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# WATER HARVESTING FOR LIVESTOCK

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## INTRODUCTION

Water harvesting, defined as the process of collecting natural precipitation from a prepared watershed for beneficial use, is an ancient practice used at various times and in various forms throughout most of the world. Water harvesting techniques have generally been used to obtain water for household use, livestock and wildlife, or growing crops. Although this paper is aimed at methods of providing water for livestock, the principles of water harvesting presented are sufficiently general that they apply for any of the three purposes.

### Historical Development

Shanan, Evenari, and Tadmor (58) excavated runoff farms that were used over 3,000 years ago for several centuries in what is now the Negev Desert of Israel. This area was intensively cultivated by an irrigation system which collected the meager rainfall by clearing large hillside areas of rocks, smoothing the soil, and concentrating the runoff by a system of contour ditches. The runoff water was used to irrigate a much smaller lower-lying area. By the time of the Roman occupation, these runoff farms had evolved into relatively sophisticated systems covering about 300,000 ha of the Negev Highlands. After the Arab conquest (630 A.D.), the ancient desert agriculture in this area slowly disintegrated. Similar, less complicated systems were used about 700 to 900 years ago by Indians of the Southwestern United States, particularly in the four corners of Arizona, Utah, Colorado, and New Mexico (49).

Collection and storage of runoff from roofs of houses is a more recent practice that is still used in some regions of the world. Some of the first catchments designed specifically to collect water were roof-like structures built in Australia in the early 1930's using galvanized sheet iron supported on a wooden frame or anchored directly to the soil surface with spikes (34, 36).

The most widely used type of catchment was developed in Australia during the mid-1950's (52). These catchments are called "roaded catchments" because the soil is graded into a series of parallel roadways or gently sloping ridges that drain into ditches separating them. These ditches carry the collected water to a storage reservoir by way of a collection ditch which

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runs perpendicular to the roadways. Several thousand acres of these catchments have been installed on the relatively uniform topography of Western Australia where many soils contain clay layers, which are exposed and compacted to provide a low infiltrating surface. These catchments are primarily used for farm water supplies, although some are used for municipal water supplies (33).

In the United States during the 1940's and early 1950's several small sheet steel and concrete catchments were built to provide drinking water for livestock and wildlife (56). Lauritzen (39) in the 1950's pioneered the use of plastic and artificial rubber membranes for catchment surfaces and reservoir linings. This work served as a basis for installing numerous butyl rubber catchments and storage bags, including over 300 installations in Hawaii and other Pacific islands (28).

In the 1960's, Cluff and Dutt, and Myers in the United States, and Hillel in Israel, began research to devise methods of waterproofing the soil surface, using the soil itself as the supporting structure (9, 31, 44). Myers' group (48) developed methods for using sprayable asphalt compounds, plastic and metal films bonded to the soil, soil compaction and dispersion, and field-fabricated asphalt fiberglass membranes. Cluff and Dutt concentrated on using sodium salts to seal the soil and on gravel-covered plastic membranes. Hillel investigated several soil treatments, like crude oil and water repellants, but worked primarily on soil smoothing and crusting.

## Potential

As population continues to increase, the necessity for an increased food supply will require the use of previously marginal lands for both crops and livestock production. Although more than 3,000 water-harvesting systems have been installed around the world, water harvesting has not received wide acceptance as a means of water supply. However, since most existing supplies from streams, springs, and wells are fully developed or already over-appropriated, future supplies must depend on transportation, desalting, or water harvesting.

The livestock- or wildlife-carrying capacity of many arid rangelands is limited more by water than by feed. Water-harvesting systems may be the only way to supply water in these areas. Improvement and proper management of properly spaced drinking water supplies increase the value of grazing lands and allow available feed to be more fully utilized (43).

Rapidly rising energy costs also make water harvesting more appealing. Unlike importation and desalting, water harvesting requires only minimal energy inputs. Most of these inputs are associated with material production and construction, since most water-harvesting systems operate by gravity.

Water harvesting will probably never be used in some areas because other water sources will be more economical to develop or because precipitation is scant and erratic. However, Hardin (28) points out that water harvesting may provide the only water supply in some cases, and may mean the difference between life and death. He also stressed the importance of more than one source of water in extended drought areas for an emergency.

Additional water may increase rangeland productivity by enabling better livestock distribution, but such results are not guaranteed. Increased water supply has been used to increase livestock numbers to the point of drastic overgrazing, which thus made the range less rather than more productive (60, 62).

## METHODS OF WATER HARVESTING

Various methods and materials have been used to increase precipitation runoff into storage facilities. Some materials, like concrete and sheet metal, will perform satisfactorily in almost any situation. However, the most economical and practical system for a particular site can be determined by evaluating several factors; soil type and depth, accessibility to equipment, climatic variables, vegetation, labor and material costs, and availability of treatment products. Whatever treatment or method is used, some maintenance will be required to insure optimum performance.

The methods used to increase runoff can be divided into four general categories: vegetation management, land alteration, chemical or physical treatments, and soil covers.

### Vegetation Management

Studies conducted throughout the world indicate that vegetation management can increase runoff from areas with precipitation in excess of 280 mm annually (57). However, the conversion efficiency for producing extra water increases as rainfall increases, at least up to 860 mm/yr (30); therefore, conversions at the lower rainfall values may not be economical or practical in arid areas. Although the success of vegetation conversion has generally been measured in terms of increased streamflow, changes in vegetation may have also produced springs and caused small streams to flow all year in some cases, which could be very beneficial to increased livestock use.

### Land Alteration

One of the simplest and least expensive methods of water harvesting is to construct walls or ditches to collect runoff from existing natural or manmade catchments like large rock outcrops, highways, airports, and parking lots. Chiarella and Beck (5) described a highway catchment system in Arizona that has been used for over 16 years with no observed detrimental effect to livestock drinking the water. According to Evans, Woolhiser, and Rauzi (22), the interstate highway system in Wyoming would provide 2 ha of catchment/1 km of highway. Assuming a 90% efficiency, the water supply from this catchment in a 250-mm rainfall zone would be almost 4,700,000 liters/km.

For land having no rock outcrops or highways, sometimes a water supply can be developed by simple land alteration treatments that increase runoff from the soil surface. Land clearing (61) is probably the least expensive treatment, but the increase in runoff is often negligible, unless storms are of high intensity or long duration. Because small storms may not produce sufficient runoff, large catchment and storage facilities must be constructed to insure an adequate water supply to carry over between major storms. Another simple treatment is constructing contour ditches to collect runoff from hillsides before it reaches natural channels or infiltrates into the soil (41).

The roaded catchments discussed previously are a more elaborate method of land alteration. It has been estimated that more than 2,500 such catchments have been built in Western Australia (4) and are mostly used for livestock water supplies.

## Chemical and Physical Soil Treatments

Treating soil surfaces with materials to prevent water from soaking into the soil is an intriguing approach to building efficient and low-cost catchments (16). Runoff from bare soil can be increased by dispersing its aggregated particles with sodium salts to reduce permeability. Hillel et al. in Israel, and Myers in Arizona, increased runoff by treating cleared and smoothed sandy loam and clay loam soils with sodium carbonate (32, 45). Both found that treatment effectiveness was lost in about 1 year and erosion was excessive. High-rate applications of sodium chloride produced over 50% runoff with no deterioration or salt movement noted after 3 years (21).

A silicone water-repellant treatment on a loamy sand soil in Arizona produced 90% runoff during the first year, but runoff gradually decreased to 60% after 4 years (46).

Care must be used in designing silicone- and salt-treated catchments since increased runoff can cause excessive erosion. Silicone treatments provide no apparent stability, and stabilizing effects of salt treatments have been limited to certain sandy loam soils (10).

A paraffin wax treatment on a sandy loam soil produced 90% runoff on test plots for over 4 years with no visual signs of deterioration (24). The molten paraffin penetrated the soil up to 25 mm and tended to stabilize the soil particles as it solidified. However, a 0.2-ha field catchment treated with paraffin was no longer water repellent or stable after freezing and thawing. Although laboratory tests in a freeze-thaw chamber confirmed the loss of effectiveness for this soil, two other operational catchments on sandy soils in Arizona have survived two winters of freezing and thawing with little apparent damage. Laboratory tests also indicated that hot summer temperatures may regenerate the wax treatments after freeze-thaw damage on some soils. These tests also indicated that wax treatments were not effective on certain soils under any climatic conditions; therefore, more research is needed to identify which soils can and cannot be effectively treated with wax.

Several researchers have reported using fuel oil to reduce infiltration. All indicated that the oil initially reduced infiltration, but completely deteriorated within 1 to 3 years, depending on the soil and the oil used (31, 37, 50, 63).

## Soil Covers

Soil covers can be applied to a wide range of soil types, since they only use the soil as a supporting structure and do not depend on its properties to provide water repellency.

Asphalt pavements for water harvesting were constructed by spraying asphalt compounds on nonswelling soils (48). Another, more durable type of asphalt catchment was constructed by placing a layer of fiberglass or polypropylene matting on the surface and spraying it with asphalt (47). A seal coat of asphalt and a protective cover of special paint produced a very durable and efficient catchment. The matting served as a reinforcing fabric, and the asphalt as a waterproofing agent. The protective paint extended the period between maintenance re-treatments by protecting the asphalt from sunlight, and reduced runoff water discoloration.

Thin plastic films have been used as ground covers, but most were destroyed by wind or were deteriorated rapidly by solar radiation. Cluff (6) developed a unique method of utilizing plastic's relatively low cost and high waterproofing characteristics. He developed equipment to install plastic film and cover it with a layer of small gravel. The gravel protects the plastic against both wind and weathering damage; however, it reduces the runoff efficiency (about 70% in the Tucson area) by retaining part of the water, which is then lost to evaporation. A catchment developed more recently by Cluff is constructed by spraying soil with a tack coat of asphalt, and immediately covering it with a 4-mil layer of polyethylene plastic (8). After the plastic is coated with an additional asphalt layer, rock chips are added as a top cover. This catchment can be used on a wide range of soil types and yields about 95% of the rainfall runoff. A similar catchment using standard roofing paper and procedures, but applied to the soil surface, has remained in good condition after 8 years and yields about 80% runoff (27).

Artificial rubber sheeting has probably been the most widely used ground cover treatment. It is easily transportable and simply installed once the site has been prepared. Several rubber sheeting catchments are still in use after 20 years in the United States (40). When correctly installed and maintained, good rubber sheeting is an efficient catchment material that provides high quality water. Problems encountered have been attributed to improper installation, lack of maintenance, poor quality material, or animal and rodent damage (17).

Corrugated sheet metal was one of the first materials used for collecting precipitation. Some early sheet metal catchments built above ground on a roof-like framework failed when the framework deteriorated or collapsed under heavy snow loads. However, sheet metal catchments built on the ground have proved very durable and essentially maintenance free (23, 28). Their runoff efficiency is perhaps the highest of any catchment material, and they have often produced runoff from dew and frost.

Use of concrete as a catchment material has been limited, mainly because of its high initial cost. Concrete requires more maintenance and has a lower runoff efficiency (60 to 80%) than several other catchment materials (27). However, when properly constructed and maintained, concrete catchments are very durable and will provide years of service.

## STORAGE OF HARVESTED WATER

Harvested water is usually stored in either excavated pits or ponds, lined ponds, bags, or tanks. One exception is direct storage in the soil profile with runoff farming. However, even with runoff farming, conventionally storing water for later controlled release to the crop may be necessary if precipitation distribution does not meet the crop requirements.

The volume of storage required is a function of the rainfall amount, variability in time, and dependability, and the use pattern of the livestock, or stocking rate and grazing period. Of the two factors, the precipitation is usually the most difficult to deal with because of probable sparcity of records for the area under consideration, and because of the uncertainty in predicting future events.

### Excavated Pits and Ponds

Although excavated pits and ponds are by far the most common means of storing water, they are also the least efficient, because of seepage and evaporation losses. If they are used, the soils and site should be selected carefully to use the finer grained materials (higher clay content), and to make the pond as deep as possible thereby minimizing seepage and evaporation.

Lined Ponds and Reservoirs

A variety of lining materials have been used to reduce seepage losses. Some of the more successful are sodium bentonite, sodium salts, reinforced asphalt, concrete, and plastic and rubber films or membranes.

Sodium bentonite, a fine-textured colloidal clay, has been used to reduce seepage in coarse-textured soils (20, 54). A good sealing bentonite must have enough exchangeable sodium to disperse the soil particles. Sodium salts have been the most successful chemical additives used to control seepage. Sodium carbonate has been most effective, considering treatment costs and ability to reduce seepage (1, 51).

Reinforced asphaltic membrane liners consist of a substrate matting of fiberglass (29) or polypropylene (3) generally made watertight by using asphalt -- either emulsion or cutback. Linings are fabricated in place in the field and are shaped like the excavated pit. They can be used as an exposed liner if properly protected from mechanical damage. Plant growth under the liners should be eliminated by using soil sterilants.

Buried plastic films of polyvinyl chloride (PVC), polyethylene (PE), and chlorinated polyethylene (CPE) have been successfully used as seepage barriers. Plastic-lined, rock-filled, excavated pits can be used and are a variation of the standard, buried, plastic-lined pond. The main difference is that the pond is completely filled with rock rather than just covered with earth to protect the plastic (10). Freedom from vandalism and reduction of evaporation losses (as much as 90%) are advantages of rock-filled pits over open storage systems.

Butyl rubber and ethylene propylene diene monomer (EPDM) are synthetic rubber membranes that can be used as exposed linings, but they must be adequately protected against damage. Synthetic rubber membranes are resistant to weathering processes that cause failure in other membrane and film materials. Rubber membranes are fabricated in numerous thicknesses and can be either fabric-supported or nonsupported. Information regarding field installations, recommendations for use, and physical property requirements are discussed in several publications (2, 25, 39).

Storage Bags

Storage bags of butyl-coated nylon have been placed in excavated pits or basins. These storage systems are completely closed and both seepage and evaporation losses are controlled. Their main disadvantages are susceptibility to mechanical damage, vandalism, and vermin attack.

Tanks

Water storage tanks have generally been made of concrete, plastered concrete-like materials, or metal. Concrete tanks usually have both sides and bottoms of the same material. Metal tanks often are made using only the metal for the vertical walls, but puddled clay, bentonite, sodium salts, concrete, or flexible membranes of plastic and rubber materials are added to the bottom to make it watertight.

Vertical-walled tanks have advantages unattainable with excavated pits. The ratio of water volume stored to water surface area is maximum when the walls are vertical; evaporation control devices, like floating covers, can be used more effectively and efficiently; and maintenance requirements are generally low and repair is easy. One main disadvantage of vertical-walled tanks is initial cost; however, when amortized, the yearly cost may be lower than some low-initial-cost storage systems.

### Evaporation Control

Of the many methods that have been investigated for evaporation suppression, floating covers are by far the most effective and usually the most practical. The best floating covers in field trials have been continuous covers of low-density, closed-cell synthetic rubber sheeting, available as 1.2-m-wide roll stock, 6 mm thick. These covers are fabricated to fit the water surface shape in vertical walled tanks (18, 19).

Paraffin wax, like that used for canning, has been successfully used in warm climates and on small tanks. The wax melts at 53° to 54°C and forms a continuous cover. The wax can be placed on the surface as blocks which will later be melted by the sun to form a wax layer 4 to 6 mm thick, or it can be melted with a heater and sprayed or poured on the water surface (12).

Polystyrene rafts constructed of 1.2 x 1.2 m sheets of expanded polystyrene, 25 mm thick, coated with emulsified asphalt and covered with a layer of rock chips have also been used successfully, although they cost more and require more labor than the other covers (7).

All three covers -- foamed rubber, paraffin wax, and polystyrene rafts -- reduce evaporation 85 to 95%. The cost of water saved in high evaporation areas is generally considerably less than the cost of obtaining the water from alternate sources. Joining the polystyrene rafts together helps to minimize the wind problem, as does maintaining an adequate freeboard with the foamed rubber. The wax covers have withstood winds up to 22 m/s on small tanks with only 25 mm freeboard.

## FACTORS TO CONSIDER IN SYSTEM DESIGN

Designing a water harvesting system to achieve optimum efficiency at a minimum cost is a very complicated procedure involving many factors. These factors are climate, topography, soil characteristics, grazing programs, system maintenance, and, since no one system is best suited under all conditions, the system materials and features themselves.

### Climatic Factors

Amount of precipitation, temporal and spatial distribution, ratio of snow to rain, probability of occurrence, and intensity affect the size of the catchment and storage facilities required. The number of freeze-thaw cycles and expected maximum or minimum temperatures can limit the types of materials used. Some treatments may be damaged by heavy snow loads; in other situations, it may be advantageous to induce snow drifts on the catchment surface with snow fences.

## Topography

In many areas, moving the system location slightly may provide better slope, soil depth, wind protection, etc., and could increase livestock use of otherwise undesirable grazing areas. Some catchment treatments such as paraffin wax require maximum soil temperatures and would benefit from southern exposures. This may also be true for water access facilities. Length of overland flow on the catchment surface and surface roughness may also be influenced by topographic features and have considerable effect on potential soil erosion when land alteration, chemical, and physical treatments are considered. The accessibility of the site to installation equipment can also determine what treatment may be used.

## Soil Characteristics

Soil texture, type, and clay content influence the kinds of catchment and storage used. If properly installed, asphalt-fiberglass or sheet metal catchments can be satisfactorily used on almost any soil type. Roaded catchments, popular in Australia, depend on a rather tight clay layer near the soil surface (4). On the other hand, chemical treatments like paraffin wax are most effective on sandy soils. Depth and type of soil can also determine the location and type of storage to use. Rock layers near the surface increase construction efforts for excavated storage.

## Grazing Program

The grazing program being used can influence size, number, and location of water harvesting systems. Cows consume 30 to 45 liters of water per day, depending on forage conditions, distance to water, temperature, and size and condition of the animal (15). Sheep use only 3 to 7 liters per day (35), but should not trail more than 0.7 km to water for best results. If the animals are using the area during or after the season of high rainfall, the water storage system can usually be smaller than if the water must be stored for the dry season. If long-term storage is required, methods of conserving the collected water, like good evaporation control methods, are essential.

Grazing management systems that use low-density, long-term grazing, usually require smaller watering facilities than the newer, high density, rotational grazing systems which require units capable of providing large quantities of water for short periods.

## System Maintenance

System maintenance is necessary for any successful water-harvesting system. If a system is readily accessible and periodic maintenance can be provided, a lower initial cost system may be used. For remote, difficult-to-reach locations, a more costly but less maintenance-intensive system may be desirable. To insure that water is available when needed, some maintenance will be needed, even in the off season when the area is not in use. This is often when water is collected for the next use period.

## System Features

Although rather sophisticated computer programs have been developed to aid system design, they only consider a few of the numerous factors involved, and no procedure is available to provide the optimum design (25, 26). Instead, the system is designed by using compromise methods that consider a few factors, plus the experience and judgment of the designer. Size of the catchments is normally based on average annual or seasonal precipitation, and storage is often determined from livestock requirements during the grazing period. The numbers used will be influenced by how much chance the user is willing to accept that there will, or will not, be water available when needed.

Ideally, water harvesting systems for supplying water to livestock should be designed on the basis of normal forage availability or carrying capacity of the range. In most areas, forage production is correlated with previous precipitation (59). Therefore, if system design is based on average carrying capacity, in years of below-normal precipitation the forage production will probably be less than usual, but the water harvesting system will also collect a correspondingly smaller amount of water. This helps to insure proper use of the range and thus reduce overgrazing. Conversely, in years of above-normal precipitation with plentiful feed, the water harvesting system will be able to provide ample drinking water.

Management of grazing areas can be improved using properly designed and located watering facilities. Multiple units not only provide better distribution of grazing, but also increase the odds of collecting some water from scattered rains. Numerous smaller units may be slightly more expensive than one large unit, but equipment requirements and water distribution advantages easily offset cost.

## EXAMPLE SYSTEM AND COSTS

Equipment, labor, and cost data are seldom made available in the construction of water-harvesting facilities. However, adequate data were provided on construction of two similar water-harvesting systems installed on the Arizona Strip by the Bureau of Land Management during September 1974 (14). Following is a description of one unit to show economics of this type of system.

The 0.4-ha catchment is about 72 km south of St. George, Utah, on the west side of Hurricane Wash. Average annual precipitation in the area is about 30 cm, approximately half of which falls in winter as rain and snow showers and the other half in summer as thundershowers (55). The catchment is constructed on a clay loam soil at a slope of 5 to 8%. The apron was graded, treated with a soil sterilant, and wet compacted before the paraffin wax was applied.

The treatment consisted of applying 53°C average melting point (AMP) paraffin wax to the soil surface at a rate of 0.92 kg/m$^2$. The wax (supplied in 910-kg cartons, each containing 182 5-kg blocks) was loaded by hand into a 7,570-liter-capacity asphalt distributor truck and then melted to 132°C with the truck's burners. Once the entire 3,000- to 4,000-liter load was melted (4 hours), it was sprayed on the apron in only 30 minutes through the truck's spreader bar.

Water collected is stored in a 300,000-liter tank with steel sides and concrete bottom. The multiplate corrugated sectional steel sides were bolted together and the joints sealed at the site. After assembly, a 15-cm reinforced concrete floor was poured using ready-mix concrete. Water is conveyed from the catchment apron to the tank by a 38-cm-diameter corrugated steel pipe. Evaporation is controlled by a floating cover of about 0.6-cm-thick foamed rubber that is slightly smaller in diameter than the steel tank. The floating cover is protected from blowing or floating off the tank by galvanized wires stretched across the top, and by a series of holes in the tank wall, near the top, for overflow. Water is supplied to a water trough through a 3-cm plastic pipe, using a float valve in an underground float box for water level control. The entire water harvesting system, except the trough, is surrounded by a 2.4-meter-high net wire fence to prevent damage by livestock and wildlife.

Rainfall at the site totaled 27 cm between September 1974 and September 1975. Assuming 90% runoff efficiency (based on similarly treated plots at the U. S. Water Conservation Laboratory's experimental test site, and observations of runoff during rainfall at the site, nearly 1,003,000 liters of water should have been collected. An estimate of the disposition of the collected water follows:

| | |
|---|---|
| Evaporation loss .................................... | 19,000 liters |
| Used by cows (70 head for 270 days) .................. | 719,000 liters |
| Storage in tank at end of year (observed) ............ | 246,000 liters |
| Remainder = spill during year (some spill observed) ... | 19,000 liters |
| Total water collected ................................ | 1,003,000 liters |

Evaporation at the site is estimated to be 183 cm per year (11), which would have amounted to nearly 189,000 liters of water. Cooley and Myers (13) found that floating foam rubber covers reduced evaporation losses by about 90%, which would save 170,000 liters of water per year.

Cost of the various components of the system and the labor and equipment required for installation (1975 prices) are presented in Table 1.

Table 1. Cost of water harvesting system.

| | | |
|---|---|---|
| Apron: | Paraffin wax ........................................ | 1250 |
| | Truck and driver .. 5 hrs at $38/hr ..................... | 190 |
| | Soil sterilant ........................................ | 100 |
| | | $1540 |
| | (Cost per square meter of apron ($.39/m$^2$) | |
| Tank: | 300,000 liter, steel sides ............................... | 2900 |
| | Concrete bottom (20 m$^3$) ................................ | 670 |
| | Reinforcing wire, seam sealer, etc. ...................... | 265 |
| | Floating 0.6-cm foamed rubber cover ...................... | 350 |
| | | $4185 |
| | (Cost per 1000 liters of storage ($13.95/1000 liters) | |
| Other: | 38-cm culvert with flared end ............................ | 1000 |
| | 76 m of 3-cm pipe, water trough .......................... | 175 |
| | 2.4 m net fencing and barbed wire ........................ | 450 |
| | | $1625 |
| Installation: | BLM crews and equipment .......................... | $1800 |
| Total cost of system | ............................................. | $9150 |

A first estimate of the cost of the collected water can be made by dividing the total cost of the completed water harvesting system by the total amount of water collected during the year. This calculation is presented in the upper portion of Table 2. Based on this 1-year method, any water collected in the future would be free, unless additional costs for maintenance or re-treatment are incurred. Even if all of the costs are charged to this first year of operation, the costs of the collected water are competitive with the $1200 to $3000 per kilometer costs for piping or the $4 to $10 per 1000 liter costs reported for hauling water (53), especially when these figures are adjusted for the rough terrain and remoteness of this area and for the increased costs since these figures were compiled.

A more realistic approach would be to amortize the cost of the system over at least 10 years. Maintenance and re-treatments cost must be added to initial costs in this case. Estimated costs of the collected water, assuming the same amount of water collected each year and two wax re-treatments on the aprons, are presented in the lower portion of Table 2.

Table 2. Cost of collected water.

| | |
|---|---|
| Total cost absorbed in first year | |
| Cost of system | $9150 |
| Water collected | 1,003,000 liters |
| Cost per 1000 liters | $9.12/1000 liters |
| Cost amortized over 10 years | |
| Maintenance cost (valves, floats, etc.) | $ 120 |
| Re-treatment cost (2 treatments at .5 kg/$m^2$) | 1450 |
| | $1570 |
| Average maintenance and re-treatments costs per year.. | $ 157 |
| Average cost per year of initial investment at 8% interest ($9150 x 0.149) (42) | $1363 |
| Total cost per year for 10 years ($1363 + $157) | $1520/yr |
| Cost of water collected ($1520 ÷ 1,003,000) | $1.52/1000 liters |

Regardless of the method used to determine the cost of the water collected, this method of supplying water is competitive with other methods such as hauling or piping. Of even greater economic benefit is the water saved by the floating foamed rubber cover. As shown in Table 1, this cover costs $350. Amortized over a 10-year period, this amounts to $350 x 0.149 = $52.15/yr. The cost of the 170,000 liters saved each year would therefore be ($52.15 ÷ 170,000) x 1000 = $0.31/1000 liters, or about one-fifth the cost for collecting the water originally.

SUMMARY

Water harvesting is an ancient art used by farmers in the Negev Desert of Israel over 3,000 years ago where they cleared hillsides to increase rainfall runoff and directed the water to cultivated fields in the valleys. This practice was then essentially abandoned until the early 1930's, except for collecting rainfall from rooftops in some areas. Although revival of water-harvesting techniques began in the early 1930's, most construction and research activity did not begin until the late 1950's. Even this research effort and the development of new materials have not yet produced widespread use of water harvesting methods to provide water supplies.

All of the commonly used water harvesting methods fall into one of four categories -- vegetation management, land alteration, chemical or physical treatments, or soil covers. Annual precipitation in excess of 280 mm is generally required to assure successful vegetation management results, and potential for increasing runoff yield increases as annual precipitation increases. Land alteration methods are especially attractive where impervious areas already exist (highways, airports, rock outcrops, etc.), and only collection and storage facilities are required, or where labor costs are low and soil conditions are suitable. Chemical and physical soil treatments, like salts, silicones, and waxes, have been applied successfully to certain soils, but more research is required to delineate the conditions under which each can be used. Soil covers are not generally restricted by soil and climatic conditions; however, initial cost of the system will generally be higher than for the other methods discussed. Regardless of the material or method used, erosion protection, routine maintenance, and protection of the catchment and storage should be considered.

Collected water can be stored for later use by livestock in excavated pits or ponds, bags, or tanks. If open storage facilities are used, evaporation control using floating covers should be considered.

Proper design of a water harvesting system is a complicated procedure that involves climatic factors, topographic features, soil characteristics, grazing programs, system maintenance, and the system materials and features themselves. No procedure is known for considering all of these variables, and most designs are based on a few measurable variables plus previous experience. For livestock water supply on rangelands, the water harvesting system should be designed for normal carrying capacity or forage conditions. Proper sizing and spacing of units will provide the manager a tool for better utilizing available forage without overgrazing close to watering facilities, and without sacrificing animal growth.

Operational water harvesting systems in semiarid rangelands have been both effective and economical, providing water for less cost than either hauling or piping. Water harvesting systems may provide the only source of water in some areas and can provide a low-energy-input, economical water source in many others.

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