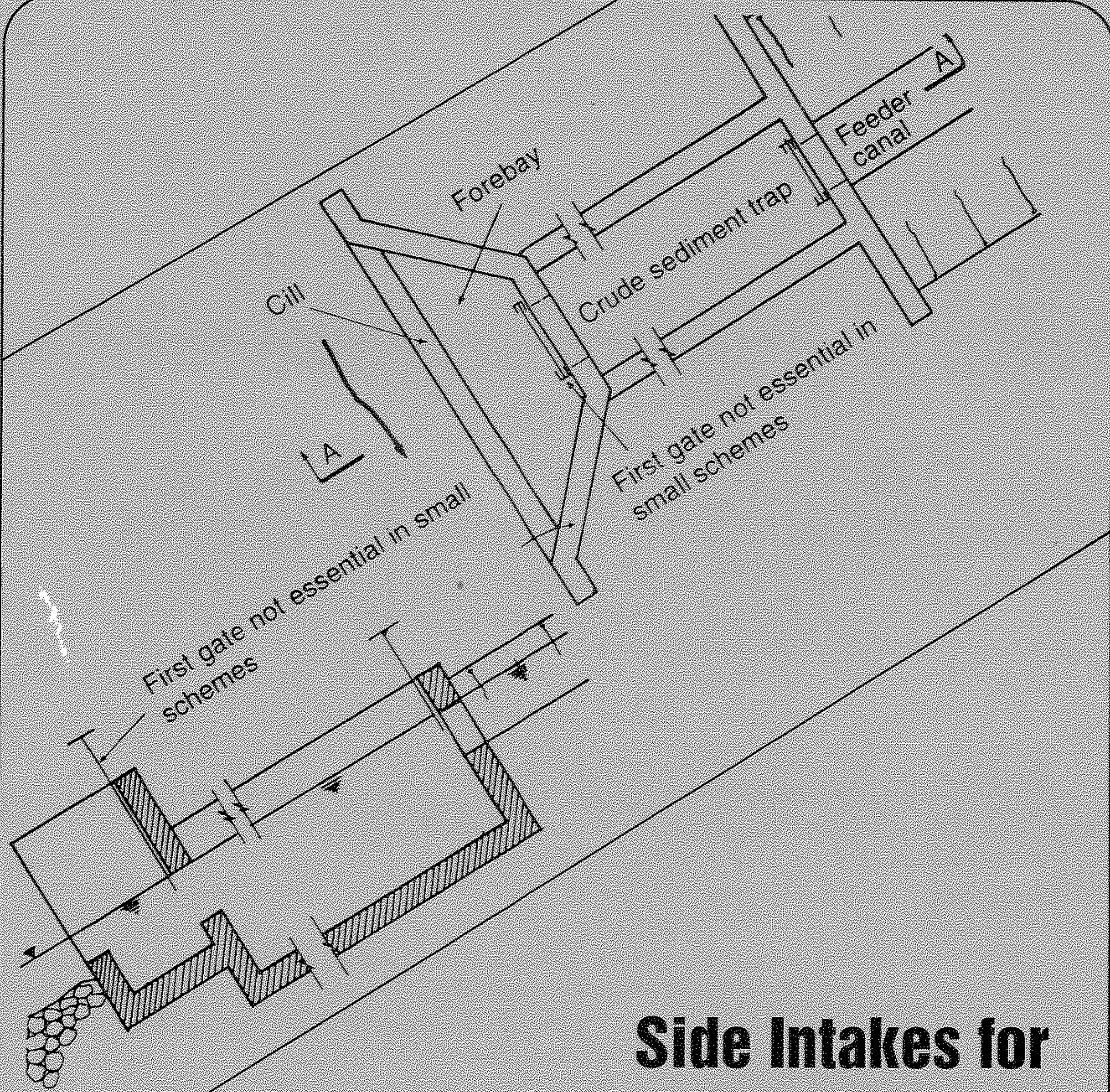
Poverty Alleviation Through Employment Generation in Irrigation Works Programmes

APPROPRIATE DESIGN OF SMALL-SCALE HILL IRRIGATION STRUCTURES



Side Intakes for Hill Irrigation Schemes

NEPAL SPECIAL PUBLIC WORKS PROGRAMME
MANUAL NO. 2

Module No 1

ILO

SIDE INTAKES FOR HILL IRRIGATION SCHEMES

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What is a Side Intake?

In its simplest form, a side intake is an opening on the bank of a river which extracts water from the river for irrigation purposes.

Why Side Intakes?

Side intakes are easy to build, operate and maintain. Side intakes are similar to farmers' traditional intakes, hence farmers can quickly learn the principles of operation and maintenance for these intakes.

Side intakes are less expensive than other types of intakes and are less complicated.

Location of Side Intakes

Side intakes must be correctly located for maximum safety and effectiveness.

They must be safe against boulder impact and flood water entry. They are most effective when built on the outer bend of the river, or near natural pools, see Figure 1.1 and Photograph 1A.

Figures 1.2, 1.3, 1.4, 1.5 and 1.6 show examples of side intake locations. Side intakes are effective in confined mountain rivers with "single channel" patterns (see Figures 1.2, 1.3, and 1.4). When several active channels exist, as in Figures 1.5 and 1.6, the following problems arise:

- longer diversion weirs will be required to divert river flow,
- the main river channel may change course,
- diversions may not be effective.

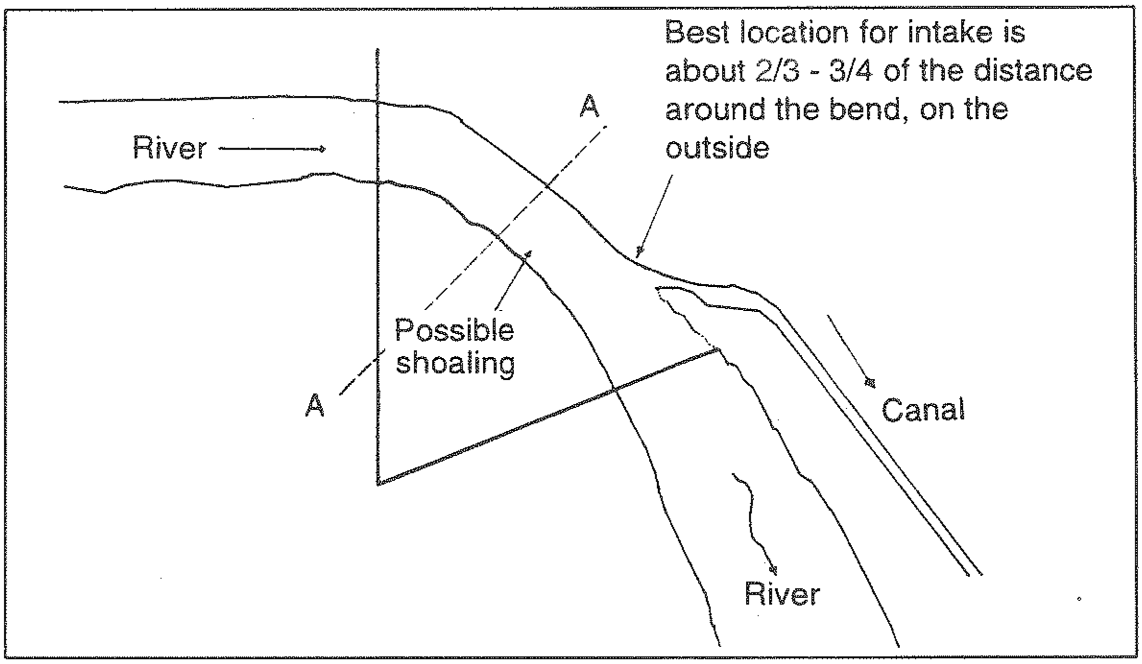
Effect of Landform Changes on Intakes

Proper selection and siting of intakes needs careful study of the landform changes that are taking place near the proposed intake location (see Figure 1.7). Some landform changes can take place quickly, say over two or three monsoon seasons, while others may take several years.

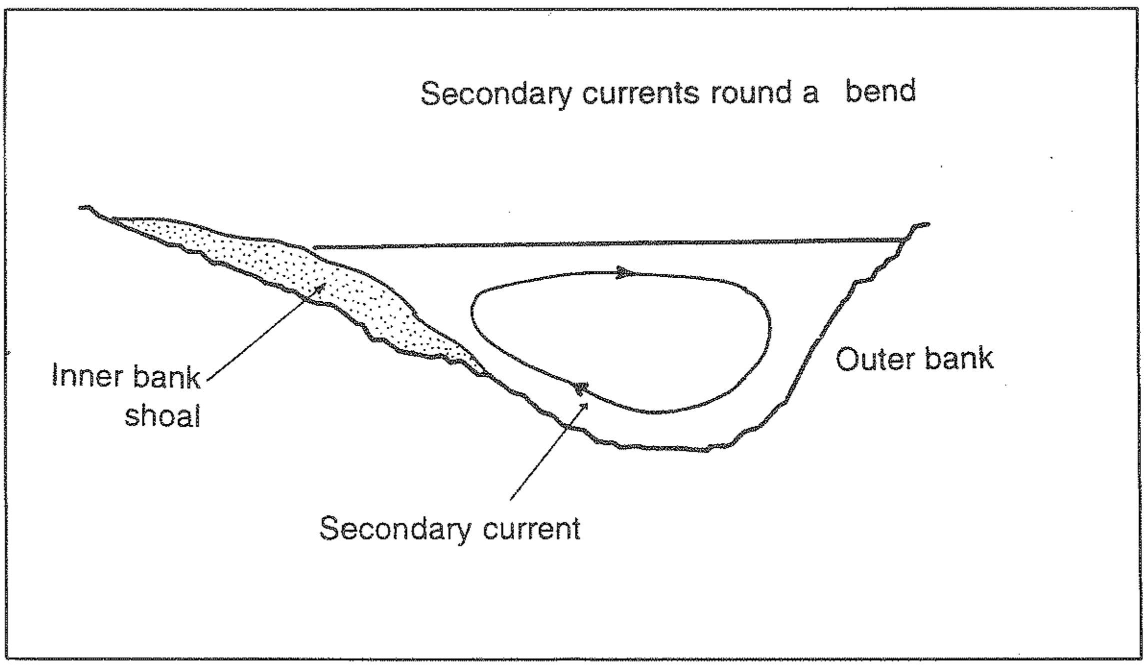
Seek Advice From the Local Farmers

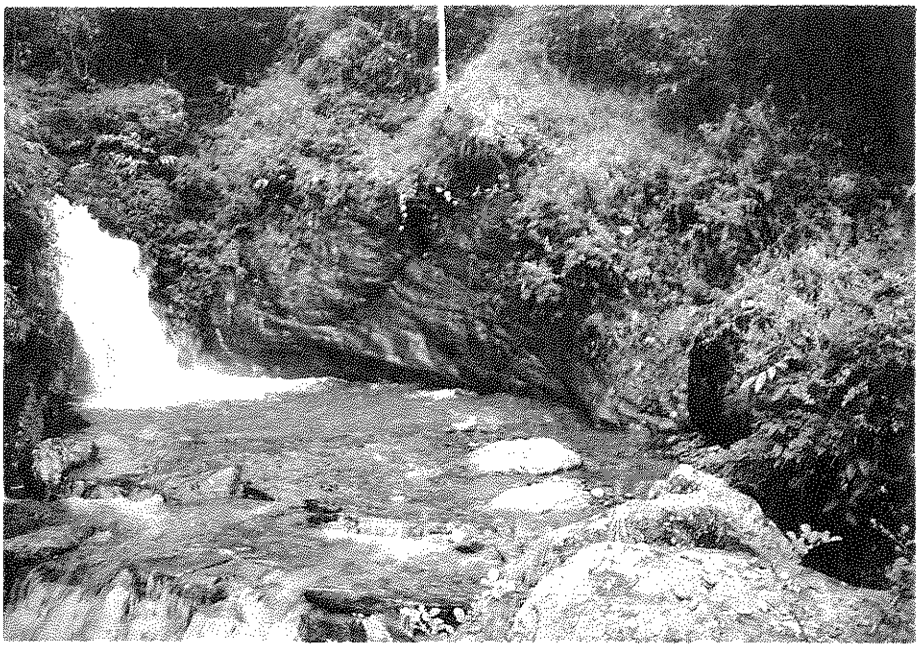
Local farmers are the best people to advise you on river processes that have occurred or are likely to occur. Their observation of the river over a long period of time makes them a valuable group of knowledgeable resource persons.

Figure 1.1
Best Side Intake Location - On the Outer Bend



Cross-Section AA





Photograph 1A
Ideal Location for Simple Side Intakes

The photograph above shows a small waterfall.

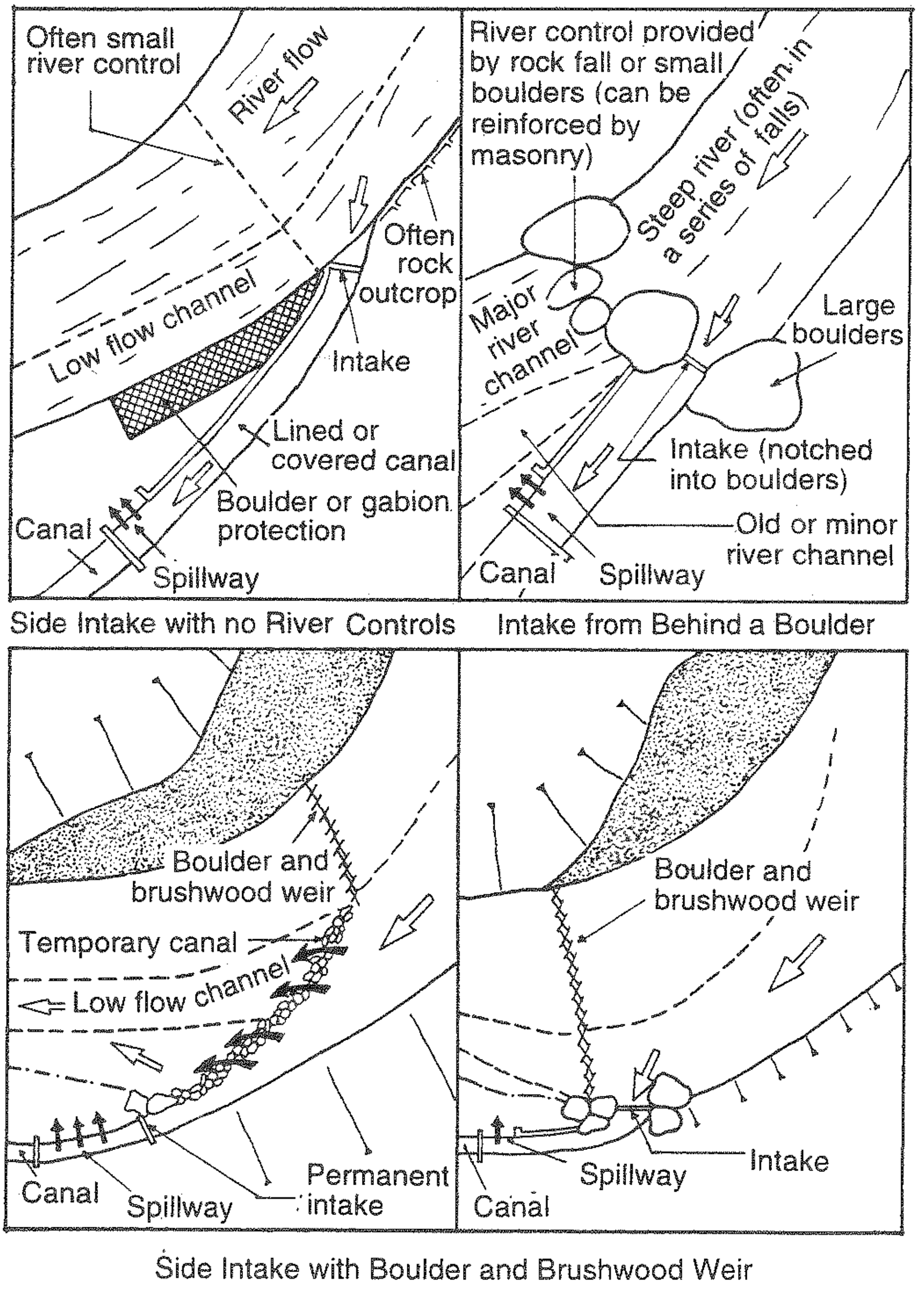
The waterfall is well established on the rocky river bed, and would take several years to change shape and location.

There is a natural pool immediately downstream of the waterfall.

The rock outcrop downstream of the pool extends from bank to bank and controls the water level of the pool.

This is an ideal location for a simple side intake for a small to medium sized irrigation project.

Figure 1.2
Ideal Locations For Simple Side Intakes
(in confined mountain rivers)



Side Intake with no River Controls

Intake from Behind a Boulder

Side Intake with Boulder and Brushwood Weir

Figure 1.3
Ideal Locations For Simple Side Intakes
(in confined mountain rivers)

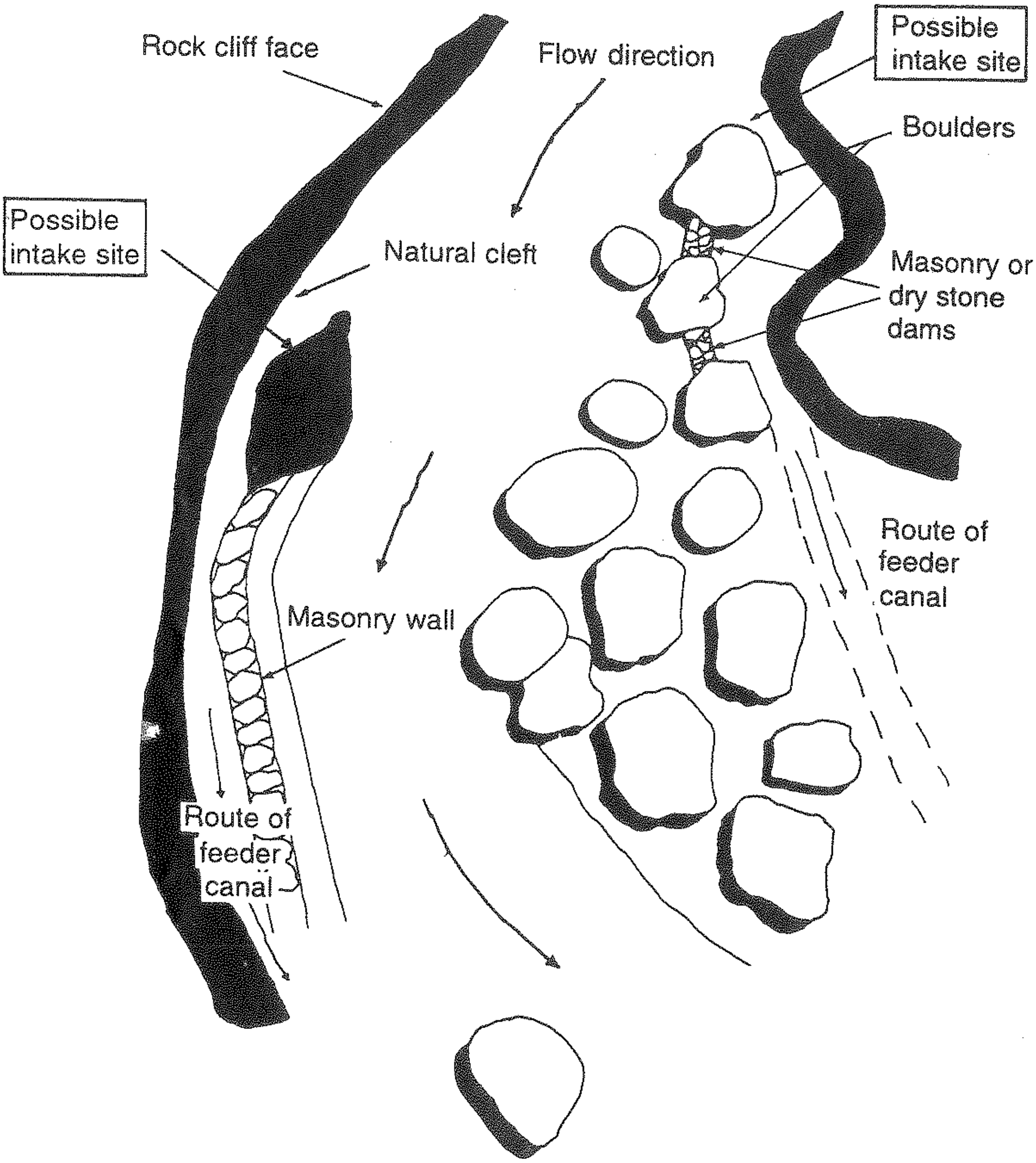


Figure 1.4
Ideal Locations For Simple Side Intakes
(in confined mountain rivers)

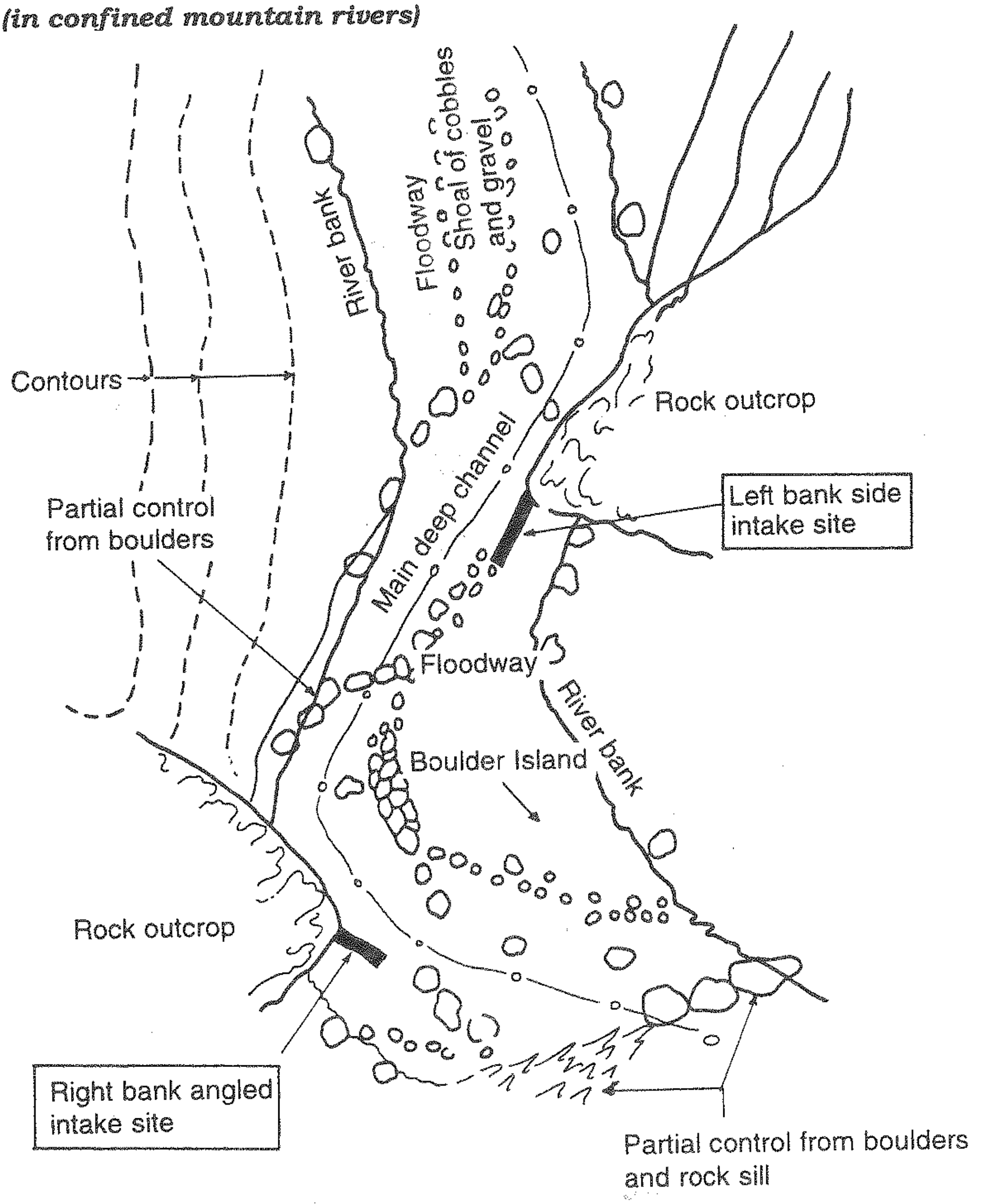


Figure 1.5
Ideal Locations For Simple Side Intakes
(in mountain rivers with multiple channel patterns)

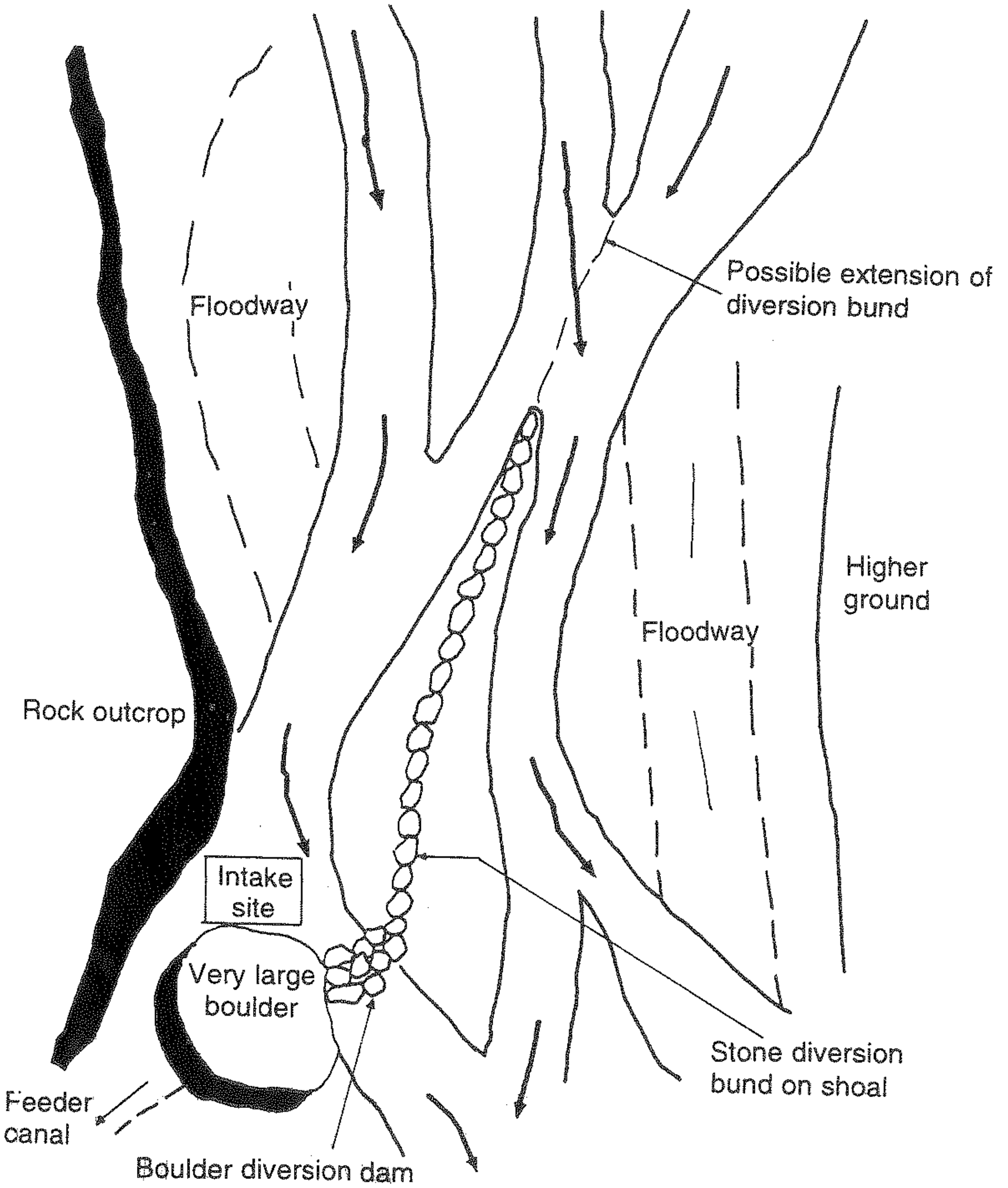
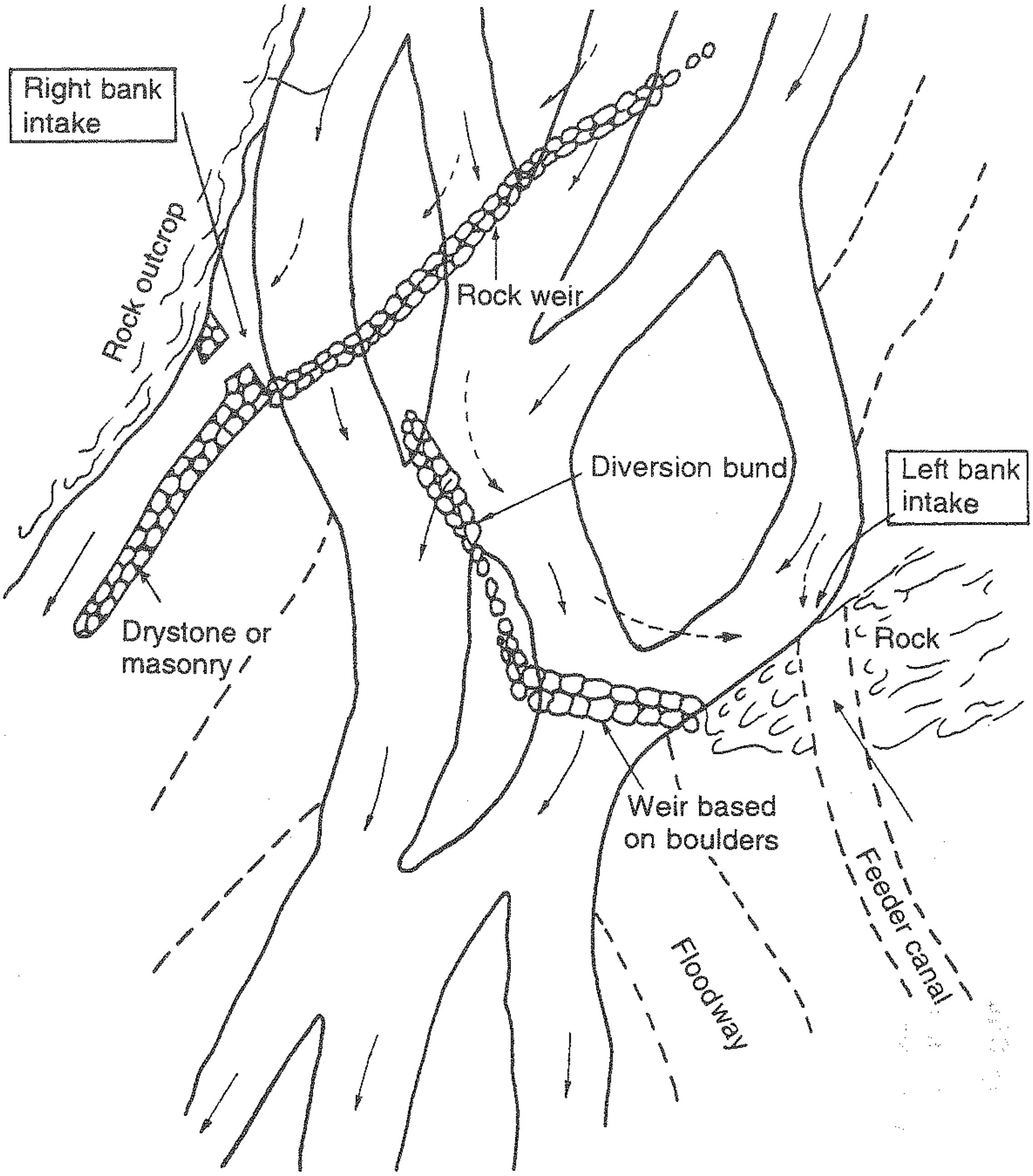


Figure 1.6
Ideal Locations For Simple Side Intakes (in mountain rivers with multiple channel patterns)



Note: Flow arrows in full lines show flows before works are carried out. Broken arrows indicate diverted flow.

Figure 1.7
Landform Changes Near Intake Locations: How to Indentify Them

Landform changes that can occur in a river reach are:	How do you know these changes are taking place ? Indicators of landform changes are:
EROSION OF THE RIVER BED (a general lowering of the river bed)	CHANGES IN THE COMPOSITION OF THE RIVER BED MATERIAL. Bed material changing from predominantly gravel/sand to predominantly boulder indicates erosion. Bed material changing from predominantly boulder to predominantly gravel/sand indicates aggradation.
AGGRADATION OF THE RIVER BED (a general building up of the river bed)	
SHIFTING OF THE RIVER COURSE (due to meandering and splitting up of the main river channel)	PRESENCE OF SMALL ISLANDS, MULTIPLE RIVER CHANNELS, UNEVEN DEPOSITS OF RIVER BED LOAD, AND UNEVEN EROSION OF THE RIVER BED INDICATE A HIGH PROBABILITY OF THE RIVER COURSE SHIFTING IN THE FUTURE.
EROSION OF RIVER BANKS (due to weak unstable banks)	WEAK BANK SLOPES OF HIGHLY WEATHERED ROCK OR ORDINARY EARTH CAN ERODE RAPIDLY WHEN SUBJECTED TO STRONG RIVER CURRENTS. (If you visit the intake location during low flow time in the river, visualise the new water/land boundary at high flood level to assess possible bank erosion).
LOCAL SCOURING (due to obstructions in the river path)	LARGE NATURAL OR MANMADE OBSTRUCTIONS IN THE RIVER LEAD TO LOCAL SCOURING. Heavy scouring caused by these objects can affect intakes built near them.

Side Intakes Need Protection

Side intakes built on river banks must be protected against flood damage and boulder impact:

- they can be built into rock outcrops, see Photograph 1B,
- they can be built between huge boulders, see Photograph 1C, or,
- they can be built behind other protection works, see Photograph 1D.

In some cases, intakes can be built away from the main river and linked to the river by an approach canal. Such intakes are safe against flood and boulder damage, see Photographs 1E and 1F.

Diversion Weirs

When river levels are low (during winter months), diversion or pond-up weirs are needed to direct the water towards the intake. In most cases temporary farmer-built diversions are adequate.

Temporary farmer-built diversions have the advantage that during high flood they will break-up, without ponding the water in front of the intake, thereby minimising the risk of flood flow entering the canal.

If farmer-built diversions are too easily damaged and have to be rebuilt very often, stronger diversion weirs can be built to replace them.

Gabions are most suitable for building diversion weirs because they are strong and flexible, and the stones needed for filling the gabions can be found locally. Gabion weirs must be designed and constructed properly for maximum effectiveness.

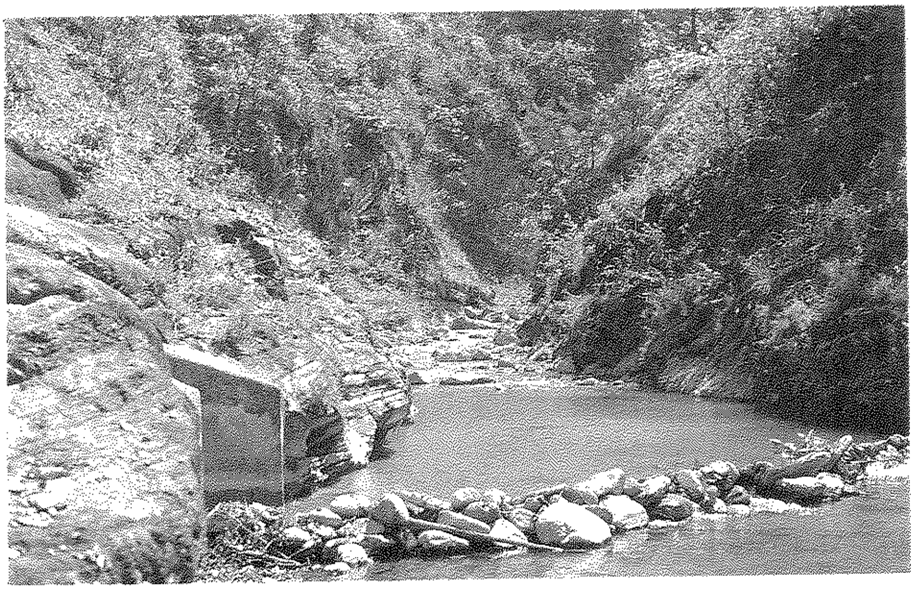
Diversion weirs must be correctly placed to:

- divert the river flow towards the intake during low flow, and
- prevent erosion of the opposite bank during high flood in the river.

Weirs for Ponding Water

Some side intake locations may require the ponding-up of water in front of the intake, particularly during times of low flow in the river.

Gabions are suitable for constructing ponding weirs but they need to be built across the river bed from bank to bank and made leakproof. Geotextile membranes must be provided between the gabions, and between the gabions and the soil foundation, in order to make the gabion weirs leakproof



Photograph 1B
Side Intake Built into a Rock Outcrop

The rock outcrop provides protection against erosion and impact damage to the side intake.

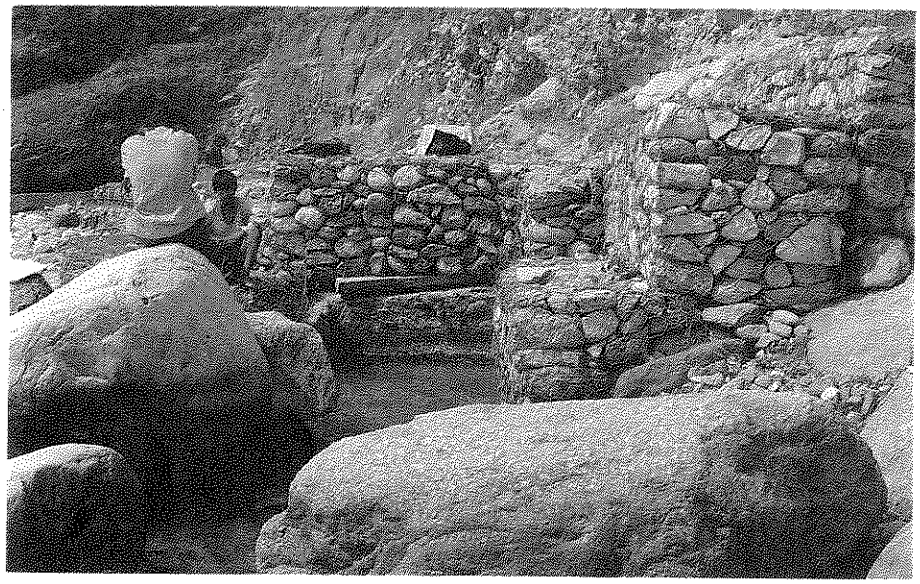
A temporary farmer-built weir diverts flow into the intake.

The farmers use branches and river boulders to build temporary diversion weirs.

When heavy floods occur in the river the temporary diversion weir breaks up, preventing ponding-up of water near the intake.

This prevents/reduces flood water entry into the intake.

This is the farmers' way of providing a safety arrangement against flood damage.



Photograph 1C
Side Intake Built Between Large Boulders

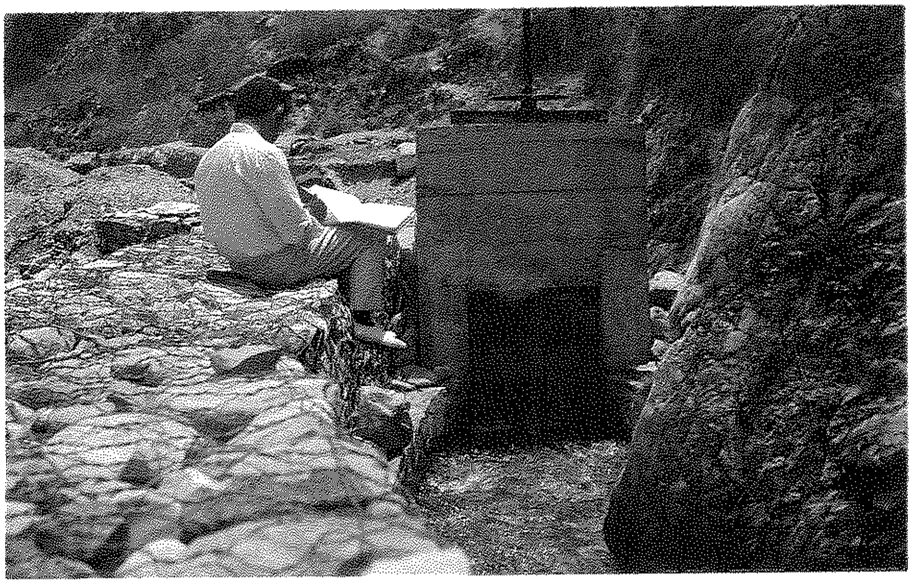
Large boulders can protect side intakes by deflecting flood flow away from them.

They can absorb much of the impact force of rapidly flowing water.

They can also provide adequate anchorage for any concrete or masonry work required for the intake.

WARNING

Local scouring may be induced if large boulders project too much into the river bed.

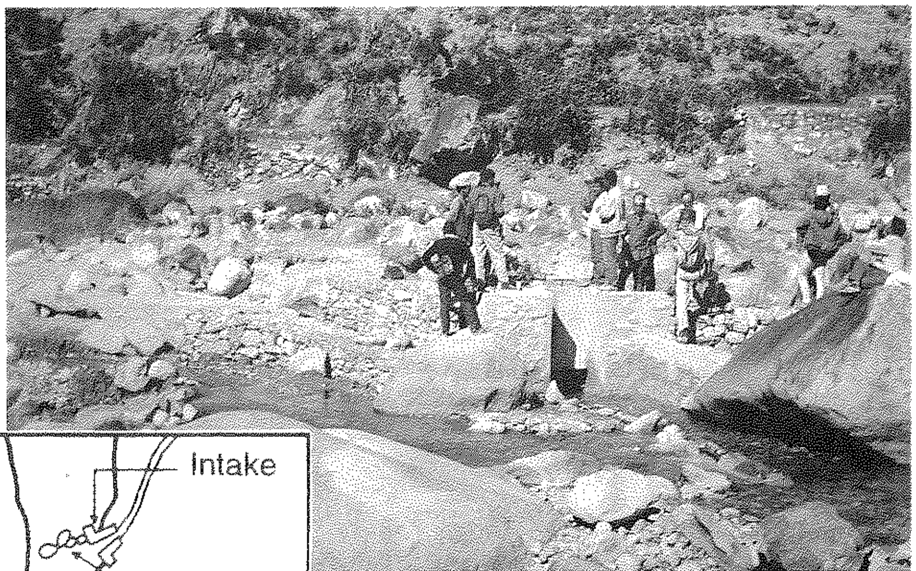


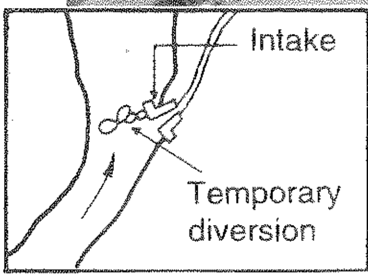
Photograph 1D
Side Intake Built Behind Gabion Protection

Strong gabions can provide protection by deflecting flood flow away from side intakes.

The gabions must be heavy and have adequate aprons.

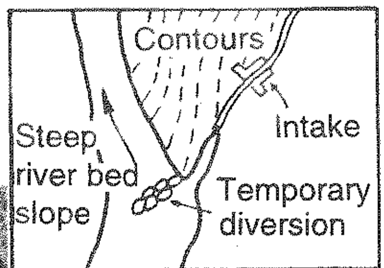
The foundation of such gabion works must be set below the maximum probable scour level of the river bed.

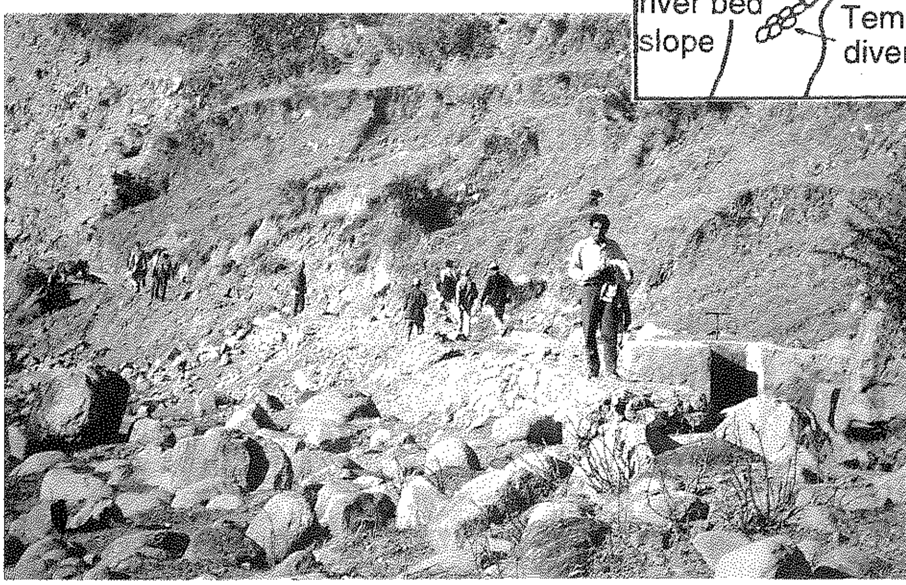




Photograph 1E
Flood Effect on Side Intakes Located on the Bank of the Main River Course

Side intakes are sensitive to floods. This side intake is almost within reach of the maximum flood level line. It is therefore more affected by changes in flood levels





Photograph 1F
Flood Effect on Side Intakes Located Away From the Main River Course

This intake* is well above the maximum flood level line. It is therefore less affected by changes in flood levels.

* This situation may occur when the river bed near the intake location has a steep gradient.

Guidelines for Small Diversion Weirs

- Build low weirs to divert or pond-up water for side intakes.
- Avoid building weirs across the river from bank to bank - unless ponding-up of water is necessary during the winter low-flow seasons.
- Avoid building long, spur type weirs perpendicular to the river that will divert the river flow towards the opposite bank. This will cause erosion of the opposite bank and lead to river flow bypassing the intake in the future.
- Do not build more than half a metre above the existing river bed - the river regime is affected when large obstructions are built across its path.
- Provide adequately deep foundations of up to maximum scour depth - maximum scour is a function of the maximum discharge intensity in the river.
- Provide a launching apron of sufficient length - aprons prevent structural failure of gabion works caused by erosion of foundations.
- Provide gabion boxes large enough to withstand strong river currents: check structural stability of gabion against sliding and overturning.

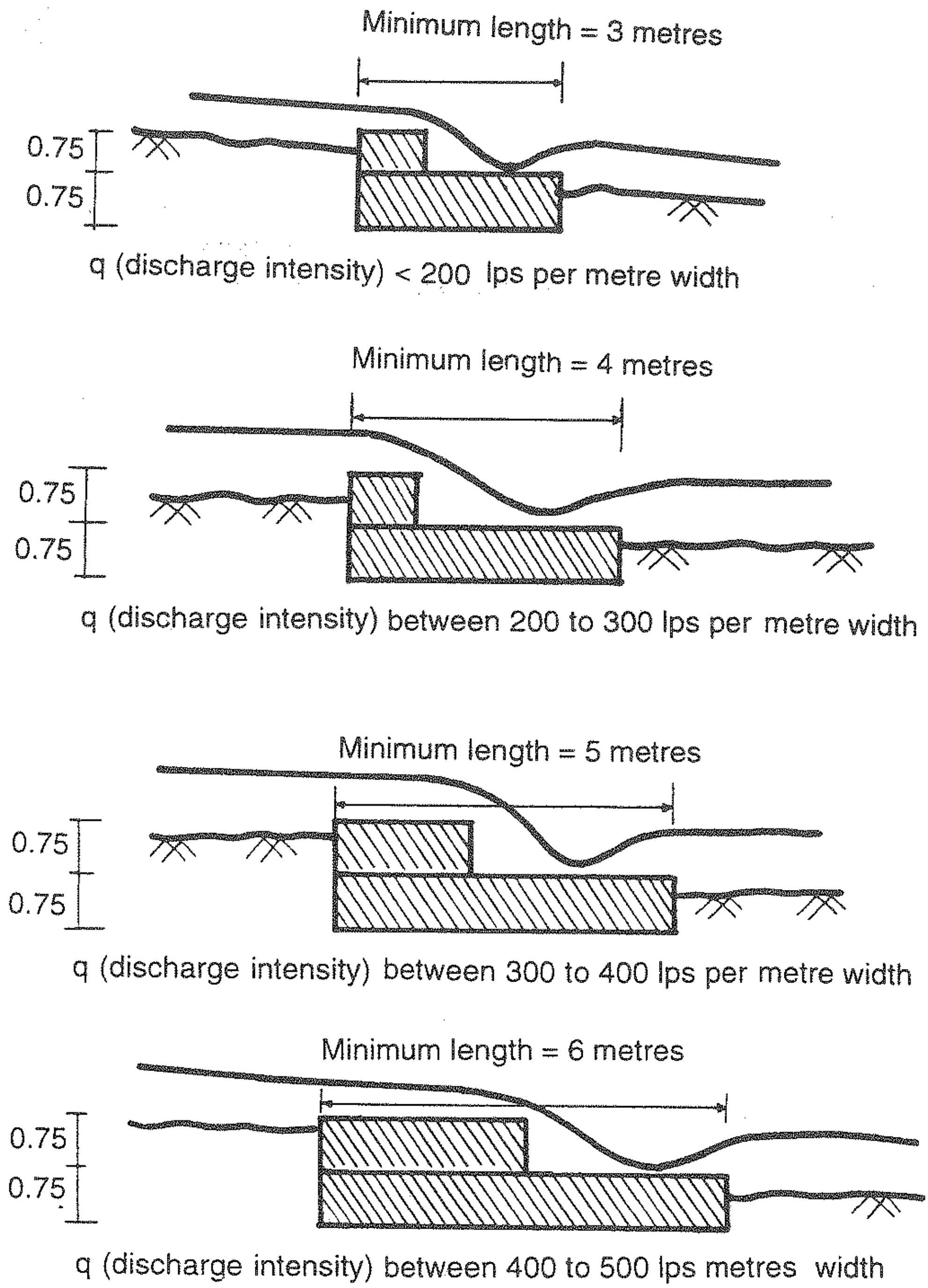
Gabion weir designs will vary with maximum intensity of river flow.

Suggested gabion weir cross-sections are given in Figure 1.8. If winter discharges are very low, gabion weirs must be made leakproof. Total leakproofing is difficult and is also undesirable from the downstream users' point of view - traditional farmer methods using mud and dead leaves for leakproofing are recommended.

Note: Bank to bank, low, leakproof gabion weirs can however be used to raise eroded river bed levels near existing side intakes where river bed erosion is taking place or has already taken place.

These can be built with sloping crests and central or side spillways, depending on requirements.

Figure 1.8
Typical Dimensions for Gabion Diversion Weirs across Small Rivers



Note: All weirs must be built on level non-erodible foundations. If foundations are erodible then they must be founded below maximum probable scour depth.

Effect of Changing River Water Level on Side Intakes

Side intakes are sensitive to river water levels.

When situations permit, it is advisable to build side intakes away from the river bank. Such locations are common when the river bed drops rapidly near the location of the intake. Intakes away from the river bank are more safe from river flood damage.

Design of Side Intakes

In its simplest form, a side intake consists of an ungated orifice in a masonry wall. The water entering the orifice is carried away to a stilling basin/settling pool by means of a rectangular masonry canal (also called a link canal).

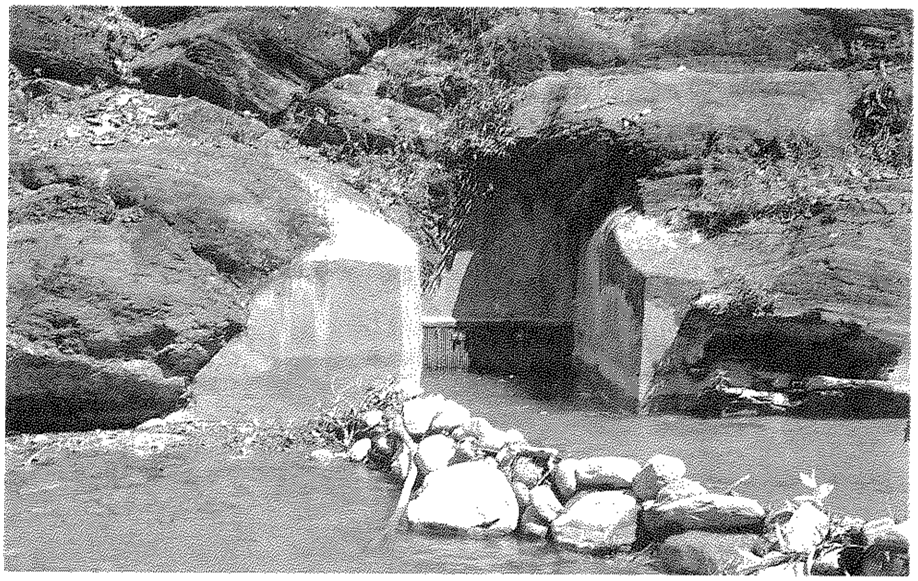
A masonry link canal is preferred because of the need to maintain silt-carrying velocities in the link canal. The size of the orifice is an important factor in the design of a side intake. A very small orifice will not allow sufficient water intake, while a very large orifice can allow flood water to enter and cause damage to the canal.

The design method is as shown below:

Step 1. Select a suitable size of orifice in relation to the required discharge (see Photograph 1G). Choose rectangular dimensions with width equal to, or greater than, twice the height of the orifice.

The orifice size is usually determined in consideration of the low-flow period in the river *(Baisak)*.

The chosen dimensions must, however, be checked to ensure the safety of the canal during high river flow periods *(Bhadra)*.



Photograph 1G
A Side Intake with a Well-Proportioned Orifice Opening

The size of the orifice opening MUST bear a sensible relation to the amount of water that needs to be extracted from the river. Recommended width to depth ratio of the orifice opening equals 2:1 approximately.

Large openings increase the risk of flood water entry into the canal.

Opening size must be more or less equal to the size of the link canal that connects the intake to the settling basin.

Trash racks such as the one shown in the photograph above should only be used in cases where they are easily accessible for cleaning during the monsoon.

Step 2. Compute discharge using appropriate formula.

During low-flow periods the flow through the orifice is usually submerged. During high flood levels the flow pattern through the same orifice may change into a shooting flow or remain submerged depending on the river water level and the hydraulic parameters of the link canal, see Figure 1.9 for appropriate formula.

Step 3. Check maximum intake flow at high flood level.

The link canal and automatic spill of the stilling basin must be adequate to cope with the expected intake flow at high flood level in the river, as computed using the appropriate formula.

If conditions of Step 3 cannot be satisfied, proceed to Step 4.

Step 4. Re-design using following options.

Option 1

Try different combinations of orifice size, link canal capacity and auto-spilling capacity of the settling basin.

Option 2

If Option 1 is not feasible, provide a control gate at the orifice.

Option 3

Provide a “double orifice” intake.

Double orifice type intakes are suitable for rivers with large variations in water levels between normal and flood times.

See the PDSP Design Manuals, Part D2, Vol. 1, Chapter 11.4.3 and Part D2, Vol. 3, example T9 for detailed design procedures.

Gates for Intake Structures

Steel gates or wooden gates?

Wooden gates with few steel parts, which can be fabricated by village carpenters, are most suitable for use with small intakes in small schemes in the hills. Although they need to be replaced more often than steel gates, replacement wooden gates can be easily fabricated and fitted by the villagers. A damaged or jammed imported steel gate may never be replaced due to lack of money. However, steel gates are more appropriate for large intakes with higher discharges.

Boulder impact can damage a steel gate by bending it. Bent gates soon become jammed when the operators try to open or close the gate.

A gate jammed in an open position can allow floods into the canal. Therefore, when providing gates, especially steel gates that are expensive to replace, adequate measures must be taken to prevent boulder damage. Steel gates, and parts of gates, tend to get stolen from remote intakes: pilferage-proof designs can partly solve this problem but can make replacement very difficult.

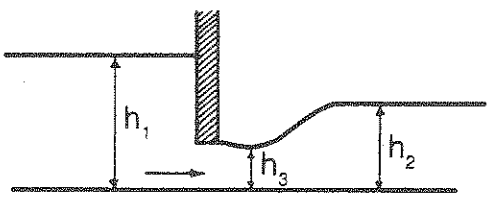
Future Plans for Protecting and Preserving the Intake

River beds and banks are continually changing. Ideally, an intake should be located where these changes are likely to take place only very slowly. Nevertheless, some changes in the river bed and banks can occur, either as a natural process little influenced by the intake, or as a result of the presence of the intake itself. A side intake that diverts high flow from the river can influence local changes in the river bed and river bank. It is therefore necessary to monitor these changes and to provide remedial measures to prevent the intake falling into disuse. If local landform changes are foreseen then it is advisable to take preventive measures because these will be less costly than remedial measures.

Figure 1.9
Hydraulics of Free Flow and Submerged Flow Through an Orifice

Free flow can occur only when the downstream flow depth in the canal is equal to or less than the sequent depth, h_2.

Free Flow



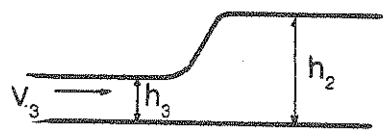
$$Q = C_d C_v\, b\, a^{3/2} \sqrt{2g\left(\frac{h_1}{a} - 0.63\right)}$$

Where $C_d = 0.6$
$C_v = 1$

Sequent depth, h_2, is a function of Froude Number, F.

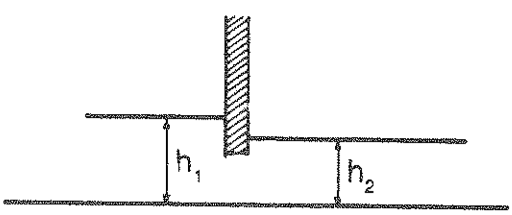
$$F = \frac{V_3}{gh_3}$$

$$\frac{h_2}{h_3} = 0.5\{\sqrt{1+8F^2} - 1\}$$



When the downstream water depth in the link canal is greater than the sequent depth, the orifice will become submerged and submerged flow equations will apply.

Submerged Flow



$$Q = C_d C_v\, b\, a \sqrt{2g(h_1 - h_2)}$$

Where $C_d = 0.6$
$C_v = 1$
b = width of orifice
a = height of orifice

Which Design?

The PDSP Design Manuals discuss three alternative side intake designs:

- simple side intake (masonry headwall and restricted opening),
- side intake with small sediment trap and forebay, see Figure 1.10,
- double orifice intake, see Figure 1.11.

The simple side intake is very often the most desirable solution because the farmers can control the intake of water with just one gate. A suitably designed link canal, will bring most of the silt entering the canal to the settling basin where it can be flushed away, either continuously, periodically or manually, depending on the availability of water.

A further technical refinement would be to build a sediment trap immediately after the intake. Two vertical gates, as shown in Figure 1.10, need to be installed with this arrangement. The first gate is not essential in small schemes where the source river is not very big. The second gate is the main control on canal discharge, and is intended to protect the canal from high velocity and turbulence during high flood levels in the river. There are both advantages and disadvantages to this design - these are explained later on.

An even more elaborate refinement is the double orifice intake. As the name implies, the intake consists of two openings, one at the river bank and the other a little inside on the hill slope.

The principle of the design is as follows:

Variability of upstream river water levels means that the first orifice may deliver an excessive flow to the canal during times of high river levels. A sidespill and a second orifice are therefore necessary to further control the intake into the canal. Again, there are both advantages and disadvantages to this design - these are explained later on.

Advantages and Disadvantages of a Simple Side Intake

Advantages

Easy to construct.

Only one gate, as opposed to two in the other designs, means that the farmers can easily learn how to set the gate for different upstream river levels.

Disadvantages

The link canal must have sufficient slope to generate silt-carrying velocity to transport the silt to the settling basin, implying a significant drop from intake to the stilling basin.

If the link canal is short, high velocity in the link canal can interfere with the settling of sediment in the settling basin.

Advantages and Disadvantages of a Bank Intake with an Adjoining Sediment Trap

Advantages

Sediment can be trapped very near the intake before it enters the canal, particularly useful if the river carries sediment all year round.

Disadvantages

Two orifice openings: to keep head losses low during low river levels designers will tend to use large wide orifice openings and recommend gate operation during floods. Flood water will enter the canal if these gates are accidentally left open during a flood.

(See example T8 of the PDSP Design Manuals, Part D2, Vol. 3.)

Site conditions may not allow large sediment traps to be built adjoining the intake.

Advantages and Disadvantages of a Double Orifice Intake

Advantages

Can function automatically if properly designed with appropriate orifice openings and spill length.

A double orifice intake, with orifice size of 0.5 x 0.35m (both orifices) and a spill length of 2m, is capable of extracting 250 litres of water per second from a river source with a water level variation of 1.5m, with only a small margin of increase during high floods.

(See example T9 of the PDSP Design Manuals, Part D2, Vol. 3.)

Disadvantages

Large head loss because of two orifice openings.

Requires a suitable spill location within 20 to 30 metres of the first orifice otherwise the structure will be very long and expensive.

The link canal curvature is often around the hillside. This affects the automatic sediment ejecting process of the sidespill, requiring manual operation of the flush gates across the sediment ejection channel.

Listen to the Users' Point of View

A good intake design is one that the farmer knows how to operate and maintain.

In most cases, the farmers would be happy with a simple gated bank intake because it is very similar to their traditional intake and gives them more freedom to vary, or shut down completely, the intake flow.

Complicated intakes with several gates only confuse the farmer; he may operate the intake contradictory to the rules.

Complicated intakes and more gates will need more maintenance.

Selection of the type and location of side intakes must be made jointly with the users of the intake.

Figure 1.10
Bank Intake Structure with Small Sediment Trap and Forebay

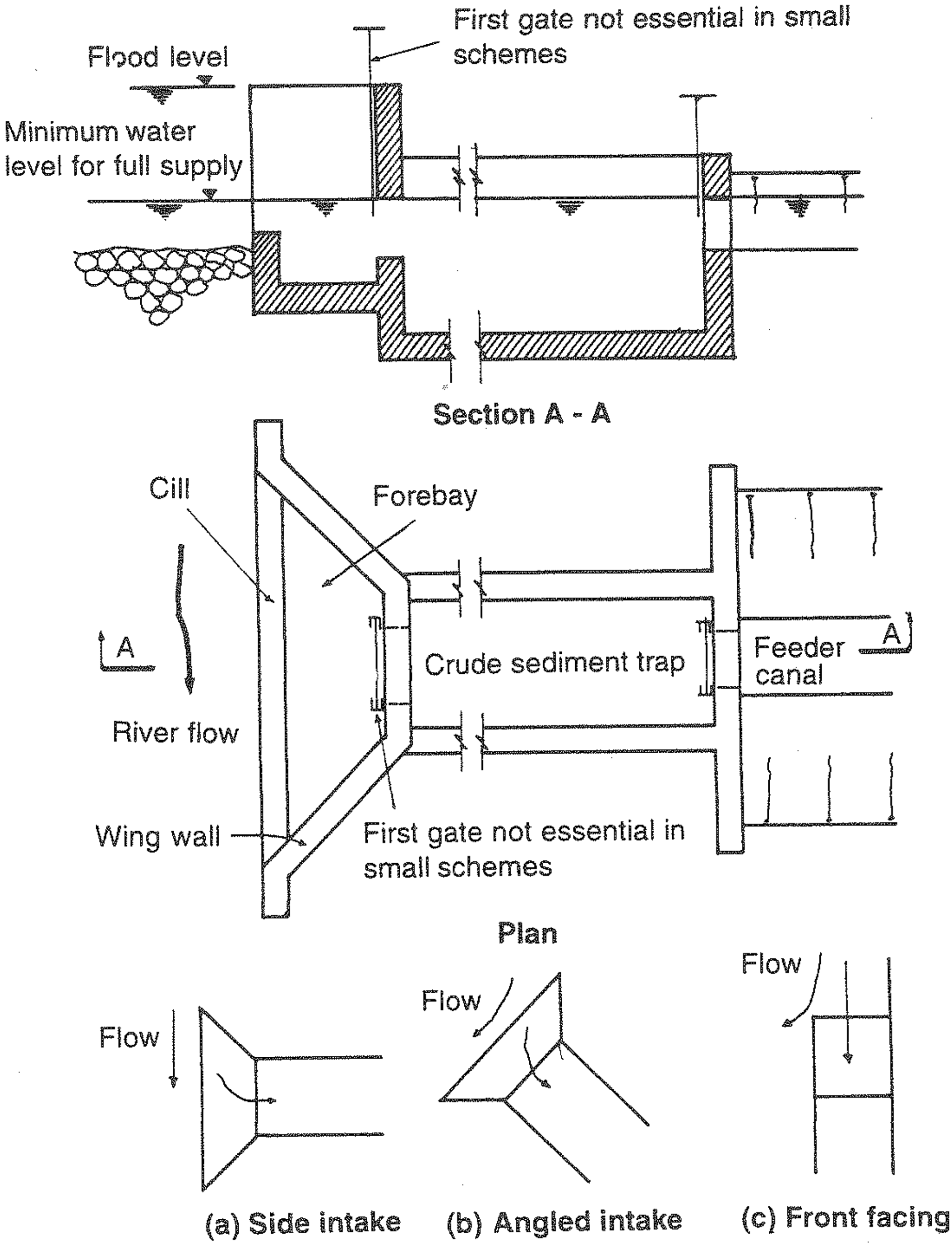


Figure 1.11
Double Orifice Intake