PROJECT: I80-115 C-1,LLC
DW501 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0235
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	1.07

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 34.82 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 11.08 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.45

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 4.99 fps

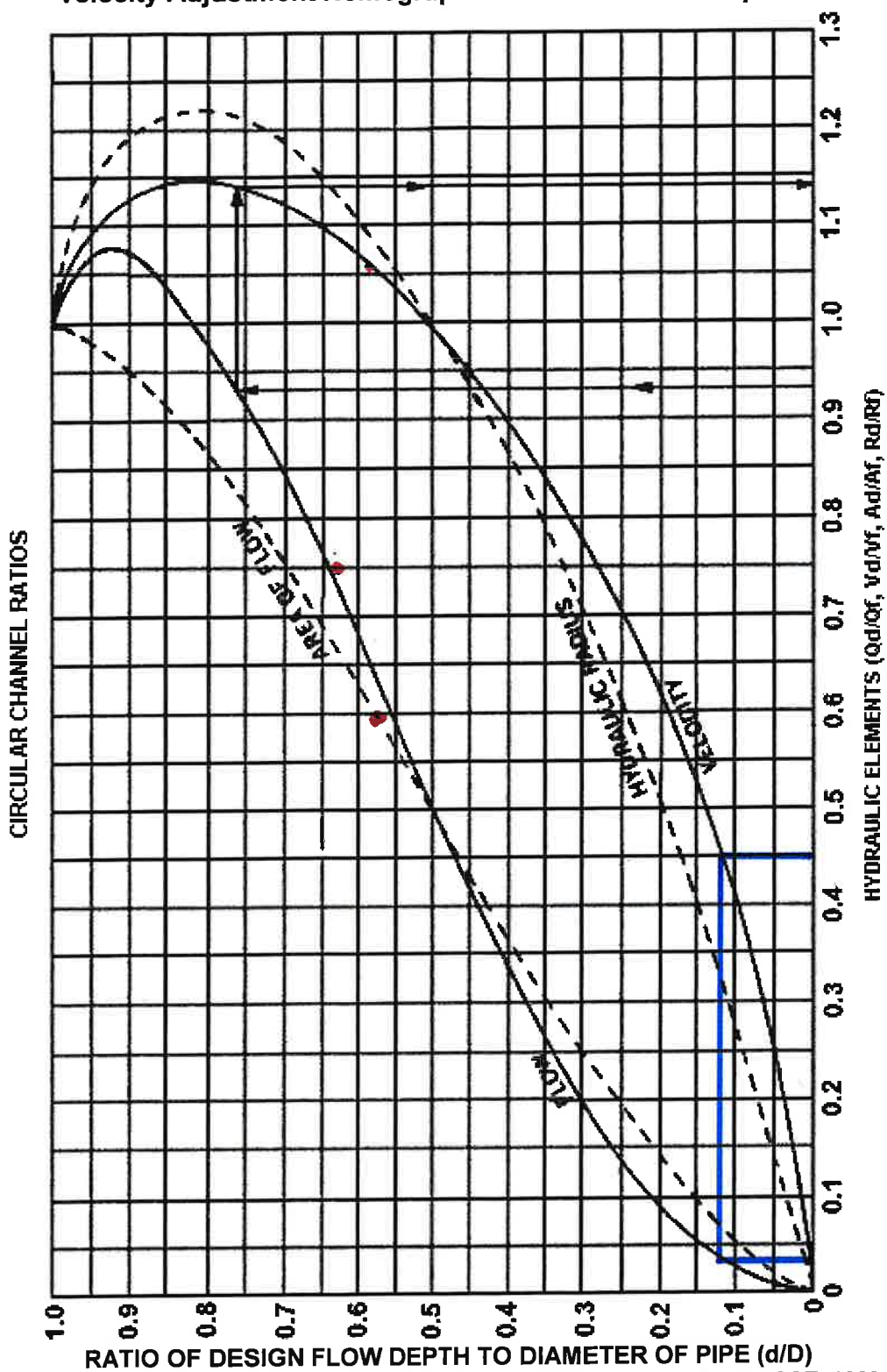
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.03

DW 501

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



$V_d = 4.99$ ft/s

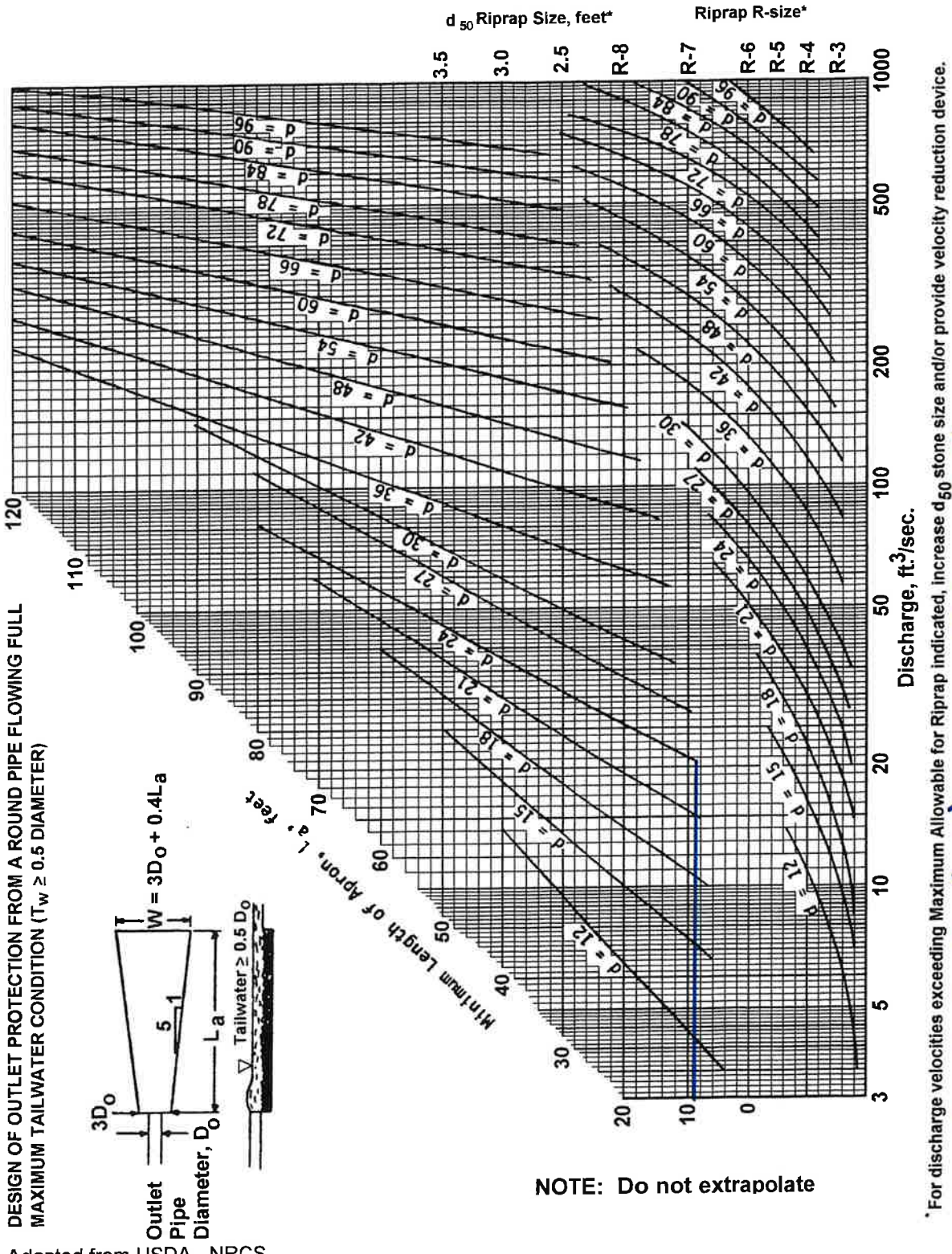
use R-3 Rock

Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 501

FIGURE 9.4
Riprap Apron Design, Maximum Tailwater Condition



*For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

NOTE: Do not extrapolate

Adapted from USDA - NRCS

Not to be used for Box Culverts

$Q_d = 1.07$ cfs (min)

$3D_o = 6$ ft

$W = 6\text{ ft} + 0.4(9\text{ ft}) = 9.6$ ft

use $L_a = 9$ ft

PROJECT: I80-115 C-1,LLC
DW601 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0113
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	6.26

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 24.15 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 7.69 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.84

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 6.46 fps

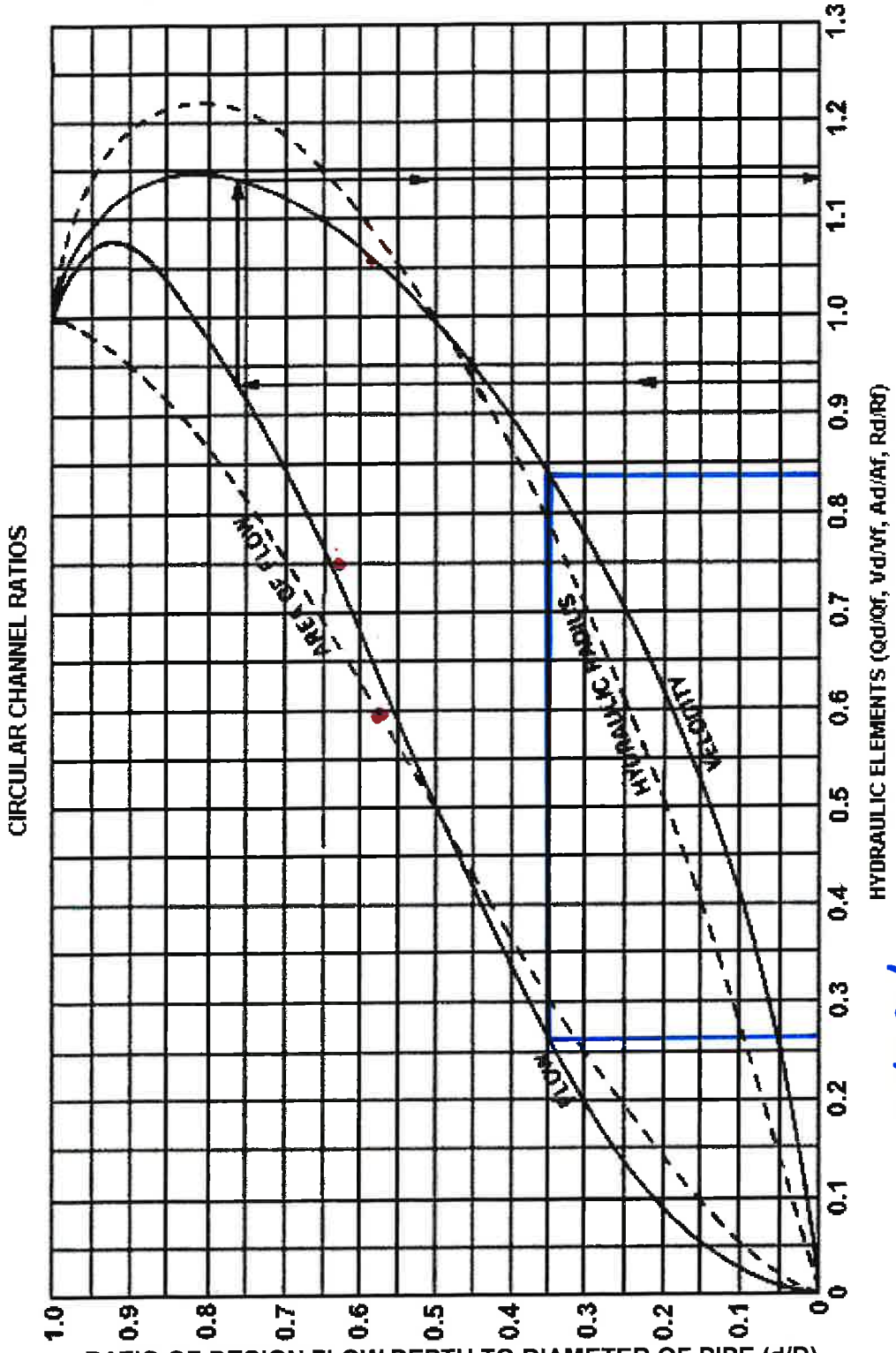
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.26

DW 601

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



$V_d = 6.46$ ft/s

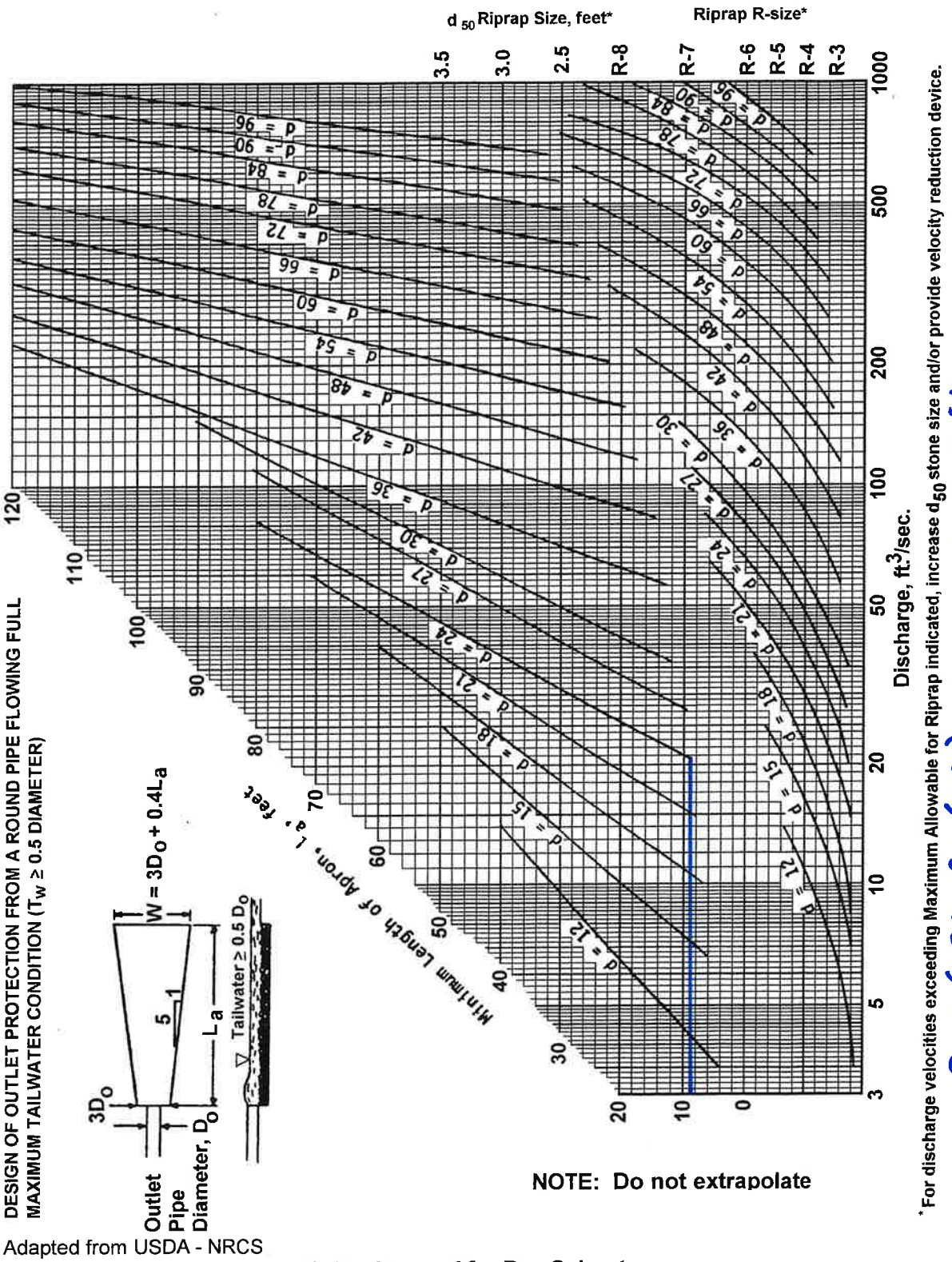
use R-3 Rock

Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 601

FIGURE 9.4
Riprap Apron Design, Maximum Tailwater Condition



Adapted from USDA - NRCS

Not to be used for Box Culverts

$3D_o = 6\ ft$

$W = 6\ ft + 0.4(9\ ft) = 9.6\ ft$

$Q_d = 6.26\ cfs\ (min)$

Use $L_a = 9\ ft$

PROJECT: I80-115 C-1,LLC
DW1001 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0286
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	5.91

* **The full flow capacity of the pipe should be determined from the following equation.**

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 38.42 cfs

* **Use the Continuity Equation to determine the full-flow velocity:**

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 12.23 fps

* **Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:**

= 0.73

* **Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.**

V_d = V_f * Velocity Ratio

V_d = 8.93 fps

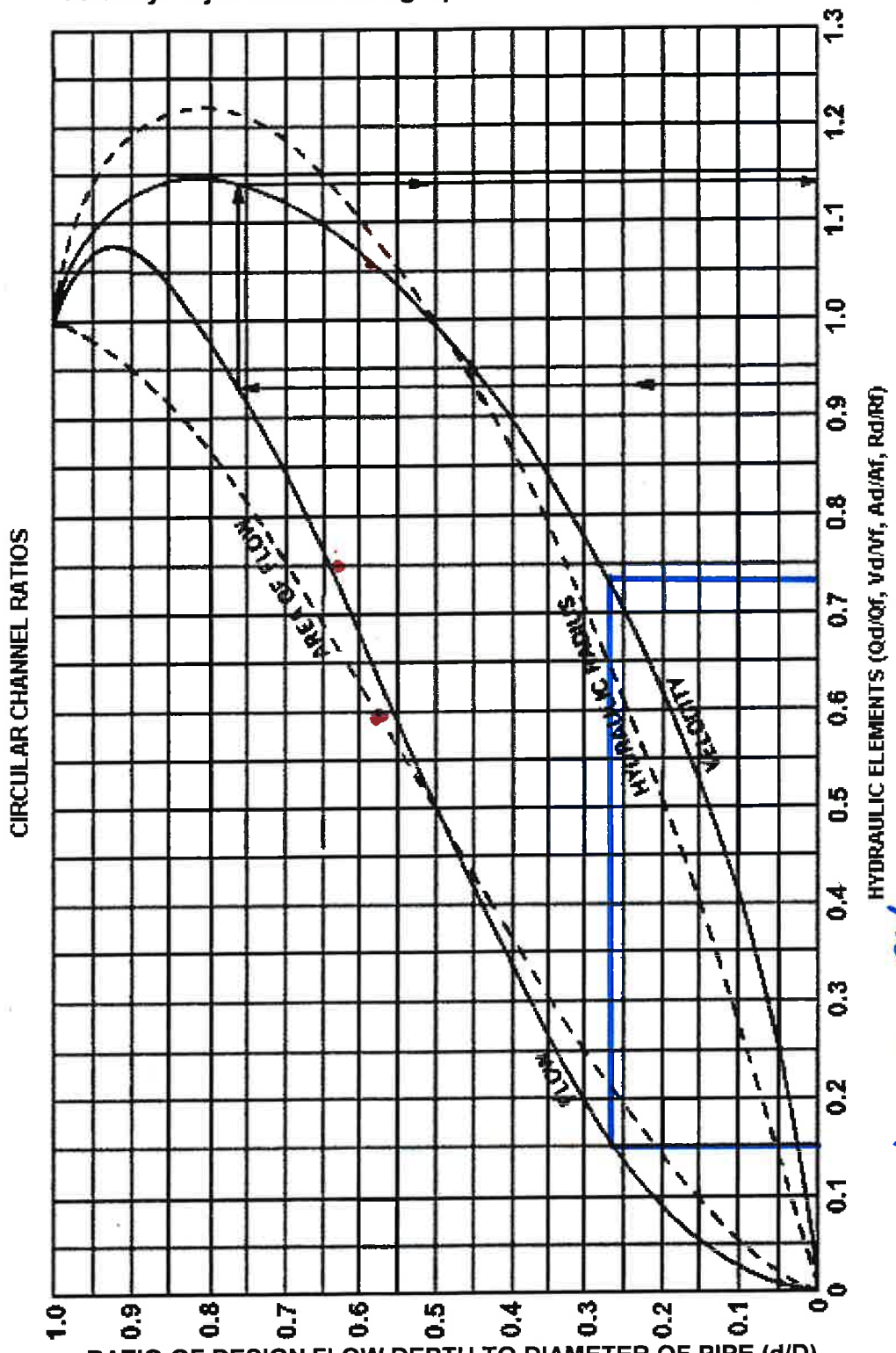
* **Calculate the ratio of partial to full-flow discharge:**

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.15

DW 1001

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



$V_d = 8.93$ ft/s

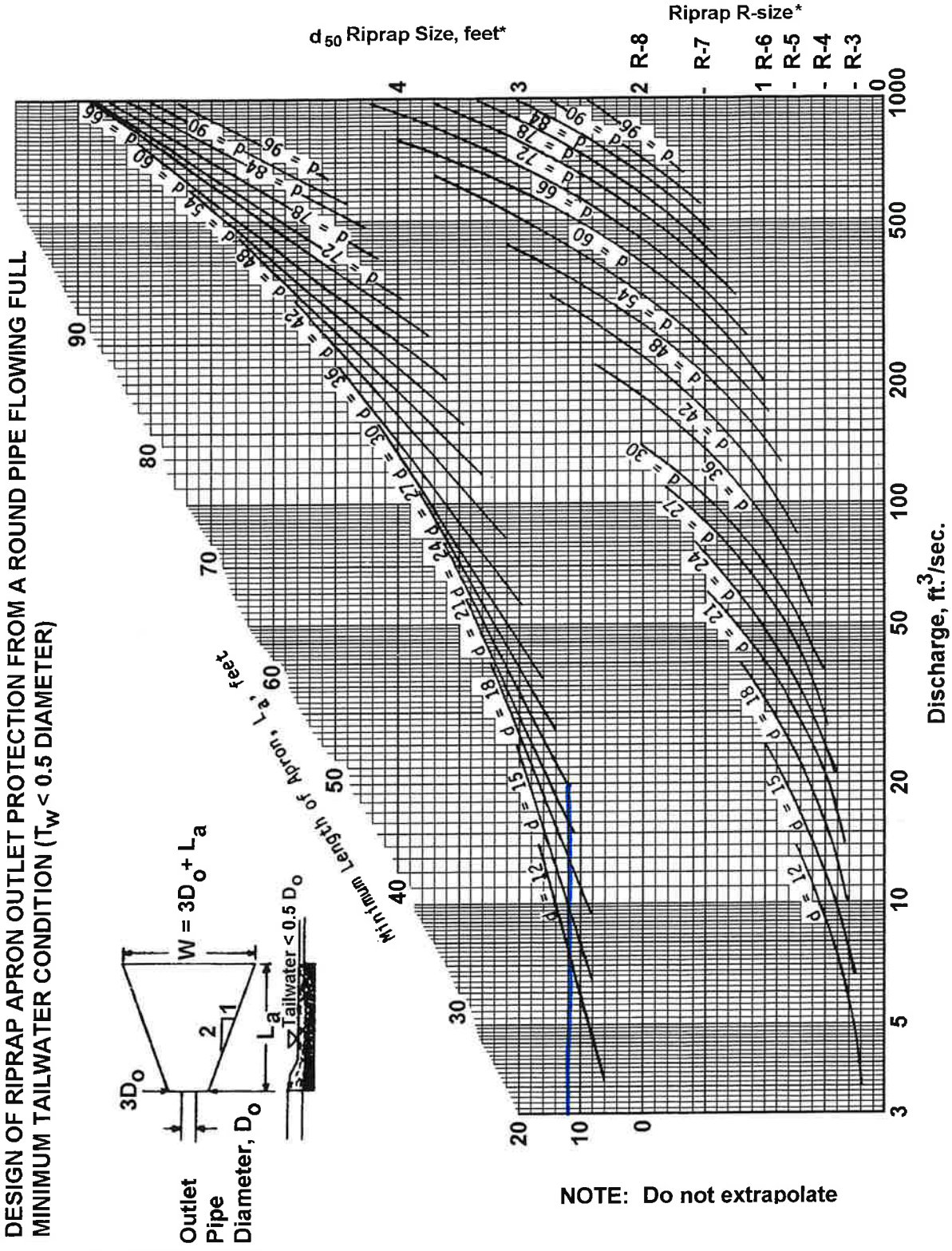
use R-4 Rock

Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 1001

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



DESIGN OF RIPRAP APRON OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T_w < 0.5 DIAMETER)

Adapted from USDA - NRCS

* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

$Q_d = 5.91$ cfs (min)

$3\,D_o = 6$ ft

$W = 6$ ft + 12 ft = 18 ft

use $L_a = 12$ ft

Not to be used for Box Culverts

PROJECT: I80-115 C-1,LLC
DW1101 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0400
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.60

* **The full flow capacity of the pipe should be determined from the following equation.**

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 45.43 cfs

* **Use the Continuity Equation to determine the full-flow velocity:**

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 14.46 fps

* **Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:**

= 0.25

* **Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.**

V_d = V_f * Velocity Ratio

V_d = 3.62 fps

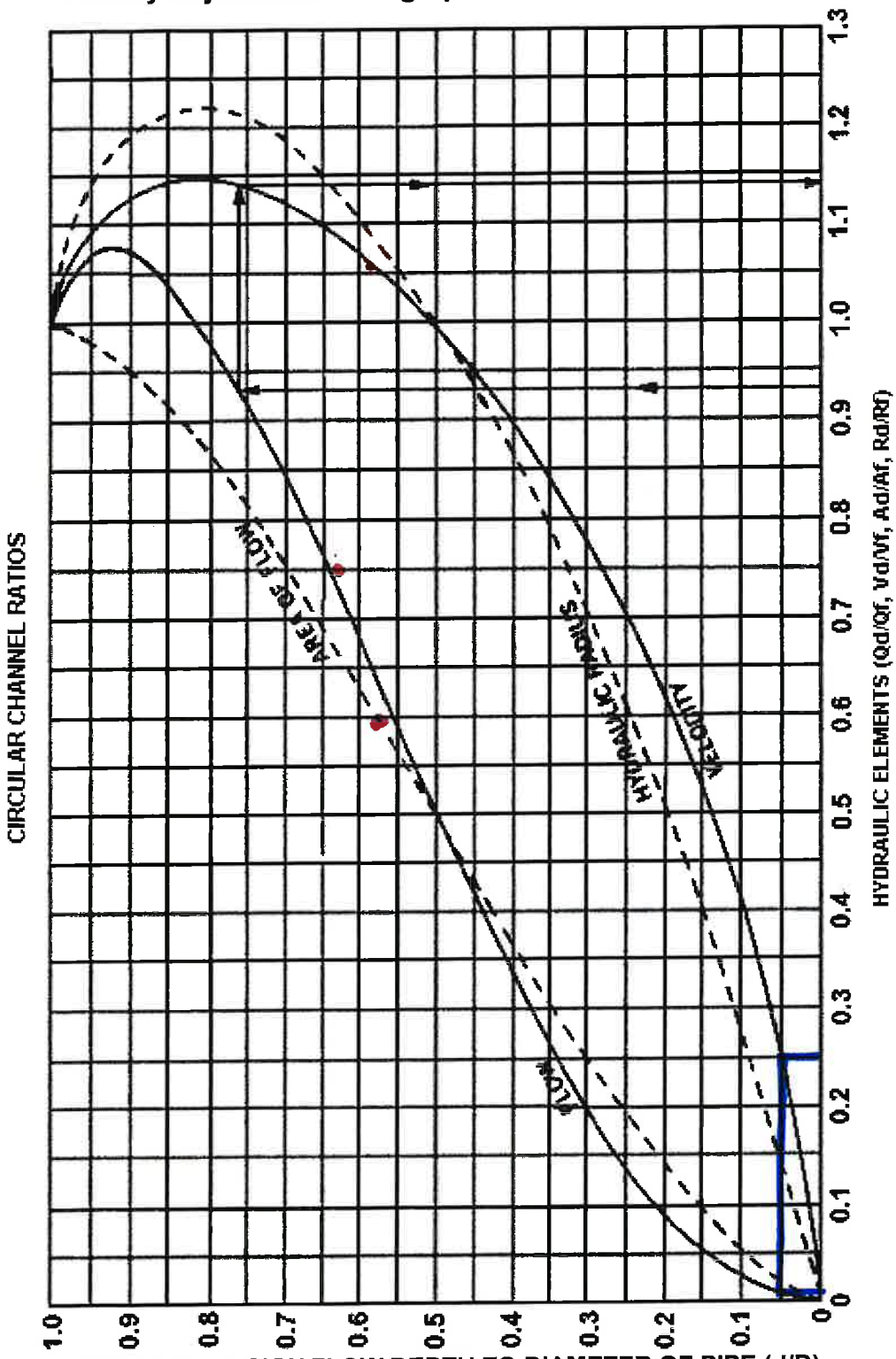
* **Calculate the ratio of partial to full-flow discharge:**

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.01

Dw 1101

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

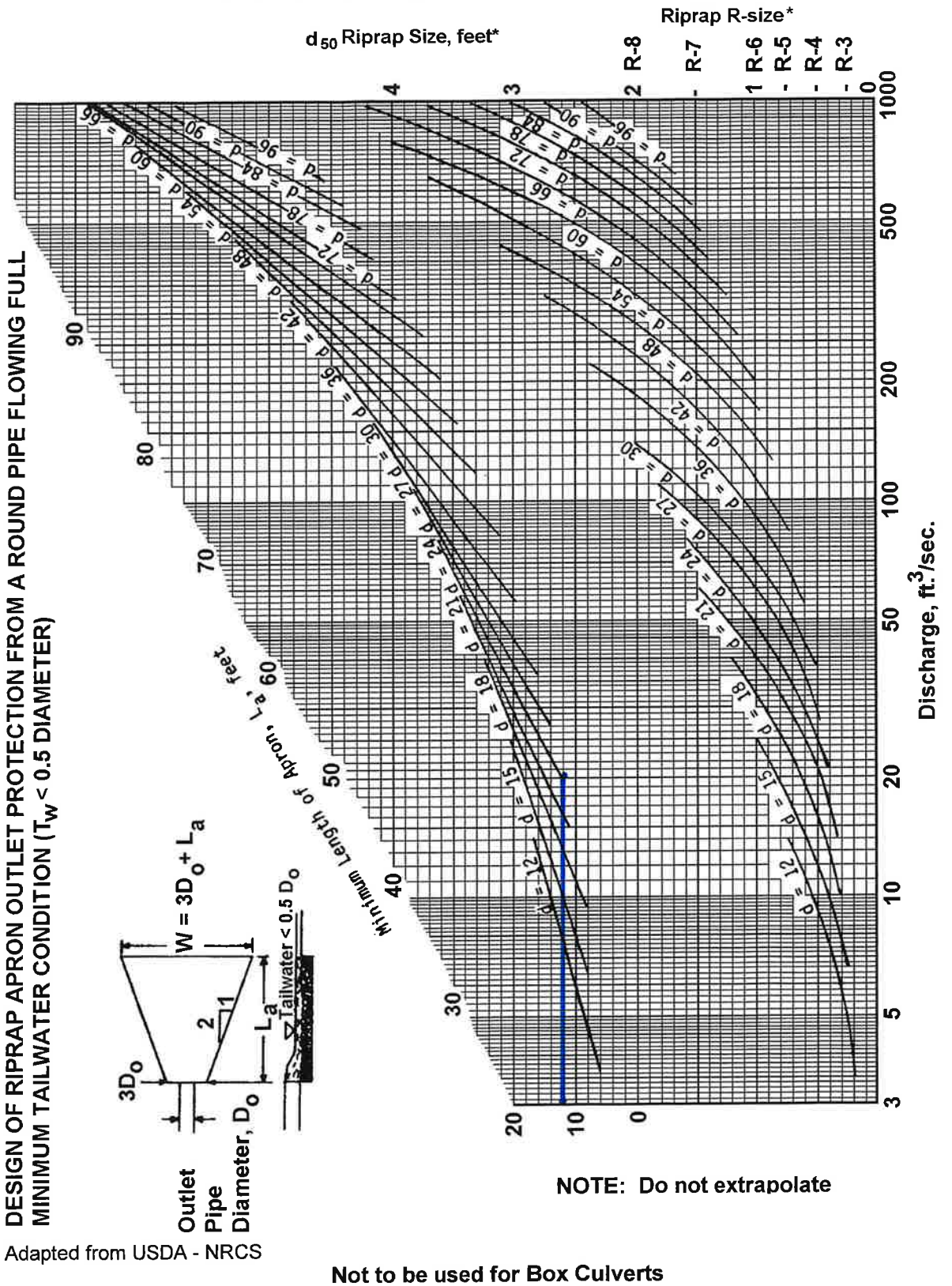
$V_d = 3.62$ ft/s

Use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 1101

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

Adapted from USDA - NRCS

Not to be used for Box Culverts

$Q_d = 0.60$ cfs (min)

$3D_o = 6$ ft

use $L_a = 12$ ft

$W = 6$ ft $+ 12$ ft $= 18$ ft

PROJECT: I80-115 C-1,LLC
DW1201 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0350
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.99

* **The full flow capacity of the pipe should be determined from the following equation.**

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 42.50 cfs

* **Use the Continuity Equation to determine the full-flow velocity:**

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 13.53 fps

* **Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:**

= 0.35

* **Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.**

V_d = V_f * Velocity Ratio

V_d = 4.73 fps

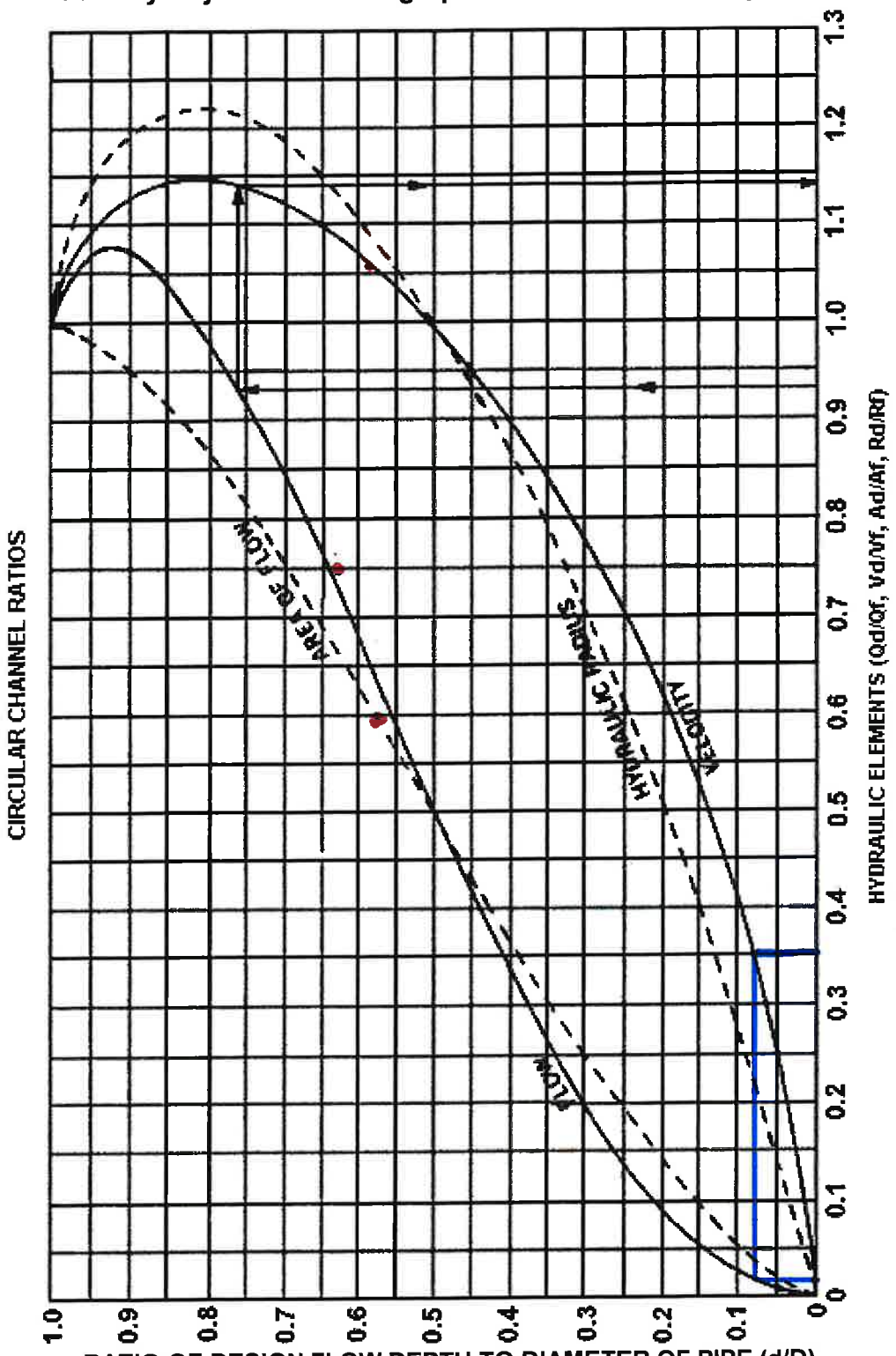
* **Calculate the ratio of partial to full-flow discharge:**

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.02

Dw 1201

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

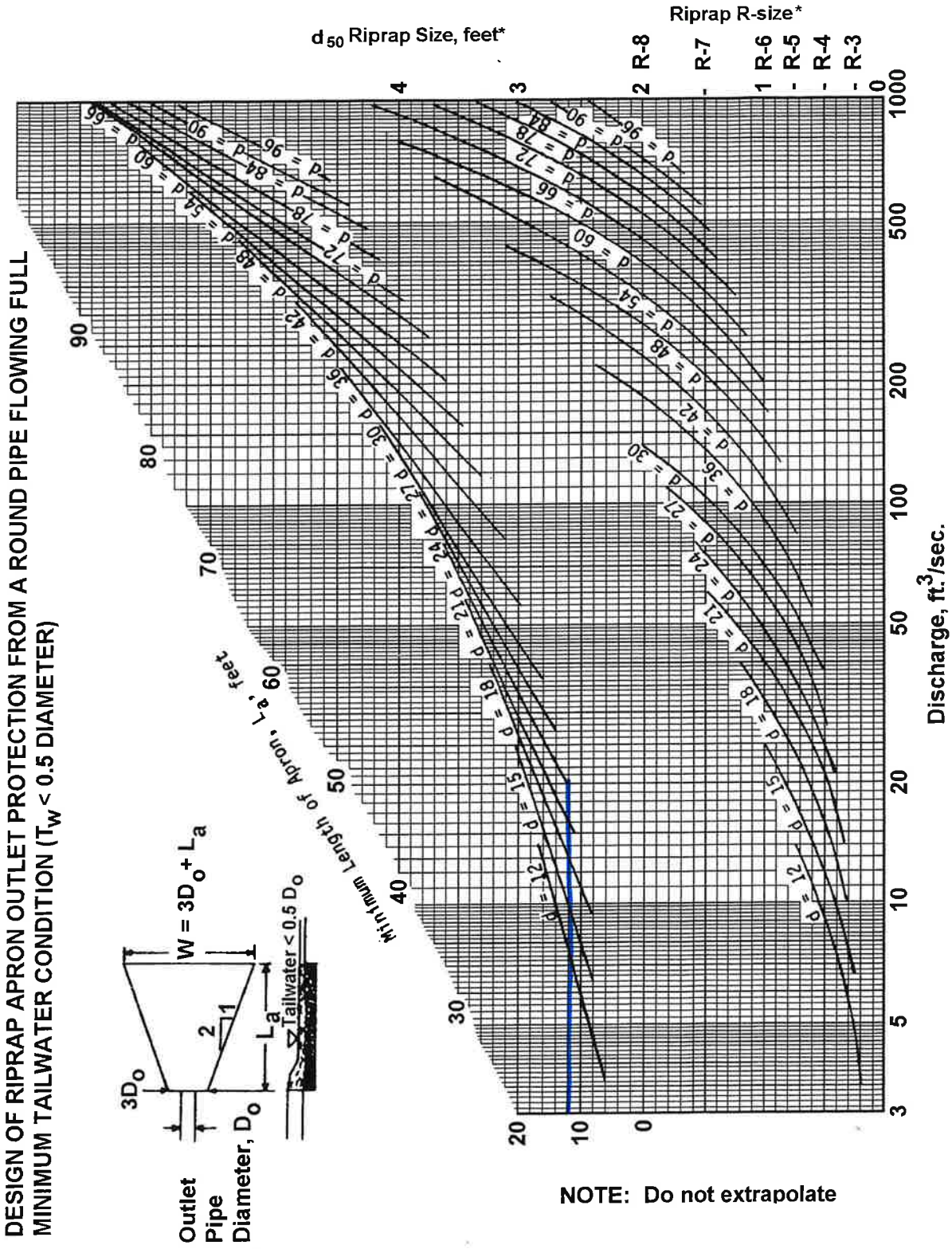
$V_d = 4.73$ ft/s

Use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 1201

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

$Q_d = 0.99$ cfs (min)

$3D_o = 6$ ft

$W = 6$ ft + 12 ft = 18 ft

use $L_a = 12$ ft

Adapted from USDA - NRCS

Not to be used for Box Culverts

PROJECT: I80-115 C-1,LLC
DW1301 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0200
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.96

* **The full flow capacity of the pipe should be determined from the following equation.**

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 32.12 cfs

* **Use the Continuity Equation to determine the full-flow velocity:**

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 10.23 fps

* **Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:**

= 0.45

* **Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.**

V_d = V_f * Velocity Ratio

V_d = 4.60 fps

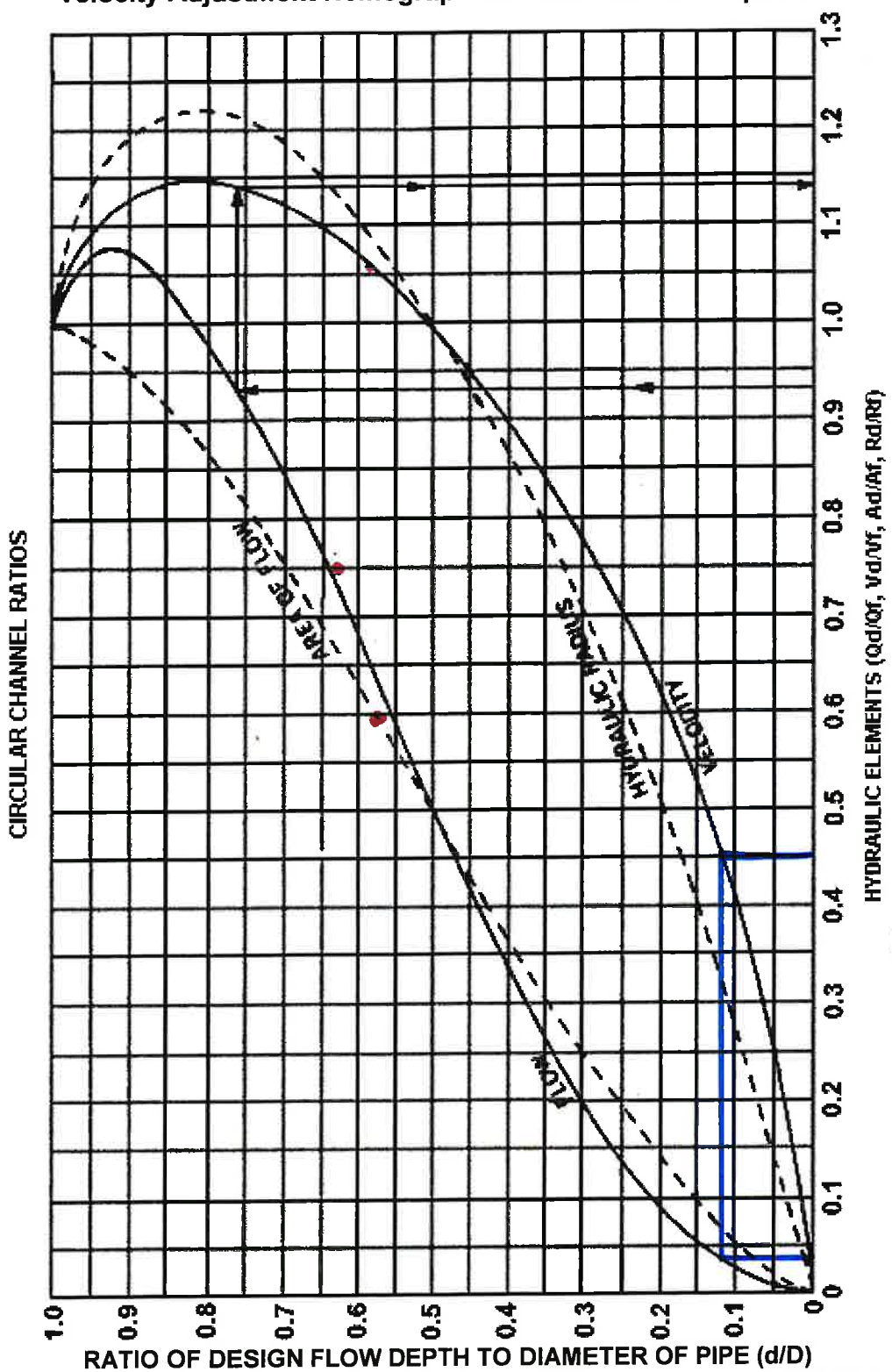
* **Calculate the ratio of partial to full-flow discharge:**

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.03

Dw 1301

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

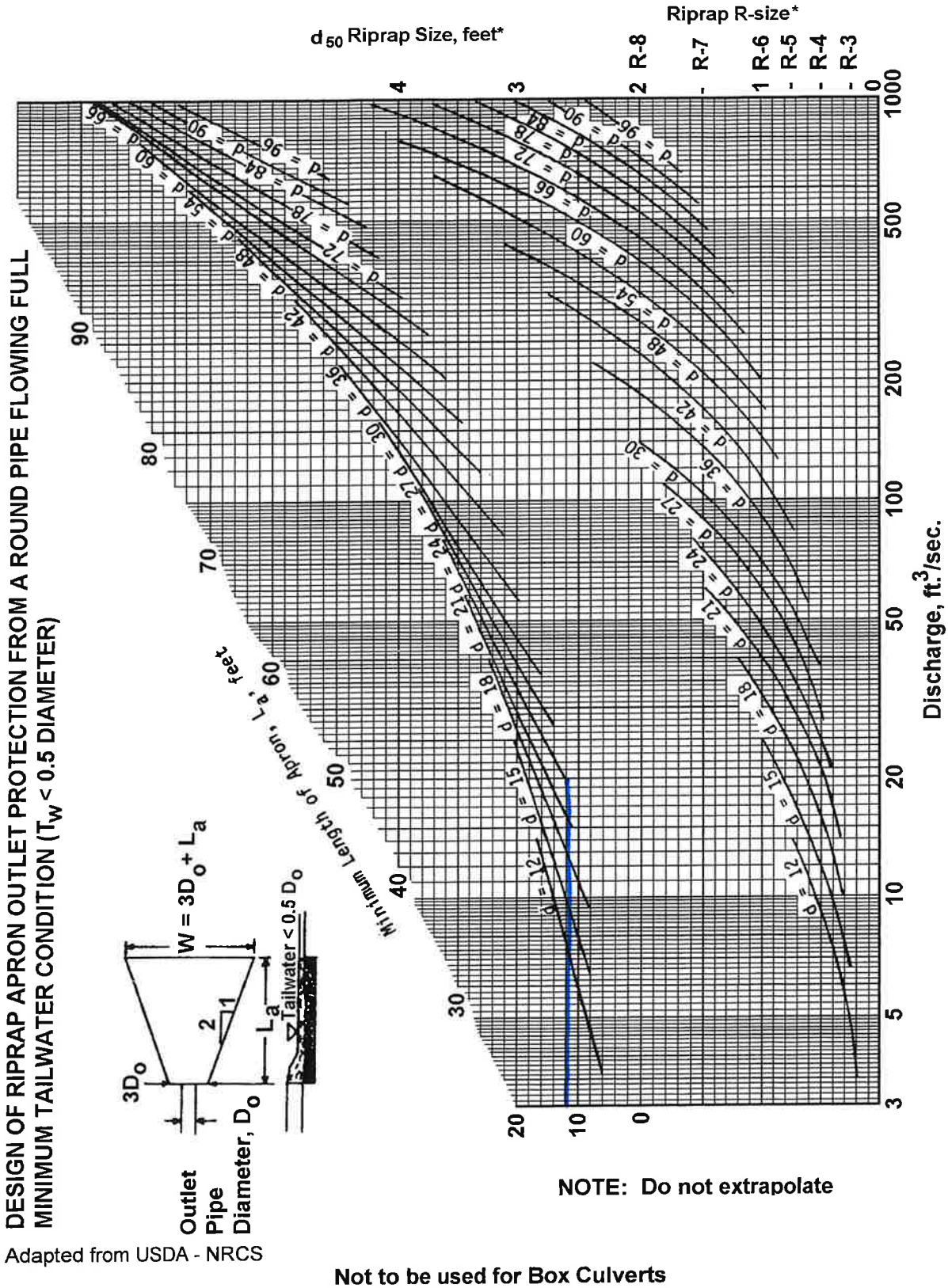
$V_d = 4.60$ ft/s

use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

Dw 1301

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

Adapted from USDA - NRCS

Not to be used for Box Culverts

$Q_d = 0.96$ cfs (min)

$3\,D_o = 6$ ft

$W = 6$ ft $+ 12$ ft $= 18$ ft

use $L_a = 12$ ft

PROJECT: I80-115 C-1,LLC
DW1501 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0250
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.54

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 35.92 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 11.43 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.35

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 4.00 fps

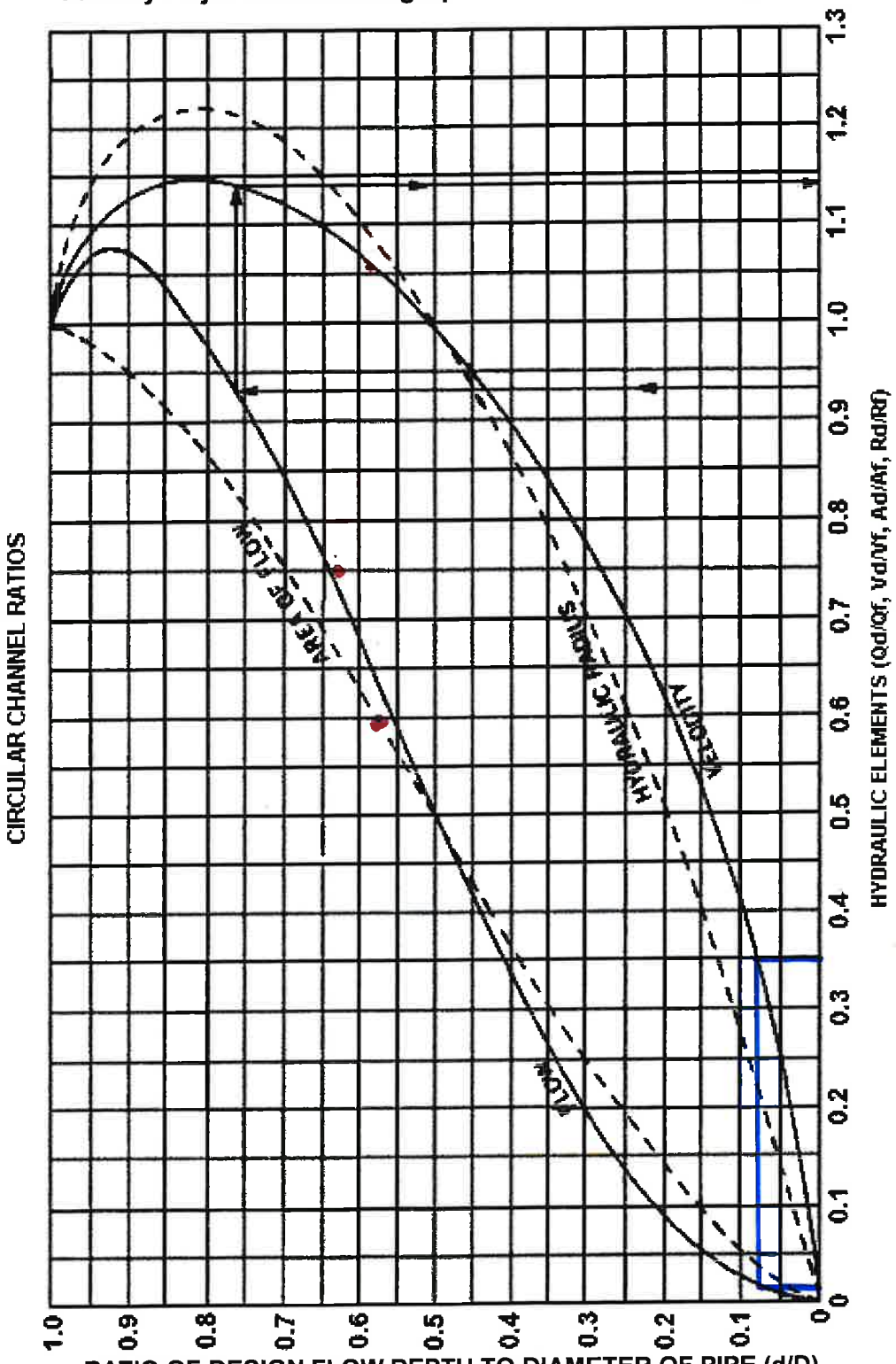
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.02

DW 1501

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

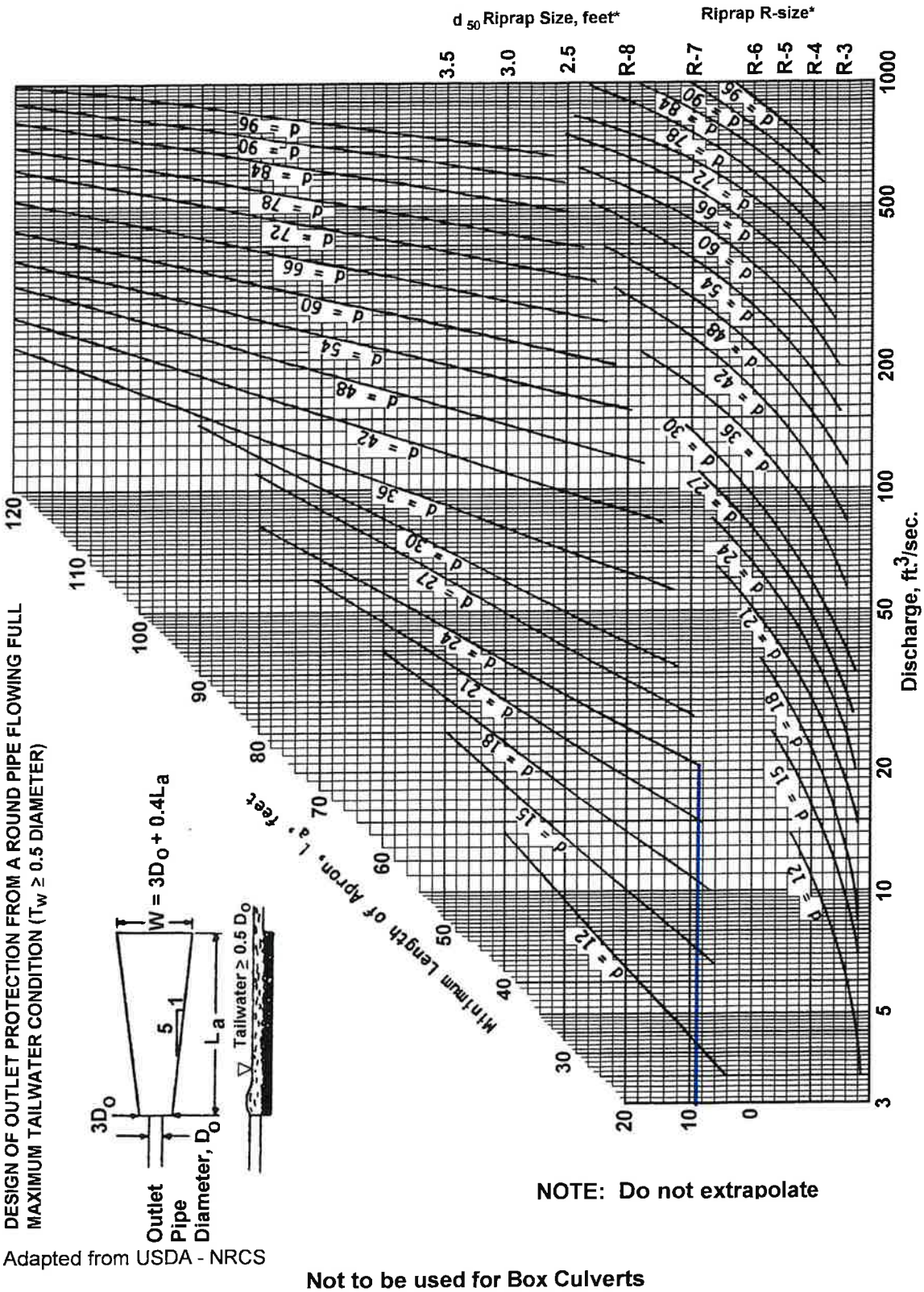
$V_d = 4.00$ ft/s

use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 1501

FIGURE 9.4
Riprap Apron Design, Maximum Tailwater Condition



Adapted from USDA - NRCS

Not to be used for Box Culverts

$Q_d = 0.54$ cfs (min)

$3D_o = 6$ ft

$W = 6\text{ ft} + 0.4(9\text{ ft}) = 9.6$ ft

use $L_a = 9$ ft

PROJECT: I80-115 C-1,LLC
DW1401 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0100
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.69

* **The full flow capacity of the pipe should be determined from the following equation.**

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 22.72 cfs

* **Use the Continuity Equation to determine the full-flow velocity:**

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 7.23 fps

* **Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:**

= 0.45

* **Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.**

V_d = V_f * Velocity Ratio

V_d = 3.25 fps

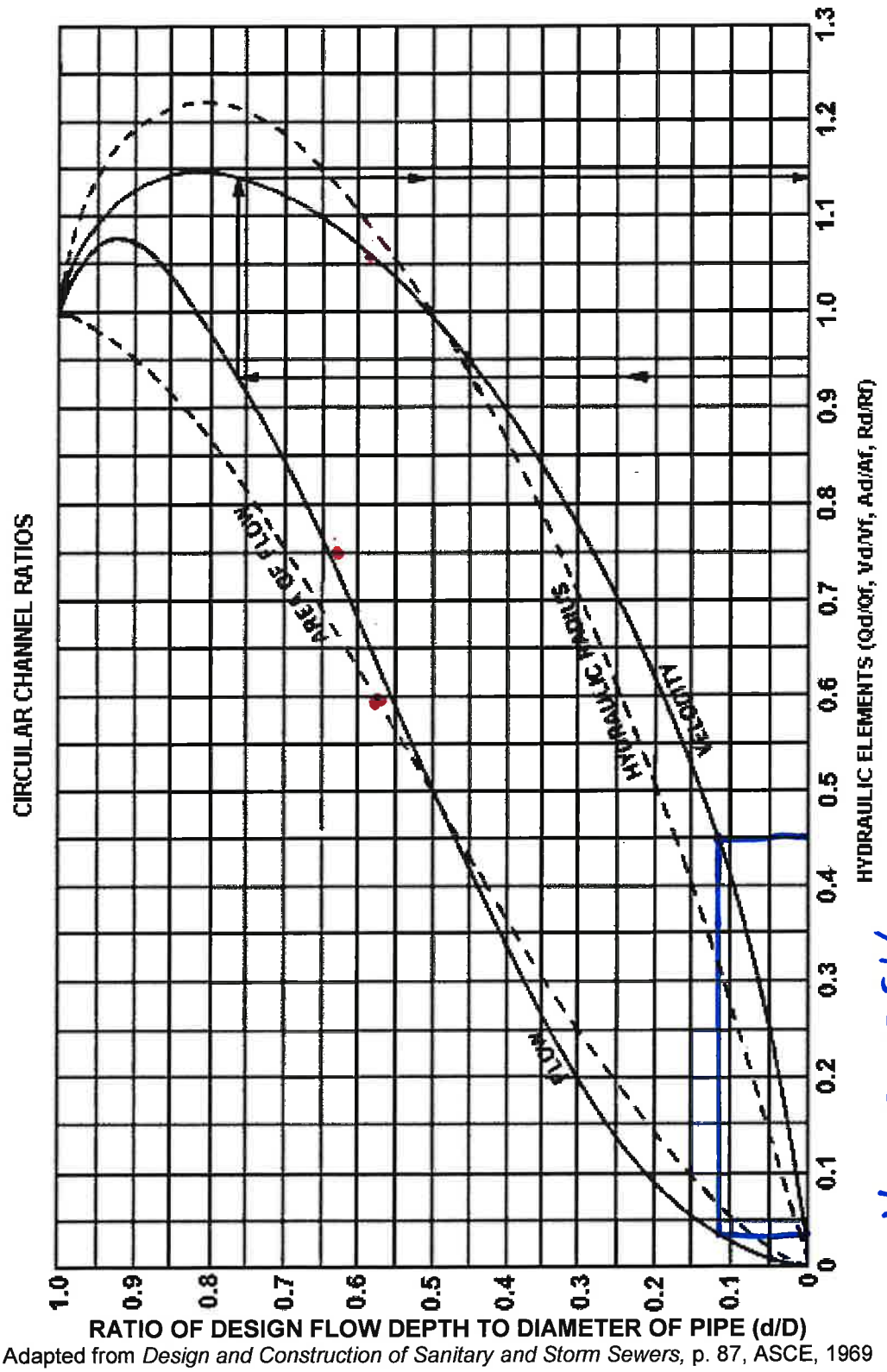
* **Calculate the ratio of partial to full-flow discharge:**

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.03

DW 1401

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

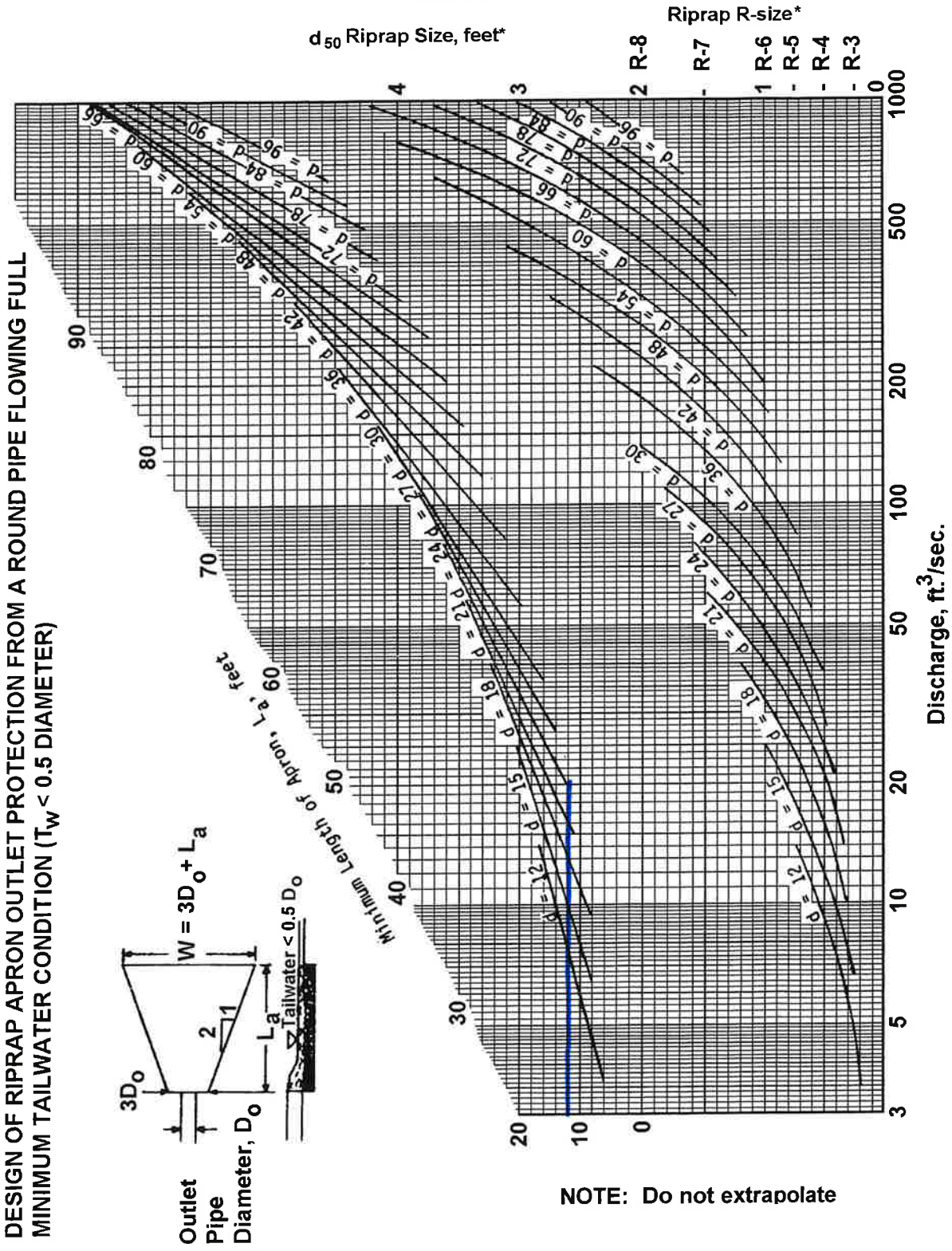
$V_d = 3.25$ ft/s

Use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

Dw 1401

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

Adapted from USDA - NRCS

Not to be used for Box Culverts

$Q_d = 0.69$ cfs (min)

$3D_o = 6$ ft

use $L_a = 12$ ft

$W = 12\text{ft} + 6\text{ft} = 18$ ft

PROJECT: I80-115 C-1,LLC
DW701 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0167
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.15

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 29.36 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 9.34 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.25

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 2.34 fps

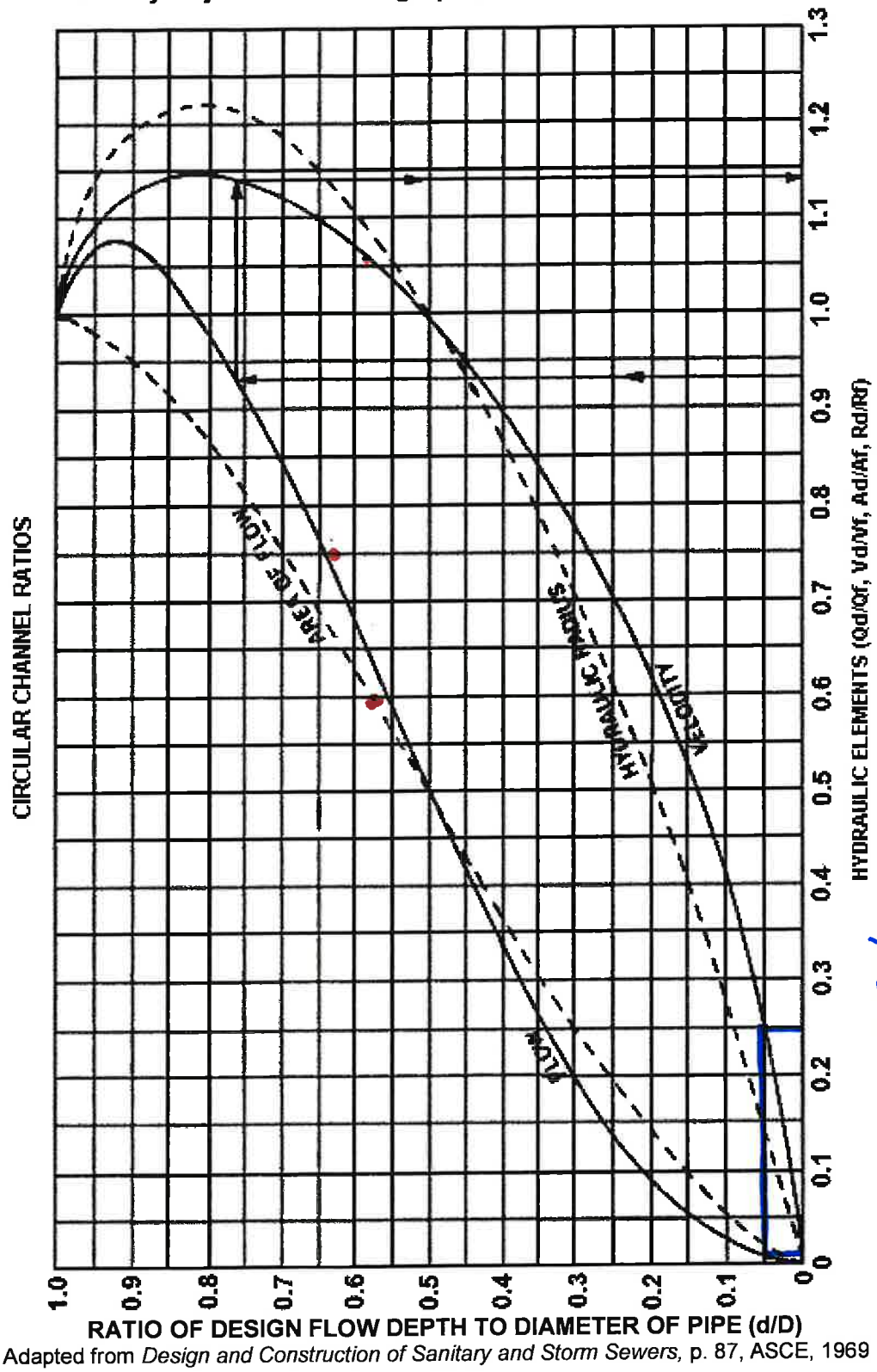
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.01

DW 701

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

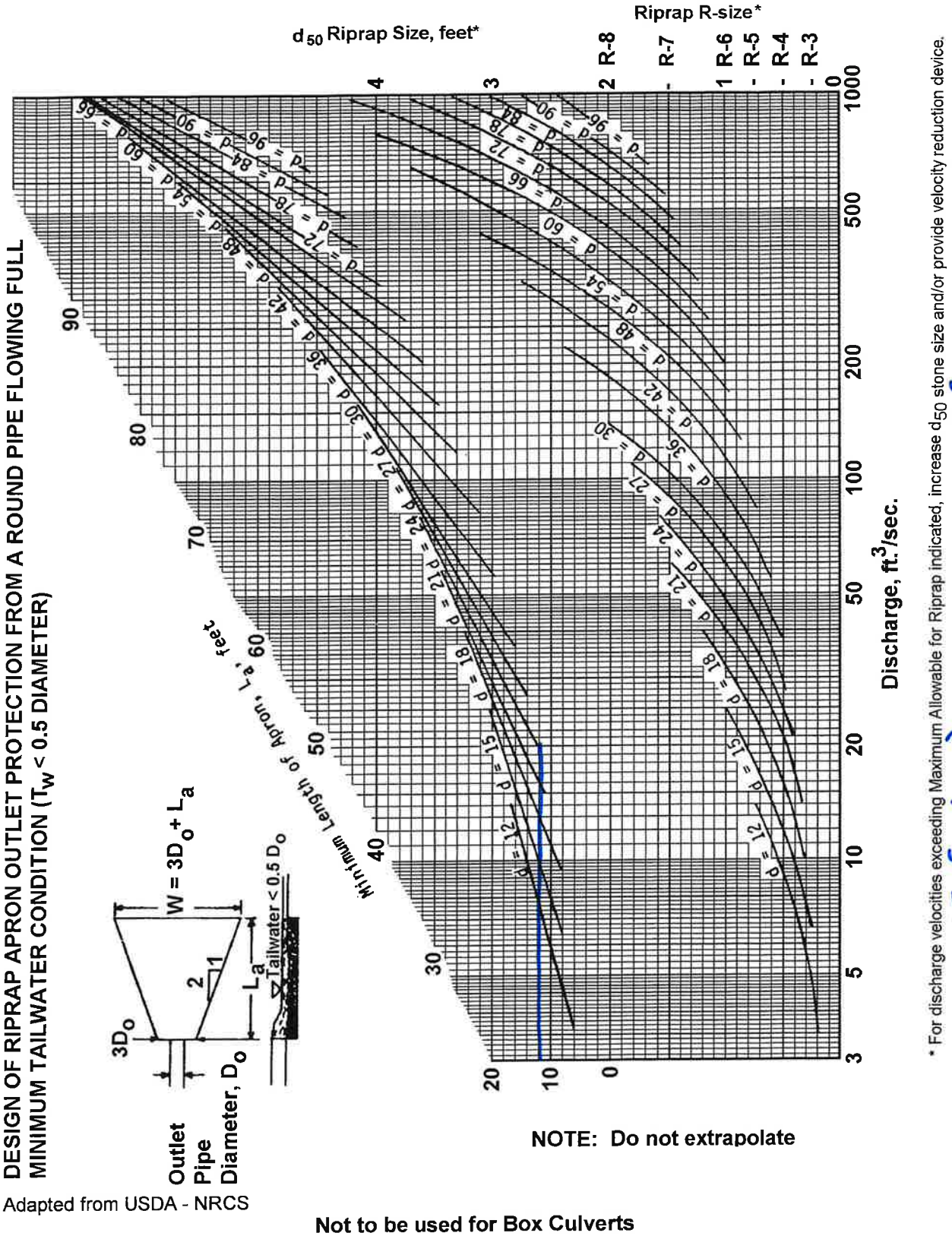
$V_d = 2.34$ ft/s

Use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

Dw 701

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

$Q_d = 0.15 cfs$ (min)

$3 D_o = 6 ft$

use $L_a = 12 ft$

$W = 6 ft + 12 ft = 18 ft$

Adapted from USDA - NRCS

Not to be used for Box Culverts

PROJECT: I80-115 C-1,LLC
DW801 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0250
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.23

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 35.92 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 11.43 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.25

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 2.86 fps

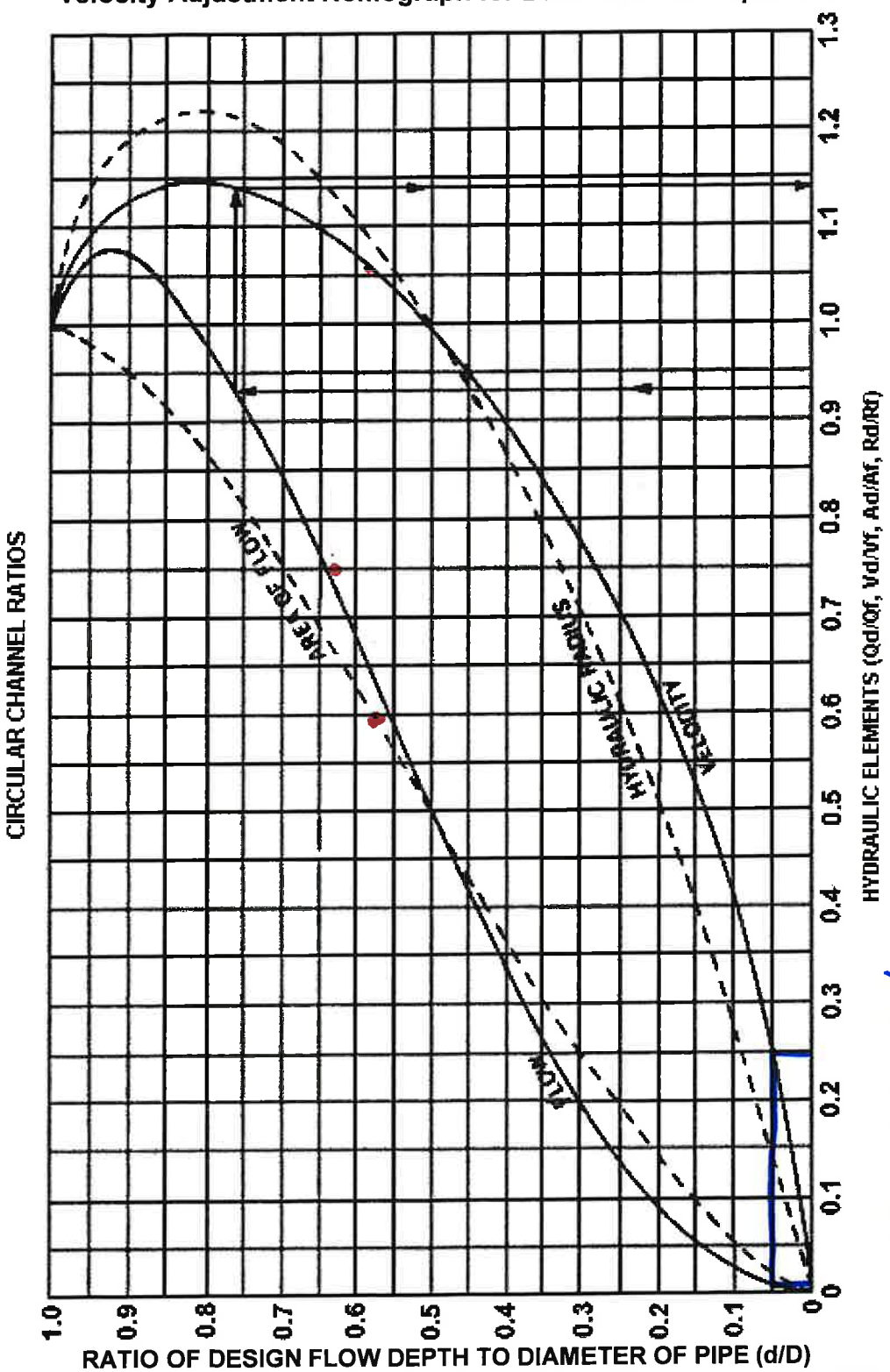
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.01

DW 801

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

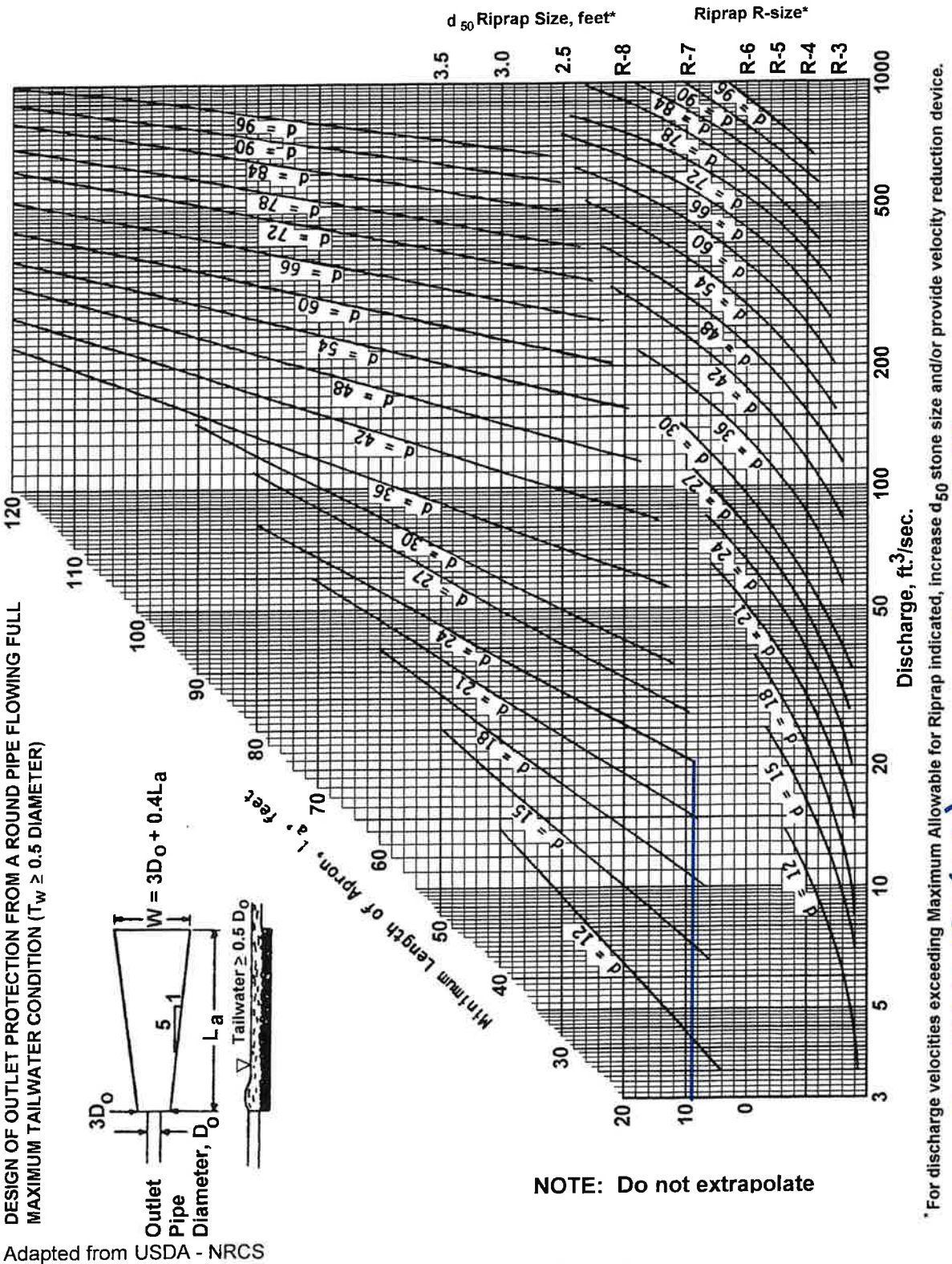
$V_d = 2.86$ ft/s

Use R-3 Rock

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 801

FIGURE 9.4
Riprap Apron Design, Maximum Tailwater Condition



Adapted from USDA - NRCS

Not to be used for Box Culverts

$Q_d = 0.23$ cfs (min)

$3D_o = 6$ ft

$W = 6\text{ft} + 0.4(9\text{ft}) = 9.6$ ft

use $L_a = 9$ ft

PROJECT: I80-115 C-1,LLC
DW901 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0667
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.78

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 58.67 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 18.67 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.25

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 4.67 fps

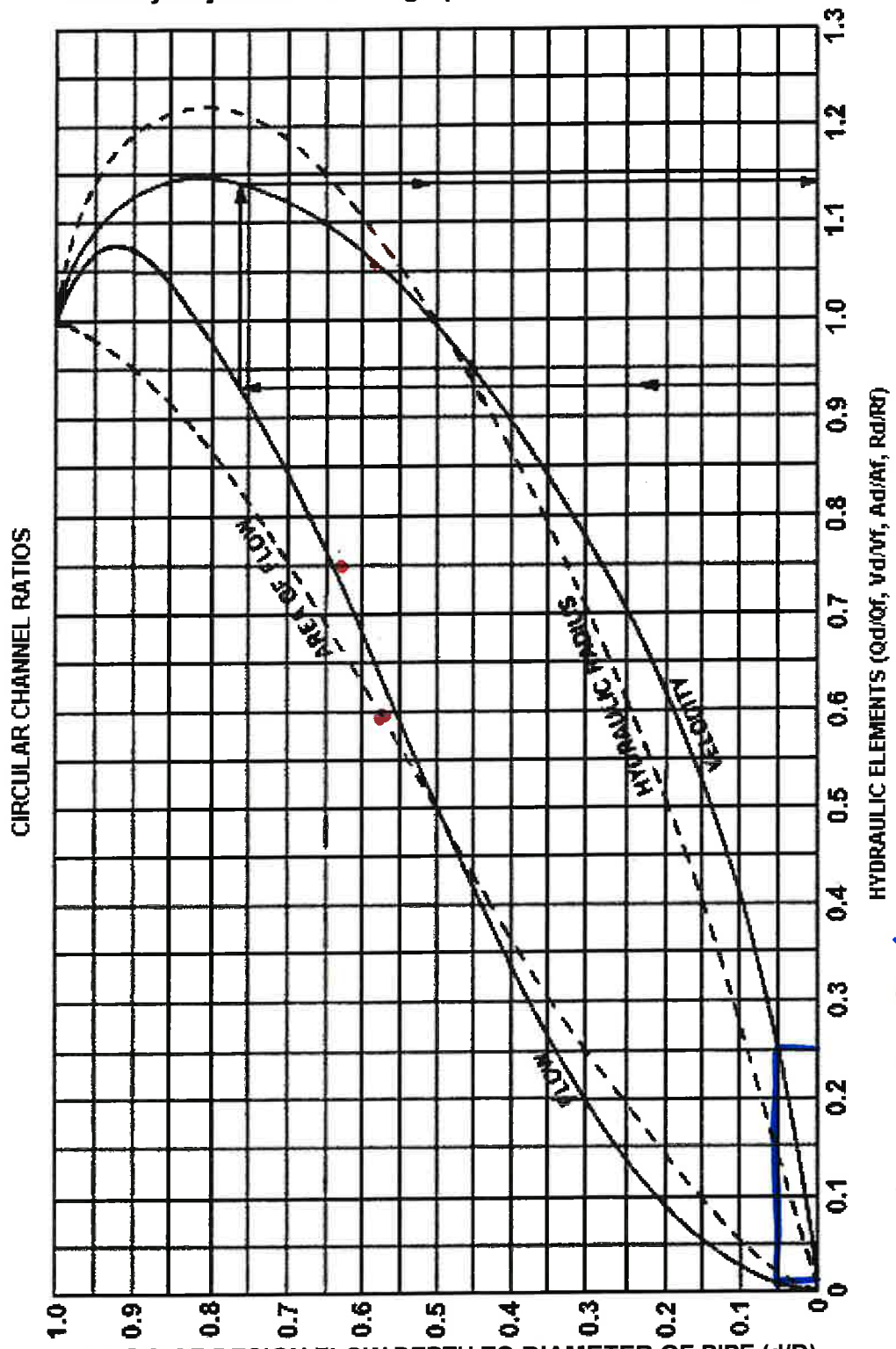
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.01

DW 901

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



$V_d = 4.67$ ft/s

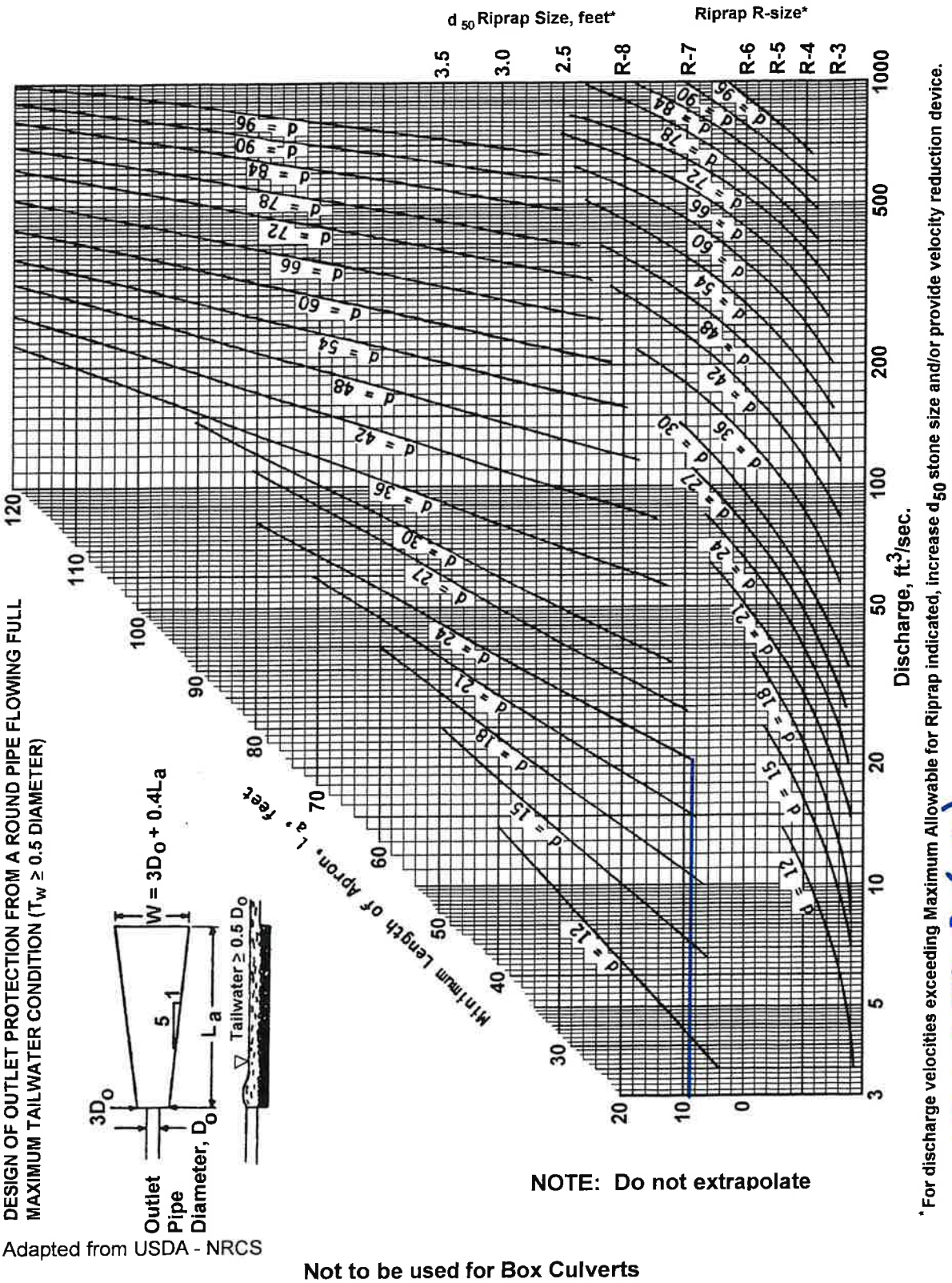
Use R-3 Rock

Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 901

FIGURE 9.4
Riprap Apron Design, Maximum Tailwater Condition



Adapted from USDA - NRCS

Not to be used for Box Culverts

$3D_o = 6ft$

$W = 6ft + 0.4(9ft) = 9.6ft$

$Q_d = 0.78\ cfs\ (min)$

use $L_a = 9\ ft$

PROJECT: I80-115 C-1,LLC
DW404 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	2.00
S =	Slope of Pipe (ft/ft)	0.0100
R =	Radius of Pipe (ft)	1.000
Q_d =	Design Discharge (cfs)	0.37

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 22.72 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 3.1416

V_f = 7.23 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.35

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 2.53 fps

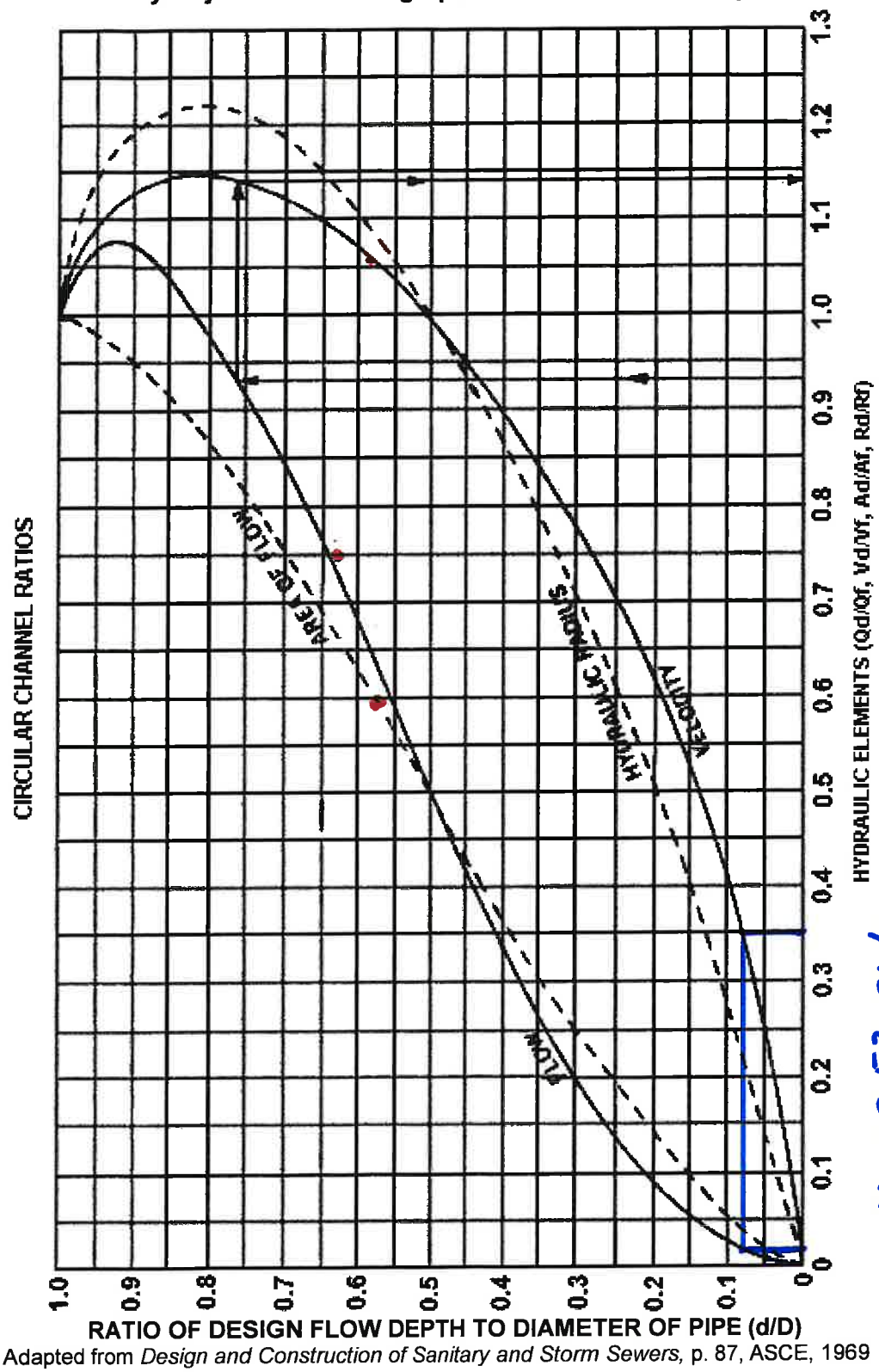
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.02

DW 404

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



$V_d = 2.53$ ft/s

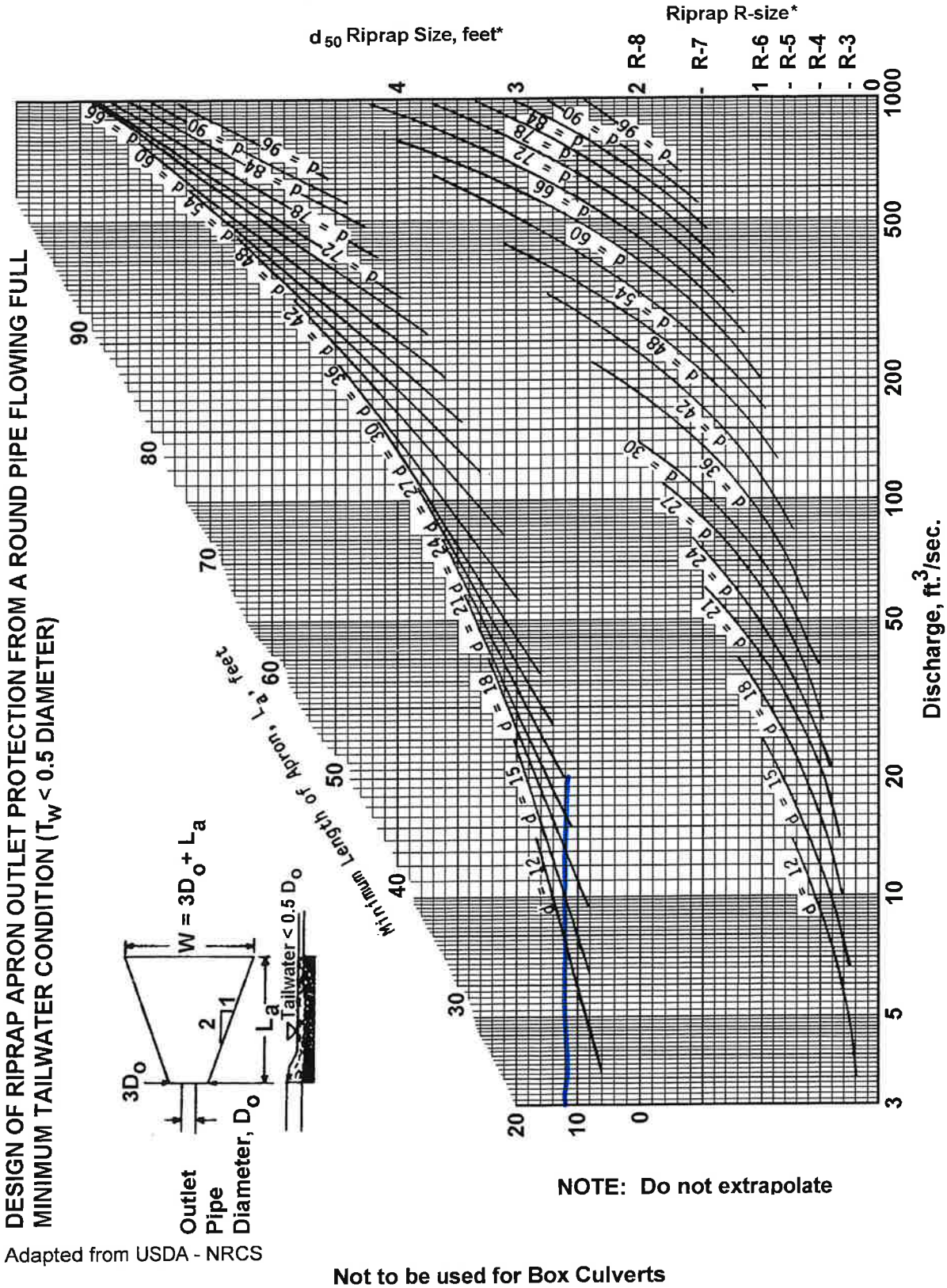
Use R-3 Rock

Adapted from *Design and Construction of Sanitary and Storm Sewers,* p. 87, ASCE, 1969

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 404

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

$Q_d = 0.37$ cfs (min)

$3 D_o = 6$ ft

$W = 12$ ft $+ 6$ ft $= 18$ ft

use $L_a = 12$ ft

PROJECT: I80-115 C-1,LLC
DW102 RIPRAP APRON

Where:

n =	Manning's n	0.013
D =	Diameter of Pipe (ft.)	3.50
S =	Slope of Pipe (ft/ft)	0.0167
R =	Radius of Pipe (ft)	1.750
Q_d =	Design Discharge (cfs)	9.51

* The full flow capacity of the pipe should be determined from the following equation.

$$Q_f = \frac{0.464}{n} * D^{8/3} * S^{1/2}$$

Q_f = 130.80 cfs

* Use the Continuity Equation to determine the full-flow velocity:

$$V_f = \frac{Q_f}{A}$$

Where:

Area = $PI * R^2$

= 9.6211

V_f = 13.59 fps

* Using Figure 9.1 in the DEP Manual to determine the Velocity Ratio:

= 0.58

* Multiply the velocity ratio calculated from the Continuity Equation to determine the less than full velocity.

V_d = V_f * Velocity Ratio

V_d = 7.88 fps

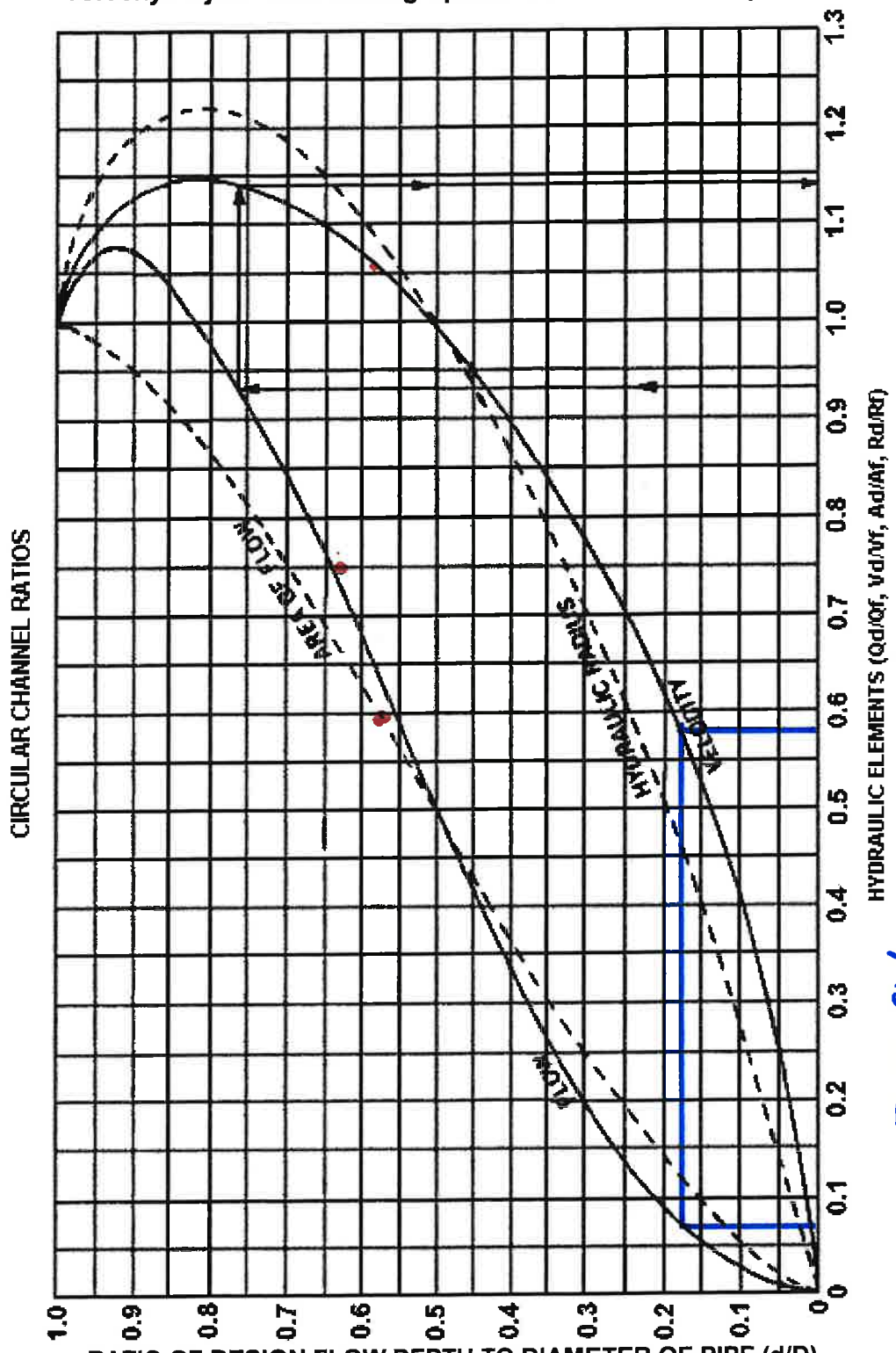
* Calculate the ratio of partial to full-flow discharge:

$$d/D = \frac{Q_d}{Q_f}$$

d/D = 0.07

DW 102

FIGURE 9.1
Velocity Adjustment Nomograph for Less Than Full Pipe Flow



$V_d = 7.88$ ft/s

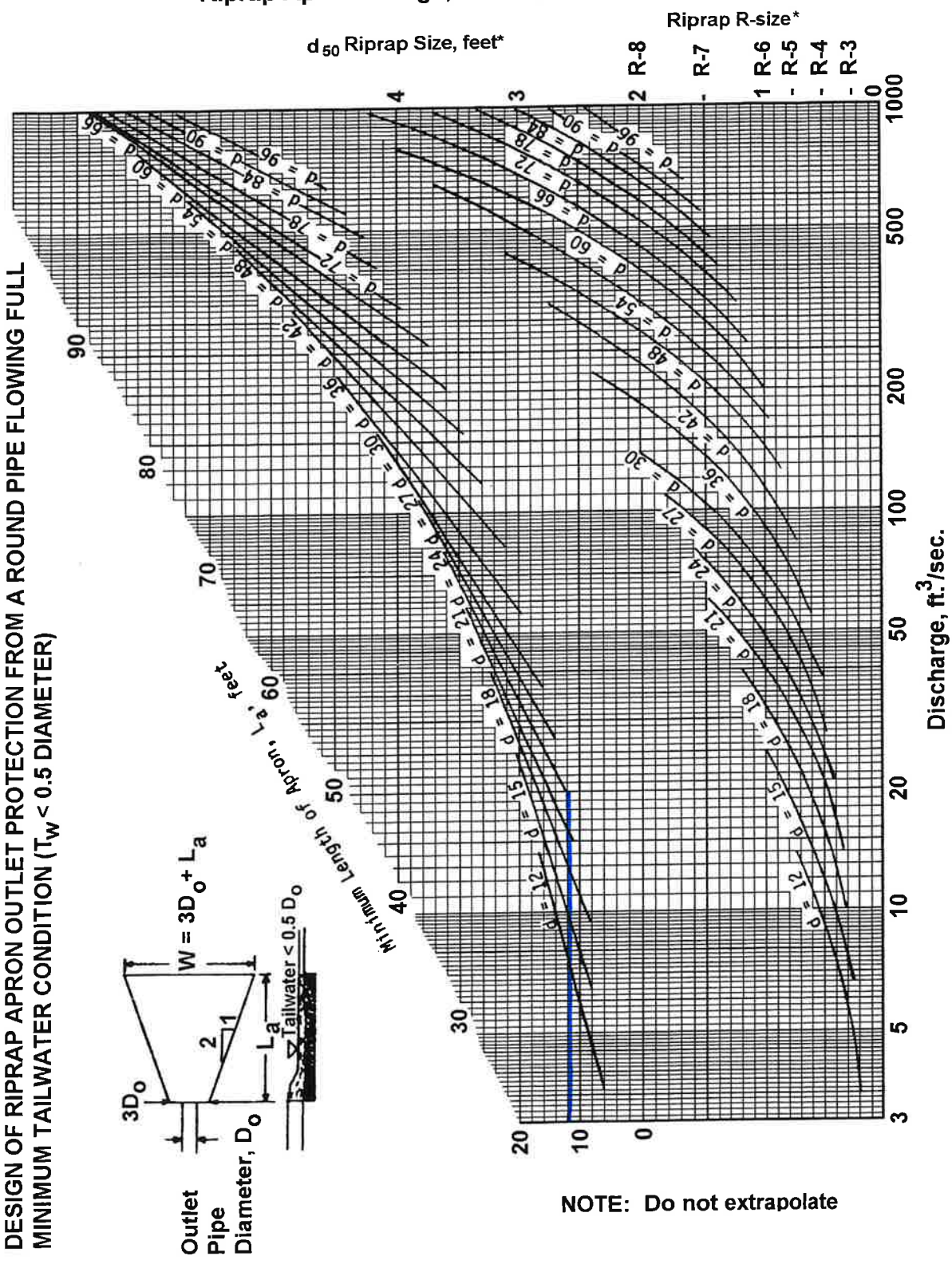
use R-4 Rock

Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969

Do not use this nomograph to determine "equivalent pipe sizes" for discharges (Q_d) that do not intersect curves corresponding to proposed pipe sizes on Figures 9.3 and 9.4.

DW 102

FIGURE 9.3
Riprap Apron Design, Minimum Tailwater Condition



DESIGN OF RIPRAP APRON OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T_W < 0.5 DIAMETER)

Adapted from USDA - NRCS

* For discharge velocities exceeding Maximum Allowable for Riprap indicated, increase d_{50} stone size and/or provide velocity reduction device.

$Q_d = 9.51$ cfs (min)
Use $L_a = 12$ ft

$3\,D_o = 10.5$ ft
$W = 10.5$ ft + 12 ft = 22.5 ft

Not to be used for Box Culverts