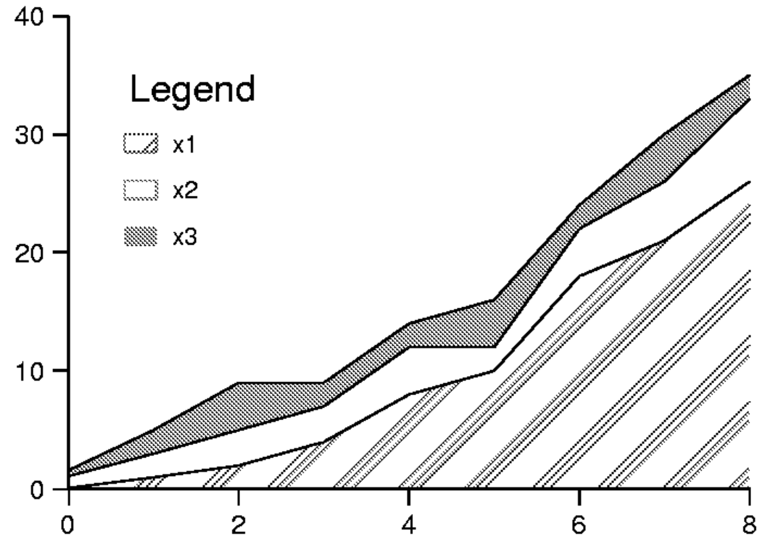

Figure 16.10 Cumulative line graph.

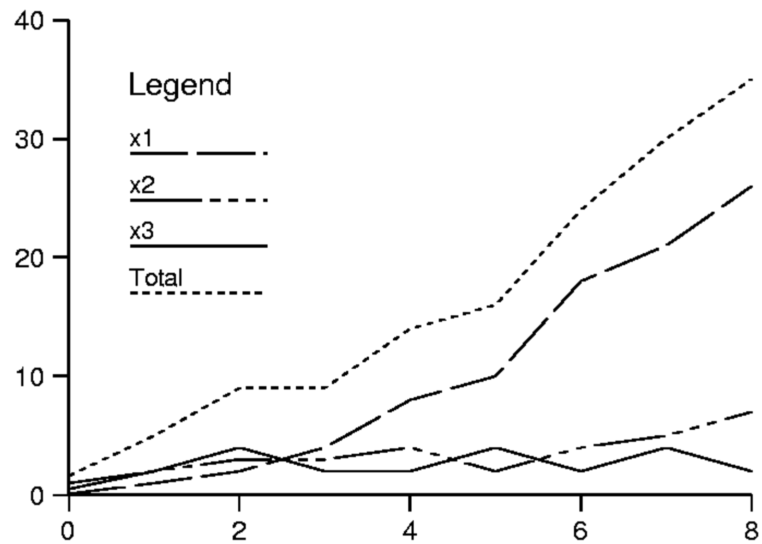

Figure 16.11 Variables of figure 16.10 plotted individually.

16.2.5 Length

Judgements of length are required when symbols or bars are to be measured which do not have a common datum, and where no common scale is available. Figure 16.12 shows the simplest such case, determination of the length of two offset bars. Which is longer is difficult to visually determine. An example requiring the use of length judgments are the bars displayed on the map of figure 16.3.

To make these judgments more precise, a common scale can be added to each bar. This is done in figure 16.13 as a framed rectangle. The rectangle surrounding each bar is of exactly the same length, a common reference frame. It is now easier to see that the first bar is indeed longer than the second. This is because the judgment is made using positions of the white areas within the common scale. Their relative differences are greater than the shaded bars, and so more easily seen. In situations where a common datum is impossible such as multiple stiff or other diagrams located on a map, adding a frame of reference will improve the viewer's precision in discerning differences.

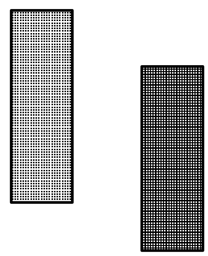

Figure 16.12 Judgement of length without a common scale or datum.

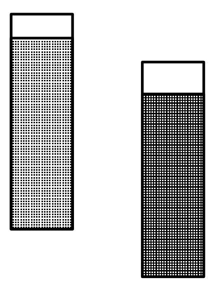

Figure 16.13 Framed rectangles of the figure 16.12 data, adding a common scale.

16.2 6 Position Along Nonaligned Scales

Framed rectangles are examples of graphs with a common but nonaligned scale, ie. without a common datum. Another graph in this category is a stacked bar chart: stacked (figure 16.14). These graphs of segmented bars require judgments of position and/or length. Only the lowest segments of each bar possess a common datum --they are the easiest to compare. All other comparisons between bars, and among segments within a bar, are more difficult without a common datum. For example, in figure 16.12 it is difficult to determine which of the top two squares of bar 1 is larger. How about the top and bottom squares (D vs A) of bar 3? Or group B squares for bars 1 and 3?

To make comparisons more precise, stacked bars can always be unstacked and placed side-by-side, producing grouped bar charts (figure 16.15). These graphs belong in the highest precision category -- position along a common scale (common datum). By using a common datum, smaller differences are more easily seen. For example. in bar 1 it is now easy to see that C is larger than D. Square A is larger than D in bar 3, and the group B square for bar 1 is larger than bar 3. The precision with which the graph can be read is greater for the grouped bar chart than the stacked chart, a distinct advantage.

Often bars are stacked so that their totals are easy to compare. With grouped bar charts this is easily accomplished by plotting separate bars of group totals. As both types of bar charts are equally familiar to viewers, it is difficult to see why stacked bars should ever be used over grouped bar charts.

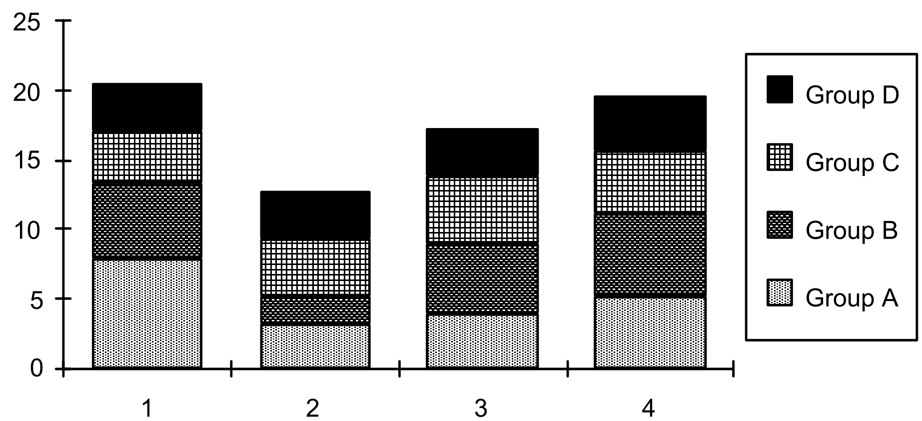

Figure 16.14 Stacked bar charts.

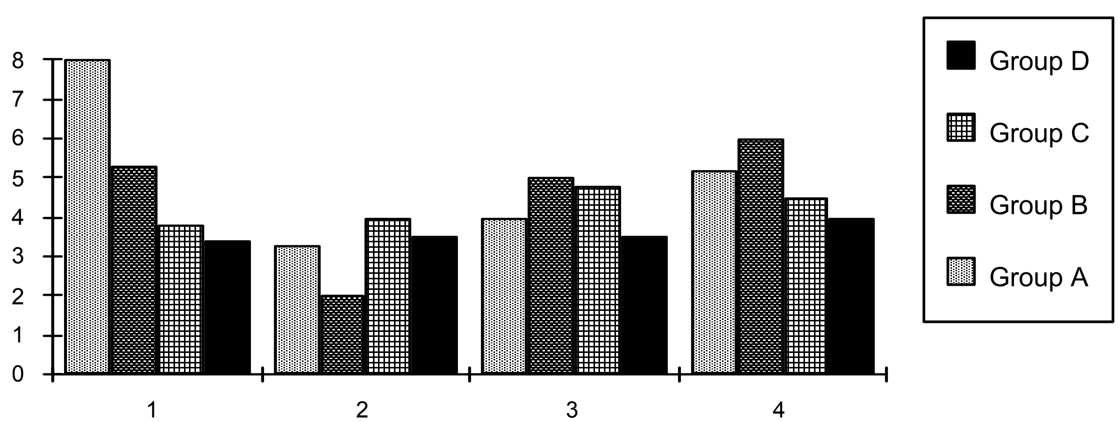

Figure 16.15 Grouped bar charts for the figure 16.14 data.

16.2.7 Position Along an Aligned Scale

Grouped bar charts are one example of graphs where data are shown as a position along an aligned (common datum) scale. Also in this category of highest precision are the dot charts of Cleveland (1984). These "skinny bar charts" (figure 16.16) remove some of the visual confusion of bar charts due to the area and shading of the bars. The dots highlight the only information present -- the position at the top of the bar. Though for simple situations the two graphs are equivalent, for complex situations dot charts more clearly show the information. A final advantage to dot charts are that error bars around each value can easily be added.

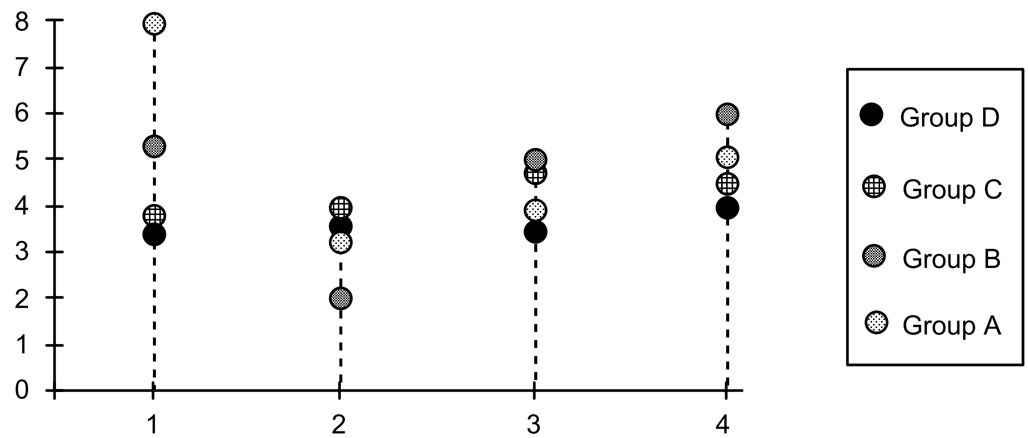

Figure 16.16 Dot chart for the figure 16.15 data.

Other more-familiar types of graphs also belong in this category, including scatterplots and boxplots. Though discussed and used fully throughout this book, the strengths of boxplots bear repeating. Many boxes can be placed on a page, allowing precise summaries and comparisons of a large amount of information. In figure 16.17 are boxplots for a two-way ANOVA situation. Differences in concentration due to both land-use category and to sewering are easily seen, as are skewness and outliers, by comparing the boxes.

16.3 Misleading Graphics To Be Avoided

16.3.1 Perspective

Figures are often put into perspective, that is tilted to give an impression of three dimensions, in newspaper and other popular graphics. The intent is to make the figure look more "solid". Unfortunately by doing so, judgments of area, length and angle used by the viewer to extract information become impaired. Numerical values are altered by the tilting so that they no longer can be accurately read. Thus the appearance may be more solid, but the information is less so.

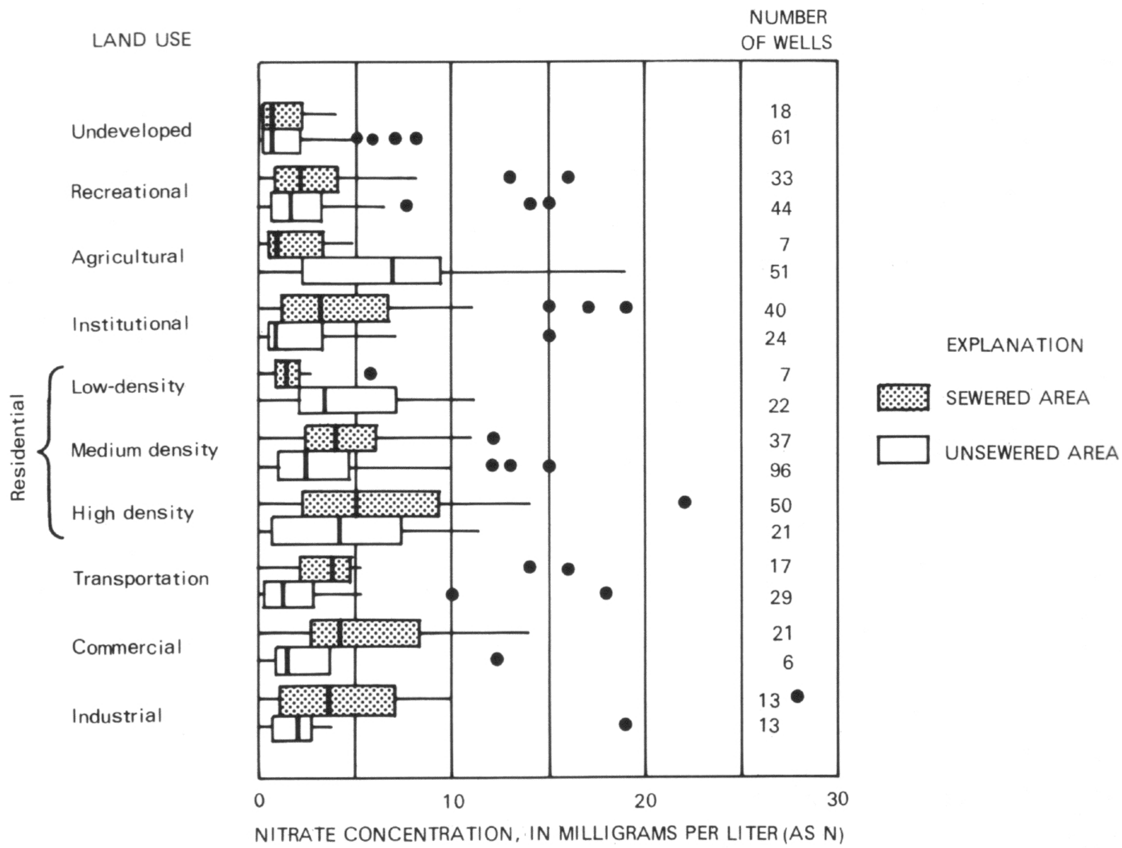

Figure 16.17 Boxplots of nitrate concentrations by land use and sewering. From Eckhardt et al., 1989.

One example is given in figure 16.18. A pie chart is presented on the left with three slices (labeled A, B and C) of exactly equal size. After being put into a perspective view at the right, the slices no longer appear equal. Judgements of angle such as these are impossible to get correct once the angles are altered by perspective. A second example is figure 16.19. There bar charts are placed into perspective so that lots of bars can be crammed into one figure. A resulting problem is that some bars are hidden by others. A more serious problem is that comparisons of bar heights must be done along a sloping plane. The base of the graph is not level, but increases towards the back. This makes judgments between bar heights difficult. For example, which is higher, the thermoelectric withdrawals for 1965 or irrigation withdrawals for 1970?

Viewers will tend to see bars towards the back as higher than they should in comparison to bars nearer the front when perspective is used to tilt the base. Thus the front of the "thermoelectric" bars must be compared to the back of the "irrigation" bars in order to accurately assess the data portrayed by bar heights. Comparisons of heights across non-adjacent rows is even more difficult. The two bars cited above have exactly the same value of 130,000 million gallons per day, though the one at the back appears higher.

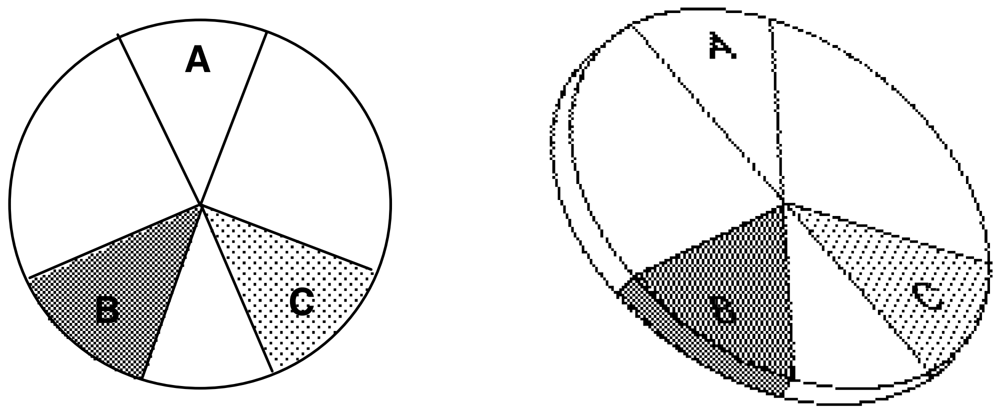

Figure 16.18 Pie chart before and after being placed into perspective view.

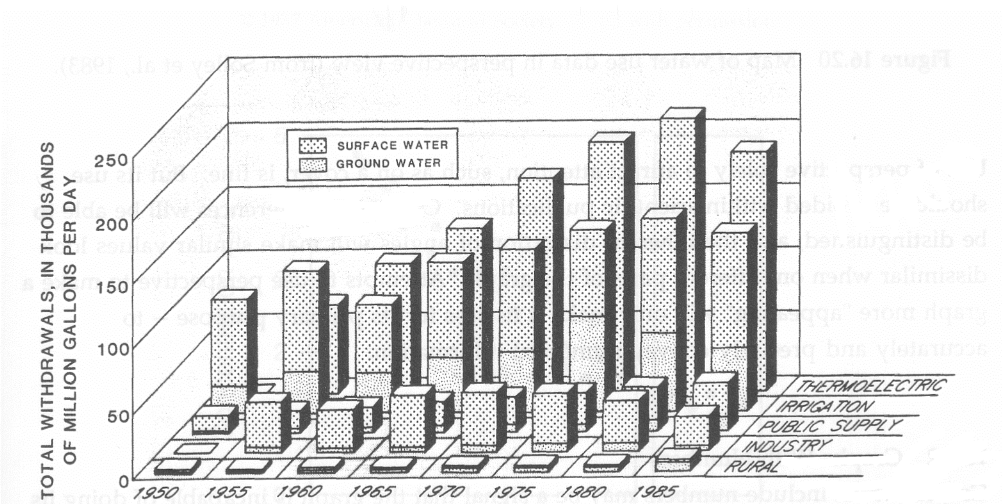

Figure 16.19 Bar chart of water use data, in perspective view (from Solley et al., 1988).

Perspective should also be avoided when presenting maps. Figure 16.20 is a perspective map of water use in the United States (Solley et al., 1988). Because the base of the map is tilted, values at the back will look higher than those in the front for the same quantity. Comparisons between Montana (at the back) and Louisiana (at the front), for example, are quite difficult. From a table inside the report, Louisiana has a larger value, but it doesn't appear that way on the map. Note also that several states are again partially or totally hidden.

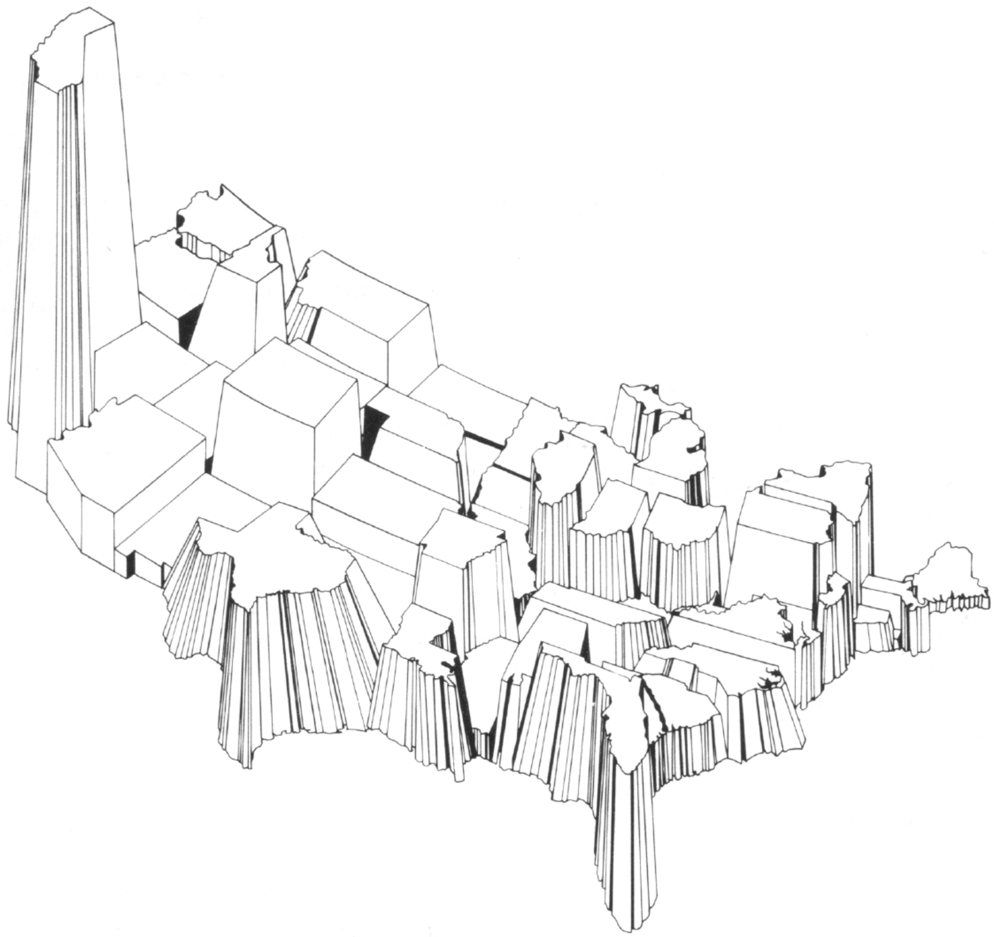

Figure 16.20 Map of water use data in perspective view (from Solley et al., 1983).

Use of perspective solely to attract attention, such as on a cover, is fine. But its use should be avoided within scientific publications. Only large differences will be able to be distinguished, and the inherent distortion of angles will make similar values look dissimilar when on different parts of the graph. Attempts to use perspective to make a graph more "appealing" will only make it useless for its primary purpose -- to accurately and precisely convey numerical information.

16.3.2 Graphs With Numbers

Graphs which include numbers may be a signal that the graph is incapable of doing its job. The graph needs to be made more precise. See for example figures 16.7 and 16.26. Tables providing the necessary detail for computations can be placed elsewhere in the report if required. But they do not provide the insight needed to quickly comprehend primary patterns of the data. Adding numbers to graphs which also do not portray those patterns does not add up to an effective graph.

16.3.3 Hidden Scale Breaks

Breaks in the scale of measurement on a graph can be very misleading to the viewer. If scale breaks are used, it is the job of the presenter to make them as clear as possible. For example, the scale break in figure 16.21 is not very obvious (it is also not necessary). Bars are drawn right through the data, incorrectly implying that no break is present.

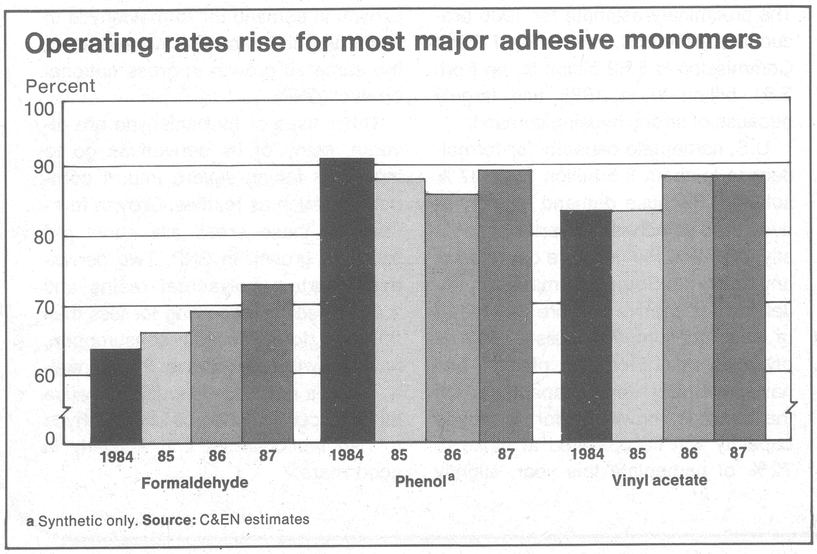

Figure 16.21 Hidden scale break, from Greek (1987)

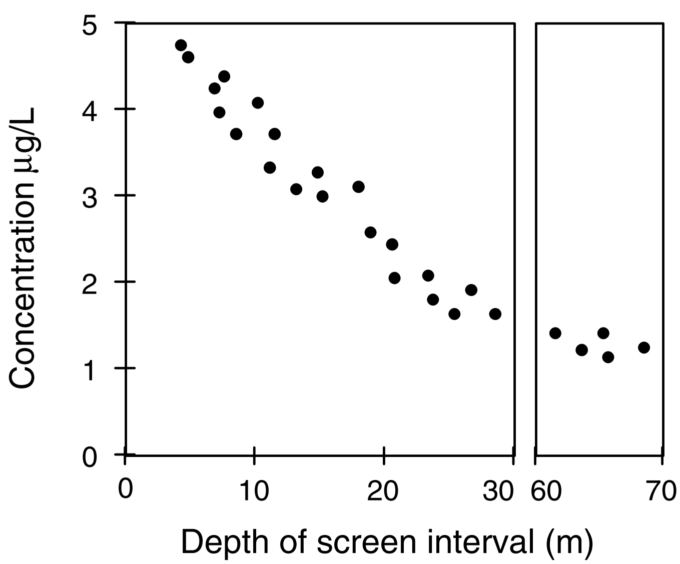

Figure 16.22 Full scale break.

To make a scale break more obvious, Cleveland (1984) suggested the use of a "full scale break" as in figure 16.22. There the jump in depth of wells used for sampling is clearly portrayed. It is difficult for the viewer to misinterpret a scale break using this method. We heartily recommend use of full scale breaks when breaks must be used. Better yet, avoid using scale breaks by employing a transformation of the data such as logarithms to make the break unnecessary.

16.3.4 Overlapping Histograms

Overlapping histograms are one of the worst graphs for comparing groups of data, and yet are quite common. They totally obscure differences and similarities between groups. With the excellent alternative of group boxplots available there is little reason to use them. Figure 16.23 shows two sets of overlapping histograms, effective porosity (A) and infiltration capacity (B). Three groups are being compared in A, and two groups in B. There is no way a reader could verify or disprove any conclusions reached in the report concerning these variables by looking at these histograms. The use of lines for shading, automatically produced by many graphics software programs, only makes matters worse. In general, avoid using overlapping histograms!

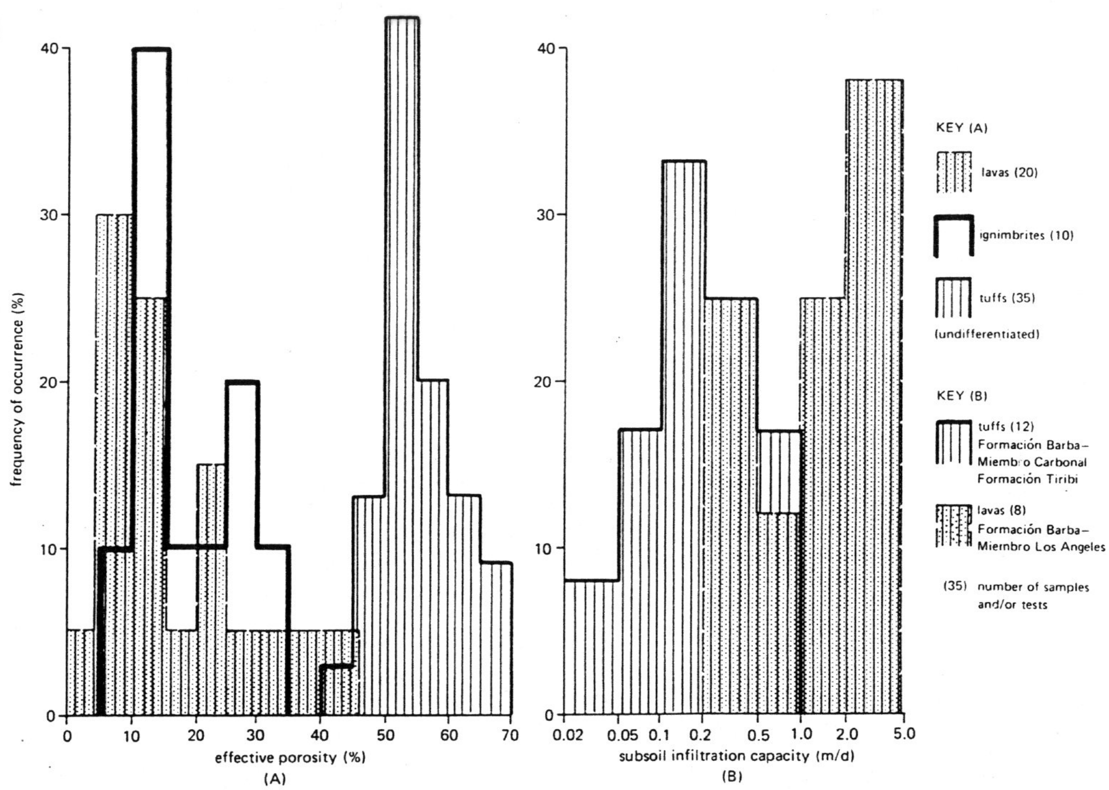

Figure 16.23 Overlapping histograms of two variables. From Foster et al. (1985).

Exercises

16.1 Field and laboratory pH were measured on the same samples by Bachman (1984) to determine if values changed over the time it took for shipment to the lab . The data were plotted in the figure below. How might the graph be improved in order to show this comparison?

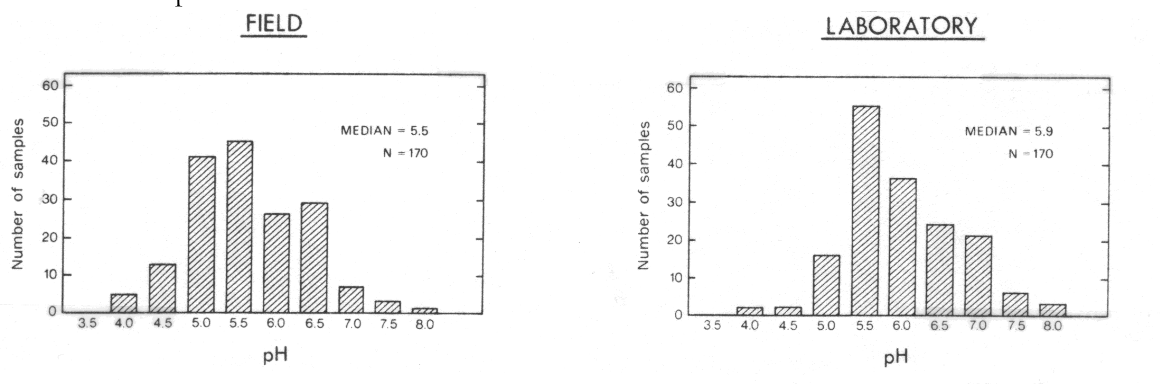

Figure 16.24 Field versus lab pH. From Bachman, 1984.

16.2 Seasonal patterns of specific conductance for stations along the Merced River are shown below. How might this graph be improved to better show both seasonal and downstream differences?

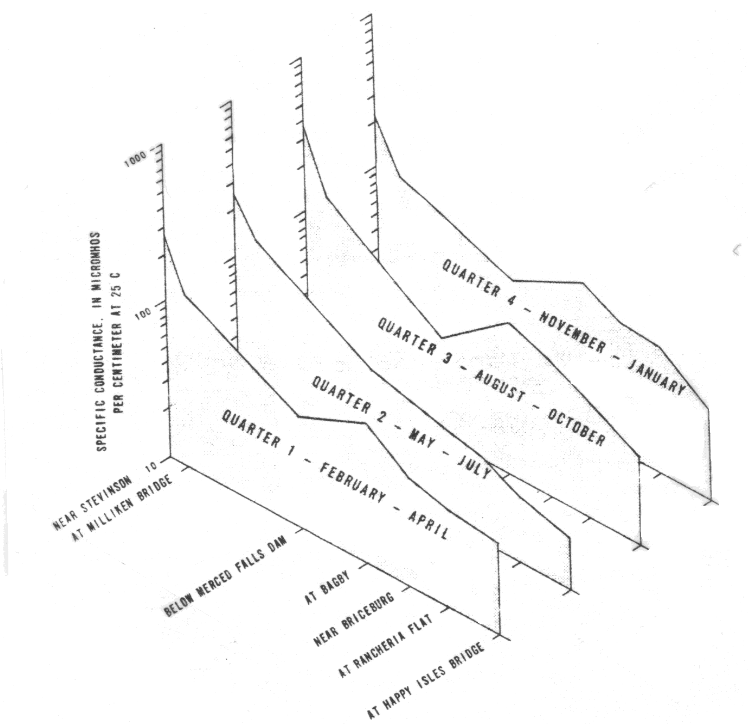

Figure 16.25 Specific conductance along the Merced River. From Sorenson, 1982.

16.3 Variations in dissolved oxygen and biochemical oxygen demand (BOD) were documented along the Trinity River watershed. How might the graph be improved in order to better show differences between sites?

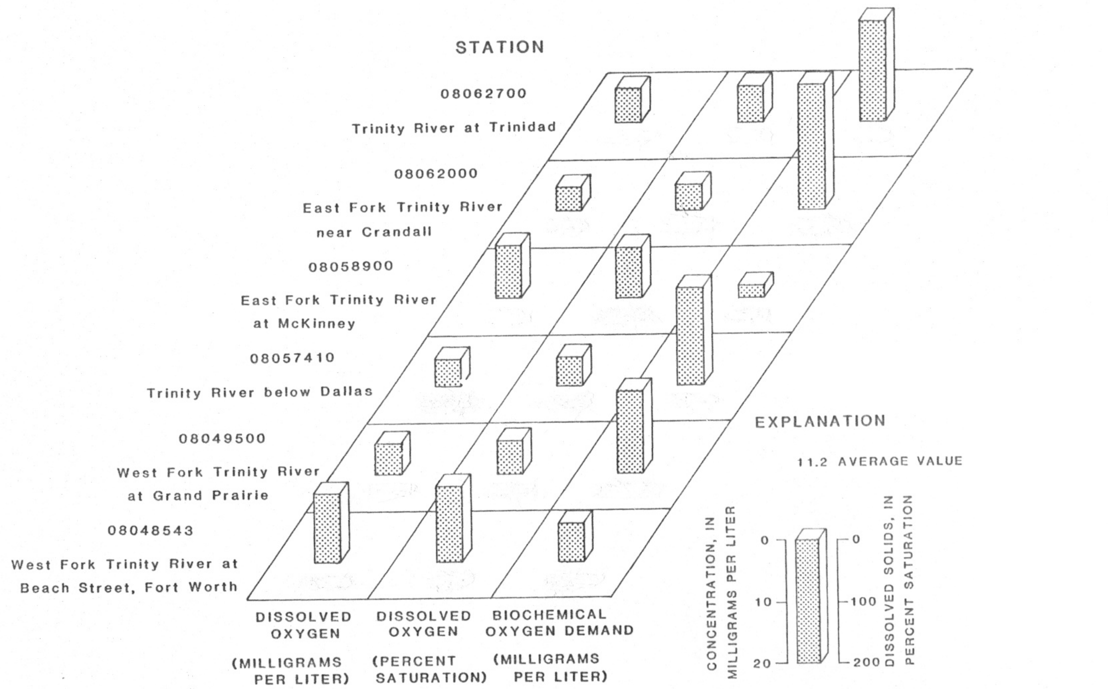

Figure 16.26 DO and BOD in the Trinity River, TX. From Wells et al., 1986.

16.4 Ice volumes of several glaciers at differing altitudes are compared in the following figure. How might it be changed to better show those differences?

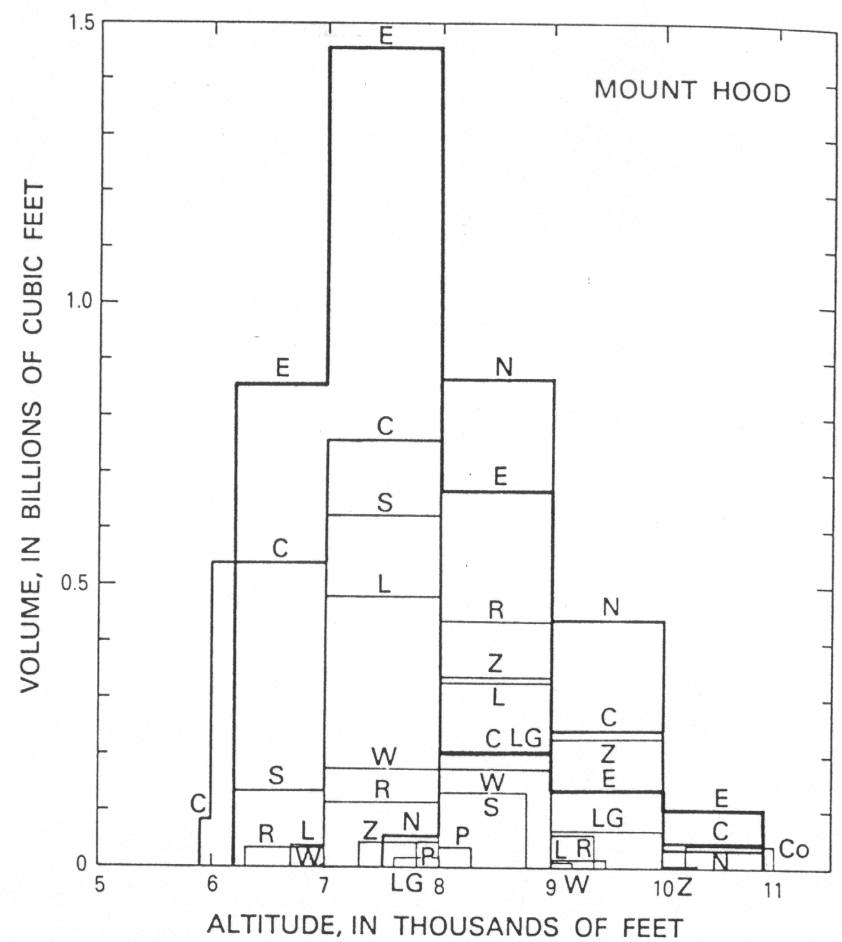

Figure 16.27 Ice volumes of Mount Hood glaciers. Each letter represents a different glacier. From Drieger and Kennard, 1986.

16.5 Water quality (major ions) was displayed for 13 numbered sites below. What other types of plots might have shown this more clearly?

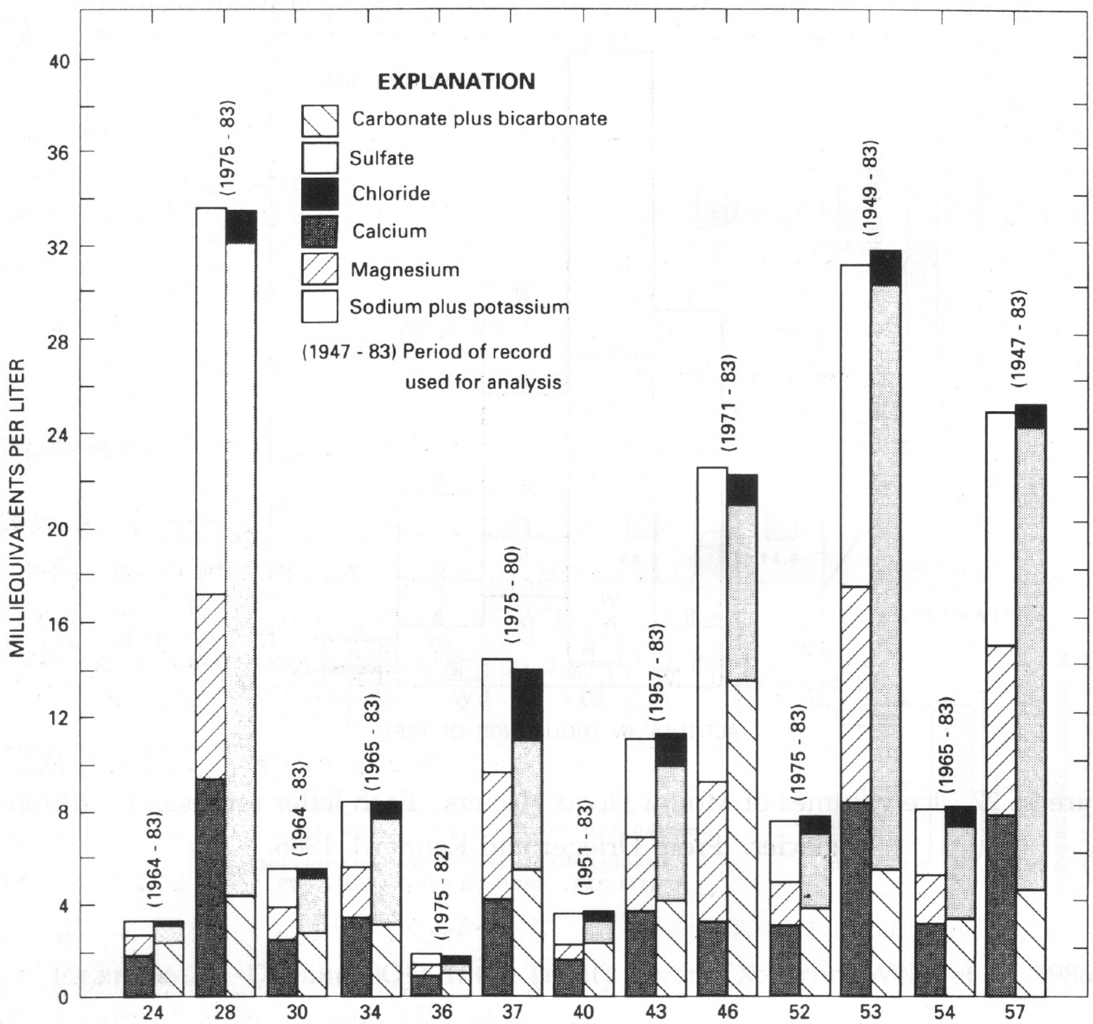

Figure 16.28 Chemical composition of streamwaters at 13 sites.
From Liebermann et al., 1989.