Photogrammetric Reference Sheet

Photographic scale is the ratio between a distance measured on a photograph and the corresponding distance on the ground.

$$\text{Photo scale} = \frac{\text{Flying height (AMT)}}{\text{Focal length (inches)}}$$

The majority of photogrammetric mapping projects use a 6" focal length lens.

Ground control targets should be placed where they are free from the possibility of obstructions and in a manner where they surround the project limits.

The scale of a photograph can be determined by comparing a distance measured on the photograph with the corresponding distance measured on a map of known scale. The photograph scale is then found by the following relationship:

$$\frac{\text{photo scale}}{\text{map scale}} = \frac{\text{photo distance}}{\text{map distance}}$$

Both the photo scale and map scale must be in the same units and must be expressed as a fraction.

S = scale in inches per foot

f = focal length of camera typically given in inches

H = flying height above datum typically given in feet

h = average terrain elevation typically given in feet

d = distance on photograph typically given in inches

D = corresponding distance on ground typically given in feet

H-h = flying height or height above mean terrain (AMT)

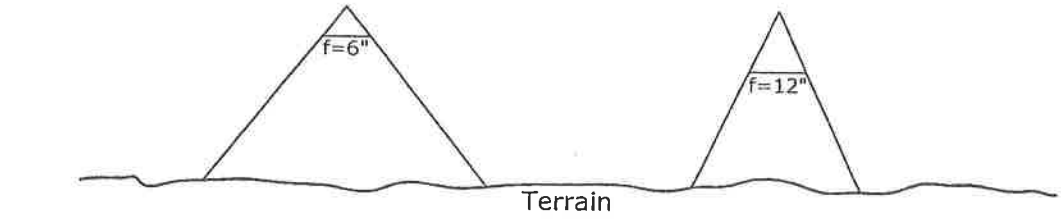
Formulas:

$$S = \frac{f}{H - h}$$

$$C\ factor = \frac{H - h}{contour\ interval}$$

Photogrammetry

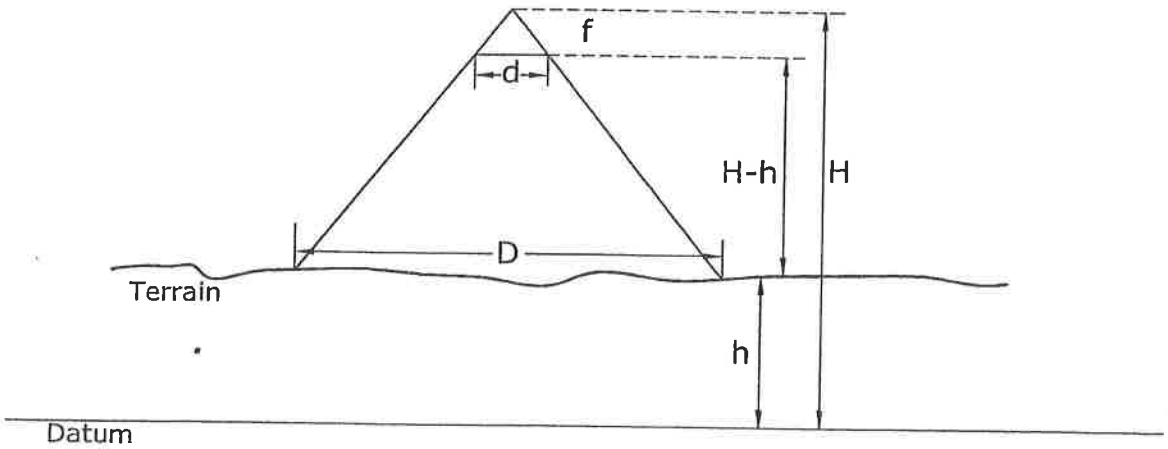
Relationship of focal length to photography coverage.



Datum

Scale 1"=400'
9"x9" Photo.

Scale 1"=200'
9"x9" Photo.



16-4. PHOTOGRAPHIC SCALE Photographic scale is the ratio between a distance measured on a photograph and the corresponding ground distance. A vertical photograph resembles a planimetric map in that it shows the planimetric and cultural features of a portion of the ground in their relative positions. It is different from a planimetric map, however, in two respects: (1) The vertical photograph does not contain standard map symbols, which are essential to a map; (2) the planimetric map has a uniform scale throughout, whereas the scale of a vertical photograph varies in different portions of the photograph because of ground relief (see Section 16-5). The photograph is a perspective projection of the ground onto the focal plane of the camera. Consequently, points lying in a plane closer to the camera at the time of exposure will have larger images than those points lying in a plane farther from the camera. The scale will vary across the area of the photograph also because of tilt of the optical axis at the time of exposure.

In Fig. 16-6(a) points A, O, and B all lie at the same elevation. The horizontal distances AO and OB are equal to $A'O'$ and $O'B'$ on a reference datum.

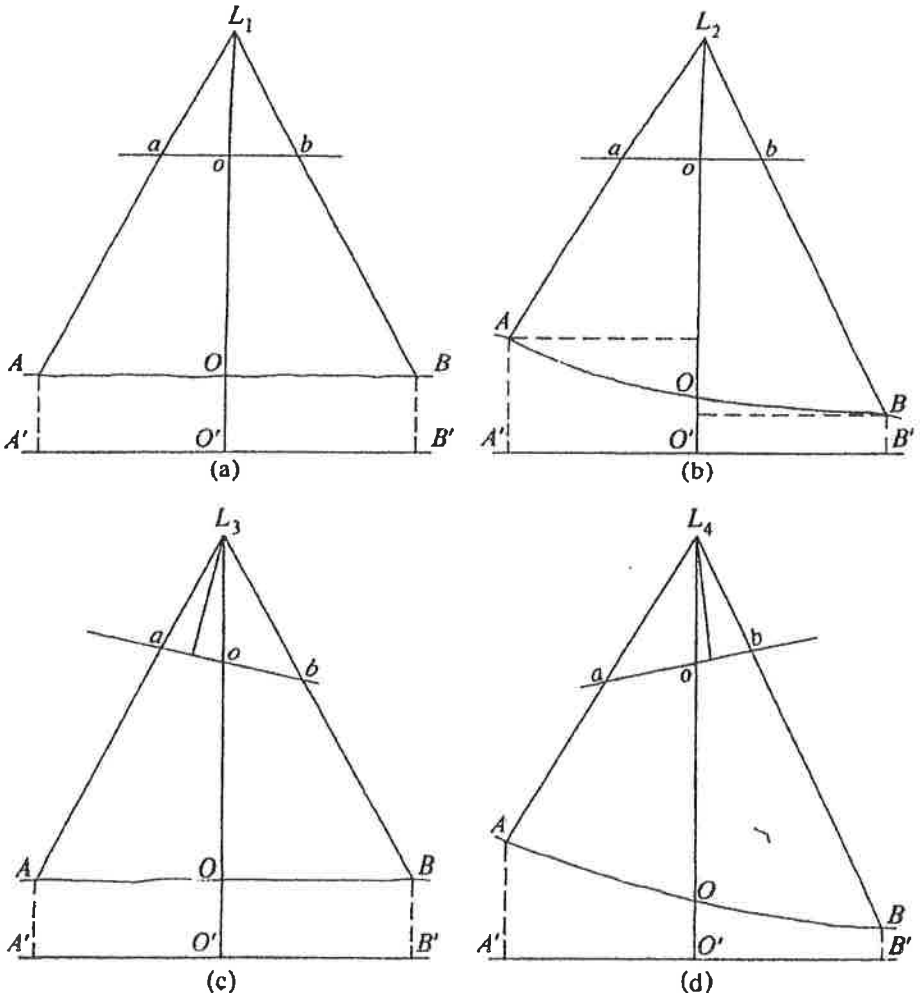


Figure 16-6. Effect of relief and tilt on photographic scale.

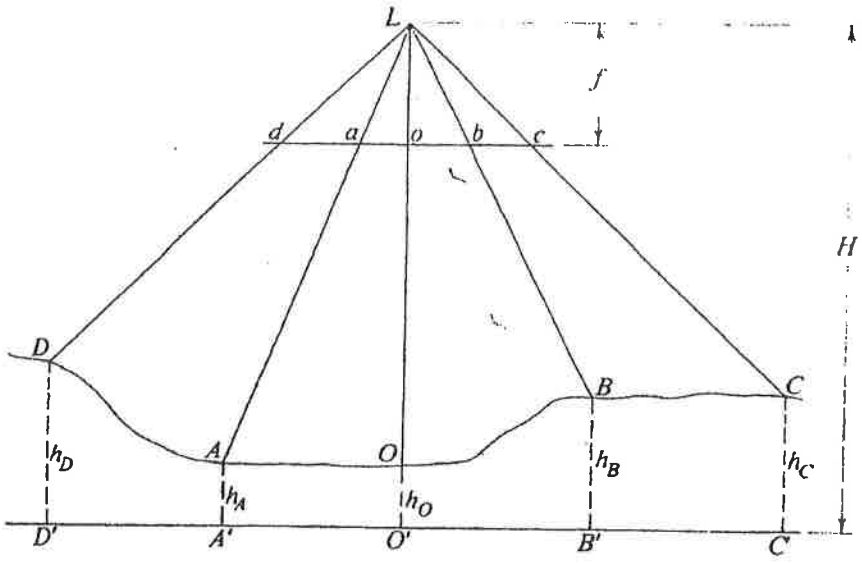


Figure 16-7. Photographic scale.

A truly vertical photograph taken with the camera at L_1 would show the positions of A, O, and B at a, o, and b. The ratio ao/AO equals the ratio ob/OB, and the scale of the photograph is uniform across the photograph.

In Fig. 16-6(b) points A, O, and B are at different elevations, and the horizontal distances between A and O and between O and B are $A'O'$ and $O'B'$, respectively. If a vertical photograph is taken with the camera at L_2, the points A, O, and B would appear at a, o, and b on the photograph. The ratio $ao/A'O'$ does not equal the ratio $ob/O'B'$, and the scale of the photograph is seen to vary from point to point because of the variation in the elevations of the ground points.

In Fig. 16-6(c) points A, O, and B all lie at the same elevation. A tilted photograph taken with the camera at L_3 shows the positions of the ground points at a, o, and b. The ratio ao/AO does not equal the ratio ob/OB, and consequently the scale varies across the photograph. In Fig. 16-6(d) the combined effect of both relief and tilt on the scale of a photograph is shown.

The scale of a vertical photograph at a point, along a line or in an area, can be determined from the relationship between the focal length of the camera, the flying height of the aircraft at the time of exposure, and the elevation of the point, the line, or the area. In Fig. 16-7 points O and A are at the same elevation, and so $AA' = OO'$ or $h_A = h_0$. Points B and C lie at elevation $h_B = h_C$, and D lies at elevation h_D. By similar triangles

$$\frac{ao}{AO} = \frac{Lo}{LO}$$

or

$$\frac{ao}{AO} = \frac{f}{H - h_A} = \frac{f}{H - h_0}$$

Similarly,

$$\frac{bc}{BC} = \frac{f}{H - h_B} = \frac{f}{H - h_C}$$

But the ratios ao/AO and bc/BC are the scales of the photograph along lines ao and bc, respectively. Therefore, in general,

$$S_E = \frac{f}{H - h} \tag{16-1}$$

in which S_E is the scale of a vertical photograph for a given elevation; f is the focal length, either in inches or in millimetres; H is the flying height above the datum, in feet or metres; and h is the elevation of the point, line, or area above the datum, in feet or metres. The focal length given for most modern aerial camera lenses is expressed in millimetres. Although a scale can be expressed in terms of the number of feet per millimetre, this is quite uncommon. When working with photo scales, it is more convenient to convert millimetres to either inches or feet by dividing by 25.4 or 304.8, respectively.

Example 16-1

In Fig. 16-7 the elevation of points O and A is 267 ft, that of points B and C is 524 ft, and that of D is 820 ft. The flying height above sea level is 1769 ft, and the focal length of the camera is 8.23 in. Determine the scale of the photograph along the line ao, along the line bc, and at point d, expressing each scale as a number of feet corresponding to 1 in.

Solution: The value of S_E for line ao is 8.23/(1769 − 267). Reducing the numerator to unity gives a scale of 1 in. = 182.5 ft. The value of S_E for line bc is 8.23/(1769 − 524), and the scale is 1 in. = 151.3 ft.

The value of S_E at point d is 8.23/(1769 − 820), and the scale is 1 in. = 115.3 ft. The corresponding representative fractions expressing the scale are 1/2190, 1/1816, and 1/1384, respectively.

Quite often the *average* scale of a single photograph or of a set of photographs is desired in order to be able to measure distances in any area of the photograph or photographs. If the average scale is known, it can be applied to a scaled distance to give a reasonable value of the corresponding ground length, provided that the relief is not extremely variable. The average scale is given by the relationship

$$S_A = \frac{f}{H - h_{av}} \tag{16-2}$$

in which S_A is the average scale of the photograph, which may be reduced to either an engineer's scale or a representative fraction; f is the focal length, in inches or millimetres; H is the flying height above the datum, usually sea level, in feet or metres; and h_{av} is the average elevation of the area covered by the photography, in feet or metres.

If the photographic scale is to be expressed as a representative fraction, the numerator of Eq. (16-1) or (16-2) must be expressed in feet or metres and then reduced to unity. In Example 16-1 the representative fraction form of the scale at point d is (8.23/12) ft/(1769 − 820) ft or 0.686 ft/(1769 − 820) ft. If the numerator is reduced to unity, the representative fraction is 1/1384.

The scale of a photograph can be determined by comparing a distance measured on the photograph with the corresponding known ground distance. The ground distance may have been measured directly, or it may be a distance of common knowledge as, for example, the length of a section line (see Chapter 18), a city block, or a stretch of a highway.

The scale of a photograph can be determined by comparing a distance measured on the photograph with the corresponding distance measured on a map of known scale. The photograph scale is then found by the following relationship:

$$\frac{\text{photo scale}}{\text{map scale}} = \frac{\text{photo distance}}{\text{map distance}} \tag{16-3}$$

Both the photo scale and the map scale must be in the same units and must be expressed as a fraction. For example, if the distance between two road intersections is 4.34 in. on a photograph and 1.55 in. on a map drawn to a scale of 1 in. = 800 ft,

$$\frac{1 \text{ in.}/X \text{ ft}}{1 \text{ in.}/800 \text{ ft}} = \frac{4.34 \text{ in.}}{1.55 \text{ in.}}$$

Hence $X = 285$ ft, and the photo scale is 1 in. = 285 ft. Note that the quantity X is the denominator of the photograph scale. Equation (16-3) can be expressed also as

$$D_P = \frac{M}{P} D_M \tag{16-4}$$

in which D_P is the denominator of photograph scale; D_M is the denominator of map scale, in the same units as D_P; P is the photograph distance; and M is the map distance, in the same units as P.

Example 16-2

The distance between two points measures 24.62 mm on a map whose scale is 1/24,000. The distance between the same two points appearing on a vertical aerial photograph measures 32.05 mm. What is the scale of the photograph?

Solution: By Eq. (16-4),

$$D_P = \frac{24.62}{32.05} \times 24{,}000 = 18{,}436 \text{ or } 18{,}450 \text{ (approx.)}$$

The photo scale is thus 1/18,450.

Example 16-3

If the focal length of the camera lens of Example 16-2 is 152.4 mm, what is the flying height above the ground in metres?

Solution: Assuming a datum to lie at the average elevation of the area, then by Eq. (16-2),

$$\frac{1}{18{,}450} = \frac{152.4 \text{ mm}}{(H - 0) \text{ m}} = \frac{0.1524 \text{ m}}{(H - 0) \text{ m}}$$

giving $H = 2812$ m above the ground (approx.).

4.6.11

Photogrammetry Questions:

1. When establishing horizontal control targets for a stereo photogrammetric survey, targets should not be:

A. Placed away from the shadows of treelines and buildings
B. Placed close together
C. Placed so they can be seen on 2 adjacent photographs OVERLAP X 60%
D. Clearly marked in an X,V, T or Y formation.

2. On an aerial photograph, the measured distance between two points is 3.80 inches. On a USGS Quad map (1:24,000 scale), the measured distance between the same two points is 0.71 inches. The nominal scale ratio of the photograph is most likely: 1420/3.8

A. 1:4484
B. 1:373
C. 1:2698
D. 1:5396

3. What are the dimensions of a Section?

A. 1 mile x 1 mile
B. 2000' x 2000'
C. 24,000' x 24,000'
D. 12,000' x 12,000'

4. The distance on a vertical aerial photograph between two east-west hedge lines is measured and found to be 4.14 inches. The hedge lines are approximately the north and south section lines of Section 16, which is regular. The terrain is approximately level. What is the approximate photo scale in the area between the two hedges? 4.14 5280

A. 1"=106'
B. 1"=1275'
C. 1"=794'
D. 1"=330'

5. An enlargement is made at 20"x20" from a 9"x9" aerial photograph negative. The negative was produced with a 6" focal length camera at an altitude of 3,000' AMT. What is the approximate photo scale of the negative? 3000

A. 1"=150'
B. 1"=300
C. 1"=1,000'
D. 1"=500'

6. Regarding the above question, what are the dimensions of the area of the enlargement?

A. 10,000' x 10,000'
B. 4500' x 4500'
C. 1800' x 1800'
D. 5500' x 5500'

7. What is the minimum flying height (above the tallest structure) of a fixed wing aircraft when it comes to stereo photogrammetric mapping projects?

A. 100'
B. 500'
C. 1000'
D. 1200'

8. If you are mapping a project in the mountains of Western Maryland, what altitude do you need to fly at in order to achieve a nominal negative scale of 1"=250' assuming you are using a 6" focal length lens?

A. 1500' AMT
B. 1000' ASL
C. 1000' AMT
D. 1500' ASL

9. How many ground control targets are needed for the smallest stereo photogrammetric mapping project where the desired product is 2' contours?

A. 2
B. 3
C. 4
D. 5

10. Which of the following is not used in the aero triangulation process?

A. Focal length
B. Altitude of the aircraft
C. USGS Camera Calibration Report
D. Speed of the aircraft

11. A project is setup for acquiring 1' contours on a site which is 5000' x 8000'. The site is cleared of all vegetation and relatively flat. Assuming the client is requesting the site be flown at 1200' AMT, what is the approximate photo scale at which the project should be planned?

A. 1"=200'
B. 1"=333'
C. 1"=250'
D. 1"=1200'

12. Regarding the question above, what is the focal length on the camera?

A. 6"
B. 8"
C. 10"
D. 12"