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The Evolution of Applied Geographic Information Systems for Oil Spill Response in California: Rapid Data Dissemination for Informed Decision Making

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ABSTRACT 298926:

Computing technology has advanced to the point where it is now standard practice to employ complex Geographic Information Systems (GIS) within the Incident Command Post (ICP). Simultaneously, field data collection has been migrating to mobile computing applications which output GIS files that are quickly displayed for real-time situational awareness. From the initial emergency response through clean-up and sign-off much data with a spatial component is generated and many disparate data sets are collected. More efficient data integration, management and visual analysis affords Incident Commanders and Section Chiefs the ability to make informed and timely planning, operational and strategic decisions.

Traditionally GIS maps were created in the ICP from field sketches, field notes and verbal reports. Processing of these data by the GIS Unit is very time consuming and prone to error. Preliminary efforts to streamline and automate field data collection by the California Department of Fish and Wildlife (CDFW, formerly the California Department of Fish and Game), Office of Spill Prevention and Response (OSPR) utilized Global Positioning System (GPS) receivers to record waypoints and track lines. Since then more elegant electronic field data collection applications installed on small, handheld computers have been developed including those for “Wildlife Recovery and Transport”, “Resources at Risk” over flights, and the “Shoreline Cleanup and Assessment Technique” (SCAT). Other recent advancements allow for real-time aerial remote sensing for oil slick detection and detailed mapping of its properties, and displaying the output from coastal High Frequency (HF) radar installations for real-time visualization of local ocean surface current fields. These field data collection applications are explained in more detail in the body of this paper.

Once these data are incorporated into the GIS a web-based Common Operational Picture (COP) is utilized for timely dissemination of relevant geospatial data. OSPR has worked closely with the National Oceanic and Atmospheric Agency (NOAA) to develop “Southwest ERMA” (Environmental Response Management Application) as California’s COP for web-based data dissemination and incident situational awareness.

At the Deepwater Horizon (MC-252) Incident Command Post (ICP) in Houma, Louisiana many responders were from outside of the region and unfamiliar with the local geography. Area base maps with a standardized coast line and place names were not readily available for several days which added unnecessary confusion to the mix. As a lesson learned and in order to avoid this situation for an oil spill response in California, OSPR and

NOAA have pre-loaded Southwest ERMA with pertinent base maps, charts and spill response planning data from the three California Area Contingency Plans (ACPs). These data are deliberately made freely available to the general public via the Southwest ERMA web-viewer without any user login credentials required.

INTRODUCTION:

Timely dissemination of geospatial data is critical during an emergency oil spill response. GIS, once bulky and cumbersome to deploy outside of an office setting is now commonplace in an oil spill response ICP. Oil spill response has an organizational structure that is based on the National Incident Management System (NIMS) and employs the Incident Command System (ICS) organization. The structure and function of the various organizational elements and personnel are described in the Department of Homeland Security (DHS) document titled "Incident Management Handbook" (U.S. Coast Guard, 2006). The IMH is not a policy document but rather a guide and job aid for response personnel. GIS is part of the Situation Unit and supports the individual ICS units and branches defined in the IMH with data analysis for strategic planning and situational awareness.

In an effort to distribute pertinent response data quickly and effectively OSPR has pursued a path towards efficient field data collection to streamline the flow of information from the field to the decision makers. Software applications written for hand held computers, tablets, smart phones, etc. allow for efficient electronic field data capture in GIS format. The resulting files can be quickly input to the GIS in the ICP and used for informative decision making. This process provides the ability to 1) quickly merge field derived GIS data sets with other disparate information for rapid analysis, and 2) provides the ability to disseminate the information within the ICP and directly to field responders electronically in near real time.

BACKGROUND:

OSPR is the lead State agency charged with oil spill prevention and response within California's marine environment. The Lempert-Keene-Seastrand Oil Spill Prevention and Response Act of 1990 established OSPR and provided a mechanism for continuous funding. Both spill prevention and a spill response organization, OSPR retains CDFW's public trustee and custodial responsibility for protecting and managing the State's fish, wildlife, and plants. The OSPR Administrator has substantial authority to direct spill response, cleanup and natural resource damage assessment (NRDA) activities. The OSPR Administrator is required to provide the "Best achievable protection" for the resources of the State of California by using the "Best achievable technology" (California Department of Fish and Wildlife, Office of Spill Prevention and Response, 2013a).

Shortly after the formation of OSPR in 1990 the OSPR Administrator identified GIS technology as a component for the developing scientific program. Initially, GIS on UNIX based workstations was utilized in the Sacramento headquarters by the OSPR Scientific Branch for the production of biological resource maps of California's coastal and marine environment. Taking UNIX technology into an ICP environment was difficult due the bulk of the system and the delicacy of a UNIX network. OSPR first deployed GIS to the field for the SS Cape Mohican oil spill response in 1997 at the San Francisco dry dock facility. By then, commercial GIS software had been ported to the Microsoft Windows environment and the laptop computer became a viable platform for field response.

The flow of information starts with field data collection. Traditionally, during an oil spill event GIS maps were created in the command post from data forms and field sketches or notes and verbal reports. Processing of these data by the GIS Unit was very laborious and prone to error. Field data forms came back to the ICP with locational information based on geographic or colloquial place names (e.g. "Clam Beach, approximately 500m south of the mouth of the Little River"). At best that provided gross spatial accuracy, at worst the provided place names were wrong as the responder was unfamiliar with local geography. Preliminary efforts by OSPR to streamline field data collection utilized GPS receivers to record track line and waypoint data. Although this provided much better locational information, input to the GIS was still slow as the raw GPS data had to be post processed to account for Selective Availability (SA), the intentional degradation of public GPS signals by the U.S. Department of Defense (DoD) for national security reasons. In May of 2000 by order of the President SA was discontinued permanently by the DoD (The White House Office of the Press Secretary, 2000). This eliminated the need for post processing and opened the door for quicker incorporation of the GPS based data into the GIS, and begat faster data analysis and map display.

FIELD DATA COLLECTION APPLICATIONS:

Efficient field data collection is the underlying key to rapid data analysis and information dissemination. OSPR parameters for GPS based data collection, recording and reporting are datum WGS 84 and geographic coordinate values set to decimal degrees. OSPR requires all electronic field collection applications to output data in GIS format, specifically ESRI shapefile format, datum WGS 84 with geographic (unprojected) coordinates. The following sections describe the current electronic field data capture applications used by OSPR during emergency oil spill response.

Shoreline Cleanup Assessment Technique (SCAT)

SCAT teams comprised of trained representatives from trustee agencies and the Responsible Party (RP) reconnoiter along discrete segments of shoreline to assess the degree of oiling and provide a recommendation for treatment. This information is used for planning for operational cleanup. The NOAA document "Shoreline Assessment Manual" describes this response function in detail (NOAA, 2013). As a lesson learned from the response to the M/V Cosco Busan oil spill in 2007, OSPR field responders have pre-determined specific statewide SCAT segments for the outer coast and harbors. When an oil spill event occurs in California SCAT teams can be deployed to the field quickly without the delay of ad hoc SCAT segment determination (Haffner et al, 2011). The most challenging task for the GIS Unit during the M/V Cosco Busan response was processing the daily SCAT data. The data were collected using traditional paper SCAT forms. There were four main SCAT teams and three reconnaissance SCAT teams all converging on the ICP in the late afternoon. Collating and processing the SCAT field data quickly became a cumbersome and sometimes a daunting process as spatial coordinate information was delivered in several modes (e.g. decimal degrees, decimal minutes and degrees minutes seconds) or with incomplete values. This required much post processing before the data could be entered into the GIS. Currently, OSPR uses a mobile GIS application called PocketSCAT, a commercial product, which allows electronic capture of SCAT data in the field on a hand held computer (Haffner et al, 2012). SCAT data can be transmitted back to the GIS Unit in the ICP via Wi-Fi if available, or else downloaded in the ICP when the teams return from the field. Resulting GIS maps are used to track the progress of cleanup operations and help develop the incident action plan (IAP) for the next operational period. The ShoreAssess extension to ArcGIS produces digital GIS output from the PocketSCAT files quickly and eliminates much error from the process allowing for timely and more informed operational decisions. OPSR field personal have monthly training exercises with this application in order to maintain proficiency.

Wildlife Recovery, Transportation and Processing

Wildlife recovery and transport teams are deployed by the Operations Branch for collecting debilitated animals and carcasses. At the wildlife receiving and processing center standardized protocols are in place to ensure that techniques and effort for all data collection are uniform (PRBO Conservation Science and UC Davis Wildlife Health Center, 2009). OSPR now has a mobile GIS application that is used to record a GPS based location plus ancillary data about the animal when they are collected or captured. At the wildlife intake center the collected animals are logged in and the attribute data are entered into either of two local databases, 1)"Live" and 2) "Dead". The animals are then banded or tagged with a unique ID that is used to track the animal's fate. The resulting shapefiles are imported into the GIS in the ICP where wildlife stranding maps are made and used as a planning tool for the next cycle of field recovery and transport team deployments. Post emergency response wildlife transportation and recovery GIS layers are used for the NRDA.

In 2001 as part of the search for the source of the San Mateo Mystery oil spill (later determined to be the wreck of the SS Jacob Luckenbach) wildlife stranding maps were used by modelers to "hind-cast" where the birds had encountered the mystery oil. This was one piece of evidence used to narrow the geographic search for the source of the mystery oil (Muskat et al, 2003).

Resources at Risk Over-flights

OSPR employs a team of trained aerial observers to fly reconnaissance missions looking for biologic resources at risk. Using a standardized set of protocols, the aerial survey team will characterize their pelagic transects for abundance, distribution, and species identities of on-water marine birds and mammals, in or near the spill area. The resulting information is used to help direct wildlife recovery and transport teams, and is particularly important for larger offshore spills. Protocols for observation and documentation are described in Bonnell et al, 1993. In the early 1990's the information captured from these over-flights was displayed as a simple gridded pattern color coded for risk value as high, medium or low. This display is still valid for a generalized overall view. Currently, the observers use an application that captures the aircraft flight path and specific observation locations via GPS track and waypoints. The raw data are processed into shapefile format then transmitted via email to the GIS Unit in the ICP for map production and display. The resulting survey maps are used by the Wildlife Coordinator for mission planning for the next operational period. Post emergency response, these GIS data are used as part of the formal cooperative NRDA.

Aerial Multispectral Remote Sensing

Through the OSPR Scientific Study and Evaluation Program (SSEP), OSPR and Ocean Imaging Corp. (OI) collaborated to develop a rapidly deployable aerial multispectral sensor utilizing 4 channels in the visible-near infrared (IR) that accurately maps the extent of an oil slick (Svejkovsky 2007). Further research and development added one channel in the thermal IR enhancing the ability to determine thickness values within the oil slick (Svejkovsky et al 2008, Svejkovsky and Muskat 2009). The system was used successfully for several small oil spill responses in California. The interpreted remote sensing images, replete with thickness classification values are transmitted to the ICP in GIS format in real time and can be quickly incorporated into the GIS for analysis and display.

During the emergency response to the Deepwater Horizon (MC-252) oil spill the OI mapping system was used extensively, flown daily, sometimes twice daily over the source of the spill and specific target areas. Oil slick spatial extent and thickness estimation maps derived from the multispectral aerial imaging system were successfully utilized for multiple types of applications such as source area oil distribution for response resource management and trajectory modeling, location of recoverable oil targets, the location and extent of beached and marsh-entrained oil, and for a quick look to determine the effectiveness of dispersants. The operational utilization of the OI remote sensing system is described in full detail by Svejkovsky et al, (2012).

High Frequency Radar

High frequency (HF) radar systems measure the speed and direction of ocean surface currents in near real time. An OSPR SSEP funded research project took advantage of the existing HF radar coverage along the California coast by developing a methodology for real-time tracking of drifting material (e.g. an oil film on the ocean surface). The purpose was to automate the production of GIS files from the raw HF radar data and thus have the ability to generate real time maps of surface current fields and to use these data as input to a GIS and for trajectory modeling. (Garfield et al, 2007). HF Radar data for California is now posted hourly to an FTP site hosted by the Scripps Institution of Oceanography. Data postings are in two file formats: 1) ESRI shapefile for direct import into GIS and 2) NetCDF format using structure and variable names specified by NOAA for direct assimilation into the NOAA Office of Restoration and Response (OR&R) General NOAA Operational Modeling Environment (GNOME) application that provides trajectories and forecasts of the oil spill. As a result, OSPR now has operational capability for integration of surface current maps in GIS applications (Otero, 2010).

Web-Based GIS

In 2008, through the OSPR SSEP, OSPR let out a research contract to develop a web-based interactive mapping application. This was OSPR's first attempt at web-based GIS for data dissemination directly to responders in real time. Access to the web-site was controlled via individual login credentials (Svejkovsky, 2009). This web-based application was used operationally for the response to a spill from an oil production platform in the Santa Barbara Channel in 2008 (Muskat et al, 2011).

The ERMA® Common Operational Picture

At the beginning of the Deepwater Horizon (MC-252) oil spill response in ICP Houma, isolated pockets of GIS activity cropped up to meet the immediate needs of the individual ICS functions. GIS maps and remote sensing imagery were delivered to responders as paper maps and electronic email attachments (e.g. PDF and KMZ file formats). Less than a week into the response NOAA OR&R established a responder only Deepwater Horizon ERMA to provide situational awareness to the five ICPs around the Gulf of Mexico and to agency headquarters around the country (NOAA, 2012). A month into the response, NOAA also released a public Deepwater Horizon ERMA site with data approved for release by the Unified Command. This release also allowed the USCG National Incident Command (NIC) to designate ERMA as the COP for the overall Deepwater Horizon response. This public COP provided much needed transparency between the response and the public, while at the same providing the RP and Agency response community controlled access to operationally sensitive information. ERMA was used for USCG Command briefings at the Unified Area Command (UAC) and at the ICPs as well as to the NIC in Washington, D.C. The incorporation of field data supported real-time decision making at all levels of the response as well as for the NRDA and the subsequent restoration planning that are currently ongoing (Svejkovsky et al, 2012). At ICP Houma a large GIS Unit headed by a contractor to the RP. This contractor also deployed a COP that the RP controlled and preferentially used to load their data. Both COPs were excellent tools for operational planning however the net result of two separate COPs was that neither of these tools showed the same operational picture. With an RP COP and a government COP, two different perspectives were often reflected in this "common" picture and this reality was a source for some confusion and at times frustration.

Today, both the responder-access Deepwater Horizon ERMA and the public- ERMA Deepwater Gulf Response" sites continue to be updated with incident and NRDA data.

Southwest ERMA

In order to avoid a similar situation in California of multiple COPs being used in the ICP, OSPR has dropped its original GIS web-mapping application and is supporting NOAA's Southwest ERMA for use in California as the COP for oil spill response and as a pre-spill planning tool. OSPR is collaborating with NOAA OR&R and the USCG District 11 to make Southwest ERMA the model and template for a national oil spill planning tool and COP. The OSPR GIS Unit works closely with OSPR's first responders to ensure the information they need for planning and field response is made available in ERMA. OSPR has loaded Southwest ERMA with response maps, charts, and pertinent information from the three California Area Contingency Plans (ACPs, California Department of Fish and Wildlife, Office of Spill Prevention and Response, 2013b), see Figure 1. OSPR now uses Southwest ERMA operationally for oil spill drills and response.

ERMA was written using open source software. There are no proprietary software licensing or maintenance fees required once an ERMA site is established, an attractive feature for a State Agency given the current economic climate. However, there are additional costs to support an ERMA site such as cost for custom tool development and potential costs associated with base data. Southwest ERMA is a work in progress and can be accessed on the web through the NOAA OR&R Website at https://www.erma.unh.edu/southwest/.

DISCUSSION:

The Flow of data begins in the field. In a perfect world, data are electronically collected then transmitted to the Situation Unit (SITU) where they are first verified, then processed and posted to the COP for display in the ICP thus creating a near real-time dynamic situation map. At the same time anyone with responder level login credentials and an internet connection can access information from their desktop (figure 2). In the real world, however, electronic devices fail, cell phone coverage is spotty at best, internet connectivity is slow and field data comes to the ICP for processing late in the evening of an already long day. OSPR has made a consistent effort over the past 20 years to streamline or automate field data collection in order to expedite data entry into the GIS for rapid dissemination thus giving the ability for informed decision making at every level of an oil spill response.

These days many industry vendors are unveiling and displaying their versions of a COP and these are increasingly in use at industry drills. The use of a COP for situational awareness is rapidly becoming the standard for presenting situational awareness across the broad response. Now is the time for industry and agencies to come together, possibly through a series of workshops, and make these COPs truly common through the development of GIS standards for oil spill response. Currently there are no standards for an oil spill response COP. Pettit et al (2011) makes a case for GIS standards for oil spill planning and response at a national level. Specifically, common layer names, common database structure and common display symbology. Although it was not the specific intention when ERMA was first unveiled, NOAA has potentially started the process of uniting national oil spill response from the federal to the local level with the roll out and the establishment of several regional ERMAs. OSPR has populated Southwest ERMA with GIS layers and links to the three California ACPs. The next step forward involves creating the standard GIS database templates and symbol sets. At the 2011 International Oil Spill Conference a workshop attended by Agencies and Industry was held to discuss GIS standards for oil spill response. As a result NOAA OR&R established three GIS workgroups; the GIS Data Standardization Workgroup, the GIS Symbolization Workgroup, and the GIS Data Management/Needed Changes to ICS workgroup in order to begin the process of tackling these issues. NOAA has been working with a variety of Industry and Government collaborators to push these very critical topics forward. Since Deepwater Horizon, the landscape has become very crowded and the Department of Homeland Security has also stepped in. Without a national mandate or designated authority this is proving to be a slow process.

An important consideration for the Unified Command early on in an emergency response is to agree upon a single data viewer to serve as the official incident COP. Ideally the COP will be based in the SITU, have the ability to grant access at both a secured responder level and a general public level. Within the Situation Unit there should be a formal cooperative GIS Unit that can both meet the short term immediate needs of the response (e.g. base maps, rapid field data dissemination) and the longer term need for data management. Preferably the GIS Unit will be managed by an Assistant Situation Unit Leader (SITL) whose sole purpose is GIS coordination. A signed, formal data sharing agreement between trustee agencies and the RP would insure that all parties involved have access to all response related data sets (e.g. SCAT surveys). Improvements to the USCG IMH addressing a data sharing agreement and information management plan and staffing would formalize this information management concept. At ICP Houma, the formal GIS Unit reported directly to the Planning Chief. They were very focused on building an enterprise GIS, ultimately necessary for the long haul as the data repository. Unfortunately, the GIS Unit leader did not recognize nor respond to the more pressing immediate responder needs such as standardized base maps with geographic place names. This in particular was a cause of unnecessary confusion as responders were arriving daily from around the nation and international locations with little knowledge of the local geography. The inclusion of base maps, charts, and response strategies for pre-identified environmentally sensitive sites, pre-determined response infrastructure (e.g. operational divisions and other ACP data sets) into Southwest ERMA is a significant lesson learned from the Deepwater Horizon experience. For better data management in the ICP, the OSPR GIS Unit has established an operational mobile GIS server. The server contains copies of the CDFW and OSPR GIS libraries, provides networking capabilities for GIS staff plus enough disk capacity to provide a common workspace. The server is equipped with both Ethernet and Wi-Fi capabilities and provides secure VPN access to the CDFW network. The server has several security access levels preventing non-OSPR GIS Technical Specialists from accessing confidential files while working in the common workspace.

CONCLUSION:

GIS is fully integrated into oil spill prevention and response in California. GIS is an excellent data management and organizational tool. The inherent ability to import and display convergent data layers provides the incident Unified Command with a powerful decision making tool.

The first few days of an oil spill response can be chaotic until an ICP is set up and functioning. In the case of the response to the Deepwater Horizon (MC-252), a spill of national significance, it took weeks to build the GIS infrastructure in the ICP (e.g. wired internet access, networking, server storage, plotting capabilities, roles and responsibilities). The result was disconnected isolated pockets of GIS that happened out of necessity to serve the individual ICP functions. While the initial Deepwater Horizon ERMA site was deployed within the first week of the response, it was not accepted as the Federal COP until the NIC established this mid-June, nearly two months after the initial incident, which contributed to the confusion of how best to get information for decision making.

A regional web-based GIS mapping application and COP such as Southwest ERMA, pre-loaded and maintained with relevant oil spill response and planning layers gives first responders access to basic framework data layers during the crucial first days of the response and can provide a visual display of situational awareness to the broader response community for the duration of the emergency response and through the NRDA process. The cooperative GIS Unit should be an integral part of SITU coordinated by an Assistant SITL. This will provide a centralized and unique location for GIS services, up to date data management and information dissemination via the COP.

A proposed suite of national GIS standards will give any web-based COP a common look and feel and therefore be more understandable and useable to those responders arriving from outside of the local area.

Figures

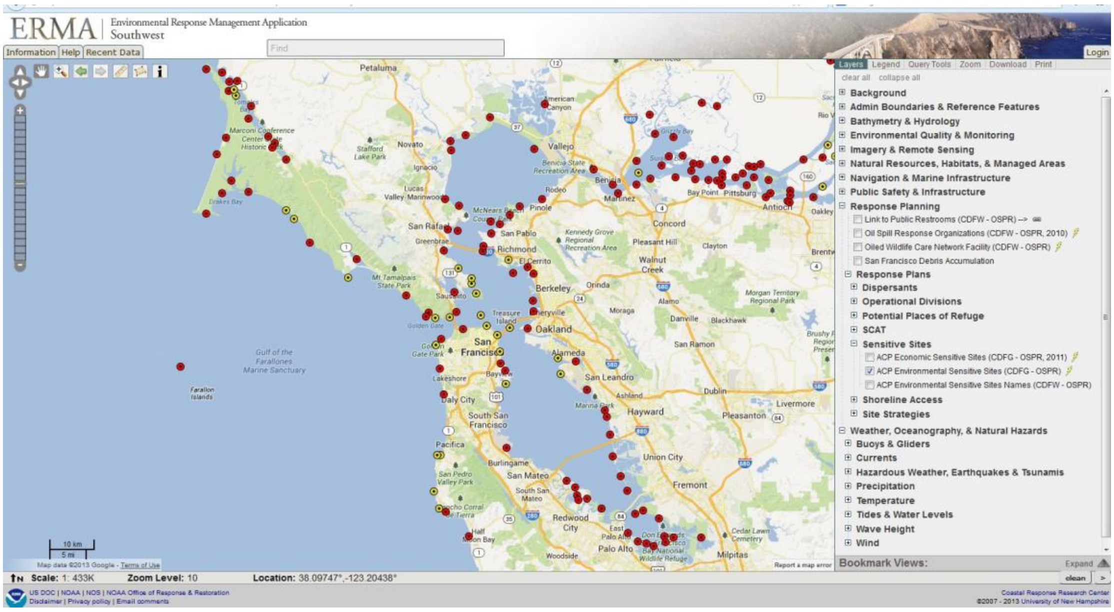

Figure 1. Southwest ERMA has five access levels, the most common being “public” and “responder”. The public can view oil spill planning data with no login required. Responder level requires login credentials to access confidential data. Other access levels include “NRDA”, “Trustee”, “Federal”, and “Sensitive Resource”. This map at public level access shows sensitive environmental sites along the California coast. Imbedded hyper-links take the user deeper into the data, e.g. a mouse click on a sensitive site marker will pop-up the site protection strategy diagram from the ACP document.

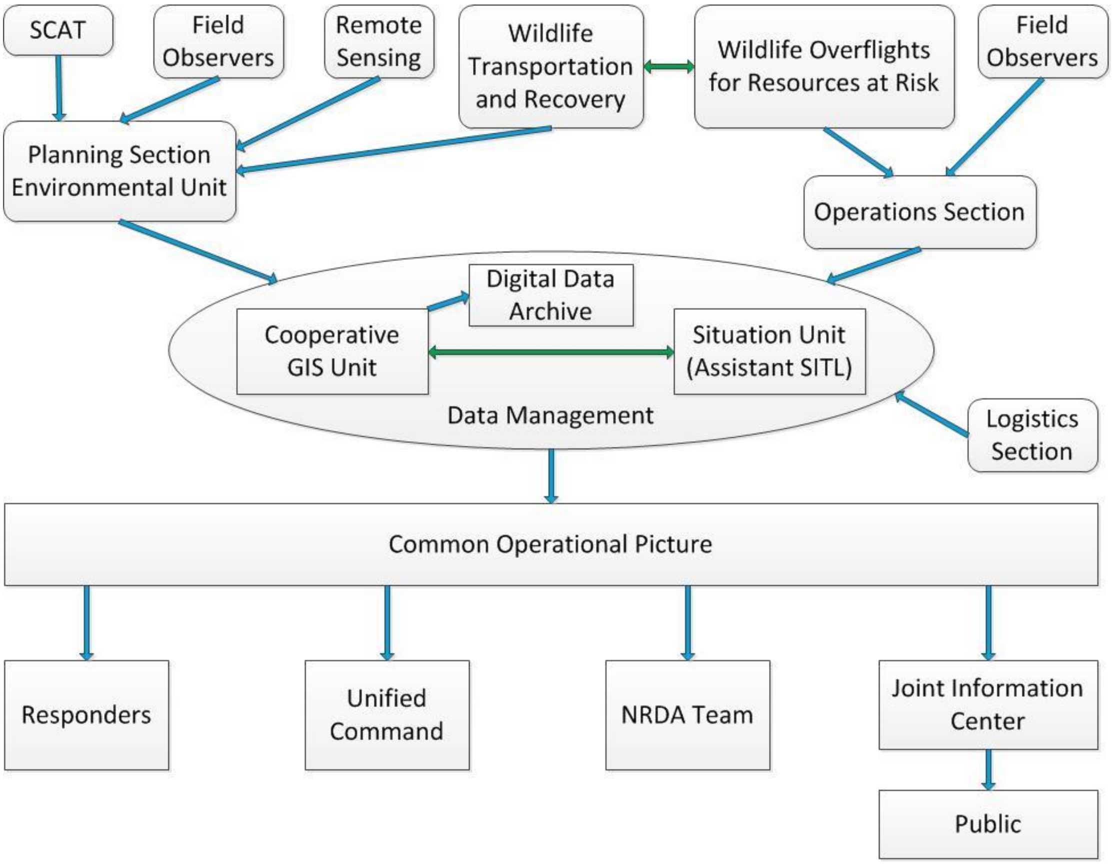

Figure 2. This figure diagrams the flow of information from the field through the Planning and Operations Sections to the Situation Unit. There the field data is verified, processed and digitally archived by the cooperative GIS Unit. The data/information is then posted to the COP for dissemination to responders and displayed in the ICP for situational awareness.

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