- Explain if the pre-feasibility report is intended to be used for obtaining approval for the proposed project.

3.3.1.3 The Project Area And The Need For The Project

This section establishes the need for the project. It should cover. the following :

(a) Project Area

- Give geographical description of the project area with reference to map / maps, describe special features such as topography, climate, culture, religion, migration, etc. Which may affect project design, implementation and operation
- Map showing administrative and political jurisdiction
- Describe, if any, ethnic, cultural or religious aspects of the communities which may have a bearing on the project proposal.

(b) Pollution Pattern

- Estimate population in the project area, indicating the source of data or the basis for the estimate
- Review previous population data, historic growth rates and causes
- Estimate future population growth with different methods and indicate the most probable growth rates and compare with past population growth trends
- Compare growth trends within the project area, with those for the region, state and the entire country
- Discuss factors likely to affect population growth rates
- Estimate probable densities of population in different parts of the project area at future intervals of time e.g. five, ten, and twenty years ahead
- Discuss patterns of seasonal migration, if any, within the area
- Indicate implication of the estimated growth pattern on housing and other local infrastructure.

(c) Economic and Social Conditions

- Describe present living conditions of the people of different socio-economic and ethnic groups
- Identify locations according to income levels or other indications of socio-economic studies
- Show on the project area map locationwise density of population; poverty groups and ethnic concentrations, and the present and future land uses (as per development plan)
- Information on housing conditions and relative proportions of owners and tenants

- Provide data on education, literacy and unemployment by age and sex
- Provide data and make projection on housing standards, and average household occupancy in various parts of the project area
- Describe public health status within the project area, with particular attention to diseases related to water and sanitary conditions; provide data on crude maternal and infant mortality rates, and life expectancy
- Discuss the status of health care programmes in the area, as well as other projects which have bearing on improvements in environmental sanitation.

(d) Sector Institutions

- Identify the institutions (Government, Semi-Government, Non-Government) which are involved in any of the stages of water supply and sanitation project development in the area, (planning, preparing projects, financing, implementation, operation and maintenance, and evaluation).
- Comment on roles, responsibilities and limitation (territorial or others) of all the identified institutions, in relation to water supply and sanitation (This may also be indicated on a diagram).

(e) Available Water Resources

- Summarise the quantity and quality of surface and ground water resources, actual and potential, in the project area and vicinity (give sources of information)
- Indicate studies carried out or being carried out concerning development of potential sources, and their findings
- Mention the existing patterns of water use by all sectors (irrigation, industrial energy, domestic etc.), comment on supply surplus or deficiency and possible conflicts over the use of water, at present and in future
- Comment on pollution problems, if any, which might affect available surface and ground water resources.
- Mention the role of agencies/authorities responsible for managing water resources, their allocation and quality control.

(f) Existing Water Supply Systems and Population served

- Describe each of the existing-water supply systems in the project area, indicating the details as under
- Source of water, quantity and quality available in various seasons, components of the system such as head works, transmission mains, pumping stations, treatment works, balancing/service reservoirs, distribution system, reliability of supply in all seasons
- Areas supplied, hours of supply, water pressures, operating problems, bulk meters, metered supplies, un-metered supplies, supply for commercial use, industrial use, and domestic use

- Private water supply services such as, wells, bores, water vendors etc
- Number of people served according to water supply systems of the following category:
  - Unprotected sources like shallow wells, rivers, lakes, ponds, etc.
  - Protected private sources like wells, bores, rain water storage tanks etc., Piped water system
- Number of house connections, number of stand pipes
- Consumers opinion about stand-pipe supply, (e.g. Distance, hours of supply, waiting time etc.)
- How many people obtain water from more than one source, note these sources, and how their waters are used, e.g., Drinking, bathing, washing etc. and reasons for their preferences
- Explain un-accounted for water, probable causes and trends and efforts made to reduce losses
- Comment on engineering and social problems of existing systems and possible measures to resolve these problems and the expected improvement

(g) Existing Sanitation Systems and Population served

Even if the proposed project may be for providing a single service i.e. water supply and not sanitation, the existing sanitation arrangements should be described, giving details of the existing sanitation and waste disposal systems in the project area, and the number of people served by each system. Comment on the impact of existing system on drinking water quality and environment.

(h) Drainage and Solid Wastes

Briefly describe existing systems of storm water drainage and solid waste collection and disposal. This discussion should be focussed in terms of their impact on water supply and environment.

(i) Need for a Project

Comment as to why the existing system cannot satisfy the existing and projected demands for services with reference to population to be served and the desired service standards, other demands like commercial and industrial. Describe the consequences of not taking up a project (which may include rehabilitation/augmentation of the existing system and/or developing a new system), indicate priorities to improvement of existing system, expansion of system, construction of new system, supply for domestic use, industrial and commercial use; assessment of the need for consumer education in hygiene; and comments on urgency of project preparation and implementation.

3.3.1.4 Long Term Plan for Water Supply

(a) Improvement in water supply services has to be planned as a phased development program and any near-term project should be such as would fit in the long term strategy. Such a long term plan or the strategic plan should be consistent with the future overall development plans for the areas. A long term plan may be prepared for a period of 25 to 30 years, and alternative development sequences may be identified to provide target service coverage and standards at affordable costs. From these alternative development sequences, a priority project to be implemented in near-term can be selected. It is this project which then becomes the subject of a comprehensive feasibility study.

(b) Alternative development sequences should be identified in the light of the service coverages to be achieved during the planning period in phases. This calls for definition of the following:

- Population to be covered with improved water supply facility
- Other consumers to be covered (industrial, commercial, government, institutions, etc.)
- Service standards to be provided for various section of population (e.g. House connections, yard-taps, public stand post and point sources)
- Target dates by which the above mentioned service coverage would be extended within the planning period, in suitable phases

(c) It must be noted that service standards can be upgraded over a period of time. Therefore, various options can be considered for different areas. While selecting service standard, community preferences and affordability should be ascertained through dialogue with intended beneficiaries. Only those projects which are affordable to the people they serve, must be selected. This calls for careful analysis of the existing tariff policies and practices, cost to the users for various service standards and income of various groups of people in the project area.

(d) Having determined the service coverage in stages over a planned period, requirements of water can be worked out for each year (or in suitable stages), adopting different standards; at different stages. To this may be added the demand for industrial, commercial and institutional users. Thus, water for the projected needs throughout the planned period can be quantified, (duly considering realistic allowances for unaccounted for water and the daily and seasonal peaking factors) for alternative service standards, and service coverage. These demands form the basis for planning and providing system requirements.

The annual water requirements should also take into consideration water demands for upgrading sanitation facilities, if proposals to that effect are under consideration. Consistency and coordination has to be maintained between projections for both water supply and sanitation services.

(e) It must be noted that availability of funds is one of the prime factors which will ultimately decide the scope and scalc of a feasible project.

(f) Selection of a Strategic Plan

Each of the alternative development sequences, which can overcome the existing deficiencies and meet the present and future needs, consists of a series of improvements and expansions to be implemented over the planned period. Since all needs cannot be satisfied in immediate future, it is necessary to carefully determine priorities of target groups for improvement in services and stages of development and thus restrict the number of alternatives.

(g) Planning For System Requirement Includes Consideration Of The Following

- Possibilities of rehabilitating and/or de-bottlenecking the existing systems
- Reduction in water losses which can be justified economically, by deferring development of new sources
- Alternative water sources, surface and ground water with particular emphasis on maximising the use of all existing water sources
- Alternative transmission and treatment systems and pumping schemes
- Distribution system including pumping station and balancing reservoirs
- Providing alternative service standards in future, including upgrading of existing facilities and system expansion

(h) Need Assessment For Supporting Activities

It may also be necessary to ascertain if supporting activities like health education, staff training and institutional improvements etc. are necessary to be included as essential components of the project. All the physical and supporting input need to be carefully costed (capital and operating) after preparing preliminary designs of all facilities identified for each of the alternative development sequences. These alternatives may then be evaluated for least cost solution by net present value method; which involves

- Expressing all costs (capital and operating) for each year in economic terms;
- Discounting future costs to present value;
- Selecting the sequence with the lowest present value.

(i) Costings And Their Expressions

As stated above, costs are to be expressed in economic terms and not in terms of their financial costs. This is because the various alternatives should reflect resource cost to the economy as a whole at different future dates. Costing of the selected project may however, be done in terms of financial costs, duly considering inflation during project implementation.

3.3.1.5 Proposed Water Supply Project

(a) Details Of The Project

The project to be selected are those components of the least cost alternative of development sequence, which can be implemented during the next 3-4 years. Components of the selected project may be as follows:

- Rehabilitation and de-bottlenecking of the existing facilities
- Construction of new facilities for improvement and expansion of existing systems
- Support activities like training, consumer education, public motivation etc. Equipment and other measures necessary for operation and maintenance of the existing and expanded systems
- Consultancy services needed (if any) for conducting feasibility study, detailed engineering, construction supervision, socio-economic studies, studies for reducing water losses, tariff-studies, studies for improving accounts support activities

(b) Support Documents Required

All project components should be thoroughly described, duly supported by documents such as:

- Location maps
- Technical information for each physical component, and economic analysis where necessary
- Preliminary engineering designs and drawings in respect of each physical component, such as head works, transmission mains, pumping stations, treatment plants, balancing reservoirs, distribution lines

(c) Implementation Schedule

A realistic implementation schedule should be presented, taking into consideration time required for all further steps to be taken, such as conducting feasibility study, appraisal of the project, sanction to the project, fund mobilisation, implementation, trial runs and commissioning. In preparing this schedule, due consideration should be given to all authorities/groups whose inputs and decisions can affect the project and its timing.

(d) Cost Estimates

Cost estimates of each component of the project should be prepared and annual requirement of funds for each year should be worked out, taking into consideration the likely annual progress of each component. Due allowance should be made for physical contingencies and annual inflation. This exercise will result in arriving at total funds required annually for implementation of the project.

(e) Environment And Social Impact

The pre-feasibility report should bring out any major environment and social impact the project is likely to cause and if these aspects will affect its feasibility.

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(f) Institutional Responsibilities

The pre-feasibility report should identify the various organisations/departments/agencies who would be responsible for further planning and project preparation, approval, sanction, funding, implementation and operation and maintenance of the project and indicate also the strength of personnel needed to implement and later operate and maintain the project. It should also discuss special problems likely to be encountered during operation and maintenance, in respect of availability of skilled and technical staff, funds, transport, chemicals, communication, power, spare parts etc. Quantitative estimates of all these resources should be made and included in the project report.

(g) Financial Aspects

The capital cost of a project is a sum of all expenditure required to be incurred to complete design and detailed engineering of the project, construction of all its components including support activities and conducting special studies. After estimating component-wise costs, they may also be worked out on annual basis, throughout the implementation period, taking into consideration construction schedule and allowances for physical contingencies and inflation. Basic item costs to be adopted should be of the current year. Annual cost should be suitably increased to cover escalation costs during the construction period. Total of such escalated annual costs determines the final cost estimate of the project. Financing plan for the project should then be prepared, identifying all the sources from which funds can be obtained, and likely annual contribution from each source, until the project is completed. The possible sources of funds include:

- Cash reserves available with the project authority
- Cash generated by the project authority from sale of water from the existing facilities
- Grant-in-aid from government
- Loans from government
- Loans from financing institutions like Life Insurance Corporation, Banks, HUDCO etc.
- Open market borrowings
- Loans/grants from bilateral/international agencies
- Capital contribution from voluntary organisations or from consumers

(h) If the lending authority agrees, interest payable during implementation period can be capitalised and loan amount increased accordingly.

(i) The next step is to prepare recurrent annual costs of the project for the next few years (say 10 years) covering operating and maintenance expenditure of the entire system (existing and proposed). This would include expenditure on staff, chemicals, energy, spare parts and other materials for system operation, transportation, up-keep of the systems and administration.

The annual financial burden imposed by a project comprises the annual recurring cost and payment towards loan and interest (debt servicing). This has to be met from the operational revenue, which can be realised from sale of water. The present and future tariff for sale of water should be identified and a statement showing annual revenue for ten years period, beginning with the year when the project will be operational, should be prepared. if this statement indicates that the project authority can generate enough revenue to meet all the operational expenditure as well as repayment of loan and interest, the lending institution can be persuaded to sanction loans for the project.

(j) Every State Government and the Government of India have programmes for financing water supply scheme in the urban and rural areas, and definite allocations are normally made for the national plan periods. It will be necessary at this stage to ascertain if and how much finance can be made available for the project under consideration, and to estimate annual availability of funds for the project till its completion. This exercise has to be done in consultation with the concerned department of the Government and the lending institutions, who would see whether the project fits in the sector policies and strategies, and can be brought in an annual planning and budgetory cycle taking into consideration the commitments already made in the sector and the overall financial resources position. The project may be finally sanctioned for implementation if the financing plan is firmed up.

3.3.1.6 Conclusions And Recommendations

(a) Conclusions

This section should present the essential findings and results of the pre-feasibility report. It should include a summary of:

- Existing service coverage and service standards
- Review of the need for the project
- Long-term development plans considered
- The recommended project, its scope in terms of service coverage and service standards and components
- Priorities concerning target-groups and areas to be served by the project
- Capital costs and tentative financing plan
- Annual recurring costs and debt servicing
- Tariffs and projection of operating revenue
- Urgency for implementation of the project
- Limitation of the data/information used and assumptions and judgements made; need for indepth investigation, survey, and revalidation of assumption and judgements, while carrying out feasibility study.

The administrative difficulties likely to be met with and risks involved during implementation of the project should also be commented upon. These may pertain to boundary question for the project area, availability of water, sharing of water sources with other users, availability of land for constructing project facilities, coordination with the various agencies, acceptance of service standards by the beneficiaries, tenancy problems, acceptance of recommended future tariff, shortage of construction materials, implementation of support activities involving peoples' participation, supply of power, timely availability of funds for implementation of the project and problems of operation and maintenance of the facilities.

(b) Recommendations

(i) This should include all actions required to be taken to complete project preparation and implementation, identifying the agencies responsible for taking these actions. A detailed time table for actions to be taken should be presented. if found necessary and feasible, taking up of works for rehabilitating and/or de-bottlenecking the existing system should be recommended as an immediate action. Such works may be identified and costed so that detailed proposals can be developed for implementation.

(ii) It may also be indicated if the project authority can go ahead with taking up detailed investigations, data collection and operational studies, pending undertaking feasibility study formally.

(iii) In respect of smaller and medium size projects, the pre-feasibility report can be considered sufficient for obtaining investment decision for the project if :

- The results of the pre-feasibility study are based on adequate and reliable data/ information
- Analysis of the data and situation is carried out fairly intensively
- No major environmental and social problems are likely to crop up that might jeopardise project implementation
- No major technical and engineering problems are envisaged during construction and operation of the facilities

(iv) In that case the pre-feasibility study with suitable concluding report, should be processed for obtaining investment decision for the project. The feasibility study, can then be taken up at the beginning of the implementation phase and results of the study if noticed to be at variance with the earlier ones, suitable modification may be introduced during implementation.

(v) In respect of major projects however, and particularly those for which assistance of bilateral or international funding agencies is sought for, comprehensive feasibility study may have to be taken up before an investment decision can be taken.

3.4 FEASIBILITY REPORT

Feasibility study examines the project selected in the pre-feasibility study as a nearterm project, in much greater details, to see if it is feasible technically, financially, economically, socially, legally, environmentally and institutionally. Enough additional data/ information may have to be collected to examine the above mentioned aspects, though the details necessary for construction of project components may be collected during execution of works.

It is a good practice to keep the authority responsible for taking investment decision, informed of the stage and salient features of the project. if there are good prospects of the project being funded immediately after the feasibility study is completed, detailed engineering of priority components may be planned simultaneously.

3.4.1 CONTENTS

The feasibility report may have the lowing sections :

- Background
- The proposed project
- Institutional and financial aspects
- Conclusion and recommendations

3.4.1.1 Background

In this section describe the history of project preparation, how this report is related to other reports and studies carried out earlier and in particular its setting in the context of a pre-feasibility report. It should also bring out if the data/information and assumption made in the pre-feasibility report are valid, and if not, changes in this respect should be highlighted. References to all previous reports and studies should be made.

In respect of the project area, need for a project and strategic plan for water supply, only a brief summary of the information covered in pre-feasibility report, should be presented, highlighting such additional data/ information, if any, collected for this report. The summary information should include planning period, project objectives, service coverage, service standards considered and selected for long-term planning and for the project, community preferences and affordability, quantification of future demands for services, alternative strategic plans, their screening and ranking, recommended strategic plan and cost of its implementation.

3.4.1.2 The Proposed Project

This section describes details of the project recommended for implementation. Information presented here is based on extensive analysis and preliminary engineering designs of all components of the project. The detailing of this section may be done in the following sub-sections:

(a) Objectives

Project objectives may be described in terms of general development objectives such as health improvements, ease in obtaining water by consumers, improved living standards, staff development and institutional improvements; and also terms of specific objectives such as service coverage and standards of service to be provided to various target groups.

(b) Project Users

Define number of people by location and institutions who will benefit and/or not benefit from the project area and reasons for the same, and users involvement during preparation, implementation and operation of the project.

(c) Rehabilitation and De-bottlenecking of the Existing Water Supply Systems

In fact rehabilitation, improvements and de-bottlenecking works, if necessary, should be planned for execution prior to that of the proposed project. If so these activities should be mentioned in the feasibility report. if, however, these works are proposed as components of the proposed project, necessity of undertaking the rehabilitation/improvement/ de-bottlenecking works should be explained.

(d) Project Description

This may cover the following items in brief:

- Definition of the project in the context of the recommended development alternative (strategic plan) and explanation for the priority of the project
- Brief description of each component of the project, with maps and drawings
- Functions, location, design criteria and capacity of each component
- Technical specification (dimension, material) and performance specifications
- Stage of preparation of designs and drawings of each component
- Method of financing and constructing in-house facilities, like plumbing and service connection etc.

(e) Support Activities

Need for and description of components such as staff training, improving billing and accounting, consumer education, health education, community involvement etc. and timing of undertaking these components and the agencies involved.

(f) Integration Of The Proposed Project With The Existing And Future Systems

Describe how the various components of the proposed project would be integrated with the existing and future works.

(g) Agencies Involved In Project Implementation And Relevant Aspects

- Designate the lead agency
- Identify other agencies including government agencies who would be involved in project implementation, describing their role, such as granting administrative approval, technical sanction, approval to annual budget provision, sanction of loans, construction of facilities, procurement of materials and equipment etc.

- Outline of arrangements to coordinate the working of all agencies
- Designate the operating agency and its role during implementation stage
- Role of consultants, if necessary, scope of their work, and terms of reference
- Regulations and procedures for procuring key materials and equipment, power, and transport problems, if any,
- Estimate number and type of workers and their availability
- Procedures for fixing agencies for works and supplies and the normal time it takes to award contracts
- List of imported materials, if required, procedure to be followed for importing them and estimation of delivery period
- Outline any legislative and administrative approvals required to implement the project, such as those pertaining to riparian rights, water quality criteria, acquisition of lands, permission to construct across or along roads and railways, high-tension power lines, in forest area and defence or other such restricted areas
- Comments on the capabilities of contractors and quality of material and equipment available indigenously

(h) Cost Estimates

- Outline basic assumption made for unit prices, physical contingencies, price-contingencies and escalation
- Summary of estimated cost of each component for each year till its completion and work out total annual costs, to know annual cash flow requirements
- Estimate foreign exchange cost if required to be incurred
- Work out per capita cost of the project on the basis of design population, cost per unit of water produced and distributed and compare these with norms, if any, laid down by government or with those for similar projects

(i) Implementation Schedule

Prepare a detailed and realistic implementation schedule for all project components, taking into consideration stage of preparation of detailed design and drawings, additional field investigations required, if any, time required for preparing tender documents, notice period, processing of tenders, award of works/supply contract, actual construction period, period required for procurement of material and equipment, testing, trials of individual component and commissioning of the facilities etc.

If consultants' services are required, the period required for completion of their work should also be estimated.

A detailed PERT diagram (ref. Appendix 3.1) showing implementation schedule for the whole project, as well as those for each component should be prepared, showing linkages and inter-dependence of various activities.

Implementation schedule should also be prepared for support-activities such as training, consumers' education etc. and their linkages with completion of physical components and commissioning of the project should be established.

(j) Operation And Maintenance Of The Project

Estimate annual operating costs, considering staff, chemicals, energy, transport, routine maintenance of civil works, maintenance of electrical/mechanical equipment, including normal cost of replacement of parts and supervision charges. Annual cost estimates should be prepared for a period of 10 years from the probable year of commissioning the project, taking into consideration expected out-put levels and escalation.

Proposal for monitoring and evaluating the project performance with reference to project objectives should be indicated.

(k) Environmental Impact

Brief description of the adverse and beneficial impacts of the project may be given covering the following aspects:

BENEFICIAL IMPACT	ADVERSE IMPACT
Ease and convenience in obtaining water by the consumers	Risk of promoting mosquito breeding, effect of with-drawing surface/ground water
Improvement in public reuse of water in household premises or by water authority.	Effect of disposal of backwash water and sludge from water treatment plant.
Effect of construction of storage reservoirs on flood moderation, navigation, ground water table, power generation etc.	Effects of construction of storage reservoirs on ground water table, down stream flow of the stream, the reservoir bed etc. and effects on ecology.

3.4.1.3 Institutional And Financial Aspects

(a) Institutional Aspects

It is necessary to examine capabilities of the organisations who would be entrusted with the responsibility of implementing the project and of operating the same after it is commissioned. The designated organisation(s) must fulfil the requirements in respect of organisational structure, personnel, financial, health and management procedures, so that effective and efficient performance is expected. This can be done by describing the following aspects :

- History of the Organisation, its functions, duties and powers, legal basis, organisational chart, (present and proposed), relationship between different functional groups of the organisation, and with its regional offices, its relation with government agencies and other organisations involved in sector development

- Public relations in general and consumer relations in particular, extension services available to sell new services, facilities for conducting consumer education programme, and settling complaints
- Systems for budgeting for capital and recurring expenditure and revenue, accounting of expenditure and revenue, internal and external audit arrangements, inventory management
- Present positions and actual staff, comments on number and quality of staff in each category, ratio of staff proposed for maintenance and operation of the project to the number of people served, salary ranges of the staff and their comparison with those of other public sector employees
- Staff requirement (category wise) for operating the project immediately, after commissioning, future requirements, policies regarding staff training, facilities available for training
- Actual tariffs for the last 5 years, present tariff, tariff proposed after the project is commissioned, its structures, internal and external subsidies, procedure required to be followed to adopt, new- tariff, expected tariff and revenues in future years, proposal to meet shortage in revenue accruals
- Prepare annual financial statements (income statements, balance sheets and cash flows) for the project operating agency, for three years after the project is commissioned, explain all basic assumptions for the financial forecast and the terms and conditions of tapping financial sources, demonstrate ability to cover all operating and maintenance expenditure and loan repayment, workout rate of return on net fixed assets and the internal financial rate of return of the project

(b) Financing Plan

Identify all sources of funds for implementation. of the project, indicating year-by-year requirements from these sources, to meet expenditure as planned for completing the project as per schedule; state how interest during construction will be paid, or whether it will be capitalised and provided for in the loan; explain the procedures involved in obtaining funds from the various sources.

3.4.1.4 Conclusions And Recommendations

This section should discuss justification of the project, in terms of its objectives, cost-effectiveness, affordability, willingness of the beneficiaries to pay for services and the effect of not proceeding with the project.

Issues which are likely to adversely affect project implementation and operation should be outlined and ways of tackling the same should be suggested. Effect of changes in the assumptions made for developing the project, on project implementation period, benefits, tariff, costs and demand etc. should be mentioned.

Definite recommendations should be made regarding time-bound actions to be taken by the various agencies, including advance action which may be taken by the lead agency pending approval and financing of the project.

CHAPTER 4
MEASUREMENT OF FLOW

4.1 POINTS OF MEASUREMENT

The measurement of flow in water supply systems is of importance in connection with assessment of source and its development, transmission, treatment, distribution, control of wastage and other factors.

The probable locations where flow measurement may be needed in a water supply system are:

(a) River flow gauging-upstream of intake-by floats and current meters or weirs and flumes or dilution methods.

(b) Measuring yield from wells (yield test) using the head differential through an orifice meter or venturi meter for pipe flows or by weirs or flumes for open channel flow.

(c) Intake structure-raw water input rate by venturi or orifice meter for pipe flows or by weirs or flumes for open channel flow.

(d) Flow at the entry to the treatment works (normally after aeration if it is practiced) by weirs or flumes.

(e) Filtrate flow from each filter by weirs or notches or orifice meters or venturi meters.

(f) Bulk flow measurements of water supplied from treatment plant and clear water reservoir by venturi meter.

(g) Bulk flow measurements (integrating and instantaneous) for supply to distribution zones, sub-zones or industries by bulk meters or venturi meters.

(h) Measurement of domestic water supply through service connections by domestic consumer water meters.

(i) Assessment of wastages and leakages in pipes and plumbing systems by waste flow measuring or recording meters.

There are several types of flow measurements of which the more common ones are described below with some detail. The choice of the particular type depends on the specific circumstances and desired accuracy.

4.2 MEASUREMENT IN OPEN CHANNELS

4.2.1. USE OF HYDRAULIC STRUCTURES

Several types of hydraulic structures like notches, weirs, flumes and drops are in use for measurement of flow in open channels.

4.2.1.1. Notches

These are cut from thin metal plates, the general forms being either triangular or trapezoidal.

(a) Triangular Notches

90^0 triangular notches are used for measuring small quantities of flows upto about 1.25 m^3/s

(i) Installation Requirements

The approach channel should be reasonably smooth, free from disturbances and straight for a length equal to at least 10 times the width. The structures in which the notch is fixed shall be rigid and water-tight and the upstream face vertical. The downstream level should be always at least 5 cm below the bottom-most portion of the notch (inverted apex) ensuring free flow.

(ii) Specification for Materials

The plate should be smooth and made of rust-proof and corrosion-resistant material. The thickness should not exceed 2 mm, with the downstream edge chamfered at an angle of not less than 45^0 with the crest surface.

(iii) Measurement of Head Causing the Water Flow

The head causing flow over the notch shall be measured by standard hook gauge upstream at a distance of 3 to 4 times the maximum depth of flow over the notch.

(iv) Discharge Equation

The discharge Q (in m^3/sec) for V-Notch is given by the expression :

$$Q = \frac{8}{15} C_e \sqrt{2g} \tan\frac{\theta}{2} h^{2.5} \tag{4.1}$$

where,

C_e	=	effective discharge coefficient
g	=	acceleration due to gravity (9.806 m/s^2)
θ	=	angle of the notch at the centre
h	=	measured head causing flow in m,

For 90^0 V-Notch which is generally used, the discharge is given by the expression

$$Q = 2.362\, C_e\, h^{2.5} \qquad (4.2)$$

C_e values vary from 0.603 to 0.686 for values of head varying from 0.060 to 0.377m.

(v) Limitations

The triangular notches should be used only when the head is more than 60 mm.

(vi) Accuracy

The values obtained by the equation for triangular notches would vary from 97 to 103% of the true discharge for discharges from 0.008 to 1.25 m^3/s.

(b) Rectangular Notches

The installation requirements, specifications, head measurements, head limits and accuracy will be the same as for triangular notches. The width of notch should be at least 150 mm.

There are two types of rectangular notches viz. (i) with end contractions and (ii) without end contractions.

(i) With End Contractions

The contraction from either side of the channel to the side of the notch should be greater than 0.1 m.

The discharge (m^3/s) through a rectangular notch with end contractions is given by the equation:

$$Q = \frac{2}{3} C_e \sqrt{2g}\ b_e H^{1.5} \qquad (4.3)$$

where,

b_e = effective width = actual width of the notch + k (value of k being 2.5 mm, 3 mm and 4 mm for b/B ranges of upto 0.4, 0.4 to 0.6 and 0.6 to 0.8 respectively);

$\frac{b}{B}$ = ratio of the width of the notch to the width of the channel;

H = effective head = actual head measured (h) + 1 mm;

g = acceleration due to gravity (9.806 m/s^2) ; and

C_e = varies from 0.58 to 0.70 for values of b/B from 0 to 0.8.

(ii) Without End Contractions

The discharge (m^3/s) through a rectangular notch without end contractions is given by the following expression:

$$Q = \frac{2}{3} C_e \sqrt{2g} b H^{1.5} \qquad (4.4)$$

where,

b = width of the notch (m)

H = effective head = actual /measured head (h) + 1.2 mm

$C_e = 0.602 + 0.075\ h/p$

where,

p = height of the bottom of the notch from the bed of the channel

(c) Trapezoidal Notches (Cipoletti Notches)

The main advantage in a trapezoidal or Cipoletti notch is that as the flow passes over the weir, the end contractions are either eliminated or considerably reduced. The sides of the notch should have a slope of 1 : 4 such that the top width of discharge is equal to the bottom width of the notch (b) + half the head of water over the sill of the notch (1/2 h). Thus the loss of discharge due to end contractions is made good. Discharge equation $Q = 1.859\ bh^{3/2}$ where b is bottom width of notch and h is the head over the sill.

4.2.1.2 Weirs

These are similar to rectangular notches but the thickness in the direction of flow is considerable and therefore coefficient of discharge will be less. The installation conditions will be the same as for the notches.

(a) Without End Contractions (Suppressed Weirs)

The discharge equation to be used is:

$$Q = 0.5445 C_e \sqrt{g} b h^{1.5} \qquad (4.5)$$

C_e varies from 0.864 to 1.0 depending upon the h/p (ratio of measured head to length of weir in the direction of flow) value from 0.4 to 1.6; for h/p values lower than 0.4, C_e may be taken as 0.864.

(b) With End Contractions

Same equation 4.5 is to be used replacing the 'b' by '(b-0.1 nh)' where n is the number of contractions.

(c) Limitations

The weirs should be used only when the head is more than 60 mm. Minimum width of the weir should be 300 mm.

(d) Accuracy

The discharge values obtained by weir measurements would vary from 95 to 105% of the true discharge.

4.2.1.3 Flumes (Free Flowing)

There are two types of flumes, namely:

- Standing wave flumes in which standing wave of hydraulic jumps is formed down stream.

- **Venturi flumes**

The installation conditions will be the same as for the notches.

(a) Standing Wave Flumes

(i) **Discharge equation** : The discharge equation for standing wave fumes is given by :

$$Q = \frac{2}{3}\sqrt{2g}C_f(B_0 - mb - 2C_c mH)H^{1.5} \qquad (4.6)$$

Where,

Q = discharge in m^3/s

C_f = coefficient of friction having the following values

0.97 for Q = 0.05 to 0.3 m^3/s

0.98 for Q = 0.3 to 1.5 m^3/S

0.99 for Q = 1.5 to 15 m^3/s

1.00 for Q = 15m^3/s and above

B_0 = overall throat width including piers

m = number of piers

b = thickness of each pier

C_c = Coefficient of contraction, having a value of 0.045 for piers with round nose and 0.040 for piers with pointed nose and $H = D_1 + h_v$ = upstream head over sill corrected for velocity of approach

$$H = D_1 + \frac{V_a^2}{15.2}$$

Where,

D_1 = the depth upstream over sill of throat and

V_a = the mean velocity of approach. Effect of velocity of approach is greater than $V_a^2/2g$ because the velocity in the central portion will be higher than V_a. Therefore, the head due to velocity of approach should be taken as :

$$h_v = \frac{V_a^2}{15.2}$$

(ii) Limitations

Standing wave flumes should be used only when the head is more than 60 mm. Ratio of D_2/D_1 (Depth downstream above sill of throat/depth upstream over sill of throat) should always be greater than 0.5 for the application of standing wave flumes. If this ratio is less than 0.5, drop may be adopted.

Minimum width of the flumes should be 90 mm.

(iii) Accuracy

The discharge values obtained by measurements with standing wave flumes would vary from 95 to 105% of the true discharge.

Parshall Flume is a type of standing wave flume widely used. However, its use requires application of different equations, based on the throat size, if accuracy in results similar to other types of flumes is expected.

The approximate equation applicable for the entire range of its usage, namely, discharges varying from 0.001 m^3/s to 100 m^3/s (i.e. throat widths varying from 75 to 15,000 mm) is given by:

$$Q = 2.42\ W\ h^{2.58}$$

Where,

Q = discharge in m^3/s

W = throat width in m and

h = upstream gauged depth in m,

The numerical factors 2.42 and 2.58 are subject to 4% variation in extreme cases (less in case of smaller widths).

The minimum head and accuracy will be the same as for standing wave flumes.

(b) Venturi Flumes

(i) Discharge equation

The discharge equation is given by

$$Q = 0.5445 C_v C_e \sqrt{g} b h^{1.5} \qquad (4.8)$$

Where,

C_v is the coefficient of velocity which varies from 1.04 to 1.15.

C_e is the effective coefficient of discharge varying from 0.885 to 0.99 depending upon h/l varying from 0.05 to 0.70 where 'l' is the length of throat in the direction of flow.

(ii) Limitations

Venturi flumes should be used only when head available is between 50 and 1800 mm. Minimum width of the flume should be 90 mm.

(iii) Accuracy

The discharge values obtained by measurement with venturi volumes would vary from 95 to 105% of the true discharge.

4.2.1.4 Drops

(i) Discharge Equation

When the flow falls freely from a channel or conduit to a lower level (ground), measurement can be conveniently made at the point of drop which offers a rough estimate