



**Wisconsin
State Cartographer's Office**



Concepts and Methods for Rule-Based Web Cartography

SCO Technical Paper

Version History

Version	Date	Notes	Author/Contact
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Introduction

One of the ways that interactive Web-based maps are different from traditional paper maps is that Web maps permit users to dynamically change map scale by interacting with a zoom tool. For example, Google Maps allows users to interactively zoom from small-scale world maps (which have a scale of one to several hundred million, depending on screen resolution) to very large-scale maps (which have a scale of one to tens of feet). Contrast this with traditional paper maps, where scale is fixed, or where larger- and smaller-scale representations are available only through a limited set of inset and overview maps.

The ability to dynamically change map scale poses some challenges for cartographic design, since the mapping engine must be prepared to effectively render map data for different scale displays. This can be accomplished in part through the use of stored rules that define how features are selected and symbolized at different scales. For extreme changes in scale it may also be necessary to store multiple versions of map geometry that are toggled on or off at different scale ranges.

This paper presents some simple concepts and methods to facilitate effective rule-based Web mapping in the context of dynamic scale change. The paper focuses on two main topics related to scale change:

- ✓ Content selection
- ✓ Feature symbolization

These are discussed with specific examples drawn from ControlFinder, an online application developed by the Wisconsin State Cartographer's Office (maps.sco.wisc.edu/ControlFinder).

ControlFinder is an open source application based on the GeoMoose web application framework, the OpenLayers Javascript Library, JQuery Javascript functions, the MapServer mapping engine, and a PostGIS/Postgresql database system for storing spatial data. ControlFinder makes use of the Google Maps API for basemap display. This paper provides some examples showing how content selection and symbolization methods are implemented in this software environment.

Objectives of this Technical Paper

This Technical Paper provides a quick overview of concepts and methods for Web-based cartography, with specific reference to issues of content selection and feature symbolization in the context of scale change. This paper is not an exhaustive discussion of these topics or of Web-based cartography in general. This paper explains

- ✓ Basic principles of content selection as a function of map scale, including layer-based selection, feature-based selection, multiple representations, and handling of feature labels (annotation).
- ✓ Illustration of content selection with reference to the SCO's ControlFinder application.
- ✓ Design of map symbols as a function of scale, with reference to ControlFinder.

At present the discussion is limited to:

- ✓ Symbolology and annotation examples for simple point and line features.
- ✓ Implementation examples involving cartographic integration with a Google basemap.

After reading this paper you should have a better understanding of some basic principles of selection and symbolization for Web-mapping, and be able to implement simple selection and symbolization rules to support dynamic scale change.

Content Selection

Content selection is a cartographic operation that defines the set of features to be displayed on a map of a specific scale. Larger-scale maps (e.g., US Geological Survey 1:24,000 topo maps) show more features than smaller-scale maps (e.g., a 1:500,000 state wall map). Smaller-scale maps tend to show only the most important features, while larger-scale maps are also able to show less important, local features.

In the context of multiple display scales, content selection involves specifying which features display across which scale ranges. Selection operates at both the layer level and the individual feature level. These operations are shown in the examples below.

Layer-Based Selection. Figure 1 shows a small-scale map of Wisconsin on the left (Fig. 1a; originally produced at a scale of 1:6,000,000) and a larger-scale map of southern Wisconsin on the right (Fig. 1b; originally produced at a scale of 1:3,000,000). (Note that map labels have not been included in any of these maps; labeling is discussed later in this document.)

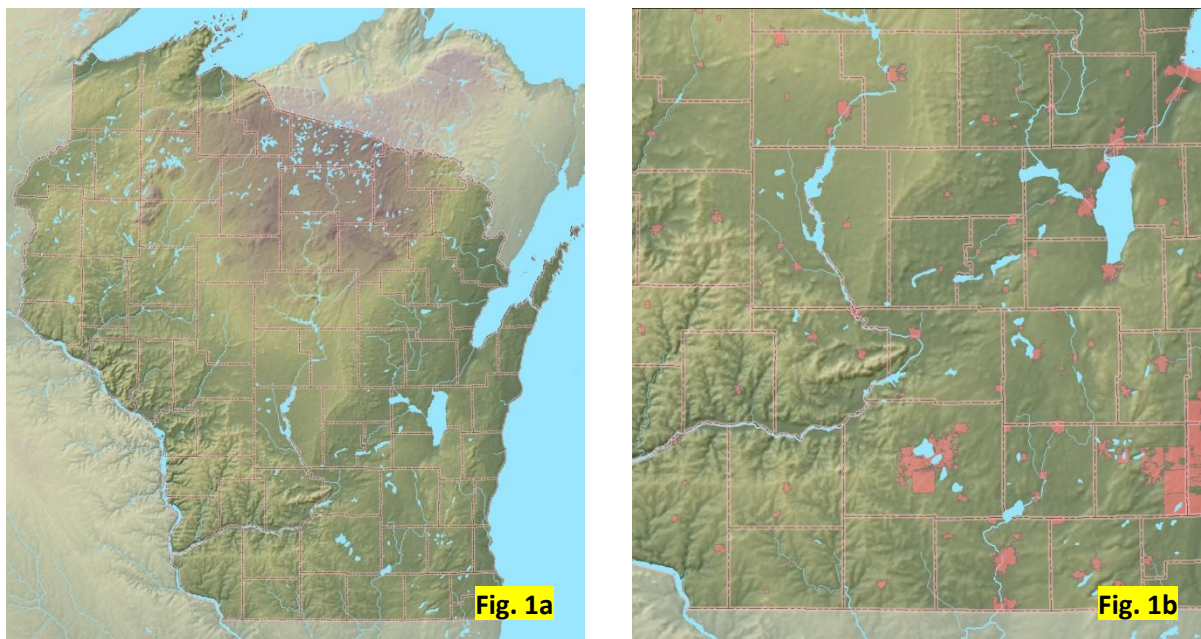


Fig.1: Example showing layer-based content selection

In layer-based selection, specific map layers are turned on or off as map scale changes. The county boundary layer (pink lines) appears on the small-scale map (Fig. 1a). This means that this layer is set to display at scales as small as 1:6,000,000. However, the city boundary layer (pink polygons) appears only on the larger-scale map on the right (Fig. 1b). This layer is set to begin displaying at scales of 1:3,000,000.

Technically, we can define an attribute – the minimum display scale – for each of these layers:

```
min_display_scale[county] = 1:6,000,000  
min_display_scale[city] = 1:3,000,000
```

We can use these values in a simple rule that states:

```
If current_map_scale >= min_display_scale[layer_x] then display layer_x  
Else do not display layer_x
```

For example, on a map at a scale of 1:4,500,000 only counties, not cities, will display. This is because current_map_scale (1:4,500,000) is larger than the minimum display scale for the county layer (1:6,000,000). However, since current_map_scale is smaller than the minimum display scale for the city layer (1:3,000,000), the city layer will not display.

Feature-Based Selection. Figure 2 shows the 1:3,000,000-scale southern Wisconsin map on the left (Fig. 2a), and a larger-scale map centered on Dane County on the right (Fig. 2b; originally produced at a scale of 1:1,500,000). In feature-based selection, specific features within a map layer are turned on or off as map scale changes. The linear hydrography network in Fig. 2b has more detail than that in Fig. 2a; for example note the additional rivers and streams that appear (such as the Yahara River; see arrow).

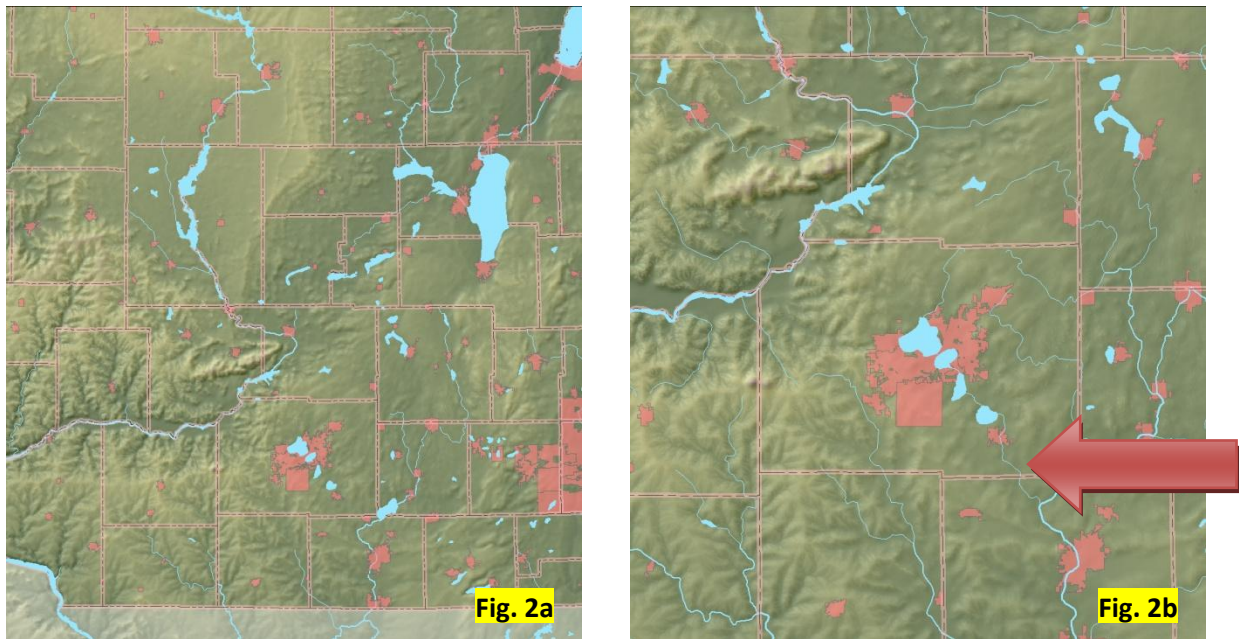


Fig. 2: Example showing feature-based content selection

For feature-based selection to work, we need an attribute that is populated with minimum scale values for each feature. The attribute table for linear hydrography might look something like this:

feature_id	feature_name	feature_type	min_display_scale
6498	Yahara	Stream/River	1:1,500,000
6546	Rock	Stream/River	1:3,000,000
...			

We can use this attribute in a rule that states:

If current_map_scale \geq min_display_scale[feature_x] then display feature_x
 Else do not display feature_x

Hence the Yahara River will only display on maps of 1:1,500,000 or larger, while the Rock River will display all the way up to scales of 1:3,000,000.

Attaching minimum scale values to all features in a layer can be an expensive and time-consuming task. For this reason, it is often possible to use more readily available surrogate values. For example, polygon hydrography is often attributed with an area value. Area can be used as a rough surrogate for minimum display scale, with the smallest polygons displaying only at the largest scales. Likewise, transportation data may contain a road jurisdiction attribute (e.g., Interstate, US Highway, State Highway, etc.) that can be used to toggle specific features on and off. Occasionally, however, using such surrogate values causes unwanted results, such as gaps in the road or hydrologic network.

Multiple representations. Figure 3 shows the 1:1,500,000-scale map centered on Dane County on the left (Fig. 3a), and a larger-scale map centered on Madison on the right (Fig. 3b; originally produced at a scale of 1:750,000).

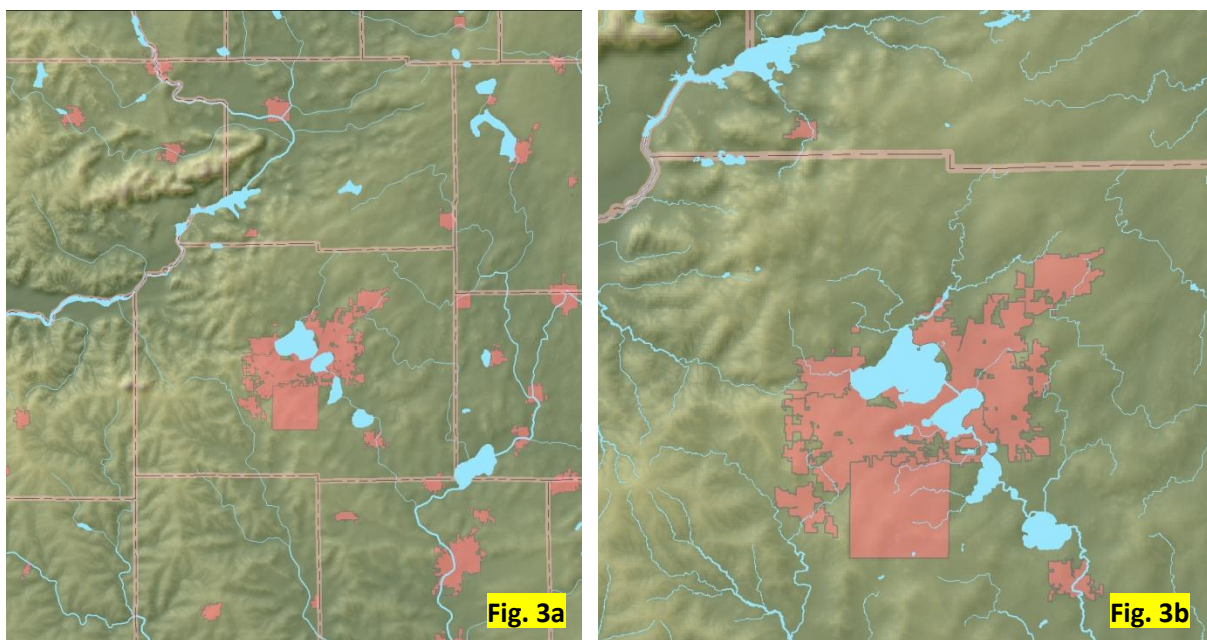


Fig. 3: Example showing multiple representations

This example illustrates the multiple representations concept. Often, it is not enough to display additional features as map scale increases. Most layers have a maximum scale at which they can be displayed; at larger scales than this, they begin to look overly simplified and generalized. In such instances it is necessary to substitute a new, more detailed layer. In the example above, the generalized hydrographic layer in Fig. 3a is replaced with a more detailed hydrographic layer in Fig. 3b.

To implement this method, two hydrographic layers reside in the database, and each is set to toggle on and off at a specified scale. This requires that, in addition to a minimum scale value for each layer, there is also a maximum scale value defining the largest scale at which the layer displays. For example:

```
min_display_scale[simple_hydro] = 1:6,000,000
max_display_scale[simple_hydro] = 1:750,000
min_display_scale[detailed_hydro] = 1:750,000
max_display_scale[detailed_hydro] = 1:125,000
```

We can use these values in a simple rule that states:

```
If current_map_scale >= min_display_scale[layer_x] and
   current_map_scale < max_display_scale[layer_x] then display layer_x
Else do not display layer_x
```

For example, if the map scale is 1:1,500,000 then only the simple hydrography layer will display, but if the scale is 1:500,000 then only the detailed hydrography layer will display.

The 1:125,000 value for max_display_scale for the detailed hydrography layer implies that another, even more detailed layer will be used for maps at scales larger than 1:125,000.

Web-Mapping Example

With a few simple modifications, these basic concepts of content selection can be applied to Web-based maps. To do this let's examine ControlFinder, the SCO's online geodetic control application.

ControlFinder uses the Google Maps API to deliver a basemap containing most of the map reference information needed for users to accurately navigate to areas of interest. Features included on the basemaps include hydrography, transportation, parks and preserves, populated places, and major administrative boundaries (countries and states). Since Google basemaps are delivered as pre-rendered image tiles, map content is fixed. Google cartographers have implemented their own rules to define content selection at each zoom level for which image tiles are available.

Figure 4 shows the Google basemap for the ControlFinder application.

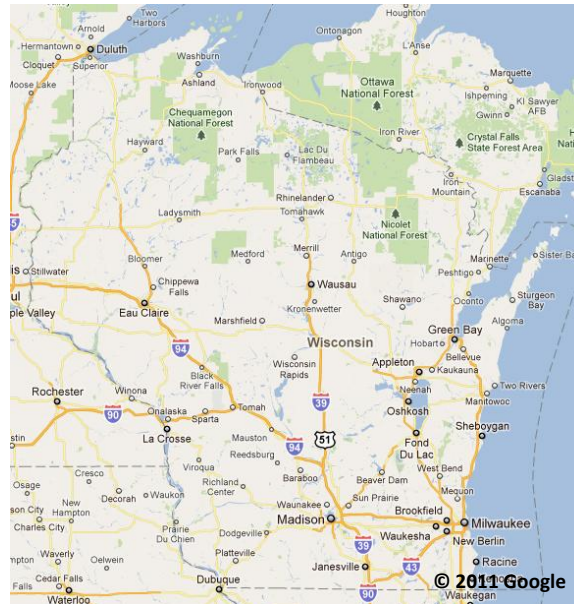


Fig. 4: Google base map in ControlFinder

Map layers that are not represented in Google basemaps must be superimposed on top. For ControlFinder, the following layers were added as Web Map Services (WMS):

- ✓ Geodetic control points from local governments, the National Geodetic Survey, the Wisconsin Department of Transportation, and the US Geological Survey. These are point layers with each type of control drawn with a separate symbol.
- ✓ County boundaries, including both the boundary linework and the county name.
- ✓ Public Land Survey System (PLSS) townships, including township boundaries and designation.
- ✓ PLSS sections, including section boundaries and number.

Since ControlFinder is a Web-based mapping application, content selection rules are implemented based on zoom level rather than map scale. The relationship between zoom level and map scale is specified by Google as part of their image tiling scheme. For ControlFinder the scale for each zoom level is as follows:

Zoom level	Approximate scale
1	1:3,500,000
2	1:1,750,000
3	1:875,000
4	1:438,00
5	1:219,000
6	1:109,000
7	1:55,000
8	1:27,500
9	1:13,800
10	1:6900
11	1:3500
12	1:1750
13	1:875

The following are the minimum zoom levels defined for all four layers of custom ControlFinder content. The `min_zoom_level` is the minimum zoom level (most zoomed out level) at which the layer displays. This is analogous to the `min_display_scale` attribute for paper maps.

Layer	min_display_zoom
Geodetic control	1
Counties	1
Townships	4
Sections	6

We can use these values in a simple rule that states:

If `current_zoom_level >= min_display_zoom[layer_x]` then display *layer_x*
Else do not display *layer_x*

For example, when the map is at zoom level 4 the following layers will be displayed: geodetic control, counties, and townships. When the user zooms in to level 6, sections will also be displayed.

The figures below illustrate these rules for zoom levels 1, 4 and 6.

Figure 5 shows the custom layers that have been selected to display at zoom level 1: geodetic control points (the colored dots) and county boundaries:

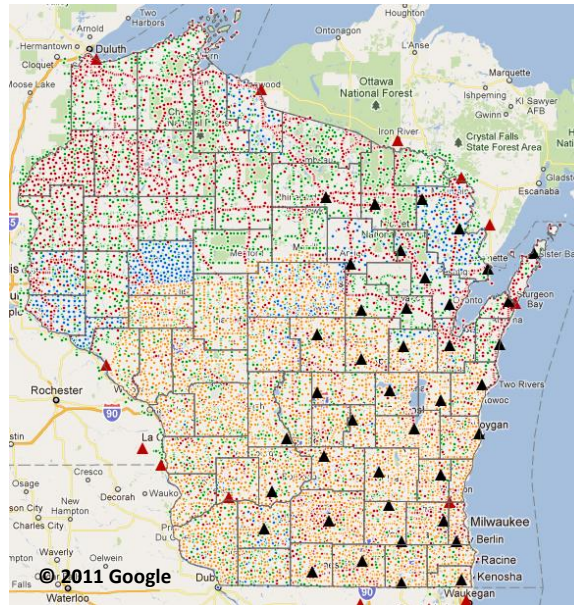


Fig. 5: Zoom level 1 in ControlFinder

Figure 6 shows ControlFinder at zoom level 4. At this level, PLSS townships first appear (in pink). Control points and counties continue to display as well.

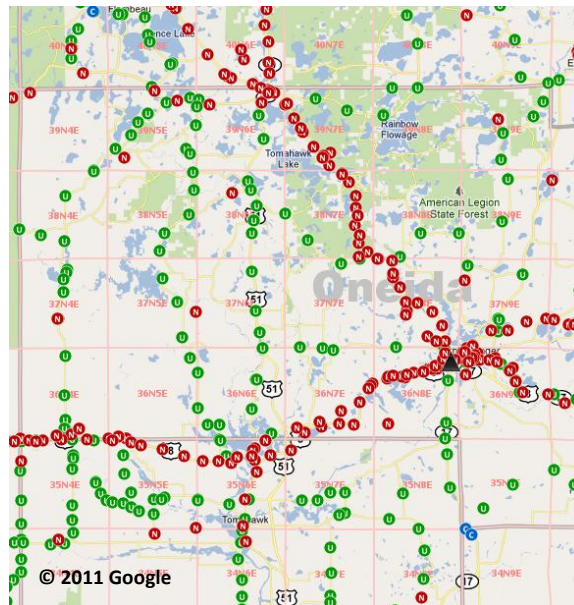


Fig. 6: Zoom level 4 in ControlFinder

Figure 7 shows ControlFinder at zoom level 6. At this level, PLSS sections first appear. Control points, counties and townships continue to display as well.

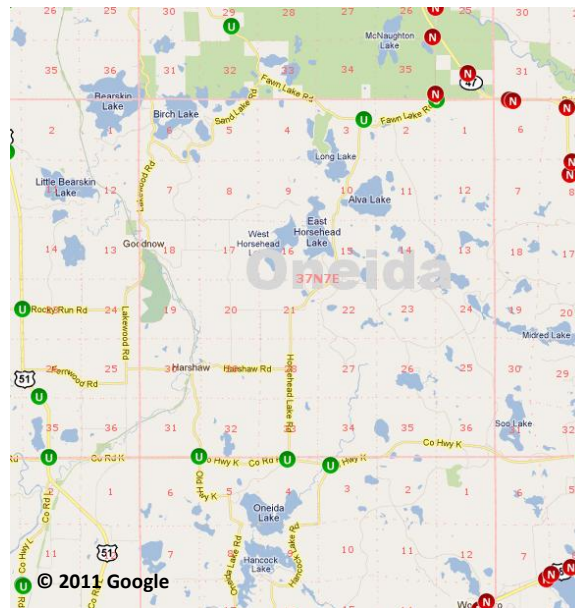


Fig. 7: Zoom level 6 in ControlFinder

The four custom layers in ControlFinder – geodetic control points, counties, townships and sections – are set to display at certain zoom levels (map scales) in ControlFinder based on layer-based content selection. At this time, feature-based selection and multiple representations are not used in ControlFinder for custom content (although they are used by Google in the development of the map tiles forming the ControlFinder basemap).

Labels and Annotation

It is noteworthy that the annotation (feature labels) associated with ControlFinder’s custom layers is also subject to selection rules, and that these rules are somewhat independent of the rules for layer geometry.

First, note that on zoom level 1 (Fig. 5), county boundaries display while county names do not, primarily because names are not legible at this scale. As this case illustrates, there may be cases where there is some cartographic value in displaying feature geometry without corresponding feature names. County boundaries, even without names, assist users in orienting themselves on the map and navigating to an area of interest.

Township designations and section numbers (in contrast to county names) display at zoom levels 4 and 6, respectively, the same zoom levels as the geometry with which they are associated (Figs. 6 and 7).

In contrast to layer geometry, which continues to display all the way to the most detailed zoom levels, annotation begins to disappear as the user zooms into the map. This is because we reach a zoom level where the area covered by the map window is much smaller than the area of the feature itself. For

example, by zoom level 7 in ControlFinder, the map window covers a small fraction of a typical Wisconsin county. At this point the county name is turned off.

This is conventional practice in cartography to avoid floating labels. In other words, we want to avoid placing labels that refer to geographic features with significantly larger areal extent than the map. This is why you would not normally see labels like “United States” or “Wisconsin” on a map of a city neighborhood.

To implement this rule in ControlFinder we define minimum and maximum zoom levels for our annotation layers. The minimum zoom level is the zoom at which the annotation layer starts to display, while the maximum zoom level is the most detailed zoom level at which it displays.

For ControlFinder, the values for county, township and section annotation are as follows:

Annotation layer	min_display_zoom	max_display_zoom
County names	3	6
Township names	4	8
Section numbers	6	12

The rule used to drive map labeling is as follows:

```
If current_zoom_level >= min_display_zoom[annotation_layer_x] and
   current_zoom_level <= max_display_zoom[annotation_layer_x] then
   display annotation_layer_x
Else do not display annotation_layer_x
```

Note that we use “<=” (less than or equal to) for maximum zoom, rather than “<” (less than) as we do for scale, since zoom levels are discrete, while scale is continuous.

The figures below show how these rules are implemented for ControlFinder.

Figure 8 compares ControlFinder at zoom levels 6 and 7. County names turn off at level 7.

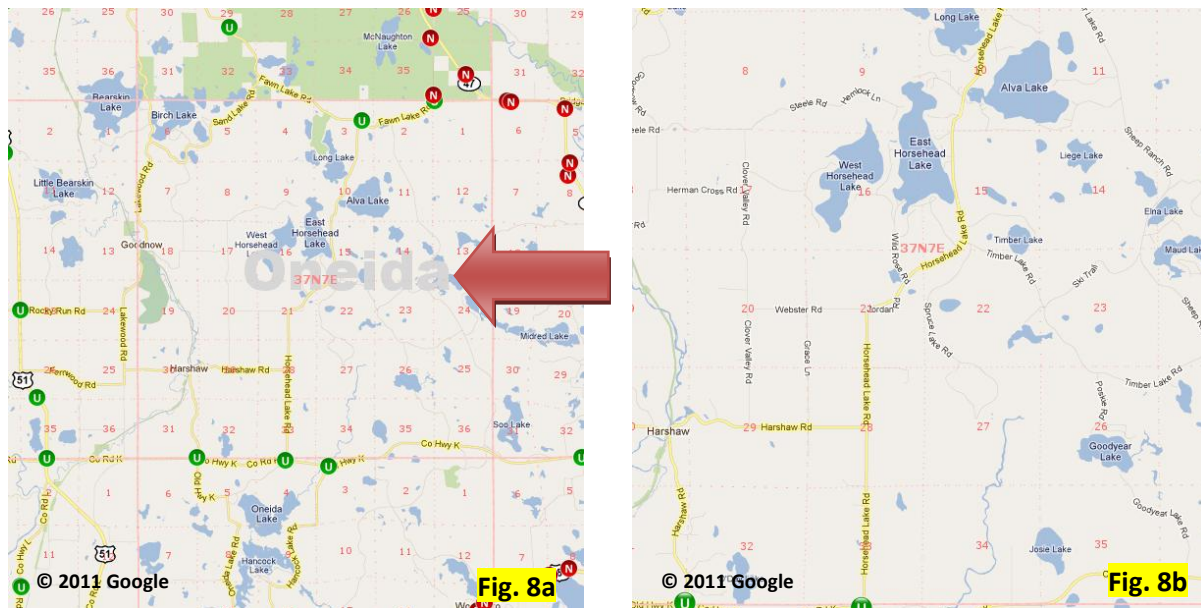


Fig. 8: Zoom level 6 (Fig. 8a; left) and 7 (Fig. 8b; right) in ControlFinder

Figure 9 compares ControlFinder at zoom levels 8 and 9. Township names turn off at level 9.

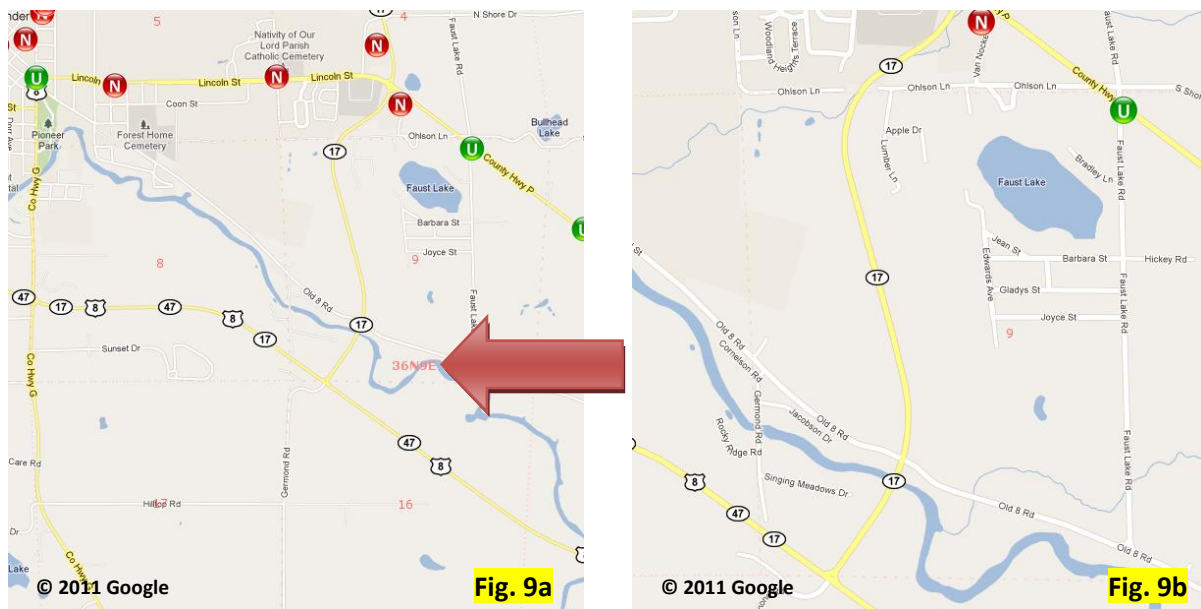


Fig. 9: Zoom level 8 (Fig. 9a; left) and 9 (Fig. 9b; right) in ControlFinder

Figure 10 compares ControlFinder at zoom levels 12 and 13. Section numbers turn off at level 13.

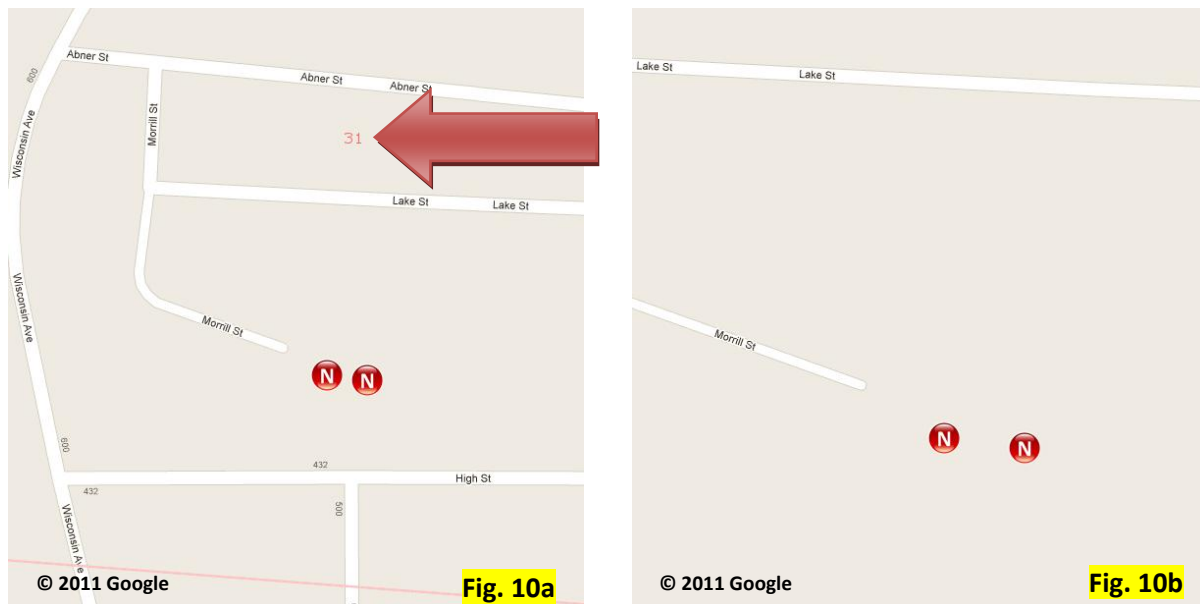


Fig. 10: Zoom level 12 (Fig. 10a; left) and 13 (Fig. 10b; right) in ControlFinder

Map Symbols

Map symbols are another aspect of Web maps that need to account for the dynamic effects of changes in map scale. In conventional paper map cartography, where scale does not change, symbols can be optimized for a single scale. For Web-based maps, multiple symbols need to be designed for a variety of zoom levels; this is similar in some ways to the multiple representations concept in that the size and complexity of the symbol varies with zoom level. Too often, Web maps use a single symbol at all zooms, resulting in a cluttered looking map at the highest zoom levels, and underpowered symbols at the most detailed zoom levels. While a unique symbol is not necessarily required for every single zoom level, a single symbol is generally not suited to producing effective maps across a wide range of zooms.

For ControlFinder, it was necessary to engineer a series of point symbols (for geodetic control points), line symbols (for county, township, and section boundaries) and text symbols (for county names, township names, and section numbers). (Control point labels are also used in ControlFinder but these labels are displayed only when users perform queries, and so they are not discussed here.)

One basic rule for designing symbols – whether point, line, or text – for Web maps is that when the size of the symbol increases with map scale, the increase should be at a declining rate. In other words, as the user zooms in, symbols get larger, but not at the same rate as features on the ground. If you zoom in on an image (an air photo or satellite image) centered on a highway, the width of the highway increases in direct proportion to map scale. If you zoom in on the same area on a map, the symbol representing the highway increases in width much more gradually.

This effect is illustrated below (Fig. 11) using Google basemaps as an example.



Fig. 11: Google satellite view (top row) and street view (bottom row) at zoom level 10 (left column) and 13 (right column)

The satellite and map views on the right (Figs. 11b and 11d) have a map scale eight times that of the views on the left (Figs. 11a and 11c). This scale difference is accurately reflected in the width of roads on the satellite view (compare Figs. 11a and 11b), but on the map view, road width differences are barely perceptible (compare Figs. 11c and 11d).

More detailed analysis of road widths on Google maps results in a graph similar to the following (Fig. 12). As this graph shows, road widths on Google maps increase at a much lower rate than the features they represent on the ground. In addition, “plateaus” exist (see arrow) where there is minimal increase in width across a range of scales.

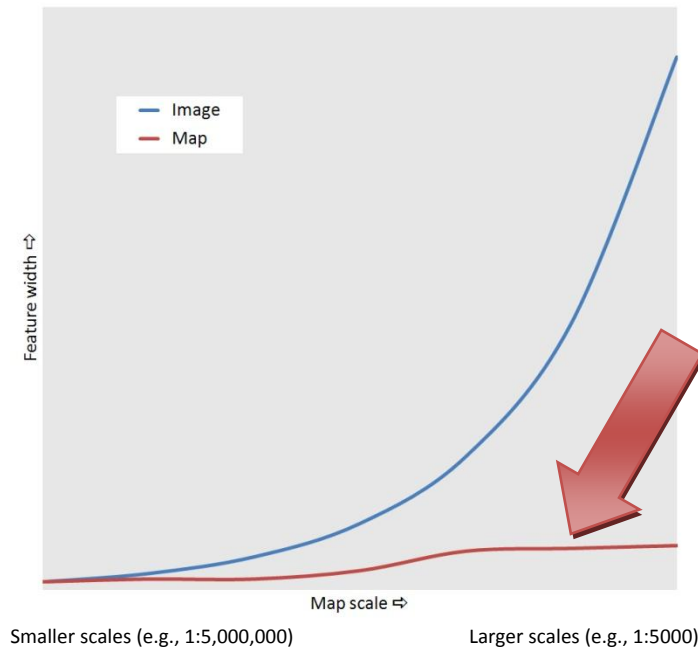


Fig. 12: Sample road widths on Google map and image views

This relationship is not unique to Google maps but reflects standard cartographic practice, as can be seen by comparing maps of different scales in road and world atlases.

Line Symbols and Labels in ControlFinder

As noted above, ControlFinder is an open source application. Implementation of selection and symbolization methods is achieved using MapServer mapfiles (<http://mapserver.org/mapfile/index.html>). Mapfiles define how features are drawn, including symbol specifications and layer selection rules.

As an example, let’s consider the mapfile for PLSS townships. Townships are defined as a layer in the mapfile; within the layer, multiple classes are defined, each of which represents a scale range at which townships display on the map.

For example, the class definition for zoom level 4 – the first zoom level at which townships display – looks something like the following. (Note that the class definition examples shown here are for explanatory purposes only and may not contain all necessary parameters).

```

CLASS #Zoom 4#
  NAME "PLSS_Township"
  MINSCALEDENOM 400000
  MAXCALEDENOM 450000
  STYLE
    OUTLINECOLOR 255 200 200
    SIZE 1.5
  END
END

```

The keywords in this class definition define both selection rules and symbolization for township boundaries.

In terms of selection, the minimum display scale is defined by the parameter *MAXCALEDENOM* and the maximum display scale is defined by the parameter *MINSCALEDENOM*. This terminology reflects the fact that MapServer uses the representative fraction denominator (e.g., 400,000 rather than 1:400,000). Other than the terminology difference, the concept is the same as discussed in this paper.

The minimum and maximum scale ranges must be designed to encompass the map scale at each zoom level. For ControlFinder, which uses Google basemaps, this requires knowledge of the map scales defined by Google's map image tiling scheme. In the example above, for zoom level 4 map scale is between 1:400,000 and 1:450,000.

A class definition must exist for any zoom level at which townships are to display. For example, since townships also display at zoom 5, the mapfile also contains a class definition for the scale range associated with zoom level 5. In fact, since townships display all the way to zoom 13, there are ten class definitions in the mapfile, one for each zoom level between 4 and 13, inclusive. (From an implementation perspective, it is possible to collapse multiple class definitions into a single class if display specifications do not change across scales.)

In terms of feature symbolization, various mapfile parameters play a role. *OUTLINECOLOR* defines the color of the polygon linework as an RGB (red-green-blue) tuple with values from 0 to 255. The tuple 255 200 200 yields a pink color.

SIZE is the width of the line and is given in output image pixels.

The table below summarizes key parameters for PLSS townships in ControlFinder.

Zoom level	Minimum display scale	Maximum display scale	Symbol	Color	Size
4-7	1:450,000	1:50,000	Solid line	255 200 200	1.5
8-13	1:30,000	1:300	Solid line	255 200 200	2.0

Note that township line thickness changes only once, as the map jumps from zoom level 7 to 8.

The mapfile also contains class definitions for township names. Since township names start appearing at zoom level 4, the first class definition is:

```
CLASS #Zoom 4, East Range#
  NAME "PLSS_Township"
  MINSCALEDENOM 400000
  MAXSCALEDENOM 450000
  TEXT ([twp]N[rng]E)
  LABEL
    TYPE truetype
    SIZE 7
    FONT "verdana-bold"
    POSITION Auto
    BUFFER 2
    COLOR 255 135 135
    PARTIALS FALSE
    FORCE TRUE
  END
END
```

As with township geometry, the class definition includes the scale range at which the class displays. A class definition similar to the above exists for each scale range at which township names appear on the map. Since township names stop appearing after zoom level 8, there only five class definitions in the file, one for each zoom level between 4 and 8, inclusive.

The class definition also includes the text specifications and automated labeling parameters for township names.

The table below summarizes key parameters for township names in ControlFinder.

Zoom level	Minimum display scale	Maximum display scale	Font	Color	Size
4	1:450,000	1:400,000	Verdana bold	255 135 135	7.0
5	1:250,000	1:200,000	Verdana bold	255 135 135	8.0
6	1:125,000	1:100,000	Verdana bold	255 135 135	9.0
7	1:60,000	1:50,000	Verdana bold	255 135 135	10.0
8	1:30,000	1:25,000	Verdana bold	255 135 135	10.0

Point Symbols in ControlFinder

Point symbols in ControlFinder are handled in a similar way through the use of mapfiles. One difference is that at most zoom levels these symbols are images (PNG files) created specifically for the ControlFinder application.

The various symbols refer to control points from local governments, the National Geodetic Survey, the Wisconsin Department of Transportation, and the US Geological Survey. The specific meaning of each point type is not important to this discussion. However, detailed explanations can be found on the ControlFinder interface if desired

(www.sco.wisc.edu/index.php?option=com_content&view=article&id=1540&Itemid=697).



Fig. 13: Geodetic control point symbols used in ControlFinder

For the purposes of this discussion we will focus on the red NGS (National Geodetic Survey) symbol. The symbol shown in Figure 13 is actually the most detailed version of the symbol and appears at only the most detailed zoom levels. In fact, this symbol has four main variants used at different zoom levels in ControlFinder.

At the smallest map scales (zoom levels 1 through 3) the symbol is simply a red dot with a white halo. There is no “N” character within the dot (Fig. 14).

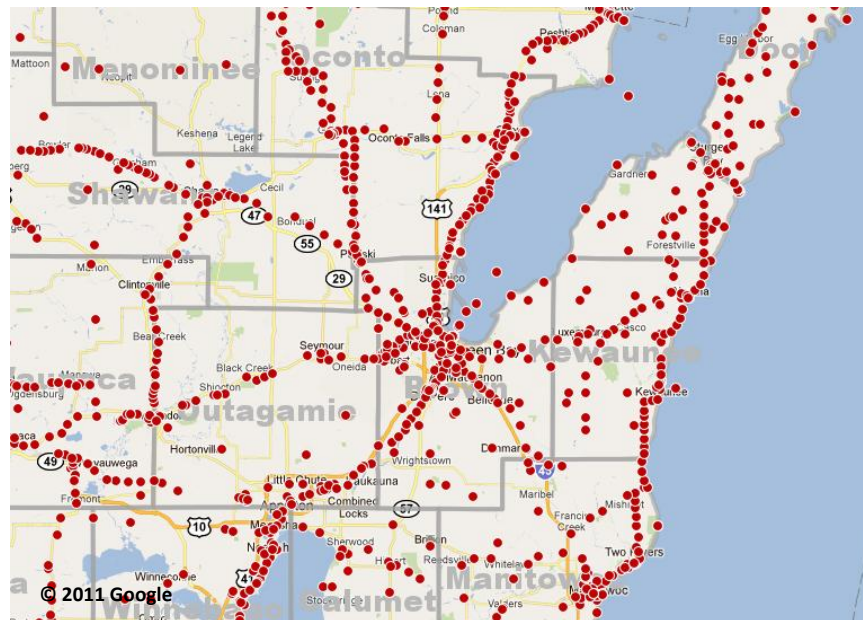


Fig. 14: NGS points in ControlFinder at zoom level 3

At zoom levels 4 and 5 an “N” character is added to the dot (Fig. 15).

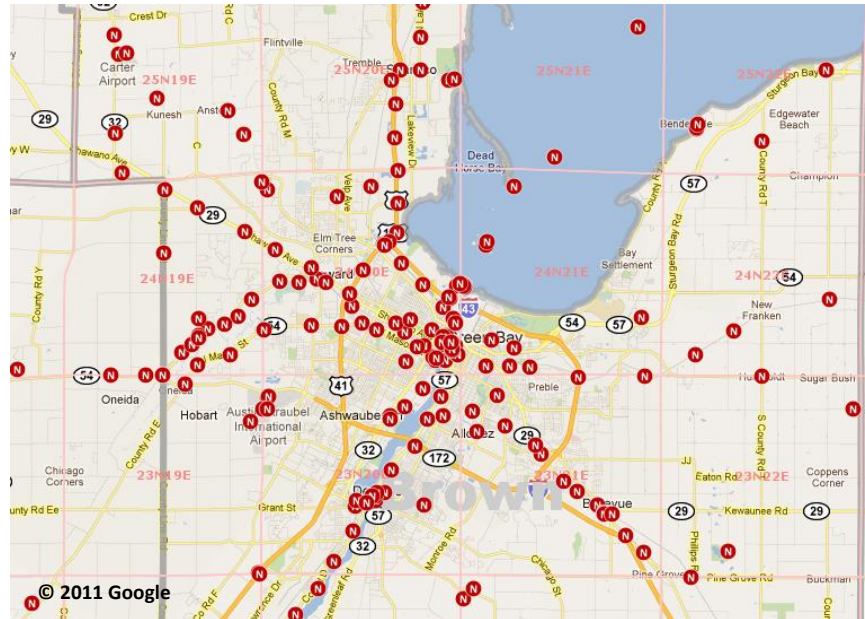


Fig. 15: NGS points in ControlFinder at zoom level 5.

At zoom level 6 a gradient is added to the symbol (Fig. 16).

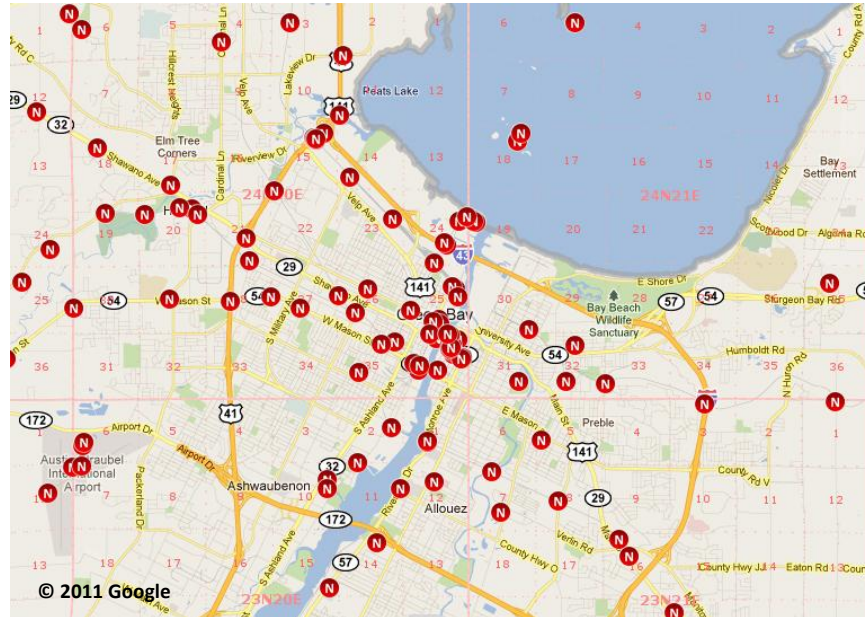


Fig. 16: NGS points in ControlFinder at zoom level 6.

At zoom levels 7 through 13 additional visual effects are added to the symbols to give them a spherical appearance (Fig. 17).

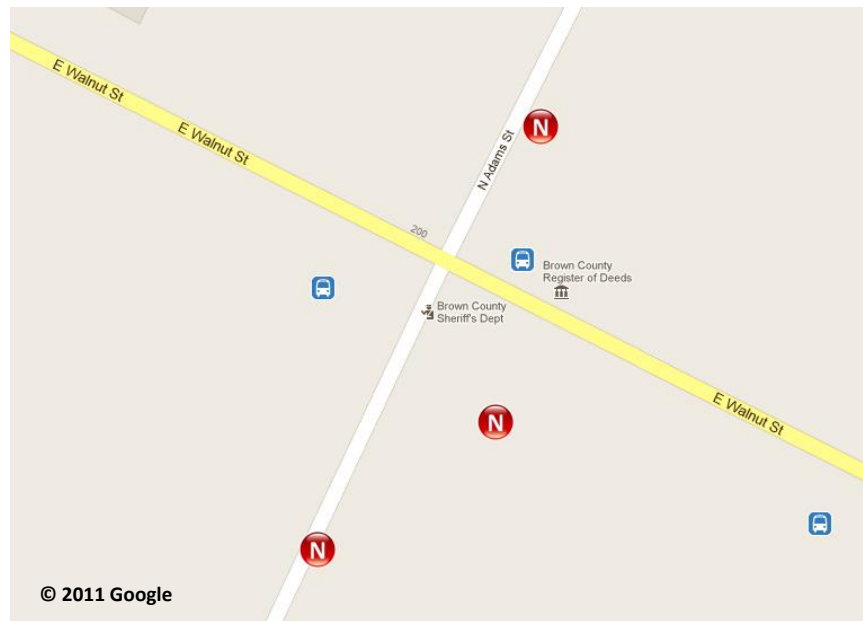


Fig. 17: NGS points in ControlFinder at zoom level 13.

These changes are controlled by a mapfile that defines the symbols to be used at each zoom level. At the first three zoom levels the symbol is drawn using native MapServer functionality, rather than calling on a stored PNG file. The class definitions at these three zoom levels look similar to the following:

```
CLASS #Zoom 1#  
  MAXSCALEDENOM 3500000  
  MINSCALEDENOM 3400000  
  NAME "circle_NGS"  
  SYMBOL 'circle'  
  SIZE 4  
  COLOR 189 1 1  
  OUTLINECOLOR 255 255 255  
END
```

This class definition gives the scale range at which the defined symbol is to be used (MAXSCALEDENOM and MINSCALEDENOM), and defines the size, color, and outline color (halo) of the symbol.

Similar class definitions exist for zoom levels 2 and 3 as well.

The keyword SYMBOL points to a symbol definition in another file (symbol.sym) containing a more detailed description of the symbol design. Starting at zoom level 4, SYMBOL points to a PNG rather than a detailed symbol description.








```

CLASS #Zoom 4#
  MAXSCALEDENOM 500000
  MINSCALEDENOM 400000
  NAME "NGS"
  SYMBOL 'NGS_4'
END

```

The symbol *NGS_4* points to a file called *zoom4_red_circle.png*, which is stored on the map server. Similar class definitions exist for zoom levels 5 through 13, each pointing to a slightly different version of the NGS symbol.

The table below summarizes this information for all zoom levels.

Zoom level	Minimum display scale	Maximum display scale	Circle definition	Appearance
1	1:3,500,000	1:3,400,000	SYMBOL 'circle', SIZE 4, COLOR 189 1 1, OUTLINECOLOR 255 255 255	•
2	1:1,800,000	1:1,600,000	SYMBOL 'circle', SIZE 6, COLOR 189 1 1, OUTLINECOLOR 255 255 255	•
3	1:900,000	1:800,000	SYMBOL 'circle', SIZE 9, COLOR 189 1 1, OUTLINECOLOR 255 255 255	•
4	1:450,000	1:400,000	<i>zoom4_red_circle.png</i>	
5	1:250,000	1:200,000	<i>zoom5_red_circle.png</i>	
6	1:125,000	1:100,000	<i>zoom6_red_circle.png</i>	
7	1:60,000	1:50,000	<i>zoom7_red_circle.png</i>	
8	1:30,000	1:25,000	<i>zoom8_red_circle.png</i>	
9	1:15,000	1:10,000	<i>zoom9_red_circle.png</i>	
10-13	1:7500	1:300	<i>zoom10_13_red_circle.png</i>	

Summary

This paper has presented some simple concepts and methods to facilitate effective Web-based mapping in the context of dynamic scale change. The two main topics discussed in the paper are content selection and feature symbolization. These topics are discussed with specific examples drawn from ControlFinder, an online application developed by the Wisconsin State Cartographer's Office (maps.sco.wisc.edu/ControlFinder).

In summary:

- ✓ Content selection is a cartographic operation that specifies the features to be displayed on maps of different scales.
- ✓ Selection can be implemented at the layer or feature level. In layer-based selection, specific map layers are turned on or off as map scale changes. In feature-based selection, specific features within a map layer are turned on or off.
- ✓ Both layer-based and feature-based selection can be implemented by invoking display rules that reference a minimum display scale, which is the minimum scale at which the layer or feature displays.
- ✓ With large changes in scale it is often necessary to employ multiple representations, separate layers in the cartographic database designed for different scale ranges. This approach requires both a minimum and a maximum display scale for each layer, where the maximum scale is the largest scale at which the layer displays.
- ✓ Content selection rules may be implemented for Web maps using zoom level rather than map scale.
- ✓ Annotation layers (feature labels) are also subject to selection rules, but these rules are somewhat independent of the rules for layer geometry. There are many instances in which geometry appears on the map while associated labels do not.
- ✓ Annotation often toggles off at detailed zoom levels to avoid floating text, i.e., instances where the area covered by the map window is much smaller than the area of the feature itself.
- ✓ Map symbols for Web maps need to be designed for a variety of zoom levels. This is similar to the multiple representations concept in that the size and complexity of the symbol varies with zoom level.
- ✓ When the size of a symbol increases with zoom level, the increase should be at a declining rate. As the user zooms in, symbols may get larger, but not at the same rate as features on the ground.
- ✓ Implementation of selection and symbolization rules in ControlFinder is achieved using MapServer mapfiles, which define symbol specifications and layer selection rules.
- ✓ Mapfiles use class definitions to render symbols at different zoom levels. A class definition must exist for any zoom level at which features are to display.
- ✓ ControlFinder references multiple image files to draw point symbols of varying complexity at different zoom levels.

Future versions of this paper will include more advanced topics. Please let the State Cartographer's Office know what topics would be of value to you:

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