APPENDICES

SYMBOLS AND NOTATION

GLOSSARY

SYMBOLS AND NOTATION

Physical constants

g: acceleration due to gravity, g= 9.81 m/s^2, 32.2 ft/s^2.
ρ_{water}: density of water at 4°C, ρ_{water}= 1000 kg/m^3, 62.5 lb/ft^3.
μ_{water}: dynamic viscosity of water, $\mu_{water}= 1.05\times10^{-3}$ $N.s/m^2$.

Math constants

e: natural logarithm base, e= 2.718281828459…
π: ratio of a circle circumference to its diameter,
π= 3.14159265358979…

Notation

For each quantity the dimensions are given in terms of the fundamental dimensions of length, L, time, T, mass, M, and force, F.

A: area, either drainage area or flow cross sectional area [L^2]
a: specific catchment area [L]
$C(\psi)$: specific moisture capacity, $d\theta/d\psi$ [1/L]
$D(\theta)$: soil water diffusivity [L^2/T]
d: effective grain diameter [L]
D: soil moisture deficit [L]
$\overline{D}$: catchment mean soil moisture deficit [L]
E: evapotranspiration rate [L/T]
F: cumulative depth of infiltrated water [L]
f: infiltration rate [L/T]
f_i: steady state infiltration capacity parameter in Horton's equation [L/T]
F_a: depth of water retained in watershed, SCS method [L]
f_c: infiltration capacity [L/T]
f_o: initial infiltration capacity parameter in Horton's equation [L/T]
F_p: cumulative depth of infiltration at ponding [L]
f_t: infiltration rate at time t [L/T]
h: hydraulic head [L]
I_a: initial abstraction, SCS method [L]
I_t: Antecedent precipitation index at day t [L]
$K(\theta)$: hydraulic conductivity as a function of θ [L/T]
K: hydraulic conductivity [L/T]
k: intrinsic permeability [L^2]
k: recession factor parameter in Horton's equation [1/T]
k: recession factor parameter in antecedent precipitation index [Unitless]
K_p: hydraulic conductivity parameter in Philip's equation [L/T]

K_{sat}: saturated hydraulic conductivity [L/T]
L: depth to the wetting front [L]
M_m: mass of mineral grains [M]
$M_{s\,dry}$: mass of soil sample when dry [M]
$M_{s\,wet}$: mass of soil sample when wet [M]
n: porosity of soil [Unitless]
P: precipitation rate [L/T]
P: precipitation depth [L]
P: Combined moisture content difference and wetting front suction product Green-Ampt model parameter [L]
p: pressure [F/L^2]
P_t: precipitation at day t [L]
Q: flow rate, discharge [L^3/T]
Q: runoff rate [L/T]
q: lateral moisture flux across a unit contour width [L^2/T]
q: specific discharge [L/T]
q_{cap}: lateral flow capacity of soil profile [L^2/T]
r: runoff [L/T]
R_e: Reynold's number [Unitless]
S: potential maximum retention, SCS method [L]
S: tan(β), slope [Unitless]
S_d: degree of saturation [Unitless]
S_e: effective saturation [Unitless]
S_p: sorptivity in Philip's equation [$L/T^{0.5}$]
T: transmissivity [L^2/T]
T_o: transmissivity of a saturated soil profile [L^2/T]
t_p: time to ponding [T]
v: flow velocity [L/T]
V_a: volume of air in a soil sample [L^3]
V_m: volume of mineral grains [L^3]
V_s: total volume of a soil sample [L^3]
V_w: volume of water in a soil sample [L^3]
w: relative wetness of soil [Unitless]
w: surface water input [L/T]
z: depth below soil surface [L]
z_w: depth of water table [L]
Δθ: difference between initial and saturated moisture contents [Unitless]
γ: soil topographic wetness index [ln(T/L)]
λ: topographic wetness index [ln(L)]
θ: volumetric moisture content [Unitless]
θ_a: plant available moisture content [Unitless]
θ_e: effective porosity [Unitless]
θ_{fc}: field capacity [Unitless]

θ_o: initial moisture content [Unitless]
θ_{pwp}: permanent wilting point [Unitless]
θ_r: residual or irreducible moisture content [Unitless]
ρ_b: bulk density of soil [M/L^3]
ρ_m: mineral density of soil particles [M/L^3]
$\psi(\theta)$: pressure head as a function of moisture content [L]
ψ: pressure head [L]
ψ_a: air entry head [L]
ψ_f: suction head [L]

GLOSSARY

Online Resource

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Anisotropic medium

A medium having properties that vary depending on the direction of measurement. An example would be hydraulic conductivity that may be different in a vertical and lateral direction due to layering and alignment of the soil grains.

Antecedent moisture conditions

Soil-moisture content preceding a given storm.

Baseflow

Stream discharge derived from groundwater seepage; a time-based definition relating to runoff sustained without precipitation, largely composed of groundwater; outflow from extensive groundwater aquifers, which are recharged by water percolating down through the soil mantle to the water table (Butler, 1957; Langbein and Iseri, 1960; Tischendorf, 1969).

Bulk density

The dry density of the soil; the mass of the solid mineral and organic components of soil divided by the total volume.

Capillary fringe

The unsaturated zone containing water in direct hydraulic contact with the water table, and held above the water table by capillary forces (Butler, 1957) resulting in a negative pressure potential in the soil matrix (Hillel, 1971).

Contributing area

The area upslope of any point on a watershed or topographic surface; the area of a catchment contributing to storm runoff (Betson, 1964), dimensioned as [L^2].

Darcy's Law

An experimentally-derived relationship stating that rate of fluid flow through a permeable medium is directly proportional to the hydraulic gradient and to the hydraulic conductivity. It is valid only for flow velocities within the laminar range. Being originally stated for saturated flow, it was extended by Richards in 1931 to

embrace unsaturated flow. (Swatzendruber, 1960; Hillel, 1971; Wind, 1972).

Depression storage

The volume of water, forming part of surface detention, which is contained in small natural depression in the land surface during or shortly after rainfall, none of which runs off (Horton, 1933; Horton, 1935; Langbein and Iseri, 1960; Tischendorf, 1969).

Distributed hydrologic model

A hydrologic model that allows for spatial variability of model parameters and inputs. The spatial resolution of distributed parameters and inputs depends on available physical data.

Drainable porosity

The difference between moisture content at saturation and at field capacity; quantifies the porosity of the soil that gravity drains within a time frame of a few days. Quantitatively, it is defined as porosity minus the field capacity moisture content corresponding to a pressure head between -100 and -500 cm.

Elevation head

The elevation above an arbitrary horizontal datum, also called gravitational head.

Field Capacity

The moisture content remaining in soil after a few days of gravity drainage. Quantitatively, it is defined as the moisture content corresponding to a pressure head between -100 and -500 cm.

Hydraulic conductivity

A coefficient of proportionality describing the rate at which water can move through a porous medium under a hydraulic gradient. A function of both the porous medium and fluid properties. Hydraulic conductivity depends upon the pore geometry determined by soil texture and structure and the fluid viscosity and density. The hydraulic conductivity is at its maximum when the soil is saturated and decreases with decreasing water content or increasing water tension.

Hydraulic head

The equivalent height of a liquid column corresponding to a given pressure (Hillel, 1971); usually called simply "head" of the fluid (Dingman, 2002). Hydraulic head is measured with respect

to an arbitrary horizontal datum and is the sum of pressure head and elevation head.

Hydraulic gradient

The gradient of hydraulic head that induces flow of water, expressed as head drop per unit distance in the direction of flow.

Hydrograph

A graph or table of stream discharge versus time.

Hyetograph

A graph or table of water input (rainfall or snowfall) or runoff generated versus time.

Hysteresis

A phenomenon that occurs during the draining and wetting of soils whereby the relationship between soil moisture content and negative pressure head depends upon the history of drying and wetting.

Infiltration capacity, f_c

The maximum rate at which a given soil can absorb falling rain (or melting snow), when it is in a specified condition (Horton, 1933; Horton, 1941).

Infiltration excess overland flow

Overland flow that occurs when the infiltration capacity drops below the water input rate from rainfall or snowmelt. Also known as Hortonian overland flow and saturation from above.

Infiltration rate, f

The volume rate of the passage of water through the surface of the soil, via pores or small opening, into the soil (Horton, 1933; Horton, 1941).

Interception

Water retained in the vegetation canopy for some period, however short, after rain has struck the vegetative material above the soil surface (Tischendorf, 1969).

Interflow

An intermediate component of runoff, between overland flow and groundwater flow. Interflow is made up of subsurface flow,

which never reaches the water table but instead returns to form surface runoff (Amerman, 1965).

Intrinsic permeability

A property of a porous medium which determines the ease with which a fluid will move through the matrix. Intrinsic permeability depends on the pore geometry determined by soil texture and structure. It does not contain any fluid properties so is more general than hydraulic conductivity because it applies to the flow of all fluids through the porous medium. It is equal to Nd^2 where N is a pore shape factor and d is a pore size scale measure (such as the average pore diameter or grain size).

Kinetic energy

The energy associated with the motion of a substance (Serway, 1998). For fluid flow kinetic energy is proportional to the square of the velocity.

Lateral moisture flux [L^2/T]

The flow rate in a lateral or horizontal direction through a soil profile. This is normalized by the corresponding width so is expressed as volume per unit width per time. This is integrated over the full depth of the soil profile conducting flow laterally.

Lateral flow capacity [L^2/T]

The capacity of a soil profile to conduct flow in a lateral or horizontal direction. When lateral flow is driven by the hydraulic gradient this maximum capacity is generally slope or topographic gradient times the transmissivity.

Lumped hydrologic model

A hydrologic model with spatially averaged parameters and inputs. Lumped model parameters often must be developed through optimization or calibration rather than calculating directly from field measurements or existing data.

Manometer

A device for measuring pressure, one end of a U-shaped tube containing liquid is open to the atmosphere, and the other end is connected to a system of unknown pressure.

Overland flow

Part of streamflow which originates from rain which fails to infiltrate the soil surface at any point as it flows over the land

surface to stream channels (Langbein and Iseri, 1960; Tischendorf, 1969; Hewlett and Nutter, 1970).

Partial area concept

Storm runoff generated by only a part of the surface of a catchment (Betson, 1964).

Piezometer

A tube used to measure the head of fluids of constant density. The hydraulic head at any "point" in a ground-water or porous medium flow can be measure as the height above the selected arbitrary datum to which water rises in a tube connecting the "point" to the atmosphere.

Ponding time

Time to the first occurrence of ponding from the beginning of a surface water input event (such as a rainstorm).

Porosity

The volume of voids or pore spaces in a soil or rock expressed as a fraction of the bulk volume.

Potential energy

Gravitational potential energy, is the energy of an object resulting from its position in a gravitational field.

Precipitation excess

The surface water input that does not infiltrate and ponds on the surface contributing to depression storage or overland flow runoff.

Pressure head

The equivalent height of a liquid column corresponding to a given pressure. Pressure head is measured relative to the height at which pressure is measured and is pressure divided by the weight density of water.

Return flow

Infiltrated water which returns to the land surface after having flowed for some distance in the subsurface.

Runoff

Overland and subsurface flow components that contribute to the quickflow in a stream, leaving a watershed within a time scale of about a day following surface water input. Runoff is also used to refer to all water leaving a watershed, the sum of quick flow, base flow and groundwater outflow.

Saturation excess overland flow

Surface runoff occurring when the soil is saturated. This is also called the Dunne mechanism or saturation from below and occurs most commonly in humid and vegetated areas with shallow water tables, where infiltration capacities of the soil surface are high relative to normal rainfall intensities. Saturation excess overland flow is most common on near-channel wetlands (Betson, 1964; Dunne and Black, 1970).

Soil particle density

The weighted average density of the mineral grains making up the soil; mass of the soil divided by the volume of mineral grains (Dingman, 2002).

Soil texture

The classification of a soil based on the distribution of particle sizes within the soil. Clay is defined as particles with diameter less than 0.002 mm. Silt has a particle diameter range from 0.002 mm to 0.05 mm and sand has particle diameter range from 0.05 to 2 mm. The USDA soil texture triangle assigns names, such as sandy loam, silty clay loam, sandy clay based upon the relative fractions of particles in these size ranges.

Soil water diffusivity

A property that quantifies the flux of water per unit gradient of water content. This is a quantity that appears in Richard's equation describing the flow of water in unsaturated soil.

Sorptivity

A parameter expressing the macroscopic balance between capillary forces pulling water in to a soil and hydraulic conductivity that limits the flow rate. This parameter appears in Philip's solution to Richards equation for unsaturated flow and is the proportionality constant in the expression indicating that in the absence of other forces the quantity of water absorbed is proportional to the square root of time.

Specific catchment area

Contributing area per unit contour width; dimensioned as [L].

Specific discharge

The volume rate of flow per unit area through a porous medium.

Specific moisture capacity

A parameter representing the rate of change of soil moisture content with respect to pressure head, that appears in Richard's equation.

Subsurface runoff

The movement of subsurface storm water within the soil layers to stream channels at a rate more rapid than the usual groundwater flow (Hursch, 1936).

Subsurface stormflow

The part of streamflow which derives from the lateral subsurface flow of water which discharges into the stream channel so quickly as to become part of the stream flow associated directly with a given rainstorm.

Surface detention

That portion of rainwater, other than depression storage, which remains in temporary storage on the land surface as it moves downslope by overland flow and either runs off, is evaporated or is infiltrated after the rain ends (Horton, 1933; Horton, 1937; Butler, 1957; Chow, 1964).

Surface runoff

The stream outflow from a region.

Tensiometer

A device used to directly measure the capillary tension of soil moisture under field conditions; as explained in Dingman (2002), a tensiometer "consists of a hollow metal tube, of which one end is closed off by a cup of porous ceramic material and the other end is fitted with a removable airtight seal. A manometer, vacuum gage, or pressure transducer is attached to the end of the tube. The tube is completely filled with water and inserted into the soil to the depth of the measurement. Since the water in the tube is initially at a pressure somewhat above atmospheric, there is a pressure-induced flow through the porous cup into the soil

that continues until the tension inside the tube equals that in the soil. When this equilibrium is reached, the manometer or gage gives the tension in the tube and in a roughly spherical region immediately surrounding the cup."

Throughfall

The portion of rainfall which penetrates the vegetation and reaches the surface through spaces in the vegetative canopy and as drip from leaves, twigs and stems. Throughfall is precipitation that is not retained as interception.

Throughflow

Downslope flow of water occurring physically within the soil profile, usually under unsaturated conditions except close to flowing streams, occurring where permeability decreases with depth (Kirkby and Chorley, 1967).

Topmodel

An approach for predicting saturation overland flow based on the idea that
the location and size of zones of surface saturation that generate saturation overland flow can be predicted based on the distributed topographic attributes and soil properties of a catchment (Beven and Kirkby, 1979).

Topographic wetness index

The ration of specific catchment area to slope or its natural logarithm, denoted $\ln(a/S)$, or $\ln(a/\tan\beta)$. The topographic wetness index quantifies the dependence of soil moisture deficit on catchment area and slope. The probability distribution of the topographic index can be used to describe the hydrologic response of watersheds.

Transmissivity

The integral over soil depth of hydraulic conductivity. If the soil is relatively homogenous and flow paths are horizontal, transmissivity may be defined as the depth times the hydraulic conductivity.

Variable source area

That portion of a watershed contributing to saturation excess overland flow.

Viscosity

Used in fluid flow to characterize the degree of internal friction in the fluid. This internal friction or viscous force is associated with the resistance of two adjacent layers of the fluid against moving relative to each other (Serway, 1998).

Volumetric soil moisture content

The ratio of water volume to soil volume (Dingman, 2002).

References

Amerman, C. R., (1965), "The Use of Unit-Source Watershed Data for Runoff Prediction.," Water Resources Research, 1(4): 499-508.

Betson, R. P., (1964), "What Is Watershed Runoff?," Journal of Geophysical Research, 68: 1541-1552.

Beven, K. J. and M. J. Kirkby, (1979), "A Physically Based Variable Contributing Area Model of Basin Hydrology," Hydrological Sciences Bulletin, 24(1): 43-69.

Butler, S. S., (1957), Engineering Hydrology, Prentice-Hall, New Jersey, 356 p.

Chow, V. T., ed. (1964), Handbook of Applied Hydrology, McGraw-Hill, New York.

Dingman, S. L., (2002), Physical Hydrology, 2nd Edition, Prentice Hall, 646 p.

Dunne, T. and R. D. Black, (1970), "An Experimental Investigation of Runoff Production in Permeable Soils," Water Resources Research, 6(2): 478-490.

Hewlett, J. D. and W. L. Nutter, (1970), "The Varying Source Area of Streamflow from Upland Basins," Symposium on Interdisciplinary Aspects of Watershed Management, Montana, p.65-83.

Hillel, D., (1971), Soil and Water: Physical Principles and Processes, Academic Press, New York and London, 288 p.

Horton, R. E., (1933), "The Role of Infiltration in the Hydrological Cycle," Trans. Am. Geophys. Union, 14: 446-460.

Horton, R. E., (1935), "Surface Runoff Phenomena - Part I. Analysis of the Hydrograph," Horton Hydrological Laboratory, Vorheesville, New York.

Horton, R. E., (1937), "Hydrologic Interrelations of Water and Soils," Proc. Soil Sci. Soc. Am, 1: 401-429.

Horton, R. E., (1941), "An Approach toward a Physical Interpretation of Infiltration Capacity," Proc. Soil Sci. Soc. Am, 5: 399-417.

Hursch, C. R., (1936), "'Storm-Water and Absorption', in 'Discussion on List of Terms with Definitions; Report of the Committee on Absoption and Transpiration'," Trans. Am. Geophys. Union, 17: 301-302.

Kirkby, M. J. and R. J. Chorley, (1967), "Throughflow, Overland Flow and Erosion," Bull. Intern. Assoc. Sci. Hydrology, 12.

Langbein, W. B. and K. T. Iseri, (1960), "General Introduction and Hydrologic Definitions: Manual of Hydrology. Part I: General Surface-Water Techniques," Water Supply Paper 1541-A, US Geological Survey.

Serway, R. A., ed. (1998), Principles of Physics, Saunders College Publishing.

Swatzendruber, D., (1960), "Water Flow through a Soil Profile as Affected by the Least Permeable Layer," J. Geophys. Res., 65: 4037-4042.

Tischendorf, W. G., (1969), "Tracing Stormflow to Varying Source Area in Small Forested Watershed in the Southeastern Piedmont," Thesis, University of Georgia.

Wind, G. P., (1972), "A Hydraulic Model for the Simulation of Non-Hysteretic Vertical Unsaturated Flow of Moiture in Soils," J. Hydrology, 15: 227-246.