

# Contents

|                                             |          |
|---------------------------------------------|----------|
| <b>Topoliner. Short manual</b>              | <b>1</b> |
| Installation . . . . .                      | 1        |
| Interface language . . . . .                | 1        |
| Tools . . . . .                             | 2        |
| Quick start . . . . .                       | 2        |
| A polygon coverage . . . . .                | 2        |
| A line layer . . . . .                      | 3        |
| Two thresholds . . . . .                    | 3        |
| 1.01 Polygon topology check . . . . .       | 3        |
| 1.02 Line topology check . . . . .          | 5        |
| 1.03 Polygon topology cleanup . . . . .     | 6        |
| 1.04 Line topology cleanup . . . . .        | 7        |
| 1.05 Node and vertex snapping . . . . .     | 8        |
| 1.06 Insertion of missing nodes . . . . .   | 9        |
| 1.07 Assembly check by attribute . . . . .  | 9        |
| 2.01 Topology-preserving simplify . . . . . | 10       |
| 2.02 Polygon borders as lines . . . . .     | 11       |
| What is handled on shared borders . . . . . | 12       |
| Z values . . . . .                          | 12       |
| Warnings in the report . . . . .            | 12       |
| Limitations . . . . .                       | 13       |
| Output layer field reference . . . . .      | 13       |
| The findings layer . . . . .                | 13       |
| The edit points layer . . . . .             | 14       |
| The inserted nodes layer . . . . .          | 14       |
| The borders layer . . . . .                 | 14       |
| The cleaned and snapped layers . . . . .    | 15       |
| Verifying the code . . . . .                | 15       |

## Topoliner. Short manual

[Русская версия](#)

Version 0.6.0

The plugin adds a **Topoliner** group with six tools to the Processing panel. Its purpose is to bring a polygon coverage into order without the manual routine of snapping a layer to itself.

---

### Installation

**Plugins - Manage and Install Plugins - Install from ZIP**, choose **topoliner.zip**. Restarting QGIS is not required.

The tools appear in the **Processing** panel, group **Topoliner**.

---

### Interface language

The plugin is bilingual. The language is taken from the QGIS locale, not from the system one: if QGIS is set to English, the plugin interface is English too. Names, parameters, help texts, reports and violation names are all translated.

---

## Tools

The tool number sets both the group and the order in the Processing panel: group **1. Topology** holds 1.01 to 1.06, group **2. Generalisation** holds 2.01. The order within the first group follows the workflow: check, clean, snap separately if needed, verify the assembly.

| Tool                                     | What it does                                                        | Modifies the layer    |
|------------------------------------------|---------------------------------------------------------------------|-----------------------|
| <b>1.01 Polygon topology check</b>       | Finds violations, produces a point layer and a summary              | No                    |
| <b>1.02 Line topology check</b>          | Undershoots, overshoots, dangles, pseudo nodes                      | No                    |
| <b>1.03 Polygon topology cleanup</b>     | Fixes everything that is debris                                     | Yes, into a new layer |
| <b>1.04 Line topology cleanup</b>        | Trims overshoots, closes undershoots, inserts nodes                 | Yes, into a new layer |
| <b>1.05 Node and vertex snapping</b>     | Only reconciles nodes and vertices                                  | Yes, into a new layer |
| <b>1.06 Insertion of missing nodes</b>   | Adds nodes without changing shape or area                           | Yes, into a new layer |
| <b>1.07 Assembly check by attribute</b>  | Checks whether groups assemble into one body. Polygons and lines    | No                    |
| <b>2.01 Topology-preserving simplify</b> | Thins vertices of polygons and lines without tearing shared borders | Yes, into a new layer |
| <b>2.02 Polygon borders as lines</b>     | Outputs borders as separate lines, each one once                    | No                    |

All tools work in models and in batch mode. The input layer is never modified; the result always goes to a new layer.

---

## Quick start

### A polygon coverage

Four steps, in this order.

**Step 1. Check.** Run **1.01 Polygon topology check** with a tolerance of 2 and an area threshold of 1. Read the summary in the Processing panel. It answers the main question: how much will be fixed silently and how much has to be looked at by hand.

**Step 2. Clean.** Run **1.03 Polygon topology cleanup** with the same thresholds. Read the report, especially the line about the area.

**Step 3. Check again.** Repeat step 1 over the result. The **auto** column should be empty. Whatever remains under **review** is sorted out by hand.

**Step 4. Check the assembly.** Run **1.07 Assembly check by attribute** on the block field, then on the panel field. This is the acceptance criterion.

## A line layer

**Step 1. 1.02 Line topology check** with a tolerance of 2. See how many undershoots and overshoots there are against dangles: the first two are fixed, the third is left to you.

**Step 2. 1.04 Line topology cleanup** with the same tolerance.

**Step 3.** Repeat step 1. Only dangles should remain.

**Step 4.** If needed, **1.07 Assembly check by attribute**: does a group of lines assemble into one connected chain.

---

## Two thresholds

All behaviour is set by two numbers.

**Tolerance**, in layer CRS units. The maximum vertex displacement and the search radius for neighbouring edges. Take it slightly above the real size of the discrepancies and well below the width of the narrowest object. For borders digitised from plans this is usually 1 to 2 metres.

**The main rule for the tolerance: it must be smaller than the width of the narrowest object.** An object narrower than the tolerance has its opposite banks stick together and collapses into itself. Tool 1.05 prints the minimum and median ring width before the computation and reports how many rings are narrower than the tolerance. Such rings are left untouched by default and serve as anchors for their neighbours.

**Area threshold**, in square CRS units. The area below which a fragment is treated as technical debris. A reasonable starting point is the tolerance squared: with a tolerance of 2 metres that is 4 square metres, though 1 is often enough in practice.

**Overlaps are judged by width, not by area.** A strip as wide as the tolerance and tens of metres long collects a hundred square units while still being a consequence of vertex movement. Debris is an overlap narrower than the tolerance; a wider one is a dispute over real area.

If in doubt, start small: underestimating a threshold is safe, overestimating is not.

---

## 1.01 Polygon topology check

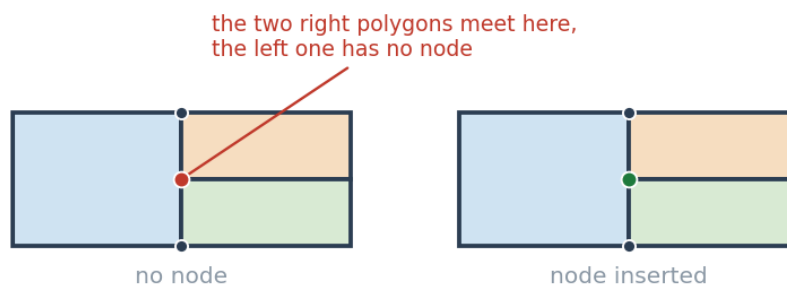


Figure 1: A T-junction: two polygons on the right meet at a point on the left polygon edge, and the left one has no vertex there.

**Input.** A polygon layer. Selected features only is supported.

**Output.** A point layer with the fields type, label, severity, fid\_a, fid\_b, value, note and grp.

**How to read it.** Style the layer by severity. The review points are the working list; the auto points do not need looking at, the cleanup tool will remove them.

**A tolerance hint.** After the check the tool prints how the discrepancies are distributed in this layer: how many there are, the median, the 95th percentile and the maximum. If the distribution has a break, it is named: below it lies digitising error, above it a disagreement between sources. If there is no break, the tool says so instead of inventing a number.

A ceiling is printed separately: the value above which the tolerance should not be set, because it would collapse short edges and narrow objects. It is computed from the fifth percentile of edge length and the minimum object width.

If the median discrepancy turns out to be close to the tolerance given, the distribution is truncated: the check does not look beyond the tolerance, and the real discrepancies are larger. It is worth repeating with a larger one.

**Two similar violations are worth telling apart.** *A vertex lies on a neighbour edge* means a distance of zero: the borders coincide geometrically but the neighbours have different vertices. That is a defect under any tolerance. *A vertex near an edge* means mere proximity, and the count is set entirely by the tolerance. If the median in the summary is close to the tolerance rather than to zero, you are looking at neighbouring objects, not at defects.

**The grouping field** is needed when the layer is not a single coverage, for example when zones of several seams share one layer. Such objects overlap by design, and without grouping every overlap lands in the findings. On a real zone layer of 379 objects a whole-layer check produced 166 findings, while grouping by seam gave 41.

**The cavity area threshold** separates a pillar, a lake or an unmapped area from a coverage defect: a small hole is an error, a very large one is almost always part of the design.

## Parameters

| Parameter                                            | Default | What it sets                                                                                      |
|------------------------------------------------------|---------|---------------------------------------------------------------------------------------------------|
| Layer to check (polygons)                            | -       | The layer is not modified                                                                         |
| Tolerance (in layer CRS units)                       | 2       | The distance below which a discrepancy counts as a digitising error                               |
| Debris area threshold (square CRS units)             | 1       | The area below which a fragment counts as technical debris                                        |
| Grouping field or fields, <i>optional</i>            | -       | Violations are searched within each group separately. Needed when a layer holds several coverages |
| Cavity larger than this area is not counted as a gap | 0       | A pillar, a lake, an unmapped area. Zero switches it off                                          |
| Find overlaps, duplicates and nested objects         | yes     |                                                                                                   |
| Find gaps in the coverage                            | yes     |                                                                                                   |
| Find vertices without a node on a neighbour edge     | yes     |                                                                                                   |
| Findings                                             | -       | Output point layer                                                                                |

## 1.02 Line topology check

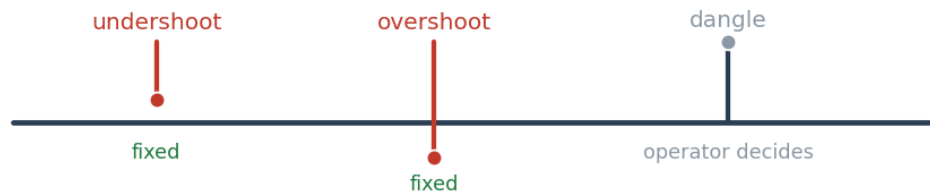


Figure 2: Three cases at a line end. Undershoots and overshoots are fixed, a dangle is left to the operator.

The layer is not modified. The output is a point layer with the findings and a summary in the Processing panel.

Lines have their own set of violations. Gaps, overlaps, nested objects and slivers do not apply to them, while undershoots, overshoots, dangles and pseudo nodes appear.

**Three cases at a line end are worth telling apart.** An *undershoot* is an end that did not reach a neighbouring line: the distance is below the tolerance, a digitising trace. An *overshoot* is a tail sticking out past an intersection, also a digitising trace. A *dangle* is an end with nothing to connect to: in a stream network or a set of mine workings it is usually an outlet or a dead end, so the decision is left to the operator.

The order of checks matters: the end of a tail past a node is also away from the neighbouring line, so overshoots are looked for before undershoots.

**A pseudo node** is a joint of two lines end to end with nothing else there. The check is off by default: in many layers the splitting into segments is deliberate.

### Parameters

| Parameter                                | Default | What it sets                                                                                                                                            |
|------------------------------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Layer to check (lines)                   | -       | The layer is not modified<br>Undershoots and overshoots below the tolerance count as debris<br>Shorter lines land in the findings. Zero switches it off |
| Tolerance (in layer CRS units)           | 2       |                                                                                                                                                         |
| Line length threshold                    | 0       |                                                                                                                                                         |
| Find dangles, undershoots and overshoots | yes     |                                                                                                                                                         |
| Find crossings without a node            | yes     | Off on purpose: in many layers the splitting into segments is deliberate<br>Output point layer                                                          |
| Find pseudo nodes                        | no      |                                                                                                                                                         |
| Findings                                 | -       |                                                                                                                                                         |

## 1.03 Polygon topology cleanup

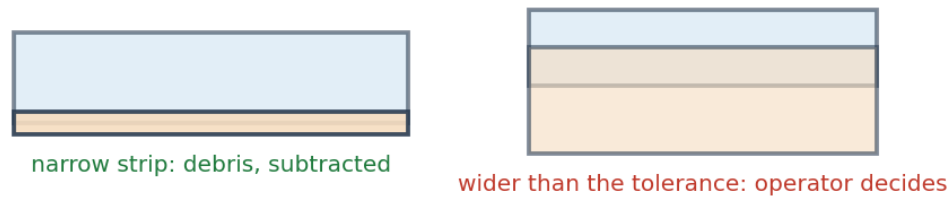


Figure 3: An overlap is judged by width, not by area.

**Fixed silently:** repeated vertices, spikes, vertices lying on a neighbour edge without a node, edge crossings without shared vertices, discrepancies below the tolerance, tiny holes and tiny parts, invalid geometry, narrow overlaps, small gaps.

**Never done:** wide overlaps, large gaps, duplicates, nested objects, sliver polygons, deletion of tiny objects without explicit permission. All of this goes to the **Remaining problems** layer with an explanation in note.

**Order of steps.** Vertex artefacts, then tiny parts and holes, then snapping, then repair of invalid geometry, then overlaps, then gaps. The order is fixed: spikes must go before snapping, otherwise they turn into false nodes and get spread across neighbours; validity repair must come after snapping, because snapping can itself produce a self-intersection.

**Guarantees.** No vertex moves further than the tolerance. An edit taking more than a quarter of an object's area is cancelled and the object is restored. A repeat run changes nothing. Attributes are preserved.

The output layer is always of multi type: a repair may split an object.

### Parameters

| Parameter                                            | Default           | What it sets                                                 |
|------------------------------------------------------|-------------------|--------------------------------------------------------------|
| Input layer (polygons)                               | -                 |                                                              |
| Tolerance (in layer CRS units)                       | 2                 | The maximum vertex displacement                              |
| Debris area threshold (square CRS units)             | 1                 | The line between debris and possible meaning                 |
| Grouping field or fields, <i>optional</i>            | -                 | Objects of different groups are neither snapped nor disputed |
| On overlap the area is kept by                       | the larger object | The other option: the object with the smaller identifier     |
| Delete objects smaller than the area threshold       | no                | Off: deleting destroys the attributes too                    |
| Cavity larger than this area is not counted as a gap | 0                 |                                                              |
| Spike angle threshold, degrees                       | 1                 | A turn back within this angle counts as a spike              |
| Snap vertices and nodes                              | yes               |                                                              |
| Repair invalid geometry                              | yes               | With area loss control                                       |
| Remove small overlaps                                | yes               | Narrow strips, below the tolerance in width                  |

| Parameter                           | Default | What it sets                                               |
|-------------------------------------|---------|------------------------------------------------------------|
| Fill small gaps                     | yes     | A gap goes to the neighbour with the longest shared border |
| Restore Z values                    | yes     | From the nearest original vertex                           |
| Cleaned layer                       | -       | Always of multi type                                       |
| Remaining problems, <i>optional</i> | -       | Point layer: what the operator decides                     |

## 1.04 Line topology cleanup

Fixes what is certainly a digitising trace.

Removes repeated vertices and spikes, trims overshoots back to the intersection point itself, closes undershoots onto their projection on the neighbouring line, inserts missing nodes, removes zero-length lines.

**What is not done:** dangles are not touched, lines shorter than the threshold are not deleted without explicit permission, pseudo nodes are not merged.

**Guarantee.** A line end does not move further than the tolerance. A repeat run over the result changes nothing.

### Parameters

| Parameter                                      | Default | What it sets                                                                                  |
|------------------------------------------------|---------|-----------------------------------------------------------------------------------------------|
| Input layer (lines)                            | -       | The maximum end displacement and the maximum trimmed tail length                              |
| Tolerance (in layer CRS units)                 | 2       |                                                                                               |
| Line length threshold                          | 0       | The tail is cut back to the intersection point itself<br>The end is moved onto its projection |
| Trim overshoots past a node                    | yes     |                                                                                               |
| Close undershoots onto the neighbouring line   | yes     | Off: deleting destroys the attributes too                                                     |
| Insert missing nodes                           | yes     |                                                                                               |
| Delete lines shorter than the length threshold | no      |                                                                                               |
| Spike angle threshold, degrees                 | 1       |                                                                                               |
| Cleaned layer                                  | -       |                                                                                               |
| Remaining problems, <i>optional</i>            | -       |                                                                                               |

## 1.05 Node and vertex snapping

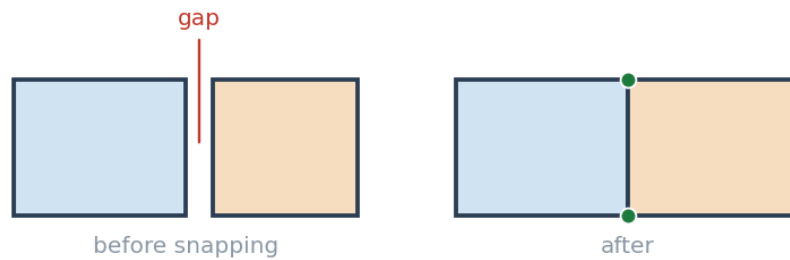


Figure 4: A gap below the tolerance is closed by merging vertices.

Use it when the coverage is otherwise fine and only the borders need reconciling. It does not touch overlaps or gaps.

A useful habit: run it first in **Insert nodes only** mode. It does not move a single existing coordinate and shows the real amount of discrepancy through the number of inserted nodes.

**The reference layer** is a separate parameter. Its vertices are treated as fixed and attract the input layer; the reference itself is not modified and does not appear in the result. Use it when a new area is stitched to a border that has already been accepted.

### Parameters

| Parameter                                         | Default                                        | What it sets                                                                     |
|---------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------|
| Input layer (polygons or lines)                   | -                                              |                                                                                  |
| Tolerance (in layer CRS units)                    | 2                                              | The maximum vertex displacement                                                  |
| Mode                                              | merge vertices and insert nodes                | Other options: insert nodes only, vertices then do not move; merge vertices only |
| Reference layer, <i>optional</i>                  | -                                              | Its vertices are fixed and attract the input layer. It is not modified           |
| Which object attracts which                       | larger attract smaller                         | The other option: by object order in the layer                                   |
| Z value of an inserted node                       | interpolate along the edge                     | The other option: take from the attracted vertex                                 |
| Insert nodes at edge intersections                | yes                                            |                                                                                  |
| Do not modify objects narrower than the tolerance | yes                                            | Such an object would collapse into itself, so it stays as an anchor              |
| If snapping broke the geometry                    | repair, and restore the original if that fails | Other options: restore the original geometry at once; leave as is                |
| Check geometry validity before and after          | yes                                            |                                                                                  |
| Snapped layer                                     | -                                              |                                                                                  |
| Edit points, <i>optional</i>                      | -                                              | Where vertices moved and nodes were inserted                                     |

## 1.06 Insertion of missing nodes

Adds nodes where a vertex of one object lies on the edge of another. Nothing else.

**How it differs from snapping.** Snapping moves vertices to close discrepancies. Here there is no discrepancy at all: the borders already coincide, only the vertices differ. Insertion therefore moves nothing, and the total area stays exactly the same.

**When it is needed.** Different vertices do not affect rendering and are invisible to the eye, but they break dissolve by attribute, overlays, generalisation and loading into a database with strict topology. A typical source is independent construction of polygons on either side of a shared straight line, such as a fault line or the edge of a clipping mask.

**Several passes may be required:** an inserted node sometimes lands on the edge of a third object. The tool repeats passes while nodes are still found.

**The deviation from the edge** is not a tolerance. The distance here is zero, and the number only acts as a safeguard. The default matches coordinate precision; setting metres is wrong.

### Parameters

| Parameter                              | Default  | What it sets                                                                                            |
|----------------------------------------|----------|---------------------------------------------------------------------------------------------------------|
| Input layer (polygons or lines)        | -        | A source of nodes. Not modified and not present in the result                                           |
| Donor layer, <i>optional</i>           | -        |                                                                                                         |
| Allowed vertex deviation from the edge | 0.000001 | Not a tolerance but a safeguard. Metres should not be used here                                         |
| Insert nodes at edge intersections     | yes      | Two or three are enough for a consistent coverage. Reaching the limit means the layer is not a coverage |
| Maximum number of passes               | 10       |                                                                                                         |
| Layer with nodes                       | -        | The points where nodes appeared                                                                         |
| Inserted nodes, <i>optional</i>        | -        |                                                                                                         |

## 1.07 Assembly check by attribute

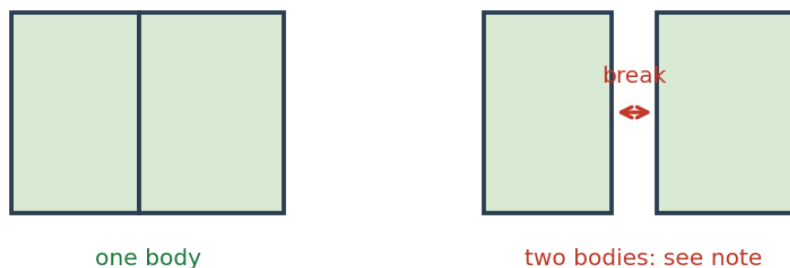


Figure 5: A group either assembles into one body or falls apart.

Checks that the union of objects sharing an attribute value gives exactly one part without interior rings. The layer is not modified.

**What is found.** *The group split into parts* means a break remains inside the group; the note field holds the distance to the nearest part, which is exactly the tolerance that was missing. *An interior ring within a group* means a hole remains inside.

**An important property.** The check finds what a coverage-wide gap search cannot: a gap reaching the outer edge is not a hole in the union, yet it cuts the group in two during assembly.

**When a group need not be whole.** One attribute value often describes several separated bodies: contour polygons of one level, islands, areas of one type. Set the **maximum gap** for such data. The sign that it is needed shows at once: if note holds hundreds of metres, these are not assembly defects.

### Parameters

| Parameter                     | Default | What it sets                                                                    |
|-------------------------------|---------|---------------------------------------------------------------------------------|
| Layer (polygons or lines)     | -       | The layer is not modified                                                       |
| Grouping field or fields      | -       | Required. With several fields their combination becomes the key                 |
| Debris area threshold         | 1       | Below this area an interior ring counts as debris                               |
| Maximum gap within one body   | 0       | How far apart parts still count as one body. Zero means the group must be whole |
| Interior rings are acceptable | no      | For data where a cavity is part of the design                                   |
| Assembly findings             | -       | Output point layer                                                              |

## 2.01 Topology-preserving simplify

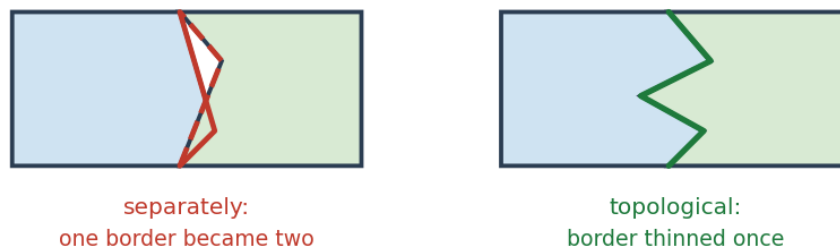


Figure 6: Independent simplification tears a shared border apart.

Thins vertices so that a border shared by two neighbours stays shared.

**Why.** Ordinary simplification processes each polygon separately, so the same border is thinned twice and differently, producing gaps and overlaps. Measured on a zone layer with a tolerance of 5: the topological version produces no violations at all, the independent one produces 46 overlaps, 25 gaps and 189 mismatched nodes.

**Two thinning methods.** Douglas-Peucker measures the deviation of a vertex from the chord: it holds corners, but leaves visible facets on a smooth curve. Visvalingam measures the area of the triangle formed by three neighbouring vertices: on smooth lines the result is softer, though a sharp corner made of short edges may be cut off.

**Smoothing** cuts corners after thinning, over the same arcs, so a shared border stays shared. Chaikin's scheme does not leave the original line, so no overshoots and no new self-intersections appear. Each pass roughly doubles the vertex count.

**How it works.** Shared edges are glued into arcs between branch nodes, each arc is thinned exactly once, and both neighbours receive the same result. Arc ends are fixed, so the nodes where three polygons meet do not move.

The area changes during simplification, that is its purpose. Topology is not damaged: check the result with 1.01, the number of findings must not grow.

### Parameters

| Parameter                                   | Default         | What it sets                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input layer (polygons or lines)             | -               | The other option:<br>Visvalingam, by triangle area<br>The maximum deviation of the simplified line from the original. For Visvalingam it is converted into an area<br>Protection for short border stretches. Zero switches it off<br>Corner cutting after thinning. Each pass roughly doubles the vertex count |
| Thinning method                             | Douglas-Peucker |                                                                                                                                                                                                                                                                                                                |
| Simplification tolerance                    | 1               |                                                                                                                                                                                                                                                                                                                |
| Do not simplify arcs shorter than, vertices | 0               |                                                                                                                                                                                                                                                                                                                |
| Smoothing, number of passes                 | 0               |                                                                                                                                                                                                                                                                                                                |
| Precision for matching shared vertices      | 0.000001        | Not a simplification tolerance. Needed when neighbours are stored with different coordinate precision                                                                                                                                                                                                          |
| Grouping field or fields, <i>optional</i>   | -               | Borders of different groups are not treated as shared                                                                                                                                                                                                                                                          |
| Keep Z values                               | yes             |                                                                                                                                                                                                                                                                                                                |
| Simplified layer                            | -               |                                                                                                                                                                                                                                                                                                                |

## 2.02 Polygon borders as lines

Outputs the borders of a coverage as separate lines, from node to node. The layer is not modified.

**How it differs from converting polygons to lines.** The usual conversion outputs a shared border twice, once from each neighbour: two coincident lines stacked on each other. The style lands on both and the width doubles. Here the border comes out once.

**Three kinds of border:** between objects, the outer edge of the coverage, the edge of a cavity. If another object lies in the cavity, it is a border between objects instead.

**Attributes:** kind, label, fid\_a, fid\_b, length. If a field is chosen, val\_a and val\_b are added, the value of that field for each neighbour. For geological borders these are the seam on the left and the seam on the right.

**A line breaks** where three or more objects meet and where the pair of neighbours changes. A border between two bodies therefore comes out as a single piece.

**The deviation for matching shared vertices.** If neighbours have different vertices, a shared border is not recognised. Such nodes are added before the analysis and the vertices do not move. The layer can be checked in advance with tool 1.01.

### Parameters

| Parameter                                                   | Default  | What it sets                                                                        |
|-------------------------------------------------------------|----------|-------------------------------------------------------------------------------------|
| Input layer (polygons)                                      | -        | The layer is not modified                                                           |
| Field whose values to record on both sides, <i>optional</i> | -        | The value of that field for each neighbour ends up in the line attributes           |
| Deviation when matching shared vertices                     | 0.000001 | Nodes are added before the analysis, the vertices do not move. Zero switches it off |
| Precision for matching shared vertices                      | 0.000001 |                                                                                     |
| Borders                                                     | -        | Output line layer                                                                   |

### What is handled on shared borders

| Case                                                              | Result                                      |
|-------------------------------------------------------------------|---------------------------------------------|
| A neighbour has a vertex on the shared border, we do not          | A node is inserted, coordinates do not move |
| A T-junction of three polygons                                    | The node appears where it was missing       |
| Four polygons meeting at a corner within the tolerance            | All corners merge into one point            |
| A corner overshooting into a neighbour by less than the tolerance | Vertices merge, the overshoot disappears    |
| Edges crossing without shared vertices                            | Nodes are placed at the intersections       |
| A slanted border that already matches                             | Nothing changes, no false nodes             |
| A mismatch larger than the tolerance                              | Left alone, this is a meaningful case       |

### Z values

When snapping, a vertex takes the plan coordinates of the leader and keeps its own elevation, so seams with different Z do not get mixed.

In the cleanup tool the intersection operations work in plan, so Z is restored from the nearest original vertex. For coverages this is correct; for layers with sharp elevation changes along a border the result should be checked.

### Warnings in the report

**The total area changed by more than one per cent.** Almost always means the area threshold is too high.

**Degenerate rings removed.** The tolerance exceeds the size of the objects themselves.

**Objects disappeared.** An object was lost entirely during repair. Find it in the remaining problems layer by the lost type.

**Repairs cancelled due to area loss.** The safeguard worked: repairing invalid geometry would have taken more than a quarter of the area, so the object was left unchanged.

**Objects with ring self-touches.** GEOS considers such geometry valid while SQL Server may reject it. Apply MakeValid on the server side when loading.

---

## Limitations

**Gaps are found as holes in the union of the coverage.** A gap reaching the outer edge is not a hole and is not found this way. Such gaps are closed by vertex snapping when their width is below the tolerance.

**The layer is read into memory in full.** Measured on a cadastral layer: 11,866 objects, 15,700 rings, 726,000 vertices.

| Tool                                                 | Time |
|------------------------------------------------------|------|
| 1.01 Topology check, tolerance 2                     | 51 s |
| 1.06 Insertion of missing nodes                      | 78 s |
| 2.01 Topology-preserving simplification, tolerance 5 | 6 s  |

For layers of millions of vertices, process them in parts.

**The magnitude of the coordinates affects precision.** In systems where coordinates run into millions of metres, such as Web Mercator, a double resolves about a nanometre. The edge between vertices exists as a formula, and the sign of the determinant that decides which side a point is on is computed from differences of large numbers, where the leading digits cancel. That is where overlaps of a few dozen square microns come from: they have no width, only length. The tool treats them as debris because it judges an overlap by width. In a local system with six-digit coordinates there is an order of magnitude less of this noise.

**Lines have their own group 3:** check and cleanup. Lines are also accepted by 1.05 snapping, 1.06 node insertion, 2.01 simplification and 1.07 assembly check.

**Automation cannot know which of two disputed borders is correct.** It only tells scale: a centimetre overlap is an error, a hectare one is a disagreement between sources. Wide overlaps and large gaps therefore always stay with the operator.

---

## Output layer field reference

### The findings layer

Produced by **1.01**, **1.02**, **1.07**, and by the cleanup tools as the remaining problems layer. The geometry is a point placed where the violation was found.

| Field | Type   | What it holds                                                                         |
|-------|--------|---------------------------------------------------------------------------------------|
| type  | string | Violation code: overlap, gap, on_edge, dangle and others.<br>Convenient for filtering |
| label | string | The same in the interface language, for reading                                       |

| Field    | Type    | What it holds                                                                                                                                                |
|----------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| severity | string  | auto - debris, the cleanup tool will fix it. review - the operator decides                                                                                   |
| fid_a    | integer | Object identifier. For paired violations, the first of the pair                                                                                              |
| fid_b    | integer | The second object of the pair, or -1 if the violation concerns one object                                                                                    |
| value    | real    | The measured quantity: the area of an overlap or a gap, the distance to a neighbouring line, the number of removed vertices. The meaning depends on the type |
| note     | string  | An explanation with the measured value: how this case differs from the next one of the same type                                                             |
| grp      | string  | The group key, if a grouping field was set                                                                                                                   |

**How to style it.** A rule on severity: review in red and larger, auto small and grey. The working list is then visible at once.

### The edit points layer

Produced by **1.05**.

| Field | Type    | What it holds                                           |
|-------|---------|---------------------------------------------------------|
| kind  | string  | move - a vertex was moved, insert - a node was inserted |
| dist  | real    | The amount of displacement. Zero for an inserted node   |
| ring  | integer | The number of the ring the edit belongs to              |

### The inserted nodes layer

Produced by **1.06**.

| Field | Type   | What it holds                                                      |
|-------|--------|--------------------------------------------------------------------|
| kind  | string | insert - a node on an edge, cross - a node at an edge intersection |
| dist  | real   | The deviation of the vertex from the edge. Usually zero            |

### The borders layer

Produced by **2.02**. The geometry is linear, each line runs from node to node.

| Field  | Type    | What it holds                                                                                              |
|--------|---------|------------------------------------------------------------------------------------------------------------|
| kind   | string  | shared - a border between two objects, outer - the outer edge of the coverage, hole - the edge of a cavity |
| label  | string  | The same in the interface language                                                                         |
| fid_a  | integer | The identifier of the object on one side                                                                   |
| fid_b  | integer | On the other side. For an outer edge and a cavity edge, -1                                                 |
| length | real    | The length of the stretch                                                                                  |
| val_a  | string  | The value of the chosen field for the first neighbour. Only if a field was set                             |
| val_b  | string  | The same for the second neighbour. Empty for an outer edge                                                 |

**How to style it.** A rule on kind: the outer edge thicker, borders between objects thinner, a cavity edge dashed. For geological borders, a rule on the pair val\_a and val\_b: the border between two particular seams gets its own style.

### The cleaned and snapped layers

The attributes of the input layer are preserved in full. No fields are added. The geometry of a cleaned layer is always of multi type: a repair may split an object into several parts.

### Verifying the code

The geometric logic is kept out of QGIS and covered by tests:

```
cd toponliner
python -m unittest discover -s tests -v
```

QGIS is not required for the tests. Overlap and gap checks are tested against Shapely, which uses the same GEOS as QGIS.