

ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION



PLACER MINING SETTLING POND DESIGN HANDBOOK

ALASKA WATER QUALITY
MANAGEMENT PLANNING
PROGRAM

NOTES

This handbook deals with the design, construction, and operation of settling ponds, which, properly designed and operated, are capable of removing the coarser fraction of soil particles contained in placer mining wastewater; they also reduce turbidity. However, in most cases, they do not assure compliance with the State water quality standards for turbidity. Consequently, it must not be assumed that the installation and operation of settling ponds in accordance with this handbook would ensure compliance with all State regulations and standards. On the other hand, properly designed and operated settling ponds may be an important unit process used in conjunction with additional treatment processes, such as recycling or filtration.

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PLACER MINING SETTLING POND
DESIGN HANDBOOK

STATE OF ALASKA
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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EXAMPLE
STEP-BY-STEP WORKSHEET

- 1) Sluice box:
 - a) Slope _____ (in/ft)
 - b) Width _____ (in)
 - c) Depth-of-flow _____ (in)
 - d) Flow rate (figure 7) _____ (gpm)
- 2) Daily volume of material processed _____ (cu. yds.).
- 3) Presettling pond depth _____ (ft).
- 4) Desired presettling pond cleaning interval _____ (days).
- 5) Presettling pond surface area = results from figure 9 x (3 ÷ depth) = _____ (ft²).
- 6) Presettling pond length-to-width ratio _____.
- 7) Presettling pond length (figure 8) _____ (ft).
- 8) Presettling pond width = length ÷ L:W ratio = _____ (ft).
- 9) Percent recycle _____.
- 10) Design volumetric flow rate = [sluice box flow rate] x [1 - (% recycle ÷ 100)] = _____ (gpm).
- 11) Settling pond surface area necessary to meet 0.2 ml/l settleable solids limit without installing baffles (figure 6) _____ (acres).
- *12) Settling pond surface area necessary to obtain maximum sedimentation without installing baffles (figure 6) _____ x (acres).
- 13) Settling pond length-to-width ratio _____.
- 14) Settling pond length (figure 8) _____ (ft).
- 15) Settling pond width = length ÷ L:W ratio = _____ (ft).
- 16) Number of outlets (figure 5) _____.

* In most cases the pond surface area will need to be the size determined in this step.

EXAMPLE

- 17) Riser pipe diameter _____ (in).
or
Total spillway width (figure 5) _____ (ft)
and individual spillway widths = total ÷ number _____ (ft).
- 18) Dimension summary

<u>Presettling pond</u>	
Cleaning interval	_____ (days)
Length	_____ (ft)
Width	_____ (ft)
Depth	_____ (ft)
 <u>Settling pond</u>	
Length	_____ (ft)
Width	_____ (ft)
 <u>Outlets</u>	
Number	_____
Pipe diameter	_____ (in)
Spillway width(s)	_____ (ft)

SETTLING POND DESIGN HANDBOOK

This handbook presents recommendations for the design construction and operation of settling ponds to reduce the amount of soil particles in wastewater discharges from placer mining operations.

The amount of sedimentation that occurs in a settling pond is affected by many variables. Some of the most significant factors include:

- Surface area of the pond
- Rate of flow through the pond
- The grain size distribution of the incoming sediment
- Short circuiting of flow across the pond
- Entrance and exit effects

Other factors that can affect sedimentation include the specific gravity and shape of the incoming solids, the water temperature, and the turbulence within the pond as a result of wind, rainfall, and other forces.

RECOMMENDATIONS REGARDING WATER USE

A minimum of water should be used. The less water used to mine, the less wastewater that needs to be treated in the mining operation. Any device or method that can be used to cut down

water use and treatment helps. A reduced volume of water used in the mining process results in a reduced size of settling pond necessary to achieve a given level of sediment removal.

Classification of sluice feed material (using grizzlies, trommels, screens, wobblers, vibrating tables, washing plants and conveyors) is helpful in cutting down on the water used.

Reuse of process water can also reduce the quantity of water to be treated and discharged to the receiving stream. Reuse of water is particularly advantageous where there is little water available. Normally, presettling of the sluice discharge would be desirable to remove coarse sediments before the water is recirculated back to the sluice.

SETTLING POND LAYOUTS

For effective sedimentation, overburden should not be allowed to enter the settling pond and the mine discharge water and stream water should not be allowed to mix upstream of the settling pond. Thus, construction of a settling pond within a widened section of the stream is not recommended. Location of settling ponds outside of the stream bed is also an important consideration for avoiding washouts of the settling pond during periods of high stream flow or floods.

It should be noted that the construction of a settling pond within a fish stream would require a stream blockage permit from the Alaska Department of Fish and Game. (AS 16.05.840, Fishway Required)

An example of a good layout of a mining operations is shown in Figure One.

CONTAINMENT DAMS AND CONTROL STRUCTURES

Containment Dams

Proper design and construction of settling pond containment dams is a necessity to avoid dam failure. Factors to be considered in the design of these dams include:

- Height of the dam
- Crest width and fill slopes of the dam
- Materials used in dam construction
- Construction procedures
- Avoidance of flood damage
- Details of outlet structures

For safety reasons, dams should usually not exceed 10 feet in height. If terrain conditions or other factors indicate that a greater height would be necessary to achieve the required pond size, it would often be more desirable to construct several

smaller ponds in series that have lower dam height. Construction of dams that have a height greater than ten feet may require a permit from the Alaska Department of Natural Resources and site specific engineering design if a downstream hazard to people or property exists.

Dam and pond sites are limited on a mining claim but effort should be made to choose the best available site. This will prevent failure and subsequent rebuilding. Care should be taken not to locate a dam where its failure would result in loss of life, injury to people or equipment, or interruption of other operations. The suitability of a site is also dependent on the ability of the soils to hold water.

Mining and exploration drilling provide an excellent opportunity for site investigation. When borings or test pits are made, the resulting samples should be viewed in terms of site suitability as well as gold content. A record can be kept during exploration and/or mining showing location, depth and classes of material. This is later used to find the best location for the settling pond.

An ideal dam/pond site is on or underlain by a thick layer of fairly impervious consolidated material. Where these materials occur at the surface or where bedrock has already been reached by mining, no special measures are required.

It is recommended that containment dams have a crest width of at least twelve feet and upstream and downstream slopes of 2:1 (horizontal:vertical) or flatter when constructed of granular tailing material. Flatter slopes (3:1 or less) may be appropriate where dam heights exceed ten feet, or where fine grained materials are used in dam construction.

Granular tailings material is usually suitable for dam construction, provided that the inner core of the dam is constructed of relatively impervious material. This can be achieved by use of an impermeable barrier of plastic sheeting within the dam or by mixing silty overburden materials with the tailings. The mixture should contain at least 12 percent, by weight, of silt sized particles as measured with respect to the weight of those tailing that will pass a 3 inch mesh sieve.

It is desirable that the impervious material in the dam extend through surficial pervious foundation soils into underlying bedrock or other impervious soils.

A typical cross section of a settling pond containment dam is shown in Figure Two.

The dam should be constructed by placing the tailings in thin layers (less than twelve inches loose thickness) and thoroughly

compacting each layer before the next layer is placed. As a minimum compactive effort should consist of repeated passes of heavy earthmoving equipment until a dense, firm embankment is achieved.

Pond Inlets

It has been found that settling ponds are more effective if sluiced material is discharged to a meandering tailrace that leads to the pond. This allows tailings and sand particles to settle out before they reach the settling pond, prolonging the life of the pond before it becomes filled with sediment.

Construction of a small presettling pond at the pond entrance will reduce inflow velocities and result in additional deposition of coarse sediment before it reaches the pond.

The recommended presettling pond can often be constructed with relatively little effort by placement of a shallow berm of tailings across the tailrace. Coarse sediments deposited behind the berm can usually be removed without difficulty with a bulldozer. Frequent removal of this material would typically be required. Construction of a presettling pond with a berm of tailings can also serve to spread the entering flow across the entire width of the settling pond, thus reducing the potential for flow to become concentrated in only a portion of the width of

the pond ("short circuiting"). Multiple inlet structures may serve to reduce short circuiting and thus could enhance pond efficiency.

The surface area of the presettling pond should be about one square foot for each gallon per minute of flow through the pond.

Outlet Structures

Outlets should be constructed to limit the level of the water surface to at least one foot below the top of the dam. It is recommended that, where a containment dam is subject to periods of high flow, an emergency overflow spillway be constructed in a low portion of the dam. This emergency spillway should be designed to release storm surges before overtopping of the dam occurs. As such, the required width of the emergency spillway is site dependent, varying with the flood flow characteristics of the stream. The elevation of the emergency overflow spillway should typically be about one half foot above the normal water surface elevation in the pond.

Outlet structures may be of the overflow spillway type or may consist of a culvert pipe with riser, as described below.

Overflow Spillways

Overflow spillways from settling ponds need to be carefully designed and constructed to avoid erosion or washouts from the pond discharge. Spillway erosion protection on the downstream slope of the containment dam and at the toe of the spillway should consist of a minimum two foot thickness of angular rock, averaging eight inches in its least dimension. The crest of dam spillway should be protected with at least a one foot thickness of four inch angular rock. The width of the spillway should be at least one foot for each 400 gallons per minute of flow through the pond. This should limit the velocity of the pond discharge sufficiently to avoid erosion of the containment dams if the above recommended erosion protection measures are provided. At least one spillway should be provided for each 150 feet of pond width to limit nonuniform flow velocities ("short circuiting") through the pond. If a source of angular rock is not available for erosion protection, a riser type of outlet should be used. Alternatively, filter cloth, plastic sheeting, timber cribbing, or other materials may be used in the spillway for protection from erosion.

The recommended design details are illustrated in Figure Three.

Riser Outlets

Riser outlets should be constructed of culvert pipes having a diameter of at least 18 inches to limit the potential for obstructions from floating debris. At least one inch of pipe diameter should be provided for each 100 gallons per minute of flow through the pond. At least one riser should be provided for each 150 feet of pond width to limit nonuniform flow velocities through the pond.

Several cutoff collars should be installed around the portion of the pipe that passes through the containment dam. These collars are necessary to prevent erosion of fill materials by seepage along the pipe. The cutoff collars may consist of sheet metal, polyethylene sheeting or other impervious materials and should extend at least two feet beyond the pipe.

An apron of large rock (approximately 8" min. dimension) or other suitable material should be provided at the pipe outlet to prevent erosion at the toe of the dam.

The recommended design details for a riser type of outlet structure is illustrated in Figure Four.

The required number of riser or spillway outlets, the required size of riser pipes and the required total spillway width can be

determined from Figure Five, given the settling pond width and discharge flow.

POND SIZING AND DIMENSIONS

Typical permit conditions for placer mining limit the amount of settleable solids in the water leaving settling ponds to 0.2 ml of solids per liter of water. Recent field tests of placer mine settling ponds conducted in Alaska showed that removal by sedimentation of suspended soil particles larger than 0.02 mm is necessary to consistently meet this limitation on settleable solids. Results from these same field tests indicate that sedimentation of 0.02 mm soil particles will occur if the settling pond overflow rate is 3700 gallons per minute per acre, or less. (The overflow rate is the flow rate through the settling pond, divided by the surface area of the settling pond. For example, a settling pond having a surface area of two acres and a flow of 1500 gallons per minute through the pond would have an overflow rate of 750 gallons per minute per acre).

Sedimentation is considered to be effective in removing only those suspended soil particles that are larger than 0.002 mm. Therefore, to reduce the sediment concentration of the settling pond discharge to its minimum attainable level the settling pond should be sized to remove soil particles that are 0.002 mm in diameter, or larger. Results from settling pond field tests

indicate that the sedimentation of particles of this size requires a settling pond with an overflow rate of less than 860 gallons per minute per acre.

Settling ponds should be designed to achieve the maximum removal of suspended particles that can be attained by the sedimentation process when receiving stream dilution is not sufficient to permit compliance with state turbidity standards. Since, in many cases, sedimentation will not be sufficient to meet state turbidity standards, additional treatment will be necessary to meet these standards. Complete recycling would reduce the need for any stream discharge or additional treatment.

The necessary settling pond areas to reduce settleable solids concentrations to less than 0.2 ml/l and to achieve maximum sedimentation can be determined from Figure Six, given the flow rate through the sluice box and the percent of water that is reused and not returned to the stream. The flow rate through the sluice box can be estimated from measurements of the flow depth and the slope and width of the sluice box using Figure Seven. This Figure is based on Manning's equation for uniform flow through an open channel, with an effective roughness coefficient of 0.032 feet^{1/6}, based on flow measurements through a number of operating sluice boxes. If the effective roughness coefficient differs from this value, the flow estimate will be off to that degree.

In order to limit short circuiting of flow, ponds should be constructed with a length that is at least twice the width. A length-to-width ratio of 5:1 or greater is desirable, where possible.

The installation of baffles or other partitions that divide the pond into several compartments will also reduce short circuiting. A baffled pond can thereby be as effective in removing sediment as a larger, unbaffled pond.

The required dimensions of the pond needed to satisfy needed surface area and length-to-width ratios can be determined from Figure Eight.

MAINTENANCE AND RESTORATION

Frequent removal of coarse sediments from presettling ponds will normally be necessary. This would be expected to be accomplished without difficulty using a dozer.

The percentage of processed pay dirt that is deposited by sedimentation in a presettling pond is dependent upon the size distribution of soil particles in the pay dirt, the length and configuration of the tailrace between the sluice and the pond, the rate of water use, the surface area of the pond, and other variables. Typically, however, about 1/6 of the volume of pay

dirt is composed of sand sized particles that would be too small to be deposited in the tailrace and too large to pass through the presettling pond. Figure Nine shows the approximate relationship between the surface area of a presettling pond, the rate of processing of pay dirt, and the interval between cleaning operations in the pond.

Cleaning of settling ponds should be accomplished when the pond is filled with sufficient sediment to lower the quality of water discharged from the pond below acceptable standards. Monitoring pond effluent on a regular basis with an Imhoff cone is the best method to determine if the pond is becoming ineffective due to "fill up" or other causes such as short circuiting.

Cleaning can usually be best performed with a dragline. If a dragline is not available, it may be practical to remove the accumulated sediment with a dozer during the spring while the surface is thawing but the underlying sediment is still frozen and can support sediment removal equipment.

Sediment removed from settling ponds should be stacked to allow drainage to occur and capped with a layer of tailings or other granular materials to prevent erosion.

If cleaning is impractical, or the settling pond is to be abandoned for other reasons, it should be drained and capped with sufficient thickness of tailings to form a firm, stable surface.

Draining can be accomplished by breaching the containment dike, provided that a lower containment dike of permeable granular material is constructed downstream of the pond outlet to prevent accumulated sediments from entering a stream.

DESIGN EXAMPLE

A placer mine processes 750 cubic yards of pay dirt per day through a sluice box having a slope of 1 1/2 inches per foot and a width of 42 inches. The depth of flow in the box is four inches.

1. What is the rate of water flow through the sluice box?

Flow = 3700 gal./min. (See Figure Seven)

2. What size should the presettling pond be to remove sand sized and larger particles?

Presettling ponds should have a surface area of at least one square foot for each gallon per minute of flow through the pond.

(1 sq. ft./gal./min.) (3700 gal./min.) = 3700 sq. ft.

3. What size should the presettling pond be to limit required cleaning to a two week interval?

Assume a 2:1 length-to-width ratio.

A surface area of approximately 14,000 square feet would be required for the presettling pond, assuming a uniform 3 foot depth and sedimentation in the pond of 1/6 of the total volume of the material being mined. (See Figure Nine)

A 14,000 square foot surface area at a 2:1 length-to-width ratio requires a length of 168 feet and a width of 84 feet. (See Figure Eight)

4. What size should the settling pond be to reduce settleable solids concentrations to 0.2 ml/l (no water reuse)?

To achieve settleable solids concentrations of less than 0.2 ml/l the settling pond should have an overflow rate of not more than 3700 gallons per minute per acre. The pond length should be at least two times its width to limit short circuiting of flow through the pond.

Minimum Surface Area, acres = (Flow Rate, gpm) (3700 gpm per acre)

= 1.0 acre (See Figure Six)

Minimum Length (using the minimum 2:1 length-to-width ratio)
= 296 (See Figure Eight)

Minimum Width = Length / 2 = 148 feet

5. What size should the settling pond be to obtain maximum sedimentation (i.e. result in sedimentation of particles having a diameter of 0.002 mm and larger)?

Assume no water reuse.

To obtain maximum sedimentation, the settling pond should have an overflow rate of not more than 860 gallons per minute per acre.

Minimum Surface Area, acres = (Flow rate, gpm) (860 gpm per acre)

= 4.3 acres (See Figure Six)

Minimum Length (using the minimum 2:1 length-to-width ratio)
= 612 feet (See Figure Eight)

Minimum Width = Length / 2 = 306 feet

6. How many outlets should be provided and what size should they be?

At least one riser pipe or spillway outlet is required for each 150 feet of pond width. Thus, for a pond having a width of 306 feet, three outlets would be required, consisting of 18" riser pipes or spillways having a total width of at least 10 feet. (See Figure Five)

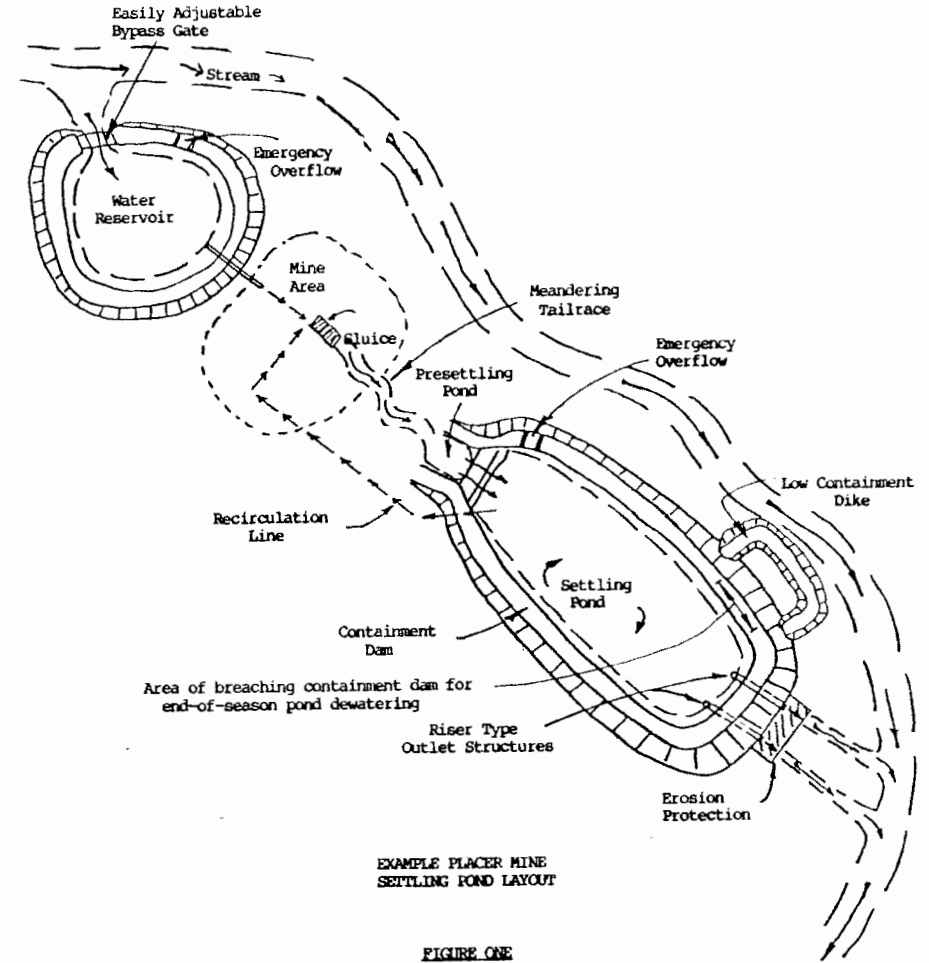
7. What size of settling pond is necessary to obtain maximum sedimentation if half of the process water is recirculated through the sluice box?

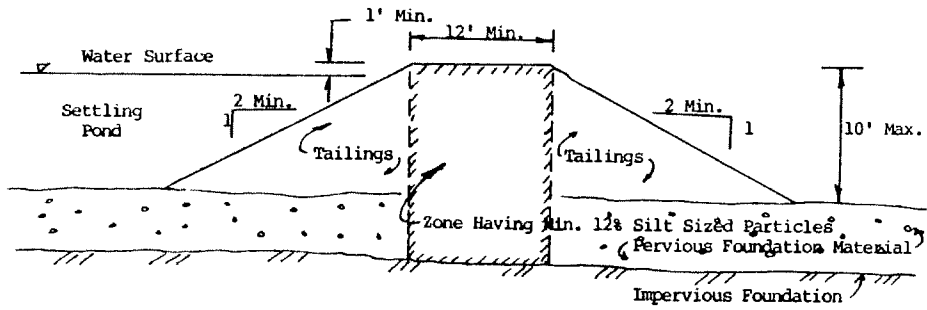
Assume a 2:1 length-to-width ratio of the pond

Surface Area = 2.2 acres (See Figure Six)
 Pond Length = 432 feet (See Figure Eight)
 Pond Width = 216 feet

A comparison of pond dimensions for the nonrecycle case and the 50 percent recirculation case, as presented above, is as follows:

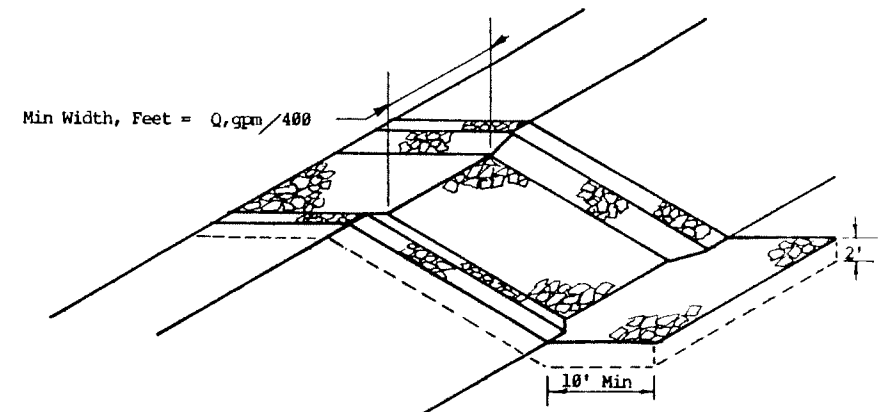
	<u>No Recirculation</u>	<u>50% Recirculation</u>
Pond Width	306 Feet	216 Feet
Pond Length	612 Feet	432 Feet
Pond Area	4.3 Acres	2.2 Acres



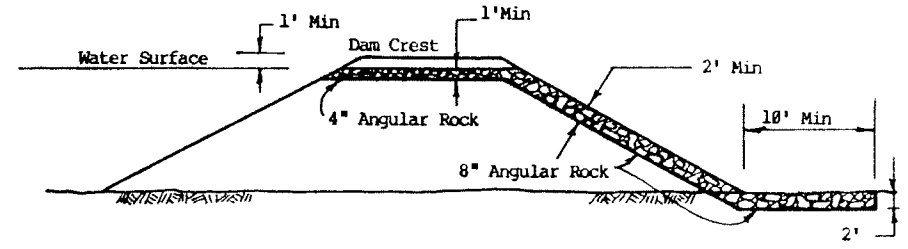


TYPICAL SECTION OF CONTAINMENT DAM

FIGURE TWO



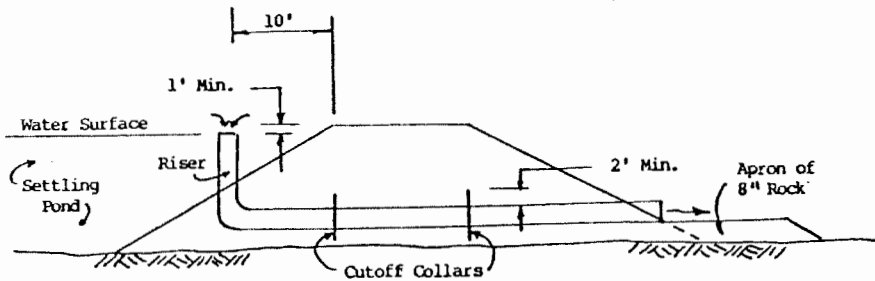
TYPICAL OVERFLOW SPILLWAY CONSTRUCTION



OVERFLOW SPILLWAY SECTION

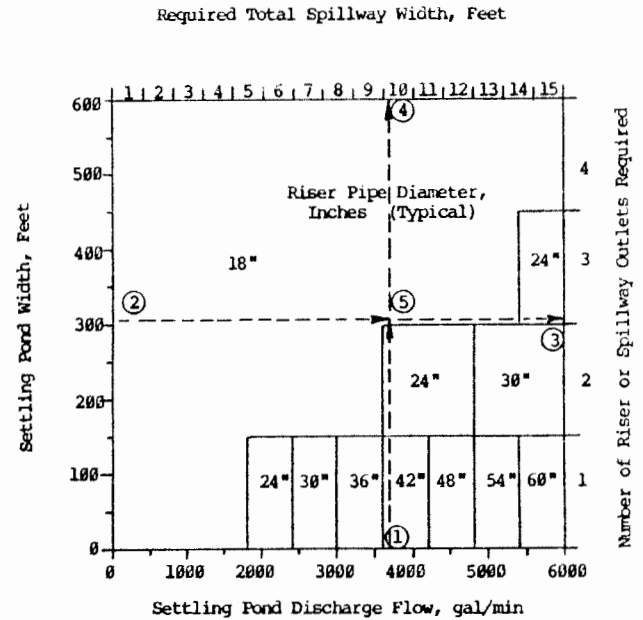
FIGURE THREE

Overflow Spillway Construction



TYPICAL RISER TYPE OUTLET

FIGURE FOUR



Given:

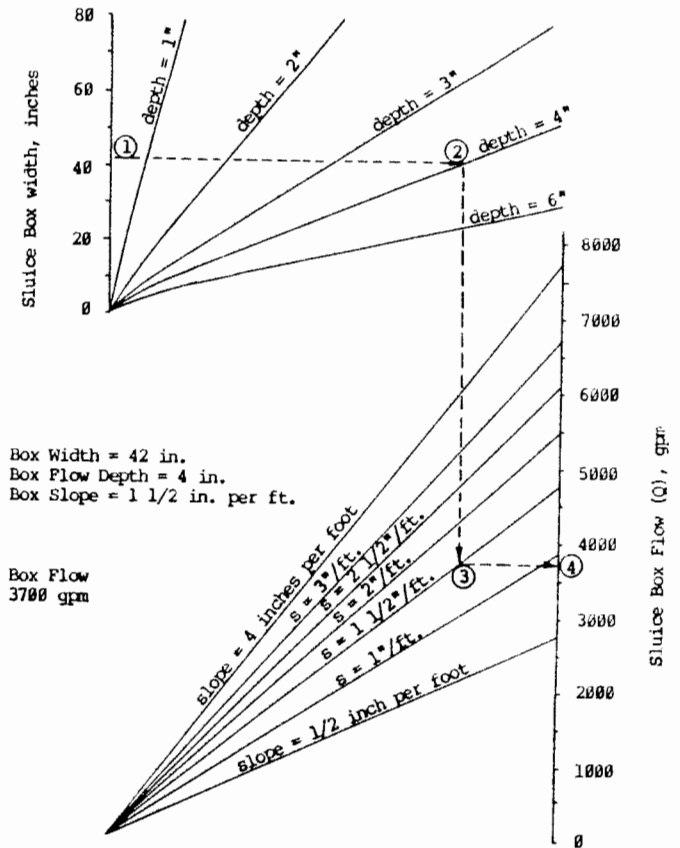
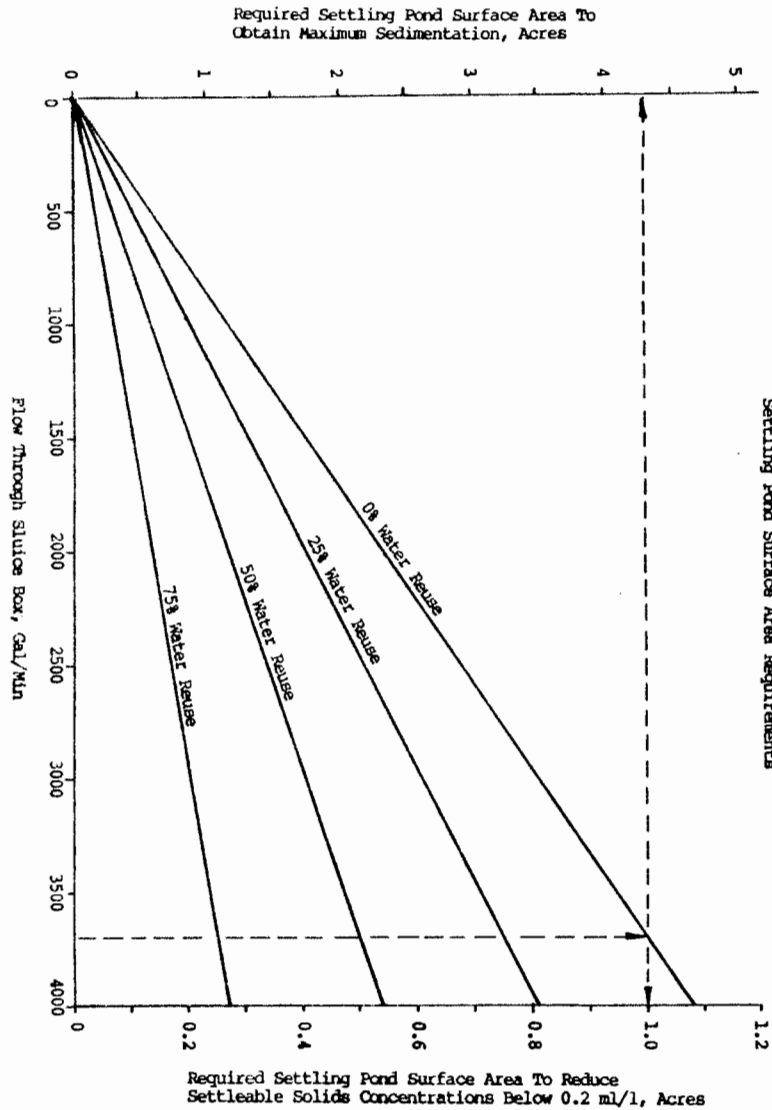
- ① Settling Pond Discharge Flow = 3700 gpm
- ② Settling Pond Width = 306 feet

Find:

- Number of required riser or spillway outlets
- Required total spillway width (if spillway outlets are provided)
- Required diameter of riser pipes (if riser outlets are provided)
- ③ 3 Riser or spillway outlets required
- ④ Required total spillway width = 10 feet
- ⑤ Required diameter of riser pipes = 18 inches (as indicated at discharge flow and pond width intercepts)

FIGURE FIVE

Design Requirements For Riser Pipe And Spillway Outlets From Settling Ponds



Given:

- ① Sluice Box Width = 42 in.
- ② Sluice Box Flow Depth = 4 in.
- ③ Sluice Box Slope = 1 1/2 in. per ft.

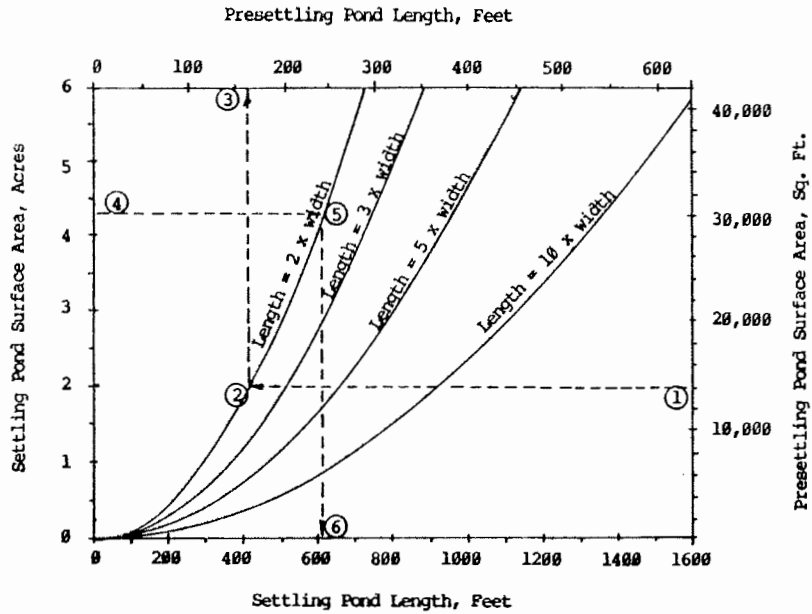
Find:

- ④ Sluice Box Flow
Flow = 3700 gpm

Curves are based on Manning's Equation

$$Q = \frac{1.49A}{n} R^{2/3} S^{1/2}$$

$$n = 0.032 \text{ ft.}^{1/6}$$



Given:

① Presettling Pond Area = 14,000 sq. ft.

② Length = 2 x Width

Find:

Presettling Pond Dimensions

③ Pond Length = 168 feet

Width = Length/2
= 84 feet

Given:

④ Settling Pond Area = 4.3 acres

⑤ Length = 2 x Width

Find:

Settling Pond Dimensions

⑥ Pond Length = 612 feet

Width = Length/2
= 306 feet

FIGURE EIGHT

Relationship of Length, Width and Surface Area
Of Rectangular Settling and Presettling Ponds

FIGURE NINE

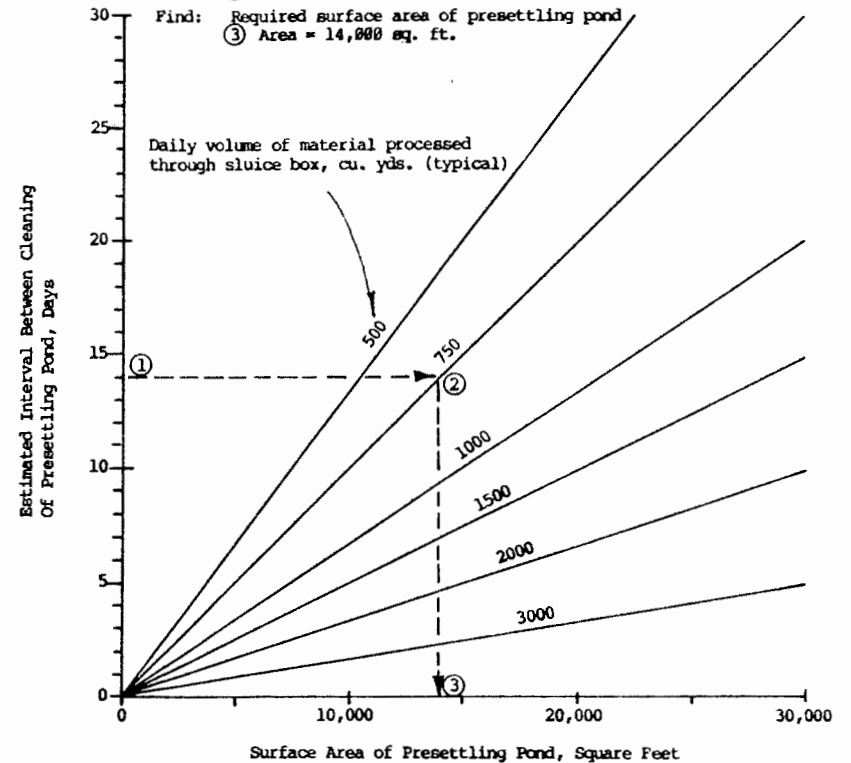
Relationship Between Cleaning Interval and Surface Area of Presettling Ponds

Given: ① Desired cleaning interval of presettling pond = 14 days

② 750 cu. yds. of material processed through sluice box per day

Find: Required surface area of presettling pond

③ Area = 14,000 sq. ft.



Assumptions:

1. Uniform 3 foot depth of presettling pond

2. 1/6 of total volume of material processed through sluice box deposited in presettling pond.