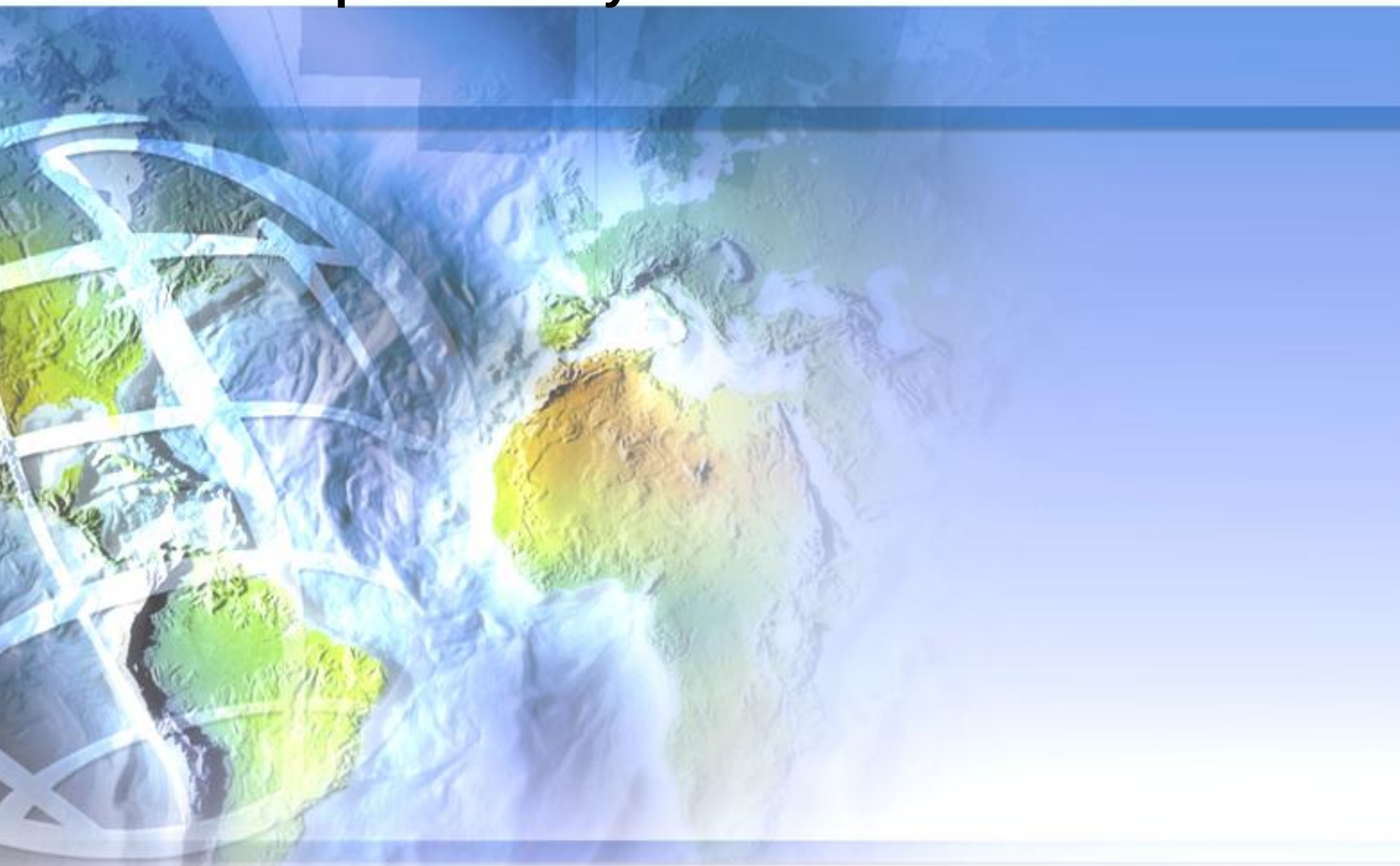
Enterprise GIS System Architecture



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Contents

1.0 Executive Summary

This report provides a GIS system design appropriate to the business needs identified by the planning group listed in appendix 9.1. Those needs emphasized the importance of creating a centralized system of shared GIS resources and capabilities, complemented by departmental resources. Key objectives included reducing data duplication, improving the currency and accuracy of information used in decision-making, and increasing the reliability of systems.

The proposed design takes advantage of the State's existing successes with GIS technology and enhances it with a central server-based, services-oriented infrastructure. This infrastructure emphasizes the re-use of existing server systems and design appropriate to the network capabilities of the State. In addition to being the most cost-effective way of meeting the stated objectives of the planning group, the central server infrastructure will allow the State to extend the benefit of its GIS technology and assets to more business processes and non-GIS professionals in a variety of business units.

The report recommends a modest investment new server resources and a small number of WAN gateway upgrades over the next three years. In addition, it recommends Staging and Development Environments with specific protocols aimed at improving system reliability and performance. The report's 7th section, Technology Architecture, presents the specific recommendations in detail. The key recommendations are:

1. Provide a central ArcGIS Server system supported by hardware virtualization.
2. Start using Citrix's XenApp technology to centrally provision and administer ArcGIS Desktop software
3. Expand the Capitol Hill SAN to support the storage needs of the central GIS server technologies
4. Build a central services infrastructure which exposes appropriate services end-points for transactional editing, analysis, and viewing, based on a variety of clients.
5. Use reverse proxy technology to leverage a single, ArcGIS Server infrastructure for both internal- and external- applications, with appropriate security provisions.
6. Use ArcGIS Online services as base map content for public facing services as this will reduce the burden on the State's Internet connection.

The main body of the report is bracketed by the identification of the driving business requirements and a summary of how this report addresses each.

2.0 Methods, Constraints, and References

2.1 Purpose & Methodology

The purpose of this document is to communicate the architectural observations and recommendations for State of Rhode Island's GIS systems, throughout their enterprise. Inputs to this document include documents and artifacts from State of Rhode Island and a series of architecture design meetings held at the customer site. ESRI uses best practice architectural principles from IT and GIS and the experiences of our Enterprise Implementation Services Team, among other sources, in formulating our recommendations. Our design process, and this report, is based upon The Open Group Architecture Framework (TOGAF), a standard framework for system architecture. Capacity information, as well as many design artifacts, in this report was generated by System Designer version 1.0.0.7.

2.2 Assumptions and Constraints

The approach, analysis, proposed architecture, and proposed recommendations contained within this document take into consideration the following assumptions and constraints:

- Though many implementation details will be included as part of the design process, any detailed implementation topics covering specific procedures, security details, and software migration fall outside the scope of the system architecture design product.
- *User requirements* are defined as those related to total users, concurrent users, user locations, and user workflows. The term does not refer to user application or software functional requirements.
- *System requirements* relate to only those that impact the system architecture design and not the IT organization or infrastructure as a whole. For example, a requirement stating that high-availability is a must is applicable, but a requirement stating that dual power feeds to the system rack is required is out of scope.
- As appropriate, existing hardware will be considered for inclusion as part of a new or updated GIS system architecture. Server hardware is assumed to be at the end of its production life cycle when it is 3 or more years old.
- The target time frame for the designs in this report is a three year period. Capacity calculations are based on estimates of the peak user activity that could occur in that time frame. As such, they do not represent typical system loads; they represent peak loads that the system should be designed to handle.
- Processing burdens (service times) and network payloads have not been calculated for ETL, data download, or data upload operations as there is not a clear basis to establish reasonable values on which to project. However, as many of these activities happen at off-peak hours, this is a low-risk for the capacity calculation results.
- Information not provided on the following topics is addressed as follows:
    - Internet bandwidths/pathways: The requirements for Internet bandwidth are calculated based on available information.
    - Workflow frequency information for Internet users (except HPHC):

Workflows are described in the design, but excluded from capacity analysis
- WAN latency: The design assumes that SONET latency allows for acceptable performance of ArcGiS Desktop connecting to RDBMS data sources and that other WAN link latencies are too large for that.
- Existing Hardware: Existing specifications were used where provided. In cases of incomplete information, guesses were made based on the other systems.

2.3 Reference Documents

State of Rhode Island staff generously provided the following documents to support this system architecture design process.

- Business Plan for Rhode Island Enterprise GIS, 2007 (PDF)
- DOT GIS Inventory (Visio)
- EMA Situational Awareness System Diagram (PDF)
- URI Environmental Data Center Overview (PDF)
- State of Rhode Island Department of Public Health GIS Deployment Summary (paper)

2.4 Acknowledgements

Esri would like to thank and acknowledge State of Rhode Island staff for providing valuable, detailed information that served as a basis for the system architecture review and this resultant document. This includes detailed information regarding the current IT infrastructure, GIS system architecture, and the current GIS applications and their use. Participating staff are listed in the Appendices.

3.0 Architecture Vision

The State of Rhode Island envisions a common system of GIS capabilities and resources that support the needs of a growing number of departments and agencies that use GIS in their operations. Shared resources, including enterprise data warehousing, data, services, and applications should be centrally provisioned and available throughout the State's network.

At the same time, most departments will continue to maintain resources, particularly data resources, that are specific to them. The system must provide flexibility to end-user departments to use the client-side technologies of their choosing (e.g. Rich Desktop applications, browser-based applications, mobile applications, etc.). The system must provide the flexibility for end-user departments to host their own server infrastructure, where appropriate, and integrate with the enterprise GIS through services and when appropriate through data replication.

Finally, the system must provide flexibility to support new operations/workflows and new business units over time.

The diagram below illustrates the conceptual design relative to the business units and workflows that are known today.

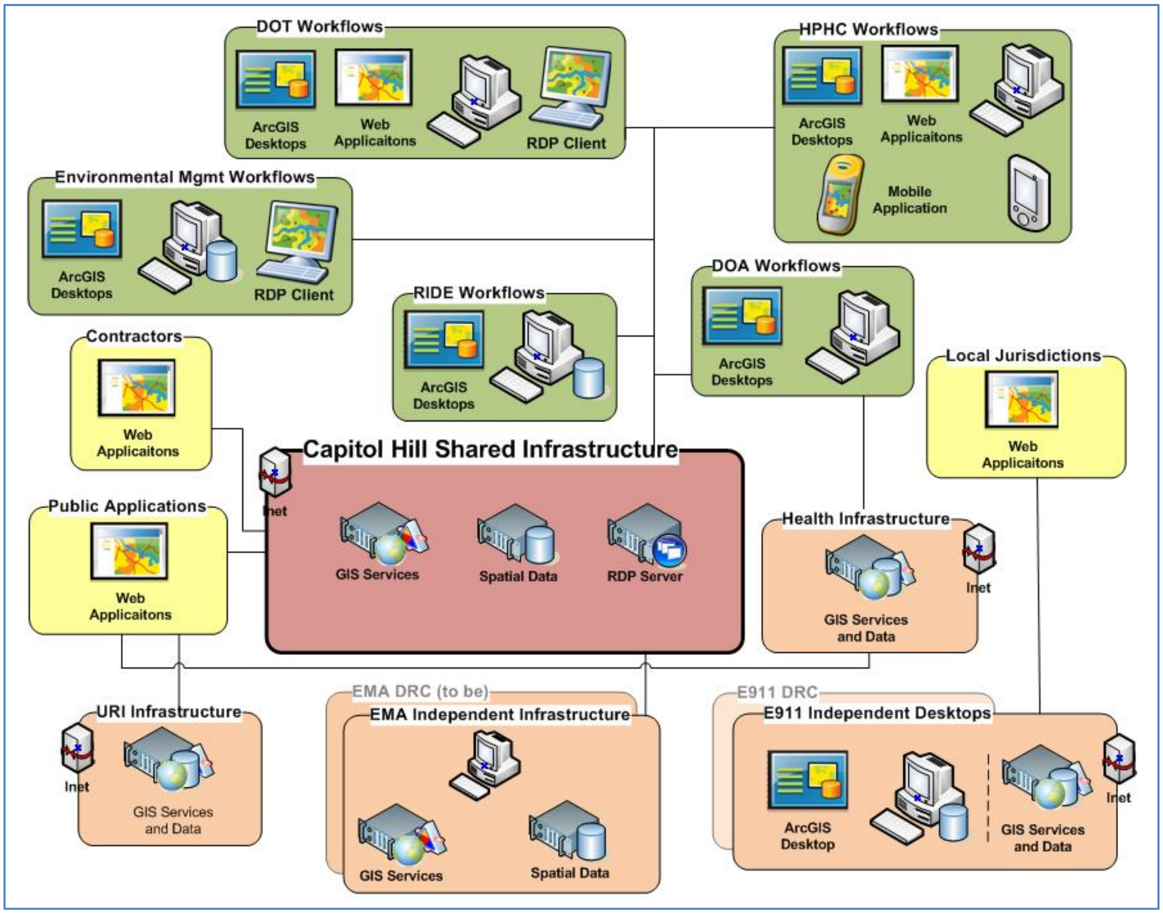

Figure 1: Conceptual Overview of System

4.0 Business Architecture

This section describes the business requirements and preferences that guide the design presented in this report.
The design will allow the integration of new needs and new business units over time. However, it is based on the specific requirements described by the departments that participated in the planning engagement:

- Department of Administration
- Department of Transportation
- E911
- Emergency Management Agency
- Department of Environmental Management
- Department of Heath
- Historic Preservation and Heritage Commission
- University of Rhode Island Environmental Data Center
- Rhode Island Department of Elementary and Secondary Education
- Department of Information Technology

4.1 Driving Business Requirements

The following business requirements were identified as significant motivators for the creation and design of a state-wide enterprise GIS system.

No.	Item	Description
1	Reduce data duplication	Currently, many datasets, such as “RIGIS”, are stored on many client and server systems throughout the state. This is costly in terms of storage. And, it results in analysis on out-of-date data. Duplicated data is also difficult to keep synchronized and provides the potential for usage of out-of-date or obsolete data.
2	Improve the currency of data used for analysis and visualization	For example, E911 address data, used to locate callers, is sporadically updated. More frequent updates would improve efficiency and be much more effective in delivering timely emergency services.
3	Decentralize data maintenance	Currently, much data maintenance is handled by a small number of GIS professionals on behalf of the business unit subject matter experts. This causes delays in data maintenance activities and keeps GIS professionals from being able to focus on improving and evolving the GIS capabilities and systems in the state. Ideally, spatial data maintenance, like non-spatial data maintenance, should be handled by the business units directly.
4	Improve GIS system	Most GIS systems currently have a good record

	availability and stability	of uptime. However, improved uptime, and availability to more business units, would allow the state to get more out of its investments in GIS systems. This is particularly important as GIS resources are centralized. There is also the expectation that an enterprise solution will provide enhanced capabilities and increased reliability in case of failures.
5	Improve utilization of systems resources	In a system where each department maintains its own resources, most systems have very low utilization relative to their capacity. Providing more central, common resources allows those systems to be "right-sized" relative to their use. This generates efficiency savings throughout the state.
6	Use of standards in data and development	Using standards for GIS application development and for GIS data offers many efficiencies for GIS application development and improves the effectiveness of state employees as they make use of GIS data.
7	Maintain and evolve a coordinated approach to GIS	Organizational standards for GIS technologies and their implementation offers the same benefits available to non-GIS technologies such as RDBMSes, hardware virtualization, etc.

In addition to these shared business drivers, individual departments articulated motivators that are specific to their operations:

No.	Item	Description
DOT1	Support performance management	The DOT currently has an initiative to manage performance with data and analysis throughout the lifecycle of DOT work (design – construction – maintenance). GIS is seen as a critical technology that allows the integration of different datasets in a common frame of reference for performance analysis.
DOT2	Improve design by providing feedback from maintenance	Transportation system designers currently get little feedback from how their designs perform with respect to maintenance (or other factors). Including designers in a spatially-enabled work order management system will improve coordination.
DOT3	Allow GIS users access to CAD design data	Currently, computer aided design (CAD) users are able to use GIS data to understand the contexts of their designs. However, GIS users are unable to benefit from the design work of

		CAD users. The workflows to facilitate the usage of GIS data in CAD environments also need to be simplified.
DOT4	Improve coordination with HPHC	DOT has been very successful in coordinating with HPHC. As historic preservation is complex and sometimes very costly, tighter coordination between the departments promises more efficiency and effectiveness.
DOT5	Develop transportation asset and workflow management solution	RI DOT is planning to develop and deploy a GIS-centric transportation facilities Asset and Work Order Management system to support the agency's needs.
EMA1	Better sharing of information with emergency personnel in the field	Current methods of email static map images, ftp, etc. mean that field personnel have difficulty obtaining timely and accurate information in emergencies.
HPHC1	Improved field data collection by staff and contractors	Currently, field data collection is paper based. It is difficult or impossible to bring relevant historical maps into the field. And, the collection of data is slow, error prone, and requires a "data entry" step separate from collection. This is very costly.
RIDE1	Improve facility planning and build public consensus around 5 year plans	Currently, it is difficult to make resource allocation decisions for schools because the location of complementary/replacement resources is not evident. And, planning decisions are hard to share with the public for evaluation and feedback.
URI1	Improve the reliability of public facing services and applications	URI system administration is currently the part-time duty of one person. While the system has a good record of uptime, down time does occur and can be protracted in the case of an absence or other priorities.
URI2	Maintain less hardware and simplify	Each piece of server infrastructure technology requires attention that could be spent on other activities.
URI3	Make it easier for participants to publish data/services	Currently, all publishing work is brokered through a single individual.

4.2 Business Continuity/Availability

The departments articulated the needs with respect to system availability and business continuity

No.	Item	Description
1	Data recovery time objective	It should take no longer than ½ day to recover data from a data tier failure
2	Data recovery point objective	The maximum amount of data loss that can be tolerated in the case of a system failure is 1 day
3	Disaster Recovery Facility	The enterprise GIS does not need to operate in the case of the loss of its production facilities in the case of a disaster. EMA and E911 require separate provisions for Disaster Recovery Facilities
DOT1	Uptime Requirement	98% (7 days of planned/unplanned downtime per year)
Health1	Uptime Requirement	99.9% (1 day of planned/unplanned downtime per year)
E911_1	Uptime Requirement	E911 does not maintain any server systems. A full complement of individual user workstations, with all data resources local, must be operational at all times.
E911_2	Disaster recovery	E911 maintains a disaster recovery facility.
EMA_1	EMA access	A current copy of all common datasets need to be available in the EMA in the case of emergency and absence of network connections
EMA_2	Uptime requirement	99.99% (1 hour of planned/unplanned downtime per year)
EMA_3	Disaster recovery	EMA is working on provisions for a disaster recovery facility. EMA is also deploying its own in-house high availability GIS.

4.3 IT Standards and Policies

The State's IT department identified the standards, policies, and preferences below.

No.	Item	Description
1	Hardware Virtualization	VMWare is the standard. The State has a growing investment in hardware virtualization. Current capacity is limited by the size of the SAN (all virtual machines are configured to use SAN storage whereas physical machines use local storage)
2	Application/Session	While GIS has not made much use of Citrix

	Virtualization	or Windows Terminal Services, the State's IT Department has deployed Citrix and/or Windows Terminal Services for a number of applications.
3	Cloud Computing N/A	IT is not actively pursuing cloud computing at the moment. It is being considered, however, as a potential future solution. Rhode Island is participating in efforts by several States to consider the applicability of cloud computing solutions.
4	Development Platforms Microsoft	IT favors Microsoft technologies for server and developer platforms.
5	Database	SQL Server is preferred
6	Hardware	Master Purchase Agreements exist with both HP and Dell. Going forwards, IT prefers HP hardware.
7	Off-premises Wireless	There is no provision of off-premises wireless (e.g. to support field-based personnel)
8	WAN Technology	The Capitol Hill complex has a high-bandwidth redundant SONET implementation. Other State facilities have a variety of WAN technologies. Latency information was not provided. This report assumes that SONET latencies are low enough to allow acceptable ArcGIS Desktop performance when connecting to RDBMS and web services resources over SONET links. This report also assumes that all other WAN link latencies are incompatible with that design.
9	Internet access	No information was provided about the Internet access infrastructure. This report assumes that all sites have direct Internet access with sufficient bandwidth for their needs. The Internet bandwidth needs of each site are presented in the Technology Architecture section.
10	Authentication/Authorization	The State does not have an enterprise-wide system for authentication and authorization. Departments implement their own systems.

5.0 Application Architecture

The enterprise GIS system for the State of Rhode Island is designed to be adaptable to many uses and different business units over time. Rather than precisely designed system for discrete and structured workflows, appropriate design must be based on extensible patterns for the functional and non-functional attributes of the system and the most appropriate ways of provisioning those requirements under different circumstances.

This section presents application patterns appropriate to the requirements and workflows of the organization. Throughout this section, logical diagrams are used to illustrate the design concepts of these patterns. The Appendices include corresponding physical diagrams. As the total design encompasses a very large number of workflows, the diagrams included in this report are representative, not comprehensive with respect to the total design.

5.1 ArcGIS Desktop Analysis and Data Maintenance

ArcGIS Desktop provides a rich set of analytical and data maintain capabilities for the trained GIS professional. ArcGIS Desktop software is designed for LAN environments with relatively high bandwidth, low latency network connections to data sources. The following solution patterns illustrate how to provision users with these toolsets in a variety of circumstances.

Several departments within the State already benefit from having GIS professionals that are proficient with these tools. These users currently have ArcGIS Desktop locally installed and work with data that is local to their machines or local to departmental file or RDBMS servers. This report recommends evolving this pattern to the patterns described below.

5.1.1 High bandwidth / Low Latency Link to Central Repository

In a high bandwidth/low latency network environment, ArcGIS Desktop can be deployed to perform very well when working with data centralized data sources and services such as Enterprise Geodatabases, ArcGIS Image Server services, ArcGIS Map Services, etc.

ArcGIS Desktop users on the Capitol Hill campus benefit from a high bandwidth, low-latency network. Under these circumstances, ArcGIS Desktop software, installed on end-user computers, can connect to RDBMS, service, and other data sources directly for viewing, analysis, and editing.

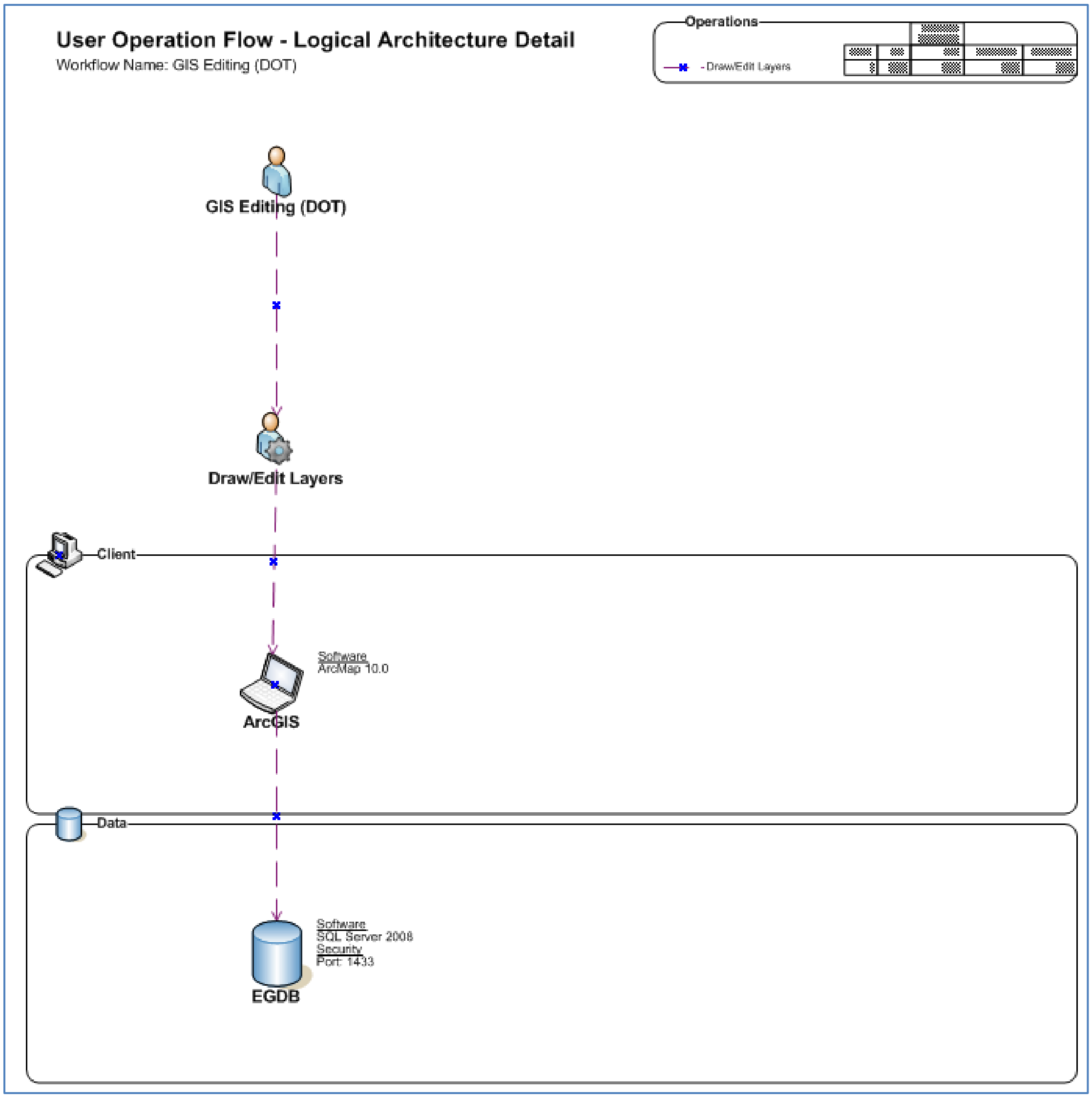

Figure 2: ArcGIS Desktop use of network resources; Logical

In addition to working directly with the Enterprise Geodatabase repository, consuming ArcGIS Server services offers a number of benefits including use of data that comes with cartographic standards and leveraging server-side processing. This makes ArcGIS Desktop the most versatile and powerful GIS client. The diagram below shows an example of a Planning and Analysis workflow at the Department of Administration that accesses operational data directly and through a service published through a firewall from the Health department. In addition, it consumes base map and imagery services from the central ArcGIS Server infrastructure.

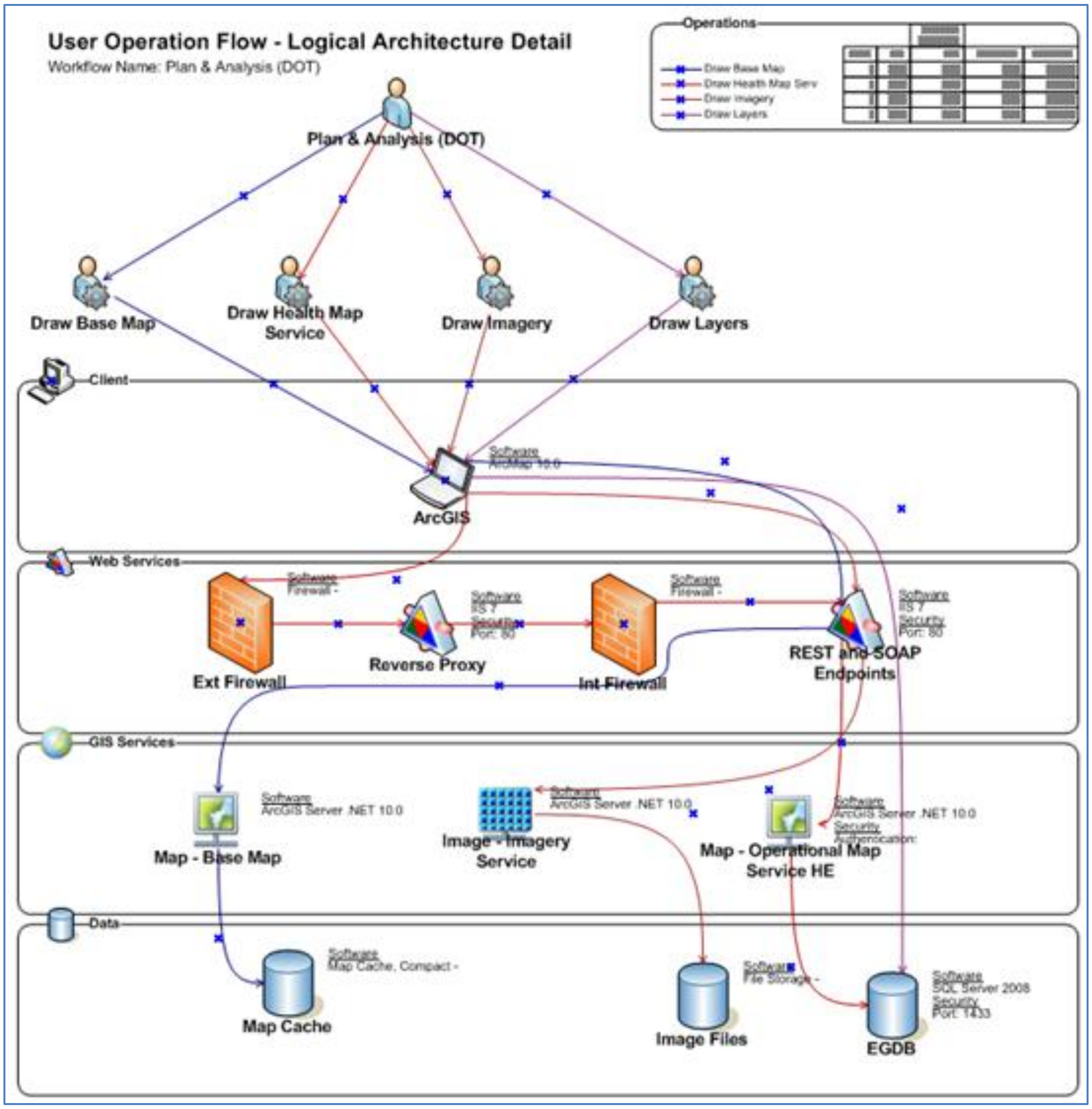

Figure 3: ArcGIS Desktop use of network resources; Logical

This pattern applies to user workflows at the following locations:

Dept	Workflow	Location
DOT	GIS Editing	2 Capitol Hill
DOT	Map Production	2 Capitol Hill
DOA	Planning & Analysis	1 Capitol Hill
Health	Planning & Analysis	3 Capitol Hill
ENV	Project Work	Foundry

5.1.2 Low bandwidth / High Latency Link to Central Repository

There are two patterns appropriate for users that are remote, in network terms, from the central data repository: Session/Application Virtualization and Partially Disconnected Operations.

Session/Application Virtualization

Citrix's XenApp Server and Microsoft's Windows Terminal Services (WTS) allow ArcGIS Desktop software to execute and be administered on a central server system. Users access the applications as if they were local but with much lower network bandwidth requirements and higher tolerance for network latency[1].

This solution is the primary recommendation for the following reasons:

1. Central administration of ArcGIS Desktop is efficient and makes it easier to manage the releases of the client software to more users.
2. Reduced resource requirements on end-user computers lowers the cost of deploying the software to more users.

[1] Down to 128Mbps or less bandwidth per user with latency up to 100 milliseconds.

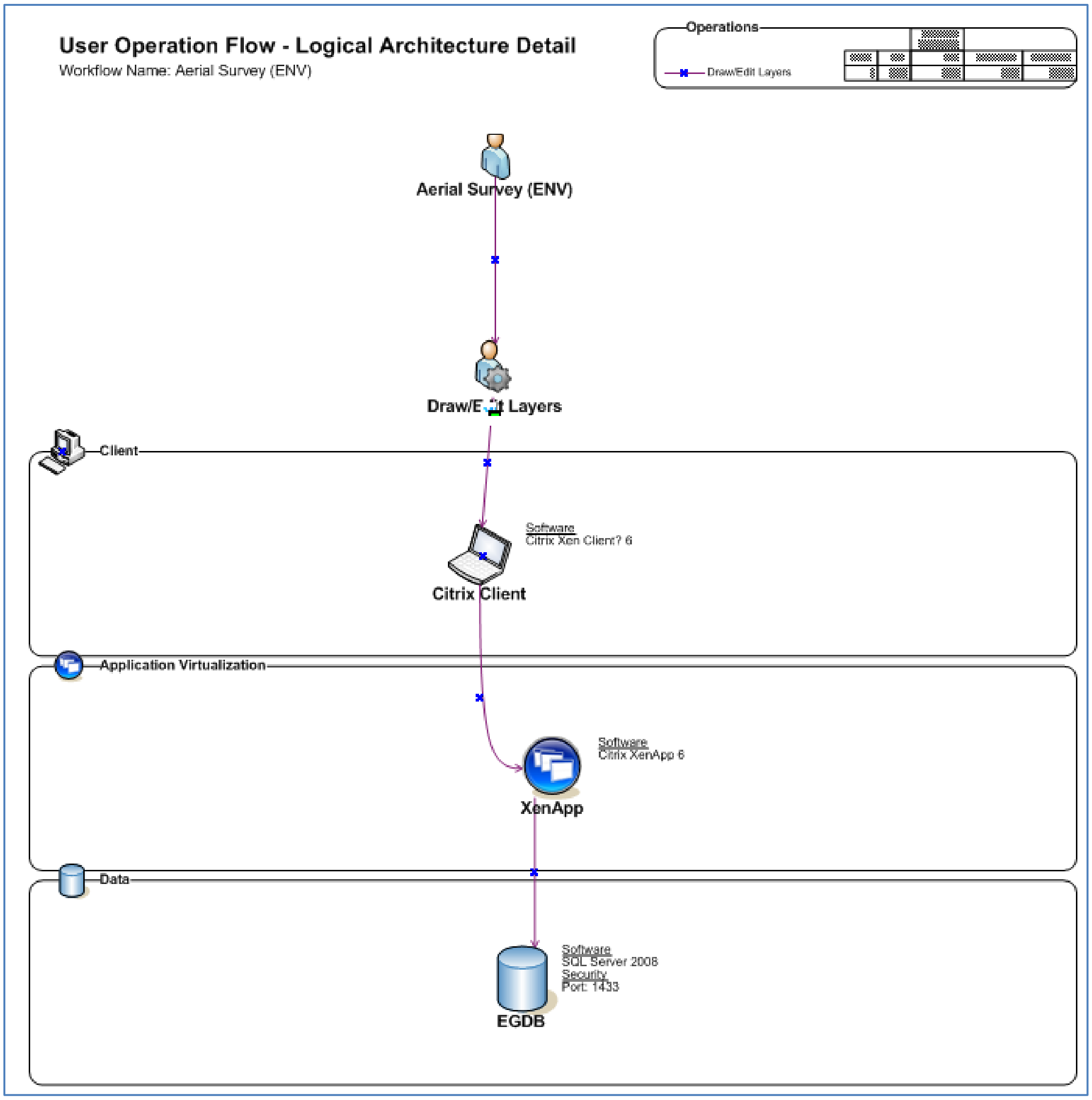

Figure 4: ArcGIS Desktop design for low network bandwidth; Logical

This pattern is appropriate under the following circumstances:

1. Users will not be performing 3D analysis or visualization
2. Users will not require access to large (>10MB) datasets that are local to their machines
3. Users will not need to work completely disconnected from the network
4. Users will not need to print maps at their location.

This pattern applies to user workflows in the following locations:

Dept	Workflow	Location
ENV	Aerial Surveys of pest infestations	Forestry
ENV	Enforcement	25 Holden St
DOT	Viewing & Analysis	Lincoln Ave
RIDE	Desktop Analysis	RIDE

Partially Disconnected Operations

Another pattern appropriate to low-bandwidth, high-latency links is to organize the ArcGIS Desktop workflows to happen in a disconnected manner and then automatically ship any updated data to the central repositories at off-peak times. For versioned datasets, this can be accomplished with Disconnected Editing[2]. For non-versioned datasets, particularly those that are small and have a small rate of updates, automated ETL can be used[3]. Simple geoprocessing models can automate the Extract-Transform-Load procedures to move user's edits to the central repository. Map Services can be used to provide network-efficient access to up-to-date GIS data.

The second pattern pattern, making use of a local fGDB and automated ETL for edited data, appears to be most appropriate to the requirements of several workflows in the State, primarily in the Environmental Management Department. It may be worth a more detailed examination of these workflow requirements, however, to determine whether the capabilities could be met with a browser-based application which would be simpler and more cost effective to deploy.

[2] More information on Disconnected Editing: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00170000000v000000.htm.

[3] For more information on scheduled execution of geoprocessing tasks: http://resources.arcgis.com/content/kbase?fa=articleShow&d=27553; http://resources.arcgis.com/content/kbase?fa=articleShow&d=35371. For more information on geoprocessing itself: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/What_is_geoprocessing/002s00000001000000/; http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Tutorial_Creating_tools_with_ModelBuilder/002w0000007v000000/

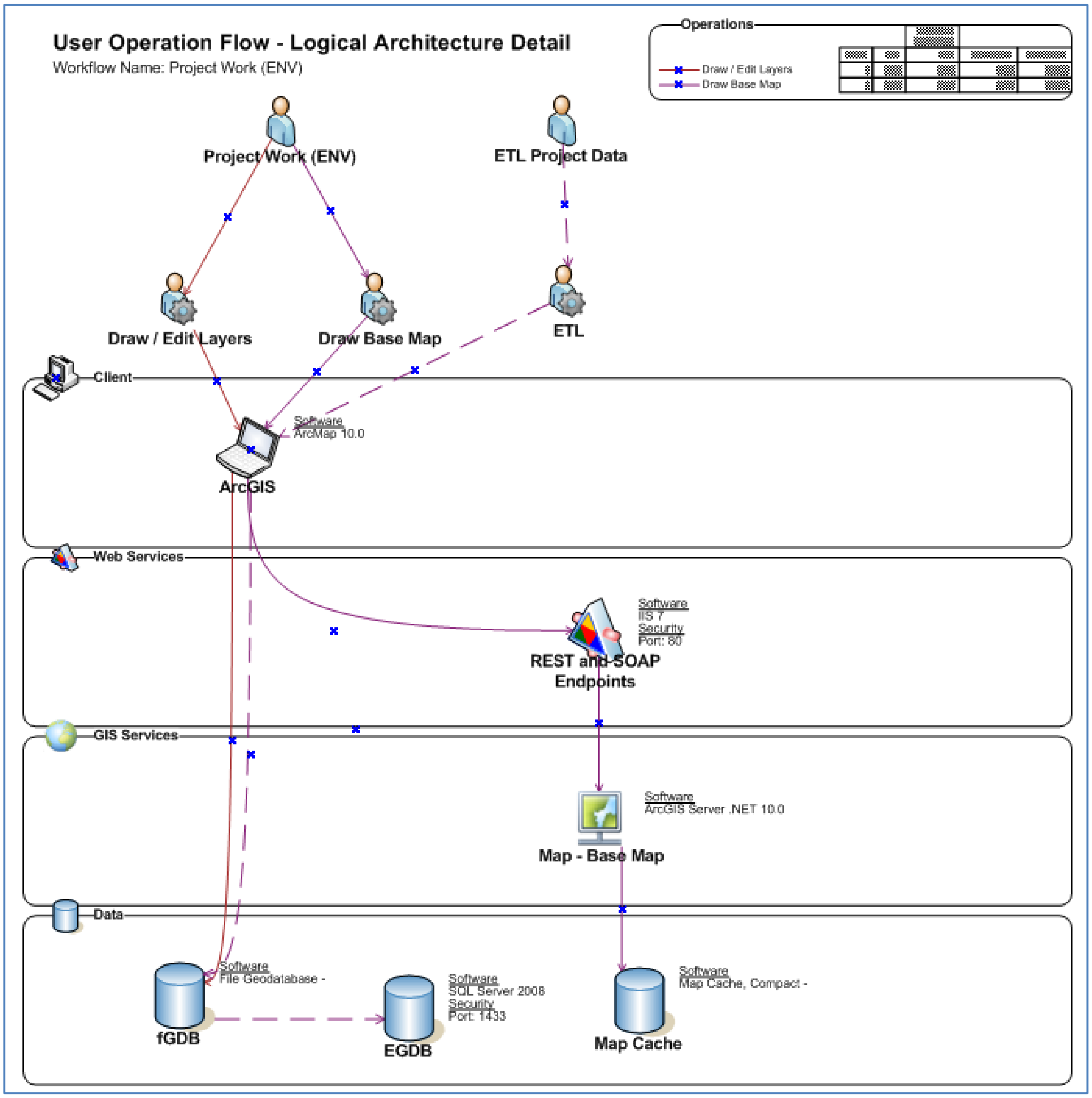

Figure 5: ArcGIS Desktop deployed for low network bandwidth; Logical

This pattern is appropriate under the following conditions:

1. A single editor is responsible for maintaining a single dataset
2. The edited datasets are small in size (10MB or less)
3. The demand for data currency in the central repository is low (1-5 day lag is acceptable)

This pattern applies to user workflows in the following locations:

Dept	Workflow	Location
ENV	Project Work	Fish & Wildlife

5.1.3 Independent Workstations

The final pattern in this desktop category is for workstations that are configured to be independent of all network resources. This pattern is currently in use with E911 where all workstations are configured with data local to their machines. In this fashion, there is no dependency on networks or server systems to support the Telecommunicators' workflows.

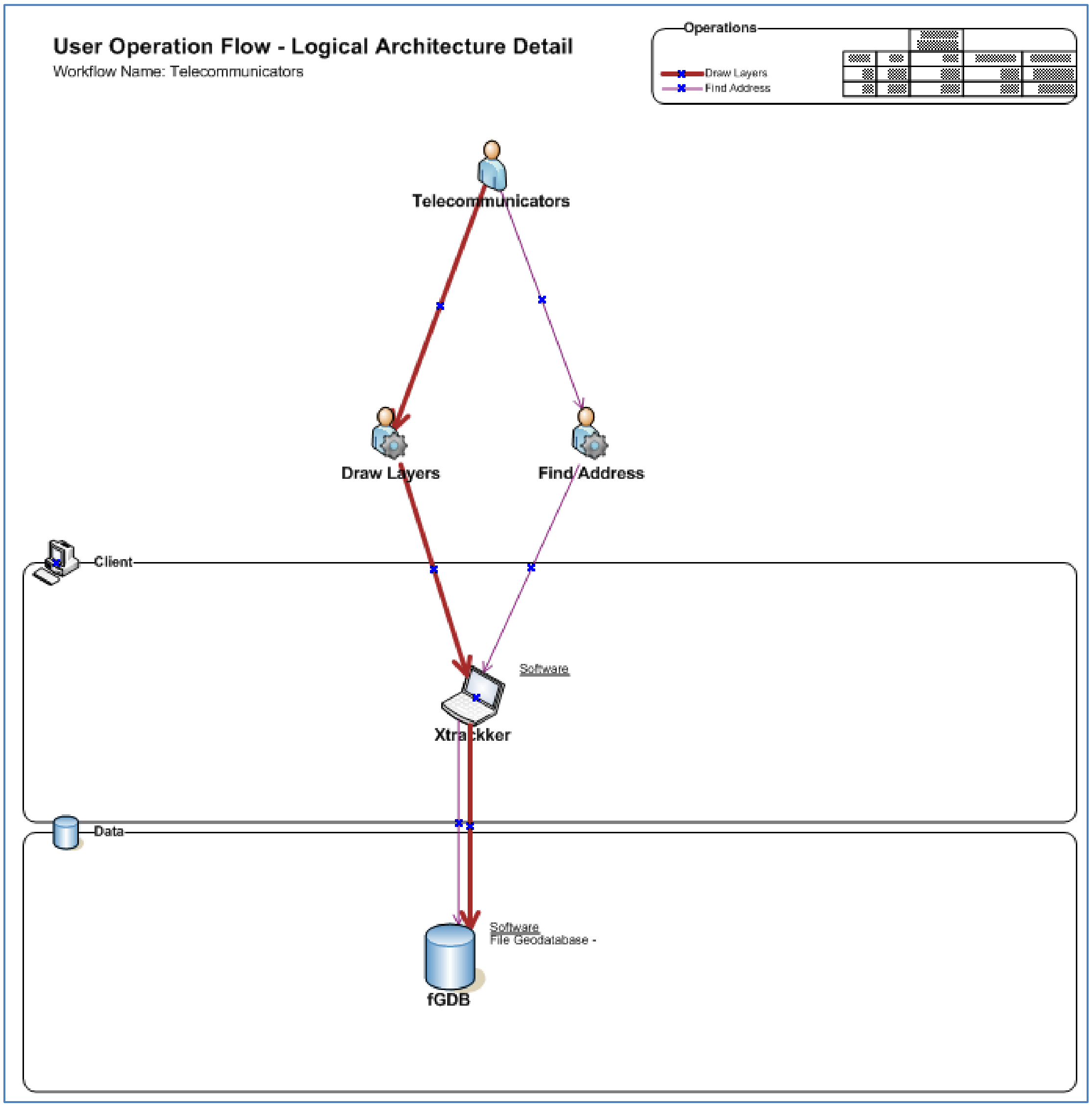

Figure 6: ArcGIS Desktop deployed for no dependency on network; Logical

5.2 Browser-Based Viewing, Analysis, & Data Maintenance

While ArcGIS Desktop provides a powerful set of tools to the trained GIS user, most workflows that make use of spatial data and analysis do not require that suite of tools. Browser-based applications can deliver powerful viewing and analysis capabilities with more application structure. This reduces the training burden and allows non-GIS users to benefit from GIS systems. Similarly, browser-based applications can be used to allow non-GIS business unit staff to make simple updates to spatial data, rather than delegating the task to a GIS professional. Finally, browser-based applications are more tolerant of low network bandwidth and high network latencies, compared to ArcGIS Desktop applications.

These characteristics make browser-based applications the recommended pattern for the vast majority of GIS-supported workflows in the State, particularly those locations that are not directly on the SONET ring.

Browser-based applications can support internal workflows and external workflows. The following diagrams show the same logical ArcGIS Server infrastructure serving both internal and external workflows. Depending on the security and scalability needs of the applications, the physical infrastructure can be the same for both or distinct (a consideration discussed more thoroughly in the Technology Architecture section).

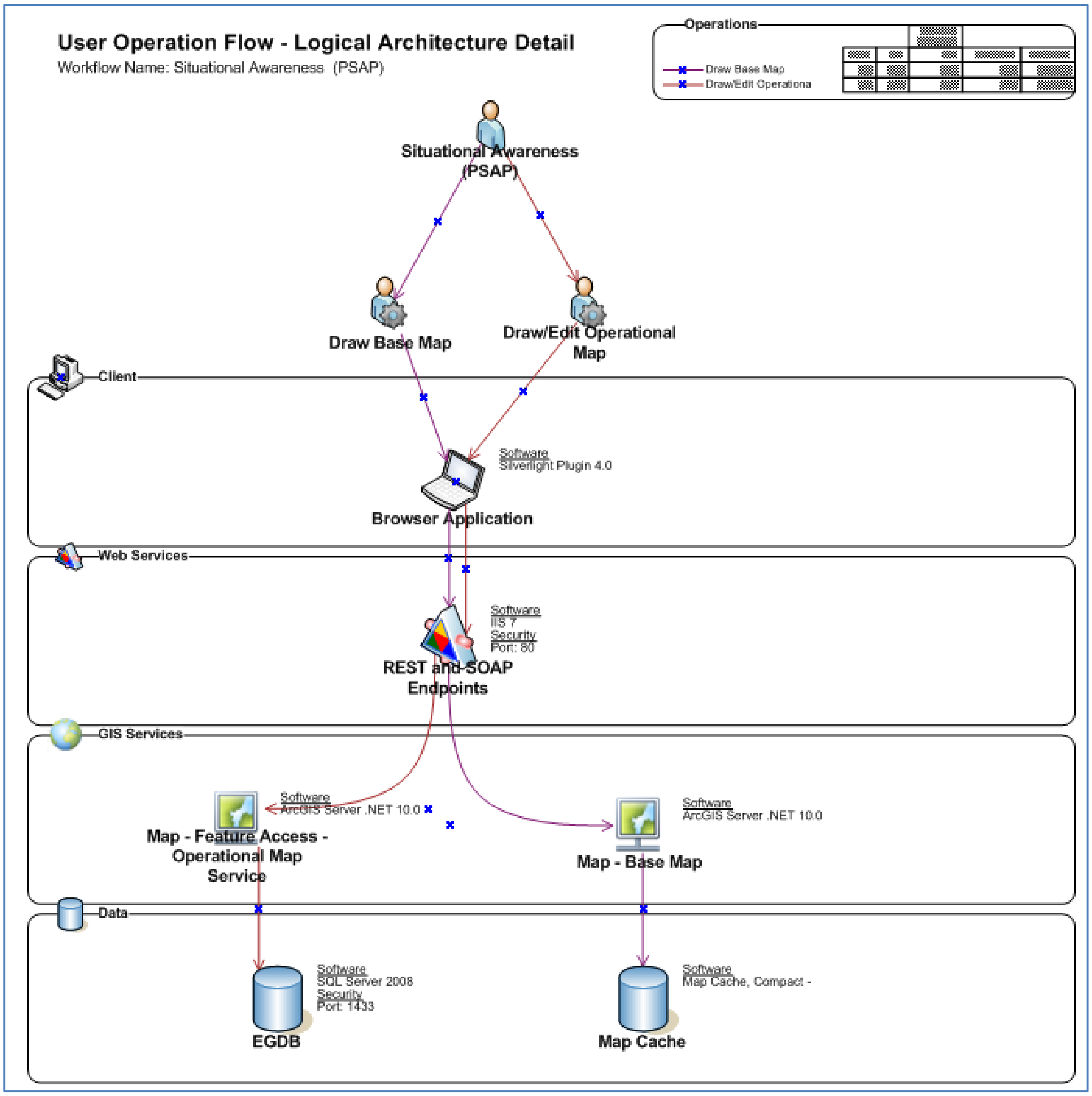

Figure 7: Browser-based application with editing capability, Logical

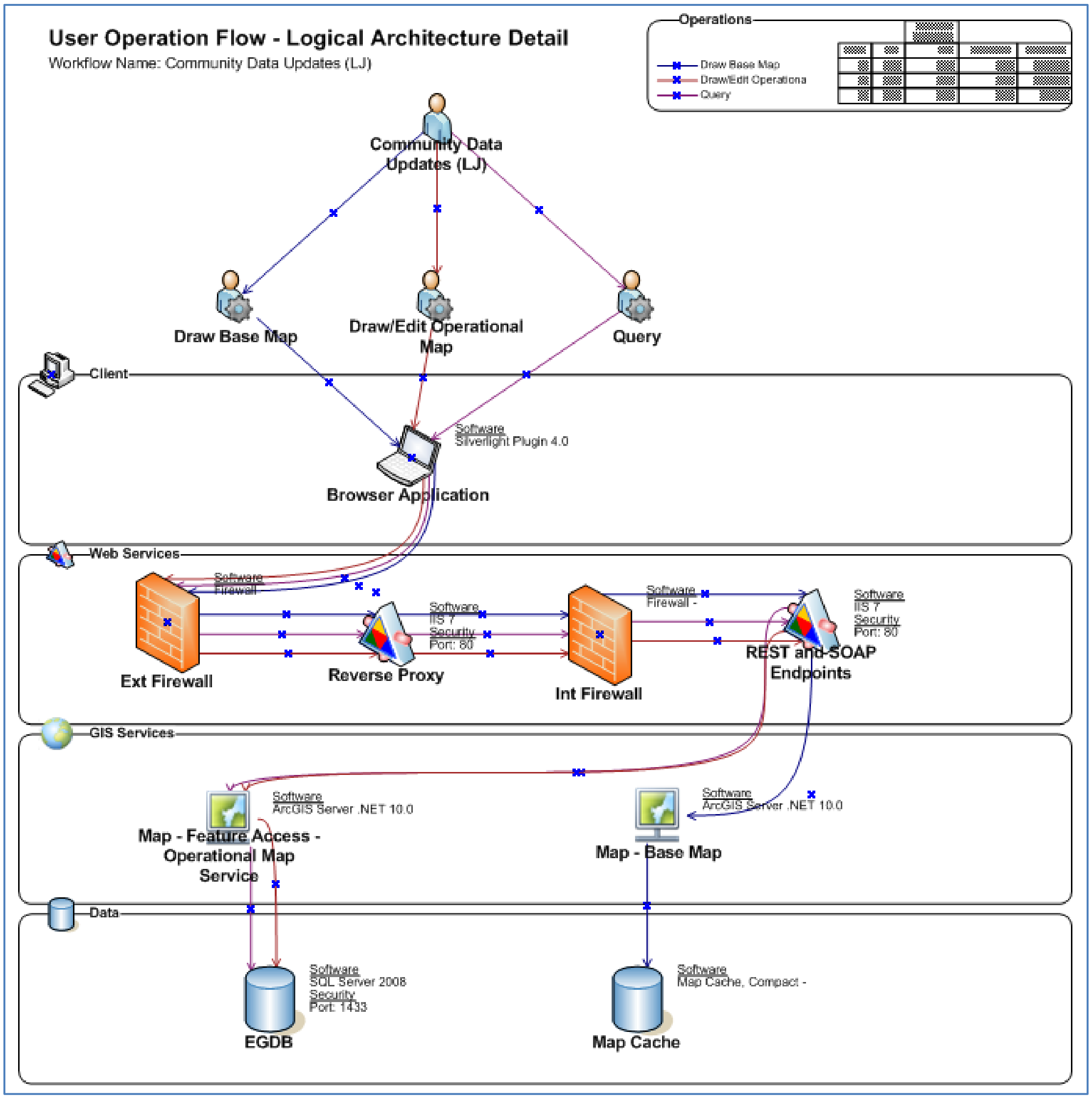

Figure 8: Browser-based application with editing capabilities, Logical

This pattern applies to user workflows at the following locations:

Dept	Workflow	Location
EMA	Situational Awareness	New London
EMA	WebEOC	New London
Health	Census, Hospital, FacReg	EOHHS Pastore
HPHC	Digital Submission	Internet
HPHC	Field-based data collection	Internet[4]

[4] This workflow was reclassified from ArcGIS Server Mobile after the initial report was created. In addition, new and more specific information about the state's preferences for this application was disclosed. The result is that this approach to this workflow received less detailed analysis than those discussed during the on-site engagement. The changes are within the tolerance of the report's designs. However, no new capacity calculation was run. This version of the report

HPHC	Public Access	Internet
EMA	Situational Awareness (public access)	Internet
RIGIS	Public Access	Internet
DOT	TMC	2 Capitol Hill
HPHC	HPHC Updates	Benefit St.
DOT	View HPHC Projects	2 Capitol Hill
DOT	Work Order Management	2 Capitol Hill, Lincoln Ave, Maintenance Facilities
ENV	Viewing	Fish & Wildlife, Forestry, Foundry
E911	Community Data Updates	Internet
EMA	Situational Awareness, Local Jurisdictions	Internet
EMA	WebEOC, Local Jurisdictions	Internet
DOT	Viewing and document access	Maintenance Facilities

5.3 Data Search and Discovery

In organizations with distributed GIS practices and operations, it is not always practical to physically centralize all GIS resources. Esri's Geoportal Server provides a means of central search and discovery for distributed data, service, and application assets. The Geoportal Server does this by aggregating light-weight metadata about resources centrally.[5] This does require extra effort to create and maintain the metadata. Users can search the metadata repository through a browser-based application or with a plug-in to ArcGIS Desktop.

As business units within the State of Rhode Island wish to keep some data, services, and applications outside of the centrally provisioned system, there is not a single, central physical authority to discover all GIS resources in the State. However, discovering what resources exist, and knowing something about their currency and how to access them, is a critical capability of Rhode Island's enterprise GIS. The Geoportal Server can be used to help ensure that the distributed GIS users can discover the most recent GIS resources for their work.

assumes that the workload throughputs of the HPHC Field-based data collection and Public Access workflows account for this activity as well. If need be, revised capacity calculations can be run as part of the planned time and materials contract support for this effort (Esri Quote Number: P11-5487).

[5] Information about Geoportal Server: http://www.esri.com/software/arcgis/geoportal/index.html.

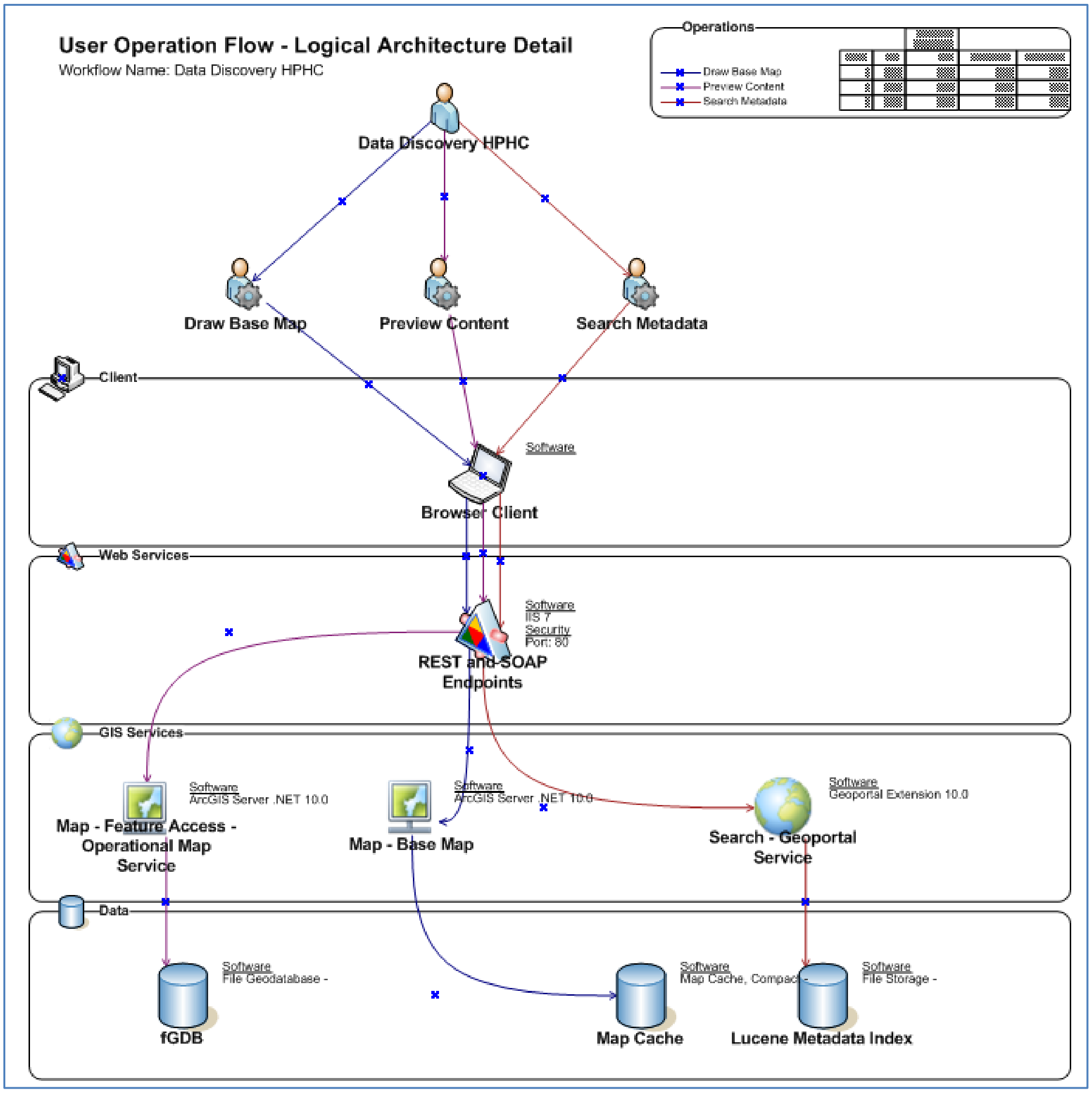

Figure 9: Data Search & Discovery; Logical

This application pattern would be applicable to all sites that allow browser-access to Intranet resources.

5.4 Field Data Collection

Esri offers a number of mobile technologies that support field workers with situational awareness and the ability to capture data in the field. ArcPAD provides an application aimed at GIS professionals using small format devices. ArcGIS Engine allows for the development of custom applications to run on laptops or tablets. And, ArcGIS Server's Mobile technology allows for the configuration and/or development of mobile solutions for non-GIS personnel.

Currently, most GIS workflows in the State are best supported by ArcGIS Desktop or Browser-based applications. RIDOH reports that they have implemented or plan to implement ArcGIS Server Mobile. Going forwards, other departments may wish to do so as well.

At the moment, HPHC will support mobile users with a web browser-based application. This will allow access to the broadest number of platforms, internal and external users, with the fewest resource and system requirements. In the future, HPHC may wish to enable internal users to work in a sometimes connected mode and task-oriented applications. These personnel need access to historical maps which may not be practical to bring into the field in paper form to survey, discover, and document historical features at sites. The ArcGIS Server Mobile technology would allow these users to be provisioned with a data collection application aimed at the non-GIS professional. The application can take advantage of GPS, camera, and range-finder capabilities of mobile devices. And, historical maps can be made available on these devices in digital form. While disconnected, local data allows the application support the user in data collection, honoring the rules of the Enterprise Geodatabase. When connected, through Internet or Intranet, the application allows the edits to be synchronized.

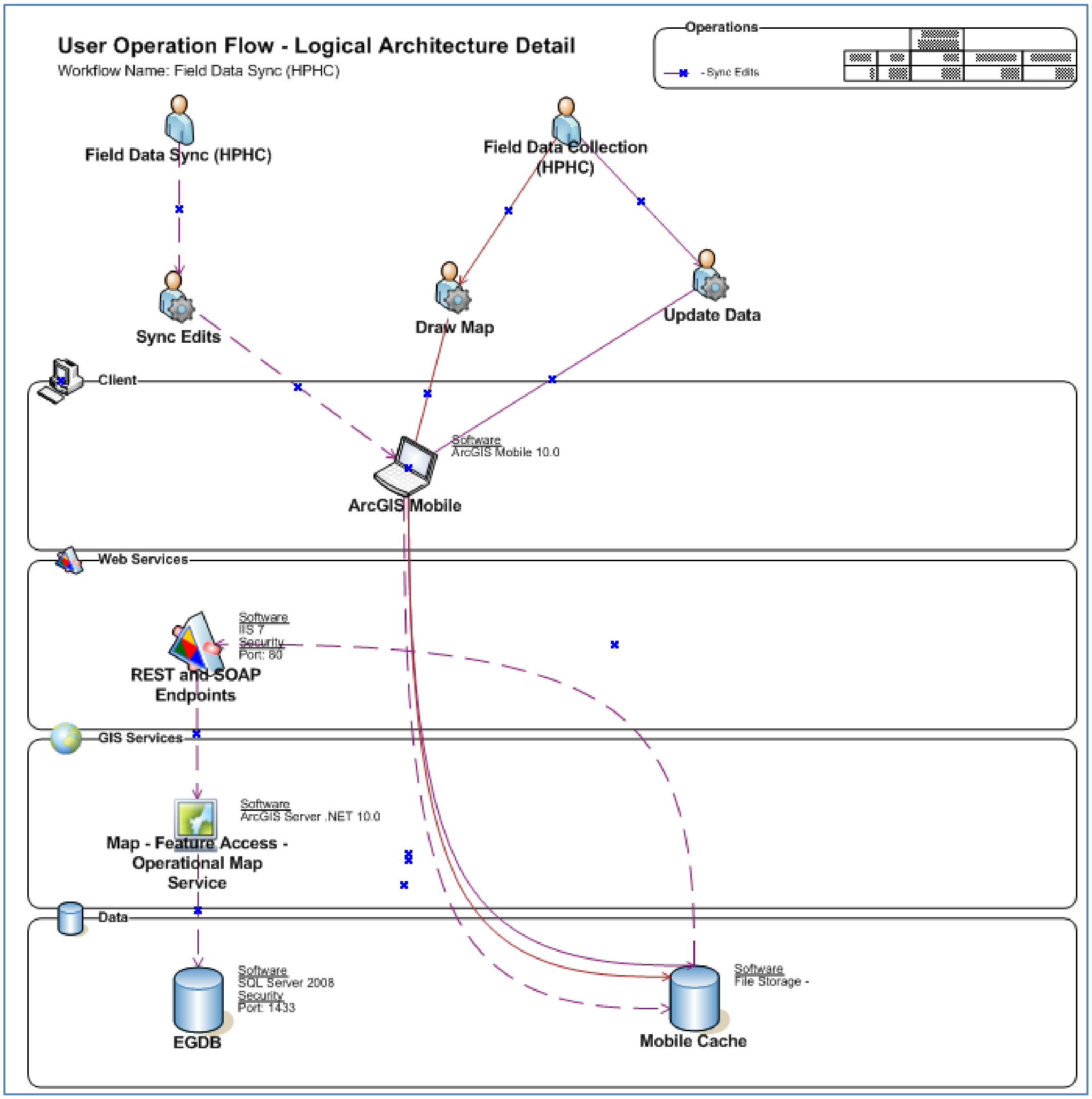

Figure 10: Future possible Field Data Collection; Logical

Presently, this application pattern is a future consideration for HPHC field data collection needs. Current field data collection workflows will be supported by a web browser-based application.

5.5 Products, Releases, and Deployment

The application patterns described above can be supported with the following Esri products and technologies:

- ArcGIS Desktop[6]

[6] The State of Rhode Island GIS staff is already familiar with the capabilities of the license levels within ArcGIS Desktop. In general, viewing and light analysis can be accomplished with ArcView. ArcEditor is required for any user that would edit an RDBMS-based Geodatabase. ArcInfo

- ArcGIS Server, Enterprise Advanced
    - ArcGIS Viewer for Silverlight
    - ArcGIS Server Mobile
    - ArcGIS Server Image Server Extension
- Geoportal Server

The number of licenses required is discussed in the Technology Architecture section.

The solutions patterns in this document assume an ArcGIS 10 (or better) release implementation. In addition, to work effectively as a single enterprise system, the releases of the Esri products must be coordinated. The critical target for this effort is typically ArcGIS Desktop deployments.

For example, the database tier components cannot upgrade to a release higher than the lowest release of a Desktop (or other client) that wishes to connect to it. Therefore, there is great advantage in the State centralizing release control of Esri software. Technologies such as Citrix provide this capability automatically. That contributes to the strength of their fit for the State's enterprise GIS needs. However, it is clear that not all of the State's Desktop GIS needs will be met with Citrix. Esri software is designed to work with a variety of centralized deployment technologies[7]. Adopting State-wide release standards, and using such automation to help implement it is also a viable pathway.

It is common for organizations that pursue an enterprise implementation to also pursue an Enterprise License Agreement (ELA)[8]. An ELA can be useful in helping each member agency maintain their access to current technology so as not to either hold back the enterprise or risk splitting from it[9].

5.6 Training Needs

The gradual move towards developing enterprise GIS resources and increasing their utilization does not substantially change the training needs or options available to the State.

Users of ArcGIS Desktop software will have the well-known training needs that they do today. However, with more personnel being productive in browser-based

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provides additional geoprocessing tools and bundles a number of extensions: http://www.esri.com/software/arcgis/about/gis-for-me.html. Similarly, GIS staff are already familiar with their Desktop Extension needs: http://www.esri.com/software/arcgis/about/desktop-extensions.html.

[7] For more information: http://resources.arcgis.com/content/white-papers?fa=viewPaper&PID=67&MetaID=1625.

[8] For more information: http://www.esri.com/industries/ela/index.html.

[9] RIDOH indicated its support for an ELA quite strongly, on more than one occasion, during this System Design project.

applications, there should be a reduced need for ArcGIS Desktop training[10]. Users of browser-based and mobile applications will have very limited training needs which likely can be met with in-house training tactics.

It is worth noting the skills and experience required of central administration staff. The investment in central resources will concentrate the need for Server and Developer expertise in a smaller group than decentralization by department. This makes training and certification investment in these individuals both more important and more cost effective. This report recommends cross-training at least two individuals in each of the areas below. Each area corresponds with an Esri certification that describes the requisite skills and knowledge. Courses listed identify related opportunities for training, should they be appropriate.

Enterprise Administration Associate (ArcGIS Server Admin)

- ArcGIS Server: Web Administration Using the Microsoft .NET Framework

Enterprise Geodatabase Management Associate (Data Admin)

- Managing Imagery Using ArcGIS
- ArcGIS Server Enterprise Configuration and Tuning for SQL Server
- Managing Editing Workflows in a Multiuser Geodatabase

Web Application Developer Associate

- Creating Effective Web Applications Using ArcGIS Server
- Authoring and Serving ArcGIS Mobile Projects
- Web Editing with ArcGIS Server 10
- Building Web Applications Using the ArcGIS API for Microsoft Silverlight/WPF

If the State wishes to more broadly address its GIS training needs, ESRI Educational Services offer a Training Plan[11] service that can help identify and tailor a training program for the needs of the entire organization, or just one part.

5.7 Application Tier Security

With few exceptions, the State did not identify significant security requirements with respect to the applications themselves. The Health Department stipulates that their security mandates (HIPAA and others) require them to maintain their own enterprise-class infrastructure separate from the rest of the State. They offered the following description:

> *RIDOH has been directed by the State CIO for the Private Drinking Water Wells Program to have a three-tiered security model. For which, they are using an SSL 3rd party certificate on a proxy server for client requests. The proxy server rule points to a Virtual VMWare Web Application Server with application ArcGIS Server*

[10] Esri's Training site provides a small application to help identify training opportunities appropriate to different needs: http://training.esri.com/gateway/index.cfm?fa=catalog.gateway&tab=0.

[11] For more information: http://www.esri.com/news/arcuser/0309/trainplan.html.

local-level security. Then these requests point to an ArcSDE database server that includes local user access securities.

For the remainder of State applications, it appears that simply providing the appropriate applications to the appropriate individuals is sufficient. This begins with having separate applications for the public and internally, that provide different functionality and data.

Three applications, however, will require additional security considerations. Accepting community updates (e.g. from Local Jurisdictions) to address and street data through E911, allowing digital submittals from HPHC contractors, and HPHC field data collection will benefit from additional security measures.

With respect to digital submission, contractors may be providing information that is proprietary in nature or, at the very least, should not be immediately visible to other contractors. And, the State needs a way to be certain of the identity of the submitter. For these reasons, this application should be protected with SSL encryption (using a 3rd party certificate) and application-tier security. Much of the information submitted is non-geographic and would require ASP.NET Forms-based Authentication, or a similar technology. An ArcGIS Map Service, with Feature Access enabled, should be secured with Token-based authentication.[12] The use of a Proxy Page pattern will provide very good security for the tokens themselves to protect the application against play-back attacks.[13]

These same patterns would be applied to the browser-based application that allows state personnel and contractors to collect and submit for consideration HPHC data. A key motivation for security provisions in this application is the sensitivity of archaeological areas. Most users should have access to generalized representations of the archaeological features. Users with specific needs should have access to the fully-detailed representation. An appropriate security pattern would be to start in the data tier with two different layers with different data access permissions. Two different map services would be published based on these different layers. Following authentication in the application tier, application logic would control which map service is presented to the end-user. An addition need for security in this application is to differentiate between HPHC and non-HPHC staff. Non-HPHC staff should have the ability to view data and propose changes. HPHC staff should have those rights, plus the ability to accept changes, accept with changes, or reject changes. Again, the two layer pattern, one for proposed changes and one for accepted data, can be used.

[12] For more information: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/Internet_security_overview/0093000000pp000000/.

[13] For more information: http://resources.esri.com/help/9.3/arcgisserver/apis/javascript/arcgis/help/jshelp_start.htm#jshelp/ags_proxy.htm.

Role-based authorization at the application tier would be used to provide appropriate access and rights to the data in the application.

With respect to accepting community update information, there is some value in knowing the identity of individuals offering the information. However, since the information must be field-verified before it is applied to the production database, the value of having certain knowledge of the identity of the contributors is low. In this case, the State could leverage a 3rd party system of Authentication such as Windows Live ID or it could implement its own with ASP.NET Forms-based Authentication[14] or a similar technology. Once authenticated, the application would be able to relate the identities of the community updaters with the information that they offer.

[14] For more information: http://msdn.microsoft.com/en-us/library/bb676633.aspx.

6.0 Data Architecture

This section presents the data repository, recovery model, and access patterns appropriate to the system design.

Specifically, this section addresses the data design needs of the central repository aspect of the State's enterprise GIS system. It does not address departmental needs that are planned to be addressed exclusively within those departments (such as the Health Department's management of its own data or EMA's management of its own data).

6.1 Thematic Inventory

The State's GIS data estimates are estimated to have the storage requirements below.

Theme	Today	3 Years
Vector[15]	1GB	1.3GB
Aerial Photography	2TB	Unknown
LiDAR and derived products	200GB	Unknown
Pictometry[16]	2TB	5TB

In addition to these requirements, the State will need storage for map caches for base maps. The map caches created by URI probably provide the best guidance about the likely storage needs for the caches that the State may want to house itself.

6.2 Repository Organization

Several logical repositories are appropriate for Rhode Island's central data storage needs. These logical repositories can and should be provisioned in a physically centralized manner.

6.2.1 Vector Data

Vector data should be managed in three central repositories.

RDBMS-based Transactional Repository

At least one SQL Server database should be used as a transactional repository for edits made by all ArcGIS clients (Desktop, Mobile, and Web Applications). Multiple databases may be useful to support (a) different back-up and recovery needs for different data and/or (b) different versioning strategies for different data. The single database schema (aka "dbo schema") should be used to allow each database to be completely separable from every other database for the purposes

[15] 10% growth per year.

[16] Pictometry is not a traditional GIS data asset. Currently, it is managed and served outside of Esri technologies. However, it is a useful data set for many GIS and non-GIS personnel.

of back-up/recovery and versioning. While versioning[17] can be useful to allow editing with advanced Geodatabase features such as Topology, Networks, Archiving, etc., it should be deployed only as needed. Non-versioned editing[18] is sufficient for many GIS editing needs and is considerably less complicated to administer and maintain. State GIS staff did not identify any datasets or editing requirements that clearly required the use of versioning technology.

RDBMS-based data warehouse

Read-only access to GIS data for viewing and analysis by ArcGIS Desktop clients should be provisioned with a SQL Server database that is used as a data warehouse. This should be a database that is separate from the transactional database(s). However, it may be in the same instance of SQL Server[19]. A dedicated database allows for (a) a schema that is optimized for query and analysis activities and (b) a separate back-up and recovery schedule appropriate to data that is refreshed on an interval (as opposed to transactionally updated).

File Geodatabase

ArcGIS Server services that do not support editing will perform better when using a File Geodatabase as their data source, than when using an RDBMS-based data source. Similar, automated ETL procedures that refresh the RDBMS-based data warehouse can be used to refresh a File Geodatabase. So, the cost of this repository is primarily the additional storage space for the File Geodatabase, which would be less than 1GB.[20]

6.2.1 Raster Data

The challenges of managing raster data are in (a) the volume of information and (b) the many types of uses there are for the data.

Optimal Solution

For the State of Rhode Island's needs, there is a very elegant and efficient solution that meets 99% of the requirements. This solution is to store all of the raster data in a central location, providing access through ArcGIS Server's Image Server Extension.

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[17] More information on versioning: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/What_is_a_version/00270000000q000000/.

[18] More information about non-versioned editing: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/A_quick_tour_of_working_with_nonversioned_data/002700000006000000/.

[19] Divergent instance-level configuration and tuning objectives could lead to the conclusion that the transactional and data warehouse repositories should be in separate SQL Server instances. But, that is an unlikely possibility, based on the conditions uncovered during the on-site engagement.

[20] Refreshing data sources that are served by ArcGIS Server requires attention to schema locks that act to preserve the function of services as data changes. Given the uptime requirements of the State, it is recommended that scheduled map service downtime be used to release the schema locks to refresh the data.

The Image Server Extension allows the many individual files to be served up as unified logical information products. This greatly simplifies the work of data viewers and analyzers as they no longer need to identify the specific files that they need and stitch-together the final information products. Image Server allows the data to be stored in its original format and served in a compressed form when sent over the network[21]. This eliminates the time-consuming and storage-intensive processes of cache-building and RDBMS data loading, and preserves the original pixel values for analytical purposes. The compressed data can be served to Web and Desktop applications for viewing purposes. And, Desktop users that perform analysis access the raw pixel values through the service.

There are two primary limitations to the use of Image Services for the State's needs. The Image Service data source is appropriate to all analytical operations, including Spatial Analyst operations. But, it is currently not supported with 3D Analyst. This means that Image Services cannot be used in ArcScene. However, 3D clients (ArcGlobe and ArcGIS Explorer) can be supported by including the Image Service in a Globe Service[22] which will support 3D visualization needs. In addition, Desktop clients that are performing analysis on large areas will need high-bandwidth pathways to the service end-points.[23]

Sub-Optimal Solution

If the State's Desktop analysis needs cannot be met completely with Image Server, either because of the functional requirements related to 3D Analyst or because of the bandwidth limitations of the clients, the alternative solution is to use Image Server Services for all circumstances except heavy Desktop analysis. Heavy Desktop analysis would require the ability to identify and copy specific files of interest to local storage on a Desktop computer for local analysis. This is inconvenient for end-users and imposes considerable storage requirements on end-user workstations. It also continues the problems of data duplication and analysis based on out-of-date information.

6.3 Back-up/Recovery

The Recovery Time and Recovery Point objectives for the central data resources can easily be met with traditional tape back-up and recovery strategies for the data assets.

The RDBMS-based, transactional repository should use SQL Server's Full

[21] Image Server is able to serve a variety of source formats. However, lossy-compressed formats (including wavelet compressed) are less optimal than lossless compressed formats: http://resources.esri.com/help/9.3/arcgisimageserver/help/index.htm#optimization_considerations_for_arcgis_image_server.htm.

[22] Information about Globe Services: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#//009300000n46000000.htm.

[23] Clients accessing the data for viewing purposes will retrieve highly compressed data and will often be working with "service overviews", not the raw pixels. This makes the network foot print much smaller.

Recovery Model and an automated schedule of Full, Incremental, and Transaction Log back-ups appropriate to the volume of edits.

The RDBMS-based data warehouse repository can use the Simple recovery model. In the event that this database is lost, it may be recreated from the transactional repository(s). The File Geodatabase for ArcGIS Server can similarly be reconstructed from the transactional repository if it is lost. So, there is not great value in backing up this database, unless administrators find it more convenient to recover from back-up.

Raster data products may not need back-up if media on which it is delivered to the State is (a) stored in a convenient, secure location and (b) relatively easily re-copied from delivery media if/when recovery is needed. If the delivery media are not convenient for this purpose, a single back-up of raster data products should be made when they are delivered.

6.4 Data Tier Security

As the State does not currently have an enterprise-wide system for authentication, RDBMS security must be provided with RDBMS user accounts. The use of RDBMS roles for Viewer, Editor, and Creator functions will ease the administrative burdens of managing user permissions.[24] The State's requirements for image security do not suggest a need for security, other than to limit access to the source data so that it is not inadvertently deleted. Image Services can be secured with Token-based authentication if the State subsequently develops a need to restrict viewing and analysis access to certain datasets within the population of State employees.[25]

[24] For more information on RDBMS authentication with SQL Server: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/Adding_database_authenticated_logins_to_a_SQL_Server_database/002q0000002m000000/. For more information about roles with SQL Server: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/User_permissions_for_geodatabases_in_SQL_Server/002q0000002s000000/.

[25] Information about the Token Service: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/Configuring_the_Token_Service/0093000000q5000000/.

7.0 Technology Architecture

This section presents the technology portion of the system design described in this report. It includes the capacity calculations for the loads on the server and network infrastructure.

7.1 Existing Infrastructure

The State's existing hardware includes the following server systems:

Site	Server Function	Model	Cores	Spec/ Core	Mem (GB)	Storage (GB)
2 Cap Hill	DB_SVR	PowerEdge M600 (Intel Xeon E5430, 2.66 GHz)	8	13	8	900
HDOC	GIS_SVR	PowerEdge 2950 III (Intel Xeon X5470, 3.33 GHz)	8	16.75	32	540
New London	DB_SVR	PowerEdge R210 (Intel Xeon L3426, 1.86 GHz)	4	19.275	32	1800
New London	GIS_SVR	PowerEdge R210 (Intel Xeon L3426, 1.86 GHz)	4	19.275	32	450
URI	DB_SVR	PowerEdge T300 (Intel Xeon E3113, 3.00 GHz)	2	21.25	4	0
URI	GIS_SVR	PowerEdge R410 (Intel Xeon X5560, 2.80 GHz)	8	28	32	0
URI	WEB_SVR	PowerEdge 2900 III (Intel Xeon X5260, 3.33 GHz)	4	17.42	16	0

The State has a varied WAN infrastructure. The Capitol Hill campus and Pastore site are served by a SONET ring with relatively high bandwidths. Other sites have bandwidths ranging from 2 T1's to fractions of a T1. Details appear in the Capacity section below.

The State reports that “primary” sites have 100Mbps segments to client machines with 1Gbps backbones. Other sites have 10Mbps to client machines.

7.2 Target Design

As previously described, the target design provides a central system of data, service, and application resources available from the Capitol Hill campus and used, along with local department resources, throughout the State’s organization.

7.2.1 Design Over-All

The following diagram shows a map-based schematic of the workflow-infrastructure relationships of the system over-all.

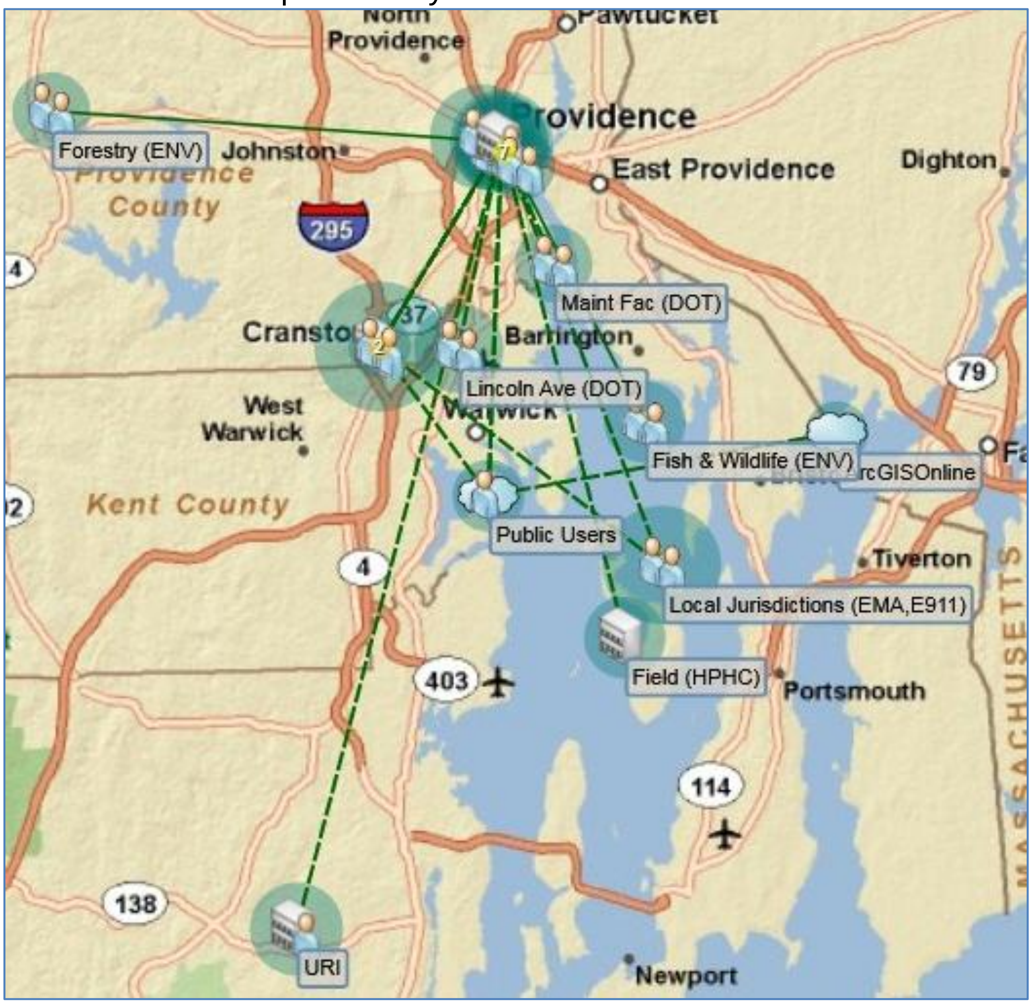

Figure 11: Solution Overview Map

The touch-stone of the design is a common ArcGIS Server system that serves applications and services to business units that require GIS capabilities throughout the State. This design provides a low-administration, low-cost-per-user pathway to provide critical GIS-based capabilities to a wide variety of business units and users throughout the State. The Workflow Traceability diagram below illustrates the number of workflows, and their locations, that are supported by the central infrastructure in this design. Note that the GIS Server supports the largest number of workflows.

Workflow	Site
Data Discovery DOA	1 Cap Hill
Plan & Analysis (DOT)	1 Cap Hill
Data Discovery DOT	2 Cap Hill
TMC (DOT)	2 Cap Hill
View HPHC Projects (DOT)	2 Cap Hill
Work Order Mgmt (DOT,CH)	2 Cap Hill
Data Discovery HPHC	Benefit St
HPHC Updates	Benefit St
Field Data Sync (HPHC)	Field
Data Discovery ENV	Fish & Wildlife
Project Work (ENV)	Fish & Wildlife
Viewing (ENV)	Fish & Wildlife
Data Discovery ENV	Forestry
Viewing (ENV)	Forestry
Data Discovery ENV	Foundry
Project Work (ENV)	Foundry
Viewing (ENV)	Foundry
Data Discovery HE	HDOC
Data Discovery DOT	Lincoln Ave
Work Order Mgmt (DOT,Lincoln)	Lincoln Ave
Community Data Updates (LJ)	Local Jurisdictions
View & Doc Access (DOT)	Maint Fac
Work Order Mgmt (DOT,Maint)	Maint Fac
Data Discovery EMA	New London
Data Discovery HE	Pastore
Health Workflows HE	Pastore
General Public Access	Public Users
Health Workflows PU	Public Users
HPHC Contractors	Public Users
View HPHC Projects	Public Users
Data Discovery URI	URI

Workflow	Site
GIS Editing (DOT)	2 Cap Hill
Map Production (DOT)	2 Cap Hill
TMC (DOT)	2 Cap Hill
Work Order Mgmt (DOT,CH)	2 Cap Hill
HPHC ETL	Benefit St
Field Data Sync (HPHC)	Field (HPHC)
ETL Project Data	Fish & Wildlife
Aerial Survey (ENV)	Forestry
Enforcement (ENV)	Foundry
Project Work (ENV)	Foundry
View & Analysis (DOT)	Lincoln Ave
Work Order Mgmt (DOT,Lincoln)	Lincoln Ave
Community Data Updates (LJ)	Local Jurisdictions
Work Order Mgmt (DOT,Maint)	Maint Fac
HPHC Contractors	Public Users
View HPHC Projects	Public Users
Desktop Analysis (RIDE)	RIDE

Workflow	Site
Desktop Analysis (RIDE)	RIDE
Enforcement (ENV)	Foundry
View & Analysis (DOT)	Lincoln Ave
Aerial Survey (ENV)	Forestry

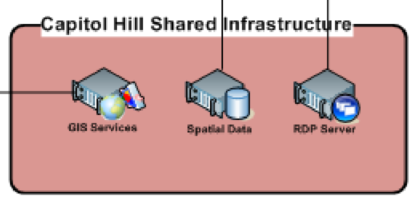

Figure 12: Workflow to Hardware Traceability Diagram

The primary costs of this design approach are in (a) providing appropriate WAN bandwidth (discussed in the Capacity section that follows) and (b) provisioning staff and systems to provide the requisite uptime (listed in Business Architecture section).

The second hallmark characteristic of this report's design is the continued use of ArcGIS Desktop technologies throughout the organization. ArcGIS Desktop has been a successful implementation pattern for the State for a number of years. It is most successful where in the hands of GIS professional and some non-professionals which have GIS as a significant portion of their regard duties. The only proposed change for these users is the use of a central RDBMS repository for vector data and the use of Image Services for raster data. In addition, for new users, and occasional users, this report recommends deploying the ArcGIS Desktop software via Citrix or WTS as discussed in more detail below.

ArcGIS Desktop has been less successfully deployed for non-GIS professionals and occasional GIS users. This report recommends transitioning these kinds of users to browser-based applications as they are easier to support and have a much lower training requirement.

7.2.2 Hardware Virtualization

Hardware virtualization allows physical systems to be aggregated and subdivided into virtual machines with resources that are right-sized to the loads that they must serve. Esri testing and customer experience confirms that ArcGIS Server technology can be successfully deployed with hardware virtualization. In addition to cost-savings through right-sizing, virtualization provides a mechanism to provide high availability or improved system uptime by allowing virtual systems to be moved to alternate hardware in the case of failure or planned maintenance.

For these reasons, this design proposes that the central ArcGIS Server system be provisioned on virtual hardware.

This report recommends physical systems for the other (RDBMS and XenApp) server systems for reasons discussed in the Capacity section below).

7.2.3 Application Virtualization

Application virtualization (a.k.a. “Session Virtualization”, “Presentation Virtualization”, or “RDP Server”) allows ArcGIS Desktop users to access the full power of the ArcGIS Desktop suite in a way that is easy to administer and provides performance over limited network bandwidth. ArcGIS Desktop software runs on central server systems. The reduced network bandwidth loads are achieved by light-weight display information is shipped to connected clients and light-weight keyboard and mouse commands being sent to the servers where the commands are executed.

Esri testing and customer experience confirm that virtualization can be successfully delivered through XenApp and/or Windows Terminal Server (WTS) systems. Successful implementations depend on the following:

1. Users do not need to need ArcGIS Desktop when disconnected from the network[26]
2. Minimum effective bandwidths start at 128Mbps (single user, no raster content)
3. Users with limited bandwidth do not require the use of large datasets that are stored on their local systems or output to their local systems
4. 3D visualization is not supported

As the State has many existing ArcGIS Desktop users, this report does not propose replacing their current deployments with Citrix or WTS. However, Citrix/WTS should be the default choice for new ArcGIS Desktop deployments going forward and should be considered for any existing users that use the software infrequently. This will provide a gradual way to help the State achieve

[26] In principle this can be provisioned with “VDI” solutions. However, there is no Esri test data and little customer experience to date.

its goals of improved system reliability and uptime in a highly cost-effective manner. As users are added to this system, the State should consider an Active-Active N+1 redundancy model for these servers. In practice, this would mean adding a second server.

7.2.4 Data Formats and Access

The Data Architecture section offers a detailed discussion of the design of the central data repositories. At a highly level, an RDBMS repository is recommended for the vector data for following needs only:

1. Editing against a central repository (Desktop, Browser, or Mobile)
2. ArcGIS Desktop visualization and Analysis

An important implication of this is that the majority of data access needs can be provisioned through ArcGIS Server's use of file Geodatabases that are local to it and ArcGIS Server Image Services. This strategy will provide the best performance and scalability. The cost of this approach is a small amount of vector data duplication and scheduled ETL processing. Among the advantages of this approach, however, are improved uptime for server systems.

7.2.5 Storage

One of the hallmark characteristics of the central GIS resource needs is storage. While the central processing burdens of the GIS activities do not require a large number of server cores, the amount of data that is required is substantial. Consolidating these data resources into a central repository avoids the alternative expense of providing duplicate storage across several departments. So, while the line-item to provision this central storage may appear significant, many alternatives would be more costly (though may not appear as clearly in a central budget).

The report recommends that the server storage needs of the central ArcGIS Server system be provided with SAN storage. In part, this is driven by the IT standard of provisioning virtual machine storage from the SAN. However, an equally important consideration is to help the State achieve its uptime objectives.

SAN systems are typically configured to provide excellent storage uptime and resilience to failure of individual disks within their subsystems. Compared to many local, physical disk configurations, this provides much better uptime for server systems.

The use of SAN storage for the ArcGIS Server system would like require SAN infrastructure investment beyond the State's current-year budget plans. However, the time horizon for this design is three years which allows an opportunity to incorporate SAN expansions in future budget years.

7.2.6 Public Access and Public-Facing Applications

Reverse Proxy technology provides a commonly-implemented pattern for allowing public users access to internal server systems with very limited security implications. The primary competing pattern is the provisioning of a duplicate server infrastructure in a perimeter network (a.k.a. “DMZ”). That approach further reduces the theoretical “attack surface” at the cost of considerable additional infrastructure and administrative burden.[27]

The Health Department has already pioneered the use of Reverse Proxy within the State. This report recommends extending this pattern to the central ArcGIS Server system envisioned in this design. This will leverage the central investment and provide a single infrastructure to provision with uptime procedures and systems (which is one of the most difficult tasks and significant costs in system administration).

In addition, this report recommends using ArcGIS Online Base Map services for all public-facing applications. ArcGIS Online provides a variety of vector and imagery base map services which are updated by Esri, Esri customers, and commercial data providers.[28] Use of these services provides a highly scalable, highly available system for base map content at no cost.

Use of these base maps in public facing applications also reduces the uplink bandwidth burden on the State’s Internet gateways as the base map content does not pass through the State’s infrastructure at all. This is very valuable as uplink bandwidth is typically more costly than downlink bandwidth.

For internal applications, this report recommends using internal base maps and image services for two reasons. First, this saves the State on downlink Internet bandwidth. Second, internal base map requirements may be better served with different content cartographic standards than are available from ArcGIS Online[29].

7.3 Capacity

The system design for the State’s enterprise GIS system emphasizes the use of existing hardware and network resources and attempts to minimize the needs for new or upgraded infrastructure.

7.3.1 Production Server Hardware

The following table summarizes the server hardware that would support this design and capacity. New hardware is highlighted in yellow.

[27] Additional information on Firewalls and Reverse Proxys with ArcGIS Server: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/Firewalls_and_ArcGIS_Server/0093000000p8000000/.

[28] More information about ArcGIS Online services: http://www.esri.com/software/arcgis/arcgisonline/standard-maps.html

[29] For example: internal-only imagery, use of a local coordinate system, label/annotation styles tailored to internal applications.

Site	Server Role	Model	Virtual	Core	% Util	Spec / Core	Active/ Passive
2 Cap Hill	APP_SVR	ProLiant SL170z G6 (2.93 GHz, Intel Xeon X5570)	FALSE	8	2.4	30.75	1
2 Cap Hill	DB_SVR	PowerEdge M600 (Intel Xeon E5430, 2.66 GHz)	FALSE	8	2.2	13	1
2 Cap Hill	GIS_SVR	ProLiant SL170z G6 (2.93 GHz, Intel Xeon X5570)[30]	TRUE	4	37.8	30.75	1
HDOC	GIS_SVR	PowerEdge 2950 III (Intel Xeon X5470, 3.33 GHz)	FALSE	8	1.3	16.75	1\1
New London	DB_SVR	PowerEdge R210 (Intel Xeon L3426, 1.86 GHz)	FALSE	4	N/A	19.27	1
New London	GIS_SVR	PowerEdge R210 (Intel Xeon L3426, 1.86 GHz)	FALSE	4	47.6	19.27	1
URI	DB_SVR	PowerEdge T300 (Intel Xeon E3113, 3.00 GHz)	FALSE	2	N/A	21.25	1
URI	GIS_SVR	PowerEdge R410 (Intel Xeon X5560, 2.80 GHz)	FALSE	8	N/A	28	1
URI	WEB_SVR	PowerEdge 2900 III (Intel Xeon X5260, 3.33 GHz)	FALSE	4	N/A	17.42	1

[30] This is an 8 core system in its physical form. Any number of cores (4 or greater) can be used for the hypervisor. The specification of this system is simply to indicate an appropriate class of processor technology. The key factor is the per-core spec rate (30).

2 Capitol Hill Database Server

The existing database server at 2 Capitol Hill offers considerably more processing power than is needed for the demands of the GIS system. In principle, this makes it a candidate for hardware virtualization. However, Esri has found that successful hardware virtualization with RDBMS systems can be difficult. This is because RDBMS systems are often sensitive to storage i/o and storage i/o is common bottleneck with hardware virtualization. For this reason, Esri does not recommend hardware virtualization for RDBMS servers. However, that remains an option if the State is looking for ways to consolidate server hardware.

2 Capitol Hill Application Virtualization Server

This report recommends the acquisition of a new server for the XenApp software. The primary objective in system specification in the table above is to obtain the best available per-core SPEC rate with the fewest number of cores. XenApp systems are very sensitive to processor capacity, so it is critical to provide a system with per-core SPEC rates that are as high as possible. Due to contemporary server standards, this means purchasing a minimum of 8 cores. Like the database system, this system would have a low level of utilization based on the number of concurrent users. This is proposed as an acceptable cost of doing business for two reasons. First, this report recommends that the State use Citrix, instead of local Desktop installations, as much as possible going forwards. This will mean that the utilization of this system will grow over time. Second, Esri customer experience with running XenApp on virtualized hardware has been mixed. While some customer sites report success, others report many performance and scalability problems. At this time, Esri does not recommend using hardware virtualization with application virtualization for its ArcGIS Desktop technology.

2 Capitol Hill ArcGIS Server

This server is specified as a virtual server with 4 virtual cores. This provides reasonable processor utilization with room to grow. The details of the system specification are for the underlying hypervisor. The details other than the per-core SPEC rate are relatively unimportant. So long as the per-core SPEC rate of the underlying system is high (around 30), and there are 4 cores assigned to the virtual system, the system will meet this report's design specification. Esri's testing, and considerable customer experience, indicate that hardware virtualization is quite compatible with most uses of ArcGIS Server technology.[31]

The well-designed[32] use of hardware virtualization offers many important benefits beyond improved utilization. Hardware virtualization also provides important

[31] Esri's observations are summarized in this white paper: http://www.esri.com/library/whitepapers/pdfs/arcgis-server-virtualization.pdf.

[32] A well-designed virtual machine would have a modestly-sized boot volume that contains the operating system and applications and separate volume or volumes containing the data resources. In the case of ArcGIS Server, these data resources are considerable (i.e. raster data,

opportunities to protect the system from hardware failures and meet the State's uptime objectives. In the event of hardware failure, the virtual machine could be spun-up on another system.

Other Servers

As the workload information for the Health Department's servers was incomplete, the utilization shown in the table is unlikely to be what actually occurs. The utilization of the New London GIS server is fairly good, given the reported workloads. Workload information for the URI servers was not available for this report.

Replacement Cycle

Server hardware should be on a replacement cycle that keeps machines under warranty. Servers running ArcGIS Server or Citrix technology should be on a 3-year replacement cycle as a minimum standard. These technologies are very sensitive to changes in processor capacity and aging chip technology will not be able to deliver contemporary performance standards for end-users.

7.3.2 Production Software Licensing and Hardware Summary

The following table summarizes the software and releases that should be deployed on server hardware (existing and new).

Site	*Host*	*Cores*	*Software*	*Release*
2 Cap Hill (DOT)	APP_SVR	8	Citrix XenApp	Current
	DB_SVR	8	SQL Server	2008
	GIS_SVR	4	ArcGIS Server .NET	10.0
			Geoportal Extension	10.0
			IIS	7
HDOC	GIS_SVR	8	ArcGIS Server .NET	10.0
			IIS	7
			SQL Server	2008
New London (EMA)	GIS_SVR	4	ArcGIS Server .NET	10.0
			IIS	7
	DB_SVR	4	SQL Server	2008

map caches, file Geodatabase, etc.), so separating them from the systems-portion of the virtual machine helps with management.

7.3.3 Production Client Hardware

Client hardware running ArcGIS Desktop should be performance-oriented workstations and should be on a 3-year replacement cycle to maintain performance standards. Esri's Hardware Partner's Promotional Offers provides examples of contemporary systems.[33]

Client hardware for web browser applications and Citrix clients have no unique system requirements and can be provisioned according to the standards of the organization.

A variety of mobile hardware designs and capacities are available based on the specific needs of field personnel. Esri's Hardware Partner's Promotional Offers provides examples of a variety of form factors and capabilities.

7.3.4 Network

The following table shows the stated[34] site gateway bandwidths and the calculated loads[35] for those gateways. In most cases, the calculated loads are well within the stated limits. Rows what that is not clearly the case have been highlighted in pink.

Site	Type	Gateway	Stated Mbps	Calc Load (Mbps)
1 Cap Hill	WAN	inet	0	0
1 Cap Hill	WAN	sonet	150	2.03
2 Cap Hill	WAN	inet	0	11.68
2 Cap Hill	WAN	sonet	150	19.65
Benefit St	WAN	inet	0	0
Benefit St)	WAN	wan	1.54	0
Fish & Wildlife	WAN	inet	0	0
Fish & Wildlife	WAN	wan	0.38	1.02
Forestry	WAN	inet	0	0
Forestry	WAN	wan	0.38	0.04
Foundry	WAN	inet	0	0
Foundry	WAN	sonet	150	13.06
HDOC	WAN	inet	0	1
HDOC	WAN	sonet	150	0.05
Lincoln Ave	WAN	inet	0	0
Lincoln Ave	WAN	wan	3	2.29
Maint Fac	WAN	inet	0	0
Maint Fac	WAN	wan	0.38	1.16
New London	WAN	inet	0	20.62

[33] Hardware Promotions page: http://www.esri.com/partners/apps/hw_promo/index.cfm.
[34] Cases where gateway bandwidth was not available show "stated" values as "0".
[35] Calculated loads exclude values for most Workflows from the Internet. See "Assumptions and Constraints" for additional information.

New London	WAN	wan	0.38	0
Pastore	WAN	inet	0	0
Pastore	WAN	sonet	50	0
PSAP	WAN	inet	0	0
PSAP	WAN	wan	1.54	0
RIDE	WAN	inet	0	0
RIDE	WAN	wan	1.54	0.1
URI	WAN	inet	0	N/A[36]
URI	WAN	wan	0.38	0

Calculated Internet gateway bandwidths should be checked against the bandwidths of the pathways to the Internet from these sites.

WAN gateways bandwidths that appear in yellow should be upgraded to meet the projected load. As most of the workflows at these facilities are browser-based or rely on disconnected editing workflows, there are no design options to reduce the network loads that do not adversely impact the work itself.

7.4 Staging and Development

Staging and Development environments are critical resources for the provisioning of reliable GIS systems.

7.4.1 Staging Environment

Individual departments, including Health and EMA, have made their own arrangements for staging and development systems.

Staging environments provide resources for the following activities:

1. User Acceptance Testing (UAT). Prior to rolling-out new applications or releases, users should test the system before it is deployed in a production environment.
2. Production Deployment Procedure Development. Prior to making changes to production systems, the procedures should be tested and documented on a system that is a close match for the production system in terms of software releases and configuration.
3. Service Staging. Staging environments are also useful to allow end-users to prepare map and data resources for publishing on a production ArcGIS Server system.
4. Developing and Validating Recovery procedures. Staging environments are also useful for developing recover from back-up procedures. Once developed, these procedures should be regularly validated to confirm that the integrity of back-ups and the preparedness of staff generate the correct results in a timely fashion.

[36] No information was provided about Internet workload frequency for the Internet-facing services and applications at URI.

The regular use of staging systems for this purpose increase the reliability and uptime of systems by increasing the number of issues that are caught and resolved outside of the production environment.

It is valuable for staging systems to match the software release and configuration details of the production systems that they support. However, staging systems can be provisions with much lesser resources. This report recommends the use of virtual machines for a staging environment for the common central system of the Rhode Island enterprise GIS. URI may wish to consider establishing its own staging environment for these purposes as well.

7.4.2 Staging Hardware and Licenses

A single hypervisor, or portions of an existing cluster of hypervisors, could be used to provision virtual servers for the following purposes:

Function	Virtual Cores	Software
DB_SVR	1	RDBMS
GIS_SVR	1	ArcGIS Server, Image Server, Geoportal Server
APP_SVR	1	XenApp

Most vendors, including Esri, offers server licensing to help make this critical function more affordable.

In addition to the staging servers, a small number of physical client machines should be used for UAT activities. It may be possible to use an existing training lab for such purposes.

7.4.3 Development Environment

Development environments provide resources for the following activities:

1. Application Development: Application developers build new functionality.
2. Functional/Unit Testing: Functional and unit testing should be performed on all newly developed features and software upgrades in a development environment before going on to UAT.

Development environments are usually provisioned to individual machines assigned to development or system administration personnel. Esri provides “EDN” licenses to support these environments.[37]

8.0 Business Requirements Traceability Summary

The design and recommendations in this report are designed to meet the business drivers identified by the State in a manner that is consistent with its

[37] Information about the ESRI Developer Network (EDN): http://www.esri.com/software/arcgis/edn/index.html.

constraints and preferences. The following tables relate these design elements and recommendations to the identified business drivers.

8.1 Shared Business Drivers

No.	Item	Description
1	Reduce data duplication	Most datasets are consolidated into the central, physical repository. Data duplication occurs only to overcome network limitations.
2	Improve the currency of data used for analysis and visualization	Internet-facing applications allow for Local Jurisdictions, and others, to submit information updates for review by appropriate staff.
		Intranet applications allow subject-matter experts in business units to perform data maintenance themselves rather than queuing updates for GIS professionals.
		All business units have access to common services and data sources that always contain up-to-date data.
		A Data Search & Discovery system allows GIS resources to be discovered, regardless of where it is or how it is accessed.
3	Decentralize data maintenance	Intranet applications allow subject-matter experts in business units to perform data maintenance themselves rather than queuing updates for GIS professionals.
4	Improve GIS system availability and stability	Centralized GIS systems are designed to perform at contemporary standards and scale to the anticipated loads.
		Use of virtualization provides a highly affordable approach to high availability
		Centralized administration by an appropriately skilled, cross-trained staff
		Use of SAN increases uptime of data resources over local disk systems.
		Appropriate use of Staging and Development Environments catch problems outside of Production
		ArcGIS Online provides highly available base map services for public facing web applications.
		A single ArcGIS Server infrastructure, for public-facing and internal-facing applications allows better administrative procedures and attention, benefiting both types of applications.

5	Improve utilization of systems resources	Centralization of data, service, and application infrastructure increases utilization over duplicate infrastructures in business units.
		Hardware virtualization allows right-sizing of ArcGIS Server.
		Access to imagery through Image Server eliminates the need to copy large datasets to locations where they get little use.
6	Use of standards in data and development	The central repository provides an opportunity to define standards for how information is represented in schemas.
		Staging and Development Environments allow for the shared development of standard approaches to data modeling.
7	Maintain and evolve a coordinated approach to GIS	The design is predicated on business units collaborating and coordinating in their GIS efforts.

8.2 Departmental Business Drivers

No.	Item	Description
DOT1	Support performance management	The applications and workflows planned for DOT personnel will captures data appropriate for performance management.
		Use of browser-based applications allows access by non-GIS professionals that is critical to sharing and making use of performance information.
DOT2	Improve design by providing feedback from maintenance	The applications and workflows planned for DOT personnel will captures data appropriate for performance management.
		Use of browser-based applications allows access by non-GIS professionals that is critical to collaboration.
DOT3	Allow GIS users access to CAD design data	Automation of this process does not appear practical at this time as DOT reports that CAD drawing standards are not automation-suitable.
DOT4	Improve coordination with HPHC	Use of browser-based applications allows access by non-GIS professionals that is critical to collaboration.
DOT5	Develop transportation asset and workflow management solution	This system can be supported with the design described in this document. However, this system's workflows were not fully uncovered. Therefore, they are not explicitly listed throughout the document and they are not part

		of the capacity calculation.
EMA1	Better sharing of information with emergency personnel in the field	Use of browser-based applications allows access by non-GIS professionals over low-bandwidth links. Unlike emailed PDF documents, information can be dynamic as situations evolve.
HPHC1	Improved field data collection by staff and contractors	The Field Data Collection pattern allows field inspectors to be more productive.
RIDE1	Improve facility planning and build public consensus around 5 year plans	The applications and workflows planned for RIDE personnel will support this objective.
URI1	Improve the reliability of public facing services and applications	Not directly addressed by this report.
URI2	Maintain less hardware and simplify	Not directly address by this report.
URI3	Make it easier for participants to publish data/services	Consider the use of a Staging Environment.

8.3 Business Continuity / Availability

No.	Item	Description
1	Data recovery time objective	Appropriate data recovery models and back-up provisions.
		Use of SAN eliminates the need for many recovery scenarios.
2	Data recovery point objective	Appropriate data recovery models and back-up provisions.
		Use of SAN eliminates the need for many recovery scenarios.
3	Disaster Recovery Facility	The enterprise GIS does not need to operate in the case of the loss of its production facilities in the case of a disaster. EMA and E911 require separate provisions for Disaster Recovery Facilities
DOT1	98% Uptime Requirement	Use of virtualization provides a highly affordable approach to high availability
		Centralized administration by an appropriately

		skilled, cross-trained staff
		Use of SAN increases uptime of data resources over local disk systems.
		Appropriate use of Staging and Development Environments catch problems outside of Production
Health1	99.9% Uptime Requirement	Health has already implemented a design for this objective.
E911_1	Uptime Requirement	E911 does not maintain any server systems. A full complement of individual user workstations, with all data resources local, must be operational at all times.
E911_2	Disaster recovery	E911 maintains a disaster recovery facility.
EMA_1	EMA access	A recent copy of all common datasets need to be available in the EMA in the case of emergency and absence of network connections
EMA_2	99.99% Uptime requirement	Not addressed directly in this report.
EMA_3	Disaster recovery	EMA is working on provisions for a disaster recovery facility.

9.0 Appendices

9.1 Summary of New Hardware and Software

This report recommends a number of hardware and software additions and improvements. They are summarized in the tables below. Client hardware and software is not included.

9.1.1 New Production Server Hardware

Server Role	Model	Virtual	Core	Spec/ Core	Active/ Passive	Software
APP_SVR	ProLiant SL170z G6 (2.93 GHz, Intel Xeon X5570)	FALSE	4	30.75	1	Citrix XenApp
GIS_SVR	ProLiant SL170z G6 (2.93 GHz,	TRUE	4	30.75	1	ArcGIS Server, Image

	Intel Xeon X5570)[38]					Server Extension, Geoportal Server

GIS staff should work with IT staff to identify the amount of SAN storage that would be necessary to support these new systems, in addition to

9.1.2 New Staging Hardware and Software

Function	Virtual Cores	Software
DB_SVR	1	RDBMS
GIS_SVR	1	ArcGIS Server, Image Server, Geoportal Server
APP_SVR	1	XenApp

The storage needs of the staging environment should also be factored into the Capitol Hill SAN storage needs.

9.1.3 Network Gateway Upgrades

Site	Type	Gateway	Stated Mbps	Calc Load (Mbps)
2 Cap Hill	WAN	inet	0	11.68
Fish & Wildlife	WAN	wan	0.38	1.02
Forestry	WAN	wan	0.38	0.04
HDOC	WAN	inet	0	1
Lincoln Ave	WAN	wan	3	2.29
Maint Fac	WAN	wan	0.38	1.16

Network gateways should have a nominal capacity that considerably exceeds the calculated loads in this table to accommodate (a) other non-GIS uses of the gateway and (b) the fact that it is not practical to get 100% of the nominal bandwidth out of a gateway.

9.1.4 Development Environment

EDN licenses should be acquired as needed for developers.

9.2 Participants

Emily Pysh, Mitigation Officer, RI Emergency Management
Christina Delage Baza, GIS Specialist II, RI DOA, Division of Planning
John Washburn, Operation Chief, RI Emergency Management
Shane White, GIS Coordinator, RI DOA Division of Planning
Paul Jordan, GIS Manager, RI Dept of Environmental Management
Steve Kut, GIS Manager, RI DOT
Greg Bonynge, Geospatial Extension Specialist, URI Environmental Resource Center
Jared Rhodes, Chief, RI_DOP/State-wide Planning

[38] This is an 8 core system in its physical form. Any number of cores (4 or greater) can be used for the hypervisor. The specification of this system is simply to indicate an appropriate class of processor technology. The key factor is the per-core spec rate (30).

Bill Lincourt, DBA, RI DOT
Greg Scungio, Principal Project Manager, RI 911
Kevin Baillargeon, AK Associates GIS Analyst, RI 911
Bill Gasbarro, Contracts and Specifications Officer, RI 911
Steve Sawyer, GIS Manager, RI DOH
Patrick Craft, Private Well Program, DI DOH
Manuel Cordero, Asst School Construction Coordinator, RIDE
Joseph da Silva, School Construction Coordinator, RIDE
Rick Greenwood, Deputy Director, RIHPHC
Barry Simpson, Principal Historical Preservation Specialist, RIDOT – Cultural
Ted Cooper, IT Guy, DOIT DOH
Chuck LaBash, EDC, URI,
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John Cassidy, Account Executive, Esri
Paul Rooney, Account Executive, Esri
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9.3 Implementation Best Practice Notes

9.3.1 Manage Map Size in Browser-based Applications

In browser-based GIS applications, the map accounts for the vast majority of the network bandwidth utilization of the application. The size of the map is the main factor controlling the level of utilization. For each doubling of an image dimension (e.g. doubling of map width), the size (in bytes) of the image quadruples. As WAN bandwidth resources are limited, controlling the size of the map canvas may be the single most important opportunity to control end-user performance and system scalability. For example, the Texas Beach Watch application has a map of the same size regardless of the size of the client's screen. As a result, the average transaction payloads are reliably in the 75-150KB range. The Washington Interactive Geologic Map, by comparison, has a transaction payload that varies based on the size of the browser window. The range starts at 150KB and can easily run as high as 500KB for browser windows that are maximized to common desktop screen dimensions and resolutions[39].

[39] The lower end of the range starts at a higher value because the application allows many, complex map services to be included in the map simultaneously. Some Streamline applications will require similar design, which is why it will be important to manage the size of the map canvas.

9.3.2 Map Service Image Format

ArcGIS Server supports a wide variety of image formats when publishing map and image services. Optimizing format selection is import for managing image quality and network payloads.

Map services should include only vector data[40]. Raster data should be published via Image Services. This separation of content allows each type to be compressed with an optimal algorithm for quality and size. Map services get best results with PNG8. PNG formats with greater bit depth (e.g. PNG16, 24, and 32) allow for more color depth in ranges that most users and applications cannot appreciate.[41] For Image Services, JPEG compression adds a small amount of processing time on the server, which is normally worthwhile for the benefit in reduced network transport time[42].

9.3.3 Database Connections

Esri technology can connect to RDBMS-based Geodatabases in two ways. The best practice is to use the "direct connect" configuration method.

A server-side ArcSDE process can broker connections to the RDBMS. In this case, Esri technology manages the network parameters between client and server. This configuration is sometimes called, "application server connect".

The other method, called "direct connect", makes use of RDBMS networking. Instead of converting client commands to SQL statements on the server-side, the translation happens on the client. This configuration, "direct connect", is the preferred method for a variety of reasons. First, it offers greater compatibility with a variety of RDBMS high availability techniques that "application server connect" does not. Second, if the ArcSDE server-side process is not deployed, there is no ArcSDE-related licensing required for that machine. Finally, most performance metrics show "direct connect" out-performing "application server connect".

9.3.4 Cartographic Optimizations

ArcGIS offers many techniques for optimizing maps for cartographic expressiveness with fast display times. The same principles and techniques apply to both Server and Desktop environments. The following links provide valuable guidelines for both environments:

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[40] Map services should also not include other map services in their definition. Map services should integrate at the application level, not be "in-lined" at the service-definition level.

[41] This discussion of image formats suitable for map caches also applies to the image format for dynamic map services: http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/Available_map_cache_properties/00930000006r000000/.

[42] See discussion here: http://help.arcgis.com/en/imagemanagement/10.0/help/imageserver_sm/index.html#/Optimization_considerations_for_ArcGIS_Image_Server/008r00000020000000/.

- http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#/Map_authoring_considerations_for_ArcGIS_Server/009300000052000000/
- http://help.arcgis.com/en/arcgisserver/10.0/help/arcgis_server_dotnet_help/index.html#//00930000006q000000.htm
- http://blogs.esri.com/dev/blogs/arcgisserver/archive/2008/08/05/design-patterns-for-web-maps.aspx
- http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00sq00000018000000.htm

While not an optimization per se, Cartographic Representations provides the ability to store a dataset's symbols with the dataset itself in the Geodatabase. While this is display-time neutral, it offers the benefit of providing end-users with one or more default representations of data when accessing it directly from the database. This helps to promote a common look-and-feel for data in the organization, simplifies the use of data for most end-users, and continues to provide "power-users" with maximum cartographic flexibility.

9.4 Capacity Plan User Workflow Detail

The following table lists details about the frequency of the user workflows used in the capacity calculation.[43]

Site	Workflow	Users Total	Users Active Total	Pacing (Sec)	Throughput (Wkf/hr)
1 Cap Hill (DOA)	Data Discovery DOA	1	1	3600	0
1 Cap Hill (DOA)	Plan & Analysis (DOT)	9	3	0	0
2 Cap Hill (DOT)	Data Discovery DOT	1	1	3600	0
2 Cap Hill (DOT)	GIS Editing (DOT)	0	0	0	0
2 Cap Hill (DOT)	Map Production (DOT)	1	1	0	0
2 Cap Hill (DOT)	TMC (DOT)	7	7	0	0
2 Cap Hill	View HPHC	3	3	1800	0

[43] After the initial delivery of this report, the State clarified preferred design pattern options for HPHC field data collection workflows. Rather than using ArcGIS Server Mobile, they specified that they preferred to use a browser-based application. The target number of active users for the workflow is without consequence for the server capacity calculations. It is estimated that the existing T1 network connection for these users would be sufficient to support this workflow in a browser. In addition, the State added information about an asset management workflow at DOT. That asset management workflow can be supported by the design patterns in this document. But, there was insufficient information to include it in the capacity calculation.

(DOT)	Projects (DOT)				
2 Cap Hill (DOT)	Work Order Mgmt (DOT,CH)	15	10	0	0
Benefit St (DOT/HPHC)	Data Discovery HPHC	1	1	3600	0
Benefit St (DOT/HPHC)	HPHC ETL	0	0	0	0
Benefit St (DOT/HPHC)	HPHC Updates	5	1	1800	0
Field (HPHC)	Field Data Collection (HPHC)	4	4	0	0
Field (HPHC)	Field Data Sync (HPHC)	0	0	0	0
Fish & Wildlife (ENV)	Data Discovery ENV	1	1	3600	0
Fish & Wildlife (ENV)	ETL Project Data	0	0	0	0
Fish & Wildlife (ENV)	Project Work (ENV)	3	1	3600	0
Fish & Wildlife (ENV)	Viewing (ENV)	30	2	0	0
Forestry (ENV)	Aerial Survey (ENV)	1	1	3600	0
Forestry (ENV)	Data Discovery ENV	1	1	3600	0
Forestry (ENV)	Viewing (ENV)	12	1	3600	0
Foundry (ENV)	Data Discovery ENV	1	1	3600	0
Foundry (ENV)	Enforcement (ENV)	1	1	3600	0
Foundry (ENV)	Project Work (ENV)	6	2	0	0
Foundry (ENV)	Viewing (ENV)	300	20	0	0
HDOC	Data Discovery HE	1	1	3600	0
HDOC	Health Desktop	10	8	0	0
Lincoln Ave (DOT)	Data Discovery DOT	1	1	3600	0
Lincoln Ave (DOT)	View & Analysis (DOT)	2	2	0	0
Lincoln Ave (DOT)	Work Order Mgmt (DOT,Lincoln)	5	5	0	0
Local Jurisdictions (EMA,E911)	Community Data Updates (LJ)	39	10	300	0
Local	Situational	72	36	0	0

Jurisdictions (EMA,E911)	Awareness (LJ)				
Local Jurisdictions (EMA,E911)	WebEOC (LJ)	39	18	0	0
Maint Fac (DOT)	View & Doc Access (DOT)	0	0	0	0
Maint Fac (DOT)	Work Order Mgmt (DOT,Maint)	9	3	0	0
New London (EMA)	Data Discovery EMA	1	1	3600	0
New London (EMA)	Incident Command Support (EMA)	4	4	0	0
New London (EMA)	Library (EMA)	1	1	3600	0
New London (EMA)	Situational Awareness (PSAP)	168	100	900	0
New London (EMA)	WebEOC (PSAP)	81	48	900	0
Pastore (HE)	Data Discovery HE	1	1	3600	0
Pastore (HE)	Health Workflows HE	0	0	0	0
PSAP (E911)	Data Maintenance	2	2	0	0
PSAP (E911)	Telecommunicator s	10	10	0	0
Public Users	General Public Access	0	0	0	300
Public Users	Health Workflows PU	0	0	0	0
Public Users	HPHC Contractors	2	2	3600	0
Public Users	Situational Awareness (PU)	0	0	0	0
Public Users	View HPHC Projects	0	0	0	150
RIDE	Desktop Analysis (RIDE)	4	3	1800	0
URI	Data Discovery URI	1	1	3600	0
URI	Project Analysis URI	11	9	0	0

The definition of these Workflows by Operation and Operation frequency are available upon request.

9.4.1 Definitions

Operation: An Operation is a unit of work as seen from the software perspective. With ArcGIS Server, typical Operations are ExportMap, Find, Geocode, etc. In this case, it is common to name Operations for the REST API methods that they consume. With ArcGIS Desktop, typical Operations are DrawMap, Complex Edit, Identify, Geocode, etc. In this case, there is not a canonical list of software-specific methods to use for Operation naming. There is a 1:N relationship between transactions and operations. A transaction can be composed of a single operation. Or, a transaction can be composed of multiple operations. With server-based applications, it is quite common for a single transaction to be composed of multiple operations. For example, an operation that buffers a feature may create the buffer (one operation) and cause the map to redraw (a second operation) to show the buffer. The composition of transactions depends upon the design of the application. An Operation is also the subject of a Benchmark Model. A benchmark seeks to establish the Service Times and Network Loads that a given Operation generates.

Load Factor: When a workflow is repeated frequently with respect to its duration (e.g. Pacing < 10 * Workflow Duration), the System Designer assumes a uniform load distribution and no load increase (Load Factor = 100%). In cases when there is high probability of workflow clustering , System Designer assumes a user load (workflows) follow a Poisson Distribution and estimates additional load factor (Load Factor>100%).

Pacing: Pacing, sometimes referred to as “Idle time”, is the time between workflow cycles or iterations. If a user completes all of the transactions in a workflow and immediately moves on to the next piece of work (i.e. the last transaction is immediately followed by a new first transaction), then the pacing is zero. On the other hand, if a user completes all of the transactions in a workflow and must wait for the next unit of work (like at a public counter) or perform other tasks (e.g. putting documents away, attending to email, etc.) then the pacing time between cycles will be non-zero.

Service Time: The service time is the amount of time the processor spends working on a request. In Esri’s benchmark models, the service time of interest is the service time at the maximum throughput of the system. This value is calculated from the maximum throughput and the processor activity at the maximum throughput.

Think Time: User’s requests (transactions) are composed of response time and think time durations. You can think of response time as the time that the system is busy and think time as the time that the user is busy. They could be actually busy thinking. But, they might also be busy doing something else like responding to an email. Think time is modeled on a per-operation basis.

Workflow: A Workflow is a collection of Operations that are used to complete a given task. For example, a Workflow could be "View Election Results". And, it could be composed of 10 "Draw Map" Operations, a "Geocode" Operation, and 4 "Identify" Operations. The quantities of each Operation represent an average of how the typical Workflow is carried out. Individual instances may be greater or lesser in their counts of Operation Occurrences.

9.4.2 Benchmark Models

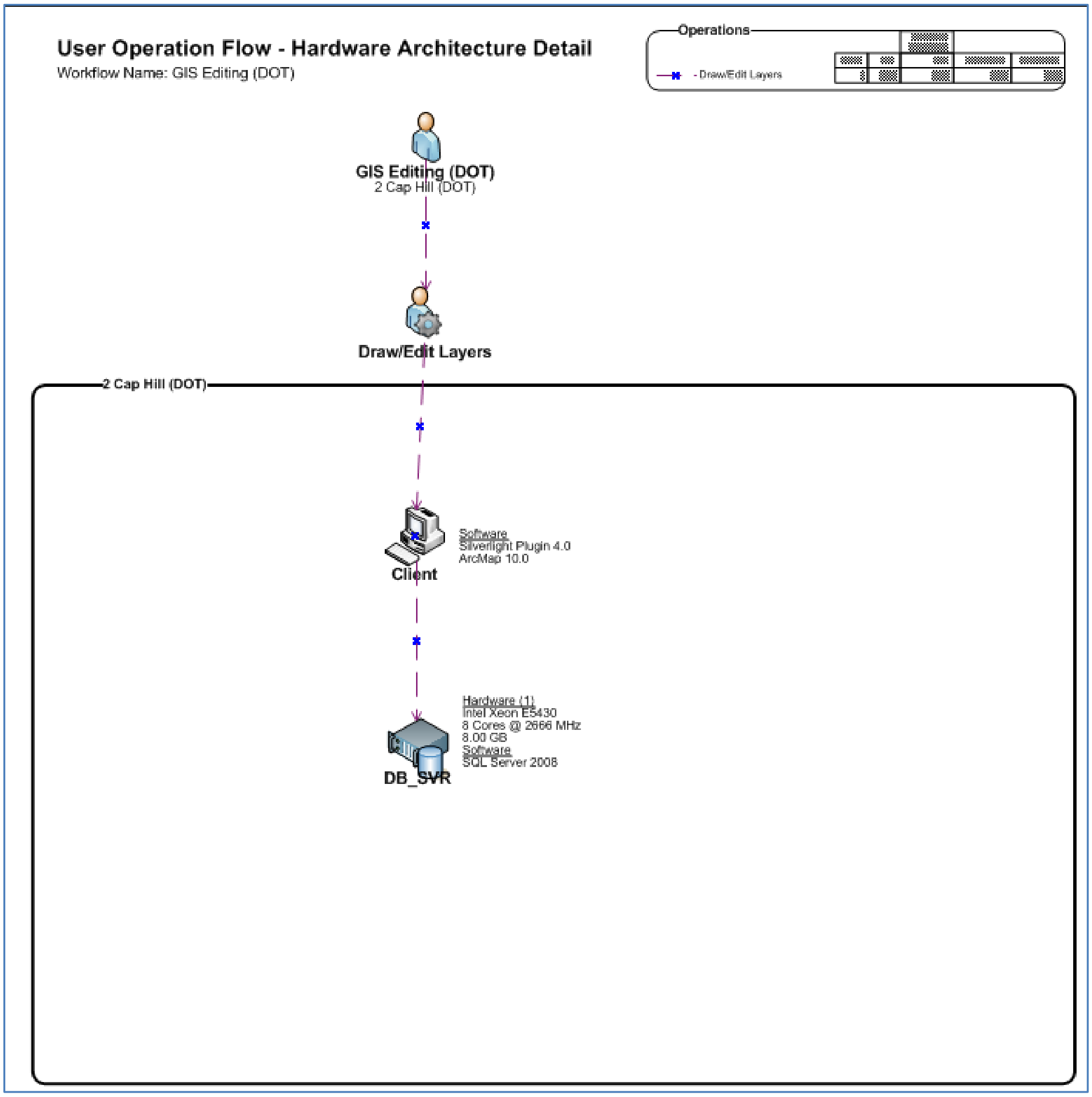
The following benchmark models are used in the capacity calculation.

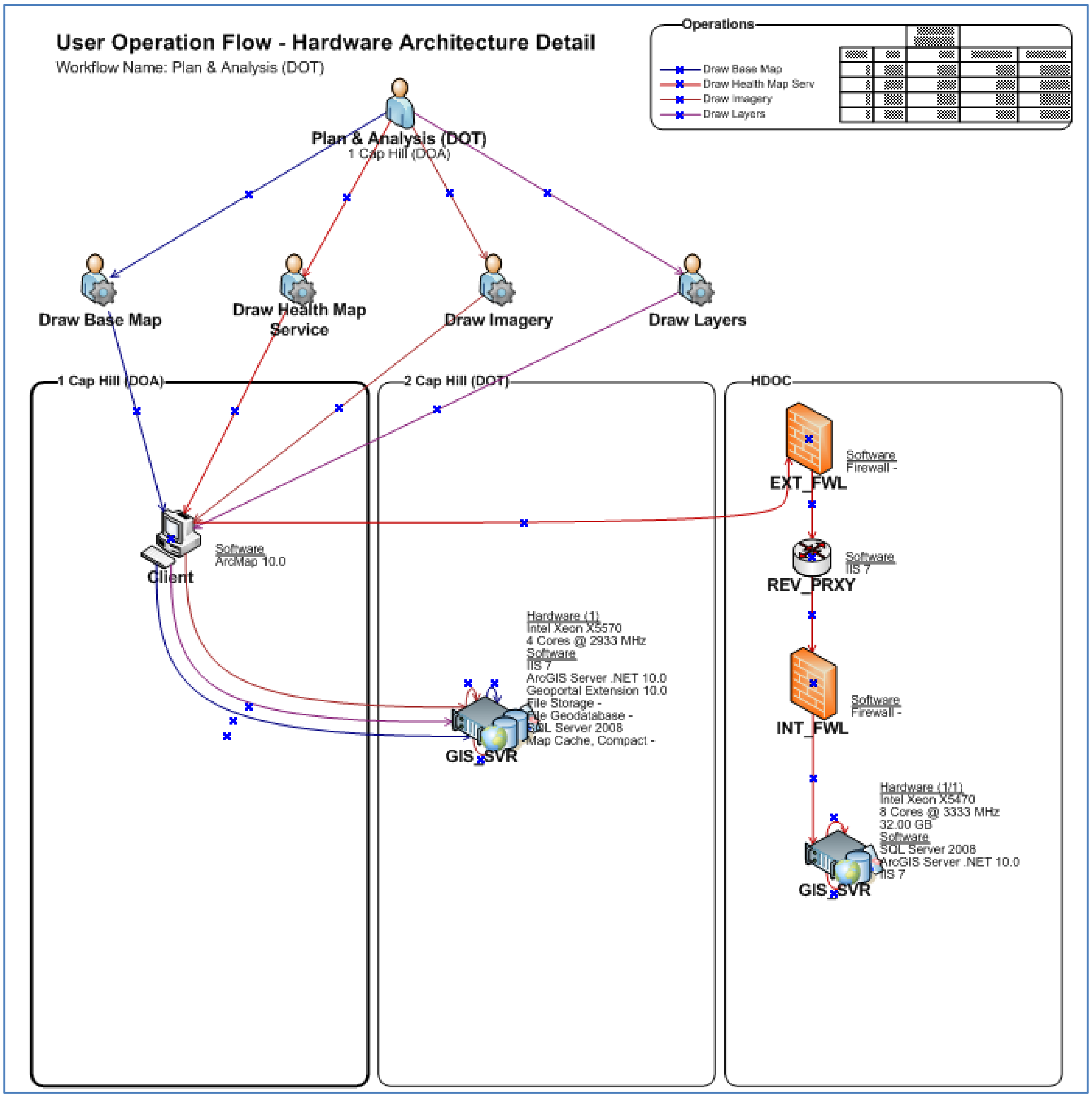
Name	App Virt		Web Serv		GIS Serv		Data Tier		Notes	SPEC
	ST	Mb/tr	ST	Mb/tr	ST	Mb/tr	ST	Mb/tr		
Draw Layers	0.42	1.20					0.01	8	Use of ArcGIS Desktop	35
Export Image	0.01	1.95	0.01	1.95	0.06	80			Use of Image Services	35
Export Map	0.01	1.20	0.01	1.20	0.06	1.20	0.01	8	Use of Dynamic Map Service	35
Get Tiles	0.01	1.20	0.01	1.20	0.00	1.20			Use of Cached Map Service	35
Query	0.04	0.01	0.04	0.01	0.01	0.01	0.01	0.01	Query of Dynamic Map Sevice	13.5
Get Records			0.06	0.56	0	0			Metadata Search	13.62
Find Address Candidates			0	0.07	0.04	0			Geocode	13.5

9.5 Application Pattern Physical Diagrams

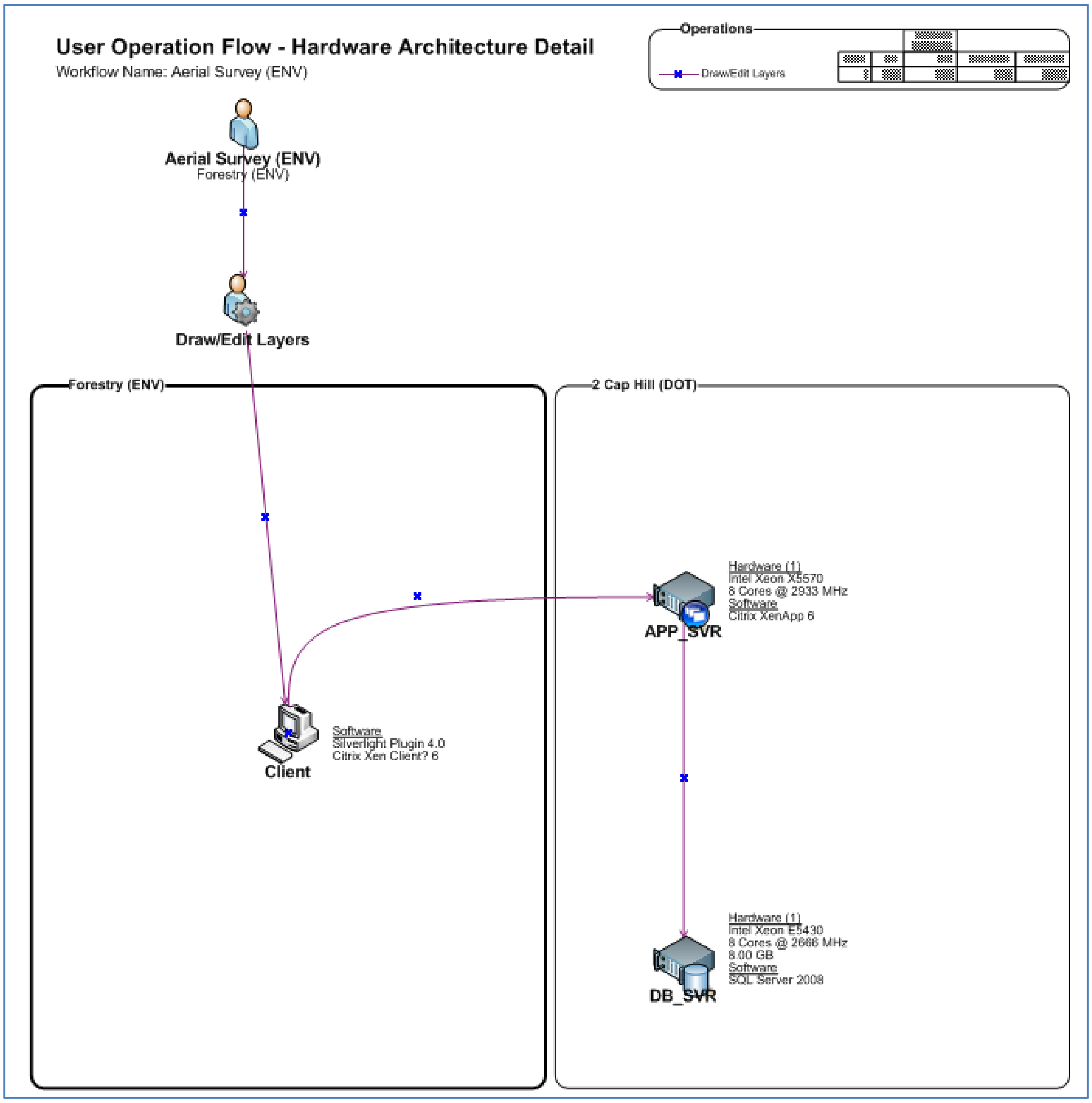
The diagrams below present physical designs that correspond to the logical design diagrams presented in the Application Architecture section.

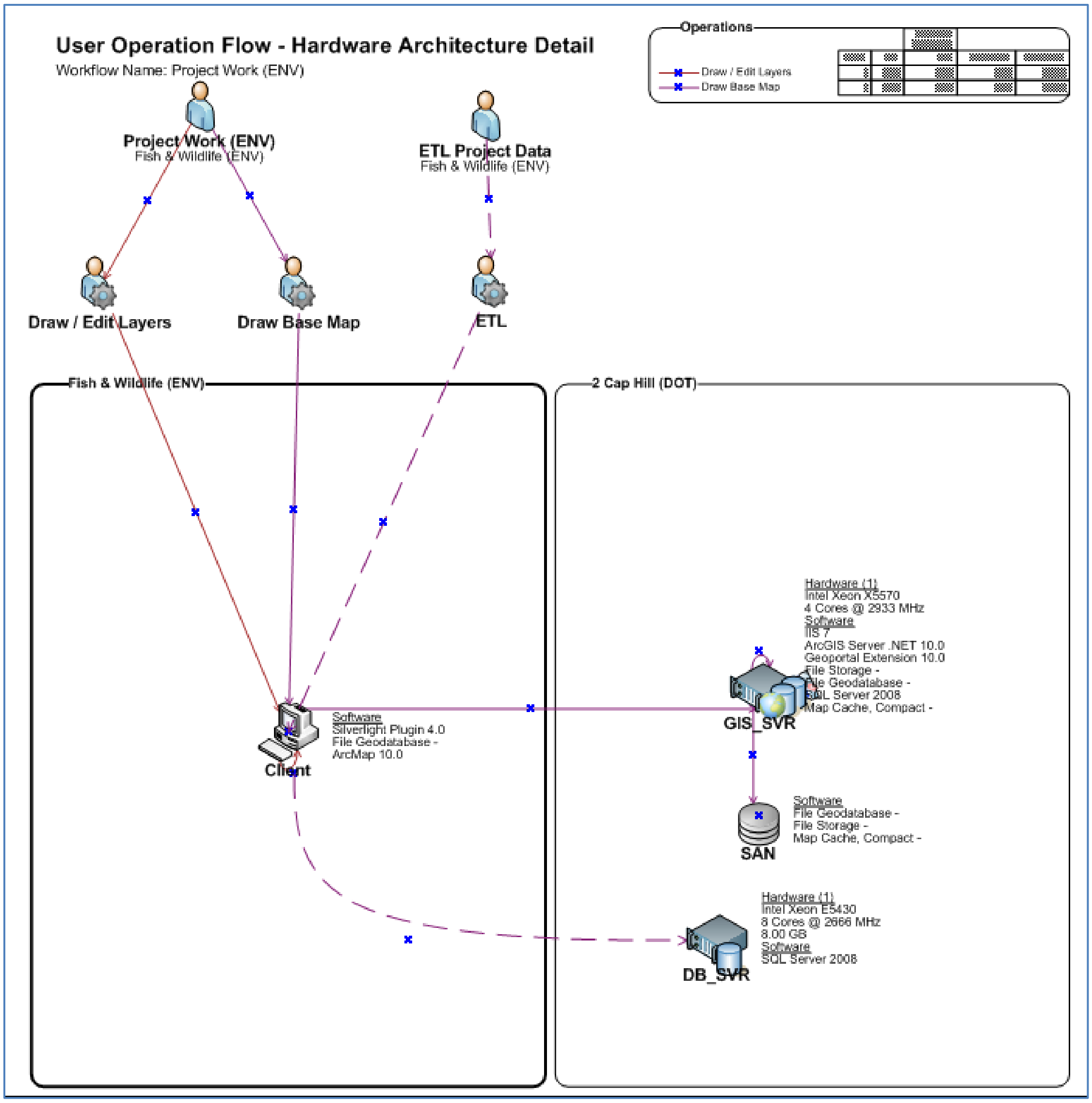
9.5.1 High Bandwidth / Low Latency Link to Central Repository


User Operation Flow - Hardware Architecture Detail
Workflow Name: GIS Editing (DOT)
Operations
- Draw/Edit Layers
GIS Editing (DOT)
2 Cap Hill (DOT)
Draw/Edit Layers
2 Cap Hill (DOT)
Software
Silverlight Plugin 4.0
ArcMap 10.0
Client
Hardware (1)
Intel Xeon E5430
8 Cores @ 2666 MHz
8.00 GB
Software
SQL Server 2008
DB_SVR



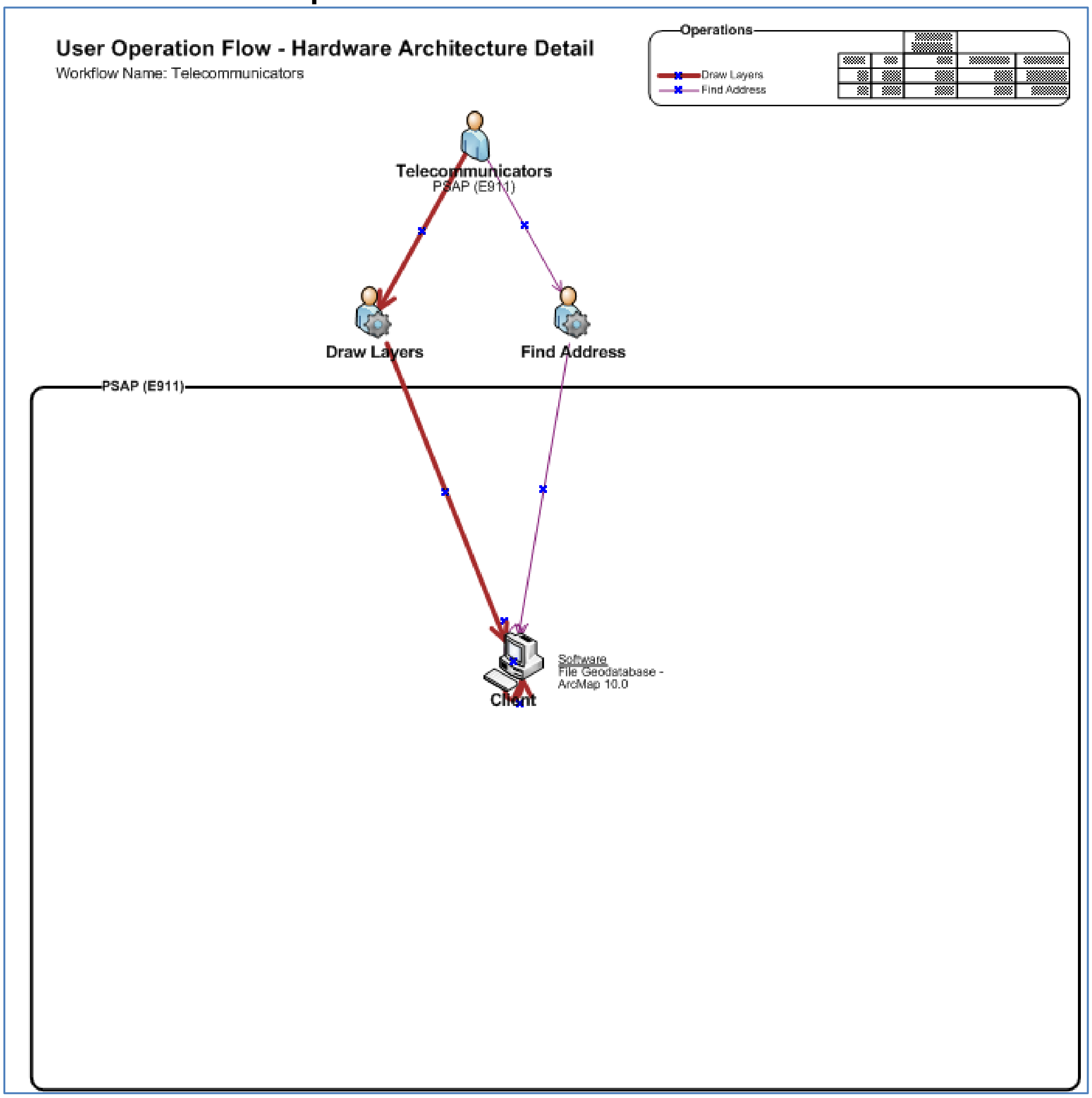
9.5.1 Low bandwidth / High Latency Link to Central Repository


User Operation Flow - Hardware Architecture Detail
Workflow Name: Aerial Survey (ENV)
Operations
Draw/Edit Layers
Aerial Survey (ENV)
Forestry (ENV)
Draw/Edit Layers
Forestry (ENV)
2 Cap Hill (DOT)
Hardware (1)
Intel Xeon X5570
8 Cores @ 2933 MHz
Software
Citrix XenApp 6
APP_SVR
Software
Silverlight Plugin 4.0
Citrix Xen Client? 6
Client
Hardware (1)
Intel Xeon E5430
8 Cores @ 2666 MHz
8.00 GB
Software
SQL Server 2008
DB_SVR

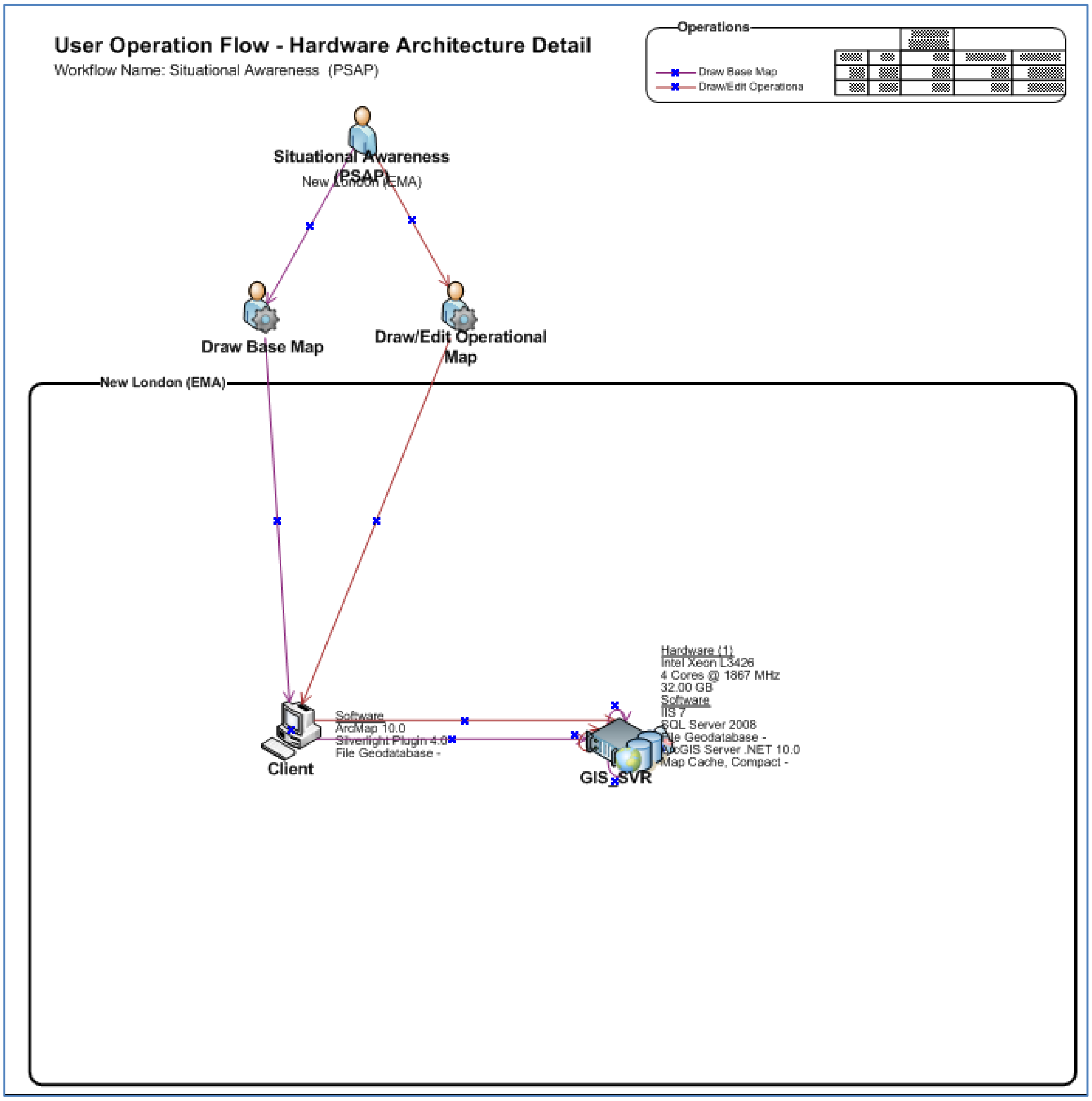


User Operation Flow - Hardware Architecture Detail
Workflow Name: Project Work (ENV)
Operations
Draw / Edit Layers
Draw Base Map
Project Work (ENV)
Fish & Wildlife (ENV)
ETL Project Data
Fish & Wildlife (ENV)
Draw / Edit Layers
Draw Base Map
ETL
Fish & Wildlife (ENV)
2 Cap Hill (DOT)
Hardware (1)
Intel Xeon X5570
4 Cores @ 2933 MHz
Software
IIS 7
ArcGIS Server .NET 10.0
Geoportal Extension 10.0
File Storage -
File Geodatabase -
SQL Server 2008
Map Cache, Compact -
GIS_SVR
Software
Silverlight Plugin 4.0
File Geodatabase -
ArcMap 10.0
Client
Software
File Geodatabase -
File Storage -
Map Cache, Compact -
SAN
Hardware (1)
Intel Xeon E5430
8 Cores @ 2666 MHz
8.00 GB
Software
SQL Server 2008
DB_SVR

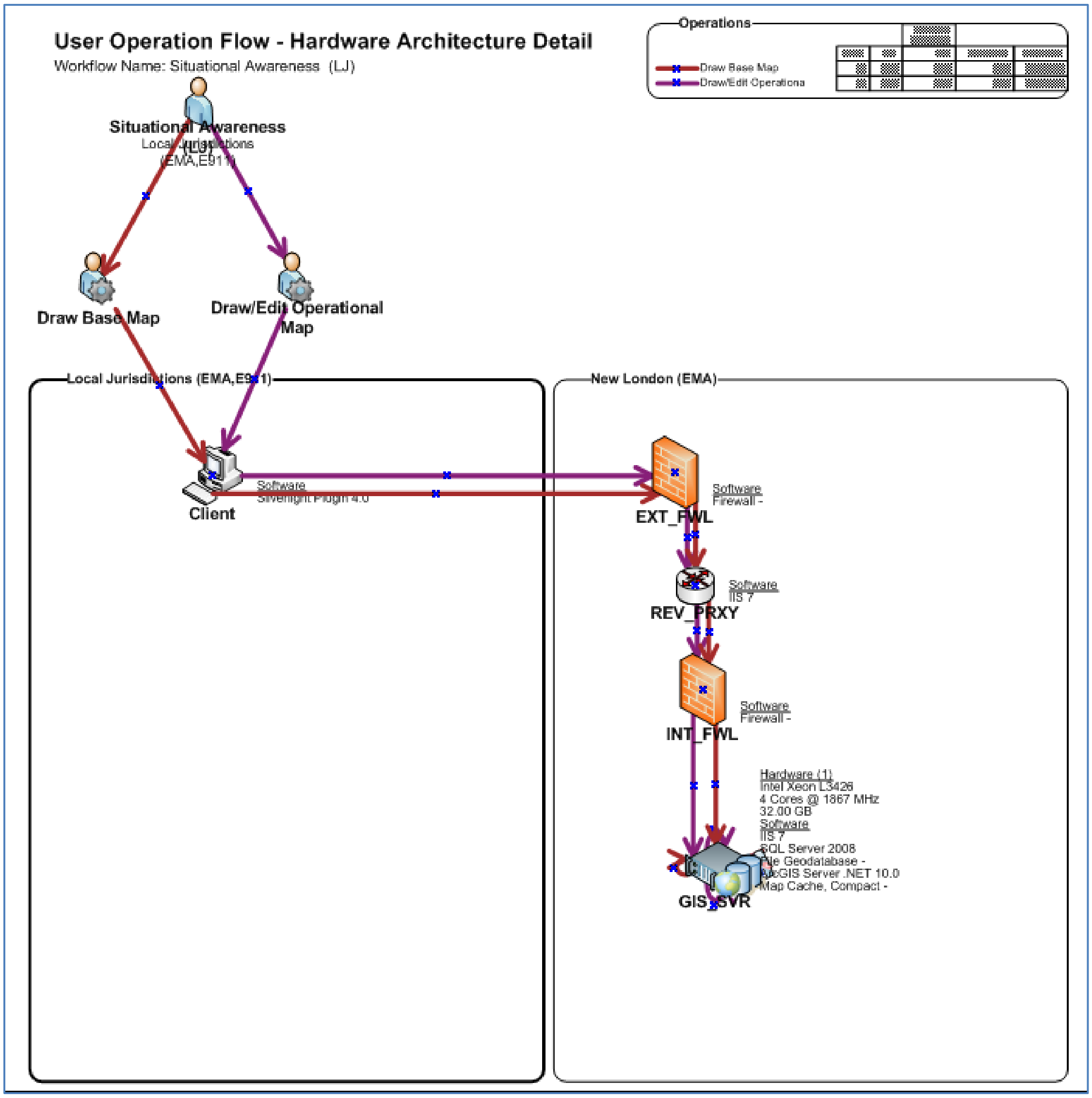
9.5.2 Independent Workstations



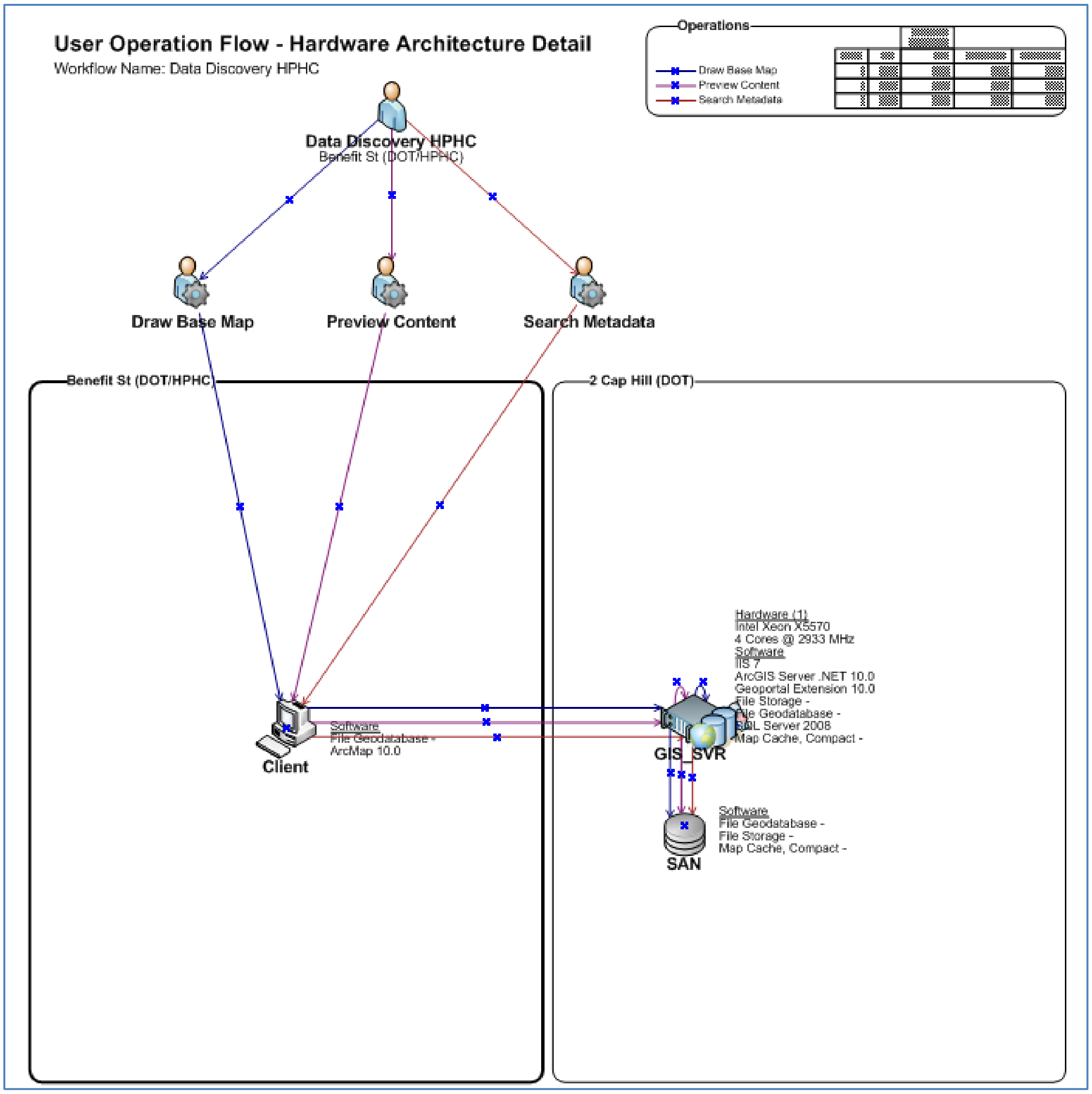
9.5.3 Browser-based Viewing and Analysis



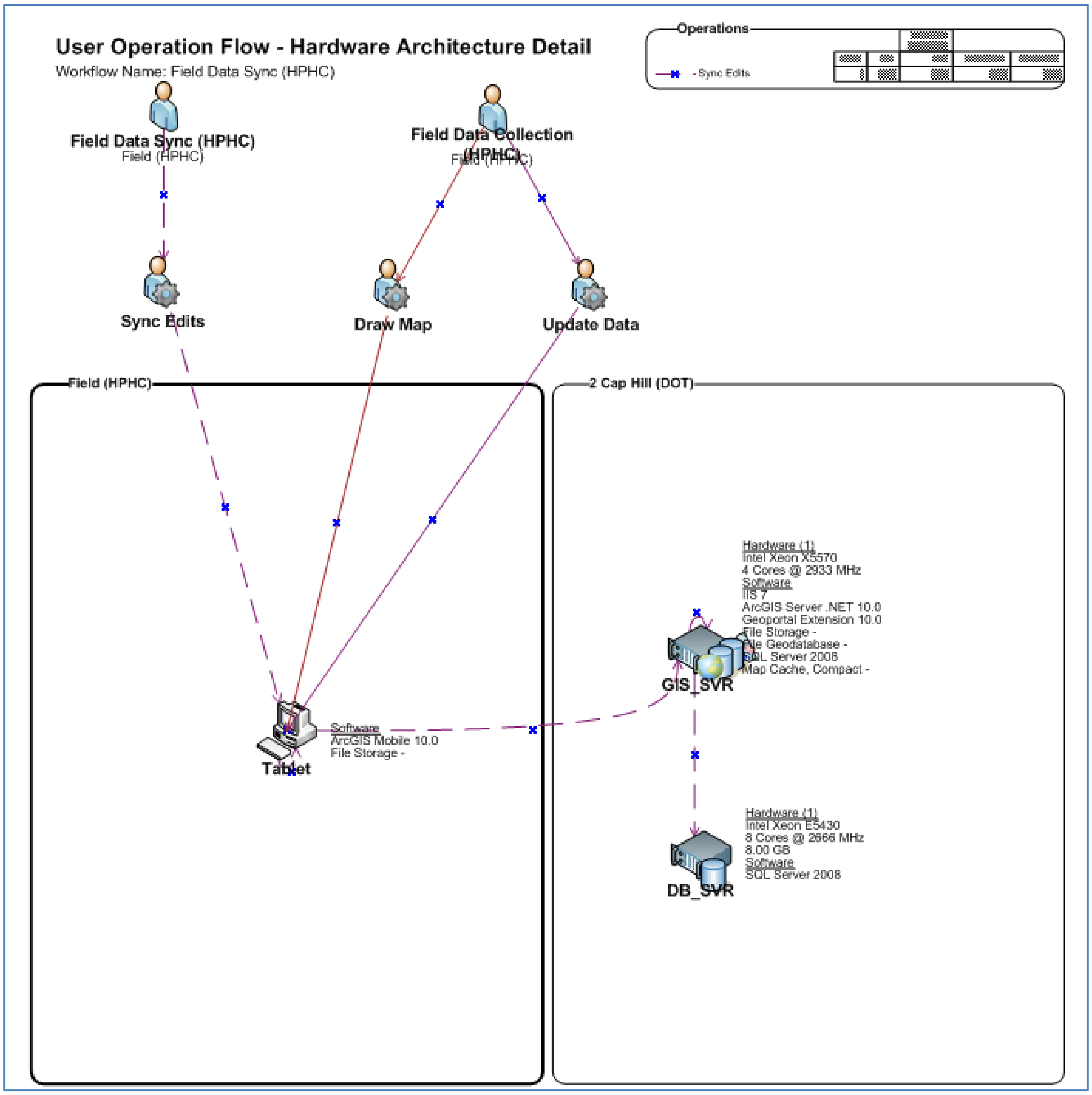
User Operation Flow - Hardware Architecture Detail
Workflow Name: Situational Awareness (PSAP)
Operations
Draw Base Map
Draw/Edit Operationa
Situational Awareness (PSAP)
New London (EMA)
Draw Base Map
Draw/Edit Operational Map
New London (EMA)
Software
ArcMap 10.0
Silverlight Plugin 4.0
File Geodatabase -
Client
Hardware (1)
Intel Xeon L3426
4 Cores @ 1867 MHz
32.00 GB
Software
IIS 7
SQL Server 2008
File Geodatabase -
ArcGIS Server .NET 10.0
Map Cache, Compact -
GIS_SVR



9.5.4 Data Search & Discovery



9.5.5 Field Data Collection



User Operation Flow - Hardware Architecture Detail
Workflow Name: Field Data Sync (HPHC)
Operations
- Sync Edits
Field Data Sync (HPHC)
Field (HPHC)
Field Data Collection (HPHC)
Field (HPHC)
Sync Edits
Draw Map
Update Data
Field (HPHC)
2 Cap Hill (DOT)
Hardware (1)
Intel Xeon X5570
4 Cores @ 2933 MHz
Software
IIS 7
ArcGIS Server .NET 10.0
Geoportal Extension 10.0
File Storage -
File Geodatabase -
SQL Server 2008
Map Cache, Compact -
GIS_SVR
Software
ArcGIS Mobile 10.0
File Storage -
Tablet
Hardware (1)
Intel Xeon E5430
8 Cores @ 2666 MHz
8.00 GB
Software
SQL Server 2008
DB_SVR