GRAIP_Lite and Slope Stability: Nation-wide Model Runs for Watershed Condition Classification Assessments – General Methods and Processing Steps

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Input Data

USGS NED 1 arc-second DEM tiles were downloaded between January 30, 2020, and January 31, 2020. These tiles were extracted from the .zip files, assembled to run extents using ArcToolbox – Data Management Tools – Raster – Raster Dataset – Mosaic To New Raster, projected to NAD83, UTM coordinates selected for each run using ArcToolbox – Data Management Tools – Projections and Transformations – Raster – Project Raster (cell size rounded to nearest integer and resampling technique set to cubic), and then clipped to the run area (the HUC boundaries generalized and buffered by 500m) using ArcToolbox – Spatial Analyst – Extraction – Extract by Mask. The final DEM rasters were saved to ArcGrid format for use with GRAIP_Lite and then exported to GeoTiff format for slope stability calculations.

The source road layer was downloaded from an internal FS GeoDatabase Miscellanous_Data.gdb in April 2020; the RoadCore_Existing layer was chosen as it appears to be the most complete layer available. This layer was projected to NAD83 UTM coordinates for each run and then clipped using ArcToolbox – Analysis Tools – Extract – Clip to the HUC boundaries for the model run. See the Source information in the feature class metadata for Source Metadata.

The WBD_HUC12 layer was downloaded from an internal FS GeoDatabase EDW_MapServiceDataStatic.gdb at the same time the source road layer was downloaded. This layer provided the source for defining the model run areas and initially reporting the various results. See the Source information in the feature class metadata for Source Metadata.

The WCATT HUC12 layer was downloaded from an internal FS GeoDatabase S_USA.WCATT_WBD.gdb\S_USA.WCATT_HU12. See the Source information in the feature class metadata for Source Metadata.

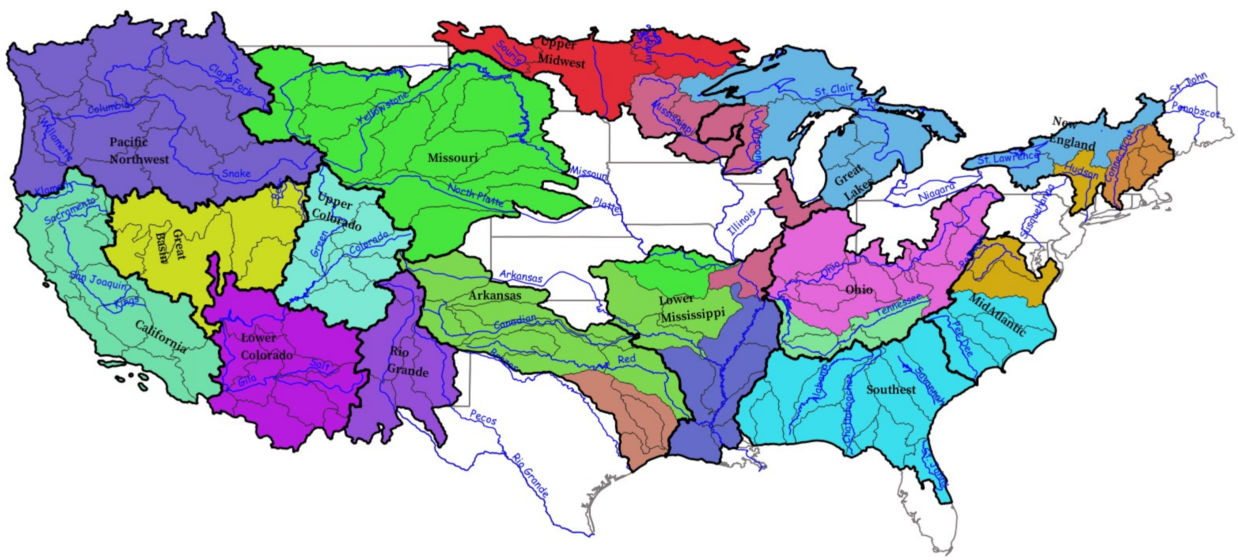
Model Run Calibration

These model runs used a modified version of the Default GRAIP_Lite calibration data. The baserate used for these model runs was set equal to 1 kg/yr/m of elevation change. This unit baserate was selected because, while we have baserate data for a number of locations, we do not have this information across the whole country. We do have data that shows that this baserate has the potential to vary widely depending on soil types and climatic conditions. Using a unit baserate effectively removes this variability and allows comparisons of effective road design factors (position on the landscape relative to drainage features, road slopes and surfacing, and the effective maintenance frequency and traffic volumes) across wide areas without the complicating factors of soil and climatic variability.

The rest of the Default GRAIP_Lite calibration was left as is, which means that vegetation factors for surface type and maintenance level combination and the delivery curves are based on this large set of data.

Model Run Area Selection

Each model run was selected such that, to the extent possible, one model run did not contribute to a downstream model run; the primary exceptions are some runs within the upstream contributing area of the Lower Mississippi River run (the Upper Missouri River, Upper Midwest, and Ohio being the principle examples). One other criterion was that each model run needed to be small enough that ArcPro could handle processing it on the supplied computer (HP 640G1, Class 2, upgraded to 16Gb RAM).



As you can see above, the model runs do not necessarily correspond to 1st-Code HUCs, but are generally based on the 1st-Code HUCs; black lines show the run boundaries while different 1st-Code HUCs are shown by different colors.

Model Setup and Methods

Model runs were set up in their own folders, with the model inputs for each run stored within those folders. Input roads and HUCs were stored in the InputRoads.gdb within each model run folder. The DEM was named based on the model run and the UTM coordinate space and stored in the Layers folder within each model run folder. An ArcPro project was set up for each run using the model run folder.

I did make a couple of corrections to the data prior to splitting up the national road layer into separate runs. First, I set the Operational Maintenance Level to ML5 for State and US Highways that did not have that attribute set. The selection parameters for this was (SYSTEM = 'I - INTERSTATE HIGHWAY' OR SYSTEM = 'SH - STATE HIGHWAY' OR SYSTEM = 'US - US HIGHWAY OR ROUTE') AND (SURFACE_TYPE = 'AC - ASPHALT' OR SURFACE_TYPE = 'P - PAVED' OR SURFACE_TYPE = 'PCC - PORTLAND CEMENT CONCRETE') AND OPER_MAINT IS NULL.

I also set invalid values for OPER_MAINT_LEVEL to NULL; examples of invalid values include NA – NOT APPLICABLE and D – DECOMMISSIONED. This forces the model to set these to 2 – HIGH CLEARANCE VEHICLES.

Once the input data was set up and organized, the ArcPro version of GRAIP_Lite (v. 221) was used to process the model runs. The Basic Run tool was utilized in order to minimize the amount time involved with the model runs.

A couple of the runs required a couple tweaks to get them to run correctly. The Arkansas River run had six missing grid cells that intersected a gravel surfaced road; this was causing the model to crash, as it usually does if road extends beyond the *CalibrationZone* boundary. I deleted a segment of road approximately 90m in length to accommodate this. A similar issue occurred with the Alaska run where roads crossed sea level grid cells, which GRAIP_Lite considered to be NO DATA cells; the original run is Alaska and the run with some problematic roads removed is Alaska2.

The Great Basin is a closed basin, and the difference between the original DEM and the pit-filled DEM was over 700m in places, with some Forest Service road covered by nearly 200m of "pit filling". In order to get around this, I used the Processing tools and, for the DEM Processing tool, I made direct copy of the original DEM, named this *Fil* (what the ArcHydro tools call the pit-filled DEM), and then used the ArcHydro tools instead of GRAIP_Lite's DEM Processing tool. This appears to have accounted for the large closed basins and produced a more believable result. An original run is in the GB project folder and the "fixed" run is in GB2. This modified run required using the tools in GRAIP_Lite's Processing Toolbox with the individual ArcHydro DEM processing tools replacing GRAIP_Lite's DEM Processing step.

Since we were going to be aggregating the results at the HUC12 level, we initially tried using the HUC12 field as a join feature, but that caused problems with R and ArcGIS interpreting that text field as numeric because it only contained numbers. Any HUC12 code that began with "0" would have the "0" dropped off, which meant that joining data this way was unreliable even when using a schema.ini file (ArcGIS would drop the "0" and then interpret the number as text). Instead, I created a dedicated field to use for the joins (and called it JoinField) by using the Field Calculator to insert "HUC12_" in front of each HUC12 identifier, thereby creating a unique field that could only be interpreted as text.

Once the join field was set up, the ArcToolbox – Analysis Tools – Overlay – Intersect tool was used to attach the HUC12 data to the GRAIP_Lite drainpoints (the RoadDrainPoint feature class). The attribute table for the resulting layer was exported to a text file, which was then read and aggregated using R. One complication was that any drainpoint that occurred on a HUC12 boundary resulted in additional records being created, effectively a copy of the drainpoint for each HUC12 that it intersected. Prior to aggregation, the attribute tables were processed in R to clean up such cases. Since the RID field is unique for each road segment and drainpoint in GRAIP_Lite, it was used to find these duplicates. Where more than one record had the same RID, the values were divided by the number of duplicates, effectively creating an even split between the multiple HUCs intersecting that drainpoint. Aggregations were performed for three different road populations: all roads, only Forest Service System Roads, and only open Forest Service System Roads. Summary tables from R were joined to the HUC data and then exported to the appropriate national geodatabase. Regional layers were then exported by selecting all HUCs that intersect the administrative boundaries of the forests within that region. WCF scores were set based on the criteria for road density and proximity/connection (all roads, FS roads, open FS roads). The GRAIP_Lite data is available in both SI and USC unit systems and either as a single national layer or in separate layers for each Forest Service region. Layers for Forest Service regions contain only those HUCs that intersect the Forest Service administrative boundaries for forests within that region.

Slope stability calculations used TauDEM 5.3.7, specifically the Dinf slope, flow direction, and contributing area functions. These processes and the resulting rasters provided the basis for the rest of the calculations that were performed in R. First, the slope needed to be changed from a fractional slope to radians, which was done using the atan function, and resulted in the demslprad raster. Next we calculate *w = min(demsca/(500*sin(demslprad)),1)*. Finally, we calculate *C_min = sin(demslprad) – cos(demslprrad)*(1-0.625*w)*. C_min is our index value for slope stability across the landscape.

The Road_Cmin raster was created using the ArcToolbox – Spatial Analyst Tools – Extraction – Extract by Mask tool to extract values from the C_min raster (demc_min) along the whole road network. Versions of the C_min raster were also created for just the Forest Service System Roads and the open Forest Service System Roads using the same method. This raster was then used to create a filter raster by reclassifying the data such that values <=0 were set to no data. Multiplying the road_Cmin raster by the filter results in a raster that only contains cells that contain values >0. This results in having six rasters per run in addition to the whole landscape raster.

Using ArcPro's ArcToolbox – Spatial Analyst Tools – Zonal – Zonal Stats as Table, we can then calculate the summary statistics from the raster for each HUC. This was done for each raster in each of the runs. Each set of tables (the landscape tables, the road cmin tables [for each road class, all roads, only FS roads, only open FS roads], and the filtered road cmin tables) was appended together to form a master table for the country. These tables were then joined to the WCATT HUCs to add that data to the WCATT HUC layer. Regional layers were then exported by selecting all HUCs that intersect the administrative boundaries of the forests within that region.

All data aggregation steps were completed using NAD83 Albers Equal Area projection, and reported areas (HUC12_sqkm, HUC12_sqmi, Admin_sqkm, Admin_sqmi, FS_Land_sqkm, and FS_Land_sqmi) were all calculated in that projection using the Calculate Geometry tool for those fields.

Relevant Links

GRAIP_Lite - Nation-wide Model Runs for Watershed Condition Classification Assessments

Watershed Condition Classification (WCC) Technical Guide

Watershed Condition Framework (WCF) Overview