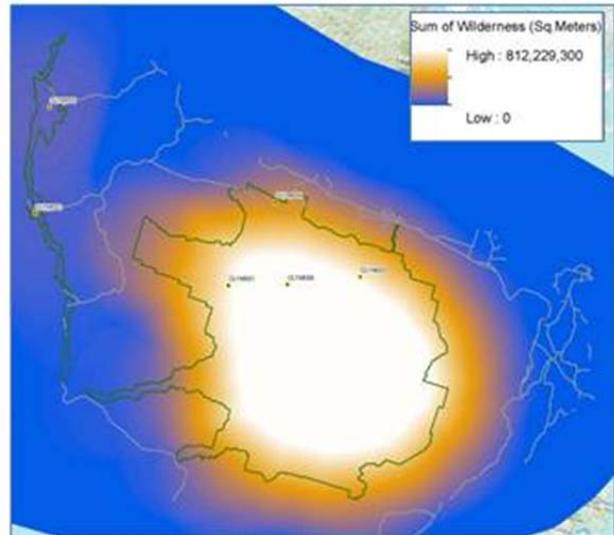
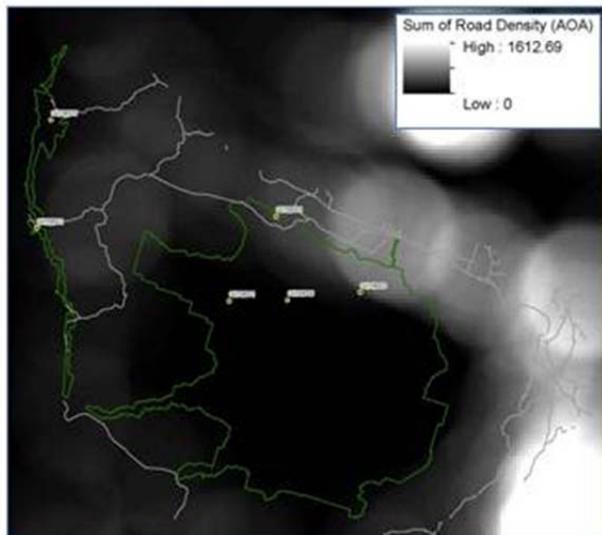
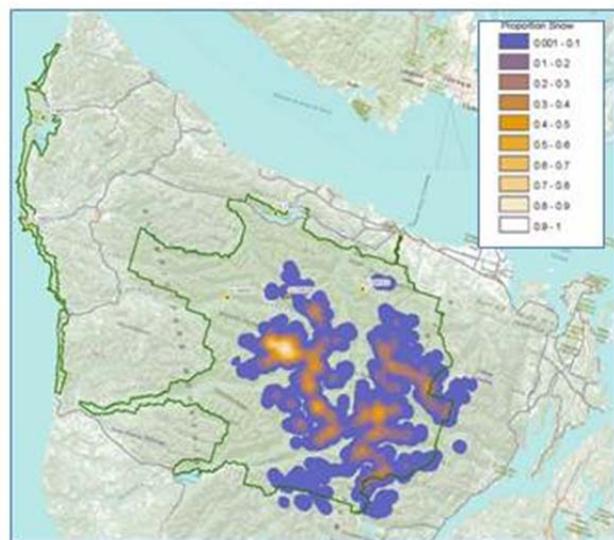
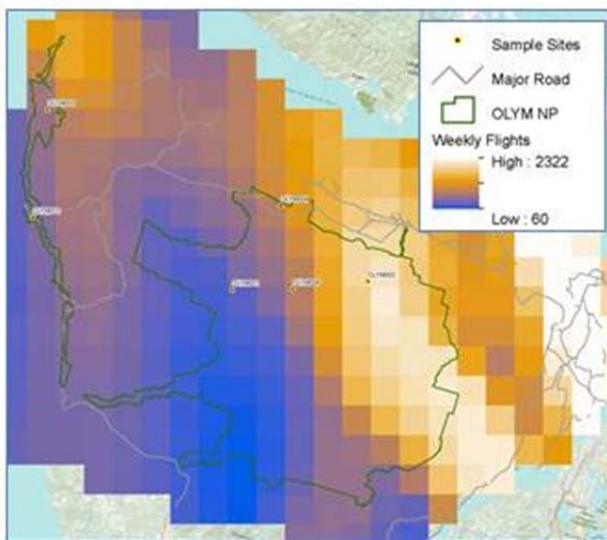




GIS Metrics - Soundscape Modeling

Standard Operating Procedure

Natural Resource Report NPS/NRSS/IMD/NRR—2012/596



ON THE COVER

Example explanatory variable products which were derived for each sounds modeling study site. In these four examples the explanatory variable products have been derived for Olympic Peninsula, Washington.

Upper Left - Sum of weekly flight observations (John A. Volpe National Transportation Systems Center 2010) at a 10 mile Area of Analysis (AOA) extent (FlightFreq10).

Upper Right - Proportion of snow land cover (NLCD - 2006) at a 1 mile AOA extent (Snow1).

Lower Left - Sum of road density (km/km^2) for major roads, ESRI roads database - NPS NPScape roads, at a 10 mile AOA extent (RddMajor10).

Lower Right - Sum of designated wilderness (m^2) (Wilderness.net 2011) at a 10 mile AOA extent (Wilderness).

GIS Metrics - Soundscape Modeling

Standard Operating Procedure

Natural Resource Report NPS/NRSS/IMD/NRR—2012/596

Kirk R. Sherrill

National Park Service
1201 Oakridge Dr.
Fort Collins, CO 80525

December 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm>).

Please cite this publication as:

Sherrill, K. R. 2012. GIS metrics - soundscape modeling: Standard operating procedure. Natural Resource Report NPS/NRSS/IMD/NRR—2012/596. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vi
1. Introduction.....	1
2. Data Acquisition.....	2
3. Data Processing.....	5
3.1 Land Cover.....	5
3.1.1 Scripts & Variables.....	6
3.2 Elevation.....	6
3.2.1 Scripts & Variables.....	7
3.3 Climatological Data.....	8
3.3.1 Script & Variables.....	9
3.4 Distance to Roads.....	9
3.4.1 Scripts & Variables.....	10
3.5 Road Density.....	11
3.5.1 Scripts & Variables.....	12
3.6 Naturalness Index.....	13
3.6.1 Scripts & Variables.....	13
3.7 Flight Frequency.....	14
3.7.1 Scripts & Variables.....	15
3.8 Military Flight Paths.....	16
3.8.1 Scripts & Variables.....	16
3.9 Slope.....	17
3.9.1 Scripts & Variables.....	18

Contents (continued)

	Page
3.10 Topographic Position Index.....	18
3.10.1 Scripts & Variables	19
3.11 Distance NHD Coastline.....	20
3.11.1 Scripts & Variables	20
3.12 Distance to Streams by Stream Order.....	21
3.12.1 Scripts & Variables	22
3.13 Distance NHD Waterbody.....	23
3.13.1 Scripts & Variables	24
3.14 Stream Slope.....	25
3.14.1 Scripts & Variables	26
3.15 Wilderness	26
3.15.1 Scripts & Variables	27
3.15 Wind Power	28
3.15.1 Scripts & Variables	28
3.16 Distance to Railroads.....	28
3.17 Distance to Airports.....	29
3.17.1 Scripts & Variables	30
4.Sounds Modeling GIS Database	31
5. Citations	32
6. Python Scripts.....	34

Figures

	Page
Figure 1. Study sites where sounds data were collected and used for training of soundscape models.....	3
Figure 2. Flow chart of processing steps for the land cover variable.	6
Figure 3. Flow chart of Elevation processing steps and associated scripts and outputs.....	7
Figure 4. Flow chart of climatic data processing steps and associated scripts and outputs.....	9
Figure 5. Flow chart of distance to roads data processing steps and associated scripts and outputs.....	10
Figure 6. Flow chart of road density data processing steps and associated scripts and outputs.....	12
Figure 7. Flow chart of road density data processing steps and associated scripts and outputs.....	13
Figure 8. Flow chart of flight frequency data processing steps and associated scripts and outputs.....	15
Figure 9. Flow chart of military flight paths data processing steps and associated scripts and outputs.....	16
Figure 10. Flow chart for slope data processing steps and associated scripts and outputs.....	18
Figure 11. Flow chart for the topographic position index processing steps and associated scripts and outputs.	19
Figure 12. Flow chart for distance to NHD coastline processing steps and associated scripts and outputs.....	20
Figure 13. Flow chart for distance to streams by stream order processing steps and associated scripts and outputs.	22
Figure 14. Flow chart for distance to NHD waterbody processing steps and associated scripts and outputs.	24
Figure 15. Flow chart for stream slope processing steps and associated scripts and outputs.....	26

Figures (continued)

	Page
Figure 16. Flow chart for the Wilderness processing steps and associated scripts and outputs.....	27
Figure 17. Flow chart for Wind Power Class processing steps and associated scripts and outputs.....	28
Figure 18. Flow chart for Distance to Railroads processing steps and outputs.	29
Figure 19. Flow chart for Distance to Airports processing steps and associated scripts and outputs.....	30
Figure 20. Example of the output Sounds Modeling GIS database, and the compiled explanatory variable table (CONUS_Explanatory).	31

Tables

	Page
Table 1. Explanatory variables and data sources.	2
Table 2. Explanatory variable statistics, values and the AOA scale.	4

1. Introduction

This SOP documents the process that was followed to create GIS based metrics, which have been selected as potential explanatory variable for soundscape modeling efforts. These explanatory metrics attempt to measure the complex biological, geophysical and anthropogenic sources and interactions which constitute a soundscape (Pijanowski et al. 2011-1, Mennitt et. al. In prep) across national parks and their surrounding landscapes. More specifically, the derived metrics from the Soundscape Modeling Geospatial Database (SMGB) have been used as training data in random forest (Breiman, L. 2001) soundscape models. Modeling efforts have been performed by the Natural Sounds Night Skies division of the Natural Resource Stewardship and Science (NRSS) directorate of the NPS. Using the GIS metrics that were identified as significant in the training models, predictive ambient sound pressure soundscape models have been created at park units and surrounding NPS landscapes (Mennitt et. al. In prep).

In brief, this SOP provides specific information about data sources, the Python scripts utilized, and how metrics were calculated for subsequent compilation in the SMGD. In addition to documentation of workflow steps, this SOP is intended to facilitate efficient calculation of explanatory variables for sites where ongoing soundscape monitoring data are being collected.

2. Data Acquisition

The emerging field of soundscape ecology draws upon many principles from the field of landscape ecology (Pijanowski et. al. 2011-2). Of particular relevance to this study is the understanding that landscapes are defined by multi-scaled spatial and temporal relationships between patterns and ecological processes (Urban et. al. 1987, and Turner 1989). A soundscape is loosely defined as “the collection of biological, geophysical and anthropogenic sounds that emanate from a landscape and which vary over space and time” (Pijanowski et. al. 2011-1). Three terms in particular are important to define: *biophony*, the cumulative of sounds created by living organisms; *geophony*, which describes all abiotic related sounds, and *anthrophony*, the sum of sounds created by humans (Pijanowski et al. 2011-1).

With this in mind, GIS metric development was performed with an understanding that pattern influences process (sounds within a landscape) and that soundscapes result from multi-scaled biogeophysical and anthropogenic interactions. Thus GIS metrics were selected to attempt and measure patterns in biogeophysical and anthropogenic elements that have known and unknown mechanistic relationships with soundscapes.

Explanatory variables were derived from 18 data sources as defined in Table 1 for each of the 262 sounds modeling study sites (Figure 1), which were distributed across the contiguous US. In efforts to account for multi-scale soundscape drivers, for each study site GIS metrics were derived at one of six areas of analysis (AOA) scales. AOA scales were calculated at circular radius of 1, 10, 25 miles, 200, and 5,000 meters, or as point extractions as defined in (Table 2).

Table 1. Explanatory variables and data sources.

Explanatory Variable	Source Data (scale/resolution)
Land Cover	National Land cover Data (NLCD) 2006 (30 m)
Elevation	National Elevation Dataset (NED), Digital Elevation Models (DEM) (10 m)
Climatic Data (Precip, Temp)	PRISM Climate Group - Precipitation and Temperature (4 km)
Distance to Roads	ESRI Streetmap roads (2010), NPScape roads measure (2010)
Road Density	NPScape roads measure (2010) (1 km)
Naturalness	Naturalness Index (Theobald 2010) (270 m)
Flight Frequency	Weekly flight observations (John A. Volpe National Transportation Systems Center) (7 km)
Military Flight Paths	Sum of designated military flight paths and distance to military flight path
Slope	Slope (Degrees) - derived from NED DEM (10 m)
Topographic Position Index	Topographic Position Index (Theobald 2009) - derived from NED DEM (10 m)
Distance NHD Coastline	National Hydrography Dataset, NPS Hydrographic Impairment Data (1:24,000)
Distance NHD WaterBody	National Hydrography Dataset, NPS Hydrographic Impairment Data (1:24,000)
Distance Stream by Stream Order	National Hydrography Dataset Plus - Version 1. Strahler Calculator stream order (Pierson et. al. 2008) (1:100,000)
Stream Slope	National Hydrography Dataset & National Elevation Dataset (1:24,000 & 10 m)
Wilderness	Designated Wilderness (Wilderness.net 2011)

Table 1. continued

Wind Power	Wind Power categorical potential densities at a height of 50 meters (W/m^2) state level high resolution wind products (NREL 2012)
Distance Railroads	National Atlas major railroads 2012 GIS data (1:1,000,000)
Distance Airports	Public use airport data for the continental US - 2012 National Transportation Atlas

Figure 1. Study sites where sounds data were collected and used for training of soundscape models.



Table 2. Explanatory variable statistics, values and the AOA scale.

Explanatory Variable	Statistics	Area of Analysis (AOA)
Land Cover	Proportional land cover NLCD Level I (Developed, Barren, Forest, Shrubland, Herbaceous, Cultivated, Wetlands, Water) & Level II (Deciduous, Coniferous and Mixed Forest and WaterOnly and Snow)	0.2 & 5 km and 1 & 10 mile radius
Elevation	Elevation (m)	Point
Climatic Data	Average Yearly, Summer (Jun, Jul, Aug) and Winter (Dec, Jan, Feb): Precipitation (mm * 100), Max & Min Temperature (Deg C * 100), Average Dew point (Deg C * 100)	Point
Distance to Roads	Distance to roads (m), if greater than 10 miles = 9,999	Point - 10 mile radius
Road Density	Sum of road density: all roads, major roads and weighted roads (km/km ²)	0.2 & 5 km and 1 & 10 mile radius
Naturalness Index	Max, Mean, Min, Range, Std. Dev., & Range	Point, 5 km and 1 & 10 mile radius
Flight Frequency	Sum of weekly flight observations	10 mile, 25 km, & 25 mile radius
Military Flight Paths	Sum of designated military flight paths	25 mile radius
Slope	Slope (Degrees)	Point
Topographic Position Index	Ridge (1), Upper Slope (2), Middle Slope(3), Flat(4), Lower Slope(5), Valleys(6)	Point
Distance NHD Coastline	Distance to (NHD) CoastLine (m), if greater than 10 miles = 9,999	Point - 10 mile radius
Distance NHD WaterBody	Distance to (NHD) WaterBody (m), if greater than 10 miles = 9,999	Point - 10 mile radius
Distance Streams by Stream Order	Distance to NHD Plus flowline with a Strahler Calculator stream order greater than 1, 3, & 4.	Point - 10 mile radius
Stream Slope	Max, Mean, Min, Range, Std. Dev., & Range (Degrees)	10 mile radius
Wilderness	Sum of designated Wilderness (m ²)	10 mile radius
Wind Power	Wind Power categorical potential	Point
Distance Railroads	Distance to railroads (m)	Point
Distance Airports	Distance to airports by enplanement and airport type (m)	Point

3. Data Processing

3.1 Land Cover

Data from the National Land Cover Database (NLCD) 2006 was clipped to the extent of the 1 and 10 mile AOA scales for each study site. At each AOA scale per study site the proportion cover by NLCD level I (Anderson Land Cover) class (and level II – Snow / Water / Deciduous / Evergreen / Mixed) was derived. Land cover, which is usually readily available, has traditionally been used as a best available designator of homogenous acoustic zones for NPS soundscape monitoring efforts (Miller 2008). With the rationale being that geophony and biophony sources broadly exhibit a consistent level of ambient noise level by land cover types.

Land cover variables were processed at 0.2 & 5 km, and 1 & 5 mile AOA extents.

Barren 1Mile/10Mile/200m/5000m - Proportion of AOA barren land - 1 & 10 mile and 0.2 & 5 km AOA.

Cultivated 1Mile/10Mile/200m/5000m - Proportion of AOA cultivated - 1 & 10 mile and 0.2 & 5 km AOA.

Developed 1Mile/10Mile/200m/5000m - Proportion of AOA developed land - 1 & 10 mile and 0.2 & 5 km AOA.

Forest 1Mile/10Mile/200m/5000m - Proportion of AOA forest land cover - 1 & 10 mile and 0.2 & 5 km AOA.

Deciduous 1Mile/10Mile/200m/5000m - Proportion of AOA deciduous forest land cover - 1 & 10 mile and 0.2 & 5 km AOA.

Evergreen 1Mile/10Mile/200m/5000m - Proportion of AOA evergreen forest land cover - 1 & 10 mile and 0.2 & 5 km AOA.

Mixed 1Mile/10Mile/200m/5000m - Proportion of AOA mixed forest land cover - 1 & 10 mile and 0.2 & 5 km AOA.

Herbaceous 1Mile/10Mile/200m/5000m - Proportion of AOA herbaceous land cover - 1 & 10 mile and 0.2 & 5 km AOA.

Shrubland 1Mile/10Mile/200m/5000m - Proportion of AOA shrubland land cover - 1 & 10 mile and 0.2 & 5 km AOA.

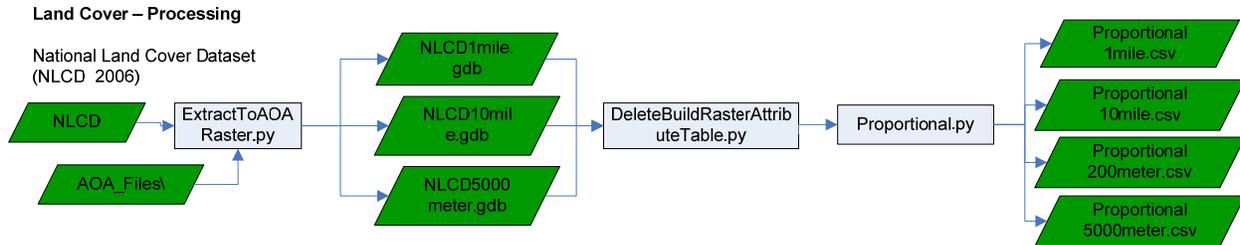
Snow 1Mile/10Mile/200m/5000m - Proportion of AOA snow land cover - 1 & 10 mile and 0.2 & 5 km AOA.

Wetlands 1Mile/10Mile/200m/5000m - Proportion of AOA wetlands land - 1 & 10 mile and 0.2 & 5 km AOA.

WaterOnly 1Mile/10Mile/200m/5000m - Proportion of AOA water land cover - 1 & 10 mile and 0.2 & 5 km AOA.

The land cover measures work flow and associated python scripts, data inputs and outputs are outlined in Figure 2.

Figure 2. Flow chart of processing steps for the land cover variable.



3.1.1 Scripts & Variables

ExtractToAOARaster.py – Extracts input NLCD data to the desired AOA.

- inputWorkspace – workspace with rasters to be extracted (NLCD).
- aoaFile - geodatabase (ArcGIS 10) with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outGdb - output Geodatabase workspace (NLCD1mile.gdb & NLCD10mile.gdb)
- prefix - Prefix name applied to each clipped output (e.g. Land cover).
- snapRaster - raster to snap derived output.
- parkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” - unique study site name. Field “SiteID_Park” - unique study site name and associated park.

DeleteBuildRasterAttributeTable.py - Deletes the existing attribute table and builds a new attribute table.

- Inputworkspace - geodatabase with clipped NLCD data (NLCD1mile.gdb & NLCD10mile.gdb).

Proportional.py - For NLCD (2006) level I land cover data returns the proportion within the defined AOA.

- file - geodatabase with clipped NLCD data (NLCD1mile.gdb & NLCD10mile.gdb).
- outTable - Name of final exported table with summary statistics per AOA (Proportional1mile, Proportional10mile, Proportional200meter, Proportional 5000meter).

3.2 Elevation

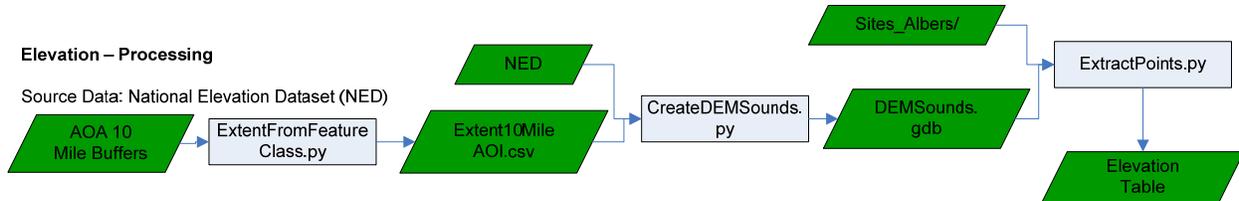
National elevation data (NED 30m) was tiled together and clipped to the extent of the 10 mile AOA scale for each study site. Being a general measure of the physical environment, elevation is commonly associated with broad landscape patterns associated with various geophysical elements including precipitation patterns. For example the abiotic relationship of decreasing temperature with increasing elevation. In the scope of Soundscape modeling, precipitation and

temperature relationships, as measured via the elevation proxy, can have pronounced effects on biophony, geophony and anthrophony sound sources.

ELEV - Elevation (point - meters).

The elevation work flow and associated python scripts, data inputs and outputs are outlined in Figure 3.

Figure 3. Flow chart of Elevation processing steps and associated scripts and outputs.



3.2.1 Scripts & Variables

ExtractFromFeatureClass.py - For each feature in the defined feature class the bounding box extent will be exported to a .csv file.

- file – feature class or workspace with the AOA per study site.
- fileType – switch defining if the “file” variable contains one or multiple feature class files (“Single” | “Multiple”).

CreateDEMSounds.py - For each AOA extent as defined by the output extent .csv file, the script uncompresses, mosaics and clips digital elevation model (DEM) data. This script processes DEM data which has been obtained from the USGS which is packaged in 1 degree compressed .adf raster files across the contiguous US.

- Workspace - output workspace for mosaicked DEMs (DEMSounds.gdb).
- extentList - file (.csv) with the bounding box extent per AOA (Output from ExtractFromFeatureClass.py script).
- RawDEM - root workspace with raw zip DEM data.
- aoa - Location holding the AOA data in the desired output projection.
- aoaSuffix - out DEM suffix (e.g.1 km).
- clip - Switch defining if a DEM will be clipped to a specific feature class boundary (“Yes” | “No”).
- projDem - DEM defining the desired output projection (e.g. Albers) typically will match the projection of the AOA data.
- projGCS - Raster dataset with a GCS/NAD 83 projection, is used to define initial DEM projection prior to reprojecting.
- ziptool – path to the 7zip executable, which is called in the script to unzip the compressed files.

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- **pointWorkspace** - workspace with point files per study site.
- **rasterWorkspace** - workspace/geodatabase with DEM rasters to be extracted (DEMSounds).
- **outGdb** - workspace/geodatabase to house output table (DEMSounds.gdb).
- **siteList** - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" – unique study site name. Field "SiteID_Park" - unique study site name and associated park.
- **outTable** – Name of final exported table with raster point values per study site (Elevation).
- **fieldname** – Name of output field in the extracted output table (e.g. ELEV).

3.3 Climatological Data

Climatological data was obtained from the PRISM Climatic Group. PRISM (Parameter-elevation Regressions on Independent Slopes Model) climatic data comes from the PRISM Climate Group at Oregon State University. Using point-based observational data, PRISM data is modeled using the PRISM climate mapping system. PRISM data is spatially continuous for the continental US, and has been modeled from the year 1895 to the present. The spatial resolution of PRISM data is 0.5 arcminutes (800 m), and it is modeled at a monthly time step (i.e. temporal resolution).

Four climatic variables precipitation, maximum and minimum temperature and average dew point temperature across three temporal time ranges were extracted and derived from PRISM data for each of the 262 sounds study sites. Climatic variables precipitation, dew point, maximum and minimum temperatures can have pronounced effects on biophony, geophony and anthrophony sound sources.

PRISM 10 year norms (2001 - 2010):

PPTNorms - Average yearly precipitation (Point - millimeters times 100).

TMINNorms - Average yearly minimum temperature (Point - C° * 100).

TMAXNorms - Average yearly maximum temperature (Point - C° * 100).

TDEWNorms - Average yearly dew point temperature (Point - C° * 100).

PRISM 10 year ((2001 - 2010) summer norms (June, July, August):

PPTSummer - Average summer precipitation (Point - millimeters times 100).

TMINAvgSummer - Average summer minimum temperature (Point - C° * 100).

TMAXAvgSummer – Average summer maximum temperature (Point - C° * 100).

TDEWAvgSummer - Average summer dew point temperature (Point - C° * 100).

PRISM 10 year (2001 - 2010) winter norms (December, January, February):

PPTWinter - Average winter precipitation (Point - millimeters times 100).

TMINAvgWinter - Average winter minimum temperature (Point - C° * 100).

TMAXAvgWinter – Average winter maximum temperature (Point - C° * 100).

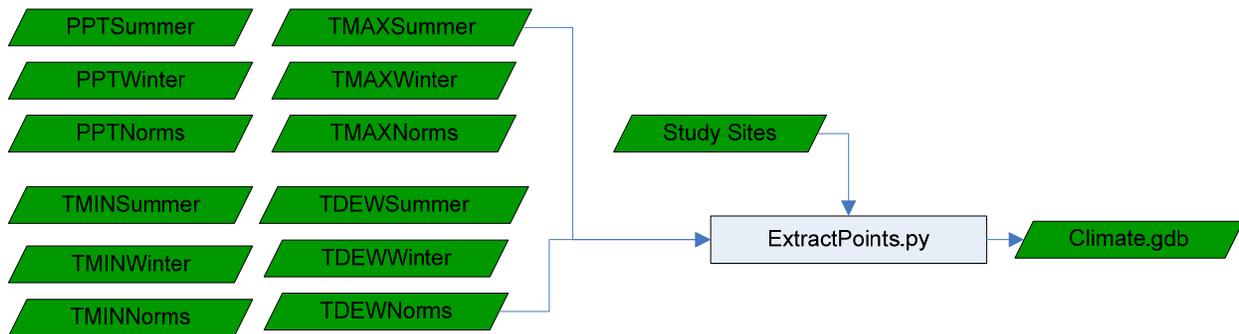
TDEWAvgWinter - Average winter dew point temperature (Point - C° * 100).

The climatic data work flow and associated python scripts, data inputs and outputs are outlined in Figure 4.

Figure 4. Flow chart of climatic data processing steps and associated scripts and outputs.

Climate – Processing

PRISM Climatic Data (PRISM Group)



3.3.1 Script & Variables

ExtractPoints.py - For each study site location extracts the input PRISM data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - workspace/geodatabase with PRISM rasters to be extracted.
- outGdb - output geodatabase workspace (Climate.gdb).
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- outTable – Name of final exported table with raster point values per study site (ClimateData).
- fieldname – Name of output field in the extracted output table (e.g. PPTNorms, etc).

3.4 Distance to Roads

Distance to road measures were derived for each study site using previously compiled road network data attained from the NPScape roads measure data (National Park Service, 2010). Source roads data used in the NPScape road measure products are from ESRI Streetmaps data and reflect 2006 condition (ESRI 2010).

Distances to road metrics have been derived to indirectly measure anthropogenic sound sources. Increasing distance from roads would be expected to result in decreased anthropy sound

resulting from a reduced human presence. Greater distances from roads are expected to have accompanying reductions in automobile usage, and other non-natural land use practices such as agriculture, energy extraction, urban-semi urban development etc. Likewise firmly documented within the road ecology literature is the concept of the road effect zone, where road effects on biophony and geophony in general are expected to decrease with increasing distance from roads (Forman et al. 2002).

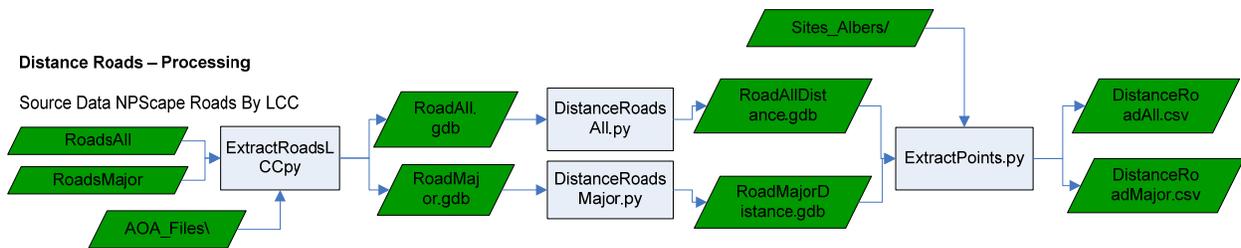
Calculated distance to roads included two variables derived at a 10 mile AOA extent:

DistRoadsAll – Distance to all roads in the ESRI Streetmaps data (point - meters).

DistRoadsMajor – Distance to major roads only in the ESRI roads database. Major roads are defined as interstate or major roads using the feature class codes (FCC:A10 - A38) in the ESRI Streetmaps roads data (point - meters).

The distance to roads work flow and associated python scripts, data inputs and outputs are outlined in Figure 5.

Figure 5. Flow chart of distance to roads data processing steps and associated scripts and outputs.



3.4.1 Scripts & Variables

ExtractRoadsLCC.py - Extracts roads data by USFWS Landscape Conservation Cooperative units to the desired AOA.

- aoaFile – workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outGdb1 - output geodatabase workspace.
- prefix - Prefix name applied to each clipped output file (e.g. RoadAll).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park. Note this List is unique to the LCC roads data by sounds study site (LCC_Name_SitedId.csv).

DistanceRoadAll.py & *DistanceRoadMajor.py* - Calculates Euclidean distance from roads within the defined AOA.

- prefix - Prefix name applied to each derived output file (e.g. Distance).
- outWorkspace - output geodatabase for distance files per AOA (RoadAllDistance.gdb & RoadMajorDistance.gdb).

- sourceFile - Workspace/geodatabase with road files (RoadsAll.gdb & RoadsMajor.gdb).
- sourceFilePrefix - Standardized source file suffix (e.g.RoadAll), needed for syntax logic.
- bufferFile - geodatabase with AOA files.
- bufferSuffix - Standardized AOA file suffix (e.g. 10 mile), needed for syntax logic.
- parkList - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" - unique study site name. Field "SiteID_Park" - unique study site name and associated park.
- snapRaster - raster to snap derived output.

ExtractPoints.py - For each study site extracts the input raster data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - geodatabase with Road Distance rasters to be extracted (RoadAllDistance.gdb & RoadMajorDistance.gdb).
- outGdb - workspace/geodatabase to house output table (RoadAllDistance.gdb & RoadMajorDistance.gdb).
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" – unique study site name. Field "SiteID_Park" - unique study site name and associated park.
- outTable – Name of final exported table with raster point values per study site (DistanceRoadsAll & DistanceRoadsMajor).
- fieldname – Name of output field in the extracted output table (e.g. DistRoadsAll, etc).

3.5 Road Density

Road density measures were derived for each study site using previously compiled road network data attained from the NPScape roads metric data (National Park Service, 2010). Source roads data used in the NPScape road measure products are from ESRI Maps and Data (ESRI 2010). Increased road density values is expected to have increased anthrophony noise, and increased alteration of the naturally occurring biophony due to biota avoidance of roaded areas.

Sum of Road density values were derived at 0.2 & 5 km, and 1 & 5 mile AOA extents:

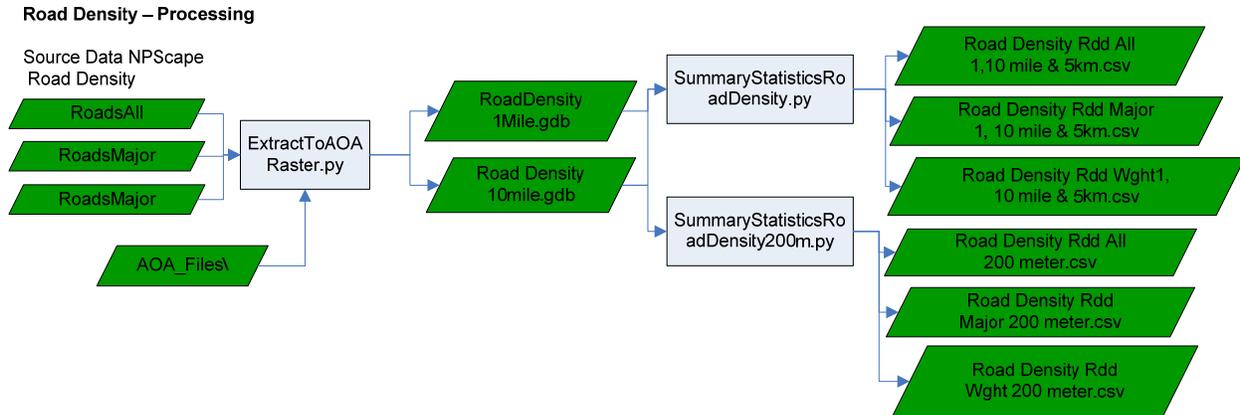
RddAll 1Mile/10Mile/200m/5000m – Sum of road density all roads, ESRI roads database - NPScape roads metric - 1 & 5 mile and 0.2 & 5 km AOA - km/km².

RddMajor 1Mile/10Mile/200m/5000m – Sum of road density major roads, ESRI roads database - NPScape roads metric - 1 & 10 mile and 0.2 & 5 km AOA - km/km².

RddWeighted 1Mile/10Mile/200m/5000m – Sum of road density weighted roads, ESRI roads database - NPScape roads metric - 1 & 10 mile and 0.2 & 5 km AOA - km/km².

The road density work flow and associated python scripts, data inputs and outputs are outlined in Figure 6.

Figure 6. Flow chart of road density data processing steps and associated scripts and outputs.



3.5.1 Scripts & Variables

ExtractToAOARaster.py - Extracts input road density data to the desired AOA.

- inputWorkspace - workspace with rasters to be extracted.
- aoaFile - workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outGdb1 - output geodatabase workspace.
- prefix - Prefix name applied to each clipped output file (e.g. RoadAll).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” - unique study site name. Field “SiteID_Park” - unique study site name and associated park.

SummaryStatisticsRoadDensity.py & *SummaryStatisticsRoadDensity200m.py* (200 meter only) - Calculates summary statistics for a defined AOA.

- inputWorkspace - Input workspace with data to be summarized (RoadDensity1Mile.gdb & RoadDensity10mile.gdb).
- inputWild - Wildcard syntax to grab all desired files (e.g. Rdd_All* | Rdd_Major* | RDD_Weighted*) with the list raster/feature gp function.
- aoaData - Workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outTablePrefix - Name of final exported table with summary statistics per AOA.
- dataType - Switch defining if feature class or raster data is being processed (Raster).
- rasterTable - Switch defining if the raster dataset has a raster attribute table (No).

3.6 Naturalness Index

Naturalness Index values were attained from Theobald (2010), where Naturalness values are summarized (Maximum, Mean, Minimum, Range, Standard Deviation, and Sum) at 5 km, and 1 & 5 mile, and point AOA extents. Increased natural values are expected to have an overall reduction in anthropophony noise, however greater naturalness is also likely to have an increase in naturally occurring biophony. Overall increased naturalness would be expected to have lower overall soundscape noise levels due to the reduction in anthropophony.

NatMin 1Mile/10Mile/5000m/Point - Minimum naturalness value - 1 & 5 mile and 5km, and point AOA.

NatMax 1Mile/10Mile/5000m/Point - Maximum naturalness value - 1 & 5 mile and 5km, and point AOA.

NatMean 1Mile/10Mile/5000m/Point - Mean naturalness value - 1 & 5 mile and 5km, and point AOA.

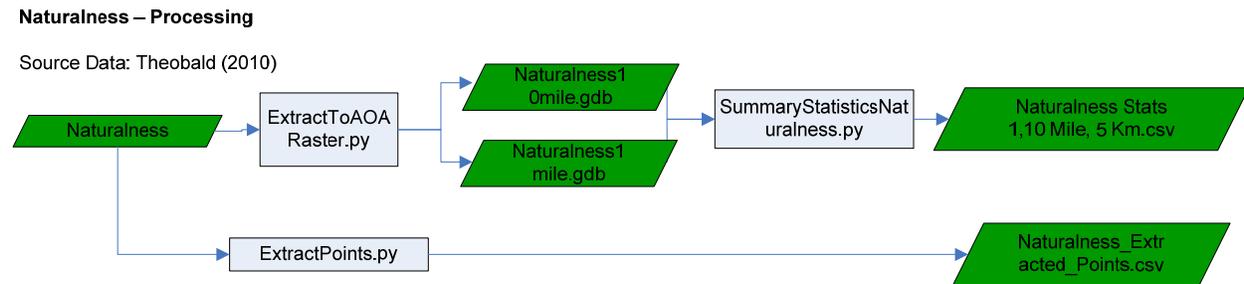
NatRange 1Mile/10Mile/5000m/Point - Range of naturalness values - 1 & 5 mile and 5km, and point AOA.

NatStd 1Mile/10Mile/5000m/Point - Standard deviation of naturalness values - 1 & 5 mile and 5km, and point AOA.

NatSum 1Mile/10Mile/5000m/Point - Sum of naturalness values - 1 & 5 mile and 5km, and point AOA.

The naturalness index work flow and associated python scripts, data inputs and outputs are outlined in Figure 7.

Figure 7. Flow chart of road density data processing steps and associated scripts and outputs.



3.6.1 Scripts & Variables

ExtractToAOARaster.py - Extracts input NLCD data to the desire AOA.

- inputWorkspace – workspace with rasters to be extracted.
- aoaFile – workspace/Geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.

- outGdb1 - output Geodatabase workspace.
- prefix - Prefix name applied to each clipped output file (e.g. RoadAll).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - workspace/geodatabase with PRISM rasters to be extracted.
- outGdb - workspace/geodatabase to house output table
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- outTable – Name of final exported table with raster point values per study site.
- fieldname – Name of output field in the extracted output table (e.g. Naturalness, etc).

SummaryStatisticsNaturalness.py - Calculates summary statistics for a defined Area of Analysis.

- inputWorkspace - Input workspace with data to be summarized.
- inputWild – Wildcard syntax to grab all desired files (e.g. Naturalness*) with the list raster/feature gp function.
- aoaData – Workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outTablePrefix - Name of final exported table with summary statistics per AOA.
- dataType – Switch defining if feature class or raster data is being processed (“Feature” | “Raster”).
- rasterTable – Switch defining if the raster dataset has a raster attribute table (“Yes” | “No”).

3.7 Flight Frequency

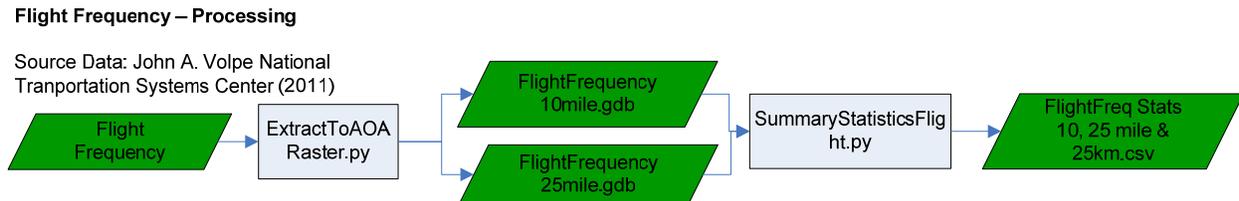
Weekly flight frequency observation data for the continental US at a 7 km spatial resolution were attained from the John A. Volpe National Transportation Systems Center (2011). Increasing flight frequency is expected to correspondingly have an increase in anthropony.

At 10 & 25 mile and 25 km AOA extents per study site the sum of weekly observed flights were derived:

FlightFreq 10Mile/25Mile/25km - Sum of weekly flight observations -10 & 25 mile and 25 km AOA).

The flight frequency work flow and associated python scripts, data inputs and outputs are outlined in Figure 8.

Figure 8. Flow chart of flight frequency data processing steps and associated scripts and outputs.



3.7.1 Scripts & Variables

ExtractToAOARaster.py - Extracts input NLCD data to the desired AOA.

- inputWorkspace - workspace with rasters to be extracted.
- aoaFile - workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outGdb1 - output geodatabase workspace.
- prefix - Prefix name applied to each clipped output file (e.g. RoadAll).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” - unique study site name. Field “SiteID_Park” - unique study site name and associated park.

SummaryStatisticsFlight.py - Calculates summary statistics for a defined Area of Analysis.

- inputWorkspace - Input workspace with data to be summarized.
- inputWild - Wildcard syntax to grab all desired files (e.g. Flight*) with the list raster/feature gp function.
- aoaData - Workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.25 km), needed for syntax logic.
- outTablePrefix - Name of final exported table with summary statistics per AOA.
- dataType - Switch defining if feature class or raster data is being processed (“Feature” | “Raster”).
- rasterTable - Switch defining if the raster dataset has a raster attribute table (“Yes” | “No”).

3.8 Military Flight Paths

Military flight path data was obtained from the Department of Defense (March 2011). Vector format flight path data is designated with unique names, contact affiliation and flight path operation times. An assumption was made with all flight paths being treated as equal. Increased flight path length is expected to have increased aircraft usage resulting in increased anthropony.

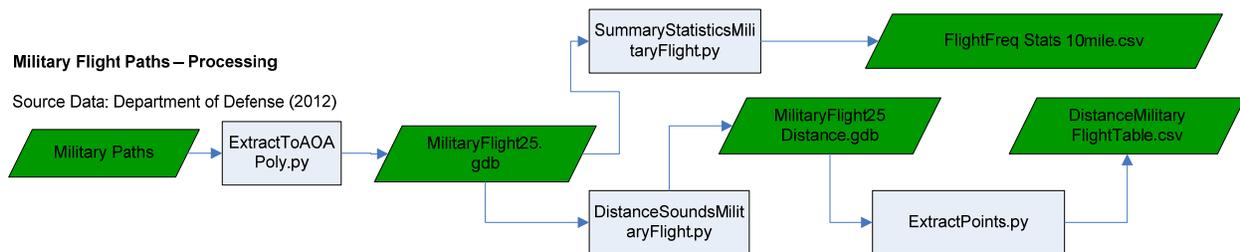
At a 25 mile AOA extent per study site the sum of military flight paths and distance to nearest military flight path variables were derived:

MilitarySum - Sum of designated military flight paths (25 mile AOA - Meters).

DistanceMilitary - Distance to nearest military flight path (25 mile AOA - Meters).

The flight frequency work flow and associated python scripts, data inputs and outputs are outlined in Figure 9.

Figure 9. Flow chart of military flight paths data processing steps and associated scripts and outputs.



3.8.1 Scripts & Variables

ExtractToAOAPoly.py - Extracts input military flight path data feature class data to the desired AOA.

- inputData - workspace with features to be extracted.
- aoaFile - workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g.1 km), needed for syntax logic.
- outGdb1 - output geodatabase workspace.
- prefix - Prefix name applied to each clipped output file (e.g. RoadAll).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.

SummaryStatisticsMilitaryFlight.py - Calculates summary statistics for a defined Area of Analysis.

- inputWorkspace - Input workspace with data to be summarized.
- inputWild - Wildcard syntax to grab all desired files (e.g. MilFl*) with the list raster/feature gp function.

- `aoaData` - Workspace/geodatabase with AOA files.
- `aoaSuffix` - Standardized AOA suffix (e.g. 1 km), needed for syntax logic.
- `outTablePrefix` - Name of final exported table with summary statistics per AOA.
- `dataType` - Switch defining if feature class or raster data is being processed (“Feature” | “Raster”).
- `rasterTable` - Switch defining if the raster dataset has a raster attribute table (“Yes” | “No”).

DistanceSoundsMilitaryFlight.py - Calculates Euclidean distance from flight paths within the defined AOA.

- `prefix` - Prefix name applied to each derived output file (e.g. Distance).
- `outWorkspace` - output geodatabase for distance files per AOA.
- `sourceFile` - Workspace/geodatabase with road files.
- `sourceFilePrefix` - Standardized source file suffix (e.g.MiFl), needed for syntax logic.
- `bufferFile` - geodatabase with AOA files.
- `bufferSuffix` - Standardized AOA file suffix (e.g.10mile), needed for syntax logic.
- `parkList` - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- `snapRaster` - raster to snap derived output.

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- `pointWorkspace` - workspace with point files per study site.
- `rasterWorkspace` - workspace/geodatabase with PRISM rasters to be extracted.
- `outGdb` - workspace/geodatabase to house output table
- `siteList` - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- `outTable` – Name of final exported table with raster point values per study site.
- `fieldname` – Name of output field in the extracted output table (e.g.DistanceMilitary, etc).

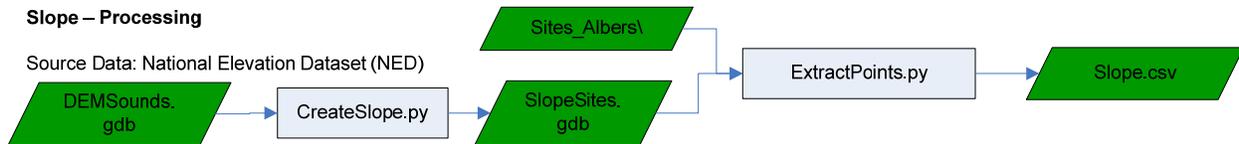
3.9 Slope

Slope data was derived from the digital elevation model (DEM) data derived in section 3.2, per study site at 10 mile AOA extent:

Slope – Slope derived from a 10 meter digital elevation model (Point - Degrees).

The slope work flow and associated python scripts, data inputs and outputs are outlined in Figure 10.

Figure 10. Flow chart for slope data processing steps and associated scripts and outputs.



3.9.1 Scripts & Variables

CreateSlope.py - creates slope for a defined AOA extent using a DEM.

- inputWorkspace - workspace with digital elevation model data.
- aoaFile - Workspace/geodatabase with AOA files.
- outGdb - output geodatabase workspace.
- parkList - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" - unique study site name. Field "SiteID_Park" - unique study site name and associated park.
- prefix - Prefix name applied to each derived output file (e.g. Slope).

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - workspace/geodatabase with Slope rasters to be extracted.
- outGdb - workspace/geodatabase to house output table.
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" - unique study site name. Field "SiteID_Park" - unique study site name and associated park.
- outTable - Name of final exported table with raster point values per study site.
- fieldname - Name of output field in the extracted output table (e.g. Slope).

3.10 Topographic Position Index

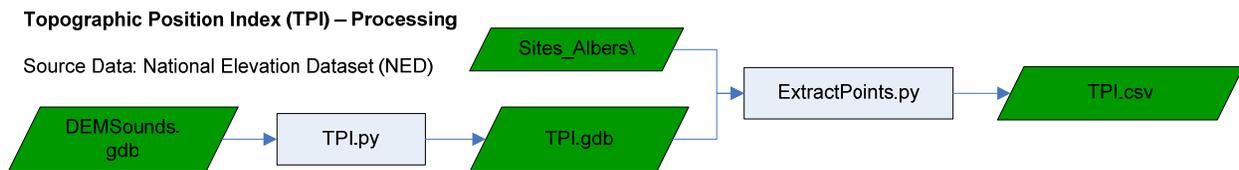
Topographic position index (TPI) data (Theobald 2009) was derived from 10 meter NED DEMs, using an annulus neighborhood with inner and outer radius of 5 and 10 meters respectively. Topographic position is known to have influences on biophony, geophony, and anthrophony sound sources. For example a ridge top often will have increased wind noise, relative to other TPI classes. Similarly relative to higher sloped TPI classes (e.g. Ridge, Upper Slope) lower sloped TPI classes (e.g., flat, valley) due to ease and suitability for use, may be expected have

greater noise from anthropony sources resulting from increased road traffic and other human activity.

TPI - Topographic Position Index: 1 - Ridge, 2 - Upper Slope, 3 - Middle Slope, 4 - Flat, 5 - Lower Slope, 6 - Valleys (Point).

The topographic position index work flow and associated python scripts, data inputs and outputs are outlined in Figure 11.

Figure 11. Flow chart for the topographic position index processing steps and associated scripts and outputs.



3.10.1 Scripts & Variables

TPI.py - Derives topographic position index (TPI) for the defined AOA using DEM and Slope neighborhood analysis relationships. TPI logic was obtained from Theobald (2009).

Topographic index: 1 - Ridge, 2 - Upper Slope, 3 - Middle Slope, 4 - Flat, 5 - Lower Slope, 6 - Valleys.

- inGdb - workspace with DEM's.
- demSuffix - Standardized DEM suffix (e.g.DEM), needed for syntax logic.
- outGdb - output geodatabase workspace.
- workGdb - work geodatabase for processing
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" - unique study site name. Field "SiteID_Park" - unique study site name and associated park.

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - workspace/geodatabase with TPI rasters to be extracted.
- outGdb - workspace/geodatabase to house output table.
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field "SiteID" - unique study site name. Field "SiteID_Park" - unique study site name and associated park.
- outTable - Name of final exported table with raster point values per study site.
- fieldname - Name of output field in the extracted output table (e.g.TPI).

3.11 Distance NHD Coastline

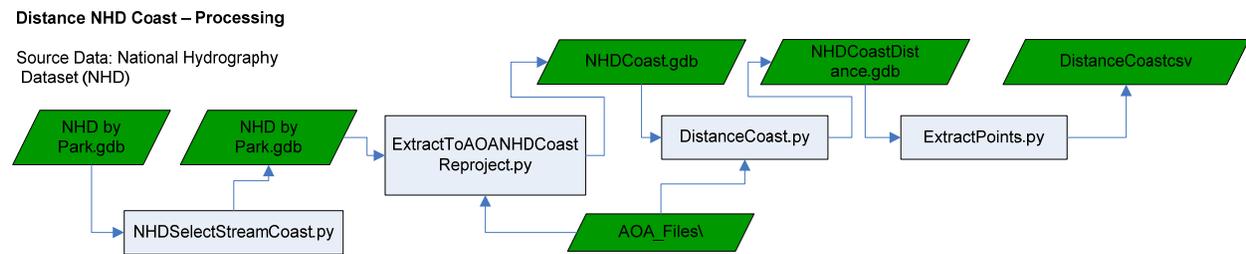
Distance to coastline calculations were derived from National Hydrographic Dataset (NHD)(1:24,000) defined coastline data (FType = 566) using NHD data which has been compiled for each NPS unit (Ling et. al. 2011). Increasing distance from the coast is expected to have a reduction in geophony resulting from wave action occurring near shoreline. Similarly increased distance from the coast would be expected to have a reduction in anthrophony resulting from recreation use of the shoreline from activities such as swimming, fishing, sun bathing, etc.

Distance measures were calculated at a 10 mile AOA extent per study site:

DistanceCoast –Distance to National Hydrology Dataset (NHD) coastline (10 mile AOA - Meters).

The distance to NHD coastline work flow and associated python scripts, data inputs and outputs are outlined in Figure 12.

Figure 12. Flow chart for distance to NHD coastline processing steps and associated scripts and outputs.



3.11.1 Scripts & Variables

NHDSelectStreamsCoast.py - Extracts National Hydrographic Data (NHD) Stream (FType = 460) and NHD Coast (FType = 566), creating NHD_Stream and NHD_Coast feature classes.

- workspace – workspace with NHD geodatabase (mdb) files.

ExtractToAOANHDCoastReproject.py - By defined AOA file extracts NHD coast data and reprojects to the desired projection.

- inputWorkSpace – workspace with park specific NHD files and coast data to be extracted.
- aoaFile - workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g. 10 mile), needed for syntax logic.
- outGdb1 - output geodatabase workspace (NHDCoast.gdb).
- prefix - Prefix name applied to each clipped output file (e.g. Coast).
- rpjFile - Feature class defining the desired output projection (e.g. Albers) typically will match the projection of the AOA data.

- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” - unique study site name. Field “SiteID_Park” - unique study site name and associated park.

DistanceCoast.py - Calculates Euclidean distance from NHD coastline within the defined AOA.

- prefix - Prefix name applied to each derived output file (e.g. Distance).
- outWorkspace - output geodatabase for distance files per AOA(e.g. NHDCoastDistance.gdb).
- sourceFile - Workspace/geodatabase with coast files per AOA files (NHDCoast.gdb).
- sourceFilePrefix - Standardized source file suffix (e.g.Coast), needed for syntax logic.
- bufferFile - geodatabase with AOA files.
- bufferSuffix - Standardized AOA file suffix (e.g.10 mile), needed for syntax logic.
- parkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- snapRaster - raster to snap derived output.

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - workspace/geodatabase with distance coast rasters to be extracted.
- outGdb - workspace/geodatabase to house output table (NHDCoastDistance.gdb).
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” - unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- outTable - Name of final exported table with raster point values per study site (DistanceCoast).
- fieldname - Name of output field in the extracted output table (e.g. DistanceCoast).

3.12 Distance to Streams by Stream Order

Distance to stream calculations were derived using NHD Plus datasets (1:100,000 National Hydrography Dataset Plus - Version 1) and associated Strahler Calculator (SC) Stream order data (Pierson et al. 2008). A relationship between distance to stream and distance to stream by stream size (i.e. order) is expected to capture the geophony resulting from water movement within streams. Increasing distance from a stream is expected to result in reduced geophony from water movement (i.e. waterfalls/cascades, etc). While the distance at which the effects from water movement geophony are influential are expected to increase with increasing stream order size.

Distance to streams by three stream order sizes were calculated for each study site:

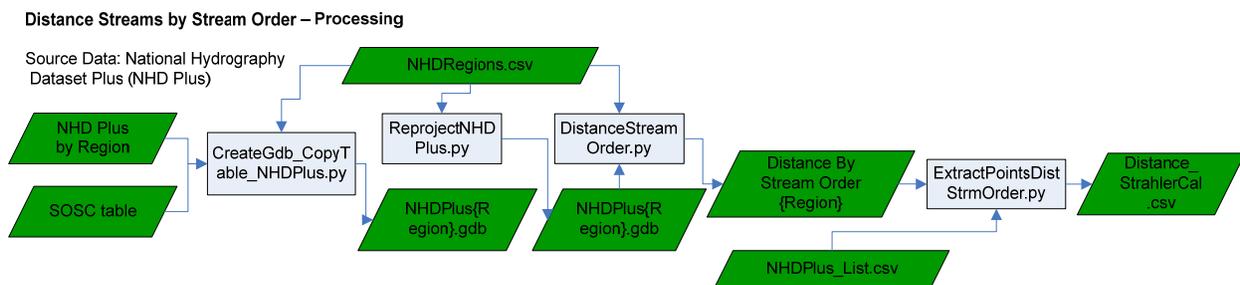
DistStrahlerCalgt1 - Distance to NHD Plus flowline with a SC stream order greater than 1.

DistStrahlerCalgt3 - Distance to NHD Plus flowline with a SC stream order greater than 3.

DistStrahlerCalgt4 - Distance to NHD Plus flowline with a SC stream order greater than 4.

The distance to streams by stream order work flow and associated python scripts, data inputs and outputs are outlined in Figure 13.

Figure 13. Flow chart for distance to streams by stream order processing steps and associated scripts and outputs.



3.12.1 Scripts & Variables

CreateGdb_CopyTable_NHDPlus.py - Creates geodatabases by NHDPlus region and populates with the respective nhdfowline stream data and Strahler Stream Order (SO) and Strahler Calculator (SC) stream order table.

- workspace - scratch workspace.
- outWorkspace - output directory for NHDPlus region geodatabases.
- processList - List of NHDPlus regions to be processed (.csv file).

ReprojectNHDPlus.py - Reprojects nhdfowline data from GCS NAD83 to Albers Equal Area Conic USGS version (or other desired projection).

- workspace - scratch workspace.
- outWorkspace - output directory with NHDPlus region geodatabases.
- suffix - Suffix to be added to the reprojected nhdfowline feature class.
- processList - List of NHDPlus regions to be processed (.csv file).
- projFile - File with desired projection (i.e. Albers).

DistanceStreamOrder.py - For NHDPlus region (.gdb), using NHDFlowline and SOSC stream order table, a distance to stream by stream order is calculated. Stream order can be defined as either Strahler Order (SO) or Strahler Calculator (SC).

- workspace - scratch workspace.
- outWorkspace - output directory with NHDPlus region geodatabases.
- processList - List of NHDPlus regions to be processed (.csv file).
- streamOrder - Stream order greater than by which distance to stream calculations are performed.
- orderType - Stream order calculation type, either Strahler order or Strahler Calculator.
- snapRaster - Raster to snap output distance to stream rasters.
- memory - Switch defining if memory processing should be used ('yes'|'no').

ExtractPointsDistStrmOrder.py - Extracts distance to streams by stream order type raster values from the respective NHDPlus region geodatabase which is coincident with the defined study site point location.

- workspace - scratch workspace.
- rasterWorkspace - Directory with NHDPlus region geodatabases
- rasterSuffix - Standardized raster file(s) suffix (e.g.StrahlerCal_3), needed for syntax logic.
- pointWorkspace - Location with study site point feature classes.
- pointSuffix - Standardized point file(s) suffix (e.g.site), needed for syntax logic.
- outGdb - Geodatabase to house the outTable with the distance values per study site.
- outTable - Name of final exported table with raster point values per study site.
- fieldName - Field name in outTable with raster point values per study site (i.e. StrahlerCal_3 or StrahlerCal_1).
- siteList - List of study sites and the associated NHDPlus region .gdb it is spatially coincident with.
-

3.13 Distance NHD Waterbody

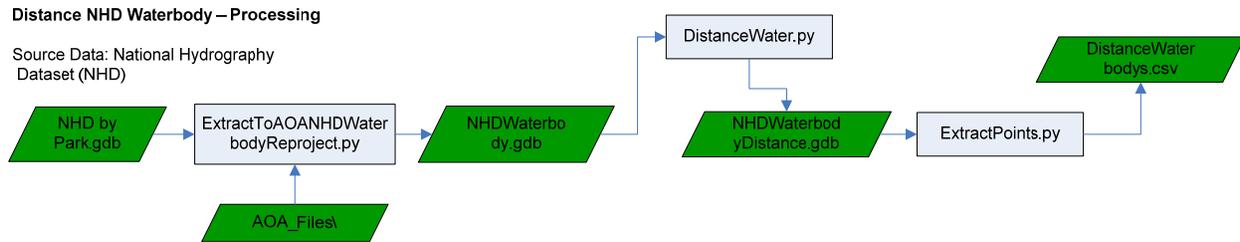
Distance NHD Waterbody calculations were derived from National Hydrographic Datasets (NHD) (1:24,000) defined waterbodies using NHD data which were compiled for each NPS unit (Ling and Tucker 2011). Similar to coastline with increasing distance from waterbodies the effect of wave action geophony and anthrophony from human recreation is expected to decrease.

Distance measures were calculated at a 10 mile AOA extent per study site:

DistanceWaterbody –Distance to National Hydrology Dataset (NHD) waterbody (10 mile AOA – Meters).

The distance to NHD Waterbody work flow and associated python scripts, data inputs and outputs are outlined in Figure 14.

Figure 14. Flow chart for distance to NHD waterbody processing steps and associated scripts and outputs.



3.13.1 Scripts & Variables

ExtractToAOANHDWaterbodyReproject.py - By defined AOA file extracts NHD waterbody data and reprojects to the desired projection.

- inputWorkSpace - workspace with park specific NHD waterbody data to be extracted.
- aoaFile - workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g. 10 mile), needed for syntax logic.
- outGdb1 - output geodatabase workspace (NHDWaterbody.gdb).
- prefix - Prefix name applied to each clipped output file (e.g. Waterbody).
- rpjFile - Feature class defining the desired output projection (e.g. Albers) typically will match the projection of the AOA data.
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.

DistanceWater.py - Calculates Euclidean distance from NHD waterbody within the defined AOA.

- prefix - Prefix name applied to each derived output file (e.g. Distance).
- outWorkspace - output geodatabase for distance files per AOA(e.g. NHDWaterbodyDistance.gdb).
- sourceFile - Workspace/geodatabase with road files (NHDWaterbody.gdb).
- sourceFilePrefix - Standardized source file suffix (e.g. Stream), needed for syntax logic.
- bufferFile - geodatabase with AOA files.
- bufferSuffix - Standardized AOA file suffix (e.g.10 mile), needed for syntax logic.

- parkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- snapRaster - raster to snap derived output.

ExtractPoints.py - For each study site point extracts the input raster data value and exports to a compiled extracted points table.

- pointWorkspace - workspace with point files per study site.
- rasterWorkspace - workspace/geodatabase with distance coast rasters to be extracted.
- outGdb - workspace/geodatabase to house output table.
- siteList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” - unique study site name. Field “SiteID_Park” - unique study site name and associated park.
- outTable - Name of final exported table with raster point values per study site (DistanceWaterBody).
- fieldname - Name of output field in the extracted output table (e.g. DistanceWaterBody).

3.14 Stream Slope

Stream slope calculations (degree) were derived using the previously extracted NHD stream segment (Section 3.12), and digital elevation model (DEM) (Section 3.2) data per study site. Stream slope was derived using slope calculations from DEM cells which are spatially coincident with stream segments. Stream slopes were summarized (Mean, Range, and Standard Deviation) at a 10 mile AOA extent per study site. Higher stream slope values within the AOA would be expected to measure areas which have high geophony resulting from water movement (i.e. waterfalls/cascades, etc).

StreamSlopeMean - Mean stream slope (10 mile AOA - Degree)

StreamSlopeRange - Range of stream slope (10 mile AOA - Degree)

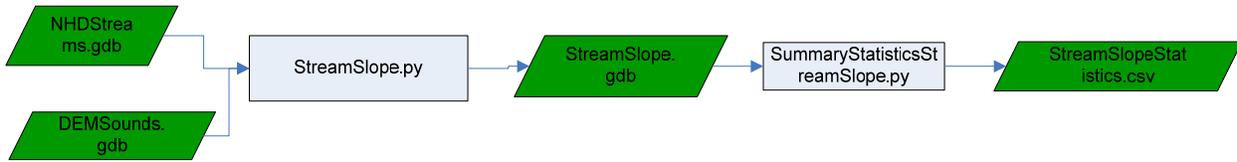
StreamSlopeStd - Standard deviation of stream slope (10 mile AOA - Degree)

The Stream slope work flow and associated python scripts, data inputs and outputs are outlined in Figure 15.

Figure 15. Flow chart for stream slope processing steps and associated scripts and outputs.

Stream Slope – Processing

Source Data: National Hydrography
Dataset (NHD) & National Elevation Data (NED)



3.14.1 Scripts & Variables

StreamSlope.py - Using NHD stream and DEM data stream slopes per defined AOA are derived. Stream slope calculation is derived using DEM cells that are directly coincident with stream segments.

- inFile - workspace with NHD stream files (NHDStreams.gdb)
- inPrefix - Standardized in file suffix (e.g. Stream), needed for syntax logic.
- demGdb - workspace with DEM data (DEMSounds.gdb)
- prefix - Prefix name applied to each derived output file (e.g. slope).
- outWorkspace - output geodatabase workspace (StreamSlope.gdb).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.

SummaryStatisticsStreamSlope.py - Calculates summary statistics for a defined Area of Analysis.

- inputWorkspace - Input workspace with data to be summarized (StreamSlope.gdb).
- inputWild - Wildcard syntax to grab all desired files (e.g. Slope*) with the list raster/feature gp function.
- aoaData - Workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g. 10 mile), needed for syntax logic.
- outTablePrefix - Name of final exported table with summary statistics per AOA (FlightFreq_10mile_Stats).
- dataType - Switch defining if feature class or raster data is being processed (Raster).
- rasterTable - Switch defining if the raster dataset has a raster attribute table (Yes).

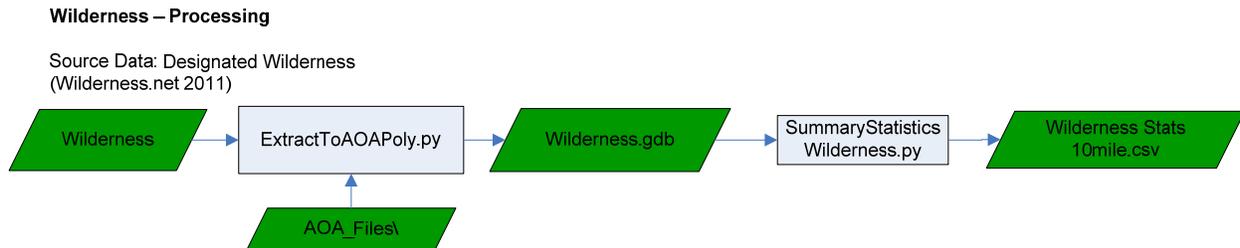
3.15 Wilderness

The total (sum) designated wilderness per study site at a 10 mile AOA extent was derived using wilderness data which was downloaded from Wilderness.net (2011). Greater proportions of designated wilderness lands are expected to have an overall reduction in anthropony noise and an increase in naturally occurring biophony.

Wilderness - Sum of designated wilderness (m²)

The wilderness work flow and associated python scripts data inputs and outputs are outlined in Figure 16.

Figure 16. Flow chart for the Wilderness processing steps and associated scripts and outputs.



3.15.1 Scripts & Variables

ExtractToAOAPoly.py - Extracts input wilderness data feature class data to the desired AOA.

- inputData – workspace with features to be extracted (Wilderness).
- aoaFile – workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix (e.g. 10 mile), needed for syntax logic.
- outGdb1 - output geodatabase workspace.
- prefix - Prefix name applied to each clipped output file (e.g. Wilderness).
- siteId_ParkList - Comma separated value (.csv) table with the list of parks to be processed. Field “SiteID” – unique study site name. Field “SiteID_Park” - unique study site name and associated park.

SummaryStatisticsWilderness.py - Calculates summary statistics for a defined Area of Analysis.

- inputWorkspace - Input workspace with data to be summarized (Wilderness.gdb).
- inputWild - Wildcard syntax to grab all desired files (e.g. Wild*) with the list raster/feature gp function.
- aoaData - Workspace/geodatabase with AOA files.
- aoaSuffix - Standardized AOA suffix needed for syntax logic (10 mile).
- outTablePrefix - Name of final exported table with summary statistics per AOA (Wilderness_Stats_10mile).
- dataType - Switch defining if feature class or raster data is being processed (Feature).
- rasterTable - Switch defining if the raster dataset has a raster attribute table (No).

3.15 Wind Power

Wind Power categorical potential densities at a height of 50 meters (W/m^2) were attained from the Natural Resource Energy Laboratory state level high resolution wind products (NREL 2012). Wind induced vegetation noise is a common source of coupled bio-geophony (Miller 2008). Increasing wind speeds would be expected to have an increase in wind induced vegetation noise.

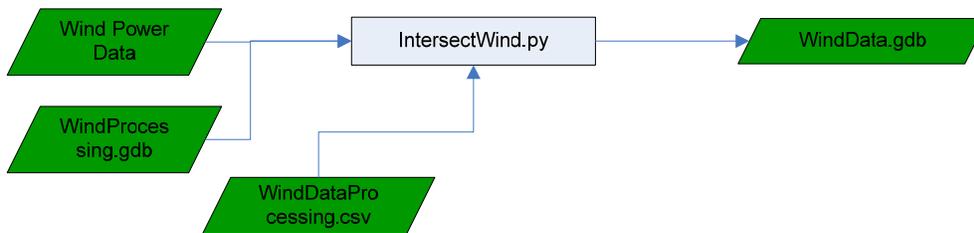
Wind - Wind Power Class, 1 - Poor ($0 - 200 \text{ W/m}^2$), 2 - Marginal ($200 - 300 \text{ W/m}^2$), 3 - Fair ($300 - 400 \text{ W/m}^2$), 4 - Good ($400 - 500 \text{ W/m}^2$), 5 - Excellent ($500 - 600 \text{ W/m}^2$), 6 - Outstanding ($600 - 800 \text{ W/m}^2$), and Superb ($> 800 \text{ W/m}^2$) - (Point).

The Wind Power Class work flow and associated python scripts, data inputs and outputs are outlined in Figure 17.

Figure 17. Flow chart for Wind Power Class processing steps and associated scripts and outputs.

Wind Power

Source Data: Natural Renewable Energy Laboratory (NREL)
http://www.nrel.gov/gis/data_wind.html



3.15.1 Scripts & Variables

IntersectWind.py - Using NHD stream DEM data stream slope per defined AOA is derived. Steam slope calculation is derived using only DEM cells that are directly coincident with stream segments.

- workspace - scratch workspace.
- outWorkspace - output geodatabase workspace.
- suffix - suffix name applied to each clipped output file (e.g. Wilderness).
- processList - List of study sites by state, with associated point files and wind power data locations.

3.16 Distance to Railroads

Using 1:1,000,000 scale major railroads polyline GIS data for the US, Euclidean distances (m) from railroads were calculated. The 2012 railroad data was downloaded from the national atlas (<http://www.nationalatlas.gov/mld/1rails.html>) in November of 2012. Closer proximity to railroads is expected to have increased anthropony resulting from train traffic.

DistRailroads - Euclidean distance (meters) to National Atlas 1:1,000,000 major railroads 2012 GIS data - (Point).

The Distance to Railroads metric work flow, data inputs and outputs are outlined in Figure 18.

Figure 18. Flow chart for Distance to Railroads processing steps and outputs.



3.17 Distance to Airports

Public use airport data for the continental US were obtained from the 2012 National Transportation Atlas at

http://www.bts.gov/publications/national_transportation_atlas_database/2012/zip/airports.zip.

All airports located within 50 miles of the contiguous US were subsequently extracted for use in euclidean distance calculations by airport type and airport usage metrics. The public use airport data set designates airports by the follow types: airports, seaplane bases, heliports, ultralight, ballon ports, and gliderports. Airport usage was evaluated using 2010 enplanement numbers for each respective airport. Enplanement refers to the number of individuals that get on a plane in a particular airport.

Closer proximity to airports and in particular airports with high usage as measured via enplanement numbers are expected to have increased anthropony noise, and increased alteration of the naturally occurring biophony.

DistAirportsAllMotorized - Distance to all motorized airports: Airports, Seaplane bases, Heliports, and Ultralights- (Meters - Point).

DistAirportsSeaplane - Distance to all airports and seaplane bases only - (Meters - Point).

DistHeliports - Distance to heliports only - (Meters - Point).

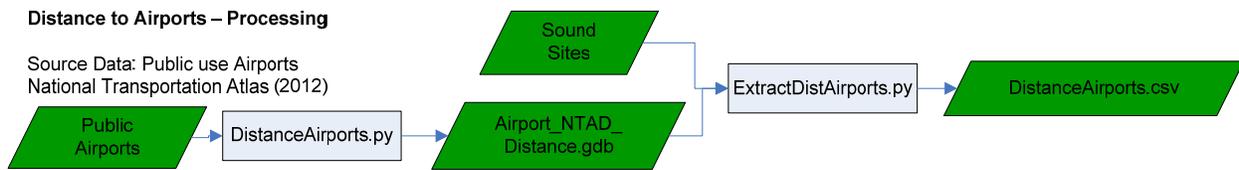
DistHighAirports - Distance to all airport types with greater than 1 million enplanements - (Meters - Point).

DistModerateAirports - Distance to all airport types with greater than 250,000 enplanements - (Meters - Point).

DistLowAirports - Distance to all airport types with greater than 5,000 enplanements - (Meters - Point).

The Distance to Airports work flow and associated python scripts, data inputs and outputs are outlined in Figure 19.

Figure 19. Flow chart for Distance to Airports processing steps and associated scripts and outputs.



3.17.1 Scripts & Variables

DistanceAirports.py - Using the National Atlas public airport data, Euclidean distance values to airports by airport type and enplanement values are derived. An input table with a name field and data path field is used to define the categories of airport distance rasters to be derived.

- workspace - scratch workspace.
- inTable - Table with airport data files to be processed. Input table must define a Name (column 1), and the file path (column 2) to the respective airport feature class datasets.
- outGdb - output geodatabase workspace.
- cellSize - raster cell size for output distance raster
- snapRaster - raster to snap derived output rasters
- extentRaster - raster defining the desired output rasters spatial extent

ExtractDistAirports.py - Distance to airport raster values per respective distance raster are extracted to a study site point feature class.

- workspace - scratch workspace.
- pointFile - point file to extract raster values.
- rasterWorkspace - workspace or geodatabase with distance to airport rasters.
- outGdb - output geodatabase workspace.

4. Sounds Modeling GIS Database

The last step in the soundscape modeling GIS database process involved compiling the explanatory variable processing outputs (Section 3) into the Soundscape Modeling Geospatial Database (SMGB) database. For each explanatory variable the *.csv and excel tables were imported into an Access SMGB database (SoundsModelingGISDatabase.accdb), with the desired statistics per variable and study site being queried into a final explanatory variable table (Conus_Explanatory) to be used in the subsequent spatial modeling process. The SMGB database is available for download on the NPS data store at <https://irma.nps.gov/App/Reference/Profile?code=2191476>.

A screen shot of the final output database (SoundsModelingGISDatabase.accdb) and study site explanatory variable table (Conus_Explanatory) is given in Figure 20.

Figure 20. Example of the output Sounds Modeling GIS database, and the compiled explanatory variable table (CONUS_Explanatory).

SiteID	SiteID_Park	ELEV	PPTSummer	PPTWinter	PPTNorms	TMAXAvgSumm
ACAD001	ACAD001_ACAD	1.85188901424408	24738	33096	124339	
ACAD002	ACAD002_ACAD	119.108001708984	24491	34940	126462	
ACAD004	ACAD004_ACAD	93.0823211669922	24244	36493	128978	
ARCH001	ARCH001_ARCH	1541.65795898438	5396	4553	24536	
ARCH002	ARCH002_ARCH	1487.10998535156	5327	4542	24296	
ARCH003	ARCH003_ARCH	1255.86694335938	5347	3966	22372	
ARCH005	ARCH005_ARCH	1252.21801757813	5246	3908	21988	
ARCH008	ARCH008_ARCH	1495.71496582031	5426	4737	24740	
BADL001	BADL001_BADL	805.93499758594	18028	3062	45674	
BITH002	BITH002_BITH	67.1302795410156	32527	34560	136596	
BITH003	BITH003_BITH	53.2340087890625	32872	37289	140520	
BLMNV001	BLMNV001_LAKE	1073.73400878906	3837	6906	18969	
BLMNV002	BLMNV002_LAKE	954.580078125	4362	7479	22763	
BLMNV003	BLMNV003_LAKE	992.270874023438	3939	5215	15546	
BLMNV004	BLMNV004_LAKE	879.001892089844	3630	5108	15158	
BLMNV005	BLMNV005_LAKE	1531.55895996094	6014	6639	20009	
BRCA009	BRCA009_BRCA	2208.06396484375	9432	9828	38522	
BRCA014	BRCA014_BRCA	2362.85693359375	9793	10414	40830	
BRCA015	BRCA015_BRCA	2523.59106445313	9793	10414	40830	
BRCA016	BRCA016_BRCA	2504.18701171875	9432	9828	38522	

5. Citations

Breiman, L. 2001. Random Forest. *Machine Learning* 45(1), 5-32.

Department of Defense, United States. Military Flight Paths, obtained spring 2011.

ESRI. 2010. U.S. and Canada Detailed Streets. Compiled by Tele Atlas North America (2005), Inc., distributed by ESRI. Redlands, CA. DVD.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R.L., Goldman, C.R., Heanue, K., Jones, J., Swanson, Fl., Turrentine, T., and T.C. Winter. 2002. *Road Ecology: Science and Solutions*. Island Press - 504 pages.

John A. Volpe National Transportation Systems Center – Flight Frequency Data (2011)

Ling, J., and Tucker, D. Hydrographic and Impairment Statistics Databases by respective park. National Park Service.

Mennitt, D., Sherrill, K. R., and K. Frstrup. In Prep. A geospatial model of ambient sound pressure levels in the continental United States. *The Journal of the Acoustical Society of America*.

Miller, N.P. 2008. US National Parks and management of park soundscapes: A review. *Applied Acoustics*(69):77-92.

National Elevation Dataset (NED). <http://ned.usgs.gov/>

National Land Cover Data (NLCD) 2006. http://www.mrlc.gov/nlcd06_data.php.

National Renewable Energy Laboratory (NREL) 2012. http://www.nrel.gov/gis/data_wind.html.

National Park Service. 2010. NPScape roads measure – Phase 2 road metrics processing SOP: Road density and distance from roads. National Park Service, Natural Resource Program Center. Fort Collins, Colorado. <https://irma.nps.gov/App/Reference/Profile/2166959>

National Park Service Hydrographic Impairment Data - Dean Tucker (2009).

National Hydrography Dataset Plus - Version 1 <http://www.horizon-systems.com/nhdplus/data.php>.

Pierson, S.M., Rosenbaum, B.J., Mckay, L.D., and T.G. Dewald. 2008. Strahler Stream Order and Strahler Calculator Values in NHDPlus. US Environmental Protection Agency's Office of Research and Development National Health and Environmental Effects Research Laboratory - Western Ecology Division, Corvallis, Oregon. <http://www.horizon-systems.com/nhdplus/download.php> - SO/SC Technical Paper.

Pijanowski, B.C., Villanueva-Rivera, L.J., Dumyahn, S.L., Farina, A., Krause, B.L., Napoletano, B.M., Gage, S.H., and N. Pieretti. 2011. Soundscape Ecology: The Science of Sound in the Landscape. *Bioscience* (61): 203-216.

Pijanowski, B.C., Farina, A., Gage, S.H., Dumyahn, S.L., and B.L. Krause. 2011. What is soundscape ecology? An introduction and overview of an emerging new science. *Landscape Ecology* (26): 1213-1232.

PRISM Climate Group, Oregon State University, <http://www.prism.oregonstate.edu/> .

Theobald, D.M. 2009. LCAPv1.0: Landscape Connectivity and Pattern tools for ArcGIS.

Theobald, D.M. 2010. Estimating natural landscape changes from 1992 to 2030 in the conterminous US. *Landscape Ecology* (25): 999-1011.

Wilderness.net. 2011. Designated wilderness downloaded Dec 1, 2011 from <http://www.wilderness.net/index.cfm?fuse=NWPS&sec=geography>.

6. Python Scripts

The python scripts which have been defined in this SOP are available for download on the NPS data store at <https://irma.nps.gov/App/Reference/Profile?code=2191476>.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 909/117766, December 2012

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship & Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov