COASTAL ALABAMA
PILOT HEADWATER STREAM SURVEY STUDY

LEVEL II – FIELD SURVEY- DRAFT REPORT

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This Project Developed By:

Alabama Department of Environmental Management
Mobile Branch -Coastal Programs
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This project has been developed in support of the
Alabama Coastal Nonpoint Pollution Control Program

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1. INTRODUCTION

This Coastal Alabama Pilot Headwater Stream Survey Study was developed in conjunction with Coastal Hydrology, Inc. in response to a request by Mobile County Soil and Water Conservation District (MCSWCD) and Alabama Department of Environmental Management (ADEM) for the purpose of locating, identifying and documenting baseline stream conditions for headwater streams within the ***Alabama Coastal Nonpoint Pollution Control Program*** **(***ACNPCP***)** *Management Area***,** throughout the Mobile and Baldwin County subwatersheds for coastal Alabama.

The Coastal Alabama Pilot Headwater Stream Survey was developed to locate, identify, document and assess baseline data for natural stream conditions, while also comparing any observed Land Use/Land Cover impacts in close proximity to selected headwater streams within the Mobile and Baldwin County area. The documentation of existing stream conditions may be used to reflect existing Land Uses and Land Cover (LUC), as a possible correlation of implemented management measures as Best Management Practices (BMPs) in close proximity to those surveyed stream site reaches. In addition, this Coastal Alabama Pilot Headwater Stream Survey (Headwater Stream Survey) information will be utilized to verify or plan and target any new approaches for implementation of Management Measures (MMs) described in the 1993 EPA document, *Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters*, as another means to address the conditions of approval for Alabama's coastal nonpoint program requirements as described by the *Alabama Coastal Nonpoint Program Findings and Conditions,* June 1998, and the *Joint Interim Decision Document*, March 2005.

Four objectives were originally developed for the implementation of this project:

1. Survey, Document and Comparatively Assess low impact "natural" headwater reference Stream segments.
2. Survey, Document and Comparatively Assess more impacted headwater stream segments.
3. Assess and correlate Land Use/Cover valuations with surveyed fluvial geomorphology and water quality parameters present in order to gage a new coastal headwaters assessment tool for these systems.
4. Derive new data and amend the 2005 *Coastal Alabama Regional Curve and Reference Reach* designs for Natural Stream Design and Restoration projects.

This regional project seeks to provide a detailed preliminary study of representative channel characteristics by surveying coastal headwater stream morphology, including multiple cross-sections, riffles, pools, and meander bends. This study has also focused on synoptic water quality parameters in conjunction with several assessment tools that may provide further data in order to compare each stream's robust attributes. An accurate physical survey of these streams was considered essential, along with consideration of surrounding land uses and statistical analysis of the data resulting from these efforts.

2. BACKGROUND

Universal physical laws govern streams, yet every stream passes in a unique way through its landscape. Gravity and water are constants, so all streams tend toward a single ideal form; however, differences in location and physical conditions create the range of forms we see. Each stream balances erosion, transport, and deposition in the context of its climate and landscape.
We may classify stream channels in terms of eight major variables: width, depth, velocity, discharge, slope, roughness of bed and bank materials, sediment load, and sediment size (Leopold, 1964). Natural systems are not random in their variation, but tend to cluster around the most likely combinations of variables based on physical and chemical laws rather than act randomly in their variation. This tendency to seek a probable balance of factors lends itself to classification (Harrelson,1994).

When any of the factors controlling stream classification change, the others will adjust along with it toward a new, balanced state. Because change is continuous, so is the process of adjustment. In streams the strongest physical medium for adjustment is the flow of water. In adjusting, the stream will show measurable change along the continuum determined by this flow (Rosgen,1994).

Local streams that traverse the southern Coastal Plain, largely across gentle gradients, often exhibit continuous changes in several parameters as they transition from one state (small bayhead stepped pools, seeps, or artesian flow) to another (exhibiting channel characteristics with meanders, pools, and riffles). They tend to develop wide floodplains to maintain channel competency, vertical stability and absorb storm runoff. Sharp boundaries, such as eastern Mobile Bay's terraced bluff landforms, tend to be the exception rather than the rule. Distinct specific events (such as coastal storm events, large trees falling into the stream, landslide/slumps across the channel, or construction and development impacts) may drive the stream's active adjustment process in a new direction. Understanding these processes of change takes both accurate measurement and scientific interpretation. The selection of stream reference sites allows opportunities to establish documentation of baseline conditions, in order to provide an accurate basis for measuring these changes. (Harrelson, 1994).

The abundance and quality of waterbodies in our coastal areas attracts tourists, retirees, and approximately over 53% of the US population. Historically, coastal urban development was carried out in high density build out scenarios that increase impervious cover, reducing natural landscapes that would buffer coastal waterways from the excess pollution. Coastal watersheds have unique ecosystems, services, and considerations compared to upland watersheds and better management tools are needed to safeguard the sensitive balance of resources, natural habitats, commodities, and people that live, work, and visit the Alabama coast.
[see http://www.cwp.org/2013-04-05-16-15-03/coastal-watersheds]

The Federal Clean Water Act provides for "maintaining the biological integrity of the nation's waters", from the mouths to the headwaters. In support of that goal the Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) has been proactively involved in the development of standardized approaches to evaluate conditions for natural streams within Alabama. Our Alabama Coastal Nonpoint Source (NPS) Program identified that there is a need for a methodology that could quantify conditions and correlate Land Use/Land Cover (LUC) impacts for Alabama's coastal streams, especially in the upstream headwaters areas. In the recent past our field work had revealed that these sensitive small headwater streams were being affected or disappearing at an alarming rate. Impacts from construction activities, residential development, drought, and agricultural expansion appeared to be the primary culprits impacting the diminishment of these important sensitive waterbodies. It is well established in the referenced scientific literature that headwater streams are important to the quality of water and critical to conserve biological communities in larger streams to which these primary headwater streams are tributary.

This *Coastal Alabama Pilot Headwater Stream Surve*y Project was initiated in 2009 as a multi-year project. The tragic occurrence of British Petroleum's MC252 Gulf Oil Spill in early 2010 reprogrammed critical survey and field work, resulting in the delay of this project until it could be reinitiated, with new work occurring from 2012 into 2014. As stated previously the documented *Headwater Stream Surve*y information will be utilized to verify baseline data that may inform planning and target the implementation of Management Measures (MMs) in the 1993 EPA document, *Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters* and further Alabama's coastal nonpoint program to full approval. This project will also gather pertinent baseline data that may relate to conditional approval issues cited in the *Alabama Coastal Findings and Conditions* document that relate to the Agriculture, Forestry, Urban Runoff, Hydromodification, and Wetlands, Riparian Areas, and Vegetated Treatment Systems (VTS) category sections. In total, this study completed the preliminary field reconnaissance of approximately seventy 12-digit subwatersheds by walking potential streams that were evaluated for the final intensive survey assessment and data measurements. Of these, fourteen (14) headwater stream sites were selected for this comparative Coastal Alabama Pilot Headwater Stream Survey.

Headwater streams are typically considered to be first- and second-order streams (Gomi et al. 2002, Meyer and Wallace 2001), meaning streams that have no upstream tributaries (i.e.,"branches") and those that have only first order tributaries, respectively. Use of stream order to define headwater streams is problematic because stream-order designations vary depending upon the accuracy and resolution of the stream delineation (Fritz, K.M., et al. 2006.).
The size of the headwater streams studied in this Project are quite small; all headwater reference streams were selected as being less than 1.0 square miles (sq.mi.) in total drainage area. Impacted streams that exhibited perennial characteristics had larger drainage areas, up to 2.3 sq.mi. Many of these selected reference streams did not show up as solid lines on USGS 1:24,000 topographic quadrangle maps, although almost all of them were indicated on county soil maps. This made the selection of our designated stream sites more difficult, as well as more intensive.

2.1 Alabama Coastal Nonpoint Pollution Control Program (ACNPCP)

During the past several years, the Alabama Department of Environmental Management–Field Operations Division-Coastal Section (ADEM-Coastal Section) has operated jointly with the Alabama Department of Conservation and Natural Resources-State Lands Division Coastal Section (ADCNR-Coastal Section) to administer and implement the Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) through coordination with the NOAA-OCRM and EPA-Region IV. Also, the ADEM-External Affairs Nonpoint Source (NPS) Unit representatives have participated extensively to aid the ACNPCP's development of programmatic approaches and projects that address the implementation of Management Measures (MMs). ADEM-Coastal

Section has retained dedicated staff members since 1999 who have continued a key role in the development and implementation of this Program and vital implementation projects, in order to address the many and varied water quality-related aspects of coastal nonpoint source pollution impacts and issues. The ACNPCP has facilitated and launched a variety of actions and projects that include tracking, permitting, monitoring, restoration projects and comprehensive studies to target and implement management measures for the Riparian Areas and Wetland-related issues throughout the designated subwatersheds of Baldwin and Mobile Counties (i.e. the federally recognized ACNPCP *Coastal Management Area*). Based upon the accepted components of *ACNPCP's Project Template*, Alabama's CNPCP will target the cyclic continuation of these efforts as a high priority for these categories and issue areas, with dedication to a continuing goal to raise public awareness and to implement category–related projects. This *Headwater Stream Survey* project was developed to verify existing coastal stream conditions for low order headwater streams that may correlate to potential impacts from existing Land Use /Land Cover (LUC). This is a good example of an ADEM-Coastal Section project that illustrates the State's ongoing multi-faceted efforts to implement and enhance components of the "Wetland and Riparian Areas Management Measures" requirements described on pp 7-02 through 7-56 in Chapter 7 of the 1993 EPA document, *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (g-Guidance). Through this *Headwater Stream Survey*, ACNPCP provides tangible engineering tools that have been calibrated for use in this local region, which enable natural stream design restoration using science-based measurements. This project serves to compare likely LUC impacts by identifying, documenting, assessing and comparing baseline stream conditions for our coastal headwater streams.

2.2 Coastal Alabama Geography

Alabama's two southernmost coastal counties, Baldwin and Mobile, encompass over **2,800 sq.mi.** with terrain consisting mainly of mixed forest, evergreen forest, and agriculture-related cover types. Regional studies have shown that Urban-related land cover has steadily increased as wetland, marsh and riverine habitats have decreased in quantity and relative quality. Coastal Alabama is characterized by important habitat areas and drainages including: (1) the Mobile-Tensaw River Delta, (2) Mobile Bay, (3) the Escatawpa River, (4) the Perdido River (5) the Mississippi Coastal area and adjacent barrier islands.

[see http://www.ogb.state.al.us/gsa/coastal/OFR/DamInventory_0705.pdf]

Alabama's coastal counties contain approximately **271,000 acres (1,097 km^2)** of wetlands. This acreage represents 12.5% of the total acreage of the designated Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) Management Area. An additional **400,000 acres (1,619 km^2, approximately 18%)** of coastal streams and estuarine waters are encompassed within this two county area, which possesses a unique geology and topography that makes up this deltaic and estuarine Mobile Bay complex.

[see http://adem.alabama.gov/programs/water/waterforms/2012AL-IWQMAR.pdf]

Alabama recognizes the resource value and the functioning of wetlands and riparian areas to abate NPS pollution and improve water quality in the coastal areas. At 10 miles wide and 40 miles long, the **Mobile-Tensaw River Delta (HUC 03160204)** is the largest wetland in Alabama and the second largest river delta in the nation. The delta was formed by soil deposition from the Coosa, Tallapoosa, Black Warrior, Tombigbee and Alabama Rivers. The Mobile-Tensaw River Delta includes 250,000 acres of marsh, cypress tupelo swamp and bottomland hardwoods and filters approximately 20 percent of the country's fresh water.

[see http://www.beachapedia.org/State_of_the_Beach/State_Reports/AL/Beach_Description]

As the fourth largest estuary in the nation, **Mobile Bay (HUC 03160205)** encompasses **413 sq.mi**. It is approximately 31 miles long and has a maximum width of 24 miles. Mobile Bay is a shallow estuary that provides a transition between the fresh water wetlands of the Mobile-Tensaw River Delta and the marine environment of the Gulf of Mexico. One of Mobile Bay's primary functions is as a nursery ground for many commercially and recreationally valuable species. [see http://www.beachapedia.org/State_of_the_Beach/State_Reports/AL/Beach_Description]
The southeastern mouth of Mobile Bay is framed by the Fort Morgan Peninsula. At the south-western side of Mobile Bay lies Dauphin Island. These barrier islands serve to protect the mainland and estuarine habitats by diminishing storm related wind and wave energy. Additionally, the estuarine and nearshore waters of Mobile Bay provide the nursery habitats that support a crucial multi-million dollar seafood industry for coastal Alabama.

The coastal lowlands of Alabama, with gently undulating to flat topography, basically follow the shoreline along the Gulf of Mexico, Mississippi Sound and Mobile, Perdido, and Bon Secour Bays. The ecological environments and geomorphology consist of features such as coastal streams, wetlands (i.e., tidal marsh, bay-gum and cypress swamp), two large peninsulas, a delta, lagoons, islands, and bays. The presence of a saline and/or fresh, high water table gives rise to the abundance of various wetland habitat types that are found within Alabama's coastal area. The upland unconsolidated alluvial sand, gravelly sands, and clays found along the Alabama coast, when combined with varying amounts of precipitation, cause dramatic effects on the turbidity of the shallow receiving waters in Mississippi Sound, Perdido and Mobile basins.
[see http://pubs.usgs.gov/sir/2006/5287/pdf/StatewideSummaryforAlabama.pdf]
As observed in this Project, most Headwater Streams in southern Alabama, specifically Mobile and Baldwin counties, typically originate from sloped wetland seeps or bayheads that usually initiate with a steeper gradient and transition onto wider floodplains to maintain channel competency, vertical stability and absorb storm runoff.

2.3 Context of Human Influences

These coastal riparian systems, wetlands, and estuarine ecosystems in Alabama provide critical habitat for a diverse number of fascinating wildlife, including a number of endangered species that are at potential risk because of stressors that are commonly associated with anthropogenic factors. Surveys conducted in 1998 by the Mobile and Baldwin County offices of the Alabama Soil & Water Conservation Districts (Mobile and Baldwin County Unified Assessments, 2000) indicated that 45% of Mobile County and 32% of Baldwin County were associated with developed land cover uses (e.g urban, agriculture, or pasture). Of the remainder that was classified as "forested", a major portion is not natural habitat, but is being managed for silviculture. Regional studies have shown that Urban-related land cover has steadily increased, as wetland, marsh and riverine habitats have decreased in quantity and relative quality (*Alabama Coastal Counties Wetland Conservation Plan*, 2001).

Data indicates that without sustainable management, many of these critical resources are under threat from a steadily increasing human population. Census projections illustrate that the combined Mobile conurbation (Mobile and Baldwin Counties) reached a population of 601,895 in 2005 [see http://cber.cba.ua.edu/edata/est_prj/alpop20002025.prn]. Projections of additional growth from 2005 to 2025 predict a conservative increase of over 15 % for both counties, which may result in an anticipated coastal population of over 691,989 by 2025.

Alabama's coastal riparian and riverine systems have been subjected to increasing pressure from a variety of proliferating land use-related activities, ranging from oil and gas extraction and refining, industrial construction and waste discharges, transportation needs, shipping, navigation and channel excavation, agriculture and silviculture production, commercial and recreational fishing, municipal waste treatment discharges and accidental spills, to poorly planned commercial and residential development projects that result in the degradation of these waterbodies and increase the potential harm from any of the pollutants associated with nonpoint source runoff from those identifiable land or water uses.
[see http://pubs.usgs.gov/sir/2006/5287/pdf/StatewideSummaryforAlabama.pdf]

As we have developed and implemented the Alabama Coastal Nonpoint Pollution Control Program, especially as we developed tools to address approaches for the environmental management of our coastal streams, the abundance of our waterways became evident. However it also indicated that science-based assessment and surveys were needed to provide documentation for existing conditions that could provide input for adequate planning, protection, and preservation of their health and qualities.

Referencing prior ACNPCP and ADEM WQ studies, it was noted that in some instances as much as 30% of upstream sites were compromised through time because of many of the LUC-related development actions cited above. It was noted that these impacts were occurring primarily in the low order or headwater stream reaches. Based upon applying suitable management measures pertinent to several categories, the ACNPCP undertook the task to gain more information concerning coastal headwater streams with the objective of bringing more attention to these systems, while obtaining and archiving vital Reference Reach Regional Curve data. Another focus was to document the resultant conditions associated with dominant LUC practices for Alabama's southwestern coastal streams. Understanding current conditions as they relate to the diversity and status of these coastal ecosystems provides a foundation for determining actions needed to define and restore these habitats. This valuable science-based information can be used to enhance restoration efforts and guide the development of future enforcement and regulatory permitting practices, as well.

Figure1. Baldwin County Subwatersheds with Coastal HDWTRSS Sites ⊕

Figure 2. Mobile County Subwatersheds with Coastal HDWTRSS Sites ⊕

3. SITE SELECTION AND ASSESSMENT

3.1 Characterization of Study Area

The proposed study area is located in Mobile and Baldwin Counties, Alabama within the eight 8-digit HUC sub-watersheds listed as follows:

03140106	**Perdido River**
03140107	**Perdido Bay**
03150204	**Lower Alabama River**
03160203	**Lower Tombigbee River**
03160205	**Mobile Bay**
03160294	**Mobile Tensaw Delta**
03170009	**Mississippi-Coastal**
03170008	**Escatawpa River**

This portion of the study includes identifying and documenting baseline stream characteristics and observed fluvial geomorphology throughout these eight HUC areas to assess their suitability for further study. All stream segments are entirely contained within the Gulf Coastal Plain Physiographic Province, which is characterized by broad valleys, low topographic relief, and gentle land slopes. Within the coastal region of Alabama, there are negligible differences in precipitation and runoff between study sites (Gerbert et al., 1987). Precipitation averages between 55 and 65 inches annually. Rainfall runoff values range from 18 to 30 inches annually (Gerbert et al., 1987). Coarse-textured soils are prominent throughout the province, due to prolonged exposure of marine terrace sediments. The drainage density of the middle Coastal Plain is higher and more well-established than that of the lower Coastal Plain (Miller and Robinson, 1994). The underlying geology is primarily composed of sands, clays, and organics from the Pleistocene, Holocene, and Pliocene eras.

The Level II portion of the Headwater Stream Survey study includes final site selection, identifying and documenting baseline stream fluvial geomorphology throughout these eight coastal HUC areas, and comparison of streams based on observed field site conditions and impervious cover. Following the reconnaissance during the last few years of work in coastal Alabama, the selection of these Headwater sites (see *County Subwatersheds with Coastal HDWTRSS Sites* maps on pages 10 &11 above) were based upon observed potential for "natural" conditions, as well as observable differences suitable to illustrate and contrast these selected stream reaches and drainage areas (e.g. Rural vs. Urban; and Reference vs. Impacted). Additionally, stream segments were designated as being in *Urban Areas* if located within municipal limits, or within drainage areas having greater than 10% impervious cover. Stream research generally indicates that certain zones of stream quality exist, most notably at about 10% impervious cover, where sensitive stream elements are lost from the system. A second threshold appears to exist at around 25 to 30% impervious cover, where most indicators of stream quality consistently shift to a poorer condition (e.g., diminished aquatic diversity, water quality, and habitat scores). [http://www.stormwatercenter.net]

3.2 Site Selection Criteria

This ***Pilot Headwater Stream Survey Study*** format was based on assessing existing physical conditions for selected low order headwater streams in Mobile and Baldwin counties. Field reconnaissance visits were conducted on all sites in 2012 for the Level I survey to determine suitability for inclusion in this study. Minimum criteria for inclusion in the study included the following:

1. The stream reach should be a single-thread channel, but where necessary to establish regional geomorphic and water quality characteristics, Rosgen DA (anastomosed) stream types may be included (Rosgen, 1994).

2. Beaver dams must not hydraulically impact the site. This process did not rule out beaver activity in the watershed, just at the project reach.

3. The channel must be free to naturally adjust its dimension; e.g., the channel must not be armored by riprap.

4. Sites with recent dredging and/or bank vegetation removal were eliminated.

5. All reference streams were selected as being less than 1.0 sq.mi. in total drainage area.

6. Sites selected will be located in urban and rural areas and from both impacted and natural (i.e., reference) sites. Stream segments were designated as being Urban if located within municipal limits, or within drainage areas having greater than 10% impervious cover.

7. For most sites an initial drive-through survey was completed throughout the watershed to verify that land use was not rapidly changing. Many potential sites were rejected due to the presence of swampy systems. Deeply-incised streams were not considered or recommended for inclusion for the reference segments in this survey. The bank height ratio (lowest bank height divided by the bankfull maximum depth) must be less than 1.5 for gage stations and 1.2 for reference reaches. Rosgen (1996) reported that a bank height ratio of 1.3 or greater is indicative of an unstable reach. Some of these were used for Impacted Stream segments comparisons.

Based on the findings of the Level I survey, the Level II stream sites were selected for detailed measurements and analysis of stream-reach fluvial geomorphology. These water quality data were then gathered by the ADEM project staff through 2013, with supplemental samples into the R-3 Winter rotation in early 2014, with the collected data being incorporated for bio-statistical analysis.

4. PROJECT METHODOLOGY

4.1 Development of the HDWTRSS Project:

Approaches to study Coastal Headwater Streams

A. GIS-based selection of Watersheds & Identification of potential headwater streams:
Criteria-based selection of potential reference and impacted sites.

B. Select suitable headwater streams based upon preliminary reconnaissance and observed LUC.

C. Obtain access to study all stream sites. The NRCS and local S&WCDs were invaluable in providing contacts and acquiring proper access to these stream sites.

D. Select and flag stream reaches to conduct requisite Geomorphology Survey.

E. Measure selected Water Quality parameters in three seasonal sampling rotations:
R-1 Spring/Summer, **R-2** Fall, and **R-3** Winter.

F. Measure Land Use-Land Cover parameters:
Intensive onsite and follow-up measurements, with tight scaled GIS.

G. Conduct suite of assessments and compare data for Coastal Headwater Streams.

H. Develop conclusions based upon comparisons of:
Measurable differences of stream site data, Water Quality, Land Use/ Land Cover, Project Assessments , Comparative Assessment Index, and Geomorphology.

Initial Field reconnaissance was conducted on selected headwater or low order streams throughout Mobile and Baldwin Counties, Alabama in 2012 to support the following Level II field survey, which included stream habitat assessments information (see Appendix II), fluvial geomorphology characteristics, and water quality information.

Data collected for the Level I phase during 2012 and 2013 included site characteristics (i.e., presence of permanent hydrology, channel alterations, surrounding landscape, land-uses and any noticeable impacts), photographs (not at every site), GPS location, and general physical land survey location. This was supplemented during the Level II data collection phase in 2013 with detailed channel morphology, land use/land cover and habitat assessment, including collection of water quality parameters with inferences to be based upon comparative and statistical analyses.

All statistical analyses were carried out using Project R (R version 3.0.3). Statistically significant differences were accepted at an alpha level of 0.05. Data were analyzed with parametric general linear procedures and Pearson's product-moment correlation when the assumptions of normality and homogeneity were met. When parametric assumptions were not met, the nonparametric Spearman's rank correlation and Kruskal-Wallis rank sum test analyses were used.

4.2 Stream Geomorphology

At each selected HDWTRSS stream site, a Leica TC307 Total Station and Ranger TDS data collector (with Survey Pro software by Tripod Data Systems 2005) were used to complete a longitudinal profile and cross-sections, along a minimum reach length of 20 times the bankfull width (or at least one meander wavelength). Cross-sections were surveyed at three representative riffles, pools, runs, and glides. In some instances the reach length was not long enough to provide all of the cross-sectional information needed for comparisons. Morphological features were surveyed moving left to right, looking downstream, including top of bank, bankfull stage, edge of channel, edge of water/water surface, thalweg, and channel bottom (Harrelson et al., 1994; USGS, 1969). Permanent pins were established at some of the cross sections and tied to the longitudinal profile station. The data were downloaded from the Ranger, and the following bankfull dimensions were calculated: width, cross-sectional area, maximum depth, mean depth, ratio of width/mean depth, bank height ratio, and entrenchment ratio (riffles only). The data were then entered into Microsoft Excel for graphing and comparisons.

Longitudinal survey measurements were generally collected at the beginning of each bed feature (heads of riffles and pools) and included: thalweg, water surface, bankfull stage, and top of low bank. The slope of a line developed using bankfull indicators was compared to a best fit line through the water surface points. Leopold (1994) used this technique to verify the feature as bankfull if the two lines were generally parallel and consistent over a long reach. The data were processed the same as discussed for the cross-sectional data, and valley slope and average water surface slope were calculated.

Channel pattern was determined from the survey points and from aerial photographs, as necessary. More extensive surveys would have been needed to depict pattern statistics on many of the agricultural reaches. For that reason, aerial photos were often used to measure those parameters; however, it was not possible to determine the exact location of the stream channel on the aerials (as it was on many of the smaller reaches) because the surrounding vegetation was quite dense. In those cases, pattern measurements were based solely on the survey points.

4.2.1 Bed Material Measurements

Since most of the project sites had sand-dominated bed material, the Wolman pebble count procedure was not applied in all situations (Bunte and Abt, 2001); instead, where possible, protrusion heights from woody material were collected along the wetted bed at the represented riffle cross-section (Morris, 2012; Yochum et al., 2012). A total of one hundred samples were collected and used to document roughness and bankfull discharge.

4.2.2 Stream Classification

Each project reach was classified using the Rosgen (1994, 1996) method. The width of the floodprone area was measured from survey data or topographic maps (where survey data were insufficient due to wide, heavily vegetated floodplains). In cases where the clear survey shots could be collected across the valley, a complete cross-section was surveyed across the floodplain, and the floodprone area width was taken from this cross-section.

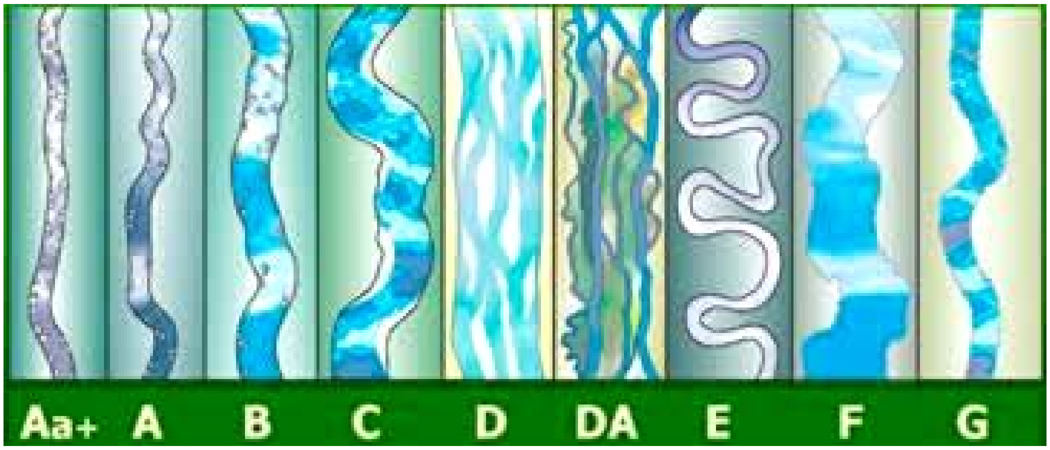


Figure 3. Rosgen Stream Classification Planiforms. **US Environmental Protection Agency**.

4.3 Assessments Tools for the *Coastal Alabama HDWTRSS*

Based upon previous field work with environmental projects during the last few decades, along with interagency discussions with other environmental scientists, the Coastal NPS Program decided upon a suite of assessments that would provide calibrated measures of those important factors or indicators. These assessments were done for each selected HDWTRSS Stream Site. This would provide a numeric and measurable ***Composite Assessment Index*** for each *Coastal Alabama HDWTRSS* site. The assessments utilized for this purpose of the study are attached in Appendix II and are listed here:

A. ***Coastal HDWTRSS Land Use/ Land Cover (LUC) Assessment*** **(Form#6), 2012**
B. ***Coastal HDWTRSS Forest Canopy Assessment,*** **2008**
C. ***North Carolina Stream Identification Assessment*** **(4.0), 2010**.
D. ***ADEM Wadeable Stream Habitat Assessment*** **(FOD-I Form36), 2011**.
E. ***ACNPCP Coastal Stream Assessment*** **(Form#3), 2009**
F. ***Coastal HDWTRSS Composite Assessment Index,*** **2008**

4.3.A Coastal HDWTRSS Land Use-Land Cover (LUC) Assessment

The National Land Use/Cover categories along with observed coastal conditions helped determine the assignment of broad "**Land Use/Cover Classifications**" that were selected. These were designated in the HDWTRSS LUC Assessment, being selected for this study as:

Natural
Forested
Cleared, Select Cut, ReGen Stand, 20Yrs+
Agriculture
Cattle, Crops, Orchards, Pasture,
Urban
Transportation/Parking
Commercial
Residential,
Density – High, Medium, Low
Utilities, ROWs, and Parks, Greenspace
Waterbody

Using the **2006 National Land Cover Data (NLCD 2006)** information as a guide, these *HDWTRSS* Site conditions were selected, observed and documented onsite at each of the HDWTRSS stream sites chosen for this study [refer to http://www.mrlc.gov/nlcd11_leg.php]. These observations were reviewed and enhanced by measurements calculated with the use of GIS tools, including consultation of aerial photography and USGS topographic mapping.

Initial *Field Reconnaissance LUC* forms were developed for the prior Level I phase of the project. The data collected from these field determinations provided critical information to further develop and calibrate the current ***Coastal HDWTRSS Land Use/ Land Cover (LUC) Assessment*** **(Form#6), 2012** (HDWTRSS LUC Assessment) for this project. This HDWTRSS LUC Assessment (see Appendix II) was used to guide the final selection of the Project's coastal Headwater Streams, both Reference Streams and Impacted Stream sites. It also played a huge role for this Project by providing the GIS-reviewed HDWTRSS LUC assessment data used to derive the final HDWTRSS **Composite Assessment Index** scores for the selected sites.

4.3.B *Coastal HDWTRSS Forest Canopy Assessment*, 2008

The *Convex Spherical Forestry Densiometer* utilized to conduct the forest canopy assessment, allows accurate, one-person measurement of tree canopies. The use of this instrument and procedure generates a numeric measurement of the forest overstory density. The densiometer uses a spherical-shaped reflector mirror engraved with a cross-shaped grid of twenty-four 1/4" squares. Operation and calculation procedures were adopted based upon the CDPR-Environmental Branch manual. [see http://www.cdpr.ca.gov/docs/emon/pubs/sops/fsot00201.pdf]

4.3.C *North Carolina Stream Identification Assessment* (4.0), 2010.

The purpose of this assessment procedure, using the manual and accompanying field data form, is to identify and evaluate geomorphic, hydrological and biological stream features that distinguish between ephemeral, intermittent and perennial streams. This assessment was included to gage it's measurement of Alabama coastal headwater streams, which was integrated as an important quantitative factor into the **Composite Assessment Index** for the HDWTRSS project. (see Appendix II.)

4.3.D ADEM Field Data and Habitat Assessments for Wadeable Streams

This interconnected suite of ADEM habitat assessment procedures was integrated into the HDWTRSS project to evaluate another important set of factors. Documentation of these components (see Appendix II.) allow accurate use of the ADEM ***Glide Pool Habitat Assessment*** as a numeric value that could be calculated into the **Composite Assessment Index** score.

1) **ADEM *Gen Phys Char, Substrate & WQ Field Data Sheet* (FOD-I Form36), 2011**.http://web-server/intranet/QA/internalforms/Surface%20Water%20Field%20Data/FOD%20I-Form%2036%20Form%20Rev%203-04-11.pdf
2) **ADEM *Abbreviated Stream Flow Measurement Data Sheet* (FOD I-Form 9), 2006** http://web-server/intranet/QA/internalforms/Surface%20Water%20Field%20Data/Stream%20Flow%20Form%20%20FOD%20I%20Form%209%201-25-06.pdf
3) **ADEM *Glide Pool Habitat Assessment* (FOD I-Form 14), 2013**. http://web-server/intranet/QA/internalforms/Surface%20Water%20Field%20Data/FOD%20I-Form%2014%20Form%20Rev%202-14-13.pdf

4.3.E *ACNPCP Coastal Headwater Stream Assessment* (Form#3), 2009

These assessment procedures were developed to identify important Coastal Headwater Stream components using the accompanying field data form to identify and score geomorphic, hydrological and biological stream features that are important to evaluating coastal headwaters stream characteristics (see Appendix II).

4.3.F *Coastal HDWTRSS Composite Assessment Index*, 2008

The selection and incorporation of these 5 informative functional assessment tools allowed development of an accurate Coastal HDWTRSS Comparative Assessment Index. This project provides good science-based information that should promote further development of this preliminary tool. This **Composite Assessment Index** is a final assessment calculation that combines the selected assessment tool factors and seeks to generate an encompassing numeric factor, with a scaled minimum score of 0.0, up to a maximum score of 1.0. A zero would represent a negligible headwater coastal stream system, with a perfect score of 1.0, being an **ideal headwater stream ecosystem**.

5. WATER QUALITY: COASTAL HEADWATER STREAMS

5.1 HDWTRSS Field Project Design

Water Use designations are promulgated in ADEM Admin. Code R. 335-6-11(2008). Section **335-6-11-.01** states that "Use classifications utilized by the State of Alabama are as follows:

A. OAW Outstanding Alabama Water
B. PWS Public Water Supply
C. S Swimming and Other Whole Body Water-Contact Sports
D. SH Shellfish Harvesting
E. F&W Fish and Wildlife
F. LWF Limited Warmwater Fishery
G. A&I Agricultural and Industrial Water Supply

All streams reaches selected for this HDWTRSS project are designated as **Fish and Wildlife (F&W).**

These field protocols and standards were selected and implemented in order to complete the *Coastal Alabama Pilot Headwater Stream Survey*:

1. Base-flow was determined as the most desirable metric to gage Stream Flow for each HDWTRSS stream site. Based upon prior Stream Recon information and the small drainage area for each site, it was determined that optimum measurements would be ≥24hrs after a measurable or observable precipitation event.

2. All instrument calibrations and field techniques followed the QA/QC criteria and procedures set forth in the Alabama Department of Environmental Management's *Standard Operating Procedures and Quality Control Manual.* In-situ field measurements were taken at each headwater stream station shown in the maps on page 10 and 11 (Figures 1 and 2).

3. Cross-sectional *HDWTRSS* stream sampling sites were permanently marked and flagged using GPS positioning to facilitate locating stream reference flag-markers placed onsite.

4. All other related HDWTRSS project parameters were measured and recorded at each headwater stream site (see Table 2 below), which were permanently marked and flagged to ensure accurate site sampling replication.

5. Water quality data were recorded at each permanent field station for the selected field parameters. A multi-parameter datasonde unit (YSI Model #600XLM Multi-Parameter Water Quality Monitor®) was used to measure Dissolved Oxygen (DO), Salinity, Conductivity, pH, Temperature, and Depth. These datasonde water quality readings were recorded at mid-depth from surface of water. Turbidity measurements were conducted using the Orbeco-Hellige Turbidimeter per ADEM SOP# 2044. Other field parameters recorded at each station include air temperature, and weather conditions observations.

6. All headwater stream flow measurements were taken for each site at mid-depth using a USGS Pygmy Meter -Model 6205, which is used only for measuring shallow streams, mounted onto a USGS Top Setting Wading Rod per ADEM *SOP# 2040*. *HDWTRSS* Stream Flow calculations were determined using ADEM *Stream Flow Calculation Workbook* and these were verified calculating each cross-section sub-segment total. Subsurface Grab samples were taken at each permanent cross-sectional stream station to measure turbidity. These were taken prior to setting up the flow stations for each stream site. Sediment grain sampling was collected after the subsurface grab and Datasonde readings were completed. All sampling containers, sediment collection, and field equipment devices were examined and cleaned between each station to prevent contamination according to the applicable ADEM SOPs (Tables listed on page 22).

5.2 Field Quality Control and SOPs

The standard ADEM SOPs were followed for calibration and operation of field equipment that was used to measure the parameters recorded at these stream sites. The field staff collected duplicate measurements at 10% of the sites. These HDWTRSS water sampling procedures, including protocol-required Duplicates, were all processed by the ADEM Mobile Branch staff. Routine maintenance and calibration protocols on all instrumentation and field equipment outlined by the manufacturers were followed.

Tables 2 and 3 (below) list the water quality parameters collected at each site, and also lists the applicable ADEM *General Surface Water SOPs* for this *HDWTRSS* project. Table 2 lists the specific parameters documented and the measurable units specific for each one. Table 3 cites the appropriate SOP method reference number utilized for each of the Project parameters, including Flow, Temp., pH, Specific Cond, Turbidity, Surface Water DO, Data Sonde, and General Surface Water Sampling.

Table 1: In-Situ Parameters Recorded or Observed

In Situ Parameters	
Flow	cfs
Depth	ft.
Temp: Air and Water	ºC
pH	s.u.
Dissolved Oxygen (DO)	mg/L
Salinity	ppt
Specific Conductivity	µmhos/cm
Turbidity	NTU
Weather Conditions	observations

Table 2: ADEM Environmental Sampling SOP Documents

SOP #	Rev #	General Surface Water 2000-2099
2040	5.0	Stream Flow Abbreviated Measurement Method
2041	3.1(a)	Temperature Field Measurements
2042	4.0	pH Field Measurements
2043	4.0	Conductivity Field Measurements
2044	4.2	Turbidity Field Measurements
2045	4.0	SW Dissolved Oxygen Field Measurements
2047	1.1	Datasonde Field Measurements
2061	4.0	General Surface Water Sample Collection

5.3 HDWTRSS Field Water Quality Data

These are the HDWTRSS water quality and field measurements that were collected at each selected headwater stream site. These parameters were determined as critical to this effort, and were documented and recorded by the HDWTRSS team staff. The following 3 Tables list the Water Quality data results that were collected seasonally by ADEM staff on these 14 HDWTRSS Stream Sites:

Table 3. R1 – Late Spring/Early Summer WQ Sampling

Coastal Alabama HDWTRSS		SPRING/SUMMER-R1						
Site Names	Air Temp (^{0}C)	Water Temp. (^{0}C)	pH (s.u.)	Dissolved Oxygen (mg/L)	Specific Cond. (umhos/cm)	Salinity (ppt)	Turbidity (NTU)	Flow Pygmy (cfs)
UT 2 Halls Creek	29	22.2	4.7	7.8	29	0.01	2.7	0.221
UT 2 Perdido River #1	29	21.3	3.6	6.4	29	0.01	0.7	0.904
UT 2 Perdido River #2	31	22.8	3.9	6.1	30	0.01	1.3	0.632
UT 2 Wolf Creek	29	29.1	5.3	4.5	46	0.02	2.1	0.201
UT 2 Borrow Creek	29	22.1	4.4	7.9	22	0.01	1.3	0.177
North Yancey Branch	26	23.2	5.7	7	54	0.02	11.4	1.647
UT 2 Joe's Branch	27	25.1	7	5.4	176	0.08	5.3	0.015
UT 2 Red Creek #1	27	23.6	5.9	0.6	309	0.15	9.5	0.01
UT 2 Red Creek #2	28	23.7	6.4	2.4	243	0.11	11.4	0.024
UT 2 Perch Creek	30	25.9	6.55	5.43	127	0.06	13.7	0.91
Three Mile Creek	32	29.3	6.3	12.3	76	0.03	3.5	0.385
Twelve Mile Creek	30	30.5	7.9	10.8	220	0.1	3.2	0.265
UT2 Cowpen Creek	31	31.2	6.5	6.5	47	0.02	27.2	0.772
UT 2 Page Creek	25	26	6.7	6.9	116	0.05	13.7	0.025

KEY: It should be noted that all WQ Graphs and Tables in this HDWTRSS Report will use this color key to designate their primary associated Land Use Group and Stream Types:

Reference Streams	Impacted Urban	Impacted Agriculture

Table 4. R2- Autumn WQ Sampling

Coastal Alabama HDWTRSS		AUTUMN-R2						
Site Names	Air Temp (^{0}C)	Water Temp. (^{0}C)	pH (s.u.)	Dissolved Oxygen (mg/L)	Specific Cond. (umhos/cm)	Salinity (ppt)	Turbidity (NTU)	Flow Pygmy (cfs)
UT 2 Halls Creek	23	21.44	5.44	7.71	23	0.01	1.3	0.248
UT 2 Perdido River #1	25	20.3	4.75	7.77	20	0.01	0.7	0.93
UT 2 Perdido River #2	26	21.5	5.07	7.18	27	0.01	1.8	0.897
UT 2 Wolf Creek	29	26.3	5.11	4.8	45	0.02	0.9	0.189
UT 2 Borrow Creek	21.5	19.25	5.3	7.56	23	0.01	1.4	0.203
North Yancey Branch	27	22.98	6.14	7.1	58	0.03	12.1	1.612
UT 2 Joe's Branch	30	23.95	7.28	5.19	239	0.11	7.2	0.038
UT 2 Red Creek #1	21	21.13	6.3	2.59	293	0.14	6.4	0.019
UT 2 Red Creek #2	21	20.66	6.67	3.55	229	0.11	6.8	0.021
UT 2 Perch Creek	28	24.56	7.44	4.03	274	0.13	19.5	0.246
Three Mile Creek	24	23.07	6.38	5.1	82	0.04	13.75	0.396
Twelve Mile Creek	24	24.07	6.73	7.38	210	0.1	13.5	0.285
UT 2 Cowpen Creek	31	25.04	7.25	7.95	216	0.1	15.5	0.433
UT 2 Page Creek	21	18.63	7.43	7.97	113	0.05	13.5	0.027

Table 5. R3- Winter WQ Sampling

Coastal Alabama HDWTRSS		WINTER-R3						
Site Names	Air Temp (^{0}C)	Water Temp. (^{0}C)	pH (s.u.)	Dissolved Oxygen (mg/L)	Specific Cond. (umhos/cm)	Salinity (ppt)	Turbidity (NTU)	Flow Pygmy (cfs)
UT 2 Halls Creek	14	13.8	4.3	10.01	35	0.02	4.6	0.908
UT 2 Perdido River #1	13	12.67	4.3	9.02	21	0.01	1.2	0.838
UT 2 Perdido River #2	12	9.46	3.65	9.49	27	0.01	0.6	0.501
UT 2 Wolf Creek	14	11.58	4.66	9.26	48	0.02	0.8	0.191
UT 2 Borrow Creek	18	14.66	3.71	9.87	27	0.01	2	0.192
North Yancey Branch	21	17.16	5.67	8.67	58	0.03	12.6	1.61
UT 2 Joe's Branch	21	16.94	7.05	7.95	217	0.1	6.4	0.105
UT 2 Red Creek #1	25	19.46	6.28	1.91	353	0.17	11.4	0.046
UT 2 Red Creek #2	25	16.34	6.31	3.1	231	0.11	13	0.057
UT 2 Perch Creek	14	8.78	6.43	9.81	216	0.1	8.5	0.185
Three Mile Creek	16	11.58	6.28	10.61	76	0.04	13	0.447
Twelve Mile Creek	17	13.27	7.76	12.92	238	0.11	14.45	0.366
UT 2 Cowpen Creek	17	11.01	6.36	9.48	65	0.03	40	0.054
UT 2 Page Creek	13	11.9	6.5	11.7	111	0.05	19.8	0.047

5.3.1 Stream Flow

Stream flow measurements and observations are an integral part of interpreting water quality data, so stream flow for each headwater stream site was required as a critical part of the initial *HDWTRSS* project plan, in order to obtain the most accurate stream flow estimates using ADEM's Abbreviated Stream Velocity Measurement Method. Initially the flow measurements were attempted using a doppler unit, but in these small flow coastal headwater stream sites the USGS Pygmy Meter -Model 6205, proved more suitable for this endeavor.

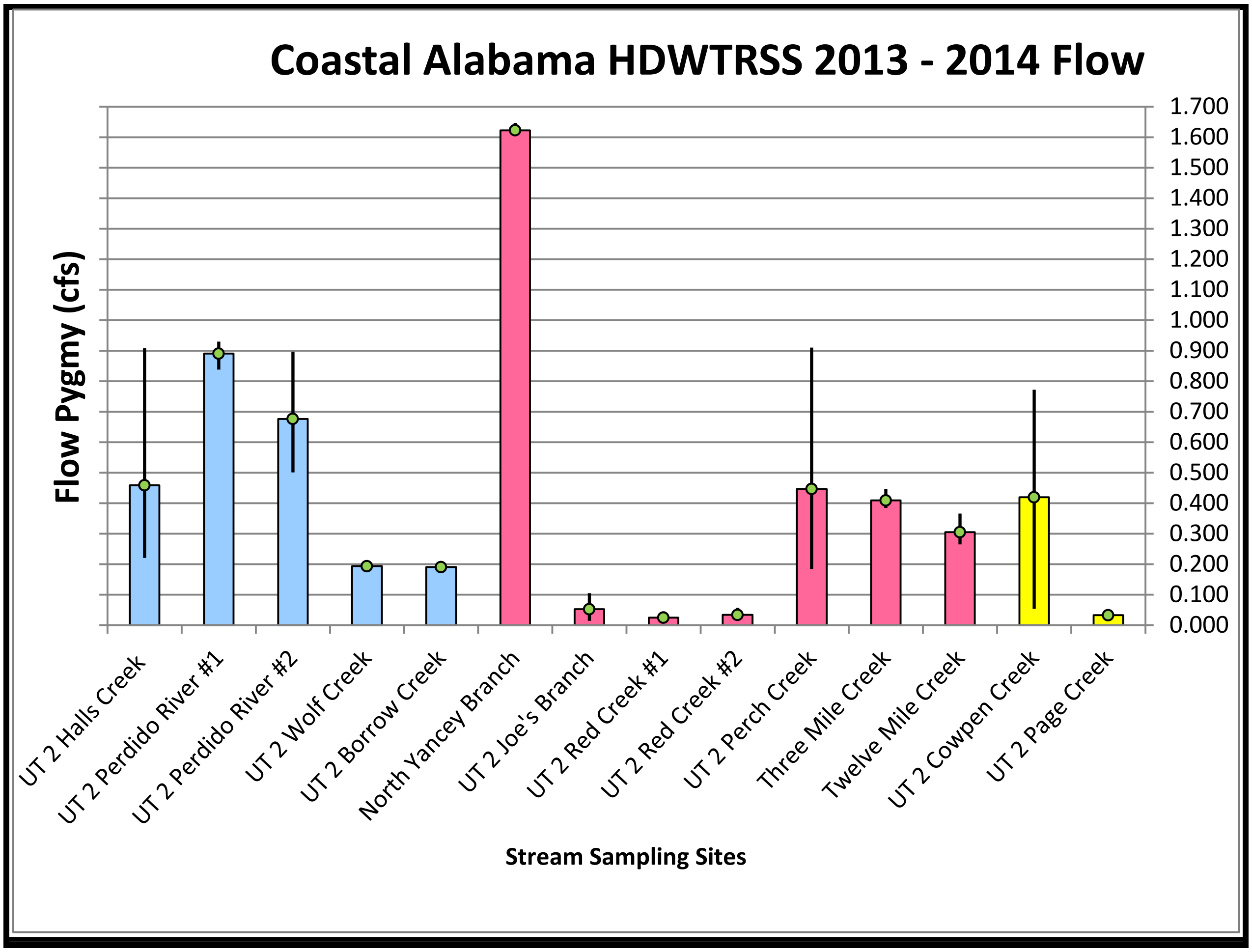


Figure4. Stream Flow data for HDWTRSS stream sites.

Overall Stream Flow Data

The HDWTRSS Stream Flow data ranged from low baseflow streams at 0.01 cfs up to 1.647 cfs. The stream flow data was widely distributed, with no obvious groupings or patterns for the data based upon LUC or geographic distribution.

5.3.2 Temperature

All air and water temperatures taken at the HDWTRSS stream sites were recorded in degrees Celsius (°C). The resulting raw data values show only very slight total temperature differences for either Air Temperature, or Water Temperature.

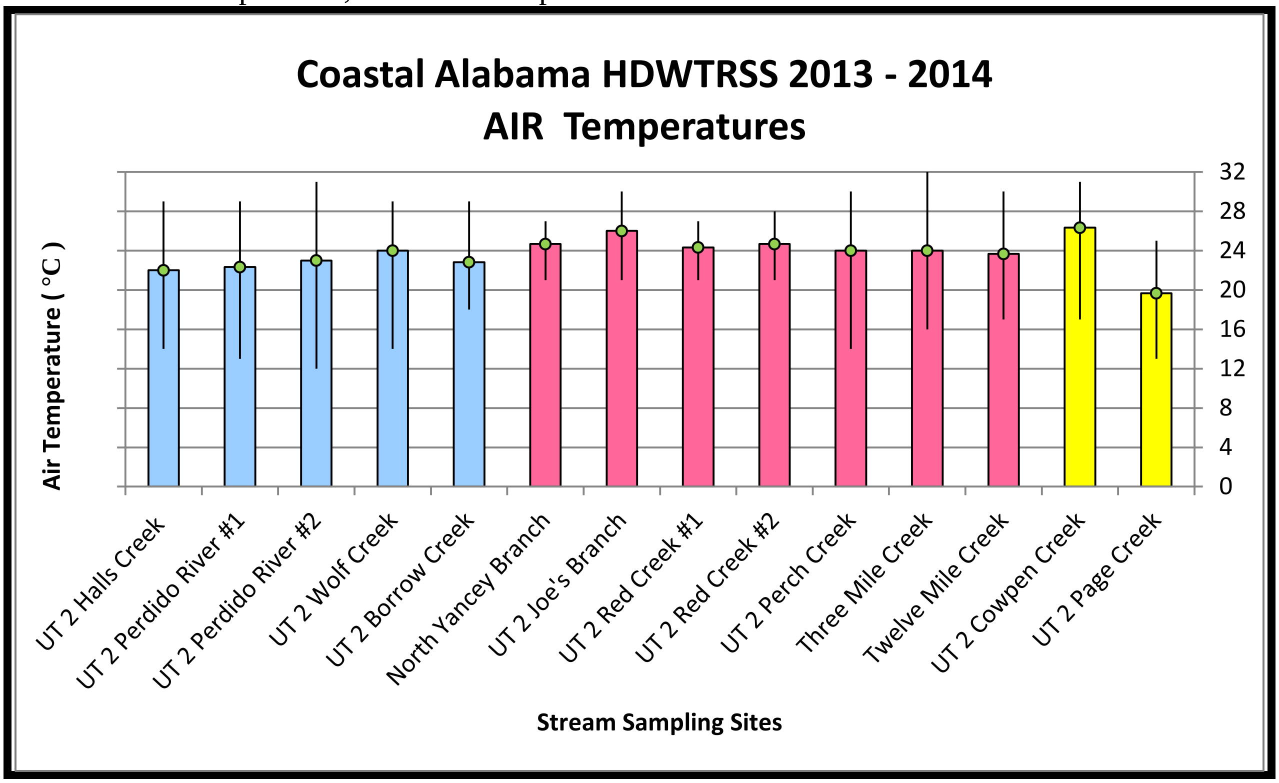


Figure 5. Air Temperature data for HDWTRSS stream sites.

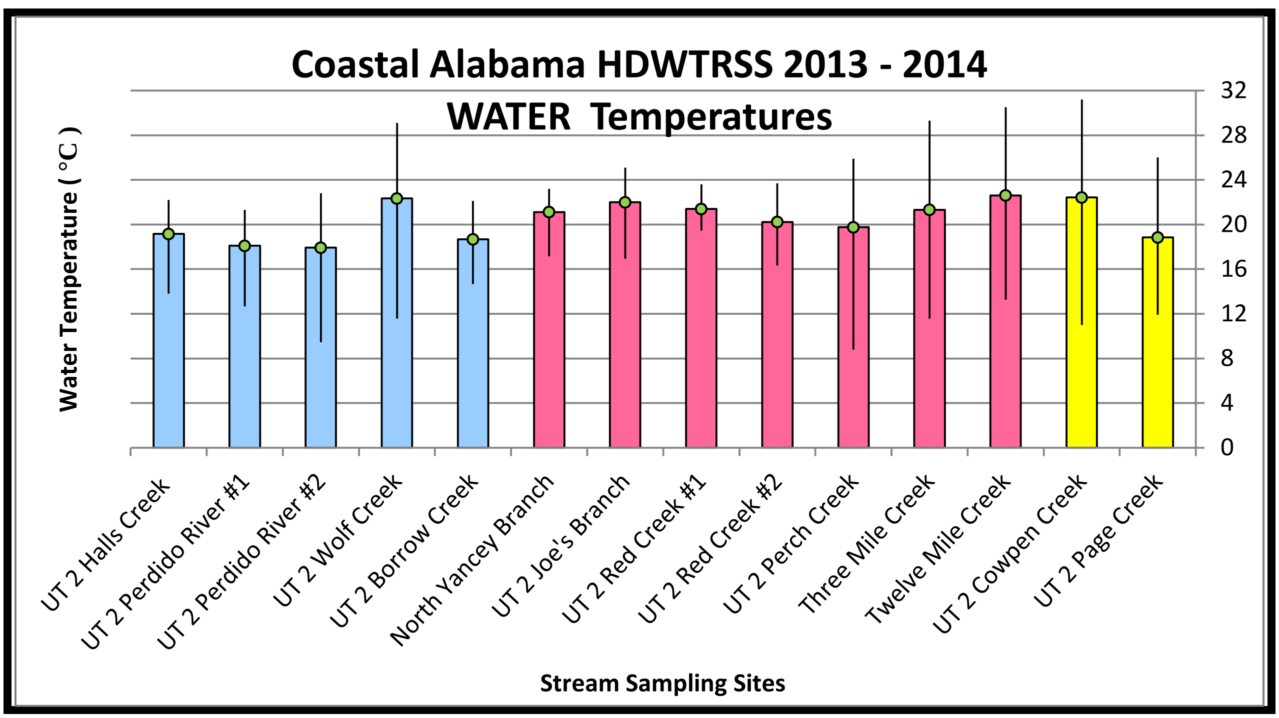


Figure 6. Water Temperature data for HDWTRSS stream sites.

Comparison of Air and Water Temperatures: Averaged Differences (±Δ)

There was no statistically significant difference in the raw temperature data for any of the selected headwater streams sites (see *Tables 3, 4, and 5 above*). The only observable data groupings for the recorded temperature data involved calculating the change (±Δ) of average mean temperature between the water and the air for each site, using the water temperature as the more stable value, minus the air temperature. It is worth noting that the calculated average of the Reference Streams temperature change **(±Δ)** value was slightly larger at -3.60°C (i.e. colder), than the averaged values of the Impacted Urban Streams and the Impacted Agriculture Streams, at -3.27°C and -2.37°C respectively. Although not overwhelming in terms of total temperature, this seems to indicate that the Reference Streams with their more complete forest canopy cover appear to maintain a cooler stream environment.

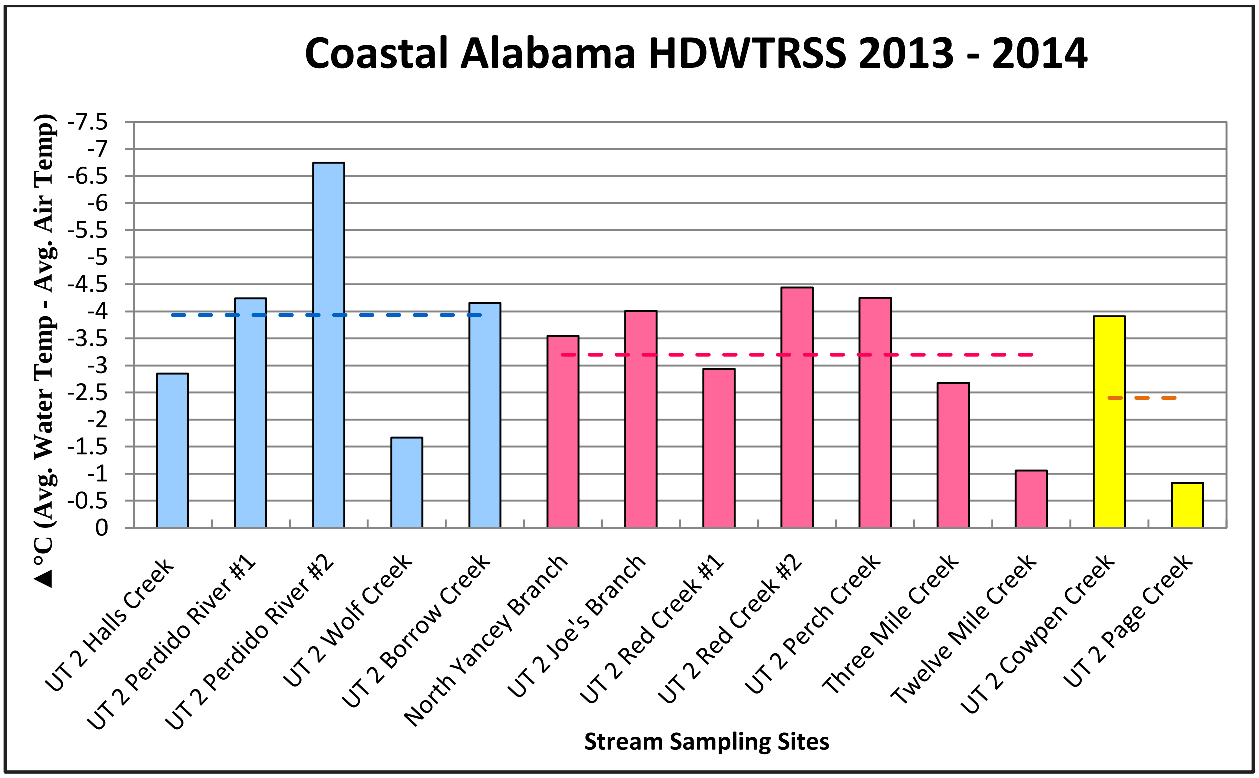


Figure 7. Comparison of Average Site Water-Air ±Δ Temp Graph for HDWTRSS stream sites

The **relative averaged temperature difference (±Δ)** shows that **Impacted Urban Streams were 9% warmer**, while the comparative difference of the **Impacted Agriculture sites** was calculated as being **34% warmer**, when compared to those averaged ±Δ values for these Reference Headwater sites.

Overall Temperature data: Air and Water

Both water and air temperatures for our coastal streams were reflective of the seasonal sampling conditions. The temperatures for all sampled headwater streams were below ADEM regulatory standards for the FISH & WILDLIFE classification, which require that "the maximum for those streams shall not exceed 90°F" (32.2°C). [**ADEM Admin. Code R. 335-6-10-.09(5)(e)3(i)**].

5.3.3 pH:

ADEM 2005 Division 6 Regulations state that for the FISH and WILDLIFE designation to which classification these stream reaches are assigned, "wastes shall not cause the pH to deviate more than one unit from the normal or natural pH, nor be less than 6.0, nor greater than 8.5.**" (ADEM Admin. Code R. 335-6-10-.09 (5).** This statement generally applies to the designated use classifications statewide. However *Alabama's 2014 §303(d) List Fact Sheet* reports that low pH is a natural condition for many native streams that flow across Alabama's Coastal Plain. "Some waterbodies in this sub-ecoregion are blackwater streams. Blackwater streams flow through primarily sandy soils, which tend to be more acidic than upland soils, and are surrounded by trees which produce tannins, such as Pines, Cedars, and Oaks. The tannins and acidic soils tend to make the water pH more acidic."
[see http://adem.alabama.gov/programs/water/wquality/2014AL303dFactSheet.pdf]

Many coastal waterbodies have geographic watershed characteristics that can cause the naturally occurring pH to be lower, at times, than the ADEM numeric criterion. These streams tend to be located in flatland areas, which can cause stream velocity to be slower than normal. Sandy soils, surrounding vegetation that produce tannins and other factors create swampy and backwater stream conditions which tend to make the waters more acidic. This is the natural state of these waterbodies and does not indicate use impairment or impact. (ADEM-Water Division, 2014).

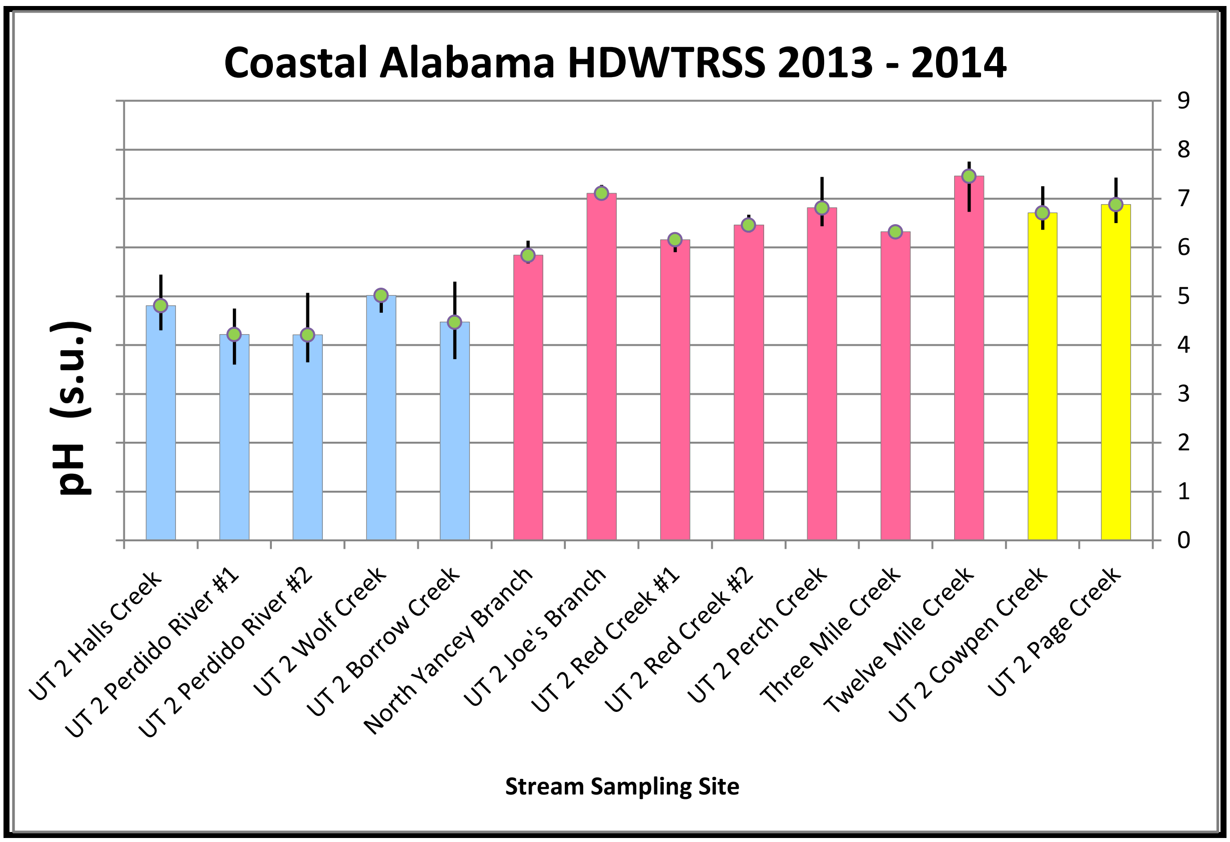


Figure 8. pH at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

The natural watershed landscape for the majority of these headwater Reference Streams were primarily composed of large-parcel legacy pine plantations, with small scatterings of oaks and cedars with large native buffers, largely comprised of a sweet bay-swamp tupelo assemblage that drain across low gradient sandy soils. These coastal Reference Streams exhibited a calculated average **value of 4.55 for pH**. The observed readings ranged from a warm weather low of 3.60 standard units (s.u.), but ranging upwards to a pH of 5.44 s.u. Initial Level I reconnaissance observations and supporting field spectrophotometer readings (AquaFluor® Handheld Fluorometer preliminary tests proved ineffective due to the presence of tannins) from these sites confirmed that the Reference Streams sampled are indeed low pH “blackwater streams”, as described. Therefore these coastal streams display natural characteristics of low pH, and are not viewed as impaired due to pH, based on available water quality data and information collected at these selected sites. The averaged value for each Reference Stream site was from **4.21, up to 5.02 s.u.** These streams are classified as “Fish and Wildlife” but as noted will often exhibit these lower pH values that have been adjusted for their local natural conditions. The consistency or grouping of these pH readings is a reflection of the natural environmental factors that are typically associated with these coastal Reference stream reaches.

Impacted Headwater Streams:

These streams averaged significantly higher pHs than those compared with the Reference Streams in this study. The Impacted Streams as a total group averaged at a **pH of 6.63**. This is a substantial **difference of over 2.0 standard units of pH**.

Many factors may account for this, but the most observable components that differ in the more impacted Urban Stream reaches, relate to the ubiquitous presence of limestone, gravel, and concrete-derived structures that would raise the averaged observed **pH to 6.59 s.u.** in these coastal headwater streams. These largely surficial structures are most common throughout more urbanized watersheds. These structures may range from commercial parking areas, residential driveways, and curbing, to stormwater conveyances with box culverts, armoring, gabions, and rip-rap. There were no discernable data clusters within this group.

For the Impacted Streams with surrounding agriculture land use, they exhibited slightly higher values as compared to the Urban Streams. The Agricultural Streams averaged a **pH of 6.79**, also more than 2 s.u. higher than the sampled Reference Stream sites. It is probable that basic soil amendments, associated with agricultural or land use practices surrounding these stream reaches, may play a major role for this upward shift in pH.

Overall pH:

The designated Reference Stream headwater reaches sampled exhibited pH readings that ranged from 3.60 to 5.44, with an overall average of 4.55 for those pH values. Reference Stream sites for this study included the coastal sub-watersheds of Barrow Creek (HUC 31602040103), Halls Creek (HUC 31602040104), Clear Springs Church(HUC 31401060701) and Sandy Creek (HUC 31401070201), within coastal Alabama. Interestingly, the Impacted Stream segments exhibited pH values closer to mid-range, with an average pH of 6.69 s.u. for those segments.

Statistically there was a strong negative correlation between pH and composite score for fall, spring and winter seasons (Spearman's rank correlation, p=0.00003, 0.0004, 0.00045, r=-0.8185, -0.812, -0.809, respectively), indicating the pH declined with increasing composite score.

5.3.4 Dissolved Oxygen

Dissolved oxygen (DO) concentration is an essential constituent that affects the biological health and the chemical composition of surface waters. Biological processes, oxidation, and sediment loads all may contribute to impacts associated with the measurable presence of Dissolved Oxygen in surface water (Murgulet, Cook, 2010).

ADEM 2005 Division 6 Regulations [**CHAPTER 335-6-10]** state that, "In coastal waters, surface dissolved oxygen concentrations shall not be less than (the concentrations stated below)":

SWIMMING AND OTHER WHOLE BODY WATER-CONTACT SPORTS:
5.0 mg/L, except where natural phenomena cause the value to be depressed.
(ADEM Admin. Code R. 335-6-10-.20)

SHELLFISH HARVESTING:
5.0 mg/L, except where natural phenomena cause the value to be depressed
(ADEM Admin. Code R. 335-6-10-.24)

FISH AND WILDLIFE:
5.0 mg/L, except where natural phenomena cause the value to be depressed
(ADEM Admin. Code R. 335-6-10-.27)

OUTSTANDING ALABAMA WATER:
5.5 mg/L, except where natural phenomena cause the value to be depressed
(ADEM Admin. Code R. 335-6-10-.14)

LIMITED WARMWATER FISHERY:
Dissolved oxygen (May--November): treated sewage, industrial wastes, or other wastes shall not cause the dissolved oxygen to be less than **3.0 mg/L**.
(ADEM Admin. Code R. 335-6-10-.29)

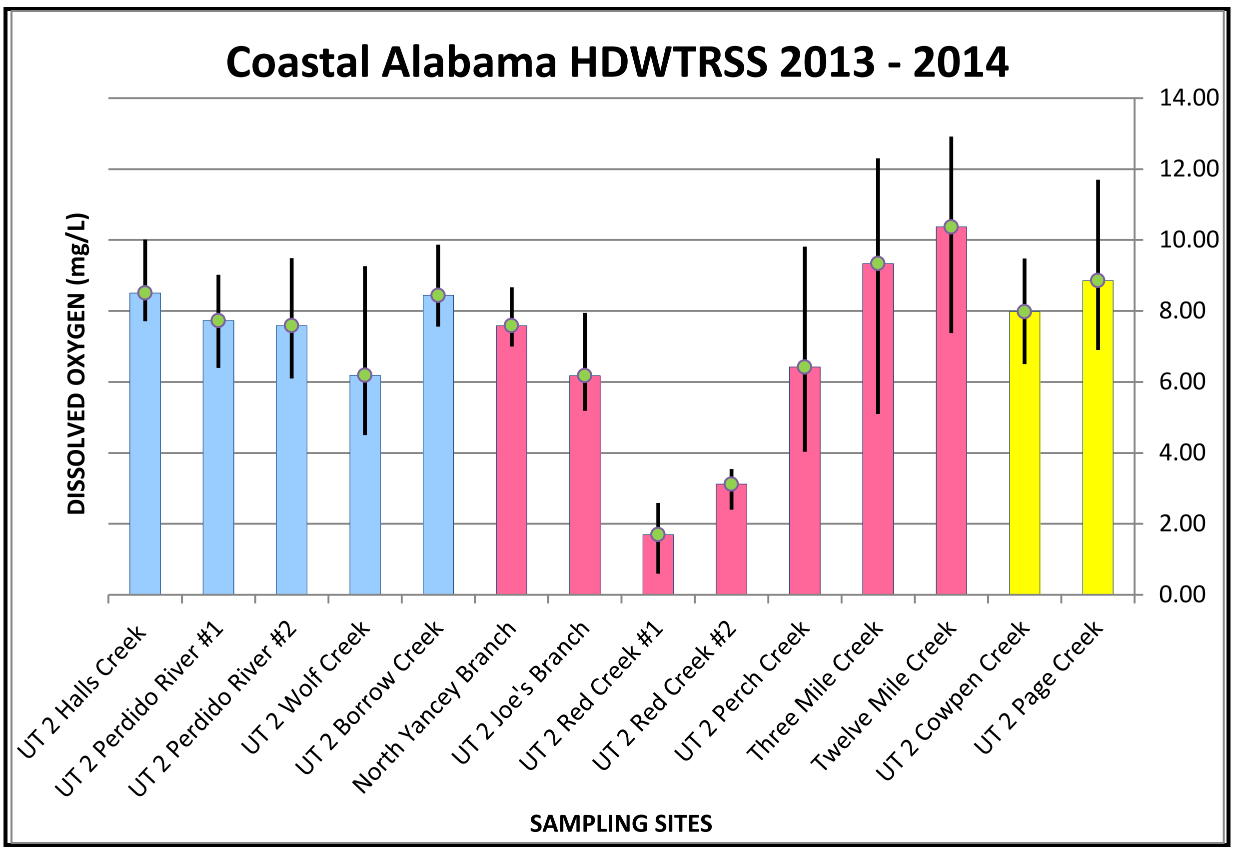


Figure 9. Dissolved Oxygen at HDWTRSS Stream Sites

Potential Reference Headwater Streams:
For this set of *in situ* samplings the Reference Streams exhibited a composite average value of 7.69 mg/L for Dissolved Oxygen. The observed DO readings ranged from warm weather lows of 4.5 mg/L to colder weather readings up to 10.1 mg/L. The averaged value for each Reference Stream site ranged from 6.1 to 8.51 mg/L. This is well within the ADEM Water Quality Standards for these coastal streams, which are classified as “Fish and Wildlife” with a requisite DO range of 5.0 to 10.0 mg/L. The consistency or grouping of these DO readings is a reflection of natural environmental factors typically associated with these Reference Stream reaches.

Although the site averages at 6.19 mg/L, the outlier sample values were below 5.0 mg/L for the UT2 Wolf Creek stream site may be determined by natural conditions. Two factors may have contributed to these lower DO readings: 1.These values were observed during warm weather conditions, as it is the southernmost study site. 2. This stream reach’s upstream origins are from a shallow blackwater swamp wetland that has been modified into a small pond. The stream receives the pond’s excess surface flow south of Swift Church road. Although those site readings for DO are below standards, other WQ parameters and Assessment scores provide data that allows the relative placement of this stream with our Reference Stream Group.

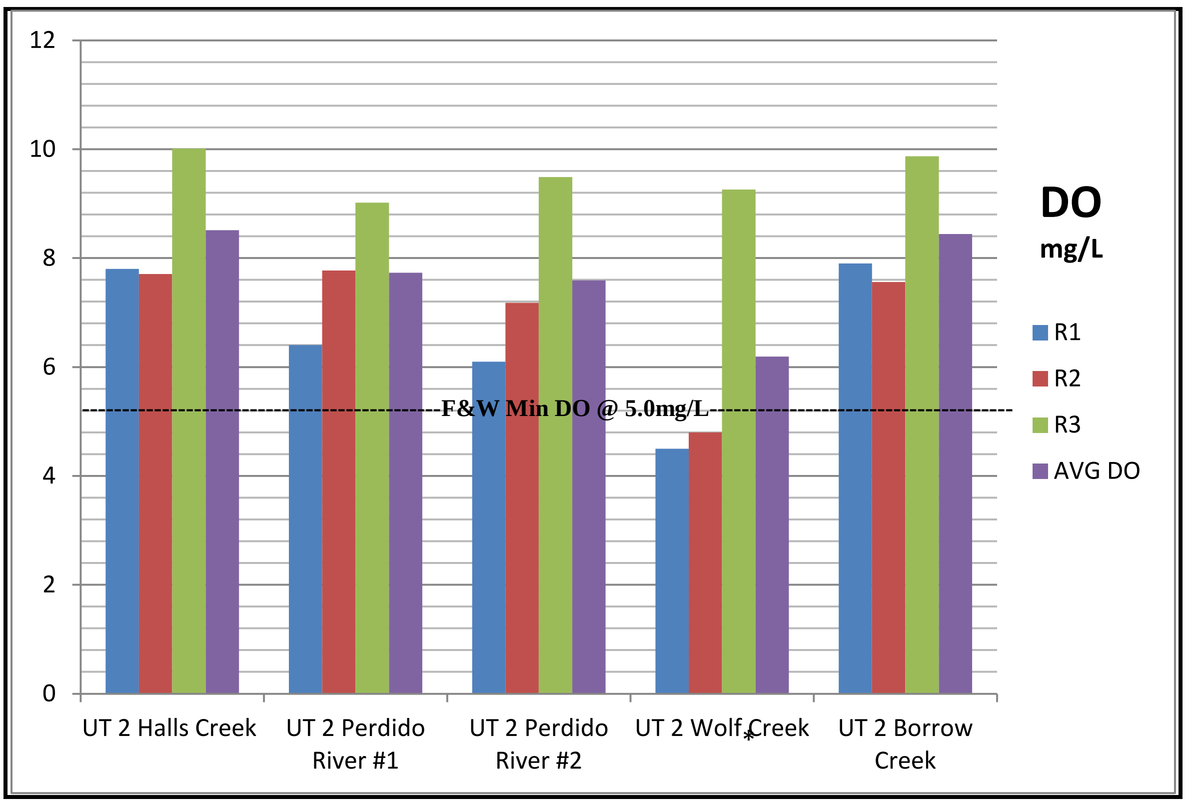


Figure 10. Dissolved Oxygen at HDWTRSS Reference Stream Sites

Impacted Headwater Streams:
For this group of DO data the Impacted Urban Streams exhibited a composite average value of 6.38 mg/L for Dissolved Oxygen. The observed DO readings ranged differently for this group and seemed to display three distinct value sets. Two Urban Streams exhibited very low DO with a total average of 2.45 mg/L. These two streams both appeared to have artesian spring origins

with DO readings ranging from 0.6 to 3.55 mg/L. Three Urban Streams with more moderate DO values that averaged 6.73 mg/L, were encompassed within urban sections that had been established with more contiguous vegetative cover along their riparian buffers. The moderate DO group values may be a reflection of those environmental factors. Two Urban coastal streams exhibited rather high DO values with a total average of 9.85 mg/L, with an upper range up to 12.92 mg/L for those sites. The grouping of the DO readings for the low and high groups can be indicators of unstable, flashy urban stream conditions, especially for coastal streams. Accordingly, those urban stream sites with more saturated DO readings, exhibited destabilizing characteristics with obvious evidence of more intensive upstream impacts, e.g. failed armoring with numerous incising headcuts and plunge pools. The DO values for Agriculture Impacted Streams were within normal standards at an average value of 8.142 mg/L.

Overall DO Observations for Headwater Streams:

The Dissolved Oxygen concentrations that were sampled and recorded for the HDWTRSS revealed generally higher DO in cold weather during the R-3Winter sampling, as would be expected. Figure 11 below, reasonably depicts the expected seasonal pattern observed for DO at each of the 14 coastal headwater stream locations.

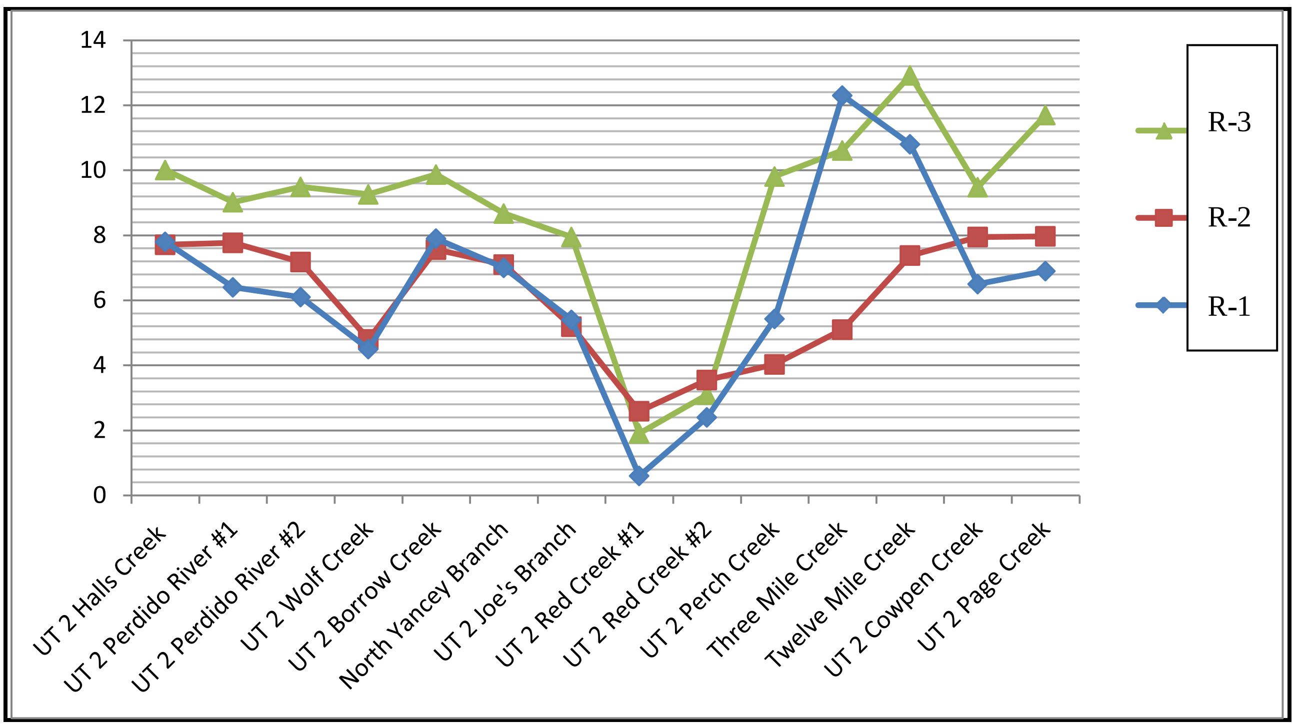


Figure 11. Seasonal Sampling shows the pattern of relative DO measurements from each site.

5.3.5 Salinity

Salinity is a measure of the relative content of mineral salts present in these coastal streams. Salts are highly soluble in surface and groundwater and can be transported with water movement. Salinity is the total of all non-carbonate salts dissolved in water, usually expressed in parts per thousand (1 ppt =1000 mg/L). It provides a direct measure of the relative influence of tidal and freshwater sources. Salinity affects the distribution, abundance and composition of biological resources [http://www.nerrs.noaa.gov/doc/siteprofile/acebasin/html/envicond/watqual/wqintro.htm]. These low salinity values illustrate that these HDWTRSS stream reaches are distinctly above tidal influences.

The ADEM Water Quality Standards provide no limiting values for salinity in these "Fish and Wildlife" designated headwater streams. The observations concerning these parameters are based upon their relative values, which were **all recorded below 0.2 ppt, or 20 mg/L**.

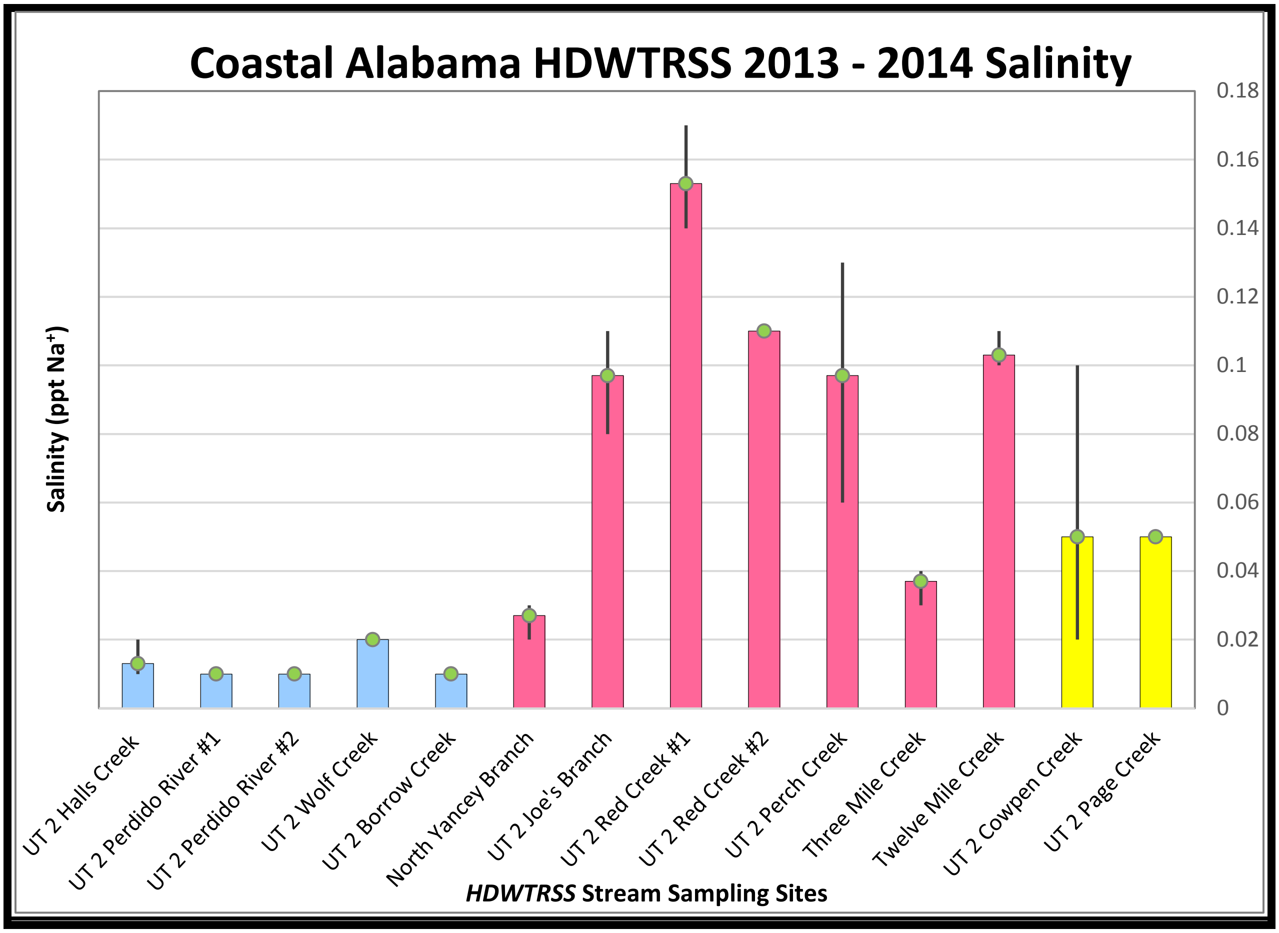


Figure 12. Salinity at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

The consistency or grouping of these Salinity readings for the sampled Reference Stream sites are a reflection of natural environmental factors and minimal LUC impact effects associated with these stream reaches. The salinity readings for these selected headwater streams were observed within 0.01ppt to 0.02ppt.

Impacted Headwater Streams:
For this Impacted Urban Streams group the averaged salinity values were reported at 0.085ppt. Interestingly, they exhibit a larger value than the Impacted Agriculture steam sites sampled, which averaged salinity values at 0.05 ppt.

Overall Salinity Observations for Headwater Streams:
Based upon their relative values, the HDWTRSS sites exhibit expected differences for salinity. The raw data show rather low salinity values, as would be expected for these headwater streams. The Reference Streams data exhibited extremely low values for salinity, their combined average being less than 0.02 ppt. The Impacted Agriculture sites were observed to have an increased average of 0.03 ppt. The Impacted Urban sites averaged data showed a comparative increase of 0.065 ppt relative to the Reference Stream salinity data. These LUC-associated differences are further substantiated in the Specific Conductivity data reviewed below, in section 5.3.6.

Salinity was significantly different among stream types in all three seasons evaluated (Kruskal-Wallis rank sum test, p=0.009, 0.009, 0.007) with median values ranging for Agriculture from 0.035 – 0.75, Reference 0.01 average, and Urban streams 0.08 – 0.11 ppt.

5.3.6 Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity [http://water.epa.gov/type/rsl/monitoring/vms59.cfm]. When conductive compounds or elements are present in surface and groundwater, they are easily transported in these primary headwater streams. Conductivity for the HDWTRSS project were measured in micromhos per centimeter (µmhos/cm) using a datasonde unit. The datasonde unit utilizes a temperature compensated specific conductivity probe for the measurement of *in situ* conductivity automatically corrected to 25°C. A good frame of reference is to evaluate the Conductivity of distilled water, which has Conductivity in the range of 0.5 to 3.0 µmhos/cm.
[http://web-server/intranet/QA/sop/pdfs/SOP%202000/SOP2041.pdf]

The ADEM Water Quality Standards provide no limiting values for Conductivity in these "Fish and Wildlife" designated headwater streams. The HDWTRSS observations concerning these parameters can be grouped by LUC-associated groupings, based upon their *in situ* values, which **ranged widely from 22.0 µmhos/cm, up to 353.0 µmhos/cm.**

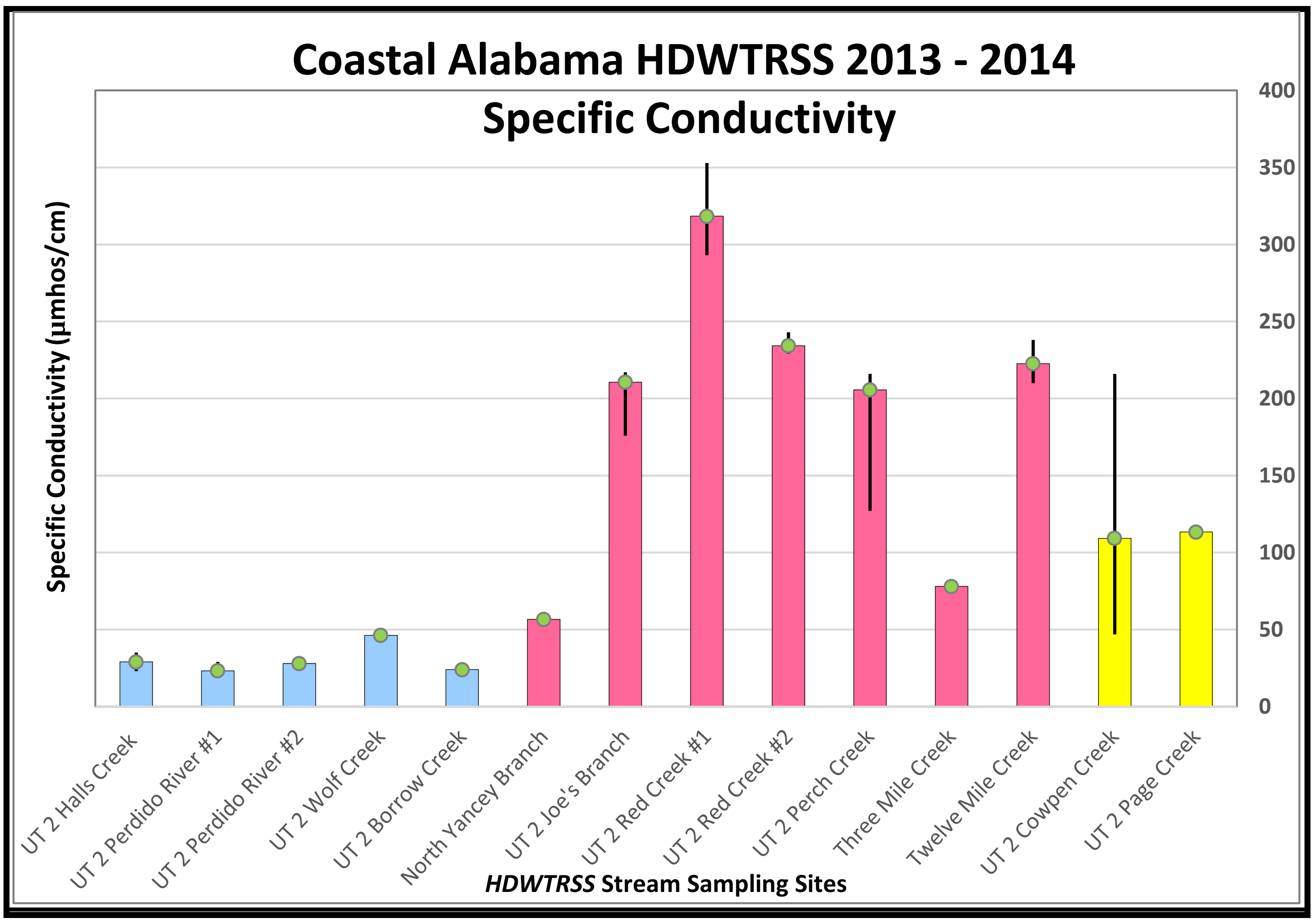


Figure 13. Specific Conductivity at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

The averaged Conductivity readings for these Reference headwater streams were **calculated at 30.13 µmhos/cm**. Similar to other WQ data, the consistency of the Conductivity readings for the sampled Reference Stream sites seem to correlate to more natural environmental conditions, with minimal observed LUC impact effects.

Impacted Headwater Streams: Urban and Agriculture

For this **Impacted Urban Streams** group the averaged Conductivity values were reported at **189.48 µmhos/cm.** Again, the Impacted Urban headwater steams exhibit a larger value than the **Impacted Agriculture** steam sites sampled, which averaged Conductivity values at **111.33 µmhos/cm.** These comparisons are more dramatic in terms of basic unit of measure.

Overall Specific Conductivity

Based upon their averaged Conductivity values, the HDWTRSS sites exhibit expected differences similar to those noted for salinity. The Conductivity data show a larger contrast between the attributed LUC groupings. The **Reference Streams data exhibited lower Conductivity readings**, with their total average being at 30.13 µmhos/cm. The **Impacted Agriculture** sites recorded an increased average Conductivity at 111.33 µmhos/cm.

The Conductivity of the Agriculture stream sites yielded increased values that were **370%, larger** than the Reference Group headwater stream data. The **Impacted Urban** stream sites' averaged data (189.48 µmhos/cm) showed a comparative **increase of almost 630%**, relative to the averaged Reference Stream group data.

Based upon the field observations at the headwater stream project sites, these differences for Conductivity measurements are strong indicators of the impacts associated with more intensive land uses. It is probable that the increase in stream Conductivity values correlate with the increased percentage of impervious surfaces and associated land cover, and resulting increased runoff within the drainage of each headwater stream reach.

Specific conductance was significantly different among stream types in all three seasons evaluated (Kruskal-Wallis rank sum test, p=0.0102, 0.007, 0.008) with median values ranging for Agriculture from 82-165, Reference 23-29, and Urban streams 117-229 µmhos/cm.

5.3.7 Turbidity

Turbidity was selected for the HDWTRSS project to provide a comparable functional field measure of suspended solids that are transported by these headwater coastal streams. These suspended solids may include a varied assortment of materials, both organic and inorganic. Many principal pollutants associated with stormwater runoff into these streams may be suspended in the water column (USEPA, 1993). Suspended particles may serve as substrates for other pollutants such as pathogens and some heavy metals; thereby high Turbidity readings may indicate many problems for water quality. **Turbidity is measured in Nephelometric Turbidity Units (NTU)**, as the amount of light scattered from a sample making it a measure of the cloudiness or murkiness of the water column. Turbidity may be best described as a function of total suspended solids present in the water column. High Turbidity readings indicate a reduction in the amount of light that penetrates the water; and furthermore are indicative of high concentrations of sediment and particles that may impart negative effects on aquatic systems, both physically and biochemically (NSCU, 1994). **ADEM Admin. Code R. 335-6-10-0.9(5)(e)9 (pg 10-29) states that "**there shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 NTUs above background."

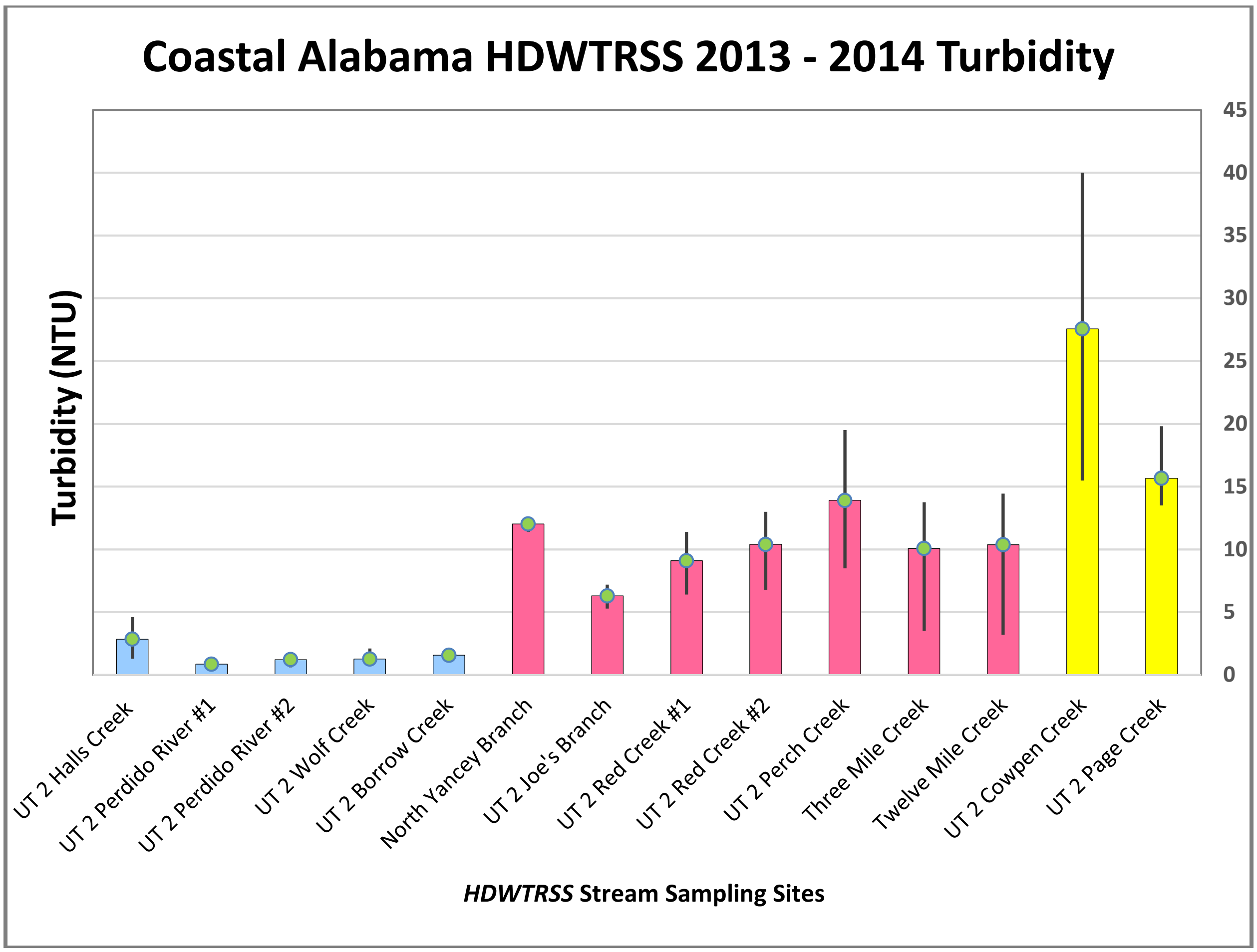


Figure 14. Turbidity at HDWTRSS Stream Sites

Potential Reference Headwater Streams:
These *HDWTRSS* Reference Streams exhibited a composite average **value of 1.56 NTU for Turbidity**. The observed readings ranged from a low of 0.6 NTU, up to a Turbidity of 4.6 NTU*. The consistency or grouping of the Reference Streams Turbidity data seem to indicate more stable environmental factors, with minimal LUC impact effects associated with these Reference stream reaches.
*this event was above normal UT2Hall Creek baseflow due to an unknown rain event within the standard precipitation interval.

Impacted Headwater Streams: Urban and Agriculture
These Urban Headwater streams averaged significantly higher Turbidity compared with the Headwater Reference Streams in this study. The Urban-Impacted Streams as a group averaged a **Turbidity of 10.31 NTU**. This is a substantial and significant **increased difference of over 660%**. Many factors may account for this, but the most observable components that differ in these more impacted Urban Stream headwater reaches, usually relate to the substantial amounts of impervious surface, reduced canopy, and alteration or hydromodification of coastal stream reaches. These impacts usually create major changes in the hydrology, increasing erosion and sedimentation, and making these streams relatively unstable. There were no discreet data clusters within the Impacted-Urban Stream group.

For those headwater streams sampled that had agriculture-related land use, the increase was even more dramatic, at an **average of 21.62 NTU, yielding an increase of over 1385%,** as compared with the HDWTRSS Reference streams. The observed characteristics that are most apparent for these impacted rural, agricultural headwater streams relate to almost complete removal of the tree canopy along the riparian zone with scant vegetative buffers, along with intensive hydromodification impacts using mis-applied BMP practices. These impacts seem to promote conditions that may cause relative instability of these headwater stream reaches. There may be opportunities to promote agricultural awareness of lower impact BMPs or practices (e.g. cross-fencing to provide or protect vegetative riparian buffers, and proper alignment and placement of stream culverts at road crossings).

Overall Turbidity
None of these HDWTRSS streams sampled within the ACNPCP Management Area exhibited Turbidity readings that exceeded the State regulatory limits for these parameters.

Turbidity was significantly different among stream types in all three seasons evaluated (Kruskal-Wallis rank sum test, p=0.009, 0.005, 0.004) with median values ranging for Agriculture from 14.5 – 29.9, Reference 1.2 – 1.3, and Urban streams 9.5 – 12.6 NTU.

6. FINAL *HDWTRSS* DATA

More than 200 tabletop mapping sites were identified as potential sites, and were field verified, during the Pilot Headwater Stream Survey conducted through September 2012. Of the 200 sites considered, field visits determined that only 144 sites were recognized as potential headwater stream systems with the remainder of the sites being found to have been obliterated or have non-existent channel features (see Appendix I for all streams documented).

Based on the 144 sites identified during the Level I Inventory, very few were selected for the final Level II stream survey assessment. Many of the sites were either not perennial in nature or there was too much disturbance upstream and downstream of the study reaches. During Level II survey, additional sites that met the necessary minimum characteristics were identified for inclusion into this study. A total of 14 sites (listed in Table 6 below) were ultimately selected for this study and they were observed and placed in 4 potential categories: Reference or Impacted, Rural or Urban; with resulting designations for Impacted Urban Streams and Impacted Agriculture Streams being grouped for comparison with the designated Reference Streams in this study.

Final Geomorphic Field Headwater Stream surveys were conducted between March 2013 and August 2013 in Baldwin and Mobile Counties. Most of the omitted field sites were hydrologically limited by not having permanent water flow year round. Other sites were impacted by channelization or upstream land use impacts (i.e., agriculture ditches and drainages) along with lack of visible evidence of channel features. There were a few sites impacted by sedimentation from unpaved roads and many were swampy in nature due to beaver activity or an extremely low gradient.

ADEM Water Quality Headwater Stream field sampling was initiated concurrently with the Geomorphic Survey work, but continued forward to collect seasonal site parameters into February of 2014.

6.1 *Selected HDWTRSS Stream Sites*

These were the 14 coastal headwater stream sites that were selected for the 2013 Coastal Alabama Pilot Headwater Stream Survey Study:

Table 6. Level II Inventory Sites during the 2013 Field Survey.

SITE NAME	HUC #	HUC NAME	TYPE	COUNTY
UT 2 Borrow Creek	31602040103	Farris Creek-Barrow Creek	R/Ru	Mobile
UT 2 Halls Creek	31602040104	Little Halls Creek-Halls Creek	R/Ru	Baldwin
UT 2 Perdido River #1	31401060701	Clear Springs Church-Perdido River	R/Ru	Baldwin
UT 2 Perdido River #2	31401060701	Clear Springs Church-Perdido River	R/Ru	Baldwin
UT 2 Wolf Creek	31401070201	Sandy Creek-Wolf Creek	R/Ru	Baldwin
North Yancey Branch	31602050205	Fly Creek	I/U	Baldwin
UT 2 Joe's Branch	31602040505	Tensaw River-Apalachee River	I/U	Baldwin
UT 2 Red Creek #1	31602040304	Red Creek-Eight Mile Creek	I/U	Mobile
UT 2 Red Creek #2	31602040304	Red Creek-Eight Mile Creek	I/U	Mobile
UT 2 Perch Creek	31602050103	Lower Dog River	I/U	Mobile
UT 2 Three Mile Creek	31602040504	Toulmins Spring Branch-Three Mile Creek	I/U	Mobile
Twelve Mile Creek	31602040504	Toulmins Spring Branch-Three Mile Creek	I/U	Mobile
UT 2 Cowpen Creek	31602050204	Lower Fish River	I/Ru	Baldwin
UT 2 Page Creek	31700080405	Spring Creek-Escatawpa River	I/Ru	Mobile

Key to observed **TYPE**: R/Ru = Reference/ Rural, I /U=Impacted/Urban, I/Ru=Impacted/Rural, I/Ru was later changed to Impacted/Agriculture.

6.2 *HDWTRSS Stream Geomorphology*

6.2.1 Geomorphic Conditions for Selected Headwater Streams

Stream survey sites ranged in drainage area from 0.1 to 2.3 sq.mi. with reference sites selected for a maximum drainage area of 1.0 sq.mi. each. These project stream sites exhibited an impervious surface area percentage for each watershed (12-digit HUC) ranging from a minimum of 0.0% to a maximum of 47.8% (see Table 7). This provides an interesting contrast to the Land Use/Cover Assessment scores presented in Table 8 below, which are based upon the surrounding LUC estimated within the 500ft. radius for each coastal headwater stream site.

There were five reference reaches surveyed, with four being in Baldwin County and one in Mobile County. A total of seven sites were located in rural settings and the remaining five were from urban landscapes. Reference data showed a good distribution of channel sizes (i.e., bankfull width, depth and cross sectional area), along with gradient variations (i.e., 0.003 to 0.034 ft/ft) and channel pattern (Table 2). Most of the sites were classified as being E stream types with several from C and two from B types. Channel bed material was collected at each site and ranged from very fine material (i.e., clay) to coarse substrates (i.e., gravel). Even though many of the surveyed sites had sand as their primary particle size distribution, protrusion heights were collected from 7 of the 14 streambed sites to improve bed roughness calculations and bankfull discharge. Protrusion heights from the remaining seven sites were not collected due to a lack of features to measure, or material sizes that were greater than 2.0 mm.

Statistically there are strong positive correlations between channel sinuosity and composite score (Spearman's rank correlation, $p = 0.0003$, $r = -0.8185$), indicating greater channel sinuosity with a greater composite score.

Table 7. Geomorphic Stream Characteristics for the Level II study.

HDWTRSS Stream Site	Drainage Area (mi^2)	Bankfull Width (ft)	Bankfull Depth (ft)	Bankfull Cross-Sectional Area (ft^2)	Channel Material D_{50} (mm)	Water Surface Slope (ft/ft)	Channel Sinuosity	Stream Type	Impervious Cover (%) [HUC]
UT 2 Borrow Creek	0.1	7.08	0.86	6.06	15.3	0.01678	1.53	E4/5	0.0
UT 2 Halls Creek	0.5	4.97	0.77	3.85	4.99	0.00360	1.53	E4/5	0.1
UT 2 Perdido River #1	0.5	7.26	1.08	7.85	20.16	0.00365	1.30	E4/5	0.3
UT 2 Perdido River #2	0.9	6.00	1.15	6.87	19.3	0.00485	1.44	E4/5	0.3
UT 2 Wolf Creek	0.2	4.99	0.42	2.1	8.07	0.01321	1.33	E4/5	0.8
UT 2 Joe's Branch	0.1	8.22	0.74	6.05	33.3	0.03411	1.24	B4	47.8
North Yancey Branch	0.6	9.79	1.13	11.05	0.5	0.0035	1.48	E5	7.1
UT 2 Red Creek #1	0.2	4.10	0.18	0.72	0.5	0.00431	1.05	C5	2.7
UT 2 Red Creek #2	0.2	9.87	0.60	5.9	0.5	0.01265	1.29	C5	4.7
UT 2 Perch Creek	0.1	6.65	0.69	4.61	0.5	0.00426	1.17	E5	28.5
UT 2 Three Mile Creek	2.3	10.06	0.72	7.28	0.5	0.00508	1.11	C5	10.6
Twelve Mile Creek	2.1	19.74	1.46	28.77	270	0.01118	1.03	B2c	18.8
UT 2 Cowpen Creek	0.2	10.27	0.74	7.64	4.99	0.00314	1.04	C4/5	0.1
UT 2 Page Creek	0.1	6.86	0.50	3.44	0.062	0.00827	1.07	C6	0.2

6.2.2 HDWTRSS Reference Geomorphology and the Coastal Alabama Regional Curve

Figure 15 and ***Figure 16*** below, depict geomorphic reach data that is detailed in ***Appendix III*** for the 5 Reference reaches sites surveyed during this study. These five reference sites were compared with the *Alabama Riparian Reference Reach and Regional Curve* (Alabama Curve) study to determine applicability with enhancing overall curve development (USFWS, 2005).

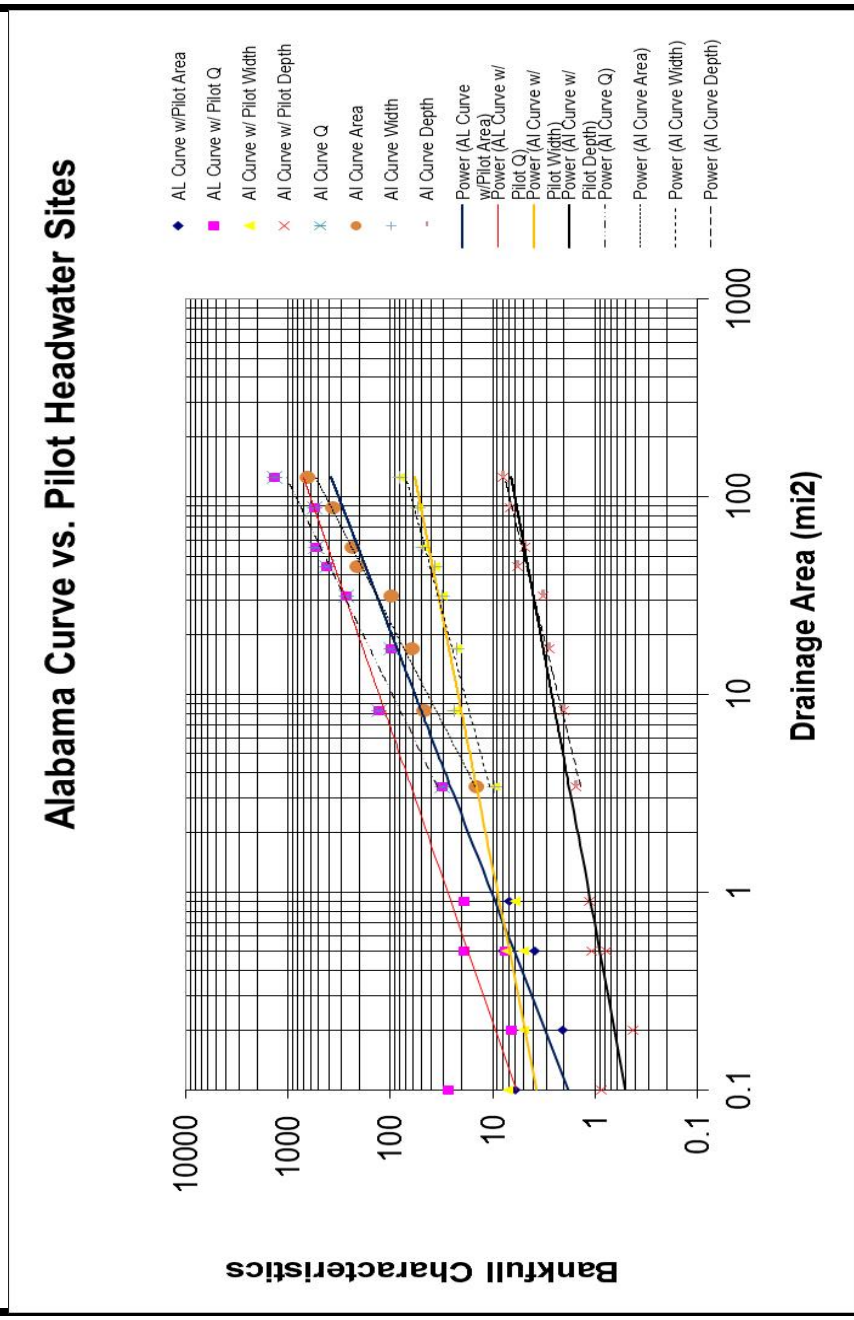
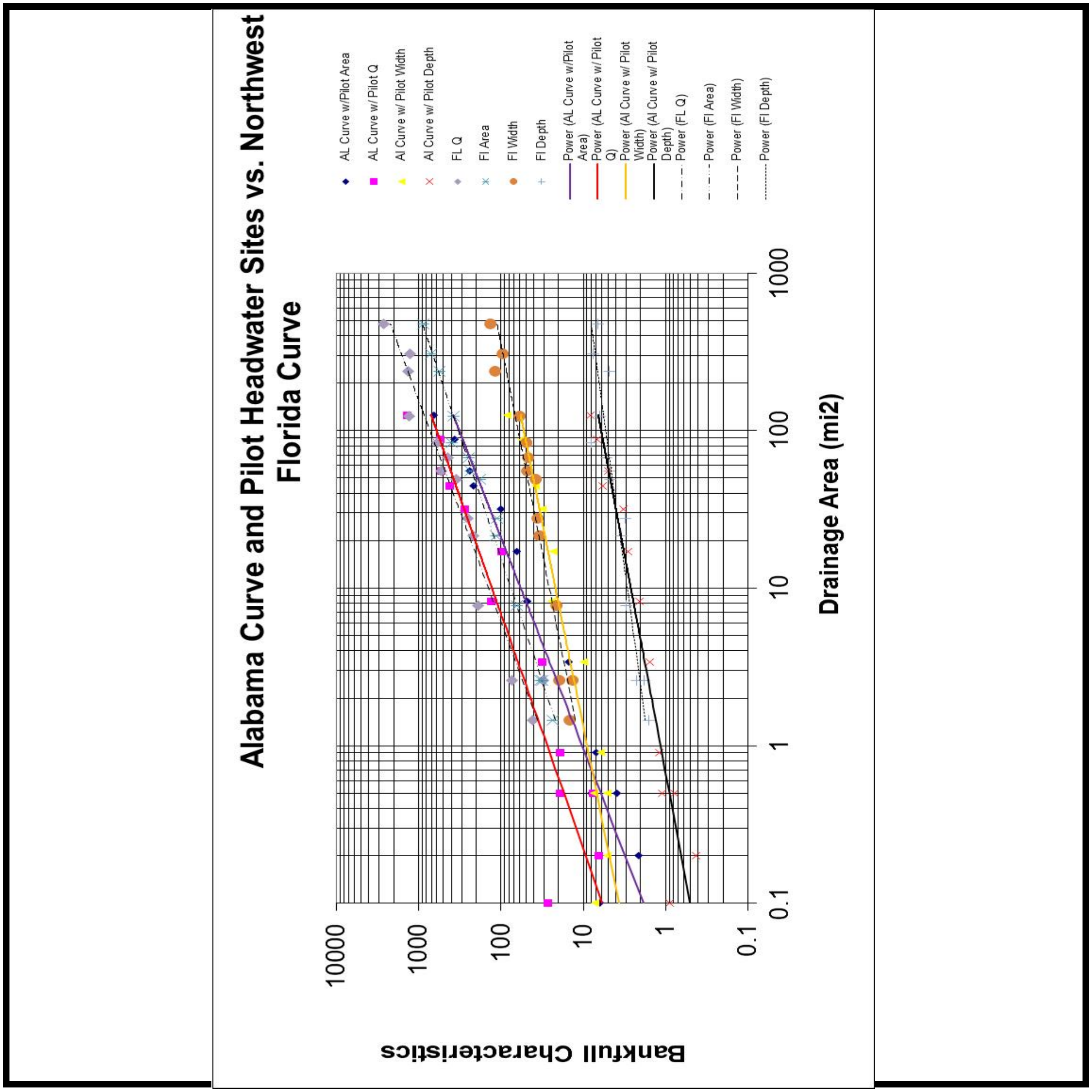


Figure 15. Alabama Curve vs. HDWTRSS Sites

Five reference sites were incorporated into the Alabama Curve and showed significant changes to the lower portion of the curve (Figure 15). In fact, when compared with the Northwest Florida Regional Curve, the Alabama Curve looks very similar (Figure 16). For bankfull discharge and width, the two curves were almost identical. Bankfull depth was only slightly smaller while the bankfull cross-sectional area was generally lower through the lower drainages.

Figure 16. Coastal Alabama Curve and HDWTRSS Reference Sites vs. Northwest Florida Curve Sites



6.3 *HDWTRSS* Project Assessments Data

These *HDWTRSS* Assessments were conducted thoroughly by the ADEM *HDWTRSS* team for each selected headwater stream site prior to the Geomorphic Surveys. Any additional information needed was observed and recorded during the R1- Spring/Summer sampling. The *HDWTRSS* Assessment forms utilized are included in ***Appendix II***. Because several of the coastal headwater stream site assessments were conducted on private lands the *HDWTRSS* Assessment Sheets may contain sensitive Personally Identifiable Information (PII); therefore, the information collected in the Assessments is presented in Table 8 below with the PII omitted.

Table 8. *HDWTRSS Site Assessment Data*

Coastal Alabama HDWTRSS		STREAM SITE ASSESSMENT SCORES				Composite HDWTRSS Assessment Index
Site Names	Canopy	Land Use/Cover	NC Stream 4.0	ADEM Habitat	AL Coastal HDWTR	
UT 2 Halls Creek	0.8038	0.865*	0.752	0.9208	0.9267	**0.854**
UT 2 Perdido River #1	0.9338	0.937*	0.720	0.9333	0.960	**0.897**
UT 2 Perdido River #2	0.880	0.887*	0.712	0.9125	0.910	**0.860**
UT 2 Wolf Creek	0.965	0.935*	0.705	0.9583	0.948	**0.902**
UT 2 Borrow Creek	0.936	0.870*	0.7626	0.9625	0.981	**0.902**
North Yancey Branch	0.8438	0.500*	0.748	0.7083	0.760	**0.712**
UT 2 Joe's Branch	0.875	0.450*	0.694	0.908	0.928	**0.771**
UT 2 Red Creek #1	0.840	0.300*	0.475	0.5542	0.606	**0.555**
UT 2 Red Creek #2	0.860	0.360*	0.629	0.5833	0.772	**0.640**
UT 2 Perch Creek	0.0125	0.230*	0.6475	0.529	0.525	**0.388**
Three Mile Creek	0.0262	0.354*	0.7266	0.5917	0.5856	**0.456**
Twelve Mile Creek	0.020	0.200*	0.795	0.3208	0.366	**0.340**
UT 2 Cowpen Creek	0.0762	0.55*	0.5035	0.554	0.523	**0.440**
UT 2 Page Creek	0.000	0.585*	0.475	0.333	0.507	**0.380**

* GIS Review Completed

Composite assessment scores showed a highly significant difference among stream types (Kruskal-Wallis rank sum test, $p=0.0082$) with median values of 0.410, 0.897, 0.555 for Agricultural, Reference, and Urban stream groups respectively.

7. SUMMARY and CONCLUSIONS

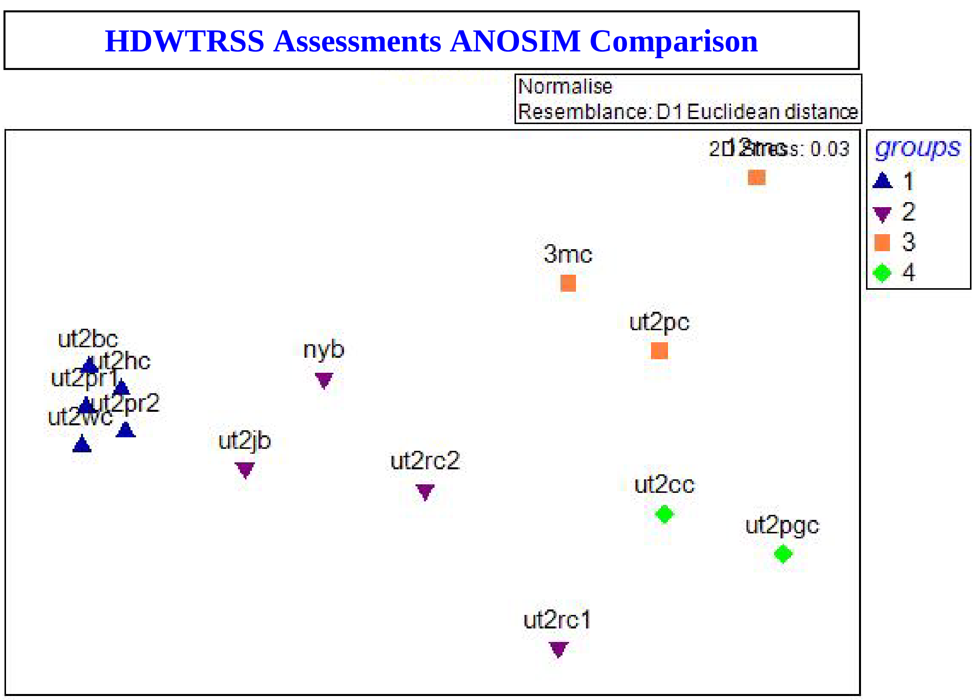
This Level II phase of the survey project was completed in FY2013 with additional WQ and QA/QC conducted by the Department in 2014, which included the 14 sites designated as meeting the criteria for inclusion in this comparative process. The primary focus of the *Coastal Alabama Pilot Headwater Streams Survey and Study* was to evaluate differences in Land-Use and Land-Cover conditions relative to those stream reach geomorphic and water environments. This project would evaluate streams relative to the observed habitat assessments and recorded water quality conditions for each selected stream site. The selection of designated "Reference Streams" was based upon determining the associated LUC impacts and the relative estimation of observed onsite conditions for those selected coastal headwater streams. A comparison of the 5 proposed 'reference sites', along with 9 'more impacted' sites, was of particular interest for the implementation of this study.

As stated previously one of the envisioned objectives of this HDWTRSS project is the eventual development of a full spectrum tool for comparative headwater stream assessment. This project provided the selection of concise functional tools that would evaluate and inform this process, allowing science-based development of an accurate Coastal HDWTRSS Comparative Assessment Index. This project provides good information that should allow further development of this preliminary tool, so that it may be more precisely calibrated, ecologically for this region.

7. 1 HDWTRSS Sites Grouping: Analysis With PRIMER

Originally proposed as the possible Reference Sites assemblage for the HDWTRSS Project and based upon the results of the following statistical analysis for those streams, the Group 1 waterbodies are shown to exhibit relatively distinct data quality characteristics, both in Composite Assessment, and analysis of the documented water quality conditions.

Figure 17. PRIMER ANOSIM Graph and Table of HDWTRSS data.



```
Sample statistic (Global R): 0.907
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 2522520)
Number of permuted statistics greater than or equal to Global R: 0
```

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
1, 2	0.8	0.8	126	126	1
1, 3	1	1.8	56	56	1
1, 4	1	4.8	21	21	1
2, 3	0.796	2.9	35	35	1
2, 4	0.786	6.7	15	15	1
3, 4	0.917	10	10	10	1

The ANOSIM graph above depicts the abbreviated names of the projected coastal HDWTRSS Streams in this study. The illustrated factor types are denoted by proposed Stream Type:
1 Reference Streams
2 Impacted-Urban Set I
3 Impacted-Urban Set II
4 Impacted-Agriculture

The ANOSIM is a distribution-free method of multivariate data analysis widely used by biologists and community ecologists. It is primarily employed to compare the variation in abundance and composition among sampling units in terms of the described grouping factor or experimental treatment levels. ANOSIM is simply a modified version of the Mantel Test based on a standardized rank correlation between two distance matrices. It uses a model matrix coding for group membership (or treatment levels) as the explanatory variable in an ANOVA-like analysis [see http://www.marine.usf.edu/user/djones/anosim/anosim.html].

The ANOSIM graph above depicts these four Groups for the HDWTRSS:

Table 9. HDWTRSS Groups compared using ANOSIM statistics.

Group 1	Group 2	Group 3	Group 4
Reference Streams	Impact-Urban Set I	Impact-Urban Set II	Impact-Agriculture
UT2BorrowCreek	N. Yancey's Branch	UT2 Perch Creek	UT2 Cowpen Creek
UT2 Halls Creek	UT2 Joe's Branch	Three Mile Creek	UT2 Page Creek
UT2 Perdido Creek#1	UT2 Red Creek #1	Twelve Mile Creek	
UT2 Perdido Creek#2	UT2 Red Creek #2		
UT2 Wolf Creek			

The ANOSIM analysis calculated the significance level of these streams as being <5% for all other Groups (2 through 4), which shows Reference Group 1 as being statistically distinct from all others. The analysis shows that the Impact Group 2 differs statistically from Impact Group 3 at 2.9%. It also depicts a greater statistical similarity for the Impact Group 3 and the Impact Group 4. These results show good differentiation using the selected Composite Assessment components. These analyses indicate that the Composite Assessment may provide a statistically reliable model for assessment of Coastal Headwater Streams.

Although, basic statistical modeling predicts the relative **potential** rather than **actual** stream quality, thus, the reference condition for a coastal headwater stream is ideally a high quality, non-impacted stream within that given ecoregion or sub-ecoregion. It can be expected that some individual stream reaches or segments will exhibit specific conditions that individually may depart from the predictions of the developed tools. Rather than being a shortcoming, these "outliers" may help watershed managers better understand the spectrum of interaction that occurs between the local watershed and stream dynamics.

[see http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm]

For example, an "outlier" stream may be a result of past legacy disturbances, such as channelization, agricultural drainage, or poor forestry practices that happened many years ago to alter the landscape or the reach drainage area. In some few cases the stream reach may have established a new hydrological equilibrium, such that many of the original functions have been restored. The emulation of this progression is a major goal for stream restoration, with the hope that we can take impacted stream reaches and reclaim them economically, and in a similar manner. By comparatively studying the surrounding landscape influences, for both reference and impacted streams, we may better understand those changes associated with their structure and complex eco-processes by which they function to diminish storm event impacts, while enhancing water quality and providing important habitats that are associated with our coastal streams.

7.2 HDWTRSS Statistical Evaluations

Another objective for this HDWTRSS project was the comparison of this collected data. It is important to look at LUC-associated stressors relative to the bio-assessment tools and water quality data. It is interesting that the overall statistical analysis for these Headwater Stream parameters and data revealed that most determined values (i.e., composite assessment score, pH, conductivity, salinity, turbidity, and channel sinuosity) had significant levels of difference between the LUC-associated stream types. Based upon our limited sampling, we collected data to explore whether these streams were similar, or if they exhibited significant statistical differences. Our onsite field observations of surrounding land use and land cover suggested that the designated Reference Streams should differ significantly, as compared to the suite of selected Impacted Streams. The data indicated for these associated land uses, i.e. Reference vs. Impacted (both Urban and Agriculture), that these coastal headwater streams indeed differ and the analysis of the HDWTRSS data supported these conclusions.

7.3. *HDWTRSS* PROJECT TIMELINE

JAN 29, 20013:
<u>Contract signed</u> and executed by all primary parties. WORK BEGINS!

MARCH to JUNE2013:
<u>ADEM WQ Sampling</u> R-1 Spring-Summer Sampling

MARCH 2013:
<u>Survey/Assessment of Sites:</u> R-UT Joes Branch-BC /R-UT Wolf Creek-BC / R-Hubbards Landing-BC

APRIL 2013:
<u>Survey/ Assessment of Sites:</u> R-UT Perdido#1/ R-UT Perdidio#2 – all BC

MAY 2013:
<u>Recon of Additional Potential Stream Sites:</u> MC and BC

JUNE 2013:
<u>Survey/ Assessment of Sites:</u>
Ag-Watts Ln / U-Red Creek # 1 &2/ U-3 Mile Creek/U-12 Mile Creek/R-Borrow Creek- all MC / Ag- UT Cowpen Creek/ U- Upper Yancey Branch - BC

JULY-AUG 2013:
<u>Follow Up Stream Assessments Data:</u>
including Watts Ln / UT Joes Branch / Upper Yancey Branch

AUG 2013:
<u>Contractor Survey Field Work Completed.</u>

OCT 2013:
<u>ADEM WQ Sampling</u> R-2 Fall Sampling

JAN to FEB 2014:
<u>ADEM WQ Sampling</u> R-3 Winter Sampling

FEB 2014:
<u>ADEM WQ Sampling Completed / HDWTRSS Field Activities Completed.</u>

MARCH-JUNE 2014:
<u>Water Quality Statistics Data Analysis</u>

AUG 2014:
<u>LUC Calibration and Data Analysis</u>

NOV to DEC 2014:
<u>Complete and finalize HDWTRSS Project Report</u>

8. PROJECT BIBLIOGRAPHY

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9. PROJECT DISCLAIMERS

Confidentiality, Property Ownership, Endorsements, and Uses :

A. Personally Identifiable Information relating to the specific location and identity of the Survey participants, which includes the geographic coordinates, shall be marked as Confidential and will not be released except as HUC location.

B. Any copy of any work products relating to BMP implementation produced under this contract, which are intended for general public distribution by the Contractor or the Department, shall not include any geographical coordinates or precise locational data relating to the identity of the Survey participants.

C. All other developmental information, software design(s), and final product(s) associated with this project shall be acknowledged property of the Department.

D. Photos of the field sites were taken throughout the duration of the Project, both in the prior Stream Recon visits from the Level I phase, and the field visits during the recent Field Survey and Sampling events at these headwater stream sites.

E. Although this work was conducted and reviewed by ADEM staff and approved for submission, it may not necessarily reflect official Department policy. The mention of trade names or brand names in this document is for illustrative purposes only and does not infer any endorsement by the Alabama Department of Environmental Management, the Alabama Department of Conservation and Natural Resources, the U.S. Environmental Protection Agency, or the National Oceanic and Atmospheric Administration.

F. The authors have used references from published scientific literature to assist the interpretation of the data included in this report. Reference to any particular set of values or concentrations must not be construed as acceptance of, nor support of the value as a Federal, or State standard or criteria.

G. This project is not intended to assess water quality with respect to water quality standards or use classification(s) support. By definition, headwater streams have small contributing drainage areas resulting in limited or intermittent flow regimes which may not be representative of the stream as a whole. Therefore, the data contained within this report is not intended to be used to exemplify water quality standards or use classification calibration purposes."