Should Florida Revisit Comparative Assessment of Municipal Wastewater Disposal Methods in the Southeastern Part of the State?

Frederick Bloetscher

The Southeast Florida Condition

Regulatory, political, and economic constraints have shaped wastewater management strategies in Southeast Florida. Until the 1960s, South Florida was somewhat undeveloped and wastewater disposal was often to canals and other water bodies. The degradation caused by this practice became obvious in the late 1960s, and with passage of the Clean Water Act, other options were pursued.

Currently, three wastewater disposal options are available: Class I injection wells, ocean outfalls, and reclaimed water. Ocean outfalls were constructed in the early 1970s, with deep well construction starting after 1977 because, in contrast to most of the rest of the state, both options are available as a result of the nearby deep waters of the ocean and a deep zone for injection. Both options require secondary treatment.

The fact that the southeast coast has more centralized systems makes expensive bulk disposal methods like deep wells and outfalls more cost effective than in other regions of the state, but over the last 10 years, a number of issues have been raised about the appropriateness of both methods. These concerns are ostensibly related to environmental advocates and those desiring to limit explosive growth.

The focus of this article is the criticism of the injection well option. The discussion will include a summary of the injection well environment, the two risk assessments conducted for Class I injection wells in Florida, the proposed alternative to injection wells, and the areas where more study is required.

The Injection Horizon

There are nearly 200 Class I injections wells used for disposal of secondary wastewater effluent in the state of Florida. Nearly half are located in Southeast Florida (see Figure 1, page 20), where they are used to dispose of over 200 million gallons of secondary treated wastewater per day.

For wastewater discharge via underground injection, the facility must be designed to achieve an effluent after disinfection containing not more than 20 milligrams per liter (mg/L) $CBOD_5$ and 20 mg/L TSS—or 90 percent removal of each of these pollutants from the wastewater influent. Normally, appropriate disinfection and pH control of the effluents is required. The injection zone generally is 2,600 to 3,500 feet deep.

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Unlike many areas of the state and the nation, Southeast Florida is underlain by a thick sequence of carbonate rocks, limestone, and dolomite, along with lesser amounts of unconsolidated clastics consisting of sand silt, clay, and minor amounts of evaporites (gypsum and anhydrite). Carbonate rocks are the principal rock types. The evaporites are present in the lower (deep) part and the clastics are present in the upper (shallow) part. The movement of groundwater occurs principally through the carbonate rocks (Englehardt, et. al., 2001).

In coastal Southeast Florida, the base of the Floridan Aquifer System (FAS) is at an approximate bottom depth of 3,500 feet. Ranging from the oldest to youngest in age, the various geologic formations of the FAS are: Cedar Keys, Oldsmar and Avon Park Formations, the Ocala and Suwannee Limestones, and the Tampa Limestone. Evaporite deposits present in the Cedar Keys Formation constitute a lower confining unit marking the base of the active groundwater flow system (Meyer, 1989).

The permeable limestones and dolomites of the various formations are interconnected hydraulically to a degree, which varies as does the permeability. In general, the rocks comprising the FAS resemble a layer cake composed of numerous zones of alternating high and low permeability (Meyer 1989).

In South Florida, the upper FAS, which contains brackish water, exists at depths ranging from approximately 900 feet to 1,800 feet. This portion of the upper FAS has interbedded layers of horizons that have high to low hydraulic conductivities. As a result, this zone has been selected for the aquifer storage and recovery zone(s) (Englehardt, et. al, 2001).

Above the FAS are the clays, marls, and clay-stones present in the Hawthorn Formation (Group), a 300-to-800-foot thick confining sequence that isolates the Floridan Aquifer from the beds forming the Biscayne and Shal-

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low Aquifers in Southeast Florida (Miller 1986). Figure 2 shows a profile of the FAS and confining units as described by the USGS (EPA, 2003).

Each effluent injection well system in Southeast Florida (which may be more than one Class I well) has at least one dual-zone monitor well with two associated monitor zones at different depths in the FAS. The depths of these aquifers vary spatially but are designed to measure water quality and pressure above and below the potential underground source of drinking water (USDW), which is considered to contain water with total dissolved solids concentrations of 10,000 mg/L or greater.

As of 2005, there were 90 active Class I injection wells with 74 upper and 78 lower monitoring zones in Southeast Florida (see Figure 3). Five wells had been plugged and abandoned. Figure 3 shows the size of the well, where that data is available. Most of the injection wells are constructed with a 24-inch diameter final casing string to the top injection zone. Figure 4 shows the range of the top and bottom of the monitoring wells.

Water quality data was gathered from the Florida Department of Environmental Protection (FDEP) computer data. The data is cumbersome to manipulate, but a download to EXCEL is possible. This data was reconfigured to review three parameters: sulfate, chlorides and total dissolved solids.

After this inventory was developed, the data was analyzed to determine its veracity. The data was reviewed to detect any changing water quality trends, but for the majority of injection well sites, the trends showed a consistent water quality over the period of record, indicating confinement of the injectate.

Figures 5, 6, and 7 are graphs that correlate total dissolved solids with, respectively, the top of the well depth for all wells, the lower monitoring zone only, and the upper monitoring zone only (using MATLAB). The results of these graphs are typical for conductivity, sulfates, and total dissolved solids for all monitoring wells—regardless of whether the x-axis was top, bottom, or average well depth. As a result the conclusion is that the shallower the well, the higher the water quality. This tracks with the expectation of FDEP in locating the monitoring wells.

It should be noted that all but one of the upper monitoring zone wells had a total dissolved solids concentration below 10,000 mg/L, the USDW value, as would be expected because the upper monitoring zone should be located above the USDW. For the lower monitoring zone, a large percentage of the wells were below the USDW (greater than 10,000 mg/L total dissolved solids), but not all the wells. This would indicate that some of the

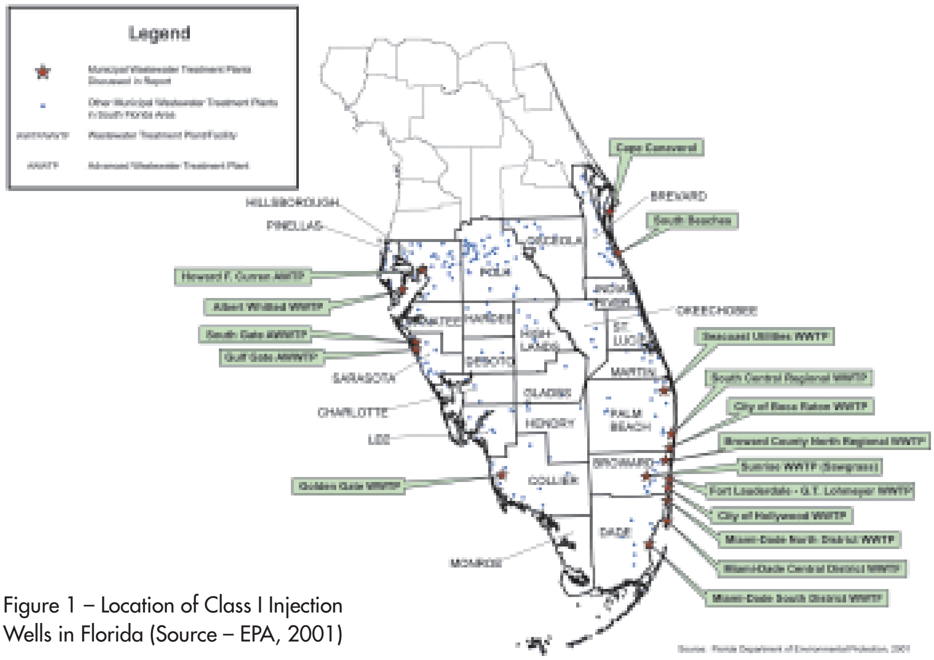

Figure 1 – Location of Class I Injection Wells in Florida (Source – EPA, 2001)

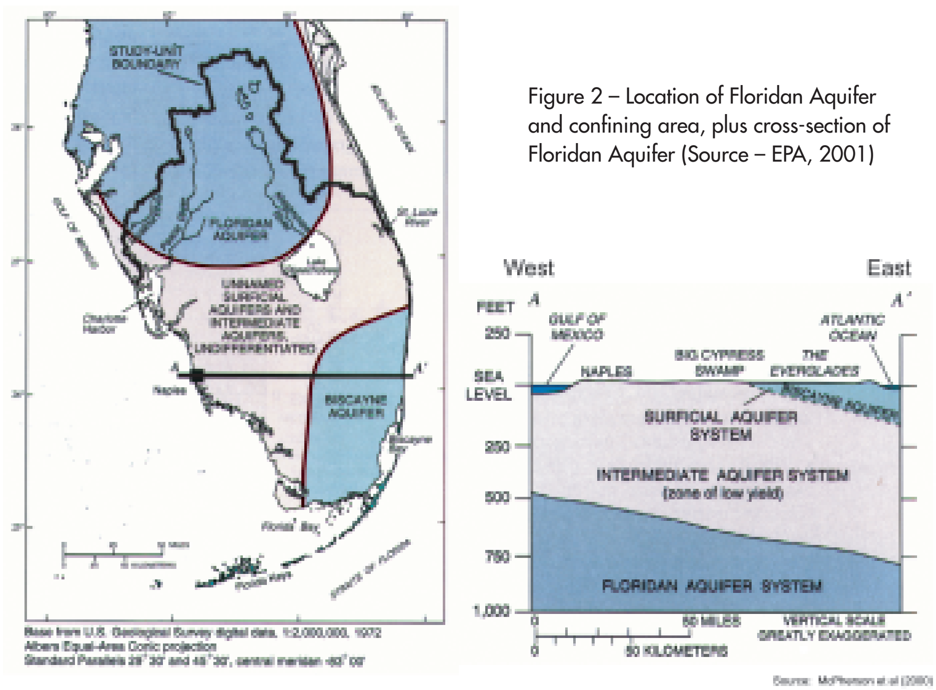

Figure 2 – Location of Floridan Aquifer and confining area, plus cross-section of Floridan Aquifer (Source – EPA, 2001)

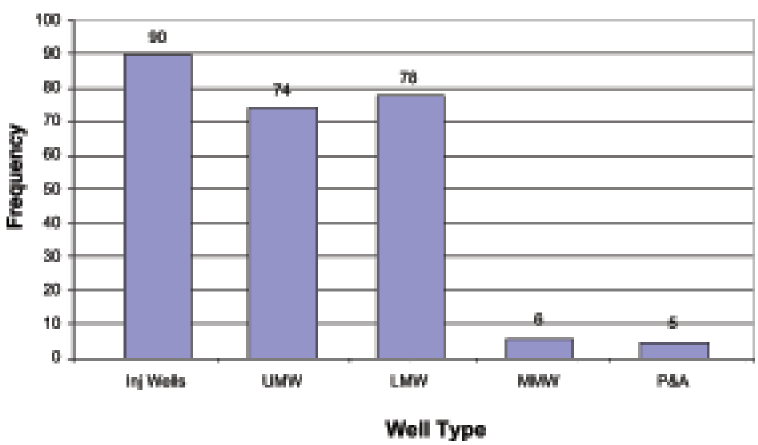

Figure 3 – Number of wells by type: Injection wells, upper monitoring well zone wells, lower monitoring well zones, middle monitoring wells, and plugged/abandoned wells (Source – Bloetscher and Muniz, 2005)

lower monitoring zone wells are not located below the USDW.

University of Miami & EPA Studies

A comparative assessment of the risks of three effluent disposal alternatives currently available to wastewater utilities in Southeast Florida was undertaken at the University of Miami (Englehardt, et al, 2001, Bloetscher, et al, 2002, 2003, 2005 – See Table 1, page 22). The study assessed the human and ecological impacts of ocean discharges, deep well discharges, and surface water discharges into canals, since that is the most obvious large-scale disposal option. The following points were noted:

- Health risks shown for injection wells are generally lower than for other alternatives.
- The research team used a worst-case, theoretical scenario and still concluded that deep well is the least-risk alternative.
- Deep wells provide the greatest separation between human contact and the treated effluent.

The proximity of injection wells to aquifer storage and recovery wells was a determining factor for injection well risk. The proximity to Class V aquifer storage and recovery wells was studied further and found to be the risk driver for the use of Class I injection wells for disposal, based on distance between the two types

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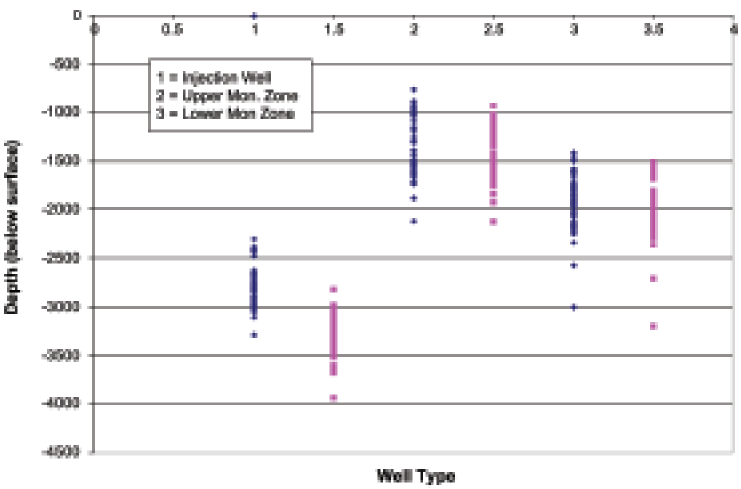

Figure 4 – Location of the top and bottom of wells by well type: Injection wells, upper monitoring well zone wells, lower monitoring well zones, middle monitoring wells, and plugged/abandoned wells

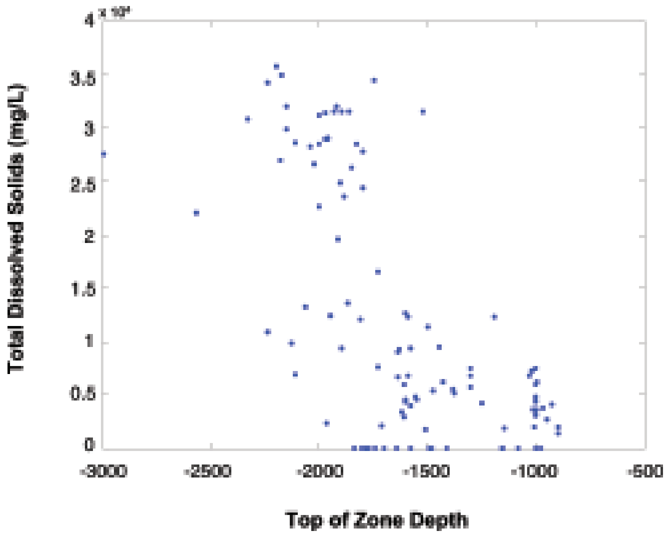

Figure 5 – Graph correlating Total Dissolved Solids and top of well depth – all wells. The results of this graph are typical for the conductivity, sulfates, and total dissolved solids for all monitoring wells, regardless whether the x-axis was top, bottom, or average well depth. (Source – Bloetscher and Muniz, 2005)

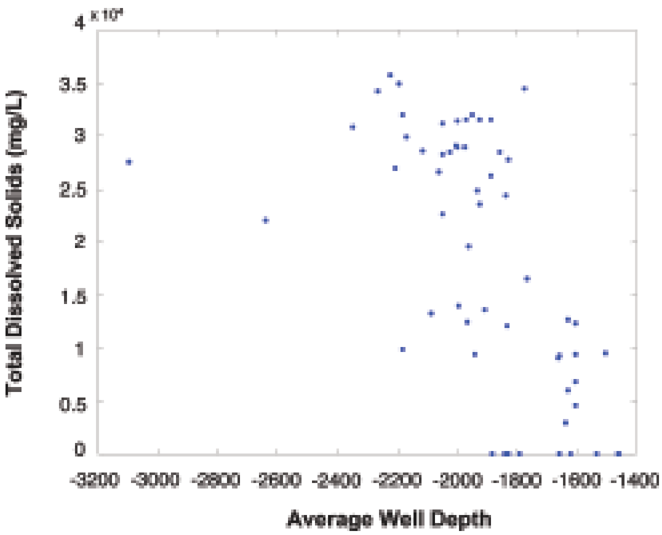

Figure 6 – Graph correlating Total Dissolved Solids and top of well depth – for the lower monitoring zone only. The results of this graph are typical for the conductivity, sulfates and total dissolved solids for lower zone monitoring wells, regardless whether the x-axis was top, bottom, or average well depth. Note that for the lower monitoring zone, a large percentage of the wells were below the USDW (greater than 10,000 mg/L TDS), but not all the wells. This would indicate that some of the lower monitoring zone wells are not located below the USDW. (Source – Bloetscher and Muniz, 2005)

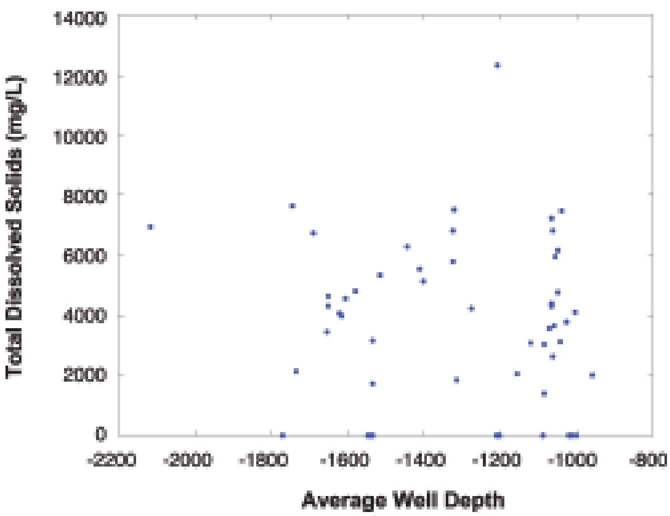

Figure 7 – Graph correlating Total Dissolved Solids and top of well depth – for the upper monitoring zone only. The results of this graph are typical for the conductivity, sulfates and total dissolved solids for the upper zone. It should be noted that all but one of these wells had a total dissolved solids concentration below 10,000 mg/L, the USDW value, as would be expected. The upper monitoring zone should be located above the USDW. (Source – Bloetscher and Muniz, 2005)

TABLE 1 – Relative Risk Indicators for Disposal Alternatives Where Injection and ASR Wells are Located Five Miles Apart not Considering Violation of the USDW (Bloetscher, 2002)

Alternative Disposal Methods	Mean Believed Violation Days In 30 Years[1]	Relative Risk to Injection Well Initial Study	Relative Risk to Injection Well Magnitude
Deep well injection – 5 miles from ASR[2] well	0.002	n/a	n/a
Ocean outfall	30	n/a	10^{-4}
Canal / Aquifer recharge	40	n/a	10^{-4}

[1] Higher values represent higher potential frequency of, and/or higher uncertainty in the probability of, violating surface and drinking water standards given current treatment requirements, for a generalized scenario in Southeast Florida. Values less than one indicate a lower believed risk of violating standards for injection well disposal relative to the alternative.

[2] Aquifer Storage and Recovery

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of wells (see Figure 8 – Bloetscher, 2002).

The U.S. Environmental Protection Agency (EPA) performed a separate risk assessment to compare the relative risks of deep injection wells, ocean outfalls, surface discharges, and "reuse." Much of the University of Miami data was used for the EPA study, but the EPA study used the premise that "South Florida" includes Tampa Bay and Brevard County (EPA, 2001), which means they combined Central Florida Class I wells with Southeast Florida wells.

Central Florida wells are much shallower and have much less confinement than Southeast Florida wells, so the EPA study includes significantly differing geology within the state into one homogeneous grouping, which adversely impacts the utilities in Southeast Florida. The University of Miami study was careful to distinguish the Southeast Florida geology from that the rest of the state for four reasons:

1) In Tampa Bay, injection is much shallower.
2) In Central Florida/Tampa Bay, the water supply is within the same aquifer formation as the injection zone: the Floridan Aquifer.
3) Outside Southeast Florida, the Hawthorn clays are generally limited or absent.
4) In Southeast Florida, the Floridan is saltwater (requiring reverse osmosis treatment), unlike areas north of Lake Okeechobee where the Floridan is generally a fresh drinking water supply and therefore is far more likely to be in contact with humans than the Boulder Zone such as in South Florida.

In neither study was there enough data about the geophysical properties of individual wells to perform an actual modeling of an injection well that could resolve the density differential and dilution issues.

The methodology for the two studies are also different; both were appropriate, although there are two caveats to the EPA study:

- The concentrations of contaminants resulting from models developed for the EPA do not compare results with ambient receiving water concentrations.
- The University of Miami study used probabilistic methods as opposed to generalized models for things like travel time.

As a result, the EPA deep well models use vertical travel time data that oversimplified the geology, attenuation from activity in the aquifer (biological, sorptive, reaction kinetics, etc.), and density of the water—the injected water will rise only until the dilution reaches ambient conditions.

The native water gets less dense toward the top of the Floridan Aquifer. At some point, the dilution of the injected water will meet ambient conditions and the plume rise will stop. Also, the injected water will not rise through clay because preferential flow paths in clay are not realistic.

Both studies noted that because of regional differences in the state, it would seem appropriate that disinfection regulations be specific to areas of the state based on risk. Treatment along the lines of ocean outfalls, which includes disinfection but not filtration, would seem appropriate for Southeast Florida wells (EPA study page 4-41).

The Rule EPA Promulgated

The federal regulation for underground injection control is 40 CFR 146. The rules were established under the authority of Safe Drinking Water Act approved in 1974 and amended in 1986 and 1996. They set forth standards for underground injection control programs which are mirrored in many states.

The regulations include an extensive set of definitions concerning injection wells. The underground injection control legislation is used to protect underground sources of drinking water, prevent degradation of the quality of other aquifers adjacent to the injection, and govern the construction and operation of injection wells. To address the issues raised by the challenges to the implementation of the UIC program in Southeast Florida, the EPA promulgated a revised rule (EPA, 2006), stating "…continued injection would be allowed

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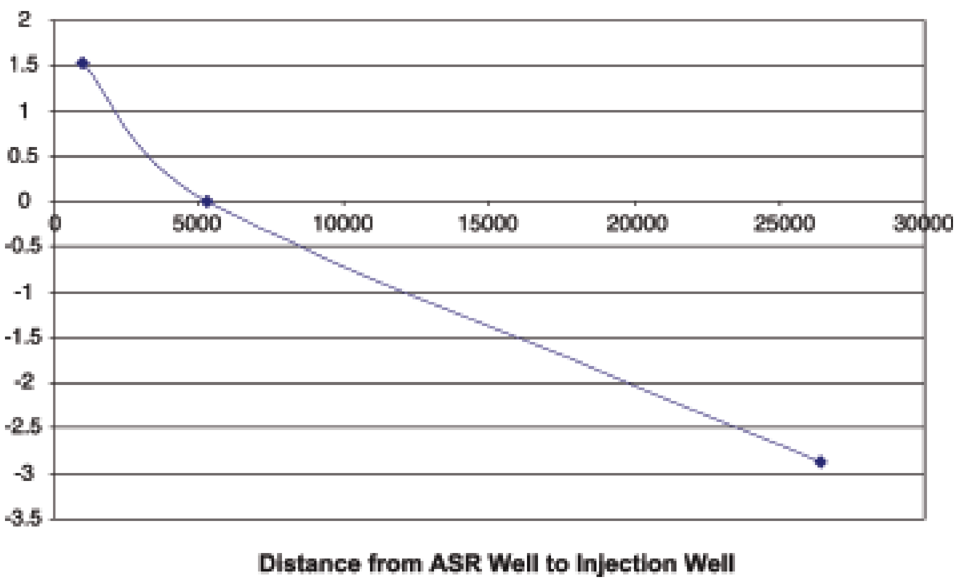

Figure 8 – Reduction with distance of predictive Bayesian risk assessment for deep wells at intervals of 1,000 feet, one mile (used in the relative risk assessment), and five miles from ASR wells in Southeast Florida for NDMA. (Source – Bloetscher, 2002)

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only if owners or operators met certain additional requirements that provide adequate protection for USDWs." EPA co-proposed two primary options for the additional requirements:

Option 1: Advanced Wastewater Treatment With a Non-Endangerment Demonstration

The authorization to inject under Option 1 would have required that the owner and/or operator of a Class I municipal disposal well injecting domestic wastewater effluent treat the wastewater by advanced treatment methods and high-level disinfection and demonstrate that injection would not cause fluids that exceed the national primary drinking water regulations or other health-based standards to enter the USDW. The non-endangerment demonstration would focus on any contaminants that still exceed national drinking water regulations or other health-based standards after wastewater treatment.

Option 2: In-Depth Hydrogeologic Demonstration and Advanced Treatment, as Necessary

The authorization to inject under Option 2 would have required that the owner and/or operator of a Class I municipal disposal well injecting domestic wastewater effluent provide a hydrogeologic demonstration that the injection operation would not cause the USDW to exceed national primary drinking water regulations or other health-based standards.

The EPA anticipated that this hydrogeologic demonstration would be an extensive evaluation, similar in detail to those required for an RCRA land ban no-migration petition, and consist of an analysis of the contaminants in wastewater prior to injection, include monitoring data from deep wells at the base of the USDW, and also include detailed hydrogeologic modeling of vertical and horizontal fluid transport in the injection zone and USDWs.

If it is anticipated that the fluids may enter the USDW, the demonstration would have to show that the fluids would not cause the USDW to exceed primary drinking water regulations in 40 CFR Part 141 or other health-based standards. Operators who could not successfully demonstrate that the injection operation meets these criteria would have been required to treat their injectate to address the contaminants of concern and satisfy additional requirements proposed to be added in a new 40 CFR 146.15(d).

This second option also proposed a provision whereby all facilities qualifying for authorization to inject under this option would be required to install *advanced wastewater treatment* and high-level disinfection by 2015.

The EPA proposed to limit the applicability of the rule to existing Class I municipal disposal wells that have caused or may cause fluid movement into USDWs in specific counties and under certain geologic conditions in Florida. The proposed counties were: Brevard, Broward, Charlotte, Collier, Flagler, Glades, Hendry, Highlands, Hillsborough, Indian River, Lee, Manatee, Martin, Miami-Dade, Monroe, Okeechobee, Orange, Osceola, Palm Beach, Pinellas, St. Johns, St. Lucie, Sarasota, and Volusia. These counties were targeted in the proposal because they have the unique geologic conditions that are predominated by carbonate rocks.

Note that the counties in question are the only counties practicing Class I injection or effluent. The rule approved by the EPA goes beyond the treatment recommendation to requiring reclaimed quality water and does not distinguish between Central Florida wells and Southeast Florida wells. While it is ostensibly oriented toward the use of reclaimed water, reclaimed wastewater does not meet the 3:1 advanced wastewater treatment standards for nitrogen and phosphorous as suggested for aquifer recharge in the EPA report or the rule proposal for advanced wastewater treatment.

Advanced wastewater treatment was the requirement assumed in the University of Miami study for surface water discharges (limited to canals) in Southeast Florida, since surface water discharges could in some cases be akin to indirect aquifer recharge. This is significant because the Biscayne Aquifer is a highly porous formation that readily accepts water from the surface, so reuse would be akin to direct recharge of the aquifer from the surface (reuse becomes water supply).

The current standards for reuse would not meet regulatory requirements for direct aquifer recharge. Migration downward of wastewater related chemicals, nutrients, microbiologicals, and perhaps endocrine disruptors, will not be prevented because there is a lack of significant soil, as demonstrated in the literature. The EPA's citations indicate that pathogens might live two months in groundwater (Bloetscher, 2001). The longest time reported in the literature is 270 days in Germany (for viruses – Bloetscher, 2001).

It would seem difficult to believe that viruses would remain viable in injection wells for 14 years, the minimum travel time to the USDW calculated in the EPA's modeling; therefore, the wells in Southeast Florida would seem to protect drinking water supplies in contrast with the statement on page ES-23 that "pathogenic microorganisms pose a *significant* human health risk for deep-well injection ….." The EPA study showed that migration of microbial contaminants through the Hawthorn Formation clay is unrealistic.

The Proposed Alternatives

The proposed alternative wastewater disposal mechanism is reuse. The use of reclaimed water is a stated goal of the Comprehensive Plan for Florida. Our state is among the leaders in reclaimed water use in the United States, with some 400 facilities using reclaimed water in a variety of ways, including irrigation of agricultural land, golf courses, roadway medians, and residential landscaping, as well as industrial uses such as cooling towers. The state and its agencies, especially the South Florida Water Management District, have become aggressive in directing local utilities toward reuse of treated wastewater.

Southwest Florida and Central Florida have been pursuing reclaimed water for over 40 years, largely because there are no other obvious disposal alternatives (lacking access to streams, deep oceans or injection well strata), and because many of the wastewater treatment plants have their origins as small, developer-owned systems designed to serve their development and later deeded to local governments. In such scenarios, the costs of ocean outfalls and injection wells can not be justified, so the reuse (usually by percolation ponds) of small quantities of wastewater as reuse was the chosen alternative for disposal. Most of their water supplies are inland of their development, so the reclaimed water is downstream of the water supplies.

Southeast Florida has a much longer developed history, smaller lots with denser development, and ready access to the Intracoastal Waterway, the ocean, and injection well disposal options for the larger, regional systems created in the 1960s and 1970s. As a result, Southeast Florida has had larger quantities of wastewater to dispose of for over 50 years, and centralization of treatment has made outfalls and injection wells economically justifiable. Also, water supplies are immediately beneath development, so application of reclaimed wastewater is on top of the water supply.

As a result, while the use of reclaimed wastewater is a goal of the state, the areas where it has been pursued can be differentiated from Southeast Florida from several perspectives:

- Southeast Florida relies on the largely surficial, sole-source Biscayne Aquifer for its water supply. There are numerous municipal wells that are less than 70 feet deep and few over 150 feet deep. The Biscayne Aquifer has one of the highest transmissivity values recorded, making it both productive and subject to the migration of large quantities of water over a short period of time. In contrast, much of the state north of Lake Okeechobee relies on the Floridan

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Aquifer System, which has its production zone up to 400 to 600 feet below the surface and much lower transmissivity values.

- The Biscayne Aquifer can be characterized as a karst formation that has flow channels. Secondary porosity in the Biscayne Aquifer is higher than in the Floridan Aquifer.
- There is a clear component of vertical migration in the Biscayne Aquifer, as well as a horizontal component that originates in the Everglades, whereas it is less clear that the vertical component is a primary concern in the Floridan Aquifer.

Little criticism or focus has centered on the practice of reuse, yet a number of the issues identified in the EPA risk study are evident in the reuse option. The little data that is available has indicated problems, and although the study of potential effects in Florida is limited, utility and environmental experts have begun to question the unquestioned push to reuse as a result of several issues that have come to light recently:

- The city of Tallahassee's spray field has been identified as the source of nutrient contaminants via dye tests in a spring downstream of the spray field, after many years of arguments against such contaminations. This example shows that karst formations can transmit contaminants in water for long distances.
- Viruses have been found routinely in reclaimed wastewater, likely because of the fact that chlorine does not inactivate viruses effectively. Viruses and bacteria have been shown to live 28 to 90 days in groundwater and move seven to 30 meters routinely (Asano, 1985, Teusch, et al., 1991). Viruses have been found to remain active and migrate for up for at least 270 days (Bloetscher, 2001).
- Small quantities of viruses are capable of causing illness. Potable water treatment methods in Southeast Florida, primarily lime softening and filtration, are not designed to remove viruses completely (current regulations are in place to require 4-log removal, but most utilities currently can not meet this standard).
- Recent research indicates that pharmaceutically active compounds (PhACs) are accumulating in levels harmful to the environment. Hormonal pharmaceuticals may disrupt the endocrine system of animals, including humans. Endocrine disruptors are used in animals and people to regulate metabolic activities such as ion balance, reproduction, basal metabolism, and stress responses through changes in hormones. Endocrine glands are interconnected, and chemicals such as birth control drugs and synthetic chemicals can disrupt this system in a range of species, causing reduced sperm counts in males, early development in females, reproductive failure, and other abnormalities. This is part of a broader problem related to the accumulation of PhACs in the environment (Daughton and Ternes 1999), discussed on page 28. Endocrine disruptors have been found in effluent treated to advanced wastewater standards at levels that could impact aquatic species. This treatment level is significantly higher than the typical treatment for reclaimed water.
- Antibiotics routinely have been found in wastewater, and there is no reason to expect that even effluent treated to advanced wastewater standards will be free of them since such wastewater contains measurable concentrations of estrogen (Bloetscher, 2001).

The state's rules for reclaimed water (62-610, Florida Administrative Code) include a series of requirements for reclaimed water systems that must be met. The most important ones affecting Southeast Florida are for slow-rate, non-public access systems; for slow-rate, public access systems; and for looking at aquifer options such as groundwater recharge.

For all slow-rate reuse systems involving irrigation of sod farms, forests, fodder crops, pasture land, or similar areas, the reclaimed water must meet secondary treatment and basic disinfection levels before the land application. If the system is a subsurface application system, it is limited to 10 mg/L of TSS.

Slow-rate land application systems must maintain a distance of 100 feet from the edge of the wetted area to buildings that are not part of the treatment facility, utilities system, or municipal operation; or to the site property line, 100 feet from outdoor public eating, drinking, and bathing facilities. The setback can be reduced to 50 feet if the setback is planted with trees or shrubs to create a continuous visual barrier and 25 feet if high-level disinfection is provided in addition to the setback vegetation.

A 500-foot setback distance must be provided from the edge of the wetted area to potable water supply wells or storage ponds to potable water supply wells. Clearly some concern exists about the constituents of reclaimed water and water supply sources.

More traditional public access reuse systems involve the irrigation of areas intended to be accessible to the public, including residential lawns, golf courses, cemeteries, parks, landscape areas, and highway medians. Such reclaimed water can not contain more than 5.0 milligrams per liter of suspended solids before the application of the disinfectant.

Filtration is required for TSS control. By removing TSS before disinfection, the expectation is that filtration serves to increase the ability of the disinfection process to inactivate virus and other pathogens. Filtration also serves as the primary barrier for removal of protozoan pathogens (Cryptosporidium and Giardia).

Groundwater monitoring wells are required to be located adjacent to unlined storage ponds or lakes and to be tested for Giardia and Cryptosporidium. Again, there are obvious concerns about potential pathogens in water, and viruses are not removed efficiently by filtration or chlorine disinfection.

The water quality for aquifer storage and recovery of reclaimed water involves:

- Wells injecting reclaimed water into groundwater containing greater than 3,000 mg/L of total dissolved solids also requires principal treatment and disinfection requirements. Principal treatment is basically defined as:
  - Carbonaceous Biochemical Oxygen Demand CBOD5 – 5 mg/L
  - Total Suspended Solids (TSS) – 5 mg/L
  - Total Nitrogen (as N) – 3 mg/L
  - Total Phosphorus (as P) – 1 mg/L
  - Total Organic Halogens (TOX) – 2 mg/L
- However, if the receiving groundwater is a Class F-1 or G-1 aquifer or a Class G-II aquifer that contains less than 3,000 mg/L of total dissolved solids, then full treatment and disinfection is required, which means:
  - The parameters listed as primary drinking water standards are applied as maximum single sample permit limits.
  - The primary drinking water standards for bacteriological parameters are applied via the disinfection standard.
  - The primary drinking water standard for sodium is applied as a maximum annual average permit limitation.
  - Except for pH, the parameters listed as secondary drinking water standards are applied as maximum annual average permit limits.
  - All pH observations must fall within the pH range established in the secondary drinking water standards.
  - Additional reductions are required of pollutants that otherwise would be discharged in quantities which reasonably would be anticipated to pose risk to public health because of acute or chronic toxicity.
  - Total organic carbon (TOC) can not exceed 3.0 mg/L as the monthly average limitation; no single sample can exceed 5.0 mg/L.
  - Total organic halogen (TOX) can not exceed 0.2 mg/L as the monthly average limitation; no single sample can exceed 0.3 mg/L.
  - The treatment processes must include processes that serve as multiple barriers for control of organic compounds and pathogens.

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- Treatment and disinfection requirements are additive to other effluent or reclaimed water limitations.
- The distance between groundwater injection wells with full treatment and water supply and potable water supply wells is a minimum of a mile.

Clearly, the rules have been created because of concerns about the potential for human contact with wastewater. When indirect potable reuse is anticipated, the full treatment (membranes, most likely) requirement is initiated.

Full treatment is designed to remove the over 100 microorganisms that have been identified as human pathogens which may cause disease in weaker or immune-system-impaired individuals (even some healthy ones). The routes to infection include ingestion, dermal absorption, wounds, and body orifices. The sources of the pathogens include infected persons, which excrete large numbers of these pathogens.

Presently, fecal coliforms are utilized as an indicator organism to detect the potential for human contamination in the soil or water. Since fecal coliforms make up a significant percentage of fecal matter excreted by humans, the assumption used for coliform tests is that since coliforms exist at levels that are many magnitudes greater than other organisms typically found in the human intestinal tract, when fecal coliforms are eliminated, the others, by reference, are also eliminated.

While this standard has served the water and wastewater industry relatively well, the underlying assumption is not true—especially in an aquifer setting. A number of pathogenic microorganisms such as *Giardia lamblia, Cryptosporidium parvum, Pseudomonas aeruginosa*, and most viruses are resistant to chlorine, so even if no fecal coliforms exist, these organisms may remain after disinfection. If these organisms survive the treatment process, which most do, they will be picked up in reuse supplies. Viruses are particularly persistent in groundwater.

But microbes are not the only issue that remains unresolved. The concentration of PhACs in the environment is low (in the µg/L or ng/L range) compared to conventional priority pollutants, but higher than needed to create impacts in wastewater. Noticeable environmental response can be elicited from aquatic organisms in the 1 ng/L (10^{-12}) range, and questions exist about the cumulative effects of the hundreds of PhACs that may be present in wastewater (Daughton and Ternes, 1999).

Wastewater treatment plant secondary effluents contain measurable concentrations of more than 1,000 manmade compounds, including a variety of pesticides, herbicides, cleaning solvents, laundry detergents, household products, surfactants, and PhACs and their residues—only a portion of which have been identified.

Municipal wastewater effluent may constitute a major pollution source of PhACs in the aquatic environment. Unused prescriptions also are often disposed of through the sewage system. It is not uncommon for 40 percent of a drug dosage to be excreted to the sewage system after normal therapeutic use.

The actions of these chemicals may not be mutually exclusive (Harries, et. al., 1997), since PhACs are by nature biologically active compounds that are used and excreted in large quantities in modern society. In Europe, naproxen, estrogens, clofibric acid, and diclofenic were frequently detected downstream of treated effluent discharge in surface waters at the µg/L level (Stumpf, et. al., 1999).

Two factors work against the typical organisms in wastewater plants effectively breaking down PhACs: exposure and low concentrations. Wastewater organisms create enzymes to break down wastes, so if the organism has never been exposed to a PhAC, the enzymes are not created. If the concentration is very small compared to other organic compounds, the organisms preferentially will create enzymes to break down the most efficient food source.

Studies on influent and effluent in Germany confirm that PhACs are present in wastewater treatment plant influent and effluent, and many appear to undergo little change during the treatment process. The lack of discernable impacts does not mean there are no impacts, as has been realized increasingly worldwide among fish, bird, amphibian and reptile populations.

The introduction of estrogenic compounds or low levels of antibiotics into Southeast Florida water supplies is not desirable. Existing lime softening water treatment does not remove these compounds, nor is it particularly effective against viruses. The discharge of reuse on the surface of a G-1 aquifer that is used for water supplies would appear to be akin to the requirements for full treatment for application. This is not contemplated in the rule change.

The only comparable study for this proposal is the 1977 Pomona virus survey, but the treatment plant discharging to the ground included reverse osmosis, lime softening, and GAC, which basically offers full treatment.

Conclusions & Recommendations

A comparative assessment of the risks of the potential effluent disposal alternatives currently available to wastewater utilities in Southeast Florida was conducted in 2000 and 2001 and presented previously. The alternatives evaluated include:

- Deep well injection following secondary treatment.
- Ocean outfall following secondary treatment.
- Surface water (canal) discharges following secondary wastewater treatment, filtration, and nutrient removal.

Two previous risk assessments indicated that Class I injection wells posed the least risk to the public. Cost and public perception were not considered, nor was reclaimed water use, since that was not a significant part of the effluent disposal program at the time. Despite this conclusion, the EPA has proposed substantial increases in treatment for Southeast Florida that appear to be aimed at forcing these utilities to reuse, but no study has reviewed the risks associated with reclaimed wastewater in Southeast Florida when compared to the other alternatives and the treatment objectives required.

Reclaimed wastewater would require filtration and high-level disinfection but would not require nutrient reduction. The reclaimed water would be applied to the surface, directly above the Biscayne aquifer, which is located some four feet below land surface. On the surface, it would appear that concerns about viruses, endocrine disruptors, and nutrients may be a concern. The issues are summarized in Table 2, page 30.

While no attempt was made to evaluate the political implications resulting from this assessment, nor is there an attempt to evaluate reuse in other areas of the country or state, it seems reasonable that a risk assessment should be undertaken to review the potential for problems before utilities spend an estimated $15 billion or more to implement reuse. Such a study should assess the relative risk of large-scale use of reclaimed water in Southeast Florida. Specific objectives should be:

- Assembling existing literature and data relating to the frequency of occurrence and potential migration involving nutrients, endocrine disruptors, and viruses in the subsurface and in reclaimed wastewater.
- Identifying pathogens, their fate, and infectious dose-response characteristics.
- Identifying exposure routes of nutrients, endocrine disruptors, and viruses in the subsurface and in reclaimed wastewater.
- Developing a probabilistic assessment of human health effects of large-scale reclaimed water practices in Southeast Florida for nutrients, endocrine disruptors, and viruses in the subsurface and in reclaimed wastewater using new inferential methods.
- Providing recommendations for addressing

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Salient Issue	Injection Wells	Canal Recharge	Reuse plus piping	Aquifer Recharge	Ocean Outfalls
Treatment Required	Filtration, High Level Disinfection	Filtration, UV Disinfection Nutrient Reduction to 3:1 TN:TP	Filtration, High Level Disinfection, Pumping	Filtration, Reverse Osmosis, Advanced Oxidation, UV Disinfection	Secondary Treatment
Cost	$2-3 per Gallon Capital and, $2-3 per 1000 Beyond Current Costs	$5 per gallon Capital, Plus Delivery to Canals, $7-10/1000 gal	$2/gal Capital plus Piping; $2-3/1000 gal Operating Cost	$10+/gallon capacity, $10/1000 gal	Minimal-Investment Made
Water Supply Benefit	None	80% Lost to Tide	Replace Potable Water - About 50% Actually Might Be Used	Upwards of 50%	None
Highest Reliability	Currently Over 100 Systems Operating, Limited Issues in SE FL	No Current Examples, Maybe Issue During Wet Season	Current Operating Systems, No Issues with Reliability as Long as Back-up Disposal is Present	Only One Existing, Reliable system in US, Requires 6 Mo Travel Time in Ground	No Demonstrated Public Health or Ecosystem Effects of Outfalls in SE Florida
Local Decision Making	Control via Permit	No Control of Outgoing Effluent	Control if Own Plant via Permit, Users Not Controlled	No Control of Geology	Control via Permit
Public Perception	Effluent 3000 ft Below Surface, Limited Objection	Environmental Perception Maybe Negative, Carbon Footprint Issues	No Issues Unless People Find Out it May Get Into Water Supplies	People Drinking "Poop" Water is not a Popular Concept, Carbon Footprint	Perception is Outfalls = Algae on Reef, Which is Untrue

TABLE 2 – Summary of Treatment, Cost, Reliability and Perception issues involved in Alternative Wastewater Disposal Practices in SE Florida

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any concerns that might be raised.

- Reviewing reclaimed water needs in light of the health risks from current disposal options.

Prior to a major rule-making implementation with substantial impacts to residents, three questions should be answered:

1. Why were the risk assessments basically ignored?
2. Is this a means by the FDEP to force southeast utilities to reuse (a complaint for many years)?
3. Is there no real demonstration of negative effects?

Presently, the concerns are that the answers to all three questions are deemed to be "yes" by many parties.

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