

“Improved Operational Efficiencies with Geospatial Analysis”

Eleza Kollannur¹, Amol Kulkarni², Tim Clay³

¹ GIS Analyst, Stantec ResourceNet India Pvt. Ltd., Pune

² Lead GIS Analyst, Stantec ResourceNet India Pvt. Ltd., Pune

³ Project Technical Lead, Stantec, Leeds, UK

Stantec ResourceNet India Pvt. Ltd., 5th Floor, Bajaj Brand View, Survey No 25 A/1, 25 C, CTS No 31, Final Plot no 38,
Pune, India - 411003

Abstract:

Geospatial analysis and programming is improving operational efficiencies in the Wastewater Sector resulting in faster and higher-quality decision-making, saving both time and money. As such, we have developed a suite of ArcGIS based routines using Python Scripting and Model Builder, to identify catchment needs and opportunities across a study area on current and future scenarios, considering factors such as climate change and population growth.

These tools identify opportunities to remove surface water from drainage network and areas of new development, which forms a key part of an environmentally friendly and sustainable future, whilst also ensuring resilience around critical infrastructure such as hospitals. One of the routines also help auto generate standard forms and maps for survey data collected through ArcCollector.

These tools combine the strength of programming with geoprocessing to clean, check and consolidate input data from various sources into a structured dataset for further geospatial analysis. It has helped share information with other stakeholders, allowing quick decisions and sharing of information, using ArcOnline.

The tools have used several geospatial analysis techniques including:

- Calculating distance and gradient from the lowest point of development to the nearest drainage option using raster processing, proximity analysis and attribute querying,

About the Author:



Mrs. Eleza Kollannur, GISP-AP, FRGS

Eleza Kollannur is GIS Analyst with 9 years' work experience and has background in architecture and Environmental Planning. She is a python enthusiast and has experience in developing several desktop and web based GIS tools for spatial analysis, watershed management, post processing ArcGIS Online Survey Data, mapping and reporting. She has worked on several Drainage Management, Mobile Survey and Master planning projects in the Middle East and UK.

Email ID: Eleza.Kollannur@stantec.com

Contact: +919881468588

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- Identifying flooding extent caused by sewer blockage using hydrology tools,
- Iteratively tracing and querying geometric network to generate hydraulically independent areas.

All these tools have given Stantec a competitive edge in the Wastewater Sector. The abstract will share details on how several water companies have opted for these technologies over their current practices to provide reliable drainage solutions to the communities they serve. It will discuss upon advantages and challenges of combining geospatial analysis with programming. It will also touch upon a checklist to follow when you develop a customized GIS toolbox for a client.

Introduction

The wastewater industry is facing a range of environmental challenges from factors such as global population growth, new developments, climate change and urban creep. A solution to this problem requires assessing the drainage network to clearly understand catchment needs such as flooding to properties and critical infrastructure and pollution to watercourses, before opportunities to target these needs can be undertaken. Such initiatives also helps maximize engagement between various stakeholders including environmental agencies, local councils and other local interest groups, and deliver multiple benefits across the catchment area.

Traditionally, identifying catchment needs and opportunities has been a labour intensive task. A suite of ArcGIS based routines using python Scripting and Model Builder have been developed which are quick to run, improve quality and offer a competitive operational efficiency over existing methods.

Geospatial Tools for Drainage Management

The routines developed for drainage management is based on the methodology below:

- Wastewater sewer networks comprise foul, combined and storm water pipes, which passes through a series of hydraulic breakpoints such as combined sewer overflows (CSOs), pumps, Sewerage Treatment Works (STWs) or outfalls, before spilling into a watercourse. Each routine runs with hydraulic modelling data exported such as InfoWorks ICM.
- The routine iteratively traces upstream from each hydraulic breakpoint as shown in Fig: 1. until the entire network is traced.

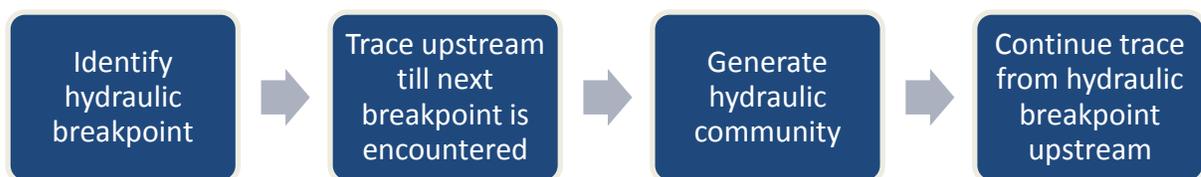


Fig: 1 – Automating geometric Network Trace

- (iii) The sewer network it is categorized as foul and combined with surface water or storm sewers discharging directly into it (F/C) or Surface Water and Overflow Network (SW) based on attribute queries and further updates each trace with the id of the breakpoint.
- (iv) At times a bifurcation is encountered where flow could split in more than one different sewer pipe. In such cases the primary flow direction is determined based on a set of rules starting by selecting the lowest pipe invert level, then the largest diameter and followed by other rules until the primary flow direction is ascertained.
- (v) When traces for each hydraulically independent catchment have been determined, the routine generates hydraulically independent regions or drainage community by merging together the sub-catchments draining assigned to each node in the trace as shown in Fig: 2

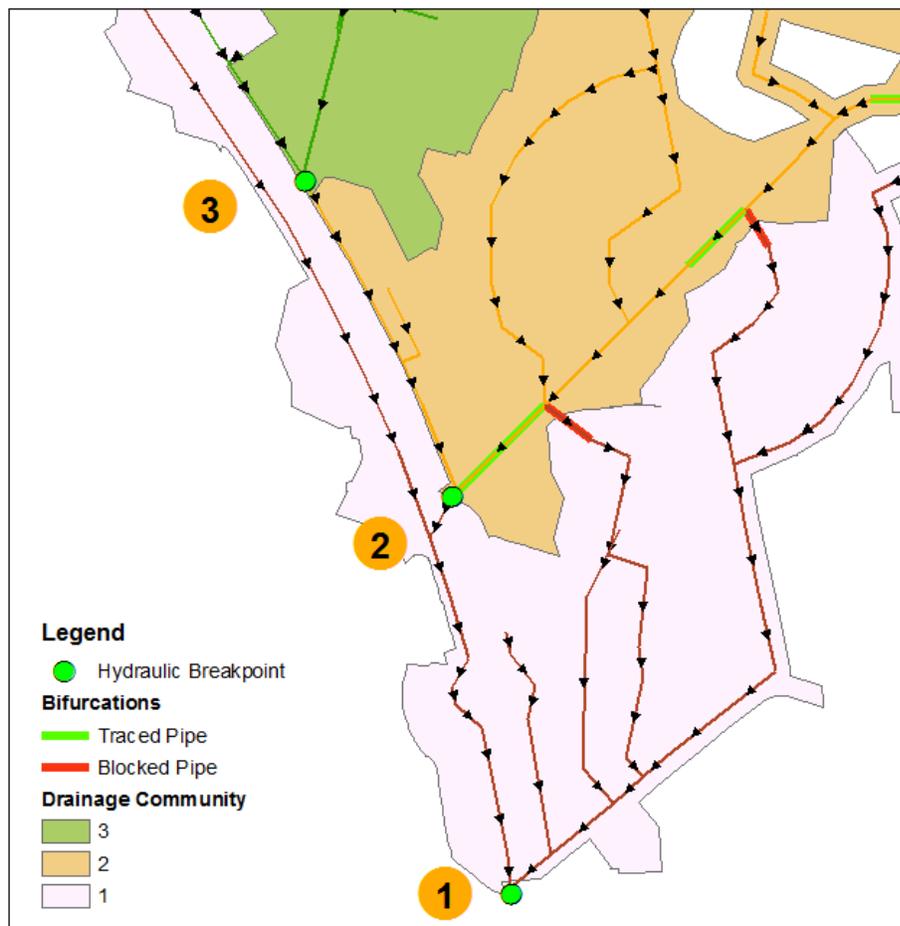


Fig: 2 – Drainage Community Definition

Advantages using ArcGIS routine are listed as follows:

- (i) Time saving: Automated tracing/querying saves up to 80% time taken using traditional method. This process was initially done by printing the network on paper and identifying drainage communities based on flow direction arrows,
- (ii) Improved Quality: This process ensures consistent and repeatable approach, offering greater quality and more accurate outputs. Previous manually defined outputs gave inaccurate or inconsistent outputs.
- (iii) Scalable solution: The routine can be applied across catchments of varying size and complexity.
- (iv) Future Analysis: The routine organizes the network for further analysis including:

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- a. Identifying opportunities where sustainable drainage solutions (SuDS) or storm water management systems could be retrofitted, including in highways and on existing structures.
 - b. Identifying parts of the sewer networks that are currently at capacity, or will become at capacity in the future if no interventions are implemented.
 - c. Identifying opportunities where surface water sewers could be removed from the foul combined network.
 - d. Identifying opportunities to drain areas of future planned new development or redevelopment in a more sustainable way, including where the surface water could be drained to surface sewers or watercourses with available hydraulic capacity and prevented from draining to the foul/combined sewer.
 - e. Identifying drainage communities where the foul or combined sewer network has available capacity.
 - f. Identifying surface water management discharge opportunities.
- (v) Ease of use: These tools have a well-documented user interface which enables an engineer or analyst to run the routines without going into the complexities of geo spatial analysis. An example of routine interface is as given below in Fig: 3.

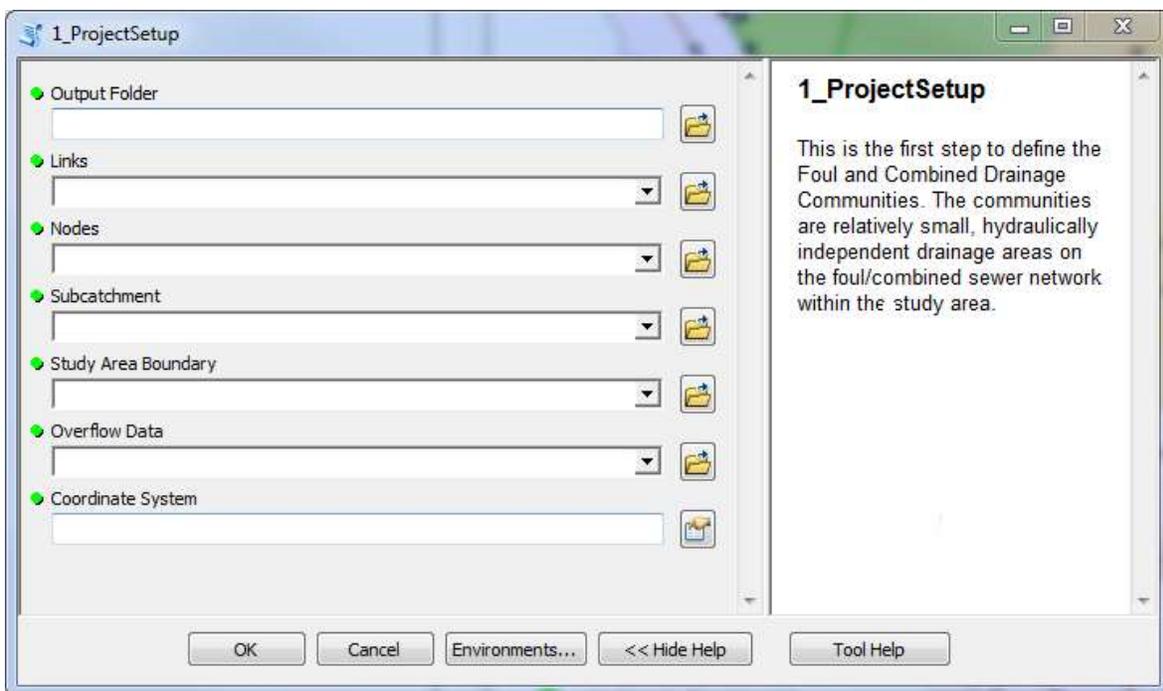


Fig: 3 – Drainage Community Definition Routine

Improving Efficiency on Site (ArcCollector Mobile Survey App)

The sewer hydraulic model is a fundamental tool to define catchment needs and identify opportunities. An accurate hydraulic sewer model requires survey data to define sewer connectivity, pipe sizes, gradients and condition. Survey work is captured by specialist survey teams as defined in the methodology in Table 1 given below

Table 1 - Comparison of Survey Methods

Traditional Survey Method	Proposed Survey Method
Hard copy map is used to locate the asset	GIS data is queried on Arc Collector to locate the asset
Paper forms are used to capture the data/readings	Digital Forms and related tables used to capture data/photos/ videos
Forms are digitized into excel/csv	Automated post processing of data to replicate standard form as excel/pdf/email
Data is stored on server paths without metadata	Data is stored centrally in the cloud and accessible through desktop app/ web

Survey work requires significant processing, which can incur errors taking or inputting data. In most of the cases field survey teams have to:

1. Locate the asset on ground.
2. Collect modeling properties for the asset wherever they are missing.
3. Collect hydraulic modeling details at desired locations.

Traditionally, survey information is collected using hard copy forms. These forms are predesigned to capture the relevant and specific information required for modeling that network. Some forms provide a picture number, which is then used to sort and attached the pictures to respective forms back at the surveyor's office. Arc Collector Mobile Survey data collection has now accelerated this process using digital forms in the app.

Survey information is then issued to the modeling engineer who will build and calibrate the hydraulic model. Time is of great importance as this process cannot start unless the survey collects valid information. The Collector App allows information to be shared immediately and any queries or ambiguity with data can be resolved quickly.

Transitioning from the traditional survey forms to mobile apps formats takes some familiarizing and it is easier if the data collected through digital form is reproduced to look like the standard form/maps using web or desktop application. This is done using python scripting which generate pdf or email of the standard form layout by accessing ArcGIS Online Rest service data. Since they can access data anytime during the survey, with a quick glance at the data, they can determine if the values are correct. This eliminates the need for a resurvey as the engineer can alert the ground teams to revisit any location quickly.

Advantages of combining geospatial analysis with programming

The advantages of combining geospatial analysis with programming is as given below:

- (i) Check input data: The routine can iterate through the headers and alert the user on missing fields, mismatch of data type like point, line or polygon. Missing fields can then be completed.
- (ii) Automating routines: Scripting gives better control over geospatial processing such as using conditional loops to repeat sections of the routines until you get the relevant result. For example tracing upstream from each hydraulic breakpoint iteratively until hydraulically independent areas are generated for all the connected network.
- (iii) Reusability: Create functions to structure large routines, which can be used to repeat several processes. For example creating a function to generate a feature layer with a list of selected fields fixed to it. This helps remove irrelevant fields passed on during a spatial join which has to be otherwise deleted to reduce data size and increase processing speed. Functions also helps in testing the code part by part.
- (iv) Make routines faster: Use local variables to free up memory once its scope is over. Deleting temporary layers created for selection queries, tracing etc., to clear the cache and make the routines run faster.

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- (v) Error handling/ missing data: The routines can be run on study areas of varying size and it is possible that some queries or data is not valid for that area. Use try-except to make sure the routine can move forward if a specific selection is not available, or give a specific warning rather than let the process crash without giving the user a clue.
- (vi) Add inline comments: This helps to understand the code and make changes on a later date or by a different user
- (vii) Testing: Run the code multiple times with different pieces of data to generate different outputs.

Preparing customized GIS toolbox – Checklist to follow

- (i) Putting together disparate datasets: The users can import data from various sources to run the tools. Making an input register to ensure all input data is collated in specific format like feature classes, csv, raster, geodatabase and so on is helpful. Also ensure the correct coordinate system is used.
- (ii) Schema check: A user documentation has to be provided with the tool to ensure all the table headers are included with information of measurement in correct units.
- (iii) Creating folder structure: Create a folder structure with set output folders/geodatabase named accordingly so that the user can identify which is the final output of each routine and set apart the temporary files created.
- (iv) Checking license and extensions: ArcGIS provides options to check licenses and extensions to ensure they are available to run the routine successfully. Ensure that the correct ArcMap version for the routine required is specified.
- (v) Metadata: Update metadata for the tool so that the interface is user friendly and provides required information for the user to run the tool.
- (vi) Creating log files: ArcGIS provides an option to print out geoprocessing steps to result window, but is not easily accessible to the user once ArcGIS is closed. An alternate approach is to generate log files in .txt format which includes all input/output data used, customized messages showing error, routine progress and start/stop date/time for the process. This helps the user to send across the log for QA/QC in case of any query.
- (vii) Limitations: Check if the routines can be run on a study area with different coordinate system or with different types of data. Prepare a note on limitations on usage and on any decisions taken based on the results generated, if any.

Challenges Ahead

- (i) Future development and maintenance: Additional budget needs to be secured for future development and maintenance activities such as checking tools compatibility with future versions of ArcGIS/ ArcPro, migration of scripts from Python 2.x and 3.x version change.
- (ii) Intellectual property rights and reuse: Be clear on the IP rights of the tools created. It could belong to the client you developed the tool for, be individual research output or belong to the company under which you developed the routines.

Conclusion

The developed tools were compared to the traditional manual method to analyze the time efficiency to identify catchment needs and opportunities for 3 different sites of varying scale in UK. The results showed the tools were 80% quicker. The tools also ensured a consistent and repeatable solution. These tools have helped develop drainage management strategies clearly and visually with a range of technical and non-technical stakeholders.