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A Proposal to

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Submitted by David Venhuizen, P.E.

To investigate

Setting Up, Permitting and Running of a Subdivision-Scale Rainwater Harvesting System as the Water Supply Strategy for Subdivisions in the Texas Hill Country

THE VISION

Building-scale rainwater harvesting systems, integrated with a backup supply system, are proposed to be investigated as the water supply strategy for subdivisions. This strategy envisions collecting rainwater off building roofs and routing this water to a cistern, perhaps integrated into the structure of each building but certainly "associated" with that building – e.g., a free-standing cistern on the same lot. Each building would therefore incorporate a self-contained water supply system, including all facilities required to filter/treat/disinfect the water so that it can be used to supply all water demands—including potable—within and around that building. However, all buildings would be "connected" to a development-wide water system through the backup supply scheme.

Building-scale rainwater harvesting is one of a limited number of options for a rural Central Texas development. The others include private wells, a community well and small-area distribution system, a high-producing well or well field and a large-area distribution system, and importing water from reservoirs in "regional" scale water transmission mains. These are all essentially large-scale rainwater harvesting systems, with the reservoirs or aquifers serving as the system's "cistern". This highlights that there is nothing "exotic" about rainwater harvesting as a water supply strategy. Since all fresh water derives from rainfall, just about every water supply system in the world is a rainwater harvesting system. They differ only in how long and convoluted the link is between the precipitation and the water usage, so they essentially differ only in system scale.

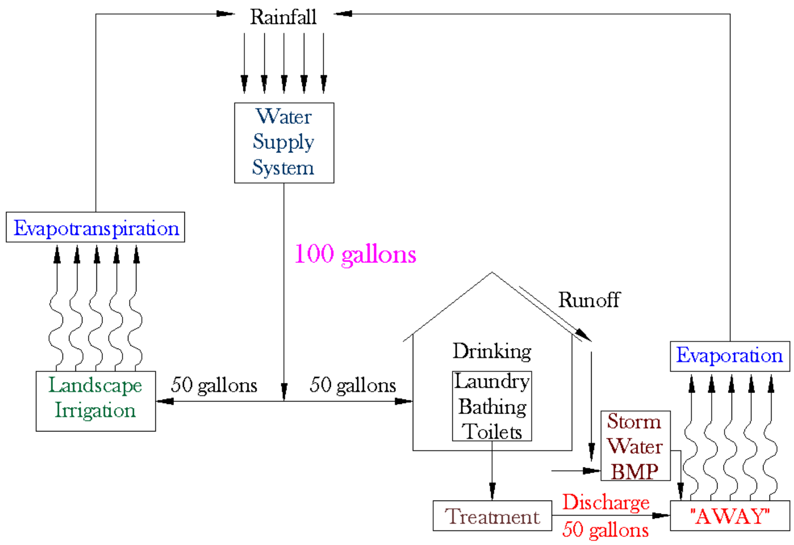
The findings and recommendations in "Rainwater Harvesting Potential and Guidelines for Texas", the report to the 80th Texas Legislature subsequent to the charge issued in HB 2430, indeed make it clear that a rainwater harvesting water supply strategy is anything but a wild idea out of the blue. Rather it is a mainstream-method-waiting-to-happen, given an appropriate context. This study proposes to examine building-scale rainwater harvesting as the water supply strategy in the context of developments in rural areas of Central Texas, with emphasis on areas drawing water from the Edwards, Trinity and other aquifers, in the Texas Hill Country.

This water supply strategy is envisioned as part of an integrated water resources management system. Our water resource exists within a closed system – called the hydrologic cycle – but traditional approaches used in residential and commercial developments "silo" the management of each of those functions into totally separate systems – water supply, stormwater, and wastewater. If we are to maximize the efficient and effective use of water, and so maximize sustainability of water resources, our management strategies must recognize that ***all*** water exists in the context of this closed system. We must therefore design our management approaches in accord with that understanding – as ***integrated systems***, with the infrastructure that addresses each function being designed as an integrated component of an overall system. The illustrations on the following page compare a non-integrated – or "silo'd" – system with an integrated management system, illustrating how rainwater harvesting might be integrated into the overall water resources management system. This shows how husbanding of the water resource may be enhanced by "tightening" the water loops, using strategies such as building-scale rainwater harvesting.

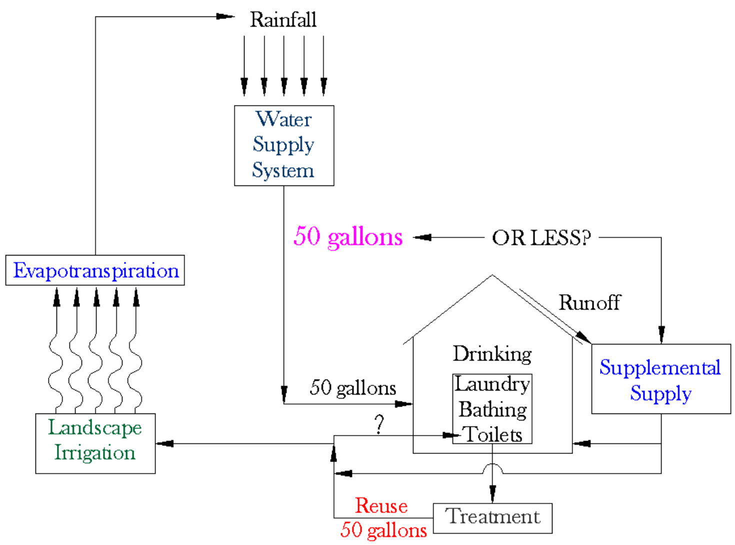
The immediately obvious question about rainwater harvesting as a water supply strategy is, what happens in a drought? The building-scale rainwater harvesting system can be made as immune to loss of supply as any other system by providing an ***assured*** backup supply system. As noted, this organized backup supply system is the "connection" to a development-wide water supply system. The only question is how "practical" and cost efficient those provisions may be in any given context vs. simply connecting to one of those larger-scale water supply systems. This would require organization, possibly some permitting, and management. Defining these needs is a central focus of the proposed investigation.

A major reason to favor building-scale rainwater harvesting in the Edwards and Trinity areas is to limit routine, everyday withdrawals from the aquifers. Some other reasons to expect that a building-scale rainwater harvesting strategy may provide a more fiscally reasonable, more societally responsible, and a more environmentally benign water supply strategy than the other options – especially a sprawl-inducing regional pipeline – include:

- While the initial cost per gallon incurred by them may be higher, the building-scale rainwater harvesting facilities are relatively small incremental investments that require only the expenditure of resources needed to serve development actually being installed, freeing considerable resources for alternate investments. Since up front costs are minimized, the short-term cost efficiency for the developer may be compelling.
- Over the long term, the time value of money may also favor a pay-as-you-go strategy. The large-scale infrastructure is an "all-or-none" decision requiring a very large investment well in advance of *any* delivery of service, financing large-scale facilities that would not be fully utilized for many years. All users of this system would be paying the cost of these unused facilities throughout that period.



NON-INTEGRATED SYSTEM



INTEGRATED SYSTEM

- Given the rural location of the projects combined with uncertainty about future transport fuel costs, ***and*** given the uncertainty about the real estate market generally due to the credit crisis, if buildout does not proceed as contemplated, the developer and/or system users would be left to pay back a large up front investment with short revenues, perhaps drastically increasing water rates or taxes for the customer base. The larger scale the system, the bigger the gamble.
- The cost and timing of the large-scale infrastructure installation is typically out of the developer's (and the eventual users') control, as would be the cost of water obtained from that system. The cost and timing of the building-scale facilities are entirely within the users' control, and the on-going cost of water would be low ***and*** would not be prone to escalation.
- In the large-scale system, treatment problems, line breaks, etc., would have broad ranging impacts, with unpredictable costs to the users. In the building-scale system, any problems would be isolated and amenable to remediation by individual users and/or the local operating entity. Thus, from a certain viewpoint, the building-scale system is ***more*** reliable than the large-scale system.

- Building-scale rainwater harvesting is an inherently more sustainable strategy in terms of water resources management than the other options, since the development would in large measure live on the water that falls upon it. Needing to do this engenders a conservation ethic, and stimulates pursuit of efficiency strategies which may not appear cost efficient—and thus would be retarded—once there is a large sunk cost in a piped water system. Enhancing efficiency would enhance water supply sustainability generally.
- The water supply from a building-scale rainwater harvesting system may be of higher quality than would be obtained through a piped water system. Rainwater is soft and "pure", being polluted only by materials that may have been deposited on the roof since the last rain. In the large-scale rainwater harvesting systems, there is no control of the collection area, so the storage tank receives water of random quality, including whatever pesticides, fertilizers, and other pollutants that wash off the land, so may require considerable treatment to attain potable quality. Also, the large-scale delivery system requires that the treated water be heavily chlorinated. All this results in the water that is delivered to the points of use being quite degraded relative to the original quality of the rainwater.
- A large-scale treatment system and a far flung distribution system entail considerable demand for increasingly expensive energy. A point of use treatment and pressurization system would demand far less energy, and would thus entail considerably lower operating cost.

The confluence of such fiscal, societal and environmental pluses for building-scale rainwater harvesting urges the consideration of this strategy to serve as a development-wide, water supply system. This proposal sets forth a course of investigation to evaluate that strategy – fiscally, societally and environmentally – and to provide guidance for how to implement it and to properly govern it so that it would provide a continuously-assured water supply to users of the development, thus rendering this strategy as reliable as any of the other water supply options.

SUMMARY OF PROJECT OUTCOMES

The expected outcomes of this project include:

- Results of a modeling process, showing the roofprint and cistern volume requirements relative to presumptions of water demand to be served and the frequency of backup supply that these choices would impose. These results define the infrastructure requirements of the system.
- A review of options for a backup supply system, including expected costs and permitting and management requirements.
- A review of the expected impacts of using the building-scale rainwater harvesting water supply strategy on the marketability of the properties so served.
- A review of the expected impacts of using this strategy on the sustainability of water resources, with emphasis on the Edwards and Trinity aquifers.
- A review of the expected permitting and governance issues entailed in using this strategy as a development-wide system.
- A review of the expected incremental costs of buildings that would be incurred to employ this strategy.

Each of these aspects of the proposed investigation is reviewed in the following sections.

YIELD/DEMAND MODELING

The first step in evaluating any water supply system is to understand the level of demand that it would need to supply. A "standard" water supply system design typically presumes "established" demand rates. However, modeling indicates that maximizing the value of a rainwater harvesting system strongly urges achieving lower per capita demand rates. It also urges maximizing effective irrigation reuse of the wastewater produced in the building, if the users desire to maintain an irrigated landscape. A model is used to explore the impact of these factors on system requirements.

The model, developed by the proposer, allows the user to input roofprint (collection area), cistern (storage) volume, and daily water use. The model is run using 20 years of historical rainfall data from weather stations near the project site. Presuming that future rainfall patterns would not markedly depart from those experienced in that historical period, this can be used to predict the expected shortfall in supply that may occur, given the roofprint, cistern volume and demand that was input. This then offers a prediction of how much, and how frequently, backup demand would be required in the future. This allows the system designer to choose the most cost efficient system design, including the costs and operational issues of the backup system, and to set the water demand standards that should be met to achieve the desired overall system performance.

The inherent risk of using the results of this modeling process as the basis for defining a backup supply system is that, due to climate change in this region, rainfall patterns may be different in the future. The investigation would provide available information on the predicted impacts of climate change, and the level of confidence of those predictions.

An example of the modeling process for a house highlights the information that may be derived from it. A roofprint of 4,000 sq. ft. is presumed. Examining several floor plans of a builder active in the Hill Country, it is determined that more than 4,000 sq. ft. of total roof area could be provided by adding a veranda around, at most, three sides of the house, leaving the fourth side open for the air conditioner and utility line entries. The model also presumes the cistern volume is 30,000 gallons. This could be accommodated by a containment about 4 feet deep under the resulting veranda floor area. These sizes are therefore considered "reasonable" standards in this example. This design strategy is further reviewed in the cost section of this proposal.

The demand presumed is 200 gallons/day, which is 4 persons using 50 gallons/day, or 5 persons using 40 gallons/day. These occupancies are considered the norm for a 3-bedroom and a 4-bedroom home, respectively. (Demographics of most Hill Country developments show that occupancy is typically somewhat lower than 4 persons/household, but of course the system needs to be designed to accommodate the house capacity.) People who design and install rainwater harvesting systems to serve as whole-house supply report that they routinely use as little as 35 gallons/person/day as a planning number. Given use of efficient fixtures and appropriate attention to leak control, a usage of 40 gallons/person/day should be readily attainable without any meaningful compromises in lifestyle. As implied previously, pursuing rainwater harvesting as a water supply strategy would entail the users being aware of the value of water and acting accordingly. Such limiting of the demand rate, and all the cost and marketing implications of that, is a matter to be considered in the course of the investigation.

The results of the model with these inputs, employing data from the Wimberley weather station (in the area where considerable development pressure now exists), indicate that backup supply would have been required in 3 of the 20 years covered by the model (1987-2006), that the total amount of backup supply over those 20 years would have been 22,000 gallons, and that the largest amount of backup supply required in any one year would have been 10,000 gallons, which occurs once. In the other two years when backup is required, 6,000 gallons would have been required in each year. (Note that the model presumes backup supply is provided in 2,000-gallon increments, so the modeled backup supply will always be in multiples of that quantity.)

In another run of the model, it is presumed that when cistern volume drops below an “alarm” level of 4,000 gallons, the users would “tighten their belts” and reduce their usage to 80% of the nominal presumption. In this model run, a backup supply would still have been required in 3 of the 20 years, but the total amount of backup supply over 20 years would have been only 14,000 gallons. The peak amount in any year would have been 6,000 gallons, which occurs in two years, with 2,000 gallons required in the other year. This illustrates how an “enhanced conservation ethic” among the users would significantly benefit the overall supply strategy. This behavior is indeed routinely urged by the drought contingency plans of all water supply entities in this region.

The model can also include consideration of irrigation demands, to see how this would impact on backup requirements. Another model run presumed that it was desired to maintain 2,500 sq. ft. of irrigated landscaping, and that irrigation would be curtailed if the cistern “alarm” level were reached—just as drought contingency plans of all existing water suppliers curtail irrigation use. This showed that, with the same roofprint, cistern volume and interior demand, backup water supply would have been needed in 12 out of the 20 years, with the total backup supply being 102,000 gallons. In the year with the largest backup demand, 18,000 gallons would have been required, and 12,000 gallons would have been required in 3 other years. This shows that supporting any significant amount of irrigated landscaping directly from the rainwater supply would require either a significantly larger system (roofprint and/or cistern volume) or significantly more frequent backup supplies.

The model can examine the impact of using reclaimed wastewater to defray the irrigation demands—the integrated strategy suggested in the previous illustrations. This could be effectively accomplished by dispersing the reclaimed water in a subsurface drip irrigation field. The model presumes that 90% of interior demands would appear as wastewater and applies this amount to defraying irrigation demands. Another run of the model with this feature included shows that the frequency of need for backup supply would have been reduced to 4 years out of 20, with the total backup supply volume reduced to 16,000 gallons. The highest backup supply volume required in any one year would have been 6,000 gallons, in two of the years, with 2,000 gallons required in the other two. This graphically illustrates the value of irrigation reuse of reclaimed water to the rainwater harvesting supply system, if any significant area of irrigated landscape is to be maintained.

This model would be used to evaluate all these factors for a number of locations in the Hill Country. This information will frame the choices for developers, builders and system users to arrive at the most expeditious combination of roofprint area, cistern volume, demand control, and backup supply availability. These in turn would inform them of the various costs – direct and indirect, immediate and on-going – that would be incurred to implement and run a development-wide water supply predicated on the choices made.

BACKUP SUPPLY SYSTEM

As just reviewed, the modeling procedure would indicate the requirements for the backup system. The building-scale rainwater harvesting system would not include any waterlines through which a backup supply could flow to each house – it is the elimination of this cost that provides the incentive to invest instead in the building-scale supply facilities. Therefore, the presumed backup system would consist of a fleet of tank trucks and a contract assuring water availability from a potable source. This may be a municipal or other organized supply system, or a well and storage tank on the property, to be used only for backup supply. The investigation would examine the various available sources and offer estimates of the water price that would be charged to the system users.

The practicality of this backup supply strategy would also be examined. The major problem with this concept is that when backup supply is needed, most likely just about every house would need it. For example, in a development with 500 houses, if every house needed a truckload in a given month, and assuming there are 22 work days in a month, this would generate about 23 truck trips per day. Assuming each truck could make 6 trips per day, there would need to be 4 trucks available. Unfortunately, unless some other use could be found for these trucks – a use which could be suspended at will so they could be dedicated to supplying backup water for a month or more straight – they represent an investment that would lie idle most of the time. However, since the houses in any development would typically be built over a number of years, it is an investment that can be phased.

Also to be considered are permitting issues and management requirements. All these factors would be examined to evaluate the costs and practicality of providing organized, continuously-assured backup supply systems.

IMPLICATIONS FOR MARKETING

The fiscal viability of a development-wide building-scale rainwater harvesting system relative to the other available options would be a major determinant of marketability. This would entail investigating the cost of the large-scale system infrastructure plus the charge for water vs. the incremental costs to provide building-scale collection, storage and supply facilities and the cost of a reliable system to provide backup supply. All these factors would be studied to evaluate the apparent marketability, from a fiscal standpoint, of the building-scale rainwater harvesting water supply strategy, and to elucidate the characteristics of a development that would favor or diminish that strategy.

Another aspect of marketability is perception. Relying on building-scale rainwater harvesting for water supply may be a marketing issue simply because it is not currently the norm, and people fear the unknown. The degree of concern would probably depend on the arrangements made for an assured backup supply, as that would no doubt be the greatest concern of potential users, and of their sources of financing, highlighting the need to evaluate the backup supply strategy.

Potential buyers may also be concerned about holding down water use to keep their backup demand in check. As noted, it would be this very need to modulate demand that may urge and bolster investments in water use efficiency to control water use. This issue would be studied to evaluate the “reasonableness” of attaining the demand rates that appear to be required, based on the modeling and evaluation of backup supply strategy. Relative to sustainability issues, the concept of turning this need into a “badge of greenness” for the project will also be considered as a marketing issue. This would entail consideration of how LEED and Green Builder standards may relate to this overall water management strategy.

On a “rational” level, there are very tangible water quality benefits to the users. And as long as there is an assured backup supply system, drought can be addressed. Curtailments might be urged to minimize backup supply, but as noted previously all water systems in Central Texas routinely impose use restrictions during droughts. When coupled with a wastewater system that drip irrigates the reclaimed water to defray landscape irrigation demands, the restrictions required for the building-scale system could be considerably less compromising. These are other aspects of marketing to be considered.

All these facets of marketability would be investigated and reviewed by consulting with realtors, brokers, builders, potential buyers, agencies that issue standards, etc. What is learned will offer guidance on how competitively developments utilizing the building-scale rainwater harvesting water supply strategy might be marketed, with special emphasis on Hill Country areas that would otherwise be served by wells in the Edwards or Trinity aquifers, or by regional transmission mains.

IMPLICATIONS FOR SUSTAINABILITY

As noted previously, one reason for considering the rainwater harvesting water supply strategy is to minimize demands on limited supplies like the Edwards and Trinity aquifers, to render these resources more sustainable in the face of continuing growth. The concept envisions that developments using building-scale rainwater harvesting would *displace* a significant amount of development that would have drawn *all* of its water supply from the aquifer – understanding that simply choosing a different sort of water supply system will not change the overall market for housing or any rules that govern/restrict development – so the aquifer would be drawn down more slowly with the onset of drought. Therefore, although these systems would require a backup supply just at the time the resource is being strained by drought, since less development is imparting a routine, everyday demand on the aquifer, its overall sustainability would be enhanced even if that backup supply were being drawn from that aquifer.

It has been indicated that the building-scale rainwater harvesting water supply strategy would require more careful attention to water use efficiency by system users. This is certainly a characteristic that would be desirable and beneficial for any water supply system, especially those which draw water from aquifers like the Edwards and the Trinity, again because these resources are being increasingly strained by growth in the region.

In any case, from a long-term sustainability perspective, it may be necessary to advance water use efficiency by all means available. If the population growth forecast for the area which draws its water supply from the Highland Lakes and local aquifers indeed occurs, and if the per capita water demand on those sources does not significantly decrease, it is expected that this region would have to begin importing water in the not-very-distant future. It is an open question just where this water might come from, as the adjacent river basins are expected to also be over-committed. The rational conclusion is that developments indeed "should" be designed to enhance water use efficiency as much as practical. Whether building-scale rainwater harvesting, and the practices which it may stimulate, is a "practical" avenue to this end is an investigation that appears reasonable to consider.

The impact of rainwater harvesting on the stormwater management problem is also a significant factor to consider. Direct rainwater catchment and sequestration can play a significant role. The building-scale rainwater harvesting system would be more "efficient" in converting rainfall into water supply than would the large-scale systems using lakes or aquifers as the storage system. A USGS study reported that more than 80% of rainfall falling on this area is lost to evapotranspiration, implying that in a large-scale system, only a small minority of total rainfall ever reaches the storage. This does not mean that the majority of the rainfall is "wasted" since it is this portion of the rainfall that maintains plant cover in the watershed.

When development occurs, much of the rainfall onto impervious surfaces is converted into quickflow, greatly in excess of that generated by the land in its "natural" condition, exacerbating flooding and channel erosion. When a significant portion of a watershed is developed, this would severely decrease the volume of baseflow and recharge, which can negatively impact on the riparian environment, aquifer storage, and downstream water uses. Indeed blunting these impacts is a major thrust of various rules systems which may govern stormwater management in Central Texas.

In the building-scale rainwater harvesting system, the rooftops used as catchment—typically a very significant fraction of total impervious cover in a development—capture and sequester a very high percentage of the rainwater falling on them. So this catchment and storage prevents a significant portion of the additional quickflow imparted by development from occurring. Especially when coupled with a "waste" water system which utilizes effluent for landscape irrigation, the captured rainwater, which becomes that effluent after serving interior water uses, can even more efficiently perform its plant maintenance function, and some of this irrigation water may percolate to contribute to aquifer recharge and maintenance of baseflow.

As illustrated in sketches shown previously, this is one way in which the water management functions could be integrated. Again it is increasingly being recognized that integrated, watershed-based water resources management can be expected to enhance overall water use efficiency. All these sustainability issues would be examined to offer an expectation of the amount of demand on "normal" water supplies that might be defrayed by broadscale implementation of building-scale rainwater harvesting as a water supply strategy, again with emphasis on the Edwards and Trinity aquifers.

PERMITTING AND GOVERNANCE

Under current rules, a building-scale rainwater harvesting system would not be subject to any permitting or other governmental oversight. As noted, the development-wide rainwater harvesting strategy would, however, make each of these systems in effect a "connection" to the development-wide backup supply system. The backup system may have to be "justified" to, and perhaps permitted by, a governmental entity in the process of showing there is a safe and adequate water supply source to support the level of development proposed. The development-wide entity that runs the backup system would also have an interest in minimum standards for each of the building-scale rainwater harvesting systems – in particular minimum roofprint and cistern volume relative to house size. Means to "ration" water use to attain the presumed demand rates may also need to be considered. Other approval processes may be identified in the course of investigating those requirements. These issues would be reviewed to offer guidance on governmental approvals processing and on organization of governance entities and the content of their rules. An optional activity in the investigation would be to engage legal expertise to produce model rules or codes.

One other "approval" issue is what impact lack of a piped water system might have on fire insurance rates. It is envisioned that fire protection would be provided by water in the cistern – and perhaps from other nearby cisterns, if the fire prevents drawing from the cistern of the house on fire. Of course, there would be an indeterminate amount of water in each cistern when a fire occurs. This may dictate a rule that a minimum amount always be retained for "fire flow", which would impact on infrastructure costs. It is an open question, however, if this strategy would be a "sufficient" substitute for a piped water supply that can provide a designated "fire flow". The fire insurance issue would be reviewed and guidance offered for minimizing fire insurance rates.

SYSTEM COST ANALYSIS

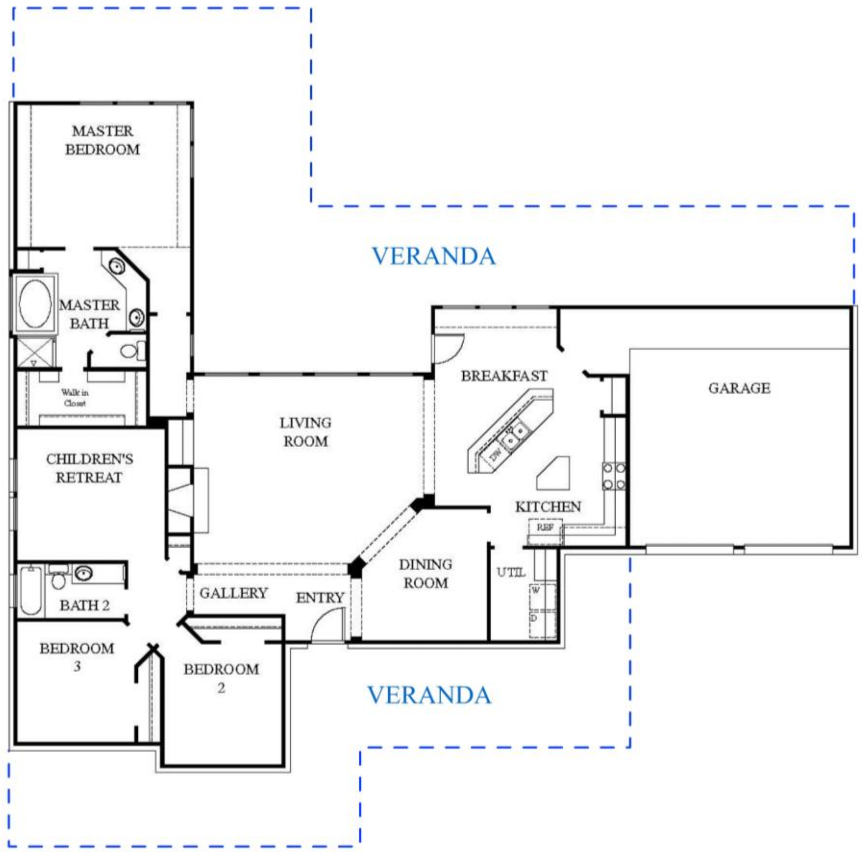
Besides the costs of backup water supply and of running the backup supply system discussed previously, the costs incurred by the building-scale facilities must be evaluated. The cost factors for a building-scale rainwater harvesting system include provision of the required roofprint, the required cistern volume, and the treatment and pressurization facilities. The costs of all these components would be investigated by consulting with architects, builders, and construction tradesmen. The cost analysis would address all these factors and provide cost estimates for implementing this rainwater harvesting system.

It is understood that of most immediate concern to the districts governing the Edwards and Trinity aquifers are single-family home subdivisions that tax the aquifer by using either individual wells or a central well and subdivision-scale water system, or perhaps would get pipes extended by water supply systems that have wells in these aquifers. The cost analysis for collection and storage facilities in this investigation would therefore center on single-family houses.

This is not to say that a rainwater harvesting strategy could not be used for developments that include commercial buildings. The feasibility of this would depend on the land uses housed by those buildings. Land uses, such as office buildings, that did not incur a greater "water use intensity" (ratio of daily water demand to roofprint) than houses might be "reasonably" supplied by rainwater harvesting. The cost of each system would no doubt be rather context-sensitive, so deriving generalized cost estimates for commercial building rainwater harvesting facilities would be problematic. The investigation would, however, review at least one "typical" example, to provide some guidance on using this strategy for commercial buildings.

For single-family home facilities, "rain barns" to obtain the required roofprint and free-standing cisterns for storage could be used, and these strategies would be investigated. However, the "veranda strategy" suggested previously may create a more cost efficient system that also delivers some side benefits.

It is envisioned that the veranda, and the cistern beneath it, could be readily accommodated without significantly altering the builder's processes and specifications. It would have no significant impact on the rest of the house design – it would entail simply pouring more foundation and adding on porch roofs – and it would not encumber the lot with a free-standing cistern. This design concept is what the proposer terms a "Hill Country rainwater harvesting vernacular" house design concept. As noted previously, it appears that existing house plans of builders currently active in Hill Country developments can readily be modified to obtain a fairly large roofprint and cistern volume using this strategy. An example is shown in the illustration below. It is to be expected that house plans generated on this concept from the start could even more efficiently encompass the required roofprint. The investigation would review this design strategy to determine its costs and practicality.



The additional cost of this "veranda strategy" should be at least partially offset by the value of the sizable outdoor living spaces added onto the house, spaces which are useful over a large portion of the year in this climate. The veranda roof would also provide shade around part of the house perimeter, which would enhance the energy efficiency of the house. These factors would also be evaluated to produce an estimate of the overall value of the rainwater harvesting system.

CONDUCT AND COST OF INVESTIGATIONS