Utah State University
DigitalCommons@USU

Progress reports US/IBP Desert Biome Digital Collection

1974

Measurement of Evapotranspiration with a Monolith Lysimeter

D. W. Young

D. D. Evans

T. W. Sammis

Follow this and additional works at: http://digitalcommons.usu.edu/dbiome_progress

Part of the Natural Resources and Conservation Commons

Recommended Citation

Young, D. W.; Evans, D. D.; and Sammis, T. W., "Measurement of Evapotranspiration with a Monolith Lysimeter" (1974). *Progress reports.* Paper 64.
http://digitalcommons.usu.edu/dbiome_progress/64

This Article is brought to you for free and open access by the US/IBP Desert Biome Digital Collection at DigitalCommons@USU. It has been accepted for inclusion in Progress reports by an authorized administrator of DigitalCommons@USU. For more information, please contact dylan.burns@usu.edu.

UtahStateUniversity
MERRILL-CAZIER LIBRARY

1974 PROGRESS REPORT

MEASUREMENT OF EVAPOTRANSPIRATION WITH A MONOLITH LYSIMETER

D. W. Young, D. D. Evans (Project Leader) and T. W. Sammis
University of Arizona

US/IBP DESERT BIOME
RESEARCH MEMORANDUM 75-42

in

REPORTS OF 1974 PROGRESS
Volume 3: Process Studies
Abiotic Section, pp. 27-35

1974 Proposal No. 2.3.5.5

Printed 1975

The material contained herein does not constitute publication. It is subject to revision and reinterpretation. The author(s) requests that it not be cited without expressed permission.

Citation format: Author(s). 1975. Title.
US/IBP Desert Biome Res. Memo 75-42.
Utah State Univ., Logan. 9 pp.

Utah State University is an equal opportunity/affirmative action employer. All educational programs are available to everyone regardless of race, color, religion, sex, age or national origin.

Ecology Center, Utah State University, Logan, Utah 84322

ABSTRACT

A 4.0-m-diameter by 1.0-m-deep monolith hydraulic weighing lysimeter was constructed around the root ball of a 6-foot creosotebush (*Larrea tridentata*) growing in undisturbed soil in a semiarid desert environment. Total weight of the container, soil and shrub is approximately 22,000 kg. The weighing mechanism placed under the lysimeter consists of 92 m of 10.3-cm butyl rubber irrigation tubing filled with an aqueous solution connected to a standpipe and to an electrical transducer/recorder for continuous monitoring. Weight changes are detected by measuring the differential pressure between the active standpipe and a dummy standpipe. The tentative sensitivity of the system is 1.44 mm which is equivalent to 1.0 mm of water over the surface area (12.7 m^2) of the lysimeter.

INTRODUCTION

Evapotranspiration losses have become an ever-increasing problem to the various water management and use agencies within arid and semiarid regions. Extensive research projects to determine ET losses from indigenous vegetation have been undertaken in the southwestern regions of the United States, notably in Arizona, New Mexico and southern California. Such research has met with more or less success depending on the case and the methods employed.

Determination of ET losses for a large area involves two major divisions: 1) evaluation of ET of specific vegetative types; and 2) computation of total losses based on the density of cover over an area by vegetative types. Recent refinement of remote sensing techniques has greatly facilitated density estimates; however, accurate and reliable measurement of ET from specific vegetated plots has proven to be a problem (Abd El Rahman and Batanouny 1965).

The monolith lysimeter appears to be the only reliable, direct method of ET data acquisition. Other techniques being employed to estimate ET require a standardization source with which to compare over the range of interest (Garstka 1974). As a great deal of valuable research of this nature is being conducted within the southwestern regions, it was felt that the construction of a monolith lysimeter would contribute greatly toward the direct determination of precise ET rates, and in the interpretation of existing and future research results employing indirect techniques of measurement

This report deals mainly with the site selection and construction of a monolith lysimeter within the Silverbell Validation Site near Marana, Arizona. Future reports will deal more with the lysimeter's calibration, data acquisition systems and continuing ET rate determination.

OBJECTIVES

This project involved the undertaking of construction of a hydraulic monolith weighing lysimeter within a desert biome, and the operation of the lysimeter to determine evapotranspiration rates by typical desert vegetation.

Specifically, the lysimeter was to be installed around a stand of *Larrea tridentata* (creosotebush) growing in undisturbed soil under typical desert conditions and operated on a continuing basis to obtain data on water dynamics and evapotranspiration by creosotebush.

METHODS

Through analysis of soil topographic maps and aerial photographs, several suitable site locations for construction of the lysimeter were located. Further ground-level inspections narrowed the number of sites to two on the basis of their soil type, nearness to existing hydrologic and storage installations, and proximity to electrical power facilities. Test holes were dug with a backhoe in the vicinity of the sites to determine soil stratification and the presence of rocky and/or consolidated material. On these bases the present site was selected (Fig. 1). Selection of a representative creosotebush was made on the bases of its size, shape, condition and relative proximity to neighboring shrubs, since adequate distance ($\pm$ 4m) was required during the construction phase for heavy equipment operation.

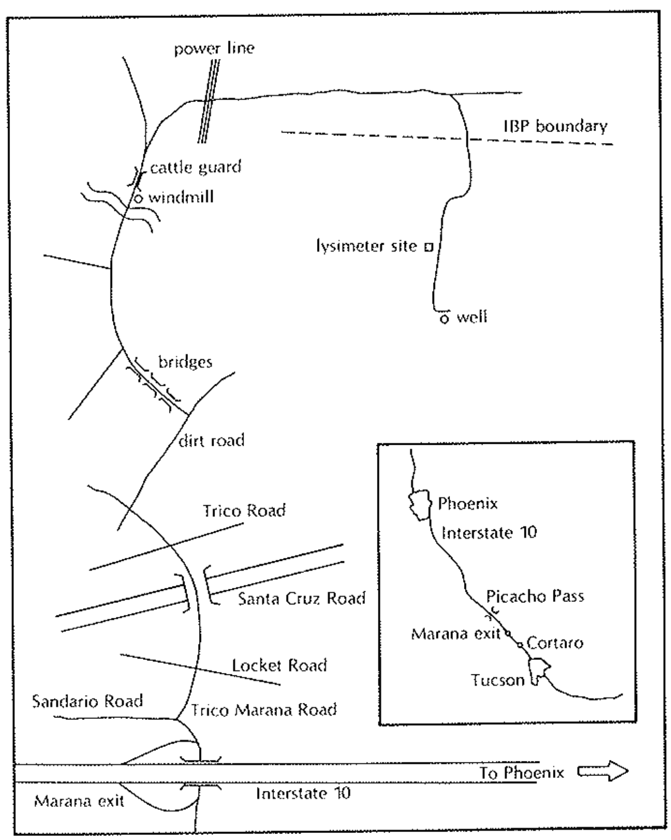

Figure 1. Map of site.

Design of the lysimeter was taken from that of Hanks and Shawcroft (1965) as modified by Fritschen et al. (1973). Further modification of Fritschen's design was required to suit a creosotebush and to meet the runoff measurement requirements. Actually, this mostly required a simplification of design since we were not concerned with the enormous sway stabilization problems encountered by Fritschen in building a lysimeter for a 28-m Douglas-fir tree.

With the aid of a local steel fabricating company (Automation Supply and Engineering, Inc.) components for the lysimeter were designed and manufactured. The lysimeter basically consists of four major components: an inner shell, an outer shell, a bottom floor plate and a transducer assembly (see Figs. 2 through 5 for details). The inner and outer shells were each fabricated from 12-gauge steel as two halves of a right cylinder (1 m deep x 4 m diameter) which could be bolted together and later welded in the field. This was necessitated by transportation difficulties which would have been encountered in attempting to deliver two cylinders each over 4 m in diameter to the job site. For similar, and construction reasons, the bottom floor plate was fabricated in the shop in sections 4.6 m long x 30.1 cm wide by welding 4.6 m long x 15 cm wide x 5 cm deep, 4.8 mm thick tubular steel planks edge to edge. Continuous weld was used on one side and 2.54 on 30.48 cm weld on the other. Solid bar stock steel 20.3 cm wide x 5 cm deep was used for the leading and trailing ends of the floor plate to give greater strength in the weld between the inner shell and the plate for emergency lifting purposes.

This yielded 13 sections of bottom floor plate which would be installed one by one under the lysimeter. The leading edge of the solid stock was outfitted with a cutting wedge of 6.35-mm steel set at a 50° angle to facilitate pushing through the soil column. Also, a water cock was fitted to one end of the cutting wedge and holes cut in the cutting face to aid in the process.

A transducer supporting plate, also fabricated in two sections, and the instrument well top cover together with the previously mentioned items were delivered on-site on April 29, 1974.

The university contracted with a local construction firm (Carreon Development and Construction, Inc.) for the actual installation of the lysimeter and excavation began on May 2, 1974. The two halves of the inner shell were set around the selected creosotebush on the soil surface and bolted together (Figs. 6 and 7). After excavation of a trench 1.5 m deep x 0.6 m wide around the outside of the inner cylinder (using a backhoe), the soil column was shaved to allow the shell to slide down around it. The inner shell was carefully leveled and blocked in place (Fig. 8). It had been surmised that a soil column of 4 m in diameter x 1 m deep would contain approximately 95%$^+$ of the plant's root structure (Cannon 1911). This appears to be substantiated since only very fine root hairs were encountered while shaving the soil column. Work done in the adjacent vicinty by Dr. John Thames (1972) of the Department of Watershed Management, University of Arizona, showed that creosotebush depth rarely penetrated below 1 m in depth.

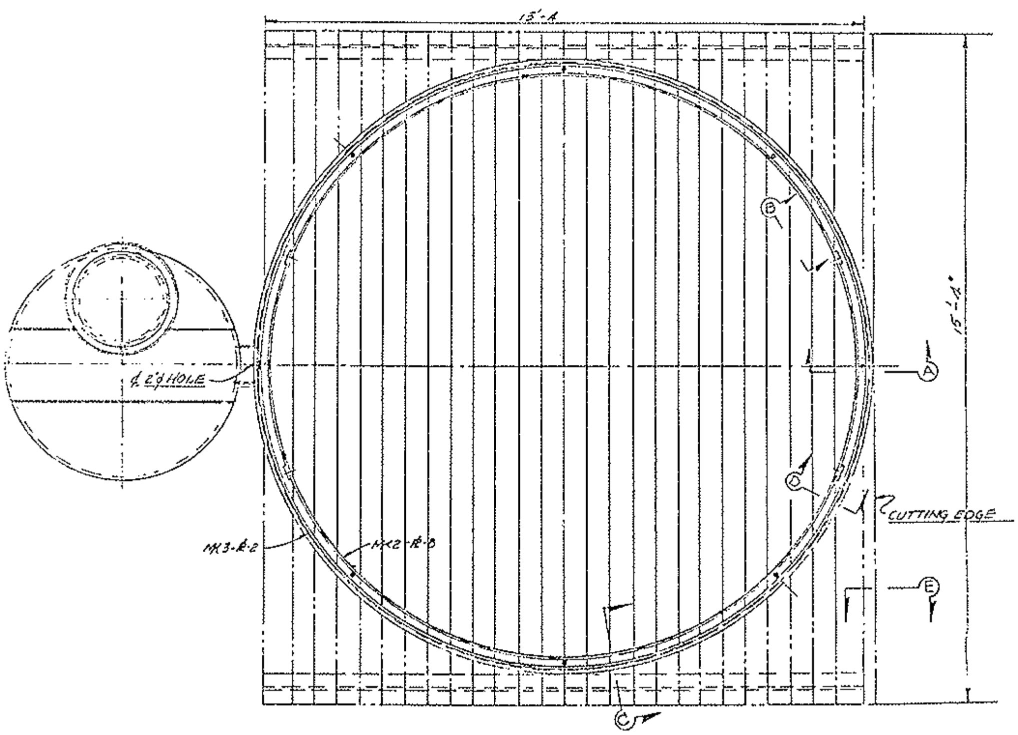

Figure 2. Plan view of lysimeter showing inner and outer cylinders, floor plate sections and instrument well.

Further excavation on one side of the plot was accomplished to yield a construction pit approximately 4.5 x 6 m. This area would later be used to bury the instrument well.

After carefully setting and aligning the bottom I-beams along the sides of the trench, and building the necessary cribbing to support the custom-made hydraulic jacks (36 tons), we were ready to embark upon what became the most difficult of all the phases of the project -- installation of the bottom floor plate. Dr. Leo Fritschen of the University of Washington, following the construction of his lysimeter, when asked how the tree was put in the lysimeter replied, "With great difficulty." This proved to be a considerable understatement of the fact!

Two bottom planks at a time were laid edge to edge on the supporting I-beams and field-welded to form a plate 4.6 m long x 60.1 cm wide x 5 cm deep. The first section contained the cutting wedge which was placed beveled edge up and was forced between the I-beams and the bottom of the inner cylinder under hydraulic pressure by the two 36-ton jacks blocked against the back of the trench bank. Each subsequent plank was welded and placed behind the previous one and likewise jacked forward (Fig. 9).

Due to misalignment and shifting of the cribbing supporting the jacks and unequal hydraulic pressures and various other maladies, we were able to gain only about 5 cm per day on the advance of the floor planks under the inner shell. This process continued on through the summer months until July when about four-fifths of the way under the lysimeter a consolidated rock strata, heretofore undiscovered, was encountered. We were unable to wash away the restrictive formation with the water induction system built into the cutting edge, nor were we able to push the plate forward with the jacks as we had maximized the hydraulic pressure system and blown seals on the jacks on several occasions. Obviously, a new tack was required (see Fig. 10).

Once we had the inner cylinder onto the floor plate they were welded together along the bottom periphery of the inner shell in a continuous watertight weld. Before welding could be accomplished, however, the inner cylinder had to be returned to a cylindrical configuration since stresses set up during installation of the bottom floor plate had warped the shell out of round by as much as 25 cm at points of maximum deflection. To accomplish this, approximately 25 cm of soil were removed by hand from around the periphery of the inner cylinder, the shell manipulated back into a

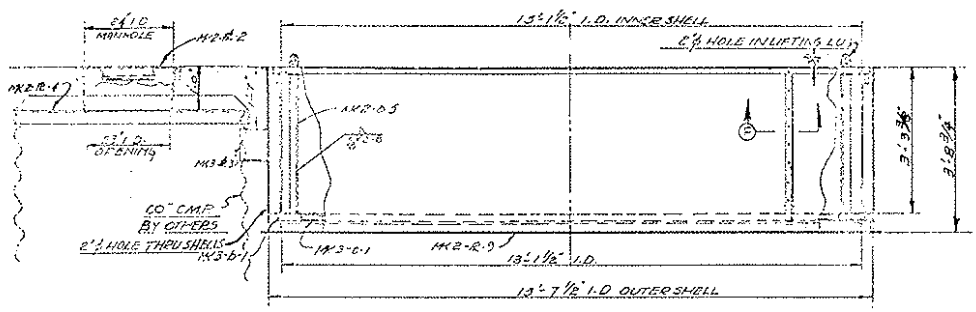

Figure 3. Cross-sectional view of lysimeter.

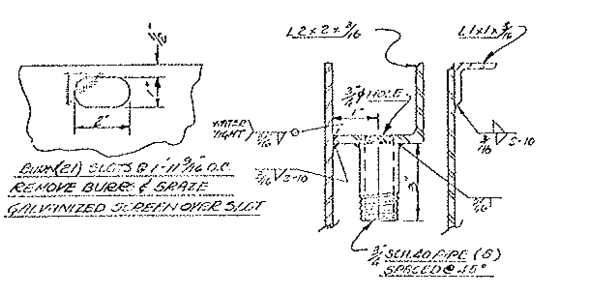

Figure 4. Detail of inner and outer cylinders and runoff channel.

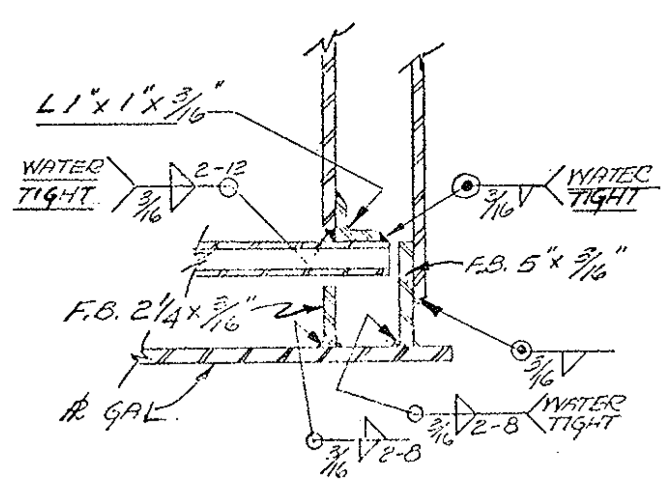

Figure 5. Detail of bottom floor plate and transducer support plate.

cylindrical shape (plus or minus 2.54 cm at points of maximum deflection) by means of mechanical "come-alongs," and finally, repacked with native soil to give a continuous and consistent soil column throughout. The supporting I-beams were tack-welded to the outer edges of the floor plate and 25-ton jacks placed on each corner. The inner cylinder, now containing the entire soil column and the floor plate, was then carefully jacked vertically approximately 1 m in progressive stages while 10 x 15 cm-hardwood cribbing was placed underneath the outer corners.

With the soil column raised we were now ready to begin installation of the transducer supporting plate and water-filled transducer tubes. We had previously contracted with Watersaver Company, Inc., Denver, Colorado, for 150 m of 10.3-cm butyl rubber (60 mil) irrigation tubing cut into 15-m lengths and vulcanized shut on both ends. An air/water valve was vulcanized into each section approximately 30 cm from one end. These tubes were filled in the field with a $\pm$ 2% calcium chloride/copper sulfate solution to serve as a fungicide and antifreeze mechanism. They were laid out on plastic sheets and allowed to warm by solar radiation and de-aired by "walking" the tubes their full length. We experienced considerable difficulty with leaks

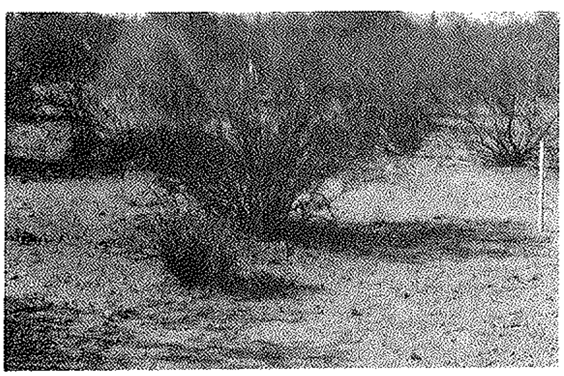

Figure 6. Selected creosotebush.

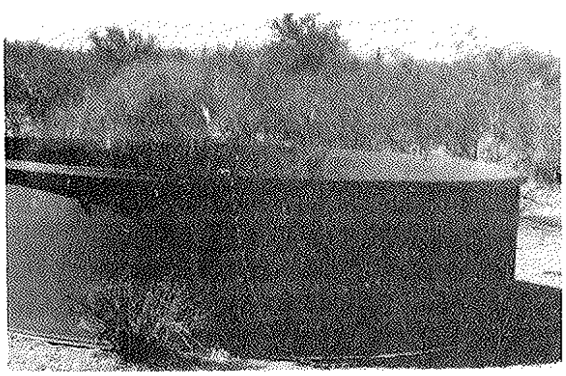

Figure 7. Inner shell around bush.

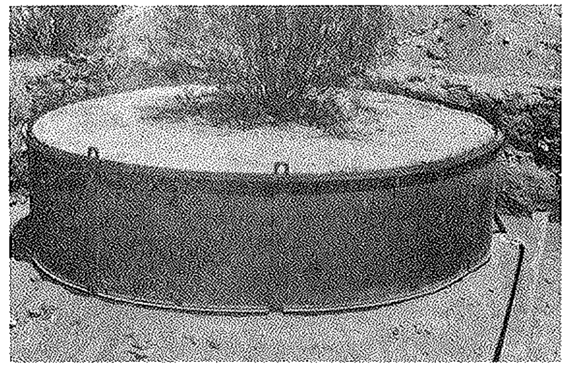

Figure 8. Inner shell around soil column.

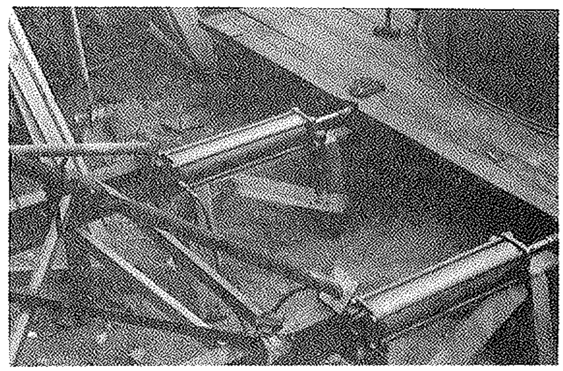

Figure 9. Jacking installation showing floor plate, custom fabricated 36-ton hydraulic jacks and push bar assembly.

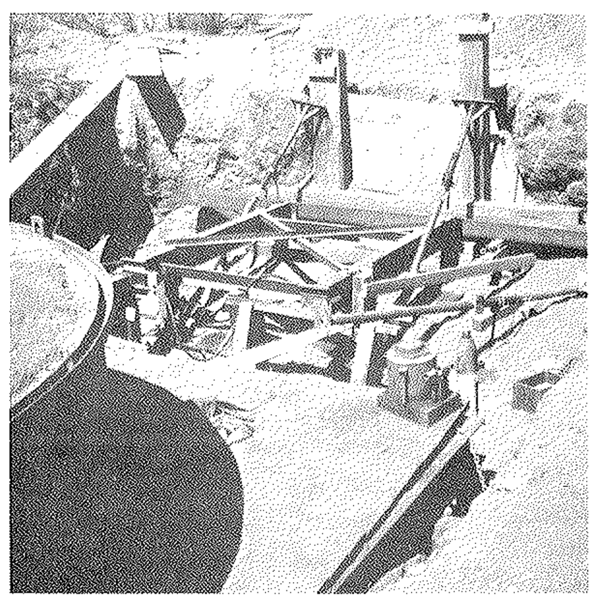

Figure 10. Bottom floor plate partially installed.

due to the vulcanizing being poorly done and several tubes had to be resealed locally. It is felt that a better substitute could be found for such application, perhaps in the area of electronic load cell transducers.

The bed on which the transducer support plate was to lie under the lysimeter was prepared by adding approximately 3.8 m^3 of pea gravel to the excavation and grading by hand. Proper elevation was achieved through the use of a transit. The transducer support plate was then installed in place, carefully leveled, cleaned and made ready to accept the transducer tubes (Figs. 11 and 12). Three layers of 10-mil black plastic sheet were placed on the support plate and the water-filled transducers coiled into place from the outside toward the center (Figs. 13 and 14). The air/water valve assembly on each tube was inserted through a hole drilled in the support plate, and a short length of 8-mm tygon tubing pulled through to the exterior. The transducer tubes were coiled alternately, i.e., every other tube was installed in a clockwise direction; the remaining tubes in a counterclockwise direction. This facilitated aligning the valve assemblies in a straight line from the outer edge of the support plate to the center. A trough was installed under the support plate to carry the tygon tubes attaching the transducer tubes to the manometers. Seven separate manometers were installed on a supporting upright as a temporary means of checking the condition and operation of each transducer individually.

The excess plastic sheet under the transducer was trimmed and folded over the top of the tubes to aid in protecting the fragile butyl tubes and to hold them in place. Further protection was added in the form of a 3.7 x 3.7-m section of heavy-duty, rubberized carpet padding laid between the bottom of the lysimeter and the top of the transducers. The lysimeter containing the soil column and creosotebush was then gently lowered, by means of four 25-ton jacks, into the transducer package.

The next, and final, phase of construction consisted of cutting off the excess bottom floor plate, and installing the

Figure 12. Cleaning of the transducer support plate in preparation for installing butyl tubes.

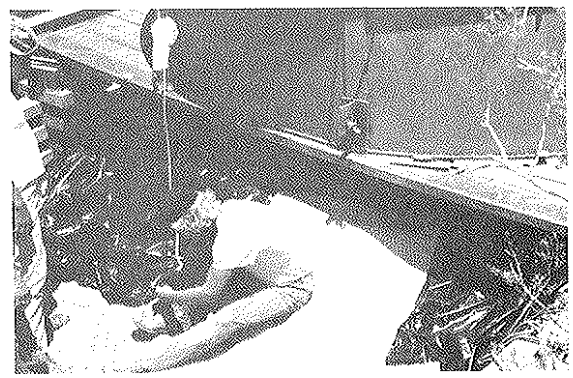

Figure 13. Preparations for installation of transducer tubes.

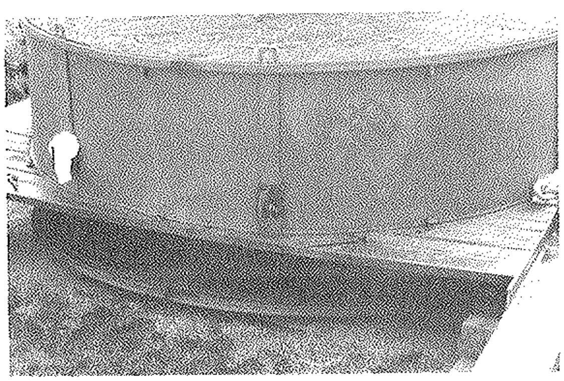

Figure 11. Transducer support plate in place under the lysimeter.

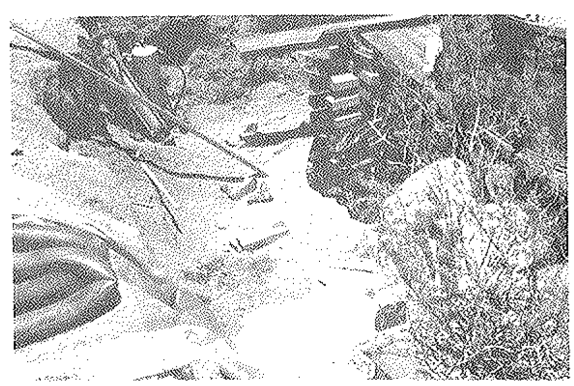

Figure 14. Installation of butyl transducer tubes.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my new-found friend and associate, Ernest Carreon, Jr., President of Carreon Development and Construction, for his tremendous assistance in the design and construction of the lysimeter. Without his technical ability and, especially, his incredible perseverance, this project could not have been accomplished.

I would also like to thank Kenneth McCleery, Chief Engineer of Automation Supply and Engineering Corp., for his assistance in the structural and fabrication design of the lysimeter, and to Dr. Leo J. Fritschen of the University of Washington for tolerating my incessant phone calls and letters.

LITERATURE CITED

ABD EL RAHMAN, A. A., and K. H. BATANOUNY. 1965. Transpiration of desert plants under different environmental conditions. J. Ecol. 53:267-272.

CANNON, W. A. 1911. The root habits of desert plants. Carnegie Inst. of Wash. Pub. 131. 96 pp. Washington, D. C.

FRITSCHEN, L. J., L. COX, and R. KINERSON. 1973. A 28-meter Douglas-fir tree in a weighing lysimeter. Res. Rep. 95, US/IBP Coniferous Forest Biome Rep. 95. Forest Sci. 19:256-261.

GARSTKA, W. U. 1974. Water resources and the national welfare, Topic No. 29, pp. 92-95, Pine, Colo.

HANKS, R. J., and R. W. SHAWCROFT. 1965. An economical lysimeter for evapotranspiration studies. Agron. J. 57(6):634-636.

KLUTE, A., and W. R. GARDNER. 1962. Tensiometer response time. Soil Sci. 93:204-210.

THAMES, J. L., (coordinator) et al. 1972. Tucson Basin Validation Sites report. US/IBP Desert Biome Res. Memo. 72-3. Utah State Univ., Logan. 72 pp.