An Analysis of Watershed Condition Framework Database for the Apache-Sitgreaves National Forest

By Russell Winn Ph.D., Associate Professor Emeritus, Department of Government, New Mexico State University, Las Cruces, NM 88003

Overview of Watershed Condition Framework

In the 2010-2015 Strategic Plan for the Department of Agriculture the restoration of watersheds and forest health is listed as a key management objective of the national forests (U.S. Department of Agriculture, 2010). In 2006 the Office of Management and Budget issued a rating that said that the Forest Service's watershed program was "Not Performing" (Office of Management and Budget (OMB), 2006). In particular the rating indicated that there were three problems with the Forest Service's watershed program:

- The Watershed Program lacks long-term outcome-based and efficiency measures for the performance of land management activities on national forest and non-federal watersheds or of demonstrated water quality improvement over time.

- Although annual performance accomplishments are collected for annual reports, the Forest Service lacks statistically valid water quality data, both nationally and locally, that reflects the effects of resource management activities.

- The Forest Service lacks a nationally consistent approach to prioritize watersheds and for management activities on national forests and for providing grants to non-Federal entities (OMB, 2006).

By the time the 2006 report was issued the Forest Service was already working on developing a nationwide system for evaluating the quality of watersheds that were at least partially under the agencies control. A plan for measuring the overall quality was developed and in 2010 data were gathered on all 15,064 6th-level HUC watersheds[1] that included at least some Forest Service land. This database was to be updated annually. In 2011 the Forest Service issued two reports that described the program (United States Department of Agriculture, 2011a) and a technical guide that described how the variables in the database were calculated and what they meant (United States Department of Agriculture, 2011b).

Along with the creation of the new database, the Watershed Condition Framework created a new paradigm for restoring watersheds (United States Department of Agriculture, 2011a). Instead of treating the watersheds that were in the worst condition this new paradigm emphasized treating

[1] A 6th-Level HUC (Hydrologic Unit Code) watershed is the smallest watershed in the National Watershed Boundary Database. It designates a watershed that covers an area of between 10,000-40,000 acres (U.S. Geological Survey and U.S. Department of Agriculture, Natural Resource Conservation Service, 2006).

the "best" watersheds by removing risk factors that might threaten the watershed. This effort would focus on a few watersheds (priority watersheds) that would be targeted for restoration over a 5-year period.

In 2012 the Forest Service updated their Watershed Condition Framework database to include additional variables (see discussion below).

Background on Watershed Condition Variables

As mentioned above the documentation on how the Forest Service (FS) came up with the variables included in the Watershed Condition Framework dataset is found in the Forest Service document "Watershed Condition Classification Technical Guide" published in July 2011 (United States Department of Agriculture, 2011b). This Guide was published prior to the release of the updated dataset. We have tried to figure out how the FS handled the added variables in the new database. This background section represents a summary of our findings and why the new database will provide us with better information on the relationship between various factors and overall watershed condition.

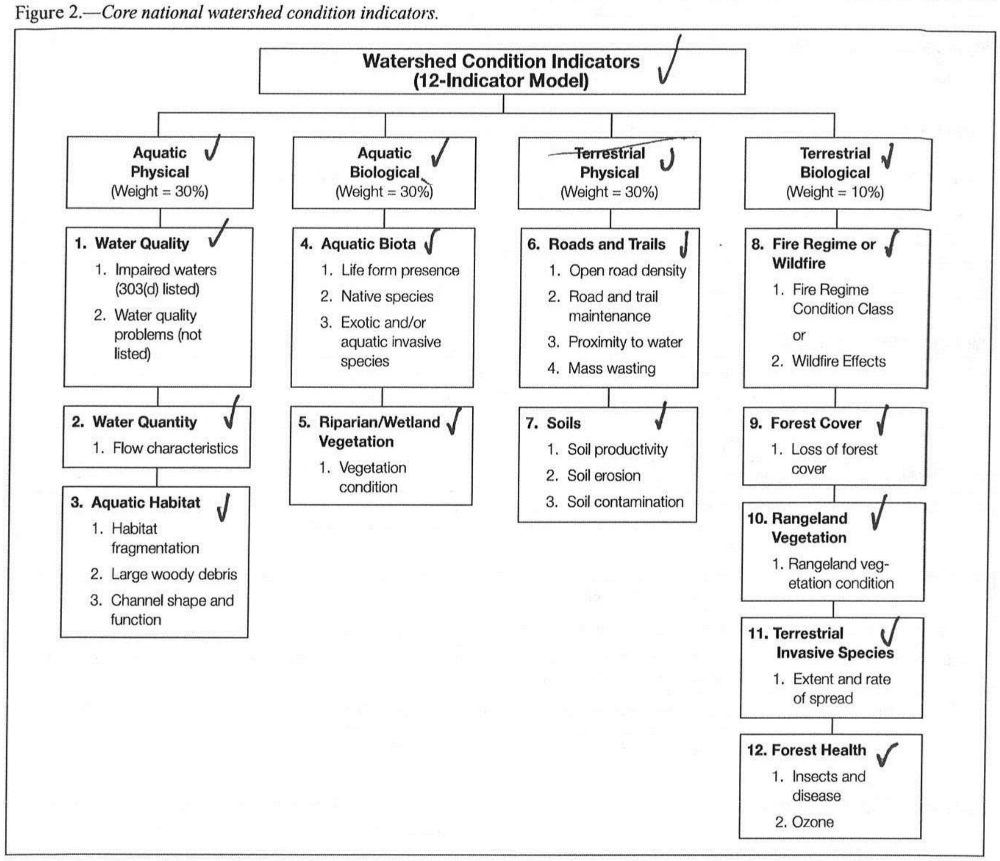
Background on old database

The old database classified all watersheds into one of three classes (Functioning Properly, Functioning at Risk, and Impaired Functioning). The titles given to these three classes are actually meaningless and really only reflect arbitrary divisions between those watersheds with low scores (Good condition) and those with high scores (Poor condition). The FS uses a weighted average of four "process categories" to come up with the final Watershed Conditions. These four categories are Aquatic Physical Processes, Aquatic Biological Processes, Terrestrial Physical Process, and Terrestrial Biological Processes. The score on the first three of these categories is multiplied by .30 and Terrestrial Biological is multiplied by .10. These four scores are added together and the resulting distribution of scores is then collapsed into three classes mentioned in the first sentence.

Each of the four process "Category" scores is computed by averaging from two to five "Indicators." There are a total of 12 indicators within the dataset. In turn each of these 12 indicators is computed by averaging from one to four "Attributes." There are a total of 24 Attributes with each watershed ranked as Good, Fair, or Poor on each of these "Attributes" (See Figure 1 below). In the old dataset each watershed is placed into a class (Good, Fair, or Poor) on each Attribute, Indicator, and Category. These variables are called "Class" variables because they put watersheds into one of three classes. For a complete list of all the Attributes, Indicators, Categories and how they fit together see the table below that is taken Forest Service's Technical Guide (Table 2). For more information on what is meant by Good, Fair, or Poor on each of the 24 Attributes, see the Technical Guide Appendix.

Figure 1:

Figure 2.—*Core national watershed condition indicators.*



New Dataset

The new dataset includes all of the variables in the old dataset. In addition more detailed measures of the Indicators, Categories, and Overall Watershed Condition are included in the seventeen “Score” variables. The new dataset not only includes values on the classes (Good, Fair, Poor) but also scores that range from 1.0 (extreme Good score) to 3.0 (extreme Poor score) on each of the Indicator and Category variables. In the “Score” variables the value is carried out to one decimal point. For example if a particular watershed had Attribute values of Good (1) on Soil productivity and Poor (3) on Soil erosion and Good (1) on Soil contamination, then the averaged value for Soils Indicator would be (1.6666…) this value is rounded to 1.7 on the Soils Score variable. This provides for 21 possible values on each variable with "Score" values. While the FS documentation does not specify this, from what we can tell a watershed that has a score on the Indicators and Category from 1.0 to 1.6 has a value of 1 or "Good" on that "Class" variable, a score of 1.7 to 2.2 has value of 2 or "Fair" and a score of 2.3 to 3.0 has a value of 3 or "Poor". In the example from above the Soils Class variable would equal 2 or "Fair." The same cut-points are used on the overall Watershed Condition variable. If the weighted average of the four "Category" variables is between 1.0 and 1.6 the watershed has a "Class" value equal to 1 or "Functioning Properly." A watershed with a weighted average of 1.7 to 2.2 is translated into 2 or "Functioning at Risk" and from 2.3 to 3.0 it is classified as 3 or "Impaired Functioning." Note that this classification system is arbitrary. There is nothing to say that a watershed with a "Functioning Properly" designation is actually functioning properly in an ecological sense, it just means that the final Watershed Condition score falls in the low third (low scores represent good conditions) of all possible scores.

Why is this important?

The new "Score" variables allow us to distinguish quality differences between watersheds with much more accuracy. For example take three watersheds one with an overall Watershed score of 1.0, a second with a score of 1.6, and a third with a score of 1.7. In the old data set the first two watersheds would have been classified as "Functioning Properly" while the third would be classified as "Functioning at Risk." Using the "Score" variables in the new dataset, we are able to distinguish between watersheds much more accurately by saying that the second two watersheds are more alike, and in worse condition, than the watershed with a 1.0 score.

A second reason that the new "Score" variables are important is that they allow us to use more powerful statistical tests on the data. The type of statistical test that is appropriate for a given variable is dependent on the variable's level of measurement (nominal, ordinal, or interval). A nominal level variable is one where the values are simply different. There is no implied ordering within the variable. The typical example of a nominal level variable is gender where the two possible values (male or female) are simply different. On the Watershed Condition dataset variables such as Forest Service Region or Name of Forest are examples of nominal level variables. The next more detailed level of measurement is an ordinal level variable. With ordinal level measures the possible values are different and they can be rank ordered along some dimension. The classic example of an ordinal level of measurement is satisfaction. A person who answers "Very Satisfied" to a question is assumed to have more satisfaction than someone who answers "Satisfied." On the Watershed Condition dataset the "Class" variables (Good, Fair, Poor or Functioning Properly, Functioning at Risk, Impaired Functioning) are examples of ordinal level variables. The highest level of measurement is interval. With interval level measures the possible values are different, they are rank ordered, and the difference between possible values measures the same thing across the range of the variable. The classic example of an interval level of measurement is age. The difference between a 14 year old and a 15 year old is one year. The difference between a 28 year old and a 29 year old is that same one year. In the old dataset the variables Total Watershed Acres or Percent of Watershed Controlled by Forest Service are examples of interval level variables. While all of the new "Score" variables violate some of the assumptions of an interval level variable, they can be treated as interval level for the purpose of statistical tests. Having interval level "Score" variables allows us to use more powerful statistical tests and to create more complex models that look at the interrelationships between variables.

In this analysis we downloaded the original 2010 Watershed Condition Framework database from the Forest Service website (http://www.fs.fed.us/publications/watershed/) as an Excel spreadsheet and then converted it to a Statistical Package for the Social Sciences (SPSS) file. In calculating the correlation coefficients for this analysis we used two different statistical tests. When we compared Score variables with other Score variables we used a Pearson's correlation coefficient (r). When correlating a Class variable with a Score variable we used Spearman's Rank Order correlation coefficient (r_s) since this statistic is appropriate when combing interval and ordinal level data.

The publically available database has not been updated to include the 2011 or 2012 data collection cycles. The Draft Environmental Impact Statement for the Apache-Sitgreaves National Forest Land Management Plan (U.S. Department of Agriculture, 2013) (DEIS) as well as the Watershed Specialist Report (U.S. Department of Agriculture, 2012) use data from the Watershed Condition Framework 2011 iteration. The 2010 and the 2011 data are very similar. The major change appears to be that the number of watersheds increased by about 12% (see Table 1).

Table 1

Comparison of 2010 and 2011 Watershed Condition Framework datasets for the Apache-Sitgreaves National Forest Percentage of all watersheds on Watershed Conditions class

	2010 data	2011 data
Functioning Properly	34%	32%
Functioning at Risk	66%	68%
Impaired Functioning	0	<1%
Total number of watersheds	152	170

Results of Analysis

As indicated in Table 1 about two-thirds of the A-S watersheds are Functioning at Risk, with the remaining third Functioning Properly. In comparing the data from 2010 with that reported in the DEIS for 2011 we see a slight decline in watershed quality. This does not include the impact that the Wallow fire has had on watersheds. As the DEIS indicates "There are 50 watersheds potentially affected. Some watersheds were heavily affected, resulting in a probable shift to a lower class." (U.S. Department of Agriculture, 2013, p. 65) Therefore it is reasonable to conclude that overall watershed condition has declined substantially over the last three years. The question now is how we can start to restore these watersheds. While many of the factors affecting watershed quality are beyond human control (i.e. impacts of climate change) one thing that we can control are the roads and trails within a watershed.

Impact of roads and trails

One of the most important factors affecting watershed quality is the overall condition of roads and trails. The Roads and Trails indicator is strongly correlated with overall Watershed Condition (*r*=.439) (See Table 2). The Roads and Trails indicator variable in the Watershed Condition Framework dataset has the 5th highest correlation coefficient among the 11 indicator variables[2] in the Watershed Condition Framework dataset.

Table 2

Correlations of Indicator and R & T attribute variables with Watershed Condition score

Indicator Variables	Watershed Condition Score
Aquatic Biota	.580
Water Quantity	.528
Aquatic Habitat	.565
Riparian/Wetland Vegetation	.529
Roads and Trails	.439
Roads and Trails attribute variables	
Open Road density	.219
Road and trails maintenance	.227

The Roads and trails indicator has both a direct and an indirect effect on watershed condition. The Roads and Trails indicator is related to two of the other indicators, Riparian/Wetland Vegetation and Aquatic Habitat (See Table 3). Both of these indicators are themselves related to Watershed Condition (See Table 2).

[2] While there should be 12 indicator variables. The Apache-Sitgreaves Forest classified all 152 watersheds as having a “Good” rating on the Terrestrial Invasive Species indicator. This makes it impossible to calculate correlation coefficients for this variable.

Table 3

Correlations of Roads and Trails Indicator and R & T attribute variables with other Indicator variables

Indicator	Roads and Trails Indicator	Open Road Density (attribute)	Roads and Trails Maintenance (attribute)
Aquatic Biota		.216	
Water Quantity		.265	
Aquatic Habitat	.321	.238	.216
Riparian/Wetland Vegetation	.259	.153	.206

As mentioned above the Roads and Trails indicator is computed using four separate attribute scores, Open road density, Roads and trails maintenance, Proximity to water, and Mass wasting. The Proximity to water and Mass Wasting attributes would be difficult to alter since both deal with the location of existing roads. To improve a watershed's score on these attributes would involve reconstruction of routes. The Open road density and Roads and trails maintenance could be improved by simply closing open roads and increasing the percentage of roads that are maintained using Best Management Practices (BMP). Both of these attributes are themselves related to Watershed Condition (See Table 2). Again this is only the direct affect. Open road density is correlated with the following indicators Aquatic Biota, Water Quantity, Aquatic Habitat, and Riparian/Wetland Vegetation. The Roads and trails maintenance attribute is correlated with Aquatic Habitat and Riparian/Wetland Vegetation (See Table 3). As mentioned above, all of these indicators are significantly related to Watershed condition (See Table 2). Thus closing roads and improving the maintenance of the remaining roads would improve overall watershed condition both directly and indirectly.

Bibliography

Office of Management and Budget (OMB). (2006). *Forest Service watershed program assessment.* Washington, DC: Office of Management and Budget.

U.S. Department of Agriculture. (2010). *Strategic Plan FY 2010-2015.* Washington, DC: U.S. Department of Agriculture.

U.S. Department of Agriculture. (2012). *Watershed Specialist Report: Forest Plan Revision.* Washington, DC: U.S. Department of Agriculture.

U.S. Department of Agriculture. (2013). *Programmatic Draft Environmental Impact Statement for the Apache-Sitgreaves National Forest.* U.S. Forest Service. Washington, DC: U.S. Department of Agriculture.

U.S. Geological Survey and U.S. Department of Agriculture, Natural Resource Conservation Service. (2006). *Federal Guidelines, Requirements, and Procedures for the National Watershed Boundary Database.* Washington, DC: U.S. Geological Survey.

United States Department of Agriculture. (2011a). *Watershed Condition Framework.* Washington, DC: U.S. Department of Agriculture.

United States Department of Agriculture. (2011b). *Watershed Condition Classification Technical Guide.* Washington, DC: U.S. Department of Agriculture.