Paper Title

Texas Commission on Environmental Quality - Environmental Monitoring Response System

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Paper Abstract
This paper will discuss the Texas Commission on Environmental Quality's (TCEQ) Environmental Monitoring Response System (EMRS). EMRS will function as a new agency GIS-based system to monitor near real-time environmental events for both air and water within the state of Texas. The EMRS application will help focus agency resources (regional staff) to manage facilities regulated by the TCEQ in the event of an environmental upset. EMRS will leverage Oracle/ArcSDE, ArcIMS, and ArcGIS Server products and meteorological, DEMS, NHD, and GDT/Dynamap data layers as well as utilize external air and water models within this construct.

Introduction

The TCEQ EMRS application is designed to provide a tool that enhances the ability of regional staff to monitor near real-time environmental conditions and as a result will help provide a more effective response to environmental upsets. This document describes the EMRS project and how it fits into the TCEQ Enterprise Spatial Data Architecture.

A primary objective of EMRS is to harvest environmental and administrative (non-spatial) data from various agency enterprise databases and integrate these data with spatial data in ArcSDE as a final output. Non-spatial data complements and adds value to the existing spatial data layers. For example, merging regulated facility data with qualified spatial data can help field staff quickly determine who should be contacted if a certain contaminant is observed in excess at a monitoring station. The Enterprise Spatial Data Architecture is providing the foundation for environmental spatial data management and access by providing a construct to integrate, model, and disseminate data for agency decision making activities.

“Converting information into knowledge and acting upon it swiftly” is the concept driving EMRS, insofar as harvesting TCEQ data to provide an effective perspective on the intersection of the regulated community and the natural environment. A network of real-time air quality monitors in the Houston ship channel region provides the air sensory input for EMRS air pilot project. A network of real-time water quality monitoring stations in the Texas Bosque/Leon watershed (northwest of Waco) provides the water sensory input for EMRS water pilot project. Two fundamental EMRS goals are: 1) provide a geographic perspective of real-time environmental upset events for agency staff, and 2) provide targeted industry notification as events occur.

Real-world scenario

Real-time monitoring stations in the field continuously receive data that are transmitted to the TCEQ LEADS system (IPS MeteoStar Leading Environmental Analysis and Display System). The LEADS system consumes and processes meteorological and real-time monitoring station data. Constituent thresholds are set in the LEADS system – an exceedance of these thresholds will trigger a chain of events.

A background process is continuously harvesting monitoring station and meteorological data to provide a data buffer source for event creation. Once an exceedance occurs, the buffered monitoring station and wind vectors (for air) / precipitation and stream flow (for water) are prepped for time-series analysis. These data are then modeled with ArcGIS Server. The Spatial Analyst extension in ArcGIS Server will be used to model air events. The 3D Analyst extension in ArcGIS server will be used to model water events.

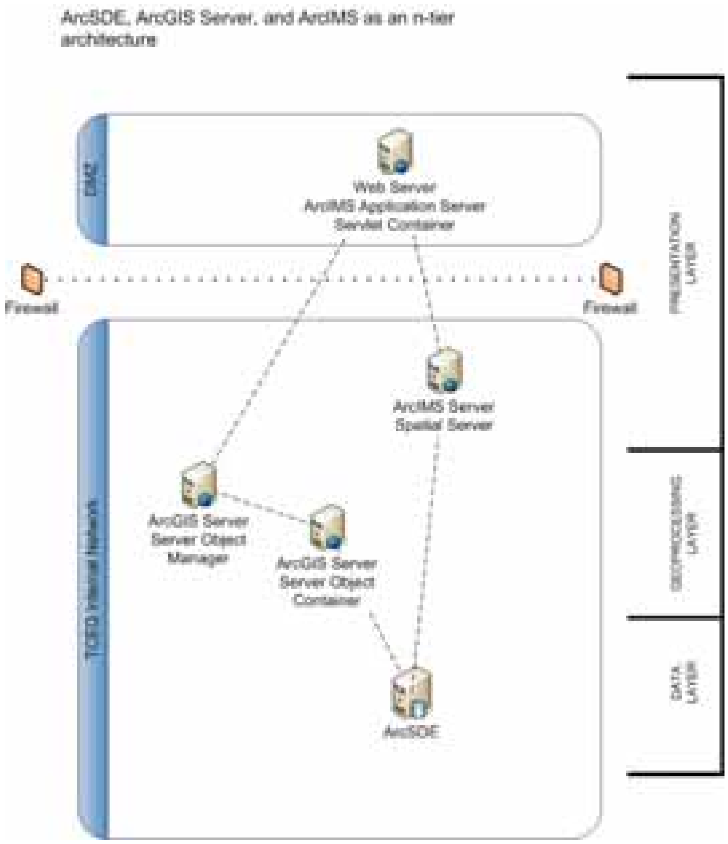
For Air:
Probability rings, similar to hurricane forward trajectories but in reverse, will provide back trajectories based on wind vectors and constituent properties. Within these back trajectory probability areas, the specific constituent that triggered the event will be geographically cross referenced with known emission inventory sources. These results would then be consumed by an ArcIMS viewer to provide a geographic perspective for TCEQ regional staff on the event for follow-on activities and will be used to provide a targeted notification to the regulated community who have the constituent within the probability area.

For Water:
Digital Elevation Models will provide the 3D modeling foundation for EMRS water. USGS 1:24K National Hydrography Dataset will be used to provide an upstream trace to geographically determine where a contaminant possibly originated. Precipitation data would be used within this model to help refine what areas of the watershed possibly had higher streamflow contribution. The watershed would be divided into probability zones and geographically cross referenced with known constituent sources. These results would then be consumed by an ArcIMS viewer to provide a geographic perspective for TCEQ regional staff on the event for follow-on activities and will be used to provide a targeted notification to the regulated community who have the constituent within the probability area.

Primary data sources:
LEADS – real-time meteorological and monitoring station data (for air and water)
Emissions Inventory – inventory of regulated sources (for air)
Central Registry – administrative data on regulated community (for air)
CAFOs – Concentrated Animal Feeding Operations – cow, pig, chicken operations (for water)

Approach

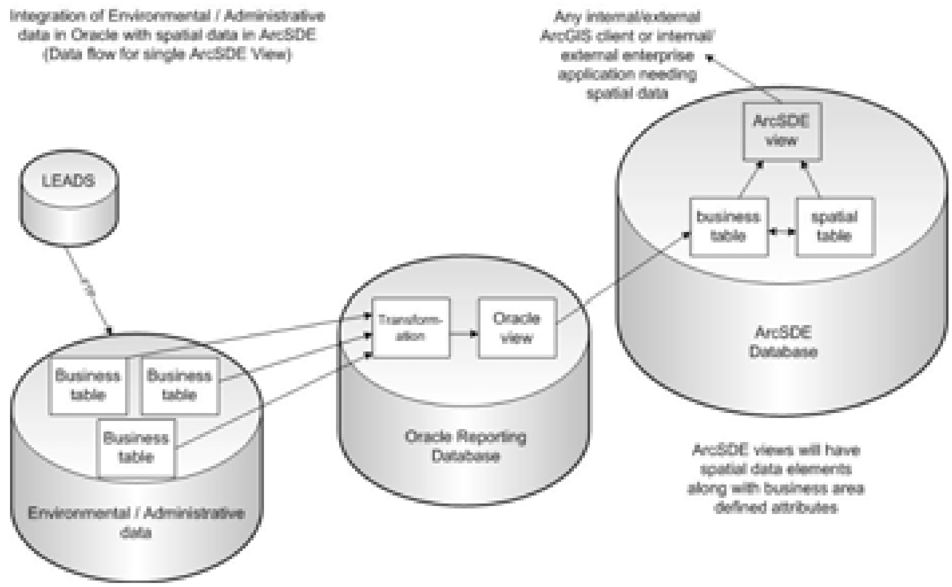
EMRS will be constructed within an n-tier architecture to separate the data tier (database), application logic (application servers/geoprocessing server), and presentation tier (user interfaces). This systems architecture affords flexibility by allowing appropriate resource allocation in each functional layer. Each tier is discreet and adheres to standard protocols. For example, HTTP and XML within the presentation tier, Java / J2EE (ArcIMS/AGS Server) for the application logic tier, and Oracle/ArcSDE within the data tier. Offloading spatial data processing to the database and application servers is the preferred approach because it produces a small footprint on the network, a minimal load on the client machine, and is easier to manage version control.



The following steps outline the dataflow for EMRS air and water:

1) TCEQ receives real-time monitoring and meteorological data through the agency's LEADS system,
2) The data in LEADS is continuously consumed via an Oracle chron job,
3) The data is then transformed and converted to an Oracle view, which is
4) Then joined with spatial data in ArcSDE and converted to an ArcSDE view,
5) To be consumed by ArcGIS Server for model geoprocessing,
6) Metrological data, monitoring station data, potential regulated sources, DEMs, and supporting spatial data layers will be modeled to generate a probable geographic polygon – atmospheric back trajectories and watershed upstream trajectories,
7) These results would then be disseminated via ArcIMS into a customized application.

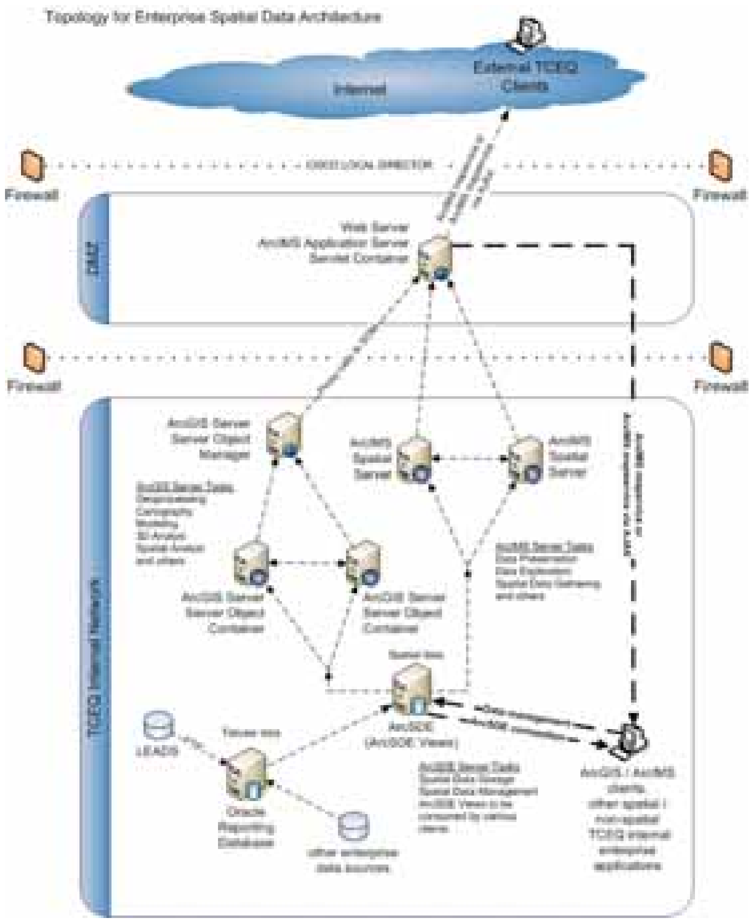
The following graphic displays how the data will be extracted, transformed, and loaded into ArcSDE to create an ArcSDE view for geoprocessing.



An Oracle reporting database will provide a bridge to data stored in agency enterprise databases, such as LEADS. According to stakeholder requirements, a view of the non-spatial data will be generated on the reporting server, and will be merged with the spatial data in ArcSDE. These data could either be used as an input for modeling or disseminated to a variety of spatial and non-spatial clients. Using views will help provide reporting data in a preconfigured manner that requires minimal resources to execute and manage. Additionally, these views will have near real-time updates from the original repositories.

<u>Architecture</u>

The architecture incorporates ArcSDE, ArcGIS Server, and ArcIMS, combined with other architectural elements.



Techniques employed within this architecture will promote the integration of environmental and administrative data sources with geographic data in Oracle/ArcSDE. These data will be merged with ArcSDE geographic data and then presented out via ArcIMS, either directly or after geoprocessing through ArcGIS Server. This architecture affords the flexibility to query from: 1) an ArcGIS client, 2) a web client, and 3) a specialized spatial data aware client. Oracle views as well as ArcSDE views will provide a current state of the original data repositories, and will have a minimal impact on database and network resources.

Data Presentation

As previously mentioned, the n-tier architecture provides several benefits besides the scalability and reliability. An inherent feature of all geographic data is its *projection*: the means by which the data were transformed from three real-world dimensions on the surface of the Earth to a flat, two-dimensional representation on paper or on a monitor screen.

Because different datasets require different projections during creation, problems arise when integrating these data with other base map or project data. Datasets covering the same geographic area but cast in different projections will not overlay when stacked on top of each another.

Reprojecting the data during the data load into the database through ArcSDE seems an obvious answer, but is not a satisfactory one. The net effect of this process is that no one will be satisfied because of the errors introduced by reprojecting or because of program-specific projection concerns. An acceptable solution to the presentation issue is to leverage ArcGIS tools to reproject the spatial data dynamically through ArcIMS.

One of the architecture's crucial components offers a solution. ArcIMS presents data within a map service to many different clients. ArcIMS's design model, as a server-side network application, distributes data presentations quickly to a multitude of GIS clients, as well as through lightweight web applications using only a web browser as the interface.

Reassigning the load of reprojecting to ArcIMS provides several benefits. By assigning and defining projection information while creating the data presentation using XML, ArcIMS reprojects datasets on-the-fly and presents them in re-projected form to clients. Furthermore, by using smarter ArcGIS clients and custom applications, this reprojection can be assigned at runtime by the end user. Dataset accuracy within the geodatabase remains untouched, allowing the dataset to be used in its 'native projection' when needed. End users are simultaneously empowered with the freedom to choose their projection of choice when using ArcIMS map services.

Data Maintenance

Data are intrinsically dynamic in nature. To remain viable and useful for decision making, they must be constantly updated. Because of this, any solution that fails to address the basic functionality necessary for data refresh is not feasible.

The proposed architecture provides many avenues for data stewards to edit and add to program area/project specific datasets. This can be done with COTS software from ESRI (ArcGIS desktop clients) used in conjunction with the centralized database connectivity provided by the Enterprise Spatial Data Architecture.

More importantly the proposed architecture allows the use of customized applications which are lightweight and available without the requisite overhead associated with the desktop clients. In moving the processing of the spatial data to the server, fewer licenses can provide more users with greater access to editing and adding data. Using small, targeted lightweight applications also opens the door to the data maintenance process to non-traditional GIS users without forcing them to endure the learning curve of the more complex desktop applications. Finally, centralizing this process will mean that said changes will be available to all users on a near real-time basis.

Benefits

Constructing and utilizing this environment will provide the following benefits:

- Minimize duplication of geographic data by removing degrees of separation from the original data source.
- Minimize duplication of spatial data islands, and version control issues.

- Encourage data sharing by having a single spatial repository.
- Leverage Oracle security and backup environment for spatial data.
- Minimize overhead in accessing and utilizing spatial data.
- Scalable client / server architecture.
- Provides a comprehensive view of TCEQ business within one geographic context.

<u>Challenges</u>

The challenges for this project are typical of these sorts of initiatives.

- An audience of users which are not GIS specialists but wish to have spatial questions answered to do their job.
- Creating another online mapping application providing rich user functionality and responsiveness.
- Integrating many legacy database sources with spatial data.
- Combining many different technologies into a single seamless application/process that would accomplish our goals.

<u>Where Are We?</u>

This is a work in progress. By the end of August 2006, we will have created and deployed the n-tier architecture at the application level to create EMRS. We will have created the first phase of the web application that integrates user requirements with the scope of EMRS including but not limited to: 1) Viewing multiple datastreams for a given extent, 2) Inserting an arbitrary set of coordinate pairs via defined xml schema dynamically, and 3) Creating new spatial features that are available as a table or imported into SDE. We will have in place an algorithm for building out the Enterprise Spatial Data Infrastructure and a test case for integrating a single legacy data source with our current spatial datasets.

For subsequent releases, air and water models will be integrated within this construct to analyze environmental events. This action will require the evaluation of ingesting a larger meteorological parameter dataset and the subsequent review and exploration of atmospheric models.

In an effort to comply with software development best management practices, 1) a Project Charter has been created to outline the project description, goals, and outline the scope of work, 2) a Software Requirements Specification document is tracking stakeholder requirements, and 3) a Functional Software Design Description documents the design of the software being developed to insure the application meets the requirements of the Software Requirements Specification.

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