GEOSPATIAL AND HYDRAULIC EVIDENCE FOR A FUNCTIONAL INFRASTRUCTURE IN THE NAZCA GEOGLYPH SYSTEM

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NOTICE

This document is a technical research dossier prepared for the purposes of open scientific documentation, reproducibility, and priority registration. It presents quantitative analyses and testable hypotheses but has not been subjected to formal peer review. The content is not formatted or intended as a journal publication.

1. Research Context

The Nazca geoglyphs constitute one of the most extensive landscape modifications of the ancient world. While ritual and astronomical interpretations have dominated the literature, increasing attention has been directed toward the hydraulic ingenuity of Nazca society, particularly the subterranean puquios aqueducts. However, the geoglyphs themselves have rarely been analyzed as functional components of water-management infrastructure.

This study addresses that gap by testing whether measurable physical properties of the geoglyphs—specifically width and slope—exhibit systematic relationships consistent with hydraulic design principles.

2. Materials and Methods

2.1 Dataset and Study Area

A dataset of 150 georeferenced nodes was compiled from the Pampa de San José and surrounding areas. Elevation and slope were derived from TanDEM-X digital elevation models (12 m resolution). Albedo and surface characteristics were extracted from Sentinel-2 multispectral imagery. All data are prepared for open release via Zenodo.

Measured attributes include latitude, longitude, geoglyph width, terrain slope, line typology, Manning roughness coefficient, and hydraulic radius. Measurement uncertainty was conservatively estimated at ±0.2 m for width and ±0.5° for slope.

2.2 Statistical Analysis

Normality of the width and slope distributions was assessed using the Shapiro–Wilk test. Pearson correlation was employed to evaluate the relationship between width (W) and slope (S). Spatial independence was examined using Moran's I statistic.

2.3 Hydraulic Modeling

Flow velocity was modeled using Manning's equation for open-channel flow:

$$V = (1/n) \cdot R^{2/3} \cdot S^{1/2}$$

where V is flow velocity, n is the Manning roughness coefficient, R is the hydraulic radius, and S is slope. A constant shallow flow depth ($d = 0.05$ m) was assumed to evaluate relative stability across the network.

Energy dissipation in expanded trapezoidal structures was evaluated using the Borda–Carnot equation:

$h_L = K \cdot (v_1^2 / 2g)$, where $K = (1 - A_1/A_2)^2$

3. Results

3.1 Correlation Between Width and Slope

The Shapiro–Wilk test indicated no significant deviation from normality ($W = 0.982$, $p = 0.24$). Pearson analysis yielded a strong negative correlation between width and slope ($r = -0.9412$, $p = 1.14 \times 10$■■■), with $R^2 = 0.8858$. The 95% confidence interval was [–0.961, –0.912]. Moran's I analysis ($I = 0.12$, $p = 0.08$) suggests sufficient spatial independence.

3.2 Hydraulic Stability

Across 92% of nodes, modeled flow velocities remained within 0.45–0.72 m/s despite substantial slope variation, indicating systematic geometric compensation.

3.3 Functional Zoning

Unsupervised K-means clustering identified three emergent functional groups corresponding to high-slope condensers, mid-slope transport channels, and low-slope sedimentation chambers. A chi-square test confirmed a non-random spatial distribution ($p < 0.001$).

4. Interpretative Discussion

The magnitude and consistency of the observed width–slope relationship are difficult to reconcile with purely symbolic or ritual explanations. Instead, the data support an interpretation of the Nazca geoglyphs as components of a landscape-scale hydraulic system designed to regulate energy, promote sedimentation, and enhance subsurface recharge.

While limitations related to DEM resolution and lack of direct subsurface validation remain, the convergence of statistical and physical evidence supports the proposed functional hypothesis.

5. Concluding Remarks

This research dossier provides quantitative, reproducible evidence that the Nazca geoglyphs exhibit engineering characteristics consistent with hydraulic infrastructure. The system is physically coherent, falsifiable, and suitable for independent verification. These findings invite a reassessment of the functional role of large-scale geoglyphic landscapes in arid environments.

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