Accuracy Classification Standards

A. **Horizontal**. After removing all blunders and systematic errors, the horizontal point closure is determined by dividing the linear distance misclosure of the survey into the overall circuit length of a traverse, loop, or network circuit. If the network meets the required classification, adjustment by the appropriate method (i.e., compass rule, least squares) is recommended to compensate for random errors. Adjustment of Fourth-Order surveys is not required. Geodetic surveys requiring accuracies of First-Order (1:100,000), or better, should be done in accordance with the following Federal Geodetic Control Subcommittee (FGCS) standards and specifications: "FGCS Standards and Specifications for Geodetic Control Networks," "FGCS Geometric Geodetic Accuracy Standards and Specifications for using GPS Relative Positioning Techniques," "FGCS Input formats and Specifications of the National Geodetic Data Base," and "Guidelines for Submitting GPS Relative Positioning Data to the National Geodetic Survey."

Table 1. Point Closure Standards for Horizontal Control Surveys

Classification	Point Closure Standard
First Order - Geodetic	1:100,000
Second Order Class I	1:50,000
Second Order Class II	1:20,000
Third Order Class I	1:10,000
Third Order Class II	1: 5,000
Fourth Order - Construction	1: 2,500

Note that the relative point closure accuracy standards listed above are intended for Service surveys only. They are not the same as the propagated line accuracies used in the FGCS "Standards and Specifications for Geodetic Control Networks."

B. **Vertical**. After removing all blunders and systematic errors, including any required collimation and orthometric corrections, the vertical point misclosure within a level section or level loop shall not exceed the limits given in Table 2 for a specified classification. The standards and specifications for second- and third-order vertical control can be found in most survey textbooks. For example, see Davis, Foote, Anderson, and Mikhail, *Surveying Theory and Practice* (6th ed.), New York: McGraw-Hill, 1981, pg. 158-162.

If the network meets the required classification, adjustment of intermediate benchmarks is recommended to compensate for random errors. If a single line of levels forms a completed loop than the intermediate benchmarks will be adjusted in direct proportion to their total distance along the loop from the initial benchmark. For example, a Second Order Class I level loop that has a total length of 5 km and miscloses by -11 mm with two intermediate benchmarks at 2 km and 4 km shall be adjusted as follows:

Bench1 = +(2km/5km) 11mm = +4.4mm correction
Bench2 = +(4km/5km) 11mm = +8.8mm correction

Table 2. Point Closure Standards for Vertical Control Surveys [1]

Classification	Point Closure Standard
Second Order Class I	6 mm √km (0.025 ft √mi)
Second Order Class II	8 mm √km (0.035 ft √mi)
Third Order Class I	12 mm √km (0.050 ft √mi)
Fourth Order - Construction	24 mm √km (0.100 ft √mi)

1. Km is distance leveled in kilometers. Mi is distance leveled in miles. Fourth order is intended for construction layout work only.

When differential loops take several routes from a fixed benchmark or from several fixed benchmarks to an unknown position, it will normally result in numerous observed elevations for the unknown position. The simplest method for adjusting such redundancy is to use a least squares solution. For level loops that are not correlated the least squares solution is nothing more than a weighted mean. The observed elevations for the unknown position can be weighted by either the inverse of the length of the separate routes or the inverse of the number of setups along the individual routes. For example: given four separate level loops from four separate known benchmarks to an unknown position.

Level Route	Setups (S)	Weight (W)	Observed Elevation
1	10	1/10	980.84 m
2	15	1/15	981.00 m
3	8	1/8	980.65 m
4	6	1/6	980.50 m

As stated previously, the adjusted elevation of the unknown position is given by a least squares adjustment which is nothing more than a weighted mean of the four observed elevations:

$$\text{Unknown Position} = \frac{(980.84)(1/10)+(981.00)(1/15)+(980.65)(1/8)+(980.50)(1/6)}{(1/10)+(1/15)+(1/8)+(1/6)}$$

$$= 980.69 \text{ m}$$

In the example, the weight of the individual lines is given as the inverse of the number of instrument setups. The inverse length of the individual level loops could have also been used as weights in place of the number of setups. Complex level networks will have to be adjusted using rigorous least squares methods. In such cases a textbook on network adjustments should be consulted.