Modeling Stormwater Runoff from Business Parcels to Snohomish County's Municipal Separate Storm Sewer System Using ArcHydro

Brenden Mclane, Senior GIS Analyst

Snohomish County Surface Water Management

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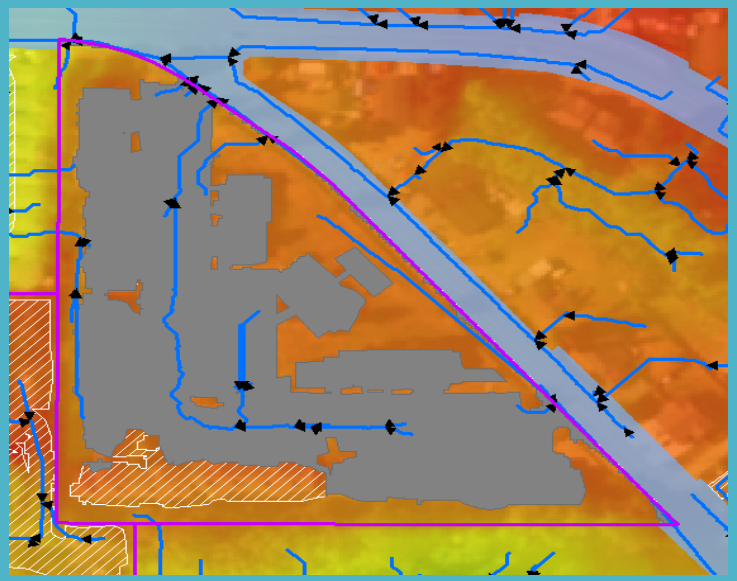
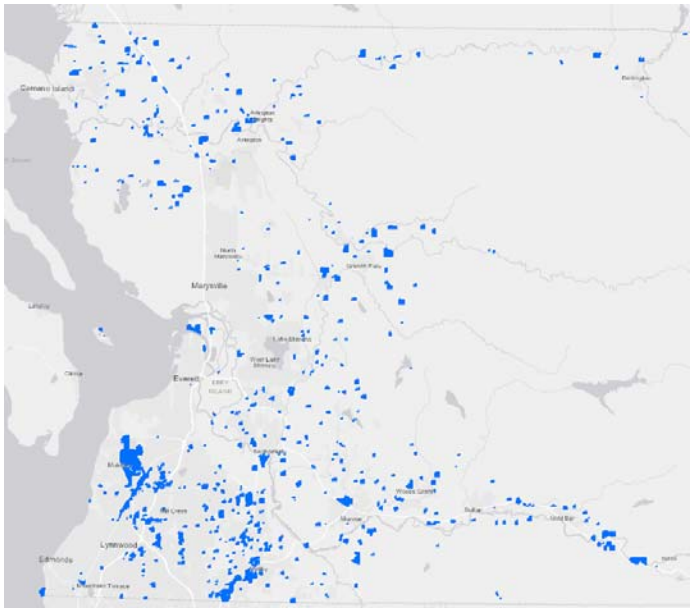


What is the MS4?

- "Municipal Separate Storm Sewer System" – i.e. the County's owned or operated storm water drainage pipes, ditches, and other drainage infrastructure.
    - Separate from Sanitary Sewer

- National Pollutant Discharge Elimination System (NPDES) permit requires SWM to inspect potential commercial and industrial sources of pollution. (Phase 1 Municipal Stormwater Permit S5.C.7)

Background and Purpose



- Snohomish County has over 1,700 business parcels on current inspection list, inspected on a 2-year cycle on average.

- Analyzing potential stormwater discharge to MS4 from each parcel helps prioritize inspections until field visits can verify discharge.
    - Specifically, where water flows from impervious surfaces into the MS4

Methodology Overview

1. 1.5 foot Digital Elevation Model was developed from 2014-2015 LiDAR flights (PSLC and USGS).

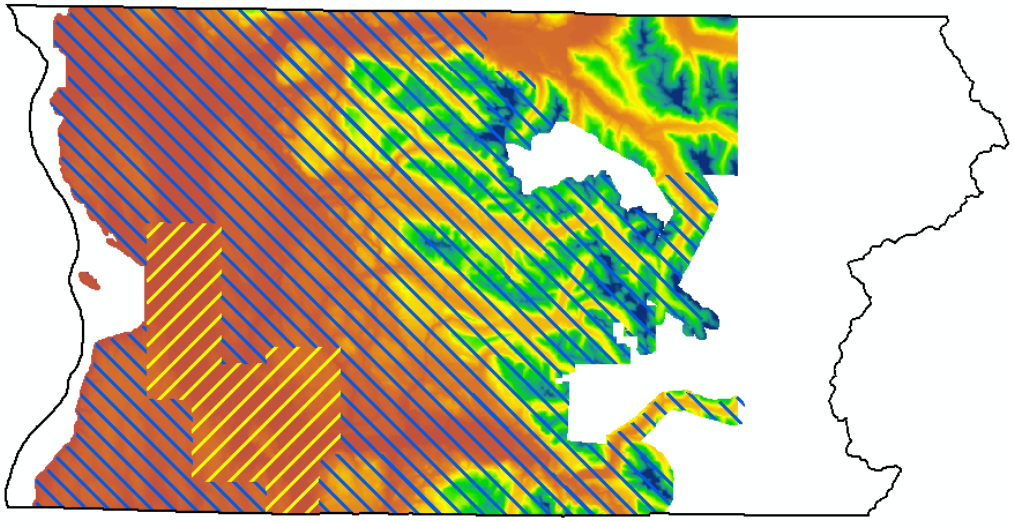
2. Ancillary layers assembled: impervious areas, stream and storm drainage data

3. ArcHydro tools utilized within a Python script to model drainage on each parcel.

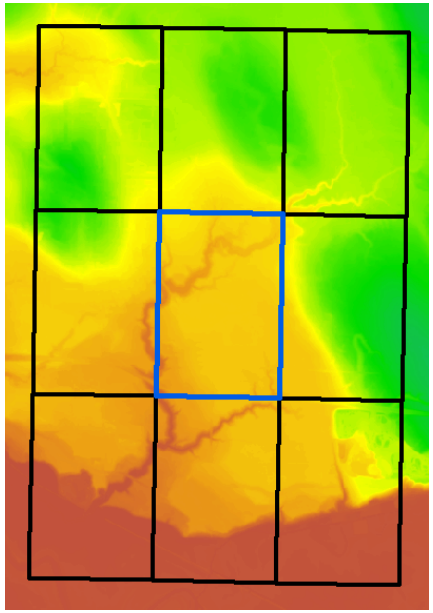
4. ArcHydro output analyzed within Python script to summarize impervious area within parcel that drains to the MS4.

1) DEM Preparation Overview

- 2014 Cedar River Watershed project data (441 tiles)
- 2015 USGS 3DEP LiDAR data (2,315 tiles)



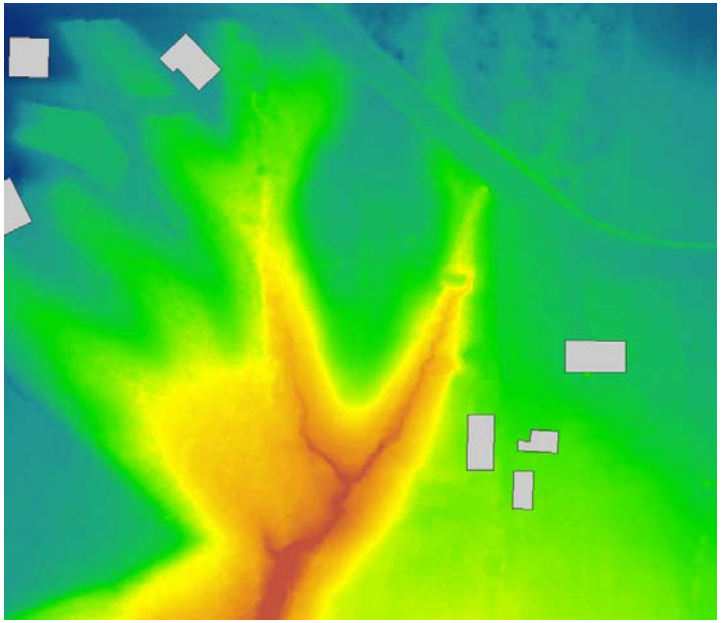
DEM Preparation Methodology

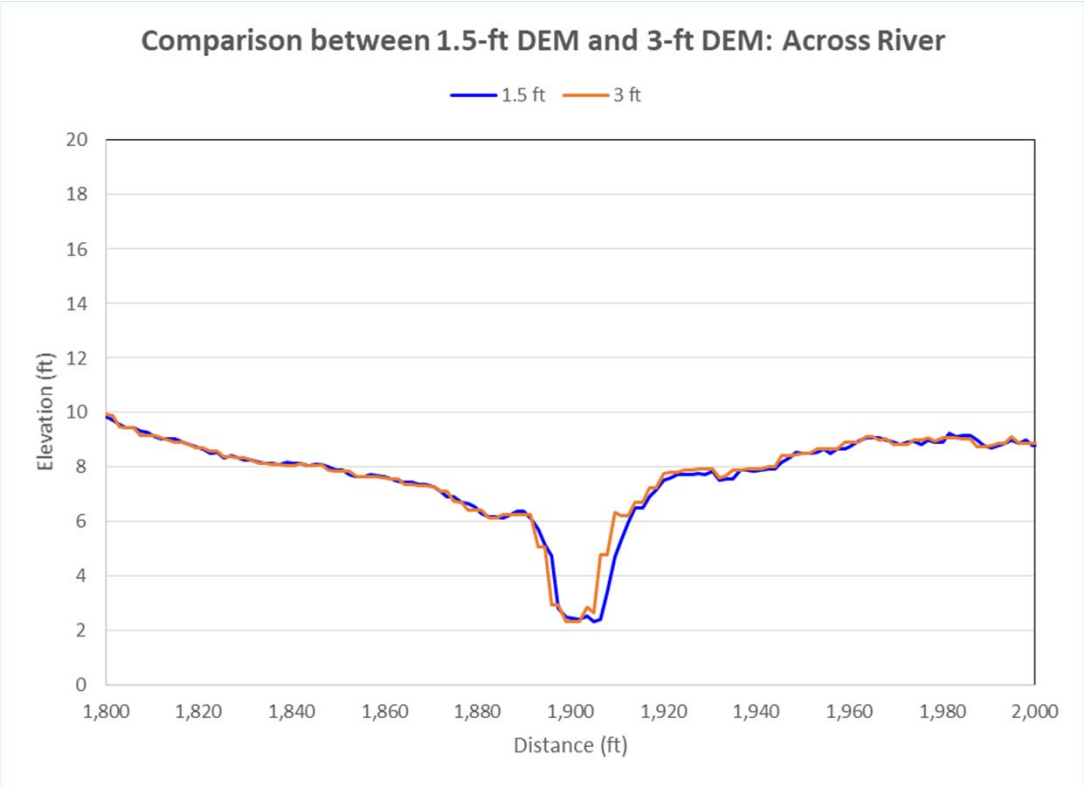


- Point cloud tiles were interpolated (using average of elevations in “bin”) into DEM using surrounding tiles to avoid “edge” effect.
- Overlapping tiles were then mosaicked using “BLEND” method.
- Issues:
  - LAZ files in collection area near Darrington had missing point clouds, so a 3ft LiDAR DEM was resampled to fill in that area.
  - Processing time on PC was quite long

DEM Preparation Results

- 250 GB of data, but improved smoothness over 3ft





2) Ancillary Layers

- Impervious surfaces mapped by merging 3 existing layers
  - Bing and OSM building roofprints
  - 2015 NOAA Coastal Change Analysis Program land cover (1-meter)
  - SWM's internal impervious layer (incorporated county only)

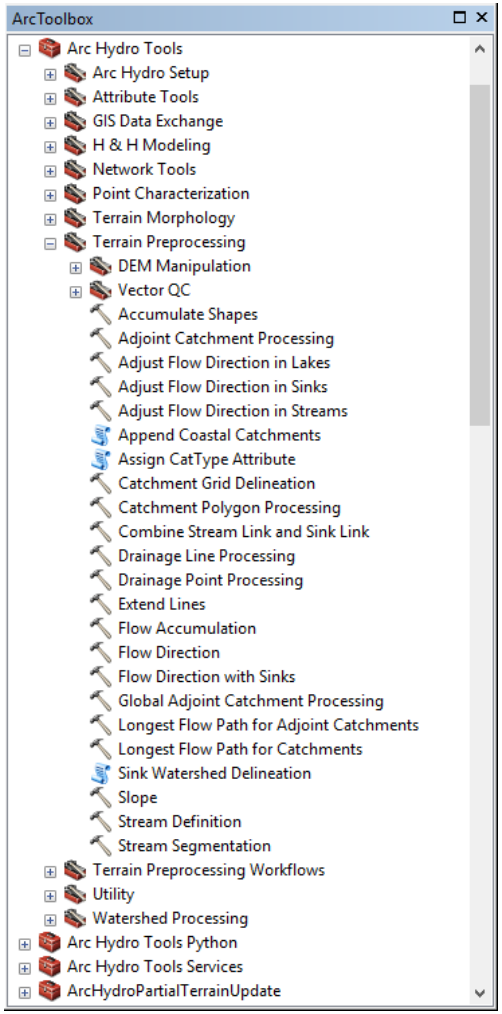
- Minor editing of county stream layer for consistent direction of digitization.

3) ArcHydro Overview

- What is ArcHydro?
  - *"Arc Hydro is a GIS data structure that links hydrologic data to water resource modeling and decision making methods."*
  - *https://www.esri.com/library/fliers/pdfs/archydro.pdf*

- *ArcHydro tools include many tools from Spatial Analyst toolset, as well as custom tools for creating data in the ArcHydro data model.*

- *http://downloads.esri.com/archydro/archydro/Setup/*



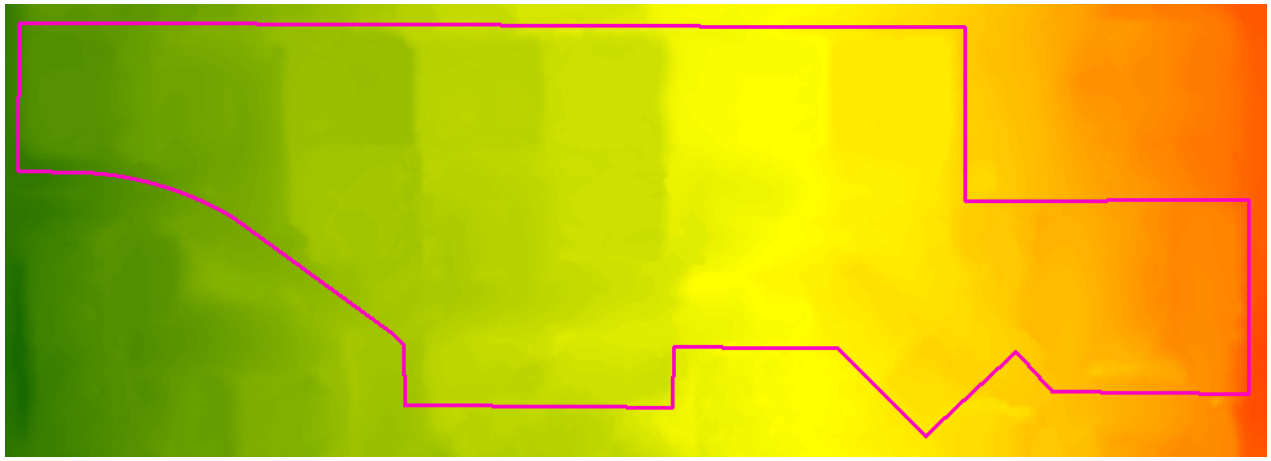
Producing Drainage Basins using ArcHydro

- To produce drainage basins and lines layers for each business parcel, these ArcHydro / Spatial Analyst tools were used.

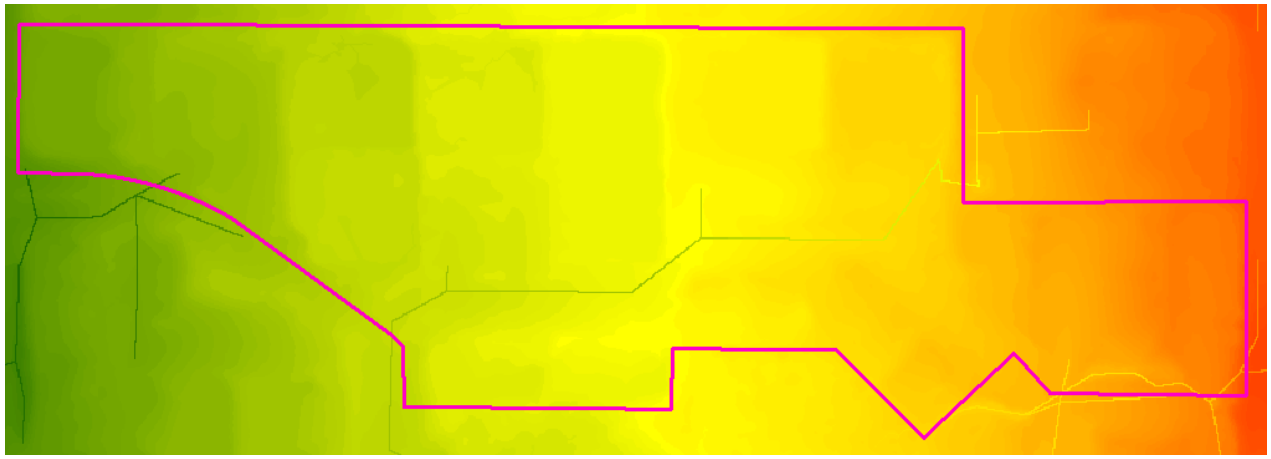
1. “Clip” DEM to buffer of the selected parcel
2. “Filter” using low pass 3x3 to reduce anomalies (smoothing)
3. “DEM Reconditioning” to burn county stream and storm water network into DEM
4. “Optimized Pit Removal” tool to fill sinks in the DEM
5. “Flow Direction”
6. “Flow Accumulation”
7. “Stream Definition”
8. “Stream Segmentation”
9. “Drainage Line, Point, and Catchment processing”

DEM Reconditioning

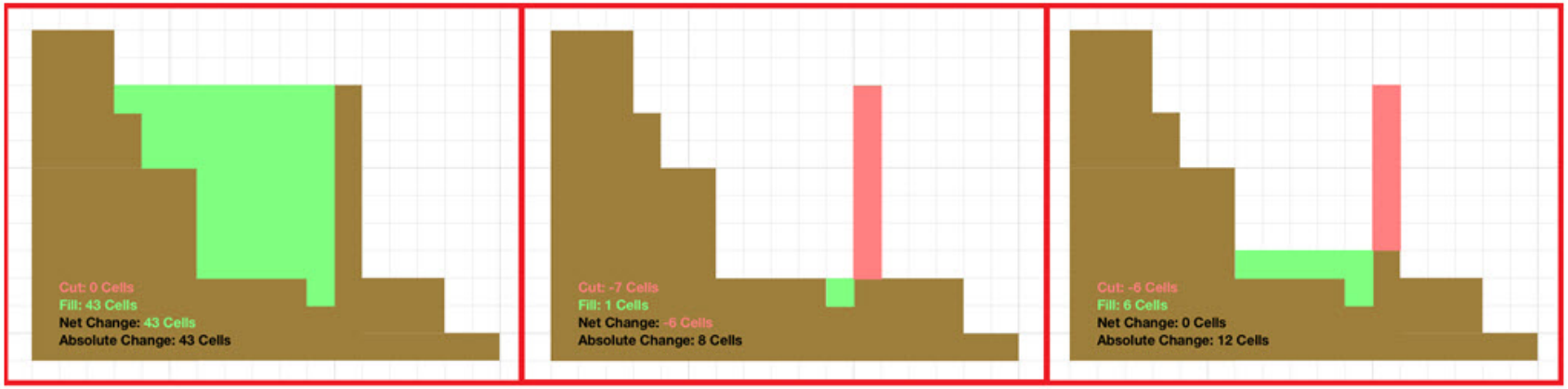
Original DEM



Reconditioned DEM w/ 15ft drainage burn



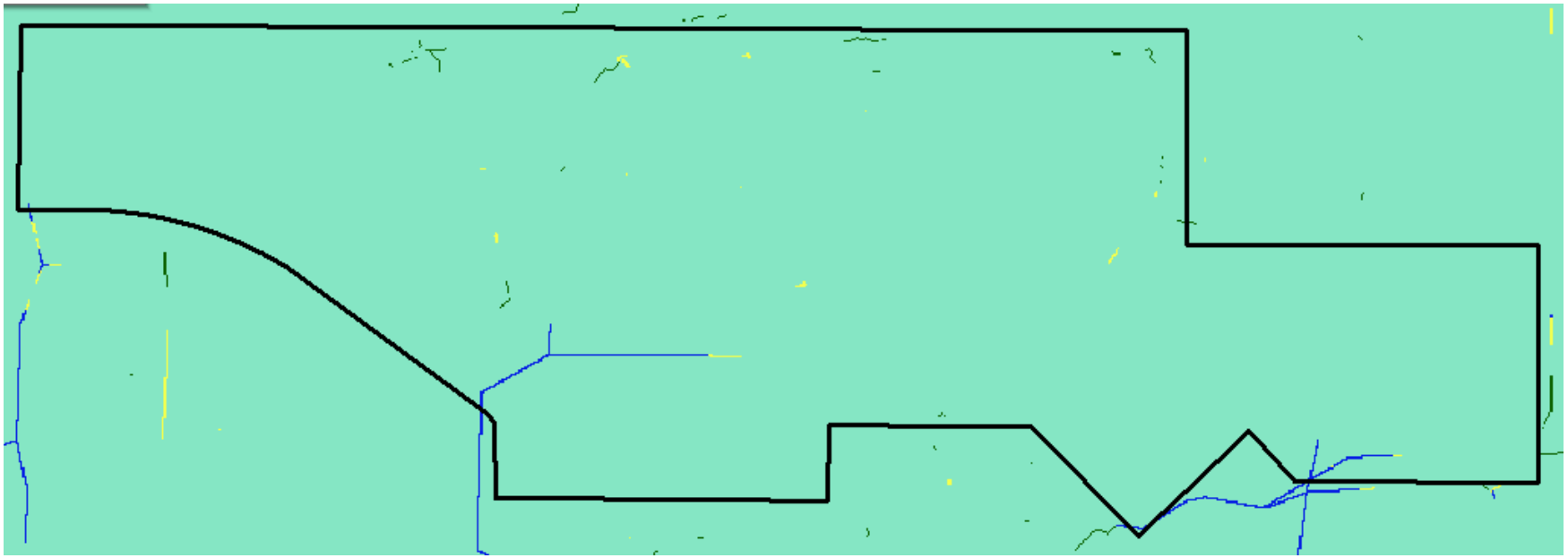
Optimized Pit Removal



Pit Removed Using Fill | Pit Removed Minimizing Absolute Change | Pit Removed Minimizing Net Change

https://www.esri.com/arcgis-blog/products/product/water/optimized-tool-for-dem-pit-removal-now-available/

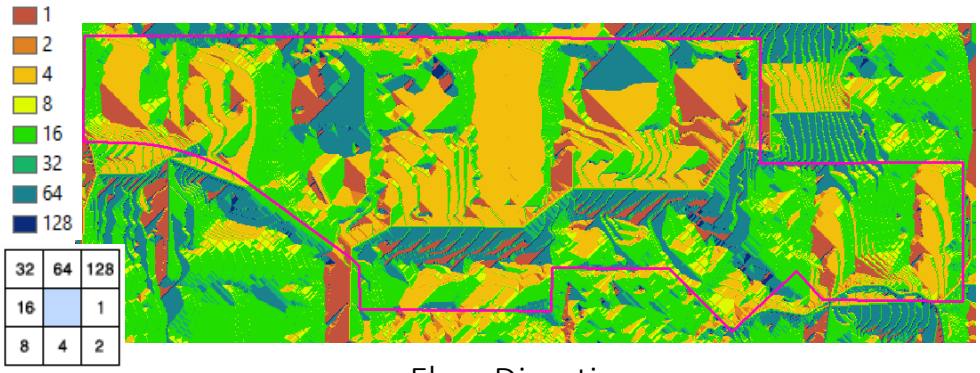
Pit Removal Comparison



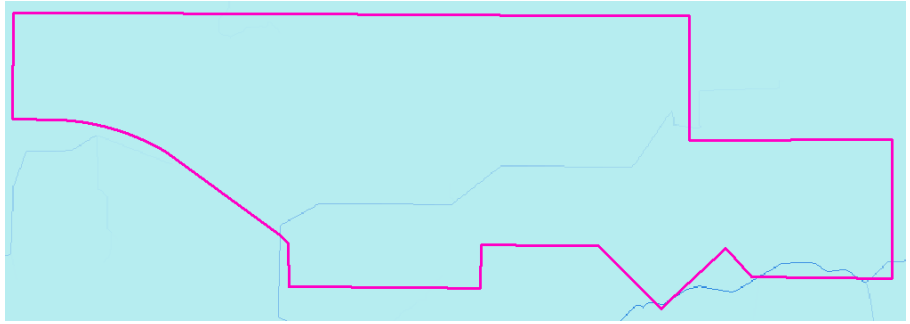
-16 - -1
-0.99 - 0
0 - 1
1 - 15

Positive value means pixel was filled, negative value means pixel was cut. Filled areas are mostly where drainage network was burned into the DEM. In this image, only 75 cells were untouched using “Minimize Absolute Elevation Change mode and 0.1 step size.

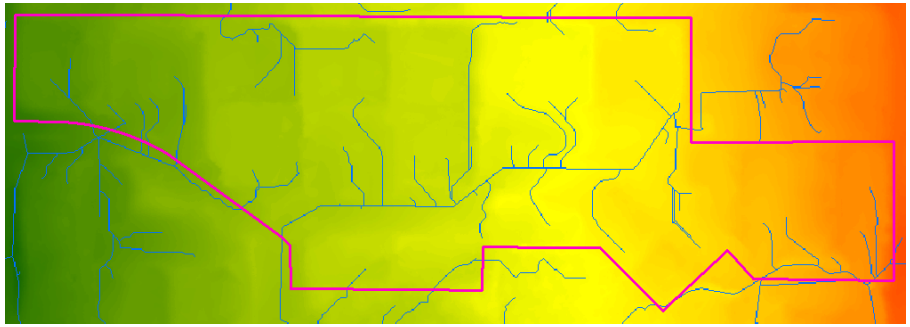
Flow Modeling



Flow Direction



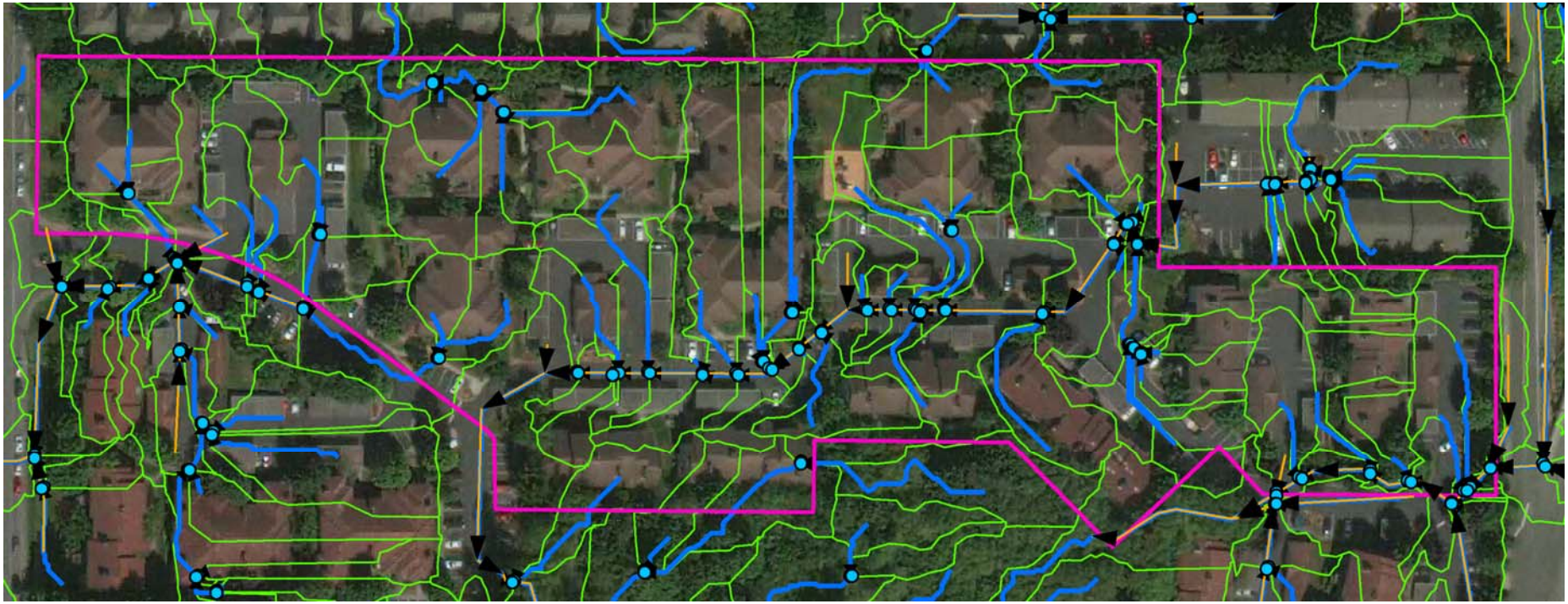
Flow Accumulation



Stream Definition (1000 pixel threshold)

Stream Segmentation

Catchment and Drainage Processing



4) Analysis of ArcHydro Output

I. Trace from the county MS4 to the parcel, removing drainage lines flowing to streams based on proximity.
   - Use traced drainage lines to selected basins within parcel
   - Use selected basins to clip impervious area

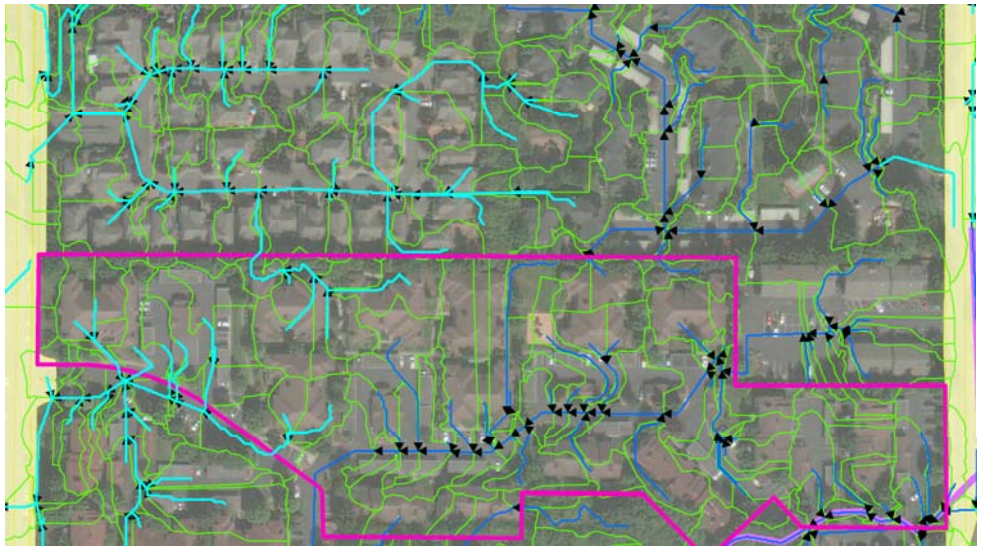
II. Trace from any unassigned areas downstream, to see if water is discharging to an "MS4 stream" (a stream that eventually enters the county MS4), then upstream from any found MS4 streams in the area.
   - Use traced drainage lines to selected basins within parcel
   - Use selected basins to clip impervious area

III. Update a statistics table using clipped impervious area

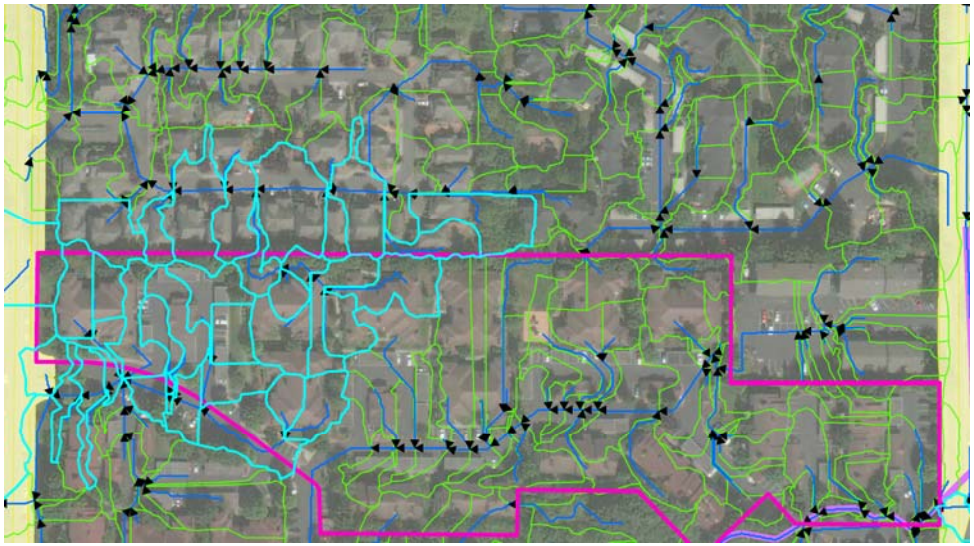
BusinessParcel_Stats

OBJECTID *	PARCEL_ID *	Flows to MS4	Total SQFT to MS4	Stream flows to MS4	SQFT to MS4 via Stream	StreamFlag
1646	00372900100106	YES	75512.545352	NO	0	YES
1645	00707600007500	YES	3689.788617	NO	0	YES
1644	01095500009700	NO	0	NO	0	NO
1643	00509400001600	YES	21696.493414	NO	0	NO
1642	00509000001302	YES	578.512828	NO	0	NO
1641	00707600008500	YES	4172.189214	NO	0	NO
1640	00372700200103	YES	18222.087972	NO	0	NO
1639	00372700800402	YES	8405.105288	NO	0	NO
1638	00372900100605	YES	20234.14248	NO	0	YES

Example of Network Trace and Basin Selection

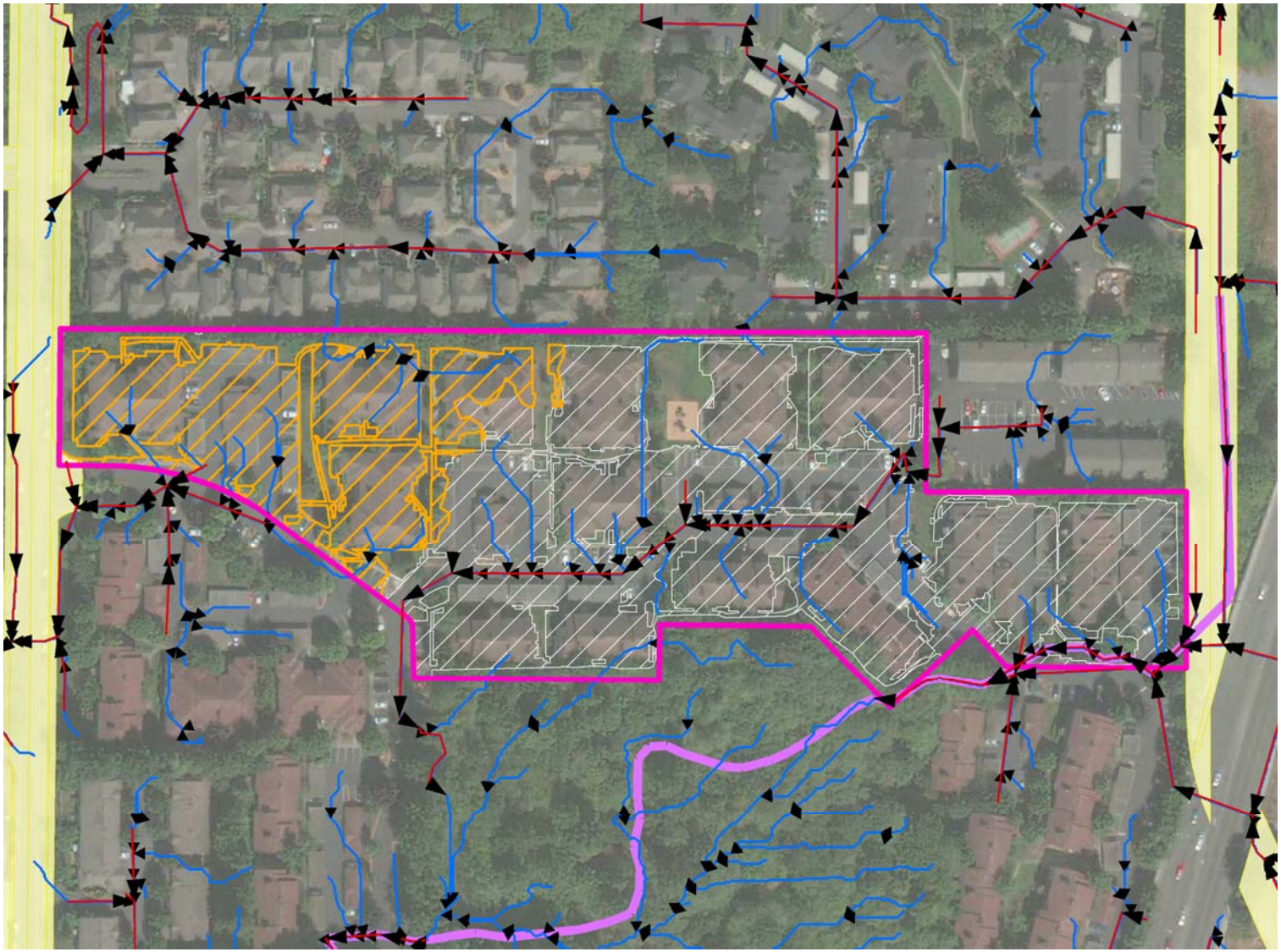


Tracing from the MS4 to Parcel



Selecting basins within the parcel based on the trace. Selected basins are used to clip impervious areas.

ArcHydro Output Analysis Results



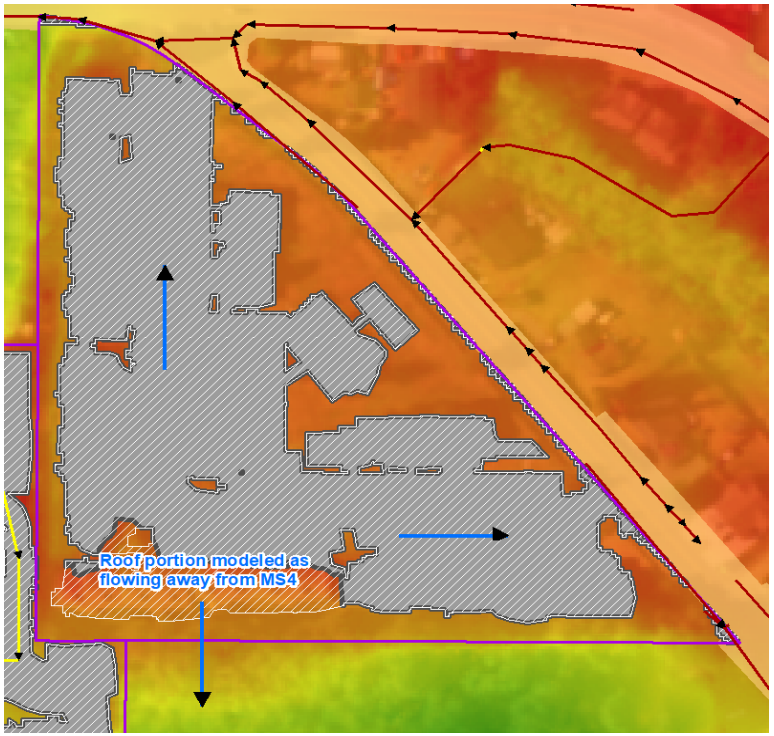
Statistics

- 3,252 business parcels analyzed
  - 817 with no impervious surfaces flowing to MS4
  - 2,435 with impervious surfaces flowing to MS4
- 4,743 acres of impervious surfaces flowing to MS4 from business parcels
  - Average of 1.5 acres per parcel
- Review of 10% of results found error rate of 1.3%
  - Included under- and over-estimation of impervious flowing to MS4

Limitations

- Surface flow vs underground flow
- “Effective impervious” vs channelized flow
- Eliminating false positives due to flow under the MS4 via culverts

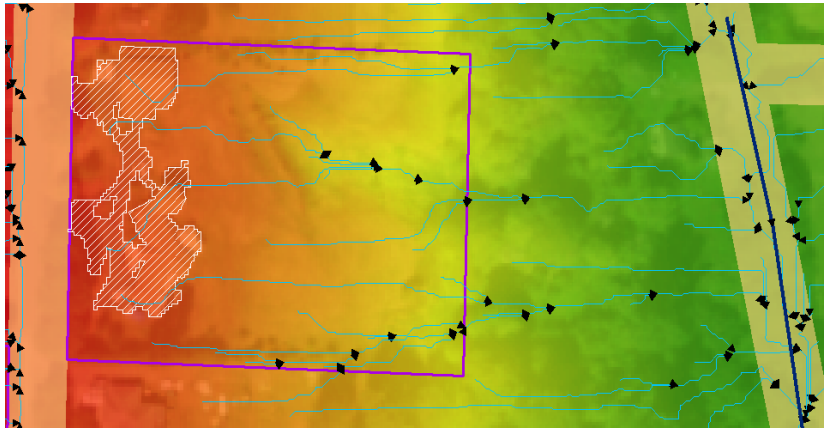
Limitations: Surface Flow vs Underground Flow



- Complex overlapping underground drainage modeled as “ditches”
- Gutters and downspouts can alter flow, model uses bare earth instead of first return LiDAR (buildings removed)

Limitations: “Effective Impervious” vs Channelized Flow

- Draft NPDES permit states “100 ft” as the threshold for “Effective Impervious”.
- Channelized flow over pervious ground can still deposit water to the MS4.



- Errors can occur when flow is going away from the MS4, but impervious is within 100ft of upstream MS4.

Limitations:
Eliminating False Positives

- Model is not 3D, therefore water flowing under the MS4 via a culvert can be falsely identified as contributing to the MS4.
- In example, the southern portion of the parcel flows under the MS4 to a nearby stream, while the northern portion enters the MS4.

Technical Issues

- Software:
  - ArcGIS 10.5.1
  - ArcHydro 10.5.0.90
  - PyScripter 2.6.0.0
  - IDLE 2.7.13
- "COM CALL COMPONENT" errors after running tool in loop on 50+ parcels
  - Issue was reproduced in multiple PCs running same script
  - Issue has occurred only in scripts using ArcHydro
  - Issue began occurring with ArcHydro 10.5.0.90 and ArcGIS 10.5.1
  - Eliminating excess memory didn't help the problem
- Certain ArcHydro tools in 10.5.0.90 had to be reprogrammed using spatial analyst to avoid error, although they worked in previous versions.
  - DEM Reconditioning
  - Drainage Polygon Processing

Recommendations

- ArcHydro is good for small and simple drainage modeling tasks, but scale dependent issues can occur
  - At large scale (small area), errors are more likely due to flow simplification or data gaps
  - At small scale (large area), reconditioning DEM is challenging due to image size
    - Optimized Pit Removal has 50,000,000 cell limit
  - Advanced modeling can increase accuracy, but at a high cost in time and money
- Software version issues could cause instability
- This analysis is good for NPDES related modeling activities, if no other drainage data exist at the proper scale and resolution.
- Ensure good drainage inventory exists to recondition the DEM. Otherwise, modeled flow can be vastly different if roads, etc. are blocking streams.

Questions?

- Contact:
  - brenden.mclane@snoco.org
  - 425 262-2574 (office)