



EVALUATION OF RAINFALL/RUNOFF PATTERNS IN UPPER COLORADO RIVER BASIN

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Study Area

Colorado Basin Upstream of the Highland Lakes.

- Touches 42 Counties, mainly in 34 Counties.
- Final Project will contain at Least 13 USGS Gage Sites, 10 of which are locations in which BBASC and TCEQ set eflow standards.
- This area has been in severe drought, but recent flows believed to be lower than expected.
- Involves review of observed streamflows, observed springflows, naturalized flows, precipitation records, groundwater elevations, land uses, other studies, etc.

Streamflow Gages Used in Analysis

Will focus on only 2 Sites in today's presentation:

- Concho River at Paint Rock (C2)
- Brady Creek at Brady (E2)



ASSESS STREAMFLOW CONDITIONS

Assess whether streamflows have diminished over time. If so, gain insight for reasons for reductions:

- Reduction in Precipitation Amounts.
- Changes in Precipitation Patterns.
- Changes in Rainfall/Runoff Relationships.
- Changes in Land Use Patterns.
- Increases in Water Use.
- Addition of New Water Users.
- Changes in Groundwater Levels
- Changes in Temperature/Evaporation
- Combination of several of the above.



INFORMATION REVIEWED

- USGS Observed Streamflow and Springflow.
- NCDC Precipitation and Temperature Records.
- TCEQ Naturalized Flows.
- Numerous GIS Coverages (TCEQ Water Rights, TCEQ Dam Safety, USGS NHD, NLDC, etc).
- TWDB Precipitation and Gross Evaporation Information.
- USACOE Observed Evaporation Information.
- Published Reports and Other Information.
- Insights from Entities in the Watershed.



TECHNIQUES USED

- Compare Recent Flows to what?
- Meaningful Period of Record.
- Study's analysis period is 1940-2016, to the extent possible and reasonable.
- Extract Monthly Naturalized Flows for each Site and Develop Complete Precipitation Record for same.
- Analyze Information over Long Term.
 - Trends Over Entire Period.
 - Identify Discrete Periods that Should be Comparable.
 - Attempt to Compare Naturalized Flow against Precipitation.
- Try to reconcile Naturalized Flow with Historical Precipitation.



GAGED (OBSERVED) STREAMFLOW

Observed Streamflow is of Limited Use to Assess Rainfall/Runoff Relationship Changes over Time

- All Watersheds have water rights upstream.
- [Most watersheds have major reservoirs upstream.](#)
- Most of these activities did not exist in the early period of record; thus observed flow should be high in early years and lower in later years.
- Need to examine observed streamflows after adjustments have been made for man's known historical activities.
- All of above leads to use of Naturalized Flow.
- Note that Naturalized Flow of sites with complete observed streamflow information are more desirable to draw conclusions from.



Naturalized Flow

- Readily Available, on a monthly timestep from TCEQ.
- Used as Inflows to TCEQ's WAM Model - Period of Record is 1940-2013.
- Concept begins with observed streamflow at each site, then adjusts flows to the extent water rights in the watershed actually diverted, returned, or stored water over time.
- Many sites do not have a complete period of record – missing periods had to be filled in using relationships with other sites.
- Organized into Sub-Watersheds – same identifiers were adopted in this analysis (study area map). Enables dissection of flows by incremental watershed.
- Approximates the amount of water that would have been present if appropriative water rights and permitted dischargers had not been in place historically.



Naturalized Flow (Cont)

- Is a theoretical quantity of water that did not actually occur and cannot be measured in the field.
- Comparing Nat Flow between the early and late period can be problematic:
 - Naturalized hydrology with regard to regular water right impacts.
 - May not be naturalized hydrology with regard to Man's Activities not accounted for in Naturalized Flow process.
- Un-accounted for activities are imbedded in naturalized flows for the years they occurred.
- **If** unaccounted for activities are a large factor and occurring more in the later period, improper conclusions could be made.



Precipitation

- [Schematic of Precip Gage Locations Used to Create Complete Times Series for Concho at Paint Rock.](#)
- [Example of Daily Precip Gages used to Complete Time Series for Concho at Paint Rock.](#)
- Similar Approach was done for all Sites
- Seasonal Considerations
- [Example of Daily and Monthly Precipitation Analysis \(Concho at Paint Rock Watershed \(C1\)\)](#)
- [Example of Monthly Detailed Precipitation Analysis Concho at Paint Rock Watershed \(C1\)\)](#)
- **CONCLUSION:** Historical precipitation does not appear to be declining; Instead, steady or small increase over time.
- Same basic findings at all study sites.



PLOTS – FLOWS v PRECIPITATION

Cumulative Plot - Flow (Observed and Natural) and Observed Precipitation plotted against Time

- (1) Time is X Scale.
- (2) Streamflow and Natural flow on left Y axis.
- (3) Precipitation on right Y axis.

Double Mass Plot - Naturalized Flow plotted against Observed Precipitation

- (1) Natural Flow on X Axis (observed not presented).
 - (2) Precipitation on Y Axis.
 - (3) Labels used along the Curve to indicate time.
- Concho River near Paint Rock
 - [Total](#)
 - [Incremental](#)



Initial Conclusions

In most cases, after determining that that precipitation has not decreased over long term:

- Even after all water rights and all major reservoir impacts are accounted for, flows still show a general decrease over time.
- Relating naturalized flow to precipitation indicates that the relationship between the two has changed over time.

Other categories explored to gain insight to reasons:

- Exempt Reservoirs
- Groundwater Use / Aquifer Levels
- Brush Infestation (Phreatophytes)
- Temperature
- Evaporation
- Land Use Changes



Exempt Reservoirs

- Texas Law exempts certain reservoirs from permitting.
 - Must have a normal capacity of less than 200 acre-feet.
 - Built for purposes designated as exempt, such as livestock/domestic.
 - Cannot be on a navigable stream.
- Small Waterbodies - Some Published Estimates (Based on USGS's NHD coverage) conclude:
 - Approximately 44,000 small impoundments in the watershed between Mansfield dam and Ivie and Brownwood reservoirs (as of 2003).
 - Combine surface area of these impoundments estimated to be 26,400 acres, approximately same combined surface area of Lakes Buchanan and LBJ when full.



Exempt Reservoirs (cont)

- These estimates appear to be generally reasonable, based on review NHD Small Water Body Coverage with Aerial Photography and USGS Topo Maps for a few select watersheds.
- Exempt reservoirs or small water-bodies?
- No information as to when these small water-bodies came into existence; thus unable to assess how they impacted flows over study period.
- Merged NHD Small Water Body Coverage with Project's Sub-watershed Coverage to develop summary table of Small Impoundments for Entire Study Area.
- [NHD Waterbodies by Sub-Watershed](#)



TCEQ Dam Safety Database

Provide by TCEQ Dam Safety Team.

- Locations and limited parameters for several hundred reservoirs in the Study Area.
- Has information for reservoirs, regardless of whether the reservoir is associated with an appropriative water right or not (i.e. includes exempt reservoirs).
- One of the Attributes is “Year Completed”.
- Merged Dam Safety Database with Watershed Coverage to develop summary table of:
 - [Number of Ponds per Watershed](#)
 - [Normal Storage Capacity per Watershed](#)



WRAP Approach to Estimate Impacts

Colorado WAM model structure was used to assess the theoretical impact for known exempt reservoirs in a single test watershed.

New code was developed in WRAP to enable these reservoirs to:

- Deplete water during the period of record they **did not exist**
- Not deplete water during the period of record they **did exist**.
- This was done to enable a “fair” comparison across the entire period of record.
 - All regular water right’s impacts have already been adjusted out (naturalized flow process).
 - All **known** exempt reservoir’s impacts have been imposed on the entire period of record (by this process for the period before they existed, and already imbedded in nat flows for the period after they existed).



EXAMPLE FOR SELECT WATERSHED

Test #1 - Brady Creek Watershed

- Per Dam Safely Database, 44 Reservoirs in watershed, only Brady Creek Reservoir adjusted for in Naturalized Flow Process.
- 2 Other reservoirs associated with appropriative water rights but only diversion adjusted for in Naturalized Flow process (not storage).
- Small Water Body Coverage Count Shows 1,383 in this Watershed

Results

- [Amount of Water Depleted Exempt Reservoirs in Test](#)
- [Cumulative Mass Plot](#)
- [Double Mass Plot Before and After Exempt Reservoirs Inserted](#)

Other Literature Suggests that small impoundments have greater impacts in watersheds with minimal precipitation.



Groundwater Use and Well Inventory

- TWDB Reported Groundwater Use, By County, By Aquifer.
- TWDB Groundwater Well Inventory.
 - [Drillers Database](#)
 - Other Databases
- TWDB Monitor Well Database; most counties in study area reviewed.
- Only wells with multiple observations through time were reviewed. Results over the entire study area are mixed (decline, steady, increases).
- Decliners - [Concho](#) and [Tom Green](#) Counties.
- TWDB Groundwater Use by County
 - [Groundwater Use for Concho and Tom Green Counties.](#)



Brush Infestation / Control

4 Main Varieties Targeted

- Ashe Juniper (Cedar)
- Honey Mesquite
- Tamarisk (Salt Cedar)
- Estimated to consume as much as 200 gal/day/plant

Examples of Ongoing Projects

North Concho (Cedar and Mesquite).

- 17.8 Million dollar project
- Problem Matured by 1960; Project began in 2000.
- 432,485 acres targeted for treatment (45% of C7).
- 302,000 acres have been cleared (2006).
- On-going Monitoring efforts to show benefit.

Thomas to Spence Watershed (Cedar, Mesquite, Salt Cedar)

- Began in 2005
- 11,400 acre treated by herbicide (2007).
- Corridor near Colorado River Only.



Observed Temperature Information

Long Term Temperature Data Not Available at Most Sites.

- Good Records at Major Airports, Military Bases, etc.
- Generally, Average Daily Temperature Not Reported, Daily Maximum and Daily Minimum are.
- Averaged Daily Max and Daily min to Approximate Daily Average.
- Validated this Approach Against Sparse Periods that had Daily Average Temperature Reported.
 - [Austin Camp Maybry.](#)
 - [San Angelo Mathis Airfield.](#)



Evaporation Information

Long Term Lake Evaporation Data from TWDB

- By 1 degree grid for entire state.
- (11) 1 degree quads cover the study area.
- Current Period of record is through 2015
- Some Problems with Evap Information before 1954
 - TWDB does not support 1940-1953 period anymore because of inconsistent observation techniques.
 - [Example Results for Quad 608 \(Middle of Study Area – near Colorado River nr Stacy\) for 1954-2015.](#)

US Army Corps of Engineer Observed Evaporation Data

- [Proctor \(Brazos Basin\), OC Fisher, Hord's Creek](#)



LAND USE

Besides Land Use Concepts Already Discussed Today:

- Population growth by counties in Study Area with some discussion of associated water use.
- Land Fragmentation. More Owners...
 - May mean more exempt reservoirs in future.
 - Added complications in getting agreement to do large scale brush control.
 - More Absentee Landowners....may not have the same interests as land owners living in watershed
- Animal Count Statistics (by head) by county (USDA).
- Acreages of Woody Brush over time (NRCS), to the extent it is available.
- Farm Acreages by Crop by Year by County.



SUMMARY - CHANGES OVER TIME

- Numerous Large Reservoirs Have Been Built.
- Water Use by Water Rights of Record Have Increased for Most Watersheds.
- Woody Brush Acreages and Densities Have Increased, Especially in the Farthest North and West Areas of the Basin.
- Several Brush Control Projects have been Implemented.
- Large Numbers of Groundwater Wells Have Been Drilled.
- For some counties, groundwater use has increased and monitor wells show large declines.
- Temperature Has Increased, Evaporation Has Increased, Precipitation Has increased.
- Large Numbers of Small Reservoirs have been installed throughout the Basin.
- [Summary of Results for Paint Rock and Brady](#)



Current Status of Project

- Budget is Very Limited.
- Begin to Write Draft Report Soon.
- Draft Report Due to TWDB June 30, 2017.
- TWDB Comments on Draft Due July 31, 2017.
- Final Report Due August 31, 2017.
- Thoughts / Ideas / Issues / Other ?