Title: Flow of fluids

Topics: Flow, continuity equation, mass flow rate hydrology, geography	**Time**: 90 Minutes	**Age**: 12-15

Differentiation:

Guidelines, ICT support etc.:

Use the applet.
Use the maps – geography.
Read articles and news about weather conditions.

Equipment needed for this activity:

Tape measure, stopwatch, string, gauges, load – stone, worksheet, internet access

Required knowledge:

Ph – volume, speed, measurement of distance, M – calculation of surface, graphs, Geo – map of Europe

ICT – basic knowledge – Excel, Internet

Health and Safety:

Risk of falling into the river, in the case of slippery bottom fording need of protective equipment (high boots)

Learning outcomes for this activity:

- Students can distinguish between laminar and turbulent flow
- Students can calculate the volumetric flow rate
- Students prepare and carry out field measurement - measurement of the flow of the river at the place of residence
- Students work with the Internet and other study literature - seek and process information about the turbulent flow, and hydrology

Lesson description

Initial activity

Motivation - students discuss from historical and contemporary perspective the importance of water coarse. Think over flooding in the past and at present. Explain how human activity affects nature.

Main activity

Students revise work with graphs, representation of vectors, calculate ratios. Become familiar with the concepts of volume flow, laminar and turbulent flow. After studying the theory students prepare and carry on laboratory tasks.

Final activity

Students discuss the results of their measurements.

Additional activity - students prepare a presentation on the topic: a) floods, b) turbulent flow - Karman vortex path, c) hydrology- what does it study, what information is important for the residents.

Motivation

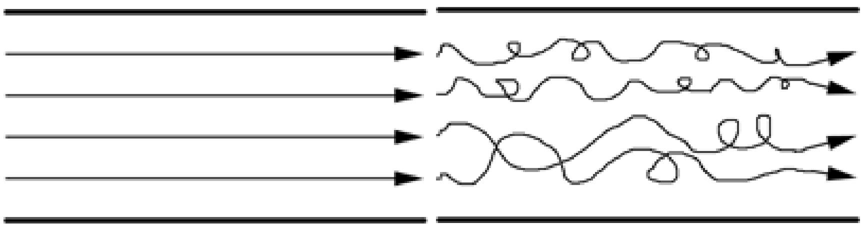
Interdisciplinary relationships - history, mathematics, geography (hydrology), physics

In the past human settlements always emerged near water courses. Water was a source of drinking and utility water, food, transport artery, formed part of the defense system of settlements. Also were utilizes regular floods in major rivers (Nile, Euphrates), which gave rise to fertile soil and agricultural development. People have learned to live near rivers, if there was a flood, they were able to protect themselves. In our country in the early 20th century people started an extensive regulation of water flows as protection against flooding. Concurrently the construction of both residential and industrial buildings in close proximity to rivers (in floodplains) was expanded. Perhaps people have lost their "historical memory". It was proved by the floods that hit Moravia in 1997 and Bohemia in 2002 http://cs.wikipedia.org/wiki/Seznam_povodn%C3%AD_v_%C4%8Desk%C3%BDch_zem%C3%ADch. Learn more about floods - http://en.wikipedia.org/wiki/2013_European_floods.

Measurement of flow velocity and mass water flow rate.

Fluid flow arises due to the pressure difference. Streamlines are lines that depict the trajectory of flowing fluid particles. Direction of particle velocity is determined by the tangent to the streamline at that point.

The flow can be a) laminar (streamlines are parallel), b) turbulent (create a vortex).



a) b)

Fig. 1 Streamlines a) laminar flow, b) turbulent flow

Fig. 2 Creation of vortices behind floating submarine

(http://upload.wikimedia.org/wikipedia/commons/thumb/8/8d/Los_Angeles_attack_sub_2.jpg /200px-Los_Angeles_attack_sub_2.jpg)

Steady floating of an ideal fluid – through each section of the tube passes at the same time the same volume of fluid. We introduce a variable volumetric flow rate Q_V

$Q_V = V/t$,

where V means the volume of the fluid and t is the time (seconds).

The following applies: $s = v{\cdot}t$ (path travelled by the particle in time t with the velocity v), the volume of liquid can be expressed using the cross-sectional area S as $V = S{\cdot}v{\cdot}t$. After substituting we get the formula for the volume flow in the form

$$Q_V = S \cdot v$$

Volumetric flow rate is measured in units of $m^2 \cdot m \cdot s^{-1} = m^3 \cdot s^{-1}$.

Based on the assumption of steady flow a continuity equation is applied

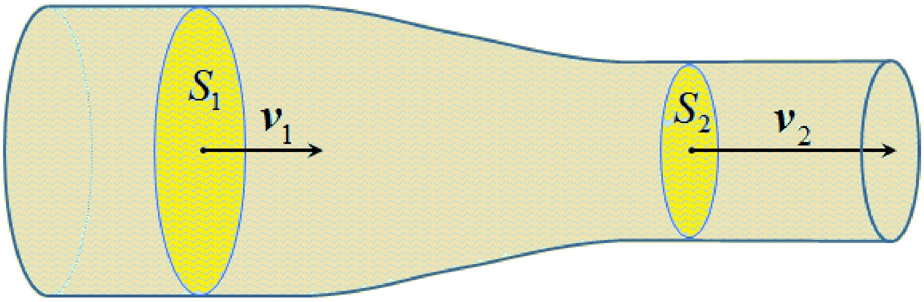


Fig. 3 Steady flow in a pipe

$$S_1 \cdot v_1 = S_2 \cdot v_2$$

Water flow in the river

The flow velocity in the river is determined by the drop in the river bed and water depth. In the bed of the river the flow velocity changes, at the surface, banks and bottoms it is slower due to the friction impact. The fastest velocity we can measure in the flow path at a certain depth below the surface (see Fig. 4).

The flow velocity of the water can easily be measured by using the *float method* (cork, ball), when we measure the time during which the float travels a certain distance.

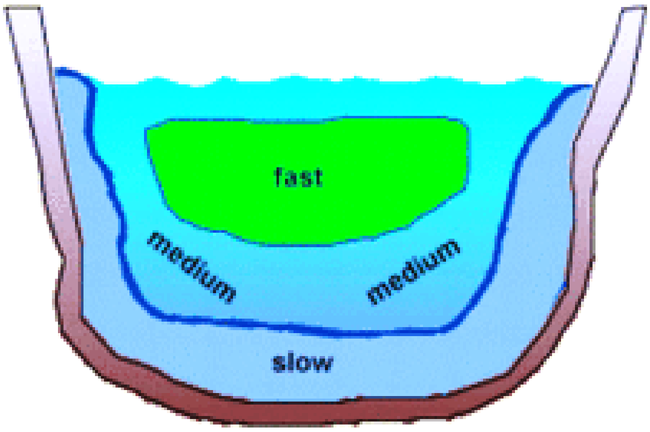


Fig. 4 Cross-section of a river showing the general pattern of curent velocity.

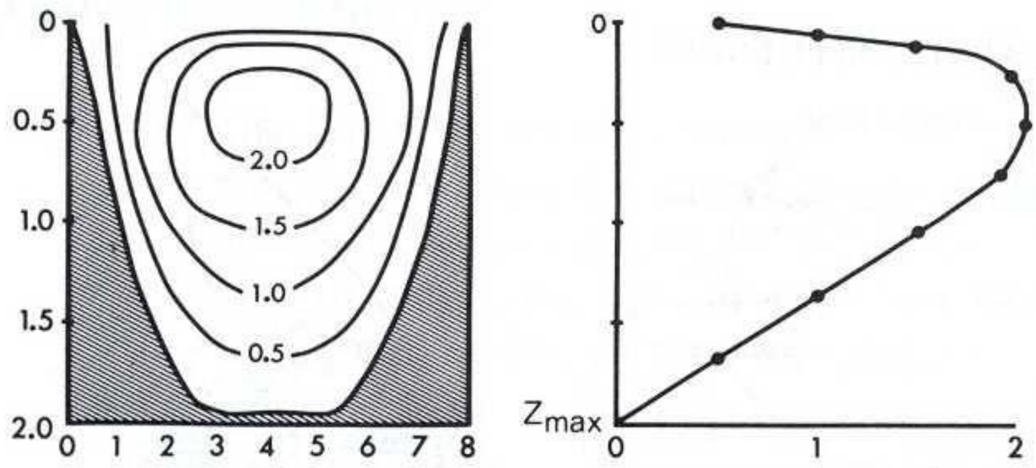
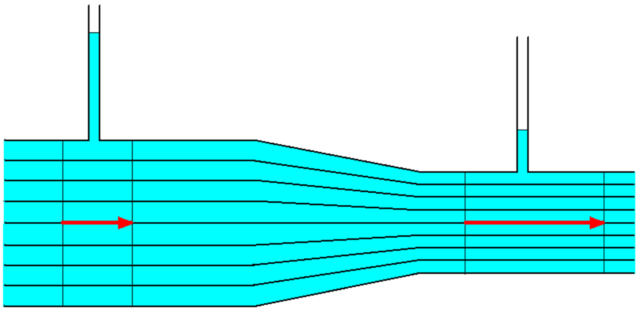


Fig. 5 Distribution of flow velocity profile in the transverse (*y*-axis – depth of water, axis *x* - the width of the channel) and the vertical profile (*x*-axis - current speed)
http://www.eoearth.org/view/article/155233/

Flow velocity

To measure the flow velocity of liquids and gases we can use the Venture tube. It looks like a part of the tube, which is narrowed down in a certain place and this place is connected to a differential pressure gauge. Using this gauge we can measure the difference in pressure in the main pipe and the tubing.



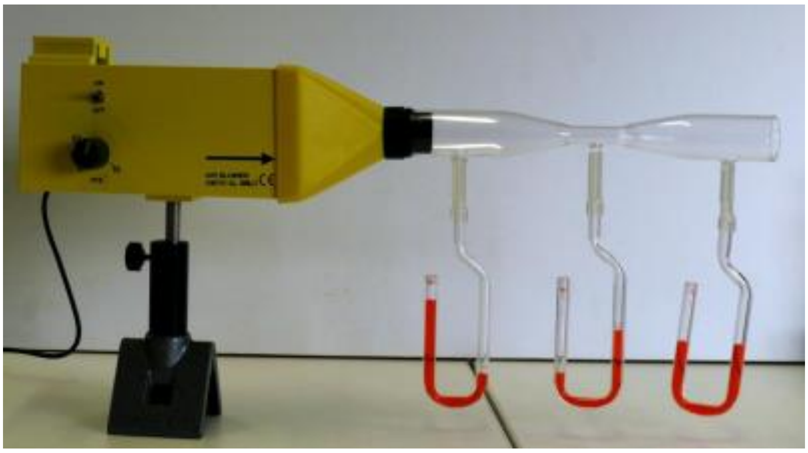


Fig. 6 Measurement using the Venture tube

Mass water flow rate - measurement

The flow is expressed by the volume of water that flows through the flow profile per unit time (m^3 / s)

$Q = S \cdot v$,

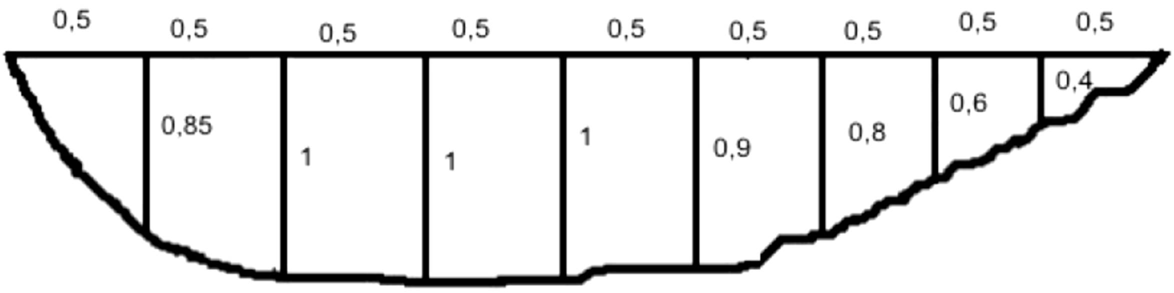
where S is the area of the flow passage; v is the average velocity of mass water flow rate.

Direct measurement of mass water flow rate – volume - directly determines the amount of water that flows over a certain spillway

Indirect measurement - using hydrometric propeller (supplied by Company Pasco and Vernier) http://www.prutoky.cz/kapaliny/teorie/priklady-meter-metod/

Calculation of the average mass water flow rate velocity "*v*" is performed by vertical perpendiculars on the tape (rope) that is stretched between the two sides and divided into equal segments (e.g. 0.5 m). The own flow area is divided into a number of sub-tabs with a certain value of flow rate (Fig. 7)

The resulting value is an average one obtained from the further measured values.



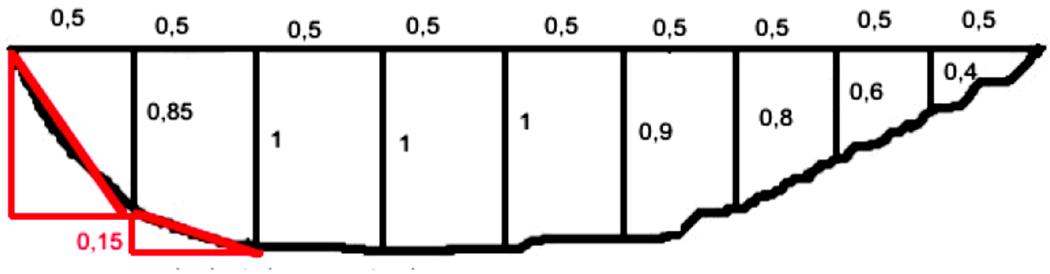


Fig. 7 Procedure for measuring the flow velocity profile in a transverse flow (distance in meters)

For the calculation we use elementary mathematics - the formula for the rectangle.

In case a current-meter is not available we measure only the surface velocity of the water flow.

How to measure the flow rate:

Assume that the velocities across the river are parallel to one another. The cross section is located at a point of the river where the stream is straight for about 50 m above and below the point of measurement and the depth of flow is greater than 30 cm. The stream is steady, not flood characteristics appears. The velocity distribution is a Newtonian – parallel shape of the velocity diagram (Fig. 8)

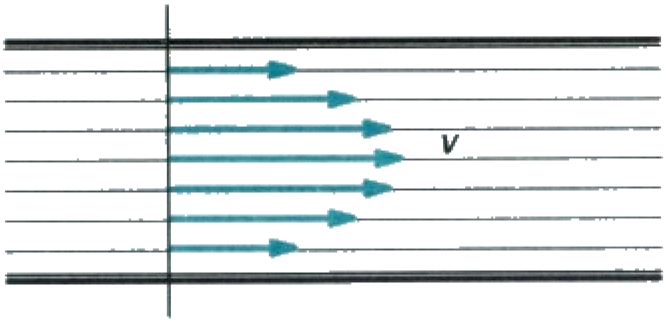


Fig. 8 Velocity vectors

The velocity varies across a channel, and measurements must be provided at several points. The depth of the river varies across its width, so the usual practice is to divide the cross-section of the stream into a number of vertical sections as shown in Figure 4. We measure the velocity at each of these sections. One section should be about 20 per cent of the total size between the river banks. Mostly we need about 10 sections).

Laboratory work - measuring mass water flow rate in the river

Tools: rope, string, tape, weight, PET bottle, stopwatch

Progress of work:

1. Measure by rope the width of the stream (a small river ford on the other side and measure the distance between the banks, in case of a big river measure from the bridge).

2. Between the two banks (on the bridge), stretch a tape. On the tape mark the sections at 1 m distance (regarding the width of the river 0.5 - 1 m).

3. On the shore you measure out the distance from the bridge - the segments on which we'll measure the speed of the current.

4. Prepare a half-empty PET bottle and tie it on a string. The string will be used to pull the bottle out of the river and repeat the measurement.

5. In the taped sections throw the bottle into the river and measure the time for which the bottle will travel a path laid out along the river bank. Record the measurement results into the prepared table.

6. Calculate the speed of the current.

7. In the taped section of the bridge measure by the weight attached to a string the depth of the river. Roughly determine the profile of the river bed.

8. Calculate the volumetric flow of the river - multiply the surface profile by the velocity of the river current.

9. Compare the date obtained from the calculation with the information date on the basin website for the river (in case of Morava river http://www.pmo.cz (VH dispatching - Stocks and flows).

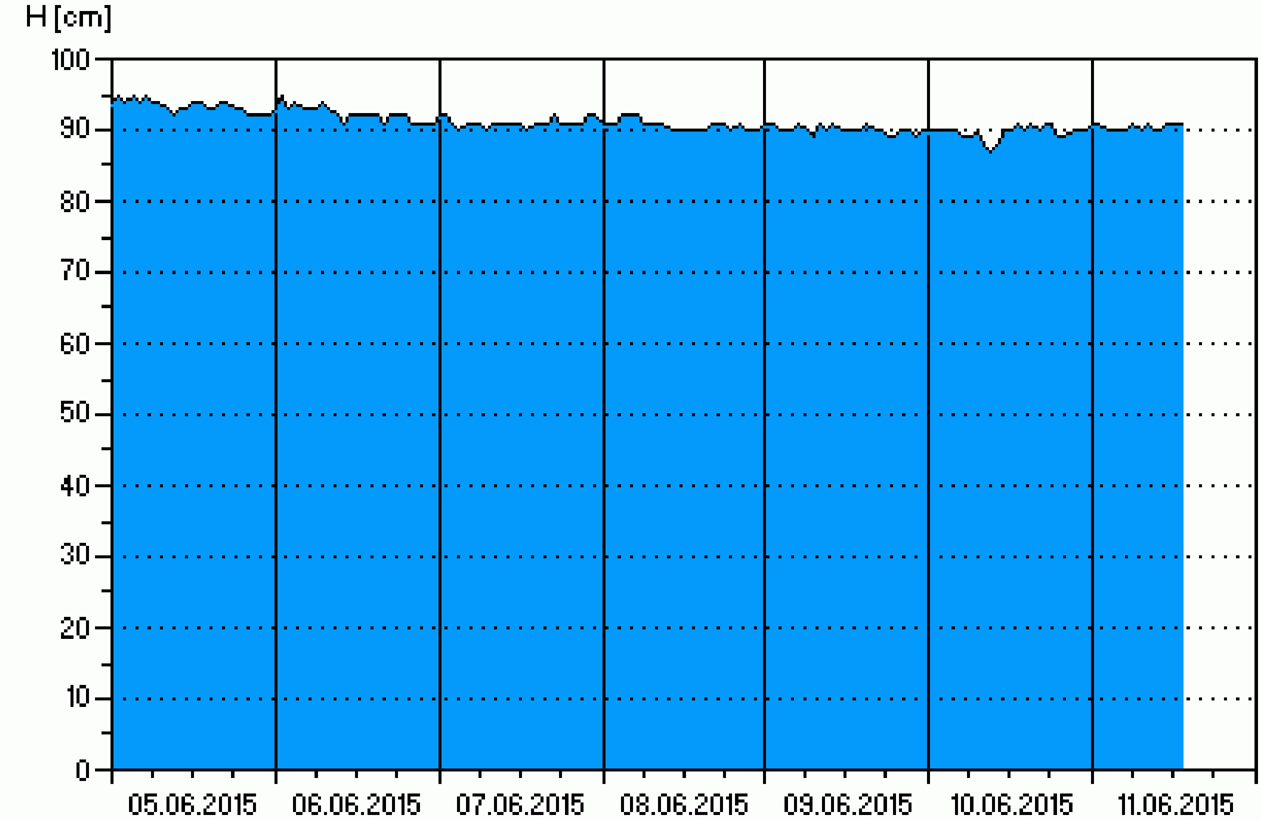
Discussion:

1. What is the current state of the water flow rate (dry, normal, high flow)?
2. When a level of a flood activity is announced at the river?
3. How does a flood rise?

Answer questions 1 – 3 !

Example:

Due to the measurements at June 2015, the flow rate and the water height in the river Morava in Olomouc city (Czech Republic) you can see in the figure bellow. Reading the data calculate the velocity of the water. You know that the distance of banks is 19.7 m. During floods in 1997 the flow rate was 760 $m^3 \cdot s^{-1}$. What can you say about the amount of water and its´ speed at that time?


H [cm]
100
90
80
70
60
50
40
30
20
10
0
05.06.2015
06.06.2015
07.06.2015
08.06.2015
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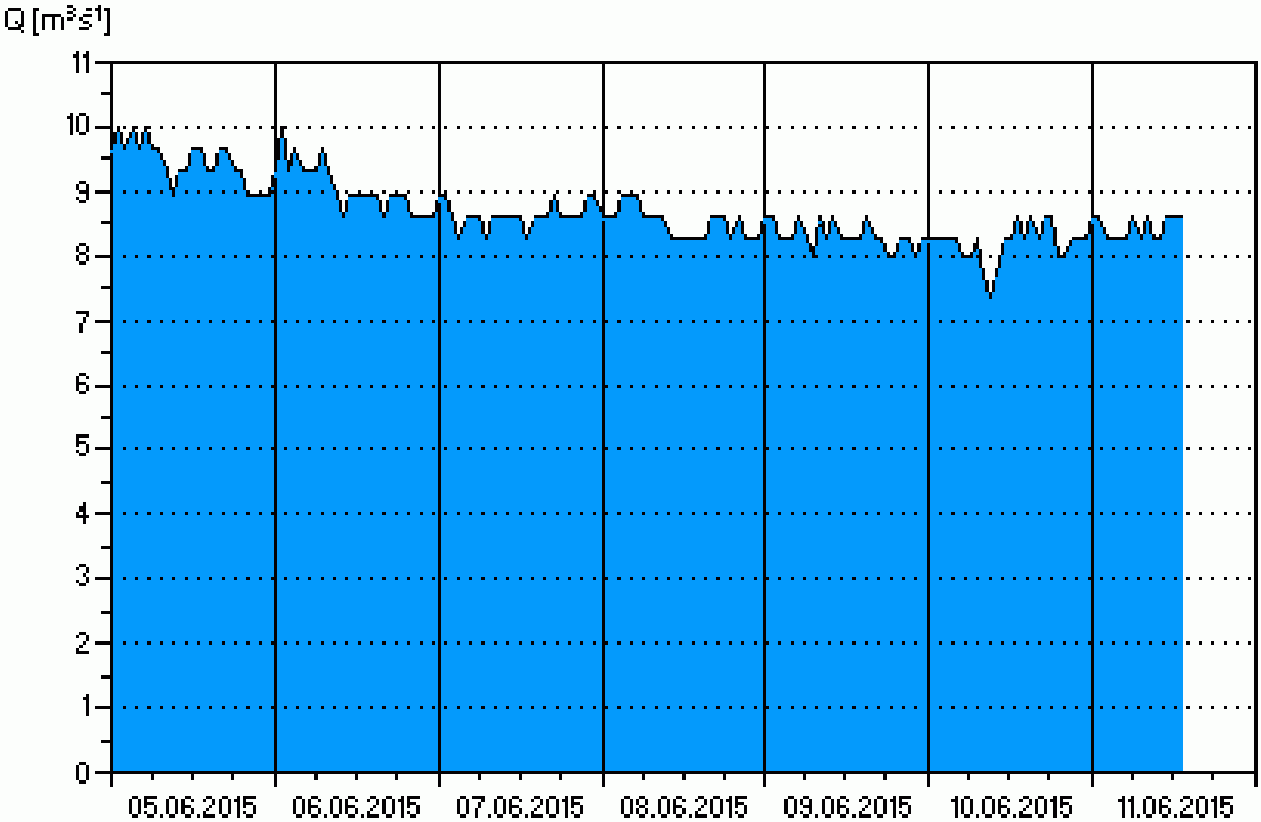
10.06.2015
11.06.2015


Q [m³s⁻¹]
11
10
9
8
7
6
5
4
3
2
1
0
05.06.2015
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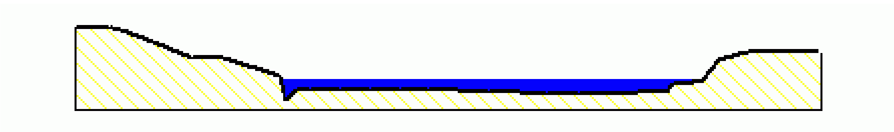
Shape of the river bank



$Q_V = S \cdot v$

$S = H \cdot s$

$S = 19.7\ m \cdot 0,91\ m = 17.3\ m^2$

$v = Q_V / S$

$v = 8.6 / 17.3\ m \cdot s^{-1} = 0.50\ m \cdot s^{-1} = 1.8\ km \cdot h^{-1}$

Floods

Brainstorming – causes of flooding:

a) Physical factors - for example - infiltration capacity of the surface, intense precipitation, snow melt
b) Human factors – dams, agriculture, deforestation, urbanisation

Enhance curriculum - cross-discipline links

1. Explain the principle of measuring blood pressure with tonometer
2. Karman vortex path
3. Hydrology - Information on the hydrological situation

Ad 1)

Blood pressure is recorded as the ratio of systolic and diastolic pressure. It is stated in millimeters of mercury (in tore). To measure we use tonometer and stethoscope. Stethoscope finds sound phenomena that arise with a blood flow. Systolic pressure we take when a blood flow to the limb is restored (air pressure is equal to the blood pressure in the brachial artery). We listen to the sounds of the turbulent flow - the so called Korotkoff phenomena. Diastolic pressure is taken when sound effects disappear. Blood flow is laminar again. (http://cs.wikipedia.org/wiki/Krevn%C3%AD_tlak).

Ad 2)

http://cs.wikipedia.org/wiki/Theodore_von_K%C3%A1rm%C3%A1n

http://en.wikipedia.org/wiki/Theodore_von_K%C3%A1rm%C3%A1n

http://cs.wikipedia.org/wiki/Proud%C4%9Bn%C3%AD

http://petrik.bigbloger.lidovky.cz/c/108307/Karmanovy-viry-v-tekutinach.

Ad 3)

http://voda.chmi.cz/

http://floods.jrc.ec.europa.eu/