Human-Robot Collaboration for Disaster Relief

Graduation Progress Week 2.3(.1)

Graduation Studio Extraterrestrial Architecture MSc 3 | Maria Dumitrache

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Syabrubesi – Bhote Koshi Flood, Aug 2026
Position: Human-robot Collaboration

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3. SITE SELECTION BASED ON LANDSLIDE RISK
4. CONCEPT DESIGN
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1. RECAP

1.1. Location Description and Problem Statement

Bhote Koshi flood at Syabrubesi, Nepal

Event Data

A major flash flood entered Nepal through the Bhote Koshi River at approximately 9:00 AM on 26 August 2026, causing significant loss and damage across Rasuwa, Nuwakot and Dhading districts. (Nepal Flash Flood 2026 - Nepal | ReliefWeb, n.d.)

The cause of the flood remains under investigation, with authorities assessing the possibility of a glacial lake outburst flood (GLOF) or another upstream hydrological event. (India, n.d.)

1,453 people reported dead
5,179 people still missing
13,795 people have been rescued
1,109 displaced people remain in 21 displacement centers

Context

By official count, the Bhotekoshi flood now the deadliest flood in Nepal's modern record.

The Rasuwa corridor floods again and again. Between 2022 and 2026, five significant flash floods hit the Rasuwa district. In 2025, the Lhende-Bhote Koshi river system flooded twice, on 8 and 30 July. Together, the floods killed at least 20 people. The cause of the July 2025 event was different: a supraglacial lake on Tibet's Purepu Glacier rapidly drained, causing a flash flood.



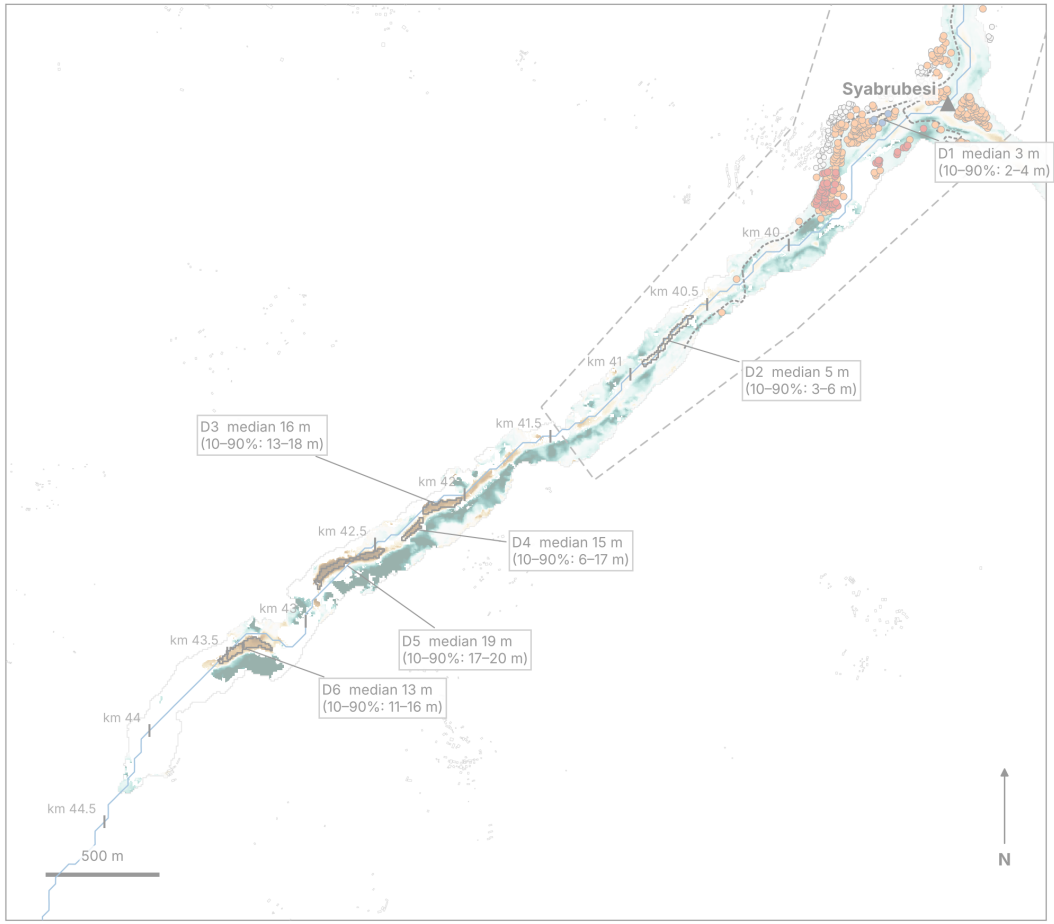


Syabrubesi, Napal

1. RECAP

Below Syabrubesi: the destroyed bazaar and the 13–19 m deposit 3–4.5 km downstream

Geopera dh raster (stereo DSM minus pre-event HMA DEM, 2 m, bias-corrected, measured cells only; SHA-256 verified). Shown only inside the modelled flood extent. Buildings: Copernicus EMS EMSR927 AOI01 grading.





Thickness inside the deposition polygons (dh raster, measured cells)

D1	km 39.2	median 3.4 m	90th pct 3.9 m	9 thousand m³
D2	km 40.8	median 4.6 m	90th pct 6.3 m	27 thousand m³
D3	km 42.1	median 16.1 m	90th pct 17.6 m	79 thousand m³
D4	km 42.3	median 15.2 m	90th pct 16.7 m	34 thousand m³
D5	km 42.7	median 18.8 m	90th pct 19.7 m	146 thousand m³
D6	km 43.4	median 13.5 m	90th pct 16.4 m	102 thousand m³

D1–D6: 397 thousand m³ in 32,640 m² (98% of polygon area measured).
D2–D6 (km 40.5–44.0): 388 thousand m³ = 68% of the 567 thousand m³ Geopera measured in the bins of that reach.

Caveats: the colours outside D1–D6 include valley-wall pixels; Geopera's floor mask is not public, so wall values are not flood signal. Uncertainty raster not applied (not received). Deep erosion next to D5–D6 may be real incision or wall pixels; not separable here. Grain size unknown: thickness ≠ usable stone.

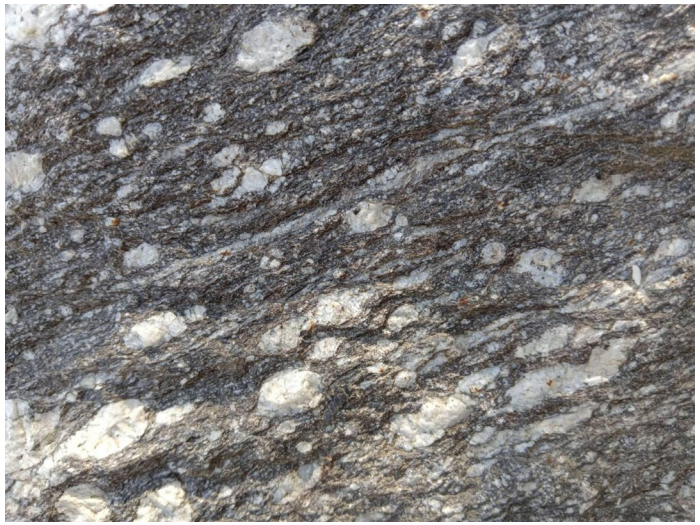
Sources: Geopera v1.1 bhotekoshi_dh_syabrubesi_2m.tif, deposition polygons, flood extent, centreline (CC BY-NC 4.0, derived from WorldView-3 © Vantor) · Copernicus EMS EMSR927 AOI01 (© European Union). EPSG:32645.

2. MATERIAL CONTENTS

2.1. Local rock types present in the sediment

Two classes for building: gneiss and quartzite;

Phyllite and schist are platy and only suitable as packing.





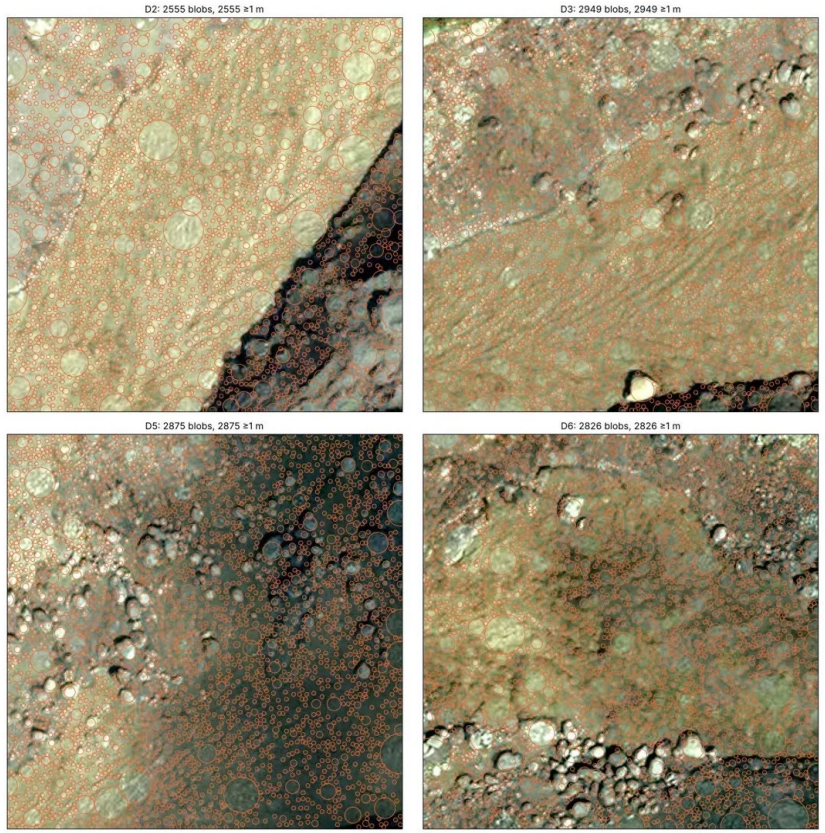


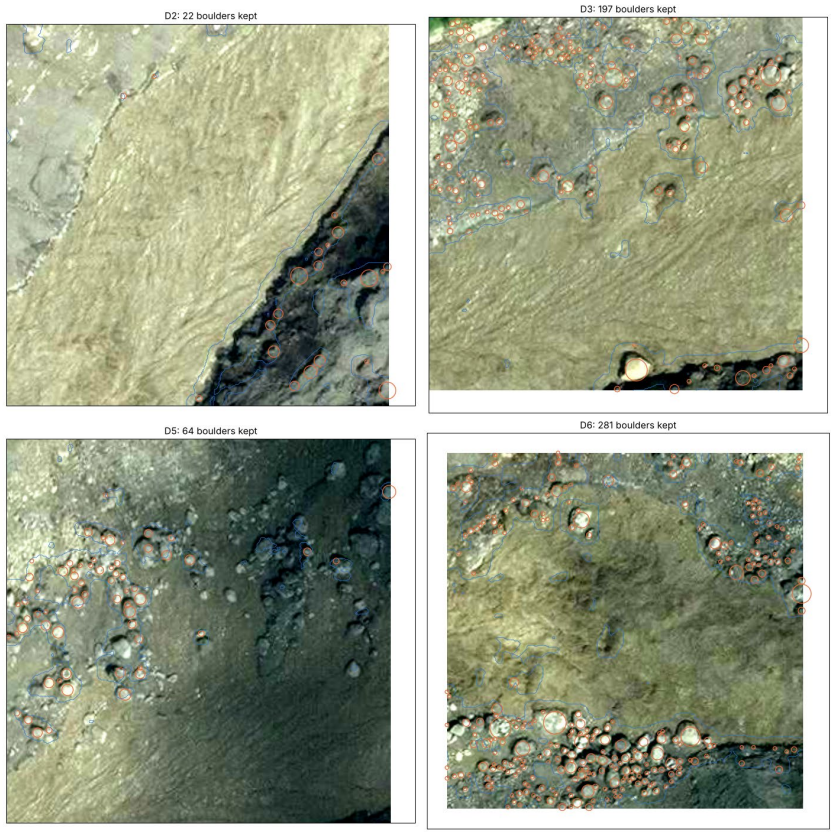
left to right: augen gneiss, banded gneiss and two-mica gneiss

2. MATERIAL CONTENTS

2.2. Satellite imagery + statistics (based on Walther J, Johns R, Kolvenbach H, Bickel V, Hutter M., 2024)

loam (43% sand, 34% silt, 23% clay), with stones over 2 mm making up about 26% of the volume.





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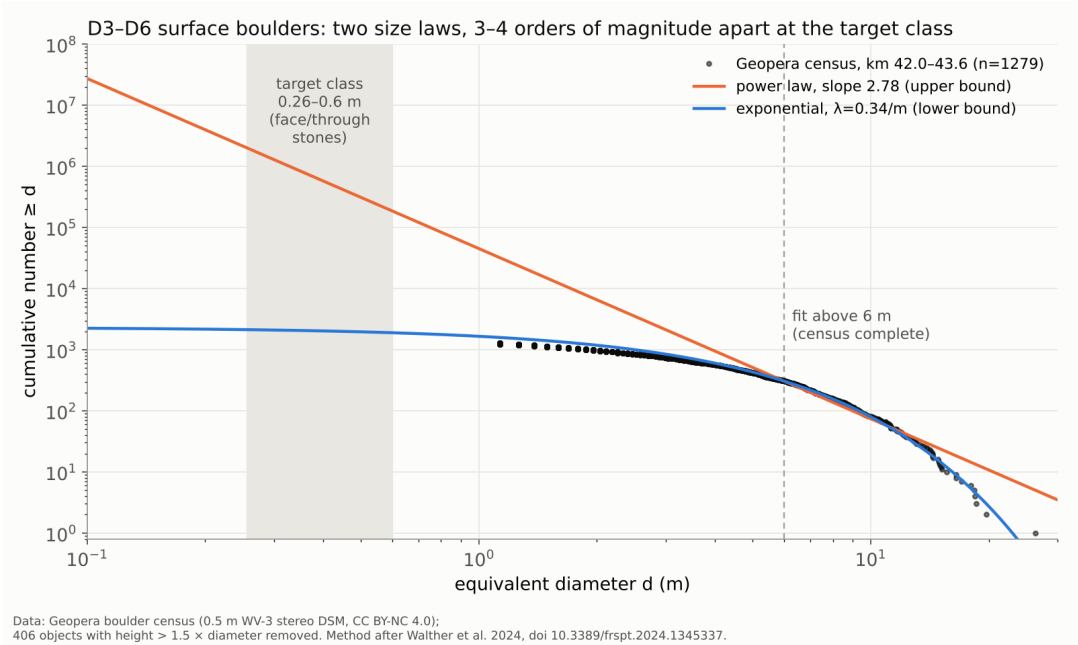
Composition of D1–D6 (397,000 m^3), first version

	Estimate	Based on
Natural sediment vs building debris	at least ~90% natural; building debris **at most ~10%**	199 buildings likely washed away × ~207 m^3 each. This ceiling assumes all of it stopped here, which it didn't.
Rock type of the stones	**≥ ~95% gneiss/granite**, ≤ ~5% phyllite	Geology map: the whole flow path from km 0 to 40 is gneiss/granite. Phyllite first appears at km 40–43.6, right at the deposit, so it can only come from local bank erosion. Phyllite also breaks up on the way and ends up as sand and silt.
Eroded soil (fines)	loam: 43% sand, 34% silt, 23% clay; **26% of the volume is stones over 2 mm**	SoilGrids, 0–200 cm. This describes only the soil part that the flood picked up, not the deposit itself.
Large blocks ≥1.5 m	measured: ~62,000 m^3 standing above the surface in the D3–D6 stretch (km 42–43.6)	Boulder census
Wall stones, 0.26–0.6 m	**anywhere from 4 m^3 to 18,000 m^3** on the D3-D6 surface	Both size laws estimated down from the census. See the chart.



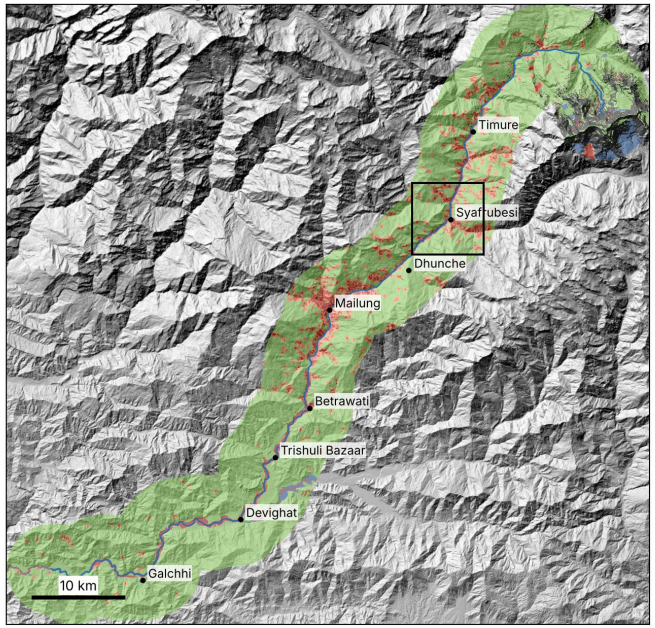
3. SITE SELECTION BASED ON LANDSLIDE RISK

a. situation fixes most of the risk
b. *landscape engineering*
c. *shelters with some resistance programed*

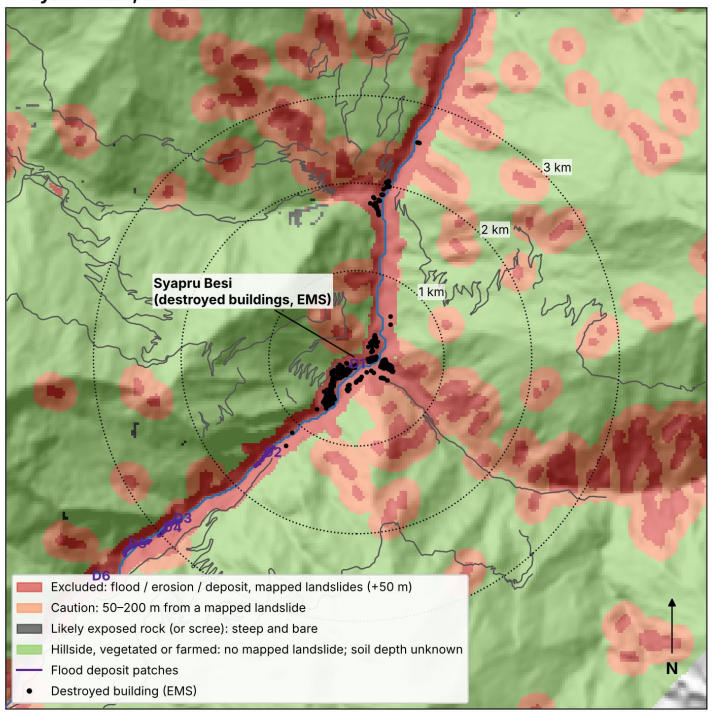
Where the ground is safe enough to rebuild: a remote screening of the Bhote Koshi–Trishuli corridor

Landslide and flood exposure first; slope is not treated as a hazard. This rules ground out; it cannot certify it.

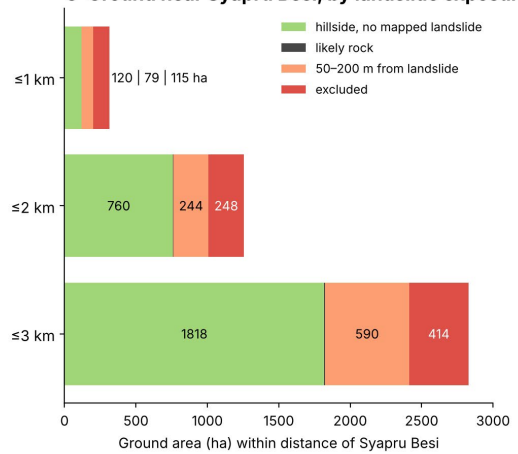
A Corridor screening (5 km either side of the river)



B Syabrubesi, 8 × 8 km



C Ground near Syapru Besi, by landslide exposure



Within 1 km: 120 ha of hillside clear of mapped landslides (need ≈ 5–8 ha). Likely exposed rock: 0 ha (≤1 km), 5 ha (≤3 km): at 30 m, rock under thin soil or vegetation is invisible.

Read with care
- Slope is not used as a class (kept as slope_deg_30m.tif for reference).
- Mapped landslides show past failures only; rockfall from above is not modelled.
- Height above river uses the main river only; the Langtang Khola and side-stream debris fans are not screened.
- Rock vs scree vs thin soil needs high-resolution imagery or a site visit.
- Landslides: Langtang inventory and the 2015 Gorkha earthquake inventory; older or dormant slides may be missing.

Sources: Copernicus DEM GLO-30 (© DLR/Airbus, ESA) · ESA WorldCover 2021 · Gnyawali et al. 2016 landslide inventory (USGS ground-failure data series) · Langtang landslide inventory (source to be cited) · Copernicus EMS EMSR927 (© European Union) · Geopera v1.1 (CC BY-NC 4.0) · OSM (ODbL). EPSG:32645.

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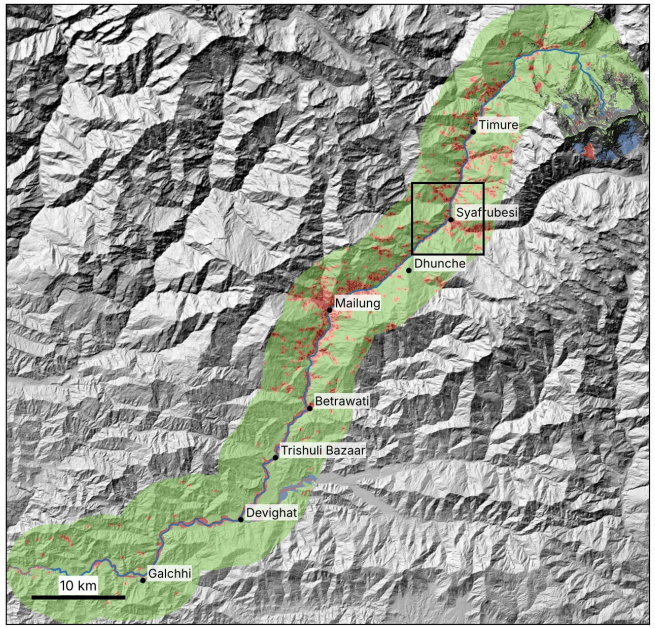

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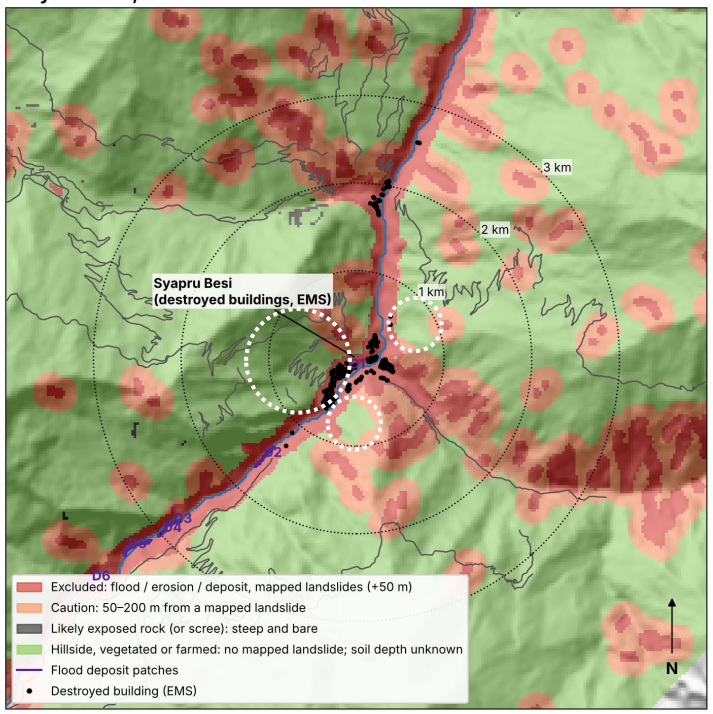

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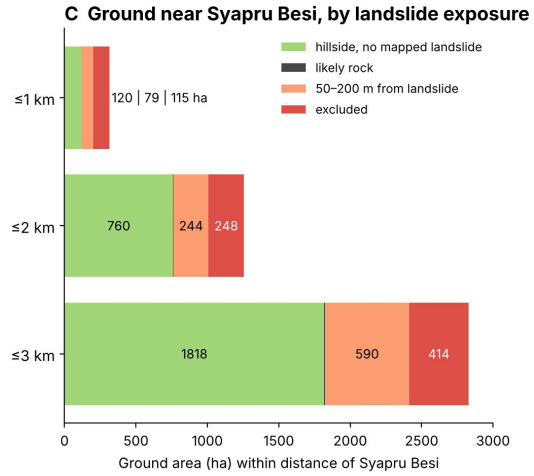

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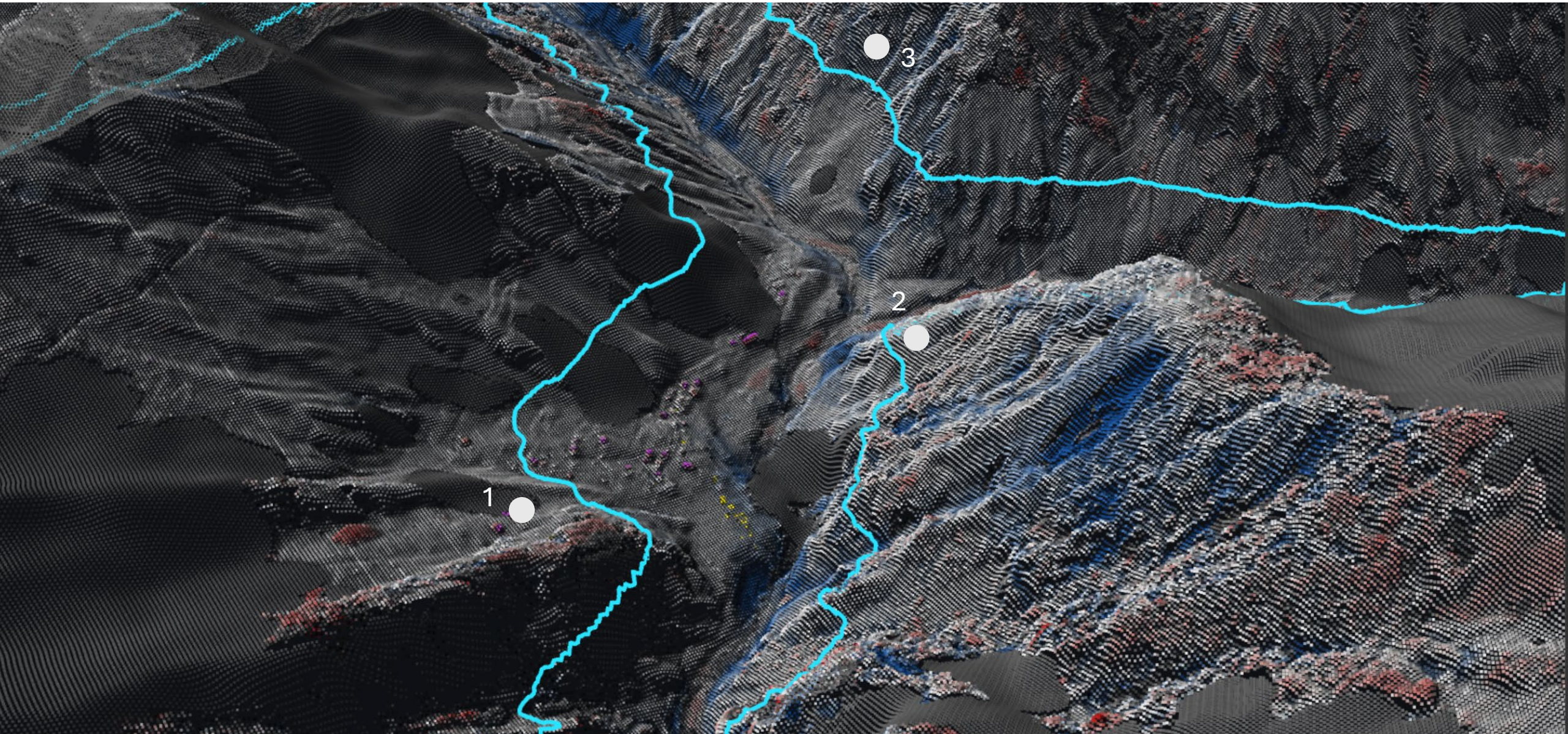
3. SITE SELECTION BASED ON LANDSLIDE RISK

1 *– overlaps previous location, but avoiding the main valley line*
2 *– steep terrain*
3 *– steep*

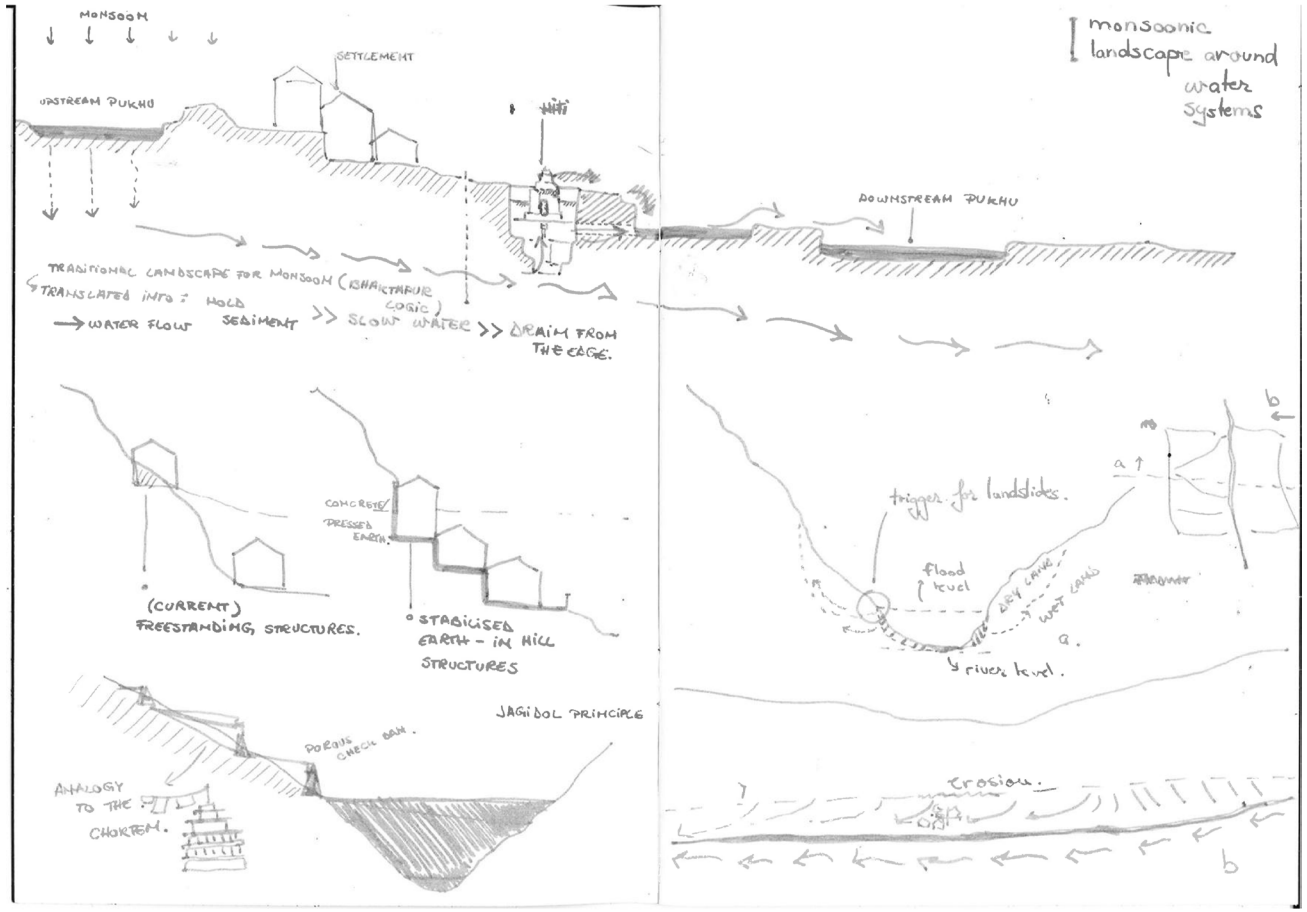
a. situation fixes most of the risk
b. *landscape engineering*
c. *shelters with some resistance programed*

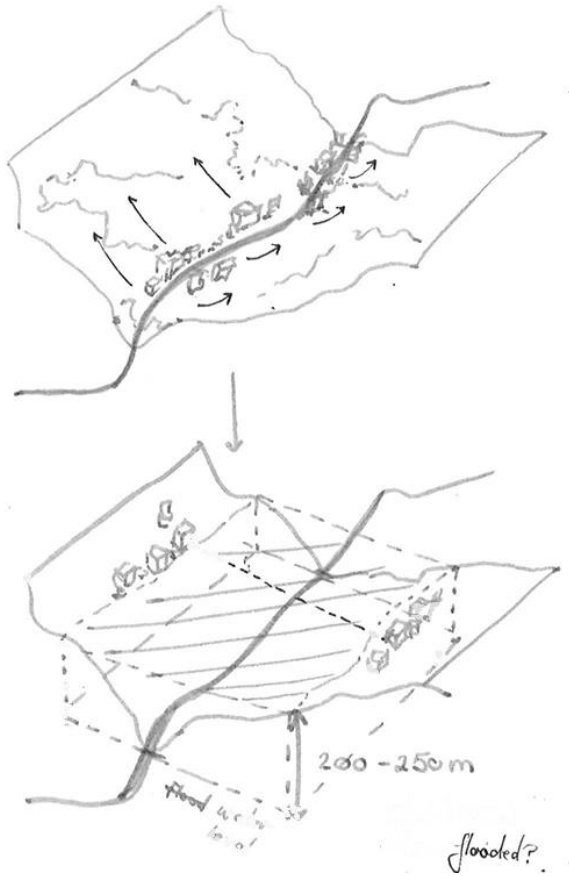


4. CONCEPT DESIGN

4.1 Vernacular landscape strategies

a. *situation fixes most of the risk*
b. landscape engineering
c. *shelters with some resistance programed*





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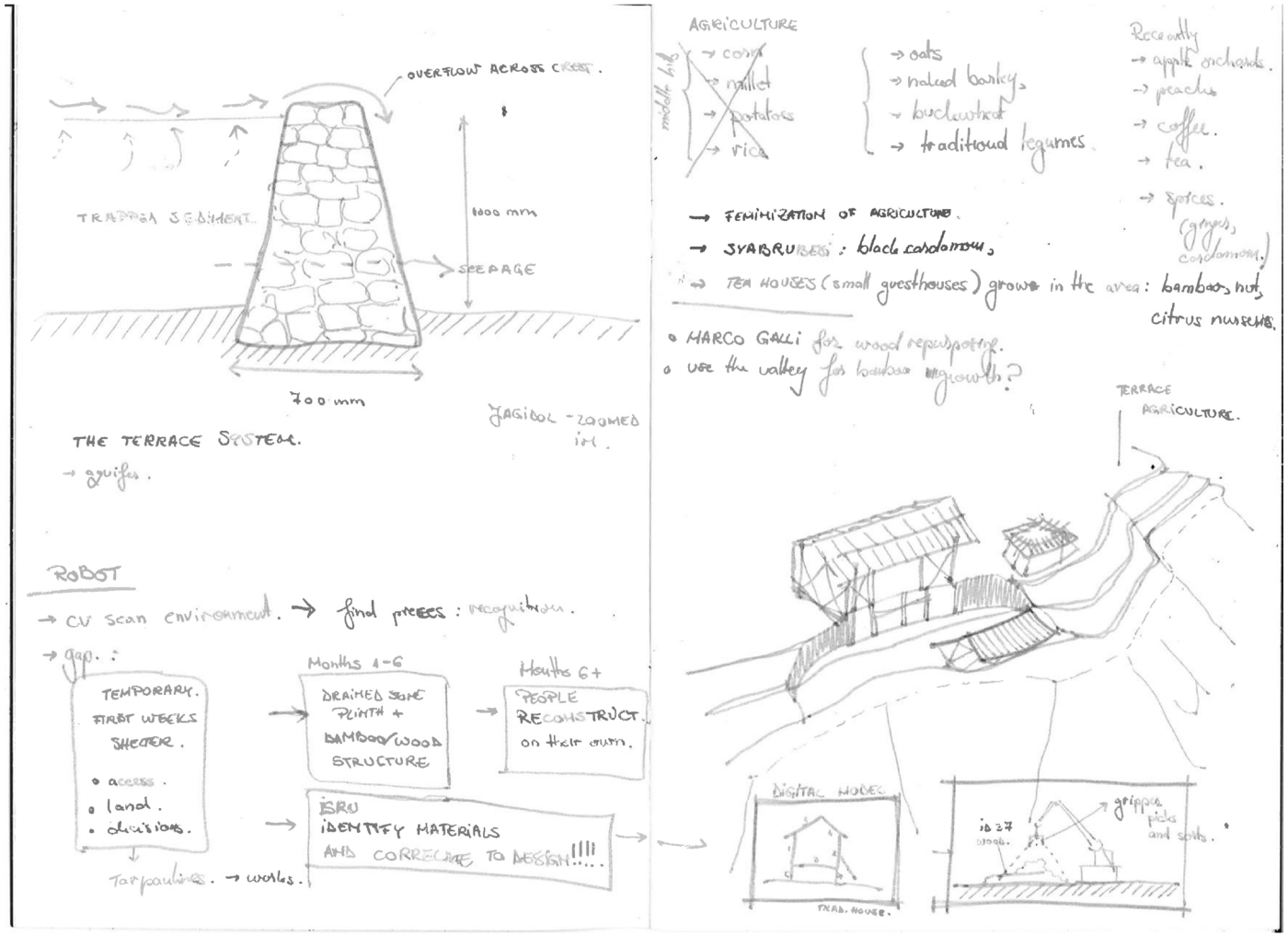
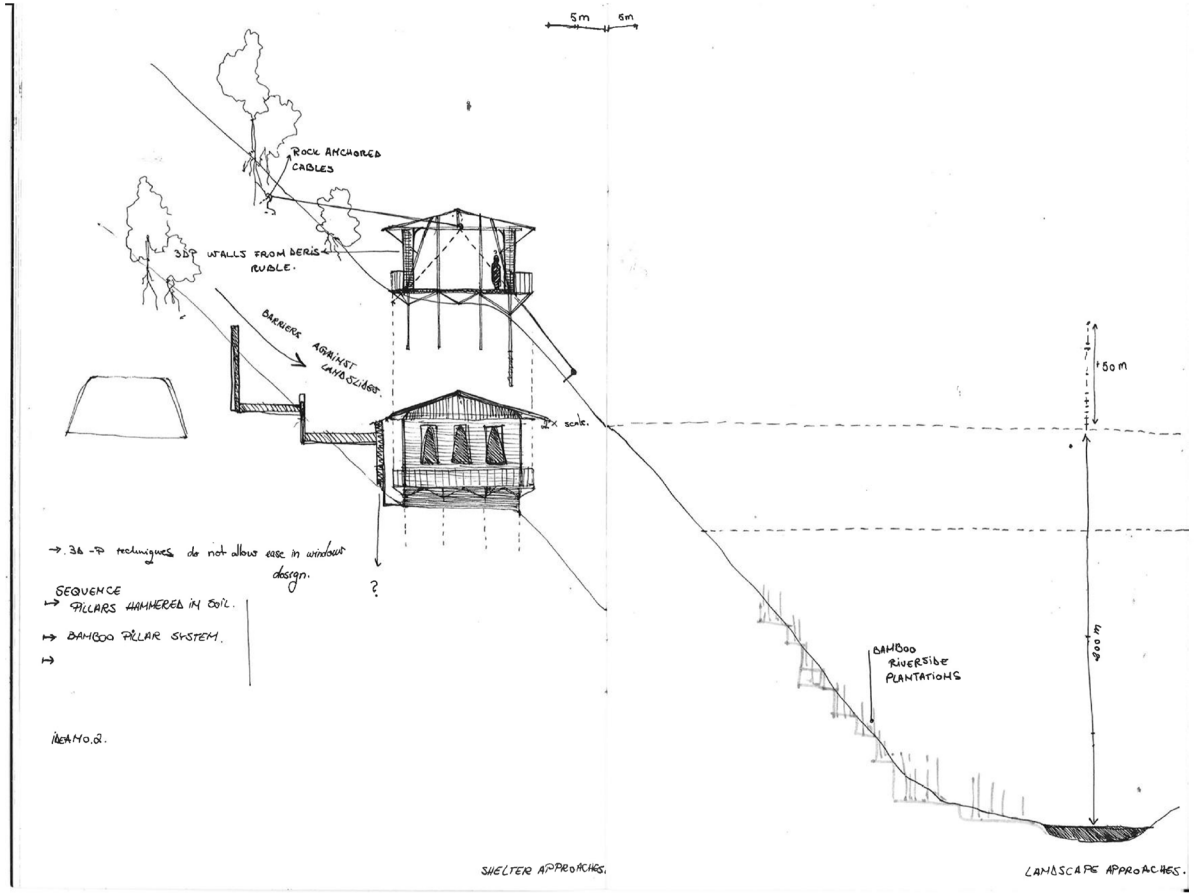


4. CONCEPT DESIGN

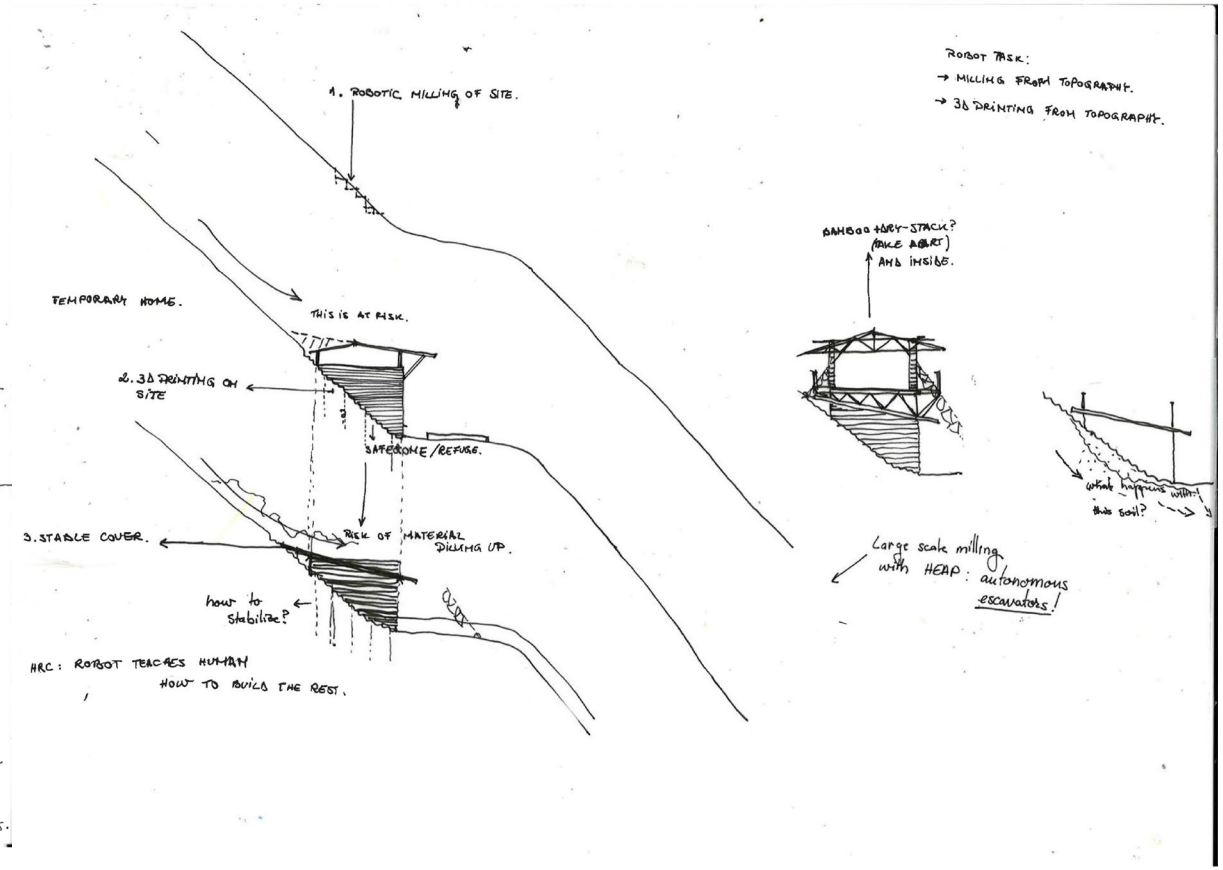
4.2 Shelter unit: 2 ideas, bunker base + top designed for collapse

a. *situation fixes most of the risk*
b. *landscape engineering*
c. shelters with some resistance programed

4.2.1 Shelter on stilts, 3DP walls, bamboo structure on top



4.2.2 Emergency shelter unit + later constructed top



4. CONCEPT DESIGN

4.3 Shelter unit requirements

4.2.2 Emergency shelter unit + later constructed top

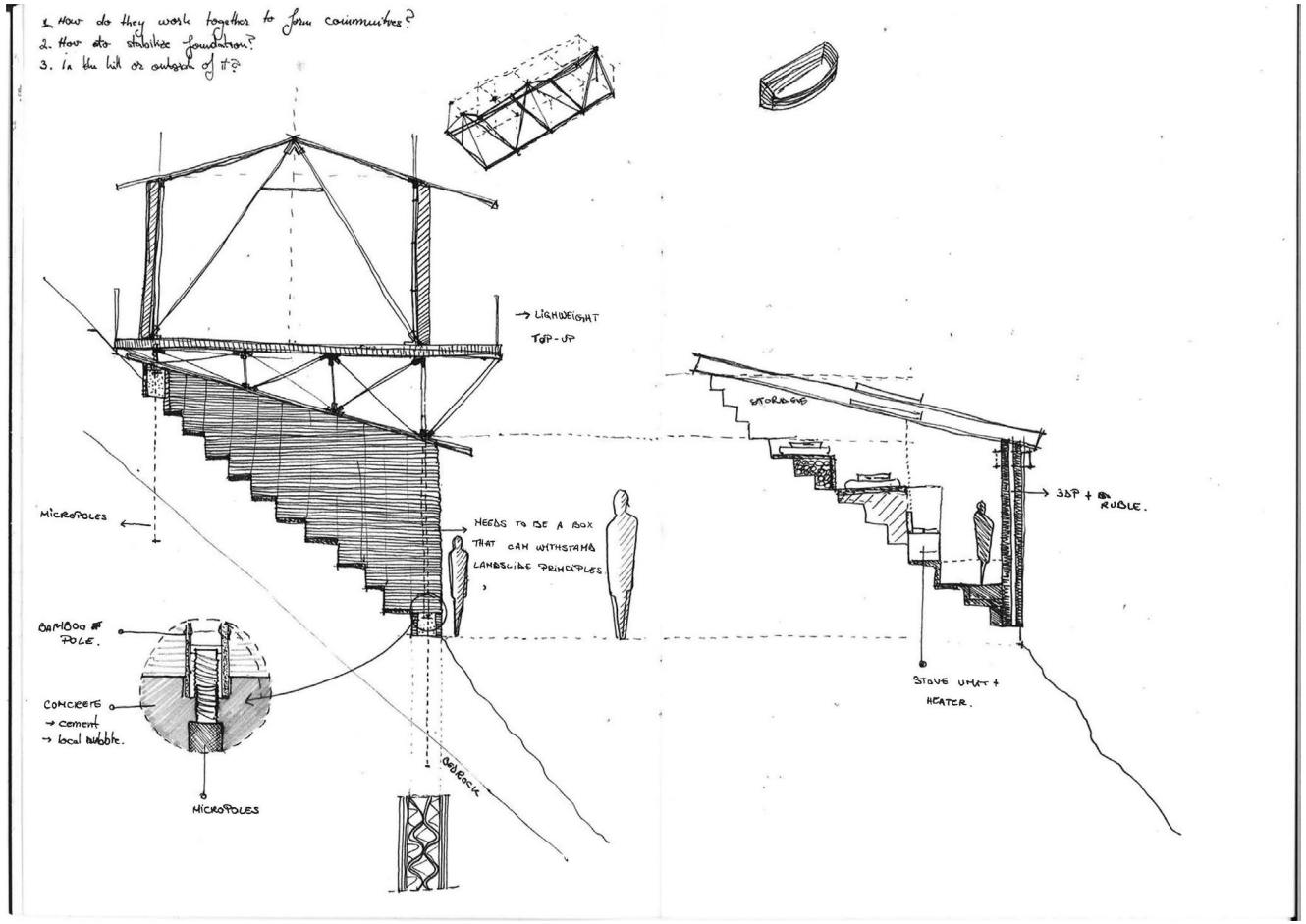
3d printed shelter unit:

combination of:
1. *Concrete-earth casting/3dp form with boulders and*
2. *Lightweight deployable top up*

2 parts to maximize isolation and resistance of bunker walls, while creating the option for a more livable house on top.

Options for base:

3d printed form: *round corners for better printability – less resistance to external factors* ***Mold built-up:*** *straight surfaces for ease of mold build – requires more materials*



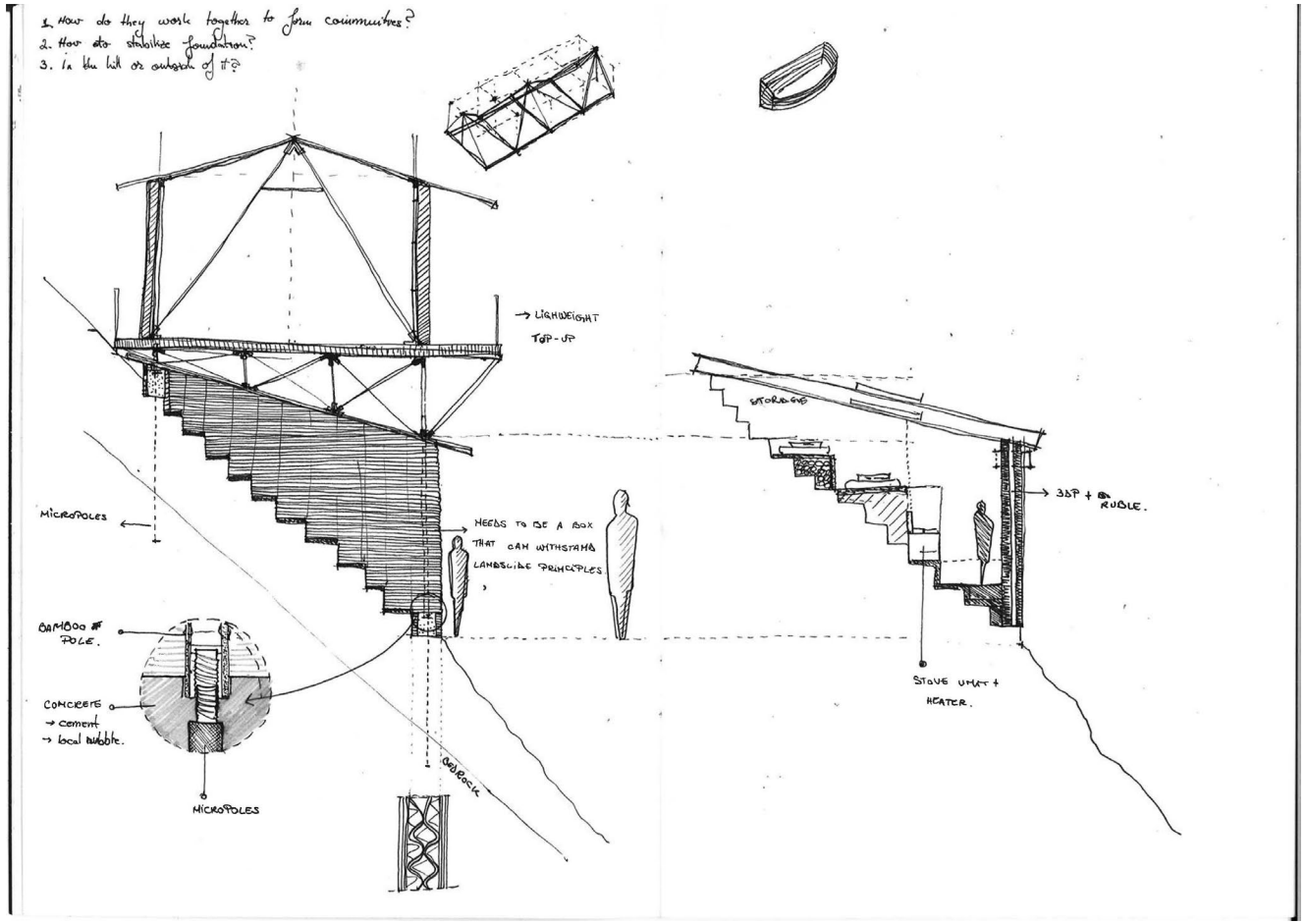
4. CONCEPT DESIGN

ROBOTIC TASKS

4.2.2 Emergency shelter unit + later constructed top: bamboo + prefab 3DP/drystack

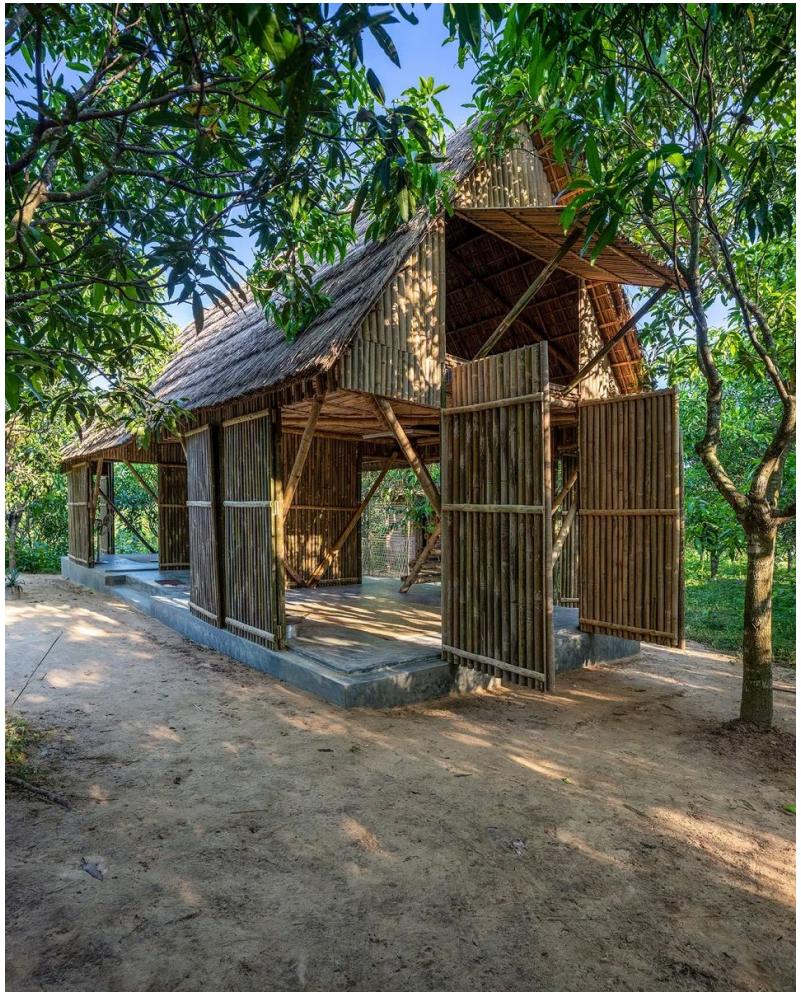
"The flood reached Syabrubesi around 8:50 am after crossing into Nepal at 8:40 am, while SMS alerts were sent between 9:15 am and 9:16 am."

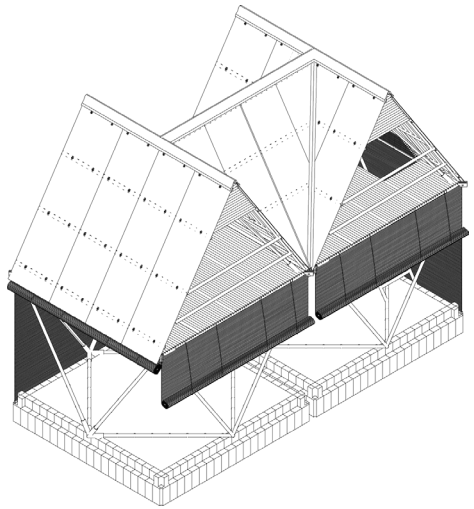
1. ***Scan material database***
2. ***Determine estimated module count***
3. ***Determine order of fabrication on map***
4. ***Scan environment***
5. ***Create milling Task***
6. ***Scan Environment***
7. ***Create foundation task***
8. ***Create 3DP task***
9. ***Human-Robot collaboration for building***

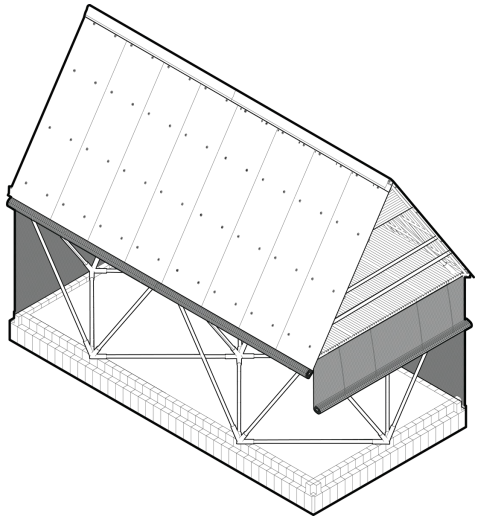


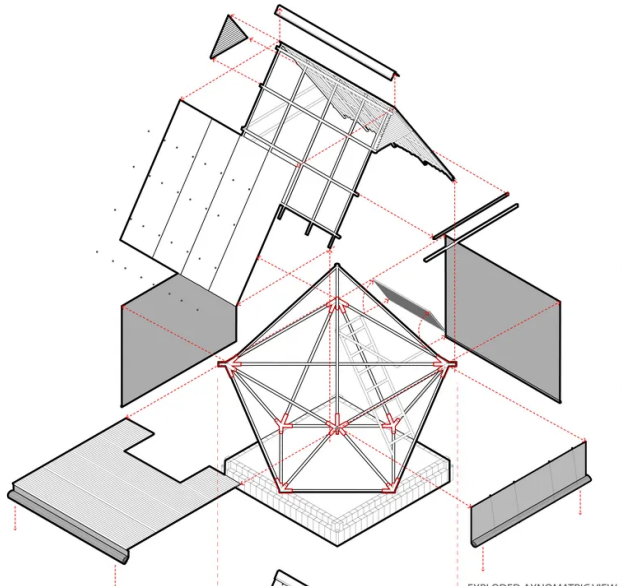
4. CONCEPT DESIGN

2.2 Shelter unit – case study, demountable bamboo structure, Khudi Bari - Marina Tabassum

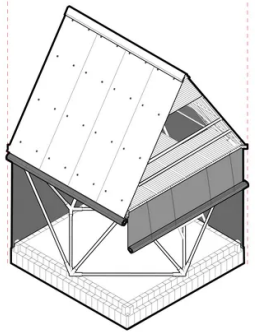








EXPLODED AXNOMATRIC VIEW



AXNOMATRIC VIEW

4. CONCEPT DESIGN

2.2 Shelter unit – case study, 3D printed bunker

(46 sq m) in just 40 hours.

IIT-Hyderabad builds world's highest on-site 3D-printed military bunker at 11,000ft in Leh

Swati Bharadwaj / TNN / Updated: Apr 18, 2025, 11:27 IST

Share AA

IIT-Hyderabad, Simpliforge Creations, and the Indian Army have achieved a groundbreaking feat by constructing the world's highest 3D-printed military bunker in Leh. Built on-site at 11,000 ft using locally sourced materials under Project Prabal, the bunker showcases indigenous technology and academia-industry collaboration.



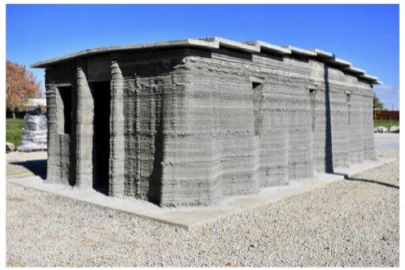
HYDERABAD: It took just five days and a total printing time of 14 hours to build what is being touted as the world's highest ever on-site 3D-printed military bunker in Leh. This feat was executed by the Indian Institute of Technology, Hyderabad (IIT-H), along with Hyderabad-based Simpliforge Creations and the Indian Army. This marks the world's highest-ever in-situ 3D construction printing feat to be accomplished under extreme high altitude and low oxygen (HALO) conditions.

1. The printing makes the formwork; the protection comes from the infill. In the shelter cases that describe their walls (UTU's Irpin safe room, its permanent formwork), the printed layers are a shell, and the protective mass is poured or packed inside. This links straight to G-10a. Take a printed shell made from local material and fill it with on-site granular material or flood debris. The infill can be dug out again, so the structure can be taken apart and the material returned to stock.

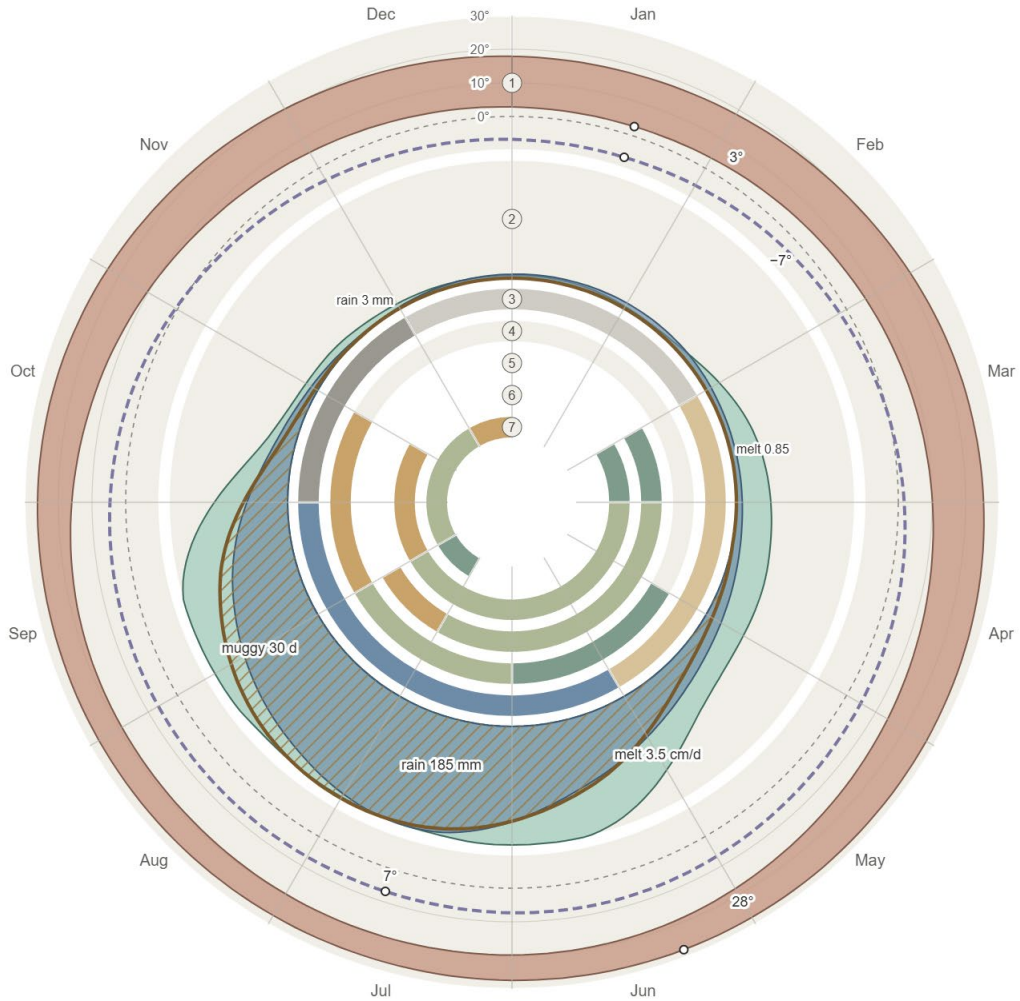




(a)



(b)



Rings, outer to inner

1 Temperature, −10 to 30 °C
2 Monsoon waves, each scaled to its own peak
3 Season
4 Upper valley (3,400–3,900 m): potato, barley, buckwheat
5 Mid valley (~2,200 m) potato
6 Mid valley maize
7 Mid valley beans

Key

Syabrubesi low–high (est.) — Kyanjin mean (est.)
Rain — Muggy days — Snow + ice melt
Winter — Pre-monsoon — Monsoon — Post-monsoon
Sow — Growing — Harvest

Temperatures: WeatherSpark Kathmandu, lapse-rate adjusted (6.5 °C/km).
Rain, muggy: Kathmandu, unadjusted. Melt: Langtang debris-ice rates.
Crops: ICIMOD/HI-AWARE Gatlang; upper valley indicative.