Appendix 7G

Lake Travis Contamination Modeling

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Lake Travis, located northwest and upstream of Austin Texas, was formed by the construction of Mansfield Dam across the Colorado River in 1939. Mansfield Dam is 266 feet high and 7,089 feet long. Lake Travis is about 64 miles long and its maximum width of 4.5 miles. At normal levels, the lake covers 18,929 acres with a capacity of 1,170,752 acre-feet.

In addition to the Colorado River, Lake Travis is fed by the Pedernales River. The Pedernales River enters the reservoir about 30 miles upstream from the dam. At the normal pool levels, the lake inundates the river a distance of about 10 miles upstream from its mouth.

The Army Corps of Engineer's CE-QUAL-W2 two dimensional water quality model was used to estimate the transport of contaminants through Lake Travis. CE-QUAL-W2 is a two-dimensional, longitudinal/vertical, hydrodynamic and water quality model. Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow waterbodies exhibiting longitudinal and vertical water quality gradients. The model predicts water surface elevations, velocities, and temperatures. The water quality component of the model includes advection, dispersion, and decay. Inputs to the model include the magnitude and temperature of inflows, the magnitude of outflows, bathymetry, and meteorology. Time dependent data such as meteorology and inflow data can be input at any time period (e.g., hourly, monthly) (Cole, 1995).

The bathymetry of the reservoir is represented in the model by dividing the reservoir into a series of segments. The length of each segment is user defined and the total length of the segments equals the length of the reservoir. Each segment is further subdivided into layers with a user defined thickness and a width equal to the average reservoir width at that location.

Volatilization is not included in the CE-QUAL-W2 model. The effects of volatilization on concentration were estimated outside of the model based on procedures described in Thomann and Mueller (1987). The concentration of material in a one-dimensional water body due to an instantaneous spill is Thomann and Mueller (1987):

$$C(x,t) = \frac{M}{2A\sqrt{pEt}} \exp(\frac{-(x-Ut)^2}{4Et} - Kt) \quad (1)$$

Where:

C(x,t)	=	concentration at a distance x and time t [mg/L]
M	=	mass of spilled material [kg]
A	=	cross-sectional area of mixed layer depth in reservoir [m^2]
E	=	longitudinal dispersion coefficient [m^2/s]
U	=	average velocity in reservoir [m/s]
K	=	loss rate due to volatilization [1/s]

The size of the mixed layer and average velocity in the mixed layer were obtained from the CE-QUAL-W2 model results. The loss rate due to volatilization was estimated based on "two film" theory. This theory assumes that volatilization takes place across two thin layers, one in the water and one in the air. The rate of volatilization, the volatilization transfer coefficient, is the harmonic mean of the transfer coefficient through water and air (Thomann and Mueller, 1987):

$$\frac{1}{k_l} = \frac{1}{K_l} + \frac{1}{K_g H_e} \quad (2)$$

Where:

k_l	=	volatilization transfer coefficient [m/s]
K_l	=	the liquid film coefficient [m/s]

K_g = the gas film coefficient [m/s]

H_e = Henry's constant [atm*m^3/mole]

The liquid film coefficient, K_l, is assumed to be related to the oxygen transfer rate and the ratio of the diffusivity of oxygen to the diffusivity of the chemical of interest in water. Since the diffusivity of a chemical can be related to the chemical's molecular weight, a simple relationship for liquid film coefficient can be stated (Thomann and Mueller, 1987):

$$K_l = (\frac{32}{M})^{1/4} K_L \qquad (3)$$

Where:

M = molecular weight of the chemical [g/mole]

K_L = oxygen transfer rate [m/s]

The oxygen transfer coefficient is the oxygen reaeration coefficient calculated as:

$$K_L = (D_L \frac{U}{H})^{1/2} \qquad (4)$$

where:

D_L = oxygen diffusivity [m^2/day]

U = average velocity in the reservoir mixed layer [m/s]

H = mixed layer depth [m]

The gas film coefficient was calculated similarly using equation 5 (Thomann and Mueller, 1987):

$$K_g = 168(\frac{18}{M})^{1/4} U_w \qquad (5)$$

where:

M = molecular weight [g/mole]

U_w = wind speed [m/s]

Note, that it was assumed that the concentration of the chemical of interest in air above the reservoir surface is zero. It was also assumed that if the chemical was predominately below the surface of the reservoir that volatilization was negligible.

3.1 INFLOW DATA

Data for the Pedernales and Lower Colorado River include temperature and flow rate. Inflow to Lake Travis from the Lower Colorado River was assumed to equal the release flows from Lake Marble Falls which were obtained from LCRA. Monthly average release flows for the years 1989 through 1998, excluding 1992, were used as input. Year 1992 was an extreme flow year. If data from 1992 were included in the calculation of the monthly average flow rate, the average flow rates for January through March would be from 20 to 70 percent larger.

The average flow in the Pedernales River was obtained from daily flow records in the Pedernales River Near Johnson City for USGS gage #08153500 for the years 1939 through 1997. Table 3-1 below shows the inflows used in the model.

Table 3-1
Average Monthly Flow in the Colorado and Pedernales River

Month	Colorado [m^3/s]	Pedernales [m^3/s]
January	12.5	3.64
February	25.6	6.00
March	42.1	4.79
April	31.4	6.91
May	51.3	9.61
June	86.8	9.66
July	25.0	2.92
August	29.4	3.37
September	30.1	5.74
October	24.6	6.45
November	12.3	2.50
December	51.0	5.14

Temperature data were not available for the Colorado and the Pedernales rivers. It was assumed that the average monthly river temperatures were equal to the average monthly air temperatures.

3.2 OUTFLOW DATA

Daily outflow data from Lake Travis was obtained from LCRA for the years 1989 through 1999 except for 1992 and 1995 when only monthly totals were available. These data were used to calculate the average daily release flows from the reservoir. Because 1992 was an extreme year, 1992 data were not used to calculate the averages. Figure 3-1 shows the outflow data used in the analysis.

3.3 METEOROLOGY DATA

Meteorology data consists of air temperature, cloud cover, relative humidity, and wind speed and direction. Mean monthly values were used. Data were obtained from the National Climatic Data Center (NCDC), “Local Climactic Data for Austin Texas.” Table 3-2 lists the data used in the model.

Table 3-2
Mean Monthly Meteorology Data for Austin Texas
(NCDC)

Month	Air Temperature [°C]	Dew Point Temperature [°C]	Wind Speed [m/s]	Wind Direction [radians]	Cloud Cover [tenths]
January	9.3	3.6	4.2	0.0	6.3
February	11.5	5.4	4.4	3.14	6.1
March	16.9	8.5	4.6	2.79	6.0
April	20.9	12.5	4.5	3.14	6.2
May	24.2	18.2	4.2	2.79	6.2
June	27.4	20.9	3.9	3.14	5.2
July	29.2	21.1	3.7	3.14	4.7
August	29.3	20.9	3.4	3.14	4.6
September	26.8	18.8	3.5	3.14	5.0
October	21.7	14.4	3.6	3.14	4.7
November	16.0	9.3	4.0	3.14	5.4
December	10.9	5.4	4.0	0.0	6.0

3.4 BATHAMETRY DATA

A digitized bathymatric map of Lake Travis was supplied by LCRA (this data is considered LCRA proprietary). The map was used to generate the segments and layers used in the model. Table 3-3 (at end of text) presents the data used for the main body of Lake Travis including the length of each segment, the distance from the dam to the downstream end of the segment and the width of each layer. Table 3-4 presents the data used to model the Pedernales branch of the reservoir. The Pedernales branch joined the main branch at Segment 11.

Table 3-3
Model Segment and Layer Width Data Used in the CE-QUAL-W2 Model

Layer No.	Layer Width (meters)																	
Seg. No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Length	7620.	4572	4572	6096	6096	6096	6096	6096	4572	4572	6096	6096	3048	4572	6096	6096	6096	7620
Dist. From Dam	94489	88393	83821	78487	72391	66295	60199	54103	48769	44197	38863	32767	28195	24385	19051	12954	6858	0
2	92	317	259	448	477	536	336	443	456	715	504	770	849	1154	1096	1023	2128	966
3	53	200	258	228	271	368	287	386	390	453	382	500	670	673	852	924	997	922
4	11	70	214	194	229	316	239	349	353	371	343	472	632	623	732	816	932	877
5			54	142	187	254	201	298	306	312	319	445	596	567	592	661	841	840
6			26	87	145	206	178	258	269	290	302	421	562	528	529	552	786	776
7			8	31	90	168	153	224	241	265	283	387	518	504	492	492	744	687
8					28	87	101	164	204	230	258	338	446	466	465	477	701	616
9						15	33	94	161	193	231	285	345	404	443	446	639	558
10								32	98	151	199	241	259	351	416	397	580	520
11									30	65	135	201	212	285	346	354	533	484
12											44	131	179	208	259	302	443	411
13												67	146	167	205	259	327	340
14												27	75	121	167	221	249	296
15													11	64	125	177	210	255
16														19	66	127	167	213
17															16	51	103	172
18																	33	107

Table 3-4
Model Segment and Layer Width Data Used in the CE-QUAL-W2 Model for the Pedernales Branch of Lake Travis

Layer No.	Layer Width (meters)				
Seg. No.	22	23	24	25	26
Length [m]	4572	3048	3048	3048	1524
Distance From the mouth [m]	12192	8382	5334	2286	0
2	113	155	213	242	254
3	102	131	148	187	226
4	57	80	104	153	189
5		24	83	123	155
6		4	53	90	128
7			10	50	99
8				15	57
9					16

3.5 MODEL VERIFICATION

Simulations were conducted starting on January 1 with the reservoir at a constant temperature of 12°C. Data were not available to calibrate the model. However, reservoir profiles at seven stations for each month of the year 1988 were available for comparison. Since 1988 meteorology data were not available for the simulations, the comparison is meant as a “reality” or reasonableness check rather than a calibration.

Profiles of temperature collected monthly in 1988 were compared to predicted temperature values. Figure 3-2 compares observed and predicted seasonal temperature profiles. The model showed a quicker warming of the surface of the lake and a slower forming of the mixed layer but showed similar mixed layer depth and general surface temperatures. Figure 3-3 compares measured temperatures for July to predicted July temperatures. The figures indicate that the model reasonably reproduces the thermal stratification in the reservoir. The data indicated that the reservoir was basically one-dimensional, with temperature, consistent with the predicted values.

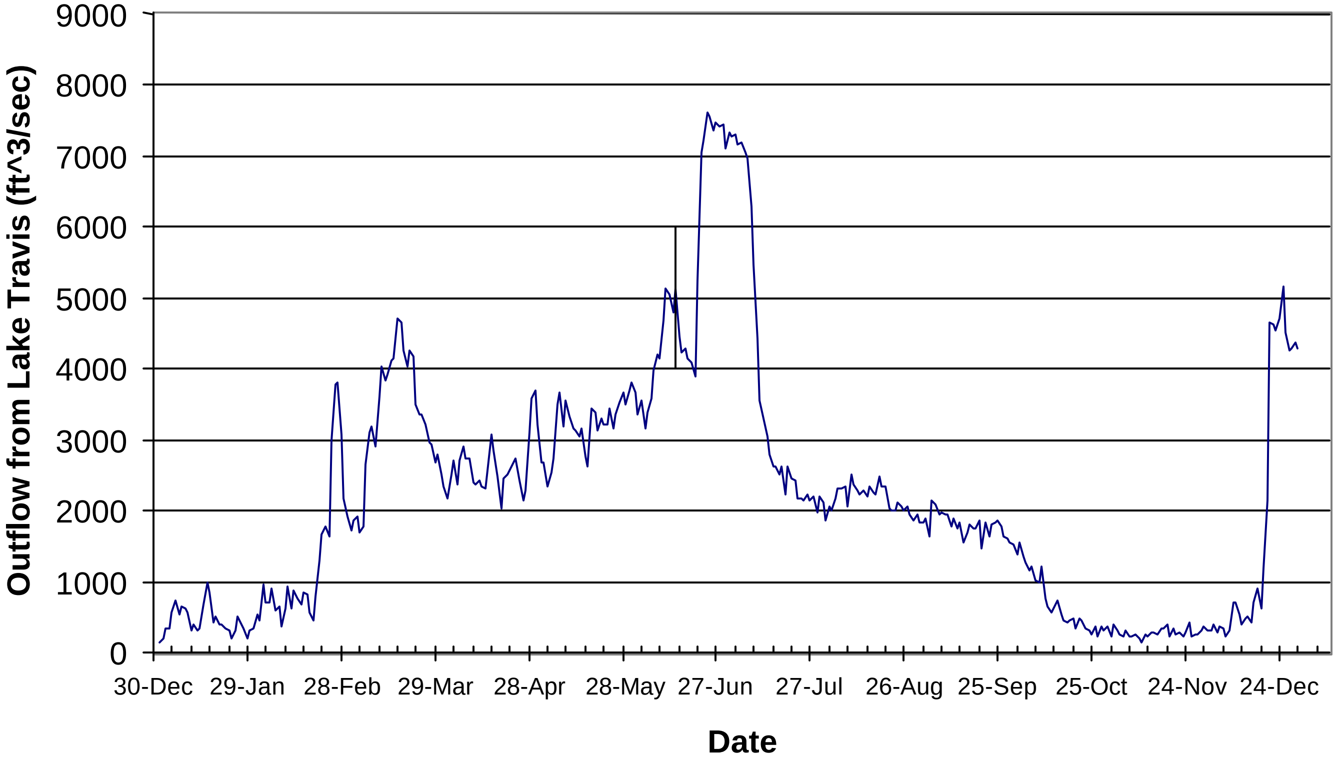

Figure 3-1
Average Outflow from Lake Travis

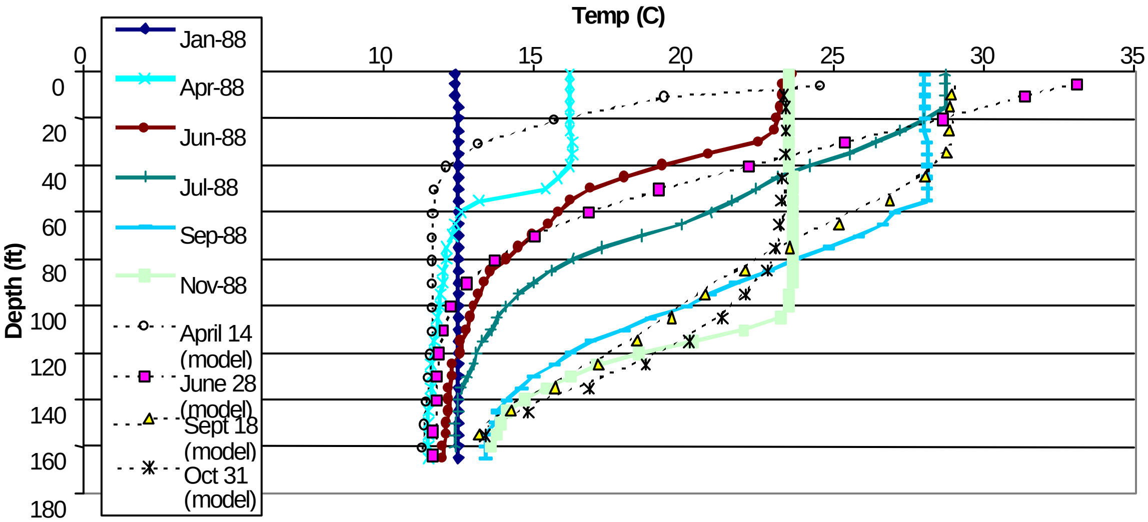

Figure 3-2. Comparison Between 1988 Temperature Profiles for Lake Travis and Model at Dam

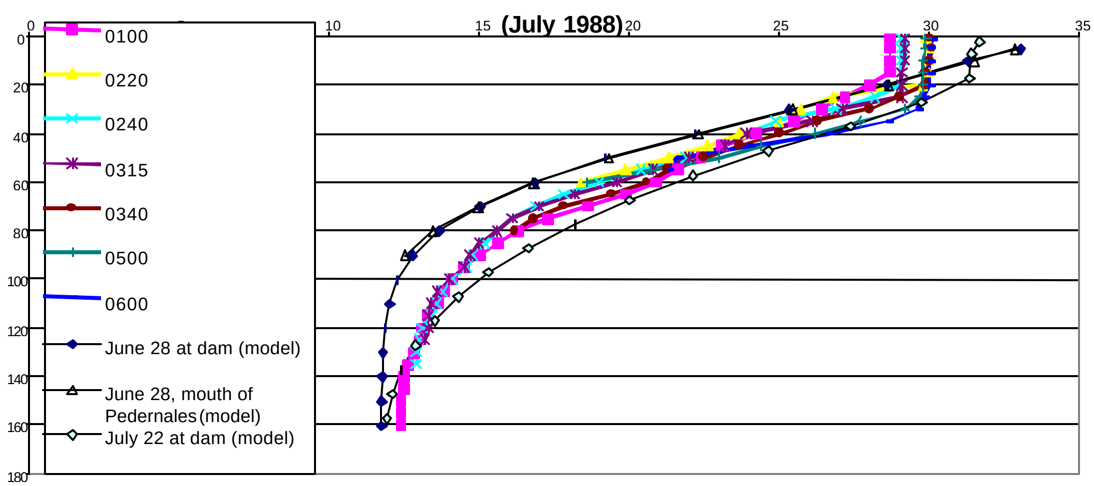

Figure 3-3. Temperature Profiles for All Sites on Lake Travis

4.1 TARGET ANALYSES

The modeling which was performed was carried out in three stages. In the first stage, modeling was performed to determine the concentration of the contaminants MTBE and benzene that would be reached at two critical points in Lake Travis – near Lago Vista, 28 to 31 miles from Mansfield Dam, and at the penstocks to Mansfield Dam. Lago Vista is the first public water supply system which would be impacted by a spill in the Pedernales watershed, and is used to represent the risk to Lake Travis communities. Water flows through the Mansfield Dam into Lake Austin, approximately 15-20 miles upstream from city of Austin water supply intakes. This modeling was performed in order to refine statements made in the draft EA that a spill in the Pedernales watershed of gasoline containing MTBE could result in non-potable concentrations of MTBE in Lake Travis for a prolonged period of time.

In the second stage, a set of iterative runs were performed to determine the maximum spill volume which could occur at the Pedernales crossing under flood flow conditions, in response to a request by the LCRA that restrictions in pipeline pumping rates might mitigate the risks posed by a release during flood stages.

In the third stage, two separate modeling runs were performed to evaluate the sensitivity of the model to specification of what level in the lake contaminants from the Pedernales would mix into lake water. In one run, it was assumed that the contaminants would all mix into the epilimnion due to a warm inflow to Lake Travis, posing the highest risk to landowners and communities along Lake Travis who primarily draw domestic water from above the thermocline. In a second run, it was assumed that the contaminants would all mix into the hypolimnion due to a cold inflow to Lake Travis, posing the highest risk to the city of Austin supply as reductions in concentration would not take place through volatilization once contaminated Pedernales water mixed into the lake.

4.2 SELECTION OF MODELED SPILL DATE

Lake Travis is not operated uniformly throughout the year. The seasonal variation in outflow from Lake Travis can be seen in Figure 3-1. The outflow from Lake Travis in the summer is 7 times greater than the winter outflows. This variation in flow rate has a significant impact on the transport of contaminants through the reservoir. During high flow periods contaminants will be advected relatively quickly through the reservoir and deeper into the reservoir (towards the low level outlet). There will be little opportunity for volatilization. During low flow periods, advection through the reservoir is insignificant and transport is primarily due to diffusion. Contaminants are more likely to stay near the surface where volatilization can reduce concentrations.

Figure 4-1 shows the 30-day running average residence time in the reservoir based on the outflow rate. It was calculated as the volume of the reservoir divided by the outflow rate. It is a measure of the average time that a particle of water would remain in the reservoir. During the summer the residence time is less than one year. During the winter the residence time is several years. The critical period (i.e., the period that would produce the maximum concentration at the dam) would be when the residence time is the shortest. This would minimize the opportunity for volatilization and also would result in the deepest contamination since most of the advection occurs deep in the reservoir due to the low level outlet. Therefore, the simulations were conducted assuming that the spill entered the lake on March 1.

4.3 IMPACTS OF SPILL EVENLY MIXED INTO LAKE TRAVIS

Two spill sizes were modeled as inputs to Lake Travis. Both occur during flood stages in the Pedernales River. Under the first spill size, approximately 83,000 gallons, RJ Brandes modeled that approximately 620 kg of benzene and 30,000 kg of MTBE would reach mile 10 on the Pedernales River. Under the second spill size, approximately 270,000 gallons, Brandes modeled that approximately 2,100 kg of benzene and 70,000 kg of MTBE would reach mile 10 on the Pedernales River.

The first set of model runs was performed using both modeled spill sizes, with a spill being distributed evenly between the hypolimnion and epilimnion upon passing from the Pedernales River to Lake Travis. No volatilization term was incorporated into these analyses. Data showed that under lower spill volumes and these conditions, MTBE concentrations would be in excess of the 20 ppb target standard at both Model Segment 12 (Lago Vista) and at Mansfield Dam. No excesses of 5 ppb benzene were modeled at Segment 12 or at Mansfield Dam. These results were repeated for the higher spill volume.

4.4 CALCULATION OF SPILL VOLUME THAT RESULTS IN WATER QUALITY EXCEEDANCE

4.4.1 Spill into Lake Travis Assuming No Volatilization

As MTBE was determined during the first modeling stage to provide the greatest risk to drinking water quality, multiple runs were performed to determine a maximum mass of MTBE which could enter Lake Travis and not cause an exceedance of 20 ppb at the penstocks to Mansfield Dam.

It was determined iteratively that without volatilization a spill with a mass of 8,400 kilograms of MTBE discharged into Lake Travis at about mile 10 on the Pedernales River will result in a concentration of MTBE at the Dam and intake of 20 ppb. Figures 4-2 and 4-3 show the concentration of MTBE in the lake at two locations between the dam and the mouth of the Pedernales River for an 8,400 kg spill into the lake.

As shown in the figures, over time the MTBE gets drawn deeper into the reservoir as the outflow rates increase. However, some of the MTBE does remain near the surface above the thermocline. This MTBE gets drawn down to the intake after arriving at the dam resulting in two peaks at the intake. The first peak is due to the MTBE that arrived at the dam from the surface flows (which is later pull down toward the intake). The second peak is due to the MTBE that arrived due to deeper flows. Figure 4-4 shows the profile of the MTBE concentration at the dam.

Figure 4-5 shows the time history of maximum MTBE concentration at the dam and other locations for an 8,400 kg discharge into the Lake. At the dam, the concentration is predicted to remain near 20 ppb for about 130 days. Note that the concentration in the discharge would be lower since the intake withdrawals water over a range of depths.

A benzene spill into the reservoir will behave similarly as the MTBE transport discussed above. A spill into Lake Travis of about 1,930 kg will result in a maximum concentration at the dam of 5 ppb. Figure 4-6 presents the predicted concentration of benzene at the dam and at segments 12 and 16 similar to Figure 4-5 for MTBE.

4.4.2 Spill into Lake Travis With Volatilization

As shown in Figures 4-2, 4-3, and 4-4 much of the MTBE will be below the surface of the reservoir and therefore not available for volatilization. However, assuming that the spill enters the Pedernales River at the surface it will remain near the surface until it enters the main body of the reservoir. During this period volatilization will occur. The rate at which volatilization occurs depends upon the depth of the MTBE.

CE-QUAL-W2 indicates that the MTBE will be in the top five meters of depth in the Pedernales River and most will be in the top 3 meters. At these depths significant volatilization can occur. Table 4-1 below summarizes data from Squillace, Pankow, Korte and Zogorski (1997) on the half-life of MTBE in streams or rivers under calm conditions. They presented results for several velocities, however, only the lowest velocity which apply to lakes are presented in the table. These half-lives are shorter than the value of 137 days reported by EPA (1994) for lakes.

Table 4-1
Estimated Half-life of MTBE in Slow-moving Water Bodies (velocity = 0.032 m/s)
(from Squillace, Pankow, Korte and Zogorski (1997))

Water Depth (m)	Half-life at 5 °C (days)	Half-life at 25 °C (days)
0.1	0.17	0.063
0.32	0.72	0.32
1.0	3.3	1.7
3.2	16	8.9
10	85	49

For slow-moving water, 3.2 meters deep the expected half-life is between 9 and 16 days.

In lakes volatilization is limited by transport of the compound within the water phase (as opposed to through the air-water interface). This results in volatilization rates approximately independent of the value of Henry's law constant (i.e., independent of the volatility of the compound) (Squillace et al., 1997). For example, MTBE and benzene can volatilize to the atmosphere during certain flow conditions at essentially the same rate even though they have different Henrys law values (Squillace et al., 1997). Therefore, the values for volatilization for MTBE and benzene should be about the same.

Table 4-2 show the data used in the MTBE volatilization calculations. The volatilization transfer coefficient is calculated to be 0.044 m/day, equal to a half-life of 15.7 days. This is consistent with the results reported by Squillace, Pankow, Korte and Zogorski (1997) shown in Table 4-1.

The concentration in the Pedernales River was re-calculated including volatilization. Figure 4-7 shows the results after 15 days. These results indicate that about half of the MTBE could volatilize if the spill enters the lake at the surface and remains there for at least several weeks. After this time, the model indicates that the plume enters the main body of the lake and the peak concentration is no longer at the surface. Under these circumstances a spill mass of about 16,800 kg could enter the lake and still not exceed 20 ppb at the dam.

4.5 WORST CASE ANALYSIS

A worst case analysis was conducted for a spill into the Pedernales River in order to evaluate extreme mixing scenarios. The worst case scenario assumes a 272,000 gallon gasoline spill into the Pedernales River, with a flow rate in the river was of 5,000 cfs occurring during the spill (storm conditions). This mass of MTBE and benzene discussed in 4.4.1 were input to the lake model and the concentrations at the dam and other locations predicted. Because of the uncertainty in when the spill could occur, the river at the time of the spill could be either positively or negatively buoyant. Two scenarios were modeled: first, assuming that the Pedernales River was warmer than Lake Travis and, therefore, positively buoyant; and second, the river was colder than Lake Travis and, therefore, negatively buoyant.

4.5.1 Positively Buoyant Spill into Lake Travis

The spill was modeled similar to the spill results discussed in Section 4.2 except the Pedernales River was assumed to be warmer than Lake Travis and, therefore, the Pedernales inflow would stay near the surface of the lake. In March, top layers of Lake Travis were modeled at 16°C, while lower layers were at 11°C. In this case volatilization could occur. Data used for the volatilization is the same as presented in Table 4-2.

Figure 4-7 shows the results at the mouth of Pedernales River. At the mouth of the river the peak concentration of MTBE is about 8 mg/L if volatilization is ignored; however, including volatilization, reduces the peak concentration to about 3 mg/L. The concentration of MTBE is further reduced when the Pedernales River enters Lake Travis, due to dilution. Because volatilization is partially driven by the concentration gradient between the air and lake, after MTBE is mixed into Lake Travis, the volatilization rate is reduced. Figure 4-8 shows the concentration of MTBE in the surface layer at Lago Vista. The peak concentration is about 400 ppb. Figure 4-9 shows the concentration profile at Lago Vista at the time of the peak concentration. The MTBE is confined to the top 6-7 meters.

For benzene the maximum concentration without volatilization is about 0.24 mg/L at the mouth of the Pedernales River. After mixing with Lake Travis and including volatilization, the concentration is reduced to about 12.2 ppb. The results for benzene are shown in Figure 4-10. Figure 4-11 shows the concentration profile for benzene at Lago Vista at the time of the peak concentration. The benzene is confined to the top 6-7 meters.

Table 4-2
Data Used in Volatilization Calculation in the Pedernales River
(benzene value in parenthesis)

Parameter	Value	Unit	Comment
(data for transfer coefficient)			
Henry's Law Constant	5.50E-04 (5.43e-03)	atm m^3/mole	USEPA (1994)
Universal gas constant	8.21E-05	atm*m^3/K/Mole	
Molecular Weight	88.15 (78.11)	g/mole	
Diffusivity of Oxygen	0.000181	m^2/day	Thoman and Mueller (1987)
Dimensionless Henry's Law	0.022875 (0.2258)		
(Reservoir Data)			
Time to peak concentration	15	Days	from CE-QUAL 2
Mixed Layer Depth	3.37	M	from CE-QUAL 2
Average Wind Speed	3.7	m/s	
Surface Temperature	20	C	
slope of reservoir bottom	5.00E-08		
average reservoir width	200	M	
Distance	6.6	Miles	
Calculated Values			
Average water velocity	0.008198	m/s	from CE-QUAL 2
water velocity	0.026889	ft/s	
water depth	11.0536	Feet	from CE-QUAL 2
average width	656	Feet	
Time to peak concentration	1296000	Seconds	15 days
Oxygen transfer rate	0.195	m/day	
Liquid film coefficient	0.151	m/day	
Gas Film Coefficient	417.85	m/day	
Water Temperature	298	K	
Volatilization transfer coefficient	0.044212 (0.066787)	m/day	15.7 half – life (10.3)

4.5.2 Negatively Buoyant Spill into Lake Travis

The spill was modeled similar to the spill results discussed in Section 4.2 except the Pedernales River was assumed to be colder than Lake Travis and, therefore, the Pedernales River inflow would sink into Lake Travis and travel below the thermocline. In this case there would be no volatilization. Two cases were modeled for benzene – Pedernales River water at 14°C (which would enter right below the thermocline), and Pedernales River water at 10°C (which would sink to the bottom of Lake Travis).

Figure 4-12 shows the results for MTBE at the dam. The peak concentration of MTBE is about 1.1 mg/L. Figure 4-13 shows the concentration profile and outflow profile at the dam at the time of the peak concentration. Because the Pedernales River was assumed to be much colder than Lake Travis when the spill occurred, the MTBE is concentrated at the bottom. Note, that the concentration in the outflow would be much smaller than shown on the figure because the outlet withdraws water from many layers. The flow weighted concentration is about 0.23 mg/L.

The results for benzene in the 14°C case, which is deemed most probable, are shown in Figures 4-14 and 4-15. The maximum concentration in any depth layer at Mansfield Dam is about 0.008 mg/L of benzene, and the concentration at the pinstocks is approximately 0.006 mg/L. In the 10°C case, all benzene would be concentrated in a 10-meter thick layer with a peak concentration of 0.034 mg/L within the layer. The pinstock concentration would still be approximately 0.006 mg/L.

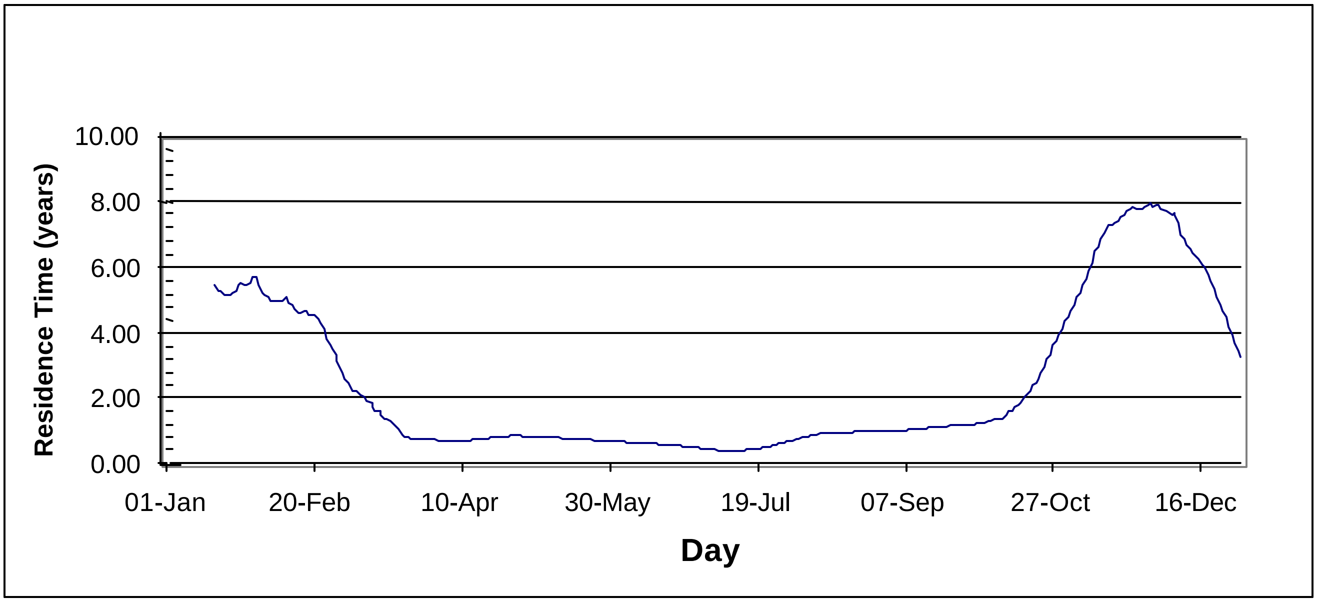

Figure 4-1
30 Day Average Residence Time in Lake Travis based on Average Outflow Rate

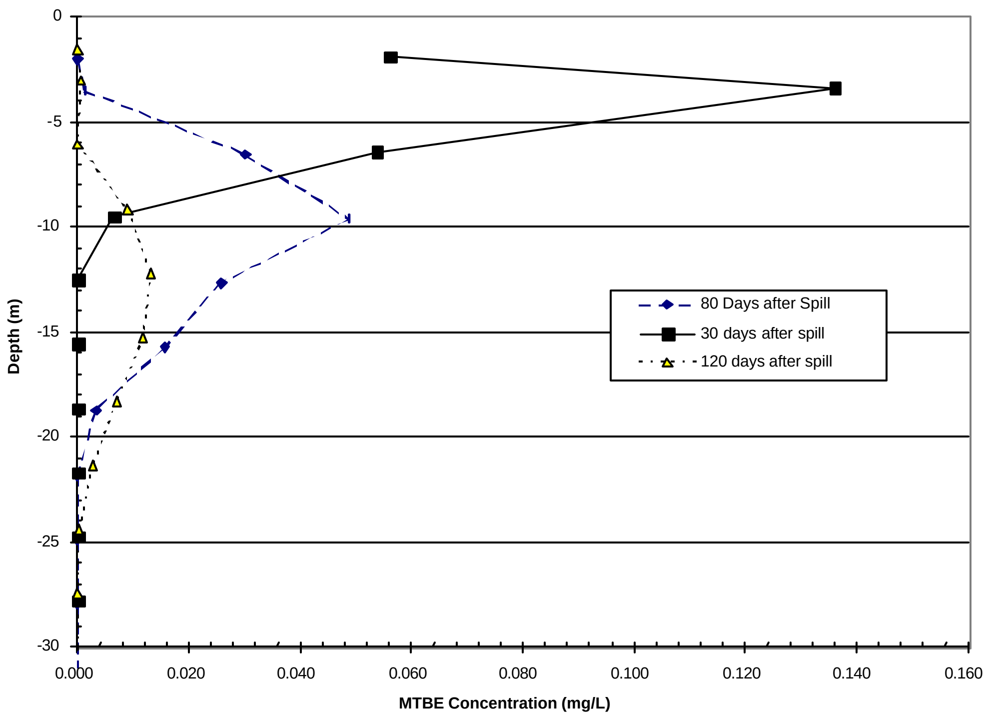

Figure 4-2
Predicted MTBE Concentration due to 6,500 bbl Spill
Lake Travis Segment 12 (28 to 31 miles upstream from the dam)

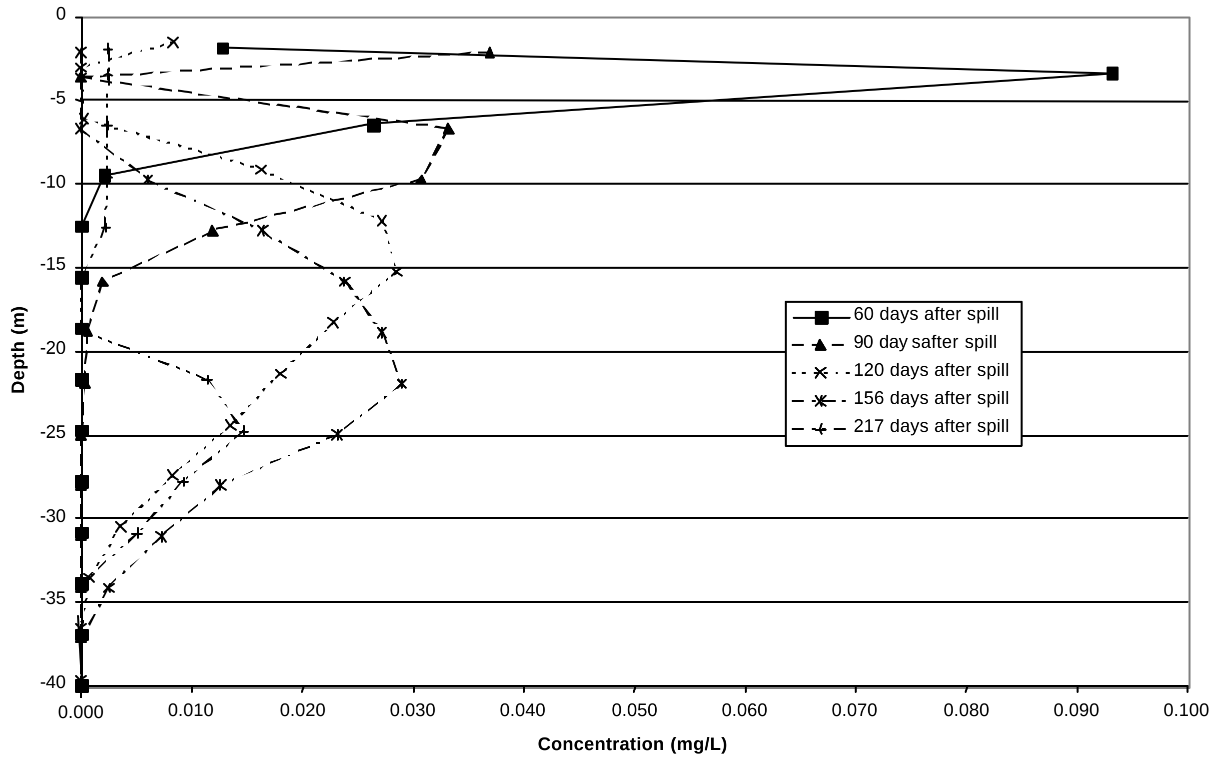

Figure 4-3
Predicted MTBE Concentration due to 6,500 bbl Spill
Lake Travis Segment 16 (12 to 15 miles upstream from the dam)

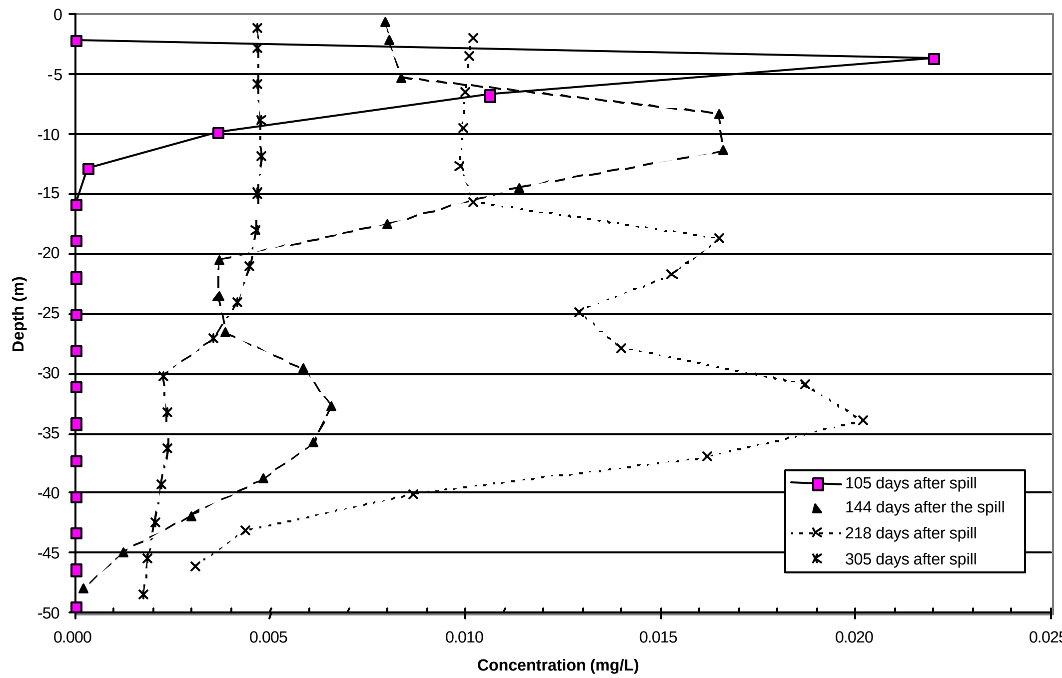

Figure 4-4
Predicted MTBE Concentration at Dam due to 6,500 bbl Spill Discharge

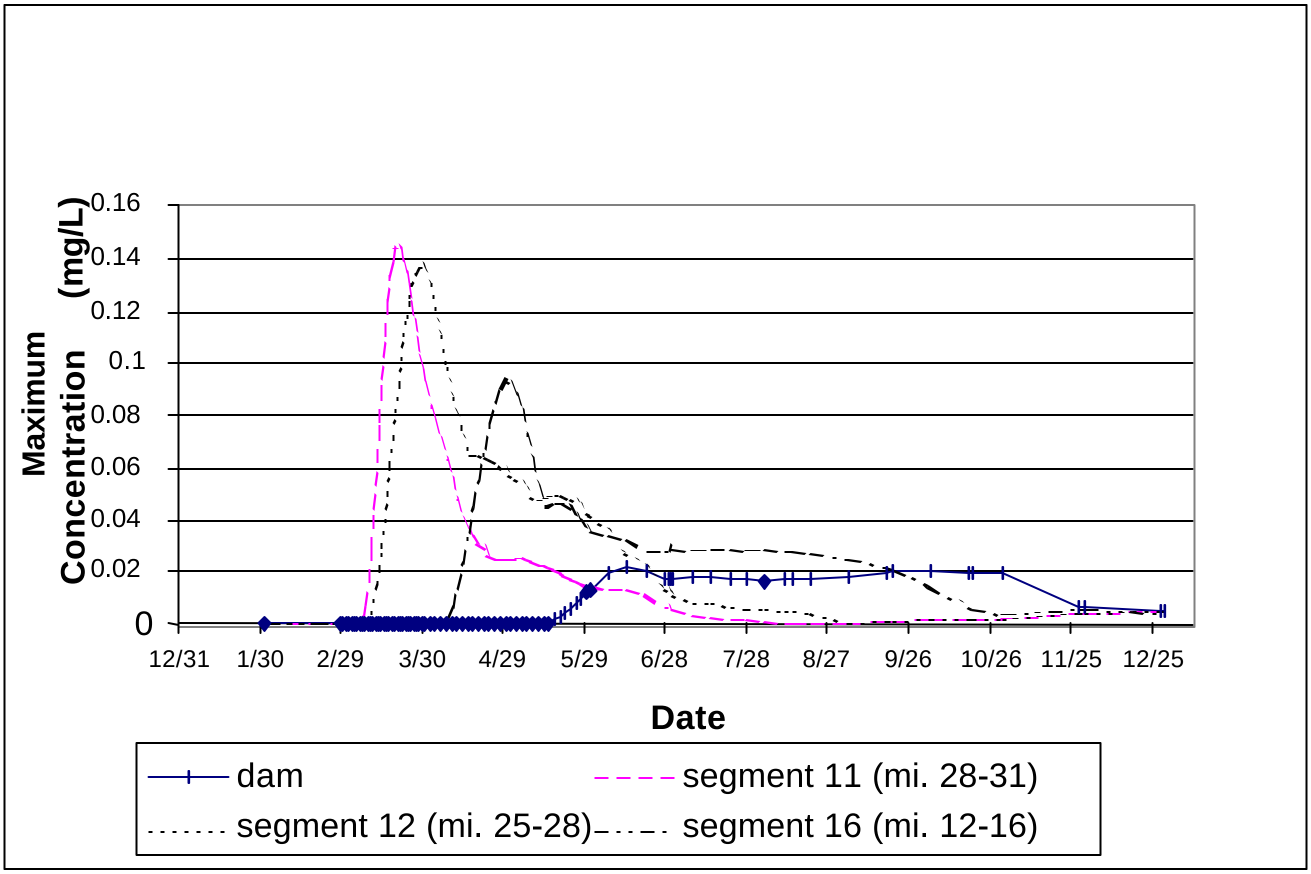

Figure 4-5
Maximum Predicted Concentration of MTBE after 6,500 bbl Spill In Various Lake Travis Segments (Spill Enters on March 1)

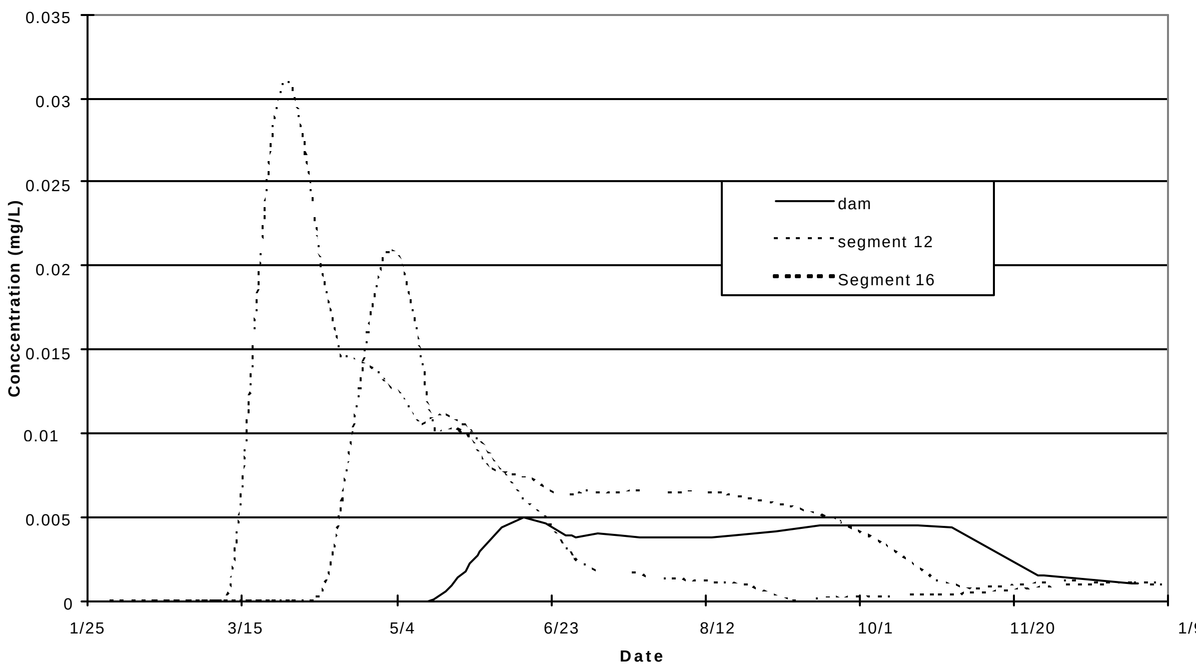

Figure 4-6
Maximum Predicted Concentration of Benzene after 6,500 bbl Spill in Various Lake Travis Segments (Spill Enters on March 1)

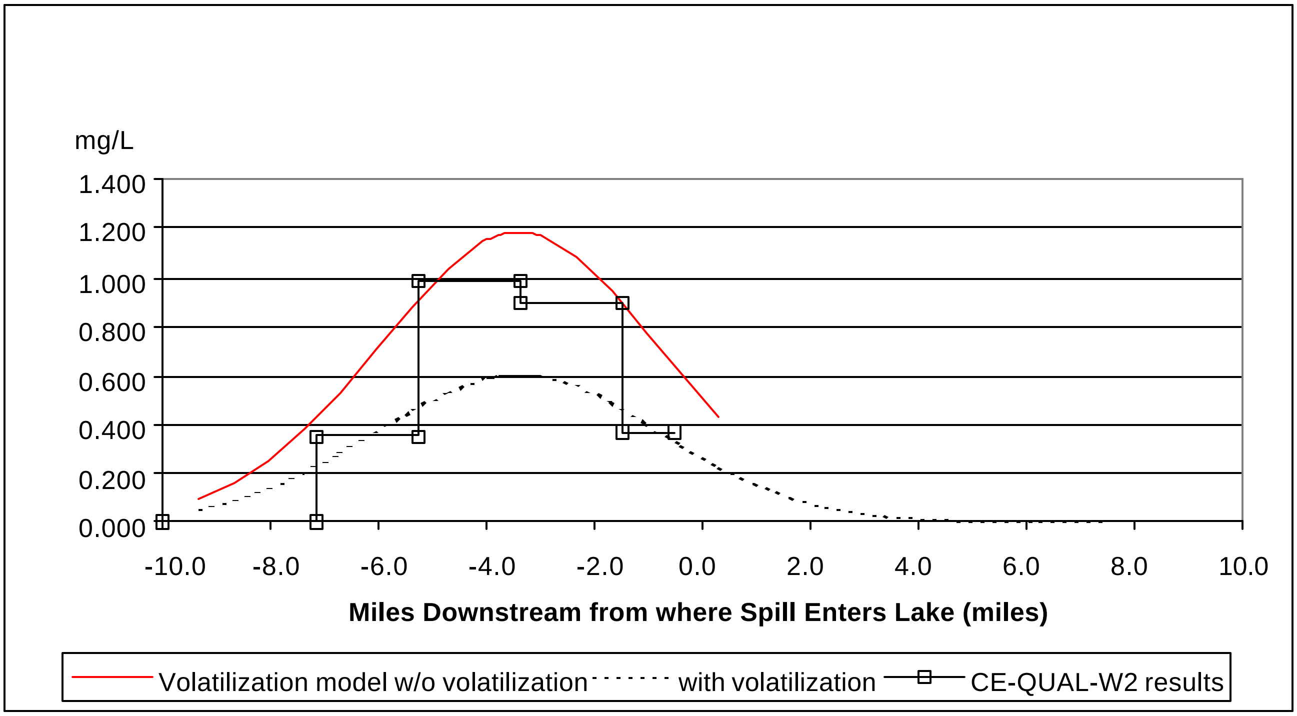

Figure 4-7
MTBE Concentration in the Pedernales River (after 15 days) Including Volatilization

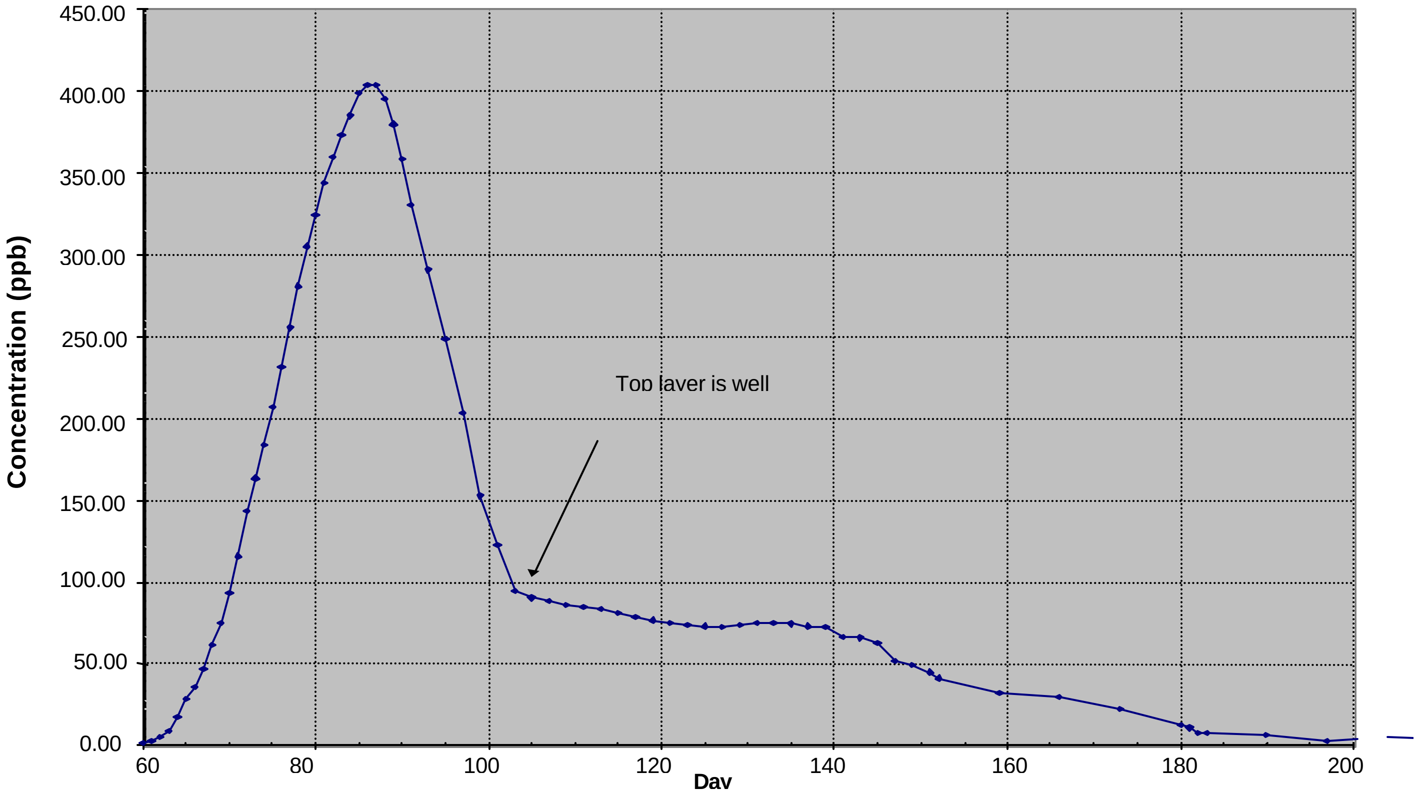

Figure 4-8
Maximum MTBE Concentration at Lago Vista for 6,500 bbl Spill
Warm Spill with Volatilization

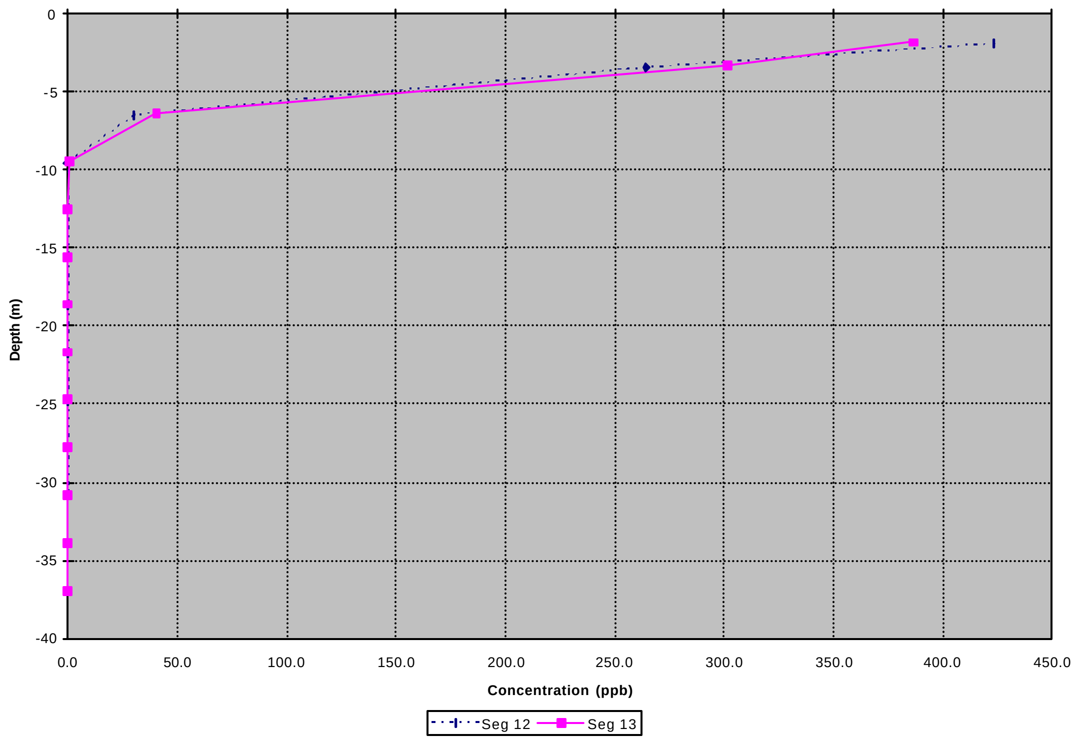

Figure 4-9
Concentration of MTBE at Time of Maximum Concentration Versus Depth at Lago Vista
6,500 bbl Spill – Warm Spill with Volatilization

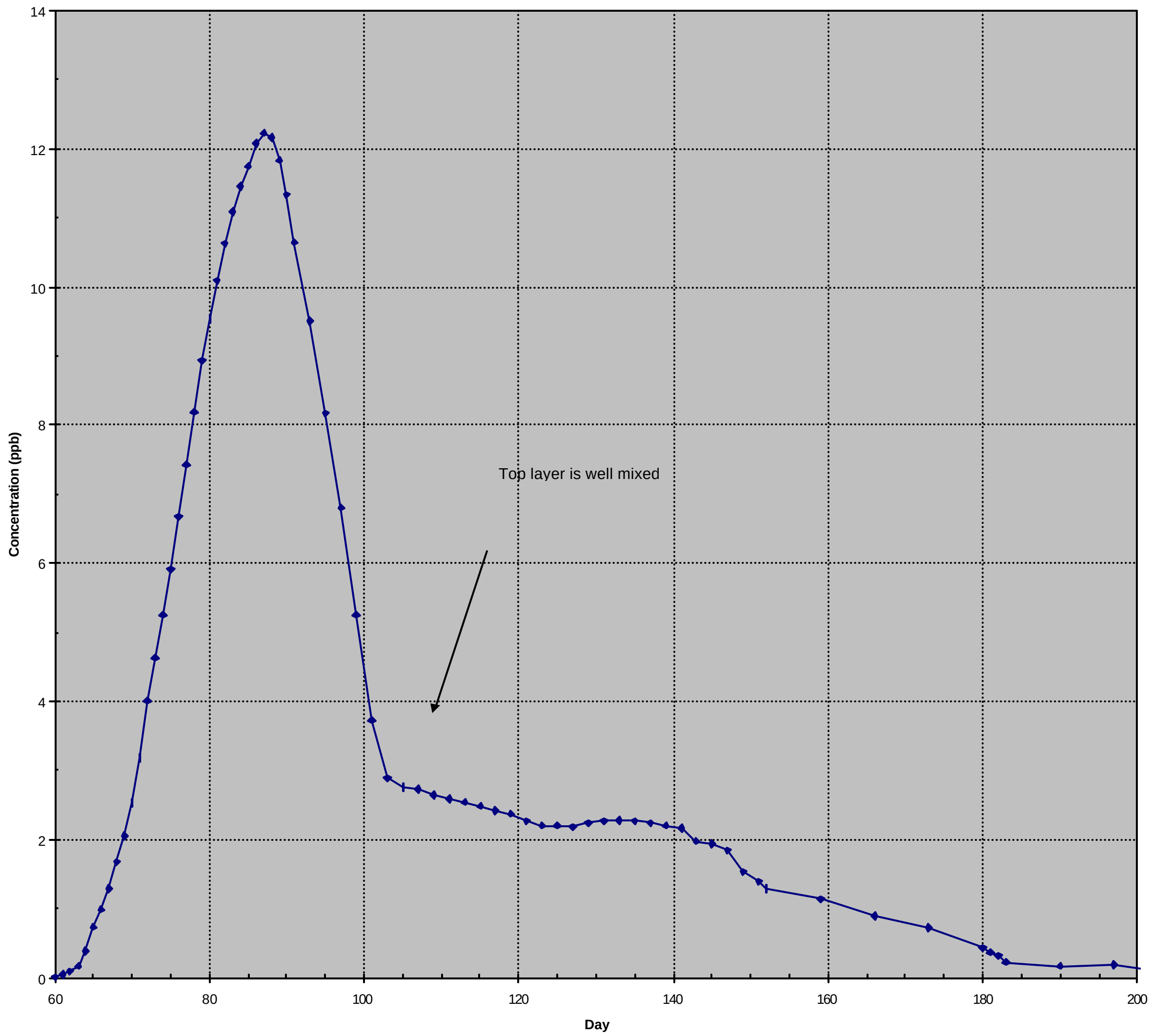

Figure 4-10
Maximum Benzene Concentration at Lago Vista for 6,500 bbl Spill
Warm Spill with Volatilization

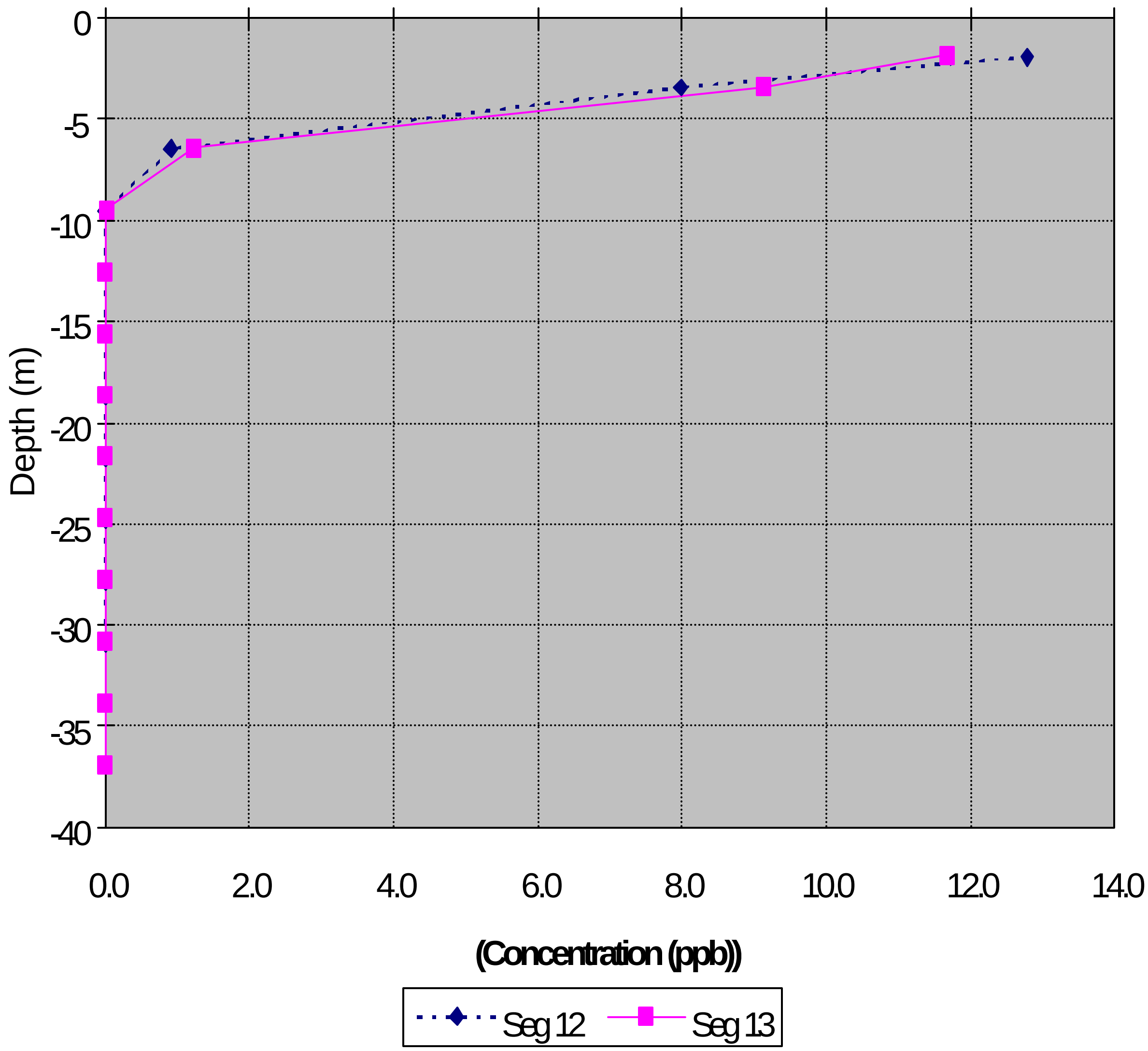

Figure 4-11
Concentration of Benzene at Time of Maximum Concentration Versus Depth at Lago Vista
6,500 bbl Spill – Warm Spill with Volatilization

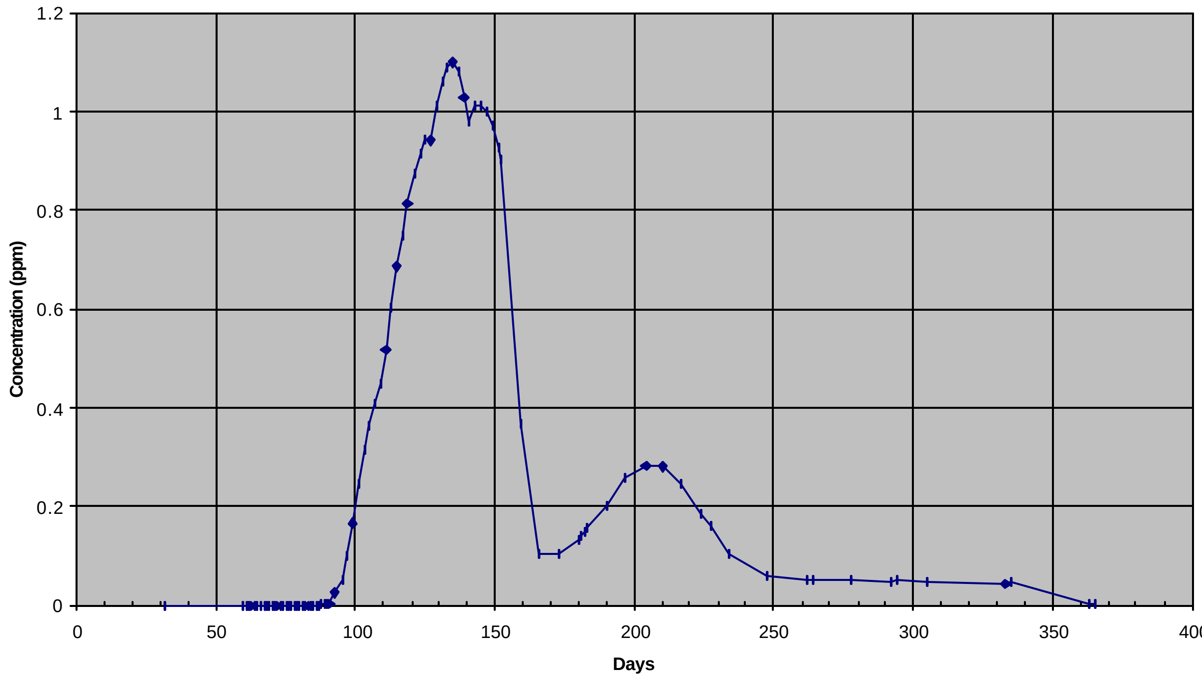

Figure 4-12
Maximum MTBE Concentration at Mansfield Dam for 6,500 bbl Spill
Cold Spill with Volatilization

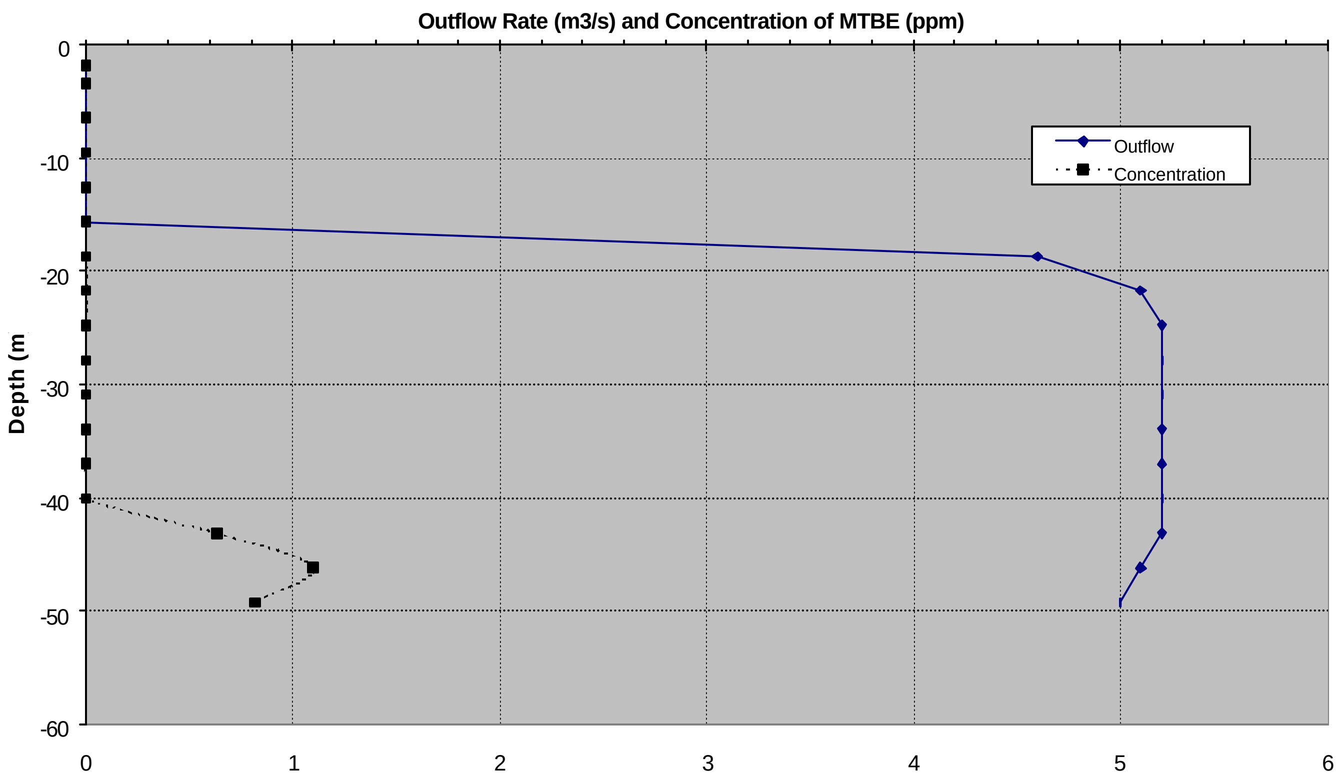

Figure 4-13
Concentration of MTBE at Time of Maximum Concentration Versus Depth at Mansfield Dam
6,500 bbl Spill – Cold Spill with Volatilization

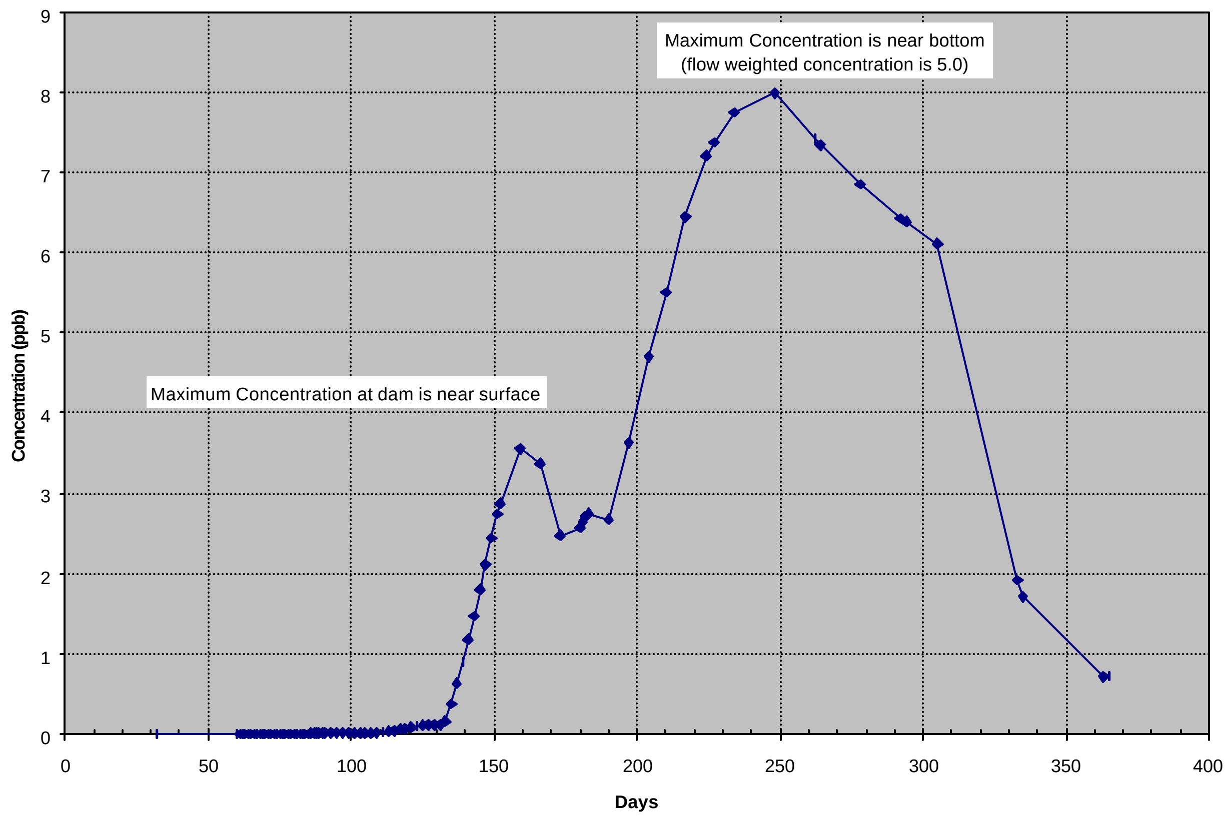

Figure 4-14
Maximum Benzene Concentration at Mansfield Dam for 6,500 bbl Spill
Cold Spill with Volatilization

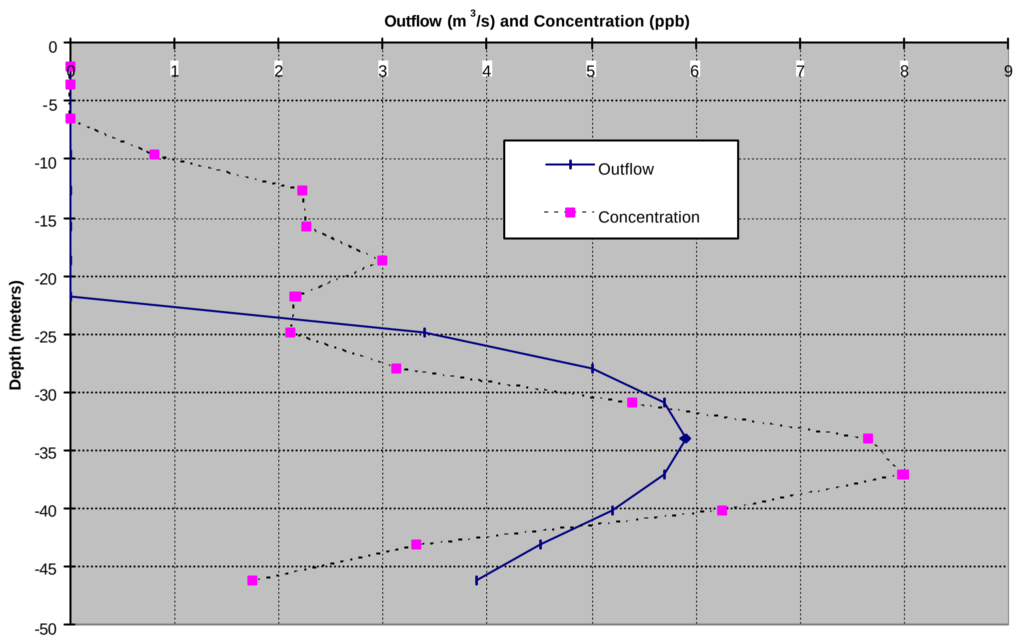

Figure 4-15
Concentration of Benzene at Time of Maximum Concentration Versus Depth at Mansfield Dam
6,500 bbl Spill – Cold Spill with Volatilization

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