# Developing a Geographic Information System for the Upper Delaware Scenic and Recreational River

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# Contents

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# Abstract:

Natural resources afforded by rivers and adjacent land areas have inherent spatial qualities that make them well suited for monitoring using geographic information systems (GIS). Such riparian areas are usually subject to certain spatial regulations and are often overseen by multiple authorities, further supporting the use of GIS in their management. The main goal of this project was to develop a GIS to support resource management at the Upper Delaware Scenic and Recreational River (UPDE), a unit of the National Park Service and the National Wild and Scenic Rivers System that surrounds the northernmost stretch of the Delaware River in Pennsylvania and New York. A web-enabled GIS was created for use by Park Service personnel and their collaborators from the region. The system integrates natural resource data with information on land use regulations and zoning in a way that supports the "project review" process used to guide management activities at UPDE. A secondary goal of this project was to use the knowledge gained during system development to devise a framework for incorporating GIS into the routine management of riparian areas, especially at Wild and Scenic Partnership Rivers. This framework is a process-oriented outline intended to help personnel with little to no GIS experience design and develop a system that supports their resource management needs. UPDE's GIS and the framework both have potential to promote effective and efficient management of riparian resources in the Upper Delaware region and beyond.

# 1. Introduction:

## 1.A. GIS in Riparian Management

Rivers and their adjacent land areas provide important assets to people and the environment. This includes freshwater supply for anthropogenic and ecological uses, along with less obvious assets provided by healthy adjacent lands. These riparian areas are defined by the Environmental Protection Agency as "vegetated ecosystems along a water body through which energy, materials, and water pass" (Environmental Protection Agency 2005, p. 11). Ecological and environmental functions imparted by riparian areas include water quality regulation through pollutant filtering and uptake, ground water exchange, and flood control, among others (ibid). Healthy vegetation communities along river banks also provide important terrestrial habitat for wildlife, shade the aquatic environment, and help stabilize the shoreline (ibid).

Natural resource managers have many tools at their disposal for monitoring and evaluating rivers and riparian areas. Geographic information systems (GIS) are particularly important when handling data that have a spatial component, and there is a long history of using GIS in water and riparian resource management. To illustrate, three decades ago, Goulter and Forrest (1987) reviewed and discussed the use of GIS in river basin management, specifically addressing if and how it should be used. They concluded that "GIS represents a powerful methodology for improving the operations of water resources planning agencies and those consulting planners/engineers who work with them" (p. 86). At the same time, however, they cautioned that GIS should be used as part of a larger decision support system to help guide managers in their decision making (Goulter and Forrest 1987).

In recent decades, the use of GIS in river and riparian resource management has grown more sophisticated, evolving beyond simply providing information about the locations of resources. For example, GIS has been used in conjunction with remotely sensed data to delineate riparian zones based on functional ecosystem characteristics (Holmes and Goebel 2011). Additionally, GIS has been used to perform complex biophysical river catchment modeling (Brierley et al. 2002), and has been used to simulate the consequences of alternative land use and management decisions on river health (Baker and Miller 2013). Such applications take advantage of the analytical capabilities of a GIS to integrate multiple data types and perform complex geospatial modeling.

This report describes the design and development of a GIS to support riparian resource management at the Upper Delaware Scenic and Recreational River (UPDE), a member of the National Wild and Scenic Rivers System. As described in the methods, the GIS was designed to meet one of the the most pressing resource management needs at UPDE, which at present is the interactive mapping and review of resources and regulations.

## 1.B. National Wild and Scenic Rivers

The United States' National Wild and Scenic Rivers System was created by Congress in 1968, the purpose being "to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations" (National Wild and Scenic Rivers System n.d.). A hallmark of the system is that it seeks to balance protecting component rivers' "special character" while at the same time allowing for "their appropriate use and development" (ibid). This is an important consideration for design of a GIS to support management of rivers in the National Wild and Scenic Rivers System. To date, the system protects segments of 208 rivers spanning more than 12,000 miles. While the extent of this protection is valuable, it accounts for only a tiny fraction (<0.0025%) of US rivers (ibid).

Certain rivers in the National Wild and Scenic Rivers System are known as Partnership Rivers, and are managed through collaborative efforts of the National Park Service, local and state governments, and adjacent communities (National Park Service 2010). These Partnership Rivers are comprised primarily of privately owned property and focus on local land use control and regulation to effectively manage the rivers and their riparian resources, while ensuring protection of their water quality, free-flowing character, and the outstandingly remarkable values for which each component river was designated. Given their collaborative management structure, and the utility of GIS in river and riparian resource stewardship, Partnership Rivers would likely benefit from routine use of GIS to help inform decision-making. While there is little precedent for doing so in the current management climate of Partnership Rivers, members like the Upper Delaware Scenic and Recreational River (UPDE) are interested in developing their GIS capabilities (C. Hauser Hahn, UDPE Management Assistant, personal communication, 10-Sept-2014).

## 1.C. Upper Delaware Scenic and Recreational River

UPDE is a unit of the National Wild and Scenic Rivers System surrounding the northernmost stretch of the Delaware River in Pennsylvania and New York (Fig 1). The entire Upper Delaware region is rural in nature, having large blocks of mixed deciduous and coniferous forests interspersed with small communities and tracts of agricultural land. In regards to resources, UPDE is known for its high water quality and ecological integrity, along with the great recreational opportunities it affords (National Park Service n.d.[a]). Notably, several locations in and around the Upper Delaware region have also been identified as priority conservation areas for continued vitality of the entire Delaware River Basin (The Nature Conservancy 2011). Managing the riparian resources afforded by this area is consequently of great importance.


**Figure 1**. Map showing the location of UPDE in Pennsylvania and New York. Source: data from the National Park Service (UPDE river corridor) and Natural Earth (reference features).

UPDE's boundary, also known as the river corridor[1], encompasses 55,574.5 acres of land and water starting at the confluence of the East and West branches of the Delaware River, and stretches

[1] The terms "boundary" and "river corridor" are used interchangeably to refer to the UPDE's area of authority.

south for 73.4 miles (Fig. 1). This river corridor, extending approximately ¼ mile from either side of the river, was established to meet the resource protection requirements of the Wild and Scenic Rivers Act, though most of the land within it is privately-owned. The river corridor intersects five counties – Delaware, Sullivan, and Orange in NY, and Wayne and Pike in PA – and 15 municipalities, called towns in NY and townships in PA (Fig. 2).

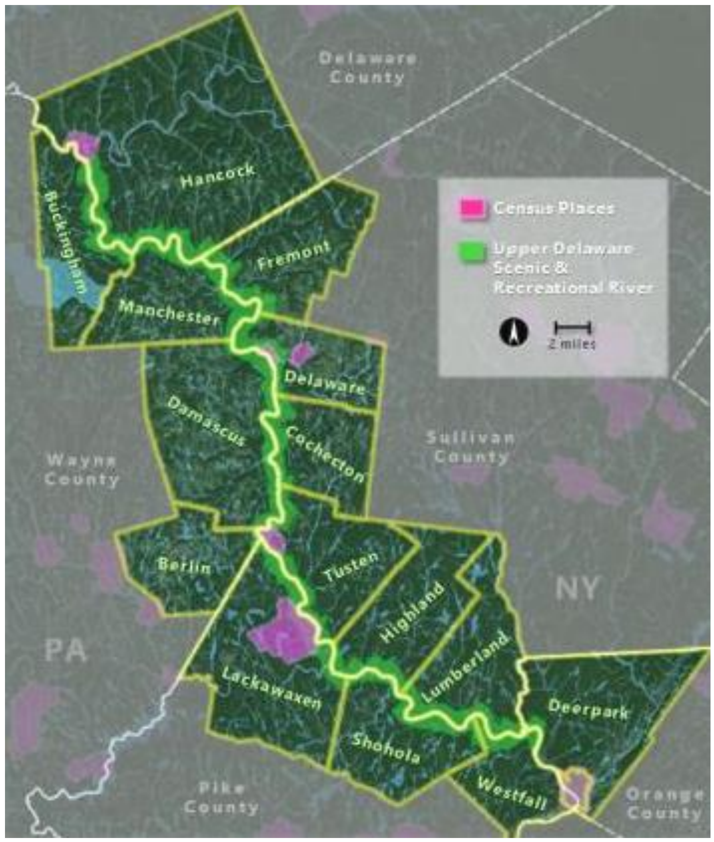


**Figure 2**. Map showing the counties and towns/townships that intersect the river corridor. Source: data from the National Park Service (UPDE river corridor), the US Census Bureau (administrative boundaries), the USGS (hydrology features) and the USDA (NAIP Imagery).

Natural resources within UPDE's boundary are managed in accordance with a River Management Plan, written and adopted in 1986 (Conference of Upper Delaware Townships 1986). UPDE is not an official Partnership River, but instead is considered a "hybrid" park, because while the National Park Service operates in partnership with communities, it still has management authority over the area (C. Hauser Hahn, UPDE Management Assistant, personal communication, 15-Sept-2015). Nonetheless, UPDE shares many characteristics with Partnership Rivers, especially regarding land ownership and collaborative management.

As stipulated by the River Management Plan, federal land ownership in UPDE's boundary is limited to 124 acres or ~0.2% of the total area in the river corridor, and land must be acquired from a willing seller (Conference of Upper Delaware Townships 1986). The National Park Service currently owns only about 30 acres within the river corridor and, like Partnership Rivers, collaborates with adjacent communities to manage the land and water resources. The main management partners are the National Park Service, a non-profit management council group called the Upper Delaware Council (under agreement with the National Park Service), members of state government from Pennsylvania and New York, and representatives of local governments from the 15 towns/townships that intersect the river corridor (Fig. 2).

### 1.D. Goals and Objectives

The primary goal of this project is to create a GIS for the Upper Delaware Scenic and Recreational River that will aid in natural resource stewardship activities in the region. A secondary goal is to use the knowledge gained from this process to generate a framework for incorporating GIS into the routine management of Partnership Wild and Scenic Rivers. These goals will be realized by meeting the following three objectives:

*Objective 1:* Perform a needs assessment to identify the information products, data, system functionality, and accessibility requirements of UPDE's GIS.

*Objective 2:* Based on outcomes of the needs assessment, develop a GIS for UPDE that will serve as an effective and efficient decision support tool for natural resource management.

*Objective 3:* Use the knowledge gained from carrying out the first two objectives to devise a framework that other Partnership Rivers could use to guide their adoption of GIS.

## 2. Methods

Design and development of UPDE's GIS and the riparian GIS framework was carried out through three main steps corresponding to the project objectives: Needs Assessment, System Development, and Review and Generalization.

## 2.A. Needs Assessment

A needs assessment was conducted to identify specific requirements of the GIS to be developed for UPDE. This was accomplished primarily through in-person, email and telephone interviews, along with small focus group discussions with key stakeholders from UPDE and their partner organization, the Upper Delaware Council. A "technology seminar" presentation was also given to members and representatives of the Upper Delaware Council to showcase a prototype of the GIS and elicit additional feedback. A summary of key people involved in the needs assessment is given in table 1.

**Table 1**. Stakeholders involved in the needs assessment process.

| Name | Position/Role | Organization | Survey method(s) |
|---|---|---|---|
| K. Heister | Superintendent | National Park Service, UPDE | Interview, Focus Group |
| D. Hamilton | Resource Manager | National Park Service, UPDE | Interview, Focus Group |
| J. Myers | Biologist/GIS Lead | National Park Service, UPDE | Interview, Focus Group |
| C. Hauser-Hahn | Management Assistant | National Park Service, UPDE | Interview, Focus Group |
| L. Ramie | Executive Director | Upper Delaware Council | Focus Group |
| T. O'Dell | Resource Specialist | Upper Delaware Council | Interview, Focus Group |
| C. Odell | Secretary | Upper Delaware Council | Focus Group |
| Various | Representatives | Upper Delaware Council | Technology Seminar |

Additionally, further insights into system needs were gained from a comprehensive review of UPDE's 1986 River Management Plan, the guiding document for managing land and water resources in the river corridor. This helped ensure that the system aligned well with the "business needs" of UPDE.

The six questions listed below were targeted throughout the needs assessment process. These topics closely mirror major system components that Tomlinson (2007) asserts should be considered in the GIS planning process. These are "information products, data, software, hardware, procedures, and people" (ibid p. 4).

1. *How can GIS improve riparian resource management activities at UPDE?*
2. *Who needs to use the GIS, and what is the best method for accessing it?*
3. *What information products need to be generated by the GIS?*
4. *What data are needed to generate the information products?*
5. *What is the preferred workflow for generating the information products?*

6. *What hardware/software is needed for the system?*

## 2.B. System Development

Insights gained from the needs assessment were used to guide system development for UPDE's GIS. An iterative design-develop-review process was used throughout with the aim of optimizing the system for the users' needs. In this way, the assessment and development processes were not entirely sequential, and instead worked in a cyclic fashion. For instance, initial insights from interviews and focus groups were used to create a working prototype of the GIS, which was in turn demonstrated to potential users. Feedback received during the presentation was then incorporated into the design in a new iteration of the GIS.

This method is loosely reminiscent of the Agile software development process in that it seeks to make enhancements incrementally in response to change and feedback (Cohen et al. 2003). An agile approach to GIS development has been used and documented by a variety of organizations, including a group that created a spatial decision support system for planning marine protected areas in California (Merrifield et al. 2013). At the time of this writing, iterative development of UPDE's GIS is ongoing.

## 2.C. Review and Generalization

The third project objective was met by reviewing and generalizing knowledge gained from the needs assessment and system development stages. The result of this step is a framework that can be used by other organizations to adopt GIS for the routine management of riparian resources. The main audience of this framework is Partnership Wild and Scenic Rivers; however, the lessons learned could be applied by any number of organizations focused on riparian resource management. The following aims were identified for the framework:

- The framework should be process oriented so that it can act as a practical guide for groups interested in adopting GIS.
- The framework should be thorough but accessible for groups with little to no GIS design experience.
- The framework should be instructive without being prescriptive so that it can be adapted to different geographies and resource management needs.

# 3. Results

## 3.A. Summary of Needs

Knowledge gained from the needs assessment is explained below in the form of answers to the six questions posed in section 2.B.

*1. How can GIS improve riparian resource management activities at UPDE?*

UPDE is a “hybrid” Wild and Scenic River, meaning that the National Park Service has management authority over the river corridor and its resources, but is expected to exercise its duties in collaboration with surrounding communities. Further complicating this situation is the fact that the vast majority of the river corridor is privately owned, and ownership by the National Park Service is limited to only ~0.2% of the corridor’s total area. How then does the National Park Service carry out its stewardship duties, and can the current process be enhanced by the use of GIS?

The 1986 River Management Plan articulates a set of Land and Water Use guidelines that “seek to protect water quality, preserve natural features, provide for recreational uses, provide for the continuation of agriculture, conserve river resources, and maintain existing land use patterns” (Conference of Upper Delaware Townships 1986, p. vii). As stipulated by the Plan, the National Park Service and Upper Delaware Council are responsible for reviewing and making decisions about proposed land use change or development projects within the river corridor in a process called project review. According to individuals surveyed during the needs assessment, this is a crucial activity for promoting stewardship of land and water resources in the river corridor

During the project review process, resource managers gather information about the conditions at the project location, and evaluate whether the proposed project follows UPDE’s Land and Water Use guidelines. They then use this information to guide progression of the project so as to ensure “substantial conformance” with the plan’s guidelines, and thereby promote stewardship of the region. Another responsibility of the National Park Service under the River Management Plan is to provide “technical assistance” to local governments to aid in their compliance with the Plan’s guidelines (Conference of Upper Delaware Townships 1986).

Currently, resource managers carry out the project review process roughly as follows (Fig. 3):

A. Receive project proposal, or learn about proposed project through various means (e.g. newspaper announcement).
B. Find the location of interest on a map of the region to determine if it is in the river corridor, and ascertain its administrative setting (i.e. state, county, and town/township).
C. Inspect zoning maps to identify land use and zoning regulations for that location, and evaluate project compliance with these.
D. Determine if the project adheres to Land and Water Use guidelines of the River Management Plan.
E. Examine other maps to identify nearby significant riparian assets or ecologically sensitive areas.
F. Guide progression of the proposed project in a manner that promotes responsible resource stewardship and "substantial conformance" to land and water use guidelines.


**Figure 3**. Photographs illustrating how UPDE resource managers currently carry out the project review process (C. Hauser-Hahn, UPDE Management Assistant shown). Source: photos by the author.

This method requires managers to perform a mental overlay of location information from a variety of printed/digital maps akin to the digital layering enabled by a GIS. Since individual managers likely have different perceptions of a mental overlay, this process is inefficient at best, and subjective or inaccurate at worst. One of the major conclusions drawn from the needs assessment is that UPDE's project review process could be significantly enhanced by the use of a GIS that includes up-to-date and accurate land use, zoning, and resource distribution data. Therefore, a vision for UPDE's GIS was articulated as follows: the GIS will be an effective and efficient spatial decision support tool for project review.

*2. Who needs to use the GIS, and what is the preferred method for accessing it?*

Based on information gathered during the needs assessment, UPDE's GIS will need to be employed by four user groups representing the main management partners involved in the project review process. These groups are summarized in Table 2.

**Table 2**. Users who will need to access UPDE's project review GIS.

| Group | Level of GIS experience | Expected number of users |
|---|---|---|
| Staff of the National Park Service | Novice to Experienced | 5 regular users |
| Staff of the Upper Delaware Council | Novice to Intermediate | 1 regular user<br>1 occasional user |
| Members of local government from Upper Delaware Counties | Intermediate | 5 occasional users (county planning boards) |
| Members of local government from Upper Delaware Towns & Townships | Novice | 15 regular users (code enforcement officers)<br>15 occasional users (townships supervisors) |

Several key considerations related to accessibility also emerged from the needs assessment. First, the four user groups need to be able to access the system from different computers and offices, which do not all sit on the same side of the National Park Service's network firewall. Users should also be able to use the system synchronously or asynchronously from these different locations, and the system should be accessible from mobile devices (i.e. smart phones and tablets) to permit review and monitoring in the field. Finally, certain data layers containing sensitive information need to be secured for access only by approved users. Together, these requirements indicate that UPDE's project review GIS should be web-based and should include basic security controls for some data layers.

*3. What information products need to be generated by the GIS?*

The key information to be derived from UPDE's project review GIS is visual evaluation of current conditions at and around project review sites. These information needs are illustrated in Figure 4, and explained further below.

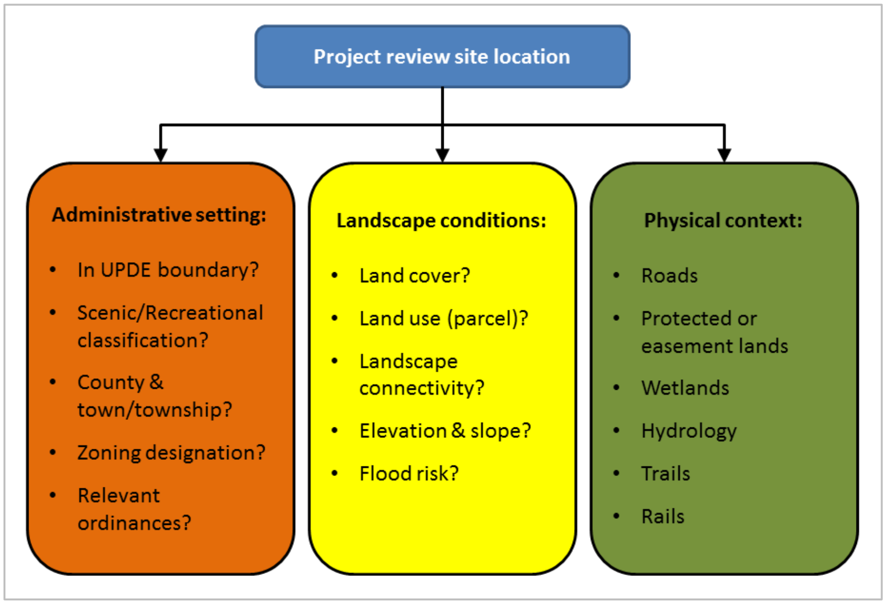


**Figure 4**. Schematic diagram of the key information needed from UPDE's project review GIS. Source: diagram by the author.

The first piece of information needed from the system is the location of a project review site. Given the importance of identifying the correct location for review, these sites need to be identified unequivocally. The next information products needed from the system are the landscape conditions at project review sites. These information products can be grouped into three main categories – Administrative setting, Landscape conditions, and Physical context – and are defined by the project review process, requirements of the 1986 River Management Plan, and interests of UPDE's resource managers.

As outlined above, resource managers need to gather information about the administrative setting of the proposed project, including its whereabouts relative to the river corridor, whether it is in a scenic or recreational section of the river corridor, and the state, county, and town/township it is in. The project review process also requires managers to obtain information about any zoning and land use regulations that exist for the site in question.

Many of the Plan's Land and Water Use guidelines stipulate information requirements about landscape conditions and physical context that would be made more tangible by mapping in a GIS. These include terrain slope, land cover, parcel demarcations, locations of floodplains, and locations of hydrology features, among others. An example regulation from the River Management Plan pertaining to terrain slopes is shown in Fig. 5.

Principle A

*Maintain the high water quality found in the Upper Delaware River*

**Objective 1:** Limit soil erosion and sedimentation from construction on steep slopes, using one or more of the following measures:

- A requirement for conditional use/special use review or a Professional Engineers plan for projects involving slopes over 15% in grade, or including a requirement for larger lot sizes on steep slopes)

- Requiring slopes of less than 16% in grade for the location of all principal structures with exception for agricultural and forestry uses, gardens and the like

**Figure 5**. Example of a Land Use guideline that has a spatial information component: terrain slope. Source: screenshot from the 1986 River Management Plan.

Finally, resource managers identified additional information requirements in each of the three categories that are occasionally needed during project review. These include the locations and extents of wetlands, public lands, conservation easements, roads, trails, rails, and natural gas pipelines. UPDE's resource managers have also indicated interest in using the system to track information about significant and/or sensitive ecological attributes in the river corridor and surrounding region (e.g. bald eagle nests, eel weirs, watershed characteristics, landscape connectivity, etc.). However, as of this writing, these information products have not been provided for and are instead part of the future directions for the system.

*4. What data are needed to generate the information products?*

The next step of the needs assessment involved identifying appropriate datasets for generating the required information products. Several key issues were taken into consideration when identifying the best data sources, including: data timeliness, spatial accuracy/precision, scale, and generally accepted authoritative versions. Table 3 shows the major data items identified for the system to date, along with the corresponding information products they will provide and current sources used. A more detailed treatment of some data issues is given in the following section.

**Table 3**. Summary of data needs for UPDE's project review GIS.

| Information of interest | Required data | Data source |
|---|---|---|
| Street address? (for precisely locating sites) | 911 point shapefiles | Upper Delaware counties and towns/townships |
| In UPDE boundary? | UPDE boundary shapefile | National Park Service |
| Scenic/recreational classification? | Scenic and recreational segments shapefile | National Park Service |
| County & town/township? | County & county subdivisions shapefiles | U.S. Census Bureau |
| Zoning designation? | Zoning maps/shapefiles | Upper Delaware counties and towns/townships |
| Relevant ordinances? | Zoning codes and ordinances | Upper Delaware counties and towns/townships |
| Vegetation land cover? | Vegetation map shapefile | National Park Service |
| Other land cover? | Discrete land cover rasters | USGS National Land Cover Dataset |
| Land use (parcel)? | Tax parcel shapefiles | Upper Delaware counties and townships |
| Elevation and slope? | Slope raster derived from DEM | USGS National Elevation Dataset |
| Flood risk? | Flood insurance rate maps and shapefiles | FEMA |
| Proximate roads and rails? | TIGER/Line® road and rail shapefiles | U.S. Census Bureau |
| Proximate public lands? | Protected Areas Data shapefile | USGS National Gap Analysis Program |
| Proximate wetlands? | National Wetland Inventory shapefile | US Fish and Wildlife Service |
| Proximate hydrology? | National Hydrography Dataset shapefiles | USGS |
| Landscape context? | Satellite images/aerial photos/topographic base maps | Esri |

*5. What is the preferred workflow for generating the information products?*

Recognizing the preferred workflow for information product generation is important when designing system functionality. Thus, the next step of the needs assessment involved understanding how the users would like to apply the system for generating the information of interest. The key workflow issue identified for the system was precisely mapping the project review sites based on a variety of geographic descriptors. Four processes for accomplishing this were identified and are illustrated in Fig. 6.

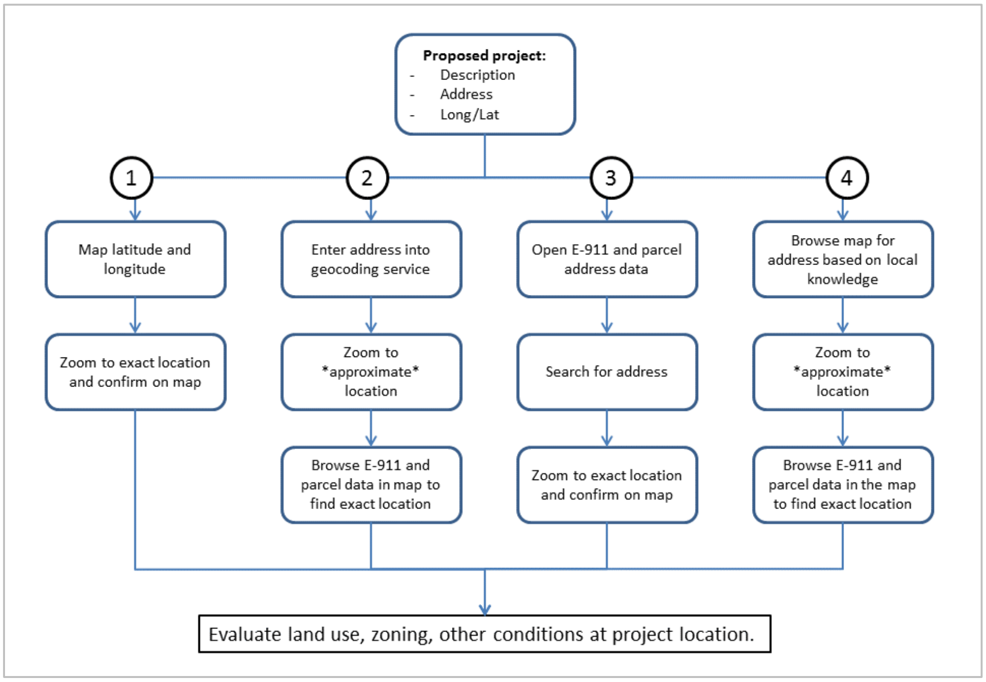


**Figure 6**. Schematic diagram of workflows for mapping project review sites. Source: diagram by the author.

Resource managers may receive location information in the form of a street address or cross-roads, tax parcel identification number, geographic coordinates, or some other combination of geographic descriptors. Thus, it is important that the system has a robust and flexible method for forward geocoding. Given that address geocoding can be error prone in rural areas like the Upper Delaware region, it is also important that the system includes official county address data for built structures and that these data be readily queried and identified on the interactive map. After finding the location, users will then access the system data layers and evaluate the administrative setting, landscape conditions and physical context of the site.

*6. What hardware/software is needed for the system?*

All of the preceding steps of the needs assessment helped define the appropriate hardware and software requirements of the system. Two other important considerations are explained here, the first relating to accessibility and the second to functionality.

As mentioned above, we concluded that UPDE’s project review GIS should be web-based for synchronous or asynchronous access by the four user groups. Thus, the system needed to use software and hardware that would allow data to be served and retrieved over the web. UPDE does not have server hardware that can be used to serve data or applications outside their firewall, and not all users will access the system from inside the Park Service's network. Another issue confounding this is that as a part of the federal government, the National Park Service is restricted to using "approved software" in their operations, including GIS software (D. Warren, GIS Specialist, National Information Services Center, personal communication, Feb-2015). Rather than conducting an independent investigation of approved GIS software, we sought the advice of National Park Service GIS personnel from the National Information Services Center as to an appropriate platform for UPDE's project review GIS.

The other hardware/software consideration that deserves attention concerns system functionality. The following functionalities were identified as important for facilitating use and upkeep of UPDE's project review GIS:

- Users should be able to map geographic coordinates, or to input a street address or cross-roads and map the approximate location using a geocoding service. Only one address would need to be mapped at a time (no batch geocoding required). The results would need to be immediately visible on the map, but then could be discarded (adding a point to represent a project review site could happen as a separate manual editing action).
- Users should be able to control data visibility, turning layers on and off at will. These should be organized in a map legend and layer list in a clear and logical way.
- Users should be able to measure the length and/or area of a feature by successively clicking on two or more locations in the map. This should use a straightforward interface, and users should be able to change the units of measurement.
- Users should be able to identify features via a simple mouse click in the map and have select attributes made visible in a pop-up window.
- Users should be able to toggle between a satellite image and topographic base map. These base maps should be as up-to-date as possible.
- Users should be able to filter or query layer attributes using a simple interface. For example, a global search function would be an acceptable solution, whereas an SQL interface would not.
- Users should be able to export and print the current map view, including a map legend, and scale information.
- UPDE personnel should be able to easily maintain the system and its component data.

Synthesizing these functionality requirements along with the "approved software" recommendations of National Park Service GIS personnel, we decided on ArcGIS Online as the preferred platform for UPDE's system. As explained further below, this allowed us to create a custom webmap of the desired data and then consume this webmap in an application tailored for use by UPDE resource managers and their partners.

ArcGIS Online is a Software as a Service (SaaS) platform that provides users with tools to create webmaps, manage and host services, develop applications, and more, all from the cloud (Esri n.d.). This presents several advantages for UPDE personnel who will maintain the system. First, it is a viable low-cost solution since it is considered "approved software" and the National Park Service already has an organizational account that UPDE can use. Second, since ArcGIS Online is a cloud-based platform, UPDE personnel will largely avoid the burden of maintaining the application or data on a public server or server instance (exceptions to this are explained below in section 3.B.). Finally, ArcGIS Online is designed to be easy to use, meaning that webmaps and applications can be developed with zero to minimal coding, an important feature for long-term maintenance of the system by UPDE personnel.

## 3.B. System Description

The main result of this project is a webmapping application designed to facilitate the project review process used at UPDE to guide natural resource management decisions. As explained above, development of this application is still ongoing; however, a working prototype has been designed to address the needs identified thus far. This prototype will serve as a solid foundation on which to complete the final system. The prototype is described in detail below focusing on the three major parts of the system – the data, webmap, and application – and then is demonstrated in a hypothetical project review scenario.

*1. Data*

The process of obtaining and preparing appropriate data (Table 3) for UPDE's GIS was fairly straightforward; however, several important data issues emerged that deserve further attention. The first pertained to digital zoning data accuracy and timeliness, and the communication obstacles that sometimes exist between county and town/township governments.

While carrying out this project, we found that oftentimes town/township personnel did not possess digital zoning data for their jurisdiction, and sometimes were unfamiliar with terms like "GIS," "shapefile," or "digital data". However, towns/townships possess the official versions of their zoning maps, often in print form only, or in the form of a pdf derived from a scanned print map. On the other hand, while counties typically had shapefiles representing town/township zoning data, sometimes they did not, and other times their data were out of date or inconsistent with the official maps on record with the towns/townships. In several cases this appeared to be due to zoning maps having been created or modified by outside contractors, and the towns/townships having not passed these along to the counties. Failures of communication were also observed in the reverse direction. To illustrate, some counties had changed zoning data by town/township decree, but had not delivered new maps for official record keeping purposes at the local level.

Given these obstacles, considerable time was spent identifying and performing quality assurance/quality control checks of digital zoning data for UPDE towns/townships. To date, significant issues are still outstanding with the zoning data – particularly in the representation of overlay districts – and thus some zoning data has been omitted from the prototype system until the problems can be resolved.

The second data issue that requires further attention pertains to the parcel and address data supplied by the counties, and privacy considerations surrounding personal information. County assessor's offices collect and use spatial and attribute data on legal land parcels in their jurisdiction as part of their standard operations. These data are part of public record and are published in tax maps and assessor's rolls. Attributes stored with parcel spatial data often include owner names, mailing addresses, and assessed values, among other things. Counties also routinely maintain spatial data and associated physical address attribute data for homes and buildings in their jurisdiction for use with Enhanced-911 systems. As explained above, both parcel data and address point data are needed in UPDE's project review GIS.

As a unit of the federal government, the National Park Service must follow stringent Privacy Act guidelines when handling and presenting personally identifiable information (PII), defined as "information which can be used to distinguish or trace an individual's identity …" (U.S. General Services Administration n.d.). Examples of PII include individual's names and social security numbers, among other things (ibid). Parcel data contain property owner names, and when these are overlaid with address point data, it is straightforward to infer the physical address of a particular property owner. Given all of this, there have been concerns raised as to whether or not these data and information products constitute PII and thus must be handled as such. This is the case despite the fact that the data are already publically available on county websites because the National Park Service would be republishing the data as part of their own information system.

While this PII issue has not yet been resolved, a few avenues of progression are being undertaken by UPDE personnel. The first is to determine whether the data are indeed PII by consulting with information security personnel in the federal government and assessing the precedence of this situation (i.e., searching for similar existing projects). If the data are deemed to be PII, one potential solution is to strip them of the offending attributes before incorporating them into the webmapping application. In addition, we are exploring password protecting relevant data, or instating general security controls so that only approved users may access the system.

The final major data issue that merits review relates to UPDE's boundary and the quality of existing spatial data representing the river corridor. The official version of the river corridor is that which is printed in the 1986 River Management Plan. There are eight pages of maps in the Plan, each corresponding to a section of the river corridor drawn on USGS topographic maps from the 1960-1970s. Most of the maps have areas of overlap such that the river corridor has been drawn more than once on subsequent maps. These maps were made prior to the arrival of any of UPDE's current personnel, and little information exists about how they were created. However, they appear to have been made by manually splicing and photocopying USGS maps onto transparent film. The boundary seems to have been hand-drawn on these using the guidelines put forth by the River Management Plan (Conference of Upper Delaware Townships 1986, p. 59-61). As explained in the Plan, the river corridor "is a topographic and hydrologic boundary line which includes all of those resources which most directly relate to the river itself" (p. 60).

Prior to starting this project, the official GIS dataset representing the river corridor was created in 2006 to meet a particular need that did not require a high degree of spatial accuracy or precision. Given that the people accessing UPDE's project review GIS must to be able to reliably evaluate the location of a project review site relative to the boundary, the decision was made to create a new vector dataset for the river corridor using the georeferenced topographic maps as sources. The goal of this endeavor was to ensure the highest degree of spatial accuracy possible in the boundary dataset, and to meet standards of the Federal Geographic Data Committee (FGDC).

Our plan for creating a new vector dataset of UPDE's boundary (described below) was approved on March 17, 2015 by the Chief of the National Park Service Lands Resources Office, who is responsible for assuring accuracy of official boundary datasets shared nationwide. First we identified source data for the spliced base maps in the River Management Plan by inspecting all 1:24,000 quadrangle maps of the Upper Delaware River region published by the USGS between 1965 and 1985 (as found in Historic Topographic Map Collection). Second, we georeferenced and rectified the spliced base maps to their sources using over 100 control points per section and an adjust transformation to minimize local and global alignment errors.

As mentioned previously, sections of the eight River Management Plan's maps have areas of overlap on successive pages. Numerous minor discrepancies and two major discrepancies were observed in the location of the drawn boundary in these areas of overlap. One of the major discrepancies has been previously observed and settled as an erratum in the River Management Plan (Conference of Upper Delaware Townships 1986, Errata). The other area of major inconsistency – in Lackawaxen Township – had not been previously addressed, and resolving the issue required meetings between administrators with the National Park Service, the Upper Delaware Council, and Lackawaxen Township. Ultimately, the township passed a resolution accepting one particular version of the boundary (as displayed on page 5 of the Plan). Areas of overlap with minor discrepancies were addressed by myself and National Park Service personnel in a way that sought to adhere to the intentions of the plan (i.e. smooth lines and transitions between pages rather than jagged edges or large "jumps" in the boundary's trajectory). These were documented in detail, approved by the UPDE Superintendent, and can be found in the new dataset's FGDC compliant metadata.

Finally, the boundary was digitized based on the georeferenced maps using standard best practices for heads-up digitizing. As directed by UPDE's Superintendent, K. Heister, the outside of the drawn line was followed during digitization to err on the side of resource protection. This new vector dataset has been approved by the National Park Service's Chief Cartographer, R. Johnson, and was published in the Integrated Resource Management Applications Portal on January 7, 2016 as the new official GIS dataset of UPDE's boundary (National Park Service n.d.[b]).

*2. Webmap*

After identifying and assembling the data (Table 3), it was necessary to then arrange the layers in a custom webmap. This is the key precursor step to application development in ArcGIS Online. As explained by Esri, "a web map is a configuration file that stores map definition (e.g., layers, visibility, and extent) and behaviors (e.g., pop-up windows)" and is considered an integral component of the ArcGIS platform. Users with an ArcGIS Online organizational account can create webmaps directly in their web browser, and control their sharing (i.e. keep private, make available to other organization users, or release to the public).

A webmap was created to serve as the base for UPDE's webmapping application (Fig. 7). Data included in the map are listed in Table 3 above. When possible, these data layers were coded to draw from existing web services to minimize the need for re-serving data and to ensure that authoritative data sources were used (i.e. the USGS National Hydrography Dataset for hydrology features). This can help facilitate timely updates of data layers when changes are made by the serving agency, thus easing some of the maintenance burden. However, it also means that little can be done to fix issues in the webmap when service outages or other problems arise from originating agencies. Regardless, we felt that the advantages outweighed the potential risks, and chose to use preexisting web services when possible.

Some required data – such as municipal zoning, parcels, address points, and derived slope – were not available as preexisting web services, and thus new web feature services had to be created for these layers. To date, these services have been handled by National Park Service GIS personnel at the National Information Services Center, and are being hosted on their public server. Some of the services use cache tiling as the data contains large numbers of features. For the future, we are exploring creating hosted web layers of the data to be served directly from ArcGIS Online. This may help performance of some of the services in the webmap, and would also simplify the workflow from data to published service by eliminating the need to go through a second party.

The look and feel of the webmap was tailored to the needs identified throughout the first part of this project (Fig. 7). For example, some of the key considerations included:

- Setting appropriate <u>scale-dependent visibility</u> for the data based on their intended uses in the webmap and their collection scale.
- <u>Organizing layers</u> hierarchically so that they draw in a logical order and so that users will have ready access to visibility controls for layers that are expected to be used frequently.
- Using <u>feature symbologies</u> that are consistent, easy to understand, and follow accepted norms – i.e. standards for land use and land cover layers.
- <u>Labeling features</u> judiciously and unambiguously to prevent information overload.
- Configuring <u>pop-up windows</u> so that pertinent attributes are easy to access and understand.

- Choosing a default basemap that will meet user needs in the majority of cases.

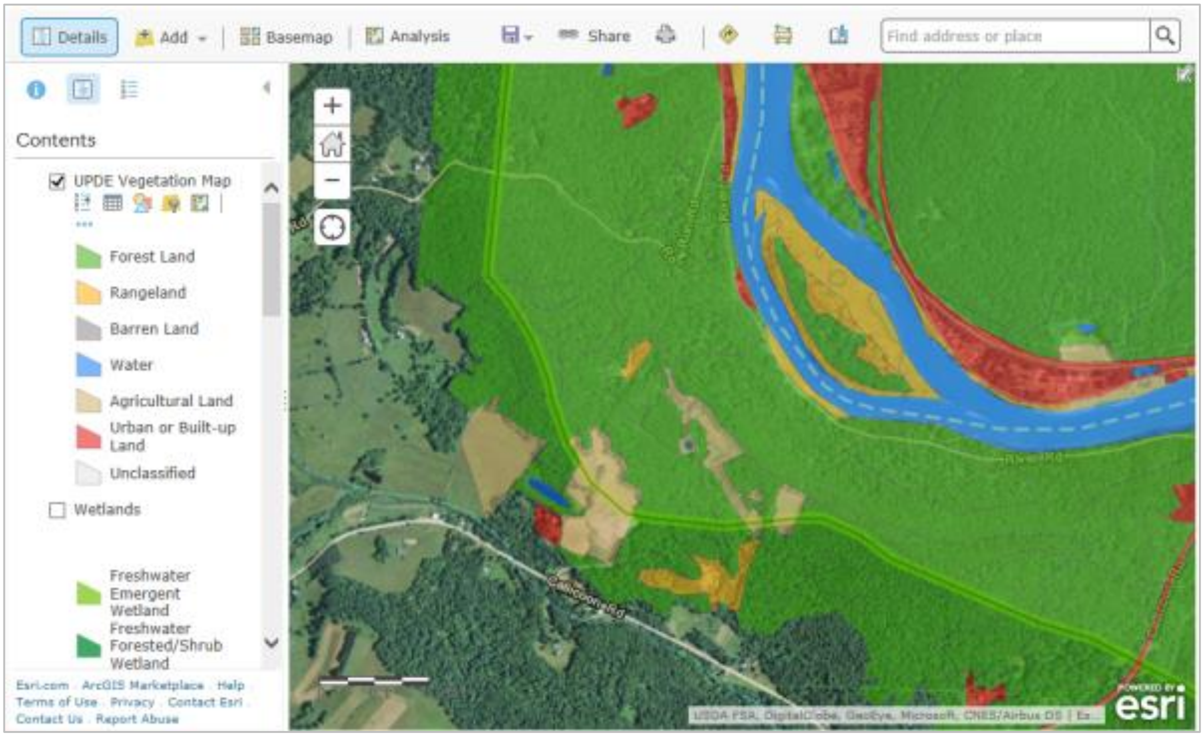


**Figure 7**. Webmap created in ArcGIS Online for UPDE's project review GIS. Source: screenshot from ArcGIS Online.

### *3. Application*

UPDE's project review GIS is a webmapping application built using Web AppBuilder for ArcGIS. This program allows ArcGIS Online users to create custom webmapping applications using preexisting themes and widgets. Themes are ready made but adjustable templates that define the overall appearance of the application. Esri (2015) explains that "contents in a theme include a collection of panels, styles, and layouts, and a set of preconfigured theme widgets." The "tab" theme was selected for UPDE's application because it is versatile (it can incorporate any widget) and robust (it is suitable for more complex workflows) (ibid).

Widgets are small "out-of-the-box" tools that "provide fundamental functions to easily create web apps" (Esri 2015). Mixing and matching existing widgets in a webmapping application is a relatively easy and straightforward way to build in desired functionality. Widgets were selected for UPDE's system so as to meet the system requirements described throughout the needs assessment section above.

These, and other important features of the application, are labeled in the screenshot shown in Fig. 8, and are outlined in Table 4 below.

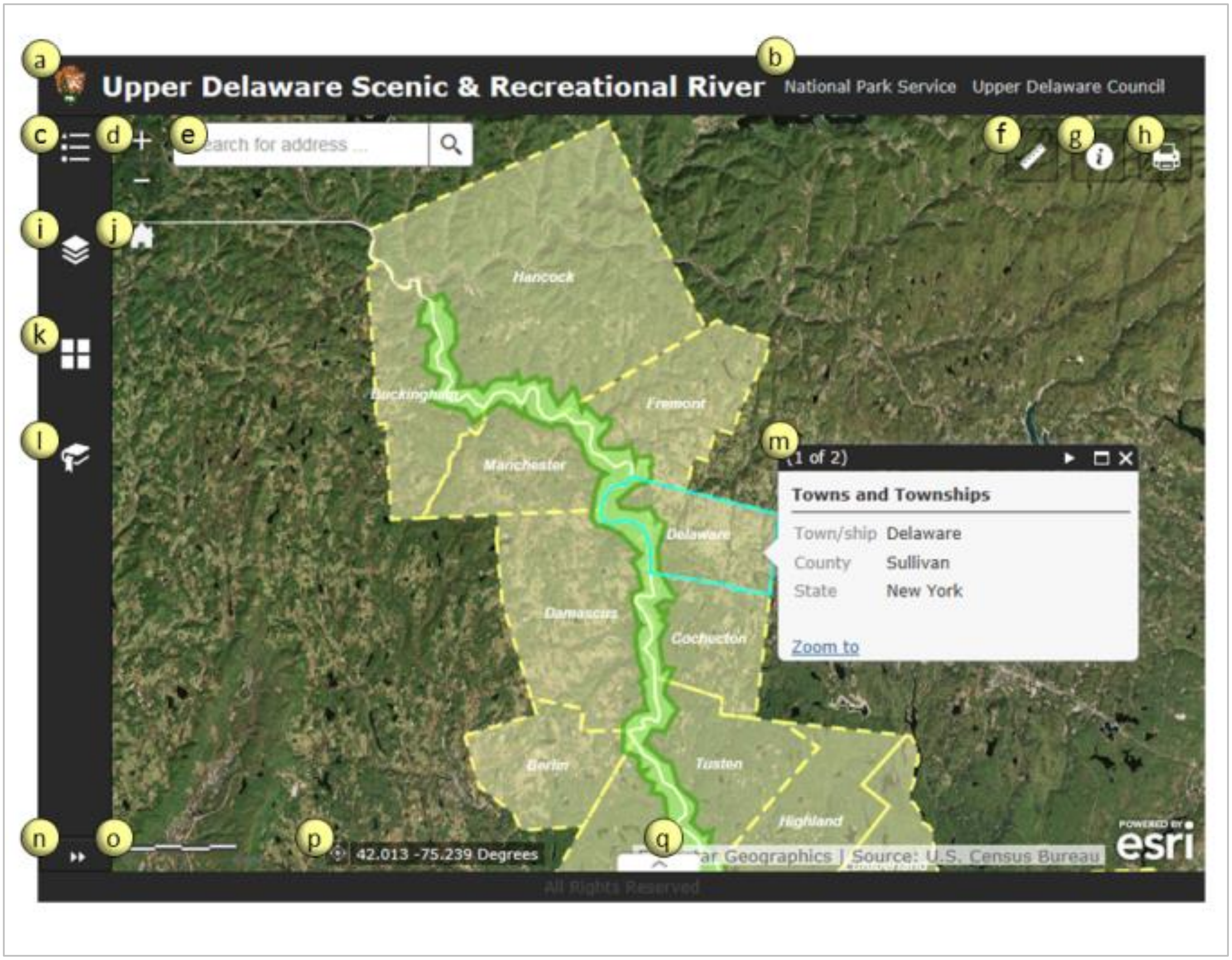


**Figure 8**. Overview of the webmapping application created in ArcGIS Online for UPDE's project review GIS. Letter annotations point out key application features as outlined in Table 4. Source: screenshot from ArcGIS Online.

**Table 4**. Key features of UPDE's project review webmapping application (see Fig. 8).

| Widget or Application Feature | | Short Description |
|---|---|---|
| a | **Application title** | Title of the webmapping application. |
| b | **Website links** | Links to UPDE (National Park Service) & Upper Delaware Council websites. |
| c | **Legend widget** | Opens the legend for items currently visible in the map. |
| d | **Zoom Slider widget** | Controls scale of the displayed map (zoom in & out). |
| e | **Search widget** | Allows users to perform simple geocoding operations or to search map content. |
| f | **Measurement widget** | Allows users to measure lengths or areas in the map using successive mouse clicks. Users may also choose from a list of available units. |
| g | **About widget** | Provides information about the application, its content and appropriate use. |
| h | **Print widget** | Allows the users to create a printable file from the map view. Users can control the print resolution, dimensions, and file format. |
| i | **Layer List widget** | Enables users to control the visibility of data layers (turn layers on or off) and their transparency in the application. |
| j | **Home Button widget** | Brings the map view back to the original default extent. For UPDE's application this is the entire river corridor and town/township extents. |
| k | **Basemap Gallery widget** | Provides users with a selection of basemaps for the application. For UPDE's system, this includes satellite imagery (default), and several topographic maps. |
| l | **Bookmark widget** | Stores and allows users to select from a number of predefined map views. Bookmarks for UPDE's system focus on the town/township extents. |
| m | **Feature ID window** | A single mouse click in the map window activates a feature identification popup window. Users can toggle through a list of identified features. |
| n | **Sidebar visibility control** | Allows users to collapse and expand the sidebar window (where the legend, layer list, basemap gallery, and bookmark widgets are displayed when active). |
| o | **Scale bar** | A map scale bar that automatically adjusts based on zoom level. |
| p | **Coordinate widget** | Displays geographic coordinates (longitude & latitude) for the location over which the user's mouse pointer is hovering. |
| q | **Attribute Table widget** | Provides users with access to select layer attribute tables. Users can filter results, control column visibility, export results to a table, and zoom to selected features. |

Source: Descriptions based on information in Esri (2015).

*4. Hypothetical scenario*

As explained above, the overall vision for UPDE's GIS is that the system will be an effective and efficient spatial decision support tool for project review. To demonstrate how the system may be used by resource managers, a hypothetical scenario was invented. This scenario, which was presented in the technology seminar described in section 2.A., uses National Park Service property as an example.

*Scenario*: The National Park Service proposes building a 5,000 square foot paved parking lot on their property at 1152 River Road in Milanville, PA. Resource managers reviewing the proposal must answer the following questions at the outset of the project:

- Is the property in the river corridor?
- If so, what section of the river classification does it fall in – scenic or recreational?
- What township and county does the property fall in?
- What is the zoning designation at this location?
- Is the property in or near a flood hazard area?
- What is the approximate terrain slope on the property?
- What types of land cover are present at the site?
- How big is the parcel and how much of it is already covered in impervious surfaces?

The first step a user would undergo to start answering these questions would be to find the property in question in the webmapping application. All four of the workflows shown in Fig. 6 are supported by the application, but we will consider approach two for illustration purposes. The user would type the address in the search widget, click to zoom to the identified site, and then confirm that the correct location was found by inspecting the address point and parcel data. After locating the site in question, users would then proceed by identifying features in the map (i.e. county, township, river corridor classification), panning and zooming the map to understand the context of the location, turning select data layers on and off to retrieve additional attributes, and performing in-map measurements using the measure tool. The user could then save (and print) views of the webmap for record keeping purposes. Fig. 9 shows a screen shot of the application being used to address this scenario.


**Figure 9**. Image showing how the GIS could be used in a hypothetical project review scenario. Parcel, address, and a derived slope layer are drawn over the satellite basemap. Source: screenshot from ArcGIS Online.

Carrying out the above steps in the prototype system yielded the following information: The property is within the river corridor, approximately 850 feet east of its western border, and falls within an area of the corridor classified as recreational. The property is in Damascus Township in Wayne County, PA, and is in the Damascus River zoning District. Both 1% and 0.2% annual chance flood hazard areas pass through the property, and areas of restrictive slope (>15%) are present near the creek on the southern part of the property. Finally, the property is a mix of residential developed, floodplain forest, and river land covers; it is ~76,000 square feet in size, and is already covered by ~2,500 square feet of impervious surfaces (roof).

Answering these questions with UPDE's project review GIS took approximately 5 minutes of work. In contrast, getting this same preliminary information using the current project review workflow could have taken hours or more of investigation. As well, any other user could have gathered the same information without having to apply a great deal of subjective reasoning or inference. These observations point to increased efficiency and effectiveness in the project review process using the GIS. Still though, it is important to note that the information collected from the system cannot and should not serve as a substitute for a site specific survey or review. Instead, information provided by the GIS can paint an overall picture of conditions at the site, and can draw attention to important land use and landscape characteristics that need to be considered during the in-depth investigation. As such, the project review GIS is intended to operate as part of a larger decision support structure of resource management at UPDE, consistent with the recommendations of Goulter and Forrest (1987).

## 3.C. Framework Overview

The third and final objective of this project was to develop a framework that other Partnership Rivers could use to guide their adoption of GIS for routine resource management tasks with a geographic component, like project review at UPDE. We developed the framework by reviewing and generalizing the knowledge gained from the needs assessment and system development steps of this project. At its core, the framework is an application of standard GIS design principles to riparian resources and their managers. The framework is intended to serve as a practical process-oriented guide that can be adapted for different geographies and resource management needs by groups with little or no GIS experience.

Thus far, a basic outline of the framework has been devised and is given below, but we would ultimately like to flesh this out into a short (5-10 page) guidebook that could be distributed to Partnership Rivers interested in using GIS. The framework outline is organized into six actionable phases:

1. *Plan*

   First, resource managers research information needed from the system (i.e. investigate land and water use regulations that have a spatial component, identify management goals for the river and how these might integrate into the system). They then brainstorm and develop an overall vision for the system.

2. *Formulate*

   Based on the outcomes of the planning step, resource managers then identify the intended users, information projects, and required functionalities of the system, and they outline accessibility, security, cost capacity, and timetable considerations. They also take stock of the current GIS capabilities of their organization and identify internal or external budget and personnel resources that may be available.

3. *Prepare*

   After *Formulate*, resource managers then start preparing to build the system. They collect, process, and analyze data relevant to their management activities, and identify the target platform (software/hardware) that will meet the needs identified in the preceding steps. They also pinpoint additional system components (i.e. widgets, applications) that may be required.

4. *Build*

   Next, resource managers carry out an iterative Develop and Review process to create the system. This entails putting pieces together into a working prototype, testing the prototype and evaluating its design, and then ultimately going back to adjust or fine-tune the system. Users should be involved in the process and provide feedback that can help refine the design.

5. *Implement*

   After the system has been built, resource managers then put it into use. This may involve promoting the system to different user groups, creating user guides, and/or demonstrating the advantages of the system to encourage its adoption.

6. *Maintain*

   Finally, the resource managers need to maintain the system so that it stays up to date and relevant. This could require developing a maintenance plan, assigning upkeep responsibilities to different stakeholders, and/or scheduling periodic check-ins with users.

# 4. Discussion and Future Directions

UPDE's project review GIS and the GIS Framework are still works in progress. As mentioned above, there are several outstanding data issues that need to be resolved for the GIS (i.e. zoning overlays and the PII question surrounding parcels and addresses). Likewise, design of the prototype system still needs to be revisited in light of insights gained from the latest technology seminar that was held for Upper Delaware Council members.

UPDE resource managers have also expressed interest in extending the tool in a few other ways. First, they would like to incorporate higher resolution land cover data into the webmap as it becomes available through the Delaware River Basin land cover mapping project being carried out by C. Jantz and colleagues (Jantz et al. 2015). Second, there is interest in incorporating other datasets and workflows that would aid in tracking invasive species, identifying and protecting priority conservation areas, and monitoring significant ecological features like bald eagle nests in the river corridor. Finally, in the future, resource managers at UPDE would also like to be able to use the system to store and track project review data. This may entail creating an editable point feature class in the system which managers would use to map the locations of project review sites and store their associated attribute information.

Another important future direction for using GIS in resource management at UPDE is to investigate the relationships between land cover and land use regulations in the region, and then to apply these findings in collaborative management activities. Land use regulations are important tools for resource management, especially in regions where it is necessary to co-manage human activities and natural systems (e.g. see Hull et al. 2011). Furthermore, zoning has been shown to impact land use patterns, development, and deforestation in a variety of landscapes (Croissant 2004, and Munroe et al. 2005). This is particularly pertinent in the UPDE region given the development trends observed there over the past few decades (Goetz et al. 2011, Jantz and Morlock 2011). Indeed, several authors have collectively called for promotion of smart growth and conservation easement strategies in the region, and have pointed out the importance of collaborations between the National Park Service and local communities in accomplishing these recommendations (ibid).

There are also several steps that need to be carried out before the prototype system can move to a final state. These include teaching resource management partners how to use the system to their advantage, strengthening relationships among partners to promote data sharing, and planning for long-term maintenance of the system. Some strategies that could be used to accomplish these are creating a user handbook for the GIS, along with holding a workshop to introduce users to the system and motivate them to be active partners in handling zoning data updates. Finally, as mentioned above, there is interest in expanding the GIS framework for riparian resource management into a short guidebook that could be shared with Partnership Rivers. As part of this, UPDE's system and the design process used herein could be presented as a model for other rivers' systems.

While there is still much work to be done to realize the full potential of GIS at UPDE, this project represents a solid first step toward this goal. We succeeded in developing a prototype of an efficient and effective decision-support tool for project review, which will help facilitate the goal of the National Wild and Scenic Rivers system – preserving the river's special character while allowing for appropriate growth and development (National Wild and Scenic Rivers System n.d.) – and will help fulfill the National

Park Service's obligations under the River Management Plan (Conference of Upper Delaware Townships 1986).

# References

Baker, T. J., & Miller, S. N. (2013). Using the Soil and Water Assessment Tool (SWAT) to assess land use impact on water resources in an East African watershed. *Journal of hydrology*, *486*, 100-111.

Brierley, G., Fryirs, K., Outhet, D., & Massey, C. (2002). Application of the River Styles framework as a basis for river management in New South Wales, Australia. *Applied Geography*, *22*(1), 91-122.

Cohen, D., Lindvall, M., & Costa, P. (2003). Agile software development. *DACS SOAR Report*, (11).

Conference of Upper Delaware Townships (1986) Final River Management Plan, Upper Delaware Scenic and Recreational River. Retrieved on 10-Sept-2015 from http://www.upperdelawarecouncil.org/publications/upper_delaware_river_management_plan_1986_updated_2015/

Croissant, C. (2004). Landscape patterns and parcel boundaries: an analysis of composition and configuration of land use and land cover in south-central Indiana. *Agriculture, ecosystems& environment*, *101*(2), 219-232.

Environmental Protection Agency (2005) National Management Measures to Protect and Restore Wetlands and Riparian Areas for the Abatement of Nonpoint Source Pollution, EPA-841-B-05-003. Retrieved 05-Sept-2015 from http://nepis.epa.gov/Exe/ZyPDF.cgi/20005FGX.PDF?Dockey=20005FGX.PDF.

Esri (2015) Web AppBuilder for ArcGIS. Retrieved 9-Jan-2016 from https://doc.arcgis.com/en/web-appbuilder/create-apps/themes-tab.htm.

Esri (n.d.) ArcGIS Online. Retrieved 9-Jan-2016 from http://www.esri.com/software/arcgis/arcgisonline.

Goetz, SJ, Jantz, CA, and Sun, M (2011). Forecasting future land use and hydrology: A case study of the Upper Delaware Watershed. Watershed Science Bulletin. Fall issue: 18-26.

Goulter, I. C., & Forrest, D. (1987). Use of geographic information systems (GIS) in river basin management. *Water Science & Technology*, *19*(9), 81-86.

Holmes, K. L., & Goebel, P. C. (2011). A functional approach to riparian area delineation using geospatial methods. *Journal of Forestry*, *109*(4), 233-241.

Hull, V, Xu, W, Liu, W, Zhou, S, Viña, A, Zhang, J, Mao-Ning, T, Huang, J, Linderman, M, Chen, X, Huang, Y, Ouyang, Z, Zhang, H, and Liu, J. (2011). Evaluating the efficacy of zoning designations for protected area management. *Biological Conservation*, *144*(12), 3028-3037.

Jantz, CA, Morlock, L. (2011) Modeling Urban Land Use Change in the Upper Delaware River Basin. Retrieved 15-July-2014 from http://webspace.ship.edu/cajant/documents/UPDE_modeling_final_report_051211.pdf

Jantz, C. A., Drzyga, S., O'Neil-Dunne, J., & Claggett, P. (2015) A land cover mapping, modeling and monitoring system for the Delaware River Basin. Retrieved 10-Jan-2016 from http://www.ship.edu/uploadedFiles/Ship/Geo-ESS/DRB/DRB_Mapping_Modeling_Concept_Jan2015.pdf.

Merrifield, M. S., McClintock, W., Burt, C., Fox, E., Serpa, P., Steinback, C., & Gleason, M. (2013). MarineMap: a web-based platform for collaborative marine protected area planning. *Ocean & Coastal Management*, *74*, 67-76.

Munroe, D. K., Croissant, C., & York, A. M. (2005). Land use policy and landscape fragmentation in an urbanizing region: Assessing the impact of zoning. *Applied Geography*, *25*(2), 121-141.

National Park Service (2010) Partnership Wild & Scenic Rivers. Retrieved 10-Sept-2015 from http://www.nps.gov/pwsr/index.htm.

National Park Service (n.d.[a]) Foundation Document Overview: Upper Delaware Scenic and Recreational River. Retrieved 15-July-2014 from http://www.nps.gov/upde/parkmgmt/upload/UPDE_OV_SP.pdf.

National Park Service (n.d.[b]) IRMA Portal: Integrated Resource Management Applications. Retrieved 9-Jan-2016 from https://irma.nps.gov/App/Portal/Home.

National Wild and Scenic Rivers System (n.d.) National Wild and Scenic Rivers System. Retrieved 10-Sept-2015 from www.rivers.gov

The Nature Conservancy (2011) Delaware River Basin Priority Conservation Areas and Recommended Conservation Strategies. Retrieved 8-Sept-2014 from: http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/ED_marine_DEbasin_fullreport2011.pdf

Tomlinson, R. F. (2007). *Thinking about GIS: geographic information system planning for managers*. ESRI, Inc..

U.S. General Services Administration (n.d.) Rules and Policies – Protecting PII – Privacy Act. Retrieved 9-Jan-2016 from http://www.gsa.gov/portal/content/104256.