Role of GIS in Tracking and Controlling Spread of Diseases

Final Draft

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Abstract

In order to properly plan, manage and monitor any public health programme, it is vital that up-to-date, relevant information is available to decision-makers at all levels of the public health system. For the epidemic to break out it is not sufficient to have a source of infection alone, but also an appropriate mechanism of transmission. Four mechanisms of infection transmission are: (i) faecal-oral; (ii) air-borne; (iii) transmissive; and (iv) contact and the main factors involved in transmission of infection are: air, water, foods, soil, and arthropods. As every disease problem or health event requires a different response and policy decision, information must be available that reflects a realistic assessment of the situation at local, national and global levels. This must be done with best available data and taking into consideration disease transmission dynamics, demographics, availability of and accessibility to existing health and social services as well as other geographic and environmental features. Recently, GIS has emerged as an important component of many projects in public health and epidemiology. GIS is particularly well suited for studying these associations because of its spatial analysis and display capabilities. [Rajiv Gupta, Map India Conference 2003]

The paper discusses case studies related to various infectious diseases with detailed literature review and also common methodology used for various diseases with a special treatment to West Nile virus using GIS.

1. Introduction

GIS combines layers of information about a place to give you a better understanding of that place. What layers of information you combine depends on your purpose, finding the best location for a new store, analyzing environmental damage, viewing similar crimes in a city to detect a pattern, and so on. [ESRI]
http://www.nww.usace.army.mil/gis/definition.htm

Geographic information systems (GIS) provide ideal platforms for the convergence of disease-specific information and their analyses in relation to population settlements, surrounding social and health services and the natural environment. They are highly suitable for analyzing epidemiological data, revealing trends and interrelationships that would be more difficult to discover in tabular format. Moreover GIS allows policy makers to easily visualize problems in relation to existing health and social services and the natural environment and so more effectively target resources.

GIS has been used in the surveillance and monitoring of vector-borne diseases, water-borne diseases, in environmental health, analysis of disease policy and planning, health situation in an area, generation and analysis of research hypotheses, identification of high-risk health groups, planning and programming of activities, and monitoring and evaluation of interventions. GIS enabled researchers to locate high prevalence areas and populations at risk, identify areas in need of resources, and make decisions on resource allocation.

GIS has applications in different fields such as, Business, Cartography and Map Publishing, Communications, Defense, Education, Engineering, Government, Natural Resources, Transportation, Utilities, and finally but not the least Health and Human Services.

In Health and Human Services alone GIS has a wide range of applications,

1) GIS provides a common analytical framework in which public health authorities can understand problems and formulate a response, improving incident management and health planning.
2) GIS is becoming a vital tool for scientists and public health officials investigating the cause and spread of deadly diseases around the world.
3) Outbreaks of infectious diseases such as SARS can be quickly analyzed using GIS tools

Fig 1- Web site established in Hong Kong

4) The screen shot above contains a Web site established in Hong Kong to track the locations of reported SARS cases. GIS allowed early recognition that a large multi-story residential complex was a "reservoir" for the infection. [Map India 2001 Conference]

2. Problem Statement

Understanding the determinants of a disease, and its spread from person to person and community to community has become increasingly global (ESRI White Paper, 1999). GIS plays a vital tool in strengthening the whole process of epidemiological surveillance information management and analysis. GIS provides excellent means for visualizing and analyzing epidemiological data, revealing trends, dependencies and inter-relationships that would be more difficult to discover in tabular formats. Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for monitoring and management of diseases and public health programs.

The underlying factors likely to lead to increased incidence of diseases, including adverse environmental, behavioral and socio-economic conditions, needs to be monitored regularly. By tracking the sources of diseases and the movement of contagions, health agencies can respond more effectively to the outbreaks of epidemics by identifying populations at risk.

Software packages such as Body Viewer by GeoHealth, help medical personnel visualize clinical data. Integration of clinical information is accomplished by linking unique codes directly to a graphical representation of the human body and to the geographical location where the patient has originated (ESRI White Paper, 1999). Such geo-clinical information system is a useful tool when evaluating environmental risks and exposures.

3. Objectives

The main objective of this paper is to discuss the role of GIS in tracking and controlling the spread of diseases which are of epidemic nature and the feasible applications of GIS in identifying their catchment area. The paper discusses the common methodology for various diseases with a special treatment to West Nile virus using GIS.

4. Methodology of Study

The methodology used in this study is as follows,

- Studying the spread of disease and applying techniques in tracking and controlling it.
- Extensive literature has been studied related to the problem
- Presenting Case studies
- Finally concluding and providing recommendations

One of the methodologies used

Many factors contribute to the emergence of infectious diseases. Those frequently identified include microbial adaptation and change, human demographics and behavior, environmental changes, technology and economic development, breakdown in public health measures and surveillance, and international travel and commerce. Factors that can influence receptivity include climate and environmental conditions, sanitation, socioeconomic conditions, behavior, nutrition, and genetics. The human population is more vulnerable because of aging, immune-suppression from medical treatment and disease, the presence of prostheses, exposure to chemicals and environmental pollutants that may act synergistically with microbes to increase the risk of diseases, increased poverty, crowding and stress, increased exposure to Ultra Violet radiation, and technologic changes. **Table 1** lists the different infectious diseases, its Aetiology (cause of disease), epidemiology, and vulnerable group/ conditions.

A common methodology could be to develop the related databases regarding climate and environmental conditions, sanitation, socioeconomic conditions, behavior, nutrition, genetics, etc. according to the factors given in column (2). Spatial parameters like environmental conditions, temperature, soil conditions, etc. have to be interpolated using a suitable spatial analytical technique. Column (3) epidemiology provides the information regarding the carriers. The database regarding sanitation, socio-economic, behavior, etc. should be created and related maps should be digitized accordingly. The movements of the carriers should be interpolated, which could be done by using the buffer operations. Last column (4) provides the information about the group, which is vulnerable. These groups/ conditions could be easily identified and can be located on maps/ images. Temporal features like rainfall, low-high temperature, etc, should be identified in regions/ zones. Overlaying these images will give a good picture of the vulnerable area to that disease. (Map India Conference 2003)

Table 1: Infectious diseases, its Aetiology, epidemiology, and vulnerable group/ conditions [Map India Conference 2003]

Disease (1)	**Aetiology (2)**	**Epidemiology (3)**	**Vulnerable group/ conditions (4)**
Typhoid fever	Stable in environment; water, food, soiled hands, environmental objects	Patient	
Paratyphoid fevers A and B	Stable in environment; water, food, soiled hands, environmental objects	Patient, animal	
Salmonellosis	Low temperature, dry dung, home dust, animal faeces, food	Man, animal, contact infection	
Pseudo-tuberculosis	Vegetables, milk, low temperature, water,	Cats, cattle, sheep, goats, wild animals	Army, schools, bodies boarding collective
Yersiniosis	Low temperature, optimum 25 C	Dogs, cats, cattle, rodents, human	Canteen, collective bodies restaurant,

Intestinal infections	Soil, open water bodies, food, milk products, Common in nature, optimum 20 to 37 C	Soil, open water bodies, food, milk products	Food catering establishments
Staphylococcal Toxaemia	Stable to heat	Patients with supportive foci, diseased animals, dairy products	
Botulism	optimum 28 to 37 C	Pickled mushrooms, home- canned vegetables, home-smoked meat	
Dysentry	Soil, utensils, food	Humans, food, water, soiled hands, environmental objects	
Amoebiasis	Water, moist faeces, low temperature	Contact, sanitary conditions,	Common for countries with hot climate
Escherichia infections Coli	River, well and tap water, foods	Food, water, calves, pig, poultry, milk products, meat	
Cholera	Faeces, soil, milk products, food	Patient, carrier	
Rotaviral Gastroenteritis	Faeces, food	Patient	
Viral Hepatitis	Water sources, soil	Vegetables, berries, soiled hands, dishes, toys	
Poliomyelitis	Water, milk, faeces	Dishes, toys,	5-7 years children
Non-poliomyelitis Enteroviral Infections	Faeces, nasopharyngel discharge, blood	Water (swimming pool), food, direct contact	
Brucellosis	Soil, milk, sheep cheese, wool, food	Domestic animal (Goats, sheep, cattle, swine, cats, dogs, camels, deer, horses)	
Leptospirosis	Water bodies, soil, foods	Rodents, cattle, dogs, cats, rats, poultry, bird	Vicinity of lakes, swamps rivers,
Respiratory			
Influenza	Chick embryo, hamsters, mice, pole cats, air	Diseased humans (sneezing, coughing, talking)	Living conditions, overcrowding, intensive migration of population
Parainfluenza	Human embryo kidney(lab conditions)	Air-borne	Infants

Adenovirus	Air	Diseased humans (nasal, nasopharyngel mucus, sputum, conjunctival discharge): contact, food, water	Infants: 6 months -3 years
Smallpox	Dry pustules and exudates, water	Diseased humans coughing, talking), dust (sneezing,	Eradicated
Diphtheria	Objects (toys, dishes), food (milk)	Diseased humans coughing, talking), over (sneezing, crowding	
Scarlet Fever	Food (milk & sugar)	Diseased humans, fomites, foods (ice-cream, sweets)	
Measles	Human and monkeys, food	Diseased humans	Morbidity increases in Cold season
Rubella	Tissue cultures	Diseased humans	
Whooping cough	Pathogenic to human	Diseased humans	Preschool children
Parapertusis		Diseased cases humans, sporadic	Kinder gardens, school
Chickenpox	Food	Diseased contagious humans, highly	Large season cities, cold
Mumps	Highly contgiosity	Diseased humans, sporadic cases	5-15 years
Meningococcal infection		Diseased humans	
Psittacosis	Low temperatures	Birds (pigeons, ducks, etc.,)	
Legionellosis	Natural conditions, open water (blue-green algae)	Inhalation of minutest droplets of infected water	Alcohol, diabetes mellitus, smoking
	Blood Infections		
Rickettsioses			
Epidemic Typhus and Brill's disease	Lice faeces	Diseased humans	
Endemic Typhus		Rodents, fleas & gamasoidea ticks	Food contaminated with urine of infected mice
Q fever	Drying & ultra violet radiation, tap water, milk, oil & meat	Animals & birds, ixodes & birds, milk, faeces, urine, placenta, amniotic fluid of animals	
Borrelioses			

Relapsing fever	Human beings, lice	Diseased humans, lice	
Endemic fever relapsing	Human beings	Diseased animals humans, rodents,	
Tick-borne Encephalitis	Low temperature freezing &	Albino mice, hamsters, monkeys, sheep, goats, horses, cows	
Malaria	Protozoa of the Plasmodium genus	Diseased humans, mosquitoes	
Leishmaniasis (Mediterranean, kala azar, Indian kala azar, East African, Chinese & American	Rodents, dogs, cats, monkeys & human beings	Diseased humans, dogs, jackals, foxes, rodents,	1- 5 years
Haemorrhagic Fever			
Tick-borne: Crimean-Congo, Omsk, Kyasanur Forest disease.	Wild animals domestic animals, of 20 species and ticks	Human beings, animals, transfusion, air-borne rodents, birds, monkeys blood route,	
Mosquito-borne: Yellow fever, Dengue Fever, Chikumgunya, Rift Valley	Blood serum	Monkeys, rodents	
Contagiouszoonotic: haemorrhagic fever with renal syndrome, Argentinian, Bolivin, Lassa, Marburg, and Ebola		Voles, mice, rats (faeces, urine and saliva), Diseased humans, food, contacts, dust inhalation	
Plague	Dead (frozen) rodents, humans, dead pus, water	Rodents, sousliks, voles, marmots and rats, animals, fleas	

Tularaemia	Water, frozen foodstuffs, dried pelts, grains & straw	Rodents, water muskrats, hamsters rats, hares,	
Skin Infections			
Anthrax	Uncultivated underlying soil layers soil,	Cattle, goats, deer, pigs, camel sheep, horses,	
Rabbies	Central nervous systems of human and animals	Animals (foxes, wolves, jackals and polar foxes, etc.)	
Tetanus		Dust, soil, and animal faeces	Woman during labor & gynecological manipulations
Erysipeas		Cooling, disease fatigue, and other	Woman
Acquired Deficiency Syndrome Immune	Blood, saliva semen, urine,	Transfusion of bloods, sexual intercourse, coagulation factors, erythrocytes, leucocytes, thromboctes	

5. Literature Review

There are various categories under which the infectious diseases fall. These include vector borne diseases, airborne diseases, waterborne diseases, food borne diseases, and plant and fish diseases. These categories are influenced by various factors. Three obligatory factors are necessary for the onset and continuous course of an epidemic process: source of pathogenic microorganism, the mechanism of their transmission, and microorganisms susceptible to infection. Basic concepts in disease emergence are: Emergence of infectious diseases is complex; Infectious diseases are dynamic; Most new infections are not caused by genuinely new pathogens; Agents involved in new and reemerging infections cross taxonomic lines to include viruses, bacteria, fungi, protozoa &helminthes.

High-risk areas can be identified using GIS and remote sensing technologies that would otherwise be difficult to detect using traditional methods. Control and education programs can be directed toward these areas with more confidence and effectiveness. The following images show the analysis part done in ArcView GIS. GIS provides excellent means for visualizing and analyzing epidemiological data, revealing trends, dependencies and inter-relationships. GIS serves as a common platform for convergence of multi-disease surveillance activities. Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for monitoring and management of epidemics. GIS helps us out in many ways. These include the following applications.

- Find out geographical distribution and variation of diseases
- Identify gaps in immunizations
- Map populations at risk and stratify risk factors
- Forecast epidemics
- Monitor diseases and interventions over time
- Manage patient care environments, materials, supplies and human resources
- Monitor the utilization of health centers
- Route health workers, equipments and supplies to service locations
- Locate the nearest health facility. [Rajiv Gupta, Map India Conference 2003]

Experts consider rapid and reliable communication between national and international public health agencies essential to an effective response to the threat of infectious disease. Communication of disease conditions between public and animal health communities including those dealing with domestic animals, wildlife, and other animals such as zoo animals is very weak and hinders tracking of emerging infectious diseases.

The outbreak of WN virus in New York City highlights the validity of these concerns. Poor communication resulted in the public perceiving government response as chaotic and disjointed. This perception led to criticism that the government was uncaring or incapable of protecting people from the disease or the chemicals used to control the outbreak. In fact, given the resources available, government did a superb job. The real failure was in communicating the problem and how government was handling it.

This instance points out the need for better collection of field data, integration of data for decision making, and improved methods for communicating findings and decisions to other agencies and the public. Current systems either do not allow or do not facilitate rapid communication. Information on disease outbreaks is not directly shared between countries, federal agencies, states, or laboratories, whether on the local, state, or regional level, and the private sector has no vehicle for sharing information with human health or veterinary professionals.

Although these concerns have been identified, no organization on a national level has stepped to the forefront with a comprehensive response that provides for an integrated reporting structure, enables timely data collection and assessment, and promotes rapid communication with key organizations and the public. However, the State of Pennsylvania has developed and implemented a system that addresses these issues. [ARC USER 2001]

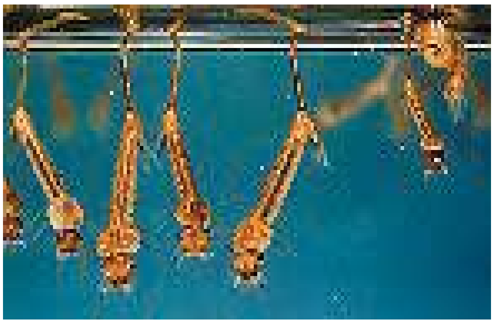

Fig 2-Preventative measures have concentrated on reducing the mosquito population. [ARC USER 2001]

The WNV Tracking System is a spatially driven surveillance program for following and responding to the spread of WNV in the State. The system collects information on the presence of virus in any vector, identifies mosquito-breeding areas, and helps target control efforts. Key innovations include field collection of data using handheld computers and ArcPad software and a Web application that enables data submittal from State laboratories. The system uses ESRI software to display data for decision makers and the public. [ARC USER 2001]

An important feature of the WNV Tracking System is the ID number, a unique preprinted, bar-coded number that is placed on each sample bottle. This ID number is used when entering data into the handheld computer in the field so that all the information about a sample can be kept together in the database. After the field data is uploaded, a quality assurance/quality control (QA/QC) program verifies the accuracy of the data. Only verified data can be added to the central database.

When samples arrive at the laboratory, staffs electronically scan the ID number from the sample bottle into a Web form designed for the project. Mosquito species are identified, the numbers of mosquitoes are counted, and this data is added to the database. If the sample is sent to another lab for further testing, the transfer is noted in the database, and final results from any other testing are entered in the database by lab workers using Web forms. Consequently, results are available almost instantly. [Eric R. Conrad]

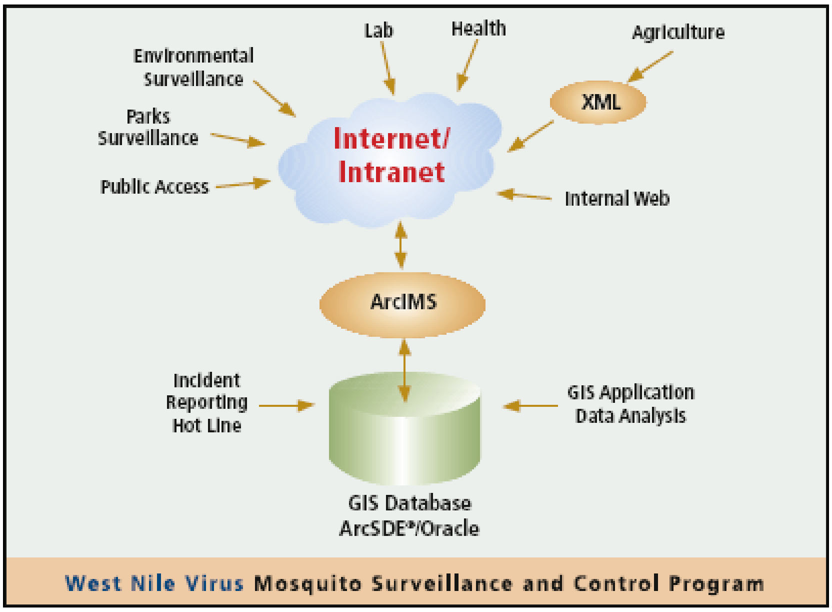

Fig 3-Tracking Diseases with GIS; Eric R. Conrad

In humans, WNV infection usually produces either asymptomatic infection or mild febrile disease, sometimes accompanied by rash, but it can cause severe and even fatal diseases in a small percentage of patients. The human case-fatality rate in the U.S. has been 7% overall, and among patients with Neuroinvasive WNV disease, 10%.Unlike WNV within its historical geographic range, or St. Louis encephalitis (SLE) virus in the Western Hemisphere, mortality in a wide variety of bird species has been a hallmark of WNV activity in the U.S. The reasons for this are not known; however, public health officials have been able to use bird mortality (particularly birds from the family

Corvidae) to effectively track the movement of WNV. WNV has now been shown to affect 162 species of birds. Previous early-season field studies have determined that areas with bird mortality due to WNV infection were experiencing ongoing enzootic transmission. However, most birds survive WNV infection as indicated by the high Seroprevalence in numerous species of resident birds within the regions of most intensive virus transmission. The contribution of migrating birds to natural transmission cycles and dispersal of both WN and SLE viruses is poorly understood.

WNV has been transmitted principally by Culex species mosquitoes, the usual vectors of SLE virus.

Thirty-six species of mosquitoes have been shown to be infected with WNV. This wide variety of WNV-infected mosquito species has widened this virus' host-range in the U.S. 27 mammalian species have been shown to be susceptible to WNV infection and disease has been reported in 20 of these (including humans and horses). It must be remembered, however, that the detection of WNV in a mosquito species is necessary but not sufficient to implicate that species as a competent vector of WNV. [Centers for Disease Control and Prevention Epidemic/Epizootic West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control]

http://www.cdc.gov/ncidod/dvbid/westnile/publications.htm.

6. Case Studies

In this paper three case studies will be discussed,

- First one deal with the vector born diseases, airborne diseases, waterborne diseases, food borne diseases, plant and fish diseases. This case aims at finding out the population that is vulnerable to vector borne disease in Birla Institute and Technology and Science, Pilani (BITS) campus.
- Second one deals with the cases of West Nile Virus diagnosed in the State of Colorado than any other state and trying to educate the public by providing information to the media, and target spraying activities, the Colorado Public Health and Environment department developed a simple ArcIMS site that tracked the results of animal testing in near-real time.
- Third one deals with the Vector Surveillance and Control Program (VSC) of the County of San Diego Department of Environmental Health, they have provided

countywide mosquito surveillance and control services. Implementation of GIS in the VSC program has helped communicate and respond to the increased activity associated with the threat and imminent arrival of West Nile Virus.

6.1 1st Case Study, Disease Surveillance and Monitoring using GIS:

This case aims at finding out the population that is vulnerable to vector borne disease in Birla Institute and Technology and Science, Pilani (BITS) campus. The digital map of the campus is taken and the basic operations such as Geo referencing, digitizing, etc. are carried out. The different hostels, institute, staff quarters, wells, market places were digitized as a polygon theme and the road network was also digitized as a separate theme. The first phase utilizes landscape epidemiology to explore the relationship between landscape elements and the vectors breeding sites. The goal of this phase was to assess the capabilities of GIS and remote sensing to identify high vector breeding sites. The approach utilizes landscape composition methods. Using remotely sensed data to distinguish between different landscapes elements, it was determined that dairies, stagnating water, areas of vegetation had the highest vector abundance. The vectors must find larval habitats, blood meal sources and resting sites within a 1-km radius, in order to successfully reproduce. In the second phase GIS was used to determine the landscape composition of a 1-km buffer around each site. Using stepwise discriminant and regression analyses, it was determined that the whole BITS campus was vulnerable to the vector disease. The only restriction is that the climatic factors influence the breeding of the vectors. The climatic conditions of Pilani don’t favor many vectors to survive.

Common methodology to identify vector borne disease

1. The data on different types of vectors causing infectious diseases, their survival conditions and other data’s relevant to the vectors are collected.
2. The distribution of the population in a given region is gathered and sorted according to age group.
3. The map of the given region is obtained from the respective source. All the features in the map are digitized into their respective themes.

4. The vector breeding sites in that particular region is identified using suitable techniques.
5. The landscape composition and the population distribution are digitized on the map. The population database is also stored corresponding to the population age wise.
6. Buffers are created for the given population categorizing them into commercial area, institutes, and residential areas. Depending on the flight range of different vectors, suitable buffers are created from the vector breeding sites taking into consideration all the environmental and seasonal factors.
7. All these buffers are analyzed and using suitable operations such as union, intersection, overlay, network the vulnerable areas and the vulnerable group of population are assessed.
8. Depending on the results suitable preventive and control measures are taken.

Common methodology to identify airborne disease

1. The details of microorganisms present in air are obtained from suitable sources.
2. The data regarding the sustainable environmental factors are gathered and analyzed with respect to the given region.
3. The directions, flow rate, humidity conditions of air are obtained from Indian meteorological department.
4. For the given region, a direction profile for the flow of air is created.
5. Humidity and temperature profiles are created from the data obtained.
6. From all the data’s, an analysis is performed and the vulnerable areas of airborne disease are identified.
7. Depending on these results suitable preventive and control measures are taken.

Common methodology to identify water borne diseases

1. All water sources are marked on the map of the given region. These are further classified as running water, stagnating water. The stagnating water is further classified as shallow and deep waters. Mostly the stagnating water causes diseases.

2. The stagnating water bodies are identified, since these are the sources.
3. Buffers are created for these water bodies and hence the nearby areas prone to these microorganisms are identified depending on the pipe network and flow condition from these sources.
4. The population distribution vulnerable to these diseases is identified using suitable analysis depending on the data obtained.
5. Depending on these results suitable control and preventive measures are taken.

The Fig. 4 shows the map of BITS campus. It also shows the different hostels, staff quarters, institute, wells, stagnant water bodies, shopping centre, and grounds. Fig. 5 shows the 2d view of the flow pattern of water depending on the elevation of ground at different sites. Fig. 6 shows a particular flow direction of air taken into consideration. The flow of air is considered to be point vectors and the vulnerable areas to that particular flow direction are identified. Fig. 7 shows the overlay of the buffers created for the hostels, staff quarters, institute, market place and the vector breeding sites. Since the flight range of vectors are generally within 1km radius from different vector sites, the whole BITS campus falls vulnerable to vector disease. But certain environmental and seasonal changes prevent the survival of many vectors.

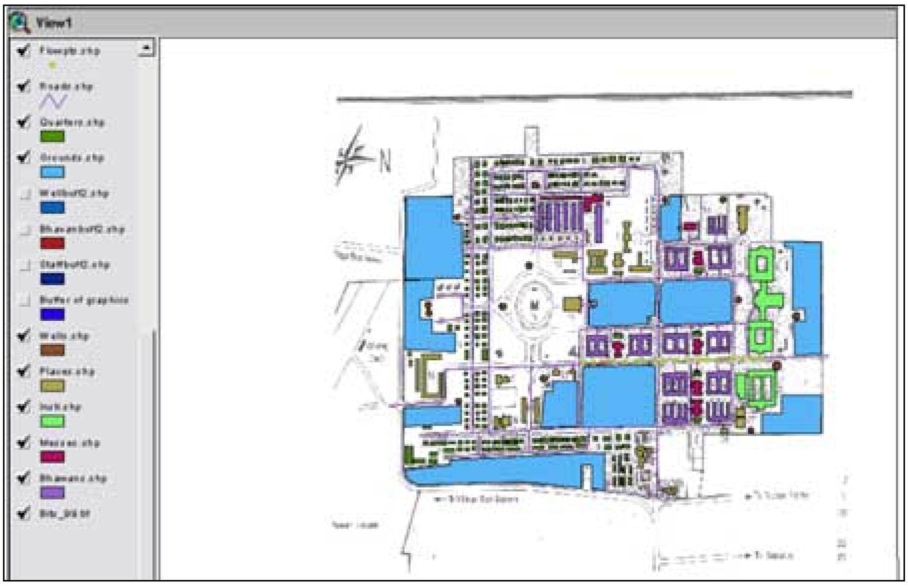

Fig. 4- Map of BITS Campus

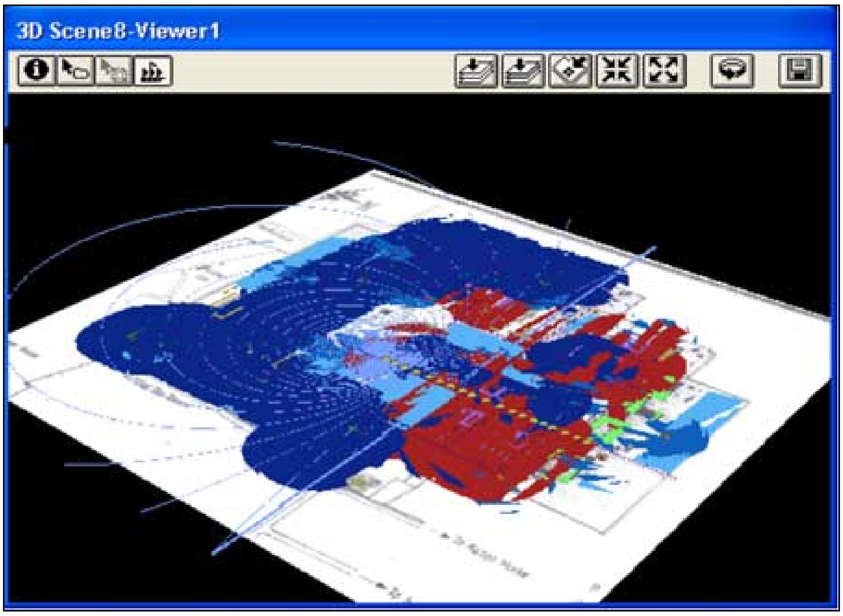

Fig. 5-2d View of the Flow Pattern of Water

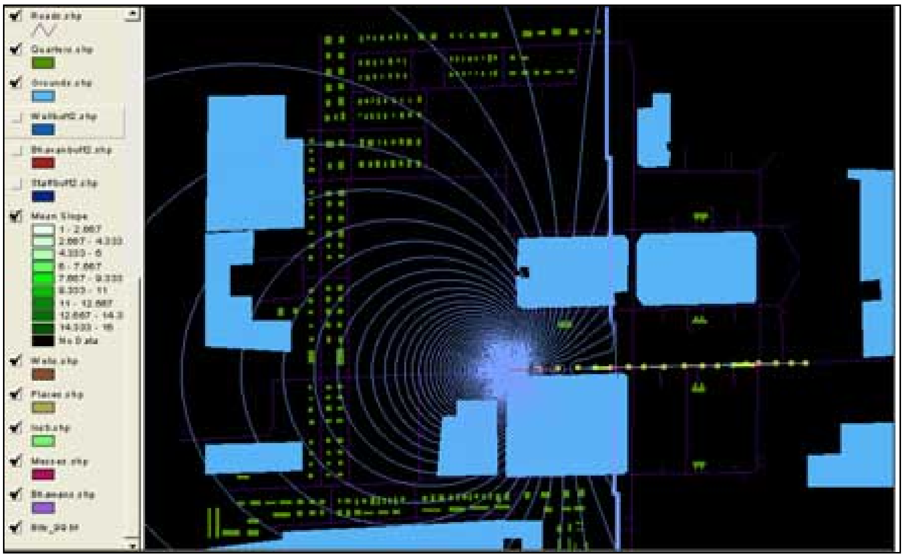

Fig. 6-Particular Flow Direction of Air

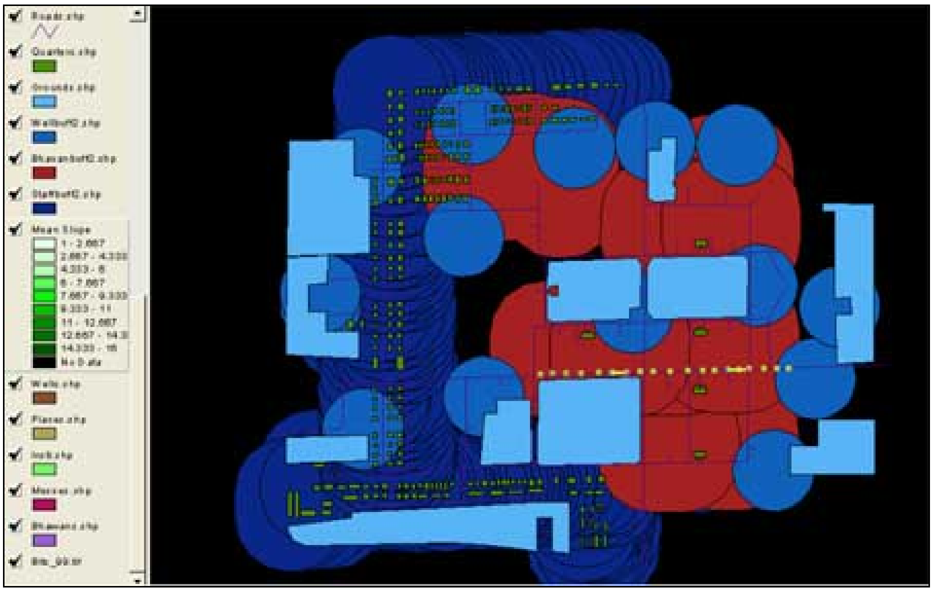

Fig. 7- Overlay of the Buffers

A GIS contains four types of information and computer files: geographic, map, attribute, and data-point files. In general, modeling involves the integration of GIS with standard statistical and health science methods. Spatial interaction models analyze and predict the movements of people, information, and goods from place to place. By accurately modeling these movements, it is possible to identify areas most at risk for disease transmission and thus target intervention efforts. Spatial diffusion models analyze and predict the spread of phenomena over space and time and have been widely used in understanding spatial diffusion of diseases. By incorporating a temporal dimension, these models can predict how diseases spread, spatially and temporally, from infected to susceptible people in an area. Spatial variation in health related data is well known, and its study is a fundamental aspect of epidemiology. Representation and identification of spatial patterns play an important role in the formulation of public health policies. Some of the graphic and exploratory spatial data analytic techniques are: point patterns, line patterns, area patterns, time series analysis, temporal cluster analysis, and spatio temporal analysis.

Conclusions for 1st Case Study

- Factors like movement of population, social conditions, environmental, soil conditions were analyzed and the diseases were classified accordingly.
- The populations at risk, catchment area, forecasting of outbreaks was found using suitable analysis.
- The vulnerable regions prone to these diseases were identified. This analysis was carried out by identifying the vector breeding sites, flow direction of the air, locating the places of stagnant water.
- By tracking the sources of diseases and the movement of contagions, the populations at risk were identified. Buffers were created for the hostels; staff quarters and the population at risk were identified.

6.2 2nd Case Study, Web-Based Disease Tracking: A West Nile Virus Example:

West Nile virus has emerged in recent years in temperate regions of Europe and North America, presenting a threat to public and animal health. The most serious manifestation of West Nile virus infection is fatal encephalitis (Inflammation of the brain) in humans and horses, as well as mortality in certain domestic and wild birds. West Nile virus first appeared in Colorado during the 2002 season. Public health agencies began testing birds, horses and mosquitoes to track the spread of this disease, and to identify areas where humans may be at risk for contracting the disease. By the end of the 2002 season, the West Nile virus had been detected in animals in some parts of the state (figure 8). Less than 10 human cases of the disease were diagnosed during the 2002 season. West Nile virus was much more widespread in Colorado during the 2003 season. As the 2003 season progressed, large numbers of animals tested positive for the disease. By the end of the season, 2944 humans had been diagnosed as having contracted West Nile virus, and 54 people died of complications from this disease.

Mapping the spread of the West Nile virus

GIS has played a role in combating the West Nile virus during the 2002, 2003 and 2004 (current) season. During the 2002 season, maps were posted to the web showing the areas where testing was being done, and where animals tested positive for the virus.

During the 2002 season, The Colorado Department of Public Health and Environment (CDPHE) collected and mapped West Nile virus animal data. From these maps, it was determined that the animals that tested positive were being collected primarily in the two eastern Colorado River drainages (the South Platte and the Arkansas). It was apparent that the virus had spread into the front-range communities by the end of the season, and that these communities would be vulnerable during the upcoming 2003 season.

Static maps continued to play a role during the subsequent West Nile virus seasons. These maps are a "snapshot" of conditions at any particular moment, and can be an effective way to communicate information about the spread of this virus in both animals and humans.

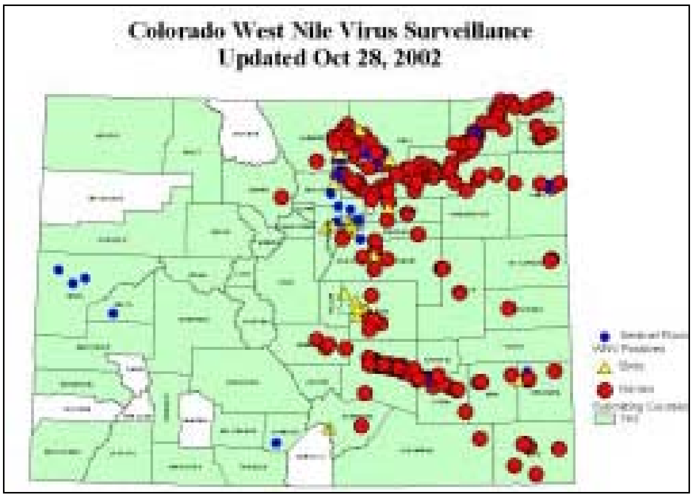

Figure 8- The 2002 end of season map showing the results of the West Nile virus animal testing program

Interactive maps

Prior to the onset of the 2003 season, a database was put in place that allowed the sharing of animal testing information among the agencies working on the West Nile virus problem. Persons responsible for entering data could access the database on the web. Prior to the start of the 2003 season, a simple ArcIMS site was built to map the animal testing data (http://emaps.dphe.state.co.us/wnv3/viewer.htm). ArcIMS had been recently installed at CDPHE, and the site was kept simple, in order that the site could be adequately supported during the season. A “location” table was automatically exported from the animal testing database and ftp’ed to the GIS web server. This location table was used to manually prepare the shape files that were used by the ArcIMS website. The interactive map allowed the user to view information about a particular species, or a particular area. The map was especially useful for identifying areas where the virus was prevalent.

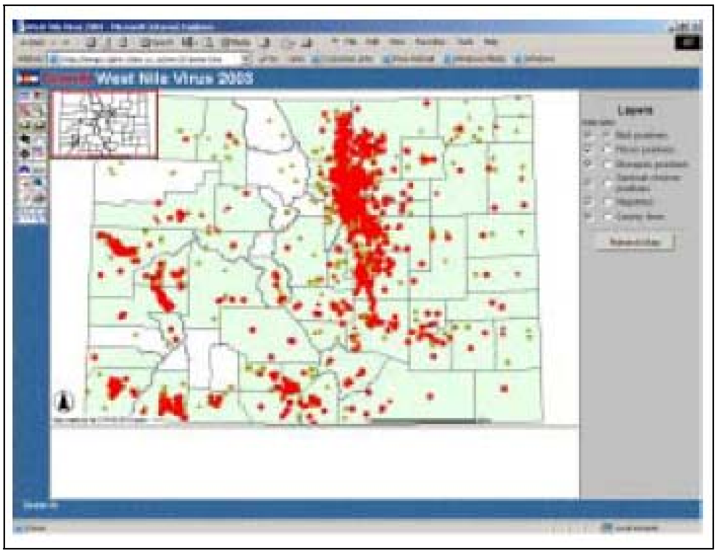

Figure 9- Screen capture of the West Nile Virus 2003 "Interactive map". The site was functional, and was widely used by public health workers and the press. However, the public seemed to find the site difficult and confusing

Dynamically updated interactive maps

Prior to the start of the 2004 season, an application was developed for CDPHE by ESRI contractors. This application was developed for a CDPHE Intranet site, where authorized users could map infectious diseases.

The 2004 site also connects directly to the location table that is ftp’ed from the testing database to the GIS web server. The application builds “acetate” layers from the location table, eliminating the need to manually re-build the points shape files. The net result is that the new application is much easier to maintain, and is always “synced” with the testing database. Lastly, the plotting/printing features are enhanced, replacing the need to manually generate the static maps. Now, any user can build “snapshots” directly from the interactive mapping application.

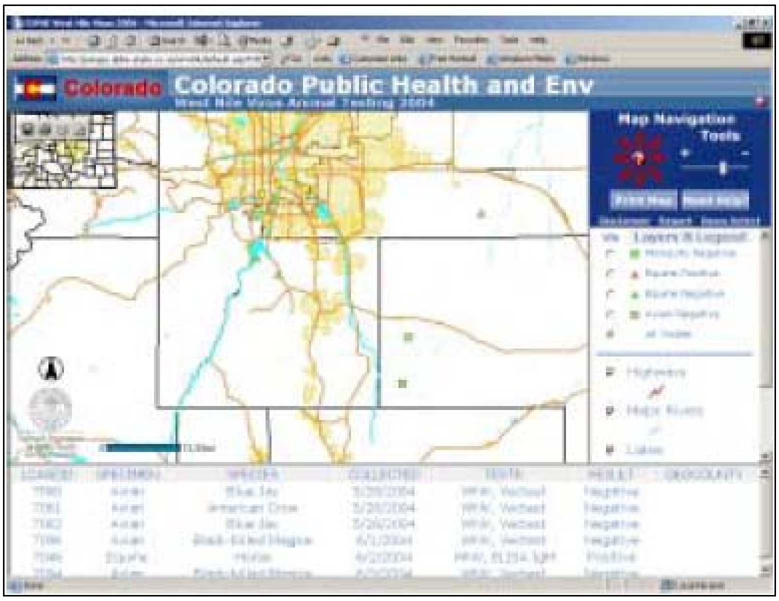

Figure 10- The improved 2004 Interactive mapping site showing detail of area south of Denver. Some sample locations (yellow) have been selected

The supporting infrastructure in 2004

Even though the end products seem relatively simple, being able to dynamically map public health data can require a great deal of infrastructure. Sometimes security of machines and security of the data can be a big concern.

The author believes that even a small amount of infrastructure can be expensive if it supports one or two applications and is not fully utilized. Infrastructure is cheap and deemed necessary if it supports a wide range of applications and a wide range of users.

The following items make up the infrastructure that supports the West Nile virus dynamic interactive map (the 2004 application);

- Database server.
- Database programmers and support staff.
- GIS web server.
- ArcIMS software.
- A mature GIS program and a complete “suite” of GIS software tools.

- Web and ArcIMS applications development.

Future plans

Initially, the role that GIS played in the efforts to combat West Nile virus was simply to prepare static maps, or "snapshots" of the data. As the virus became more widespread, GIS was also used to visualize and map the data as soon as it became available in the database.

Presenting point data as interactive maps on the web can be a difficult problem. A great deal of infrastructure and effort was required to "automate" the transfer of information between the database and the mapping website, and then to display the information in a way that could be easily understood by all types of users.

This work has also contributed to the adoption of GIS by a number of public health workers in the state. Some public health professionals in the state are starting to see the ability to interactively map point data on the web as a fundamental part of managing almost any disease outbreak, as well as some homeland security issues.

6.3 3rd Case Study: FIGHT THE BITE WITH GIS

The Vector Surveillance and Control program (VSC) of the County of San Diego Department of Environmental Health (DEH) has provided countywide vector surveillance and control measures since 1989. Housed within an environmental health department, the DEH VSC program has an emphasis on promoting healthy behavior and protecting the environment. The magnitude and seasonality of VSC program services vary, yet VSC continually focuses on mosquito control, rat control, and surveillance activities for vector-borne diseases such as plague and Hantavirus. Mosquitoes are a well-known vector capable of transmitting disease such as malaria and encephalitis to humans. Most recently, West Nile Virus (WNV) has been transmitted to humans from mosquitoes at a rapid rate since its appearance in North America in 1999.

This paper focuses on use of GIS in DEH VSC program. Substantive information on WNV can be found on Internet sites designed to provide scientific, preventative, and medical information on WNV to the public. Nonetheless, some basic information about WNV is warranted for background to the discussion of GIS projects presented in this paper. WNV is transmitted to humans through mosquito bites. Mosquitoes become infected when they feed on infected birds that have high levels of WNV in their blood. Infected mosquitoes can then transmit WNV when they feed on humans or other animals. The bird population has acted as a host and allowed rapid spread of the virus across North America. WNV predominantly infects birds with some bird species being more susceptible than others; however, horses and humans can become infected as well. A vaccine exists for horses but not for humans. A person infected with WNV may experience mild symptoms or in severe cases experience paralysis or death. In order to prepare and respond to the inevitable arrival of WNV to the San Diego region, several County of San Diego Departments including County Health and Human Agency (HHSA) and DEH, worked together to develop a West Nile Virus Strategic Response Plan (Plan). The Plan was designed to integrate resources to combine educational messages and mosquito control measures, and to develop a coordinated response to WNV.

USE OF GIS IN THE SURVEILLANCE & CONTROL OF MOSQUITOS

For several years VSC supervisors, vector ecologists, and vector control technicians have recorded daily field activities in Access database(s) and has marked by pencils in map books or pins on poster size maps. The ability to capture, analyze, and display this information has been made possible by working together to develop several GIS datasets. GIS has been used as a tool in preparing for WNV including mosquito control, vector surveillance, and outreach and education.

1. MOSQUITO CONTROL

a) Mosquito Breeding Source Locations

The first GIS project implemented in VSC was to map the known mosquito breeding sources. These sources are referred to as sites by the VSC staff and are recorded in an Access database using a unique site number.

Many of the mosquito sources (or sites) are large water bodies while others are smaller sources such as standing water in storm water conveyance systems. Many of the known breeding sources are a result of citizen complaints. These breeding sources may be located on publicly owned land or easements or on private land. The accuracy of the initial source GIS layer was lacking the accuracy needed to perform a point-to-polygon geoprocessing technique to assign property ownership to each source. The personal knowledge of staff was used to create a new dataset since this was considered a more accurate means of obtaining a more precise location for known mosquito breeding sources.

In order to map the sources, VSC staff received training on a DEH GIS intranet based mapping application developed in ESRI Map Objects. The mapping application allows staff to access a low-cost, simplified GIS interface for basic query and mapping functions. VSC staff used the application to identify breeding site locations and obtain property owner information. Using the refined site location a new mosquito breeding source GIS point layer was created. The following image shows the DEH GIS mapping application interface, the mosquito breeding sources (yellow triangles), and the results of a basic report (or query) on a selected site.

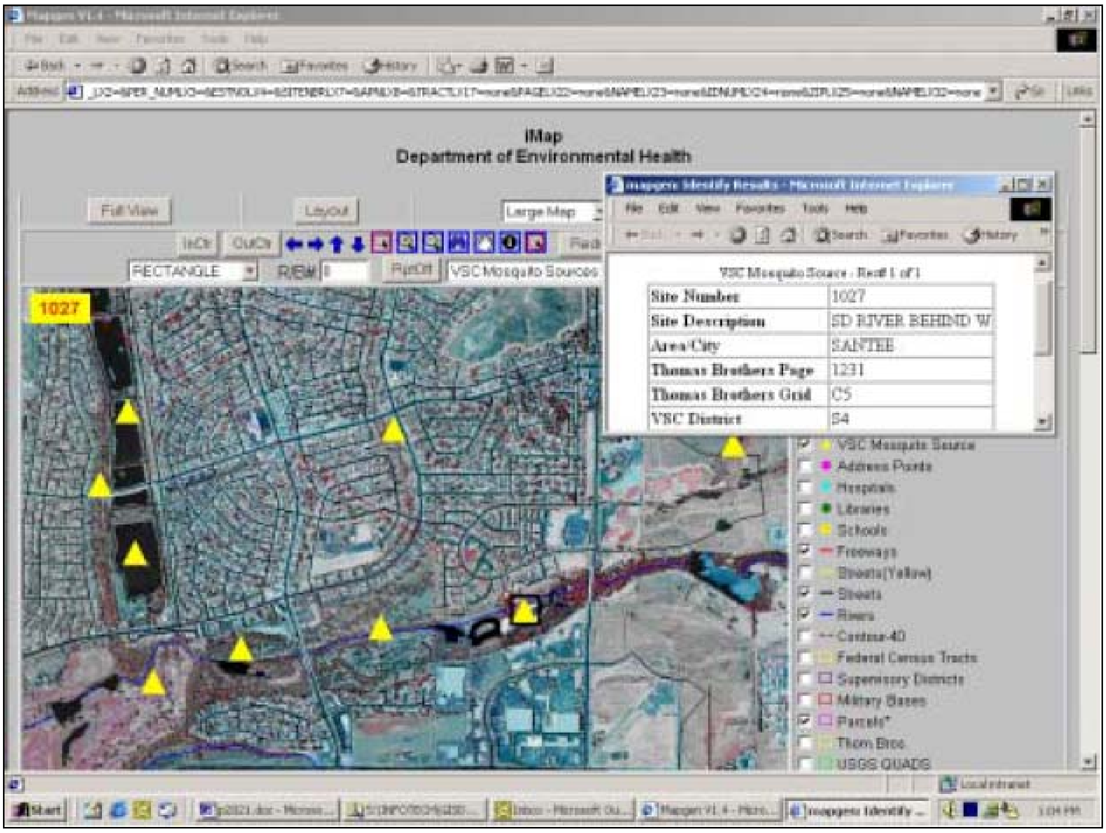

Fig 11- DEH GIS Mapping Application Interface, Mosquito Breeding Sources (Yellow Triangles), and Results of a Basic Report (or Query) on a Selected Site

Staff assignments change in order to respond to increased complaints and/or to reflect new route assignments, and the mapping application has proved helpful in allowing a newly assigned VSC field technician to locate mosquito-breeding sites throughout the County.

VSC staff also received training on Global Positioning Systems (GPS) technology.

Integration of GPS with GIS allows the field technician to capture the site location in the field. GPS was used in identifying some sites and in refining the locations of other sites. Despite the training, due to a limitation in staff time and the inventory of GPS units, this technology was not relied upon given the demand to complete a map of mosquito breeding sources before the mosquito season.

b) GIS increases Knowledge and Communication

VSC management used the mosquito breeding source GIS information to communicate mosquito problems and control measures with public and private landowners, cities and public agencies in the County of San Diego. The GIS information was also used to create and mail notifications to private landowners regarding planned mosquito control measures designed to reduce the risk of WNV.

In addition, VSC field technician route assignments have been mapped into a GIS layer enabling staff to easily view and review routes for quick assignment and response to mosquito complaints.

c) Mosquito Fish as a Control

Mosquito fish (Gambusia affinis) are an important part of the VSC program. These small, guppy-sized fish feed on mosquito larvae. Mosquito fish are considered a biological control as they allow for the reduction of chemical application and are considered part of an Integrated Pest Management (IPM) strategy. The fish are suitable for use in ornamental ponds and animal watering troughs.

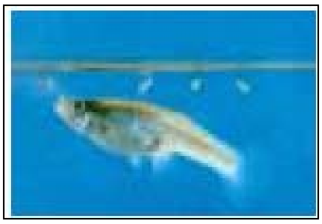

Fig 12- Mosquito fish (Gambusia affinis) **Fig 13- Mosquito fish being reared in tanks**

Fig 14- Map for Public Access

d) Aerial Applications of Larvicide's as a Control

GIS techniques were used to determine exact location, area, and amount of larvicide's for treatment, and in turn, allowed for better contract specifications and communication among VSC staff, contractors, helicopter pilots, administrators, other agencies and the public.

As part of the planning phase, GIS was used to create polygons to mark the location of the proposed application. The polygons were merged into groups based on watershed and project logistics. The following map illustrates the aerial mosquito larvicide's applications.

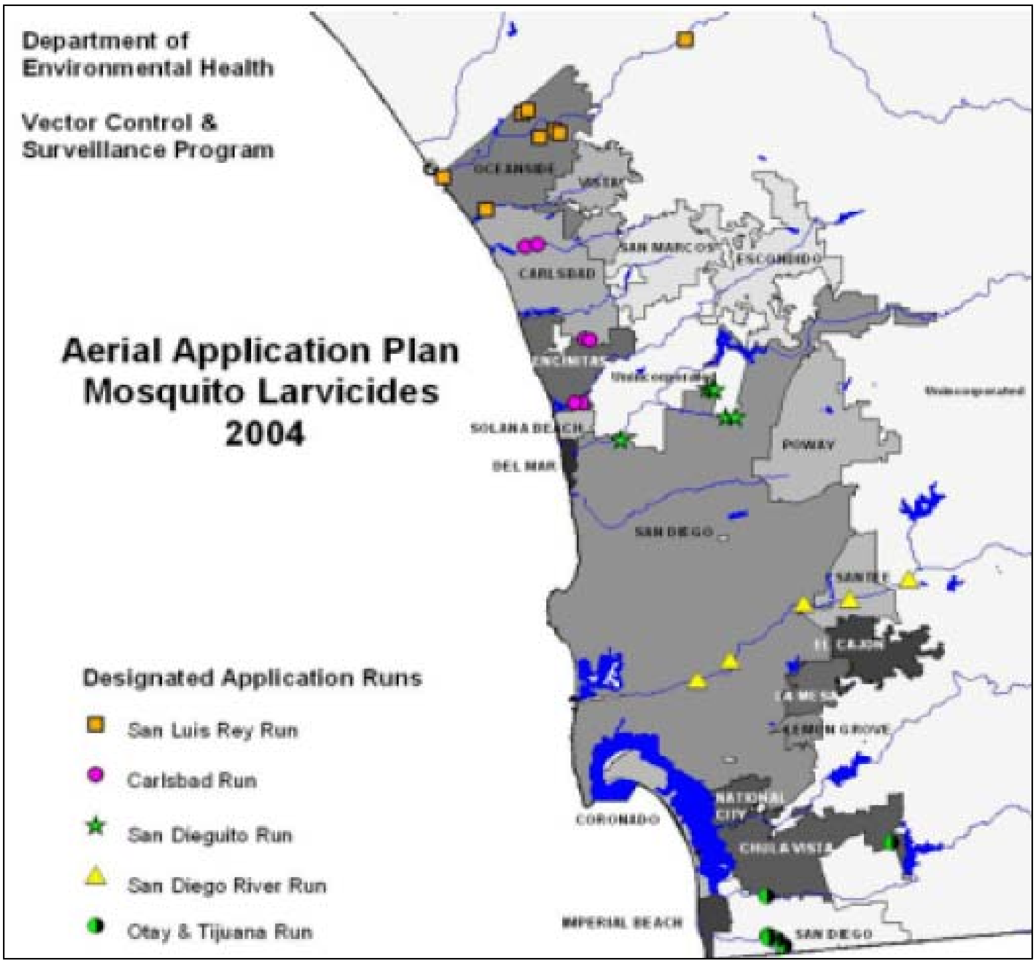

Fig 15- Map Illustrates the Aerial Mosquito Larvicide's Applications

Area was calculated and reported in square acres using GIS tools. The square acreage is used to calculate the amount of mosquito larvicide's necessary to treat a given volume of water. Thus, GIS provided refined project costs and provided better contract specifications.

2. VECTOR SURVEILLANCE

Location is critical to designing surveillance or monitoring plans and to understanding the resultant data or observations. GIS software was used to create shape files and to map various types of surveillance data.

Surveillance mosquito trap locations have been mapped using heads up digitizing and GPS technology. The traps are located throughout the County. In addition, trap locations can be reviewed and identified for best locations to monitor efficacy of aerial larvicide's applications and/ or to deploy field staff into areas where traditional control measures can be employed.

Sentinel chicken flocks are located at three sites in the County. These sites have been mapped as GIS layer. Blood samples are collected every two weeks and are tested as part of the disease surveillance program.

As part of the WNV surveillance activities, if a dead bird meets certain requirements, then it is picked up and shipped to a state laboratory for testing. The pickup locations of the dead birds have been mapped using the X, Y coordinate tool feature of the DEH GIS mapping application.

Special GIS projects have included mapping data associated with vector-borne disease such as plague and Hantavirus. Fly complaints and fly population counts associated with residential development in traditional agricultural land use areas have also been mapped. In order to communicate information and resolve issues, these maps were exported as JPEG images and incorporated in a Microsoft PowerPoint presentation with attribute data tables illustrating fly population counts.

3. Outreach and Education

As WNV threatens public health, DEH has strived to remain highly visible in the services that VSC provides to the citizens of the County and to continuously provide WNV educational resources and informational updates.

The map (below) resides on the website and informs the public of WNV test results in San Diego County.

Fig 16- Map resides on the Website and Informs the Public of WNV Test Results in San Diego County

Additional educational resources that utilize GIS map products include a speaker bureau consisting of VSC staff that may be scheduled to present WNV information to special interest groups or to school groups, or to the general public. During pilot testing, a GIS buffer technique was used to identify and notify schools near the area of aerial application. Maps were created in ESRI ArcGIS software and exported as Adobe PDF documents for posting to the website and for dissemination in press release packets. These aerial application activities and associated press conferences provided an opportunity to educate a large sector of the public on WNV.

Conclusions for 3rd Case Study

- Implementation of the Plan includes much of the control, surveillance, and outreach components. It may be concluded that GIS has played an instrumental role in the success of the Plan.
- Overall, the use of GIS technology has improved the VSC program by providing problem-solving and decision-making tools, by allowing a mechanism for improving communication, and by increasing the type of outreach media available to the public, and by inspiring the innovation of a growing GIS savvy work force.

- Future plans for the VSC program includes migrating the existing DEH GIS intranet mapping application from ESRI Map Objects to an ESRI ArcIMS application. This is planned for August 2004.

7. Data and their Sources

A GIS contains four types of information and computer files: geographic, map, attribute, and data-point files. In general, modeling involves the integration of GIS with standard statistical and health science methods. Spatial interaction models analyze and predict the movements of people, information, and goods from place to place. By accurately modeling these movements, it is possible to identify areas most at risk for disease transmission and thus target intervention efforts. Spatial diffusion models analyze and predict the spread of phenomena over space and time and have been widely used in understanding spatial diffusion of diseases. By incorporating a temporal dimension, these models can predict how diseases spread, spatially and temporally, from infected to susceptible people in an area. Spatial variation in health related data is well known, and its study is a fundamental aspect of epidemiology. Representation and identification of spatial patterns play an important role in the formulation of public health policies. Some of the graphic and exploratory spatial data analytic techniques are:

- Point Patterns: As the name implies, also known as dot maps, attempt to display the distribution of health events as data locations. The ability to overlay data locations with other relevant spatial information is a general tool of considerable power. It is useful for delimiting areas of case occurrences, identification of contaminated environmental sources, visual inspection of spatial clusters, and analyzing health care resources distribution. A classical example of point pattern analysis in epidemiology is the identification of the source of cholera spread in London.
- Line Patterns: Vectors or lines are graphic resources that aid in the analysis of disease diffusion and patient-to-health care facilities flow. In their simplest form, lines indicate the presence of flow or contagion between two sub-regions which may or may not be contiguous. Arrows with widths proportional to the volume of flow between areas are important tools to evaluate the health care needs of

different locations. Use of line pattern analysis is quite common in epidemiology to describe the diffusion of several epidemics, such as the international spread of AIDS.

- Area Patterns: The first stage of data analysis is to describe the available data sets through tables or one-dimensional graphics, such as the histogram. For spatial analysis, the obvious option is to present data on maps, with the variable of interest divided into classes or categories, and plotted using colors or hachure within each geographic unit, know as a choropleth map. The use of stem and leaf plots to classify data before area pattern analysis is more intuitive, easier to use and presents another method of incorporating dynamic graphics into GIS for use.
- Surface and Contour Patterns: Data of epidemiological or public health interest often occur as spatial information during each of several time epochs. The analytical techniques described previously require the pooling of information in administrative areas with well-defined geographic boundaries, and the presentation of the spatial process with maps constrained to them.
- Statistical Monitoring: A common measure used by epidemiologists to identify increases in case occurrence of diseases, is the ratio of case numbers at a particular time to past case occurrence using the mean or median.
- Time Series Analysis: The common analytical framework uses time series models to forecast expected numbers of cases, followed by comparison with the actual observation. Detection of changes from historical patterns through forecast error uses the difference between the actual and estimated values at each point in time. In contrast to other monitoring schemes, time series methods use the correlation structure of the data at different time intervals in making estimates.
- Temporal Cluster Analysis: Detection of temporal clusters, understood as a change in the frequency of disease occurrence, is important to stimulate research into the causes, and to encourage the development of preventive strategies. Detection of increases in the rate of occurrence of a disease uses either the time interval of successive events or the number of events on specified time intervals.
- Spatio-Temporal Analytic Techniques: Space-time interaction among health events or between health events and environmental variables is as an

important component for epidemiological studies and public health surveillance. The bulk of the development in spatio-temporal patterns of health problems has been based on modeling and simulation because of the paucity of available data sets. [Map India Conference 2003]

8. Prevention and Control

Prevention and control of arboviral diseases is accomplished most effectively through a comprehensive, integrated mosquito management program using sound integrated pest management (IPM) principles.

Programs consistent with best practices and community needs should be established at the local level and, at a minimum, should be capable of performing surveillance sensitive enough to detect West Nile Virus (WNV) enzootic/epizootic transmission that has been associated with increased risk of disease in humans or domestic animals. Integrated mosquito management programs designed to minimize risk of WNV transmission and prevent infections of humans and domestic animals should optimally include the following components (modified from information provided by the American Mosquito Control Association, the New Jersey Mosquito Control Association, and the Florida Coordinating Council on Mosquito Control)

A. Surveillance

Effective mosquito control begins with a sustained, consistent surveillance program that targets pest and vector species, identifies and maps their immature habitats by season, and documents the need for control. Records should be kept on the species composition of mosquito populations prior to enacting control of any kind and to allow programs to determine the effectiveness of control operations. All components of the integrated management program must be monitored for efficacy using best practices and standard indices of effectiveness. The following is a list of surveillance methodologies used by mosquito control agencies.

1. Larval Mosquito Surveillance

Larval surveillance involves sampling a wide range of aquatic habitats for the presence of pest and vector species during their developmental stages. Most established programs have a team of trained inspectors to collect larval specimens on a regular basis from known larval habitats, and to perform systematic surveillance for new sources. A mosquito identification specialist normally identifies the larvae's species.

Properly trained mosquito identification specialists can separate nuisance and vector mosquito species. Responsible control programs target vector and nuisance populations for control and avoid managing habitats that support benign species.

2. Adult Mosquito Surveillance

Adult mosquito surveillance is used to monitor species presence and relative abundance of adult mosquitoes in an area. Information derived from adult mosquito surveillance programs using standardized and consistent surveillance efforts provide information essential to monitoring potential vector activity, setting action thresholds, and evaluating control efforts. Various methods are available for this purpose and have been demonstrated to be effective in collecting a variety of mosquito species.

3. Virus Surveillance

The purpose of this component of the vector management program is to determine the prevalence of WNV in the mosquito population. This is often expressed simply as the number of WNV-positive mosquito pools of a given species collected at a defined location and time period. While the number of positive pools provides valuable information, it does not provide an index of virus prevalence in the vector population. Preferably, the proportion of the mosquito population carrying the virus should be expressed as the infection rate (IR, expressed as the estimated number of infected individual mosquitoes per 1,000 specimens tested). This is a more useful index of virus prevalence.

B. Source Reduction

Source reduction is the alteration or elimination of mosquito larval habitat breeding. This remains the most effective and economical method of providing long-term mosquito control in many habitats. Source reduction can include activities as simple as the proper disposal of used tires and the cleaning of rain gutters, bird baths and unused swimming pools by individual property owners, to extensive regional water management projects conducted by mosquito control agencies on state and/or federal lands. All of these activities eliminate or substantially reduce mosquito breeding habitats and the need for repeated applications of insecticides in the affected habitat. Source reduction activities can be separated into the following two general categories:

1. Sanitation

The by-products of human's activities have been a major contributor to the creation of mosquito breeding habitats. An item as small as a bottle cap or as large as the foundation of a demolished building can serve as a mosquito breeding area. Sanitation, such as tire removal, stream restoration, catch-basin cleaning and container removal, is a major part of all integrated vector management programs.

2. Water Management

Water management for mosquito control is a form of source reduction that is conducted in fresh and saltwater breeding habitats. Water management programs for vector control generally take two forms, described below.

a) Impoundment Management

Impoundments are mosquito-producing marshes around which dikes are constructed, thereby allowing water to stand or to be pumped onto the marsh surface from the adjacent estuary. This eliminates mosquito oviposition sites on the impounded marsh and effectively reduces their populations. Rotational Impoundment Management (RIM) is the technique developed to minimally flood the marsh during the summer months and then use flap gated culverts to reintegrate impoundments to the estuary for the remainder of the year, thereby allowing the marsh to provide many of its natural functions.

b) Open Marsh Water Management (OMWM)

Ditching as a source-reduction mosquito control technique has been used for many years. Open marsh water management is a technique whereby mosquito-producing locations on the marsh surface are connected to deep-water habitat (e.g., tidal creeks, deep ditches) with shallow ditches. Mosquito broods are controlled without pesticide use by allowing larvivorous fish access to mosquito-producing depressions.

c) Management in Storm water Retention Structures

Source reduction and water management practices may also be applied to storm water retention structures designed to hold runoff before it is discharged into groundwater or surface water. Mosquito control should be considered in the design, construction, and maintenance of these structures, as appropriate. Storm water retention structures should be designed in consultation with experts in mosquito biology and control to prevent as much mosquito production as possible, and to facilitate proper functioning and maintenance in the future.

C. Chemical Control

Insecticides can be directed against either the immature or adult stage of the mosquito life cycle when source reduction and water management are not feasible or have failed because of unavoidable or unanticipated problems, or when surveillance indicates the presence of infected adult mosquitoes that pose a health risk.[63]

1. Larviciding

Larviciding, the application of chemicals to kill mosquito larvae or pupae by ground or aerial treatments, is typically more effective and target-specific than adulticiding, but less permanent than source reduction. An effective Larviciding program is an important part of an integrated mosquito control operation. The objective of Larviciding is to control the immature stages at the breeding habitat before adult populations have had a chance to disperse and to maintain populations at levels at which the risk of arbovirus transmission is minimal

2. Adulticiding

Adulticiding is the application of pesticides to kill adult mosquitoes. The ability to control adult mosquitoes is an important component of any integrated mosquito management program, and like the other components of the program, its use should be based on surveillance data. Mosquito adulticiding may be the only practical control technique available in situations where surveillance data indicate that is necessary to reduce the density of adult mosquito populations quickly to lower the risk of WNV transmission to humans.

D. Resistance Management

In order to delay or prevent the development of insecticide resistance in vector populations, integrated vector management programs should include a resistance management component (modified from Florida Coordinating Council on Mosquito Control, 1998).

E. Biological Control

Biological control is the use of biological organisms, or their by-products, to control pests. Bio-control is popular in theory, because of its potential to be host-specific and virtually without non-target effects. Overall, larvivorous fish are the most extensively used bio-control agent for mosquitoes.

F. Continuing Education of Mosquito Control Workers

Continuing education is directed toward operational workers to instill or refresh knowledge related to practical mosquito control. Training is primarily in safety, applied technology, and requirements for the regulated certification program mandated by most states.

G. Vector Management in Public Health Emergencies

A surveillance program adequate to monitor WNV activity levels associated with human risk must be in place.

H. Adult Mosquito Control Recommendations

Ground-based (truck-mounted) application of adult mosquito control agents has several positive attributes. Where road access is adequate, such as, in urban and suburban residential areas, good coverage may be achieved. In addition, ground-based application can be done throughout the night, thereby targeting night-active mosquito species.

Aerial application is capable of covering larger areas in shorter time periods than a ground-based application. This is a critical positive attribute when large residential areas must be treated quickly. In addition, aerial application is less prone to patchy coverage than ground-based application in areas where road coverage is not adequate. [Centers for Disease Control and Prevention Epidemic/Epizootic West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control]

9. Conclusions

1. GIS is an effective tool to monitor and control the various infectious diseases. A number of papers discuss the applications of GIS in controlling, monitoring, and surveillance of infectious diseases.
2. However, no research covers a wide number of contagious diseases with a common methodology with special treatment to a disease with respect to GIS application.
3. The West Nile Virus Tracking System is a spatially driven surveillance program for following and responding to the spread of WN virus.
4. GIS response has proven to be an invaluable tool and has been integrated as a major component of the West Nile virus Surveillance and Treatment Program.
5. Tracking Analyst makes it possible to explore, visualize, and analyze West Nile Virus data relative to time. Overall, Tracking Analyst has been very useful in determining the scope of an area that must be monitored.
6. A major benefit of the ArcView and Tracking Analyst has been in time saving against doing manual process.
7. GIS aids in faster and better health mapping and analysis than the conventional methods. It gives health professionals quick and easy access to large volumes of data. It provides a variety of dynamic analysis tools and display techniques for monitoring and management of epidemics.
8. The possibilities that can be explored are limitless, depending on the skill and imaginative use of the researchers and the willingness of health sector management to resource its implementation.
9. By tracking the sources of diseases and the movement of contagions, the populations at risk were identified

10. Recommendations

1. Many mosquitoes are most active at dusk and dawn. Consider staying indoors during these times or use insect repellent and wear long sleeves and pants. Light-colored clothing can help you see mosquitoes that land on you
2. Get rid of mosquito breeding sites by emptying standing water from flower pots, buckets and barrels
3. Health administrators, professionals and researchers need training and user support in GIS technology, data and epidemiological methods in order to use GIS properly and effectively
4. Developing vaccines and treatments as no specific vaccines or treatments exist for West Nile virus

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Web-Based Disease Tracking: A West Nile Virus Example (1131) Mark Egbert

12. Appendices

12.1 Case Study 1

Disease Surveillance and Monitoring using GIS

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Introduction

There are various categories under which the infectious diseases fall. These include vector borne diseases, airborne diseases, waterborne diseases, food borne diseases, and plant and fish diseases. These categories are influenced by various factors. Three obligatory factors are necessary for the onset and continuous course of an epidemic process: source of pathogenic microorganism, the mechanism of their transmission, and microorganisms susceptible to infection. Basic concepts in disease emergence are: Emergence of infectious diseases is complex; Infectious diseases are dynamic; Most new infections are not caused by genuinely new pathogens; Agents involved in new and reemerging infections cross taxonomic lines to include viruses, bacteria, fungi, protozoa, and helminthes.

High-risk areas can be identified using GIS and remote sensing technologies that would otherwise be difficult to detect using traditional methods. Control and education programs can be directed toward these areas with more confidence and effectiveness. The following images shows the analysis part done in arcview GIS. GIS provides excellent means for visualizing and analyzing epidemiological data, revealing trends, dependencies and inter-relationships. GIS serves as a common platform for convergence of multi-disease surveillance activities. Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for monitoring and management of epidemics. GIS helps us out in many ways. These include the following applications.

- Find out geographical distribution and variation of diseases
- Identify gaps in immunizations
- Map populations at risk and stratify risk factors
- Forecast epidemics
- Monitor diseases and interventions over time
- Manage patient care environments, materials, supplies and human resources
- Monitor the utilization of health centers
- Route health workers, equipments and supplies to service locations
- Locate the nearest health facility.

Factors Influencing Diseases

Climate

Infectious diseases that are responsive to climate can be divided into two groups. The first group comprises those diseases for which there are clearly documented links between incidence and climate and weather factors. The second group comprises diseases whose incidence is cyclical, thereby suggesting a link to climate, but for which the potential mechanisms linking climate factors to incidence are either unknown or only tentatively established (Giesecke 1999).

Temperature

Microorganisms carried by vectors, such as mosquitoes, ticks, and other blood-sucking arthropods, are strongly influenced by temperature of the microenvironment within their cold-blooded vector hosts. The survival rates of vectors and the rates of multiplication and transmission of the microorganisms that infect them are temperature dependent. Over the low temperature threshold, the rates of development of the parasite and the vector population increase with temperature, thereby increasing transmission capacity.

Precipitation

Precipitation, especially in the form of rainfall, can affect disease transmission via the effects of normal, as well as severe (i.e., flooding and drought), events on vector populations. Flooding can influence disease transmission in a number of ways, most notably by increasing run-off and disturbing breeding grounds and habitats (Clark, 1993).

Wind and ocean currents

Sea-surface temperature, height, and concentration of nutrients in seawater are associated with waterborne diseases. Ocean currents and tides are connected with various epidemiological patterns (Colwell, 1996).

Human population movement

Human population movement (HPM) is a term that encompasses a variety of ways that people travel from one area to another. Population movement has historically contributed to the spread of many infectious diseases that have left their mark on human growth and progress. Humans travel for a variety of reasons and causes. The understanding of these factors is the first stage in controlling the development and spread of communicable diseases. These various factors include push and pull factors, circulation, temporal dimensions, spatial dimensions and migration. Depending on these factors the infectious diseases are categorized and the transmission settings and the vulnerable groups are tabulated in Table I.

Circulation

Daily: Leaving place of residence for up to 24 hours (e.g. commuting, trading, and cultivation) *Periodic:* Period varies from 1 day to 1 year but usually of shorter duration than seen in seasonal circulation (e.g. trading, pilgrimage, mining, and tourism).

Seasonal: Period defined by marked seasonality in the physical or economic environment (e.g. fishing, laboring, and pastoralism).

Long-term: Absence from place of residence for longer than 1 year (e.g. urbanization, colonization, and traders).

Migration: Long-term: Population movement resulting in a permanent change of residence. (e.g. urbanization, refugees, and colonization).

Infectious disease category	Important examples	Transmission settings	Affected population
Vaccine-preventable diseases in children	Measles Mumps Rubella Varicella Pertussis Hepatitis B* Hib Polio Tetanus Diphtheria Pneumococcal disease*	Population ECC Schools	Children
Vaccine-preventable diseases in adults	Influenza Pneumococcal disease Tetanus Hepatitis B	Population Workplace	Adults, especially elderly
Respiratory diseases (often linked to socioeconomic deprivation and crowding)	Meningococcal disease Tuberculosis Rheumatic fever Mycoplasma RSV Pneumococcal disease Respiratory infectious diseases generally	Home, especially deprived communities with high level of household crowding Prisons	Socioeconomically deprived

Infectious disease category	Important examples	Transmission settings	Affected populations
Enteric disease with food-borne transmission	Campylobacteriosis* Salmonellosis VTEC* Yersiniosis Listeriosis* Norwalk-like virus Food intoxicants (eg. staphylococcal) Botulism Marine biotoxins	Home Commercial food premises	All, especially children
Enteric disease with water-borne transmission	Cryptosporidiosis* Giardiasis* Campylobacteriosis*	Anywhere with a water supply	All
Diseases from close physical contact	Giardiasis* Rotavirus Helicobacter Hepatitis A* Adenovirus EBV Skin infections and cellulitis Invasive streptococcal disease Impetigo Head lice Scabies Mycotic diseases (including dermatophytes)	Population ECC and schools	Children
Zoonotic disease linked to direct animal contact	Leptospirosis* Typhus Emerging diseases (eg, lysavirus) VTEC, cryptosporidiosis and other enteric diseases*	Farms Homes with pets	All, especially in rural areas
Occupational infectious disease	Hepatitis B* Leptospirosis* Enteric diseases in some occupational groups*	Workplaces, especially farms, health care, laboratories	All, especially farmers, health workers, laboratory workers
Diseases from contaminated environments	Legionellosis Cryptosporidiosis* Amoebic meningoencephalitis	Recreational water and pools Contact with soil/compost Farms	All
Travel-associated and imported infectious diseases	Dengue fever Malaria Rabies Schistosomiasis Yellow fever Typhoid Cholera Shigellosis Traveller's diarrhoea Leprosy Hepatitis A* Tuberculosis* HIV/AIDS*	Overseas countries, especially developing countries	Travellers Immigrants, especially refugees

Infectious disease category	Important examples	Transmission settings	Affected populations
Vector-borne diseases (especially with introduction potential)	Ross River virus Dengue fever*	Borders and airport	All, if diseases introduced
Congenital and perinatal infections	Hepatitis B* Listeriosis* Congenital rubella syndrome Toxoplasmosis Group B streptococcal disease Cytomegalovirus	Maternal and neonatal care settings	Pregnant women Neonates
Blood-borne diseases and those linked to transplants and sharing injecting equipment	Hepatitis C HIV/AIDS* HTLV 1&2 CJD Newly recognised blood-borne diseases	Population Health care settings Prisons	All, especially hospitalised Injecting drug users
Sexually transmitted infections	Chlamydia Gonorrhoea Syphilis HIV/acquired immune deficiency syndrome* HPV HSV Hepatitis B*	Population	All, especially young adults Men who have sex with men Immigrant populations
Hospital acquired infections	MRSA *Clostridium difficile* Surgical-site infections (SSI) Blood-stream infections (BSI) Device-related infections Opportunistic infections	Health care settings	All, especially elderly
Diseases caused by antibiotic-resistance organisms	Penicillin resistant pneumococci VRE (enterococci) MDR TB PPNG (gonococci) Newly emerging resistance organisms	Human populations Animal populations Health care Veterinary Farming	All, especially hospitalised
Bioterrorism agents	Anthrax Other agents	Population, especially in government facilities	All, especially 'first responders'

* Disease appears in more than one category because it has more than one important mode of transmission or control.

Case Study

This case aims at finding out the population that is vulnerable to vector borne disease in Birla Institute and Technology and Science, Pilani (BITS) campus. The digital map of the campus is taken and the basic operations such as Geo referencing, digitizing, etc. are carried out. The different hostels, institute, staff quarters, wells, market places were digitized as a polygon theme and the road network was also digitized as a separate theme. The first phase utilizes landscape epidemiology to explore the relationship between landscape elements and the vectors breeding sites. The goal of this phase was to assess the capabilities of GIS and remote sensing to identify high vector breeding sites. The approach utilizes landscape composition methods. Using remotely sensed data to distinguish between different landscapes elements, it was determined that dairies, stagnating water, areas of vegetation had the highest vector abundance. The vectors must find larval habitats, blood meal sources and resting sites within a 1-km radius, in order to successfully reproduce. In the second phase GIS was used to determine the landscape composition of a 1-km buffer around each site. Using stepwise discriminant and regression analyses, it was determined that the whole BITS campus was vulnerable to the vector disease. The only restriction is that the climatic factors influence the breeding of the vectors. The climatic conditions of Pilani don't favour many vectors to survive.

Common methodology to identify vector borne disease

1. The data on different types of vectors causing infectious diseases, their survival conditions and other data's relevant to the vectors are collected.
2. The distribution of the population in a given region is gathered and sorted according to age group.
3. The map of the given region is obtained from the respective source. All the features in the map are digitized into their respective themes.
4. The vector breeding sites in that particular region is identified using suitable techniques.
5. The landscape composition and the population distribution are digitized on the map. The population database is also stored corresponding to the population age wise.
6. Buffers are created for the given population categorizing them into commercial area, institutes, and residential areas. Depending on the flight range of different vectors, suitable buffers are created from the vector breeding sites taking into consideration all the environmental and seasonal factors.
7. All these buffers are analyzed and using suitable operations such as union, intersection, overlay, network the vulnerable areas and the vulnerable group of population are assessed.
8. Depending on the results suitable preventive and control measures are taken.

Common methodology to identify airborne disease

1. The details of microorganisms present in air are obtained from suitable sources.
2. The data regarding the sustainable environmental factors are gathered and analyzed with respect to the given region.

3. The directions, flow rate, humidity conditions of air are obtained from Indian meteorological department.
4. For the given region, a direction profile for the flow of air is created.
5. Humidity and temperature profiles are created from the data obtained.
6. From all the data's, an analysis is performed and the vulnerable areas of airborne disease are identified.
7. Depending on these results suitable preventive and control measures are taken.

Common methodology to identify water borne diseases

1. All water sources are marked on the map of the given region. These are further classified as running water, stagnating water. The stagnating water is further classified as shallow and deep waters. Mostly the stagnating water causes diseases.
2. The stagnating water bodies are identified, since these are the sources.
3. Buffers are created for these water bodies and hence the nearby areas prone to these microorganisms are identified depending on the pipe network and flow condition from these sources.
4. The population distribution vulnerable to these diseases is identified using suitable analysis depending on the data obtained.
5. Depending on these results suitable control and preventive measures are taken.

The Fig. 1 shows the map of BITS campus. It also shows the different hostels, staff quarters, institute, wells, stagnant water bodies, shopping centre, and grounds. Fig. 2 shows the 2d view of the flow pattern of water depending on the elevation of ground at different sites. Fig. 3 shows a particular flow direction of air taken into consideration. The flow of air is considered to be point vectors and the vulnerable areas to that particular flow direction are identified. Fig. 4 shows the overlay of the buffers created for the hostels, staff quarters, institute, market place and the vector breeding sites. Since the flight range of vectors are generally within 1km radius from different vector sites, the whole BITS campus falls vulnerable to vector disease. But certain environmental and seasonal changes prevent the survival of many vectors.

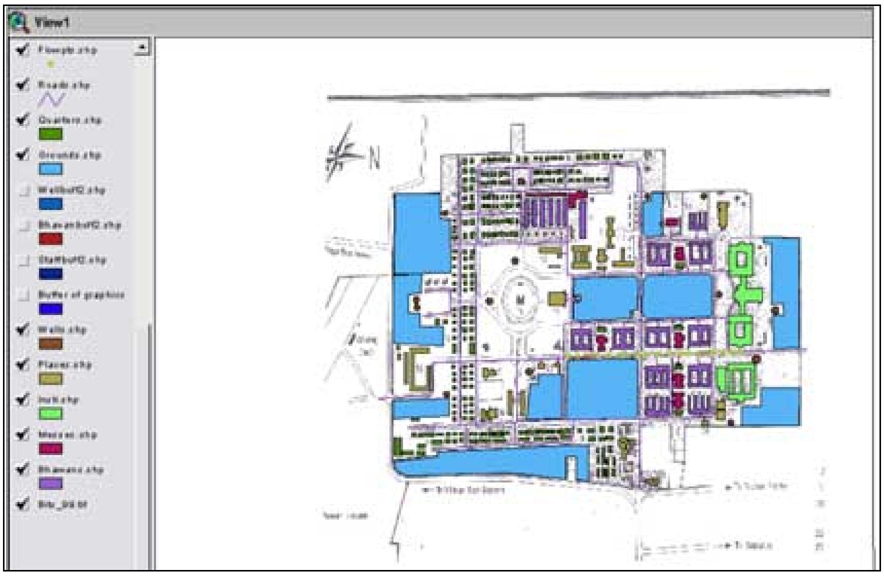
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Fig. 1

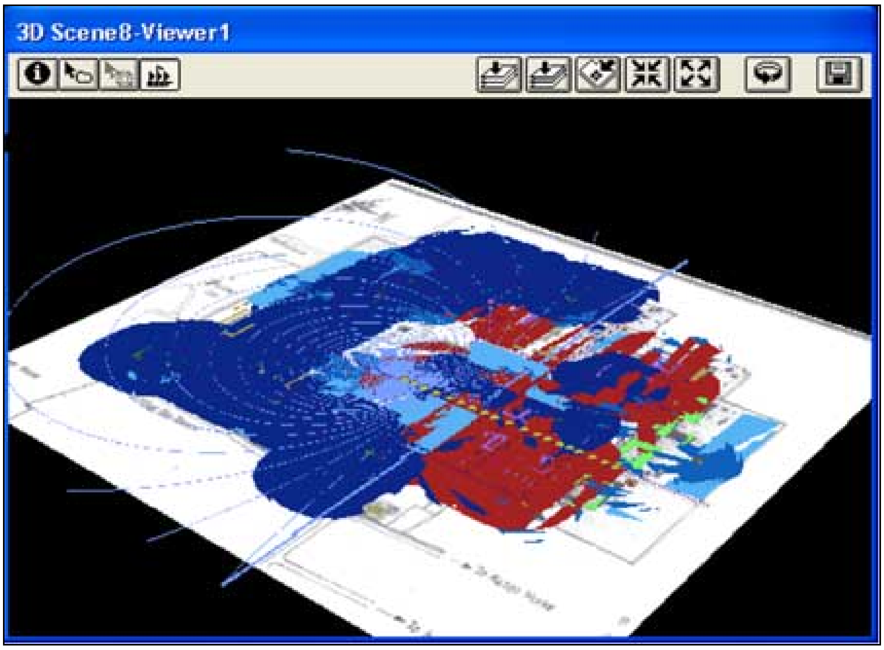
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Fig. 2

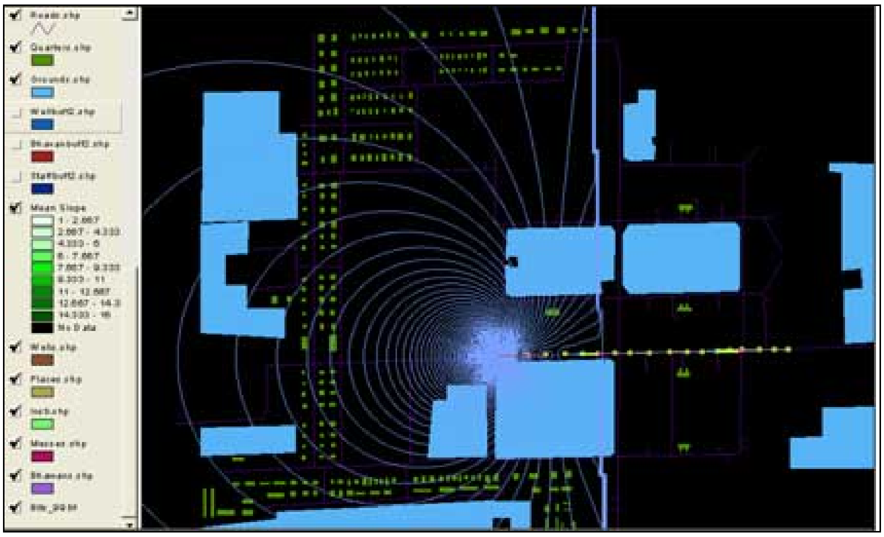

Fig. 3

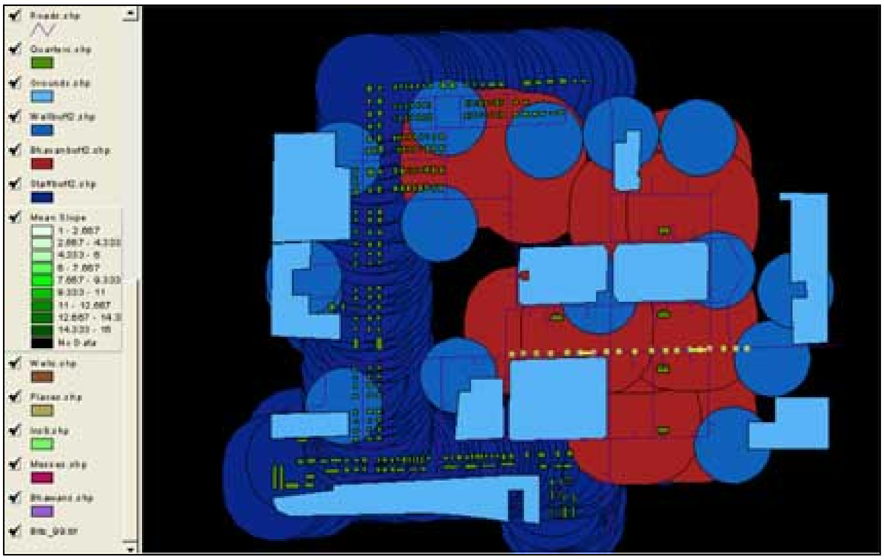

Fig. 4

A GIS contains four types of information and computer files: geographic, map, attribute, and data-point files. In general, modeling involves the integration of GIS with standard statistical and health science methods. Spatial interaction models analyze and predict the movements of people, information, and goods from place to place. By accurately modeling these movements, it is possible to identify areas most at risk for disease transmission and thus target intervention efforts. Spatial diffusion models analyze and predict the spread of phenomena over space and time and have been widely used in understanding spatial diffusion of diseases. By incorporating a temporal dimension, these models can predict how diseases spread, spatially and temporally, from infected to susceptible people in an area. Spatial variation in health related data is well known, and its study is a fundamental aspect of epidemiology. Representation and identification of spatial patterns play an important role in the formulation of public health policies. Some of the graphic and exploratory spatial data analytic techniques are: point patterns, line patterns, area patterns, time series analysis, temporal cluster analysis, and spatio temporal analysis.

Conclusion

Factors like movement of population, social conditions, environmental, soil conditions were analyzed and the diseases were classified accordingly. The populations at risk, catchment area, forecasting of outbreaks was found using suitable analysis. In this paper, the diseases were classified as water borne, vector borne, air borne, food borne and an analysis were made in campus. The vulnerable regions prone to these diseases were identified. This analysis was carried out by identifying the vector breeding sites, flow direction of the air, locating the places of stagnant water. By tracking the sources of diseases and the movement of contagions, the populations at risk were identified. Buffers were created for the hostels; staff quarters and the population at risk were identified. The present paper is a step towards to find a common methodology to identify the vulnerable area of infectious disease using GIS. However, in some cases it requires highly accurate data.

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12.2 Case Study 2

Paper Title: Web-Based Disease Tracking: A West Nile Virus Example (1131) Mark Egbert GIS Coordinator Colorado Department of Public Health and Environment (303)692-2246 mark.egbert@state.co.us Paper Abstract: In 2003, the State of Colorado had more diagnosed cases of West Nile Virus than any other state in the country. In order to educate the public, provide information to the media, and target spraying activities, the department developed a simple ArcIMS site that tracked the results of animal testing in near-real time. This site was very successful. Future plans include ArcIMS sites to display real-time animal testing results and real-time human cases (to authorized users). Introduction: West Nile virus has emerged in recent years in temperate regions of Europe and North America, presenting a threat to public and animal health. The most serious manifestation of West Nile virus infection is fatal encephalitis (inflammation of the brain) in humans and horses, as well as mortality in certain domestic and wild birds. The first appearance of West Nile virus in North America occurred in 1999, with encephalitis reported in humans and horses. In subsequent years, the virus spread throughout much of the United States. As of April 2004, West Nile virus has been documented in 46 states and the District of Columbia. West Nile virus first appeared in Colorado during the 2002 season. Public health agencies began testing birds, horses and mosquitoes to track the spread of this disease, and to identify areas where humans may be at risk for contracting the disease. By the end of the 2002 season, the West Nile virus had been detected in animals in some parts of the state (figure 1). Less than 10 human cases of the disease were diagnosed during the 2002 season. West Nile virus was much more widespread in Colorado during the 2003 season. As the 2003 season progressed, large numbers of animals tested positive for the disease. By the end of the season, 2944 humans had been diagnosed as having contracted West Nile virus, and 54 people died of complications from this disease. For more information about West Nile virus in Colorado, visit: http://www.cdphe.state.co.us/dc/zoonosis/wnv/wnvhom.html

Mapping the spread of the West Nile virus; GIS has played a role in combating the West Nile virus during the 2002, 2003 and 2004 (current) season. During the 2002 season, maps were posted to the web showing the areas where testing was being done, and where animals tested positive for the virus. During the 2002 season, The Colorado Department of Public Health and Environment (CDPHE) collected and mapped West Nile virus animal data. From these maps, it was determined that the animals that tested positive were being collected primarily in the two eastern Colorado river drainages (the South Platte and the Arkansas). It was apparent that the virus had spread into the front-range communities by the end of the season, and that these communities would be vulnerable during the upcoming 2003 season. Static maps continued to play a role during the subsequent West Nile virus seasons. These maps are a "snapshot" of conditions at any particular moment, and can be an effective way to communicate information about the spread of this virus in both animals and humans.

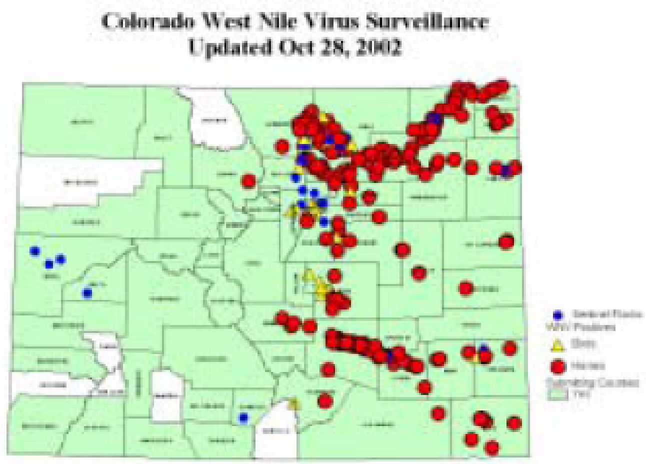


Figure 1: The 2002 end of season map showing the results of the West Nile virus animal testing program.

Interactive maps.

Prior to the onset of the 2003 season, a database was put in place that allowed the sharing of animal testing information among the agencies working on the West Nile virus problem. Persons responsible for entering data could access the database on the web. Data was made available to the various participants via web pages, email and ftp. The net result of this effort was that during the 2003 season, public health workers, the press and the public had access to a great deal of current information regarding the spread of this virus.

Prior to the start of the 2003 season, a simple ArcIMS site was built to map the animal testing data (http://emaps.dphe.state.co.us/wnv3/viewer.htm). ArcIMS had been recently installed at CDPHE, and the site was kept simple, in order that the site could be adequately supported during the season.

A “location” table was automatically exported from the animal testing database and ftp’ed to the GIS web server. This location table was used to manually prepare the shapefiles that were used by the ArcIMS website. Using this manual process, the mapping website was updated 1-2 times per week for most of the season.

The interactive map allowed the user to view information about a particular species, or a particular area. The map was especially useful for identifying areas where the virus was prevalent.

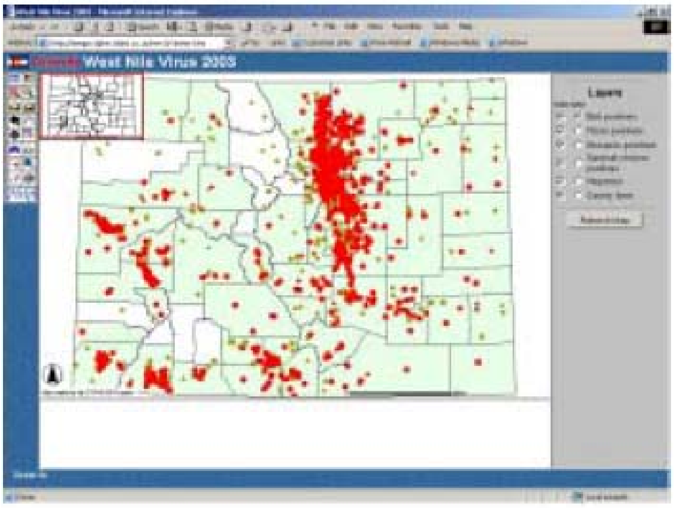


Figure 2: Screen capture of the West Nile Virus 2003 "Interactive map". The site was functional, and was widely used by public health workers and the press. However, the public seemed to find the site difficult and confusing.

Dynamically updated interactive maps:

Prior to the start of the 2004 season, an application was developed for CDPHE by ESRI contractors. This application was developed for a CDPHE Intranet site, where authorized users could map infectious diseases.

The code from the infectious diseases mapping site was used to develop the modified 2004 West Nile virus animal testing site (http://emaps.dphe.state.co.us/wnv04/default.asp?DSN=Animals). This new mapping site is more intuitive and easier to use by all types of users – vastly expanding the overall usability of the application.

The 2004 site also connects directly to the location table that is ftp’ed from the testing database to the GIS web server. The application builds “acetate” layers from the location table, eliminating the need to manually re-build the points shapefiles. The net result is that the new application is much easier to maintain, and is always “sync-ed” with the testing database.

Lastly, the plotting/printing features are enhanced, replacing the need to manually generate the static maps. Now, any user can build “snapshots” directly from the interactive mapping application.

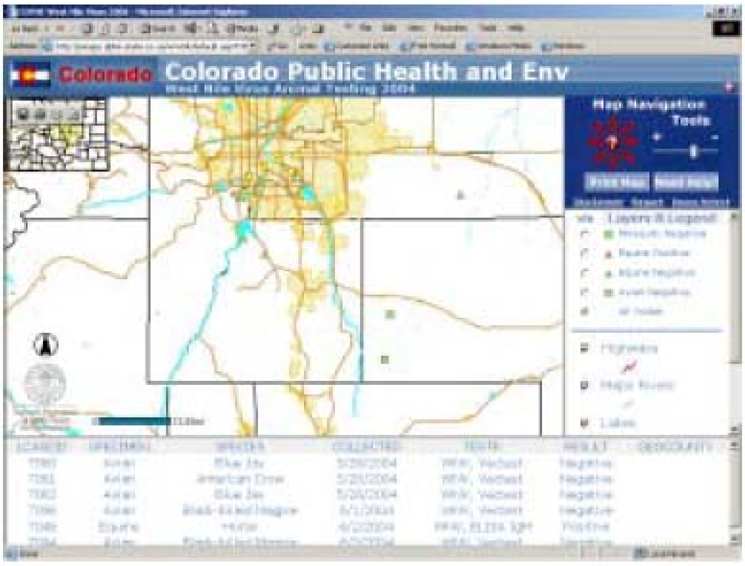


Figure 3: The improved 2004 Interactive mapping site showing detail of area south of Denver. Some sample locations (yellow) have been selected.

The supporting infrastructure in 2004:

Even though the end products seem relatively simple, being able to dynamically map public health data can require a great deal of infrastructure. Often, the tabular data is found on different machines. Sometimes security of machines and security of the data can be a big concern. The infrastructure supporting the web-based mapping solution described here is complex (and clearly, this is not the only solution to this problem). However, it is important to note that most of the infrastructure described here also supports a number of other public health and environmental programs.

The author believes that even a small amount of infrastructure can be expensive if it supports one or two applications and is not fully utilized. Infrastructure is cheap and deemed necessary if it supports a wide range of applications and a wide range of users.

The following items make up the infrastructure that supports the West Nile virus dynamic interactive map (the 2004 application);

- Database server.
- Database programmers and support staff.

- GIS web server.
- ArcIMS software.
- A mature GIS program and a complete “suite” of GIS software tools.
- Web and ArcIMS applications development.

Future plans:

Initially, the role that GIS played in the efforts to combat West Nile virus was simply to prepare static maps, or “snapshots” of the data. As the virus became more widespread, GIS was also used to visualize and map the data as soon as it became available in the database.

Presenting point data as interactive maps on the web can be a difficult problem. A great deal of infrastructure and effort was required to “automate” the transfer of information between the database and the mapping website, and then to display the information in a way that could be easily understood by all types of users.

Clearly, the basic functionality found in dynamically updated, interactive web-based mapping has important implications for many public health issues. At CDPHE, the work done for West Nile virus has inspired other efforts related to anti-bioterrorism, disease surveillance. This work has also contributed to the adoption of GIS by a number of public health workers in the state. Some public health professionals in the state are starting to see the ability to interactively map point data on the web as a fundamental part of managing almost any disease outbreak, as well as some homeland security issues.

12.3 Case Study

FIGHT THE BITE WITH GIS

Author: Pamela Villa

ABSTRACT

Since 1989, the Vector Surveillance and Control Program (VSC) of the County of San Diego Department of Environmental Health has provided countywide mosquito surveillance and control services. Implementation of GIS in the VSC program has helped communicate and respond to the increased activity associated with the threat and imminent arrival of West Nile Virus. The VSC staff

have moved from narrative descriptions and map books to an ESRI MapObjects intranet mapping application to view mosquito-breeding sources and to respond to citizen complaints.

Management of staff and resources can be analyzed geographically using maps generated from ESRI ArcGIS software. Location, acreage, and cost of aerial treatment methods are determined using GIS tools. Surveillance locations to monitor disease patterns have been digitized or mapped with GPS. GIS has helped the VSC program realize management goals such as improved communication, reduction in resources and costs, and enhanced staff technical skills.

INTRODUCTION

The Vector Surveillance and Control program (VSC) of the County of San Diego Department of Environmental Health (DEH) has provided countywide vector surveillance and control measures since 1989. Housed within an environmental health department, the DEH VSC program has an emphasis on promoting healthy behavior and protecting the environment. The magnitude and seasonality of VSC program services vary, yet VSC continually focuses on mosquito control, rat control, and surveillance activities for vector-borne diseases such as plague and hantavirus.

Mosquitos are a well-known vector capable of transmitting disease such as malaria and encephalitis to humans. Most recently, West Nile Virus (WNV) has been transmitted to humans from mosquitos at a rapid rate since its appearance in North America in 1999.

This paper focuses on use of GIS in DEH VSC program. Substantive information on WNV can be found on Internet sites designed to provide scientific, preventative, and medical information on WNV to the public. Nonetheless, some basic information about WNV is warranted for background to the discussion of GIS projects presented in this paper.

WNV is transmitted to humans through mosquito bites. Mosquitos become infected when they feed on infected birds that have high levels of WNV in their blood.

Infected mosquitoes can then transmit WNV when they feed on humans or other animals. The bird population has acted as a host and allowed rapid spread of the virus across North America. WNV predominantly infects birds with some bird species being more susceptible than others; however, horses and humans can become infected as well. A vaccine exists for horses but not for humans. A person infected with WNV may experience mild symptoms or in severe cases experience paralysis or death. In order to prepare and respond to the inevitable arrival of WNV to the San Diego region, several County of San Diego Departments including County Health and Human Agency (HHSA) and DEH, worked together to develop a West Nile Virus Strategic Response Plan (Plan). The Plan was designed to integrate resources to combine educational messages and mosquito control measures, and to develop a coordinated response to WNV.

USE OF GIS IN THE SURVEILLANCE & CONTROL OF MOSQUITOS

Until 2003, geographic information related to VSC program has been marked by pencils in map books or pins on poster size maps. For several years VSC supervisors, vector ecologists, and vector control technicians have recorded daily field activities in Access database(s). The ability to capture, analyze, and display this information has been made possible by working together to develop several GIS datasets. GIS has been used as a tool in preparing for WNV including mosquito control, vector surveillance, and outreach and education.

1. MOSQUITO CONTROL

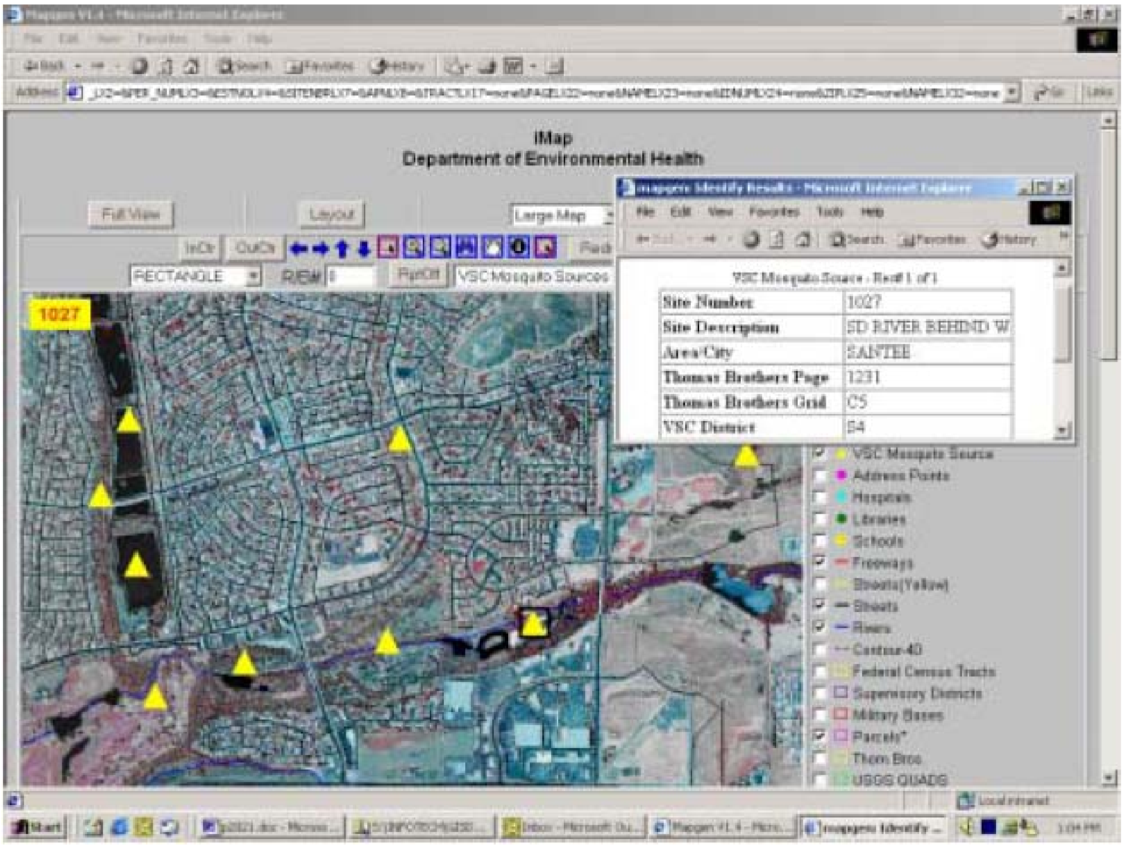
a) Mosquito Breeding Source Locations

The first GIS project implemented in VSC was to map the known mosquito breeding sources. These sources are referred to as sites by the VSC staff and are recorded in an Access database using a unique site number. Each VSC field technician has an assigned route that corresponds to Thomas Brothers map book pages. Using field technician map books as a source map, a point layer was created using heads up digitizing. Hundreds of point locations were transferred from the map book into an ESRI ArcView shapefile. Brief narrative descriptions of each site was consulted and joined as an attribute text field from the Access database using the unique site number. Additional information such as amount of treatment material applied and the site visit date is associated with each site number.

Many of the mosquito sources (or sites) are large water bodies while others are smaller sources such as standing water in stormwater conveyance systems. Many of the known breeding sources are a result of citizen complaints. These breeding sources may be located on publicly owned land or easements or on private land.

The accuracy of the initial source GIS layer was lacking the accuracy needed to perform a point-to-polygon geoprocessing technique to assign property ownership to each source. VSC field technicians visit these sites regularly. Thus, the personal knowledge of staff was used to create a new dataset since this was considered a more accurate means of obtaining a more precise location for known mosquito breeding sources.

In order to map the sources, VSC staff received training on a DEH GIS intranetbased mapping application developed in ESRI MapObjects. The application contains departmental GIS data and regional SanGIS data layers. The mapping application allows staff to access a low-cost, simplified GIS interface for basic query and mapping functions. VSC staff used the application to identify breeding site locations and obtain property owner information. Using the refined site location a new mosquito breeding source GIS point layer was created. The following image shows the DEH GIS mapping application interface, the mosquito breeding sources (yellow triangles), and the results of a basic report (or query) on a selected site.



Staff assignments change in order to respond to increased complaints and/or to reflect new route assignments, and the mapping application has proved helpful in allowing a newly assigned VSC field technician to locate mosquito-breeding sites throughout the County.

VSC staff also received training on Global Positioning Systems (GPS) technology. Integration of GPS with GIS allows the field technician to capture the site location in the field. GPS was used in identifying some sites and in refining the locations of other sites. Despite the training, due to a limitation in staff time and the inventory of GPS units, this technology was not relied upon given the demand to complete a map of mosquito breeding sources before the mosquito season.

b) GIS increases Knowledge and Communication

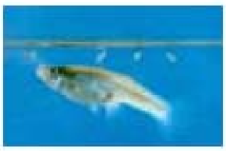
VSC management used the mosquito breeding source GIS information to communicate mosquito problems and control measures with public and private landowners, cities and public agencies in the County of San Diego. The GIS information was also used to create and mail notifications to private landowners regarding planned mosquito control measures designed to reduce the risk of WNV.

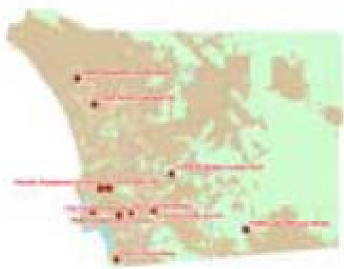
The distribution, location, and ownership of mosquito breeding sources has provided insight into program implementation and allowed evaluation by VSC management as the VSC program develops a zero-based budgeting scenario.

In addition, VSC field technician route assignments have been mapped into a GIS layer enabling staff to easily view and review routes for quick assignment and response to mosquito complaints.

c) Mosquito Fish as a Control

Mosquito fish (Gambusia affinis) are an important part of the VSC program. These small, guppy-sized fish feed on mosquito larvae. Mosquito fish are considered a biological control as they allow for the reduction of chemical application and are considered part of an Integrated Pest Management (IPM) strategy. The fish are suitable for use in ornamental ponds and animal watering troughs. DEH VSC provides mosquito fish free to the public. Mosquito fish are reared in tanks by the VSC program. With the increase threat of WNV, VSC has increased the distribution location from one location to eleven locations throughout the County. These locations have been mapped and posted as a map for public access via the Internet.

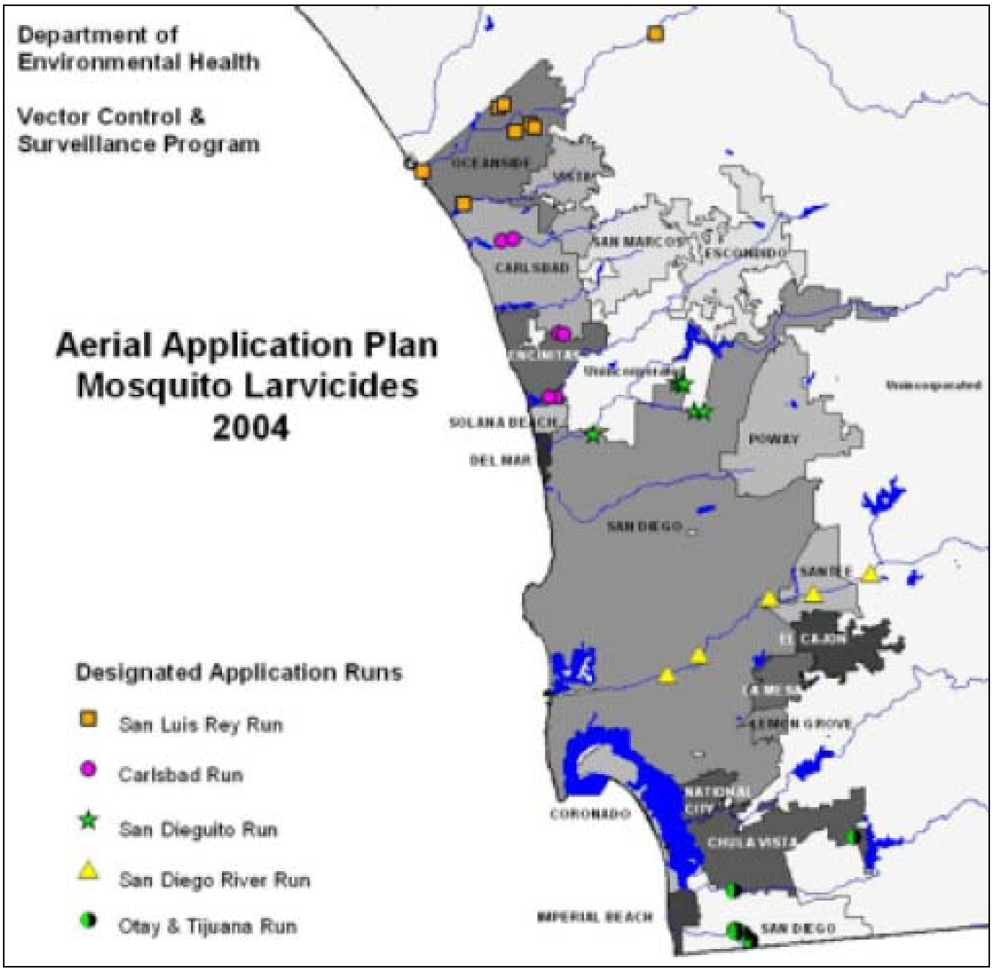




d) Aerial Applications of Larvicide as a Control

GIS techniques were used to determine exact location, area, and amount of larvicide for treatment, and in turn, allowed for better contract specifications and communication among VSC staff, contractors, helicopter pilots, administrators, other agencies and the public.

For the 2004 mosquito season VSC is conducting monthly aerial mosquito larvicide applications near high-risk urban areas and in sensitive or difficult-to-access habitats. These larvicides reduce mosquito population by targeting the larvae. In water; the larvicide acts specifically on mosquito larvae and will not harm other wildlife. As part of the planning phase, GIS was used to create polygons to mark the location of the proposed application. The polygons were merged into groups based on watershed and project logistics. The following map illustrates the aerial mosquito larvicide applications.



This mosquito control effort involves the use of a helicopter to apply or drop larvicide into water bodies near urban areas. For this purpose detailed maps were created for the use in staging the activities and in communicating target mosquito sources with the helicopter pilot.

Area was calculated and reported in square acres using GIS tools. The square acreage is used to calculate the amount of mosquito larvicide necessary to treat a given volume of water. Thus, GIS provided refined project costs and provided better contract specifications.

2. VECTOR SURVEILLANCE

Location is critical to designing surveillance or monitoring plans and to understanding the resultant data or observations. GIS software was used to create shapefiles and to map various types of surveillance data.

Surveillance mosquito trap locations have been mapped using heads up digitizing and GPS technology. The traps are located throughout the County. A long history of stored information is maintained in an Access database. Adult mosquito population counts by trap per event or by season can be mapped to illustrate trends. Test results can be assigned as a feature attribute for each trap. In addition, trap locations can be reviewed and identified for best locations to monitor efficacy of aerial larvicide applications and/ or to deploy field staff into areas where traditional control measures can be employed.

Sentinel chicken flocks are located at three sites in the County. These sites have been mapped as GIS layer. Blood samples are collected every two weeks and are tested as part of the disease surveillance program.

As part of the WNV surveillance activities, if a dead bird meets certain requirements, then it is picked up and shipped to a state laboratory for testing. The pickup locations of the dead birds have been mapped using the X, Y coordinate tool feature of the DEH GIS mapping application.

Additional surveillance activities and sample results can be mapped and analyzed at the request of VSC Vector Ecologists. Special GIS projects have included mapping data associated with vector-borne disease such as plague and hantavirus. Fly complaints and fly population counts associated with residential development in traditional agricultural land use areas have also been mapped. In order to communicate information and resolve issues, these maps were exported as JPEG images and incorporated in a Microsoft PowerPoint presentation with attribute data tables illustrating fly population counts.

3. OUTREACH AND EDUCATION

DEH is recognized as a leader in educating the regulated community and the public on environmental health issues. As WNV threatens public health, DEH has strived to remain highly visible in the services that VSC provides to the citizens of the County and to continuously provide WNV educational resources and informational updates.

The DEH VSC has developed a website, SDFightthebite.com that is regularly updated by VSC staff and public information officers. The map (below) resides on the website and informs the public of WNV test results in San Diego County.

Additional educational resources that utilize GIS map products include a speaker bureau consisting of VSC staff that may be scheduled to present WNV information to special interest groups or to school groups, or to the general public. Also, VSC joins other DEH programs in promoting environmental health via an educational display or booth at fairs and other public events. The outreach and education resources have been developed as part of, and in implementation of, the WNV Strategic Response Plan. Pamphlets and brochures include precautions, resources, and information on WNV in English and Spanish.

The aerial mosquito larvicide application is a highly visible control method. VSC prepared press releases and media events in order to notify the public of the aerial application of larvicide to waterbodies using a helicopter. During pilot testing, a GIS buffer technique was used to identify and notify schools near the area of aerial application. Maps were created in ESRI ArcGIS software and exported as Adobe PDF documents for posting to the website and for dissemination in press release packets.

These aerial application activities and associated press conferences provided an opportunity to educate a large sector of the public on WNV.

CONCLUSION

The WNV Strategic Response Plan (Plan) has been recognized with a 2004 National Association of Counties (NACO) Achievement Award. Implementation of the Plan includes much of the control, surveillance, and outreach components discussed in this paper. While perhaps still underutilized, it may be concluded that GIS has played an instrumental role in the success of the Plan.

Overall, the use of GIS technology has improved the VSC program by providing problem-solving and decision-making tools, by allowing a mechanism for improving communication, and by increasing the type of outreach media available to the public, and by inspiring the innovation of a growing GIS savvy work force.

Future plans for the VSC program includes migrating the existing DEH GIS intranet mapping application from ESRI MapObjects to an ESRI ArcIMS application. This is planned for August 2004.

ACKNOWLEDGEMENTS

Information on vector control and surveillance including the WNV information has been obtained by working daily with VSC staff, who I must acknowledge for the breadth of their combined knowledge, and who I must thank for allowing me to learn beside them and to bring GIS into their program where together we can Fight the Bite with GIS. The regional GIS data such as roads, property ownership, city boundaries, Thomas Brother Page boundaries, and aerial photo images are from SanGIS (San Diego Geographic Information Source) and SANDAG (San Diego Association of Governments). These agencies create and provide regional GIS datasets in a shared environment to the San Diego region and thus have allowed DEH to develop an interactive mapping application and in-house GIS layers using consistent and reliable data sources. All information and maps presented in this paper have been presented publicly to groups via educational outreach and media events, speakers bureaus, as well as posted on the DEH managed website, SDFighttheBite.com.

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