

Peak Flows and Chinook Survival in the Stillaguamish Watershed: Spatial Prioritization for Conservation and Restoration Action

Detailed Analysis Methodology

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This document provides a step-by-step explanation of the methodology used to implement the four analysis stages for this project: Watershed Land Use, Management and Ownership Characterization, Mature Forest Cover Retention Priority, Floodplain Restoration Priority and Floodplain Conservation Priority.

Data Sources

The following spatial datasets were acquired from third party sources for use as analysis inputs or as reference during the course of this project:

- **100-year Flood Elevation Cross-section** for the North and South Forks of the Stillaguamish River (date unknown); Snohomish County
- **Administrative and Ownership Boundaries**, Mt. Baker-Snoqualmie National Forest (January 22, 2013): U.S. Forest Service
- **Central Puget Sound Public, Tribal and Protected Lands Database** (December 2012); Forterra
- **Designated Wilderness Boundaries**, Mt. Baker-Snoqualmie National Forest (January 22, 2013): U.S. Forest Service
- **DNR Managed Land Parcels** (acquired January 22, 2013); Washington State Dept. of Natural Resources
- **Flow Accumulation as Pour-Points** (2006); Stillaguamish Tribe of Indians
- **Land Resource Management Plan**, Mt. Baker-Snoqualmie National Forest (January 22, 2013): U.S. Forest Service
- **LiDAR “Bare Earth” Digital Elevation Model**, 6-foot resolution (various dates); Puget Sound LiDAR Consortium
- **Mean Annual Precipitation**, 4,060 foot resolution (January 2006); MGS Engineering Consultants on behalf of the Washington State Dept. of Transportation
- **NAIP Aerial Photography**, 1 meter resolution (summer 2011); U.S. Dept. of Agriculture, Natural Resource Conservation Service
- **National Conservation Easement Database**, Pacific Region (May 15, 2013); The Trust for Public Land and Ducks Unlimited
- **National Elevation Dataset Digital Elevation Model**, 1/3 arc-second resolution (acquired February 2013); U.S. Geological Survey
- **National Forest Inventoried Roadless Areas** (2003); U.S. Forest Service, Geospatial Service and Technology Center
- **NRCS Conservation Easement Area Boundaries** (acquired January 28, 2013); U.S. Dept. of Agriculture, Natural Resource Conservation Service

- **Rain On Snow Zones** (November 1991); Washington Dept. of Natural Resources, Forest Practices Division
- **Skagit County tax parcel boundaries** with land owner, value, use and other assessment characteristics (January 17, 2013); Skagit County
- **Snohomish County tax parcel boundaries** with land owner, value, use and other assessment characteristics (January 16, 2013); Snohomish County
- **Stillaguamish Watershed Land Cover**, 30 meter resolution (2011); created through guided classification from LandSat imagery in 2013 by CoreGIS on contract to the Stillaguamish Tribe of Indians
- **USFWS Administered Lands** from the USFWS Cadastral Framework (acquired January 13, 2014); U.S. Fish and Wildlife Service Realty Program
- **WA State Park Boundaries** (acquired January 29, 2013); Washington State Parks Commission
- **Washington State Incorporated Municipality Boundaries** as recorded by the Washington State Office of Financial Management (January, 2013); Washington State Department of Transportation, Office of Cartography and GIS
- **Watershed Resource Inventory Areas** for Washington State, 1:24,000 (2013); Washington Dept. of Ecology
- **WDFW Interim Land Information System** (acquired February 26, 2013); Washington department of Fish & Wildlife
- **WRIA 5 Sub-basin Boundaries** (August 25, 2008); Stillaguamish Watershed Lead Entity

Land Base Characterization

Combine County Datasets

The Stillaguamish Watershed lies partially within both Snohomish and Skagit Counties. Creating a watershed-wide tax parcel dataset requires combining data from both counties. Because each county manages their data independently, they each include a somewhat different set of attribute fields. For those fields they track in common, they each use different field names. To produce a watershed tax parcel dataset, determine which fields both counties track in common and normalize the content of those fields under new field names.

1. Use the Select by Location tool to extract parcels from each county tax parcel dataset that lie within the watershed. Use the watershed boundaries defined in both the WRIA 5 Sub-basin and Watershed Resource Inventory Areas datasets as the source layers, and use the intersect selection method. Name these new layers Parcels_Skagit and Parcels_Snoho accordingly.
2. Review all attribute fields included in each county dataset. In a new Microsoft Excel file named LandCharacterization_TaxParcelAttributes_Normalization.xlsx, organize and document an approach to normalizing attribute fields between counties as follows:
 - a. Create a separate worksheet for each county
 - b. List all field names and their descriptions
 - c. Evaluate fields for their potential relevance to the prioritization analyses
 - d. Document the availability of corresponding information between counties
 - e. Document the normalization operations needed, if any

3. In the Parcel Normalization Excel file, create a new worksheet to summarize the content that will appear in the final watershed parcel dataset, and describe how it will be derived:
 - a. Create a new “normalized” field name for each field that will appear in the output;
 - b. Create an additional column for each county to document the sources for this information and how it will be derived:
 - i. For output fields that correspond directly to a source field for a given county, list the corresponding source field name;
 - ii. For output fields that must be created, calculated or derived by combining multiple source fields, describe the operation required.
4. For fields that must be created, calculated or derived through combination, use ArcGIS to create and populate fields in the source data according to the approach defined in the Parcel Normalization Excel file as follows:
 - a. Assign county name;
 - b. Assign Record ID as a two-letter county abbreviation (SK or SH) followed by a unique, consecutive integer;
 - c. For both counties, concatenate owner city, state and zip code;
 - d. For Snohomish County, concatenate taxpayer city, state and zip code fields;
 - e. For Skagit County, concatenate site street name and number fields;
 - f. For Snohomish County, concatenate site city, state and zip code fields;
 - g. For Snohomish County, identify the location of each parcel relative to current incorporated municipal boundaries as follows:
 - i. Use the Polygon to Point tool to convert all parcel polygons, specifying that the resulting point be located within the source polygon;
 - ii. Use the Delete Fields tool to remove all fields other than Record ID;
 - iii. Intersect the parcel point layer with the state Incorporated Municipalities polygon layer;
 - iv. Create a new text field District_City in the Snohomish parcel layer;
 - v. Perform a Spatial Join of the intersected points layer to the Snohomish parcel layer using Record ID as the join field;
 - vi. Use the Field Calculator to populate the District_City field with the name of the city each parcel point is located within, if any;
 - vii. Remove the join;
 - viii. Within the Snohomish parcel layer, Select by Attributes all parcels that are not located within an incorporated municipality and use the Field Calculator to populate the District_City field for those records with “Snohomish County”.
 - h. For Skagit County, calculate the acreage of each parcel polygon as mapped in the GIS data;
 - i. For Skagit County, calculate the market value of the land by subtracting market building value from total market value;
 - j. For Snohomish County, calculate the total assessed value by adding the assessed improvement and land values;

- k. For both counties, normalize the assessed land use for each parcel and create a more simplified categorization of land use as follows:
- i. For both counties, use the Dissolve tool to combine all parcels having the same assessed land use category into a single feature and export the attribute table for the resulting layer for use in Excel;
 - ii. Create a new Excel file named LandCharacterization_LandUse_Normalization.xlsx to be used to organize and document an approach, and import both county land use dissolve tables as separate worksheets;
 - iii. In both county worksheets, create a field to record the normalized land use category that will correspond to each assessed land use category assigned by the county, and populate that field as consistently and with as few categories as deemed necessary;
 - iv. In rare cases, reassign assessed land use to more accurately reflect apparent use, ownership and management categories as they relate to this analysis. For example, the county- and privately-owned parcels in Skagit County assessed as “(920) TREES” were reclassified “(910) UNIMPROVED LAND” to distinguish them from the DNR and USFS lands that comprised the bulk of the land in that category
 - v. Create a new field Land Use Group in both county worksheets and group all normalized land use categories into one of the following 11 types:
 - Agriculture
 - Commercial or Industrial
 - Forestry
 - Infrastructure
 - Park or Designated Open Space
 - Recreation
 - Residential
 - Social, Governmental or Cultural Uses
 - Undeveloped or Vacant Land
 - Unknown
 - Water Area

This field will serve as a more simplified categorization of assessed and normalized land uses in the prioritization analyses to follow;
 - vi. Export both county worksheets as geodatabase tables named <countyname>_LandUse_Normalized to serve as lookup tables;
 - vii. Perform Tabular Joins between both lookup tables and their respective counties, using the assessed land use field as the join field, and export them as new layers named Parcels_Skagit_JOIN_Landuse and Parcels_Snoho_JOIN_Landuse, as appropriate;
 - viii. For Skagit County, perform a Tabular Query on the PARCELTYPE field to identify certain land uses that are otherwise unattributed, as follows:
 - For PARCELTYPE = 2, set LandUse_Normalized = “Transportation” and LandUse_Group to “Infrastructure”;
 - For PARCELTYPE = 1, set both LandUse_Normalized and LandUse_Group Equal to “Water Area”.

Note: unless otherwise explained, use the Field Calculator to populate fields wherever concatenation or assignment are necessary.

5. Export the attribute tables of the parcel layers with joined, normalized land use fields for both counties to independent tables for use in Microsoft Access;
6. Import each county table into Access to rename and reorder fields to match the normalized field names and their desired order as documented in the Tax Parcel Attribute Normalization Excel file;
7. Export both normalized county attribute tables as geodatabase tables;
8. Export copies of the parcel layers for both counties with joined, normalized land use fields and use the Delete Field tool to remove all fields except Record ID;
9. Perform a Tabular Join of the geodatabase tables from Access to the appropriate, unattributed county parcel boundaries using Record ID as the join field and export them as new layers
10. Use the Merge tool to combine the county parcel layers with normalized attributes into a watershed-wide parcel feature class.

Address Multiple Records for the Same Parcel

Among the Snohomish County parcels within the watershed a significant number are represented by more than one record in the dataset. In these circumstances, multiple records are represented by identical parcel geometries but with different attributes for such fields as ownership, valuation, or land use.

The Find Identical Tool produces a table noting which records, reported by OBJECTID, share an identical geometry. Out of 29,883 records there are 2,498 duplicates, among which were only 812 unique geometries. Inspection reveals that, in nearly every case, this situation occurs because the Snohomish County Assessor is using duplicate geometries to represent either multiple land uses or multiple interests (fee simple versus mineral rights) on the same property, and are assessing property values separately for each record.

The prioritization analyses all require that there be only one parcel record for a given piece of land. In order to satisfy that condition, review by hand all instances of parcel geometries with duplicate records to identify underlying issues and rectify as appropriate to ensure there is only one record for every parcel.

The following is an overview of the most common issues and how they are to be addressed by editing the watershed parcel dataset:

- When only one record documents “850 Mining Claims, Mineral Rights or Mining NEC” as the assessed land use, assume that record represents the ownership of the underlying mineral rights and delete that record.
- When the assessed land use for one record represents a manufactured home on a site leased from a different owner:
 - If the other record indicates an essentially undeveloped or vacant land use, reassign the land use for that record to reflect the residential use, and delete the record for the manufactured home without incorporating the property values for that home into the retained record;
 - If the other record indicates a more intensive land use, such as residential, commercial, agricultural or forestry, retain that record and delete the record for the manufactured home without incorporating the property values for that home into the retained record.

- When one record represent a manufactured home and the other record reflects the same owner:
 - If the other record indicates an essentially undeveloped or vacant land use, reassign the land use of the other record to reflect the residential use, add the property values from the manufactured home record to the retained record, and delete the record for the manufactured home;
 - If the site record indicates a more intensive land use, retain the record for that land use and add the property values from the manufactured home record to the retained record, and delete the record for the manufactured home.
- In cases where one record represents a single family or manufactured home land use and an additional record records the land use as “110 Senior Citizen Exempt Residual”, incorporate the property values from the senior citizen record into the single family or manufactured home record to account for the full value of the property and delete the senior citizen record.
- In cases where the residential use of a property appears to be secondary to another use, particularly a commercial, industrial or public use, and both records reflect the same ownership, add the residential property values to the values for the non-residential land use record and delete the residential use record.
- For multiple records representing distinctly different land uses that are more intense than vacant (e.g. residential and utility, agriculture and forestry), use the Split Polygons tool to divide the polygons into separate features corresponding to the areas under the different uses. Use the 2011 NAIP aerial photography as a reference to approximate which sections of the property are under the different uses. This will result in two separate records being retained, each with their respective boundaries, land use and property values corresponding to the appropriate portion of the property.
- In cases where multiple records appear identical, delete the duplicate records to retain only one.
- In cases where multiple records include the assessed land use “143 Single Family Residence Condominium Multiple”, choose one record to retain and change the OwnerName field for that record to “various”, then delete the other records for that parcel.
- In cases where one or more records contain no attributes, delete the records with no attributes.

After addressing and removing all multiple records, use the Calculate Geometry tool to recalculate values for the Acres_GIS field.

Aggregate Related Landowners

For a number of reasons, it is important to identify from the data which parcels within the watershed are owned by the same, or even closely related, entities. Both floodplain prioritization analyses in particular use the number of landowners holding land within each floodplain unit as an analysis criteria. Additionally, aggregated ownership information will be a useful reference for any organization using this data to plan or implement conservation or recreation actions.

While both counties document the owner of record for all parcels, it is common to find names misspelled, or even to find multiple spellings for the same owner. Additionally, business entities often will hold land under a number of different subsidiaries or related companies. Private individuals or families will also occasionally do the same for various reasons.

Use the following two approaches, in sequence, to identify and document parcels owned by the same or related entities.

Multiple Spellings and Forms of the Same Name

1. In the watershed parcel layer, create a new text field named ControllingEntity.
2. Use the Field Calculator to copy values from the OwnerName field to the ControllingEntity field.
3. Begin an editing session and sort all records alphabetically on the ControllingEntity field so that similarly spelled names will appear adjacent to each other.
4. Review all records to compare values for the ControllingEntity field, using values recorded for landowner name and address for confirmation.
5. Identify identical or closely related landowners and manually adjust values for the ControllingEntity field to reflect the same or closely related owners.
6. Upon completing review of all records, save edits and end the editing session.

Note: for records entirely missing values for the owner name (and for Snohomish County, taxpayer name), set the ControllingEntity field to “unknown”

Different Names Having the Same Owner Address

1. Create a new text field Address_DSLV and populate it by using the Field Calculator to concatenate values for Owner_Address1 and Owner_Address4.
2. Create new integer field AddressID and populate it with a unique integer for every record by using the Field Calculator to copy values from the OBJECTID field.
3. Create a new integer field DissolveCount and populate it using the Field Calculator to set the value for every record equal to one.
4. Create a new integer field DissolveID and populate it using the Field Calculator to set the value for every record to zero.
5. Use the Dissolve tool to combine all records having the same value for the Address_DSLV field and report statistics for the sums of the DissolveCount and DissolveID fields.
6. In the resulting dissolve layer, repopulate the DissolveID_SUM field with unique integers for every record using the Field Calculator to copy the values from the OBJECTID field.
7. Use the Polygon to Point tool to create a point version of the watershed parcels layer, specifying that the resulting points be located within the parent polygons.
8. Use the Delete Fields tool to remove all fields except AddressID from the parcel centerpoints layer.
9. Use the Intersect tool to combine the dissolved parcel polygon layer with the parcel centerpoints layer.
10. Perform a Tabular Join to link the attribute table for the parcel intersect point layer with the original watershed parcel layer using AddressID as the join field.
11. Use the Field Calculator to copy values from the DissolveID_SUM field and Dissolve_Count_SUM fields in the joined table to the DissolveID and DissolveCount fields in the watershed parcel layer, respectively, and then remove the join.
12. Begin an editing session with the watershed parcel layer and sort records by the DissolveID field so that parcels owned by entities with similar or the same mailing address are grouped together.

13. Review records to compare values for the DissolveID field, using values recorded for landowner name and ControllingEntity for further confirmation. Identify related or associated landowners and manually reassign values for the ControllingEntity field accordingly, using the following general guidelines:
 - Rather than review every record, focus instead on larger number of parcels having the same owner address;
 - Review all records for which four or more parcels have the same value for the Address_DSLV field;
 - Review all records for which two or three parcels have the same value for the Address_DSLV field only where the combined acreage exceeded 20 or 10 acres, respectively.
 - Multiple companies are more likely candidates for having the same controlling entity than are several apparently unrelated individuals. Therefore, be more conservative in reassigning multiple parcels owned by private individuals to the same controlling entity.
 - Whenever associating parcels under the same controlling entity, particularly for corporate owners, check for other parcels that have already been assigned the same Controlling Entity but that have different owner addresses, and reassign them all together.
14. Upon completing this review, save edits and end the editing session.
15. Within the watershed parcels layer create and three new fields as follows:
 - a. An integer field NameID
 - b. An integer field named NumParcelsControlled
 - c. A decimal field named AcresControlled_GIS
 - d. A decimal field named AcresControlled_Recorded
16. Populate the NameID field with a unique integer for every record by using the Field Calculator to copy values from the OBJECTID field.
17. Populate the NumParcelsControlled field using the Field Calculator to set the value for all records to one.
18. Use the Polygon to Point tool to create a new point version of the watershed parcels layer, specifying that the resulting points be located within the parent polygons.
19. Use the Delete Fields tool to remove all fields except NameID from the new parcel centerpoints layer.
20. Use the Dissolve tool to combine all records from the watershed parcel polygon layer having the same value for the ControllingEntity field. Report sum statistics for the NumParcelsControlled, Acres_GIS, and Acres_Recorded fields.
21. Begin an editing session in the resulting dissolve layer, delete records for which ControllingEntity is “unknown” and “various” as these do not represent accurate aggregations, save these edits and close the editing session.
22. Use the Intersect tool to combine this second dissolved parcel polygon layer with the newest parcel centerpoints layer.
23. Perform a Tabular Join to link the attribute table for this second intersect point layer with the original watershed parcel layer using NameID as the join field.
24. Use the Field Calculator to transfer the values for three fields in the joined table to their counterparts in the watershed parcel attribute table, as follows:
 - a. NumParcelsControlled_SUM to NumParcelsControlled;
 - b. Acres_GIS_SUM to AcresControlled_GIS;
 - c. Acres_Recorded_SUM to AcresControlled_Recorded.
25. Remove the join.

Assign Public, Tribal and Protection Status

While county tax parcel data documents public, tribal, and conservation non-profit ownership, it does not identify which of those lands have been designated for conservation or recreation purposes, address the management characteristics of those lands, or include recognition of other private lands restricted by conservation easement. The following process incorporates that additional information into the watershed parcel dataset.

1. Create in the watershed parcel layer five new fields to capture public, tribal and protection status information, as follows:
 - Ownership Type (text)
 - PublicLand (integer)
 - ProtectedLand (integer)
 - LandDesignation (text)
 - ProtectionLevel (integer)

The following list defines the range of classes attributable to the five public, tribal and protection status fields, which will be assigned in the steps below.

Ownership Type:	private tribal	municipal federal	county	state
PublicLand:	(1) publicly-owned land		(2) not publicly owned land	
ProtectedLand :	(1) protected land		(2) not protected land	
	Note that “protected” status requires permanent, legal protection for conservation, resource production or recreation values.			
LandDesignation:	Cemetery		Postal Services	
	Conservation Easement		Public Administration	
	Ecological Research Natural Area		Public Utility	
	Economic Development		Public Water Access	
	Education Services		Social Services	
	Emergency Services		State Fish Hatchery	
	Health Services		State Natural Resource Conservation Area	
	Indian Reservation			
	Land Trust Fee Land		State Other Conservation Area	
	Local Ecological Conservation Area		State Park	
	Local Open Space		State Trust Aquatic Land	
	Local Park or Recreation Area		State Trust Forest Land	
	Military Installation		State Wildlife Area	
	National Forest		Transportation Infrastructure	
	National Wilderness Area		Tribal Land	
			unknown	

- ProtectionLevel:
- (0) No ecological protection
 - (1) An area with an active management plan in operation that maintains natural conditions and within which natural disturbance events are generally allowed to proceed without interference. The management objective has legal standing and cannot be altered at the discretion of the administering agency, organization, or individual.
 - (2) An area managed generally in a non-extractive way for its natural values, but which may receive uses that degrade the quality of the natural communities that are present. Management objectives are not legally mandated for biodiversity conservation, and such objectives may be subject to administrative discretion.
 - (3) An area for which legal mandates prevent permanent conversion, but which is subject to extractive uses.
 - (4) Lands managed in ways that may preclude the holistic maintenance of native plant and animal assemblages.
 - (99) Privately protected or public lands managed for purposes other than natural resource conservation or ecological protection.
- Note that ecological protection levels 1-4 are those defined by the U.S. National Gap Analysis Program.

2. To assign public, tribal and protection status to the various fields for parcels located in Snohomish County, compare watershed parcels in that county with corresponding information documented in the 2012 Central Puget Sound Public, Tribal and Protected Lands Database (PLDB) as follows:
 - a. Use the Polygon to Point tool to create a point version of the watershed parcels layer, specifying that the resulting points be located within the parent polygons;
 - b. Use the Delete Fields tool to remove all fields except RecordID from the parcel centerpoints layer;
 - c. Use the Intersect tool to combine the parcel centerpoints layer with the 2012 PLDB;
 - d. Perform a Tabular Join to link the attribute table for the parcel intersect point layer with the original watershed parcel layer using RecordID as the join field, keeping only matching records in the resulting joined layer.
 - e. Using the PLDB data dictionary as a guide, use values from select fields in the joined table to assign values in the public, tribal and protection status fields of the watershed parcel layer as follows:
 - OwnershipType values will correspond to values in the OWNTYPE and OWNER fields;
 - PublicLand values will correspond to values in the OWNTYPE field;
 - ProtectedLand values will correspond to values in the AG_USE, FOR_USE, REC_USE, ECO_USE and ADMIN_USE fields;
 - LandDesignation values will correspond to values in the FEATURE1 field;
 - ProtectionLevel values will correspond to values in the PROTLEVEL field.
 Additional notes:
 - Some management designations for National Forest and Wilderness lands cross parcel boundaries. In these cases, assign LandDesignation and ProtectionLevel values to parcels based on the location of the parcel centers;
 - Designate all private water purveyors as “public utility”;

- Designate Arlington Airport lands as “public transportation”;
 - In an editing session, manually split all parcel polygons for which only a portion of the land area is protected by conservation easement in order to differentiate the protected from the unprotected portions.
 - f. After completing all field value assignments, remove the join and visually compare the results to the watershed parcel layer with the 2012 PLDB and make any necessary corrections manually.
- 3. No comprehensive source of public, tribal and protected land information exists for Skagit County. Assign public, tribal and protection status values to parcels in that county as follows:
 - a. Compare watershed parcels in Skagit County with the following agency and conservation reference datasets using the point-intersect-join approach described in step 2 above for Snohomish County:
 - Administrative and Ownership Boundaries, Mt. Baker-Snoqualmie National Forest
 - Designated Wilderness Boundaries, Mt. Baker-Snoqualmie National Forest
 - DNR Managed Land Parcels
 - Land Resource Management Plan, Mt. Baker-Snoqualmie National Forest
 - National Conservation Easement Database, Pacific Region
 - National Forest Inventoried Roadless Areas
 - NRCS Conservation Easement Area Boundaries
 - USFWS Administered Lands
 - WA State Park Boundaries
 - WDFW Interim Land Information System
 Additional notes:
 - Some management designations for National Forest and Wilderness lands cross parcel boundaries. In these cases, assign LandDesignation and ProtectionLevel values to parcels based on the location of the parcel centers;
 - Designate all private water purveyors as “public utility”;
 - In an editing session, manually split all parcel polygons for which only a portion of the land area is protected by conservation easement in order to differentiate the protected from the unprotected portions.
 - b. Additional public, tribal and private conservation lands will not be recorded in the above data sources. Identify and classify these additional lands as possible using a number of attribute fields derived from the county tax parcel database:
 - Owner_Name and Owner_Address_1 will identify lands owned by public agencies, tribes and nonprofit conservation organizations, and information in these fields will guide the classification of the OwnershipType and PublicLand fields;
 - LandUse_Assessed, in combination with Owner_Name and Owner_Address_1 will guide classification of the LandDesignation field. If information is insufficient to otherwise inform a classification, assign a value of “unknown” to the LandDesignation field;
 - Classify all lands owned by nonprofit conservation organizations as Protected Land. Classify public lands as Protected based on assessed land use and Land Designation. When uncertain, classify public lands as unprotected;
 - Assign ProtectionLevel classifications based on those made for similarly managed and designated lands in the PLDB for Snohomish County.

4. After having identified all publicly owned parcels in both counties, perform a Tabular Query to select all other parcels and use the Field Calculator to set the PublicLand field for these parcels equal to zero.
5. After having identified all privately owned lands that are protected in both counties, perform a Tabular Query to select all other privately owned parcels and use the Field Calculator to set the ProtectedLand and ProtectionLevel fields for these parcels equal to zero.
6. Use a Tabular Query to select all parcels in both counties that are neither public land nor protected land and use the Field Calculator to remove the NULL value in the LandDesignation field for these parcels using the following calculation:

$$\text{LandDesignation} = \text{''}$$

Adjust Land Use Categories

It is important to have an accurate classification of the predominant use of parcels within the watershed. All three prioritization analyses rely on the land use classification of a parcel as an analysis criteria. Additionally, land use information will be a useful reference for any organization using this data to plan or implement conservation or recreation actions. For public lands, the assessed land use assigned to a given parcel can often be inaccurate, inconsistent, or both.

Adjust land use fields for select federal and state lands to be more consistent with land designations, as follows:

- a. Identify state trust forest land and change Land Use Normalized to "State Forest Land" and Land Use Group to "Forestry".
- b. Based on Land Resource Management Plan data identify National Forest lands designated any of the following management types and change Land Use Normalized to "Federal Forest Land" and Land Use Group to "Forestry".
 - Late-Successional Old Growth
 - Late-Successional Reserve
 - Adaptive Management Area
 - Available
- c. Based on Land Resource Management Plan data identify National Forest lands designated "Administratively Withdrawn" management type and change Land Use Normalized to "Parks" and Land Use Group to "Park or Dedicated Open Space".
- d. Identify lands designated National Wilderness, Ecological Research Natural Areas and State Parks, Wildlife Areas, NRCAs and other state conservation areas and change Land Use Normalized to "Parks" and Land Use Group to "Park or Dedicated Open Space".
- e. Identify National Forest Inventoried Roadless Areas within the National Forest and change Land Use Normalized to "Parks" and Land Use Group to "Park or Dedicated Open Space". Note that Roadless designation trumps Land Resource Management Plan management type designations.

Note management type and roadless designations for National Forest and Wilderness lands in many cases cross parcel boundaries. In these instances, assign land use to parcels based on the category that applies to the larger portion of the parcel.

Mature Forest Cover Retention Priority

Data Preparation

In addition to the work described previously to develop the watershed-wide parcel dataset, the following data preparation steps are necessary before beginning the process of calculating the analysis metrics.

Metric Raster Dataset Parameters

Because this analysis will be conducted using a raster-based approach, it is essential to first define analysis raster cell size. Given the dimensions of smallest forest parcel, the ideal cell size would be smaller than 12ft square. In order to best preserve the spatial accuracy of all the source raster datasets during resampling, the ideal cell size also approximates a common denominator of the three source raster dataset cell sizes: land cover (98.4 ft), elevation (28.0 ft) and precipitation (4,060.0 ft). The largest cell size that best meets both these criteria is 7ft.

Begin the preparation of raster data with the slope metric, which has the highest resolution (smallest cell size) among all three of the source datasets. The analysis input raster layers for all other metrics should then be snapped to the 7ft slope raster to achieve greater precision in the results.

Reproject (if necessary) all input raster datasets to the working coordinate system: NAD 83 HARN, State Plane WA North (US feet).

Forest Parcels Raster Mask

Create a new vector data layer (Watershed Parcel Mask) to be used as a “mask” for defining the processing extent when extracting portions of input raster data that occur within the watershed study area. This layer should comprise the extent of all parcels within the watershed as defined by the Characterized Watershed Parcels layer, and is created by dissolving that layer into one single feature with no attributes other than OID. Manually edit as needed to fill in any holes within the extent of the layer so that the result is one, continuous polygon.

Working Forest Parcels Raster

Create a vector dataset (Forest Parcels) that comprises all working forest parcels within the watershed, to be used for evaluating the mature forest priority metrics, as follows:

1. Extract working forest lands from the Characterized Watershed Parcels dataset to create the Forest Parcels data layer. Working forest lands comprise all parcels for which the field LandUseGroup = Forestry.
2. Create a new integer field TmpID to provide a unique identity for all polygons in the dataset, and use the Field Calculator to populate it using the equation:
$$\text{TmpID} = \text{OBJECTID}$$
3. Use the Polygon to Raster tool to create a raster version of the forest parcel vector layer, ForParc7ft, at a cell size of 7ft. Use TmpID as the Value field, and snap the output to the 7ft. Slope input raster.

Metric Calculation

Calculate the metrics associated with each of the five mature forest retention priority criteria on an equivalent scale of values. Note that final scores for each of the metrics must be assigned such that larger values indicate greater favorability for mature forest cover retention.

Topographic Slope

1. Acquire 1/3 arc-second (approximately 10m) resolution National Elevation Dataset (NED) DEM coverage for the watershed and mosaic all component tiles using the Mosaic to New Raster tool.
2. Reproject the DEM mosaic into the working coordinate system using the cubic convolution technique and the Watershed Parcel Mask vector layer as the output extent.
3. Use the Raster Calculator tool to recalculate elevation cell values from meters to feet by multiplying by 3.2808.
4. Resample the DEM to a cell size of 7ft. using the cubic convolution technique.
5. Use the Spatial Analyst Extension's Slope tool to calculate a slope raster in degrees.
6. Use the Raster Calculator tool to normalize slope values to a scale of 1-100 as follows:
Minimum: 0
Maximum: 87.74244
$$\text{"Slope7ft_degrees_Norm"} = 100 * ((\text{"Slope7ft_degrees"} - 0) / (87.74244 - 0))$$
7. Run the Zonal Statistics as Table tool on the Slope7ft_Degrees_Norm raster with Forest Parcels 7ft raster layer to define the zones. Set the tool to ignore "no data" values within each zone. Save the output as a table named Slope_ParcelZone_Statistics
8. Create a copy of the Forest Parcels layer in which to record analysis results, and name that layer Forest Parcels Priority.
9. Create the following new decimal fields in the Forest Parcels Priority Layer:
 - MEAN_Slope_SCORE
 - STD_Slope_SCORE
 - SUM_Slope_SCORE
10. Perform a Tabular Join of the Slope zonal statistics table to the Forest Parcels Priority layer using tmpID and VALUE as the join fields and use the Field Calculator to transfer the MEAN, STD and SUM statistics from the joined table to the new slope statistics score fields created in step 9 above, then remove the join.

Local Precipitation Amount

1. Use the Clip Raster tool to extract data from that portion of the Mean Annual Precipitation source raster within the watershed study area using the Watershed Parcel Mask vector layer.
2. Reproject the clipped raster into the working coordinate system using the cubic convolution technique.
3. Resample the Precipitation raster to a cell size of 7ft using the cubic convolution technique and set the processing extent to snap the output to the 7ft. Slope input raster.
4. Use the Raster Calculator tool to normalize mean annual precipitation values to a scale of 1-100 as follows:
Minimum: 27.5113
Maximum: 185.557
$$\text{"MAPrecip_7ft_Norm"} = 100 * (\text{"MAPrecip_7ft"} - 27.5113) / (185.557 - 27.5113)$$
5. Run the Zonal Statistics as Table tool on the MAPrecip_7ft_Norm raster with Forest Parcels 7ft raster layer to define the zones. Set the tool to ignore "no data" values within each zone. Save the output as a table named Precipitation_ParcelZone_Statistics

6. Create the following new decimal fields in the Forest Parcels Priority Layer:
 - MEAN_Precip_SCORE
 - STD_Precip_SCORE
 - SUM_Precip_SCORE
7. Perform a Tabular Join of the Precipitation zonal statistics table to the Forest Parcels Priority layer using tmpID and VALUE as the join fields and use the Field Calculator to transfer the MEAN, STD and SUM statistics from the joined table to the new precipitation statistics score fields created in step 6 above, then remove the join.

Forest Maturity

1. Use the Reclassify tool to change the cover classes in the original land cover raster into maturity classes defined below so that higher values represent a greater degree of hydrological maturity:
 - Maturity 100: Mature evergreen forest (1)
Medium evergreen forest (2)
 - Maturity 85: Deciduous forest (3)
 - Maturity 60: Shrubs and small trees (4)
 - Maturity 35: Grass (5)
 - Maturity 10: Bare ground (6)
 - Maturity 1: Medium density development (7)
High density development (8)
Alpine rock/talus slope (9)
Open water (10)
Snow (11)

Note that the numbers in parenthesis indicate the values representing each land cover class in the original raster.

2. Resample the reclassified land cover (maturity class) raster to a cell size of 7ft using the nearest neighbor technique and set the processing extent to snap the output to the 7ft. Slope input raster. Name the resulting layer "ForestMaturity_7ft. Note that the source land cover raster was provided in the working coordinate system for this analysis, so there is no need to reproject the data.
3. Run the Zonal Statistics as Table tool on the ForestMaturity_7ft raster with Forest Parcels 7ft raster layer to define the zones. Set the tool to ignore "no data" values within each zone. Save the output as a table named Maturity_ParcelZone_Statistics
4. Create the following new decimal fields in the Forest Parcels Priority Layer:
 - MEAN_Maturity_SCORE
 - STD_Maturity_SCORE
 - SUM_Maturity_SCORE
5. Perform a Tabular Join of the Maturity zonal statistics table to the Forest Parcels Priority layer using tmpID and VALUE as the join fields and use the Field Calculator to transfer the MEAN, STD and SUM statistics from the joined table to the new maturity statistics score fields created in step 4 above, then remove the join.

Elevation-related Seasonal Precipitation Patterns

1. Reproject the source vector Rain On Snow data layer to the working coordinate system.
2. Use the Intersect tool to extract the reprojected Rain On Snow data where it intersects with the Watershed Parcel Mask layer.

3. Create a new field ROS_Value in the intersected Rain On Snow layer to represent the following values representing an approximation of the probability of a rain-on-snow event within each of the elevation zones and use the Field Calculator to fill-in those values as follows:
 - HL (Highland) 10
 - SD (Snow-dominated) 70
 - RS (Peak Rain-On-Snow) 100
 - RD (Rain-dominated) 25
 - LL (Lowland) 1
4. Use the Polygon to Raster tool to rasterize the intersected Rain On Snow layer to a cell size of 7ft. Use the Maximum Area cell assignment type, set the raster attribute value field to ROS_Value and set the processing extent to snap the output to the 7ft. Slope input raster. Name the resulting layer ROS_7ft.
5. Run the Zonal Statistics as Table tool on the ROS_7ft raster with Forest Parcels 7ft raster layer to define the zones. Set the tool to ignore “no data” values within each zone. Save the output as a table named ROS_ParcelZone_Statistics
6. Create the following new decimal fields in the Forest Parcels Priority Layer:
 - MEAN_ROS_SCORE
 - STD_ROS_SCORE
 - SUM_ROS_SCORE
7. Perform a Tabular Join of the ROS zonal statistics table to the Forest Parcels Priority layer using tmpID and VALUE as the join fields and use the Field Calculator to transfer the MEAN, STD and SUM statistics from the joined table to the new ROS statistics score fields created in step 6 above, then remove the join.

Timber Harvest Intensity

1. In the Forest Parcels vector dataset, create a new field to record forest Management Type and use the Field Calculator to assign classes as follows:
 - a. Assign National Forest lands to the following classes based on the USFS Land Resources Management Plan management type designations for the Mt. Baker-Snoqualmie National Forest. Assign lands with no apparent designation to the class most prevalent among the adjacent parcels:
 - USFS Late-Successional Old Growth
 - USFS Late-Successional Reserve
 - USFS Adaptive Management Area
 - USFS Available
 - b. Assign all lands owned by the Tulalip, Sauk-Suiattle or Stillaguamish Tribes as “Tribal Forest”.
 - c. Assign all lands managed by the WA Department of Natural Resources Trust Forest program as “State Forest”.

- d. Divide private lands into two categories based on landowner name as follows:
 - Assign private lands whose landowners are generally assumed to manage their lands primarily or exclusively to maximize income to the “Commercial or Industrial Forest” category. Assignment to this category will include known timber companies as well as other companies, “incorporateds” and most LLCs.
 - Assign private lands whose landowners are generally assumed to manage their lands less intensively, and often with other priorities in addition to income generation, to the “Family Forest” category. Assignment to this category will include individuals, family partnerships and trusts, LLCs and “incorporateds” with either family names or “Farm” in their names, as well as LPs and LLPs.
 - Assign lands owned nonprofit organizations with a known conservation purpose to the “Family Forest” category.
 - Assign the small remaining amount of forest land in the watershed owned by religious institutions, foundations and other nonprofit organizations to a category based on the appearance of their land in 2013 aerial photography: Lands that appear to be managed heavily for timber production should be assigned to the “Industrial/Commercial” category, and those that do not should be assigned to the “Family”.
2. Create a new field HarvestIntnsty_SCORE in the Forest Parcels layer and use the Field Calculator to populate it with the following ratings based on the Management Type field:
 - Tribal Forest: 10
 - USFS Late-Successional Reserve: 10
 - USFS Adaptive Management Area: 30
 - USFS Available: 40
 - Family Forest: 70
 - State Forest: 70
 - Commercial or Industrial forest: 100
3. Use the Polygon to Raster tool to create a raster versions of the Forest Parcel vector data, using HarvestIntnsty_SCORE to populate the raster Value field. Use the Maximum Area cell assignment type and set the processing extent to snap the output to the 7ft. Slope input raster. Name the resulting layer HrvstIntnsty_7ft.

Overlay Analysis

Weight and combine the scores for each of the five mature forest cover retention priority metrics, then aggregate the results for the individual cells to the forest parcels they fall within to arrive at an overall assessment of priority for all forest parcels.

1. Use the Weighted Sum overlay analysis tool to overlay and combine the values of each metric dataset, naming the output raster WeightedSumOverlay. Set the weighting factor for each metric as follows:
 - Topographic Slope 1.0
 - Elevation-Related Seasonal Precipitation 1.5
 - Timber Harvest Intensity 2.0
 - Forest Maturity 2.5
 - Local Precipitation Amount 3.0

2. Run the Zonal Statistics as Table tool on the weighted sum overlay results with the Forest Parcels 7ft raster layer to define the zones. Set the tool to ignore “no data” values within each zone
3. Create the following three new decimal fields in the Forest Parcels Priority:
 - MEAN_WeightedSum_SCORE
 - STD_WeightedSum_SCORE
 - SUM_WeightedSum_SCORE
8. Perform a Tabular Join of the weighted sum zonal statistics table to the Forest Parcels Priority layer using TmpID and Value as the join fields, and use the Field Calculator to transfer the MEAN, STD and SUM statistics from the joined table to the new weighted sum overlay statistics score fields created in step 3 above, then remove the join.

Floodplain Restoration Priority

Data Preparation

In addition to the work described previously to prepare the watershed-wide parcel dataset for this analysis, the following steps were necessary before beginning the process of calculating the analysis metrics.

For the purposes of this analysis, the assignment of a riverbank as either “left” or “right” will in all cases be made from a perspective oriented in the direction of flow. In other words, if one were to be floating along the river facing downstream, the left bank will be located to one’s left, and the right bank to one’s right.

Floodplain Units

A floodplain is an area of low-lying ground adjacent to a river, with soils formed mainly of river sediments and subject to periodic flooding. Floodplain Units (FPUs) are those discrete portions of the floodplain that could reasonably be expected to be affected as the result of any restoration or mitigation activity, undertaken at a particular location, which increases inundation of the floodplain.

The following criteria guided the delineation of floodplain units:

1. Land areas that are less than or equal to 5 feet above the 100 year flood elevation of the adjacent stream.
2. Individual FPU’s include land that is on only one side of the stream.
3. FPU’s are split by major highways or other infrastructure deemed unlikely to be removed.
4. FPU’s are bordered by the subject stream.
5. An FPU must be significantly wider than the bank-full width (BFW) of the adjacent river channel.
6. An FPU must be greater than 5 acres in area.
7. An FPU with multiple lobes should be split if the lobes are hydrologically distinct.

The following steps were performed to create the initial Floodplain Unit Boundary data layer:

1. Extract the 100-yr Flood Elevation Cross Section line dataset for the watershed to the floodplain area of interest.
2. Use Feature Vertices to Points tool to convert all vertices of the 100-year Flood Elevation Cross Section line dataset within the area of interest to a point feature layer (the “Flood Elevation Point” layer).
3. Use the Inverse Distance Weighted Interpolate to Raster tool to create an elevation raster dataset from the Flood Elevation Point layer (the “Flood Elevation” raster). Use a floodplain area mask to clip the result to the area surrounding the floodplain.
4. Use the Mosaic to New Raster tool to create a complete floodplain LiDAR elevation raster for the North and South Forks of the Stillaguamish River.
5. Use the Raster Calculator tool to subtract the Flood Elevation raster from the floodplain LiDAR elevation raster to create a “Flood Neutral Elevation” raster.
6. Use Raster Calculator to identify from within the Flood Elevation Neutral Raster the land area corresponding to elevations less than or equal to 5 (the “FPU Eligible Area Raster”). These are the areas that satisfy FPU Criteria 1, above.
7. Create a polygon version of the FPU Eligible Area Raster using the Raster to Polygon tool (the “FPU Eligible Polygon” layer).

8. Manually digitize stream banks at bank-full width (BFW) throughout the floodplain area of interest based on visual inspection of the 2011 NAIP aerial photography. Use the Feature to Polygon tool to enclose the area between the bank lines and create the BFW Wetted Area polygon layer.
9. Remove the area of the river channel at bank-full width from the preliminary FPU areas using the Erase Tool to erase the BFW Wetted Area polygon layer from the FPU Eligible Polygon.
10. Use the Multipart to Singlepart tool to separate the FPU Eligible Polygon multipart features into singlepart features.
11. Add a new decimal field Area to the FPU Eligible Polygon layer and populate using the Calculate Geometry tool with units in acres.
12. In an editing session, select and delete all FPU Eligible Polygon features that are less than 5 acres in area in accordance with FPU Criteria 6, above.
13. In an editing session, select and delete all FPU Eligible Polygon features that are more than 5 feet above the 100-year flood elevation in accordance with FPU Criteria 1, above.
14. In an editing session, manually correct all floodplain unit boundaries as necessary to meet FPU Criteria 3 – 7 above, including the following steps to simplify unnecessarily complex boundaries:
 - a. Delete vertices to smooth floodplain unit boundaries;
 - b. Fill all small holes otherwise entirely surrounded by floodplain unit polygons, which represent small areas within individual floodplain units that rise above the 5-foot elevation limit.
15. Add a new integer field FPU and manually number each floodplain unit beginning at the confluence of the North and South Forks and increasing sequentially upstream, but with even numbers for floodplain units bordering the river's right bank (facing downstream) and odd numbers for those bordering the left bank.
16. Add a new text field Fork to identify which fork of the river each floodplain unit lies along, and populate that field with "North Fork" or "South Fork" as appropriate.
17. Add a new text field FPU_ID to serve as a unique ID for each floodplain unit. Use the Field Calculator to populate the field by appending the floodplain unit number to either an "N" or an "S" to indicate which fork of the river the floodplain unit is located along, as follows:
 FPU_ID = "N" & FPU -or- FPU_ID = "S" & FPU
18. Name the resulting floodplain unit boundary polygon layer Floodplain Unit Boundaries.

Centerline Station Points

Three floodplain metrics – Armoring, Channel Constriction and Sinuosity – will be calculated using a technique that employs a data layer composed of point features (Centerline Station Points) located along the main river channel centerline spaced at distances of 50 feet starting from the confluence of the North and South Forks and continuing upstream to the upper limit of Chinook spawning habitat. The three metrics will be calculated at the location of these station points, the station points will then be associated with the floodplain unit bordering them along both the left and right banks of the rivers, and then the statistical average of each metric at the location of all station points along a given floodplain unit will be used to generate that metric's score for the floodplain unit.

Create the initial Centerline Station Points data layer as follows:

1. Manually digitize the stream centerline of the both the North and South Forks from the confluence to upper limit of the analysis area of interest as two single polyline features.

2. In an editing session, use the Split command within the Editor Tools to split the stream centerline layer into 50-foot segments.
3. Use the Feature Vertices to Point tool to convert segment midpoints in the stream centerline layer to points, naming the resulting layer Centerline Station Points.
4. Add a new integer field named Station to the Centerline Station Points layer to serve as a unique ID field and populate it using the Field Calculator as follows:

$$\text{Station} = \text{FID} + 1$$
 Check and edit results as needed to ensure that Station 1 is 25 feet from the confluence and station numbers continue in order to the upper limit of the analysis area.
5. Add a new integer field named RiverFeet to the Centerline Station Points layer and populate it using the Field Calculator as follows:

$$\text{RiverFeet} = (\text{Station} * 50) - 25$$
6. Add new decimal fields named X_Coord and Y_Coord and populate them using the Calculate Geometry tool with the latitude and longitude coordinates of each point feature, in units of feet.

Floodplain Parcels

Extract all features from the Characterized Watershed Parcels layer that intersect the Floodplain Unit layer and save them in a new layer named Floodplain Parcels for use in the calculations of the Number of Landowners and Land Use Types metrics as described below.

Metric Calculation

Calculate the metrics associated with each of the six floodplain restoration priority criteria using an equivalent scale of values. Note that final scores for each of the metrics must be assigned such that larger values indicate greater favorability for restoration.

Bank Armoring

The analysis metric for river bank armoring will be calculated as the percent of armored river frontage along each floodplain unit.

1. Add two new text fields, BANK and Armor, to the Stream Banks BFW polyline layer created during the process of delineating floodplain units.
2. In an editing session, classify which side of the stream each line lies upon as 'LEFT', 'RIGHT', or 'END' where the latter denotes the limits of the floodplain area of interest and encloses the left and right banks.
3. In an editing session, manually split bank lines as needed to delineate the beginnings and ends of each armoring feature based on a visual interpretation of the 2011 NAIP aerial photography and classify the ARMOR field attribute for each segment as 'YES' or 'NO' as appropriate. Note: Six members of the Tribal natural resources staff with current, first-hand experience of the North and South forks provided review and correction for this information.
4. Use Selection and Export tools to create separate polyline layers representing the left and right banks of both Forks of the river.
5. Use the Dissolve tool to create a single-feature version of the left- and right-bank layers, preserving none of the parent attributes.
6. In an editing session, use the Split by Distance tool to split these dissolved left- and right-bank polyline layers into 50-foot segments.

7. Use the Feature Vertices to Point tool to convert segment midpoints into point layers (“Left Bank Station Points” and “Right Bank Station Points”).
8. Use the Spatial Join tool to assign the presence or absence of armoring recorded in the Stream Banks BFW polyline layer as new “Armor” attributes to each of the two Bank Station Points layers.
9. Add a new integer field ArmorCode to each of the two Bank Station Points layers. Use the Tabular Selection and Field Calculator tools to populate ArmorCode so that banks with no armoring = 0; right banks armored = 10; left banks armored = 20.
10. Perform a Spatial Join between the two Bank Station Point layers using the Right Bank layer as the Join features and the Left Bank layer as the target features, producing a new “Left Bank Attributed Station Points” layer. Specify a new decimal field Join_Distance to record the Euclidean distance between each point joined between the two layers.
11. Create a new integer field ARMOR in the Left Bank Attributed Station Points layer and populate it using the Field Calculator as follows: $ARMOR = ArmorCode + ArmorCode1$. The resulting field values will then be either 0 (no armoring), 10 (right bank armoring), 20 (left bank armoring), or 30 (armoring along both banks).
12. Create a new decimal field BFW to the Left Bank Attributed Station Points layer and populate it using the Field Calculator with the values from the Join_Distance field. Note: This step will produce the actual bank-full width distance measurements (A_BFW field) that will be used in the Channel Constriction metric calculations below.
13. Perform a Spatial Join of the Left Bank Attributed Station Point layer to the Centerline Station Points 1 layer in order to associate armoring length information to the centerline station point locations. Name the resulting layer Centerline Station Points 2.
14. In ArcMap, create a new version of the Floodplain Units polygon layer named “FloodplainUnits_Analysis”, to be used to aggregate the results of the Armoring as well as the five additional analysis metrics, the calculation of which will be described in later sections.
15. From the Floodplain Units Analysis layer, select and export the features along the left banks and then again along the right banks of the rivers as separate layers named Floodplain Units Left and Floodplain Units Right, respectively.
16. Perform Spatial Joins of first the Left and then the Right floodplain unit layers to the Centerline Station Points 2 layer to create new layers Left Join and Right Join, respectively, in order to associate the FPU_ID for the floodplain unit along which each station point is located with the measurements for armoring.
17. Inspect the results of each join and edit as needed to ensure that:
 - All of the points that represent the centerline of the main channel adjacent each floodplain unit are included in the join, especially where the stream is at its widest;
 - No extraneous centerline points remain such as in cases where floodplain unit boundaries are near sharp river bends.
18. Export the attribute tables for both the Left Join and Right Join layers to Excel, append them, and remove the records for any station point that was not joined to a floodplain unit.

19. In Excel, add the following fields to the Station Point worksheet and populate them for each station point using the calculations indicated:
 - FPU_Bank: The side of the river that the floodplain unit each station point is assigned to lies along.

$$\text{FPU_Bank} = \text{IF}(\text{ISEVEN}([\text{FPU}] = \text{TRUE}), \text{"RIGHT"}, \text{"LEFT"})$$
 - Armor_Right: The length of armoring in feet along the right side of the river at each station point.

$$\text{Armor_Right} = \text{IF}(\text{OR}([\text{ARMOR}] = 30, [\text{ARMOR}] = 10) = \text{TRUE}, 50, 0)$$
 - Armor_Left: The length of armoring in feet along the right left side of the river at each station point.

$$\text{Armor_Left} = \text{IF}(\text{OR}([\text{ARMOR}] = 30, [\text{ARMOR}] = 20) = \text{TRUE}, 50, 0)$$
 - Armor_ft: The length of armoring in feet along the river frontage of each floodplain unit.

$$\text{Armor_ft} = \text{IF}([\text{FPU_Bank}] = \text{"RIGHT"}, [\text{Armor_Right}], [\text{Armor_Left}])$$
 - Armor_Op: The length of armoring in feet along the opposite-side bank of the river of each floodplain unit.

$$\text{Armor_Op} = \text{IF}([\text{FPU_Bank}] = \text{"LEFT"}, [\text{Armor_Right}], [\text{Armor_Left}])$$
20. Derive the lengths of armoring in feet along both the river frontage as well as along the opposite bank of each floodplain unit by using the pivot table functionality of Excel to calculate the sum of those measurements for all station points associated with each floodplain unit.
21. Load the Excel pivot table containing the floodplain unit armoring measurements into ArcMap as a table.
22. In the Floodplain Units Analysis layer, create the following new decimal fields to receive the armoring measurements for each floodplain unit that were calculated using Excel:
 - Armor_ft; Armor_Op
23. Join the table derived from Excel containing the armoring measurements to the Floodplain Units Analysis layer using FPU_ID as the join field.
24. Use the Field Calculator to transfer the armoring measurements from the joined table to their corresponding fields in the attribute table of the Floodplain Units Analysis layer, then remove the join.

Once the Armoring metrics were represented as attributes in the Floodplain Units Analysis layer, the restoration score for all floodplain unit polygons can be calculated as follows:

1. In the Floodplain Units Analysis layer create a new decimal field Armor_Percent and populate that field with the calculation of the percent of the FPU frontage that is armored as follows:

$$\text{Armor_Percent} = \text{Armor_ft} / \text{Frontage_f}$$
2. Create a new integer field Armor_SCORE_Restoration and populate it using the Field Calculator to convert the percentage of each floodplain unit that is armored from a fraction to a scale of 1-100 as follows:

$$\text{Armor_SCORE_Restoration} = 100 * \text{Armor_Percent}$$
3. Several floodplain units within the watershed are unarmored and thus score "0" for the armoring metric: To facilitate accurate calculation of priority, use the Field Calculator to set $\text{Armor_SCORE_Restoration} = 1$.

Stream Sinuosity

The analysis metric for river channel sinuosity will be calculated as the ratio of the distances between two points along the centerline of the river channel divided by the Euclidean, or straight-line distance between those same two points, averaged along the length of the river channel adjacent to each floodplain unit.

1. Export the attribute table for the Centerline Station Points 2 layer, created during step 13 of the Armoring metric, above, to Excel in order to calculate the sinuosity measurement at each station point.
2. In Excel, add a new field named SIN_2500 in which to calculate the sinuosity. Populate that field with a formula that, for every station point, divides the riverfeet distances of all pairs of stations 1,250 riverfeet upstream and 1,250 riverfeet downstream of that point by the Euclidean distance between those same upstream and downstream point's geographic coordinates, as follows:

$$\text{SIN}_{2500} = (\text{RF}_{\text{up}} - \text{RF}_{\text{down}}) / (\text{SQRT}(((\text{X}_{\text{down}} - \text{X}_{\text{up}})^2) + (\text{Y}_{\text{down}} - \text{Y}_{\text{up}})^2))$$

Where:

- RF_{up} = Riverfeet of the station 1,250 feet upstream
- RF_{down} = Riverfeet of the station 1,250 feet downstream
- X_{up} = X coordinate of the station 1,250 feet upstream
- X_{down} = X coordinate of the station 1,250 feet downstream
- Y_{up} = Y coordinate of the station 1,250 feet upstream
- Y_{down} = Y coordinate of the station 1,250 feet downstream

Note that "Riverfeet" refers to the distance of a given station point along the meandering course of the river from the confluence of the two forks of the river as calculated during step 5 of the creation of the Centerline Station Points layer above.

3. Use the pivot table functionality of Excel to calculate statistics for the sinuosity measurements of all station points associated with each floodplain unit, creating the following three fields:
 - Avg_SIN_25: Average of all sinuosity station point measurements along the channel adjacent each floodplain unit
 - Min_SIN_25: Minimum sinuosity station point measurement along the channel adjacent each floodplain unit
 - Max_SIN_25: Maximum sinuosity station point measurement along the channel adjacent each floodplain unit

Note that the process of associating station points with the FLU_ID of the floodplain units adjacent to them was completed in steps 14-17 of the process for calculating the Armoring metric above.

4. Load the Excel pivot table containing the sinuosity statistics for each floodplain unit as a table into ArcMap.
5. In the Floodplain Units Analysis layer, produced in step 14 of the Armoring metric, above, create the following three new decimal fields to receive from the pivot table the sinuosity statistics for each floodplain unit:
 - Avg_SIN_25; Min_SIN_25; Max_SIN_25
6. Join the pivot table to the Floodplain Units Analysis layer using FLU_ID as the join field.

7. Use the Field Calculator to transfer the sinuosity statistics from the joined table to its corresponding field in the Floodplain Units Analysis layer attribute table, then remove the join.

Once the Sinuosity metrics have been represented as attributes in the Floodplain Units Analysis layer, calculate the restoration score for all floodplain unit polygons as follows:

1. Given the technique used to measure average sinuosity along the river frontage of each floodplain unit, values range from approximately 1 to 1.57, with lower values indicating less sinuous or straighter stretches of river. To ensure that straighter stretches of river, which are more favorable candidates for restoration, are represented by higher scores for this metric as required by the analysis methodology, reverse the numeric scale for sinuosity by creating a new decimal field Avg_Sinuosity_Inverse and populating it using the Field Calculator as follows:

$$\text{Avg_Sinuosity_Inverse} = 1/\text{Avg_SIN_25}$$
2. Create a new decimal field Sinuosity_Score_Prelim_Restoration in the Floodplain Units Analysis layer and populate it using the Field Calculator to multiply the inverse values by 100 to raise the scale into values above 1 as follows:

$$\text{Sinuosity_Score_Prelim_Restoration} = 100 * \text{Avg_Sinuosity_Inverse}$$
3. Create a new decimal field Sinuosity_SCORE_Restoration and populate it with sinuosity score values normalized to a scale of 1-100 as follows:
 Minimum: 63.543221
 Maximum: 99.95482

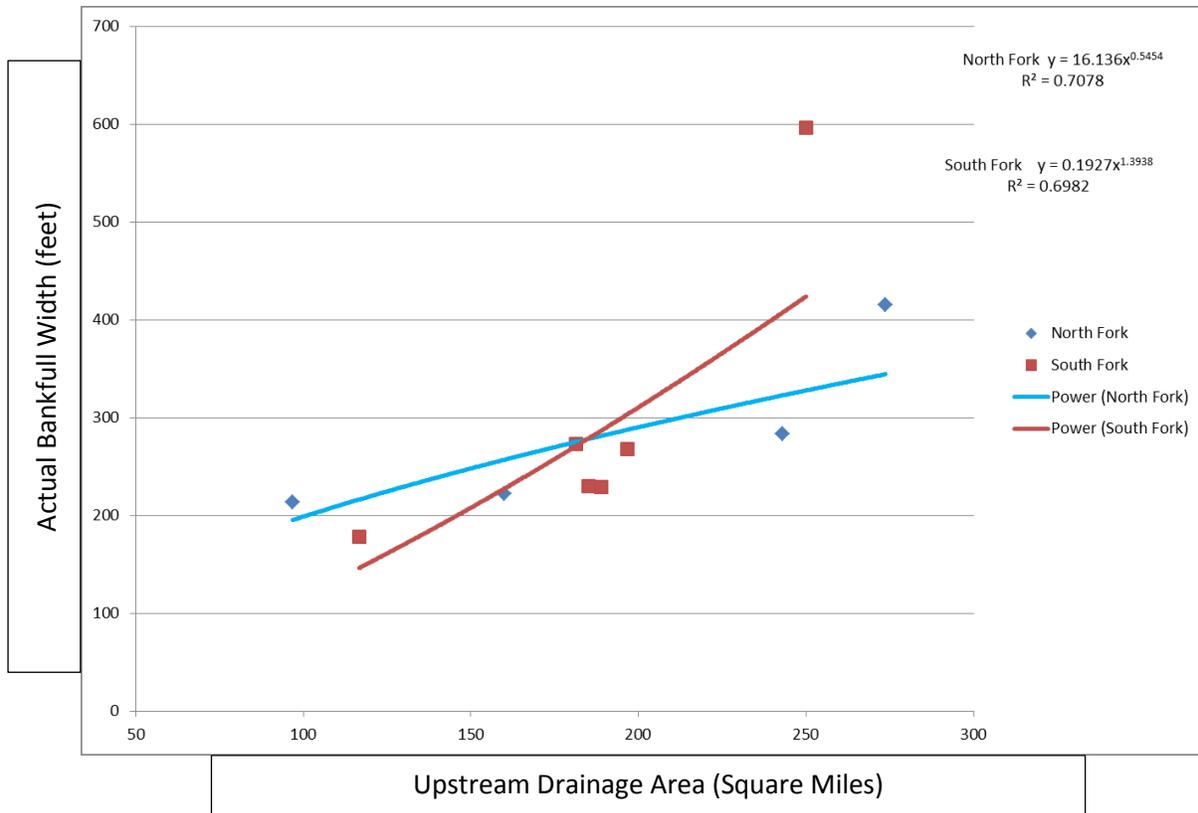
$$\text{Sinuosity_SCORE_Restoration} = 100 * ((\text{Sinuosity_Score_Prelim_Restoration} - 62.543221) / (99.95482 - 62.543221))$$

Channel Constriction

The analysis metric for channel constriction will be calculated as the ratio of the average actual bank-full width divided by the average “expected” bank-full width of the river channel adjacent each floodplain unit. Regression analysis will be used to establish an exponential relationship between the area drained, represented by flow accumulation derived from pour-point data, and the bank-full width of the river at unconstrained locations along the river. That relationship, in the form of an equation, will then be used to calculate an estimate for the “expected” bank-full width of the river at each station point.

1. In ArcMap, add the Flow Accumulation as Pour Points (“Flow_Acc_Mainstems”) data layer, which was derived from LiDAR and other DEM’s and contains upstream drainage area values (“Sq_M_Drain” field) in square miles for points along the North and South Forks.
2. Perform a Spatial Join of Flow_Acc_Mainstems to the Centerline Station Points 2 layer, created in step 13 of the Armoring metric, above, to assign flow accumulation values to the centerline station points. Note that the Centerline Station Points 2 layer already contains the actual bank-full width measurements at each point, which were created in step 12 of the Armoring metric. Name the resulting layer Centerline Station Points 3.
3. In ArcMap, separately for each Fork, display in four quantitative classes the area drained measurements within the Centerline Station Points 3 layer.
4. As inputs to the regression analysis, select a station point from each Fork of the river within each of the four quantitative classes of area drained (select eight points total). Choose points that appear to be as free as possible of artificial or natural barriers that would constrain the river’s movement or width. Measurements of actual bank-full width at these points will serve as models for the expected bank-full width of an unconstrained channel.

5. In a separate Excel worksheet, create new fields for the actual bank-full width (A_BFW) and square miles drained (Sq_M_Drain), then enter the corresponding values for the model centerline station points.
6. Create scatter plots of the model centerline station points for each fork of the river using the values for square miles drained along the x-axes, and the values for actual bank-full width values along the y-axes.
7. Use the regression analysis tools in Excel to calculate the best fit trend-line and its corresponding equation describing the relationship between the actual bank-full width and area drained for the four model station points along each Fork of the river.



The scatter plot shown above portrays the selected station point data with the actual bank-full width along the y-axis and the area drained in square miles along the x-axis. The trend-line shows the best fit exponential prediction of the expected bank-full width for an unconstrained channel along each of the four flow accumulation (area drained) ranges. The equations describing that relationship for each fork will be used to estimate the Expected Bankfull Widths for all other station points along the appropriate fork within the floodplain area of interest.

8. Working in Excel with the attributes exported from the Centerline Station Points 3 data layer, calculate the Expected Bank-full Width (E_BFW) for all station points using the following formulae for each fork, where “y” represents the expected bank-full width and “x” the flow accumulation area in square miles:

North Fork: $y = 16.136x^{0.5454}$
 South Fork: $y = 0.1927x^{1.3938}$

9. Create a new field A_E_BFW in Excel and calculate the metric for channel constriction at each station point as the actual bank-full width (A_BFW) divided by the expected bank-full width (E_BFW).
10. Use the pivot table functionality of Excel to calculate statistics for the actual and expected bank-full width measurements and the channel constriction metric (actual divided by expected) of all station points associated with each floodplain unit, creating the following fields:
 - Avg_A_BFW: Average of all actual bank-full width station point measurements along the channel adjacent each floodplain unit
 - Min_A_BFW: Minimum actual bank-full width station point measurement along the channel adjacent each floodplain unit
 - Max_A_BFW: Maximum actual bank-full width station point measurement along the channel adjacent each floodplain unit
 - Avg_E_BFW: Average of all expected bank-full width station point measurements along the channel adjacent each floodplain unit
 - Min_E_BFW: Minimum expected bank-full width station point measurement along the channel adjacent each floodplain unit
 - Max_E_BFW: Maximum actual bank-full width station point measurement along the channel adjacent each floodplain unit
 - Avg_A_E_BF: Average of all actual divided by expected bank-full width station point measurements along the channel adjacent each floodplain unit
 - Min_A_E_BF: Minimum actual divided by expected bank-full width station point measurement along the channel adjacent each floodplain unit
 - Max_A_E_BF: Maximum actual divided by expected bank-full width station point measurement along the channel adjacent each floodplain unit
11. In the Floodplain Units Analysis layer, produced in step 14 of the Armoring metric calculations, above, use ArcMap to create the following new decimal fields to receive the bank-full width and channel constriction statistics, calculated using Excel, for each floodplain unit:
 - Avg_A_BFW; Min_A_BFW; Max_A_BFW; Avg_E_BFW; Min_E_BFW; Max_E_BFW; Avg_A_E_BF; Min_A_E_BF; Max_A_E_BF
12. Load the Excel pivot table containing these statistics for each floodplain unit into ArcMap as a table.
13. Join the Excel pivot table to the Floodplain Units Analysis layer using FPU_ID as the common field.
14. Use the Field Calculator to transfer the statistics from the joined table to their corresponding fields in the attribute table of the Floodplain Units Analysis layer, then remove the join.

Once the Channel Constriction metrics are represented as attributes in the Floodplain Units Analysis layer, calculate the restoration score for all floodplain unit polygons as follows:

1. Given the technique used to estimate channel constriction of the river adjacent to each floodplain unit, constriction values range from approximately 0.59 to 1.79, with lower values indicating more constricted channels. To ensure that more constrained channels, which are more favorable candidates for restoration, are represented by higher scores for this metric as required by the analysis methodology, reverse the numeric scale for channel constriction by creating a new decimal field Avg_Constriction_Inverse and populating it using the Field Calculator as follows:

$$\text{Avg_Constriction_Inverse} = 1 / \text{Avg_A_E_BFW}$$

2. Create a new decimal field `Constriction_Score_Prelim_Restoration` in the Floodplain Units Analysis layer and populate it using the Field Calculator to multiply the inverse values by 100 to raise the scale into values above 1 as follows:

$$\text{Constriction_Score_Prelim_Restoration} = 100 * \text{Avg_Constriction_Inverse}$$
3. Create a new decimal field `Constriction_SCORE_Restoration` and populate it with sinuosity score values normalized to a scale of 1-100 as follows:
 Minimum: 55.951506
 Maximum: 169.65802

$$\text{Constriction_SCORE_Restoration} = 100 * ((\text{Constriction_Score_Prelim_Restoration} - 54.951506) / (169.65802 - 54.951506))$$

Floodplain Elevation

The floodplain elevation metric will be calculated as the average depth of each floodplain unit relative to the 100-year flood elevation.

1. Use the Zonal Statistics as Table tool to derive the Average Relative Elevation metric for each floodplain unit as follows:
 - a. Specify the Floodplain Units polygon layer as the input feature zone layer;
 - b. Set the `FPU_ID` field as the zone field;
 - c. Use the Flood Neutral Elevation raster, created in step 5 of the Floodplain Unit section of the Data Preparation work, as the input value raster;
 - d. Report the mean relative elevation statistic in the output table.
2. In the Floodplain Units Analysis layer, create a new decimal field `Ave_Rel_El` to receive the calculations for the average elevation of each floodplain unit relative to the 100-year flood level.
3. Perform a Tabular Join of the Zonal Statistics table, created in step 1, to the Floodplain Units Analysis layer using `FPU_ID` as the join field.
4. Use the Field Calculator to transfer the average relative elevation calculations from the Zonal Statistics table to the Floodplain Units Analysis layer, and then remove the join.
5. Use the Raster Calculator to create a new raster layer named `Below_Flood` that identifies all grid cells within the Flood Neutral Elevation raster that lie below the 100-year flood elevation using the following expression:

$$[\text{Below_Flood}] = [\text{Flood Neutral Elevation}] \leq 0$$
 In the resulting raster, the value for all cells above the 100-year flood elevation will be 0 and, for those at or below that elevation, 1.
6. Use the Zonal Statistics as Table Tool to derive the percentage of each floodplain unit that lies below the 100-year flood elevation as follows:
 - a. Specify the Floodplain Units Boundary layer as the input feature zone layer;
 - b. Set the `FPU_ID` field as the zone field;
 - c. Use the raster layer `Below_Flood` as the input value raster;
 - d. Report the sum and count statistics in the output table.
7. In the Floodplain Units Analysis layer, create a new decimal field `PCT_BelowF` to receive the calculations for the percent of each floodplain unit's area that lies below the 100-year flood level.
8. Perform a Tabular Join of the Zonal Statistics table, created in step 6, above, to the Floodplain Units Analysis layer using `FPU_ID` as the join field.
9. Use the Field Calculator to transfer the percent below flood elevation calculations from the Zonal Statistics table to the Floodplain Units Analysis layer using the following expression:

$$\text{PCT_BelowF} = \text{Sum/Count}$$
 Then remove the join.

Once the Floodplain Elevation metrics have been represented as attributes in the Floodplain Units Analysis layer, calculate the restoration score for all floodplain unit polygons as follows:

1. Given the technique used to measure average elevation of each FPU relative to the 100-year flood level, values range from approximately -8.28 to 3.06 ft. To avoid the complication of using measurements that include both positive and negative numbers and ensure that lower average floodplain elevation, which are more favorable candidates for restoration, are represented by higher scores for this metric as required by the analysis methodology, adjust and reverse the numeric scale for floodplain elevation recorded in the Floodplain Units Analysis layer as follows:
 - a. Create a new decimal field Avg_FPU_Elevation_Plus9 and populate that field using the Field Calculator as follows:

$$\text{Avg_FPU_Elevation_Plus9} = \text{Ave_Rel_EI} + 9.28471$$
 - b. Create a new decimal field Avg_FPUelevationPlus9_Inverse and populate it with the inverse of the adjusted average using the Field Calculator as follows:

$$\text{Avg_FPUelevationPlus9_Inverse} = 1 / \text{Avg_FPU_Elevation_Plus9}$$
2. Create a new decimal field FPUelevation_Score_Prelim and populate it using the Field Calculator to multiply the inverse values by 100 to raise the scale into values above 1 as follows:

$$\text{FPUelevation_Score_Prelim} = 100 * \text{Avg_FPUelevationPlus9_Inverse}$$
3. Create a new decimal field FPUelevation_SCORE and populate it with sinuosity score values normalized to a scale of 1-100 as follows:

Minimum: 8.101935
Maximum: 100

$$\text{FPUelevation_SCORE} = 100 * ((\text{FPUelevation_Score_Prelim} - 7.101935) / (100 - 7.101935))$$

Land Use Type

The metric addressing the favorability of different land use types found within the floodplain will be calculated by rating each use on a scale from 10-100 and multiplying that rating by the proportion of each floodplain unit corresponding to that use.

1. Create a new integer field LandUse_Favor in the Floodplain Parcels data layer and use the Tabular Selection tool and Field Calculator to assign values to that field indicating favorability based on the LandUse_Group field values according to the following relationships:
 - Water Area 100
 - Undeveloped/vacant 100
 - Mining 100
 - Forestry 90
 - Park/Open Space 90
 - Agriculture (Current Use tax) 80
 - Recreation 70
 - Agriculture (other than Current Use) 50
 - Residential 50
 - Social or Governmental Services 30
 - Infrastructure (transportation/ utility) 20
 - Commercial 10
 - Industrial 10

2. Make a temporary copy of the Floodplain Parcels layer and remove all fields except LandUse_Favor.
3. Create a temporary copy of the Floodplain Units Analysis layer and remove all fields except FPU_ID and FPU_Acres.
4. Intersect the temporary Floodplain Units Analysis layer with the temporary Parcels layer.
5. Dissolve the intersect layer by values for the LandUse_Favor, FPU_ID and FPU_Acres fields to create a new layer named FPU_Parcels_LandUseDSLVS.
6. Create new decimal fields Dissolve_Acres and Dissolve_Percent in the FPU_Parcels_LandUseDSLVS layer and populate these fields by using the Calculate Geometry tool to calculate the combined acreage of each land use type within each FPU, and then the Field Calculator tool to calculate the proportion of each land use type in each FPU, respectively.
7. Create a new decimal field LandUse_Score in the FPU_Parcels_LandUseDSLVS layer and populate it using the Field Calculator to multiply LandUse_Favor and Dissolve_Percent.
8. Dissolve the FPU_Parcels_LandUseDSLVS layer on the FPU_ID field and calculate as a statistic the sum of the LandUse_Score values. Name the resulting layer FPU_Parcels_LandUseDSLVS_SUM.
9. Create a new decimal field LandUse_prelim_Score in the Floodplain Units Analysis layer.
10. Join the FPU_Parcels_LandUseDSLVS_SUM layer to the Floodplain Units Analysis layer using FPU_ID as the join field and use the Field Calculator to transfer the values from the LandUse_Score_SUM field in the FPU_Parcels_LandUseDSLVS_SUM layer to the LandUse_prelim_Score field in the Floodplain Units Analysis layer.
11. Remove the join.

Once the Land Use Type metric has been represented as an attribute in the Floodplain Units Analysis layer, calculate the restoration score for all floodplain unit polygons as follows:

1. Create a new decimal field named LandUse_SCORE and populate it using the Field Calculator with the preliminary score values normalized on a scale of 1-100 as follows:

Minimum: 33.139507

Maximum: 99.999998

LandUse_SCORE = $100 * (\text{LandUse_Prelim_Score} - 32.139507) / (99.999998 - 32.139507)$

Number of Landowners

The metric addressing the number of landowners within each floodplain unit will be calculated using a formula that considers both the number of distinct owners of those parcels that comprise at least 1% of the total area of a floodplain unit and the number of owners of those parcels for which at least 25% of the total parcel area is located within a floodplain unit. This formula does not count owners of parcels that comprise less than 1% of the floodplain, and favors floodplain units with a fewer number of landowners overall as well as landowners whose parcels are less than 25% within the floodplain.

1. Create a temporary copy of the Floodplain Units Analysis layer and remove all fields except FPU_ID and FPU_Acres.
2. Create a temporary copy of the Floodplain Parcels layer and remove all fields except Parcel_Acres and ControllingEntity.
3. Intersect the temporary Floodplain Units Analysis layer with temporary Floodplain Parcels layer to produce a new layer FPU_Parcels_OwnersISECT that contains separate polygons for the portions of every parcel within each FPU.

4. Within the intersect layer, create a new field ParcelAcres_inFPU and populate it with the acreage of each polygon using the Calculate Geometry tool.
5. Within the intersect layer, create a new field PercentParcel_inFPU and populate it by using the Field Calculator to calculate the percent of the original parcel that lies within each FPU as follows:

$$\text{PercentParcel_inFPU} = \text{ParcelAcres_inFPU} / \text{Parcel_Acres}$$
6. Within the intersect layer, create a new field ParcelPercent_ofFPU and populate it by using the Field Calculator to calculate the percent of the entire FPU that each parcel comprises as follows:

$$\text{ParcelPercent_ofFPU} = \text{ParcelAcres_inFPU} / \text{FPU_Acres}$$
7. Select all features from the intersect layer that comprise at least 1% of the entire FPU (ParcelPercent_ofFPU >= .01) and export those features as a new layer named FPU_Parcels_OwnersISECT_1pctFPU.
8. Use the Dissolve tool to union features in the FPU_Parcels_OwnersISECT_1pctFPU layer based on their values in the FPU_ID and ControllingEntity fields, and name the output layer FPU_Parcels_OwnersISECT_1pctFPU_DSLV.
9. Create a new integer field in the FPU_Parcels_OwnersISECT_1pctFPU_DSLV layer named NumOwners1pctFPU and set the value of all records in the layer to equal one (1) using the Field Calculator.
10. Dissolve the FPU_Parcels_OwnersISECT_1pctFPU_DSLV layer based on the FPU_ID field and calculate statistics for the sum of the NumOwners1pctFPU field. Name the output layer FPU_Parcels_Owners_OwnSum_1pctFPU.
11. From the FPU_Parcels_OwnersISECT_1pctFPU layer select all polygons for which the value of the PercentParcel_inFPU field is greater than or equal to 0.25 and export that selection as a new layer named FPU_Parcels_OwnersISECT_25pctAbove.
12. Dissolve the FPU_Parcels_OwnersISECT_25pctAbove layer based on the FPU_ID and ControllingEntity fields, and name the output layer FPU_Parcels_OwnersISECT_25pct_DSLV.
13. Create a new integer field in the FPU_Parcels_OwnersISECT_25pct_DSLV layer named NumOwners25pctInFPU and set the value of all records in the layer to equal one (1) using the Field Calculator.
14. Dissolve the FPU_Parcels_OwnersISECT_25pct_DSLV layer based on the FPU_ID field and calculate statistics for the sum of the NumOwners25pctInFPU field. Name the output layer FPU_Parcels_Owners_OwnSum_25pctAbove.
15. In the Floodplain Units Analysis layer, create new integer fields NumOwners1pctFPU and NumOwnersParcels25pctAbove.
16. Join the FPU_Parcels_Owners_OwnSum_1pctFPU to the Floodplain Units Analysis layer using FPU_ID as the join field, use the Field Calculator to set the values of the NumOwners1pctFPU field to be equal to the SUM_NumOwners1pctFPU field from the joined table, and then remove the join.
17. Join the FPU_Parcels_Owners_OwnSum_25pctAbove to the Floodplain Units Analysis layer using FPU_ID as the join field, use the Field Calculator to set the values of the NumOwnersParcels25pctAbove field to be equal to the SUM_NumOwners25pctInFPU field from the joined table, and then remove the join.
 Note in the case of eleven FPUs, there will be no owners who hold parcels that are at least 25% within the FPU., use the Field Calculator to manually set the values of the NumOwnersParcels25pctAbove field for these records to zero (0).

Once the Number of Landowners metrics have been represented as attributes in the Floodplain Units Analysis layer, calculate the restoration score for all floodplain unit polygons as follows:

1. In the Floodplain Units Analysis layer, create a new decimal field named NumOwners_prelim_Score and populate it by using the Field Calculator to score each FPU based on the number of landowners holding at least 1% of the FPU by area, discounted by the number of owners whose parcels are more than 25% within the FPU, using the following equation:

$$\text{NumOwners_Prelim_Score} = 100 * ((\text{Log} (100 / ([\text{NumOwners1pctFPU}] - 0.25 * ([\text{NumOwners1pctFPU}] - [\text{NumOwnersParcels25pctAbove}])))) / 2.12494$$

2. Create a new field named NumOwners_SCORE and populate it with the preliminary score values normalized on a scale of 1-100 as follows:

minimum: 25.476585

maximum: 99.999941

$$\text{NumOwners_SCORE} = 100 * (\text{NumOwners_Prelim_Score} - 24.476585) / (99.999941 - 24.476585)$$

Overlay Analysis

Weight and combine the scores for each of the six floodplain restoration priority metrics to arrive at an overall assessment of priority.

1. Create a new integer field Restoration_WeightedSum_Results in the Floodplain Units Analysis layer to represent the weighted and combined sum of all metric scores and use the Field Calculator to populate it using the equation below:

<u>Metric</u>	<u>Weighting Factor</u>
Channel Constriction:	1.0
Sinuosity:	1.5
Land Use Types:	2.0
Armoring:	2.5
Number of Landowners:	2.5
Floodplain Elevation:	3.0

$$\text{Restooration_WeightedSum_Results} = 1 * \text{Constriction_SCORE_Restoration} + 1.5 * \text{Sinuosity_SCORE_Restoration} + 2 * \text{LandUse_SCORE} + 2.5 * \text{Armor_SCORE_Restoration} + 2.5 * \text{NumOwners_SCORE} + 3 * \text{FPUelevation_SCORE}$$

Floodplain Conservation Priority

Calculate the metrics associated with each of the six floodplain conservation priority criteria on an equivalent scale of values. Note that final scores for each of the metrics must be assigned such that larger values indicate greater favorability for conservation.

Data Preparation

No additional work is necessary to prepare data for the Floodplain Conservation Priority metric calculations.

Metric Calculation

The floodplain conservation priority analysis will use the same six metrics used in the restoration priority analysis. Conservation priority, however, is intended to favor those floodplain units that retain the greatest amount of natural hydrological integrity. For three of the metrics – Floodplain Elevation, Land Use Types and Number of Landowners – use the exact same value ranges and scores as were used in the restoration priority analysis. In the case of the remaining three – Armoring, Sinuosity and Channel Constriction – for which the value scores were oriented to favor the most degraded hydrological conditions, reverse the value scales for the conservation priority analysis.

Armoring

The conservation priority analysis will use the same base metric for armoring as was used for the restoration priority analysis, but with a reversed value scale.

1. Create a new integer field `Armor_SCORE_Conservation` in the Floodplain Units Analysis layer and populate it using the Field Calculator to calculate the inverse of the restoration score multiplied by 100 as follows:

$$\text{Armor_SCORE_Conservation} = 100 * (1 - \text{Armor_NearBank_Percent})$$

Sinuosity

The conservation priority analysis will use the same base metric for sinuosity as was used for the restoration priority analysis, but with a reversed value scale.

Given the technique used to measure average sinuosity along the river frontage of each FPU, values range from approximately 1 to 1.57, with higher values indicating more sinuous stretches of river, which are more favorable for conservation.

1. Create a new decimal field `Sinuosity_Score_Prelim_Conservation` and populate it with average sinuosity calculations raised to a scale for which the maximum value is 100 using the Field Calculator as follows:

$$\text{Sinuosity_Score_Prelim_Conservation} = \text{Avg_SIN_25} * 63.543221$$

2. Create a new decimal field `Sinuosity_SCORE_Conservation` and populate it with the preliminary sinuosity score values normalize to a scale of 1-100 using the Field Calculator as follows:

$$\text{Minimum: } 63.571943$$

$$\text{Maximum: } 100$$

$$\text{Sinuosity_SCORE_Conservation} = 100 * ((\text{Sinuosity_Score_Prelim_Conservation} - 62.571943) / (100 - 62.571943))$$

Channel Constriction

The conservation priority analysis will use the same base metric for channel constriction as was used for the restoration priority analysis, but with a reversed value scale.

Given the technique used to estimate channel constriction of the river adjacent to each FPU, values range from approximately 0.59 to 1.79, with higher values indicating less constricted channels, which are more favorable candidates for conservation.

1. Create a new decimal field `Constriction_Score_Prelim_Conservation` and populate it with the average constriction calculations raised to a scale for which the maximum value is 100 using the Field Calculator as follows:

$$\text{Constriction_Score_Prelim_Conservation} = \text{Avg_A_E_BF} * 55.951506$$

2. Create a new decimal field `Constriction_SCORE_Conservation` and populate it with the preliminary sinuosity score values normalize to a scale of 1-100 using the Field Calculator as follows:

Minimum: 32.978993

Maximum: 100

$$\text{Constriction_SCORE_Conservation} = 100 * ((\text{Constriction_Score_Prelim_Conservation} - 31.978993) / (100 - 31.978993))$$

Floodplain Elevation

Conservation priority for floodplain elevation will use the same value scale as that used for restoration priority, as recorded in the field `FPUelevation_SCORE`.

Land Use Types

Conservation priority for the range of land use types within a FPU will use the same value scale as that used for restoration priority, as recorded in the field `LandUse_SCORE`.

Number of Landowners

Conservation priority for the number of landowners within a FPU will use the same value scale as that used for restoration priority, as recorded in the field `NumOwners_SCORE`.

Overlay Analysis

Weight and combine the scores for each of the six floodplain conservation priority metrics to arrive at an overall assessment of priority.

2. Create a new integer field Conservation_WeightedSum_Results to represent the weighted and combined sum of all metric scores and use the Field Calculator populate it using the equation below:

<u>Metric</u>	<u>Weighting Factor</u>
Channel Constriction:	1.0
Sinuosity:	1.5
Land Use Types:	2.0
Armoring:	2.5
Number of Landowners:	2.5
Floodplain Elevation:	3.0

$$\begin{aligned} \text{Conservation_WeightedSum_Results} = & 1* \text{Constriction_SCORE_Conservation} + \\ & 1.5* \text{Sinuosity_SCORE_Conservation} + \\ & 2* \text{LandUse_SCORE} + \\ & 2.5* \text{Armor_SCORE_Conservation} + \\ & 2.5* \text{NumOwners_SCORE} + \\ & 3* \text{FPUelevation_SCORE} \end{aligned}$$