engaging the public.

Chapter 7: Conclusions and Future Directions

This chapter draws conclusions about the SFPAM and looks at future directions to improve data quality and the application.

7.1 Conclusions

The thesis answers the proposed research questions. The sections are divided by research question.

7.1.1 How can a comprehensive, interactive, dynamic map of public art and architecture for San Francisco be built from disparate data sources?

The San Francisco Public Art Map is a comprehensive, interactive, dynamic map that integrates multiple kinds of curated data to provide San Francisco public art and architecture information to citizens for free. The Esri PIM was transformed from a disaster map to a public art map. New functionality incorporated Stamen Design web tiles for basemap options and added Panoramio and Instagram to social media layer options. The administrator can easily add new layers to the application through configuration changes. Data and location quality can be improved incrementally without impacting the application.

AGOL maps and services were created so that users can contribute art or building features without modifying the backend database; upload images for contributed art; and have a mobile solution using Esri's ArcGIS for Mobile or Collector. The functionality available to the user varies by client.

7.1.2 What is a common, extensible data model for public art and architecture?

A data model for art and buildings was designed and implemented in ArcMap using an ArcSDE SQL Server database. Data from multiple sources was mapped to the data model. The data

model is extensible to implement additional functionality. If art is removed or destroyed the database serve as a historic repository by saving information and images about the feature.

7.1.3 How can social media be used to provide information about San Francisco's public art?

Institutionally curated data from the SFAC and SFPC was integrated with administratively curated, peer-reviewed VGI from SF Mural Arts and Waymarking.com to create a database of art POIs and architecture. By publishing data as REST services using ArcGIS Server, a variety of application clients can consume the data. The web application was configured to dynamically acquire art POIs for San Francisco from Instagram, Panoramio, Flickr, and YouTube. Mapping art using social media is a unique implementation in an art application.

7.1.4 How can institutional, peer-reviewed VGI, and social media data sources for San Francisco public art and architecture be evaluated for quality?

The requirements for accuracy and data quality for art and building POIs were discussed and defined. Evaluation of the different data layers showed that peer-reviewed VGI from Waymarking.com could provide more accurate spatial data than institutional sources such as SFAC. Peer-reviewed VGI also provided images of POIs, while institutional data provided more attribute information. Social media sources such as Instagram complemented institutional and peer-reviewed data sources through focusing on street art and murals, providing a timestamp of when data was captured, and including images. The KDC framework provided a means of assessing different data sources and showed that each dataset had both strengths and limitations.

7.2 Future Directions for Improving Data Quality

Using the Lego metaphor, the different datasets can build a better inventory of San Francisco public art. Images from social media can be used as links to corresponding features in the

SFAC dataset. Overlapping images from Waymarking.com or SF Mural Arts can help correct the positional accuracy of the SFAC features. Flickr and Instagram features can be converted to permanent features and added to the backend database, as location and additional content are determined.

The primary tasks for data quality improvement are to: verify and update feature locations; to add image links and POI descriptions; to verify POI status, and to add new POIs. The building dataset should be expanded to include more examples of San Francisco architectural styles and interesting buildings.

Data quality can be improved through administrator efforts to compare datasets, to continue data extraction, and to remove or update POI fields. While the administrator can also collect and correct data in the field, the number of art and building POIs are more than a single person can track on a volunteer basis. Field data collection is time consuming. Both the Collector and ArcGIS for mobile applications drain an iPhone 4s battery within an hour. A more promising strategy is to recruit others to help with data improvement and collection.

The sections following look at different approaches for improving data quality using volunteers.

7.2.1 Recruiting and Training Community of Experts

One approach is to train a small number of volunteers to perform specific tasks. Tasks could take the form of researching image links for POIs and updating link and HTML fields with properly formatted URL references for the POIs. Volunteers could also fill in missing descriptions by researching a POI. With training, volunteers could relocate poorly placed POIs using location descriptions, Google Street View, Google Satellite view (for large sculptures), local knowledge, Internet information, or field research.

7.2.2 User Ratings and Feedback

Users can improve data quality through feedback and assessment (Grira, Bédard, and Roche 2010). Feick and Roche (2013) suggest methods such as user ratings and notes similar to Yelp or Trip Advisor. They argue that notes and ratings promote community learning, innovation, and communication as well as provide insights into, "how individuals and groups use VGI to reshape and redefine how places are represented and understood." The data model for the SFPAM is easily extensible to accommodate tables for users, ratings, and notes that can be linked to POIs. Functionality would need to be added to the client applications.

7.2.3 Gamification

Another approach to soliciting feedback and quality improvement is through gamification. The Android Ingress game (www.ingress.com) developed by Google's Niantic Labs is an augmented reality massively online multiplayer game. Landmarks such as public art, monuments, unique or historic buildings, libraries, transit stations, entrance signs for parks, and water towers function as energy portals. Factions battle to control landmarks and can suggest new portals or corrections to existing portals. The Niantic team reviews all user portal recommendations. Players must get physically close to the portals to benefit. One of the game's intentions is to get people outside and interacting with their environment. Google is likely using the game as a means to collect information about landmarks across the world. Carney (2012) speculates on various purposes for the data collection such as Google Maps improvement, Google Glass applications, and location-based advertising. The opening video for Ingress at www.ingress.com features multiple public artworks in San Francisco. Figure 26 shows a clip featuring the "*Double L*" sculpture by San Francisco's City Hall.
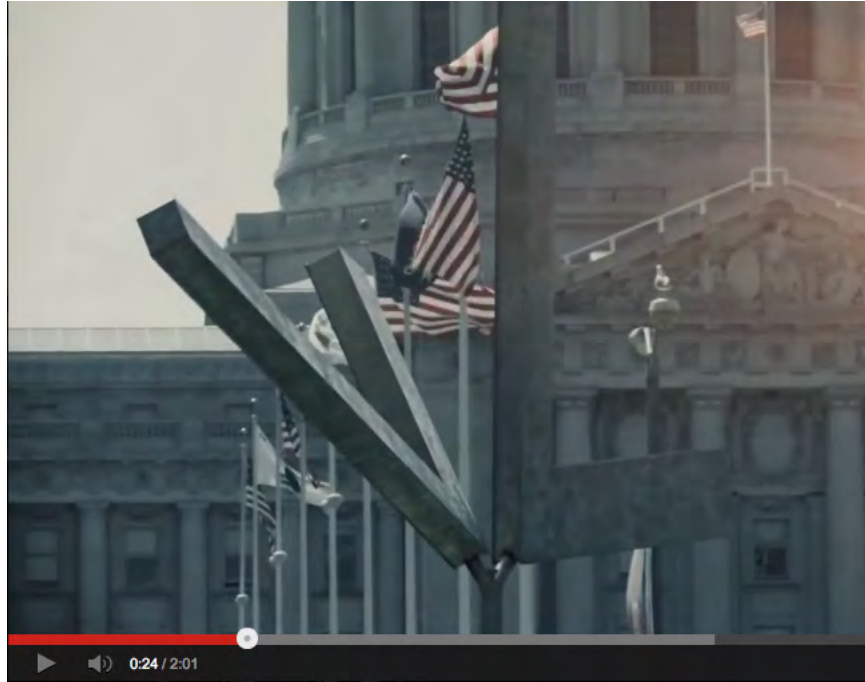
Figure 26 Screen capture from www.ingress.com of public art "portal" (last accessed 10 December 2013)

Figure 27 shows a description of a portal referencing "Cupid's Span," a sculpture in San Francisco. A title, image, and spatial location are captured for each landmark registered as a portal. A user submitting a new portal can also include a description of the portal's significance or history. Inaccurate titles for art as well as locations sometimes make it past the Ingress team review.

**Figure 27 Ingress portal identification for "Cupid's Span" from
http://www.ingress.com/intel (last accessed 10 December 2013)**

Users can also submit corrections for existing portal locations, images, titles, descriptions and

request removal of portals. As Carney (2012) notes, Google has made data collection a game and

convinced people across the world to volunteer for the work.

The New York Public Library (NYPL) also recently developed a program to extract building

polygons and attributes from scanned pages of 19th and 20th century historical atlases (Arteaga 2013).

Processing an atlas page of 55,000 polygons takes 23.5 hours of time, compared to three years for

volunteers to extract 170,000 polygons manually. The automated process generates errors, so the

library launched a program called Building Inspector (http://buildinginspector.nypl.org/ last

accessed 10 December 2013). The application crowdsources whether the generated building

polygons are correct. The website asks each user to inspect a building polygon to verify the accuracy

of the generated feature compared to the original atlas. At least three people are asked to vote on

each building with a Yes (outline matches), No (outline is not around a building), or Fix (outline

needs a little adjustment) response. If there is 75 percent or greater agreement on the polygon, the

building is removed from the inspection list.

Mauricio Giraldo Arteaga, the lead developer from the NYPL Labs, remarked in a private conversation, 7 November 2013, that the Building Inspector program response surpassed everyone's wildest expectation. In the first two weeks over 5000 people had voted 350,000 times on polygons. 63,000 out of 65,000 total polygons had received 75 percent agreement of three or more votes. NYPL Labs will provide more scanned maps for inspection and look at how they can crowd source fixing the polygons flagged for fixing.

Google draws on the appeal of playing a competitive team game with an evolving story line to collect data. The added appeal of Google's approach is people participate by physically engaging with landmarks. NYPL Labs leverages the popularity of the New York Public Library. The Building Inspector application provides a simple way to participate in quality control that appeals to people's interest in old maps, requires minimal training, and consists of a set of tasks that take only minutes.

7.3 Future Directions for the SFPAM Application

The SFPAM application can be improved and enriched in several ways. Functionality should be added to the www.sfpublicart.com web application to cluster and buffer backend data points similar to the way social media layers are handled. Clusters and buffered selections would then display multi-pane popups. Searching and display by attribute and navigation to a POI could also be implemented. Some changes can engage users to improve data quality through soliciting feedback.User profiles, comments, ratings, and artist tables could be added to the data model and database. The application could add functionality for users to provide feedback, view others' comments, and learn more about artists.

Twitter code could be refactored to include OAUTH authentication on the server side so that a user could log in to Twitter. Once a user logs in, Twitter can be searched for art tweets and the results displayed as a layer.

The mobile and tablet offering can be improved either by developing native applications for Android and iOS or by converting the web client code to responsive design. A Google Glass application potentially could consume REST services as JSON or KML and alert the wearer to public art or architecture nearby with feature details.

Finally, the data model can be shared as an extensible way of capturing public art and architecture. The web application code can be shared for public art use in other communities or adapted for other purposes to combine social media with institutional datasets. As backend data is reviewed and corrected, the information can be shared with organizations such as the SFAC so that their official dataset can be corrected. As art works are removed, the database becomes a historical repository by retaining information about removed art. Forging relationships with art administration agencies can lead to a partnership that benefits citizens interested in public art and architecture by making accurate, complete, and timely information readily available to those who want to discover the city's treasures.

References

Apple. 2013. iOS SDK 6.1, XCode 4.6. Cupertino, CA: Apple.

ArcGIS Server Development Team. 2010. Lessons learned developing a Web map for volunteered geographic information (VGI) and social media. http://blogs.esri.com/esri/arcgis/2010/11/04/lessons-learned-developing-a-web-map-for-volunteered-geographic-information-vgi-and-social-media/ (accessed 11 December 2013).

Arteaga, M. G. 2013. Historical map polygon and feature extractor. In *MAPINTERACT '13*. Orlando, FL,USA: ACM.

Barbier, G., R. Zafarani, H. Gao, G. Fung , and H. Liu. 2012. Maximizing benefits from crowdsourced data. *Computational and Mathematical Organization Theory* 18: 257-279.

Boulos, K., N. Maged, B. Resch, D. N. Crowley, J. G. Breslin, G. Sohn, R. Burtner, W. A. Pike, E. Jezierski, and K. Y. S. Chuang. 2011. Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples. *International Journal of Health Geographics* 10: 67-67.

Budhathoki, N. R., B. Bruce , and Z. Nedovic-Budic. 2008. Reconceptualizing the role of the user of spatial data infrastructure. *GeoJournal* 72: 149–160.

Carney, M. 2012. Google's Ingress is more than a game, it's a potential data exploitation disaster. In *PandoDaily*. http://pandodaily.com/2012/11/19/googles-ingress-is-more-than-a-game-its-a-potential-data-exploitation-disaster/ (accessed 11 December 2013).

Cartiere, C. 2008. *Coming in from the Cold: A Public Art History*. In The Practice of Public Art, ed. C. Cartiere and S. Willis, 7-17. New York: Routledge.

Chen, W. C., A. Battestini, N. Gelfand , and V. Setlur. 2009. Visual summaries of popular landmarks from community photo collections. 789-792. ACM.

Chrisman, N. R. 1984. The role of quality information in the long-term functioning of a geographic information system. *Cartographica,* 21: 79-87.

Connors, J. P., S. Lei , and M. Kelly. 2012. Citizen Science in the Age of Neogeography: Utilizing Volunteered Geographic Information for Environmental Monitoring. *Annals of the Association of American Geographers,* 102: 1267-1289. NewYork: ACM.

Cuff, D., M. Hansen , and J. Kang. 2008. Urban sensing: out of the woods. *Communications of the ACM*. 51 (3): 24-33. New York: ACM.

Dangermond, J. 2011. A 'New Geospatial Modality' - Interview with Jack Dangermond. In *Geospatial*

World, 14-22.

Elwood, S., M. F. Goodchild , and D. Z. Sui. 2012. Researching Volunteered Geographic
Information: Spatial Data, Geographic Research, and New Social Practice. *Association of*
American Geographers. Annals of the Association of American Geographers, 102 (3): 571-590.

Esri. 2013. ArcGIS API for JavaScript 2.7, ArcGIS For Mobile (iOS) 10.1.2, ArcGIS Online,
ArcGIS Runtime SDK for iOS 10.1.1, ArcMap 10.2, ArcMap 10,1 ArcServer 10.2. ArcServer
10.1., Collector for ArcGIS 10.2 (iOS), Public Information Map 2.0. Redlands, CA: Esri.

Feick, R. , and S. Roche. 2013. Understanding the Value of VGI. In *Crowdsourcing Geographic*
Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice, 15-29. Dordrecht:
Springer Netherlands.

Flanagin, A. J., and M. J. Metzger. 2008. The credibility of volunteered geographic information.
GeoJournal, 72 (3/4): 137-148.

Goodchild, M. F. (2007) Citizens as sensors: the world of volunteered geography. *GeoJournal,* 69 (4):
211-221.
——— 2008. Commentary: whither VGI? *GeoJournal,* 72 (3): 239-244.

Goodchild, M. F. , andJ. A. Glennon (2010) Crowdsourcing geographic information for disaster
response: a research frontier. *International Journal of Digital Earth,* 3 (3): 231-241.

Hall, G. B., R. Chipeniuk, R. D. Feick, M. G. Leahy , andV. Deparday (2010) Community-based
production of geographic information using open source software and Web 2.0. *International*
Journal of Geographical Information Science, 24 (5): 761-781.

Harvey, F. 2013. To Volunteer or to Contribute Locational Information? Towards Truth in Labeling
for Crowdsourced Geographic Information. In *Crowdsourcing Geographic Knowledge: Volunteered*
Geographic Information (VGI) in Theory and Practice, 31-42. Dordrecht: Springer Netherlands.

Hein, H. 2006. *Public Art: Thinking Museums Differently*. Lanham, MD.: AltaMira Press.

Howe, J. 2006. The Rise of Crowdsourcing. *Wired.*
http://www.wired.com/wired/archive/14.06/crowds.html (accessed 11 December 2013).

Hwang, S. , andD. Yu (2012) GPS Localization Improvement of Smartphones Using Built-in
Sensors. *International Journal of Smart Home,* 6 (3): 1-8.

Kennedy, L., M. Naaman, S. Ahern, R. Nair , and T. Rattenbury. 2007. How Flickr helps us make
sense of the world: context and content in community-contributed media collections.
Proceedings of the 15th *international conference on multimedia,* 631-640. ACM.

Knight, C. K. 2008. *Public Art: Theory, Practice, and Populism*. Malden, MA: Blackwell.

Liu, S. B. 2011. Grassroots heritage: A multi-method investigation of how social media sustain the living heritage of historic crises. Doctoral Thesis. University of Colorado at Boulder.

Lunden, I. 2012. Nielsen: Smartphones Used By 50.4% Of U.S. Consumers, Android 48.5% Of Them. In *TechCrunch*. (accessed 11 December 2013).

Microsoft Corporation. 2010. Microsoft SQL Server 2008 R2. Redmond, WA: Microsoft Corporation.

Miles, M. 2008. Critical Spaces: Monuments and Changes. In *The Practice of Public Art,* ed. C. Cartiere and S. Willis, 66-90. New York: Routledge.

———. 2009. *Public Art. Encyclopedia of Urban Studies. SAGE Publications, Inc.* Thousand Oaks, CA: SAGE Publications, Inc.

Milholland, N. , and E. Pultar. 2013. The San Francisco Public Art Map Application: Using VGI and Social Media to Complement Institutional Data Sources. In *MAPINTERACT '13*. Orlando, USA: ACM.

Mooney, P., H. Sun, and L. Yan. VGI as a dynamically updating data source in location-based services in urban environments. In *Proceedings of the 2nd annual workshop on ubiquitous crowsourcing,* 13-16. ACM.

Newsam, S. 2010. Crowdsourcing What Is Where: Community-Contributed Photos as Volunteered Geographic Information. *IEEE Multimedia,* 17 (4):36-45.

Phys.org. 2013. Android smartphones rise as iPhone slips, IDC finds. *Phys.org.* http://phys.org/news/2013-08-android-smartphones-iphone-idc.html (accessed 11 December 2013).

Pultar, E., M. Raubal, T. J. Cova , and M. F. Goodchild. 2009. Dynamic GIS Case Studies: Wildfire Evacuation and Volunteered Geographic Information. *Transactions in GIS,* 13: 85-104.

Raubal, M., Winter, S. 2002. Enriching Wayfinding Instructions with Local Landmarks. In *Second International Conference, GIScience*, 243-259. Boulder, CO: Springer.

Roche, S. 2011. De la cartographie participative aux WikiSIG. In *Les SIG au service du développement territorial,* ed. O. Walser, L. Thévoz, F. Joerin, M. Schuler, S. Joost, B. Debarbieux, and H. Dao, 117–129. Lausanne: Presses polytechniques et universitaires romandes.

Rosoff, M. 7 February, 2013. Smartphone market share on public transit in San Francisco. *CITEWorld.* http://www.citeworld.com/mobile/21403/smartphone-market-share-public-transit-san-francisco (accessed 11 December 2013).

Smith, M. L., R. Spence, and A. T. Rashid. 2011. Mobile Phones and Expanding Human Capabilities. *Information Technologies & International Development*, 7 (3): 77-88.

Tsou, M.-H. , andM. Leitner (2013) Visualization of social media: seeing a mirage or a message? *Cartography and Geographic Information Science,* 40 (2): 55-60.

Wright, A. and R. Haranci. 2011. City's art is a victim of neglect, damage and loss. *The New York Times.* http://www.nytimes.com/2011/04/17/us/17bcart.html?pagewanted=all&_r=1& (accessed 11 December 2013).

Appendix

A. Art Application Assessment

This section contains detailed information for reviewed applications. Section A.1 contains

the URL links for each reviewed application. Section A.2 lists the client and mapping platforms for

each application. Section A.3 contains details on how each application uses public art information

and VGI. Section A.4 describes the basic mapping functionality for each application.

A.1 Art Application URLs

The URLs for application websites are shown below. If the application runs only on a native

client, a link to the Google Play store or iTunes is included. Applications starred with an "*" do not

run or have had their web page removed. The URLs were last accessed 11 December 2013.

Name	URL
1. Art and Architecture – San Francisco	http://www.artandarchitecture-sf.com/wp-content/uploads/map2.php
2. Art Around	http://theartaround.us
3. Art Around SF*	http://laughingsquid.com/artaround-sf-an-app-for-finding-public-art-in-san-francisco/
4. Art Basel Miami Beach	https://play.google.com/store/apps/details?id=com.insideguidance.artbasel.miamibeach&hl=en
5. Art Guide	https://play.google.com/store/apps/details?id=com.mobileiq.artfund
6. ArtTrax Public Art	http://www.southdublin.ie/artsworks/map.aspx
7. Belfast Public Art Guide	https://play.google.com/store/apps/details?id=belfastPublicArt.main&feature=search_result#?t=W251bGwsMSwxLDEsImJlbGZhc3RRdWJsaWNBcnQubWFpbiJd
8. Belfast Murals Guide	https://play.google.com/store/apps/details?id=helloGridView.main&feature=more_from_developer#?t=W251bGwsMSwxLDEwMiwia GVsbG9HcmlkVmlldy5tYWluIl0.
9. Bristol Street Art Map	http://www.bristol-street-art.co.uk/map-of-bristol-street-art
10. Culture Now: Museum without walls	http://www.culturenow.org
11. Field Trip	http://www.fieldtripper.com
12. Fontly	http://font.ly
13. Gone Tomorrow SF	http://gonetomorrowsf.com/san-francisco-art-map/
14. Graffiti Mapper	http://graffitimapper.org
15. Hong Kong Art Guide	https://play.google.com/store/apps/details?id=com.easyapps.hkag
16. Laguna Beach Public Art Map	http://www.lagunabeachcity.net/cityhall/art/publicartmap.asp
17. ExperienceLA.com Public Art LA*	https://play.google.com/store/apps/details?id=eph.crg.xla.android&feature=search_result#?t=W251bGwsMSwxLDEsImVwaC5jcmcueGxhLmFuZHJvaWQiXQ.
18. Mural Locator	http://murallocator.org/
19. NYC Subway Art*	https://play.google.com/store/apps/details?id=com.appbuilder.u55951p120064&hl=en
20. PDX Art Trekker	https://play.google.com/store/apps/details?id=com.SparkChicks.PDXArtTrekker

21.	Privately-Owned Public Open Space (POPOS) and Public Art	http://www.sf-planning.org/index.aspx?page=3339
22.	Project Neon	http://projectneon.tumblr.com/
23.	Public Art Finder	http://sf.publicartapp.mobi
24.	Public Art Fund	http://www.publicartfund.org/
25.	Public Art Locations *	http://www.artmapper.org/
26.	Public Art in Public Places	https://sites.google.com/a/publicartinpublicplaces.info/public-art-in-public-places-project/
27.	Public Art Omaha	http://publicartomaha.org/search/by_location
28.	Public Art PDX	http://publicartpdx.com/
29.	San Francisco Mural Project	https://maps.google.com/maps/ms?ie=UTF8&t=h&oe=UTF8&msa=0&msid=105626627087097777761.000491082eb7e90c594eb&dg=feature
30.	San Francisco Civic Art Finder	https://itunes.apple.com/us/app/san-francisco-civic-art-finder/id531528632?mt=8
31.	San Francisco Landmarks Google Map	http://www.sf-planning.org/index.aspx?page=3313
32.	San Francisco Public Art – SF Art*	https://play.google.com/store/apps/details?id=air.com.SFART.app&feature=search_result#?t=W251bGwsMSwxLDEsImFpci5jb20uU0ZBUlQuYXBwIl0.
33.	SF Arts.Org	http://www.sfarts.org
34.	SF Mural Arts	http://www.sfmuralarts.com
35.	SF Public Art	https://itunes.apple.com/us/app/sf-public-art/id580998955?mt=8
36.	SFAC Public Art	http://www.sfartscommission.org/pubartcollection/pubart-projects/2008/10/21/public-art-projects-map
37.	SF Street Art Map	Street art locations primarily in Haight Ashbury, San Francisco
38.	SF Street Art	600 photos documenting 250 sites in San Francisco
39.	Street Art SF	Street Art Photos and locations - no map available
40.	SF's Secret Spaces and Hidden Oases from SPUR	Includes POPOS
41.	STQRY	Art, culture, and historic sites.
42.	The Living New Deal	New Deal public works projects in the US. More than public art and architecture. 322 projects for San Francisco some of which are art and architecture.
43.	Tram Art*	Art in the vicinity of Amsterdam's trains
44.	1:AM Mobile Application	Archive of street art movement and community of street art enthusiasts.

A.2 Art Application Client and Mapping Platforms

Name	Client	Mapping Platform
1. Art and Architecture – San Francisco	Web	Google
2. Art Around	iOS, Android, Web	Google
3. Art Around SF*	N/A	N/A
4. Art Basel Miami Beach	Android	Google
5. Art Guide	Android	Google
6. ArtTrax Public Art	Web , iOS, Android	Google
7. Belfast Public Art Guide	Android	Google
8. Belfast Murals Guide	Android	Google
9. Bristol Street Art Map	Web	Google
10. Culture Now: Museum without walls	iOS, Android, Web	Google
11. Field Trip	iOS, Android	Google
12. Fontly	iOS, Android, Web	Google
13. Gone Tomorrow SF	Mobile friendly web version	Google

Name	Client	Mapping Platform
14. Graffiti Mapper	IOS, Web	Leaflet, Open Street Maps
15. Hong Kong Art Guide	Android	Google
16. Laguna Beach Public Art Map	Web	Google
17. ExperienceLA.com Public Art LA*	Android, Web	Google
18. Mural Locator	Web	Google
19. NYC Subway Art*	Android	Unknown
20. PDX Art Trekker	Android	Google
21. Privately-Owned Public Open Space (POPOS) and Public Art	Web	Google
22. Project Neon	iOS	Google
23. Public Art Finder	Web	Google
24. Public Art Fund	Web	Google
25. Public Art Locations*	Web	Google
26. Public Art in Public Places	Web	Google
27. Public Art Omaha	iOS, Android, Web	Google
28. Public Art PDX	iOS, Web	Google
29. San Francisco Civic Art Finder	iOS	Google
30. San Francisco Landmarks Google Map	Web	Google
31. San Francisco Mural Project	Web	Google
32. San Francisco Public Art – SF Art*	Android	Google
33. SF Arts.Org	iOS, Android, Web	Mapquest
34. SF Mural Arts	IOS, Web	Google
35. SF Public Art	iOS	Google
36. SFAC Public Art	Web	Google
37. SF Street Art Map	Web	Google
38. SF Street Art	iOS	Google
39. Street Art SF	Web	N/A
40. SF's Secret Spaces and Hidden Oases from SPUR	iOS, Web	Apple
41. STQRY	iOS, Android,, Web, Windows	Mapbox
42. The Living New Deal	Web	Google
43. Tram Art*	Android	Google
44. 1:AM Mobile Application	iOS	Google

A.3 Art Location Data, VGI and Social Media

Name	Public Arts Commission layer(s) or data	Art Events	VGI: User Contributed Art Locations	VGI: User comments (C), ratings (R), photos (P), flag for offensive (F), like (L)	VGI: User generated content through social media stream	Review of user art submissions	Share art location/ event with social media - Twitter, Foursquare, Facebook, g+
1. Art and Architecture – San Francisco	Y includes subset of public art commission POIs.	N	N	C (on blog entry)	N	N	Y (can share blog entry)
2. Art Around	Unknown	Y	Y	C, P	N	Y	N
3. Art Around SF*	N	N/A	N/A	N/A	N/A	N/A	N/A
4. Art Basel Miami Beach	N	Y	N	N	N	N	N
5. Art Guide	Y	Y	N	N	N	N	N
6. ArtTrax Public Art	Y	N	N	N	N	N	N
7. Belfast Public Art Guide	Y	N	N	N	N	N	N

Name	Public Arts Commission layer(s) or data	Art Events	VGI: User Contributed Art Locations	VGI: User comments (C), ratings (R), photos (P), flag for offensive (F), like (L)	VGI: User generated content through social media stream	Review of user art submissions	Share art location/ event with social media - Twitter, Foursquare, Facebook, g+
8. Belfast Murals Guide	N	N	N	N	N	N	N
9. Bristol Street Art Map	Unknown	Y	Y	P	N	Y	N
10. Culture Now: Museum without walls	Y	Y	Y	N	N	Y	Twitter, Faceboook
11. Field Trip	Y	N	N	C, F	N	N	Twitter, g+
12. Fontly	N	N	Y	L, P	N	N	Twitter
13. Gone Tomorrow SF	N	N	N	C	N	N	Y (can share blog entry)
14. Graffiti Mapper	N	N	Y	P	N	N	N
15. Hong Kong Art Guide	N	Y	N	C	N	N	Fscebook
16. Laguna Beach Public Art Map	Y	N	N	N	N	N/A	N
17. ExperienceLA.com Public Art LA*	Y (subset)	N	N	Unknown	N	N	N
18. Mural Locator	N	Y	Y	C	N	Y	Twitter, Facebook, g+
19. NYC Subway Art*	N	N	Unknown	Unknown	N	Unknown	Unknown
20. PDX Art Trekker	Y	N	N	N	N	N	N
21. Privately-Owned Public Open Space (POPOS) and Public Art	N	N	N	N	N	N/A	N
22. Project Neon	N	N	N	R	N	N/A	Twitter, Facebook
23. Public Art Finder	Y	N	N	N	N	N/A	N
24. Public Art Fund	Y	Y	N	P	N	N/A	Twitter, Faceboook
25. Public Art Locations*	N	N	Y	P, Photo required for submission	Y, @PublicArtApp twitter hastag	N	N
26. Public Art in Public Places	Y	N	N	N	N	N/A	N
27. Public Art Omaha	Y	N	N	N	N	N/A	N
28. Public Art PDX	Y	N	Y	Adjust accuracy of location	N	Y	N
29. San Francisco Mural Project	N	N	N	N	N	N/A	N
30. San Francisco Civic Art Finder	Y	N	N	N	N	N/A	N
31. San Francisco Landmarks Google Map	N	N	N	N	N	N/A	N
32. San Francisco Public Art – SF Art*	Y	N	Unknown	Unknown	N	N/A	Unknown

Name	Public Arts Commission layer(s) or data	Art Events	VGI: User Contributed Art Locations	VGI: User comments (C), ratings (R), photos (P), flag for offensive (F), like (L)	VGI: User generated content through social media stream	Review of user art submissions	Share art location/ event with social media - Twitter, Foursquare, Facebook, g+
33. SF Arts.Org	Y (limited)	Y	Events	N	N	Y	Yahoo, Myspace, Deliscious, Twitter, Facebook, Digg, Google, Messenger, StumbleUpon, Moreemail
34. SF Mural Arts	Y	N	Y	C	N	Y	Twitter, Facebook, g+
35. SF Public Art	Y	N	N	N	N	N/A	N
36. SFAC Public Art	Y	N	N	N	N	N/A	Twitter, Pinterest, Facebook, g+
37. SF Street Art Map	N	N	Y	N	N	N	N
38. SF Street Art	N	N	N	N	N	N/A	Facebook, Twitter
39. Street Art SF	N	Y	Y	P	N	Y	Twitter, Facebook, g+
40. SF's Secret Spaces and Hidden Oases from SPUR	N	N	N	L, F	N	N	Facebook, Twitter
41. STQRY	Y	N	N	N	N	N	Facebook, Twitter
42. The Living New Deal	N	N	N	N	N	N	Facebook, g+, Twitter
43. Tram Art*	N	N	Unknown	Unknown	N	Unknown	Unknown
44. 1:AM Mobile Application	N	N	Y	C,R,F	N	N, unless flagged	Facebook, Twitter

A.4   Basic Mapping Functionality

Name	Map and location focused	Navigation	Search Functionality	Layer Control	Basemap Choices	Clustering of Points	Route Finder
Art and Architecture – San Francisco	N	Pan, Zoom	On blog site, not map	N	Y	N	N
Art Around	Y	Pan, Zoom	Y	N	Y	N	N
Art Around SF*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Art Basel Miami Beach	N	Pan, Zoom	Y	N	N	N	N
Art Guide	N	Pan, Zoom	Y	N	N	N	Y
ArtTrax Public Art	N	Pan, Zoom	N	N	N	N	Y
Belfast Public Art Guide	Y	Pan, Zoom	Y	N	N	N	Y
Belfast Murals Guide	Y	Pan, Zoom	Y	N	N	N	Y
Bristol Street Art Map	Y	Pan, Zoom	Y	N	Y	N	N
Culture Now: Museum without walls	Y	Pan, Zoom	Y	N	Y	Y	N

Name	Map and location focused	Navigation	Search Functionality	Layer Control	Basemap Choices	Clustering of Points	Route Finder
Field Trip	Y	Pan, Zoom	N	Y	Y	N, but buffered selection	Y
Fontly	Y	Pan, Zoom.	Y	N	N	Y	N
Gone Tomorrow SF	Y	Pan, Zoom	Y	N	Y	N	Y
Graffiti Mapper	Y	Y	N	N	N	N	N
Hong Kong Art Guide	N	Pan, Zoom	Y	N	N	N	N
Laguna Beach Public Art Map	Y	Pan, Zoom	N	N	Y	N	Y
ExperienceLA.com Public Art LA*	Y	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Mural Locator	N	Pan, Zoom	Search web site	N	Y	N	N
NYC Subway Art*	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
PDX Art Trekker	Y	Pan, Zoom	N	N	N	N	N
Privately-Owned Public Open Space (POPOS) and Public Art	Y	Pan, Zoom	Y	Y	Y	N	N
Project Neon	Y	Pan, Zoom	Y	N	N	N	Y
Public Art Finder	Y	Pan, Zoom	N	N	Y	N	N
Public Art Fund	N	Y	Y	N	N	N	Y -
Public Art Locations*	Y	Pan, Zoom	Y	N	Y	N	N
Public Art in Public Places	N	N	N	N	N	N	N
Public Art Omaha	Y	Pan, Zoom	Y	N	Y	N	N
Public Art PDX	Y	Pan, Zoom	Y	N	N	N	N
San Francisco Mural Project	Y	Pan, Zoom	Y	N	Y	N	Y
San Francisco Civic Art Finder	Y	Pan, Zoom	Y	N	Y	Y	Y
San Francisco Landmarks Google Map	Y	Pan, Zoom	N	N	Y	N	N
San Francisco Public Art – SF Art*	Unknown	Unknown	Y	Unknown	Unknown	Unknown	Unknown
SF Arts.Org	N	Pan, Zoom	Y	N	Y	N	Web calls up Hop Stop without auto filling destination
SF Mural Arts	Y	Pan, Zoom	Y	N	Web only	Mobile only	Y
SF Public Art	Y	Pan, Zoom	N	N	Y	Y	Y
SFAC Public Art	Y	Pan, Zoom	Y	N	Y	N	Y
SF Street Art Map	Y	Pan, Zoom	Y	N	Y	N	Y
SF Street Art	Y	Pan, Zoom	N	N	N	N	N
Street Art SF	N	No map	Y	N/A	N/A	N/A	N/A
SF's Secret Spaces and Hidden Oases from SPUR	Y	Pan, Zoom	N	Y	N	Y	Y
STQRY	Y	Pan, Zoom	Y	Y	N	N	Y
The Living New Deal	Y	Pan, Zoom	On web site	N	Y	N	
Tram Art*	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
1:AM Mobile Application	Y	Pan, Zoom	Y	N	N	Y	Y

B. Model Builder Script: Convert Directory of KML/MKZ to Feature Classs

The Model Builder script in shown in Figure 28 converts a directory of KML/KMZ files to feature

classes and layer files. A geodatabase is created for each KMZ/KML input. Further processing can

be performed to combine the resulting feature classes using the ArcGIS Data Management Append tool.
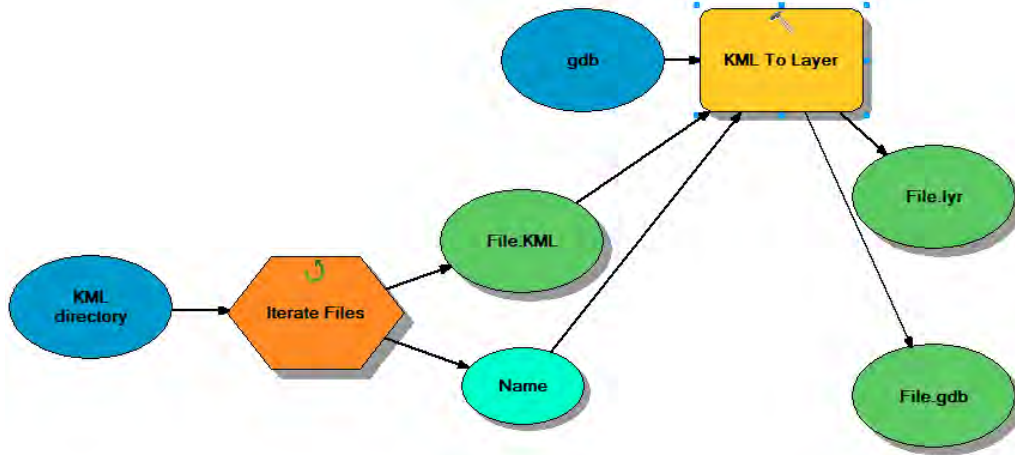
Figure 28 Convert Directory of KMZ/KML to Feature Class

C.   Popup Information Template

The following template was used in ArcMap to configure PopupInfo fields containing HTML to display correctly when selecting the POI in the web application.

```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
xmlns:fo="http://www.w3.org/1999/XSL/Format" xmlns:msxsl="urn:schemas-microsoft-com:xslt">
        <xsl:template match="/">
                <html>
                        <head>
                        </head>
                        <body>
                                <table>
                                <tr><td style="white-space: nowrap;">
                                        <xsl:choose>
                                                <xsl:when test="FieldsDoc/Fields/Field/FieldName">
                                                        <xsl:apply-templates
select="FieldsDoc/Fields/Field/FieldName[contains(., 'PopupInfo')]/.." />
                                                </xsl:when>
                                                <xsl:otherwise>
                                                        <xsl:apply-templates select="FieldsDoc/Fields/Field"/>
                                                </xsl:otherwise>
                                        </xsl:choose>
                                </td></tr>
```

```
                              </table>
                          </body>
                     </html>
            </xsl:template>

            <xsl:template match="Field">
                     <xsl:value-of select="FieldValue" disable-output-escaping="yes"/>
            </xsl:template>
</xsl:stylesheet>
```

D. Code Snippets for Basemaps

The following sections contain code snippets for configuring basemaps for inclusion in

SFPAM, as well as some of the coding to use Stamen Design web tile maps.

D.1 Basemaps.js Configuration Snippet

```
// START ITEM
{
        uniqueID: 'wtr',
        title: 'StamenWatercolor',
        thumbnail: 'images/basemap/stamen_watercolor.jpg',
        stamen: true,
        url: 'http://${0}.stamen.com/watercolor/${1}/${2}/${3}.jpg',
        copyrightText: '&#169; Map Tiles by <a href="http://www.stamendesign.com/" target="_blank">Stamen
Design</a> under <a href="http://creativecommons.org/licenses/by-sa/3.0/" target="_blank">CC-BY-SA</a>.<br /> Data by
<a href="http://openstreetmap.org">OpenStreetMap</a>, under <a href="http://creativecommons.org/licenses/by-sa/3.0">CC
BY SA</a>.'
},
        // END ITEM
        // START ITEM
{
        uniqueID: 'tnr',
        title: 'StamenToner',
        thumbnail: 'images/basemap/stamen_toner.jpg',
        stamen: true,
        url: 'http://${0}.stamen.com/toner/${1}/${2}/${3}.png',
        copyrightText: '&#169; Map Tiles by <a href="http://www.stamendesign.com/" target="_blank">Stamen
Design</a> under <a href="http://creativecommons.org/licenses/by-sa/3.0/" target="_blank">CC-BY-SA</a>.<br /> Data by
<a href="http://openstreetmap.org">OpenStreetMap</a>, under <a href="http://creativecommons.org/licenses/by-sa/3.0">CC
BY SA</a>.'
},
// END ITEM
        // START ITEM
{
        uniqueID: 'stp',
        title: 'StamenTerrain',
        thumbnail: 'images/basemap/stamen_terrain.jpg',
        stamen: true,
        url: 'http://${0}.stamen.com/terrain/${1}/${2}/${3}.jpg',
        copyrightText: '&#169; Map Tiles by <a href="http://www.stamendesign.com/" target="_blank">Stamen
Design</a> under <a href="http://creativecommons.org/licenses/by-sa/3.0/" target="_blank">CC-BY-SA</a>.<br /> Data by
<a href="http://openstreetmap.org">OpenStreetMap</a>, under <a href="http://creativecommons.org/licenses/by-sa/3.0">CC
BY SA</a>.'
},

        // START ITEM
{
```

```
                    uniqueID: 'gry',
                    title: 'Light Grey',
                    thumbnail: 'images/basemap/light_gray_canvas_with_labels__ne_usa.jpg',
                    services: [
                        {
                                    url:
'http://services.arcgisonline.com/ArcGIS/rest/services/Canvas/World_Light_Gray_Base/MapServer'

                        },
                        {
                                    url:
'http://services.arcgisonline.com/ArcGIS/rest/services/Canvas/World_Light_Gray_Reference/MapServer'

                        }
                    ]
            }
            // END ITEM
```

D.2 mapBasemaps.js Code Snippet to Determine if Basemap is from Stamen

```
/*----------------------------------*/
// BASE MAP TOGGLE FUNCTIONS
/*----------------------------------*/
function configureBasemaps(){
            var i;
            var j;
            var mq = ["a.tile", "b.tile", "c.tile"];
    var abc = ["a", "b", "c"];

            if(userConfig.basemapItems){
                    // ADD CONTAINER
                    $('#basemapMenu').html('<div id="baseContainer"></div>');
                    // HTML
                    var html = '';
                    for(i = 0; i < userConfig.basemapItems.length; ++i){
                            userConfig.basemapArray[i] = [];
                            console.log (userConfig.basemapItems[i].stamen);
                            if(userConfig.basemapItems[i].osm){
                                    userConfig.basemapArray[i][0] = new esri.layers.OpenStreetMapLayer({
                                            id: userConfig.basemapItems[i].uniqueID + '0',
                                            visible: false
                                    });
                                    map.addLayer(userConfig.basemapArray[i][0]);
                            }
                            else if (userConfig.basemapItems[i].stamen) {
                                    //Add Stamen layers
                                    userConfig.basemapArray[i][0] = new
esri.layers.WebTileLayer(userConfig.basemapItems[i].url, {
                                                    id: userConfig.basemapItems[i].uniqueID + '0',
                                                    visible: false,
                                                    tileServers: mq
                                    });
                                    map.addLayer(userConfig.basemapArray[i][0]);
                            }
                            else{
                                    for(j=0; j < userConfig.basemapItems[i].services.length; j++){
                                            userConfig.basemapArray[i][j] = new
esri.layers.ArcGISTiledMapServiceLayer(userConfig.basemapItems[i].services[j].url, {
                                                            id: userConfig.basemapItems[i].uniqueID + j,
                                                            visible: false
                                            });
```

```
                                                map.addLayer(userConfig.basemapArray[i][j]);
                                        }
                                }
                                var extraClass = '';
                                var clearDiv = false;
                                if((i + 1) % 2 === 0){
                                        extraClass = 'MB ML';
                                        clearDiv = true;
                                        if((i + 1) === userConfig.basemapItems.length){
                                                extraClass = 'ML';
                                        }
                                }
                                var bmSelected = '';
                                if(i === 0){
                                        bmSelected = 'basemapSelected';
                                }
                                html += '<div data-basemap-id="' + i + '" title="Switch to the ' + userConfig.basemapItems[i].title +
' Basemap" class="baseMap ' + bmSelected + ' ' + extraClass + '"><div class="baseImage"><img width="100" height="67"
class="BG" src="' + userConfig.basemapItems[i].thumbnail + '" /></div><div class="baseTitle">' +
userConfig.basemapItems[i].title + '</div></div>';
                                if(clearDiv){
                                        html += '<div class="clear"></div>';
                                }
                        }
                        html += '<div class="clear"></div>';
                        $('#baseContainer').html(html);
                        configBasemap();
                }
}
```

D.3 mapBasemaps.js Code Snippet to create WebTileLayer Class

```
// define the WebTileLayer class
dojo.ready(function() {
  dojo.declare("esri.layers.WebTileLayer", [esri.layers.TiledMapServiceLayer], {
    constructor: function(urlTemplate, options) {
      var ext = new esri.geometry.Extent({"xmin":-22041259,"ymin":-
33265069,"xmax":22041259,"ymax":33265069,"spatialReference":{"wkid":102100}});
      var lods = [
        {"level" : 0, "resolution" : 156543.033928, "scale" : 591657527.591555},
        {"level" : 1, "resolution" : 78271.5169639999, "scale" : 295828763.795777},
        {"level" : 2, "resolution" : 39135.7584820001, "scale" : 147914381.897889},
        {"level" : 3, "resolution" : 19567.8792409999, "scale" : 73957190.948944},
        {"level" : 4, "resolution" : 9783.93962049996, "scale" : 36978595.474472},
        {"level" : 5, "resolution" : 4891.96981024998, "scale" : 18489297.737236},
        {"level" : 6, "resolution" : 2445.98490512499, "scale" : 9244648.868618},
        {"level" : 7, "resolution" : 1222.99245256249, "scale" : 4622324.434309},
        {"level" : 8, "resolution" : 611.49622628138, "scale" : 2311162.217155},
        {"level" : 9, "resolution" : 305.748113140558, "scale" : 1155581.108577},
        {"level" : 10, "resolution" : 152.874056570411, "scale" : 577790.554289},
        {"level" : 11, "resolution" : 76.4370282850732, "scale" : 288895.277144},
        {"level" : 12, "resolution" : 38.2185141425366, "scale" : 144447.638572},
        {"level" : 13, "resolution" : 19.1092570712683, "scale" : 72223.819286},
        {"level" : 14, "resolution" : 9.55462853563415, "scale" : 36111.909643},
        {"level" : 15, "resolution" : 4.77731426794937, "scale" : 18055.954822},
        {"level" : 16, "resolution" : 2.38865713397468, "scale" : 9027.977411},
        {"level" : 17, "resolution" : 1.19432856685505, "scale" : 4513.988705},
        {"level" : 18, "resolution" : 0.597164283559817, "scale" : 2256.994353},
        {"level" : 19, "resolution" : 0.298582141647617, "scale" : 1128.497176}
      ];
      this.spatialReference = new esri.SpatialReference({ wkid: 102100 });
```

```
    this.initialExtent = this.fullExtent = ext;

    this.tileInfo = new esri.layers.TileInfo({
      "rows" : 256, // can also be height
      "cols" : 256, // can also be width
      "origin" : { "x" : -20037508.342787, "y" : 20037508.342787 },
      "spatialReference" : { "wkid" : 102100 },
      "lods" : lods
    });

    this.copyright = options.copyrightText || "";
    this.urlTemplate = urlTemplate;
    this.tileServers = options.tileServers || [];

    this.loaded = true;
    this.onLoad(this);
  },

  getTileUrl: function(level, row, col) {
    var tileServer = this.tileServers[parseInt(Math.random()*this.tileServers.length)];
    // console.log("tile server is: ", tileServer);
    var tileUrl;
    if ( tileServer ) {
      tileUrl = dojo.string.substitute(this.urlTemplate, [tileServer, level, col, row]);
    } else {
      tileUrl = dojo.string.substitute(this.urlTemplate, [level, col, row]);
    }
    // console.log("tile url: ", tileUrl);
  }

    return tileUrl;
```

E.   Sample REST Feature Configuration Using Unique Value Rendering

The code following is an excerpt from the layers.js file which defines REST services to

include in the application. The REST service is configured to use unique value rendering based on

the values found in the attribute field, "Type."

```
//Start Item
//FEATURELAYERS REFERENCE THE FEATURES IN A LAYER, DOES NOT INCLUDE THE SYMBOLOGY AS MAP
SERVICES
// CHOOSE RENDERER TO SYMBOLIZE FEATURES – SimpleRenderer, ClassBreakRenderer UniqueValueRenderer
//START ITEM: CLASS BREAK RENDERER - Symbolizes graphic based on value of a numeric attribute
        {
                uniqueID: 'art', // Unique ID (string) for layer
                featureLayer: {
                        cluster: true,
//Sample URL to rest endpoint of a layer in a map service
                        url: 'http://nmilholl.usc.edu:6080/ArcGIS/rest/services/SFPubArt84M/MapServer/0',
                        uniqueValueRenderer: {
                                attributeField: 'Type',
//this is case sensitive. Look up the attribute's exact case and spelling using the rest endpoint //you defined above.
                                categories: [
                                        //Default
                                        {
```

```
                uniqueValue: ",
                symbol: {
                        type: 'point',
                        style: 'circle',
                        size: 10,
                        color: "red"
                },
                label: 'Default',
                description: 'Default'
        },
        //Fiber
        {
                uniqueValue: 'Fiber',
                symbol: {
                        type: 'picture',
                        url: 'images/legend/fiber.png',
                        height: 20,
                        width: 20
                },
                label: 'Fiber',
                description: 'Fiber arts'
        },


        //Glass/Light
        {
                uniqueValue: 'Glass/Light',
                symbol: {
                        type: 'picture',
                        url: 'images/legend/glass.png',
                        height: 20,
                        width: 20
                },
                label: 'Glass/Light',
                description: 'Glass and Light art pieces'
        },
                                                //Glass/Light
        {
                uniqueValue: 'Glaze/Mosaic',
                symbol: {
                        type: 'picture',
                        url: 'images/legend/tile.png',
                        height: 20,
                        width: 20
                },
                label: 'Glaze/Mosaic',
                description: 'Glaze and Mosaic pieces'
        },

        //Mural
        {
                uniqueValue: 'Mural',
                symbol: {
                        type: 'picture',
                        url: 'images/legend/mural.png',
                        height: 20,
                        width: 20
                },
                label: 'Mural',
                description: 'Murals'
        },
```

```
                                //Painting/Drawing
                                {
                                        uniqueValue: 'Painting/Drawing',
                                        symbol: {
                                                type: 'picture',
                                                url: 'images/legend/painting.png',
                                                height: 20,
                                                width: 20
                                        },
                                        label: 'Painting/Drawing',
                                        description: 'Paintings and Drawings'
                                },
                                //Sculpture
                                {
                                        uniqueValue: 'Sculpture/Mixed media',
                                        symbol: {
                                                type: 'picture',
                                                url: 'images/legend/sculpture.png',
                                                width: 20,
                                                height: 20
                                        },
                                        label: 'Sculpture/Mixed Media',
                                        description: 'Sculpture and Mixed Media'
                                } //ADD OR REMOVE BREAKS AS NEEDED
                        ]
                }
        },
        infoWindow: {
                windowTitle: 'San Francisco Art',
                attributes: [
                        {
                                'title': "Title",
                                'attributeLabel': 'title',//this is case sensitive.
                                'url': false
                        },
                        {
                                'title': 'Artist',
                                'attributeLabel': 'artist',
                                'url': false
                        },
                        {
                                'title': 'Medium',
                                'attributeLabel': 'medium',
                                'url': false
                        },
                        {
                                'title': "Type',
                                'attributeLabel': 'Type',
                                'url': false
                        },
                        {
                                'title': 'Location',
                                'attributeLabel': 'location_d',
                                'url': false
                        }
                ]
        },
        //DESCRIPTIVE INFORMATION FOR LAYER LIST
        layerInfo: {
                title: 'Art', // Title visible in the Layers drops down list
                description: 'San Francisco Public Art information courtesy of <a
```

href="https://data.sfgov.org/d/zfw6-95su" target="_blank">data.sfgov.org and the San Francisco Arts Commission.',
//*Layer description visible from the layer's info menu in the layer list*
transparencySlider: true,
// *Does your layer require transparency? Valid values are 'true' and 'false'*
transparency: 0.9,
// *If so, what is the default transparancy value? Values range from 0.0 to 1.0, where 0.0 is 100% //transparent and 1.0 has no transparency.*
visible: true, // *Is the layer visible by default when the app loads?*
legendIcon: 'images/legend/painting.png' // *Reference your own image*
},
customLegend : ""
},
//END ITEM

F. ArcGIS Domain Values

This section lists the full set of domain values that describe architect names, neighborhoods,

and building styles.

F.1 Architect Names (Archnames) Domain Values

Description	Coded Value
A. Page Brown	A. Page Brown
Bernard Maybeck	Bernard Maybeck
Ernest Coxhead	Ernest Coxhead
Frank Lloyd Wright	Frank Lloyd Wright
George Applegarth	George Applegarth
Henry Doelger	Henry Doelger
James Dunn	James Dunn
Joe Esherick	Joe Esherick
John Galen Howard	John Galen Howard
Joseph Eichler	Joseph Eichler
Julia Morgan	Julia Morgan
Julius Krafft	Julius Krafft
Other	Other
Samuel Newsom	Samuel Newsom
Timothy Pflueger	Timothy Pflueger
Unknown	Unknown
Walter Bliss and William Faville	Walter Bliss and William Faville
William Mooser II	William Mooser II
WIlliam Mooser III	WIlliam Mooser III
Willis Polk	Willis Polk

F.2 Neighborhood Domain Values

Description	Coded Value
Alcatraz	Alcatraz
Bayview	Bayview

Description	Coded Value
Bernal Heights	Bernal Heights
Castro/Upper Market	Castro/Upper Market
Chinatown	Chinatown
Diamond Heights	Diamond Heights
Downtown/Civic Center	Downtown/Civic Center
Excelsior	Excelsior
Financial District	Financial District
Glen Park	Glen Park
Golden Gate Park	Golden Gate Park
Inner Richmond	Inner Richmond
Inner Sunset	Inner Sunset
Lakeshore	Lakeshore
Marina	Marina
Mission	Mission
Nob Hill	Nob Hill
Noe Valley	Noe Valley
North Beach	North Beach
Ocean View	Ocean View
Outer Mission	Outer Mission
Outer Richmond	Outer Richmond
Outer Sunset	Outer Sunset
Parkside	Parkside
Potrero Hill	Potrero Hill
Russian Hill	Russian Hill
Seacliff	Seacliff
SFO Airport, San Francisco, San Mateo County	SFO Airport, San Francisco, San Mateo County
South of Market	South of Market
Sunnyside	Sunnyside
Treasure Island/YBI	Treasure Island/YBI
Twin Peaks	Twin Peaks
Visitacion Valley	Visitacion Valley
West of Twin Peaks	West of Twin Peaks
Western Addition	Western Addition

F.3 Building Style (Style)

Description	Coded Value
Art Deco	Art Deco
Arts and Crafts	Arts and Crafts
Beaux Arts	Beaux Arts
Brutalism	Brutalism
Colonial Revival	Colonial Revival
Deconstructionism	Deconstructionism
EarthQuake Cottage	EarthQuake Cottage

Description	Coded Value
Edwardian	Edwardian
False Front	False Front
First Bay Tradition	First Bay Tradition
Gothic Revival	Gothic Revival
Greek Revival	Greek Revival
International Style	International Style
Italianate	Italianate
Neoclassical Revival	Neoclassical Revival
Norman Revival	Norman Revival
Other	Other
Post-war California Ranch	Post-war California Ranch
Post Modernism	Post Modernism
Queen Anne	Queen Anne
Second Bay Tradition	Second Bay Tradition
Spanish Colonial Revival	Spanish Colonial Revival
Stick Eastlake	Stick Eastlake
Storybook	Storybook
Streamline Modern	Streamline Modern
Structural Expressionism	Structural Expressionism
Third Bay Tradition	Third Bay Tradition
Tudor Revival	Tudor Revival

G. Organization and Data Source URLs

G.1 Organization URLs

The URL for each organization the SFPAM used or consulted for data is listed below. The

URLs were last accessed December 11 2013.

Organization	Organization URL
Art and Architecture-SF	http://www.artandarchitecture-sf.com
City College of San Francisco (CCSF)	www.ccsf.edu
data.sf.gov	https://data.sfgov.org
Living New Deal	http://livingnewdeal.berkeley.edu
Precita Eyes	http://www.precitaeyes.org/
San Francisco Airport Museum (SFOM)	http://www.flysfo.com/web/page/sfo_museum/
San Francisco Arts Commission (SFAC)	http://www.sfartscommission.org
San Francisco Mural Arts (SFMA)	http://www.sfmuralarts.com

San Francisco Planning Commission (SFPC)	http://www.sf-planning.org/index.aspx?page=2426
University of California San Francisco (UCSF)	http://chancellor.ucsf.edu/MBA/
Waymarking.com	http://www.waymarking.com
Yerba Buena Gardens (YBG)	http://www.yerbabuenagardens.com

G.2 Dataset URLs

The organization, dataset description, and specific map or URL for accessing dataset

information is listed below. The URLs were last accessed December 11 2013.

Organization	Dataset	Map or dataset URL
Art and Architecture-SF	Art and architecture POIs scraped from html and JavaScript, additional details from website	http://www.artandarchitecture-sf.com/wp-content/uploads/map2.php http://www.artandarchitecture-sf.com
CCSF	Ocean Campus Art	Shapefile that is not publicly available
data.sf.gov	SF Neighborhoods	https://data.sfgov.org/Geography/Planning-Neighborhoods/qc6m-r4ih
Living New Deal	Reference information, location and, pictures	http://livingnewdeal.berkeley.edu/map/
Precita Eyes	Hard copy map	http://www.precitaeyes.org/
SFAC, data.sf.gov	Excel spreadsheet with 692 entries, additional images and descriptions from website	https://data.sfgov.org/Arts-Culture-and-Recreation-/SF-Civic-Art-Collection/zfw6-95su http://www.sfartscommission.org/pubartcollection/pubart-projects/2008/10/20/public-art-projects-list/
SFOM	Location of exhibitions	http://www.flysfo.com/web/page/sfo_museum/exhibitions/map/location_map.html http://www.flysfo.com/web/page/sfo_museum/exhibitions/ for specific exhibition information
SFMA	JSON data of San Francisco neighborhood murals scraped from accessing Google map	http://www.sf-planning.org/index.aspx?page=3313
SFPC	Landmarks from KML file	http://www.sf-planning.org/index.aspx?page=3313
SFPC, data.sfgov.org	POPOS from KML files	https://data.sfgov.org/Geography/Privately-Owned-Public-Open-Space-POPOS-and-Public/55um-v9vc?
UCSF	UCSF Mission Bay Art Locations from PDF map and site visit	http://chancellor.ucsf.edu/MBA/docs/MBA03_10.pdf
Waymarking.com	KML downloads generated by search for art, monuments, statues, and murals in San	http://www.waymarking.com

	Francisco.	
Yerba Buena Gardens (YBG)	Data collected from website and site visit	http://www.yerbabuenagardens.com/features/gardens.html http://www.yerbabuenagardens.com/features/public-art.html http://www.yerbabuenagardens.com/maps.html