A Verification Study on a Reservoir Sediment Deposition Model

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This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 24, No. 2, pp. 340, 341, 342, 343, 344, 345, 346, 352, 1981)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

ABSTRACT

THE USDA-SEA Watershed Research Unit in Columbia, Missouri, has been monitoring three agricultural reservoirs for over 7 years. Data from two of these reservoirs, Callahan Reservoir and Bailey Reservoir, were used in a verification study with the DEPOSITS model. The DEPOSITS model is a conceptual design model for predicting the sediment trapping performance of small impoundments. A brief outline of the model is presented. The model gave good estimates of the performance of two reservoirs during the 13 storm events used in the study. An alternative predictive method, which is commonly used, gave much poorer estimates of the performance of the reservoirs. A method for developing the inflow sedimentgraphs to the reservoirs is incorporated in the DEPOSITS model, and gave good estimates of the actual inflow sedimentgraphs for these two reservoirs.

INTRODUCTION

Estimating the trap efficiency of an impoundment is an important design criteria for ponds and reservoirs. The amount of sediment storage provided in the impoundment determines its probable useful life. A poor estimate of the required sediment storage will generally result in either a much shorter active life than that desired or else the added expense of constructing a larger structure than necessary. On surface mines and in urban development areas in several states, sediment detention ponds are required to control sediment movement below drastically disturbed areas. In some cases, multipurpose impoundments are constructed to control floods and sediment. These ponds, however, are usually poorly sized, and either allow discharges with high sediment concentrations or else require frequent cleanout due to underestimations of the sediment depositions. The annual cost of damages associated with waterborne sediment has been estimated to be several hundred million dollars (EPA, 1976).

The major problem in estimating the trap efficiency (percent of the influent sediment-load trapped) of an impoundment is that the traditional methods for estimating the efficiency do not adequately account for the factors determining the transport of waterborne sediment (Ward et al., 1977). This paper describes the results of a verification study with a conceptual model DEPOSITS (Detention Performance Of Sediment In Trap Structures). that estimates basin trap efficiency and effluent sediment concentrations as a function of basin hydraulic characteristics, sediment physical properties, sediment inflow-time distribution and basin inflow hydrograph. Analysis of over 30 storm events on 12 different impoundments indicated that the DEPOSITS model is capable of explaining over 90 percent of the variation in trap efficiency for the different events (Ward et al., 1979). Thirteen of the storm events evaluated occurred on two Missouri agricultural watersheds. The data collected by the USDA-SEA Watershed Research Unit in Columbia, Missouri, was the best data used in the DEPOSITS verification studies. The results of the study on Callahan and Bailey reservoir are presented in this paper.

THE DEPOSITS MODEL

The DEPOSITS model was developed by the Agricultural Engineering Department at the University of Kentucky. One of the main objectives of this research was to develop a model suitable for use as a design method. Inputs to the model have been kept to a minimum and have been limited to parameters that might be readily determined by the impoundment designer. Where only limited watershed data is available, default parameters, based on extensive literature searches, have been incorporated into the model. Basin inputs into the model are:

1 Stage-area curve for the impoundment.
2 Stage-discharge curve for the basin spillway system.
3 Withdrawal characteristics of the spillway system.
4 Particle-size distribution and specific gravity of the sediment load.
5 Inflow hydrograph to the basin.
6 Sediment load or inflow sedimentgraph associated with the inflow hydrograph.
7 Viscosity of the flow.
8 Degree of dead storage (the storage volume that is not exchanged) or short-circuiting (the passage of flow from the inlet to the outlet at a quicker rate than that predicted by plug flow concept) in the pond.

Several papers describing the model have been published, including a comprehensive design manual (Ward et al., 1979). Only a brief outline of the basic concepts incorporated into the model will be described.

BASIC CONCEPTS

Flow within an impoundment is idealized by plug flow.

Article was submitted for publication in January 1980; reviewed and approved for publication by the Soil and Water Division of ASAE in April 1980. Presented as ASAE Paper No. 79-2060.

The work reported in this paper was supported in part by the Kentucky Institute for Mining and Minerals Research and in part by the Kentucky Agricultural Experiment Station and is published with the approval of the Director of the Station as Journal Article No. 79-2-106.

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Plug flow subdivides the inflow into increments of flows (plugs) that are routed through the impoundment on a first in, first out basis. The concept assumes no mixing within the impoundment. Ideal plug flow also assumes that no short-circuiting of flow contained in the impoundment will occur between the inlet and outlet. Generally, some partial mixing will occur within the pond. The DEPOSITS model does not attempt to model the actual flow hydraulics within the pond. Plug flow is assumed and may then be modified through the input of several control variables to account for short-circuiting, dead storage and turbulence. The flow is routed through the impoundment by a numerical procedure based on the Four Quadrant Graph Method of Kao (1975). The change in storage for each increment of time is given by the equation:

$$(S_2 + O_2\,\Delta t/2) - (S_1 - O_1\,\Delta t/2) = (I_2 + I_1)\,\Delta t/2 \quad [1]$$

where S_1 and S_2 are the pond capacities at times one and two, respectively; I_1 and I_2 are the inflow rates; O_1 and O_2 are the outflow rates at times one and two; and Δt is the time increment between times one and two. In the model, the stage-capacity curve is computed from the stage-area curve of the pond. The stage-discharge curve is entered as an input at the same stage points as the stage-area curve. The accuracy of the routing method depends on the time increment between successive inflow points and the height increment between successive stage points. The following factors are determined for each plug of outflow:

1 The plug volume.

2 The fraction of the storm sediment load contained in the plug during inflow.

3 The fraction of the storm sediment load remaining in the plug when discharged.

4 The detention time of the plug.

5 The average depth of flow of the plug during detention.

6 The average stage during outflow.

The plug-flow-routing procedure for a passive discharge system is illustrated in Fig. 1. Provision is provided in the model for simulating the routing of a storm event through a pond containing a permanent pool. With the plug flow concepts, this previously stored flow will be discharged before the discharge associated with the design storm event. The detention time of the plug in the pond is the time required for a plug of inflow to flow from the inlet to the outlet of the basin and then be discharged.

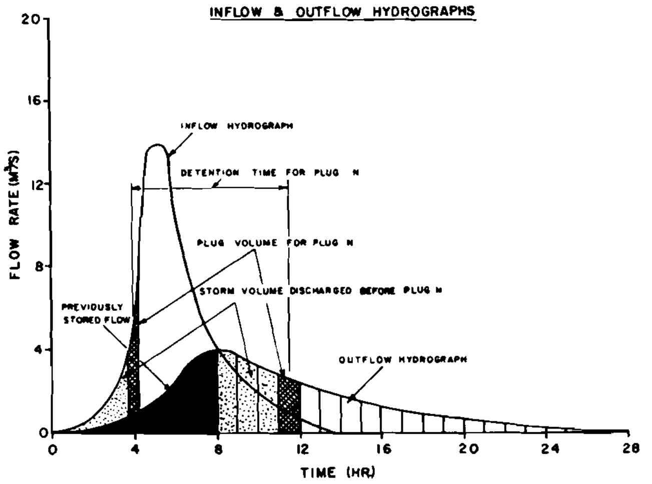

FIG. 1 Plug flow routing.

Sediment Transport

Each plug of inflow is subdivided into four layers of equal depth. When the flow first enters the pond, the sediment load may either be specified as being uniformly distributed between all the layers or else as a density current. If the flow is specified as a density current, all the sediment is partitioned into the bed layer of flow. The amount of sediment remaining in suspension in each layer is calculated based on Stoke's Law, the detention time of the plug, the particle-size distribution of the suspended load, and the average fall depths associated with particles falling from layer to layer. The bed is considered a perfect absorber of sediment, and resuspension or saltation of the particles is disregarded. Selective withdrawal from the four layers of flow is provided for at the outlet. Because of the short detention time of most flow events in sediment ponds and the small storage volumes of these ponds, temperature stratification is not modeled.

The model requires the input of either a sediment load for the storm event or the input of an inflow sedimentgraph. Characterization of the sediment load is probably the most important single factor in determining the performance of a sediment-detention pond. Usually an estimate of the inflow sedimentgraph will not be available and an estimate of the sediment load will be determined. Many methods exist for estimating sediment yields (Haan and Barfield, 1978). The sedimentgraph associated with the design storm event may then either be modeled, using one of the methods, which have recently been developed (Bruce et al., 1975; Williams, 1978; Rendon-Herrero, 1974), or it may be modeled by a method incorporated into the DEPOSITS model. The method used in the DEPOSITS model is defined by the equation:

$$M = kq^p \quad [2]$$

where M is the sediment load (metric tons) contained in the plug of flow entering at a flow rate q (m^3/s). The constant k is determined by the sediment load and the coefficient p will depend on the watershed characteristics. Very little information is currently available for p. An analysis of the modified universal soil loss equation would suggest a value of 1.12 for p. The results of Fogel et al. (1979) indicate that a value of 2.0 for p for Black Masa coal spoils. For the watersheds evaluated in this study a value of 1.6 for p gives the best estimate of the inflow sedimentgraph. The model uses a default value of 2.0 if p is unknown.

A good estimate of the inflow sediment particle-size distribution is extremely important since gravity settling depends primarily on particle size. The distribution will generally vary throughout the duration of a storm event. As the intensity of the event increases and the runoff rates increase, the amount of coarse material contained in the sediment runoff load will become proportionately larger. At very high runoff rates near the peak of the runoff hydrograph, the distribution of the particle sizes will resemble that of the parent material being eroded. In the DEPOSITS model, the variation of particle-size distribution with flow rate has been modeled by the equation:

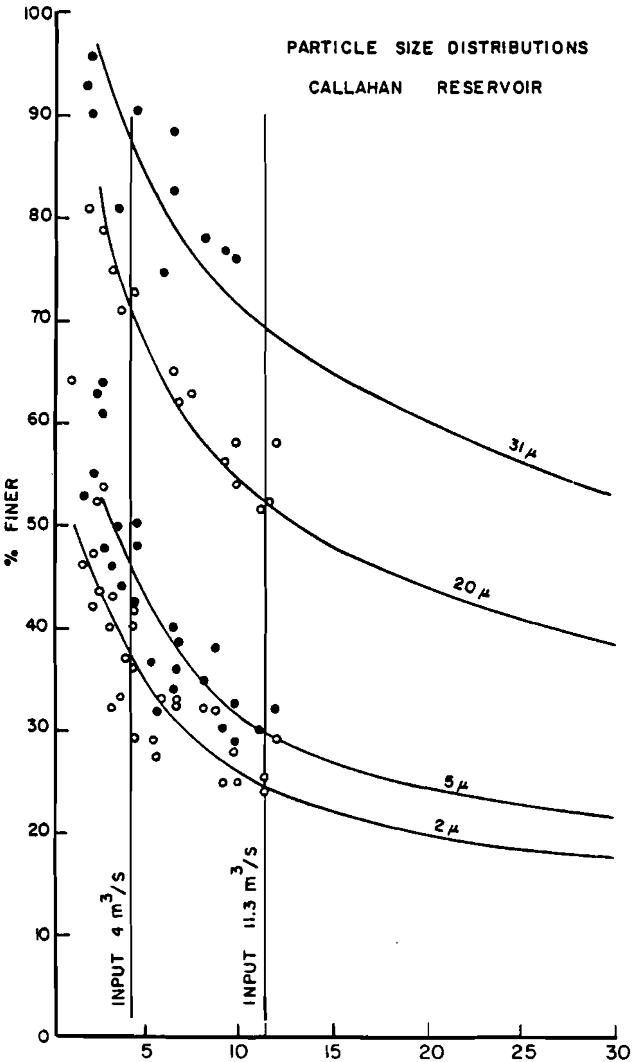

FIG. 2 Particle size variation with flow rate.

$$P_d^* = (q_b/q)^{0.3} P_d \quad [3]$$

where P_d is the percent finer for a given particle size measured at a flow rate q_b(m³/s); q is the runoff rate (m³/s) at any given time during the storm event; and P_d* is the percent finer at the runoff rate q. This relationship was developed based on data collected at Callahan Creek Reservoir (Rausch and Heinemann, 1975). The data are plotted on Fig. 2.

Short-Circuiting and Dead Storage

During most flow events, some inflow will begin to be discharged before all the previously stored flow is discharged. Often part of the permanent pool volume will not be exchanged, even though the inflow volume is many times the pool volume. Short-circuiting will tend to occur throughout a storm, and will be combined with some degree of mixing between the plugs of flow. The initial short-circuiting of part of the permanent pool may be simulated by the input of a dead storage volume into the DEPOSITS storm data set. This volume will be bypassed when the sediment is routed through the pond. In verification studies with the model, Ward et al. (1979) found that the volume of dead storage will probably range between 10 to 30 percent of the permanent pool volume for a well-designed pond with a surface withdrawal outlet system. For a bottom withdrawal system, the dead storage volume will be large if the inflow occurs as a density current. During the storm event, short-circuiting may be simulated through use of a control variable. If the variable is made equal to one, the sediment is routed as plug flow. A value of 1.1, for example, will deplete the inflow sedimentgraph at a rate 1.1 times faster than the rate described by ideal plug flow. The detention time of each plug of flow is, therefore, reduced, resulting in a more rapid peak on the outflow sedimentgraph and a lower trap efficiency.

MISSOURI AGRICULTURAL WATERSHEDS

The Watershed Research Unit in Columbia, MO, have been monitoring three reservoirs for over 7 years (Rausch and Heinemann, 1975). Data from Callahan Reservoir and Bailey Reservoir were made available to verify the DEPOSITS model. Only a small sample of a very extensive data base was used and all the results from this study with the DEPOSITS model are presented.

Callahan Creek Reservoir and Watershed

Callahan Creek Reservoir is located on a 1440-ha agricultural watershed. About 50 percent of the gently rolling watershed is cropland, 36 percent is pasture, and 24 percent is forest. These data are of excellent quality, except that 20 percent of the watershed was ungauged. The ungauged area was mostly pasture and forest and contributed almost no sediment. The main characteristics of the drainage area and reservoir are presented in Table 1. Fig. 3 is a map of the watershed showing the sampling points at the inlet and outlet to the reservoir. The stage-storage and stage-discharge relationships for the reservoir are presented in Fig. 4.

Bailey Reservoir and Watershed

Bailey Reservoir is a small agricultural reservoir, located on a 94-ha watershed in Missouri (Fig. 5). About 50 percent of the watershed is cultivated and the rest of the watershed is grasslands and forest. The main characteristics of the reservoir in 1973 are presented in Table 1. About 45 percent of the watershed was ungauged; however, the ungauged area produced almost no sediment since it is predominantly grasslands and forest. In August 1975, the spillway was converted from a surface discharge to a bottom withdrawal system by adding 19 m of 46 cm corrugated metal pipe to the inlet of the hooded inlet pipe. This system withdrew the water from an aver-

TABLE 1. WATERSHED AND RESERVOIR CHARACTERISTICS

Watershed or reservoir characteristics	Callahan watershed	Bailey watershed (1973)	Units
Total storage	560,000	127,000	m^3
Permanent pool	160,000	63,500	m^3
Principal spillway	1.2 x 2.4 m drop. Inlet Riser.	46 cm Smooth Steel hood inlet	
Length	Approx: 1200	360	m
Width	Average: 60	110	m
Pond depth	Average: 2.0 Maximum: 5.0	Average: 2.0 Maximum: 3.5	m m
Watershed area	1,440	94	ha
Watershed slope	1-11	1-11	%
Channel slope	1.0	1.1	%

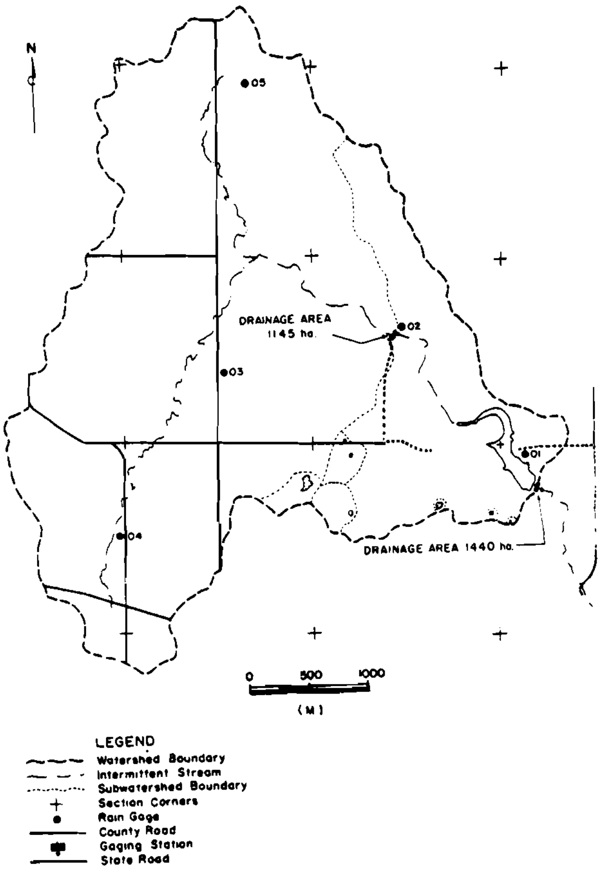

FIG. 3 Callahan Creek watershed reservoir C-1.

age depth of 3.3 m. The reservoir storage below this withdrawal elevation is only 2500 m³. The permanent pool water surface is, however, maintained at the original level, since the syphoning action is broken automatically by an air vent near the apex of the pipe (Rausch and Heinemann, 1975). The stage-storage and stage-discharge relationships for the reservoir are shown in Fig. 6.

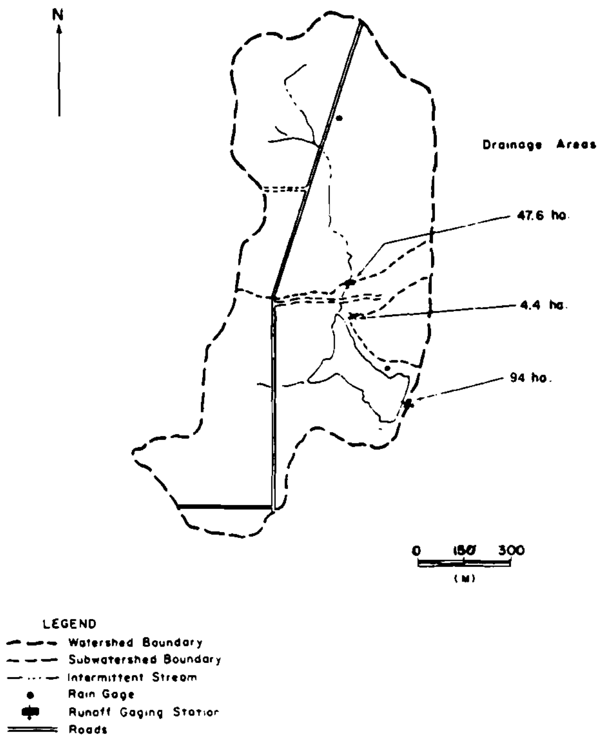

FIG. 5 Bailey reservoir watershed.

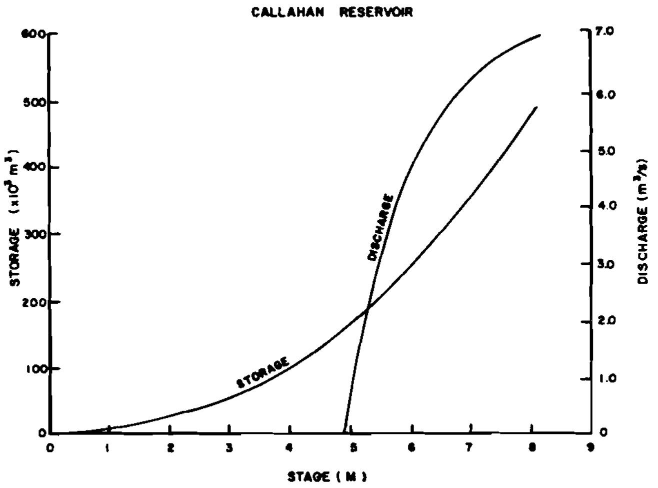

FIG. 4 Callahan reservoir basin geometry and spillway rating curve.

Sample Analysis

The inflow was automatically sampled at each gauging station with a PS-66 pumping sampler developed by St. Anthony Falls, Inter-Agency Hydraulics Laboratory in Minneapolis. A 400-mlL sample was taken at intervals ranging from 4 min to 2.5 h, depending on the flow rate and water stage. Outflow from each reservoir was sampled at the discharge end of the spillway pipe with a Columbia spillway sampler (Rausch and Haden, 1974), which collects a 2-1 sample every 2 or 3 h, when the flow was greater than base flow. Manual samples were collected during base flow.

The sediment concentrations of the samples were determined by two methods. The 400-mlL inflow samples were vacuum-filtered through Gooch crucibles with glass fiber filters that retain at least 90 percent of the 1-μm particles (Dendy et al., 1979). The filters were oven dried and weighed, and an average tare weight for the filter was subtracted to find the net weight of the sediment. The variation in filter weight may cause a maximum concentration error of 12 mg/lL in these samples. The 2-1 outflow samples were analyzed by another method, since they contained high percentages of colloidal particles and readily plug the filters. These sample jugs were allowed to settle for 2 weeks or more. Then, the supernatant was decanted down to the sediment. The sediment was then washed into a pretared 400-mlL beaker and then evaporated to dryness in an oven. Dissolved solids in the supernatant were analyzed separately and subtracted from the dried sample weight. The amount of

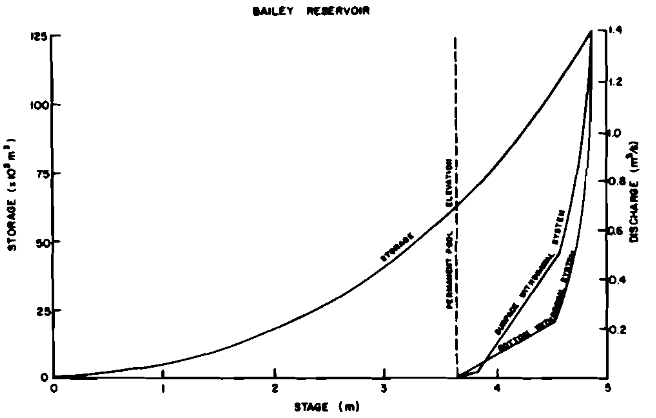

FIG. 6 Bailey reservoir basin geometry and spillway rating curves.

dissolved solids depends on the volume of liquid left in the sample jug. If 100 mlL of supernatant is dried for dissolved solids and 100 mlL is left in the jug with the sediment, then the dissolved solid weight can be subtracted directly from the sample dry weight.

For both sets of samples, the sediment concentration is the weight of sediment without the dissolved solids divided by the total sediment volume (mg/lL). Sediment yield can be computed by multiplying the sediment concentration for each sample by the volume of water it represents. The trap efficiency for each storm is then computed from the sediment mass in the inflow to the reservoir and from the sediment mass when the same water leaves the reservoir. In the computational procedures, plug-flow routing of the flow was assumed.

DEPOSITS ANALYSIS OF CALLAHAN RESERVOIR DATA

Data from a 2-month period during 1973 were used for analysis. This data set was selected because the data were of a high quality with several very large events occurring during this period. The best particle size information was also collected during this period. Rausch and Heinemann (1975) have reported several results based on this data set. The period was subdivided into six inflow events. The distribution of the rainfall over the watershed varied during each event. During the end of April and May, most of the runoff was from the drainage area, which was gauged, and little error resulted in routing the gauged inflow through the reservoir. The three events that occurred at the beginning of the period being analyzed, resulted in a more uniform rainfall distribution and had very significant runoff volumes from the ungauged pastures and forested areas. We felt that the sediment yields from these areas was fairly low, but some error occurred in routing only the gauged flow rates through the reservoir. Because of the reservoir's long length and the fact that most of the ungauged runoff entered the reservoir at various points along its length, we felt that accuracy would not be improved by synthesizing the inflow rates to the reservoir based upon the observed outflow rates.

The actual trap efficiency of the reservoir was determined for each event based upon the procedure described earlier. In general, we felt that fairly good estimates of the actual efficiency were obtained, although the efficiency during the first storm was based upon a limited number of outflow samples.

We used three methods to predict the trap efficiency during each event:

1 The Environmental Protection Agency overflow rate method (EPA, 1976).

2 The DEPOSITS model, using the observed inflow sedimentgraphs.

3 The DEPOSITS model, using the model default sedimentgraphs, based on observed sediment loads.

The EPA method is based on a method developed by Camp (1945) for quiescent settling and uses the equation:

$$V = Q/A \qquad [4]$$

where V is the fall velocity (m^3/s); Q is the average or peak discharge rate (m^3/s); and A is the pond surface area (m^2). Generally, the surface area A is reduced by 0.8 to account for dead storage. This allowance, however, was not made in this analysis. We estimated the particle-size distribution at the peak flow rate using the results contained in Fig. 2, and in each calculation the average flow rate was used for Q. We felt that the method was applied in the most advantageous way and that estimates of the reservoir efficiency would be even lower if we had adopted any other procedures.

The results of the three studies are presented in Table 2. Generally, the DEPOSITS model gave very good estimates of the reservoir sediment-trapping performance. The efficiency of the pond was usually slightly less during the smaller events despite the increased detention times in the reservoir. The reason for this is because the small

TABLE 2. CALLAHAN RESERVOIR

Date of event		Inflow, mm	Sediment, metric tons	Peak flow rates, m^3/s		Detention time, (h)		Trap Efficiency, %			
Inflow	Outflow		Inflow	Inflow*	Actual discharge†	Average‡	Minimum§	Actual‖	EPA**	DEPOSITS††	DEPOSITS‡‡
March 24-25	March 24-30	32	355	7.9	5.9	70	15	68	58	67	53
March 31	March 31 -April 5	33	770	17.9	6.1	57	15	78	68	73	73
April 14-16	April 15-21	24	215	7.9	5.4	93	27	78	62	78	81
April 15-22	April 16-22	50	1524	27.5	6.5	35	10	79	74	76	80
May 7-21	May 21-26	33	1359	29.9	7.0	100	11	88	75	88	88
May 26-27	May 26-30	50	2581	124.5	7.1	24	7	85	85	84	85

*About 20% of the watershed drainage area is ungauged.

†The reservoir discharge reflects the inflow from the total drainage area.

‡Volume weighted averaged assuming plug flow.

§Minimum detention time of any plug.

‖Based on influent and effluent sediment loads.

**Maximum possible efficiency using V = Q/A and particle-size distribution at peak inflow rate (where V = Fall velocity, Q = average flow rate and A = surface area at the peak stage).

††Using observed inflow sedimentgraphs.

‡‡Using the DEPOSITS default inflow sedimentgraph.

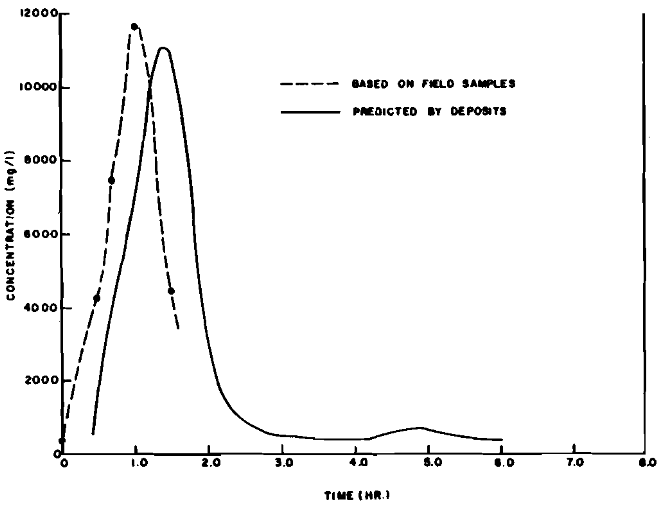

FIG. 7 Callahan reservoir inflow sedimentgraph large May storm event.

events contained proportionately more finer particles. For the six events, the average trap efficiency is just over 83 percent. The EPA method predicted an overall efficiency of 77 percent, whereas the two DEPOSITS methods estimated overall efficiencies of 81 and 82 percent. Except for the first event, there is little difference between the estimates made by the two different procedures using the DEPOSITS model. For this watershed, the calculated DEPOSITS method for predicting the inflow sedimentgraphs gave good estimates of the observed inflow sedimentgraphs. Fig. 7 shows the predicted and observed sedimentgraphs for the large event of May 26-27. The DEPOSITS method was not developed based upon data from this watershed. In both DEPOSITS procedures, the inflow particle-size distribution was varied throughout the storm event. For the small events with peak inflow rates less than 11.3 m^3/s, the single distribution for a flow rate of 4 m^3/s was entered into the model, and, for the other events, the single distribution at 11.3 m^3/s was used. The DEPOSITS model then varied these distributions by using equation [3]. We also conducted an analysis with the model using a single distribution to represent the whole storm event. The distribution at the peak flow rate was used and the results varied by 1 to 3 percent from those obtained in the first DEPOSITS analysis.

The model generally gave fairly good estimates of the outflows concentrations, although the peak concentrations predicted by the model occurred 2 to 6 h laters than those observed. Three factors contributed to the observed peaks occuring earlier than predicted.

1 Dead storage and short-circuiting in the reservoir.
2 Actual flow rates through the basin were higher than those used in the simulation because of the contributions from the ungauged areas.
3 Observed peak inflow loads occurred 20-30 min. earlier than the peak inflow rates.

Calculated loads were also slightly larger than those observed because the DEPOSITS model does not account for mixing between the plugs, and also because the observed flow concentrations had been slightly diluted by the cleaner flow from the ungauged areas. Several particle-size distributions for the sediment contained in the effluent were obtained during this period.

Generally, these samples indicated that over 95 percent of the sediment being discharged was finer than 5μm, and that over 85 percent was finer than 2 μm. The DEPOSITS model predicted that over 99 percent of the sediment would be finer than 2 μm. Apparently, the model makes a good estimate of the coarse-size particles being trapped, but has some difficulty estimating the fractions of finer-size particles trapped.

BAILEY RESERVOIR ANALYSIS WITH THE DEPOSITS MODEL

Using the DEPOSITS model, we could make good estimates of the performance of Callahan Reservoir and we decided to extend the study to an analysis with some data from Bailey Reservoir. One of our objectives in extending the study was to see if the model were capable of predicting the change in performance of Bailey Reservoir when it was converted from a surface-withdrawal spillway to a bottom-withdrawal system. Seven different storm events were evaluated — five during 1973, when the surface-withdrawal system was in operation, and one in 1976 and 1977, when the bottom-withdrawal system was operating.

Bailey Reservoir is much smaller than Callahan Reservoir, and a much larger portion (about 45 percent) of the watershed was not gauged. To reasonably estimate the detention time of the flow in the basin, it was necessary to develop inflow hydrographs for each event, based upon observed outflow rates and changes in stage within the reservoir. We felt that most of the ungauged flow would have entered the reservoir at the southwest inlet to the basin and would have travelled through most of the body of the reservoir. The peak inflow rates, shown in Table 3, reflect only the gauged inflow rates. Inflow sedimentgraphs were developed based on observed concentration for the gauged portion of flow and by assuming that the load was negligible from the ungauged pastures

TABLE 3. SUMMARY OF BAILEY RESERVOIR STUDY

Date	Runoff, mm	Sediment inflow, metric tons	Peak inflow, m^3/s*	Peak outflow, m^3/s	Detention time, h†	Trap efficiency observed, %	Trap efficiency calculated,† %
March 4-10, 1973	43	12.3	0.58	0.42	295	68‡	87
March 10-15, 1973	38	20.0	0.96	0.42	358	85	87
March 24-31, 1973	64	41.8	0.89	0.43	225	89	87
March 31 - April 8, 1973	38	14.5	0.98	1.19	359	72‡	85
April 20 - May 1, 1973	86	87.3	2.55	1.07	81	92	84
March 3-15, 1976 §	38	12.3	1.11	0.28	55	59	57
May 6-15, 1976 §	61	11.8	1.80	0.18	50	66	64

*Only 55 percent of the watershed is gauged.
†Calculated with the DEPOSITS model.
‡Based on only a few samples.
§Spillway converted to a bed-withdrawal system.

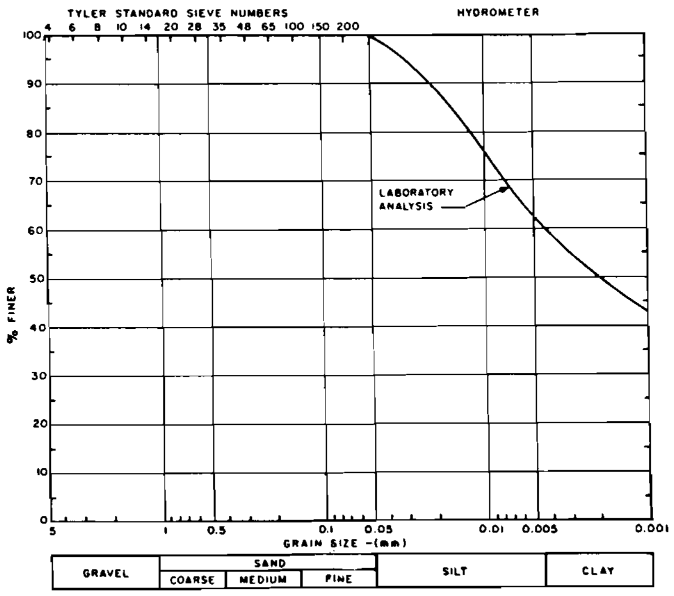

FIG. 8 Inflow sediment distribution for Bailey reservoir.

and forest areas. The DEPOSITS model gave good estimates of the basin performance for all the events, except for the two during which only a limited amount of outflow samples were obtained.

For the surface-withdrawal system, the overall observed trap efficiency was about 87 percent, and the calculated efficiency slightly higher than 85 percent. For the bottom-withdrawal system, the observed efficiency was about 62 percent or 2 percent higher than predicted. The DEPOSITS model not only gave good estimates of the efficiency during each event, but also modeled the change in performance due to the different systems. For the bed-withdrawal system, we assumed that the flow entered the pond as a density current and that only 2500 m^3 of previously stored flow would be discharged before the discharge of any of the storm events. (This is the same assumption used in calculating the 'actual' efficiency.) The rest of the permanent pool volume of about 61,000 m^3 was considered dead storage.

The DEPOSITS sedimentgraph default option was tested on the two events for the bottom-withdrawal system and gave results similar to those obtained with the tests using the observed inflow sedimentgraphs. Again, the DEPOSITS model gave good estimates of the outflow concentrations and the discrepancy in time between the observed peak outflow concentrations and the calculated peak effluent concentrations was considerably less than that for Callahan Reservoir. No outflow sediment, particle-size distributions were available for Bailey Reservoir because of the much smaller sediment loads contained in the effluent.

DISCUSSION OF RESULTS

The DEPOSITS model gave good estimates of the performance of both Callahan and Bailey Reservoirs during all the storm events. The model also predicted the change in performance of Bailey Reservoir when the spillway system was changed to a bottom-withdrawal system. In general, the DEPOSITS model gave better estimates of the basin performance than the method currently adopted by the EPA. For Bailey Reservoir, this method gave calculated trap efficiencies of less than 60 percent for all the flow events, including those that occurred when the surface-withdrawal system was in operation. Both reservoirs trapped most of the particles larger than 5 μm. Less variation in particle-size distribution with flow rate seemed to occur on Bailey Reservoir, and a single inflow sediment distribution was used for all the flow events (Fig. 8). No relationship has been developed between the flow rate and particle-size distribution for this watershed since only a limited data base was available. In general, however, the flow rates on this watershed were considerably smaller than those on Callahan Creek Watershed, and the range in peak flow rates between the seven storm events evaluated was much smaller than that in peak rates during the six events on Callahan Creek watershed. The study also highlighted some of the difficulties in establishing an effective monitoring program and of determining the actual performance of a reservoir. Heinemann (1978) reported that only about 20 reservoirs have been studied in enough detail to provide adequate data to evaluate reservoir trap-efficiency performance. One major problem with this type of research is the installation of an effective monitoring system and the ability to determine the actual trap-efficiency of the impoundment. Actual trap-efficiencies are usually calculated based on either a procedure which assumes plug flow or else by 'tracking' the peak loads through the basin. With a long term, continuous, monitoring system, such as that used in Missouri, a good estimate of the overall efficiency of the structure is obtained because the errors associated with 'tracking' volumes of flow from the inlet to the outlet are minimized. Generally, reservoirs do not have single inlets and accurately monitoring inflow to the basin is difficult.

SUMMARY AND CONCLUSIONS

The DEPOSITS model gave good estimates of the performance of the spillway and reservoir systems evaluated. The results obtained were also compared with predicted estimates using a numerical procedure commonly used. This method seemed to underestimate the performance of the structure and gave very poor estimates for Bailey Reservoir. The syphon system used on Bailey Reservoir was very effective in reducing the efficiency of the structure. The DEPOSITS model method for estimating the inflow sedimentgraphs for the different storm events gave good approximations of the observed inflow sedimentgraphs.

More research is needed in evaluating different spillway systems and also in characterizing waterborne sediment loads. Predicting the performance of a structure using a model such as DEPOSITS, is possible and probably presents no more of a problem than trying to measure the actual performance of a structure. Any effective method for predicting impoundment performance will depend on a good estimate of the sedimentload characteristics. Much more research is required in this area.

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