ENVXR 202: EARTH, AIR, WATER
EXPERIMENTAL PROJECTS for Water (W) 25 Feb 2003

As we said about the Energy experiments, this hand-out is meant to get you started. After progressing with these basic questions*, please pose some of your own questions of the experiment, and report on them in your lab-book.* Often this will involve changing something about the experiment to see the effect on the primary phenomenon. A useful idea is, when looking at a steady process (like a steady tornado) you can often learn something by seeing how it develops from 'the beginning'; in this case watching the tornado develop as the flow is turned on, and by doing something to change its intensity. Another tactic is to change the 'environment' of the experiment; in this case the tornado is very sensitive to the symmetry of the tank; if it is not round, or the drain is not in the center, or there is a 'mountain' somewhere at the base of the fluid, it may be disorganized, it can develop oscillations, or it may not form at all. These are useful observations (telling us why tornadoes are only found where conditions are right).

W1 OCEAN WAVES

Waves on water are generated by wind and flow, and can control the flows of rivers and streams (where they can 'stand still'). This cxperiment involves finding the relation between frequency and wavelength, looking at the velocity of the, fluid beneath the waves, seeing the great behavioral difference between waves in shallow water and in deep water, watching the increase in amplitude of the motion when waves approach a shore. This will involve both a long, thin Plexiglas channel and a smaller glass fish-tank, Images of the motion of the fluid can be made with a digital camera, Storm surges are great invasions of coastal lowlands by wind-driven waves; if they come at high tide they can be particularly bad, and they (not the wind) account for the majority of damage when hurricanes come to land. In the low-lying country of Bangladesh tropical cyclones can send ocean water over vast areas of the Ganges/Brahmaputra river delta, leading to major loss of lift. Ocean waves also have analogs in many other systems, for example something like the refraction of light beams is seen as waves approach a beach.

1. Set up the long (8-foot) plexiglass channel with about 5 cm. of water in it. Using a small piece of plexiglass as a paddle make waves (try to avoid making scratches, by taping up the end of the paddle).

2. Set up a smaller tank…aquarium or short plexiglass tank…and make waves in deep water (at least 25 cm deep). How do they differ from waves in shallower water, say 5 cm. deep (you can compare simply by reducing the water depth here), and in very shallow water (less than 1 cm deep)?

3. Observe the motion of particles floating beneath the surface and on the surface. Describe the velocity pattern of water beneath a wave.

4. Visit the flume and try making surface waves using a plate (aluminum or plexiglas) as a wave maker). In the 'peninsula' experiment (W4 part 4.) look at waves that try to move upstream through the narrows where the flow is strong. This is a model

of the waves you experience as a kayaker in Puget Sound or the San Juan Islands: big waves are found in unexpected places because of the pattern of the strong tidal flow.

(It would be possible to make digital images of the particles and waves with our lab camera).

W2 OCEAN ESTUARIES AND TIDES

Estuaries are formed where rivers spill into the sea, They are often regions of great biological productivity, with biological food chain active from microscopic plankton to large sea creatures and birds. At one end the ocean provides salty, dense water rich with nutiients; at the other, the river water is very buoyant and floats out over the salt water. The tides totally change the circulation: these mix up the river water and lead to an 'overturning circulation' (seaward at the top, landward at the bottom). The strength of this circulation far cxceeds the simple river inflow, and it is important in ventilating the estuary with oxygen and nutrients. In this experiment we want to explore the overturning circulation, its dependence on tides and river flow and other mixing. There may be ridges on the seafloor that are involved, and layering of the density is important to examine. A separate hand-out exists for starting up this experiment. (This was attached to the paper hand-out).

W3 CIRCULATION OF THE GLOBAL OCEAN AND CLIMATE CHANGE

At a much larger scale than an ocean estuary, we find some similar events: the entire global ocean has a circulation that involves sinking at high Iatitude, and rising elsewhere. This kind of circulation, sometimes known as a 'conveyor belt' brings nutrients to the sea surface where in the sunlight they make for very active growth. PhytopIankton, the 'grass of the seas', grow there and lead to a whole spectrum of animal life A fundamental property is the 'layering' of the ocean, with dense (cold or salty) waters at the bottom and buoyant (warm or fresh) waters at the top. It is very difficult to move vertically against this density difference. In the experiment we want to observe the form of the ocean circulation when at the surface the water is made dense or less dense by cooling and heating or by 'rainfall' and evaporation.

1. One of the simplest ways to begin is to use a small amount of crushed ice to cool the surface and observe the circulation that follows, using colored dyes, ink, or small particles in the water. The rates of circulation can be observed, as well as internal wave motions, where regions of different density move in a 'silent surf.'

2. Put saline water (made by dissolving 10 g of salt per 100 g of water) in a spray-bottle. It's density will be close to 10% greater than fresh water. Instead of crushed ice, spray this water on the surface of the experiment near one end, and used dyes to trace the circulation that develops. This is a similar circulation, showing that evaporation at the sea surface or rainfall (which change the surface salinity) can drive deep-ocean circulation. (*Please be careful not to spray the salt water anywhere but in the tank, and wipe up salt crystals which appear elsewhere).*

3. Note the vertical motion of the fluid, comparing the sinking regions with the regions of rising water (this is an appropriate model of the global ocean circulation, and

its form largely controls where the biological communities in the world's oceans can be active).

4. You may want to examine the competing effects of heat and salt on the ocean circulation. Of great importance is the observation that the oceans are cooled at one end of the 'tank'; look at the difference in circulation when the crushed ice is uniformly distributed along the surface, compared with placing it all near one end.

W4 RIVER FLOW, SEDIMENT TRANSPORT AND EROSION

On geological timescales sediment transport from the continents to the oceans is central to the cyclical process or mountain building and erosion that shapes our continents. Sediments can be transported across continents by wind, ice and rivers but rivers are globally the dominant mechanism. The high sediment loads carried by rivers produce rich soils on flood plains and repeated floods can replenish the soils in agricultural region. However, human actions can reduce the rate of sediment erosion, transport, and deposition by the construction of dams and by channelizing rivers to protect towns or farmlands. In this experiment you will work in the flume to understand the basics of sediment transportation and erosion.

1. Determine the minimum fluid velocity for sediment motion – the flow meter will not work (for long) in sediment-rich water so you will have to time ping-pong balls.

2. Observe how individual grains move, Why do ripples (analogous to sand dunes on land) form - try leveling out a section of sand and see what happens.

3. Study the patterns and rates of erosion around a pebble, a post, a curve (remove the baffles at one end of the flume), a spur or any object that interests you,

4. Put a 'peninsula' in the flume using one of the curved aluminum sheets from the ends. This makes a constriction of the flow, leading to strong effects on sediments (and also on gravity waves on the water surface).

W5 GROUNDWATER FLOW -AQUIFERS AND POLLUTION

Groundwater is a critical component fresh water supplies. In many regions groundwater is being withdrawn at unsustainable rates. In others, groundwater supplies have been damaged by pollution that can be very difficult to remediate. Cape Cod, Massachusetts is a sand-spit created by melting glaciers at the end of the last Ice Age (~ 12,000 years ago). Its inhabitants drink water from wells (and have septic systems), and yet sometimes experience salt water in their wells. In the US Midwest, great aquifers are a 'mined' for farming dry lands, using center-pivot irrigation (those circles you see from an airplane). The movement of water through these underground rivers is very slow.

In this experiment you will study the basic mechanisms of groundwater flow through a porous medium and will look at simulations of flow through a permeable aquifer and the formation of a salt wedge beneath a coastline (i.e., and Intrusion of salty water beneath fresh groundwater).

1. Using vertical column filled with sand and water measure the rates of gravity driven water flow through the column

2. Using dyes of various colors as models of pollutants in groundwater, see if they follow the water or get 'stuck' on the sand particles (this is called adsorption). Is the result affected by the presence of air pockets?

3. Working in a fish tank (and with our help) construct a model of a permeable aquifer or of ground water near a coastline. Fresh water, being lighter (less dense) than salt water, floats on top of it (even when both are inside a sandy layer). The ocean penetrates the coastal sands and can invade people's drinking wells. The fresh water is a lens-shaped region that requires constant recharging (rain) to hold back the sea.

We can use a time-lapse video camera in this experiment to study the motion of dye pulses and the effects of water withdrawal from wells.

W6 IRRIGATION - EVAPORATION m SALINIZATION

Irrigated fields account for about 30% of the world's agricultural production and are crucial for food supplies, In arid regions, a significant proportion of the water used for irrigation is wasted by evaporation both from holding reservoirs and canals and from the irrigated lands. Evaporation leaves behind dissolved salts and in' the absence of rain to wash the salt away this can, over time, lead to salinization (salt deposits) and low crop yields. The Colorado River, for example, is a major source of irrigation for the huge farming enterprise in California. Its salinity (concentration of salt, measured as kg of salt per kg of solution) is very small yet the effect accumulates just as some chemicals accumulate in our bodies.

1. In this experiment we will use Petrie dishes and the a scale measure rates of evaporation. This is the same scale used in the Energy Unit to weigh burning candles. Make up a small beaker of sand saturated with water, and let it evaporate.

2. How do the rates of evaporation compare for a water layer (a reservoir), water-saturated sand and wet unsaturated sand?

3. What are the effects of wind, sun (heat lamp), and humidity (close the door on the scales or place the Petrie dishes beneath an inverted fish tank - we will use wet and dry bulb thermometers and psychrometic tables to measure humidity)? What are the effects of placing dissolved salt in the water?

4. We want to know where the salt ends up when the water evaporates. Use colored dyes as well as salt to explore this. Are there mechanisms which move the salt upward and downward in the beaker? You can take small samples from different depths once the water has escaped, and then put them in a clean beaker, add water and determine the salinity with a refractometer or the salinity probe….though small concentrations of salt are difficult to measure (you might instead try to 'wash the salt out' and dry it, weighing the white residue).

Because things happen slowly in this experiment, consider part of your assignment to look at the ground water problem, W5. You can participate, or just make active notes on what others are doing.

W7 MICROCOSMS AND BIOSPHERES

We will continue the Microcosm experiment from the last unit: it involves air, water and much more, and is sufficiently important that we would like more students to work with it Oxygen production uptake by aquatic plants and animals, and exchange from air to water.

Here we have the opportunity to emulate the major biological cycle on Earth. We can attempt to make a small world where plants eat carbon dioxide and produce oxygen, while animals do the reverse. If things are not kept in balance this world will radically change (Amory Lovins describes the many-million-dollar attempt to build a 'Biosphere' in Arizona to keep 6 or so humans alive, in a self-contained 'world' isolated from the real one, for a year or more…it failed).

Air is:	23% oxygen	by weight,	21% by volume
	75.5% nitrogen	"	78% "
	1.3% argon	"	0.934% "

So, dry air has 1.3 x 0.23 or 0.3 grams oxygen per liter of air. That amount of air and oxygen should be enough to oxidize roughly 0.3 grams of carbohydrates (sugar, starch, cellulose).

$$O_2 + CH_2O \rightarrow CO_2 + H_2O$$
$$32\text{ g} \quad 30\text{g} \quad 44\text{g} \quad 18\text{g}$$

A typical reaction with the weights of the oxygen, carbohydrate, carbon dioxide and water is just above.

1. Estimate the oxygen consumed by a 1 gram gold-fish who eats 0.01 gram per day of fish-food (carbohydrate). What volume of air would contain this amount of oxygen?
2. Using a 3 liter flask with a stopper and electronic oxygen probe, design an environment which will provide one or more goldfish with enough air to survive. In particular the water level will determine the amount of air above, and this is the supply. We will measure the oxygen level using the probe and computer, over a period of a couple of days.
3. In a similar 3 liter Florence flask, with the same amount of water, place several grams of aquatic plant (weighed out of water). Insert the oxygen probe with tight stopper. Shine a light on the experiment, measuring its intensity with the radiometer. Log this data on the computer for a day or two. Determine how much oxygen is produced by the known weight of aquatic plant life.
4. Design a microcosm in which both of the above are present: green plants and gold-fish.

5. A separate but related question: oxygen moves across a water surface from the air, increasing the dissolved oxygen in water until no more can be taken up. Can we see this happening?[*Carry out this experiment with oxygen-sensitive dyes if the primary microcosm experiment is 'cooking' for a long period of time.]*

5.1 Take a 250 ml beaker, fill with 125 ml of potassium hydroxide (KOH) solution we will provide.

5.2 add a few crystals of methylene blue.

5.3 add 5 grams of dextrose sugar

5.4 stir and let sit

5.5 this solution should become clear (transparent)

5.6 shake the solution which will force oxygen into the water, causing it to turn deep blue. This will be temporary because the oxygen will be then taken up by the KOH.

5.7 place the solution in a beaker with an open surface. If the amounts of chemicals are right, you may see that the water very near the surface is blue, and plumes of blue descend from it. This is the remarkable process of oxygen 'invading' the water from the air.

applications: this experiment relates to the basic biology and chemistry of the Earth and the oxygen and CO_2 of its atmosphere. Greenhouse warming of the Earth is happening as the CO_2 gets out of balance following our fossil fuel burning (and burning of forests). There have beem very warm eras in the past (like the Cretaceous period that ended 66 million years ago: the age of dinosaurs. During the Cretaceous there seems to have been no ice or snow on Earth, with jungles in Antarctica.