Yield Analyses for East-Central Illinois' Community Surface Water Supply Systems

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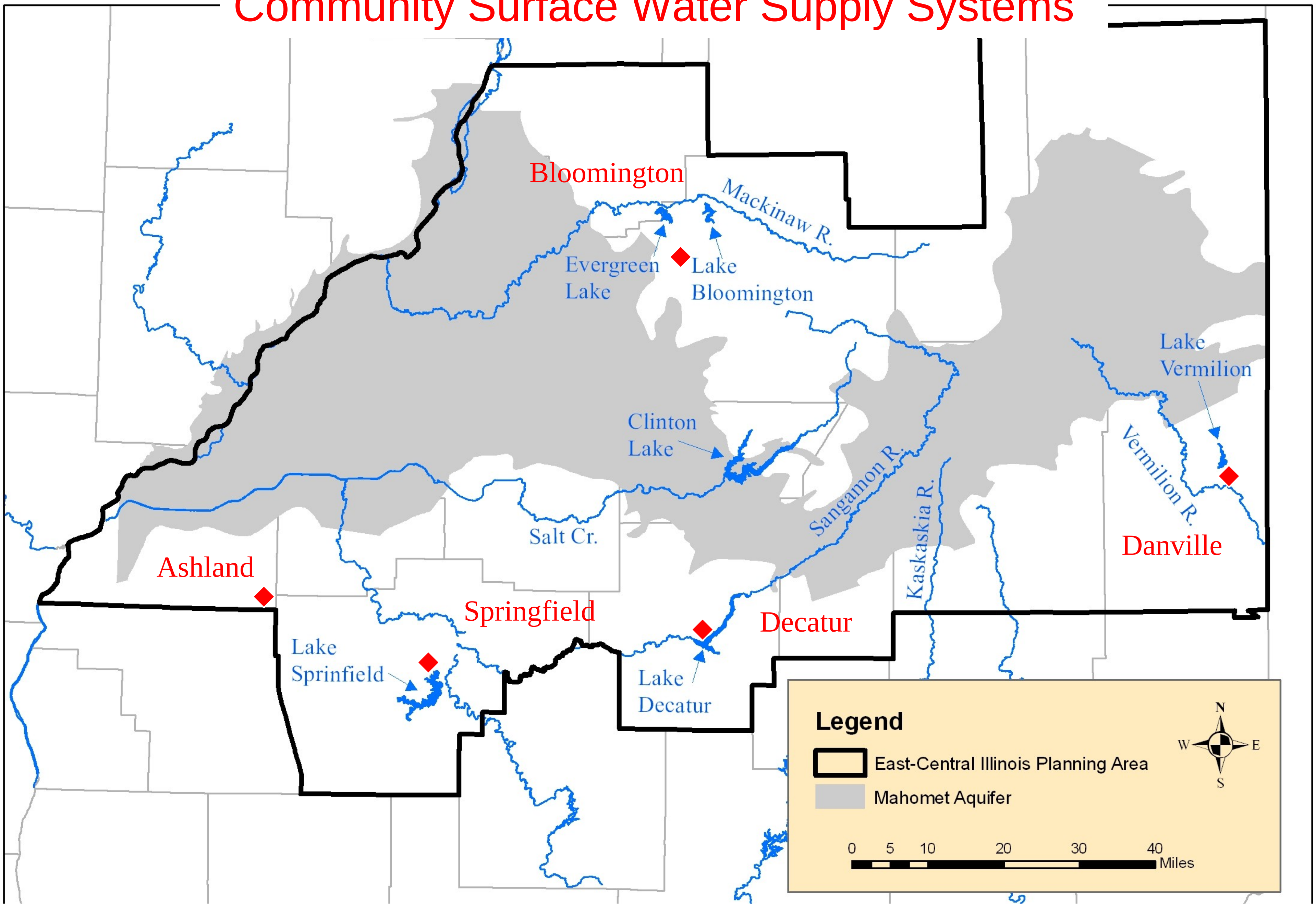
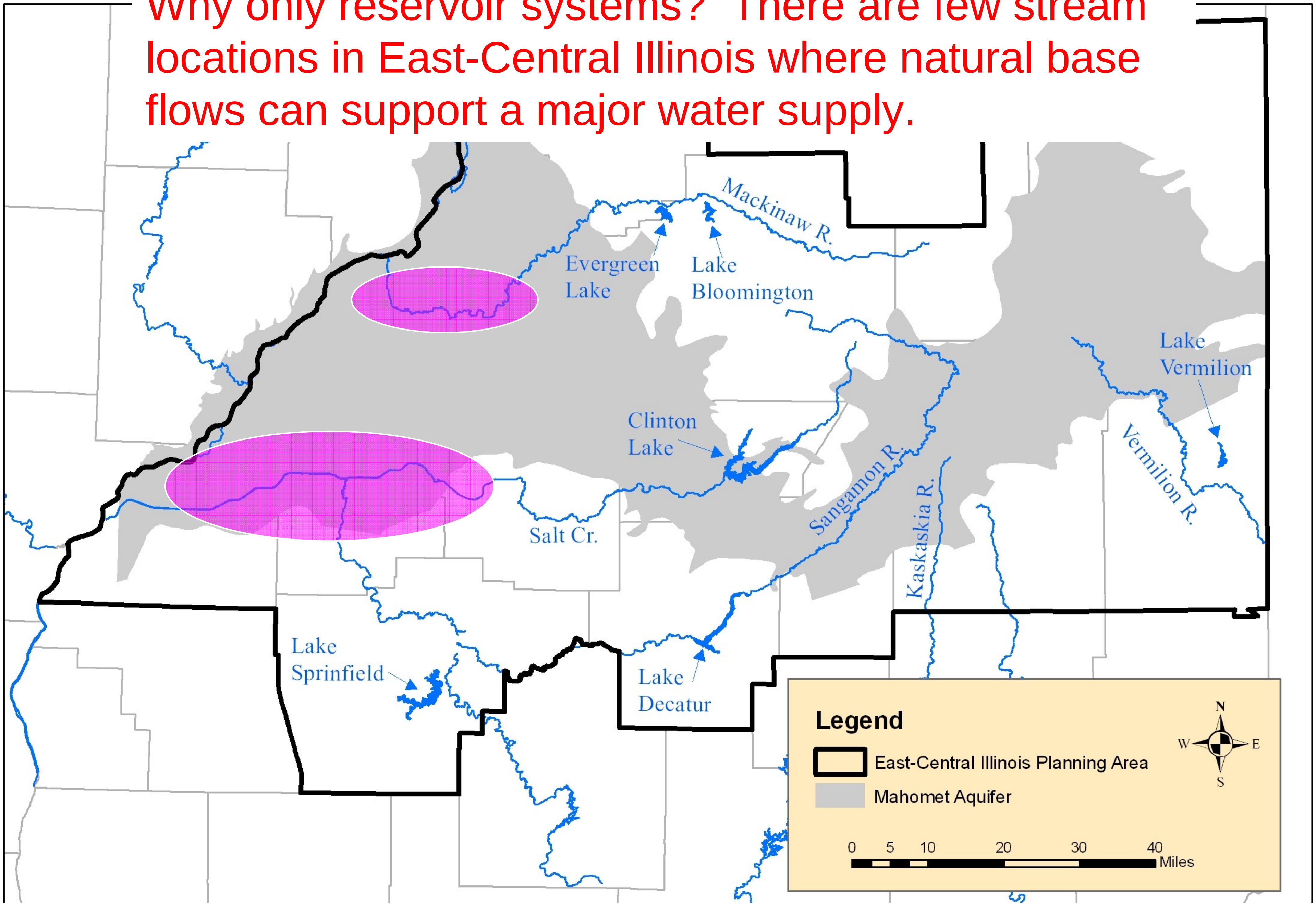
Community Surface Water Supply Systems



Why only reservoir systems? There are few stream locations in East-Central Illinois where natural base flows can support a major water supply.



Yield versus sustainability

- Availability of surface waters is typically limited only during severe hydrologic droughts
- Surface waters are a quickly renewable resource
- Sustainability issues relate primarily to:
  - reservoir capacity losses from sedimentation
  - Impacts to ecosystem

Frequency of Severe Water Supply Drought

- When the ISWS first started analyzing surface water supply yields in the 1950s, the drought of record was considered to be a 40-year drought. Today, that same drought is now considered to have a 75-100 year frequency (Yield estimates for a specific frequency have been going up because we haven't had many severe droughts in the past 50 years).
- The occurrence of severe water supply droughts tend to be clustered. Most of Illinois' severe droughts occurred in the 1930s, 1940s, and 1950s. Paleoclimatic evidence indicates that severe drought have occurred in previous centuries; thus, unless there is a permanent shift in climate we expect they may occur again, including the possibility of new "record" droughts.
- Examples: 2007-2008 Georgia Drought
Western United States

ISWS Studies on Surface Water Yields

- Estimating Impounding Reservoir Yields
  - Hudson and Roberts, 1955 (Bulletin 43)
  - Stall, 1964 (Bulletin 51)
  - Terstriep, et al., 1982 (Bulletin 67)
- Estimating Side-Channel Reservoir Yields
  - Knapp, 1982 (Bulletin 66)
- Adequacy of Surface PWS Systems
  - Hudson and Roberts, 1955 (Bulletin 43)
  - McConkey and Singh, 1989 (CR-477)

Reservoir Yields are Estimated Using a Water Budget Analysis

In a simplified analogy:

- Reservoir Storage – “Accumulated Savings”
- Surface Inflow and Precipitation – “Projected Income”
- Water Use Withdrawals and Evaporation – “Projected Expenses”

Biggest challenges: Projecting surface inflow
For how long will you have limited inflow?

* Unaccounted factor – the potential exchange of water between the reservoir and groundwater

- Assumed to be zero. We have no data to estimate this.
- Good reservoir sites have minimal exchange with GW.

Example of differences in Runoff / inflow during droughts (inches) -Springfield

	12 months	18 months
Average years	9.0	12.0
1999-2000/ 1988-1989 droughts	1.1	3.5
1953-1954 drought	0.1	0.4

Water Budget Analysis

- Can use either:
  - historical sequences of hydrologic and climate records
  - nonsequential statistical estimates of selected drought frequencies (50- or 100-year events)
- Nonsequential analysis typically combine the worst conditions from different historical droughts
  - For example, the lowest 9-month flow amount may have occurred during the 1930 drought; the lowest 12-month amount may have occurred during the 1940 drought
  - The hottest and driest weather (highest evaporation) may have occurred during the 1934 drought, whereas the lowest flows may have occurred in 1954

Characteristics of previous studies

- Since the 1960s, ISWS analyses have focused on estimating yields associated with specific drought frequencies such as the 40-, 50-, and 100-year droughts
- These studies have used the "non-sequential" drought analysis (avoids the issue of historical droughts having different severity at different durations). Easier for mass application across hydrologic regions.
- Drought yields have been considered to be "firm" numbers

New approaches with the current study

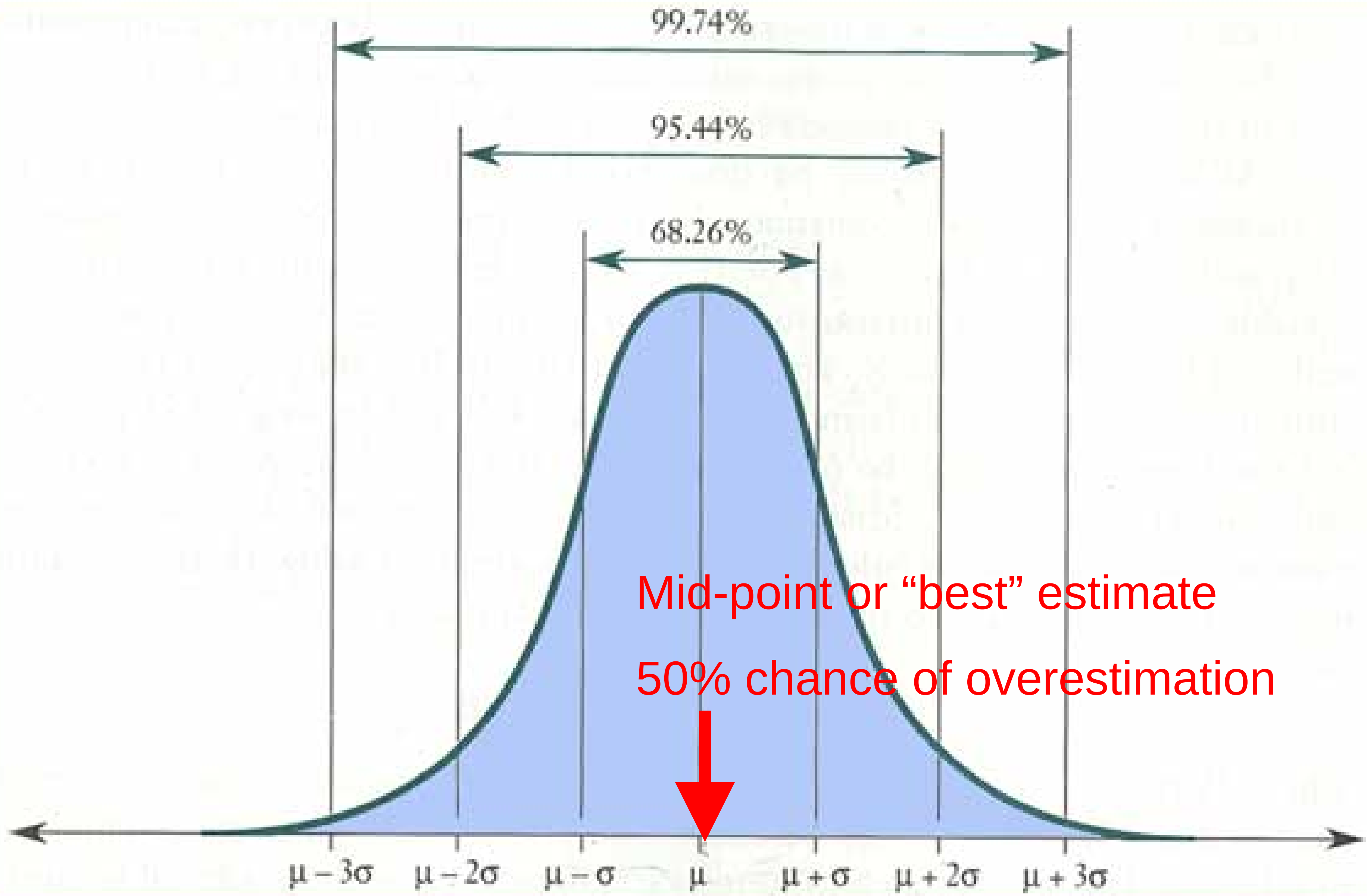
- Greater attention to estimating yields for specific historical drought sequences (drought of record)
  - Greater accuracy in estimating yields for specific droughts when you have good data
  - Provides for better communication to the public
    - A lot of people do not understand what a 50-year drought implies
- Analysis of uncertainties in data and methods
- Provide confidence limits on our yield estimates

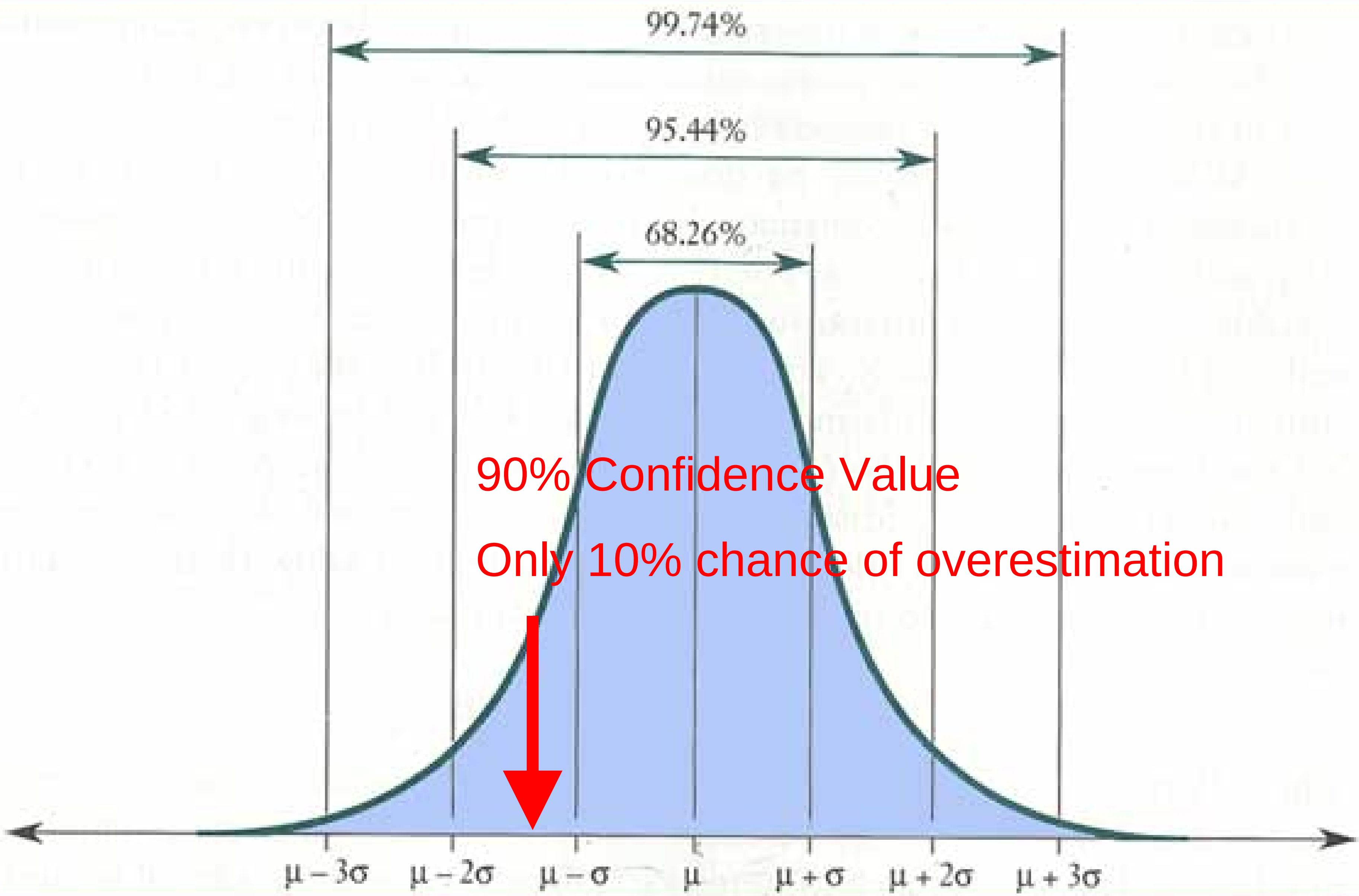
Uncertainties in Reservoir Water Budget Analysis – New Approach

- Previous ISWS reservoir yield studies have provided a "Best" estimate of yield based on the available data, but not evaluated the probability that the available data may either underestimate or overestimate the "true" amount of water
- This past year, ISWS studies began analyzing data uncertainties for major reservoir water budget components, which can be used to provide confidence limits on our yield estimates
- The "Best" estimate is the 50% confidence level (equal chance that it is over- or under-estimated)

Uncertainties in Reservoir Water Budget Analysis – New Approach

- Our biggest concern is that reservoir storage and inflow data may overestimate the amount of available water (producing a false positive)
- For this reason, we will now also calculate a 90% confidence yield value…
- …such that we are 90% confident that the “true” yield is equal to or greater than the 90% yield (i.e. the one-sided tail of the error distribution)
- I believe that this will be the value that communities will want to depend on.


99.74%
95.44%
68.26%
Mid-point or “best” estimate
50% chance of overestimation
μ − 3σ
μ − 2σ
μ − σ
μ
μ + σ
μ + 2σ
μ + 3σ


99.74%
95.44%
68.26%
90% Confidence Value
Only 10% chance of overestimation
μ – 3σ
μ – 2σ
μ – σ
μ
μ + σ
μ + 2σ
μ + 3σ

What drought severity/frequency should a community plan for?

- A 40-, 50-, or 100-year drought, the drought of record?
- Most ISWS analyses of system adequacy have used 50-year droughts
- There are no State requirements
  - IEPA guidelines: 6-months storage for a 40-year drought
  - Hudson and Roberts (1955) suggested 6-months at drought's end
- Even when a shortage doesn't occur, there can be situations where the threat of shortages is imminent. We can't forecast when the drought will end, how low will your reservoir drop before drastic measures are adopted?
- Instead: What are the potential impacts of a water shortage and what chance is the community willing to take that such shortages will occur?
  - Small community versus large community

Uncertainties in Major Data Components

- Reservoir storage
  - The best measurement methods typically have a 10% standard error
  - Otter Lake example (differences between the sedimentation and bathymetric surveys)
  - Most PWS reservoirs in Illinois have never had a survey. Unmeasured estimates of storage have a standard error of up to 30%.

Uncertainties in Major Data Components

- Inflow
  - Drought flow values at USGS streamgages expected to have less than a 10% error for “good” records
  - Use of “surrogate” gages or regional flow equations may be off by 20 to 60% depending on watershed size and drought duration
  - Sangamon River example (Monticello .vs. Oakley gages during 1953-1954 drought)
- Evaporation and Precipitation
  - Evaporation cannot be directly measured. Equations have been shown to have a standard error of 14%.

Availability of Hydrologic Data for the 3 Major East-Central Illinois Systems

- Springfield, Decatur, and Bloomington have all had recent reservoir surveys (past 10 years).
- Decatur inflows (Sangamon River) measured upstream at Monticello (1914 to present)
- Inflow into Lake Bloomington measured from 1933–1982. No data for Evergreen Lake inflow.
- No USGS records for Lake Springfield inflow.
- Lake levels available for all systems
  - But to be useful, need to recreate conditions for each drought

Surface Water Sources Considered in the Yield Analysis

- Bloomington
  - Lake Bloomington, Evergreen Lake, Mackinaw River Pumping Station
- Decatur
  - Lake Decatur, DeWitt Well Field, Vulcan Gravel Pit, Lake Tokorozawa
- Springfield
  - Lake Springfield, South Fork Pumping Station
- Danville – Lake Vermilion
- Ashland – 2 small reservoirs, stream withdrawal

Other factors to consider in yield analysis

- Usable storage
  - For most cases, ISWS assumes that the lowest 10% of reservoir storage is not usable.
  - In many cases there are physical limits on pumping water (intake elevation and location). If there is an open intake, we will consider it usable (Bloomington usable storage < 10%)
  - More importantly, just how low of a water level is a community willing to experience? What if only 30 days of supply remain? When do certain "essential" uses of water become non-essential?
  - Springfield defines its usable storage threshold (33% capacity) as the elevation (548 feet) at which it would need to shut down most of its power plants.
  - For Decatur, 10% of storage represents 17 days of remaining water. Even when Sangamon River inflow is considered, the remaining supply may be only 25 days.

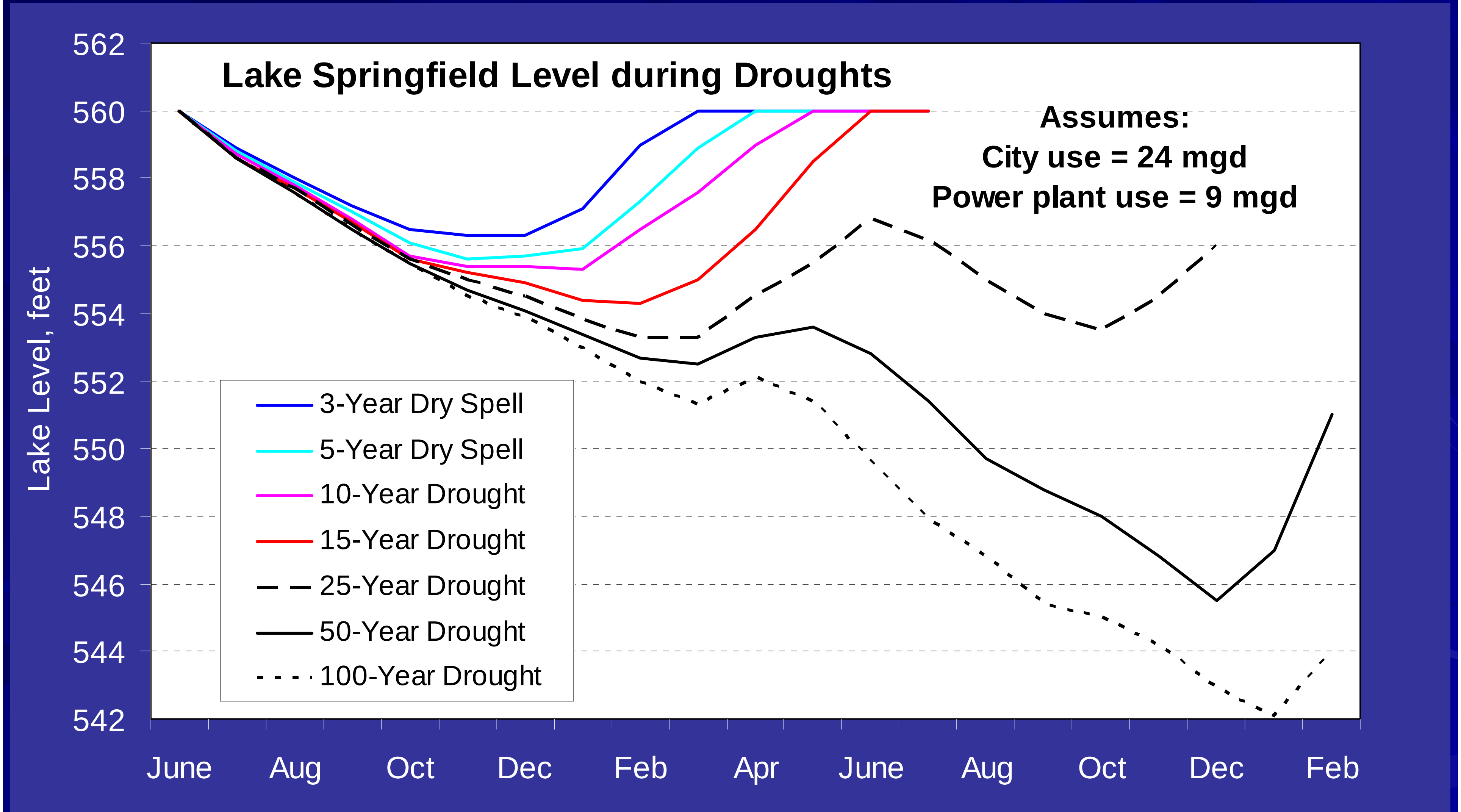
Other factors to consider in yield analysis

- Each community’s drought response plans
  - When are the use of alternate supplies triggered?
- Constant demand versus variable demand?
  - The potential effects of voluntary and mandatory use restrictions are variable and often not well known

Variable water use during droughts

- Water supply droughts almost always start during the summer, following months of dry weather
- Water use during any dry summer period can be very high (at times 25 or 30% above normal summer water use)
  - The key is that we can't forecast whether a dry summer is going to turn into a drought
- It is often not until fall when low water levels force restrictions. Most restrictions are related to outdoor water use and thus may not have much effect when first implemented in the fall or winter.

How soon can you differentiate a severe drought from a moderate dry spell?



Variable versus constant demand

- Even when there is a noticeable drop in water use in later stages in the drought, it is unlikely to make up for the difference caused by heavy use during the initial summer period
- Thus, total water use over the entire course of a drought is typically greater than average water use
- The exception is when there can be major reductions in industrial-commercial use (Decatur)
- McConkey and Singh(1989) suggested that communities should plan for drought water use that is 20% above normal, but current analysis suggests this is excessive
- ISWS yields are based on constant demand, and communities must determine the level that they need to provide during a drought

This presentation focuses on the 3 larger systems. Results for the other 2 systems are:

- Danville
  - "Best" estimate of yield (50-yr drought) = 14.1 mgd
  - 90% Confidence yield (50-yr drought) = 10.9 mgd
  - Yield reduction by 2050 (sedimentation) = 2.3 mgd
  - Current water use = 8.4 mgd
  - 2050 Projected use = 9.0 mgd
- Ashland
  - "Best" estimate of yield (1954 drought) = 0.12 mgd
  - 90% Confidence yield (1954 drought) = 0.06 mgd
  - Water use = 0.11 mgd
  - Ashland is expected to move to Cass County RWD

Worst Historical Droughts

	Decatur	Bloomington	Springfield
#1	**1930-31**	**1939-40**	**1953-54**
#2	1914-15	1930-31	1930-31
#3	1953-54	1988-89	1933-34
#4	1963-64	1955-56	1914-15

Bloomington Historical Droughts

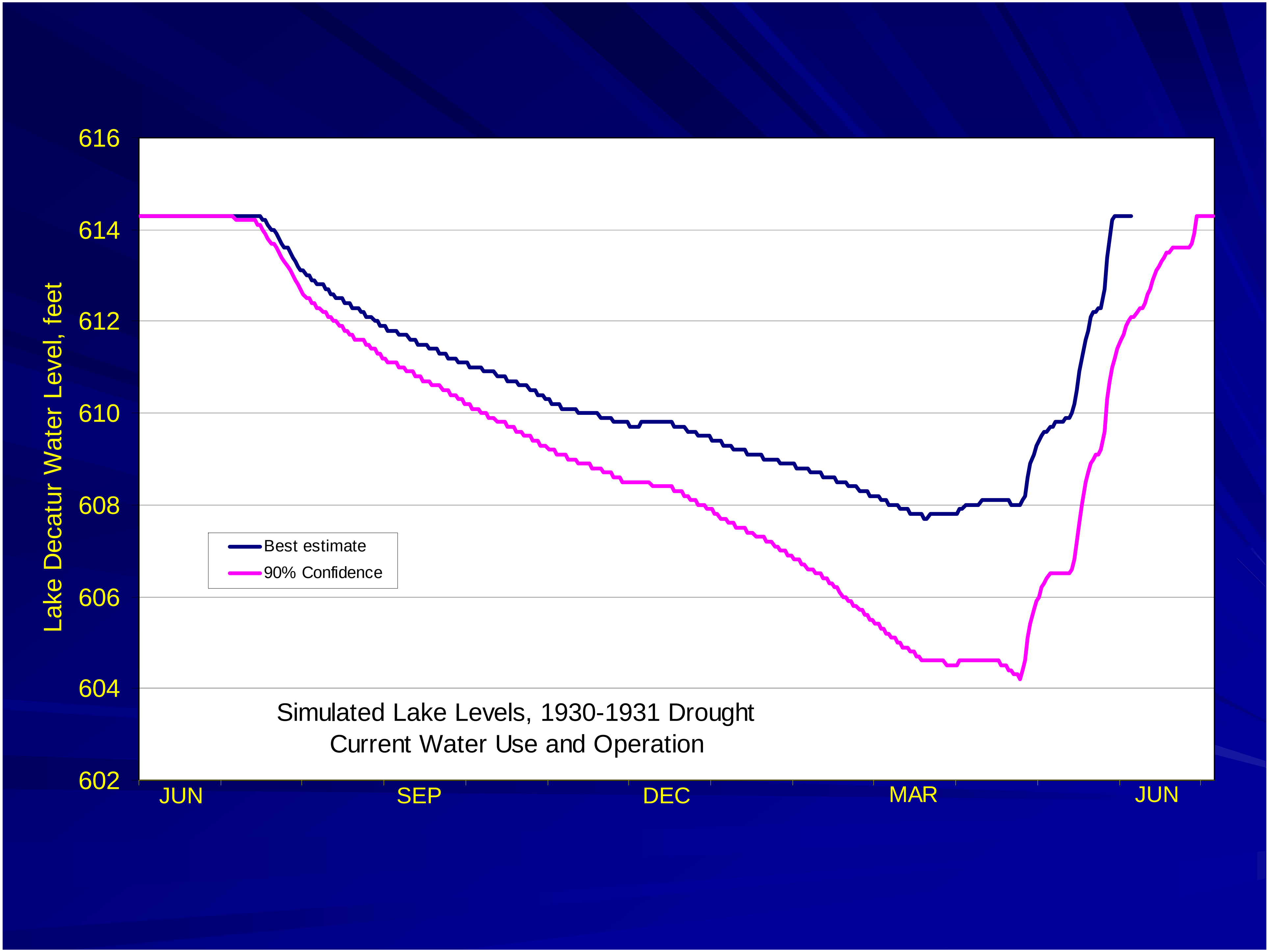
Best Estimate of Yield

Dates	Duration (months)	YIELD (mgd)
July 21, 1939 – March 31, 1941	20	13.6
May 12, 1930 – Nov. 30, 1932	31	14.2
May 2, 1988 – January 18, 1990	21	14.6
June 21, 1955 – March 27, 1957	21	16.0

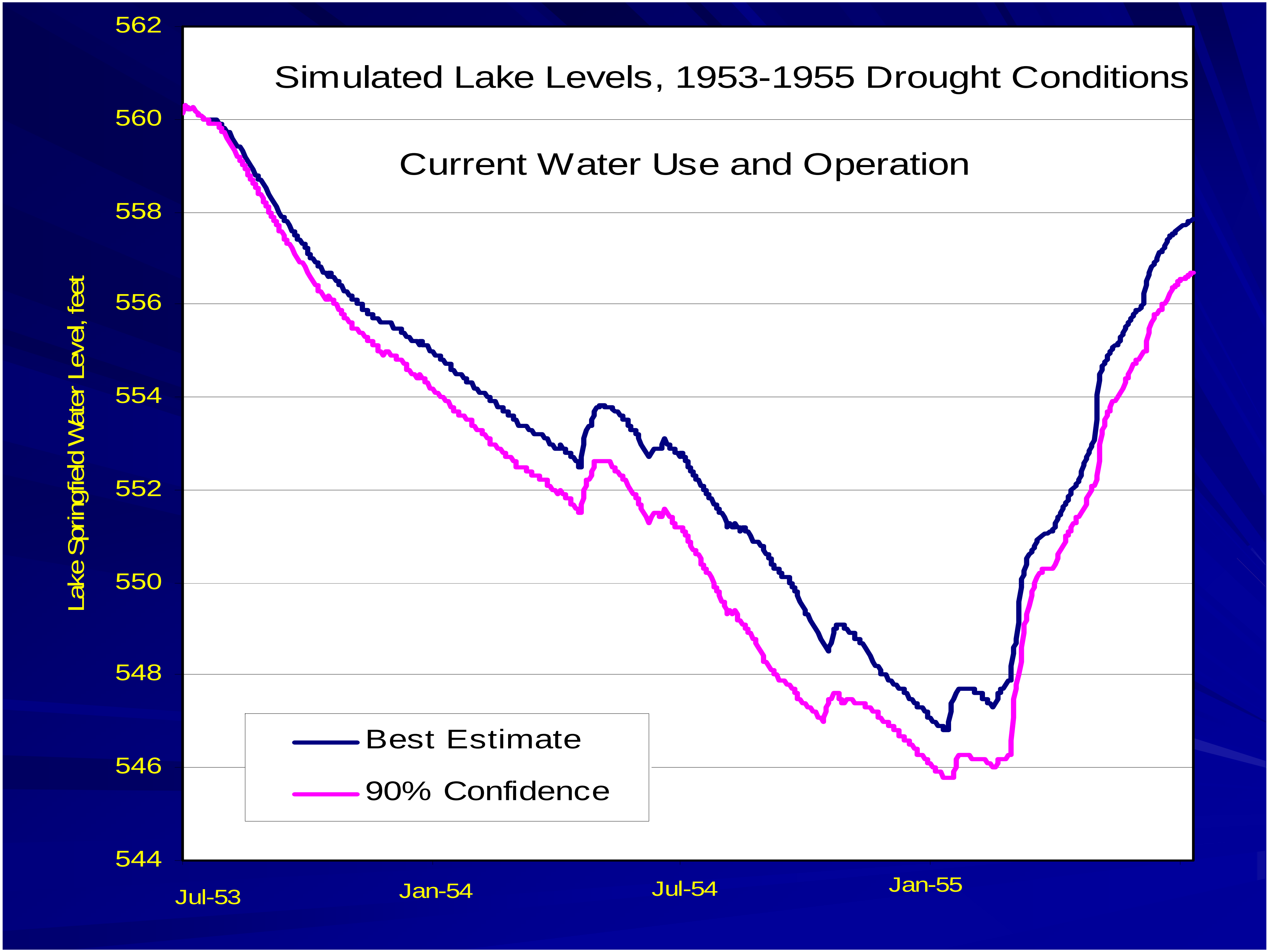
Decatur Historical Droughts

Best Estimate of Yield

Dates	Duration (months)	YIELD (mgd)
July 14, 1930 – April 20, 1931	9.3	40.2
June 10, 1914 – Jan. 31, 1915	7.7	40.8
July 28, 1953 – Jan. 26, 1954	6.0	45.6
June 14, 1963 – Jan. 19, 1964	7.2	46.4



Lake Decatur Water Level, feet
616
614
612
610
608
606
604
602
JUN
SEP
DEC
MAR
JUN
Best estimate
90% Confidence
Simulated Lake Levels, 1930-1931 Drought
Current Water Use and Operation


Simulated Lake Levels, 1953-1955 Drought Conditions
Current Water Use and Operation
Lake Springfield Water Level, feet
562
560
558
556
554
552
550
548
546
544
Jul-53
Jan-54
Jul-54
Jan-55
Best Estimate
90% Confidence

Comparison of "Mid" Estimate to 90% Confidence Estimate

DROUGHT OF RECORD

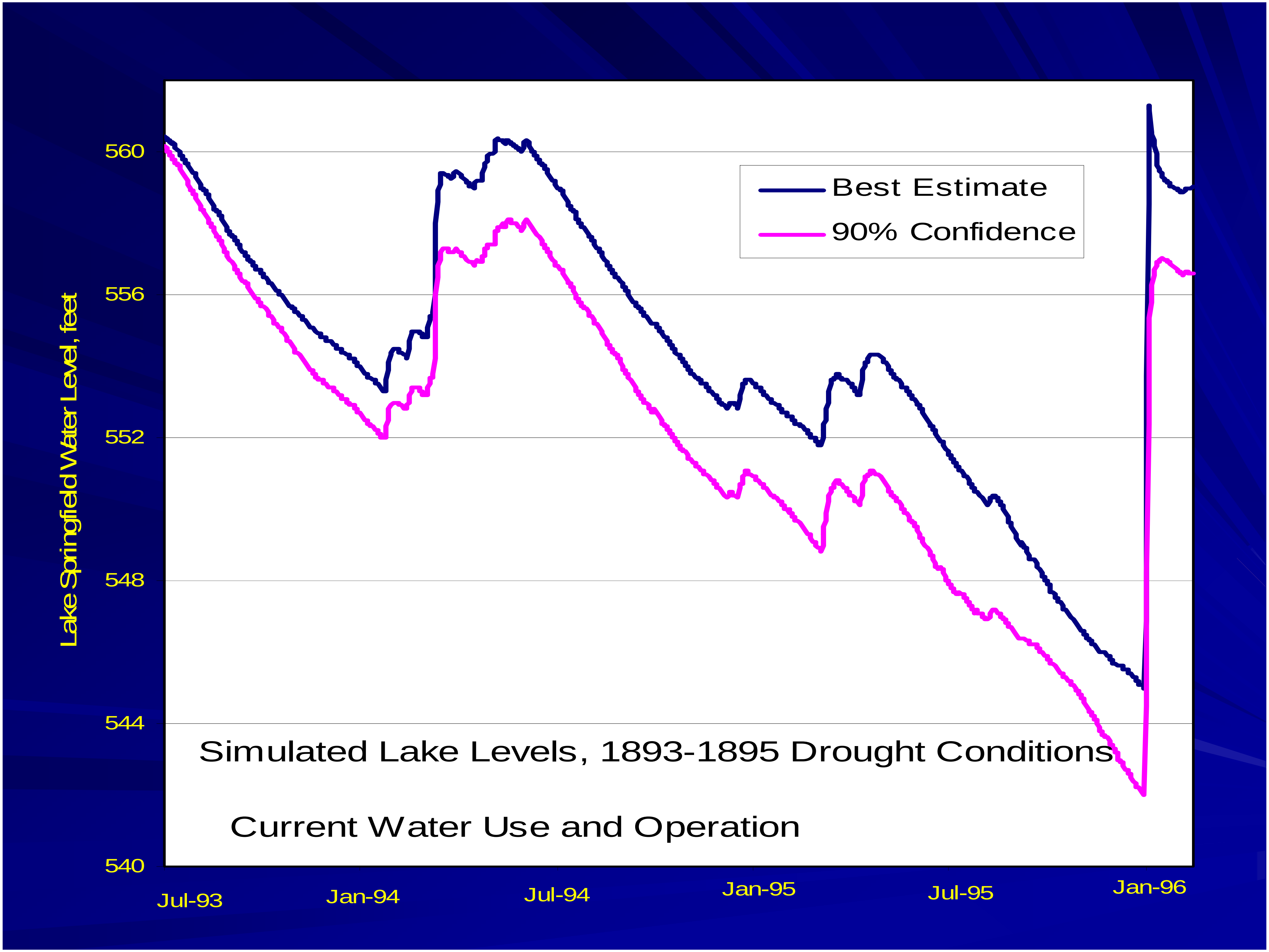
- Bloomington (current use = 12 mgd)
  - Mid estimate = 13.6 mgd
  - 90% estimate = 11.0 mgd
- Decatur (current use = 37 mgd)
  - Mid estimate = 40.2 mgd
  - 90% estimate = 34.6 mgd
- Springfield (current use = 32 mgd)
  - Mid estimate = 27.6 mgd
  - 90% estimate = 23.4 mgd

Projecting into the Future
DECLINING YIELD VERSUS 2050 DEMAND
(2050 Baseline Scenario)

- Bloomington (projected demand = 16 mgd)
  - Mid estimate = 12.6 mgd
  - 90% estimate = 10.1 mgd
- Decatur (projected demand = 56 mgd)
  - Mid estimate = 40.2 mgd
  - 90% estimate = 34.6 mgd
- Springfield (projected demand = 37 mgd)
  - Mid estimate = 25.9 mgd
  - 90% estimate = 21.8 mgd

Worse (sic) case drought

- There is no guarantee that future droughts will be no worse than the previous drought of record
- A worse-case drought may be one that is only slightly different than the drought of record, but have noticeable impact on yield
  - Again, the recent Georgia drought is an example that such worse-case events can occur
  - For Decatur, a worse-case drought may be similar to the 1930-31 drought but start one month earlier in June instead of July
  - For Bloomington or Springfield, a worse-case drought may extend from 2 years to 3 years in duration
  - Duration, rather than intensity is often the key factor


Lake Springfield Water Level, feet
560
556
552
548
544
540
Best Estimate
90% Confidence
Simulated Lake Levels, 1893-1895 Drought Conditions
Current Water Use and Operation
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96

Conclusion

- The “Best” (50%) yield estimates for the drought of record at Bloomington and Decatur exceed current water use, but the 90% confidence yield does not
- As shown by both the 50% and 90% yield estimates, low water levels in Lake Springfield during a severe drought would cause a shut down in power plants. Sufficient water would still be available for potable water use.
- All 3 communities have insufficient yield for a worse-case drought
- All 3 communities need to develop additional sources of supply to meet projected future use

Are additional surface water sources available for future growth in these communities?

- It's a matter of 1) cost, 2) environmental concerns, and 3) legal/institutional hurdles and restrictions.
- For example, can the Sangamon River support some of the proposed uses of its water and still address aquatic habitat concerns?
- In upcoming months, we expect to do additional simulations of streamflow levels based on such future scenarios, as well as potential climate change impacts

Where to go and how far for surface water? Again, there are few stream locations in East-Central Illinois where natural base flows can support a major water supply, and many of these are public waters. Additional surface water storage may be needed (off-channel storage options?).