Planimetric Change Detection Using Elevation Models & Vector-Based Comparisons

Milwaukee County Land Information Office
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1) DTM vs. LiDAR DEM for Planimetric Change Detection: Observations

A change detection method was developed to compare the combined 2005 DTM (digital terrain model) elevation points and breakline points to its 2010 equivalent, a LiDAR-derived DEM (digital elevation model) raster. The 2005 DTM points were converted to a raster with a cell size matching the 2010 LiDAR DEM cell size using ESRI's interpolation tool, allowing for a direct comparison between the two datasets via ESRI's raster math tools.

In areas where change was known, particularly through knowledge of subdivisions created since 2005, this method indicated elevation differences between the two time periods that corresponded well to planimetric changes observable in aerial photography. Following this, preliminary test areas were evaluated to determine how reliably change could be detected in areas where there was *not* a pre-existing awareness of change. A key test area, which covered the north half of T7R22, was evaluated using the DTM vs. DEM method. This highly urbanized area consists mostly of small, established residential parcels and includes a high density of vacant City of Milwaukee properties.

In this test area, there was not a strong relationship between elevation change and planimetric change. In the numerous small residential parcels in this area, on-the-ground modifications that would result in measurable elevation changes are largely not present, even when a significant planimetric change occurred, such as the razing of a structure or the addition of a structure on a formerly vacant lot. The potential for landscaping or other statistically-significant changes in grade appears to decrease as lot size decreases. Also, the land use of parcels in this area tended not to change, as is typically the case with subdivisions, where significant re-grading (and hence detectable changes in elevation between two time periods) occurs on former agricultural or manufacturing lands during the construction of streets, sidewalks, and individual lots.

Planimetric change using this method is dependent on a reasonable correlation to elevation change, which was not observed in this test area. If planimetric change

occurred, but there has been no detectable change in elevation, then planimetric change is missed via this method.

Error

Error is problematic when attempting to directly compare these two different types of data. Error introduced during the interpolation process (points to raster), which results in the generation of a considerable number of false elevation differences, is difficult to filter out. Also, the resolution of the 2005 DTM seems to contribute error, especially as lot size decreases. The number of points placed at the discretion of the photogrammetrist per unit area decrease as lot size decreases, resulting in in-parcel 2005 DTM point-to-raster interpolation error. PG-based points are not regularly placed, resulting in an inconsistent number of points per unit area. LiDAR provides a consistent number of elevation data values per unit area, and coverage is consistent, even at the surfaces of water bodies.

Future Potential of LiDAR for Detecting Change

Currently, the comparison of 2005 DTM to 2010 LiDAR DEM.datasets requires one to make the unreliable assumption that planimetric change follows elevation change. When the next cycle of LiDAR data becomes available in the near future, the comparison of LiDAR data from two difference points in time may prove to be a viable method for detecting change. Change discovered through differences in surface elevation between DSMs from t_0 and t_1, which include elevation values directly associated with planimetric features that rise above ground level, would offer the possibility of directly locating planimetric change. To test this, the sample surface model data obtained for the LiDAR pilot study conducted in 2008-09 could be compared to MCAMLIS' current LiDAR DSM, captured in 2010.

Despite the limitations observed in this study, the results of a DTM vs. DEM comparisons can be used to augment the set of changes discovered through more conventional GIS techniques (Section 2), acting as a "fine-tooth comb" method for locating change not otherwise found.

2) Vector-Based Planimetric Change Detection

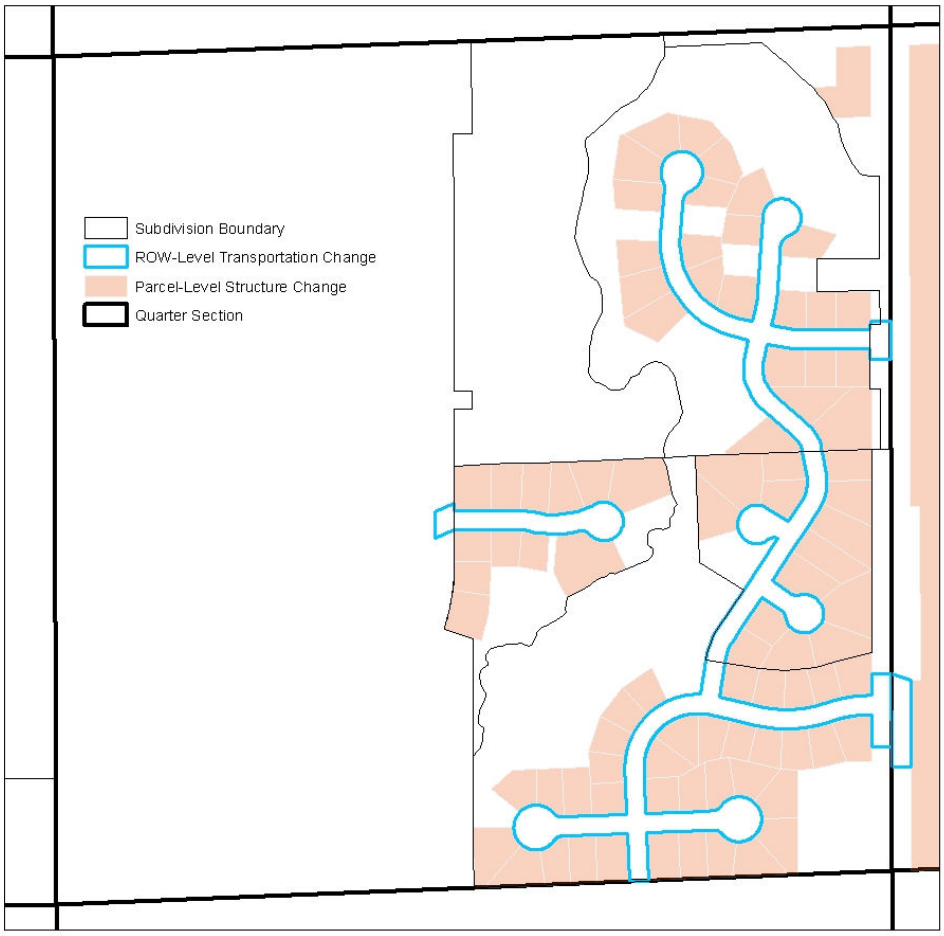
A) Methods

Though not as cutting edge as the method described in Section 1, methods for locating change using MCAMLIS-maintained vector datasets have proven to be more direct and reliable. Though elevation change associated with subdivision-level planimetric change appears to be reliably detectable via the comparison of elevation datasets from two time periods (Section 1), subdivision boundaries are maintained as part of MCAMLIS' cadastral mapping efforts; advanced techniques are not required to determine the locations and extents of subdivisions added since 2005. Currently, locating planimetric change using existing subdivision boundaries and other cadastral features as guides is the most efficient and direct method available.

In addition to known cadastral changes, planimetric change may be discovered using various GIS techniques and logic applied to MCAMLIS feature classes through the comparison of primary structure footprints in their 2005 and 2010 states. In this analysis, planimetric change at the parcel level was driven by locating changes in primary structures: improved to vacant, vacant to improved, and structure relocation, i.e. razed buildings being replaced with new structures of a different size, shape, or location.

"Change polygons" based on parcel and right-of-way boundaries were compiled and summarized to determine change rates and change counts at the quarter-section level. The sum of the proportion of the areas of individual change polygons within their respective quarter section was used to determine a rate of change for each quarter section (Figure 1). These values may be used as benchmarks toward complying with National Map Accuracy Standards, and to prioritize future planimetric re-mapping efforts - quarter sections with higher change rates will be assigned higher re-mapping priority.

Figure 1: Determination of Quarter Section Change Rate



- quarter section area = 6,868,973 ft^2
- total area of all change polygons within quarter section = 1,640,341 ft^2
- quarter section change rate: 1,640,341 / 6,868,973 = 23.9%

Change Sources & Indicators Driving Vector-Based Change Detection

- known highway construction projects

- subdivisions developed since 2004-05

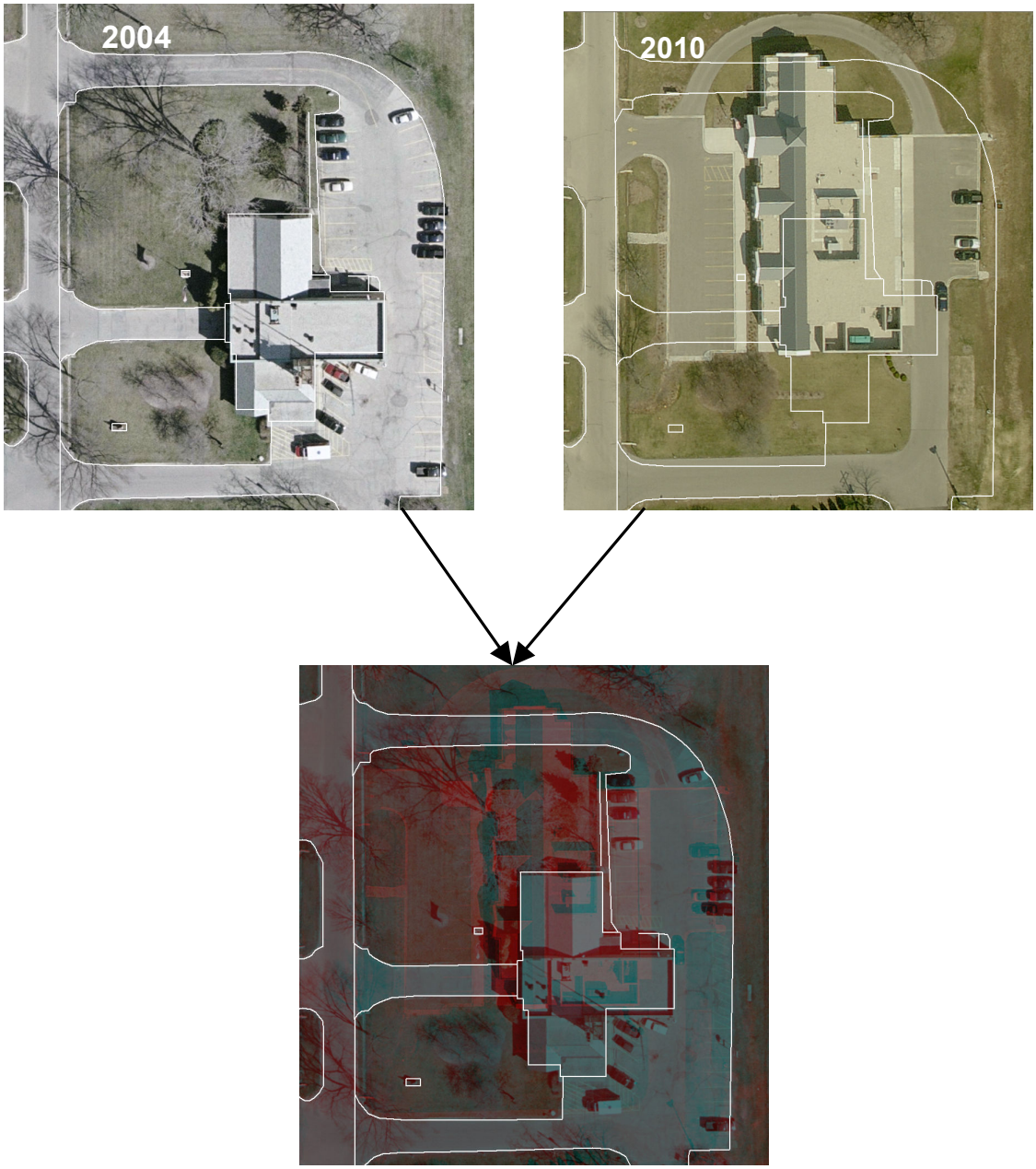
- footprints of addressable primary structures

- footprints of primary structures mapped in 2004-05

- change discovered visually using a “red over cyan” overlay of 2010 and 2005 orthophotography (Figure 2)

Figure 2: "Red Over Cyan" Method of Visualizing Change

Fox Point Village Hall: shades of cyan represent features that existed in 2004-05 but were removed by 2010. Shades of red represent features added after 2004-05. White lines delineate transportation and planimetric features mapped in 2004-05. This example also illustrates the coincidence of transportation-related change with primary structures change.



Change Polygons Compiled and Summarized for Quarter Section Change Rate Analysis:

- parcel-level structure change:
  parcels containing footprints of primary structures that have changed shaped or location, or have been razed or built between 2005 and 2010

- ROW-level transportation change:
  portions of rights-of-way containing changes related to intersections, interchanges, sidewalks, street alignments, etc.

- parcel-level transportation-related parcel change:
  parcels containing changes related to parking lots, driveways, private streets, etc.

Opportunities for In-House Updating of Planimetric Mapping

In many cases, changes that occurred at ground level are not subject to parallax, building lean, or other common orthophotographic phenomena that affect one's ability to accurately discern the edges of photo-observable features. Required updates to the 2004-05 planimetric mapping datasets related to ground-level transportation-related change, as well as structure-related planimetric change where a structure was razed and not replaced (i.e., situations where parcels were improved in 2004-05 but by 2010 were vacant), should not require the expertise of a photogrammetry specialist. For this reason, change polygons compiled for this analysis were classified by change type so that those instances of change that may be remapped in-house can be located and summarized:

- improved-to-vacant/unimproved
- vacant/unimproved-to-improved
- improved-to-improved (primary structure changed in shape, size, or location)
- transportation-related

B) Results

Maps 1-3 summarize change by quarter section, and provide a means for deciding which quarter section to target for planimetric mapping updates, for estimating re-mapping costs, for prioritizing re-mapping efforts, or for determining which areas may be re-mapped in-house.

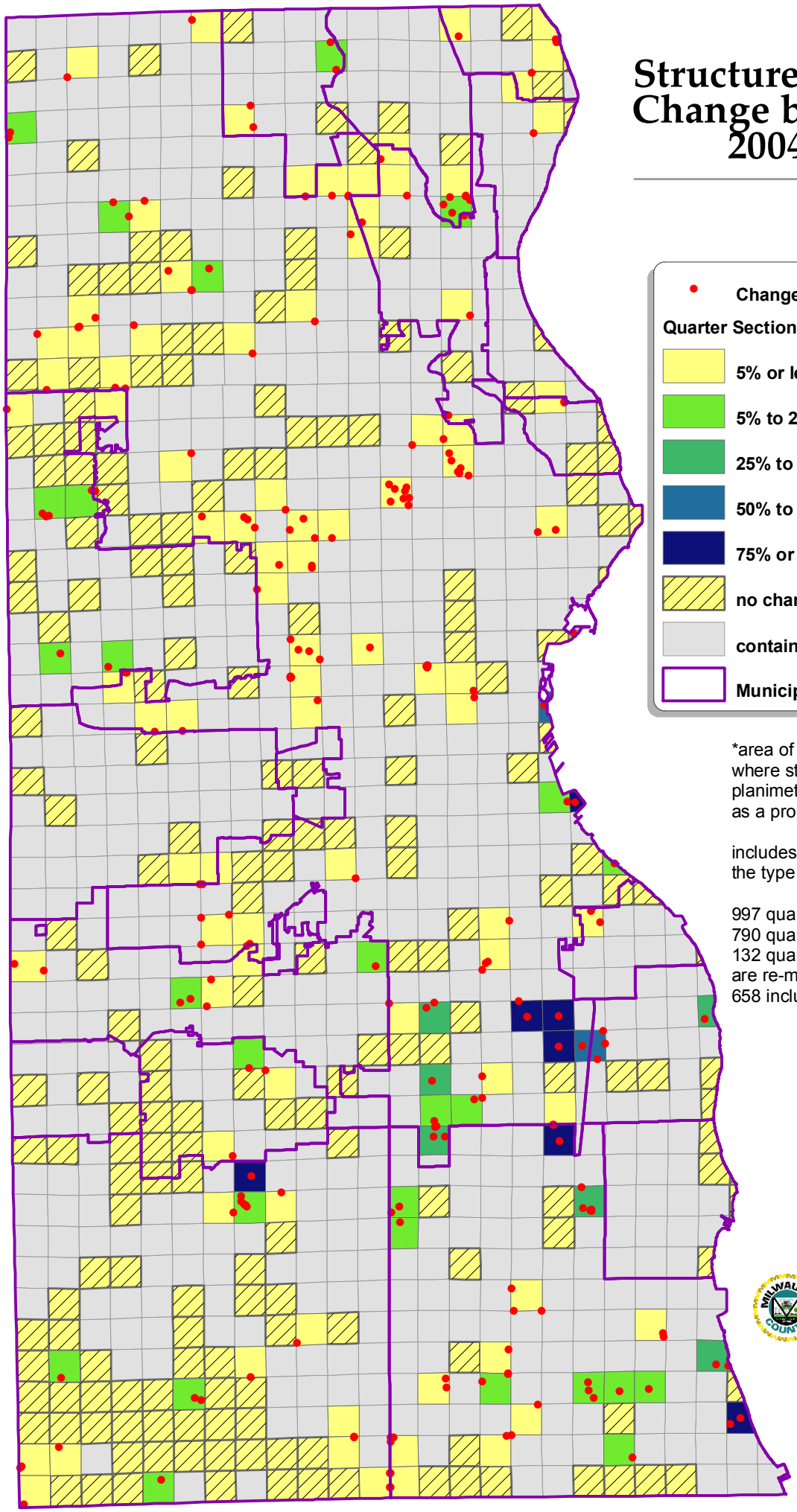
Map 1: summarizes quarter sections that contain only transportation-related and improved-to-unimproved structure-related changes (areas where re-mapping may be performed in-house), as a proportion of quarter section

Map 2: summarizes quarter sections that contain changes that require contract services for remapping (unimproved-to-improved and improved-to-improved changes), as a proportion of quarter section

Map 3: distribution of change instance by change type

Map 1: Structure & Transportation Change by Quarter Section: 2004-05 vs. 2010 *

2011 Q2



- Change at Parcel or ROW Level (225 instances)

Quarter Section Change Rate

- 5% or less (88)
- 5% to 25% (28)
- 25% to 50% (7)
- 50% to 75% (2)
- 75% or more (7)
- no change (207)
- contain change not re-mappable in-house (658)
- Municipal Subdivisions

*area of parcels or portions of ROW where structure- or transportation-related planimetric change has occurred as a proportion of total quarter section area

includes only those quarters where the type of change is re-mappable in-house

997 quarters total
790 quarters have changed
132 quarters contain only changes that are re-mappable in-house
658 include changes that are not re-mappable in-house

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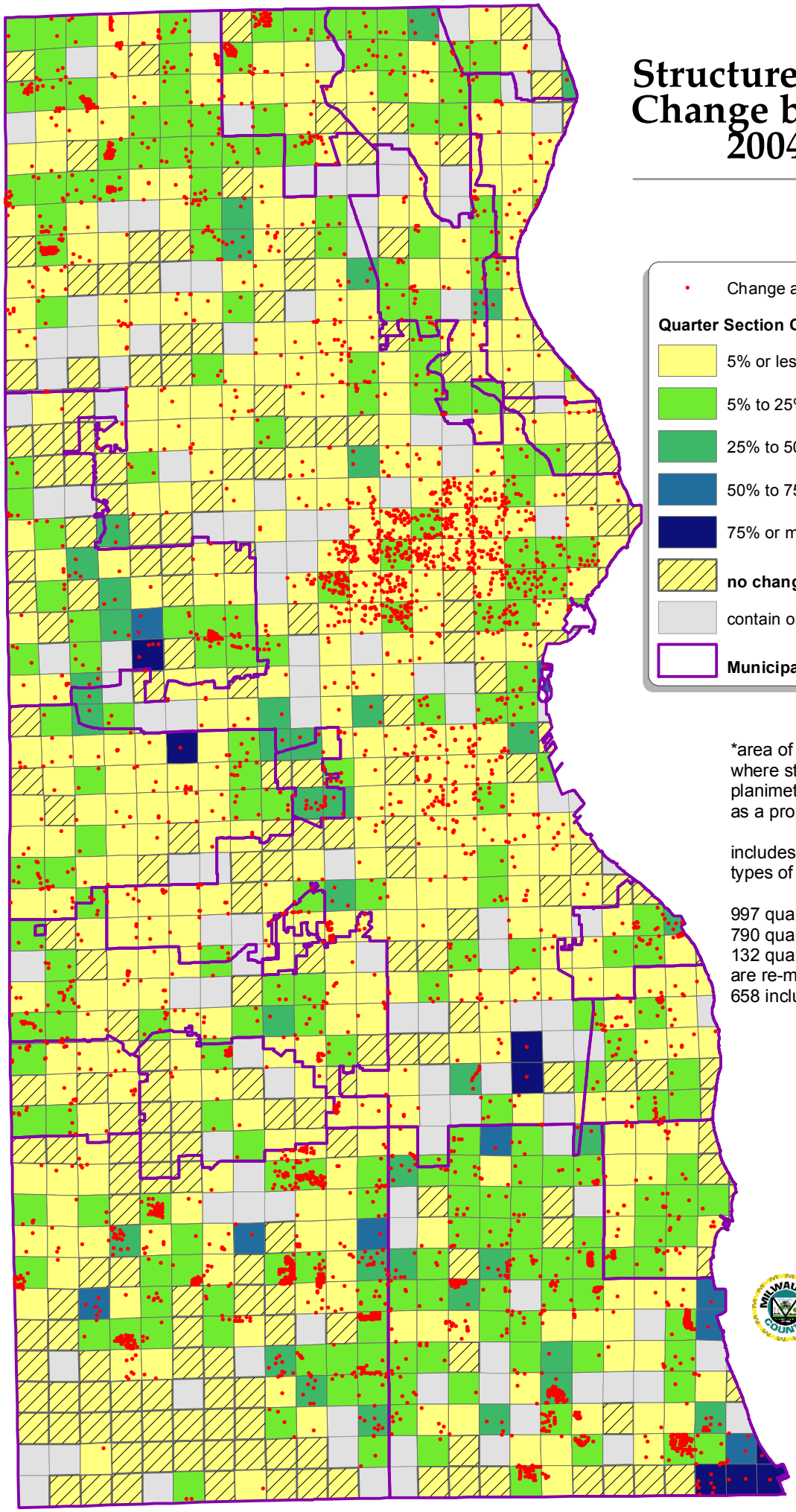
Map 2: Structure & Transportation Change by Quarter Section: 2004-05 vs. 2010 *

2011 Q2



Change at Parcel or ROW Level (4,183 instances)

Quarter Section Change Rate

- 5% or less (375)
- 5% to 25% (228)
- 25% to 50% (38)
- 50% to 75% (9)
- 75% or more (8)
- **no change (207)**
- contain only changes that are re-mappable in-house (132)
- **Municipal Subdivisions**

*area of parcels or portions of ROW where structure- or transportation-related planimetric change has occurred as a proportion of total quarter section area

includes only those quarters that include types of change that are not re-mappable in-house

997 quarters total
790 quarters have changed
132 quarters contain only changes that are re-mappable in-house
658 include changes that are not re-mappable in-house

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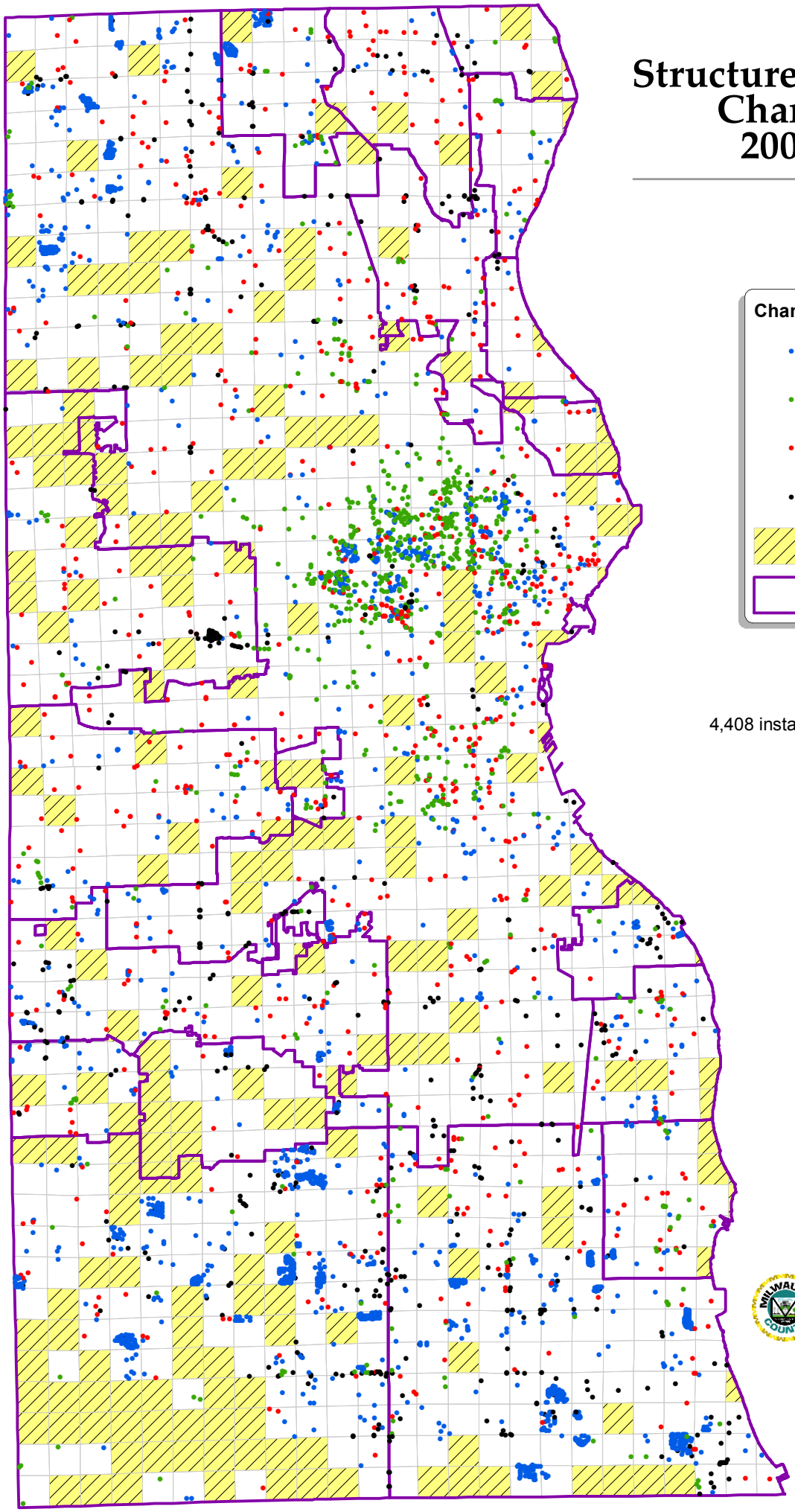
Map 3: Structure & Transportation Change Instances: 2004-05 vs. 2010

2011 Q2



Change Instances

- unimproved to improved (2,155)
- improved to unimproved (816)
- improved to improved (789)
- transportation (648)
- **no change (207 quarters)**
- **Municipal Subdivisions**

4,408 instances of change in 790 of 997 quarters

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