Pasadena Water and Power – GIS Preparation: More Than Just Data

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Abstract

Pasadena Water and Power Department (PWP) and consultants MWH TAG recently completed a comprehensive, ESRI-based Geographic Information System (GIS) Design and Implementation Plan. This Plan included identifying, designing, and specifying system components, GIS applications, architecture, data conversion, systems integration, and organizational changes. It was designed to support PWP's core business requirements, technology, staffing, and business solution to ultimately achieve a comprehensive GIS solution.

PWP's staff reacted with excitement and apprehension, as most engineering, planning, O&M and data trending tasks had been completed manually for many years, with the majority of the mapping data updated in paper format. In order to make a smooth transition into the GIS, PWP GIS Management produced an educational and training campaign to address organizational, task, and staffing changes.

This paper discusses how the Implementation Plan was developed, how the staffing/political impacts encountered throughout the project were addressed, and the current status of the project.

Background

PWP is a municipally owned and operated utility that has served approximately 58,000 citizens and businesses within the City of Pasadena, California for almost 100 years. PWP owns and operates its own power generation station, has transmission interconnections to the California power grid, and has joined with the California Independent System Operator. PWP also owns and operates its citywide power distribution system, which is managed by the Power Delivery Business Unit (PDBU).

PDBU's service area is approximately 26 square miles. The distribution system is comprised of approximately 11,000 poles (both municipally and jointly owned), 2/3 of which are rear property poles and approximately 6,000 underground vaults (including private property vaults) being fed from 12 substations and two receiving stations. There are approximately 44,000 electric service points connected to electric poles.

In the spring of 2003, PWP embarked on the implementation of a GIS. PWP's approach to the implementation of the GIS was to:

- Work with the City to convert the landbase data (already complete) and to coordinate with the City on core components of GIS architecture (ongoing).
- Develop applications and convert PWP water and power data independent from the City, while maintaining alignment on common issues and architecture and sharing applications where practical.

To support user needs, PWP identified and specified 10 applications; conducted a data assessment; prepared a data conversion plan; and prepared an implementation and integration plan.

Vision

The vision for the GIS is to embed institutional knowledge of water and power network assets into the GIS to support long-term management. The implementation of the GIS will facilitate the timely and accurate capture, documentation, and distribution of network asset information to the entire workforce. This will enable PWP to improve customer service, meet competitive challenges, and achieve key performance indicators (KPIs) established by key utility and community based stakeholders.

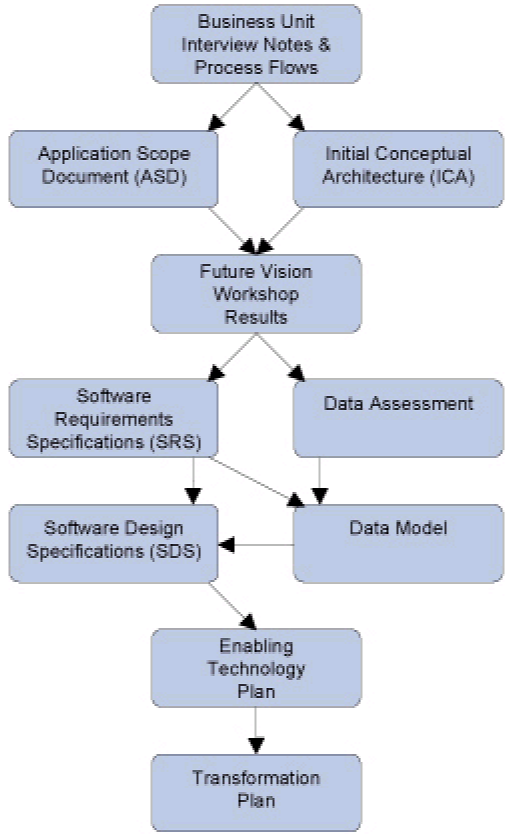
The GIS should achieve this in a way that:

- Reduces the time and effort currently required to manage network asset information
- Improves the quality and completeness of this information
- Supports long transaction planning and optimization of asset renewal and creation
- Minimizes the need for paper records
- Creates an information portal to present and manage information in a way that supports good decision making while minimizing information overload on the users
- Is sustainable by PWP
- Aligns with City of Pasadena's GIS where possible to foster common solution components and value
- Minimizes the time to locate maps and information
- Eliminates duplication in storing and updating maps

Method

The project team used a structured approach, adapted from the Rational Unified Process for software development, to produce an appropriate transformation plan for implementing the GIS and associated organizational changes. The major steps of the approach are described below and illustrated in Figure 1.

Figure 1. Transformation Plan Approach



1. Review all previous work by PWP to develop context of the project.

2. Conduct staff interviews with 17 functional groups to document major business functions, data sets, and applications. These meetings were documented in Interview Notes with supporting business process models of high level processes.

3. Develop simple Application Scope Documents for 22 GIS applications that would support the work processes identified in Step 2. These documents described the major functions, benefits, integration points, and costs of common applications used in utilities around the country.

4. Select ten priority applications based on user requirements and business drivers identified during the staff interviews.

5. Produce an Initial Conceptual Architecture for PWP's GIS deployment. This document confirms basic assumptions, industry best practices, and guidelines that PWP has established early in the project. The Initial Conceptual Architecture later evolved into the Lifecycle Conceptual Architecture that documented the next level of detail on cost and specification of key systems.

6. Inventory and assess PWP's data sources for data conversion to support the 10 priority applications. Results were documented in a Data Assessment Report.

7. Produce ten Software Requirement Specifications to confirm the scope of PWP's priority applications.

8. Produce ten Software Design Specifications to document current approach and core components of the solutions.

9. Produce a Transformation Plan to move PWP to true implementation. This plan covered system integration, business process improvement, data conversion, staffing, and budget.

Results

PWP's Transformation Plan provides a comprehensive roadmap for system implementation and documents the practical steps required to implement applications and convert data. The major components of the plan are described in the table below. Each component was prepared in conjunction with the others so that, for example, staffing in the Human Resource Plan matches resource allocations, and tasks in the Tactical Action Plan match cost estimates presented in the Tactical Action Plan.

Component Name	Description
Technology Plan	Describes the technology required to implement the applications, including hardware, software and enterprise technology coordination.
Business Process Plan	Describes the major business process changes that will result from the implementation of the applications.
Human Resources Plan	Describes the human resource impacts and requirements required to implement and achieve the goals of the GIS.
Data Conversion Plan	Provides information about the estimated cost for data conversion, the recommended process to convert data, data sources, and quality assurance and control recommendations.
Systems Integration Plan	Provides guidance and planning level assumption for integration of the 10 specified applications and associated systems.
Value Plan	Documents the cost to implement the GIS and maintain the GIS as well as the expected value that will be derived from the GIS.

Highlights of the individual plan components are presented in the following sections.

Technology Plan

PWP's Technology Plan identified major design considerations, conceptual architecture and associated functional components, and user applications for PWP's GIS.

Major Design Considerations

Major design considerations are the high level goals or constraints that must be factored into the system architecture. These considerations relate to overall system design and performance rather than the requirements of any individual application or workflow. Major design considerations were identified and validated prior to determining the conceptual GIS/IT architecture. Important considerations for PWP's system were:

- **System Independence.** The system must support critical wide area network (WAN) segment independence so that critical local area network (LAN) segment elements, such as the dispatch center, can continue to function during periods of WAN downtime. This approach maximizes system uptime and reliability and provides for redundancy and disaster recovery. The issue of WAN independence isolates process communication within the critical WAN segment (e.g. no remote calls to external data sources that can be interrupted by WAN failure.)

- **Preference for COTS Components.** Commercial off-the-shelf (COTS) software will provide the foundation for user applications.

- **GIS Data Distribution.** Validated read-only GIS data must be automatically replicated between critical WAN segments. GIS edit environment data (data being worked on or not yet validated by the GIS data administrator) should be isolated in the edit environment and not replicated or visible to the wider GIS.

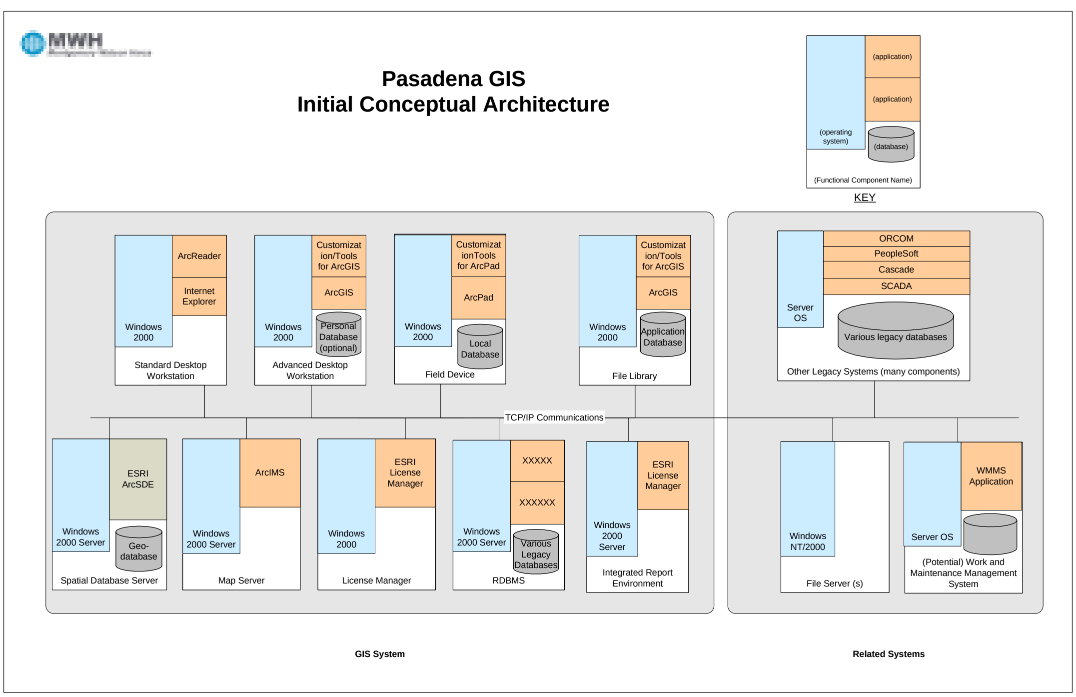
- **Thin Client Application Preference.** In general, thin client applications are preferable to Windows-based terminal server applications, and Windows-based terminal server applications are preferable to desktop applications. Thin client solutions generally have lower deployment costs and require less robust client hardware and software as well as less maintenance. Windows terminal server access to applications represents a cost-effective means to share applications licenses and reduce overall software costs where thick client application functionality is required.

- **GIS as Primary Asset Register.** The GIS will serve as the main Asset Register for PWP distributed assets. The GIS datastore is the logical system (given the absence of a Work Management System) within which to consolidate the PWP Asset Register.

Initial Conceptual Architecture

The Initial Conceptual Architecture (ICA) for PWP's GIS was driven by major design considerations stated in the previous section and functional requirements captured during staff interviews. The evolution of the ICA is expected during application design and implementation, but core assumptions should remain constant. Figure 2 below shows the main logical ICA components and their relationships. Where possible, specific applications and components have been named. For example, the ESRI ArcGIS application for desktop analysis was a known component.

Figure 2 High Level ICA Diagram



The functional components of the Initial Conceptual Architecture are described in the table below.

Component	Description
Standard Desktop Workstation	The standard desktop workstation services casual users that need view access to GIS data without heavy data processing. This component will be deployed with minimal client software cost (e.g. via web). The standard desktop workstation will have read-only access to data that is maintained by an advanced desktop workstation.
Advanced Desktop Workstation	The advanced desktop workstation is for users needing more complex data maintenance and processing capability. This environment will support several applications such as routing and advanced geospatial analysis. This component will likely be built on ESRI's ArcGIS Product Suite. This suite is a modular suite of GIS applications that includes ArcView, ArcEditor, ArcInfo and ArcGIS Extensions.
Field Device	The field device will be used by field staff needing map-driven data access while disconnected from the City's network. Several configurable component options exist within the preferred vendor suite (ESRI) to fulfill functional requirements. Final component selection will be based on a detailed review of user requirements and implementation costs. Hardware for the field devices will most likely be ruggedized Windows 2000/XP machines with substantial hard drives (greater then 40 MB). Hard drive requirements are driven by the need for large numbers of scanned documents in the field.
Spatial Database Server	The spatial database servers will likely use ESRI's Spatial Database Engine (SDE) to provide enterprise level spatial data access. The spatial database server supports data transactions including read and write operations, and works with DBMS replication services and backup utilities for spatial and tabular data resources. Indexing and caching algorithms provide high performance access to all GIS data sources.
Map Server	The map server component will, most likely, use ESRI's ArcIMS to publish map products over the web. ArcIMS includes administrative and authoring tools to support a majority of GIS information product publishing requirements out of the box. This software serves as the main information portal to GIS data stored in ArcSDE.
License Manager	If ESRI technology is specified, an ESRI license manager will be required. This administrative service component is configured for license management of network-managed applications (typically floating licenses of ArcGIS).
RDBMS Server	A relational database management server (RDBMS) provides efficient, reliable, secure data management for high-end applications such as high volume on-line transaction processing (OLTP) environments, query-intensive data warehouses, and demanding internet applications. It includes a common set of application development features including SQL object-relational capabilities and programmatic interfaces for writing stored procedures and triggers. This system will be used to store information related to GIS features in the geo-database Asset Register.

Component	Description
Integrated Reporting Environment	The integrated reporting environment (IRE) is a web-based system for reporting, analysis and information delivery. It provides the scalability and reliability that forms an enterprise solution.
File Library	This architectural component functions as a library system for the storage, retrieval, cataloging and check-in/check-out of external files to be associated to GIS spatial features contained within the Asset Register. This is not a fully functional document management system, instead it is a repository for managing/storing the associated/linked files. File types may include scanned drawings, AutoCAD drawings, scanned documents and photos.

Applications

The following 10 applications were identified by PWP as core components for the implementation:

1. **Facility Placement and Record Management for Power.** Application to manage the update and entry of power related features and attributes to the GIS. This is the primary maintenance tool for ongoing management of GIS information. This application includes the administrative components of posting changes to the production environment of the GIS.

2. **Facility Placement and Record Management for Water.** Application to manage the update and entry of water related features and their attributes to the GIS. This is the primary maintenance tool for ongoing management of GIS information. This application would include the administrative components of posting changes to the production environment

3. **Markup Management.** Application to manage the routing and administration of GIS and CAD mark-ups from the entire GIS user base. Changes are routed to the person responsible for updates of the related data set.

4. **Map Production**. Application to support the generation and distribution of structured mapping and schematics such as circuit maps and facility schematics.

5. **Web Portal.** Application to act as the main point of entry for the GIS for most users. It includes functionality that allows query and view of features, mark-up of GIS errors (redlining), report generation, thematic mapping, viewing facility schematics, and attaching and viewing files related to features.

6. **Operations Data Trending**. Application to capture and allow the display of multiple operations data sources (query and trending). This application will likely be an extension of the web portal and field portals.

7. **File Management.** Application to act as the file archive for PWP allowing scanned images, drawings and other files to be related to features and viewed through the web (and other GIS applications) based on a selected feature or features.

8. **Incident and State Management.** Application to allow asset state changes such as valve position or switch settings to be updated by field staff without the need to have Engineering staff update the GIS. The application also allows incidents such as complaints or asset failures to be noted against the asset or a location for later analysis or review.

9. **Engineering Analysis/Modeling for Power** - Application to integrate the model of the power delivery system with the GIS such that a change in the GIS is replicated into the model and state (boundary conditions) and loading (demand) can be generated for the model from the GIS, SCADA and billings system.

10. **Field Portal** - Application to provide a portal that can be used by field personnel in either network connected or disconnected state to:

    - Mark-up (redline) the GIS
    - View files related to a feature
    - View and query features
    - View facility schematics and related files.

Business Process Plan

In general, the GIS has resulted in process changes that force the creation and maintenance of one centralized version of asset information that is used in many ways to support different PWP personnel. Where documentation would previously have been captured in several locations, based on the need of the person capturing the information, it will now be captured once and presented in many different ways based on the need of the user.

The majority of process changes are in the area of data capture and creation. The changes focus on ensuring that the field and construction staff have the means to convey asset data changes back to the staff responsible for documentation, and that suitable tools and procedures are in place to effectively enter the data. The top ten business processes to be improved with the implementation of the GIS are as follows:

1. Create and edit new water service
2. Create and edit new power service
3. Construct new water or power facility
4. Correct or edit general PWP feature
5. Correct or edit general PWP feature
6. Record incident or facility state change
7. Maintain critical customer data
8. Create and publish standard map series
9. Administer the GIS dataset
10. Manage as-built drawing files

Human Resources Plan

The human resource plan covered the initial implementation of the program as well as the three years following (2006-2008). During this period, there will be two main operating conditions for PWP. The first is the GIS development and implementation. The second is ongoing GIS management. The human resource requirements of each phase are significantly different and require different staff numbers, skills and effort. Where possible, key resources used in the development and implementation will be transitioned into the new ongoing positions and roles.

Minimizing new permanent positions was a key consideration of PWP during the preparation of the human resource plan. Based on levels of effort over the five-year planning period, two additional full time equivalents (FTEs) are required. A number of temporary staff will be required during the first two years. The organization of the implementation program is based on four teams coordinated and managed by the program manager. The PWP program coordinator is responsible for day-to-day coordination of the program. The function of each team is as follows.

- **Technology Team.** Provide and maintain the core GIS infrastructure as well as supporting the other teams with specialist IT support. PWP staff on this team will transition into long-term GIS administration and management roles.

- **Application Team.** Develop and implement the 10 priority applications. This team will be dissolved at the completion of the implementation. PWP staff on the team will continue in their roles of application leads and trainer.

- **Data Conversion Team.** Create and convert asset data to populate the GIS. This team will be dissolved at the completion of the data conversion phase. Engineering and the Engineering Aide staff will transition to ongoing data maintenance and data maintenance supervisory roles.

- **Program Team**. Coordinate the implementation of all aspects of the GIS, ensure the quality of the applications and data conversion, as well as documenting the applications for ongoing support and management. This team will be dissolved at the completion of the project.

A significant part of the GIS implementation program will be the initial training and deployment of GIS applications to all PWP users. Training has been established in two categories. The first is direct vendor training for end users and/or training of a PWP trainer (train-the-trainer approach). The second is PWP training of PWP staff. In addition to direct training for GIS applications, a role of Change Manager has been created for the GIS Deployment and Implementation Program. This person will be responsible for facilitating the implementation of business process changes in conjunction with the deployment of applications.

Data Conversion Plan

The strategy for data conversion is to maximize the use of paper data sources. Where significant data gaps exist, field data collection will be conducted to ensure that the converted data meets a minimum quality level that makes it useful to the operations and maintenance of the system. The goal is to complete the conversion within a 12-month period. The data conversion program has four main components:

- Pilot data conversion

- Field data collection:

  - Overhead structures and assets including phasing of primary and secondary
  - City and private property vaults
  - Water and power meter locations linked to meter records in the billing system
  - Water valves and hydrants

- Scrubbing and conversion of existing paper documents
- Validation of underground data and additional field inspection if required

Systems Integration Plan

The system integration strategy is structured around two primary approaches: centralized datastores and use of ESRI-based COTS applications. For data, all spatial data will be stored and managed in the ESRI geodatabase. All non-spatial data will be stored in the centralized data warehouse. Within this data warehouse, two types of data will exist—transaction data related to new GIS applications and read-only data from other legacy systems for the purpose of reporting.

At the application level, the primary strategy is a preference to ESRI application extensions, which require little to no custom integration. This is true for five of the eight applications on the advanced desktop workstation. Development on other portals (web portal and field portal) is less defined due to the uncertainty of specific applications. However, design assumptions state a strong preference to ESRI compliant technology.

Cost

Implementation costs were broken into the following logical categories:

- Hardware - servers, switches, field devices, desktop computers and printers
- COTS Software - list prices of off-the-shelf software to be used in the GIS
- Configuration and Development - vendor labor required to develop custom software and implement/configure custom and COTS software
- Training - vendor training courses for PWP staff in the development and use of the GIS system.
- Data Conversion - field data collection, PWP, contract and vendor labor to administer and conduct the conversion.
- PWP Labor - The PWP current and proposed labor required to implement the program.
- Contract labor - labor used to supplement the PWP team supplied through the program manager.

Benefit

PWP, like many other utilities, has found itself in a position where the data needed to effectively manage assets is no longer well maintained or easily available. This situation has resulted from pressure over time to reduce manpower without the corresponding investment in new data management approaches to mitigate the reduction in manpower. Over the last ten years, there has been an explosion in the application of GIS to address this problem and support utility staff in capturing and managing asset data for operations, maintenance, planning and design. It is now rare for a utility, large or small, to operate without a GIS.

Typically, a utility will spend in the order of $7 to $12 per customer connection on GIS, inclusive of data conversion and applications. The wide range of expenditure depends on three main factors—the cost of data conversion, economies of scale, and the sophistication of applications. While most utilities see the inherent need to manage asset data using a GIS, it is extremely difficult to put a dollar value on the data as the majority of the benefits derive from supporting the utility in indirect ways.

The following discussion looks at how PWP is currently constrained by not having a GIS and the benefit PWP would derive (avoiding cost, reducing risk or improving service) from removing the constraints. It also looks at how long-term financial benefits would be derived from reduced asset lifecycle management costs through improved investment strategies (e.g. targeted renewals and replacements, phase load optimization and/or capacity planning). Benefits are based on the assessment of GIS application functional requirements established at the beginning of this project.

Data Quality

If the GIS (or some equivalent effort) were not to proceed, there would be continued degradation of the quality of asset data available to support management of the water and power networks. This would likely result in increased cost to operate and maintain the networks. Typically two major mechanisms would drive increased cost. First, in situations where information is lacking (or inaccurate), decisions are made to mitigate risk by increased capital spending. Second, is operating costs rise, as capital and operating programs cannot be targeted to optimize lifecycle cost. Phase balancing is an example of this for power networks. Improvements in the following aspects of data quality are expected.

- **Currency**. PWP's asset data is maintained in a large number of formats and locations by a wide array of people. While the underlying structure of the data is sound, the speed with which updates make it from the field to the documents of record is slow. It is not uncommon for it to take over six months for a change to make it onto the document(s) of record.

- **Accuracy**. In addition to the lag in documentation described above, there is a generally low level of confidence in the accuracy of PWP's asset data. The lack of confidence in the data derives mainly from the lack of documentation and propagation of past changes. For example, there is a low level of confidence in underground vault and manhole cards.

- **Completeness**. In general, there are complete data sets to a suitable level of detail to support the majority of PWP's needs. The one major exception to this is overhead power, where the data is complete from a land coverage perspective but is of insufficient detail to properly support operations tasks.

- **Accessibility**. Accessibility to data is a matter of timeliness. In most operations, data needs to be accessible in near real time to support good decision-making in the field. PWP's data is generally not easily accessible as it resides in multiple documents and in some cases multiple version of the same document. Accessibility for planning and engineering purposes is better, but still requires significant effort to extract and consolidate data for these purposes.

- **Usability**. The usability of the data to support operations and planning efforts is also limited. While the data is well structured by conventional paper standards, it is difficult and unfriendly to use by modern digital standards. A good example of this is the ability to identify customers connected to a water main or power conductor. At PWP, this is a difficult task requiring a significant effort. With a GIS, this task becomes trivial and can be completed in minutes.

- **Maintainability**. The maintenance of PWP asset data is presently distributed across multiple groups and requires updates to a large number of documents. For example, a new valve requires documentation on district sheets, valve books, and valve slips. Following the change, new versions of these documents need to be distributed to all users. Introduction of the GIS would result in the change being made instantly to the geodatabase and available to all users. Separate updates to the valve book and valve slip would not be required as these presentation formats are derived from the same geodatabase data set.

Planning

One of the most significant efforts facing the water and power departments (and all utilities) in the coming years is the renewal and replacement of aging assets. The water department alone has approximately $200 million in capital works to compete over the next ten years.

Detailed planning, design, construction and documentation of this expenditure will require a significant effort. The current systems are not structured to support this efficiently. The introduction of the GIS in the early stages of the project to support coordination, document control, and targeting of expenditure is likely to have significant financial and performance benefits. Simple examples of how the GIS will facilitate this program are:

- Generation of customer lists for shutdown notifications when a main replacement is in progress
- Documentation of pipes abandoned in place for future record
- Ability to capture and attach a photo of valve clusters to the GIS record while the trench is open thus avoiding expensive and complicated future investigations
- Access to production and consumption data spatially connected to the assets delivering the service and the customers receiving the service

For power, introduction of the GIS will facilitate more educated decisions around such things as cable replacement programs and tree trimming programs. In addition, the power group will benefit from the ability to conduct more accurate phase loading and transformer load management analysis with the benefit of optimizing existing capacity (e.g. deferring capacity increases and increasing reliability).

Operations and Safety

Availability of accurate information concerning the location and state of water and power assets is essential to efficient and safe operation. Currently, the operations' staff work from asset data that must be augmented with significant operator experience. While this is currently sufficient, PWP's work force is aging and there will be a rapid transition from existing field staff to a new generation that does not have the experience with PWP assets. This poses a significant long term health and safety risk.

The GIS is one of the most effective tools available to PWP to capture the knowledge of the aging workforce and institutionalize it for use by operations and the wider PWP workforce. Doing this has a number of significant advantages:

- All PWP employees, not just field personnel, gain access to the information to support decision-making
- Safety is improved, as the current condition and state of assets is better known, minimizing the potential for dangerous mistakes
- Customer service is improved, as the implications of an asset change or shutdown are more easily determined

- Operations saves time in investigating faults and complaints, as they have topologically correct data that links assets all the way to customers
- The history of asset performance is available for review to support decision-making
- Outage management response is improved with better information and, SAIDI and CAIDI performance indices improved
- Access to detailed construction drawings and documents reduce the time to investigate prior to digging and or preparing for USA Street marking
- The time required to generate and distribute circuit and district maps is reduced - this could potentially save a day per week in the generation and distribution of circuit maps
- Reduces the effort required to structure and plan meter replacement program

Construction

There are several significant advantages to the construction process from the introduction of the GIS. These include:

- Improved access to data to support the planning of new construction jobs
- Connection of customer data to assets to support planned outage notifications
- Improved process for the documentation and transmittal of as-built information to data maintainers
- Improved accessibility to historic construction drawings

Design

The GIS can support both water and power designs in a number of ways:

- Provision of analytical data to support modeling and asset sizing
- Provide land base and associated utility mapping for the general arrangement and layout of assets - the placement of planned assets into the GIS for general display and export to CAD tools will facilitate the communication of construction projects and speed the detailed documentation of projects
- Minimize the number of repetitive field visits to support the design process

Analysis and Reporting

One of the most significant benefits for non-operations groups at PWP is the ability to access and report on assets and related data to support improved decision-making. The GIS has been designed to enable the generation of reports across major information sources to improve efficiency and effectiveness. Some examples include:

- Association of customers to assets to support demand and customer analysis by circuit, zone, billing code, or special program take-up
- Analysis of assets by age and operating conditions to forecast remaining economic life
- Support targeting of water and power conservation programs and analysis of program effectiveness

- Support analysis of rebate program effectiveness in identification of underlying trends in demographic response

Acknowledgments

The author would like to thank the entire staff at PWP for their commitment and involvement in this exciting project. The following individuals deserve specific recognition: Casty Fortich for PWP's overall project management, Aaron Guiterrez leading PWP's water department, Joe Armstrong leading PWP's power department and Mark Sorensen for providing overall program quality control.

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