An Esri® White Paper • February 2011

Geographic Information Systems and Pandemic Influenza Planning and Response

Esri, 380 New York St., Redlands, CA 92373-8100 USA
TEL 909-793-2853 • FAX 909-793-5953 • E-MAIL info@esri.com • WEB esri.com

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An Esri White Paper

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Executive Summary

Around the world, public health organizations at all levels of government and the partners that support them are responding to pandemic influenza. Infectious disease experts predicted a pandemic, saying it was not a question of if but when. They were right. Drawing on recent experiences with severe acute respiratory syndrome (SARS), avian influenza (H5N1), and novel influenza A (H1N1), the World Health Organization (WHO) and other health authorities urged nations and local governments to prepare pandemic influenza response plans. Many ministries of health (MOH) and subnational departments of health (DOH) around the world have activated those plans and are sharing data as required by the updated International Health Regulations (IHR).

Esri believes that geographic accuracy is essential in detecting and responding to any infectious disease outbreak, whether it is pandemic influenza, seasonal influenza, or a local outbreak of food-borne illness. Based on extensive work with many DOHs in the United States, the U.S. Department of Health and Human Services (DHHS), and the Centers for Disease Control and Prevention (CDC); international public health organizations such as WHO, Pan American Health Organization (PAHO), and the European Centre for Disease Prevention and Control (ECDC); and numerous national MOHs and subnational DOHs on all continents, Esri has identified the use of a geographic information system (GIS) as critical in

- Assessing risks
- Evaluating threats
- Tracking outbreaks
- Maintaining situational awareness
- Documenting disparity
- Ensuring the focused allocation of resources (e.g., vaccines, antivirals)
- Notifying communities
- Minimizing the disruption caused by necessary community health interventions

The current pandemic presents a major opportunity to leverage Esri's global footprint in health GIS. Building on the experience and readiness of Esri's existing global user community will increase the likelihood that promising GIS practices are implemented in other jurisdictions. Leveraging Esri's global footprint in health GIS will also facilitate a seamless flow of geographically relevant data as a component of the response to pandemic influenza, from local to global levels. A compelling case exists for building on top of the health GIS that is already in place both in the United States and around the world.

After reading this paper, leadership and senior staff of MOHs, DOHs, and other public health organizations should understand the following:

- The importance of geographically enabling public health business processes to support responses to pandemic influenza
- How GIS can support *their* business processes
- How to learn more about specific Esri® technology solutions

Appendix 3 includes selected presentations and journal articles relevant to GIS and pandemic influenza. These publications contain model GIS practices through which public health professionals can learn valuable lessons from peers regarding effective GIS solutions.

Pandemic Influenza

Definition and Scope

Pandemic influenza is a global outbreak of disease that occurs when a new influenza A virus appears or emerges in the human population; causes serious illness; and spreads easily from person to person, occurring over a wide geographic area and often crossing geographic boundaries. Pandemic outbreaks are caused by subtypes of influenza virus that have never before circulated among people. Previous pandemics have occurred in 1968–1969, 1957–1958, and 1918–1919.[1]

According to WHO, the 2009 influenza pandemic has spread internationally with unprecedented speed. According to CDC, H1N1 is a new flu virus of swine origin that was first detected in April 2009 and has spread from person to person. It is thought that H1N1 spreads in the same way that regular seasonal influenza viruses spread—mainly through the coughs and sneezes of people who are sick with the virus.[2]

In response to a pandemic outbreak, public health efforts include

- Planning mass vaccination campaigns (including adverse event reporting) with a specific emphasis on high-risk groups[3] such as
  - Pregnant women
  - Infants and children
  - Household contacts and caregivers for children younger than six months of age
  - Elderly
  - Persons who have health conditions associated with higher risk of medical complications from influenza

[1] See cdc.gov/flu/avian/gen-info/pdf/pandemic_factsheet.pdf.
[2] See cdc.gov/H1N1flu/qa.htm.
[3] See cdc.gov/h1n1flu/vaccination/acip.htm.

- Coordinating donations of vaccines to increase supply to populations that would not otherwise have access

- Continued H1N1 surveillance, with an emphasis on the most severe cases

- Reporting required by the International Health Regulations[4]

- Epidemiological investigations to understand virus transmission

- Distribution of antivirals, personal protective equipment, and other supplies

  - In the United States, distribution through the strategic national stockpile (SNS)

- Efforts to reduce transmission within communities

  - Increased education of clinicians and the public
  - Social distancing measures

Importance of Location

Location information is critical to decision making associated with large outbreaks, whether animal or human. Animal health authorities have stated that GIS is one of the most powerful weapons they have to control diseases and minimize economic loss,[5] largely due to its unique abilities to answer location-based questions such as those regarding avian flu:

- Where are the infected flocks?
- Where are the surrounding flocks?
- Which ones should we monitor?
- What routes should trucks transporting birds take to avoid the infected flocks?

Location information has also been a cornerstone in epidemiology and public health practice, from John Snow's mapping of cholera in the 1850s to the recent use of GIS in investigating and responding to SARS. More recently, the authors of many nations' pandemic influenza plans have recognized the importance of location-based information. For example, geographic information is critical to answering many of the questions in the Pandemic Influenza Plan for the United States,[6] including

- What amounts of antiviral drugs and influenza vaccines are available from public and private inventories, and where are they?

- How quickly is the influenza spreading, and where is it going?

- What does surveillance data on the number of hospitalizations and deaths suggest with regard to

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[4] See cdc.gov/eid/content/15/8/pdfs/09-0665.pdf for a summary of use of the revised IHR.
[5] See The Threat of Avian Flu in Pennsylvania, available at upenn.edu/pennnews/sourcesheet.php?id=132.
[6] See hhs.gov/pandemicflu/plan/.

- Distribution of hospital supplies and hospital beds on a regional or statewide basis

- How quickly local and regional hospital resources are being depleted

■ Does statistical modeling of surveillance data help predict where and how fast the pandemic will spread?

While most public health organizations recognize the importance of location, location-based information is not always collected in routine public health practice. However, initiatives are under way to improve the geographic reference requirements and conventions in existing public health and hospital health information standards, such as HL7.[7] With the trend toward establishing electronic health records, the intrinsic value that a patient's address has to public health should be recognized and preserved. Accurate geographic information should be embedded as part of any international, federal, state, or local health information system solution. Following are several situations that highlight the challenge:

■ A disease outbreak has rapidly progressed to widespread status in a community, and public health officials can no longer hope to contain the outbreak through contact tracing and quarantine. A series of community-level interventions must now be evaluated and implemented to contain the outbreak. Location-based information can be used to inform multiple, specific community interventions and activities. Using common types of GIS analysis, such as mapping where things are, mapping the "most" and "least," mapping disease density, finding "what's inside" or "what's nearby," and mapping change,[8] public health authorities can prioritize interventions. Health officials may overlay outbreak data with other location-based information such as public gathering places, schools, health facilities and services, and transportation centers. GIS supports possible interventions such as

  - Choosing sites for community influenza clinics and vaccination stations
  - Monitoring and evaluating impact of vaccination clinics and stations.
  - Canceling public events, meetings, and gatherings
  - Closing schools, public places, and office buildings
  - Restricting use of public transportation systems
  - Identifying potential group quarantine and isolation facilities
  - Enforcing community or personal quarantines

■ Public health officials in a jurisdiction are distributing the H1N1 vaccine. However, due to the evolving epidemiology of the virus, the current vaccination priorities are slightly different than those they had identified in prior pandemic influenza planning using geographic analysis. In addition, in the midst of this effort, it becomes clear there will not be a sufficient supply of vaccine. Utilizing the previously defined model of geographic analysis, a GIS analyst is able to run an updated analysis based on the new vaccination priorities and georeferenced demographic data. As a result,

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[7] See the *HL7 and Spatial Interoperability Standards for Public Health and Health Care Delivery* white paper at esri.com/hl7.

[8] See six common types of GIS analysis referred to in Andy Mitchell's *Esri Guide to GIS Analysis,* version 1.

public health officials are able to not only visualize the amounts of vaccine already distributed but also prioritize the locations for distributing limited remaining vaccines by asking and answering several what-if scenarios.

- International airline passengers are screened by public health officials at a large urban airport and asked to complete a standardized health status questionnaire and submit to temperature checks for fever. Passengers are asked to state both origin and destination addresses. Subsequently, a disease cluster is reported in another country, and public health officials need to identify how many people have traveled from or have recently visited that same location. Utilizing GIS functions such as address geocoding (when available) and other geocoding methods (e.g., calculating centroids of administrative units), public health officials are able to use the information collected in the questionnaire in their estimate of exposures and to prioritize investigations. A standardized system to geographically reference each passenger's place of origin and travel destination will save the public health community valuable time in understanding the transmission dynamics and potentially containing the outbreak.

- A patient seen in a hospital emergency room is tested for H1N1, but the rapid test ends up being a false negative. Days later, when the lab test results are positively confirmed, the public health agency is notified to investigate, only to discover that the patient's address is not valid, has been mistakenly recorded, or does not exist, and vital time is lost in locating the patient. GIS technology provides a mechanism for validating the address against an existing address database at the time it is recorded. GIS gives the ability to rapidly capture standardized and geocoded addresses for confirmed cases, suspected cases, and case contacts during the critical early phase of the pandemic period, providing essential support for attempts to slow the spread of disease throughout the community.

Challenges Faced by Ministries of Health

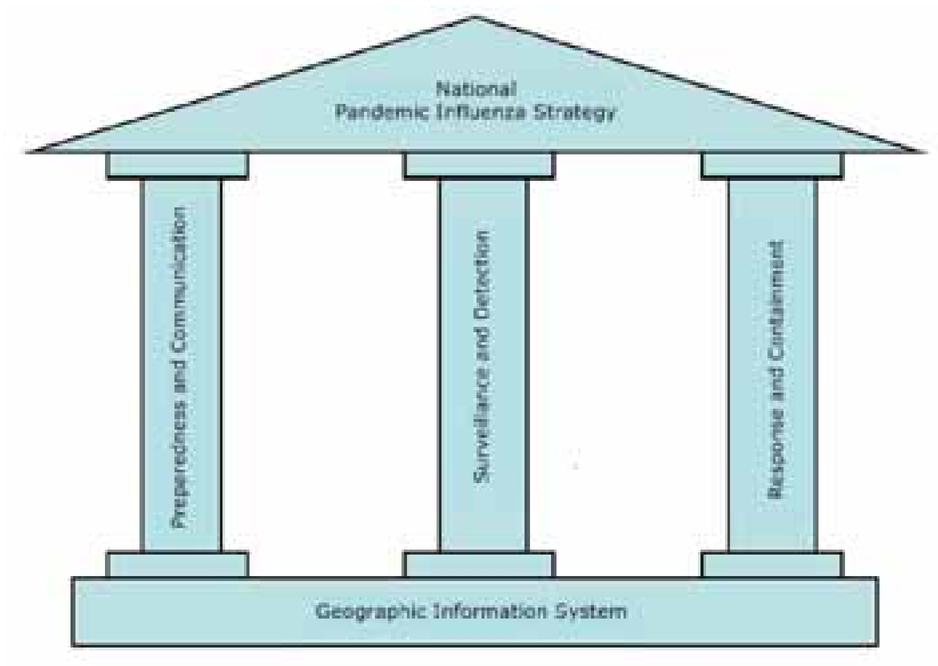
Public health leaders recognize the extraordinary logistical challenges communities face in response to a novel influenza virus. During the current pandemic, there are dozens, perhaps hundreds, of response efforts going on simultaneously in many affected communities, through both the public and private sectors. Maintaining situational awareness at any level of government is a tremendous challenge. It is also difficult for the traditional surveillance, case management, and outbreak response activities of MOHs and DOHs to sufficiently scale to meet the demands. Required capabilities beyond traditional activities include the ability to utilize available data to make community outbreak containment decisions (including specific social distancing interventions that minimize economic disruption to communities), prioritize and manage high-volume antiviral medication distribution (and vaccine distribution in the future), increase and maximize the surge capacity of medical response in a community or region, and communicate with partners and the public. Perhaps the greatest challenge is deciding how and where to deploy limited MOH and DOH staffs.

Every nation's pandemic influenza plan is different, but they do share many similarities. The national strategy of the United States is supported by three core pillars:

- Preparedness and communication
- Surveillance and detection

- Response and containment

All these activities are community based, thereby requiring in-depth awareness and understanding of location and, specifically, the spatial representation of the community. These activities also require knowing the location of identified response resources within the community, as well as the spatial distribution of the confirmed cases and at-risk populations. GIS serves as a foundation on which these pillars rest (as illustrated below).



What Is GIS?

A GIS is an integrated collection of computer software and data used to view and manage information connected with specific locations, analyze spatial relationships, and model spatial processes. GIS technology integrates common database operations, such as query and statistical analysis, with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to public health organizations for explaining events, predicting outcomes, and planning strategies. In this sense, GIS is much more than a computer map—it is a decision support system. Mapmaking and geographic analysis are not new, but a GIS performs these tasks better and faster than the manual methods. Before GIS technology, few people had the skills necessary to use geographic information to help with decision making and problem solving.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases are often included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a health facility. The wide availability of GPS-enabled devices, combined with recent advances in the mobile components of server-based GIS technology, makes GIS even more useful for public health organizations.

Many people associate specialized software and powerful computers with the idea of geographic information systems. GIS actually has five equally important components: people, hardware, software, data, and applications. GIS technology is of limited value without people who can manage and use the system, ranging from technical specialists to spatial analysts to casual users. Possibly the most important component of a GIS is the data. Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. A GIS will integrate spatial data with other data resources and can use a database management system (DBMS), commonly used by most organizations to organize and maintain data, to manage spatial data. A successful GIS operates according to the data needs, models, and operating practices unique to each organization. Applications are designed to enhance and automate everyday procedures or produce informative statistics on the state of public health or the results of a given public health program.

Understanding Geography as a Common Frame of Reference

Modernization of public health information systems to facilitate more efficient public health core functions, such as assessment, policy development, and assurance, requires geographically referenced information. The science of geography recognizes that almost everything that exists can be expressed in terms of its location and, therefore, a standard framework of spatial coordinates has been established to communicate and relate the placement of people, things, and events, wherever that may be. Therefore, geography provides a spatial baseline that can be used for storing, analyzing, and communicating most types of data. Eventually, geography supplies structurally coherent common ground for decision support mechanisms. Many MOHs and DOHs stand to benefit profoundly from the enhanced application of geographic intelligence through GIS technology.

Existing GIS within Health and Human Services Agencies

WHO, CDC, and numerous other public health organizations have made the case for the importance of public health mapping and spatial analysis. Infectious disease experts have also concluded that GIS is an IT tool ideally suited for infectious disease surveillance, outbreak investigation, and planning and response activities. MOHs and DOHs around the world have embraced GIS as a tool for collecting and analyzing data, evaluating health programs, and communicating results (internally to policy makers and externally to the public). These organizations use GIS on a daily basis to analyze the spread of infectious disease, promote and encourage healthy behaviors (e.g., targeted marketing), protect the public against hazards, prevent injuries (e.g., analyze traffic injuries by location), respond to disasters and assist communities in recovery (e.g., situational awareness, identification of vulnerable populations), and ensure the quality and accessibility of health services, as well as many other programs and services. Appendix A provides an overview of Esri's global footprint in the health and human services sector worldwide as of 2011.

Enterprise GIS

GIS is not just a stand-alone analytic tool for health planning or epidemiological research. It spans the entire public health enterprise, serving multiple divisions, programs, and people from computer desktops, Web applications, mobile phones, and PDAs. Enterprise GIS is a geographic information system that is integrated through an entire organization so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs, including data creation, modification, visualization, analysis, and dissemination.

Many MOHs and DOHs have developed, or are currently developing, enterprise-wide GIS services. These include map services, geocoding services, and other analytic services. Such services are discussed in greater detail in the ArcGIS® Server section of this paper.

Geographically Enabling Business Processes Critical to Pandemic Response

GIS offers many practical opportunities for improving the efficiency of existing public health business processes critical to pandemic response by leveraging the power of place. Below are descriptions of the relevance of GIS to several business processes.

Surveillance and GIS

The spread of disease—especially infectious disease—is unavoidably spatial.[9] Public health experts have described infection moving "from individual to individual following a network of contacts within a population through local or even global transmission."[10] Certain infectious diseases may also be carried through intermediate hosts and vectors, such as animals and insects, whose habitats and behaviors are understood through geography, field data collection, and remote sensing. Since the majority of data in public health has a spatial component, GIS adds a powerful graphic and analytic dimension by bringing together the fundamental epidemiological triad of person, time, and place.[11]

GIS serves as a common platform for standardized surveillance and monitoring of indicators from different areas (e.g., georeferencing of epidemiological data). Using this common platform, health organizations generate maps showing case distribution at multiple scales (e.g., world, country, regional, provincial, and district levels) and predict which populations are most vulnerable based on their proximity to risks. Disease distribution maps and risk maps at global (WHO), national (MOH), and state and local (DOH) levels help monitor the situation, target prevention and control measures, and inform local policy makers with jurisdiction over disease control budgets. With GIS, the spread of infectious disease becomes more visible through temporal animation of maps and network analysis. Jurisdictions with syndromic surveillance systems also use GIS-based methods (e.g., proximity, hot spot, and density analyses) to enhance their early detection capabilities.

According to Salinksy and Gursky, "the most important building block for improving disease surveillance and timely outbreak response, and for optimizing efficiencies in public health's traditional community-based programs and delivery of personal health care services, will be realized through electronic information systems. The gains in accuracy, effectiveness, resource tracking, and cost savings (to name a few) clearly justify sound and robust investments in the implementation of information technology (IT) solutions throughout the entirety of the public health sector."[12]

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[9] Holmes, E. E. Basic epidemiological concepts in a spatial context. In: D. Tilman and P. Kareiva, eds. *Spatial Ecology: The Role of Space in Population Dynamics and Interspecific Interactions.* Princeton, New Jersey, Princeton University Press, 1997: pp. 111–136.

[10] Law, D. and R. Wilfert. Mapping for Surveillance and Outbreak Investigation. *Focus on Field Epidemiology,* Volume 5, Issue 2 (available at nccphp.sph.unc.edu/focus/vol5/issue2/5-2 Mapping_issue.pdf).

[11] Public Health Agency of Canada. *GIS for Public Health Practice.* Retrieved March 19, 2008, from phac-aspc.gc.ca/php-psp/gis_e.html.

[12] Salinksy, E., and E. Gursky (2006). "The Case for Transforming Governmental Public Health," *Health Affairs,* Vol. 25, No. 4: pp. 1017–1028.

Many MOHs and DOHs use Esri products out of the box for surveillance functions. Others have leveraged GIS solutions offered by Esri business partners.

Note: The GIS capacities mentioned above are helpful not only for pandemic influenza planning and response but also for many other public health programs, including seasonal influenza, HIV/AIDS, and so forth.

Outbreak Investigation and GIS

When an outbreak is detected and public health personnel go into the field for additional investigation, GIS strengthens local data collection, management, and analysis. From the beginning, GIS provides a baseline for monitoring and evaluating outbreak investigation activities. Mobile GIS allows field personnel to leverage GPS devices to navigate more efficiently and quickly to locations for data collection. This is critical when time is of the essence. Surveillance of case locations is maintained more effectively, so the geographic progression of the disease is continually monitored. High-transmission areas (e.g., gathering places) or areas with environmental conditions ideal for disease vectors (e.g., standing water) are more easily identified when field staff have maps, imagery, and descriptive metadata at their fingertips. GIS also facilitates targeting of prevention and control measures based on priority locations. For example, recent research has shown the effectiveness of implementing integrated vector control within a defined distance buffer of known dengue case locations.[13] As referenced earlier in this paper, GIS has also proved to be a cost-effective technology for controlling animal outbreaks (e.g., avian influenza).[14] In other outbreak situations, GIS is a valuable tool for designing economically feasible population-based public health investigations (e.g., generating a spatially random sample during rapid needs assessments).

The U.S. CDC has encouraged capacity development in the area of outbreak management through funding state- and local-level efforts to perform more robust investigative analyses. While it is not widely believed that contact tracing will be an effective strategy for containing disease during a pandemic, it can be invaluable to efforts in the earliest stages of an outbreak to slow the spread of disease. The capture of location data, including home address, work address, and travel history, in a standardized manner through the use of GIS tools can extend the effectiveness of contact-tracing methods by facilitating prioritization of limited epidemiological resources, more rapid analysis, and information sharing across governmental jurisdictions. With accurate location information, GIS can provide spatial visualization of complex relationships between cases, contacts, and objects in the environment in both time and space. Spatial visualization helps in identifying disease sources and the best implementation of countermeasure and response strategies including prophylaxis, quarantine, and sheltering in place.

Many MOHs and DOHs use Esri's mobile GIS products and partner solutions (see below) for outbreak investigation. Esri Professional Services personnel also have significant experience in projects that require complex logistical solutions for fieldwork in limited-resource environments.

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[13] Kittayapong, P., et al. "Suppression of Dengue Transmission by Application of Integrated Vector Control Strategies at Sero-Positive GIS-Based Foci." *American Journal of Tropical Medicine and Hygiene,* 78(1), 2008, pp. 70–76 (available at ajtmh.org/cgi/reprint/78/1/70).

[14] See The Threat of Avian Flu in Pennsylvania, available at upenn.edu/pennnews/ sourcesheet.php?id=132.

Note: The GIS capacities mentioned above are helpful not only for pandemic influenza planning and response but also for many other public health programs, including environmental health.

Logistics and GIS

One of the major challenges in responding to pandemic influenza is the distribution of personnel, antivirals, vaccines, and other medical supplies. Health organizations, such as hospitals, medical clinics, public health agencies, and pharmaceutical manufacturers, face significant supply chain and inventory management challenges that geographic analysis can resolve. Public health officials need to prioritize the evidence-based distribution of antivirals, vaccines, and laboratory specimens. Many MOHs and DOHs have utilized GIS analysis to determine where to preposition stockpiles and find the best sites for vaccination delivery.[15] They have based these analyses on the best available demographic data and locations of available staff. In past years, during vaccine shortages, GIS has proved to be a useful tool for tracking and redistributing vaccines.[16] GIS-based programs also generate maps for routing delivery vehicles to the dispensing points.

Many MOHs and DOHs use Esri's out-of-the-box logistics solutions, and others use Esri partner solutions that leverage GIS functionality. Esri Professional Services also has experience developing a solution enabling communication of vaccine inventory by jurisdiction as well as evaluating the demographic demand for vaccine by geographic area.

Note: The GIS capacities mentioned above are helpful not only for pandemic influenza planning and response but also for many other public health programs, including seasonal influenza vaccine tracking, nurse home-visitation programs, management of teams collecting data in the field,[17] and distribution of insecticide-treated bed nets.

Mass Immunization and GIS

Many DOHs have conducted mass immunization exercises in local jurisdictions to prepare for pandemic influenza. More recently, with the prospect of an H1N1 vaccine, MOHs have been planning mass immunization at a larger scale. Local jurisdictions have affirmed that GIS has proved to be a capable, efficient tool for analysis during mass vaccination. They have identified several areas in which the technology can benefit decision makers.[18] Geocoding of patient address information allows analysis of treatment coverage during mass immunization efforts. Such real-time analysis has proved to be an invaluable decision-making tool for strategizing solutions that improve coverage (e.g., activating mass notification systems for particular geographies), which is critical during an emergency. It is also anticipated that GIS will have applicability to the postadministration surveillance of the new pandemic vaccine.

For many years, MOHs and DOHs have used Web-based service locators to inform the public of available services. GIS is used to calculate the closest service and provide directions. MOHs and DOHs with existing public-facing service locators should be able to leverage them as one component of their mass immunization campaigns.

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15 See proceedings.esri.com/library/userconf/health08/docs/tuesday/pod_planning.pdf.

16 See esri.com/news/arcnews/fall06articles/health-and-human.html.

17 See proceedings.esri.com/library/userconf/health08/docs/tuesday/streamline_public_health.pdf.

18 See GIS Analysis Utilized for Decision Making during a County-Wide Mass Vaccination Exercise—Statement of Importance, available at custom.cvent.com/E2F46B11083E47A5A69B18166638F969/files/event/7c509ff1d4f0484b853b23060b417e3c/0a6271c94f2648dfa4d9ea3ae8a9ad0b.pdf.

Many MOHs and DOHs use Esri's out-of-the-box products to build Web-based service locators, and others use Esri partner solutions that leverage GIS functionality. Esri Professional Services personnel have extensive experience in this domain area.

Note: The GIS capacities mentioned above are helpful not only for pandemic influenza planning and response but also for many other public health programs, including seasonal influenza vaccine administration campaigns and monitoring/evaluation of other public health events and campaigns. In addition, MOHs and DOHs building new Web-based service locators for mass immunization should be able to utilize them to inform the public regarding other public health services.

Situational Awareness and GIS

During outbreaks and pandemics, public health organizations are stretched by multiple demands. They must coordinate activities with many partners, report to governing bodies and funders, and communicate with the public. At times, leaders must make decisions based on incomplete science. Situational awareness systems aggregate data from many sources into map-based interfaces that promote better understanding. Such systems enable public health leaders to

- Forecast the short-term and long-term impact of events.
- Make decisions about resource allocation.
- Communicate more effectively with other agencies.
- Notify vulnerable populations.
- Implement interventions such as quarantine and isolation.

GIS is the core of many situational awareness systems, whether part of a hospital,[19] MOH, or DOH emergency operations center or a Web-based system accessed by multiple jurisdictions. GIS provides a common platform for the visualization and interactive mapping of static data such as roads, health infrastructure, and stockpile locations, integrated with real-time data streams including outbreaks/incident locations, hospital status (diversion), first responder locations, traffic conditions, weather, and 911 call data.[20] Some systems include more advanced analysis and modeling capabilities.

Many MOHs and DOHs use Esri's out-of-the-box products to build situational awareness systems, and others use Esri partner solutions that leverage GIS functionality. Esri Professional Services personnel have extensive experience in this domain area.

Note: The GIS capacities mentioned above are helpful not only for pandemic influenza planning and response but also for many other public health emergencies, including natural and man-made disasters.

Communication and GIS

GIS can effectively assist MOH and DOH communication efforts ranging from sharing a situation assessment with the media and the public to helping the public find the nearest vaccination site. Many MOHs and DOHs publish online health atlases for numerous infectious and chronic diseases. Maps also help communicate emergency information regarding school closures, public meeting cancellations, and other community disease containment measures. GIS is also now a standard component of mass notification

[19] See proceedings.esri.com/library/userconf/health08/docs/monday/sit-awareness_hospitals.pdf.
[20] See astho.org/pubs/Hippocrates_GruberDPHPMeetingOct08.pdf.

systems, enabling MOH and DOH staff to send out messages to staff, partners, or the public based on appropriate geographic boundaries.

Many MOHs and DOHs use Esri's out-of-the-box products to create maps and publish them to the Web. Esri and its partners develop scalable solutions that provide access to specific community information over the Internet and mobile devices.

Note: The GIS capacities mentioned above are helpful not only for pandemic influenza planning and response but also for many other public health communications, such as beach closings, "boil water" orders, and chemical spills.

Modeling, Simulation, and GIS

GIS helps scientists simulate how an epidemic could evolve and model the potential impact of interventions such as social distancing. For example, one might create a routine in Esri's ModelBuilder™ to overlay maps of the distribution of affected populations (calculated using spatial statistics tools within ArcGIS or another program such as SAS or R), then intersect those polygons with other criteria such as infrastructure components impacting the health of the public (e.g., hospital or clinic locations, schools, day-care facilities, senior centers, major employers, transportation routes, shopping malls, event venues, mass gathering places).

Numerous modeling initiatives are utilizing Esri's out-of-the-box products for visualization as well as tracking analysis and animation.[21] Such initiatives range in scale from the global spread of pandemic influenza[22] to efforts to prevent nosocomial infections within hospital settings.[23]

Components for Cross-Cutting Solutions

With an enterprise GIS that sits on top of existing information management systems, MOHs and DOHs can connect their databases of health facilities, population health data, and other static data with dynamic systems (e.g., vehicle locations, hospital diversion status) to improve assessment, policy development, assurance, and situational awareness and response. Having such a system in place helps the organization manage response to events such as pandemic influenza, "whose scale, timing, or unpredictability threatens to overwhelm routine capabilities."[24] Such an enterprise system requires core components including

- Address management and geocoding
- Desktop GIS analysis
- Server GIS
- Mobile GIS
- Data

[21] See proceedings.esri.com/library/userconf/health08/docs/tuesday/pandemic_simulation.pdf.
[22] See plosmedicine.org/article/info:doi/10.1371/journal.pmed.0040013.
[23] See proceedings.esri.com/library/userconf/health07/docs/closing/able.pdf.
[24] Nelson, C., N. Lurie, J. Wasserman, S. Zakowski, and K. Leuschner. Conceptualizing and Defining Public Health Emergency Preparedness. RAND Working Paper No. WR-543 (2008). Retrieved June 10, 2009, from rand.org/pubs/working_papers/WR543/.

Below are brief descriptions of these core GIS components with a special emphasis on pandemic influenza scenarios. Each description is followed by several questions any MOH or DOH should consider as it assesses its current GIS capacities.

Address Management and Geocoding

A reliable address management/geocoding service is a critical foundation for public health assessment, policy development, and assurance. An address coder assigns geographic codes to address records to verify each address and its exact location. For MOHs and DOHs to accomplish high-quality analysis necessary for intervention (i.e., immunizations), such analysis will be hampered if the underlying geolocations of facilities such as hospitals, churches, schools, clinics, physician offices, day-care centers, and so forth, are inaccurate. For some analyses and interventions, patient locations will have to be verified and analyzed. Many existing hospital patient registration systems achieve only a 75 percent accuracy rate for street addresses, thus compromising the ability to utilize clinical information for epidemiological investigation, isolation management, delivery of medical interventions, and communication of geographic exposures and risks to the public.

Some DOHs have built their own address management/geocoding services so that they may geocode the street addresses of facilities and residences. Others are using Web services offered by Esri or its partners. The key is to have effective and standardized management of addresses and their subsequent geocoding from any patient registration, electronic health record, surveillance, or registry system. Esri technology, including Address Coder™ software, supports geocoding in ArcGIS Desktop, and it is also possible to build simple geocoding Web applications with ArcGIS Server. In addition, Esri and many of its business partners offer services in address management and geocoding.

In countries where address-level geocoding is not feasible (e.g., in rural areas lacking exact addresses for buildings and residences), MOHs have undertaken initiatives to collect accurate geographic coordinates of all health facilities nationwide. A critical tool for such assessment is GPS-enabled hardware for field data collection. Efforts are under way to standardize the way such information is collected.[25]

Leadership of MOHs or DOHs should consider the following questions:

- Can we geocode street addresses with a high degree of reliability (in batches or in real time)?
- Do we have the necessary hardware, software, and data to geocode physical locations of facilities (e.g., with GPS)?
- Do we have policies in place regarding geocoding standards?

Desktop GIS Analysis

ArcGIS Desktop is a powerful tool for the management, display, query, and analysis of spatial information. The extensible architecture of ArcGIS Desktop software has enabled Esri to develop optional plug-in modules, dramatically extending the software's functional capabilities.

[25] See *The Signature Domain and Geographic Coordinates: A Standardized Approach for Uniquely Identifying a Health Facility* at cpc.unc.edu/measure/publications/pdf/wp-07-91.pdf.

ArcGIS Desktop links traditional data analysis tools, such as spreadsheets, databases, and business graphics, with maps for a completely integrated analysis system. By integrating a public health organization's data geographically with ArcGIS Desktop, new patterns can be uncovered and new insights gained. Several recent developments relevant to pandemic influenza response include

- Improved support for PDF documents (i.e., users can author a map document and export it in PDF for wide distribution while passing along the ability for increased end-user interaction with the document beyond simple viewing)
- Linked maps, graphs, charts, and scatterplots for the user to perform exploratory spatial data analysis (ESDA)
- A significant spatial statistics toolbox featuring tools for spatial autocorrelation, analyzing spatial patterns (e.g., clustering or dispersion), and assessing spatial distributions
- A model-building tool that facilitates iterative modeling capabilities as well as sharing of models with other colleagues

The public health community has utilized ArcGIS Desktop for many years. MOHs and DOHs have been using desktop GIS to determine accessibility to services and analyze disparities in health services and outcomes. Pandemic response requires rapid prioritization and efficient distribution of antiviral medications and vaccines based on the identification of key health care personnel and at-risk populations. GIS supports hundreds of spatial analyses as well as the ability to create models that integrate with other commonly used statistical packages such as SAS and R. Many epidemiologists and program managers have leveraged other ArcGIS extensions to extend the functionality of ArcGIS for public health business processes. For example, ArcGIS Spatial Analyst enables capability, sensitivity, and predictive analyses; site suitability modeling; site location analysis; and demographic analysis. ArcGIS Network Analyst provides network-based spatial analysis including routing, travel directions, closest facility, and service area analyses. Descriptions of all Esri-supported desktop extensions are available at esri.com/extensions.

Leadership of MOHs or DOHs should consider the following questions:

- Can we publish static maps of the H1N1 situation for internal meetings, press briefings, and communication with the public?
- Can we use desktop GIS and demographic data to identify vulnerable populations and site vaccination clinics?
- Can we link our maps, graphs, charts, and scatterplots to perform exploratory spatial data analysis?
- Can we create models to simulate interventions to contain the further spread of H1N1?

- Can we route our vehicles efficiently?

Server GIS

Simply put, ArcGIS Server allows MOHs and DOHs to put their maps, data, and tools on the Internet. ArcGIS Server connects people with geographic information via Web applications and services. MOHs and DOHs use ArcGIS Server to distribute maps and GIS capabilities over the Web to improve internal workflows, communicate vital issues, and engage stakeholders. By providing key technologies and supporting interoperability with standards such as .NET 2.0; Enterprise JavaBeans™; Web Services Interoperability Organization (WS-I)-compliant Web services; and Open Geospatial Consortium, Inc.® (OGC®), the ArcGIS Server technology platform is ideally suited to service-oriented architecture (SOA) deployment by MOHs and DOHs.

Below are several examples of ArcGIS Server in action:

- A DOH creates a geocoding service to facilitate real-time location of vital events such as births and deaths, as well as morbidity. While saving time and money, this service also allows more timely analysis. The enterprise-wide geocoding service is also leveraged for pandemic influenza response as a shared business capability (allowing staff to geocode locations of interest).

- A public health planner creates a model using desktop GIS to determine site locations for a stockpile of antivirals and vaccines. The DOH then publishes the map and analytic services using ArcGIS Server. Then, planners in the MOH and other DOHs run the model with their own data and turn layers of data on and off, all with or without GIS software. This facilitates greater collaboration and shared understanding of site location best practices.

- An epidemiologist creates a map showing the localized spread of H1N1 including community gathering places. The epidemiologist also creates a model to determine possible social distancing measures based on the spatial distribution of confirmed and suspected cases. The DOH publishes the map, features, and analytic services using ArcGIS Server. Then, epidemiologists in the MOH and other DOHs can run the model with their own data and turn layers of data on and off, all with or without GIS software. This facilitates greater collaboration and sharing of best practices regarding community containment.

- A DOH contracts with a consultant to build a situational awareness system leveraging ArcGIS Server. For the first time, the DOH is able to make evidence-informed and targeted decisions about resource allocation and community interventions. The DOH is also able to communicate more effectively with other agencies by granting them access to the system.

Many MOHs and DOHs are establishing enterprise-wide map services and geocoding services using ArcGIS Server. Others are using ArcGIS Server to build situational awareness systems and publish Web-based service locators and Web-based data query systems (e.g., online health atlases). All these services and applications have added value during a pandemic.

Leadership of MOHs or DOHs should ask the following:

- Do we have an enterprise-wide geocoding service?
- Can we publish map services to our own internal staff and outside partners?
- Have we published a Web-based service locator so the public can find health or other services and get directions?
- Have we published a Web-based data query system so our partner agencies and the public can better understand disease distribution?
- Can we publish GIS analytic services (models) to support multiple users in different locations?
- Do we have a situational awareness system that leverages ArcGIS Server?

Mobile GIS

Mobile GIS enables field staff to capture, update, and analyze geographic information. It lets them deploy intuitive mobile applications to increase the accuracy and improve the currency of GIS data across their organizations.

In routine public health practice, heath departments use mobile GIS to collect and manage critical information. This typically includes inspections of many types of facilities and businesses as well as enforcement of health codes, laws, and regulations. Pandemic planning and response require maximum efficiency of mobile workforces and resources for situational awareness in real-time. At the core of this capability are reliable solutions for easy map navigation, creating optimized routes, and creating and deploying simple data collection forms.

MOHs and DOHs are using ArcGIS Mobile and ArcPad® for infectious disease outbreaks as well as rapid needs assessments following hurricanes and other emergencies. The trend is for health departments to implement mobile GIS applications, replacing paper-based field data collection. As a result, they are more efficiently routing field-workers and teams to specific locations, collecting data more quickly and reliably, and analyzing results in a more timely fashion. Another component for mobile resource management is the ability to solve staffing and scheduling problems.

Leadership of MOHs or DOHs should ask the following:

- Are we still using paper data collection in public health emergencies?
- Can we conduct our next rapid needs assessment using GIS technology on mobile devices?
- Can our field staff find the best route to their next inspection or survey location?

Data

As mentioned earlier, data is one of the critical components of any GIS. All policy analyses rely on data, another building block supplementing internal agency data with current population estimates, other demographic data, road data, and more. Planners determine the location of at-risk populations based on the most recent epidemiological profiles and demographic data. They use GIS to identify geographic gaps in prevention, care, and treatment services (e.g., based on locations of health facilities, workforce/volunteers, program coverage, and supplies). They determine the optimal locations for routine service delivery as well as emergency dispensing sites, sometimes referred to as Points of Dispensing, or PODs.

In addition to the data and maps offered with Esri software products, Esri has numerous additional data offerings (esri.com/data) and bundled data products. Examples include the ArcGIS Data Appliance (e.g., terabytes of prerendered imagery and streets, as well as geocoding and routing tasks); ArcGIS℠ Online Map Services; and business, consumer, and demographic data. Esri data and online access provide 24/7 access to critical demographic data that can inform risk assessment models and be easily transformed into useful logistical service information such as the number of inoculations or identification of high-risk populations.

Leadership of MOHs or DOHs should ask the following:

- Do we have the most recent demographic data for our jurisdiction to inform pandemic influenza planning and response?
- Do we have updated street data?
- Should we supplement our internal agency data by purchasing business or consumer data?

How to Get Started

Ministries of Health and Subnational Health Departments

MOHs and DOHs needing software sales, support, training, or consulting services can find their Esri distributors at esri.com/locations. Esri's health team includes domain specialists who are prepared to have discussions with staff from MOHs and DOHs regarding how GIS can support their program goals. Contact these experts by e-mail at healthinfo@esri.com.

Staff of MOHs and DOHs should consider the following resources:

- Subscribe to *HealthyGIS*, a quarterly newsletter about software news, events, and user stories affecting the health and human services GIS community.
- Join the Esri Health and Human Services User Group, an active community of more than 1,000 professionals dedicated to sharing information, ideas, and experiences about Esri technology in the health and human services industry.
- Order *GIS Tutorial for Health* and other titles from Esri Press.
- Attend the Esri Health GIS Conference or Esri International User Conference.
- View content from the Esri Virtual Campus.

- Find out more about Esri Professional Services.
- View ArcGIS Server live user sites.
- Download the ArcGIS Server 10 Functionality Matrix.
- Download Esri white papers:
  - ArcGIS Server
  - Geospatial Service-Oriented Architecture
  - Esri-Supported Open Geospatial Consortium, Inc., and ISO/TC 211 Standards
  - System Design Strategies
  - HL7 and Spatial Interoperability Standards for Public Health and Health Care Delivery

Another resource is the Esri Partner Network, which has more than 2,000 partners providing best-in-class GIS solutions in disease surveillance, health atlases, data warehouses, data mining, business intelligence solutions, and inspection/field data collection solutions.

Vendors, Systems Integrators, and Developers

Esri has an extensive array of software products and professional and technical services that can assist any prime contractor in fulfilling all GIS-related requirements of proposals. Esri is prepared to provide all necessary documentation, including assigned staff and their resumés, as well as reference sites, required by a request for proposal (RFP) to address all GIS-related requirements and to provide specific pricing for both software and professional services. Contact Esri Professional Services for further information or assistance at esri.com/services.

In addition to the white papers, demos, and other resources described above for staff of MOHs and DOHs, systems integrators and developers should also consider the following:

- The Esri Developer Network (EDN℠) is a cost-effective way to use and leverage ArcGIS products and technologies in applications and systems they design and build.
- The Esri Developer Summit is an opportunity for them to connect with Esri staff and software developers from around the world to explore trends, tips, and best practices for effective GIS development.

Conclusion

This paper and the accompanying suggested readings highlight ways that MOHs and DOHs around the world are leveraging GIS technology to support pandemic influenza planning and response. Leaders of MOHs and DOHs are encouraged to contact Esri to discuss opportunities for collaboration.

For more information on Esri Health and Human Services, visit esri.com/health.

Appendix A: Esri Global Footprint in Health and Human Services (2011)

Esri technology is present in

- 119 national health ministries (62 percent of all nations)
- 50 U.S. state health departments and the District of Columbia health department
- 50 largest U.S. local health departments
- World Health Organization
- Pan American Health Organization
- U.S. Centers for Disease Control and Prevention
- European Centre for Disease Prevention and Control
- More than 600 U.S. city and county health departments
- 500 major hospitals worldwide
- 85 percent of all European Union Member States
- 95 percent of all accredited U.S. schools of public health
- 88 percent of U.S. state social service departments
- More than 500 local human services agencies and nongovernmental organizations in the United States
- More than 5,000 health professionals worldwide using ArcGIS Desktop daily

Esri customers use GIS technology primarily to

- Track and manage infectious diseases.
- Determine geographic accessibility of health services.
- Identify geographic health disparities and vulnerable populations.
- Locate health and social care facilities and services.
- Recommend health policy and public protection.
- Identify potential health threats to life and safety.
- Conduct research on community health status.

- Add geographic intelligence to the medical record.
- Collect and verify community health data.
- Conduct monitoring and evaluation of health interventions and programs.

Esri promotes global health through royalty-free software licenses for

- WHO's HealthMapper Program (since 1996)
- CDC's EpiMap Program (since 1997)
- PAHO's SIGEpi Program (since 1998)

Appendix B: Suggested Reading

Bossard, A., and S. Corbett. "Situational Awareness for Hospitals." Presented at the 2008 Esri Health GIS Conference. Available at proceedings.esri.com/library/userconf/health08/docs/monday/sit-awareness_hospitals.pdf.

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Esri. "Health and Human Services Tracks Stockpile Shipments on the Web." *ArcNews*, Fall 2006. Available at esri.com/news/arcnews/fall06articles/health-and-human.html.

Esri. *GIS Empowers Emergency Response and Public Health Awareness.* Case study available at esri.com/library/fliers/pdfs/cs-southcarolina.pdf.

Esri. *Mobile GIS Speeds Disaster Relief*. Case study available at esri.com/library/fliers/pdfs/cs-nchealth.pdf.

Esri. *New Zealand Animal Health Board*. Case study available at esri.com/library/casestudies/new_zealand_animal_health_board.pdf.

Esri. *North Carolina Implements Statewide Mobile GIS for Public Health Emergency Evaluation*. Case study available at esri.com/partners/common/hp/healthy_gis_norcar.pdf.

Esri. *Pandemic Flu: Prepare or Panic*. Video available at esri.com/industries/federal/gis-business/demos.html.

Esri. "Spatial Analysis Gives Insight into Source of Legionnaires' Disease." *HealthyGIS* reprint available at esri.com/industries/health/pdf/healthygis_spatial.pdf.

Esri. "Tracking SARS in China with GIS." *ArcNews,* Summer 2004. Available at esri.com/news/arcnews/summer04articles/tracking-sars.html.

Gruber, D. "Hippocrates New Jersey's Health System Situational Awareness System." Presented at the ASTHO 2008 DPHP Meeting. Available at astho.org/pubs/Hippocrates_GruberDPHPMeetingOct08.pdf.

Kho, A. "GIS Brings Advances to Hospital Infection Control." Presented at the 2007 Esri Health GIS Conference. Available at proceedings.esri.com/library/userconf/health07/docs/closing/able.pdf.

Kinabrew, C. "Geographic Information Systems and Pandemic Influenza Plans." Presented at the 2006 NAPHIT Annual Conference. Available at naphit.org/global%5Clibrary%5Cann_mtg_2006%5CPresentations%5CGIS_Pandemic_Influenza_Kinabrew.ppt.

Kinabrew, C. "Geographic Information Systems and Pandemic Influenza Plans." Presented at the 2007 URISA Annual Conference. Available upon request (contact healthinfo@esri.com).

Ma, M. "Use of ArcGIS in PODS Planning." Presented at the 2008 Esri Health GIS Conference. Available at proceedings.esri.com/library/userconf/health08/docs/tuesday/pod_planning.pdf.

Meyer, K. "Targeting Information Dissemination to Improve Neighborhood Protection during a Wildlife Rabies Outbreak." Presented at the 2007 Esri Health GIS Conference. Available at proceedings.esri.com/library/userconf/health07/docs/HealthGIS2007_Rabies.pdf.

Ohkusa, Y. "Application of an Individual Based Model with Real Data of Transportation Mode and Location to Pandemic." Presented at the 2008 Esri Health GIS Conference. Available at proceedings.esri.com/library/userconf/health08/docs/tuesday/pandemic_simulation.pdf.

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University of Pennsylvania. The Threat of Avian Flu in Pennsylvania. Available at upenn.edu/pennnews/sourcesheet.php?id=132.

About Esri

Since 1969, Esri has been helping organizations map and model our world. Esri's GIS software tools and methodologies enable these organizations to effectively analyze and manage their geographic information and make better decisions. They are supported by our experienced and knowledgeable staff and extensive network of business partners and international distributors.

A full-service GIS company, Esri supports the implementation of GIS technology on desktops, servers, online services, and mobile devices. These GIS solutions are flexible, customizable, and easy to use.

Our Focus

Esri software is used by hundreds of thousands of organizations that apply GIS to solve problems and make our world a better place to live. We pay close attention to our users to ensure they have the best tools possible to accomplish their missions. A comprehensive suite of training options offered worldwide helps our users fully leverage their GIS applications.

Esri is a socially conscious business, actively supporting organizations involved in education, conservation, sustainable development, and humanitarian affairs.

Contact Esri

1-800-GIS-XPRT (1-800-447-9778)
Phone: 909-793-2853
Fax: 909-793-5953
info@esri.com
esri.com

Offices worldwide
esri.com/locations

esri
380 New York Street
Redlands, CA 92373-8100 USA

Printed in USA