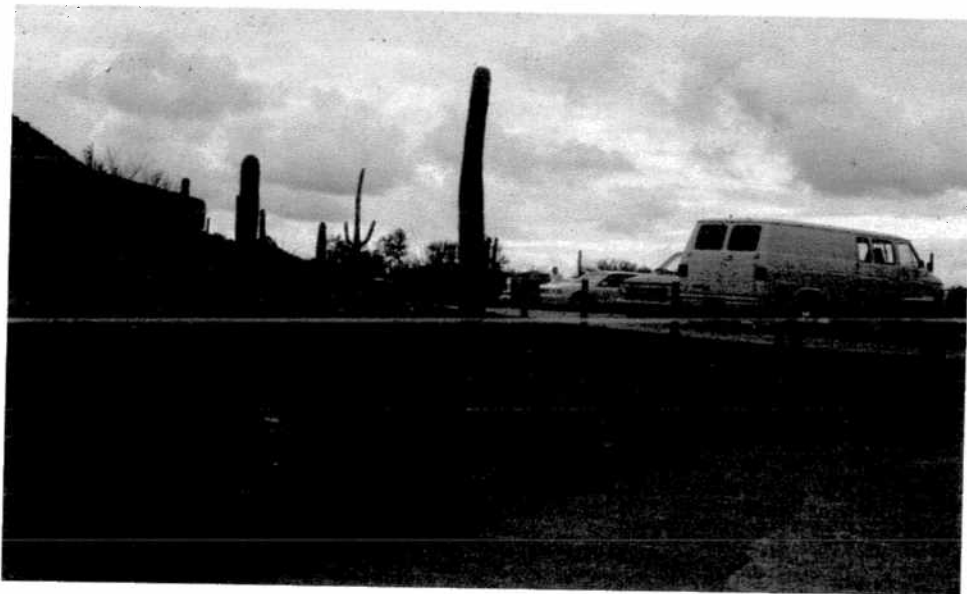


TRANSPLANTING SAGUAROS



Survival and Growth of Re-Located Saguaros in the Red Hills Visitor Center Landscape



**Saguaro National Park
Tucson Mountain District
1992 – 2004**

TRANSPLANTED SAGUAROS at the RED HILLS VISITOR CENTER

Building in the Desert

Construction of the Red Hills Visitor Center was completed in 1994. To look at the facility today, one would think it was lowered into place whole into the desert, as it is surrounded by full-grown Sonoran desert shrubs, trees and cacti (*below*). However, the site of the Red Hills Visitor Center was once desert that was completely cleared for construction, and re-planted with nursery-grown material and plants salvaged from the site prior to construction and returned to the site thereafter.



The Red Hills Visitor Center, Tucson Mountain District, Saguaro National Park

Part of this landscaping project was the salvage and transplanting of large saguaro cacti (*Carnegiea gigantea*) on the construction site. As the park's namesake species and the plant that best characterizes the Sonoran desert, the park needed to save as many of these cacti as possible from construction impacts. In transplanting saguaros for the landscape project, park staff kept records of the number and condition of larger saguaros being moved and re-planted

Moving Cacti

Some desert plant species have deep tap roots to reach ground water, while others have shallow but extensive surface root systems to intercept precipitation at the soil surface; cacti generally are in the latter category. Because of their shallow root system, and water and nutrient reserves stored in their tissues, even in arid environments cacti can be transplanted whole (with the top and root system); this is also true for saguaro cacti.

Some species like cholla and prickly-pear can also grow a new plant from a removed piece or “joint” (one of the strategies for species propagation). However, the top of a saguaro stem or a removed arm, planted in the ground, will not produce a new plant. Saguaros must be moved whole, with roots intact.

Smaller saguaros can be transplanted and moved using hand tools and muscle; park restoration staff salvaged and transplanted close to 50 smaller saguaros by hand. Larger saguaros require a truck with a hydraulic lift to hoist and move the cacti and the park hired a local contractor to transplant larger saguaros.

Getting Started

The Red Hills landscaping was installed for the new visitor center, as well as maintenance facility, residence, and for improvements to the operations building (the former visitor center). To save saguaros from construction zones, park staff studied blueprints to determine construction boundaries. Any plant not removed from these areas would be cleared from the site.

A logistical challenge for this project was that saguaros needed to be moved from construction zones, but couldn't be returned until work in that area was completed. In some cases, saguaros were moved *twice*, first to a holding area, then moved back into the landscape. Because construction was phased in different areas, some saguaros were moved from an area prior to construction directly into areas where work was completed – this was done for saguaros less likely to withstand the stress of being moved twice, such as larger plants with arms (**below**).



In all, park staff identified 46 saguaros to be transplanted by contractor, ranging in height from 1.6m to 9.0m tall; of these transplanted saguaros, 19 had arms. All transplanted saguaros were photographed, mapped and measured (height, arms and general health). Saguaros were transplanted between 1992 and 1994. Records for one saguaro were lost and we could not determine if it was ever moved.

We returned in 2004 to determine the survival and general health of the transplanted saguaros. We measured height directly on smaller plants and with a clinometer for taller specimens. We based current saguaro health on a number of attributes: color, girth, new growth, presence of spines, lack of wounds, etc. and assigned transplanted saguaros very general health categories of *good*, *fair*, *poor* or *dead*.

Saguaro Transplant Survival

We found overall survival of contractor-transplanted saguaros in the Red Hills landscape in 2004 was 69%. There are 14 transplanted saguaros we characterized as currently in good health (31%) and 12 transplanted saguaros that are in fair health (27%). There are also 5 transplanted saguaros we characterized as currently in poor health (11%) and 14 transplanted saguaros that died since transplant (31%).

When examined by height classes, 50% of the saguaros over 6m tall survived transplanting (5 out of 10); 63% of the saguaros between 4m-6m tall survived (10 out of 16); and, 93% of saguaros between 2m-4m tall survived transplant (13 out of 14) between 1992 and 2004. Transplanted saguaros less than 2m tall had 60% survival – the contractor only moved 5 saguaros of this size and two did not survive transplant. Of transplanted saguaros with arms, 11 (58%) have survived; however, one of the largest saguaros moved (7.5m tall with 6 arms) did not survive. Records were not kept for survival of smaller saguaros that were hand-transplanted by park staff.

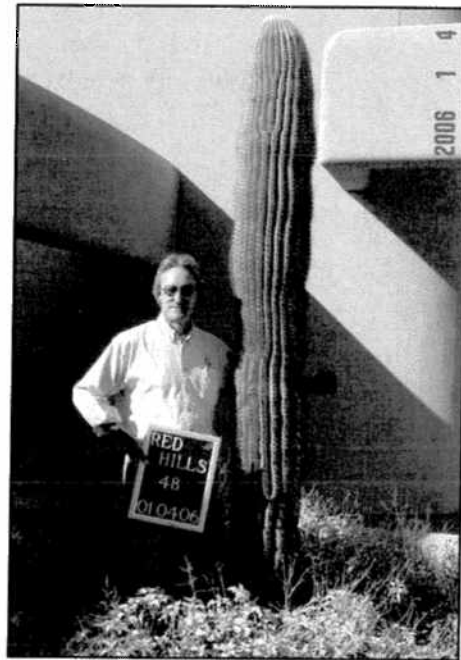
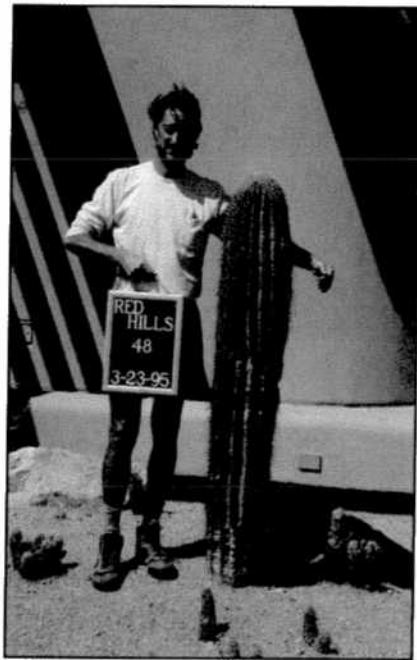
How does the mortality of the transplanted Red Hills saguaros (31%) compare to that of a natural population? In 1990, 30 saguaros 2m tall or taller were chosen at random to be monitored on twenty long-term saguaro monitoring plots each in the Tucson Mountain District. We returned to these twenty plots in 2000 to determine the health of the 600 saguaros, and can compare the mortality of this sample of saguaros of the same size over roughly the same time period. We determined the average mortality of the saguaros on monitoring plots through the district between 1990 and 2000 was 18%, with much variation ($\pm 12\%$) (Duriscoe and Graban 1992, Turner and Funicelli 2000).

Saguaro Post-Transplant Growth

Accurate growth measurements for transplanted Red Hills saguaros are difficult to determine because precise height readings with a clinometer (to the nearest cm) are difficult to obtain. Also, some saguaros were re-planted deeper than they were originally found. Saguaros that are re-planted too deeply usually experience early mortality – transplanted Red Hills saguaros that have survived were likely planted to about the proper depth, but growth measurements should be viewed only as estimates.

Transplanted saguaros characterized as currently being in good health grew an average total of 27cm; those in current fair health grew an average of 24cm; and, those characterized as being in poor health grew an average of 5cm.

When examined by height classes, transplanted saguaros greater than 6m tall showed no growth; saguaros between 4m-6m tall grew an average of 21cm; and, saguaros between 2m-4m tall grew an average of 28cm between 1992 and 2004. Transplanted saguaros less than 2m tall grew an average of 80cm; however, results are skewed by the fact that one of the three surviving transplanted saguaros showed no growth while another grew an impressive 150cm between 1992 and 2004 (pictures, below). This amount of growth is more the exception than the rule for transplanted saguaros.



The same transplanted saguaro at the Red Hills Visitor Center, March 1995 and January 2006.

The growth rate of a healthy saguaro depends on its size, as well as other environmental factors such as climate and microsite (Steenbergh and Lowe 1983, Steenbergh and Lowe 1977). On average, the growth rate of a saguaro seedling increases as its size increases, peaking when the plant reaches about 2m-3m tall; at this point a cactus can grow up to 12cm per year (like the cactus above). Once exceeding this size, height growth reduces as the cactus transfers energy from stem growth into reproductive potential through production of arms, flowers and fruit (Steenbergh and Lowe 1983).

We can compare the growth of transplanted Red Hills saguaros to the random sample of similar-sized saguaros on long-term monitoring plots. There were 202 saguaros measured in 1990 between 2m-4m tall that survived to 2000 on the 20 monitoring plots in the Tucson Mountain District. These saguaros grew an average total of 1.0m between 1990 and 2000, or about 10cm per year, but with a great deal of variability (± 0.5 m) (Duriscoe and Graban 1992, Turner and Funicelli 2000). Transplanted Red Hills saguaros of the same size grew an average of only 2.3cm per year.

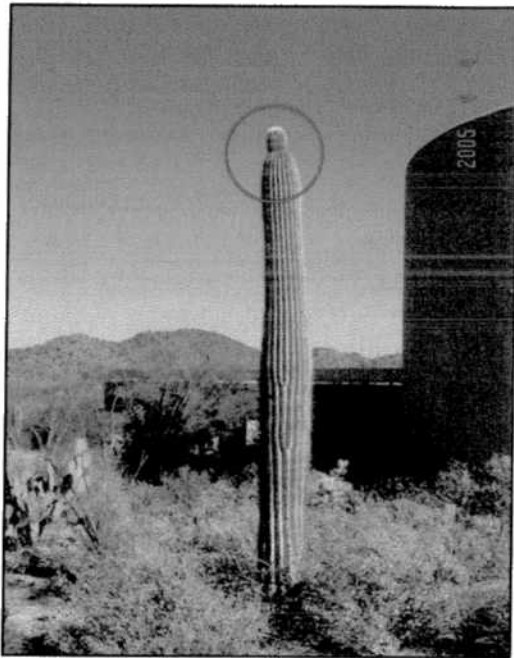
Discussion

One challenge to moving saguaros is size: the larger the saguaro, the harder it is to move due to its height, weight and arms. In general, taller saguaros are less likely to survive transplanting because the broad, shallow root system of the saguaro is reduced to a smaller area immediately around its base (**below**). This affects the transplanted saguaro's ability to take up water and nutrients and also reduces its physical support system, making larger plants much more prone to wind-throw.



Fewer lateral roots reduce water and nutrient uptake, and physical support for larger saguaros.

Besides size, another factor in transplant survival for saguaros is how carefully they are moved. Because they are heavier and generally have more arms (a mature specimen can weigh as much as 8 tons), larger saguaros are simply harder to move. However, even smaller saguaros, if abused during transplanting, may not survive the process. For successful transplanting, as much root mass as possible must be excavated, and a similar-sized hole must be provided and carefully back-filled so that roots are not broken, compacted or exposed to air pockets.



Transplanted saguaro with constricted tip

In general, transplanted Red Hills saguaros have grown little between 1992 and 2004. Those saguaros between 2m-4m tall, generally the size of peak growth for saguaros, grew an average total of 28cm in that period. According to Steenbergh and Lowe (1983), these saguaros could have potentially grown over 100cm over the same period. The transplanting process likely reduces saguaro height growth due to root injury and overall root reduction (Harris *et al.* 2004). Recent long-term drought may have also affected growth. Many of the larger transplanted Red Hills saguaros are constricted at the tip, suggesting that growth has been stunted (left).

Transplanting Saguaros – Other Local Experiences

The Arizona-Sonora Desert Museum found that the survival rate for transplanted saguaros over about 4.5m (15ft) tall is less than 10%, but those around 3.5m (10ft-12ft) tall or less almost always transplant successfully if treated with proper care (Dimmitt 2000). However, observations of large-scale saguaro salvage in southern Arizona generally attest to low survival rates for transplanted saguaros (Dimmitt 2000).

In a much larger study, the Harris Environmental Group in Tucson has tracked the survival of 1000 saguaros at the Raven Golf Course and Sabino Springs residential development starting in 1995: 800 saguaros were transplanted, 100 were preserved within the development, and 100 were the control group in undisturbed desert just outside the development. At nine years into the study, they estimated 34% of transplanted saguaros have died; however, 30% of the saguaros preserved in the development have also died, compared to only 3% mortality for the control group (Harris *et al.* 2004). In the study, transplanted saguaros under 2m tall had around 20% mortality, which increased with saguaro height. Mortality was greatest in the largest plants (>7m tall) in all three treatments, but was 30% in the undisturbed desert population versus greater than 60% for both transplanted and preserved-in-development saguaros (Harris *et al.* 2004).

Both the Desert Museum and the Harris study point out that transplanted saguaros mortally impacted by their move may persist for a number of years in a weakened condition before succumbing to the stresses of transplanting (Dimmitt 2000, Harris *et al.* 2004). Longer-term evaluations of saguaro transplants may necessary to gauge the success of transplant operations accurately.

The Larger Issue

The State of Arizona, Pima County and municipal governments have passed plant protection ordinances requiring, in areas to be impacted by development, that saguaros be moved or mitigation be provided to plants left in place in the landscape. However, transplanting saguaros, even if performed by careful contractors, appears to increase the chances of mortality, especially in older, larger specimens.

Even when mitigation is provided for saguaros left in place in the developed landscape, the results can be similar. Buildings and paved surfaces that encroach on saguaros reduce available soil surface area to intercept precipitation and cause more extreme temperature fluctuations (Harris *et al.* 2004). Also, heavy construction equipment operated around saguaros compacts soil, damaging roots and reducing water infiltration.

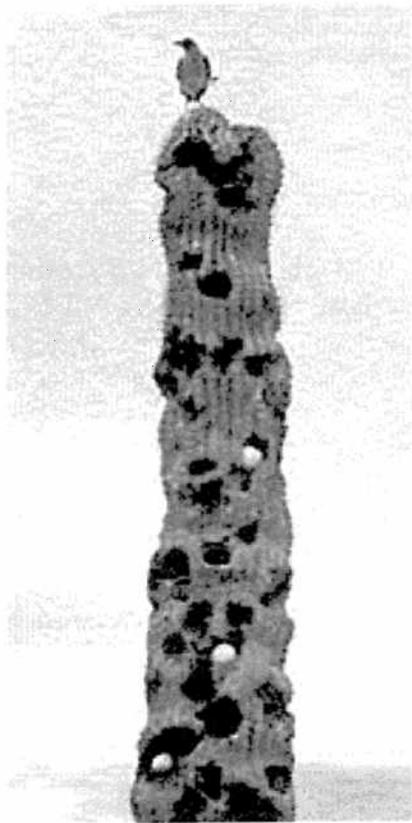


Photo: James S Wood, Arizona Daily Star

Human activities – over-watering, damage and vandalism – also reduce the vigor of saguaros in developed areas. The Harris study found that saguaros in the developed zone showed signs of repeat injuries from vehicles, and those close to the golf course fairway are severely damaged and pocked with holes from golf balls (left), as well as increased damage from animals such as birds. The study found that, although transplanted saguaros had initially higher mortality than those preserved within the development, in the long-term mortality for both was roughly equivalent – injuries and stresses in developed areas such as paving, soil compaction, over-watering and loss of other protective plant cover eventually take their toll on all saguaros in this environment, leading to early mortality for many cacti (Harris *et al.* 2004).

Recommendations

- When saguaros must be transplanted, concentrate on moving a greater number of smaller saguaros, and placing them into more protected areas. Salvage operations often concentrate on moving larger “trophy” saguaro specimens, which are more costly to move and will likely have lower transplant success (Harris *et al.* 2004). Also, if saguaros are moved to roadsides, medians or other developed areas where the chance of damage is increased, this also increases the chances for early mortality – they should be moved into areas preferably with other desert vegetation.
- For preservation-in-place, development (buildings, roads, parking lots, golf courses) should be kept at a distance to improve saguaro survival. Development designs can reduce development and use impacts to the land. The concept of “density” is often loathed by developers and homebuyers, but good design can cluster development together while increasing shared open space for all residents. An added benefit of clustered development is reduced costs for infrastructure and utility installation and maintenance – roads, power, water and sewer need not be stretched as far when structures are closer together.
- The standard for “successful” transplantation of saguaros should take a longer-range perspective. Because transplanted saguaros can persist in a weakened state for years before succumbing to planting stress, contractors should be held to a longer period (at least 5 years) as a criterion for transplanting to be considered successful, and/or match the natural mortality of nearby natural populations.

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