Agios Germanos River

Geomorphological Study

Technical Appendices, Calculations and Evidence Archive

Full analytical and reproducibility record

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This volume documents the methods, evidence checks and calculations supporting the completed geomorphological assessment. It reconciles the field observations, grain-size analyses and sediment estimates used to compare restoration options, including their assumptions and uncertainty. Numerical inputs and analytical releases retain the dated R1 baseline. Exact source-table filters allow each headline value in the main study to be traced to its analytical evidence.

Contents

Document control **1**

How to use this analytical record **iv**

A Evidence archive and reconciliation **1**
A.1 Clean Data Assimilation and Provenance . . . 1
A.1.1 Assimilation architecture . . . 1
A.1.2 Canonical identifiers and relational keys . . . 2
A.1.3 Field-note and morphology assimilation . . . 2
A.1.4 Width and branch metadata . . . 3
A.1.5 Surface-clast assimilation . . . 3
A.1.6 Bulk-sieve assimilation . . . 4
A.1.7 Photographs and spatial evidence . . . 4
A.1.8 Hydrological assimilation . . . 5
A.1.9 Geometry, topography and control assimilation . . . 5
A.1.10 RTK receipt-stage lineage and controlled promotion . . . 6
A.1.11 Frozen-baseline validation . . . 6
A.2 Headline calculation reconciliation . . . 7
A.3 Full calculation reconciliation catalogue . . . 8
A.4 Sediment assessment and contribution of further measurements . . . 31

B Spatial framework, morphology and sediment evidence **32**
B.1 Reconciled Morphology, Process Domains and Routed Topology . . . 32
B.1.1 Why a process-domain classification is required . . . 32
B.1.2 Parent domains . . . 32
B.1.3 Lower-corridor subdomains . . . 33
B.1.4 Routed topology . . . 34
B.1.5 Passage reconciliation . . . 35
B.1.6 Mountain observation assignment . . . 36
B.1.7 Connectivity dimensions . . . 36
B.2 Domain-Specific Transport and Storage Proxies . . . 37
B.2.1 Observed sediment fractions . . . 37
B.2.2 Annual hydraulic transport opportunity . . . 38
B.2.3 Potential bed-material capacity at eligible alluvial patches . . . 39
B.2.4 Passage and storage contrasts . . . 40
B.2.5 Wood-forced multithread reaches . . . 40
B.2.6 Mountain high-flow transfer opportunity . . . 41
B.2.7 Coarse-granite downstream front . . . 41
B.2.8 Connected delivery potential . . . 42

C Hydrology and hydraulics **42**
C.1 Hydrological Forcing and Reach Hydraulics . . . 42
C.1.1 Native-time-step hydrograph . . . 42
C.1.2 High-flow event definition . . . 43
C.1.3 Spatial flow reconstruction . . . 44
C.1.4 Surveyed cross-section hydraulics . . . 44
C.1.5 Process-reach geometry . . . 45
C.1.6 Energy slope . . . 46
C.1.7 Boundary stress and skin-friction partition . . . 46
C.1.8 Hydraulic validation gates . . . 47

D Fraction-specific structural connectivity **47**
D.1 Fraction-Specific Structural Connectivity . . . 47

D.1.1 Directed graph representation . . . 48
D.1.2 Source availability . . . 48
D.1.3 Control transmission . . . 48
D.1.4 Path transmission . . . 49
D.1.5 Control importance and scenario contrasts . . . 50
D.1.6 Observed and inferred stores . . . 50
D.1.7 Hillslope connectivity index for fines . . . 50
D.1.8 Connectivity outputs . . . 51

E M2 capacity and delivery calculation 51
E.1 Executed M2 Capacity and Delivery Scenario . . . 51
E.1.1 Result class and estimand . . . 51
E.1.2 M2 eligibility and MoRPh constraint . . . 52
E.1.3 Frozen input and outer-state ledger . . . 53
E.1.4 Flow-transfer ensemble . . . 55
E.1.5 Surface bootstrap and conditional parameters . . . 55
E.1.6 Rectangular hydraulic solution and Wong–Parker models . . . 56
E.1.7 Executed Recking sensitivity . . . 56
E.1.8 Inundation, integration and water-year support . . . 56
E.1.9 Nested uncertainty and convergence . . . 57
E.1.10 Executed results . . . 60
E.1.11 Dimensioned delivery scenarios . . . 60
E.1.12 Why conformal prediction is not used . . . 60
E.1.13 Machine-readable QA and claim boundary . . . 60
E.2 Uncertainty Propagation, Sensitivity and Quality Gates . . . 61
E.2.1 Uncertainty classes . . . 61
E.2.2 Nested ensemble design . . . 61
E.2.3 Conditional summaries . . . 64
E.2.4 Current clean-baseline QA summary . . . 64
E.2.5 Governed analysis and release gates . . . 64

F Whole-reach local input, M20 transfer and planning load 65
F.1 Whole-Reach Supply and Total-Load Planning Scenarios . . . 66
F.1.1 Question, spatial domains and claim class . . . 66
F.1.2 Evidence architecture and MoRPh reconciliation . . . 67
F.1.3 Local earth-bank input model . . . 69
F.1.4 Engineered coarse supply from failing gabions . . . 70
F.1.5 Three resolvable reporting fractions . . . 70
F.1.6 Regional Prespa analogue model . . . 71
F.1.7 Analogue-conditioned total transported-load planning envelope . . . 73
F.1.8 Nested uncertainty design . . . 75
F.1.9 Local-corridor results . . . 76
F.1.10 SWAT+ landscape-erosion diagnostic and its outlet-yield interpretation boundary . 80
F.1.11 Permitted use and stopping rule . . . 80
F.2 Reference bank and gabion components . . . 81
F.3 Prespa rate–area–density reconciliation . . . 81
F.4 M20 coarse-store component . . . 81

G Passage evidence and RTK technical record 83
G.1 Controlled receipt and present analytical use . . . 83
G.2 Survey-association gates . . . 85
G.3 Association precision and review states . . . 85
G.4 Interpretation and use of existing evidence . . . 85
G.5 Route to relative geometry . . . 86

H Reproducibility, QA and release control **87**
H.1 Implementation Sequence, Outputs and Reproducibility . . . 87
H.1.1 Current implementation status . . . 87
H.1.2 Executable stages . . . 88
H.1.3 Stage 00 clean-baseline command . . . 88
H.1.4 Run configuration and output key . . . 89
H.1.5 Required machine-readable outputs . . . 90
H.1.6 Required figures . . . 94
H.1.7 Reproducibility and archive release . . . 94
H.2 Confidence and appropriate use . . . 94
H.2.1 Field coverage and representativeness . . . 95
H.2.2 Sediment resolution . . . 95
H.2.3 Topology and spatial geometry . . . 95
H.2.4 Hydrological forcing . . . 96
H.2.5 Hydraulic and transport equation limits . . . 96
H.2.6 Structure and storage interpretation . . . 96
H.2.7 Whole-reach supply-scenario limits . . . 97
H.2.8 Annual-yield interpretation boundary . . . 97
H.2.9 Existing-data controls . . . 98
H.3 Publication revisions and reproducibility . . . 98
H.4 R1 revised-publication regeneration . . . 99
H.5 Recorded software environment . . . 99
H.6 Shared publication-value control . . . 99

I Evidence archive and visual-output catalogue **100**
I.1 Immutable release inventory . . . 100
I.2 Archive controls . . . 100
I.3 Visual-output inventory . . . 100
I.4 Visual-output register . . . 110
I.5 Analytical dictionaries and controlled ledgers . . . 115
I.6 Core Data Dictionary . . . 115
I.7 Surface-Count Statistics and Bootstrap . . . 117
I.8 Module Process and Sample Register . . . 118
I.9 Initial Scenario and Parameter Register . . . 122
I.10 Final Claim-Audit Vocabulary . . . 124

How to use this analytical record

The appendices follow the calculation chain from evidence receipt to released outputs. Appendices A–D establish the controlled evidence, morphology, hydrology and structural-connectivity framework. Appendices E–F give the executed M2, local-input, M20 and catchment-load calculations. Appendix G records passage and RTK evidence. Appendices H–I provide exact regeneration routes, release manifests and the visual-output catalogue.

The machine-readable `calculation_reconciliation_register.csv` is the controlling crosswalk. For each headline value it records the estimand, units, year, model and scenario, uncertainty meaning, exact table row filter, parameter ledger, code stage, seed, draw count, source-table SHA-256, QA gate and independent check.

Notation	Meaning in this volume
q05 / q50 / q95	Conditional simulation quantiles within one named model and structural state, unless a table explicitly defines another basis
Reference state	Declared central physical-assumption set; it is not an observed probability distribution over alternative states
Outer states	Restrictive, reference and permissive/event-open alternatives retained separately and never probability-averaged unless an explicitly labelled prior sensitivity is shown
Planning span	Unweighted union of structurally different analogue states; it does not have confidence-interval semantics
Component	Quantity with its own accounting boundary; local input, M20 transfer, M2 capacity and catchment load are not added

Opening the photographic and GIS evidence

Keep the package folders together and open the package browser (`index.html` in the package root). The following local links open the supplied evidence:

- July photo browser: filter by date, module or filename and open the full-resolution original.
- master_photos.csv and master_reconciled.gpkg: original photo register and GIS layers for modules, photos and observations.
- Photo_Manifest.csv: joins source filenames and master rows to the portable image paths, module, date and recorded location basis.

If a PDF viewer blocks local links, use the package browser or the folder `04_July_Survey_Photographs`. The CSV and GeoPackage are in its `03_Source_Registers` subfolder; the portable manifest is in `02_Registers`. Open the GeoPackage in GIS software. Its original source paths are preserved; use the portable manifest to find the packaged images. Module or waypoint associations do not establish a surveyed camera footprint. There are 213 distinct photographs in 214 original files (one metadata variant), covering 213 of 214 master records. M15/Garmin 058 remains unavailable.

A Evidence archive and reconciliation

This appendix fixes the evidence cut, provenance, identifier policy and analytical eligibility rules. The reconciled field database and the dated analytical and RTK releases remain unchanged by the publication build.

Controlled release chain

Field and documentary sources are reconciled into canonical records; analytical stages consume those records and immutable hydrology inputs; released tables and figures are hashed; publication values are generated from exact released-table filters; both report volumes consume the same shared macros.

A.1 Clean Data Assimilation and Provenance

A.1.1 Assimilation architecture

The analytical database is built as a sequence of immutable raw inputs, explicit parsing rules, QA flags and analysis-ready views. Raw files are never silently overwritten. Corrections are stored as interpreted values beside the original value, and exclusions are controlled by boolean fields rather than by deleting records. Figure 1 shows the required flow.

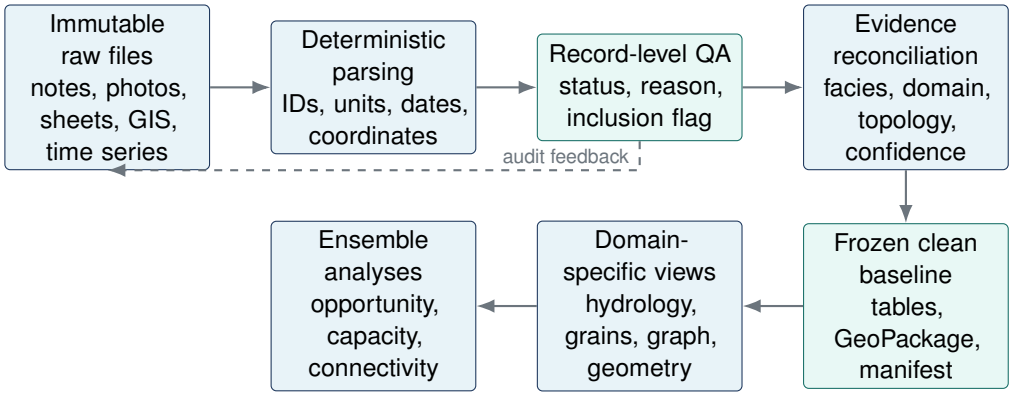


Figure 1: Clean-data assimilation architecture. Dashed feedback changes parsing rules or metadata, never the archived raw source.

The principal analysis-ready files are listed in Table 1.

Table 1: Clean baseline tables and present record support.

Dataset	Support	Analytical role
`master_modules.csv`	26 records	Module/source key, coordinates, widths, grain summaries and process context.
`master_photos.csv`	214 records / 213 named assets	Date-resolved Garmin/mobile photo register and spatial evidence; one M15 record has no filename.
`morph_features_all.csv`	1,180 rows	Conservative free-note feature crosswalk with evidence status, confidence and denominator.
`grain_pebble_clasts.csv`	11 modules	Individual b-axis surface clasts, sample role and M2 primary/sensitivity QA.
`grain_pebble_stats.csv`	count-level	D16, D50, D84 and D90 by count; sample statistics remain separate.
`grain_bulk_sieves.csv`	80 raw / 74 accepted	Mass passing 50, 19, 8, 5 and 2 mm with row-level QA.
`reach_context_reconciled.csv`	26 records	River, process domain, functional role, topology, eligible proxy and evidence.
`master_reconciled.gpkg`	spatial layers	Module, photo and morphology layers in a portable analysis package.

A.1.2 Canonical identifiers and relational keys

The module key is the text field `module`: M1–M25 plus SRC. Numeric module values are retained only for sorting within the original field block. The surface-count key is `sample_code`; the bulk-sieve key is the original sample code plus a row fingerprint where duplicate detection is required. Photo linkage uses acquisition date plus Garmin waypoint because Garmin numbers repeat between field days.

The minimum referential rules are:

- every sediment and morphology record maps to exactly one canonical module;
- every module maps to exactly one reconciled context record;
- every located photograph records its coordinate source (Garmin, mobile fallback or unlocated);
- every analysis result records the sample/facies, process reach, water year, parameter scenario and code version that produced it;
- SRC observations remain non-channel source samples and are never merged with the Siroka bed distribution.

A.1.3 Field-note and morphology assimilation

M1–M20 have free-text notes. The original coding script applied a shared baseline and interpreted unmentioned features as absent. The re-audited crosswalk uses the observation states in Table 2. This follows the broader principle in the MoRPh manuals that codes refer to observed properties over a stated denominator; blank or unrecorded evidence is not equivalent to zero cover (Gurnell and Shuker, 2022).

Table 2: Evidence states used in the free-note crosswalk.

Evidence state	Code	Meaning
Explicit observation	P/T/E or text	Feature or value is stated directly in the module note.
Explicit absence	A	The note explicitly says the feature is absent; never assigned from silence.
Inferred	I	A process follows from an explicit configuration but was not named directly.
Copied background	retained + flag	Repeated field text is preserved but assigned lower coding confidence.
Not recorded	U	No defensible observation is available.
Recorded descriptive	–	Numeric value, count, raw process code or non-abundance description.

Each row also receives `observation_denominator` (for example wetted-bed area, bank-face area, bank length or module count), `evidence_source` and `coding_confidence`. The resulting file is a transparent note crosswalk, not a retrospective claim that a complete formal MoRPh abundance survey was performed. In particular, exposed unvegetated bed is not converted to a mid-channel bar, and a field-called island is not automatically promoted to the formal island class without relative-elevation evidence.

The raw process code is retained exactly. Thus M8–M14 retain the field string `ED,T`; any later primary-process and transfer flags are derived in new fields rather than rewriting the source note.

A.1.4 Width and branch metadata

Widths are parsed together with their scope and quality. M1–M7 are recorded single-channel wetted widths; M8–M12 are approximate main-limb widths; M13–M17 are right- or left-limb widths; and no total width is assigned to M18–M20. The fields are:

- `water_width_m`;
- `water_width_scope` = wetted channel, main limb, left limb, right limb or not measured;
- `water_width_quality` = field measured, approximate, not measured multithread or not recorded;
- `water_width_raw`, preserving the note line.

This prevents an approximate 5 m limb or an invented 8 m value from being used as the active width of a multithread corridor.

A.1.5 Surface-clast assimilation

Surface counts use the measured intermediate (b) axis in millimetres, in accordance with standard pebble-count practice (Bunte and Abt, 2001). Statistics are computed from individual clasts using explicit plotting positions; count-level statistics are retained separately so that a module median cannot conceal different sampled surfaces.

M2 required a specific reconciliation. Two grids are present in the field note but absent from the original master workbook. The note states that a bar and an island were sampled, but it does not identify which grid represents which facies. Both grids are therefore labelled `bar_or_island_unresolved`. Seventy clast pairs are directly readable. Five retained records depend on non-canonical transcription: two decimal-comma interpretations, one malformed decimal

and two pairs reconstructed from a compound line. The five are marked `include_in_primary = False`; they remain available as a sensitivity set. Table 3 shows that the primary result is insensitive to their inclusion.

Table 3: M2 b-axis count reconciliation. Percentiles are in millimetres.

Analysis set	n	D_{16}	D_{50}	D_{84}
Primary, directly readable	70	10.0	20.0	30.0
All interpreted records	75	10.0	20.0	30.0

The M7–M9 and M12 counts are retained as exploratory because of their small sample sizes. HM13 is followed downstream by the M20 proximal coarse tailwater store and then the M19 distal stratified sorting store. M21–M25 represent independent mountain pocket or local-alluvial-mantle observations; they are not a module-number routing sequence. These roles are carried into every grain table.

A.1.6 Bulk-sieve assimilation

The bulk samples record total mass and cumulative mass passing 50, 19, 8, 5 and 2 mm. They are not "fine-sediment distributions": the mass below 2 mm is unresolved and cannot be divided into sand and silt. The primary outputs are therefore observed fraction masses or percentages in the bins < 2, 2–19, 19–50 and > 50 mm. An interpolated D50 is permitted only when 50% passing is bracketed by valid sieve points, and is labelled as an interpolation of the bulk sample rather than a true full-range GSD.

The row-level QA rules are:

1. preserve raw total and sieve cells;
2. normalise totals 1988 and 2089 to 1.988 and 2.089 kg where the sieve masses demonstrate gram entry;
3. flag an exact duplicate fingerprint and exclude it from summaries;
4. reject a row if passing mass exceeds total mass beyond tolerance;
5. reject non-monotonic cumulative passing masses;
6. retain all rows and record the semicolon-separated `qa_status`.

Of 80 rows, 74 enter descriptive summaries. The two unit corrections remain included; one exact duplicate and five physically inconsistent rows are excluded.

A.1.7 Photographs and spatial evidence

The reconciled master contains 214 photo records. Of these, 213 name a locally recoverable image asset; one M15 sample-photo record retains its field-register identity but has no filename. Day-specific Garmin waypoints are preferred because QField/mobile positions show large drift at some sites. A mobile position is used only where no dated Garmin match exists, and the source is recorded. Repeated physical copies in cumulative field packages are treated as copies rather than additional photographs; any newly identified asset must be matched through filename, date and location evidence before assignment.

The photo workflow retains:

- original file and acquisition date;
- Garmin/QField label and canonical module;
- photo type and direction where recorded;
- coordinate source and confidence;
- later analytical annotations for bedrock, framework, pocket cover, lithology and store type in a separate table.

Photo-derived cover or lithology classification is performed blind to the hydraulic result where practicable, and at least a subset is independently reclassified to quantify observer agreement.

A.1.8 Hydrological assimilation

The primary forcing series is the raw HCMR stage/discharge record at Laimos, not a daily aggregation. The archive contains approximately 102,924 valid source-workbook discharge values and an observed maximum near 9.12 $\mathrm{m^3\,s^{-1}}$; the executed assimilation contains 105,579 timestamps after incorporating the corrected April 2026 workbook. The source timestamps contain no embedded time zone. They are documented as Europe/Athens local civil time and the source clock is retained for elapsed intervals rather than inventing a UTC/DST conversion. Ingested fields include timestamp, stage, discharge, source column, validity flag and gap/rating-period identifier. Duplicate timestamps, non-monotonic time, negative values, repeated plateaux and implausible step changes are flagged before any resampling.

Daily means are derived products for comparison only. Competence duration and event metrics use the native valid interval because brief floods may disappear from a daily mean.

Spatial flow support comprises:

- repeated spot discharges at the mouth, SPP building, Gaidouritsa and Siroka;
- simultaneous 30 June 2023 measurements at the mouth (0.454 $\mathrm{m^3\,s^{-1}}$), Laimos (0.533 $\mathrm{m^3\,s^{-1}}$), Gaidouritsa (0.269 $\mathrm{m^3\,s^{-1}}$) and Siroka (0.317 $\mathrm{m^3\,s^{-1}}$);
- the surveyed HCMR cross-section and stage/depth record;
- SWAT+ water routing and abstraction schedules as secondary interpolation support.

Because the tributary sum exceeds the Laimos measurement despite intervening area, abstraction or channel loss is material. Drainage-area ratios are not accepted as the sole flow-scaling method. The SCIMABIO attributes `velocity_H` and `prof_HCMR` repeat gauge conditions for a survey day and are explicitly excluded as local obstacle hydraulics.

A.1.9 Geometry, topography and control assimilation

Spatial processing uses WGS84 (EPSG:4326) for archive interchange and Greek Grid GGRS87 (EPSG:2100) for distance, area and chainage. A dataset with missing CRS metadata is assigned a CRS only after coordinate range and overlay checks; the assigned CRS and justification are written to the processing log.

Two DEM products remain distinct:

- the ORP watershed DEM, 20 m resolution;
- the processed Copernicus GLO-30 surface, approximately 26.35 m resolution.

They are not described as 5 or 10 m data. The current DEM-derived lower channel is displaced by approximately 70–317 m from the observed corridor and is used only after correction/snap

review; it cannot provide point-scale module slope.

The routed corridor is assembled from the 2020 Kastridis stream/intervention mapping, the 2023 UAV/RHS plates, 2025 walked lines and obstacle mapping, field/Garmin evidence and the cross-section. The three Irish passages are fixed at HM15, HM14 and HM13 using their independently corroborated coordinates. Engineered point elevations are excluded where their datum is inconsistent.

A.1.10 RTK receipt-stage lineage and controlled promotion

Three provider-undocumented XYZ exports were received on 10 August 2026. The source files were retained unchanged and checksummed; the receipt-stage ingest parsed point identifier, easting, northing and elevation without correcting source values. Package identities were assigned from their broad alignment with the canonical HM13, HM14 and HM15 passage controls under the working EPSG:2100 interpretation.

Table 4: RTK receipt-stage QA and promotion into the dated context release.

Passage	XYZ rows	Receipt-stage QA	Controlled promotion
HM13	1,327	Source retained; 27 redundant exact XYZ records isolated in derivative QA.	Context-only release 2026-08-10_R1_context_only; provider CRS/datum/control and manual feature review govern later relative-geometry use.
HM14	1,176	Source retained; 25 high-precision records retained as review-sensitive.	Context-only release 2026-08-10_R1_context_only; provider metadata and review of the precision block govern later relative-geometry use.
HM15	1,156	Source retained; 1 severe elevation anomaly excluded and 1 record retained for review.	Context-only release 2026-08-10_R1_context_only; provider metadata and manual feature review govern later relative-geometry use.

The release passed 6 of 6 survey-association gates. It supports receipt confirmation, broad plan alignment, local coverage mapping and evidence navigation. Provider reference-system confirmation and manual feature review provide the controlled progression from this context product to passage-specific relative geometry. Appendix G gives the release gates, association states and permitted analytical route in full.

A.1.11 Frozen-baseline validation

Before an analysis run, an automated audit must pass the following checks:

- schema, data type and allowed-enumeration checks;
- uniqueness of module and analysis-run keys;
- referential integrity across modules, samples, photographs and context;
- coordinate bounds, CRS and geometry validity;
- grain-axis positivity and percentile order $D_{16} \leq D_{50} \leq D_{84}$;
- cumulative sieve monotonicity and mass balance;
- strictly increasing hydrological timestamps within each source series;
- explicit missingness and no silent width, slope or facies imputation;
- file manifest containing path, byte size, modification time and SHA-256 hash;

- analysis configuration, random seed and software environment captured with every output package.

Only a frozen baseline that passes these checks may be used to generate report figures or annual metrics. A failed check blocks the affected analysis view but does not erase the underlying record.

A.2 Headline calculation reconciliation

The R1 register contains 132 required rows. It covers every substantive main-report numerical interface: the evidence inventory; spatial and accounting interfaces; passage-store sample counts and D_{50} endpoints; hydrology and connectivity controls, including integrated high-flow excess; M2 simulation controls and all model-specific quantiles; local input and its bank/gabion components; all seven Prespa rate points, their independent-terminal selection, the preferred rate–area–density conversion and the separate Alpine context; M20 threshold and transfer quantiles; and RTK receipt, anomaly and association facts. Each row records the publication display, exact source value, source field, released table or JSON object, row filter, SHA-256 digest, calculation stage, uncertainty meaning and QA route. Every mandated field is explicit; deterministic or context rows use a controlled not-applicable value for simulation-only fields. Values therefore move from the dated release into both documents without transcription from a report PDF.

Result family	Authority	Reconciliation rule
Evidence inventory	T03; frozen sample-total summary	Select the named evidence stream; retain database records, available assets, 17 accepted surface groups and the 66 channel plus 8 SRC accepted bulk records as separate scopes
Spatial and store interfaces	T02; T06; F09; T25	Select the accepted catchment area, routed distances, HM15 receiving reach, reference M2 active width and passage-store sample endpoints
Gauge opportunity	T05	Select threshold, event rule, water year, count, supported duration and integrated excess volume separately
Structural connectivity	T04	Preserve all four fraction-specific values and reconcile their common three-decimal central display
M2 capacity	T06; G4	Select simulation controls, water year, reference outer state, equation family and q05/q50/q95 field
Local sediment input	T09	Select water year and `whole_reference`; retain bank and gabion q50 components beside the draw-by-draw combined q05/q50/q95 distribution
Catchment planning load	T21; T24; T25; Prespa rate and comparability ledgers	Reproduce all seven named Prespa rates, select the four independent terminal basins, and retain the rate, area, volume and density steps; keep Prespa, French total-load and Austrian monitored-bedload families separate
M20 transfer	C03; T15	Preserve the > 50 mm threshold, then select one physical state and q05/q50/q95 field; 2021 and 2022 mass states are invariant
RTK and associations	AF22 status; source QA; SA01–SA06; validation and decision snapshots	Select passage/field or exact JSON count; retain paired duplicate handling, zero manual decisions and candidate status explicitly

A.3 Full calculation reconciliation catalogue

The catalogue below reproduces all 132 governed interfaces. The supplied 23-column CSV retains exact values, uncertainty semantics, seeds, draw counts and hashes.

Table 5: Calculation reconciliation catalogue: publication, authority and QA crosswalk.

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
PUBLICATION_INPUT_RELEASE_ID	2026-08-17_R1_revised release ID; Exact revised publication-input identity	Main: Document control and digital-package reference; technical: Appendices A and H / release control	release_identity.csv; filter: identity_type=publication_input	exact-release-ID rejection gate; hand-check: analytical release remains 2026-08-17_R1; publication input is 2026-08-17_R1_revised
EVIDENCE_MODULES	26 module/source locations; Spatial observations	Main: Section 1 / evidence snapshot; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Spatial observations	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_MORPH_ROWS	1,180 coded evidence rows; MoRPh/free-note crosswalk	Main: Section 1 / evidence snapshot; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=MoRPh/free-note crosswalk	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_PHOTO_RECORDS	214 database records; Reconciled photograph records	Main: Section 1 / evidence snapshot; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Reconciled photograph records	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_PHOTO_ASSETS	213 image assets; Records with a named image asset	Main: Section 1 / evidence snapshot; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Records with a named image asset	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_CLASTS_RETAINED	611 individual clasts; Surface clasts retained	Main: Sections 1 and 2 / evidence snapshot; MR03; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Surface clasts retained	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
EVIDENCE_ CLASTS_ PRIMARY	606 individual clasts; Surface clasts in primary statistics	Main: Sections 1 and 2 / evidence snapshot; MR03; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Surface clasts in primary statistics	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_ BULK_ROWS	80 samples; Bulk sieve records	Main: Sections 1 and 2 / evidence snapshot; MR14; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Bulk sieve records	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_ BULK_ACCEPTED	74 samples; Accepted bulk sieve records	Main: Sections 1 and 2 / evidence snapshot; MR14; technical: Appendix A / T03	T03_sediment_observation_summary.csv; filter: evidence_stream=Accepted bulk sieve records	G0;G1;G5; hand-check: T03 row-identity and released-manifest hash check
EVIDENCE_ SURFACE_ ACCEPTED_ GROUPS	17 sample groups; Accepted surface-count sample groups represented in the released bootstrap summary	Main: Section 2 / MR03; technical: Appendix A / evidence sample totals	evidence_sample_totals.csv; filter: metric_id=surface_ accepted_groups	G1;G5;publication source-hash gate; hand-check: COUNT(released sample rows); source SHA-256 1ed04fec 1860ad295950d544c9fcd761 abc17cf0c05c5f2e964548aa 69acffd4
EVIDENCE_ BULK_ ACCEPTED_ CHANNEL	66 records; Accepted channel-module bulk-sieve records, excluding SRC source-material records	Main: Section 2 / MR14; technical: Appendix A / evidence sample totals	evidence_sample_totals.csv; filter: metric_id=bulk_ accepted_channel	G1;G5;publication source-hash gate; hand-check: COUNT(include_in_summary= True AND module!=SRC); source SHA-256 113c0edbce461777 f1647b9dba33134de8377bba d3d5e0b3c2e24e56537690c9
EVIDENCE_ BULK_ ACCEPTED_ SOURCE	8 records; Accepted SRC source-material bulk-sieve records	Main: Section 2 / MR14; technical: Appendix A / evidence sample totals	evidence_sample_totals.csv; filter: metric_id=bulk_ accepted_source	G1;G5;publication source-hash gate; hand-check: COUNT(include_in_summary= True AND module=SRC); source SHA-256 113c0edbce461777 f1647b9dba33134de8377bba d3d5e0b3c2e24e56537690c9

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
CATCHMENT_AREA_KM2	73.374 km2; Accepted Agios Germanos catchment accounting area	Main: Section 2 / MR01; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=preferred_independent_terminal	G4_total_load_planning_envelope; hand-check: T25 area equals TL01=73.374 km2
HM13_TO_M20_DISTANCE	20 m; HM13-to-M20 routed distance	Main: Section 2 / store-sequence diagram; technical: Appendix B / routed topology	routed_topology_edges.csv; filter: edge_id=E08	G1; hand-check: unique E08 edge; from/to identity checked
M20_TO_M19_DISTANCE	138 m; M20-to-M19 routed distance	Main: Section 2 / store-sequence diagram; technical: Appendix B / routed topology	routed_topology_edges.csv; filter: edge_id=E09	G1; hand-check: unique E09 edge; from/to identity checked
M20_SURFACE_COUNT_COUNT	3 counts; M20 surface-count sample records	Main: Section 2 / store-sequence cards; technical: Appendix B / F09	F09_passage_samples.csv; filter: module=M20	G1;G5; hand-check: unique sample codes within M20
M20_D50_LOW	55 mm; M20 surface-count D50 range endpoint	Main: Section 2 / store-sequence diagram and cards; technical: Appendix B / F09	F09_passage_samples.csv; filter: module=M20	G1;G5; hand-check: recomputed minimum across released M20 rows
M20_D50_HIGH	60 mm; M20 surface-count D50 range endpoint	Main: Section 2 / store-sequence diagram and cards; technical: Appendix B / F09	F09_passage_samples.csv; filter: module=M20	G1;G5; hand-check: recomputed maximum across released M20 rows

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M19_SURFACE_COUNT_COUNT	4 counts; M19 surface-count sample records	Main: Section 2 / store-sequence cards; technical: Appendix B / F09	F09_passage_samples.csv; filter: module=M19	G1;G5; hand-check: unique sample codes within M19
M19_D50_LOW	16.5 mm; M19 surface-count D50 range endpoint	Main: Section 2 / store-sequence diagram and cards; technical: Appendix B / F09	F09_passage_samples.csv; filter: module=M19	G1;G5; hand-check: recomputed minimum across released M19 rows
M19_D50_HIGH	43 mm; M19 surface-count D50 range endpoint	Main: Section 2 / store-sequence diagram and cards; technical: Appendix B / F09	F09_passage_samples.csv; filter: module=M19	G1;G5; hand-check: recomputed maximum across released M19 rows
STORE_SEQUENCE_SURFACE_COUNT_TOTAL	7 samples; M20 and M19 facies-specific surface-count samples	Main: Section 2 / store-sequence finding; technical: Appendix B / F09	F09_passage_samples.csv; filter: module IN (M20,M19)	G1;G5; hand-check: M20 count plus M19 count equals combined count
SPATIAL_HM15_RECEIVING_REACH	1.76 km; HM15-to-reporting-outlet routed receiving reach	Main: Sections 2 and 5 / MR01; MR12; technical: Appendix B / T02	T02_routed_node_register.csv; filter: node_id=HM15	G1; hand-check: HM15 chainage agrees with topology_chainage_m
M2_ACTIVE_PATCH_WIDTH	3.70 m; Reference M2 active-patch width	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: all six reference model/year rows have active_width_m=3.7

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
HYDRO_ THRESHOLD_P95	3.52 m3 s-1; Accepted-gauge high-flow threshold	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2021;event_separation_h=24	G2; hand-check: threshold is identical in all T05 sensitivity rows
HYDRO_EVENT_ SEPARATION	24 h; Reference independent-event separation	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: event_ separation_h=24	G2; hand-check: one row per accepted year at 24 h separation
HYDRO_ THRESHOLD_ EXCEEDANCE_ PERCENT	5 %; Accepted-record share above the pooled P95 threshold	Main: Section 3 / high-flow opportunity; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: event_ separation_h=24	G2; hand-check: 100 - 95 = 5 percent
HYD_2021_ EVENT_COUNT	16 events; Independent high-flow events in accepted water year	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2021;event_separation_h=24	G2; hand-check: release audit and event-separation sensitivity
HYD_2021_HIGH_ FLOW_HOURS	236 h; Supported record above the accepted high-flow threshold	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2021;event_separation_h=24	G2; hand-check: duration is invariant to event-separation sensitivity
HYD_2021_HIGH_ FLOW_HOURS_ DECIMAL	235.8 h; Supported record above the accepted high-flow threshold	Main: not_applicable — Technical Appendix C only; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2021;event_separation_h=24	G2; hand-check: one-decimal display rounds to the separately registered whole-hour headline

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
HYD_2021_SUPPORTED_PERCENT	3.0 %; High-flow duration as share of supported accepted record	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_year=2021;event_separation_h=24	G2; hand-check: 100 * high_flow_hours / supported_record_hours
HYD_2021_MAX_EVENT_PEAK	7.36 m3 s-1; Maximum independent-event peak in accepted water year	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_year=2021;event_separation_h=24	G2; hand-check: matches accepted-year maximum discharge audit
HYD_2021_INTEGRATED_EXCESS_MILLION_M3	0.755 million m3; Integrated accepted-gauge discharge volume above the fixed high-flow threshold	Main: Section 4 / local-input explanation; MR06; technical: Appendices C and F / T05	T05_gauge_high_flow_opportunity.csv; filter: water_year=2021;event_separation_h=24	G2;G4_whole_reach_supply; hand-check: integrated_excess_volume_m3 divided by 1,000,000
HYD_2022_EVENT_COUNT	16 events; Independent high-flow events in accepted water year	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_year=2022;event_separation_h=24	G2; hand-check: release audit and event-separation sensitivity
HYD_2022_HIGH_FLOW_HOURS	572 h; Supported record above the accepted high-flow threshold	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_year=2022;event_separation_h=24	G2; hand-check: duration is invariant to event-separation sensitivity
HYD_2022_HIGH_FLOW_HOURS_DECIMAL	571.5 h; Supported record above the accepted high-flow threshold	Main: not_applicable — Technical Appendix C only; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_year=2022;event_separation_h=24	G2; hand-check: one-decimal display rounds to the separately registered whole-hour headline

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
HYD_2022_ SUPPORTED_ PERCENT	6.7 %; High-flow duration as share of supported accepted record	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2022;event_separation_h=24	G2; hand-check: 100 * high_flow_ hours / supported_record_hours
HYD_2022_MAX_ EVENT_PEAK	6.78 m3 s-1; Maximum independent-event peak in accepted water year	Main: Section 3 / MR04; technical: Appendix C / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2022;event_separation_h=24	G2; hand-check: matches accepted-year maximum discharge audit
HYD_2022_ INTEGRATED_ EXCESS_ MILLION_M3	1.439 million m3; Integrated accepted-gauge discharge volume above the fixed high-flow threshold	Main: Section 4 / local-input explanation; MR06; technical: Appendices C and F / T05	T05_gauge_high_flow_opportunity.csv; filter: water_ year=2022;event_separation_h=24	G2;G4_whole_reach_supply; hand-check: integrated_excess_ volume_m3 divided by 1,000,000
CONNECTIVITY_ FRACTION_ COUNT	4 fractions; Sediment fractions evaluated in each routed connectivity scenario	Main: Section 3 / MR04; technical: Appendix D / T04	T04_fraction_connectivity_scenarios.csv; filter: reporting_ node=OUTLET;flow_class=EVENT;scenario=central; source_weighting=source_zone_equal	G3; hand-check: four unique fraction IDs and no duplicate central rows
CONNECTIVITY_ CENTRAL_INDEX	0.032 dimensionless; Central connected source-zone index across the four sediment fractions	Main: Section 3 / MR04; technical: Appendix D / T04	T04_fraction_connectivity_scenarios.csv; filter: reporting_ node=OUTLET;flow_class=EVENT;scenario=central; source_weighting=source_zone_equal	G3; hand-check: all four exact central indices round to 0.032
M2_DRAW_ COUNT	20,000 draws; Monte Carlo draws per M2 model/year/outer-state cell	Main: Section 4 / M2 calculation; technical: Appendix E / G4	G4_M2_capacity_delivery.json; filter: jsonpath=$.draws	G4_M2_capacity_delivery; hand-check: G4 draw_count_ and_seed_frozen and complete Cartesian draw-ID check

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M2_MODEL_FAMILY_COUNT	3 models; Separately retained M2 bedload-equation families	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: outer_scenario=reference;water_year IN (2021,2022)	G4_M2_capacity_delivery; hand-check: three unique equation identifiers in each reference year
M2_2021_WONG_PARKER_MAIN_LOW	0.00 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_WONG_PARKER_MAIN_MEDIAN	0.8 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_WONG_PARKER_MAIN_HIGH	7.2 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_WONG_PARKER_ALTERNATIVE_LOW	0.15 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_alternative	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_WONG_PARKER_ALTERNATIVE_MEDIAN	2.0 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_alternative	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M2_2021_WONG_PARKER_ALTERNATIVE_HIGH	13 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=wong_parker_alternative	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_RECKING_2013_LOW	131 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=recking_2013	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_RECKING_2013_MEDIAN	213 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=recking_2013	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2021_RECKING_2013_HIGH	343 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2021; outer_scenario=reference;equation=recking_2013	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_WONG_PARKER_MAIN_LOW	0.00 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_WONG_PARKER_MAIN_MEDIAN	0.07 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M2_2022_WONG_PARKER_MAIN_HIGH	1.8 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=wong_parker_main	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_WONG_PARKER_ALTERNATIVE_LOW	0.00 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=wong_parker_alternative	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_WONG_PARKER_ALTERNATIVE_MEDIAN	0.31 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=wong_parker_alternative	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_WONG_PARKER_ALTERNATIVE_HIGH	7.3 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=wong_parker_alternative	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_RECKING_2013_LOW	292 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=recking_2013	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck
M2_2022_RECKING_2013_MEDIAN	479 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=recking_2013	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_internal_handcheck

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M2_2022_ RECKING_2013_ HIGH	777 t water-year-1; Supply-unlimited annual capacity of the 3.70 m M2 active patch	Main: Section 4 / MR05; technical: Appendix E / T06	T06_m2_capacity_envelope.csv; filter: water_year=2022; outer_scenario=reference;equation=recking_2013	G4_M2_capacity_delivery; hand-check: G4_M2_capacity_ internal_handcheck
LOCAL_ RECRUITMENT_ 2021_LOW	1.7 t year-1; Gross earth-bank and failing-gabion sediment input to the active M1-M20 corridor	Main: Section 4 / MR06; MR17; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year= 2021;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: G4_whole_reach_ supply_internal_handcheck
LOCAL_ RECRUITMENT_ 2021_MEDIAN	4.4 t year-1; Gross earth-bank and failing-gabion sediment input to the active M1-M20 corridor	Main: Section 4 / MR06; MR17; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year= 2021;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: G4_whole_reach_ supply_internal_handcheck
LOCAL_ RECRUITMENT_ 2021_HIGH	10.0 t year-1; Gross earth-bank and failing-gabion sediment input to the active M1-M20 corridor	Main: Section 4 / MR06; MR17; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year= 2021;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: G4_whole_reach_ supply_internal_handcheck
LOCAL_INPUT_ 2021_BANK_ MEDIAN	3.75 t year-1; Earth-bank material entering the active corridor	Main: Section 4 / MR17; MR06; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year= 2021;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: component q50 selected directly from T09 whole_ reference; combined q50 is not the sum of component q50 values
LOCAL_INPUT_ 2021_GABION_ MEDIAN	0.54 t year-1; Material released from documented local gabion failures	Main: Section 4 / MR17; MR06; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year= 2021;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: component q50 selected directly from T09 whole_ reference; combined q50 is not the sum of component q50 values

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
LOCAL_RECRUITMENT_2022_LOW	2.7 t year-1; Gross earth-bank and failing-gabion sediment input to the active M1-M20 corridor	Main: Section 4 / MR06; MR17; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year=2022;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: G4_whole_reach_supply_internal_handcheck
LOCAL_RECRUITMENT_2022_MEDIAN	6.6 t year-1; Gross earth-bank and failing-gabion sediment input to the active M1-M20 corridor	Main: Section 4 / MR06; MR17; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year=2022;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: G4_whole_reach_supply_internal_handcheck
LOCAL_RECRUITMENT_2022_HIGH	15.2 t year-1; Gross earth-bank and failing-gabion sediment input to the active M1-M20 corridor	Main: Section 4 / MR06; MR17; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year=2022;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: G4_whole_reach_supply_internal_handcheck
LOCAL_INPUT_2022_BANK_MEDIAN	5.69 t year-1; Earth-bank material entering the active corridor	Main: Section 4 / MR17; MR06; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year=2022;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: component q50 selected directly from T09 whole_reference; combined q50 is not the sum of component q50 values
LOCAL_INPUT_2022_GABION_MEDIAN	0.83 t year-1; Material released from documented local gabion failures	Main: Section 4 / MR17; MR06; technical: Appendix F / T09	T09_whole_reach_local_supply.csv; filter: water_year=2022;outer_scenario=whole_reference	G4_whole_reach_supply; hand-check: component q50 selected directly from T09 whole_reference; combined q50 is not the sum of component q50 values
TOTAL_LOAD_PREFERRED_LOW	24.3 kt year-1; Catchment-scale transported-load planning context	Main: Section 4 / MR07; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=prespa_preferred_state_density_interval	G4_total_load_planning_envelope; hand-check: deterministic identity checks and convergence audit

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
TOTAL_LOAD_PREFERRED_CENTRE	29.1 kt year-1; Catchment-scale transported-load planning context	Main: Section 4 / MR07; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=prespa_preferred_state_density_interval	G4_total_load_planning_envelope; hand-check: deterministic identity checks and convergence audit
TOTAL_LOAD_PREFERRED_HIGH	34.5 kt year-1; Catchment-scale transported-load planning context	Main: Section 4 / MR07; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=prespa_preferred_state_density_interval	G4_total_load_planning_envelope; hand-check: deterministic identity checks and convergence audit
TOTAL_LOAD_CORE_LOW	14.9 kt year-1; Catchment-scale transported-load planning context	Main: Section 4 / MR07; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=prespa_core_structural_envelope	G4_total_load_planning_envelope; hand-check: deterministic identity checks and convergence audit
TOTAL_LOAD_CORE_CENTRE	29.1 kt year-1; Catchment-scale transported-load planning context	Main: Section 4 / MR07; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=prespa_core_structural_envelope	G4_total_load_planning_envelope; hand-check: deterministic identity checks and convergence audit
TOTAL_LOAD_CORE_HIGH	62.7 kt year-1; Catchment-scale transported-load planning context	Main: Section 4 / MR07; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=prespa_core_structural_envelope	G4_total_load_planning_envelope; hand-check: deterministic identity checks and convergence audit
TOTAL_LOAD_REGIONAL_LOW_LOW	14.9 kt year-1; Catchment-scale transported-load structural-state estimate	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=regional_low	G4_total_load_planning_envelope; hand-check: T25 state row matches T24 structural envelope identity

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
TOTAL_LOAD_REGIONAL_LOW_CENTRE	17.9 kt year-1; Catchment-scale transported-load structural-state estimate	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=regional_low	G4_total_load_planning_envelope; hand-check: T25 state row matches T24 structural envelope identity
TOTAL_LOAD_REGIONAL_LOW_HIGH	21.2 kt year-1; Catchment-scale transported-load structural-state estimate	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=regional_low	G4_total_load_planning_envelope; hand-check: T25 state row matches T24 structural envelope identity
TOTAL_LOAD_REGIONAL_HIGH_LOW	44.2 kt year-1; Catchment-scale transported-load structural-state estimate	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=regional_high_closest_analogue	G4_total_load_planning_envelope; hand-check: T25 state row matches T24 structural envelope identity
TOTAL_LOAD_REGIONAL_HIGH_CENTRE	52.9 kt year-1; Catchment-scale transported-load structural-state estimate	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=regional_high_closest_analogue	G4_total_load_planning_envelope; hand-check: T25 state row matches T24 structural envelope identity
TOTAL_LOAD_REGIONAL_HIGH_HIGH	62.7 kt year-1; Catchment-scale transported-load structural-state estimate	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=regional_high_closest_analogue	G4_total_load_planning_envelope; hand-check: T25 state row matches T24 structural envelope identity
PRESPA_PREFERRED_SPECIFIC_VOLUME_RATE	287.897 m3 km-2 year-1; Area-weighted specific transported-sediment volume rate across four independent Prespa terminal basins	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id=prespa_legacy_transported_sediment;structural_state=preferred_independent_terminal	G4_total_load_planning_envelope; hand-check: four independent terminal rates reproduce T25 preferred rate; rate times 73.374 km2 reproduces annual volume

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
CATCHMENT_ PLANNING_ VOLUME_ MEDIAN	21,124 m3 year-1; Preferred Prespa specific rate multiplied by the accepted Agios Germanos catchment area	Main: Section 4 / MR07; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id= prespa_legacy_transported_sediment;structural_state= preferred_independent_terminal	G4_total_load_planning_ envelope; hand-check: four independent terminal rates reproduce T25 preferred rate; rate times 73.374 km2 reproduces annual volume
CATCHMENT_ DRY_BULK_ DENSITY_ MEDIAN	1.376 t m-3; Frozen-ensemble median of the governed triangular dry-bulk-density distribution	Main: Section 4 / MR07; technical: Appendix F / T25; TL04	T25_total_load_family_summary.csv; filter: family_id= prespa_legacy_transported_sediment;structural_state= preferred_independent_terminal	G4_total_load_planning_ envelope; hand-check: T25 q50_t_ y / annual_volume_m3_y equals 1.3760640859417013 t m-3; closed-form triangular q50 1.375834261322606 differs by less than 0.001
PRESPA_RATE_ GOLEMA	176.9 m3 km-2 year-1; Named Golema Reka transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Golema Reka	G4_total_load_planning_ envelope; hand-check: transported volume / area; independent_terminal_basin= true
PRESPA_RATE_ BRAJCINSKA	523.8 m3 km-2 year-1; Named Brajcinska Reka transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Brajcinska Reka	G4_total_load_planning_ envelope; hand-check: transported volume / area; independent_terminal_basin= true
PRESPA_RATE_ ISTOCKA_TOTAL	303.3 m3 km-2 year-1; Named Istocka Reka transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Istocka Reka	G4_total_load_planning_ envelope; hand-check: transported volume / area; independent_terminal_basin= true
PRESPA_RATE_ BOLNSKA	255.9 m3 km-2 year-1; Named Bolnska Reka transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Bolnska Reka	G4_total_load_planning_ envelope; hand-check: transported volume / area; independent_terminal_basin= false

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
PRESPA_RATE_ISTOCKA_SUBCATCHMENT	388.3 m3 km-2 year-1; Named Istocka subcatchment transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Istocka subcatchment	G4_total_load_planning_envelope; hand-check: transported volume / area; independent_terminal_basin= false
PRESPA_RATE_KRANSKA	294.5 m3 km-2 year-1; Named Kranska Reka transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Kranska Reka	G4_total_load_planning_envelope; hand-check: transported volume / area; independent_terminal_basin= true
PRESPA_RATE_LEVA	327.8 m3 km-2 year-1; Named Leva Reka transported-sediment specific-volume rate	Main: Section 4 / MR07; technical: Appendix F / Prespa rate ledger	regional_prespa_analogue_rates.csv; filter: catchment= Leva Reka	G4_total_load_planning_envelope; hand-check: transported volume / area; independent_terminal_basin= false
PRESPA_INDEPENDENT_TERMINAL_COUNT	4 catchments; Independent terminal Prespa basins included in the preferred weighted rate	Main: Section 4 / MR07; technical: Appendix F / Prespa comparability ledger	prespa_analogue_comparability.csv; filter: independent_terminal_basin=True	G4_total_load_planning_envelope; hand-check: Golema, Brajcinska, Istocka total and Kranska are the four true rows
FRENCH_ALPINE_LOW	20.8 kt year-1; French Alpine total-load scaling context at the Agios Germanos area	Main: Section 4 / MR18; technical: Appendix F / T24; T25	T24_total_load_planning_envelope.csv; filter: envelope_id=french_alpine_transferability_stress	G4_total_load_planning_envelope; hand-check: T25 values reproduce T24 French Alpine envelope
FRENCH_ALPINE_LOW_TONNES	20,769 t year-1; French Alpine total-load scaling context at the Agios Germanos area	Main: Section 4 / external-context prose; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_id=french_alpine_transferability_stress	G4_total_load_planning_envelope; hand-check: tonne display and MR18 kilotonne display are unit-equivalent

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
FRENCH_ ALPINE_CENTRE	63.7 kt year-1; French Alpine total-load scaling context at the Agios Germanos area	Main: Section 4 / MR18; technical: Appendix F / T24; T25	T24_total_load_planning_envelope.csv; filter: envelope_ id=french_alpine_transferability_stress	G4_total_load_planning_ envelope; hand-check: T25 values reproduce T24 French Alpine envelope
FRENCH_ ALPINE_CENTRE_ TONNES	63,655 t year-1; French Alpine total-load scaling context at the Agios Germanos area	Main: Section 4 / external-context prose; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_ id=french_alpine_transferability_stress	G4_total_load_planning_ envelope; hand-check: tonne display and MR18 kilotonne display are unit-equivalent
FRENCH_ ALPINE_HIGH	175.8 kt year-1; French Alpine total-load scaling context at the Agios Germanos area	Main: Section 4 / MR18; technical: Appendix F / T24; T25	T24_total_load_planning_envelope.csv; filter: envelope_ id=french_alpine_transferability_stress	G4_total_load_planning_ envelope; hand-check: T25 values reproduce T24 French Alpine envelope
FRENCH_ ALPINE_HIGH_ TONNES	175,767 t year-1; French Alpine total-load scaling context at the Agios Germanos area	Main: Section 4 / external-context prose; technical: Appendix F / T24	T24_total_load_planning_envelope.csv; filter: envelope_ id=french_alpine_transferability_stress	G4_total_load_planning_ envelope; hand-check: tonne display and MR18 kilotonne display are unit-equivalent
AUSTRIAN_ JOHNSBACH_ BEDLOAD	4.56 kt year-1; Monitored Austrian >8 mm bedload at Johnsbach	Main: Section 4 / MR18; technical: Appendix F / T21	T21_alpine_yield_comparison.csv; filter: dataset_id= rindler_2024_austria;site=Johnsbach;load_scope=bedload >8 mm	G5 evidence-class boundary; hand-check: specific_yield_t_ km2_y multiplied by area_km2
AUSTRIAN_ URSLAU_ BEDLOAD	18.50 kt year-1; Monitored Austrian >8 mm bedload at Urslau	Main: Section 4 / MR18; technical: Appendix F / T21	T21_alpine_yield_comparison.csv; filter: dataset_id= rindler_2024_austria;site=Urslau;load_scope=bedload >8 mm	G5 evidence-class boundary; hand-check: specific_yield_t_ km2_y multiplied by area_km2

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
AUSTRIAN_ VENT_BEDLOAD	30.68 kt year-1; Monitored Austrian >8 mm bedload at Vent	Main: Section 4 / MR18; technical: Appendix F / T21	T21_alpine_yield_comparison.csv; filter: dataset_id= rindler_2024_austria;site=Vent;load_scope=bedload >8 mm	G5 evidence-class boundary; hand-check: specific_yield_t_ km2_y multiplied by area_km2
AUSTRIAN_ NEARBY_LOW	4,560 t year-1; Range endpoint across Johnsbach, Urslau and Vent monitored >8 mm bedload	Main: Section 4 / MR18; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id= austrian_nearby_area_bedload;structural_state=three_ site_min_median_max	G4_total_load_planning_ envelope; hand-check: minimum/maximum of the three named site rows
AUSTRIAN_ NEARBY_HIGH	30,684 t year-1; Range endpoint across Johnsbach, Urslau and Vent monitored >8 mm bedload	Main: Section 4 / MR18; technical: Appendix F / T25	T25_total_load_family_summary.csv; filter: family_id= austrian_nearby_area_bedload;structural_state=three_ site_min_median_max	G4_total_load_planning_ envelope; hand-check: minimum/maximum of the three named site rows
BRAJCINSKA_ MASS_MEDIAN	51,676 t year-1; Density-converted median annual mass for the closest-area Brajcinska comparison	Main: Section 4 / MR07; MR18; technical: Appendix F / Brajcinska conversion	brajcinska_mass_conversion.csv; filter: catchment= Brajcinska Reka	G4_total_load_planning_ envelope; hand-check: transported volume multiplied by the governed triangular density draw
M20_COARSE_ THRESHOLD_MM	50 mm; Lower grain-size boundary of the M20 coarse-store component	Main: Section 4 / M20 accounting box; technical: Appendix F / C03	coarse_parameter_ledger.csv; filter: input_id=C03	G4_coarse_store_transport; hand-check: C03 variable names >50 mm and records M20 0.20/ 0.382/0.60; M19 0.086/0.198/ 0.276
M20_TRANSFER_ RESTRICTIVE_ LOW	0.0008 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=restrictive	G4_coarse_store_transport; hand-check: G4_internal_ independent_handcheck

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M20_TRANSFER_RESTRICTIVE_MEDIAN	0.0009 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=restrictive	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
M20_TRANSFER_RESTRICTIVE_HIGH	0.0010 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=restrictive	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
M20_TRANSFER_REFERENCE_LOW	0.41 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=reference	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
M20_TRANSFER_REFERENCE_MEDIAN	0.47 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: Section 4 / accounting boxes; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=reference	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
M20_TRANSFER_REFERENCE_HIGH	0.49 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=reference	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
M20_TRANSFER_EVENT_OPEN_LOW	58.47 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=permissive	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
M20_TRANSFER_EVENT_OPEN_MEDIAN	65.78 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: Section 4 / accounting boxes; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=permissive	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
M20_TRANSFER_EVENT_OPEN_HIGH	69.44 t year-1; M20 >50 mm annual outlet-planning transfer component	Main: not_applicable — Technical Appendix F only; technical: Appendix F / T15	T15_coarse_annual_pulse.csv; filter: water_year=2021; outer_scenario=permissive	G4_coarse_store_transport; hand-check: G4_internal_independent_handcheck
RTK_PASSAGE_COUNT	3 passages; Passage sites represented in the context-only RTK release	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id IN (HM13,HM14,HM15)	SA01-SA06; hand-check: unique passage IDs are HM13, HM14 and HM15
RTK_TOTAL_POINTS	3,659 points; Received RTK point records across the three passages	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id IN (HM13,HM14,HM15)	SA01-SA06; hand-check: association validation counts.rtk_points=3659
RTK_13_POINTS	1,327 points; HM13 received point records	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM13	SA01-SA06; hand-check: release table and source-lineage QA
RTK_13_REVIEW_SENSITIVE	0 records; HM13 review-sensitive records	Main: not_applicable — Technical Appendix G only; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM13	SA01-SA06; hand-check: release table and source-lineage QA

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
RTK_13_SEVERE_EXCLUDED	0 records; HM13 severe elevation anomalies excluded	Main: not_applicable — Technical Appendix G only; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM13	SA01-SA06; hand-check: release table and source-lineage QA
RTK_14_POINTS	1,176 points; HM14 received point records	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM14	SA01-SA06; hand-check: release table and source-lineage QA
RTK_14_REVIEW_SENSITIVE	25 records; HM14 review-sensitive records	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM14	SA01-SA06; hand-check: release table and source-lineage QA
RTK_14_SEVERE_EXCLUDED	0 records; HM14 severe elevation anomalies excluded	Main: not_applicable — Technical Appendix G only; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM14	SA01-SA06; hand-check: release table and source-lineage QA
RTK_15_POINTS	1,156 points; HM15 received point records	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM15	SA01-SA06; hand-check: release table and source-lineage QA
RTK_15_REVIEW_SENSITIVE	1 records; HM15 review-sensitive records	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM15	SA01-SA06; hand-check: release table and source-lineage QA

Table 5: Calculation reconciliation catalogue (continued).

ID	Display and estimand	Publication locations	Released authority and filter	QA and independent hand-check
RTK_15_SEVERE_EXCLUDED	1 records; HM15 severe elevation anomalies excluded	Main: Section 5 / MR09; technical: Appendix G / AF22	AF22_rtk_context_status.csv; filter: passage_id=HM15	SA01-SA06; hand-check: release table and source-lineage QA
RTK_13_REDUNDANT_RECORDS	27 records; HM13 redundant exact XYZ records	Main: Section 5 / RTK QA table; technical: Appendix G / source QA	survey_anomaly_counts_context.csv; filter: passage_id=HM13;category=exact_duplicate_xyz	SA01;SA02; hand-check: 54 flagged occurrences form 27 exact duplicate pairs
RTK_SA_GATES_PASSED	6 of 6 gates; Passed context-release survey-association audit gates	Main: Section 5 / RTK QA table; technical: Appendix G / SA01-SA06	SA01_SA06_topography_context_release.csv; filter: check_id IN (SA01,SA02,SA03,SA04,SA05,SA06)	SA01-SA06; hand-check: six unique check IDs and no false passed value
RTK_EVIDENCE_LINKS	2,895 links; candidate evidence links	Main: not_applicable — Technical Appendix G only; technical: Appendix G / association validation	validation_summary.json; filter: jsonpath=$.counts.evidence_links	SA04; hand-check: all link foreign keys and candidate-status checks pass
RTK_PENDING_LINKS	331 links; links pending manual review	Main: not_applicable — Technical Appendix G only; technical: Appendix G / association validation	validation_summary.json; filter: jsonpath=$.counts.pending_review_links	SA04; hand-check: all link foreign keys and candidate-status checks pass
RTK_MANUAL_DECISIONS	0 decisions; Manual association decisions recorded at the evidence cut	Main: not_applicable — Technical Appendix G only; technical: Appendix G / decision ledger	association_decisions_snapshot.csv; filter: all data rows	SA04; hand-check: snapshot is header-only; no automated link is confirmed

A.4 Sediment assessment and contribution of further measurements

The geomorphological assessment combines mapped sources and temporary stores, detailed sediment-size evidence, hydrological records and estimates of sediment movement. Strong river forcing destroyed the traps twice in 2026 despite repeated measurement efforts. The absence of a usable trap record led to greater emphasis on source identification, grain-size characterisation and estimates with explicit uncertainty. The resulting spatial interpretation explains how the restoration reach receives, stores and transmits material within its catchment setting. It supports restoration scoping and comparison of the crossing options. The distinctions below define what that assessment establishes and what additional measurements would contribute.

Transport calibration

The available evidence includes discharge records, sediment-size samples, mapped channel conditions and declared hydraulic assumptions. It supports the M2 capacity calculations and supply/transmission scenarios in Appendix E. It does not contain paired sediment-flux observations that can calibrate and independently test a sediment rating relationship. Hydraulic calibration or flow-transfer fitting is not calibration against transported sediment. The sieved samples describe the mass fractions of collected deposits or source material; they are not sediment-trap catches measured over a sampling interval. No calculated capacity curve should be described as an empirically calibrated sediment-transport curve.

Functioning traps would measure captured material over known sampling periods. With paired discharge, specified grain-size coverage and documented sampler efficiency and losses, these observations could constrain local transport, support rating-curve calibration and test model performance. Their value depends on coverage of relevant flows; a limited trap record would not automatically establish an annual load. Independent observations would still be needed for testing. The delivered q05/q50/q95 summaries describe uncertainty within a stated model state, while wider scenario spans describe changes in assumptions. Neither is an empirically validated error bound for actual transport. Such validation would require new measurements.

Erosion and deposition accounting

The delivered evidence maps erosion sources, deposits and controls and quantifies selected components under stated assumptions. The local bank and gabion account ends where new material enters the M1–M20 network, about 1.54 km including both HM14 limbs. M2 is a sampled-patch capacity calculation; M20 represents a finite store; the Prespa analogue is a catchment planning estimate. The 1.76 km receiving reach below HM15 is a further appraisal domain. These quantities have different boundaries, time meanings and evidence. Adding or subtracting them cannot establish a restoration-area balance.

A closed balance would require incoming and outgoing sediment fluxes, local inputs and change in stored sediment for the same defined reach and period. Repeat bed/bank and deposit surveys, defensible density and porosity conversion, and observations of significant transport events would be needed alongside the flux measurements. The delivered source/store assessment and scenario ranges support planning, but the net erosion or deposition over a common period remains unquantified. Missing trap data are one constraint; they are not the only missing observation needed to close this balance.

Implications for interpretation

The assembled evidence is sufficient for the geomorphological scoping of restoration and comparison of crossing options. Mapped sources, grain-size distributions and routing controls explain spatial differences and downstream dependencies that a flux record at one location would not resolve alone. Separate capacity, local-input, store-transfer and catchment estimates frame the quantities and sensitivities relevant to that appraisal. Explicit assumptions, uncertainty ranges and reconciliation to source records make the analysis traceable; they do not confer empirical flux calibration. Additional trap measurements would strengthen local testing and help constrain transport. A closed balance would also require compatible repeat surveys and boundary measurements. These additions would refine the quantitative evidence and support subsequent design without replacing the completed process assessment. Appendix H retains the wider analytical limitations and reproducibility record.

B Spatial framework, morphology and sediment evidence

This appendix documents the routed topology, process-domain interpretation, grain evidence, sample eligibility and statistical treatment used by the calculations.

Spatial clarification retained from R2

The representative mountain paths terminate at the Laimos gauge for routing; this does not place the mountain tributary confluences at Laimos. Giovanitsa joins Gaidouritsa and the combined branch joins Siroka upstream of Agios Germanos village, as checked against the frozen route geometry. M1–M25 are field modules, not a series of surveyed cross-sections. The 73.374 km^2 R1 accounting boundary must be matched by outlet and delineation before comparison with other studies; it is not asserted to be the exact physical gauge catchment. Earlier delineations of about 59.4 and 65.6 km^2 differ in both boundaries and downstream support. The revised main-volume MR01 and MR15 use the union of the 18 accounting subbasins. The archived R1 display outline actually encloses about 73.775 km^2 and must not be read as the exact accounting boundary. The revised MR15 locates all twenty-five module anchors.

B.1 Reconciled Morphology, Process Domains and Routed Topology

B.1.1 Why a process-domain classification is required

Hydraulic transport equations assume a particular bed type, sediment supply and scale of averaging. Those assumptions are materially different between a continuous lower alluvial bed, a stored tailwater deposit and a steep bedrock–boulder cascade. The field classification is therefore used first as an equation-eligibility filter, and only second as a descriptive reach label.

The reclassification is based on five evidence streams: the July notes and photographs; surface and bulk sediment samples; HCMR RHS observations and UAV plates (HCMR, 2024); 2020/2025 obstacle and route mapping; and the field lead's catchment-scale interpretation. No single source is allowed to convert a local patch sample into a reach-wide bed class.

B.1.2 Parent domains

Two parent domains are supported.

Mountain bedrock–boulder cascade/step-pool network Siroka, Gaidouritsa, Giovanitsa and the upper Agios Germanos are steep mountain channels with cascade, riffle, pool and step-pool units, large framework boulders, bedrock exposure, wood and discontinuous alluvial pockets. The field lead identifies the M25 process morphology—not its sampled loose-pocket D_{50}—as representative of this parent domain across the tributaries and along the upper main stem until granite-bearing coarse deposits cease to be reported downstream of Laimos. M21–M25 remain independent representative observations; they are not connected to one another by module number. Independent SCIMABIO and HCMR descriptions support the mountain-versus-lower-alluvial contrast (HCMR, 2024; Caudron and Vigier, 2025).

The hydraulic implication is not zero transport. It is discontinuous, availability-limited transfer between pockets, with a potentially large but unmeasured share of total stress consumed by form drag around steps, boulders and wood. Gross reach slope cannot be treated as skin-friction slope acting uniformly on an unlimited gravel bed. This is the specific steep-channel condition under which conventional alluvial relations can substantially overpredict transport unless immobile-grain drag and mobile-sediment availability are represented (Yager et al., 2007; Nitsche et al., 2011).

Lower engineered alluvial corridor M1–M20 occupy a laterally confined corridor between high embankments and gabion protection. The bed and stores contain material below 2 mm, sand, gravel and locally cobble. Floodplain exchange is strongly restricted, but local sources include eroding banks, field drainage and failing gabion fill. Wood, bars, backwaters, split flow and the three Irish passages create strong internal storage and sorting.

This parent domain supports alluvial threshold calculations only at sampled loose surfaces whose process reach has defensible geometry. Structure tailwaters, multithread stores and protection-derived clasts require separate analyses.

B.1.3 Lower-corridor subdomains

Table 6 defines the working subdomains.

Table 6: Reconciled process domains and permitted proxy families.

Process domain	Field support	Dominant controls and roles	Permitted proxies
Mountain framework network	M21–M25 independent representative observations plus archive	Bedrock/boulder framework, steps, wood, pocket stores	High-flow transfer opportunity after site-flow gates, pocket availability and scenario connected length; no framework mobility or alluvial mass rate
Coarse-granite transition	Downstream of Laimos toward HM13	Reported downstream disappearance of granitic coarse clasts; storage, sorting and abrasion are alternatives	Censored lithology/calibre interval after photo classification; not a measured travel distance
HM13 coarse-store complex	HM13 → M20 proximal → M19 distal	Engineered hydraulic reset, cobble tailwater store and stratified sorting bar	Bracketed transmission scenarios, calibre contrast and store persistence; no inferred efficiency or free-reach formula
Wood-forced multithread	M15–M18	Split flow, wood form drag, backwaters and tree-stabilised stores	Limb scenarios, form-drag sensitivity and storage/fractionation
HM14 complex	M12 immediate tailwater; M11 next downstream; M13 right and M14 left upstream	Downstream tailwater sequence, parallel upstream limbs and passage control	Facies-aware contrasts and bracketed passage scenarios with M12–M11 retained in the route
Lower inter-ford reach	M1–M11	Embanked alluvium with local bars, erosion and wood	Loose-patch thresholds at eligible facies; local source/store ranking
HM15/downstream boundary	HM15 to mouth	First passage, reported downstream degradation/incision and unsampled outlet reach	Archive morphology and boundary transmission; no July downstream sample comparison

The word "braided" is retained wherever it occurs in the raw M15–M20 field notes. The analytical class for M15–M18 is *wood-forced multithread/anabranching, braid-like*; M20 and M19 instead belong to the HM13 proximal/distal store complex. This avoids interpreting a confinement- and wood-driven planform as evidence of a freely adjusting, high-supply braided sediment regime.

B.1.4 Routed topology

Figure 2 is a conceptual routing diagram, not a map. The implemented topology is a directed GeoPackage graph built from the observed corridor and a physical reference route. Observed and snapped locations remain separate. Routed chainage is issued only where the graph relation is approved. The graph retains the downstream order HM14–M12–M11–M10. M12 keeps its field-supported immediate-tailwater relation but no precise topology chainage because its nearest reference-line projection conflicts with the field note; M11's route projection agrees with its position downstream of M12.

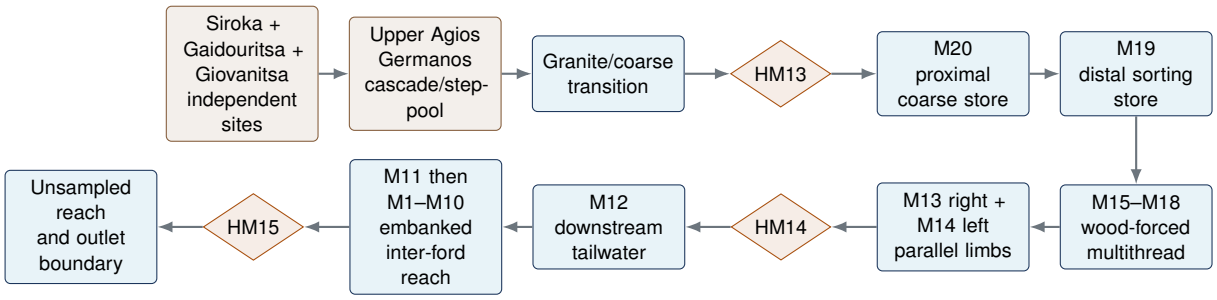


Figure 2: Conceptual downstream routing follows the arrows. HM13 is followed by M20 then M19; M13 and M14 are the parallel limbs immediately upstream of HM14; M12 is immediately downstream of HM14; M11 follows M12 downstream; and HM15 bounds the sampled corridor.

The graph contains node types `source`, `confluence`, `store`, `control`, `observation` and `target`. Required edge fields are river, branch, upstream/downstream node, routed length, chainage interval, slope ensemble, width/geometry source, process domain, alluvial-cover class and evidence confidence.

B.1.5 Passage reconciliation

The three Irish passages are ordered counting from downstream as shown in Table 7. Coordinates are supported by independent SPP, SCIMABIO and field mapping. Ecological barrier attributes are retained as context but are not translated directly into sediment passability (Panagiotou et al., 2022).

Table 7: Passage-to-module topology used in the connectivity graph.

Control	WGS84 location	Sample context	Initial sediment interpretation
HM15	21.114034, 40.828324	M1 immediately upstream; no equivalent July module downstream	First-passage and sampled-corridor boundary; downstream delivery remains unverified
HM14	21.121063, 40.829772	M12 immediate tailwater; M11 next downstream; M13 right and M14 left limbs immediately upstream	Passage state is scenario-dependent; the branch topology and downstream order HM14–M12–M11 are explicit
HM13	21.128151, 40.832028	M20 proximal downstream coarse store; M19 distal downstream sorting store	Coarse downstream storage is observed; event transmission is a bracketed hypothesis, not a measured efficiency

The field statement that stones "jump" HM13 is stored as a process hypothesis. The observations show only that coarse material is present in M20 and that a more distal sorting store occurs at M19. This configuration is consistent with one or more past transmission events, but it does not establish the material source, transmitted mass, event timing or retention efficiency. Local engineered or bank inputs also remain alternatives. The passage hypothesis can be tested only through structure geometry, event hydraulics and comparable multi-date storage evidence.

B.1.6 Mountain observation assignment

M21–M25 are independent representative observations, not a longitudinal sequence. Their routed assignments and confidence are given in Table 8; the implemented graph snaps them independently and never creates an edge from module-number order.

Table 8: Mountain module interpretation and sample meaning.

Module	River assignment	Sampled pocket/patch D50	Interpretation
M21	Siroka, high confidence	31 mm	Bedrock slabs, boulder steps/cascades, wood and discontinuous pocket material
M22	Giovanitsa near confluence, moderate	60 mm	Photo-limited bedrock–boulder cascade/plane-bed unit; local patch
M23	Giovanitsa, high confidence	62.5 mm	Coarse step/riffle with local alluvial mantle
M24	Probably Gaidouritsa	no count	Bedrock slabs and boulder steps with bulk-sampled pocket
M25	Gaidouritsa, high confidence	55 mm	Bedrock–boulder step-pool/cascade analogue; loose pocket/store value, never framework D50

The one/few photographs per site are insufficient to reconstruct formal reach-scale A/T/P/E abundance. The graph therefore records a parent domain and photo-level local unit with separate confidence.

B.1.7 Connectivity dimensions

The universal field phrase "strong/direct" is retained only as an original note. The analytical database replaces it with:

- `floodplain_connectivity`;
- `lateral_source_type` and `lateral_source_coupling`;
- `longitudinal_connectivity_<fraction>`;
- `store_type`, `store_activity` and `store_capacity_class`;
- `control_type`, `crossing_relative_position` and flow-dependent passability;
- `alluvial_cover`, `sample_facies` and `sample_role`;
- `branch_id`, routed chainage and target section.

The consistent working conceptual model is: loose mountain fines may be conditionally connected, gravel transfer is episodic, and cobble transfer is a high-flow pocket-to-pocket hypothesis; the lower embanked corridor is laterally isolated from its floodplain but contains direct local sources; in-channel fines have fewer structural restrictions in the graph scenarios but are repeatedly stored; and HM13 is an unknown-to-partial coarse-control scenario followed by the observed M20–M19 store sequence. These are process interpretations, not measured transfer rates.

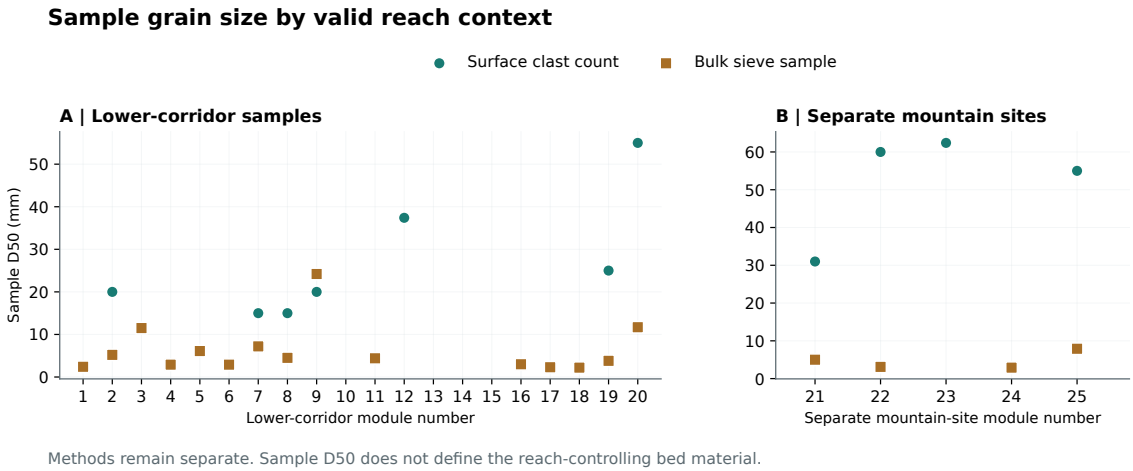


Figure 3: Reconciled sample D50 context. M1–M20 form the lower campaign block but include branches, controls and stores rather than one ordinal reach sequence; M21–M25 are independent mountain sites. Values describe sampled material, not automatically the controlling reach bed or framework.

B.2 Domain-Specific Transport and Storage Proxies

B.2.1 Observed sediment fractions

For bulk sample s, total dry mass M_s and cumulative passing mass $m_{s,j}$ at aperture D_j, the passing fraction is

$$P_s(D_j) = \frac{m_{s,j}}{M_s}. \tag{B.1}$$

A valid record satisfies

$$0 \le P_s(2) \le P_s(5) \le P_s(8) \le P_s(19) \le P_s(50) \le 1. \tag{B.2}$$

Resolved mass fractions are calculated by differencing adjacent cumulative values:

$$f_{<2} = P(2), \qquad f_{2-5} = P(5) - P(2), \tag{B.3}$$

$$f_{5-8} = P(8) - P(5), \qquad f_{8-19} = P(19) - P(8), \tag{B.4}$$

$$f_{19-50} = P(50) - P(19), \qquad f_{>50} = 1 - P(50). \tag{B.5}$$

Where percentile p is bracketed by two supported apertures, log-size interpolation is

$$\ln D_p = \ln D_\ell + \frac{p - P(D_\ell)}{P(D_u) - P(D_\ell)} \left(\ln D_u - \ln D_\ell\right). \tag{B.6}$$

If $p < P(2)$ or $p > P(50)$, the result is censored as $D_p < 2$ or $D_p > 50$; it is not extrapolated. Surface-count percentiles use the explicit type-7 quantile convention documented in Appendix I.7.

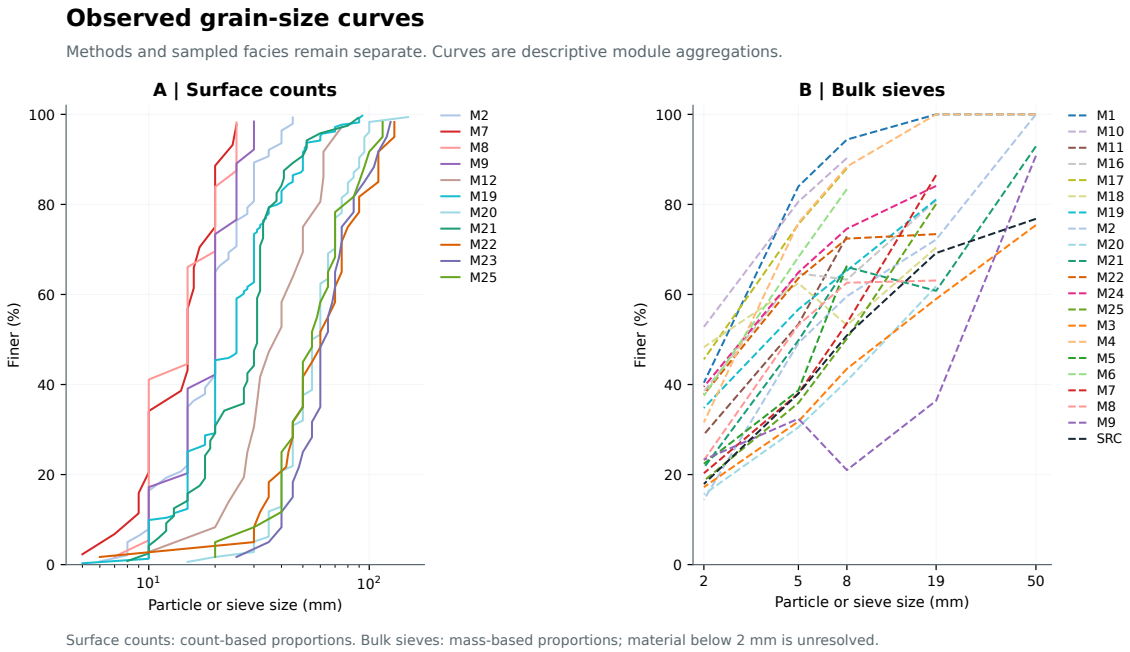


Figure 4: Observed count-based surface curves (solid) and mass-based bulk-sieve curves (dashed). The methods and sampled facies remain separate; material below 2 mm is unresolved.

B.2.2 Annual hydraulic transport opportunity

For sample/fraction i, use the operational threshold $Q_i^\dagger$ from Equation C.11. With irregular valid intervals Δt_t, competent time in water year y is

$$H_{i,y} = \sum_{t \in y} \mathbf{1}\left[Q(t) \geq Q_i^\dagger\right] \Delta t_t. \tag{B.7}$$

The event catalogue provides the corresponding independent event count $N_{i,y}$, peak-discharge distribution and event durations. Integrated excess Shields forcing is

$$J_{\theta,i,y} = \sum_{t \in y} \max[\theta_i(t) - \theta_{c,i}, 0]\, \Delta t_t. \tag{B.8}$$

Gross and unit stream power are

$$\Omega(t) = \rho_w g Q(t) S_e, \qquad \omega(t) = \frac{\Omega(t)}{B(t)}, \tag{B.9}$$

following the energy-rate framework of Bagnold (1966). Excess unit-power forcing relative to the operational threshold is

$$J_{\omega,i,y} = \sum_{t \in y} \max\left[\omega(t) - \omega(Q_i^\dagger), 0\right] \Delta t_t. \tag{B.10}$$

These metrics are reported for D_{50} and D_{84} separately. M2 is the primary lower-patch *candidate*; M7–M9 are exploratory candidates. Results require co-located sampled facies, local flow, process-reach slope, hydraulic geometry, inundation and mobile-patch width. Those empirical G2/G3

gates do not currently pass for an observation-constrained result. Section E.1 documents a separate assumption-driven M2 branch in which the open variables are declared as outer states. M7–M9 remain exploratory and are excluded from that primary ensemble. M12, M19 and M20 use the structure/store methods below rather than a generic free-reach interpretation.

B.2.3 Potential bed-material capacity at eligible alluvial patches

Potential capacity is secondary to the threshold metrics. The primary result is calculated per unit mobile-bed width because wetted width is not automatically the width of the sampled mobile facies. The equations below define the eligible method. The empirical local-flow, slope, inundation and mobile-width gates remain open; an explicitly assumption-driven M2 scenario is nevertheless executed in Section E.1. Conditional tonnes are issued only for M2, accepted WY2021/WY2022 and a named active-width state. No value is an actual load or annual yield.

Let $s = \rho_s/\rho_w$. The corrected Wong–Parker reanalysis of the Meyer–Peter–Müller relation is (Wong and Parker, 2006)

$$\Phi_b = \frac{q_{bv}}{\sqrt{(s-1)gD_{50}^3}} = 3.97\left[\max(\theta_b - 0.0495, 0)\right]^{3/2}, \tag{B.11}$$

so that

$$q_{bv} = \Phi_b\sqrt{(s-1)gD_{50}^3}, \tag{B.12}$$

where q_{bv} is solid-volume transport per unit width. The alternative Wong–Parker fit

$$\Phi_b = 4.93\left[\max(\theta_b - 0.0470, 0)\right]^{1.60} \tag{B.13}$$

is retained as model-form sensitivity. The fitted threshold in each published relation remains fixed. A calculation that instead samples a general θ_c is labelled a generalized MPM scenario, not the Wong–Parker equation.

If a mobile-patch width $B_m(t)$ is mapped, annual supply-unlimited solid mass capacity is

$$M_{\mathrm{cap},y} = \rho_s \sum_{t\in y} B_m(t) q_{bv}(t)\Delta t_t. \tag{B.14}$$

Without B_m, only $M_{\mathrm{cap},y}/B_m$ is reported. Porosity is not applied to solid mass; it is required only when converting deposited solid mass to bulk deposit volume.

The reach-averaged relation of Recking (2013) is a separate sensitivity model for eligible simple alluvial patches. The generic expression below uses the model hydraulic radius; the executed M2 branch closes the Recking flow-resistance relation explicitly in Equation E.11 and the equations that follow:

$$\theta_{84} = \frac{RS_e}{(s-1)D_{84}}, \tag{B.15}$$

$$\theta_m = (5S_e + 0.06)\left(\frac{D_{84}}{D_{50}}\right)^{4.4\sqrt{S_e}-1.5}, \tag{B.16}$$

$$\Phi_R = \frac{14\theta_{84}^{2.5}}{1 + (\theta_m/\theta_{84})^4}, \tag{B.17}$$

$$q_{bv,R} = \Phi_R \sqrt{g(s-1)D_{84}^3}. \tag{B.18}$$

This method requires a non-truncated surface D_{50} and D_{84}, reach width, slope and hydraulic radius. It is not applied to M12, M15–M20 or the mountain framework sites. Equation results are never summed over serial or nested modules because that would count the same transported material multiple times.

B.2.4 Passage and storage contrasts

No retention efficiency is calculated without upstream and downstream fluxes. Instead, the passage analysis uses descriptive size contrasts. For percentile D_p,

$$R_{D_p} = \frac{D_{p,\mathrm{down}}}{D_{p,\mathrm{up}}}, \qquad \Delta_p = \ln R_{D_p}, \tag{B.19}$$

and for observed fraction k,

$$\Delta F_k = F_{k,\mathrm{down}} - F_{k,\mathrm{up}}. \tag{B.20}$$

M13 and M14 remain separate upstream limbs at HM14 until a defensible flow/facies weighting is available. M20 is the proximal HM13 downstream store and M19 the distal sorting bar; neither is labelled an upstream-blocked wedge.

For repeated mapped store polygons,

$$\Delta A = \frac{A_{t_2} - A_{t_1}}{A_{t_1}}, \qquad J = \frac{|A_{t_1} \cap A_{t_2}|}{|A_{t_1} \cup A_{t_2}|}, \tag{B.21}$$

where J is Jaccard overlap. Georegistration uncertainty is propagated by perturbing control points or buffering polygon boundaries by the registration RMSE. Area change is not converted to mass without measured or defensibly bounded thickness, porosity and bulk density.

The passage evidence package contains upstream/downstream sample contrasts, crest and tailwater geometry, store length/area, event-flow class, multi-date photograph interpretation and graph passability scenarios. The output is a process diagnosis, not a single retention coefficient.

B.2.5 Wood-forced multithread reaches

M15–M18 require separate limb hydraulics. For ensemble member m, total flow is divided as

$$Q(t) = \sum_{r=1}^{n_{\text{limb}}} Q_r(t), \qquad Q_r(t) = f_{r,m}(t)Q(t), \qquad \sum_r f_{r,m}(t) = 1. \tag{B.22}$$

Each limb receives its own width, inundation state, roughness/form-drag factor and sediment/store class. The principal outputs are the range in limb competence, fractionation between faster gravel-rich and backwater fine-rich limbs, and sensitivity of downstream graph transmission to wood/branch state. No single imputed width or single module-wide stress is used.

B.2.6 Mountain high-flow transfer opportunity

Once site-flow and reach-geometry gates pass, mountain analyses may use site-specific flow quantiles $Q_{r,p}$ for $p = 0.90, 0.95, 0.99$. High-flow duration in reach r, year y is

$$H^{\text{HF}}_{r,y,p} = \sum_{t \in y} \mathbf{1}[Q_r(t) \geq Q_{r,p}]\Delta t, \tag{B.23}$$

and integrated unit-power exposure is

$$E_{\omega,r,y,p} = \sum_{Q_r \geq Q_{r,p}} \omega_r(t)\Delta t. \tag{B.24}$$

A dimensionless energy-ranking scale is

$$\omega^*_{84} = \frac{(Q/B)S_e}{\sqrt{(s-1)gD^3_{84}}}. \tag{B.25}$$

Because D_{84} represents pocket material, ω^*_{84} ranks event energy relative to that material; it is not an incipient-motion criterion for the boulder/bedrock framework. Results are combined with pocket availability and graph connected length under low, central and high event-passability scenarios. The current executed hydrology result is limited to observed Laimos gauge high-flow opportunity and is not transferred to M21–M25. No M21–M25 "mobile days", framework-mobility or mass-capacity values are calculated; specifically, the M25 loose-pocket D_{50} is never used as the framework threshold grain size.

B.2.7 Coarse-granite downstream front

Photo/sample observations are classified by date, routed chainage, lithology, size bin and confidence. For size class k and date t, the last confirmed downstream presence is

$$x_{\text{front},k,t} = \max\{x_i : \text{ granite present}, \ D_i \in k, \text{confidence} \geq c_{\min}\}. \tag{B.26}$$

The preferred result is the censored interval

$$x_{\text{front}} \in [x_{\text{last presence}}, x_{\text{first confirmed absence}}], \tag{B.27}$$

not a false point boundary. Separate fronts by size and date test whether coarse granite disappears upstream of finer granite, and whether the front persists between 2023, 2025 and 2026 evidence. Broad alluvium/geology polygons provide source context only.

At the current revision the required lithology/photo observation ledger and comparable-date classification have not passed their eligibility gate. The field interpretation therefore supports only a broad transition downstream of Laimos; no exact granite-front chainage or movement distance is issued.

B.2.8 Connected delivery potential

Where a dimensionless annual opportunity score $O_{i,k,y} \in [0, 1]$ is required, it is combined with source availability and path transmission as

$$CDP_{k,y,e,s} = \frac{\sum_i A_i a_{i,k,s} O_{i,k,y} T_{i,k,e,s}}{\sum_i A_i a_{i,k,s}}. \tag{B.28}$$

The normalization of O (for example by the maximum observed water-year exposure) is stated explicitly. CDP is a relative connected-delivery potential. It is not multiplied by an assumed catchment sediment mass and reported as tonnes. If future measured source or flux data become available, the graph can be upgraded without changing its topology or evidence model. Until local opportunity and source-measure gates pass, the implemented result remains decomposed into observed gauge high-flow opportunity and a relative structural source-zone index; combining them cannot create actual yield.

C Hydrology and hydraulics

The analytical hydrology uses the accepted native-cadence Laimos gauge record. At the declared P95 threshold of 3.52 $m^3\ s^{-1}$ and 24-hour event separation, WY2021 contains 16 events and 235.8 supported high-flow hours; WY2022 contains 16 events and 571.5 hours.

C.1 Hydrological Forcing and Reach Hydraulics

C.1.1 Native-time-step hydrograph

All event and competence calculations use the valid native HCMR time step. The cleaning sequence is:

1. record that source timestamps contain no embedded time zone, document them as Europe/Athens local civil time, retain the source clock for elapsed intervals and audit duplicates without inventing a UTC/DST conversion;
2. sort by time and preserve the original row/source identifier;
3. identify duplicates, negative values, implausible spikes, repeated plateaux and known sensor-malfunction periods;
4. calculate the actual interval Δt_t between valid values;
5. mark gaps rather than filling them by default;
6. assign water year 1 October–30 September;
7. derive daily/monthly values only as secondary summaries.

The logging cadence changes through the archive from approximately 10 minutes to 30 minutes and then hourly; the record is not treated as uniformly spaced. For a time-integrated annual metric, a gap contributes neither zero forcing nor interpolated forcing unless a documented gap

model is invoked. No interpolation is permitted across a gap longer than twice the local nominal interval in the primary event analysis. Completeness is reported as valid hours divided by the expected hours in each water year. A primary annual statistic requires at least 90% time-weighted coverage, no missing interval longer than seven days, and no unresolved gap that spans an event being analysed. A 95% coverage sensitivity is also reported. Years failing a rule are reported as partial.

The executed assimilation contains 105,579 timestamps from 3 July 2020 to 1 May 2026 after incorporating the corrected April 2026 workbook. The interval 1 June 2023 to 31 July 2024 is excluded as a known rating/sensor-malfunction period. Table 9 reports the implemented, time-weighted acceptance decision. Only WY2021 and WY2022 support annual gauge high-flow statistics; WY2021 passes the primary 90% rule narrowly and fails the 95% and one-cadence sensitivities.

Table 9: Implemented October–September HCMR discharge acceptance audit. "Accepted" applies only to observed gauge high-flow opportunity.

WY	Supported coverage	Maximum retained Q ($\mathrm{m^3\,s^{-1}}$)	Longest uncovered gap	Annual status / principal reason
2020	21.5%	3.75	237.1 h	Rejected: partial source span and coverage
2021	90.1%	7.36	134.4 h	Accepted narrowly: high-flow use only; 49 zero-Q/positive-depth flags retained
2022	97.4%	6.78	3.7 h	Accepted
2023	62.4%	3.20	2,928 h	Rejected: coverage and rating exclusion
2024	16.7%	0.60	7,320 h	Rejected: coverage and rating exclusion
2025	88.7%	1.82	977.5 h	Rejected: coverage and gap
2026	57.6%	9.12	41.0 h	Rejected: partial source span

C.1.2 High-flow event definition

Two event families are distinguished:

- **sample-facies threshold events**, defined by $Q(t) > Q_i^{\dagger}$ only after the local-flow, geometry, slope, facies and inundation gates pass; these have not yet been issued for any module;
- **hydrological high-flow events**, implemented at the gauge using $Q(t) > 3.52\ \mathrm{m^3\,s^{-1}}$, the pooled accepted-year time-weighted P95. P90 and P99 (2.77 and 4.74 $\mathrm{m^3\,s^{-1}}$) remain sensitivity thresholds.

For the implemented gauge catalogue, exceedance intervals separated by no more than 24 h are assigned to the same event only within the same accepted water year and continuous valid-data segment. Events never merge across an uncovered segment or a water-year boundary. The primary inter-event separation is therefore **24 h**, with **6- and 12-hour sensitivity runs**. The event table records start, end, high-flow duration, peak time, peak discharge, integrated discharge excess above P95 and data completeness. This is a hydrological event definition; no sediment response or competence is inferred.

Table 10: Implemented primary gauge high-flow opportunity at P95 and 24-hour separation. Excess volume is water-discharge excess, not sediment load.

WY	Events	High-flow hours	Integrated Q excess (m^3)	Maximum event peak ($m^3\,s^{-1}$)	Sensitivity
2021	16	235.83	754,848	7.36	Event count remains 16 at 6 and 12 h
2022	16	571.52	1,439,227.2	6.78	Event count is 19 at 6 h and 17 at 12 h

C.1.3 Spatial flow reconstruction

Drainage-area scaling is inadequate because abstraction and channel loss affect the main stem. Site flows are reconstructed from paired spot measurements and the continuous gauge record. For site r, the initial statistical model is

$$\log Q_r(t) = \alpha_r + \beta_r \log Q_g(t) + \gamma_{1,r} \sin\left(\frac{2\pi d_t}{365.25}\right) + \gamma_{2,r} \cos\left(\frac{2\pi d_t}{365.25}\right) + \varepsilon_{r,t}, \tag{C.1}$$

where Q_g is Laimos discharge, d_t is day of year and $\varepsilon_{r,t}$ is a residual with prediction uncertainty. If the seasonal terms are unsupported by the small sample, the simpler power relation is used. The fit is assessed using leave-one-date-out cross-validation, not an in-sample R^2 alone.

At confluences, reconstruction is checked against

$$Q_{\text{down}} = \sum_r Q_r + Q_{\text{local}} - A(t) - L(t), \tag{C.2}$$

where A is known/configured abstraction and L represents unmeasured loss or exchange. Neither term is forced to zero. SWAT+ water routing may provide the shape of Q_{local}, A or L, but its result is bias-corrected to the observations and its uncertainty is retained.

The reconstructed time series are ensembles generated from coefficient and residual prediction distributions. They are never presented as locally observed hydrographs.

C.1.4 Surveyed cross-section hydraulics

The Laimos cross-section is digitised as 28 ordered station–elevation vertices (x_j, z_j) across the 27.90 m surveyed extent; repeated structural verticals are retained. For water-surface elevation z_w, the conditional wetted geometry is computed directly from the piecewise-linear section:

$$A(z_w) = \int \max[z_w - z(x), 0]\ \mathrm{d}x, \tag{C.3}$$

$$P(z_w) = \sum_{j \in \text{wet}} \sqrt{(x_{j+1} - x_j)^2 + (z_{j+1} - z_j)^2}, \tag{C.4}$$

$$R(z_w) = \frac{A(z_w)}{P(z_w)}, \tag{C.5}$$

with top width $B(z_w)$ calculated from the water-line intersections. The surveyed bed is near 902 m; the previously quoted 856 m elevation belongs near the downstream model outlet and is

not assigned to the gauge.

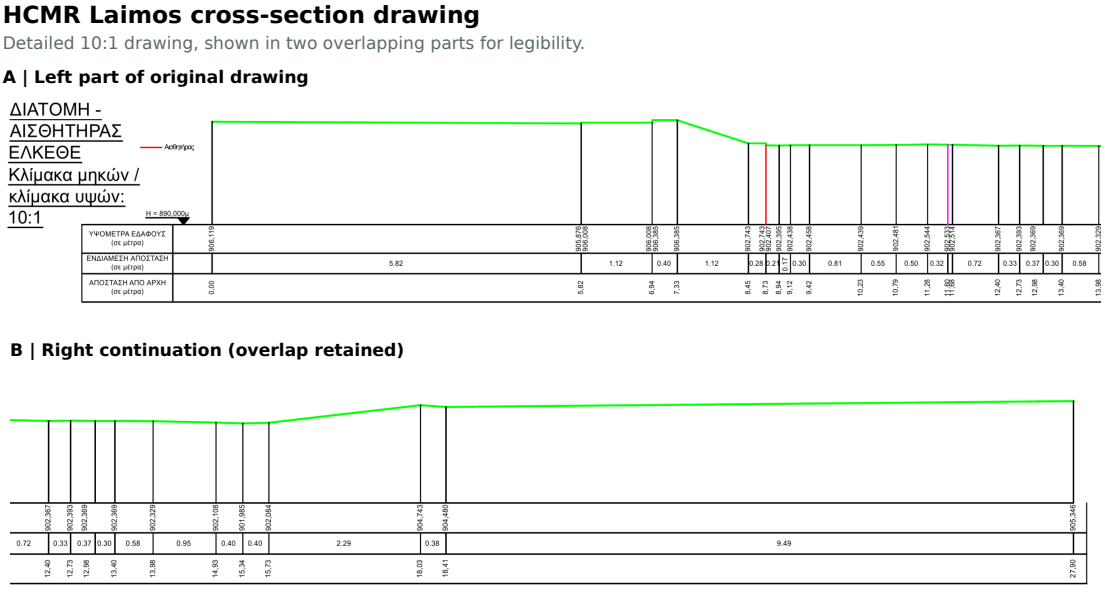


Figure 5: Preview of the surveyed HCMR cross-section used to digitise the stage–area–radius–width relationship, enlarged as two overlapping parts. The original PDF/DWG remains the measurement source. Open the original PDF in `08_Full_Size_Figures/Source_Drawings`.

The current geometry lookup is accepted only below 902.70 m, the selected left control crest. It passes monotonic area, non-negative top-width and physical hydraulic-radius checks. However, the sensor-depth-to-survey-datum offset is undocumented, and the one Laimos current-meter total has no matched surveyed stage and lies within the logger rating-malfunction period. The logger series is therefore not joined to the survey geometry in the current release.

For a trial roughness n and energy slope S_e, discharge would be computed with the Manning relation

$$Q(z_w) = \frac{1}{n} A(z_w) R(z_w)^{2/3} S_e^{1/2}. \tag{C.6}$$

Observed stage–discharge pairs can constrain n and any rating offset only after the datum and observation matching are resolved. Cross-section parameters would be accepted only if they reproduced independent current-meter observations and the continuous rating within stated measurement uncertainty. Because that gate is open, the implemented output is conditional section geometry only: no boundary stress, local critical discharge, stream power or capacity is calculated from it.

C.1.5 Process-reach geometry

Lower-reach hydraulic units use observed/UAV geometry rather than a universal rectangle. Depending on evidence, the cross-section model is one of:

- digitised surveyed or UAV-derived section;

- trapezoid with observed wetted width, bank geometry and uncertainty;
- separate limb sections with a flow-split ensemble;
- structure/tailwater model for HM13–HM15, for which uniform normal flow is not assumed.

The field width is a conditioning observation, not necessarily bankfull or effective transport width. M8–M12 use the approximate main-limb width; M13–M17 use limb widths; M18–M20 require UAV/photo-derived total and active widths.

C.1.6 Energy slope

Slope is assigned to a routed process reach. The preferred source order is:

1. surveyed/UAV water-surface or thalweg elevations;
2. engineering drawings with verified datum;
3. robust elevation regression along the corrected observed centreline;
4. coarse DEM slope as a low-confidence prior only.

For centreline profiles, slope is estimated over multiple windows (for example 100, 250 and 500 m where the reach length permits) using robust regression and a monotonic profile check. Window choice becomes an uncertainty factor. A negative or implausibly stepped local value triggers geometry review rather than absolute-value correction. Published/archived mean reach slopes may be used as broad priors but not as local energy slopes.

C.1.7 Boundary stress and skin-friction partition

For an eligible alluvial reach, total boundary stress is

$$\tau_0 = \rho_w g R S_e. \tag{C.7}$$

Only the grain-related component is used for incipient motion:

$$\tau' = f_{\mathrm{skin}} \tau_0, \qquad 0 < f_{\mathrm{skin}} \leq 1. \tag{C.8}$$

The factor f_{skin} represents the stress remaining after bank, bar-form, wood, boulder, step and planform drag. It is constrained by the roughness decomposition and morphology rather than fixed to one value. As a diagnostic, if grain and total Manning roughnesses are estimated consistently, $f_{\mathrm{skin}} = (n_{\mathrm{grain}}/n_{\mathrm{total}})^2$ is evaluated; independent scenario bounds are retained because roughness components are not strictly additive (Rickenmann and Recking, 2011; Yager et al., 2007).

The dimensionless Shields stress for size D_i is

$$\theta_i(Q) = \frac{\tau'(Q)}{(\rho_s - \rho_w) g D_i}. \tag{C.9}$$

No universal θ_{c} is assumed. For loose gravel surfaces the screening ensemble brackets the visually based range approximately 0.030–0.073 reported in the incipient-motion literature, with a separate reference-transport range approximately 0.052–0.086 (Buffington and Montgomery, 1997). The selected range and prior shape are reported for every analysis. Hiding/exposure and sand content are addressed through the mixed-size sensitivity model, not by quietly changing θ_{c}

for selected modules.

Critical discharge is the numerical root

$$Q_{c,i}: \quad \theta_i(Q_{c,i}) - \theta_{c,i} = 0, \tag{C.10}$$

solved on the monotonic discharge–depth relationship. An ensemble member is rejected if no physical root lies within the stated hydraulic extrapolation range.

For an elevated bar, island or tailwater surface, hydraulic competence is not relevant until the sampled facies is inundated. The operational threshold is

$$Q_i^{\dagger} = \max(Q_{c,i}, Q_{\mathrm{inund},i}), \tag{C.11}$$

where $Q_{\mathrm{inund},i}$ is obtained from the mapped/section elevation of the sampled patch. This term is mandatory for M2 and M7–M9. If patch elevation is not recoverable from UAV, cross-section or photographic control, the result is reported conditionally over an explicit inundation scenario rather than assuming continuous wetting.

C.1.8 Hydraulic validation gates

Before transport metrics are calculated, each reach/scenario must pass:

- positive, monotonic Q–depth relation;
- mass-continuous flow split at branches within tolerance;
- width and depth within observed/photographic bounds;
- Froude number and relative submergence checked for formula applicability;
- no use of normal-flow hydraulics inside the ford crest or immediate rapidly varied tailwater zone;
- observed gauge/cross-section validation for any parameter transferred from Laimos;
- explicit flag if the calculated Q_c exceeds the maximum observed flow.

Failure changes the output to “not resolved with current geometry”; it does not justify widening the parameter range until a result appears.

D Fraction-specific structural connectivity

This appendix preserves the dimensionless structural-connectivity formulation, routed source/control/path ledgers, fraction states and sensitivity analysis. Structural connectivity is interpreted as comparative pathway support and is not substituted for a physical mass-transmission efficiency.

The dimensionless 0.032 central index is a routed comparison under equal source-zone weighting, not a measured sediment delivery fraction. Testing one opened control at a time is a sensitivity exercise for evidence and monitoring priorities; it does not establish a removal ranking.

D.1 Fraction-Specific Structural Connectivity

D.1.1 Directed graph representation

The river system is represented as a directed graph $G = (V, E)$. Nodes V represent sediment sources, confluences, observations, stores, controls and reporting targets. Edges E are routed process reaches. The graph follows the source–pathway–store framing of sediment connectivity (Fryirs et al., 2007; Heckmann et al., 2018); it is not a graph of fish passability or a relabelled DEM stream network.

The graph is evaluated separately for the following observed fractions:

$$k \in \{< 2\ \text{mm},\ 2\text{–}19\ \text{mm},\ 19\text{–}50\ \text{mm},\ > 50\ \text{mm}\}. \tag{D.1}$$

Bedrock and framework clasts > 256 mm form a control/cover class rather than a sampled mobile fraction. The < 2 mm class is not subdivided into sand and silt.

For each edge and node, the graph stores evidence state, data date, confidence, process domain, cover class and active flow class. A graph release is rejected if a source has no downstream route, an edge is cyclic without a documented side-channel return, or branch fractions do not sum to one within tolerance.

The implemented spatial graph contains 31 nodes and 31 directed edges and has a maximum observation-to-reference-route snap distance of 51.6 m. It passes the spatial gate with limits: M12 is retained as the field-supported downstream tailwater of HM14 but has no approved precise topology chainage; M11 follows M12 downstream before M10; M22 retains medium river-assignment confidence; and the unsampled reach downstream of HM15 remains an explicit boundary. Those limits propagate into every scenario rather than being removed by interpolation.

D.1.2 Source availability

For source i, fraction k and evidence scenario s, availability is $a_{i,k,s} \in [0, 1]$. It represents the degree to which mapped material is available to the channel, not an erosion rate. The mapped source measure A_i is either area or channel length and is never mixed within one normalized result. In the current implementation, source length and area are not sufficiently resolved, so the 11 source zones receive equal source-zone units. The resulting C is a relative source-zone connectivity index, not connected metres, square metres or mass.

Primary results are reported first with $a_{i,k,s} = 1$ for all confirmed sources so that topology is visible without subjective weighting. Availability-weighted results are then provided using categorical evidence:

- direct active source (fresh bank failure, failing gabion or connected gully);
- conditional/event source;
- stored/relict material with uncertain remobilisation;
- unknown availability;
- explicitly disconnected source.

The numeric mapping of these categories is a scenario table, not a calibrated probability. Source-area uncertainty and category uncertainty are retained separately.

D.1.3 Control transmission

For control j, fraction k, flow class e and scenario s, define

$$p_{j,k,e,s} \in [0, 1]. \tag{D.2}$$

This is a scenario transmission multiplier. It is not a measured retention efficiency and is not inferred from trout passability. The primary categories and sensitivity values are shown in Table 11.

Table 11: Initial structural-transmission scenarios. Values are transparent sensitivity settings, not calibrated probabilities.

Evidence class	Low-flow setting	High-flow setting	Interpretation
Free	1	1	No mapped structural interruption for the fraction
Blocked	0	0	Extreme closed-path scenario
Unknown	$\{0, 0.5, 1\}$	$\{0, 0.5, 1\}$	Full epistemic range retained
Event-passable	0	$\{0, 0.5, 1\}$	Closed at low flow; uncertain event transmission
Partial/storage-producing	$\{0.1, 0.35, 0.75\}$	$\{0.1, 0.35, 0.75\}$	Sensitivity range with downstream/upstream store evidence

The HM13 central scenario treats event transmission as partial for coarse gravel and cobble. This is an explicit hypothesis bracketed by closed and open states because M20 records coarse material in a proximal downstream store; that observation does not demonstrate where the material originated or when/how it crossed HM13. The scenario therefore neither assumes complete continuity nor estimates a measured retention efficiency.

D.1.4 Path transmission

For a source with one downstream route, cumulative transmission is

$$T_{i,k,e,s} = \prod_{j \in \mathrm{path}(i)} p_{j,k,e,s}. \tag{D.3}$$

For alternative limbs r, let $f_{i,r,e,s}$ be the flow-route fraction, with $\sum_r f_{i,r,e,s} = 1$. Then

$$T_{i,k,e,s} = \sum_r f_{i,r,e,s} \prod_{j \in r} p_{j,k,e,s}. \tag{D.4}$$

This treatment is required for the M13 right and M14 left limbs immediately upstream of HM14 and for the M15–M18 wood-forced multithread domain. M12 is the downstream HM14 tailwater, not a third branch; M11 is the next module downstream. An unweighted 50:50 split is an explicit sensitivity, not an observed division of flow.

The connected source measure is

$$M_{k,e,s} = \sum_i A_i a_{i,k,s} T_{i,k,e,s}, \tag{D.5}$$

and normalized connectivity is

$$C_{k,e,s} = \frac{M_{k,e,s}}{\sum_i A_i a_{i,k,s}}. \tag{D.6}$$

Both numerator and denominator are reported so that a high normalized value cannot conceal a very small mapped source domain.

D.1.5 Control importance and scenario contrasts

The marginal structural importance of control j is the assumption-sensitivity difference obtained by setting its multiplier to 1.0

$$I_{j,k,e,s} = C_{k,e,s}(p_j = 1) - C_{k,e,s}(p_j = p_{j,k,e,s}). \tag{D.7}$$

This identifies controls whose assumed state most affects downstream connectivity. It is not interpreted as the sediment benefit of removal because removal may also change local supply, scour, grade control and downstream storage.

Required scenario contrasts are:

- low-flow versus event-state transmission;
- fine versus gravel versus coarse fractions;
- pessimistic, central and optimistic control states;
- confirmed-only versus confirmed-plus-uncertain sources;
- alternative M22/M24 stream assignments where network snapping remains moderate confidence;
- HM13 closed, partial and open event states;
- observed branches versus equal/uncertain flow splits.

D.1.6 Observed and inferred stores

Stores are not represented only as transmission losses. Each store node has a fraction-specific residence/activity class and may become a later source. Required store types are pocket, side bar, stratified bar, field-called island, wood wedge, backwater, upstream wedge, tailwater deposit and relict/stable store. Activity classes are fresh/active, persistent, stable/relict and unknown.

When time-specific evidence exists, a store transition is represented between dates; otherwise the graph is a structural scenario rather than a dynamic sediment-routing model. No annual release rate is inferred from store presence alone.

D.1.7 Hillslope connectivity index for fines

A raster Index of Connectivity may be calculated as a secondary analysis for the < 2 mm hillslope-source problem (Borselli et al., 2008; Cavalli et al., 2013). For cell i,

$$IC_i = \log_{10}\left(\frac{D_{\mathrm{up},i}}{D_{\mathrm{dn},i}}\right), \tag{D.8}$$

with

$$D_{\mathrm{up},i} = \bar{W}_i \bar{S}_i \sqrt{A_i}, \tag{D.9}$$

$$D_{\mathrm{dn},i} = \sum_q \frac{d_q}{W_q S_q}, \tag{D.10}$$

where W is a land-surface weighting, S slope, A contributing area and d_q flow-path length. Before this calculation, the DEM/channel alignment is repaired and the result is tested across both DEM products. This raster index does not replace the channel control graph and is not applied to gravel/cobble bedload.

D.1.8 Connectivity outputs

The minimum outputs are:

1. routed node/edge GeoPackage and topology audit;
2. source and store inventory by size fraction and confidence;
3. control-transmission matrix by fraction, flow class and scenario;
4. unweighted and availability-weighted connected area/length;
5. control-importance ranking;
6. maps of pessimistic, central and optimistic event connectivity;
7. a claim field stating whether each result represents structural connectivity, hydraulic opportunity or connected delivery potential.

The current structural scenario run uses 14 mapped source observations, 11 equal source-zone units, 20 source-to-target paths and 18 controls. Its multipliers are sensitivity values, not probabilities. The pessimistic outlet index is zero for every fraction because the allowed HM15 unknown-state bracket includes a closed outlet path; the non-zero central and optimistic indices are structural scenario results only. They do not establish annual passage, sediment movement or outlet yield, and remain subject to formal scenario and independent technical-review gates.

E M2 capacity and delivery calculation

The M2 calculation reports each transport relation separately. For the reference 3.70 m active patch, the annual-capacity medians are 0.8, 2.0 and 213 t in WY2021, and 0.07, 0.31 and 479 t in WY2022 for Wong–Parker main, Wong–Parker alternative and Recking respectively. The separation of model families is part of the result.

M2 denotes a field module and a sampled active patch. The 3.70 m reference active width does not constitute a complete surveyed cross-section. Local slope, flow transfer and hydraulic states remain declared model inputs.

E.1 Executed M2 Capacity and Delivery Scenario

E.1.1 Result class and estimand

The existing-data workflow now executes a bounded scenario branch for M2. It does not alter the empirical G2 conclusion that local flow transfer, energy slope, facies elevation and mobile width

are unmeasured. Instead, those open dependencies are represented by registered outer states. The result class is therefore *assumption-driven model scenario*, not an observation-constrained or calibrated estimate.

For accepted water year y, model m and outer state e, the primary estimand is solid-mass capacity per unit active-patch width over the supported hydrograph intervals:

$$C'_{y,m,e} = \rho_s \sum_{t \in y} q_{bv,m,e}(t)\, I_e(t)\, \Delta t_t, \qquad [C'] = \mathrm{t\,m^{-1}\ supported\ WY^{-1}}, \tag{E.1}$$

where $I_e(t)$ is the outer-state patch-activation indicator and Δt_t is `supported_hours_primary` converted to seconds. No interpolation or coverage scaling is applied to unsupported time. Conditional total capacity is

$$C_{y,m,e} = B_{m,e} C'_{y,m,e}, \tag{E.2}$$

only where the active width $B_{m,e}$ is named. Equation E.1, not Equation E.2, is primary because the field 7.4 m width is a wetted-channel measurement at unspecified flow and is not an observed mobile-patch width.

Interpretation constraint

"Annual" in this result means integration over the supported native intervals of accepted WY2021 or WY2022. It is not a 365-day extrapolation, calendar-year load, long-term mean or observed flux. Actual annual yield remains unmeasured.

E.1.2 M2 eligibility and MoRPh constraint

M2 is the only primary site because the reconciled MoRPh-informed atlas marks it as a lower-embanked-alluvial `candidate_alluvial_patch`. Its two direct surface grids contain 70 primary clasts. M7–M9 remain small-count, wood-affected sensitivity sites and do not enter the primary draws. M12 and M15–M20 are structure, tailwater, multithread, wood or store facies. M21–M25 are mountain bedrock–boulder framework observations; their loose-pocket grain metrics are excluded. In particular, the M25 loose-pocket $D_{50} = 55$ mm is not used in any capacity calculation.

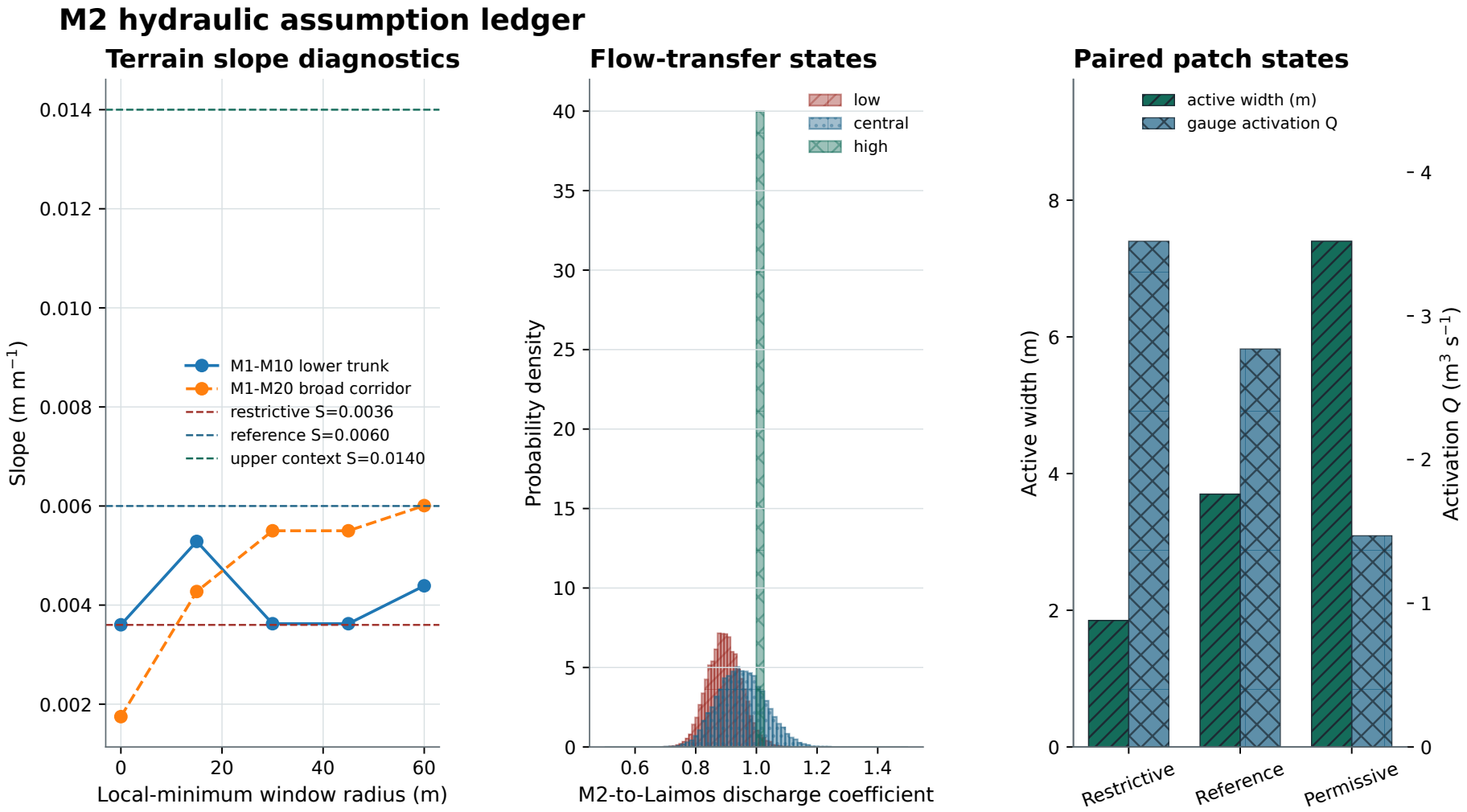
The two M2 bulk samples are also excluded from surface-equation inputs. Their mass-based D_{50} values and material below 2 mm describe a different sampled population and cannot be substituted for the count-based surface D_{50}–D_{84} pair.

E.1.3 Frozen input and outer-state ledger

Table 12: Executed M2 outer states. No probability weights are assigned.

State	Flow transfer	S_e	n	f_{skin}	Activation	Active width
Restrictive	QA-filtered equal-date-mean ratio, interpolated by chainage	0.0036	0.070	0.20	gauge P95	1.85 m
Reference	QA-filtered ratio-of-means, interpolated by chainage	0.0060	0.050	0.45	gauge P90	3.70 m
Permissive	$Q_{M2} = Q_g$	0.0140	0.035	0.75	gauge P50	7.40 m

The slope states have different evidence strength. The 26.35 m Copernicus DEM was sampled at routed M1–M20 node positions. For local-minimum square windows of 0, 15, 30, 45 and 60 m radius, ordinary least-squares elevation against upstream-increasing routed chainage gives 0.00360–0.00529 for M1–M10 and 0.00175–0.00601 for the broader M1–M20 corridor. The reference value rounds the upper terrain-diagnostic range. The 0.014 state is a published mean for the last 3.5 km and is retained as upper reach context, not local M2 energy slope. The withdrawn value 0.03667, obtained from a location offset approximately 104 m from the route, is not used.



Terrain slope, flow transfer and patch-state inputs define the current scenario ledger; site-specific measurements would constrain each declared input.

Figure 6: M2 hydraulic assumption diagnostics. The terrain regressions, flow-transfer bootstrap and paired patch states condition the scenario but do not constitute surveyed local hydraulics.

E.1.4 Flow-transfer ensemble

The spatial proxy contains 21 mouth–Laimos paired dates after excluding the documented HCMR rating-malfunction interval 1 June 2023–31 July 2024. Let $Q_{o,j}$ and $Q_{g,j}$ be the mouth and gauge values on paired date j. The observed equal-date mean ratio, ratio of means and through-origin coefficient are 0.816407, 0.918952 and 0.964795, respectively. The gauge training range is 0.17875–1.445 $\mathrm{m^3\ s^{-1}}$.

The routed gauge-to-M2 fraction is

$$\lambda_x = \frac{x_{\mathrm{Laimos}} - x_{M2}}{x_{\mathrm{Laimos}} - x_{\mathrm{outlet}}} = 0.5646507. \tag{E.3}$$

For every conditional draw, the 21 dates are resampled as blocks. The low mouth coefficient is

$$r_o^{(L)} = \frac{1}{21} \sum_j \frac{Q_{o,j}}{Q_{g,j}}, \tag{E.4}$$

and the reference coefficient is

$$r_o^{(R)} = \frac{\sum_j Q_{o,j}}{\sum_j Q_{g,j}}. \tag{E.5}$$

Both are transferred to M2 as

$$r_{M2} = 1 + \lambda_x (r_o - 1), \qquad Q_{M2}(t) = r_{M2} Q_g(t). \tag{E.6}$$

The same coefficient draw is applied to every timestamp and to both water years; independent timestamp noise is prohibited because it would manufacture high-frequency variance before applying a nonlinear transport equation. The permissive state sets $r_{M2} = 1$. All capacity-generating flood flows exceed the paired-data training maximum and are flagged as extrapolation.

E.1.5 Surface bootstrap and conditional parameters

The M2 grids contain 27 and 43 primary clasts. Each conditional realisation selects two grids with replacement, resamples the selected grid populations to the original 27/43 target sizes, concatenates the 70 values, and derives D_{50} and D_{84} jointly. This preserves $D_{84} \geq D_{50}$ and their dependence. The five interpreted records are used only in the registered 75-record one-at-a-time sensitivity.

Sediment density follows a declared triangular $(2600, 2650, 2750)$ kg $\mathrm{m^{-3}}$ distribution. Water density is fixed at 1000 kg $\mathrm{m^{-3}}$. Total Manning roughness and sediment-effective stress are outer paired states rather than independent random variables. The diagnostic decomposition

$$n_{\mathrm{grain}} = 0.041 D_{84}^{1/6}, \qquad f_{\mathrm{skin}} = \left(\frac{n_{\mathrm{grain}}}{n_{\mathrm{total}}} \right)^2 \tag{E.7}$$

is retained in the draw ledger but is not silently substituted for the three declared primary stress-partition states.

E.1.6 Rectangular hydraulic solution and Wong–Parker models

For each discharge bin and conditional draw, normal depth h is the positive monotonic solution of

$$Q = \frac{1}{n} Bh \left(\frac{Bh}{B + 2h} \right)^{2/3} S_e^{1/2}, \qquad R = \frac{Bh}{B + 2h}, \tag{E.8}$$

with $B = 7.4$ m. The implemented vectorised log-Newton iteration is checked for positive depth, monotonicity, finite Froude number and depth below the approximately 7 m embankment-height constraint. Sediment-effective Shields stress is

$$\theta' = \frac{f_{\text{skin}} R S_e}{(s-1) D_{50}}. \tag{E.9}$$

The main and alternative corrected Wong–Parker forms are exactly Equations B.11 and B.13; their published thresholds are fixed and not sampled.

E.1.7 Executed Recking sensitivity

The executed Recking relation uses its separate reach-scale flow-resistance closure rather than the Manning radius. With unit discharge $q = Q/B$,

$$X = \frac{q}{\sqrt{g S_e D_{84}^3}}, \qquad p = \begin{cases} 0.23, & X < 100, \\ 0.30, & X \geq 100, \end{cases} \tag{E.10}$$

and

$$R_R = \left[\frac{2}{B} + 74 p^{2.6} (g S_e)^p q^{-2p} D_{84}^{3p-1} \right]^{-1}. \tag{E.11}$$

Then

$$\theta_{84} = \frac{S_e R_R}{(s-1) D_{84}}, \tag{E.12}$$

$$\theta_m = (5 S_e + 0.06) \left(\frac{D_{84}}{D_{50}} \right)^{4.4\sqrt{S_e} - 1.5}, \tag{E.13}$$

$$\Phi_R = \frac{14 \theta_{84}^{2.5}}{1 + (\theta_m / \theta_{84})^4}, \tag{E.14}$$

$$q_{bv,R} = \Phi_R \sqrt{g (s-1) D_{84}^3}. \tag{E.15}$$

Recking and Wong–Parker are model-form alternatives. They are not averaged or assigned posterior weights.

E.1.8 Inundation, integration and water-year support

For outer state e, activation is

$$I_e(t) = \mathbf{1}[Q_g(t) \geq Q_{g,p_e}], \qquad p_e \in \{0.95, 0.90, 0.50\}. \tag{E.16}$$

The corresponding local threshold uses the same coefficient draw as Equation E.6; this makes the indicator algebraically coherent with the transferred hydrograph. Pooled supported-time gauge quantiles are P50=1.47, P90=2.77, P95=3.52 and P99=4.74 $m^3\ s^{-1}$.

Discharge values are grouped by their exact recorded value and supported hours before evaluation. This is an exact computational compression because the capacity relation in this model has no path-dependent state. It does not average discharge before applying the nonlinear equation. WY2021 and WY2022 are integrated separately and share parameter draws, permitting paired interannual comparison.

E.1.9 Nested uncertainty and convergence

Each water-year–outer-state–equation result contains 20,000 conditional draws from the fixed PCG64 seed 20260713. The three outer states, three equations and two accepted water years remain separate. Within-state reported 5th, 50th and 95th percentiles are *conditional simulation quantiles*; the restrictive-to-permissive span is not a confidence or credible interval.

Convergence is checked at $N = 2500$, 5000, 10000 and 20000. The final doubling passes if each headline quantile changes by at most 2%, or by at most 0.1 t m^{-1} where a near-zero result makes relative error unstable. The hybrid materiality rule is frozen in the QA output. It must not be described simply as a 2% rule.

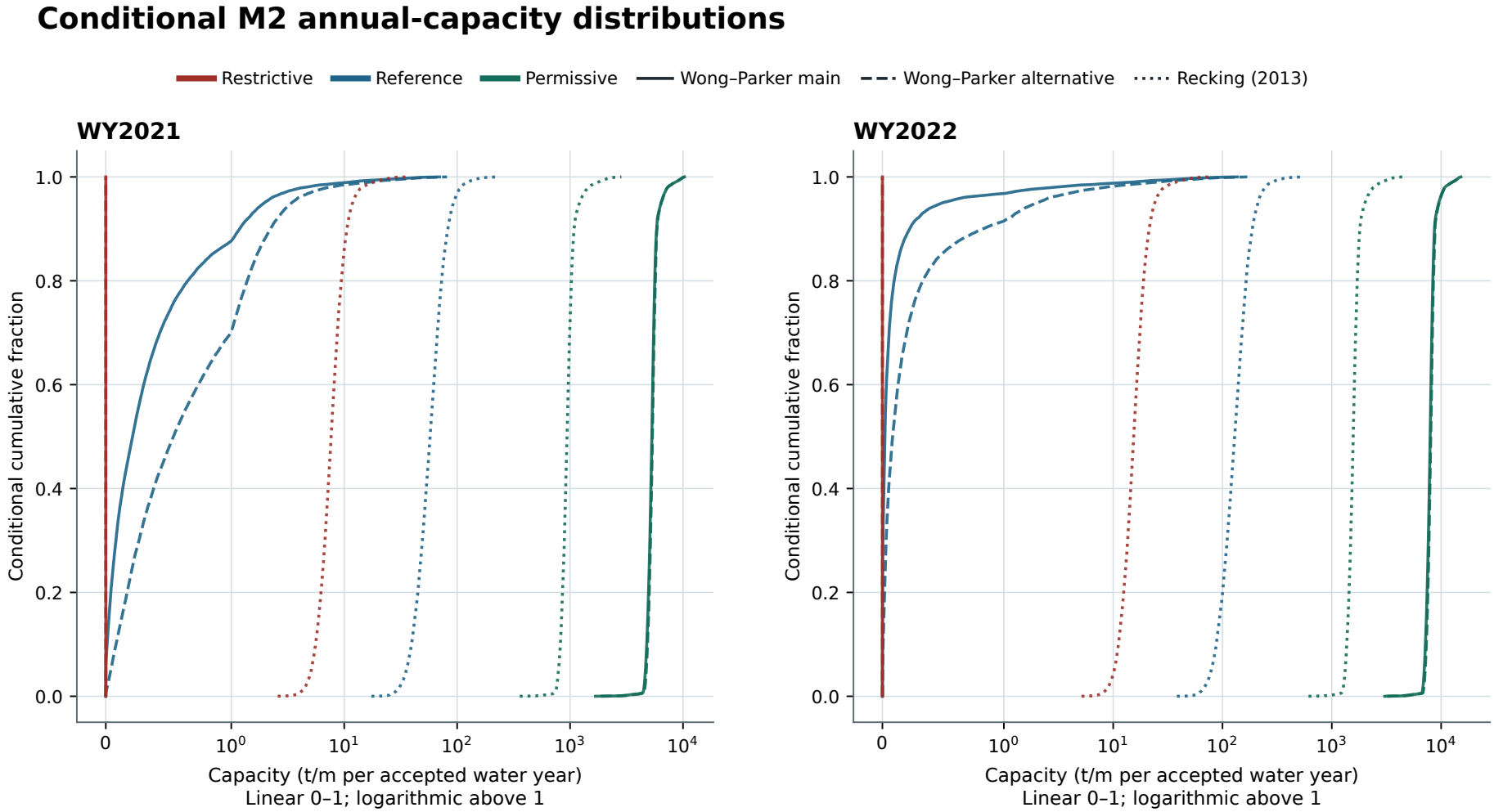


Figure 7: Conditional cumulative distributions for M2 capacity. Outer states and equations remain separate and unweighted.

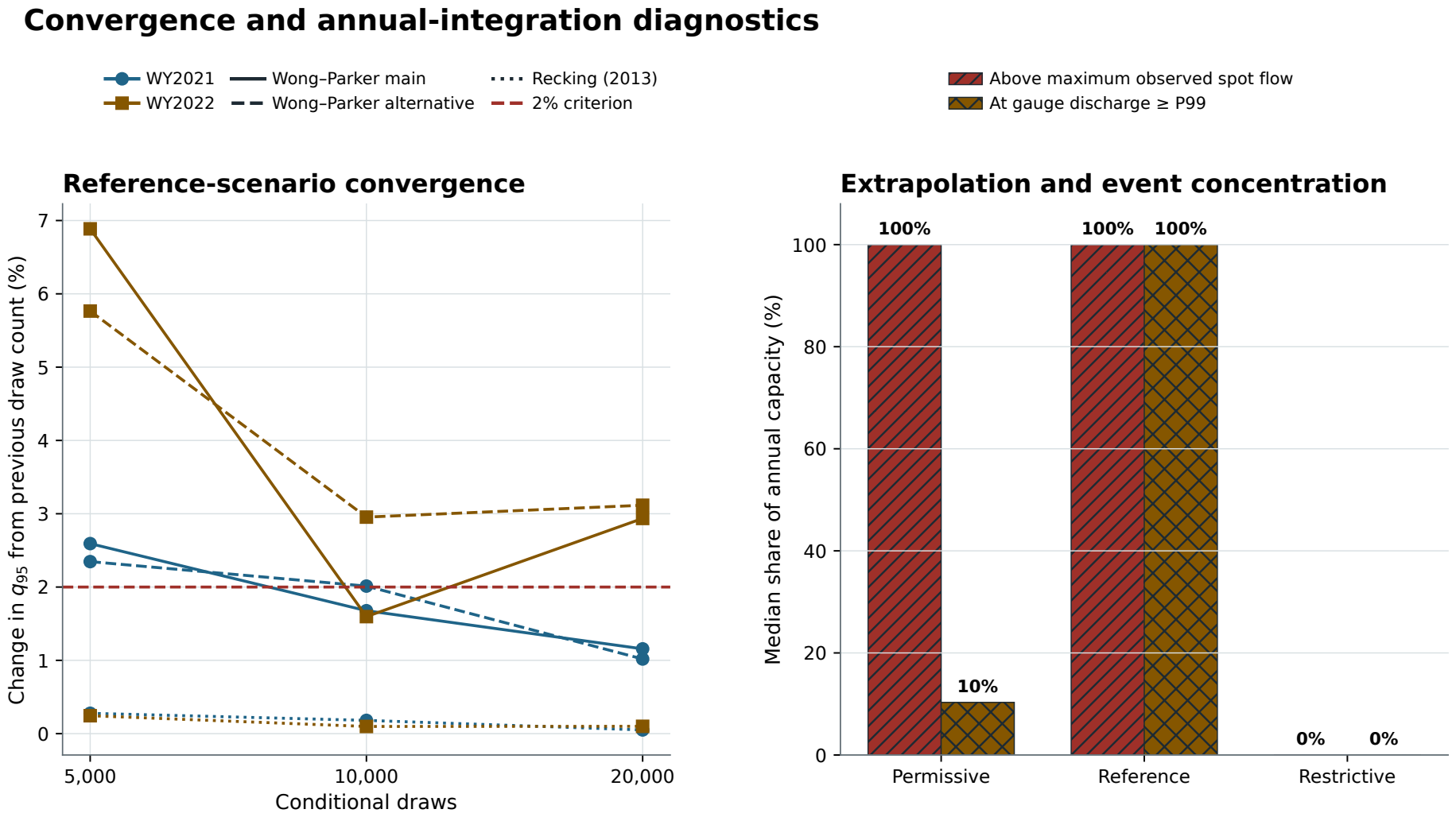


Figure 8: Monte Carlo convergence, flood-transfer extrapolation and high-flow concentration diagnostics. Numerical stability does not validate the hydraulic assumptions.

E.1.10 Executed results

Table 13: Reference-state M2 capacity conditional quantiles. Values are solid mass per metre of active patch over supported intervals.

Equation	WY	q05	q50	q95	Units / limit
Wong–Parker main	2021	0.0	0.2	2.0	t/m supported WY; supply unlimited
Wong–Parker alternative	2021	0.0	0.5	3.4	same
Recking (2013)	2021	35.5	57.6	92.6	same
Wong–Parker main	2022	0.0	0.0	0.5	t/m supported WY; supply unlimited
Wong–Parker alternative	2022	0.0	0.1	2.0	same
Recking (2013)	2022	78.8	129.4	210.1	same

The reference equation medians span 0.2–57.6 t/m in WY2021 and 0.0–129.4 t/m in WY2022. With the reference active width of 3.70 m, the corresponding separate-equation total medians span 1–213 t and 0–479 t. The much wider restrictive-to-permissive envelope demonstrates structural uncertainty rather than a probabilistic prediction range.

E.1.11 Dimensioned delivery scenarios

For supply state a and physical-transmission state b,

$$S_{y,a} = \lambda_a C_y, \qquad Y_{y,a,b} = \eta_b \min(C_y, S_{y,a}), \tag{E.17}$$

where $\lambda_a \in \{0.05, 0.25, 1\}$ and $\eta_b \in \{0, 0.25, 1\}$. Every state has blank probability weight. Automated checks require $0 \leq Y \leq C$ and exact reconciliation of $Y/C = \lambda_a \eta_b$. The relative structural-connectivity index is not η_b, trapping efficiency or delivery probability and does not appear in Equation E.17.

Under the illustrative limited-supply/partial-transmission state, separate equation medians span 0–213 t in WY2021 and 0–479 t in WY2022. These are assumption-driven transformations, not actual or expected annual yield.

E.1.12 Why conformal prediction is not used

Conformal prediction requires exchangeable observed response labels and a nonconformity score derived from out-of-sample prediction errors. The project contains no bedload-flux or annual-yield response observations. Applying a conformal wrapper to capacity or outlet delivery would therefore calibrate nothing and could not provide a valid finite-sample coverage claim. The nested scenario–Monte Carlo design is appropriate to propagate declared inputs and assumptions, but it likewise cannot create validation data.

E.1.13 Machine-readable QA and claim boundary

The executed stage writes the full parameter ledger, 20,000 draw parameters, compressed draw-level capacities, annual summaries, sensitivity, convergence, delivery matrices, plotted-data sidecars and `G4_M2_capacity_delivery.json`. Release promotion additionally requires

an independent benchmark/annual-integration hand-check whose hashes match the current summary and QA files.

The permitted headline is:

> The accepted records support an assumption-driven, supply-unlimited M2 sampled-patch capacity envelope for accepted WY2021 and WY2022 under named flow, slope, roughness/stress, inundation, active-width and equation states.

The prohibited headline is that Agios Germanos has a predicted, expected, measured or calibrated annual yield. Actual annual yield remains unmeasured and unresolved.

E.2 Uncertainty Propagation, Sensitivity and Quality Gates

E.2.1 Uncertainty classes

Four uncertainty classes are kept separate:

1. **Observational uncertainty**: clast counting, bulk-sample replication, stage/discharge measurement, cross-section digitising, photographic classification and georegistration.
2. **Parameter uncertainty**: roughness, skin-friction fraction, critical Shields stress, slope, inundation elevation, mobile width, discharge-transfer coefficients and material density.
3. **Topology/scenario uncertainty**: stream assignment, branch flow split, source availability and control transmission.
4. **Model-form uncertainty**: cross-section representation, flow-transfer model and transport relation.

Interannual hydrological variability is reported across water years; it is not folded into the epistemic confidence interval and then described as parameter uncertainty.

E.2.2 Nested ensemble design

The propagation follows the general Monte Carlo principle of sampling input distributions through the complete measurement/model function while retaining the resulting output distribution (JCGM, 2008).

The ensemble has three nested levels.

Outer evidence/scenario loop The outer loop enumerates discrete states that do not have defensible probability distributions:

- confirmed versus alternative topology for moderate-confidence sites;
- pessimistic, central and optimistic control transmission;
- branch flow-split scenarios;
- confirmed-only versus expanded source inventory;
- facies/domain eligibility alternatives;
- M2 primary 70-clast versus 75-record sensitivity dataset;
- transport equation choice.

Results remain conditional on the scenario label. A percentile across arbitrary scenario values is not called a probability interval.

Observation bootstrap Surface counts are bootstrapped hierarchically: field replicate/count is resampled first, then clasts are resampled within the selected count. For a single count, the interval represents count uncertainty only and does not imply spatial representativeness. Bulk samples are resampled within a confirmed facies/domain; samples of unknown or different facies are not merged merely to increase n. Paired spatial-flow dates are resampled as date blocks so that simultaneous sites remain paired.

Water years and events are reported individually. A block bootstrap may be used for a long-run expected metric, but it does not replace the observed year-by-year table.

Photo lithology/cover annotations are resampled from the confusion/agreement matrix where duplicate classification exists. Store polygons are perturbed by the image-registration error distribution.

Hydraulic/model ensemble Within each outer scenario and observational bootstrap, continuous or ordered inputs are sampled jointly. Table 14 states the initial treatment; the final run table replaces generic descriptions with the actual fitted distribution and source.

Table 14: Uncertainty inputs and required treatment.

Input	Uncertainty class	Initial treatment	Constraint / note
Surface D16/D50/D84	observational	hierarchical non-parametric bootstrap	Count and mass distributions remain separate; facies retained
M2 transcription	scenario	primary 70 and sensitivity 75	Five interpreted records never enter primary silently
Bulk fractions	observational	sample-replicate bootstrap	< 2 mm remains unresolved; censored quantiles not extrapolated
Water-year forcing	interannual	observed complete years separately	Incomplete years reported separately; cadence is irregular
Spatial flow relation	observation/model	coefficient and residual prediction ensemble	Leave-one-date-out validation; mass balance and abstraction checked
Stage datum / section	observational	digitising and datum-offset ensemble	Validated against independent current-meter observations
Reach slope	parameter/model	source and window ensemble	Routed reach only; no nearest offset-channel cell
Wetted/mobile width	parameter/scenario	observed/UAV bounds and inundation state	Mobile-patch width distinguished from total wetted width
Roughness and f_{skin}	parameter	morphology-conditioned joint ensemble	Form drag explicit; no mountain uniform-bed stress
Generalized θ_c	parameter	triangular (0.03, 0.045, 0.07) screening sensitivity	Published Wong–Parker thresholds stay fixed in that model
Water/sediment density	parameter	documented narrow material range	Lithology/source documented; no porosity in solid-mass capacity
Control transmission	scenario	discrete matrix by fraction and flow class	Sensitivity multiplier, not probability or measured efficiency
Branch split	scenario/parameter	observed or simplex-constrained fractions	Fractions sum to one for each event/scenario
Equation	model form	threshold metrics, Wong–Parker and eligible Recking runs	Executed model families remain separate

E.2.3 Conditional summaries

For continuous inputs within one model/scenario, report median and 5th/95th percentiles, together with the number of valid ensemble members. Scenario envelopes are shown outside those conditional intervals. When model form M is discrete, total variance may be decomposed as

$$\mathrm{Var}(Y) = \mathrm{Var}\{\mathrm{E}[Y \mid M]\} + \mathrm{E}\{\mathrm{Var}[Y \mid M]\}\,. \tag{E.18}$$

The first term describes between-model uncertainty and the second within-model parameter/observation uncertainty.

Rank correlations or standardized regression are used for continuous-input sensitivity after monotonicity checks. Discrete effects are summarized as between-scenario or between-model contrasts. Sobol indices are used only if the input independence assumptions are defensible.

Numerical convergence is checked by doubling the ensemble size and requiring headline conditional quantiles to change by less than 2%. The random seed, generator and ensemble size are written to the run manifest.

E.2.4 Current clean-baseline QA summary

Table 15 provides the current record audit. These counts are tested automatically during every rebuild.

Table 15: Current clean-data QA counts.

Component	Count	QA interpretation
Module/source master	26	M1–M25 plus SRC; each has one context record
Reconciled July photo records	214	213 unique filenames resolve to local image assets; one M15 record has no filename; cumulative package copies are not counted as additional photographs
Morphology crosswalk	1,180	187 explicit, 7 explicit absence, 8 inferred, 556 copied background, 335 not recorded, 87 descriptive
Surface clasts retained	611	606 primary; five interpreted M2 records sensitivity-only
Surface-count modules	11	Facies and process-role eligibility retained
Bulk sieve rows	80	74 accepted for summaries
Accepted non-canonical sieve cells	3	Parsed correction retained in QA status
Unit corrections	2	1988/2089 interpreted as 1.988/2.089 kg
Duplicate exclusions	1	Exact row fingerprint retained but excluded
Physical sieve exclusions	5	Non-monotonic and/or passing mass above total
HCMR timestamps	104,868	Irregular cadence; full timestamp audit required
Valid HCMR Q values	102,924	313 zeros, no negative values or duplicate timestamps in preliminary audit

E.2.5 Governed analysis and release gates

The controlled release register expands the analytical checks into eight result-specific gates:

G0 Baseline and result preregistration: schema, IDs, units, QA flags, hashes, result definitions

and claim vocabulary.

G1 **Spatial and MoRPh sign-off**: directed topology, branch/control relations, independent mountain assignments, chainage limits and process-domain eligibility.

G2 **Hydrology and geometry**: timestamp/rating/gap QA, accepted years, event extraction, section geometry, spatial-flow transfer, reach slope and width.

G3 **Sample and scenario eligibility**: facies/method, M2 primary/sensitivity split, exclusion of mountain framework and structure/wood reaches from uniform-bed formulae, and evidence for scenario multipliers.

G4 **Technical results**: reproducibility, units, physical/graph invariants, independent checks, uncertainty and convergence.

G5 **Claim audit**: observations, interpretations and scenarios remain distinct. High-flow opportunity, potential capacity and connected potential are not promoted to movement, load or yield.

G6 **Non-specialist review**: morphology, topology, figures and claim boundaries are understood without the derivations.

G7 **Release**: approved figures/tables, compiling volumes, evidence pack, hashes and signed issue decision agree.

At this revision, the clean baseline has passed its automated checks; G1 has an implemented *pass with limits*; G2 has a scoped hydrology pass for WY2021 and WY2022 plus conditional cross-section geometry but remains open for local flow and stress; and descriptive sediment and controlled connectivity subsets have been executed under G3 limits. The M2 sampled-patch capacity family has passed the assumption-driven scenario gate, conditional convergence checks and independent numerical hand-check; it has not passed the empirical local-flow, surveyed-slope, sediment-supply or observed-load gates. Independent technical approval, claim approval, non-specialist review and external release decisions remain pending. An open gate never triggers silent imputation: the affected output is marked "not resolved", its reason is recorded, and independent lower-risk analyses may continue.

F Whole-reach local input, M20 transfer and planning load

Four accounting quantities are retained separately: gross M1–M20 local sediment input, M20 coarse-store transfer, M2 sampled-patch capacity and catchment-scale transported-load context. Their spatial and process boundaries overlap, so they support comparison rather than addition. The frozen analytical tables label the first quantity "gross local recruitment"; this appendix uses *modelled local bank/gabion input* or *local-input account* for the same estimand.

Accounting scope retained from R2

The 4.4 and 6.6 t/yr rounded reference medians describe new local material entering the M1–M20 lower-river network in WY2021 and WY2022. Its routed length is about 1.54 km including both HM14 limbs. Bank evidence occurs at M2, M6, M7, M9, M10 and M14; gabion evidence at M6 and M15. Nominal field coverage of 330–420 m is extended through the declared coverage factor. Neither continuous observation of all 1.54 km nor catchment-wide yield is implied.

F.1 Whole-Reach Supply and Total-Load Planning Scenarios

F.1.1 Question, spatial domains and claim class

The existing-data extension addresses two questions that differ from the M2 transport-capacity calculation. The bottom-up branch asks how much material could be recruited annually from documented sources under explicit dimensions and rates. The top-down branch asks what representative annual total transported load is reasonable for planning when conditioned on regional analogues. Neither branch measures how much sediment crossed HM15, the river mouth or any other monitoring section in a particular water year.

Five quantities or model families are deliberately kept separate:

1. **Local corridor input:** earth-bank material and released gabion fill from the M1–M20 network;
2. **Mapped M20 coarse-store transfer:** annual > 50 mm release from one finite store under named physical states;
3. **Regional analogue evidence:** reported transported-sediment volumes from neighbouring Prespa catchments and external Alpine context;
4. **Total-load planning prior:** an analogue-conditioned, catchment-scale representative annual transported mass; and
5. **SWAT+ uncalibrated landscape-erosion diagnostic:** the magnitude produced by the current uncalibrated landscape-erosion setup.

These are not alternative measurements of one common response. They refer to different source domains, may overlap physically, and have different delivery definitions. They are therefore neither summed nor averaged. The reported quantiles are conditional scenario quantiles produced by propagating declared inputs. They are not confidence intervals, calibrated prediction intervals or conformal intervals.

Interpretation constraint

In this section, "whole reach" means the modelled M1–M20 lower-corridor network, including both routed HM14 limbs, for the local-input model. It does not mean that every tonne is transmitted through the full reach. The regional model instead uses the adopted GIS catchment area of 73.374 km^2. The total-load planning prior uses that same catchment area but a top-down analogue accounting boundary. Every result must therefore retain its spatial domain, material scope and claim class.

The governing mass-accounting distinction is

$$G_y^{\mathrm{loc}} = M_y^{\mathrm{bank}} + M_y^{\mathrm{gab}}, \tag{F.1}$$

where G_y^{loc} is gross material recruited to the channel within the modelled corridor during water year y. A flux at a downstream section would add routing, storage and transmission terms that are not observed:

$$Y_{o,y} = \mathcal{R}\left(G_y^{\mathrm{loc}}, S_{0,y}, I_{u,y}, \boldsymbol{\eta}_y, \boldsymbol{C}_y\right), \tag{F.2}$$

where $S_{0,y}$ is initial in-channel stock, $I_{u,y}$ is upstream input, $\boldsymbol{\eta}_y$ represents physical transmission and retention states, and $\boldsymbol{C}_y$ represents the sequence of local transport constraints. None of these

terms is sufficiently observed to evaluate the routing operator $\mathcal{R}$ as an outlet-yield model. In particular, serial reach capacities must not be summed and the structural-connectivity index must not be inserted as a mass efficiency.

F.1.2 Evidence architecture and MoRPh reconciliation

The source inventory follows the reconciled morphology rather than treating the river as one uniform erodible bed. M21–M25 and the contributing Siroka, Gaidouritsa and Giovanitsa headwaters remain bedrock–boulder cascade/step-pool systems with discontinuous loose pockets. Their framework and sampled-pocket grain sizes are not converted to annual bank or bedload supply. M1–M20 form the engineered lower alluvial corridor, where direct local supply, abundant fines, wood-forced stores, bank undercutting and failing protection are documented.

Within that corridor, explicit active-bank observations occur at M2, M6, M7 and M14; extensive undercutting is recorded at M9 and M10. Failing gabion supply is explicitly associated with M6 and M15. Stable banks with signs of past erosion are not silently recoded as active in the restrictive/reference source set. Likewise, the repeated description of approximately 7 m-high embankments is reach background, not a set of measured active bank faces. The model therefore samples a lower active face/toe height and never equates the full embankment height with annual erosion depth.

The MoRPh technical manual defines nominal survey-module lengths from channel- width classes and defines bank-length abundance codes including trace, present and extensive classes (Gurnell and Shuker, 2022). These rules provide a reproducible way to construct a sampling footprint, but the field archive contains point modules and recorded wetted/limb widths rather than mapped module polygons or continuous eroding banklines. Consequently:

- L_i is a *nominal MoRPh footprint* assigned from the registered width/context class, not a surveyed eroding-source length;
- $f_{\mathrm{active},i}$ converts the recorded bank abundance class to a bounded fraction of that nominal footprint;
- the routed network length, 1,539 m, includes both HM14 limbs and is not interchangeable with main-stem chainage; and
- $k_{\mathrm{cov}} = 4.2$ expands the sampled nominal footprint to that network only under an explicit spatial-coverage assumption. It is not an observed multiplier.

Figure 9 shows how these local observations and regional evidence enter the three model families.

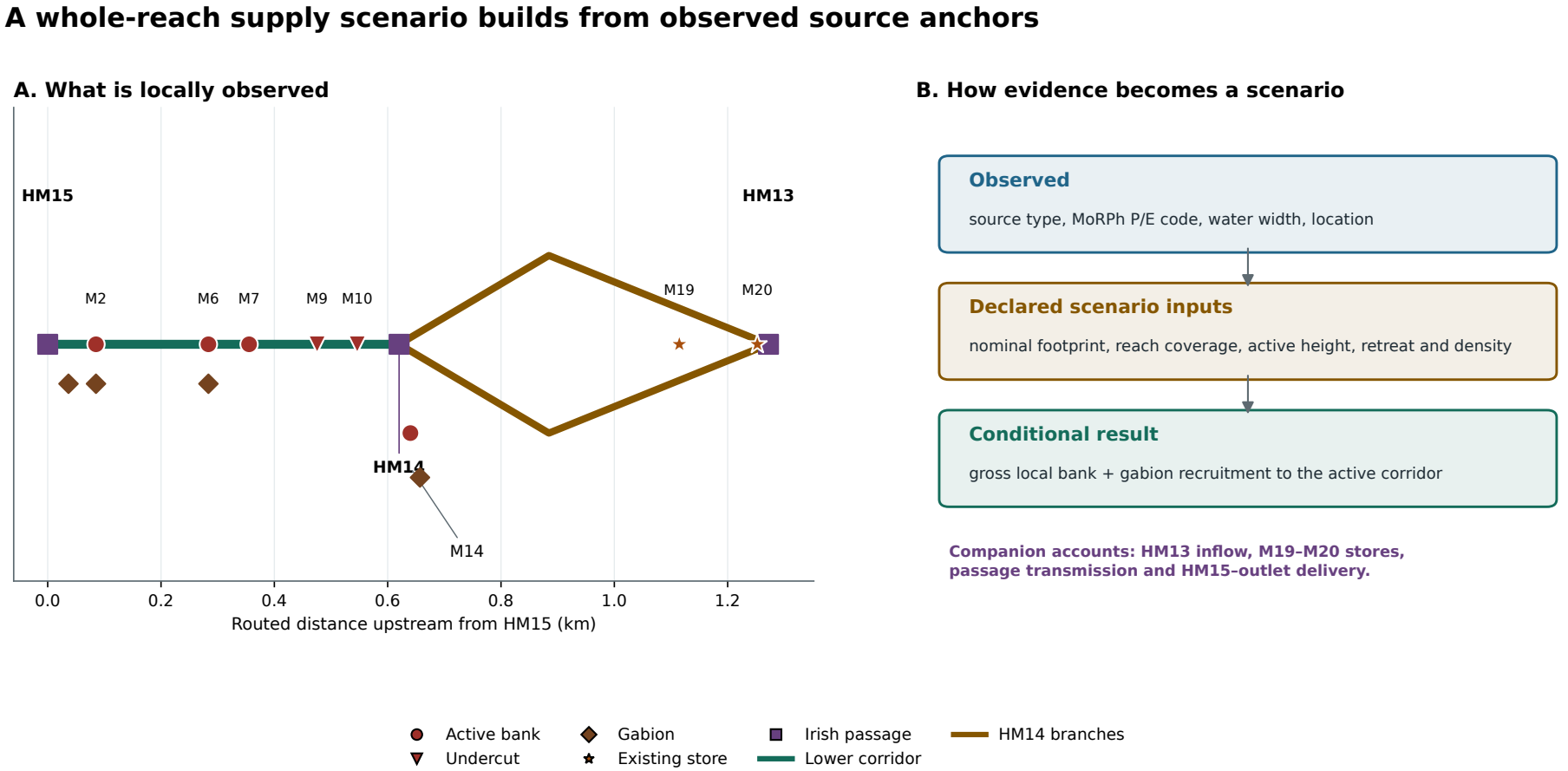


Figure 9: Evidence architecture for the whole-reach supply scenarios. Local source observations, nominal survey footprints, regional transported-volume context and rejected/diagnostic SWAT+ information remain visibly separated. Point observations and nominal footprints are not mapped source lengths.

F.1.3 Local earth-bank input model

For documented source module i and accepted water year y, earth-bank recruitment is represented by

$$M_y^{\text{bank}} = \sum_{i=1}^{N_s} k_{\text{cov}}\, L_i\, f_{\text{active},i}\, n_{\text{bank},i}\, H_i\, R_{i,y}\, \rho_{b,i}\, \eta_{\text{rec},i}, \tag{F.3}$$

with units

$$[M^{\text{bank}}] = 1 \times \text{m} \times 1 \times 1 \times \text{m} \times \text{m}\,\text{yr}^{-1} \times \text{t}\,\text{m}^{-3} \times 1 = \text{t}\,\text{yr}^{-1}. \tag{F.4}$$

The terms in Equation F.3 are:

- k_{cov}: assumed coverage extrapolation from nominal surveyed footprints to the modelled network;
- L_i: nominal module footprint, not measured bankline;
- $f_{\text{active},i}$: sampled proportion consistent with the recorded MoRPh bank-activity abundance class;
- $n_{\text{bank},i}$: number of banklines represented, because several notes identify activity without establishing whether both banks are affected;
- H_i: active eroding face/toe height, distinguished from total embankment height;
- $R_{i,y}$: annual face-normal retreat or equivalent erosion depth;
- $\rho_{b,i}$: dry bulk density of recruited bank material; and
- $\eta_{\text{rec},i}$: fraction of detached mass entering the active channel rather than remaining at the toe or on the bank.

No L_i, H_i or $R_{i,y}$ value is directly measured. The local observations constrain where a source mechanism is plausible and whether activity is present/extensive; the rate and geometry distributions remain assumptions. Published Mediterranean bank-gully retreat provides only an order-of-magnitude external check, because the monitored semi-arid gullies are not equivalent to protected river banks in Agios Germanos (Vandekerckhove et al., 2001). The study is not treated as a local calibration.

The two accepted water years are distinguished using the observed gauge volume above the pooled P95 threshold:

$$R_{i,y} = R_{0,i} \left(\frac{V_y^{\text{excess}}}{\overline{V}^{\text{excess}}} \right)^{\alpha}, \qquad \overline{V}^{\text{excess}} = \frac{1}{2} \sum_{y \in \{2021,2022\}} V_y^{\text{excess}}. \tag{F.5}$$

Here $R_{0,i}$ is the assumed baseline annual retreat/equivalent-depth draw and α is an assumed hydrological elasticity. The gauge-derived excess volumes are observations of high-flow forcing opportunity, not observations of bank retreat. Equation F.5 therefore allocates a declared rate scenario between WY2021 and WY2022; it does not infer a local erosion rating curve or prove that the year with larger excess volume eroded a proportionally larger bank volume.

F.1.4 Engineered coarse supply from failing gabions

Gabion-derived material is represented separately because its geometry, density and texture differ from an earth bank. A basket-equivalent formulation is

$$M_y^{\mathrm{gab}} = \sum_{g=1}^{N_g} N_{\mathrm{be},g}\, V_{\mathrm{be},g}\, f_{\mathrm{loss},g,y}\, \rho_{\mathrm{pack},g}\, \eta_{\mathrm{rec},g}, \tag{F.6}$$

where N_{be} is the number of represented basket-equivalent units, V_{be} is their nominal filled volume, f_{loss} is the annual released fraction, ρ_{pack} is packed-rock bulk density including voids, and η_{rec} is the fraction entering the channel. The explicit failure observations at M6 and M15 establish the mechanism, not these dimensions or the release chronology. Mineral particle density used in the M2 capacity model is not substituted for ρ_{pack}.

The reference state uses M6/M15. Only the permissive sensitivity also admits M1/M2 basket-equivalent release because repeated lower-reach background notes describe widespread failing protection. That text is not treated as two independent dimensional failure surveys; M6/M15 remain the explicit local anchors and the restrictive state uses M6 alone.

The gabion term is retained as a distinct engineered coarse component. It is not used as evidence for natural upstream coarse transmission, and it is not assigned the Siroka hillslope-source fractions described below.

F.1.5 Three resolvable reporting fractions

Eight accepted SRC bulk samples from small hillslope streams entering Siroka provide the only replicated source-material fraction evidence used by this extension. They are not river-bed samples, annual loads or direct samples of the M1–M20 bank faces. Their observed texture is therefore used only in the regional-analogue source-texture allocation, under the conditional assumption that it is informative for material made available to the network.

The local-corridor total mass remains the primary local result. Its optional three-bin allocation is assumption-led: earth-bank < 2 mm content is sampled from a fine-earth range supported qualitatively by the notes, the residual is split between 2–19 and > 19 mm, and gabion fill is assigned a strongly coarse- weighted composition. No local bank or gabion material was sieved. Those local fraction totals must therefore be labelled secondary scenario allocations, not observed grain-size composition.

For regional-analogue bootstrap draw b from SRC sample s, the model resolves

$$f_{<2}^{(b)} = p_{2,s}^{(b)}, \tag{F.7}$$

$$f_{2-19}^{(b)} = p_{19,s}^{(b)} - p_{2,s}^{(b)}, \tag{F.8}$$

$$f_{>19}^{(b)} = 1 - p_{19,s}^{(b)}, \tag{F.9}$$

so that the fractions remain non-negative and sum to one. Sample identity is resampled rather than independently drawing the two passing percentages; this preserves their within-sample dependence. The accepted sample medians are 14.25% passing 2 mm and 70.3% passing 19 mm, but the ensemble retains the between-sample spread.

Only two of the eight source samples include a 50 mm threshold. The evidence is therefore insufficient to make a stable 19–50/>50 mm split. All supply results stop at >19 mm, and the two available 50 mm values are retained as a diagnostic rather than extrapolated to the other six samples. This is a data- resolution limit, not evidence that material larger than 50 mm is absent.

F.1.6 Regional Prespa analogue model

The Transboundary Fish and Fisheries Management Plan reports transported- sediment volumes for neighbouring North Macedonian Prespa catchments of approximately 177–524 $\mathrm{m^3\ km^{-2}\ yr^{-1}}$, with a reported median near 303 $\mathrm{m^3\ km^{-2}\ yr^{-1}}$ (Spirkovski et al., 2012). This is the closest numerical regional context identified in the project archive. It is a planning- model estimate rather than an Agios Germanos monitoring series, and the source does not provide the calibration, sediment-mode split or outlet definition needed to treat it as a transferable yield observation.

The conditional volume model is

$$V_y^{\mathrm{reg}} = A_{\mathrm{AG}}\, k_{\mathrm{transfer}}\, r_v, \tag{F.10}$$

where $A_{\mathrm{AG}} = 73.374\ \mathrm{km^2}$, r_v is sampled from the reported regional volume-rate range, and k_{transfer} is a named structural transfer factor representing the uncertain comparability of source lithology, vegetation, relief, management and routing. Conditional mass is

$$M_y^{\mathrm{reg}} = \rho_{b,\mathrm{reg}}\, V_y^{\mathrm{reg}}, \tag{F.11}$$

where $\rho_{b,\mathrm{reg}}$ is a bulk-density assumption, not the M2 mineral particle density. The regional scenario therefore retains volume as the primary quantity; its mass conversion is secondary and density-conditional. Greek mountainous-catchment studies provide a broad external sense check but are not used as a calibration because high-yield flysch catchments are not process-equivalent to the granite/bedrock and vegetated parts of Agios Germanos (Karalis et al., 2018).

The conditional regional analogue has a median volume of 22,255 $\mathrm{m^3\ yr^{-1}}$, bracketed by 12,979 and 38,437 $\mathrm{m^3\ yr^{-1}}$. After the sampled bulk-density conversion, its median mass is 31,161 $\mathrm{t\,yr^{-1}}$, bracketed by 17,133 and 55,209 $\mathrm{t\,yr^{-1}}$. These values are not added to the local bank and gabion estimate because catchment material can include, feed, store and rework the same material represented locally.

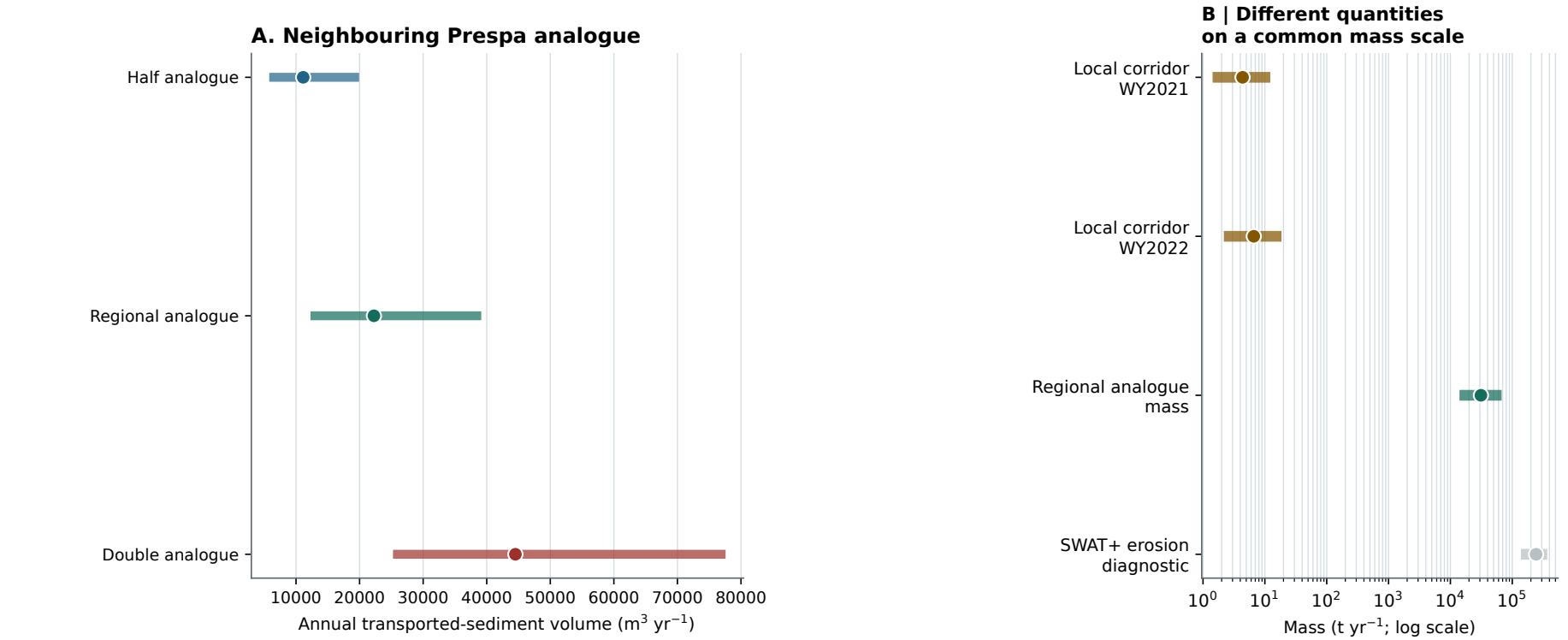


Figure 10: Regional and model context for annual sediment supply. The Prespa analogue remains a conditional volume scenario and the SWAT+ result remains an uncalibrated landscape-erosion diagnostic; neither is an observed Agios Germanos outlet yield. Axes and annotations retain the distinct estimands.

F.1.7 Analogue-conditioned total transported-load planning envelope

The matched-area evidence supports one further, explicitly top-down quantity: an *analogue-conditioned representative annual dry-mass transported load* for the adopted GIS catchment area of 73.374 km^2. This is a planning prior for a catchment/outlet-scale accounting boundary. It is not water-year specific and it is not conditioned on an Agios Germanos sediment-flux observation. In compact form,

$$Y_{\mathrm{tot}}^{\mathrm{plan}} = A_{\mathrm{AG}}\, r_v\, \rho_b, \tag{F.12}$$

where the analogue rate r_v is retained as a named structural state and ρ_b is the shared triangular dry-bulk-density distribution. The three Prespa states are `regional_low`, `preferred_independent_terminal` and `regional_high_closest_analogue`. They are unweighted structural alternatives, not event probabilities. Within each fixed state, q05–q50–q95 summarise density-conversion uncertainty. The resulting core structural planning envelope is 14,935–29,068–62,749 t yr^{-1}, where the three displayed positions are respectively the regional-low lower bound, the preferred-state median and the regional-high upper bound. Within the preferred state alone, the q05–q50–q95 mass is 24,308–29,068–34,485 t yr^{-1}.

The model families and their roles are summarised in Table 16. The French Alpine relation defines an independent geographical-transfer sensitivity family rather than an extra sample in the Prespa prior. Its published point at the Agios Germanos area is 63,655 t yr^{-1}; the 20,769–175,767 t yr^{-1} range is empirical between-catchment model dispersion and is explicitly not a prediction or confidence interval (Pitlick et al., 2021). Brajčinska is the closest-area Prespa check, with density-converted q05–q50–q95 of 43,287–51,676–61,286 t yr^{-1}. It is already embedded in the Prespa high-rate state and is not independent evidence.

Table 16: Total transported-load planning families and their interpretation.

Family	Representative annual mass	Role and limit
Prespa core structural envelope	14,935–29,068–62,749 t yr^{-1}	Permitted planning headline; union of unweighted rate states and within-state density uncertainty
Preferred Prespa state	24,308–29,068–34,485 t yr^{-1}	Preferred analogue conditioning; q05–q50–q95 is not a measured-yield interval
Brajčinska closest-area check	43,287–51,676–61,286 t yr^{-1}	Embedded Prespa check; do not pool with the Prespa family
French Alpine family	scaling point 63,655 t yr^{-1}; sensitivity range 20,769–175,767 t yr^{-1}	Independent geographical-transfer sensitivity comparison; no pooled central estimate

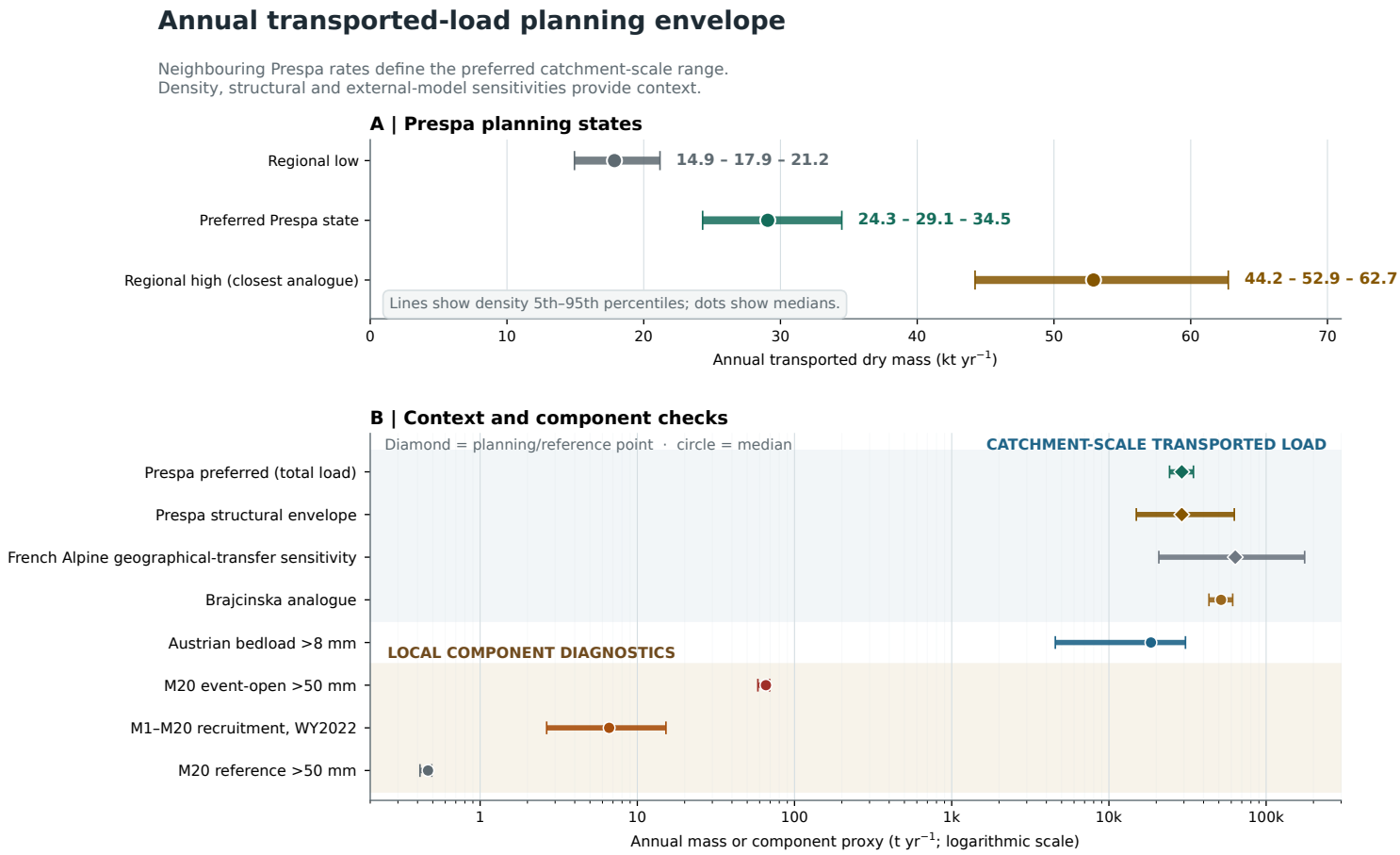


Figure 11: Analogue-conditioned representative annual total transported-load planning envelope. Panel A shows three Prespa planning states and their density-uncertainty intervals. Panel B compares the preferred Prespa state, wider structural envelope and French Alpine transfer sensitivity with the Brajcinska analogue, Austrian bedload context, M20 coarse-store transfer and gross local bank input. These accounts have different scopes and are not added together. M2 capacity, connectivity and SWAT outputs are not plotted.

Interpretation constraint

The total-load planning prior is a top-down total, not a new source term. Gross M1–M20 bank/gabion input and M20 > 50 mm store transfer may already be nested within that total and have different grain-size and spatial boundaries. M2 capacity is a carrying potential, the connectivity index is dimensionless, and SWAT channel routing is disabled. None is added to, subtracted from or used to calibrate the planning envelope.

F.1.8 Nested uncertainty design

The calculation uses 20,000 conditional Monte Carlo draws. The design separates structural states from within-state distributions in accordance with the distribution-propagation principles of JCGM 101 (JCGM, 2008):

1. select and retain a named outer source/coverage state; outer states receive no fitted probability weights;
2. draw the shared hydrological elasticity and year factor;
3. draw source-geometry, activity, retreat, density and recruitment terms from the registered conditional ranges;
4. for the regional family, bootstrap SRC sample identity to obtain coherent < 2, 2–19 and > 19 mm source-texture fractions; retain the separate assumption-led allocation for local earth/gabion material;
5. evaluate the earth-bank and gabion mechanisms separately, then sum them only within the same local-input draw;
6. evaluate the regional-volume and conditional-mass model as an independent structural family; and
7. summarise conditional 5th, 50th and 95th percentiles, component shares, fraction totals and uncertainty-driver diagnostics without pooling the outer states.

The total-load branch follows the same structural-versus-within-state discipline but remains a separate family. The three Prespa rate states receive no fitted probability weights. Density q05–q50–q95 is evaluated within each state. French between-catchment dispersion is retained as an independent geographical-transfer sensitivity comparison, not pooled with Prespa draws and not relabelled as a prediction interval. The cross-family union 14,935–175,767 t yr^{-1} has no central estimate or probability meaning.

This is an assumption-driven simulation evaluated before comparison with observed annual load. Conformal prediction is not applicable because the archive contains no exchangeable set of observed annual sediment yields, fitted predictions and residuals with which to calibrate coverage. Increasing the Monte Carlo sample size reduces numerical noise; it does not reduce ignorance about bank height, retreat, spatial coverage or physical delivery.

Table 17: Evidence status of the principal whole-reach supply variables.

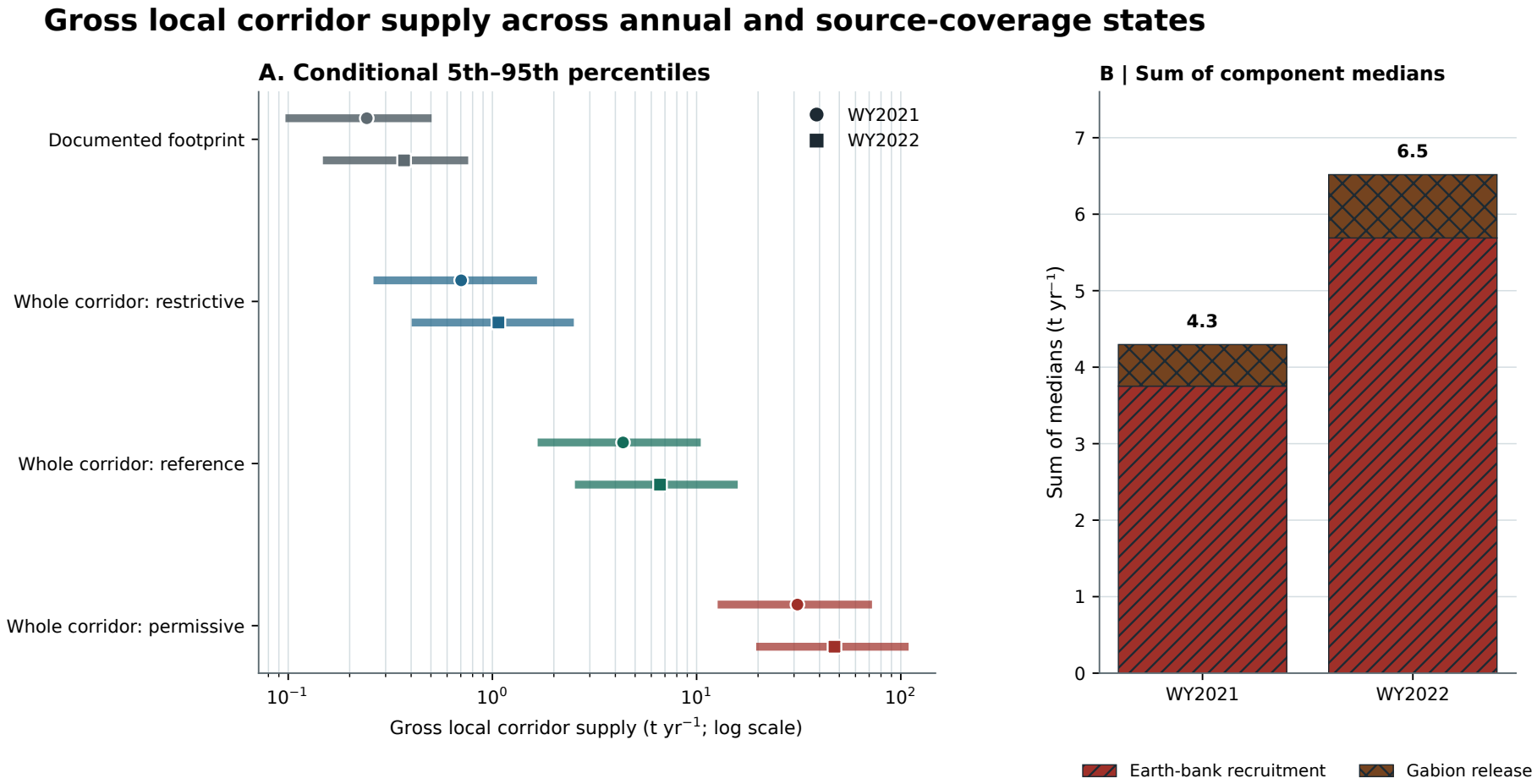
Variable	Status	Constraint	Interpretation limit
V_y^{excess}	Observed / derived	Accepted Laimos hydrograph, pooled P95 threshold and supported intervals	Gauge high-flow volume; not local retreat or sediment flux
Source presence/class	Observed	Explicit M2, M6, M7, M9, M10 and M14 bank evidence; M6/M15 gabion evidence	Point/module evidence; no mapped source dimensions
L_i, k_{cov}	Assumed / derived	Nominal MoRPh footprint and routed-network coverage calculation	Not surveyed eroding length or probability-sample expansion
f_{active}	Class-conditioned	Recorded MoRPh trace/present/extensive abundance class	Bounded class interpretation, not mapped bankline
H_i, n_{bank}	Assumed	Outer morphology/source state	Full 7 m embankment height is prohibited as active-height evidence
R_0, α	Assumed with external check	Declared rate/elasticity ranges; Mediterranean gully study as context only	No local repeat bank survey or erosion rating curve
ρ_b, η_{rec}	Assumed	Conditional bulk-density and channel-recruitment ranges	SoilGrids density is contextual; mineral particle density is not bulk density
Local fractions	Assumed secondary allocation	Fine-earth bank range and coarse-weighted gabion composition	No M1–M20 bank/gabion sieve; local total mass is primary
Regional source fractions	Observed plus transfer assumption	Bootstrap of eight SRC samples at 2 and 19 mm	Texture only; no 19–50/>50 split and no annual production rate
Gabion terms	Mechanism observed; magnitude assumed	M6/M15 failure evidence plus basket-equivalent ranges	No measured failed volume, fill loss or failure chronology
r_v	Regional analogue	Prespa management-plan range	Planning-model volume, not monitored Agios Germanos yield
k_{transfer}	Assumed	Named regional-comparability state	Prevents analogue from being treated as direct calibration
Total-load structural state	Analogue-conditioned	Regional-low, preferred independent-terminal and regional-high/closest-analogue rates	Unweighted planning alternatives; not probabilities or water-year states
$Y_{\mathrm{tot}}^{\mathrm{plan}}$	Derived planning prior	Catchment area, analogue rate and dry-bulk-density distribution	Representative annual total transported load; not measured/calibrated outlet yield
External Alpine family	Independent geographical-transfer sensitivity context	Published French total-load scaling and between-catchment residual dispersion	Sensitivity comparison only; not pooled with Prespa and not a prediction interval

F.1.9 Local-corridor results

The reference local state gives a conditional gross local-input distribution of 1.7–10.0 $\mathrm{t\,yr^{-1}}$ for WY2021, with median 4.4 $\mathrm{t\,yr^{-1}}$. For WY2022 the corresponding distribution is 2.7–15.2 $\mathrm{t\,yr^{-1}}$,

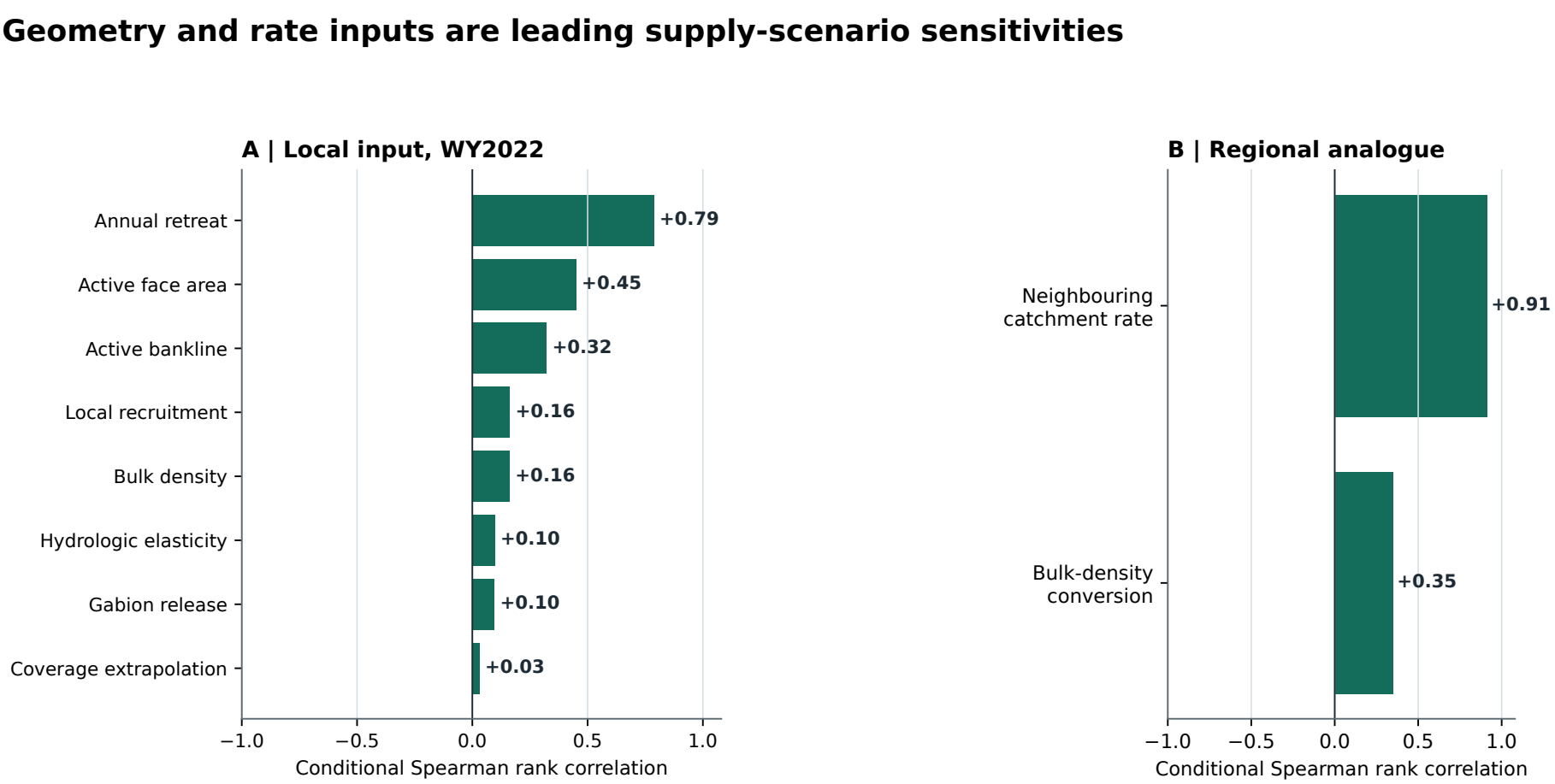
with median 6.6 $\mathrm{t\,yr^{-1}}$. Across all unweighted outer states, the visible scenario envelope extends from 0.3 to 104.5 $\mathrm{t\,yr^{-1}}$.

These totals comprise earth-bank input plus released gabion fill after the assumed recruitment/release fractions. They are gross source terms summed over the M1–M20 corridor, not mass passing M2, HM15 or the mouth. The water-year difference follows Equation F.5; it is a conditional response to the observed difference in high-flow excess volume, not a detected year-to-year change in bank position.



Stacks sum the separate bank and gabion medians (4.3 / 6.5 t yr^{-1}). Joint-draw medians are 4.4 / 6.6 t yr^{-1} (main report Figure 11): the median of a sum need not equal the sum of medians. Conditional states remain separate.

Figure 12: Conditional local-corridor gross sediment input for accepted WY2021 and WY2022. Outer states remain unweighted and visible. Distributions combine earth-bank input and released gabion fill; they do not include routed upstream input, store turnover or physical transmission to an outlet.



Conditional rank correlations identify influential inputs within the declared distributions. Correlated derived terms, including active face area, are interpreted together.

Figure 13: Conditional uncertainty-driver diagnostics for the local and regional supply scenarios. Effects describe the registered model and input ranges; they are not calibrated causal importances or a substitute for field validation.

The uncertainty-driver analysis in Figure 13 is a model diagnostic rather than evidence ranking. A parameter can dominate the conditional variance because its assumed range is wide, not because field data show that it is physically dominant. Conversely, an observed categorical source location may contribute little numerical variance while remaining essential to model structure.

F.1.10 SWAT+ landscape-erosion diagnostic and its outlet-yield interpretation boundary

The current SWAT+ landscape/routing-unit outputs are non-zero. After the documented active-subbasin exclusion, they produce approximately 169–302 kt yr^{-1} over the available annual runs. This corrects the narrower statement that all SWAT+ sediment fields are zero: the landscape fields are non-zero, while the channel sediment-routing fields are zero.

The result is not usable as channel supply or outlet yield because channel sediment routing is disabled: channel sediment parameter links are null, channel sediment/degradation switches are inactive, and the annual channel files report zero sediment inflow, outflow, bank erosion, degradation and deposition. Land-cover management/conservation assignments are also null or homogenised, size-class outputs are internally uninformative, sediment was not calibrated, and the represented active HRU area does not exactly match the adopted GIS catchment area. The 169–302 kt yr^{-1} range is therefore retained only as an uncalibrated landscape-erosion diagnostic. It is excluded from the central Monte Carlo prior and must not be used to cap, validate or combine with the local or regional results.

F.1.11 Permitted use and stopping rule

The supply extension narrows the previous complete absence of a dimensioned source term, but it does not close the sediment-budget equation. Its permitted uses are:

- compare the scale and fraction composition of named, conditional source scenarios;
- use the preferred Prespa state and the core structural envelope for catchment-scale planning and order-of-magnitude screening;
- identify which unmeasured terms control the gross local-input envelope;
- test whether a proposed capacity or intervention claim is strongly supply-sensitive; and
- provide transparent parameter targets if future imagery, maintenance records or repeat topography become available.

It may not be described as measured supply, expected annual load, calibrated bedload, sediment delivered past HM15, or outlet yield. Coupling supply to capacity would require a common fraction basis, source position, intervening store exchange and a physical transmission model. A schematic $Y = \eta \min(S, C)$ is valid only after those quantities refer to the same routed control volume. The current M2 capacity and whole-corridor gross local input do not satisfy that requirement.

Likewise, the analogue-conditioned total-load result may be described only as a representative annual planning prior under named analogue states. It must not be made water-year specific, reported as a monitoring result or decomposed by adding or subtracting the local-input, M20, M2, connectivity or SWAT diagnostics.

The existing archive can support a transparent, dimensioned annual-supply *scenario*, because source occurrence, morphology, two accepted high-flow years and regional context are available. Its numerical width is governed by assumed source footprint, retreat, active height, bulk density and recruitment. The scientifically defensible gain is therefore a bounded sensitivity result with explicit evidence status—not a newly measured annual yield.

F.2 Reference bank and gabion components

The `whole_reference` ensemble uses 20,000 paired draws per accepted water year. Earth-bank material entering the active corridor has a q50 of 3.75 t yr^{-1} in WY2021 and 5.69 t yr^{-1} in WY2022. Material released from documented local gabion failures has corresponding q50 values of 0.54 and 0.83 t yr^{-1}. For each draw j, the combined local input is

$$I_{y,j} = I_{y,j}^{\mathrm{bank}} + I_{y,j}^{\mathrm{gabion}}.$$

The reported combined q50 is therefore evaluated from the *combined draw vector*; it is not formed by adding the two separately rounded component medians. The resulting combined q05–q50–q95 values are 1.7–4.4–10.0 t yr^{-1} for WY2021 and 2.7–6.6–15.2 t yr^{-1} for WY2022.

The hydrological forcing index integrated above the accepted threshold is 0.755 million m^3 in WY2021 and 1.439 million m^3 in WY2022. It controls the declared annual-response scaling in this local-input model; it is a water-volume index rather than a sediment volume.

F.3 Prespa rate–area–density reconciliation

The preferred analogue state is the area-weighted specific-volume rate from the 4 independent terminal Prespa basins: 287.897 m^3 km^{-2} yr^{-1}. Applying that rate to 73.374 km^2 produces 21,124 m^3 yr^{-1}. The frozen 50,000-draw ensemble q50 of the governed triangular dry-bulk-density distribution is 1.376 t m^{-3}, giving the 29.1 kt yr^{-1} planning centre. Appendix A's reconciliation catalogue retains every named Prespa point and its independent/nested status, plus the French total-load and Austrian monitored bedload values shown in the main report. The independent terminal basins are Golema, Brajčinska, total Istočka and Kranska. The dry-density distribution is triangular (minimum 1.05, mode 1.35, maximum 1.75 t m^{-3}); its ensemble median is not its mode. The preferred-state 24.31–34.49 kt/yr range reflects density variation. The wider 14.94–62.75 kt/yr span compares unweighted analogue-rate states, not a 90% confidence interval. These are planning values, not measured lake export or a quantified removal pulse.

F.4 M20 coarse-store component

The released stock-turnover model represents the annual > 50 mm transfer component from the finite mapped M20 store. Its state-specific q05–q50–q95 values are 0.00–0.00–0.00 t yr^{-1} (restrictive), 0.41–0.47–0.49 t yr^{-1} (reference), and 58.47–65.78–69.44 t yr^{-1} (event-open). The calculation uses 20,000 draws and seed 20260715.

M20 estimand

For stock S and declared annual turnover r and physical downstream transmission η, the component is $Y_{M20} = S\,r\,\eta$. Grain-competence fractions are reported beside this component and do not rescale it. This keeps physical state, stock uncertainty and hydraulic opportunity visible as separate controls.

G Passage evidence and RTK technical record

G.1 Controlled receipt and present analytical use

The dated context release contains 3,659 received RTK points: 1,327 at HM13, 1,176 at HM14 and 1,156 at HM15. All 6 of 6 survey-association checks SA01–SA06 pass for context-only use. The release supports receipt confirmation, broad plan alignment under the working EPSG:2100 interpretation, local coverage mapping and navigation between RTK and field-evidence records.

Passage	Received points	Review-sensitive	Severe Z excluded	Controlled status
HM13	1,327	0	0	Context-only; exact duplicates isolated in source QA
HM14	1,176	25	0	Context-only; mixed-precision records retained for review
HM15	1,156	1	1	Context-only; severe anomaly excluded and one secondary sequence retained for review

Table 18: RTK receipt and point-level QA summary from the dated context release.

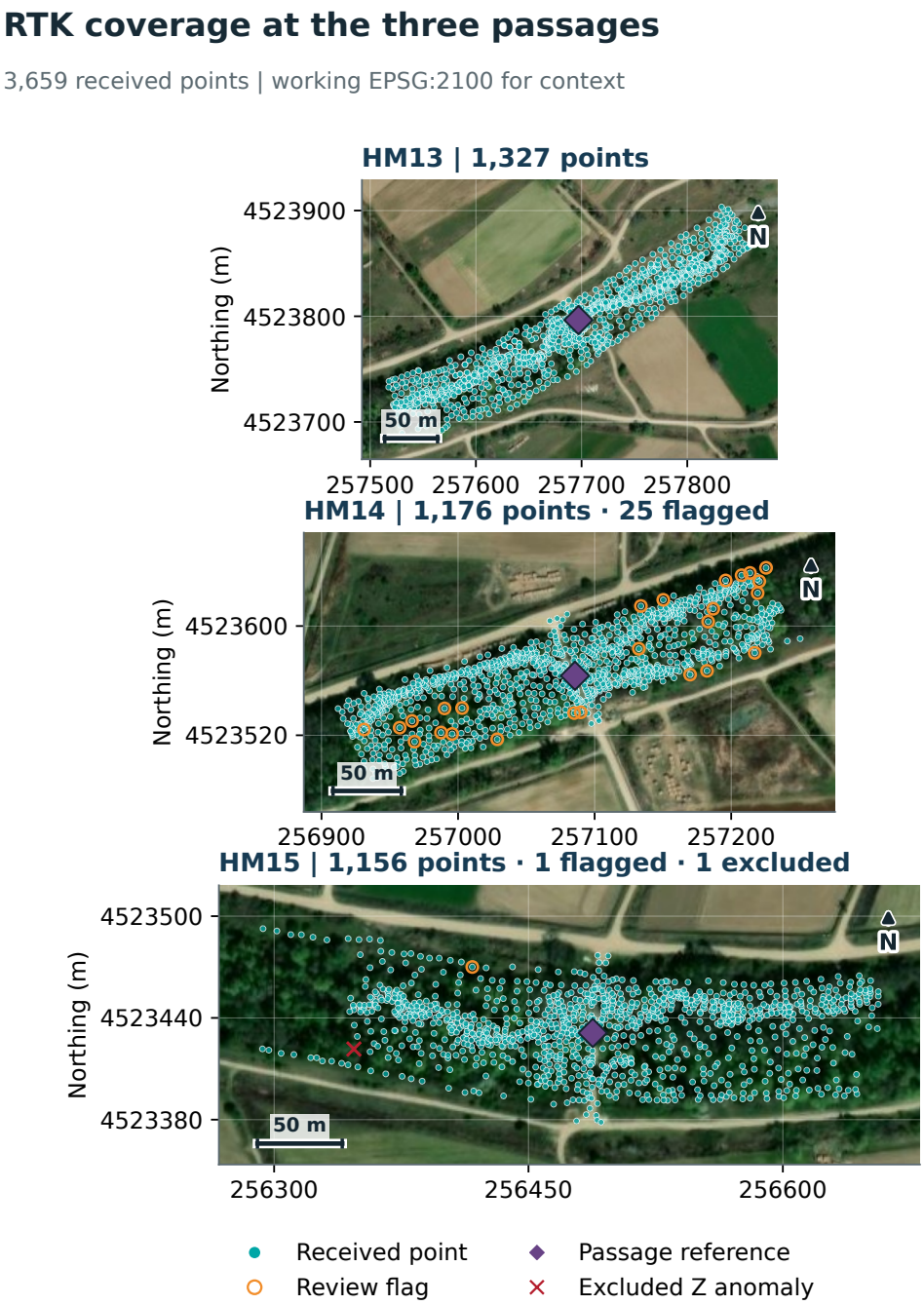


Figure 14: RTK imagery and received-point coverage at HM13–HM15, with review flags and canonical passage references. No interpolation-support outline or surveyed embankment boundary is shown. The horizontal CRS is assumed for context; provider confirmation of the reference system, vertical datum, survey metadata, control and feature coding is needed before relative-geometry use.

G.2 Survey-association gates

Table 19: Survey-association gates in release `2026-08-10_R1_context_only`.

Gate	Name	Passed content
SA01	Release identity and use class	Exact release and source-package identities; use class fixed as context-only
SA02	Immutable source provenance	Receipt, alignment, gate and anomaly sources retained by hash
SA03	Spatial-context boundary	Broad passage alignment under assumed EPSG:2100; imagery and vertical-reference qualifications retained
SA04	Evidence-association integrity	Sanitised 2D association layers; automated relationships remain candidates
SA05	Report-safe context artifact	Portrait coverage plate with fonts, scale, north arrow, attribution and assumed-CRS note
SA06	Manifest and product boundary	Release-local hashes and schemas pass; elevation-derived products remain outside this release

G.3 Association precision and review states

Canonical photo positions use reconciled Garmin coordinates while EXIF positions and bearings remain QA alternatives. Exact spatial joins, 10 m proximity, 10–25 m corridor context and module-topology context create candidate relationships. Grain and morphology records without independent coordinates remain module-context records. Confirmed interpretive relationships require an append-only reviewer decision with basis, confidence and date; the R1 decision snapshot contains no manual confirmations.

At the 10 August 2026 evidence cut, the atlas contains 2,895 candidate evidence links, including 331 links flagged for pending manual review. There are **zero manual association decisions at this evidence cut**: the append-only decision ledger is header-only (0 rows). No automated link is emitted as confirmed; consequently, none of these candidate relationships supports a report interpretation as a confirmed association at R1.

The passage-specific evidence inventories keep HM14 core and wider-corridor evidence separate, preserve the local character of HM15 coverage, and retain HM13's M20–M19 store sequence without converting spatial sorting into temporal change.

G.4 Interpretation and use of existing evidence

The limitations above are the status recorded in the 10 August context release. They do not imply that a survey was never undertaken or that every point needs to be surveyed again. Check the received survey and later provider documentation, validate usable geometry, and collect only identified gaps. The local HM15 footprint and the 1.760 km receiving reach remain distinct coverage questions. At HM14 the analytical network has two principal limbs; the field record also describes local additional splitting around wood and an island. This does not establish a third principal model route or its flow share. The 2025 SPP feasibility study assesses the HM14 fishway as inadequate (p. 58) and describes species- and flow-dependent partial passability of the whole crossing (p. 59). This does not support a claim that no fish ever pass. Retain fish passage in the ecological option appraisal and verify performance by species and flow. The main report's HM14 photograph is from the SCIMABIO reference archive, separate from the July survey collection.

G.5 Route to relative geometry

Provider confirmation of the horizontal reference, vertical datum/geoid, surveyor/date, control and accuracy is followed by manual classification of bed, margin, structure, crest, toe, road and unresolved points. A passage is promoted only through a dated relative-geometry release after reproducible surface support, profile conventions and independent checks pass. This controlled progression uses the present context archive to narrow design uncertainty without changing the B0 calculations.

H Reproducibility, QA and release control

H.1 Implementation Sequence, Outputs and Reproducibility

H.1.1 Current implementation status

The workflow separates completed reconciliation, executed result subsets and analyses stopped by open gates. Table 20 prevents a methods annex from being mistaken for a completed sediment-yield study.

Table 20: Implementation status at the 10 August 2026 R1 evidence cut.

Component	Status	Evidence/output
Field-note and morphology re-audit	Complete	Reconciled context, 1,180-row evidence-state crosswalk and module audit
M2 surface-count restoration	Complete	70-primary/75-sensitivity clast records and strict count statistics
Bulk-sieve QA and terminology	Complete	80 retained rows, 74 accepted, explicit fraction resolution
Project-wide data inventory	Complete	Existing-data and analysis registers
Clean baseline manifest/validation	Complete	33-file SHA-256 manifest; 20 blocking checks passed
Legacy uniform-capacity safeguard	Complete	Withdrawn outputs labelled; legacy script blocked by default
Routed channel/branch topology	Implemented with limits	31-node/31-edge graph; M12–M11 downstream order retained; M12 conceptual HM14-tailwater relation without precise topology chainage; M22 medium confidence
Laimos cross-section geometry	Conditional subset	28 vertices and monotonic geometry lookup below 902.70 m; logger/survey datum and hydraulic validation remain open
Native hydrograph/event QA	Scoped pass	WY2021 and WY2022 accepted; gauge P95 opportunity at 24-hour separation with 6/12-hour sensitivities
Spatial-flow/reach hydraulics	Empirical gate open; M2 scenario executed	No accepted M2 hydrograph or surveyed process-reach slope. Three named hydraulic states use the screened mouth–gauge relation, terrain diagnostics and declared roughness/stress-partition assumptions
Structural connectivity scenarios	Executed with limits	Fraction-specific equal-source-zone scenarios generated. The structural index remains dimensionless and is never used as a mass-transmission efficiency
Domain-specific annual proxies	M2 capacity analysis complete	Conditional, supply-unlimited M2 capacity for WY2021/WY2022, plus dimensioned delivery scenarios. No observed bedload, calibrated supply, physical transmission efficiency or actual annual yield
Whole-reach conditional supply	Implemented with assumption limits	Local M1–M20 gross bank/gabion recruitment for WY2021/WY2022; independent Prespa transported-volume analogue; SWAT+ uncalibrated landscape-erosion diagnostic. No calibrated channel supply or outlet yield
Passage/store and granite-front analyses	Open	M20–M19 sequence and HM14 topology reconciled; causal transmission, store change and precise lithology front unresolved
Integrated uncertainty/results package	Implemented with assumption limits	Named outer states, 20,000 M2 and 20,000 supply conditional draws per state, model-family separation, convergence tests, automated QA and an independent numerical hand-check; external technical and reader review remain appropriate

H.1.2 Executable stages

The production pipeline is divided into numbered stages. A later stage reads only frozen outputs from earlier stages and checks the result-specific gate status. A failed dependency stops that output family while independent fail-soft analyses continue with the limitation recorded.

00 **Freeze clean baseline.** Rebuild the master, morphology crosswalk and grain tables; validate keys/QA; write SHA-256 manifest and environment record.

01 **Build routed topology.** Create observed centreline, confluence/branch/control nodes, approved routed chainage and explicit null/alternative states where topology is unresolved.

02 **Extract geometry and slopes.** Georeference UAV plates, digitise the HCMR section, derive process-reach width/slope ensembles and mobile-patch/inundation geometry.

03 **Assimilate hydrology.** Audit cadence/rating/gaps, create water-year/event tables and fit observation-constrained site flow relations.

04 **Build fraction-specific graph.** Attribute sources, stores, controls, passability scenarios and alternative branch splits.

05 **Run hydraulic opportunity.** Solve reach hydraulics, Q_{c}, inundation threshold, annual hours/events and integrated excess forcing only for sites passing the local geometry/facies gates; otherwise retain observed gauge high-flow opportunity alone.

06 **Consolidate passage and store evidence.** Register the executed grain contrasts and store-context outputs with their declared claim boundaries.

05B **Run the existing-data M2 extension.** Apply the reconciled M2 eligibility gate, screened mouth–gauge transfer, terrain slope diagnostics, named hydraulic states and separate Wong–Parker and Recking closures; integrate only the accepted WY2021/WY2022 intervals and keep supply and downstream transmission as explicit named scenarios.

05C **Run the existing-data whole-reach supply extension.** Apply the explicit local source ledger, nominal MoRPh footprints, unweighted coverage/rate states and accepted water-year forcing; retain the neighbouring-Prespa volume analogue and SWAT+ uncalibrated landscape-erosion diagnostic as independent, non-additive model families.

07 **Propagate uncertainty and sensitivity.** Execute nested bootstrap/scenario/model loops and convergence tests.

08 **Generate outputs and claim audit.** Produce tables, figures, GeoPackages, machine-readable metadata and the final results report.

H.1.3 Stage 00 clean-baseline command

The implemented baseline command is:

Clean-baseline build

`python projects/morphology/src/reconciliation/build_sediment_clean_baseline.py`
Outputs:

- `projects/morphology/outputs/working/connectivity_bedload_workflow/clean_data_manifest.csv`
- `projects/morphology/outputs/working/connectivity_bedload_workflow/clean_data_validation.json`

At the report data cut, all 20 blocking validation checks pass and no manifest file is missing.

Whole-reach conditional-supply build

`python projects/morphology/src/sediment_connectivity/05c_whole_reach_supply.py`
Principal governed outputs:

- `data/whole_reach_supply_annual_summary.csv`;
- `data/regional_prespa_supply_summary.csv`;
- `tables/T09_whole_reach_local_supply.csv`;
- `tables/T10_regional_prespa_supply_analogue.csv`;
- `tables/T11_supply_parameter_ledger.csv`; and
- `qa/G4_whole_reach_supply.json`.

All relative paths are under `projects/morphology/outputs/release/connectivity_bedload_workflow/2026-08-17_R1/`.

H.1.4 Run configuration and output key

Every numerical output has a compound key:

$$(\text{run_id}, \text{scenario}, \text{model}, \text{water_year}, \text{process_reach}, \text{sample/facies}, \text{fraction}, \text{statistic}). \tag{H.1}$$

The run configuration records:

- clean-baseline manifest hash;
- source-code version/hash and execution timestamp;
- Python/package versions and operating system;
- random seed and ensemble size;
- topology, passability and source-availability scenario IDs;
- hydrological rating/gap treatment;
- geometry/slope source and window;
- roughness, stress partition and Shields specification;
- equation choice and applicability decision;
- claim class and units.

Output file names contain the stage and stable subject, not parameter values. Parameter values remain in the configuration table to avoid unmanageable names.

H.1.5 Required machine-readable outputs

Table 21 defines the minimum production package.

Table 21: Required production outputs and minimum fields.

Output	Minimum content	Principal source	Claim supported
`topology.gpkg`	Nodes, edges, branch, chainage, controls, confidence	Garmin/photos, Kastridis, UAV/RHS, SCIMABIO	Routed structural basis
`sample_fractions.csv`	Sample/facies, method, resolved fractions, censored quantiles, bootstrap	Clast and bulk tables	Observed sediment character
`hydro_water_year.csv`	Time-weighted coverage, gaps, peaks, rating status	HCMR native series	Annual forcing support
`hydro_events.csv`	Threshold/quantile event timing, peak, duration, completeness	Clean native hydrograph	Event opportunity
`site_flow_ensemble.csv`	Site coefficients, predictions and validation	Gauge, repeated and simultaneous flows	Spatial forcing estimate
`reach_geometry.csv`	Section source, width, area/radius lookup, slope windows, quality	Survey/UAV/observed corridor	Hydraulic geometry
`control_matrix.csv`	Fraction, flow class, scenario, p, evidence	Obstacle graph and storage evidence	Structural scenario
`connectivity_results.csv`	Connected area/length, C, importance and scenario	Directed graph	Fraction-specific connectivity

Table 21: Table 21 continued.

Output	Minimum content	Principal source	Claim supported
`opportunity_annual.csv`	Q_c, Q_{inund}, $Q^{\dagger}$, hours, events, J_θ, J_ω	Hydraulics + native flow	Hydraulic opportunity
`capacity_annual.csv`	Per-width and optional mapped-width capacity by model	Eligible loose patches	Potential capacity only
`m2_capacity_annual_summary.csv`	Named outer state, equation, water year, conditional quantiles, per-width and active-width capacity	Reconciled M2 surface count, accepted hydrographs and declared hydraulic assumptions	Assumption-driven, supply-unlimited M2 capacity only
`m2_delivery_scenario_summary.csv`	Capacity draw, supply multiplier, physical-transmission multiplier and dimensioned delivery quantiles	M2 capacity ensemble plus named scenario states	Possible delivery under assumptions, not actual annual yield
`whole_reach_supply_annual_summary.csv`	Water year, unweighted outer state, earth/gabion components, three-bin secondary allocation and conditional quantiles	Explicit M1–M20 source observations, nominal MoRPh footprints, gauge forcing and declared geometry/rate assumptions	Gross local corridor recruitment; not flux at HM15 or the outlet
`whole_reach_supply_source_ledger.csv`	Source module, mechanism, activity code, nominal footprint and evidence limits	Reconciled field notes and MoRPh manual	Traceable source-occurrence basis; not mapped eroding length
`whole_reach_supply_parameter_ledger.csv`	Evidence and assumption class, values/ranges, source and limitation	Full supply evidence audit	Parameter governance and claim boundary
`regional_prespa_supply_summary.csv`	Transfer state, annual transported volume, density-conditional mass and SRC three-bin texture allocation	Seven neighbouring Prespa planning estimates, adopted GIS catchment area and eight SRC samples	Regional conditional analogue; not local calibration or additive supply

Table 21: Table 21 continued.

Output	Minimum content	Principal source	Claim supported
`total_load_model_family_ledger.csv`	Source family, independence group, load scope, structural role and inclusion decision	Prespa legacy transported-volume evidence plus French Alpine, Brajčinska and Austrian context	Auditable analogue conditioning; common display does not imply common estimand or independence
`total_load_family_summary.csv`	Structural state, representative annual mass, interval semantics and claim limit	Validated Stage 05F model families	Family-specific planning quantities; no cross-family pooled central estimate
`total_load_planning_envelope_summary.csv`	Prespa core, preferred-state and French geographical-transfer sensitivity envelopes with basis fields	Named structural states and density/residual uncertainty	Representative annual planning prior; not water-year-specific or measured yield
`total_load_nonadditive_diagnostics.csv`	Local input, M20 transfer, M2 capacity, connectivity and SWAT comparison classes	Existing bounded result families	Diagnostic comparison only; values are never summed
`G4_total_load_planning_envelope.json`	Seed, arithmetic, structural-state, interval and non-additivity checks	Stage 05F outputs and configuration	Reproducible assumption-limited gate status
`T24/T25/T26 total-load tables`	Concise planning envelope, model-family summary and non-additive diagnostics	Validated Stage 05F sidecars	Report-ready values with structural and claim semantics retained
`swat_landscape_sediment_stress_test.csv`	Annual routing-unit erosion, represented area and routing-disabled flag	Current SWAT+ routing-unit and channel configuration	Uncalibrated landscape-erosion diagnostic only
`whole_reach_supply_sensitivity.csv`	Conditional driver ranks for local and regional families	Nested supply ensembles	Model-range sensitivity, not calibrated causal importance

Table 21: Table 21 continued.

Output	Minimum content	Principal source	Claim supported
`G4_whole_reach_supply.json`	Automated reconciliation, scope and claim-boundary checks	Stage 05C outputs and configuration	Assumption-limited gate status
`passage_storage.csv`	Grain contrasts, store area, persistence and registration error	HM13–HM15 samples/imagery	Structure/store diagnosis
`mountain_opportunity.csv`	High-flow hours/events, power and connected length	Mountain flow/geometry/graph	High-flow transfer opportunity
`granite_front.gpkg`	Presence/absence, size, date, confidence and censored front	Photos, samples and lithology	Realised coarse-connectivity tracer
`sensitivity.csv`	Input, rank/effect, model variance and convergence	Nested ensemble	Uncertainty attribution
`claim_audit.csv`	Result, claim class, valid wording, prohibited wording	All final outputs	Reporting control

H.1.6 Required figures

The final results report should contain, at minimum:

1. catchment/process-domain map with gauge, modules, sources, stores and controls;
2. routed source–transfer–store graph with branch identities;
3. data-assimilation/QA flowchart;
4. representative mountain, lower-alluvial, HM14 and HM13/M19–M20 photo panels;
5. separate surface-count and bulk-mass GSD figures with uncertainty;
6. native hydrograph showing cadence/rating periods, gaps and accepted water years;
7. time-weighted annual flow-duration curves;
8. Laimos cross-section, geometry functions and current-meter validation;
9. site-flow transfer and abstraction/loss diagnostics;
10. process-reach slope/window and width/inundation evidence;
11. $\theta(Q)$ and $Q^{\dagger}$ distributions for D50/D84;
12. annual competent hours, events and integrated excess forcing;
13. per-unit-width Wong–Parker/Recking model comparison for the eligible sampled M2 loose patch, with outer hydraulic states and equations kept separate;
14. whole-reach source-evidence architecture, local conditional gross- recruitment distributions and independent regional/SWAT context;
15. analogue-conditioned representative annual total transported-load envelope with structural states, preferred-state uncertainty and a separate independent French Alpine geographical-transfer sensitivity family;
16. passage/store grain contrasts and multi-date store change;
17. size-specific graph maps under pessimistic, central and optimistic event scenarios;
18. mountain high-flow opportunity and connected-length scenarios;
19. granite-front interval by size/date;
20. global sensitivity ranking; and
21. final diagram separating opportunity, capacity, connected delivery and measured yield.

H.1.7 Reproducibility and archive release

A release directory contains only generated outputs, configuration, logs and the report; raw inputs remain referenced by hash. The release is complete when:

- Stage 00 validation is `pass`;
- every table/figure can be regenerated from a documented command;
- numerical tables and plotted data share the same run ID;
- PDF table/figure captions contain claim class and uncertainty meaning;
- no output depends on the withdrawn legacy mobility/capacity CSVs;
- the report compiles from a clean `build/` directory; and
- the release manifest includes source and output hashes.

H.2 Confidence and appropriate use

H.2.1 Field coverage and representativeness

The July observations target priority reaches and controls rather than a spatially balanced probability sample of the entire network. M1–M20 provide dense evidence in the engineered corridor, while M21–M25 are sparse mountain representative observations with one or a few photographs at several sites. They are independent sites, not a routed module sequence. The mountain parent domain is strongly supported by user, HCMR and SCIMABIO evidence, but local cover abundance and pocket frequency are not measured continuously.

The current master contains 214 reconciled photo records; 213 unique filenames resolve to locally recoverable image assets and one M15 record has no filename. The archive also contains repeated physical copies within cumulative field packages; those copies are not additional observations. Any new association requires filename, date and location evidence and is not assigned by visual expectation alone.

Surface counts represent selected deposits/pockets. Small counts at M7–M9 and M12 give count uncertainty and cannot quantify reach spatial variability. M19 and M20 intentionally sample stores. M2 has a robust percentile sensitivity but unresolved grid-to-bar/island facies mapping. The bootstrap cannot create spatial representativeness that the sampling design did not collect (Bunte and Abt, 2001).

H.2.2 Sediment resolution

Bulk sieves stop at 2 mm. The substantial < 2 mm fraction remains one unresolved observed mass class. The analytical record therefore reports the supported sieve fractions and keeps suspended-mode composition outside their interpretation.

No clast lithology tally was designed in the original sample table. The granite front must be reconstructed from photographs and remaining sample material, with observer confidence and censored intervals.

H.2.3 Topology and spatial geometry

M13/M14 branch structure is explicit, with M12 retained as the downstream HM14 tailwater and M11 retained as the next downstream module. M12 has no precise topology chainage because its nearest physical reference-route projection contradicts the field topology. Final reconnection of all M15–M18 multithread limbs requires the UAV plates and observed centreline. M22 remains a medium-confidence assignment near the Giovanitsa–Gaidouritsa confluence; M24 is retained as a probable Gaidouritsa observation. Neither is forced into a module-number sequence.

The UAV/RHS products available in the project are flattened plates rather than the raw orthophoto, DSM and vector delivery. Georeferencing introduces error that must be included in width, store-area and change estimates. The surveyed cross-section is at Laimos; transfer to lower process reaches requires section shape/roughness scenarios. Field widths are wetted/limb observations and are not bankfull or mobile-patch widths.

The 20 m ORP DEM and approximately 26.35 m Copernicus surface are too coarse for step, ford or short-module energy slope. The existing DEM-derived lower channel is offset 70–317 m. Process-reach slopes remain low/medium confidence unless UAV or engineering elevations can be recovered.

The three 10 August RTK packages provide dense local point coverage around the passages under a diagnostic EPSG:2100 interpretation. Their present use is contextual because survey

date/provider issue, declared horizontal and vertical reference systems, control/accuracy information, feature codes and breaklines are absent. The HM13 duplicate records, HM14 precision block and HM15 elevation and identifier anomalies are isolated transparently rather than repaired by inference. A filtered triangulation can guide manual review, but it is not an accepted bed/embankment surface and does not support passage drops, removal volumes, lake-level comparisons, hydraulics or change through time at this evidence cut.

H.2.4 Hydrological forcing

The HCMR record changes cadence. The interval 1 June 2023–31 July 2024 is excluded as a known rating/sensor-malfunction period; WY2025 has a long gap and WY2026 is partial. Only WY2021 and WY2022 pass the primary annual gauge high-flow rules, and WY2021 passes narrowly. Logger stage and logger discharge may not be independent if discharge was produced from the same rating curve. The current-meter measurements and repeated SPP flows are therefore essential independent checks before hydraulic transfer beyond the gauge.

Repeated tributary/site flows are sparse relative to flood dynamics. Site hydrographs are modelled predictions with substantial uncertainty. Abstraction, channel exchange and ungauged inflow prevent unqualified drainage-area scaling. SWAT+ water routing may support interpolation. Its landscape/routing-unit erosion fields are non-zero, but channel sediment routing is disabled and all channel sediment flux/storage fields are zero. Sediment was not calibrated, so neither output family supplies sediment calibration or validation.

H.2.5 Hydraulic and transport equation limits

Normal-flow hydraulics are approximations in a nonuniform, vegetated and structure-rich channel. Stress partition between grains, wood, banks, bars and large roughness is a dominant uncertainty. A gross-slope calculation overstates grain stress where form drag is large.

The Wong–Parker/MPM and Recking equations are supply-unlimited predictors with specific calibration domains (Wong and Parker, 2006; Recking, 2013). Their application at eligible lower loose patches is a sensitivity analysis, not local calibration. They are excluded from:

- bedrock–boulder mountain framework reaches;
- rapidly varied ford crest/tailwater zones;
- the M20 proximal coarse store and M19 distal stratified store;
- wood-forced multithread reaches without resolved limb hydraulics;
- sampled bars whose inundation and mobile width are not constrained.

Even at an eligible patch, potential capacity is not actual transport if the patch is exhausted, armoured, not replenished or disconnected downstream.

H.2.6 Structure and storage interpretation

Coarse material in M20 below HM13 is consistent with one or more event- transmission pathways but does not demonstrate passage, identify the source or quantify transmission efficiency. M20 is the proximal coarse store and M19 the distal sorting store; their sequence does not quantify how much material was retained. Deposit persistence/area change does not give mass without thickness, porosity and density. The field hypothesis of momentum-driven stones crossing the passage is testable but remains a hypothesis.

Similarly, an apparent upstream/downstream grain contrast may reflect different sample facies, local bank/protection inputs, wood, selective inundation or prior events. Contrast tables retain sample role and do not automatically attribute causation to the passage.

H.2.7 Whole-reach supply-scenario limits

The local annual-supply extension is assumption-led. Source presence and activity class are observed at selected modules, but physical eroding length, active height, annual retreat, number of active banks, bulk density and direct recruitment fraction are not measured. Nominal MoRPh footprints and the 4.2 coverage multiplier are modelling devices, not mapped source lengths or a statistically valid probability-sample expansion. The approximately 7 m embankment description is not evidence that a 7 m face erodes annually.

The gauge excess-volume term distinguishes accepted WY2021/WY2022 forcing, but there is no paired bank-position record to calibrate the exponent or annual retreat response. SRC samples constrain three source-material classes (< 2, 2–19 and > 19 mm) only under a texture-transfer assumption. They do not measure bank material or annual production. Only two of eight SRC samples have a 50 mm threshold, so a 19–50/> 50 split is prohibited.

The Prespa analogue has regional value but is a planning-model transported- volume range whose sediment mode, calibration and outlet definition are not resolved. Its transfer factor and volume-to-mass density are assumptions. The SWAT+ 169–302 kt yr^{-1} landscape result is not an outlet prediction: channel sediment parameter links and routing/degradation switches are inactive, and channel sediment outputs are zero. Neither external family is added to the local input result because their source domains overlap.

The analogue-conditioned total-load envelope improves planning context but does not remove those limitations. Its Prespa rate states are structural alternatives with no fitted probabilities; its within-state q05–q50–q95 values propagate dry-bulk-density conversion rather than observed annual variability. The preferred state is a declared comparability choice, not a most-likely measured load. Brajčinska belongs to the same Prespa evidence family and cannot be treated as an independent replicate. The French Alpine family has different lithology, morphology, hydrology and modelling assumptions; its 20,769–175,767 t yr^{-1} dispersion is retained only as an independent geographical-transfer sensitivity comparison.

H.2.8 Annual-yield interpretation boundary

The project contains no continuous suspended-sediment concentration, bedload sampler/trap, repeat deposit volume with density, or calibrated sediment rating curve at the outlet. Consequently, an annual tonne value can only be a potential-capacity or conditional source/analogue scenario. It cannot be labelled actual yield. The planning prior can be reported as a representative annual total transported-load envelope under named analogue states, but not as mass observed in WY2021, WY2022 or an average monitoring year. The absence of new measurement capacity does not invalidate the workflow; it determines the permitted claim. Conformal prediction is unavailable because there are no observed annual sediment-yield labels or residuals with which to calibrate coverage.

H.2.9 Existing-data controls

Table 22: Principal limitations and existing-data mitigation.

Limitation	Mitigation	Residual claim
Sparse independent mountain modules	Combine field-lead domain interpretation with HCMR/SCIMABIO routes, obstacles and photos	Domain/gauge-relative high-flow opportunity only after site-flow gates; not framework mobility or reach mass
No lower cross-sections	Georeference UAV plates; use section ensembles and field limb widths	Conditional hydraulic opportunity
Coarse/offset DEM	Correct observed centreline; multiple slope sources/windows	Slope scenario envelope
Sparse site flow	Paired regression, mass balance, abstraction and SWAT-water sensitivity	Predicted site-flow ensemble
No sediment flux	Separate opportunity, capacity, gross local-input and connectivity metrics	No actual yield
No mapped source geometry/retreat	Nominal MoRPh footprint, explicit coverage and conditional rate/height states	Assumption-driven gross local supply simulation evaluated before comparison with observed annual load
Regional transfer uncertain	Keep Prespa transported-volume analogue independent and expose transfer/density assumptions	Regional context, not local calibration or additive supply
Analogue-conditioned total-load prior	Separate unweighted Prespa states, within-state density quantiles and the independent French geographical-transfer sensitivity family	Representative annual planning envelope; not measured yield, probability interval or additive budget
SWAT channel sediment disabled	Retain non-zero landscape erosion only as an uncalibrated landscape-erosion diagnostic	No SWAT channel supply or outlet yield
Store thickness absent	Area/persistence/Jaccard metrics with registration error	Relative storage evidence
Barrier efficiency absent	Discrete fraction/flow scenarios and importance analysis	Structural sensitivity, not calibrated efficiency

H.3 Publication revisions and reproducibility

The final R7 package retains copies of the complete R1 numerical inputs and analytical figures. R2 changes the English and Greek communication, corrects the tributary schematic, replaces the old catchment outline with the union of the accounting subbasins, and adds the full M1–M25 locator. It does not recalculate the analytical baseline or promote a new survey interpretation. R3 adds the fuller drainage context and the response to the September review. R4 explains the trap failures and the role of estimates and uncertainty ranges. R5 incorporates the completed visual corrections and clean delivery organisation. R6 clarifies the completed appraisal scope and the complementary role of trap measurements. The report date is 30 September 2026; editorial changes are recorded separately in the delivery record. The portable source in `06_Editable_Source/English` includes the TeX sections, copied values, figures and `build_signoff.ps1`. That script compiles the R7 volumes with `pdflatex-dev`; the package manifest records the delivered identities. The commands below reproduce the historic R1 publication and are retained for analytical provenance, not as instructions to overwrite a circulated issue.

H.4 R1 revised-publication regeneration

From the repository root, the authoritative route builds and audits an isolated staging package first:

Controlled submission build

```
$m = "projects/morphology"
$submit = "$m/src/submission/build_submission.py"
$spec = "$m/deliverables/specs/2026-08-17_R1_revised.toml"
uv run --no-project python $submit --spec $spec
```

After the staged bytes and all acceptance gates have been independently reviewed, the explicit promotion command validates the same manifests and hashes again and refuses a non-empty destination:

Controlled promotion

```
uv run --no-project python $submit --spec $spec --promote
```

For component-level technical-volume QA, rebuild the shared values and catalogues, then compile this volume:

Commands

```
$inputs = "$m/reports/shared/build_publication_inputs.py"
$tech = "$m/reports/technical_appendices/build_report.ps1"
uv run --no-project python $inputs --release-id 2026-08-17_R1_revised
powershell -ExecutionPolicy Bypass -File $tech
```

The input builder rejects any publication identity other than `2026-08-17_R1_revised`. It reads the exact analytical, hydrology and topography releases named in document control; it never resolves an implicit alias or a receipt-stage path. A standalone report build runs the input builder first. The submission orchestrator may use `-SkipPublicationInputBuild`; that mode validates the pinned release-status file and every publication-input manifest hash before compilation, so both PDFs consume one shared build.

H.5 Recorded software environment

The frozen stage run metadata record Python `3.11.15` on `Windows-10-10.0.26200-SP0`. The JSON files in `projects/morphology/outputs/release/connectivity_bedload_workflow/2026-08-17_R1/logs/` are the authority for each stage's script, interpreter, platform, input hashes and output hashes. They should be read with the parameter ledgers, registered seeds and draw counts. The evidence cut does not contain a complete Python package lock or environment export, so R1 supports deterministic regeneration against the recorded inputs and code stages but does not claim package-exact environment reproduction.

H.6 Shared publication-value control

Both report volumes consume `publication_values.tex`. Component files retain the same generated values for targeted inspection. A release-local manifest hashes all governed inputs, generated macros, registers and TeX catalogue fragments. This removes the former dependency

in which the technical report imported generated files from the consultancy-report directory.

I Evidence archive and visual-output catalogue

The archive summary is generated from release-local manifests. It records the controlled analytical and RTK context holdings referenced by this final issue without reproducing raw source data or treating a PDF thumbnail as analytical authority. The communication layer contains the complete revised MR00–MR18 suite; MR14–MR18 expose the bulk-sieve evidence, corridor sampling framework, four accounting boundaries, bank/gabion calculation and external Alpine context in the lean study.

I.1 Immutable release inventory

Release	Files	Size	Role
2026-08-17_R1	246	166.8 MB	Analytical tables, plotted data, figures, QA and run metadata
2026-08-10_R1_context_only	41	15.8 MB	Context-only RTK evidence-association and coverage release
2026-07-29_v3_18	17	7.6 MB	Pinned hydrology handoff: gauge, calibration, spatial, model and released products

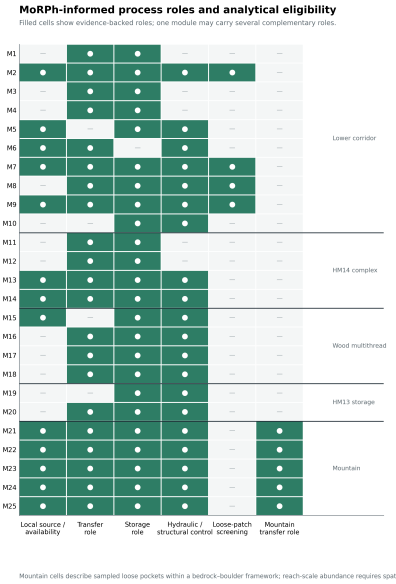
Analytical category	Files	Size (MB)
data	102	125.7
figures	72	38.8
gis	2	1.4
logs	14	0.1
qa	26	0.3
release_root	1	0.0
tables	29	0.4

I.2 Archive controls

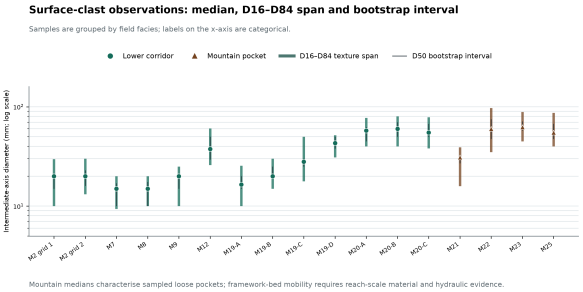
Each manifest row records a release-relative path, byte size and SHA-256 digest. The calculation reconciliation register points to exact table filters; the visual-output register connects each governed figure ID to its released master, sidecar and review gate. Source data remain in their governed locations and are not copied into this PDF.

I.3 Visual-output inventory

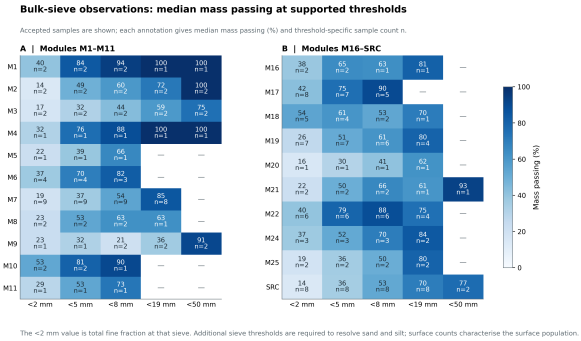
The governed register contains 64 entries. These contact sheets provide navigation thumbnails; each panel links to its full-size PDF in `08_Full_Size_Figures/Figures`. The 35-panel figure atlas with acknowledgement cover collects the same panels for offline reading. The final issue improves presentation; frozen R1 tables remain the numerical authority. Original register paths retain their provenance role.



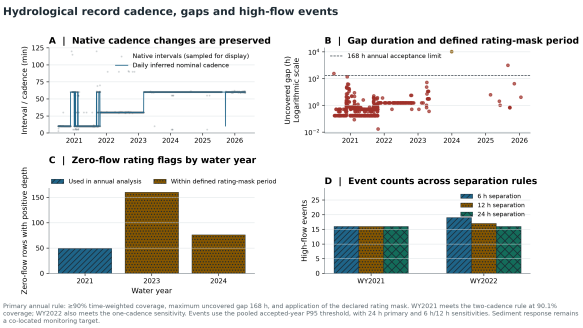
AF02: Complete MoRPh evidence matrix



AF03: Surface-count bootstrap atlas

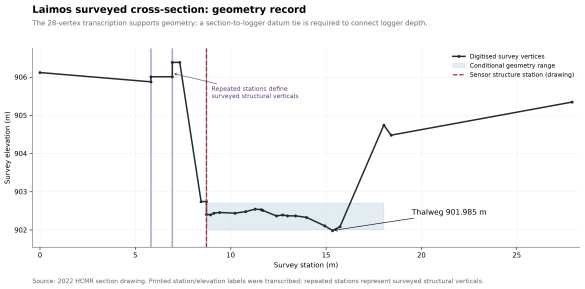


AF04: Bulk-sieve QA atlas

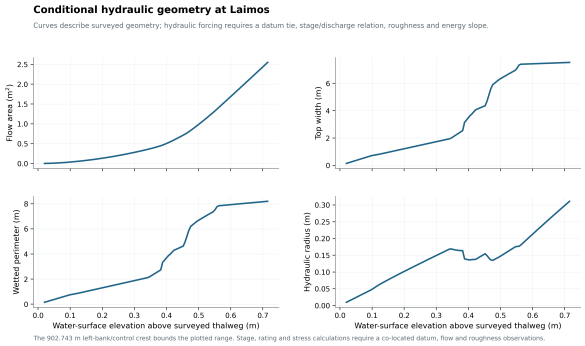


AF05: Hydrological cadence, gaps and event separation

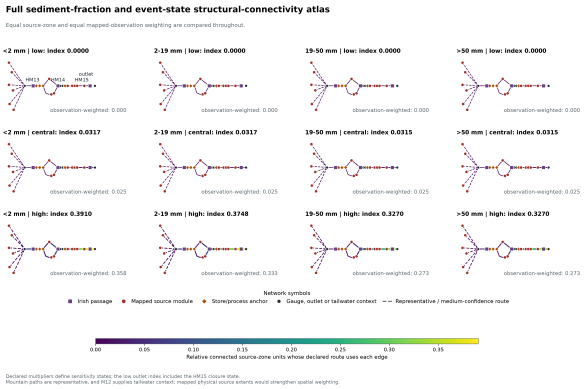
Figure 15: Archive visual-output contact sheet 1. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



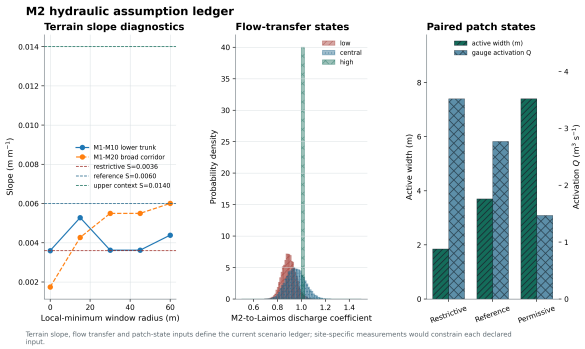
AF06: Digitised Laimos cross-section



AF07: Conditional cross-section hydraulic geometry

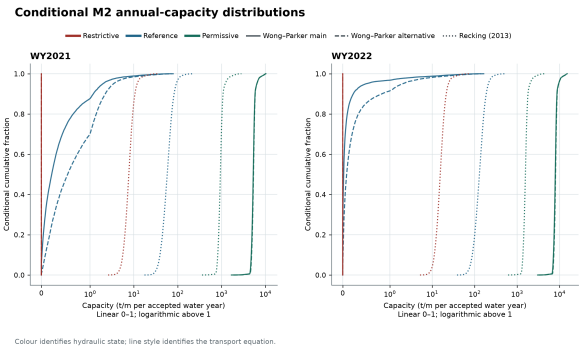


AF09: Full fraction-by-scenario connectivity atlas

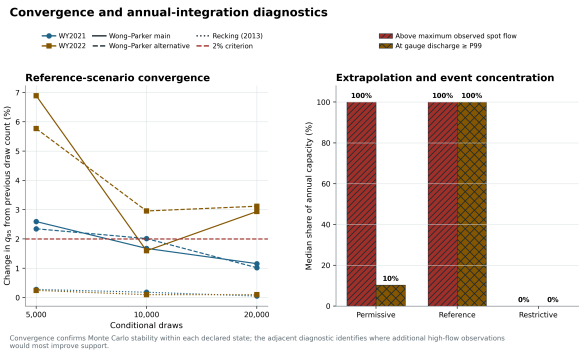


AF10: M2 hydraulic assumption diagnostics

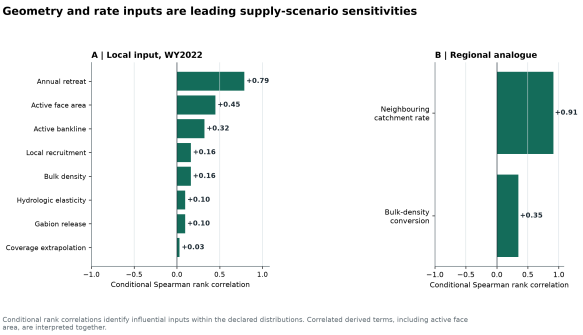
Figure 16: Archive visual-output contact sheet 2. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



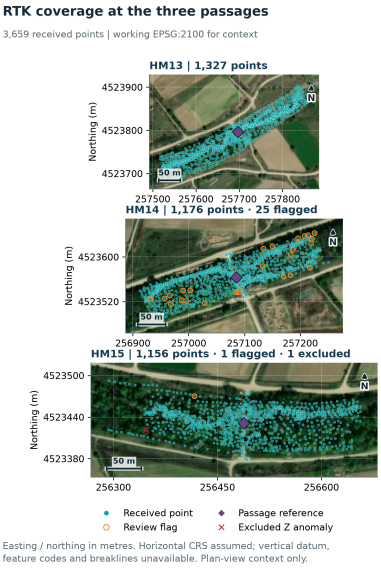
AF11: Conditional M2 annual-capacity distributions



AF12: M2 convergence and annual-integration diagnostics

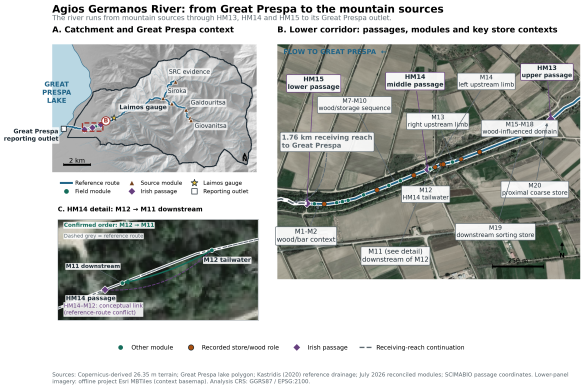


AF21: Whole-reach supply uncertainty drivers

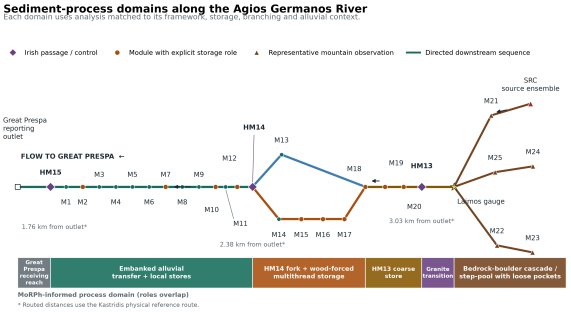


AF22: RTK imagery coverage context

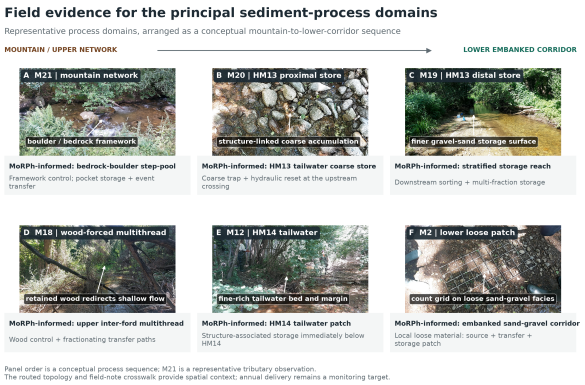
Figure 17: Archive visual-output contact sheet 3. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



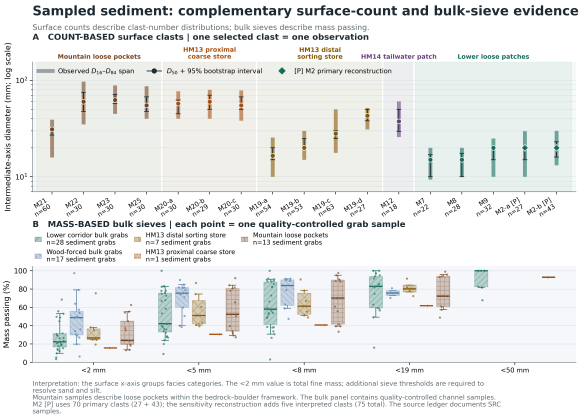
F01: How is the sediment system organised?



F02: How does river morphology change downstream?

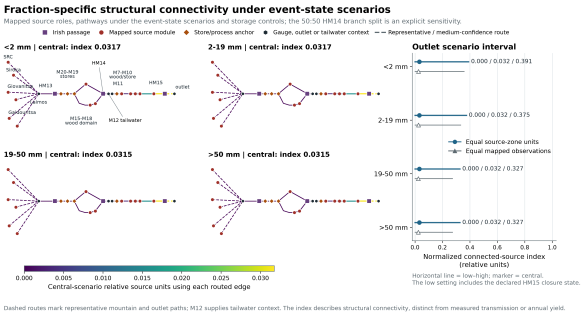


F03: What do the process domains look like?

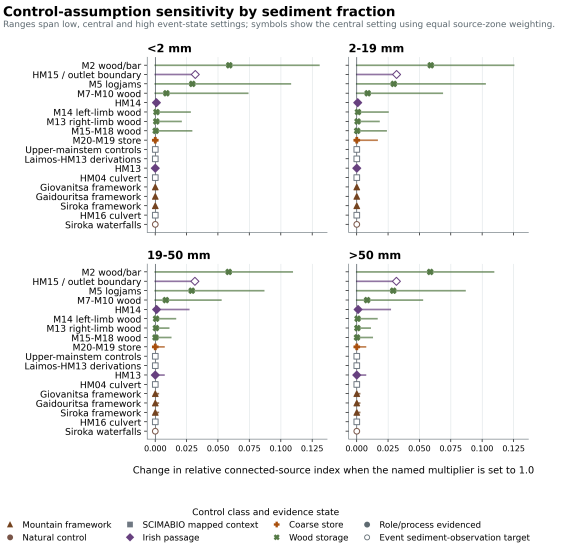


F04: What sediment was actually sampled?

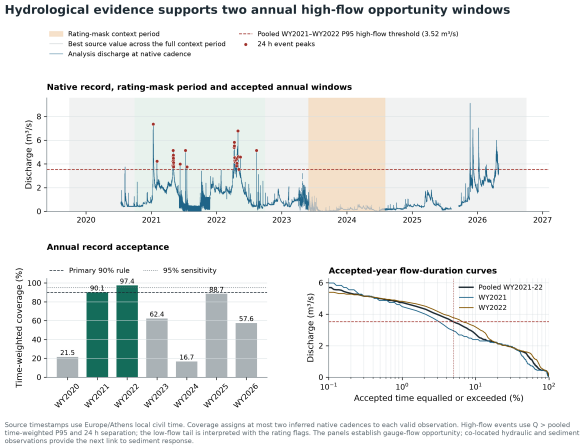
Figure 18: Archive visual-output contact sheet 4. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



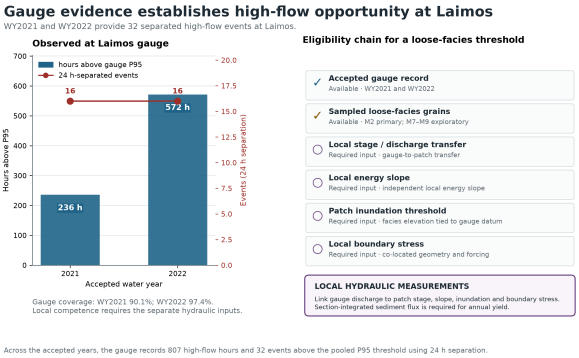
F05: Which sediment fractions remain connected?



F06: Which controls most affect connectivity?

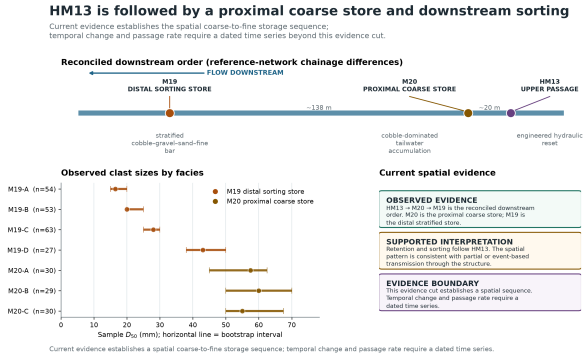


F07: Which hydrological periods support annual analysis?

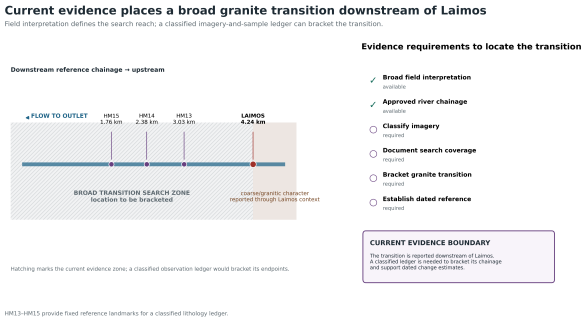


F08: Gauge-record eligibility at Laimos

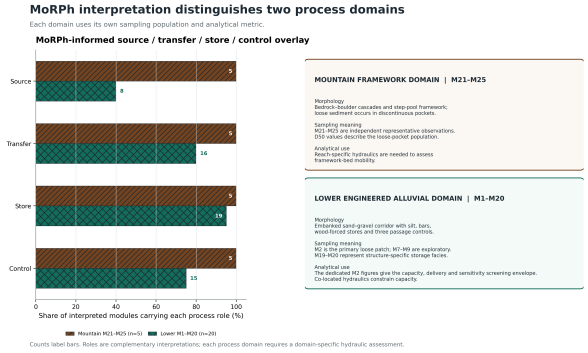
Figure 19: Archive visual-output contact sheet 5. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



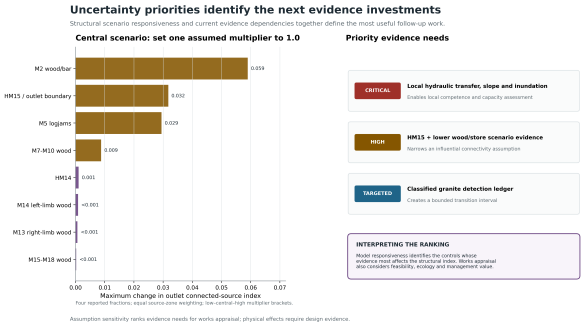
F09: How do passages transmit and store material?



F10: Where does coarse granitic material disappear?

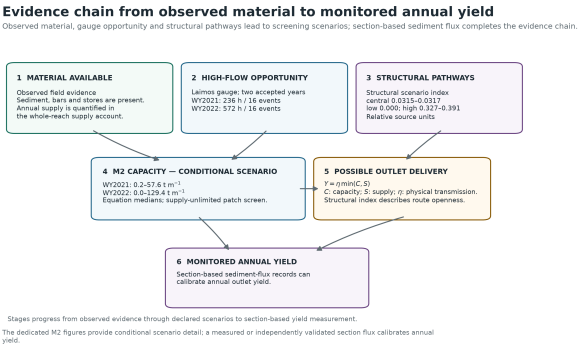


F11: How do mountain and lower domains differ?

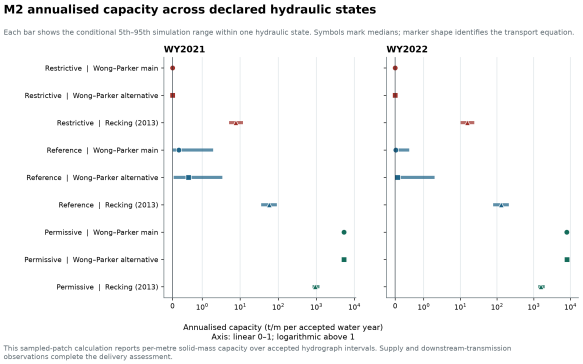


F12: What controls uncertainty and management relevance?

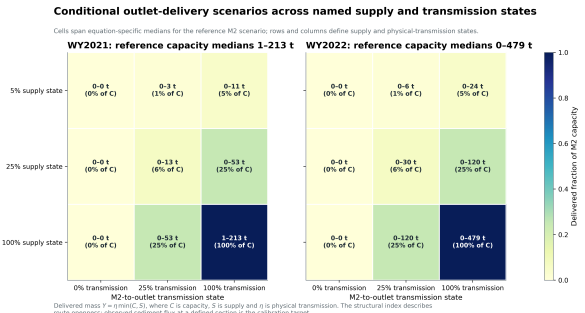
Figure 20: Archive visual-output contact sheet 6. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



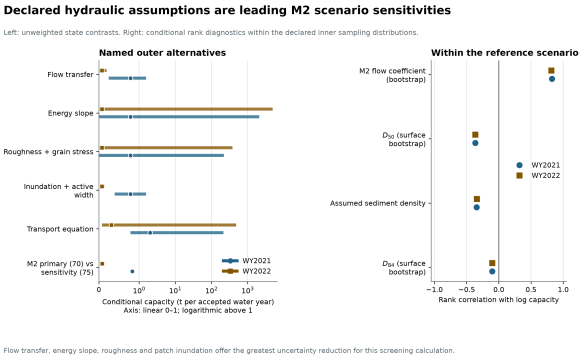
F13: What can and cannot be concluded?



F14: How large is the assumption-driven M2 capacity envelope?

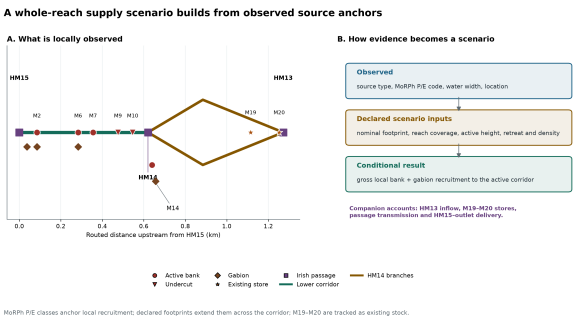


F15: How do assumed supply and physical transmission constrain possible outlet delivery?

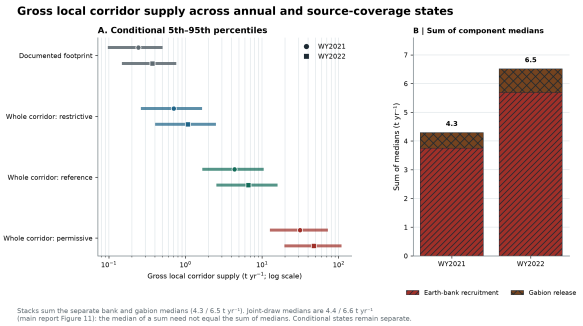


F16: Which assumptions dominate the M2 scenario envelope?

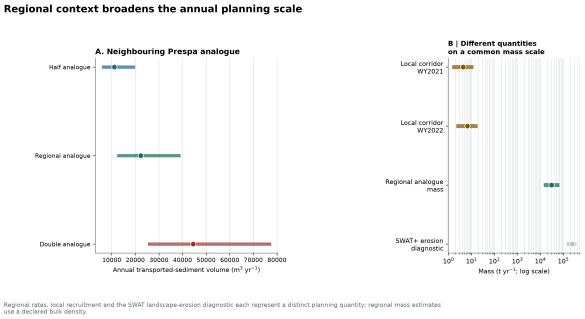
Figure 21: Archive visual-output contact sheet 7. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



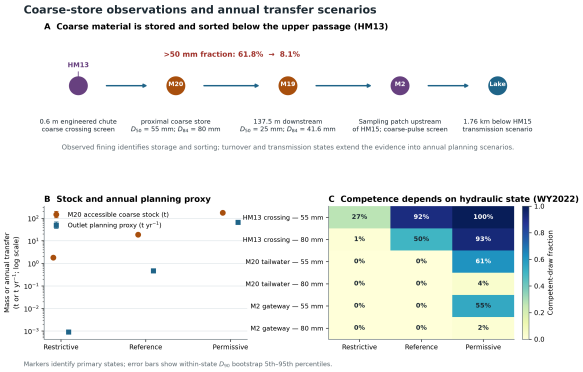
F17: What whole-reach source evidence is actually observed?



F18: How much material could the observed corridor sources recruit annually?

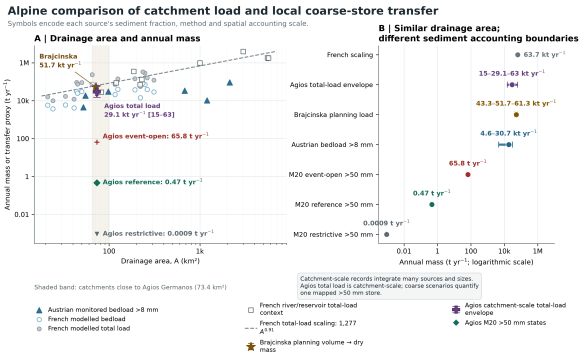


F19: What does nearby Prespa evidence imply for catchment-scale transported sediment?

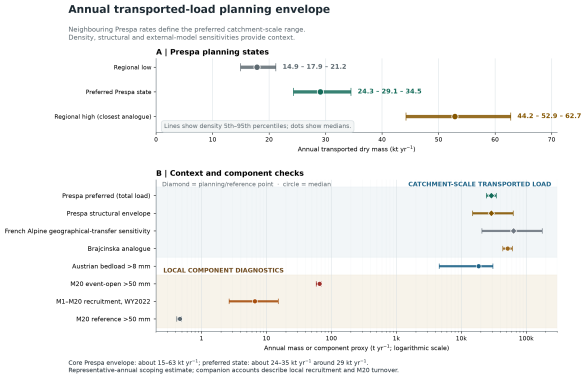


F20: Existing-data coarse-store and coarse-pulse planning evidence

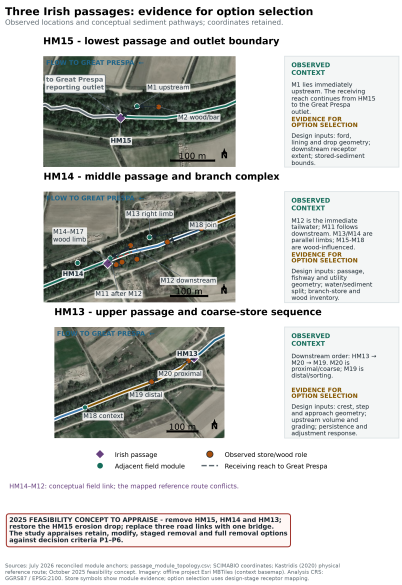
Figure 22: Archive visual-output contact sheet 8. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.



F21: Alpine yield context and accounting-boundary comparison



F22: Analogue-conditioned total transported-load planning envelope



F23: Where are the three Irish passages and what evidence guides action?

Figure 23: Archive visual-output contact sheet 9. Click a panel for its full-size PDF. The complete atlas is in folder 08; frozen data sidecars control numerical interpretation.

I.4 Visual-output register

Table 23: Governed visual outputs, execution state and sidecar status.

ID	Registered purpose	Execution / QA	Sidecar status
MR00	From mountain sources to Great Prespa	produced	frozen release
MR01	Catchment and Great Prespa setting	produced	not applicable
MR02	River character changes downstream	produced	not applicable
MR03	Surface-clast evidence	produced	frozen release
MR04	High-flow opportunity is recurrent	produced	frozen release
MR05	M2 capacity depends strongly on transport model	produced	frozen release
MR06	Modelled annual input from lower-corridor banks and failing gabions	produced	frozen release
MR07	Prespa-derived catchment planning estimate	produced	frozen release
MR08	The three passages occupy different geomorphic settings	produced	not applicable
MR09	RTK coverage provides dense local context	produced	frozen release
MR10	HM13 storage sequence anchors the appraisal	produced	not applicable
MR11	HM14 passage and branch routing form one design unit	produced	not applicable
MR12	HM15 receiving reach sets the lakeward design boundary	produced	not applicable
MR13	The study provides the platform for formal restoration design	produced	frozen release
MR14	Bulk-sieve evidence	produced	frozen release

Table 23: Governed visual outputs, execution state and sidecar status (continued).

ID	Registered purpose	Execution / QA	Sidecar status
MR15	Irish-passage and sampling corridor	produced	not applicable
MR16	Four quantitative accounting boundaries	produced	frozen release
MR17	Bank and gabion evidence-to-calculation	produced	frozen release
MR18	Alpine context	produced	frozen release
AF01	Clean-data assimilation and QA flow	not produced fail soft or not required	working reference not submitted
AF02	Complete MoRPh evidence matrix	produced pass with stated limits	working reference not submitted
AF03	Surface-count bootstrap atlas	produced pass with stated limits	working reference not submitted
AF04	Bulk-sieve QA atlas	produced pass with stated limits	working reference not submitted
AF05	Hydrological cadence, gaps and event separation	produced pass with stated limits	working reference not submitted
AF06	Digitised Laimos cross-section	produced pass with stated limits	working reference not submitted
AF07	Conditional cross-section hydraulic geometry	produced pass with stated limits	working reference not submitted
AF08	Spatial flow and abstraction diagnostics	not produced fail soft or not required	working reference not submitted
AF09	Full fraction-by-scenario connectivity atlas	produced pass with stated limits	working reference not submitted
AF10	M2 hydraulic assumption diagnostics	produced assumption driven scenario	frozen release
AF11	Conditional M2 annual-capacity distributions	produced assumption driven scenario	frozen release

Table 23: Governed visual outputs, execution state and sidecar status (continued).

ID	Registered purpose	Execution / QA	Sidecar status
AF12	M2 convergence and annual-integration diagnostics	produced assumption driven scenario	frozen release
AF13	Ford sample-comparison atlas	not produced fail soft or not required	working reference not submitted
AF14	Store registration and minimum detectable change	not produced fail soft or not required	working reference not submitted
AF15	Wood-reach flow-split and form-drag scenarios	not produced fail soft or not required	working reference not submitted
AF16	Mountain high-flow opportunity atlas	not produced fail soft or not required	working reference not submitted
AF17	Historical unexecuted figure registration	not produced fail soft or not required	working reference not submitted
AF18	Routed fining and sorting atlas	not produced fail soft or not required	working reference not submitted
AF19	Historic planform and intervention chronology	not produced fail soft or not required	working reference not submitted
AF20	Integrated connected-delivery components	not produced fail soft or not required	working reference not submitted
AF21	Whole-reach supply uncertainty drivers	produced assumption driven scenario	frozen release
AF22	RTK imagery coverage context	produced context only survey qa	frozen release
F01	How is the sediment system organised?	produced pass with stated limits	working reference not submitted
F02	How does river morphology change downstream?	produced pass with stated limits	working reference not submitted
F03	What do the process domains look like?	produced pass with stated limits	working reference not submitted
F04	What sediment was actually sampled?	produced pass with stated limits	working reference not submitted

Table 23: Governed visual outputs, execution state and sidecar status (continued).

ID	Registered purpose	Execution / QA	Sidecar status
F05	Which sediment fractions remain connected?	produced draft scenario pending formal review	working reference not submitted
F06	Which controls most affect connectivity?	produced draft scenario pending formal review	working reference not submitted
F07	Which hydrological periods support annual analysis?	produced pass with stated limits	working reference not submitted
F08	Gauge-record eligibility at Laimos	produced with explicit unresolved result	working reference not submitted
F09	How do passages transmit and store material?	produced pass with stated limits	working reference not submitted
F10	Where does coarse granitic material disappear?	produced with explicit unresolved result	working reference not submitted
F11	How do mountain and lower domains differ?	produced pass with stated limits	working reference not submitted
F12	What controls uncertainty and management relevance?	produced pass with stated limits	working reference not submitted
F13	What can and cannot be concluded?	produced with explicit unresolved result	not applicable
F14	How large is the assumption-driven M2 capacity envelope?	produced assumption driven scenario	frozen release
F15	How do assumed supply and physical transmission constrain possible outlet delivery?	produced assumption driven scenario	frozen release
F16	Which assumptions dominate the M2 scenario envelope?	produced assumption driven scenario	frozen release
F17	What whole-reach source evidence is actually observed?	produced assumption driven scenario	frozen release
F18	How much material could the observed corridor sources recruit annually?	produced assumption driven scenario	frozen release
F19	What does nearby Prespa evidence imply for catchment-scale transported sediment?	produced assumption driven scenario	frozen release

Table 23: Governed visual outputs, execution state and sidecar status (continued).

ID	Registered purpose	Execution / QA	Sidecar status
F20	Existing-data coarse-store and coarse-pulse planning evidence	produced assumption driven scenario	frozen release
F21	Alpine yield context and accounting-boundary comparison	produced contextual non equivalent comparison	frozen release
F22	Analogue-conditioned total transported-load planning envelope	produced planning prior with structural uncertainty	frozen release
F23	Where are the three Irish passages and what evidence guides action?	produced passage action context	not applicable

I.5 Analytical dictionaries and controlled ledgers

The following generated copy preserves the complete data dictionary, grain-statistics specification, module/process register, initial parameter register, reproducibility paths and final claim-audit vocabulary from the analytical record. Release references are resolved to the dated R1 snapshot.

I.6 Core Data Dictionary

Table 24: Core analysis fields (part 1 of 2).

Field	Type / units	Definition
`module`	text	Canonical field identifier M1–M25 or SRC
`river`	category	Routed watercourse assignment and confidence
`branch_id`	text	Directed limb/branch identifier; M13 and M14 differ
`chainage_m`	m	Routed distance along a defined river/branch datum
`process_domain`	category	Equation-eligibility and morphology domain
`reach_control`	category	Alluvial, wood, structure, bedrock/boulder or source control
`sample_code`	text	Stable field/laboratory sample or count identifier
`sample_facies`	category	Active bed, bar, island unresolved, tailwater store, pocket or source
`sample_role`	category	Source, transfer material, store or framework/context
`method`	category	Surface b-axis count or bulk sieve 2–50 mm
`include_in_primary`	boolean	Primary analysis inclusion after QA
`qa_status`	text	Accepted/correction/exclusion reason; raw record retained
`observation_status`	category	Explicit, absence, inferred, copied background or not recorded

Table 25: Core analysis fields (part 2 of 2).

Field	Type / units	Definition
evidence_basis	text	Note, photo, sample, map/report and/or user reconciliation
confidence	ordinal	High, medium or low with reason
water_width_m	m	Recorded wetted/limb width; never assumed total corridor width
water_width_scope	category	Wetted channel, main limb, left/right limb or not measured
water_width_quality	category	Measured, approximate, multithread not measured or missing
control_id	text	HM/N/AG or derived control node identifier
relative_position	category	Upstream, downstream, at, near or unknown relative to control
store_type	category	Pocket, bar, island, wood wedge, backwater, wedge or tailwater
alluvial_cover	category	Continuous, patchy, pocket/discontinuous or unknown
fraction	category	< 2, 2–19, 19–50, > 50 mm or framework
flow_class	category	Low flow, specified quantile/event or observed event ID
scenario	text	Topology/source/passability/branch scenario key
claim_class	category	Opportunity, capacity, connected potential or actual yield

I.7 Surface-Count Statistics and Bootstrap

For sorted b-axis measurements $x_{(1)}, \ldots, x_{(n)}$, the clean baseline uses the Hyndman–Fan type-7 sample quantile. For probability p,

$$h = (n-1)p + 1, \qquad j = \lfloor h \rfloor, \qquad \gamma = h - j, \tag{I.1}$$

$$\widehat{D}_p = (1-\gamma)x_{(j)} + \gamma x_{(j+1)}, \tag{I.2}$$

with boundary handling at $j = n$. The primary statistics are D_{16}, D_{50}, D_{84} and D_{90}. The geometric sorting index used for description is

$$\sigma_g = \sqrt{\frac{D_{84}}{D_{16}}}, \tag{I.3}$$

when both percentiles are positive.

For module m with replicate counts r:

1. sample R_m replicate IDs with replacement;
2. for every selected replicate, sample its n_r clasts with replacement;
3. calculate replicate and pooled descriptive percentiles;
4. retain the facies/replicate identity in the bootstrap result;
5. repeat for the configured number of iterations and test convergence.

The pooled result is used only as a module-level descriptive view. Hydraulic eligibility is assessed at the sample/facies level.

I.8 Module Process and Sample Register

Table 26: Reconciled module process role and permitted analytical use.

ID	River/domain	Morphology/role	Sample interpretation	Permitted use
M1	Agios Germanos / lower inter-ford	Sand–gravel transfer with local stores; upstream of HM15	Bulk sample; no surface count	Morphology/fraction description only
M2	Agios Germanos / lower inter-ford	Bar/island, wood, erosion and scour	Two unresolved bar-or-island grids; 70 primary + 5 sensitivity; bulk	Primary loose-patch opportunity with inundation/mobile-width scenarios
M3	Agios Germanos / lower inter-ford	Sand–gravel with side bar	Bulk sample	Fraction/store description
M4	Agios Germanos / lower inter-ford	Depositional bar/store	Bulk sample	Fraction/store description
M5	Agios Germanos / lower inter-ford	Two log jams; bank-side protection clasts	Bulk sample; boulders likely protection	Wood/store and local engineered-source diagnosis
M6	Agios Germanos / lower inter-ford	Active bank erosion and failing gabion	Bulk samples	Local source coupling and fraction description
M7	Agios Germanos / lower inter-ford	Island/logjam split, scour, deposition and fine drape	Small surface count plus bulk samples	Exploratory patch opportunity with inundation

Table 26: Module process register continued.

ID	River/domain	Morphology/role	Sample interpretation	Permitted use
M8	Agios Germanos / lower inter-ford	Approx. main limb, gravel side bar and woody margin	Small side-bar count plus bulk	Exploratory patch opportunity with inundation
M9	Agios Germanos / lower inter-ford	Central/side gravel deposits and undercut	Small deposit count plus bulk	Exploratory patch opportunity with inundation
M10	Agios Germanos / lower inter-ford	Logjam pool and downstream fine store	Bulk samples	Fine-store and wood-control diagnosis
M11	Agios Germanos / below HM14	Next module downstream of M12; coarser gravel near second passage	Bulk sample	Descriptive lower-trunk context retained in the M12–M11–M10 route
M12	Agios Germanos / HM14 tailwater	Coarse downstream patch and field-called island	18-clast tailwater count	Structure-specific contrast/threshold only
M13	Agios Germanos / HM14 upstream	Right limb, wood and field-derived fines	Visual/bulk context; no surface count	Separate upstream branch context
M14	Agios Germanos / HM14 upstream	Left limb, extensive bank-side wood, gabions, fines and erosion	Visual/bulk context; no surface count	Separate upstream branch and wood-control context

Table 26: Module process register continued.

ID	River/domain	Morphology/role	Sample interpretation	Permitted use
M15	Agios Germanos / wood multithread	Bifurcation, backwaters and gabion supply	Visual/bulk context	Limb/store/source scenario
M16	Agios Germanos / wood multithread	Three wood-forced limbs and stable stores	Bulk samples	Limb/fractionation scenario
M17	Agios Germanos / wood multithread	Sand-to-gravel transition	Bulk samples	Transition/fractionation scenario
M18	Agios Germanos / wood multithread	Fine-rich and gravel-rich limbs; first cobbles	Bulk samples; no total width	Limb/fractionation scenario
M19	Agios Germanos / HM13 store complex	Distal stratified sorting bar	Four surface counts plus bulk	Store-specific calibre/persistence; no free-reach capacity
M20	Agios Germanos / HM13 store complex	Proximal cobble tailwater trap	Three deposit counts plus bulk	Passage/store-specific analysis; no free-reach capacity
M21	Siroka / mountain framework	Bedrock/boulder cascade and pockets	Pocket/patch count plus bulk	Domain/pocket description; site high-flow opportunity only after G2

Table 26: Module process register continued.

ID	River/domain	Morphology/role	Sample interpretation	Permitted use
M22	Giovanitsa near confluence / mountain	Photo-limited cascade/plane-bed patch	Local patch count plus bulk	Domain/pocket description; site-flow and topology sensitivity
M23	Giovanitsa / mountain framework	Coarse step/riffle and local mantle	Local patch count	Domain/pocket description; site high-flow opportunity only after G2
M24	Probably Gaidouritsa / mountain	Bedrock slabs/boulder steps and pocket	Bulk pocket samples	Source/pocket description; topology sensitivity
M25	Gaidouritsa / mountain framework	Representative bedrock–boulder step-pool/cascade	Loose pocket/store count plus bulk; not framework grain size	Domain/pocket description; no framework mobility, mobile days, capacity or annual yield
SRC	Siroka hillslopes	Non-channel source reconnaissance	Eight bulk source samples	Source availability/fine connectivity only

I.9 Initial Scenario and Parameter Register

Table 27: Minimum configuration entries required before an ensemble run.

Configuration	Representation	Required provenance/constraint
Topology release	graph hash + alternative ID	Observed corridor, branch and control evidence
Source inventory	confirmed/expanded	Mapped area/length, fraction and confidence
Passability	discrete by j, k, e, s	Evidence class and explicit sensitivity values
Branch fractions	simplex values	Observed/site model or named equal/uncertain scenario
Hydrological series	rating/gap version	Native cadence, time zone, valid intervals and WY coverage
Event independence	primary 24 h; sensitivities 6/12 h	Same accepted water year and continuous valid-data segment; no merging across unqualified gaps
Spatial flow model	formula/coefficient draw	Paired-date validation and mass-balance check
Section model	source/datum/draw	Survey/UAV/trapezoid and valid stage range
Energy slope	source/window/draw	Routed reach; regression and monotonic check
Roughness	domain-conditioned draw	Calibration/analogue source and valid hydraulic range
Skin fraction	draw or roughness diagnostic	Form drag explicit; correlated with morphology
Critical Shields	model-specific or generalized draw	Published fixed threshold retained where applicable

Table 27: Minimum configuration entries required before an ensemble run (continued).

Configuration	Representation	Required provenance/constraint
Inundation Q	observed/scenario draw	Patch elevation and uncertainty
Mobile width	mapped/scenario draw	Distinguished from wetted/total corridor width
Transport equation	threshold / WP / Recking	Applicability gate and version/citation
Density	documented values	Water temperature and sediment lithology assumptions
Monte Carlo	seed and N	Convergence test and package versions
Local supply source state	documented / restrictive / reference / permissive	Explicit bank/gabion evidence; outer states unweighted
Source footprint and coverage	nominal L_i and k_{cov}	MoRPh width-class protocol and routed network; explicitly not mapped eroding length
Bank recruitment terms	$f_{\mathrm{active}}, n_{\mathrm{bank}}, H, R, \rho_b, \eta_{\mathrm{rec}}$	Evidence/assumption class and declared conditional distribution
Regional supply analogue	$r_v, k_{\mathrm{transfer}}, A, \rho_b$	Seven Prespa planning estimates, adopted GIS catchment area and structural transfer state
Total-load Prespa state	regional-low / preferred independent-terminal / regional-high	Named unweighted analogue-rate alternatives; retain within-state density q05–q50–q95 separately
Total-load external family	French scaling point and empirical residual dispersion	Independent geographical-transfer sensitivity comparison only; do not pool with Prespa
Total-load reproducibility	seed 20260714 and registered draws	Preserve family ledger, convergence test and non-additive diagnostics

I.10 Final Claim-Audit Vocabulary

Table 28: Required wording control for final results.

Result type	Permitted wording	Prohibited wording
$H_{i,y}$, $N_{i,y}$	Sample-facies hydraulic transport opportunity	The reach bed was mobile for x days
J_θ, J_ω	Integrated excess forcing under stated hydraulics	Measured transport work or sediment load
Mountain high-flow metric	High-flow transfer opportunity / energy ranking	M25 mobile days or headwater tonnes
WP/Recking mass	Potential supply-unlimited capacity	Actual transport or yield
Local whole-reach source mass	Conditional gross M1–M20 bank/gabion recruitment under a named outer state	Measured supply, mass passing HM15/mouth or actual yield
Regional Prespa volume/mass	Conditional regional transported-volume analogue and density-based mass context	Local calibration, additive source term or expected outlet yield
Analogue-conditioned total transported load	Representative annual planning prior under named Prespa structural states; French family retained as independent geographical-transfer sensitivity context	Measured or calibrated yield, water-year-specific load, probability interval or additive sum of local input, coarse transfer, capacity, connectivity and SWAT diagnostics
SWAT landscape erosion	Uncalibrated landscape-erosion diagnostic	Channel supply, bedload or outlet yield
Graph C	Structural/availability-weighted connectivity scenario	Measured barrier efficiency
CDP	Relative connected delivery potential	Outlet sediment yield
Store area/Jaccard	Relative store persistence/change	Mass retained without thickness/density
Granite front	Censored realised coarse-connectivity tracer	Exact transport limit or source attribution

References

References

Bagnold, R.A. (1966). *An Approach to the Sediment Transport Problem from General Physics*. U.S. Geological Survey Professional Paper 422-I. https://doi.org/10.3133/pp422I.

Borselli, L., Cassi, P. and Torri, D. (2008). Prolegomena to sediment and flow connectivity in the landscape: a GIS and field numerical assessment. *Catena*, 75(3), 268–277. https://doi.org/10.1016/j.catena.2008.07.006.

Buffington, J.M. and Montgomery, D.R. (1997). A systematic analysis of eight decades of incipient motion studies, with special reference to gravel-bedded rivers. *Water Resources Research*, 33(8), 1993–2029. https://doi.org/10.1029/96WR03190.

Bunte, K. and Abt, S.R. (2001). *Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring*. USDA Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-74. https://doi.org/10.2737/RMRS-GTR-74.

Caudron, A. and Vigier, L. (2025). *Assessment of the Prespa Trout Population in Relation to the Habitat Quality of the Agios Germanos River*. SCIMABIO report prepared for the Society for the Protection of Prespa and WWF, 37 pp.

Cavalli, M., Trevisani, S., Comiti, F. and Marchi, L. (2013). Geomorphometric assessment of spatial sediment connectivity in small Alpine catchments. *Geomorphology*, 188, 31–41. https://doi.org/10.1016/j.geomorph.2012.05.007.

Edwards, T.K. and Glysson, G.D. (1999). *Field Methods for Measurement of Fluvial Sediment*. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter C2 (1998 edition). https://doi.org/10.3133/twri03C2_1998.

Fryirs, K.A., Brierley, G.J., Preston, N.J. and Kasai, M. (2007). Buffers, barriers and blankets: the (dis)connectivity of catchment-scale sediment cascades. *Catena*, 70(1), 49–67. https://doi.org/10.1016/j.catena.2006.07.007.

Gurnell, A. and Shuker, L. (2022). *The MoRPh Survey Technical Reference Manual*, version 14. Modular River Survey, October 2022. https://modularriversurvey.org/wp-content/uploads/MoRPh-Manual-ver-14_Oct22.pdf.

Hellenic Centre for Marine Research, Institute of Marine Biological Resources and Inland Waters (HCMR/IMBRIW) (2024). *Hydromorphological Assessment of the Agios Germanos River — River Habitat Survey and Morphological Quality Assessment*. Technical report prepared for the Society for the Protection of Prespa and WWF.

Heckmann, T., Cavalli, M., Cerdan, O., Förster, S., Javaux, M., Lode, E., Smetanová, A., Vericat, D. and Brardinoni, F. (2018). Indices of sediment connectivity: opportunities, challenges and limitations. *Earth-Science Reviews*, 187, 77–108. https://doi.org/10.1016/j.earscirev.2018.08.004.

Joint Committee for Guides in Metrology (JCGM) (2008). *Evaluation of Measurement Data — Supplement 1 to the Guide to the Expression of Uncertainty in Measurement: Propagation of Distributions Using a Monte Carlo Method*. JCGM 101:2008. https://doi.org/10.59161/JCGM101-2008.

Karalis, S., Karymbalis, E. and Mamassis, N. (2018). Models for sediment yield in mountainous Greek catchments. *Geomorphology*, 322, 76–88. https://doi.org/10.1016/j.geomorph.2018.08.035.

Meyer-Peter, E. and Müller, R. (1948). Formulas for bed-load transport. *Proceedings of the 2nd Meeting of the International Association for Hydraulic Research*, Stockholm, Sweden, 39–64.

Nitsche, M., Rickenmann, D., Turowski, J.M., Badoux, A. and Kirchner, J.W. (2011). Evaluation of bedload transport predictions using flow resistance equations to account for macro-roughness in steep mountain streams. *Water Resources Research*, 47, W08513. https://doi.org/10.1029/2011WR010645.

Panagiotou, A., Zogaris, S., Dimitriou, E., Mentzafou, A. and Tsihrintzis, V.A. (2022). Anthropogenic

barriers to longitudinal river connectivity in Greece: a review. *Ecohydrology & Hydrobiology*, 22(2), 295–309. https://doi.org/10.1016/j.ecohyd.2021.10.003.

Recking, A. (2013). Simple method for calculating reach-averaged bed-load transport. *Journal of Hydraulic Engineering*, 139(1), 70–75. https://doi.org/10.1061/(ASCE)HY.1943-7900.0000653.

Pitlick, J. et al. (2021). Sediment production in French Alpine rivers. *Water Resources Research*, 57, e2021WR030470. https://doi.org/10.1029/2021WR030470.

Rickenmann, D. and Recking, A. (2011). Evaluation of flow resistance in gravel-bed rivers through a large field data set. *Water Resources Research*, 47, W07538. https://doi.org/10.1029/2010WR009793.

Rindler, R. et al. (2024). Integrative monitored bedload transport yield in different catchment areas in Austria. *INTERPRAEVENT 2024 Proceedings*, 357–360. https://www.interpraevent.at/reference/media/2459/download/2024_C26_0357-0360.pdf?v=1.

Spirkovski, Z. et al. (2012). *Transboundary Fish and Fisheries Management Plan for the Prespa Lakes Basin*. Integrated Ecosystem Management in the Prespa Lake Basin project, United Nations Development Programme / Global Environment Facility.

Vandekerckhove, L., Poesen, J., Oostwoud Wijdenes, D. and Gyssels, G. (2001). Short-term bank gully retreat rates in Mediterranean environments. *Catena*, 44(2), 133–161. https://doi.org/10.1016/S0341-8162(00)00152-1.

Wong, M. and Parker, G. (2006). Reanalysis and correction of bed-load relation of Meyer-Peter and Müller using their own database. *Journal of Hydraulic Engineering*, 132(11), 1159–1168. https://doi.org/10.1061/(ASCE)0733-9429(2006)132:11(1159).

Yager, E.M., Kirchner, J.W. and Dietrich, W.E. (2007). Calculating bed load transport in steep boulder bed channels. *Water Resources Research*, 43, W07418. https://doi.org/10.1029/2006WR005432.