Term	Definition
Wet Well	A pump intake basin or sump having a confined liquid volume with a free liquid surface designed to hold liquid in temporary storage to even out variations between inflow and outflow. *See* Forebay.

9.8.8.2 Nomenclature

Table 9.8.8.2 — Nomenclature

Sym.	Definition	Reference Location
A	Distance from the pump inlet centerline to the intake structure entrance	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
A_e	Empty area	Table C.1, Table C.2
A_t	Total area	Table C.1, Table C.2
a	Length of constricted bay section near the pump inlet	Fig. 9.8.2.1.4b, Table 9.8.2.1.4a
B	Distance from the backwall to the pump inlet bell centerline	Fig. 9.8.2.1.4a and b, Table 9.8.2.1.4a
C	Distance between the inlet bell and floor	Fig. 9.8.2.1.4a and b, Table 9.8.2.1.4a
C_b	Inlet bell or volute clearance for circular pump stations	9.8.2.3.2.1, 9.8.2.3.2.4, Fig. 9.8.2.3.1a, b, c, d, e, f
C_f	Floor clearance on circular pump stations	9.8.2.3.2.1, 9.8.2.3.2.2, Fig. 9.8.2.3.1a, b, c, d, e, f
C_w	Wall clearance on circular pump stations	9.8.2.3.2.1, 9.8.2.3.2.3, Fig. 9.8.2.3.1a, b, c, d, e, f
D	Inlet bell diameter or inlet bell design diameter (may also refer to pipe inside diameter if a pipe is used instead of a bell inlet)	9.8.2.1.3, 9.8.2.1.4, Eq. 9.8.2.1.4-1, Eq. 9.8.2.1.4-2, Fig. 9.8.2.1.4a, Fig. 9.8.2.1.4b, Table 9.8.2.1.4a, Table 9.8.2.1.4b, 9.8.2.4.7, 9.8.2.4.8, 9.8.2.4.9, Fig. 9.8.2.6.5, 9.8.2.7.2, 9.8.2.7.4, 9.8.3.2.3.1, 9.8.3.2.3.2, Fig. 9.8.3.2.2, 9.8.3.3.3, Fig. 9.8.3.4.4, 9.8.3.4.4.1, 9.8.4.3, 9.8.5, Table 9.8.5.2a, b, Fig. 9.8.5.2a, b, 9.8.6.2, Eq. 9.8.6-1, Fig. 9.8.6.3, Fig. A.10, Fig. A.11
D	Tank outlet fitting inside diameter	9.8.2.5.4, Fig. 9.8.2.5.5, 9.8.2.5.5
D_1	Vertical can riser inside diameter	Fig. 9.8.2.6.4
D_1	Can inside diameter	Fig. 9.8.2.6.5, Fig. G.1
D_b	Inlet bell or volute diameter	9.8.2.3.2.1, 9.8.2.3.2.2, 9.8.2.3.2.3, 9.8.2.3.2.4, 9.8.2.3.2.6, Fig. 9.8.2.3.1a, b, c, d, e, f
D_e	Diameter of circle with area equivalent to rectangular area at FSI entrance	9.8.2.2.3, Eq. 9.8.2.2.3-1
D_M	Well motor cooling shroud diameter	Fig. G.1

Table 9.8.8.2 — Nomenclature (*continued*)

Sym.	Definition	Reference Location
D_p	Inside diameter of approach pipe	C.2, C.4, Table C.1, Table C.2
D_s	Sump diameter	9.8.2.3.2.1, 9.8.2.3.2.5, Fig. 9.8.2.3.1a, Fig. 9.8.2.3.1b
d	Diameter at outlet of formed suction intake	Fig. 9.8.2.2.2, Type 10 formed suction intake
d	Diameter of the pipe at the swirl meter	Eq. 9.8.4.5-1, Fig. 9.8.2.3.1b
EGL	Energy grade line	C.4.3
F	Froude number (general)	9.8.4.3, Eq. 9.8.4.3-1
F_D	Froude number (calculated at diameter D)	Fig. 9.8.2.1.4a, Eq. 9.8.2.1.4-1, Eq. 9.8.2.1.4-2, Table 9.8.2.1.4a, 9.8.2.1.4, 9.8.2.2.3, Eq. 9.8.2.2.3-1, 9.8.2.5.4, 9.8.2.7.4, Fig. 9.8.3.2.2, Eq. 9.8.6.2-1, 9.8.6.2
F_r	Froude number ratio, F_m/F_p	9.8.4.3, Eq. 9.8.4.3-2
F_m	Froude number of physical model	9.8.4.3, Eq. 9.8.4.3-2
F_p	Froude number of prototype	9.8.4.3, Eq. 9.8.4.3-2
G	Geometry	9.8.6.2
g	Acceleration of gravity	9.8.2.1.4, Eq. 9.8.2.1.4-1, 9.8.2.5.4, 9.8.4.3, Eq. 9.8.4.3-1, 9.8.6.2, 9.8.6.3
H	Minimum liquid depth	Fig. 9.8.2.1.4a and b, Fig. 9.8.2.1.4b, Table 9.8.2.1.4a
H_f	Height of FSI	Fig. 9.8.2.2.2, 9.8.2.2.3, Fig. 9.8.2.4.1b
h	Minimum height of constricted bay section near the pump	Fig. 9.8.2.1.4b, Table 9.8.2.1.4a
L	A characteristic length (usually bell diameter or submergence)	9.8.4.3, Eq. 9.8.4.3-1
L_r	Geometric scale of physical model	Eq. 9.8.4.3-3, Eq. 9.8.4.3-4, Eq. 9.8.4.3-5
L_v	Characteristic length of a cubic cage-type vortex suppressor	Fig. A.13
N_Γ	Circulation number	9.8.6.2
n	Revolutions/second of the swirl meter	Eq. 9.8.4.5-1
n	Manning's number	C.4.2, Tables C.1 and C.2
Q	Flow	Table 9.8.5.2a and b, Fig. 9.8.5.2a and b, 9.8.6.2, 9.8.7.3, Fig. 9.8.6.3a and b
Q	Inflow into sump	B.2, Eq. B.1-1, Eq. B.1-2, Eq. B.1-3, Eq. B.1-4
Q_m	Flow scale in physical model	Eq. 9.8.4.3-4
Q_p	Flow scale in prototype	Eq. 9.8.4.3-4

Table 9.8.8.2 — Nomenclature (*continued*)

Sym.	Definition	Reference Location
Q_r	Flow scale ratio, physical model/prototype	Eq. 9.8.4.3-4
R	Reynolds number	9.8.4.3
r	Radius of curvature	Fig. 9.8.2.2.2, 9.8.3.2.3, Fig. 9.8.3.2.2
r	Radius of tangential velocity component	9.8.6.2
S	Minimum submergence depth	Fig. 9.8.2.1.4a, Eq. 9.8.2.1-2, 9.8.2.1.4, Table 9.8.2.1.4a, 9.8.2.2.3, Fig. 9.8.2.2.2, 9.8.2.3.2.1, Fig. 9.8.2.3.1a, Fig. 9.8.2.3.1b, c, d, e, f, Fig. 9.8.2.4.1b, 9.8.2.5.4, Fig. 9.8.2.5.4, Fig. 9.8.2.7, 9.8.2.7.4, Fig. 9.8.3.2.2, Fig. 9.8.3.4.4, 9.8.6.3, 9.8.6.2, Eq. 9.8.6.2-1, Fig. 9.8.6.3a and b
T	Total cycle time in seconds	B.2, Eq. B.2-1, Eq. B.2-2, Eq. B.2-3, Eq. B.2-5
T_m	Time scale of physical model	Eq. 9.8.4.3-5
T_p	Time scale of prototype	Eq. 9.8.4.3-5
T_r	Time scale ratio, physical model/prototype	Eq. 9.8.4.3-5
u	Average axial velocity (such as in the suction bell)	9.8.4.3, Eq. 9.8.4.3-1
u	Average axial velocity at the swirl meter	Eq. 9.8.4.3-6
V	Velocity	Eq. 9.8.2.1.4-1, 9.8.2.1.4, 9.8.2.2.3, 9.8.2.5.4, 9.8.2.5.5, Fig. 9.8.2.5.5, Fig. 9.8.2.6.4, 9.8.2.7.4, 9.8.5, Table 9.8.5.2a, b, Fig. 9.8.5.2a, b, 9.8.6.2
Vol	Active sump volume	B.2, Eq. B.2-1, Eq. B.2-2, Eq. B.2-3, Eq. B.2-5
V_c	Cross-flow velocity	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
V_m	Velocity scale in physical model	Eq. 9.8.4.3-3
V_p	Velocity scale in prototype	Eq. 9.8.4.3-3
V_r	Velocity scale ratio, physical model/prototype	Eq. 9.8.4.3-3, Eq. 9.8.4.3-4, Eq. 9.8.4.3-5
V_t	Tangential velocity	9.8.6.2
V_x	Pump bay velocity	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
VT	Vortex type	9.8.6.2
We	Weber number	9.8.4.3
W	Pump bay entrance width	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a, Fig. 9.8.2.1.4b
W	Width of FSI	9.8.2.2.3, Fig. 9.8.2.2.2, Fig. 9.8.2.4.1b
w	Constricted bay width near the pump	Fig. 9.8.2.1.4b, Table 9.8.2.1.4a

Table 9.8.8.2 — Nomenclature (*continued*)

Sym.	Definition	Reference Location
X	Pump bay length	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
Y	Distance from pump inlet bell centerline to traveling screen	9.8.2.1.4, Fig. 9.8.2.1.4a,Table 9.8.2.1.4a
y	Depth	Table C.1, Table C.2
Z_1	Distance from pump inlet bell centerline to diverging walls	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
Z_2	Distance from pump inlet bell centerline to sloping floor	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
α	Angle of floor slope	Fig. 9.8.2.1.4a, Table 9.8.2.1.4a
β	Angle of wall divergence	9.8.2.1.4, Fig. 9.8.2.1.4a,Table 9.8.2.1.4a
ε	Angle of sidewall of trench	Fig. 9.8.3.2.2
f	A function	9.8.6.2
ρ	Liquid density	9.8.4.3
Γ	Circulation of the flow	9.8.4.3, 9.8.6.2
ν	Kinematic viscosity of the liquid	9.8.4.3
θ	Swirl angle	Eq. 9.8.4.5-1
σ	Surface tension of liquid/air interface	9.8.4.3
ϕ	Angle of divergence from constricted area to bay walls	Fig. 9.8.2.1.4b, Table 9.8.2.1.4a

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Appendices

These appendices are not part of this standard, but are presented to help the user in considering factors beyond the standard sump design.

Refer to Section 9.8.1 of the standard, which allows for an intake designed to a geometry other than presented in the standard and such as contained in these appendices, to be deemed to comply with the standard, if the intake is tested by prototype testing or a physical model study performed in accordance with Section 9.8.4, and the test results comply with the acceptance criteria in Section 9.8.4.6.

Requirements for a physical model study are given in Section 9.8.4.

Appendix A

Remedial measures for problem intakes

Information in this appendix is not part of this standard, but is presented to help the user in considering factors beyond the standard sump design.

Refer to Section 9.8.1 of the standard, which allows for an intake designed to a geometry other than presented in the standard and such as contained in these appendices, to be deemed to comply with the standard, if the intake is tested by prototype testing or a physical model study performed in accordance with Section 9.8.4, and the test results comply with the acceptance criteria in Section 9.8.4.6

Requirements for physical hydraulic model study are given in Section 9.8.4.

A.1 Introduction

The material presented in Appendix A is provided for the convenience of the intake design engineer in correcting unfavorable hydraulic conditions of existing intakes. None of the remedial measures described herein are part of the standard intake design recommendations provided in Section 9.8. A portion of the material in Appendix A transmits general experience and knowledge gained over many years of improving the hydraulics of intake structures, and such educational material may not include the specific recommendations appropriate for a standard. Corrections described herein have been effective in the past, but may or may not result in a significant improvement in performance characteristics for a given set of site-specific conditions. Other remedial fixes not provided herein may also be effective, and a physical model test is needed to verify whether or not a given remedial design feature results in acceptable flow conditions. This is particularly true because adding a remedial feature to solve one flow problem may have detrimental effects on other flow phenomena of concern.

Appendix A concentrates on rectangular intakes for clear liquids, but the basic principles can be applied to other types of intakes. The material is organized by the general type of hydraulic problem in an upstream to downstream direction, because proper upstream flow conditions minimize downstream remedial changes.

A.2 Approach flow patterns

The characteristics of the flow approaching an intake structure is one of the foremost considerations for the designer. Unfortunately, local ambient flow patterns are often difficult and expensive to characterize. Even if known, conditions are often unique, frequently complex, so it is difficult to predict the effects of a given set of flow conditions upstream from an intake structure on flow patterns in the immediate vicinity of a pump suction.

When determining direction and distribution of flow at the entrance to a pump intake structure, the following must be considered:

- The orientation of the structure relative to the body of supply liquid
- Whether the structure is recessed from, flush with, or protrudes beyond the boundaries of the body of supply liquid
- Strength of currents in the body of supply liquid perpendicular to the direction of approach to the pumps
- The number of pumps required and their anticipated operating combinations

Velocity profiles entering pump bays can be skewed, regardless of whether or not crosscurrents are present. Several typical approach flow conditions are shown in Figure A.1 for rectangular intake structures withdrawing flow from both moving bodies of liquid and stationary reservoirs. Figure A.2 shows several typical approach flow conditions for different combinations of pumps operating in a single intake structure.

The ideal conditions, and the assumptions on which the geometry and dimensions recommended for rectangular intake structures in this section are based, are that the structure draws flow so that there are negligible ambient currents (cross-flows) in the vicinity of the intake structure that create asymmetrical flow patterns approaching any of the pumps, and the structure is oriented so that the boundary is symmetrical with respect to the centerline of the structure. As a general guide, cross-flow velocities are significant if they exceed 50% of the pump bay entrance velocity. Recommendations (based on a physical model study) for analyzing departures from the ideal condition are given in Section 9.8.4.

A.2.1 Open versus partitioned structures

If multiple pumps are installed in a single intake structure, dividing walls placed between the pumps result in more favorable flow conditions than found in open sumps. Open sumps, with no dividing walls, have been used with varying levels of success, but adverse flow patterns can frequently occur if dividing walls are not used. The trench-type intake structure, described in Sections 9.8.2.4 and 9.8.3.2, is a type of open sump that is an exception. Open sumps are particularly susceptible to crosscurrents and nonuniform approach flow patterns. Even if approach flow at the entrance to the structure is uniform, open sumps result in nonuniform flow patterns approaching some of the pumps when operating pumps are arranged asymmetrically with respect to the centerline of the intake structure. This situation can occur when various combinations of pumps are operating or if the intake structure is designed to accommodate additional pumps at some future date. Figure A.3 is an example of flow approaching the pumps in both a partitioned structure and an open sump, both operating at partial flow rate.

The example facilities contain four units with two of the four operating. In both structures, flow is withdrawn from a reservoir with no velocity component perpendicular to the longitudinal centerline of the intake structures. In the partitioned structure, flow enters the bay of pump 1 fairly uniformly. It enters the bay containing pump 2 nonuniformly, with a separation area near the right sidewall. However, the length of the bay relative to its width channels the flow and allows it to become more uniform as it approaches the pump. In Figure A.3, example ii, the dashed line at the wing walls shows a rounded entrance configuration that minimizes flow separation near the entrance to the outer pump bays.

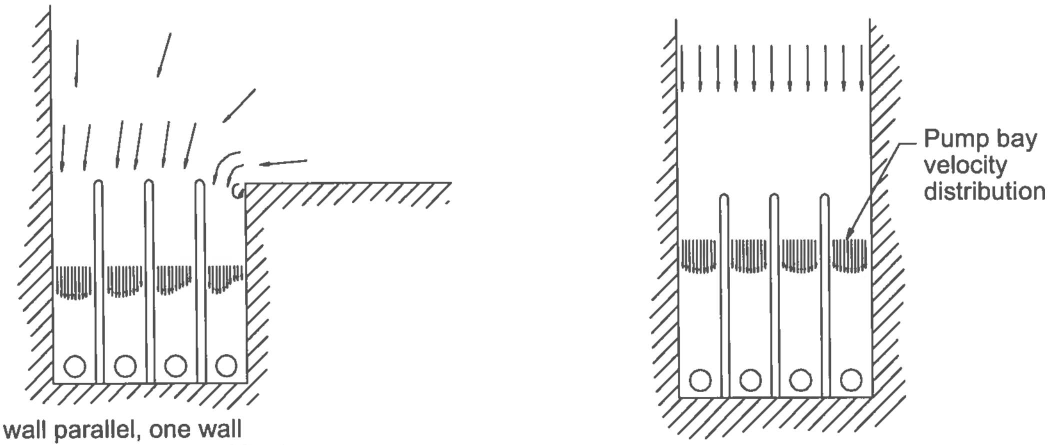
In open sumps (Figure A.3, example i), flow may enter the structure uniformly with respect to the centerline of the structure. However, since the location of the two operating pumps is not symmetrical with the respect to the centerline of the structure, flow separates from the right wall of the structure and approaches pump 2 with a tangential velocity component, greatly increasing the probability of unacceptable levels of preswirl.

If all four pumps in the open sump were to operate simultaneously, approach flow would be reasonably uniform, but other adverse phenomena could be present. For example, when two adjacent pumps are operating simultaneously, submerged vortices frequently form, connecting both pumps.

A.3 Controlling cross-flow

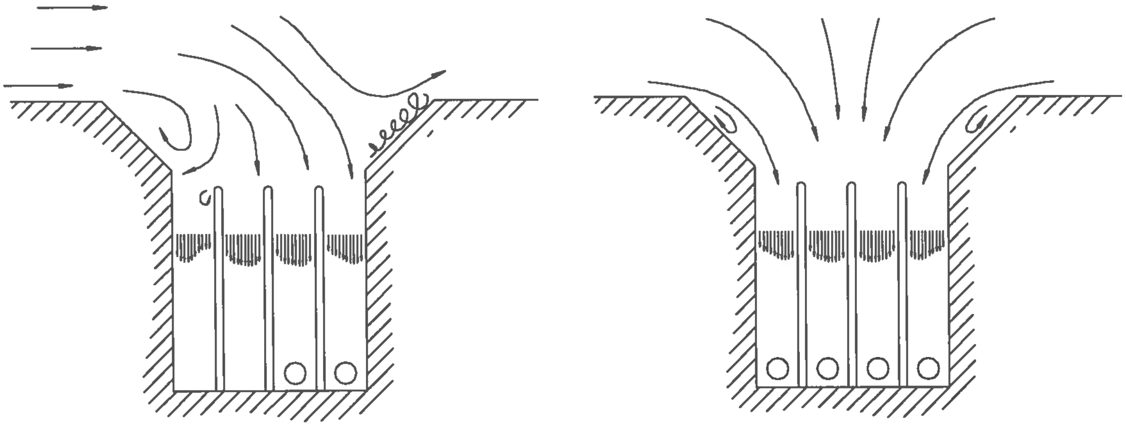
If cross-flow is present (i.e., if the pump station is withdrawing flow from the bank of a canal or stream), trash racks with elongated bars can provide some assistance in distribution flow as it enters the pump bay, but if the flow profile is skewed when it enters the trash rack, it will be skewed as it exits. To be effective in guiding flow, trash racks must be placed flush with the upstream edges of the pump bay dividing walls. In this example the trash rack must be vertical or match the incline of the entrance. Both trash racks and dividing walls must be in line with the stream bank contour. Trash racks recessed from the entrance to pump bays, and through-flow traveling screens have a negligible flow-straightening effect (see Figure A.4).

Partially clogged trash racks or screens can create severely skewed flow profiles. If the application is such that screens or trash racks are susceptible to clogging, they must be inspected and cleaned as frequently as necessary to prevent adverse effects on flow patterns.



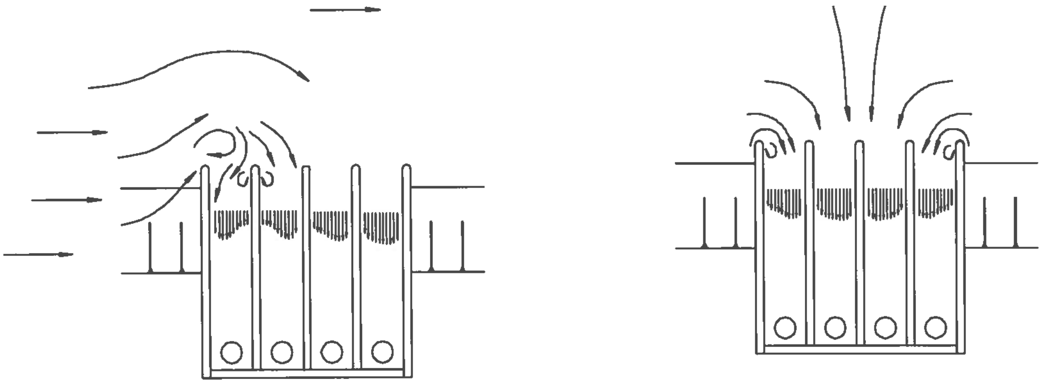
i - One wall parallel, one wall perpendicular to direction of final approach

ii - Straight approach, structure located at the terminus of a long canal



iii - Wing walls, with crosscurrents

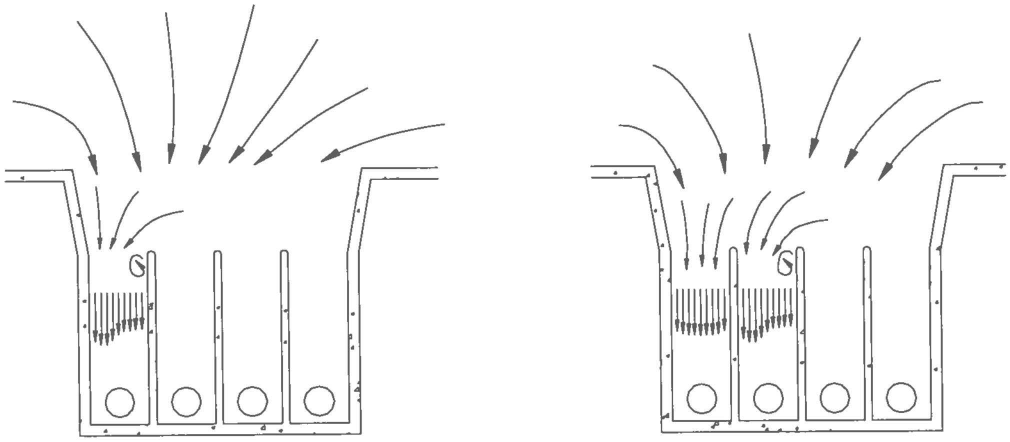
iv - Wing walls, with no crosscurrents



v - No wing walls, with crosscurrents

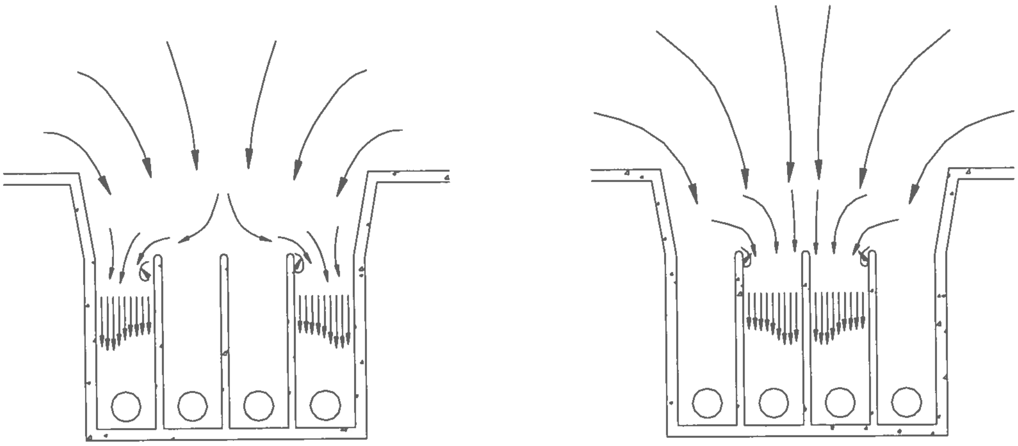
vi - No wing wall, with no crosscurrents

Figure A.1 — Examples of approach flow conditions at intake structures and the resulting effect on velocity, all pumps operating



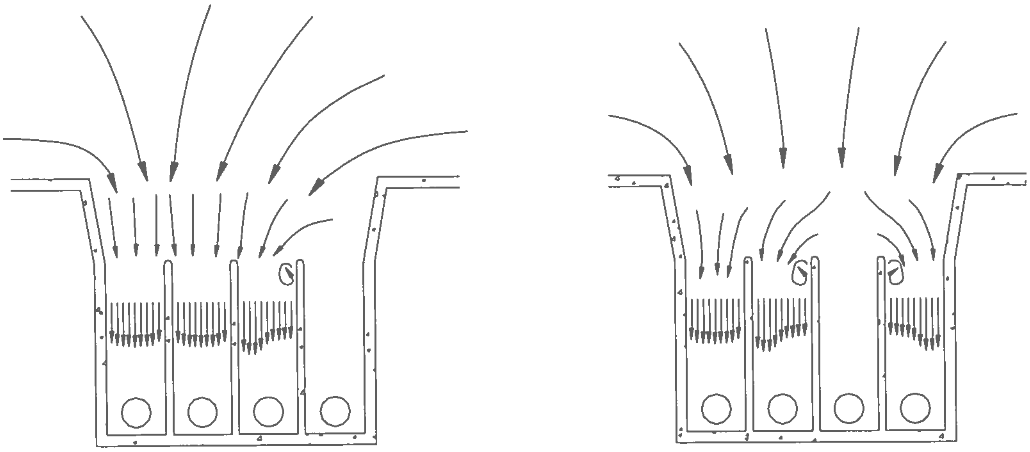
One pump running

Two pumps running



Two pumps running

Two pumps running



Three pumps running

Three pumps running

Figure A.2 — Examples of pump approach flow patterns for various combinations of operating pumps

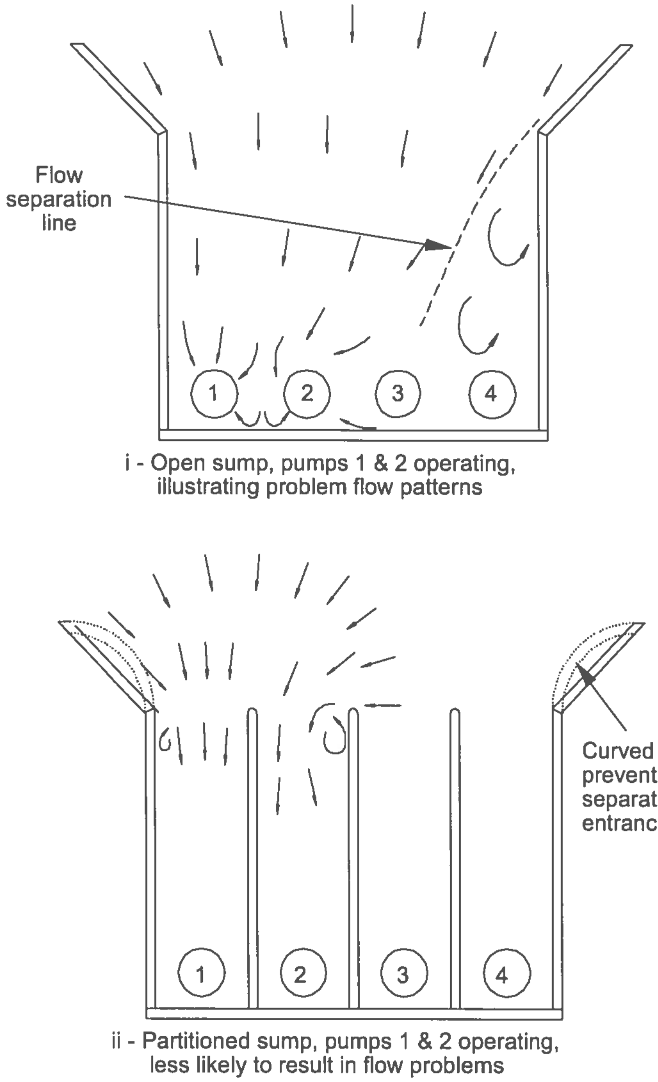


Figure A.3 — Comparison of flow patterns in open and partitioned sumps

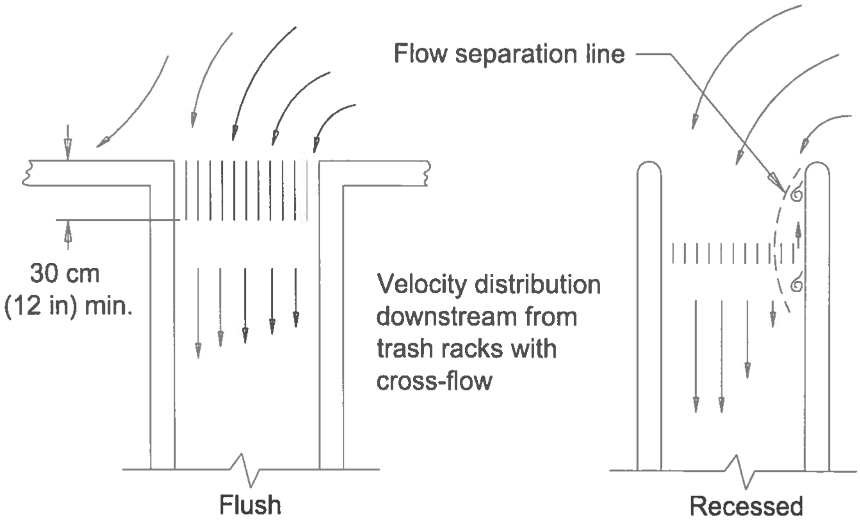


Figure A.4 — Effect of trash rack design and location on velocity distribution entering pump bay