Memo

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To:	Brazos G Regional Water Planning Group		
From:	Cory Shockley, PE David Dunn, PE	Project:	Brazos G 2011 Regional Water Plan
CC:	Trey Buzbee, Brazos River Authority		
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RE: Alternative Safe Yield Assumptions as a Planning Concept to Account for Potential Climate Variability

Background

Climate change is an issue that has recently received considerable attention in the press and in political, scientific and cultural debate. The earth's climate is known to vary, as evidenced by historical ice age periods. Whether or not natural climate variability is being impacted by man's activities, however, is where most of the debate centers. Whatever the reason for climatic variability, prudent water supply planning should acknowledge and account for the uncertainty that future climatic variability imposes. Future changes in climatic variability could impact rainfall cycles, and be manifested as droughts more severe than the drought of the 1950's, which over much of Texas is considered to be the drought of record.

Safe yield concepts are utilized widely in West Texas to provide protection against the effects of a future drought that may be worse than the drought of record. Basically, utilizing a safe yield is a management tool whereby dependable supplies are considered to be less than the firm yield and a reservoir is operated to supply that lesser amount. This often requires that alternative supplies be available to offset the difference between the firm yield of the reservoir and the lesser demand under which it will be managed.

Most safe yield concepts assume that a volume equivalent to a one-year supply remains in storage during the critical month of the drought of record analysis. Some entities utilize a 6-month safe yield estimate. However it is defined, the yield analysis for water supply planning is based upon historical hydrology, for which we currently have roughly only 60 years of streamflow and other hydrologic data.

While much research continues to investigate the potential for increased climatic variability, little can be predicted accurately that would form a solid basis for changing the hydrologic data contained in current WAMs to account for future climatic conditions. Any such changes to the fundamental hydrology would be speculative at best. An alternative approach is to revise the concept of safe yield to allow for periods longer than one year of supply remaining in storage in order to provide an additional level of protection against future droughts. Essentially, this would consider operating a reservoir under an assumed supply that is less than a firm yield or a conventional 1-year safe yield. For this analysis, we investigated whether or not a 2-year or a 3-year safe yield would allow supply to be maintained during a drought worse than the drought of record.

Selection of Candidate Reservoirs

Twenty reservoirs were picked from throughout the Brazos Basin that met some key criteria for this analysis. These key criteria generally included:

- Geographic coverage throughout the Brazos G Area,
- Reservoirs that constitute a primary source of supply, and
- Reservoir capacity less than 30,000 acre-feet.

A few exceptions to these criteria were allowed to include a larger number of reservoirs in the analysis, and to include reservoirs located in the Clear Fork of the Brazos Basin. This area of the basin has an updated water availability model (WAM) that covers the 1940 – June 2008 period of record. Many reservoirs in this basin have experienced a new “critical drought” and utilize a 1year safe yield supply, and were included in this analysis even though they did not meet all of the above criteria.

Estimation of Alternative 2-year and 3-year Safe Yields

Each reservoir was simulated using the latest Brazos G WAM applicable to the reservoir: the “mini-WAM”, with the extended period of record, for reservoir in the Clear Fork of the Brazos Basin, and the Brazos G “full-WAM” for all others, which has a period of record ending in 1997. The simulations consisted of several runs. The first step was to determine the 2-year and 3-year safe yields for each reservoir under 2000 (current) and 2060 (future) sedimentation conditions. For reservoir in the basin below Possum Kingdom Reservoir, the 1-year safe yield was also determined; for reservoirs upstream of Possum Kingdom Reservoir, the 1-year safe yield is used as a source of supply and had already been determined. A safe yield is defined as the amount of annual demand that can be placed on a reservoir such that the minimum storage encountered in the reservoir during the simulation is equal to a specified amount. In the case of a 2-year safe yield, the minimum storage must be at least two times the annual demand on the reservoir, and for a 3-year safe yield, three times the annual demand. For example, under a 3-year safe yield demand of 1,000 acre-feet per year (acft/yr), the minimum storage during the model simulation would be 3,000 acft. The 1-year, 2-year and 3-year safe yields for the reservoirs included in the study are shown in Table 1.

Simulation of Alternative Safe Yield Demands during a Severe Drought

Predicting the severity, duration, and frequency of future droughts is uncertain and complicated. Historical hydrology is our best indicator of how a reservoir might perform in the future, but its use does limit predictive capabilities. The recent drought in the upper Brazos basin is a good example of this concept. The recent drought was of a shorter duration than the drought of the 1950’s, but was more intense with substantially smaller streamflows.

In order to evaluate the effects of a future unknown drought, three different scenarios were developed that focus on one particular aspect of a drought occurrence – reduced streamflows. New drought scenarios were developed that retained the same duration as the historical droughts, but increased the intensity of these droughts by 10%, 20% and 30%. Drought intensity was increased by decreasing the naturalized flows for the entire basin by these percentages during the drought period. For the full WAM this included reductions for the years of 1947 – 1956, and for the mini-WAM an additional reduction was included for 1998 – 2007. These modified inflow sets were then simulated for the 2060 reservoir sedimentation conditions under 2-year and 3-year safe yield demands to determine if the reservoirs could reliably meet these demands while experiencing these "new" droughts.

Table 1. Alternative Safe Yields Estimated for Specific Brazos G Reservoirs.

	Sedimentation Condition			
	2000		2060	
Reservoir	2-Year Safe Yield (acft/yr)	3-Year Safe Yield (acft/yr)	2-Year Safe Yield (acft/yr)	3-Year Safe Yield (acft/yr)
Bistone	265	200	30	20
Gordon	2	1	2	1
Somervell	990	770	990	770
Strawn	200	147	200	147
Throckmorton	142	115	142	115
Cisco	1,016	921	1,010	910
Daniel	165	135	147	120
Fort Phantom Hill (with CFS Sub)	12,050	9,330	10,645	8,210
Graham	3,125	2,675	2,475	2,070
Hubbard	27,775	23,923	27,370	23,670
Stamford	4,280	3,420	3,890	3,084
Sweetwater	865	740	840	713
Trammel	420	339	420	338
Hamlin	60	50	60	47
Anson North	50	38	50	38
Woodson	20	10	20	10
McCarty	100	80	100	80
Baird	47	35	47	35
Moran City Lake	40	25	40	25
Bryson	32	27	32	27

A comparison of safe yield supplies is shown in Table 2 for the 2060 sediment conditions. Overall, 2-year and 3-year safe yield operations substantially reduce available supply. As shown, operating under a 2-year or 3-year safe yield would reduce the available supply from the reservoirs to 74% and 57%, respectively, of the 1-year safe yield supply.

Table 2. Comparison of Year 2060 Safe Yield Supplies.

	2060 Sedimentation Conditions				
	1-Year Safe Yield (acft/yr)	2-Year Safe Yield		3-Year Safe Yield	
Reservoir		Yield (acft/yr)	Percent of 1-Year	Yield (acft/yr)	Percent of 1-Year
Bistone	47	30	64%	20	43%
Gordon	3	2	69%	1	46%
Somervell	1,382	990	72%	770	56%
Strawn	300	200	67%	147	49%
Throckmorton	210	142	68%	115	55%
Cisco	1,130	1,010	89%	910	81%
Daniel	205	147	72%	120	59%
Fort Phantom Hill (with CFS Sub)	15,145	10,645	70%	8,210	54%
Graham	3,215	2,475	77%	2,070	64%
Hubbard	32,600	27,370	84%	23,670	73%
Stamford	5,300	3,890	73%	3,084	58%
Sweetwater	1,030	840	82%	713	69%
Trammel	540	420	78%	338	63%
Hamlin	80	60	75%	47	59%
Anson North	65	50	77%	38	58%
Woodson	30	20	66%	10	33%
McCarty	120	100	83%	80	67%
Baird	60	47	78%	35	58%
Moran City Lake	70	40	57%	25	36%
Bryson	40	32	80%	27	68%
Average Percent of 1-Year Safe Yield			74%		57%

Results from the operations analysis under the different drought scenarios are shown in Table 3, which states whether or not each reservoir would successfully maintain the 1-year, 2-year or 3-year safe yield supply during each drought scenario, e.g., whether or not the reservoir would go dry operated under those alternative yield demands during the more severe droughts. For the reservoirs included in this analysis:

- Under a drought 10% more severe than the drought of record, the 1-year safe yield supply could be maintained in 16 of the 20 reservoirs, indicating that the 1-year safe yield is a reasonable concept when contemplating protection of supply during a drought of moderately more severe intensity than the drought of record. Of those remaining four reservoirs, three would be protected using either a 2-year or 3-year safe yield operation.
- Under a drought 20% more severe, the 1-year safe yield supply could be maintained in 12 of the 20 reservoirs. Of those eight for which supply could not be maintained, only one would be maintained under a 2-year safe yield, and another four would be maintained under a 3-year safe yield operation. Under this drought scenario, a 2-year safe yield operation would protect supply in 13 of the 20 reservoirs and a 3-year safe yield operation would protect supply in 17 of the 20 reservoirs.

- Under a drought 30% more severe, the 1-year safe yield could be maintained in six of the reservoirs. Of those 14 for which supply could not be maintained, five would be maintained under a 2-year safe yield, and another four would be maintained under a 3-year safe yield operation. Under this drought scenario, a 2-year safe yield operation would protect supply in 11 of the 20 reservoirs and a 3-year safe yield operation would protect supply in 15 of the 20 reservoirs.

In general, the concept of safe yield for determining supplies from reservoirs is useful for protecting and ensuring assumed supplies can be met reliably during future droughts that may be more severe than the drought of record. In general and supported by this limited analysis, a 1-year safe yield supply appears capable of being maintained during a drought of moderately worse intensity than the drought of record. For assumptions involving more severe droughts, it appears that utilizing a 3-year safe yield supply may be more effective than adopting a 2-year safe yield supply. This assurance of reliable supply comes at the cost of a substantial reduction in the supply achieved from a reservoir. If this supply is less than projected water demands, additional sources of supply would need to be developed to supplement the reduced safe yield supply. However, because this additional source would not be need to provide the full water demand for an entity, it could be more modestly sized and operated in conjunction with the original reservoir supply.

Much depends upon the characteristics of each specific reservoir and the watershed controlled by the reservoir. Additionally, this analysis focused solely on droughts of durations identical to the drought of record, but with increased intensity. Reservoir responses to future droughts that are longer in duration than experienced historically may be quite different, due to evaporative losses.

HDR recommends that the Brazos G Regional Water Planning Group consider adopting a 2-year or 3-year safe yield supply for a reservoir only when requested to do so by a Water User Group or Wholesale Water Provider. This action would also require the approval of the Texas Water Development Board.

Table 3. Effectiveness of Alternative 2-year and 3-year Safe Yields.

Reservoir	Is Supply Maintained During a Worse Drought? (2060 Sedimentation Conditions)											
	1-Year Safe Yield (acft/yr)	Drought Scenario			2-Year Safe Yield (acft/yr)	Drought Scenario			3-Year Safe Yield (acft/yr)	Drought Scenario		
		10%	20%	30%		10%	20%	30%		10%	20%	30%
Bistone	47	Yes	Yes	No	30	Yes	Yes	No	20	Yes	Yes	Yes
Gordon	3	No	No	No	2	Yes	No	No	1	Yes	No	No
Somervell	1,382	Yes	Yes	Yes	990	Yes	Yes	Yes	770	Yes	Yes	Yes
Strawn	300	Yes	Yes	Yes	200	Yes	Yes	Yes	147	Yes	Yes	Yes
Throckmorton	210	Yes	Yes	Yes	142	Yes	Yes	Yes	115	Yes	Yes	Yes
Cisco	1,130	Yes	Yes	Yes	1,010	Yes	Yes	Yes	910	Yes	Yes	Yes
Daniel	205	No	No	No	147	No	No	No	120	Yes	No	No
Fort Phantom Hill (with CFS Sub)	15,145	Yes	Yes	No	10,645	Yes	Yes	Yes	8,210	Yes	Yes	Yes
Graham	3215.1	Yes	Yes	No	2,475	Yes	Yes	No	2,070	Yes	Yes	No
Hubbard	32,600	Yes	Yes	Yes	27,370	Yes	Yes	Yes	23,670	Yes	Yes	Yes
Stamford	5,300	Yes	Yes	No	3,890	Yes	Yes	Yes	3,084	Yes	Yes	Yes
Sweetwater	1,030	Yes	Yes	No	840	Yes	Yes	Yes	713	Yes	Yes	Yes
Trammel	540	Yes	Yes	No	420	Yes	Yes	Yes	338	Yes	Yes	Yes
Hamlin	80	Yes	No	No	60	Yes	No	No	47	Yes	Yes	Yes
Anson North	65	Yes	No	No	50	Yes	Yes	Yes	38	Yes	Yes	Yes
Woodson	30	No	No	No	20	No	No	No	10	Yes	Yes	Yes
McCarty	120	Yes	No	No	100	Yes	No	No	80	Yes	Yes	Yes
Baird	60	Yes	No	No	47	Yes	No	No	35	Yes	Yes	No
Moran City Lake	70	Yes	Yes	Yes	40	Yes	Yes	Yes	25	Yes	Yes	Yes
Bryson	40	No	No	No	32	No	No	No	27	No	No	No