Scale and Measurement

Scale can be defined as a statement of the relationship between the distance of a map or image in relation to the distance on the Earth surface. This association may be displayed using several different techniques.

*Representative Fraction* (RF) is a numerical statement of the scale relationship. E.g., 1:24,000 or 1/24,000

*Verbal Scale* is a statement of meaningful map distance in relation to meaningful earth distance. E.g., in RF 1:50,000 one unit of linear distance on the map or image portrays 50,000 of the same linear units on the Earth’s surface.

In 1:24,000 or 1/24,000 one inch on an aerial photograph represents 2,000 feet (24,000 in.)

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Scale and Measurement

*Graphic or Bar Scale* is a line symbol, subdivided to show map lengths of earth distance units. One end of the bar scale is usually subdivided further, allowing users to measure distance more precisely.

![Graphic or Bar Scale](image)

Figure 1-2. Scale 1:24,000.

*Area Scale* refers to the ratio of areas on the map to those on the Earth.
Note:

Enlarging or reducing a map photographically does not affect the accuracy of a graphic scale, but it does render the RF invalid, i.e., the RF is a statement of the relationship between the map and the ground area it portrays.

If a user modifies the size of one of the components, the user will have changed the nature of the scale association.

If the map and the accompanying graphic scale are enlarged or reduced by the same amount, the scale representation is maintained.
Determining Scale By Comparison with Maps of Known Scale

1. Locate the same two points on each map or image of a particular Earth surface area

2. In using vertical aerial photo as part of your scale determination, try to select points so that the line between them pass through or close to the center (principal point) of the photo.
Determining Scale By Comparison with Maps of Known Scale

3. Measure the straight-line distances and use the following equation for the calculation:

\[
\frac{AB}{1} = \frac{A'B'}{1}
\frac{25,000}{X}
\]

where \( AB \) is the distance from point A to point B on map of known scale (1:25,000). \( A'B' \) is the distance between the same two ground points on the image of unknown scale.

4. The resulting arithmetic ratio can then be solved by cross-multiplication. The value determined for \( X \) in the equation will be the denominator for the unknown RF.

Example: If \( AB = 1.12 \) in.; \( A'B' = 3.59 \) in.;

The map scale where \( AB \) was measured is 1:25,000 (1/25,000)

\[
\frac{1.12}{1} = \frac{3.59}{1}
\frac{25,000}{X}
\]

\[
X = 7800
\]

Therefore, unknown RF of airphoto is 1:7,800 (1/7,800)
Computing Scale By Ground Measurement vs. Photographic Size

The scale, \( S \), of a vertical aerial photograph obtained over nearly level terrain is the ratio of the size of the object as measured on the aerial photograph, \( ab \), compared to the actual measured length of the object in the real world, \( AB \):

\[
S = \frac{ab}{AB}
\]

This relationship is based on the geometry of similar triangles \( \angle ab \) and \( \angle AB \).

For Example: If a measured distance from point A to point B on a vertical aerial photograph is 0.113 in. The same distance measured on the ground is 56.1 ft. The scale of the photograph is:

\[
S = \frac{ab}{AB} = \frac{0.113'}{56.1'} = \frac{0.113''}{673.2''} = \frac{1'}{5957.52}
\]

Representative fraction: 1 : 5,957 (1/5,957)

Verbal scale: 1 in. = 496.46 ft.
\[ s = \frac{ab}{AB} = \frac{0.113''}{56.1'} = \frac{0.113''}{673.2''} = \frac{1'}{5957.52} \]

\[ \frac{0.113''}{673.2''} = \frac{1'}{X} \quad X = \frac{1' \times 673.2''}{0.113''} = 1' \times 5957.52 = 5957.52 \]

Representative fraction:
1 : 5,957 (1/5,957)

**Computing Scale by Relating Focal Length to Altitude Above-Ground-Level**

Scale can also be expressed in terms of camera focal length, \( f \), and flying height above the ground, \( H \), by equating the geometrically similar triangles \( \angle oa \) and \( \angle PA \) in the Figure.

\[ S = \frac{f}{H} \]
**Computing Scale by Relating Focal Length to Altitude Above-Ground-Level**

For example: if a vertical aerial photograph is obtained over flat terrain with a 12-in. focal-length camera lens from an altitude of 60,000 ft. above-ground-level, the scale of the vertical aerial photograph should be:

\[
\frac{s}{H} = \frac{12''}{60000'} = \frac{1'}{60000'}
\]

RF: 1: 60,000;
Verbal scale: 1 in. in photo equals 5,000 ft on the ground.

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**Scale of a Vertical Aerial Photograph Over Variable Terrain**

\[
s = \frac{f}{H - h}
\]

\(h\) is the measurement of the elevation of a point above the sea level and the \(H\) is the altitude above sea level. Average scale can be derived by calculating the scale for minimum elevation point and maximum elevation point, i.e.,

\[
s_{\text{min}} = \frac{f}{H - h_{\text{min}}} \quad s_{\text{max}} = \frac{f}{H - h_{\text{max}}}
\]

\[
s_{\text{ave}} = \frac{f}{H - h_{\text{ave}}}
\]

The average scale is only at those points which lie at average elevation, and it is only an approximate scale for all other locations on the photograph.
<table>
<thead>
<tr>
<th>Scale</th>
<th>Feet per in.</th>
<th>in. per rev.</th>
<th>miles per in.</th>
<th>Acres per sq. in.</th>
<th>Hectares per sq. in.</th>
<th>Meters per cm</th>
<th>cm per km</th>
<th>km per cm</th>
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</thead>
<tbody>
<tr>
<td>1:200</td>
<td>41.87</td>
<td>126.52</td>
<td>0.008</td>
<td>0.0195</td>
<td>0.0016</td>
<td>0.0196</td>
<td>0.008</td>
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<tr>
<td>1:400</td>
<td>51.00</td>
<td>102.60</td>
<td>0.006</td>
<td>0.0279</td>
<td>0.0023</td>
<td>0.0269</td>
<td>0.006</td>
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<td>1:1,000</td>
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<td>63.66</td>
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<td>0.0400</td>
<td>0.0040</td>
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<tr>
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<td>0.002</td>
<td>0.0777</td>
<td>0.0077</td>
<td>0.0770</td>
<td>0.002</td>
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<tr>
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<td>19.12</td>
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<td>0.2048</td>
<td>0.2041</td>
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<td>15.64</td>
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<td>0.001</td>
<td>0.025</td>
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<td>0.001</td>
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<td>0.001</td>
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<td>0.000025</td>
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<td>40.9200</td>
<td>40.8000</td>
<td>0.000025</td>
<td>0.004</td>
</tr>
</tbody>
</table>

[Table 6-2: Scale Conversion Chart (after Rafter and Weaver, 1990)]