Geospatial Technologies in Water Resource Management

The Master Matrix

Spatial Modeling & Infrastructure

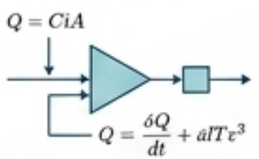
Focus: Physical landscape, engineering

1. Watershed Planning

3. Reservoir Management

5. River Morphology

9. Hydrological Modeling



11. Infrastructure Planning

Hazard & Risk Management

Focus: Temporal urgency, early warning

2. Flood Monitoring

4. Drought Assessment

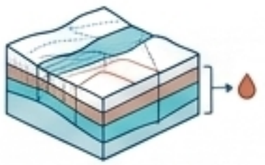
10. Climate Change Security

12. Real-Time Monitoring & EWS

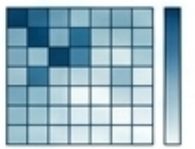
Resource Accounting & Quality

Focus: Budgets, mass balance, interpolation

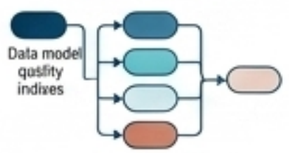
6. Environmental Quality



7. Groundwater Assessment

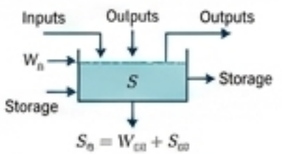


8. Rainfall Analysis



13. Emerging Tech

14. Water Balance



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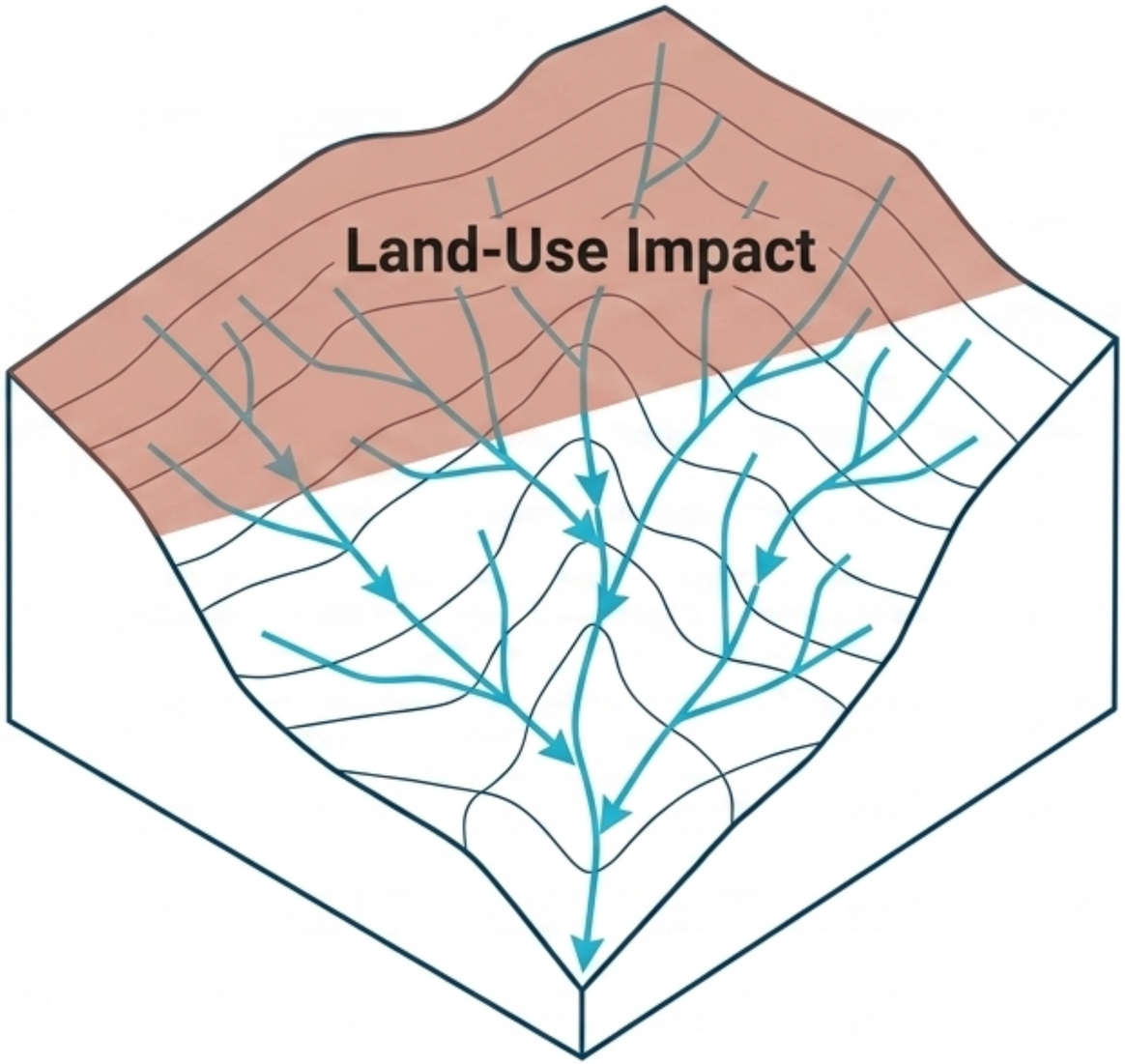
1. Watershed Planning

$$Dd = \sum \frac{L}{A}$$

- **Catchment Characterization:** Area, perimeter, circularity, elongation, slope.
- **Interpretation:** High Dd = Rapid surface runoff, **high erosion risk**, **low groundwater infiltration**.
- **Action:** Overlay Soil + Land-Cover maps to simulate peak discharge changes.



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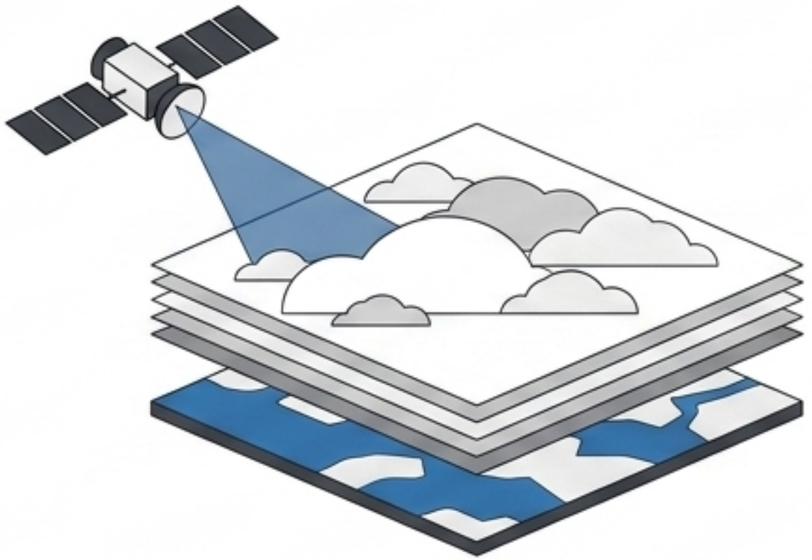
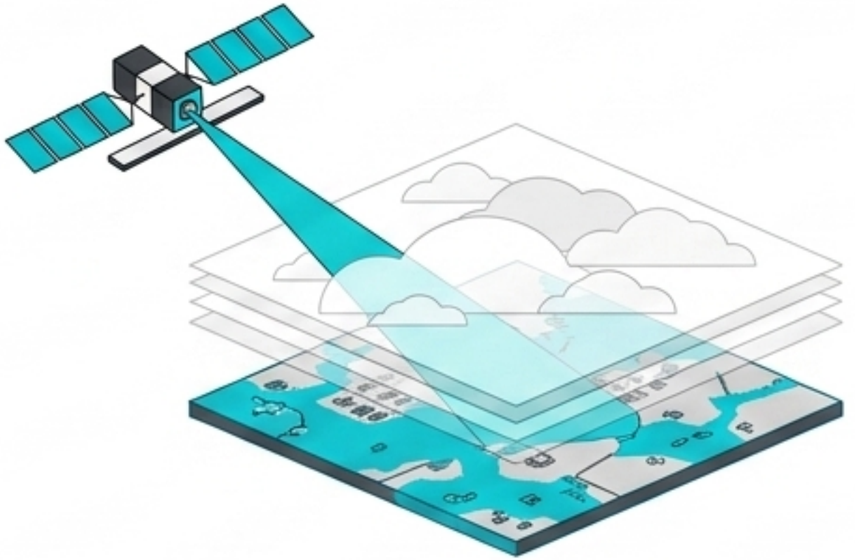
2. Flood Monitoring & Hazard Mapping

Optical Satellite



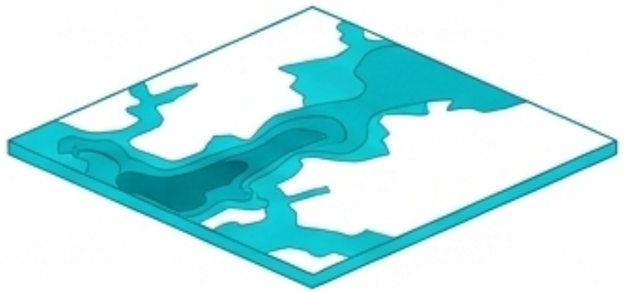
Blocked by Clouds.
Limited effectiveness during monsoon.

Synthetic Aperture Radar (SAR)



Penetrates Clouds.
Maps water bodies day/night.

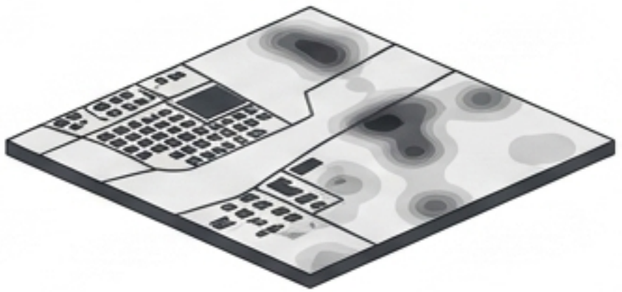
SAR Inundation Depth



SAR Inundation Depth

+

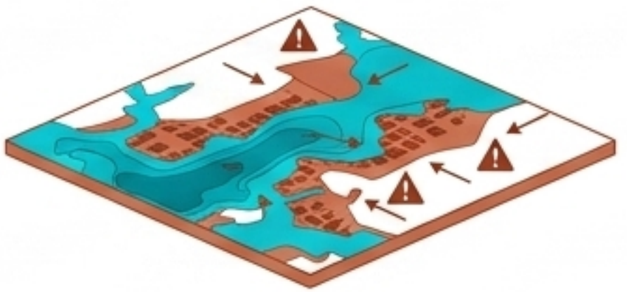
Building Footprints/Population



Building Footprints/Population

=

Immediate Evacuation Zones



Immediate Evacuation Zones

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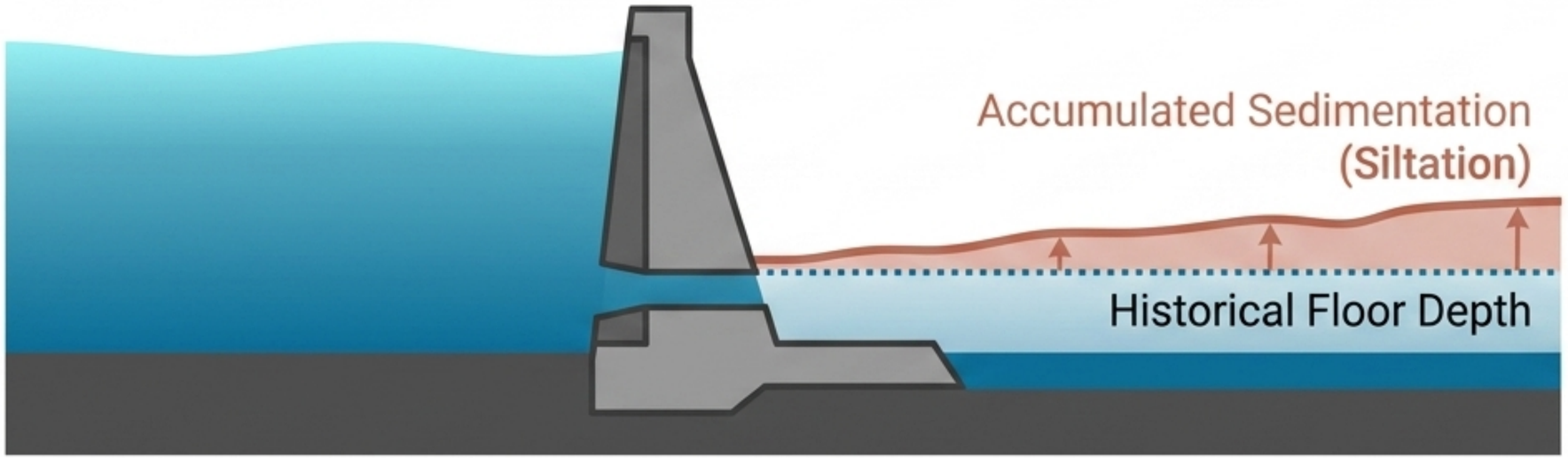
3. Reservoir Management & Siltation Studies

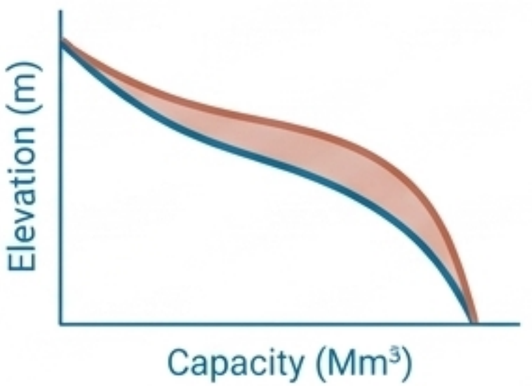


Replaces expensive underwater bathymetric surveys using multitemporal satellite area mapping.

Satellite Precipitation Data → **Rainfall-Runoff Model** → **Reservoir Inflow Forecast**

Forecasting logic based on upstream rain gauge and satellite data to predict inflow.

Elevation-Area-Capacity Curve



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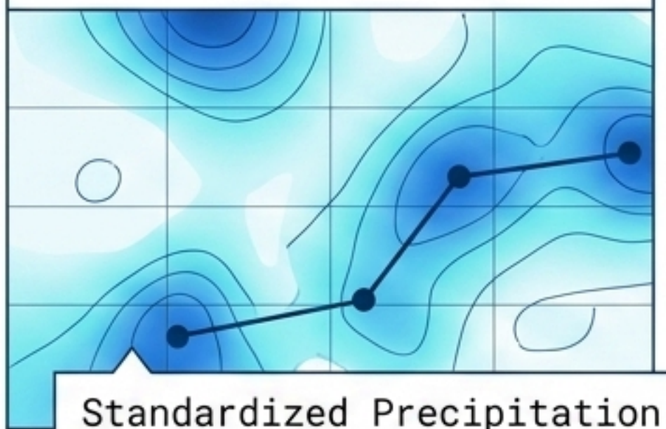
4. Drought Assessment & Drought Indices

Tier 1

Meteorological Drought

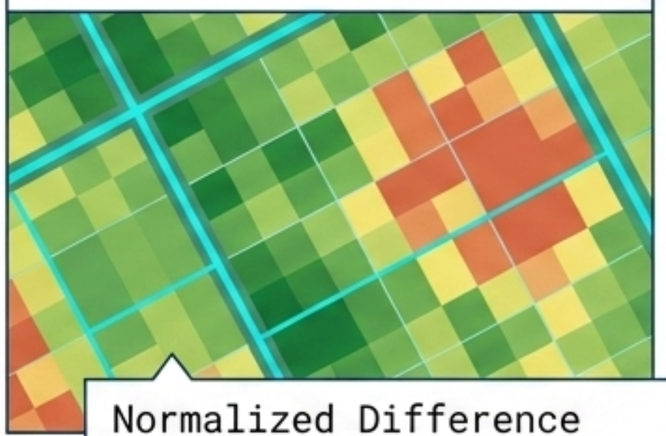


`Standardized Precipitation Index (SPI)`

Tracking rainfall deficits across catchments.

Tier 2

Agricultural Drought

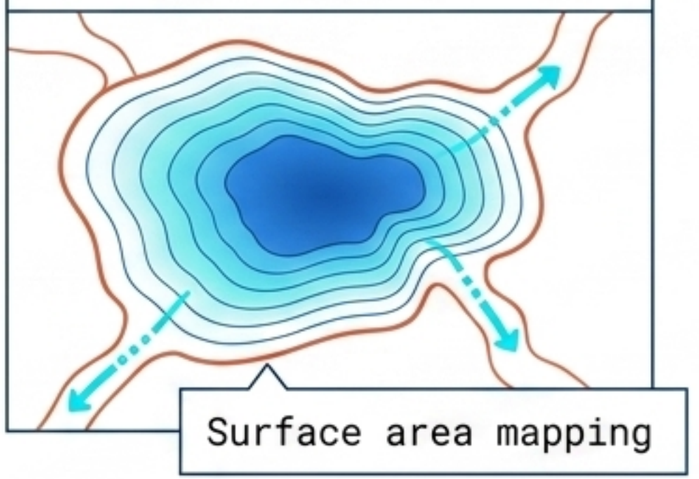


`Normalized Difference Vegetation Index (NDVI)`

Anomalies in vegetation health indicate water shortages.

Tier 3

Hydrological Drought



`Surface area mapping`

Water table decline and streamflow depletion in wetlands/reservoirs.

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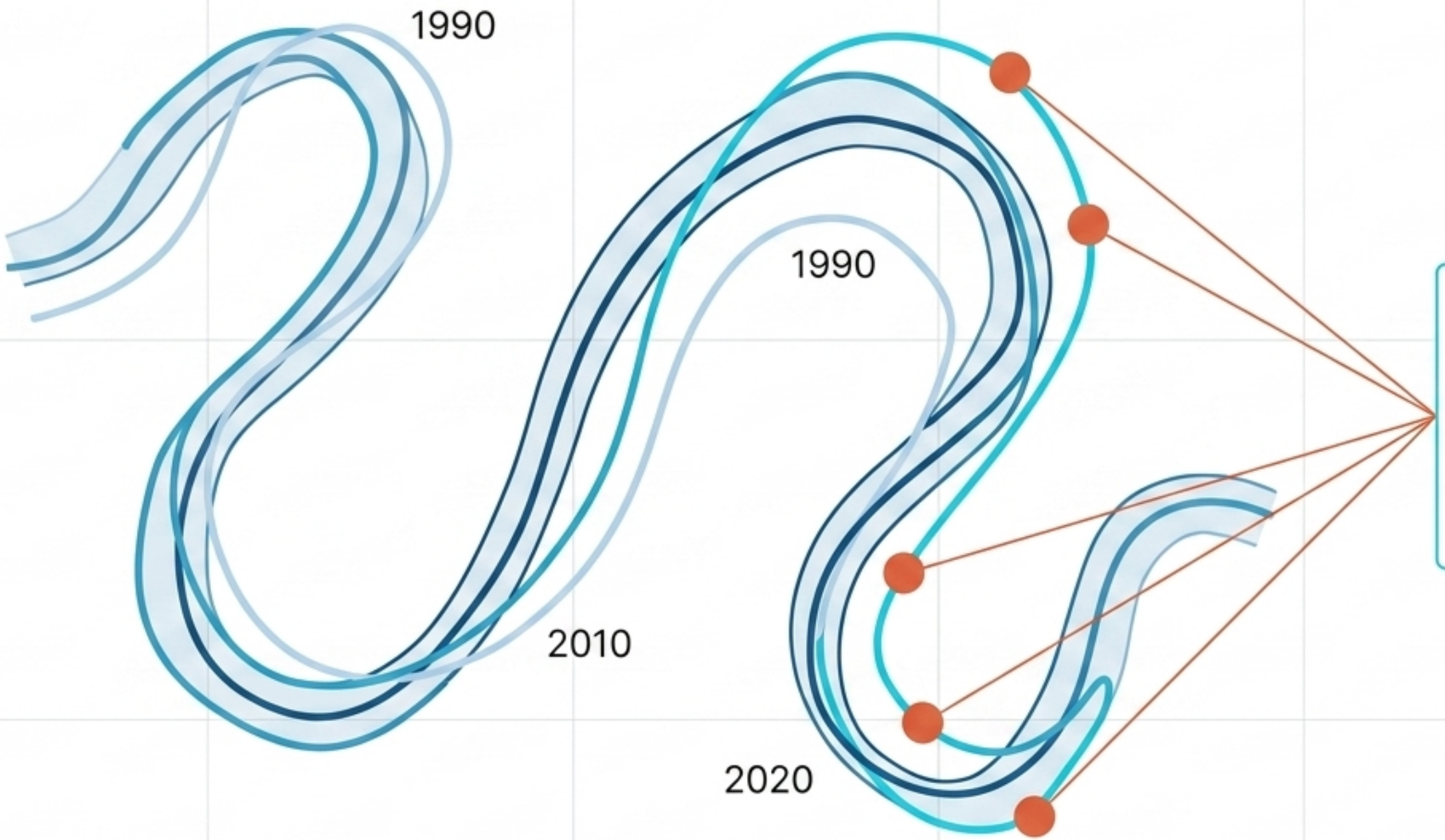
5. River Morphology & Channel Shifting



High-vulnerability bank erosion zones identified for protective structures (e.g., gabion walls, guide bunds).

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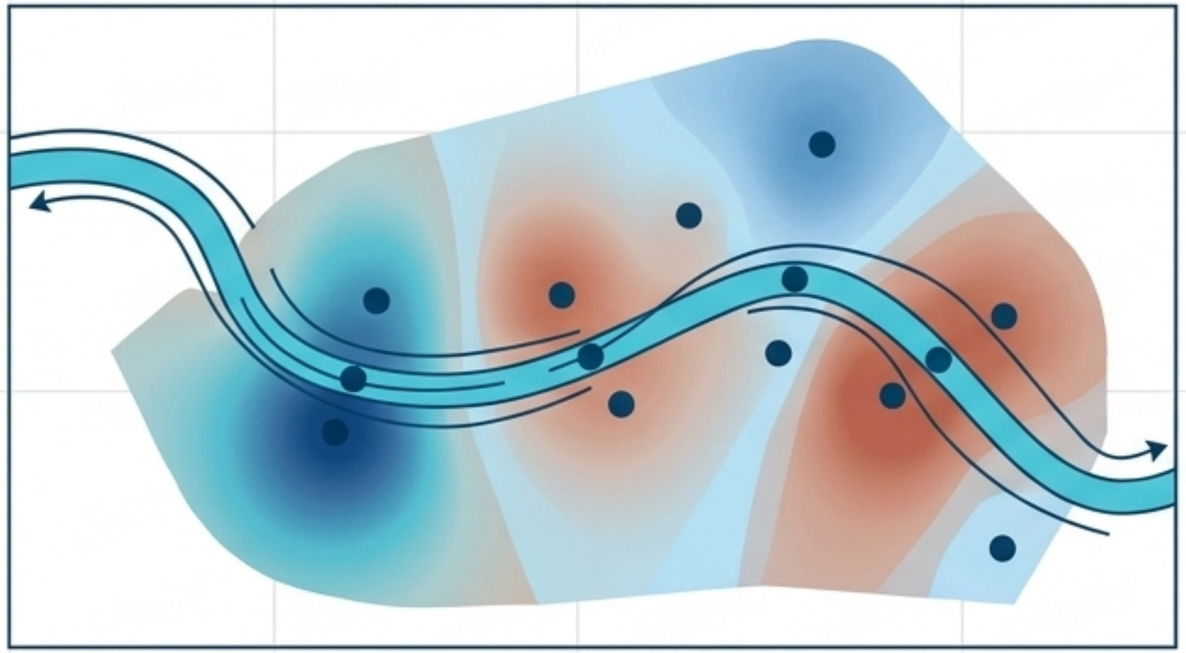
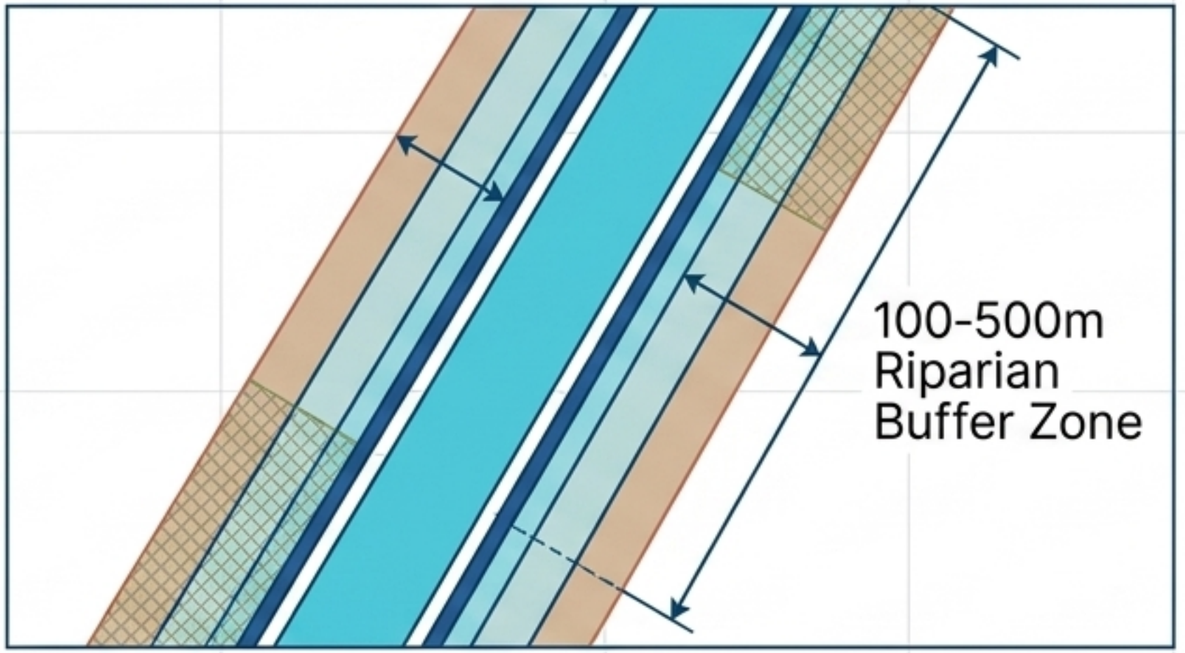
6. Environmental & Water Quality Monitoring

Water Quality Mapping



Interpolation Techniques

Riparian Buffer Zone Assessment



Vegetation within buffer filters agricultural runoff and stabilizes banks.

`Hydropower Layout Map + Real-Time Discharge Database = Downstream Ecological Flow Compliance`

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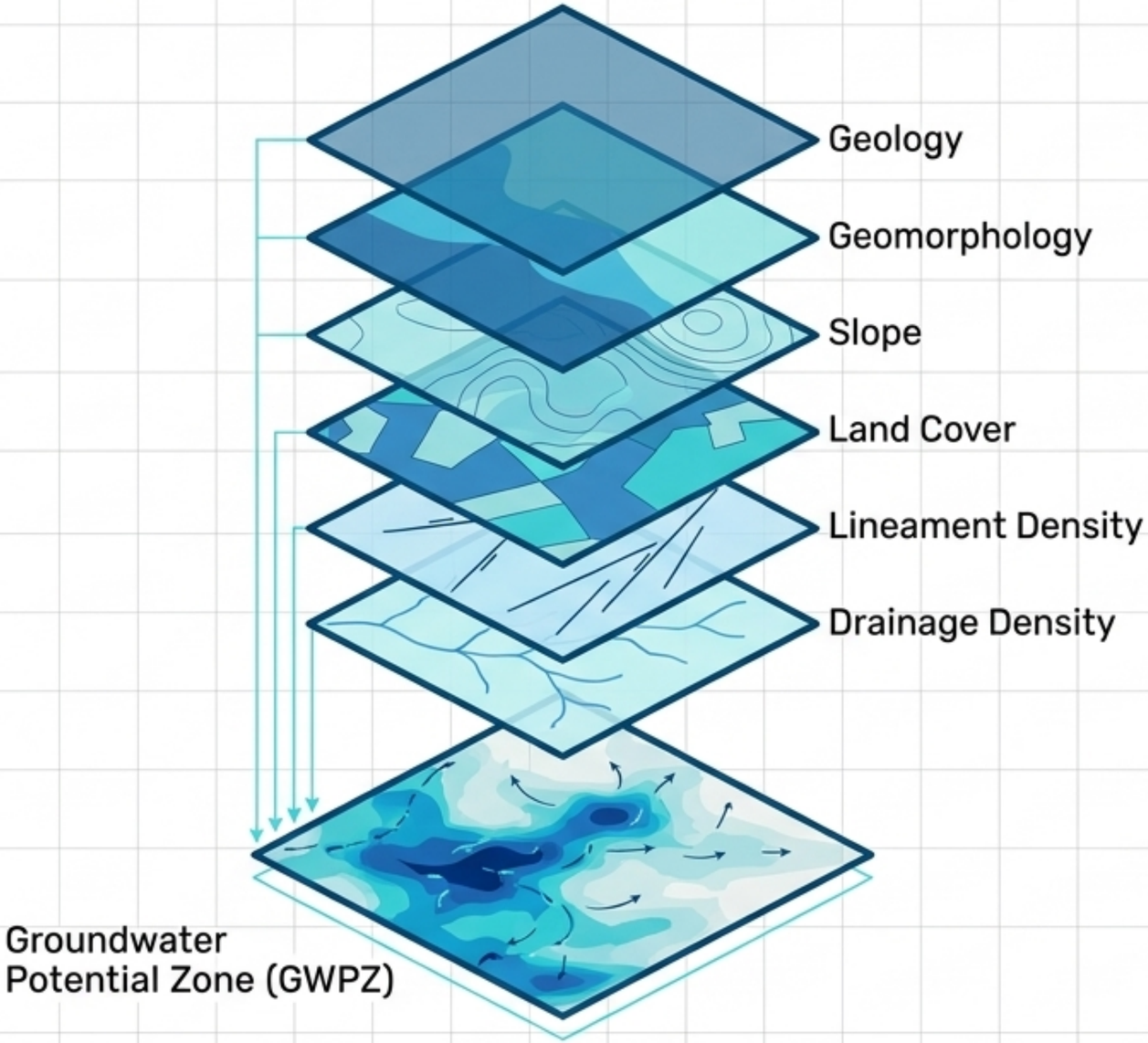
7. Groundwater Assessment & Aquifer Mapping



Aquifer Vulnerability

DRASTIC model:

- Depth to water, net Recharge,
- Aquifer media,
- Soil media,
- Topography,
- Impact of vadose zone, hydraulic Conductivity.

Macro-Scale Gravity Monitoring

GRACE Satellite Tracking: Measures regional gravity variations to calculate long-term total water storage and depletion rates.

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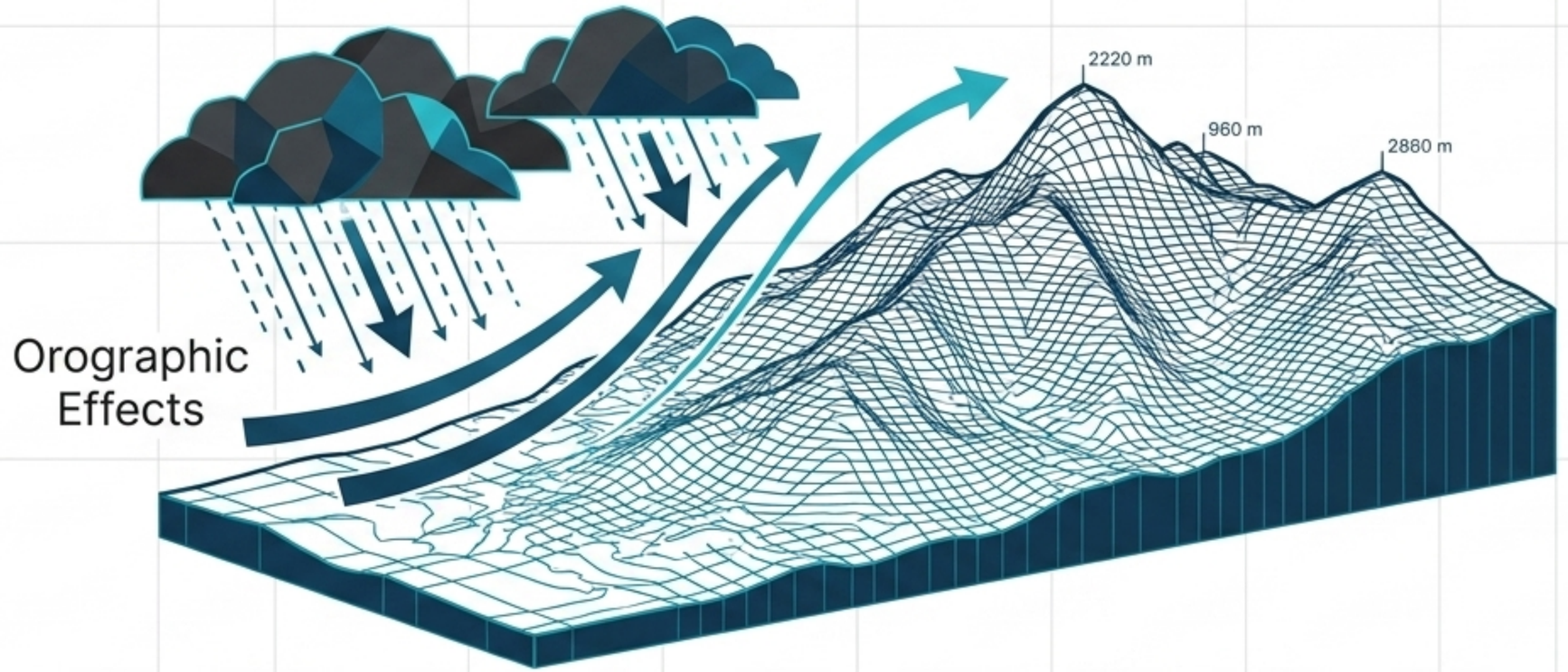
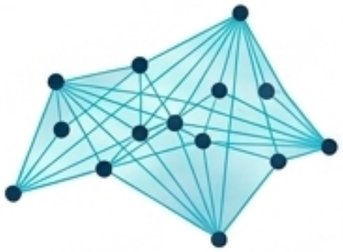
8. Rainfall Analysis & Hydrometeorology



Spatial Interpolation

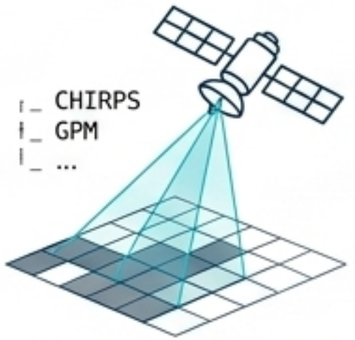
Converting point weather station data to continuous surfaces using Inverse Distance Weighting (IDW), Kriging, and Spline.



$$f(x) = \sum_{i=1}^{n} (g(x_i - x_j)(t - x_i))^2$$

Satellite Rainfall Estimates (SRE)

Modeling hydrology in ungauged/remote basins via high-resolution gridded datasets (CHIRPS, GPM).



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9. Hydrological Modeling & Decision Support Systems

1

Geospatial Parameters (GIS)

Catchments, slopes, land cover, soil classifications.

2

Physical Models

Coupling GIS data into SWAT and HEC-HMS.

3

Scenario Analysis

Testing land-use changes & infrastructure development impact on discharge dynamics.

4

Web-Based Dashboards

Interactive portals visualizing real-time streamflow, quality, and reservoir levels.

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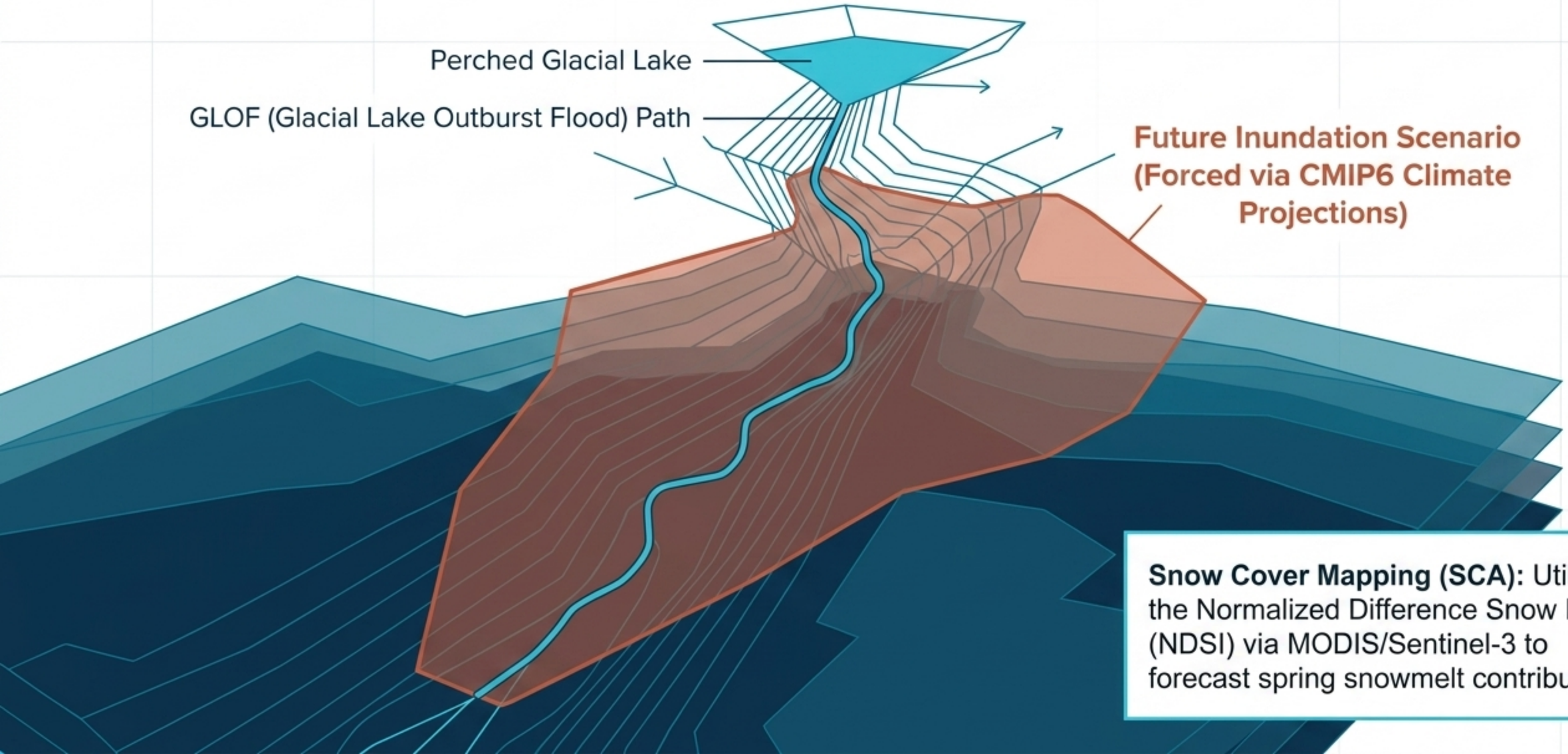
10. Climate Change & Water Security



Snow Cover Mapping (SCA): Utilizing the Normalized Difference Snow Index (NDSI) via MODIS/Sentinel-3 to forecast spring snowmelt contributions.

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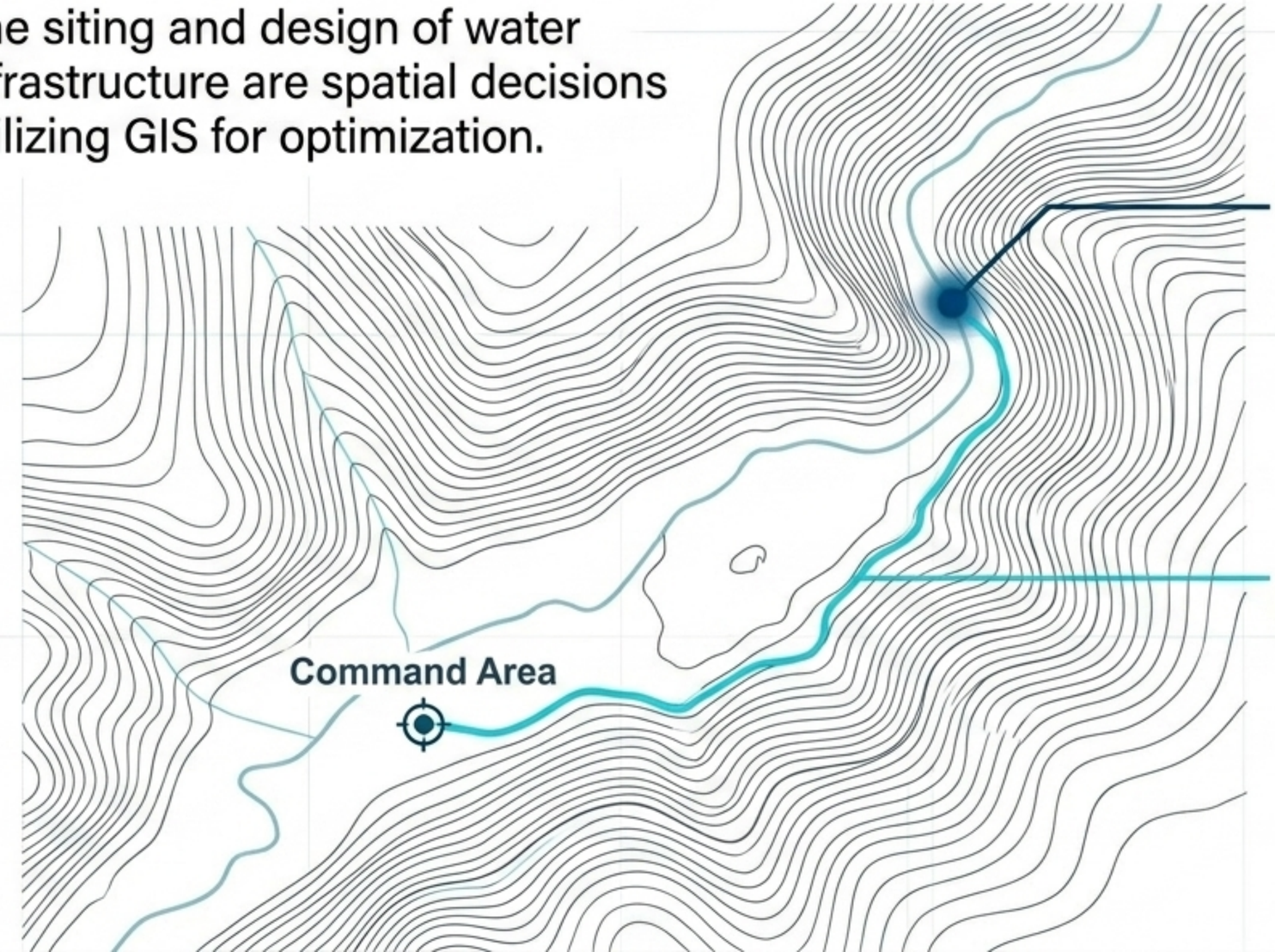
11. Water Infrastructure Planning

The siting and design of water infrastructure are spatial decisions utilizing GIS for optimization.



Multicriteria Evaluation (MCE)
Output: Optimized for storage capacity, slope stability, geology, and environmental impact.

Least-Cost Path Analysis utilizing DEMs to minimize excavation and pumping energy.

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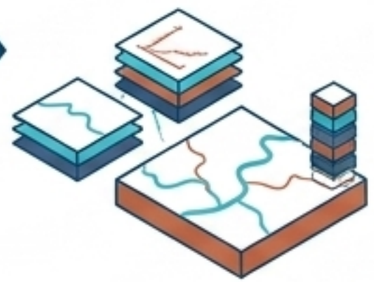
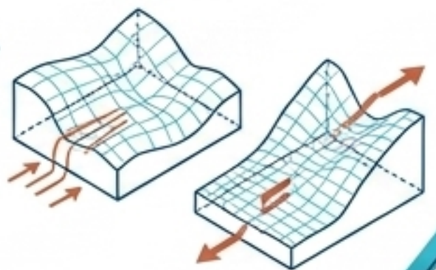
12. Real-Time Monitoring & Early Warning Systems

Telemetry Integration



Rapid Flood Inundation Models



Public Alert Mapping

Geosapatric Integration (Live river levels/discharge overlaid on GIS risk maps)

Rapid flood **models** **Utilizing pre-calculated flood libraries to generate immediate maps during extreme storms.**

Public Alert Mapping Generating spatial alert zones to trigger targeted SMS and local broadcast network notifications.

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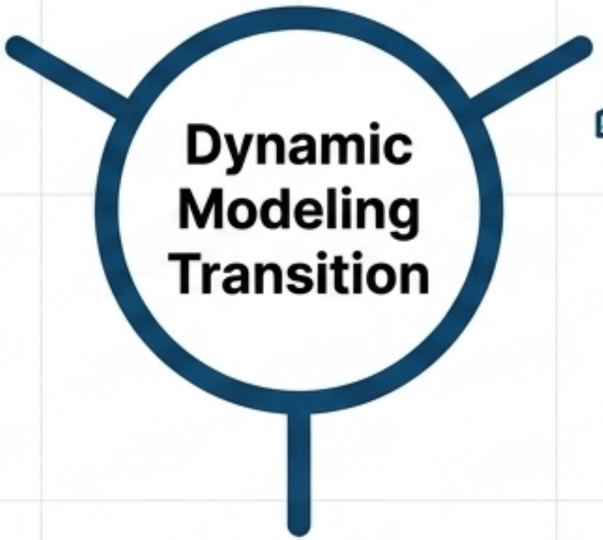
13. Emerging Technologies in Water Management

Cloud Computing (Google Earth Engine)

Processing petabytes in seconds for national-scale surface monitoring and long-term climate analysis.



UAVs & LiDAR

Ultra-high-resolution topography/bathymetry for riverbank stability and hydraulic models.

AI & Machine Learning

Predicting flood inundation, forecasting rainfall-runoff, and classifying imagery.

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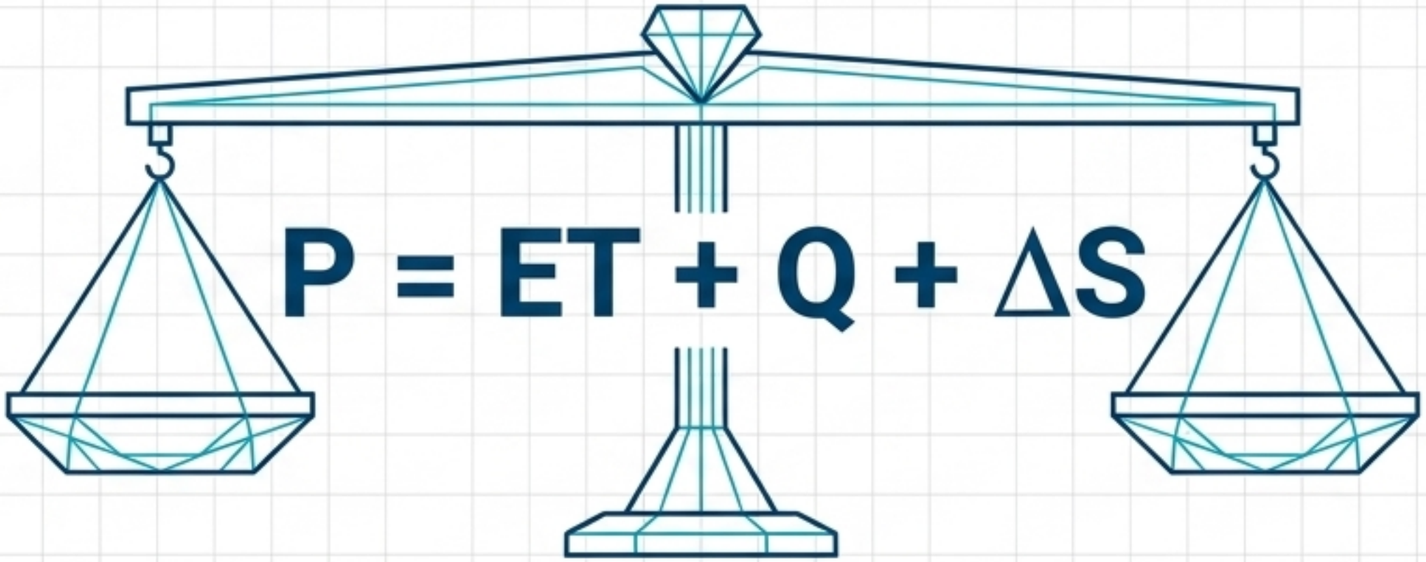
14. Water Balance & Water Accounting



P (Precipitation)

Remote sensing rainfall estimates.

ET (Evapotranspiration)

Thermal satellite bands (Landsat-8/9) measuring actual crop water consumption via METRIC/SEBAL surface energy balance models.

Q (Streamflow)

Live telemetry data.

Basin-Wide Auditing: Compiling standardized water accounts (e.g., WA+ framework) to allocate water rights equitably across agriculture, energy, and urban sectors.

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