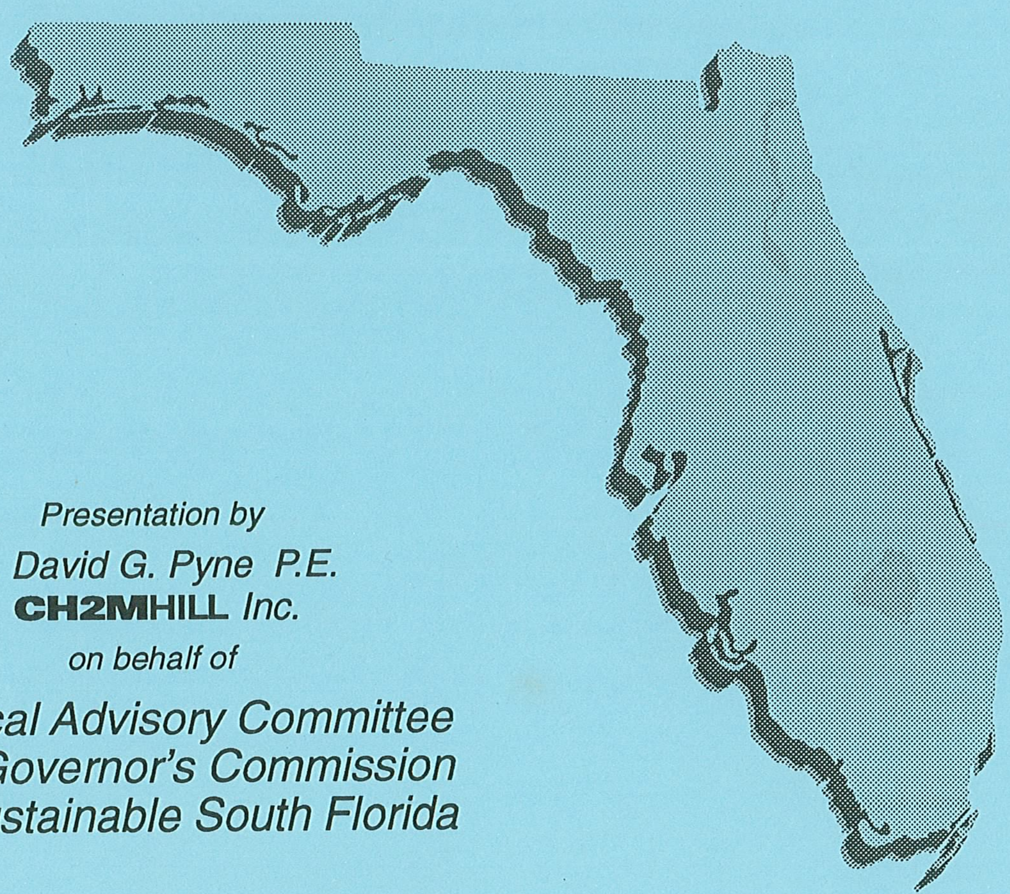
R.T. VERRASTRO

# Aquifer Storage Recovery

## *Potential Water Storage Alternatives for South Florida*




*Presentation by*

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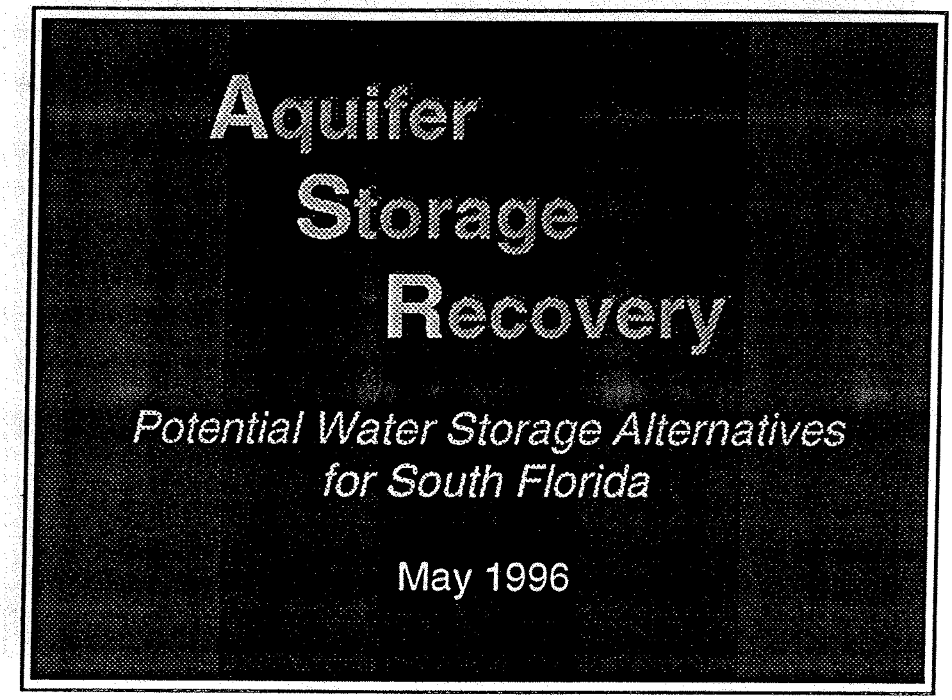
**CH2MHILL** *Inc.*

*on behalf of*

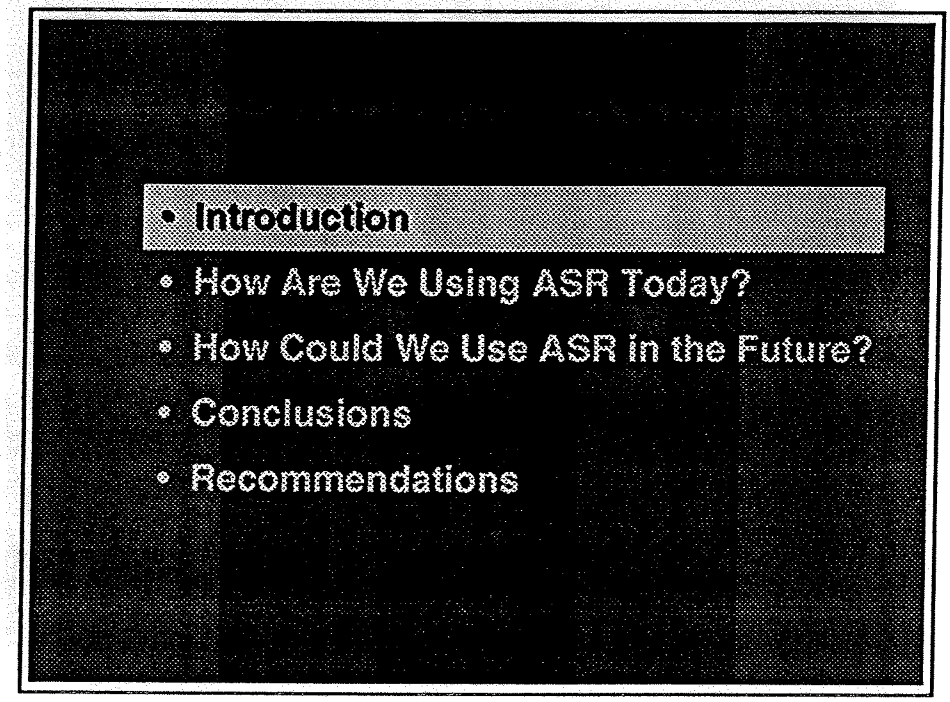
*Technical Advisory Committee to the Governor's Commission for a Sustainable South Florida*


Aquifer
Storage
Recovery
Potential Water Storage Alternatives
for South Florida
May 1996

# Purpose

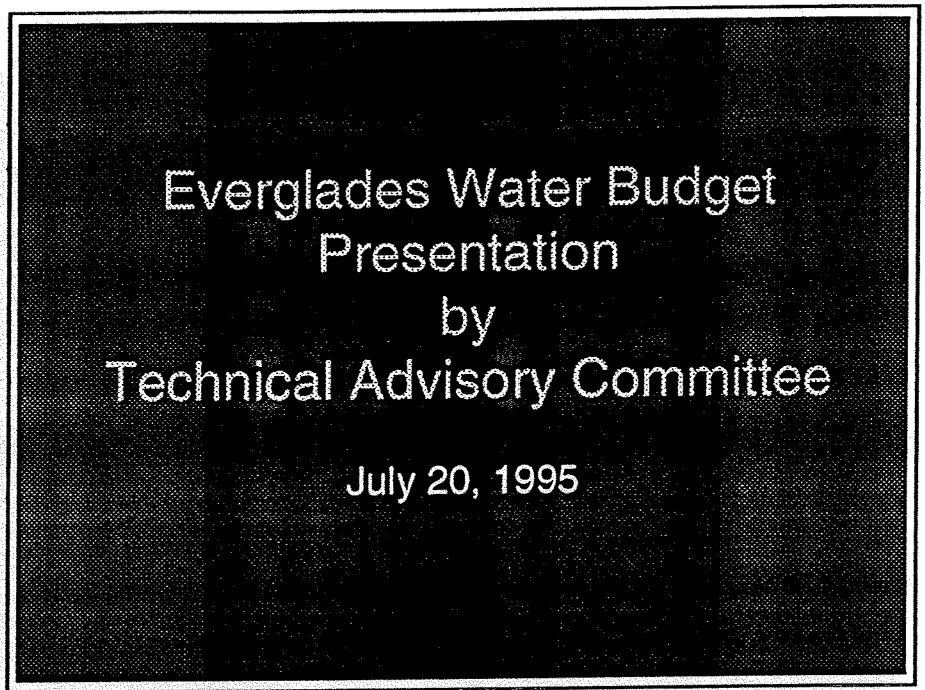
Present a current assessment of the Aquifer Storage Recovery technology to aid in managing water storage needs in South Florida

This will include recommendations to the Governor's Commission regarding ASR testing, permitting and implementation.

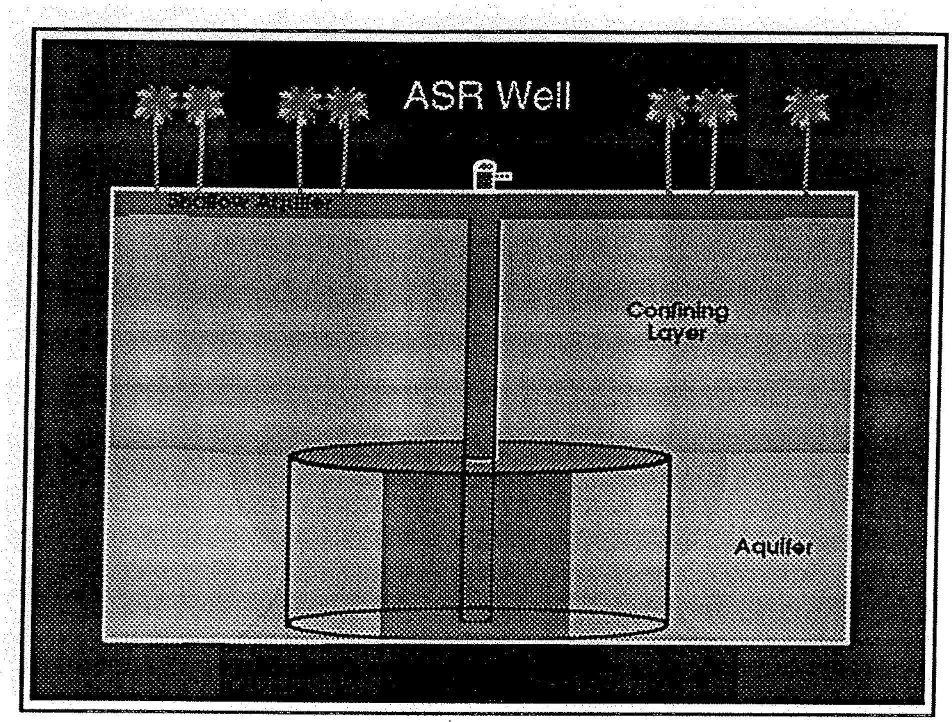



This is a consensus document, representing the opinions of the Technical Advisory Committee and the Aquifer Storage Recovery (ASR) Subcommittee, developed between June 1995 and the present.

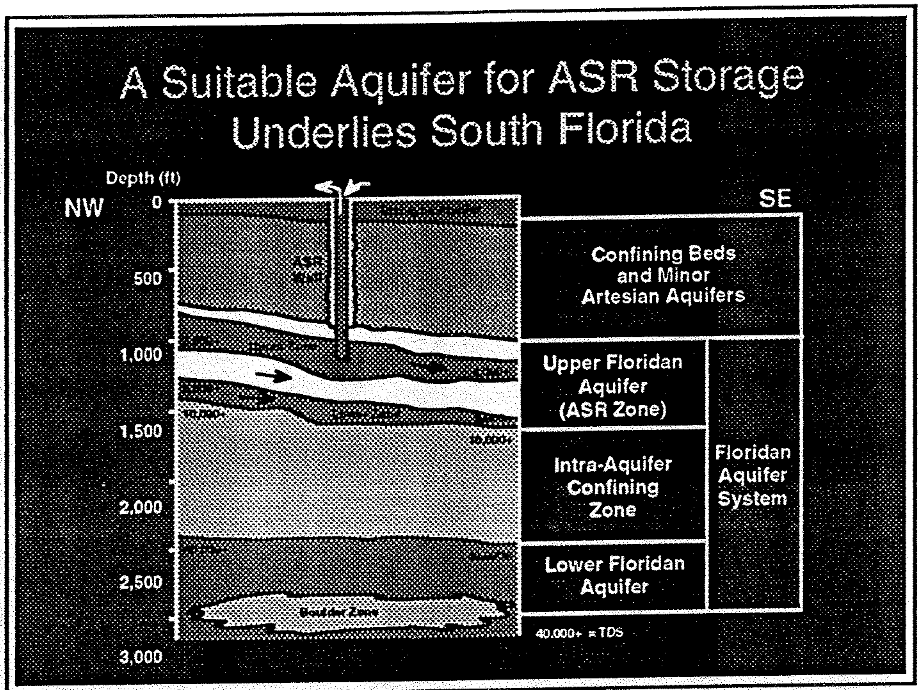
In the first part of this presentation we will discuss what ASR is and how it works, including our need for water storage in South Florida. We will then discuss how it is being used today to store potable water and raw groundwater. Then we will discuss how ASR could be used in the future to store surface water. Finally we will present conclusions and some recommendations.



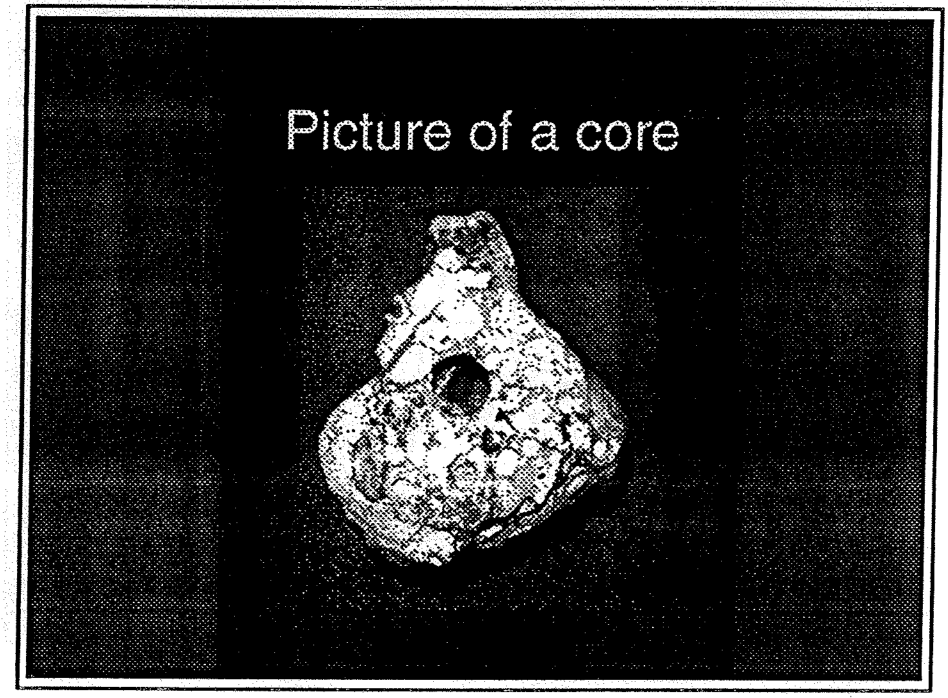

- The Everglades Water Budget presentation by the Technical Advisory Committee to the Governor's Commission on July 5, 1995, showed excess seasonal flows during the wet season and maximum demands during the dry season.
- We need storage to bridge seasonal variability.
- ASR could help to meet storage needs. It is currently being used to meet seasonal variations in utility water demands. However, it is not a proven technology for meeting regional water storage needs.
- This presentation will summarize the potential and also the uncertainties associated with regional water storage using ASR wells.



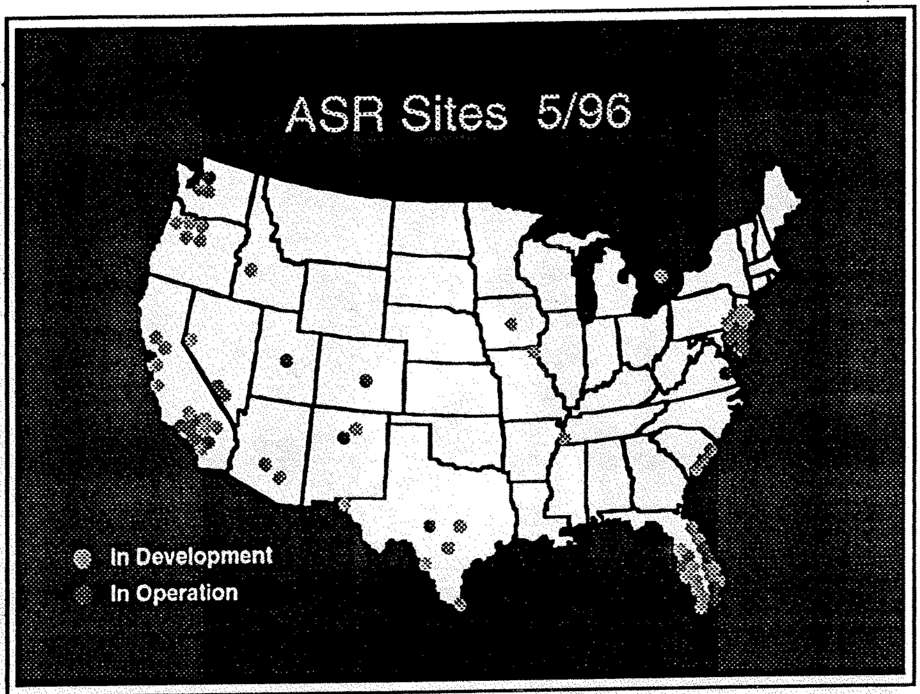

- ASR technology allows aquifers to be used as underground reservoirs.
- An ASR facility consists of a source of available fresh water, a well as a conduit to a suitable aquifer, and a pumping system for storage and recovery.



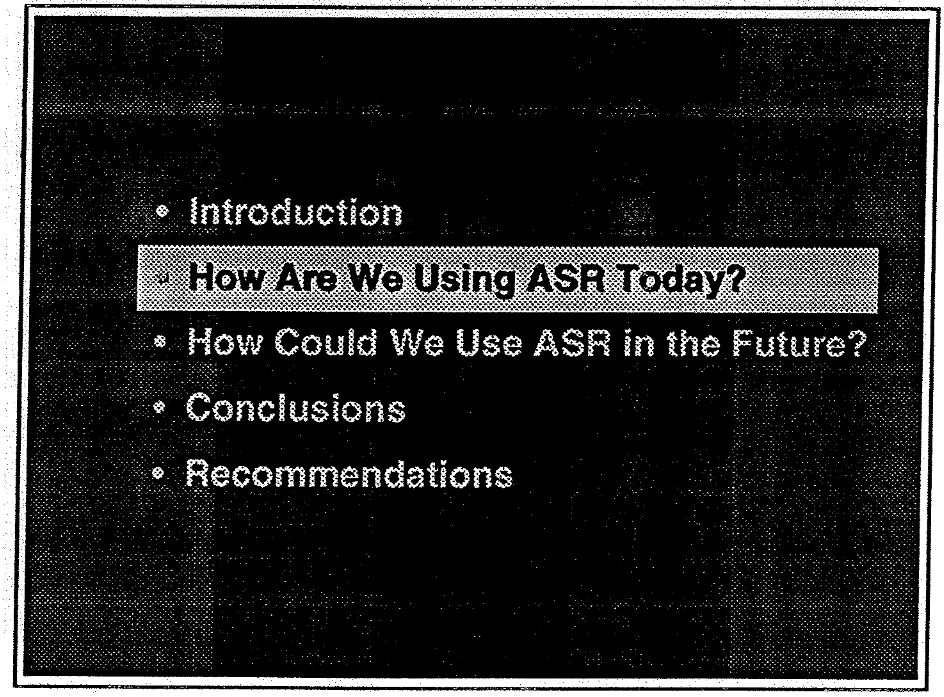

- A typical southeast Florida cross-section from west to east shows the upper Floridan aquifer, which is the ASR storage zone.
- The upper Floridan aquifer contains brackish water with total dissolved solids concentrations ranging from about 3000 to 6000 mg/l. This may be compared to potable water at 500 mg/l and seawater at 35,000 mg/l. The aquifer ranges in depth from about 800 feet to 1,600 feet, increasing slightly toward the coast.
- The upper Floridan Aquifer is a confined, limestone aquifer under pressure.
- The stored water in an ASR well displaces the ambient brackish water, creating a bubble of fresh water around the well.




- This is a sample of rock from the upper Floridan Aquifer, about 6-inches long.
- Porosity is a measure of the water-bearing space within the pores of the rock. Within the upper Floridan Aquifer, the porosity varies from perhaps 5% to more than 35%, however a reasonable estimate of the average porosity is about 15%.
- Water can be recharged into, and recovered from, the pores of the rock by pumping down into a well or pumping back from a well extending into the upper Floridan Aquifer.




- ASR is gaining acceptance globally, with systems operational in the United States, England, Holland, Israel and Australia, and being developed in Canada.
- 25 ASR sites are currently operational in the United States, all of them storing water meeting drinking water standards. Many more sites are under development. The oldest site has been in operation since 1968 in New Jersey. The oldest site in Florida began operation in 1983 in Manatee County. The smallest site is at Marathon, Florida, with a capacity of 0.5 MGD (1.5 acre feet/day). The largest site is at Las Vegas, Nevada, with about 30 wells and a total recovery capacity of 100 MGD (307 acre feet/day). Most ASR systems have begun operation since 1983.

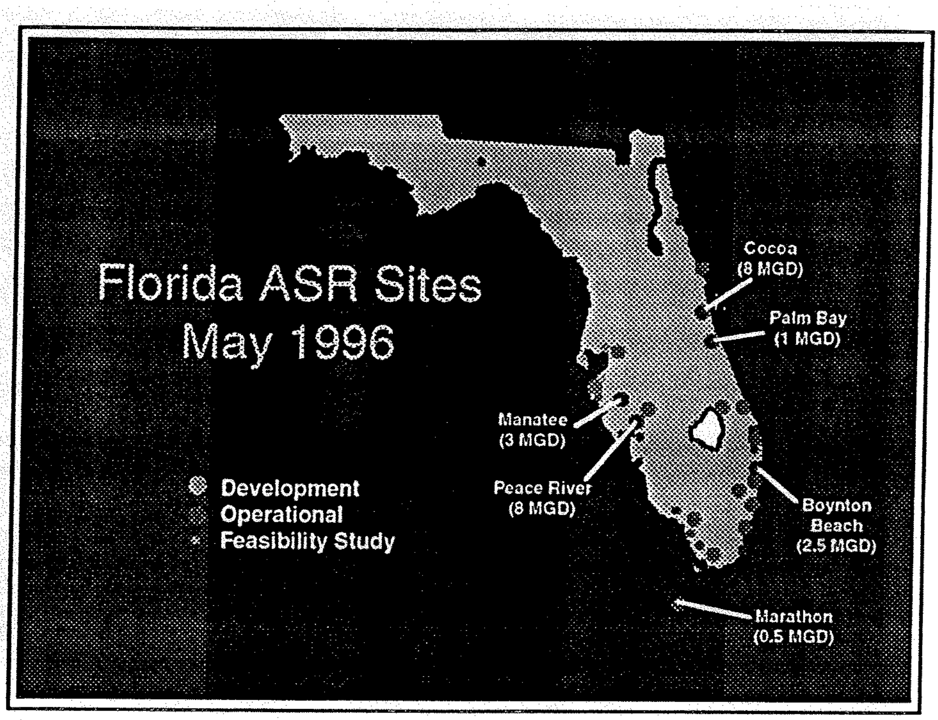



This section addresses water meeting all drinking water quality standards, including treated drinking water and raw groundwater.

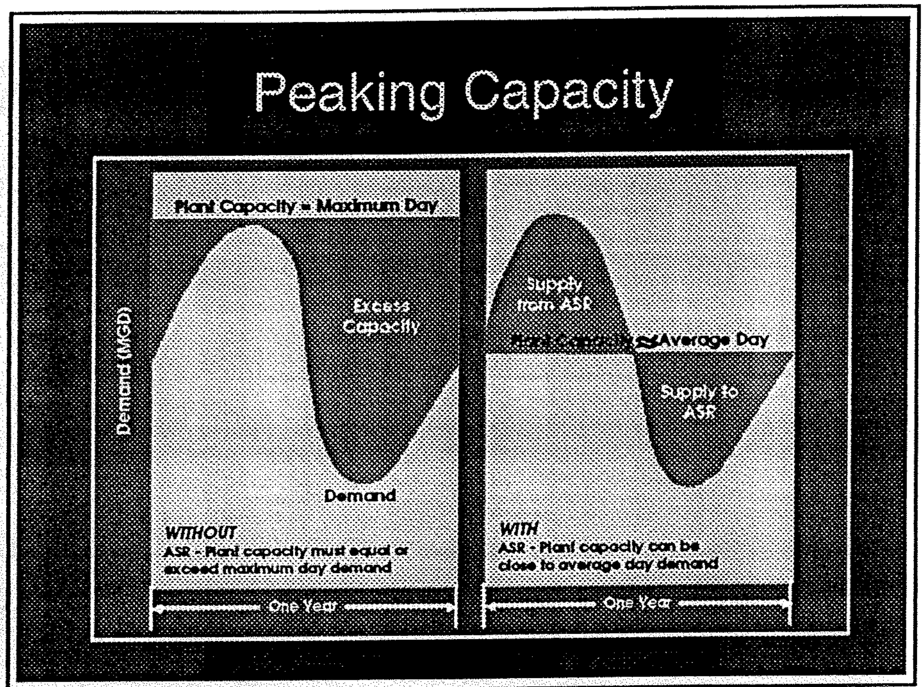
## ASR Well Yields Are Up to About 5 MGD

| Storage Interval (ft depth) | Source | Expected Yield (MGD) |
|---|---|---|
| 800-1300 | Treated Drinking Water and Water Meeting Regulatory Standards | 1 to 5 |

The Boynton Beach ASR system is operating at 2.5 MGD and the Miami-Dade system is expected to operate at 5 MGD for each well.




- Florida has six operational drinking water ASR systems, the largest of which are at Cocoa (6 wells) and Peace River (9 wells), both with 8 MGD (25 acre feet/day) total recovery capacity. Boynton Beach stores water meeting drinking water standards in the upper Floridan aquifer and has about 2.5 MGD (8 acre feet/day) recovery capacity from a single well. Four of the six operational systems have been, or are being, expanded to meet increasing demands. At least seven additional Florida ASR systems are under construction or testing.
- The primary reasons why ASR has been implemented in the water utility industry are its low cost relative to other water storage alternatives and its benefits through minimizing adverse environmental effects. It achieves this by switching to ASR sources during droughts, thereby reducing the effects of withdrawals from shallow aquifer wellfields, streamflows and wetlands.




- Water supply and demands are variable. During times when water is available at rates exceeding system demand, it may be stored. Recovery can occur whenever demand exceeds system capacity. Water may be stored in early years after a treatment plant expansion, and recovered in later years when demand increases or it may be stored in wet months and recovered during dry periods. With appropriate design, all of these objectives can be met.
- Typical variability in seasonal demand is 20 to 40% of average demand.
- With treated water ASR, the expensive components of a water system such as the water treatment plant may be sized closer to average instead of peak demands, thereby reducing costs.
- In addition to helping to meet peak demands, ASR wells are being used to help prevent salt water intrusion in south Florida by reducing shallow aquifer demands during the dry season.

## ASR Capital Costs Compared to Other Peak Demand Options

| | $ Million for 10 MGD System |
|---|---|
| Raw Groundwater ASR* | 1.0 - 2.5 |
| Raw Groundwater ASR w/Treatment | 12.0 |
| Treated Water ASR | 2.0 - 6.0 |
| Other Options: | |
| – Blending Wells | 2.0 |
| – Shallow Aquifer Wells | 10.0 |
| – Brackish Water / RO | 15.0 |
| – Reclaimed Water | 10 to 50 |
| – Seawater Desalination | 40 - 70 |

* Meeting regulatory requirements

- The primary driving force for potable water ASR expansion in the United States has been economics.
- These are capital cost estimates for expansion of existing peak water supply system capacity by 10 MGD using various technologies. For the shallow aquifer wells, this includes a 10 MGD water treatment plant expansion.
- Different options have different potential yields. Treated water ASR could augment existing potable water supplies by about 160 MGD within the Lower East Coast. Blending wells could augment supplies by up to about 80 to 100 MGD, and reclaimed water by up to 200 MGD for irrigation. Biscayne/ Shallow Aquifer potential increase in yield is unknown. Brackish water desalination yield is unknown while seawater desalination yield is large, but may be limited by concentrate disposal options.
- ASR is a low cost water management alternative to augment potable water supply in south Florida. A preliminary cost estimate for a 5 MGD ASR well is up to $1.5 million. Nationwide average costs for ASR systems range from $200,000 to $600,000 per MGD peak capacity, with a best estimate of $400,000 per MGD.

## Water Storage Capital Costs

| ASR ($ Million) | Site | Surface Reservoir ($ Million) |
|---|---|---|
| 18 | Columbus, Ohio | 161 |
| 45 | Peace River | 108 |
| 2 | Manatee County | 18 |
| 3 | Texas | 30 |
| 5 | Florida Keys | 35 |
| 9 | Ontario, Canada | 75 |
| ? | Lower East Coast | ? |

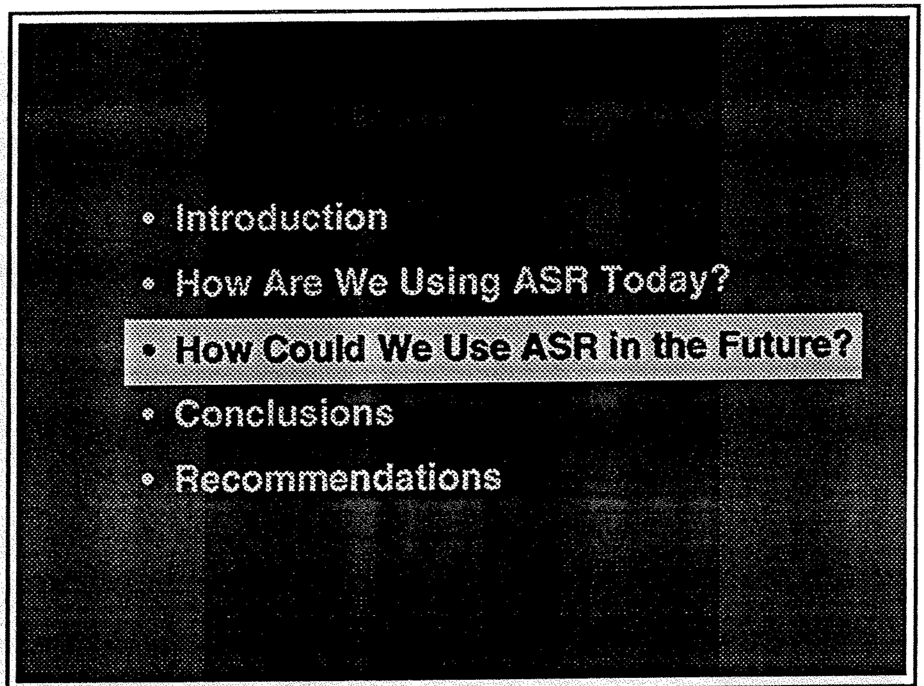
Source: CH2M Hill

- In these instances, storing water below-ground in a reservoir provided by nature has been less expensive than constructing above-ground storage, and may have less environmental impact.
- Depending upon site-specific circumstances, capital cost savings of 50% or more may be possible.

## Summary of Current ASR Use

- ASR with treated drinking water is cost-effective, viable and widely implemented.
- ASR with raw groundwater is cost-effective, viable, and beginning to be implemented.
- Potential yield of treated drinking water ASR wells is limited to about 20% of peak water demand for South Florida utilities, or currently about 160 MGD.
- Potential yield of raw groundwater ASR wells is probably greater, however additional water treatment plant capacity would be required.

This section of the presentation has addressed ASR storage of drinking water and raw groundwater that meets all drinking water quality standards, which includes treated drinking water and raw groundwater. For some utilities, this may also include high quality reclaimed wastewater that meets drinking water standards.

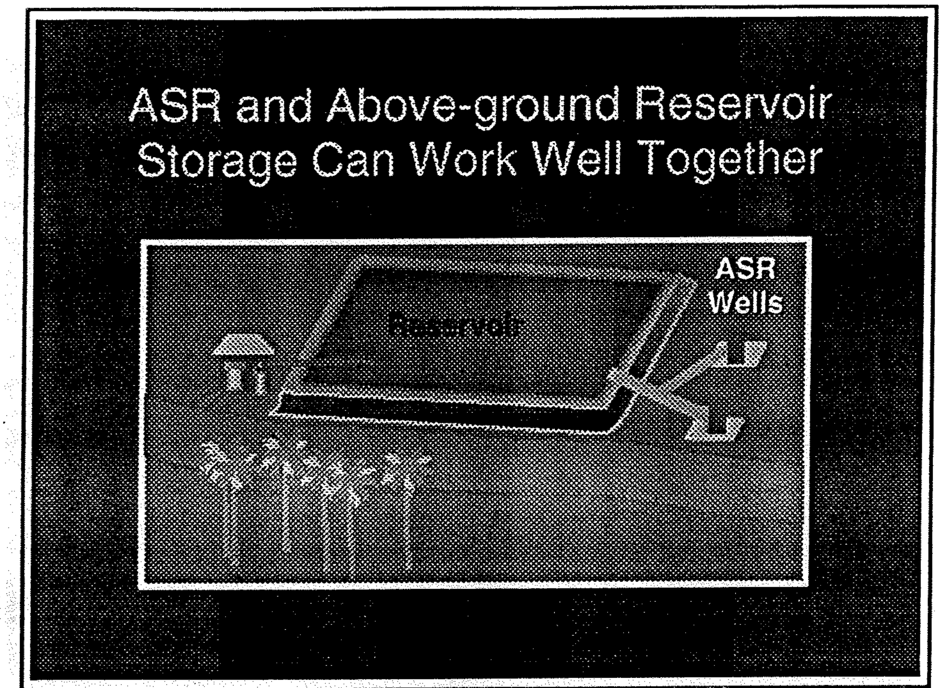



- The Everglades Water Budget report to the Governor's Commission showed that modern discharges to Atlantic estuaries are approximately 2 million acre feet per year more than in pre-drainage times. This water is potentially available for storage. ASR could provide storage, however several technical uncertainties, water quality issues, and regulatory constraints concerning both recharge and recovery inhibit reliance upon this option for regional water management.
- The next part of this presentation addresses these regulatory, water quality, technical, and economic issues.
- In the future we may be able to expand current use of ASR wells for storage of treated drinking water, raw groundwater and reclaimed water, all meeting regulatory water quality standards for well recharge.
- The big opportunity, and the challenge, is to also achieve ASR storage of high quality water that may not meet certain government standards and would not adversely impact public health or the upper Floridan Aquifer.

## Potential Future ASR Benefits

- Capture and store excess surface water and groundwater and recover when needed.
- Water storage at volumes comparable to other storage alternatives being considered.
- Current operational experience indicates that there may be significant potential for large-scale cost savings.
- Enhance regional management of storage in Lake Okeechobee by diversifying some of the storage in the aquifer at Lake Okeechobee and other areas.
- Substantially increase urban water supply storage at low cost.
- Substantially increase system storage for agricultural areas and regional water management.
- ASR storage can be phased to suit desired incremental needs.

- A reduced operating stage could be achieved in Lake Okeechobee by shifting water storage to beneath the lake, using the lake more for detention of flood flows and other beneficial purposes.
- Urban water supplies could be increased by about 500 mgd, compared to current water use of about 800 mgd in the Lower East Coast. This would require less than one-fourth of the water now annually flowing to tide.
- This could improve water management options for farmers and also for wetland systems.
- A particular advantage is that ASR wellfields are readily constructed in small phases, as funds are available and as the demand changes.




A combination of ASR wells and surface storage can increase the volume stored by allowing capture of high volume, high rate surface flows associated with storm events. This would increase water supply yield, improve recharge water quality, and reduce harm to the estuaries from peak flows.

## ASR Cost-Effectiveness

- ASR applications may be cost-effective in supplementing water supplies during water shortage periods.
- Based on reasonable assumptions, this technology has the potential to economically deliver enough water to make it worthwhile to resolve the technical issues.
- Based on reasonable assumptions, ASR will not necessarily be cost-effective for all applications.

## Estimated Cost of Water Recovered from ASR Wells

| | *Lake Okeechobee Alternatives* | | | |
|---|---|---|---|---|
| Recovery Capacity (MGD) | 5 | 5 | 5 | 10 |
| Construction ($ million) | | | | |
| - Well | 1.00 | 1.00 | 1.00 | 1.50 |
| - Treatment | – | 0.05 | 0.05 | – |
| - Disinfection | – | – | 0.45 | – |
| - Total | 1.00 | 1.05 | 1.50 | 1.50 |
| Operation ($/year) | 75,000 | 100,000 | 150,000 | 100,000 |
| $ / Acre Foot | 107 | 126 | 188 | 76 |

- A reasonable possibility exists that testing may confirm the areawide presence of a high capacity zone at the base of the upper Floridan aquifer at a depth of around 1600 feet, as found at the existing Lake Okeechobee ASR test well and other sites. If present, individual well yields may be close to 10 MGD in this aquifer. This would substantially reduce the unit costs for ASR operations using surface water and raw groundwater. If this zone is absent, well yields would probably be closer to 5 MGD and unit costs would be higher.
- Recovery duration has a direct effect upon unit costs. For water utilities, recovery duration will tend to be quite short, typically occurring several times each year for a period of several days. For wetland systems or agricultural irrigation, longer continuous recovery periods may be appropriate. Recovery duration will vary widely between wet and dry years.
- For this cost-estimate, a recovery duration of 90 days during a one-year operational period was assumed for all four alternatives. Other assumptions include well life – 30 years; interest rate – 6%; treatment of recharge flows with ring filtration and possibly chlorine disinfection. Well construction includes monitor well requirements, estimated at one monitor well for two ASR wells.
- Several factors may affect unit costs, such as recovery duration; land availability; well yield; recovery efficiency; reservoir storage and disinfection requirements.

## Storage of 1 Million Acre Feet

| | Acres | Depth (feet) | Levee (miles) |
|---|---|---|---|
| Lake Okeechobee | 500,000 | 2 | – |
| Alternative Impoundment | 200,000 | 5 | 158 |
| | 100,000 | 10 | 112 |
| | 30,000 | 33 | 61 |

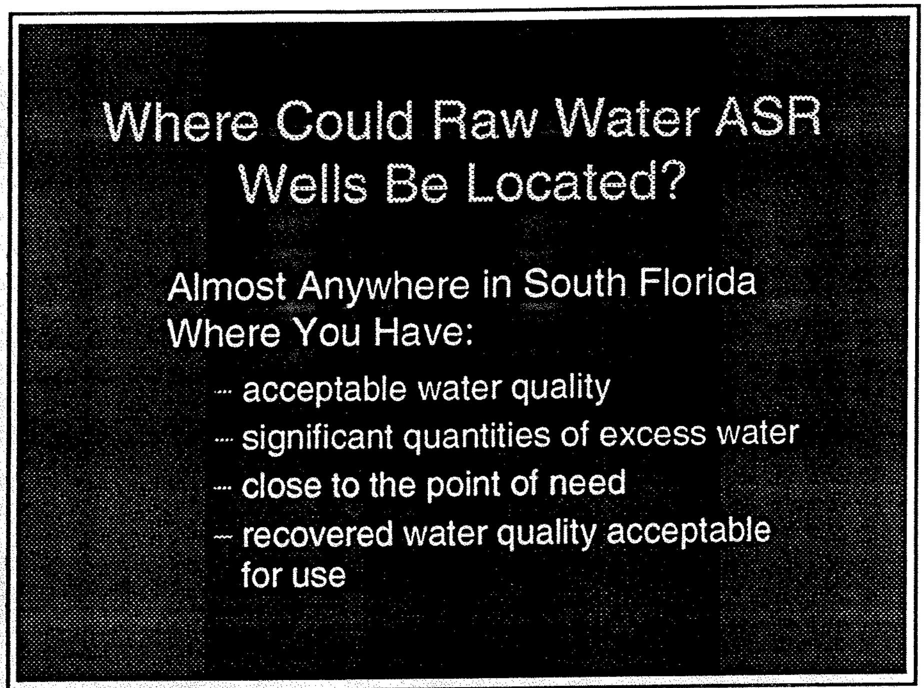
| | No. Wells | Yield (mgd/well) |
|---|---|---|
| ASR System | 178 | 5 |
| | 89 | 10 |

- One million acre feet is less than 2 feet of storage within Lake Okeechobee and is about one-sixth of the regional volume of storage lost due to historic drainage and land use practices.
- Providing 1 MAF of storage above ground could include additional storage at existing impoundments or entail reservoir construction at an assumed five sites with a levee total length of at least 112 miles and flooding 100,000 to 200,000 acres to a depth of 5 to 10 feet. If only 30,000 acres are acquired, the levees would be 61 miles long and reservoir depth would be 33 feet.
- Providing 1 MAF of storage underground would entail construction of 89 to 178 ASR wells. This number of wells would require 12 months of continuous recharge to store 1 MAF.
- ASR wells would probably be located in clusters adjacent to Lake Okeechobee, canals, rivers, wellfields, lakes and Buffer Preserve areas.
- An effective water management strategy for south Florida would involve a balance of land acquisition, surface reservoir construction and ASR to meet regional water storage needs.

1 ACRE FOOT = 326,000 gallons.



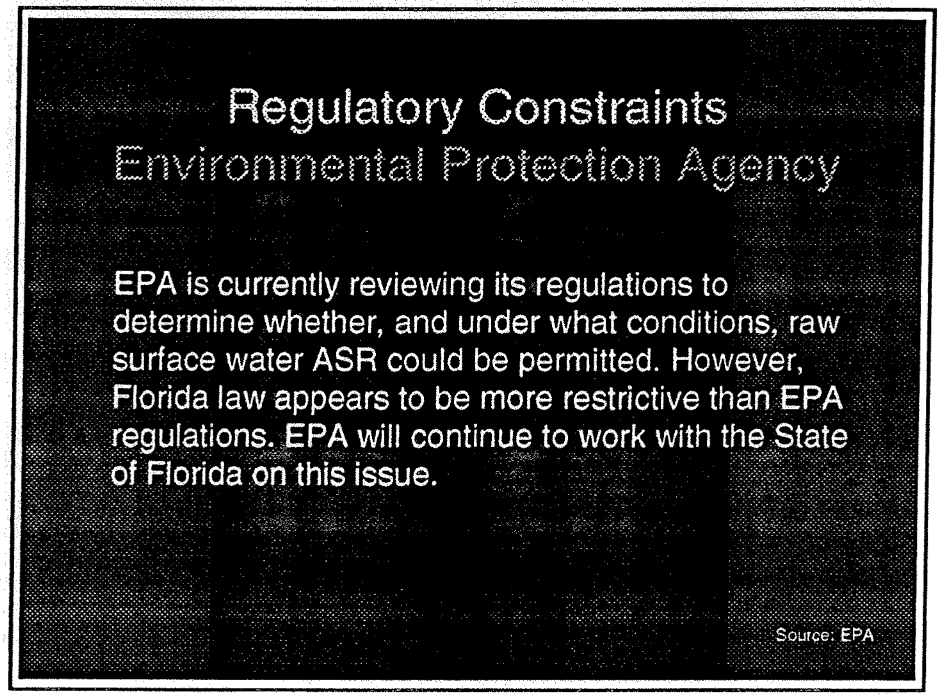
3 acre feet ≅ 1 million gallons.




- The Everglades Water Budget presentation showed a two million acre foot increase in flows to the Atlantic estuaries results from the combined effects of drainage and wellfield pumpage of the urban areas and from seepage from the Water Conservation Areas and Everglades National Park, in an approximate 50-50 split.
- Some portion of this water could be pumped from existing wellfields and stored in ASR wells instead of flowing to tide.
- During wet years such as 1995, tremendous volumes of water flowed to tide. A substantial portion of these flows is potentially available for storage without causing adverse environmental effects. During dry years, flows available for storage may be greatly reduced.

Some examples:

- At the south end of Lake Okeechobee, recharging high quality surface water from the lake.
- Along the Caloosahatchee River, recharging some of the water that would otherwise flow to tide.
- Along the St. Lucie River, recharging some of the water that would otherwise flow to tide.
- Along the east coast levee and drainage canals, recharging some of the water that would otherwise flow to tide.
- Along the coast, to offset leakage flows around salinity barriers and to capture some of the water flowing to tide.
- Other locations where seasonal storage and recovery of high quality surface water would be beneficial.




- The Environmental Protection Agency regulates all classes of injection wells as established under the 1984 Safe Drinking Water Act. Implementation of the UIC Program has been delegated to the Florida Department of Environmental Protection, however, at the request of Florida, EPA has remained actively involved in specific program implementation through participation in individual project TAC's and associated permitting activities.
- EPA primary drinking water standards include coliform bacteria, a bacteria that is naturally-occurring in raw surface water. Monitoring for coliform bacteria, if it is determined that raw water injection can meet federal and state requirements, may be conducted at the wellhead or other suitable location.
- Florida law currently requires compliance with primary MCL 's at the point of injection, consistent with EPA's historic enforcement policy.

**(Material on this page provided by EPA)**

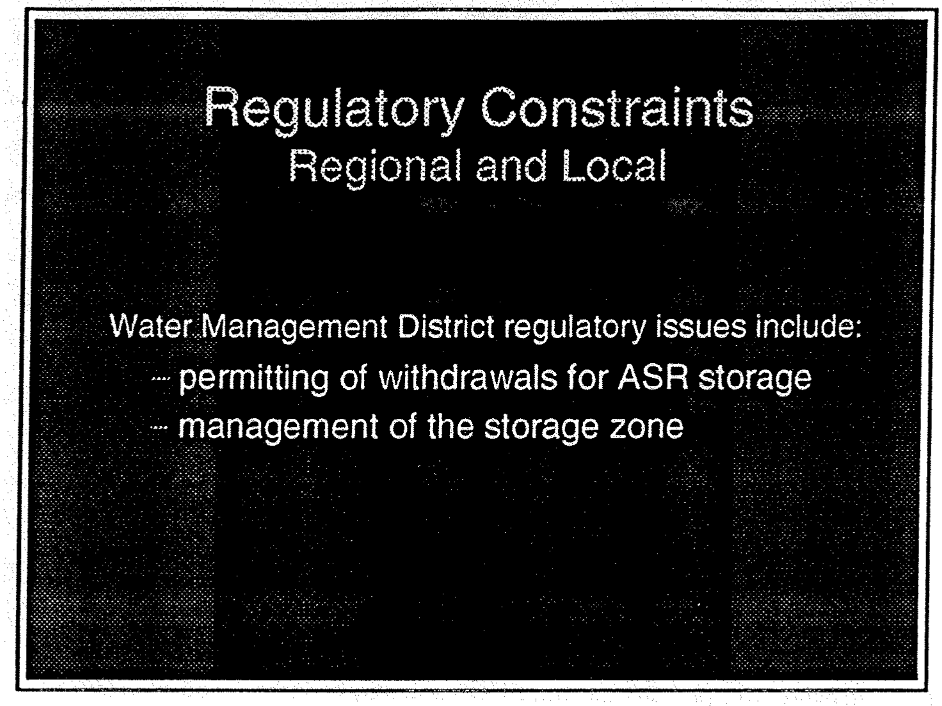
## Regulatory Constraints Florida Department of Environmental Protection

- FDEP acknowledges that numerous ASR projects have the potential to be a beneficial water use project which may not result in water quality violations.
- Currently water quality standards are imposed at the wellhead during recharge.
- An alternative compliance location is available for projects designed to recharge or for conservation of water of comparable quality.
- Any regulatory interpretation will comply with the federal UIC requirements, and state law.
- Encourage the Governor's Commission to recommend that FDEP and EPA approve a protocol for a regional ASR pilot study utilizing surface water for recharge or conservation uses.

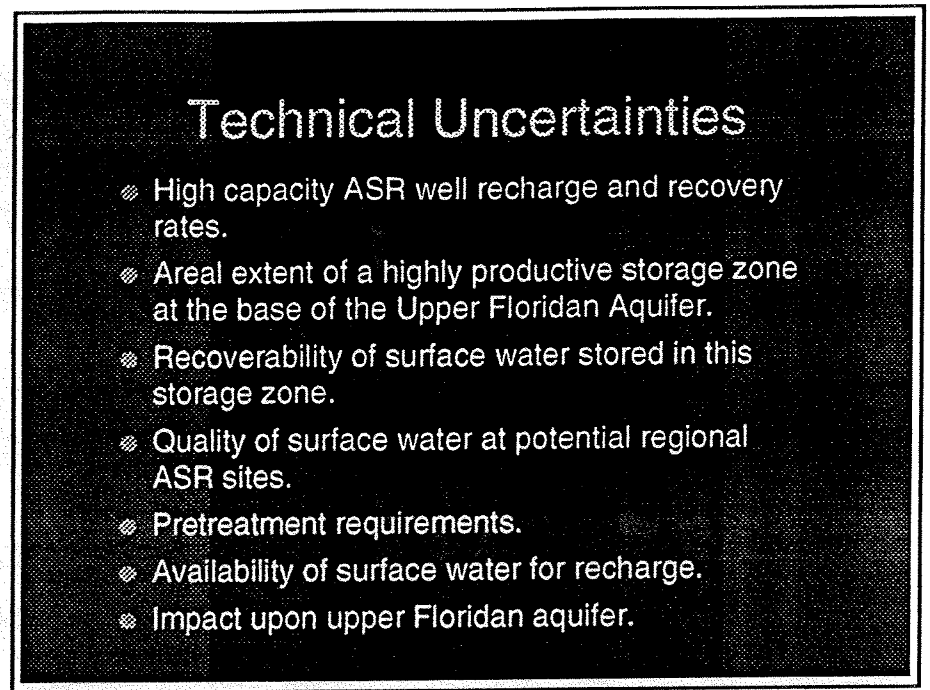
Source: FDEP

- FDEP water quality standards for protected ground waters include the primary and secondary drinking water standards, and minimum criteria.
- The federal Underground Injection Control (UIC) program only allows an aquifer exemption to obtain relief from the primary drinking water standards. The state has regulatory relief mechanisms to address the additional state standards.
- FDEP received delegation of the federal UIC program in 1983. The state regulations meet the federal requirements, and FDEP and EPA have a working protocol for all UIC projects. Innovative technology and beneficial use projects which can satisfy the federal minimum standards can be supported whenever environmental protection is ensured.

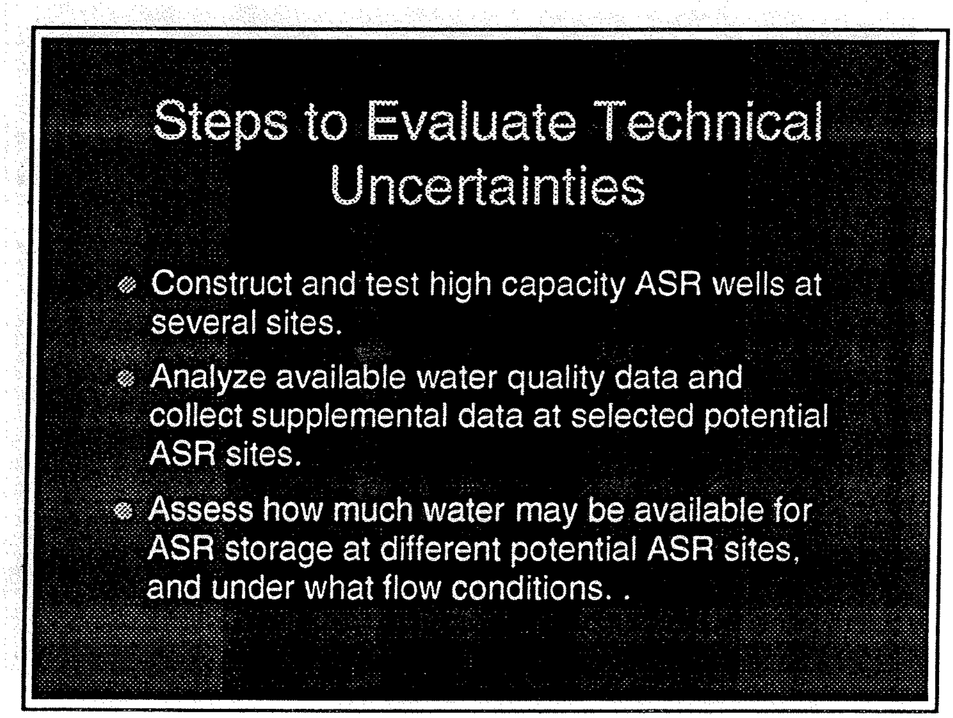
(Material on this page provided by FDEP)




- Management of the storage zone may include multiple uses such as ASR storage, brackish water withdrawals for desalination, and blending wells.
- Local government permits are also required.




- Recharge and recovery rates probably exceed 5 MGD and may be in the range of 10 MGD if the full thickness of the upper Floridan aquifer can be used for ASR purposes, generally between 800 and 1600 feet depth.
- The full thickness of the aquifer may be used if it is found that a highly transmissive zone is present at the base of the aquifer. This zone has been identified at the SFWMD ASR test well at the north end of Lake Okeechobee and also in the Miami-Dade West Wellfield ASR test/monitor well. It has also been found in Broward County by the SFWMD.
- We estimate that about 70% of the stored water can ultimately be recovered from an ASR well in this aquifer, however testing is required to confirm this. Of greater interest is whether the wells are capable of recovering the volume of water needed at an adequate rate, regardless of the recovery percentage.
- Preliminary analysis of several years of data from publicly-owned water treatment plants withdrawing water from the south end of Lake Okeechobee suggests that raw water from this source meets primary drinking water criteria except for coliform bacteria. Analysis of data from other potential surface water ASR sites in south Florida is needed so that we can focus on storing water from better water quality sites.
- If the full thickness of the upper Floridan aquifer is used for surface water ASR, including a highly productive zone at the base of the aquifer, pretreatment of the recharge water to remove solids will probably be unnecessary. If shallower productive intervals are used for storage, solids removal may or may not be necessary, depending upon the well and wellhead design and operation. A normal part of ASR well operation is periodic backflushing of the well to remove accumulated solids before they impact well productivity. Backflushing frequency is usually every few weeks or months.
- We know that about 3 to 5 MAF of water flows to tide each year on the Atlantic coast. This is generally 2 MAF more than occurred in predevelopment conditions. At this time, we do not know how much of this 2 MAF could be diverted and stored without triggering environmental harm. We estimate that at least 0.7 MAF may be acceptable.
- We do not know the potential impacts upon water levels in the upper Floridan aquifer resulting from large scale ASR operations. This determination will require better definition of aquifer hydraulic characteristics than is currently available.




- We need to conduct appropriate testing in high capacity ASR wells, to determine the yield, recoverability and quality of water stored in these wells. Potential sites include the south end of Lake Okeechobee, along the C-51 canal, the C-111 canal, Caloosahatchee River, St Lucie River, the lake-belt area of northwest Dade county, the levee along the east side of the Water Conservation Areas and Everglades National Park, and the existing SFWMD Lake Okeechobee test well at the north end of the lake. Additional testing is needed on ASR wells storing water in upper and lower portions of the aquifer, to determine yield and recoverability of each of these intervals separately.
- At each selected site, an analysis of available water quality data will indicate its suitability for ASR. At some sites, supplemental data collection may be required to demonstrate compliance relative to drinking water standards.
- Recovered water quality must be evaluated to determine its suitability for various applications, including environmental restoration.

# Summary of How We Could Use ASR in the Future

- ASR offers cost benefits however it has several technical uncertainties that will affect cost.
- Changes in state regulations plus changes in interpretation of federal regulations are needed to accomodate surface water ASR while protecting the environmental integrity of the upper Floridan aquifer.
- Testing and investigations are required to evaluate technical uncertainties and the suitability of recovered water from ASR for environmental restoration and other applications.

## Conclusions

- ASR with treated drinking water is cost-effective, viable and widely implemented.
- ASR with raw groundwater is cost-effective, viable, and beginning to be implemented.
- Only water meeting applicable quality standards will be used for ASR.
- ASR with surface water offers potential cost benefits. However, further effort is required to evaluate technical and economic uncertainties as well as regulatory impediments.
- The Governor's Commission has the opportunity to encourage resolution of these uncertainties. Such resolution may help to sustain South Florida in the future.

# Governor's Commission Should Strongly Recommend the Following Actions:

- Encourage ASR testing to evaluate technical uncertainties with high capacity ASR wells.
- Seek a suitable solution to regulatory constraints.
- Encourage water quality analysis of source and recovered water at selected potential ASR sites.
- Support Aquifer Simulation Modeling of ASR Systems.
- Encourage development of a technical and operational plan for the utilization of the Floridan Aquifer for ASR and other purposes.
- Request Corps of Engineers and South Florida Water Management District to incorporate ASR as an option to be evaluated in the Comprehensive Review Study.