# INDEX

abrupt waves, see surges advection-aridity approach 136-138 example of implementation 136-137 albedo 57, 63 anisotropy in porous materials 271-273 Darcy's law 272 antecedent precipitation index 132, 345 aquifer 2, 249 confined 2 unconfined 2 atmospheric boundary layer 36-41 bulk similarity 50-55 general structure 38 similarity functions 42-55 atmospheric surface layer 39 neutral 43 with density stratification 46 baseflow definition 2, 366 effect of evaporation 417 sources 416-418 baseflow, catchment-scale parameterizations 416-431 aquifer slope effects 429-431 exponential decay process 418-420 geomorphic assumptions 422 recession rate analysis, in terms of basin characteristics 422-424 recession rate analysis, of hydrograph data 420-421 related to local aquifer outflows 416-418, 422 to derive aquifer parameters 424-429 basin 9 see also catchment binomial distribution 522-523 Boltzmann transform for desorption 349 for hydraulic groundwater outflow 392 for sorption 311-313 Boussinesq, correction coefficient 165 Boussinesq equation 384 linearized form 398-399 steady state form 385

Bowen ratio 122 bulk transfer method 119-121 capillarity, see surface tension capillary barrier 456-457 capillary conductivity 274 calculation with conceptual models 282-287 determination 275-276 empirical functions 279-280 hysteresis 276 capillary rise 257, 259 capillary rise with evaporation 346-357 field applications 350-357 steady flow from water table 346-347 time compression approximation 352-354 unsteady drying as desorption process 347-350 capillary zone number 372, 377, 381 catchment 9 catchment-scale response parameterizations to precipitation linear non-stationary 498-500 linear stationary, see unit hydrograph and unit response nonlinear, stationary 493-498 celerity 176 characteristics, propagation of disturbances 179, 191, 201-202, 203-204 channel roughness (Gauckler-Manning) 172-173 Chézy equation 171 Chinook 91 cloud cover 61 conservation, equation of energy 28 mass 14 mass and momentum in hydraulic groundwater theory 382-385 mass and momentum in porous materials 287-298 mass in hydraulic theory 163-164, 167 mean specific humidity 35 momentum 16 momentum in hydraulic theory 166, 167 water vapor 35 continuity, equation of at a point 14 constant density fluid in rigid porous material 287

### INDEX

600

continuity, equation of (cont.) finite control volume 15 in hydraulic theory 163-164, 167, 384 water, air and solid in deformable porous material 290 convolution integral 593 causal, or non-anticipatory system 593 discrete formulations 473, 595 finite memory system 594 illustration of folding 594 moments 595-597 nonlinear (stationary) series 494, 597-598 non-stationary (linear) 499 regular (linear, stationary) 470 creeping flow 270, 277 in a tube (Hagen-Poiseuille) 271 with free surface cyclone 83 Dalton number 41, 585 Darcy's law additional driving forces 279 at a point 268 dimensional basis for creeping flow 270-271 in a sand column 268 in anisotropic medium 272 in deformable materials with two immiscible fluids 294 in hydraulic theory 382-383 in partly saturated materials 274 limitations for high flows 277-278 limitations for low flows 278-279 delta function (Dirac) 591-592 density dry air 24 moist air 25 water 17 water vapor 24, 25 density function (probability) 510 depression storage 2 desorption as model for field soil evaporation 349-357 boundary conditions 349, 392 solutions 349, 393 desorptivity capillary 349 hydraulic 392 diffusion approximation of free surface flow 184-189 advectivity 185, 186 advecitivity and kinematic wave celerity 186 and the Muskingum method 238 applicability 187 diffusivity 185, 186, 188-189 displacement height 43 distribution function (probability) 510

applications of theoretical functions 519-543 initial 531-532 parameter estimation 518 symmetrical 512 theoretical 517-518 double mass curve 96 drag coefficient 42 drainable porosity 378-379 drainage area 9 see also catchment drought flow 3, 366 Dupuit formula 388 exactness of 388-389 dynamic sublayer 41, 43 eddy correlation 118 effective stress in soil 291, 295, 333 elastic porous material case of constant vertical load 295-297 stresses and strains 288-293 stresses and strain rates of fluids 293-295 energy budget at the surface diurnal self-preservation 138-142, 356-357 equation 55, 123 global long-term averages 6, 71 local examples 57 minor terms 70 energy budget method for wet surfaces 125-128 for wet surfaces without advection 128-130 with Bowen ratio 124-125 with profiles of wind and scalar 125 equilibrium evaporation 129 as basis for empirical equations 129-130 evaporation average values 4 climatology and examples 148-151 definition 3 maximal values 5 mechanisms 117 methodologies 117 operational methods 131-138 evaporation, daily from soil as desorption processes 349, 351-352 disaggregation with diurnal self-preservation 356-357 effect of vegetation 354 first and second stage of drying 348 two stages with time compression approximation 352-354 evapotranspiration, definition 3 event water 445-447 expected value 512 extreme value distributions 531 asymptotic 532 first asymptote 531-535

## CAMBRIDGE

Cambridge University Press 0521824796 - Hydrology: An Introduction Wilfried Brutsaert Index More information

#### INDEX

601

generalized 538 third asymptote 535-538 extreme values 531-532 fair weather flow 3 Föhn 91 Forchheimer's equation 278 free surface approximation in unconfined aquifer 377-382 condition 161-162 condition in porous material 379-380, 381 free surface wave celerity dynamic 176, 182, 220 kinematic 182, 184, 190-193 Lagrange's 176, 220 frequency (relative) 509 frequency curve 514 see also probability plots (empirical) friction slope 165, 167-173 effect of rain drop impact 169, 170 empirical equations 171-173 from similarity considerations 169-170 friction velocity 38 as related to friction slope 168 fronts cold 82 occluded 85 warm 83 Froude number 170, 179, 199 gas constant (specific) dry air 24 moist air 25 water vapor 25 Gauckler-Manning (GM) equation 172 generalized gamma distribution 528-529 generalized log-gamma distribution 530 geometric distribution 519-522 groundwater 2 groundwater advecitivity, hydraulic 409, 415, 456 groundwater diffusivity, hydraulic 399, 409 headwater basins 441-442 hillslope flow number (groundwater) 410 historical information on hydrologic data 543-546 hurricanes 90 hydraulic conductivity 268 effective values 274 empirical functions 279-280 in partly saturated materials 274 see also capillary conductivity scale dependence 273-274 second-order tensor 272 hydraulic head in porous material 268 gradient 270, 294 hydraulic theory

assumptions in open channel flow 166 assumptions in unconfined aquifer 382, 384 groundwater flow 382-385 open channel flow 163-167 steady groundwater flow 385 hydrograph 2, 441 hydrologic analysis methodologies 7 practical scope 2 hydrologic cycle changes in 6 definition 2 hydrologic cycle, origins of the concept 557-586 Aristotle's views 563-566 atmospheric 557, 558 Common Opinion 572 rainfall percolation theory 560-563 hydrologic data inclusion of historical information 543-546 regionalization of flood data 546-550 hydrology, definition 1 hysteresis effect of entrapped air 261 in soil water characteristic 259-267 independent domain 262-267 infiltration 2, 307-346 infiltration and other losses at catchment scale 343-346 independent of rainfall 343-345 initial loss 344 proportional to rainfall intensity 345-346 infiltration capacity, local 308-310, 326-332 a closed-form solution 328-330 cumulative 313, 327 effects of air and soil variability 330-331 empirical expressions 331-332 horizontal, see sorption rate 314, 327 scaling 315, 329 wetting front 315 infiltration, local rainfall 310, 332-343 boundary conditions 310 compression reference time 338 sharp wetting front approximation 334-337 time compression approximation 337-343 time to ponding 334-337 instability, conditional 91 instantaneous unit hydrograph (IUH) 470-471 related to S hydrograph 472 related to unit hydrograph 471 see also unit response at catchment scale interception 2, 100-106 amounts 100, 104 empirical methods 105-106 evaporation 102

#### INDEX

interception (cont.) loss 100 loss mechanisms 100-104 vegetation structure parameters 104 Karman constant, von 43 kinematic approach 18 kinematic flow number 199 kinematic wave approximation of free surface flow celerity 190, 191, 415-416, 456 in unconfined sloping aquifer 415-416 linear case 192-193 linear kinematic channel 193, 491 overland flow 199, 201-210 Kleitz-Seddon law 191, 224 Laplace equation as steady state form of Boussinesq equation 385 describing initial state at onset of drainage 374 for mass and momentum conservation in porous materials 288 for surface tension 255-257 lapse rate definition 30 dry adiabatic 30 saturated adiabatic 33 latent heat CO<sub>2</sub> fixation 57 fusion 27 sublimation 27, 57 vaporization 6, 27, 57 leaf area index 68, 69, 106 Leibniz formula 590 logarithmic profile in free surface flow 169-170 in lower atmosphere 43-44 lognormal distribution 526 loss rate 343-346 lumped kinematic approach definition 18 free surface flow in open channels 193-194 interception 103 overland flow 210-212 streamflow routing 224-241 lysimeter 147, 580 macropores 446, 579 mean 512 mean profile methods 121-123 median 513 mixed layer 39 mixing ratio 24 moments 511-513

momentum equation at a point 16 finite control volume 17 in hydraulic theory 166, 167 monoclinal rising wave 222-224 monsoons 89 Muskingum streamflow routing 224-241 adjustment for nonlinearity 240-241 conceptual derivation 224-228 estimation of parameters by calibration 232-236 estimation of parameters from channel characteristics 236-241 implementation 229-232 numerical diffusion 236-238 storage function 225 time of travel 227 unit response function and moments 228-229 Muskingum-Cunge-Dooge method (MCD) 238 application 239-240 Navier-Stokes equation 16, 164 new water 447 nonlinear response parameterizations at catchment scale functional analysis with nonlinear convolution 494, 597-598 physical rationale for nonlinear storage elements 497-498 runoff routing with nonlinear storage elements 495-497 normal distribution 523-526 normalized difference vegetation index (NDVI) 70 Obukhov length 46 occlusion 85 old water 447 overland flow 2, 161, 198-212, 443-446 as basis for design parameterizations 443 infiltration excess 443-444 kinematic wave 200, 201-210 lumped kinematic approach 210-212 occurrence 443, 444-446 saturation excess 444-446 overland flow, kinematic approach recession hydrograph (steady inflow) 204-208 rising hydrograph (steady inflow) 202-204 short rainfall burst 208-209 time to steady equilibrium 204 unsteady lateral inflow 201-202 parameterization, definition 9 parameterizations (concise) of catchment unit response 476-493 cascade of several storage elements 488-492 combinations of storage elements 486-492 kinematic channel 193, 491

rational method 477-479

adjustment with historical information 545-546

method of 518

theorem of 597

regionalization for floods 550

© Cambridge University Press

602

## CAMBRIDGE

Cambridge University Press 0521824796 - Hydrology: An Introduction Wilfried Brutsaert Index More information

### INDEX

603

single concentrated storage element 484 stochastic interpretations 492-493 tank models 486-492 translation in series with storage element 483-486 translation with time-area function 480-482 with basin characteristics 476-477 parameters effective 11, 274 requirements 11-12 Pearson Type III distribution, see generalized gamma distribution Penman approach 126 adjustment for atmospheric stability 128 percentiles 513 permeability (intrinsic) definition 270 dimensional basis for creeping flow 270-271 permeameter 268 photosynthesis 70 plotting position 514-516 Weibull 515-516 pore size 257 size distribution 257-259, 542 volume, see porosity porosity 249 potential evaporation 130-131 apparent 131, 136 apparent as complement of actual evaporation 136-138 of interception 102 Penman approach 126 proportional to actual evaporation 131-132 true 131-138 power law (or fractal) distribution 540-543 precipitation areal average 92-95 average values 4 data for design 95, 97-99 data reliability 106-109 duration 97-99, 477-479 excess 343, 345, 443, 465 maximal values 5 measurement techniques 108 mechanisms 79-81 net 100 orographic effects 90-92 recycling 80 return period 97-99, 542 spatial distribution 95 temporal distribution 95-97 types 81-82 precipitation gages minor losses 109 wind effect on catch 106 preciptiable water 23, 26

pre-event water 445, 447 preferential flow paths 446-448 capillary barrier 456-457 catchment experimental studies 448-454 fingering flows 448 fragipan cracks 447 shrinking clay soils 447 probability 509 probability (graph) paper 516-517 probability plots (empirical) 514-517 quantiles 513 estimation from basin characteristics (floods) 547-550 radiation extraterrestrial 61 long-wave 57, 63-66 net 57 short-wave 57, 58 rainfall excess 343, 345, 443, 465 see also precipitation random variable 509 continuous 510 discrete 509 rational method 345-346, 477-479 design duration of rainfall event 477-479 design intensity 479 recurrence interval see return period regionalization of flood data 546-550 quantiles from multiple regression with basin characteristics 547-550 relative humidity 24 residence times 4, 23 return period 513-514 adjustment with historical information 544-545 Reynolds analogy 44 equation 164 fluxes 35 stresses 164 Reynolds number 168 in porous material 277 Richards equation 288, 298 for flow in riparian aquifier 367 for infiltration 307 riparian aquifer outflow rate as function of time for long times 398, 423 for short times 393, 422 from a hillslope 410-412, 413, 423 from linear horizontal aquifer 403, 405-406, 423 roughness (length) for momentum 43, 45, 46 for sensible heat 44, 46 for water vapor 44, 46

## CAMBRIDGE

Cambridge University Press 0521824796 - Hydrology: An Introduction Wilfried Brutsaert Index More information

roughness (length) (cont.)

### INDEX

604

in free surface flow 170, 172 scalar 46 routing 216 runoff coefficient 345, 477 runoff, average values 4 S hydrograph 468-469 Saint Venant equations, see shallow water equations satiation 261 saturation degree of 258 effective 258 residual degree of 258 scale, definition 9 scaling atmospheric stability effects 46-55 capillary effects 372 catchment-scale baseflow 424 hillslope aquifer outflow 409, 410 linear aquifer outflow 400, 403 long-time aquifer outflow 395, 396 overland flow 199 short-time aquifer outflow 392 slope effects 409-410 steady-state aquifer outflow from rain 386 steady-state saturated aquifer outflow 376 unit- and S hydrograph 469-470 shallow water equations 163-164, 166, 167, 198 numerical solutions 212, 216 relative magnitude of terms 184 scaled for overland flow 199 steady flow 166 see also hydraulic theory (open channel flow) shallow water equations, linearized complete system 179-184 diffusion analogy 186-189 dynamic part 175-179 general form 174, 180 kinematic approach (quasi-steady-uniform flow) 192-193 sheet flow, see overland flow shock waves dynamic, see surges kinematic, see monoclinal rising wave similarity, turbulence 41 bulk ABL 50-55 for turbulent fluxes 41 Monin-Obukhov 46-50 neutral surface layer 43 skew, coefficient of 512 soil heat flux empirical methods 67-70 measurement 67 soil moisture 2

see also soil water soil water characteristic 252 empirical functions 267-268 hysteresis 259-267 soil water content (volumetric) 251 residual 258 soil water diffusion formulation 276-277 for infiltration capacity 327 for rainfall infiltration 334 for sorption 311-315 soil water diffusivity 277 direct measurement 316-317 empirical functions 280-282, 323-325 for exact solution of sorption 317 of linearized soil 326 sorption, as description of infiltration capacity 308, 310-326 an exact solution 317-320 nearly exact solution for nonlinear soil 321-325 solution for linear soil 325-326 wetting front 315 sorptivity 314 role in infiltration capacity 328, 329 specific heat of air for constant pressure 25, 29 for constant volume 25, 29 specific heat of water ice 27 liquid 27 specific heat of water vapor 25, 29 squall line 83 stability of atmosphere 29-34 state, equation of 24-25 stemflow 100, 104 storage equation 15 vegetation canopy 101 see also lumped kinematic approach storm runoff 3 mechanisms 443-457, 458 parameterization options 457-461 subsurface flows 2, 446 stream orders 441-442 sublimation, definition 3 sunshine duration 61 surface flux, specific any passive admixture of the air 123 latent heat 6, 55 sensible heat 6, 37 water vapor 6, 36 surface resistance to evaporation 133-135 surface runoff 2 surface tension 255-257 surges 217-222 analysis 219-220 flood disasters 220-222 types 217-219

### INDEX

temperature potential 32 virtual 25 virtual potential 32 tensiometer 253 Terzaghi-Jacob equation 297-298 throughfall 100, 102 throughflow, in permeable soil layer 454-455 time of concentration 477-479 time of travel Muskingum channel 227 time to ponding, during rain infiltration 334-337 scaling 336 time to saturation for interception 102, 103 time to steady equilibrium overland flow kinematic wave 204 lumped kinematic approach 212 time, compression reference 338 example calculation 341 from correct time to ponding 339 from precipitation intensity 339-341 time-area function 480 transfer coefficients 41, 42 transpiration, definition 3 true velocity in porous materials 271 turbulent fluctuations 34 turbulent fluxes, see Reynolds fluxes and Reynolds stresses typhoons 90 unconfined riparian aquifers boundary conditions 369-370 common assumptions 368-369 effective parameter functions 368 importance of capillary zone 370-373, 381 initial fully saturated state 373-376 similarity criteria 370-373 simplified geometry 368 unsteady flow in 366-376

unconfined riparian aquifers, steady hydraulic flow from as a result of uniform precipitation 385-387 between two parallel open channels 387-389 unconfined riparian aquifers, unsteady hydraulic flow from general boundary conditions 390 hillslope, lineralized case 408-413 incorporation of capillary zone 415 linearized case, horizontal bed 400-405 linearized formulation 398-400 long-time behavior 394-398 outflow rate in general 390 short-time behavior 390-394

605 unit hydrograph 465 direct determination from available data 472-476 instantaneous 470-471 limitations 466-468 parameterization with characteristics of ungaged catchments 476-477, 493 rescaling 469-470 see also unit response at catchment scale unit impulse 590-592 see also delta function unit response 593 see also convolution integral unit response at catchment scale concise parameterizations 476-493 to calculate outflow in response to arbitrary input 470-471, 473-474 see also unit hydrograph unit response for different linearized channels complete St Venant channel 181 diffusion channel 187 kinematic channel 193 Muskingum channel 228 purely dynamic channel 177 unit response for linear riparian aquifers hillslope 413 horizontal bed 404 vadose zone 2 vapor pressure 24 saturation 27 variance 512 variance methods 119 variation, coefficient of 512 Vedernikov number 184 viscosity water Volterra series 494, 597-598 water budget

atmospheric at mesoscale 144-145 closure techniques at catchment scale 143 global scale 4 methods to estimate evaporation 117, 142-148 soil moisture profile at local scale 145-148 terrestrial at catchment scale 142-144 water table 2 watershed, see catchment wave-like motion of water table 415-416, 455-456 weather systems with precipitation extratropical convective 86-87 fronts 82-86 large-scale tropical convective 89 seasonal tropical 87-89 width function 482 construction 482