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Research Article

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Posted Date: October 14th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11075754/v1>

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Additional Declarations: No competing interests reported.

A Terrain-Based Method for Mapping Coastal River Outlets and Contributing Areas

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Abstract

Coastal drainage outlets are difficult to inventory consistently on small, steep islands, where short channels, complex coastlines, local depressions, and engineered transfers challenge conventional map-based delineation. We present a reproducible terrain-based workflow that routes uniformly spaced seeds over a 10 m digital surface model, records correction provenance, incorporates the Eiði hydroelectric diversion, consolidates termini within 50 m, and ranks outflows by sampled contributing-area share. Applied to 19 Faroese islands, the audited workflow retained all 92,259 analyzable land seeds and produced 6,535 outlets with no unresolved paths. The number of ranked outlets required to represent 90% of sampled drainage (N90) ranged from 22 on Lítla Dímun to 546 on Eysturoy. Across all 279 reference points, 51 (18.3%) were within 50 m of a modelled outlet; the median nearest-outlet distance was 98.7 m, and 86.4% were within 200 m. All-island sensitivity tests show that smoothing and seed placement preserve most baseline outlet area, whereas absolute outlet and N90 counts depend strongly on the consolidation radius. An unconditioned local D8 comparison exposes the importance of depression and flat treatment but is not presented as a conditioned-tool benchmark. The catalogue, persistent spatial identifiers, concentration metrics, correction records, and seed-to-outlet mappings provide auditable inputs for later precipitation and discharge studies.

Keywords: coastal outlets, digital surface model, drainage ranking, Faroe Islands, reproducible geospatial workflow

1 Introduction

Hydrological, coastal management, and coupled land–ocean studies require reliable locations for coastal freshwater inputs. On small, steep islands, however, the term “river” is not a useful computational threshold. A nearly symmetric hill may drain through many short, similarly sized channels, while an elongated island may concentrate much of its runoff into a few valleys. Whether a channel is named or mapped also depends on survey practice and local usage. A method intended for complete island coverage should therefore identify and rank coastal drainage outlets without first imposing a binary river/non-river classification.

Digital elevation models (DEMs) make systematic drainage analysis possible, but rugged island terrain introduces practical difficulties. Coastal cells are geometrically complex, short paths may terminate only a few pixels from the sea, and unconditioned elevation surfaces contain local minima caused by true basins, infrastructure, interpolation artefacts, or insufficient raster resolution. Conventional flow-routing methods provide the foundation for extracting drainage networks from gridded elevations O’Callaghan and Mark (1984); Jenson and Domingue (1988); Tarboton (1997). Grid orientation can also create preferred drainage directions, while noise can create artificial pits Fairfield and Leymarie (1991). A national outlet catalogue therefore requires reproducible decisions about seed density, unresolved minima, endpoint consolidation, and the meaning of outlet importance.

This paper presents a computational workflow for identifying coastal outlets directly from a high-resolution elevation surface and ranking them by a sampled contributing-area proxy. Rather than selecting a fixed number of “main rivers,” we report the minimum numbers of ranked outlets needed to represent 50, 80, and 90% of sampled island drainage (N50, N80, and N90). These thresholds describe drainage concentration as a distribution and remain meaningful when no single outlet dominates. Analyst annotations are used only where automatic routing stalls inland, making the necessary corrections explicit and repeatable.

We evaluate the workflow on 19 Faroese islands using the 10 m national elevation product and recorded island-specific settings. The contributions are: (1) a deterministic method from terrain seeds to consolidated coastal outlets; (2) auditable correction provenance for local minima and engineered topology; (3) an archipelago-wide ranked catalogue with cumulative drainage shares and rank-independent spatial identifiers; (4) all-island sensitivity tests for consolidation, smoothing, routing radius, seed spacing, and grid phase; (5) comparison with the repository’s conventional local D8 implementation on four contrasting islands; and (6) all-distance validation against an independent inventory of 279 mapped drainage points. Precipitation weighting and discharge estimation are deliberately outside the present scope. The generated seed-to-outlet mappings support that extension without treating elevation alone as discharge.

2 Background

Drainage extraction from a gridded elevation model usually assigns each land cell a downslope direction and accumulates the cells contributing to each location. The D8

method routes flow to one of eight neighbouring cells [O’Callaghan and Mark \(1984\)](#); later formulations, including D-infinity, distribute flow according to continuous slope direction [Tarboton \(1997\)](#). These approaches are commonly paired with depression filling or breaching so that every land cell belongs to a drainage network [Jenson and Domingue \(1988\)](#); [Soille et al. \(2003\)](#). Priority-Flood provides an efficient and explicit approach to depression removal and flow-direction assignment [Barnes et al. \(2014\)](#), while open toolchains such as GRASS provide both single- and multiple-flow routing options [GRASS Development Team \(2025\)](#). Such conditioning can alter flats and local drainage structure; grid artefacts and artificial pits remain recognised limitations of raster drainage extraction [Fairfield and Leymarie \(1991\)](#).

The present problem differs from conventional channel-network extraction. The required output is a list of points where terrain-supported drainage reaches an island coast, together with a transparent measure of their relative support. A mapped river mouth and a terrain-derived coastal outlet need not coincide: an inventory may record a named channel, a surveyed centreline, or a point displaced inland, whereas the algorithm records the coastal endpoint reached on the raster mask. Consequently, reference-inventory comparison is treated as a positional check, not as a complete classification of true and false outlets.

Outlet importance is also scale dependent. Under spatially uniform runoff, contributing area is a defensible first-order proxy for relative flow, but it is not discharge. The Faroe Islands have substantial spatial precipitation gradients: the DMI 1991–2020 normal for Tórshavn is 1399.2 mm yr⁻¹, coastal areas broadly receive about 1000 mm yr⁻¹, and central parts of the highest islands exceed 3000 mm yr⁻¹, with some locations above 4000 mm yr⁻¹ [Cappelen and Drost Jensen \(2021\)](#). The earlier 1961–1990 DMI climatology likewise reports about 884 mm yr⁻¹ at Akraberg, 823 mm yr⁻¹ at Mykines, nearly 3300 mm yr⁻¹ at Hvalvík, and more than 3000 mm yr⁻¹ in the northern mountains [Cappelen and Laursen \(1998\)](#). Both reports attribute the pattern mainly to orographic lifting, while wind direction and exposed coastal conditions also contribute. Spatially varying precipitation, evapotranspiration, storage, groundwater, and engineered diversions can therefore change the ranking. We store mean seed elevation only as a topographic covariate for possible future precipitation weighting, while preserving seed-to-outlet assignments so that calibrated precipitation or runoff fields can be applied later without repeating outlet detection.

3 Implementation and Data Preprocessing

3.1 Elevation and island masks

The analysis uses the 10 m national digital surface model (DSM) selected for the island-processing workflow [Faroese Data Service \(2017\)](#); [Føroyakort \(2024\)](#). The DSM was downloaded on 7 May 2024. The local files are named FO_DSM_2017_FOTM_10M.tif and FO_DSM_2017_FOTM_5M.tif. The source raster is handled with Rasterio [Gillies and Contributors \(2024\)](#) and analysed in the Faroese projected coordinate system EPSG:5316. Geographic coordinates are transformed with pyproj/PROJ [Snow and Contributors \(2023\)](#). A product-agreement check averaged the available 5 m DSM onto the native 10 m grid for Fugloy, Sandoy, and Eysturoy;

elevation RMSE was 5.22, 2.71, and 2.43 m, respectively. This is not a 5 m routing experiment. National routing remains at 10 m because masks, physical-radius conversions, correction coordinates, and the complete audit are native to that grid; a valid 5 m routing comparison requires rebuilding those inputs.

Each of the 19 islands is represented by a cached raster subset containing elevation, a connected land mask, raster indices within the national DSM, and geographic bounds. Analyzable land is the intersection of the cached mask with finite, positive DSM cells; zero is the explicit sea/nodata sentinel. The mask-derived area is the number of analyzable cells multiplied by 100 m²; the combined analysed area is 1,403.6 km². Island-specific parameters are read from the processing records so that the catalogue reproduces the settings used while checking and correcting each island, rather than retrospectively imposing one seed density on geometrically different domains.

3.2 Reference inventory

An independent spreadsheet contains 279 mapped drainage locations distributed over 18 of the 19 analysed islands; no reference entry is available for Tindhólmur. Its embedded document metadata record an edit on 8 May 2024, but the supplied file does not identify its creator, survey date, collection protocol, licence, or whether coordinates denote coastal mouths or inland reference points. Coordinates are transformed to EPSG:5316 before distance calculations. The inventory is not used to fit, move, or filter computed outlets. It therefore supplies a positional comparison between potentially different mapped objects, not field-verified coastal-mouth ground truth.

3.3 Recorded inland corrections

Unconditioned DSM routing can stop in inland local minima. During the original island processing, an annotation tool displayed stalled endpoints over the elevation surface and allowed an analyst to associate each with a plausible downstream coastal outlet. The selections are stored as JSON records and replayed in subsequent runs. In the audited national run, 19,420 seeded trajectories used a recorded reroute, including 525 Eiði transfers; no path required automatic coast snapping, no trace was discarded, and no stalled path remained. Figure 2 illustrates the distinction between automatic coastal completion and a recorded inland correction, although only the latter occurred in this run.

3.4 Engineered diversion at Eiði

Eysturoy contains an important non-natural routing case associated with the hydro-electric plant at Eiði. The national processing reads three intake-line geometries, the reservoir region around Eiðisvatn, and the plant outlet. A path that approaches an intake by at most 50 m is truncated at the intake and extended to the plant outlet; a path terminating inside the reservoir region is treated similarly. These rerouted paths are included in the main outlet catalogue before endpoint consolidation, so delivered freshwater is represented at the plant rather than at the corresponding natural terrain termini.

Figure 1 shows the upper Eysturoy rerouting case directly. The figure retains the intake markers, the engineered plant outlet, natural courses, and paths redirected through the intake and reservoir system, while cropping away the southern half of Eysturoy where this diversion is not located.

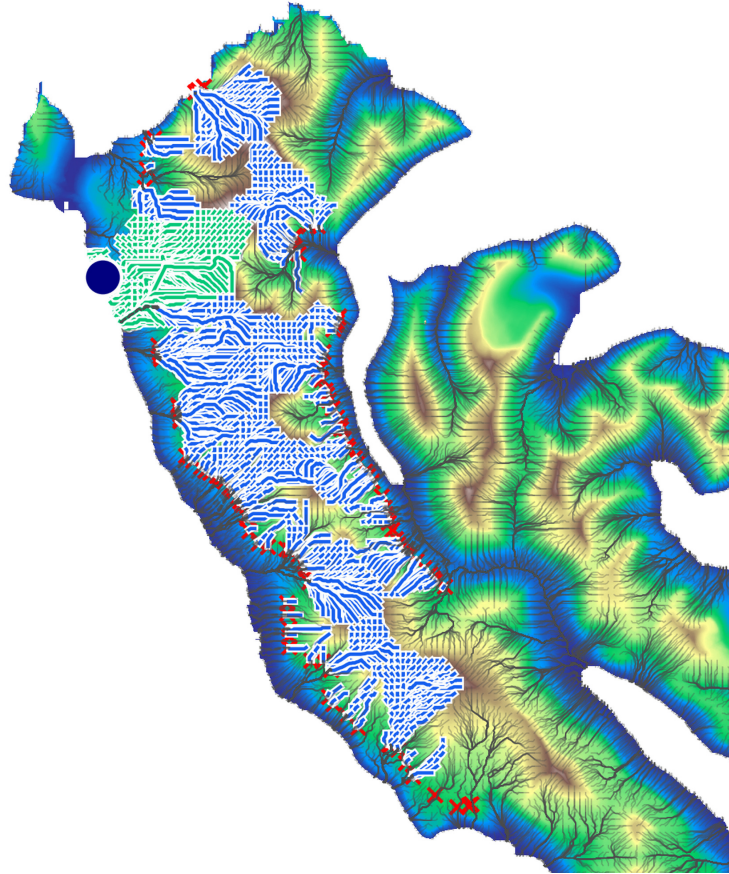


Fig. 1 Focused upper- and central-Eysturoy view of the Eiði hydroelectric diversion. Red crosses mark intake locations, the navy circle marks the engineered plant outlet, blue paths show intake reroutes, green paths show reservoir reroutes, and gray dashed lines show natural courses. Local-minimum corrections remain active in the computation but are omitted from this overlay to keep the engineered diversion legible. The lower half and eastern side of Eysturoy are omitted.

4 Methods

The workflow in Fig. 3 converts each masked elevation raster into ranked coastal outlets and a seed-to-outlet mapping.

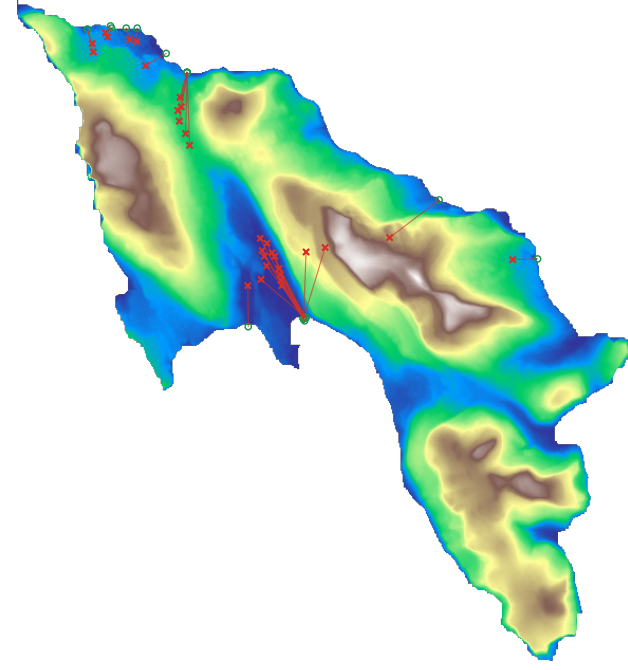


Fig. 2 Available treatments for paths that do not initially reach the coast. Endpoints close to the sea may be snapped to the nearest coastal cell; inland minima are linked to an analyst-recorded outlet and the decision is replayed on later runs. The audited national run used recorded reroutes but required no automatic snaps.

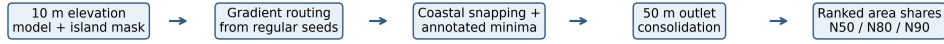


Fig. 3 Workflow from island DSM and land mask to corrected paths, consolidated endpoints, ranked outlets, and cumulative drainage thresholds.

4.1 Algorithm: seed placement and descent routing

The routing surface is the masked elevation raster after Gaussian smoothing with standard deviation $\sigma = 1.2$ pixels. This suppresses isolated one-pixel irregularities while retaining the island-scale topographic structure. Seeds are placed on a regular grid over valid land cells. The established island runs use spacings of 50–250 m, with wider spacing on the largest domains; spacing is recorded per island and is not re-estimated during analysis.

Let $z_s(r, c)$ denote the smoothed elevation at raster row r and column c , and let the current sub-pixel position be $\mathbf{x}_t = (r_t, c_t)$. At each iteration, the implementation rounds $\mathbf{x}_t$ to the current raster cell $(\hat{r}_t, \hat{c}_t)$ and defines a circular candidate neighbourhood

$$\mathcal{N}_t = \{(r, c) : (r - \hat{r}_t)^2 + (c - \hat{c}_t)^2 \leq R_j^2\}, \quad (1)$$

where R_j is the active island-specific search radius expressed in pixels. Routing first uses the configured 60 or 100 m radius; if no lower cell exists, the radius expands in increments up to the recorded 60–200 m maximum. Candidates outside the raster are

ignored. The next target is the candidate with the smallest smoothed elevation that is strictly lower than the current cell:

$$\mathbf{y}_t = \arg \min_{(r,c) \in \mathcal{N}_t, z_s(r,c) < z_s(\hat{r}_t, \hat{c}_t)} z_s(r, c). \quad (2)$$

Thus, “steepest descent” here means descent toward the lowest reachable cell in the active search neighbourhood, not a finite-difference gradient evaluated only at the immediately adjacent eight cells. If more than one candidate has the same minimum value, the first candidate encountered in the deterministic raster scan is retained. The path then advances one pixel toward $\mathbf{y}_t$ (or the remaining distance if shorter):

$$\mathbf{x}_{t+1} = \mathbf{x}_t + \min(1, \|\mathbf{y}_t - \mathbf{x}_t\|) \frac{\mathbf{y}_t - \mathbf{x}_t}{\|\mathbf{y}_t - \mathbf{x}_t\|}. \quad (3)$$

The path is recorded at the rounded raster position at each step. It terminates when elevation reaches the explicit zero sea/nodata sentinel, when no strictly lower candidate exists at the maximum radius, or when the maximum of 1,500 steps is reached. The former eight-point minimum was removed because it silently discarded valid short coastal traces and their sampled area; the minimum retained length is now one point. If a path stops within ten pixels (100 m) of the sea, it can be extended to the nearest coastal cell. Otherwise, the stored local-minimum annotations described in Section 3 are applied by connecting the trace to its designated outlet with a discrete straight segment. All 92,259 analyzable land seeds were retained in the audited run, with no unresolved paths.

4.2 Deterministic endpoint consolidation

Several seeds from the same sampled catchment commonly terminate on adjacent coast pixels. Let E be the multiset of completed endpoint coordinates and let $r_c = 50$ m. For every unassigned endpoint location, the algorithm counts unassigned endpoints within r_c . It selects the location with the greatest count as a representative, assigns all endpoints in that neighbourhood, and repeats until none remain. Ties are resolved by raster row and column. This dense-neighbourhood procedure is deterministic and consolidates raster-scale endpoint spread without prescribing the number of outlets.

Because Euclidean distance alone can span a headland or opposing shores, an audit screen samples the straight chord from each endpoint to its assigned representative and flags assignments crossing mapped land. This conservative diagnostic does not prove an erroneous merge and cannot detect every narrow-strait case, but it quantifies locations requiring coastline-aware review.

Figure 4 shows the routed seeds for Fugloy. Each catalogue record has a persistent spatial identifier formed from the island slug and its rounded 10 m EPSG:5316 grid cell. Rank is stored separately because it can change between workflow versions.

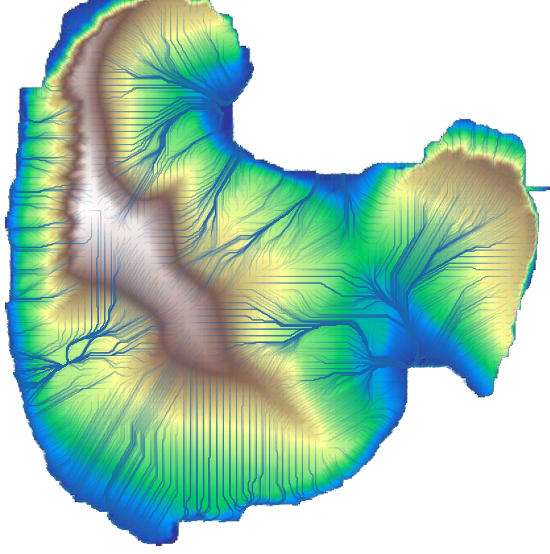


Fig. 4 Representative Fugloy result. Many routed seeds converge on fewer coastal endpoint groups, illustrating the basis for subsequent outlet consolidation and ranking.

4.3 Drainage-area proxy and concentration metrics

For island j , let s_{ij} be the number of valid seeds assigned to outlet i , and let $S_j = \sum_i s_{ij}$. The sampled drainage share is

$$w_{ij} = \frac{s_{ij}}{S_j}. \quad (4)$$

Outlets are sorted by decreasing s_{ij} , with raster coordinates resolving ties. A physical area proxy is $A_{ij} = w_{ij}A_j$, where A_j is the mask-derived island area. The proxy conserves island area by construction but should not be interpreted as a hydrologically conditioned catchment polygon or measured discharge.

For each outlet, we additionally record the mean starting elevation of its contributing seeds. If I_i is the set of seeds assigned to outlet i and z_k is the original DSM elevation at the starting cell of seed k , this quantity is

$$\bar{z}_i = \frac{1}{|I_i|} \sum_{k \in I_i} z_k. \quad (5)$$

This is an outlet-level topographic covariate, not the mean elevation of every cell in a delineated catchment and not a discharge estimate. It is retained only so a calibrated precipitation or runoff field can be applied in future work. Precipitation gradients, windward/leeward exposure, evapotranspiration, storage, seasonality, and calibration are absent from the present analysis.

For a target fraction q , the concentration count is

$$N_q = \min \left\{ n : \sum_{i=1}^n w_{ij} \geq q \right\}. \quad (6)$$

We report N50, N80, and N90. These quantities avoid imposing a “main river” label: a concentrated island has a small N_q , while a near-symmetric or highly dissected island may require many similarly weighted outlets.

4.4 Inventory matching and sensitivity analysis

Each inventory point is matched to its nearest computed outlet on the same island. We report the complete distance distribution, counts within 25, 50, 100, 200, and 500 m, and the median, 75th, 90th, and 95th percentiles. The strict 50 m result is retained for comparison. Unmatched computed outlets are not labelled false positives because the inventory is not an exhaustive coastal-outlet reference. A deterministic screen uses coastline distance and distance to unconsolidated endpoints to select representative mismatches for subsequent expert review; these labels are diagnostic rather than field-verified causes.

Sensitivity analysis covers all 19 islands. Consolidation radius is varied over 25, 50, 75, and 100 m; Gaussian smoothing over 0, 0.8, 1.2, and 2 pixels; and routing radii by factors of 0.75, 1, and 1.25. Seed design is tested at the recorded and halved spacing and at two grid phases. Comparisons report outlet count, N50/N80/N90, largest-and-top-ten-outlet shares, location overlap within 50 m, matched baseline area share, stalls, discarded area, and runtime.

The repository’s local D8 implementation supplies a conventional single-direction baseline on Lítla Dímun, Streymoy, Sandoy, and Eysturoy. It routes each seed to its steepest lower neighbour without depression conditioning. Unresolved paths are excluded from coastal-outlet aggregation and their seed fraction is reported. This comparison diagnoses sensitivity to local pits and flats; it is not equivalent to a conditioned Priority-Flood, GRASS, or WhiteboxTools benchmark.

5 Testing and Reproducibility

The complete analysis is implemented in Python using NumPy, SciPy, Rasterio, Matplotlib, pyproj, and Numba. Routing uses the recorded parameter file for each island and has no random stage. A Numba-compiled implementation accelerates the path loop while preserving the decisions of the reference Python implementation. Twelve unit tests cover endpoint grouping and barrier diagnostics, tie resolution, coordinate conversion, cumulative thresholds, persistent identifiers, seed phase, explicit sea level, search-radius expansion, D8 direction, and area conservation. The original audited output records Python 3.10.14. Release verification in an isolated Python 3.12.6 environment with pinned dependencies passed all twelve tests and reproduced the national catalogue, all 279 validation records and the island summary to a numerical tolerance of 10^{-12} , excluding runtime; every seed-to-outlet mapping array matched exactly.

The original outputs are retained alongside the verification evidence rather than overwritten.

One national command produces the outlet catalogue, island summary, persistent-ID seed mappings, figures, and tables. The output manifest records configuration and inventory SHA-256 checksums. A separate consistency command verifies catalogue counts, consecutive ranks, unique identifiers, per-island area shares, all 279 validation records, threshold totals, mapping membership, and complete seed retention. The national routing stage totalled 50.8 s over 19 islands on the development workstation after just-in-time compilation; plotting and export were timed separately. The sensitivity matrix contains 266 island–scenario records.

6 Results

6.1 Archipelago-wide outlet catalogue

The audited workflow retained all 92,259 analyzable land seeds and produced 6,535 consolidated outflows across 19 islands. No trace was discarded, automatically coast-snapped, or left unresolved. Figure 5 maps outflows through each island’s N90 threshold, while Table 1 reports the full outlet count and concentration metrics. The sum of island-level N90 values is 2,881.

Table 1 Mask-derived island area, total consolidated outlet count, and the numbers of ranked outlets required to reach cumulative sampled-area shares of 50%, 80%, and 90%.

Island	Area (km ²)	Outlets	N50	N80	N90
Streymoy	376.6	759	18	96	277
Eysturoy	287.3	1006	32	290	546
Vágar	177.0	572	7	38	143
Suðuroy	167.2	809	19	156	334
Sandoy	112.0	483	10	61	138
Borðoy	94.9	639	42	236	364
Viðoy	40.9	337	14	97	160
Kunoy	35.4	304	27	102	153
Kalsoy	30.6	424	43	152	222
Svínoy	27.3	268	11	60	108
Fugloy	11.1	151	6	31	58
Mykines	10.5	190	5	42	78
Nólsoy	10.4	160	16	54	81
Skúvoy	10.0	109	3	15	37
Hestur	6.1	83	6	27	42
Stóra Dímun	2.6	74	10	30	42
Koltur	2.3	92	10	35	50
Lítla Dímun	0.8	37	9	17	22
Tindhólmur	0.6	38	8	20	26
Total	1403.6	6535	296	1559	2881

N90 ranges from 22 outlets on Lítla Dímun to 546 on Eysturoy. N50 ranges from three on Skúvoy to 43 on Kalsoy. The largest single outlet accounts for 33.0% of sampled drainage on Skúvoy, whereas the Eiði outflow accounts for 11.4% of Eysturoy’s sampled drainage. Thus, neither island area nor total outlet count alone determines concentration.

The cumulative curves in Fig. 6 show the complete island-to-island contrast. Vágur reaches N50 with seven outlets but requires 143 for N90; Streymoy requires 18 and 277, respectively. Eysturoy has N50 of 32 and the highest N90. Reporting multiple thresholds preserves differences that would be obscured by a single “main river” count.

6.2 Inventory comparison

Of 279 independent inventory locations, 12 (4.3%) are within 25 m of a modelled outlet, 51 (18.3%) within 50 m, 142 (50.9%) within 100 m, 241 (86.4%) within 200 m, and 272 (97.5%) within 500 m. Across all points, the median nearest-outlet distance is 98.7 m; the 75th, 90th, and 95th percentiles are 154.1, 227.4, and 287.6 m. Among the 51 strict matches, median and 95th-percentile separation are 35.3 and 48.7 m.

The diagnostic mismatch screen assigns 167 points to the inland-reference class, 29 to conceptual mismatch, 19 to a possibly displaced outlet in the same system, and 13 to possible consolidation displacement. These are reproducible screening categories based on spatial evidence, not field-verified causes. Figure 7 therefore presents the national distance distribution and scales island markers by inventory sample size rather than allowing small samples to dominate visually.

6.3 Routing comparison

Table 2 compares the proposed workflow with the local unconditioned D8 baseline. On the small Lítla Dímun domain, D8 assigns 79.9% of land seeds and gives the same N90. On the three larger domains, local minima leave most D8 seeds unresolved: assigned fractions are 15.5% for Streymoy, 17.6% for Sandoy, and 27.2% for Eysturoy. D8 shares are normalized only over resolved seeds, so their concentration counts cannot be interpreted as a conditioned full-area benchmark.

Table 2 Proposed routing and unconditioned local D8 comparison. Assigned fraction is the fraction of analyzable land seeds reaching a coastal outlet; unresolved D8 paths are excluded from outlet aggregation.

Island	Method	Outlets	N50	N80	N90	Assigned fraction
Lítla Dímun	Proposed	37	9	17	22	1.000
Lítla Dímun	D8	35	8	17	22	0.799
Streymoy	Proposed	759	18	96	277	1.000
Streymoy	D8	566	150	380	473	0.155
Sandoy	Proposed	483	10	61	138	1.000
Sandoy	D8	420	48	177	284	0.176
Eysturoy	Proposed	1,006	32	290	546	1.000
Eysturoy	D8	771	204	521	646	0.272

6.4 Sensitivity and consolidation audit

Smoothing is comparatively stable. Across alternatives of 0, 0.8, and 2 pixels, N90 changes by -7.7% to $+10.8\%$, and the median share of baseline area attached to a matched outlet is at least 99.6% . Routing-radius factors of 0.75 and 1.25 change N90 by -5.4% to $+8.5\%$ and -19.2% to $+1.2\%$, respectively.

Changing grid phase at the recorded spacing changes N90 by -15.4% to $+2.4\%$, with median matched baseline area of 99.0% . Halving spacing increases the number of minor outlets by 2.2% to 47.8% , while N90 changes by -7.7% to $+12.5\%$; median matched baseline area remains 100% .

Consolidation radius is the dominant sensitivity. Relative to 50 m, a 25 m radius raises outlet count by 19.1% – 89.2% and N90 by 30.0% – 104.5% ; 75 m lowers N90 by 13.6% – 38.5% ; and 100 m lowers it by 29.9% – 46.2% . Absolute outlet and N90 counts must therefore be interpreted with their consolidation scale. The conservative straight-chord audit flags 1,544 clusters and 13,404 seed assignments (14.5% of retained seeds) as possible cross-headland cases. These are review candidates rather than confirmed errors and motivate a future coastline-geodesic constraint.

7 Discussion

The results support describing outlet importance as a ranked distribution rather than a categorical set of main rivers. The appropriate number depends on both island geometry and the desired represented fraction. N50 identifies concentrated drainage, while N90 includes the long tail of small coastal sectors. An idealised radially symmetric island, for example, would have no uniquely meaningful main outlet even though every coastal sector participates in drainage; the proposed cumulative metrics remain defined in that case.

The all-island experiments show different kinds of stability. Smoothing, seed phase, routing radius, and halved spacing preserve most baseline outlet area, although minor-outlet counts and some N90 values change. Consolidation radius has a substantially larger effect on absolute counts. The 50 m value is therefore part of the operational outlet definition, not a universally scale-free truth. The straight-chord screen also identifies many possible across-headland assignments; field or coastline-geodesic review is needed before claiming that Euclidean consolidation respects every coastal barrier.

The absence of unresolved paths shows that annotation records replay successfully, but the 19,420 rerouted trajectories include expert judgement and the Eiði engineering model. Their value is auditability: each correction has a stored source point and designated outlet and can be revised if a hydrologically conditioned terrain model becomes available. The D8 comparison reinforces the importance of depression and flat treatment, but its low assigned fractions on large islands prevent it from serving as a performance comparison with modern conditioned D8 software.

The strict inventory agreement is low, but the full distance distribution provides essential context: half of the reference points lie within about 100 m and 86.4% within 200 m. The supplied inventory metadata do not establish that all coordinates represent coastal mouths. The spatial screening identifies inland points, possible consolidation shifts, and more distant cases for review, but does not establish causes without

imagery, source records, or field evidence. The 18.3% strict result should therefore guide targeted inspection, not be interpreted as an 81.7% false-negative rate. A reference set designed around coastal mouth coordinates and field-verified catchments is needed for stronger accuracy claims.

The intended use of the catalogue follows from this distinction. It should not be read as a field-verified inventory of named river mouths. Instead, it provides a reproducible terrain-derived candidate layer for locating possible freshwater inputs, prioritising manual inspection, and attaching later precipitation or discharge estimates to persistent spatial outlet identifiers. Rank remains version-dependent. The inventory comparison is a diagnostic check on positional agreement with an independently mapped product, not the sole measure of catalogue validity.

Sample count is an area proxy only under uniform seed placement. Scaling shares by island-mask area conserves total area but does not delineate exact catchment polygons, and neither area nor rank is discharge. Spatial precipitation, evapotranspiration, infiltration, storage, and human diversions are absent. Applying precipitation fields to the preserved seed assignments is the natural next step, but it is reserved for follow-up work so that outlet-detection errors can be evaluated separately from meteorological forcing. Such outlet estimates could subsequently be supplied as freshwater forcing to regional ocean models, where river-discharge representation is known to affect coastal simulations [Sotillo et al. \(2021\)](#); [Matte et al. \(2025\)](#).

The method is most useful as a reproducible candidate generator and prioritisation tool. The CSV catalogue and appendix allow users to choose a cumulative threshold appropriate to their application rather than accepting a universal count. The per-island supplement maps and stable outlet identifiers also make disagreements traceable to specific coast locations.

The Eiði hydroelectric plant demonstrates why delivered freshwater routing must be represented explicitly. Intake lines and the Eiðisvatn reservoir redirect runoff from several natural valleys to one engineered plant outlet. Applying this diversion before endpoint consolidation makes Eiði the largest ranked Eysturoy outflow in the delivered-water catalogue, while preserving the underlying terrain routes for audit and comparison.

8 Conclusion

We developed and tested a deterministic workflow that routes regularly sampled land points over a high-resolution elevation surface, replays recorded corrections for inland minima, incorporates the Eiði engineered diversion, consolidates nearby endpoints, and ranks the resulting outflows by sampled drainage support. Applied to the Faroe Islands, the audited workflow retained all 92,259 analyzable land seeds and produced 6,535 outlets across 19 islands with no unresolved paths. Island N90 values range from 22 to 546, confirming that drainage concentration varies too strongly for a universal “main river” definition.

The catalogue is reproducible and explicit about its limits. All-island sensitivity tests show that smoothing and seed design preserve most baseline outlet area, while consolidation radius strongly controls absolute counts. Of 279 reference locations,

18.3% are within 50 m and 86.4% within 200 m; incomplete positional metadata prevent stronger causal interpretation. The D8 experiment documents the role of pits and flats but does not replace comparison with a conditioned conventional tool. The present deliverables—persistent coordinates, version-dependent ranks, cumulative shares, correction records, maps, and seed mappings—form an auditable basis for future precipitation and discharge work.

Statements and Declarations

Author contributions. J.K. led the conceptualisation, software development, analysis, visualisation, and manuscript preparation. J.S. contributed to the methodology, validation, interpretation, and manuscript review. Both authors approved the final manuscript.

Competing interests. The authors declare no competing interests.

Funding. No specific funding was received for this work.

Data availability. The source code is publicly available at <https://github.com/JohannusK/Avrenningarokid>. The versioned analysis release (version 1.0.0) is archived at Zenodo: <https://doi.org/10.5281/zenodo.22794571>. It contains the processing code, exact configurations, correction records, outlet catalogue, seed-to-outlet mappings, validation outputs, figures, and file checksums supporting the reported results. The digital surface model (DSM) files used were FO_DSM_2017_FOTM_10M.tif and FO_DSM_2017_FOTM_5M.tif, downloaded on 7 May 2024 from the official US.f0 service https://gis02.us.f0/refserver/rest/services/dsm/FO_DSM_2017_25m/ImageServer. They are not redistributed in the archive and remain subject to the provider’s terms, including attribution, source-reference, and third-party notice requirements (<https://www.foroyakort.f0/um-foeroyakort/terms-and-conditions-in-english>). The 279-point reference inventory was made by Knud Simonsen and is not included in the public release; it is available only subject to the data holder’s permission. These input-data restrictions do not prevent reproduction of the released code and derived outputs when the user has lawful access to the corresponding inputs.

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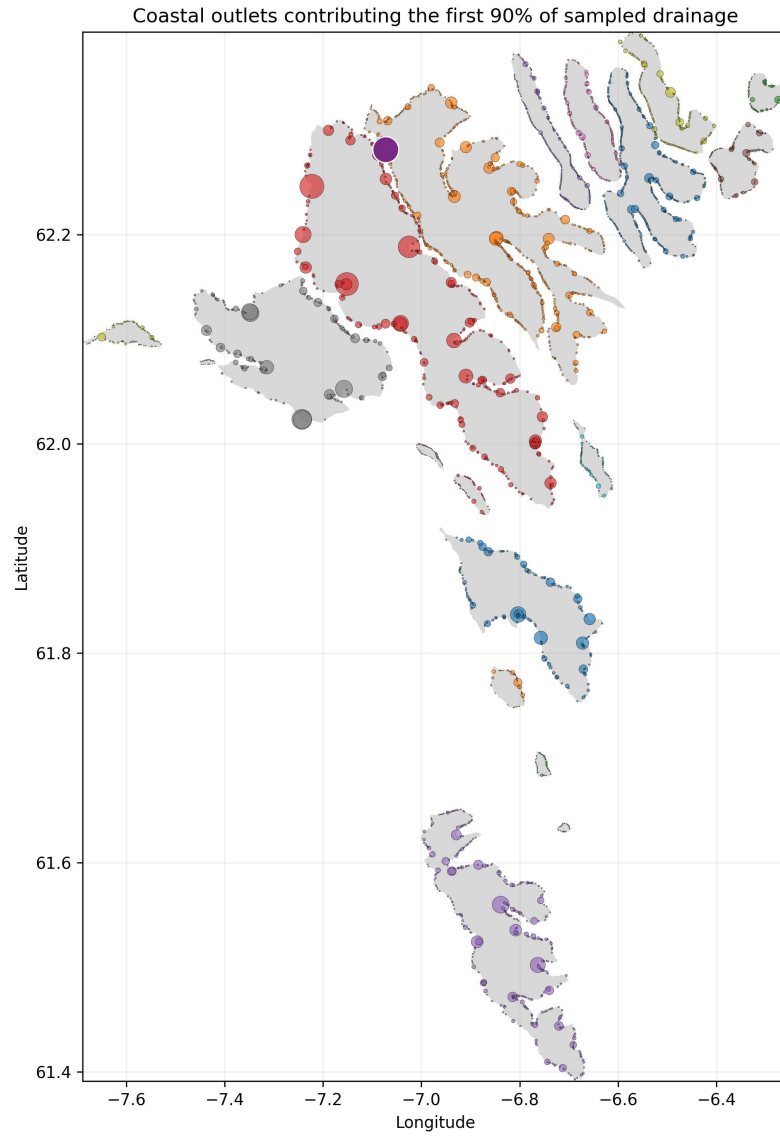


Fig. 5 Computed outflows through N90 for all 19 analysed islands. Point area is proportional to the sampled contributing-area proxy in km² using one scale across the archipelago; coastlines are derived from the analysed masks. The purple point on Eysturoy marks the Eiði hydroelectric station, where diverted paths are consolidated and ranked with other outflows.

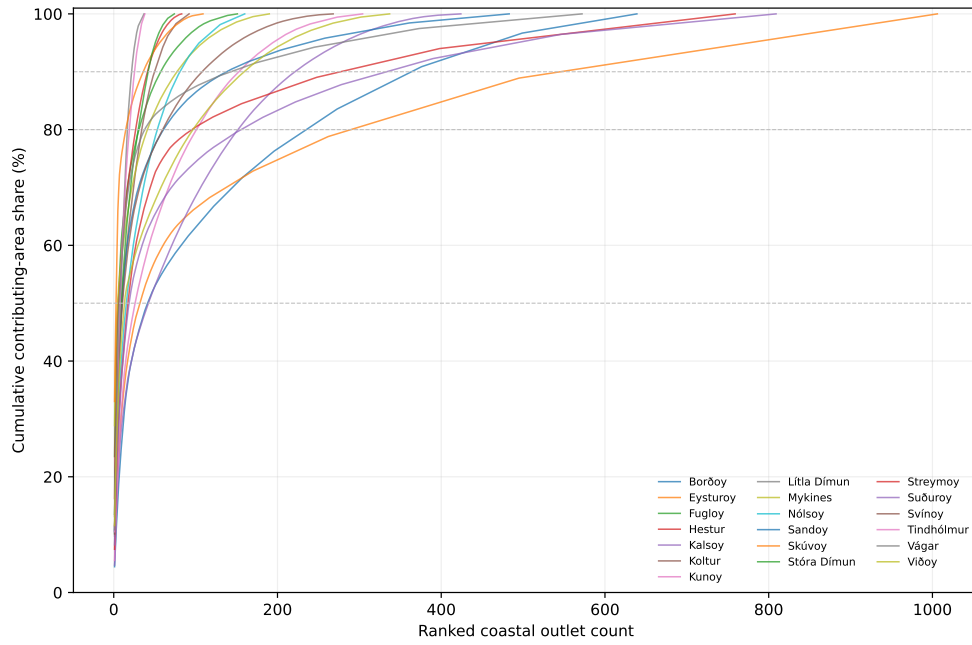


Fig. 6 Ranked cumulative sampled-drainage curves for all 19 islands. Intersections with 50%, 80%, and 90% define N50, N80, and N90.

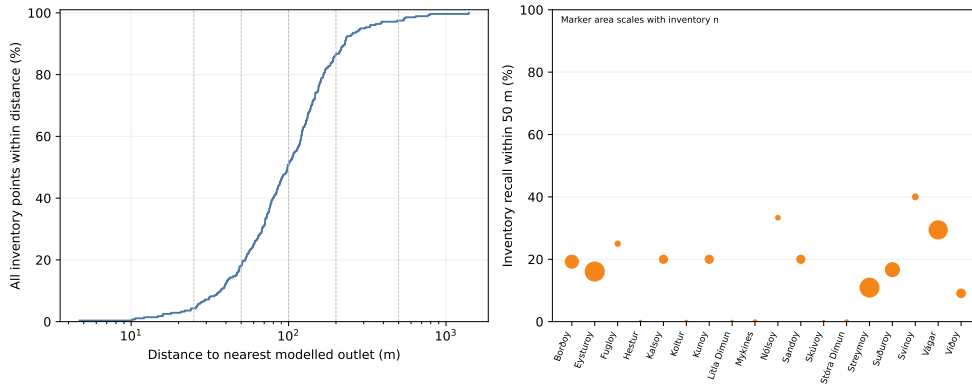


Fig. 7 Inventory comparison for all 279 reference points. Left: empirical cumulative distribution of nearest modelled-outlet distance with the five reporting thresholds. Right: island-level recall at the strict 50 m threshold; marker area scales with island inventory size.