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The Incorporation of GIS Technologies in Emergency Preparedness and Response:

- DRAFT -

White paper submitted to The New York City Department of Health and Mental Hygiene

Provided by the Center for Public Health Preparedness, in conjunction with the National Center for Disaster Preparedness

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Why use GIS in Public Health?

Public health agencies make decisions that have far reaching consequences, and geography impacts these decisions on a daily basis. Geographic information systems (GIS) are powerful computer software programs which can enable agency staff to visualize spatial information in new ways, so that they can become better planners and problem solvers, particularly in the areas of disaster preparedness and response (Chang, 2002).

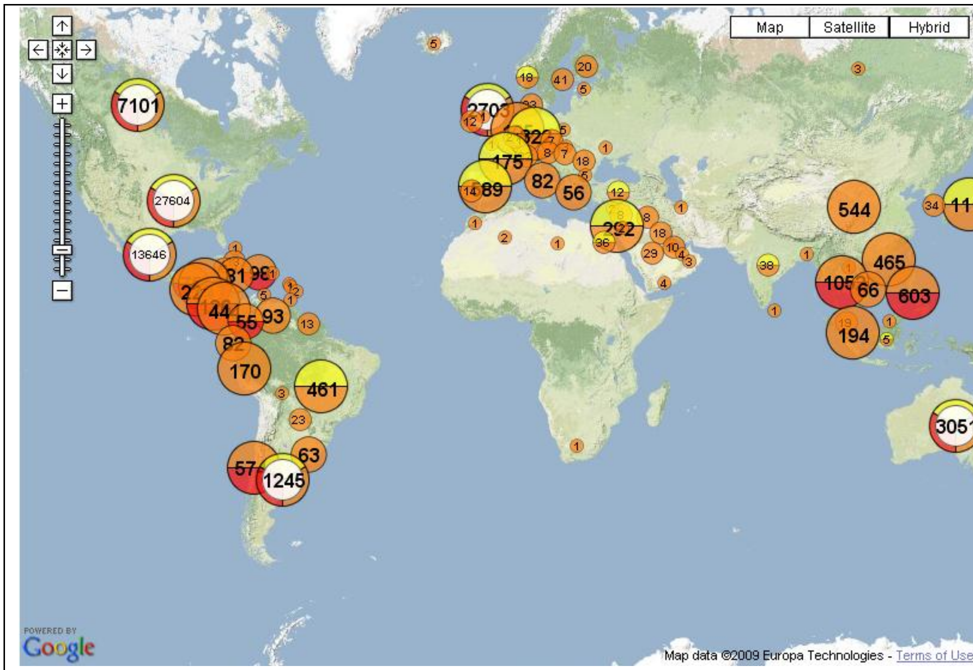
Yet, although GIS is becoming more well-known, it is still a technology in its infancy, with the majority of public health staff not gaining all of the competencies required to utilize it effectively in the workplace. Although several departments within an agency, such as epidemiology and city planners, are often leveraging this technology, there are many other staff involved in disaster preparedness and response who are not using it, but who may need to in the upcoming months (Blanco & Mathur, 2005).

The Ubiquity of Geographic Information

Recent demands on the public health workforce suggest that the geographic facets of disaster mitigation, preparedness, response, and recovery need to be addressed more specifically. This coincides with a set of developments from the information technology and geography fields. To begin with, from a technological perspective, there is increasing dissemination of the web based technologies, with online geographic processes increasingly integrated into the daily lives of millions of individuals worldwide. Google Earth, for example, can be used to display satellite imagery of varying resolution of the Earth's surface, thus allowing the general public to see content such as cities and houses perpendicularly or at an oblique angle. Google Earth also enables users to search for U.S.

and overseas addresses, enter coordinates, or simply use the mouse to browse for a specific location. Perhaps more importantly, the program also incorporates “live” data, such as current traffic information, which can be used by emergency responders as well as the general public to immediately determine which roads are accessible during and after a disaster. Similarly, hundreds of research organizations are now providing “network links” which can be opened up in Google Earth for the viewing of more detailed live content. This past year, for instance, researchers from various universities have streamed real-time data pertaining to H1NI, thus providing useful new geographic information about the rising number of patients, and subsequently deaths in various regions of the world. Further, it is now common after a disaster for television news organizations, such as CNN, to incorporate Google Earth’s real-time data and geographic visualization into their news coverage (Boulos & Honda, 2006)..

New geospatial Web 2.0 technologies, such as Google Maps, have also moved into the realm of the general public, due to freely available Application Programming Interfaces (APIs). With these advances, Google Maps, with its “My Maps” options now serves as a resource for involving communities in the epidemiologic research process, by enabling individuals to enter their own information in real-time. One well-known past use of Google Maps for user-driven input came in the aftermath of Hurricane Katrina (Singel, 2005). Evacuees used Google Maps “mash-ups” to place messages as attributes in geographic “pinpoints.” The benefit of such resources was that members of the general public without extensive geographic training could control the content of their own markers, in order to disseminate location based information. Now, with the development of the “My Maps” option in Google Maps, nonspecialists can also create geographically referenced data (points, lines, and polygons) that can be shared in Google Maps or exported to a Google Earth keyhole markup language (KML) file for use in Google Earth or back into more robust GIS software packages, such as ESRI's ArcGIS, which can permit the interpolation of data. Interested parties can thus read, write, alter, store, test, represent, and present information in ways that they need and in formats and environments that were not possible to visualize only one year ago (Chang, & Li, 2007).



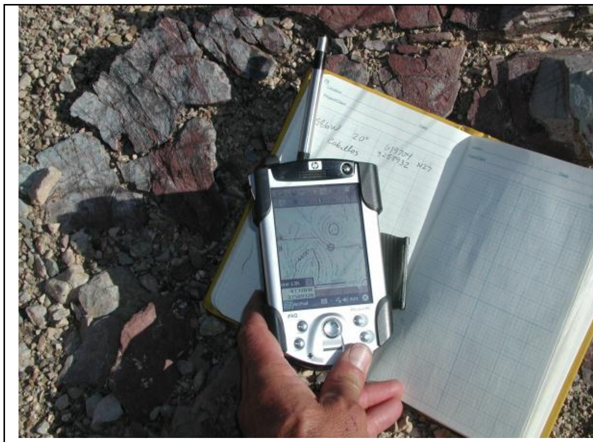
This map and the data behind it were compiled by Dr. Henry Niman, a biomedical researcher in Pittsburgh, Pennsylvania, using technology provided by Rhiza Labs and Google. The map is compiled using data from official sources, news reports and user-contributions and updated multiple times per day.

Although the aforementioned new Internet based trends suggest that the ubiquity of geographic information has the potential to improve sharing of public health information, it is the new accessibility of "just in time" geographic content, combined with more robust GIS programs such as ESRI's ArcGIS, which is often of most value for emergency preparedness staff, particularly for planning, response, and rapid needs assessments. This new capability combines many of the Internet based advantages discussed previously, but applies them to actual disaster situations in which geographic information needs to be collected and analyzed instantaneously (Kataoka, 2007).

Perhaps the most innovative linkage of large scale GIS projects to the Internet involves ERSI's ArcIMS software, which makes it possible for a single ArcGIS PC to become an Internet web server, thus making it possible to stream GIS desktop mapping content from a web address, and subsequently a global audience. Such a software tool can be of value to emergency preparedness staff since live updates – along with extensive online querying capabilities not found in the aforementioned Google technologies - can be accessed by thousands of people at any given time. Moreover, viewers of this live content need nothing more than a web browser and Internet connection in order access the web address. In most circumstances, cell phone devices with web capabilities, such as Apple's I-Phone, can visualize this content as well (Kataoka, 2007).

Syndromic surveillance with ArcGIS is one such solution for providing live web based health data in order to discover and monitor disease outbreaks or bioterrorist offensives. Such web based GIS systems have been deployed using ArcIMS in combination with proprietary hospital software for routinely collecting laboratory, pharmacy, and clinical data, such as a patient's initial complaint upon arrival at an emergency room. The availability of GIS in this regard can fundamentally enhance surveillance systems by enabling decision makers to better interpret and analyze clusters of data. In particular, geographic information about the location of cases and their chronological evolvement is becoming indispensable to those responsible for pinpointing and controlling an outbreak. Hospital emergency room data is often readily available and well-suited to syndromic surveillance in this context. Such data can be amassed by collecting the hourly aggregate of in and out patient times as well as the discharge diagnoses. ArcIMS' query functionality can also enable filtering of the data by syndrome, along with demographic variables such as age and sex. Detailed queries can center on particular geographic locations, such as by ZIP code, and permit analysis of chronological trends using specific dates. In most circumstances, such systems are housed on secure servers which provide SSL encryption (Hakim & Bitto, 2004).

Likewise, after a disaster occurs, it is also possible to use GIS technologies to rapidly determine who needs help, and where such people are located. For example, if torrential rains suddenly flood a particular municipality, it is necessary to quickly determine what the community needs. Are families in need of shelter? Do people with chronic health conditions need special assistance? If so, where are they located? Has there been a disruption of essential services such as water and electricity? If so, in what locations? The ability to carry out a rapid needs assessment can considerably reduce the amount of time it takes to answer these essential questions and ascertain where attention and resources should be first provided. Additionally, the usage of GIS handheld technologies, such as GPS enabled Windows mobile devices, can effectively streamline this entire process (Smith, 2009).

	ArcPad is designed for field teams who require GIS capabilities. It provides staff with the ability to capture, edit, display, share and analyze geographic information.

For instance, after a disaster, all housing units in a sampled cluster need to be counted, and those which have been destroyed or damaged need to be noted immediately. The people in each selected household are then counted, and these numbers are used to estimate the size of the overall post-disaster population. Handheld GIS devices can add value here because GIS base maps can be easily loaded on them and utilized for situational awareness within each field interviewer's device. The customized interface used by field interviewers provides digital forms and pick-lists to simplify data entry. Consequently, much of the time that would have previously been spent by the field team filling out paper forms and re-entering this data back in the office can thus be used for more efficient and accurate data collection processes. Additionally, all of the data collected can be geocoded and mapped to a specific geographic location. This location based information can also be stored, evaluated and sent wirelessly to other researchers located off-site. Such processes can be accomplished through the incorporation of a built in global positioning system (GPS) in each ArcPad handheld device, along with usage of a wireless Internet card (Smith, 2009).

Geocoding

There are also several new ways in which public health staff can geocode thousands of addresses in one instance. Geocoding of public health surveillance system data is increasingly carried out by state and local health departments, as is geocoding of databases for study populations established for large scale epidemiologic investigations. Perhaps the most commonly used method again involves ESRI's ArcGIS software, which contains tools for geocoding in its package of features. An address locator can link the address data to the reference streetfile and provide a seamless bridge between them. The speed with which several thousand entries can be geocoded, the interactive review and rematching process, and the variety of maps that can be created from different combinations of reference files and address locators all can be done when using ArcGIS (Greene, 2002).

That being said, ArcGIS also requires a user license of more than $1,000 per PC, along with relevant background knowledge about the fundamentals of geocoding. In contrast, there are also free open source technologies, such as www.batchgeocoder which provide basic, easy to use geocoding features, but without the validation features found in full-GIS programs. On the batchgeocoder open source website, it is possible to quickly geocode an Excel file containing up to 500 addresses, along with attribute information. This program also produces a KML file for viewing in Google Earth, a webpage for viewing online, along with map analysis options, such as distance calculations. More experienced users can also use batchgeocoder.com to convert the data into an ArcGIS shapefile. While not a solution for most research teams, this online tool can be quite useful for those with little previous GIS experience who need to quickly pinpoint geographic locations (Boulos, & Honda, 2006).

Within the past three years, increased availability of geocoded data from both the U.S. government and the private sector has also facilitated data acquisition, visualization, and analysis (Croner, 2003). Systems which were once considered cost prohibitive and within the domain of only a few experts have now become much more accessible. For instance, the U.S. Department of the Interior's online National Atlas (www.nationalatlas.gov) visualizes the patterns and trends of American life at the county level, while also providing thousands of free GIS census datasets which can be downloaded, unzipped and opened in other GIS platforms. Similarly, the U.S. Census' American Factfinder makes it possible to visualize the entire U.S. census. Census TIGER/line files also provide data at the block level for every area of the U.S. A more extensive list of free regional, national, and international GIS resources can be found below.

Online GIS Data Resources

New York City and Surrounding Area

* BYTES of the Big Apple
  http://www.nyc.gov/html/dcp/html/bytes/applbyte.shtml
* DOITT GIS Data
  http://www.nyc.gov/html/doitt/html/eservices/eservices_gis.shtml
* New York City Data at the NYS GIS Cooperative - password protected
  http://www.nysgis.state.ny.us/gisdata/inventories/member.cfm?organizationID=147
* Cornell University Geospatial Information Repository (CUGIR)
  http://cugir.mannlib.cornell.edu/
* NYC Open Accessible Open Space Information System for NYC (OASIS)
  http://www.oasisnyc.net/
* Mayor's Office of Operations My Neighborhood Statistics
  http://www.nyc.gov/html/ops/html/mns/my_stats.shtml

New York State

* Cornell University Geospatial Information Repository (CUGIR)
  http://cugir.mannlib.cornell.edu/

* NY State GIS Clearinghouse - password protected
    o Accident Location Information Sytem (ALIS) Data
    o NYS Office of Cyber Security & Critical Infrastructure Coordination (CSCIC) Orthoimagery Interactive Mapping Gateway
    http://www.nysgis.state.ny.us/gisdata/
* New York State Data Center Geography and Mapping
    http://www.nylovesbiz.com/nysdc/download_intro.asp
* NYS Department of Environmental Conservation
    http://www.dec.ny.gov/pubs/212.html

U.S. and States

* Geospatial One-Stop Portal
    http://gos2.geodata.gov/wps/portal/gos
* U.S. State Clearinghouses for Spatial Data
    http://www.columbia.edu/acis/eds/outside_data/stategis.html
* Census TIGER/Line Files®
    o Census Bureau Cartographic Boundary Files
        http://www.census.gov/geo/www/cob/
    o ESRI Census 2000 TIGER/Line Data
        http://www.esri.com/data/download/census2000_tigerline/index.html
    o New York State Data Center, Geography and Mapping
        http://www.nylovesbiz.com/nysdc/download_intro.asp
    o Census Bureau TIGER/Line® data
        http://www.census.gov/geo/www/tiger/
* IPUMS Geographic Tools
    http://usa.ipums.org/usa/volii/tgeotools.shtml
* National Historical Geographic Information System (NHGIS)
    http://www.nhgis.org/
* Social Explorer
    http://www.socialexplorer.com/pub/Home/Home.aspx
* USGS Seamless Data Distribution System
    http://seamless.usgs.gov/index.php
* USDA:NRCS Geospatial Data Gateway Home
    http://datagateway.nrcs.usda.gov/
* National Archive of Criminal Justice Data (NACJD)
    http://www.icpsr.umich.edu/NACJD/gis/data.html
* National Wetlands Inventory
    http://www.fws.gov/wetlands/
* NOAA
    http://www.noaa.gov/
    o NOAA Electronic Navigational Charts
        http://ocs-spatial.ncd.noaa.gov/encdirect/viewer.htm
    o National Climate Data Center
        http://www.ncdc.noaa.gov/oa/ncdc.html
    o National Weather Service
        http://www.nws.noaa.gov/gis/
    o NESDIS Near Real Time Spatial Products

http://www.gis.ssd.nesdis.noaa.gov/
- o Average wind speed (mph) table
  http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/avgwind.html

* National Library of Medicine - TOXMAP
  http://toxmap.nlm.nih.gov/toxmap/main/index.jsp

General World Resources

* GIS Data Depot
  http://data.geocomm.com/
* Second Administrative Level Boundaries (SALB)
  http://apps.who.int/whosis/database/gis/salb/salb_home.htm
* Global Mapping
  http://www.iscgm.org/cgi-bin/fswiki/wiki.cgi
* Columbia University's Center for International Earth Science Information Network
  http://www.ciesin.org/download_data.html (Provides U.S. Census Grids).
  o Gridded Population of the World
  http://sedac.ciesin.columbia.edu/gpw/
* Geography Network
  http://www.geographynetwork.com/
* Global Land Cover Facility (GLCF)
  http://glcf.umiacs.umd.edu/index.shtml
* GEO Data Portal
  http://geodata.grid.unep.ch/
* AQUASTAT
  http://www.fao.org/nr/water/aquastat/gis/index.stm
* Other Select Links
  o China Data Center - China Data Online
  http://141.211.142.26/

Constraints to Using GIS in Public Health

Against these positive aspects of GIS usage, a number of important constraints need to be recognized. In spite of the increased technological prowess of current systems, there are still inequalities in the opportunities to access information and the ability to effectively leverage it for emergency preparedness. The digital divide is unfortunately increasing at many public health agencies and cannot be underestimated. This is particularly evident for public health agencies relying on wireless networks that are not capable of streaming data quickly or securely, as compared to LAN, cable and DSL lines. Further, although geographic information has become more widely available, it has also been constrained by a lack of interoperability. This is particularly acute in the counties surrounding New York City, which are often using different software and file systems, subsequently making it difficult to exchange GIS data quickly beyond a specific department. In many ways, ESRI's ArcGIS software suite is equivalent to Microsoft Office; It is an industry standard prevalent on most GIS computers, but increasingly in competition with free open source technologies as well as other commercial products (Abdalla, Tao and Li, 2007)

Furthermore, most public health agencies have yet to come to terms with storage and access mechanisms for large quantities of spatial information. According to Cahan (2002), in the emergency response to the September 11, 2001 World Trade Center attack, lack of bandwidth in some areas of New York City (NYC) resulted in delays in providing processed and urgently needed orthophotography for the Emergency Mapping and Data Center (EMDC). Because of low bandwidth Internet connections, large data files had to be written to CD-ROM and driven by state police twice daily from Albany to NYC for delivery to the fire department, Federal Emergency Management Agency (FEMA), and EMDC. For public health, a variety of similar rapid developing emergency related events, including floods, fires, chemical spills and earthquakes, necessitate timely Web delivery of large geospatial databases for responsive disaster intervention and control (Croner, 2003).

Lastly, at many agencies, there is still a culture of "my" information that undermines data sharing needs. Gebbie, Valas, Merrill, & Morse (2006) assert that miscommunication and distrust between departments continues to be the primary reason why emergency responses fail to go as planned. Problems often arise because key personnel are missing and staff from different agencies are suddenly expected to work together with a mandate to solve a problem, without any previously established relationship to start from. A short list of immediate mapping needs during a disaster will usually include:

- Staging and triage areas (police, building department, property tax department)
- Helicopter landing zones (Federal aviation Administration)
- Hospitals, hospital emergency access routes, potential medical triage areas (local health authorities)
- Command posts and danger zones (police, fire, and emergency services)
- Power generation assets (local utilities)
- Shelters (school districts, social service agencies)
- Nursing homes, assisted living facilities, and board-care homes (local office of aging, state licensing agency) (GIS data available from www.hrsa.gov)
- Freeway and highway areas under construction (state or local transportation agency)

(Greene, 2002)

There will also be the need for geospatial information that may initially seem off-base when a disaster strikes. For instance, as noted by Greene (2002), one unexpected request immediately after the September 11th attacks, at the Pier 92 Mapping and Data Center in New York City was for a map product which showed all of the vacant lots in lower Manhattan, for potential use as parking lots. This data was urgently needed because emergency responders had rapidly filled the city with too many vehicles. Another unexpected request for the lower Manhattan area involved a map of concrete-slab buildings that had at least 10,000 square feet of clear space. This was needed to identify potential locations for use as temporary morgues. Without question, anticipating such needs involves considering all of the possible worst case scenarios, and then developing ways to quickly map out where the necessary resources might be located. This process could involve accessing data from outside the department, geocoding one's own data, or relying on social networking technologies. As such, preparedness staff needs to prepare templates and standard map products well ahead of time.

Best Practices:

Pennsylvania's West Nile Virus Surveillance System

In 2000, the Pennsylvania health and environmental protection departments, working with other state and local agencies, developed a means for all sixty-seven counties to trapping mosquitoes, collect dead birds, as well as monitor animals and people. Although the virus caused encephalitis, most people initially exposed only had minor flu-like symptoms, thus making it very difficult to determine patterns of the virus' emergence in new areas. The development of a GIS system was then incorporated to track virus information spatially, with content being stored in an online password protected folder. The GIS marked the location of blood samples taken from people, horses, birds, and sentinel chickens. Mapping the location of mosquito breeding areas was also critical for virus control measures. The process was accelerated in the field with ArcPad software loaded on handheld computers. Workers immediately mapped locations and entered the data on their computers instead of using handwritten notes. A web application also facilitated access to the data from state laboratories (Kataoka, 2007; Hakim & Bitto, 2004).

The tracking system also featured a bar code identification number sticker placed on sample bottles. This ID number was used when field staff entered data onto their hand-held computers. When field data was uploaded, a quality assurance program verified the accuracy of the data. The website (http://www.westnile.state.pa.us), which still continues to operate, shows a map of Pennsylvania and data tables with county outlines so that public health staff as well as the general public know where the West Nile Virus is being reported (Kataoka, 2007).

Guilford County, North Carolina Department of Public Health: Rapid Needs Assessment

As noted by Dr. Mark Smith, an epidemiologist with the Guilford County Department of Public Health, in an interview specifically for this whitepaper, the Pennsylvania Department of Health's method of disease tracking with ArcPad handheld devices helped him to conceive of how this same technology could be used for rapid needs assessment in North Carolina (Smith, 2009).

According to Dr. Smith, GIS can be a useful tool in this regard because researchers can take a more scientific approach to selecting households to interview after a disaster, due to the randomization capabilities built into the software program. That is, rather than having each individual interview team use its own method of randomization to determine which households to interview, GIS software allows organizers to choose households in advance by selecting random points and plotting them on a map for interviewers to follow. Interviews are then conducted with a resident of the house located nearest to the random point. This reduces potential sample selection bias by individual interview teams (CDC, 2009).

A second advantage to using GIS in field investigations, according to Dr. Smith, is that it allows teams to use global positioning system (GPS)-based routing rather than paper maps. With handheld computers that run GPS software, interview teams can more easily map their route as they travel through a new assessment area. This allows the teams to better orient themselves in relation to their interview sites so they can easily identify the most efficient route to follow. Paper maps take more time for teams to interpret, are often not as up-to-date as electronic GPS maps, and can be easily misplaced or destroyed, particularly in a disaster assessment situation (Smith, 2009).

Finally, and perhaps most importantly, Dr. Smith notes that GIS technology can replace paper surveys with online electronic computer-based surveys linked automatically to an offsite server. When a field team conducts an interview with members of a household, they can enter data on their handheld computers rather than writing down all of the responses. As such, it is not necessary to carry around stacks of paper which could be lost or damaged during the assessment. When researchers are ready to analyze the data in a statistical software program such as SPSS or SAS, it is not necessary to manually enter the data from paper surveys into an electronic database. Instead, data from the handheld computers are simply uploaded to a server where the data are merged into one large database through the software program. Handheld computers with GIS technology can also reduce the number of data entry errors that may occur in entering data from paper surveys to an electronic database. This makes it possible to analyze results quickly in order to guide response activities (CDC, 2009).

As Dr. Smith has indicated, another recent development in his department’s usage of ArcPad involves the in-house programming of more user friendly open source software designed specifically for public health staff conducting rapid needs assessments in Guilford, North Carolina with ArcPad. The creation of such user generated free software is noteworthy, since it opens up the possibility of further open source exchanges among public health departments of freely available software that can best suit their needs for specific tasks. Further, in terms of workforce requirements, it would certainly be beneficial for public health agencies using ArcPad to have a programmer on-staff who is capable of developing new interfaces with ArcPad (The National Center for Disaster Preparedness will be hosting a GIS conference on November 16th at Columbia University in which Dr. Smith will discuss this open source software trend more specifically. He will also provide interface examples that his department has developed).

Zanesville/Muskingum County Health Department: PODS

Another area in which the usage of GIS can be add value involves administering treatment or prophylaxis to all citizens of a particular county in the event of a public health emergency. The Zanesville/Muskingum, Ohio County Health Department (ZMCHD), for instance, has a jurisdiction of over 85,000 residents, and has been charged with the responsibility during drills and exercises of determining ways to serve as many citizens as possible through usage of GIS. In this regard, the agency has been using GIS to determine where treated citizens of a fictional flu pandemic might be from, while also allowing for strategies to be formulated on the best method for getting treatment to those still untreated (Brems, 2007).

For the evacuation scenario, address information was collected using the Secure Wireless Inventory & Pharmaceutical Emergency Response System (SWIPERS) software program, which has ad-hoc report generation capabilities. Every hour, an ad-hoc report was automatically created, containing the addresses of citizens receiving an influenza vaccination. These reports were copied into Microsoft Excel, imported into SPSS where variables were standardized in length and data type, and then exported as database (.dbf) files for use in GIS (Brems, 2007).

To calculate vaccination coverage rates, a points-to-polygon spatial join was first performed of the vaccination points to an administrative boundary (townships, villages, cities) polygon file. Once a count of points in each administrative polygon was complete, population figures for each administrative area were utilized to calculate a vaccination rate per 1000 people. After each geocode batch, a map of vaccination rates was presented to the leadership staff who then decided to activate a reverse 911 system in low participation areas. The message reminded residents that the vaccination clinic was still open and provided location and times of operation (Brems, 2007).

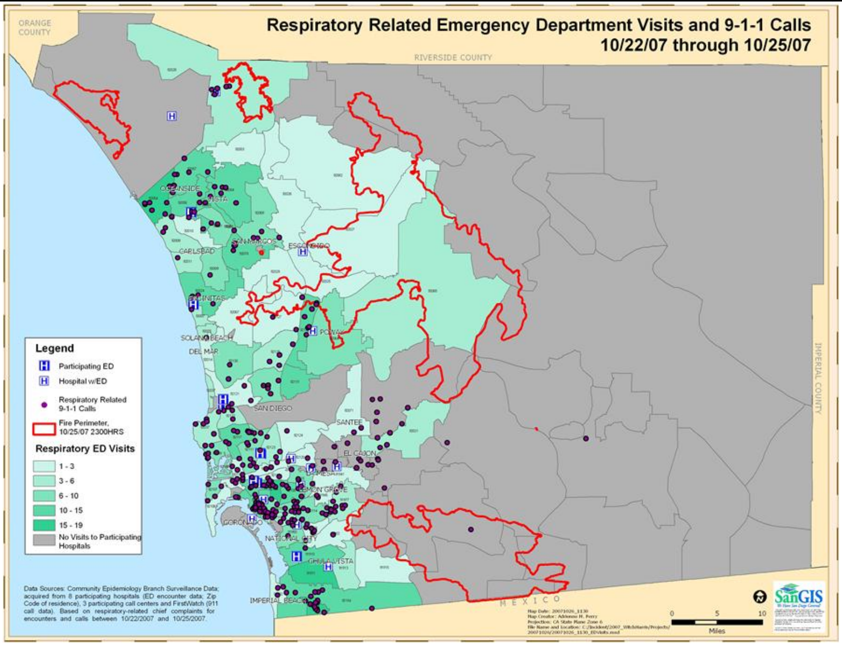
The summative evaluation of the exercise found that successful geocoding of patient address information in a POD allowed analysis of treatment coverage during clinic operations. This analysis produced information that allowed decision makers to strategize solutions to improve coverage, which would be critical during an emergency. Consequently, GIS was proven to be a capable, efficient tool for analysis of POD registration and highlighted how technology could benefit decision makers during a public health emergency. An online Powerpoint presentation in relation to this project can be found at the following web address:

http://proceedings.esri.com/library/userconf/health07/docs/gis_analysis.pdf

Usage of WebEOC in San Diego County, CA

More than 200 U.S. county and municipal EOCs rely on the WebEOC (www.esi911.com) software platform in both emergencies and day-to-day activities. One recently added feature that is compatible with ESRI's ArcGIS is called "Mapper Professional." This online feature enables users to create a geographically-based virtual map. Users can view data from multiple WebEOC boards simultaneously – or individually – on the same map and display the data with custom icons. The County of San Diego EOC used this system extensively for a major fire emergency in October, 2007. Commanders accessed the online GIS mapping capabilities to make decisions as to where reverse 911 evacuation calls should be placed and how to best send law enforcement into neighborhoods to ensure complete evacuations (County of San Diego County, 2009).

Street networks were also mapped to determine where road closures would need to be placed. Assessments were also made to determine how certain road closures might impact surrounding open highways and streets. Further, Red Cross staff and others then looked at evacuated neighborhoods to best place shelter locations. They could also judge the size of evacuation centers to make initial estimates for resources—bedding, food, and water—needed for each center. Critical infrastructure was mapped to indicate locations of assets that were high-priority protection items. Regional population estimates were used to look at the total number of people that were moved out of one area and into another. Critical care populations and hospitals were also mapped to determine which of these facilities might need to be evacuated and how to best carry out evacuations in a timely manner (County of San Diego County, 2009).



This Internet based map was used by the San Diego EOC during the October, 2007 California wildfires . It shows respiratory related emergency department visits and 911 calls.

A video documenting San Diego EOC staff usage of WebEOC can be found at this web address: http://www.youtube.com/watch?v=mVFRn_fbFlY

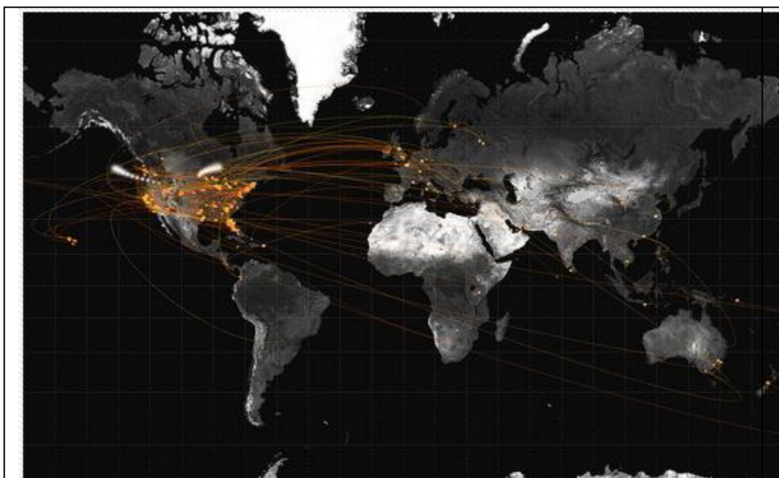
New Social Networking Tools and GIS

As noted in a *New York Times* article released at the height of the May, 2009 Swine Flu epidemic, the best way to track the spread of swine flu could be to imagine it traveling like a dollar bill across the U.S., tracked by an online website similar to Where's George (www.wheresgeorge.come), a website that tracks dollar bill serial numbers. The article quotes Dr. Dirk Brockmann, an engineering professor who leads the epidemic-modeling team at the Northwestern Institute on Complex Systems (http://rocs.northwestern.edu/projects/swine_flu), which developed an online tracking system specifically for tracking new Swine Flu cases, as based on the Where's George model. At the heart of Dr. Brockmann's system were two immense sets of data: air traffic and commuter traffic patterns for the entire country. The system was able to show how widespread fear shaped the data, because it slowed flu transmission, as did deliberate interventions like school closings and treatment with the antiviral drug Tamiflu (McNeil, 2009).

Similarly, other software developers have taken this form of analysis to new levels never previously considered before. As one recent example, Jer Thorp, a programmer from Vancouver, has geocoded Twitter feeds based on specific search terms. He describes the process as follows:

> This got me thinking about the data that is hidden in various social network information streams – Facebook & Twitter updates in particular. People share a lot of information in their tweets – some of it shared intentionally, and some of it which could be uncovered with some rudimentary searching. I wondered if it would be possible to extract travel information from people's public Twitter streams by searching for the term 'Just landed in…'.(Thorp, 2009).

As based on geocoded data from the "Just landed in" Tweets, Mr. Thorp then placed the imagery on an online map, while also producing a series of videos showing where hundreds of people had landed (Thorp, 2009)..



This map shows hundreds of geocoded twitter feeds with the search term "just landed in."

A video of this process can be found here: http://blog.blprnt.com/blog/blprnt/just-landed-processing-twitter-metacarta-hidden-data

Although this process is just an approximation, at best, it does highlight some of the potential ways in which publicly accessible social networking data can be geocoded and analyzed spatially in real time.

Lastly, it is important to note the progress made with Google's Flu Trends website (http://www.google.org/flutrends) which also includes online mapping capabilities, such as the ability to show the flu activity of each state in nearly real time. The analysis of aggregate search engine data in this manner is noteworthy, particularly because it has never been done on such a wide scale before. After all, about 90 million American adults are believed to search online for information about specific diseases or medical problems each year, thus making web search queries a uniquely valuable source of information about health trends. Further, as a "just in time" tool, immediate influenza estimates may enable public health officials and health professionals to respond better to seasonal epidemics. If a region experiences an early, sharp increase in physician visits, it may be possible to focus additional resources on that region to identify the aetiology of the outbreak, providing extra vaccine capacity or raising local media awareness as necessary (Ginsberg, Mohebbi, Patel, Brammer, Smolinski1, & Brilliant, 2009).

Competencies Needed for Using GIS

Cognitive scientists have long noted that the manipulation of visual information can improve problem solving efforts, particularly for the vast majority of the workforce without former cartographic training (Bransford, Brown, & Cocking, 2000). For public health staff, these manipulations are most useful when examining variables involving time, place, and people. For instance, describing an outbreak and the spread of a communicable disease explicitly involves a spatial component. Although this was long recognized before the development of GIS technologies (eg, the investigation of cholera outbreaks in London by John Snow), an important barrier to examining the spatial element until recently has been the lack of both digitized spatial data and the computer tools for mapping and spatial analysis.

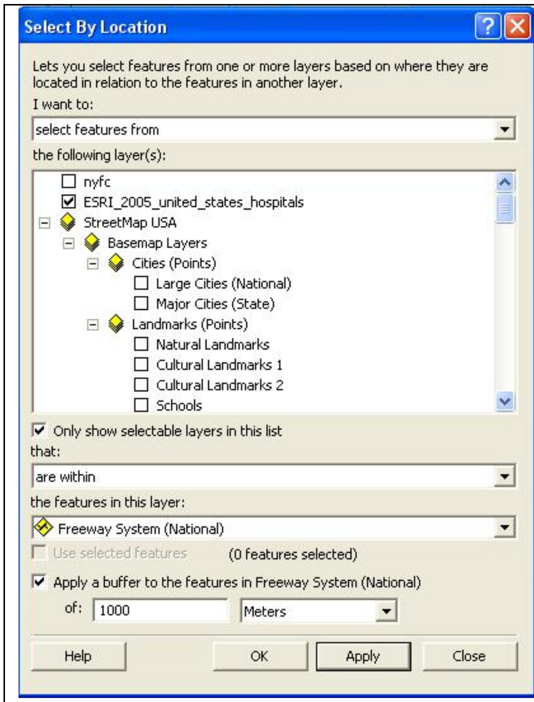
Consequently, several researchers have argued that GIS is different from other information processing systems because of its strong emphasis on spatial analysis functions not available without computer technologies (Anseline & Getis, 1992). The term “spatial analysis” with GIS has assumed various definitions over time such as “the quantitative study of phenomena that are located in space” (Bailey & Gatrell, 1995), “the process to turn raw spatial data into useful spatial information,” and “set of analytical methods which require access to both the attributes of the objects under study and to their locational information.” Researchers agree, however, that spatial data analysis plays a central role in GIS (Anselin & Getis 1992).

Table 1 synthesizes additional information about these three analytical methods.

Competencies		**Types of Questions Which Can Be Answered**
Measurement (eg, distance, shape, area, slope, aspect, orientation)		- What is the area of municipality A? - What is the orientation of an object?
Spatial Query	Transformation (eg. Buffering, polygon, overlay)	- How many public health agencies are within 1 mile of a hospital?
	Optimization (eg, location – allocation, shortest path analysis)	- What places can be reached by an ambulance in 5 minutes or less? - If a city wants to build a new hospital, which locations would be most convenient?
Spatial Statistics	Data description (eg, histogram, scatterplots	- What is the relationship between educational attainment and average income at the census track level?
	Geostatistical analysis (eg, spatial interpolation, estimation, prediction)	- What is the predicted soil distribution over an unsampled area?

The first method deals with measurement. Since all geographical entities on the Earth's surface can be clearly demarcated and positioned within some coordinate frame of reference, basic spatial properties such as distance, area, and slope can be measured easily, even in free virtual globe programs such as Google Earth. The traditional manual measurements on paper maps are more difficult to extract and less accurate when compared to the new options provided by automatic, digital measurement using GIS. This skill, along with the ability to look up street addresses, add images, and browse for geographic information, can be easily learned by those with no previous understanding of GIS technologies. The incorporation of actual photographs taken with a digital camera can also be considered among the foremost efforts to create a more realistic description, or "ground truthing," of one's own digital map. In nearly every case, visualization is an independent effort, where a user searches for patterns in a highly interactive, personal manner. Alterations of the map (including color palette and legend types) or map styles are considered further potential visualization approaches.

The second method deals with spatial queries. Spatial query often uses Boolean algebra (e.g., AND, OR, XOR, NOT) and algebraic relationships (e.g., equal to (=), greater than (>), less than (<), greater than or equal to (>=)) on multiple layers (Chang 2002). A common practice is to determine how close one item is to another. This skill requires some training, and can easily be accomplished by those without a previous understanding of GIS technologies, due to the inclusion of intuitive interfaces which help eliminate the possibility of mistakes. ESRI's ArcGIS, for instance, provides a series of buttons which, when pressed, will automatically list the fields and query terms for a database, thus making the process much more user friendly and intuitive.



This screenshot shows the ArcGIS interface for querying by location. The intuitive design does not require the user to actually write any SQL queries, thus making the process much easier. Instead, it is possible for the user to select content from a series of predetermined fields, while also applying a buffer, if needed.

Additionally, due to the ubiquity of online search engines, such as Google, a larger portion of the general public is now familiar with basic Boolean search terms than in the past. This has become evident because more people have learned how to apply data mining techniques and short-cuts in their quest to find the most relevant information.

The third method deals with spatial statistics, and often requires extensive training, along with graduate work in the social or physical sciences. There are two types of spatial statistics available in GIS, data description and geostatistical analysis (geostatistics). Data description is useful for displaying the frequency or distribution of geographic data in the form of histograms, pie charts, or scatterplots. Geostatistics use statistical methods to model spatial variations in data and to predict spatial and temporal phenomena. A principal foundation of geostatistics can be understood through Tobler (1979)'s "first law of geography," which states that, although all things are related, near things are more related than distant things. The greater similarity between closer values is the basis for interpolation methods (e.g., inverse distance weighing/IDW, kriging, polynomial interpolation). This technique is used to estimate data for continuous variables such as rainfall, temperature, or elevation based on a limited set of sampled figures.

Hall-Wallace and McAuliffe (2002) reported that investigations with GIS improve workers' analytical skills through data sorting, database searching, simple calculating, as well as the use of statistics (Thompson, Lindsay, Davis, & Wong, 1997). According to Bransford et al, GIS is highly effective in this regard because it enables users to analyze and synthesize complex problems in ways that are not possible with a pencil and paper. Ultimately, this form of analysis can help determine the probability in which specific disasters may strike certain locations, while also pinpointing the communities that will be most vulnerable. For instance, ArcGIS 9.3 provides a tool that generates spatially calibrated regression models. Known as "geographically weighted regression" (GWR), this tool generates a separate regression equation for every feature analyzed in a sample dataset as a means to address spatial variation. (The GWR tool requires an ArcInfo, ArcGIS Spatial Analyst, or ArcGIS Geostatistical Analyst license). This is an extremely useful application of GIS since it thus becomes possible to determine the probability of certain variables occurring over a geographic area where identifying every possible location would be impossible. The next section describes some of the unique ways in which researchers are leveraging GIS technologies to benefit the public health workforce.

Public Health Research Incorporating GIS Technologies

As noted by Cutter (2003: 2006), when taking geographic and social vulnerability into consideration, New York County, NY, will be the most vulnerable county in her predicted 2010 "social vulnerability index," followed by Kings County, NY, and Bronx County, NY. Such research is therefore of great importance to the New York metropolitan area. Cutter further notes that the components most frequently associated with areas of high social vulnerability are urban development, race and ethnicity, and low socioeconomic status. Within the context of natural hazards, GIS can thus help determine which communities may need specialized attention during immediate response and longterm recovery after a disaster, given the sensitivity of the populations and the lowered capacity to respond. In a broader context of social policy, GIS can also better identify municipalities that are most in need for socially based services, often involving health, welfare, housing, education—that would improve residents' ability to respond to and recover from disaster events.

In a recently initiated project, conducted in partnership with Columbia University's Earth Institute, the National Center for Disaster Preparedness (NCDP) is seeking to develop more specific measures of social vulnerability that can be mapped to hazard probabilities, to be used as a tool by policy-makers, emergency planners, and citizens. Initial work has focused on developing and testing the predictive capacity of social vulnerability measures by using pre-Katrina social indicator data matched with post-Katrina outcome data. Other work underway includes the development of computational models that permit interpolation of high-level data to smaller units of analysis, such as applying county-level data to census block groups.

Conclusion

As this paper has indicated, it has been long noted that GIS technologies can add value to emergency preparedness, particularly as decision-support tools. This is primarily evident when there is an immediate need for "just in time" spatial information pertaining to syndromic surveillance, rapid needs assessments, administering treatment or prophylaxis to all residents of a particular county, and EOC management activities. Leading GIS software companies such as ERSI, free online technologies such as Google Earth and Maps, open source GIS systems, and emerging social networking systems all have a role to play in enabling staff to obtain more complete information. Similarly, advances in Web 2.0 technologies will increasingly enhance the ways in which the public health workforce, as well as the general public understand spatial information.

That being said, GIS is only a tool for collecting, processing, visualizing, and sharing spatial data. Although the technology exists, many staff still do not have access to the information they need to make the necessary decisions. Similarly, many public health workers have not had training opportunities to better understand how this technology can really add value. As such, training in this area is clearly a necessary aim for all public health agencies to consider.

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