# Guidelines for Consistently Readable Topographic Vectors and Labels with Toggling Backgrounds

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**Abstract.** Map symbols may fail against backgrounds when their hues or color lightness levels match the immediately local background too closely, or when their shape is indistinguishable from shapes seen in the background. Strategies for legibility among toggling layers such as orthoimagery, terrain shading, and land cover include: i) deliberate use of simultaneous contrast, ii) strategic hue and lightness selection, iii) multi-band text halos, iv) transparency, v) strategic sequencing of layers, and vi) use of classical elements such as road casings. This paper describes uses of these effects for national topographic mapping for the United States.

**Keywords:** cartographic design, color contrast, interactive maps, topographic mapping

## 1. Introduction

A typical feature of interactive maps is the ability to toggle layers on and off. This functionality is now included in United States Geological Survey (USGS) "US Topo" 1:24,000 maps served in GeoPDF format. There has been little research in cartography on how vector and label symbols visually interact with varied, toggled backgrounds, despite this being a common scenario. While one effective strategy is to use different symbols for different backgrounds, this may not always be possible (e.g., mashups with unalterable service layers) or desirable. Further, layered interactive maps such as US Topo need to be graphically robust across diverse viewing environments (e.g., print, monitor and mobile screens). We present strategies used to develop vector and label designs for US Topo that maintain readability with fixed symbology across all possible layer toggle permutations. In this proceeding paper we pay particular attention to lightness contrast interactions between symbols and backgrounds. For the conference talk, we generalize these strategies to provide a set of guidelines for symbolization in multi-layer interactive mapping environments.

## 2. Background

A color's appearance is always perceived relative to its surroundings. *Simultaneous contrast* (also termed *induction*) is a perceptual effect that enhances the differences between adjacent colors. A medium lightness color on a dark surround looks lighter than that same color with a light surround. Adjacent small color elements tend to average together as partitive mixtures, rather than becoming more visible with contrast effects, so cartographers must deal with a complicated combination of contrast and mixture effects for letters, points, and lines across varied backgrounds.

Looking at our topographic symbol design challenges with particular attention to color contrast brings back to mind work done over 20 years ago by the second author for her dissertation (Brewer 1991, 1992, 1996, 1997). This research on simultaneous contrast was also a foundation for construction of ColorBrewer.org, a popular tool online that serves color specifications for thematic map symbolization, serving sequential, diverging, and qualitative schemes with 3 to 12 classes per scheme (Brewer 2003, Harrower & Brewer 2003). The arrangement of the ColorBrewer display to visualize a chosen color scheme is designed to see all contrast combinations—each color is seen as small isolated patches against a background of every other color in the scheme. They are also seen intermixed with the other colors to allow the user to visually confirm that all colors remain distinct. Optional linear features are shown across all color backgrounds as well. These arrangements of color do not prevent simultaneous contrast effects on maps; rather, they help the map designer decide whether contrast may have a negative impact on the readability of their map. (ColorBrewer tools are currently programmed and updated by Andy Woodruff of Axis Maps—thanks Andy.)

Color contrast on maps is a current topic of research as well. Of particular note is work by researchers in the COGIT Laboratory at IGN (Institut Géographique National), France, currently lead by Cécile Duchêne. Anne Ruas, the previous director, supervised two PhD theses with contrast as a core aspect for map design automation: Elisabeth Chesneau (2006), and Sidonie Christophe (2009a), who worked with Elodie Buard to formalize contrast for on-demand and topographic mapping (Buard & Ruas 2007, 2009). Chesneau (2011) uses contrast calculations to ensure risk themes and base information are easily distinguished as different colors are selected. Christophe (2009b, 2011) has a series of papers on automated and creative color selection based on personal preferences or artistic works. Her COLLEG system converts candidate color selections into palettes for map displays, and uses contrast and relative amounts of each color in the process of matching colors to feature types. COGIT continues to sponsor work on map design topics as well as automation and generalization.

# 3. Design for U.S. Topographic Mapping

Symbols may fail against backgrounds when their hues or color lightness levels match the immediately local background too closely, or when their shape is indistinguishable from shapes seen in the background. Strategies for legibility among toggling layers include: i) deliberate use of simultaneous contrast, ii) strategic hue and lightness selection, iii) multi-band text halos, iv) transparency, v) strategic sequencing of layers, and vi) use of classical elements such as road casings.

## 3.1. Contrast

While typically complicating map design and reading, simultaneous contrast can be used to ensure vectors remain visible over base maps with high graphical variation, such as orthoimages (Raposo & Brewer 2011, in press). Our designs use this in the choice of gray lightness level used for roads: the gray used appears darker when seen over bare white, hillshade and contours, but lighter over land cover and orthoimagery, contrasting distinctly in each case. Alternating dark and light dashes are used for unpaved roads and boundary lines so that, given certain backgrounds, either dash is noticed by simultaneous contrast (see horizontal dashed boundary across upper portion of *Figure 1*). On a light background, the dark dashes are seen, while on a dark background the light dashes are seen. On medium lightness backgrounds both are seen, and the contrast between consecutive dashes improves the prominence of the line.

Similarly, streams use subtly alternating triplets of blues along the line to remain prominent against varied backgrounds. With a complex orthoimage and land cover background, this alternation creates a bit of lightness contrast whether the steam surroundings are light or dark. The blues are close in hue and lightness so that, when the background is white, the differences among the blues are purposefully overwhelmed by the induced darkening of the line, and the line looks mostly the same darker blue color. Likewise, over a dark background, the line takes on a coherent lighter blue appearance. *Figure 1* shows the effect with the full background and *Figure 2* shows the same location without land cover, hillshade, or orthoimagery. Notice how the hydrography looks like single dark blue lines and the contour lines look darker in *Figure 2*.

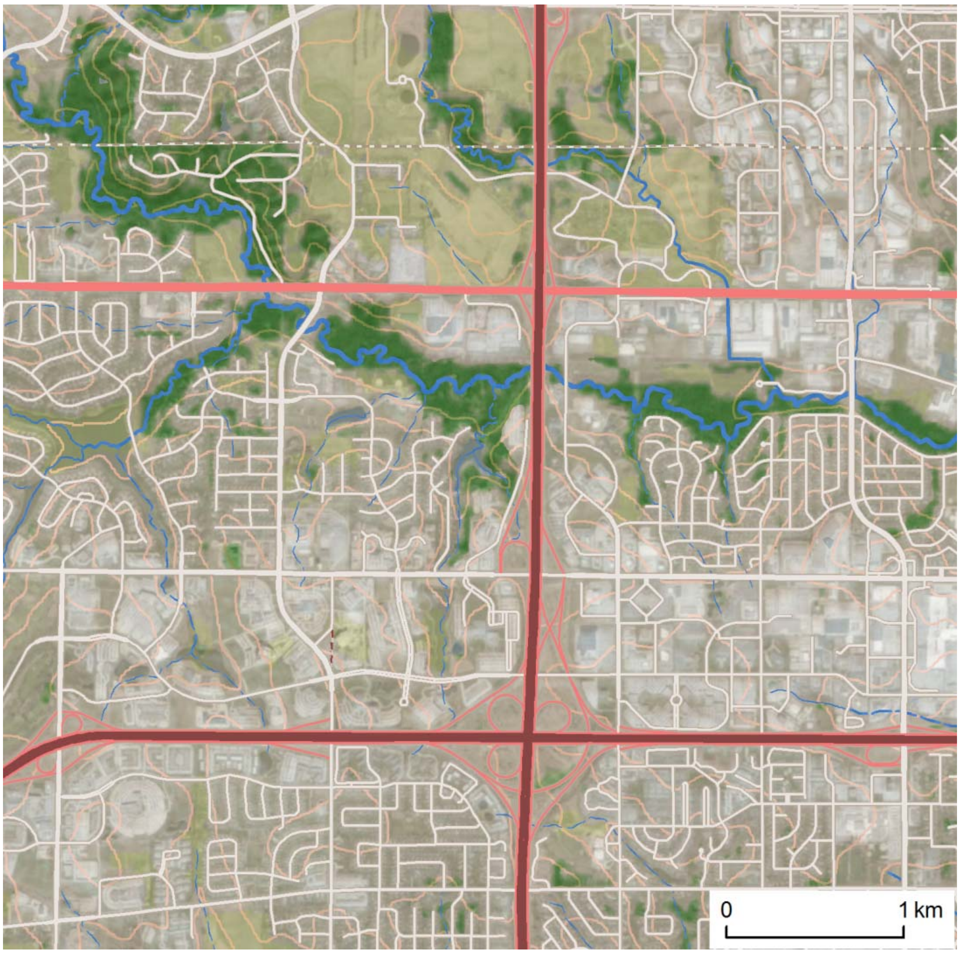



**Figure 1.** Examples of dashed boundary, lightness variation on hydro lines, contours, and road casings with hillshade, land cover, and orthoimage background layers.

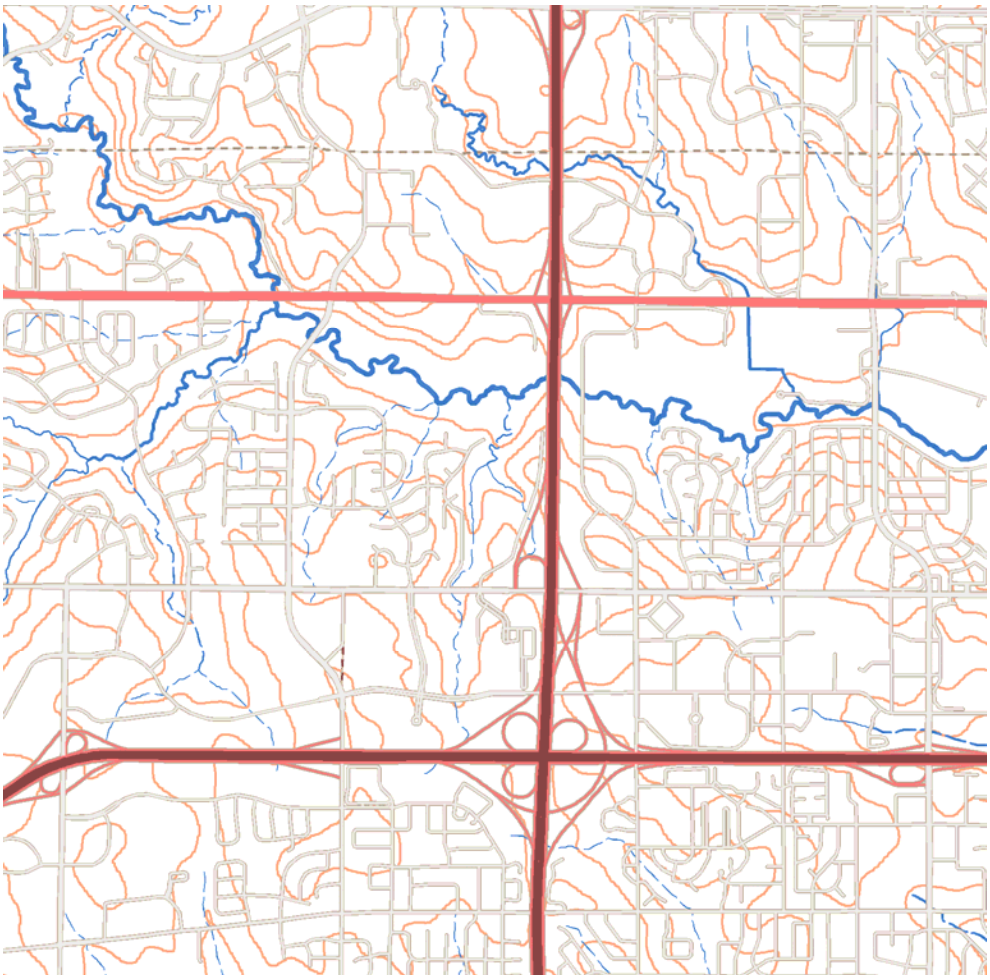


**Figure 2.** Similar to *Figure 1* without the hillshade, land cover, and orthoimage background layers. The hydrography, road, and boundary lines are all identical in specification to *Figure 1* but look quite different with a high contrast white background.

Hydrography lines are hard to see at any single lightness against these visually complex backgrounds of varied lightness. The intermittent dash has a subtle “wave” of lightness levels within dashes for contrast against busy backgrounds. The perennial line has a subtle wave of lightness levels in an embedded long dash. *Figure 3* shows an example set of three dashes over a solid line to create this effect within a multi-layer line, and color specifications for either stream type are as follows:

*Intermittent blues:*

- Top: darker blue (58, 119, 193)
- Middle: medium blue (65, 124, 199)
- Bottom: lighter blue (77, 134, 209)

*Perrenial blues:*

- Top: medium blue (65, 124, 199)
- 2nd: lighter blue (71, 129, 204)
- 3rd: medium blue (65, 124, 199)
- Bottom: darker blue (58, 119, 193)

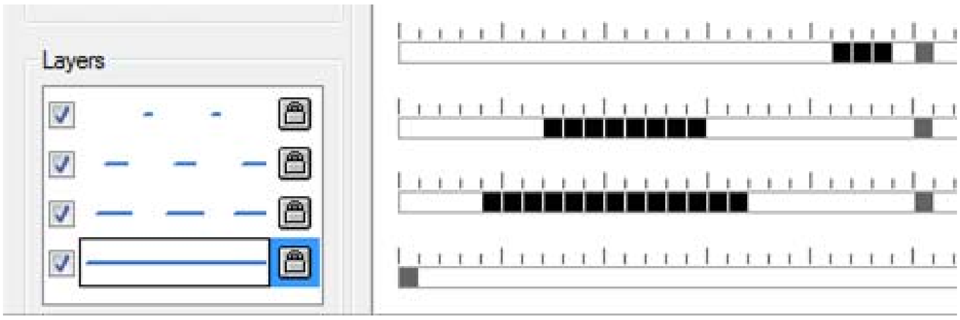



**Figure 3.** Dash specification for hydrography line variation in lightness. Ticks along bars at right show the dash templates for a four-layer line (at left).

## 3.2. Halos

We use multiple thin bands of related colors to maximize the robustness and aesthetic appeal of text halos. Darkest bands are those closest to letter forms when letters are drawn in light colors, and lightest bands are closest when letters are dark. This ensures legibility and provides a simultaneous contrast effect that enhances the internal edge of the text. In the case of white road labels (*Figure 4*), the dark inner halo ensures a prominent letter edge, and the lighter second halo blends with the road casings, linking the label with its feature. The outer halo also blends with the most common lightness levels of the land-cover colors to not cause an abrupt blot on either colorful or plain backgrounds. The double halo does make the letters larger but allows labels to visually blend with modulating backgrounds, thereby minimizing a forced appearance. This strategy is a simple imitation of a glow effect within the reduced graphical sophistication of a GIS design environment. Color specifications for road label halos are as follows:

*Road labels:*

- Text: white
- Fill: dark beige (186, 170, 153)
- Outline: beige (212, 193, 174)


**Figure 4.** Labels enlarged to show halos with outline and fill around characters.

### 3.3. Transparency and Layer Order

Transparency is used, notably for roads and hydrographic areas. This allows some perception of underlying features, such as orthoimagery, even though these may be overlaid by toggling. Transparent gray roads allow visual interaction with underlying raster land cover, where built-up areas are symbolized in colors trending toward white in a design decision reinforcing the roads.

*Vertical layer order:*

- Waterbodies; 30% transparent with opaque outlines
- Hillshade; 90% transparent (white to black ramp)
- Land cover raster; 40% transparent
- Contours; desaturated orange (RGB: 255, 167, 127)
- Orthoimage

Strategic hue selections and layer ordering are essential to ensure legibility. Contours in our design are desaturated orange, a hue unused in other layers and relatively unlikely to appear in orthoimagery. Terrain shading is included below human features (e.g., roads), but over contours, in part to ensure a combination of roads, contours and hill shading remains legible by abating the contours. Positioning contours below hillshade and land cover layers causes them to appear light on dark areas of orthoimagery, but not overly vivid.

## 3.4. Casings

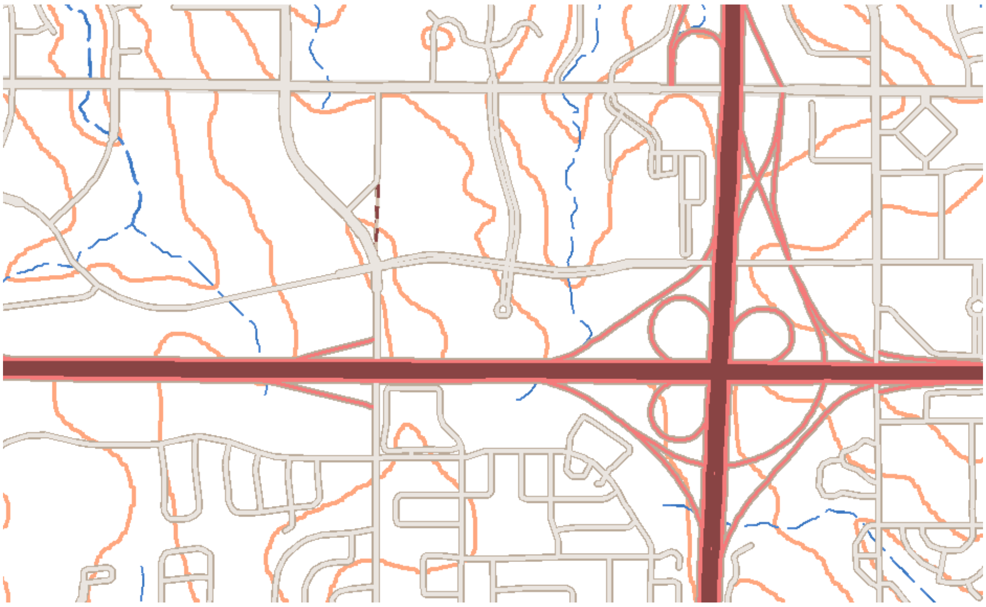
Finally, traditional elements such as road casings make vector symbols robust against toggled backgrounds by diversifying the hues and lightness levels in the symbol, and by delineating the feature, making color and shape matches with backgrounds less likely. *Figure 5* shows the road casings enlarged. Light red lines for ramps merge well into highways that are also cased in the same color. All roads are also cased in beige (see color specifications below). Light local roads provide a stylistic link to additional light roads visible in the orthoimage but omitted in the vector data (*Figure 5b*).

*Interstate 3-layer line example:*

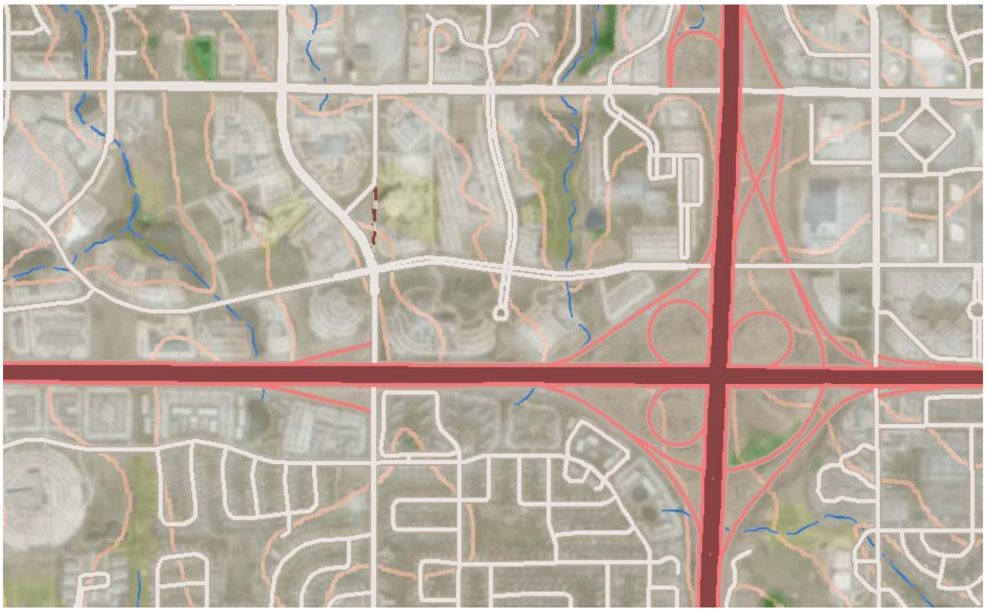
- 2.0 pt, dark red (RGB: 137, 68, 68)
- 3.5 pt, light red (245, 122, 122)
- 4.5 pt, dark beige (186, 170, 153)

*Local Road 2-layer line example:*

- 1.2 pt, light beige (234, 229, 224)
- 2.0 pt, dark beige (186, 170, 153) – same as interstate casing



a)



b)

**Figure 5.** Closer view of road casings with two backgrounds. Notice the dark beige casing links all roads on the white ground (a) and is less visible on the darker ground (b), though it protects against lines disappearing into background colors by providing a subtly consistent and contrasting ground for each line.

## 4. Summary

Readability is critical to US Topo, particularly since the maps service a diverse user base with multiple viewing environments. The guidelines discussed here are relevant to topographic maps as well as mashups, where unalterable layers impose symbolization constraints which may be successfully navigated with appropriate design decisions. The materials presented in this paper are not completed map designs, but the effects explained are intended to give consistent weight to varied features, such as those examples from hydrography and roadways treated here.

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