SCALE FACTOR

When lines are "projected" from the ellipsoid onto the cone, their lengths will be increased or shortened depending on whether they are outside or within the standard parallels. The amount of change is a function of the latitude and is often tabulated in the form of a "scale factor" which is the ratio of the distance on the cone to the distance on the ellipsoid.

Along the standard parallels the scale factor is one. For lines that run generally east and west, a single scale factor may be used, especially if the lines are short. If the beginning and end of a line are at greatly different latitudes, a "weighted average" for the scale factor should be used:

$$k = \frac{k_1 + 4 \cdot k_m + k_2}{6}$$

where	k_1	is the scale factor at the	*beginning*	of the line,
	k_m	is the scale factor at the	*middle*	of the line,
	k_2	is the scale factor at the	*end*	of the line.

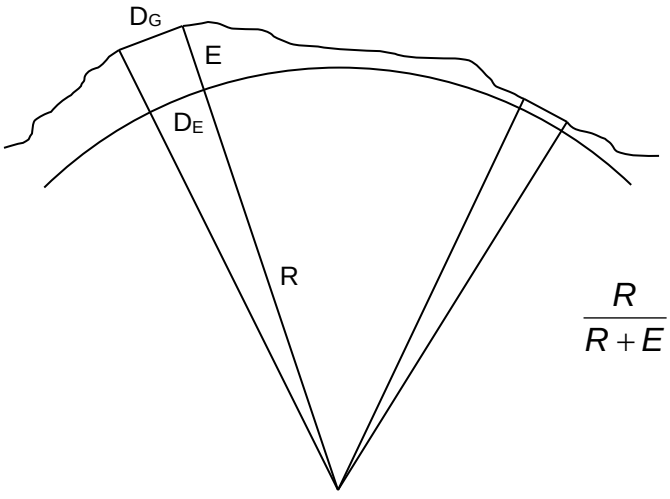
SEA LEVEL FACTOR

Before projecting the ellipsoid onto the cone, observed ground measurements which are actually made on an irregular surface, must be projected onto the ellipsoid (considered as sea level for NAD 27).

The sea level (or "ellipsoid") distance (D_E) is to the observed "ground" distance (D_G) as the sea level radius of the earth in that vicinity is to the ground level radius…

$$\frac{D_E}{D_G} = \frac{R}{R+E}$$

$$D_E = D_G \cdot \frac{R}{R+E}$$



$\frac{R}{R+E}$ = "sea level factor"

By means of the above equation (or a derived tabular “factor”) the ellipsoid distance corresponding to each ground distance can be found. These ellipsoid distances are then converted to grid distances by multiplying by the appropriate scale factor.

The sea level reduction factor is called the “elevation factor” when a geoid separation term is included (NAD83 and later). The scale factor could also be referred to as the “projection factor”. Multiplying these two factors together results in a “combined factor” or “grid factor”.

If the beginning and end of a line are at greatly different elevations, it is desirable to use a “weighted” sea level reduction factor of the type used for the scale factor. For slope distances measured electronically, however, this “weighted” average is the average of the factors for the two ends of the line.

If the two ends of the line are at greatly different latitudes and very precise work is required, the radius of the earth at the average latitude should be used. However, for most surveys of small extent in the continental United States, an average radius of 20,906,000 feet is sufficiently accurate (NAD27). For NAD83 and later the radius used is a global radius of 6,371,000 meters.

ZONES

Since the variation from a scale factor of one on the conic projection becomes quite pronounced when moving away from the standard parallels, the width of the working areas must be limited to relatively narrow bands or “zones” which are about 158 miles wide from north to south (NAD27). If a single zone is not wide enough to cover the area of a state, two or more zones are used. Each zone has its own standard parallels that correspond graphically to the circles of latitude at which the cone for that zone intersects the ellipsoid. Only one sixth of the zone width is beyond the standard parallels to the north or south.

The width of 158 miles was chosen in order that the projected map distances would not vary from the ellipsoid distances by more than about one part in ten thousand.