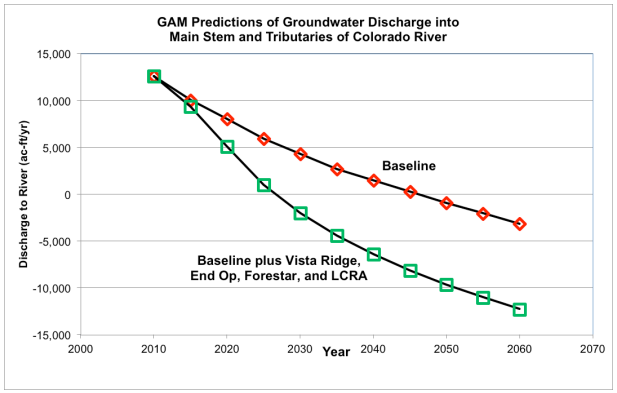
GMA-12 DFCs
Summary of ES Comments and Recommendations

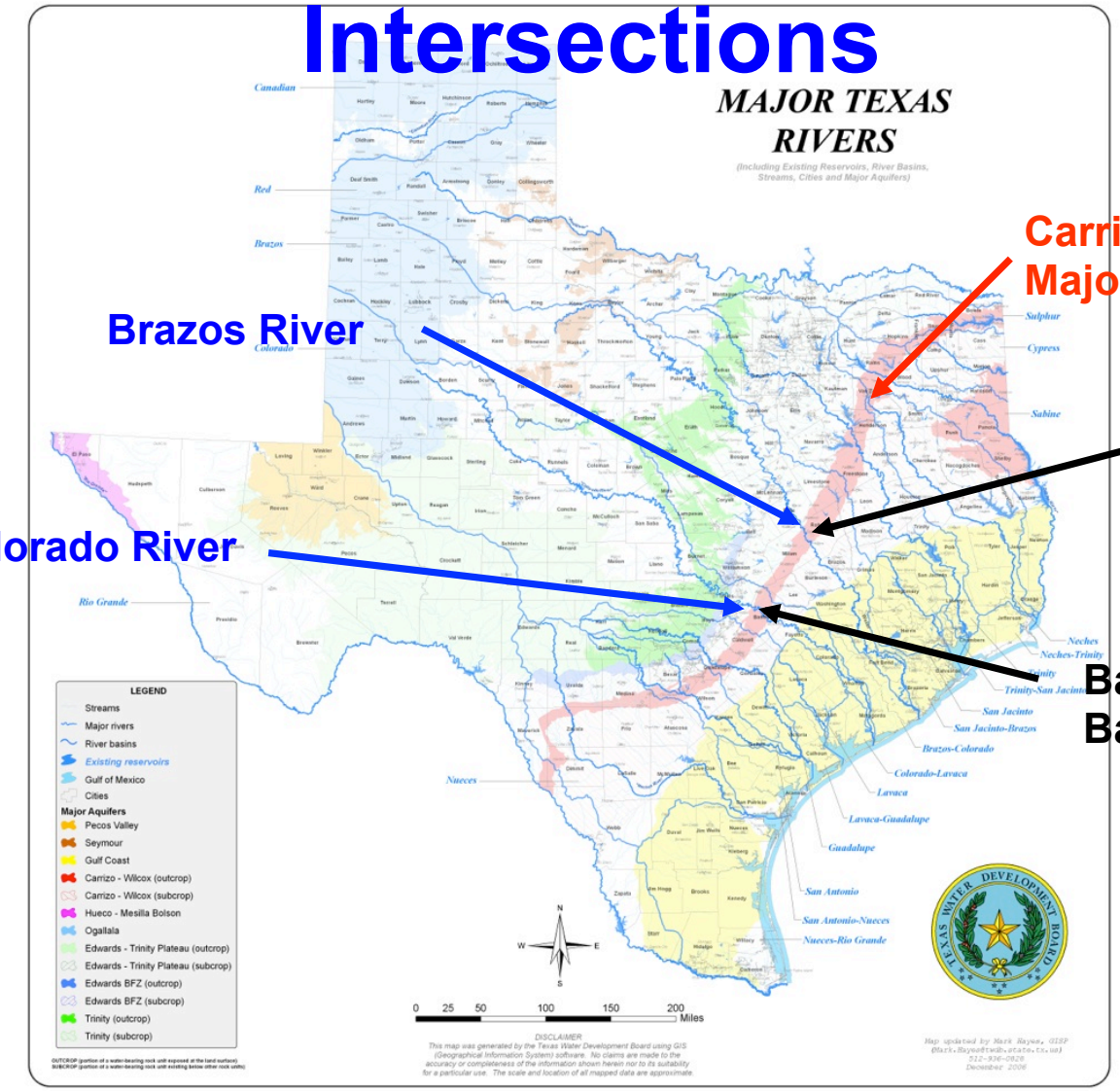


Presented to
GMA-12
February 4, 2016, Milano, Texas

Environmental Stewardship
A Sustainable Ecosphere
TM

Environmental-Stewardship.org

Ground & Surface Water Intersections



Carrizo-Wilcox Major Aquifer

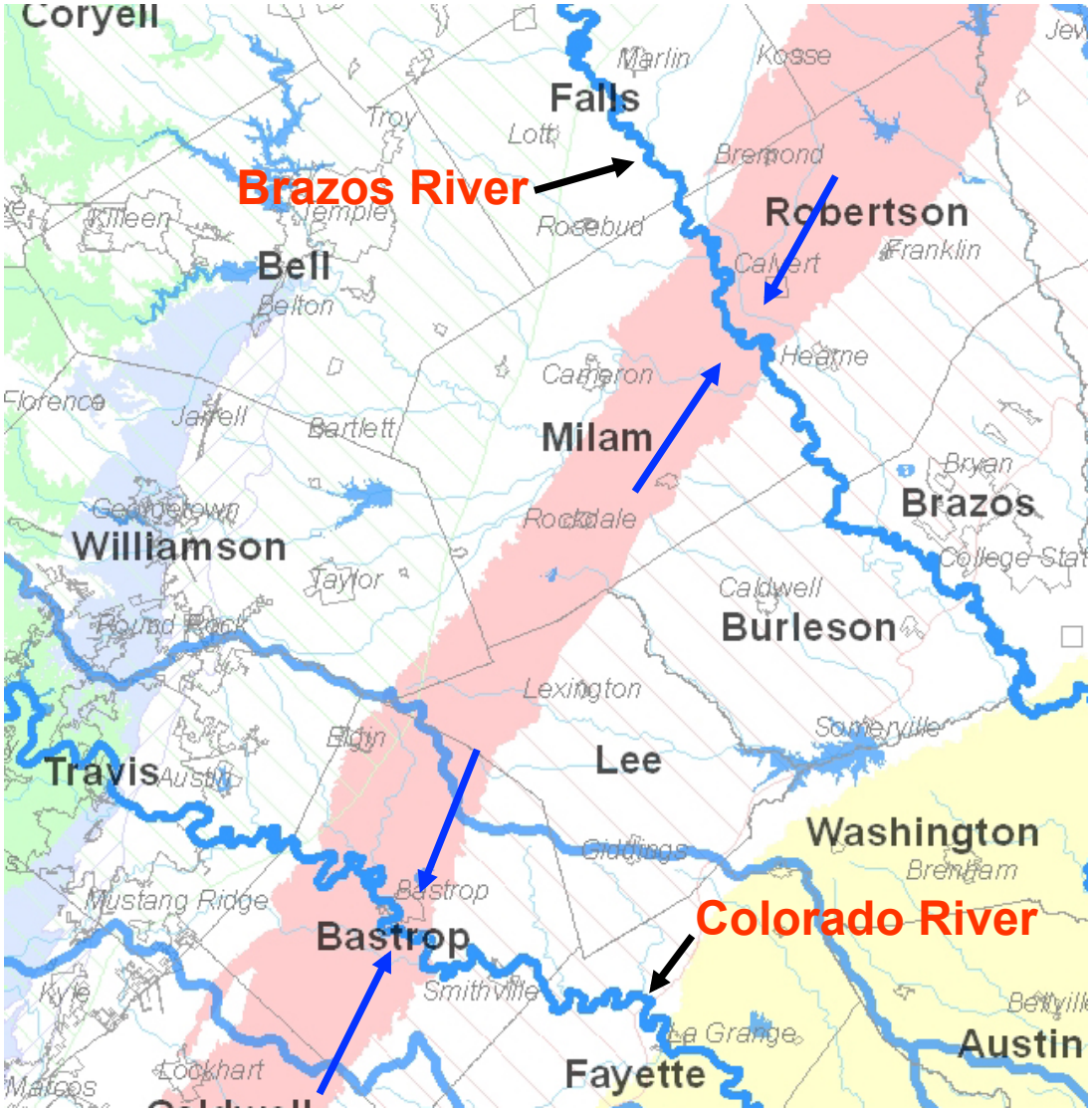
Brazos River

Milam/ Robertson Counties

Colorado River

Bastrop, TX Bastrop County

Currently the Carrizo-Wilcox Charges the Rivers



Charge to Aquifer
(Recharge)

Charge to River
(base-flow)

Under Current Conditions the Carrizo-Wilcox Aquifer Charges Water into the Colorado and Brazos Rivers (Base-flow)

Currently "Gaining" Rivers

Empirical evidence of a losing segment associated with Simsboro Aquifer above Bastrop

Current DFC Review Reveals

- The GMA-12 GAM, though robust in many ways and the best tool we have available, has deficiencies that
  - **distort some of its predictive functions, and**
  - **make quantitative estimates suspect for several important factors that are required to be considered.**

Current DFC Review Reveals

- The GMA-12 GAM, though robust in many ways and the best tool we have available, has deficiencies:
  - **Consideration 4**: The historical and recent empirical information on the relationship between the Colorado and Brazos rivers to the Carrizo-Wilcox and other aquifers is not accurately reflected in the GAM outputs.
    - MODFLOW outputs do not correlate with empirical data
    - Hydrologists contend that outflows to surface waters tend to be over-estimated.

Colorado Gaining River

▲ Historic Empirical Measurements

Table 4

Measured Groundwater Discharge to the Colorado River From the Carrizo-Wilcox Aquifer in Bastrop County

Year	Discharge (cfs)	Discharge (ac-ft/yr)	Remarks
1918	36	26,060	USGS
2005	50	36,200	LCRA
2008	30	21,720	Saunders

(New Exhibit N1-2014 – Forestar's Proposal to Pump Groundwater from the Simsboro Aquifer, George Rice, December 14, 2013)

Colorado Gaining River

The Colorado River is a "gaining" river as it crosses the Carrizo-Wilcox and other aquifers in Bastrop County.

	Gain/Loss (cubic feet per second)	
TWDB/LCRA 1989 Study (Exhibit N2)	+62 cfs	45,000 ac-ft/yr
LCRA 2005 STUDY (Attachment J)		
Austin-Bastrop	-9 cfs	
Bastrop-Smithville	+59 cfs	Net +50 cfs
LCRA 2008 STUDY (Attachment K)		
Utley-Bastrop (Bob Bryant)	+34.5 cfs	***About 22,000 ac-ft/yr***
Bastrop-Smithville	-4.5 cfs	Net +30 cfs
USGS 1918 estimate (Attachment L)		
Carrizo-Wilcox (Utley-Smithville)		Net +36 cfs
Carrizo-Wilcox GAM (Attachment L)		
Baseflow increase:	**32,400 ac-ft/year;**	
GAM calibrated to:	**26,100 ac-ft/year; 36 cfs**	

Brazos Gaining River

- **The Brazos River is a "gaining" river as it crosses the Carrizo-Wilcox and other aquifers in Brazos, Burleson, Milam, and Robertson counties.**
  - **USGS 2002 report 02-068** (Exhibit 1)
    - tabulated data on 366 known streamflow gain-loss studies conducted by the USGS in Texas
    - 47 were on the Carrizo-Wilcox aquifer
    - Prepared in cooperation with the TWDB
  - **USGS Scientific Investigation report 2007-5286** (Exhibit 2)
    - "Streamflow Gain and Loss of the Brazos River, McLenna County to Fort Bend County, Texas"
    - The gain-loss relationship of the Brazos River was established in this 2006 study
    - Prepared in cooperation with the TWDB

Brazos Gaining River

The Brazos River is a "gaining" river as it crosses the Carrizo-Wilcox and other aquifers in Brazos, Burleson, Milam and Robertson Counties.

Gain/Loss (cubic feet per second)

USGS Investigation 2007-5286 STUDY

(Exhibit 2 - Figure 11 and Table 8)

		August	
B6	Carrizo-Wilcox	**+194 cfs**	
B9	Carrizo-Wilcox	+39 cfs	
B12	Queen City/Sparta	-64 cfs	
B13	Queen City/Sparta	**+134 cfs**	
B14	Queen City/Sparta	-88 cfs	
B15	Yegua-Jackson	**+73 cfs**	
B16	Yegua-Jackson	+79 cfs	**Net ~ 367 cfs**
			265,700 ac-ft/yr

Bold font indicates gain or loss that is greater than potential measurement error for that particular reach.

Current DFC Review Reveals

- The GMA-12 GAM, though robust in many ways and the best tool we have available, has deficiencies :
  - **Consideration 3**: Water budgets produced for evaluation of hydrological conditions do not reflect the expectations expressed by the hydrologists, that:
    - **Most of the water pumped comes from storage, and**
    - **There is very little leakage between aquifers.**

Current DFC Review Reveals

- The GMA-12 GAM, though robust in many ways and the best tool we have available, has deficiencies :
  - **Consideration 3**: To the contrary, ES evaluation of the GAM results indicate that the most significant contributions of groundwater for pumping predicted by the GAM come from:
    - **A reduction in outflows to surface waters, and**
    - **Vertical flow (leakage) from other aquifers.**

PS4 Water Budget Analysis

▲Planning Scenario 4 (PS4) Water Budget

Simsboro Aquifer	GCD's Consolidated	Acre-feet per Year*				Net Change over period		
	Description	Calibration Period		DFC Period				
Technical	Layman	1975	1999	2000	2070	Calibration	DFC	Total
Recharge	To(+) aquifer	37,500	45,000	32,000	32,000	7,500	0	7,500
Et	From(-) Evapotranspiration	950	1,950	-1,000	-3,500	1,000	-2,500	-1,500
Storage Change	To(-)/from(+) storage	78,000	57,050	50,550	68,050	-20,950	17,500	-3,450
Stream leakage	To(-)/from(+) surface waters	-93,000	-30,000	-24,000	13,000	63,000	37,000	100,000
Drains	To(-)/from(+) springs	-2,500	0	0	0	2,500	0	2,500
Verticle Leakage	To(-)/from(+) other aquifers	11,700	25,200	26,400	96,200	13,500	69,800	83,300
Lateral Leakage	To(-)/from(+) other districts	-7,300	-3,500	-13,700	-16,500	3,800	-2,800	1,000
Wells	Pumping	-6,500	-38,000	-101,000	-244,000	-31,500	-143,000	-174,500
	Net:	18,850	57,700	-30,750	-54,750	38,850	-24,000	14,850

* All values are extrapolated from graph and are estimates of the actual GAM values

OBSERVATIONS: **GCD's Consolidated**

1 Outflow to surface water decreased by 63,000 ac-ft/yr during calibration and another37,000 during DFC; a total of 100,000 ac-ft/yr
2. Outflow to surface water ceases between 2020 (Post Oak) and 2060 (Lost Pines).
3. Storage increased during calibration period and decreases more significantly during DFC (drawdown)
4. Verticle leakage into Simsbor increases very significantly during DFC period
5. Lateral flow out of districts decreased slightly during calibration and increases slightly during DFC period (net outflow from District)
6. Pumping increased significanly during calibration and DFC period (total 2070 pumping is 244,000 ac-ft/yr).

ES comments dated June 18, 2015 (Consideration 3) One of six tables.

Current DFC Review Reveals

▲The GMA-12 GAM, though robust in many ways and the best tool we have available, has deficiencies :

- **Consideration 3**: The GMA-12 GAM development reports (publications) indicate that the purpose of the GAM is to provide a tool for evaluating impact of changes in pumping on:
  - **water level, and**
  - ***stream flow***
- yet the GMA-12 Consultants do not use the tool for evaluating impacts on *stream flow*.

GMA-12 - Environmental Impact Considerations

▲ Consultants provided comprehensive review of groundwater flow systems and GW/SW interaction measurements. Conclusions include:

- High quality stream gain-loss studies are difficult to conduct and relatively few good studies exist.
- ES Response:
  - **Saunders/LCRA studies on Colorado River are limited but high quality.**
  - **Consideration need to focus on impacts during drought conditions when flow is at risk.**

GMA-12 August 13, 2015. Presentation by Consultants (Steve Young): Environmental Impact Considerations

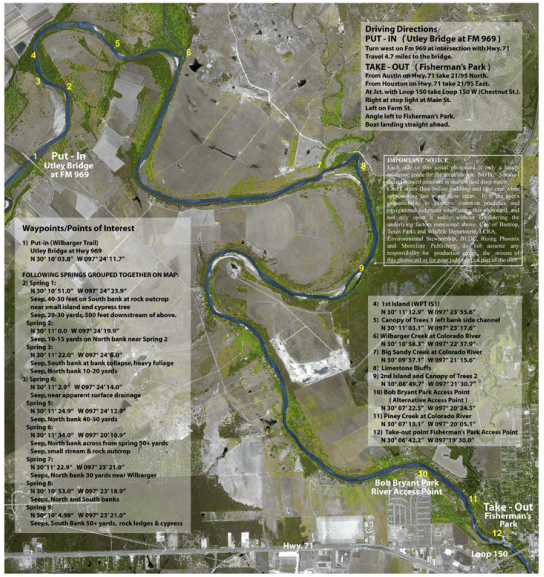
GMA-12 - Environmental Impact Considerations

▲ Consultants provided comprehensive review of groundwater flow systems and GW/SW interaction measurements. Conclusions include:

- Extremely limited spring flow data collected since 1970's
- ES Response:
  - **ES provided maps and lists of springs along the Colorado River**
  - **ES provided flow data for Bastrop Spring.**
  - **Neither have been considered.**

GMA-12 August 13, 2015. Presentation by Consultants (Steve Young): Environmental Impact Considerations

ES Provided Maps & Lists



WILBARGER TRAIL DESCRIPTION
The Wilbarger Trail is a 14 mile long paddle. It starts from the Utley Bridge at FM 969 and ending at Fisherman's Park in Bastrop. Depending on flow rates, it is a four to seven hour paddle. There are a few minor rapids and the channel is strewn with large sandstone boulders. Some of the banks are very steep with high sandstone bluffs and cliffs. There are several islands and sand bars used for camping and resting. Three tributaries, Wilbarger, Big Sandy, and Piney Creeks, enter the Colorado River along the trail.

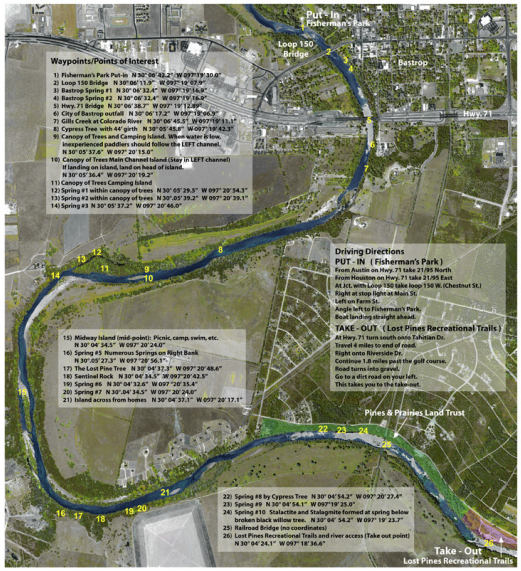
FISHING
Fishing is very good along these sections of the river. Popular fish include Guadalupe bass, largemouth bass, sunfish, blue, channel and flathead catfish.

TREES
Trees along the trails are typical of hardwoods growing in a floodplain area. Native Texas pecan trees are abundant along with eastern cottonwood, American sycamore, and black willows. Bald cypress are found single or in small groups. Hickory, ash and cedar elm are common with a dense understory of greenbriar and poison ivy. Grapevines and trumpet vines climb high in the trees. The El Camino Real trail goes through the Lost Pines region. This is a section of Loblolly Pines that became isolated from the east Texas piney woods.

WILDLIFE

The Wilbarger trail provides habitat for an endangered fish called the blue sucker. They feed on aquatic insects and can grow to over 32". They live in areas of deep fast rapids over gravel, cobble, boulders and bedrock structures. Non-game fish in his part of the river includes the red shiner, blacktail shiner and the bullhead minnow. Dusky darter, Texas logperch, suckermouth minnow, central stoneroller, chub and juvenile channel catfish are often found in riffles while flathead and channel catfish, gray redhorse sucker, Guadalupe bass, smallmouth buffalo and common carp are found in deeper water. Backwaters and shallow pools are home to largemouth bass, and longear sunfish. Alligator gar and freshwater drum are numerous. Wildlife along the river includes raccoons, opossums, and armadillos. White tailed deer, coyotes, foxes and bobcats may be seen. Many species of birds make their homes along the banks of the river including ubiquitous Black Vulture and Turkey Vulture, Crested Caracara, Osprey, Red-Shouldered Hawk, and Red-tailed Hawk. Bald Eagles are frequently spotted soaring above the river. Belted Kingfishers perch on overhanging branches and dive for fish, sometimes even next to fortunate paddlers. Great Blue Heron, Wood Duck and Killdeer are among the many other birds found along the water's edge. For more information about the wildlife and ecology of the river visit www.Environmental-Stewardship.org.

Colorado River Paddling Trail Aerial Photocard
Proposed Spring 2008 **Wilbarger Trail - Bastrop, Texas**
Distance - 14 River Miles
Float Time - 4 - 7 hours depending on water levels and flow rates



EL CAMINO REAL TRAIL DESCRIPTION
The El Camino Real trail is six miles long. It starts at Fisherman's park in Bastrop and ends at the Lost Pines Recreational Trails take-out. Depending on flow rate, it can be completed in 1-1/2 to 4 hours. The river is wide and usually slow moving with a few rapids. The bottom is composed of sand and gravel with bars and islands appearing frequently.

OPTIMUM FLOW RATES
800 - 7000 CFS Average depth is 3-8 ft.
www.texasoutside.com/lcradailyriverreport

PRIVATE PROPERTY
Respect private property by not trespassing or littering and keeping noise levels down. This river is classified as navigable, which permits public streambed and, if necessary, the banks to portage any hazard. Any other use of private river banks without permission of the landowner can be considered trespassing. Under Texas Penal Code (30.05), criminal trespass occurs when one enters property after Receiving notice not to enter. Notice includes verbal notice, a fence, sign(s), purple paint on posts or trees, or the visible presence of crops for human consumption.

SAFETY
Rivers are ever-changing dynamic systems with inherent dangers. Be sure to never boat alone, tell someone where you are going, when you expect to return, and where to call if you do not return. Plan your trip and stick to your plan. Wear a Coast Guard approved Type III-V lifejacket and protective footwear. Make sure your water skills and experience are equal to the river and conditions.

DISTANCES OF BASTROP FROM MAJOR CITIES
Austin - 30 miles
San Marcos - 43 miles
San Antonio - 92 miles
Houston - 133 miles
Waco - 133 miles
Dallas/Ft. Worth - 220 miles

Colorado River Paddling Trail Aerial Photocard
El Camino Real Trail - Bastrop, Texas
Distance - 6 River Miles
Float Time - 1.5 - 4 hours depending on water levels and flow rates

Attachments N to Original Petition:

Left = Wilbarger Paddling Trail **Right: El Camino Real Paddling Trail**

ES Provided Maps & Lists

- List of Springs of Bastrop County
  - Documented Seeps and Springs in
    - Utley – Bastrop (Wilbarger) reach of the Colorado River
      - 12 Documented seeps and springs
    - Tahitian (El Camino Real) reach of the Colorado River
      - 11 Documented seeps and springs
    - Tahitian – Smithville reach of the Colorado River
      - 6 Documented seeps and springs
- Not considered in GMA-12 review

Attachments N to Original Petition: Springs of Bastrop County. Incorporated by reference in ES comments dated June 18, 2014.

GMA-12 - Environmental Impact Considerations

▲ Consultants provided comprehensive review of groundwater flow systems and GW/SW interaction measurements. Conclusions include:

- Aquifer and GAM grid construction & GSCP summarize GAM limitations and deficiencies.
- ES Response:
  - **ES agrees that deficiencies in the GAM need to be corrected in current GAM Improvement project to enable better understanding and quantification of pumping impacts on GW-SW interaction**

GMA-12 - Environmental Impact Considerations

▲ Summary of Consultant conclusions include:

- Spring Flow and GW-Stream Exchange are potentially important environmental issues.
- Collection of representative stream gain-loss data is expensive. Very little good gain-loss data exists in GMA.
- ES Response:
  - **Saunders/LCRA studies on Colorado River are limited but high quality.**
  - **Cost of collecting data is not a sufficient excuse for avoiding serious consideration and for delaying development of good science regarding this important issue.**

GMA-12 - Environmental Impact Considerations

- Summary of Consultant conclusions include:
  - The QSCP GAM is not a good simulator of water tables or shallow groundwater flow systems because of thick grid cells in the aquifer outcrop.
  - ES Response:
    - **ES agrees that these deficiencies in the GAM need to be corrected in current GAM Improvement project to enable better understanding and quantification of pumping impacts on GW-SW interaction**

GMA-12 - Environmental Impact Considerations

▲ Summary of Consultant conclusions include:

– TCEQ Environmental Instream Flow program is set up to protect the health of the Colorado and Brazos Rivers.

– ES Response:

- **TCEQ Instream flow standards recognize that flow is especially critical during low-flow (drought) conditions.**
- **A deficiency in Environmental Flow program is its lack of GW-SW interaction considerations in TCEQ Water Availability Modeling (WAM).**

GMA-12 - Environmental Impact Considerations

▲ Summary of Consultant conclusions include:

– River authorities are currently managing in-stream flows in Colorado and Brazos rivers.

– ES Response:

- **River authorities, like TCEQ, avoid serious consideration of GW-SW interaction due to their reliance on TCEQ Water Availability Modeling (WAM).**
- **River authorities have historically resisted consideration of GW-SW interaction issues.**

GMA-12 - Environmental Impact Considerations

- Summary of Consultant conclusions include:
  - Groundwater flow into streams can be an important contributor for helping river authorities maintain critical or subsistence flows.
  - ES Response:
    - **ES strongly agrees and provided detailed review of impacts on Environmental Flows in the Colorado River in its June 27, 2014 presentation.**
    - **ES requested a hydrographic separation for the Colorado River in ES comments dated September 21, 2015.**

Rice Study

- GAM reliably predicts trends
  - Less discharge to river with more pumping
  - Less discharge to river with longer duration
  - Less discharge to river when pumping nearer to river
- GAM does not reliably quantify trends.
  - Predicted quantity of discharge to river does not agree with empirical data.

(New Exhibit N1-2014 – Forestar's Proposal to Pump Groundwater from the Simsboro Aquifer, George Rice, December 14, 2013)

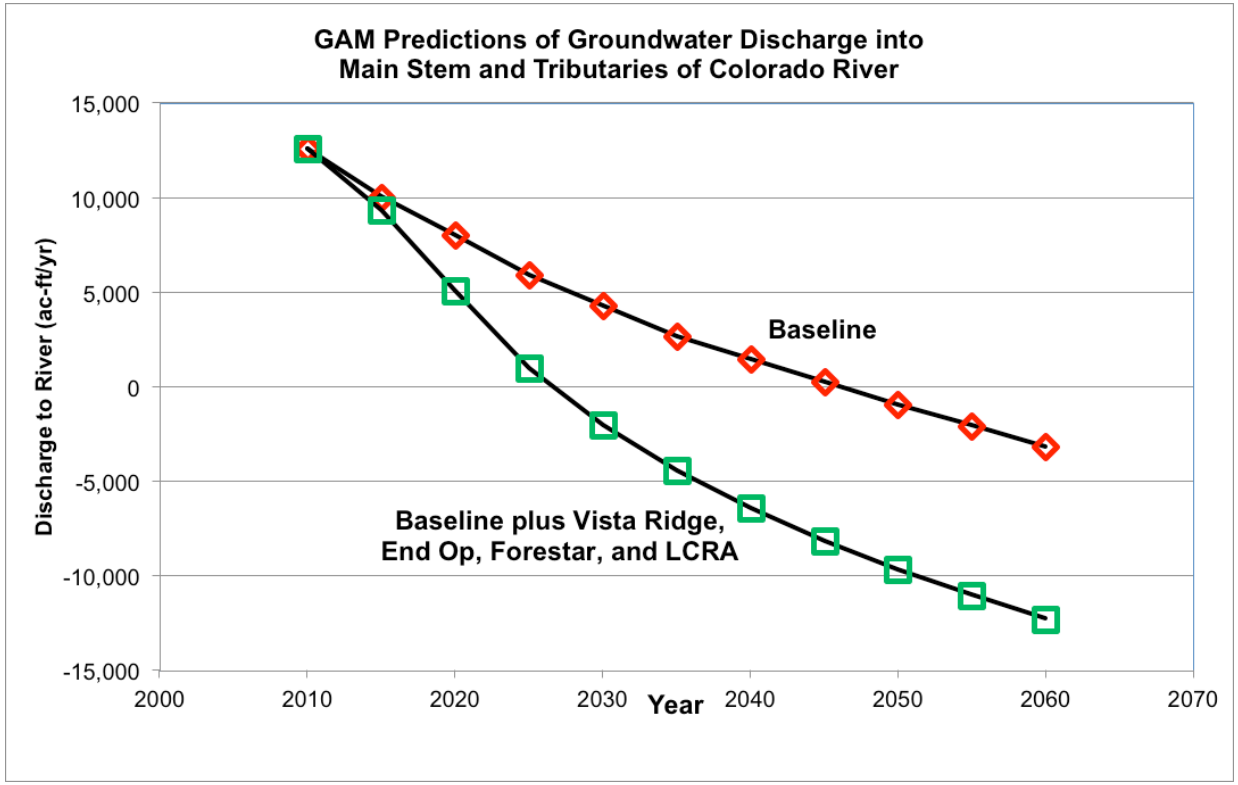
Rice Studies

- Effects of pumping on the Simsboro
  - Reduce groundwater discharge to the Colorado and Brazos rivers, thereby reducing the amount of water flowing in these streams.
  - Increase in induced leakage into Simsboro from Hooper, Calvert Bluff, Carrizo and Queen City Aquifers

New Exhibit 1-2016 – Rice, George. September 22, 2015. Effects of Vista Ridge Pumping on Groundwater and Surface Water in the Lost Pines and Post Oak Savannah GCDs.
New Exhibit 2 – 2016 – Rice, George. January 19, 2016. Supplement: Effects of Vista Ridge Pumping and Additional Pumping by End Op, Forestar, and LCRA on Groundwater and Surface Water in the Lost Pines and Post Oak Savannah GCDs.

Rice Studies

▲ GAM Trend Predictions are accurate:



(New Exhibit 2016 – Rice, George. January 19, 2016. Supplement. Effects of Vista Ridge Pumping and Additional Pumping by End Op, Forestar, and LCRA on Groundwater and Surface Water in the LPGCD and POSGCD.

Gaining River ➔Losing River

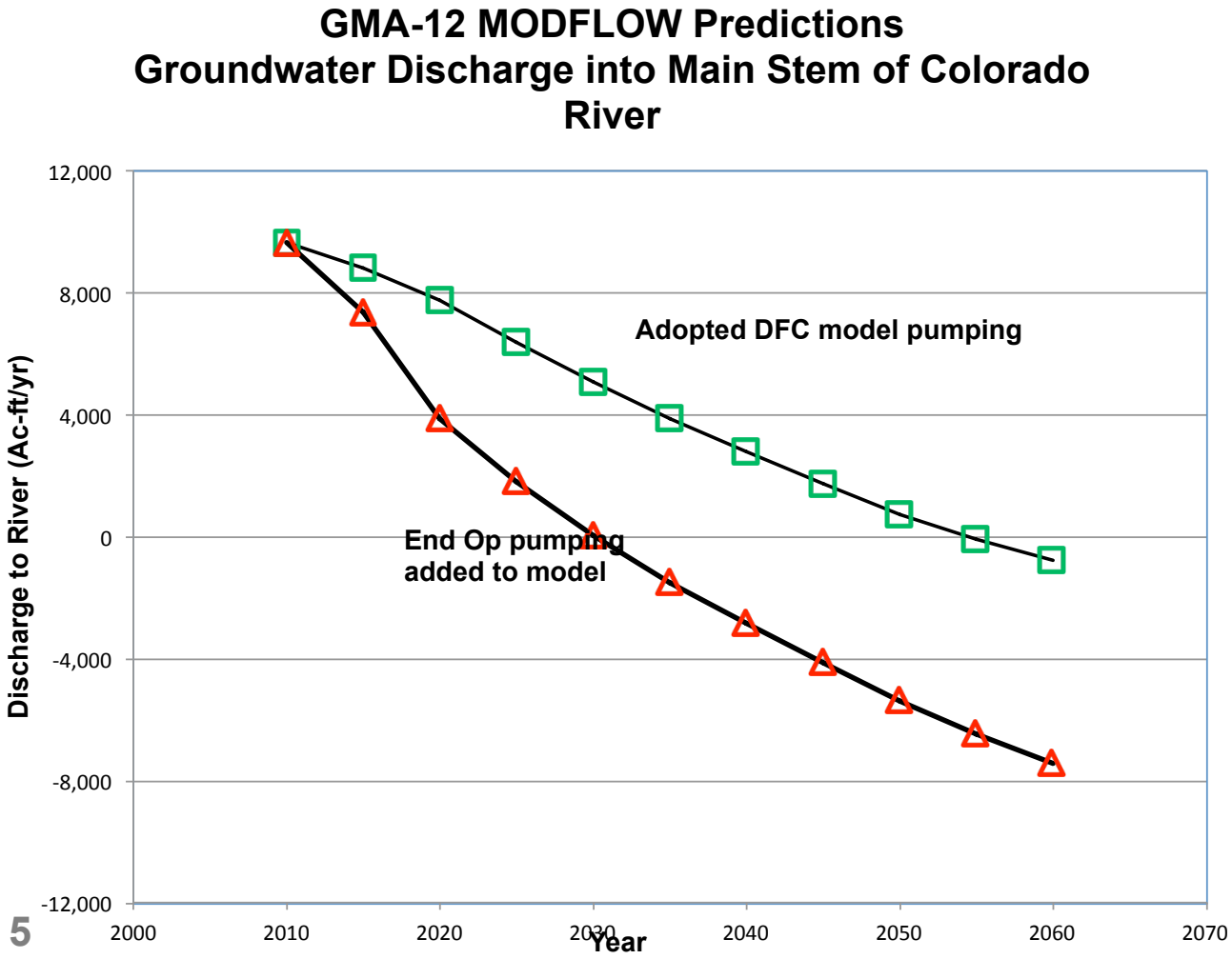
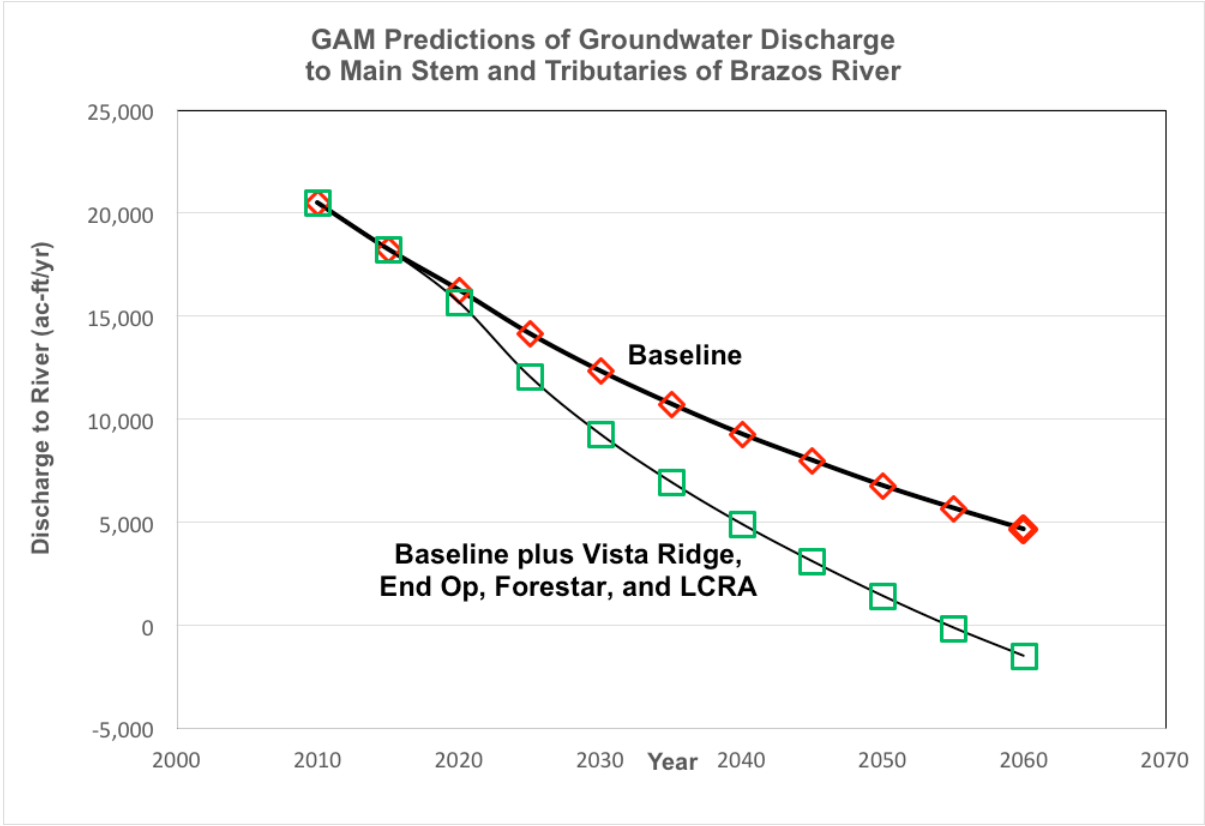


Exhibit 5

Brazos River



(New Exhibit 2016 – Rice, George. January 19, 2016. Supplement. Effects of Vista Ridge Pumping and Additional Pumping by End Op, Forestar, and LCRA on Groundwater and Surface Water in the LPGCD and POSGCD.

Environmental Flow during Drought Conditions

Critical Flow - life support during drought

River and Bay On Life Support for at least three years

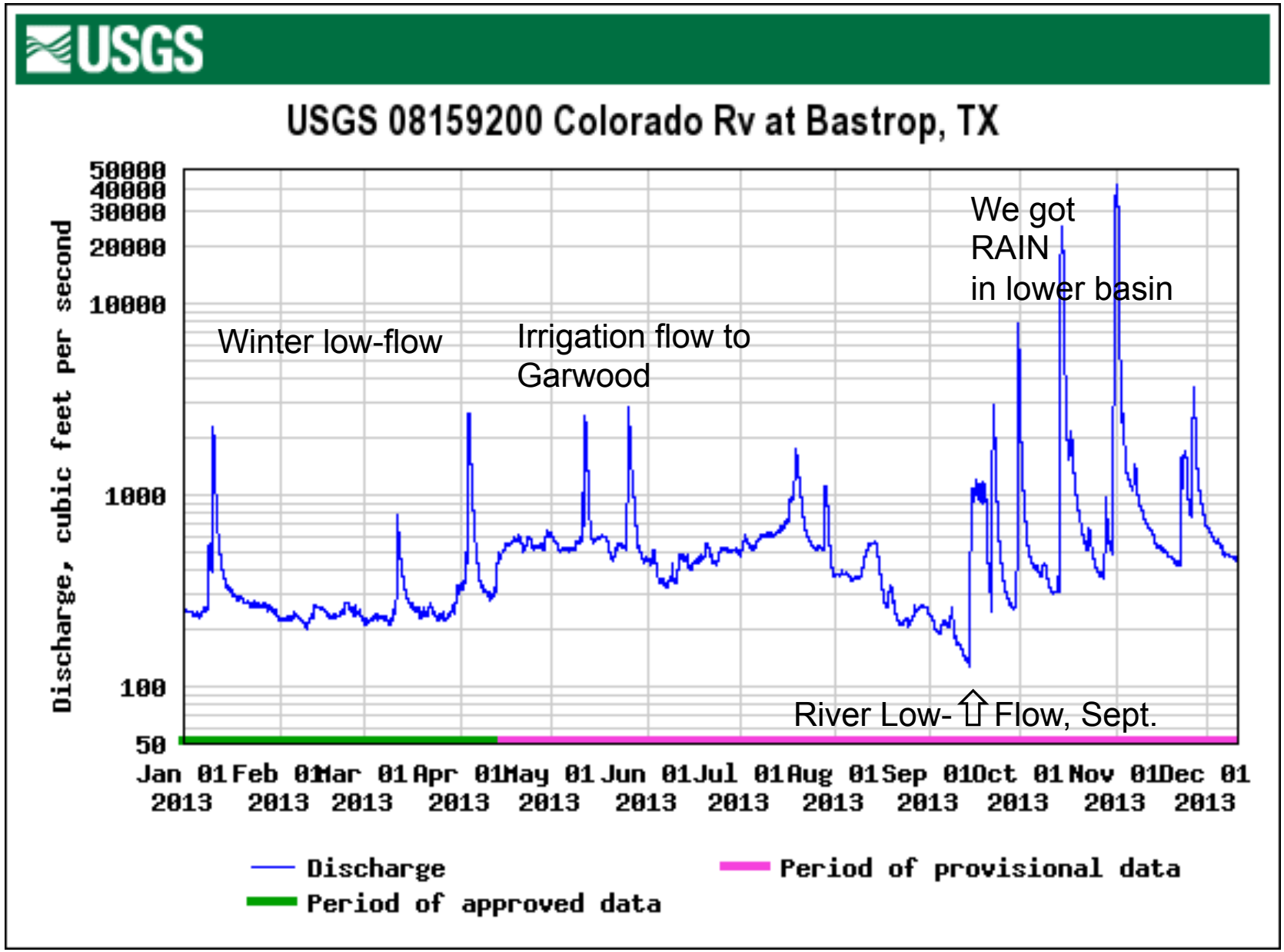
Instream Flows for the Rivers

– Bastrop Gage

- Minimum flow standard: 120 cfs (123-202 cfs)
- Low flow (Sept, 2013): 170 cfs **(Includes CoA return-flow)**
- Groundwater contribution: ~36 cfs **(30% of minimum flow)**
  - – Approximately 25,000 – 35,000 acre-feet per year.

Freshwater Inflows for the Bays

– Matagorda Bay 14,500 acre-feet/month


USGS
USGS 08159200 Colorado Rv at Bastrop, TX
Discharge, cubic feet per second
50000
40000
30000
20000
10000
1000
100
50
Winter low-flow
Irrigation flow to Garwood
We got RAIN in lower basin
River Low-⇧Flow, Sept.
Jan 01 2013
Feb 01 2013
Mar 01 2013
Apr 01 2013
May 01 2013
Jun 01 2013
Jul 01 2013
Aug 01 2013
Sep 01 2013
Oct 01 2013
Nov 01 2013
Dec 01 2013
Discharge
Period of approved data
Period of provisional data

Current DFC Review Reveals

- The GMA-12 GAM, though robust in many ways and the best tool we have available, has deficiencies:
  - **Consideration 8**: The accuracy of the GAM in predicting and quantitatively measuring drawdown in relationship to DFCs and other important parameters, such as horizontal and vertical leakage, is not well understood or quantified.
    - **ES requested information be presented to better understand the limitations in using the GAM data in comments dated October 6, 2015**.

Current DFC Review Reveals

- GMA-12 has not yet determined "sustainable" pumping levels for the aquifers as required by the Conservation Amendment to the Texas Constitution and the Texas Water Code.
- Sustainable pumping levels are needed to:
  - **Balance *conservation* and *development*, and**
  - **Protect interests and rights in private property and the rights of landowners.**
  - **Consideration 7: ES Recommendation:**
    - **A sustainable conservation standard should be defined and estimates developed before new DFCs are adopted.**
    - **Discussion of this concept should be included in Considerations 3, 4, 7, 8 and possibly 6.**

Recommended Actions:

- **Re-adopt current adopted DFCs* unchanged until the GAM improvements have been completed and adopted.**
- **Continue to consider establishing DFCs for unconfined aquifer segments.**
- **Focus discussion and analysis on how to define and develop a sustainable conservation standard to guide development of DFCs once the GAM improvements have been adopted.**

* ES does not endorse the currently adopted DFCs as being adequately and sustainably protective of the environment and the aquifers, but does recognize that this is the current legal standard and, as such, should not be changed until the GAM has been improved and better data are available on the 9 factors for consideration prior to adopting changed DFCs.

Sustainable Conservation Standard for Simsboro

- Texas Water Symposium:
  - Long-term health of the Carrizo-Wilcox Aquifer and its ability to sustainably serve the needs of a thirsty region.
  - Texas State University
    - Student Center, San Marcos, TX
    - February 11, 2016, 7:00 pm – 8:30 pm
  - Panel Moderated by Robert Mace
    - Bill Hutchinson
    - George Rice
    - James Bene
    - Steve Young

ES Requests

▲ GMA-12 DFC process include:

- **Consider impacts of reduced surface water outflows on**
  - Environment, springs and streams
  - Property rights and private wells
- **Preserve groundwater-surface water relationship**
  - Protect Environmental Flows & State Policies
- **Adaptive Management Recommendations**
  - Inform decisions and policies
  - Optimize conjunctive management
  - Avoid necessity of undoing harm
- **Set different DFCs for substantially different geographic areas**

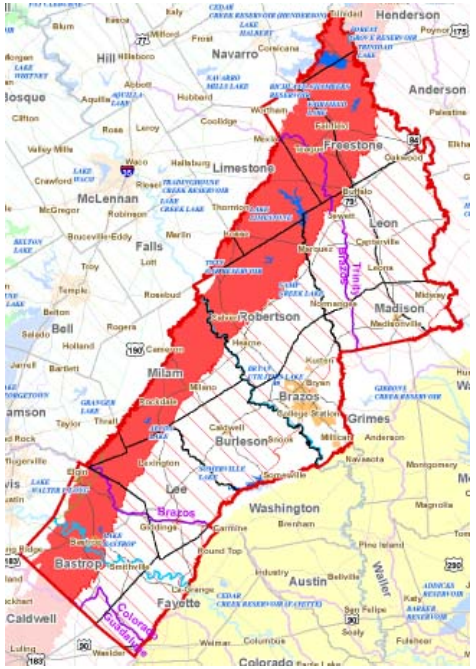
ES Requests

Adaptive Management by GMA and GCDs

- GCDs install monitoring projects to provide empirical data to detect change in the groundwater-surface water relationship in the areas of concern.
  - Develop and implement in cooperation with the river authorities, USGS, and, to the extent necessary, the regional water planning groups in the management area.
- GCDs establish triggers linked to specific actions to mitigate and limit any potential damage to the rivers, streams, springs and aquifers of the region (adaptive management).

It's GMA-12's Responsibility to the Citizens of our Region

- **To establish Desired Future Conditions** (DFC) for the aquifers in our region that protect the groundwater, surface water, and environmental resource of the area *in perpetuity*.
- **DFC's that:**
  - **Protect**
    - **the Aquifers**
    - **rivers & streams**
    - **Springs**
    - **Surface features (Trees, etc.)**
  - **Balance**
    - **Conservation and**
    - **Development**
  - **Provide needs of**
    - **Local Counties**
    - **Export where possible**



References

- “Attachments” are to Original Petition
- “Exhibits” are to Hearing Documents
- “New Exhibits” are provided
- See ES Website Page: http://www.environstewardship.org/2012/04/21/groundwater-management-area-12-environmental-stewardships-petition-appealing-desired-future-conditions/#more-506

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