9. SUMMARY AND CONCLUSIONS
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In the following sections the contents and essential results are summarised for each chapter of the monograph.

(Chapter 1): Following a brief introduction, two classifications of air-water mixtures are presented: one according to their type of generation such as condensation, dispersion, ambient surface aeration (as in flow down steep chutes or over spillways) and local surface aeration (as in hydraulic jumps or impinging jets), and another according to the observed characteristics of turbulent flow associated with them (rippled, choppy, scarified, emulsified, ebullient, spraying and separation flow). The first classification lists some of the practical problems bringing out the importance of the study of self-aeration in various fields such as Water Resources Engineering, Environmental Engineering and Industrial Engineering. A brief historical literature survey is given, and the basic definitions are derived.

(Chapter 2): Since studies of self-aerated free surface flows must rely heavily upon experimental information, one of the most important aspects of investigations of this phenomenon relates to measurement techniques and instrumentation. Mechanical, electrical and optical methods for measurement of air-concentration and air-water velocity are described including conductivity probes, hot film techniques and light absorption methods. Furthermore, instruments for measuring water surface elevations and air discharges are discussed, and some details on recent field measurement techniques are presented.

(Chapter 3): Basic information on the motion of gas bubbles in liquids is given in order to gain insight into the characteristics of bubble flows. The rise of a single bubble in an extended liquid at rest is treated, and the effects of bubble concentration and of a liquid cross flow upon the bubble behaviour are discussed. Dimensional analysis is applied to air-water mixtures in order to clarify the governing similarity laws and their implications for model studies of such flows. These basic considerations are useful in understanding the mechanics of self-generated air-water mixtures.

(Chapter 4): The onset of the appearance of "white water" in flow over spillways or chutes is termed as "Inception". For inception to occur, it is necessary that the kinetic energy of the surface eddies be greater than their surface tension energy. However, this condition in itself does not cause whiteness of water as observed in spillways: it is furthermore necessary that the turbulent boundary layer should become fully developed. Based on these two considerations, which together yield the necessary and sufficient conditions for the formation of white water, a criterion known as the "Inception Number" is formulated. The critical value of the Inception number is calculated from model and prototype data. A graphical method is proposed to locate the inception zone of air entrainment on free overfall spillways

A theoretical equation is worked out for the inception of instability of the free surface disturbances which cause local air entrainment when the depth of flow over the spillways or chutes is large, based on the principle of a Kelvin-Helmholtz instability of an interface. Vedernikov's criterion for the inception of instability of the free surface is also discussed.

(Chapter 5): In the discussion of Entrainment characteristics of self-aerated flows, terms like "Entrainment constant" and "Concentration constant" are defined and their experimental correlation is presented. Using the momentum and energy equations formulated for aerated flow in prismatic channels, an approximate relation is developed among mean air concentration, characteristic Froude number and head loss for uniform aerated flow. Considering the effects of Manning's roughness coefficient and the shape of the channel, an empirical relationship between local non-aerated Froude Number and mean air concentration is developed. A "bulkage depth factor" is defined, and its relationship with the mean air concentration is developed empirically. A method is suggested to predict aerated flow characteristics from non-aerated flow data.

(Chapter 6): As air entrains into the flow, it gets distributed throughout the flow by turbulent transport properties. The distribution characteristics of self-aerated, high velocity open channel flow involve two zones according to the turbulent characteristics of the flow, namely, - (1) a wall turbulent zone and (2) a free turbulent zone. Theoretical equations developed for air concentration and velocity in the free turbulent zone, starting from the basic equations of motion and continuity, are checked with experimental results obtained from a tilting flume and the agreement is seen to be good. The description of the velocity distribution in the wall turbulent zone by a velocity defect law is seen to fit the experimental results fairly well. The concentration distribution in the wall turbulent zone is studied by dividing the zone into an inner region and an outer region based on eddy viscosity considerations. The extrapolation of the concentration curve from the free turbulent zone into the outer region is seen to correlate well with the experimental results. The distribution of concentration in the inner region is studied theoretically by solving a transport equation which fits the experimental results well. The values of the Karman constant show an increase with increasing air concentration.

(Chapter 7): In local air-entrainment processes, one has to distinguish between the air entrainment capacity of the configuration and the downstream transport capacity of the flow, either one of which may provide the limiting condition for the process. Dimensional arguments show that the entrainment limit (in the absence of transport constraints) requires the relative air entrainment to be proportional to the square of the Froude number, with a proportionality factor k_e depending on the particular flow configuration. For the classical hydraulic jump, which entrains air only at the toe of the surface roller, the value of k_e was found to be ($5 \times 10^{-3} \pm 20\,\%$). Experimental results on the transport capacity of numerous geometrical configurations causing air entrainment in a surface roller are summarised and compared. The case of a jet striking a rigid surface is treated in detail.

Here it was found that a horizontal jet striking a vertical wall transports about 55 % of the entrained air downstream, whereas for an inclination of 30° this percentage drops to 28. These results are valid for intermediate Froude numbers (1 to 9) and are limited by the inception condition on one hand and by limitations on the downstream transport capacity on the other. Some studies on air entrainment in jets penetrating liquid surfaces are also described.

(Chapter 8): The application of the research results to practical design problems is presented and illustrated by a series of numerical examples. It is shown, that allowing for air entrainment in stilling basins seems to result in a more economical design of such structures. A sample calculation for determining the air demand in priming a siphon is given, and the design of adequate aeration vents for enclosed drop structures and dissipation chambers to avoid undesirable pressure fluctuations is illustrated. Finally, some results of Keller's field studies on air entrainment on the gated spillway of the Aviemore dam in New Zealand are presented.