provided sufficient information for a reasonable estimate of this impact. These results provided a scientific basis for compromise between the Environmental Protection Agency, interveners in the proceedings, and the utilities involved.

Ecology of the Continental Shelf The continental shelf is critical to humans. Its fertile coastal waters, which account for less than 10 percent of the total ocean area, produce 40 percent of our seafood. The research, performed by a number of laboratories and universities working in specific sectors of the shelf, is well coordinated with work conducted under the auspices of other federal agencies with related responsibilities. Some fundamental mechanisms by which pollutants, as well as nutrients, enter the food chain are being established. The research program has also included studies of mechanisms by which pollutants are carried across the continental shelf into the deep ocean and of their effects on living systems. Potential benefits include a better understanding of the effects of sea disposal of municipal and other wastes, possible effects of such offshore operations as oil development, and the consequences of oil spills and of other accidental releases of chemicals in coastal areas.

Tracing Pathways of Nuclear Wastes in the Life Cycle Environmental studies in areas other than land and water use have also yielded information on the cycling of pollutants from human activities through the environment and back to humans or to other biological organisms. Several defense-related facilities process radioactive materials in the *transuranic* category (elements heavier than uranium), which are potentially hazardous to humans. Thus laboratories at the Savannah River Plant in South Carolina have for many years studied the possible uptake of these materials in the environment and the consequent potential for human ingestion. Thus far, measurements of minute concentrations of transuranics in the air and in crops grown in soils near these defense facilities indicate that the dose to humans is minuscule compared with that which results from naturally radioactive materials. These results have been compiled and form the basis for other determinations that may be made in the future regarding civilian and military applications of nuclear technology involving transuranic elements.

A similar situation arose with the question of the fate of other radioactive materials released in fallout from nuclear-weapons tests. Tracer research, undertaken early in the period when such atmospheric tests were conducted, led to the understanding that some elements, when transmitted up a food chain, concentrate at various levels. They can pass from one level to the next only through feeding (e.g., uptake of iodine-131 in forage eaten by dairy cows, whose milk would then be consumed by humans). This research has proved extremely valuable to the development of a better understanding of the functions of biological systems, as well as to assessments of the environmental impacts of proposed nuclear facilities.

Plant Metabolism A particularly useful application of radioisotope tracers has permitted a complete mapping of the pathways of carbon in the photosynthesis process. With carbon-14 as the tracer, the process from the initial fixation of carbon dioxide from the atmosphere has been followed through to the production of glucose by green plants. This understanding of the detailed biochemistry of photosynthesis laid the groundwork for new areas of investigation, such as the acceleration of plant growth and other forms of metabolic control. Another benefit provided by carbon-14 as a tracer is detailed information on intermediate chemical products and enzymes associated with both plant and animal metabolism. A spectrum of genetic engineering techniques and developments is therefore now possible.

Land Reclamation Field research studies were undertaken at mining sites in three different environments: (1) a strip mine in a grassland area of Wyoming; (2) an arid area of New Mexico; and (3) in fertile Illinois farmland. The strip-mine studies have demonstrated less expensive and more effective use of topsoil in land reclamation. The potential savings through adoption of the technique in western mine areas alone could be $600 million over the next 20 years. The studies in New Mexico showed that several kinds of hybrid plants that are highly drought tolerant could be well adapted to the reclamation of arid areas. The research in Illinois focused on techniques for returning mined, prime farmland to production. In Illinois, as in Wyoming, less expensive methods of land reclamation were found to be at least as effective as those now in practice.

Detection and Measurement of Environmental Effects

Detecting Change Over the Ages Evaluation of the effects of pollutants on the environment, as on human health, requires the development of specialized measuring techniques. Just as a radioisotope can tell of a patient's condition and tracers can give clues to the paths taken by pollutants in the atmosphere, so, too, can a similar technique give insight into geological events of long standing. Previously unanswerable questions can now be addressed. For example: How fast is land eroding? How fast are glaciers building? How old is groundwater? How fast is it replenished?

The technique that makes it possible to answer these questions uses *isotope ratios* and evolved from basic research begun in the 1950's to an understanding of long-term changes in environmental processes. Isotopes are nothing more than differing nuclear forms of the same element and therefore have the same chemical behavior, but they can be