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MEMORANDUM

To:	Vic Ramirez, LCRA	**Date:**	July 21, 2011
From:	Elaine Darby, Anchor QEA Kirk Dean, Parsons Monica Suarez, Parsons Emily Chen, Anchor QEA	**Project:**	090577-01.01
Cc:	Lisa Hatzenbuehler, LCRA John Wedig, LCRA Jennifer Benaman, Anchor QEA Randy Palachek, Parsons		
Re:	Colorado River Environmental Modeling System (CREMS) Phase 3 Scenarios-FINAL		

INTRODUCTION

The objective of Colorado River Modeling System (CREMS) project is to develop comprehensive, linked watershed and water quality modeling tools for the Highland Lakes located on the Colorado River. Phases 1 and 2 focused on Lake Travis (completed in 2009), Phase 3 on Lake Marble Falls, Lake Lyndon Baines Johnson (LBJ),and Inks Lake (completed in 2011), and Phase 4 on Lake Buchanan (model development to begin in 2011). The CREMS project was designed to help diagnose existing water quality issues, discern water quality trends, and predict the consequences of various management decisions and associated actions on the water quality of the Highland Lakes (Parsons and Anchor QEA 2011). This memorandum summarizes the scenarios evaluated using the watershed and lake water quality models developed for Inks Lake, Lake LBJ, and Lake Marble Falls. The goal was to investigate the response of water quality in the lakes to potential changes in their respective watersheds. Specifically, nine scenarios focused on three variables and combinations of these variables:

- Changes in wastewater permitted flows and concentrations

- An increase of urbanization in subbasins undergoing potential development within the lakes' watersheds, with and without the Highland Lakes Watershed Ordinance (HLWO) in place
- An increase of nutrient and organic loadings at the upstream boundary of each lake (e.g., the load coming into Inks Lake from Lake Buchanan, which represents the load from Lake Buchanan)

The Phase 3 CREMS models are comprised of linked watershed and lake water quality models. Details on the model development, calibration, and model sensitivity can be found in the *Colorado River Environmental Modeling System Phase 3: Lake LBJ, Lake Marble Falls, Inks Lake Final Report* (Parsons and Anchor QEA 2011).

SCENARIO DEVELOPMENT

The scenarios considered changes in each of the three variables described above, as well as cumulative impacts from a combination of different changes occurring "simultaneously" over the watershed. The nine scenarios selected for simulation are detailed in Table 1. Of the nine scenarios, three (#1, #2, and #3) involved changes in concentrations and flows of Texas Land Application Permits (TLAPs) and point source discharges, two (#4 and #5) were a function solely of urbanization, one (#6) covered only an increase in upstream loading, two (#7 and #8) involved an increase in TLAPs and point source discharges and urbanization, and one (#9) scenario included changes in all three variables.

For all of the scenarios simulated, the impact was measured relative to the base case model result, which represented "current" conditions. The hydrologic condition that was simulated for the scenarios in the model was the same period as the calibration (1984 to 2008). This 25-year period represented a range of low, high, and average precipitation conditions (Figures 1a, 1b and 1c). By running the future scenarios using the same hydrology as the calibration, it was possible to observe relative impacts in the lake to changes in the watershed during both wet and dry periods.

REPRESENTATION OF THE SCENARIOS WITHIN THE MODEL FRAMEWORK

Increases in Point Source Discharges

Of the nine scenarios, six involved a change in TLAP and/or point source discharge flows and/or concentrations. For these six future scenarios, it was assumed that current TLAP permit holders were allowed to discharge at their permitted flows into streams within their watersheds or directly into the lakes at locations closest to those in their permit applications. Specification of the point sources in the lake water quality model required information on location (spatially and at depth), discharge rate, and effluent concentration. Details of this information for each watershed are provided below.

Three existing permit holders are located in the Inks Lake watershed:

- Camp Longhorn Capitol, Inc. – TLAP
- Texas Parks & Wildlife – TLAP
- Eagles Wings Retreat Center, Inc. – TLAP

Currently, all are TLAPs and therefore, they do not directly discharge into the waters of the Inks Basin. For the changes in discharge scenarios, TLAPs were set to discharge in the watershed model at their existing permitted flows and concentrations (see Table 2 and Figure 2)[1].

The Lake LBJ watershed contains nine permit holders[2] (see Table 3 and Figure 3) consisting of both TLAP and Texas Pollution Discharge Elimination System (TPDES) permit holders:

- Lake LBJ MUD No.1 - TLAP
- Aqua Sources Utilities - TPDES
- Kingsland MUD - TPDES
- Camp Longhorn, Inc. - TLAP
- City of Junction - TPDES
- City of Mason - TPDES
- City of Rocksprings – TPDES
- City of Llano (permit issued June 30, 2010)[3] - TLAP
- Murpaks, Inc.[4] - TPDES

[1] Greensmiths, Inc. permit issued November 29, 2010, but not included in scenarios.
[2] Because the T.C. Ferguson Power Plant discharge is overwhelmingly composed of once-through cooling water withdrawn from Lake LBJ, it was not considered a point source in these scenarios.
[3] For scenario development, this discharge was included in the watershed model by combining the discharge with the nearest point source (City of Mason).
[4] Now permitted as Grayson Industries, but will remain as Murpaks in this memo for consistency with the Phase 3 Report (Parsons and Anchor QEA 2011)

Directly discharging to the lake are two point sources: AquaSource Utilities and Kingsland MUD.

No existing continuously discharging point sources are located in the watershed of Lake Marble Falls. However, for the point source scenarios the following TLAP permit holders were included as directly discharging into the lake model (see Table 4):

- City of Meadowlakes - TLAP
- City of Marble Falls - TLAP
- JM Huber - TLAP

Figure 4a shows the locations of these permit holders in the watershed and Figure 4b illustrates the model segments into which the discharges were assigned for the scenarios. Discharges were placed in the lake "at depth" (about a meter above the sediment bed at all locations).

For all discharge scenarios, the concentrations of pollutants in the effluent were based on measured levels (from discharge monitoring reports [DMR]), current TPDES permit limits, estimates based on effluent measurements during the Lower Colorado River Authority-San Antonio Water Systems Project (LSWP) Colorado River low-flow survey (QEA 2004), or professional judgment if concentrations were not available. To be conservative, all phosphorus from the discharge was assumed to be immediately "available" for algal growth when it enters the lake (i.e., total phosphorus [TP] is all dissolved orthophosphate [PO_4]). The exception was for two dischargers to Lake LBJ when measured levels (e.g., from DMR values) were used in the scenarios for any constituents where information was available. In addition, total suspended solids were assumed to be all inorganic suspended solids when dischargers were included as directly discharging into the lake model. Tables 2, 3, and 4 list the assumptions for point source discharge concentrations for the base case ("current" conditions), Scenario 1, and Scenario 3 for Inks Lake, Lake LBJ, and Lake Marble Falls, respectively.

In Scenario 1, TLAP discharges were converted to direct discharges and TLAP and TPDES dischargers were assumed to be at fully permitted flows and concentrations. Scenario 2 investigated potential impacts of current TLAPs discharging during wet weather conditions to streams in the watershed or directly into the lake. The wet weather conditions for

Scenario 2 were defined through a review of SWAT model predicted flows for the Llano River (for Lake LBJ) and Backbone Creek (for Lake Marble Falls). Similar to the Lake Travis modeling approach for determining wet weather flows, probability plots were developed for the Llano River and Backbone Creek flows, and flows at approximately the 88th percentile were chosen to represent wet weather conditions (see Figures 5 and 6). For the Llano River, the 88th percentile was approximately 500 cubic feet per second (cfs). For Backbone Creek, the 88th percentile was approximately 8 cfs. Scenario 2 was set up to allow land application permittees to discharge at fully permitted flows on days when these thresholds were met or exceeded; all other discharges were maintained at the values used in the base case for each of the lakes.

For Scenario 3, TLAP discharges were converted to direct discharges and TLAP and TPDES dischargers were assumed to be at fully permitted flows and advanced treatment concentrations (see Tables 2, 3, and 4 for assumed concentrations).

Increases in Urbanization

Five scenarios evaluated an increase in urbanization in the lakes' watersheds 20 years into the future on receiving water quality (for details in assumptions made regarding urbanization, see Appendix A). Three of the scenarios (#4, #7, and #9) represented future urbanization without the HLWO in place and two (#5 and #8) assumed the HLWO to be in place. Urbanization was assumed to occur in the most common land uses that bordered currently urbanized land: brushy-rangeland, evergreen forest, and grass-rangeland. Development was assumed to increase homogeneously among all the existing developed land uses, except when the "current" (calibration) land use grid did not have an urbanized category. For those subbasins, urbanization was modeled as low density residential (<0.5 unit/acre, or on average 12% impervious). As a result, urbanization in the Lake LBJ watershed increased from 0.9% in the "current" conditions (i.e., base case) to 2.2% in the future scenario runs. For the Inks Lake and Lake Marble Falls watersheds, urbanization increased from 5.1% to 15.7% and 9.0% to 22.9%, respectively. Because the calibrations of the watershed models used data from subbasins where most of the land was not urbanized or whose urbanization was grandfathered and is not affected by the HLWO, the model parameters established during the calibrations of the watershed models reflect conditions without the HLWO in place. Therefore, urban land changes in the models for these scenarios represent urbanization occurring without the HLWO in place. An adjustment to the amount of load based on best professional judgment was required for Scenarios 5 and 8 to simulate the impact of the HLWO on reducing pollutant loading to the lakes.

The scenarios representing future urbanization with the HLWO in place (Scenarios 5 and 8) were created in several steps. First, the differences in nutrient and organic loads between the base case run and the future urbanization run (Scenario 4) were presumed to be due to urbanization without the HLWO. Then, subbasins with at least 25% of their area within the boundary of the HLWO were identified (Figures 7 to 9). Next, best management practices (BMPs), in accordance with the HLWO, were assumed to be 70% efficient, meaning that 30% of the load from the urban area enters the lake[5]. Finally, future loads with urbanization and the HLWO in place were calculated as the sum of the calibration load from the watershed model, the increase in load due to increased urbanization (for subbasins unaffected by the HLWO), and 30% of the increase in load from due to increased urbanization (for subbasins within the HLWO boundary). The BMPs were applied to each daily load and each subbasin included in the lake model; on days when future urbanization loads were lower than those for the base case, the future urbanization loads were used. The same steps were followed for Scenario 8, but because the Inks Lake and Lake LBJ models included point sources in the watershed model, the increase in load due to urbanization was calculated as the difference between the future urbanization with permitted point sources run (Scenario 7) and the run with current urbanization and point sources at permitted values (Scenario 1).

Increases in Upstream Boundary Conditions

Two model scenarios (#6 and #9) investigated an increase of upstream concentrations by 10% to simulate potential future loadings coming over each dam. The upstream loadings of algae, inorganic suspended solids (ISS), NH_4, NO_x, all organic matter groups, and PO_4 were increased.

Changes in Loadings Relative to Base Case

Each of the scenarios described above were developed to investigate the potential impact of water management within the Inks Lake, Lake LBJ, and Lake Marble Falls watersheds. The

[5] It should be noted that the BMPs treat runoff only in the newly urbanized areas, and that BMP retrofitting in established neighborhoods is not being modeled.

changes in loadings to each lake for each scenario are shown in a series of bar charts illustrating the relative percent change to the base case (e.g., calibration run).

The differences in constituent loadings relative to the base case for the scenarios are shown for Inks Lake, Lake LBJ, and Lake Marble Falls in Figures 10, 11, and 12 respectively.

Nutrient Loadings from Septic Systems

A review of 1,130 septic system inspection reports for 2007 and 2008 for areas around the Highland Lakes showed that the septic system failure rate (as indicated by surfacing effluent) was approximately 1% (Carter 2009, Personal Communication). Furthermore, in the area around the lakes, the following two factors provide greater environmental protection: (1) aerobic treatment units which produce secondary quality effluent, and (2) disposal of effluent into shallow, low-pressure dosed drainfields and drip irrigation drainfields. Consequently, nutrient loadings from septic systems are anticipated to be negligible and, thus, were not included in the scenario analysis.

SCENARIO RESULTS

Impacts of the changes in the watershed on water quality in each lake were assessed at the lake segment closest to each dam for Inks Lake and Lake Marble Falls. For Lake LBJ, the impacts were assessed at the segment closest to Wirtz Dam (Segment 54), at Horseshoe Bay Cove (Segment 100), at the confluence with Sandy Creek (Segment 41), below the confluence with the Llano River (Segment 30), and in the Colorado River arm above the Llano confluence (Segment 24). The assessment compared average and maximum of predicted daily average chlorophyll-*a* concentrations in the top 2 meters of the water column for each scenario during the entire year to the model output from the base case (or calibration run). Chlorophyll-*a* concentrations were used to determine impact because algal blooms are potentially more important to stakeholders and because the parameter is linked to changes in nutrient loadings. The model was set up to print daily average results to an output file for the 25-year simulation period; for ease of comparison, however, the average and maximum of the daily average chlorophyll-*a* concentrations over the course of the year for the entire run were used in the presentation of the model results below. Overall (i.e. long-term) average and maxima were computed from average and maximum daily mean concentrations for each year.

Model results are shown as percent changes in chlorophyll-*a* concentrations from the current concentrations over the entire 25-year simulation period. These percent changes can be considered relative to the absolute surface water chlorophyll-*a* concentrations for the base case.[6] Table 5 presents the daily average and maximum surface water chlorophyll-*a* concentrations for the 25-year base case simulation for each of the lakes, along with proposed TCEQ nutrient criteria (as chlorophyll-*a*) for Lake LBJ and Lake Marble Falls (30 TAC §307.10(6)). Tables 6 through 9 list scenario results for Inks Lake, Tables 10 through 29 list scenario results for Lake LBJ, and Tables 30 through 33 list scenario results for Lake Marble Falls.

Inks Lake

Impact of Increases to Point Source Discharges (Scenarios 1 through 3)

Scenario 1 allowed the three TLAPs in the Inks Lake SWAT model (Table 2) to discharge at permitted land application flows and concentrations, into Inks Lake tributaries rather than land application. Model results for Scenario 1 indicated that allowing the current TLAPs to continuously discharge does not significantly impact the resulting chlorophyll-*a* concentrations in Inks Lake (Tables 6 through 9). Overall increases in average and maximum concentrations were less than 0.1%. This result is as expected since Inks Lake acts as a "flow-through" reservoir, with the majority of the loadings from Lake Buchanan. In addition, the TLAPs discharged into streams and did not discharge directly to the lake, which allowed the discharge to attenuate during travel time to the lake and further reduced any impact of these potential point sources on lake chlorophyll-*a* concentrations.

Scenario 2 was not run for Inks Lake because results from Scenario 1 indicated that allowing the existing TLAPs to discharge continuously did not have a significant impact on the lake chlorophyll-*a* concentrations. Intermittent wet weather discharges (Scenario 2) would result in lower loadings from point sources than those for Scenario 1 and therefore, also would not have a significant impact.

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[6] The model results were evaluated by pairing the scenario concentration and base case concentration for each simulated year, dividing the difference between the scenario concentration and base case concentration by the base case concentration and multiplying by 100, and averaging the percent changes for each year over the entire 25-year simulation. In this manner, the average percent change captures the variability in scenario results during the entire run, which includes different hydrologic conditions. The percent change is not the change in the overall average (i.e., not the percent change between the average scenario and average base case results) and should not, therefore, be used directly to compute an absolute surface water chlorophyll-*a* concentration but instead be used in a manner relative to other scenario results.

Scenario 3 allowed the current TLAPs to continuously discharge at fully permitted application flows and assumed advanced treatment concentrations. Overall, increases in average and maximum concentrations were less than 0.1%.

Impact of Increases in Urbanization (Scenarios 4 and 5)

For scenarios that included an increase in urbanization, the model predicted larger increases in surface chlorophyll-*a* concentrations than those simulated for Scenario 1 (Tables 6 through 9). Those increases, however, were still small. Increasing the urbanization in the Inks watershed without the HLWO in place (Scenario 4) resulted in an increase of the average chlorophyll-*a* concentration in the top 2 meters of 1.4% and a maximum concentration 0.9% higher than for the base case. Having the HLWO in place in the future (Scenario 5) resulted in average and maximum concentrations that were respectively 0.8% and 0.6% higher than their counterparts for the base case. These relatively small increases in chlorophyll-*a* reflect the small amount of runoff from the watershed compared to inflows from the upstream boundary.

Impact of Increases in Upstream Boundary Conditions (Scenario 6)

For this scenario, the upstream concentrations of inorganic suspended solids, nutrients, organic matter, and algal groups were increased by 10%. This scenario resulted in increases to the annual average chlorophyll-*a* of between 7.8% and 10.3%. The overall percent change to mean and maximum surface chlorophyll-*a* concentrations was 9.3% and 10.0%, respectively (Tables 6 through 9). In this case, the increase in upstream loading resulted in an almost equivalent increase in chlorophyll-*a* concentrations at the downstream end of the lake.

Impact of Scenario Combinations (Point Source – Constant, Urbanization, and Increased Upstream Loading) (Scenarios 7 through 9)

The results of the combination scenarios were driven primarily by increases in upstream and watershed loadings. Scenario 7 results showed only a slight increase in chlorophyll-*a* concentrations over Scenario 4 (average increase of 1.5% in overall annual mean concentration), reflecting the very slight impact of point sources on lake conditions. Similarly, Scenario 8 resulted in concentrations that are slightly higher than those obtained for Scenario 5. The greatest change in chlorophyll-*a* concentrations in the lake surface layer was observed for Scenario 9 because it combined an increase in upstream loadings with increases in runoff due to urbanization without HWLO in place and wastewater treatment discharges. Results for Scenario 9 showed increases in the individual annual average chlorophyll-*a* between 7.9% and 15.5%, with an increase of 10.7% for the 25-year simulation.

Lake LBJ

Impact of Increases to Point Source Discharges (Scenarios 1 through 3)

Scenario 1 involved setting the pollutant loads from continuous point source discharges to their permit limits and allowing TLAPs to continuously discharge full permitted loads to Lake LBJ tributaries. This scenario predicted that the long-term average chlorophyll-*a* concentration would increase from 5% (in the upstream section) to 36% (near the Sandy Creek confluence). At the station nearest Wirtz Dam, Scenario 1 resulted in a 29% increase in average chlorophyll-*a* levels. The long-term average of the annual maximum chlorophyll-*a* concentration increased by 5% to 23% under Scenario 1 (see Tables 10 through 29).

Scenario 2 simulated additional point source loading from TLAPs at permitted levels in wet weather conditions. This increased loading resulted in an increase of 3 to 5% in long-term average chlorophyll-*a* concentrations, and a 2 to 4% increase in maximum annual chlorophyll-*a* concentrations.

Scenario 3 simulated the reductions in nutrient loading from TLAPs and continuous point source discharges due to advanced wastewater treatment. In this scenario, long-term average chlorophyll-*a* concentrations declined by 14% to 23%. Annual maximum chlorophyll-*a* concentrations declined by 5% to 10%, on average.

Impact of Increases in Urbanization (Scenarios 4 and 5)

Increases in urbanization without the HLWO in effect resulted in long-term average chlorophyll-*a* concentration increases of 3% to 9%, with an 8% increase at the segment nearest Wirtz Dam. Also under this scenario, the long-term average annual maximum chlorophyll-*a* concentration increased by 5% (in upstream segments) to 10% (at the segment nearest Wirtz Dam), as shown in Tables 10 through 29.

With the same increases in urbanization, but with the HLWO in effect, the long-term average and annual maximum chlorophyll-*a* concentrations increased by only 1% to 3%[7].

Impact of Increases in Upstream Boundary Conditions (Scenario 6)

A 10% increase in loading from Inks Lake resulted in long-term average chlorophyll-*a* concentration increases of 7% (upstream of the Llano confluence) to 3% (near Wirtz Dam). The increases in annual maximum chlorophyll-*a* were similar.

Impact of Scenario Combinations (Point Source – Constant, Urbanization, and Increased Upstream Loading) (Scenarios 7 through 9)

Scenario 7 reflects the combined increases of nutrient loading from point sources at fully permitted levels and increased urbanization, without the HLWO in effect. Under this scenario, the long-term average chlorophyll-*a* concentrations were projected to increase by 8% (above the Llano confluence) to 44% (at Sandy Creek confluence), with a 40% increase in the segment nearest Wirtz Dam. Annual maximum chlorophyll-*a* concentrations were projected to increase by 10% to 34%, on average.

Scenario 8 reflects the combined increases of nutrient loading from point sources at fully permitted levels and increased urbanization, with the HLWO in effect. The long-term average chlorophyll-*a* concentrations were projected to increase by 6% (above the Llano confluence) to 38% (at Sandy Creek confluence), with a 34% increase in the segment nearest Wirtz Dam. Annual maximum chlorophyll-*a* concentrations were projected to increase by 5% to 24%, on average.

Scenario 9 reflects the combined increases of nutrient loading from point sources at fully permitted levels, a 10% increase in loading from upstream, and increased urbanization without the HLWO in effect. Under this scenario, the long-term average chlorophyll-*a* concentrations were projected to increase by 15% (above the Llano confluence) to 47% (at Sandy Creek confluence), with a 41% increase in the segment nearest Wirtz Dam. Annual

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[7] The loads entering the lake from the watershed included the impact of the immediate subbasin entering the lake, as well as all upstream subbasins that flow into this most-downstream subbasin. However, the majority of the predicted urbanization in the LBJ watershed occurred in subbasins near the lake. Consequently, we assumed that if the most downstream subbasin has at least 25% of its area within the HLWO, then the increase in loadings observed due to urbanization occurred within the ordinance boundaries and the 70% reduction to the change in load was applied.

maximum chlorophyll-*a* concentrations were projected to increase by 14% to 35%, on average.

Other Observations

In most cases, the impacts of the increases in loading under various individual scenarios (Scenarios 1 through 6) produced roughly additive impacts on average and maximum chlorophyll-*a* levels in the combined scenarios (Scenario 7 through 9). Thus, it appears likely that the impacts of additional scenarios can be evaluated individually, with the cumulative effects on chlorophyll-*a* reasonably estimated by addition. This relationship may not hold when nutrient levels are increased drastically, or if the water quality impacts are evaluated over a shorter time frame.

Of the five segments modeled under these scenarios, Segment 41 (at the confluence with Sandy Creek) was often the most sensitive to changes in loading. Segment 54 (near Wirtz Dam) was also fairly sensitive to changes in loading, except for those from upstream sources in the Colorado River. The chlorophyll-*a* levels in Horseshoe Bay Cove were similar to those near Wirtz Dam.

Lake Marble Falls

Impact of Increases to Point Source Discharges (Scenarios 1 through 3)

Point sources in the Lake Marble Falls watershed were simulated as direct discharges into the lake at model segment 18 (City of Marble Falls), segment 22 (City of Meadowlakes), and segment 26 (JM Huber) as shown in Figure 4b. Increasing each of these discharges to fully permitted flows and assumed or permitted concentrations (Scenario 1) increased the annual average chlorophyll-*a* in the top 2 meters 9.9% to 100.8% with an average over all 25 years of 40.4% over base case conditions. This increase was driven by the increase in loading to Lake Marble Falls when the three TLAP holders convert to continuously discharging at fully permitted conditions. The assumption of direct discharge into the lake and relative close proximity of the point sources to the assessment location (segment 26) may also influence the results. In Scenario 2, all three dischargers (currently TLAP holders) remained at zero flow except under wet weather conditions. Minor increases in chlorophyll-*a* were noted under these conditions; the annual average chlorophyll-*a* in the top 2 meters increased from 0.3% to 4.8% with an average increase over all 25 years of 1.7% compared to base case conditions.

Scenario 3 was designed to investigate impacts on water quality if TLAP and continuous dischargers were required to institute advanced treatment to reduce constituent levels in the discharge. In this scenario, the annual average chlorophyll-*a* in the top 2 meters increased from 2.0% to 20.1% with an average over all 25 years of 8.3% increase over base case conditions.

Impact of Increases in Urbanization (Scenarios 4 and 5)

Changes in urbanization within the Lake Marble Falls watershed resulted in an increase in chlorophyll-*a* concentrations in the lake. In Scenario 4, the annual average chlorophyll-*a* increased from 0.1% to 8.1% with an average over all 25 years of 2.2% increase over base case conditions. This increase reflected the relatively low amount of runoff from the watershed compared to the inflows from upstream (Lake LBJ), short residence times in the lake after high flow events, and predicted development occurring at some distances from the lake (specifically in the area of US 281 and Highway 71). Scenario 4 represented conditions without the HLWO; Scenario 5 included the HLWO. In Scenario 5, the increase in the annual average chlorophyll-*a* in the top 2 meters was minor, ranging from 0.0% to 2.5% with an average over all 25 years of 0.7% increase.

Impact of Increases in Upstream Boundary Conditions (Scenario 6)

Upstream concentrations of ISS, PO_4, NH_4, NO_x and all organic matter and algal groups were increased 10%. As expected with Lake Marble Falls acting as a "flow-through" reservoir, the annual average chlorophyll-*a* concentrations increased on average 10.0%. The increase compared to current conditions ranged from 8.1% to 11.3% through the 25-year simulation.

Impact of Scenario Combinations (Point Source – Constant, Urbanization, and Increased Upstream Loading) (Scenarios 7 through 9)

The results of the combination scenarios were driven primarily from increased point sources, reflecting Scenario 1 results. Scenario 7 (41.3% annual average increase over base case) results showed an increase in chlorophyll-*a* concentrations over Scenario 1 (40.4% annual average increase over base case), reflecting the influence of increased urbanization in the basin. In Scenario 8 (HLWO in place), chlorophyll-*a* increases ranged from 9.9% to 101.8% with an annual average of 40.7% increase over the base case. Scenario 9 (fully permitted point sources, increased urbanization, and increased upstream loadings) results showed an average annual increase of 50.9% over the 25-year simulation. Increases ranged from 18.9% to 114.3%. Results are shown in Tables 30 through 33.

CONCLUSIONS

From the nine scenarios performed using the CREMS Phase 3 watershed and water quality models, the following conclusions were made:

- Model results indicate increased point source dischargers would have a large impact on lake water quality in Lake LBJ and Lake Marble Falls. Results were sensitive to assumptions made regarding effluent concentrations and nutrient availability. Inks Lake chlorophyll-*a* levels were only significantly impacted by increases from upstream loadings, as the assumptions made for point sources in this basin are relatively small (0.01 to 0.05 million gallons per day [MGD] at fully permitted conditions) and increases in urbanization in the basin were relatively small (130 acres per year urbanized over the next 20 years for a total of 3,853 urbanized acres out of 24,601 acres). Results for Inks Lake were sensitive to the assumptions made and may change if different discharges or urbanization scenarios were simulated.
- Allowing TLAP dischargers to discharge during wet weather increased chlorophyll-*a* slightly in Inks Lake and Lake Marble Falls (1.4% to 1.7% increases in annual averages, respectively) and more so in Lake LBJ (3 to 5% increase in chlorophyll-*a*) compared to base case conditions.
- Instituting advanced treatment for continuous dischargers in Lake LBJ watershed reduced chlorophyll-*a* concentrations in the lake (approximately 14% to 23% lower concentrations from base case, on average). At Segment 54, average concentrations over the 25-year simulation dropped to 3.9 μg/L with advanced treatment from 4.4 μg/L under base case conditions.
- The urbanization simulated resulted in some impact on water quality (through increased runoff and loadings) in Inks Lake (1.4% higher concentrations than base case) and Lake Marble Falls (2.2% higher concentrations than base case). The urbanization simulated in Lake LBJ watershed increased average chlorophyll-*a* concentrations (average annual increase over 25-year simulation of 3 to 9%) with the HLWO in place, decreasing the impact to 1% to 3% average annual increase over the 25-year simulation. Future urbanization impacts in all of the watersheds can be controlled to some degree with the HLWO.

- Increasing upstream loadings impacted the chlorophyll-*a* concentrations in all three lakes.

REFERENCES

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Parsons and Anchor QEA, 2011. Colorado River Environmental Modeling System Phase 3: Lake LBJ, Lake Marble Falls, Inks Lake Final Report. March, 2011.

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TABLES

Table 1
Scenario Overview

Scenario	Point Sources				Urbanization			Upstream Loadings	
	Continuous discharges		TLAPs						
	Flows	Concentrations	Flows	Concentrations	Current land use	Increased urbanization HLWO not in-place	Increased urbanization HLWO in-place	Current	Increased loading by 10%
0. Base Case	DMR	DMR	0	0	x			x	
1. Point sources (constant discharge, incl. WWTPs and current/pending land applications) fully permitted	FP	FP	FP	FP	x			x	
2. Point sources (wet-weather discharge) only	DMR	DMR	FP in WW	FP	x			x	
3. Point sources with advanced treatment	FP	AT	FP	AT	x			x	
4. Increased urbanization without Highland Lakes Watershed Ordinance (HLWO) in place	DMR	DMR	0	0		x		x	
5. Increased urbanization with HLWO in place	DMR	DMR	0	0			x	x	
6. Increased upstream loading	DMR	DMR	0	0	x				x
7. All point sources & increased urbanization without HLWO in place (Scenarios 1+4)	FP	FP	FP	FP		x		x	
8. All point sources & increased urbanization with HLWO in place (Scenarios 1+5)	FP	FP	FP	FP			x	x	
9. All point sources fully permitted, increased urbanization without HLWO in place & increased upstream loading (Scenarios 1+4+6)	FP	FP	FP	FP		x			x

Notes:

DMR = reported flows and concentrations from discharge monitoring reports or Colorado River LSWP low-flow survey (QEA 2004)

FP = at full permit limits

WW = wet weather conditions only

AT = advanced treatment (5 mg/L BOD, 2 mg/L Ammonium Nitrogen, 0.15 mg/L Total P)

Wet weather flow triggers for Lake LBJ (500 cfs at Llano River) and Lake Marble Falls (8 cfs at Backbone Creek)

Table 2
Inks Lake Point Sources Assumed Flows and Concentrations

Base Case Values													
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TLAP	13460001	Camp Longhorn Capital Inc.	0	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	14199001	Texas Parks and Wildlife	0	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	14622001	Eagle's Wings Retreat Center	0	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	350000	Greensmiths Inc	0	5	10	2	3.2	4	3	20	0.5	0.2

Fully Permitted Values													
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TLAP	13460001	Camp Longhorn Capital Inc.	0.03/0.0021	100	15	2	1	4	1	20	0	0
SWAT	TLAP	14199001	Texas Parks and Wildlife	0.05	20	20	2	1	4	1	20	0	0
SWAT	TLAP	14622001	Eagle's Wings Retreat Center	0.01	20	20	2	1	4	1	20	0	0
SWAT	TLAP	350000	Greensmiths Inc	0.025	10	15	2	1	4	1	20	0	0

Advanced Treatment													
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TLAP	13460001	Camp Longhorn Capital Inc.	0.03/0.0021	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	14199001	Texas Parks and Wildlife	0.05	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	14622001	Eagle's Wings Retreat Center	0.01	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	350000	Greensmiths Inc	0.025	5	5	2	0.15	4	0.15	4	0	0

Light blue	permit limits
Green	fully permitted assumptions where permit limits not available
Yellow	average of self-reported monthly average flows or concentrations
Pink	advanced treatment concentration assumptions
Tan	Colorado River low-flow survey data (QEA 2004)
Dark blue	Greensmiths, Inc. permit issued 11/29/2010, but not included in scenarios

Table 3
Lake LBJ Point Sources Assumed Concentrations and Flows

Base Case Values													
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TLAP	11217001	Lake LBJ MUD No. 1	0	5	10	2	3.2	4	3	20	0.5	0.2
CE-QUAL-W2	continuous	11332001	AquaSource Utilities	0.02	2	1.9	2	1	5.9	1	20	0.13	0.01
CE-QUAL-W2	continuous	11549001	Kingsland MUD	0.31	3.2	3.5	2	1.1	5.7	1.1	20	0.21	0.01
SWAT	TLAP	13459001	Camp Longhorn Inc	0	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	continuous	10199101	City of Junction	0.25	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	10209001	City of Llano	0	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	continuous	10670001	City of Mason	0.17	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	continuous	13490001	City of Rocksprings	0.11	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	continuous	1391000	Murpaks Inc.	0.75	5	10	2	3.2	4	3	20	0.5	0.2

Fully Permitted Values													
Model	Type	Permit Number	Permittee	Flow	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TLAP	11217001	Lake LBJ MUD No. 1	1.5	35	15	2	1	4	1	20	0	0
CE-QUAL-W2	continuous	11332001	AquaSource Utilities	0.05	5	5	2	1	4	1	20	0	0
CE-QUAL-W2	continuous	11549001	Kingsland MUD	0.75	5	5	2	2	4	2	20	0	0
SWAT	TLAP	13459001	Camp Longhorn Inc	0.02/0.0014	100	15	2	1	4	1	20	0	0
SWAT	continuous	10199101	City of Junction	0.28	30	90	2	1	4	1	20	0	0
SWAT	TLAP	10209001	City of Llano	0.60	20	20	2	1	4	1	20	0	0
SWAT	continuous	10670001	City of Mason	0.42	30	90	4	1	4	1	20	0	0
SWAT	continuous	13490001	City of Rocksprings	0.133	20	20	2	1	2	1	20	0	0
SWAT	continuous	1391000	Murpaks Inc.	2.16	10	15	2	1	4	1	20	0	0

Advanced Treatment													
Model	Type	Permit Number	Permittee	Flow	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TLAP	11217001	Lake LBJ MUD No. 1	1.5	5	5	2	0.15	4	0.15	4	0	0
CE-QUAL-W2	continuous	11332001	AquaSource Utilities	0.05	5	5	2	0.15	4	0.15	4	0	0
CE-QUAL-W2	continuous	11549001	Kingsland MUD	0.75	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	13459001	Camp Longhorn Inc	0.02/0.0014	5	5	2	0.15	4	0.15	4	0	0
SWAT	continuous	10199101	City of Junction	0.28	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	10209001	City of Llano	0.60	5	5	2	0.15	4	0.15	4	0	0
SWAT	continuous	10670001	City of Mason	0.42	5	5	2	0.15	4	0.15	4	0	0
SWAT	continuous	13490001	City of Rocksprings	0.133	5	5	2	0.15	4	0.15	4	0	0
SWAT	continuous	1391000	Murpaks Inc.	2.16	5	5	2	0.15	4	0.15	4	0	0

(blue)	permit limits
(green)	fully permitted assumptions where permit limits not available
(yellow)	average of self-reported monthly average flows or concentrations
(pink)	advanced treatment concentration assumptions
(tan)	Colorado River LSWP low-flow survey data (QEA 2004)
(lavender)	City of Llano permit issued 6/30/2010 & included in scenarios by combining the discharge with nearest point source (City of Mason).

Table 4
Lake Marble Falls Point Sources Assumed Concentrations and Flows

Base Case Values

Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
CE-QUAL-W2	TLAP	10654003	City of Marble Falls	0	5	10	2	3.2	4	3	20	0.5	0.2
CE-QUAL-W2	TLAP	11439001	Meadowlakes MUD	0	5	10	2	3.2	4	3	20	0.5	0.2
CE-QUAL-W2	TLAP	2411000	JM Huber Corp	0	5	10	2	3.2	4	3	20	0.5	0.2

Fully Permitted Values

Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
CE-QUAL-W2	TLAP	10654003	City of Marble Falls	1.5	20	20	2	1	4	1	20	0	0
CE-QUAL-W2	TLAP	11439001	Meadowlakes MUD	0.14	20	20	2	1	4	1	20	0	0
CE-QUAL-W2	TLAP	2411000	JM Huber Corp	0.025	10	15	2	1	4	1	20	0	0

Advanced Treatment

Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH_3 (mg/L)	TP (mg/L)	DO (mg/L)	PO_4 (mg/L)	NO_x (mg/L)	OrgN (mg/L)	OrgP (mg/L)
CE-QUAL-W2	TLAP	10654003	City of Marble Falls	1.5	5	5	2	0.15	4	0.15	4	0	0
CE-QUAL-W2	TLAP	11439001	Meadowlakes MUD	0.14	5	5	2	0.15	4	0.15	4	0	0
CE-QUAL-W2	TLAP	2411000	JM Huber Corp	0.025	5	5	2	0.15	4	0.15	4	0	0

(blue)	permit limits
(green)	fully permitted assumptions where permit limits not available
(yellow)	average of self-reported monthly average flows or concentrations
(pink)	advanced treatment concentration assumptions
(tan)	Colorado River LSWP low-flow survey data (QEA 2004)

Table 5
Mean and Maximum Surface Water Chlorophyll-*a* Concentrations Predicted for Base Case Conditions for Inks Lake, Lake LBJ, and Lake Marble Falls

Location	Proposed TCEQ Nutrient Criteria	Overall Average Chlorophyll-*a* (µg/L)	
		Mean	Maximum
Inks Lake (Segment 15)	N/A	7.6	23.2
Lake LBJ (Segment 24)	N/A	6.8	22.7
Lake LBJ (Segment 30)	N/A	6.4	22.5
Lake LBJ (Segment 41)	N/A	5.4	21.0
Lake LBJ (Segment 54)*	10.29	4.4	15.8
Lake LBJ (Segment 100)	N/A	4.3	14.5
Lake Marble Falls (Segment 26)*	10.48	6.1	19.3

Note:

N/A = not applicable

µg/L= microgram per Liter

* Measured at dams

Overall average concentrations computed from annual means and maxima of daily averaged model output

Table 6
Average Predicted Chlorophyll-*a* Concentrations (ug/L) at Segment 15-Inks Lake

Year	Base case	Scenario 1	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	5.0	5.0	5.0	5.1	5.1	5.5	5.1	5.1	5.6
1985	4.2	4.2	4.2	4.5	4.4	4.6	4.5	4.4	4.9
1986	3.9	3.9	3.9	4.0	4.0	4.3	4.0	4.0	4.4
1987	4.8	4.8	4.8	4.9	4.8	5.3	4.9	4.9	5.4
1988	5.4	5.4	5.4	5.4	5.4	5.9	5.4	5.4	5.9
1989	4.2	4.2	4.2	4.3	4.3	4.6	4.3	4.3	4.7
1990	6.9	6.9	6.9	7.0	6.9	7.5	7.0	6.9	7.6
1991	4.8	4.8	4.8	4.9	4.8	5.2	4.9	4.8	5.3
1992	8.0	8.0	8.0	8.0	8.0	8.8	8.0	8.0	8.8
1993	4.8	4.8	4.8	4.9	4.8	5.3	4.9	4.8	5.4
1994	10.5	10.5	10.4	10.5	10.5	11.3	10.5	10.5	11.4
1995	5.1	5.1	5.1	5.2	5.1	5.6	5.2	5.1	5.6
1996	5.4	5.4	5.4	5.5	5.5	6.0	5.5	5.5	6.1
1997	7.9	7.9	7.9	7.9	7.9	8.7	7.9	7.9	8.7
1998	8.4	8.4	8.4	8.5	8.5	9.2	8.5	8.5	9.3
1999	4.8	4.8	4.8	5.0	4.9	5.3	5.0	4.9	5.4
2000	6.8	6.8	6.8	6.9	6.9	7.5	6.9	6.9	7.5
2001	5.4	5.4	5.4	5.5	5.5	5.9	5.5	5.5	6.0
2002	15.1	15.1	15.1	15.2	15.2	16.4	15.3	15.2	16.6
2003	14.8	14.8	14.8	15.0	14.9	16.2	15.0	14.9	16.4
2004	8.4	8.4	8.4	8.4	8.4	9.1	8.4	8.4	9.2
2005	12.6	12.5	12.5	12.6	12.5	13.6	12.6	12.5	13.6
2006	10.2	10.2	10.2	10.3	10.3	11.1	10.3	10.3	11.2
2007	12.0	12.0	11.9	12.1	12.0	13.0	12.1	12.1	13.1
2008	10.8	10.8	10.8	10.8	10.8	11.6	10.8	10.8	11.7
Average	7.6	7.6	7.6	7.7	7.7	8.3	7.7	7.7	8.4

Notes:

Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 7

Percent Change in Average Chlorophyll-*a* Concentrations at Segment 15-Inks Lake

Year	Scenario 1	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	0.0	0.0	2.0	1.1	8.9	2.1	1.2	10.9
1985	0.0	0.0	6.0	3.4	9.3	6.4	3.5	15.5
1986	0.1	0.0	2.0	1.2	9.7	2.2	1.3	11.8
1987	0.1	0.0	0.3	0.1	10.3	0.4	0.2	10.7
1988	0.0	0.0	0.7	0.4	9.5	0.8	0.5	10.2
1989	0.2	0.1	3.2	1.8	9.7	3.3	2.0	13.0
1990	0.0	0.0	1.3	0.6	9.5	1.3	0.7	10.8
1991	0.2	0.1	2.0	1.2	10.0	2.2	1.4	12.1
1992	0.1	0.1	0.0	0.0	9.7	0.1	0.1	9.8
1993	0.0	0.0	1.8	1.1	10.2	1.9	1.1	12.0
1994	0.0	0.0	0.4	0.3	8.5	0.5	0.3	8.9
1995	0.1	0.0	1.1	0.6	8.8	1.2	0.6	10.0
1996	0.0	-0.1	1.5	0.8	9.6	1.6	0.8	11.2
1997	0.0	0.0	0.0	0.1	9.4	-0.1	0.0	9.4
1998	0.3	0.0	1.0	0.6	9.4	1.3	0.8	10.6
1999	0.1	0.0	3.1	2.0	9.4	3.4	2.2	12.8
2000	0.0	0.0	0.9	0.8	9.3	1.0	0.9	10.2
2001	0.1	0.2	2.6	1.7	9.2	2.9	1.9	12.1
2002	0.1	0.0	1.1	0.9	9.1	1.2	1.0	10.3
2003	0.1	0.1	1.4	1.0	9.6	1.4	1.2	10.9
2004	-0.1	-0.1	0.7	0.6	8.9	0.8	0.5	9.8
2005	-0.2	-0.2	0.0	-0.1	8.6	0.0	-0.1	8.5
2006	-0.3	-0.3	0.7	0.6	8.8	0.8	0.6	9.6
2007	-0.5	-0.6	0.4	0.1	8.3	0.7	0.4	8.8
2008	-0.3	-0.3	0.2	0.2	7.8	0.2	0.2	7.9
Average	0.0	0.0	1.4	0.8	9.3	1.5	0.9	10.7

Compared to Base Case

(red)	increase >=50%
(orange)	increase >=10% and <50%
(yellow)	increase <10%
(white)	no change <1%
(light green)	decrease <10%
(blue)	decrease >=10% and <50%
(purple)	decrease >=50%

Table 8
Maximum Predicted Chlorophyll-*a* Concentrations (ug/L) at Segment 15-Inks Lake

Year	Base case	Scenario 1	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	9.8	9.9	9.8	9.9	9.9	10.9	9.8	9.9	10.9
1985	7.9	7.9	7.9	8.0	8.0	8.7	8.0	8.0	8.8
1986	17.1	17.1	17.1	17.1	17.1	18.7	17.1	17.1	18.7
1987	12.6	12.7	12.6	12.7	12.7	14.0	12.8	12.8	14.1
1988	16.0	16.0	16.0	16.1	16.1	17.8	16.1	16.1	17.8
1989	8.4	8.4	8.4	8.4	8.4	9.3	8.4	8.4	9.3
1990	19.6	19.6	19.5	19.6	19.6	21.5	19.6	19.6	21.5
1991	9.2	9.3	9.2	9.9	9.5	10.1	10.0	9.6	10.9
1992	17.0	17.2	17.1	17.0	17.0	18.7	17.3	17.2	18.9
1993	7.5	7.5	7.5	7.5	7.5	8.4	7.5	7.5	8.4
1994	38.3	38.3	38.3	37.7	37.7	41.0	37.7	37.7	40.6
1995	11.8	11.8	11.8	11.8	11.8	12.5	11.8	11.8	12.5
1996	10.6	10.6	10.6	10.9	10.7	11.8	10.9	10.7	12.1
1997	27.2	27.1	27.1	27.3	27.3	29.9	27.3	27.3	30.1
1998	13.9	14.0	14.0	14.2	14.1	15.5	14.2	14.1	15.7
1999	9.7	9.7	9.6	9.7	9.8	10.7	9.7	9.7	10.8
2000	15.1	15.0	15.0	15.3	15.3	16.6	15.3	15.2	16.8
2001	12.4	12.4	12.4	12.8	12.7	13.5	12.8	12.6	13.9
2002	137.8	137.8	137.8	137.8	137.8	151.6	137.8	137.7	151.4
2003	44.1	44.1	44.1	45.1	45.0	48.4	45.1	45.1	49.4
2004	23.0	23.0	23.0	23.2	23.2	25.5	23.2	23.2	25.7
2005	37.0	35.7	35.7	36.8	36.9	40.0	36.9	37.0	40.0
2006	21.0	20.9	20.9	21.1	21.0	22.8	21.1	21.0	22.9
2007	29.9	29.7	29.6	29.7	29.7	33.0	29.7	29.7	32.9
2008	24.0	23.9	23.9	24.4	24.4	26.6	24.5	24.4	26.9
Average	23.2	23.2	23.2	23.4	23.3	25.5	23.4	23.3	25.6

Notes:
Table values are maxima of daily concentrations in lake surface (top 2 meters) for an entire year

Table 9

Percent Change in Maximum Chlorophyll-*a* Concentrations at Segment 15-Inks Lake

Year	Scenario 1	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	0.0	-0.2	0.1	0.1	10.5	-0.2	0.1	10.3
1985	0.1	-0.1	1.8	1.2	10.4	1.8	1.3	12.1
1986	-0.1	0.1	0.0	0.0	9.5	0.0	0.2	9.6
1987	0.6	0.1	0.4	0.2	10.9	1.0	1.1	11.7
1988	0.1	0.0	0.4	0.2	10.9	0.3	0.3	11.2
1989	-0.2	0.0	0.1	0.1	10.8	-0.1	0.1	11.0
1990	0.1	-0.1	0.4	0.4	9.7	0.0	0.4	10.1
1991	1.6	0.5	7.3	3.2	9.7	8.4	4.4	19.1
1992	1.1	0.6	0.1	0.2	10.1	1.5	1.3	10.9
1993	0.0	0.0	0.0	0.0	12.1	0.0	-0.1	12.0
1994	0.1	0.1	-1.5	-1.5	7.2	-1.5	-1.5	6.2
1995	0.2	0.1	-0.4	-0.1	5.8	-0.3	-0.2	5.5
1996	0.2	0.4	2.7	1.3	11.2	3.3	1.3	14.1
1997	-0.4	-0.4	0.3	0.4	10.0	0.4	0.3	10.5
1998	0.4	0.1	2.1	1.5	11.0	2.1	1.2	12.6
1999	-0.3	-0.5	0.6	0.8	11.0	0.5	0.2	11.8
2000	-0.1	0.0	1.5	1.4	10.1	1.3	1.2	11.6
2001	0.2	0.4	3.2	2.7	9.4	3.3	2.3	12.2
2002	0.0	0.0	0.0	0.0	10.0	0.0	-0.1	9.9
2003	-0.1	-0.1	2.2	2.1	9.6	2.1	2.1	11.9
2004	0.0	0.2	1.1	1.2	10.8	1.1	1.1	12.0
2005	-3.5	-3.4	-0.4	-0.2	8.3	-0.2	0.1	8.3
2006	-0.3	-0.4	0.4	0.2	8.8	0.4	0.2	9.0
2007	-0.8	-0.8	-0.6	-0.6	10.4	-0.6	-0.6	9.9
2008	-0.4	-0.5	1.7	1.5	10.6	1.8	1.7	11.7
Average	-0.1	-0.2	0.9	0.6	10.0	1.1	0.7	11.0

Compared to Base Case

(red)	increase >=50%
(orange)	increase >=10% and <50%
(yellow)	increase <10%
(white)	no change <1%
(green)	decrease <10%
(blue)	decrease >=10% and <50%
(purple)	decrease >=50%

Table 10
Average Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 54 (near Wirtz Dam) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	2.3	3.3	2.3	2.2	2.2	2.2	2.4	3.1	3.1	3.2
1985	3.6	4.7	3.7	3.0	4.1	3.8	3.5	5.2	4.7	5.2
1986	4.3	5.5	4.5	3.7	4.7	4.5	4.3	5.9	5.5	6.0
1987	3.2	4.0	3.6	2.8	3.4	3.3	3.4	4.2	4.1	4.3
1988	3.4	4.7	3.5	2.6	3.7	3.4	3.4	5.0	4.7	5.1
1989	2.8	4.1	2.9	2.2	3.5	3.1	2.9	5.0	4.3	4.9
1990	5.0	6.2	5.1	4.3	5.4	5.1	5.1	6.7	6.3	6.8
1991	3.2	4.4	3.3	2.5	3.8	3.4	3.3	5.2	4.6	5.1
1992	5.2	6.4	5.3	5.0	5.2	5.2	5.6	6.6	6.5	6.8
1993	2.6	3.8	2.7	2.2	3.0	2.7	2.7	4.2	3.9	4.2
1994	6.4	7.8	6.5	5.9	6.8	6.5	6.8	8.3	7.9	8.5
1995	5.4	6.3	5.4	4.7	5.8	5.5	5.4	7.0	6.5	6.8
1996	4.1	5.5	4.2	3.6	4.2	4.1	4.2	5.8	5.4	5.8
1997	5.1	5.8	5.4	4.8	4.9	5.0	5.4	5.6	5.8	5.9
1998	4.8	5.6	5.0	4.3	4.9	4.9	5.0	5.9	5.7	5.9
1999	3.8	5.1	4.0	3.0	4.6	4.1	3.8	6.1	5.3	5.9
2000	2.2	3.4	2.2	1.6	2.5	2.3	2.2	4.0	3.4	3.9
2001	3.0	3.7	3.3	2.4	3.2	3.1	3.0	4.1	3.8	4.0
2002	6.9	7.7	7.0	6.3	6.9	6.9	7.3	7.8	7.8	8.1
2003	4.0	5.0	4.1	3.2	4.3	4.1	4.1	5.4	5.0	5.4
2004	5.6	6.6	5.6	5.0	6.0	5.7	5.8	7.1	6.7	7.2
2005	8.0	9.2	7.9	7.4	8.2	8.0	8.4	9.8	9.3	9.9
2006	4.4	6.6	4.3	3.9	4.8	4.5	4.5	7.4	6.7	7.3
2007	8.3	9.2	8.7	7.8	8.5	8.5	8.6	9.5	9.4	9.8
2008	2.8	3.9	3.0	2.0	3.0	2.8	2.9	4.3	4.0	4.3
Average	4.4	5.5	4.5	3.9	4.7	4.5	4.6	6.0	5.6	6.0

Notes:
Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 11
Percent Change in Average Chlorophyll-*a* Concentration at Segment 54 (near Wirtz Dam) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	41.8	0.5	-3.8	-4.7	-2.4	2.9	34.8	37.1	37.6
1985	29.0	3.2	-16.0	12.8	4.4	-2.7	44.0	31.4	43.7
1986	25.9	3.6	-14.7	8.7	3.0	0.0	35.9	27.4	37.9
1987	24.2	10.3	-12.5	5.6	1.7	4.3	29.5	25.8	34.0
1988	38.8	4.3	-22.0	9.5	3.0	1.6	49.8	40.1	50.7
1989	45.1	2.7	-21.4	24.6	7.7	1.5	74.7	53.1	73.7
1990	24.7	2.7	-12.3	8.6	2.7	3.5	34.6	27.9	36.3
1991	37.6	3.2	-22.3	17.6	5.6	2.2	61.0	42.3	59.0
1992	23.7	3.3	-4.1	1.4	0.3	7.4	26.7	25.3	32.0
1993	43.4	2.1	-15.9	13.6	4.2	3.7	58.9	47.4	60.5
1994	20.9	1.7	-7.3	5.5	1.9	5.6	29.3	23.5	32.2
1995	18.1	1.2	-13.1	7.9	2.9	0.5	31.5	21.1	27.7
1996	35.2	2.1	-12.2	3.5	0.9	2.0	41.7	32.6	41.1
1997	14.7	5.9	-4.6	-3.1	-1.6	5.4	11.0	13.7	15.3
1998	16.5	3.3	-10.8	2.6	0.9	4.1	22.6	17.7	22.6
1999	31.8	5.4	-22.9	19.8	6.4	-0.2	58.4	37.2	54.5
2000	55.3	2.1	-26.3	15.0	4.7	2.5	81.9	56.1	77.5
2001	25.6	9.8	-19.7	8.9	2.7	1.4	36.8	28.4	36.1
2002	12.4	1.4	-8.4	0.5	-0.1	6.0	12.9	13.7	18.3
2003	24.3	3.2	-19.8	8.2	2.4	2.9	35.9	26.6	34.9
2004	18.0	1.2	-11.0	6.8	2.1	3.5	26.8	20.8	28.7
2005	15.1	-0.7	-7.1	3.4	0.9	5.4	23.0	16.9	25.0
2006	51.9	-1.6	-9.6	9.1	2.2	2.7	68.7	53.2	66.8
2007	10.7	4.7	-5.9	2.2	1.5	2.8	14.5	13.1	17.2
2008	40.4	7.1	-29.1	10.2	3.0	5.3	56.6	43.4	56.8
Average	29.0	3.3	-14.1	7.9	2.4	3.0	40.1	31.0	40.8

Compared to Base Case

	increase >=50%
	increase >=10% and <50%
	increase <10%
	no change <1%

	decrease <10%
	decrease >=10% and <50%
	decrease >=50%

Table 12
Maximum Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 54 (near Wirtz Dam) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	8.1	10.2	8.0	7.9	8.2	8.1	8.1	10.5	10.2	10.5
1985	18.9	21.8	19.9	17.0	21.2	19.4	18.7	23.6	21.9	23.6
1986	12.3	14.1	12.6	11.3	14.3	12.9	12.2	16.1	14.6	16.1
1987	30.0	31.1	30.8	29.9	29.2	29.8	30.4	30.1	30.8	30.7
1988	11.4	12.9	11.5	11.0	12.7	11.8	11.4	14.1	13.3	14.1
1989	8.9	12.9	9.3	6.8	11.3	9.8	9.1	15.1	13.7	15.1
1990	15.1	16.0	15.4	15.1	15.8	15.1	15.5	16.7	16.3	17.3
1991	7.4	11.4	7.8	7.0	9.4	8.0	7.7	14.2	12.0	14.3
1992	16.5	19.8	18.3	16.3	16.9	16.6	17.4	20.1	19.9	21.0
1993	8.7	11.1	9.1	7.2	10.2	8.8	8.9	12.4	12.0	12.5
1994	21.2	28.3	21.4	21.9	23.6	22.2	21.8	28.1	28.2	28.7
1995	20.9	21.3	21.4	19.2	23.6	21.7	21.1	24.9	22.2	23.8
1996	11.7	13.5	11.8	11.2	11.8	11.8	12.1	14.4	13.5	14.7
1997	19.6	20.2	20.1	20.4	19.1	19.4	20.7	20.3	20.5	21.9
1998	16.7	17.3	17.4	15.5	18.2	17.2	17.0	20.0	17.9	19.0
1999	10.6	12.4	11.2	8.0	12.4	11.2	10.6	15.0	12.8	14.9
2000	6.1	9.2	6.1	5.6	6.1	6.1	6.6	10.6	9.2	10.5
2001	9.5	11.1	10.3	8.2	10.5	9.8	9.5	11.9	11.4	12.0
2002	36.9	37.9	37.1	34.2	36.9	36.9	39.9	38.0	38.3	41.0
2003	7.6	10.8	7.9	5.7	9.3	8.0	7.6	13.3	11.4	13.3
2004	16.3	16.8	16.4	15.8	17.1	16.5	16.7	17.5	17.1	18.1
2005	32.9	35.6	32.7	32.9	32.7	32.9	33.5	36.9	35.6	37.5
2006	8.0	14.7	8.7	6.9	10.4	8.5	8.1	15.9	13.2	15.6
2007	33.7	35.2	34.1	39.4	31.5	33.4	33.6	32.4	33.6	32.8
2008	6.9	10.7	7.8	3.8	7.7	7.2	7.2	11.6	10.8	11.7
Average	15.8	18.3	16.3	15.1	16.8	16.1	16.2	19.4	18.4	19.6

Notes:

Table values are maxima of daily concentrations in lake surface (top 2 meters) for an entire year

Table 13

Percent Change in Maximum Chlorophyll-*a* Concentration at Segment 54 (near Wirtz Dam) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	26.1	-0.9	-1.9	1.5	0.5	0.0	29.5	26.5	29.6
1985	15.4	5.1	-10.0	11.7	2.3	-1.4	24.8	15.5	24.8
1986	14.5	2.9	-8.1	16.1	4.9	-0.7	31.0	19.3	31.5
1987	3.6	2.5	-0.4	-2.7	-0.7	1.3	0.2	2.6	2.1
1988	13.8	1.0	-3.4	11.5	3.6	0.2	24.4	16.7	24.3
1989	44.3	4.2	-23.7	26.7	9.6	2.0	69.9	54.2	69.6
1990	5.8	1.8	-0.2	4.4	0.0	2.7	10.3	7.6	14.5
1991	53.0	4.2	-5.6	26.4	7.0	3.6	90.1	61.7	92.2
1992	19.9	10.7	-1.4	2.6	0.8	5.3	21.6	20.8	27.1
1993	28.1	4.4	-16.9	17.4	1.3	2.3	42.4	37.9	44.2
1994	33.7	1.2	3.4	11.6	5.0	3.0	32.7	33.2	35.4
1995	1.6	2.3	-8.3	13.0	3.5	0.8	18.9	6.3	13.9
1996	14.9	0.8	-4.7	0.2	0.5	3.5	22.8	14.7	25.1
1997	3.2	2.6	4.2	-2.7	-1.2	5.7	3.4	4.3	11.6
1998	3.6	4.2	-7.3	9.0	3.2	1.9	20.0	7.1	14.0
1999	17.3	5.9	-24.6	16.9	6.1	0.0	42.0	21.2	41.0
2000	51.2	0.5	-7.5	0.9	0.3	9.0	74.3	51.6	72.1
2001	16.9	8.7	-13.7	10.4	3.4	0.5	25.9	20.0	26.6
2002	2.9	0.6	-7.2	0.1	0.0	8.3	3.2	3.9	11.1
2003	43.1	4.2	-24.5	23.6	6.4	0.9	75.8	50.9	76.5
2004	3.0	1.0	-3.0	4.8	1.3	2.3	7.3	5.1	11.1
2005	8.1	-0.6	-0.1	-0.7	0.0	1.8	12.2	8.2	14.0
2006	83.6	8.6	-14.2	30.7	6.9	1.7	99.5	65.2	95.3
2007	4.6	1.3	17.1	-6.4	-0.8	-0.1	-3.6	-0.1	-2.4
2008	54.3	12.1	-45.4	10.9	3.8	3.4	67.5	55.5	68.4
Average	22.7	3.6	-8.3	9.5	2.7	2.3	33.9	24.4	34.9

Compared to Base Case

Red	increase >=50%
Orange	increase >=10% and <50%
Yellow	increase <10%
White	no change <1%
Light green	decrease <10%
Light blue	decrease >=10% and <50%
Purple	decrease >=50%

Table 14
Average Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 24 (Colorado River Arm) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	4.4	4.5	4.4	4.2	4.3	4.3	4.7	4.4	4.4	4.7
1985	4.6	4.9	4.8	3.7	5.1	4.8	4.7	5.4	5.1	5.5
1986	4.9	5.2	5.1	4.0	5.3	5.0	5.2	5.6	5.3	6.0
1987	4.5	4.7	4.8	3.6	4.6	4.5	4.9	4.7	4.7	5.0
1988	5.8	6.0	6.1	4.5	5.9	5.8	6.1	6.2	6.1	6.5
1989	5.1	5.7	5.5	3.7	5.8	5.4	5.3	6.3	5.9	6.5
1990	8.4	8.9	8.7	6.8	8.8	8.5	8.9	9.3	9.0	9.8
1991	4.7	4.9	4.9	3.8	5.0	4.8	5.0	5.3	5.0	5.6
1992	7.3	7.8	7.4	7.1	7.3	7.3	8.0	7.8	7.8	8.4
1993	4.5	4.7	4.6	3.9	4.8	4.6	4.9	4.9	4.8	5.3
1994	9.6	9.9	9.7	9.1	9.8	9.7	10.3	10.1	10.0	10.8
1995	5.5	5.8	5.7	4.8	5.6	5.5	5.9	5.8	5.8	6.2
1996	5.2	5.4	5.4	4.6	5.4	5.3	5.6	5.6	5.5	6.0
1997	6.6	6.7	6.8	5.6	6.5	6.5	7.1	6.7	6.7	7.2
1998	6.7	7.0	6.9	5.9	6.8	6.8	7.2	7.0	7.0	7.5
1999	6.0	6.6	6.4	4.1	6.5	6.2	6.2	7.0	6.7	7.2
2000	5.6	5.8	5.7	4.6	5.9	5.7	6.0	6.2	5.9	6.6
2001	4.1	4.4	4.4	3.0	4.1	4.1	4.4	4.4	4.4	4.6
2002	11.0	11.4	11.3	9.6	11.2	11.1	11.9	11.6	11.5	12.4
2003	9.0	9.2	9.2	7.7	9.2	9.1	9.7	9.4	9.3	10.1
2004	7.8	8.1	8.0	7.0	7.9	7.8	8.4	8.2	8.1	8.7
2005	11.8	13.1	11.9	11.1	12.0	11.8	12.7	13.2	13.1	14.0
2006	8.8	9.6	8.8	8.2	8.9	8.8	9.5	9.7	9.6	10.4
2007	10.2	10.4	10.4	9.1	10.1	10.1	10.8	10.3	10.3	10.9
2008	8.8	9.4	8.9	7.8	9.1	8.9	9.5	9.5	9.4	10.2
Average	6.8	7.2	7.0	5.9	7.0	6.9	7.3	7.4	7.3	7.8

Notes:

Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 15
Percent Change in Average Chlorophyll-*a* Concentration at Segment 24 (Colorado River Arm) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	2.0	1.4	-4.8	-2.2	-0.8	7.7	-0.5	1.1	7.2
1985	7.0	5.3	-18.7	11.6	4.0	3.3	17.7	10.6	21.2
1986	7.5	4.6	-18.5	8.3	2.5	6.9	15.9	9.8	22.2
1987	3.4	5.5	-20.3	0.9	0.3	7.7	4.0	3.5	11.6
1988	4.8	5.1	-22.1	2.4	0.5	5.8	7.1	5.3	12.9
1989	10.3	6.8	-28.8	11.9	4.3	3.9	21.9	14.4	25.7
1990	6.3	3.7	-19.0	5.6	1.9	6.5	11.1	7.8	17.5
1991	5.1	4.7	-19.6	7.3	2.2	6.5	12.3	7.2	18.9
1992	6.1	0.4	-3.7	0.0	0.0	9.2	5.9	6.0	15.1
1993	4.5	2.6	-12.8	5.5	1.9	8.1	9.6	6.3	17.6
1994	3.0	1.2	-5.3	2.2	0.8	7.7	5.1	3.6	12.5
1995	4.7	3.4	-13.9	0.9	0.2	6.3	5.5	4.8	11.4
1996	4.0	3.0	-11.3	3.6	0.8	7.7	7.7	4.8	15.3
1997	2.1	3.5	-14.3	-0.8	-0.4	7.8	1.3	1.7	8.9
1998	3.3	2.8	-12.4	1.1	0.4	7.3	4.1	3.5	11.2
1999	8.8	7.1	-31.9	7.4	2.2	3.5	16.0	10.6	19.4
2000	4.9	2.8	-16.6	6.2	1.7	7.3	11.6	6.7	18.8
2001	6.2	6.7	-27.1	-0.1	-0.3	5.2	5.6	5.6	10.6
2002	3.7	2.6	-12.6	1.6	0.5	7.5	5.1	4.1	12.5
2003	2.4	2.0	-15.1	2.1	0.6	8.1	4.5	2.9	12.4
2004	4.0	1.7	-10.2	0.3	0.0	7.2	4.2	3.9	11.4
2005	10.7	0.6	-5.9	1.4	0.2	7.3	11.5	10.7	18.6
2006	9.2	0.4	-6.7	1.6	0.4	8.3	10.3	9.6	18.5
2007	2.1	2.7	-10.5	-0.5	-0.6	6.0	1.4	1.8	7.2
2008	6.7	1.2	-11.7	2.7	0.9	7.8	8.1	7.1	15.3
Average	5.3	3.3	-15.0	3.2	1.0	6.8	8.3	6.1	15.0

Compared to Base Case

(red)	increase >=50%
(orange)	increase >=10% and <50%
(yellow)	increase<10%
(white)	no change <1%
(light green)	decrease <10%
(light blue)	decrease >=10% and <50%
(purple)	decrease >=50%

Table 16
Maximum Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 24 (Colorado River Arm) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	10.8	11.3	11.3	9.2	11.9	11.1	11.6	12.4	11.7	13.2
1985	16.0	17.2	16.9	13.3	18.6	17.2	15.6	19.5	18.4	19.5
1986	18.0	18.0	18.0	19.1	18.0	18.0	19.4	20.0	18.0	20.0
1987	12.2	12.2	12.2	12.1	12.2	12.2	13.6	12.2	12.2	13.6
1988	13.9	13.9	14.1	13.2	14.0	13.9	15.3	14.6	14.1	15.3
1989	10.1	11.4	11.3	8.5	11.4	10.4	10.2	13.2	11.6	13.2
1990	19.4	19.8	19.4	19.0	19.4	19.4	21.4	19.5	19.9	21.4
1991	10.8	11.6	11.8	8.2	14.2	11.1	11.0	15.1	12.1	15.4
1992	18.3	18.6	18.3	17.6	18.2	18.2	20.0	18.6	18.6	20.3
1993	10.7	11.1	11.1	9.3	13.9	11.7	10.9	14.3	12.1	14.5
1994	35.1	35.0	35.1	35.6	35.0	35.1	37.8	35.0	35.0	37.6
1995	12.6	13.2	13.1	10.9	13.4	12.3	12.6	14.2	12.9	14.2
1996	11.8	12.8	12.4	11.9	14.1	11.6	12.3	14.5	12.9	14.9
1997	17.5	17.6	17.7	17.0	17.2	17.2	18.7	17.2	17.3	18.6
1998	21.6	22.3	21.7	25.4	19.9	21.0	21.6	21.8	22.0	22.2
1999	18.2	18.9	18.8	17.8	17.3	16.2	18.4	20.0	18.4	20.0
2000	15.4	15.4	15.4	15.2	15.4	15.4	17.0	15.4	15.4	17.0
2001	12.3	15.8	12.8	11.4	14.6	12.7	12.7	16.6	15.7	17.0
2002	134.6	134.6	134.6	133.4	134.6	134.6	147.9	134.6	134.6	147.9
2003	26.2	26.2	26.2	24.2	26.2	26.2	28.9	26.2	26.2	28.9
2004	23.3	23.3	23.3	23.5	23.3	23.3	25.6	23.3	23.3	25.6
2005	35.2	35.2	35.2	33.9	34.5	35.0	38.2	34.5	35.0	37.6
2006	18.6	23.6	18.8	18.1	19.5	19.3	19.8	23.9	22.9	25.1
2007	28.0	28.0	28.0	28.0	28.0	28.0	30.7	28.0	28.0	30.7
2008	16.9	17.1	16.9	16.3	16.9	16.9	18.5	18.1	17.4	19.0
Average	22.7	23.4	23.0	22.1	23.3	22.7	24.4	24.1	23.4	25.7

Notes:
Table values are maxima of daily concentrations in lake surface (top 2 meters) for an entire year

Table 17

Percent Change in Maximum Chlorophyll-*a* Concentration at Segment 24 (Colorado River Arm) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	4.9	4.6	-15.2	9.8	3.0	7.0	14.7	7.8	22.1
1985	7.4	5.6	-16.8	16.0	7.6	-2.5	21.5	15.0	22.0
1986	0.0	0.0	5.6	-0.1	0.0	7.5	10.8	-0.1	10.8
1987	0.0	0.0	-0.6	0.0	0.0	11.7	0.0	0.0	11.7
1988	0.0	1.6	-4.9	1.3	0.0	10.5	5.2	1.6	10.5
1989	13.0	11.1	-15.7	12.6	3.1	0.7	30.6	14.9	30.1
1990	1.9	0.1	-2.1	0.1	0.0	10.3	0.5	2.5	10.5
1991	7.6	10.0	-23.6	31.6	3.4	2.1	40.6	12.1	43.0
1992	1.8	0.2	-3.7	-0.2	-0.3	9.3	1.6	1.7	11.1
1993	3.6	3.8	-13.2	30.2	9.3	2.5	33.5	13.1	35.8
1994	-0.2	-0.1	1.4	-0.3	-0.1	7.6	-0.5	-0.3	7.0
1995	4.8	4.2	-13.3	7.0	-1.8	0.5	13.1	2.9	13.4
1996	9.0	5.6	0.9	19.3	-1.9	4.6	23.4	9.1	26.4
1997	0.7	1.1	-3.1	-1.7	-1.7	6.5	-1.8	-1.1	5.9
1998	3.3	0.5	17.8	-7.7	-2.5	0.1	0.9	2.2	2.7
1999	3.9	3.2	-1.9	-4.6	-11.1	1.4	10.0	1.4	10.2
2000	-0.1	0.0	-1.1	0.0	0.0	10.5	-0.1	-0.1	10.3
2001	28.2	4.0	-7.6	18.0	3.2	2.9	34.9	27.4	37.8
2002	0.0	0.0	-0.9	0.0	0.0	9.9	0.0	0.0	9.9
2003	0.0	0.0	-7.7	0.0	0.0	10.1	0.0	0.0	10.1
2004	0.0	0.0	1.0	0.0	0.0	10.0	0.0	0.0	9.9
2005	0.0	0.0	-3.7	-2.2	-0.7	8.3	-2.2	-0.7	6.8
2006	27.4	1.2	-2.4	5.0	3.9	6.9	29.0	23.6	35.2
2007	0.0	0.0	0.0	0.1	0.0	9.8	0.0	0.0	9.8
2008	1.3	0.0	-3.4	-0.1	0.0	9.5	7.4	3.3	12.7
Average	4.7	2.3	-4.6	5.4	0.5	6.3	10.9	5.5	16.6

Compared to Base Case

	increase >=50%
	increase >=10% and <50%
	increase <10%
	no change <1%

	decrease <10%
	decrease >=10% and <50%
	decrease >=50%

Table 18

Average Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 30 (below Llano confluence) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	4.0	4.2	4.1	3.5	3.9	4.0	4.2	4.1	4.1	4.3
1985	5.1	5.7	5.5	3.6	5.7	5.3	5.2	6.2	5.8	6.3
1986	4.9	5.4	5.2	3.5	5.2	4.9	5.1	5.7	5.5	5.9
1987	3.8	4.0	4.1	2.6	3.9	3.8	4.0	4.1	4.0	4.3
1988	6.0	6.5	6.5	3.9	6.2	6.0	6.2	6.7	6.6	6.9
1989	5.1	5.9	5.5	3.3	5.8	5.3	5.2	6.5	6.1	6.6
1990	7.6	8.4	8.0	5.7	8.2	7.8	8.0	8.9	8.5	9.2
1991	5.1	5.5	5.4	3.6	5.6	5.2	5.3	6.0	5.7	6.2
1992	6.7	7.7	6.8	6.2	6.7	6.7	7.2	7.7	7.7	8.2
1993	4.8	5.3	5.0	3.7	5.2	4.9	5.1	5.6	5.3	5.9
1994	9.7	10.3	10.0	8.6	9.8	9.8	10.3	10.2	10.3	10.8
1995	6.4	6.9	6.8	4.9	6.5	6.4	6.6	7.0	6.9	7.2
1996	5.4	5.9	5.7	4.4	5.8	5.5	5.7	6.3	6.0	6.6
1997	5.0	5.3	5.4	3.7	5.0	5.0	5.4	5.2	5.2	5.5
1998	5.4	5.7	5.7	4.4	5.5	5.4	5.7	5.8	5.7	6.1
1999	6.1	6.8	6.6	3.7	6.5	6.2	6.2	7.2	6.9	7.3
2000	5.1	5.7	5.3	3.8	5.7	5.2	5.3	6.3	5.8	6.5
2001	4.3	4.7	4.7	2.7	4.3	4.3	4.4	4.7	4.6	4.8
2002	9.3	9.9	9.7	7.8	9.6	9.4	9.9	10.1	10.0	10.7
2003	7.0	7.5	7.3	5.5	7.2	7.1	7.5	7.6	7.5	8.0
2004	7.7	8.2	7.9	6.3	7.8	7.7	8.1	8.2	8.2	8.6
2005	10.6	12.5	10.8	9.8	10.8	10.6	11.3	12.6	12.5	13.2
2006	8.5	10.3	8.6	7.4	9.1	8.6	9.0	10.8	10.5	11.3
2007	7.7	8.1	8.1	6.7	7.5	7.6	8.1	7.7	8.0	8.1
2008	7.8	8.7	8.0	6.2	8.3	8.0	8.3	9.1	8.8	9.6
Average	6.4	7.0	6.7	5.0	6.6	6.4	6.7	7.2	7.0	7.5

Notes:

Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 19

Percent Change in Average Chlorophyll-*a* Concentration at Segment 30 (below Llano confluence) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	4.8	3.2	-12.1	-2.6	-1.4	5.6	2.0	3.2	7.5
1985	10.9	7.9	-29.2	11.6	3.7	1.0	21.9	14.1	23.3
1986	11.0	7.1	-28.8	6.6	1.9	5.0	17.7	12.5	22.1
1987	6.2	9.0	-31.6	2.3	0.5	6.0	8.2	6.5	14.2
1988	9.2	8.2	-34.0	3.1	0.7	3.6	11.9	9.9	15.6
1989	15.2	8.3	-35.1	12.4	4.3	2.3	27.3	19.3	29.5
1990	9.6	5.5	-25.1	7.4	2.4	5.1	16.3	11.6	21.4
1991	8.9	7.0	-28.8	9.6	2.7	4.1	18.7	11.5	22.9
1992	14.6	1.1	-7.4	0.3	0.0	7.7	14.3	14.4	22.4
1993	9.5	5.2	-23.6	8.9	2.6	5.4	17.4	11.3	22.7
1994	5.6	2.5	-11.2	0.4	0.4	6.5	5.3	5.6	11.5
1995	7.9	5.7	-23.4	1.5	0.4	3.9	9.2	8.1	12.6
1996	8.5	5.1	-17.7	7.5	2.1	4.9	16.5	10.6	21.4
1997	4.1	6.8	-26.1	-1.4	-0.7	6.3	2.5	3.3	8.7
1998	5.9	5.6	-17.6	2.1	0.5	5.6	7.7	6.4	13.3
1999	11.9	8.2	-38.5	6.6	1.9	1.9	17.8	13.4	19.6
2000	11.7	4.8	-25.7	12.1	3.6	5.5	24.1	14.9	29.4
2001	8.5	9.3	-36.2	0.7	-0.3	2.8	9.3	8.2	11.9
2002	5.9	4.1	-16.9	2.9	0.9	6.5	8.5	6.6	15.0
2003	6.1	4.1	-22.6	2.3	0.6	6.2	8.3	6.5	14.3
2004	6.8	3.6	-17.4	1.3	0.6	5.3	7.3	7.0	12.7
2005	17.3	1.3	-8.1	1.6	0.0	6.3	18.4	17.3	24.6
2006	21.3	1.4	-13.0	6.4	1.6	6.4	26.9	23.5	33.0
2007	4.2	4.6	-13.6	-3.6	-1.4	4.8	-0.1	2.8	4.5
2008	11.3	1.8	-20.6	6.5	2.0	6.5	17.0	12.9	23.1
Average	9.5	5.2	-22.6	4.3	1.2	5.0	13.4	10.5	18.3

Compared to Base Case

Red	increase >=50%
Orange	increase >=10% and <50%
Yellow	increase <10%
White	no change <1%
Light green	decrease <10%
Light blue	decrease >=10% and <50%
Purple	decrease >=50%

Table 20

Maximum Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 30 (below Llano confluece) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	14.8	15.9	15.9	10.2	15.3	15.2	15.3	16.6	16.2	17.0
1985	16.6	17.6	17.5	12.8	19.1	16.8	16.5	20.3	17.8	20.4
1986	17.5	17.7	17.8	16.1	17.5	17.5	18.8	17.8	17.7	19.3
1987	10.7	12.0	12.2	8.2	12.4	11.3	11.4	13.4	12.6	13.5
1988	14.0	14.9	14.7	11.8	14.2	14.1	14.1	15.1	14.9	15.2
1989	10.3	11.7	11.4	7.1	12.0	10.2	10.3	13.7	11.5	13.6
1990	15.6	16.9	16.1	15.5	15.7	15.6	17.1	17.8	17.3	17.9
1991	11.8	12.8	13.0	10.0	13.6	12.0	11.9	14.9	13.4	15.0
1992	22.2	24.6	22.3	20.6	22.1	22.1	23.4	24.5	24.5	25.9
1993	10.5	12.2	10.9	9.5	12.5	10.8	10.7	12.8	12.5	13.0
1994	34.8	34.8	34.8	36.5	34.8	34.8	37.5	34.9	34.8	38.1
1995	15.4	16.1	15.9	13.3	14.7	14.9	15.5	15.4	15.8	15.4
1996	27.7	28.4	29.0	28.4	28.4	27.9	27.6	29.2	28.6	29.1
1997	16.1	16.2	16.2	16.5	16.1	16.1	17.4	16.2	16.2	17.5
1998	27.5	27.3	28.5	32.9	27.0	27.4	27.6	26.9	27.3	26.9
1999	16.1	17.8	17.7	12.7	19.2	16.4	16.1	20.5	18.0	20.5
2000	13.7	14.2	14.3	12.0	13.1	13.1	14.4	14.2	14.1	14.7
2001	19.8	20.9	20.5	18.4	23.6	20.5	19.9	23.9	21.3	24.0
2002	117.1	117.1	117.1	113.3	117.0	117.1	128.4	117.1	117.0	128.3
2003	19.0	19.1	19.1	17.3	18.8	19.0	20.9	19.4	19.0	20.6
2004	22.0	23.2	22.0	23.5	21.8	21.8	23.8	22.9	23.1	24.8
2005	29.8	29.9	30.0	28.6	29.8	29.8	32.1	29.9	29.9	32.2
2006	21.5	22.1	21.7	21.3	23.4	22.0	22.8	23.1	22.1	24.5
2007	23.8	24.3	24.2	28.9	23.0	23.6	24.0	22.8	24.1	24.0
2008	15.3	15.9	15.5	14.6	15.3	15.3	16.4	15.8	15.8	17.0
Average	22.5	23.3	23.1	21.6	23.2	22.6	23.8	24.0	23.4	25.1

Notes:

Table values are maxima of daily concentrations in lake surface (top 2 meters) for an entire year

Table 21
Percent Change in Maximum Chlorophyll-*a* Concentration at Segment 30 (below Llano confluence) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	7.6	7.4	-31.0	3.1	2.6	3.1	11.8	9.3	14.6
1985	6.1	5.3	-22.7	15.4	1.3	-0.6	22.6	7.6	22.9
1986	1.5	2.1	-7.7	0.2	0.1	7.9	1.7	1.5	10.5
1987	11.6	13.5	-23.7	15.3	5.5	6.2	25.1	17.1	26.2
1988	6.2	5.0	-15.9	1.0	0.2	0.2	7.9	6.2	8.1
1989	14.2	10.8	-30.8	16.8	-0.3	0.5	33.1	12.0	32.8
1990	8.1	3.2	-0.9	0.2	0.0	9.4	14.2	10.5	14.9
1991	8.5	10.5	-15.1	15.9	1.7	1.6	27.0	13.7	27.8
1992	10.6	0.2	-7.3	-0.7	-0.5	5.3	10.3	10.2	16.4
1993	16.4	3.8	-9.7	18.8	3.0	2.1	22.2	19.2	23.6
1994	0.2	0.2	5.0	0.3	0.0	7.8	0.5	0.3	9.6
1995	4.7	3.6	-13.6	-4.6	-3.2	0.6	0.1	2.7	0.3
1996	2.6	4.8	2.7	2.7	0.7	-0.3	5.5	3.4	5.2
1997	0.2	0.4	2.2	-0.2	-0.1	8.0	0.5	0.2	8.4
1998	-0.9	3.3	19.5	-2.1	-0.6	0.1	-2.5	-1.1	-2.2
1999	10.4	10.2	-20.9	19.0	2.0	0.2	27.2	11.9	27.1
2000	3.7	4.1	-13.0	-4.4	-4.6	4.9	3.3	2.7	6.8
2001	5.4	3.3	-7.3	18.7	3.3	0.4	20.5	7.2	20.8
2002	0.0	0.0	-3.2	0.0	0.0	9.7	0.0	0.0	9.6
2003	0.1	0.1	-9.3	-1.5	-0.4	9.9	2.1	-0.3	8.2
2004	5.5	0.0	6.8	-1.1	-0.7	8.4	4.2	5.1	12.8
2005	0.5	0.8	-3.8	0.0	0.0	7.7	0.5	0.5	8.2
2006	2.9	1.0	-0.6	9.1	2.8	6.4	7.9	3.0	14.1
2007	2.1	1.8	21.3	-3.5	-0.7	0.9	-4.1	1.1	0.6
2008	3.7	1.7	-4.6	0.1	0.0	7.5	3.5	3.3	10.9
Average	5.3	3.9	-7.4	4.7	0.5	4.3	9.8	5.9	13.5

Compared to Base Case

red	increase >=50%
orange	increase >=10% and <50%
yellow	increase <10%
white	no change <1%
light green	decrease <10%
light blue	decrease >=10% and <50%
purple	decrease >=50%

Table 22

Average Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 41 (Sandy Creek confluence) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	3.0	4.5	3.1	2.8	2.8	2.9	3.1	4.2	4.4	4.3
1985	4.7	6.3	4.9	3.8	5.4	4.9	4.7	7.0	6.5	7.1
1986	4.5	6.0	4.8	3.7	4.9	4.7	4.7	6.4	6.1	6.5
1987	3.6	4.8	3.9	2.8	3.9	3.7	3.8	5.1	4.9	5.3
1988	4.5	6.5	4.7	3.4	4.9	4.6	4.6	6.9	6.6	7.0
1989	3.7	5.8	3.9	2.7	4.4	3.9	3.7	6.5	6.0	6.5
1990	6.0	8.0	6.2	4.9	6.6	6.2	6.2	8.6	8.2	8.9
1991	3.8	5.8	4.0	2.8	4.6	4.0	3.9	6.5	6.0	6.6
1992	5.7	7.6	5.8	5.4	5.8	5.8	6.1	7.7	7.7	8.1
1993	3.5	5.2	3.6	2.7	4.0	3.6	3.6	5.8	5.4	5.9
1994	7.7	9.7	7.8	6.9	8.3	7.9	8.2	10.3	9.9	10.8
1995	5.5	7.4	5.7	4.8	6.0	5.7	5.7	7.8	7.5	7.9
1996	5.4	7.3	5.5	4.8	5.6	5.4	5.5	7.5	7.3	7.6
1997	5.1	6.3	5.4	4.1	5.0	5.0	5.3	6.2	6.2	6.5
1998	6.5	8.1	6.9	5.5	6.7	6.6	6.8	8.1	8.1	8.3
1999	4.9	6.9	5.2	3.7	5.6	5.1	5.0	7.6	7.1	7.7
2000	3.0	4.8	3.1	2.0	3.5	3.1	3.1	5.4	4.9	5.5
2001	4.1	5.4	4.4	3.1	4.4	4.2	4.2	5.7	5.5	5.7
2002	8.6	10.1	8.9	7.5	8.8	8.7	9.2	10.3	10.2	10.8
2003	5.9	7.7	6.2	4.5	6.6	6.2	6.1	8.2	7.8	8.4
2004	7.0	8.7	7.2	6.0	7.6	7.2	7.3	9.2	8.8	9.5
2005	9.2	11.4	9.3	8.4	9.5	9.3	9.8	11.7	11.5	12.3
2006	6.2	9.1	6.2	5.6	6.7	6.3	6.5	9.7	9.3	9.9
2007	8.6	9.7	9.0	7.5	8.7	8.6	8.9	9.8	9.7	10.0
2008	4.3	6.0	4.5	2.9	4.7	4.4	4.5	6.5	6.1	6.6
Average	5.4	7.2	5.6	4.5	5.8	5.5	5.6	7.6	7.3	7.8

Notes:

Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 23
Percent Change in Average Chlorophyll-*a* Concentration at Segment 41 (Sandy Creek confluence) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	48.1	1.5	-9.1	-7.0	-3.2	3.1	39.5	44.0	42.5
1985	36.0	5.9	-18.8	16.6	6.0	0.0	50.8	40.3	51.2
1986	33.3	5.2	-18.9	8.4	2.9	3.7	40.7	35.0	44.2
1987	33.8	9.2	-23.1	7.5	2.2	5.1	40.8	35.7	46.2
1988	44.4	5.6	-25.0	9.6	3.0	2.2	54.0	46.7	55.9
1989	58.7	5.9	-27.3	19.9	6.5	2.3	77.1	64.4	78.5
1990	33.9	4.3	-17.1	11.1	3.5	4.5	44.8	37.0	48.8
1991	51.7	5.9	-26.7	20.2	6.3	3.0	72.2	57.5	74.3
1992	32.7	1.5	-5.4	1.3	0.3	7.0	34.2	33.3	41.0
1993	51.4	4.2	-22.5	17.1	5.1	4.2	67.7	56.1	71.4
1994	27.1	1.7	-9.3	7.9	2.6	7.3	34.5	29.3	41.2
1995	33.5	3.5	-13.7	9.3	3.5	2.8	41.6	35.9	42.8
1996	34.8	2.5	-11.4	3.7	0.3	1.9	38.4	34.6	40.4
1997	23.7	5.9	-18.3	-0.2	-0.4	5.5	22.5	22.9	27.8
1998	23.7	4.9	-16.0	2.7	1.2	3.4	24.4	24.5	27.6
1999	42.4	6.7	-24.6	13.8	4.6	1.5	56.0	46.2	56.8
2000	63.9	4.7	-31.2	18.4	4.8	3.7	84.1	66.4	86.9
2001	32.8	7.8	-25.0	8.9	2.4	1.9	38.8	34.4	40.3
2002	17.4	2.7	-13.5	2.4	0.6	6.4	18.9	17.7	25.1
2003	29.2	4.6	-24.8	11.2	3.7	3.7	38.5	32.1	41.6
2004	23.5	2.7	-14.7	8.4	2.6	4.4	31.8	25.9	36.0
2005	23.6	1.1	-9.4	3.3	0.9	6.3	27.2	24.1	32.7
2006	46.7	0.3	-10.2	8.5	2.2	4.2	56.4	50.2	59.9
2007	13.1	5.0	-12.2	1.4	0.6	3.5	14.1	13.8	17.1
2008	40.2	5.3	-32.7	8.9	2.5	5.3	49.8	42.5	54.3
Average	36.0	4.3	-18.4	8.5	2.6	3.9	43.9	38.0	47.4

Compared to Base Case

	increase >=50%
	increase >=10% and <50%
	increase <10%
	no change <1%
	decrease <10%
	decrease >=10% and <50%
	decrease >=50%

Table 24

Maximum Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 41 (Sandy Creek confluence) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	10.1	13.3	10.4	8.6	11.2	10.4	10.2	14.6	13.7	14.7
1985	19.0	22.0	20.4	16.3	22.9	19.2	19.2	25.5	22.0	25.4
1986	10.9	12.1	11.2	10.2	11.2	11.0	11.5	14.4	12.6	14.3
1987	15.3	16.3	15.8	14.9	15.1	15.2	16.1	16.0	16.2	17.0
1988	21.7	22.9	22.1	20.0	21.7	21.7	21.7	22.9	22.9	22.9
1989	10.7	13.5	11.4	7.9	12.5	11.2	10.8	15.7	14.3	15.8
1990	26.9	28.3	27.4	24.7	26.9	26.9	27.2	28.2	28.3	28.7
1991	10.5	14.2	11.4	7.4	11.7	11.1	10.7	15.9	14.4	16.2
1992	17.0	18.7	17.1	17.2	17.0	17.0	18.6	18.8	18.8	20.2
1993	8.6	12.8	9.3	6.0	10.9	9.5	8.9	13.7	13.6	13.9
1994	32.7	33.1	32.8	31.5	33.2	32.8	35.8	33.7	33.3	36.9
1995	19.5	20.3	19.7	20.7	18.8	19.3	20.0	19.5	20.1	20.1
1996	19.4	22.9	19.6	18.7	20.1	19.5	19.4	24.7	23.3	24.8
1997	16.3	17.9	16.8	16.8	16.7	16.4	17.7	18.7	18.3	19.2
1998	30.4	31.8	30.7	26.4	31.2	30.7	30.5	33.2	32.3	33.2
1999	16.9	19.5	17.4	14.2	19.3	18.0	17.0	22.2	20.2	22.3
2000	8.0	10.4	8.3	8.2	7.5	6.8	8.3	12.7	11.2	12.7
2001	13.8	19.4	13.9	14.1	16.0	14.3	14.0	20.1	19.6	20.0
2002	97.5	97.7	97.6	89.5	97.4	97.4	106.3	97.7	97.7	106.6
2003	11.7	14.1	12.2	9.4	13.9	12.4	11.8	16.3	14.7	16.4
2004	17.8	19.7	17.8	15.5	18.2	17.9	19.2	20.1	19.8	21.6
2005	29.0	29.7	29.1	27.7	28.1	28.8	30.9	29.1	29.4	30.3
2006	18.3	19.2	18.4	16.7	20.1	18.5	18.8	20.5	19.9	20.7
2007	33.9	35.7	34.5	35.4	36.4	34.8	34.0	37.9	36.4	38.0
2008	9.2	13.9	10.3	6.5	10.3	9.5	9.5	15.5	14.3	16.0
Average	21.0	23.2	21.4	19.4	21.9	21.2	21.9	24.3	23.5	25.1

Notes:

Table values are maxima of daily concentrations in lake surface (top 2 meters) for an entire year

Table 25

Percent Change in Maximum Chlorophyll-*a* Concentration at Segment 41 (Sandy Creek confluence) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	32.0	2.9	-15.0	10.5	3.1	0.9	44.3	35.9	45.1
1985	15.7	7.3	-14.4	20.4	1.3	0.9	34.1	16.0	33.7
1986	11.0	2.4	-7.0	2.7	1.0	5.0	31.4	15.0	30.9
1987	6.6	3.2	-2.5	-1.4	-0.5	5.2	4.6	5.8	11.1
1988	5.5	1.9	-7.5	0.2	0.2	0.3	5.5	5.8	5.6
1989	26.1	6.2	-26.2	16.6	5.0	1.2	47.1	33.8	48.2
1990	5.3	1.7	-8.3	-0.1	0.1	1.0	4.9	5.3	6.9
1991	35.0	8.8	-29.3	12.0	6.1	1.9	52.1	37.6	54.5
1992	10.0	0.5	0.8	-0.1	-0.1	9.1	10.2	10.1	18.5
1993	49.3	8.4	-30.0	27.3	10.1	3.4	59.6	58.1	61.2
1994	1.4	0.3	-3.5	1.5	0.4	9.5	3.1	1.8	12.8
1995	4.3	1.3	6.5	-3.2	-0.8	2.9	0.2	3.1	3.5
1996	18.1	1.1	-3.4	3.9	0.5	0.4	27.7	20.2	28.0
1997	9.9	3.1	2.8	2.2	0.6	8.3	14.8	12.0	17.5
1998	4.9	1.0	-13.1	2.6	1.1	0.5	9.5	6.6	9.4
1999	15.6	3.0	-16.0	14.1	6.2	0.2	31.4	19.4	31.8
2000	29.4	2.8	1.8	-6.5	-15.0	2.9	58.1	38.9	57.4
2001	40.5	0.5	1.7	15.2	2.9	0.8	44.9	41.3	44.7
2002	0.2	0.1	-8.1	-0.1	0.0	9.1	0.2	0.2	9.4
2003	20.6	4.7	-19.2	19.4	6.2	1.5	39.9	26.3	41.1
2004	10.8	0.0	-12.9	2.3	0.6	8.2	12.9	11.5	21.4
2005	2.5	0.4	-4.4	-3.1	-0.7	6.8	0.5	1.5	4.7
2006	5.0	0.9	-8.6	10.2	1.3	3.0	12.3	9.1	13.2
2007	5.3	1.8	4.5	7.4	2.6	0.2	11.8	7.3	12.1
2008	50.9	11.9	-29.4	11.9	3.0	3.8	68.4	55.4	73.8
Average	16.6	3.0	-9.6	6.6	1.4	3.5	25.2	19.1	27.9

Compared to Base Case

	increase >=50%
	increase >=10% and <50%
	increase <10%
	no change <1%

	decrease <10%
	decrease >=10% and <50%
	decrease >=50%

Table 26
Average Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 100 (Horseshoe Bay Cove) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	2.4	3.5	2.4	2.3	2.3	2.3	2.5	3.3	3.3	3.3
1985	3.5	4.7	3.7	3.0	3.9	3.7	3.5	5.0	4.7	5.1
1986	4.1	5.4	4.3	3.5	4.3	4.2	4.2	5.6	5.4	5.7
1987	3.0	3.8	3.4	2.6	3.1	3.0	3.1	4.0	3.9	4.1
1988	3.2	4.6	3.4	2.5	3.6	3.4	3.3	5.0	4.6	5.0
1989	2.8	4.2	2.9	2.2	3.4	3.0	2.9	4.8	4.4	4.8
1990	4.3	5.7	4.5	3.8	4.7	4.5	4.5	6.0	5.8	6.1
1991	3.1	4.5	3.3	2.4	3.7	3.3	3.2	5.1	4.6	5.1
1992	5.1	6.4	5.2	4.8	5.1	5.1	5.4	6.5	6.5	6.7
1993	2.7	4.1	2.8	2.3	3.1	2.9	2.8	4.5	4.2	4.5
1994	6.3	7.6	6.4	6.0	6.6	6.4	6.6	8.0	7.8	8.2
1995	4.7	5.9	4.9	4.3	5.1	4.9	4.8	6.3	6.0	6.3
1996	4.1	5.7	4.2	3.6	4.2	4.1	4.2	5.8	5.5	5.9
1997	4.7	5.4	4.9	4.3	4.4	4.5	4.9	5.2	5.4	5.4
1998	4.6	5.6	4.8	4.2	4.7	4.7	4.8	5.8	5.7	5.9
1999	3.6	5.0	3.8	2.9	4.3	3.9	3.7	5.8	5.2	5.7
2000	2.2	3.5	2.2	1.6	2.5	2.3	2.2	4.0	3.5	4.0
2001	3.0	3.8	3.3	2.4	3.3	3.1	3.1	4.1	3.9	4.1
2002	6.8	7.7	6.9	6.3	6.8	6.8	7.2	7.8	7.9	8.0
2003	4.2	5.3	4.3	3.4	4.5	4.3	4.3	5.7	5.3	5.7
2004	5.7	6.7	5.8	5.0	6.0	5.8	5.9	7.3	6.9	7.3
2005	7.8	9.1	7.9	7.4	8.1	8.0	8.3	9.6	9.3	9.7
2006	4.4	6.9	4.3	3.9	4.8	4.5	4.5	7.5	6.9	7.4
2007	7.3	8.2	7.7	7.0	7.4	7.4	7.5	8.3	8.4	8.6
2008	2.8	4.0	3.0	2.0	3.1	2.9	2.9	4.4	4.0	4.4
Average	4.3	5.5	4.4	3.7	4.5	4.4	4.4	5.8	5.6	5.9

Notes:

Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 27

Percent Change in Average Chlorophyll-*a* Concentration at Segment 100 (Horseshoe Bay Cove) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	43.5	-0.9	-5.6	-5.2	-3.5	2.2	36.2	37.4	38.9
1985	35.2	6.0	-14.3	10.8	6.1	1.3	43.9	34.7	45.7
1986	31.9	5.0	-15.1	6.1	3.2	2.3	36.5	32.0	39.7
1987	27.0	11.6	-15.7	3.4	0.4	3.7	30.6	28.7	35.3
1988	41.9	4.6	-23.3	10.1	3.6	2.1	52.9	42.3	53.4
1989	51.7	4.0	-21.0	22.1	9.2	3.2	74.3	57.7	73.8
1990	30.8	3.1	-12.3	8.3	3.4	3.6	38.9	33.6	40.7
1991	42.8	4.0	-22.1	16.4	6.4	2.9	61.8	46.6	61.8
1992	25.7	3.1	-5.0	0.3	-0.3	6.6	27.3	28.1	32.0
1993	49.1	2.2	-16.4	13.5	4.7	3.8	64.4	52.5	65.9
1994	21.3	1.5	-5.1	4.2	1.8	5.0	27.3	23.5	30.1
1995	24.8	2.5	0.9	6.8	3.7	1.5	32.8	26.4	32.4
1996	38.4	1.2	-2.7	0.8	-0.3	1.2	39.9	33.9	41.9
1997	16.5	5.3	-13.7	-4.8	-3.2	4.3	10.7	15.8	15.8
1998	21.5	4.2	-13.4	2.0	1.0	3.8	25.0	22.7	26.9
1999	38.0	6.6	11.6	18.0	7.4	1.3	60.3	43.1	57.8
2000	60.3	1.8	83.2	13.2	4.7	2.4	84.0	60.8	80.4
2001	26.5	7.9	32.5	7.4	1.9	0.6	36.4	29.2	36.1
2002	13.6	1.7	-40.8	0.8	0.5	5.5	14.4	15.7	17.9
2003	25.6	3.7	-3.8	8.4	3.4	3.8	37.1	27.9	35.6
2004	18.1	1.5	-29.2	5.9	2.1	3.4	27.8	21.7	28.1
2005	16.0	0.3	-48.7	2.9	1.7	6.0	22.4	18.4	24.2
2006	55.6	-2.2	-8.7	7.8	3.1	2.7	70.2	55.8	68.8
2007	12.2	6.2	-44.6	1.5	1.6	2.7	14.8	15.3	18.3
2008	40.7	6.6	43.1	8.7	2.8	4.8	57.8	43.4	55.7
Average	32.4	3.7	-7.6	6.8	2.6	3.2	41.1	33.9	42.3

Compared to Base Case

(red)	increase >=50%
(orange)	increase >=10% and <50%
(yellow)	increase <10%
(white)	no change <1%
(light green)	decrease <10%
(light blue)	decrease >=10% and <50%
(purple)	decrease >=50%

Table 28
Maximum Predicted Chlorophyll-*a* Concentration (ug/L) at Segment 100 (Horseshoe Bay Cove) - Lake LBJ

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	8.1	10.5	8.0	7.9	8.4	8.2	8.1	10.6	10.4	10.6
1985	18.8	21.4	20.2	17.3	18.0	19.2	19.4	21.0	21.0	20.8
1986	10.0	10.3	10.3	9.2	9.7	9.6	10.2	11.1	10.5	11.2
1987	21.6	22.5	21.7	21.3	20.4	21.2	22.1	20.8	22.1	21.4
1988	8.6	10.9	8.7	8.2	9.7	8.9	8.6	11.3	10.6	11.6
1989	8.8	12.0	9.1	6.6	10.2	9.4	9.1	13.1	12.4	13.0
1990	11.6	12.4	12.0	11.1	12.1	11.6	11.6	13.4	12.9	13.3
1991	7.2	11.7	7.6	6.3	9.5	8.1	7.5	14.7	12.3	14.9
1992	15.5	17.3	16.1	15.5	16.0	15.7	16.7	17.5	18.1	18.7
1993	8.8	11.0	9.2	7.3	10.3	9.0	9.0	12.8	12.0	13.0
1994	24.6	25.9	26.1	23.7	26.1	25.0	26.4	28.6	27.2	29.2
1995	18.3	18.5	19.0	18.7	19.6	19.3	18.6	20.8	19.7	21.2
1996	9.9	13.0	10.2	9.5	10.4	10.2	10.2	13.3	13.0	14.3
1997	17.6	19.1	18.1	18.2	17.6	17.6	19.0	18.0	19.9	20.5
1998	13.6	13.1	14.2	13.1	13.8	13.8	13.9	14.9	13.4	14.0
1999	8.5	11.9	10.2	6.7	11.2	9.3	8.8	13.1	12.2	13.2
2000	5.4	9.1	5.5	4.9	5.6	5.5	6.0	10.0	8.7	10.0
2001	10.4	10.9	10.4	9.7	9.9	10.4	10.5	10.9	10.9	11.0
2002	45.3	43.8	45.5	39.1	45.4	45.4	49.1	46.3	45.9	47.2
2003	7.5	10.5	7.6	6.8	8.9	8.0	7.9	12.6	10.8	12.6
2004	14.3	15.1	14.4	13.6	14.9	14.4	14.5	15.4	15.7	16.3
2005	25.1	27.6	24.9	26.2	25.9	25.0	25.6	29.1	27.7	29.5
2006	8.5	14.5	9.4	7.6	11.2	9.1	8.7	16.0	13.6	15.4
2007	27.9	27.7	28.7	28.2	26.5	28.8	28.5	26.8	27.9	27.0
2008	7.1	10.8	7.8	3.7	7.8	7.3	7.2	12.0	11.0	11.8
Average	14.5	16.5	15.0	13.6	15.2	14.8	15.1	17.4	16.8	17.7

Notes:

Table values are maxima of daily concentrations in lake surface (top 2 meters) for an entire year

Table 29

Percent Change in Maximum Chlorophyll-*a* Concentration at Segment 100 (Horseshoe Bay Cove) - Lake LBJ

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	28.5	-1.1	-3.3	3.4	1.1	0.0	30.7	27.7	30.6
1985	14.1	7.4	-7.7	-4.0	2.2	3.5	11.9	11.7	11.0
1986	3.4	3.5	-7.8	-3.3	-3.5	2.4	11.4	4.8	11.7
1987	4.1	0.3	-1.6	-5.7	-1.6	2.5	-3.5	2.5	-1.1
1988	26.2	1.1	-5.3	12.7	3.3	0.1	31.3	22.3	33.9
1989	36.8	4.0	-24.3	16.5	7.1	4.1	49.9	41.0	48.3
1990	6.8	3.7	-4.6	4.2	0.5	0.5	15.5	11.5	14.7
1991	61.1	5.2	-12.7	31.5	11.4	3.7	103.1	70.7	105.7
1992	11.4	3.3	-0.1	2.9	1.0	7.3	12.6	16.3	20.4
1993	24.9	4.4	-17.9	16.6	1.7	2.3	45.2	35.6	47.0
1994	5.5	6.2	-3.6	6.2	1.7	7.6	16.4	10.9	19.0
1995	1.1	3.9	1.9	6.9	5.3	1.3	13.6	7.7	15.6
1996	31.3	3.0	-4.1	4.4	2.5	3.1	33.5	31.1	44.2
1997	8.6	2.9	3.1	-0.3	-0.3	7.7	2.1	12.9	16.6
1998	-3.9	3.8	-4.3	1.5	1.4	1.6	9.4	-1.7	2.5
1999	40.0	20.6	-20.7	31.8	9.8	4.2	54.8	43.4	55.7
2000	67.6	1.6	-9.2	3.9	2.4	10.4	84.9	59.9	85.4
2001	4.5	-0.2	-6.5	-4.9	-0.5	0.6	4.6	4.6	5.1
2002	-3.5	0.5	-13.7	0.2	0.1	8.3	2.0	1.2	4.2
2003	39.6	0.7	-9.9	18.5	6.3	5.4	67.8	43.4	67.1
2004	5.7	1.1	-4.6	4.6	1.1	1.8	7.7	10.1	14.5
2005	10.0	-0.6	4.4	3.2	-0.4	1.8	16.1	10.4	17.6
2006	71.1	10.3	-10.0	32.0	7.4	2.3	88.8	60.5	81.0
2007	-0.6	3.0	0.9	-5.1	3.4	2.0	-4.0	0.2	-3.0
2008	52.8	9.6	-47.0	10.1	3.1	2.1	69.2	55.4	67.4
Average	21.9	3.9	-8.3	7.5	2.7	3.5	31.0	23.8	32.6

Compared to Base Case

Red	increase >=50%
Orange	increase >=10% and <50%
Yellow	increase <10%
White	no change <1%
Light green	decrease <10%
Blue	decrease >=10% and <50%
Purple	decrease >=50%

Table 30
Average Predicted Chlorophyll-a Concentrations (ug/L) at Segment 26 - Lake Marble Falls

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	3.1	6.2	3.2	3.6	3.2	3.1	3.4	6.3	6.2	6.6
1985	6.0	7.5	6.1	6.3	6.1	6.1	6.5	7.4	7.5	7.9
1986	5.9	8.5	6.0	6.3	6.0	5.9	6.5	8.6	8.6	9.2
1987	4.0	4.8	4.1	4.1	4.0	4.0	4.4	4.8	4.8	5.2
1988	4.3	5.9	4.3	4.5	4.4	4.3	4.8	6.0	5.9	6.5
1989	4.2	7.6	4.3	4.8	4.5	4.3	4.6	7.8	7.7	8.2
1990	7.4	9.7	7.5	7.8	7.7	7.5	8.1	9.8	9.8	10.5
1991	4.2	6.2	4.3	4.6	4.4	4.3	4.7	6.3	6.2	6.7
1992	6.5	7.9	6.7	7.0	6.5	6.5	7.1	7.9	7.9	8.5
1993	3.9	6.1	4.0	4.3	4.0	3.9	4.3	6.1	6.1	6.5
1994	9.4	12.9	9.5	10.3	9.6	9.5	10.3	13.0	13.0	13.8
1995	8.5	11.0	8.6	9.0	8.6	8.5	9.3	11.1	11.0	11.9
1996	6.3	9.3	6.3	6.8	6.5	6.3	6.9	9.3	9.3	9.9
1997	6.1	6.8	6.2	6.3	6.2	6.2	6.7	6.8	6.8	7.4
1998	6.5	7.8	6.6	6.8	6.6	6.5	7.2	7.8	7.8	8.5
1999	5.5	8.9	5.6	6.1	5.6	5.5	6.0	9.0	8.9	9.5
2000	3.9	7.0	4.0	4.6	4.2	3.9	4.2	7.2	7.1	7.6
2001	4.4	5.8	4.5	4.7	4.5	4.4	4.9	5.9	5.8	6.3
2002	9.1	11.5	9.2	9.4	9.1	9.1	9.9	11.5	11.5	12.3
2003	5.2	6.2	5.2	5.4	5.2	5.2	5.7	6.3	6.3	6.8
2004	7.3	8.8	7.4	7.6	7.4	7.3	8.0	8.8	8.8	9.5
2005	11.0	12.9	11.1	11.9	11.1	11.0	12.0	12.8	12.9	13.7
2006	6.9	10.5	7.0	8.3	6.9	6.9	7.6	10.4	10.5	11.0
2007	11.1	12.3	11.2	11.4	11.2	11.1	12.2	12.3	12.3	13.3
2008	3.6	6.4	3.8	4.1	3.7	3.6	4.0	6.5	6.4	6.9
Average	6.2	8.3	6.3	6.6	6.3	6.2	6.8	8.4	8.4	8.9

Notes:

Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 31

Percent Change in Average Chlorophyll-a Concentration at Segment 26 - Lake Marble Falls

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	100.8	3.6	15.9	5.0	1.5	10.4	104.0	101.8	114.3
1985	24.3	0.7	3.7	0.8	0.5	8.1	23.5	24.6	30.9
1986	44.8	0.9	7.1	1.8	0.5	10.3	45.9	45.1	55.9
1987	20.9	3.2	3.9	0.1	0.0	11.1	20.8	20.9	32.2
1988	37.8	0.3	6.2	2.6	0.8	11.1	39.8	38.3	50.7
1989	80.7	3.1	13.2	7.1	2.3	9.6	85.0	82.2	94.1
1990	31.4	0.8	5.9	3.8	1.3	9.3	32.4	32.0	41.5
1991	46.0	1.9	7.7	3.3	1.0	10.7	47.3	46.4	57.0
1992	21.7	2.7	8.1	0.6	0.1	9.9	21.6	21.6	31.2
1993	56.2	1.9	10.3	2.6	0.9	10.8	55.9	56.1	66.6
1994	37.3	0.7	8.8	1.3	0.4	9.5	37.7	37.4	46.8
1995	29.8	1.0	6.3	1.6	0.5	9.9	30.4	30.0	39.9
1996	47.3	0.4	8.8	2.7	0.9	9.7	48.9	47.8	57.9
1997	10.6	0.4	2.7	0.4	0.1	9.7	10.9	10.7	20.5
1998	19.4	1.3	4.4	1.1	0.3	10.2	20.3	19.6	30.2
1999	63.4	1.8	11.5	2.6	0.8	10.5	64.7	63.7	74.0
2000	82.6	3.3	19.1	8.1	2.5	9.4	87.1	84.1	97.1
2001	31.6	1.9	6.0	1.3	0.4	10.4	32.3	31.8	41.8
2002	26.8	1.4	4.2	1.0	0.3	9.5	27.3	26.9	36.0
2003	20.6	0.8	4.8	0.9	0.3	10.5	21.0	20.7	31.1
2004	20.4	1.4	4.6	1.4	0.4	9.9	20.7	20.5	30.2
2005	17.3	1.0	8.7	1.1	0.3	9.3	16.9	17.2	25.3
2006	52.1	1.9	20.1	0.2	0.0	9.5	49.8	51.4	58.7
2007	9.9	0.8	2.0	0.1	0.0	9.3	10.0	9.9	18.9
2008	76.7	4.8	13.2	3.1	1.0	11.3	78.9	77.4	90.7
Average	40.4	1.7	8.3	2.2	0.7	10.0	41.3	40.7	50.9

Compare to Base Case

(red)	increase >=50%
(orange)	increase >=10% and <50%
(yellow)	increase <10%
(white)	no change <1%
(light green)	decrease <10%
(blue)	decrease >=10% and <50%
(purple)	decrease >=50%

Table 32
Maximum Predicted Chlorophyll-a Concentrations (ug/L) at Segment 26 - Lake Marble Falls

Year	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	9.3	21.9	9.9	11.4	9.6	9.4	10.3	23.9	22.5	24.4
1985	32.4	35.3	33.0	32.7	33.5	29.4	33.2	42.8	36.0	43.1
1986	13.5	23.1	13.7	13.9	13.5	13.5	14.9	23.1	23.1	24.4
1987	33.9	34.3	34.3	34.1	34.0	33.9	37.4	34.5	34.4	38.0
1988	11.8	15.7	11.8	11.7	12.2	12.0	13.0	16.0	15.7	16.3
1989	10.0	20.5	10.5	11.2	12.5	10.8	10.4	23.9	21.5	24.4
1990	19.6	31.7	19.5	19.5	21.8	19.6	21.4	40.9	34.2	41.2
1991	8.8	16.0	8.8	9.8	9.4	8.8	9.6	16.0	16.0	16.8
1992	17.4	25.4	18.4	17.8	17.4	17.4	19.2	26.1	25.6	27.2
1993	13.2	19.5	13.9	14.2	13.7	13.2	14.5	19.5	19.6	20.9
1994	23.7	38.0	23.6	27.5	24.1	23.8	25.8	38.7	38.2	41.6
1995	20.9	36.1	20.8	21.0	21.1	20.9	22.9	38.4	36.7	39.9
1996	14.5	23.4	14.6	15.8	15.0	14.6	16.0	24.5	23.7	25.1
1997	25.8	24.6	25.8	24.6	25.5	25.7	27.9	24.3	24.5	26.2
1998	18.2	21.5	18.7	20.1	18.2	18.2	19.8	23.0	21.9	23.8
1999	11.9	17.9	12.3	12.5	12.1	11.9	13.2	19.5	18.4	19.9
2000	11.4	18.3	11.6	13.5	11.9	11.6	12.5	20.4	19.0	20.8
2001	12.8	14.7	12.9	12.9	12.8	12.8	14.1	14.8	14.8	16.1
2002	37.8	39.5	38.3	39.2	37.8	37.8	41.5	39.5	39.5	43.2
2003	8.7	14.0	8.7	9.6	9.0	8.8	9.7	14.1	13.9	14.9
2004	20.4	21.5	20.5	20.7	20.5	20.4	22.4	21.6	21.4	23.5
2005	41.3	41.6	42.5	41.1	41.2	41.3	44.5	41.6	41.7	45.6
2006	11.1	23.0	11.8	14.6	11.0	11.2	12.2	23.0	23.0	24.4
2007	48.4	49.2	47.8	48.3	48.4	48.4	53.4	49.2	49.2	54.7
2008	7.8	15.1	8.3	8.3	8.0	7.9	8.6	15.2	15.2	15.5
Average	19.4	25.7	19.7	20.2	19.8	19.3	21.1	27.0	26.0	28.5

Notes:
Table values are averages of daily concentrations in lake surface (top 2 meters) for an entire year.

Table 33

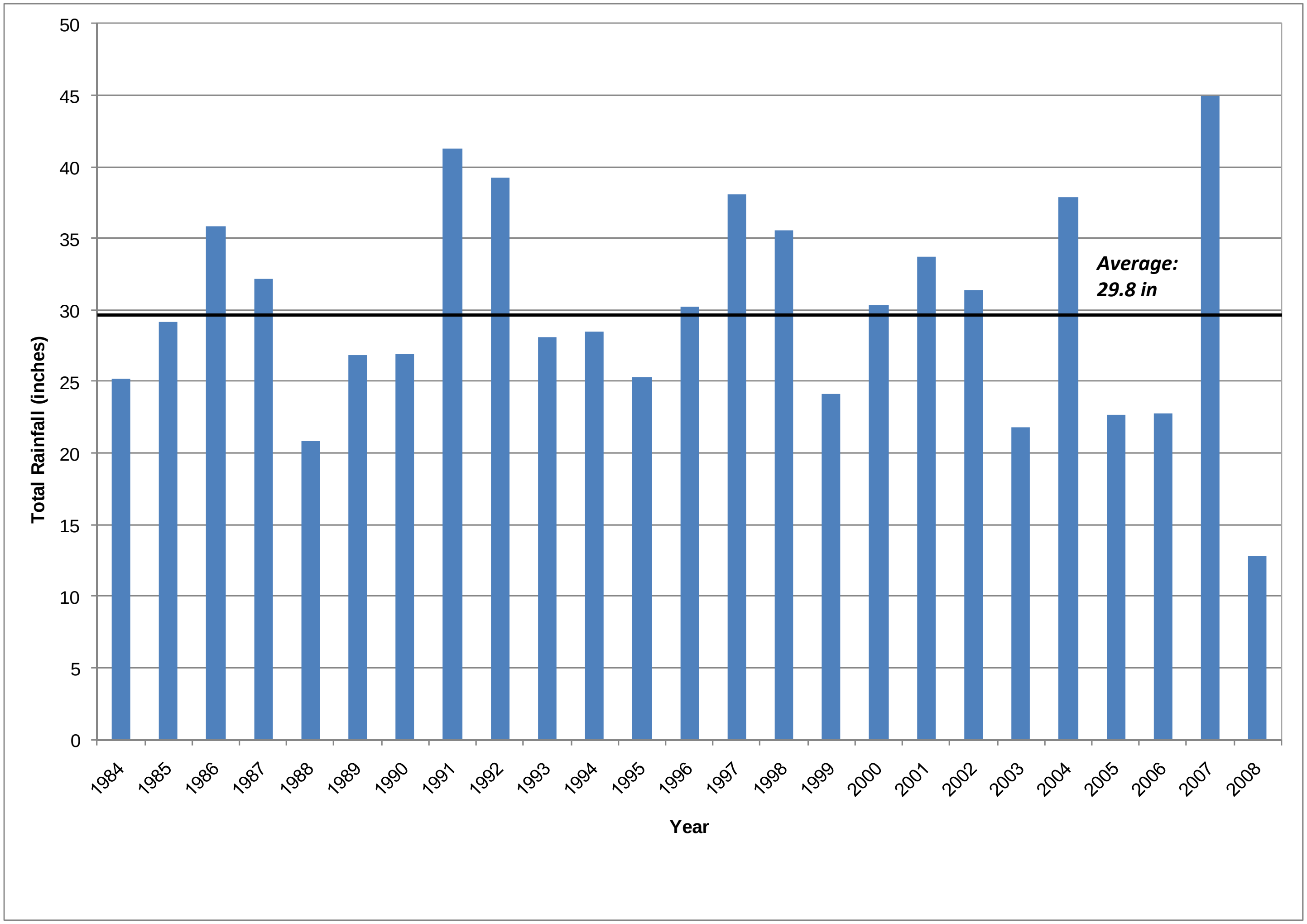
Percent Change in Maximum Chlorophyll-a Concentration at Segment 26 - Lake Marble Falls

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
1984	135.4	7.0	23.0	2.9	1.0	11.3	157.0	142.0	162.0
1985	9.0	1.7	1.0	3.2	-9.4	2.4	32.1	11.1	33.1
1986	71.8	2.0	2.9	0.1	0.0	11.0	71.9	71.6	81.1
1987	1.4	1.2	0.7	0.4	0.1	10.5	1.7	1.5	12.1
1988	33.0	-0.2	-1.3	3.6	1.1	10.0	35.6	33.0	38.1
1989	105.5	5.4	12.4	25.4	7.9	4.2	139.0	114.8	144.2
1990	62.1	-0.5	-0.4	11.4	0.0	9.1	108.8	74.8	110.6
1991	82.1	0.3	12.3	7.1	0.9	9.8	82.4	82.3	91.8
1992	45.9	5.5	2.4	0.0	0.0	10.2	49.9	47.1	56.2
1993	48.5	5.5	7.8	4.2	0.7	10.0	48.6	48.7	58.6
1994	60.5	-0.2	16.1	1.7	0.5	8.8	63.5	61.4	75.4
1995	73.3	-0.4	0.9	1.3	0.3	9.7	84.1	76.0	91.2
1996	61.4	0.4	8.6	3.1	0.9	10.3	68.6	63.6	72.8
1997	-4.6	0.0	-4.6	-1.0	-0.3	8.3	-5.7	-4.9	1.7
1998	17.7	2.4	10.1	-0.4	-0.1	8.9	26.0	20.2	30.4
1999	50.3	3.2	5.2	1.3	0.0	11.0	63.2	54.5	67.0
2000	60.1	0.9	17.9	4.0	1.1	9.6	78.0	65.8	82.0
2001	15.2	1.1	1.2	0.1	0.1	10.0	15.5	15.3	25.6
2002	4.6	1.4	3.9	0.0	0.0	9.9	4.6	4.6	14.3
2003	59.9	0.1	9.6	3.3	0.9	10.7	61.1	59.5	70.5
2004	5.0	0.3	1.3	0.3	0.0	9.6	5.5	4.9	14.8
2005	0.8	3.0	-0.5	0.0	0.0	7.8	0.8	1.0	10.4
2006	107.5	6.0	31.7	-0.3	1.1	10.1	107.4	107.8	120.1
2007	1.6	-1.3	-0.3	0.1	0.1	10.3	1.7	1.6	13.0
2008	93.6	6.6	5.8	2.4	0.8	10.7	95.0	94.2	98.6
Average	48.1	2.1	6.7	3.0	0.3	9.4	55.9	50.1	63.0

Compared to Base Case

(red)	increase >=50%
(orange)	increase >=10% and <50%
(yellow)	increase <10%
(white)	no change <1%
(light green)	decrease <10%
(blue)	decrease >=10% and <50%
(purple)	decrease >=50%

FIGURES



Based on the average of National Climatic Data Center (NCDC) data at 2 stations near Inks Lake watershed.

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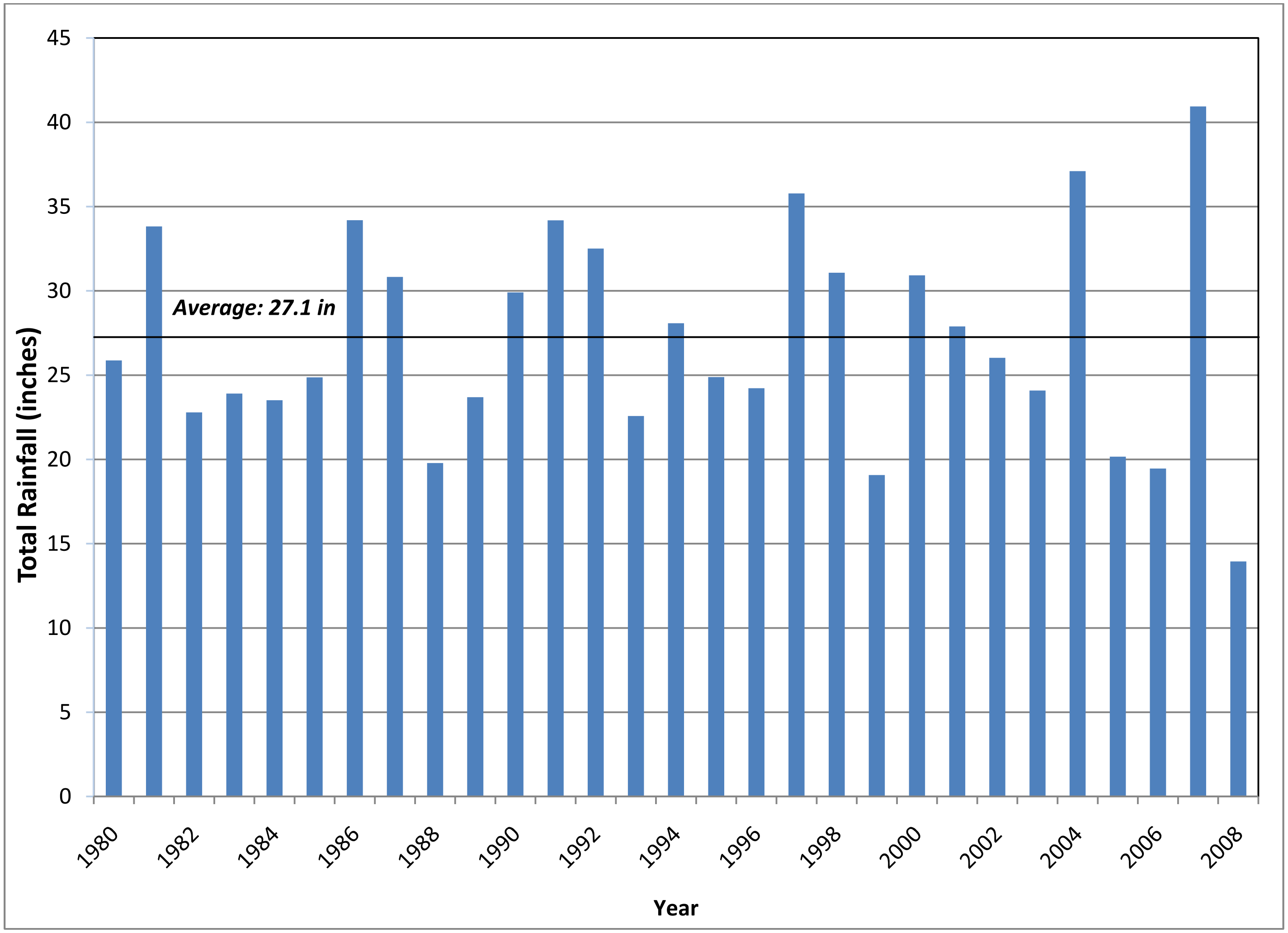
Figure 1a
Annual Precipitation in Inks Watershed
CREMS Phase 3 Scenarios
LCRA



Based on the average of National Climatic Data Center (NCDC) data at 14 stations within or near Lake LBJ watershed.

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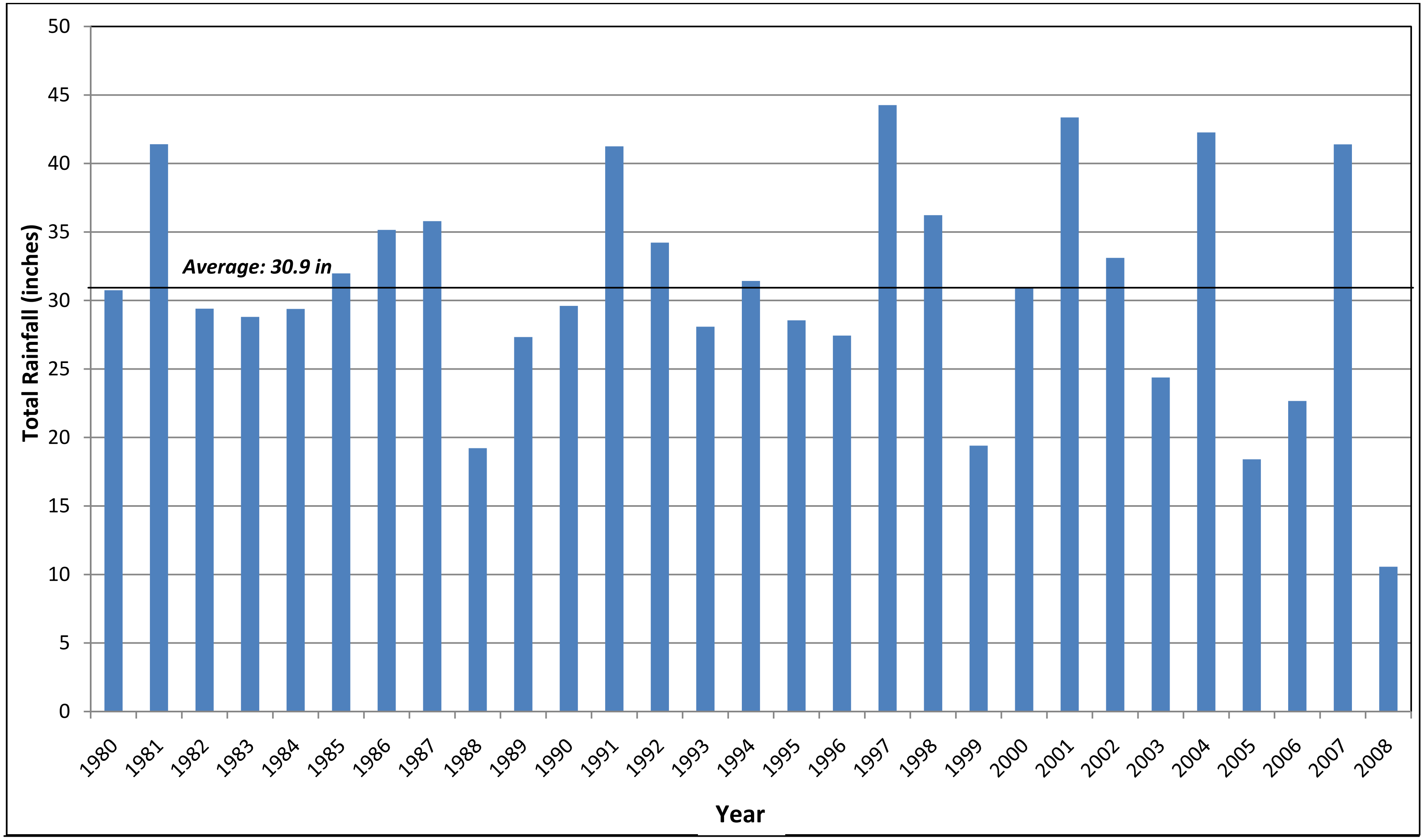
Figure 1b
Annual Precipitation in LBJ Watershed
CREMS Phase 3 Scenarios
LCRA



Based on the average of National Climatic Data Center (NCDC) data at 3 stations near Lake Marble Falls watershed.

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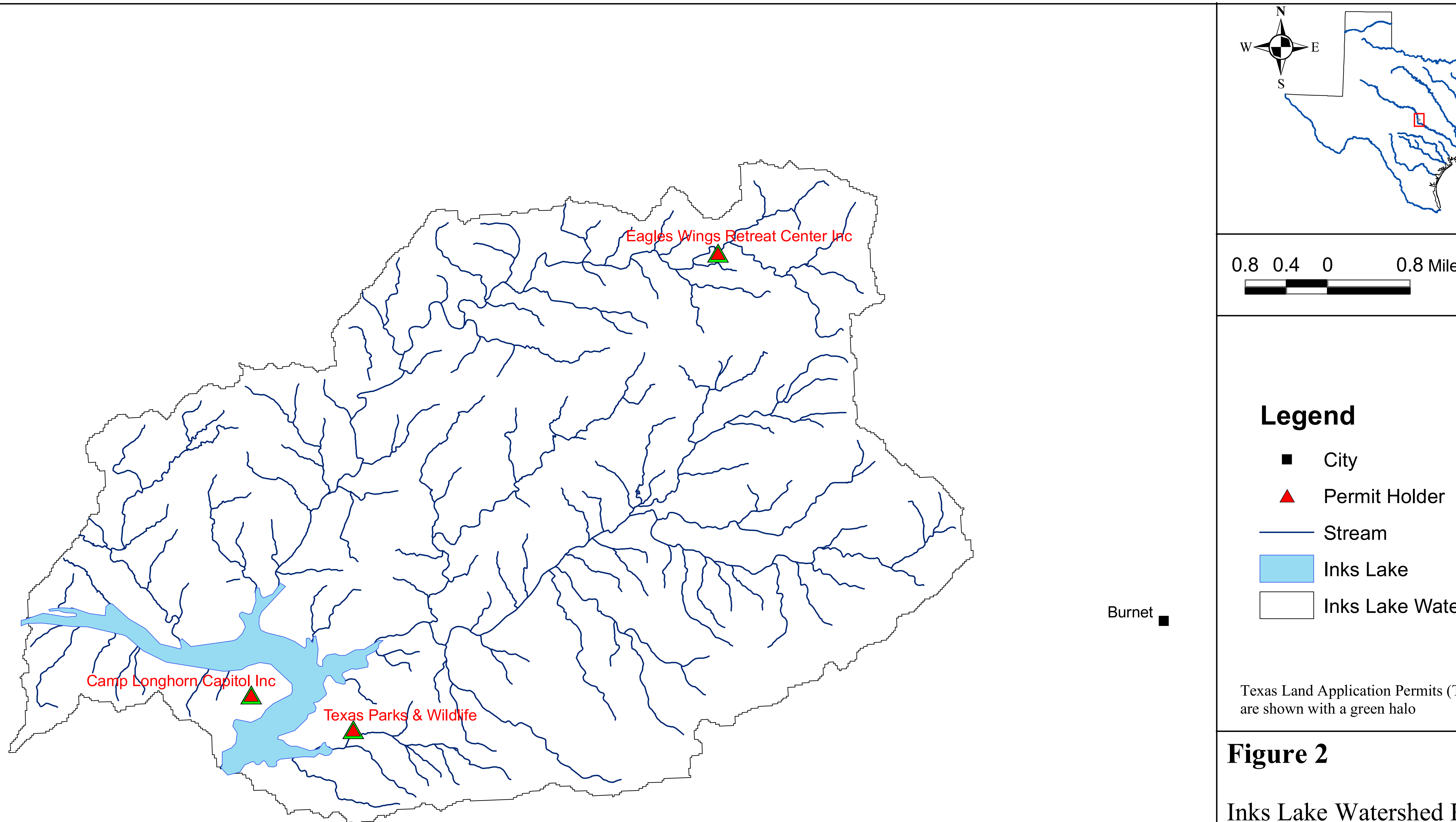
Figure 1c
Annual Precipitation in Lake Marble Falls Watershed
CREMS Phase 3 Scenarios
LCRA



Legend

- City
- Permit Holder
- Stream
- Inks Lake
- Inks Lake Watershed

Texas Land Application Permits (TLAPs) are shown with a green halo

Figure 2

Inks Lake Watershed Permit Holders

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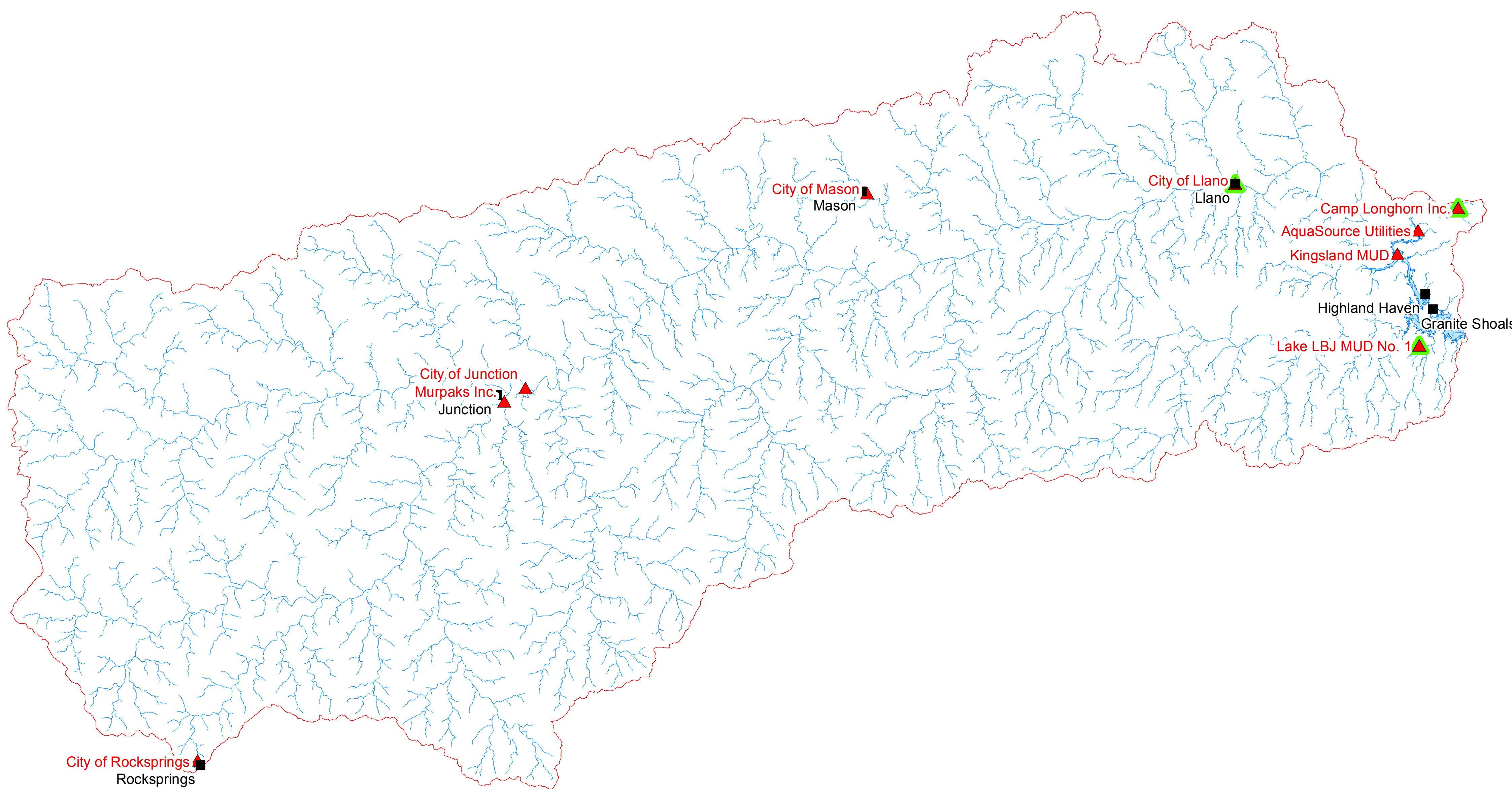
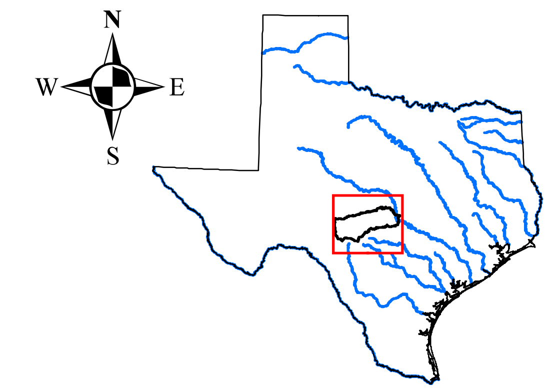




10 5 0 10 Miles

Legend

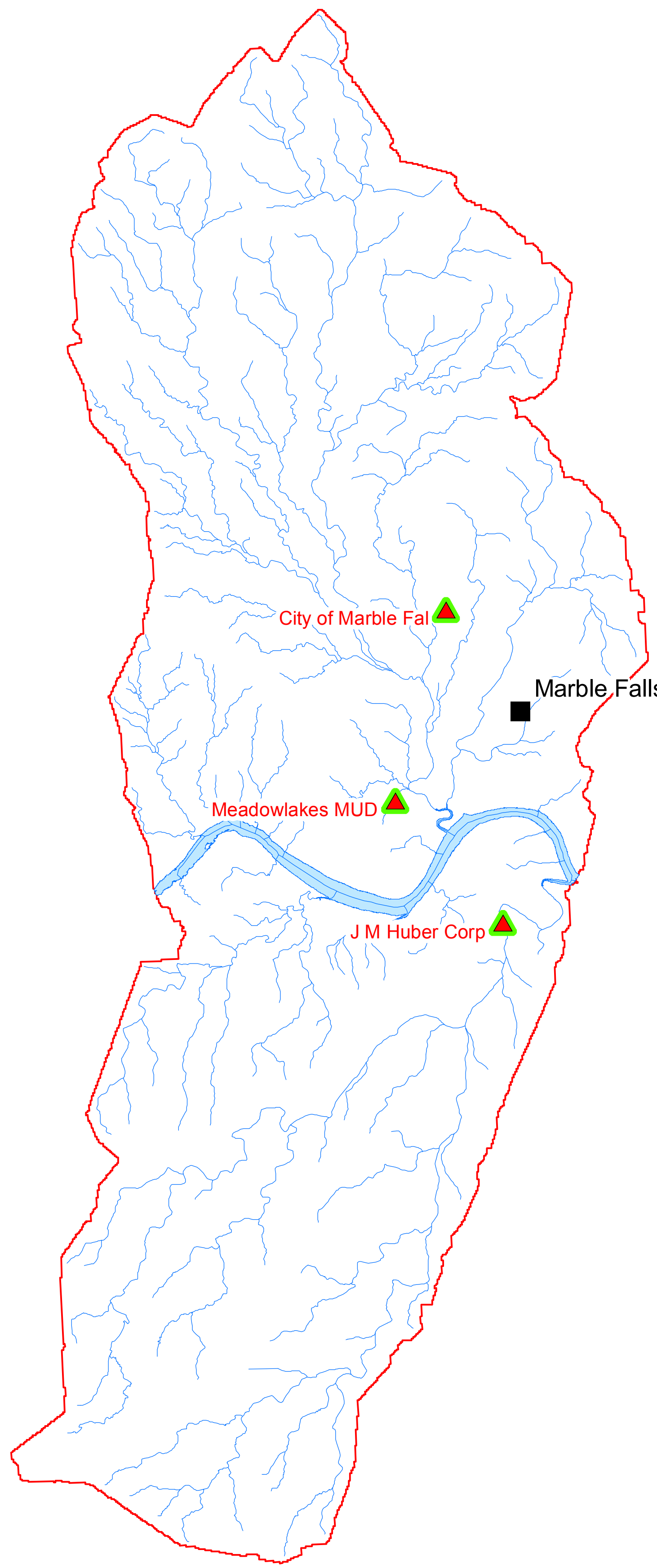
- Texas Cities
- Permit Holders
- Stream
- Lake LBJ
- Lake LBJ Watershed

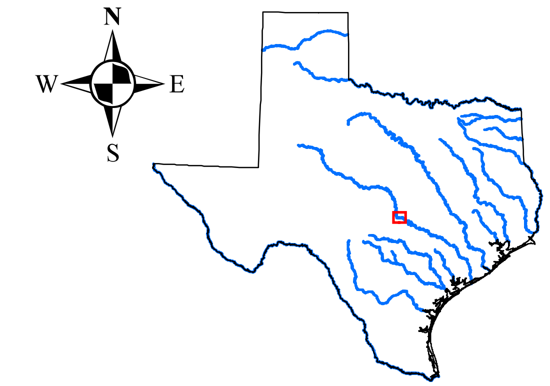
Note: Location for City of Llano discharger is approximate. Texas Land Application Permit (TLAP) are shown with a green halo.

Figure 3.

Lake LBJ Watershed Permit Holders

July 2011





2 1 0 2 Miles

Legend

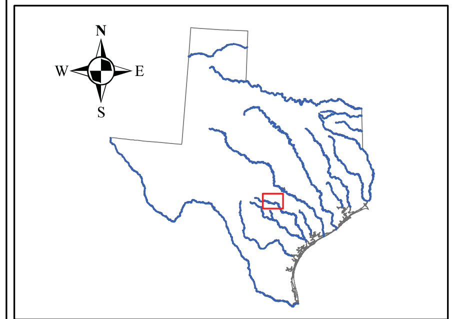
- Texas Cities
- Permit Holders
- Stream
- Lake Marble Falls Watershed
- Lake Marble Falls

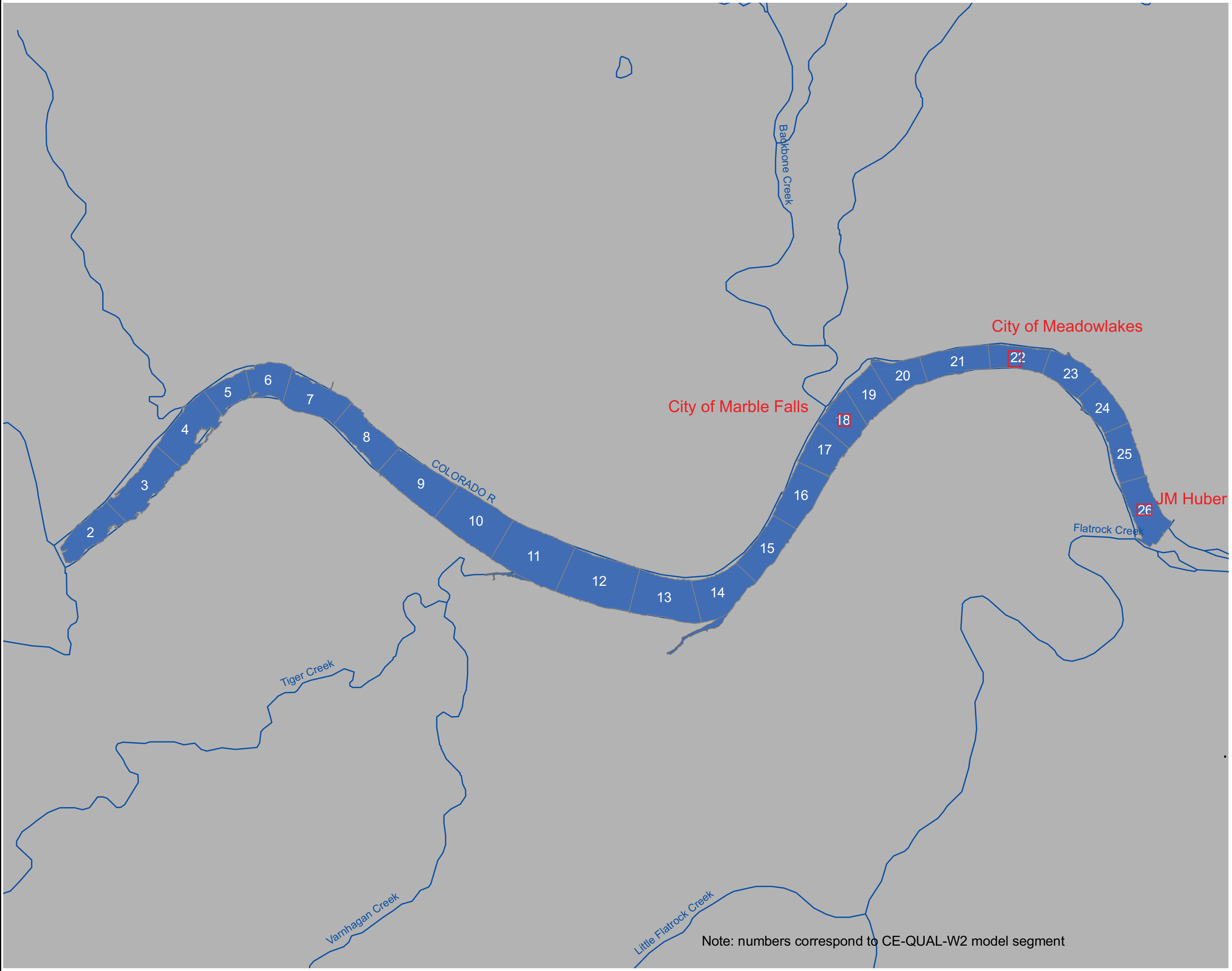
Note: Texas Land Application Permits (TLAPs) are shown with a green halo.

Figure 4a.

Lake Marble Falls Watershed
Permit Holders

July 2011





0.5 0.25 0 0.5 Miles

Legend

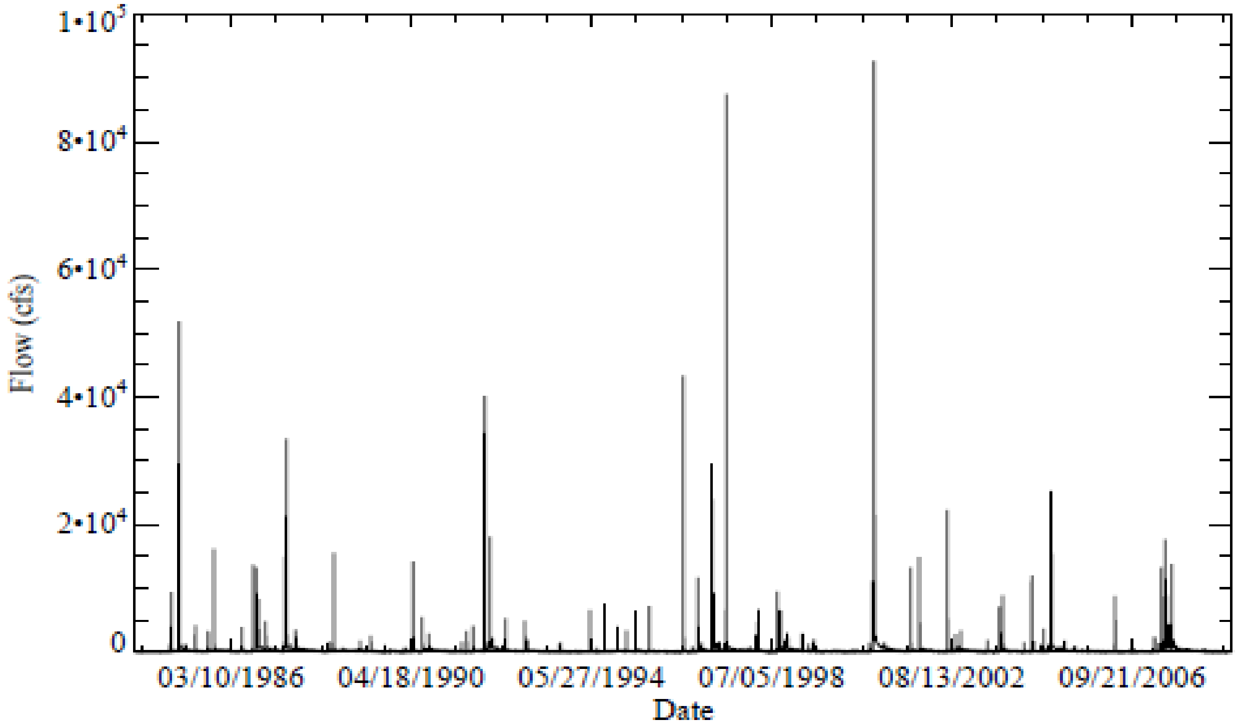
Marble Falls Lake Model Segment

Surface Water

Simulated Permit Holder Location

Figure 4b.
Lake Marble Falls
Model Segmentation with Location
of Discharge for Scenarios

July 2011



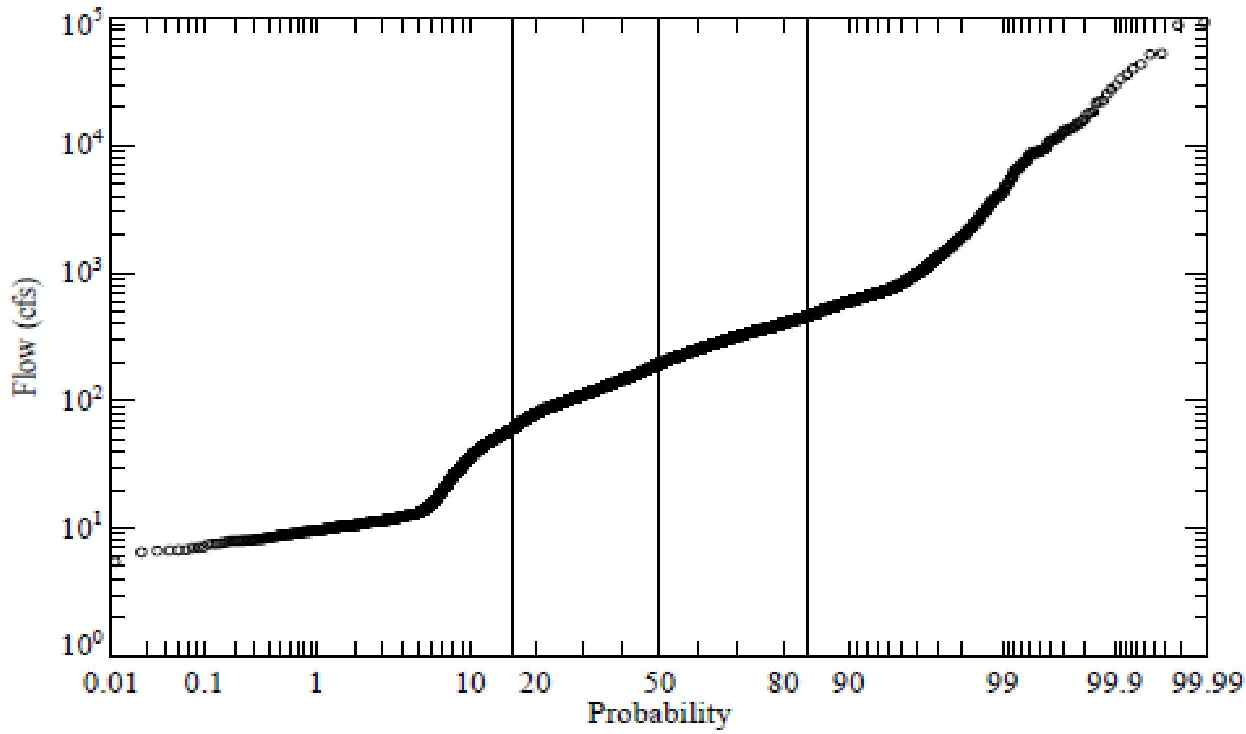
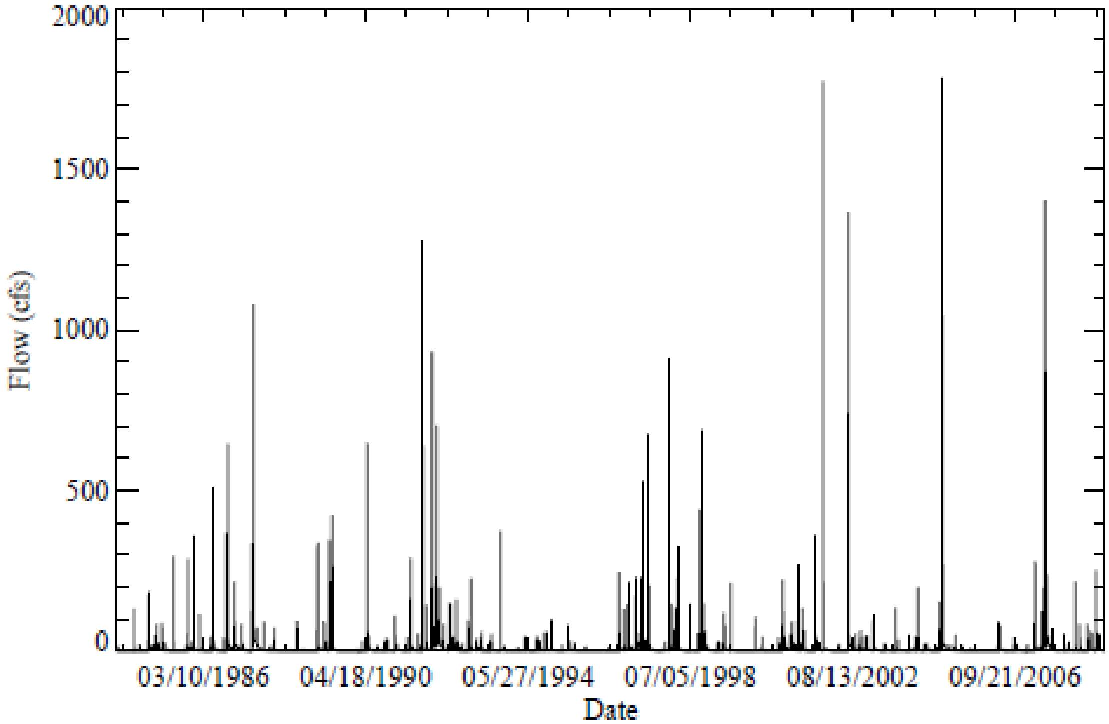


Figure 5
Temporal and Probability Plot of Model Flow for the Llano River
CREMS Phase 3 Scenarios
LCRA



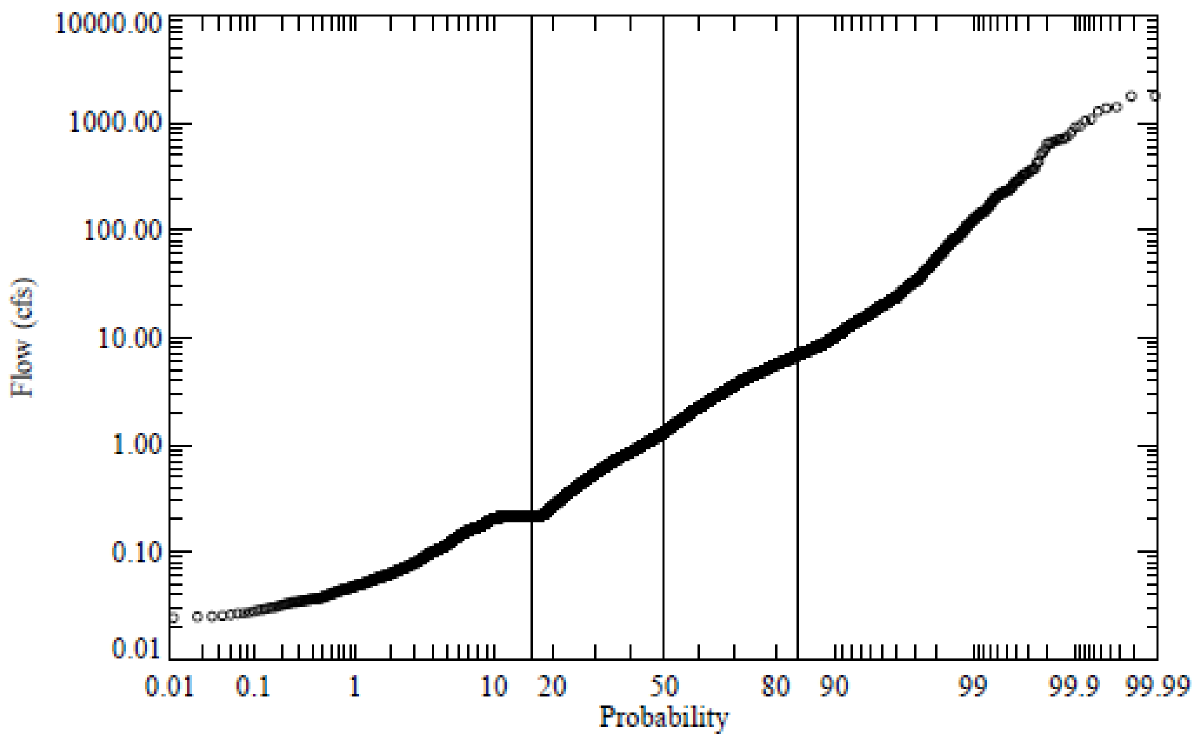


Figure 6
Temporal and Probability Plot of Model Flow for the Backbone Creek
CREMS Phase 3 Scenarios
LCRA

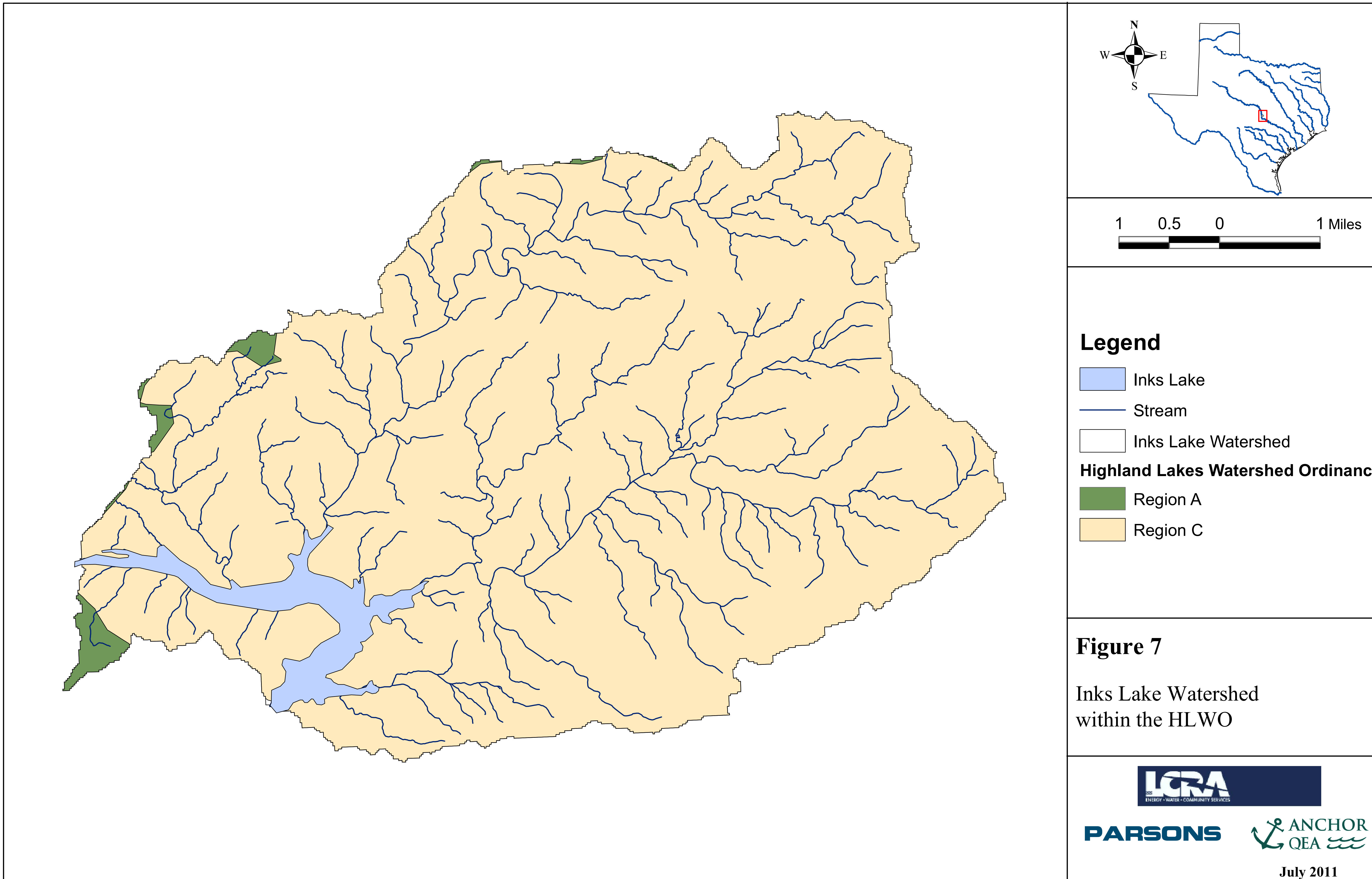


Figure 7

Inks Lake Watershed within the HLWO

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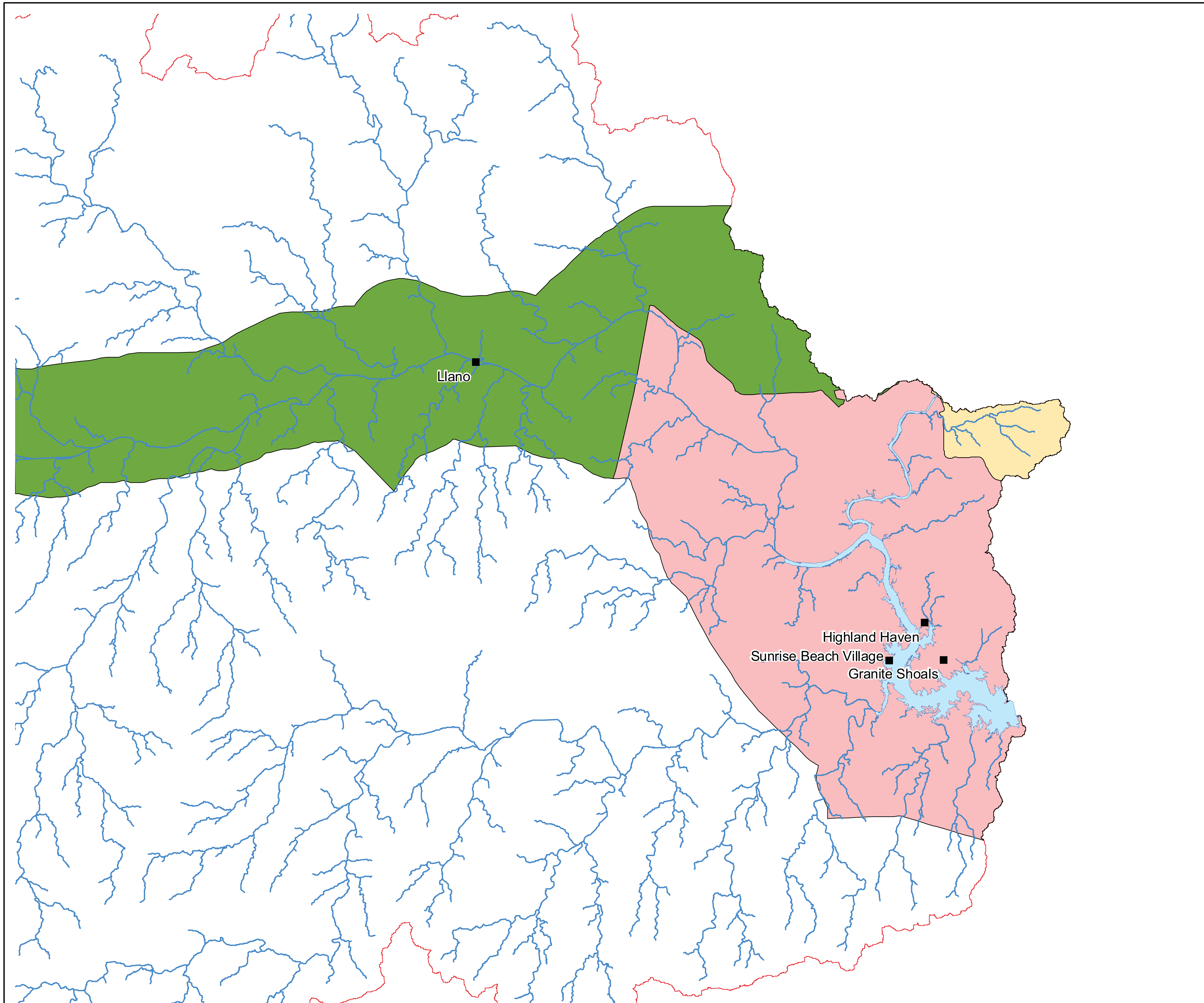


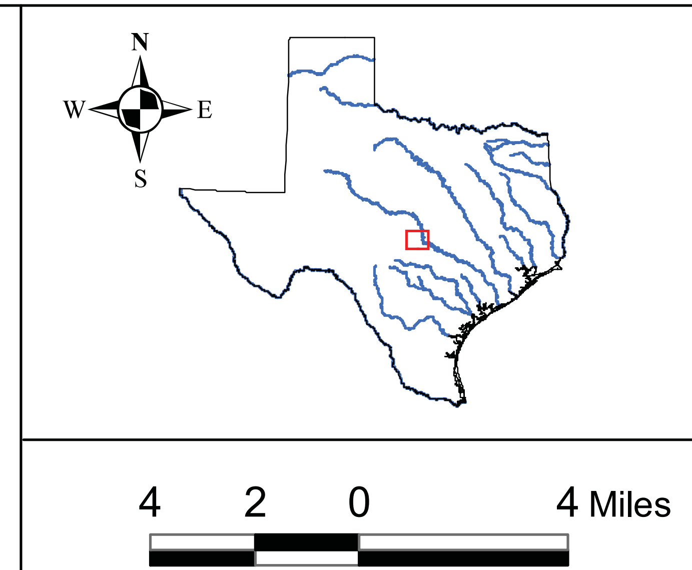


Figure 8

Lake LBJ Watershed within the HLWO

LCRA PARSONS ANCHOR QEA

July 2011

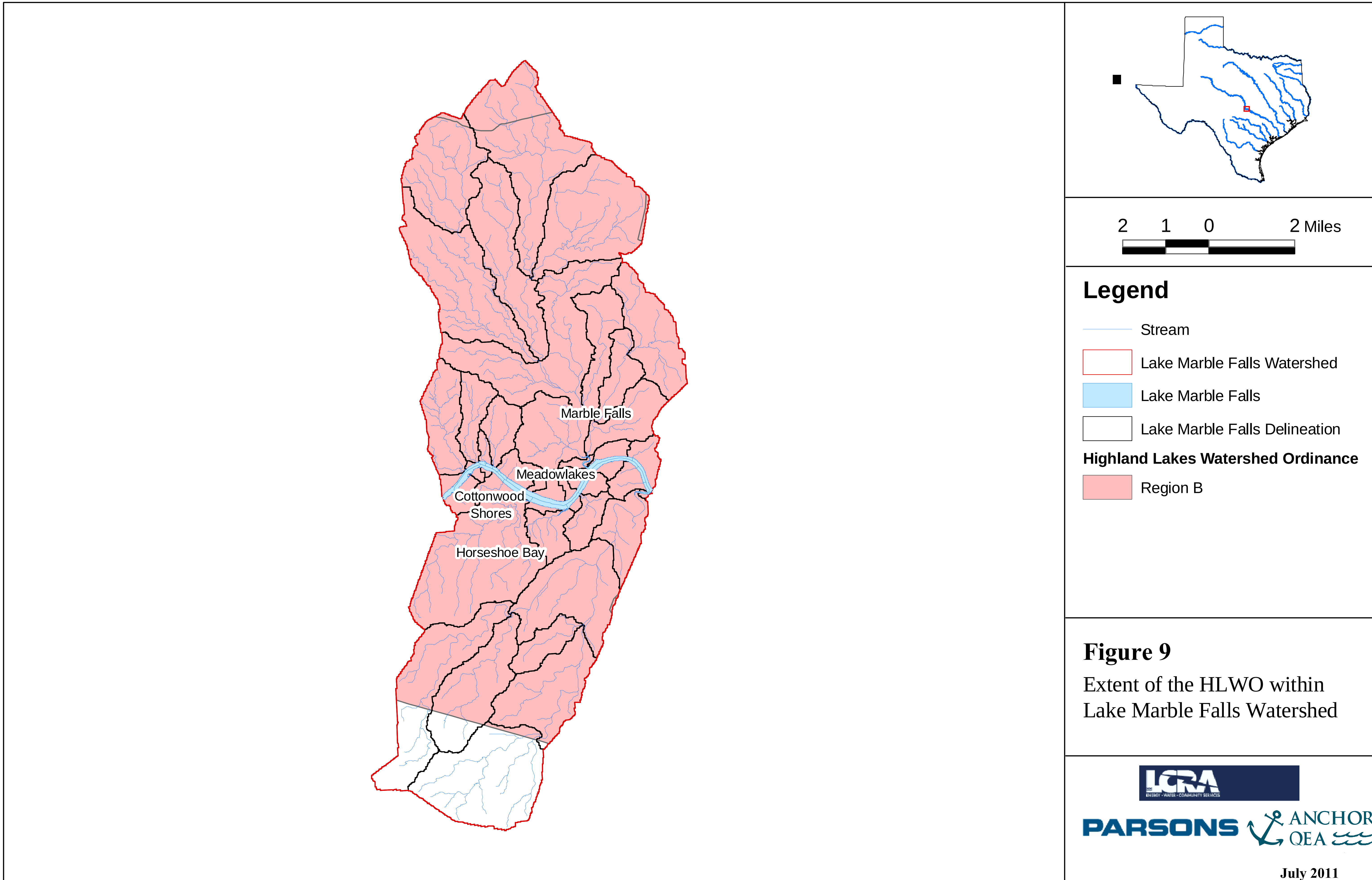
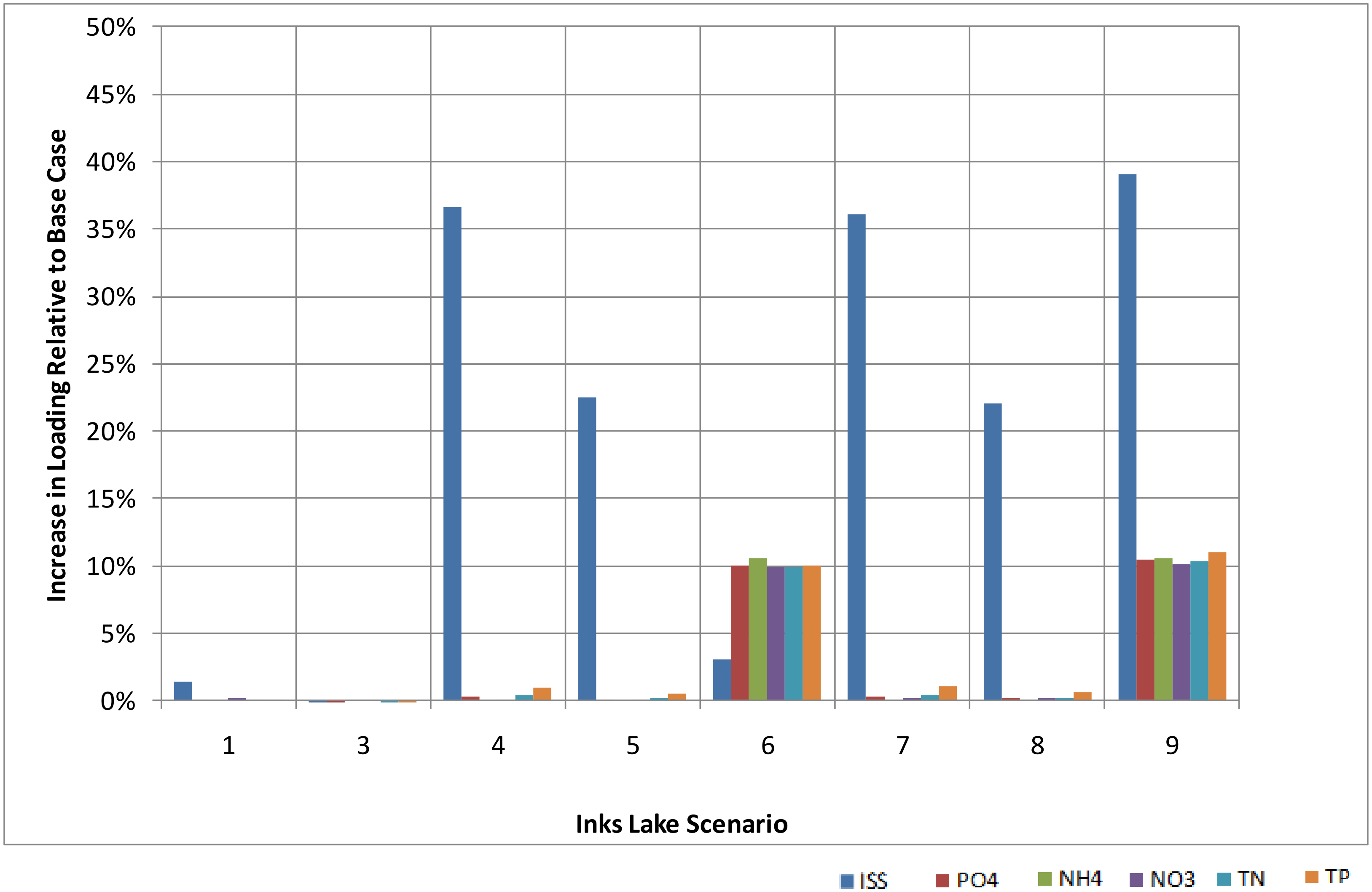


Figure 9

Extent of the HLWO within Lake Marble Falls Watershed

LCRA PARSONS ANCHOR QEA

July 2011



Note: Scenario 2 was not simulated for the Inks Lake Models

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Figure 10

Changes in Loadings to the Lake by Scenario Relative to Base Case for Inks Lake

CREMS Phase 3 Scenarios

LCRA

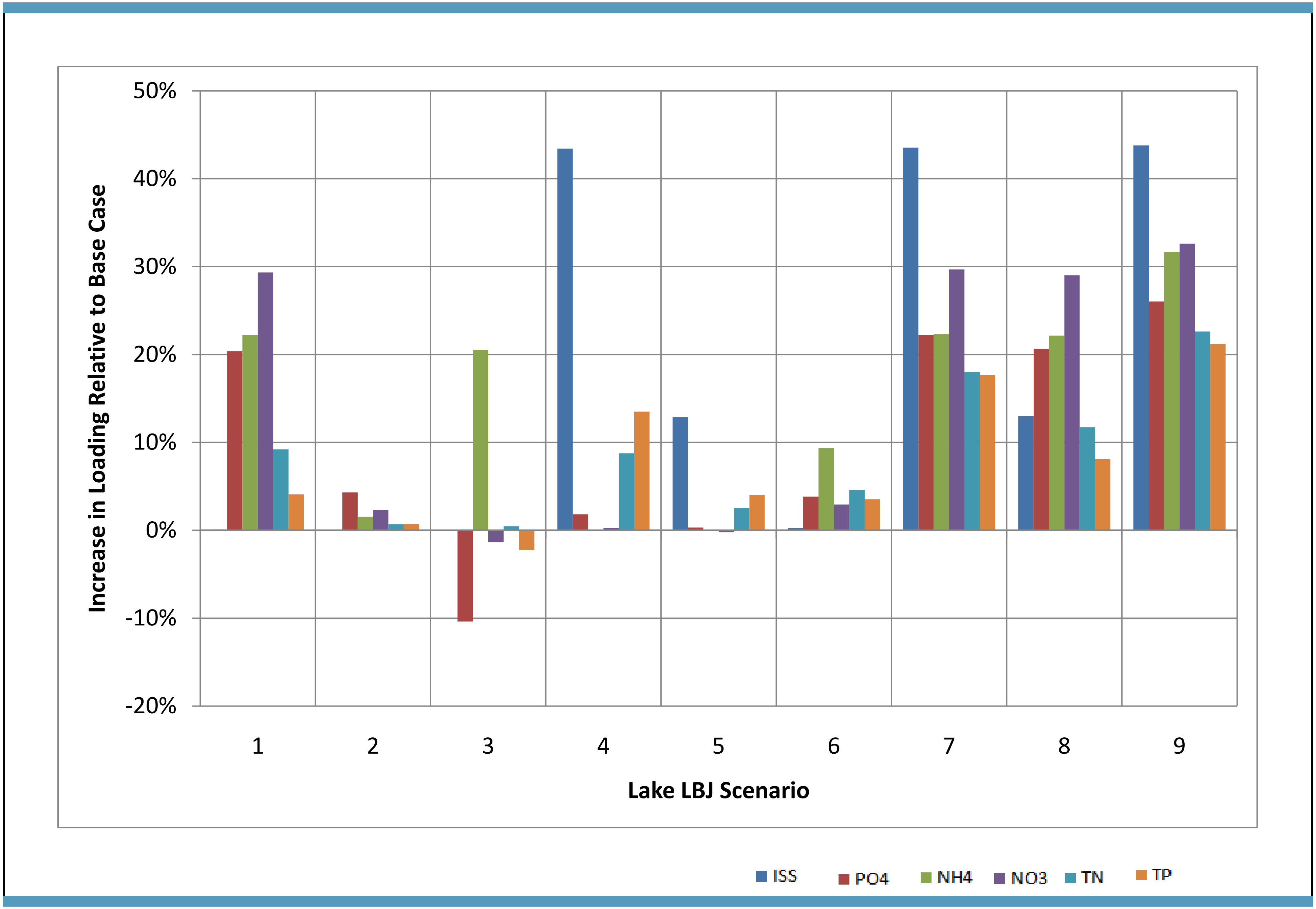

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Figure 11

Changes in Loadings to the Lake by Scenario Relative to Base Case for Lake LBJ

CREMS Phase 3 Scenarios

LCRA

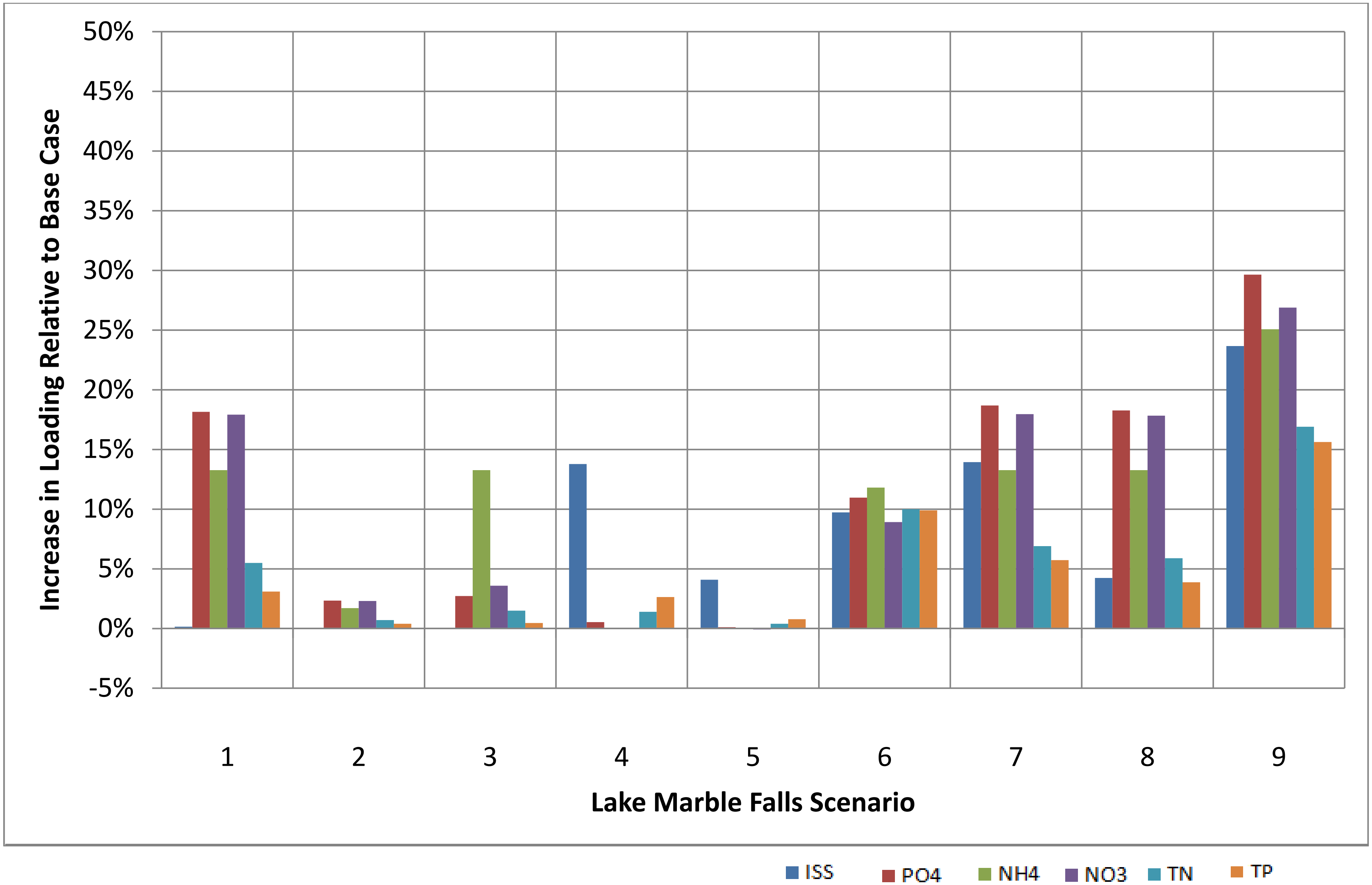

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Figure 12
Changes in Loadings to the Lake by Scenario Relative to Base Case for Lake Marble Falls
CREMS Phase 3 Scenarios
LCRA

APPENDIX A

CREMS Phase 3
Watershed Urbanization Assumptions
February 24, 2011
Prepared By LCRA Watershed Engineering & Planning

Objective – Estimate future urbanization conditions in the Lake Marble Falls, Lake LBJ and Inks Lake Watershed in approximately 20 years.

Methodology – subbasins from each watershed component were overlaid with aerial photography to assess the potential for future urbanization. Future Urbanization assumptions took into account the existing urbanization level [1], proximity to transportation networks and utilities as well as constraints such as quarry/mine operations and dedicated open space (parks, golf courses, etc.) A number of factors will affect these assumptions including economic growth patterns and regulatory environment. Repurposing of quarries and open space may open up additional land for development.

The following categories and corresponding urbanization levels were developed to establish consistency in estimating future conditions:

- Rural – areas with less than 1% urbanization in the current condition were assigned a 1% future urbanization level.
- Semi Rural – areas with low levels of urbanization but which had proximity to transportation networks or river frontage were assigned a 3-5% future urbanization level[2].
- Urbanized - areas with moderate urbanization in the current condition were assigned a 15-20% future urbanization level.
- Heavily Urbanized –currently urbanized areas with suitable transportation and utility infrastructure for continued growth were assigned a 30-35% future urbanization level[2].
- Super Urbanized - areas with significant existing urbanization or with adjacent existing urbanized or heavily urbanized areas with suitable transportation and utility infrastructure for continued growth were assigned a 50-90% urbanization level[2].

Lake Marble Falls Watershed

An urbanized core currently exists in the Marble Falls downtown area with extensive suburban development in surrounding areas while the City Cottonwood Shores has an extensive suburban component. Suburban development is prevalent along Lake Marble Falls and large lot "Ranchette" type development is scattered throughout the watershed.

Commercial Development is currently concentrated in the City of Marble Falls, with scattered development along the Hwy 281, FM 2147 and FM 1431 Corridors. Quarries, mines and wastewater application fields constrain development in several subbasins. Water Service has recently been extended to the US 281/SH 71 intersection which is expected to promote growth in this area. The current level of development provided by Anchor QEA indicates 4,530 acres out of 50,446 acres are currently urbanized (8.98%). Our 20 year prediction has an additional 7034 acres urbanizing for a total of 11,564 urbanized acres in 2031 (22.92%). This figure corresponds to 352 acres per year.

See Table A-1 Lake Marble Falls Watershed Urbanization Assumptions

Lake LBJ Watershed

An urbanized core currently exists in the Llano downtown area with moderate suburban development in surrounding areas. Mason and Junction are the only other cities with dense development, but these areas are quite small. Development Density in Horseshoe Bay is very high in some of the waterfront areas but is primarily suburban. Sunrise Beach and the Kingsland area are extensively urbanized as is the waterfront for most of Lake LBJ. Large Lot "Ranchette" type developments are found near cities and towns and in the eastern part of the watershed. Commercial Development is concentrated in the City of Llano, with scattered development along the SH 16, SH 29, FM 2147 and FM 1431 Corridors. Most of the watershed is rural with very low levels of development. The current level of development provided by Anchor QEA indicates 27,305 acres out of 3,165,283 acres are currently urbanized (0.86%). Our 20 year prediction has an additional 41,483 acres urbanizing for a total of 69,998 urbanized acres in 2031 (2.21%). This figure corresponds to 2135 acres per year.

See Table A-2 Lake LBJ Watershed Urbanization Assumptions

Inks Lake Watershed

The Inks Lake watershed contains several large lot "Ranchette" type developments off SH 29, FM 2341 and Hoover Valley Road. Inks Lake State Park constrains development for much of the waterfront while the remaining waterfront has moderate suburban development. Very little Commercial Development is found. The current level of development provided by Anchor QEA indicates 1,249 acres out of 24,601 acres are currently urbanized (5.08%). Our

20 year prediction has an additional 2604 acres urbanizing for a total of 3,853 urbanized acres in 2031 (15.66%). This figure corresponds to 130 acres per year.

See Table A-3 Inks Lake Watershed Urbanization Assumptions.

Table A-1: Lake Marble Falls Watershed Urbanization Assumptions

Subwatershed	Subwatershed Development Type	Total Area (acres)	Existing Urban Area (acres)	Existing % Urban/Sub	Future % Urban/Sub	Future Urban Area (acres)	Future Urbanization Notes	% increase
1	Semi-Rural [1]	2,336	0	0.02%	5.00%	117	Approx. 50% large lot subdivision currently	5%
2	Semi-Rural	3,789	13	0.35%	5.00%	189	Assume large lots in northern portion, typ. Suburban dev in south (below PR 4)	5%
3	Urbanized	3,197	114	3.58%	15.00%	480	Comm. potential along 281; quarries limit residential	11%
4	Heavily Urbanized	1,748	180	10.28%	30.00%	524	Exist Ind park along 281; Add'l industrial expected along Mormon Mill	20%
5	Heavily Urbanized	3,169	6	0.18%	30.00%	951	Approx. 30% SF currently,	30%
6	Urbanized	2,389	8	0.33%	15.00%	358	Large lots in north, SF in south expected	15%
7	Urbanized	3,658	150	4.10%	15.00%	549	WW irrigation fields, quarry to west should limit development	11%
8	Super Urbanized	781	392	50.21%	80.00%	625	Currently 50%, straddles 281	30%
9	Super Urbanized	2,624	820	31.24%	50.00%	1,312	Currently 30%; pot quarry re-dev to west of MF current dev limits; 281 corridor to north	19%
10	Super Urbanized	1,040	508	48.81%	80.00%	832	Currently 50%; adj to schools and PUD	31%
11	Semi-Rural	718	1	0.15%	5.00%	36	Constrained by quarries	5%
12	Semi-Rural	626	8	1.23%	3.00%	19	No road access; quarries on both sides; limited waterfront	2%
13	Super Urbanized [1]	84	0	0.00%	50.00%	42	Question exist figures; Cottonwood Shores?	50%
14	Urbanized [1]	158	0	0.00%	15.00%	24		15%
15	Semi-Rural	1,240	32	2.57%	3.00%	37	Constrained by quarries	0%
16	Super Urbanized	98	88	89.99%	90.00%	88		0%
17	Super Urbanized	368	250	67.88%	80.00%	295		12%
18	Heavily Urbanized	415	74	17.90%	30.00%	125		12%
19	Heavily Urbanized	694	68	9.78%	30.00%	208		20%
20	Super Urbanized	356	198	55.56%	80.00%	285		24%
21	Super Urbanized	88	54	61.29%	70.00%	62		9%
22	Heavily Urbanized	25	8	32.23%	35.00%	9		3%
23	Heavily Urbanized	696	64	9.17%	30.00%	209		21%
24	Heavily Urbanized	3,902	452	11.59%	30.00%	1,171	71 and 2147 corridors	18%
25	Super Urbanized	141	59	41.98%	50.00%	70		8%
26	Super Urbanized	333	151	45.30%	50.00%	167		5%
27	Heavily Urbanized	521	62	11.97%	30.00%	156		18%
28	Heavily Urbanized	623	50	8.00%	30.00%	187		22%
29	Heavily Urbanized	965	159	16.49%	30.00%	290	281 corridor; constrained by quarry to north	14%
30	Heavily Urbanized	2,476	116	4.70%	30.00%	743	New hospital and 281 corridor	25%
31	Semi-Rural	2,851	8	0.28%	5.00%	143	small amount of 71 corridor	5%
32	Super Urbanized	662	112	16.96%	50.00%	331	281/71 interchange	33%
33	Urbanized	2,087	100	4.81%	15.00%	313		10%
34	Semi-Rural	2,179	38	1.75%	5.00%	109		3%
35	Urbanized	3,406	186	5.45%	15.00%	511	281 corridor	10%
Total		**50,446**	**4,530**	**8.98%**	**22.92%**	**11,564**		

Notes:

Assuming 20 year period for urbanization   352 acres urbanized per year

[1] for future condition, assign urbanization equally across low-medium and high intensity categories

Table A-2: Lake LBJ Watershed Urbanization Assumptions

Subwatershed	Subwatershed Development Type	Total Area (acres)	Existing Urban Area (acres)	Existing % Urban/Sub	Future % Urban/Sub	Future Urban Area (acres)	Future Urbanization Notes	% increase
1	Rural	30,913	20	0.07%	1.00%	309		1%
2	Rural	36,123	57	0.16%	1.00%	361		1%
3	Semi-Rural	9,609	23	0.24%	3.00%	288	SH 16 corridor	3%
4	Semi-Rural	9,023	2	0.02%	3.00%	271		3%
5	Semi-Rural	29,781	109	0.37%	3.00%	893	SH 71 bisects	3%
6	Urbanized	13,390	213	1.59%	15.00%	2,008	Pot growth east of Llano	13%
7	Rural	13,775	27	0.20%	1.00%	138		1%
8	Rural	82,132	252	0.31%	1.00%	821		1%
9	Urbanized	14,316	467	3.26%	15.00%	2,147		12%
10	Heavily Urbanized	1,540	309	20.07%	30.00%	462		10%
11	Semi-Rural	21,097	32	0.15%	3.00%	633		3%
12	Rural	36,972	170	0.46%	1.00%	370		1%
13	Super Urbanized	366	175	47.74%	50.00%	183		2%
14	Super Urbanized	220	197	89.47%	90.00%	198		1%
15	Urbanized	3,614	183	5.07%	15.00%	542		10%
16	Semi-Rural	30,238	1,306	4.32%	5.00%	1,512	exist urban at 4.32%- US 87 & 377 corridors	1%
17	Semi-Rural	641	0	0.00%	3.00%	19		3%
18	Rural	25,989	17	0.06%	1.00%	260		1%
19	Rural [1]	2,850	0	0.00%	1.00%	28		1%
20	Rural	13,751	9	0.07%	1.00%	138		1%
21	Rural	33,813	61	0.18%	1.00%	338		1%
22	Semi-Rural	12,610	12	0.09%	3.00%	378		3%
23	Rural	36,914	95	0.26%	1.00%	369		1%
24	Rural	4,678	7	0.14%	1.00%	47		1%
25	Semi-Rural	7,779	8	0.10%	3.00%	233		3%
26	Rural	4,554	10	0.22%	1.00%	46		1%
27	Rural	8,748	25	0.28%	1.00%	87		1%
28	Rural	77,750	94	0.12%	1.00%	778		1%
29	Rural	17,901	66	0.37%	1.00%	179		1%
30	Urbanized	14,040	398	2.84%	15.00%	2,106		12%
31	Urbanized	44,183	551	1.25%	15.00%	6,627		14%
32	Rural	84,013	188	0.22%	1.00%	840		1%
33	Semi-Rural	3,162	7	0.22%	3.00%	95		3%
34	Rural	29,238	105	0.36%	1.00%	292		1%
35	Rural	134,448	223	0.17%	1.00%	1,344		1%
36	Urbanized	8,313	1,042	12.53%	15.00%	1,247		2%
37	Rural	137,797	378	0.27%	1.00%	1,378		1%
38	Rural	54,558	215	0.39%	1.00%	546		1%
39	Rural	62,666	178	0.28%	1.00%	627		1%
40	Rural	39,154	21	0.05%	1.00%	392		1%
41	Semi-Rural	16,066	342	2.13%	3.00%	482		1%
42	Urbanized	6,549	430	6.56%	15.00%	982		8%
43	Urbanized	4,692	547	11.67%	15.00%	704		3%
44	Rural	16,550	34	0.21%	1.00%	166		1%
45	Rural	17,721	3	0.02%	1.00%	177		1%
46	Urbanized	4,217	269	6.39%	15.00%	633		9%
47	Urbanized	1,938	136	7.04%	15.00%	291		8%
48	Rural	111,452	443	0.40%	1.00%	1,115		1%
49	Heavily Urbanized	3,920	944	24.08%	30.00%	1,176		6%
50	Heavily Urbanized	1,969	287	14.58%	30.00%	591		15%
51	Heavily Urbanized	3,841	976	25.40%	30.00%	1,152		5%
52	Urbanized	7,304	959	13.12%	20.00%	1,461		7%
53	Rural	74,209	857	1.16%	1.00%	742		0%
54	Rural	96,495	126	0.13%	1.00%	965		1%
55	Semi-Rural	10,758	200	1.86%	3.00%	323		1%
56	Semi-Rural	36,501	505	1.38%	3.00%	1,095		2%
57	Urbanized	1,752	123	7.04%	15.00%	263		8%
58	Heavily Urbanized	6,233	868	13.93%	30.00%	1,870		16%
59	Urbanized	12,013	875	7.28%	15.00%	1,802		8%
60	Heavily Urbanized	531	108	20.38%	30.00%	159		10%
61	Rural	92,367	253	0.27%	1.00%	924		1%
62	Urbanized	2,443	49	2.00%	15.00%	366		13%
63	Rural	28,953	11	0.04%	1.00%	290		1%
64	Rural	80,395	20	0.02%	1.00%	804		1%
65	Heavily Urbanized	2,147	526	24.52%	30.00%	644		5%
66	Rural	14,450	22	0.15%	1.00%	145		1%
67	Rural	265,621	1,830	0.69%	1.00%	2,656		0%
68	Semi-Rural	15,090	26	0.17%	3.00%	453		3%
69	Urbanized	3,930	381	9.69%	15.00%	590		5%
70	Rural	146,755	321	0.22%	1.00%	1,468		1%
71	Rural	27,313	0	0.00%	1.00%	273		1%
72	Urbanized	50,885	2,241	4.40%	15.00%	7,633		11%
73	Rural	65,789	20	0.03%	1.00%	658		1%
74	Rural	77,468	1,026	1.32%	1.00%	775		0%
75	Rural	187,807	1,844	0.98%	1.00%	1,878		0%
76	Rural	157,221	614	0.39%	1.00%	1,572		1%
77	Rural	41,932	98	0.23%	1.00%	419		1%
78	Rural	277,351	1,741	0.63%	1.00%	2,774		0%
Total		**3,165,283**	**27,306**	**0.86%**	**2.21%**	**69,998**		

Notes:

Assuming 20 year period for urbanization 2,135 acres urbanized per year

[1] for future condition, assign urbanization equally across low-medium and high intensity categories

Table A-3: Inks Lake Watershed Urbanization Assumptions

Subwatershed	Subwatershed Development Type	Total Area (acres)	Existing Urban Area (acres)	Existing % Urban/Sub	Future % Urban/Sub	Future Urban Area (acres)	Future Urbanization Notes	% increase
1	Urbanized [1]	520	0	0.00%	15.00%	78		15%
2	Semi-Rural [1]	1,308	0	0.00%	5.00%	65		5%
3	Urbanized	1,832	10	0.57%	15.00%	275		14%
4	Semi-Rural	505	2	0.31%	5.00%	25		5%
5	Urbanized	849	50	5.94%	15.00%	127		9%
6	Urbanized	748	16	2.09%	15.00%	112		13%
7	Semi-Rural	927	26	2.78%	5.00%	46		2%
8	Urbanized	540	36	6.61%	15.00%	81		8%
9	Urbanized	781	27	3.43%	15.00%	117		12%
10	Urbanized	50	3	5.51%	15.00%	7		9%
11	Urbanized	1,029	24	2.35%	15.00%	154		13%
12	Urbanized	31	3	9.55%	15.00%	5		5%
13	Urbanized	588	34	5.78%	15.00%	88		9%
14	Heavily Urbanized	872	79	9.09%	30.00%	262		21%
15	Heavily Urbanized	258	17	6.66%	30.00%	77		23%
16	Urbanized	456	20	4.41%	15.00%	68		11%
17	Heavily Urbanized	619	65	10.54%	30.00%	186		19%
18	Semi-Rural [1]	4	0	0.00%	3.00%	0		3%
19	Semi-Rural	493	10	2.10%	5.00%	25		3%
20	Urbanized	603	25	4.12%	15.00%	90		11%
21	Heavily Urbanized	781	66	8.40%	30.00%	234		22%
22	Urbanized	1,139	72	6.31%	15.00%	171		9%
23	Urbanized	526	61	11.54%	15.00%	79		3%
24	Heavily Urbanized	197	40	20.30%	30.00%	59		10%
25	Heavily Urbanized	566	78	13.81%	30.00%	170		16%
26	Urbanized	1,195	121	10.12%	15.00%	179		5%
27	Urbanized	297	14	4.67%	15.00%	45		10%
28	Urbanized	441	36	8.11%	15.00%	66		7%
29	Heavily Urbanized	101	15	15.31%	30.00%	30		15%
30	Heavily Urbanized	141	29	20.78%	30.00%	42		9%
31	Urbanized	929	25	2.67%	15.00%	139		12%
32	Heavily Urbanized	116	26	22.39%	30.00%	35		8%
33	Heavily Urbanized	326	51	15.71%	30.00%	98		14%
34	Heavily Urbanized	218	28	12.90%	30.00%	65		17%
35	Urbanized	108	3	2.90%	15.00%	16		12%
36	Urbanized	37	2	4.76%	15.00%	6		10%
37	Semi-Rural	767	8	1.07%	5.00%	38		4%
38	Urbanized	344	44	12.89%	15.00%	52		2%
39	Urbanized	440	25	5.69%	15.00%	66		9%
40	Urbanized	226	19	8.31%	15.00%	34		7%
41	Semi-Rural	97	4	3.62%	5.00%	5		1%
42	Urbanized	990	18	1.86%	15.00%	148		13%
43	Urbanized	169	7	4.29%	15.00%	25		11%
44	Semi-Rural [1]	449	0	0.00%	5.00%	22		5%
45	Urbanized	705	5	0.78%	15.00%	106		14%
46	Semi-Rural [1]	111	0	0.00%	5.00%	6		5%
47	Urbanized	174	4	2.47%	15.00%	26	exist urban. seems low	13%
Total		**24,601**	**1,249**	**5.08%**	**15.66%**	**3,853**		

Notes:

Assuming 20 year period for urbanization 130 acres urbanized per year

[1] for future condition, assign urbanization equally across low-medium and high intensity categories