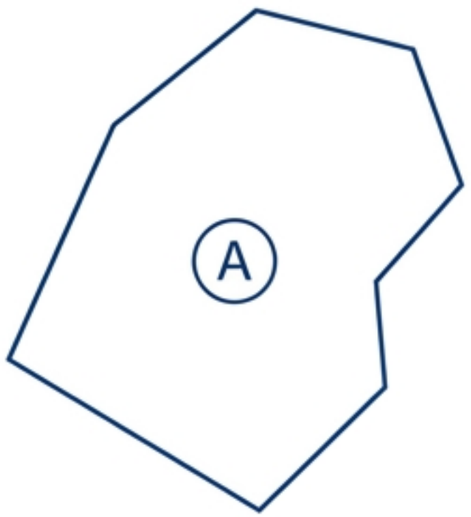
Spatial Data Standards for Hydrological Modeling

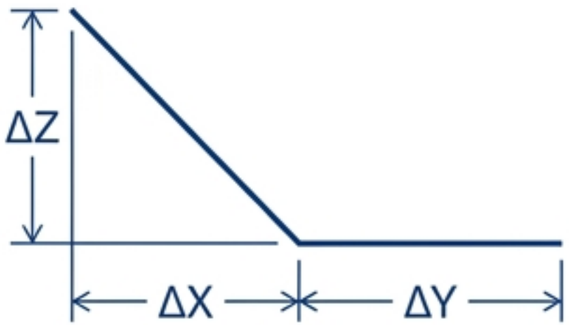
Foundational protocols for Coordinate Reference Systems (CRS) and spatial precision in QGIS.

Accurate hydrological modeling relies entirely on precise spatial geometry.



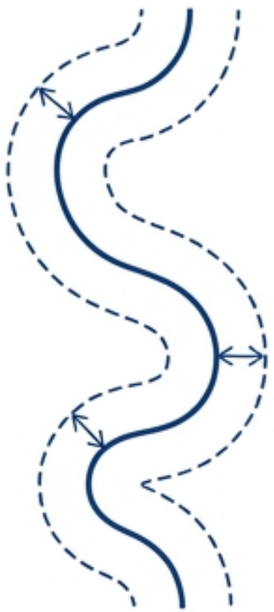
Area Calculation

Catchment area (A) determines peak runoff volume. Under incorrect systems, area computations distort heavily.



Slope & Flow Routing

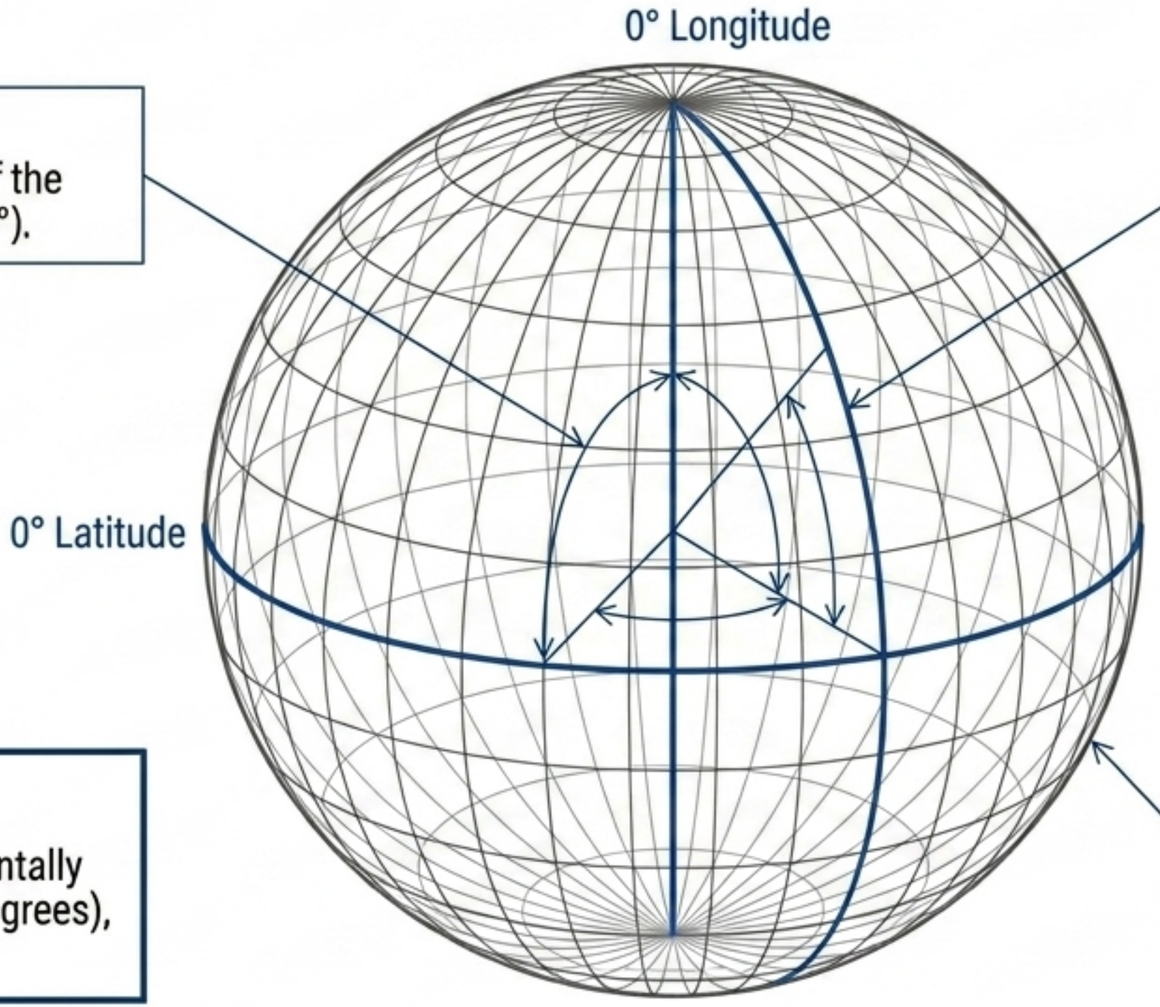
The D8 algorithm calculates flow by comparing elevation changes (ΔZ) against horizontal distance (ΔX, ΔY). If horizontal units are in degrees instead of meters, slope calculations fail, breaking stream networks.



Distance & Buffering

Delineating flood risk or riparian buffers requires constant linear units (meters).

Geographic Coordinate Systems represent the Earth as a three-dimensional sphere.



Latitude:
Angle north/south of the Equator (-90° to +90°).

Longitude:
Angle east/west of the Prime Meridian (-180° to +180°).

Key Insight Box

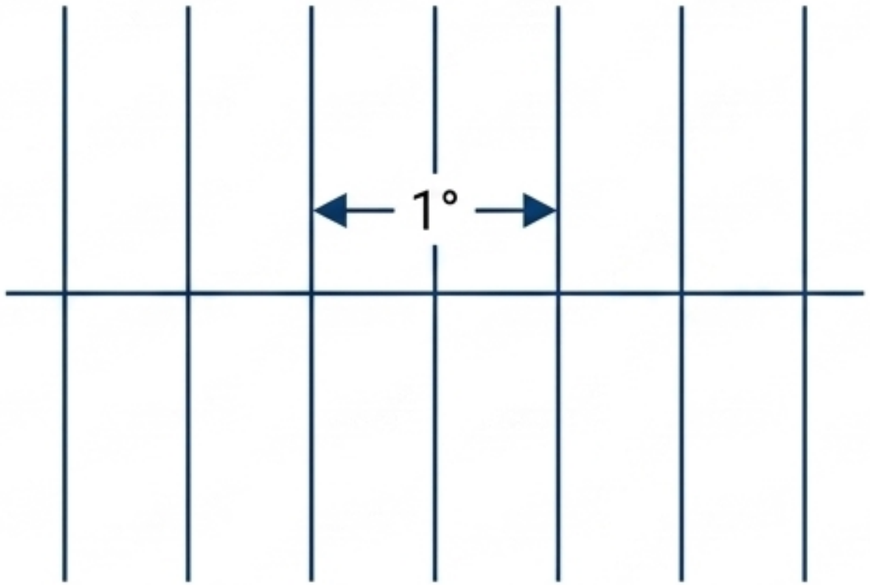
Location in a GCS is fundamentally measured in angular units (degrees), not physical distance.

Datum: The underlying ellipsoid approximating the Earth's shape. The global standard is WGS 84 (the backbone of modern GPS).

Angular measurement units inherently distort physical distances at different latitudes.

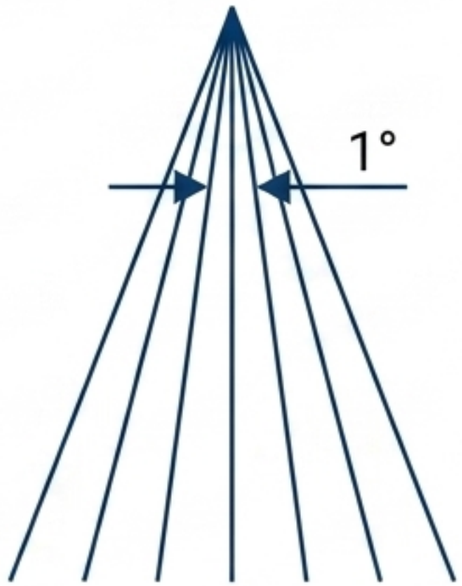
The Distance Dilemma

The Equator



At the equator, 1° ≈ 111 km.

The Poles



At the poles, 1° ≈ 0 km.

Because physical distance shrinks towards the poles, running buffer or slope calculations directly on a GCS layer will yield mathematically incorrect results.

Projected Coordinate Systems mathematically flatten the Earth to enable linear measurement.

A Projected Coordinate Reference System (PCS) uses linear units (meters or feet), making it the mandatory standard for calculating distances, areas, and slopes.

Map Projection Types

Conformable: Preserves local angles/shapes (Navigation).

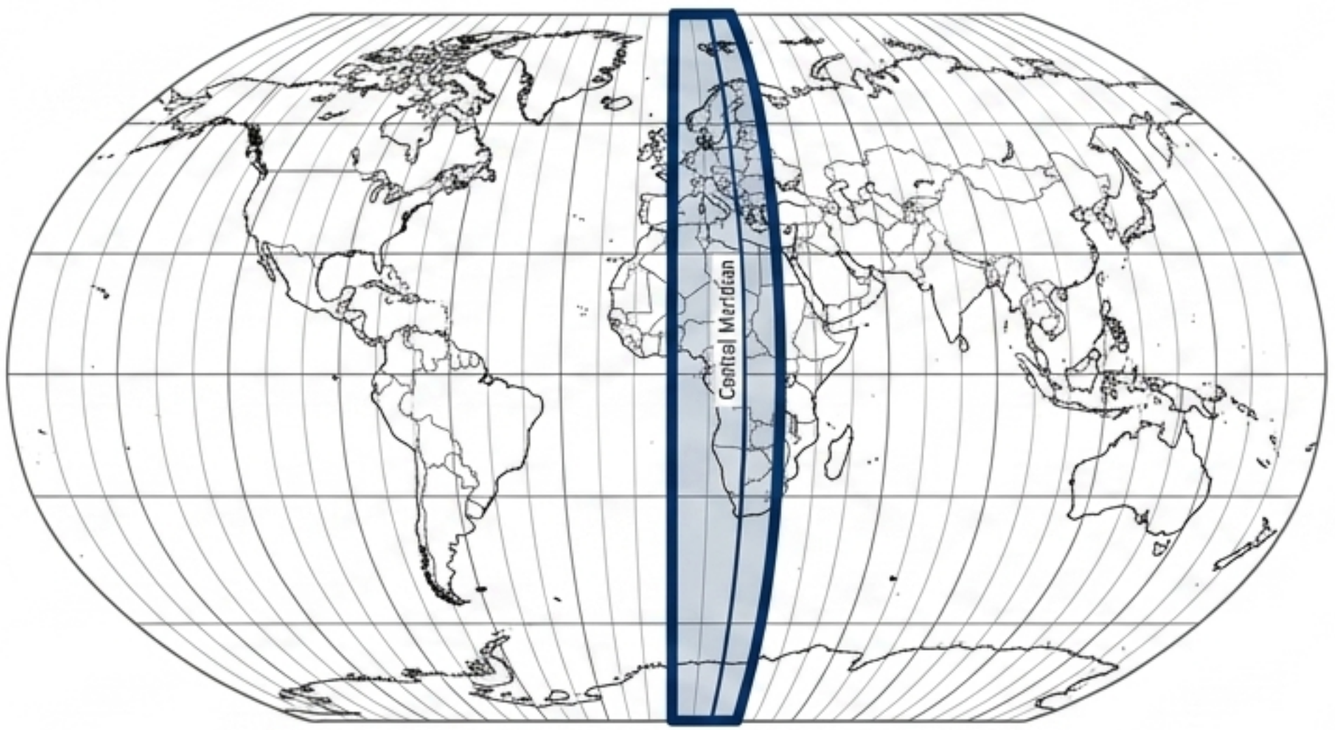
Equal Area: Preserves areas (Watershed/Soil mapping).

Equidistant: Preserves distances along specific lines.

Choosing between GCS and PCS dictates the validity of spatial calculations.

GCS (Geographic)	PCS (Projected)
Model: 3D Sphere / Ellipsoid	**Model:** 2D Flat Plane
Units: Angular (Degrees)	**Units:** Linear (Meters/Feet)
Standard Example: WGS 84	**Standard Example:** UTM
Primary Use Case: Global data sharing, GPS tracklogs, Web mapping (Leaflet/Mapbox).	**Primary Use Case:** Calculating area, flow routing, slope, and buffers.
Hydrological Viability: Invalid for analysis.	**Hydrological Viability:** Mandatory standard.

The Universal Transverse Mercator (UTM) system provides the regional standard for spatial accuracy.



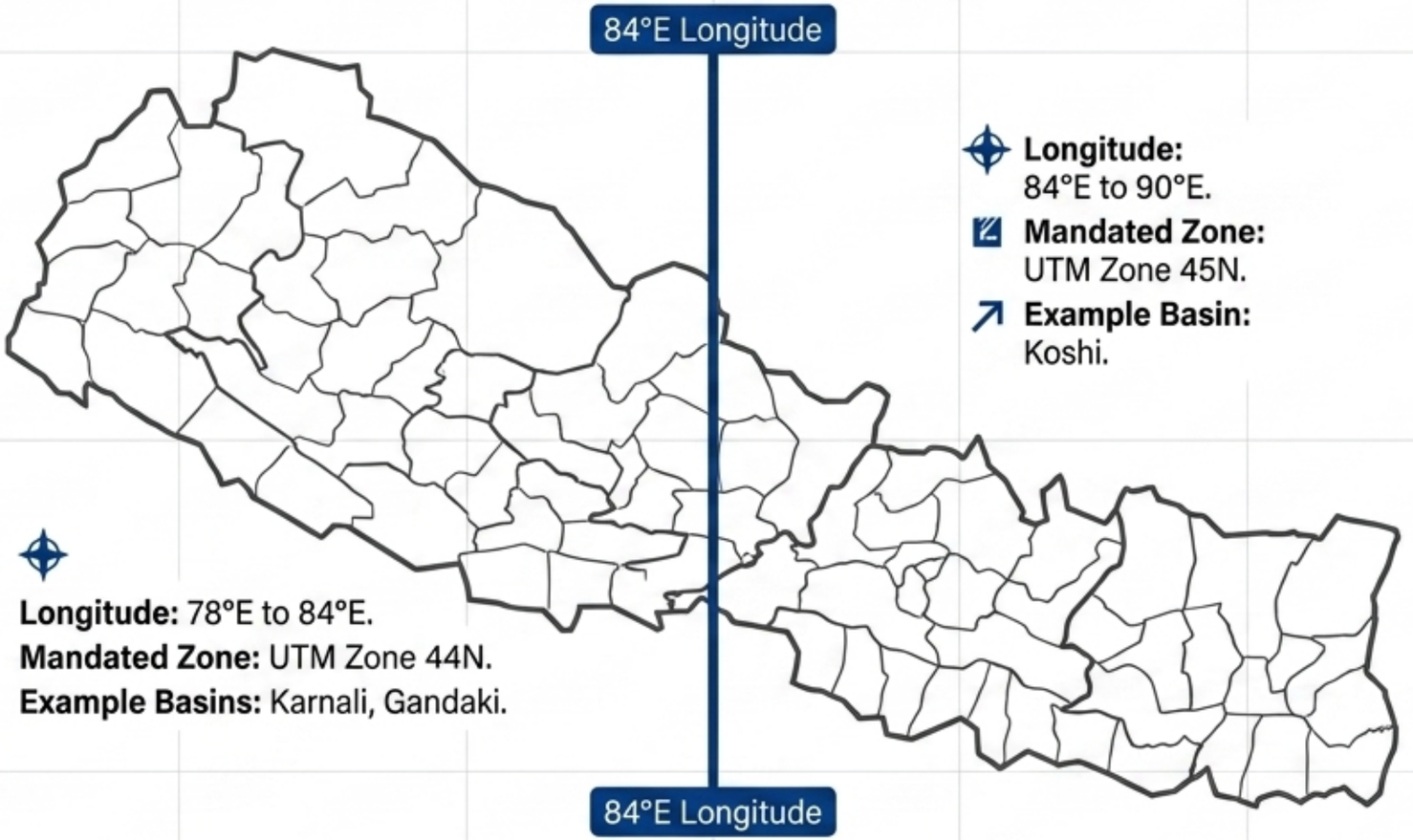
System Mechanics

- The Earth is divided into 60 vertical zones.
- Each zone is exactly 6° of longitude wide.
- Every zone possesses its own central meridian designed to aggressively minimize distortion within that specific local section.

Measurement

Locations within UTM are plotted on a **Cartesian grid** defined as **Eastings** and **Northings**, measured strictly in meters.

Hydrological projects in Nepal must adhere to specific regional UTM zones based on the 84°E meridian.



Longitude: 84°E to 90°E.
Mandated Zone: UTM Zone 45N.
Example Basin: Koshi.

Longitude: 78°E to 84°E.
Mandated Zone: UTM Zone 44N.
Example Basins: Karnali, Gandaki.

Protocol for Cross-Zone Basins

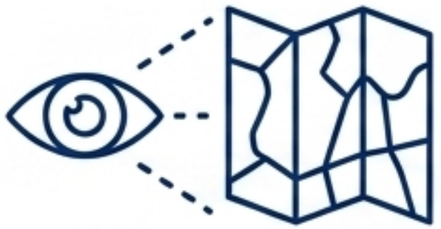
If a basin crosses the 84°E boundary, selecting either zone introduces minor edge distortion.
Standard procedure: Use a custom local Transverse Mercator projection centered on the basin, or default to the zone covering the majority of the basin's area.

Standardized EPSG codes eliminate ambiguity in spatial database management.

The European Petroleum Survey Group (EPSG) assigns a unique identifier to every coordinate system to streamline GIS software operations.

EPSG Code	Registry Name	CRS Type	Primary Application
4326	WGS 84	Geographic (GCS)	Global data sharing, web mapping (Leaflet/Mapbox), GPS tracklogs.
32644	WGS 84 / UTM Zone 44N	Projected (PCS)	Hydrological analysis and mapping in Western/Central Nepal.
32645	WGS 84 / UTM Zone 45N	Projected (PCS)	Hydrological analysis and mapping in Eastern Nepal.

Visualization algorithms differ fundamentally from permanent analytical transformations.



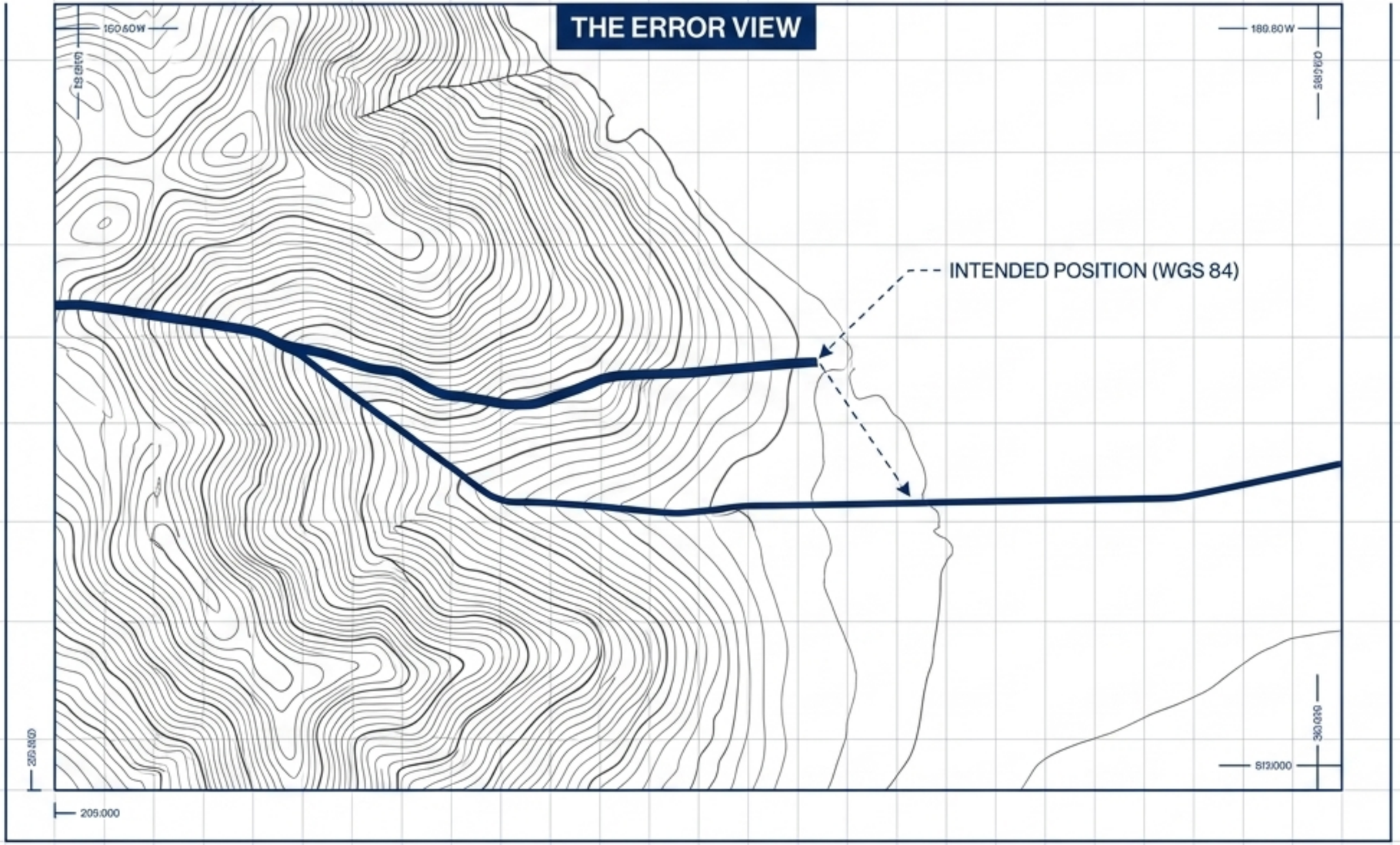
On-the-Fly (OTF) Reprojection

- **Mechanism:** Dynamic.
- **Function:** Automatically aligns datasets with different Layer CRSs onto a unified map canvas (Project CRS).
- **Limitation:** Strictly for visualization.

Permanent Reprojection

- **Mechanism:** Structural.
- **Function:** Rewrites the coordinate system stored in the source file using the ‘Reproject Layer’ tool.
- **Requirement:** Mandatory before executing processing tools (clipping, buffering) on mismatched layers to prevent systemic calculation errors.

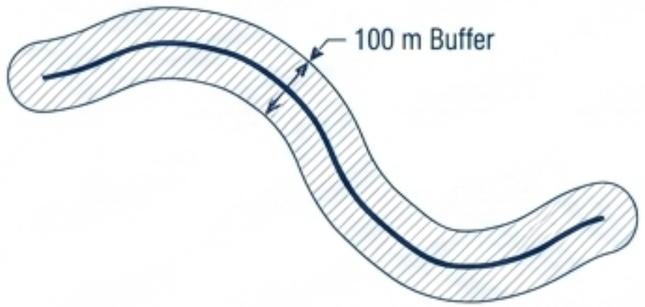
Diagnostic Warning: Incorrect datum definitions result in severe spatial misalignments.



The Shifted Layer

When datasets fail to align (e.g., a river shifted 200 meters off-target), it indicates the source file metadata contains an undefined or incorrectly assigned datum. The software cannot properly position the geometry relative to the WGS 84 ellipsoid.

Diagnostic Warning: Executing metric tools on angular data creates catastrophic scale errors.

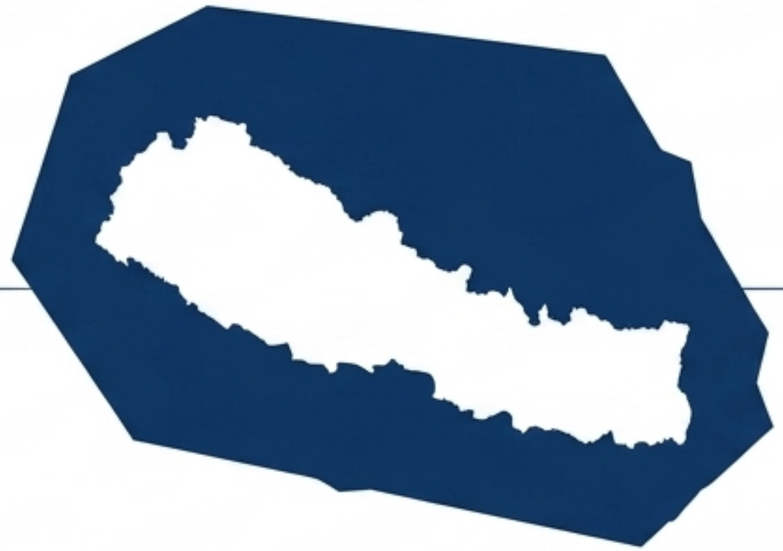


THE INTENT

Create a 100 m protective buffer zone around a specific river segment.

THE OUTCOME

The software generates a massive geometric blob that covers the entire country of Nepal.



THE DIAGNOSIS

Incorrect Buffer Units

The input layer was left in a Geographic Coordinate System (EPSG:4326). QGIS interpreted the input "100" not as meters, but as 100° of longitude—resulting in a buffer hundreds of kilometers wide.

Mandatory directives for spatial data management in hydrological modeling

Directive 01

Enforce PCS for Analysis

Never calculate area, slope, or distance using a Geographic Coordinate System. Always convert working data to a Projected Coordinate System to maintain metric linearity.

Directive 02

Standardize Regional Zones

Mandate EPSG:32644 (UTM 44N) for western/central basins and EPSG:32645 (UTM 45N) for eastern basins, split at the 84°E meridian.

Directive 03

Execute Permanent Transformations

Do not rely on On-The-Fly (OTF) visualization for analytical work. Reproject all spatial layers to a common CRS structurally before initiating spatial processing tools.