GIS Operations at the U.S. Department of Energy's Hanford Site: A Review of the Current Status and a Proposed Action to Ensure Long-Term Data Sustainability

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Abstract

Geographic Information Systems technology provides a keystone for achieving the mission and vision of the U. S. Department of Energy's Hanford Site. The Hanford Site located in Richland, Washington, is at a critical crossroads involving environmental, political, cultural, and economic concerns. The site has been collecting spatial data for a period of 60 years and now, more than ever, the organization and structure of spatial databases at Hanford provide a critical path to providing an effective, efficient, and safe cleanup mission demonstrating the effectiveness of environmental protection and restoration activities. This paper provides a current state of spatial data collections, use, management, and challenges at the Hanford Site through the development of a spatial data infrastructure. Recommendations designed to ensure data quality, usability, and sustainability now and into the future are presented.

Introduction

The Hanford Site in Richland, Washington is one of thirteen sites that the U. S. Department of Energy (USDOE) owns and maintains. The Hanford Site is a 1,517 km^2 area located adjacent to the Columbia River in a semi-arid shrub-steppe environment (see Figure 1). The primary focus of the Hanford Site's current mission is environmental restoration. This is being accomplished by removal and/or stabilization of contamination that resulted from nuclear activities associated with the Manhattan Project and Cold War dating back to 1943. For 47 years, the site was an active nuclear production facility and in 1990, the previous mission was terminated and the focus changed to environmental restoration. Cleanup efforts have been characterized as "…a vast, complex, and expensive task – one that has often been called the world's largest environmental cleanup project" (DOE-RL 2004). Paradoxically, the Hanford Site also exhibits some of the healthiest and most precious terrestrial and aquatic ecologies in the United States, including critical spawning and rearing habitat of the threatened and endangered Fall Chinook salmon. The operations at the Hanford Site are guided by two separate USDOE offices, the Richland Operations Office and the Office of River Protection. From both of these offices, a number of prime-contractors and subcontractors are working to complete the cleanup and restoration mission and vision of the USDOE.

Cutting-edge science and technology developments are key elements for achieving the cleanup objectives set out by the USDOE (Longley 2004). In specific, basic and applied sciences are actively practiced in the realm of nuclear physics, biology, hydrology, ecology, geology, chemistry, meteorology, climate, engineering, waste management, cultural resources, transportation, infrastructure, risk analysis, emergency operations, and national security. The role of geographic information systems (GIS) within the construct of these sciences is a fundamental and critical component serving various functions in a variety of ways. Some of these functions include pre- and post-processors for various physical and biological numerical models, risk analysis assessments, site and inventory management, monitoring, data repository, decision support, real-time response, and facility management.

The Hanford Site has a collective repository of over 60-years worth of analog and digital spatial data collected by numerous government entities and contractors. This spatial data represents an invaluable resource for both scientific and management purposes. However, the extent and diversity of this data presents a dynamic and challenging environment for spatial data management. Because daily work is typically focused on project-specific details, it is difficult to step back and look at the "big picture" as a collective organization. As reliance upon spatial data (both current and historical) increases, measures must be taken to ensure data quality, and in turn, long-term data sustainability and accessibility. This paper serves as a portal to an overall assessment of accomplishments and challenges in developing, maintaining, and organizing spatial data at the Hanford Site.

Discussion

The success and efficiency of solving problems can often be attributed to the approach, planning, and organization involved. When problem resolution involves data, the same attributes (approach, planning, and organization) can be applied to the data management activities undertaken to ensure that data is accurate, complete, timely, accessible, traceable, and persistent. Robust data management is necessary to ensure that the data and subsequent decisions are able to stand the test of time. Recent advances in technology have resulted in the increased volume and variety of data available. In conjunction with the increase in data production, society has increased its reliance on data derived information. Consequently, data management has become a critical component in the problem solving process. As environmental restoration of the Hanford Site continues, spatial data will play a critical role in operations, decision making, and ultimately in the transition to future uses for the site. The following sections describe data management as it applies to spatial data operations at the Hanford Site.

Entity Organization

In order to understand the complexity of the data management issues and challenges at the Hanford Site, it is necessary to detail the numerous entities involved with collecting, managing, and utilizing spatial data within the geographic domain of the Hanford Site and surrounding areas of concern (see Figure 2). Each USDOE entity performs a specific role in achieving the overall cleanup mission, whether it involves developing a socio-economic plan, modeling and mapping groundwater contaminant plumes, risk-analysis modeling, operating an emergency response center, or any number of other critically important tasks. All USDOE private contractors ultimately report to one of the two USDOE offices discussed earlier, and in turn, these offices report to the USDOE Headquarters office (USDOE-HQ). In a mutually cooperative effort, other non-USDOE entities are involved in ensuring certain data are shared and utilized to the benefit of all involved.

Business Processes and Spatial Data Organization

The USDOE contractors involved in performing specific tasks at the Hanford Site have the responsibility to maintain spatial data associated with their respective business processes as required to accomplish their respective work task(s). Each contractor applies the methodology and toolset for developing and managing their spatial data that will best suit their individual needs. Selection of tools and data management practices are often based on cost and efficiency for the project or business process owner. Opportunities for collaboration and data sharing between projects and business process owners are not always part of the selection process.

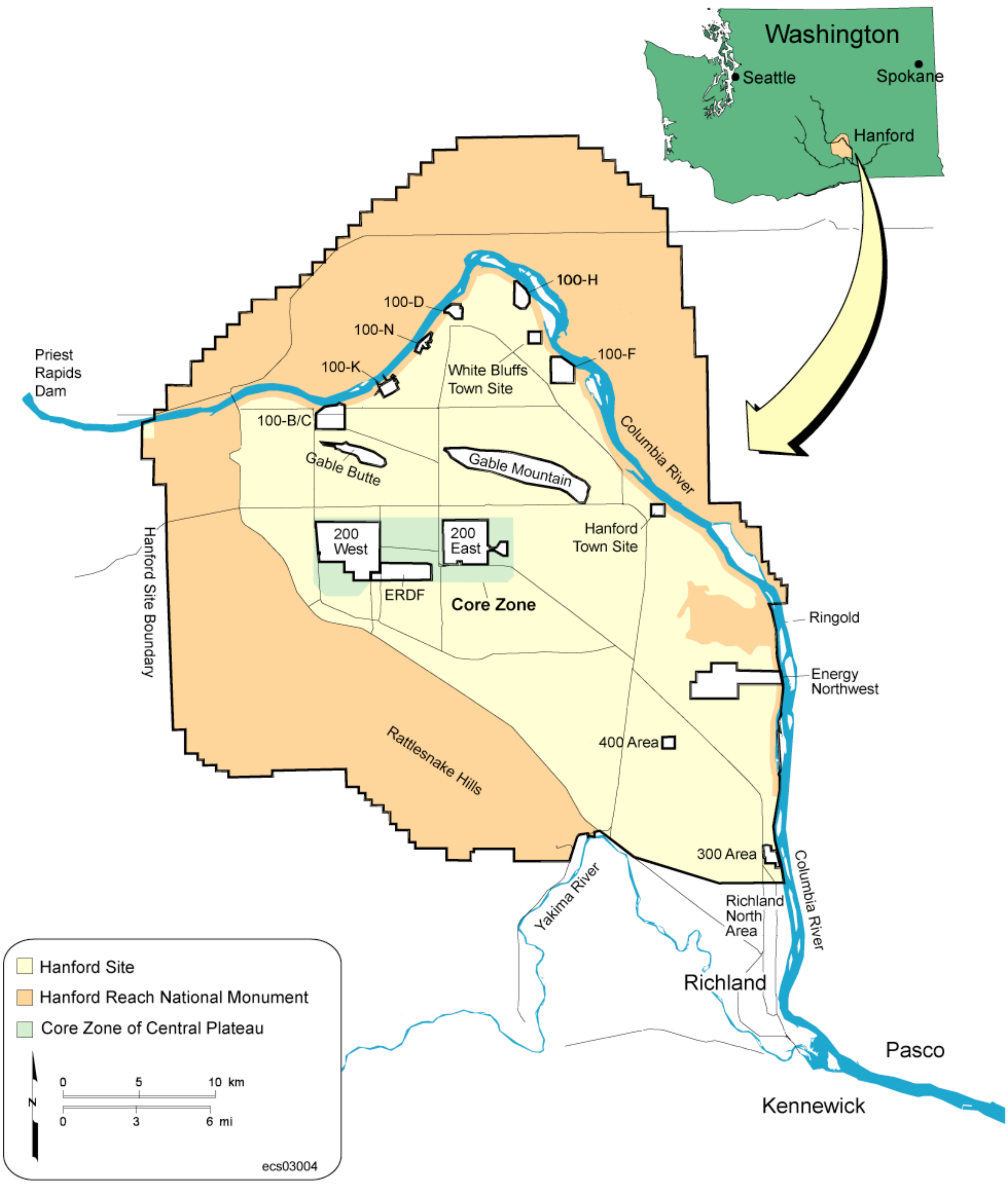

Figure 1. An overview map of the Hanford Site. The site is located in the southeast portion of Washington State, in the northwestern region of the United States.

In 1989, the need for coordination and oversight of spatial data was recognized by the USDOE. As a result, a primary USDOE contractor was given the task to bring the various entities generating, maintaining, and using spatial data closer together to address spatial data management concerns. This was accomplished by the creation of a geodata collaborative called the Site Spatial Data Council (SSDC) (Rush 1998). The role of the SSDC is to act as a neutral entity developing policy, standards, data sharing, and communications with representation from each of the USDOE contractors and USDOE. The SSDC also works to foster an interdisciplinary coordination effort, linking various skill and data sets where needed. A particular challenge for the SSDC is to develop and maintain relationships with each contractor in an environment where projects and contractors may have short duration and limited temporal presence. The framework of the SSDC is based on ideas promoted by the National Spatial Data Infrastructure (NSDI); "…reduce duplication of effort,…improve quality and reduce costs related to geographic information, to make geographic data more accessible,…increase the benefits of using available data,…establish key partnerships,…[and to] increase data availability" (NSDI 1994, FGDC 1995). To accomplish the SSDC goals, the development of a Spatial Data Infrastructure (SDI) was imperative.

Spatial Data Infrastructure

The Federal Geographic Data Committee (FGDC) defines an SDI as an "umbrella of policies, standards, and procedures under which organizations and technologies interact to foster more efficient use, management, and production of geospatial data" (FGDC 1996, Phillips *et al*. 1999). To further characterize a SDI, the Global Spatial Data Infrastructure (GSDI 2004) adds "…support information discovery, access, and use of this information in the decision-making process." Currently, the SSDC works to address, develop, accomplish, and maintain a SDI that is specific to the Hanford Site and surrounding areas. While not all aspects of the SDI have been developed, many significant accomplishments have been made that pave the road for additional elements to come into focus.

Phillips *et al*. (1999) devised five aspects that constitute a SDI. Accomplishments and challenges for the Hanford Site SDI through the SSDC are presented within the context of these five SDI aspects.

<u>Data:</u> Through the collective efforts of the USDOE and USDOE contractors, a robust set of analog and digital spatial data exists for the Hanford Site as far back as the early 1940s. Among all the geospatial participants, there is a wide array of specialties and focus areas (i.e., geologists, surveyors, infrastructure, maintenance). The SSDC identified and published lists of key individuals and organizations as points-of-contact for data. With the assistance of these key individuals and organizations, the SSDC was able to execute an extensive data discovery effort and establish a metadata clearinghouse. As stated by Foote and Lynch (1995), "Clearinghouses are an important first step in acquiring data, but they will rarely have everything you need." Ideally the most current version or official copy of spatial data would be available from a central server. However, many data sets undergo revision on a regular basis. As a result, the most up-to-date versions of many data sets reside on the local systems of the individuals who create and manage these data. Where up to the minute data is needed, investigation is often required to locate and acquire the correct dataset. The metadata clearinghouse and lists of key individuals and organizations maintained by the SSDC can be valuable tools in data discovery.

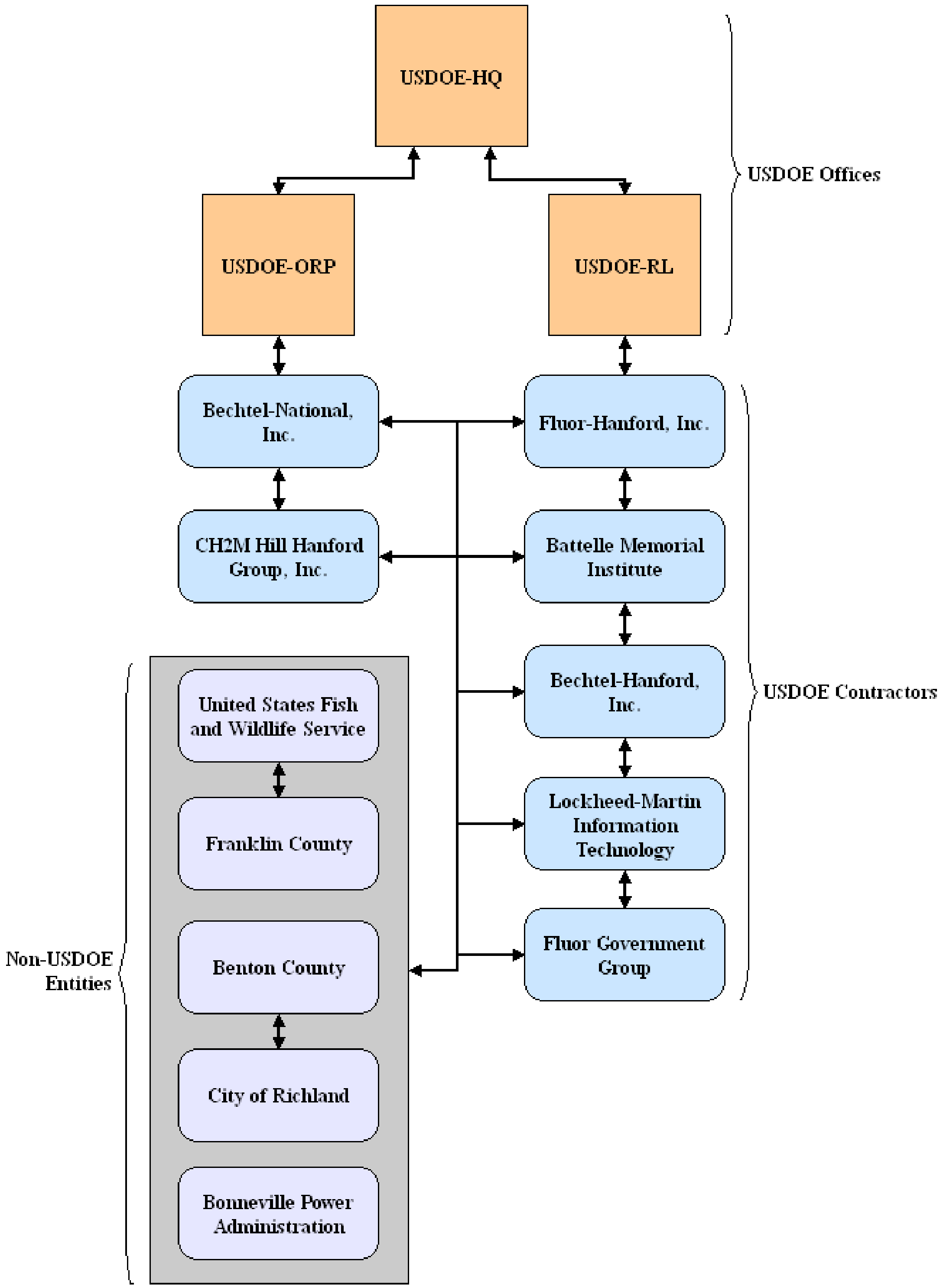

Figure 2. The organizational structure of the Hanford Site as it applies to a spatial data construct.

Communication: The SSDC brought together representatives from the relevant USDOE contractors and initiated communications concerning spatial data needs. Significant accomplishments were attained by establishing data sharing agreements amongst the contractors as well as several non-USDOE entities. Members from the SSDC actively participate in site, local, regional, and federal partnerships establishing good communication networks among Hanford geospatial users and with other relevant entities. In addition to the SSDC, other committees with interest in spatial data exist for coordinating activities associated with specific subject areas and applications. For example, the QMap Steering Committee, Hanford Technical Advisory Group, and Data Integration Groups work to coordinate data management activities associated with their respective interest areas. These groups include many of the same participants. The SSDC also conducts meetings, maintains a web site including resource lists and a metadata catalog, provides metadata training, maintains e-mail lists, and manages data sharing agreements. These are done primarily through the leadership of delegates from each organization and the voluntary participation of data users and stakeholders.

A significant challenge to the SDI Communication element is communicating needs to appropriate levels of management of the respective participating organizations. The organizational structure within the USDOE and associated contractors is bureaucratic. Consequently, organizational changes and funding needed to implement new data management practices are often slow in coming. To expedite change in a timely manner, the SSDC must work in a bi-modal fashion to encourage good business practices at the project level and work with management to establish the directives and necessary funding. This is often accomplished by members of the SSDC acting as consensus builders by fostering communication among data stakeholders and management. It is important that the SSDC have unrestricted open communication with upper-level management in order to be successful.

Up to this point in time, the SSDC has primarily been operating on a chaordic organizational model. Onsrud (2004) defines chaordic organizations as "…having the characteristics of allowing structure, people, and practices to continuously evolve in pursuit of their individual purposes while, in a narrow band of activity essential to the success of the whole, they engage in the most intense cooperation. The chaordic relationship is ultimately defined by binding operating agreements to which all parties choosing to participate must abide." Within the Hanford Site, participation in the SSDC is not mandatory and participants are often not funded for this involvement. However, the need is recognized among spatial data users and therefore, the system functions. The SSDC represents a contrast in organizational paradigms and would likely function more effectively under a funded bureaucratic organizational model.

Common Standards and Procedures: In conjunction with communication efforts, standards and procedures are a critical function for a successful SDI. Early in the SSDC charter, standards were developed through a guiding framework model which establishes a common projection system, data sharing standards and policies, and the operating guidance of the SSDC. Because the SSDC operates as a policy organization and forum for communication, the SDI Common Data Standards and Procedures should be a focus area. Management of legacy data, data versioning, and data quality reviews require project funding and are beyond the scope of the SSDC. However, the SSDC can facilitate communication between data users, data stewards, and management so that these activities can be planned and budgeted at the project level.

Partnerships: Data acquisition can be prohibitively expensive, especially for small projects. Because many organizations often have interest in the same or neighboring geographic areas, it is often possible to share data costs. The SSDC has been very successful in developing partnerships within the USDOE contractors and non-USDOE entities. For example, in 2003 an orthoimagery data collaborative was established among local municipalities, regional counties, USDOE contractors, and a state-level agency. The result was a product that was delivered at 25% of the cost that would have been incurred had the USDOE pursued this activity independently.

Technology: The technology aspects addressed by the SSDC pertain almost exclusively to the needs of the Hanford Site. The larger and more complex the organization, the greater the need is to coordinate data networks, file servers, software, and web technologies. The SSDC can help ensure that official data is easily accessible and reliable. With multiple organizations creating and managing geospatial data for their respective work scopes, it is critical that the best available data be identified as official and made available to authorized users.

Phillips *et al*. (1999) states "A SDI will not function, no matter how good the networking and technology is if communication channels, standards and procedures, partnerships and data have not been developed."

Recommendations for Collaboration and Long-Term Data Sustainability

The benefits of collaboration and long-term planning are invaluable when considering the massive cleanup effort currently taking place at the Hanford Site. The current outlook for completion of the USDOE mission is in the year 2035 (DOE-RL, 2004). Geospatial data and a robust SDI will be crucial in accomplishing this mission. Johnson *et al.* (2001) provides several key benefits for collaboration and, ultimately long-term data sustainability: 1) improved efficiency, 2) improved decision support, 3) improved data management, 4) reduced data costs, and 5) improved data quality and reliability. The following sections provide recommendations for key areas that would improve the success of the SSDC and SDI development.

Developing Data Standards that Address Multiple-Use: Understanding how a given dataset might be used will have an impact on data efficiency, usability, and long-term sustainability. We recommend that the datasets used by many organizations (i.e., infrastructure, hydrography, topography) be identified and integrated into the SSDC framework in a way that matches national and global frameworks as closely as possible. Murakami (2004) recommends "…Core and non-Core data be modeled and shared in the designs of national SDIs using emerging ISO standards by following the rules for application schema, publishing a feature catalogue, and standardizing the encoding of the data."

Develop, Educate, and Implement Data Quality Standards: Without the knowledge of how to identify data quality and how to apply it to data within a given domain, the data can realistically only be used for specific short-term needs. By following the data quality guidelines set out by United States Spatial Data Transfer Standard (SDTS, 1997), the International Organization for Standardization's ISO/ TC 211 (ISO, 2004), the European Committee for Standardization's CEN/TC 287 (CEN, 2004), and Guptill and Morrision (1995), a high-degree of quality and increased usability can be attained. The following seven areas of quality should be assessed: 1) attribute accuracy, 2) positional accuracy, 3) logical consistency, 4) completeness (spatial and temporal), 5) compatibility, 6) semantic accuracy, and 7) data lineage. The fundamental concepts of data quality need to be incorporated into the SSDC framework and communicated to the geospatial data developers and users as wells as to managers.

Stewardship and Accountability for Spatial Data: A key element to ensuring that data is accurate, complete, timely, accessible, traceable, and persistent, is to assign a stewardship and accountability model to USDOE contractors. If a particular company, group, or individual within a contracting organization has a specialty or is the best person to develop a particular type of data, an official stewardship role should be explicitly assigned. It is critical however, that the "Multiple-Use Standards" and "Data Quality Standards" be implemented universally.

Implementation of a Central Site-wide Enterprise Server: There are multiple benefits to establishing a centralized site-wide spatial data server including, 1) data security implementations, 2) data discovery, 3) efficiency of data use, 4) reduction in redundant data, 5) retrieval of data with known quality and pedigree, 6) retrieval of up-to-date data, 7) accessibility of historical data, 8) data visualization, and 9) increased use of spatial data for decision-making.

Spatial Data Librarians: We propose that a Spatial Data Librarian be identified by the USDOE field offices which will oversee the incorporation and management of spatial data into the central spatial data server from each of the contractors. The Spatial Data Librarian would be responsible for the generation or review of appropriate metadata and record submissions to the metadata clearinghouse.

Mandated Participation and Conformance: The SSDC should have the ability and capacity to create "Task Groups" which would work to identify specific issues and propose possible solutions. It is important that the SSDC be able to influence contract requirements as required to implement SDI recommendations. To influence contract requirements, the SSDC must involve the appropriate functions of management responsible for contract requirements.

Regularly Scheduled SSDC Meetings: We recommend that a regularly scheduled, monthly 2-3 hour meeting be established to provide a regular and consistent forum to communicate among data users and stakeholders, define annual goals, and work towards establishing set goals. It is also recommended that minutes be recorded and presentations be preserved in a centrally accessible location.

Establish Annual Reviews From Other DOE Offices: An annual review of the SSDC and USDOE contractor functions by another DOE office should be implemented. The power of having an outside viewpoint assess the goals and actions would provide a level of accountability, foster sharing of ideas, and ensure that SDI activities and goals are consistent with long-term objectives. This function would provide oversight for the USDOE-HQ and help to tie together the activities of the 13 sites in a beneficial way.

Outreach and Educational Opportunities: To gain a perspective on where the efforts of the SSDC and SDI are going, it is necessary to collaborate with other parallel (USDOE) and higher-order regional, (state, and federal) data sharing collaborative organizations. While the SSDC currently participates in these functions, more emphasis needs to be placed on learning from and sharing experiences with other USDOE sites.

Conclusion

The use of GIS has established itself as being an effective system to accomplish a variety of tasks for a large-array of disciplines. The theoretical developments and practice of the Geographic Information Sciences continues to evolve rapidly, providing new methodologies to solve new and existing problems affecting complex social, environmental, and economic problems. As a result of this rapidly developing science, our reliance on spatial data increases and becomes a more integral part of our daily lives. The establishment, building, and maintenance of a SDI is a key element to resolving common issues and, as stated by Montalvo (2004), "Without a coherent and consistent SDI in place, there are inefficiencies and lost opportunities in the use of geographic information to solve problems." The role of the SSDC and a fully-implemented SDI will support the Hanford Site cleanup mission and beyond, and aid making efficient and well-informed decisions that minimize risks to the environment, health, economies, and long-term stewardship of the land.

At the Hanford Site, information which documents the status of facilities, structures (especially underground structures), and environmental conditions will be required to demonstrate site conditions to support closure and transfer. This information will serve as the Objective Quality Evidence of site conditions and will ultimately be the basis of the decision by the receiving organization(s) to accept, or not accept the stewardship of the site. This information must be complete and accurate. In other words, the infrastructure and environmental databases must reliably track the emplacement of structures and release of waste from cradle to grave. Information and data will be required to defensibly describe:

- what (inventory and characteristics of emplaced features and waste)
- where (location in three-dimensional space)
- when (cradle to grave life cycle).

The SSDC must continue to work with DOE and the respective contractors at the Hanford Site to develop and maintain a robust SDI that can support the current and future needs of the site.

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References

CEN, 2004. Technical Committee for Geographic Information. European Committee for Standardization, viewed online 10 December 2004, http://www.cenorm.be/CENORM/BusinessDomains/TechnicalCommitteesWorkshops/CENTechnicalCommittees/CENTechnicalCommittees.asp?param=6268&title=CEN%2FTC+287.

DOE-RL, 2004. Message from the DOE-RL Manager, viewed on 13 December 2004, http://www.hanford.gov/rl/?page=91&parent=45.

Longley, Robert 2004, *Hanford Site: Past Horror, Future Hope*, PRIMEDIA Inc., viewed on 5 May 2004, http://usgovinfo.about.com/library/weekly/aa102497.htm.

FGDC, 1996. Appendix B: Updating the 1994 Strategic Plan for the NSDI, Federal Geographic Data Committee (US), viewed online 16 December 2004, http://www.fgdc.gov/nsdi/strategy/appendix_b.html.

FGDC, 1995, Development of a National Digital Framework, viewed on 16 December 2004, http://www.fgdc.gov/framework/framdev.html.

Foote, K.E. and Lynch M. 1995. Data Sources for GIS, The Geographer's Craft Project, Department of Geography, University of Texas at Austin, viewed on 13 December 2004, http://www.colorado.edu/geography/gcraft/notes/sources/sources.html.

Guptill, S.C., Morrison, J.L. (eds.). 1995. Elements of Spatial Data Quality, 1st ed. Elsevier Science, pp 1-135.

GSDI, 2004. Spatial Data Infrastructure Cookbook v. 2.0. Global Spatial Data Infrastructure Association, viewed on 16 December 2004, http://www.gsdi.org/gsdicookbookindex.asp.

ISO, 2004. Geographic information/Geomatics. International Organization for Standardization. Viewed online 9 December 2004, http://www.isotc211.org/.

Johnson, R., Nedovic-Budic, Z., Cover, K. 2001. Lessons from Practice: A Guidebook to Organizing and Sustaining Geodata Collaboratives. Geodata Alliance, Reston, Virginia: USA. Viewed on15 November 2004, http://www.geoall.net/.

Murakami H. Luzet, Claude (ed), 2004. 'Chapter Two: Geospatial Data Development: Building Data for Multiple Uses' in *Spatial Data Infrastructure Cookbook v. 2.0*. Global Spatial Data Infrastructure Association, viewed on 16 December 2004, http://www.gsdi.org/gsdicookbookindex.asp.

Montalvo, U.W. (ed) 2004. 'Chapter Eight: Outreach and Capacity Building' in *Spatial Data Infrastructure Cookbook v. 2.0*. Global Spatial Data Infrastructure Association, viewed on 16 December 2004, http://www.gsdi.org/gsdicookbookindex.asp.

NSDI, 1994. National Spatial Data Infrastructure. Viewed on 14 December 2004, http://www.fgdc.gov/nsdi/nsdi.html.

Onsrud, H.J., 2004. Exploring the Library Metaphor in Developing a More Inclusive NSDI, GeoData Alliance. Viewed on 16 December 2004, http://www.geoall.net/library_harlanonsrud.html.

SDTS, 1997. Spatial Data Transfer Standard (SDTS)-Part 1, Logical Specifications. American National Standards Institute, pp. 15-17.

Phillips, A., Williamson, I., and Ezigbalike C., 1999. 'Spatial Data Infrastructure Concepts' in *The Australian Surveyor*, 44:1, pp. 20-28.

Rush, Stephen 1998, *Hanford Spatial Data Activities*, Washington Geographic Information Council, viewed on 5 May 2004, http://wagic.wa.gov/Presentations/Hanfordpres.

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