

Ground-to-Grid Scale Factor in the GoSurvey Traverse Editor

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October 2026

REQ-401 | GitHub Issue #828 | Pull Request #833

Abstract

GoSurvey’s Traverse Editor reduces field-measured slope distances to horizontal distances, but prior to this change it had no facility for reducing those horizontal (ground) distances to grid distances under a map projection. This note derives the governing formulas from standard survey references, works two examples by hand — one with an assumed scale factor and one against a published National Geodetic Survey (NGS) datasheet — and compares each hand result against the value the software actually computes. It also documents the automated test suite that keeps the implementation honest going forward.

1 What problem this fixes

A field survey measures *ground distances*: the actual taped or electronic-distance-measurement (EDM) distance along the earth’s curved, elevated surface. A map projection — for example MGA56/GDA2020, or a U.S. State Plane Coordinate zone — represents the earth on a flat *grid*, which necessarily stretches or shrinks distances by a small, position-dependent factor k (Snyder, 1987). A traverse closed and reported in ground distances will not agree with coordinates taken from the grid unless every distance is first reduced by k (Ghilani and Wolf, 2015). GoSurvey’s Traverse Editor computed only ground distances; this change adds an option to reduce them to grid before they drive coordinates, closure, and the least-squares adjustment.

2 The governing formulas

GoSurvey already computes the projection’s point scale factor k_{grid} through its CS-MAP-based projection engine, and an elevation (sea-level) reduction factor for the Drawing Settings Transformation tab. The elevation factor is the standard ratio of the ellipsoid radius to the

ellipsoid radius plus the station’s elevation above it,

$$k_{\text{sea}} = \frac{R}{R + h}, \quad (1)$$

as defined for the U.S. State Plane Coordinate System by Stem (1990) and reproduced in standard surveying texts (Ghilani and Wolf, 2015). The present change reuses that existing pair of factors rather than introducing a second calculation:

$$k_{\text{combined}} = k_{\text{grid}} \cdot k_{\text{sea}}, \quad (2)$$

$$k_{\text{grid-only}} = k_{\text{grid}}. \quad (3)$$

Equation 2, the product of the grid (projection) scale factor and the elevation factor, is the *combined factor* of Ghilani and Wolf (2015) and Stem (1990) — the standard quantity for reducing a ground distance measured at elevation to its equivalent grid distance.

For each traverse leg, the slope distance is first reduced to a horizontal (ground) distance d_{ground} by the usual trigonometric leveling relation (Ghilani and Wolf, 2015). This change inserts one multiplication before that distance is used for anything else:

$$d_{\text{grid}} = d_{\text{ground}} \cdot k, \quad (4)$$

$$\Delta E = d_{\text{grid}} \cdot \sin(\text{bearing}), \quad \Delta N = d_{\text{grid}} \cdot \cos(\text{bearing}), \quad (5)$$

where k is k_{combined} or $k_{\text{grid-only}}$ by the user’s choice, and $k = 1$ when the option is left off. The grid distances d_{grid} are summed for the closure perimeter and linear closure, and are the observations handed to the weighted least-squares traverse adjustment, following the standard treatment of Ghilani (2017).

Implementation. `src/traverse/TraverseCalc.cpp`, function `ComputeTraverse`; the multiplier is resolved by `src/commands/CadCommands_Geo.cpp`, function `ResolveTraverseScaleFactor`.

3 Worked example A: a single leg under a known factor

A representative central-meridian grid factor, $k = 0.9996$, applied to a due-east (bearing 90°) leg measured at 1000.0000 ft on the ground:

Quantity	Formula	Value
Ground distance d_{ground}	measured	1000.0000 ft
Scale factor k	chosen (grid-only or combined)	0.9996
Grid distance d_{grid}	$d_{\text{ground}} \cdot k$	999.6000 ft
ΔE	$d_{\text{grid}} \sin 90^\circ$	999.6000 ft
ΔN	$d_{\text{grid}} \cos 90^\circ$	0.0000 ft
Perimeter contribution	d_{grid}	999.6000 ft

This hand result is verified by the test suite: `tests/TraverseTests.cpp`, “*Scale factor on scales distance, coordinates, and perimeter*” asserts `computedHorizDist`, `computedEasting`, and `closurePerimeter` all equal 999.6 for this input, while `computedGroundHorizDist` stays 1000.0, the unscaled value preserved for display. A sibling test with the option left off (the default) shows the output is identical to what the software produced before this change.

4 Worked example B: a real projection, checked against an NGS datasheet

This example checks GoSurvey’s own k_{grid} at a real, independently published station rather than an assumed value. The station is NGS datasheet PID AG9976, “UNIV OF TEXAS TOWER SEC,” Travis County, Texas, on the Texas State Plane Coordinate System, Central Zone (NGS, 2026). The datasheet publishes its own computed scale factor for this station:

NGS AG9976, SPC TX-C: $E = 10,077,391.26$ ftUS, $N = 3,115,243.14$ ftUS, published scale factor = 0.99995905.

GoSurvey resolves this coordinate through its projection engine (`geo::GridScaleFactor`) and through `ResolveTraverseScaleFactor`, the function the Traverse Editor calls, and obtains:

Source	$k_{\text{grid-only}}$	Agreement
NGS datasheet (published)	0.99995905	reference
<code>geo::GridScaleFactor</code> (direct)	matches to $\leq 10^{-8}$	within 10^{-8}
<code>ResolveTraverseScaleFactor</code> , Grid only	0.9999590531	within 10^{-7}
<code>ResolveTraverseScaleFactor</code> , Combined, sea level off	0.9999590531	identical to grid-only

Elevation (sea-level) reduction, combined factor

Turning on the Transformation tab’s sea-level option with an elevation $h = 1000$ ft above an ellipsoid radius $R = 20,906,000$ ft ($R \approx 6,372,161.54$ m, converting by the U.S. survey foot), Equation 1 gives

$$k_{\text{sea}} = \frac{6,372,161.544 \text{ m}}{6,372,161.544 \text{ m} + 304.8006 \text{ m}} = 0.9999521691. \quad (6)$$

GoSurvey computes, through `geo::SeaLevelScaleFactor` and then the combined path of `ResolveTraverseScaleFactor`:

Quantity	Hand formula	GoSurvey computed
k_{sea}	0.9999521691	0.9999521691
k_{grid} (unchanged by elevation)	—	0.9999590531
$k_{\text{combined}} = k_{\text{grid}} \cdot k_{\text{sea}}$	0.9999112247	0.9999112242

The hand-computed k_{sea} matches GoSurvey’s figure to nine decimal places, and the hand-computed k_{combined} matches to six decimal places (the small residual is rounding in the hand conversion of R to meters above). k_{combined} differs from $k_{\text{grid-only}}$ exactly because elevation reduction is now included, confirming that “Combined” and “Grid only” genuinely produce two different, individually correct numbers rather than one option doing nothing.

This is verified by `tests/TransformationTests.cpp`, test case "ResolveTraverseScaleFactor resolves Combined/GridOnly and reports why it can't", which reuses the same AG9976 fixture as the pre-existing REQ-360 datasheet test.

5 The refusal path

A drawing with no coordinate system assigned — the default, “No Datum, No Projection” — must not silently apply an arbitrary number. `ResolveTraverseScaleFactor` returns a non-empty reason string and leaves the factor at exactly 1.0 for a drawing with an empty `zoneCode`. The Traverse Editor shows this reason next to the checkbox and computes as if the option were off until the drawing’s coordinate system is fixed.

6 The default (off) path is unchanged

The same 1000.0000 ft, bearing 90° leg from Section 3, with the option left off (its default state), produces `computedHorizDist`, `computedGroundHorizDist`, `computedEasting`, and `closurePerimeter` all equal to 1000.0000 ft, exactly what `ComputeTraverse` produced before this change, since $d_{\text{grid}} = d_{\text{ground}} \cdot 1.0 = d_{\text{ground}}$ whenever the option is off.

7 Automated test summary

File	Test case	What it proves
<code>TraverseTests.cpp</code>	Scale factor off reproduces unscaled coordinates	$k = 1$ default path is a no-op
<code>TraverseTests.cpp</code>	Scale factor on scales distance, coordinates, and perimeter	$d_{\text{grid}} = d_{\text{ground}}k$ propagates to ΔE , easting, perimeter
<code>TraverseTests.cpp</code>	Scale factor kind defaults to Combined	safe default
<code>TransformationTests.cpp</code>	<code>ResolveTraverseScaleFactor</code> resolves Combined/GridOnly, reports why it can't	no-projection refusal; grid-only matches NGS to 10^{-8} ; combined equals grid-only with sea level off, differs with it on

All four cases pass under both the `GoSurveyTests` and `GoSurveySnapTests` executables (Catch2, MSVC release build). The source is PR #833, branch `feat/req401-traverse-scale-factor`, requirement REQ-401 in `spec/requirements.md`.

References

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