

Stream discharge in gaged watersheds at the HJ Andrews Experimental Forest, 1949 to present – HF004

Descriptions of hydrology data, gages, watershed conditions and instrumentation for stage height

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Overview

The H.J. Andrews Experimental Forest in the western Cascade mountains of Oregon comprises the full Lookout Creek Basin, which drains into Blue River, then to the McKenzie River Watershed. Lookout Creek, Mack Creek and eight small watersheds have stream gaging stations. The objectives of this research and monitoring include: (1) evaluate long-term changes in hydrology associated with various forest management treatments, notably clearcut logging, selective logging, and burning; (2) provide baseline data for affiliated precipitation and stream water chemistry and sediment transport studies; and (3) characterize the hydrologic regime of old-growth forests at different elevations. The original design for the small watersheds used a paired watershed technique to evaluate changes in streamflow due to watershed treatments. In addition to stage heights and discharge, data on stream chemistry, stream and air temperature, specific conductivity are collected at the stream gages. Many other studies within the watersheds use these hydrology data. (See [Plant biomass and nutrient stores in seven small watersheds at the H.J. Andrews Experimental Forest: A preliminary report, 2009](#))

Database details

Date and time: All times are Pacific standard time. Intervals for recording of measurements have varied and currently are 5 minutes. Historically, stage heights were recorded on charts and daily maximum and minimum archived. Data were later digitized and times of change in stage heights documents, leading to irregular time series. Data have been estimated for every 5 minutes (See Entity 5). Details of these calculations are in the PDF "[HJA_RATING_CURVE_FLOW_CALCULATION](#)".

Stage: Stage heights measured in units of feet (ft) using a float in a stilling well that is connected to a recording device or data logger. The instrumentation used to measure and record stream stage has changed through the years in response to changes in data collection technology, data management considerations, and end-user needs. Measurement uncertainties are discussed in "Instrumentation" section below. Best estimate of measurement accuracy is 0.005ft.

Discharge: Discharge units are cubic feet per second (CFS). Stage heights are converted to stream discharge by applying station specific discharge rating curves. The flumes and weirs used to measure and record stream stage have changed through the years, necessitating collection of calibration points and new rating curves for every change. Stream gage descriptions below note major changes and more details are in PDF "[HJA_RATING_CURVE_FLOW_CALCULATION](#)".

Discharge per unit area: Also termed Specific Discharge. Units are mean flow, as cubic feet per second, divided by watershed area, in units of square mile.

ESTCode: Descriptive quality control codes for each value: A=Accepted; E=Estimated; Q=Questionable; M=Missing; P= fire effects near the gage or in the watershed may have impacted the data

EVENT Code: Events that may have impacted data: MAINT= maintenance or site visit; INSREM= installation or removal of v-notch weir and-or a change in rating curve; QUALITY= event may directly

affect data quality; WEATHR= a weather event affected stream discharge measurements; BURNED = burning or wildfire within watershed; NA= no event reported, not applicable.

Andrews Watershed 1 - WS01

Stream gage GSWS01

Gaged watershed area: 95.9 ha (original surveyed value used in rating equation calculations)

Location of gage: North: 44.20733900, West: -122.25802700;

Gage Elevation: 439 m

WS treatment: Harvest years: 1963-1965 Percent Harvest: 100% Harvest type: Clearcut without roads, whole watershed was broadcast in hot fire in Oct 1966, aerial seeding in 1967 and 1968, and seedlings were planted in 1969 and replanted in 1971. Watershed burned with low to medium severity as part of 2020 Holiday Farm Fire

Gage description: Trapezoidal flume established October 1952. Flume had 18 inch bottom. Flume was damaged in a storm and rebuilt in August 1956.

Rating curve: Equation set A: 1952-1956

Rating curve: Equation set B: The original flume was rebuilt in summer 1956 and operational on 1 Sep 1956. Flume dimensions are still current today: Bottom width = 9", Angle from horizontal = 25 deg. (65 from vertical).

Rating curve: Equation set C: A v-notch plate was attached for the measurement of low flow beginning 12 July 1999 through 2023. The v-notch plate is typically installed in June and removed in October. V-notch angle = 120 deg.

Site Description: Watershed above the Watershed 1 gaging station

Bounding Coordinates (decimal degrees):

North: 44.20851700, South: 44.19901700, East: -122.23581300, West: -122.25683100

Elevation (meters): Minimum: 439, Maximum: 1027,

Slope (%): 59.35

Aspect (degrees): 286

Site History: 100% clearcut over a four-year period from fall 1962 to summer 1966... Skyline yarding equipment removed timber from the entire 237 acres of the watershed. With this method, the back end of the logs are dragged to a fixed overhead cable, then lifted free of the ground for transport downhill to the landing. No roads were constructed in this watershed. The Watershed was broadcast burned in a hot fire in October, 1966 Aerial seeding in 1967 and 1968, and seedlings were planted in 1969 and replanted in 1971. In 2020, the watershed burned with low to medium severity as part of 2020 Holiday Farm Fire. The reference watershed is the adjacent WS#2. Gaging stations are about 1.15 km apart. The reference is about 63% the area of WS#1. GIS estimated percent harvest: 95.5%

Soils: Glacial, fluvial, and mass wasting processes have affected soil development and spatial distribution, particularly in geologic contact zones and steeper areas of the HJA. Infiltration rates are high and non-localized overland flow has not been observed in any of the watersheds. In Watershed 1, soils range from shallow and stony with little profile development to moderately deep with well-developed profile features. Shallow soils predominate, though they are often located on deep (> 3 m) deposits of unconsolidated soil and rock material. Most soil series present have moderately high field capacities (approximately 20 cm H₂O for the surface 1.3 m of soil) and rapid rates of saturated moisture movement. Percolation rates are typically greater than 12 cm/hr due to the large amount and size distribution of pore spaces (Rothacher et al. 1967). Stone content is the dominant factor causing variation in soil moisture storage capacity (Dyrness 1969). In ridgetop and steep-slope positions, soils are generally loam and clay loam derived from colluvium from reddish breccias and tuffs. Stone content ranges from 35 to 50%, generally increasing on south-facing slopes, and depth to weathered parent material is usually over 1 m. Soils derived from greenish breccias and tuffs are widely distributed. The surface and subsurface horizons are loam to clay loam with up to 50% gravel content by volume. Depth to parent material is 0.6 m to 1.2 m.

Geology: The H. J. Andrews Experimental Forest is underlain exclusively by bedrock of volcanic origin. Three geologic formations have been mapped for the HJA and correspond roughly with elevation (Swanson and James 1975). Little Butte Formation bedrock (< approximately 760 m elevation), dated as Oligocene to lower Miocene, consists of massive tuffs and breccias derived from mudflows and pyroclastic flows. Sardine Formation bedrock (760 m to 1200 m), dated as middle to late Miocene, consists of two units: a lower unit containing welded and non-welded ash flows (notably less altered than underlying Little Butte rocks of similar lithology), and an upper unit containing basalt and andesite lava flows. Andesitic and basaltic lava flows (>1200 m), termed "Pliocascade" Formation, were deposited during the Pliocene and overlie Sardine Formation material. Watersheds 1, 2, and 3 span the Little Butte-Sardine contact. Geology of these watersheds is roughly stratified by elevation. Bedrock of lower elevation areas of all three watersheds is dominated by reddish and buff-colored tuffs and breccias. At the mouth of Watershed 3, these rock types are buried under many feet of mixed colluvium exhibiting evidence of several periods of deposition. Sardine greenish tuffs and breccias dominate middle elevation bedrock in all three watersheds and extend to the ridge of Watershed 1. Associated with these rocks are numerous outcroppings of mainly basaltic flow rocks. In Watersheds 2 and 3, large portions of this bedrock are covered with a mantle (6 20 m) of andesitic colluvium. Upper elevations in Watersheds 2 and 3 are underlain by deposits of Sardine andesitic flow rock. In Watershed 1, this formation is limited to the extreme northeast corner. Most bedrock of this type is relatively unweathered with many rugged escarpments and outcroppings.

Vegetation: Prior to cutting in 1962-1966, Douglas-fir was the dominant species and ranged in age from about 100 to 500 years. Hemlock was intermixed in varying amounts and was generally younger. Other coniferous species present include western redcedar, locally abundant in drainages, and individual sugar pines scattered on ridgetops. Pacific yew is common in the understory. Hardwood species are common, but generally occur only in small amounts. In decreasing order they are: bigleaf maple, Pacific dogwood, golden chinkapin, and red alder. Six understory plant communities are present: 1) hazel-salal (10% of watershed area); 2)

rhododendron-salal (10%); 3) vine maple-salal (10%); 4) vine maple-Oregon grape (25%); 5) gold-thread (25%); and 6) sword-fern (20%).

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum is about 375 mm water equiv. at highest elevation. Transient snow zone with 25% precip falling as snow at lowest elevations

Andrews Watershed 2 - WS02

Stream gage GSWS02

Gaged watershed area: 60.3 ha (original surveyed value used in rating equation calculations)

Location of gage: North: 44.21201500, West: -122.24487600

Gage Elevation: 545 m

WS treatment: 0% harvest. Upper watershed burned with low to medium severity as part of 2020 Holiday Farm Fire

Gage description: Trapezoidal flume. Dimensions are bottom width = 9", angle from horizontal = 25 deg (65 deg from vertical).

Rating curve: Equation set A: October 1952-1999.

Rating curve: Equation set C: 1999-present. Updated rating curve

Rating curve: Equation B: From 1999 - 2022, a v-notch plate was attached during summers for the measurement of low streamflow. V-notch angle = 120 deg. The v-notch plate was typically installed in June and removed in October.

Climate: Gaging station upstream and upslope from CS2MET. Directly above site canopy is open, but solid walls of trees to north and south. Large clearing and pool/road to south; stream clearing narrow. Only significant direct sun late morning spring/summer. (JWS 2001)

Site Description: Watershed above the Watershed 2 gaging station

Bounding Coordinates (decimal degrees):

North: 44.21338500, South: 44.20617800, East: -122.22974100, West: -122.24397600

Elevation (meters): Minimum: 545, Maximum: 1079

Slope (%): 53.19; Aspect (degrees): 318

Site History: Undisturbed reference. Watershed 2 serves as the reference for both WS#1 and WS#3. GIS estimated percent harvest: 2.1%. Upper portion of WS2 burned with low to medium severity as part of 2020 Holiday Farm Fire.

Soils: Loam and clay loam soils derived from colluvium from reddish breccias and tuffs occur in ridgetop and steep slope positions in Watersheds 1, 2, and 3. Stone content ranges from 35 to 50%,

generally increasing on south-facing slopes. Depth to weathered parent material is usually over 1 m. Soils derived from greenish breccias and tuffs are widely distributed. The surface and subsurface horizons are loam to clay loam with up to 50% gravel content by volume. Depth to parent material is 0.6 m to 1.2 m. Soils derived from deep deposits of andesite colluvium occupy most of the upper portions of Watersheds 2 and 3. The surface horizon is loam to sandy loam with substantial amounts of shotty concretions and andesite stones. Subsurface horizons are massive stony loams, silt loams, or clay loams containing 25 to 80% gravel. Most soil types in Watersheds 1, 2, and 3 have moderately high field capacities (approximately 20 cm H₂O for the surface 1.2 m of soil) and rapid rates of saturated moisture movement. Percolation rates are typically greater than 12 cm/hr due to the large amount and size distribution of pore spaces and stone content (Rothacher et al 1967). Stone content is the dominant factor causing variation in soil moisture storage capacity.

Geology: The H. J. Andrews Experimental Forest is underlain exclusively by bedrock of volcanic origin. Three geologic formations have been mapped for the HJA and correspond roughly with elevation (Swanson and James 1975). Little Butte Formation bedrock (< approximately 760 m elevation), dated as Oligocene to lower Miocene, consists of massive tuffs and breccias derived from mudflows and pyroclastic flows. Sardine Formation bedrock (760 m to 1200 m), dated as middle to late Miocene, consists of two units: a lower unit containing welded and non-welded ash flows (notably less altered than underlying Little Butte rocks of similar lithology), and an upper unit containing basalt and andesite lava flows. Andesitic and basaltic lava flows (>1200 m), termed "Pliocascade" Formation, were deposited during the Pliocene and overlie Sardine Formation material. Watersheds 1, 2, and 3 span the Little Butte-Sardine contact. Geology of these watersheds is roughly stratified by elevation. Bedrock of lower elevation areas of all three watersheds is dominated by reddish and buff-colored tuffs and breccias. At the mouth of Watershed 3, these rock types are buried under many feet of mixed colluvium exhibiting evidence of several periods of deposition. Sardine greenish tuffs and breccias dominate middle elevation bedrock in all three watersheds and extend to the ridge of Watershed 1. Associated with these rocks are numerous outcroppings of mainly basaltic flow rocks. In Watersheds 2 and 3, large portions of this bedrock are covered with a mantle (20 m) of andesitic colluvium. Upper elevations in Watersheds 2 and 3 are underlain by deposits of Sardine andesitic flow rock. In Watershed 1, this formation is limited to the extreme northeast corner. Most bedrock of this type is relatively unweathered with many rugged escarpments and outcroppings.

Vegetation: Watershed 2 is completely forested. Watershed 2 vegetation is typical of the western hemlock (*Tsuga heterophylla*) zone with an overstory of Douglas-fir and western hemlock. In a 1970 survey of Watershed 2 (Hawk and Dyrness 1975), approximately 67 percent of overstory trees were in the 450-year age class, with the remainder younger than 125 years. Understory species include rhododendron (*Rhododendron macrophyllum*), vine maple (*Acer circinatum*), sword-fern (*Polystichum munitum*), and Oregon grape (*Berberis nervosa*).

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum is about 375 mm water equiv. at highest elevation. Transient snow zone with 25% precip falling as snow at lowest elevations.

Andrews Watershed 3 - WS03

Stream gage GSWS03

Gaged watershed area: 101.1 ha (original surveyed value used in rating equation calculations)

Location of gage: North: 44.21944000, West: -122.24300000

Gage Elevation: 471 m

WS treatment: Three units were harvested in 1962 and broadcast burned in 1963. Douglas-fir seedlings were planted in 1964. Percent Harvest: 25% Harvest type: Clearcut in patches

Gage description: Trapezoidal flume established October 1952.

Rating curve:

Equation set A: 1953-1964, 1966-1999

Equation set B: 1964-1966. The stream gauging station was destroyed in a debris torrent in Dec 1964 and was reestablished in Jan 1966. The stream gauging station was destroyed in another large debris avalanche/torrent that occurred during a major flood event in Feb 1996. The station site was buried by 11-12 feet of debris, and it was early Sep 1996 before the original flume was excavated. The original shelter, stilling wells, and hook gage were destroyed and the station was rebuilt in Sep 1998.

Rating curve: Equation set C: 1999 -2022. V-notch plate was attached during summers for the measurement of low streamflow. The v-notch plate was typically installed in June and removed in October.

Rating curve: Equation set D: 1999-present. Updated rating curve

Site Description: Watershed above the Watershed 3 gaging station

Bounding Coordinates (decimal degrees):

North: 44.21994300, South: 44.20803100, East: -122.22402200, West: -122.24194900

Elevation (meters): Minimum: 471, Maximum: 1080

Slope (%): 52.39; Aspect (degrees): 313

Site History: Roads (2.7 km) comprising 6% of the watershed area were built in 1959. In the winter 1962-63, 25% of the watershed area was cut in 3 patches (5.3, 8.1, and 11.3 ha). A high-lead cable yarding system was used. The slash was burned September, 1963. Douglas-fir seedlings were planted in 1964. Significant debris flows occurred during flood events in Dec 1964 and Feb 1996. Both of these events resulted in the destruction of the gaging station and extended periods (1-1.5 years) of either missing or estimated streamflow data. The reference watershed is the adjacent WS#2. Gaging stations are about .95 km apart. The reference is about 60% the area of WS#3. GIS estimated percent harvest: 26.3%

Soils: Loam and clay loam soils derived from colluvium from reddish breccias and tuffs occur in ridgetop and steep slope positions in Watersheds 1, 2, and 3. Stone content ranges from 35 to 50%, generally increasing on south-facing slopes. Depth to weathered parent material is usually over 1 m. Soils derived from greenish breccias and tuffs are widely distributed. The surface and subsurface horizons are loam to clay loam with up to 50% gravel content by volume. Depth to parent material is 0.6 m to 1.2 m. Soils derived from deep deposits of andesite colluvium occupy most of the upper portions of Watersheds 2 and 3. The surface horizon is loam to sandy loam with substantial amounts of shotty concretions and andesite stones. Subsurface horizons are massive stony loams, silt loams, or clay loams containing 25 to 80% gravel. Most soil types in Watersheds 1, 2, and 3 have moderately high field capacities (approximately 20 cm H₂O for the surface 1.2 m of soil) and rapid rates of saturated moisture movement. Percolation rates are typically greater than 12 cm/hr due to the large amount and size distribution of pore spaces and stone content (Rothacher et al 1967). Stone content is the dominant factor causing variation in soil moisture storage capacity (Dyrness 1969).

Geology: The H. J. Andrews Experimental Forest is underlain exclusively by bedrock of volcanic origin. Three geologic formations have been mapped for the HJA and correspond roughly with elevation (Swanson and James 1975). Little Butte Formation bedrock (< approximately 760 m elevation), dated as Oligocene to lower Miocene, consists of massive tuffs and breccias derived from mudflows and pyroclastic flows. Sardine Formation bedrock (760 m to 1200 m), dated as middle to late Miocene, consists of two units: a lower unit containing welded and non-welded ash flows (notably less altered than underlying Little Butte rocks of similar lithology), and an upper unit containing basalt and andesite lava flows. Andesitic and basaltic lava flows (>1200 m), termed "Pliocascade" Formation, were deposited during the Pliocene and overlie Sardine Formation material. Watersheds 1, 2, and 3 span the Little Butte-Sardine contact. Geology of these watersheds is roughly stratified by elevation. Bedrock of lower elevation areas of all three watersheds is dominated by reddish and buff-colored tuffs and breccias. At the mouth of Watershed 3, these rock types are buried under many feet of mixed colluvium exhibiting evidence of several periods of deposition. Sardine greenish tuffs and breccias dominate middle elevation bedrock in all three watersheds and extend to the ridge of Watershed 1. Associated with these rocks are numerous outcroppings of mainly basaltic flow rocks. In Watersheds 2 and 3, large portions of this bedrock are covered with a mantle (6 to 20 m) of andesitic colluvium. Upper elevations in Watersheds 2 and 3 are underlain by deposits of Sardine andesitic flow rock. In Watershed 1, this formation is limited to the extreme northeast corner. Most bedrock of this type is relatively unweathered with many rugged escarpments and outcroppings.

Vegetation: The overstory is dominated by old-growth Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) trees ranging in age from 100 to 500 years. Understory species include rhododendron (*Rhododendron macrophyllum*), vine maple (*Acer circinatum*), sword-fern (*Polystichum munitum*), and Oregon grape (*Berberis nervosa*).

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum is about 375 mm water equiv. at highest elevation. Transient snow zone with 25% precip falling as snow at lowest elevations.

Andrews Watershed 6 - WS06

Stream gage GSWS06

Gaged watershed area: 13.0 ha (original surveyed value used in rating equation calculations)

Location of gage (decimal degrees):: North: 44.26150800, West: -122.18070700

Gage Elevation: 878 m

WS treatment: Harvested: 1974. Percent Harvest: 100% Harvest type: Clearcut. Broadcast burned in spring 1975. Douglas-fir seedlings were planted in 1976.

Gage description: An H flume was installed Oct 1963 and replaced with trapezoidal flume in WY 1998.

Rating curve equation set A: 1963-1997

Rating curve equation set B: 1998-present. In Oct 1997 the H flume was replaced with a trapezoidal flume and the station was remodeled. Bottom width = 4", angle from horizontal = 60 deg. (30 from vertical)

Rating curve equation set C: 1998- 2022, v-notch plate (V-notch angle = 90 deg.) was attached during summers for the measurement of low streamflow. The v-notch plate was typically installed in June and removed in September or October.

Site Description: Watershed above the Watershed 6 gaging station

Bounding Coordinates (decimal degrees):

North: 44.26680800, South: 44.26154400, East: -122.17755000, West: -122.18351000

Elevation (meters): Minimum: 878, Maximum: 1029

Slope (%): 25.19; Aspect (degrees): 165

Site History: Watershed 6 was 100% clearcut in 1974. Logging began in May 1974 and was completed in August 1974. All timber was removed in a clearcut. Logs in 90% of the watershed were yarded uphill by a high-lead cable system; logs in the remaining 10% were yarded by tractor. Logging residue was broadcast burned in the spring of 1975, and the watershed was planted with Douglas-fir seedlings in the spring of 1976. A road was constructed through the watershed. WS 6 reached canopy closure in 2004. WS6 is adjacent to WS 7 which is adjacent to WS 8 (the reference). No significant difference was found among WS 6, 7, 8 basal area pre-treatment. The Hi-15 Meteorological Station (H15MET) is centrally located just below the WS 7 gaging station. GIS estimated percent harvest: 90.9%

Soils: Soils derived from deep andesitic landslide deposits occupy about 75% of the total area in Watersheds 6, 7, and 8. Texture is generally gravelly loam to sandy gravelly loam with gravel content ranging from 5 to 20% by volume (Dyrness and Hawk, unpublished). In most locations, effective rooting depth is virtually unlimited because of very deep, unconsolidated parent material. Silt loam

soils derived from andesite and associated tuffs and breccias occupy approximately 10% of the watershed area, mostly at higher elevations in Watersheds 6 and 8 (Dyrness and Hawk, unpublished). Because the texture and structure of soils in Watersheds 6, 7, and 8 are nearly identical to those of the lower-elevation watersheds, Harr et al. (1982) suggest that the soil hydraulic properties should be nearly identical as well.

Geology: The H. J. Andrews Experimental Forest is underlain exclusively by bedrock of volcanic origin. Three geologic formations have been mapped for the HJA and correspond roughly with elevation (Swanson and James 1975). Little Butte Formation bedrock (< approximately 760 m elevation), dated as Oligocene to lower Miocene, consists of massive tuffs and breccias derived from mudflows and pyroclastic flows. Sardine Formation bedrock (760 m to 1200 m), dated as middle to late Miocene, consists of two units: a lower unit containing welded and non-welded ash flows (notably less altered than underlying Little Butte rocks of similar lithology), and an upper unit containing basalt and andesite lava flows. Andesitic and basaltic lava flows (>1200 m), termed "Pliocascade" Formation, were deposited during the Pliocene and overlie Sardine Formation material. Watersheds 6, 7, and 8 range in elevation from 860 m to 1200 m and are underlain by two units of the Sardine Formation (Swanson and James 1975). Basalt and andesite lava flows underlie ridges of all three watersheds and near the outlets of Watersheds 7 and 8. Welded and non-welded ash flow tuffs underlie middle elevations of all three watersheds and the lower elevations of Watershed 6. This rock is of similar lithology as in the middle elevations of the lower watersheds, but is noticeably less weathered. No flow rock is exposed in Watersheds 6, 7, or 8.

Vegetation: Prior to cutting, the overstory was dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) trees ranging in age from 100 to 250 years. Understory species communities included vine maple-Oregon grape (*Acer circinatum*-*Berberis nervosa*), vine maple-whipplea (*Acer circinatum*-*Whipplea modesta*), and rhododendron-Oregon grape (*Rhododendron macrophyllum*-*Berberis nervosa*). Pre-treatment: stocking density = 383 stems per ha; basal area = 70 m²/ha (std dev 10.5 over 3 1-acre plots)

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum is about 400-650 mm water equiv. at highest elevation.

Andrews Watershed 7 - WS07

Stream gage GSWS07

Gaged watershed area: 15.4 ha (original surveyed value used in rating equation calculations)

Location of gage: (decimal degrees): North: 44.26463700, West: -122.17526500

Gage Elevation: 918 m

WS treatment: Harvest years 1974; 1984; 2001. Percent Harvest: 60%/30%/thinned Harvest type: Shelterwood /Overstory removal/Young stand thinning. Broadcast burned in spring 1975. Douglas-fir seedlings were planted in 1976.

Gage description: An H flume was installed Oct 1963 and replaced with trapezoidal flume in WY 1998.

Rating curve equation set A: 1964-1997

Rating curve equation set B: 1998-present. In Nov 1997 the H flume was replaced with a trapezoidal flume and the station was remodeled. Bottom width = 4", angle from horizontal = 60 deg. (30 from vertical)

Rating curve equation set C: 1998- 2022, V-notch plate (V-notch angle = 90 deg.) was attached during summers for the measurement of low streamflow. The v-notch plate was typically installed in June and removed in September or October.

Site Description: Watershed above the Watershed 7 gaging station

Bounding Coordinates (decimal degrees):

North: 44.26974800, South: 44.26457900, East: -122.17387500, West: -122.17920900

Elevation (meters): Minimum: 918, Maximum: 1102

Slope (%): 33.68; Aspect (degrees): 158

Site History: 1974: WS7 was shelterwood cut (approximately 60% of basal area was removed, 30 to 40 trees per acre were left as overstory), WS8 was unharvested and serves as the reference. WS7 was tractor logged above the road and cable logged below the road. Tractor skidding was straight downhill in WS7. 1975: WS7 was broadcast burned just below the road. 1976: District planted all of WS7 in June of 1976. 1984: The rest of the canopy in WS7 was removed. 2001: WS7 was thinned to 14 foot spacing, which leaves about 220 trees per acre. Young Douglas-fir stand was accidentally targeted and thinned to 220 trees per acre in 2001. In the summer of 1974, 60% of the total basin area was removed in a shelter- wood cut. Temporary spur roads were constructed into the middle of and down the southwest ridge of the watershed. Logs in the upper 60% of the watershed were yarded by tractor. Skid trails were not preplanned, but tractor operators were instructed for safety reasons to yard downhill. Consequently, soil compaction by tractors was limited to short segments of main skid trails immediately upslope from the upper spur road. Logs in the lower 40% were yarded partially suspended by a skyline cable system. Logging residue was broadcast burned only on the lower half of the watershed in the spring of 1975. WS-7 is adjacent to WS 8 (the reference). No significant difference was found among WS 6, 7, 8 basal area pre-treatment. The Hi-15 Meteorological Station (H15MET) is centrally located just below the WS#7 gaging station. GIS estimated percent harvest: 95.7%

Soils: Soils derived from deep andesitic landslide deposits occupy about 75% of the total area in Watersheds 6, 7, and 8. Texture is generally gravelly loam to sandy gravelly loam with gravel content ranging from 5 to 20% by volume (Dyrness and Hawk, unpublished). In most locations, effective rooting depth is virtually unlimited because of very deep, unconsolidated parent material. Silt loam soils derived from andesite and associated tuffs and breccias occupy approximately 10% of the watershed area, mostly at higher elevations in Watersheds 6 and 8 (Dyrness and Hawk, unpublished). Because the texture and structure of soils in Watersheds 6, 7, and 8 are nearly

identical to those of the lower-elevation watersheds, Harr et al. (1982) suggest that the soil hydraulic properties should be nearly identical as well.

Geology: The H. J. Andrews Experimental Forest is underlain exclusively by bedrock of volcanic origin. Three geologic formations have been mapped for the HJA and correspond roughly with elevation (Swanson and James 1975). Little Butte Formation bedrock (< approximately 760 m elevation), dated as Oligocene to lower Miocene, consists of massive tuffs and breccias derived from mudflows and pyroclastic flows. Sardine Formation bedrock (760 m to 1200 m), dated as middle to late Miocene, consists of two units: a lower unit containing welded and non-welded ash flows (notably less altered than underlying Little Butte rocks of similar lithology), and an upper unit containing basalt and andesite lava flows. Andesitic and basaltic lava flows (>1200 m), termed "Pliocascade" Formation, were deposited during the Pliocene and overlie Sardine Formation material. Watersheds 6, 7, and 8 range in elevation from 860 m to 1200 m and are underlain by two units of the Sardine Formation (Swanson and James 1975). Basalt and andesite lava flows underlie ridges of all three watersheds and near the outlets of Watersheds 7 and 8. Welded and non-welded ash flow tuffs underlie middle elevations of all three watersheds and the lower elevations of Watershed 6. This rock is of similar lithology as in the middle elevations of the lower watersheds, but is noticeably less weathered. No flow rock is exposed in Watersheds 6, 7, or 8.

Vegetation: Prior to cutting, the overstory was dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) trees ranging in age from 100 to 250 years. Understory species communities included vine maple-Oregon grape (*Acer circinatum*-*Berberis nervosa*), vine maple-whipplea (*Acer circinatum*- *Whipplea modesta*), and rhododendron-Oregon grape (*Rhododendron macrophyllum*-*Berberis nervosa*). Pre-treatment description: stocking density = 333 stems per ha; basal area=75 m²/ha (std dev 4.8 over 3 1-acre plots)

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum is about 400-650 mm water equiv. at highest elevation.

Andrews Watershed 8 - WS08

Stream gage GSWS08

Gaged watershed area: 21.4 ha (original surveyed value used in rating equation calculations)

Location of gage (decimal degrees): North: 44.26629426, West: -122.17079300

Gage Elevation: 962 m

WS treatment: Percent Harvest 0%

Gage description: An H flume was installed Oct 1963 and replaced with trapezoidal flume in Oct 1987

Rating curve equation set A: 1964-1987

Rating curve equation set D: 1988-present. In Oct 1987 the H flume was replaced with a trapezoidal flume. Bottom width = 4", angle from horizontal = 60 deg. (30 from vertical). Equation set D replaced equation set B when more calibration points became available.

Rating curve equation set C: 1997-2022. A v-notch plate (V-notch angle = 90 deg) was attached during summers for the measurement of low streamflow. The v-notch plate was typically installed in June and removed in September or October.

Site Description: Watershed above the Watershed 8 gaging station

Bounding Coordinates (decimal degrees):

North: 44.26629400, South: 44.26588100, East: West: -122.17079300,

Elevation (meters): Minimum: 962, Maximum: 1182

Slope (%): 25.78; Aspect (degrees): 165

Site History: Undisturbed reference. WS#8 is the reference for WS#6 and WS#7. No significant difference was found among WS 6, 7, 8 basal area pre-treatment. The Hi-15 Meteorological Station (H15MET) is centrally located just below the WS#7 gaging station.

Soils: Soils derived from deep andesitic landslide deposits occupy about 75% of the total area in Watersheds 6, 7, and 8. Texture is generally gravelly loam to sandy gravelly loam with gravel content ranging from 5 to 20% by volume (Dyrness and Hawk, unpublished). In most locations, effective rooting depth is virtually unlimited because of very deep, unconsolidated parent material. Silt loam soils derived from andesite and associated tuffs and breccias occupy approximately 10% of the watershed area, mostly at higher elevations in Watersheds 6 and 8 (Dyrness and Hawk, unpublished). Because the texture and structure of soils in Watersheds 6, 7, and 8 are nearly identical to those of the lower-elevation watersheds, Harr et al. (1982) suggest that the soil hydraulic properties should be nearly identical as well.

Geology: The H. J. Andrews Experimental Forest is underlain exclusively by bedrock of volcanic origin. Three geologic formations have been mapped for the HJA and correspond roughly with elevation (Swanson and James 1975). Little Butte Formation bedrock (< approximately 760 m elevation), dated as Oligocene to lower Miocene, consists of massive tuffs and breccias derived from mudflows and pyroclastic flows. Sardine Formation bedrock (760 m to 1200 m), dated as middle to late Miocene, consists of two units: a lower unit containing welded and non-welded ash flows (notably less altered than underlying Little Butte rocks of similar lithology), and an upper unit containing basalt and andesite lava flows. Andesitic and basaltic lava flows (>1200 m), termed "Pliocascade" Formation, were deposited during the Pliocene and overlie Sardine Formation material. Watersheds 6, 7, and 8 range in elevation from 860 m to 1200 m and are underlain by two units of the Sardine Formation (Swanson and James 1975). Basalt and andesite lava flows underlie ridges of all three watersheds and near the outlets of Watersheds 7 and 8. Welded and non-welded ash flow tuffs underlie middle elevations of all three watersheds and the lower elevations of Watershed 6. This rock is of similar lithology as in the middle elevations of the lower watersheds, but is noticeably less weathered. No flow rock is exposed in Watersheds 6, 7, or 8.

Vegetation: Watershed 8 occupies the transition between western hemlock and silver fir (*Abies amabilis*) zones (Dyrness and Hawk 1972). In 1970, 33 percent of overstory trees were in the 450-year age class and 67 percent were younger than 125 years (Dyrness and Hawk 1972). Understory species communities included vine maple-Oregon grape (*Acer circinatum*-*Berberis nervosa*), vine maple-whipplea (*Acer circinatum*- *Whipplea modesta*), and rhododendron-Oregon grape (*Rhododendron macrophyllum*-*Berberis nervosa*). Pre-treatment description: stocking density = 512 stems per ha; basal area=84 m²/ha (std dev= 8.3 over 3 1-acre plots). Source: R. L. Williamson

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum is about 400-650 mm water equiv. at highest elevation.

Andrews Watershed 9 - WS09

Stream gage GSWS09

Gaged watershed area: 8.5 ha (original surveyed value used in rating equation calculations)

Location of gage (decimal degrees): North: 44.20119000, West: -122.25880100

Gage Elevation: 426 m

WS treatment: Percent harvest 0%. In 2020, the watershed burned with low to medium severity as part of 2020 Holiday Farm Fire.

Gage description: Oct 1968 an H flume was installed and replaced with trapezoidal flume in 1973

Rating curve equation A: 1969-1973

Rating curve equation C: 1974-present. In August 1973 the H flume was replaced with a trapezoidal flume. Bottom width 3", angle from horizontal – 60 deg (30 from vertical)

Rating curve equation B: Aug 1973-Oct 1979, a v-notch plate was installed for measurement of low flows during summers.

Rating curve equation D: 1997-2023. A new v-notch plate (V-notch angle = 90 deg) was attached during summers for the measurement of low streamflow. The v-notch plate was typically installed in June and removed in September or October.

Site Description: Watershed above the Watershed 9 gaging station

Bounding Coordinates (decimal degrees):

North: 44.20393300, South: 44.20111000, East: -122.25151500, West: -122.25781500

Elevation (meters): Minimum: 438, Maximum: 731

Slope (%): 58.36; Aspect (degrees): 211

Site History: Undisturbed reference watershed . WS#9 serves as the reference for WS#10. WS#9 is located just south of the mouth of Lookout Creek along the Blue River Reservoir. Watershed burned with low to medium severity as part of 2020 Holiday Farm Fire (Bush et al. 2024)

Soils: Soils are largely weathered to reddish brown latosols, in tuff and breccia parent materials. Although the parent rock may be weathered to great depths, soil horizonation is only weakly developed.

Geology: Little geologic analysis has been conducted in Watershed 9. Because Watershed 9 and Watershed 1 of Lookout Creek Watershed are adjacent, it is reasonable to assume Watershed 9 bedrock is similar to that occupying similar elevations (425 m and 700 m) in Watershed 1. Lower elevation areas (i.e., < 600 m) in Watershed 1 are dominated by reddish and buff-colored Little Butte tuffs and breccias. Sardine greenish tuffs and breccias dominate middle elevation (from approximately 600 m to 900 m) bedrock in Watershed 1. Rock outcrops are numerous in Watershed 9.

Vegetation: No comprehensive vegetation survey has been conducted for Watershed 9. Vegetation in Reference Stand 8 (located in Watershed 9) has a partially open canopy dominated by old-growth (> 250 years) Douglas-fir with an understory of emergent Douglas-fir, western hemlock, Pacific yew (*Taxus brevifolia*), and bigleaf maple (*Acer macrophyllum*) (Hawk et al. 1978).

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Transient snow zone with <25% precip falling as snow at lowest elevations.

Andrews Watershed 10 - WS10

Stream gage GSWS10

Gaged watershed area: 10.2 ha (original surveyed value used in rating equation calculations)

Location of gage: (decimal degrees): North: 44.21705700, West: -122.26105600

Gage Elevation: 461 m

WS treatment: Harvest years: 1975 Percent Harvest: 100% Harvest type: Clearcut. Slash was removed and no burning occurred in the watershed. In 1976, 2-yr old Douglas-fir seedlines were planted.

Gage description: Oct 1968 an H flume was installed and in 1973 replaced with trapezoidal flume.

Rating curve equation A: 1969-1973

Rating curve equation C: 1974-1996. In August 1973 the H flume was replaced with a trapezoidal flume. Bottom width 3", angle from horizontal – 60 deg (30 from vertical)

Rating curve equation D: 1997-present. New curve developed using new calibration points.

Rating curve equation B: Aug 1973-Oct 1979, a v-notch plate was installed for measurement of low flows during summers.

Rating curve equation D: 1997-2023. A new v-notch plate (V-notch angle = 90 deg) was attached during summers for the measurement of low streamflow. The v-notch plate was typically installed in June and removed in September or October.

Site Description: Watershed above the Watershed 10 gaging station

Bounding Coordinates (decimal degrees):

North: 44.22015200, South: 44.21678600, East: -122.25443900, West: -122.25996600

Elevation (meters): Minimum: 461, Maximum: 679

Slope (%): 58.12; Aspect (degrees): 250

Site History: 100% clearcut in 1975. Clearcutting occurred during the spring and summer of 1975, and a running skyline system yarded all logs and unmerchantable material >20 cm in diameter or >2.4 meters in length uphill to a single landing, where it was burned. No burning within the watershed. Watershed replanted in 1976 with 2-yr old Douglas-fir seedlings. A significant debris flow in Feb 1986 destroyed the gaging station. WS#9 is the reference watershed for WS#10. GIS estimated percent harvest: 91.9%

Soils: Soils are largely weathered to reddish brown latosols, in tuff and breccia parent materials. Although the parent rock may be weathered to great depths, soil horization is only weakly developed. (S1) Soils are approximately 130 cm deep and the parent material is commonly weathered to a depth of 3.7 meters over much of the watershed. Soils are classified as Typic Dystrochrepts (Inceptisols U.S. Dept. of Ag. 1960,1972) and range from gravelly silty clay loam to very gravelly clay loam. The <2-mm fractoin of these soils ranges from 20% to 50% clay and contains gravel amounting to 30%-50% of the soil volume. The forest floor ranges from 3-5 cm thick and is classified as a duff-mull.

Geology: Soils are underlain by highly weathered volcanic tuffs and breccias.

Vegetation: The entire watershed was dominated by >450-year-old Douglas-fir stands. Four major plant community types were identified before harvest: Pseudotsuga-Castanopsis (xeric), Pseudotsuga-Rhododendron-Gaultheria (warm-mesic), Pseudotsuga-Rhododendron-Berberis (mesic), and Pseudotsuga-Acer-Polystichum (cool-moist). Patches of the old-growth forest, destroyed by fire and wind, were replaced by younger age classes of Douglas-fir. Climax vegetation for the forest communities is, for the most part, Douglas-fir. Some hemlock is found near the streams. Understory vegetation includes golden chinkapin, Pacific rhododendron, salal, vine-maple, Oregon grape and sword fern.

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Transient snow zone with <25% precip falling as snow at lowest elevations.

Andrews Mack Creek Watershed - WSMACK

Stream gage GSWSMC

Gaged watershed area: 581 ha (original surveyed value used in rating equation calculations)

Location of gage (decimal degrees): North: 44.21932500, West: -122.16735000

Gage Elevation: 758 m

WS treatment: Primarily old-growth conifer. In 1962 12.9% of upper elevation of watershed was harvested in clearcut/salvage in units along the road. In 2023 whole watershed burned with mixed severity as part of Lookout Fire.

Gage description:

GSWSMA (Mack Main gage): Bottom width = 18", angle from horizontal = 14.5 deg. (75.5 deg. from vertical) Actual angle varies with height above bottom. Rating curve equation set A; 1980 to present

GSWSMF (Mack Fish passage): compound weir: 20 deg v-notch .577 ft. high with 2.5 ft.-wide rectangular section above v-notch. Rating curve equation set A: 1996-2024

Climate: gage is located in 2nd growth opening that was clearcut 1965

Site Description: Watershed above the Mack Creek gaging station

Bounding Coordinates (decimal degrees):

North: 44.22054300, South: 44.20148000, East: -122.12699600, West: -122.17282200

Elevation (meters): Minimum: 755, Maximum: 1626

Slope (%): 48.41; Aspect (degrees): 306

Site History: This watershed is in a reference area meaning no significant land-use is planned. The upper portion of the watershed has a road and few small clearcuts from 1962 near the upper ridgeline. GIS estimated percent harvest: 12.9%. Fire burned portions of the upper watershed 120 years ago. The Lookout fire burned the whole watershed with mixed severity in fall 2023.

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum varies from 375-1000 mm water equiv. At highest elevation.

Site History: Harvest years: 1962 Percent Harvest: 12.9% Harvest type: Clearcut/Salvage

Vegetation: The watershed is dominated by >450-year-old Douglas-fir stands. Hemlock and cedar are found near the streams. Understory vegetation includes golden chinkapin, Pacific

rhododendron, salal, vine-maple, Oregon grape and sword fern. After harvest upper watershed, areas replanted but revegetation includes substantial tag alder.

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April.

Andrews Lookout Creek Watershed - WSLOOK

Stream gage GSLOOK, USGS gage number: 14161500

Gaged watershed area: 6242 ha (USGS original survey = 24.1 square miles))

Location of gage (decimal degrees): North: 44.21012600, West: -122.25714600

Gage Elevation: 422 m

Gage description: open channel, see USGS gage description.

WS treatment: Harvest years: 1950-1990. Percent Harvest: 25% Harvest type: Clearcut/Salvage

Canopy: Low, deciduous; continuous, closed canopy. Surface: On edge of wide stream bed, water/rocks/leaves.

Climate: Site is over lower Lookout Creek, next to deep pool. Forest clearing for creek 5-10 m wide, oriented northeast-southwest. Though site is under continuous canopy, is immediately adjacent to large clearing. Most direct sun from early to mid-afternoon throughout year. Susceptible to cold-air drainage issues. (JW Smith 2001)

Site Description: Watershed above the Lookout Creek gaging station

Bounding Coordinates (decimal degrees):

North: 44.28226000, South: 44.20127400, East: -122.09952700, West: -122.25879300

Elevation (meters): Minimum: 421, Maximum: 1627

Slope (%): 40.28; Aspect (degrees): 267

The Lookout Creek watershed comprises the entire Andrews Forest. All other Andrews watersheds are nested within the gaged portion of Lookout Creek with the exception of Watersheds 1 (which is in the drainage below the Lookout gage) and 9 and 10 which are directly adjacent to the Lookout drainage.

Site History: The watershed is approximately 25% patch-cut from 1948 to present. GIS estimated percent harvest: 23.1%

Soils: Soils developed in these parent materials are mainly Inceptisols with local areas of Alfisols and Spodosols.

Geology: Lower elevations of the Forest are underlain mainly by Oligocene-lower Miocene volcanic rocks composed of mudflow, ash flow, and stream deposits. In higher areas bedrock is composed of andesite lava flows of Miocene age and of younger High Cascade rocks. Stream erosion, a variety of types of landslides, and glaciation have created a deeply dissected, locally steep landscape.

Vegetation: When it was established in 1948, the Andrews was covered with virgin forest. Before timber cutting began in 1950, about 65% of the Andrews Forest was in old-growth forest (400-500 years old) and the remainder was largely in stands developed after wildfires in the mid-1800s to early 1900s. Clearcutting and shelterwood cuttings over about 30% of the Andrews Forest have created young plantation forests varying in composition, stocking level, and age. Old-growth forest stands with dominant trees over 450 years old still cover about 40 percent of the total area. Mature stands (100 to 140 years old) originating from wildfire cover about 20 percent. **Pre-treatment vegetation:** A limited determination of stand basal area was made in old-growth (>450 yrs. old) using a cruising prism. Observed range of basal area measured was 70-140 m²/ha in *Pseudotsuga* stands and 70-84 m²/ha in *Tsuga-Pseudotsuga*. **Succession description:** Lower elevation forest are dominated by Douglas-fir, western hemlock, and western redcedar. Upper elevation forests contain noble fir, Pacific silver fir, Douglas-fir, and western hemlock. Low- and mid-elevation forests in this area are among the tallest and most productive in the world. Average heights are in excess of 75 m and a typically store in excess of 600 megagrams of carbon per ha. These forests are also noteworthy for the large amounts of fine and coarse woody debris they contain. As elevation increases, Douglas- fir and western red cedar decline in importance and western hemlock is gradually replaced by Pacific silver fir. Non-forest habitats include wet and dry meadows, rock cliffs, and talus slopes.

Climate: Typically, snow begins falling in November with peak snow water equivalent storage estimated to occur in Feb-April. Mean annual maximum varies from 375-1000 mm water equiv. At highest elevation. Transient snow zone with 25% precip falling as snow at lowest elevations. Mean annual precipitation: 2200-2600 mm. Mean annual radiation: 10.5 - 13.5 Megajoules per square meter per day

Instrumentation

Don Henshaw and Craig Creel

Nine watersheds within the H.J. Andrews Experimental Forest (HJA) are gaged to measure stream height or stage. The records of stage are converted to stream discharge by applying station specific discharge rating curves. The instrumentation used to measure and record stream stage has changed through the years in response to changes in data collection technology, data management considerations, and end-user needs.

General instrument changes by year

1952-1996

All gaging stations:

Prior to 1996 streamflow records were derived from stage data collected by Stevens Type A (A-35 or A-71) recorders. The Stevens Type A recorder is a float- operated recorder that provides a permanent and continuous graphic record of stream stage fluctuations. A clock movement controls the rate at which a strip chart is advanced. The rise and fall of the float moves a marking stylus laterally across the chart. The recorder chart stage is initialized to a reference measurement of stream height taken by a hook gage located in a stilling well, or in the case of Mack Creek, WS#6, and WS#7 a tape measurement of water height in the flume.

The Type A recorder has a precision of .001 feet. Accuracy of the Type A recorders is influenced by small measurement errors due to float lag and line shift. These errors have been minimized by the selection of proper floats and counterweights. The estimated error value over a range of 5 feet for line shift is .001 feet, and the estimated error due to float lag is .004 feet (Error tables provided by Stevens). Accuracy is also influenced by hook gage or tape reference height measurement variations. Rapidly fluctuating water levels or observer bias can cause variations up to +/- .001 feet during repeated measurements.

WY 1953-1959 - Stevens Type A Chart Recorder (A-35) , WS 1, 2, 3. Charts were originally only summarized on a daily basis using manual scanning techniques, but were re-digitized at FSL-Corvallis using the Summagraphics digitizer in 1988.

WY 1960-1966 - Given the small number of points representing each year, it is surmised that these years were also hand edited from the charts with points established at key changes in the slope of stage height. Points are saved at a timestep rounded to the nearest 15 minutes (:00, :15, :30, :45). It is possible that these charts were actually digitized at Coweeta, but a differing computer card format and 15 minute time-step suggest otherwise

WY 1963-1966 - Belfort water level recording charts were used the first years of WS 6, 7, 8

WY 1967-1975 - WS 1, 2, 3, Fischer-Porter punched tape recorders were used to capture records with Stevens Type A Chart Recorder (A-35) charts as backup. Stevens Type A Chart Recorders (A-35) were used at WS 6, 7, 8, 9, 10. Records were edited at FSL-Corvallis and sent to Coweeta Hydrologic Lab (CHL) in NC for processing. Tapes were read using a Fischer-Porter tape-to-card

translator. The tapes were punched at every 15 minute interval but points were reduced at CHL when difference between readings was less than prescribed limit, .001, i.e., when stage did not change. This technology was known as analog-to-digital recorder (ADR) tapes. Output from this process was punched onto computer cards and sent to the PNW-Portland for discharge calculation. More than 5 times as many points were saved per year on average compared to WY 1960-1966.

WY 1976-1985 - Stevens Type A Chart Recorder (A-35) Charts were prepared for digitizing in FSL-Corvallis and sent to Coweeta CHL for digitizing. Stage height data are reduced in this digitizing method where only "key (turning) points", that is, points where the slope or trajectory of stage height changes are saved. Output from this process was punched onto computer cards and sent to the PNW-Portland for discharge calculation. Nearly 2 times as many points were saved per year on average through this processing compared to WY 1960-1966.

WY 1986-1998- Stevens Type A Chart Recorder (A-35). Charts are prepared and digitized in FSL-Corvallis using a Summagraphics MM1812 digitizer. Point reduction from the digitizer utilized a very similar method to the digitizing done at Coweeta and the number of points saved per year were the same or slightly greater on average. In October of 1996 a Model 2 Stevens Instruments Position Analog Transmitter (PAT) and a Campbell Scientific CR-10X datalogger were installed at WS#1 in addition to the Stevens Type A recorder already present

WY 1999-2017 - The PAT with CR10X data loggers replaced the A-35 charts as the primary record in WY 1999. Points were evaluated every 5 minutes for output beginning WY 1999. The original algorithm only saved points where the slope of the stage height measurements was changing more than .003 ft. threshold. This algorithm was subsequently changed in 2002 to save any points where the gage height changed by .001 ft. from previous 5 minute value. Charts from WS 2 and 3 were hand re-digitized 1999-2001 to better capture diurnal flux at these watersheds that had been missed by the original algorithm. In April-May 2015 all Campbell Scientific's CR10X's were replaced with CR1000's except for Lookout Creek, where replacement occurred followed with a CR1000 in March 2016.

Prototype digital transmitters were used at Mack and WS#2 beginning in June of 1990. They were float operated recorders which consisted of off the shelf precision potentiometers (A single-turn at WS#2, and a 10-turn at Mack) coupled to Stevens Type A float pulley standards. These were connected to Campbell Scientific CR-10 dataloggers. No documentation could be found to describe the accuracy or precision of these transmitters, but it is likely that it was similar to the Type A recorder due to float lag and line shift errors. The records from the prototype transmitters were only used to fill in periods when the Type A recorder record was unusable. There were a variety of problems with the prototypes due to frequent failures of the potentiometer and pulley standard interface, and frequent occurrences of "electronic noise" which would cause false peaks and valleys in the hydrograph. Alterations were made to the interface coupling which did improve the record, but "electronic noise" continued to be a problem that limited the use of the record.

Summers 1996-2023

V Notch: Beginning in 1997, compound v-notch weirs were installed at our headwater gaging stations in the summers (not Mack Creek). Metal v-notch weir plates were mounted to the existing

trapezoidal flumes/weirs to increase measurement sensitivity during the low flow period. The plates were removed in early fall to allow passage of debris and to measure flows beyond the range of the v-notch weirs.

The v-notch plates were fabricated by a local metal shop. We provided rough drawings of what we wanted and very detailed specifications for the v-notch openings and their position within the existing flumes/weirs. We then worked with the fabricator to design the mounting system. Once the basic v-notch plates were complete, the fabricator then did a custom fit of each one in the field to ensure all specifications were met.

Since we were confined to the existing weir structure, some of the elements of a 'true' v-notch weir could not be met (example: proper pool depth for expected head, and plate not being exactly vertical.). Because our weirs were different we could not use the theoretical discharge formulas, so we had to develop our own discharge curves for each site.

Site Specific instrumentation

GSWS01

- o In October of 1996 a Model 2 Stevens Instruments Position Analog Transmitter (PAT) and a Campbell Scientific CR-10X datalogger were installed at WS#1 in addition to the Stevens Type A recorder already present. The PAT is float operated and consists of a float pulley shaft coupled through gears to a precision potentiometer. The output of the potentiometer drives a circuit that converts the input shaft position to a 4 to 20 mA signal. The output signal is recorded by the CR-10X and converted to a stage by the datalogger programming instructions. An 18-inch circumference float pulley was mounted on the PAT to produce a measurement range of 0 to 2.5 feet. With this configuration the PAT has a precision of .001 feet, but since it is float operated float lag and line shift errors are present. The estimated error is .005 feet over a range of 5 feet.
- o On December 12, 1996 a Campbell Scientific radio telemetry unit was connected to the CR-10X. Data now could be downloaded hourly to the base station located at the HJA headquarters.
- o On June 6, 1998 vandals destroyed the hook gage at WS #1. Tape measurements in the flume were used as the reference until a new hook gage was installed on July 1, 1998.
- o On July 1, 1998 a new hook gage was installed using the same elevation relationship to the flume intake as the old hook gage.
- o During the summer of 1999, a new shelter was constructed at WS#1
- o On September 24, 1999 the PAT was replaced with another PAT that had been altered by the removal of the output conditioning circuit (altered PAT). The PAT output now is directly from the precision potentiometer. This was done to reduce the power requirements for the PAT (17.4 VDC to 12.0 VDC). No change in PAT accuracy occurred after the alteration.

GSWS02

- o Instrumentation at WS#2 did not change until April 4, 1999 when the CR-10 connected to the potentiometer was replaced with a CR-10X, and radio telemetry was installed.
- o On October 19, 2000 an altered PAT was installed to replace the old prototype potentiometer transmitter.

GSWS03

- o On February 6, 1996 the gaging station at WS#3 was totally destroyed by a large debris avalanche/torrent that occurred during a major flood event. The station site was buried by 11-12 feet of debris, so it was early September before it was excavated down to the original elevation of the site. Fortunately the flume was still in place, but was damaged. The original shelter, stilling wells, and hook gage were never found, so the station would need to be completely rebuilt.
- o On September 19, 1996 the flume had been repaired to the point it was usable, and a temporary stilling well was installed. The well could not accommodate a Type A recorder, so a Bendix Corporation FW1 recorder was installed. Tape readings in the flume were used as the stage reference. The FW1 is a float operated chart recorder. A clock movement controls the rate that a cylinder-mounted chart is advanced. The rise and fall of the float moves a pen arm vertically across the chart leaving a continuous graphic record of stream stage. No documentation of FW1 precision could be found, but it is estimated to be .01 feet. It is estimated that the accuracy is similar to the Type A recorder due to float lag and line shift errors.
- o On December 11, 1996 another temporary stilling well and shelter was installed. The FW1 was replaced with a Type A recorder that used tape measurements in the flume as the stage reference. The temporary station operated continuously until July 29, 1998 when it was removed for construction of a permanent station.
- o On September 25, 1998 construction of the station was completed. A Type A chart recorder, altered PAT, and CR10X were installed and started. The new hook gage was not installed yet, so tape readings in the flume were used as the stage reference.
- o The new hook gage was installed on September 30, 1998. The new hook gage was installed using the same elevation relationship to the flume intake as the old hook gage. The hook gage measurements are now used as the stage reference at WS#3.

GSWS06

- o In the early fall of 1997 the H flume at WS#6 was replaced with a trapezoidal flume. On October 30, 1997 a Type A recorder, and a hook gage were installed and started at the remodeled station.
- o On December 5, 1997 an altered PAT and a CR-10X datalogger were added. All instrumentation now uses the hook gage measurement as the reference stage.

GSWS07

- o The H flume at WS#7 was replaced with a trapezoidal flume during the early fall of 1997. On November 6, 1997 a Type A recorder, and a hook gage were installed and started at the remodeled station.
- o On November 19, 1997 an altered PAT, and a CR-10X datalogger were added. All instrumentation now uses the hook gage measurement as the reference stage.

GSWS08

- o Instrumentation at WS#8 did not change until August 18, 1998 when an altered PAT, and a CR10X datalogger were added to the station.
- o On July 6, 1999 radio telemetry was added.

GSWS09

- o Instrumentation at WS#9 did not change until June 6, 2000 when an altered PAT, and a CR-10 datalogger were added.

GSWS10

Instrumentation at WS#10 did not change until November 18, 1999 when an altered PAT, and a CR-10X datalogger were added.

Mack Creek

- o Instrumentation at Mack Creek remained unchanged until January 15, 1996 when radio telemetry was added to the station. In the spring of 1996 the output from the prototype potentiometer transmitter became very unstable. On June 27, 1996 the prototype was replaced with a Stevens Instruments Pulse Generator III (PG3) transmitter. The PG3 consists of an input shaft coupled to a disk with four magnets mounted at 90 degrees around the rim. These magnets are magnetically coupled to three reed switches, which connect to a very low power circuit that keeps track of pulse count and direction of rotation. The circuit has two outputs that provide short up or down pulses that are recorded by the existing CR-10 datalogger, and converted to a stream stage value by CR-10 programming instructions. The PG3 has internal gears with a 25 to 1 ratio, resulting in 300 up or down counts per revolution of the input shaft. A 12-inch circumference float pulley was mounted on the input shaft to provide a precision of .0033 feet. Since this is a float-operated system, there are float lag and line shift errors. The estimated error is .005 feet over a range of 5 feet.

On December 7, 2000 the PG3 was replaced with an altered Model 3 PAT to standardize the stage instrumentation used at the HJA. The Model 3 PAT has the same precision and accuracy as the Model 2. An altered PAT was also added at this time to measure the water level in the precipitation collector well at the station.

Mack Creek gage, Fish Passage

o During the summer of 1995 a fish passage was built around the flume at the Mack Creek station. A compound weir (120 degree v-notch at the bottom of the weir plate with a rectangular area on top) was installed in the passage to measure the water level. A MTS Level Plus model LT420 magnetostrictive transmitter mounted in a stilling well is used to measure the stage. The transmitter consists of a ferromagnetic waveguide protected by a solid rod, a electronic assembly that determines the water level based on waveguide behavior, and a float containing a set of magnets that “ride” the outside of the waveguide protective rod.

o The water level was determined when the electronic assembly initiates a short, low current pulse that runs through the waveguide, and simultaneously starts a timer. The pulse, along with the magnetic field it generates travels the length of the waveguide. When the pulse reaches the float, the magnetic field from the pulse interacts with the magnetic field from the float and initiates a torsional “twist “ in the waveguide material. This “twist” creates a sonic wave that travels in both directions and is detected by the electronic assembly. The timer stops when the “twist” is detected. The distance from the float is determined based on the return time and the signal transmission properties of the waveguide material. The return time interval is converted into a 4-20mA loop powered output. The output from the transmitter is recorded on the existing CR-10 datalogger, and converted to a stage value by the datalogger programming instructions. The transmitter has a precision of .001 feet, and an accuracy of .002 feet over a range of four feet. A tape reading of the water level in the stilling well is used as the stage reference.

o The fish passage stage measurements began on October 5, 1995. Mack Creek streamflow is the sum of the flows from the regular flume and the fish passage compound weir from this time forward.

Addendum about instrument calibration

(see rating curve document for more about measurement uncertainty)

We do not have a system of calibration for the recorders, but do have a regular and frequent system of checks that would indicate any problems. Every week a hookgage measurement is taken and compared to the recorder readings. Significant variations from the hookgage would indicate changes in recorder operation, but factors such as chart spooling, or stilling well response time during rapidly changing stage levels must also be considered. The hookgage position/elevation in relation to the flume is surveyed every year. Tri-weekly measurements of the water level in the flume also serve as a rough check of hook gage accuracy. Accuracy of the chart recorder is controlled by the gearing of the pulley standard; there is really nothing to calibrate. The same holds true for the

PAT, but the potentiometer can malfunction resulting in electronic spikes or dead zones in the range of resistance, and we inspect annually to assure full range of resistance. The potentiometer has no adjustments, so it must be replaced if problems occur.

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