

Hydraulic Engineering: Land and Water Development

International Institute for Hydraulic and Environmental Engineering/IHE.

A course on soil and water resources development; hydraulic, agronomic, socio-economic, and climatic aspects; land reclamation; irrigation and drainage systems management. Leading to a diploma. Diploma course extendable to M.Sc.

International Course on Land Drainage

International Institute for Land Reclamation and Improvement/ILRI.

A course on subsurface drainage in humid zones, subsurface drainage in irrigated arid zones, surface drainage of flat lands with high rainfall. Leading to a Certificate of Attendance.

List of Addresses

(see also section 26.4.8)

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- Food and Agriculture Organization of the United Nations/FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.
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- International African Institute, Lionel Robbins Building, 10 Portugal Street, London WC2A 2HD, United Kingdom.
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- International Institute for Land Reclamation and Improvement/ILRI, P.O. Box 45, 6700 AA Wageningen, The Netherlands.
- International Livestock Centre for Africa/ILCA, P.O. Box 5689, Addis Ababa, Ethiopia.
- Kluwer Academic Publishers, P.O. Box 17, 3300 AA Dordrecht, The Netherlands.
- National Agricultural Library, Beltsville, Maryland MA 20706, U.S.A.

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Royal Institute of the Tropics/KIT, Mauritskade 63, 1092 AD Amsterdam, The Netherlands.

Swedish Agency for Research Cooperation with Developing Countries/SAREC, Birger Jarlsgatan 61, S-105, 25 Stockholm, Sweden.

Third World Academy of Science, Donation Programme, P.O. Box 586, 34126 Trieste, Italy.

Wageningen University of Agriculture, P.O. Box 8130, 6700 EW Wageningen, The Netherlands.

List of Abbreviations

AGRIS	International Information System for the Agricultural Sciences and Technology
ASAE	American Society of Agricultural Engineers
CABI	Commonwealth Agricultural Bureaux International
CEMAGREF	Centre National du Machinisme Agricole, du Génie Rural, des Eaux et des Forêts
CIAT	Centro Internacional de Agricultura Tropical
CTA	Centre technique de Coopération Agricole et Rurale
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations
HR-ODU	Overseas Development Unit of Hydraulics Research
ICID	International Commission on Irrigation and Drainage
IITA	Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRI	International Institute for Land Reclamation and Improvement
IPTRID	International Program for Technology Research in Irrigation and Drainage
IWASRI	International Waterlogging and Salinity Research Institute
KIT	Royal Institute of the Tropics
NEDECO	Netherlands Engineering Consultants
ODU	see HR-ODU
USDA	United States Department of Agriculture

List of principal symbols and units

Symbol	Definition	Units
a, A	Cross-sectional area, drained area	m ² , km ²
a	Distance	m
A	Amplitude	m
AMC	Antecedent Moisture Condition	—
b	Bottom width of a canal, drain, or outlet	m
B	Canal width	m
B	Distance, length	m
B/C	Benefit / Cost ratio	—
c	Compression, consolidation constant	—
c	Distance between corrugations	mm
c	Euler's constant ($c = 0.5772$)	—
c, C	Hydraulic resistance	d
c _p	Specific heat of air at constant pressure	J/kg K
C	Chézy coefficient	m ^{0.5} /s
C	Salt concentration	meq/l
C ₁	Vegetal retardance curve index	—
C _u	Coefficient of uniformity	—
CEC	Cation Exchange Capacity	meq/100g
CN	Curve Number	—
d, D	Depth, equivalent depth, thickness, height	m
d	Degrees of freedom	—
d	Diameter	mm, m
D	Duration of unit storm period (unit hydrograph)	h
D	Surface runoff	mm
D(θ)	Soil-water diffusivity	d ⁻¹
e	Efficiency	—
e	Vapour pressure	kPa
e	Void ratio	—
E	Evaporation	mm, mm/d
E	Vapour flux density	kg/m ² s
E	Modulus of elasticity	Pa
E	Elevation	m
EC	Electrical conductivity at 25°C	dS/m
ESP	Exchangeable Sodium Percentage	—
ET	Evapotranspiration	mm, mm/d
f, F	Frequency	—
f	Efficiency	—
f	Clay, mineral, or organic matter content (dry mass fraction)	—

F	Actual retention (Curve Number method)	mm
F	Freeboard	m
F	Force	N
Fr	Froude number	—
g	Acceleration due to gravity	m/s ²
G	Gravity force per unit area	Pa
G	Heat flux density into the soil or water body	W/m ²
G	Capillary rise	mm, mm/d
h, H	Altitude, elevation, height, water depth	m
h, H	(Energy) head or head loss	m
Δh	Change in watertable depth	m, mm
H	Flux density of sensible heat into the air	W/m ²
H	Saturated thickness of a (semi-)confined aquifer	m
H	Tidal range	m
ΔH	(Energy) head loss	m
HW	High Waterlevel	m
I	Infiltration	mm, mm/d
I	Irrigation	mm, mm/d
I _a	Initial abstraction (Curve Number method)	mm
I _l	Leaf area index	—
J	Julian day number	—
k	Corrugation height	m
k	Crop coefficient	—
K	Hydraulic conductivity	m/d
KD, KH	Transmissivity	m ² /d
L	Leakage factor	m
L	Length, spacing, width	m
LF	Leaching fraction	—
m	Mass of soil, water, dry solids	kg
msl, MSL	Mean Sea Level	m
n	Daily duration of bright sunshine	h
n	Manning's resistance coefficient	—
n, N	Number	—
n	Rotational speed	rev/s
n	Water factor of clay	—
N	Torque in the pump shaft	J
NHW	Number of days with a High Water level	—
NPSH	Net Positive Suction Head	m
O ₉₀	Pore size of envelope retaining 90% of soil fraction	m
p, P	Pressure	Pa
p	Penetration depth of a tubewell into an aquifer	m
P	Precipitation	mm, mm/d
P	Wetted perimeter	m
P	Power consumption	W
PI	Plasticity Index	—
q, Q	Discharge, flow rate, runoff rate, flux	m ³ /d, m ² /d, m/d
q	Drainage coefficient, drainable surplus	mm/d

q/h	Drainage intensity ratio	d ⁻¹
Q	Accumulated runoff depth (Curve Number method)	mm
r	Correlation coefficient	—
r, R	Distance, radius	m
r	Diffusion resistance	s/m
R	Percolation	mm, mm/d
R	Radiation	W/m ²
Re	Reynolds number	—
RH	Relative Humidity	—
RSC	Residual Sodium Carbonate	meq/l
s	Distance	m
s	(Watertable) drawdown	cm, m
s	Hydraulic gradient	—
s	Slope	—
s	Standard deviation	—
S	Salt concentration	t/ha
S	Pitch of the blades of an Archimedean screw	m
S	Potential maximum retention (Curve Number method)	mm
S	Seepage	mm, mm/d
S	Subsidence	m
S	Storativity	—
SAR	Sodium Adsorption Ratio	meq ^{0.5} /l ^{0.5}
SE _x	Sum of Exceedances of the watertable level x	cm
SMC	Soil Moisture Content	—
t, T	Time, period	yr, d, s
t _f	Student's t-value with f degrees of freedom	—
T	Thickness	m
T	Temperature	°C
T	Transpiration	mm, mm/d
u	Wetted perimeter	m
u	Wind speed	m/s
U	Specific surface ratio	—
v	Velocity	m/s
V	Volume	m ³
w, W	Width	m
w	Soil-water content (fraction of total dry mass)	—
w	Flow resistance	d
W	Soil moisture	mm
W	Water storage	mm
x	Distance	m
y	Water depth	m
Y	Yield	t/ha
z	Depth, height	m
z	Elevation head	m
z	Side slope ratio (horizontal/vertical)	—
Z	Amount of salt	mm dS/m
α, θ, φ	Angle	degrees, rad

α	Coefficient, factor, parameter	—
α, β	Compressibility	Pa ⁻¹
Δ	Difference	—
ε	Porosity	—
η	Dynamic viscosity	kg/m s
η	Pump efficiency	—
θ	Soil-water content (volume fraction)	—
μ	Drainable pore space, specific yield	—
ν	Kinematic viscosity	m ² /s
ξ	Energy loss factor	—
ρ	Density	kg/m ³
σ	Standard deviation of a distribution	—
σ	Surface tension of water against air	kg/s ²
τ	Stress	Pa
φ	Latitude	rad
Φ	Velocity potential	m ² /d
ψ	Water potential	m, Pa, J/kg
Ψ	Stream function	m ² /d
ω	Wave frequency	d ⁻¹
∇	Differential operator	—
∇^2	Laplacean operator	—

Glossary

- Acid sulphate soil:** A soil with a pH below 4 as a result of the oxidation of pyrite to sulphuric acid.
- Acidity:** A property of (soil) water characterized by a pH below 7.
- Actual evapotranspiration:** The sum of the quantities of water vapour evaporated from the soil and transpired by plants when the soil-water content is less than optimal. (See **Potential evapotranspiration.**)
- Aerodynamic resistance:** A resistance, similar to Ohm's law, encountered by the diffusion of water vapour from a soil or a crop canopy to the external, turbulent air at a certain height.
- Affinity laws:** A set of equations that allows a prediction of the changes in the performance of rotodynamic pumps (discharge, head, and power) as a result of slight changes in pump speed or impeller size.
- Agricultural drainage:** See **Drainage.**
- Agro-ecological zone:** A land area characterized by its suitability for agriculture according to climatic and soil criteria.
- Albedo:** The fraction of the incident short-wave radiation that is reflected by a particular surface on earth (e.g. water, a green canopy, bare soil).
- Alkali soil:** See **Sodic soil.**
- Alkalinity:** A property of (soil) water, characterized by a pH between 7 and 14.
- Allowable velocity:** Flow velocity of water in an open channel, just below the velocity that would cause bed material to detach.
- Alluvial plain:** A plain bordering a river, formed by the deposition of alluvium eroded from areas of higher elevation.
- Anisotropic:** Having different physical properties when measured in different directions.
- Apparent velocity:** A fictitious velocity of water flowing through a porous medium (e.g. soil), better referred to as the discharge per unit area. Used in Darcy's Equation.
- Application efficiency:** The ratio between the quantity of irrigation water effectively used by the crop, and the quantity of water supplied to a field. (See **Irrigation efficiency.**)
- Aquiclude:** A soil layer that is virtually impermeable to water.
- Aquifer:** A water-bearing soil layer.
- Aquifer test:** A procedure to determine the hydraulic characteristics of an aquifer. Water is pumped, for a certain time and at a certain rate, from a well in the aquifer, and regular measurements are made of the watertable in the well and in its vicinity, either during pumping (see **Pumping test**) and/or after the pumping has stopped (see **Recovery test**).
- Aquitard:** A soil layer with a low, but measurable, permeability.
- Atterberg limits:** See **Consistency limits.**
- Augerhole method:** A technique to determine the saturated hydraulic conductivity of a soil at a certain depth by augering a cylindrical hole in the soil, bailing water from it, and measuring the rate of water-level rise in the hole.
- Available soil water:** The quantity of water available to plants, defined as the quantity of water retained in the soil that is smaller than field capacity and larger than the permanent wilting point.
- Base flow:** Water flow appearing in a river or stream as a result of groundwater discharge, with a characteristic delayed reaction to recharge. Most clearly visible after direct runoff has stopped.
- Basin irrigation:** A system of surface irrigation in which water is ponded on level land parcels surrounded by earthen bunds or banks.
- Bed load:** Granular material (sand, silt, gravel, soil, and rock detritus), transported by a stream on or immediately above its bed by rolling, sliding, or saltation.
- Bedding:** A surface drainage method accomplished by ploughing land to form a series of low narrow ridges, separated by parallel furrows. Water from the furrows discharges into a perpendicular field drain at the lower end of the field.
- Bulk density:** The mass of soil per unit volume in an undisturbed condition. Normally equivalent to the dry bulk density (i.e. when only the dry soil mass is considered), but sometimes to the wet bulk density (i.e. when the mass of water present is also considered).
- Canal seepage:** Water leaving a canal by capillary action and percolation through its wet perimeter, causing a rise in the watertable in the vicinity of the canal.

Canopy resistance: A resistance encountered by water vapour diffusing from the internal cell walls, through the sub-stomatal cavities and the stomata, to the canopy surface.

Capacitance method: A non-destructive, in-situ method that uses the dielectric properties of soil components to determine the soil-water content in the unsaturated zone.

Capillary fringe: The zone above the free watertable where some or all of the capillary interstices are filled with water; this water is continuous with the water in the saturated zone, but is held above that zone by capillarity against gravity.

Capillary rise: The upward movement of water from a free watertable due to adhesion of water to the tubular soil pores (capillaries) and the cohesion of water molecules. A distinction should be made between the rate and the height of capillary rise.

Catchment: See **Drainage basin**.

Cation Exchange Capacity (CEC): The total quantity of cations that a negatively-charged unit soil mass can adsorb, usually expressed as milliequivalents per 100 grams. Measured values depend somewhat on the determination method.

Cavitation: The formation of cavities in flow, due to low or negative pressure as a result of high velocity. These cavities are filled with air and water vapour. In rotodynamic pumps, the implosion of these air bubbles may cause impellers and pump housing to wear.

Centrifugal pump: A rotodynamic pump with radial flow, its inlet being near the centre of the impeller and its outlet along its periphery. The water follows the curved impeller vanes away from the centre.

Collector drain: A drain that collects water from the field drainage system and carries it to the main drain for disposal. It may be either an open ditch or a pipe drain.

Compaction: The change in soil volume produced artificially by momentary load applications such as rolling, tamping, or vibration.

Composite drainage system: A drainage system in which field drains and collector drains are buried.

Compression: The change in soil volume produced by the application of a static external load.

Confidence interval: An interval around the computed value within which a given percentage of values of a repeatedly sampled variate is expected to be found.

Confined aquifer: A completely saturated aquifer whose upper and lower boundaries are aquicludes. In confined aquifers, the pressure of the water is usually higher than atmospheric pressure. Completely confined aquifers are rare.

Consistency limits: Soil physical values indicating the ease with which the soil can be deformed (i.e. a plastic limit and a liquid limit); also called Atterberg limits.

Consolidation: The gradual, slow compression of a cohesive soil due to weight acting on it, which occurs as water and/or air are driven out of the voids in the soil. Consolidation only occurs in clays or other soils of low permeability.

Consumptive use: See **Evapotranspiration**

Continuity: The fundamental law of hydrodynamics, which states that, for incompressible fluids and for flow independent of time, the sum of differential changes in flow velocities in all directions must be zero.

Conveyance efficiency: See **Irrigation efficiency**

Conveyance losses: Water losses due to evaporation, percolation, or breaches in the network of irrigation canals or pipes between the source of water and the field.

Correlation coefficient: A measure of the linear interdependence of two variates, ranging from -1 (perfect negative correlation) to $+1$ (perfect positive correlation).

Critical depth: (1) The depth of flow in a channel of specified dimensions at which the specific energy is a minimum for a given discharge. (2) The depth to which the watertable will fall in the absence of seepage or natural drainage, and at which capillary rise is reduced to almost zero.

Critical flow: The flow condition at which the discharge is maximum for a given specific energy, or at which the specific energy is minimum for a given discharge.

Crop coefficient: The ratio of evapotranspiration from an area covered with a specific crop, at a specific stage of growth, to the reference evapotranspiration at that time.

Crop water requirement: See **Potential evapotranspiration**.

Crowning: The process of forming the surface of land into a series of broad low beds separated by parallel field laterals.

Culvert: A square, oval, or round closed conduit used to transport water horizontally under a highway, railway, canal, or embankment.

Design discharge: A specific value of the flow rate, which, after the frequency and the duration of exceedance have been considered, is selected for designing the dimensions of a structure or a system, or a part thereof.

Diffuse double layer: An imaginary water layer of limited extent around soil-particle surfaces. In this layer, cations are more concentrated than in the surrounding soil solution, because of the negatively-charged particle surface, and anions are repelled.

Direct runoff: That portion of excess rainfall that turns into overland flow.

Discharge hydrograph: A graph or a table showing the flow rate as a function of time at a given location in a stream.

Distribution efficiency: See **Irrigation efficiency**.

Diversion channel: A channel constructed across a slope to intercept surface runoff and conduct it to a safe outlet.

Diversion drain: See **Interceptor drain**.

Drain: A channel, pipe, or duct for conveying surface water or groundwater.

Drain spacing: The horizontal distance between the centre lines of adjacent parallel drains.

Drainage: The removal of excess surface and subsurface water from the land to enhance crop growth, including the removal of soluble salts from the soil.

Drainable pore space: The ratio of the change in soil-water content in the profile above the watertable to the corresponding rise/fall of the watertable, in the absence of evaporation. (See **Specific yield**.)

Drainable surplus: The amount of water that must be removed from an area within a certain period so as to avoid an unacceptable rise in the levels of groundwater or surface water.

Drainage base: The water level at the outlet of a drained area.

Drainage basin: The entire area drained by a natural stream or artificial drain in such a way that all flow originating in the area is discharged through a single outlet.

Drainage coefficient: The discharge of a subsurface drainage system, expressed as a depth of water that must be removed within a certain time.

Drainage criterion: A specified numerical value of one or more drainage parameters that allow a design to be calculated with drainage equations.

Drainage effluent: The water flowing out of a drainage system and that must be disposed of either by gravity flow or by pumping.

Drainage gate: A gravity outlet fitted with a vertically-moving gate or with a horizontally-hinged door or plate (flap gate).

Drainage intensity: (1) An agricultural drainage criterion based on the ratio between the design discharge and the depth of the watertable. (2) The number of drainage provisions (e.g. natural or artificial open drains, pipe drains, or tubewells) per unit area.

Drainage sluice: A gravity outlet fitted with vertically-hinged doors, opening if the inner water level is higher than the outer water level, and vice versa, so that drainage takes place during low tides.

Drainage survey: An inventory of conditions that affect the drainage of an area, made at various levels, ranging from reconnaissance to design level.

Drainage system: (1) A natural system of streams and/or water bodies by which an area is drained. (2) An artificial system of land forming, surface and subsurface drains, related structures, and pumps (if any), by which excess water is removed from an area.

Drainage techniques: The various physical methods that have been devised to improve the drainage of an area.

Dynamic viscosity: In fluid dynamics, the ratio between the shear stress acting along any plane between neighbouring fluid elements, and the rate of deformation of the velocity gradient perpendicular to this plane.

Ecosystem: A dynamic arrangement of plants and animals with their non-living surroundings of soil, air, water, nutrients, and energy.

Effective porosity: See **Drainable pore space**.

Electrical Conductivity (EC): The reciprocal of the electrical resistance measured between opposite faces of a centimetre cube of an aqueous solution at a specified temperature, usually 25°C. It is a measure of the concentration of salts.

Elevation head: The vertical distance to a point above a reference level.

Energy dissipator: A hydraulic structure in which the total hydraulic head of water in a canal is safely reduced by providing a protected approach section, a drop, a stilling basin, and a protected outlet transition.

Entrance head: The head required to overcome the entrance resistance of a pipe drain. (See **Entrance resistance**.)

Entrance resistance: The extra resistance to water flow in the vicinity of a drain pipe, due to a decreased permeability of the material around the drain and/or to a contraction of the flow lines resulting from the small drain openings.

Envelope: Material placed around pipe drains to serve one or a combination of the following functions: (1) to prevent the movement of soil particles into the drain; (2) to lower entrance resistances in the immediate vicinity of the drain openings by providing material that is more permeable than the surrounding soil; (3) to provide suitable bedding for the drain; (4) to stabilize the soil material on which the drain is being laid.

Environmental impact: The effect on the environment of a certain human interference (e.g. artificial drainage).

Ephemeral stream: A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources. Its channel is at all times above the watertable.

Equipotential line: A line in a plane with a constant value of the velocity potential, equalling the product of the hydraulic conductivity and the hydraulic head.

Equivalent depth: Depth to the imaginary impermeable layer, introduced by Hooghoudt to take into account the radial flow resistance near drains in deep homogeneous soils.

Estuary: The mouth of a river, subject to tidal effects, where fresh water and sea water mix.

Evaluation: The assessment of the degree of success of a planned project or process, often undertaken at a specific moment (e.g. upon completion).

Evaporation: (1) The physical process by which a liquid (or solid) is transformed into the gaseous state. (2) The quantity of water per unit area that is lost as water vapour from a water body, a wet crop, or the soil.

Evapotranspiration: The quantity of water used for transpiration by vegetation and lost by evaporation from the soil.

Excess rainfall: That part of the rain of a given storm that falls at intensities exceeding the soil's infiltration capacity and is thus available for direct runoff.

Exchangeable Sodium Percentage (ESP): The fraction of the soil's cation exchange capacity that is occupied by sodium ions. It is a yardstick of sodicity problems in soils.

Feasibility study: A study of the existing and future parameters of a drainage (or other) project, done in such detail that a reasonable estimate of its profitability can be made.

Field capacity: The volumetric water content of a soil after rapid gravity drainage has ceased. It usually occurs about two days after the soil profile has been thoroughly wetted by precipitation or irrigation.

Field drain: (1) In surface drainage, a shallow graded channel, usually with relatively flat side slopes, which collects water within a field. (2) In subsurface drainage, a field ditch, a mole drain, or a pipe drain that collects groundwater within a field.

Field drainage system: A network that gathers the excess water from the land by means of field drains, possibly supplemented by measures to promote the flow of excess water to these drains.

Field lateral: See **Field drain**.

Filter: A layer or combination of layers of pervious materials, designed and installed to provide drainage, yet prevent the movement of soil particles in the flowing water.

Finite-difference method: A method used to solve differential equations by approximating them as algebraic terms over a grid.

Finite-element method: A method used to solve differential equations by approximating them as algebraic terms over a triangular network.

Flow-net diagram: A family of equipotential lines intersected at right angles by a family of streamlines in a cross-section in a porous medium, indicating certain flow patterns, and most often drawn as approximate squares.

Free water surface: See **Watertable**.

Frequency analysis: A statistical method of analyzing hydrological or other data, which uses the observed number of occurrences to predict how often a phenomenon may occur in the future and to assess the reliability of this prediction.

Frequency distribution: (1) A tabular arrangement of empirical data by classes, together with the corresponding class frequencies. (2) A mathematical expression of the relationship between a value and its theoretical frequency.

Froude number: A hydraulic number representing the ratio of inertia forces and gravity forces acting upon water, and making it possible to distinguish between subcritical and supercritical flow velocities.

Gamma-ray attenuation: The reduction in emitted gamma-ray transport in a wet soil, due to absorption by solids and water, allowing soil-water changes to be measured.

Gravel mole: A mole drain filled with gravel material.

Gravel pack: An artificially-graded filter placed immediately around a well screen so as to increase the local permeability, to prevent soil particles from entering the well, and to allow a somewhat larger slot size in the well screen.

Gravimetric method: A method of measuring the water content of the soil, based on determining the weight loss from a number of oven-dried field samples obtained by coring or augering.

Gravitational potential: Energy status of water due to its position in the gravity field. If expressed per unit weight, it is also called gravitational head. (See also **Elevation head**.)

Gravity outlet structure: A drainage structure in an area with variable outer water levels, so that drainage can take place by gravity when outside water levels are low.

Groundwater: Water in land beneath the soil surface, under conditions where the pressure in the water is greater than or equal to atmospheric pressure, and where all the voids are filled with water.

Groundwater quality: A judgement of the chemical suitability of groundwater for normal purposes such as irrigation, drinking water, fish ponds, or industrial use.

Gypsum requirement: The mass of calcium sulphate per unit area that would be required to reduce the exchangeable sodium percentage of the top layer of a sodic soil to an agriculturally acceptable level.

Habitat: The natural home of a plant or animal.

Horizontal drainage: A method of groundwater drainage in which low watertables are maintained by pipe drains or open ditches.

Hydraulic conductivity: The constant of proportionality in Darcy's Law, defined as the volume of water that will move through a porous medium in unit time, under a unit hydraulic gradient, through a unit area, measured at right angles to the direction of flow.

Hydraulic head: The elevation of the water level in a piezometer with respect to a reference level; it equals the sum of the pressure head and the elevation head.

Hydraulic resistance: A property of semi-confined aquifers, also called resistance against vertical flow, which is the ratio of the saturated thickness of the overlying aquitard and its hydraulic conductivity for vertical flow.

Hydraulic soil properties: Properties of the soil profile that affect the flow of water (e.g. hydraulic conductivity, soil-water content, specific water capacity, or diffusivity), often as a function of pressure head.

Hydrograph: A graph showing, for a given point, the stage, discharge, velocity, or other properties of water flow as a function of time.

Hydrological regime: The characteristic behaviour of water in a drainage basin over a period, based on conditions of channels, water and sediment discharge, precipitation, evapotranspiration, subsurface water, pollution, etc.

Hyetograph: A plot of rainfall depth or intensity as a function of time, shown in the form of a histogram.

Hysteresis: The lag phenomenon that soil-water tension at a given water content depends on the past history of wetting and drying cycles.

Ideal drain: A drain without entrance resistance.

Impeller pump: See **Centrifugal pump**

Interception: (1) The capture and subsequent evaporation of part of the rainfall by a crop canopy or other structure, so that it does not reach the ground. (2) The capture and removal of surface runoff, so that it does not reach the protected area. (3) The capture and subsequent removal of upward groundwater seepage, so that it does not reach the rootzone of crops.

Interceptor drain: A drain installed across the flow of groundwater to collect subsurface flow before it re-surfaces, normally used on long slopes and on shallow permeable surface soils overlying relatively impermeable subsoils.

Interflow: Water that has infiltrated into a soil and moves laterally through the upper soil horizons towards ditches or streams as shallow, perched groundwater above the main groundwater level.

Irrigation: The supply, distribution, and controlled applications of water to agricultural land to improve the cultivation of crops.

Irrigation efficiency: Ratio of the volume of components of the water balance of irrigation schemes, expressed as a percentage, and defined as the ratio of output over input, whereby the output (of some quantity) is a conversion of an input (of the same quantity). There are definitions covering the conveyance and distribution and application of water for plant growth.

Irrigation interval: The time between the start of successive water applications on the same field.

Isobath: A line on a map, connecting all points on a land surface that have the same height above the watertable.

Isotropic: Having the same physical properties in all directions.

K-value: See **Hydraulic conductivity**.

Kinematic viscosity: The dynamic viscosity divided by the fluid density.

Lacustrine plain: A plain originally formed as the bed of a lake from which the water has disappeared.

Laminar flow: Flow of water in separate thin layers, not influenced by adjacent layers perpendicular to the direction of flow.

Land drainage: see **Drainage**.

Land forming: Changing the micro-topography of the land to meet the requirements of surface drainage or irrigation. In land forming for surface drainage, two processes are recognized: land grading and land planing.

Land grading: Forming the surface of the land to predetermined grades so that each row or surface slopes to a drain.

Land planing: Smoothing the land surface with a land plane to eliminate minor depressions and irregularities without changing the general topography.

Land reclamation: Making land capable of more intensive use by changing its general character: (1) by drainage of excessively wet land; (2) by reclamation of submerged land from seas, lakes, and rivers, and; (3) by modification of its saline, sodic, or acid character.

Leaching: Removing soluble salts by the passage of water through soil.

Leaching requirement: The fraction of irrigation water entering the soil that must flow effectively through and beyond the rootzone to prevent a build-up of salinity resulting from the addition of solutes in the water.

Leakage factor: A geohydrological factor that determines the distribution of the leakage into a semi-confined aquifer through the overlying aquitard.

Log-normal distribution: A transformed normal distribution in which the variate is replaced by its logarithm. It is used empirically for hydrological frequency analysis.

Longitudinal profile: An annotated design drawing of a canal along its centre line, showing original ground levels, canal bank levels, design water levels, bed levels, and other relevant engineering information.

Lysimeter: A soil-filled container, in which a crop may or may not be grown, to determine one or more terms of the soil-water balance.

Main drain: The principal drain of an area, receiving water from collector drains, diversion drains, or interceptor drains, and conveying this water to an outlet for disposal outside the area.

Main drainage system: A water conveyance system that receives water from the field drainage systems, surface runoff, interflow, and groundwater flow, and transports it to the outlet point.

Mathematical model: A model that simulates a system's behaviour by a set of equations, perhaps together with logical statements, by expressing relationships between variables and parameters.

Matric head: The matric potential expressed as work per unit weight, or in metres water column. It is negative above a watertable.

Matric potential: The work that has to be done per unit quantity of pure water to overcome the attractive forces of water molecules and the attraction of water molecules to solid surfaces.

Mechanical analysis: Determining the particle-size distribution of a soil by screening, sieving, or other means of mechanical separation.

Mean Sea Level (MSL): The average water level in a tidal area.

Miscible displacement: Salt displacement in soils caused by a combination of molecular diffusion and dispersion (i.e. the mixing of solutions by uneven flow velocities).

Modelling: The simulation of some physical or abstract phenomenon or system with another system believed to obey the same physical laws or abstract rules of logic, in order to predict the behaviour of the former by experimenting with the latter.

Mole drain: An unlined underground drainage channel, formed by pulling a solid object, usually a solid cylinder with a wedge-shaped point at one end, through the soil at the proper slope and depth, without a trench having to be dug.

Net Positive Suction Head (NPSH): A head related to centrifugal pumps, expressed as 'available' at a certain site or as 'required' by the manufacturer. The available NPSH is calculated from the atmospheric pressure, the vapour pressure, and the dynamic suction head. If NPSH available drops below NPSH required, cavitation is likely to occur.

Neutron scattering: The phenomenon that fast neutrons, emitted from a radio-active source, are scattered and slowed down, mainly by hydrogen ions. As hydrogen ions are mainly present in water, neutron scattering can be used to measure soil-water content.

Normal distribution: A symmetrical, bell-shaped, infinite, continuous distribution, theoretically representing the distribution of accidental errors about their mean.

Observation well: A small-diameter pipe, at least 25 mm in diameter, in which the depth of the watertable can be observed. It is placed in the soil and perforated over a length equal to the distance over which the watertable is expected to fluctuate.

Open drain: A drain with an exposed water surface that conveys drainage water.

Open water evaporation: The theoretical quantity of water that leaves an infinite shallow water surface as vapour under the prevailing meteorological conditions. The rate of open water evaporation is often estimated with Penman's Equation.

Organic soils: Soils with a high content of composed or decomposed organic carbon and a low mineral content.

Osmotic potential: The work that has to be done per unit quantity of pure water to overcome the effect of ions in the soil solution. If expressed per unit weight, it is also called osmotic head.

Outlet: The terminal point of the entire drainage system, from where it discharges into a major element of the natural open water system of the region (e.g. river, lake, or sea).

Outlet drain: A drain that conveys collected water away from the drained area or project, either in the form of a natural channel or as a constructed drain.

Overland flow: Water flowing over the soil surface towards rills, rivulets, channels, and rivers. It is the main source of direct runoff.

Oxidation: The process in the soil by which organic carbon is converted to carbon dioxide and lost to the atmosphere.

Pan evaporation: The quantity of water lost from a standard meteorological measuring pan as water vapour.

Parent material: Weathered rock material from which soil is formed.

Peak runoff: The maximum rate of runoff at a given point or from a given area, measured during a specified period, in reaction to rainfall.

Percolation: The gravity-induced downward flow of water through soil, especially in saturated or nearly saturated soil at hydraulic gradients of one or less.

Permeability: (1) Qualitatively, the quality or state of a porous medium relating to the readiness with which such a medium conducts or transmits fluids. (2) Quantitatively, the specific property governing the rate or readiness with which a porous medium transmits fluids under standard conditions. See also **Hydraulic conductivity**.

pF: The numerical measure of the energy with which water is held in the soil, expressed as the common logarithm of the absolute value of the matric head in centimetres of water.

pH: A measure of the hydrogen ion concentration in a solution, expressed as the common logarithm of the reciprocal of the hydrogen ion concentration in mol per litre.

Phreatic level: See **Watertable**.

Phreatic surface: See **Watertable**.

Piezometer: A small-diameter pipe used to observe the hydraulic head of groundwater. It is placed in, or driven into, the subsoil so that there is no leakage around the pipe. Water can only enter the pipe through a short screen at the bottom of the pipe, or through the bottom only.

Piezometric head: See **Hydraulic head**.

Piezometric surface: The imaginary surface through all the points to which the water rises in piezometers penetrating an aquifer.

Pipe drain: A buried pipe – regardless of material, size, or shape – that conveys drainage water from a piece of land to a collector drain or to a main drain.

Polder: A tract of low land, reclaimed from the sea or another body of water, by endiking it. In a polder, runoff is controlled by sluicing or pumping, and the watertable is independent of the watertable in the adjacent areas.

Pores: See **Voids**.

Porosity: The volume of voids as a fraction of the volume of the soil.

Post-authorization study: A detailed design study that is undertaken after a project has been approved.

Potential head: See **Hydraulic head**.

Potential evapotranspiration: The theoretical quantity of water that, under the prevailing meteorological conditions, and when soil water is not a limiting factor, is lost as water vapour from an extensive cropped surface.

Precipitation: The total amount of water received from the sky (rain, drizzle, snow, hail, fog, condensation, hoar frost, and rime).

Preferential flow: Water flow in the soil through passages such as cracks, macropores, and other cavities, at a much faster rate than water flow within structural elements.

Pressure head: The hydrostatic pressure of water in the soil at a certain point, expressed as the height of a water column that can be supported by the pressure. The pressure head is negative in the unsaturated zone and the capillary fringe.

Probability: The chance that a prescribed event will occur, represented as a pure number (p) in the range $0 \leq p \leq 1$. It can be estimated empirically from the relative frequency (i.e. the number of times the particular event occurs, divided by the total count of all events in the class considered).

Protective lining: A covering for the natural bed of an open canal, made of material that is less prone to detachment by the flowing water, to enable higher flow velocities.

Pump characteristic curve: A graphic description of the performance of a pump, often showing curves for head, efficiency, power, and (for centrifugal pumps) required NPSH versus the discharge on the horizontal axis.

Pump efficiency: The hydraulic efficiency of a pump, expressed as the ratio of energy converted into useful work to the energy applied to the pump shaft, or as the ratio of the water power to the brake power.

Pumping test: A field test to find the hydraulic characteristics of an aquifer, based on the analysis of the drawdown of the watertable in the vicinity of a pumped well during pumping (See **Aquifer test**).

Radial flow: Groundwater flow towards the wet perimeter of a drain, whereby the flow lines resemble converging radii.

Radial resistance: A resistance against water flow caused by radially converging flow lines.

Reaction factor: A factor that expresses the speed at which the drainage system of an area is able to lower the watertable after a recharge by rainfall or irrigation.

Recession curve: Generally, the falling limb of a hydrograph, representing the decreasing runoff from the surface water, subsurface water, and groundwater.

Reconnaissance study: An initial, exploratory study into the conditions affecting an existing problem. Its results should allow the extent of the problem to be weighed and possible solutions in general terms to be found.

Recovery test: A test to find the hydraulic characteristics of an aquifer, based on the reduction in drawdown of the watertable in a pumped well after pumping has stopped (See **Aquifer test**).

Reference evapotranspiration: The theoretical quantity of water lost by evapotranspiration from a specified crop or surface, reflecting the prevailing climatic conditions on site. Multiplied by a crop coefficient, it gives the potential evapotranspiration.

Regression analysis: A statistical technique applied to paired data to determine the degree or intensity of mutual association of a dependent variable with one or more independent variables.

Relaxation method: A computational method to obtain steadily improved approximations of the solution of a system of simultaneous difference equations that approximate the solution of a given differential equation.

Relief drain: A drain used to lower the groundwater over relatively large, flat areas where the drainage source is percolation from precipitation or irrigation, and where gradients of both the watertable and subsurface strata do not permit the sufficient lateral movement of the groundwater.

Resistance blocks: Small blocks of material in which two electrodes are embedded that measure the electrical resistance between them in dependence of the water content in the blocks. As this water is in equilibrium with surrounding soil water, resistance blocks allow soil-water tension in a certain range to be measured.

Return flow: Water that reaches a source of groundwater or surface water after being released from the point of use, and thus becomes available for further use.

Return period: The time in which a hydrological event is estimated to re-occur according to a selected statistical criterion. It is the reciprocal of an estimated frequency.

Re-use: The use of the same water several times (e.g. using irrigation return flow or drainage water for irrigation).

Reynolds number: A hydraulic number that represents the ratio of inertia forces to viscous forces, allowing laminar flow and turbulent flow to be distinguished.

Rip-rap: Broken stones or boulders placed compactly or irregularly on dams, levees, dikes, or similar embankments, and at the downstream end of structures, to protect earth surfaces from the action of waves, current, and flowing water.

River gauging: Measuring the velocity of river water, and the area of cross-section of the water, to determine the discharge.

Roughness coefficient: A dimensionless parameter appearing in Manning's Equation for uniform steady flow in open canals, related to surface irregularity, vegetal drag, and material retardance of the wetted perimeter.

Saline soil: A non-sodic soil containing soluble salts in such quantities that they interfere with the growth of most plants.

Saline-sodic soil: A soil that contains sufficient exchangeable sodium and soluble salts to interfere with the growth of most plants.

Salinity: The content of totally dissolved solids in irrigation water or the soil solution, expressed either as a concentration or as a corresponding electrical conductivity.

Salinization: The accumulation of soluble salts at the surface, or at some point below the surface, of the soil profile.

Salt balance: Equating all inputs and outputs of soluble salts, for a volume of soil or for a hydrological area, to the change in salt storage over a given period of time.

Salt equilibrium: A situation in an agricultural soil where there is no long-term change in the salt content of the rootzone.

Salt storage: The accumulation of salts in the rootzone of an agricultural soil.

Salt tolerance: The degree to which crop development and production are not susceptible to high total salt and specific ion concentrations in the soil solution.

Saturated soil paste: A particular mixture of soil and water that glistens as it reflects light, flows slightly when the container is tipped, and slides freely and cleanly from a spatula for all soils except those with a high clay content.

Saturation extract: The solution extracted from a saturated soil paste.

Saturation percentage: The water content of a soil sample that has been brought to saturation by the addition of water during stirring, expressed as grams of water per 100 grams of dry soil.

Scaling: A frequently used technique to account for spatial variability.

Scarifying: The breaking up of the soil profile within 0.10 m of the surface.

Seepage: (1) The slow movement of water through small cracks, pores, or interstices of a material, in or out of a body of surface or subsurface water. (2) The loss of water by infiltration from a canal reservoir or other body of water, or from a field.

Semi-confined aquifer: A completely saturated aquifer that is bounded above by an aquitard and below by an aquiclude or an aquitard.

Semi-diurnal tide: A tide with two high and two low waters in a day.

Shrinkage: The change in volume of a soil, produced by capillary stresses when the soil is drying.

Simulation: The representation of a physical system by a device such as a computer or a model that imitates the behaviour of the system; a simplified version of a situation in the real world.

Single-well test: A test to find the hydraulic characteristics of an aquifer, based on measured drawdowns of the water level in a pumped well (i.e. without using observation wells or piezometers).

Singular drainage system: A drainage system in which the field drains are buried and all field drains discharge into open collector drains.

Sodicity: A soil feature indicating a problem of high sodium content. See **Sodic soil**.

Sodic soil: A soil that contains sufficient exchangeable sodium to interfere with soil structure and the growth of most crops, without appreciable quantities of other soluble salts being present.

Sodium Adsorption Ratio (SAR): A ratio for soil extracts and irrigation water that expresses the relative activity of sodium ions in exchange reactions with soil. An adjusted SAR is used to classify irrigation water according to its potential to cause infiltration problems because of its high relative sodium content.

Soil classification: The organization of types of soil in a systematic and meaningful way, based on practical characteristics and criteria.

Soil fertility: The capacity of a soil to supply the nutrients needed for the growth of crops.

Soil horizon: A layer of soil or soil material approximately parallel to the land surface, and differing from adjacent genetically-related layers in physical, chemical, and biological properties or characteristics (e.g. colour, structure, texture, consistency, or degree of acidity or alkalinity).

Soil profile: The vertical sequence of soil layers, from the soil surface downwards, caused by soil formation.

Soil ripening: The process that transforms a soft, water-saturated, and reduced sediment into a soil that can be used for agriculture. A distinction is made between biological, chemical, and physical ripening.

Soil salinity: The presence of salts in the soil profile that impair crop production.

Soil salinization: See **Salinization**.

Soil structure: The combination or aggregation of primary soil particles into aggregates or clusters (peds) that are separated from adjoining peds by surfaces of weakness.

Soil survey: The systematic examination of soils in the field, including the laboratory analysis of specific samples, their description, and mapping.

Soil texture: The relative proportions of the various-sized groups of individual soil grains in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand smaller than 2 mm in diameter (fine earth fraction).

Soil-water content: The volume of water in a soil as a fraction of the total soil volume. Normally determined by the drying of a soil sample to a constant weight at a standard temperature. Sometimes expressed as a mass fraction.

Soil-water diffusivity: The ratio of the unsaturated conductivity to the specific water capacity of the soil at a certain water content.

Soil-water potential: The energy required to move a unit quantity of water from the reference state to the point of consideration. In soil-water systems, the energy state of the water at the watertable is usually taken as the reference state. Potentials may be expressed as energy per unit mass (J/kg), energy per unit volume (Pa), or energy per unit weight (m water column).

Soil-water retention: The soil property that part of the soil water is retained by surface tension and molecular forces against the influence of gravity.

Soil-water retention curve: The graphic representation of soil-water content as a function of its pressure head, also called a pF curve.

Soil-water tension: The force per unit area that must be exerted to remove water from the soil; sometimes loosely expressed in metres or centimetres water column.

Spatial variability: The phenomenon that a property does not have a constant value within a certain area, but that individual values depart from a central tendency.

Specific speed: A characteristic parameter for a pump as a function of the shaft speed, the discharge, and the head, which facilitates the choice between different rotodynamic pumps (axial flow, mixed flow, radial flow).

Specific volume: The volume of a unit mass of dry soil in an undisturbed condition, equalling the reciprocal of the dry bulk density of the soil.

Specific water capacity: The slope of the curve relating soil-water content to its pressure head.

Specific yield: The volume of water stored or released per unit surface area of an unconfined aquifer, per unit change in head. It virtually equals the effective porosity, or the drainable pore space, because the compressibility can be ignored. See **Drainable pore space**.

Standard deviation: A statistical measure of dispersion of a frequency distribution, equal to the positive square root of the mean squared deviation of a number of individual measurements of a variate from their population mean.

Steady state: (1) A condition in which the input energy equals the output energy. (2) A fluid motion in which the velocities at every point of the field are independent of time in either magnitude or direction.

Storage coefficient: See **Storativity**.

Storativity: The volume of water released or stored per unit surface area of a confined aquifer, per unit change in the component of head normal to that surface. It depends on the compressibilities of the aquifer material and the fluid.

Streamline: A line whose tangent at any point in a fluid is parallel to the instantaneous velocity of the fluid at that point, in steady-state flow coinciding with the trajectories of the fluid particles.

Sub-critical flow: Water flow at a mean velocity less than critical; the Froude number is smaller than 1. See also **Critical flow**.

Sub-irrigation: Irrigation of plants with water delivered to the roots from below.

Subsidence: Downward movement of the ground surface for any reason (e.g. mining, pumping of groundwater), as a combined effect of compaction and compression, consolidation, oxidation, and shrinkage.

Subsurface drainage: The removal of excess water and salts from soils via groundwater flow to the drains, so that the watertable and rootzone salinity are controlled.

Subsurface drainage system: A man-made system that induces excess water and salts to flow via the soil to wells, mole drains, pipe drains, and/or open drains, from where it can be evacuated.

Supercritical flow: Water flow at a mean velocity above critical; the Froude number is larger than 1. See also **Critical flow**.

Supplementary irrigation: Irrigation used to supplement direct rainfall that in itself would be inadequate to meet the crop water requirements.

Surface drainage: The diversion or orderly removal of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by the shaping and grading of land surfaces to such channels.

Surface drainage system: A system of drainage measures, such as channels and land forming, meant to divert excess surface water away from an agricultural area in order to prevent waterlogging.

Surface irrigation: Irrigation whereby the water flows over the soil surface, thereby partially wetting the soil through infiltration, as in basin, border, and furrow irrigation.

Surface runoff: Water that reaches a stream, be it large or very small, by travelling over the surface of the soil.

Suspended load: The relatively fine part of the sediment load that is distributed throughout the flow cross-section and stays in suspension for appreciable lengths of time.

Swelling: Opposite of **Shrinkage**.

Tail recession: The part of the downward leg of a hydrograph below the inflection point (i.e. where the hydrograph section can be reasonably approximated by a decay curve).

Tensiometer: A porous cup, filled with water, that is buried in the soil at the point of interest to measure soil-water tension.

Terrace: A flat, or nearly flat, area of land bounded on at least one side by a definite steep slope rising upward from it, and on the other sides by downward slopes.

Textural class: The name of a soil group with a particular range of sand, silt and clay percentages, of which the sum is 100% (e.g. sandy clay is: 45-65% sand, 0-20% silt, 35-55% clay).

Textural triangle: A triangle indicating the boundary limits of the sand, silt, and clay percentages for each textural class.

Texture: See **Soil texture**.

Tidal drainage: The removal of excess water from an area, by gravity, to outer water that has periodic low water levels owing to tides.

Tidal river: A river whose water level is influenced by tidal water-level fluctuations over a considerable distance.

Tide: The periodic fluctuation of the seawater level that results from the gravitational attraction of the moon and the sun acting upon the rotating earth.

Tile drain: See **Pipe drain**

Total energy head: The energy of water per unit weight, equalling the sum of the velocity head, the elevation head, and the pressure head.

Tractive stress: The force per unit of wet canal area that acts on the bed material, trying to dislodge it, against cohesion, internal repose, and gravity.

Transient flow: See **Unsteady flow**.

Transition: The section of a canal or a structure that ensures an undisturbed connection between different cross-sectional profiles.

Transmissivity: The rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. It equals the product of the average hydraulic conductivity and the thickness of the aquifer.

Transpiration: The quantity of water evaporating via the cuticula and the stomata of a dry crop canopy to the outside atmosphere.

Trencher: A drainage machine that digs a trench in which a drain pipe and envelope are laid.

Tubewell: A circular well that can be used to dispose of subsurface water, to control groundwater levels, or to relieve hydraulic pressures, where local physical conditions are appropriate for their use.

Tubewell drainage: The control of an existing or potential high watertable, or of artesian groundwater, through a group of adequately-spaced wells.

Tubewell drainage system: A network of tubewells to lower the watertable, including provisions for running the pumps, and drains to dispose of the excess water.

Turbulent flow: Flow of water, agitated by cross-currents and eddies, as opposed to laminar flow. Any particle may move in any direction with respect to any other particle, and the head loss is approximately proportional to the second power of the velocity.

Two-way regression: A regression analysis of two data sets in which neither variable is considered to be the independent variable (See **Regression analysis**).

Unconfined aquifer: A permeable bed only partly filled with water, overlying a relatively impermeable layer. The upper boundary of an unconfined aquifer is formed by a free watertable under atmospheric pressure.

Uniform flow: Flow of water with no change in depth or any other element of flow (e.g. cross-sectional area, velocity, and hydraulic gradient) from section to section along a canal.

Unit hydrograph: The direct runoff hydrograph resulting from 1 mm of excess rainfall, generated uniformly over a drainage area at a constant rate, during a specified period of time or duration.

Unsaturated flow: Water flow in the unsaturated zone of the soil.

Unsaturated zone: The soil layer above the free watertable, where soil pores contain both air and water.

Unsteady flow: Flow in which the velocity changes, with time, in magnitude or direction.

Vadose zone: The soil between the surface and the watertable. It includes the unsaturated zone and the capillary fringe.

Vapour pressure: The partial pressure of water vapour in the atmosphere.

Vegetated waterway: An earthen channel to dispose of excess water safely, and therefore lined with vegetation to stabilize the channel and prevent erosion.

Velocity head: The energy of water per unit weight due to its flow velocity.

Vertical drainage: See **Tubewell drainage**.

Voids: Small cavities in the soil, occupied by air or water or both.

Void ratio: Ratio of the volume of pores to the volume of solids in a soil.

Water balance: The equation of all inputs and outputs of water, for a volume of soil or for a hydrological area, with the change in storage, over a given period of time.

Water factor: The mass of water adsorbed by a unit mass of soil, used as a measure of the degree of physical soil ripening.

Water-holding capacity: See **Field capacity**.

Waterlogging: The accumulation of excess water on the soil surface or in the rootzone of the soil.

Water management: The planning, monitoring, and administration of water resources for various purposes.

Water potential: See **Soil-water potential**.

Water quality: A judgement of the chemical, physical, and biological characteristics of water and of its suitability for a particular purpose.

Watershed: See **Drainage basin**.

Watertable: The locus of points at which the pressure in the groundwater is equal to atmospheric pressure. The watertable is the upper boundary of groundwater.

Weighting: A statistical method of adjusting the results of observations by taking into account the fact that not all the data may be of equal reliability or importance.

Well field: See **Tubewell drainage system**.

Well screen: A perforated casing that provides mechanical stabilization to the inflow area of a well, preventing it from collapsing and reducing the inflow of soil particles into the pump.

Wetlands: Lands whose saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities that live in the soil and on its surface.

Wilting point: The soil-water content at which plants wilt and fail to recover turgidity; also called the permanent wilting point.