Strengthening Public Health Preparedness with GIS

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Contents

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Introduction

The health community is in a state of reflection. As it steps back to examine the worldwide response to the COVID-19 pandemic, now is also the time to revisit health preparedness strategies and plans. Now is the time to review what lessons have emerged and what changes should be implemented.

The global response to COVID-19 has highlighted the need to engage with a wider range of collaborators. It has elevated the value of situational dashboards for communicating health issues and supporting decision-making. The pandemic has also magnified the importance of having the right data sets and applications to support business continuity and recovery of our communities.

When it comes to public health emergency preparedness and response, organizations should use every incident as a learning experience to prepare for future events. Although each event presents its own challenges that require specific response and recovery activities, they shouldn't be viewed in isolation. These events begin to follow repeatable patterns that organizations can use to build more resilient and healthier communities.

In a public health response, real-time information fuels situational awareness and data-driven decision-making. For example, the ability to improve data collection through sensors and crowdsourced information empowers leaders to deploy resources and inform stakeholders with greater precision.

Globally, there is a renewed appreciation for the critical role that public health preparedness professionals play in keeping our communities safe. The COVID-19 pandemic brought the awareness of public health emergency response into our living rooms. Now, people better understand how the health of a community impacts the economy, transportation networks, education, community design and infrastructure. The crisis' scope and complexity demonstrated that public health preparedness is a vital function. It requires careful planning and coordination, with health agencies playing a leading role.

The health community can build on lessons learned in response to previous public health emergencies, such as the Severe Acute Respiratory Syndrome (SARS) outbreak of 2002 to 2004, the Ebola outbreak in West Africa in 2014 to 2016 and the Zika virus epidemic in 2015 to 2016. Public health professionals are also responding to new developments around the opioid epidemic and homelessness.

This work has produced foundational data sets, tools and models for organizations to share. They don't have to rebuild from scratch, but rather adapt their existing plans when a new crisis occurs.

Geographic information system (GIS) is often the foundation of these efforts, transforming data into location intelligence that provides agencies and civic leaders with valuable insights. What makes GIS so critical is that it supports evidence-based decision-making.

For this report, GovLoop partnered with Esri to highlight best practices and key GIS capabilities that support public health preparedness. We also explore how the lessons learned during the COVID-19 reponse can help communities prepare for the next crisis.
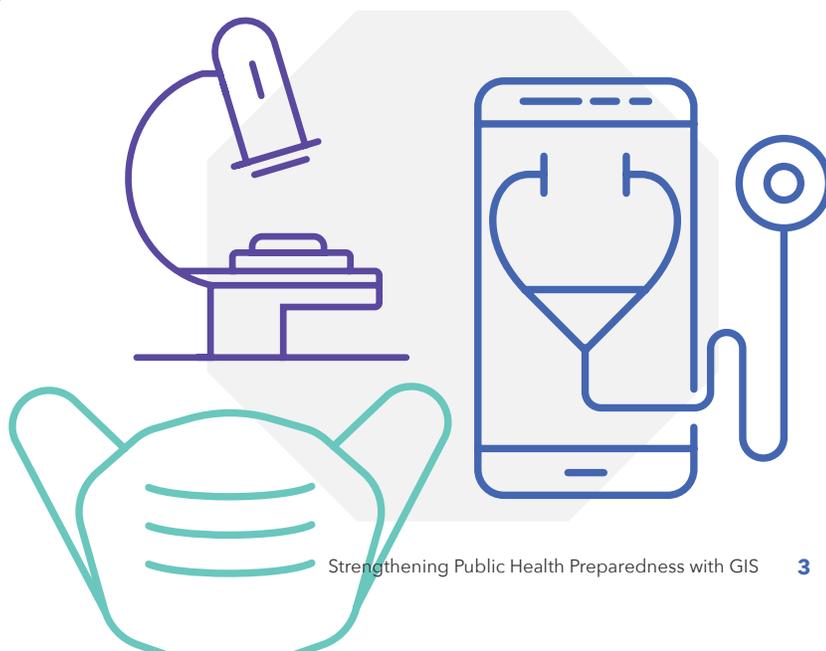
A Look Back Moves Us Forward

Humans are a resilient and adaptive species. Faced with armed conflicts, humanitarian tragedies, natural disasters and health emergencies, we learn to look at situations in new ways and to respond with innovation. The health community has seen this during the COVID-19 pandemic, which has forced health professionals worldwide to review, rethink and reimagine their health preparedness workflows. But this work is part of a larger trend of innovation in health preparedness and recovery.

Mosquito-borne malaria, West Nile virus or any disease transferred to humans from other species, is a recurring worldwide threat. Early response efforts to these diseases incorporated hand-drawn maps to plan pesticide applications and paper- or PDF-based maps to visualize cases of human disease. But the past five years have seen a dramatic shift in response efforts.

The 2015-2016 **Zika pandemic** brought a transition to fully integrated workflows that include surveillance, managing public requests, providing vector control measures, and using interactive maps for public outreach and communication. Fully digital and interoperable systems streamlined data collection, process management and accountability.

The **opioid epidemic** has driven further innovation because it is far more complex than traditional health emergencies. In particular, the range of stakeholders is vast, including not only physicians, pharmacists and other public health professionals, but also social services, public safety agencies, coroners and medical examiners, policymakers, and educators. Solutions require a cross-sectoral and collaborative approach.

Communities used GIS to connect key data points from first responders and public health authorities, and to align jurisdictional activities around local initiatives. They also found ways to destigmatize opioid addiction in the public eye and to connect people with information. For example, we saw broad participation in crowdsourcing the stories of friends and family members lost to opioid overdoses. This provided a new way to connect people to the issue. Stories draw people in and promote empathy in ways that data, statistics and charts never will.

In the past five years, the conversation around **homelessness** has increased. Several jurisdictions have declared states of emergency to increase their flexibility in managing resources to support solutions. GIS has played an instrumental role. Communities rely on GIS to automate the collection and reporting of data, to speed analysis and funding for mitigation efforts, and to support the development of evidence-based policies.

GIS has a long history when it comes to **infectious disease outbreak** response, from the plague, yellow fever and cholera to polio, Ebola and COVID-19. Whether dealing with local outbreaks or a full-scale pandemic, we've seen a whole new paradigm of spatial thinking to support decision-making, response and recovery actions. For the first time on a global scale, we've seen near-real-time surveillance via global and local map-based dashboards.

- Organizations are using human mobility data to estimate the adherence to social distancing guidelines.

- Communities are monitoring their health care systems' capacity through spatially enabled surge tools.

- Governments are using location-allocation methods to site new resources (i.e., testing sites and augmented care sites) in ways that account for at-risk and vulnerable populations.

- They are making information available to their residents with easy-to-use resource locators.

- To support next steps and reopening of economies, many communities are using maps and spatial analysis to review case trends at local levels.

- Organizations of all types are thinking spatially about indoor spaces as they consider "back-to-the-workplace" plans that account for physical distancing and employee safety needs.

Innovation happens every day in health GIS, but now it's happening at lightning speed. Agencies should be thinking about how to raise the bar for preparedness, response and recovery plans because the next crisis is just around the corner.

◄ Far left: 9/11 emergency mapping team. Left: Hurricane Michael response team. Above: Ebola Surveillance Dashboard

The Essential Role of Location in Public Health Preparedness

We can all recognize that the role geography plays in executing an effective public health response is critical. This truth became more prevalent through the dashboards displayed by organizations such as John Hopkins University, the news media, and national, state, and local governments during COVID-19. Location provided context at a more personal level, helping people nearby understand the disease's potential impact on them.

Understanding how to apply location-based thinking enhances preparedness and response efforts. GIS offers the opportunity to scale standard operating procedures; implement new response and recovery applications; engage with the public; and collaborate across organizations. Communities can also maximize resources using GIS, whether they are responding to a toxic spill, extreme heat waves, natural disasters or pandemics.

GIS makes it possible to answer the question of "where." Here are four key areas in which location supports public health preparedness plans:

1. Decision Support

The key to using location intelligence is to build it into the public health emergency preparedness plan from the beginning. When you start developing your preparedness plan, assess your data: Do you have existing systems that collect important data in real time? Can you add interoperability to connect disparate systems for a more functional and consistent common operating picture? And more generally speaking, consider how location can enhance the data you're collecting, so that you can add visualization from the start.

Data-driven decision-making is about using data to answer fundamental questions needed to inform response and management efforts. GIS is crucial because so many questions hinge on location data. Map-centric modeling and operational interfaces can support the following activities:

- Monitoring an event's impact with respect to populations affected
- Modeling outcomes based on current data and past trends
- Understanding budget and personnel impacts
- Tracking and reporting activities to ensure timely federal funding reimbursements
- Applying a social and racial equity lens to ensure positive outcomes
- Supporting continuity of operations
- Developing a communication strategy
- Establishing coordination efforts with stakeholders
- Measuring the effectiveness of policies and decisions in real time
- Understanding capacity constraints

Understanding change in ▶ unemployment rate month over month to identify at-risk populations
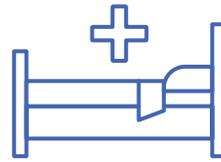
2. Resource Allocation

The key to a high-impact recovery plan is having the right resources in the right place at the right time. GIS can optimize resource allocation by placing resources precisely where they are most needed. For example, this is particularly important when identifying the closest facilities to an event, determining options for temporary facilities, or identifying quantities of supplies needed by neighborhood.

Location supports the distribution of resources at the intersection of people and need. GIS can dive even deeper by contextualizing lifestyle and socioeconomic conditions in affected areas. For example, understanding whether people have vehicles or ride public transit lets preparedness staff know whether a drive-thru facility is enough or whether organizations need to bring services directly to the neighborhoods.

GIS analysis can answer some of the following resource allocation questions:

- What is the estimated population count and demographic makeup of the affected area?
- How has the transportation network been impacted?
- Where are critical facilities or areas for potential temporary staging of services?
- Where are the at-risk population centers?
- Where do current models forecast spread or need?
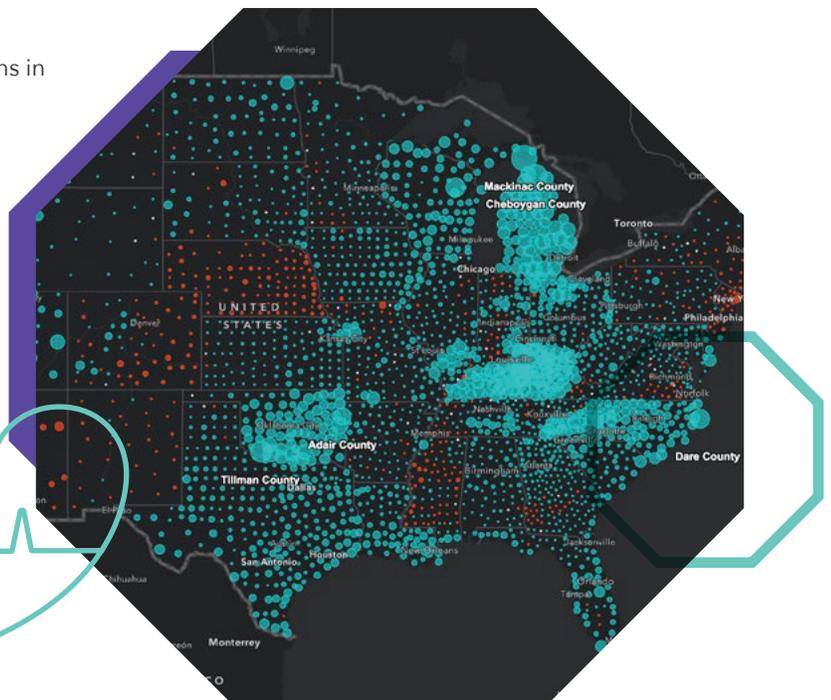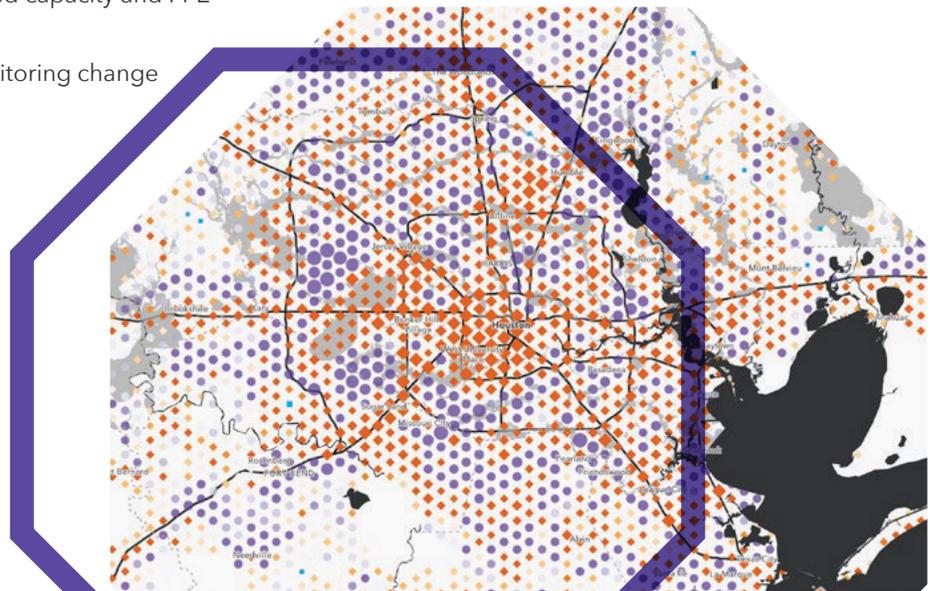
3. Communication and Collaboration

No matter how large or small the health response is, situational awareness is critical. Every health crisis requires support from a wide variety of disciplines, including emergency management, law enforcement, human services and health care. Those stakeholders need a common operational picture of what is happening and where so they can communicate and collaborate effectively.

Understanding how the response is unfolding provides the opportunity to identify where your resources are, ground truth information as it becomes available and pass the information directly to operational dashboards. Users can import resource data into models and machine learning tools. They can also deploy staff to the places and populations that need support most.

Every health emergency requires informed decision-making to minimize impacts to the environment, infrastructure and people. GIS supports a range of communication and collaboration efforts. Once the base location data in the emergency operations center has been established, organizations can feed insight into managing the event. GIS can apply to these activities by:

- Supporting situational awareness through real-time data feeds
- Overseeing workforce capacity and safety
- Mitigating the spread of disease through community contact tracing
- Managing staff and mutual aid through business continuity planning
- Monitoring hospital and facility bed capacity and PPE inventory
- Adjusting recovery efforts by monitoring change

4. Civic Engagement

Civic engagement can take on many forms before, during and after a health emergency response. Location provides context for an emergency that offers a more intuitive approach for public engagement. The more people understand the effects of the crisis in relation to where they live, work and play, the more engaged they become. The public can begin to understand the larger picture of how the crisis affects their family, friends and coworkers, in addition to the larger community.

GIS can support public education through storytelling with maps, public notifications and public input. The response to the COVID-19 pandemic demonstrated how location supports the full range of civic engagement activities. These engagements can be used at any time during the event, from the initial response to economic recovery. Examples of civic engagement during an emergency include:

- Establishment of an information and resource hub
- Story maps that educate the community on the threat and status of the event
- Situational awareness dashboards that communicate benchmarks and progression
- Collecting public sentiment through surveys or social media analytics
- Crowdsourced data on items ranging from closed businesses to reports of impacted places
- Public notifications via alerts and updates to individuals directly impacted

Monitoring population movement ▶ across Texas, before and during Hurricane Harvey

COVID-19: Our Lessons Learned

Capturing the lessons learned immediately after an emergency response or health crisis is key to the overall success of the public health preparedness profession. This step is crucial for putting in place software, data, expertise and working relationships before the next crisis. That way, communities aren't forced to cobble together insights in the midst of a crisis, when everyone is struggling to address the massive surge in work.

We have learned that a complex public health emergency, such as COVID-19, can touch on nearly every aspect of life, from transportation and education to economic development and public policy. Although health agencies might lead the response, they work closely with myriad agencies and elected officials to plan, coordinate and communicate response efforts.

Public health professionals will continue to evolve their use of technology to adapt preparedness, response and recovery efforts after the COVID-19 pandemic. But the response efforts have presented an initial road map of the core competencies required to improve an organization's capacity and to make recommendations on programs, plans, policies, laws and workforce development. The new terms and workflows introduced will now be incorporated into preparedness plans for future pandemics or smaller-scale events. That could include localized heatwaves, outbreaks of West Nile virus, or responses to hurricanes or wildfires.

After COVID-19, it is clear that every public health preparedness plan must expand their core competencies to consider the following:
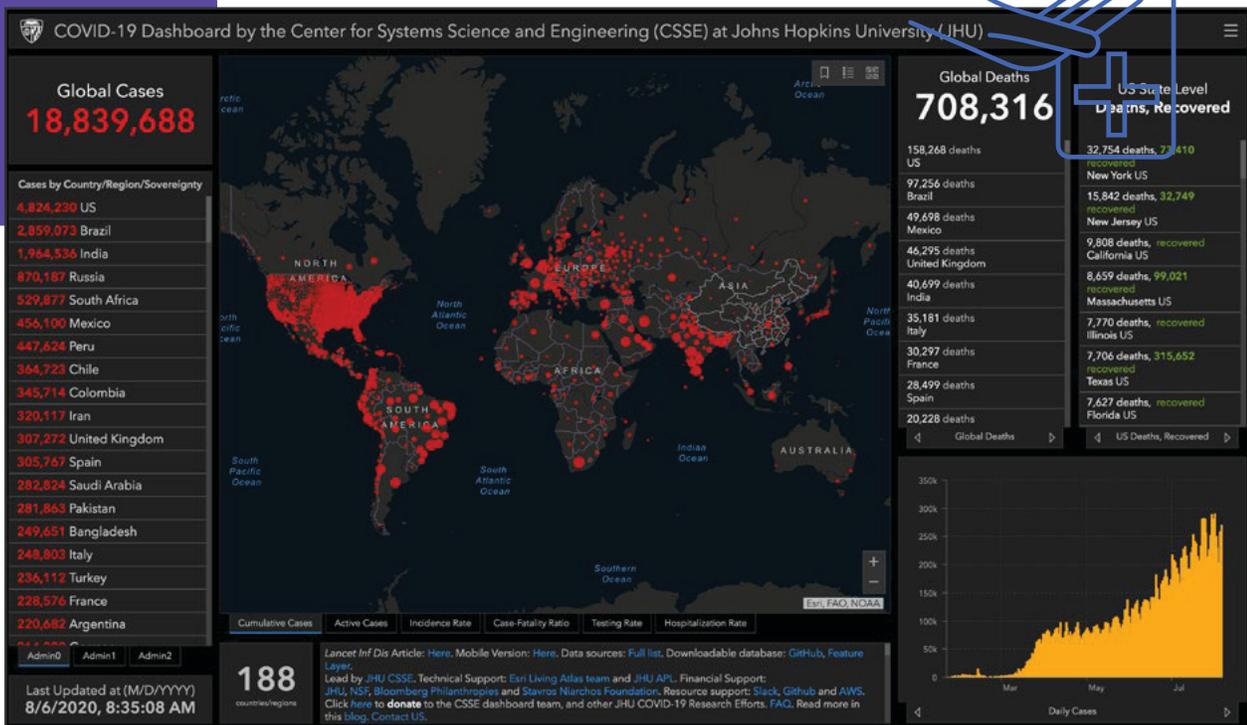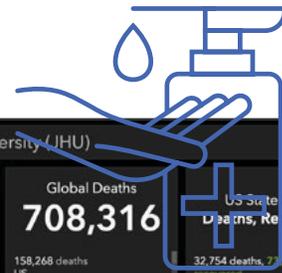
▲ COVID-19 Dashboard, Johns Hopkins University

Broader Collaboration

Past emergencies have shown the need to extend the public health preparedness network, to include outside domain experts and to improve the exchange of information and outcomes to impacted areas.

- The 1994 Northridge earthquake in California demonstrated the need to coordinate with cellular carriers to use data to locate people.
- The Oklahoma City bombing in 1995 introduced 3D modeling.
- Hurricane Katrina, in 2005, introduced improved coordination of displaced communities and volunteer efforts.
- The Deepwater Horizon oil spill in 2010 showed the need to ensure that tourism remains intact.

The COVID-19 pandemic introduced the terms "essential worker" and "essential business" and emphasized social distancing. New partnerships and data providers have emerged to support tracking and metrics associated with these new ideas.

New collaborations developed to support health, and the health community became advisers for other disciplines, such as parks and recreation, public works, urban planning, economic development, transportation, utilities, businesses, and even elections management. It's a modern-day representation of 'health in all policies.'

Lessons learned from COVID-19:

- Reassess the list of stakeholders who need to be included in decision-making.
- Acknowledge the repeatable patterns and workflows that peers use.
- Add economic recovery and reopening of communities to preparedness plans.
- Examine business and government functions that potentially put people at risk.

Shifts in Data Needs and Models

Minimum data requirements shift based on whether the incident is the result of weather, fire, terrorism or disease. The list of data resources a public health department collects for preparedness activities becomes more comprehensive as they experience a range of events and a frequency of some.

- The September 11, 2001 terrorist attacks showed how the most relevant briefing maps would create a common operating picture.
- The 2004 Indian Ocean earthquake and tsunami response taught us the value of a digital one-stop repository for geospatial data.
- The 2013 flu season taught us that additional insight could be derived from crowdsourced information and social media feeds.

The lessons learned from the COVID-19 response have been enormous. Those insights are shaped by the new technologies that are available to collect data, the depth and breadth of economic impact data required to balance the reopening and recovery phases, and statistical models that led to decisions. Crowdsourced information gave insight into economic conditions such as the location of closed businesses and daycare options for essential workers. Location-based human movement data provided a window into crowd surges and social distancing behaviors. The need to identify testing centers, maintain their supplies and determine their optimal locations based on at-risk populations increased.

Lessons Learned from COVID-19:

- Include data related to essential workers and at-risk populations.
- Monitor and model economic data such as business status and employment.
- Use sensor and crowdsourced data, such as human movement and business open rates, to augment existing data.

Automate Common Workflows with Apps

Automating workflows tends to be the most common application need during an emergency. This can be as simple as launching applications to collect authoritative data in the field on building conditions, hospital capacity and bed availability, the location and supply levels of resources, or rapid assessment of population risk and need. Applications such as these are foundational to nearly every response, from the recovery efforts of the 2011 Tuscaloosa-Birmingham tornado in Alabama to the eradication of Ebola in West Africa and Hepatitis A among San Diego County's homeless populations from 2016 to 2018.

The activities surrounding COVID-19 paved the way for new application needs and related models to keep the virus in check. For example, the operations dashboard became the most predominant tool used worldwide for disease monitoring and public communication. Along the way came applications to support business continuity to monitor workforce availability and supply chains. For example, applications emerged for modeling indoor operations and space planning to help workers return safely to the office and for travelers to move inside airports and transit stations. Community contact tracing merged old data collection processes with GIS to provide quick, new insight.

Lessons Learned from COVID-19:

- Leverage mobile solutions to improve inventory and capacity tracking.
- Expand your spatial thinking to the indoor environment.
- Workforce and supply chain management are critical elements of response.
- Communication and engagement hubs support decision-making and transparency.

Broadband Availability, Digital Equity and COVID-19 App ▲

How ArcGIS Aids Response: Inventory and Map resources

Step 1:
Map the cases

Map confirmed and active cases. fatalities, and recovered cases to identify where COVID-19 infections exist and have occured.

Step 2:
Map the spread

Time-enabled maps can reveal how infections spread over time and where you may want to target interventions.

Step 3:
Map vulnerable populations

Mapping social vulnerability, age and other factors helps you monitor the most at-risk groups and regions.

Step 4:
Map your capacity

Map facilities, employees or citizens, medical resources, equipment, and services to understand and respond to current and potential impacts of COVID-19.

Step 5:
Communicate with Maps

Use interative web maps, dashboards, apps, and story maps to help rapidly communicate your situation.

Capturing Best Practices in the Moment

Although resources and reference manuals provide guidelines from past responses, COVID-19 has exposed new gaps in our processes and procedures that could benefit from a fresh review. The use of GIS and spatial thinking is well established as a unifying way to bring together disparate disciplines and systems and improve collaboration and outcomes. Extending location-centric data can further interconnect our world. It leverages interdependencies among disciplines and extends broad subject-matter expertise.

The need to highlight the societal role of health and human services departments has increased. Events such as the pandemic have stressed the importance of these disciplines' ability to forge stronger relationships with GIS experts. The response to the pandemic underscored the connection between public health and economic health, thus supporting another example for heightened collaboration. Making these connections in the planning phases can aid in the transition to an effective response and recovery.

The importance of data during a health emergency stretches far beyond government agencies. Different people and organizations have varied perspectives and goals. They often want access to authoritative sources of data to do their own analysis, deploy resources, build and run models, and evaluate decisions. Esri, in partnership with corporate, academic, not-for-profit organizations and federal, state, and municipal governments, has taken the first step in providing standardized information that's easily accessible as public datasets. This work continues with additional resources available on the Esri COVID-19 GIS Hub.

The health community will continue to grow and adapt the basic data it needs to react effectively. On the next page are the common datasets required that had not been previously considered in responding to a pandemic. In time, additional data requirements will likely emerge.

Citizens within an 11-minute drive to an emergency room.
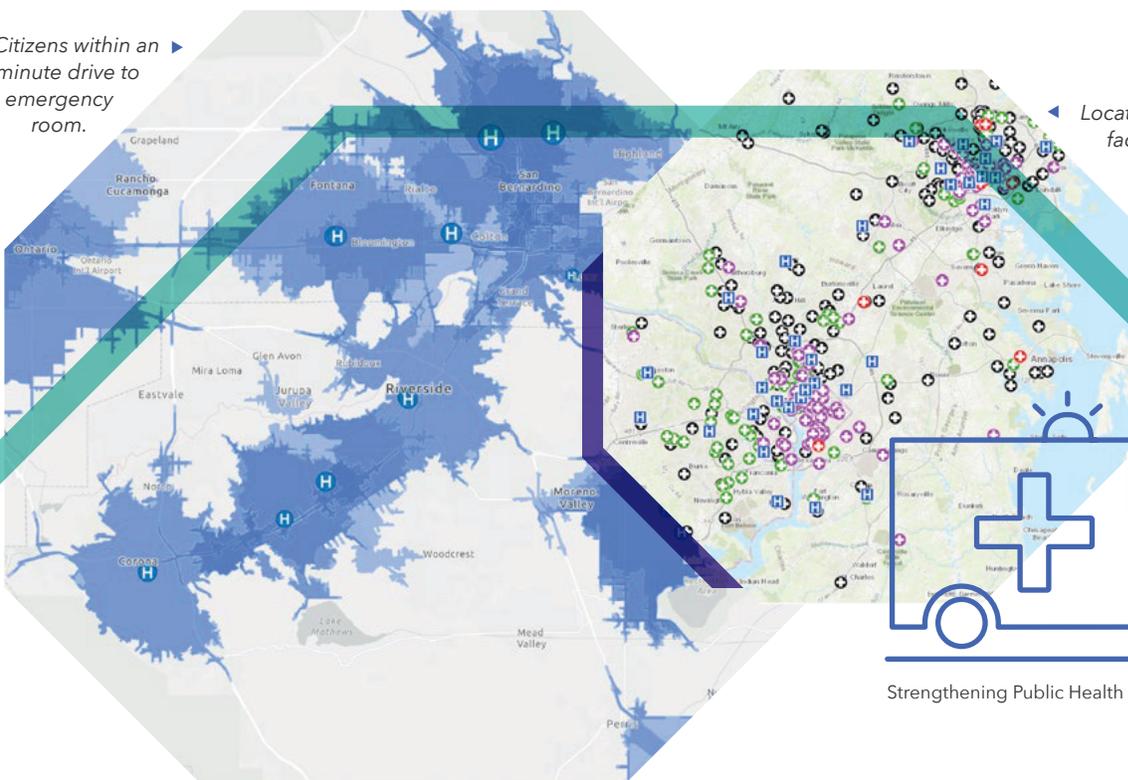
Location of healthcare facilities in the U.S.

Common Data Requirements for Public Health Preparedness

To Scope Out the Crisis

- **Healthcare facilities** (*hospitals, urgent care, nursing homes, etc.*)
- **Other facilities** (*schools, daycares, shelters, etc.*)
- **Transportation networks and infrastructure** (*roads, helicopter landing zones, public transit stations, railways, ports, airports, etc.*)
- **Boundaries** (*ZIP codes, counties, states, health districts, Federal Emergency Management Agency regions, hospital service areas, etc.*)
- **Homeland Infrastructure Foundation-Level Data**

To Map the Spread

- **Cases** (*frequencies, rates, etc.*)
- **Deaths** (*frequencies, rates, etc.*)
- **Recovered** (*frequencies, rates, etc*).
- **Projecting cases, deaths, and resource needs**
- **Tagged social media, Google searches or related surveys, hospital reported data, and purchasing behaviors (i.e. medication purchases) to support broad surveillance activities**
- **Social distancing behaviors**

To Identify Vulnerable Communities

- **Demographics** (*race, ethnicity, age groups, income, etc.*)
- **Labor statistics** (*unemployment/employment*)
- **Homeless population**
- **Essential worker**
- **Concurrent disasters that may present potential congregation points or the inability to quarantine or social distance**(*floods, wildfires, hurricanes, etc*)
- **Social vulnerability (***transportation access, healthcare coverage, poverty, disabilities, predominant language spoken, access to broadband, etc.*)
- **Comorbidities/health outcomes**
- **Populations 65+**
- **School locations**

To Allocate Resources

- **Possible staging and triage areas**
- **Temporary or emergency shelters (***i.e., schools, community centers, religious centers*)
- **Testing sites, supply of tests, and test per population group**
- **Personal protective equipment supply**
- **Ventilators supply**
- **Available beds per facility**
- **Intensive care unit beds per facility**

To Engage the Community

- **Impacted businesses**
- **Voting locations**
- **Policies per city or county boundary** (*i.e., stay-at-home orders, emergency declarations, mandatory closings, face-covering rules, travel restrictions, quarantine areas*)
- **Longitudinal case trends**
- **Daily signs and symptoms for wellness checks**
- **Changes in government services and hours**
- **School closures**

Information Products Lay Foundation for Crisis Response

Amid a public health crisis, it's difficult to think about what you need to support response and recovery efforts, and it's certainly too late to take steps to be better prepared. Public health preparedness should be an iterative process, with the experience of each crisis informing preparations for the next.

Part of this preparation is taking the time to consider what information, products and applications could help organizations with the challenges they will face. Time and communication are typically the biggest detractors to emergency response.

Drawing from past experiences, apps, as well as data products that can collect data, analyze information for quick decision-making, and support briefings should be at the ready, just as emergency management professionals carry other tools into the field.

These decision-support tools can back many functions. Based on the specific need, they can take many forms – from individual reports, charts, graphs and maps to interactive dashboards that integrate multiple elements into a common operational picture.

The following are examples of the many information products and applications that organizations worldwide have successfully leveraged for public health response. Responses from past crisis have prompted research and development of applications for new concepts, such as homelessness, the opioid crisis, community contact tracing and indoor space planning.

Emergency Management

Preparedness
Understand risk and evaluate resiliency, increase response capabilities when a disaster occurs, and increase awareness throughout a community.

Response
Address the short-term impacts of an event, maintain situational awareness, conduct initial damage assessments, and inform key stakeholders and the general public.

Recovery
Assess the full impact or extent of an event, return the community to normal operating standards, and execute service.

Mitigation
Reduce or eliminate risks to persons, lessen the actual or potential consequences of an event, and reduce the effects of unavoidable impacts.

Opioid Crisis

Tackle Opioid Epidemic
Communicate the severity of the opioid epidemic, promote treatment alternatives, and understand the effectiveness of response activities.

◄ *Predominant Occupation Vulnerable to Extreme Heat*
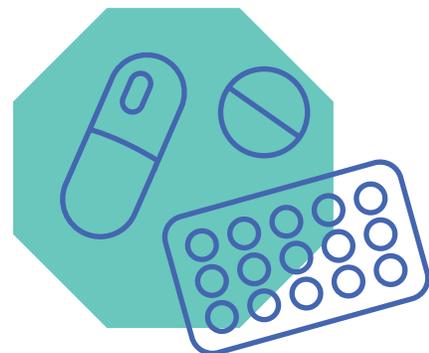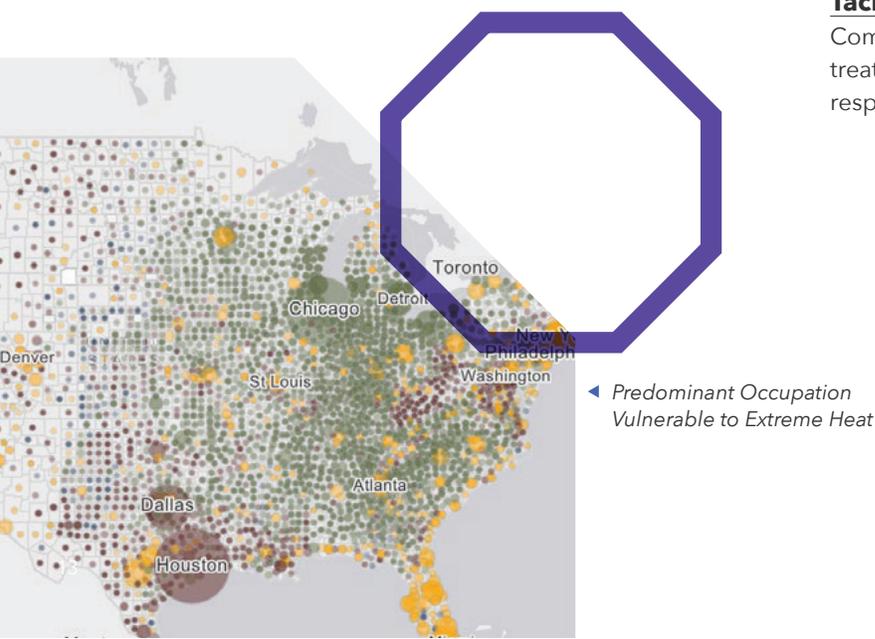
Homelessness

Address Homelessness
Count the homeless population, inventory homeless resources, and increase awareness of homeless services.

Vector-Borne Disease Surveillance and Response

Combat Vector Borne Diseases
Manage and combat the spread of vector-borne diseases.

Pandemics and Epidemics

Response
Understand the impact of the crisis and share authoritative information about the pandemic with your community.

Recovery
Monitor key recovery metrics and trends that support phased recovery efforts.

Hospitalization and PPE Inventory
Inventory hospital capacity and personal protective equipment (PPE) available at local hospitals and acute care centers.

Wellness Checks
Engage volunteers and check the wellness of vulnerable individuals throughout a community.

Testing Sites
Identify at-risk populations and develop testing site plans.

Business Reopening
Guide the decision to open or close a business location.

Small Business Recovery
Promote small businesses operating during a crisis and understand the impact of the crisis on small businesses in their community.

Business Continuity
Maintain business operations and share authoritative information with customers and stakeholders.

Great Leadership Drives Technology

There are two very important pillars of public health preparedness planning and recovery. First and foremost is that technology and data can't go it alone. Every response that involved major advancements in technology adoption was closely coupled with a leader who understood its value, could communicate what was needed to support the situation and could use technology to advance the mission at hand. More importantly, these leaders understood the long-term potential to build up and sustain the work they initiated with GIS. Secondly, GIS and location intelligence are differentiators in saving lives and safeguarding the public.

Conclusion

Public health emergency planning and response is an evolving field. The capabilities and processes developed in response to one crisis can lay the foundation for the response to future events. The key is to incorporate new tools and practices into existing workflows before the next crisis strikes.

Because of both its scale and complexity, the COVID-19 pandemic has driven a broad range of innovations in health preparedness that public health organizations and communities will draw on for years to come.

GIS serves as the common denominator for any crisis because location data is essential to every phase of planning and response. It helps communities scope out the extent of a crisis and predict the future course to allocating resources and monitoring processes and outcomes. GIS also is the common language that enables public health organizations to coordinate efforts with other agencies and external stakeholders.

The public health preparedness community can make major inroads by embracing GIS data, models, communication and engagement hubs, and location-centric applications. Esri is here to build on the past and propel the industry into a better future.

go.esri.com/health-preparedness

When Esri was founded in 1969, we realized even then that geographic information system (GIS) technology could make a difference in society. Working with others who shared this passion, we were encouraged by the vast possibilities of GIS.

Today our confidence in GIS is built on the belief that geography matters - it connects our many cultures and societies and influences our way of life. GIS leverage geographic insight to ensure better communication and collaboration.

Explore our website to discover how our customers have obtained the geographic advantage by using Esri software to address social, economic, business, and environmental concerns at local, regional, national, and global scales. We hope you will be inspired to join the Esri community in using GIS to create a better world.

GovLoop's mission is to inspire public sector professionals by serving as the knowledge network for government. GovLoop connects more than 300,000 members, fostering cross-government collaboration, solving common problems and advancing government careers. GovLoop is headquartered in Washington, D.C., with a team of dedicated professionals who share a commitment to the public sector.

For more information about this report, please reach out to info@govloop.com.

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