SHRUG
2023

ArcNLET-Py

An Integrative Approach to Groundwater Modeling with GIS

Earth, Ocean and Atmospheric Science
Florida State University

FREAC
FLORIDA RESOURCES & ENVIRONMENTAL ANALYSIS CENTER
FLORIDA STATE UNIVERSITY

Michael Core (mcore@fsu.edu)
Wei Mao & Ming Ye

Florida State University
Department of Earth, Oceans, and Atmospherics Science & Florida Resources and Environmental Analysis Center

Presentation Objectives

- Aiming for mastery of ArcNLET-Py
- Link to ArcNLET-Py GitHub:
  - ArcNLET-Py/ArcNLET-Py at dev (github.com)
- Link to ArcNLET-Py User's Manual
  - https://arcnlet-py.readthedocs.io/en/latest/
    - Introduction and background
    - Installation and application
    - GitHub
    - Explore ArcNLET-Py tools/modules
    - Real-world and theoretical uses
    - Q&A

Background

Exploring ArcNLET-Py

- Python Toolbox for ArcGIS Pro
- Models nitrate and ammonium loads from OSTDS to groundwater and surface water
- GIS integration provides a visual and data-driven approach
- Facilitates understanding and implementation of spatial information for communities and local governments
- Uses include helping decision-makers establish OSTDS setback distances

The Critical Role of Groundwater Modeling

- Essential for predicting the flow and pollutant transport
- Potential impacts for managing water resources
- Supports decision-making for conservation and planning
- Insight into pollution plumes and load estimates

OSTDS

Onsite sewage treatment and disposal systems

- Septic tanks and field/drain lines
- Small-scale sewage treatment for areas that lack sanitary sewage lines
- 2.6 million systems in Florida
- 12% of USA OSTDS

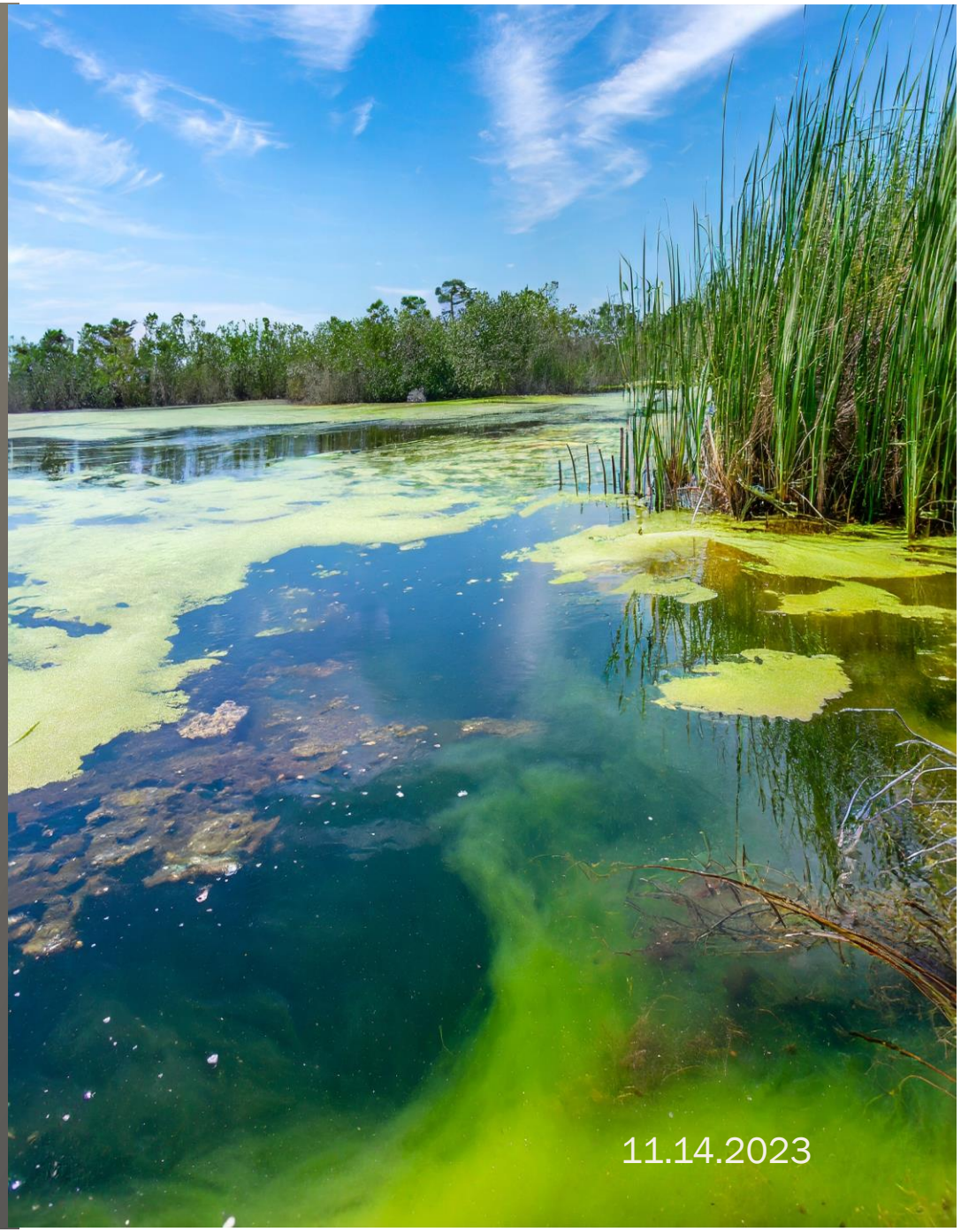
FSU - EOAS & FREAC
(FDEP 2023) (US EPA 2018)

Please note: Septic systems vary. Diagram is not to scale.

Nitrogen

Nitrogen Pros & Cons

- Essential for life on Earth
- Industrial nitrogen fixation for fertilization
- Eutrophication
- Groundwater contamination

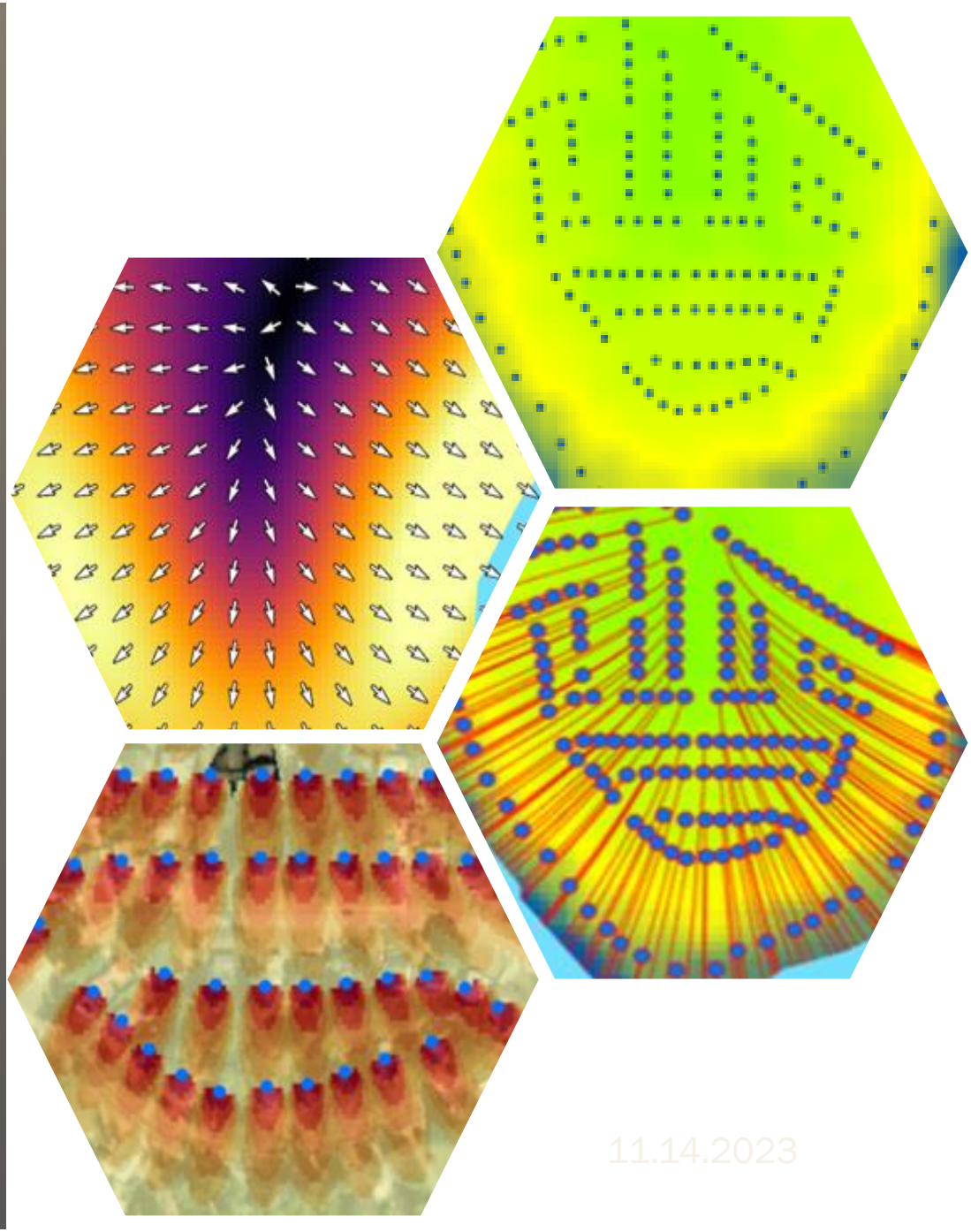


Introduction to ArcNLET-Py

Unveiling ArcNLET-Py

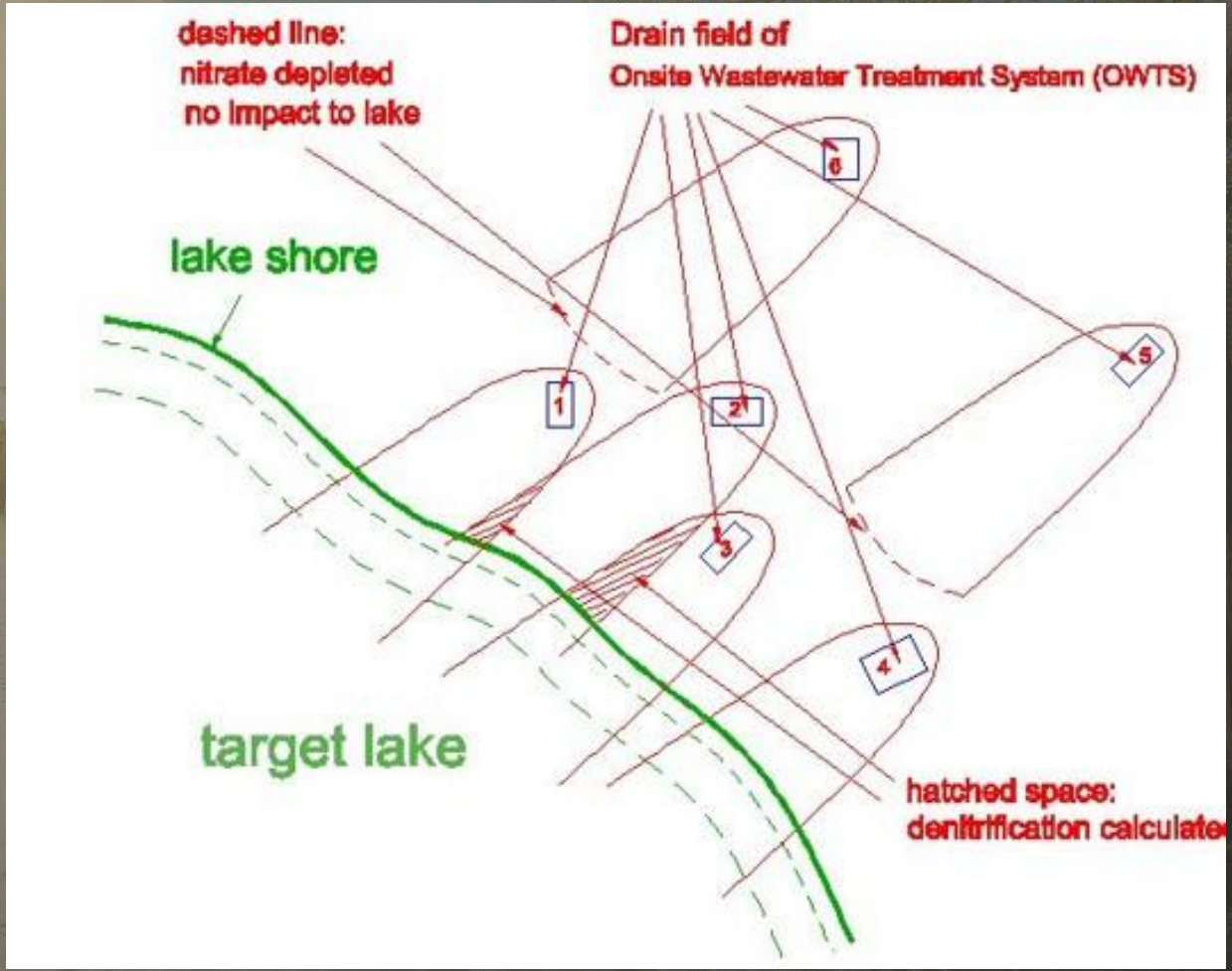
ArcGIS Pro Nitrate Load Estimation Toolbox for Python

- Developed by Dr. Ming Ye from the Department of Earth, Ocean, and Atmospheric Science at FSU
- Modeling nitrogen transport from OSTDS
- Calibration, simulation, and estimation of nitrogen load from OSTDS to waterbodies



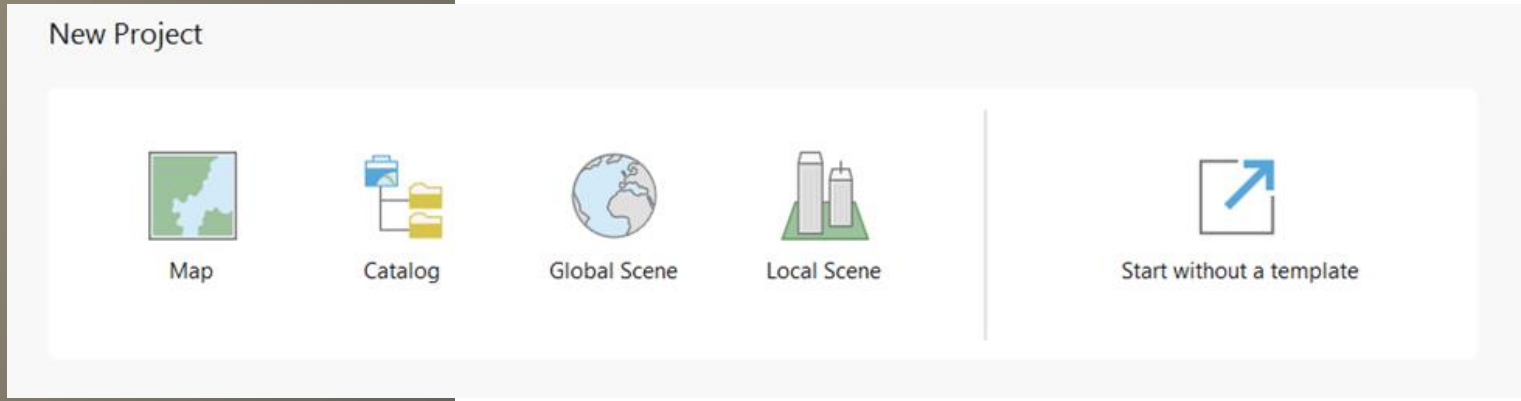
ArcNLET-Py & Hydrogeology

- Groundwater flow model
- Nitrogen transport model
  - Nitrification, denitrification, and adsorption
- Simplified model for hydrogeologic processes
- Quantitative estimates to for environmental management
  - TMDL & BMAP activities (Scopel 2012)



ArcNLET-Py and ArcGIS Pro

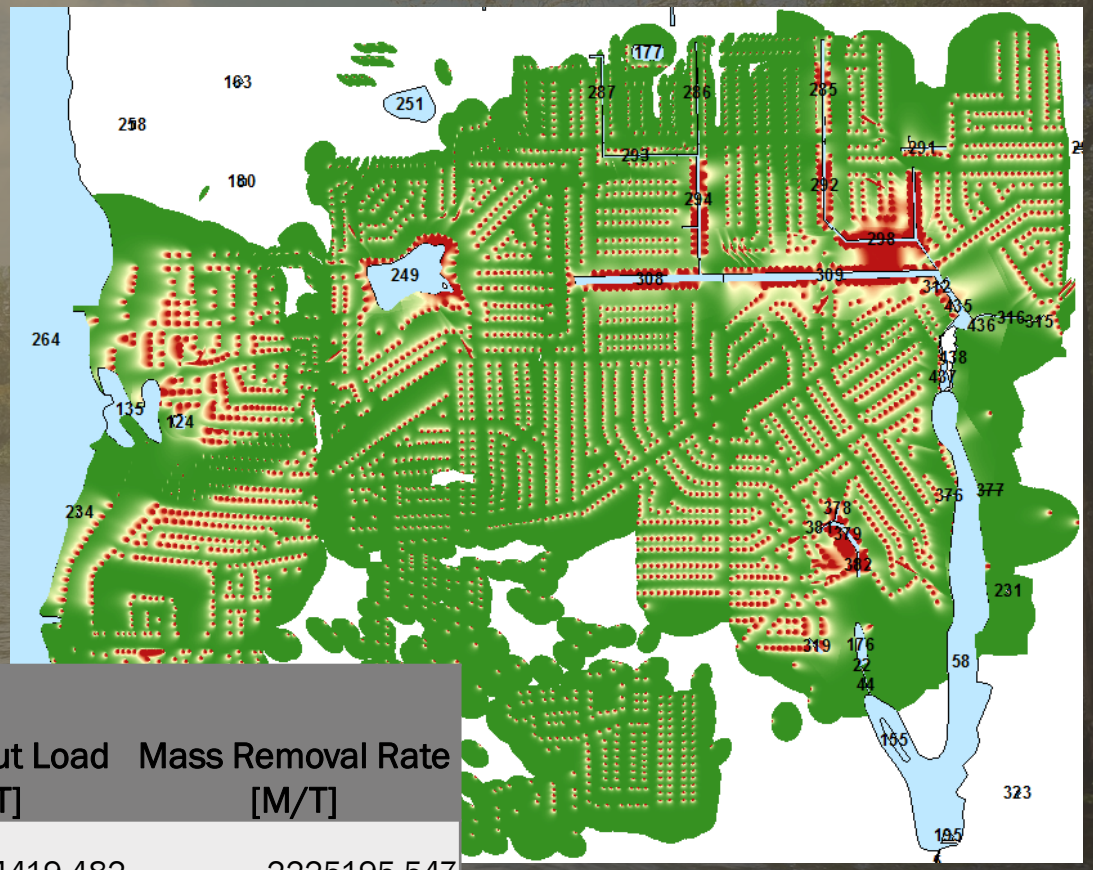
ArcGIS Pro Python Toolbox



- User-friendly ArcGIS Pro Toolbox
- ArcGIS Pro functions
  - Data handling
  - Metadata
  - Workflows
  - Error handling
  - Spatial Analysis
  - User-interface
- Use existing GIS knowledge

ArcNLET-Py End Products

- Simulate nitrate plumes and nitrate load
- Raster plumes
- Mass load input, output, and removal in CSV text file



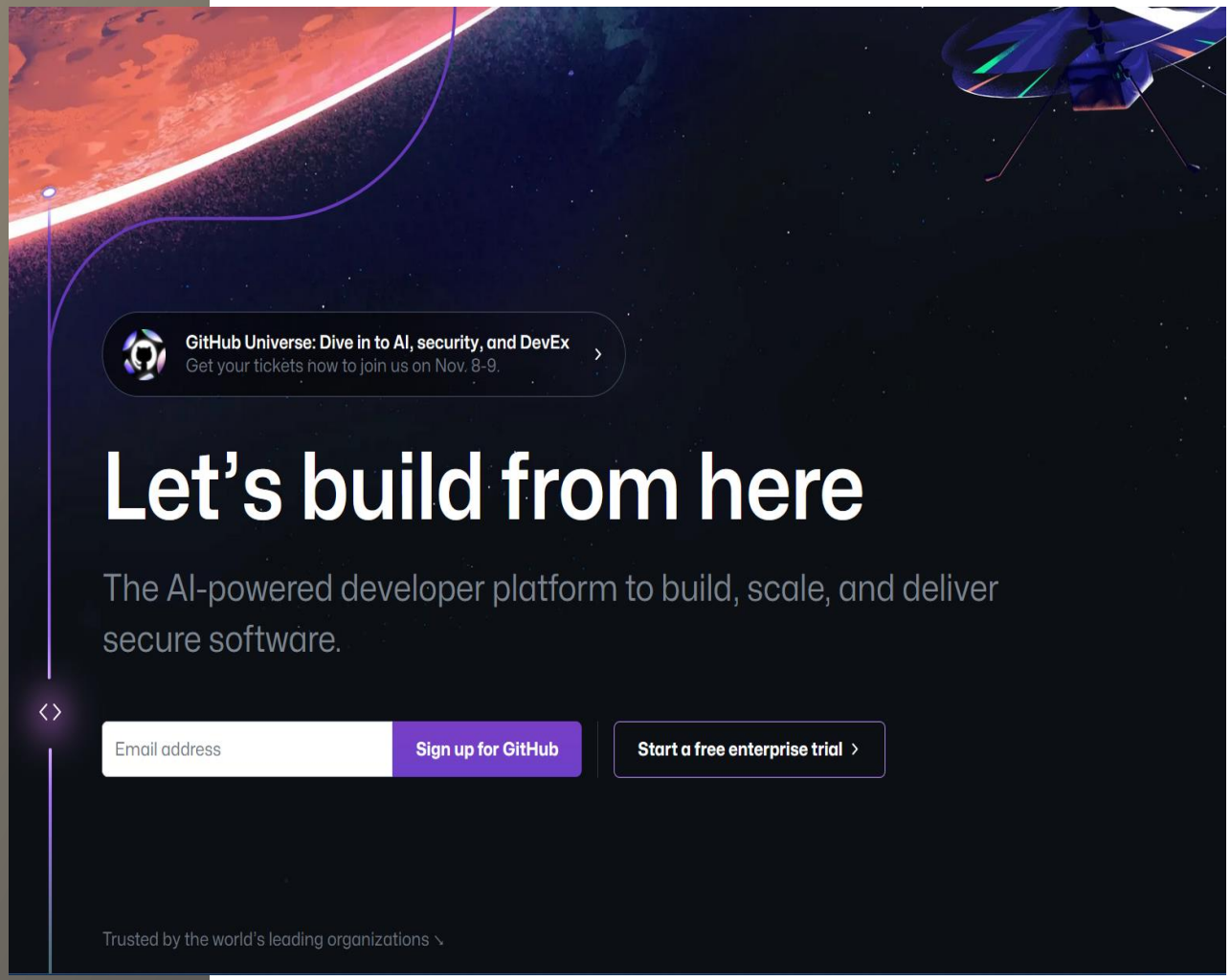
Waterbody FID	Mass Output Load [M/T]	Mass Output Load * Risk Factor [M/T]	Mass Input Load [M/T]	Mass Removal Rate [M/T]
-1	89223.93442	89223.93442	2314419.482	2225195.547
30	74871.56551	74871.56551	1961146.677	1886275.112

GitHub Basics

GitHub

Collaborate, Code, Create

- Version control and project management
- Project documentation and user support
- Markdown for documentation and websites
- Issue tracking and message boards
- Non-developer roles
- Community engagement and learning



Why use GitHub for ArcNLET-Py?

- Open-source
- Users can contribute, track changes, and download updates
- Hub for issue tracking, feature requests, and community discussion
- Collaborative development and feature tracking
- Free accounts for engaging with the community

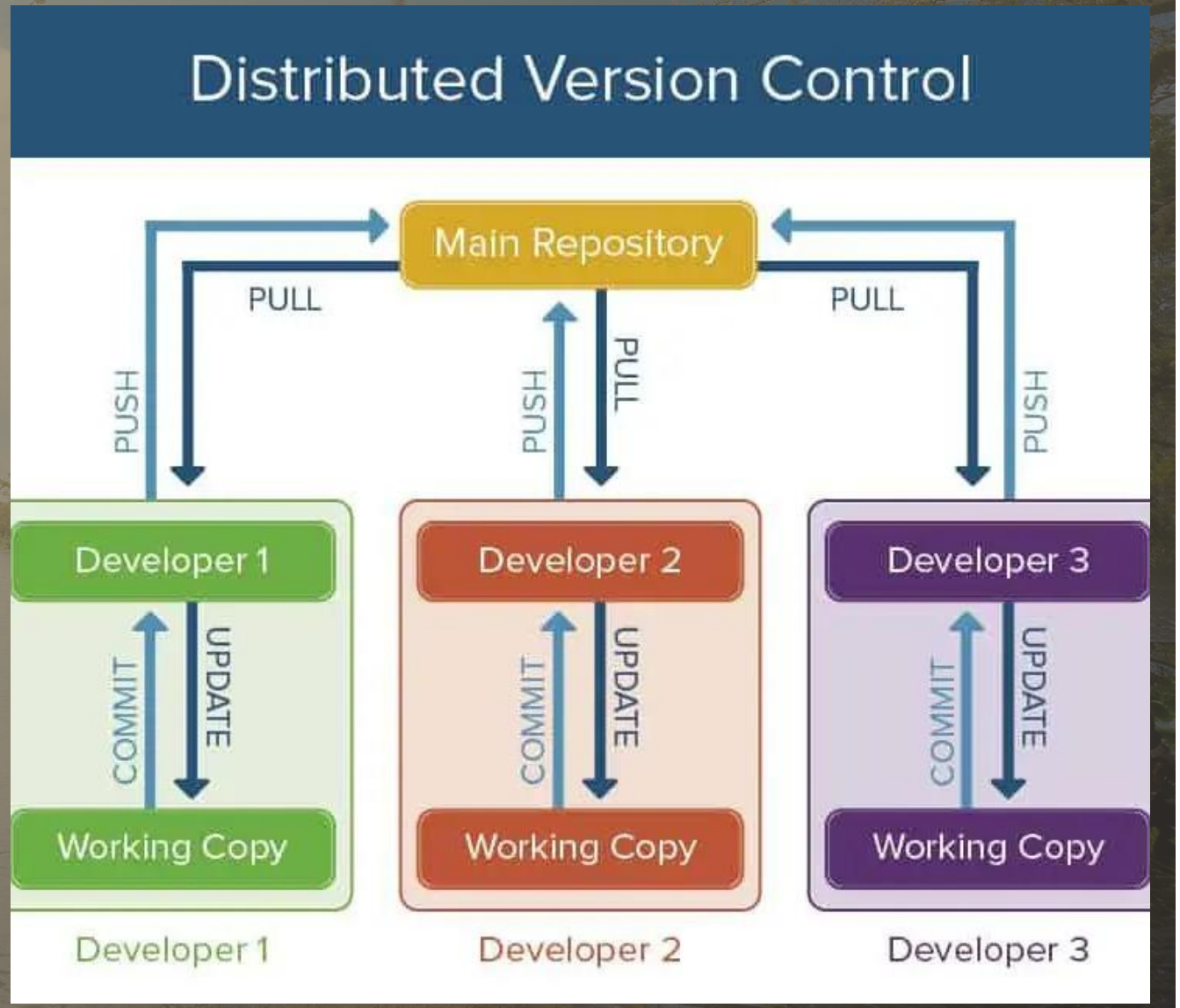
Version Control

Built on Git version control

Cornerstone of project management and collaboration

History of changes allows rollback and collaboration w/o conflicts

Track changes in documents, scripts, and other digital creations



(Eby 2017)

Markdown

Simplifying Documentation

- Create project documents online
- User-friendly, lightweight markup language
- Readme files and wikis
- Formatting, embedding images, and linking resources

HTML

```html
<picture>
 <source media="(prefers-color-scheme: dark)" srcset="YOUR-DARKMODE-IMAGE">
 <source media="(prefers-color-scheme: light)" srcset="YOUR-LIGHTMODE-IMAGE">
 <img alt="YOUR-ALT-TEXT" src="YOUR-DEFAULT-IMAGE">
</picture>
```


(GitHub 2023)

GitHub vs. Other Platforms

GitHub

- Version control and community-driven development
- Software and document management
- Pull requests, forking, and actions for automation

Other Services

- Google Drive, Dropbox,
  - No version control
  - No development support
  - No community support
  - No markdown language support
  - No issue tracking
- Bitbucket
  - Less user-friendly
  - Fewer third-party integrations
  - Generally for private repositories

Real-World Examples of GitHub Use

Developer and User Collaboration

- QGIS: A collaborative development story of an open-source GIS platform
- FloPy: Community contributions to a hydrogeological modeling tool
- Bootstrap: A front-end framework's growth fueled by GitHub collaboration

QGIS

FloPy

a Python package to create, run, and post-process MODFLOW-based models.

B

Contributing Through Communication

Reporting Issues & Documentation

- Report bugs
- Suggest features
- Seek help
- Clear, detailed issue reports aid developers
- Contributing to documentation improves usability and accessibility
- Update guides, FAQs, and tutorials
- Comprehensive and user-friendly documentation

GitHub Repository Management

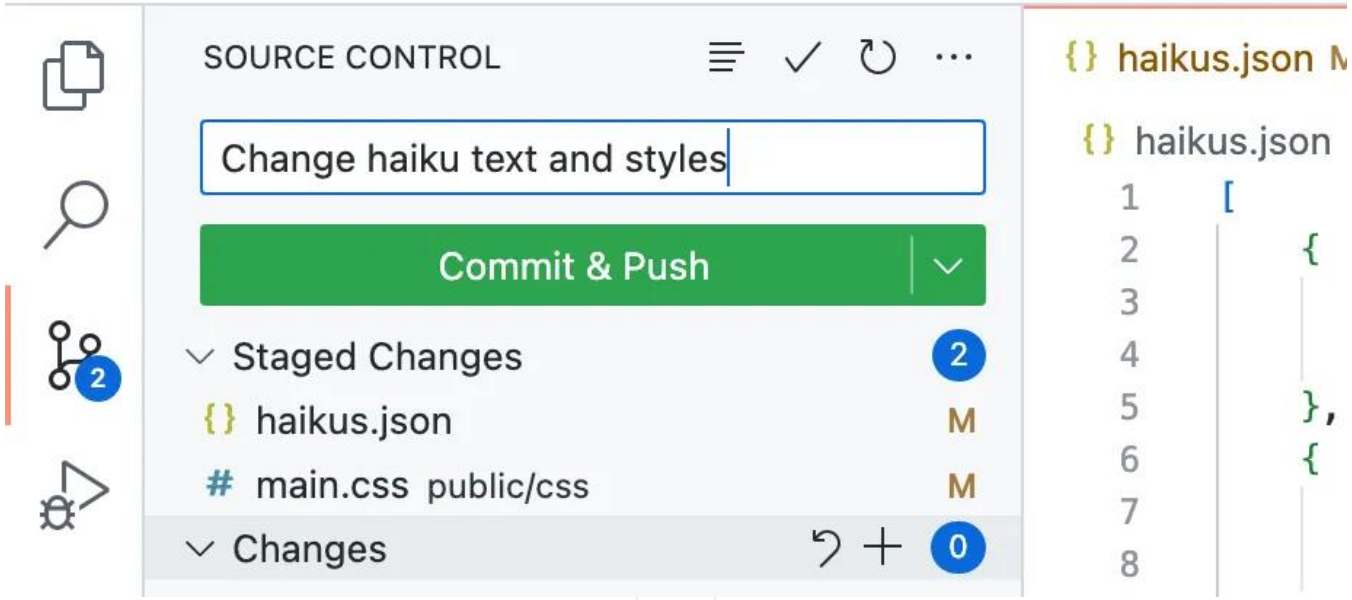
Forking and Editing Files on GitHub

- Forking allows for personalized changes without impacting the original code
- Editing files in a fork is a step towards contributing
- Branches for feature development and bug fixes
- Pull requests for proposing and discussing changes.

Committing Changes

Commit = Save

- Creates a record of changes
- Commit message
- Contribute to the project's history
- Building blocks of save points
- Changes are automatically pushed to your branch on GitHub

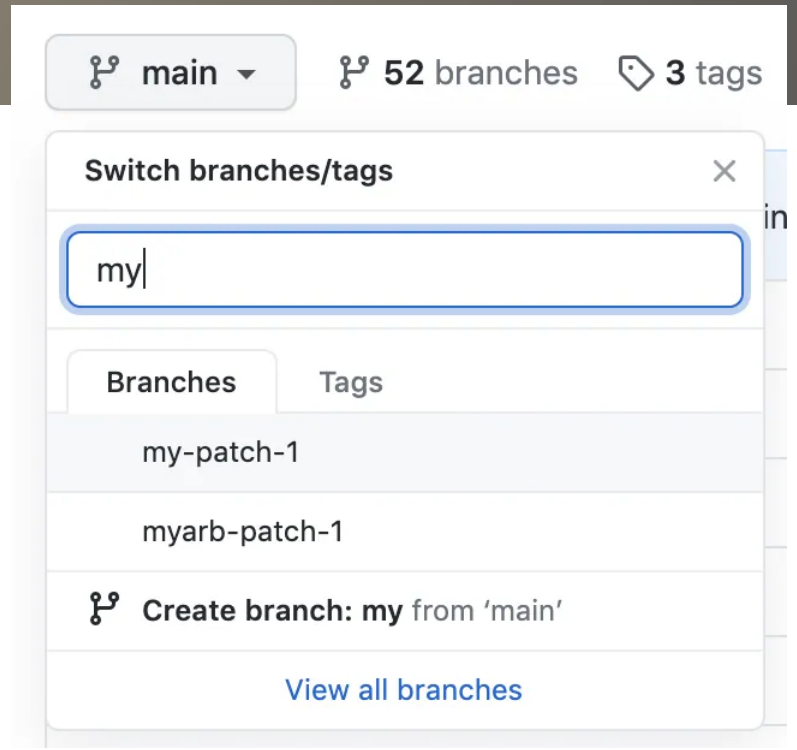


(GitHub 2023)

Pull Request

Pull request process from forked repositories to the original project

- Proposal to merge changes with the main branch
- Review and discuss changes
- Follow-up commits before merging into the base branch



(GitHub 2023)

Review & Merge

- Integrate improvements
- Quality check, standards, and goals
- Accepting pull requests to integrate changes
- Resolve conflicts
- See differences in code

10	-	# Layouts
11	+	# Grid system
12	+	Layouts are built on a 12 column grid.

rubyjazzy 1 day ago

Good call, this is more specific!

👍 3 ❤️ 1

ArcNLET-Py Repository on GitHub

Accessing the ArcNLET-Py Repository

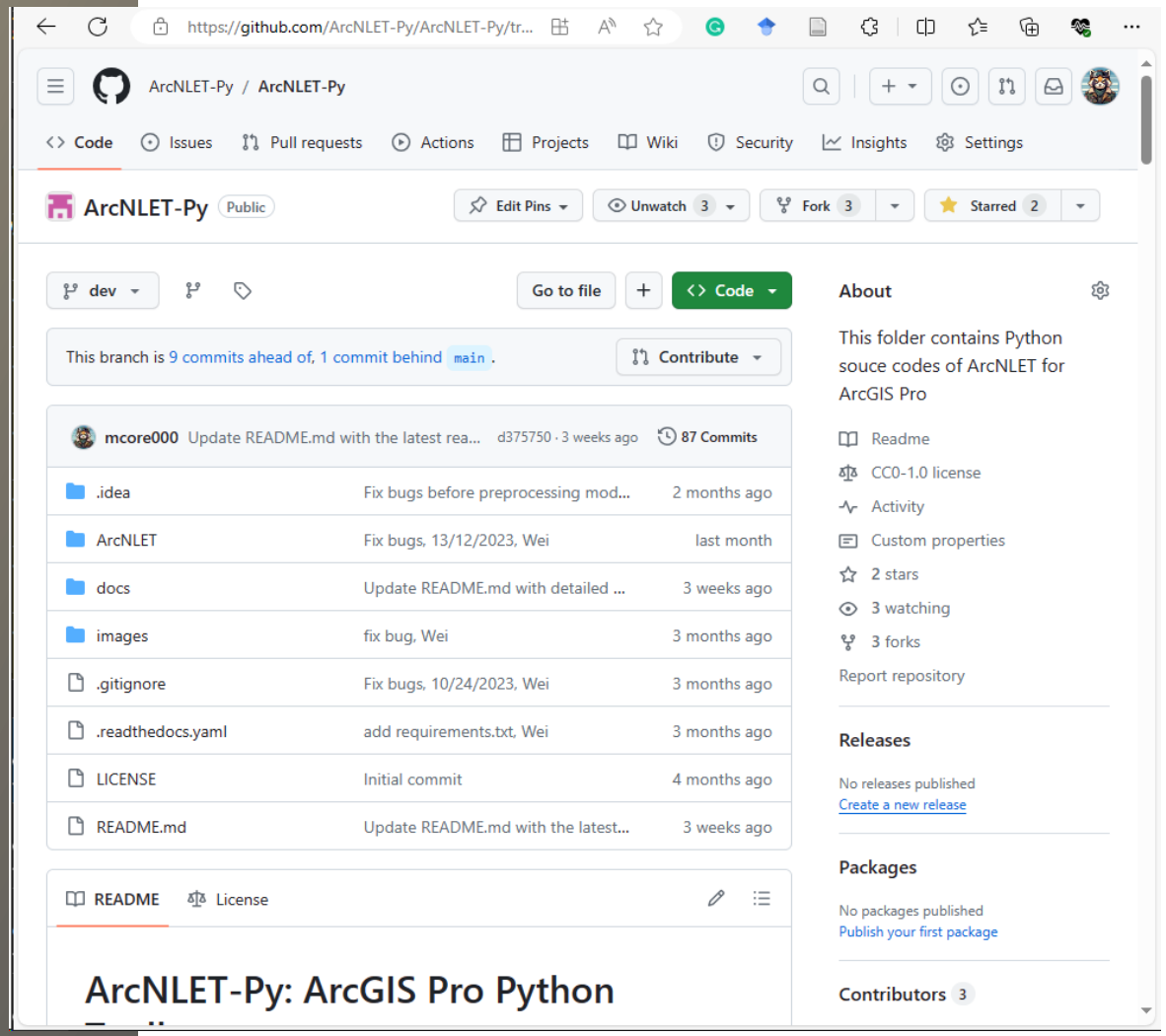
- https://github.com/ArcNLET-Py/ArcNLET-Py/tree/dev
- Understanding repository structure is key
- Development history, branches, commits, and releases
- ArcNLET-Py User's Manual
  - https://arcnlet-py.readthedocs.io/en/latest/

Exploring ArcNLET-Py on GitHub

Building a community

Please use the dev branch at the moment

- Star, watch and fork the ArcNLET-Py repository
  - Stay updated and express your support
- Repository structure and file location
- Repository README.md for guidance, use, and contribution
- Discuss issues, share experiences, offer feedback
- Find solutions to common issues



Installing ArcNLET-Py for ArcGIS Pro

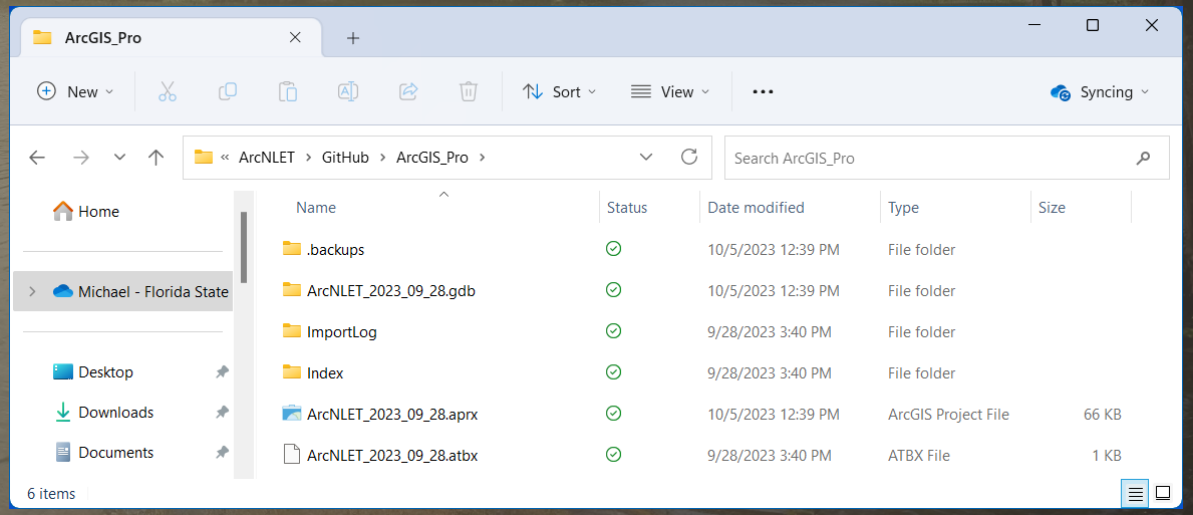
Installation Prerequisites

- Is ArcGIS Pro installed and up-to-date?
- Spatial Analysis license active
- Create an ArcGIS Pro Project File for ArcNLET-Py
- Project files help organize workflows

ArcGIS Pro 3.2 system requirements

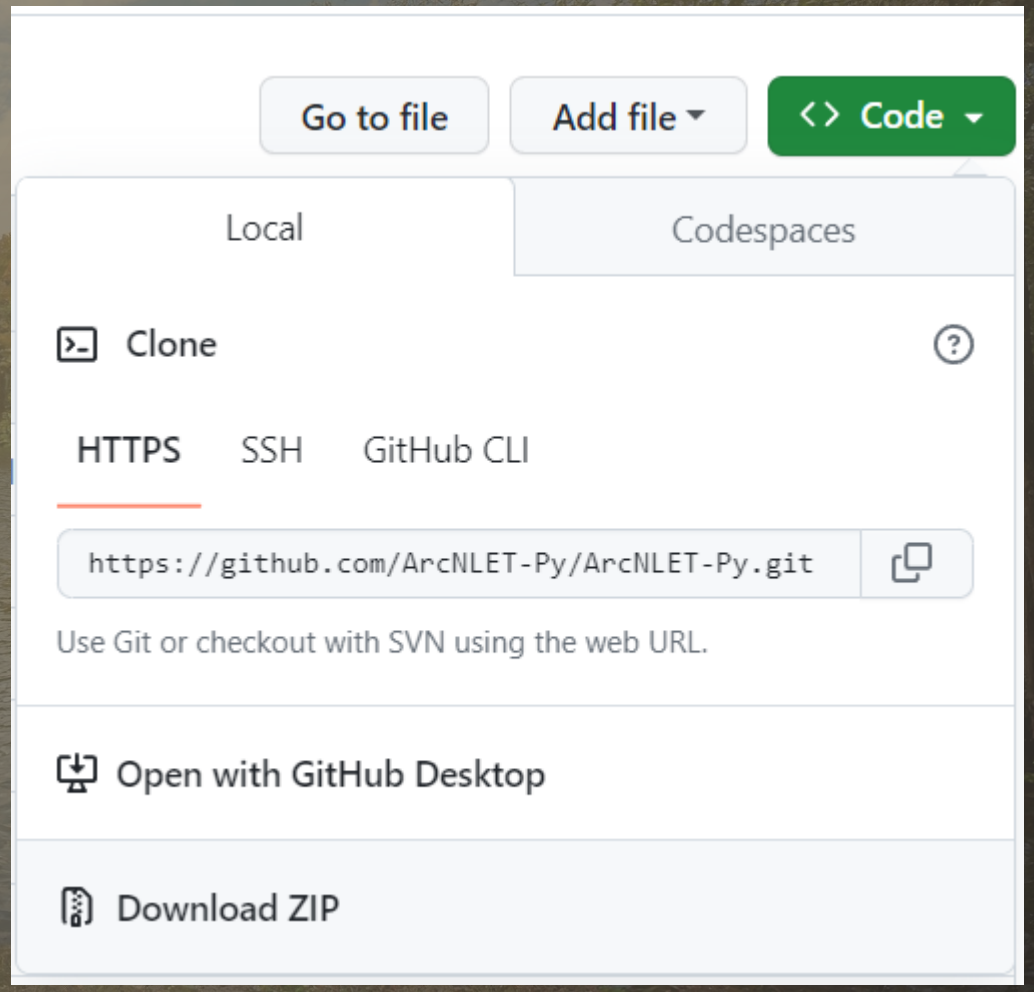
ArcGIS Pro 3.2 | Other versions | Help archive

Before installing or upgrading ArcGIS Pro on a virtual or physical machine, ensure that your system meets the minimum requirements to run it. Also, learn what resources are recommended to get the best performance.



ArcNLET-Py Repositories Download ZIP

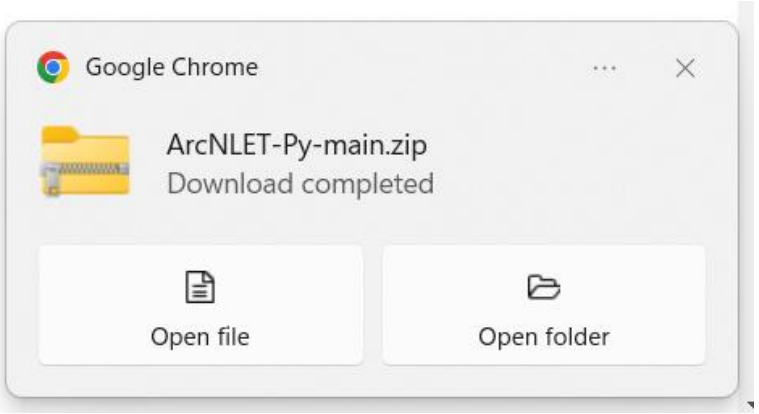
- Simplify access to all project files
- Work offline
- Access the latest version
- Users to contributors
- ‘Download ZIP’ for the ArcNLET-Py repository

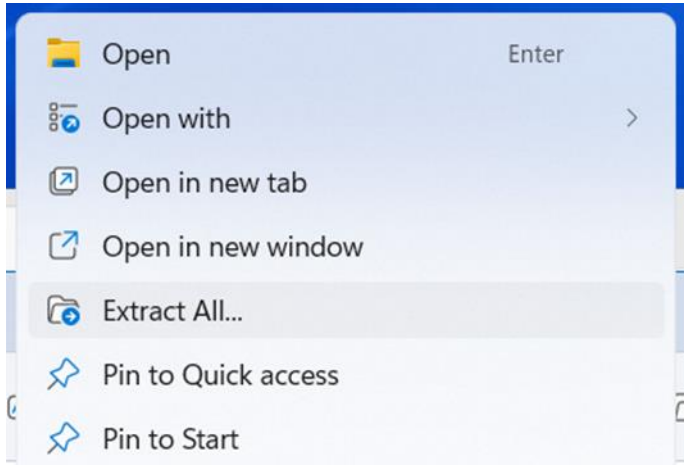


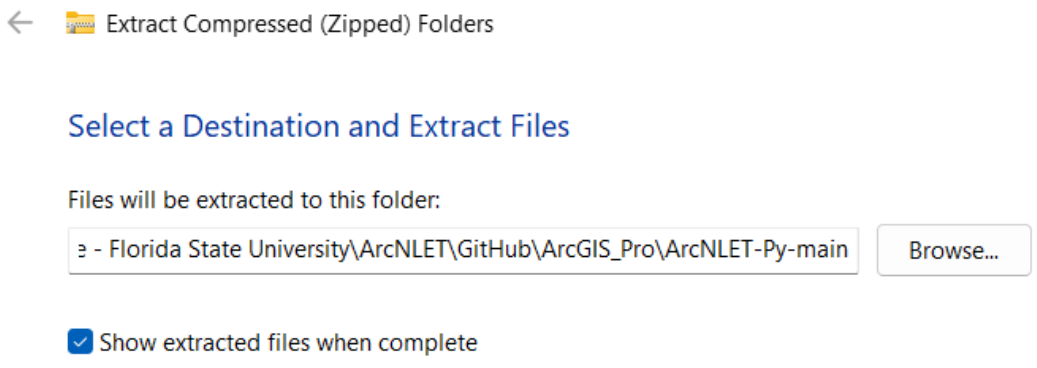
Unpacking Potential

Extracting the ArcNLET-Py Toolbox

- Opening a treasure chest of modeling tools
- Extract to your ArcGIS project directory
- Ensure all components are ready for ArcGIS Pro
- Extracting = installing







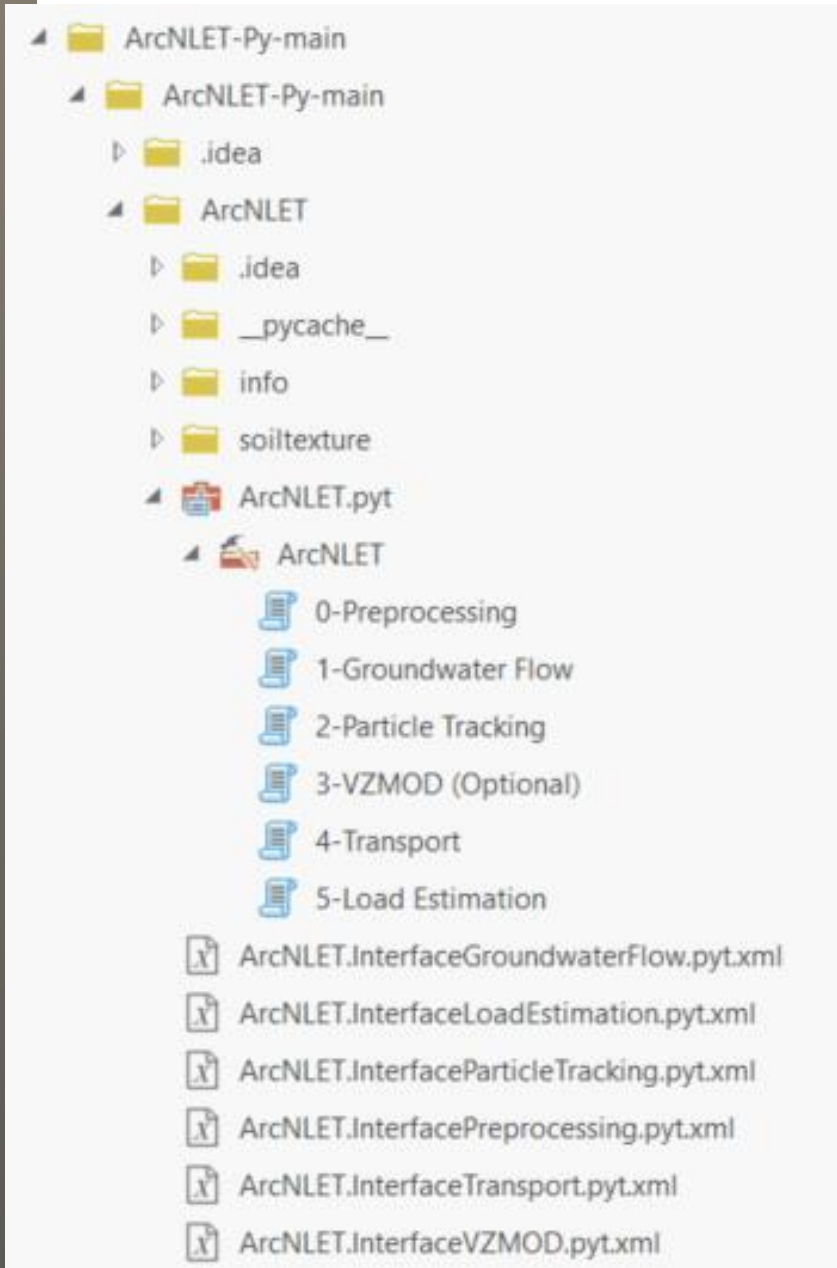
Accessing ArcNLET-Py in ArcGIS Pro

Accessing Python Toolsets

Integrating ArcNLET-Py

Note: The figure shows the main branch. It would be best to use ArcNLET-Py-dev from the dev branch for now.

- Access the ArcNLET-Py Python toolbox
  - Catalog Pane/View



Structure of ArcNLET-Py Toolsets

- Tools are organized into modules
  - 0-Preprocessing
    - Access and download SSURGO Soil DB hydraulic conductivity and porosity data
  - 1-Groundwater Flow
    - Analyzes groundwater velocity based on DEM and soil data
  - 2-Particle Tracking
    - Simulates water particle movement from sources to waterbodies
  - 3-VZMOD
    - Models nitrate and ammonium concentrations in the Vadose Zone
  - 4-Transport
    - Models nitrate and ammonium plume transport in the groundwater
  - 5-Load Estimation
    - Estimates mass loading and removal rates

Metadata

Metadata within each toolset highlights the purpose and functionality

Blue ‘i’ icon help messages help users

Custom warnings and error indicators guides workflows

Metadata Geography Table

1-Groundwater Flow

Title 1-Groundwater Flow

Description

There is no description for this item.

Usage

There is no usage for this tool.

Syntax

InterfaceGroundwaterFlow (DEM, Water bodies, Hydraulic Conductivity, Porosity, Smoothing Factor, Smoothing Cell, Fill Sinks, Merge Waterbodies, {Smoothing Factor after Merging}, Z-Factor, Velocity Magnitude, Velocity Direction, {Hydraulic Gradient}, {Smoothed DEM})

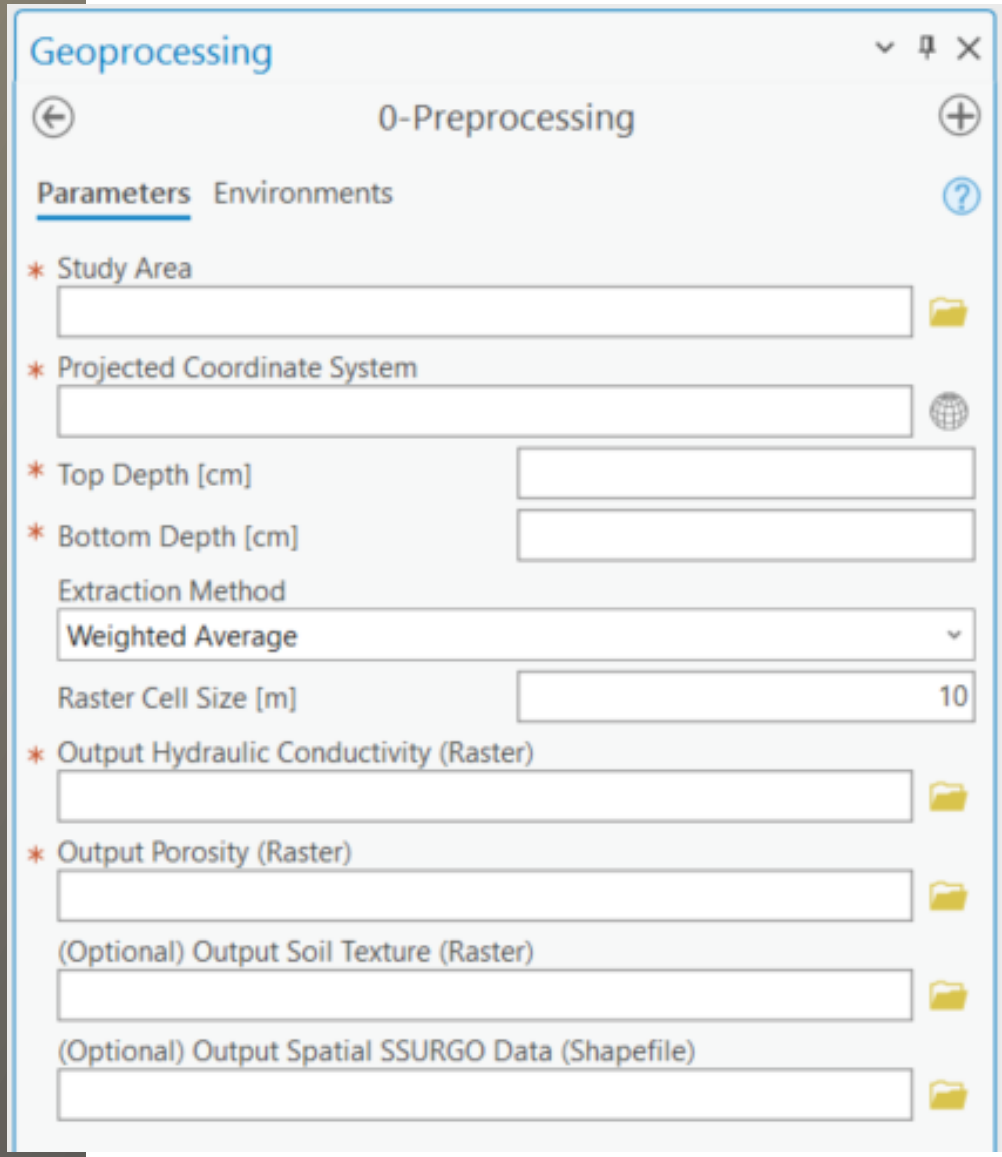
Parameter	Explanation	Data Type
DEM	Dialog Reference Used to generate an approximation to the water table. This input must be a raster layer. Note that a higher resolution DEM does not necessarily give better results, since a coarser DEM may better approximate the water table. Python Reference Test Scripting	Raster Layer
Water bodies	Dialog Reference Must be a polygon type layer. This dataset is used to determine the locations of water bodies to which groundwater will flow. There is no python reference for this parameter.	Feature Layer
Hydraulic Conductivity	Dialog Reference Must be a raster layer. This input represents a map of hydraulic conductivity for the domain. The linear units of the hydraulic conductivity must be the same as the units of the DEM. For example, if the DEM has linear (ground distance) units of meters, the hydraulic conductivity must have units of meters per unit time. The output seepage velocity magnitude will have the same units as this input. There is no python reference for this parameter.	Raster Layer
Porosity	Dialog Reference Must be a raster layer. This input represents a map of soil porosity for the domain. There is no python reference for this parameter.	Raster Layer
Smoothing Factor	Dialog Reference This controls the number of smoothing iterations that are performed on the DEM to generate a subdued replica of the topography. Higher numbers mean more smoothing and a flatter replica. As	Long

ArcNLET-Py ArcGIS Pro Python Tools

0-Preprocessing Module

Leverage SSURGO Data

- Inputs
  - Study area polygon
  - Projection coordinate system
  - Top depth
  - Bottom depth
- Parameters
  - Extraction method
  - Raster cell size
- Outputs
  - Hydraulic conductivity
  - Porosity
  - Soil texture
  - Spatial SSURGO data



How the 0-Preprocessing Module Works

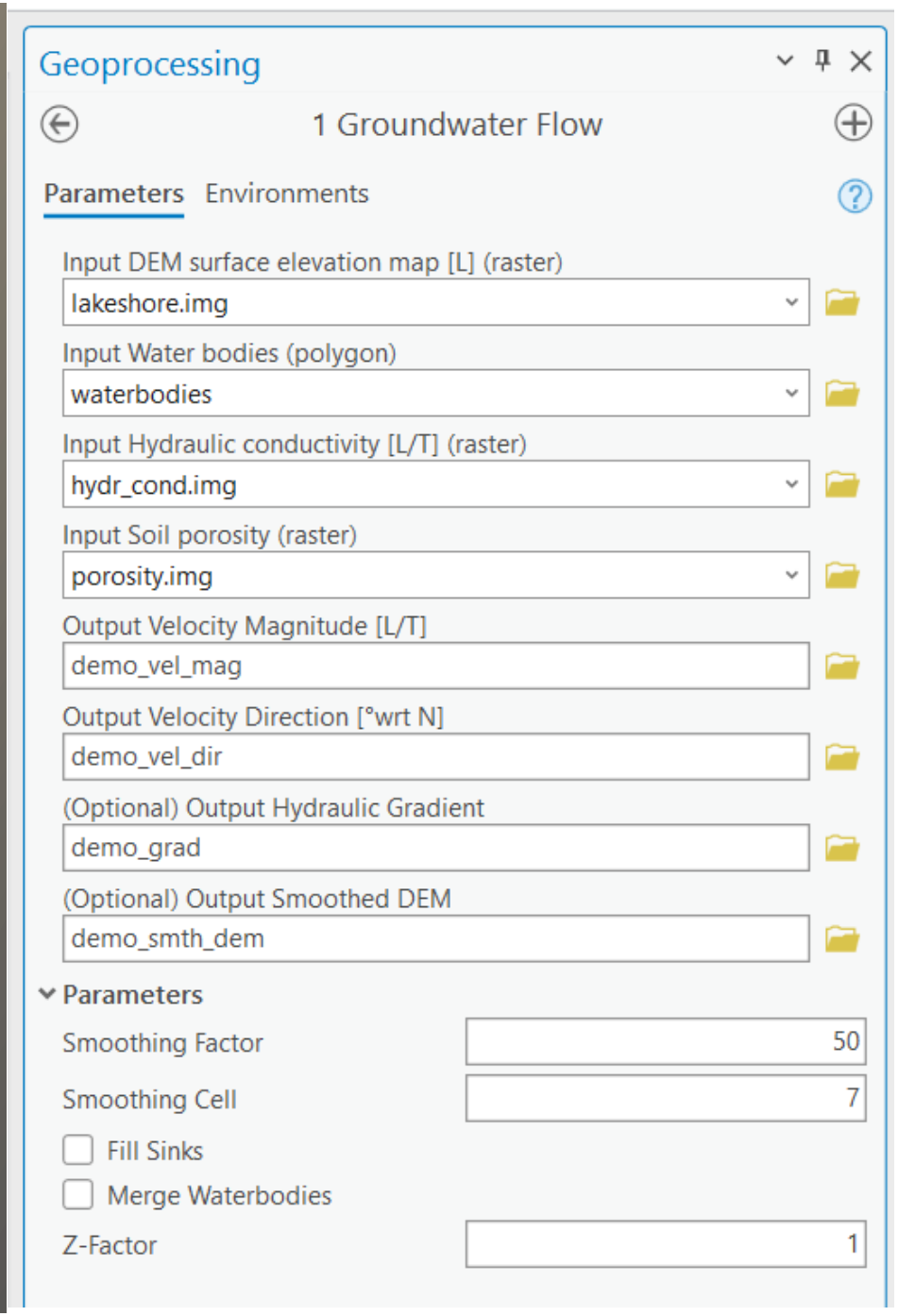
- Creates JSON data requests for the SURRGO Soil DB
- Converts the study area polygon into coordinates
- Allows the user to select coordinate systems
- Extracts data from various soil depths
- Allows for user-selected data extraction methods
- Creates hydraulic conductivity, porosity, soil texture, and SSURGO spatial data datasets

(USDA 2019)

1-Groundwater Flow Module

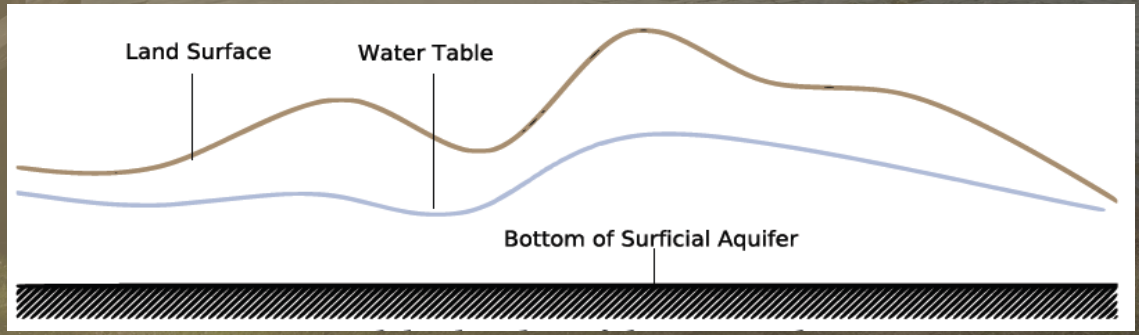
Simulates subsurface water movement

- Inputs
  - DEM
  - Hydraulic Conductivity
  - Porosity
- Parameters
  - Smoothing Factor
  - Z-Factor
- Outputs
  - Velocity Magnitude and Direction
  - Hydraulic Gradient
  - Smoothed DEM



How the 1-Groundwater Flow Module Works

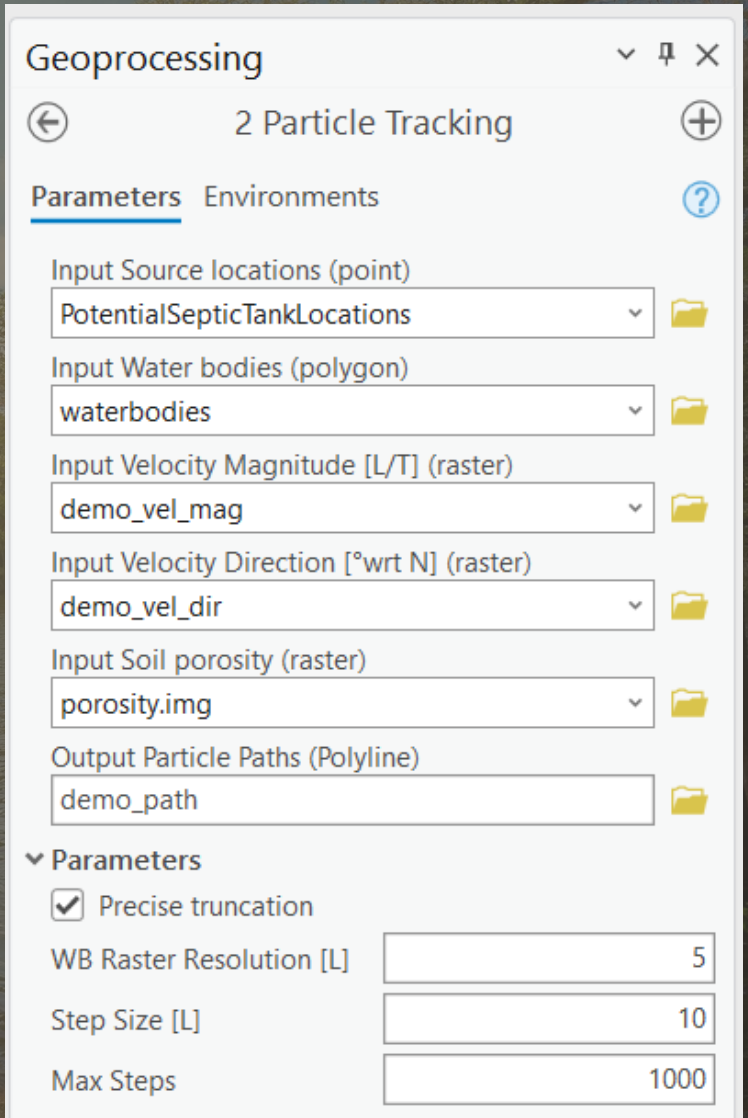
- Determine groundwater direction from OSTDS to a waterbody
- Simplification of Darcy's Law with Dupuit assumption
- Simulates 2-D horizontal groundwater flow
- Treats the water table as a subdued replica of topography
- Smooth land elevation (DEM) to obtain the shape of the water table
- Simulates the shape of the water table



2-Particle Tracking Module

Tracks the flow paths of particles from OSTDS to waterbodies

- Inputs
  - Utilizes velocity outputs from the Groundwater Flow module
  - Source locations and waterbody features
- Outputs
  - Particle paths of potential contaminant travel routes



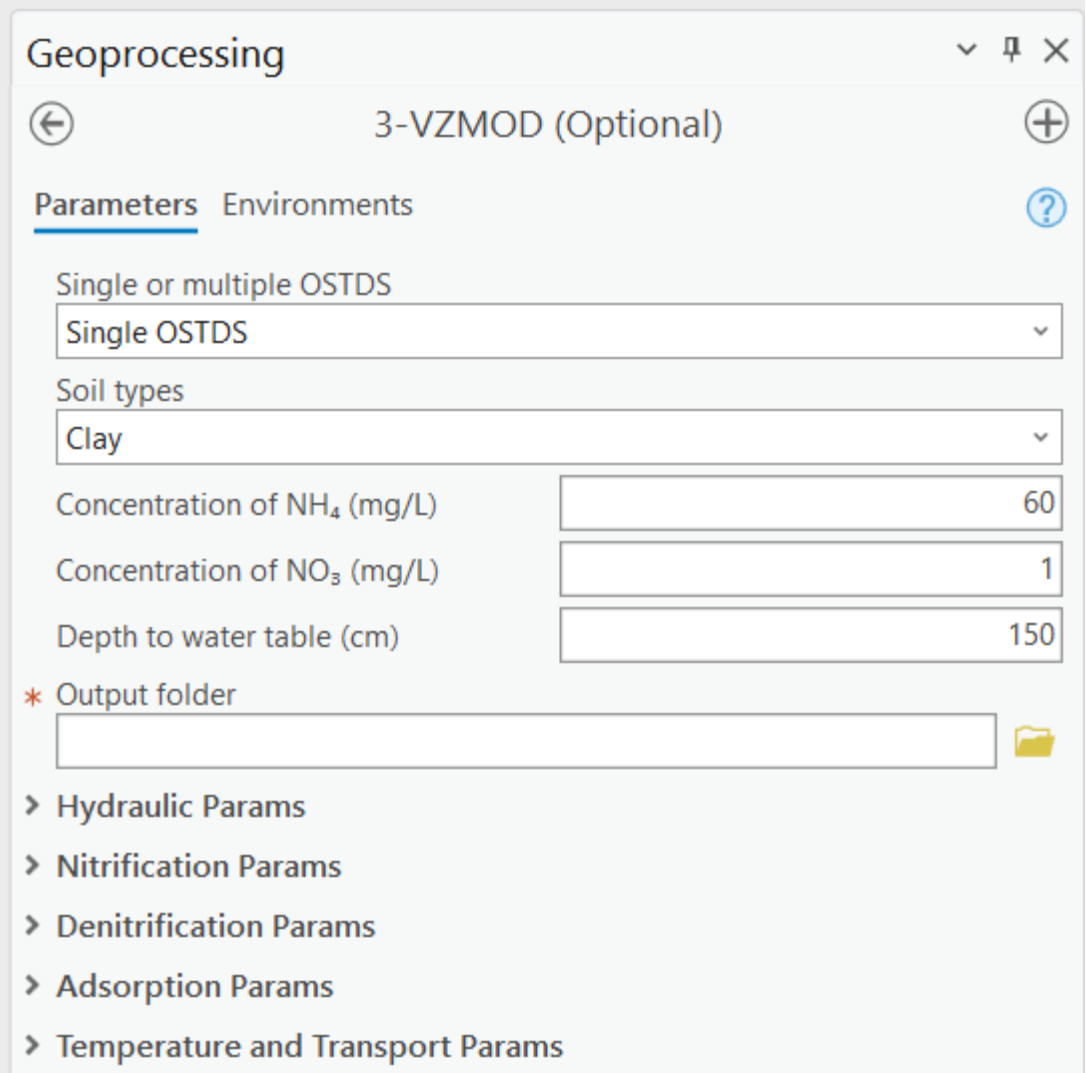
How the 2-Particle Tracking Module Works

- Creates flow paths from OSTDS points to waterbody polygons
- Uses Groundwater Flow direction magnitude for flow direction
- Uses Groundwater Flow velocity magnitude and soil porosity for time estimates

3-VZMOD

Vadose Zone nitrate and ammonium transport

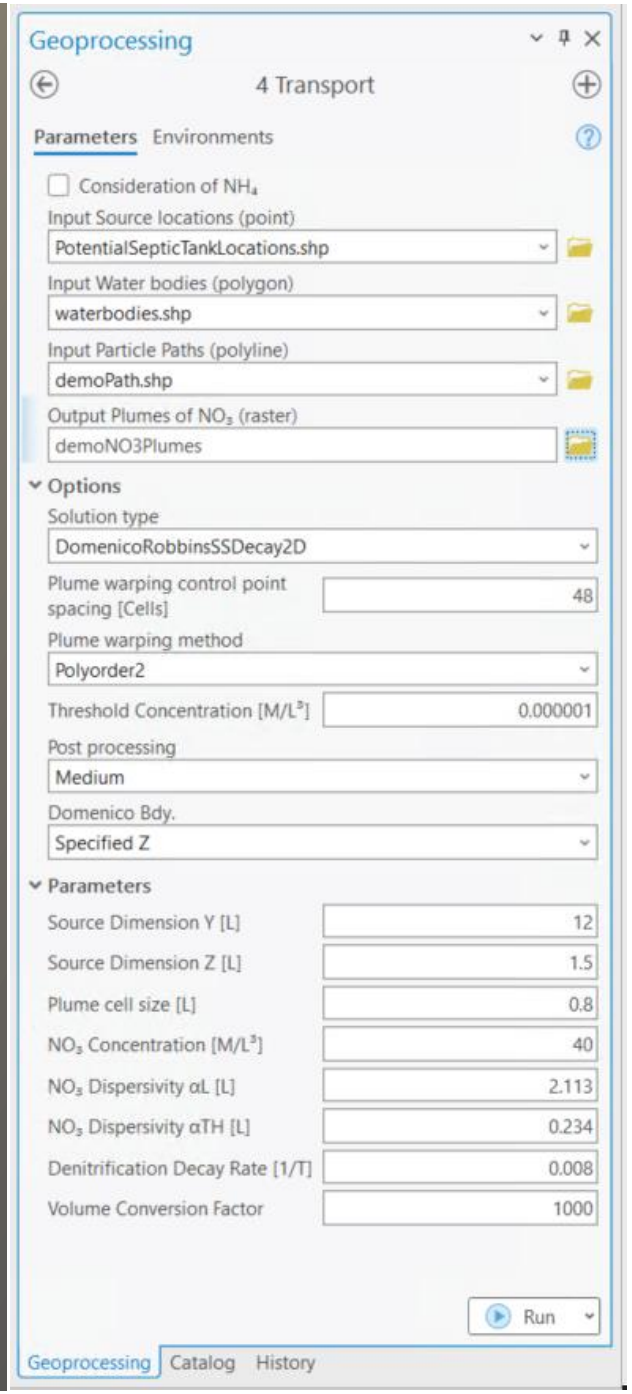
- Unsaturated flow (1-D)
- Ammonium and nitrate transport with sorption, nitrification, and denitrification
- Single or multiple OSTDS analysis
- Inputs
  - Soil types
- Outputs
  - Vertical profile of ammonium and nitrate concentrations w/depth
  - Vertical moisture content
  - Nitrification and denitrification estimates



4-Transport Module

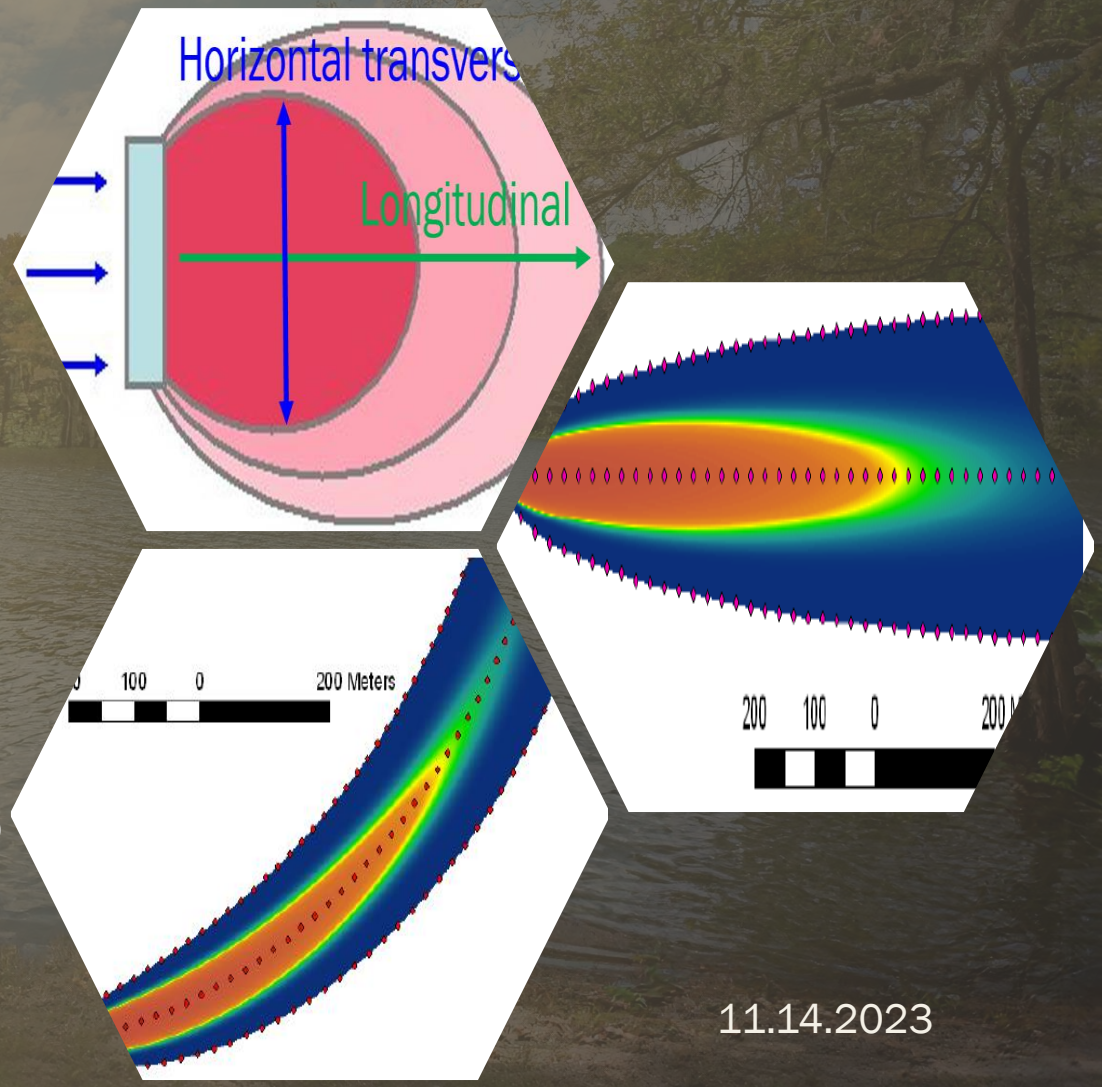
Predicting nitrate and ammonium plume spread

- Incorporates decay and absorption factors for simulation
- Inputs
  - Utilizes outputs from the Particle Path module
- Outputs
  - Plume raster of concentration distribution
  - Plume info shapefile



How the 4-Transport Module Works

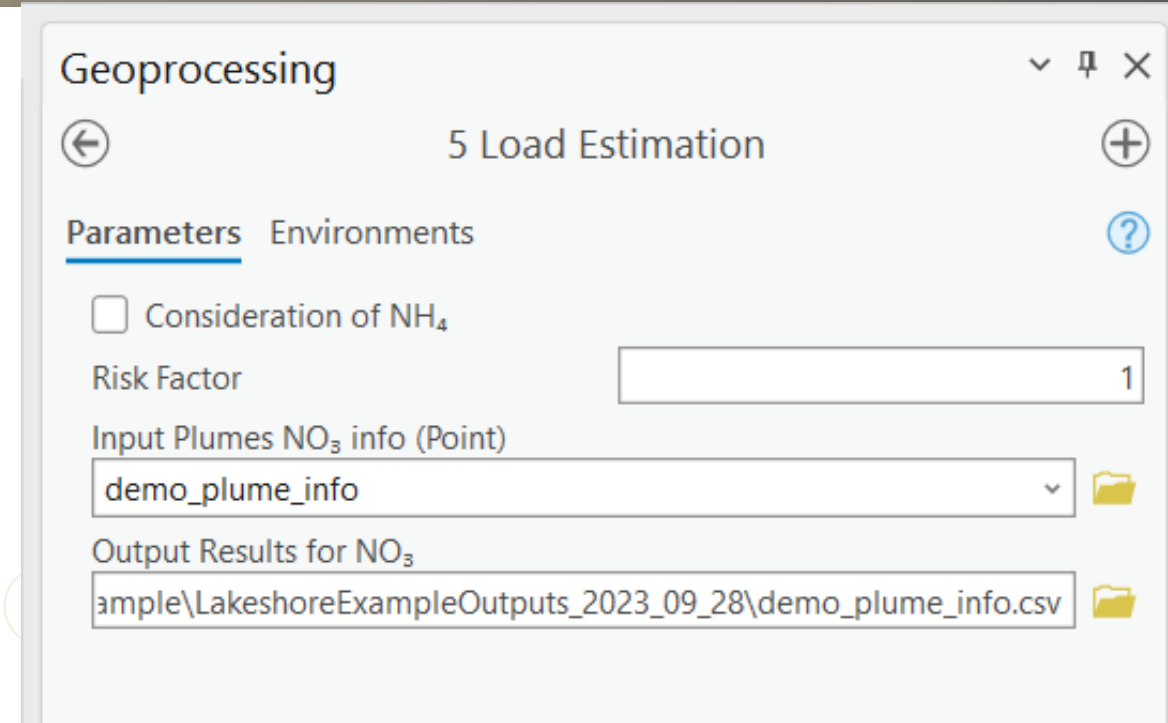
- Related to the width of the drainfield and thickness of the plume
- Uses the source concentration of nitrate at the water table
- Longitudinal dispersity
- Horizontal transverse dispersity
- Nitrogen decay
- Plume warping (spline) and Domenico solution



5-Load Estimation Module

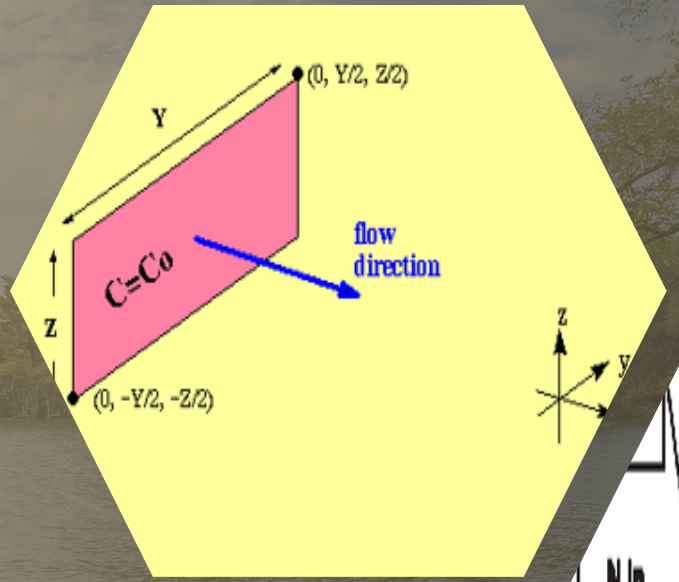
Estimating the mass of contaminants entering water bodies

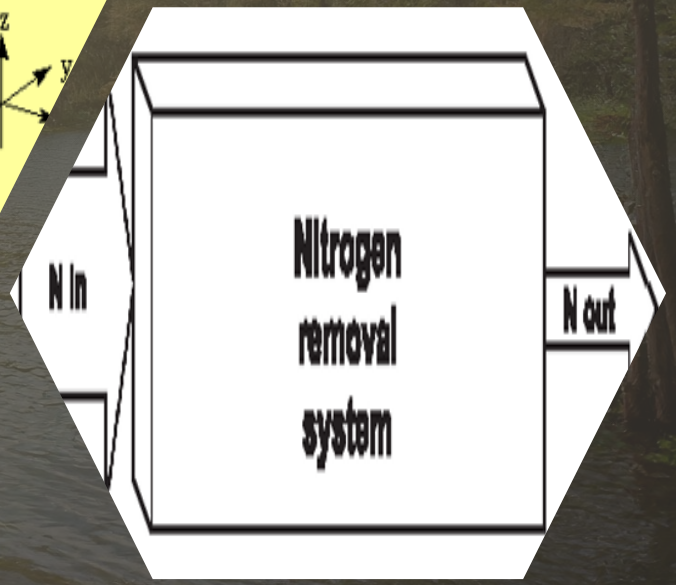
- Calculates the removal rate of nitrate and ammonium via denitrification
- Inputs
  - Plume info shapefile from the 4-Transport module
- Outputs
  - CSV
  - Mass output load
  - Mass removal rate
  - Mass input load



How the 5-Load Estimation Module Works

- Mass load to the waterbody = Mass of nitrate from OSTDS – Mass of nitrate lost to decay
- Inflow mass is approximated as nitrogen per person per day
- Considers advection and dispersive mass fluxes
- Mass in and Z (thickness of plume) are related





Preparing Data

Preparing Input DEM

- DEM
  - USGS National Map Downloader – 3DEP
  - https://apps.nationalmap.gov/downloader/
  - Resolution of 3m or 5m is preferable
  - You may clip the DEM to the study area to improve performance
- LiDAR DEM reflects small surface water bodies
- Check the DEM If flow paths are not logical
  - Features like large buildings can cause issues in the DEM

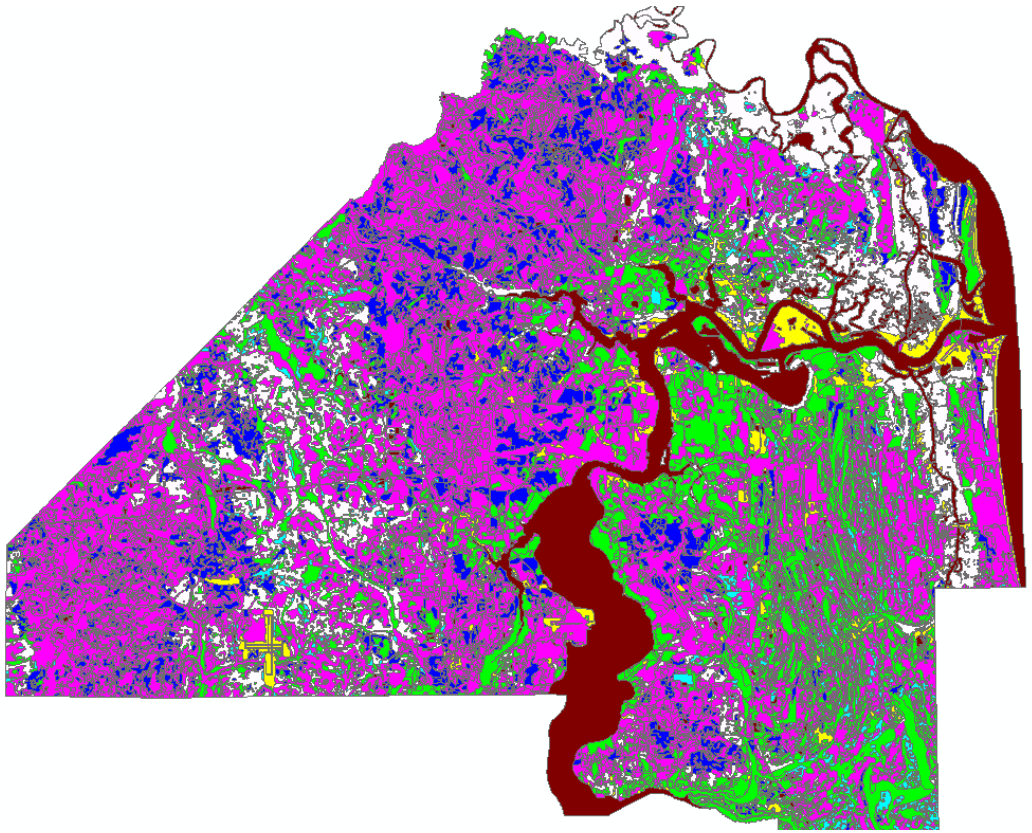
Preparing Waterbody Data

- Waterbody polygons
  - USGS National Map Downloader - Hydrography
  - https://apps.nationalmap.gov/downloader/
- Small water bodies and drainage features may be missing from the dataset
  - Polyline waterbody features have no width and will be stepped over by the raster window
  - Heads up digitization
  - Drainage features need to be connected in the waterbody dataset as they exist on earth
- LiDAR or aerial photography (Esri base map/Google Earth)
  - Use the contour tool in the Spatial Analysis Tools to aid waterbody correction

Preparing Soil Data

The Preprocessing Module Prepares the SURRGO Soil Data

- Soil Survey Geographic Database
  - Web Soil Survey
  - https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
- Porosity
  - wsatiated_r
- Hydraulic Conductivity
  - Ksat_r
- Use the data of the lowest depth for groundwater
- Convert soil polygons to a raster



Preparing OSTDS Data

- Gather OSTDS point location data from FDEP
  - https://floridadep.gov/water/onsite-sewage/content/onsite-sewage-data
- ArcNLET-Py only needs the location of the septic tank
- Septic tank concentrations should come from literature

Verify Data Outputs

- Verify there are no empty or null data sets
- Verify that pollution paths and plumes originate at the OSTDS and travel toward adjacent waterbodies
- Look for sinks that trap particle paths
- Ensure missing waterbody and drainage features are added to the dataset
- Cross-verification with field data

Troubleshooting

Common Issues

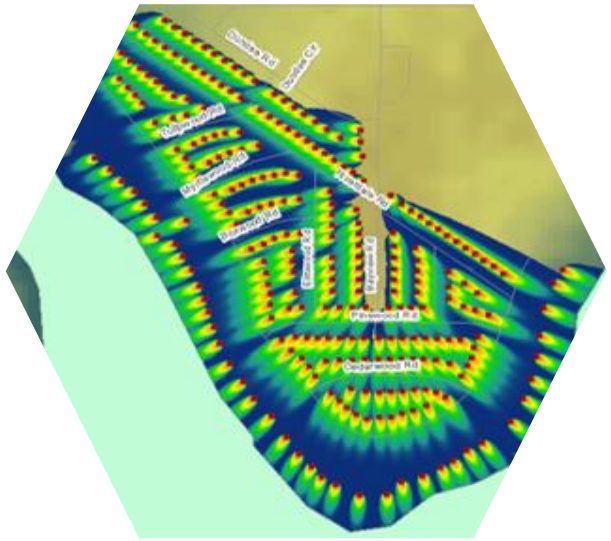
- Data format errors
- Parameter misconfigurations
    - Site-specific calibration
- DEM cell size
- Small waterbodies, creeks, and ditches
- GitHub issue tracker
- Local vs. Network locations

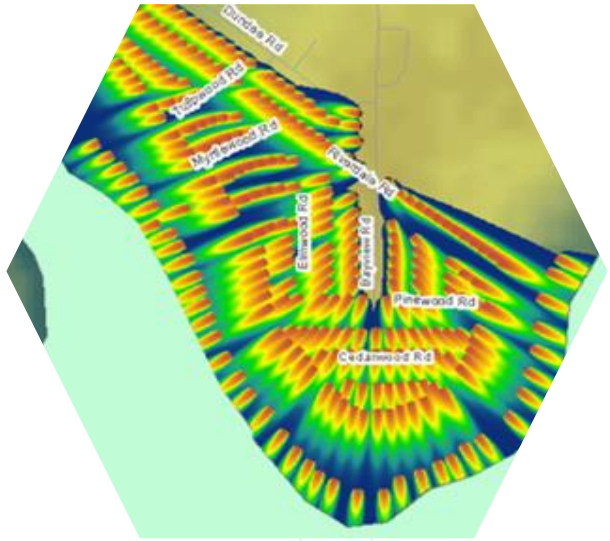
ArcNLET-Py Lakeshore Example

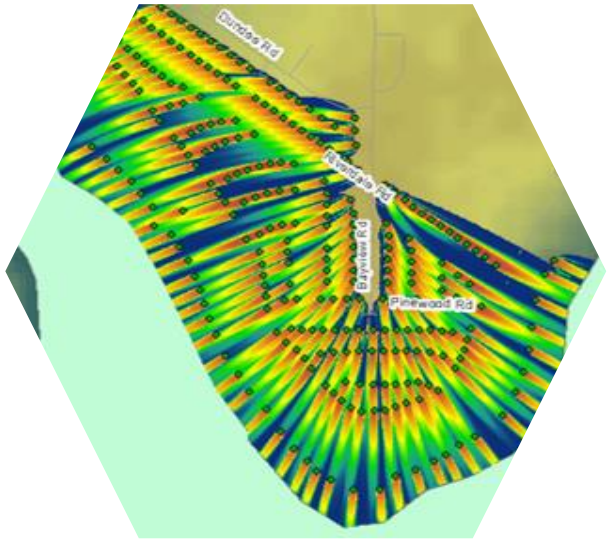
The Lakeshore Example

Accessing sample data in ArcGIS Pro

- Real-world example in Florida
- Data download
  - https://people.sc.fsu.edu/~mye/ArcNLET/lakeshore_example.ziphttps://people.sc.fsu.edu/~mye/ArcNLET/lakeshore_example.zip
- Extract example data to your ArcGIS Project Folder





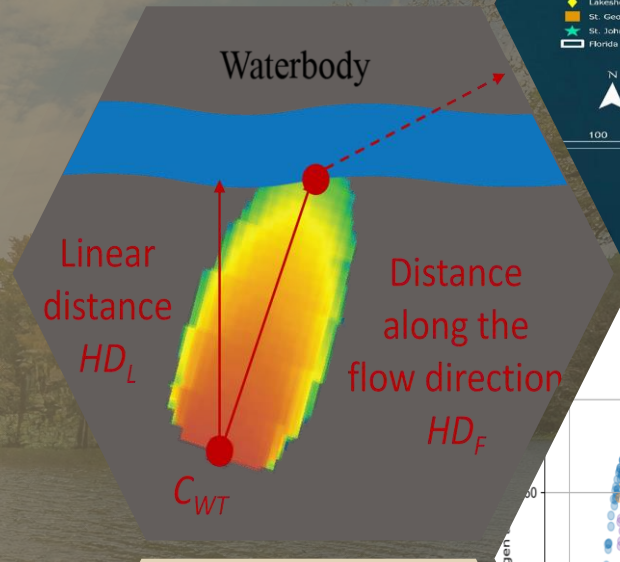


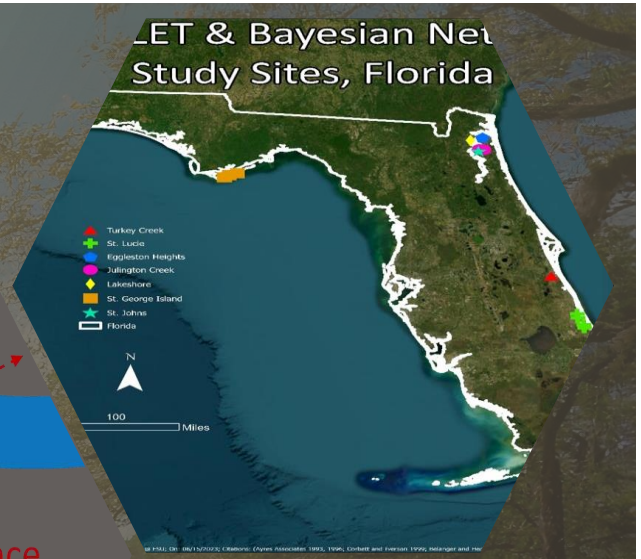
Lakeshore Example

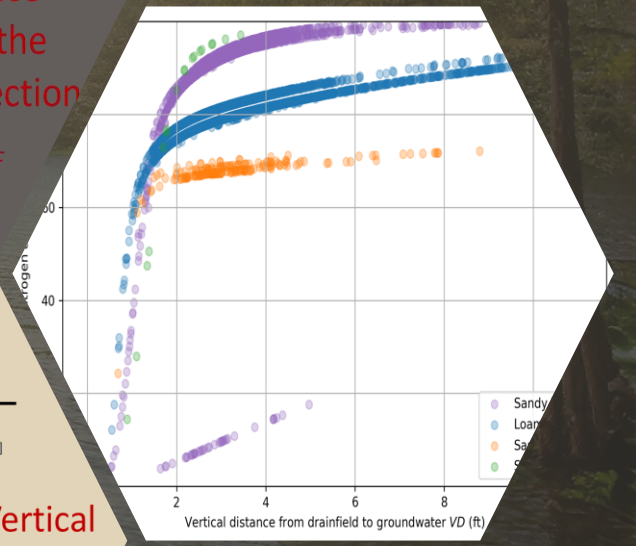
ArcNLET Application and Q&A

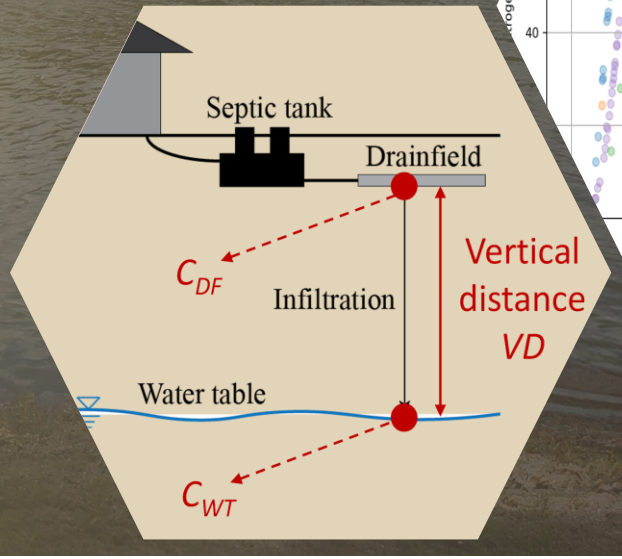
ArcNLET-Py In Practice

- Aid FDEP to investigate OSTDS setback distance
  - Vertical setback
    - Vertical attenuation rate
  - Horizontal setback
    - Horizontal attenuation rate
  - Total attenuation rate
- What should the vertical and/or horizontal setback distance be if an X% nitrogen attenuation rate is needed?





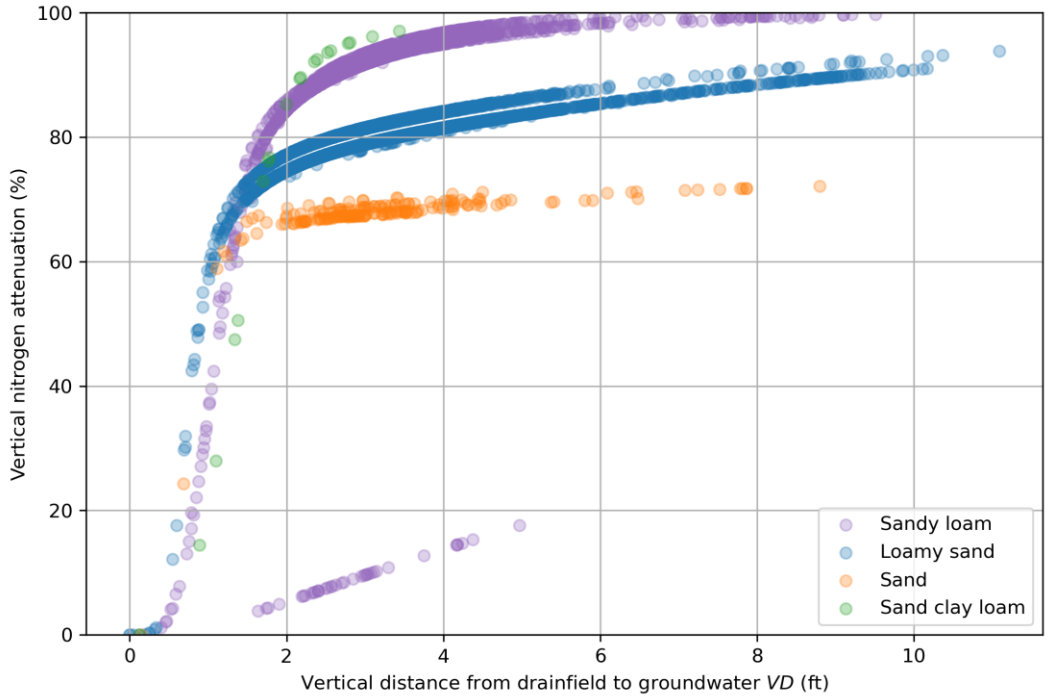


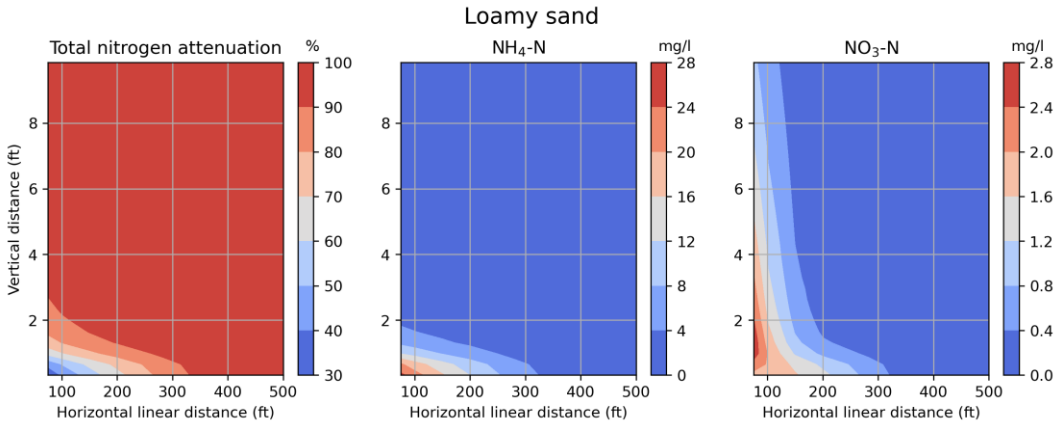


ArcNLET-Py In Practice

Estimating OSTDS Setbacks

- 5 locations were chosen where data and reports from FDEP Oculus were available
  - OSTDS concentrations
  - Hydraulic head
  - Nitrogen concentrations
- Simulated transport using calibrated data for thousands of OSTDS
- Soil types and soil saturate impact attenuation rates
- Results
  - 2-foot vertical setback from groundwater for 75% attenuation
  - 75 ft horizontal setback for surface water for 75% attenuation





Recap

ArcNLET-Py ArcGIS Pro Python Toolbox

- GitHub
- ArcNLET-Py
- Tools/Modules
- Lakeshore Example
- Real-world/hypothetical uses

THANK YOU!

Michael Core

Phone
(850)644-7358

Email
mcore@fsu.edu

Earth, Ocean and Atmospheric Science
Florida State University

FREAC
FLORIDA RESOURCES & ENVIRONMENTAL ANALYSIS CENTER
FLORIDA STATE UNIVERSITY

References

References

- Eby K (2017) The Basics of Software Version Control | Smartsheet. In: The ABCs of Software Version Control. https://www.smartsheet.com/software-version-control. Accessed 9 Nov 2023
- FDEP (2023) Onsite Sewage Program | Florida Department of Environmental Protection. In: Onsite Sewage Program. https://floridadep.gov/water/onsite-sewage. Accessed 9 Nov 2023
- GitHub (2023) Creating a pull request. In: GitHub Docs. https://ghdocs-prod.azurewebsites.net/en/pull-requests/collaborating-with-pull-requests/proposing-changes-to-your-work-with-pull-requests/creating-a-pull-request. Accessed 9 Nov 2023
- GitHub (2023) The github.dev web-based editor. In: GitHub Docs. https://ghdocs-prod.azurewebsites.net/en/codespaces/the-githubdev-web-based-editor. Accessed 9 Nov 2023
- GitHub (2023) Quickstart for writing on GitHub. In: GitHub Docs. https://ghdocs-prod.azurewebsites.net/_next/data/VKYGuWGGYxxUMVB9IvQfi/en/free-pro-team@latest/get-started/writing-on-github/getting-started-with-writing-and-formatting-on-github/quickstart-for-writing-on-github.json?versionId=free-pro-team%40latest&productId=get-started&restPage=writing-on-github&restPage=getting-started-with-writing-and-formatting-on-github&restPage=quickstart-for-writing-on-github. Accessed 9 Nov 2023
- Scopel C (2012) ArcNLET: Nitrate Load Estimation Toolkit. In: ArcGIS Blog. https://www.esri.com/arcgis-blog/products/product/water/arcnlet-nitrate-load-estimation-toolkit/. Accessed 8 Nov 2023
- USDA (2019) Web Soil Survey - Home. https://websoilsurvey.nrcs.usda.gov/app/. Accessed 11 Jan 2024
- US EPA O (2018) Types of Septic Systems. https://www.epa.gov/septic/types-septic-systems. Accessed 9 Nov 2023

ArcNLET-Py Repository

- Link to ArcNLET-Py GitHub:
  - ArcNLET-Py/ArcNLET-Py at dev (github.com)
- Link to ArcNLET-Py User's Manual
  - https://arcnlet-py.readthedocs.io/en/latest/