approximately 27 ft^3/min; this rate caused a change in atmosphere in the chamber in about 1 minute. The general test procedure was to select plants of a specific variety of uniform age and condition, to spray them with test solutions, to allow them to dry for 1 hour, and then to place them in the fumigation chamber. Before placing the plants in the chamber, the air was brought to a constant ozone concentration. After exposure to the ozonized air for a specific period of time, the plants were removed and placed in a greenhouse for observation.

After preliminary work, experiments were made on tobacco plants (*Nicotiana glutinosa*) about 8 weeks old and with only the upper six fully expanded leaves left on the plant. One-half of each leaf (right hand on two replicates and left hand on two replicates) was painted with a dispersion (2 percent by weight) of a solid catalyst under test and air dried. Four drops of a wetting agent (polyethylene sorbitan monooleate) were used in each 500 ml of solution. The dispersion was shaken and dabbed on one-half of each leaf, top and bottom, with disposable paper tissue. The dry particles tested were powdered sulfur, kaolin, diatomaceous earth, powdered clay from Tulare County, powdered ferric oxide, and powdered charcoal (Norit A); they were of a size that passed through 325-mesh screen.

Four experiments were performed where six plants were exposed to ozone in the fumigation chamber. Six leaves on each plant were treated by the systematic Latin square method. In this manner the effects of orientation and age of the leaf on the plant were minimized. In the final experiments a second measurement of ozone concentration was made by passing the exhaust gas from the chamber through a long-path (40 meter) Perkin-Elmer No. 21 infrared spectrophotometer. Before placing the plants in the chamber, the air was brought to a constant ozone concentration. After exposure to the fumigating atmosphere for a specific period of time, the plants were removed and placed in the greenhouse for recovery and observation. Typically, lesions resulting from the ozone were sometimes visible at the end of the fumigation period, at high ozone concentrations. At lower ozone concentrations, the lesions were readily visible the next morning.

The experimental results (Table 1) clearly indicate that diatomaceous earth, powdered charcoal, and powdered ferric oxide are excellent particulate protectants against ozone damage. At the typical ozone concentrations likely to be found in the field, clay—as exemplified by Tulare clay—is also effective.

Thus plants can be protected by a heterogeneous catalyst sprayed or dusted on the plant which will promote the decomposition of ozone at a regulated distance above the actual surface of the leaf (*5*).

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Groundwater: Flow Toward an Effluent Stream

Abstract. *Hydrodynamic, topographic, and geologic factors control flow of groundwater toward an effluent stream. Features of such flow are illustrated by a hydraulic model that simulates the stream and surrounding consolidated rocks. Colored ink in the flow system marks progress toward the stream. Visual analysis shows that groundwater moves into the effluent stream along curvilineal flow lines. The total head of groundwater beneath the stream increases with depth.*

One of the most interesting groundwater flow-patterns in nature occurs in the vicinity of an effluent stream, a stream which is supplied by the surrounding groundwater. Legal disputes have arisen from misinterpretation of information about the flow patterns near such streams. Water levels in wells drilled along an effluent stream can be higher than the water level of the stream, and this fact has been submitted as evidence that groundwater and surface water are not connected (*1*). Once established as a fact in court, a decision can be obtained in some states that action taken upon the groundwater body cannot possibly have any effect on the surface water body. Such a stand may be taken by a groundwater user to prove that pumping cannot deplete surface water. A groundwater user could similarly argue that he cannot contaminate surface water by discharging waste into his well. Results derived from a hydraulic model, analogous to the geologic setting commonly found near an effluent stream, show that such arguments in many cases may be spurious. Only by adequate definition of both the geology and hydraulics near the stream can the courts render sound judgment on such matters (*2*).

The model (Fig. 1) consists of a watertight plexiglass case containing a porous consolidated mixture of sand and epoxy resin (*3*). It is 30 inches long, 1 inch thick, and 12 inches high at each end and slopes down to a small channel near the center. The channel represents the cross section of the effluent stream. Ink was discharged into the model through a perforated brass tube buried in each end. The ink entering the sand progresses through it and marks the path of flow, or flow line, from each perforation. Water was recharged into both ends and discharged only from the simulated stream. The water table nearly coincided with the rock surface on either side of the stream. Figure 1 indicates the general direction of flow at several times after the flow of ink was started.

The flow lines turn up near the center and appear to defy gravity. Although the water is definitely flowing upward topographically, it is flowing downward hydraulically in accordance with physical principles. Groundwater always moves from regions of high hydraulic head to regions of low hydraulic head.

The effluent stream may be compared with a horizontal well. In a man-made well, an area of low head is produced by pumping and the groundwater thus flows from the surrounding areas of high hydraulic head to the region of lower head near the well. The effluent stream is also an area of low head, but the head distribution about the stream is a function of the topography and rainfall which have caused a high water table to form; a region of high hydraulic head surrounding the topographically low-stream channel is thus furnished. Consequently, water moves from the adjacent highland into the stream.

Figure 2 shows the flow diagram of

the effluent stream model. Flow follows the direction of maximum gradient as a ball takes the steepest path when rolling slowly down a hill. Since the gradients are maximum along paths normal to the equipotentials, the flow lines cross the equipotential lines at right angles and thus form a conjugate system. The equipotential lines beneath

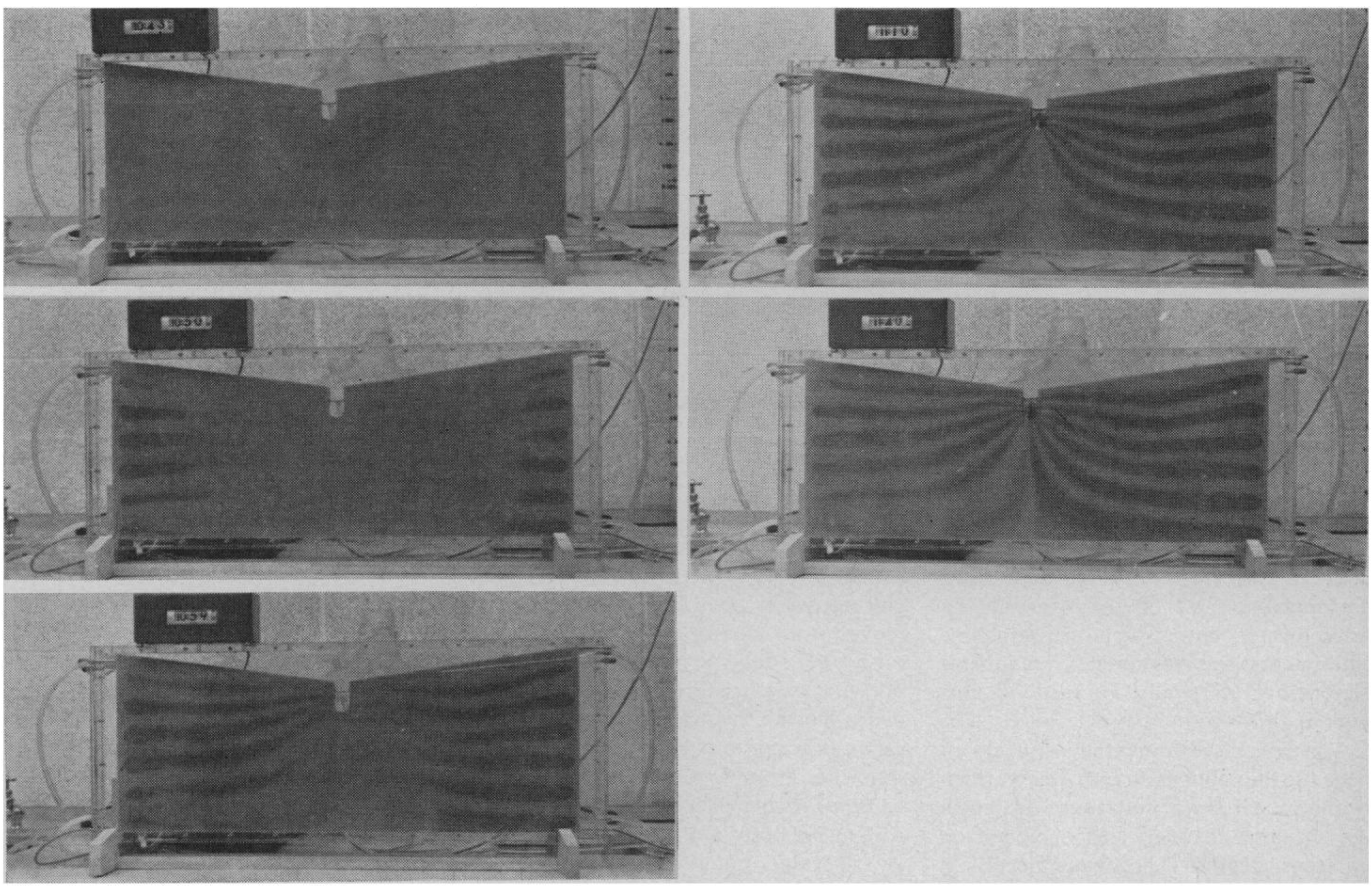

Fig. 1. Model of an effluent stream. Flow bands move through a porous medium of isotropic permeability.

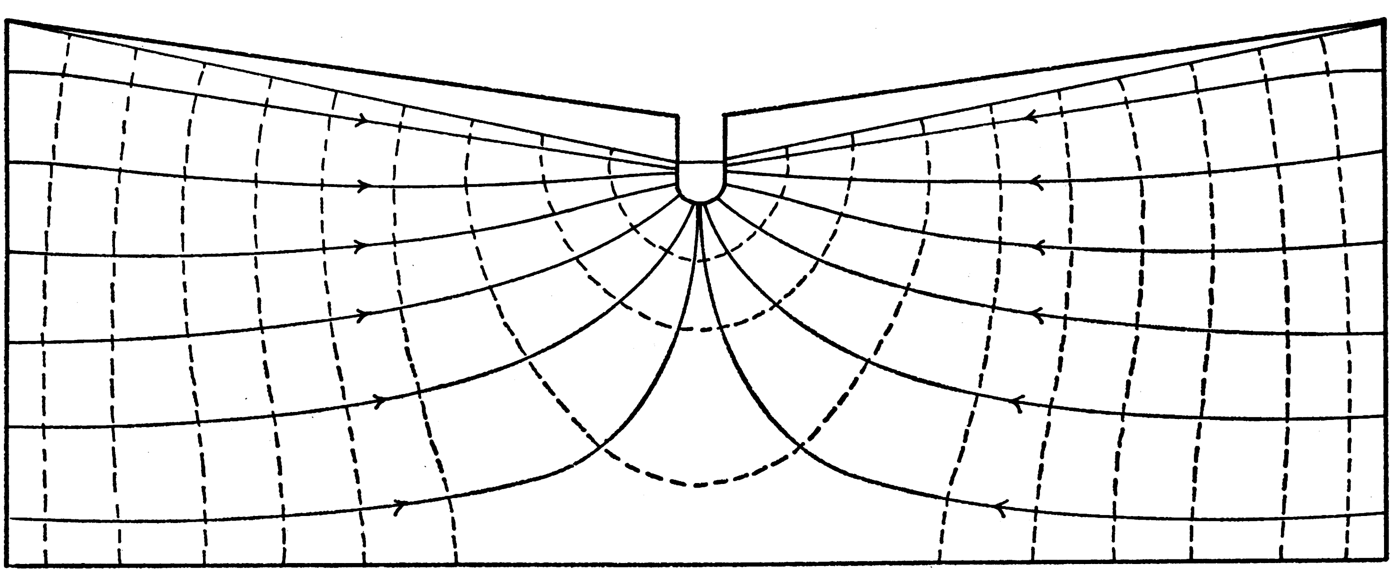

Fig. 2. Flow diagram of effluent stream model shown in Fig. 1. The path which a particle of water follows is called a flow line; these are represented by solid lines with arrows. The head decreases along the path of flow. Lines connecting points of equal head are called equipotential lines and are indicated by dashed lines. An unlimited number of flow and equipotential lines can be drawn in any flow system; however, in a flow diagram a finite number of lines suffices to illustrate best the general pattern (about ¼ actual size).

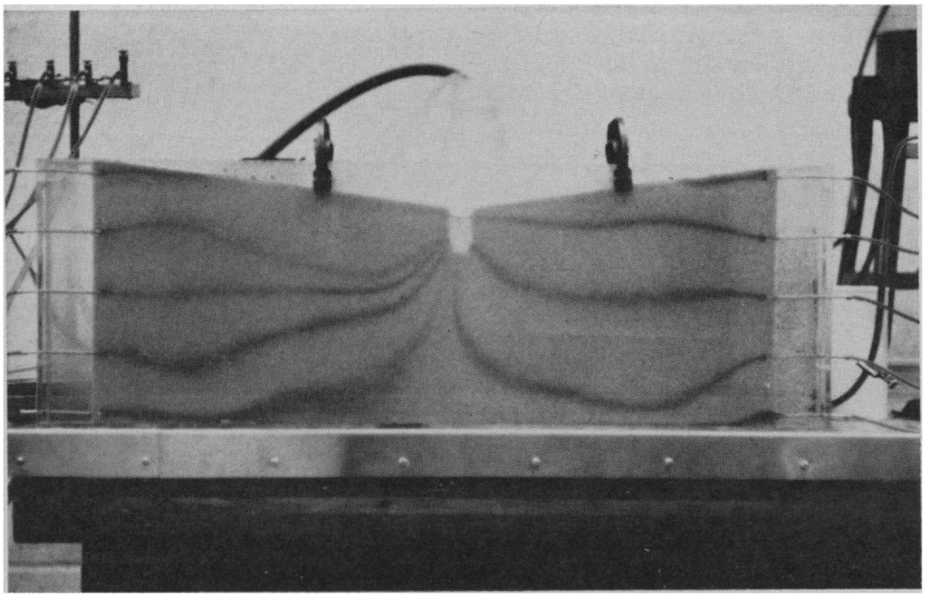

Fig. 3. Model of an effluent stream. It contains a porous medium of anisotropic permeability.

the stream become horizontal as they connect points of equal hydraulic head on opposite sides of the stream. The groundwater flow which crosses these equipotentials at right angles must therefore move vertically upward in this region.

The increased potential with depth beneath the effluent stream was verified in the model. Two wells were drilled in the stream channel and screened at different depths. The water levels in the wells rose to different heights above the level of the stream itself. The deeper of the two wells had the higher water level which indicates the higher potential at greater depth.

The model (Fig. 1) contains a homogeneous medium with an isotropic permeability which resulted in a set of flow lines following smoothly curving paths. Figure 3 shows a model of an effluent stream similar to the one in Fig. 1. The consolidated medium was sand of the same type as Fig. 1, but packed unevenly. Variations in packing caused variations in permeability, which in turn caused the tortuous paths of the flow bands (Fig. 3). Although the model in Fig. 1 was more convenient for theoretical studies of flow, the pattern of flow near an effluent stream in nature may be much less predictable because the permeability is not generally uniform.

Comparison of the rates of movement of the flow lines (Fig. 1) shows that the flow along the base of the aquifer is much slower than at points higher in the model. This knowledge is very important in studying streams near the sea which are subject to onshore winds and salt water tides. The salt water may move up the stream during a storm and raise the water level, and thus temporarily reverse the groundwater gradient. During this temporary flow reversal, salt water moves from the stream into the ground water body and because of its high density may eventually sink to the bottom of the formation (*4*). A salt-water mound is thereby formed beneath the stream channel; this mound may have a long-lasting, detrimental effect on water-supply wells in the deep portion of the aquifer near the stream channel. Although the original groundwater gradient may be resumed soon after the stream subsides, a long time will be required to wash out all the salt by the comparatively slow movement of groundwater through the deep zone. A town's water supply can be temporarily impaired beyond use by this phenomenon, but this occurrence can be avoided if water-supply wells are placed at a safe distance from the bank of any stream subject to salt-water tides.

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Malate Dehydrogenases in the Rusted Bean Leaf

Abstract. *Rust growth in the bean leaf was accompanied by the appearance of one new malate dehydrogenase isozyme and continuation of one otherwise lost during the development of the healthy leaf. The new isozyme was contributed by the fungus, the other by the leaf. Both enzymes were cytoplasmic proteins. Rusting caused the loss of a mitochondrial isozyme.*

Postinfection changes in metabolism of the host-parasite complex have been the subject of numerous papers, but changes in either host or rust fungus have only been suggested. A fuller knowledge of the two infection parameters would bring a clearer understanding of what constitutes resistance and susceptibility. We have separated proteins from rusted and healthy leaves by gel electrophoresis and surveyed their enzymatic activities.

Ten days after seeds were sown, primary Pinto bean leaves from pruned plants were inoculated by spraying with a suspension of *Uromyces phaseoli* Schw. uredospores. Ten leaves were extracted with a Pirie press (*1*) in 40 ml of 0.1*M* tris buffer, *p*H 8.0, supplemented with 17 percent sucrose, 0.1 percent ascorbic acid, and 0.1 percent cysteine-HCl. Undialyzed extracts containing 0.2 to 0.4 mg of protein were pipetted onto prepared polyacrylamide gels (*2*). When extracts of uredospores were required, 1 g of spores was ground with 10 ml of buffer and sand in a Potter-Elvehjem homogenizer. Malate dehydrogenase was detected on the gels with nitroblue tetrazolium (*3*), while breis were assayed spectrophotometrically (*4*). Mitochondria were obtained by the usual differential centrifugation techniques and purified further on sucrose density gradients.

Two malate dehydrogenase isozymes were found in the cytoplasm from healthy leaves; in contrast, there were four isozymes in rusted leaves at a late stage of infection (Fig. 1, *A* and *B*). Uredospores contained three isozymes (Fig. 1*C*).

Uredospore band 1 had the same mobility as band 1 from the infected leaf, and the substance in each was destroyed by heating at 50°C for 5 minutes. This isozyme was found only in the infected leaf; it was not detected in petiole, root, or stem. Its fungal origin seems clear and indicates little physical difference