TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

Attachment 1. Historical Daily Average Total Dissolved Solids Concentrations in the Trinity River Basin
Attachment 2. Historical Annual Average Parameter Concentrations for Trinity River Basin Classified Segments
Attachment 3. Historical Annual Average Parameters Concentrations for Trinity River Basin Unclassified Waterbodies
Attachment 4. The Impact of TDS and TDS Constituents on Turf Grass Irrigation

PROJECT OBJECTIVES

The concentrations of total dissolved solids (TDS) in waters of Texas are anticipated to change as water resource strategies such as reuse and interbasin transfers are implemented. On behalf of the Trinity River Authority of Texas (Authority), an assessment to characterize TDS and the major components of TDS in the Trinity River Basin was performed by Alan Plummer Associates, Inc. This project was financed through the Texas Clean Rivers Program in cooperation with the Texas Commission on Environmental Quality (TCEQ).

The assessment is being conducted in multiple phases. This memorandum presents a summary of the results of the second phase of the assessment. The Phase I Assessment identified the ranges of TDS concentrations in the Trinity River Basin and potential impacts associated with elevated TDS concentrations. The activities conducted for the Phase II Assessment involved identification of the ranges of TDS constituents in the Trinity River Basin, the review of literature related to the components of TDS in the Trinity River Basin, identification of the concentration levels at which TDS and the major TDS components could adversely impact various types of uses, and a comparison of the levels of the TDS components in the Trinity River Basin to the levels that potentially have an adverse impact on uses. The Phase II Assessment also identifies additional data needs to further evaluate the impact of TDS and its constituents on designated uses within the Trinity River Basin. Recommendations for future phases are identified in the Recommendations section of this report.

BACKGROUND INFORMATION

The Phase I Assessment was conducted in 2009. The purpose of the Phase I Assessment was to review available data and to identify the ranges of TDS concentrations in the Trinity River Basin. The historical median, maximum, minimum, 25th percentile, and 75th percentile TDS concentrations for each classified segment in the Trinity River Basin, and for those unclassified waterbodies for which data are available, are summarized in Attachment 1. These plots organize the segment summaries by major watershed and provide information of spatial trends. A summary of the TDS information in the Phase I report is presented below:

- The 20-year average concentrations in the classified segments range from 74 mg/L to 598 mg/L.
- The 2000 Texas Surface Water Quality Standards (TSWQS) criteria for the classified stream segments range from 200 mg/L to 850 mg/L.
- The ratio of the 20-year annual average segment concentration to the segment TSWQS criteria is less than or equal to 1.0 for all classified segments.
    - One segment has a ratio between 0.9 and 1.0.
    - Ten segments have a ratio between 0.7 and 0.9.
    - Thirty segments have a ratio less than 0.7.

The Phase I Assessment also summarized existing and proposed TSWQS criteria for TDS in the Trinity River Basin. Activities and water management strategies that may change the TDS concentrations in the Trinity River were identified. Based on this information, the Phase I Assessment provided recommendations for steps to provide a stronger technical basis for evaluating the potential impacts of proposed actions based on TDS concentrations and the existing and desired water uses. Recommendations are provided in three areas: data collection, modeling, and investigations of impacts on uses.

COMPONENTS OF TOTAL DISSOLVED SOLIDS

The typical components of TDS in surface water are the following:

- Bicarbonate (HCO_3^-)
- Calcium (Ca^{3+})
- Carbonate (CO_3^{3-})
- Chloride (Cl^-)
- Magnesium (Mg^{+3})
- Sodium (Na^+)
- Sulfate ($SO4^{3-}$)
- Potassium (K^+)
- Nitrate ($NO3^-$)
- Boron (B^{4+})
- Iron (Fe^{4+})
- Manganese (Mn^{3+})
- Fluoride (F^-)

Of the above constituents, nitrate (NO^{4-}), boron (B^{4+}), iron (Fe^{4+}), manganese (Mn^{3+}) and fluoride (F^-) are minor contributors to the overall TDS in the Trinity River Basin and, therefore, are not the focus of this assessment. However, a discussion of iron and manganese, which can impact water treatment at low concentrations, is included in the impacts section of this report.

The data for major TDS constituents were obtained by the Authority from the TCEQ Surface Water Quality Monitoring (SWQM) database. The data in the SWQM database for the Trinity River Basin were collected from 1968 to 2009 and consist of over 200,000 records. Table 1 presents a summary of the available data for the Trinity River Basin for each of the TDS constituents.

Figure 1 presents the average concentrations for each of the major constituents throughout the Trinity River Basin for all time periods. Tables 2 – 11 present an inventory of data available within the SWQM database for each constituent for each classified segment. The period of record, number of records, minimum, maximum, average, and median concentrations for each constituent are presented. A summary of the historical data presented by annual average concentrations for each TDS constituent is provided in Attachment 2. For unclassified water bodies the annual average concentrations for TDS constituents are presented in Attachment 3.

Table 1. Data for TDS Constituents for the Trinity River Basin

Constituents	Parameter Code	Period of Record	Data Count	Measured Values			
				Min	Max*	Avg	Median
Bicarbonate Ion (mg/L as HCO3)	00440	1974-1994	370	8	378	158.5	151
Calcium, Dissolved (mg/L as Ca)	00915	1980-2008	4,969	0.051	411	54.1	50
Carbonate Ion (mg/L as CO3)	00445	1981-2001	344	<1	153	4.3	2
Chloride, Dissolved (mg/L as Cl)	00941	1972-1999	748	5	1,920	64.1	39.5
Iron, Dissolved (µg/L as Fe)	01046	1981-2008	6,926	3	8,430	88.9	20
Fluoride (mg/L as F)	00950	1980-2007	5,253	0	15	0.4	0.3
Manganese, Dissolved (µg/L as Mn)	01056	1981-2008	6,791	0.2	3,000	66.0	10
Magnesium, Dissolved (mg/L as Mg)	00925	1981-2008	5,552	0.02	4,240	6.9	4.7
Nitrate, Dissolved (mg/L as N)	00618	1987-2007	1,194	0.001	20.1	2.2	0.98
Potassium, Dissolved (mg/L as K)	00935	1981-2008	5,401	0.1	96	5.8	4.89
Sodium, Dissolved (mg/L as Na)	00930	1981-2008	5,454	0.8	3,310	41.2	28
Sulfate (mg/L as SO4)	00945	1968-2009	18,056	<1	6,500	57.0	40

*An evaluation to identify potential anomalous data was not conducted.
NOTE: Data were not available for boron during the study period.

Figure 1. Composition of TDS – Average Values in Trinity River Basin

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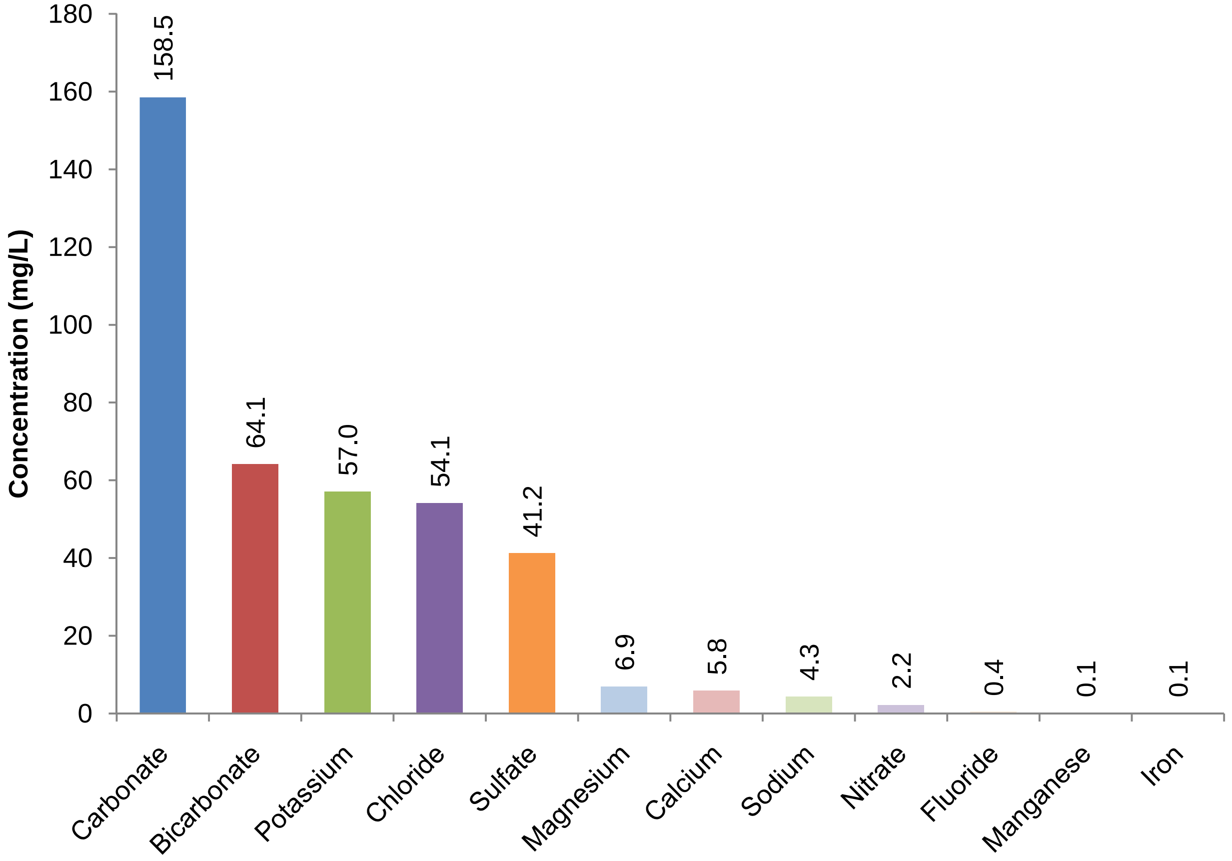


NOTE: Data were not available for boron during the study period.

Table 2. Data for Bicarbonate for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as HCO_3)			
				Min	Max	Avg	Median
0804	Trinity River Above Lake Livingston	1981 - 1988	29	75	224	138	137
0805	Upper Trinity River	1981 - 1992	174	46	303	147	145
0806	West Fork Trinity River Below Lake Worth	1981 - 1991	39	97	309	172	170
0813	Houston County Lake	1993 - 1993	1	12	12	12	12
0815	Bardwell Reservoir	1993 - 1994	2	129	153	141	141
0816	Lake Waxahachie	1993 - 1994	2	137	148	143	143
0817	Navarro Mills Lake	1993 - 1994	2	127	156	142	142
0818	Cedar Creek Reservoir	1994 - 1994	1	61	61	61	61
0819	East Fork Trinity River	1983 - 1983	1	148	148	148	148
0820	Lake Ray Hubbard	1974 - 1974	1	8	8	8	8
0821	Lake Lavon	1993 - 1993	2	158	161	160	160
0822	Elm Fork Trinity River Below Lewisville Lake	1986 - 1986	1	154	154	154	154
0827	White Rock Lake	1993 - 1994	2	68	110	89	89
0828	Lake Arlington	1993 - 1994	2	89	122	106	106
0832	Lake Weatherford	1993 - 1994	2	143	204	174	174
0834	Lake Amon G. Carter	1994 - 1994	1	88	88	88	88
0836	Richland-Chambers Reservoir	1981 - 1989	28	8	294	146	160
0840	Ray Roberts Lake	1981 - 1992	29	10	378	222	237
0841	Lower West Fork Trinity River	1981 - 1992	42	90	260	177	189

*An evaluation to identify potential anomalous data was not conducted.

Table 3. Data for Dissolved Calcium for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as Ca)			
				Min	Max	Avg	Median
0802	Trinity River Below Lake Livingston	1981 - 1999	216	3	50	25	35
0803	Lake Livingston	1980 - 2005	326	13	80	43	43
0804	Trinity River Above Lake Livingston	1980 - 2006	323	0	79	50	50
0805	Upper Trinity River	1981 - 2006	580	0	93	54	53
0806	West Fork Trinity River Below Lake Worth	1981 - 1997	153	32	90	56	55
0813	Houston County Lake	1993 - 2002	6	3	4	4	4
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	176	32	200	73	69
0815	Bardwell Reservoir	1993 - 2003	80	32	60	45	43
0816	Lake Waxahachie	1993 - 1994	2	47	52	49	49
0817	Navarro Mills Lake	1993 - 2004	116	32	57	45	44
0818	Cedar Creek Reservoir	1994 - 2001	18	16	21	19	19
0819	East Fork Trinity River	1981 - 2000	242	23	97	52	51
0821	Lake Lavon	1993 - 1999	64	36	62	47	47
0822	Elm Fork Trinity River Below Lewisville Lake	1981 - 1999	95	34	87	43	42
0823	Lewisville Lake	1985 - 1997	151	9	150	46	40
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	60	23	95	66	70
0825	Denton Creek	1982 - 2003	25	30	61	42	41
0826	Grapevine Lake	2002 - 2003	70	32	52	43	43
0827	White Rock Lake	1993 - 1993	1	36	36	36	36
0828	Lake Arlington	1992 - 2002	203	28	48	37	37
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	41	76	51	50
0830	Benbrook Lake	1989 - 1996	98	28	97	54	50
0831	Clear Fork Trinity River Below Lake Weatherford	1981 - 1996	52	25	110	80	87
0832	Lake Weatherford	1993 - 1993	1	49	49	49	49
0835	Richland Creek Below Richland-Chambers Reservoir	1981 - 1983	11	33	260	79	65
0836	Richland-Chambers Reservoir	1981 - 1989	59	29	220	70	66
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	20	39	108	66	56
0838	Joe Pool Lake	1981 - 2007	233	34	210	59	57
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	38	33	86	47	45
0840	Ray Roberts Lake	1981 - 1998	177	19	112	49	38
0841	Lower West Fork Trinity River	1981 - 2006	225	21	411	62	58

*An evaluation to identify potential anomalous data was not conducted.

Table 4. Summary of Data for Carbonate for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as CO_3)			
				Min	Max	Avg	Median
0804	Trinity River Above Lake Livingston	1981 - 1988	29	0	12	2	1
0805	Upper Trinity River	1981 - 1992	168	0	23	2	2
0806	West Fork Trinity River Below Lake Worth	1981 - 1991	39	0	20	4	2
0819	East Fork Trinity River	1983 - 1983	1	0	0	0	0
0822	Elm Fork Trinity River Below Lewisville Lake	1986 - 1986	1	2	2	2	2
0836	Richland-Chambers Reservoir	1981 - 1989	28	0	153	11	2
0838	Joe Pool Lake	2001 - 2001	1	146	146	146	146
0840	Ray Roberts Lake	1981 - 1990	28	0	40	8	2
0841	Lower West Fork Trinity River	1981 - 1992	40	0	40	4	2

*An evaluation to identify potential anomalous data was not conducted.

Table 5. Data for Dissolved Chloride for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as Cl)			
				Min	Max	Avg	Median
0801	Trinity River Tidal	1972 - 1973	10	55	1,650	428	275
0802	Trinity River Below Lake Livingston	1972 - 1973	26	16	200	72	34
0803	Lake Livingston	1972 - 1973	48	15	106	35	30
0804	Trinity River Above Lake Livingston	1972 - 1978	151	12	1,500	74	58
0805	Upper Trinity River	1972 - 1973	37	25	125	73	75
0806	West Fork Trinity River Below Lake Worth	1972 - 1973	19	25	115	54	50
0809	Eagle Mountain Reservoir	1972 - 1999	15	35	75	48	46
0810	West Fork Trinity River Below Bridgeport Reservoir	1972 - 1973	19	20	140	67	50
0811	Bridgeport Reservoir	1972 - 1973	9	35	50	37	35
0812	West Fork Trinity River Above Bridgeport Reservoir	1972 - 1973	16	15	250	66	37
0813	Houston County Lake	1973 - 1973	3	10	11	11	11
0815	Bardwell Reservoir	1972 - 1973	11	20	30	25	25
0817	Navarro Mills Lake	1972 - 1973	11	15	50	27	25
0818	Cedar Creek Reservoir	1972 - 1977	59	10	80	25	20
0819	East Fork Trinity River	1972 - 1973	19	15	95	51	50
0820	Lake Ray Hubbard	1972 - 1973	30	10	30	16	15
0821	Lake Lavon	1972 - 1973	10	10	25	16	14
0822	Elm Fork Trinity River Below Lewisville Lake	1972 - 1973	19	15	60	34	35
0823	Lewisville Lake	1972 - 1973	29	25	100	39	35
0825	Denton Creek	1972 - 1973	19	25	100	61	65
0826	Grapevine Lake	1972 - 1973	12	25	50	33	30
0827	White Rock Lake	1979 - 1979	1	63	63	63	63
0828	Lake Arlington	1972 - 1984	12	25	45	37	38
0830	Benbrook Lake	1972 - 1973	11	25	40	31	30
0831	Clear Fork Trinity River Below Lake Weatherford	1972 - 1973	16	25	75	52	50
0836	Richland-Chambers Reservoir	1972 - 1973	19	15	100	39	35
0840	Ray Roberts Lake	1972 - 1973	19	10	150	68	60
0841	Lower West Fork Trinity River	1972 - 1973	39	30	190	79	75

*An evaluation to identify potential anomalous data was not conducted.

Table 6. Data for Fluoride for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as F)			
				Min	Max	Avg	Median
0801	Trinity River Tidal	1985 - 1985	1	0	0	0	0
0802	Trinity River Below Lake Livingston	1980 - 2003	267	0	1	0	0
0803	Lake Livingston	1980 - 2005	514	0	2	0	0
0804	Trinity River Above Lake Livingston	1980 - 2006	351	0	2	1	1
0805	Upper Trinity River	1981 - 2006	558	0	2	1	1
0806	West Fork Trinity River Below Lake Worth	1981 - 1995	148	0	1	0	0
0813	Houston County Lake	1993 - 1993	1	0	0	0	0
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	176	0	1	0	0
0815	Bardwell Reservoir	1993 - 2003	80	0	0	0	0
0816	Lake Waxahachie	1993 - 1994	2	0	0	0	0
0817	Navarro Mills Lake	1993 - 2004	116	0	0	0	0
0818	Cedar Creek Reservoir	1994 - 1994	1	0	0	0	0
0819	East Fork Trinity River	1981 - 2000	242	0	3	1	1
0821	Lake Lavon	1993 - 1999	64	0	0	0	0
0822	Elm Fork Trinity River Below Lewisville Lake	1981 - 1997	91	0	1	0	0
0823	Lewisville Lake	1985 - 1997	151	0	1	0	0
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	60	0	1	0	0
0825	Denton Creek	1982 - 2003	25	0	0	0	0
0826	Grapevine Lake	2002 - 2003	72	0	0	0	0
0827	White Rock Lake	1993 - 1994	2	0	0	0	0
0828	Lake Arlington	1992 - 2002	203	0	1	0	0
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	0	0	0	0
0830	Benbrook Lake	1989 - 1996	98	0	1	0	0
0831	Clear Fork Trinity River Below Lake Weatherford	1981 - 1996	51	0	2	0	0
0832	Lake Weatherford	1993 - 1994	2	0	0	0	0
0834	Lake Amon G. Carter	1994 - 1994	1	0	0	0	0
0835	Richland Creek Below Richland-Chambers Reservoir	1981 - 1983	11	0	2	1	0
0836	Richland-Chambers Reservoir	1981 - 1989	59	0	1	0	0
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	20	0	1	0	0
0838	Joe Pool Lake	1981 - 2007	229	0	1	0	0
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	38	0	1	0	0
0840	Ray Roberts Lake	1981 - 1998	175	0	2	0	0
0841	Lower West Fork Trinity River	1981 - 2006	225	0	2	1	1

*An evaluation to identify potential anomalous data was not conducted.

Table 7. Summary of Historical Iron Data for Classified Trinity River Basin Segments

Segment	Name	Period of Record	Data Count	Measured Values (µg/L as Fe)			
				Min	Max	Avg	Median
0802	Trinity River Below Lake Livingston	1981 - 2008	172	3	1,100	156	40
0803	Lake Livingston	1981 - 2008	993	3	3,800	82	30
0804	Trinity River Above Lake Livingston	1981 - 2008	234	3	1,400	88	59
0805	Upper Trinity River	1993 - 2008	119	3	126	30	18
0806	West Fork Trinity River Below Lake Worth	1993 - 2008	45	3	370	38	10
0809	Eagle Mountain Reservoir	1989 - 2001	567	5	8,430	206	20
0811	Bridgeport Reservoir	1989 - 2001	307	5	2,700	172	30
0813	Houston County Lake	1997 - 1997	1	724	724	724	724
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	144	3	249	19	10
0815	Bardwell Reservoir	1999 - 2003	114	5	974	58	10
0817	Navarro Mills Lake	2001 - 2004	155	5	28	9	10
0818	Cedar Creek Reservoir	1997 - 2001	124	5	419	100	32
0819	East Fork Trinity River	1982 - 1994	22	4	260	62	40
0821	Lake Lavon	1996 - 1999	79	3	397	14	10
0822	Elm Fork Trinity River Below Lewisville Lake	1982 - 2008	51	3	100	18	11
0823	Lewisville Lake	1985 - 2008	193	3	1,200	46	10
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	32	4	160	19	11
0825	Denton Creek	1982 - 2003	25	5	91	17	10
0826	Grapevine Lake	2002 - 2003	133	5	923	47	10
0828	Lake Arlington	1992 - 2002	228	3	1,901	61	10
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	3	65	13	8
0830	Benbrook Lake	1989 - 2001	549	3	2,120	55	20
0831	Clear Fork Trinity River Below Lake Weatherford	1982 - 1996	26	3	1,300	61	9
0836	Richland-Chambers Reservoir	1983 - 2001	835	3	2,940	99	20
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	15	6	12	9	10
0838	Joe Pool Lake	1982 - 2007	422	3	968	33	6
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	19	3	410	52	10
0840	Ray Roberts Lake	1982 - 1998	164	3	5,800	237	10
0841	Lower West Fork Trinity River	1993 - 2008	32	3	160	55	32

*An evaluation to identify potential anomalous data was not conducted.

Table 8. Summary of Historical Manganese Data for Classified Trinity River Basin Segments

Segment	Name	Period of Record	Data Count	Measured Values (µg/L as Mn)			
				Min	Max	Avg	Median
0802	Trinity River Below Lake Livingston	1981 - 2008	176	1	250	21	10
0803	Lake Livingston	1981 - 2008	979	0	2,100	57	20
0804	Trinity River Above Lake Livingston	1981 - 2008	222	1	120	20	18
0805	Upper Trinity River	1993 - 2004	100	1	46	11	9
0806	West Fork Trinity River Below Lake Worth	1993 - 1995	38	1	28	6	3
0809	Eagle Mountain Reservoir	1989 - 2001	572	5	1,850	33	10
0811	Bridgeport Reservoir	1989 - 2001	308	5	1,910	56	10
0813	Houston County Lake	1997 - 1997	1	23	23	23	23
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	150	0	610	33	5
0815	Bardwell Reservoir	1999 - 2003	101	0	2,070	109	2
0817	Navarro Mills Lake	2001 - 2004	137	0	170	8	2
0818	Cedar Creek Reservoir	1997 - 2001	124	4	2,600	81	10
0819	East Fork Trinity River	1982 - 1994	22	1	86	35	30
0821	Lake Lavon	1996 - 1999	79	1	675	26	3
0822	Elm Fork Trinity River Below Lewisville Lake	1982 - 1997	47	1	890	55	11
0823	Lewisville Lake	1985 - 1997	191	1	1,600	108	10
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	32	1	38	9	7
0825	Denton Creek	1982 - 2003	25	1	619	114	6
0826	Grapevine Lake	2002 - 2003	113	1	1,470	119	2
0828	Lake Arlington	1992 - 2002	217	1	3,000	177	7
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	1	650	182	8
0830	Benbrook Lake	1989 - 2001	551	1	830	27	10
0831	Clear Fork Trinity River Below Lake Weatherford	1982 - 1996	26	3	77	23	19
0836	Richland-Chambers Reservoir	1983 - 2001	785	1	1,214	30	10
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	20	1	86	23	6
0838	Joe Pool Lake	1982 - 2007	420	0	1,466	55	3
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	19	1	1,600	247	59
0840	Ray Roberts Lake	1982 - 1998	164	1	2,900	298	30
0841	Lower West Fork Trinity River	1993 - 2003	26	10	610	201	160

*An evaluation to identify potential anomalous data was not conducted.

Table 9. Data for Dissolved Magnesium for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as Mg)			
				Min	Max	Avg	Median
0802	Trinity River Below Lake Livingston	1981 - 2005	277	1	6	3	4
0803	Lake Livingston	1981 - 2005	678	0	18	5	4
0804	Trinity River Above Lake Livingston	1981 - 2007	425	0	8	5	5
0805	Upper Trinity River	1981 - 2007	583	0	9	5	5
0806	West Fork Trinity River Below Lake Worth	1981 - 1997	153	2	11	7	7
0813	Houston County Lake	1993 - 2002	6	2	2	2	2
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	176	2	17	5	4
0815	Bardwell Reservoir	1993 - 2003	80	2	3	3	2
0816	Lake Waxahachie	1993 - 1994	2	2	2	2	2
0817	Navarro Mills Lake	1993 - 2004	116	3	4	3	3
0818	Cedar Creek Reservoir	1994 - 2001	18	3	4	3	3
0819	East Fork Trinity River	1981 - 2000	242	1	7	3	3
0821	Lake Lavon	1993 - 1999	64	2	5	3	3
0822	Elm Fork Trinity River Below Lewisville Lake	1981 - 2007	96	2	4,240	48	4
0823	Lewisville Lake	1985 - 1997	151	1	41	8	4
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	60	3	7	5	5
0825	Denton Creek	1982 - 2003	25	3	8	6	6
0826	Grapevine Lake	2002 - 2003	70	5	6	6	6
0827	White Rock Lake	1993 - 1993	1	2	2	2	2
0828	Lake Arlington	1992 - 2002	203	3	6	4	4
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	4	8	6	7
0830	Benbrook Lake	1989 - 1996	98	2	10	7	7
0831	Clear Fork Trinity River Below Lake Weatherford	1981 - 1996	52	4	16	11	12
0832	Lake Weatherford	1993 - 1993	1	17	17	17	17
0835	Richland Creek Below Richland-Chambers Reservoir	1981 - 1983	11	3	43	9	6
0836	Richland-Chambers Reservoir	1981 - 1989	59	2	23	6	5
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	20	3	17	6	3
0838	Joe Pool Lake	1981 - 2007	233	2	15	6	6
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	38	3	9	5	4
0840	Ray Roberts Lake	1981 - 1998	176	2	12	5	4
0841	Lower West Fork Trinity River	1981 - 2007	226	3	28	9	8

*An evaluation to identify potential anomalous data was not conducted.

Table 10. Data for Nitrate for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as N)			
				Min	Max	Avg	Median
0803	Lake Livingston	2002 - 2005	149	0	6	2	1
0804	Trinity River Above Lake Livingston	2002 - 2006	44	1	10	4	4
0805	Upper Trinity River	2001 - 2006	135	0	17	7	7
0809	Eagle Mountain Reservoir	1987 - 1987	21	0	1	0	0
0814	Chambers Creek Above Richland-Chambers Reservoir	2001 - 2007	78	0	6	1	1
0815	Bardwell Reservoir	2002 - 2004	56	0	2	1	1
0817	Navarro Mills Lake	2002 - 2004	108	0	11	2	2
0819	East Fork Trinity River	2004 - 2004	5	0	1	0	0
0820	Lake Ray Hubbard	2004 - 2004	3	1	2	1	2
0821	Lake Lavon	2004 - 2004	2	2	2	2	2
0825	Denton Creek	2002 - 2003	6	0	0	0	0
0826	Grapevine Lake	2002 - 2003	58	0	1	0	0
0828	Lake Arlington	1992 - 2002	24	0	1	0	0
0837	Richland Creek Above Richland-Chambers Reservoir	2002 - 2004	12	0	3	2	1
0838	Joe Pool Lake	2003 - 2007	144	0	2	0	0
0841	Lower West Fork Trinity River	2002 - 2006	40	1	20	9	10

*An evaluation to identify potential anomalous data was not conducted.

Table 11. Data for Dissolved Potassium for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as K)			
				Min	Max	Avg	Median
0802	Trinity River Below Lake Livingston	1981 - 2005	263	1	10	3	4
0803	Lake Livingston	1981 - 2005	643	3	25	6	5
0804	Trinity River Above Lake Livingston	1981 - 2006	390	3	96	7	6
0805	Upper Trinity River	1981 - 2006	559	2	96	8	8
0806	West Fork Trinity River Below Lake Worth	1981 - 1997	153	3	19	6	5
0813	Houston County Lake	1993 - 1993	1	2	2	2	2
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	176	0	10	4	4
0815	Bardwell Reservoir	1993 - 2003	80	3	7	5	4
0816	Lake Waxahachie	1993 - 1994	2	3	3	3	3
0817	Navarro Mills Lake	1993 - 2004	116	3	4	4	4
0818	Cedar Creek Reservoir	1994 - 1994	1	4	4	4	4
0819	East Fork Trinity River	1981 - 2000	240	1	14	7	7
0821	Lake Lavon	1993 - 1999	64	3	5	4	4
0822	Elm Fork Trinity River Below Lewisville Lake	1981 - 1997	93	3	10	5	5
0823	Lewisville Lake	1985 - 1997	151	2	12	5	4
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	60	2	9	5	4
0825	Denton Creek	1982 - 2003	25	3	6	4	4
0826	Grapevine Lake	2002 - 2003	70	4	5	4	4
0827	White Rock Lake	1993 - 1993	1	4	4	4	4
0828	Lake Arlington	1992 - 2002	203	3	6	4	4
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	3	4	4	4
0830	Benbrook Lake	1989 - 1996	98	1	4	3	3
0831	Clear Fork Trinity River Below Lake Weatherford	1981 - 1996	51	2	7	4	4
0832	Lake Weatherford	1993 - 1993	1	4	4	4	4
0835	Richland Creek Below Richland-Chambers Reservoir	1981 - 1983	11	4	16	7	6
0836	Richland-Chambers Reservoir	1981 - 1989	59	3	44	6	5
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	20	3	4	3	3
0838	Joe Pool Lake	1981 - 2007	233	4	72	10	8
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	38	3	6	4	4
0840	Ray Roberts Lake	1981 - 1998	177	0	47	4	4
0841	Lower West Fork Trinity River	1981 - 2006	225	2	22	8	9

*An evaluation to identify potential anomalous data was not conducted.

Table 12. Data for Dissolved Sodium for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as Na) Min	Max	Avg	Median
0802	Trinity River Below Lake Livingston	1981 - 2005	269	3	56	19	19
0803	Lake Livingston	1981 - 2005	679	4	99	34	29
0804	Trinity River Above Lake Livingston	1981 - 2006	397	10	114	44	40
0805	Upper Trinity River	1981 - 2006	559	13	275	53	53
0806	West Fork Trinity River Below Lake Worth	1981 - 1997	153	8	83	29	28
0813	Houston County Lake	1993 - 1993	1	6	6	6	6
0814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2007	176	8	240	48	31
0815	Bardwell Reservoir	1993 - 2003	80	15	33	25	26
0816	Lake Waxahachie	1993 - 1994	2	9	10	10	10
0817	Navarro Mills Lake	1993 - 2004	116	9	18	14	14
0818	Cedar Creek Reservoir	1994 - 1994	1	13	13	13	13
0819	East Fork Trinity River	1981 - 2000	242	7	88	39	45
0821	Lake Lavon	1993 - 1999	64	10	39	18	17
0822	Elm Fork Trinity River Below Lewisville Lake	1981 - 1997	93	8	110	24	22
0823	Lewisville Lake	1985 - 1997	151	3	110	25	18
0824	Elm Fork Trinity River Above Ray Roberts Lake	1988 - 1998	60	19	222	82	66
0825	Denton Creek	1982 - 2003	25	8	27	20	20
0826	Grapevine Lake	2002 - 2003	70	16	27	22	21
0827	White Rock Lake	1993 - 1993	1	12	12	12	12
0828	Lake Arlington	1992 - 2002	203	9	27	17	16
0829	Clear Fork Trinity River Below Benbrook Lake	1982 - 1996	26	10	23	17	18
0830	Benbrook Lake	1989 - 1996	98	3	27	18	20
0831	Clear Fork Trinity River Below Lake Weatherford	1981 - 1996	51	7	67	34	34
0832	Lake Weatherford	1993 - 1993	1	36	36	36	36
0835	Richland Creek Below Richland-Chambers Reservoir	1981 - 1983	11	10	140	73	68
0836	Richland-Chambers Reservoir	1981 - 1989	59	7	200	46	39
0837	Richland Creek Above Richland-Chambers Reservoir	2001 - 2004	20	9	222	54	17
0838	Joe Pool Lake	1981 - 2007	233	11	220	38	31
0839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	38	11	58	24	19
0840	Ray Roberts Lake	1981 - 1998	177	10	2,800	45	16
0841	Lower West Fork Trinity River	1981 - 2006	225	1	110	65	70

*An evaluation to identify potential anomalous data was not conducted.

Table 13. Data for Sulfate for Segments of the Trinity River Basin

Segment	Name	Period of Record	Data Count	Measured Values (mg/L as SO_4)			
				Min	Max	Avg	Median
801	Trinity River Tidal	1969 - 2008	328	1	453	39	32
802	Trinity River Below Lake Livingston	1968 - 2008	1,197	1	160	33	34
803	Lake Livingston	1970 - 2008	2,763	1	160	45	42
804	Trinity River Above Lake Livingston	1968 - 2008	1,101	3	646	61	60
805	Upper Trinity River	1968 - 2006	1,206	1	1,788	75	76
806	West Fork Trinity River Below Lake Worth	1971 - 2008	583	1	296	43	38
807	Lake Worth	1973 - 2008	84	9	52	25	25
808	West Fork Trinity River Below Eagle Mountain Reservoir	1973 - 1991	65	4	191	29	23
809	Eagle Mountain Reservoir	1971 - 2008	573	4	145	31	27
810	West Fork Trinity River Below Bridgeport Reservoir	1971 - 2008	170	6	230	50	40
811	Bridgeport Reservoir	1971 - 2008	217	3	50	22	21
812	West Fork Trinity River Above Bridgeport Reservoir	1968 - 2008	118	2	986	89	33
813	Houston County Lake	1973 - 2008	72	2	31	9	9
814	Chambers Creek Above Richland-Chambers Reservoir	1983 - 2008	280	3	440	87	66
815	Bardwell Reservoir	1971 - 2008	146	4	78	38	38
816	Lake Waxahachie	1973 - 2008	64	2	51	19	17
817	Navarro Mills Lake	1971 - 2008	182	13	85	30	29
818	Cedar Creek Reservoir	1971 - 2008	334	5	182	30	24
819	East Fork Trinity River	1968 - 2008	620	1	365	54	48
820	Lake Ray Hubbard	1971 - 2008	428	1	140	37	28
821	Lake Lavon	1971 - 2004	248	1	184	26	24
822	Elm Fork Trinity River Below Lewisville Lake	1971 - 2000	306	1	180	46	41
823	Lewisville Lake	1971 - 1997	294	7	460	51	30
824	Elm Fork Trinity River Above Ray Roberts Lake	1980 - 2008	189	1	500	48	49
825	Denton Creek	1971 - 2008	132	4	74	36	34
826	Grapevine Lake	1971 - 2003	122	14	170	32	30
827	White Rock Lake	1973 - 2008	34	16	134	37	31
828	Lake Arlington	1971 - 2008	441	0	324	34	29
829	Clear Fork Trinity River Below Benbrook Lake	1973 - 2008	142	3	120	35	34
830	Benbrook Lake	1971 - 2008	346	3	68	28	28
831	Clear Fork Trinity River Below Lake Weatherford	1971 - 2008	194	5	143	45	45
832	Lake Weatherford	1973 - 2008	58	13	41	29	31
833	Clear Fork Trinity River Above Lake Weatherford	1973 - 2002	81	5	338	74	67
834	Lake Amon G. Carter	1973 - 2009	43	1	82	14	11
835	Richland Creek Below Richland-Chambers Reservoir	1981 - 2001	25	7	780	83	41
836	Richland-Chambers Reservoir	1968 - 2008	706	2	390	45	35
837	Richland Creek Above Richland-Chambers Reservoir	1992 - 2004	40	2	279	71	39
838	Joe Pool Lake	1981 - 2008	348	18	430	112	105
839	Elm Fork Trinity River Below Ray Roberts Lake	1985 - 1993	39	3	62	26	22
840	Ray Roberts Lake	1968 - 1998	270	1	268	32	20
841	Lower West Fork Trinity River	1971 - 2008	403	1	290	74	69

*An evaluation to identify potential anomalous data was not conducted.

REGULATORY CONSIDERATIONS

Water quality standards for TDS and some of the major components of TDS have been established by TCEQ and the U.S. Environmental Protection Agency. The purpose of the water quality standards is to protect the designated uses of the water bodies. A brief discussion of drinking water and surface water regulations is presented below.

Drinking Water Regulations

Maximum contaminant levels (MCL) for the protection of drinking water are established for many inorganic and organic constituents. The standards are identified as primary or secondary.

The primary drinking water standards apply to all public drinking waters and are devoted to constituents affecting the health of consumers. Adverse impacts on the health of consumers at typical levels of the major constituents of TDS in the Trinity River have not been identified.

Secondary drinking water standards apply to all public drinking waters. Constituents for which secondary drinking water standards are set do not have direct impact on the health of the consumers. TCEQ may grant variances to the standards for waters that exceed secondary drinking water standards if another supply is not available for use. Secondary drinking water standards are established for chloride, sulfate, iron, manganese and TDS and are presented in Table 14. Secondary drinking water standards have not been established for the other major components of TDS.

Table 14. Federal and State Secondary Drinking Water Standards for Chloride, Sulfate, and Total Dissolved Solids

Constituent	Federal MCL (mg/L)	State MCL (mg/L)
Chloride	250	300
Iron	0.3	0.3
Manganese	0.05	0.05
Sulfate	250	300
Total Dissolved Solids	500	1,000

Texas Surface Water Quality Standards

Water quality standards for TDS, chloride, and sulfate are currently established in Title 30 Texas Administrative Code Section 307, Texas Surface Water Quality Standards (TSWQS) for classified segments. Sodium, calcium, potassium, magnesium, carbonate, and bicarbonate are not regulated surface water quality constituents.

The water quality standards for TDS, chloride, and sulfate were developed to protect general uses such as public health and aquatic life. At the present time, the TSWQS criteria for TDS, chloride, and sulfate are set based on historical water quality: i.e., ambient quality. This approach for setting the standards does not give consideration to the potential that existing uses can also be viable at concentrations greater than at ambient conditions. The TSWQS for TDS, chloride, and sulfate for segments in the Trinity River Basin are presented in Table 15.

Assessment for Determining Regulatory Compliance

The Federal Clean Water Act requires water bodies to be evaluated for the purpose of identifying water bodies that do not meet uses and applicable criteria. The water quality information included in the SWQM database is used by TCEQ to conduct this evaluation.

When a water body does not meet one or more of the TSWQS, it is considered impaired and included in the Texas Water Quality Inventory and the 303(d) List. For each impaired water body segment TCEQ will develop a strategy to address the impairment. The strategies are identified by categories.

Several segments in the Trinity River Basin have been identified as impaired. The East Fork of the Trinity River is identified on this list for TDS, as well as chloride and sulfate. One segment of the West Fork of the Trinity above Bridgeport Reservoir has been listed for chloride, and twelve areas of Lake Livingston have been listed for sulfate. Lake Livingston was first listed for sulfate in 2006. At the time the sulfate standard was 50 mg/L. Since that time, a new standard of 60 mg/L was proposed and is being reviewed by the EPA in consultation with the U.S. Fish and Wildlife Service (see Table 15).

Further studies to develop total maximum daily loads have not been initiated for any segment identified as impaired for TDS or TDS constituents in the Trinity River Basin. The segments of the West Fork and Lake Livingston are listed as Category 5b, which indicates TCEQ plans to review the water quality standards before scheduling a total maximum daily load study. The segments of the East Fork of the Trinity are listed as a Category 5c, which indicates TCEQ plans to collect additional data and information before scheduling a total maximum daily load study.

Table 15. Criteria for Classified Segments

Texas Surface Water Quality Standards, Chapter 307 Rule Amendment[A]

Watershed	Trinity River Basin Segment Number	Segment Name	Chloride (mg/L)[B]	Sulfate (mg/L)[B]	TDS (mg/L)[B]
Clear Fork	829	Clear Fork Trinity River Below Benbrook Lake	100	100	500
	830	Benbrook Lake	75	75	300
	831	Clear Fork Trinity River Below Lake Weatherford	100	100	500
	832	Lake Weatherford	100	100	500
	833	Clear Fork Trinity River Above Lake Weatherford[4]	125	125	750
West Fork	807	Lake Worth	100	100	500
	808	West Fork Trinity River Below Eagle Mountain Reservoir	100	100	500
	809	Eagle Mountain Reservoir	75	75	300
	810	West Fork Trinity River Below Bridgeport Reservoir	100	100	500
	811	Bridgeport Reservoir	75	75	300
	812	West Fork Trinity River Above Bridgeport Reservoir[A]	190	200	800
	834	Lake Amon G. Carter	150	150	400
Village and Mountain Creeks	828	Lake Arlington	100	100	300
	838	Joe Pool Lake	100	250	500
Elm Fork	822	Elm Fork Trinity River Below Lewisville Lake	80	60	500
	823	Lewisville Lake	80	60	500
	824	Elm Fork Trinity River Above Ray Roberts Lake	110	90	700
	825	Denton Creek	80	60	500
	826	Grapevine Lake	80	60	500
	839	Elm Fork Trinity River Below Ray Roberts Lake	80	60	500
	840	Ray Roberts Lake	80	60	500
East Fork	819	East Fork Trinity River	100	100	500
	820	Lake Ray Hubbard	100	100	500
	821	Lavon Lake	100	100	500
Upper Main Stem	806	West Fork Trinity River Below Lake Worth	100	100	500
	841	Lower West Fork Trinity River	175	175	850
Richland Chambers and Cedar Creek	814	Chambers Creek Above Richland-Chambers Reservoir	90	160	500
	815	Bardwell Reservoir	50	50	300
	816	Lake Waxahachie	50	50	300
	817	Navarro Mills Lake	50	75	300
	818	Cedar Creek Reservoir	50	100	200
	835	Richland Creek Below Richland-Chambers Reservoir	145	170	500
	836	Richland-Chambers Reservoir	75	110	400
	837	Richland Creek Above Richland-Chambers Reservoir	145	170	500
Lower Main Stem	803	Lake Livingston	150	60	500
	804	Trinity River Above Lake Livingston	150	150	600
	805	Upper Trinity River	175	175	850
	813	Houston County Lake	75	75	300
	827	White Rock Lake	100	100	400
Below Lake Livingston	801	Trinity River Tidal	N/A	N/A	N/A
	802	Trinity River Below Lake Livingston	125	100	600

A. The final rule is being reviewed by the EPA in consultation with the U.S. Fish and Wildlife Service.

B. The criteria for chloride, sulfate, and TDS are listed as maximum annual averages for the segment.

IMPACTS OF TOTAL DISSOLVED SOLIDS AND TOTAL DISSOLVED SOLIDS CONSTITUENTS ON WATER USES

Total dissolved solids and the total dissolved solid constituents may have an impact on residential, industrial/manufacturing, commercial, aquatic life, and agricultural/irrigation uses and on entities distributing and treating water and wastewater. These impacts may overlap various water use categories, and suitable guidelines and criteria do not exist for all of these impacts. With the exception of iron and manganese, the minor constituents of TDS (boron, iron, fluoride, manganese, nitrate) contribute to TDS to a lesser extent in the Trinity River Basin and are therefore not included in this section. Water consumed in the Trinity River Basin is used for municipal, industrial, and agricultural purposes. Municipal water use includes city-owned, districts, water supply corporations, or private utilities supplying residential, commercial, and institutional water. Regions C and H, the two primary regional water planning areas that encompass the Trinity River Basin, have significant municipal, commercial, and industrial water demands. Irrigation is also a major water demand in Region H. Figure 2 and Figure 3 document the water use, by percentage, for 2007 in Regions C and H.[1]

Figure 2. 2007 Region C Water Use

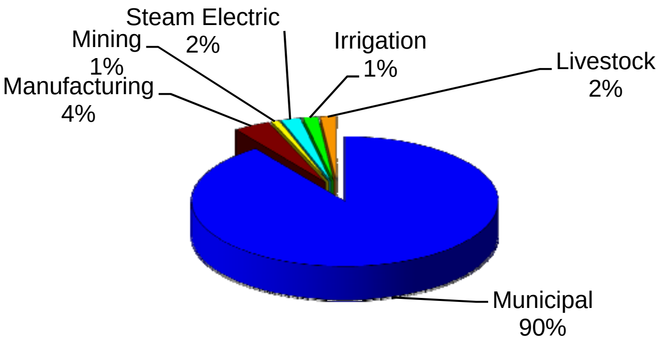
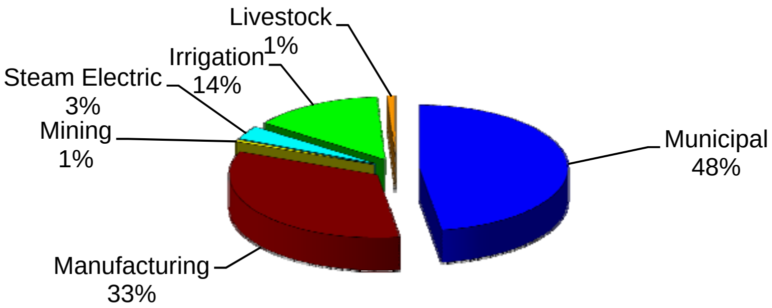


Figure 3. 2007 Region H Water Use



Residential Impacts

The impacts of total dissolved solids and the total dissolved solid constituents on residential uses are typically: reduced efficiency of detergents; reduced life of appliances and plumbing; and the cost burden on the home owner for water softening devices, under-the-sink reverse osmosis systems, and bottled water. Water hardness, the measurement of the polyvalent cations present in a water, is the main indicator for conditions that cause these nuisance issues. Several general guidelines related to the impacts of other constituents not related to water hardness are also documented in this section.

Impacts Associated With Water Hardness

The most common cations that contribute to hardness are Calcium (Ca^{3+}) and Magnesium (Mg^{+3}). Hard water has been associated with several residential nuisance issues. Waters with calcium carbonate ranges of 0 to 60 mg/L (milligrams per liter) are classified as soft; 61 to 120 mg/L is classified as moderately hard; 121 to 180 mg/L is classified as hard; and more than 180 mg/L is classified as very hard. Calcium carbonate concentration indicates the total amount of divalent salts present, and does not identify which constituents cause water hardness. [2]

Hard water is known to reduce the efficiency of detergents and soaps used in household cleaning and bathing. Calcium and magnesium are difficult to remove and may reduce the life of clothing. Hard water may also prevent the removal of soil and bacteria during bathing due to the buildup of soap film. Clothing washed in hard water may appear dingy, harsh, or scratchy. If clothing is washed in hard water continuously, the lifespan may be reduced by up to 40 percent. Bathing in hard water may also reduce the efficiency of soap during bathing, leaving a soap curd on the skin that prevents the removal of soil and bacteria. [2]

Hard water can contribute to inefficiency and higher operational costs of home appliances. Calcium and magnesium combine with other constituents such as bicarbonate, carbonate, and sulfate to form scale in boilers and other heat-exchanging equipment. This scale is heat retarding and can cause pipe clogging. Evaporative coolers and solar heating units can become coated with limescale deposits increasing the replacement frequency and maintenance costs.

Household water softeners are effective in reducing calcium and magnesium, but this process replaces calcium and magnesium with sodium, thus not reducing the overall TDS. Additionally, the calcium, magnesium, and additional sodium are released into the sanitary sewer system. “Under-the-sink” reverse osmosis units are effective in removing all salts and do not contribute to high TDS levels at wastewater treatment plants, as salts are periodically cleaned from the system. The cost burden for this additional treatment is passed onto the residential user.

Impacts Associated With TDS and TDS Constituents

Guidelines for appropriate concentrations of total dissolved solids and the total dissolved solid constituents for residential uses are documented in this section. As a general rule, water that contains 500 mg/L or less of TDS is desirable for drinking. High concentrations of magnesium in drinking waters may have a laxative effect, particularly on new users. Drinking water with chloride levels over 100 mg/L can have a salty taste and water with high chloride levels may have the potential to cause physiological damage. Sulfate is typically bitter to the taste at concentrations of 500 mg/L, and can be tasted by some at concentrations as low as 200 mg/L. Water with sulfate levels over 1,000 mg/L can have a laxative effect on users. Valence state iron (Fe2+) concentrations greater than 0.1 mg/L and manganese (Mn2+) concentrations greater than 0.2 mg/L precipitates when exposed to air and can cause increased turbidity, staining of fixtures, laundry, and cooking supplies, and may cause objectionable taste and colors in food and drinks. Although the use of bottled water will avoid the taste issues associated with salinity in water, it will not address detergent, plumbing, or appliance impacts. [2] Additional scientific studies on the potential health effects of specific types of dissolved salts are needed; and the TDS concentration at which taste becomes objectionable varies between individuals and changes as users become acclimated to specific TDS concentrations.

Industrial/Manufacturing Impacts

The most common uses of water in industrial/manufacturing applications are process water, boiler feed water, and cooling water. The potential impact levels for boiler feed and cooling water are more universal in nature than those for process water. The water quality requirements for process water are application specific; with some industries utilizing water softeners, reverse osmosis, and other advanced treatment technologies to achieve a desired quality. Some industries, such as textile, plastic, pulp, paper, and rayon, prefer concentrations of TDS less than 300 mg/L while the electronic chip manufacturing industry prefers ultra pure water with TDS concentrations close to 0 mg/L.[2] The most significant impact TDS and the TDS constituents may have on process water is the modification of treatment technologies with changing raw water quality concentrations.

For many industrial applications, TDS is associated with a reduction in the efficiency of cooling towers. Cooling towers use evaporative cooling to cool water for heat exchanger systems that provide air conditioning to many large commercial building and industrial complexes. As the water evaporates in this process, salts are lefts behind raising the concentration of salts with each cycle. In order to control the concentration of dissolved solids, water is only allowed to circulate through the system for a specific number of cycles. Accordingly, the permissible number of cycles for a high salinity source water may be lower than the number of cycles for a source water of lower salinity. Scaling issues can be controlled by chemicals increasing the allowable number of cycles, but fluctuations in makeup water TDS can require changes in the chemicals required for treatment.

TDS and the TDS constituents are also associated with a reduction in the efficiency of steam boilers due to foaming, scale formation, and corrosion. Sodium and potassium can combine with suspended solids to accelerate scale formation and corrosion in boilers at concentrations of 50 mg/L or higher. When heated, bicarbonate becomes carbonate, steam, and carbon dioxide. Carbonate combines with alkaline earth, primarily calcium and magnesium, to form calcium scale. Carbonate scale can prevent the flow of heat and fluids through pipes. Sulfate can combine with calcium to form heat retarding scale at concentrations of 250 mg/L or higher. [2]

Industry Specific Information

Industry specific preferences exist for some of the TDS constituents. The food processing industries prefer chloride levels to be less than 250 mg/L and textile processing, paper manufacturing, and rubber manufacturing prefer chloride levels less than 100 mg/L. Most industrial users prefer iron and manganese levels of less than 0.2 mg/L due to the precipitation potential of some species when exposed to air. Concentrations of 65 mg/L or higher of sodium and potassium can cause problems for ice manufacturers.[2]

Commercial Impacts

The commercial uses category is broad, typically including most uses not included in the residential, industrial/ manufacturing, and agricultural categories. However, the impacts of TDS and the constituents of TDS on commercial uses are very similar, with the exception of cooling towers, to residential uses. Hard waters (waters with high levels of calcium and magnesium) will reduce the life of appliances and plumbing, and reduce the efficiency of detergents used by schools, restaurants, hospitals, hotels, and other commercial buildings. Commercial water softeners are effective in reducing hardness in water, but contribute to high TDS levels at wastewater treatment plants. The cost burden for this additional treatment is passed onto the consumer.

While commercial cooling towers are typically less robust than those in the industrial sectors, the impacts are the same. If the source water has a high salinity, the number of allowable cycles may be smaller, to avoid precipitation of scaling of salts on equipment.

Aquatic Life Uses

Total Dissolved Solids has been identified as a potential stressor on biological conditions. The impacts of TDS and TDS constituent concentrations on aquatic ecosystems are not well understood. Aquatic species in general are adapted to an environment prone to rapid change in water quality. For example, flash flooding or prolonged drought may substantially alter conditions. Riverine species are especially well suited to endure such changes in the short-term; however, long-term impact on an individual species or complete ecosystem will vary depending on numerous interactive factors.

Fishes and macroinvertebrates are typically easy to examine for effects and may serve as indicators of changes in water quality. General observations regarding TDS constituents may be made, though the true effects of altered concentrations would have to be examined on a species-specific and likely site-specific basis to truly understand the results.

Calcium, a constituent of TDS, is important to many biological processes of fish, such as bone formation, blood clotting, and metabolic reactions. It is also vital to freshwater mussels for shell development and metabolic function. Ionic calcium in relatively high concentrations can aid maintenance of aquatic organisms' internal salt balance and reduce their loss of other salts such as sodium and potassium. Sodium and potassium are critical for heart, nerve, and muscle function in fishes and macroinvertebrates.[2]

Numerous freshwater mussel species and other macroinvertebrate species are reported to occur in the Trinity River Basin. Two of the freshwater mussel species, Texas heelsplitter (Potamilus amphichaenus) and Texas pigtoe (Fusconaia askewi) are state listed as threatened.[3] Listing of these species and general potential impacts over all freshwater mussel species in Texas is due to their sensitivity to water quality and physical habitat changes. Information regarding TDS and constituent concentration tolerance of individual species of freshwater mussels is not available, however.

Greater than 90 fish species are reported to occur in the Trinity River Basin, 10 of which are identified as intolerant to water quality changes. Total dissolved solids and constituent concentration tolerance limits are not available for these species. Limited information is available for some other fishes, which include the recreationally important and/or state regulated fishes: gizzard shad (*Dorosoma cepedianum*), channel catfish (*Ictalurus punctatus*), black basses [largemouth bass (*Micropterus salmoides*) and spotted bass (*M. punctulatus*)], white bass (*Morone chrysops*), and crappie [white crappie (*Pomoxis annularis*) and black crappie (*P. nigromaculatus*)].

Species-specific TDS and constituent concentration tolerance limits are not well defined for the species identified above. This discussion does, however, include information on TDS concentrations in which channel catfish, gizzard shad, black basses, white bass, and crappie thrive and/or are produced in hatchery settings. Much of the information available for channel catfish is derived from concentrated, high-yield production in fish hatcheries. These fishes can reproduce in a wide range of TDS concentrations; optimal range for channel catfish production in hatcheries is 500 to 3,000 mg/L.[4] Calcium is required for hardening of eggs and for normal bone and tissue development of channel catfish fry; water supplies should contain at least 30 mg/L of calcium hardness. Gizzard shad are tolerant of high TDS waters. For example, Lake Diversion, Texas, supports a viable gizzard shad population and has TDS concentrations as high as 3,185 mg/L with sulfate and chloride ions exceeding bicarbonate ions. In a more extreme example, gizzard shad survived in chloride ion concentrations up to 7,000 mg/L before they began to die in Great Salt Plains Reservoir, Oklahoma. A complete kill occurred when the chloride ion concentration rose to 11,000 mg/L.[5] Largemouth and spotted bass optimum TDS concentration is reported as 50–135 mg/L for productive waters. [6,7] White bass are found in waters with TDS of 100-800 mg/L. [8] White and black crappie maintain viable populations when TDS concentration is 100-350 mg/L.[9,10]

While these species are designated as important because of their respective fishery, regulation, or because they serve as forage for other fishes (i.e., gizzard shad), it should be noted that these species generally range throughout Texas and beyond. They are found among a broad range of water quality and habitat conditions throughout their respective ranges.

Golden Algae Considerations

Prymnesium parvum, an algal species more commonly known as golden algae, is a toxin producing algae which is known to cause mortality in gill-breathing organisms. When certain environmental conditions are present, the golden algae release chemicals that break up the cells of other organisms or immobilize them. The synthesis, release, and toxicity of these chemicals are dependent on a number of factors, including salinity, light, temperature, and nutrient availability. These environmental variables may have different effects on individual strains.

Further study on the conditions required for golden algae in lower TDS environments is needed. A recently published literature review of the environmental conditions required for *Prymnesium parvum* growth included a handful of studies where salinity was specifically reported.[11] When salinity was specifically reported, most were above 4,000 mg/L TDS.

For inland waters in Texas, a salinity of 22,000 mg/L, a temperature of 27°C, and a photosynthetic photon flux of 275 $\mu mol/m^3/s$[a] are predicted to be the optimal conditions for golden algae growth. However, non-optimal conditions for growth were found to increase toxin production and toxicity in inland waters in Texas with salinities of 4,000 mg/L or less in cooler months. [12] Texas Parks and Wildlife notes several risk factors for golden algae[12]:

- Previous golden algae blooms
- Region of the state where blooms are known to occur
- Alkaline soils and high pH (>7.0) waters have been found to be more susceptible to toxic events in Texas. This is probably due to a higher presence of the cations (e.g., dissolved metals) in the water required for the toxin to form.
- Fairly saline water (saline waters in central and west Texas appear to be suitable habitats for golden algae)

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[a] The photosynthetic photon flux (PPF) is a combination of irradiance and spectral quality and is a measure of the photosynthetically active photon irradiance. PPF is the maximum energy available; only a small portion of the photons actually are used to assimilate carbon.

Agricultural/Irrigation Uses

Water with high TDS concentrations has two potential impacts on agricultural and irrigation uses: a reduction in crop yields and the additional costs associated with flushing TDS from the root zone. Certain species are more tolerant of salts, and salt buildup is also a potential impact. Adequate drainage and the ability of a crop to consumptively use the constituents of TDS are important to crop growth.

Higher TDS water has a proven track record for turf grass and select crop irrigation throughout the United States. Accordingly, a large amount of information on TDS and turf grass irrigation is available and is included in Attachment 4. The following section describes the potential impacts of the following parameters on all irrigation uses: total dissolved solids; sodium adsorption ratio (calculated from sodium, calcium, and magnesium concentrations); residual sodium carbonate (calculated from carbonate, bicarbonate, calcium, and magnesium concentrations); and chloride.

Sodium Adsorption Ratio

The sodium adsorption ratio (SAR) is used as a measure of the sodium permeability hazard of the irrigation water. Accumulation of sodium in the soil changes the structure of the soil and causes low permeability and poor soil drainage. Clay soils are most susceptible to this change in structure. Calcium and magnesium counter the effects of sodium. SAR is calculated as the sodium concentration divided by the square root of one-half the sum of the calcium and magnesium concentrations. All quantities in this equation are in units of milliequivalents per liter. Evaluation of the soil permeability hazard must also account for the TDS concentration. Elevated TDS concentrations moderate the impact of sodium on soil permeability.

Waters with high sodium contents may cause dispersion of clay soils, which may create a relatively impermeable layer. This effect may be balanced by high calcium and magnesium levels “which will tend to keep soils permeable by exchanging with the sodium on the clay particles.”[2]

Residual Sodium Carbonate

When bicarbonate and carbonate ions exceed the calcium and magnesium ions, then the calcium and magnesium are precipitated as insoluble lime in the soil and as scale in irrigation lines.[13] The residual sodium carbonate (RSC) is calculated as the sum of the carbonate and bicarbonate concentrations minus the sum of the calcium and magnesium concentrations. All quantities in this equation are in units of milliequivalents per liter.

Precipitation of calcium and magnesium may cause the following problems[13]:

- Elevated SAR and greater sodium permeability hazard.

- Reduce the plant availability of calcium, magnesium, and potassium due to elevated sodium concentrations.
- Precipitated lime may reduce water infiltration in sandy soils.
- Elevated bicarbonate concentration can cause increased soil pH and plant deficiency in trace elements.

Chloride

Table 16 presents general information relating chloride concentration to irrigation impacts on sensitive trees and shrubs.

Table 16. Potential Impacts of Chloride on Sensitive Trees and Shrubs[13]

Constituent	**Degree of Use Restriction (mg/L)**			**Comment**
	None	**Slight to Moderate**	**Severe**	
Chloride	<70	70-355	>355	Soil accumulation and root toxicity
Chloride	<100	>100	NA	Foliage contact with sensitive ornamental plant

Soil Conditions

Site-specific soil conditions are necessary for predicting whether constituents will accumulate in the soil, whether they will alter the structure of the soil and change soil permeability, and whether they will affect soil pH. Due to the absence of site-specific soils information, the general ranges of potential impacts shown in the previous section should be used with caution.

Irrigation Schedule

As discussed above, the site-specific impacts of irrigation water quality depend on whether various constituents accumulate in the soil. This is partially determined by the permeability of the soil structure, but it is also influenced by the site-specific irrigation schedule. Applying more water than the plant takes up allows leaching of these constituents from the soil profile. The percentage of additional water necessary for leaching is called the “leaching fraction.” The leaching fraction is the ratio of the irrigation water conductivity to the soil water conductivity. To project site-specific impacts of irrigation water quality, it is necessary to determine the effectiveness of the irrigation program at leaching constituents from the soil profile.

Influence on Specific Species

In addition to site-specific information about soils and the irrigation schedule, site-specific species information should also be considered in a projection of potential irrigation water quality impacts.

Table 17 shows the general salt tolerance of various turf grasses. In the original reference, this table related soil water electrical conductivity to various turf grasses. According to the reference, the leaching fraction should be 0.67 to 1 under a "good leaching program."[13] Agriculture Handbook 60 says that the ratio of the soil water extract conductivity to the irrigation water conductivity ranges from 0.1 to 0.5.

The TDS concentrations in Table 17 were calculated using a leaching fraction of 0.5 and TDS (mg/L) =640 EC_w (dS/m or mmho/cm). Both of these relationships are approximate and should be used with caution. A poorly drained soil profile may result in a lesser leaching factor (and lesser estimated irrigation water TDS tolerance). The estimates for general irrigation water TDS tolerance resulting from the above equations mesh well with the potential range of TDS impacts shown in Table 17. Table 17 indicates that common bermudagrass is generally salt tolerant and that some hybrid Bermuda grasses are generally very salt tolerant. Table 17 may also be used to estimate the relative salt tolerance of various turf grasses.

TDS tolerance information for various crops is provided in Table 18. Tolerance is dependent on the salinity content of both the soil (soil moisture salinity) and the water. Salt tolerances in are defined by a 10 percent reduction or less in crop yields.

Table 17. Relative Salt Tolerance of Turf Grasses [13]

Turf Grass	Soil Water Extract Electrical Conductivity Tolerance (dS/m)	Description	Estimated Irrigation Water TDS Tolerance Range (mg/L)
Annual bluegrass	<1.5	Very sensitive	<480
Colonial bluegrass	<1.5	Very sensitive	<480
Rough bluegrass	<1.5	Very sensitive	<480
Centipedegrass	<1.5	Very sensitive	<480
Kentucky bluegrass	1.5-3.0	Moderately sensitive	480-960
Most zoysia species	1.5-3.0	Moderately sensitive	480-960
Creeping bentgrass	3-6	Moderately tolerant	960-1,920
Fine-leaf fescues	3-6	Moderately tolerant	960-1,920
Bahiagrass	3-6	Moderately tolerant	960-1,920
Buffalograss	3-6	Moderately tolerant	960-1,920
Blue grama	3-6	Moderately tolerant	960-1,920
Annual ryegrass	3-6	Moderately tolerant	960-1,920
Seaside bentgrass	6-10	Tolerant	1,920-3,200
Common bermudagrass	6-10	Tolerant	1,920-3,200
Tall fescue	6-10	Tolerant	1,920-3,200
Zoysia matrella (some)	6-10	Tolerant	1,920-3,200
Zoysia japonica (some)	6-10	Tolerant	1,920-3,200
Perennial ryegrass	6-10	Tolerant	1,920-3,200
Kikuyu	6-10	Tolerant	1,920-3,200
Wheatgrass	6-10	Tolerant	1,920-3,200
Hybrid bermudagrass (some)	10-20	Very tolerant	3,200-6,400
St. Augustinegrass	10-20	Very tolerant	3,200-6,400
Salt grass	10-20	Very tolerant	3,200-6,400
Alkaligrass	10-20	Very tolerant	3,200-6,400
Seashore paspalum	>20	Superior Tolerance	>6,400

Table 18. Salt Tolerance Information[2]

Crop	TDS (mg/L)[A]	
Mushrooms	highly insensitive	Low Salt Tolerance
Strawberries	427	
Beans	427	
Gladiolas	429-840	
Avocado	555	Medium Salt Tolerance
Grapes	640	
Carnations	640-1280	
Roots, bulbs, tubers	640-2560	
Apples	725	
Potatoes	725	
Corn	726	
Citrus	768	
Persimmons	768	
Macadamia	840	
Squash	853	
Poinsettias	1058-1728	High Salt Tolerance
Tomatoes	1067	
Cucumbers	1087	
Roses	1472	
Fescue	1864	
Bermuda Grass	2944	
Cotton		
Barley		
Alfalfa		

[A] During normal conditions, soil moisture salinity is approximately 1.5 * irrigation water salinity. During drought conditions, soil moisture salinity can be as much as 3.0 * irrigation water salinity.

Treatment Infrastructure Impacts

Some TDS constituents can impact both water and wastewater infrastructure. The water quality characteristics of water supplies will vary in quality depending on location of source, seasonal water quality, and factors which are generally case and site specific. Retrofitting both water and wastewater treatment plants to manage the potential impacts of TDS will increase treatment and disposal costs.

As the salinity levels of water supplies increase, water quality discharge compliance problems may be encountered at wastewater treatment facilities. Accordingly, as described in the irrigation and industrial use sections, higher TDS levels may affect the type of uses for reclaimed water. Sulfate and chloride are the primary constituents contributing to salinity related corrosion at water and wastewater facilities and may be controlled by using corrosion resistant materials such as stainless steel.

In addition to the corrosion potential of sulfate and chloride at water treatment plants, iron and manganese can result in aesthetic issues such as taste and odor, staining of laundry, and mineral deposits on plumbing fixtures. Secondary drinking water standards were established at 0.3 mg/L for iron and 0.05 mg/L for manganese to minimize these problems, but some utilities experience problems at lower concentrations. It has been recognized that manganese levels of 0.05 mg/L can deposit on system piping and later become resuspended in the water, causing significant consumer complaints.[21] Iron and manganese levels at which there are typically no noticeable aesthetic effects are 0.1 mg/L for iron and 0.02 mg/L for manganese.[21] Manganese concentrations as low as 0.02 mg/L have been problematic. Many cities have adopted treatment objectives of 0.01 – 0.015 mg/L for finished water manganese. [22,23]

COMPARISON OF IMPACT LEVELS TO TRINITY RIVER BASIN LEVELS

The average level of each TDS constituent measured in the Trinity River Basin was compared to the potential impact level identified in the literature review for major water use types. Table 19 presents the comparison for each major TDS constituent and municipal, commercial, and industrial impact concentrations.

Table 19. Comparison of Identified Impacts and Trinity River Basin Concentrations

Constituent Name	**Identified Impacts**												**Trinity River Concentrations (mg/L)**	
	Residential		**Commercial**		**Industrial/Manufacturing**		**Agricultural/Irrigation**		**Aquatic Life**		**Treatment Infrastructure**		**Average**	**95th Percentile**
	Concentration (mg/L)	**Impact**	**Concentration (mg/L)**	**Impact**	**Concentration (mg/L)**	**Impact**	**Concentration (mg/L)**	**Impact**	**Concentration (mg/L)**	**Impact**	**Concentration (mg/L)**	**Impact**		
TDS	500	Drinking Desirability			300	Textile, Plastic, Pulp, Paper, and Rayon Industry Desirability	<480	Impact concentration for very sensitive crops.	500 - 3,000	Optimal range for channel catfish production in hatcheries			256-288*	507-561*
	General reduction in the efficiency of cooling towers and steam boilers with increasing TDS.						480-960	Impact concentration for moderately sensitive crops.	50-135	Largemouth and spotted bass concentration for productive waters				
							960-1,920	Impact concentration for moderately tolerant crops.	100-800	White bass are found in waters with these concentrations.				
							1,920-3,200	Impact concentration for tolerant crops.	100-350	White and black crappie maintain viable population in these concentrations.				
							3,200-6,400	Impact concentration for very tolerant crops.	3,185	Concentration support gizzard shad in Lake Diversion, Texas.				

* The range in values represents the total filterable residue, field specific conductance, and specific conductance data (as described in the Phase I Study). In order to incorporate the conductivity measurements, an empirical conversion factor of 0.65, which is utilized by the TCEQ, was applied to the data in this table.

Table 19 (continued). Comparison of Identified Impacts and Trinity River Basin Concentrations

Constituent Name	Identified Impacts												Trinity River Concentrations (mg/L)	
	Residential		Commercial		Industrial/Manufacturing		Agricultural/Irrigation		Aquatic Life		Treatment Infrastructure			
	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Average	95th Percentile
Sodium	50	Scale and corrosion in boilers	50	Scale and corrosion in boilers	50	Scale and corrosion in boilers							41.2	99
					65	Ice Manufacturing Industry Desirability								
Calcium	Hard water can contribute to inefficiencies in equipment, high operational costs, heat retarding scale, pipe clogging.								30	Minimum calcium concentration for bone and tissue development in catfish fry.			54.1	97
	Hard water may also reduce the life of clothing and prevent removal of soil and bacteria during bathing.													
Potassium	50	Scale and corrosion in boilers	50	Scale and corrosion in boilers	50	Scale and corrosion in boilers							5.8	11
					65	Ice Manufacturing Industry Desirability								

* The range in values represents the total filterable residue, field specific conductance, and specific conductance data (as described in the Phase I Study). In order to incorporate the conductivity measurements, an empirical conversion factor of 0.65, which is utilized by the TCEQ, was applied to the data in this table.

Table 19 (continued). Comparison of Identified Impacts and Trinity River Basin Concentrations

Constituent Name	Identified Impacts												Trinity River Concentrations (mg/L)	
	Residential		Commercial		Industrial/Manufacturing		Agricultural/Irrigation		Aquatic Life		Treatment Infrastructure			
	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Average	95th Percentile
Magnesium	Hard water can contribute inefficiencies in equipment, high operational costs, heat retarding scale, pipe clogging.												6.9	15
	Hard water may also reduce the life of clothing and prevent removal of soil and bacteria during bathing.													
	High concentrations of magnesium in drinking waters may have a laxative effect.													
Chloride	100	Salty Taste			250	Food Processing Industry Desirability			7,000	Chloride concentration before gizzard shad began to die in Oklahoma.	Can cause salinity related corrosion at water and wastewater facilities.		64.1	148.3
					100	Paper and Rubber Manufacturing Desirability								
Sulfate	500	Bitter Taste			250	General Industry Desirability					Can cause salinity related corrosion at water and wastewater facilities.		57	137
	1000	Laxative Effect												

* The range in values represents the total filterable residue, field specific conductance, and specific conductance data (as described in the Phase I Study). In order to incorporate the conductivity measurements, an empirical conversion factor of 0.65, which is utilized by the TCEQ, was applied to the data in this table.

Table 19 (continued). Comparison of Identified Impacts and Trinity River Basin Concentrations

Constituent Name	Identified Impacts												Trinity River Concentrations (mg/L)	
	Residential		Commercial		Industrial/Manufacturing		Agricultural/Irrigation		Aquatic Life		Treatment Infrastructure		Average	95th Percentile
	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact	Concentration (mg/L)	Impact		
Carbonate	Carbonate combines with alkaline earth, primarily calcium and magnesium, to form calcium scale. Carbonate can also prevent the flow of heat and fluids through pipes.												4.3	19
Bicarbonate	When heated, bicarbonate becomes carbonate, steam, and carbon dioxide. Carbonate combines with alkaline earth, primarily calcium and magnesium, to form calcium scale. Carbonate can also prevent the flow of heat and fluids through pipes.												158.5	260
Manganese	Manganese can result in aesthetic issues such as taste and odor, staining of laundry, and mineral deposits on plumbing fixtures.										0.05	Can cause deposits on system piping, become resuspended, and cause customer complaints.		
											0.02	Concentration at which aesthetic effects begin.	0.07	0.29
Iron	Iron can result in aesthetic issues such as taste and odor, staining of laundry, and mineral deposits on plumbing fixtures.										0.1	Concentration at which aesthetic effects begin.	0.09	0.35

* The range in values represents the total filterable residue, field specific conductance, and specific conductance data (as described in the Phase I Study). In order to incorporate the conductivity measurements, an empirical conversion factor of 0.65, which is utilized by the TCEQ, was applied to the data in this table.

CONCLUSIONS

Within the majority of the Trinity River Basin, TDS and TDS constituents generally occur at concentrations below what are known to cause water use and regulatory impacts. However, with the projected population increases in the region, and the associated introduction of new water sources and increased water usage, TDS levels are expected to increase over time within the Trinity River Basin. In order to beneficially use the region's water resources, the continued study of the levels and potential impacts of TDS and TDS constituents should be an important component of future planning efforts within the Trinity River Basin. The development of a long term management plan for the Trinity River Basin should be developed to control and mitigate the potential future impacts of TDS on water uses.

Recommendations

Several activities, including economic evaluations, detailed aquatic life studies, and water quality monitoring, should occur prior to developing a long term management plan. While potential impacts associated with treated water sources can often be mitigated or reduced with enhanced treatment technologies, an economic analysis comparing point of use treatment, enhanced water treatment at municipal and industrial facilities, and raw water supply control should be conducted to help define the most appropriate strategy. Although treatment technologies can mitigate potential impacts of TDS on the municipal supply, the impact of TDS on aquatic life uses must be controlled in the raw water supply through the cooperation and planning of regulatory agencies and stakeholders. In order to develop control strategies for Trinity River Basin segments, further quantification of the relationship between TDS and Trinity River Basin aquatic life should be developed. Economic evaluations and aquatic life studies will both be supported by the continued water quality monitoring at locations throughout the Trinity River Basin. Following the completion of these activities, coordinated efforts involving state agencies and stakeholders to develop a long term TDS management plan will aid in the protection of municipal, industrial, agricultural, and aquatic life uses within the Trinity River Basin.

Specific activities that are needed to develop a management plan are described below.

Aquatic Life Studies

- Limited data is available regarding the relationship between TDS and aquatic life in specific Trinity River Basin habitats. Future actions should include formation of a task force (including representatives from Texas Parks and Wildlife Department, Texas Commission on Environmental Quality, Trinity River Authority, other regional stakeholders and technical specialists) to identify specific species and species studies to further evaluate the impacts of TDS and TDS constituents on aquatic life. When completed, these studies may be used as a resource for future regulatory and planning efforts to determine TDS goals for specific segments.
- Further define the variability of species in the Trinity River basin based on TDS concentrations.

Water Quality Monitoring

- Long term monitoring of TDS and TDS constituents within the Trinity River Basin at critical areas (water supply sources and key aquatic life locations).
- Increased monitoring frequency in areas known to be impacted by significant changes in TDS conditions. This monitoring would provide the most benefit if it was conducted in conjunction with future aquatic life studies and environmental flow gathering programs in the same area.

Economic Evaluations

- An economic evaluation of treatment options for industrial and commercial uses. This evaluation would consider the cost of point of use treatment versus raw water supply control.
- An economic evaluation of treatment options for municipal supply. This evaluation would consider the cost of point of use treatment, raw water supply control, and enhanced treatment at municipal water treatment plants.
- An economic evaluation of “no action”, i.e. not controlling TDS concentrations through point of use treatment, raw water supply control, and enhanced treatment at municipal water treatment plants.

Regional Water Planning Efforts

- Evaluation of the long term potential impacts of adopted water management strategies on TDS and TDS constituents in the Region C and Region H water planning efforts.
- Following the completion of the aquatic life studies, water quality monitoring, and economic evaluations, workshops with stakeholders would aid in the development of a long term TDS management plan for the Trinity River Basin.

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