THE American Surveyor
A FOOT IN THE PAST... AN EYE TO THE FUTURE
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Satellite Data Used in Land Development

>> By Marc S. Cheves, LS

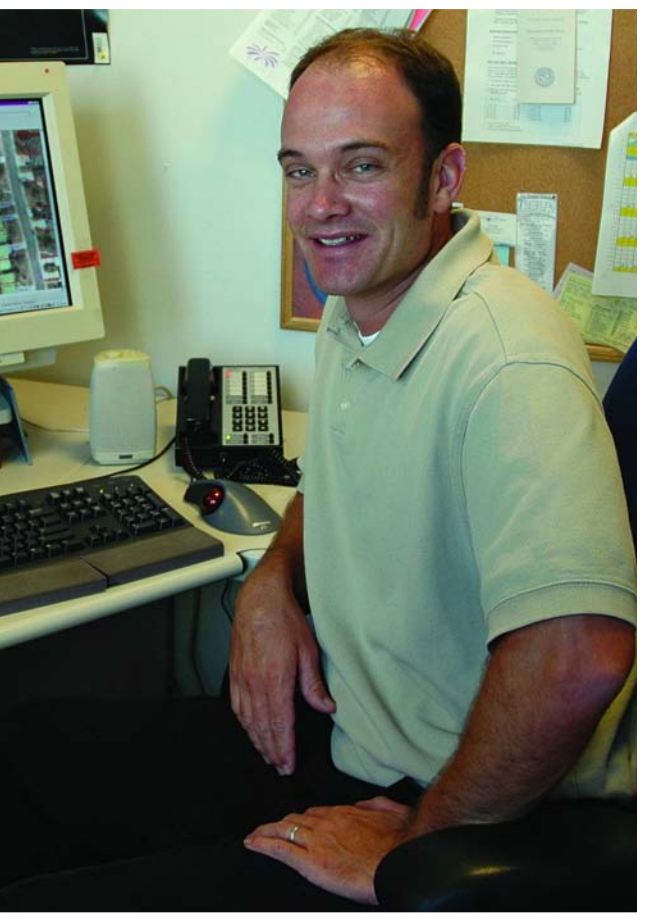
Top left: Kumar Navulur manages DigitalGlobe's product development group. His team developed the spectral analysis algorithm to extract impervious surfaces from multi-spectral imagery for this project.

There's been much speculation that satellite data will one day replace traditional aerial photography for photogrammetric applications. Yet even with the latest generation sub-meter sensors, the concept still seems unlikely. Most land development activities today rely on one-foot, or even six-inch pixel orthophotos. But in a storm water management application for the City and County of Denver, satellite data is being used to dramatically reduce the time and cost associated with using orthophoto-derived data.

I recently visited Jeff Blossom, the GIS Photogrammetry Manager with the Wastewater Management Division (WMD) of the City and County of Denver to learn about their unique application of DigitalGlobe QuickBird satellite data to calculate pervious and impervious land cover. I must admit that the concept of charging property owners for the amount of runoff they contribute to the watershed was new to me, but apparently the practice is not uncommon in the West. (Here in Maryland, we do not receive a separate charge for storm water runoff, although I'm sure that the cost of maintaining storm water facilities is somewhere in the taxes I pay.) Denver property owners receive a bi-

Middle: Jeff Blossom, GIS Photogrammetry Manager with the Wastewater Management Division of the City and County of Denver.

Right: QuickBird satellite image used to derive impervious polygons in a residential neighborhood of Denver.



Parcels Building Driveway Parking Sidewalk Other

monthly bill for water and sanitary sewer. The storm drainage bill comes annually. An independent survey in 1998-99 showed that Denver's storm drainage assessments are 35 percent lower than the national average for typical residential users.

In the last three years, the average annual residential bill for storm water runoff has climbed from $27 to $54. The reason for the increase came as a result of a study that was performed in 2000-01 that showed that Denver needs nearly $400 million worth of improvements, including annual programs. Prior to the rate increases–20 percent annually in 2003, 2004 and 2005–Denver was spending $4-8 million per year, and the extra funding will allow it to spend $20-40 million annually for the next four years. And even though the 20 percent annual increase seems steep, the current rate is about what it would have been if it had been raised annually to keep pace with inflation.

900 Miles of Facilities

A large runoff producer, such as Elitch Gardens–an amusement park in downtown Denver with an abundance of paved areas–pays roughly $60K annually. The fee is not contributed to Denver's general fund, but rather is used to manage and operate the runoff program. In addition to maintaining 1,700 miles of sanitary sewers, WMD also is responsible for 900 miles of storm drainage facilities.

Prior to 1981, storm water had been traditionally considered to be a non-point source of pollution, in contrast to point sources like wastewater treatment plants or factories. The Environmental Protection Agency (EPA) eventually determined that the outfall pipes of storm water detention facilities are indeed a point source, and the National Pollutant Discharge Elimination System (NPDES) identified end-of-pipe discharges as something that could be tested and monitored.

Denver has an aggressive, proactive and award-winning program that dates back to the enactment of the Clean Water Act in the 1980s. But a quandary was created by private facilities because WMD was responsible for all discharges to state and federal waterways, which included Cherry Creek and the S. Platte River. The area covered is immense, and although GIS has been effectively implemented across all of the various divisions within the government–the GIS has a separate water quality layer–the wastewater division, with its mandate to operate and maintain runoff facilities, was looking for ways to cut costs even further.

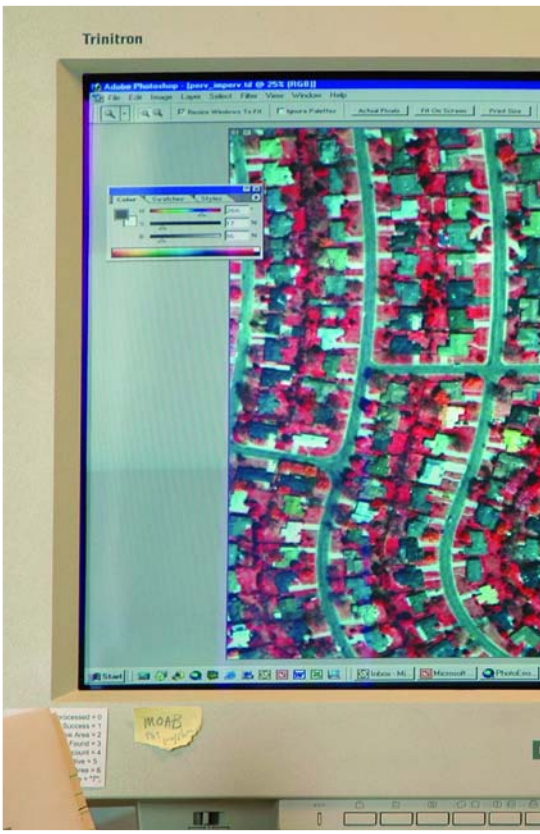
Previously, WMD had worked with 1"=660' six-inch panchromatic orthophotography, but because this approach is expensive and time-consuming, it could only afford to re-fly every two years. The time lag between photo capture and delivery–typically four to six months–also presented difficulties in mapping new construction.

Enter DigitalGlobe with its 0.6 meter product. The QuickBird two-foot color imagery is roughly one-tenth the cost of orthophotography and can be delivered within two weeks of acquisition. An exhaustive study was launched that revealed that the remotely sensed data could indeed supplement the orthophotography. Because the satellite data uses the orthophotography for rectification purposes, however, WMD will still use orthophotography, most likely on a bi-annual basis.

DigitalGlobe developed a custom algorithm based on the spectral characteristics of pervious and impervious surfaces. The prototype was developed within ENVI image processing software, using the IDL custom programming language. When applied to the QuickBird imagery, the algorithm produces an impervious/pervious thematic map. This map is imported into ArcGIS to derive impervious area per parcel.

The process is not perfect. Using the algorithm to automatically classify "impervious" introduces challenges that would not pose a problem with manual collection techniques. In initial tests, gravel rooftops were mis-classified as bare soil, and subsequently labeled as pervious. Tree canopies obscuring rooftops, driveways, or other impervious areas introduce error into the automatic collection process. Even so, with an error rate of ±4.5 percent, the method achieves an accuracy rate that, when comparing the algorithm to manually digitizing the same QuickBird image, is statistically very close. When manually digitizing the orthophotos, the accuracy approaches ±1 percent.

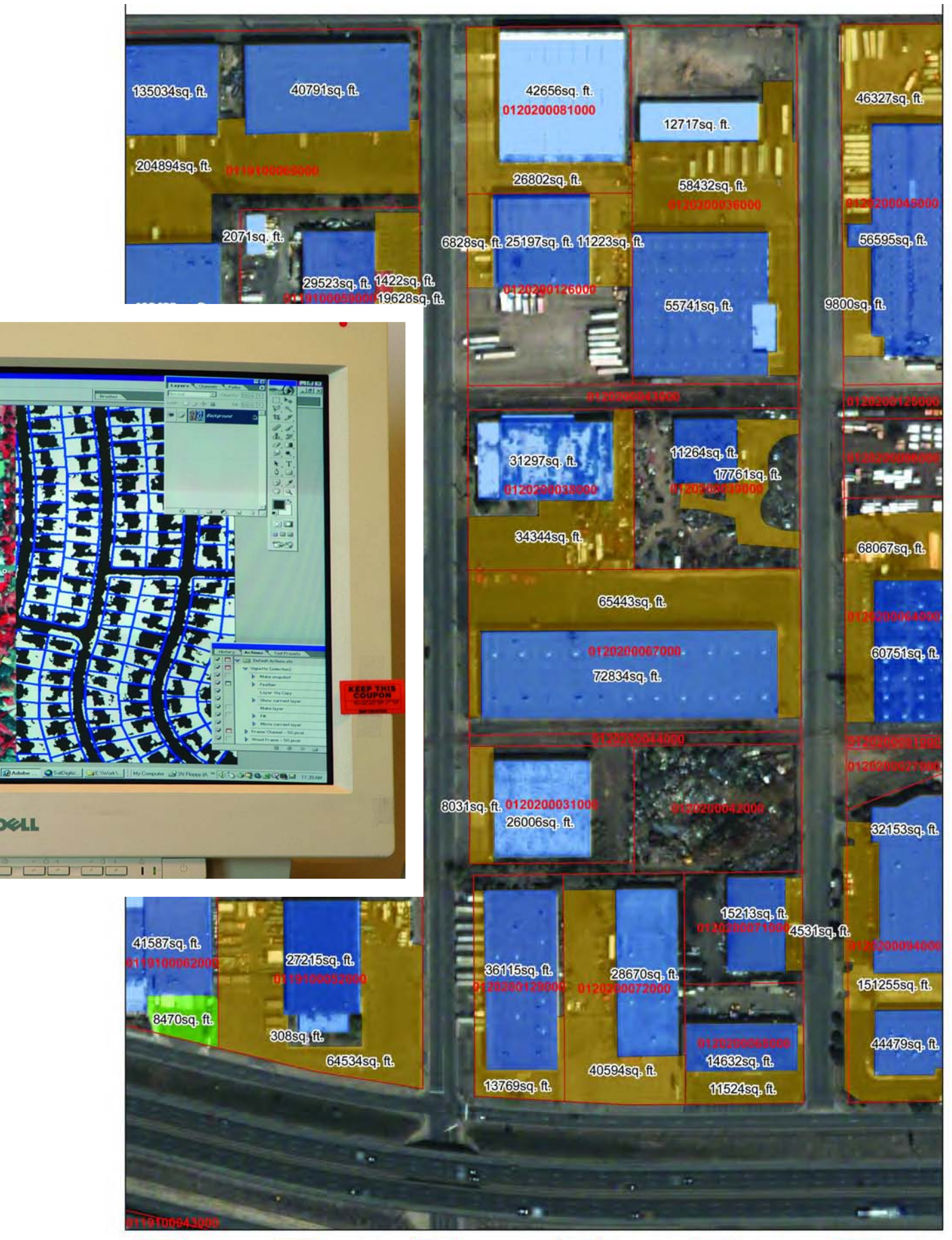
Blossom explained that the mandate under which WMD operates requires them to field verify everything they do. This does not mean "making measurements," but rather, inspecting the property to ensure that the classifications are correct (that a gravel roof is really a gravel roof, etc.). Manually digitizing the impervious features for one residential parcel takes roughly two minutes using aerial photography, and roughly 10 minutes using a scanned, geo-referenced site plan. The algorithm can calculate impervious for hundreds of parcels in a few minutes (roughly two parcels per second). Thus, using the algorithm presents an enormous opportunity for increased mapping efficiency.

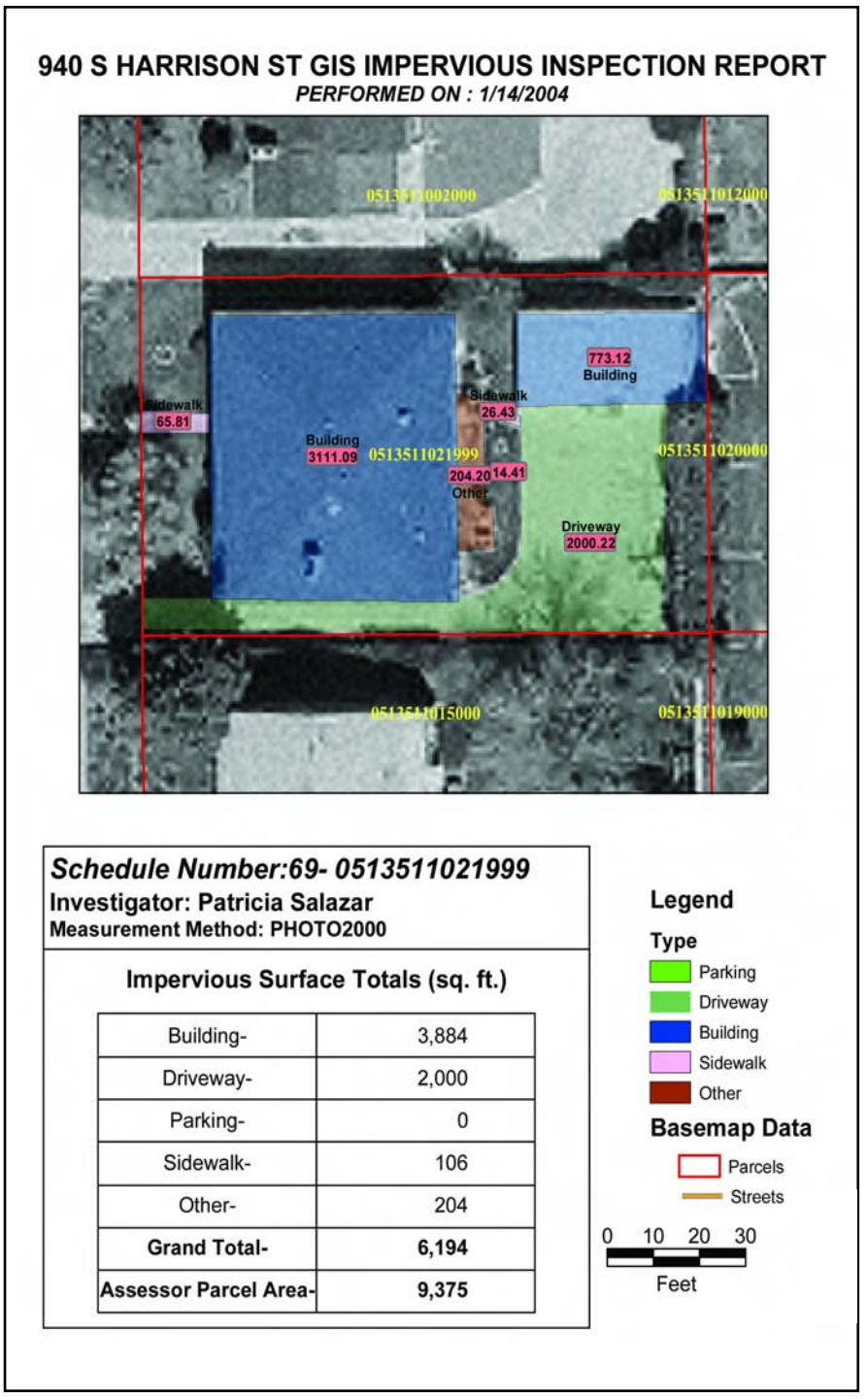


Above: Side-by-side comparison of satellite imagery and derived impervious cover.

Right: This two-foot pixel, four-band, color QuickBird satellite image was used to derive impervious polygons in an industrial neighborhood of Denver to create impervious surface maps.

Even though a visual inspection of the results from using the algorithm versus manual digitizing show marked differences, Blossom says there is room for improvement in the algorithm. Most obvious is the edge fuzziness of the algorithm's data. The digitized data exhibits





An example of an impervious surface map for a Denver property, which is sent to the customer with the storm bill.

no edge fuzziness, but requires interpolation to be used in areas where shadows or tree canopies occlude surface features. Impervious features that lie in areas of dark shadows cannot be collected using the manual technique. The algorithm collection method was not affected by shadows, probably because the algorithm uses the near-IR band of the QuickBird image to classify impervious.

Another benefit lies in detecting change. WMD's previous method for identifying properties that have changed was to visually compare existing impervious areas and the most recent imagery: all properties that exceed a ±40 percent difference are re-mapped. This is a tedious, time-consuming process, which involves panning through large areas where less than one out of twenty properties merit re-mapping. Using an algorithm to automate this process can identify changed properties within minutes for the entire city. The algorithm compares numeric data as opposed to manual visual comparison, eliminating human interpretation errors, and producing more consistent results.

Field People Use Wireless

Blossom's staff includes seven office people who perform impervious mapping. He has four field investigators whose job is to verify assessments. They use handheld wireless tablets, but after trying a completely wireless on-demand setup which didn't work very well, the field people now just download the portion of the database where they will be working. His department fields around 300 calls per month from citizens who are concerned about their bills, and WMD needs to be able to prove that their assessments are fair and accurate. Prior to 1988, WMD used the Assessor's Office square footage for buildings and didn't even include driveways or sidewalks. Blossom admitted that the automated data collection system provides the most benefit in newly constructed areas. In 2000, Denver flew 6" orthos, in 2002, 1' orthos, and in 2004, again flew 6" orthos. Moving forward, Blossom sees alternating between ortho and QuickBird imagery on a yearly basis. The most efficient use of QuickBird imagery for WMD's impervious mapping would be to collect leaf-off images in new construction areas during years in which the city is not conducting an aerial photo flight.

With the current trend of rapid expansion and change occurring in the City and County of Denver, acquiring lower cost imagery at more frequent intervals on a citywide scale would benefit many other city departments such as Environmental Health, Development Engineering Services, Infrastructure Planning & Programming, Parks & Recreation, Transportation, Engineering, Fire, Police, Emergency Services, and Central Planning Department. The Denver application clearly shows that satellite-based imagery presents a cost-effective method of supplementing traditional photogrammetry. With the next generation of satellites promising even finer resolution, we are one step closer to the long-predicted, increased utilization of satellite-based data in land development.

Marc Cheves is Editor of the magazine.