Handheld to SDE - Mapping roads with Palms and GPS

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Abstract

Fulfilling the commitments of the City of Seattle's Cedar River Watershed Habitat Conservation Plan requires assessing sediment delivery to streams and tracking road maintenance activities and best management practices. To support these efforts a comprehensive inventory of over 600 miles of forest roads was undertaken. Palm Pilots and GPS receivers were used to collect data throughout the 93,000 acre ecological reserve which were then synchronized with SDE databases and an ArcGIS route system of the road network. GPS locations were used to spatially calibrate the route system and subsequently link road inventory data that was collected based on linear distance along the roads. Applications are being built to support maintenance and updating of the road inventory. The near real-time synchronization of field observations has changed the way information is used and how planning is done. This presentation will discuss the planning, implementation, and results of this effort.

Introduction

The Cedar River Municipal Watershed in King County, Washington extends from the lowlands of the Cascade Mountains east to the Pacific Crest. The Watershed provides high quality, unfiltered drinking water for over 1.3 million people. The City of Seattle owns over 140 square miles encompassing the entire hydrologic drainage. This land has been acquired over the past century and has experienced timber harvest, with its attendant railroad and forest road construction. Today the land is managed under the Cedar River Habitat Conservation Plan (HCP) approved by the citizens of Seattle in April of 2001. Commitments in the HCP include the decommissioning of roads and improvement in fish passage structures and bridges. In addition, as a land owner the City is subject to regulatory requirements of the State for road improvement and maintenance.

Past used of the land has left a legacy of more than 600 miles of unpaved forest roads. In order to answer the most basic questions of where the roads are, what condition they are in and how they contribute sediment to the streams and waterbodies a comprehensive road inventory was undertaken. This effort involved the use of a two person field crew, GPS data loggers, precise odometers, string boxes, ArcGIS, ArcSDE, and Pendragon software running on PDA's. The results of this project provided an accurate ArcSDE feature class of the road system stored with measures based on precise odometer readings and GPS coordinates; features classes of culverts and bridges that will support additional efforts to inventory and properly name the more than 3,000 culverts in the Watershed; multiple event tables, and the potential to create more, that indicate drainage, delivery, structural issues, ditch condition, and other attributes of the road system. These data will support on-going maintenance activities and management of the road system and related structures. The database created also provides inputs to the Washington Road Surface Erosion Model (WARSEM). Outputs from this model predict sediment delivery. Having linked it to the linearly referenced road system provides the ability to display outputs from the model in map form.

Development of data dictionaries and forms

Two high level requirements drove the definition of attributes to be captured by the road inventory: structural and physical attributes required by the Operations Section and sediment and hydrologic delivery issues required by the Ecosystems Section. The decision to use the Washington Road Surface Erosion Model (WARSEM http://www.dnr.wa.gov/forestpractices/adaptivemanagement/warsem/) influenced much of the design and definition of attributes. This model also provided the basis for defining the unit of analysis or how the road system would be segmented into units for description and data collection. This model has been adopted by the Washington State Department of Natural Resources as a tool for assessment, planning, and reporting. It is focused on modeling the delivery of sediment to aquatic systems. It calculates average annual road surface erosion and sediment delivery to channels. These issues are of significant concern to the Watershed Management Division.

The Operations Section is tasked with road improvement, maintenance and decommissioning. Issues of concern to this group include structure and surfacing issues that relate to ongoing maintenance. A number of meetings were held between representatives of these two groups to determine the attributes and domains that would be collected during the road inventory. In the end 66 attributes were included. These are presented in the Appendix. More than a dozen of these attributes relate to the location or stationing of the road segments and related structures.

Data Collection

As required by the WARSEM model, drainage was the primary basis for determining road segments. Field crews drove the roads and determined how and where water will drain from the road surface. A station is recorded at the start and end of each segment indicating the distance, in feet, from the start of the road. For each segment a database record was completed by entering data into a PDA. The primary key for each record was a combination of the road name and the starting station of the segment.

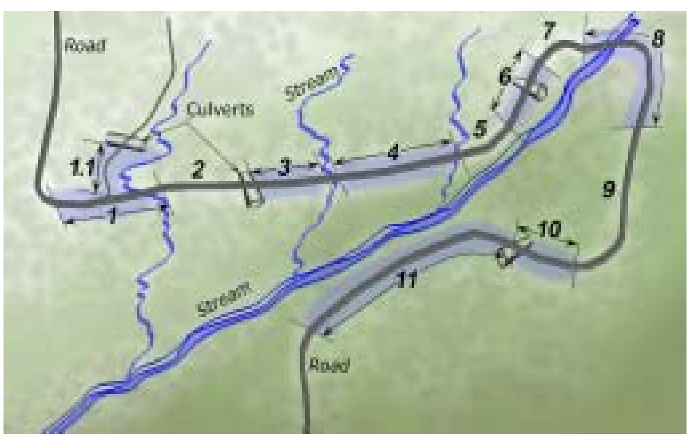

Figure 1. Determination of road segments happens in the field based on drainage and delivery of water. (WARSEM Manual, WADNR, 2004)

Following training the two field crew spent a few days together to developed a shared sense of how the data were to be collected and how to resolve questions in a common fashion. Subsequently they split into single person crews. Four different roads have been done independently by each to compare similarities and differences in how roads were being characterized. Each used a precision odometer that could be explicitly set, a PDA running Pendragon software to capture field data, and a GPS reciever to capture calibration points for the mapping component and construction of the route system. In addition each carried a string box for roads that could not be driven and a digital camera to document specific issues or concerns.

Figure 2. Road Engineer Mark Sliger prepares to head to the field. Note the GPS roof mounted antenna and datalogger, hand held PDA, and special odometer for recording road stationing.

Making it spatial - a linear referencing system of CRW roads

The nature of the data collection lent itself very nicely to events for a linearly referenced route system of roads. Each record contains a suite of attributes, a road number (route identifier), a 'from' station and a 'to' station. The additional piece that was required was a route system where the measures accurately reflect the distances and relative relationships of field measurements. If segment one lies east of a stream and segment two lies west of the stream it is important that a map locate these segments appropriately relative to the location of the stream. To accomplish this the following steps were taken. The existing road network was edited to align it with orthophotography acquired in 1998. Stationing was collected for all road intersections. In addition GPS coordinates were collected at some locations to record their location, road number, and stationing. These locations were then digitized and labeled to create a set of calibration points for the road network.

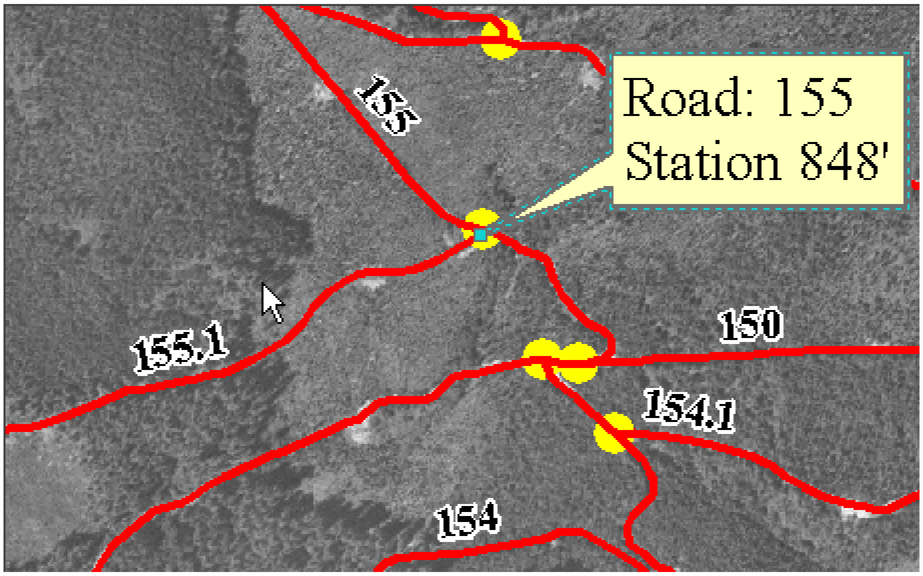

Figure 3. Calibration points used to calibrate road feature class.

The 'calibrate route wizard' was then used to assigning measures to the road network. The calibration point feature class is also a very valuable resource. When the stream network is realigned based on new LiDAR data the calibration points at stream crossing can be moved and the roads recalibrated without affecting the related event tables. A variety of event tables were then constructed from the database to display road attributes and conditions. One limitation is that no information can be mapped below the segment level. For example some road segments are more that a mile long. Roads with failing cutslopes can be symbolized but just where along that mile of road the cutslope is failing was not captured and can not be mapped more precisely. However, features for which explicit station was recorded can be precisely mapped. One such feature class is culverts.

Culverts

Stationing for all culverts was captured during the road inventory. This was a major concern of the Operations Section. So for the first time an accurate and complete map of culverts has been produced. This feature class of culverts provides a baseline for tracking all future installations, maintenance and repair of culverts.

To support tracking of culvert related activity a database schema was developed and implemented that incorporates actions, prescriptions, and conditions. The design deals with the temporal aspects of actions and modifications through time. It uses views to combine multiple one-to-many relationships. Specifically, each action, prescription, or condition creates its own record in a related table. In this way a historic reocrd of observations and actions is retained.

Coding was done to flow data from the PDA directly into SDE when the PDA is hotsynced. Upon being hotsynced data is passed through the following steps, like water being dumped bucket to bucket by a bucket brigade.

1) Capture data in a Pendragon form on a PDA.
2) Hot sync to an MS Access database mirroring the structure of the Pendragon form.
3) An ODBC link on the PC to pass data from #2 to #4
4) An Oracle view based on one or more underlying tables
5) A series of 'Instead of' triggers written against the above view
6) The underlying Oracle views created by SDE receive data from step 5
7) Another set of triggers written by ESRI pass data from #6 to #8
8) The actual SDE tables, including delta tables.

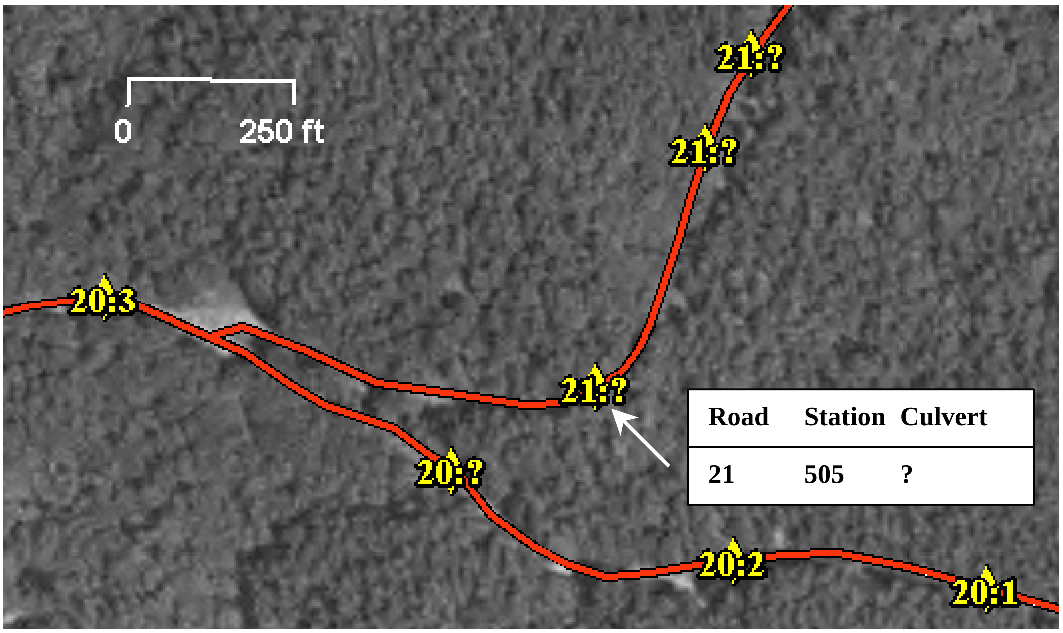

Figure 3. Culverts mapped onto road feature class using an event table. The question mark indicates

Via this mechanism data collected on a PDA using Pendragon flows directly to tables registered with SDE. When a map document published with ArcReader is opened it displays data in near real time. Current views of the status and work performed on the over 3,000 culverts that exist in the Watershed are made available to mangers.

Migration

A coverage based route system exists for the Watershed and numerous event tables are based upon this older representation of the roads. Migrating these data forward will be a challenge. In some cases the changes in stationing are minimal but in some areas they are quite extensive. As would be expected, roads with significant slope and elevation gain were significantly underestimated by the previous, planimetric, route system based on arc length, not stationing. In these areas previous 'events' need to be migrated. Possibilities include generating shapefiles and overlaying them on the new routes, however, significant realignment also occurred so this will not work in all cases.

Conclusion

Following significant effort we now have a current representation of over 600 miles of roads and a database that documents their condition and related structures for the entire Cedar River Municipal Watershed. This is a major accomplishment that provides baseline information for managers and staff. It supports asset management by providing an accurate assessment of assets and creating a mechanism for tracking the amount and type of work that is required over time.

It has been demonstrated that field data can be added to feature classes in SDE when a PDA is hotsynced. This will provide great improvements in information flow, efficiency and consistency. The challenge we now face is to solidify the reliability and use of these tools that assure information flows back into the database. If a culvert is added, where is it? It is these tools that will change the way business is done and reports are generated. By keeping the database up to date, it will become relied upon as an invaluable and indispensable resource. ArcGIS, integrated with Oracle through SDE, provides a sound foundation for taking the next steps in changing the way information is managed and activities are tracked within the Cedar River Municipal Watershed.

Acknowledgments

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Appendix: Cedar River Road Inventory Data Collection Form

Road Number	
Surveyor	
Date	
Weather	❒ Sunny ❒ Cloudy ❒ Rainy ❒ Stormy
Segment Start	ft
Segment End	ft
Road Grade	%
Full Tread Width	ft
Travel Width	ft
Tread Configuration	❒ Full ❒ Half ❒ None
Surfacing	❒ Borrow ❒ Native med-fine blocky ❒ Native coarse blocky ❒ Native fines ❒ Ballast rock ❒ Crushed rock ❒ Asphalt
Drainage Point Type	❒ Culvert ❒ Ditchout ❒ Bridge ❒ Dispersed ❒ Waterbar ❒ Sag point ❒ Natural Swale ❒ Arched Culvert ❒ Box Culvert
Drainage Point Road #	
Drn. Pt. Culvert ID	
Drainage Point Location	
DP Location Reference	❒ Beginning of Road ❒ Road Intersection

Grass	❒ Yes ❒ No
Rutted	❒ Yes ❒ No
Slope shape	❒ Concave ❒ Convex ❒ Planar
Cutslope cover density	❒ 90-100% ❒ 70-90% ❒ 50-70% ❒ 30-50% ❒ 10-30% ❒ 0-10%
Cutslope angle	❒ flatter than 1:1 ❒ 1:1 (45-50 deg.) ❒ ½:1 (50-70 deg.) ❒ ¼:1 or steeper
Cutslope average height	❒ no cutslope ❒ 2.5 ft ❒ 5 ft ❒ 10 ft ❒ 25 ft
Road Shape	❒ Flat ❒ Insloped ❒ Outsloped ❒ Crowned
Ditch Width	ft
Ditch depth	❒ <1 ft ❒ 1-2 ft ❒ >2 ft
Ditch delivery	❒ none ❒ direct ❒ direct via gully ❒ 1-100 ft ❒ 101-200 ft
Ditch veg. /rocked?	❒ Yes ❒ No
Ditch eroding?	❒ Yes ❒ No
Cutslope Structures	❒ Stable Soil ❒ Raveling large rock ❒ Solid rock ❒ Raveling fines ❒ Seepage from bank ❒ Overhanging ❒ Slumping ❒ Stream in ditch ❒ Ditch partially blocked ❒ Ditch fully blocked

Fill Slope Structures	❒ Culvert fill failing ❒ Oversteepened fill ❒ Perched Landing ❒ Potential delivery to stream ❒ Sidecast berm ❒ Sidecast cracking ❒ Sidecast erosion ❒ Shoulder slope failure ❒ Soft fill on shoulder	
Road Issues	❒ Thru Cut ❒ Thru fill ❒ Full Bench ❒ Partial Bench ❒ Road On Grade ❒ Washboarding ❒ Potholes ❒ Debris rock/soil ❒ Failed drainage structure ❒ Water running on road ❒ Road washout ❒ Variable Road Width ❒ No Ditch ❒ Two Ditches ❒ >4" ruts ❒ Potential delivery to stream ❒ Secondary segment ❒ Landing	
Culverts	**ID**	**Station**
Culvert 1		
Culvert 2		
Culvert 3		
Culvert 4		
Culvert 5		
Junctions	**ID**	**Station**
Junction 1		
Junction 2		
Junction 3		
Junction 4		
Junction 5		
Road End Station		

Comments:

References

Washington Road Surface Erosion Model Manual. Kathy Dubé , Walt Megahan , Marc McCalmon. Washington State Department of Natural Resources. February 20, 2004

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