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RESEARCH AND OBSERVATORY CATCHMENTS: THE LEGACY AND THE FUTURE

WILEY

Long-term hydro-meteorology and water quality data from low-gradient catchments of varying scales on the Santee experimental Forest, South Carolina

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Abstract

The forest landscape of the Southeastern Atlantic coastal plain of the United States is experiencing increased threats from extreme precipitation events, tropical storms, flooding, droughts, and growing urbanization impacting on vegetation, road infrastructure, water extraction and other related ecosystem processes (e.g., storm runoff, nutrient and carbon cycling) and functions (e.g., flood protection, aquatic habitat). We describe ongoing hydro-meteorologic monitoring on two first—(1.6 km^2 each), the second—(5 km^2), and the third—(52.5 km^2) order catchments. The catchments are located on the Santee Experimental Forest at the headwaters of the Cooper River that drains into Charleston Harbour, South Carolina. Monitoring started in 1946, with a gap between 1982 and 1989, includes precipitation, weather, streamflow, water table, and water quality (anions, cations, and physical parameters) at varying temporal scales. The catchments are forest ecosystems dominated by loblolly (*Pinus taeda*) and longleaf pine (*Pinus palustris*) (LLP) mixed hardwood stands on the uplands and bottomland hardwoods on well-drained to poorly-drained soils characteristic of the low-gradient Atlantic Coastal Plain. These data support multiple field and modelling studies, ranging from water and carbon budgets to hydrologic and biogeochemical processes to effects of microtopography and extreme climate on hydrology and water quality of these coastal catchments withstands regenerated since Hurricane Hugo (1989). One significant finding from the long-term data was a reversal of the pre-Hugo flow pattern between the paired watersheds 3 years after Hugo. This reversal persisted for 10 years and was attributed to change in forest vegetation due to hurricane damage to older pine and larger hardwood stands followed by delayed regeneration before full forest recovery. These publicly available data serve as a reference within a rapidly developing landscape and also for addressing potential impacts of extreme climate and forest disturbance on ecohydrology, biogeochemistry, habitat, water supply and infrastructure using validated models and tools.

KEYWORDS

forest hydrology, Hurricane Hugo, paired watershed, precipitation, streamflow, water quality, water table, weather

1 | DATA SET NAME

Long-term Hydrometeorological Data from the Santee Experimental Forest.

2 | SITE DESCRIPTION

The Santee Experimental Forest (SEF), near Huger, South Carolina, 50 km northwest of Charleston, was established in 1937 by the USDA Forest Service (USDAFS) with a mission of silvicultural research, ecological and hydro-meteorologic monitoring, and demonstration/educational activities in support of sustainable forest management practices in coastal plain forests, such as those within the Francis Marion National Forest (FMNF; Amatya & Trettin, 2019a). The SEF (33°08′15″N, 79°49′0″W) on a low-gradient (<3% slope) landscape is located within the headwaters of Huger Creek, a tributary of the East Branch of the Cooper River that drains into Charleston Harbour (Figure 1; Table 1). The first gauged first order watershed WS77 (155 ha) was established in November 1963, followed by a third order WS78 (5240 ha) and a Second order WS79 (500 ha) watershed in 1966 (Table 1; Amatya & Trettin, 2007). Later, another first order WS80 watershed (originally 206 ha reduced to 160 ha in 2001, after a new outlet was installed to divert flow from 50 ha of the area; Figure 2) was established in November 1968 making a paired system with WS77 as a treatment catchment prior to prescribed burning studies initiated in 1976 (Binstock, 1978; Richter, 1980). All monitoring ceased in 1982 and was not resumed until after Hurricane Hugo on 22 September 1989 (Hook et al., 1991). The current mixed pine-hardwood stands on the catchments (Figure 2) have regenerated since Hugo (Dai et al., 2013; Jayakaran et al., 2014).

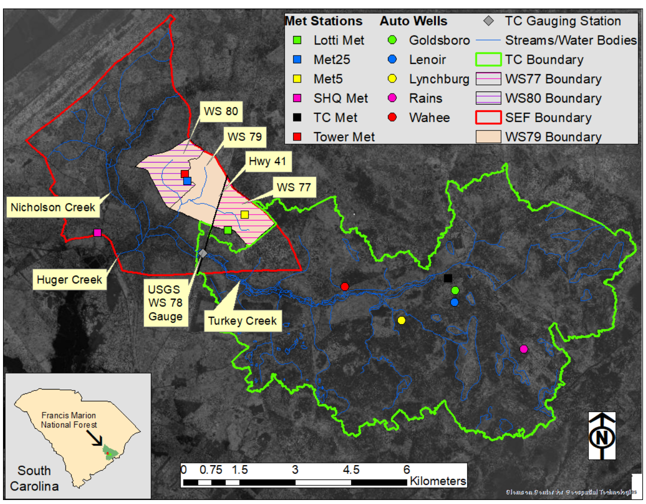

FIGURE 1 Experimental layout of first order paired watersheds (WS77 and WS80), second order (WS79) and third order WS78 (Turkey Creek) watersheds at Santee Experimental Forest (SEF) in coastal South Carolina. Also shown are met (weather) stations, auto (automatic) recording water table wells Goldsboro, Lenoir, Lynchburg, rains, and Wahee (labelled for type of soil types the wells were installed in)

Soils in the SEF are predominantly Alfisols and Ultisols of well-drained to poorly-drained Wahee sandy clay loam with high water retention capacity and low permeability (SCS, 1980; Figure 2). The site has a subtropical climate with hot/humid summers followed by short/warm winters, with an average annual precipitation, temperature and potential evapotranspiration (PET) of 1370 mm, 18.3°C, and 1135 mm, respectively (Dai et al., 2013). Detailed characteristics of the catchments are given in Table 1.

3 | LONG-TERM HYDROMETEOROLOGIC MONITORING INSTRUMENTATION AND DATA

3.1 | Meteorological (weather) monitoring

Weather data (daily precipitation and maximum/minimum air temperature) have been collected at an open space at the Santee headquarters (SHQ) Met station since 1946. Similar measurements started on the catchments in 1963 (Figures 1 and 3; Table 2; Amatya & Trettin, 2007). Precipitation volume and intensity were recorded by a recording rain gage (Belfort Instrument Co.) and verified using a co-located 200 mm diameter Standard National Weather Service (NWS) manual rain gage.

Beginning in 1992, precipitation has been collected digitally using tipping bucket gauges (model TE525WS or TE525MM, Texas Electronics, Inc. at SHQ and TC (on Turkey Creek as WS78) and RG2M model by Onset Computer Corp. at Met5 (in WS77), Met 25 (in WS80), and Lotti Met (on Lotti Road)), backed up by the NWS manual gauges. The USGS TC gauge (model Waterlog H-340, Design Analysis Associates, Inc.) at WS78 started in 2005 (Figures 1 and 3f). All precipitation measurement precisions are provided in Table 3. All gauges were in open spaces, that were occasionally cleared as trees started encroaching. Data from nearby gauges were used for gap-filling the precipitation data (Amatya & Trettin, 2019b, 2020).

An automatic Omnidata-800 system measured the weather variables (temperature, humidity, solar radiation, photosynthetically active radiation, wind speed and direction, evaporation pan head/level, and rainfall) at the SHQ Met station from 1992 until 2000 (Figures 1 and 3g). Daily evaporation was measured using a Class A evaporation pan from 1996 to 2000 and those measurements resumed in 2005. A 3-m tall weather station, with a Campbell Scientific (CS) CR10X datalogger linked to sensors was installed at the same site on a grass surface in August 2001. The sensors included a CS500 first, then an HMP45C, and recently an HMP60, both by Vaisala, Inc. for air temperature and relative humidity; Q-7.1 by Radiation and Energy Balance Systems, Inc., then an NR-LITE2 by Kipp and Zonen for net radiation; and a LI-200X by LI-COR, Inc., then an SP-110 by Apogee Instruments for solar radiation. The wind speed and wind direction were measured using Met One 034A/Met One 034B sensors. In October 2005, a 3-m tall weather station (TC Met), with CS CR10X datalogger linked to

TABLE 1 General characteristics of the long-term experimental watersheds

Parameter	WS77 (treatment)	WS80 (control)	WS79	WS78
Watershed Order	First	First	Second	Third
Latitude and longitude	33.14°N, 79.77°W	33.15°N, 79.80°W	33.08°N, 79.47°W	33.13°N, 79.78°W
Elevation (m, a.m.s.l)	4.9–10.4	3.5–10	3.5–10.4	2.0–14.0
Catchment area (ha)	155	206 until 2001; 160	500	5240
Main channel length (km)[a]	1.26	1.38	3.46	12.6
Wetland area, %[b]	11	48.5	27.2	56.5
Mean depressional storage capacity, mm[c]	10 (±0.5)	93 (±2.7)	56 (±1.2)	100 (±0.5)
Silvicultural management	Prescribed burning	None	Prescribed burning	Prescribed burning

[a]Main channel length of the stream was calculated by ArcMap tool in ArcGIS 10.7.1 version using the channel polyline in high resolution LiDAR data based DEM map and listed in the attribute table of the shape file.
[b]Percent wetland area was based on NWI classification https://www.fws.gov/wetlands/ accessed on March 17, 2021.
[c]Mean depressional storage capacity was obtained from Amoah et al. (2013) study.

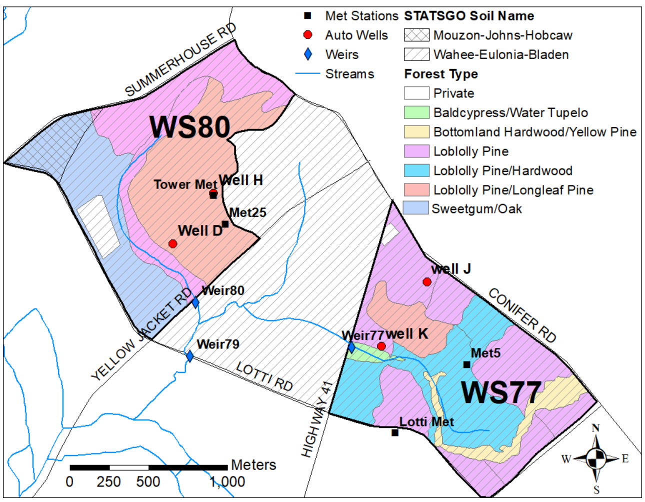

FIGURE 2 Experimental layout of WS77 (treatment) and WS80 (control) paired watersheds with their monitoring locations for weather (met stations), streamflow (weirs), and water table (auto wells). Shown are also the soil and vegetation types on the watersheds

sensors for air temperature and relative humidity (first a CS500, then an HMP45C replaced by an HMP60), solar radiation (first an LI-200X, then an SP-110), and wind speed and direction (Met One 034A/Met One 034B), was installed on WS78 in an open area with grass cover. Finally, a CS CR1000 datalogger, linked to sensors for air temperature and relative humidity (HMP45C, then an HC2S3 by Rotronic Instrument Corp., later an HMP155A by Vaisala, Inc.), net radiation (NR-LITE, then an NR-LITE2), and wind speed and direction (Met One 034B/Met One 034A), was installed on a 27-m tall tower (Tower Met) above the WS80 forest canopy (Figures 1 and 3e) in March 2010 (Amatya & Harrison, 2016). All-weather parameters were measured on a 30-s interval, with averages for each logged on a 30-min interval at the SHQ (later changed to 15-min) and TC sites, and a 15-min interval at the WS80 site. Only hourly precipitation and air and soil temperature data were collected using HOBO dataloggers at the Met5, Met25 and Lotti Met stations. (Figures 1 and 2; Table 2). Data from nearby stations were used for gap-filling. Details including measurement precisions are provided in Table 3 and Amatya and Trettin (2019b, 2020, 2021).

3.2 | Streamflow monitoring

Stage measurements at gauged catchments were recorded on magnetic tape from November 1963 (Table 1) to September 1995 at 15-min intervals by analog-to-digital recording (ADR) equipment (Amatya & Trettin, 2019a). Digital stage measurements were recorded every 10-min starting in September, 1995, by Teledyne ISCO flowmeters, with doppler sensors and Global Water WL300 pressure transducers as backups, installed at the WS77 and WS80 outlets with compound V-notch weirs (Figures 1–3; Table 2). Measurements at the WS79 outlet, with a compound V-notch weir and a dual box culvert (Figure 3i), began January 2002 using a Global Water GL300 datalogger linked to a WL300 pressure transducer replaced by a Teledyne ISCO flowmeter and doppler sensor in July 2003. All the compound weirs at WS77, WS79 and WS80 started with a 90° V-notch (45 cm above the upstream bed) expanding to 140° between 20.7 and 35.05 cm, except for WS77 which was 47.55 cm, above the V-notch. The WS77 outlet expanded to a 170° weir at 47.55 cm height above the V-notch to a full width of 6.1 m from wall-to-wall across the stream (Figure 3h). The WS80 outlet expanded to a flat-crested weir, at 35.05 cm above the V-notch, to a full width of 8.53 m from wall-to-wall under the bridge (Figure 3c). The larger WS79 outlet had a centre V-notch weir and a box culvert of 1.2 m height and 3.33 m width on either side with a bottom at the 35.05 cm height above the V-notch (Figure 3i). The stage data were used with established rating curves for compound V-notch weirs at WS77 and WS80, and for V-notch weir/box culverts at WS79 to estimate streamflow (Amatya &

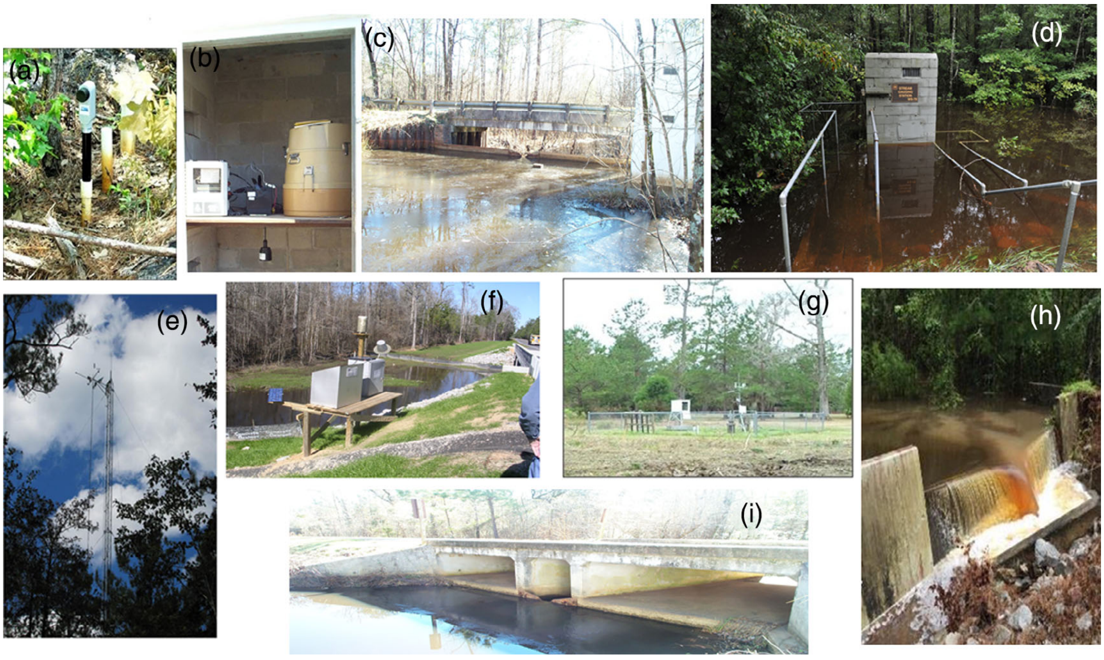

FIGURE 3 Pictures of hydro-meteorologic stations: (a) remote data systems automatic recording well, (b) Teledyne ISCO Flowmeter with a Doppler sensor and an automatic water quality sampler, (c) WS80 compound weir outlet with gauging station on the right, (d) WS79 gauging station inundated from 3 to 4 October 2015 extreme precipitation event, (e) sensors for weather parameters measured above the forest canopy on a tower (tower met) logged by a Campbell scientific CR1000 datalogger on WS80 watershed, (f) USGS real-time precipitation and flow gauging station linked to an antenna and a water quality sampler at WS78 (Turkey Creek) watershed outlet, (g) Santee headquarter (SHQ) met station for weather parameters, (h) compound weir outlet at WS77 watershed gauging station, and I) compound weir outlet with a box culvert on each side at the WS79 watershed gauging station

Trettin, 2007, 2019b, 2021). A USGS stream gauging station was established in 2005 at the WS78 outlet on the Highway 41 bridge to collect stage heights every 15-min using a Model SATLINK-2 datalogger and transmitter (Sutron Corporation) and a bubbler (Sauer & Turnipseed, 2010) at the stream bottom (Figures 1, 3f; Table 2; Amatya & Jha, 2011; Amatya & Trettin, 2022). Flow rates were calculated using a stage-discharge relationship developed using frequent in situ manual velocity measurements with a Marsh-McBirney flowmeter (Hach Co.) at the stream cross-section where the stage is measured.

3.3 | Water table monitoring

Automatic and manual measurements of water tables were made in groundwater wells of ~2.8–3 m depth on WS77 (manual only for 1964–1971 and 1992–1995), WS78, and WS80 (manual only for 1992–1995; Table 2). Global Water WL-15/WL-16 pressure transducers with a datalogger have been recording water tables on an hourly basis in wells H (since 2005) and D (since 2003) in upland and riparian setting, respectively, of WS80 (Amatya & Trettin, 2021). The same techniques are being used for water table measurements on well J (since 2005) in the upland within WS77 (Figures 1–3; Amatya & Trettin, 2019b). Remote Data Systems WL-40 recorders/loggers (Figures 2 and 3) were used to measure water table on a four-hourly basis near well H (WS80) and well J (WS 77; Amatya & Trettin, 2019b) prior to 2005. Well K with a WL-16 was installed near the WS77 riparian area in 2018 (Figure 2). In 2006 four wells (on Goldsboro, Rains, Lenoir, and Lynchburg soils) and in 2011 another well (on Wahee soil) were installed within WS78 (Amatya & Trettin 2022; Figure 1).

All loggers/sensors at the weather stations, rain and flow monitoring gauges were visited on a weekly or bi-weekly basis for regular data download, checking and maintenance, except for water table wells/recorders done on a bi-weekly to monthly basis.

3.4 | Water quality monitoring

Water samples for water quality analysis were collected manually (before 2003) as well as on a flow-proportional basis using automatic samplers (since 2003) at flow gauging stations on WS77, WS79 and WS80 (Table 2; Figures 1 and 3). Samples were collected as grab samples on a bi-weekly basis from October 2005 on the WS78 watershed. In June 2006, an ISCO automatic sampler was connected to the adjacent Sutron stage datalogger and activated based on a rise of the stage above a preset 3 mm threshold value. All samples were transported in coolers to the laboratory. After filtration, samples were shipped to USDAFS Coweeta Hydrology Laboratory for analysis starting in 2007. Prior to that samples were analyzed in-house (Amatya & Trettin, 2007, 2019b, 2021, 2022).

TABLE 2 Hydrology, meteorology and water quality parameters monitored during historic and current periods at Santee experimental Forest headquarter (SHQ) and first, second, and third order watersheds, SC (see Figure 1 for locations)

Parameters	Santee head-quarter (SHQ) 10.2737/RDS-2020-0070	First order WS77 10.2737/RDS-2019-0033	First order WS80 10.2737/RDS-2021-0043	Second order WS79 https://cybergis.uncc.edu/santee/	Third order WS78 10.2737/RDS-2022-0027
Meteorology (climate)					
Precipitation	1946 to date; Manual/Pluviometer, Automatic	1963–1971; 1990–1997; 2001 to date; Manual/ Automatic	1990–2000; 2001 to date; Manual/ Automatic	N/A	1964–2000 2001 to date; Manual/Automatic
Air temperature	1946–Manual/ Automatic	1963–1971; 1996–2000; 2001–Manual/Automatic	1996–2000; 2001–Manual/ Automatic 2010 (Canopy), Automatic	N/A	1971–2000; 2001–Manual/ Automatic
Humidity	2002–Automatic	N/A	2010 (Canopy), Automatic	N/A	2005–Automatic
Solar radiation	1996–Manual/ Automatic	N/A	2010 (Canopy), Automatic	N/A	2005–2020 Automatic
Net Radiation	2003–Manual/ Automatic	N/A	2010 (Canopy), Automatic	N/A	N/A
Wind Speed and Direction	1996–Manual/ Automatic	N/A	2010 (Canopy), Automatic	N/A	2005–2020 Automatic
Pan evaporation	1996–2000 Automatic	N/A	N/A	N/A	N/A
Soil temperature	N/A	2001–Automatic	2001–Automatic	N/A	2001–2004; 2005–2020 Automatic
Dry-wet deposition	2008–	N/A	N/A	N/A	N/A
Ozone	2008–2012	N/A	N/A	N/A	N/A
Hydrology					
Shallow water table	N/A	1964–1971; 1992–1995; 2005 to date; Manual/ Automatic	1992–1995; 2003 to date; Manual/ Automatic	N/A	2006–2019 Manual/ Automatic
Stream gauge stage	N/A	1963–81; 1989–1995; ADR 1995–2000; 2003–Automatic	1968–1981; 1989–1995; ADR 1995–1999; 2003–Automatic	1966–1973; 1989–1990; ADR 2002–2017 Automatic	1964–1984; ADR 2005–; Automatic
Streamflow	N/A	1963–1981; 1989–1995; ADR 1995–2000; 2003–Automatic	1968–1981; 1989–1995 ADR 1995–1999; 2003–Automatic	1966–1976; 1989–1990; ADR 2002–2017 Automatic	1964–1984; ADR 2005–; Automatic
Water quality					
Nutrients (NO_3^+/NO_2^--N, NH_4^+-N, TKN, TDN, PO_4^{3-}, TDP	N/A	1976–1982; 1989–1994; Manual grab 2003–Automatic	1976–1982; 1989–1994; Manual grab 2004–Automatic	1989–1994; Manual grab 2006–2017 Automatic	2006–Manual grab/ Automatic
Cations	N/A	Same as above	Same as above	N/A	Same as above
DOC	N/A	2003–Auto	2004–Auto	2006–2017 Auto	2006–Auto
Temperature	N/A	2006–Manual	2006–Manual	2006–2017 Manual	2006–Manual
Dissolved O_2	N/A	2006–Manual	2006–Manual	2006–2017 Manual	2006–Manual
Conductivity	N/A	2006–Manual	2006–Manual	2006–2017 Manual	2006–Manual
Salinity	N/A	2006–Manual	2006–Manual	2006–2017 Manual	2006–Manual
pH	N/A	2006–Manual	2006–Manual	2006–2017 Manual	2006–Manual

Note: Automatic versus manual: automatic refers to use of a tipping bucket gauge designed to measure rainfall intensity as well as total amount; manual refers to use of a receptacle without a mechanism that only collects the total amount of rainfall as well as measurements done manually in the field, for example, for water table and water quality. Automatic in case of stage, streamflow, weather and water quality parameters also means using digital and electronic sensors with dataloggers, some of which are also programmed for sensor monitoring and logging on a regular, recurring interval. (2) Canopy: the uppermost spreading branchy layer of a forest. Weather parameter measurements are taken above or near the canopy depending on the position of the sensor on the instrument lift. (3) Water quality parameters: measured cations include K^+ (potassium), Na^+ (sodium), Ca^{2+} (calcium) and Mg^{2+} (magnesium); measured anions include Cl^- (chloride), Br^- (bromide), and SO_4^{2-} (sulphate); measured nutrients include NO_3^+/NO_2^--N (nitrogen in the form of nitrate and nitrite ions), NH_4^+-N (nitrogen in the form of the ammonium ion), TKN (total kjeldahl nitrogen), TDN (total dissolved nitrogen), PO_4^{3+} (phosphate), and TDP (total dissolved phosphorus); other measured parameters include DOC (dissolved organic carbon) and dissolved O_2 (dissolved oxygen).

TABLE 3 Types and precision/accuracy/resolution of manual measurements and recording sensors for various hydro-meteorologic parameters

Parameters	Measurement type-manual or recorder or sensors	Recorder/sensor type	Precision/accuracy/resolution	Remarks/location (see Figure 1)
Precipitation	Manual chart	Belfort 20 cm gauge	0.13 cm	SHQ, Met5, Met25, Lotti
	Manual dipstick[a]	Standard NWS gauge	0.03 cm	SHQ, Met5, Met25, Lotti
	Tipping bucket	TE525WS	0.25 mm	SHQ, TC
	Tipping bucket	TE525MM	0.25 mm	SHQ
	Tipping bucket	RG2M	0.25 mm	Met5, Met25, Lotti
	Tipping bucket	RG3	0.25 mm	Met5, Lotti
	Tipping bucket	Omnidata	4%; 0.25 mm threshold	SHQ
Air temperature	Manual	Hygrothermograph	0.5°C	SHQ, Met5, Met25, Lotti
	Sensor	CS500	±0.2°C at 0°C; ±0.4°C at 20°C; ±0.6°C at 40°C;	SHQ, TC
	Sensor	HMP45C	±0.3°C at 0°C; ±0.2°C at 20°C; ±0.3°C at 40°C;	SHQ, TC, WS80
	Sensor	HMP60	±0.6°C	SHQ, TC, WS80
	Sensor	HC2S3	±0.1°C with standard configuration settings (at 23°C)	WS80
	Sensor	HMP155A	±(0.226–0.0028 × temperature)°C (−80 to +20°C); ±(0.055 + 0.0057 × temperature)°C (+20 to +60°C)	WS80
	Sensor	HOBO TMC1-HD	±0.25°C from 0 to 50°C (±0.45°F from 32 to 122°F)	Met5, Met25, Lotti
	Sensor	Omnidata	±0.25°C	SHQ
	Sensor	Apogee SP-110	W m^{-2}(Calibration Uncertainty) ± 5%	SHQ, TC, WS80
Humidity	Sensor	CS500	±3% (over 10 to 90% RH); ±6% (over 90 to 100% RH)	SHQ, TC
	Sensor	HMP45C	±2% (0% to 90% RH); ±3% (90% to 100% RH)	SHQ, TC, WS80
	Sensor	HMP60	at −40 to 0°C, ±3% (0 to 90% RH) and ± 7% (90 to 100% RH); at 0 to 40°C, ±3% (0 to 90% RH) and ± 5% (90 to 100% RH)	SHQ, TC, WS80
	Sensor	HC2S3	±0.8% RH with standard configuration settings (at 23°C)	WS80
	Sensor	HMP155A	±(1.0 + 0.008 × reading) % RH (at −20 to 40°C)	WS80
Solar radiation	Sensor	LI-200X	Absolute error in natural daylight ±5% maximum (±3% typical) Sensitivity 0.2 mV per	SHQ, TC, WS80
Net radiation	Sensor	Q7.1	Nominal Calibration Factors 9.6 W m^{-2} mV^{-1} (for positive values), 11. 9 W m^{-2} mV^{-1} (for negative values)	SHQ
	Sensor	NR-LITE	10 μV W^{-1} m^2 (nominal)	WS80
	Sensor	NR-LITE2	10 μV W^{-1} m^2 (nominal)	SHQ, WS80
PAR	Sensor	LI-190	Sensitivity 5 to 10 μA per 1000 μmol s^{-1} m^{-2}	WS80
Wind speed	Sensor	Met One 34A/B	±0.12 m s^{-1} (±0.25 mph) for wind speed <10.1 m s^{-1} (22.7 mph); ±1.1% of reading for wind speeds >10.1 m s^{-1} (22.7 mph)	SHQ, TC, WS80
Wind direction	Sensor	Met One 34A/B	±4°	SHQ, TC, WS80

TABLE 3 (Continued)

Parameters	Measurement type-manual or recorder or sensors	Recorder/sensor type	Precision/accuracy/resolution	Remarks/location (see Figure 1)
Soil temperature	Sensor	CS 107	±0.2°C (over 0 to 50°C range)	TC, WS80
	Sensor	HOBO TMC6-HD	±0.25°C from 0 to 50°C (±0.45°F from 32 to 122°F)	Met5, Met25, Lotti
Water table	Manual	Hydrolite/solinst	0.3 cm	WS77, WS78, WS80
	Recorder/sensor	WL40	0.25 cm	WS77, WS80
	Recorder/sensor	WL15/16	±0.1% of full scale at constant temperature, ±0.2% over 35 to 70°F (1.37 to 21.1°C) range	WS77, WS78, WS80
Stream gauge stage	Recorder and paper tape	ADR	<1% of flow rate; 0.01 ft water level	WS77, WS79, WS80 gauging stations
	Recorder/sensor	3210/4210 datalogger with ultrasonic level sensor	±0.006 m at ≤0.3 m level change; ±0.009 m from 0.3 to 3.3 m level change	WS77, WS79, WS80 gauging stations
	Recorder/sensor	Signature flow meter with TIENet 310 ultrasonic sensor	±0.006 m at ≤0.3 m level change; ±0.009 m at >0.3 m level change	WS77, WS79, WS80 gauging stations
	Recorder/sensor	GL300/WL300	±0.1% of full scale at constant temperature, ±0.2% over 35 to 70°F (1.37 to 21.1°C) range	WS77, WS79, WS80 gauging stations
	Recorder/sensor	GL400/WL400	±0.1% of full scale at constant temperature, ±0.2% over 35 to 70°F (1.37 to 21.1°C) range	WS77, WS79, WS80 gauging stations
	Recorder/sensor	GL500/WL400	±0.1% of full scale at constant temperature, ±0.2% over 35 to 70°F (1.37 to 21.1°C) range	WS77, WS80 gauging stations
	Recorder/sensor	WL16	±0.1% of full scale at constant temperature, ±0.2% over 35 to 70°F (1.37 to 21.1°C) range	WS79 gauging station

[a]Manual dipstick: this refers to a graduated measuring stick that is inserted into the receiving cylinder of the manual rain gauge; collected rainfall wets the stick and the amount of rainfall is determined by the extent of the wetting.

Detailed information on sensors, instruments and datalogger models, their measurement techniques, precisions and resolutions (Table 3), calibrations, error calculations, and data gap filling are provided in Metadata in data publications and/or in the provided web links.

4 | DATA USE AND APPLICATIONS ON RESEARCH STUDIES

These long-term data have supported multiple ecohydrologic studies on these coastal catchments where streamflow was primarily driven by shallow groundwater influenced by rainfall and evapotranspiration (ET; Amatya & Trettin, 2019a). Earlier studies of catchment boundary delineation, depressional areas (Amoah et al., 2013), and legacy water management structures (Trettin et al., 2008), all potentially affecting runoff, were enhanced by the availability of high-resolution LiDAR data (Amatya et al., 2013). Measured runoff was 20%–25% of annual rainfall, with wide seasonal variability, leaving the residual of 75%–80% as ET, assuming negligible deep seepage with a restrictive layer around 2–3 m depth (Amatya, Williams, et al., 2019; Callahan et al., 2012; Harder et al., 2007; Young & Klawitter, 1968). Data analysis showed a substantial increase of surface runoff when the water table was near/above the ground surface, resulting in flooding (Harder et al., 2007; Young & Klawitter, 1968). In addition, rainfall, runoff, and water table data for a 3–4 October 2015 event with total rainfall >500 mm, showed extreme high flooding over much of the experimental forest (Figure 3d) and the surrounding areas (Amatya, Harrison, & Trettin, 2016). Data evaluation from 1969 to 1978 using a paired catchment (WS77/WS80; Figures 1 and 2) approach did not show any appreciable effects of partial prescribed burning, as an operational practice, on water quantity and quality (Richter, 1980; Richter et al., 1982). Interestingly, the paired pre-Hugo monthly/annual flow relationships (WS77 > WS80) for 1969–1978, found by Richter (1980), reversed (WS80 > WS77) 3 years after Hugo (1989). The reversal persisted for 10 years before recovering to pre-Hugo levels by 2004, as initially reported by Amatya et al. (2006) and later confirmed by Jayakaran et al. (2014) using post-Hugo data through 2011. Lowered vegetative ET likely increased outflows on both catchments due to loss of trees following hurricane impact, with the treatment recovering more rapidly to pre-hurricane runoff due to the greater abundance of pine seedlings than the control catchment (Jayakaran et al., 2014). This significant finding was attributed to the long-term record and would otherwise not have been discovered had the monitoring not restarted soon after Hugo.

A new catchment-scale study (Figure 2) backed by process-based hydrologic modelling (Trettin et al., 2019) was recently initiated for evaluating longleaf pine restoration effects on WS77 water yield. Accordingly, a monthly paired flow relationship for the recovered stands was re-evaluated using data from 2011 to 2019, which is an adequate record length for pre-treatment calibration (Bren & Lane, 2014; Hornbeck et al., 1993). The pre-treatment relationship was significant for evaluating treatment effects on WS77 water yield later (Amatya, Ssegane, et al., 2021).

Other studies using long-term data included rainfall-runoff analyses (La Torre Torres et al., 2011; Walega et al., 2020), event hydrograph separation (Epps et al., 2013; Griffin et al., 2014), flow-duration and flood-frequency analyses (Amatya & Radecki-Pawlik, 2007; Ssegane et al., 2013), vegetation roughness effects on runoff (Miroslaw-Swiatek & Amatya, 2011, 2017), and precipitation intensities and design discharges (Amatya, Tian, et al., 2021). Similarly, groundwater estimates (Callahan et al., 2012), water table (Amatya, Chescheir, et al., 2019) and ET/PET dynamics (Amatya, Dai, et al., 2016; Amatya & Harrison, 2016), characterization of ecohydrology (Amatya et al., 2015), and climate impacts on hydrology (Dai, Amatya, et al., 2011) were also studied using data reported here. Studies using water quality data were reported in Trettin et al. (2021), Muwamba et al. (2016), and Dai, Trettin, et al. (2011). In addition, long-term data were used for developing/validating ecohydrology models (Amatya et al., 2022; Amatya & Jha, 2011; Amatya, Fialkowski, & Bitner, 2018; Dai et al., 2010; 2011; 2013b).

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The USDAFS Southern Research Station has funded the operation and maintenance of the monitoring stations, the authors and support staff. All data from the SEF site are in the public domain and there are no restrictions or fees placed on data use. However, users are encouraged to cite the data appropriately when used in publications/presentations.

6 | DATA SET CONTRIBUTORS

Devendra Amatya, Research Hydrologist, Carl Trettin, Supervisory Research Soil Scientist, Charles Harrison, Hydrology Technician, and Julie Arnold, Forestry Technician, all at the SEF, have been involved in field instrumentation, monitoring, data collection/management, and publication. Other contributors include Artheera Bayles, Abigail Boyer, Scott Harder, and Jim Weeg, all formerly with College of Charleston, and Zhaohua Dai, Craig Ehde, Todd Tompkins, Jim Strubble, C.E. Young, and R.A. Klaiwitter, all formerly with Forest Service.

DATA AVAILABILITY STATEMENT

All data described above and in Table 2 are processed through the SEF monitoring protocols. The data are publicly available via digital object identifiers (DOI) for the SHQ weather station (https://doi.org/10.2737/RDS-2020-0070), watershed WS77 (https://doi.org/10.2737/RDS-2019-0033), watershed 78 (https://doi.org/10.2737/RDS-2022-0027), and watershed WS80 (https://doi.org/10.2737/RDS-2021-0043). These four data sets are curated by the Forest Service Research Data Archive (https://www.fs.usda.gov/rds/archive/catalog/). Updated data are assigned a new DOI and preceding versions are maintained linking to the most recent version. Data at this URL is accessed by clicking Locations and searching for South Carolina that includes the SEF. Data through 2017 for the watershed WS79 and other watersheds are available through https://cybergis.

uncc.edu/santee/. Real-time climatic data for the SHQ station are available using SMART-FOREST portal at (https://smartforests.org/content/smart-forests-data). Data are viewed using Data Dashboard and clicking for the parameters and their time period of interest and a map in next page for the SEF site. Real-time stage, flow and precipitation at the WS78 gauge are available through the USGS site https://waterdata.usgs.gov/sc/nwis/uv?site_no=02172035. Original raw data records downloaded from all data-loggers described above and their processed data are stored and organized in digital formats on multiple on-site backups in the form of hard drives or other media and ultimately on computers at USDAFS Cordesville, SC office. All the raw data are made available upon request 1 year after their acquisition period.

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