DESIGN AND PERFORMANCE

ENHANCEMENT OF MINE DRAINAGE

SETTLING PONDS IN ALBERTA

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DESIGN AND PERFORMANCE ENHANCEMENT OF MINE DRAINAGE SETTLING PONDS IN ALBERTA

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1.0 INTRODUCTION

There has been increasing concern in recent years regarding the environmental impact of sediment laden runoffs discharged from land disturbing activities in Alberta. Settling ponds represent the most common control technology for the treatment of these wastewaters. Settling reservoirs are designed and constructed to impound contaminated waters long enough for the desired portion of the incoming sediment load to settle out.

One of the most prominent settling pond applications in Alberta is for the control of sediment in waters discharged from surface coal mines and these applications have been emphasized in the following discussion. Much of this information has been taken from the document 'Critical Analysis of Settling Pond Design and Alternative Technologies' which was prepared by Monenco Consultants for the Coal Association of Canada and The Reclamation Research Technical Advisory Committee of The Land Conservation and Reclamation Council (Monenco Consultants 1986).

2.0 THE SETTLING POND DESIGN PROCESS

There are three basic components to the settling pond design process:

- o definition of pond loading;
- o definition of pond performance criteria; and
- o evaluation of pond response.

The design process is an iterative one in which the pond characteristics are varied until the desired performance criteria are satisfied under the given loading.

2.1 POND LOADING

Pond loading is defined by the shapes of the hydrograph and sedimentgraph at the pond inlet. Hydrographs and sedimentgraphs plot the time variation in incoming flow and sediment respectively over a given time period. Figure 1 provides a conceptual illustration of these graphs. The shapes of the pond inlet hydrograph and sedimentgraph are functions of the hydraulic and sedimentologic response of the contributing watershed for the time period in question.

The critical hydrographs and sedimentgraphs for settling basin design are normally those applicable to a specified storm event. In Alberta the design event is the 1 in 10 year, 24 hour storm.

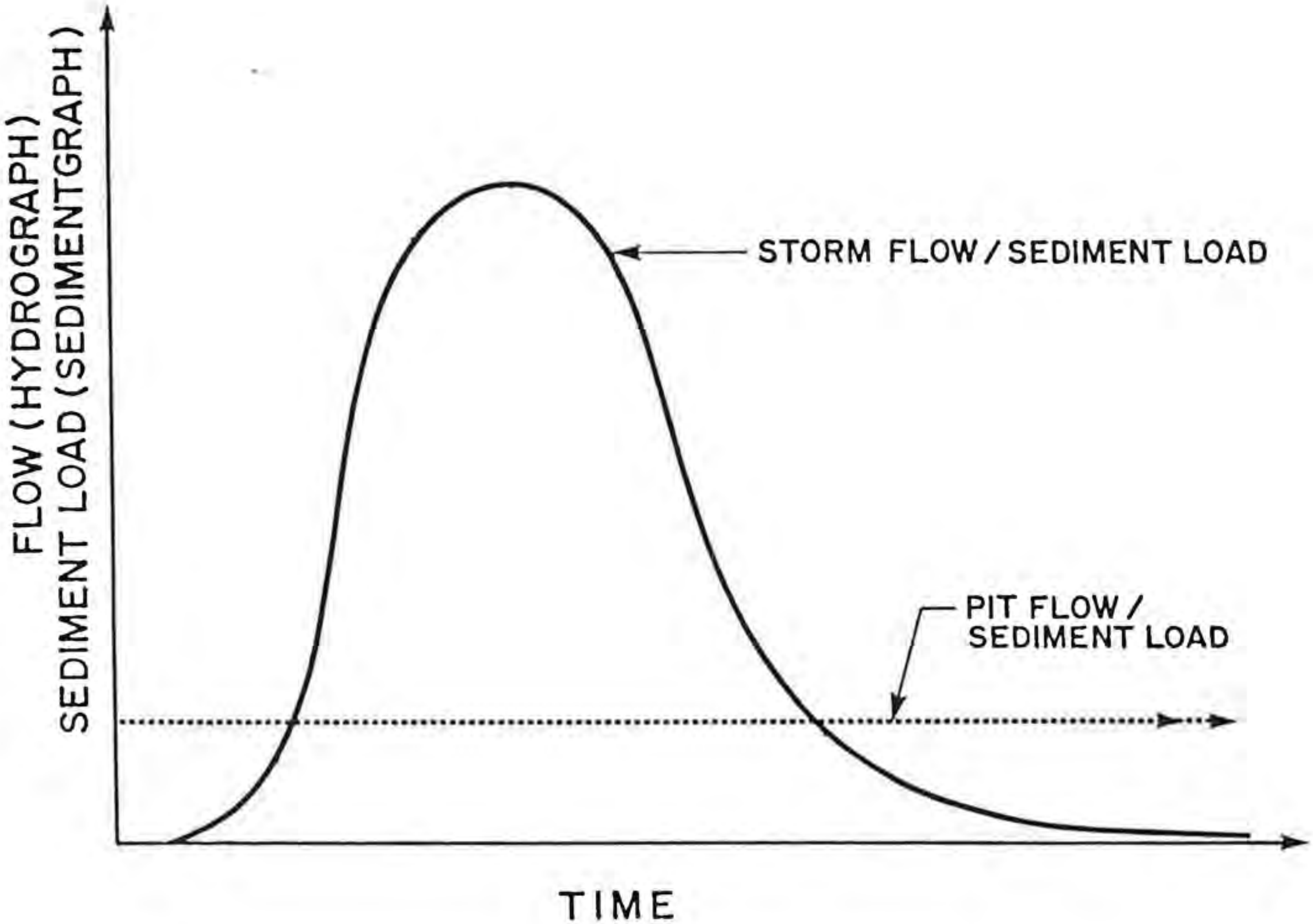


Figure 1. Conceptual illustration of Hydrographs and Sedimentgraphs

In coal mining applications the critical pond loading may not always be associated with a storm event. Runoff and groundwater in mine pits is collected in sumps and pumped to the settling pond. This pit flow is generally more constant and prolonged than storm flow. Settling ponds in Alberta should be designed for the more critical of storm or pit flow.

2.2 POND PERFORMANCE CRITERIA

Any design exercise relies on the establishment of some form of performance criteria. The criteria most commonly applied for settling pond design establish objectives for pond efficiency, detention time, effluent concentrations or solids retention.

The following criteria are those most commonly established for the design of settling impoundments:

- o minimum sediment removal efficiency; designs based on a particular sediment removal efficiency will trap a specified portion of the total sediment load during a given time period, usually that associated with the design storm event;

- o minimum detention time; detention time criteria produce ponds in which the average time any particular portion of inflow is retained is equal to a specified time period;

- o maximum suspended solids concentration; ponds designed to satisfy this criterion limit effluent suspended solids concentrations to a specified value under design flow conditions. For this criterion, the term suspended solids refers to both settleable and colloidal particle sizes;

- o maximum settleable solids concentration; settleable solids criteria are similar to suspended solids criteria except that the colloidal fraction of the incoming sediment load is allowed to be discharged; and

- o maximum sediment discharge; sediment discharge criteria limit the mass sediment load that can be discharged to the receiving watercourse over a specified time period.

The performance criteria for any particular pond are usually defined by the regulatory requirements stipulated by the jurisdiction involved. For coal mining in Alberta, Alberta Environment has prescribed limits on the average suspended solids concentration that can be discharged from a settling impoundment during any 24 hour period. The limitations apply during any storm event that does not exceed the 1 in 10 year, 24 hour storm. The Alberta guidelines are summarized in Table 1.

2.3 POND RESPONSE

As noted earlier, the settling pond design process is an iterative one in which various pond characteristics are assumed and the associated pond responses evaluated until a set of pond characteristics is established which satisfies the specified performance criteria. Pond response to a given hydraulic and sediment loading is a function of the nature of the influent and the reservoir's physical characteristics.

TABLE 1

Performance Criteria for Coal Mine

Drainage Settling Ponds in Alberta [a]

Water Contaminant or Parameter	Standard (24 hour average)
Total Suspended Solids	50 mg/L maximum absolute or 10 mg/L maximum above the natural background concentration, whichever is greater.
Total Iron	3.5 mg/L maximum absolute
pH	Within the range 6.5 to 9.5

[a] from Alberta Environment (1978)

.1 Influent Characteristics

The influent characteristics include the physical and chemical properties of the incoming water and sediment. Of particular importance are the sediment particle size distribution and specific gravity. The sediment particle size distribution refers to the relative proportions of the various particle sizes comprising the total sediment load. This parameter has a profound impact on the performance of any given pond configuration. Sediment loads consisting primarily of sand and silt particles will settle much more readily than those comprised mainly of clay sized particles.

The sediment specific gravity is a measure of the density of the individual soil particles. The particles with the highest density have the greatest probability of being retained in a pond.

The chemistry of the incoming water, particularly its ionic strength and predominant cation type, will have an impact on the flocculation process and hence on a pond's sediment removal efficiency.

.2 Pond Characteristics

The other major factor which influences pond response is the physical nature of the reservoir itself. Pond area, volume, geometry and the type and position of inflow and outflow structures all have a strong impact on the hydrologic and sedimentologic response of the pond to a given loading. These factors will combine to determine the relative proportions of the total pond volume made up of the various components illustrated in Figure 2 and described below.

- o The sediment storage volume is provided to store sediment trapped over the life of the structure, or between clean-outs.

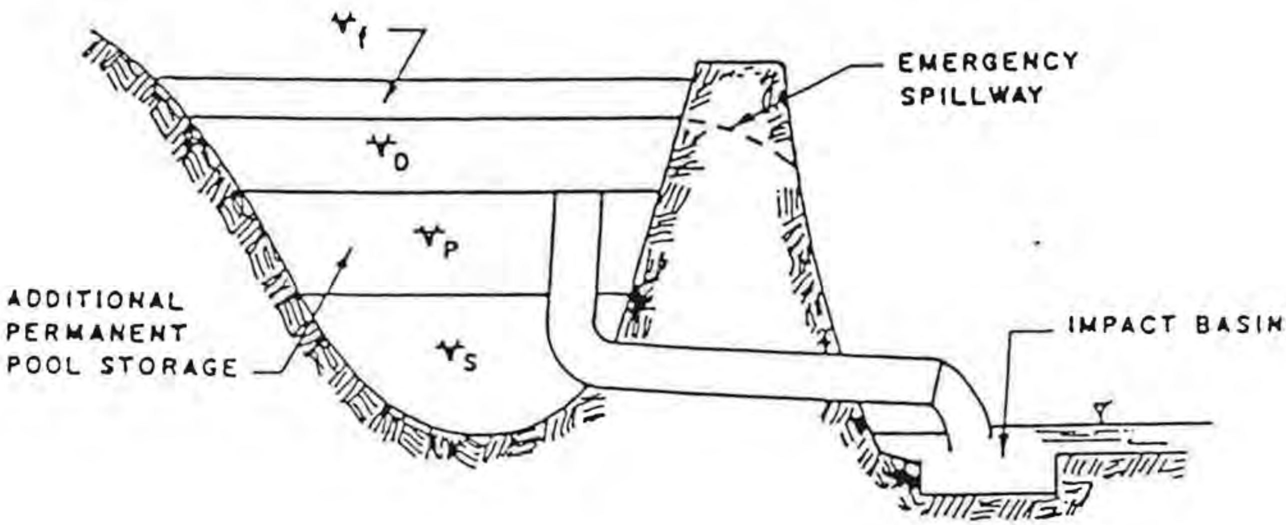


Figure 2 Schematic of sediment detention basin showing sediment storage, permanent pool, detention volume and flood storage volume. (Barfield, Warner and Haan 1981)

- The permanent pool is the volume of water above the sediment storage volume and below the crest of the emergency spillway which is not dewatered after a storm.

- The detention volume is that volume which allows the water to be retained long enough for the desired sediment fraction to settle out. It is this volume along with the permanent pool volume that most strongly influence pond performance under a given hydraulic and sediment loading.

- The flood storage volume and the emergency spillway insure that the reservoir does not overtop during a rare storm event. In Alberta, the appropriate storm return period would be defined by the Dam and Canal Safety Guidelines issued by Alberta Environment (Alberta Environment 1979).

2.4 SUMMARY OF THE DESIGN PROCESS

Figure 3 summarizes the interaction of the various components previously described in the overall settling pond design process. The initial steps are to define the pond loading (i.e. the inlet hydrograph and sedimentgraph) and to characterize the pond influent physically and chemically. A set of pond physical characteristics is then assumed and the response of the assumed configuration for the loading and influent characteristics is evaluated. This process is repeated until this evaluation shows that the predicted pond performance is adequate.

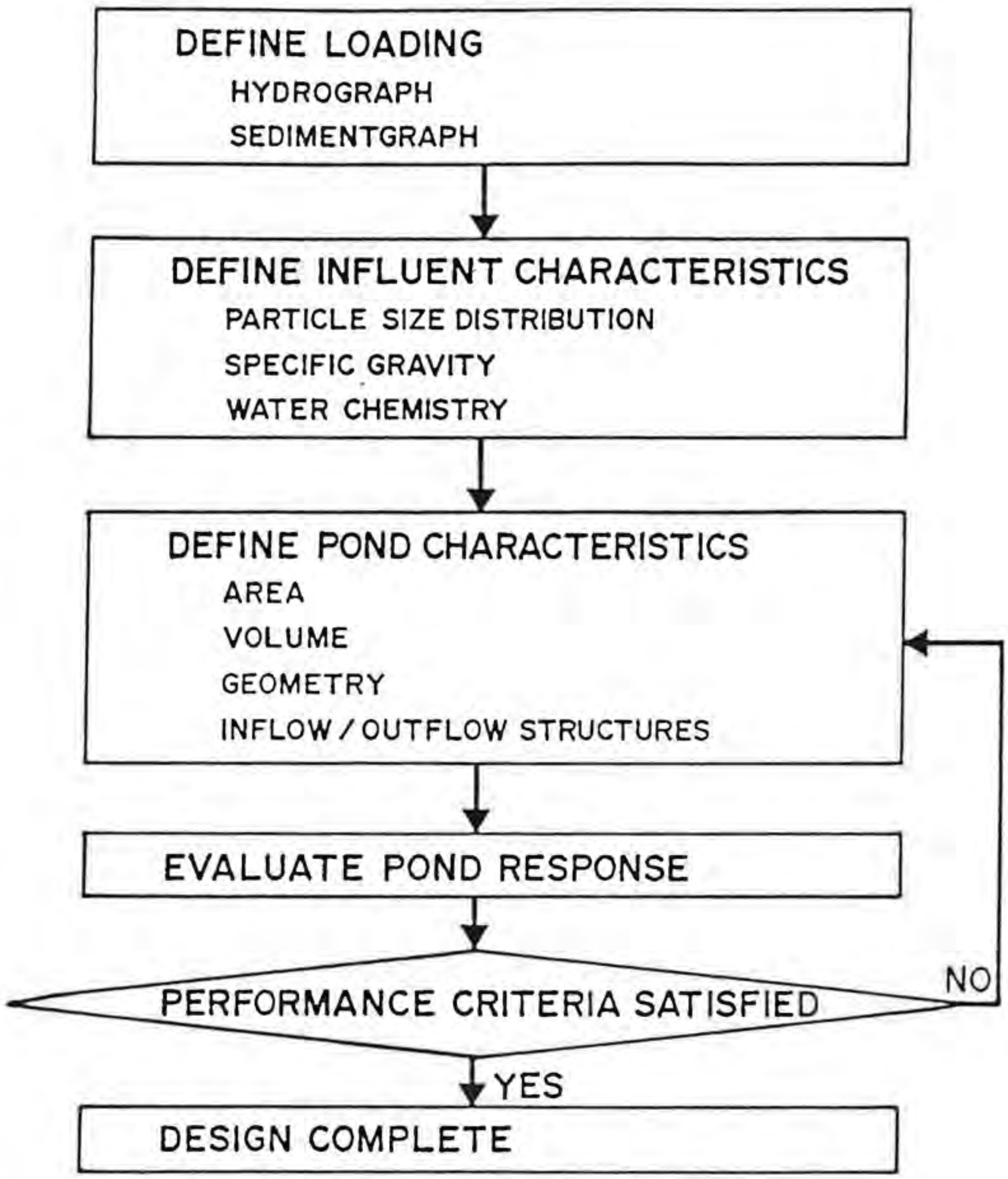


Figure 3. Summary of the settling pond design process

3.0 PREDICTIVE MODELS

The preceeding discussion outlined the settling pond design process in conceptual terms. The following paragraphs describe some of the actual design tools and techniques that are most commonly used in this process.

There are a wide variety of predictive models that can and have been used to design settling ponds. The models currently available differ greatly in sophistication and in their ability to realistically evaluate all those parameters which control sediment transport through a reservoir. The simplest models usually attempt to correlate a number of site specific parameters to a single or a relatively small number of independent variables. Simple models are easy to understand and apply but limited in their ability to realistically simulate settling basin performance.

An example of one of these simple design techniques is a steady state, overflow rate model commonly known as the USEPA model. This is not the simplest pond design model available but is typical of those relatively straightforward design tools that are commonly used. Table 2 summarizes the required inputs and predicated outputs for the USEPA model. The trapping efficiency of an assumed pond configuration is predicated for each portion of the incoming particle size distribution as a function of a single design flow, usually the peak or average pond discharge during the design storm event. The model does not account for the time variation in hydraulic and sediment load which occurs during a storm event. It should be noted that the USEPA model only evaluates basin response. Other models must be used to define the pond loading.

There are a number of design approaches considerably more sophisticated than the USEPA model that have been developed to account

TABLE 2

Summary of the USEPA Sedimentation Model

Required Inputs

- Peak or average storm discharge
- Influent suspended solids concentration
- Influent particle size distribution and specific gravity

Predicted Outputs

- Sediment removal efficiency
- Average effluent suspended solids concentration
- Average effluent particle size distribution

for all or most of the site specific parameters that influence pond performance. These models are capable of providing relatively realistic predictions of settling pond capabilities but their complexity usually increases the time and expense of the design process. An example of one of these sophisticated models, which incorporates all the components of the settling pond design process within a single framework, is the SEDIMOT II watershed model (Wilson, Barfield and Moore 1982). SEDIMOT II is used in the form of a computer program which includes algorithms that define the pond loading and evaluate basin response to that loading. The program output includes the pond outlet hydrograph and sedimentgraph and a description of peak suspended and settleable solids concentrations, average detention time and total sediment discharged during a storm event. This comprehensive output allows for the direct evaluation of pond response for any of the most common pond performance criteria. The required inputs and predicted outputs for SEDIMOT II are summarized in Table 3.

In any settling pond design exercise it is important to recognize the significance of input data quality. If input data is poorly correlated to site specific conditions, there is no design model of any level of sophistication that will be capable of providing meaningful outputs. The sensitivity of model outputs to input data quality is often more pronounced with the sophisticated models. These models typically consider a large number of site specific variables, and even if the uncertainty associated with the selected parameter values is relatively low, the combined impact of these variations can sometimes result in inaccurate evaluations of pond response.

The determination of whether a simple or sophisticated model is the most appropriate for a given design exercise will be site, time and project specific. It is not necessarily true that the most sophisticated models are always the most suitable. Factors such as project scope, land and information availability, economic constraints, ratio of controlled

TABLE 3

Summary of SEDIMOT II Watershed Model

Required Inputs

- Watershed hydraulic characteristics
- Watershed sediment characteristics

Predicted Outputs

- Pond outlet hydrograph and sedimentgraph
- Peak suspended and settleable solids concentrations
- Average detention time
- Total sediment discharge

(i.e. pumped) flow to uncontrolled (i.e. storm) flow and regulatory objectives would have to be reviewed for each proposed settling pond to define the appropriate level of design model sophistication and complexity.

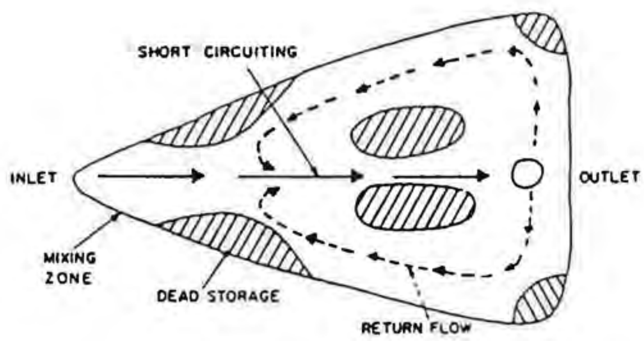
4.0 AUGMENTATIVE TECHNOLOGIES

There are a number of augmentative technologies that can be used to improve the efficiency of settling ponds. These are techniques that may be considered during the design phase but are more commonly applied to existing settling ponds that do not provide a level of performance adequate to satisfy regulatory criteria.

Techniques that can be used to increase the sediment removal efficiency of existing ponds include:

- modification of inlet and outlet structures;
- modification of reservoir flow paths; and
- use of artificial flocculants.

Inlet baffles can be used to reduce the kinetic energy of the incoming flow by distributing it as widely as possible across the inlet end of the pond. In the upper portion of Figure 4 the inlet flow possesses sufficient kinetic energy to create a turbulent jet which tends to short circuit toward the pond outlet. The bottom portion of Figure 4 illustrates how a strategically placed inlet baffle will eliminate dead storage in the centre of the pond and reduce the degree of short circuiting.



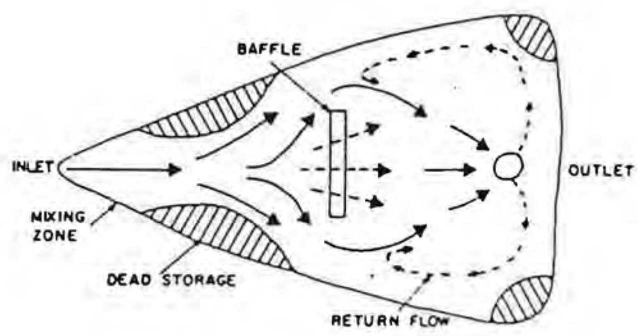


Figure 4. Sedimentation pond flow patterns (Ward, Haan, and Tapp 1979)

It may also be possible to improve pond performance by increasing the number of outlet structures and maintaining the point of water withdrawal as close to the surface as possible. Figure 5 illustrates the reduction in pond dead space that can be achieved by using two pond outlets instead of one.

Well designed settling ponds should have a flow path length to width ratio of at least two. The effective length to width ratio of existing ponds can be increased by placing baffles so that the flow path length in the pond is maximized. Figure 6 shows how baffles placed near the centre of a pond reduce the degree of short circuiting. Baffles of the sort shown in this figure can be constructed of a variety of materials. One popular design consists of plastic brattice cloth suspended on floats constructed with lengths of sealed PVC pipe. Suitable weights are anchored to the lower corners of the brattice cloth so that it will be suspended vertically in the water.

Artificial flocculation can be used to enhance the settleability of incoming sediment particles. The most common chemicals used to encourage flocculation of mine drainage sediments in Alberta are synthetic polyelectrolytes. Synthetic polyelectrolytes are long chain, water-soluble, high molecular weight organic polymers which encourage flocculation by reducing the forces of interparticle repulsion and by interparticle bridging.

Artificial flocculants can be added to the mine water in a variety of ways. One of the most common is to inject the appropriate polymer dosage directly into the pond influent stream using a small metering pump. Pond inflows and sediment load must be monitored on a regular basis to ensure that the appropriate quantity of polymer is being added to the water. In order to be effective, the polymer must be adequately mixed with the mine water. If velocity gradients in the pond

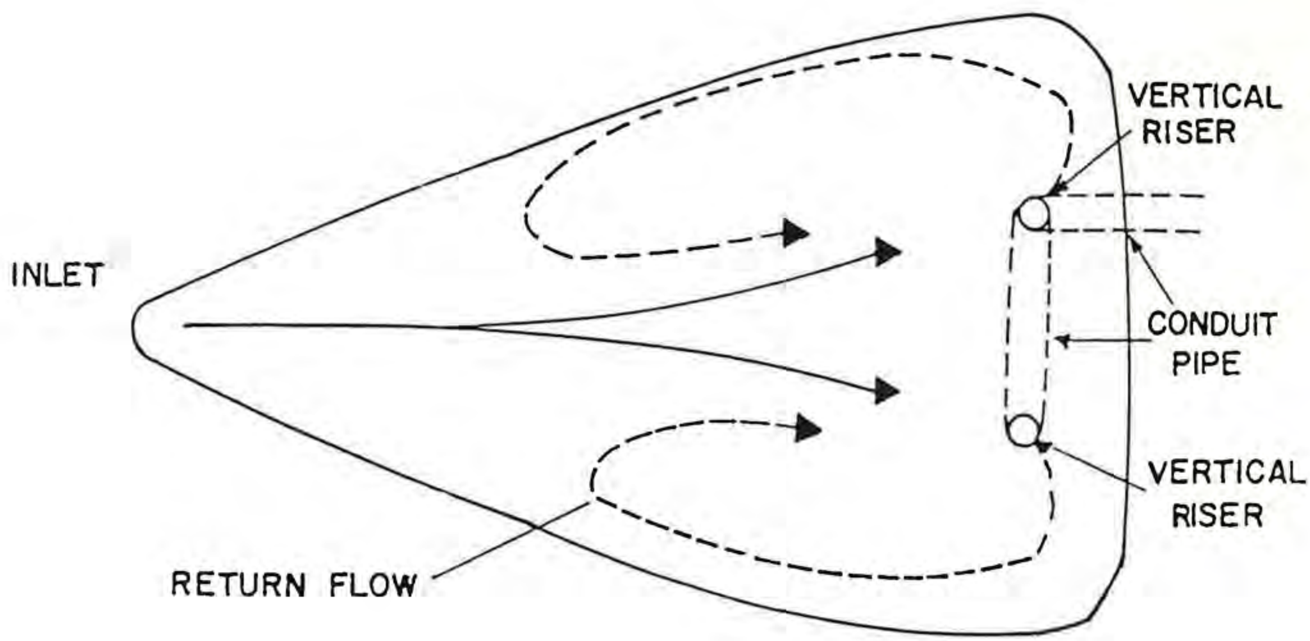


Figure 5. Probable flow patterns with a twin riser spillway (Ward, Haan, and Tapp 1979)

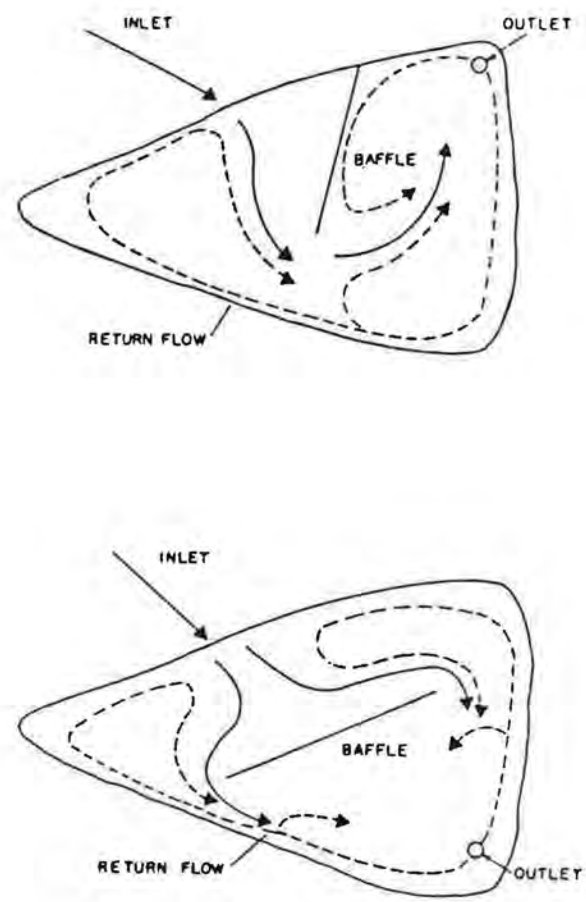


Figure 6. Pond directional baffle systems (Ward, Haan, and Tapp 1979)

inlet stream are very low, turbulence can be artifically induced to create the necessary mixing forces. The installation of rip-rap is often adequate for this purpose.

The determination of the most effective polymer and polymer dosage is usually based on field experience supplemented by the results of bench scale jar tests. In a jar test program, one litre samples of wastewater are dosed with polymer and flocculated under controlled conditions. A number of jar test and full scale pond evaluations have shown that the required polymer dosage is primarily a function of wastewater suspended solids concentration, particle size distribution and pH.

5.0 SUMMARY

Settling ponds are used in Alberta to limit the amount of sediment in waters discharged from land disturbing activities. Pond design is an iterative process in which various pond characteristics are assumed and the associated pond responses evaluated until a set of pond characteristics is established which satisfies the specified performance criteria.

There are a wide variety of predictive models that have been developed for the design of settling ponds. The simplest of these models are typically easy to use and understand but limited in their ability to realistically simulate settling basin performance. The more sophisticated models provide relatively accurate predictions of pond capabilities but their complexity increases the time and expense involved in the design process. For any design model, the quality of the input data has a strong influence on the accuracy of the predicted outputs. There is no design approach that will provide meaningful results if input data is poorly correlated to site specific conditions.

There are a number of augmentative technologies that can be used to improve the efficiency of an existing settling reservor. Inlet and outlet structures can be modified and in-pond baffles installed to reduce the amount of dead space in the pond and maximize its efficiency. Artificial flocculants can be used to increase the size and hence the settleability of the sediment particles.

6.0 REFERENCES

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PROCEEDINGS

ALBERTA RECLAMATION CONFERENCES

1985
Planning and Certification of Land Reclamation
April 16-17, 1985
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1986
Reclamation in the Eastern Slopes of Alberta
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Overlander Lodge, Hinton

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For more information on the Alberta Chapter of the Canadian Land Reclamation Association please write to CLRA, Box 682, Guelph, Ontario, Canada N1H 6L3.

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