FlowZero: Leveraging Satellite Imagery for Proactive Water Management

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Motivation

Rivers across the western United States are increasingly threatened by climate change, water overuse, and shifting precipitation patterns, jeopardizing ecosystems, agriculture, and communities. Yet, **many critical waterways remain severely under-monitored due to the high costs and logistical challenges of traditional methods** like physical stream gauges.

To address this, we have developed **FlowZero**, a **scalable, open-source, and automated monitoring pipeline that leverages high-resolution satellite imagery, spectral water detection algorithms, and cloud-based processing infrastructure.** It offers **continuous, low-cost surveillance at a fraction of the expense of conventional techniques.** By expanding access to real-time data, **FlowZero empowers proactive water conservation, supports biodiversity preservation, and drives climate resilience across California and beyond.**

Case Study: Cosumnes River — Seasonal Contrast

Approach

We detect open water using the Normalized Difference Water Index (NDWI), calculated from the green and near-infrared (NIR) spectral bands of PlanetScope satellite imagery (Ojumu, 2023). NDWI is effective for distinguishing water from surrounding vegetation and soil. The formula is:

$$NDWI_{NIR} = \frac{Green - NIR}{Green + NIR}$$

To reduce noise and isolate specific water bodies, we reproject shapefiles marking Areas of Interest (AOIs) to match the coordinate reference system (CRS) of the satellite imagery. We then crop the GeoTIFFs to these aligned AOIs for focused and efficient analysis.

We apply Otsu's thresholding to dynamically classify water vs. non-water pixels based on NDWI values. Canny edge detection is then used to trace the structure of water bodies, enabling inference of river flow conditions—particularly identifying dry or no-flow periods through reductions in water extent and edge complexity.

Data Flow and Organization

This system integrates Planet Labs APIs to retrieve and process cloud-filtered GeoTIFF imagery, **enabling precise water detection for critical conservation efforts.** The workflow includes data management, geospatial preprocessing, and analysis to **produce actionable insights for water management.**

- **Input Imagery:** 4-band and 8-band GeoTIFFs from Planet Labs, stored in AWS S3, organized by site and date.
- **AOI Definitions:** River reach and virtual gage shapefiles (.shp, .shx, .dbf, .prj) stored in S3, marking areas for water detection.
- **Configuration Files:** Python dictionaries (or JSON/YAML) that define parameters for each site.
- **Intermediate Data:** Clipped rasters and binary water masks processed in memory as NumPy arrays.

Processing Pipeline and Outputs

Processing Pipeline:

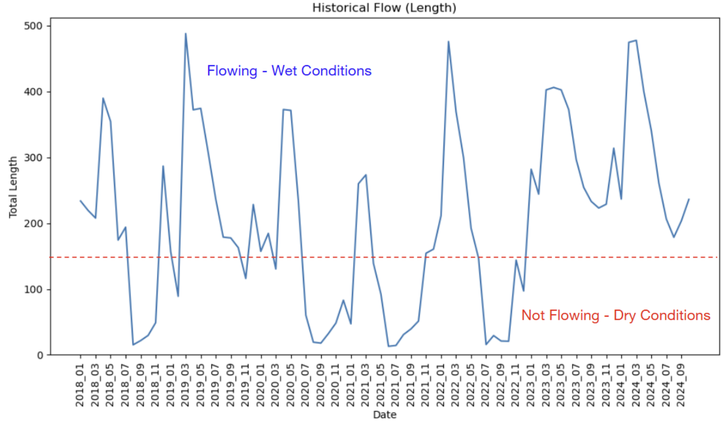
- **API Integration:** The system retrieves GeoTIFF imagery from Planet Labs' Orders API, ensuring access to key spectral data (NIR, green bands) for NDWI computation.
- **Reprojection & Cropping:** The AOI is reprojected to match the image's coordinate system, and the image is cropped to focus on the area of interest, reducing unnecessary data.
- **Water Detection:** NDWI, Otsu's thresholding, and Canny edge detection are applied to classify water and map its extent. **This analysis is used to infer flow conditions, detect dry periods, and estimate water availability.**

Pipeline Outputs:

- **Water Detection Statistics:** Area and percent coverage of water bodies over time.
- **Visualization:** PNG images displaying NDWI and binary water detection map results.
- **Time-Series Data:** CSV files capturing flow estimates and changes in water body extent.
- **Logs:** Versioned records of imagery orders and processing steps.

Time Series Results: Cosumnes River - Badger Reach

Figure 1. Time series flow calculated by considering the sum of the 3 longest water bodies for an AOI's monthly mosaics.



CLI Engineering

Command	Description	Usage
`generate_aoi`	Draw AOIs interactively	`flowzero generate_aoi --output mill_creek.shp`
`convert_shp`	Reproject shapefiles	`flowzero convert_shp --input mill_creek.shp --crs EPSG:32610`
`submit`	Place imagery orders	`flowzero submit --aoi cosumnes.shp --start 2023-01-01`
`check_quota`	Check Planet API usage	`flowzero check_quota --profile research_team`
`list_orders`	List all orders	`flowzero list_orders --status all`
`status`	Check order status by ID	`flowzero status --id 2023051709a`
`basemaps`	Manage Planet basemaps	`flowzero basemaps --list --year 2023`

Water Detection Map Results: Cosumnes River - Badger Reach

Dry Example: Cosumnes River – August 2022

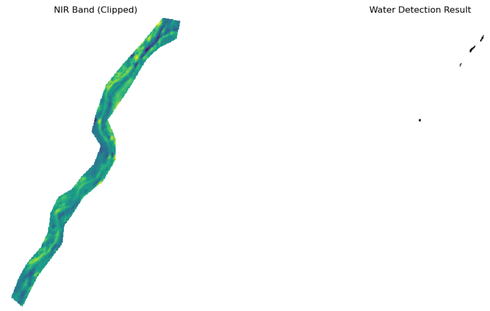


Figure 2. NDWI: NIR Band (left), Detected Water (right)

Wet Example: Cosumnes River – March 2023

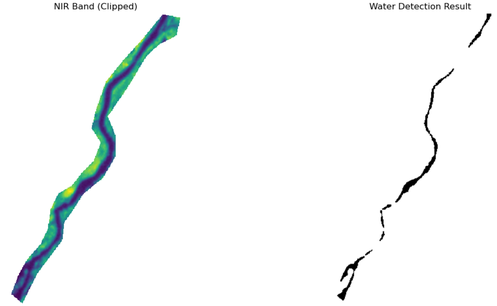


Figure 3. NDWI: NIR Band (left), Detected Water (right)

Conclusion

FlowZero is a scalable, cloud-based pipeline that transforms water resource monitoring through remote sensing, automated workflows, and open-source development. **With over 97% accuracy, it provides a significantly more affordable and accessible alternative to traditional stream gauges, enabling monitoring of previously untracked and remote waterways.**

This scalability is critical for comprehensive watershed management in regions facing water scarcity like California. **By democratizing water data collection, FlowZero expands environmental protection capabilities while reducing costs and logistical challenges of conventional monitoring methods.**

As an evolving open-source initiative, **FlowZero empowers governments, organizations, and communities with actionable insights for sustainable water management, climate resilience, and ecosystem preservation.** Its continued development through community collaboration ensures water conservation efforts benefit from the latest innovations.