Slide 1

Good morning, my name is Cindy McKay and I'm with Horizon Systems. My discipline is information technology with a complete focus on water resources. I'm on the medium resolution NHDPlus team for EPA and on the high resolution NHDPlus team for USGS.

Ever since NHDPlus was first released in 2006, I've been providing tech support to the community who wants to use the data to answer all sorts of questions. Probably 90% of those questions involve linking information to the network and then navigating the network and discovering things upstream or downstream. For example, a toxic spill and the downstream drinking water intakes or a nutrient impaired water and upstream agricultural runoff. We may want to know how far apart these things are or how long it takes the water to travels from one to the other.

So in the next 15 minutes, we're going to complete a project that involves navigation and discovery.

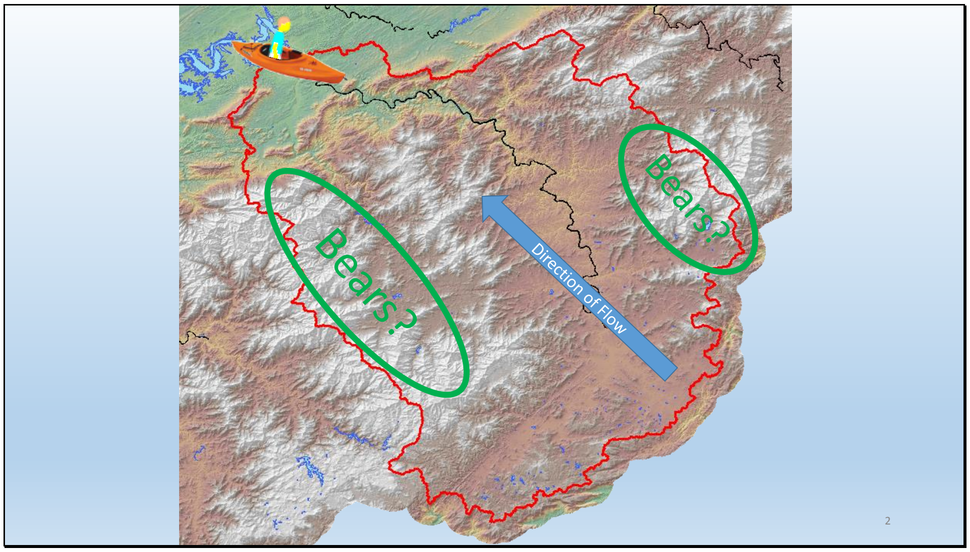
There have been grizzly bear sightings high up in the Tennessee River watershed. Of course, this is startling to everyone and the Forest Service has tasked us with finding these bears. Our only means of transportation into this dense forest land is a kayak. So our questions are: Which streams should we follow to find the bears? Oh and lets do the least amount of paddling and minimize how many dams we'll have to portage around.

Now don't be making fun of my knowledge of grizzly bears. This is supposed to be fun and I've taken liberties with the truth.

Our objective today is for you to go home and be able to develop a navigation and discovery application of NHDPlus.

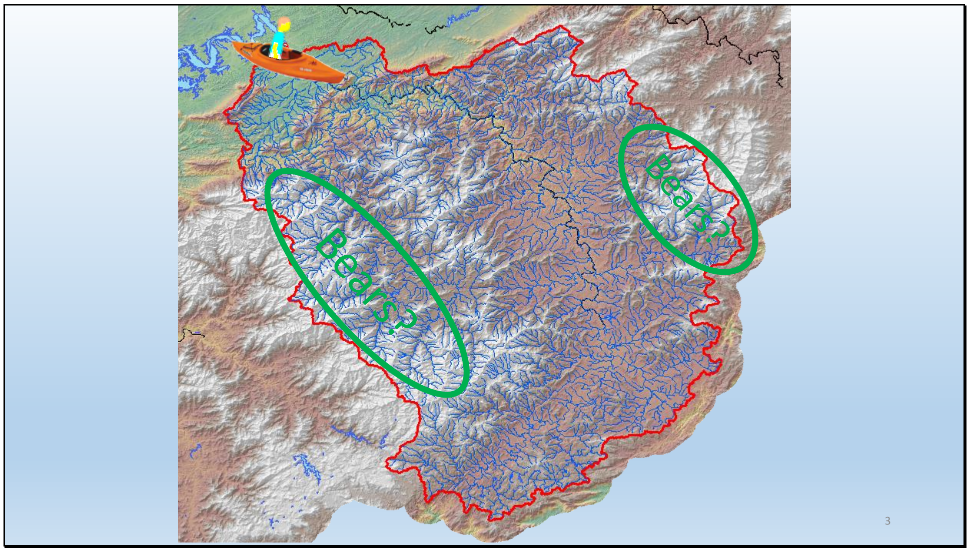
Photography: Alaska to Africa Travel

Slide 2



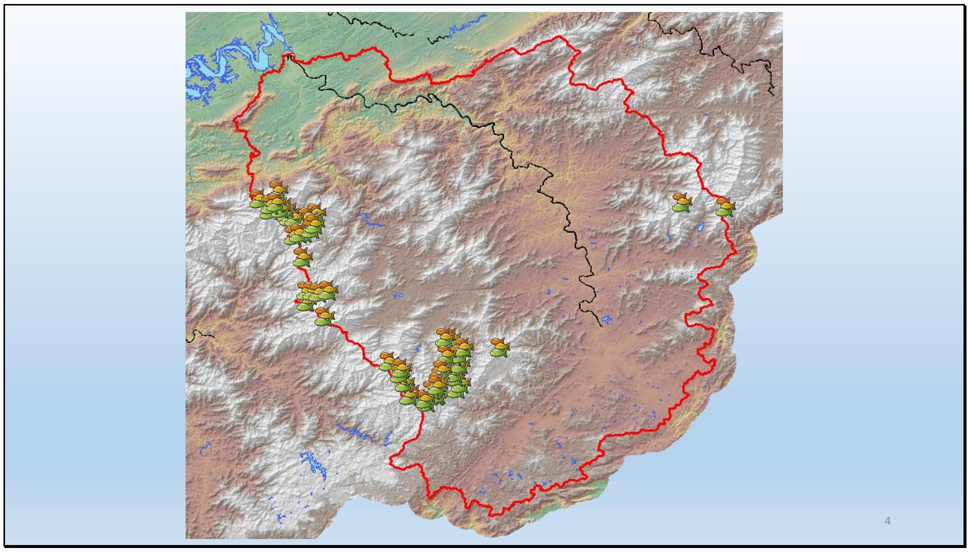
Here's the watershed where the bears were sighted. The water flows toward the northwest. The bears were sighted in the mountains. And we're down at the pourpoint of the watershed sitting in our kayak.

Slide 3



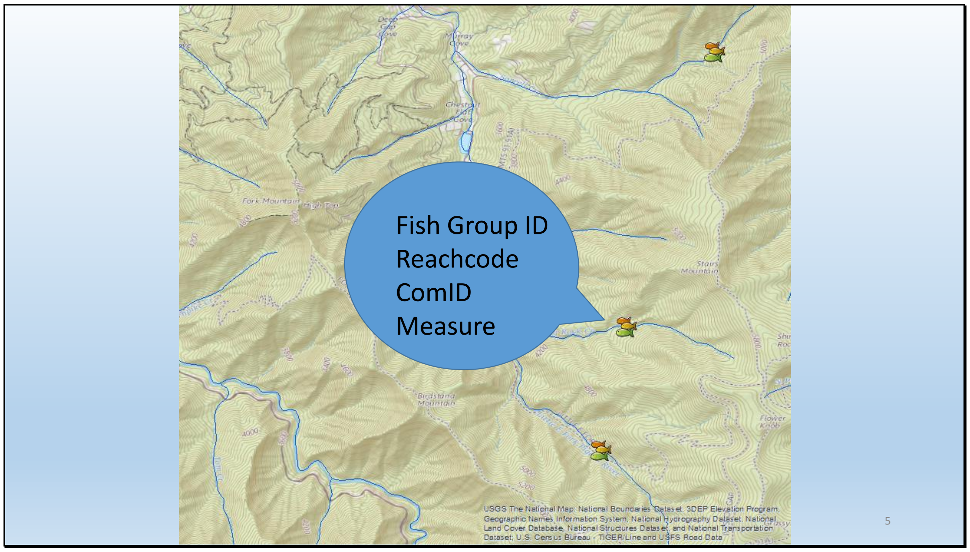
The blue lines are the stream network and there are lots of potential paths between us and the bears. This watershed is roughly 6700 square kilometers of land and has 6612 kilometers of stream.

Slide 4



But we know that our bears love fish, so our assumption is if we go to the fish, we'll find the bears. From the state Department of Fish and Wildlife, we downloaded some fish location data for our watershed.

Slide 5



This data has been linked to the NHDPlus network. For each fish location we know:

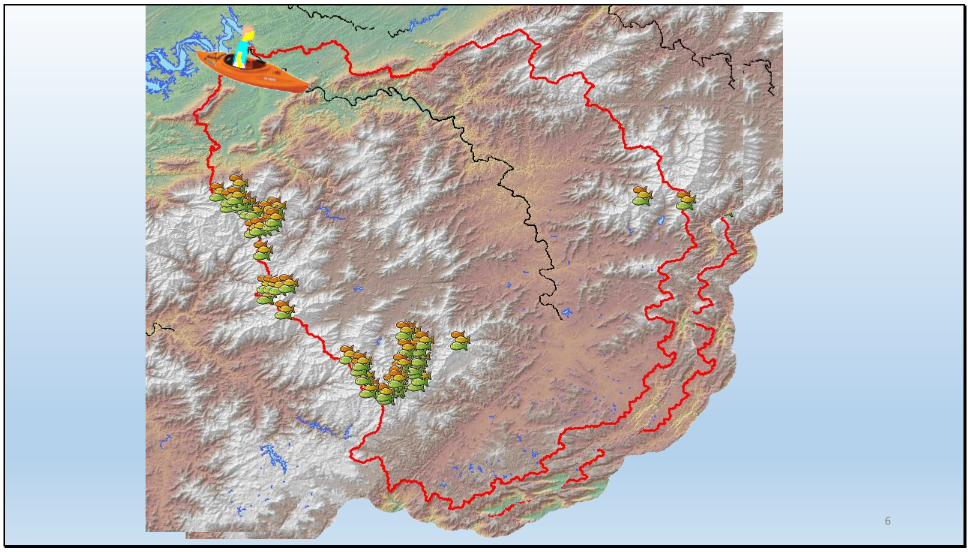
The Fish Group ID – this links us back to the Fish & Wildlife data

The NHDPlus Reachcode – which is the NHDPlus stable network identifier

The NHDPlus Flowline ComID – which is the NHDPlus ID that links all of the NHDPlus content together

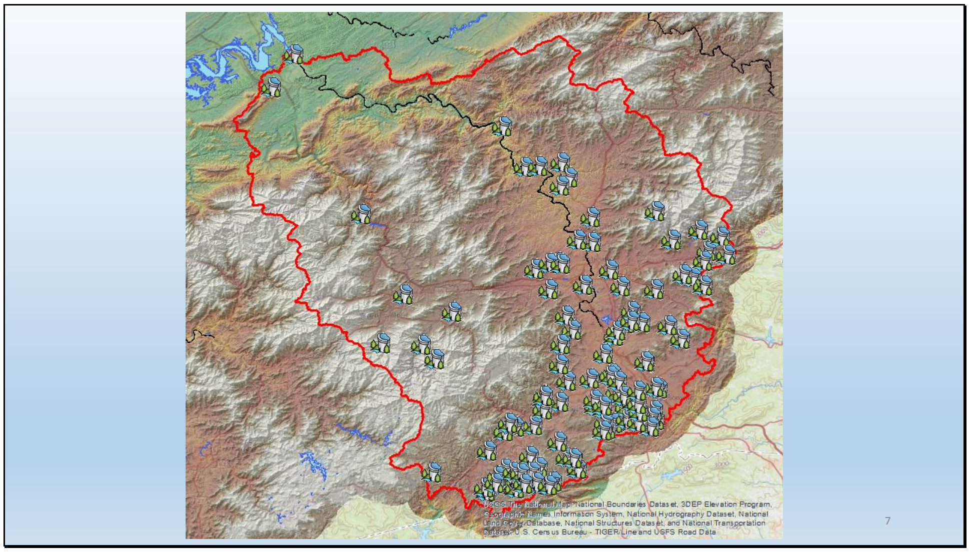
And finally, a Measure value that gives us the exact location of the fish along the flowline.

Slide 6



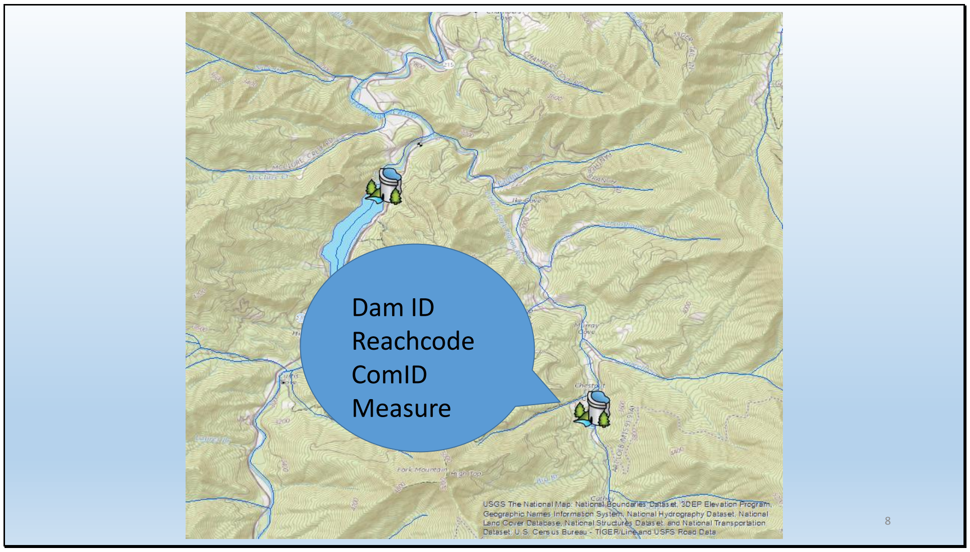
So we're going to use network navigation to find the paths from the fish to us. And we're going to compute how long these paths are so we can pick the shortest ones.

Slide 7



And while we're at it, we'll also identify the dams on those paths.   This picture shows the dams that have been linked to the NHDPlus network.

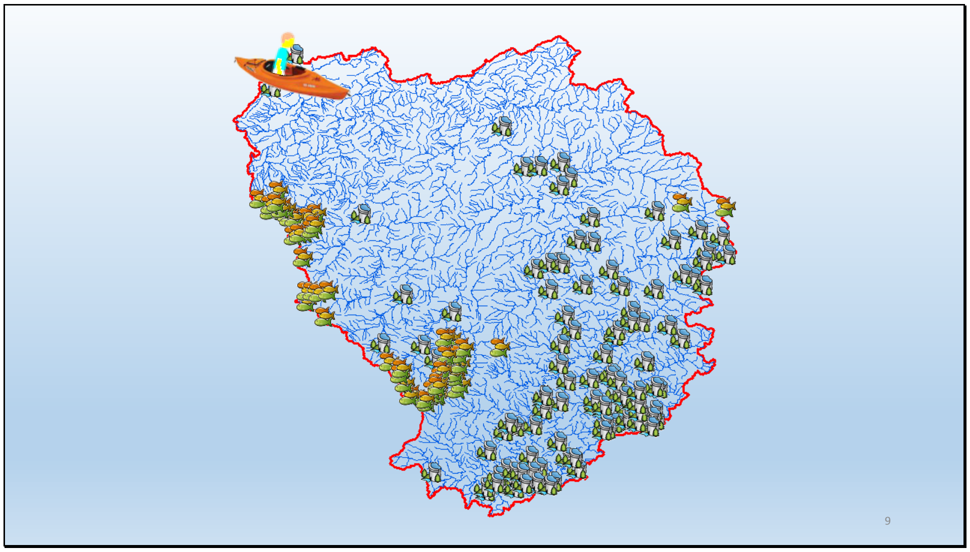
Slide 8



And just like the fish, at each dam location, we know:

The Dam ID which links us to a database of dams.
The NHDPlus Reachcode
The NHDPlus Flowline ComID
And finally, a Measure value that gives us the exact location of the dam along the flowline.

Slide 9

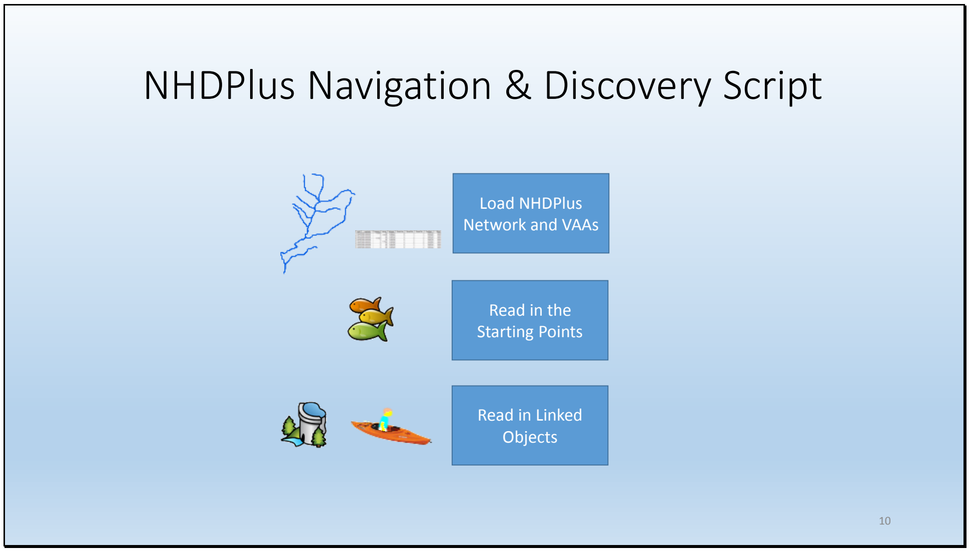


Here is our task. We’re going to start at each fish location and navigate downstream to where we are, discovering the dams along the way. And finally, we’ll compute the distance between each fish location and our location and we’ll count the dams.

You might ask why navigate downstream? The reason is efficiency. If we navigated upstream from where we are, we would follow many paths that don’t lead to the fish. But since every path leads downstream to us, starting with the fish locations and going downstream will give us all the paths we need to consider and nothing more.

There are 54 fish locations. That’s 54 navigations. Each of which has to be searched for the 122 dams. This is not a trivial exercise to perform by hand. Fortunately, there’s an APP for that.

Slide 10



During the past year, we've developed a general python script that can be the basis of this application. Not surprisingly, it's called the "Navigation and Discovery" python script. There is another NHDPlus tool called the VAA Navigator. The script calls the VAA Navigator and then performs the "discovery" using the navigation results.

So the first thing the script does is load data. It has to load up the NHDPlus network and the value added attributes.

Then it loads our starting points which are the fish locations.

Then it loads the objects linked to the network which are our dams and our location in the kayak.

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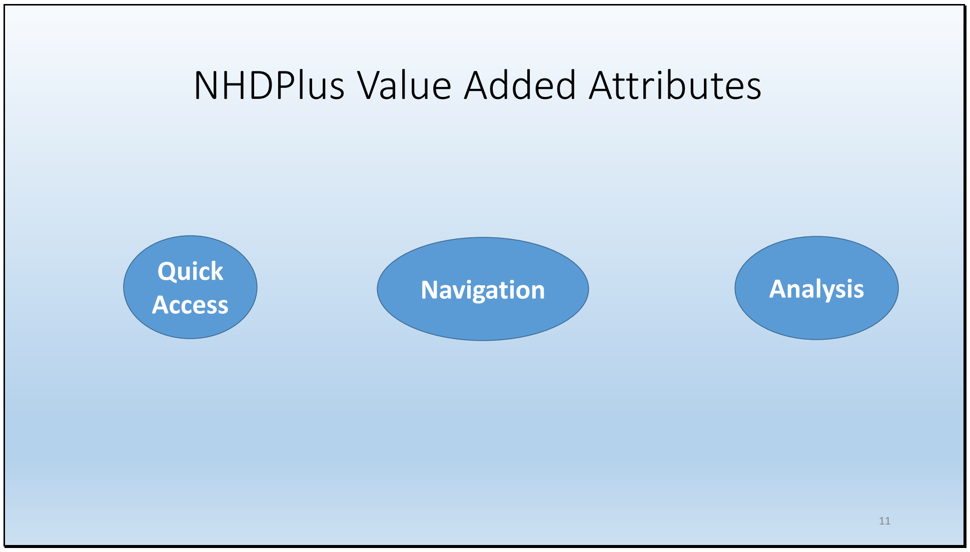

For those of you who are unfamiliar with or rusty on the NHDPlus Value Added Attributes, here is a very short course in VAAs. The VAAs are attributes that are automatically synthesized from the NHDPlus network, catchments and elevation. They are powerful pieces of information that support many application functions. They can be divided into three categories – quick access, navigation, and analysis.

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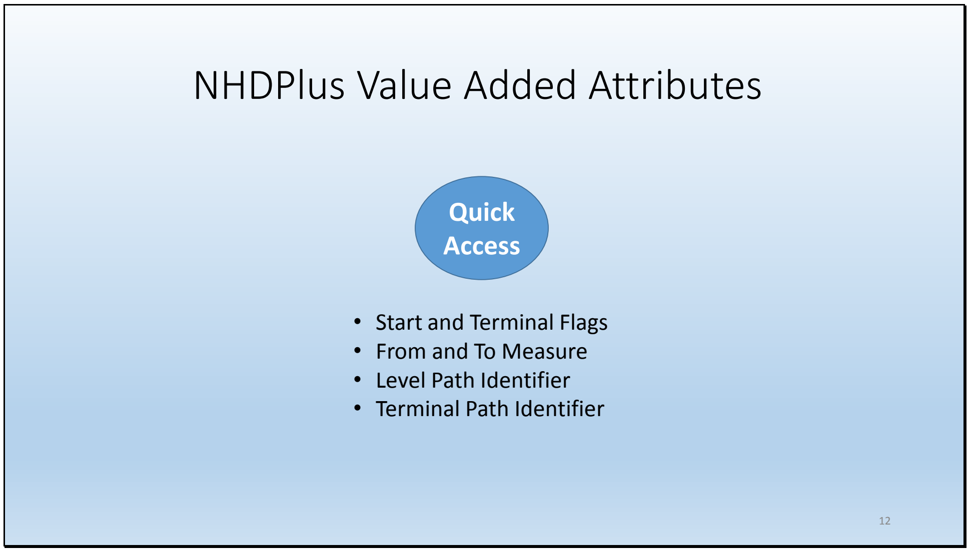


Some of the quick access attributes are:

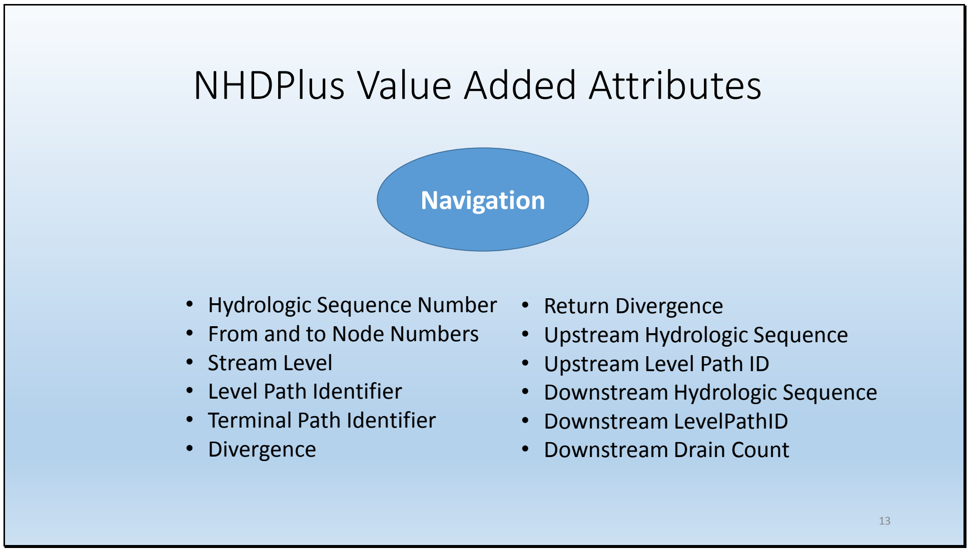
The start and terminal flags – these support the selection of the network tops and the network termini through simple queries.

The From and To Measures are the M-values from the NHD (x, y, z, m) coordinates. The m-values are difficult to see so we exposed them in NHDPlus.

Level Path Identifier supports the selection of an entire river course and also the selection of the most downstream flowline on the river with simple queries.

Terminal Path Identifier supports the selection of an entire drainage area and also the selection of the terminal drainage area flowline with simple queries.

Slide 13



We're focused on navigation today. In various combinations, the NHDPlus navigation attributes support a number of types of navigation.

Hydrologic sequence number supports network traversal either upstream or downstream by simply processing the flowlines in hydrologic sequence order.

The from and to node numbers support walking the network from one node to the next.

The remaining attributes are primarily designed for SQL Navigation Queries –

Stream level, Level Path Identifier support upstream mainstem navigation.
Terminal Path Identifier, Divergence, Return Divergence support downstream mainstem navigation.
The upstream and downstream attributes support all SQL navigations.

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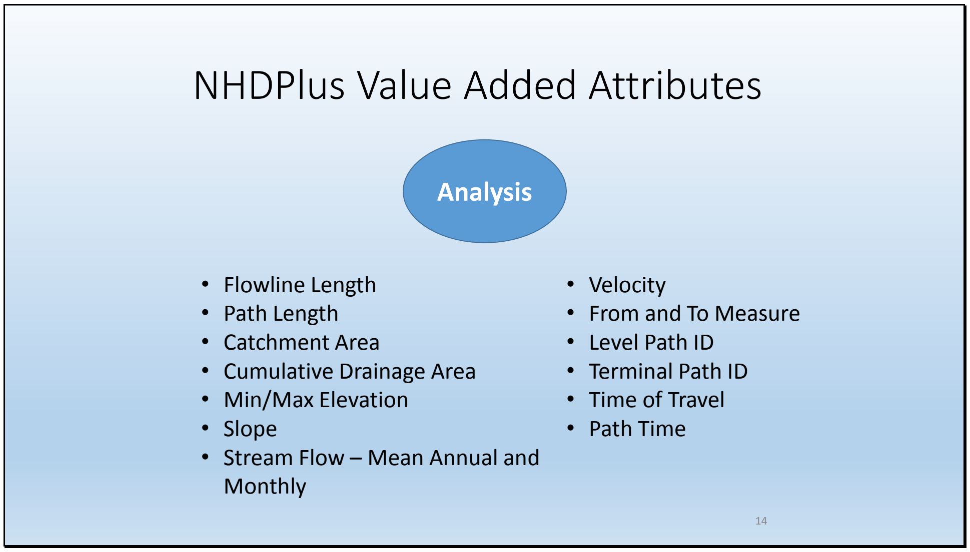


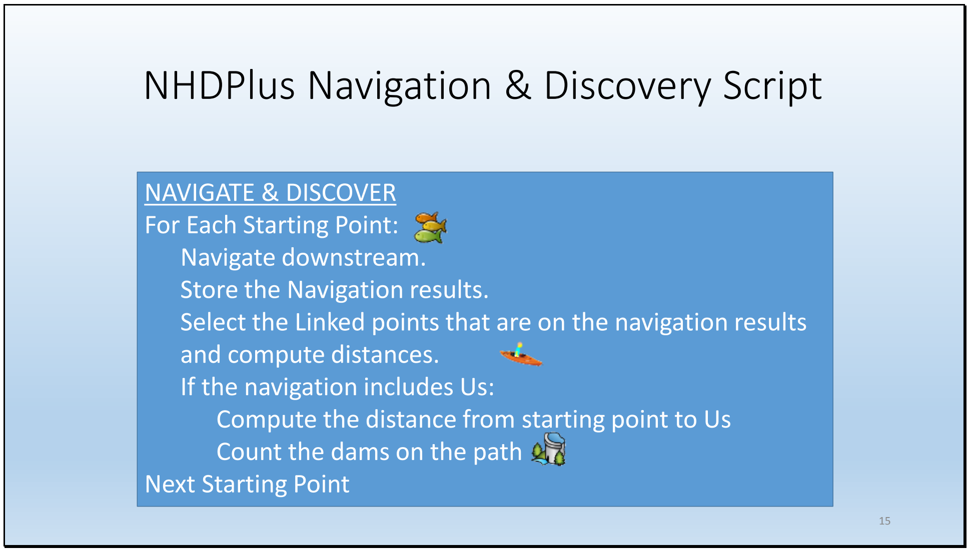
The analysis attributes are many and continue to grow. Here are just a few.

Flowline length is the length of the flowline.
Path length is the distance from where you are on the network to the terminous of the network.
Catchment area is the local drainage for a flowline
Cumulative Drainage Area is the total upstream drainage for the flowline.

Each flowline has Min/Max elevations and slope.
Stream flow statistics are computed for all flowlines gaged and ungaged.
Velocity computed from stream flow.
From and to measure support the tabular intersection of NHDPlus flowline events.
Time of Travel for the flowlines was recently released and is the time it takes water to traverse the flowline.
Path Time is the time it takes water to go from where you are on the network to the terminous of the network. This is due to be release later this spring.

This is all the time we have to talk about VAAs today. There are many other VAAs, lots of documentation, training videos, and slide presentations. It will be worth your time to really understand them.

Slide 15



After loading all the input data, the script loops through the starting points – those are our fish location. For each fish location, a downstream navigation is performed. The navigation results are stored in a table. The Linked points – these are the dams and our location – are joined to the navigation results.

Note: If the navigation didn't find us – which would only happen if the network ended at a terminal flowline such as a sink. If this happens, then the next fish location is navigated.

The navigation results and discoveries are formatted into an output file. For each dam found in the navigation, a record is written to the output file – it contains the fish identifier where the navigation started, the dam identifier and the distance between them. Finally, a record is written that contains the fish identifier, our identifier (which is “Kayak”), and the distance between the fish and us.

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POIID	LinkObjID	Distance
Fish-1	Dam-1053	81.37
Fish-1	Dam-1045	85.231
Fish-1	Dam-1116	54.485
Fish-1	Dam-1015	6.941
Fish-1	Kayak	163.761
Fish-2	Kayak	126.97
Fish-2	Dam-1053	44.579
Fish-2	Dam-1045	48.44
Fish-2	Dam-1054	37.165
Fish-3	Dam-1025	4.119
Fish-3	Dam-1074	50.633
Fish-3	Dam-1120	19.537
Fish-3	Kayak	112.221
Fish-4	Dam-1074	38.822
Fish-4	Kayak	100.41

This is what the consolidated output table looks like. It contains a row for each navigation starting point and discovered linked object combination along with the distance between them in kilometers.

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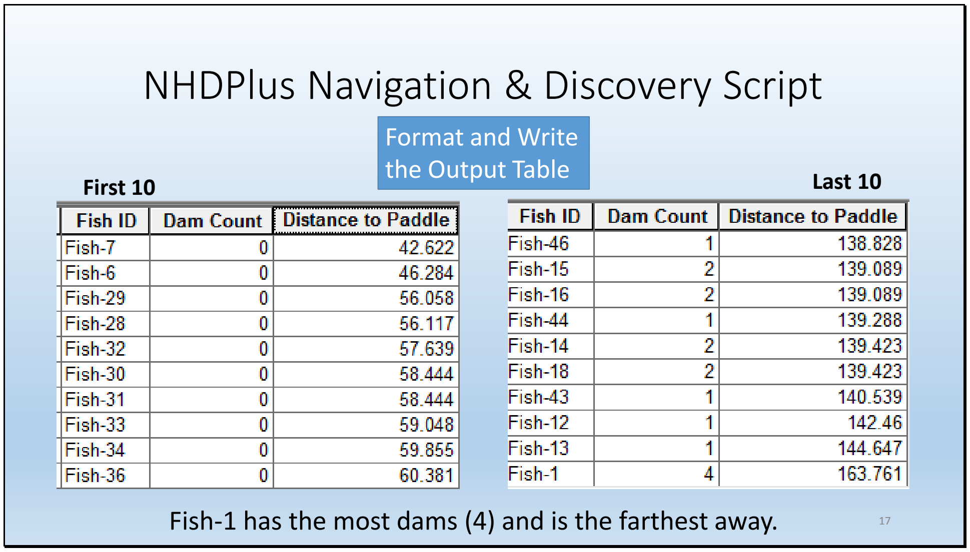
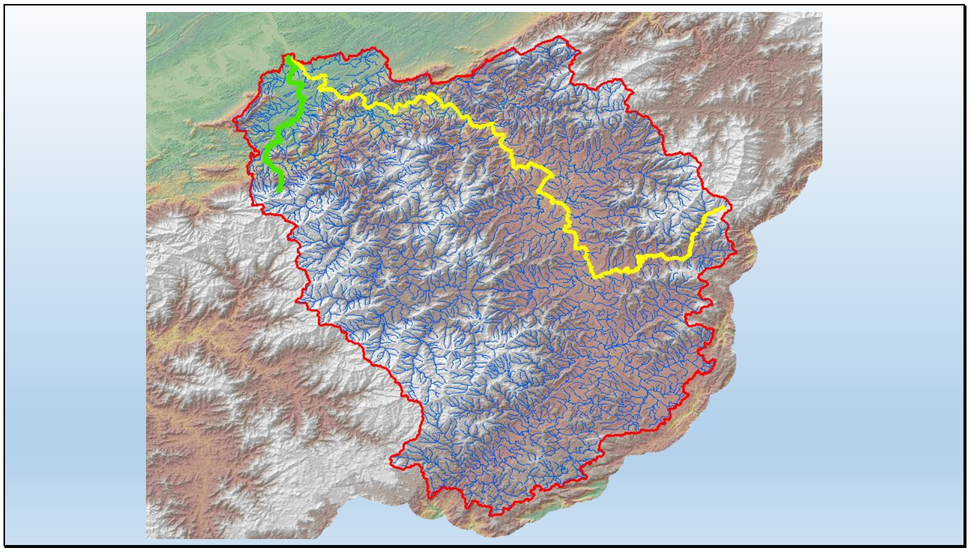


Fish ID	Dam Count	Distance to Paddle
Fish-7	0	42.622
Fish-6	0	46.284
Fish-29	0	56.058
Fish-28	0	56.117
Fish-32	0	57.639
Fish-30	0	58.444
Fish-31	0	58.444
Fish-33	0	59.048
Fish-34	0	59.855
Fish-36	0	60.381

Fish ID	Dam Count	Distance to Paddle
Fish-46	1	138.828
Fish-15	2	139.089
Fish-16	2	139.089
Fish-44	1	139.288
Fish-14	2	139.423
Fish-18	2	139.423
Fish-43	1	140.539
Fish-12	1	142.46
Fish-13	1	144.647
Fish-1	4	163.761

To get the answers that we want, we process the output table and produce a report that looks like this, sorted ascending on the “Distance to Paddle” column. On the left, are the closest 10 fish locations and on the right are the 10 that are farthest away.

This step is usually unique to each application. It does require adding Python coding to the script or, as in this case, it could be done in ArcMap by manipulating the script's output table.



Let’s look at a map of what we now know. The yellow path is the worst – it’s Fish group 1 which is 164 km away and encounters 4 dams. The green path is the best – it’s Fish group 7 which is 43 km away and encounters no dams.

So we paddle up to fish group 7 and after wandering around we see no signs of bears. We want to investigate another path. It would be nice to avoid going back to the place we started from. Fortunately, the Navigation and

Discovery script has given us all the navigation paths. And we can use that information.

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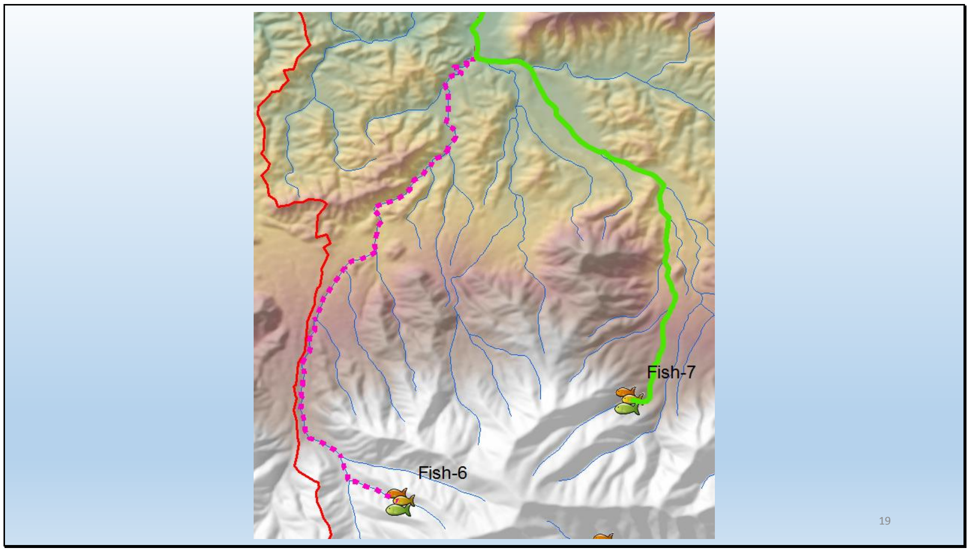

By joining the paths, we can discover the purple path. And it can be explored by paddling 7 km downstream on the green path and then upstream 10 km on the purple path. This will transport us from Fish group 7 to Fish group 6.

Once you have the results from the script, there are many things that can be done with the output data. We've only just touched the surface.

Slide 20

NHDPlus Navigation & Discovery Script Tested Operating Environment

- Windows 7
- MS SQL Server 2012 Localdb
- ArcGIS 10.5.1
- NHDPlus VAA Navigator
- Python 32 bit
- Win32Com.Client
- PythonWin or ArcGIS Python Window

  and
- NHDPlus Data

Slide 21

NHDPlus Navigation & Discovery Script

Conclusion:

- As its name implies, the Navigation and Discovery script does the heavy lifting of these two functions and can be used as a foundation for many applications.
- The script is incredibly well documented – of the 248 lines, 107 lines are comments.
- The VAA navigator is used because it performs navigation with NHDPlus VAAs using complex SQL logic to make the navigations very quick. It performs upstream mainstem, upstream with tribs, downstream mainstem or downstream with divergences. The navigation type/direction can be specified on a single line of the script.
- NHDPlus Time of Travel was released in 2017 and PathTime is about to be released. The script will be updated to compute travel time in addition to distance.

Slide 22

This is the end of our story. And, by the way, we did find the bears.

Photography: Mother Nature Network, Daniel Dietrick