Attachment 2

Mixing, Dispersion and Deposition of Suspended
Sediment from Union Electric Company
Callaway Plant Discharge

Prepared for

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In Support of Testimony on Suspended Sediment Discharge

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1.0 Problem Statement and Method of Investigation

The Missouri River total suspended solids (TSS) withdrawn at the Callaway Plant intake will be discharged at a higher concentration than in the river because the plant discharge flow rate is less than the intake flow rate due to cooling tower evaporative water loss. The discharged suspended solids will mix, disperse and settle as a plume until the background river concentration is reached. The problem is to determine the spatial distribution of the TSS concentration and settling rate in the plume for comparison to natural river scour and deposition rates. Comparison between the TSS plume settling and natural river scour and deposition over time makes it possible to determine the duration and extent of discharged TSS accumulation in the vicinity of the discharge.

Investigation of the fate of discharged TSS is performed in three steps. First, the hydrodynamics and transport of the TSS away from the discharge is formulated using a two-dimensional finite difference hydrodynamic and transport model. The model computes the flow field of the river in the vicinity of the discharge and the advection, dispersion and settling of the discharged TSS. Second, the natural river rates of scour and deposition are determined from measured cross-sectional data. Third, the rates of discharged TSS settling is compared to the natural scour and deposition rates for eleven years of monthly flows to determine the fate of discharged TSS relative to river transport.

2.0 Discharge Description and Operation

The Callaway Plant intake and discharge is located on the Missouri River near river mile 121.6 as shown in Figure 2.1. The detailed bathymetry within the vicinity of the intake and the discharge is shown in Figure 2.2. The intake extends about 100 feet outward from the indented shoreline. The discharge is on the shoreline immediately downstream of the intake. The intake structure and the downstream Corps of Engineers dike form a shallow indentation along the river bank that is about 100 feet wide and 450 feet long.

The river channel at the bottom elevation of 480 to 482 feet is immediately off the end of the intake and swings outward from the downstream dike. The top of the dike is at an elevation 506 feet and is overtopped by river flows greater than 68,000 cfs.

As Missouri River flows increase, the concentration of total suspended solids (TSS) increases and the concentration of total dissolved solids (TDS) decreases. The relationships of TSS versus river flow and TDS versus river flow, derived by Sverdrup and Parcel (1982) from recent site data, are given in Figure 2.3 and Figure 2.4.

The withdrawal rate from the river to the
~~The withdrawal rate from the river to the plant varies with river TDS.~~ ~~The cooling towers are operated at a constant TDS~~, and, ~~as river TDS decreases with increasing river flow, the cooling tower flow requirements decrease.~~ Computations by Sverdrup and Parcel (1982) showed that pumping to the plant varies from 12,500 gpm to 19,500 gpm as river TDS varies from 240 mg/L to 590 mg/L; for river flows from 323,000 cfs to 14,400 cfs. Over the same range of river flows the TSS varies from 4,400 mg/L to 20 mg/L. Tower evaporation varies from 9,900 gpm to 13,200 gpm.

3.0 Hydrodynamics and Sediment Transport of Discharge

The suspended sediment from the discharge disperses and settles approaching background river concentrations as it is advected out of the discharge area shown in Figure 2.2. The river flow into and through the indented area is a complicated two-dimensional flow governed by the river flow, river stage, the presence of the intake and dike, the bottom geometry and proximity of the channel. The flow patterns through the area determine the mixing at the discharge and the advection and dispersion of the discharged TSS away from the discharge area.

~~The flow patterns and resulting TSS plume can be determined using numerical two-dimensional vertically integrated longitudinal and lateral~~ numerical ~~hydrodynamics. The basic~~ The ~~hydrodynamic relationships used in this type of computation are quite common and have been used in other intake, discharge and sediment transport problems.~~ and sediment They are summarized in Attachment A.

3.1 Model Setup

The hydrodynamic and transport relationships summarized in Attachment A are mapped onto the computational grid for the intake and discharge region shown in Figure 2.2. ~~The grid cells are 90 feet long, 33 feet wide and have depths that vary with river stage.~~ The sizes of the cells were ~~based on~~ based on (1) the plume computations of Benedict (1974), which showed that an initial dilution of at least 10:1 would be attained within a 30 foot by 100 foot region; and, (2) grid dimensions that fit within the overall size of the bank indentation. The grid is extended outward 99 feet beyond the intake structure to intercept a portion of the total river cross section representing ten percent of the natural river flow.

The input variables to the hydrodynamic computations are: (1) the river stage; (2) the river flow; (3) the river TSS and TDS; (4) the intake pumping rate; (5) the cooling tower evaporation rate; and, (6) the TSS settling velocity. The pumping rate to the plant and the blowdown flow rate are computed using tower operatoin relationships provided by Sverdrup and Parcel (1982). The settling velocity of the clarifier sludge and the river TSS were evaluated in laboratory tests by Sverdrup and Parcel (1982) and were found to be consistent at 10 feet per hour at concentrations less than 1000 mg/L.

28000 gpm

settling vel. decreased above 1000 mg/l due to compaction

3.2 Model Simulations

The model simulations of the TSS plume and plume settling primarily on the river flow. Once the river flow is chosen, the river TSS and TDS are determined from the relationships given in Figure 2.3 and Figure 2.4. The river TDS in turn determines the tower make up and blowdown requirements. Simulations are made for a range of mean monthly river flows to determine plume dilutions and settling rates as a function of river flow, and then these parameters are evaluated for each month over eleven years of flow records.

The mean monthly flows of the Missouri River for the years 1970 to 1980 at Hermann, Missouri, just downstream of the plant site, are given in Table 3.1. Plume simulations are carried out for a range of river flows including: (1) 22,000 cfs which is the lowest mean monthly flow and occurred in January 1977; (2) 333,000 cfs which is the highest mean monthly flow and occurred in April 1973; (3) 55,000 cfs which is the eleven-year average of January monthly flows; (4) 88,000 cfs which is the eleven-year

average of November monthly flows; and (5) 129,000 cfs which is the eleven-year average of April monthly flows. Once the plume characters are determined for this range of flows, characteristics at the other monthly flows can be found by interpolation.

Results of the hydrodynamic and TSS transport computations for the range of river flows are presented in Figures 3.1 to 3.5. The figures show the input parameters for each case, the TSS concentrations in each cell corresponding to the computational grid in Figure 2.2, the velocity vectors in each cell due to the flow field, and the resulting TSS settling rate from the plume in each cell. Actual deposition of the discharge TSS on the bottom depends on the indicated plume settling rate being greater than the natural river bank scour rate which is determined in Section 4.

The simulations show that the flow pattern in the discharge area changes with river flow. The main river velocity increases with river flow as does the depth at each location. A backwater eddy is formed in the lee of the intake structure and becomes more intense as river flow increases. Velocities and depths increase in the discharge region with increasing flows. The downstream dike is overtopped when elevation 506 is exceeded.

Dilution in the immediate vicinity of the discharge increases with river flow. This is due to the increased velocities and depths in the immediate vicinity of the discharge.

The discharged TSS settling rate is highest at the discharge where the difference between in the plume TSS and river TSS is maximum. It decreases rapidly downstream and outward from the discharge due to dilution of the discharged TSS, which approaches the concentration of the river TSS. The maximum settling rate at the discharge first decreases with river flows from 22,000 cfs to 55,000 cfs, then increases with river flow. The increase in settling rate with increasing river flow is due to the greater

difference between concentrations of discharged TSS and river TSS at the
[redacted]
higher river flows. The maximum settling rate is found to be 7.8 cm/mo. at
[redacted]
the maximum monthly river flow of 333,000 cfs.
[redacted]

3.3 Monthly Variations in Plume Dilution and Settling

The plume dilution and settling rates in the immediate vicinity of the discharge are summarized for the range of river flows of the simulations in Table 3.2. The plume dilution and settling rates are interpolated from the monthly flows between 1970 and 1980 as found from Table 3.1 and are presented in Table 3.3 and Table 3.4.

The initial plume dilution, shown monthly in Table 3.1, varies from a low of 6:1 in January 1977 at the lowest monthly flow of 22,000 cfs to 774:1 in April 1973 at the highest monthly flow of 333,000 cfs. Benedict (1974) estimated a plume dilution of 10:1 within a 30 foot by 10 foot region of the discharge at low flow, hence the two-dimensional hydrodyanmic computations slightly underestimate initial discharge dilution.

The initial plume maximum settling rate varies from a low 2.1 cm/mo., mostly in December, to a high of 7.8 cm/mo. in April 1973, when river flow and river TSS were highest. The seasonal variations, as indicated by the eleven-year average in each month, are small.

4.0 River Scour and Depostion

The river bottom elevations in the vicinity of the Callaway Plant discharge change with river flow. The bottom elevations are lower at higher discharges and higher at lower discharges. The rate of bottom scour or deposition depends on the change in river flow from one month to the next.

4.1 Rate or River Bottom Scour and Deposition

Bottom topography in the vicinity of the discharge was surveyed approximately once a month from November 1974 to March 1976 by Sverdrup and Parcel (1982). The cross section in the discharge area is shown in Figure 2.2. The bottom elevations at three points along the cross section, which are near the shoreline, on the channel side slope and near the channel bottom have been determined for each survey and tabulated as a function of river flow. The results are presented in Figure 4.1.

Figure 4.1 shows that near the shoreline and on the channel slope, the bottom elevation changes about 12 feet for each 100,000 cfs change in river flow. Near the channel bottom, the change in bottom elevation with river flow is about 4 feet per 100,000 cfs change in river flow indicating that the channel bottom is more stable than the channel slope and shoreline areas.

The rate of bottom scour or deposition in cm/mo. can be determined from the change in river flow from month to month. The change in river flow from month to month for 1970 to 1980 is determined from the flows given in Table 3.1. The resulting rate of bottom scour or deposition from month to month is given in Table 4.1. From a comparison between Table 4.1

and Table 3.4, it is evident that the natural river rate of bottom scour or deposition is generally an order of magnitude greater than the rate of TSS settling at the discharge.

4.2 Plume TSS Deposition

Deposition of discharged TSS will take place when the rate of settling from the plume is ~~less~~ greater than the rate of bottom scour or when bottom deposition is taking place. Table 4.1 shows the seasonal patterns of natural bottom movement. Bottom scour takes place from February to April as river flows increase with the spring freshet, bottom deposition takes place from May to August as flows are receeding, scour takes place from September to November during increased fall runoff, and deposition takes place in December and January. The longest duration of discharged TSS deposition is over four months from May to August during which, for average conditions from Table 3.4, there is an accummulated discharged TSS deposition in the immediate vicinity of the discharge of 12.9 cm as compared to a natural bottom build up of 236 cm in the discharge area. Thus about five percent of the accummulated sediment is due to the discharge over the period of natural deposition. During the months of bottom scour, the natural rate of scour is much greater than the plume settling rate and will resuspend previously discharged TSS for transport downriver.

5.0 Summary and Conclusions

The Callaway Plant blowdown discharge is located downstream from the intake structure in an indentation of the river bank that is about 100 feet in from the edge of the main river and extends 450 feet along the river bank from the intake structure to the Corps of Engineers dike (Section 2). Within this indentation, the blowdown discharge rapidly mixes toward background river concentrations of total suspended solids (TSS) in a region about 90 feet along the river bank and extending about 33 feet out from the bank.

The discharge TSS is at a higher concentration than the intake TSS because the blowdown flow rate is less than the intake flow to the plant due to evaporative water loss. The higher discharge concentration will decrease to approach the background river concentration in the discharge area by mixing, dispersion and a tendency to settle. The net deposition of the higher discharge concentration will depend upon the rate of settling in comparison to the natural rate of river scour and deposition as the river flow changes from day to day and month to month.

The rate of discharge settling depends on the differences in concentration of TSS in the discharge area and the background concentration. At the background concentration there is a balance between bottom scour or resuspension and the settling rate. The intake TSS increases with river flow and there is a greater difference between the discharge concentration and intake concentration at higher river flows. At higher river flows, there will be a greater tendency for settling while at the same time there will be a more rapid mixing of the discharge concentration toward background levels.

The rate of settling in the immediate 33 foot by 90 foot discharge area, without accounting for natural river scour and deposition, ranges from 2 cm per month at a low monthly river flow of 22,000 cfs as occurred in January 1977 to 7.8 cm per month at a high monthly river flow of 333,000 cfs as occurred in April 1973. In both cases, the rate of settling is reduced to 0.1 to 0.2 cm per month by the time the discharge mixes to the end of the downstream dike. The tendency for deposition of the discharge TSS depends on these settling rates being greater than the natural scouring rates of the river.

Natural river scour and deposition depend on the change in river flow from month to month. River cross-sectional data collected in the discharge area show that natural scour takes place from February to April and from September to November when river flows are increasing from month to month. Natural deposition takes place from May to August and December to January when river flows are decreasing. The rate of scouring or deposition averages 60 cm per month. The rate of settling of the higher TSS concentrations immediately at the discharge is less than one tenth the average rate of natural scour and deposition. At the end of the dike it is reduced to less than one hundredth of the natural rate of scour and deposition. Deposition of the discharge will take place over a period no longer than four months when natural deposition is occurring and will be confined to the immediate discharge area. At the mean monthly flows of May to August, the deposition in the immediate vicinity of the discharge will be less than 13 cm in comparison to a natural deposition of 240 cm. The monthly natural scour rate is higher than the discharge settling rate and

will prevent deposition from taking place during natural scour. Natural scour will resuspend and transport the accummulated discharge out of the discharge area.

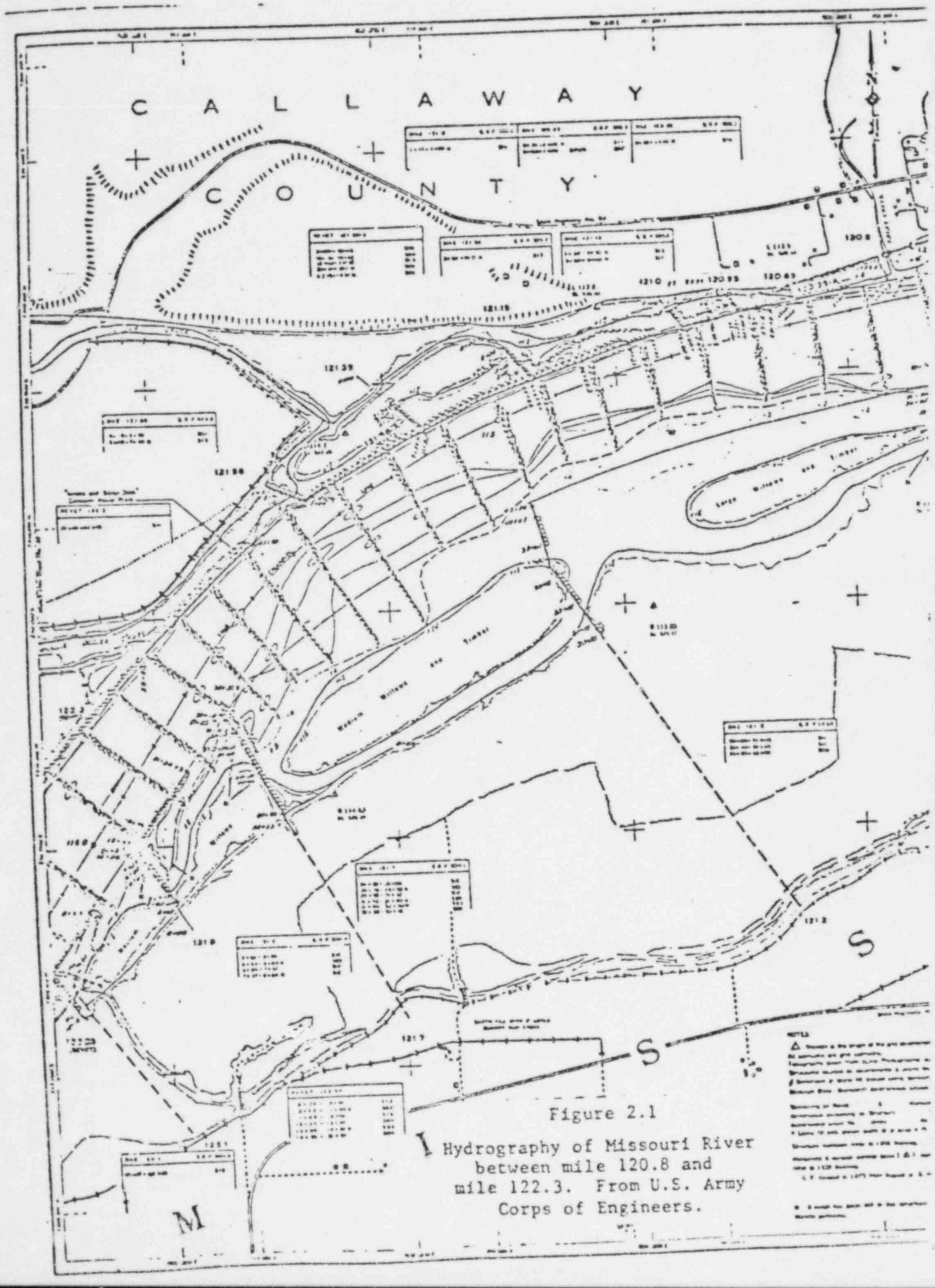

Figure 2.1

Hydrography of Missouri River between mile 120.8 and mile 122.3. From U.S. Army Corps of Engineers.

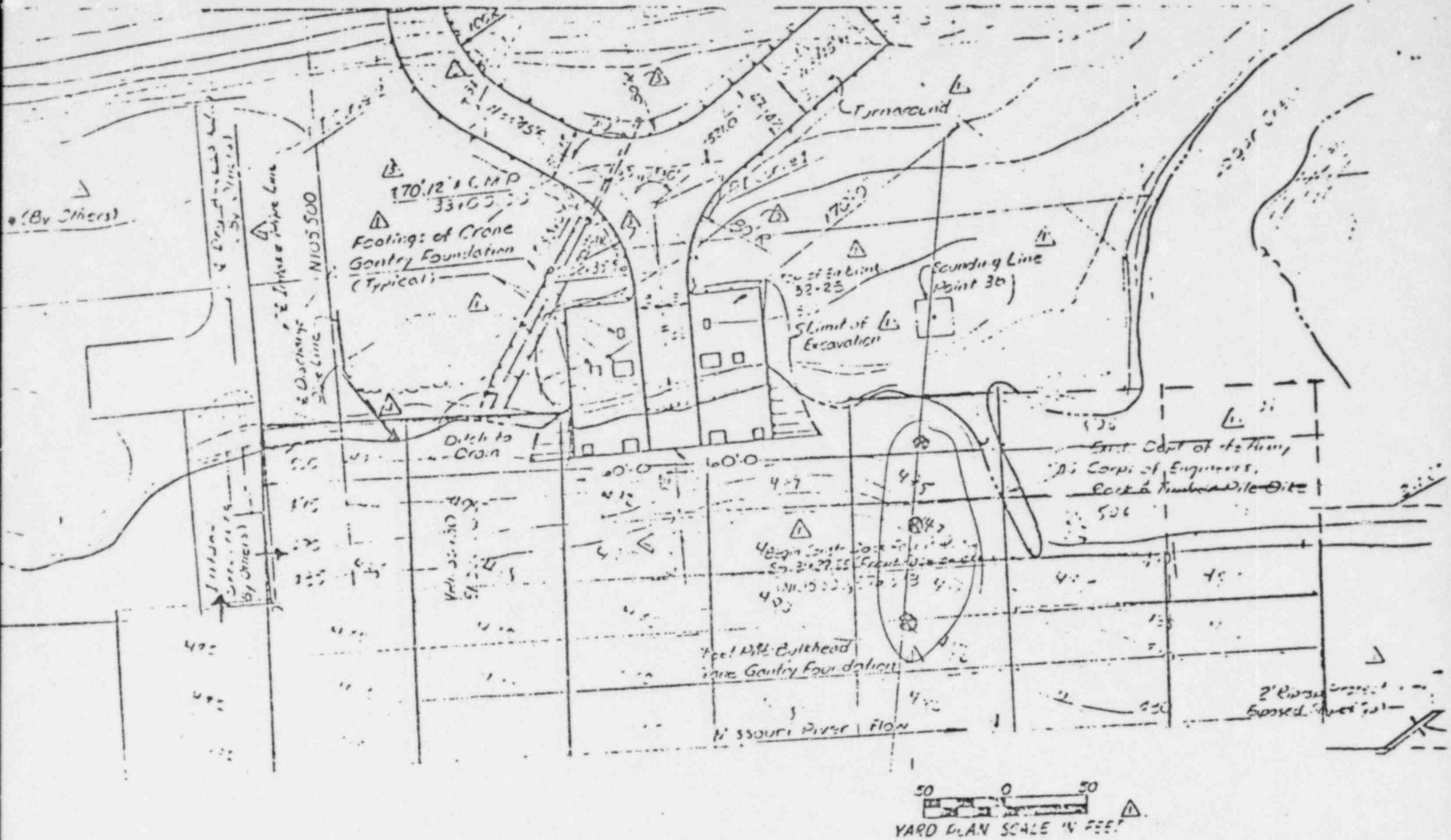

Figure 2.2 Detailed bathymetry in vicinity of Callaway Plant intake and discharge. From Union Electric Company construction drawing, provided by Sverdrup and Parcel (1982).

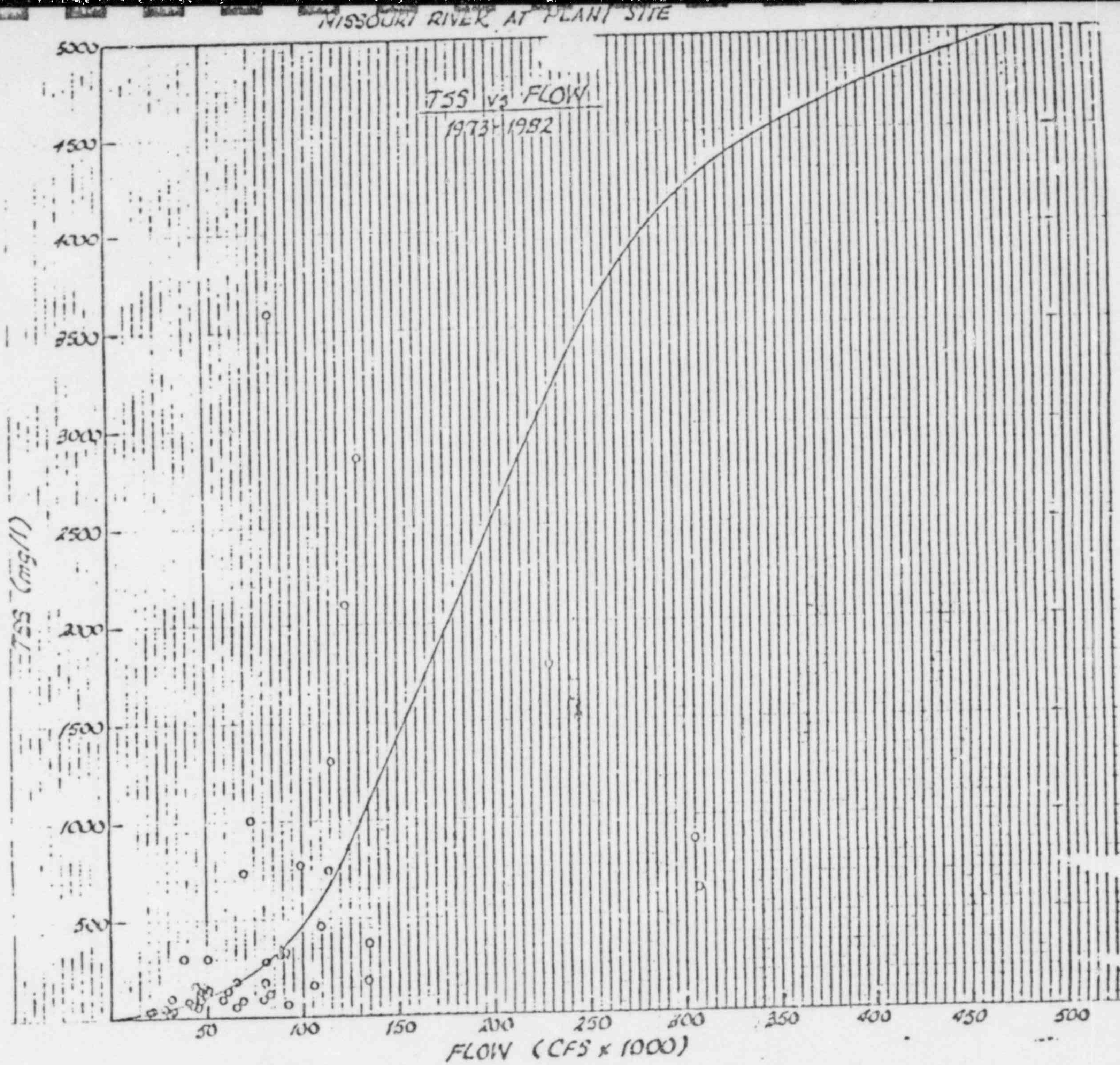

Figure 2.3 Missouri River total suspended solids versus river flow in vicinity of Callaway Plant. From Sverdrup and Parcel (1982).

Figure 2.4 Missouri River total dissolved solids versus river flow in vicinity of Callaway Plant. From Sverdrup and Parcel (1982).

Table 3.1

Missouri River mean monthly flows in thousands of cfs at Hermann, Missouri. For 1970 to 1980 from USGS flow records.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	31	42	55	119	137	138	54	60	109	100	79	51
1971	51	85	108	65	89	106	77	61	58	60	74	86
1972	48	39	61	82	116	72	63	70	85	68	134	67
1973	129	135	268	333	192	113	92	73	84	222	128	127
1974	115	116	129	87	144	133	56	54	64	51	104	55
1975	59	103	108	124	88	113	83	81	93	80	82	69
1976	40	50	80	101	104	70	59	47	44	48	46	36
1977	22	34	43	51	54	83	77	59	128	93	125	47
1978	33	27	170	173	145	89	91	80	89	68	78	54
1979	32	67	193	159	117	94	99	70	63	51	71	55
1980	42	49	73	125	59	83	49	50	51	45	47	41
AVG	55	68	117	129	113	99	73	64	79	81	88	62

10 yr. avg = 85.67 ± 23.93

Figure 3.1

Callaway Plant discharged TSS concentration distribution and settling rate for a river flow of 22000 cfs.

TSS, mg/L 40 | TDS, mg/L 570 | River stage, ft 498
Intake, gpm 28000 | evap, gpm 12900 | discharge, mg/L 112

Flow field and TSS distribution, mg/L

	54	47					
	45	42	41	41	41		
	41	41	41	41	41		
40	40	40	40	40	40	40	40
40	40	40	40	40	40	40	40
40	40	40	40	40	40	40	40

______ 1 M/S

Discharge TSS settling rate, cm/mo.

	3.0	1.6					
	1.0	0.5	0.2	0.2	0.2		
	0.2	0.2	0.2	0.1	0.1		
0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 3.2

Callaway Plant discharged TSS concentration distribution and settling rate for a river flow of 55000 cfs.

TSS, mg/L 120
Intake, gpm 28000

TDS, mg/L 465
evap, gpm 12900

River stage, ft 504
discharge, mg/L 412

Flow field and TSS distribution, mg/L

	129	125					
	125	123	122	121	121		
	122	121	121	121	121		
120	120	120	120	121	121	120	120
120	120	120	120	120	120	120	120
120	120	120	120	120	120	120	120

1 M/S

Discharge TSS settling rate, cm/mo.

	2.1	1.2					
	1.0	0.6	0.3	0.2	0.2		
	0.3	0.3	0.2	0.2	0.2		
0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1

Figure 3.3

Callaway Plant discharged TSS concentration distribution and settling rate for a river flow of 88000 cfs.

TSS, mg/L 350	TDS, mg/L 385	River stage, ft 509
Intake, gpm 28000	evap, gpm 12900	discharge, mg/L 1454

Flow field and TSS distribution, mg/L

	364	358				351	351
	357	354	352	351	351	351	351
	352	352	351	351	351	351	351
350	351	351	351	351	351	351	350
350	350	350	350	350	350	350	350
350	350	350	350	350	350	350	350

1 M/S

Discharge TSS settling rate, cm/mo.

	3.0	1.7				0.2	0.2
	1.6	0.9	0.5	0.3	0.3	0.2	0.2
	0.5	0.4	0.3	0.2	0.2	0.2	0.1
0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0

Figure 3.4

Callaway Plant discharged TSS concentration distribution and settling rate for a river flow of 129000 cfs.

TSS, mg/L 950	TDS, mg/L 302	River stage, ft 513
Intake, gpm 28000	evap, gpm 12900	discharge, mg/L 5033

Flow field and TSS distribution, mg/L

	973	963				951	951
	962	957	953	952	952	951	951
	954	953	952	952	951	951	951
950	951	951	951	951	951	951	951
950	950	950	950	950	950	950	950
950	950	950	950	950	950	950	950

1 M/S

Discharge TSS settling rate, cm/mo.

DISCHARGE TSS ACCUMULATION RATE , CM/MO.

	5.0	2.8				0.2	0.2
	2.6	1.4	0.8	0.5	0.4	0.3	0.2
	0.9	0.7	0.5	0.3	0.3	0.2	0.2
0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.1
0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1

Figure 3.5

Callaway Plant discharged TSS concentration distribution and settling rate for a river flow of 333000 cfs.

TSS, mg/L 4370
Intake, gpm 28000

TDS, mg/L 217
evap, gpm 12900

River stage, ft 524
discharge, mg/L 32221

Flow field and TSS distribution, mg/L

	4406	4398				4272	4371
	4389	4381	4376	4374	4373	4372	4371
	4377	4375	4374	4373	4372	4372	4371
4370	4371	[illegible]	4372	4372	4371	4371	4371
4370	4370	4371	4371	4371	4371	4371	4371
4370	4370	4370	4370	4370	4370	4370	4370

1 M/S

Discharge TSS settling rate, cm/mo.

	7.9	4.5				0.3	0.3
	4.2	2.4	1.3	0.8	0.6	0.4	0.3
	1.5	1.1	0.8	0.6	0.5	0.4	0.3
0.1	0.3	0.4	0.4	0.3	0.3	0.2	0.2
0.0	0.1	0.1	0.1	0.2	0.2	0.1	0.1
0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1

Table 3.2

Summary of plume simulation conditions, initial discharge dilution and plume settling rates as a function of river flow at 28000 gpm, total pumping rate and 12900 gpm evaporation rate.

River Flow cfs	River Stage ft	TSS mg/L	TDS mg/L	Dilution Ratio	Maximum Settling Rate cm/mo.
22,000	498	40	570	5.1:1	3.0
55,000	504	120	465	32.5:1	2.1
88,000	509	350	385	78.8:1	3.0
129,000	513	950	302	177.5:1	5.0
333,000	524	4370	217	773.6:1	7.8

Table 3.3

Callaway Plant discharged TSS initial dilution
at the discharge for 1970 to 1980
mean monthly river flows.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	16	25	33	158	217	219	32	40	134	112	68	30
1971	30	75	133	49	83	128	65	42	38	41	62	77
1972	28	23	42	71	151	58	46	57	76	53	201	51
1973	178	207	635	774	427	144	91	60	75	518	175	174
1974	147	149	178	78	246	195	34	32	48	31	123	32
1975	39	120	132	167	79	142	73	70	92	69	71	55
1976	24	30	70	115	121	56	40	28	26	29	27	20
1977	6	19	25	30	32	74	66	39	176	94	170	20
1978	18	12	350	362	253	80	87	69	82	53	66	32
1979	17	52	430	307	151	97	110	57	46	30	58	32
1980	25	29	61	168	39	74	29	30	30	27	28	24
AVG	48	67	190	207	164	115	61	48	75	96	95	51

Table 3.4

Callaway Plant discharged TSS maximum settling rate, cm/mo., at discharge for 1970 to 1980 mean monthly river flows.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	2.6	2.4	2.1	4.6	5.2	5.2	2.1	2.3	4.1	3.7	2.0	2.2
1971	2.2	2.9	4.1	2.4	3.1	4.0	2.7	2.3	2.2	2.3	2.7	3.0
1972	2.2	2.4	2.3	2.9	4.5	2.6	2.4	2.6	2.9	2.5	5.1	2.5
1973	5.0	5.1	7.2	7.8	6.2	4.3	3.2	2.6	2.9	6.6	4.9	4.9
1974	4.4	4.4	5.0	3.0	5.3	5.1	2.1	2.1	2.4	2.2	3.9	2.1
1975	2.2	3.8	4.1	4.8	3.0	4.3	2.9	2.8	3.3	2.8	2.9	2.5
1976	2.4	2.2	2.8	3.7	3.9	2.6	2.2	2.2	2.3	2.2	2.3	2.5
1977	3.0	2.5	2.3	2.2	2.1	2.9	2.7	2.2	5.0	3.3	4.8	2.2
1978	2.6	2.8	5.8	5.9	5.4	3.0	3.2	2.8	3.1	2.5	2.8	2.1
1979	2.6	2.5	6.2	5.6	4.5	3.4	3.6	2.6	2.4	2.2	2.6	2.1
1980	2.4	2.2	2.7	4.8	2.2	2.9	2.2	2.2	2.2	2.3	2.2	2.4
AVG	2.9	3.0	4.0	4.3	4.1	3.7	2.7	2.4	3.0	3.0	3.4	2.6

4mo Nov - Feb 73-74
18.6 cm
387 cm natural

Table 4.1

Natural scour and deposition rates cm/mo. for shoreline and channel slope stations on cross section shown in Figure 2.2. Based on change in mean monthly river flows from Table 3.1.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	-61	39	48	234	65	1	-305	21	179	-33	-76	-103
1971	1	123	87	-158	89	62	-108	-58	-9	7	51	44
1972	-139	-31	77	76	127	-163	-30	26	54	-62	240	-245
1973	227	23	481	240	-514	-286	-77	-70	42	500	-343	-1
1974	-46	3	49	-153	206	-41	-279	-8	39	-47	193	-180
1975	15	161	19	57	-131	89	-109	-7	44	-48	7	-46
1976	-104	34	113	75	10	-123	-38	-44	-13	16	-9	-35
1977	-53	46	32	28	11	108	-23	-67	254	-127	115	-283
1978	-52	-22	520	12	-101	-207	9	-40	33	-77	36	-85
1979	-79	127	456	-125	-152	-81	17	-105	-25	-45	73	-58
1980	-49	28	87	186	-238	89	-126	4	3	-20	6	-23
AVG	-31	48	179	43	-57	-50	-97	-32	55	6	27	-92

Summer about 0

negatives are depositions

References

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Attachment A

Summary of The Two-Dimensional Hydrodynamic and Sediment Transport Model

Two-dimensional hydrodynamics as described by the longitudinal and lateral momentum balances and continuity were developed for numerical simulation of waterbody circulation by Reid and Bodine (1963) and Edinger, et al. (1972). These relationships can be derived from the general three-dimensional equations of fluid flow (Edinger and Buchak, 1980; Edinger, Buchak and Binetti, 1981). The longitudinal momentum balance is:

acceleration in time & space

$$\partial U/\partial t + 1/H\ \partial UU/\partial x + 1/H\ \partial UV/\partial y = -\ gH(\partial H/\partial x)$$

$$-\ f(U|U|/H^2) + g\ H\ Sx + \tau x \qquad (1)$$

change in surface slope — wind sheer (not considered) — friction — surface slope

the lateral momentum balance is:

~~top to bottom~~

$$\partial V/\partial t + 1/H\ \partial UV/\partial x + 1/H\ \partial VV/\partial y = -\ gH(\partial H/\partial y)$$

$$-\ f(V|V|/H^2) + g\ H\ Sy + \tau y \qquad (2)$$

and continuity is:

Only have so much water in box

$$\partial H/\partial t + \partial U/\partial x + \partial V/\partial y = 0 \qquad (3)$$

In the above relationships:

U = longitudinal flow per unit width (vertically integrated), $m^2\ s^{-1}$

V = lateral flow per unit width, $m^2\ s^{-1}$

H = depth of water column, m

g = gravitational acceleration, 9.78 m s^{-2}

f = dimensionless friction factor

Sx = bottom slope in x-direction

Sy = bottom slope in y-direction

τx = x-component of surface wind stress, m^2 s^{-2}

τy = y-component of surface wind stress, m^2 s^{-2}

The momentum balances state that the fluid acceleration is due to the water surface slope (∂H/∂x), the bottom slope (Sx), and wind surface shear; and is retarded by bottom friction.

The sediment transport is determined from the flow field as:

$$\partial HC/\partial t + \partial UC/\partial x + \partial VC/\partial y - \partial(HDx\partial C/\partial x)/\partial x - \partial(HDy\partial C/\partial y)/\partial y = - VsC + BS \quad (4)$$

bottom scour

amount settled

where:

C = suspended sediment concentration at x, y and t, mg/L

Dx = longitudinal dispersion coefficient, m^2 s^{-1}

Dy = lateral dispersion coefficient, m^2 s^{-1}

Vs = settling velocity, m s^{-1}

BS = bottom scour rate, gm m^{-2} s^{-1}

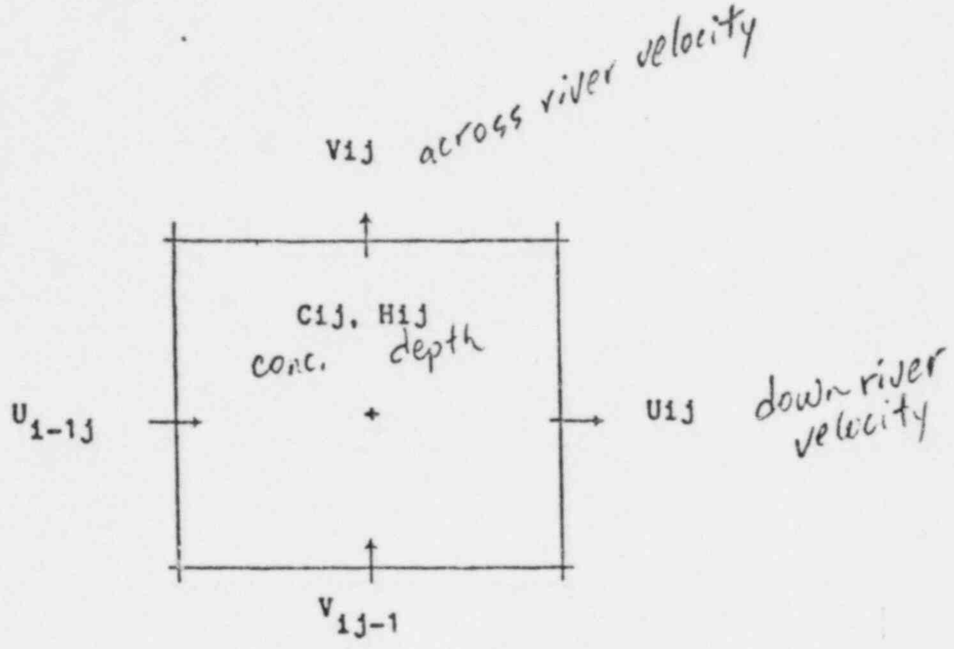
The bottom scour rate, BS, is determined from the background river concentration of suspended sediment for which the settling rate at the

settling rate = (diff in conc.) × V_s

background concentration, Co, is VsCo and is in equilibrium with bottom scour. Hence BS = VsCo. background

The above four equations are numerically solved for the unknowns of U, V, H and C on an x-y finite difference grid. The numerical forms of the equations and method of solution are presented in Edinger and Buchak (1980).

Application of the relationships requires specification of the water-body geometry, the inflow rates, inflow suspended sediment concentrations and outflow rates. The geometry of the waterbody is mapped onto a rectangular grid that attempts to preserve the main features of the waterbody without becoming too detailed to be computationally uneconomical. The variables relative to a grid cell are as follows:



The depth and the TSS are within the cell and represent cell averages. The fluxes are across the boundaries of the cell. The settling rate of the discharged TSS above background is $Vs(C \ Co)$ gm m^{-2} s^{-1}.

References-

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