FINAL REPORT

HYDROLOGIC TIME SERIES ANALYSIS
FOR VERIFICATION AND REFINEMENT OF FLOW REGIME RECOMMENDATIONS

Report to

Guadalupe / San Antonio BBEST

TWDB Contract No. 1100011217

February 2011

Prepared by

Kennedy Resource Company

EXECUTIVE SUMMARY

This research study has been undertaken by Kennedy Resource Company (KRC) under contract to the Texas Water Development Board (TWDB) and was authorized by the TWDB on December 31, 2010 pursuant to Contract No. 1100011217 between the TWDB and KRC.

The primary purpose of this study was to develop the hydrologic models and hydrologic time series analysis that would enable the Guadalupe / San Antonio Basin Bay Expert Science Team (GSA BBEST) to assess the effectiveness of their proposed environmental flow recommendations in maintaining the necessary quantities of water for environmental purposes. In addition, the analysis performed herein also provided the hydrologic basis for the refinement/validation of the numerous environmental sciences overlay process necessary for the team to move toward finalizing their recommendations.

Numerous model scenarios were developed representing several future conditions of basin wide groundwater and surface water utilization. Daily and/or monthly flows were created at eight locations deemed to be useful for the GSA BBEST team's analysis. Two large conceptual water supply projects were simulated at two of the sites, subject to the GSA BBEST team's recommendations, and the associated river flows before and after the projects were compared. This information, in the form of graphs as well as the time series data of daily and monthly river flows, was made available to the team for their use in refining their proposed environmental flow recommendations.

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1.0 INTRODUCTION

The GSA BBEST Team selected 8 locations in the Guadalupe / San Antonio River Basin for which they determined time series flow data would allow them to better understand the impact of their proposed environmental flow recommendations and also to provide a basis to test their overlay process. Seven instream flow locations were selected as well as a final location representing the total flow to the Guadalupe Estuary. Assumptions with regard to numerous future basin wide development conditions were specified and past TWDB water plans were utilized to represent large conceptual water supply projects associated with the Guadalupe and San Antonio Rivers. Each of these projects were simulated with one of the future condition scenarios without and with the large water supply projects in place, subject to GSA BBEST Teams recommended environmental flow restrictions. Comparisons of simulated flows for the without and with project case, as well as all other future scenarios were developed for the project locations and all locations downstream. For locations upstream of the project locations, comparisons of simulated flows for each of the future conditions scenarios were made. The Scope of Work for this study is included in Appendix A.

2.0 PROCESS OVERVIEW

The eight locations selected for analysis of time series flows under numerous future water use assumptions are summarized in Table 1:

TABLE 1
LOCATIONS USED IN ANALYSIS

SITE NUMBER	WAM CONTROL POINT ID	LOCATION
1	CP02	Guadalupe at Spring Branch
2	CP13	Sandies Creek near WestHoff
3	CP14	Guadalupe River at Cuero
4	CP15	Guadalupe River at Victoria
5	CP32	San Antonio River near Falls City
6	CP35	Cibollo Creek near Falls City
7	CP37	San Antonio River near Goliad
8	CPEST	Inflow to Guadalupe Estuary

The four conditions used to represent the various future surface and ground water utilization scenarios were (1) Natural; (2) Present; (3) Region L Baseline; and (4) TCEQ Baseline. TCEQ based WAM models were used to create the various scenarios and monthly regulated flows were extracted from the 4 models then disaggregated to daily flows. Sites # 3 and #7 were selected as locations to test the GSA BBEST Teams proposed environmental flows with respect to the recommendations' ability to preserve flows for the environment in the event large water supply projects were built at these sites. One of the WAM Scenarios was used as inflows at these locations and large water supply projects were modeled as depleting water subject to the proposed environmental flow recommendations, resulting in two final scenarios: (5) Guadalupe River Project; (6) San Antonio River Project. The resulting "after project flows" for each of these scenarios were compared to the "before project flows" (Scenario #3) as well as to each of the other baseline model scenarios. Annual and seasonal flow frequency plots as well as time series plots were developed comparing flows at each of the 8 locations for all of the scenarios modeled. Table 2 summarizes the scenarios modeled, with the specific details of assumptions further described in Section 4.0.

TABLE 2
OVERVIEW OF WAM MODEL SCENARIOS

SCENARIO NUMBER	SCENARIO NAME	SPRING FLOW		RETURN FLOW		BASIN DEMANDS		RESERVOIR CAPACITY	
		NAT	CUR	NONE	CUR	AUTH	CUR	AUTH	CUR
1	NATURAL	X		X		NA		NA	
2	PRESENT		X		X		X		X
3	REGION L BASELINE		X		X	X		X	
4	TCEQ BASELINE		X	X		X		X	
5	GUADALUPE RIVER PROJECT		X		X	X		X	
6	SAN ANTONIO RIVER PROJECT		X		X	X		X	

NAT = Natural ; CUR = Current; AUTH = Authorized

3.0 MODEL SETUP AND ASSUMPTIONS

3.1 WRAP MODEL

One of the goals of this analysis was to produce model scenarios consistent with the model assumptions used by the Region L Water Planning Group, which has used a specific version of the WRAP model for the past several years. This older version of WRAP contains a daily step out procedure for simulating Canyon Reservoir as well as numerous other basin specific processes for specifically representing water right activities in the Guadalupe/San Antonio River Basin, with many of these routines not being available in TCEQ's current WAM model. Although the TCEQ's version of WRAP does not contain several of these features, all of the water right activities are represented in TCEQ's version of WRAP and several new capabilities have been added to the TCEQ's version giving it the capability of representing environmental flow (eflow) requirements (albeit on a monthly timestep basis) generally consistent with the types of eflow recommendations that will likely be recommended by the GSA BBEST. Although the scope of this study did not involve the representation of eflow requirements in a monthly WAM model, because the TCEQ's WAM model has this capability, it was decided that the baseline scenarios should be developed using the TCEQ's WAM model as a base, with the input file modifications deemed necessary to generally make its results consistent with model results from the older Region L WAM model.

With this in mind, the TCEQ's RUN3 and RUN8 WAM models were obtained from TCEQ staff on January 5, 2011 and various adjustments were made to the model input files to create the four baseline scenarios consistent with the GSA BBEST request and Region L assumptions. For Scenarios 1 and 4 (Natural and TCEQ Baseline), the only modifications made to the WAM input files were to include spring flow adjustment files consistent with no withdrawals from the Edwards Aquifer (Scenario 1) and permitted and other withdrawals from the Edwards Aquifer made pursuant to SB3 of the 80th Texas Legislature (Scenario 4). For the Scenario 2 and 3 (Present and Region L Baseline) TCEQ's RUN8 and RUN3 WAM models, respectively, were used as the model basis and several modifications were made to these models to better represent assumptions adopted by the Region L Water Planning Group (e.g., Edwards withdrawals pursuant to SB3). Section 7.1.3.1.2 of 2011 Region L Plan was used by KRC as a guideline for making these Region L modifications. Most of these changes were attributable to the inclusion of Region L's estimated current return flow levels for both Scenarios 2 and 3 and the changing of demands for numerous water right activities in Scenario 2. In addition, numerous other simplifications were made to Scenarios 2 and 3 in order to produce results under the study's compressed time schedule, all of which were tested and found to make little difference in the model results, especially with regard to the operations of two example large-scale projects established as test cases by the GSA BBEST. One such simplification involved representation of the entire demand associated with Canyon Reservoir being diverted under the old priority date, even though a large portion of this authorization is associated with an amendment having a relatively junior priority date. This simplification was deemed necessary because impoundment of water under the old and junior Canyon priority dates in the Region L model is determined on a daily basis, and thus could not be precisely simulated in the TCEQ's WAM model base. Regardless of priority date at which Canyon impounds water, all authorized amounts would be diverted before the WAM model would show water available downstream for the conceptual projects implemented in this study's analysis.

3.2 FRAT MODEL

In about 2009, HDR Inc. created an Excel spreadsheet model in which a water supply activity could be simulated subject to SB3 type environmental flow recommendations such as the GSA BBEST Team has been tasked with developing. The purpose of this spreadsheet model was to be able represent the operation of a water supply activity subject to a complex matrix of environmental flow recommendations over though a long term daily time series of hydrologic conditions in order to assess both of the following:

(1) The Impact of the environmental flow recommendations on the water supply activity's ability to supply water.

(2) The impact of the water supply activity on the flows in the water course.

This process was originally used in association with the development of the Sabine Neches BBEST Team's environmental flow recommendations, and the spreadsheet model has since been refined and generalized by staff of the Texas Parks and Wildlife Department and subsequently named the Flow Regime Analysis Tool (FRAT). This model is still being refined and updated at the writing of this report with the most current version of the model being made available on the San Antonio River Authority's ftp site. Version number 3.0d was made available to KRC for the analysis in this report on January 7, 2011 and all of the FRAT analyses herein were applied using this version.

The application of FRAT in this study was for the sole purpose of assessing the impact of two large, conceptual, water supply activities for the purposes of enabling the GSA BBEST team to better understand their proposed environmental flow recommendations' ability to maintain river flows for environmental purposes. Although this involved the representation of the water supply activities in FRAT, along with some iteration of project configurations in order to establish the projects' firm yield demand, no analysis of the environmental flow recommendation's impact on water supply was analyzed or addressed in this study.

3.3 HEFR MATRIX

The Hydrology-Based Environmental Flow Regime Methodology (HEFR) was used to develop the GSA BBEST Team's proposed environmental flow recommendations and the results of this application were provided to KRC for each of the project locations. This information is included in Appendix B and Appendix C. In addition, direction related to how the information in the HEFR matrix is to be utilized with regard to the times when the various base flows and high flow pulses are to be engaged was also provided by the GSA BBEST Team and is included in Appendix D. The details of this information will be discussed in the next section.

3.4 HYDROLOGIC CONDITION

As indicated in Appendix D, the engagement of many of the various components of the GSA BBEST recommendations are dependent on the hydrologic condition, a means of determining the overall wet/dry condition believed to be occurring at the time of proposed depletion by one of the test projects. This information was provided to KRC be the GSA BBEST team and was determined for each project site based on the cumulative 12 month flow preceding the beginning of each defined season based on the historic river flow at each of the subject locations. Specifically, an array of hydrologic condition was created by calculating the total annual flow for the period 1934-2010 for each site and determining the 25^{th} and 75^{th} percentile annual flow. Beginning with the historic flow at each site, the cumulative 12 month flow was calculated at the beginning of each season and hydrologic condition was determined as follows with the resulting condition kept in place the remainder of the subject season:

- If the resulting 12 month cumulative flow was less than the 25th percentile, the season condition was deemed to be “dry”.
- If the resulting 12 month cumulative flow was greater than the 75th percentile, the season condition was deemed to be “wet’
- If the resulting 12 month cumulative flow was between the 25th and 75th percentiles, the season condition was deemed to be “average’

4.0 DETAILED PROCESS

4.1. SCENARIO DEVELOPMENT

Four Baseline Models, with their adopted assumptions are summarized as follows:

SCENARIO 1: Naturalized flows.

- No Surface Water Rights Exercised
- No Return Flows Entering the Water Courses.
- Spring Adjustments Reflecting No Historical Pumpage from the Edwards Aquifer.

SCENARIO 2: Current Conditions.

- Current Demands for All Water Rights of Record.
- Refinements to Make Consistent with Region L Planning Assumptions.
- Return Flows Reflecting Current use Levels.
- Spring Adjustments Reflecting Current Edwards Aquifer Pumpage Rules.
- Major Reservoirs Represented with Current Sedimentation Conditions.

SCENARIO 3: Full Utilization / Current Return Flows

- Full Authorized Demands for All Water Rights of Record.
- Refinements to Make Consistent with Region L Planning Assumptions.
- Return Flows Reflecting Current use Levels.
- Spring Adjustments Reflecting Current Edwards Aquifer Pumpage Rules.
- Major Reservoirs Represented with Authorized Capacities.

SCENARIO 4: Full Utilization / No Return Flows

- Full Authorized Demands for All Water Rights of Record.
- No Assumed Return Flows.
- Spring Adjustments Reflecting Current Edwards Aquifer Pumpage Rules.
- Major Reservoirs Represented with Authorized Capacities.
- TCEQ’s RUN3 WAM Model “dat” file as received from TCEQ.

After the above 4 baseline models were created, each WAM model was executed and the regulated flow for each of the 8 sites was extracted, reviewed, and tabulated. The daily gaged flow was obtained from the USGS for each of the 7 instream flow locations (with missing periods filled in from nearby gages or provided by GSA BBEST) and this daily pattern was used to disaggregate the monthly WAM regulated flow into a representation of WAM daily regulated flow. For all sites upstream of the project sites at Cuero and Goliad, a FRAT run was made using the daily WAM flows for each of the baseline scenarios for the sole purposes of taking advantage of FRAT's built in automated process of sorting the various seasonal flows necessary to create the plots for comparing the various scenarios discussed in Section 5.

For the proposed project sites, information detailing the Cuero/Sandies Creek Project on the Guadalupe River and the Goliad Project on the San Antonio River were reviewed and the elevation/area/capacity parameters, conservation capacity, estimated firm yield, and river pump capacities were noted in the planning documents. This information was used to model each project in separate copy of the Scenario 3 model for the sole purpose of ensuring that project parameters were generally understood. After noting the complicated arrangement of the Cuero project with regard to its involvement with the flows from Sandies Creek and the Guadalupe River, it was decided that this complication was not necessary to properly represent a large water supply project diverting water from the Guadalupe River near Cuero and therefore this project was simplified into a pure off-channel reservoir project with the ability to pump water from the Guadalupe River at Cuero streamflow gage site. Accordingly, the pertinent information that was settled upon from the planning documents with the simplification described above is as follows:

Guadalupe Project:

- Off-channel reservoir (OCR) project with the ability to pump water from the Guadalupe River at Cuero streamflow gaging location.
- Conservation Elevation, Area, Capacity: 232 msl, 28,154 acres, 583,975 acre-feet
- Maximum Diversion Rate from River: 1,610 cfs

San Antonio Project:

- On-Channel project located at the San Antonio River at Goliad streamflow gaging location.
- Conservation Elevation, Area, Capacity: 200 msl, 27,805 acres, 707,615 acre-feet
- Maximum Impound Rate from River: unlimited.

The two project models are summarized as follows:

SCENARIO 5: Guadalupe Run-of-River River Example Project

- Scenario 3 with Guadalupe River Project Implemented

SCENARIO 6: San Antonio Reservoir Example Project

- Scenario 3 with San Antonio River Project Implemented

4.2 PROJECT REPRESENTATION IN FRAT

As discussed in Section 4.1, the regulated flows from the monthly WAM models were extracted for each of the baseline scenarios and disaggregated into daily regulated flow estimates at each of the GSA BBEST sites. This process used the USGS's daily historical daily flow pattern for each site to the extent this information was available. For parts of the period of record in which USGS observed data was missing, KRC either estimated the daily flow pattern based on nearby streamflow gage information; or, was provided an estimate from the GSA BBEST. For the two project locations, an additional table of flows was extracted from the WAM which represented the estimate of pass through requirements for downstream water rights at each of the project locations and this monthly quantity of water was also disaggregated into daily flows using the same daily pattern as was applied to the total regulated flows. By using the flows as described above as the inflows to FRAT, the overall effect is that the projects are only able to deplete water from their respective locations after all existing upstream and downstream water rights of record have been exercised, thus enabling the representation of the projects as being junior in priority to all existing water right activities.

Since simulated depletions by the proposed projects do not impact upstream existing water rights or change river flows upstream of the project locations, Scenario 5 and Scenario 6 information for the GSA BBEST locations upstream of the project locations are the same as that presented for Scenario 3. For GSA BBEST locations at and downstream of the project sites, again existing water rights of record are not impacted by the projects because of the junior priority associated; however, river flows are impacted and therefore the depletions associated with the project representations in FRAT had to be translated downstream to the two GSA BBEST sites downstream of the project sites in order to be able to properly assess the impacts of project diversions on site # 5 (Guadalupe River at Victoria) and site #8 (Inflows to Guadalupe Estuary). This process will be will discussed later in Section 4.3.

For the two project sites, a FRAT model was constructed and after the physical project parameters were setup, the following additional data were input into the FRAT model:

(1) Daily time series of total streamflow from Scenario 3.
(2) Daily time series of pass throughs for downstream senior water rights from Scenario 3.
(3) Seasonal array of Hydrologic Condition provided by the GSA BBEST.
(4) The proposed environmental flow requirements for the site provided by the GSA BBEST.
(5) The seasonal definitions for winter, spring, summer, and fall provided by the GSA BBEST.
(6) Monthly net evaporations from the WAM model.
(7) Maximum river pump capacity (Guadalupe Project only).

The FRAT model was run with all environmental requirements turned off and the demand from the reservoir was iterated until the firm annual yield was determined. For the Cuero OCR project, it was noted that the firm annual yield in FRAT was about 50% of that seen in the same monthly WAM model representation thus the daily maximum diversion rate was increased until a similar yield was calculated. For the Goliad project, the firm annual yield of the project in FRAT was almost exactly the same as was noted in the same monthly WAM model. The GSA BBEST Team's recommended environmental flow requirements were then engaged in each of the project

FRAT models, and the project demand was again iterated until each of the projects' water supply demand was at the firm annual yield. After the FRAT model for both project scenarios was solved, subject to the GSA BBEST's environmental flow recommendations, the daily time series of flow after each project was implemented was preserved as the daily quantity of water representing Scenario 5 and Scenario 6 for the project sites.

4.3 WAM / FRAT INTERACTION

As discussed in Section 4.2, the impacts of the FRAT project depletions, in some cases, had be translated to locations downstream of the project locations in order to create Scenarios #5 and #6 for locations downstream of the projects. To accomplish this, the following two tables of information were extracted out of the FRAT models of the Cuero and Goliad projects:

(1) Monthly quantities (in acre-feet per month) of flows required to be passed for environmental purposes associated with the GSA BBEST Teams flow recommendations.

(2) Monthly quantities (in acre-feet per month) of flows depleted by each of the projects.

The Scenario #5 WAM model was then created by using the Scenario #3 model as a base with the two tables of FRAT information representing the depletions and pass throughs for the Cuero project with a priority date in WAM specified as junior to all other water rights of record. A similar approach was used to create Scenario #6 by extracting the same information from the FRAT model for the Goliad project and imputing these data into a Scenario #3 base model.

Finally, after the project scenarios were created in WAM, there was still a need to generate daily flows at the Victoria location and monthly flows at the Guadalupe Estuary in order to be able to reflect the impacts of the projects on the flows at these two GSA BBEST downstream sites. For the Guadalupe Estuary location, no additional process was needed because monthly flows are all that was needed to make comparisons for all scenarios. However, for the Victoria site on the Guadalupe River downstream of the Cuero site, the same process of disaggregating the WAM monthly regulated flow to daily flows was used to generate daily Scenario #5 flows. Review of the differences between the resulting daily flows for Scenario #3 and Scenario #5 for the Victoria site (without and with the Cuero Project in place upstream) indicates there are problems with putting information in WAM from daily FRAT results, re-running WAM, and then re-disaggregating the results back to daily estimates using the same factors that were used before the FRAT depletions were made. This is because the daily pattern of FRAT depletions are lost when the project's monthly quantities are summarized on a monthly basis in FRAT and therefore when the WAM is re-run with these monthly depletions and the resulting downstream regulated flows at Victoria are disaggregated using the same factors used to produce the flows for Scenario #3, the daily pattern of depletions associated with the FRAT model at Cuero cannot be clearly seen. Another complication is that fact that WAM has monthly channel loss factors which, of course, have no way of being related to the daily diversion patterns recorded in FRAT for the Cuero project. Since the monthly volume of water depleted by the upstream project is properly accounted for in the FRAT to WAM process, it was decided that this problem is minor and should not affect the use of any of the scenario flows at the Victoria site.

5.0 SUMMARY OF STUDY RESULTS

Graphical summaries and tables of daily or monthly simulated flows were created for each of the 8 sites. For the 7 instream flows sites, 4 of the sites were upstream of the project locations thus there were no Scenario 5 and 6 results for these locations since the project depletions only impact river flows at and downstream of the project locations. The remaining 3 instream flow sites were either at or downstream of the project location thus 5 of the scenarios are represented for these locations (Scenarios 1,2,3,4,5 for the Cuero and Victoria sites; Scenarios 1,2,3,4,6 for the San Antonio project site). All of the information for the 7 instream flow locations are presented on a daily basis as daily mean cfs. Finally, the site representing the inflows to the Guadalupe Estuary, being downstream of both project locations, is represented with all six scenarios. Note that the upstream project scenarios were simulated separately and thus no scenario reflects both upstream projects in place at the same time. All simulated results for this location are on a monthly basis in acre-feet per month.

The following summarizes the graphical output presented in Attachments 1 through 8.

APPENDICES E, F, I, J
(4 UPSTREAM INSTREAM FLOW LOCATIONS)

Guadalupe River at Spring Branch
Sandies Creek near WestHoff
San Antonio River near Falls City
Cibollo Creek near Falls City

Scenarios Represented

- All 4 of the Baseline Scenarios.

Plots Presented:

Time Series (Scenario 3 only)

- Example Dry Year (1954)
- Example Average Year (1981)
- Example Wet Year (1986)

Flow Frequency (All 4 Baseline Scenarios)

- Annual Flow
- Winter Season Flow
- Spring Season Flow
- Summer Season Flow
- Fall Season Flow

APPENDICES G, H, K
(3 INSTREAM FLOW LOCATIONS AT/OR DOWNSTEAM OF PROJECTS)
Guadalupe River at Cuero
Guadalupe River at Victoria
Inflow to Guadalupe Estuary

Scenarios Represented

- All 4 of the Baseline Scenarios.
- Associated Project Scenario
- Historical Flow.

Plots Presented:

Time Series (Scenario 3, Project Scenario, Historical Flow)

- Example Dry Year (1954)
- Example Average Year (1981)
- Example Wet Year (1986)

Flow Frequency (All 4 Baseline Scenarios, Project Scenario, Historical Flow)

- Annual Flow
- Winter Season Flow
- Spring Season Flow
- Summer Season Flow
- Fall Season Flow

Tables Presented

- Compliance Statistics for Base Flows (Attachments D & H only)
- Compliance Statistics for High Pulse Flows (Attachments D & H only)

APPENDIX L
Guadalupe Estuary Inflow Location

Scenarios Represented

- All 4 of the Baseline Scenarios.
- Both Upstream Project Scenarios.
- Estimate of Historical Flow.

Plots Presented:

Time Series (Scenario 3, Project Scenarios, Historical Flow)

- Annual Inflow to Estuary
- Monthly Inflow to Estuary During 1950’s period
- Example Dry Year (1954)
- Example Average Year (1981)
- Example Wet Year (1986)

Flow Frequency (All 4 Baseline Scenarios, Project Scenarios, Historical Flow)

- Annual Flow
- Winter Season Flow
- Spring Season Flow
- Summer Season Flow
- Fall Season Flow

APPENDIX A - SCOPE OF WORK

Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Expert Science Team (GSA BBEST)

Hydrologic Time Series Analyses for Verification and Refinement of Flow Regime Recommendations

Scope of Work
December 27, 2010

The Texas Water Development Board (TWDB), on behalf of the Guadalupe, San Antonio, Mission, Aransas Rivers, the Mission, Copano, Aransas, and San Antonio Bays Basin & Bay Expert Science Team (GSA BBEST), is contracting with Kennedy Resource Company (Consultant) to perform Hydrologic Time Series Analyses for Verification and Refinement of Flow Regime Recommendations by the GSA BBEST. The selected Consultant will perform services in accordance with this Scope of Work at the direction of the GSA BBEST or designated representative(s).

1) **Applications of the Guadalupe – San Antonio River Basin Water Availability Model (GSA WAM)**
   a) Perform six (6) scenario simulations using the version of the GSA WAM used by the South Central Texas Regional Water Planning Group subject to technical assumptions provided to the Consultant.
   b) Scenario simulations include:
      i. Region L Natural Conditions[1];
      ii. Region L Present Conditions with current water rights use and effluent (~Run8)[1];
      iii. Region L Baseline with full water rights use and current effluent (~Run1)[1];
      iv. Texas Commission on Environmental Quality (TCEQ) Permitting Baseline with full water rights use and zero effluent (~Run3)[1];
      v. Implementation of one (1) example large-scale run-of-river diversion project (i.e., Guadalupe River diversion with Sandies Creek Reservoir) with implementation subject to preliminary BBEST flow regime recommendations; and
      vi. Implementation of one (1) example large-scale mainstem reservoir project (i.e. Goliad Reservoir) subject to preliminary BBEST flow regime recommendations.
   c) Technical assumptions are expected to maintain general consistency with the 2011 Region L Water Plan.
   d) Extract and summarize monthly simulated regulated flows for six (6) scenarios at eight (8) flow regime recommendation locations (seven instream locations and the Guadalupe Estuary) in electronic tabular formats.
   e) Extract and summarize monthly unappropriated streamflows for scenario simulations v. and vi. at locations that coincide with one (1) example large-scale run-of-river diversion project and one (1) example large-scale mainstem reservoir project.

[1] Data files and executable version of GSA WAM exist for this scenario and will be provided to the Consultant.

2) **Analyses of Streamflows and Freshwater Inflows**
   a) Analyze and compare monthly simulated regulated freshwater inflows to the Guadalupe Estuary for each of the above scenarios in terms of magnitude, frequency, and duration of occurrence in electronic graphical formats approved by the GSA BBEST or designated representative(s).
   b) Distribute monthly simulated regulated streamflows to daily values at five (7) instream flow regime recommendation locations using appropriate procedures approved by the GSA BBEST or designated representative(s) for each of the above scenarios. For simulation scenarios v. and vi., such distributions are expected to include consideration of senior water rights and application of the HDR Spreadsheet referenced in Science Advisory Committee Report # SAC-2010-04.
   c) Summarize daily simulated regulated streamflows at five (7) instream flow regime recommendation locations in electronic tabular formats.
   d) Analyze and compare daily simulated regulated streamflows for each of the above scenarios in terms of magnitude, frequency, and duration of occurrence in electronic graphical formats approved by the GSA BBEST or designated representative(s).

3) **Documentation and Reporting**
   a) Upon completion and verification, deliver tabular summaries of all daily and monthly streamflows in electronic format to the GSA BBEST Chair for dissemination. Delivery of such tabular summaries shall occur within three (3) weeks of receipt of notice to proceed and no later than January 11, 2011.
   b) Upon completion and verification, deliver analyses and comparisons of monthly freshwater inflows and daily streamflows in electronic format to the TWDB and GSA BBEST Chair for dissemination. Delivery of such tabular summaries shall occur within four (4) weeks of receipt of notice to proceed and no later than January 18, 2011.
   c) Prepare and submit a draft technical memorandum summarizing applications of the GSA WAM and analyses of streamflows & freshwater inflows within six (6) weeks of receipt of notice to proceed and no later than February 1, 2011.
   d) Prepare and submit a final technical memorandum within one (1) week of receipt of comments on the draft.

4) **Participation in Meetings**
   a) Participate in two progress meetings with the GSA BBEST or designated representative(s) in Austin, Texas.
   b) Participate in one meeting of the GSA BBEST to present and discuss applications of the GSA WAM and analyses of streamflows & freshwater inflows. It is expected that this meeting will occur on January 20, 2011.

APPENDIX B - HEFR MATRIX FOR GUADALUPE SITE

	Winter (Jan, Feb, Mar)	Spring (Apr, May, Jun)	Summer (Jul, Aug, Sep)	Fall (Oct, Nov, Dec)
Overbank Flows	Qp: 45,400 cfs with Average Frequency 1 per 5 years Regressed Volume is 869,212 Regressed Duration is 42			
Overbank Flows	Qp: 24,726 cfs with Average Frequency 1 per 2 years Regressed Volume is 406,298 Regressed Duration is 29			
Overbank Flows	Qp: 16,600 cfs with Average Frequency 1 per year Regressed Volume is 246,759 Regressed Duration is 23			
High Flow Pulses	Qp: 4,610 cfs with Average Frequency 1 per season Regressed Volume is 55,284 Regressed Duration is 12	Qp: 8,873 cfs with Average Frequency 1 per season Regressed Volume is 110,152 Regressed Duration is 15	Qp: 2,110 cfs with Average Frequency 1 per season Regressed Volume is 19,318 Regressed Duration is 7	Qp: 5,195 cfs with Average Frequency 1 per season Regressed Volume is 54,653 Regressed Duration is 11
High Flow Pulses	Qp: 1,610 cfs with Average Frequency 2 per season Regressed Volume is 14,126 Regressed Duration is 6	Qp: 3,370 cfs with Average Frequency 2 per season Regressed Volume is 31,782 Regressed Duration is 8	Qp: 1,050 cfs with Average Frequency 2 per season Regressed Volume is 8,302 Regressed Duration is 5	Qp: 1,730 cfs with Average Frequency 2 per season Regressed Volume is 14,101 Regressed Duration is 6
Base Flows (cfs) – High	978(54.1%)	938(61.2%)	800(47.4%)	865(49.1%)
Base Flows (cfs) – Medium	763(68.7%)	677(75.2%)	602(64.3%)	673(65.3%)
Base Flows (cfs) – Low	550(84.6%)	413(89.1%)	386(78.7%)	480(82.0%)
Subsistence Flows (cfs)	134(99.1%)	118(98.9%)	131(94.6%)	86(97.9%)

Recognized Only

Recognized Only

Flow Levels	
	High (75th %ile)
	Medium (50th %ile)
	Low (25th %ile)
	Subsistence

Notes:

1. Period of Record used : 1/1/1936 to 12/31/2009.

APPENDIX C - HEFR MATRIX FOR SAN ANTONIO SITE

	Winter (Jan, Feb, Mar)	Spring (Apr, May, Jun)	Summer (Jul, Aug, Sep)	Fall (Oct, Nov, Dec)
Overbank Flows	Qp: 21,000 cfs with Average Frequency 1 per 5 years Regressed Volume is 320,693 Regressed Duration is 39			
Overbank Flows	Qp: 12,600 cfs with Average Frequency 1 per 2 years Regressed Volume is 172,067 Regressed Duration is 29			
Overbank Flows	Qp: 8,360 cfs with Average Frequency 1 per year Regressed Volume is 104,363 Regressed Duration is 23			
High Flow Pulses	Qp: 1,610 cfs with Average Frequency 1 per season Regressed Volume is 16,812 Regressed Duration is 11	Qp: 4,500 cfs with Average Frequency 1 per season Regressed Volume is 45,161 Regressed Duration is 14	Qp: 2,010 cfs with Average Frequency 1 per season Regressed Volume is 18,176 Regressed Duration is 11	Qp: 2,930 cfs with Average Frequency 1 per season Regressed Volume is 28,040 Regressed Duration is 12
High Flow Pulses	Qp: 728 cfs with Average Frequency 2 per season Regressed Volume is 6,305 Regressed Duration is 7	Qp: 1,920 cfs with Average Frequency 2 per season Regressed Volume is 16,119 Regressed Duration is 9	Qp: 779 cfs with Average Frequency 2 per season Regressed Volume is 5,541 Regressed Duration is 6	Qp: 1,130 cfs with Average Frequency 2 per season Regressed Volume is 8,894 Regressed Duration is 7
Base Flows (cfs) – High	336(61.9%)	308(65.0%)	240(60.0%)	315(59.8%)
Base Flows (cfs) – Medium	263(76.4%)	224(77.8%)	178(74.5%)	250(74.3%)
Base Flows (cfs) – Low	169(89.6%)	143(90.5%)	130(85.0%)	187(86.2%)
Subsistence Flows (cfs)	84(99.7%)	65(98.3%)	62(96.5%)	81(98.5%)

Recognized Only

Recognized Only

Flow Levels	
	High (75th %ile)
	Medium (50th %ile)
	Low (25th %ile)
	Subsistence

Notes:

1. Period of Record used : 1/1/1940 to 12/31/2009.

APPENDIX D
DESCRIPTION OF APPLICATION OF GSA BBEST RECOMMENDATIONS

Kirk Kennedy

From:	Vaugh, Sam <Sam.Vaugh@hdrinc.com>
Sent:	Thursday, January 06, 2011 9:49 PM
To:	Norman Johns; Debbie Magin; Ed Buskey; Scott Holt; Mike Gonzales; Gregg Eckhardt; Liz Smith; Tim Bonner; Thom Hardy; Warren Pullich
Cc:	Dan Opdyke; George Ward; Kirk Kennedy
Subject:	GSA BBEST - Example Flow Regime Recommendations For Your Immediate Review
Attachments:	Attachment 1.pdf; Attachment2.pdf; Attachment3.pdf
Importance:	High

GSA BBEST Members:

Pursuant to discussions and your request during our 12/20/2010 meeting, described herein is an example flow regime recommendation for the San Antonio River @ Goliad for your immediate review and comment. In the terms of our report Table of Contents, this might be considered an "initial hydrology-based flow regime" and is pending refinement based on biological, water quality, geomorphology, and riparian vegetation overlays as well as the results of our hydrologic time series analyses. This flow regime recommendation will be used by our consultant performing hydrologic time series analyses (Kirk Kennedy). **As he is to present the results of his work to us at our next meeting, your initial comments on this example regime recommendation are needed ASAP. It is my intent to provide example flow regime recommendation guidance for the Goliad, Cuero (Guadalupe River), and Westhoff (Sandies Creek) locations to Mr. Kennedy by close of business on 1/7/2011 (tomorrow) if at all possible.**

Following are steps by which I would suggest that you conduct your preliminary review, along with some explanatory comments:

1) Consider Attachment 1 which is simply the output summary generated by application of HEFR. This summary is a direct output of HEFR as applied by Dan Opdyke subject to assumptions tentatively adopted by the GSA BBEST.
2) Consider Attachment 2 (an edited version of Attachment 1) which more concisely defines the example flow regime recommendation. Following are explanatory comments regarding each component of the regime:
    a) Subsistence – I stayed with the seasonal HEFR calculation (median of the lowest 10% of base flows) for now. As a water quality overlay, we could consider lowering subsistence flow(s) because field measurements and water quality modeling indicate that violations of the DO standard would not likely occur. Alternatively, we could consider using only the Summer subsistence flow (62 cfs) for all seasons as summer low flow / high temperature stresses pose the greatest concerns with DO standard violation.
    b) Base – I stayed with the three-tiered (dry/average/wet) seasonal HEFR calculation (25^{th}, 50^{th}, & 75^{th} percentiles of base flows) for now. During our last meeting, the GSA BBEST expressed an initial preference to retain three tiers of base flow and define hydrologic conditions rather than proceed with a single seasonal base flow. More about hydrologic conditions below.
    c) Pulses (Magnitude) – Ranges for pulse volume and duration were eliminated and the central tendency values derived by ln/ln regression with peak flow (which generally provided a better fit based on review by Dan & me) were retained. The calculated pulses with frequencies 1 per year and 2 per year are actually overbank based on NWS data for this location, therefore, these pulses are reclassified as "Overbank Flows."
    d) Pulses (Application) – Multiple tiers of seasonal pulses are retained based on the initial preference of the GSA BBEST expressed during our last meeting. I am proposing that seasonal pulses be recommended in accordance with an hydrologic condition established at the beginning of each season and that each season be assumed independent of the preceding and following seasons with respect to pulse frequency (these clarifications are consistent with TCEQ draft rules for the Sabine-Neches). More specifically, I am proposing:

i. One 2/season pulse per season in dry conditions;
ii. Two 2/season pulses per season in average conditions; and
iii. One 1/season pulse per season in wet conditions.

This structure is consistent with the S&N BBEST recommendations (except that they did not include pulse recommendations in Fall & Winter under dry conditions). I believe that this structure is consistent with the opinions of our members that small pulses are important under dry conditions and more frequent or larger pulses are important under average and wet conditions. Hydrologic time series analyses coupled with our geomorphology overlay will provide insights as to the suitability of this proposed structure.

e) Overbank – I am proposing that the ecological value of overbank flows be recognized, but that such overbank flows not be considered a requirement within our flow regime recommendation. It is extremely unlikely that TCEQ will ever include a special condition in any future permit that would require intentional passage of a flood when such flows could have been temporarily or permanently impounded and liability for loss of life and/or property damages thereby avoided. Furthermore, I believe that our hydrologic time series analyses and geomorphology and riparian vegetation overlays will demonstrate that overbank events will occur with sufficient frequency to maintain a sound ecological environment.

3) As mentioned above, use of multi-tiered base and pulse flows within a regime recommendation necessitates definition of applicable hydrologic conditions. TCEQ's draft rules for the Sabine-Neches used reservoir storage volumes to define hydrologic conditions and the selection of these volumes was based on being in dry conditions 25% of the time, average conditions 50% of the time, and wet conditions 25% of the time. Due to the facts that 3 of the 5 major reservoirs in our basins are maintained near full for power plant operations and the other two are located in the headwaters, use of reservoir storage volume as the indicator of hydrologic conditions is not practical for the GSA BBEST. Pursuant to discussions during our last meeting and further consideration, I am proposing that we use 12-month cumulative flow volumes to define seasonal hydrologic conditions with the understanding that these volumes will be selected such that dry, average, and wet conditions will apply 25%, 50%, and 25% of the time, respectively. Use of 12-month cumulative flow volumes will provide adequate recognition of the persistence of drought and avoid more complex antecedent seasonal computations associated with shorter durations.

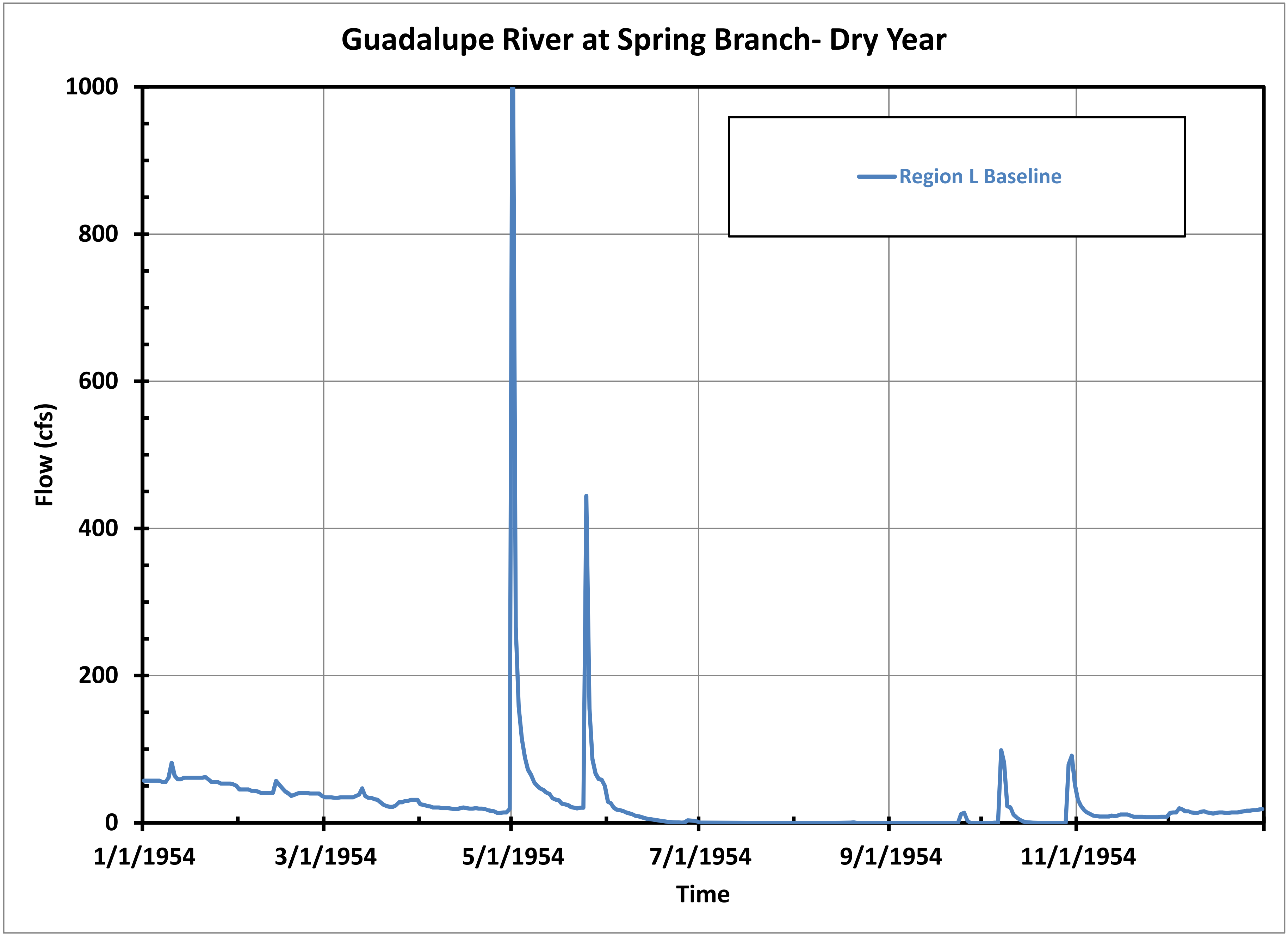
4) Application of the example flow regime recommendation will be in general conformance with the procedures summarized in Attachment 3. These procedures very closely approximate those recommended by the S&N BBEST (which were presented to the GSA BBEST during our 10/14/2010 meeting) and those included in TCEQ's draft rules for the Sabine-Neches.

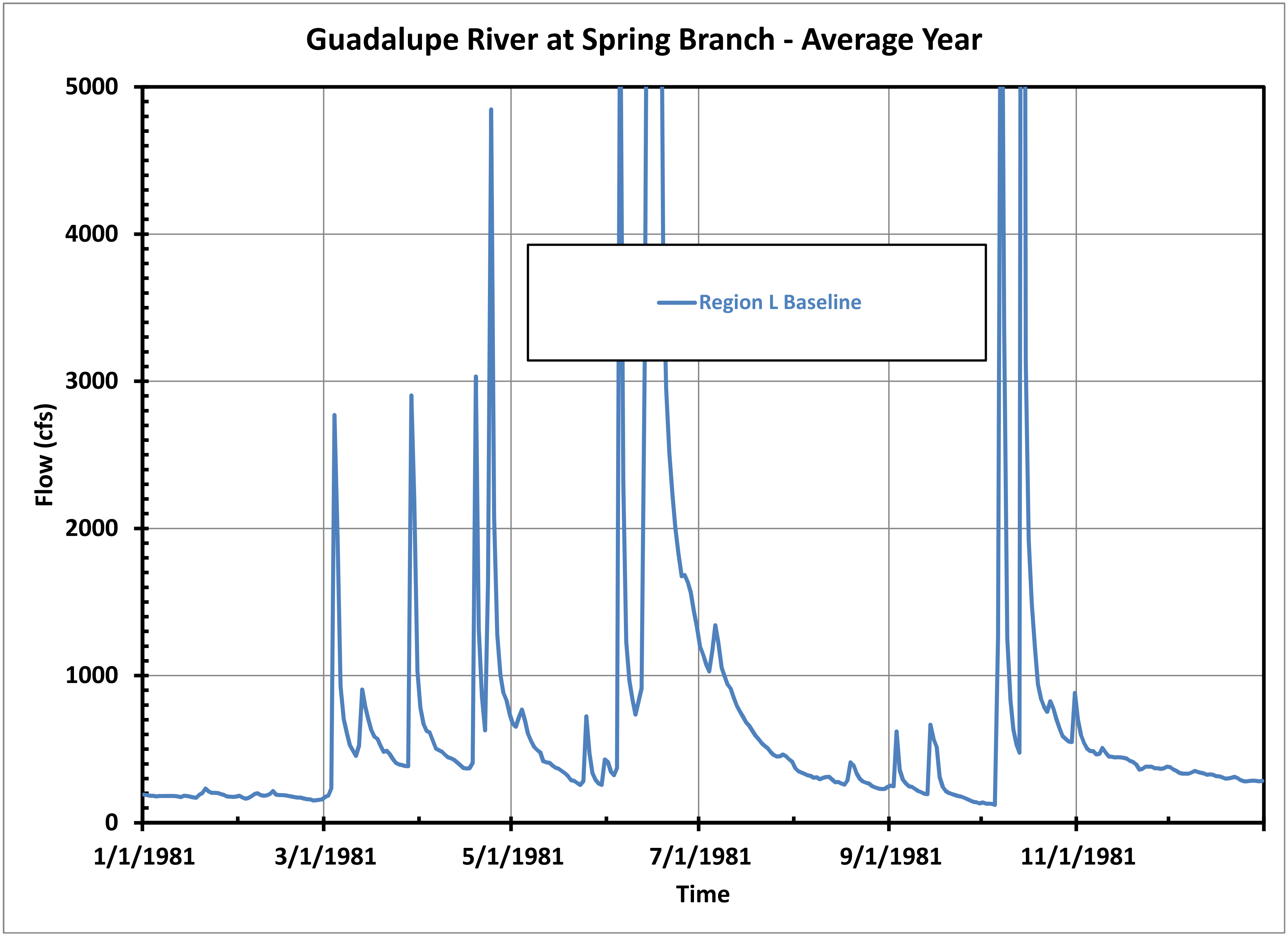
I am well aware that flow regime recommendations are complex and appreciate your timely attention to the details of this initial proposal. Please contact me at your earliest convenience to discuss any comments, questions, or concerns that you may have. I am available by cell phone (512-921-4938) tonight and early in the morning and will be in the office essentially all day tomorrow.

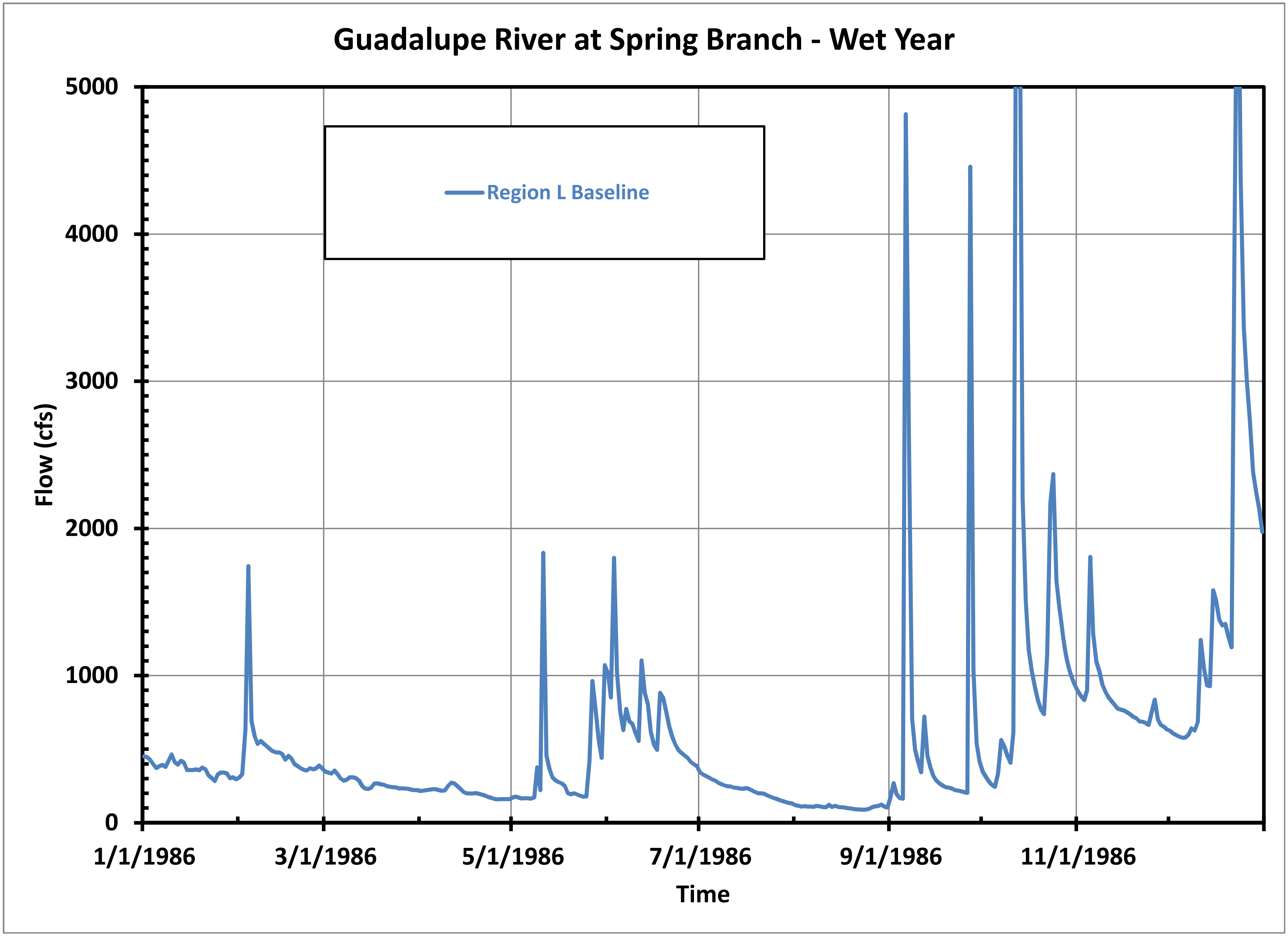
Thanks,
Sam

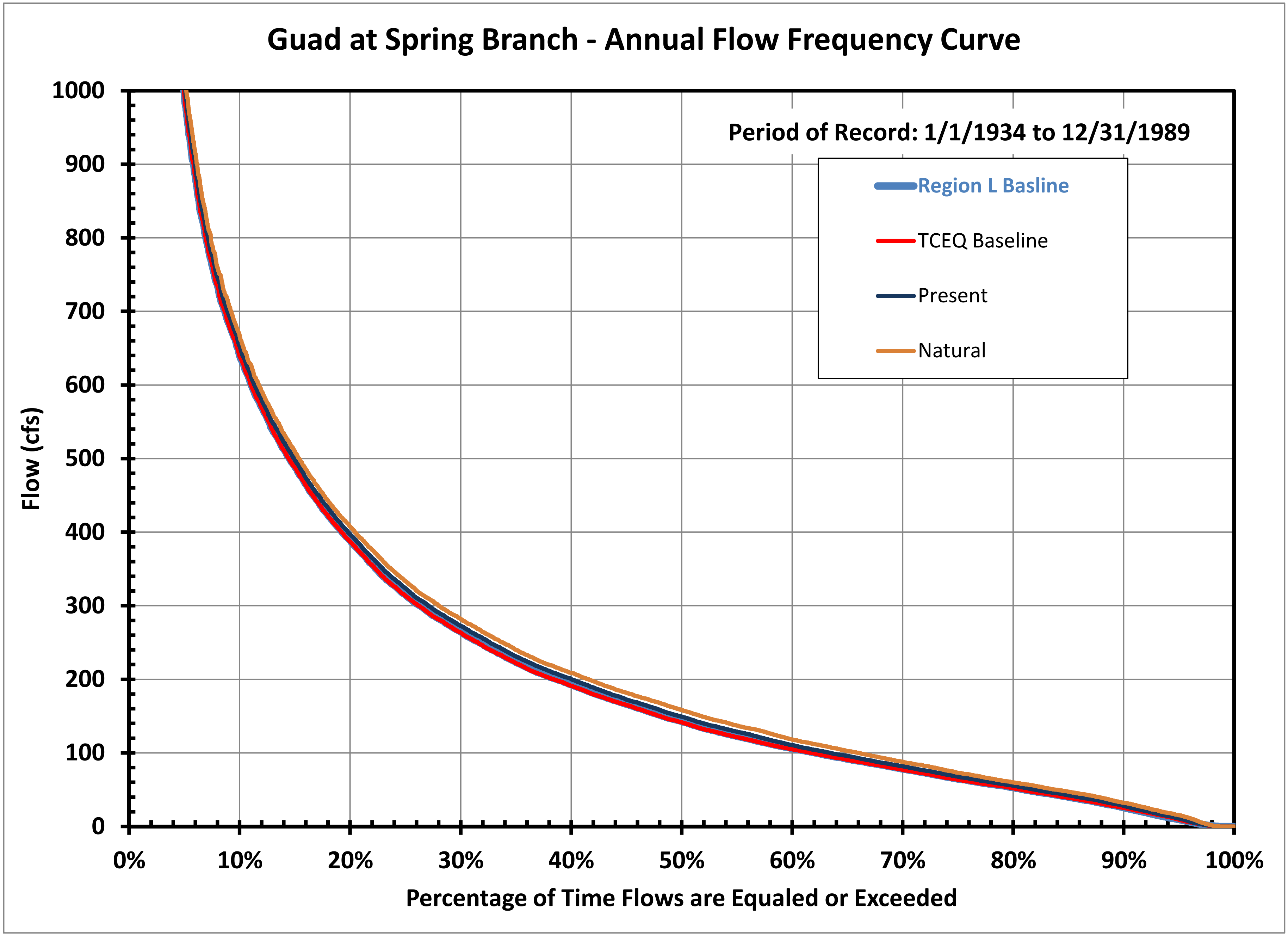
Samuel K. Vaugh, P.E.
Vice President
HDR Engineering, Inc.
4401 West Gate Boulevard, Suite 400 | Austin, TX | 78745
Phone: 512.912.5142 | Fax: 512.912.5158 | Email: Sam.Vaugh@hdrinc.com

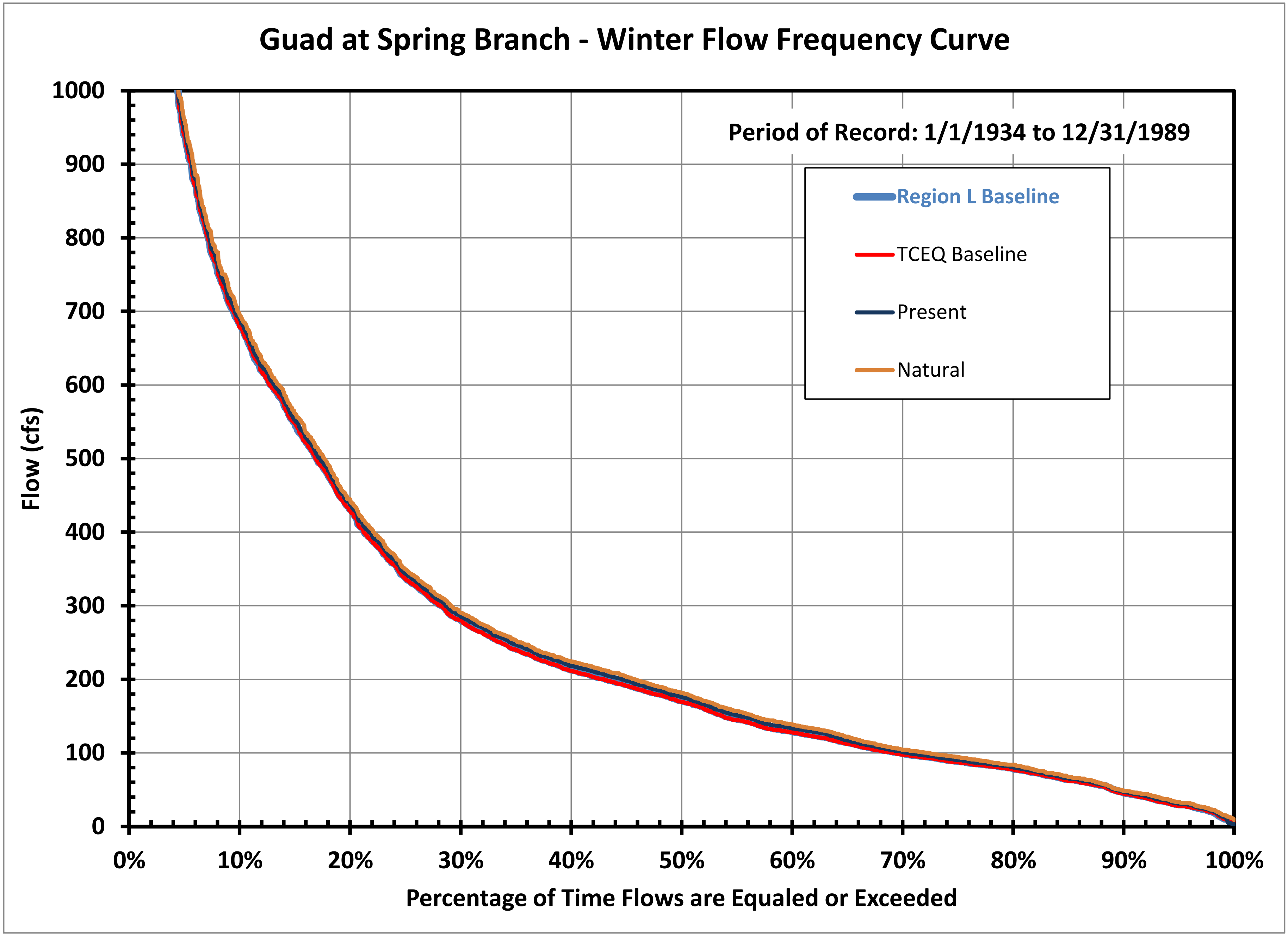
Appendix E - Guadalupe at Spring Branch

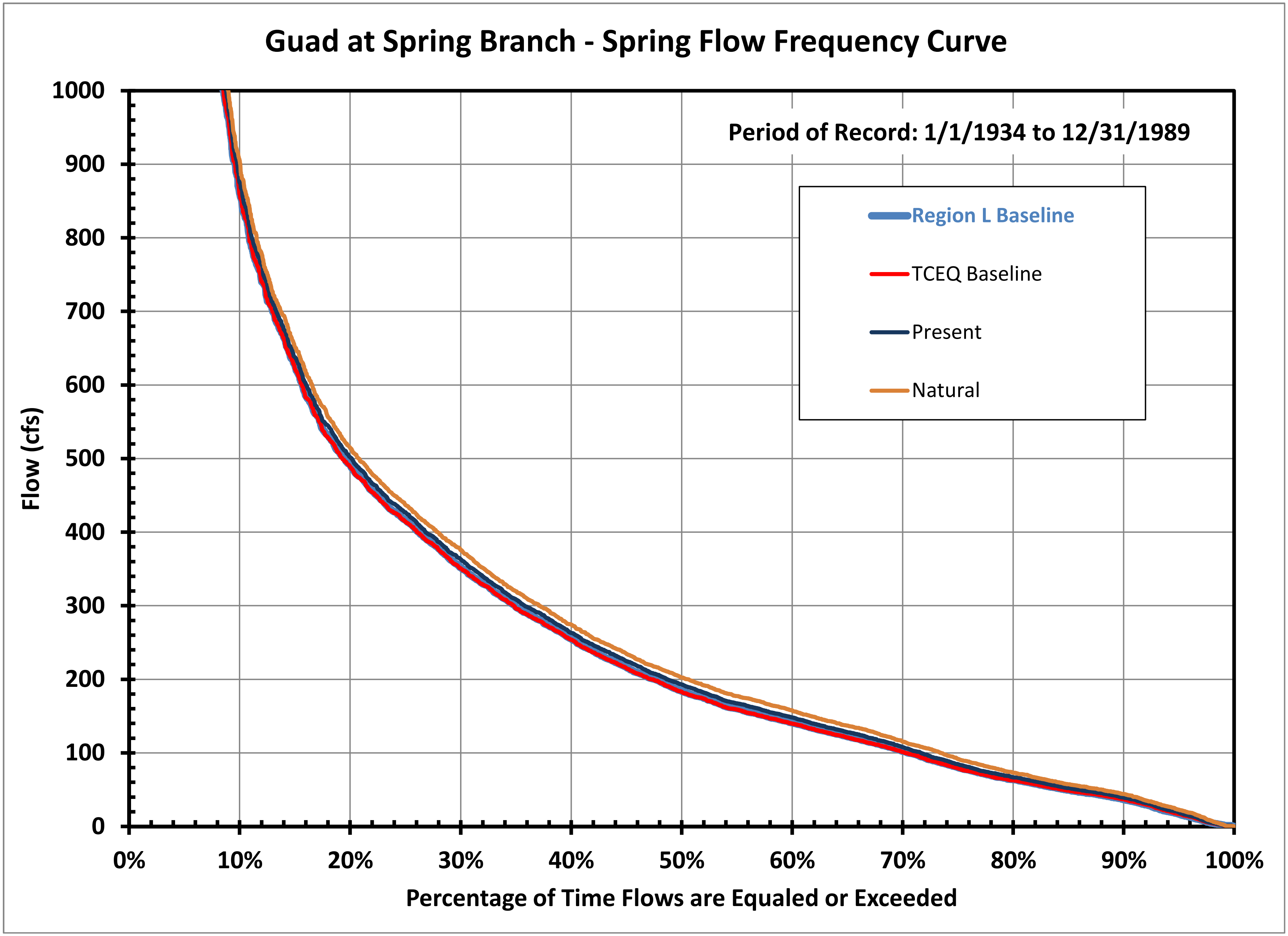

Guadalupe River at Spring Branch- Dry Year
Region L Baseline
Flow (cfs)
1000
800
600
400
200
0
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time

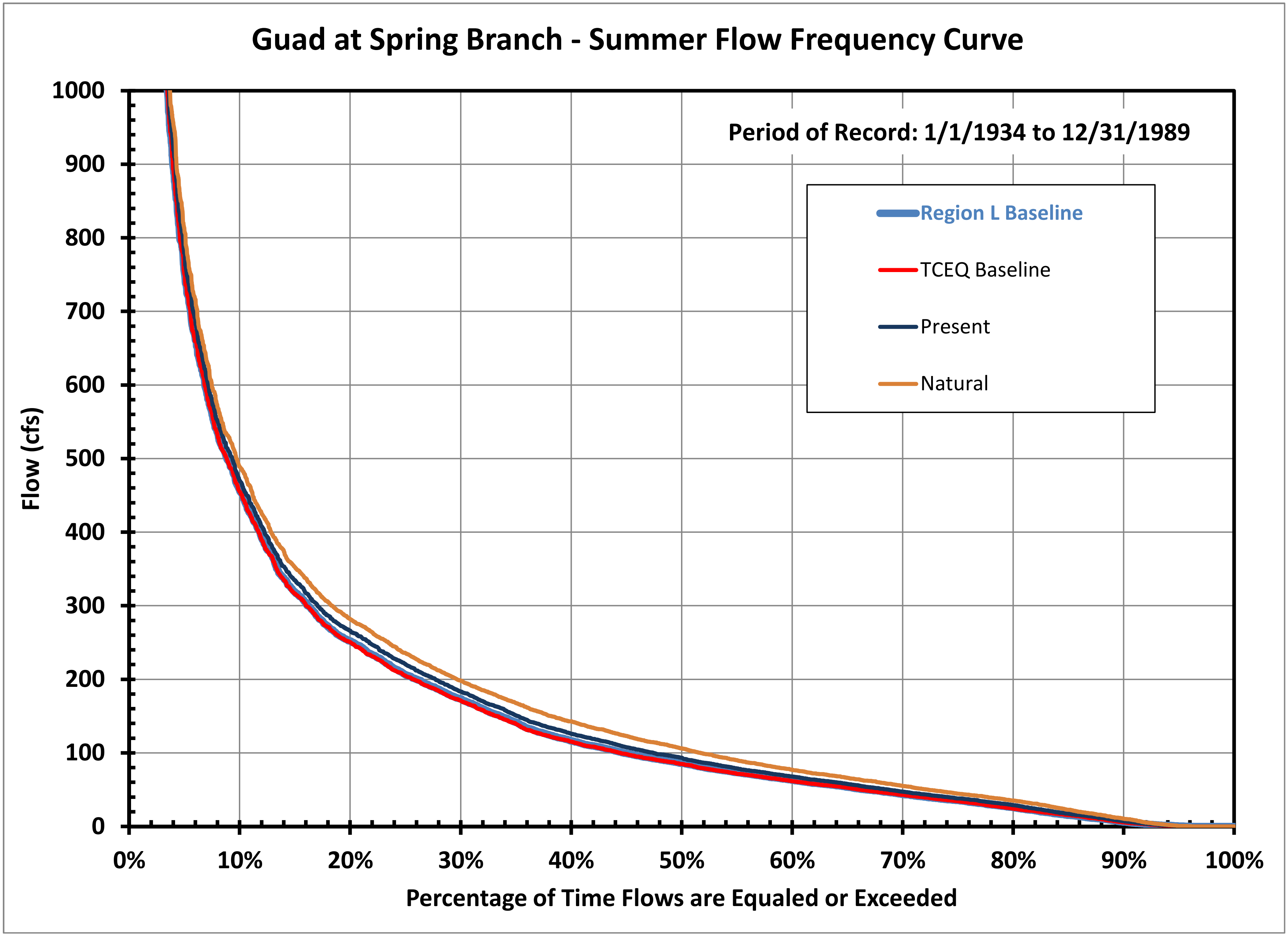

Guadalupe River at Spring Branch - Average Year
Flow (cfs)
5000
4000
3000
2000
1000
0
Region L Baseline
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

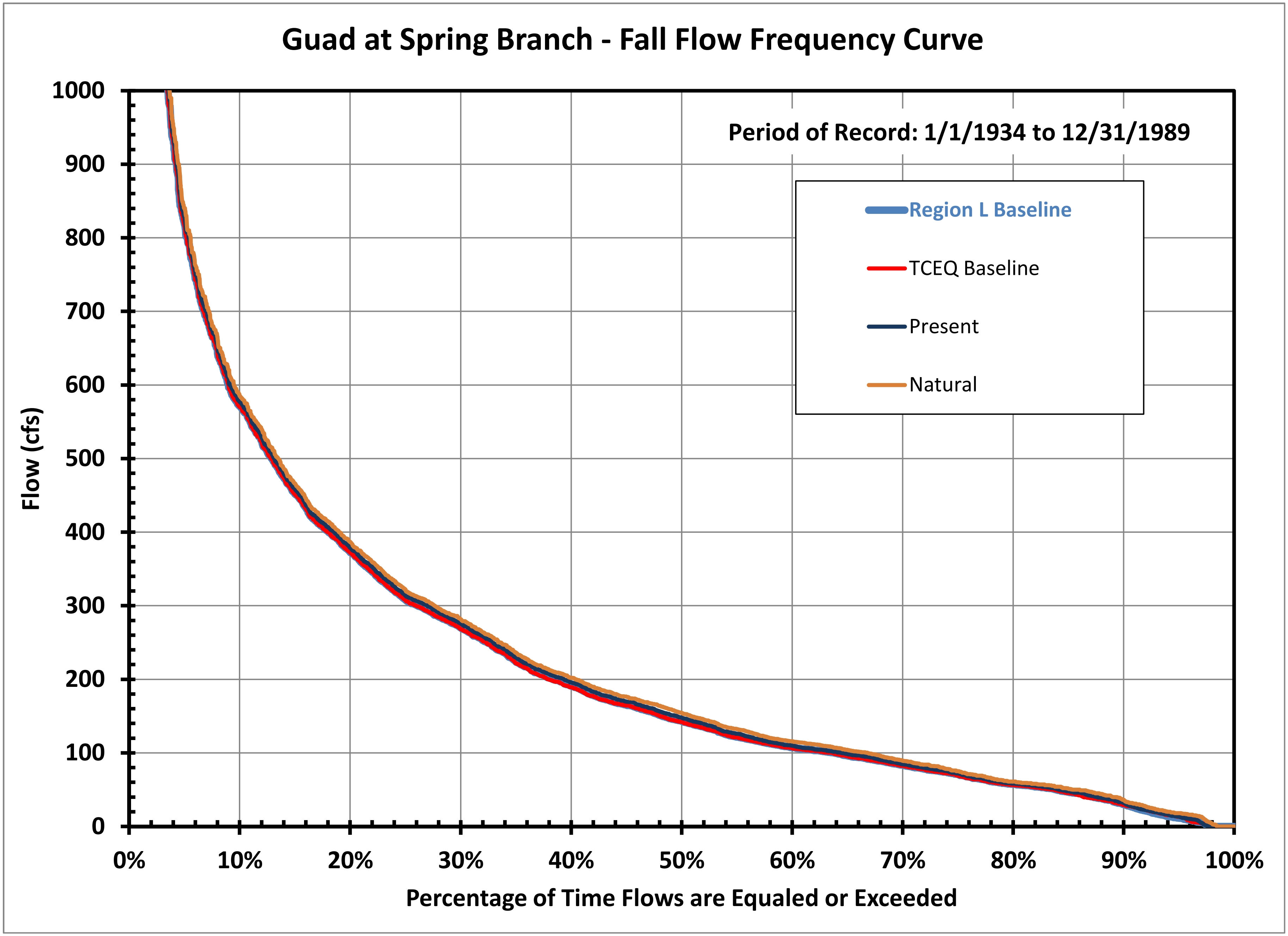

Guadalupe River at Spring Branch - Wet Year
Region L Baseline
Flow (cfs)
5000
4000
3000
2000
1000
0
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time


Guad at Spring Branch - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

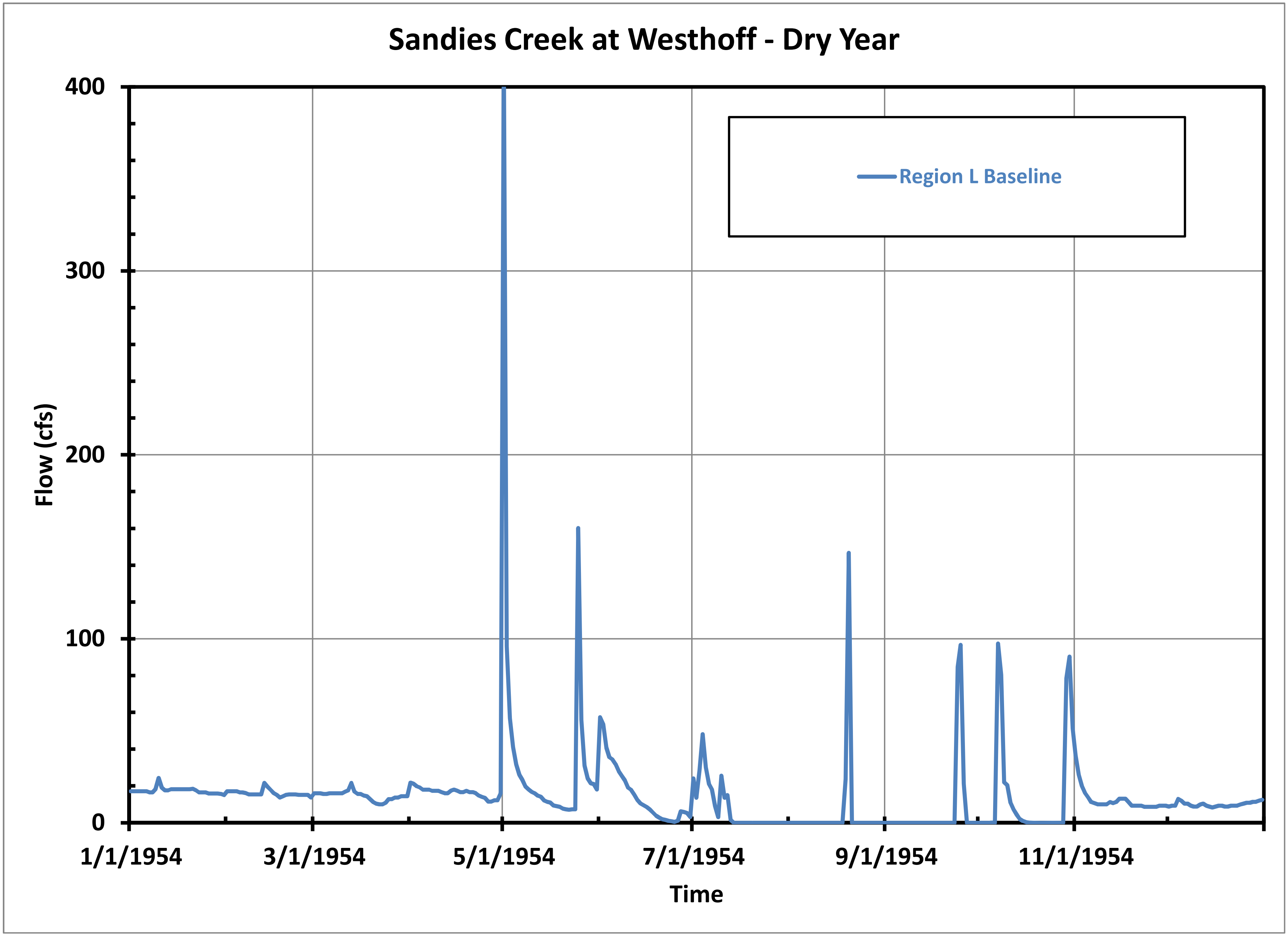

Guad at Spring Branch - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

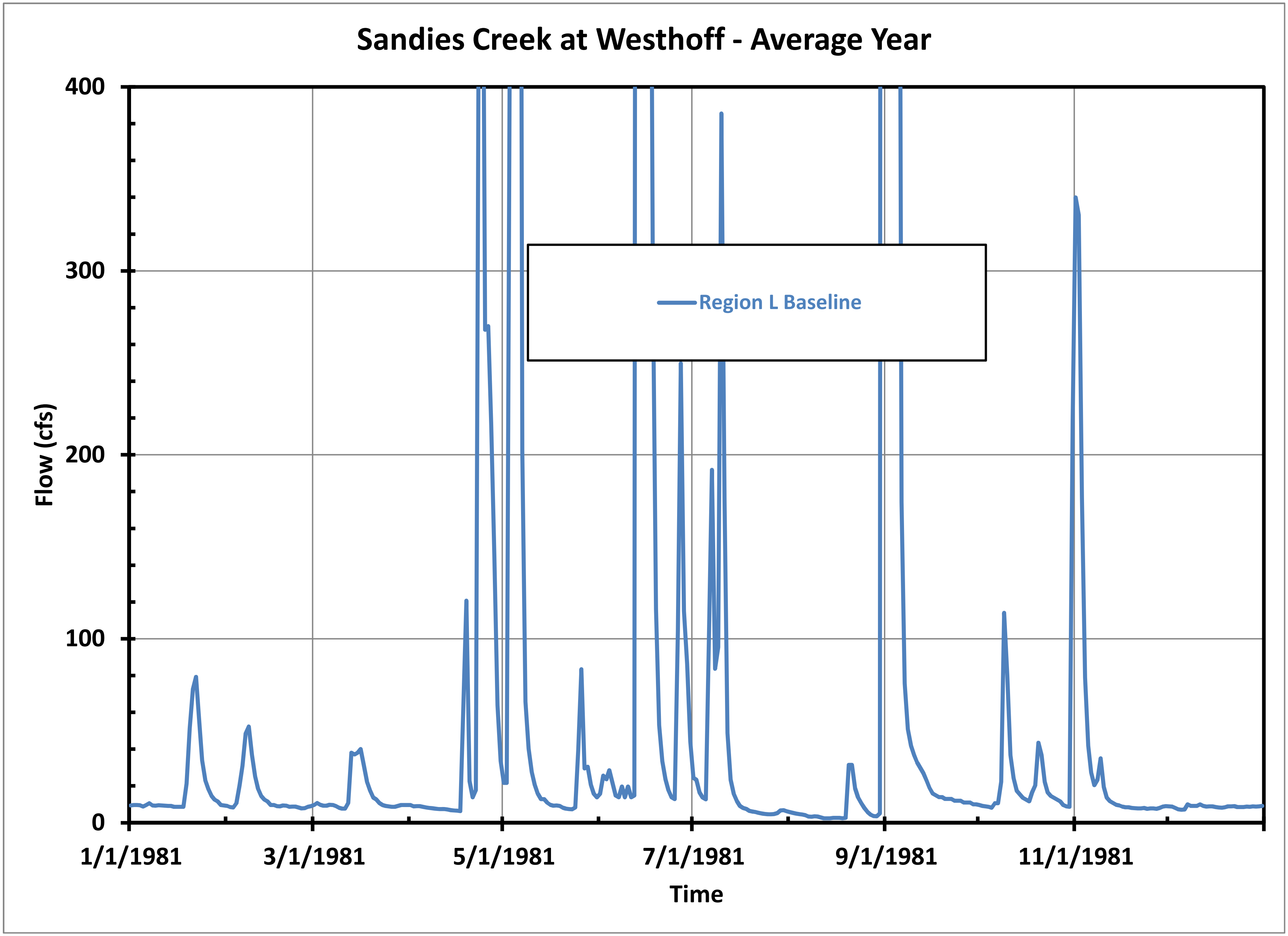

Guad at Spring Branch - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

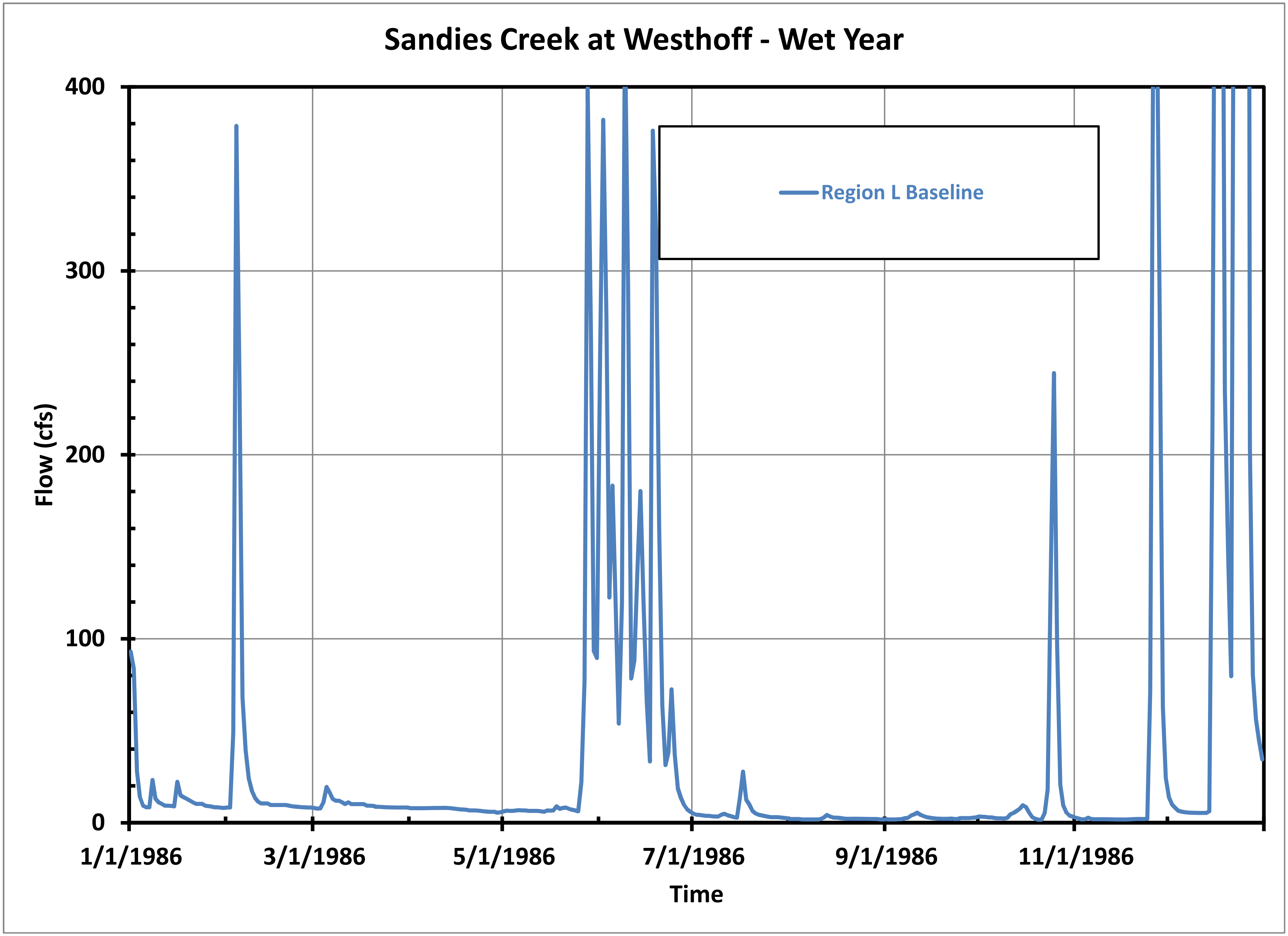

Guad at Spring Branch - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

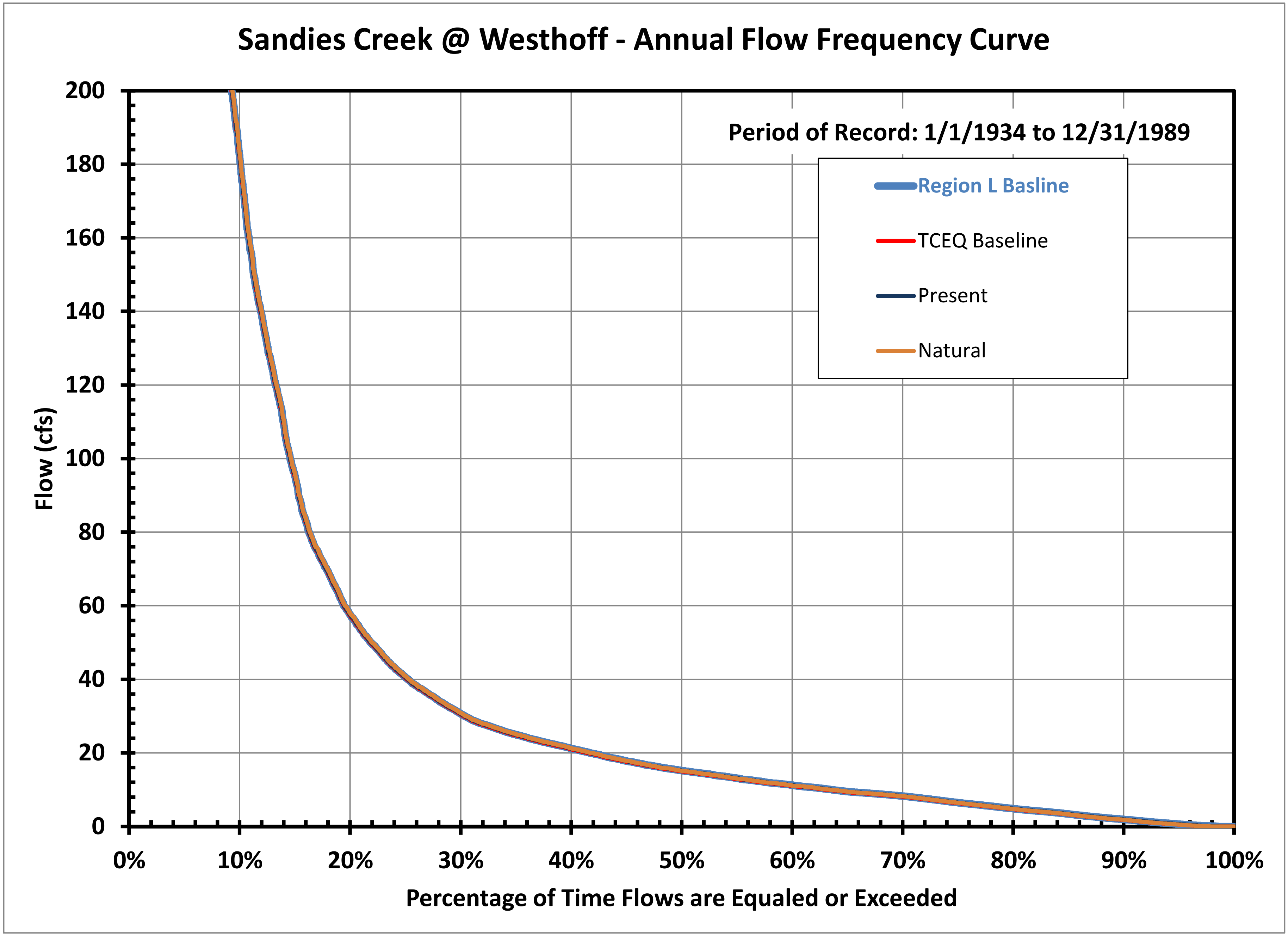

Guad at Spring Branch - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

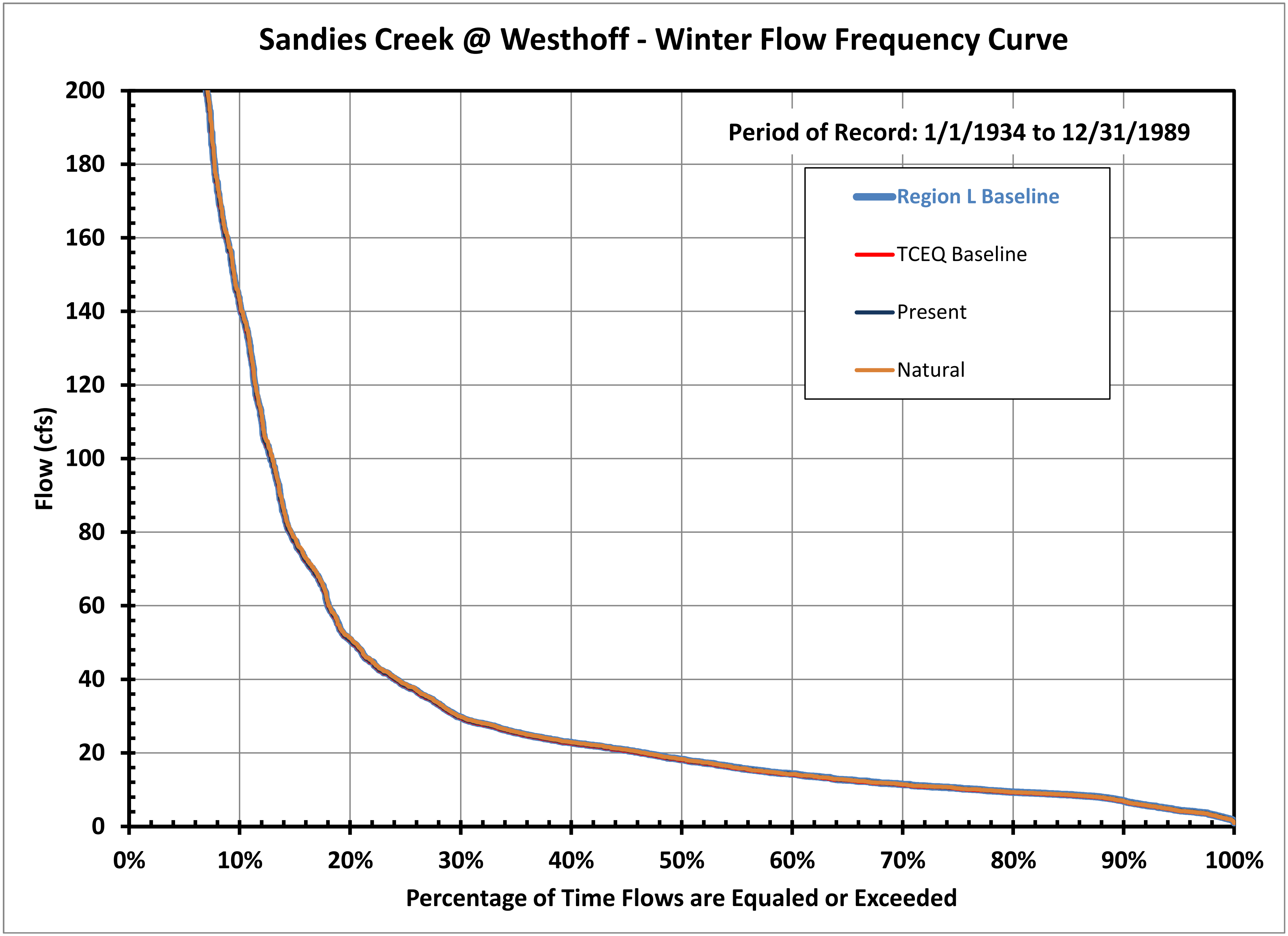
Appendix F - Sandies Creek near WestHoff

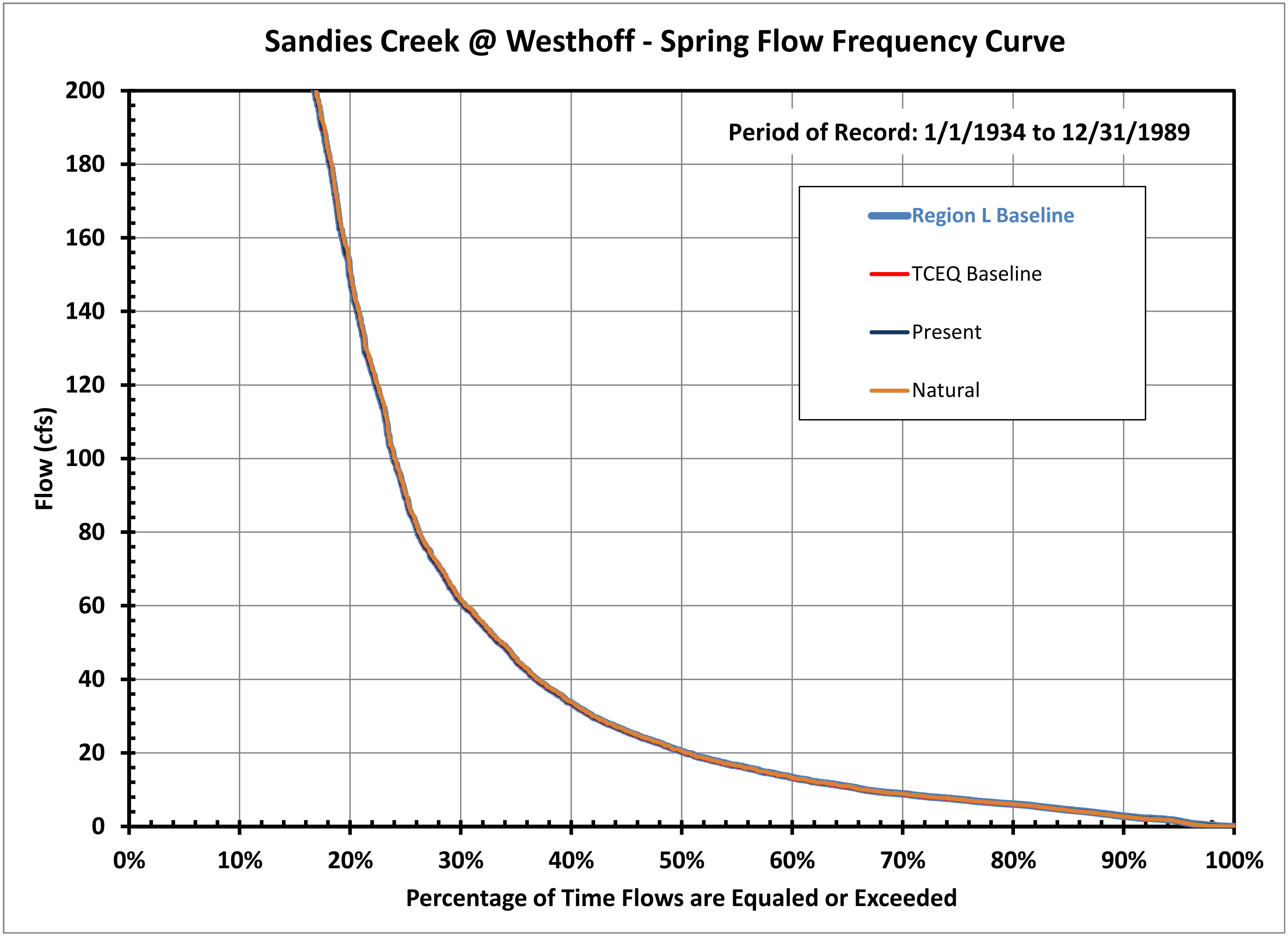

Sandies Creek at Westhoff - Dry Year
Flow (cfs)
400
300
200
100
0
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time
Region L Baseline

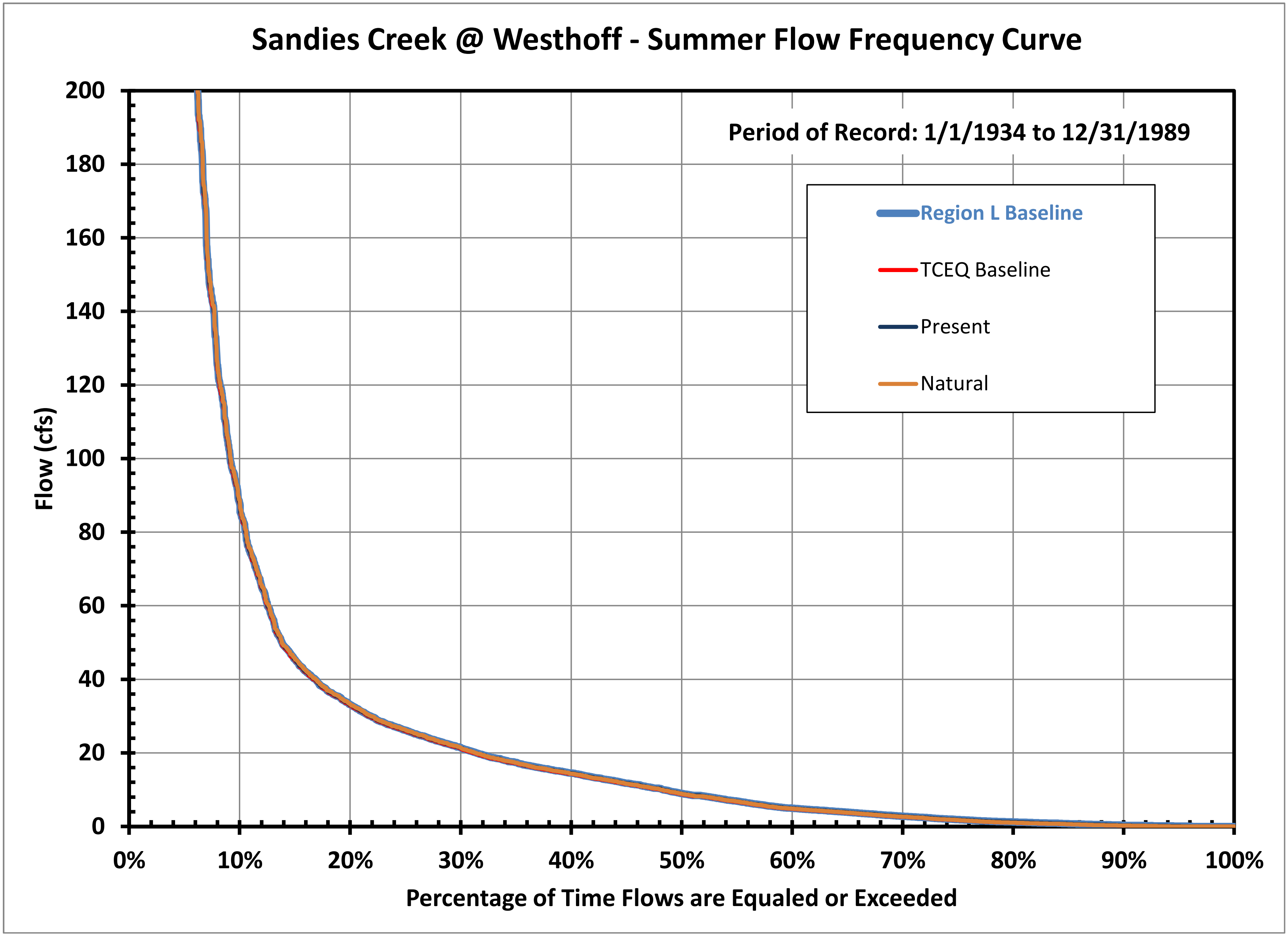

Sandies Creek at Westhoff - Average Year
Region L Baseline
Flow (cfs)
400
300
200
100
0
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

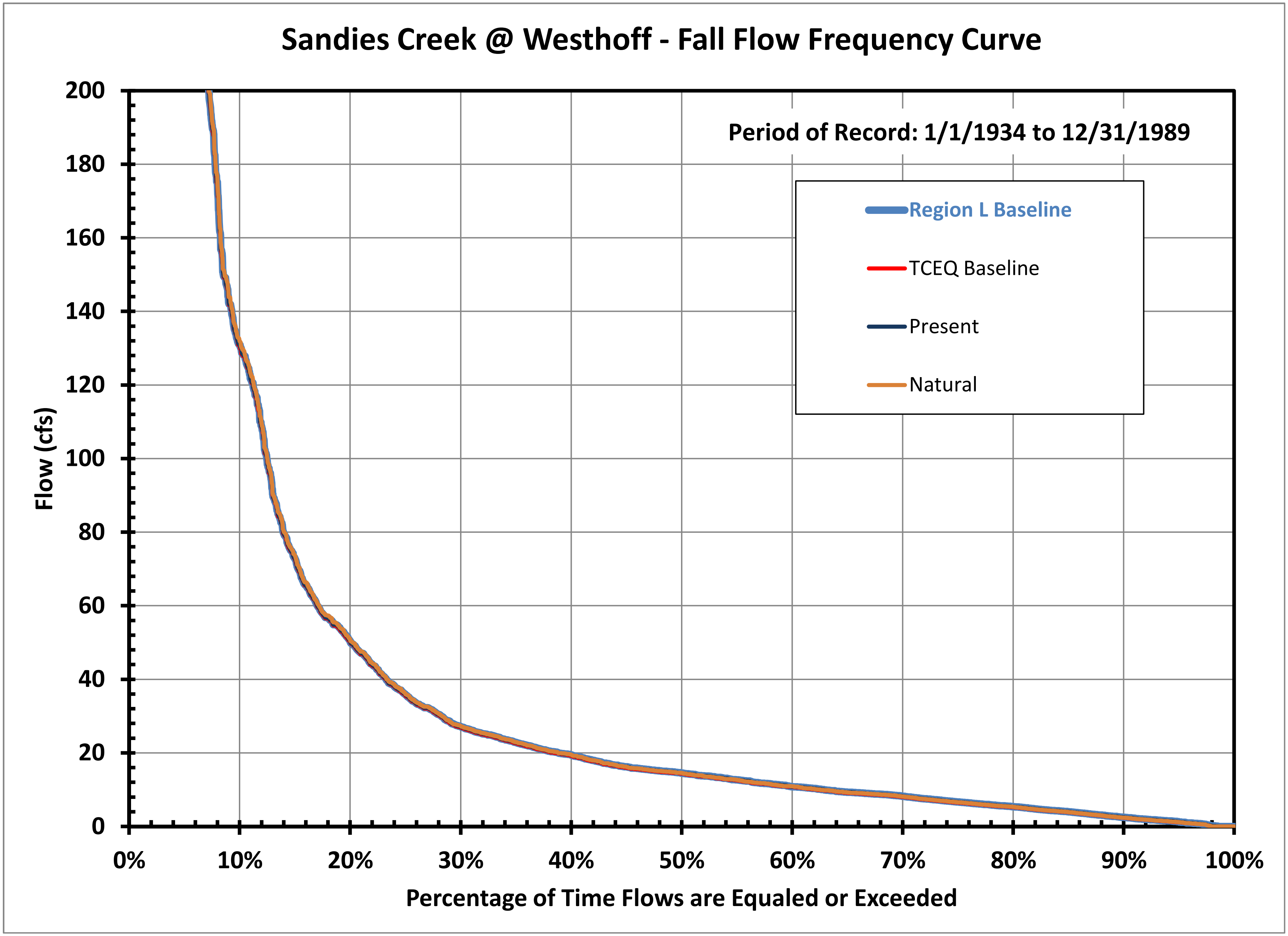

Sandies Creek at Westhoff - Wet Year
Region L Baseline
Flow (cfs)
400
300
200
100
0
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time


Sandies Creek @ Westhoff - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
TCEQ Baseline
Present
Natural
Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

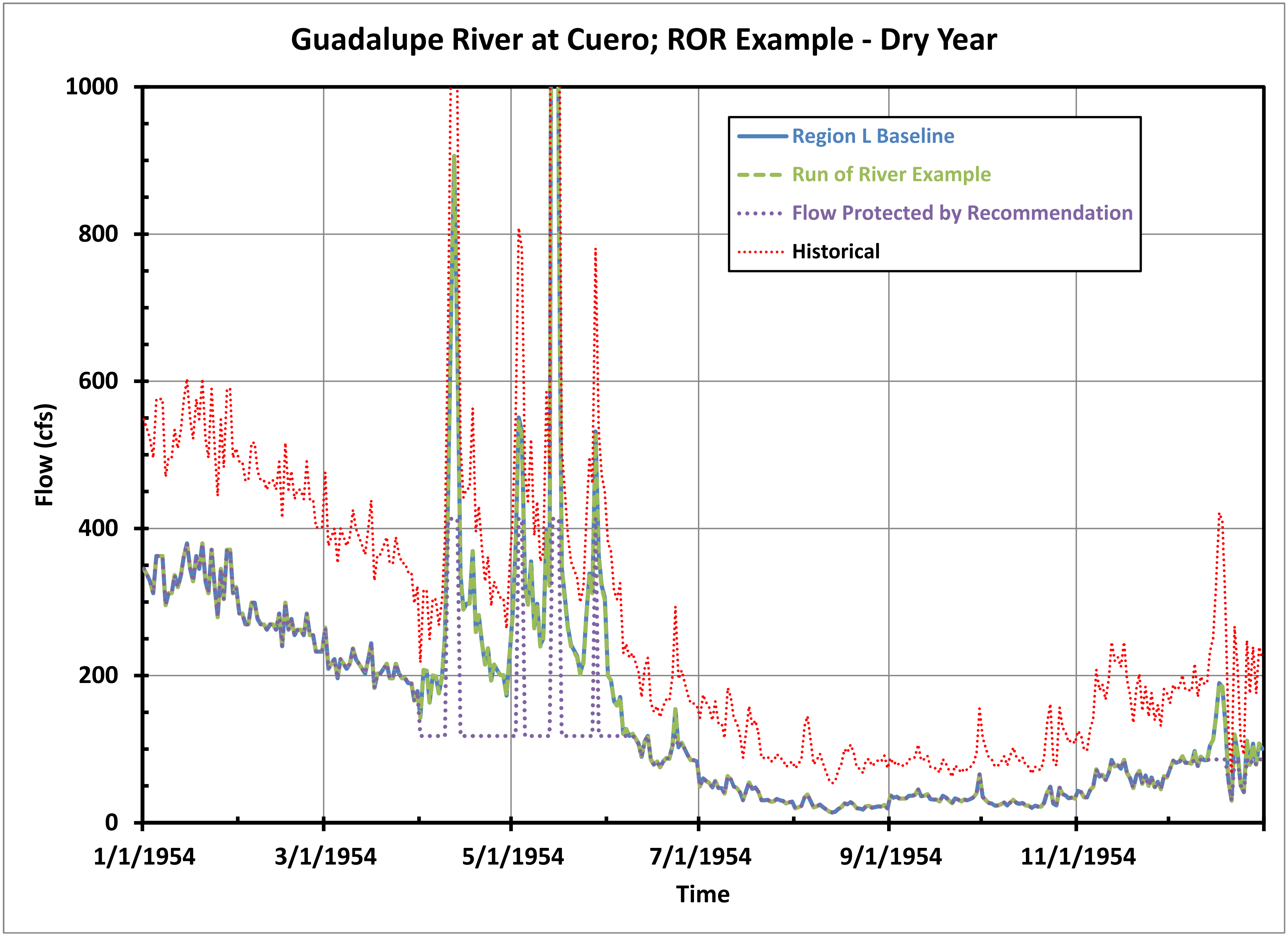

Sandies Creek @ Westhoff - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

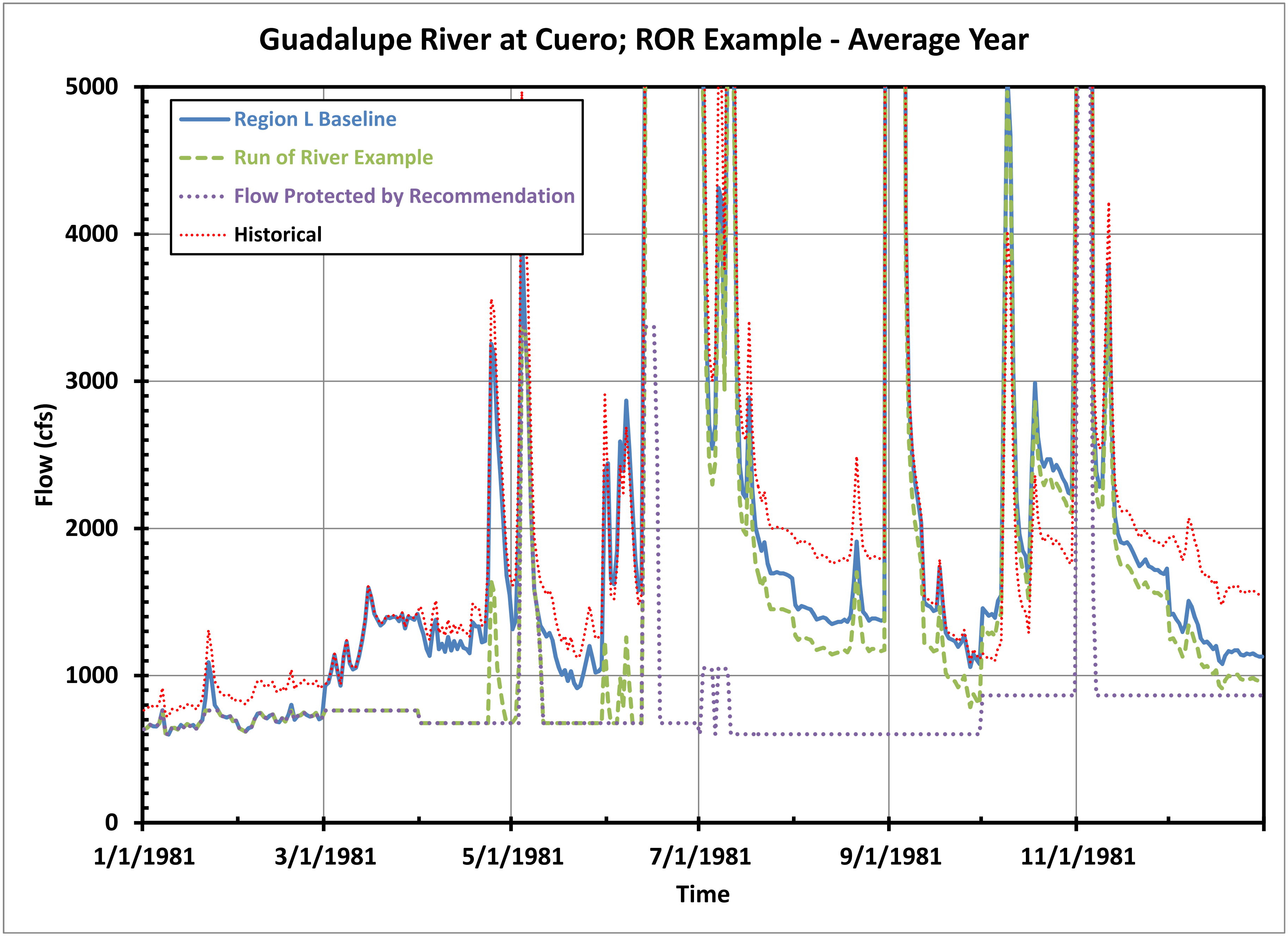

Sandies Creek @ Westhoff - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

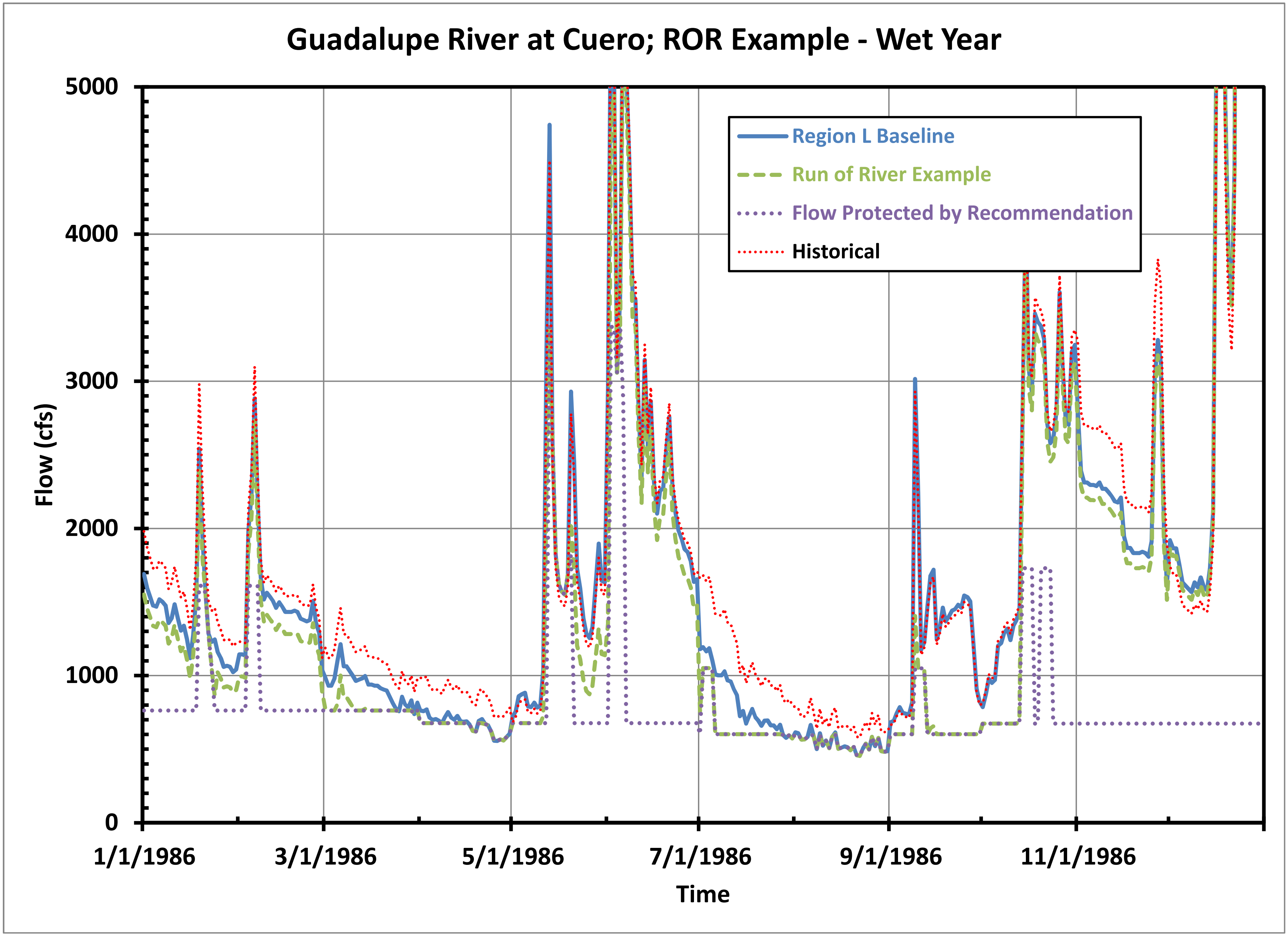

Sandies Creek @ Westhoff - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

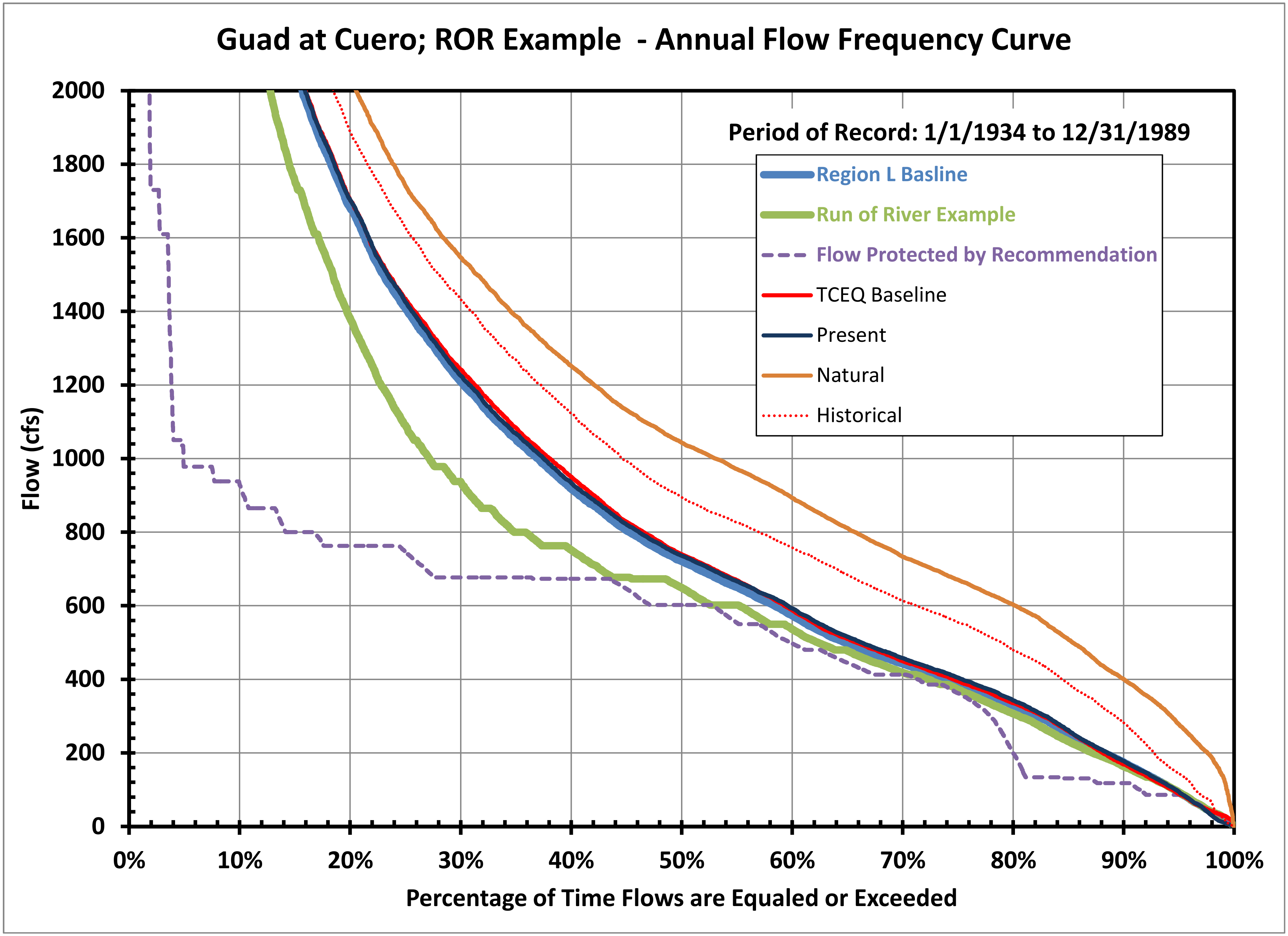

Sandies Creek @ Westhoff - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

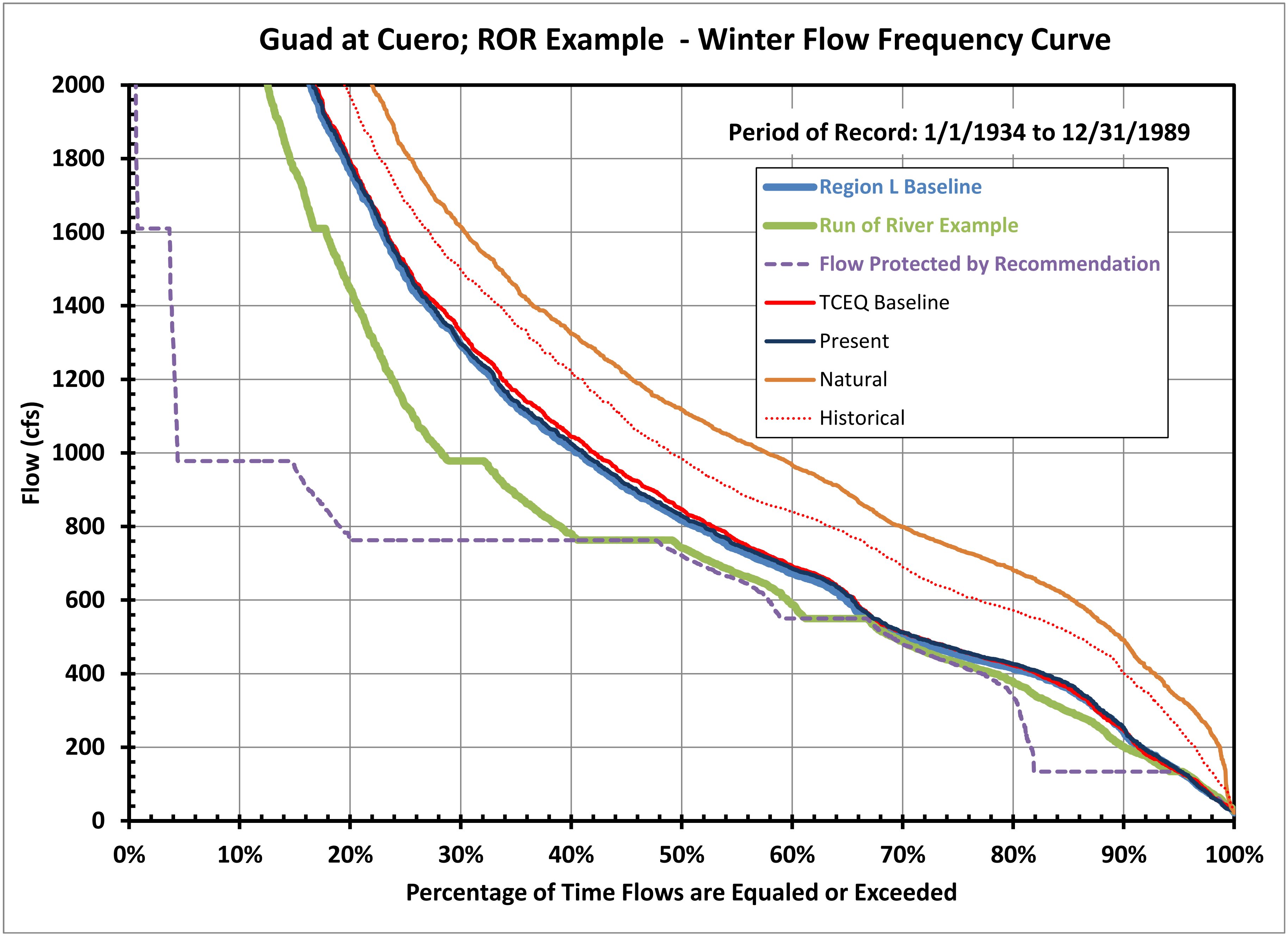
Appendix G - Guadalupe River at Cuero

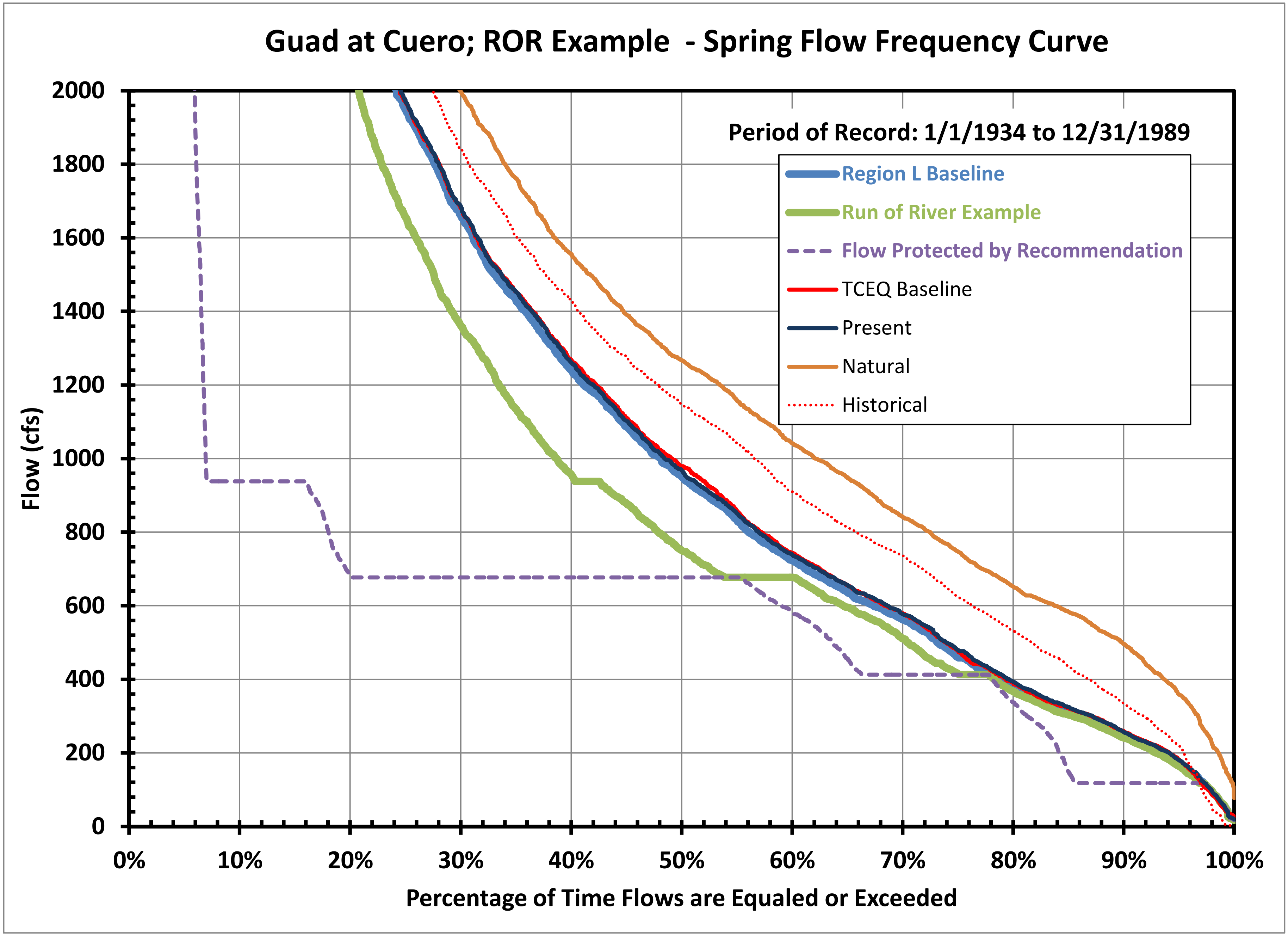

Guadalupe River at Cuero; ROR Example - Dry Year
1000
800
600
400
200
0
Flow (cfs)
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time
Region L Baseline
Run of River Example
Flow Protected by Recommendation
Historical

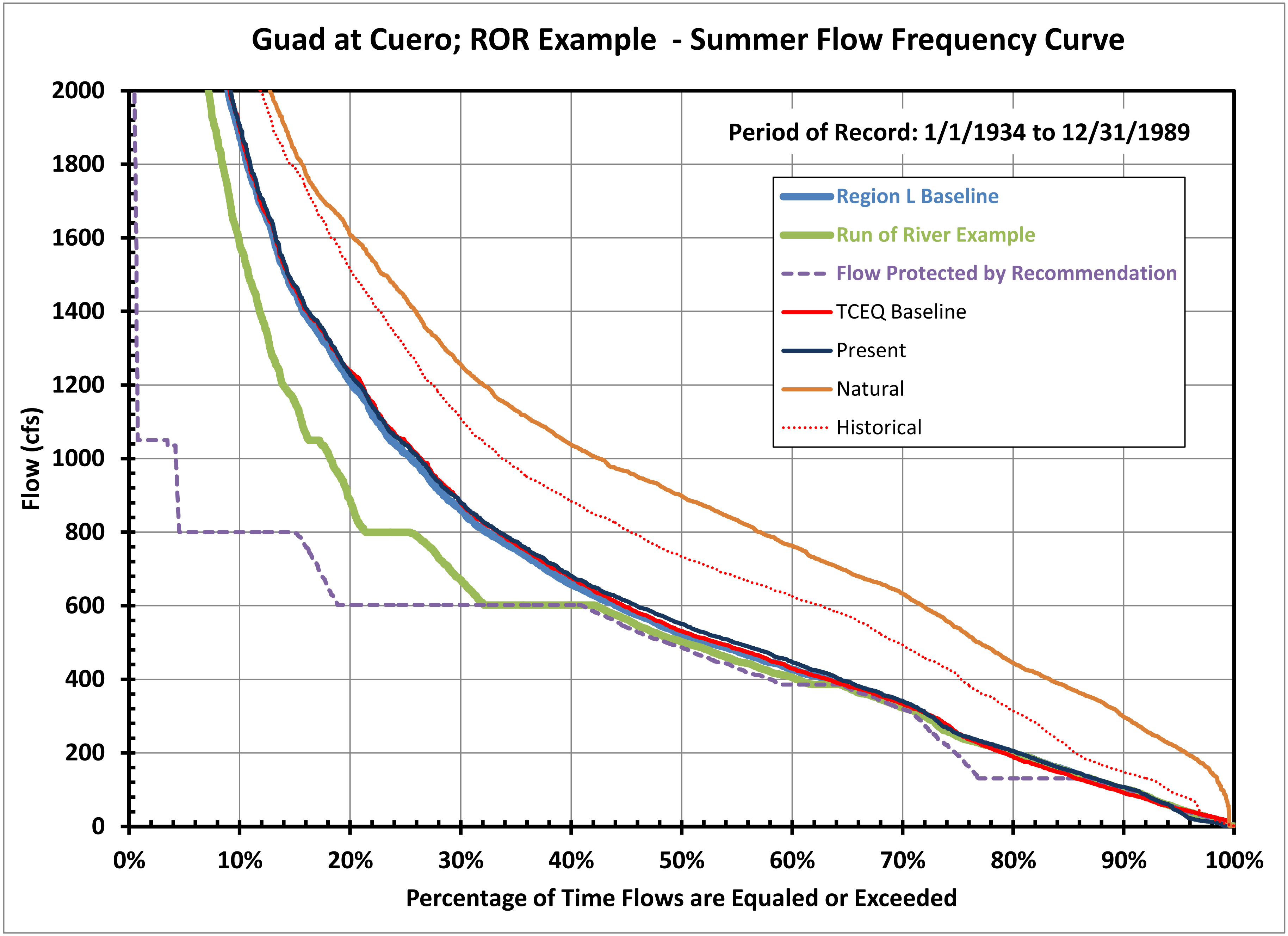

Guadalupe River at Cuero; ROR Example - Average Year
Region L Baseline
Run of River Example
Flow Protected by Recommendation
Historical
Flow (cfs)
5000
4000
3000
2000
1000
0
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

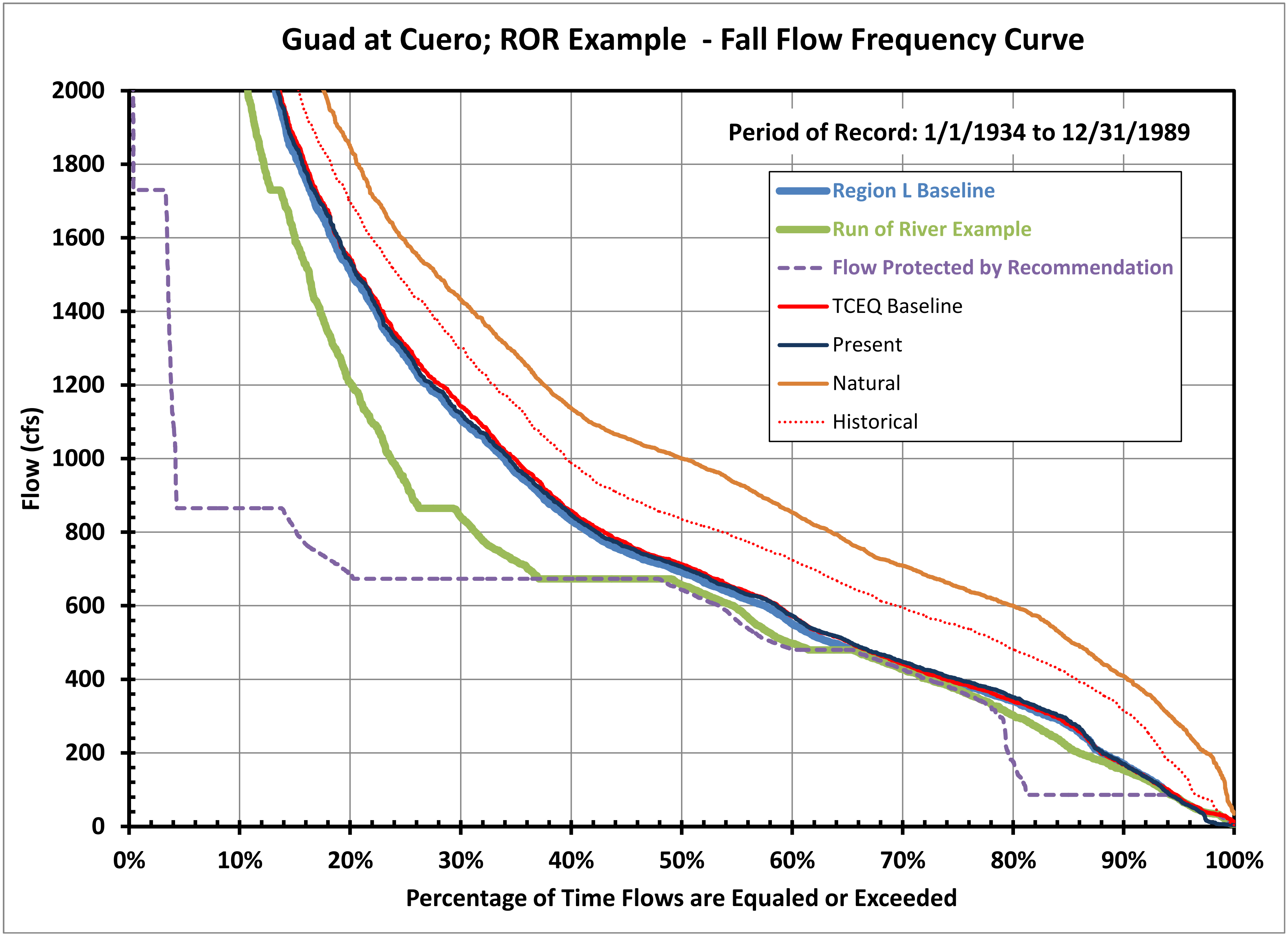

Guadalupe River at Cuero; ROR Example - Wet Year
Region L Baseline
Run of River Example
Flow Protected by Recommendation
Historical
Flow (cfs)
5000
4000
3000
2000
1000
0
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time


Guad at Cuero; ROR Example - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
Run of River Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


Guad at Cuero; ROR Example - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Run of River Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


Guad at Cuero; ROR Example - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Run of River Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


Guad at Cuero; ROR Example - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Run of River Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

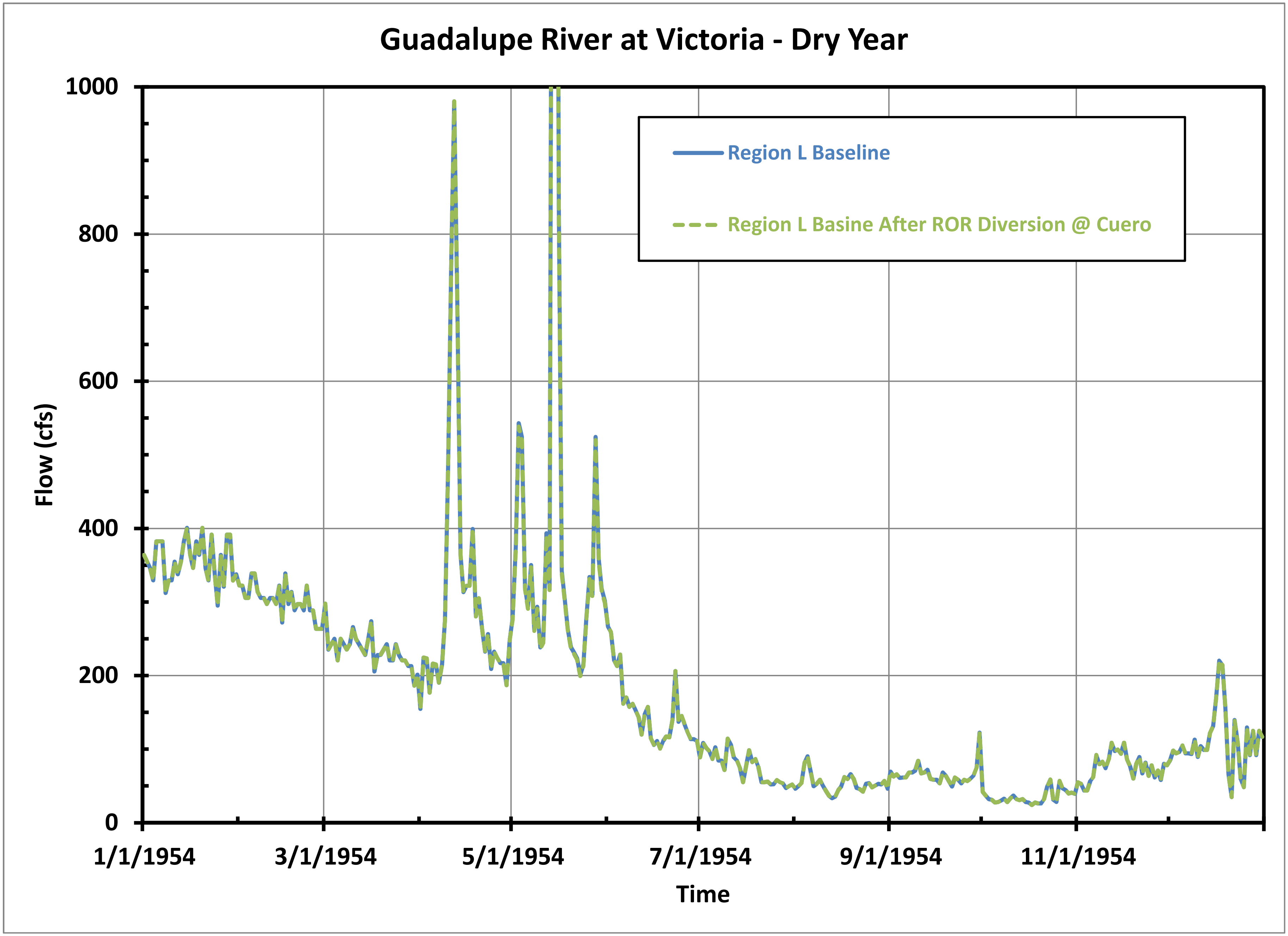

Guad at Cuero; ROR Example - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Run of River Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

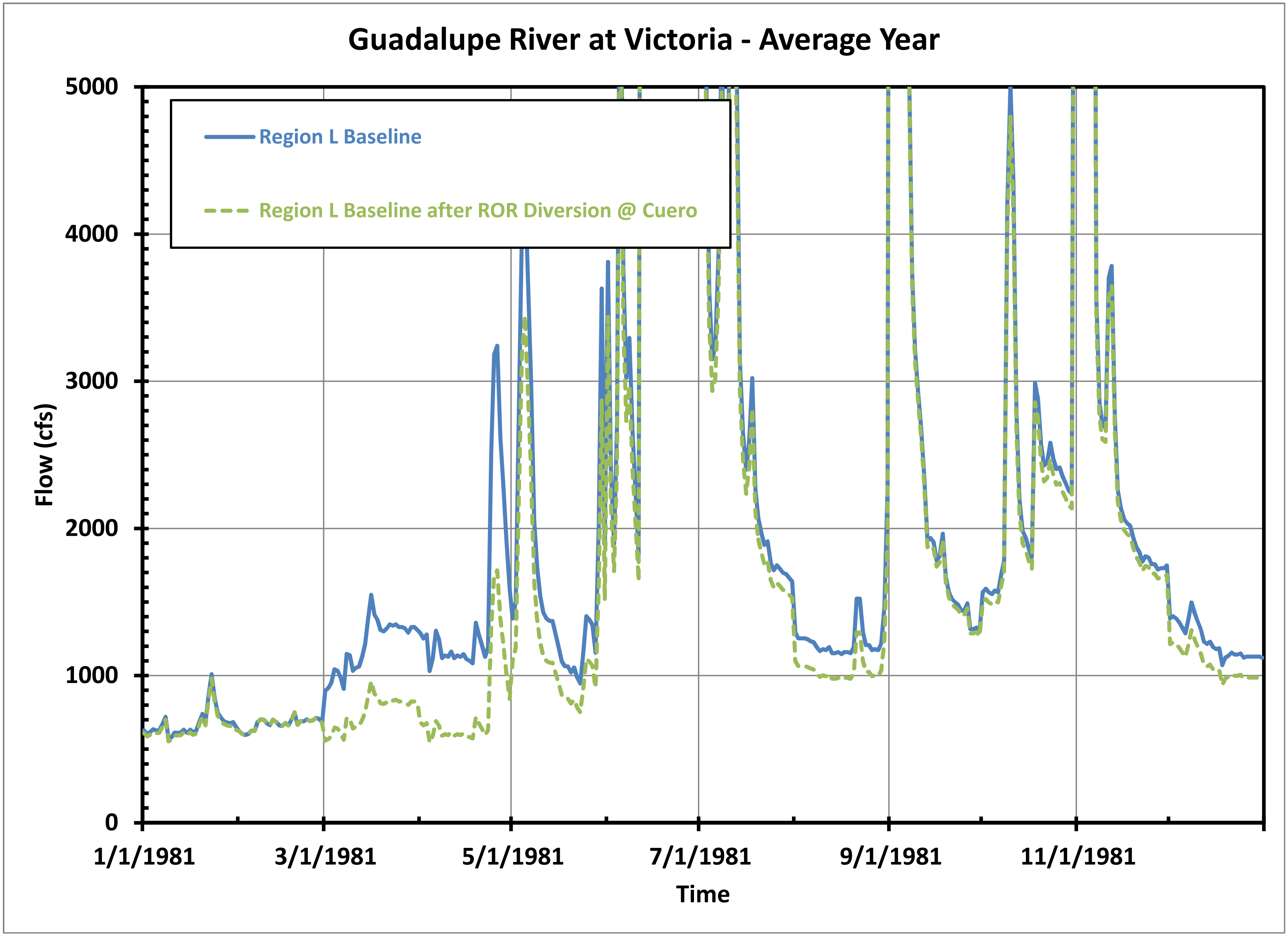
Month #	Month	Subsistence Flow			Dry Base Flow			Average Base Flow			Wet Base Flow		
		Flow Rec. (cfs)	Compliance Under Dry Hyd Cond	Compliance Under All Hyd Cond	Flow Rec. (cfs)	Compliance Under Dry Hyd Cond	Compliance Under All Hyd Cond	Flow Rec. (cfs)	Compliance Under Avg Hyd Cond	Compliance Under All Hyd Cond	Flow Rec. (cfs)	Compliance Under Wet Hyd Cond	Compliance Under All Hyd Cond
1	**Jan**	134	78%	94%	550	28%	65%	763	58%	48%	978	48%	32%
2	**Feb**	134	89%	97%	550	33%	69%	763	64%	52%	978	50%	35%
3	**Mar**	134	82%	95%	550	35%	66%	763	61%	47%	978	44%	34%
4	**Apr**	118	90%	97%	413	42%	76%	677	67%	54%	938	50%	37%
5	**May**	118	92%	98%	413	45%	79%	677	76%	65%	938	61%	50%
6	**June**	118	89%	96%	413	53%	79%	677	69%	61%	938	74%	45%
7	**Jul**	131	64%	89%	386	21%	69%	602	59%	48%	800	69%	35%
8	**Aug**	131	48%	84%	386	16%	59%	602	37%	34%	800	48%	22%
9	**Sept**	131	57%	88%	386	26%	65%	602	51%	44%	800	55%	31%
10	**Oct**	86	68%	92%	480	17%	62%	673	52%	47%	865	60%	28%
11	**Nov**	86	78%	94%	480	22%	65%	673	53%	48%	865	61%	32%
12	**Dec**	86	85%	96%	480	33%	70%	673	58%	52%	865	50%	33%
	Annual Avg:		77%	93%		31%	69%		59%	50%		56%	34%

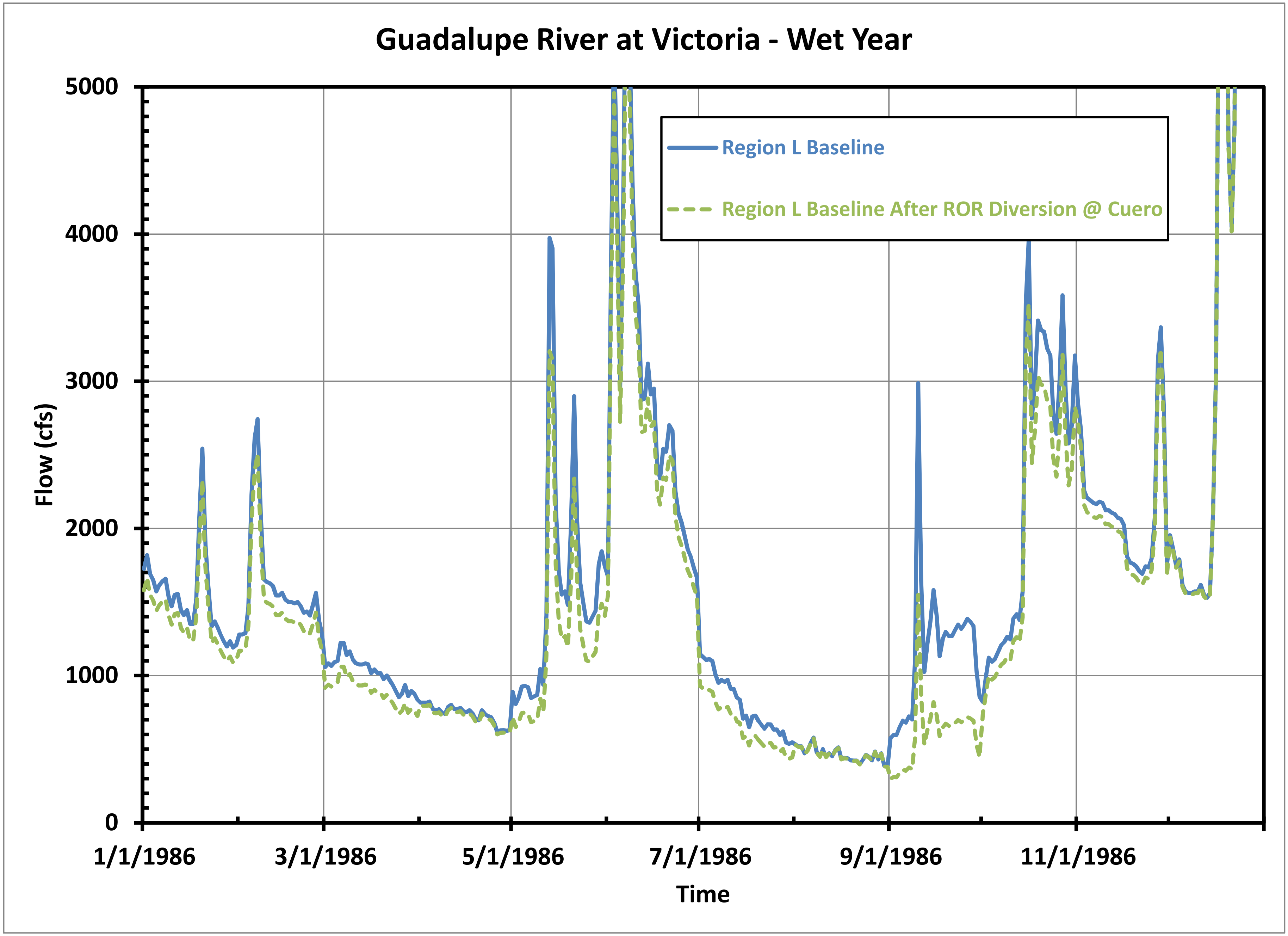
		Dry High Flow Pulse		Average High Flow Pulse		Wet High Flow Pulse	
Season #	**Season**	**HFP Rec. (#/sea)**	**Compliance Under Dry Hyd Cond**	**HFP Rec. (#/sea)**	**Compliance Under Avg Hyd Cond**	**HFP Rec. (#/sea)**	**Compliance Under Wet Hyd Cond**
1	**Winter**	1	67%	2	57%	1	38%
2	**Spring**	1	53%	2	72%	1	67%
3	**Summer**	1	56%	2	59%	1	73%
4	**Fall**	1	43%	2	63%	1	40%

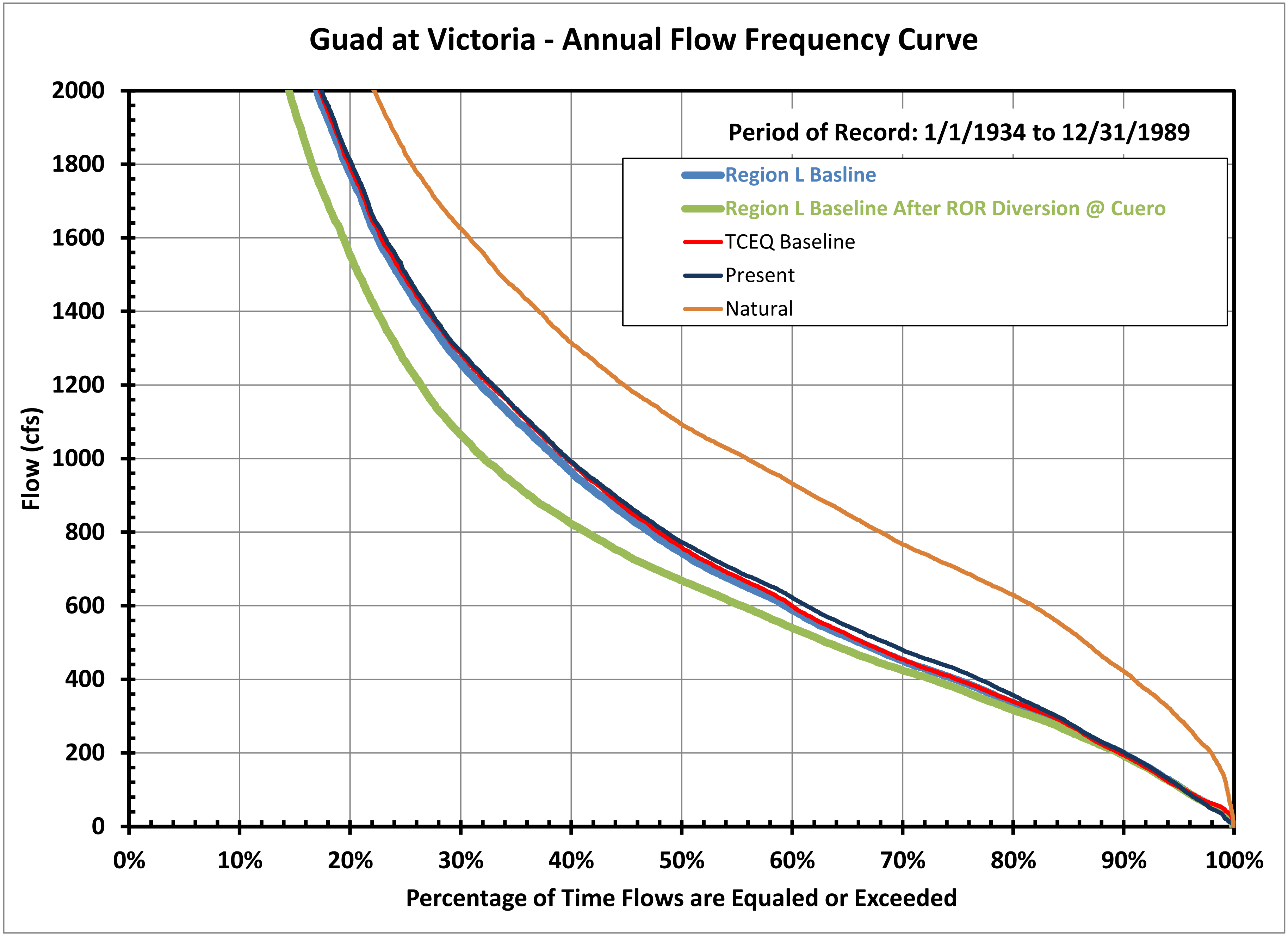
This table shows the percent of seasons meeting the requirement under the given hydrologic condition

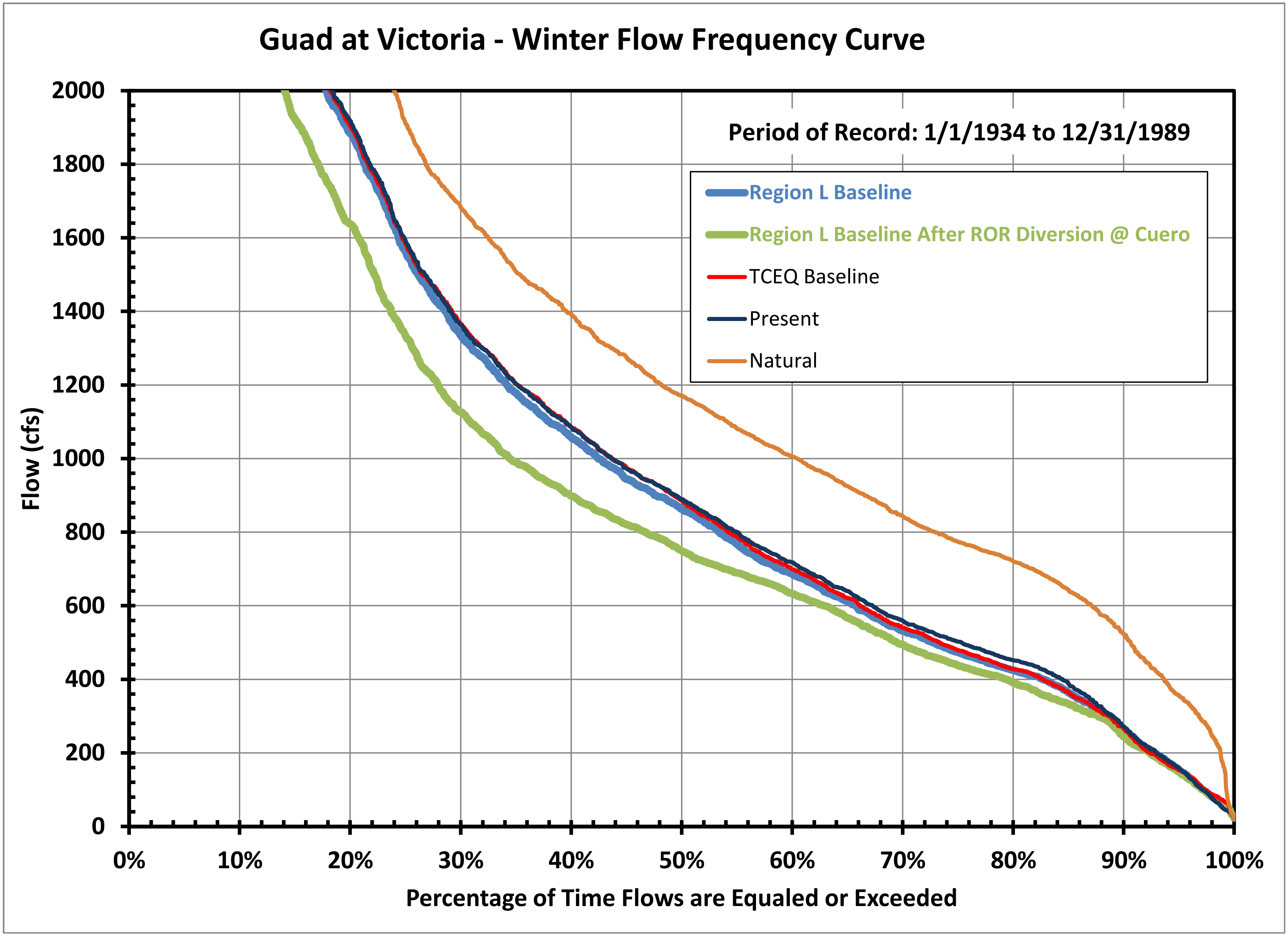
Appendix H - Guadalupe River at Victoria

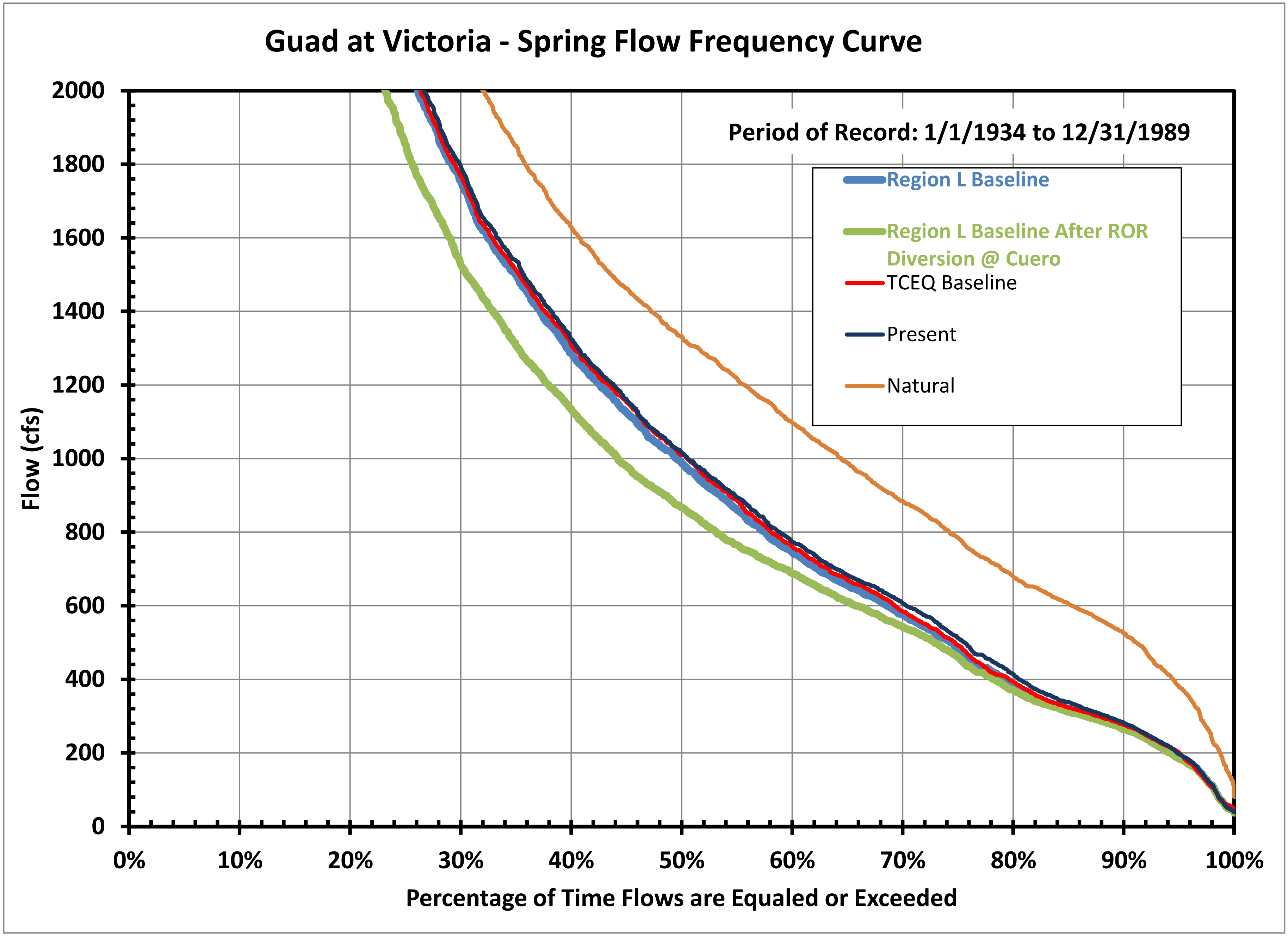

Guadalupe River at Victoria - Dry Year
Region L Baseline
Region L Basine After ROR Diversion @ Cuero
Flow (cfs)
1000
800
600
400
200
0
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time

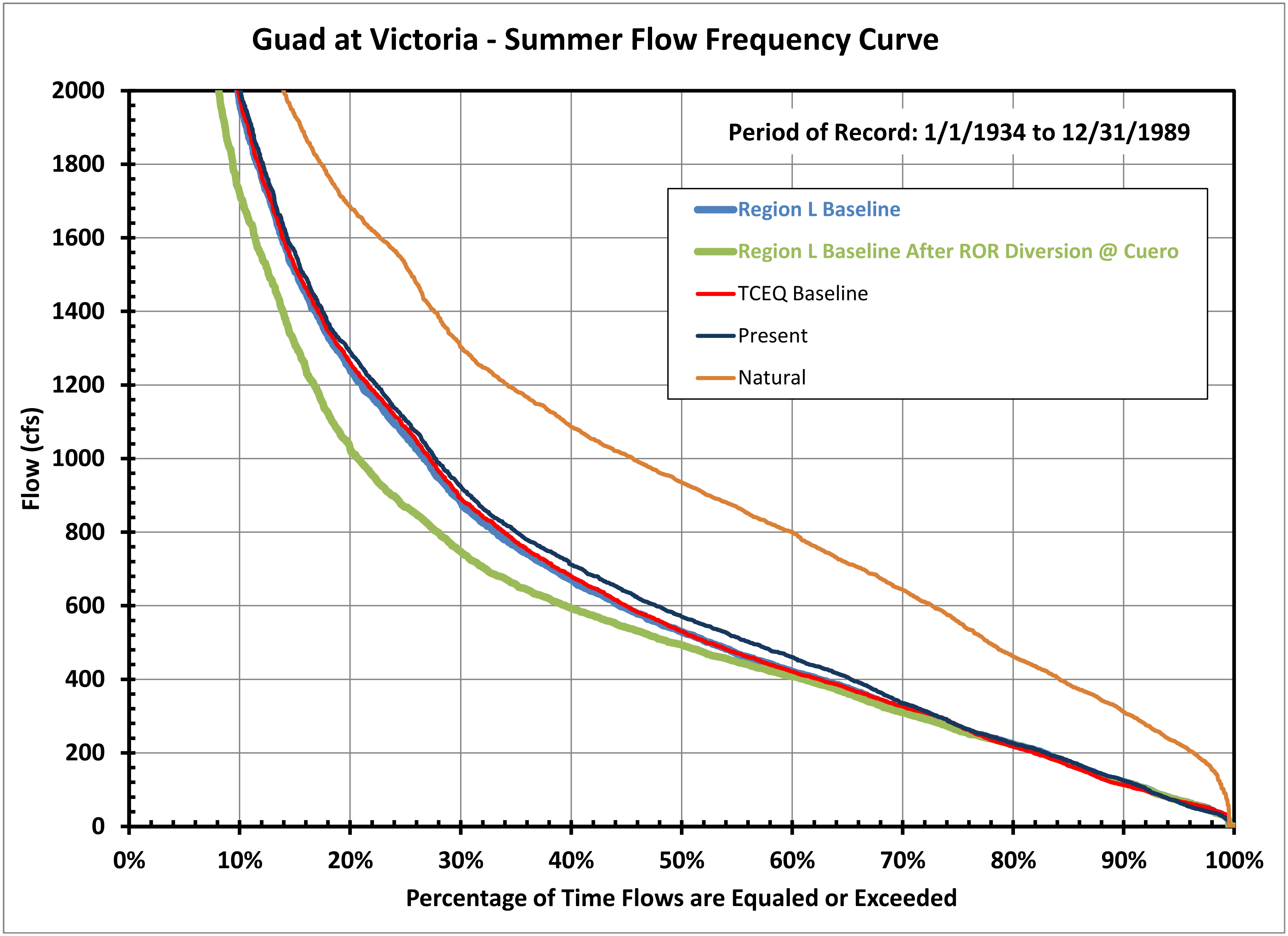

Guadalupe River at Victoria - Average Year
Region L Baseline
Region L Baseline after ROR Diversion @ Cuero
Flow (cfs)
5000
4000
3000
2000
1000
0
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

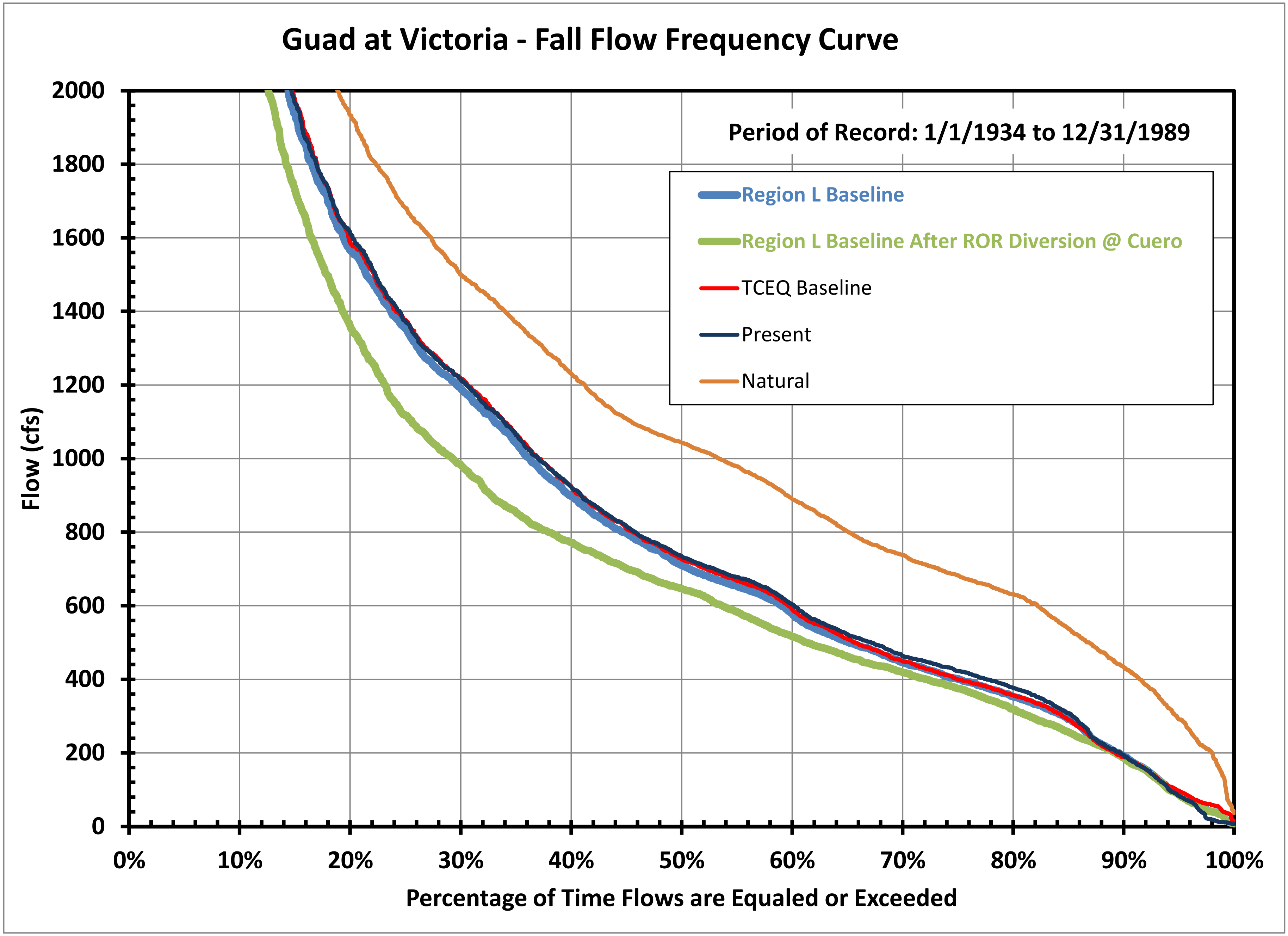

Guadalupe River at Victoria - Wet Year
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
Flow (cfs)
5000
4000
3000
2000
1000
0
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time


Guad at Victoria - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
Region L Baseline After ROR Diversion @ Cuero
TCEQ Baseline
Present
Natural
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

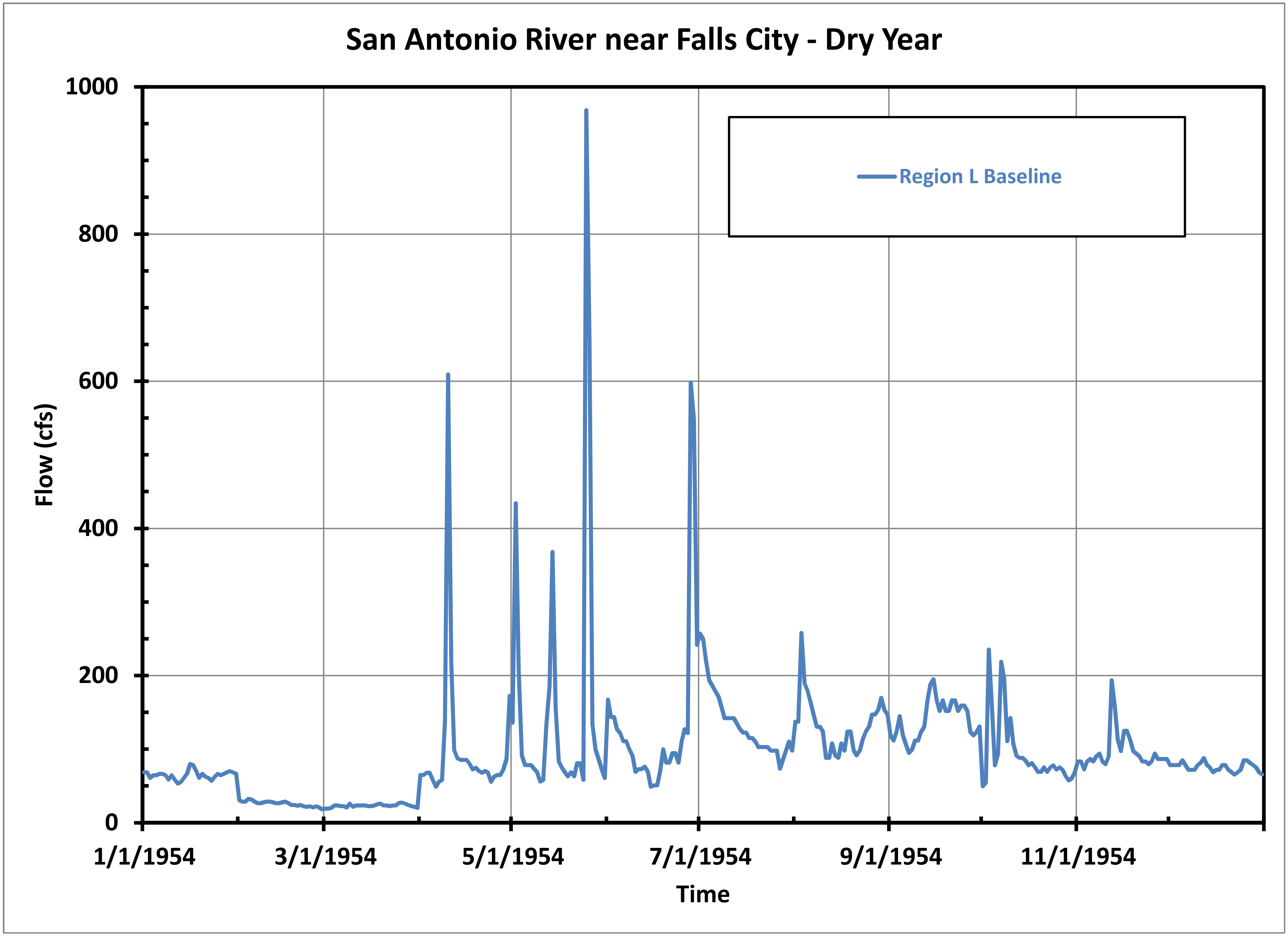

Guad at Victoria - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
TCEQ Baseline
Present
Natural
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

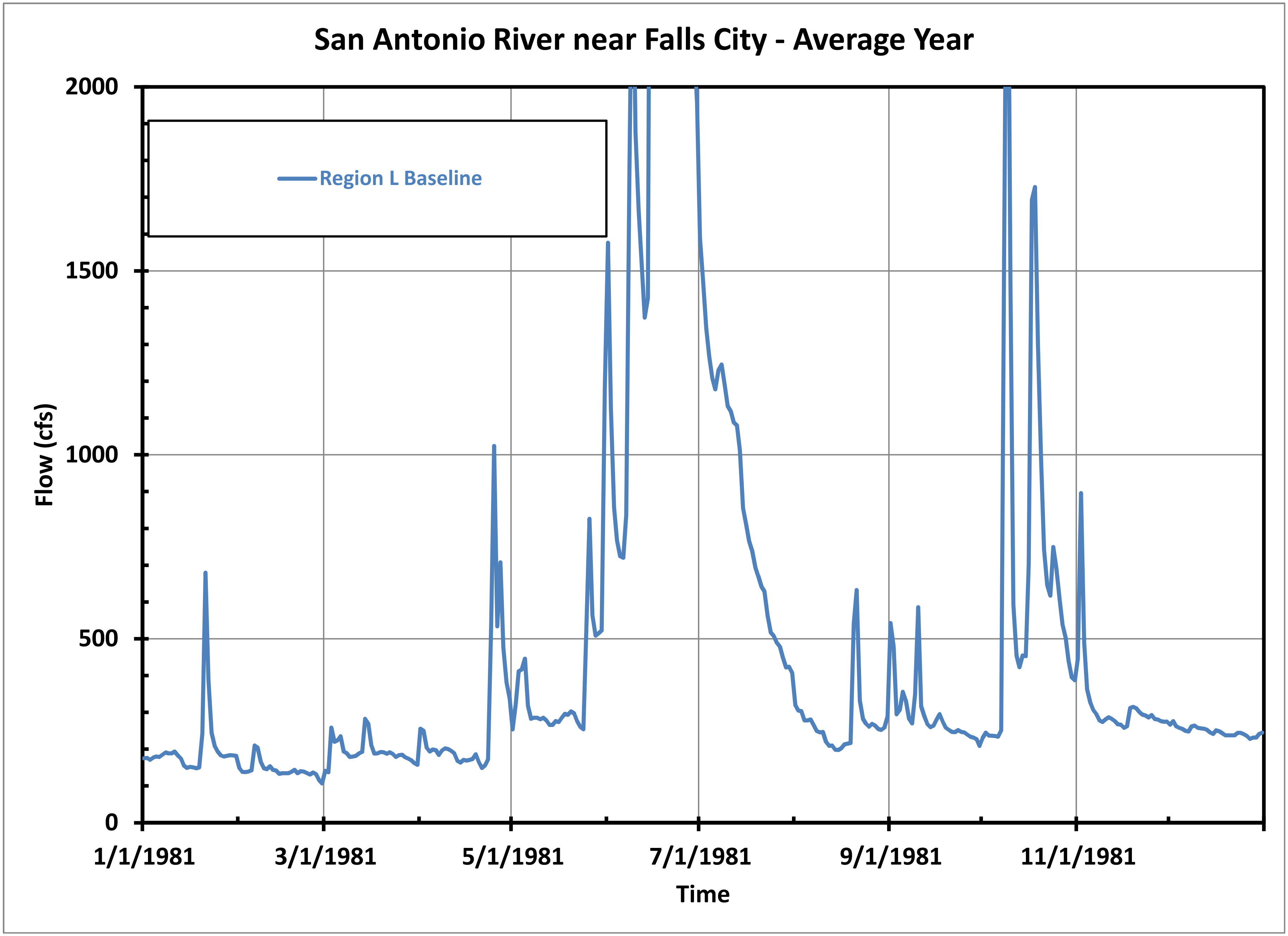

Guad at Victoria - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
TCEQ Baseline
Present
Natural
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

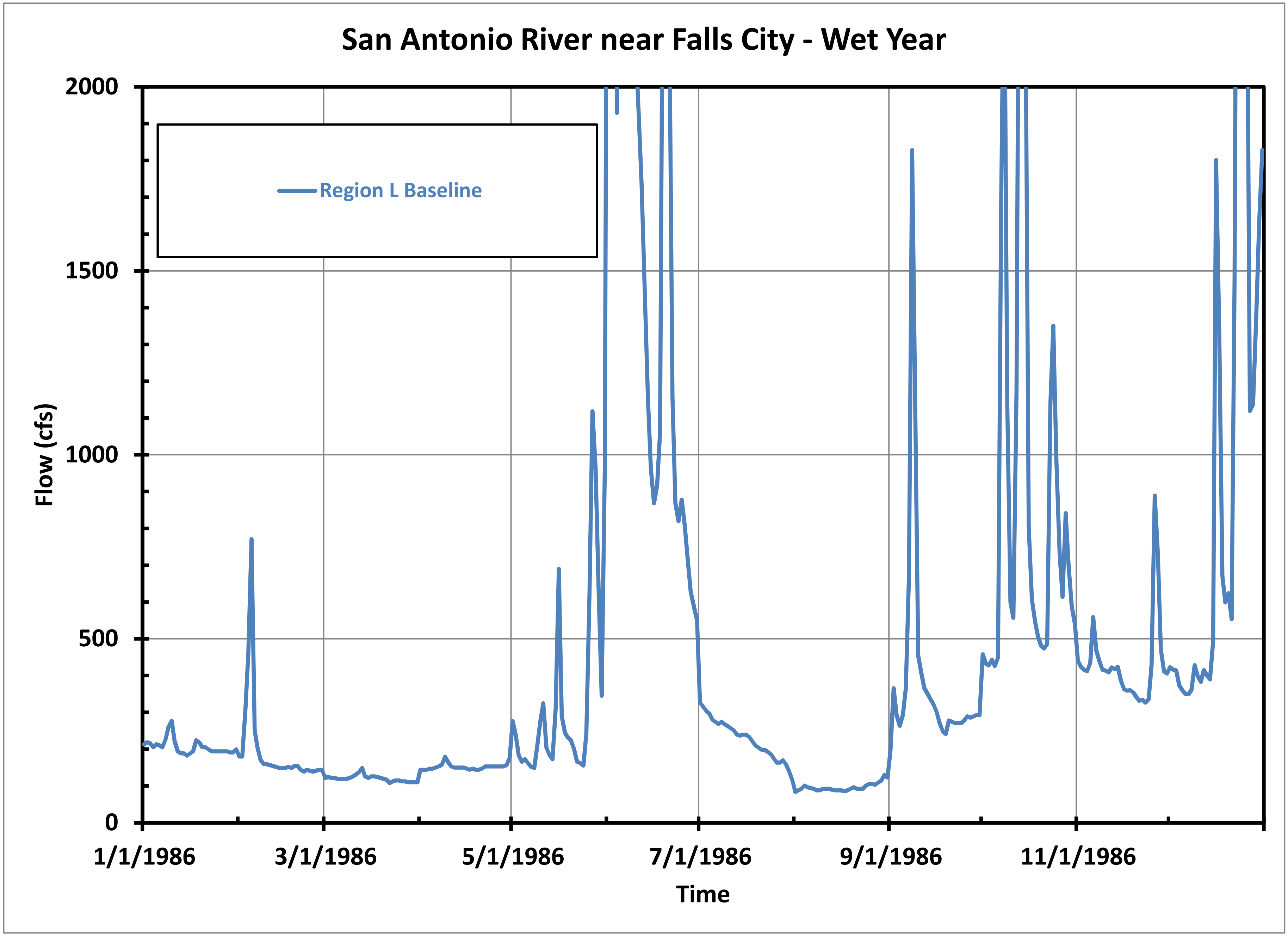

Guad at Victoria - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
TCEQ Baseline
Present
Natural
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

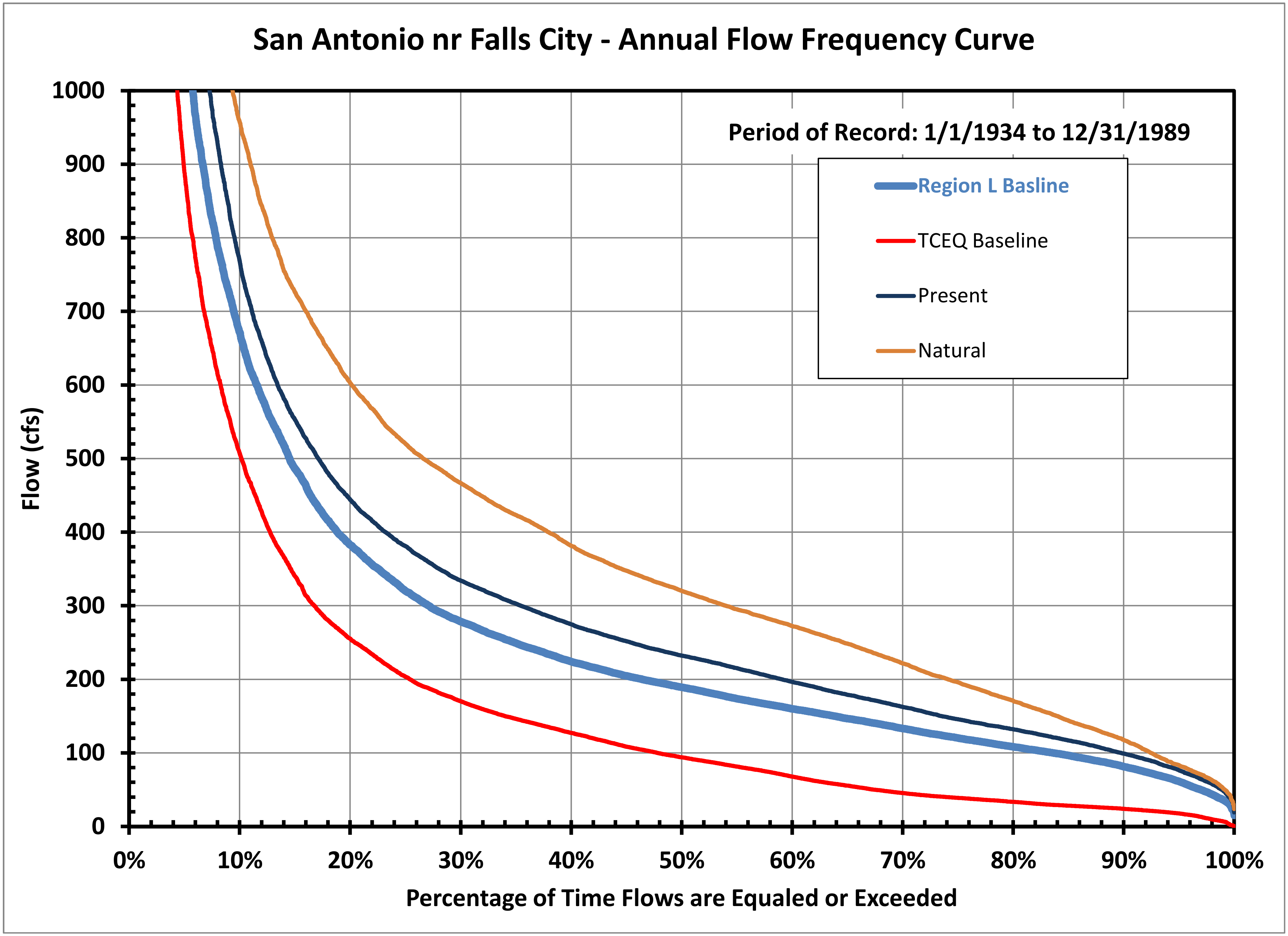

Guad at Victoria - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
TCEQ Baseline
Present
Natural
Flow (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

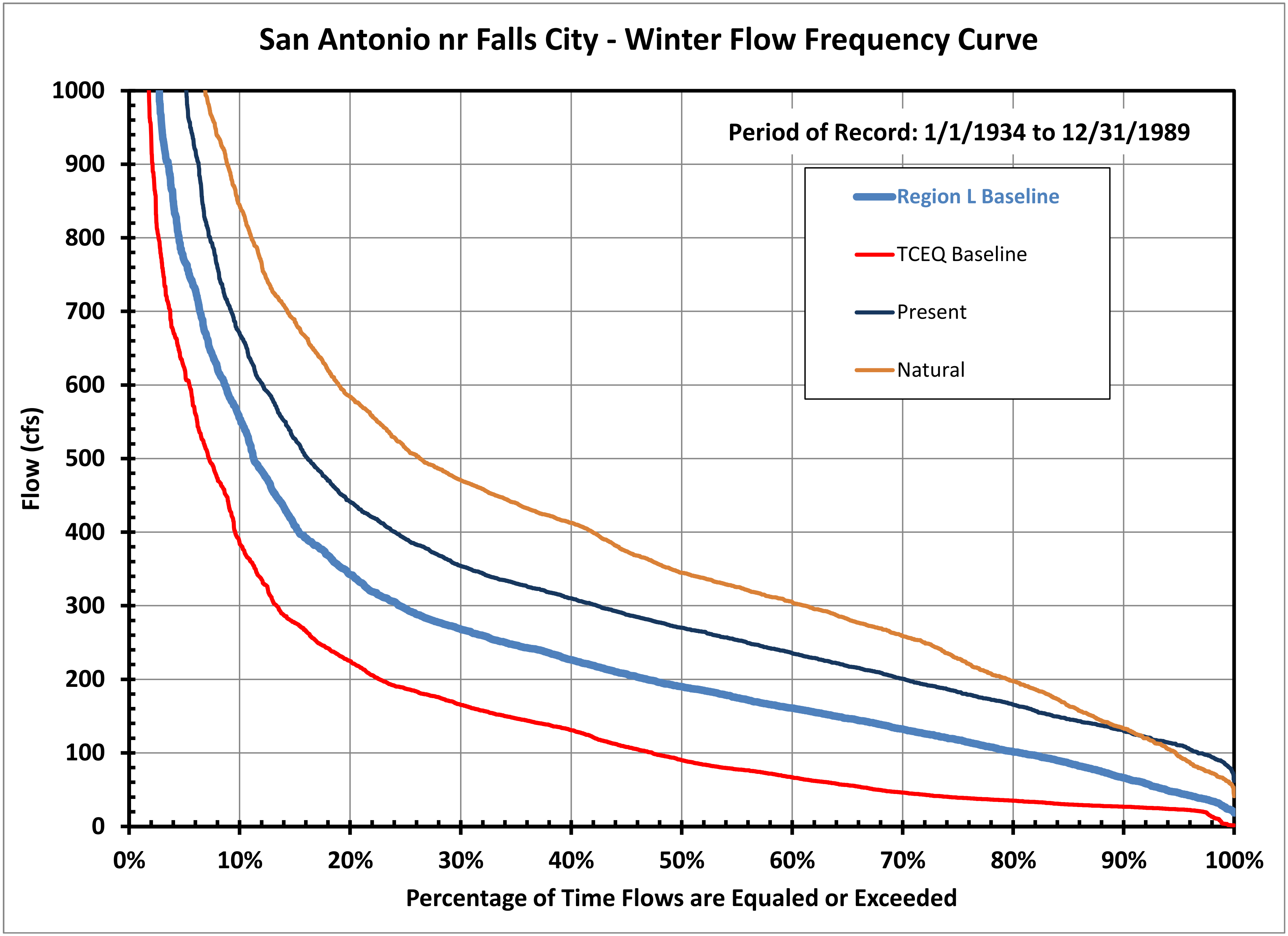
Appendix I - San Antonio River near Falls City

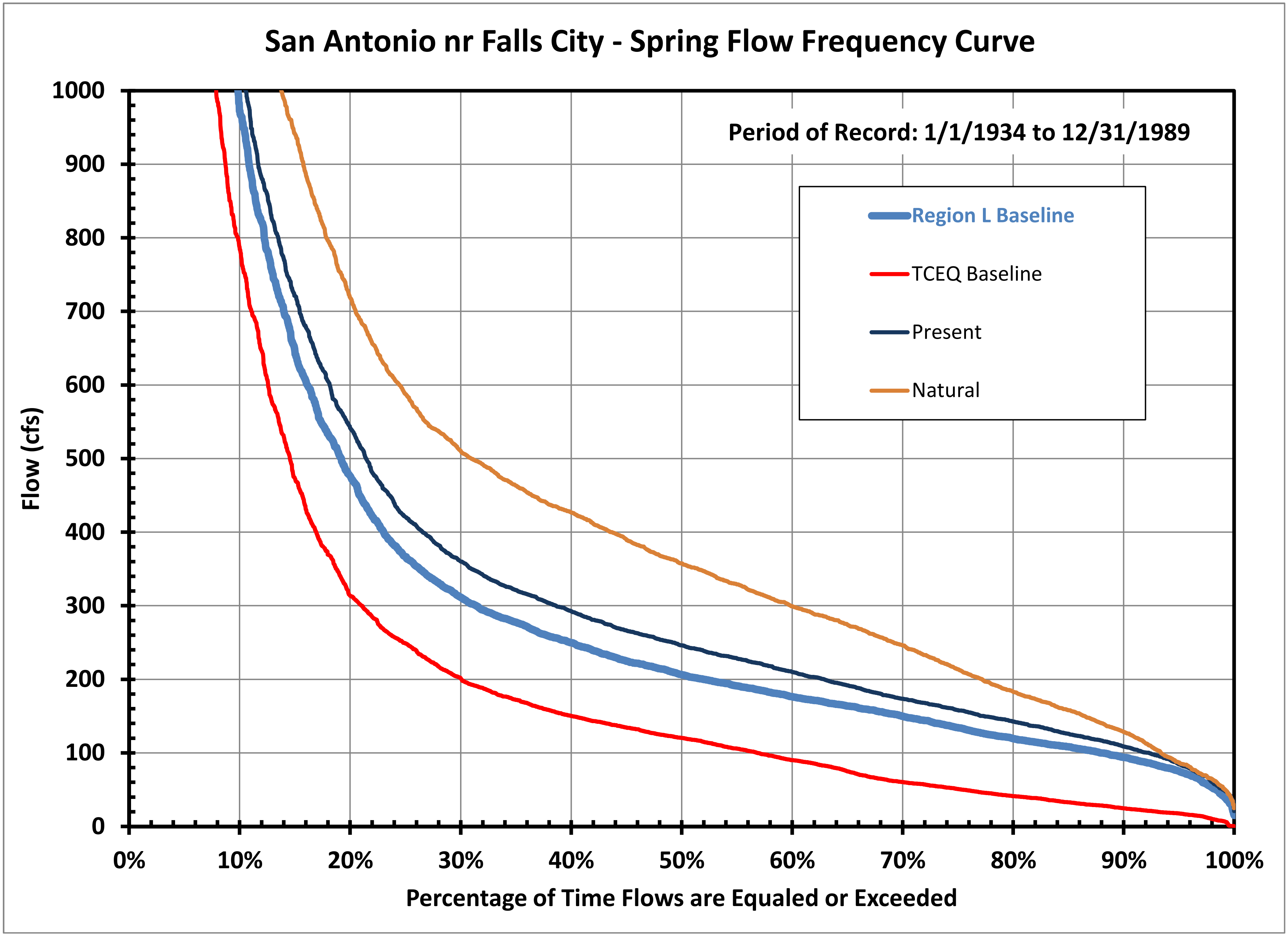

San Antonio River near Falls City - Dry Year
Region L Baseline
Flow (cfs)
1000
800
600
400
200
0
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time

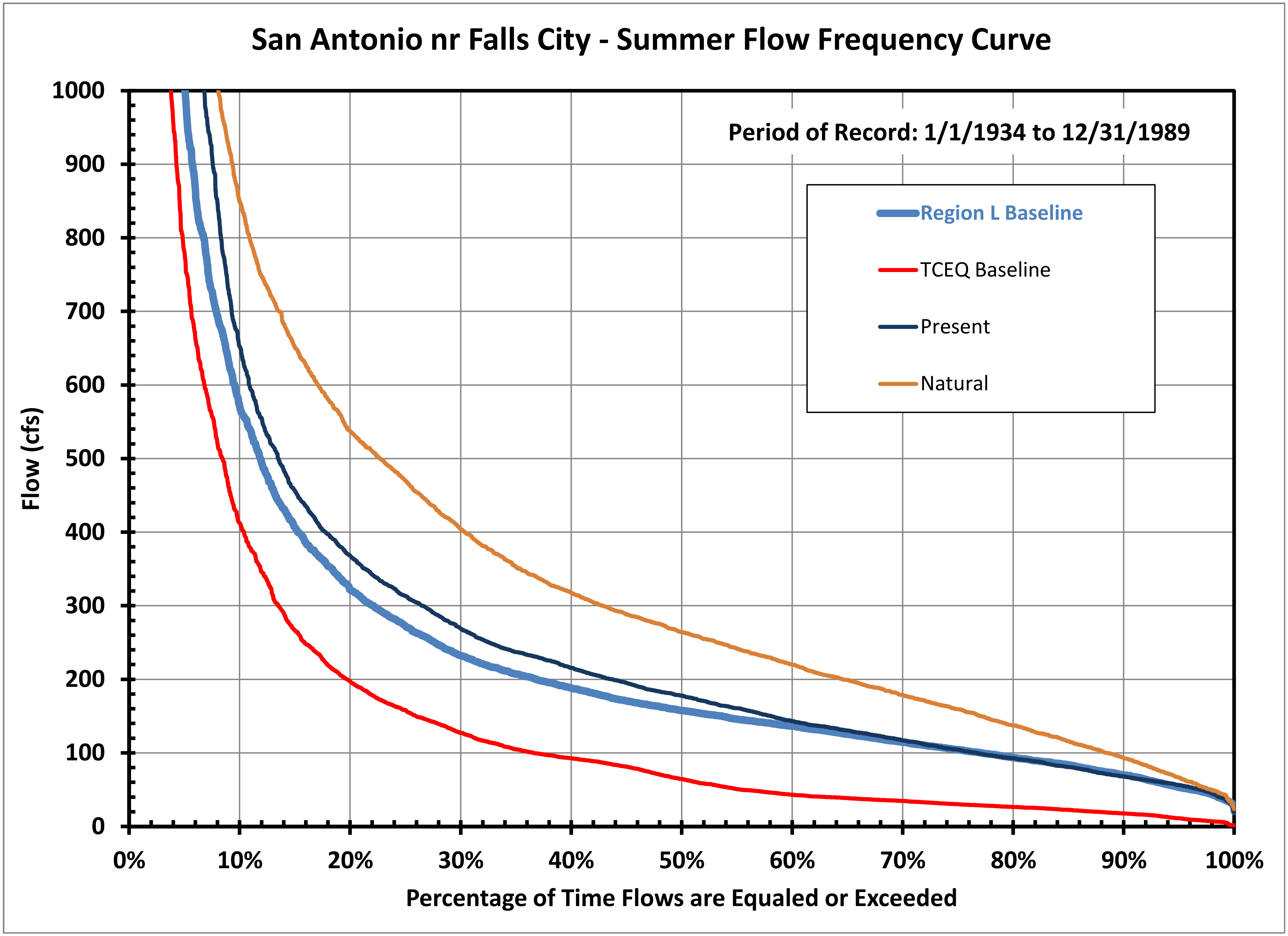

San Antonio River near Falls City - Average Year
Region L Baseline
Flow (cfs)
2000
1500
1000
500
0
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

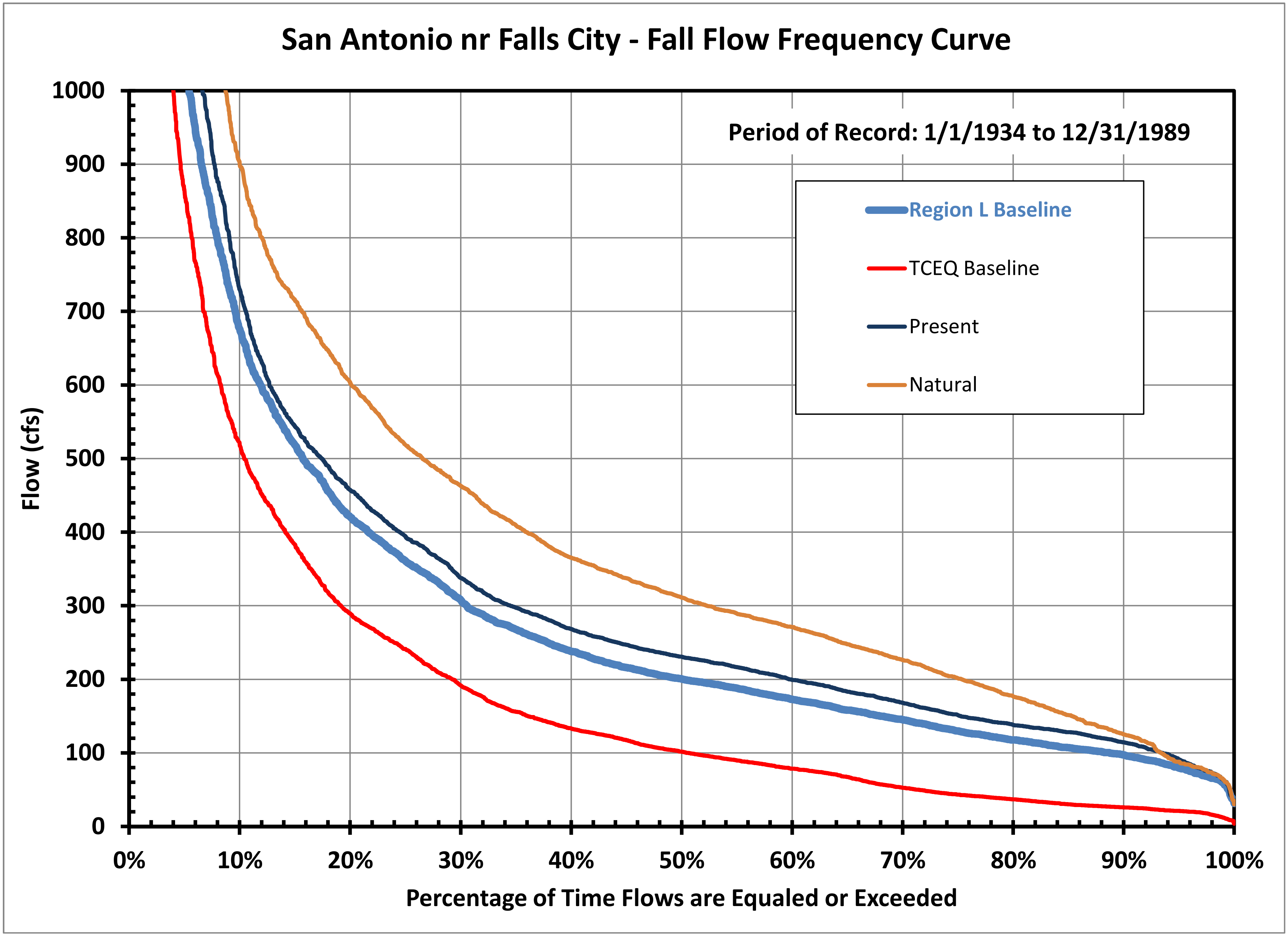

San Antonio River near Falls City - Wet Year
Region L Baseline
Flow (cfs)
2000
1500
1000
500
0
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time


San Antonio nr Falls City - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

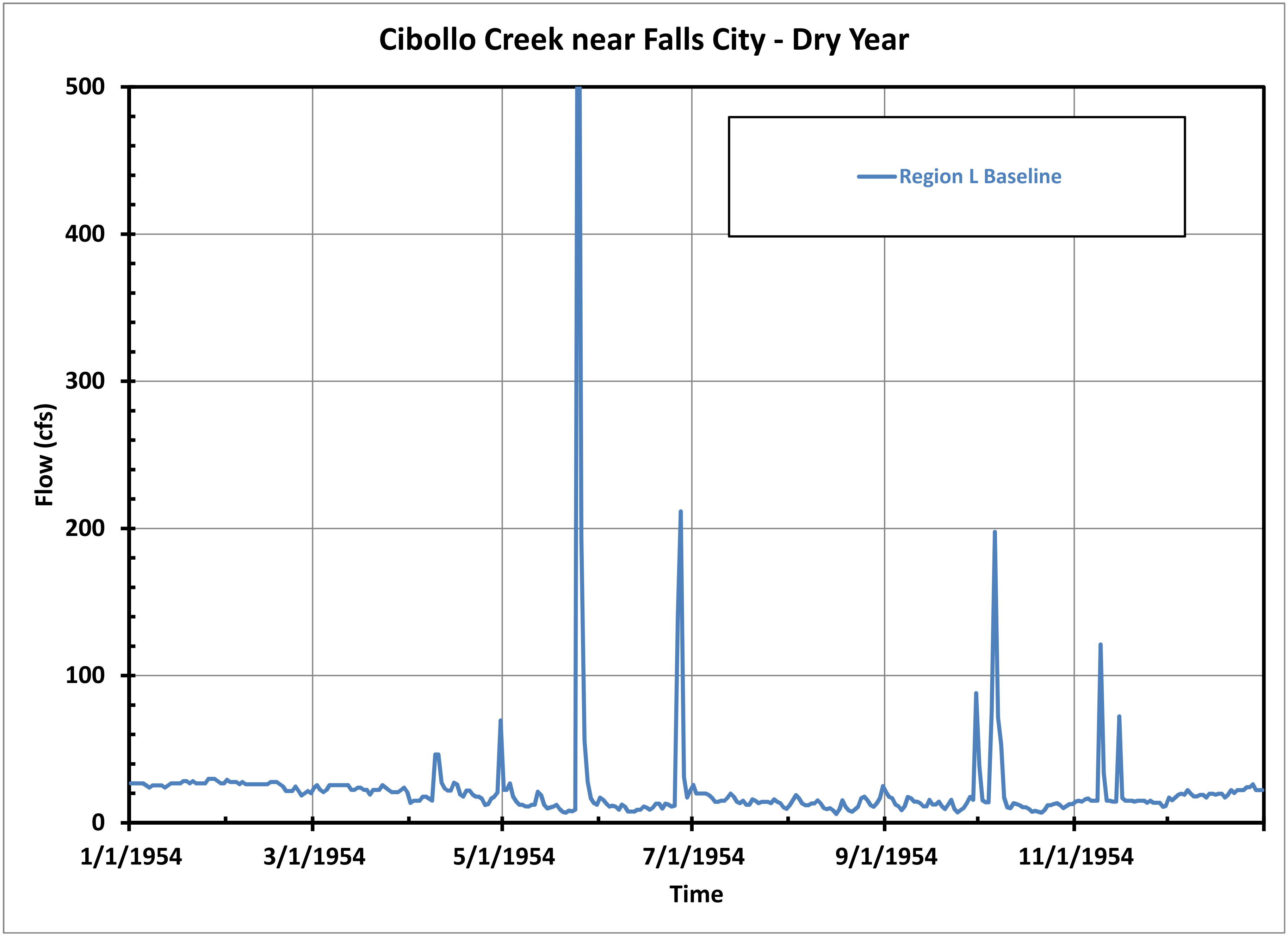

San Antonio nr Falls City - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

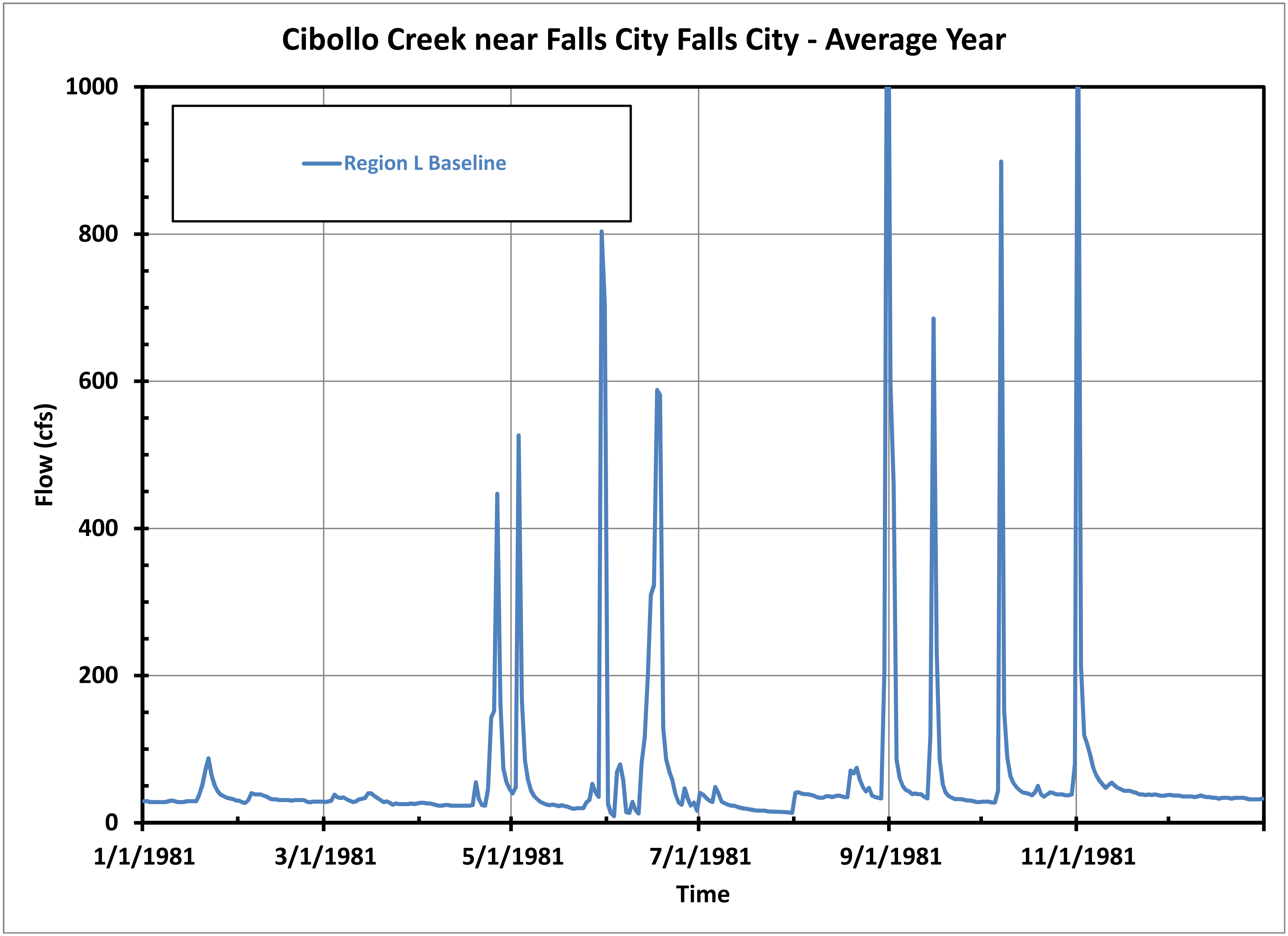

San Antonio nr Falls City - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

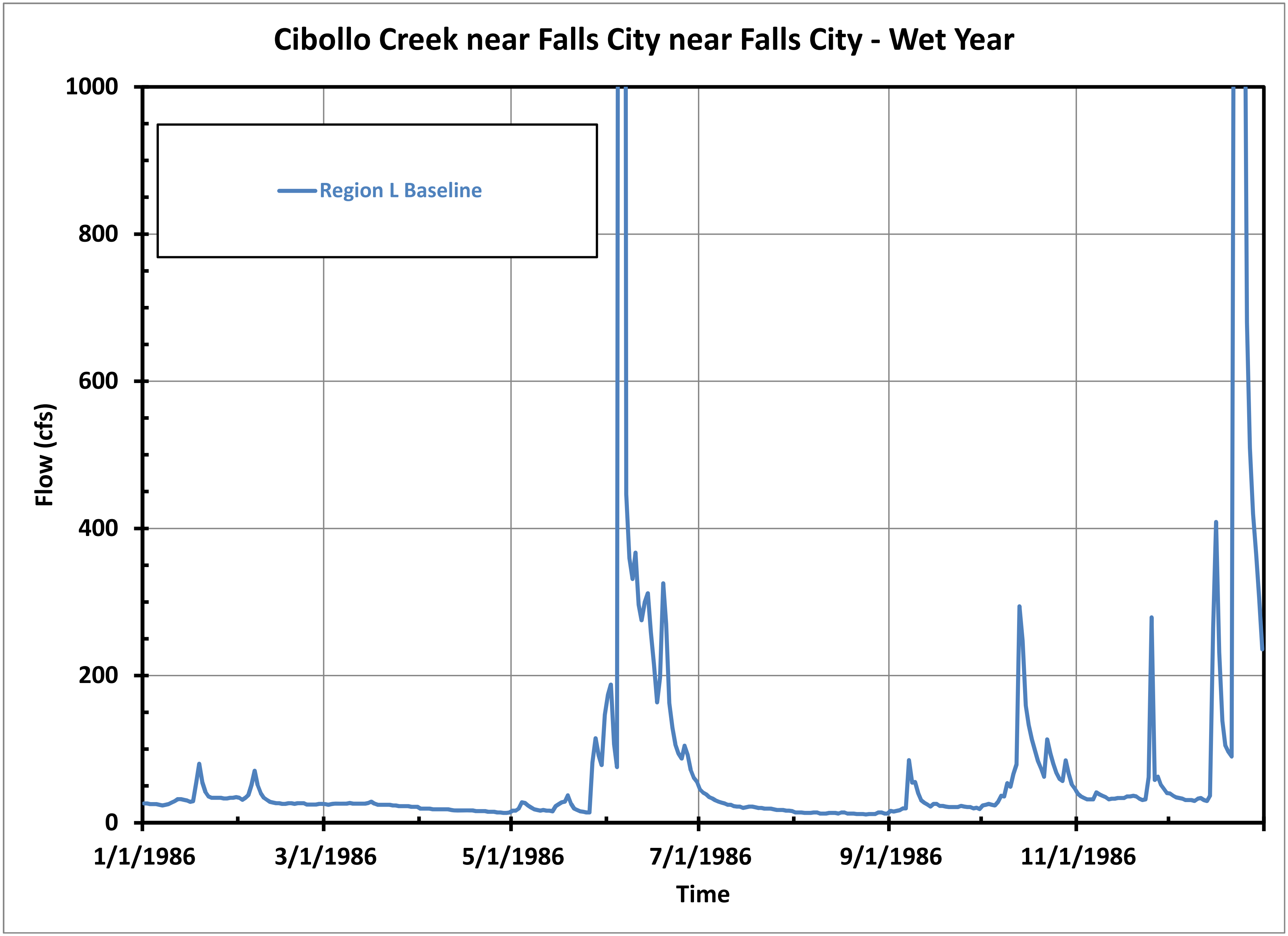

San Antonio nr Falls City - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

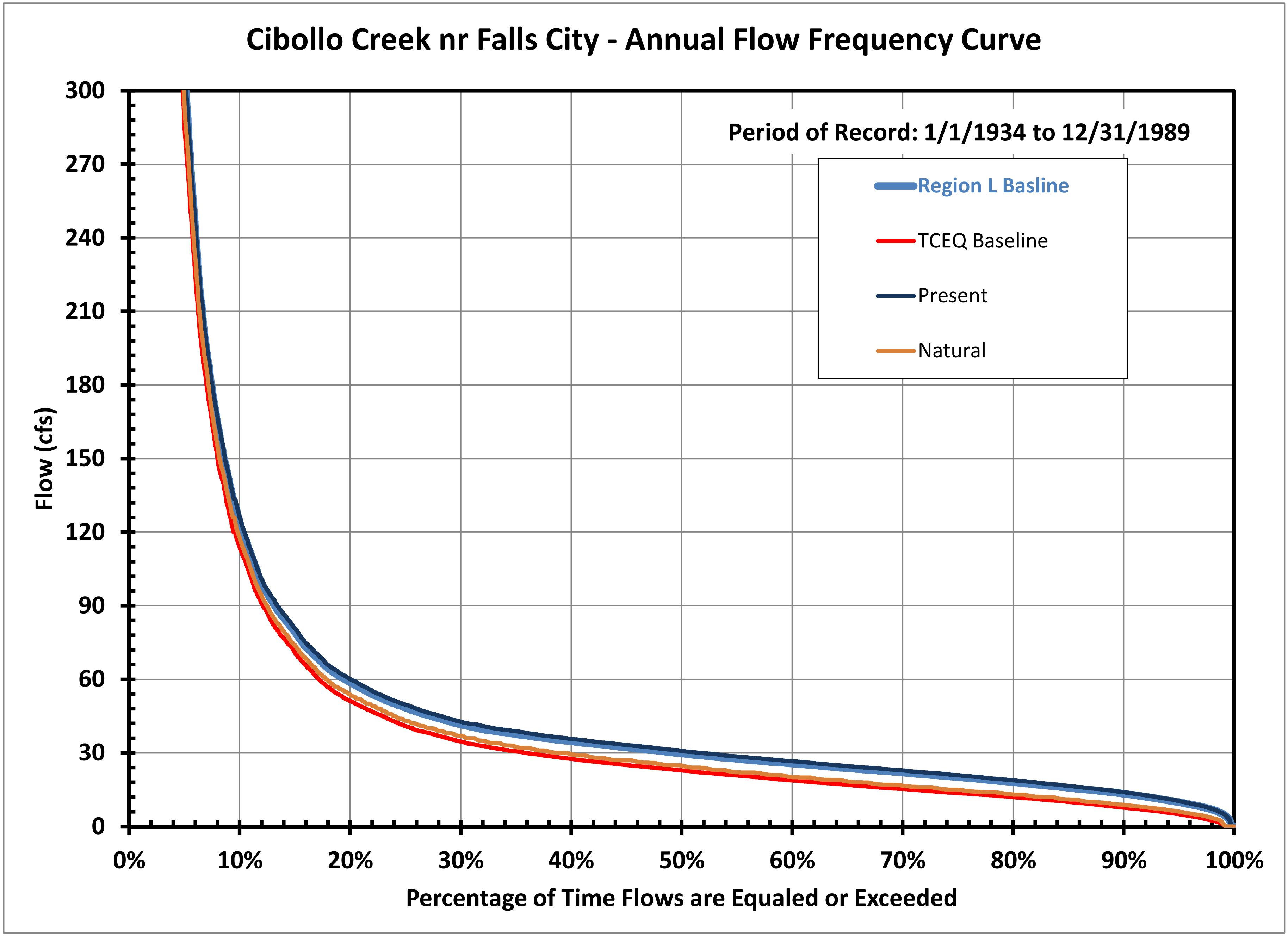

San Antonio nr Falls City - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

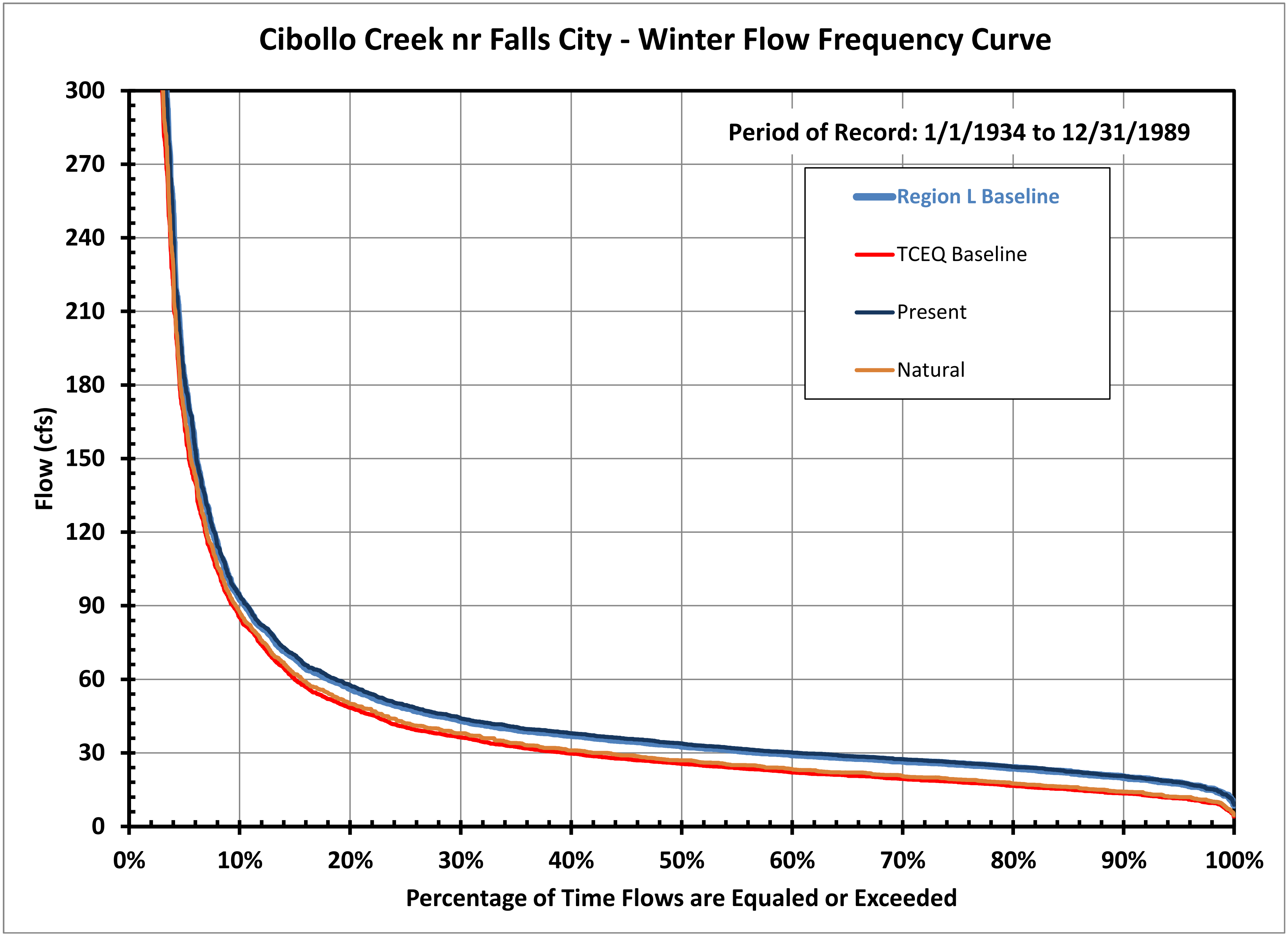
Appendix J - Cibollo Creek near Falls City

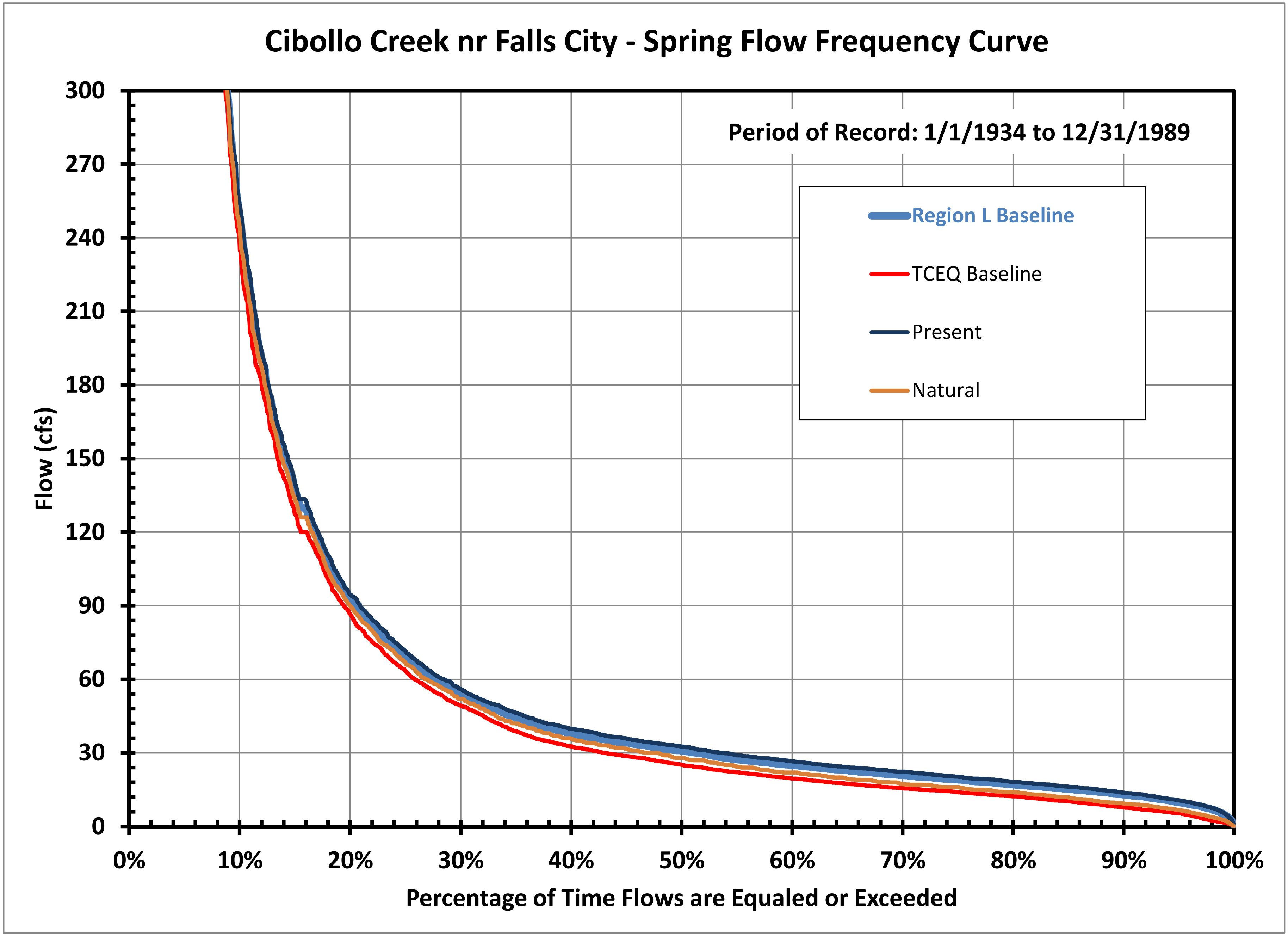

Cibollo Creek near Falls City - Dry Year
Region L Baseline
Flow (cfs)
500
400
300
200
100
0
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time

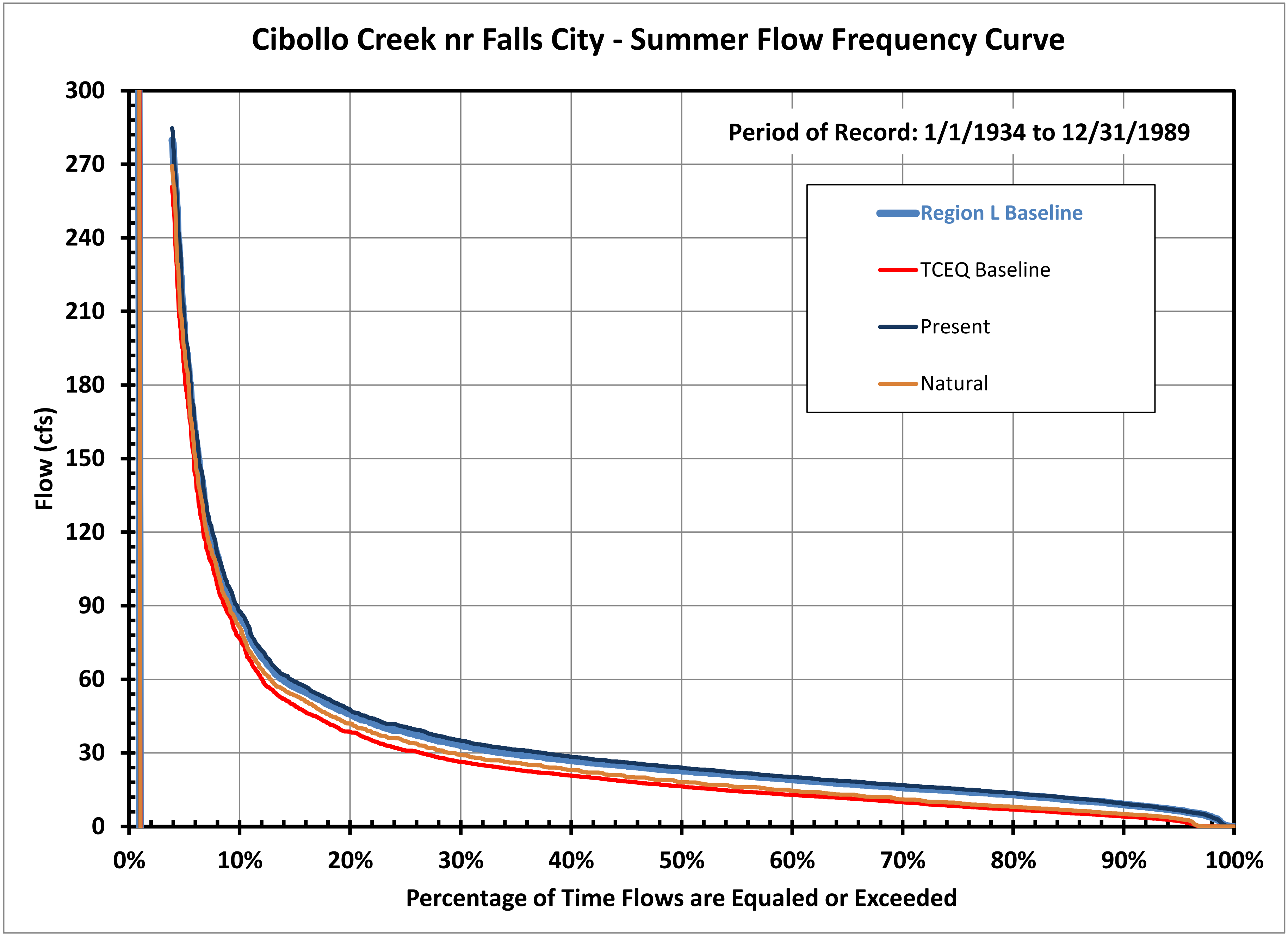

Cibollo Creek near Falls City Falls City - Average Year
Region L Baseline
Flow (cfs)
1000
800
600
400
200
0
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

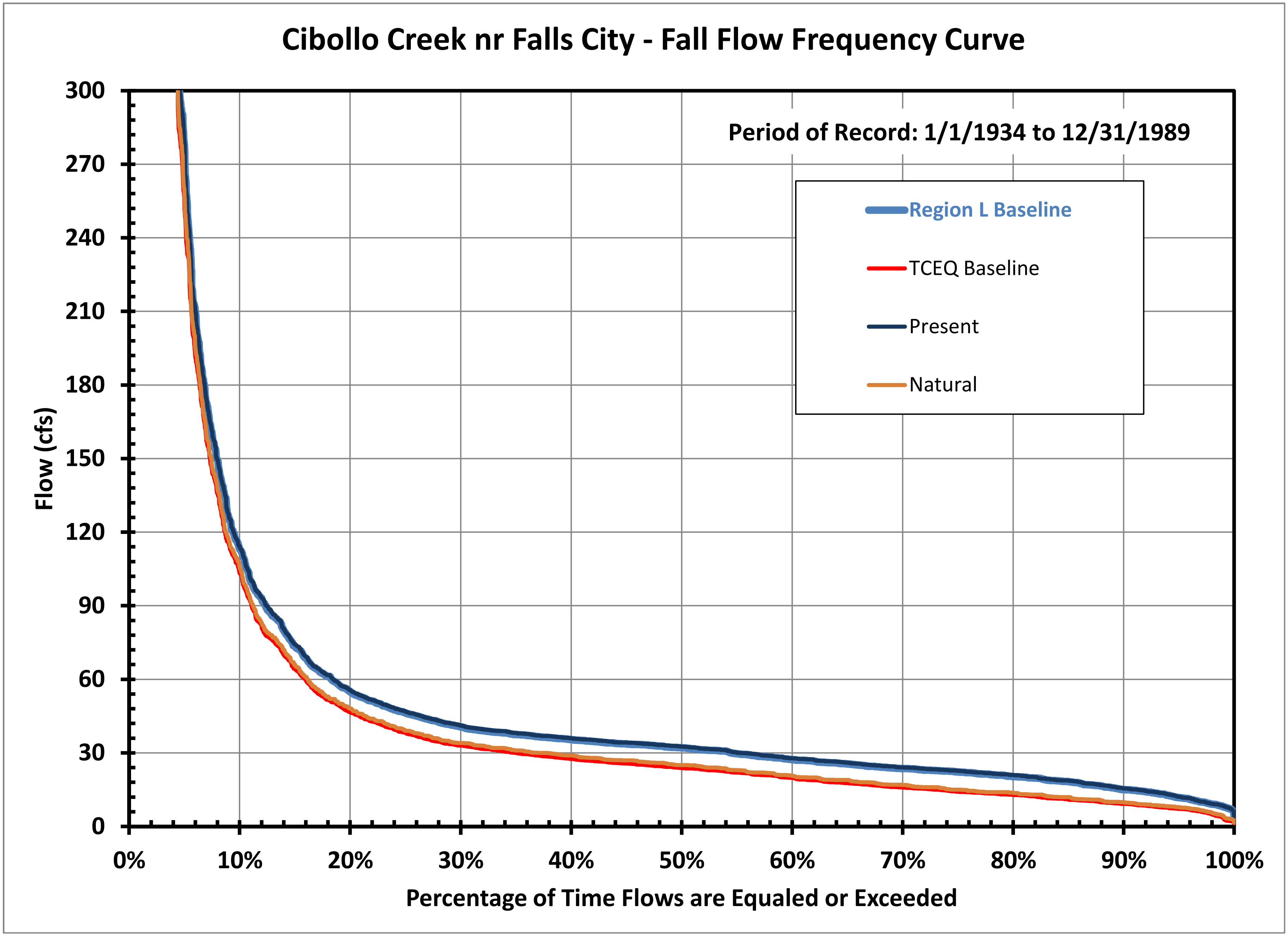

Cibollo Creek near Falls City near Falls City - Wet Year
Region L Baseline
Flow (cfs)
0
200
400
600
800
1000
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time


Cibollo Creek nr Falls City - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
TCEQ Baseline
Present
Natural
Flow (cfs)
300
270
240
210
180
150
120
90
60
30
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

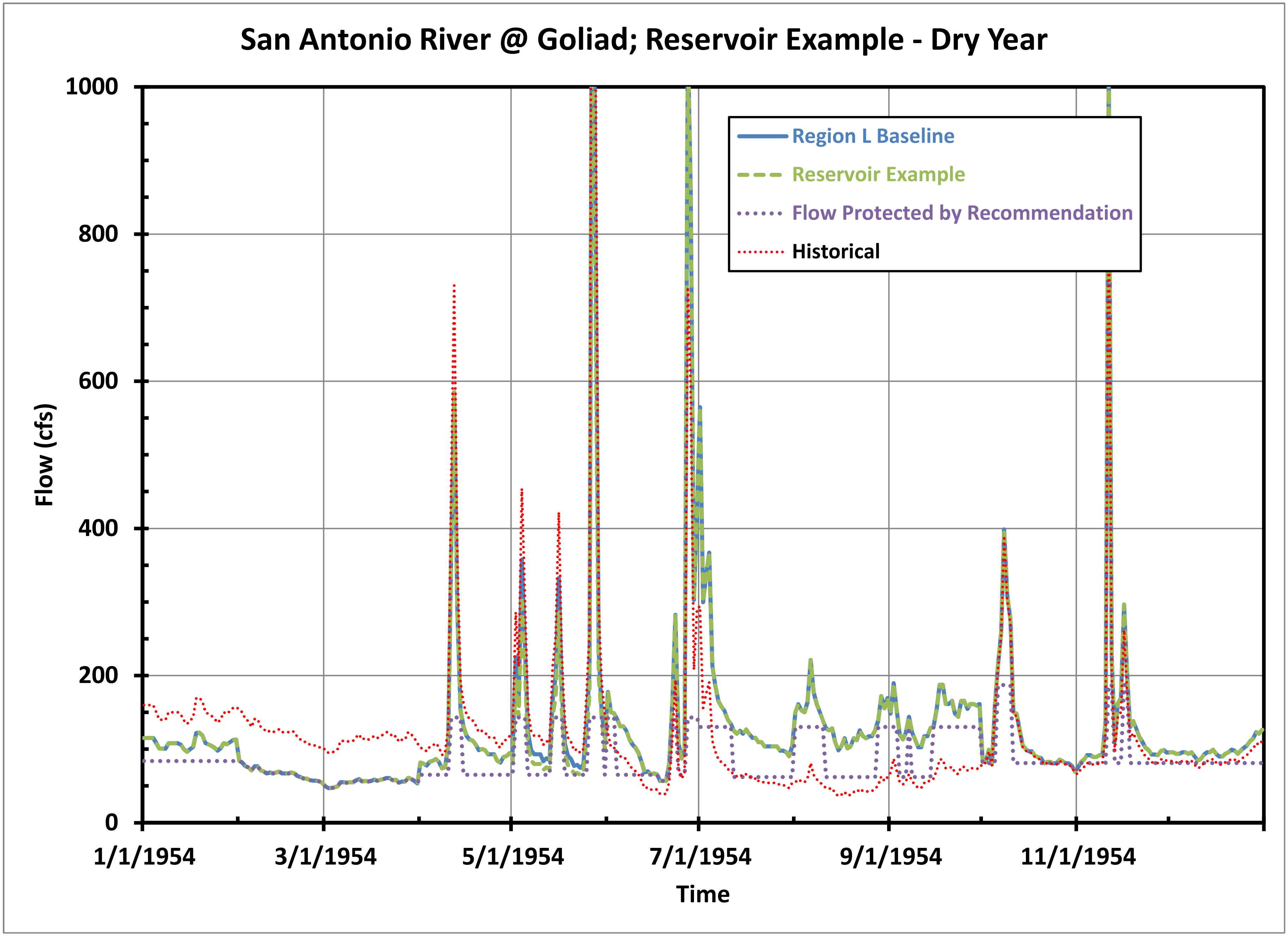

Cibollo Creek nr Falls City - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
300
270
240
210
180
150
120
90
60
30
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

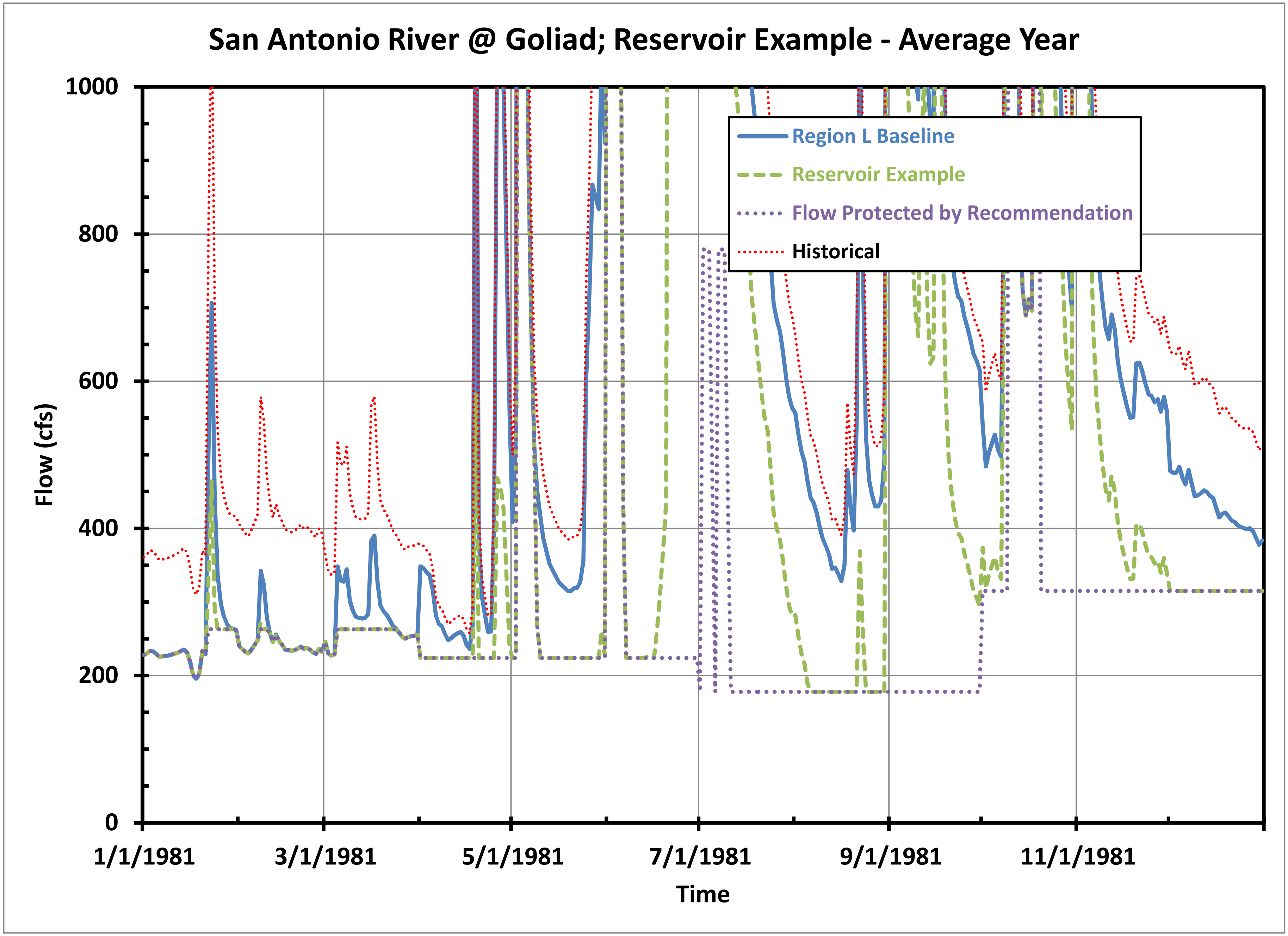

Cibollo Creek nr Falls City - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
300
270
240
210
180
150
120
90
60
30
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

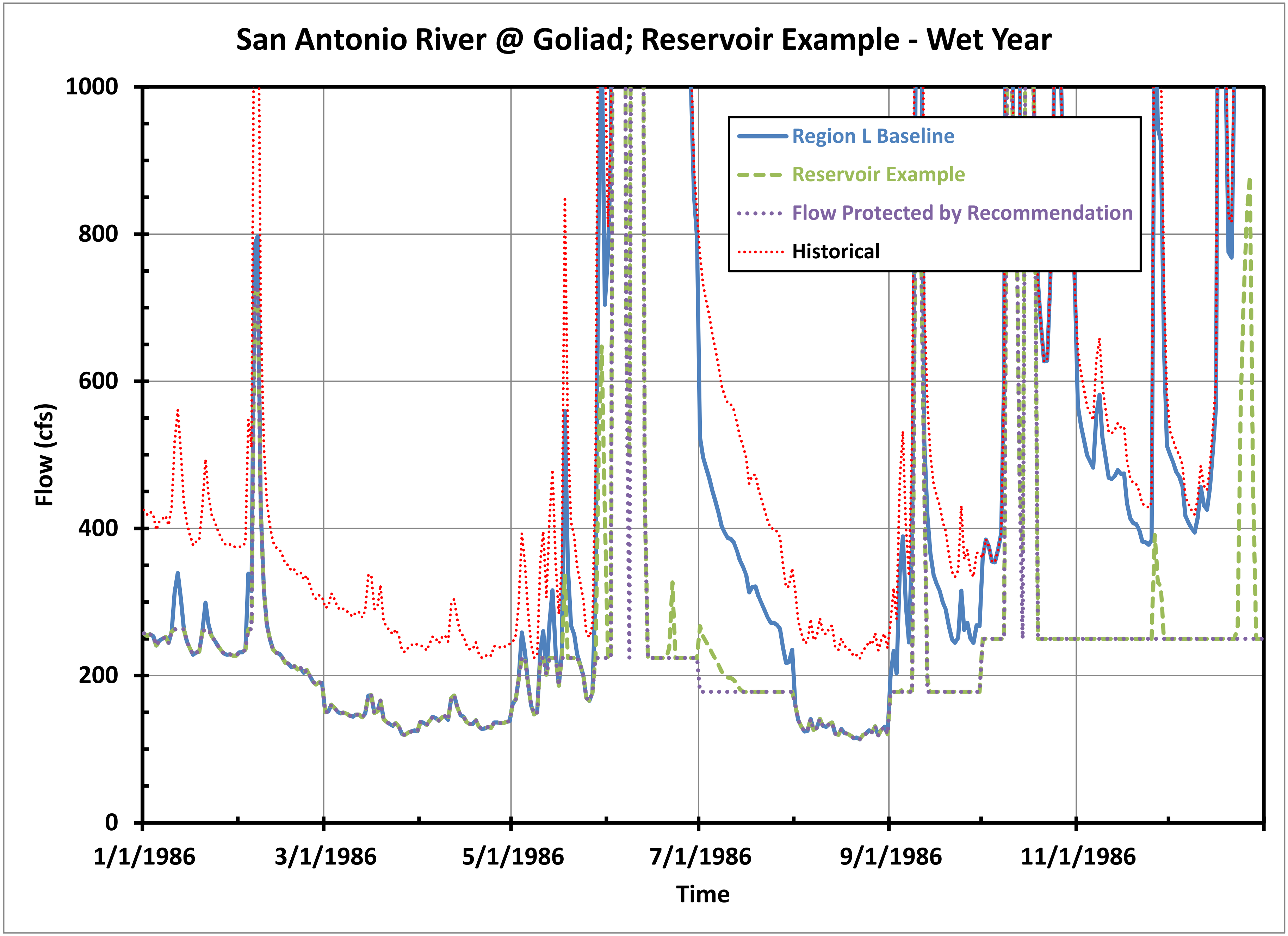

Cibollo Creek nr Falls City - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
300
270
240
210
180
150
120
90
60
30
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

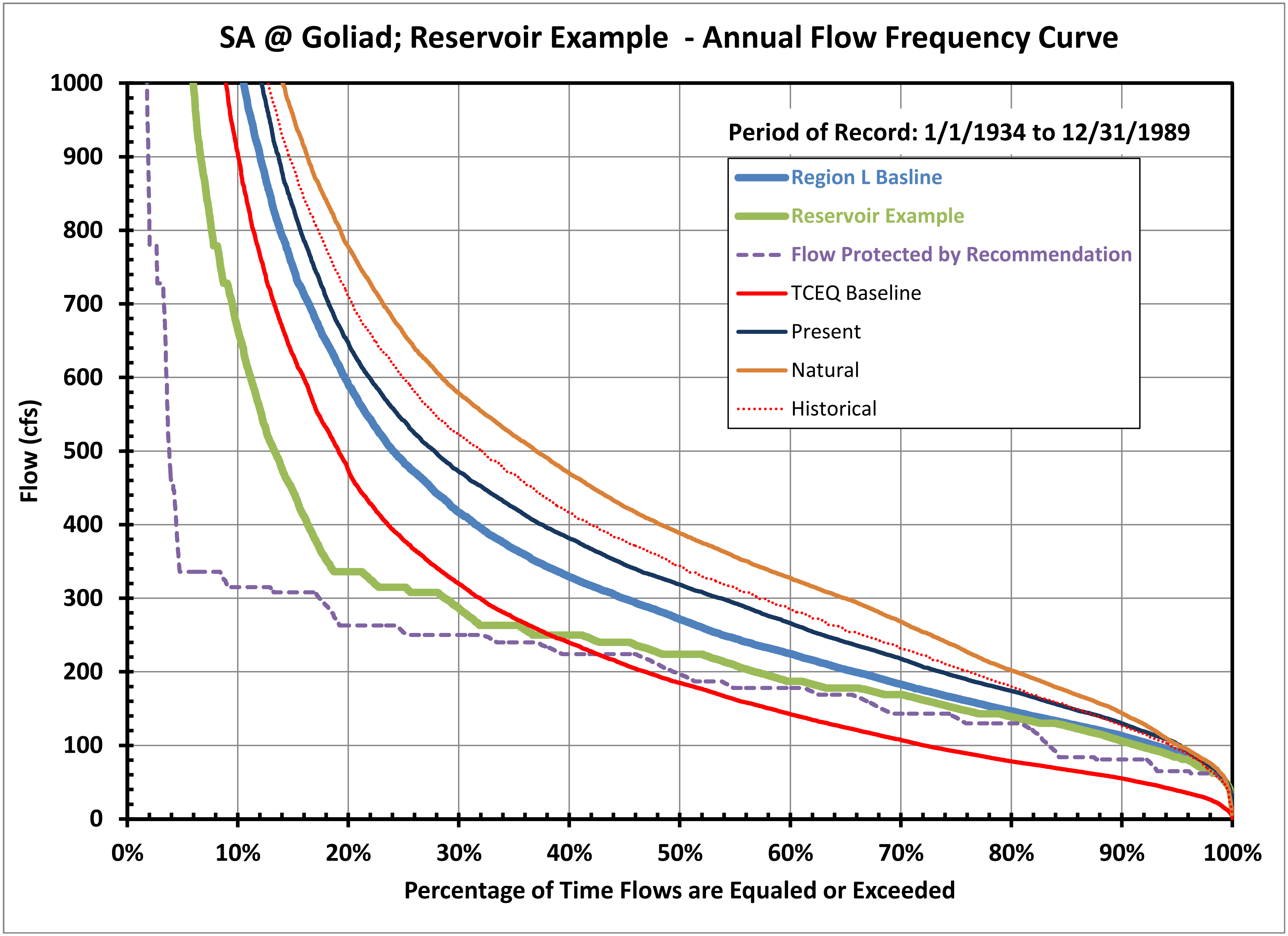

Cibollo Creek nr Falls City - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
TCEQ Baseline
Present
Natural
Flow (cfs)
300
270
240
210
180
150
120
90
60
30
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

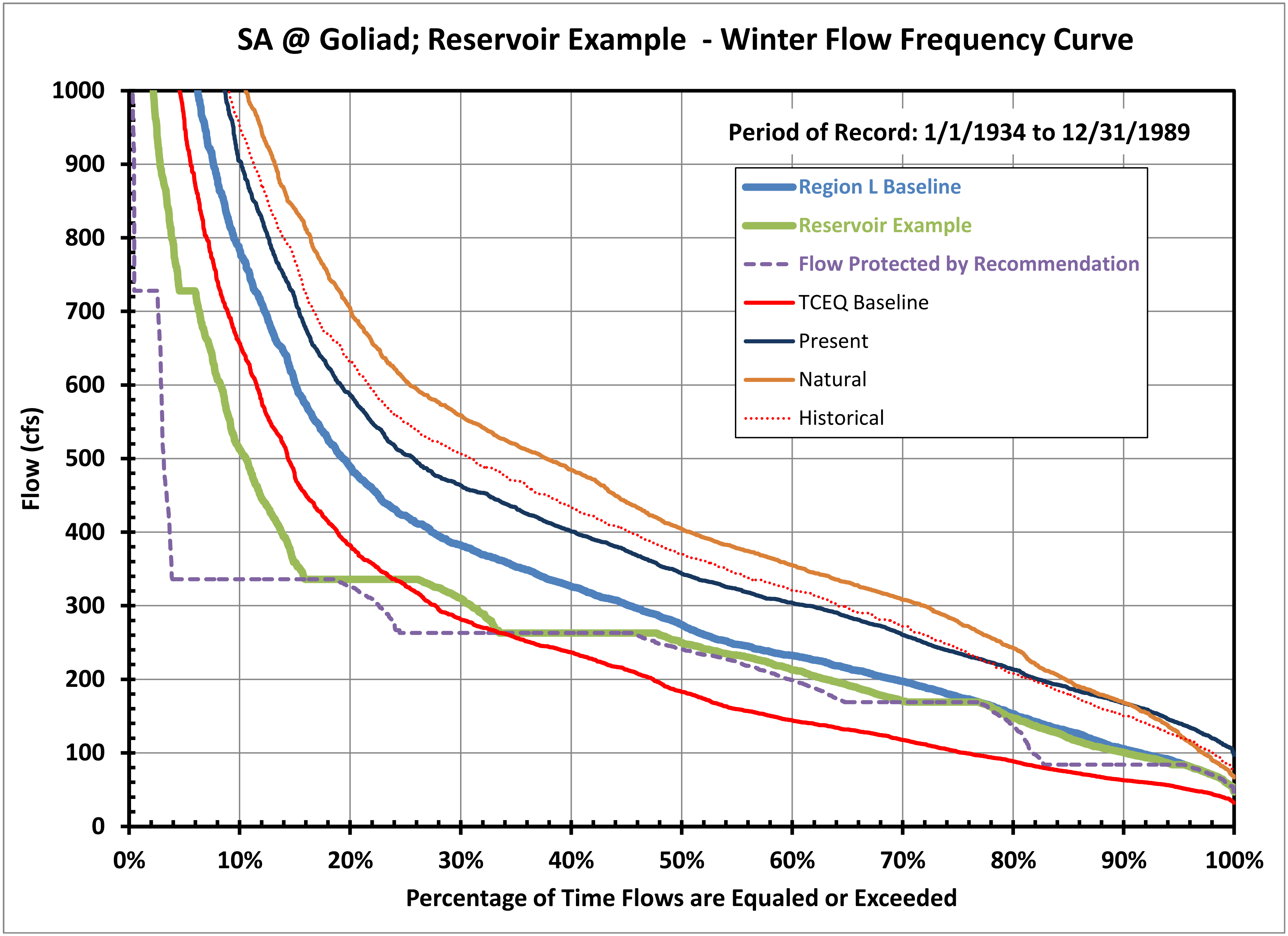
Appendix K - San Antonio River near Goliad

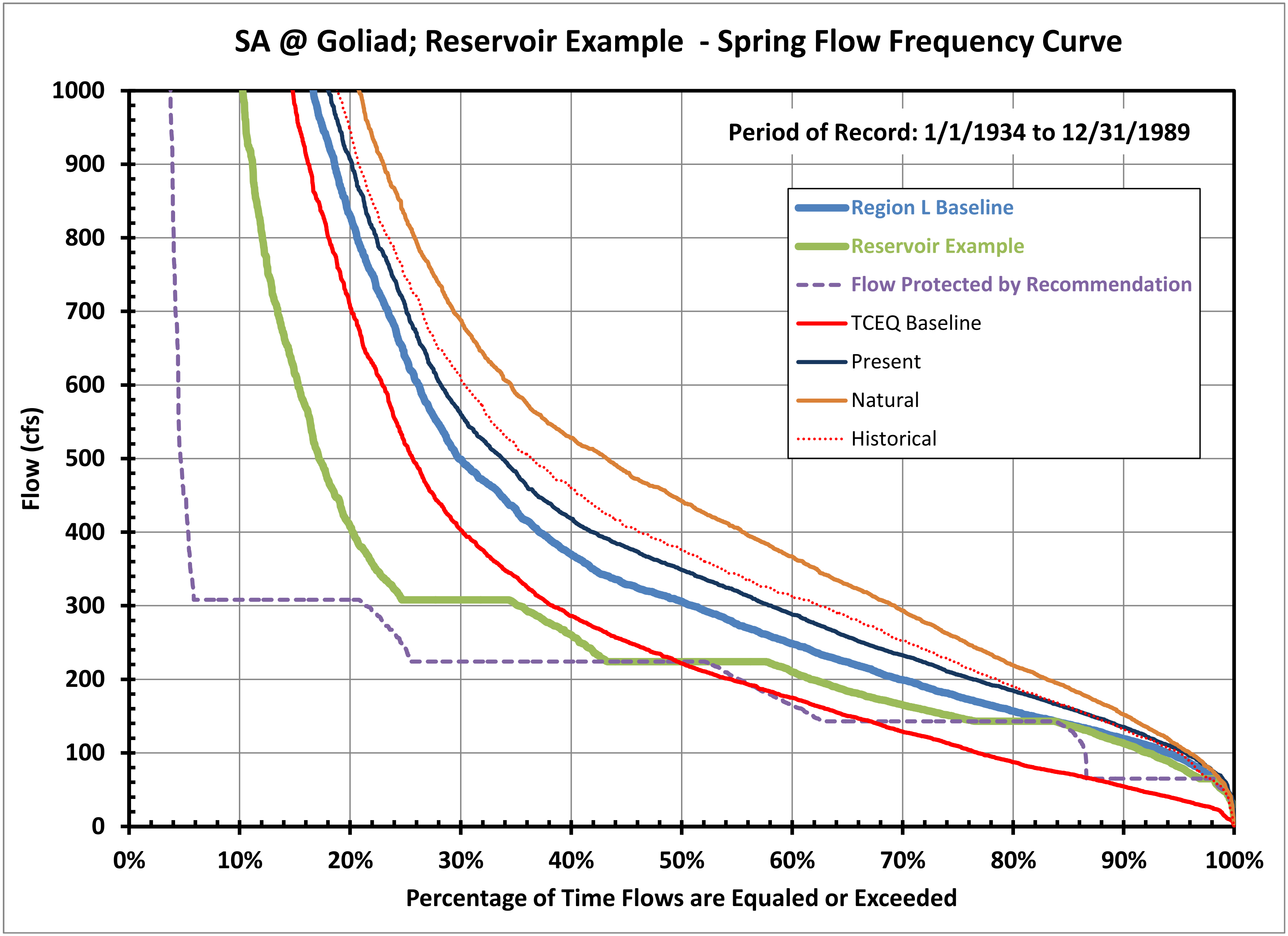

San Antonio River @ Goliad; Reservoir Example - Dry Year
Flow (cfs)
1000
800
600
400
200
0
1/1/1954
3/1/1954
5/1/1954
7/1/1954
9/1/1954
11/1/1954
Time
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
Historical

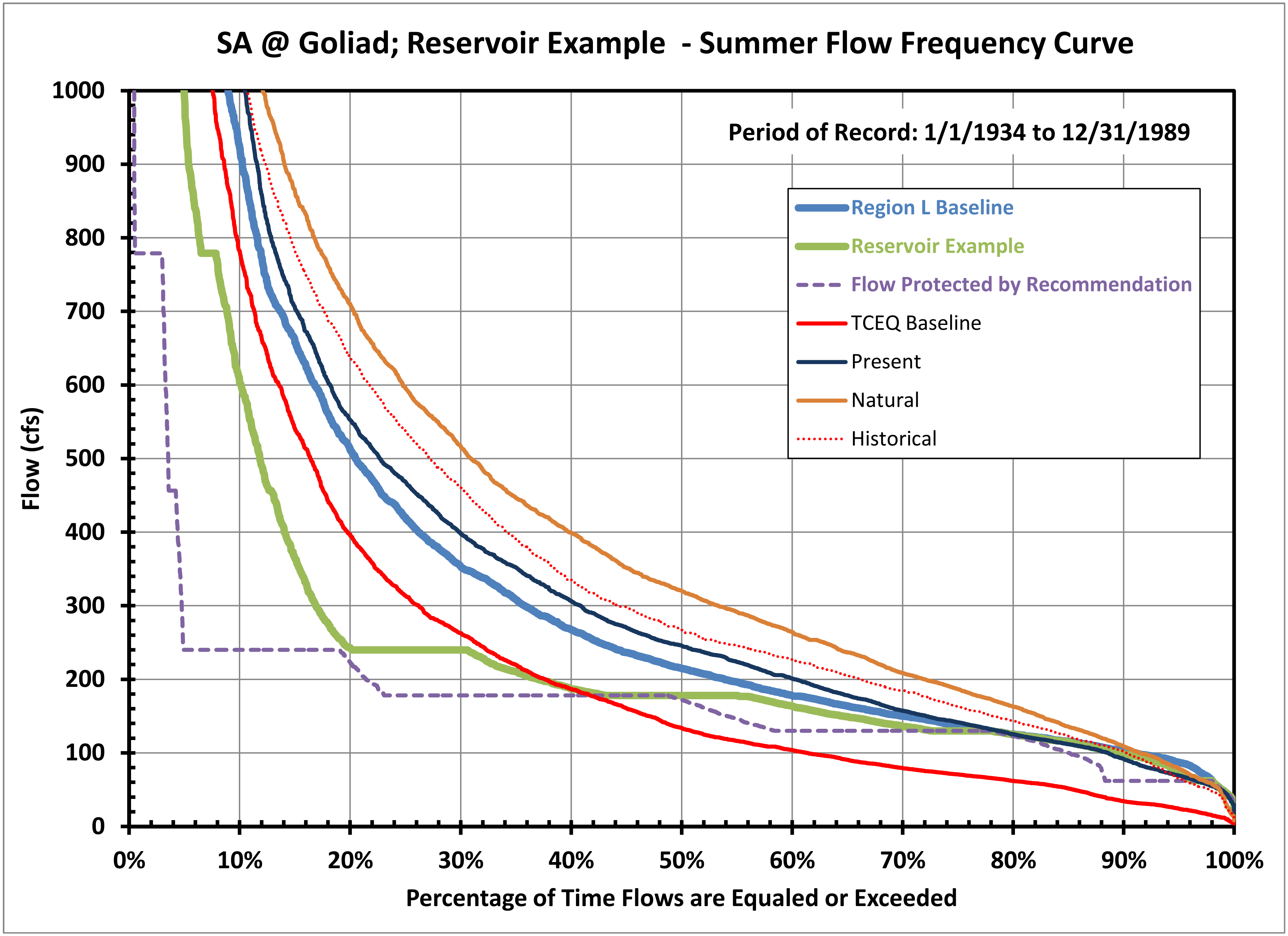

San Antonio River @ Goliad; Reservoir Example - Average Year
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
Historical
Flow (cfs)
1000
800
600
400
200
0
1/1/1981
3/1/1981
5/1/1981
7/1/1981
9/1/1981
11/1/1981
Time

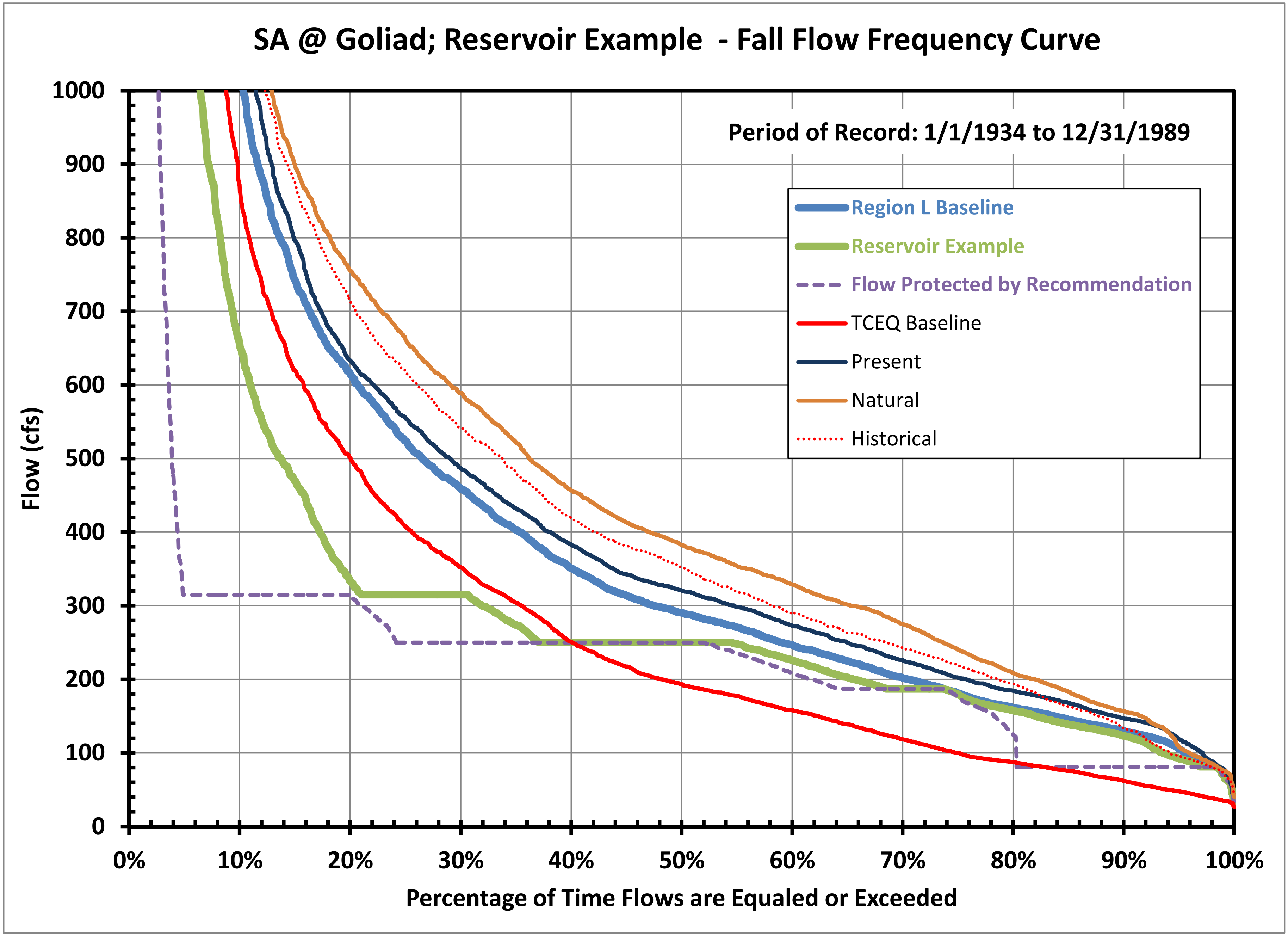

San Antonio River @ Goliad; Reservoir Example - Wet Year
Flow (cfs)
0
200
400
600
800
1000
1/1/1986
3/1/1986
5/1/1986
7/1/1986
9/1/1986
11/1/1986
Time
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
Historical


SA @ Goliad; Reservoir Example - Annual Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Basline
Reservoir Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


SA @ Goliad; Reservoir Example - Winter Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


SA @ Goliad; Reservoir Example - Spring Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


SA @ Goliad; Reservoir Example - Summer Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

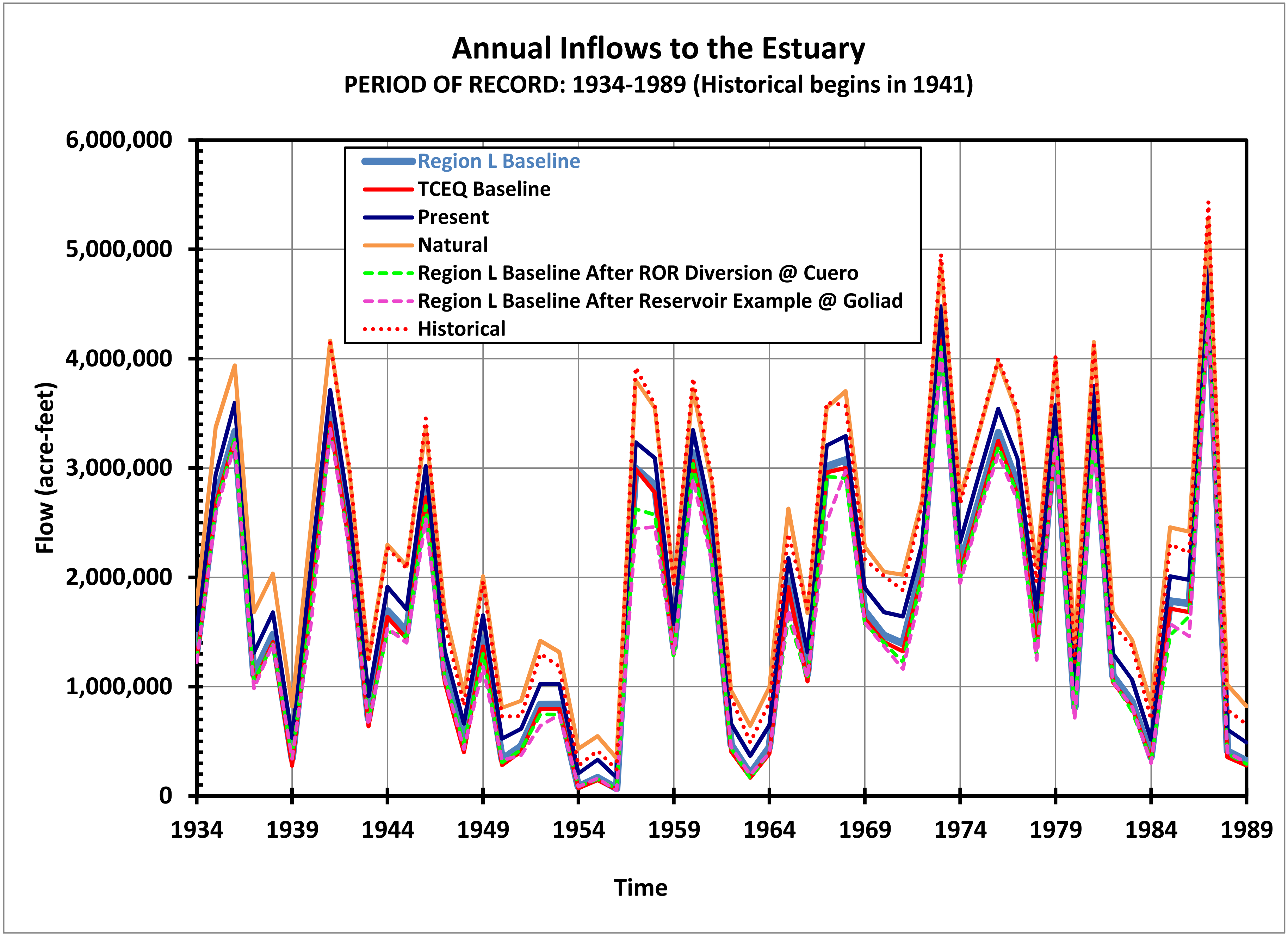

SA @ Goliad; Reservoir Example - Fall Flow Frequency Curve
Period of Record: 1/1/1934 to 12/31/1989
Region L Baseline
Reservoir Example
Flow Protected by Recommendation
TCEQ Baseline
Present
Natural
Historical
Flow (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded

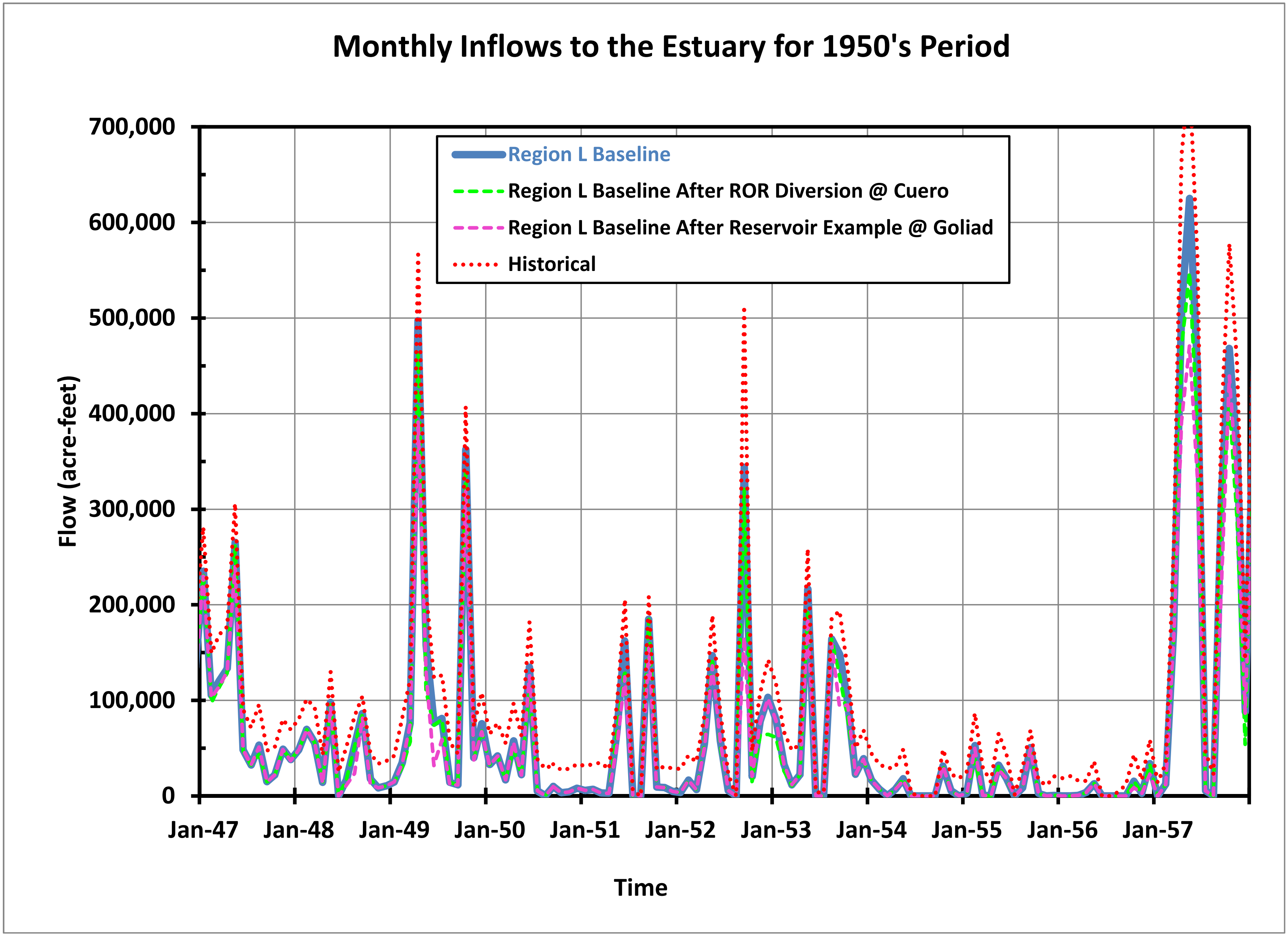
Month #	Month	Subsistence Flow			Dry Base Flow			Average Base Flow			Wet Base Flow		
		Flow Rec. (cfs)	Compliance Under Dry Hyd Cond	Compliance Under All Hyd Cond	Flow Rec. (cfs)	Compliance Under Dry Hyd Cond	Compliance Under All Hyd Cond	Flow Rec. (cfs)	Compliance Under Avg Hyd Cond	Compliance Under All Hyd Cond	Flow Rec. (cfs)	Compliance Under Wet Hyd Cond	Compliance Under All Hyd Cond
1	Jan	84	86%	96%	169	36%	78%	263	54%	50%	336	85%	30%
2	Feb	84	83%	95%	169	48%	79%	263	48%	48%	336	71%	29%
3	Mar	84	89%	96%	169	48%	74%	263	48%	44%	336	58%	23%
4	Apr	65	100%	100%	143	66%	85%	224	72%	58%	308	73%	32%
5	May	65	95%	98%	143	64%	85%	224	75%	59%	308	75%	38%
6	June	65	89%	96%	143	57%	82%	224	70%	56%	308	71%	36%
7	Jul	62	96%	99%	130	63%	78%	178	64%	58%	240	78%	32%
8	Aug	62	92%	96%	130	60%	74%	178	49%	50%	240	69%	24%
9	Sept	62	97%	99%	130	71%	82%	178	65%	58%	240	85%	37%
10	Oct	81	86%	96%	187	26%	71%	250	57%	51%	315	67%	32%
11	Nov	81	99%	100%	187	43%	76%	250	65%	54%	315	74%	30%
12	Dec	81	98%	99%	187	36%	75%	250	70%	58%	315	85%	31%
	Annual Avg:		93%	98%		52%	78%		61%	54%		74%	31%

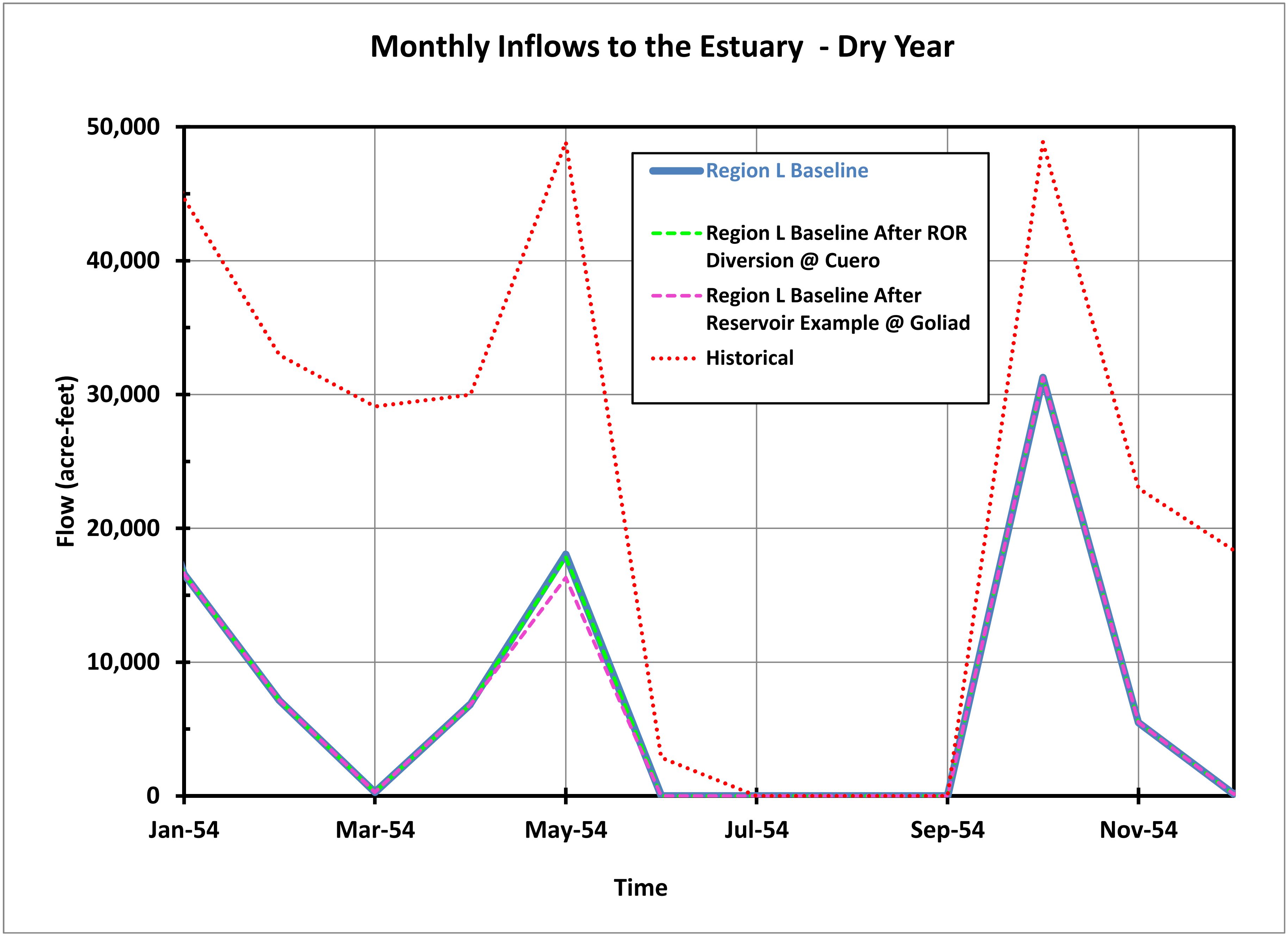
		Dry High Flow Pulse		Average High Flow Pulse		Wet High Flow Pulse	
Season #	**Season**	**HFP Rec. (#/sea)**	**Compliance Under Dry Hyd Cond**	**HFP Rec. (#/sea)**	**Compliance Under Avg Hyd Cond**	**HFP Rec. (#/sea)**	**Compliance Under Wet Hyd Cond**
1	**Winter**	1	65%	2	48%	1	33%
2	**Spring**	1	45%	2	58%	1	50%
3	**Summer**	1	78%	2	56%	1	55%
4	**Fall**	1	47%	2	52%	1	58%

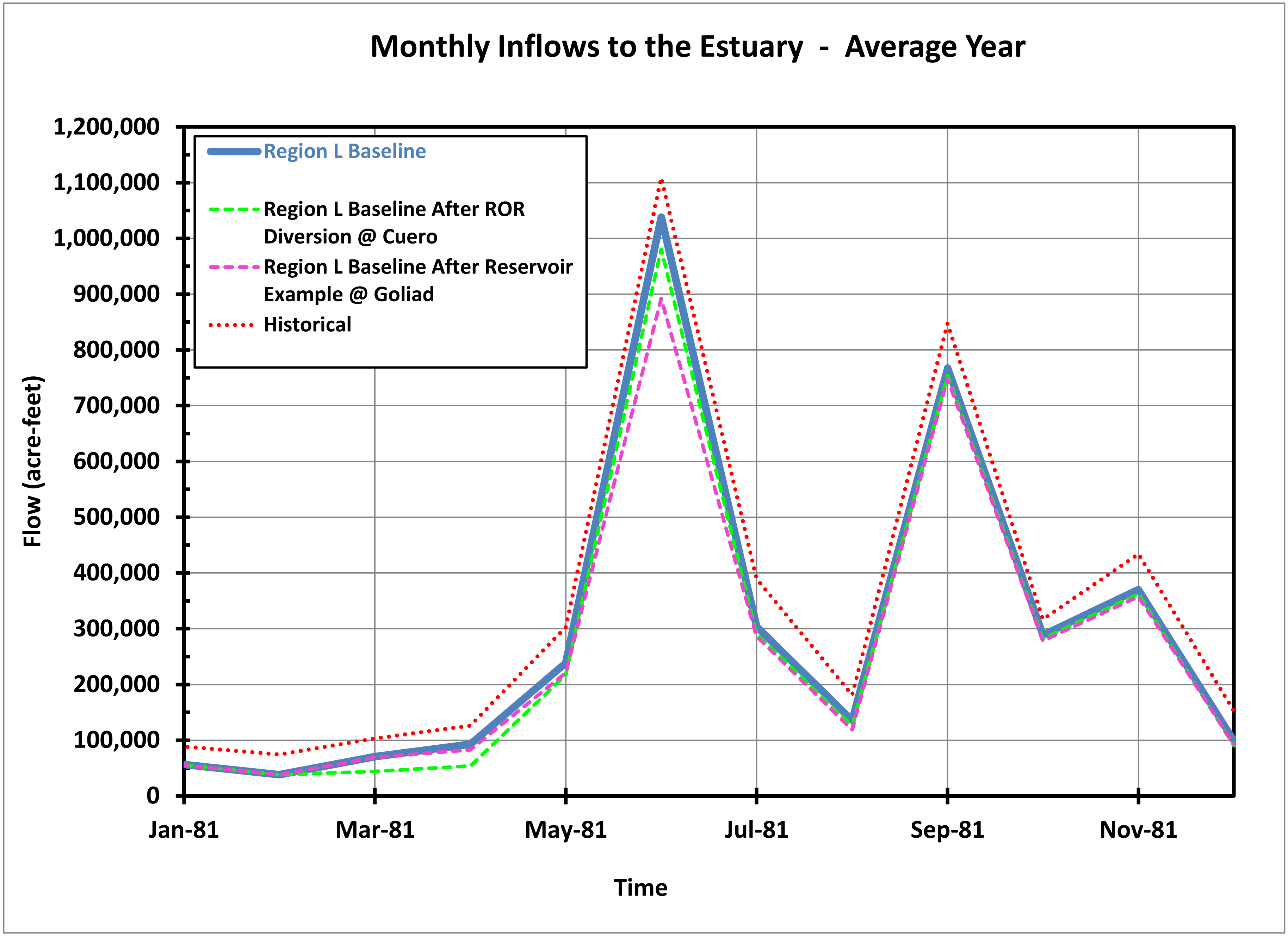
This table shows the percent of seasons meeting the requirement under the given hydrologic condition

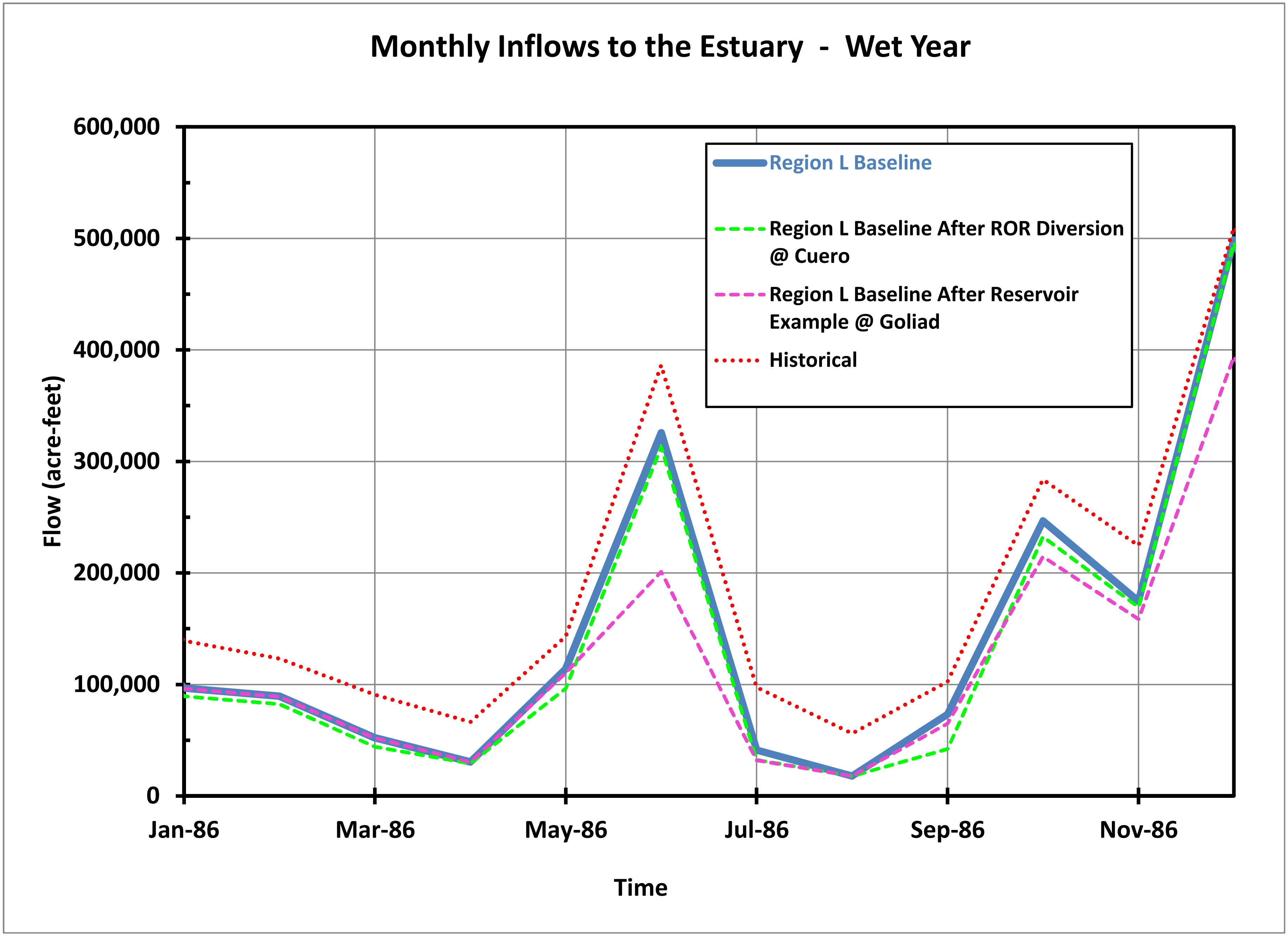
Appendix L - Inflow to Guadalupe Estuary

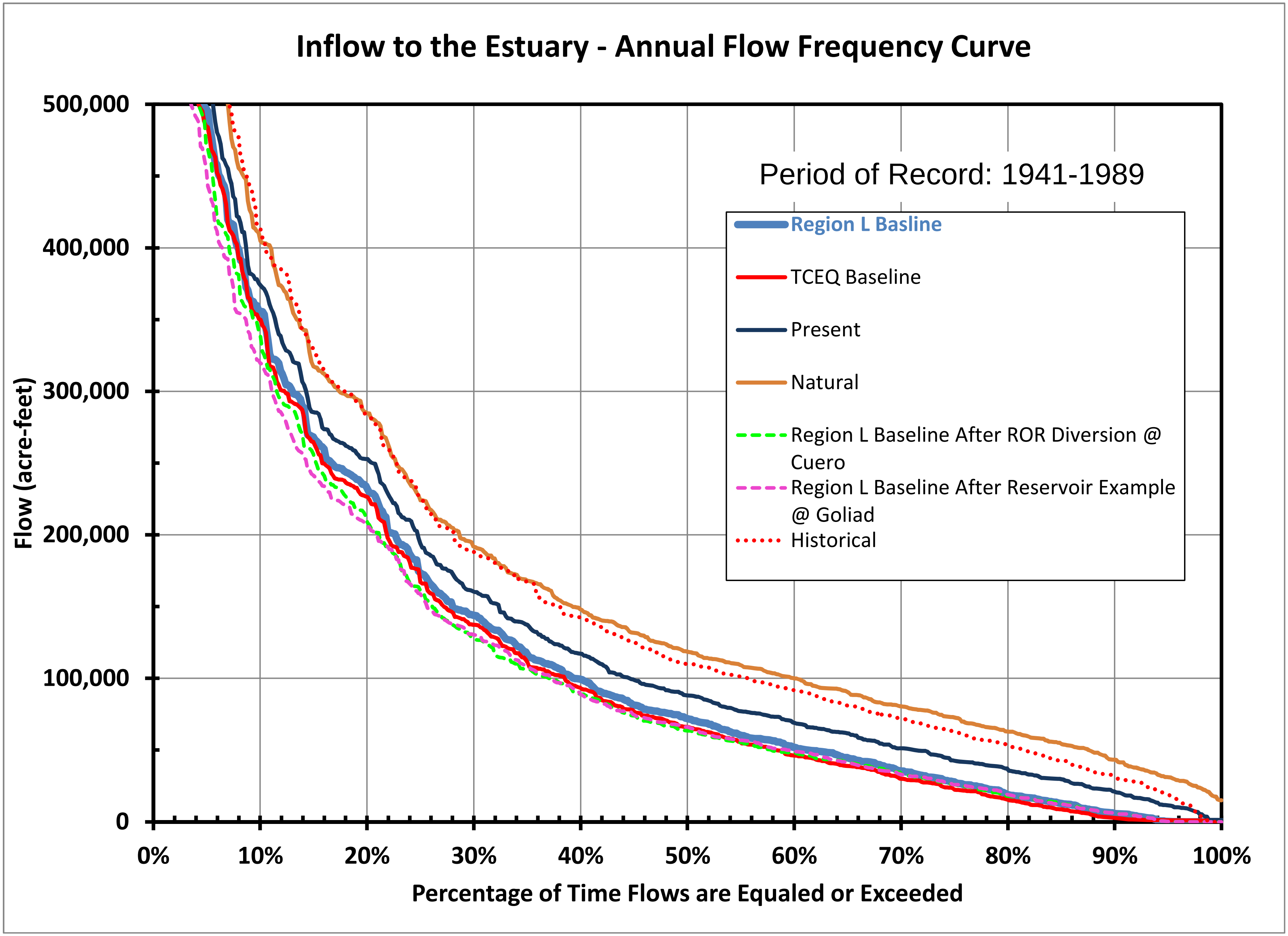

Annual Inflows to the Estuary
PERIOD OF RECORD: 1934-1989 (Historical begins in 1941)
Region L Baseline
TCEQ Baseline
Present
Natural
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1934
1939
1944
1949
1954
1959
1964
1969
1974
1979
1984
1989
Time

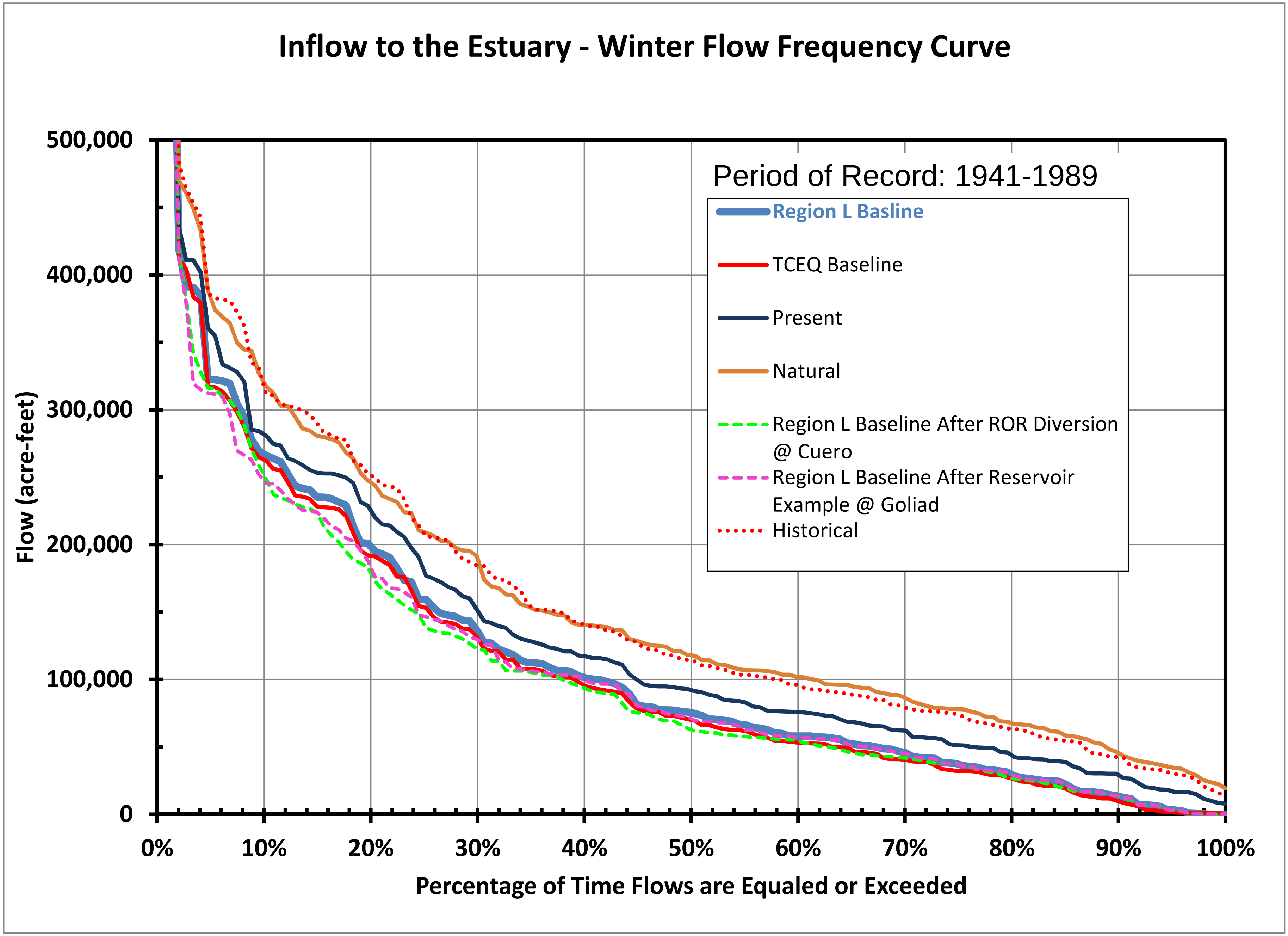

Monthly Inflows to the Estuary for 1950's Period
Flow (acre-feet)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-47
Jan-48
Jan-49
Jan-50
Jan-51
Jan-52
Jan-53
Jan-54
Jan-55
Jan-56
Jan-57
Time
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical

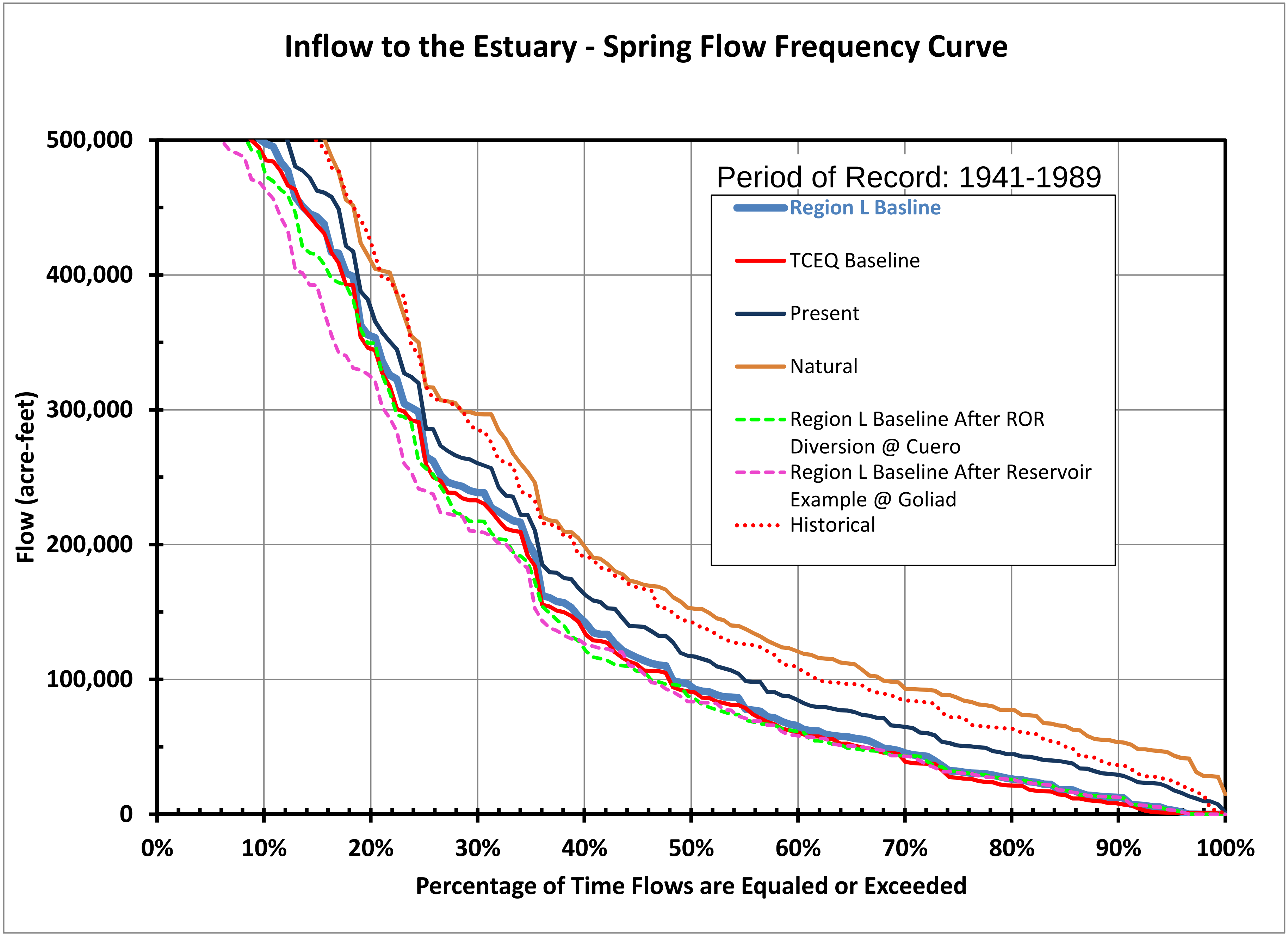

Monthly Inflows to the Estuary - Dry Year
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
50,000
40,000
30,000
20,000
10,000
0
Jan-54
Mar-54
May-54
Jul-54
Sep-54
Nov-54
Time


Monthly Inflows to the Estuary - Average Year
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-81
Mar-81
May-81
Jul-81
Sep-81
Nov-81
Time

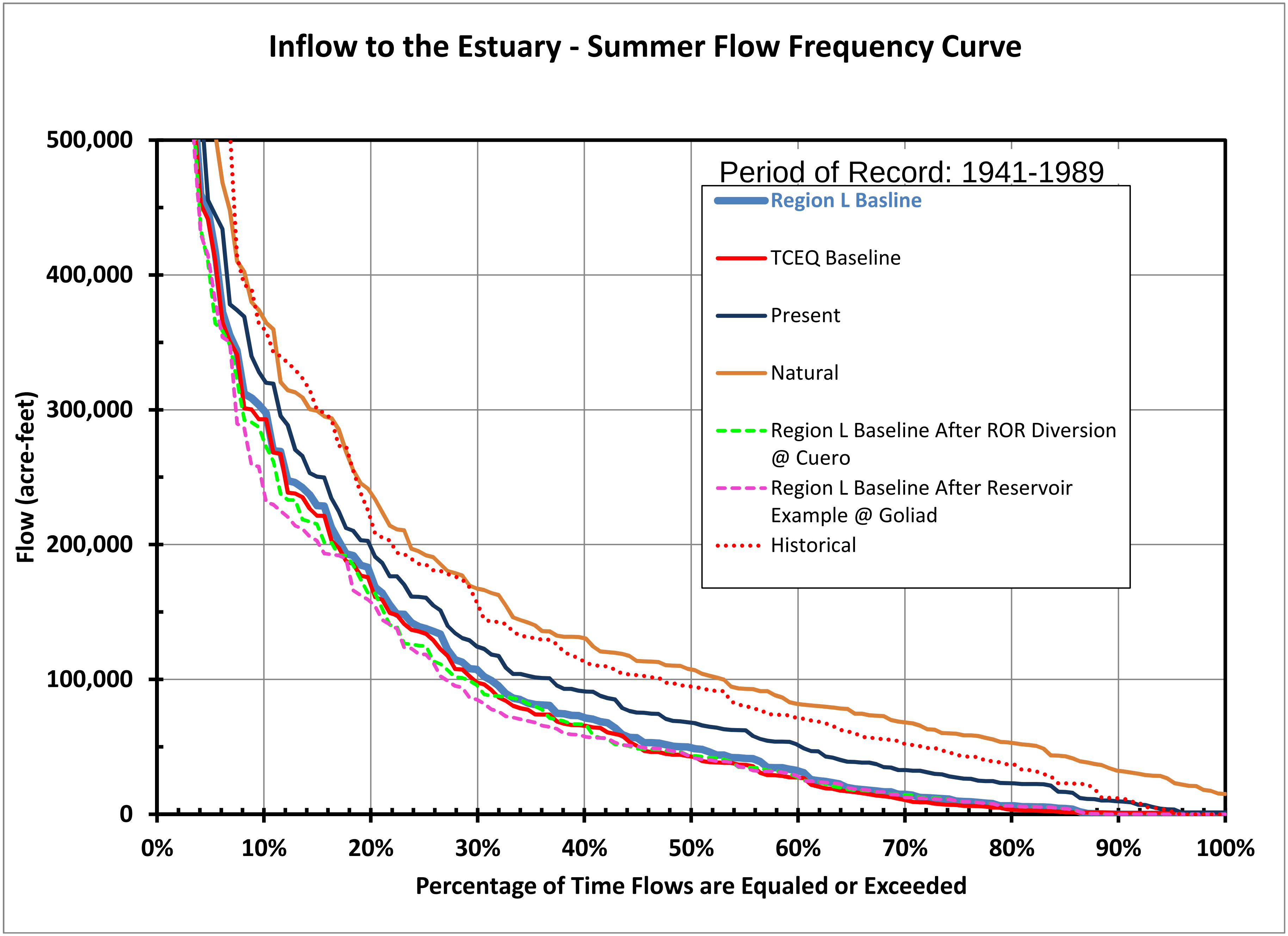

Monthly Inflows to the Estuary - Wet Year
Region L Baseline
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-86
Mar-86
May-86
Jul-86
Sep-86
Nov-86
Time

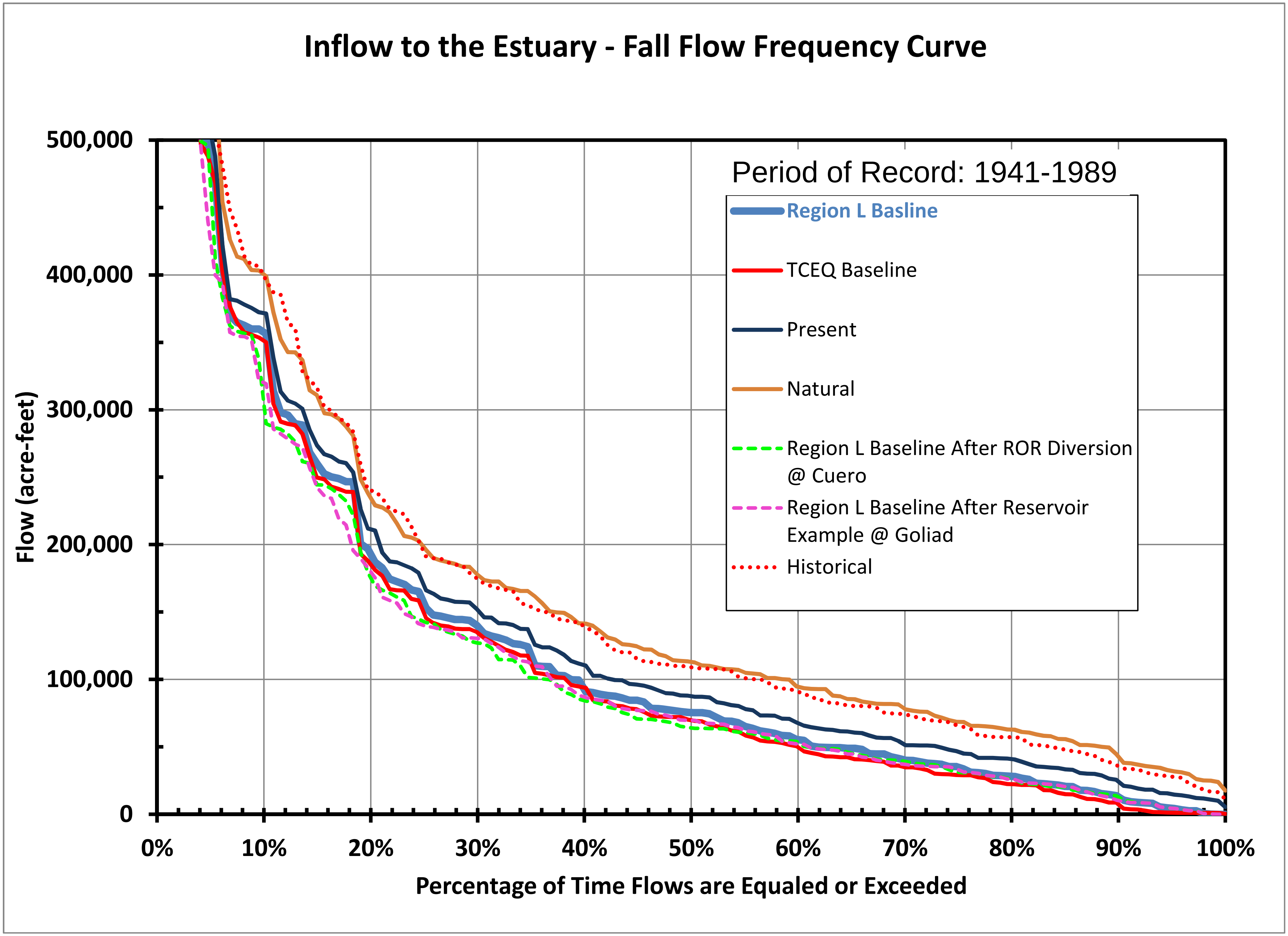

Inflow to the Estuary - Annual Flow Frequency Curve
Period of Record: 1941-1989
Region L Basline
TCEQ Baseline
Present
Natural
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
500,000
400,000
300,000
200,000
100,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


Inflow to the Estuary - Winter Flow Frequency Curve
Period of Record: 1941-1989
Region L Basline
TCEQ Baseline
Present
Natural
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
500,000
400,000
300,000
200,000
100,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded



Inflow to the Estuary - Spring Flow Frequency Curve
Period of Record: 1941-1989
Region L Basline
TCEQ Baseline
Present
Natural
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
500,000
400,000
300,000
200,000
100,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


Inflow to the Estuary - Summer Flow Frequency Curve
Period of Record: 1941-1989
Region L Basline
TCEQ Baseline
Present
Natural
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
500,000
400,000
300,000
200,000
100,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded


Inflow to the Estuary - Fall Flow Frequency Curve
Period of Record: 1941-1989
Region L Basline
TCEQ Baseline
Present
Natural
Region L Baseline After ROR Diversion @ Cuero
Region L Baseline After Reservoir Example @ Goliad
Historical
Flow (acre-feet)
500,000
400,000
300,000
200,000
100,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Time Flows are Equaled or Exceeded