7.75 River models are used to study many different types of flow situations. (See, for example, Video V7.12) A certain small river has an average width and depth of 60 ft and 4 ft, respectively, and carries water at a flowrate of 700 ft³/s. A model is to be designed based on Froude number similarity so that the discharge scale is 1/250. At what depth and flowrate would the model operate?

For Froude number similarity

$$\frac{V_m}{\sqrt{g_m \ell_m}} = \frac{V}{\sqrt{g \ell}}$$

where ℓ is some characteristic length, and with $g_m = g$

$$\frac{V_m}{V} = \sqrt{\frac{\ell_m}{\ell}}$$

Since the flowrate is $Q = VA$, where A is the appropriate cross sectional area,

$$\frac{Q_m}{Q} = \frac{V_m A_m}{V A} = \sqrt{\frac{\ell_m}{\ell}} \frac{A_m}{A}$$

Also,

$$\frac{A_m}{A} = \left(\frac{\ell_m}{\ell}\right)^2$$

So that

$$\frac{Q_m}{Q} = \left(\frac{\ell_m}{\ell}\right)^{5/2} = \frac{1}{250} \qquad (1)$$

Thus,

$$\frac{\ell_m}{\ell} = 0.110$$

and for a prototype depth of 4 ft the corresponding model depth is

$$\ell_m = (0.110)(4 ft) = \underline{0.440 ft}$$

The model flowrate is obtained from Eq. (1):

$$Q_m = \left(\frac{1}{250}\right)\left(700 \frac{ft^3}{s}\right) = \underline{\underline{2.80 \frac{ft^3}{s}}}$$