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Suggested Cooperative Research Study

on

Development of Economic Water Harvest Systems for Stock Tanks to be Located Outside of Stream Channels

with the

Salt River Project
Phoenix, Arizona

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submitted by

Water Resources Research Center
The University of Arizona
Tucson, Arizona

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Title: Development of Economic Water Harvest Techniques for Stock Tanks to be Located Outside of Stream Channels.

Justification: In the Western United States there is widespread interest in the possibility of increasing streamflow from watersheds as a means of augmenting insufficient water supplies.

The total annual streamflow yield in the 17 Western states is about 25 percent of the total precipitation. This yield drops off in the semi-arid Southwest where in Arizona it is estimated that streams yield about three percent of the total precipitation (1).

Watershed investigations to increase water yields have been centered around vegetation manipulation to reduce transpiration losses and thereby increase streamflow. This method has shown to be effective on the Salt River Watershed in the chaparral type of vegetation whereas results on the pinyon-juniper type have not been too conclusive (2). The most extensive vegetation type in Arizona is the desert shrub area. It has a water yield of less than 0.5 inch with no potential of increase through reduction of vegetation density.

Streamflow can also be increased by reducing infiltration rates of water into the soil. This reduction results in an immediate increase in runoff and a resulting decrease in water lost through evapotranspiration. This infiltration reduction is obtained through use of chemicals and materials which physically impede the movement of water into the soil. Among the earlier materials that were used for paved catchments are asphalt and concrete slabs, galvanized sheet metal and butyl rubber. Such catchments are durable and usually require little maintenance, but they are expensive, costing from two to three dollars per square yard. In the last few years catchments have been installed using asphalt membrances, plastic sheets and water repellents. The use of these

materials greatly reduce capital cost but require considerable maintenance if left exposed to destructive wind and sunlight.

The use of paving techniques to increase streamflow while not receiving the publicity of vegetation manipulation techniques, nevertheless, have been mentioned in the literature. For instance the "Barr report" mentioned in 1956 that, "...it is not beyond reasonable expectation that the cities of Central Arizona will some day pave or cover with plastic or other impervious material an area that will furnish those cities highest quality soft water.... An impervious layer over one percent of the watershed could provide an additional 100,000 acre feet of water..." (3).

In the last several years research efforts have resulted in a great reduction in the capital costs of a paved catchment (4). Future research as proposed in this report should further reduce costs to the point where cities will be seriously interested in paving as a source of a water supply.

At the present time, because of relatively high initial cost, paved watersheds are being used as a source of stock water primarily where a conventional source such as ground water or stock tank sites are not available.

Conventional stock tanks have several recognized disadvantages both to the cattleman and the downstream user. Flow in the small drainage areas on grazing lands are infrequent and erratic. Further, in semi-desert areas, water is usually heavily laden with silt. As a consequence, in order to provide carryover between storms the tendency has been for the stockmen to make their reservoirs large, thus creating great surface areas and thereby increasing losses of water by evaporation and seepage. The actual use of water by stock from a stock tank has been estimated to be about 1/3 acre foot per year in a grazing area (5). The losses to useful native vegetation along the drainage way below the pond and downstream users must be at least 10 to 100 times this

amount. A conventional stock tank located on a stream channel greatly reduces the peak flow, reducing the percentage of water reaching a downstream user.

In spite of their large capacity most stock tanks are not a dependable source of water. For example, consider two conventional stock tanks located on the Atterbury Experimental Watershed on the valley floor southeast of Tucson. The smaller tank, designated as Tank III, has a capacity of 15.0 acre feet with drainage area of 0.5 square miles. The average annual inflow into the tank is 7.5 acre feet. There is no surface outflow and yet the tank is dry over 30 percent of the time. Tank II has a capacity of 30.7 acre feet, a drainage area of 4.3 square miles, an average inflow of 55.9 acre feet, only 6.8 acre feet surface outflow and yet this tank is dry approximately 11 percent of the time. Conventional stock tanks have the added disadvantage of becoming filled with sediment which requires periodic excavation or relocation. In a study area of Northwestern New Mexico containing 15 stock tanks, the aggregate capacity of the reservoirs was reduced 39 percent by sedimentation in a five year period (6). Finally, sites for conventional stock tanks are not always available where needed for proper utilization of the range.

In contrast a paved catchment and small-sealed tank protected from evaporation and seepage losses can be built primarily where needed. The paved catchment eliminates sedimentation and provides runoff from light storms which greatly reduces the size of storage tanks required. The system is built on the ridge tops or side slopes, never in major drainage channels. Despite these advantages, this system will not replace the conventional stock tank until costs are further reduced.

Previous Work and Present Outlook: In an effort to increase the effective life of a plastic catchment, the Water Resources Research Center (WRRC) began experimenting late in 1965 with a pea gravel cover. This cover serves to protect the plastic against harmful UV radiation and wind damage. The use of a gravel cover also has considerable esthetic value in that the catchment blends very well with the semi-arid landscape.

Because of its apparent advantages, an 8 X 16 foot experimental plot was established in December 1965. Six mil black polyethylene plastic was covered with one inch pea gravel (3/16-3/8 inch diameter stone). From December 1965 to December 1966, 33 separate rainfall events were recorded totaling 12.09 inches. Runoff was obtained on 28 of the 33 rainfall events for a total of 10.58 inches or 87.5 percent of the rainfall. On a control plot only 0.69 inches of runoff were recorded for 10 of the 33 rainfall events for the same period, for a total of 5.7 percent of the rainfall.

In the spring of 1965, a plastic-laying gravel spreader was developed and used for a one-half acre, gravel-covered plastic plot installed at the WRRC Field Laboratory using imported gravel. Four mil plastic was successfully used with very little mechanical damage in the covering operation. (The side-slopes on the one-half acre plot was 5%). The gravel cover was increased to approximately two inches because of the anticipated increase in gravel movement with greater flow on the larger catchment. Because of this increased cover, only 60 percent of the rainfall has been recorded as runoff. From observations made during high intensity summer rains it was concluded that an inch cover on the one-half acre plot would be more than adequate. Additional work is needed to determine what depth of gravel to use on different slopes of varying degree and length. The water from the above catchment flows into an 100,000 gallon storage tank lined with inexpensive polyethylene and

covered with butyl rubber to eliminate evaporation and to protect the plastic from deterioration by sunlight. This one-half acre catchment and tank were constructed in Tucson at a cost of $2500. In a 12-inch rainfall area it should provide a firm water supply of about 100,000 gallons per year.

The 100,000-gallon tank being filled with clear water should have a life in excess of 20 years. While the life of the gravel-covered plastic is not yet known, pea gravel-covered plastic has been in use for landscaping purposes in Tucson for over five years. A recent examination of some of the earlier installations have shown the plastic to be in good condition. Hence it is anticipated that the catchment should last at least 10 years before the plastic would need to be replaced.

Although the cost of a conventional stock tank varies widely, a Tucson contractor, who specializes in this type of construction, estimated that a typical tank would cost $1500 and would last for 10 years before being filled with sediment. Thus the experimental water harvest system installed at the WRRC Field Laboratory appears to be competitive with typical stock tank, but capital costs must be reduced further before water harvest systems will replace the stock tank.

Recent investigations have indicated that costs of both the catchment and the storage can be further reduced. A preliminary study has shown that most range soils in Arizona contain sufficient gravel to furnish the necessary cover for plastic; asphalt or water repellents. All that is needed is a machine that will pick up range soil, screen out coarse sand and gravel, lay plastic, asphalt or water repellents, and then drop the coarse sand and gravel back on top of the surface seal. In the case of plastic, such a machine would reduce costs by one-half but, more importantly, costs would not be dependent on proximity to a local gravel source.

The Water Resources Research Center in cooperation with the Department of Agricultural Chemistry and Soils has successfully demonstrated that a treatment of sodium chloride can increase water yield (7). Research is under way to determine how much water can be harvested without reducing vegetation growth to the point where erosion would be a problem. If a gravel cover could be generated from the range soil to prevent erosion, treatment rates with sodium could be heavier with the possibility, on some soils, of increasing water yields up to 50 percent or more.

Reducing costs on the storage tank may be more difficult. However recent tests in evaporation control at the WRRC Field Laboratory indicate that floating styrofoam rafts may be used on stock ponds with about 100 percent effective reduction of evaporation on the covered water. The cost of these rafts would be about 15 cents per square foot. Further reduction in cost may be obtained by using a combination of styrofoam and aluminum foil. South West African government engineers are using molded lightweight concrete made of polystyrene sand and cement as floating rafts (8). This system will be evaluated under this research project. Seepage control is still a problem but it is hoped that the soil sifter will provide a method to cover a plastic liner. In seepage control a covered double membrane of asphalt and plastic or asphalt and paper might be desirable(9). The placement of the protective cover is the biggest cost in seepage control using membranes (10). The capacity of laying and covering a double membrane could be incorporated into the proposed soil sifter. With controlled evaporation and seepage and a paved catchment, the size of the required storage would be relatively small compared to a conventional stock tank. This factor will be very important in reducing costs. The membrane method seepage control would necessitate fencing of the reservoir but again because of its size, this should not be too expensive. Also the

fencing of stock tanks is a recommended procedure for protection of livestock, for improvement in water quality and for better control of range utilization.(11).

Objectives: The major objective of this research proposal is to develop an inexpensive water harvest system.

To attain this goal the following objectives must be met.

1. A waterproofing, soil sifter (WSS) capable of laying plastic, asphalt, or water repellents, and covering them with a layer of gravel derived from the soil must be developed.

2. The advisability of using a heavy application of sodium salts as the sealing material using the gravel generated by the WSS to reduce erosion must be determined.

3. Inexpensive floating rafts as a means of evaporation control from small reservoirs must be developed.

4. Techniques whereby the WSS could be used as a means of laying and covering membranes for seepage control must be determined.

Facilities and Equipment Available: The following major facilities and equipment are now available for investigation of water harvest systems.

1. Triplicate ponds, 53 X 78 X 9 feet deep and lined with butyl rubber, have been constructed at the WRRC Field Laboratory in Tucson. Stilling wells and hook gages are installed to determine evaporation loss.

2. An 80 X 220 X 13 feet deep plastic-lined pond is available for testing rafts. This larger pond is valuable for determining how rafts will operate on large reservoirs.

3. A weather station has been established next to the pond area. Instrumentation includes rain gages, hygrothermograph, barometer, recording anemometer and wind vane, and radiation and temperature recorders.

4. Ten United States Weather Bureau Class A evaporation pans are in place near the evaporation ponds and can be used for preliminary testing of floating rafts.

5. Eight double-walled infiltrometers, eight feet on a side, and volumetric tanks for measurement of water are available at the WRRC Field Laboratory for studying seepage control.

6. A one-half acre of pea gravel-covered plastic with a 100,000 gallon storage tank has been constructed at the WRRC Field Laboratory. Data are now available to determine water yields in an area similar to Tucson.

7. Sixteen 8 X 16 foot runoff plots, which include two plots treated with sodium chloride, one treated with gravel-covered plastic, and one with sodium chloride covered with gravel.

8. Four one acre plots located at the Atterbury Experimental Watershed. Two of these plots have been cleared of vegetation and one treated with sodium chloride. The remaining two have natural desert shrub vegetation with one being treated with sodium chloride.

9. Two 16 acre plots located at the Atterbury Experimental Watershed are being calibrated for future treatment with sodium chloride.

In addition to these facilities, five additional 8 X 16 foot plots will be constructed at the WRRC Field Laboratory using imported soil from the Atterbury Watershed. One plot will be used as a control, one treated with sodium chloride covered with gravel sifted from the soil, one treated with plastic covered with sifted gravel, one treated with asphalt covered with sifted gravel, and one treated with a water repellent, such as silicone, and covered with sifted gravel.

Based on results of the investigation, a demonstrative catchment complete with storage tank will be built on the Atterbury Experimental Watershed and

subjected to use by livestock.

Procedure: Three screening investigations will be conducted simultaneously with the development of the waterproofing, soil sifting machine.

1. The relative merits of asphalt, plastic, water repellents and sodium salts as waterproofing agents to use in conjunction with gravel protection will be determined by a screening investigation using small plots.

2. Various raft designs for evaporation control will continue to be screened, and the best design will be field tested on the 53 X 78 foot ponds.

3. Combinations of sealants in small basins such as sodium salts, asphalts and plastic to determine the best system to use for seepage control will be tried.

Much of the chance of success in fulfilling the objective of this proposal is dependent on the successful development of the waterproofing, soil sifter(WSS). A preliminary drawing of the proposed WSS is shown in Figure I. the machine is a combination of operations that have previously been used, namely:

1. The ladder concept of raising soil has been demonstrated in various types of earth-moving equipment.
2. The vibrating screen will be a proven commercial unit whose output characteristics appear to be adequate.
3. The laying of plastic and dropping gravel on top without undue damage to the plastic has been demonstrated in the earlier use of a plastic laying gravel spreader on the one-half acre plot at WRRC Field Laboratory.

The prototype WSS will be approximately 13 foot long, 5 foot high, have a four foot cutting width and will lay a four foot roll of plastic. The plastic will be joined by overlapping of 6 inches

This system requires a slope of at least five percent to assure no leakage at the overlap. This requirement is not too stringent for most range areas. The size of this prototype should be adequate for the installation of small water harvest systems for stock or domestic purposes.

The WSS can be easily modified to waterproof with asphalt or water repellents by replacing the roll of plastic with a spray nozzle. A sodium chloride treatment could also be applied in solution through the spray nozzle or broadcasted dry after the soil-sifting operation has been completed. For seepage control work a combination of asphalt and plastic or asphalt and paper could be laid simultaneously by mounting a spray bar in front of the plastic or paper roll.

In order to properly field test and develop the WSS a small dozer tractor (50 hp.) should be available for the duration of the project to pull the machine. The tractor should be equipped with a ripper and dozer for brush removal and shaping of the small storage tank. Thus, a complete catchment and tank could be constructed with these two pieces of equipment. Following the project the WSS would be available for installing demonstrative catchments on the Salt River Watershed as well as other areas in Arizona.

Probable Duration: It is proposed that the project start from January 1, 1967 and extend for 18 months to July 1, 1968.

Suggested Financial Support:

	Salt River Project	The University of Arizona
1. First year:		
Salaries		
Project Consultant (1/8 Time)		$2,000
Project Leader (1/2 Time)		5,000
Machinist (1/2 Time)		3,500
Technical Assistant (1/2 Time)		3,000
Graduate Assistant (1/2 Time)	$3,000	
Student Assistants	2,000	
	5,000	13,500
Payroll Taxes and Insurance (7.5%)	380	1,020
	5,380	14,520
Equipment		
Rental of dozer tractor with ripper	1,500	
Cost of materials and development of WSS	5,000	
Cost of Demonstrative Water Harvest System Using WSS	1,000	
Other		
Travel	400	
Miscellaneous supplies	800	
Chemical and mechanical analysis	800	
Total	$14,880	$14,520
2. Second 1/2 year:		
Salaries		
Project consultant (1/8 Time)		1,000
Project Leader (1/2 Time)		2,500
Machinist (1/2 Time)		1,750
Technical Assistant (1/2 Time)		3,000
Graduate Assistant (1/2 Time)	1,500	
Student Assistants	1,000	
	2,500	8,250
Payroll Taxes and Insurance (7.5%)	190	620
	2,690	8,870
Other		
Travel	200	
Miscellaneous supplies	400	
Chemical and Mechanical Analysis	400	
Publication		200
Total	$3,690	$9,070
Total for one and a half years	$18,570	$23,590

Discussion: The cost of the research and development of this system of installation, while running close to $45,000 can be justified on the basis of its potential for increasing streamflow and at the same time providing a more dependable stock water supply. In order to get an idea of the potential, the following assumptions will be made:

(1) An additional acre foot of water is worth $15.00 to the Salt River Project, and (2) each stock tank is reducing the streamflow by an average of 20 acre feet annually. Over a 20-year period the reduction of one stock tank would mean an increase in streamflow of 400 acre feet which would have a value of $6,000. The total impact of the successful development of this system to the SRP could easily be in the range of thousands of dollars annually.

The value of a dependable stock water supply can best be measured by the amount that ranchers are willing to pay for hauling water. Some ranchers in Northern Arizona have paid as much as $1,400/acre foot to haul water to stock. At this rate for the proposed catchment system, the water supply would be worth about $500 annually.

The basic principles of the proposed system have already been proven. Additional work is needed to develop the WSS and check out its effectiveness in the construction of catchment aprons and lining of stock tanks. The feasibility of the use of floating rafts has recently been demonstrated in West South Africa where government officials have ordered the covering of all reservoirs with floating concrete rafts. Finally, although the proposed research program is geared to providing stock water, the day is fast approaching when communities in Arizona and other semi-arid areas will be interested in obtaining high quality water from treated surfaces.

Cooperators:

1. U. S. Water Conservation Laboratory, Agricultural Research Service, U. S. Department of Agriculture, Phoenix, Arizona.
2. Fishery Unit, The University of Arizona.
3. Department of Agricultural Engineering, Agricultural Experiment Station, The University of Arizona.
4. Department of Agricultural Chemistry and Soils, Agricultural Experiment Station, The University of Arizona.

Biographical Data - C. Brent Cluff, Project Leader

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   February 20, 1935, Central, Arizona

2. Education:

   B.S., Civil Engineering, 1959
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   1961-62 California Water Resources
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4. Publications:

   "Seasonal Streamflow Forecasting for Central Highlands, Arizona", M.S. Thesis, The University of Arizona, 1961.

   "Letting Grass Take the Mud Out of Water", Progressive Agriculture, VO. XIU, the University of Arizona, November-December, 1962, (with L.G. Wilson).

   "Evaporation Reduction Investigations Relating to Small Reservoirs in Arid Regions", Progress Report No. 224, Agricultural Experiment Station, The University of Arizona, October 1964.

   "Final Report on Evaporation Reduction Investigations Relating to Small Reservoirs", Technical Bulletin 177, Agricultural Experiment Station, The University of Arizona, October 1966.

   "Using Salt to Increase Irrigation Water", Progressive Agriculture Vol. XVIII, The University of Arizona, May-June, 1966, (with Gordon R. Dutt).

5. Professional and Honorary Organizations:

   American Society of Civil Engineers

   Tau Beta Pi

Biographical Data - Sol D. Resnick, Project Consultant

1. Date and Place of Birth:

June 15, 1918 - Milwaukee, Wisconsin

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B.S., Agriculture, 1941, University of Wisconsin
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1942-43 Tennessee Valley Authority
Assistant Hydraulic Engineer
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Gamma Sigma Delta
Pi Mu Epsilon
Sigma Xi
Chi Epsilon
Sigma Tau

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