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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with operation of activated sludge wastewater treatment plants. Included are objectives, instructor guides, student handouts and transparency masters. This is the third level of a three module series and considers design and operation parameters, process control procedures, interpretation of trend chart data and the oxygen uptake test. (Author/RH)

ADVANCED ACTIVATED SLUDGE

Training Module 2.117.4.77

Prepared for the

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by

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September, 1977

SUMMARY

Module No:	Module Title: Advanced Activated Sludge
Approx. Time: 12 - 18 hours	Topics: 1. Review - Design and Operation Parameters 2. Review - Control Procedures 3. Review - Trend Charts 4. ~~Oxygen~~ Uptake 5. Process Control

Overall Objectives:

Upon completion of this module the student should be able to calculate traditional activated sludge process parameters, loading, detention times, etc. He should recognize modifications to the conventional activated sludge process and basic control methodologies. Trend chart plotting is revised and trend chart interpretation ~~is~~ addressed.

Instructional Aids:

1. Handouts
2. Transparancies
3. Calculator

Instructional Approach:

1. Lecture
2. Discussion
3. Exercise
4. Hands-on

References:

1. Recommended Standards for Sewage Works.
2. Manual of Instruction for Sewage Plant Operators.
3. Water Pollution Control Federation MOP 11.
4. Operational Control Procedures for the Activated Sludge Process, Parts III A, III B.
5. Operator's Pocket Guide to Activated Sludge, Parts I and III.
6. Dissolved Oxygen Analysis, Activated Sludge Control.

Class Assignments:

1. Read handouts
2. Solve problems
3. Plot trend charts
4. Interpret trend charts
5. Perform oxygen uptake test

Module No:	Topic: Advanced Activated Sludge

Instructor Notes:	Instructor Outline:

1. Handouts should be distributed as they appear in the module.

2. The module includes lecture, in class problem solution, trend chart plotting, discussion and laboratory exercise.

3. 12 x 20 division per inch graph paper should be made available to the student for trend chart plotting.

4. The module is most appropriately presented at at activated slduge facility as samples of process streams are needed for the oxygen uptake test. An overhead projector and screen is required.

5. Intermediate activated sludge is a prerequisite.

6. The equipment necessary to perform the oxygen uptake test includes:

   A. Dissolved oxygen analyzer with BOD bottle probe.

   B. Magnetic stirrer and stirring bar.

   C. Standard BOD bottles.

   D. 100 cc and 250 cc graduated cylinders

   E. Sampling containers.

   F. Centrifuge

   G. Stop watch or timer.

7. Recommended Standards for Sewage Works may be obtained from: (Nominal charge).

   Health Education Service
   P. O. Box 7283
   Albany, N. Y. 12224

Module No:	Topic: Advanced Activated Sludge

Instructor Notes:	Instructor Outline:
	8. Operational Control Procedures for the Activated Sludge Process, Parts III A and III B may be obtained from: Environmental Research Center U. S. Environmental Protection Agency 26 W. St. Clair St. Cincinnati, Ohio 45268 9. Operators Pocket Guide to Activated Sludge Parts I and II may be ordered from: (Nominal charge) Stevens, Thompson and Runyon, Inc. 5505 S. E. Milwaukee Ave. Box 02201 Portland, Oregon 97202 10. Dissolved Oxygen Analysis, Activated Sludge Control, XT-43 may be obtained from: Environmental Research Center Attn: Eileen Hopewell U. S. Environmental Protection Agency 26 W. St. Clair Street Cincinnati, Ohio 45268 11. The instructor should if at all possible obtain trend charts from students who pre-register some days prior to the actual workshop so that the instructor can familiarize himself with the charts and be prepared to lead discussion

Prerequisites: 1. Activated Sludge Trend Charts and Laboratory Data

2. Intermediate Activated Sludge

Module No:	Module Title: Advanced Activated Sludge
	Submodule Title: Review From Activated Sludge
Approx. Time: 1 - 2 hours	Topic: Design and Operation Parameters

Objectives:

1. Given a plant schematic, dimensions, flows and laboratory data calculate: (a) Detention times, (b) Loadings, (c) F/M, (d) Overflow rates, and (e) Sludge age.

2. Identify by labeling given sketches the following: (a) Conventional activated sludge, (b) Step-feed, and (c) Contact stabilization.

Instructional Aids:

1. Student handouts
2. Transparancies

Instructional Approach:

Lecture
In-class problem solution

References:

1. Recommended standards for Sewage Works.
2. Manual of Instruction for Sewage Plant Operators (New York Manual)
3. Water Pollution Control Federation MOP 11 (WPCF MOP 11).
4. Part III-B, Operational Control Procedures for the Activated Sludge Process.

Class Assignments:

Module No:	Topic: Review - Design and Operation Parameters

Instructor Notes:	Instructor Outline:
Student Handouts 1 and 2 contain appropriate data for the activated sludge process evaluation.	This workshop begins with a problem which should be solved in class, an extensive plant evaluation. Special attention should be given to using the <u>correct</u> flow values.
	<u>Solution:</u>
	<u>Tank Capacities</u>
	Primary Clarifiers
	2 x 3.14 x 22 x 22 x 9 x 7.48/4 = 51,155 gal.
	Aeration Tanks
	2 x 32 x 64 x 14 = 57,344 cu. ft.
	57,344 x 7.48 = 428,933 gal.
	Secondary Clarifiers
	3 x 3.14 x 25 x 25/4 = 1,472 sq. ft.
	1,472 x 9 x 7.48 = 99,095 gal.
	<u>Detention Times</u>
	Aeration tank at flow alone
Conventional design generally 6 - 8 hrs.	.428933 x 24/(.6268 - .0169) = 16.9 hrs.
	Aeration tank at flow plus return
	.428933 x 24/(.6268 - .0169 + .3140) = 11.1 hrs.
	Clarifier
Generally 2.5 hrs.	.099095 x 24/(.6268 - .0169 + .3140) = 2.6 hrs.
	<u>Overflow Rate</u>
Generally 700. This is much better	(.6268 - .0169 - .0130) x 1,000,000/1,472 = 406 gal/sq. ft./day

Module No:	Topic: Review - Design and Operation Parameters

Instructor Notes:	Instructor Outline:
	Organic Loading
	(.6268 - .0169) x 302 x 8.34 = 1,536 lbs. BOD
	1,536/57.344 - 26.8 lbs. BOD/1,000 cu. ft.
	Aeration Capacity
	(Minimum)
1,500 cu. ft./lb. BOD Generally	1,500 x 1,536 = 2,304,000 cu. ft. air/day
	Three blowers are available
	700 cu. ft./Min. x 1440 = 1,008,000 cu. ft./day
	1,000 cu. ft./Min. x 1,440 = 1,440,000 cu. ft./day
	Probably 1 - 700 SCFM and the 1,000 SCFM blower would provide sufficient air with the remaining 700 SCFM unit as backup during peak load situations.
	F/M
	F = (.6268 - .0169) x 302 x 8.34 = 1,536
Using MLVSS	M = .428933 x 3,138 x 8.34 - 11,226
	F/M = 1,536/11,226 = 0.14
	Sludge Age
New York Manual	S.A. = .428933 x 3,382/(.6268 - .0169) x 137
	S.A. = 17.4 days
MOP 11	S.A. = 3,382 (.428933 + .099095)/.013 x 8,399
	S.A. = 16.4 days
Figures are included which show conventional activated sludge and modifications.	The second section of this topic reviews the modifications to the conventional activated sludge process. The operator who is fortunate enough to have some flexibility should not only be able to identify the modifications, but also have some

Module No:	Topic: Review - Design and Operation Parameters

Instructor Notes:	Instructor Outline:
	rationale for moving process from conventional to step-feed, for example. Some discussion of this nature is included after the oxygen uptake test procedure. It should be necessary only to briefly use Figures 1, 2, and 3 as transparancies to refresh the student's memory. Part III-B should be provided to those operators who have step-feed capability.

STUDENT HANDOUT 1

Unit Process Dimensions

Primary Clarifiers

Number	2
Dimensions (each) 22' dia. x 9' depth	

Primary Sludge Pumps

Number	2
Capacity (each)	200 GPM

Aeration Tanks

Number	2
Dimensions (each) 32' x 64' x 14' deep	

Blowers

Number	3
Size	2 at 1,000 SCFM
	1 at 700 SCFM

Secondary Clarifiers

Number	3
Dimensions (each) 25 dia. x 9' depth	

Return Sludge Pumps

Number	2
Capacity (each)	200 GPM

STUDENT HANDOUT 2

Plant Data	
Flow	
Raw flow	0.6268 MGD
Primary sludge flow	0.0169 MGD
Return sludge flow	0.3140 MGD
Waste sludge flow	0.0130 MGD
BOD	
Raw	366 mg/l
Primary effluent	302 mg/l
Final effluent	14 mg/l
Total Suspended Solids	
Raw	460 mg/l
Primary effluent	137 mg/l
Final effluent	14 mg/l
Mixed Liquor	
MLTSS	3382 mg/l
MLVSS	3138 mg/l
Return Sludge	
RSTSS	8399 mg/l
Primary Sludge	
PSTSS	48,157 mg/l

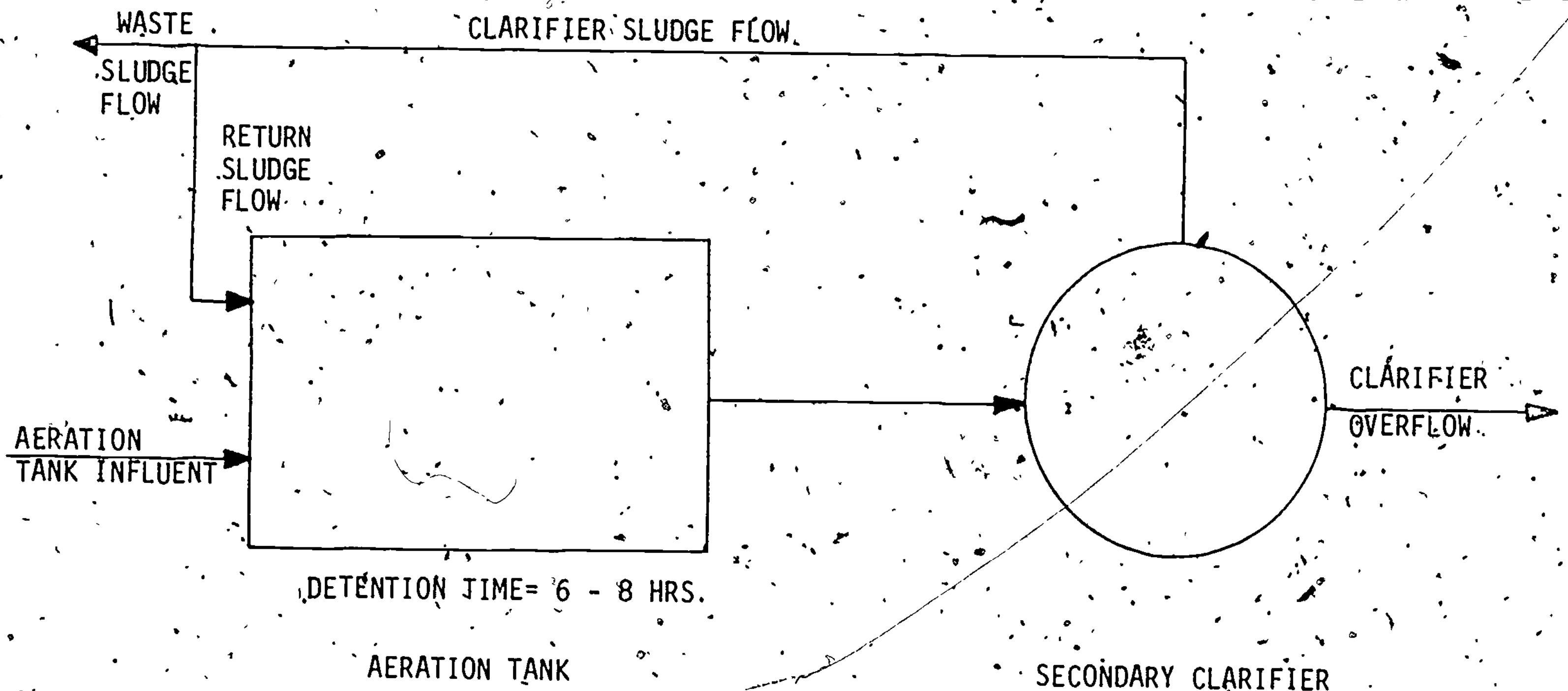


FIGURE 1
CONVENTIONAL ACTIVATED SLUDGE
PROCESS SCHEMATIC

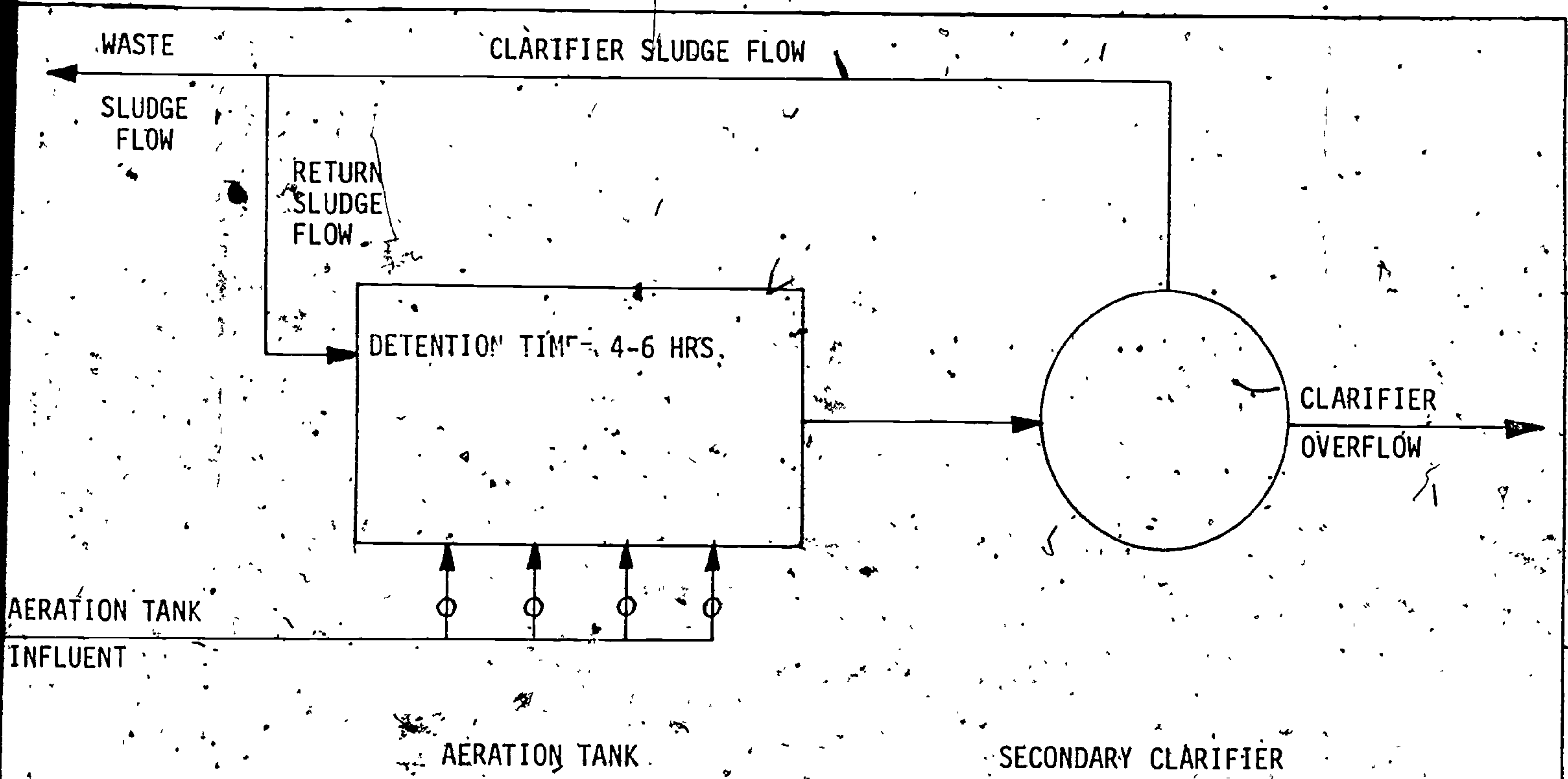


FIGURE 2
STEP-AERATION (STEP-FEED)
PROCESS SCHEMATIC

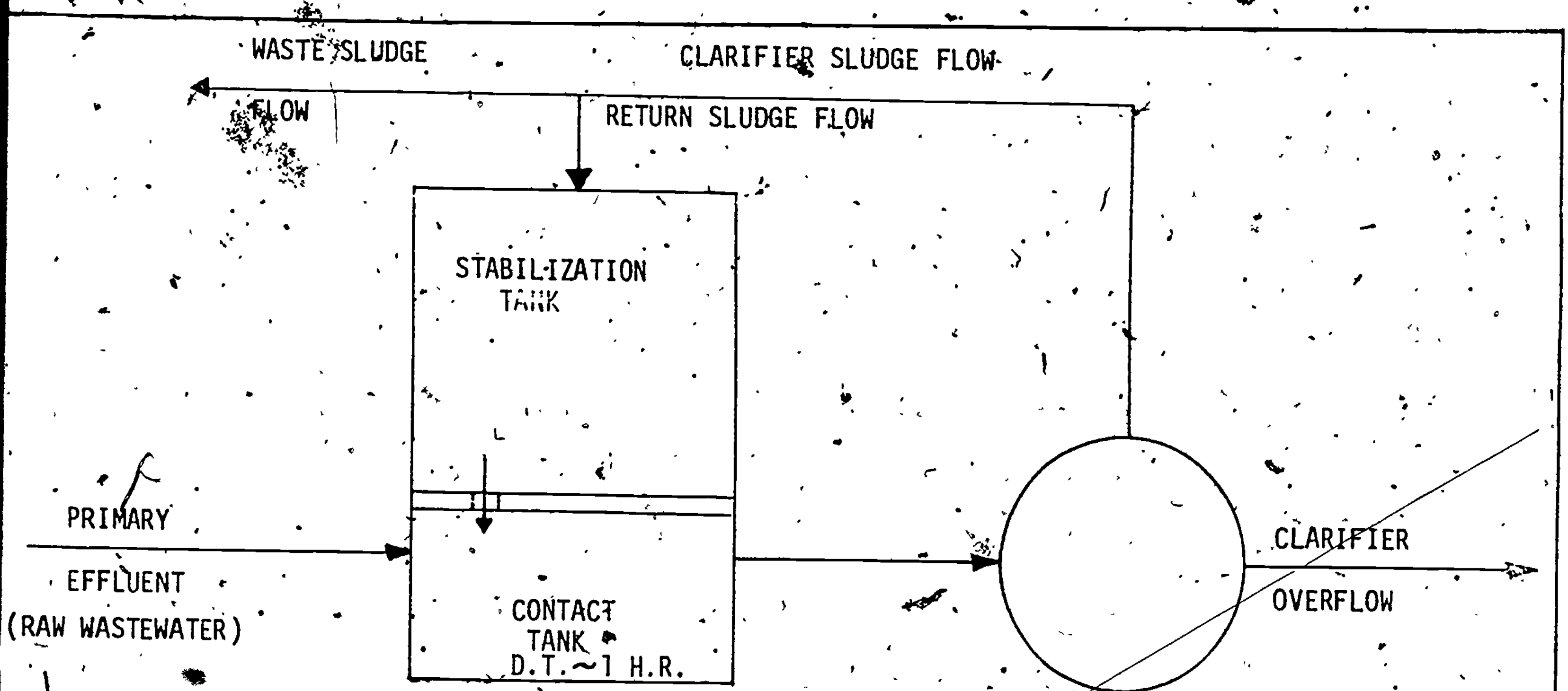


FIGURE 3
CONTACT STABILIZATION
PROCESS SCHEMATIC

Module No:	Module Title: Advanced Activated Sludge
	Submodule Title: Review from Activated Sludge
Approx. Time: 3 hours	Topic: Control Procedures

Objectives:

1. Given F/M control, constant MLVSS control, constant sludge age, list the primary control parameter and limitations of each control methodology.
2. Given appropriate data, calculate return sludge flow demand.

Instructional Aids:

1. Student handouts
2. Transparancies

Instructional Approach:

Lecture
In-class problem solutions

References:

1. Operational Control Procedures for the Activated Sludge Process, Part III-A (Part III-A).
2. New York Manual
3. WPCF MOP 11
4. Operators Pocket Guide to Activated Sludge, Parts I & II, Stevens, Thompson, and Ryan, Inc. (Pocket Guide).

Class Assignments:

Module No:	Topic: Control Procedures

Instructor Notes:	Instructor Outline:
	The following 17 pages are taken from the "Intermediate Activated Sludge" module. The material should be covered as a review, focusing primarily on the control and limitations to each methodology. The "Mass Balance" section will undoubtedly require the most time. Student handout 4 includes sufficient data to practice a "Return Sludge Flow Demand" problem.

Module No:	Topic: Control Procedures - Constant MLVSS

Instructor Notes:	Instructor Outline:

Control to a constant Mixed Liquor Volatile Suspended Solids (MLVSS) concentration (or Mixed Liquor Total Suspended Solids, MLTSS) is one of the most common control methodologies practiced in activated sludge wastewater treatment facilities. The prime limitation to this control technique lies in the fact that it is based on the consistency of the raw waste load. Stated another way, a facility that experiences wide variations in the raw waste organic load (BOD) will probably not be able to be controlled successfully by maintaining a constant aeration tank solids concentration. A second limitation lies in the fact that return sludge flow control adjustments may not be made when needed, or as a function of process demand. Typically, facilities controlled by this technique rarely adjust return flows. The return sludge flow rate generally is set somewhere in the range of 25 to 33 (up to 50) percent of raw flow. Subsequent discussion of the "mass balance" equation will help explain this return sludge flow rate.

The primary process control parameter used to maintain the constant aeration tank solids concentration is waste sludge flow. Simply stated if the target solids concentration has been exceeded waste. If solids concentrations fall below target, decrease waste sludge flow. The volume of sludge that must be removed (wasted) will vary from plant to plant and is a function of the character of the waste and type of facility among other things. Generally a good starting point is between 0.5 and 1.5 % of the average daily sewage flow. Expressed in other terms the volume would range generally between 5,000 gallons and 15,000 gallons per day per million gallons of raw sewage flow.

Module No:	Topic: Control Procedures - Constant MLVSS

Instructor Notes:	Instructor Outline:
Student Handout 3 - Problem to solve for aeration tank solids under a "constant MLTSS" mode of operation. It would also use data from any student who has "real world" data with him.	The final topic is the determination of the optimum solids level that should be maintained. Recall that this control methodology is based on the premise that the raw waste load is reasonably consistent. It then remains to select an F/M ratio, measure the load (F) coming in, and calculate the concentration of solids necessary to satisfy the required value for M. The plant should then be operated at level for preferably one month. If effluent quality is good, maintain that level of solids. If effluent quality is not acceptable, select a new F/M ratio, confirm the load (F), and recalculate the required concentration of solids necessary to satisfy the required M.

Solution to Student Handout 3 Problem

Aeration tank volume = 16 x 32 x 12 x 7.48

= 45,957 gallons each

F = 0.3 x 165 x 8.34

F = 413 lbs. BOD

F/M = 0.3

M = 413/0.3

M = 1,377 lbs. solids

MLVSS = 1,377/2 x 0.045957 x 8.34

MLVSS = 1,800 mg/l

To increase MLVSS a decreased F/M must be selected. Therefore replace 0.3 with 0.2. Assume for this problem that the load has not changed.

F = 413 lbs. BOD

F/M = 0.2

M = 413/0.2

Module No:	Topic: Control Procedures - Constant MLVSS
Instructor Notes:	**Instructor Outline:**
	M = 2065 lbs. solids MLVSS = 2,065/2 x 0.045957 x 8.34 MLVSS = 2,690 mg/l

STUDENT HANDOUT 3

Given: Two aeration tanks, each 16' x 32' x 12'

Sewage flow BOD = 165 mg/l

Raw flow = 300,000 gallons per day

Select: F/M ratio (0.1 to 0.5)

Say 0.3

Find: Mixed liquor volatile suspended solids concentration required.

1. MLVSS = ________

Final effluent quality not acceptable. The appearance of the final clarifier indicates a higher concentration of solids would improve final effluent quality.

Select a revised F/M which would result in a higher concentration of solids and then solve for the new concentration.

2. MLVSS = ________

Module No:	Topic: Control Procedures - Constant F/M

Instructor Notes:

Instructor Outline:

The second control procedure to be reviewed is control to a constant F/M ratio. In order to control by maintenance of a constant F/M ratio it is necessary to routinely determine the strength of the load (BOD, COD, TOC e.g.), the concentration of solids under aeration (MLVSS or MLSS), raw sewage flow, and calculate values for F and M in order to determine if increased or decreased waste sludge flow is in order.

It is generally accepted that values for F/M should fall within the range of 0.1 to 0.5.

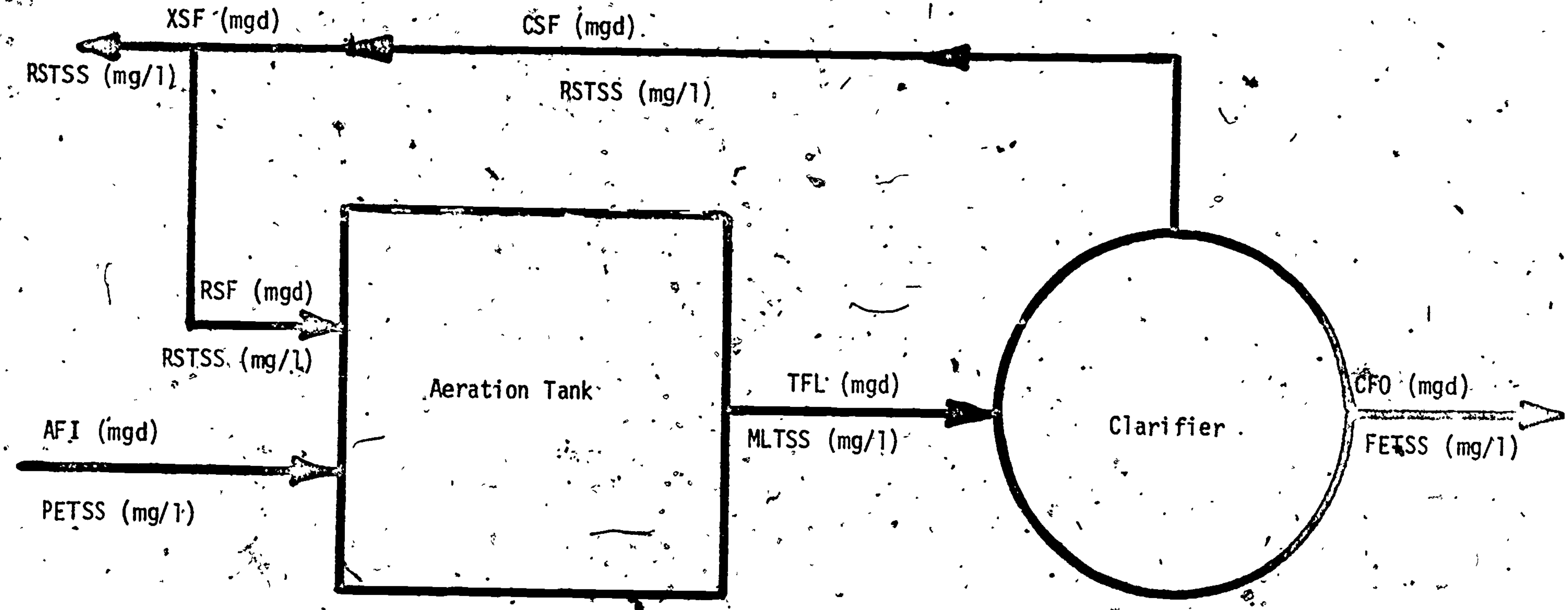
The disadvantages to control by this technique include:

1. The difficulty in obtaining a timely value of F (BOD is 5 day determination).
2. MLVSS determinations are not necessarily true measures of M (paper and dead cells show up as MLVSS).
3. Inability to make instantaneous changes in aeration tank solids concentrations.
4. F/M by itself gives little assistance to operator relative to return sludge flow adjustments.

The workshop began with a problem from Student Handout 1. If there was no difficulty with the problem, proceed. If there are any questions with solving for F or M or the F/M ratio, work another problem using data from the students.

Figure 4 - Conventional Activated Sludge Process Schematic

One of the most significant parts of this module deals with the "mass balance equation". The operator must come to grips with this equation if he is to rise to an improved understanding of the activated sludge process. The starting point is the process flow schematic. The second step is to label all flows and to assign symbols to these flows and the concentration of solids in each "pipe".



CONVENTIONAL ACTIVATED SLUDGE
PROCESS SCHEMATIC
Figure 4

Module No:	Topic: Control Procedures - Constant F/M

Instructor Notes:	Instructor Outline:

Recall that there is an equation which has been used in this module to solve for pounds, pounds of BOD or solids. You should recognize the following equations:

1. Pounds solids = Conc. (mg/l) x Volume (mg) x 8.34
2. Pounds solids per day = Conc. (mg/l) x Flow (mgd) x 8.34

The mass balance equation has as its simple premise:

Mass in equals mass out

Figure 5 - Flow Balance

Let's take one step backward before moving ahead. A flow balance should be readily understood. The flow balance premise is: Flow in equals flow out. Notice the different relationships which exist. The size of the clarifier and aeration tank do not change the relationships when the tanks are full. Flow balance is important in that sometimes process flow data can be calculated on occasion if some measured flow data is available. Flow balance equations should be done in your (the student's) facility.

Figure 6 - Mass Balance

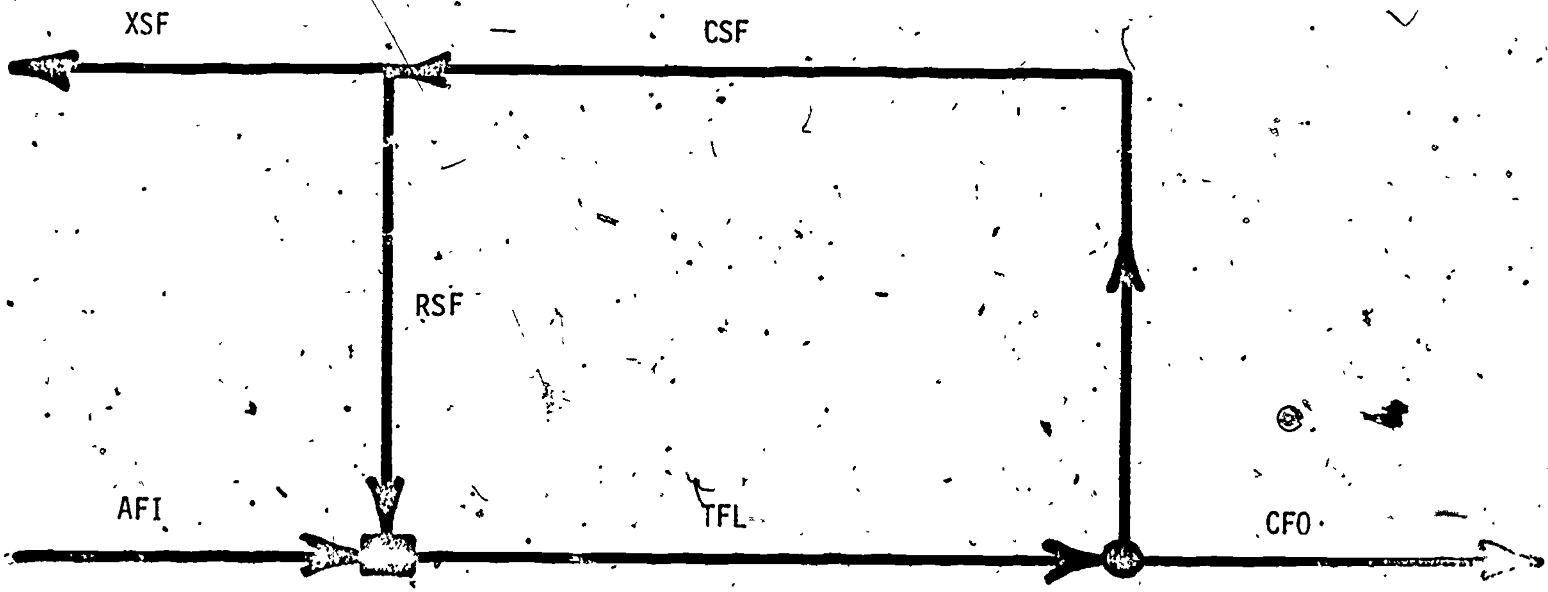
Return now to the mass balance equation:

Mass in equals mass out

Pounds will be the units of mass for our use. The equation now becomes:

Pounds in equals pounds out

Figure 3 is identical to Figure 1 except the aeration tank and clarifier have shrunk. The mass (pound) balance relationships should now be evident. The mass balance around the clarifier results in the following:



Flow in = Flow out

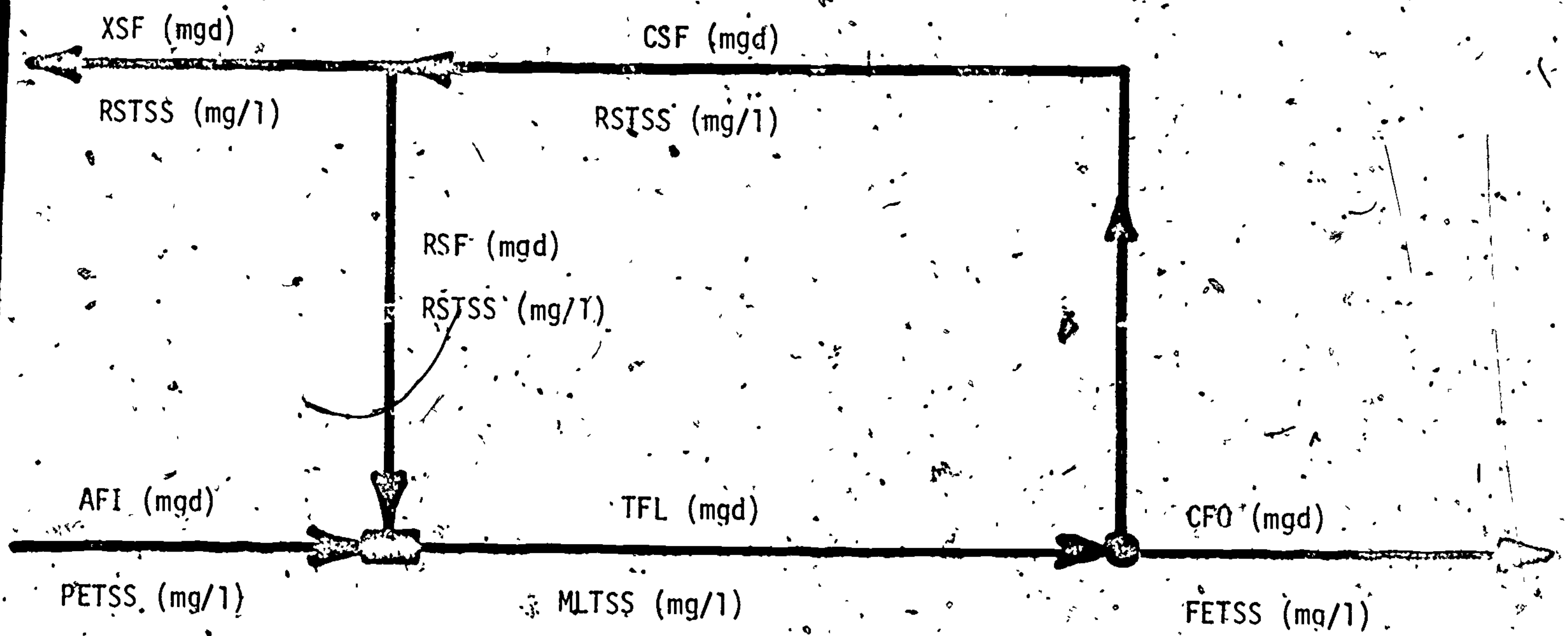
TFL = AFI + RSF

TFL = CFO + CSF

CSF = RSF + XSF

Figure 5

Flow Balance



Pounds/day = Flow (mgd) x Conc. (mg/1) x 8.34

Pounds in = Pounds out

Figure 6

MASS BALANCE

Module No:	Topic: Control Procedures - Constant F/M

Instructor Notes:	Instructor Outline:

TFL x MLTSS x 8.34 = CSF x RSTSS x 8.34 + CFO x FETSS x 8.34

First the 8.34 can be divided out resulting in:

TFL x MLTSS = CSF x RSTSS + CFO x FETSS

Next, FETSS, if final effluent quality is good, approaches zero. (At the very least it is very much smaller than either MLTSS and/or RSTSS).

The equation then becomes:

TFL x MLTSS = CSF x RSTSS

Moving around the system:

CSF x RSTSS = RSF x RSTSS + XSF x RSTSS

If there is no sludge being wasted, XSF = 0

CSF x RSTSS = RSF x RSTSS

Finally the mass balance around the aeration tank:

TFL x MLTSS = RSF x RSTSS + AFI x PETSS

These equations do have significance for the operator. The mass balance around the clarifier resulted in the following equation:

TFL x MLTSS = CSF x RSTSS

If XSF = 0

(AFI + RSF) x MLTSS = RSF x RSTSS

AFI x MLTSS + RSF x MLTSS = RSF x RSTSS

RSF x (RSTSS - MLTSS) = AFI x MLTSS

RSF = (AFI x MLTSS)/(RSTSS - MLTSS)

Module No:	Topic: Control Procedures - Constant F/M

Instructor Notes:	Instructor Outline:

This relationship can be of assistance to the operator trying to control to a constant aeration tank solids concentration of F/M control. It is most important to understand that this relationship presumes no accumulation of solids in the clarifier. Other relationships can be derived and will be in subsequent topics of this module.

The centrifuge can be utilized as an operational test device and its use should be incorporated. It does not replace gravimetric solids determinations. It rather expands the operator's capability.

There are accepted, even required procedures for "self-monitoring" data. But, that does not mean that a test or analysis not in "Standard Methods" is not appropriate as a control test. Use of the centrifuge for solids concentration determinations falls into this catagory. Percent solids by volume can be easily determined using American Petroleum Institute (API) centrifuge tubes. Determine aeration tank concentration (ATC) and Return Sludge Concentration (RSC). The equation:

RSF = (AFI x MLTSS)/RSTSS - MLTSS)

Becomes:

RSF = (AFI x ATC)/(RSC - ATC)

The centrifuge values can be rapidly determined and this test and equation can be made a part of control procedure.

This relationship can be manipulated to give an expression for the return sludge concentration (RSC). The expression is:

RSC = (AFI + RSF) x ATC/RSF

The expression for RSF implies that given mixed liquor and return sludge concentrations and a level of flow into the aeration tank, the return

Module No:	Topic: Control Procedures - Constant F/M

Instructor Notes:	Instructor Outline:
	sludge flow to maintain that system in balance can be found.
	The expression for RSC implies that given the flow values and mixed liquor concentration, the return sludge concentration necessary to maintain a balanced system can be found.
	However, there is nothing quite so simple. First of all the activated sludge process is a biological (living) process. The mass balance presented does not take into account the growth of new sludge in the aeration tank. The second concern is that the expression does not take into account the storage of sludge on occasion in the secondary clarifier. Finally the substitution for ATC = MLTSS and RSC = RSTSS assumes an identity relationship.
Part III A, Operational Procedures for the Activated Sludge Process, Page 5.	In other words ATC time a constant = MLTSS and RSC times a constant = RSTSS. If such were the case, gravimetric solids determinations could be replaced with solids determination by centrifuge, which is much easier. Such is generally not true, but the relationship and its relative change is worthy of consideration. Part III A terms this the "Sludge weight-to-concentration ratio" (WCR). The key is not the exactness of the numbers shown, rather the trend. In other words a WCR of 800 does not necessarily mean that your sludge is "normal". Your centrifuge may not rotate at the identical RPM's to the one used in Part IIIA. The operator watches the trend of the WCR in his plant. Increasing WCR's indicate the sludge is becoming relatively "older". Decreasing WCR's indicate the sludge is becoming relatively "younger".
	To solve for WCR requires only the gravimetric mixed liquor solids determination and solids by centrifuge.
	WCR = MLTSS/ATC

Module No:

Topic: Control Procedures - Constant Sludge Age

Instructor Notes:

Instructor Outline:

Probably two of the most difficult aspects of control to a constant sludge age are:

1. What equation should be used.
2. What sludge age value should be selected.

This module will not make your decision. It does seem appropriate to use the equation you the operator are most comfortable with. It also seems appropriate that more than one equation should be used and a selection then made based on which seems to work best or which best parallels process change.

With reference to a starting value for sludge age, once again no value is offered. Rather only that a value must be selected and then adjusted as a function of process demands.

WPCF MOP 11 offers the following equation for sludge age (S.A.):

$$S.A. = X\ (Va + Vc)/Qw \times Xu$$

Where

X = Average active microbrial solids concentration in the aeration tank, mg/l. (Or percent by centrifuge).

Va = Volume of aeration tank(s), gal.

Vc = Volume of final settling tank(s), gal.

Qw = Flow rate of sludge being wasted, GPD.

Xu = Average concentration of activated sludge in final settling tank underflow, mg/l. (Or percent by centrifuge).

The New York Manual states:

$$S.A. = V \times A/Q \times C$$

Where

V = Volume of aeration tank(s), gal.

Module No:	Topic: Control Procedures - Constant Sludge Age

Instructor Notes:	Instructor Outline:

A = Concentration of suspended solids in the aeration tank(s), mg/l.

Q = Sewage flow, GPD

C = Concentration of suspended solids in the sewage entering the aeration tank in mg/l exclusive of returned sludge.

The Operator's Pocket Guide suggests:

Cell Residence Time (CRT) = Total Solids/Solids Wasted

Where

Total solids - Lbs. solids in aeration tanks

Solids wasted = Lbs. solids wasted per day

NFIC Procedures uses centrifuge values and offers:

S.A. = (ASU + CSU)/TXU/day.

Where

ASU = % solids in aeration tank(s) times volume of aeration tank(s)

CSU = % solids in clarifier sludge blanket times the volume of the clarifier occupied by sludge

TXU/Day = % solids of sludge wasted times the volume of sludge wasted per day plus the % solids in the final effluent times the volume of final effluent per day

WPCF MOP 11 states the one "truth" relative to each of these four equations, "The wasting procedure will affect the effectiveness of the activated sludge plant".

Module No:	Topic: Control Procedures - Constant Sludge Age
Instructor Notes:	**Instructor Outline:**
	One additional comment relative to control by maintenance of a constant sludge age. This is a control methodology and that equation selected should lend itself to "control". For that reason the technique incorporating use of the centrifuge, its relative ease of solids determination, the ability to rapidly check the concentration of the solids being wasted, and thus to adjust the rate of waste sludge flow as frequently as desired seems quite appropriate. Final comments address adjustment of the selected sludge age value itself. Control to a constant sludge age implies an associated F/M. If the sludge age selected results in a process unrealistic F/M with final effluent quality unacceptable, a new sludge age would be selected. A change in the sewage flow i.e., a seasonal variation, loss of or addition of a significant sewage flow contributor would require sludge age value adjustments. Process indicators might dictate a change such as: A. Denitrifying sludge in final clarifiers. B. Sludge accumulation to excess in final clarifiers. C. Appearance of great volume of white foam on aeration tanks. D. Appearance of dark, greasy foam on aeration tanks. E. Other process indicators which the operator should document in his own facility.

Module No:	Topic: Control Procedures - Return Sludge Flow Control

Instructor Notes:	Instructor Outline:
	Activated sludge plants have the capability to adjust return sludge flow. If the operator is working at a facility whose flow is constant, whose sewage strength is constant, where everything is the same throughout the day and throughout the year, there is undoubtedly one value for return sludge flow. When this value was found, there would undoubtedly be no further need to adjust the return sludge flow. Having yet to see such a facility, it would seem appropriate to address a methodology for adjusting return (clarifier) sludge flow.
Part III A, Operational Control Procedures for the Activated Sludge Process	Consider the two extremes of sludge withdrawal from the clarifier. If clarifier sludge flow is too slow, sludge will accumulate in the clarifier until solids wash over the weir and are discharged. If sludge flow is too rapid, clear (treated) liquid is returned to the aeration tank. There would appear to be an optimum sludge flow somewhere within the extremes. The methodology described in Part III A is a logical approach to clarifier sludge flow control. A control test, mixed liquor allowed to settle, is observed. The sample's ability to concentrate is calculated. The clarifier sludge flow is adjusted to the end of matching the concentration of the clarifier sludge to the demonstrated ability to concentrate as shown by the settling test.
	The calculation procedure is quite simple, given the "target" time. Assume the clarifier sludge flow is being controlled to the sixty minute demand, sixty minute settled sludge concentration as determined from the settleometer and centrifuge tests. The equation and a sample problem are shown on Pages 40 and 41 of Part III A.
	Until such time that the "Part IV - "Process Control" pamphlet becomes available the following guidelines are suggested:

Module No:	Topic: Control Procedures - Return Sludge Flow Control
Instructor Notes:	**Instructor Outline:**
Student handout 4 contains sufficient data to make a practice calculation.	1. Demand time selection (sixty minute demand means the settled sludge concentration calculated from the sixty minute settling value). Demand times will vary from plant to plant and even within one plant. Factors which influence demand time selection include secondary clarifier overflow rates, organic load, sludge quality, and hydraulic limitations. Clarifiers operating at high overflow rates generally dictate that relatively short (low) demand times be selected - thirty minutes, for example. Low overflow rates allow for relatively higher demand times - sixty to ninety minutes. In general the exactness of the calculated clarifier sludge flow demand is not as important as the direction of adjustment the result indicates, increase or decrease in clarifier sludge flow. Excessive adjustments should not be made. Adjustments should be limited to no more than 20 - 25% change. Hydraulic limitations must be determined for your facility. An example would be not reducing sludge flow to a level which results in plugging draft tubes or piping. For that matter sludge flows should not be raised to levels that result in excessive turbulence in the clarifier which would impede solids separation (settling). Other process indicators must not be ignored. Process control requires total process evaluation, judgment of process demands, control adjustment, continued testing, evaluation, and judgment etc.

DATE 8/27/76 — 60 MINUTE DEMAND

DAY

TEST TIME 0800 RAW FLOW 2.65 MGD RETURN FLOW 0.90 MGD WASTE FLOW 0			TEST TIME RAW FLOW RETURN FLOW WASTE FLOW			TEST TIME RAW FLOW RETURN FLOW WASTE FLOW		
TIME	SSV	SSC	TIME	SSV	SSC	TIME	SSV	SSC
0	1000	3.20	0	1000		0	1000	
5	720	4.44	5			5		
10	540	5.93	10			10		
15	450	7.11	15			15		
30	390	8.21	30			30		
45	310	10.32	45			45		
60	290	11.03	60			60		
90			90			90		
ATC 3.2%			ATC			ATC		
RSC 14.0%			RSC			RSC		
DOB 5.9			DOB			DOB		
INITIAL TURBIDITY 5.1			INITIAL TURBIDITY			INITIAL TURBIDITY		
FINAL TURBIDITY 3.7			FINAL TURBIDITY			FINAL TURBIDITY		

$$SSC_t = \frac{1000 \times ATC}{SSV_t}$$

CSFD = CSF(RSC − ATC)/(SSC$_{60}$ − ATC)

CSFD = 1.24 MGD > 25% INCREASE ∴ 1.1

Module No:	Module Title: Advanced Activated Sludge
	Submodule Title: Review from Activated Sludge
Approx. Time: 1 - 2 hours	Topic: Trend Charts

Objectives:

1. Discuss settling curves
2. Discuss concentration curves
3. Discuss process flows (raw, primary sludge, return, and waste activated sludge).
4. Discuss sludge blanket levels
5. Discuss effluent quality curves

Instructional Aids:

1. Transparancies

Instructional Approach:

1. Lecture
2. In-class problem solution

References:

1. Part III-A

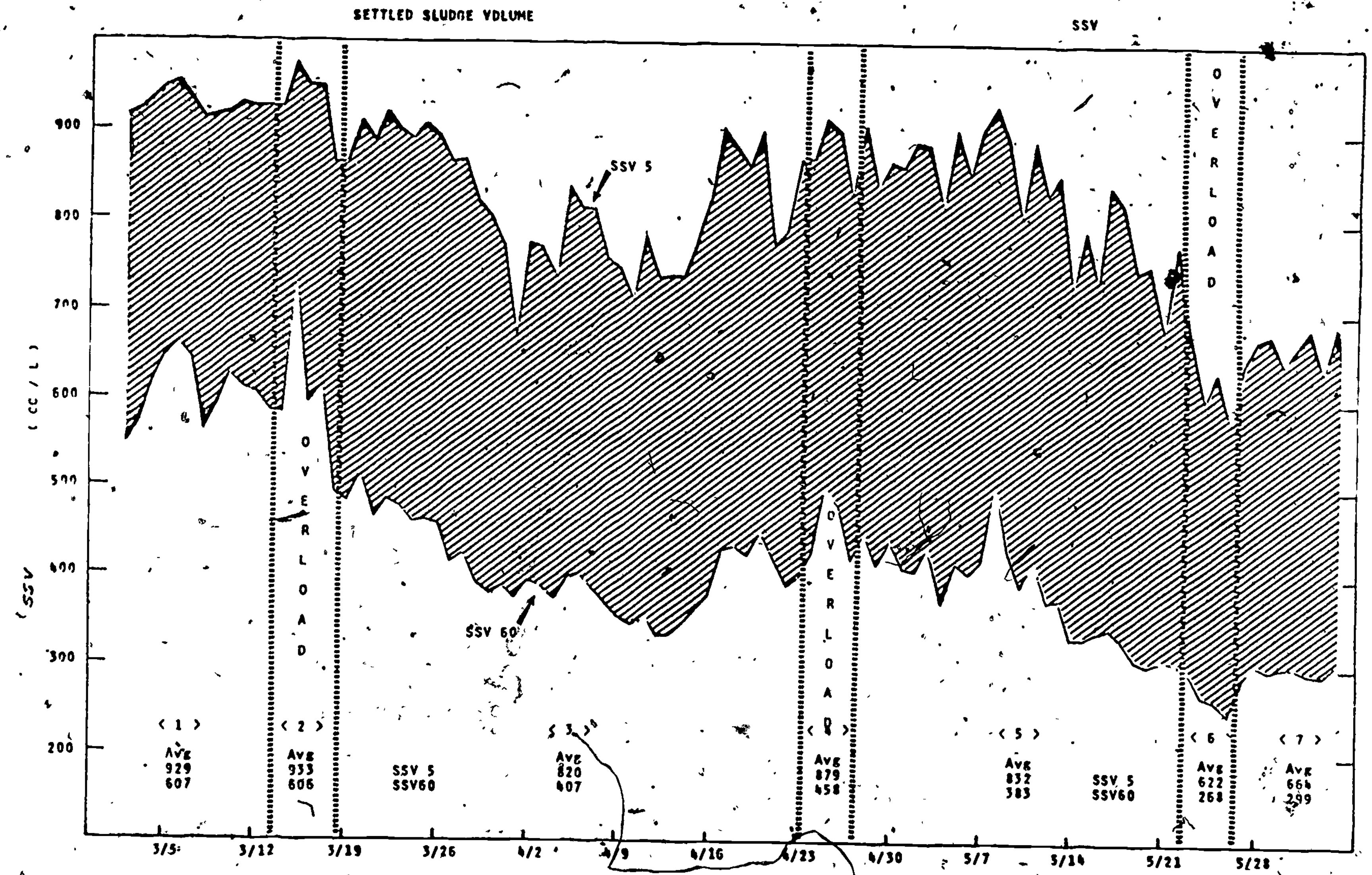
Class Assignments:

Module No:	Topic: Trend Charts

Instructor Notes:	Instructor Outline:
	Process control takes on a new dimension when trend charts are a part of process control decision making. The subsequent figures display about 13 weeks of data trend charts. These represent data summaries as opposed to true, daily maintained trend cahrts. They are missing the all important daily operational notes of unusual circumstances or events.
	The following trend charts are included:
	Settled sludge volume - Figure 7
	Settled sludge concentration - Figure 8
	Depth of sludge blanket - Figure 9
	Turbidity, Final effluent - Figure 10
	Aeration tank COD load - Figure 11
	Final clarifier overflow rate - Figure 12
	Oxygen uptake test results - Figure 13
	Weight to concentration ratio - Figure 14
	Transparancies of these figures should be made to display several of these transparancies at the same time.
	Discussion of these trend charts should include but not necessarily be limited to:
Part III A	1. Figure 14 - Recall the equation WCR = MLTSS/ATC. Note that this ratio is most certainly not constant. Compare the improved settling characteristics (Figure 7) to this increase in WCR.
	The COD load curve (Figure 11), overflow rate (Figure 12), and final effluent turbidity (Figure 10) should be displayed simultaneously. Notice that hydraulic overloads do not occur, rather organic load does occur with a resultant degradation of effluent quality.

Module No:	Topic: Trend Charts

Instructor Notes:	Instructor Outline:
	Other combinations should generate discussion. Any questions on the logistics of trend charting should be resolved. It is suggested that 10 square by 10 square per inch graph paper does not lend itself to trend charts as the units of time (the horizontal scale) can be confusing. There is available graph paper graduated 12 squares per inch horizontal by 20 squares per inch vertical.



SETTLED SLUDGE VOLUME
SSV
SSV (CC / L)
900
800
700
600
500
400
300
200
SSV 5
SSV 60
OVERLOAD
OVERLOAD
OVERLOAD
< 1 >
Avg
929
607
< 2 >
Avg
933
606
SSV 5
SSV60
< 3 >
Avg
820
407
< 4 >
Avg
879
458
< 5 >
Avg
832
383
SSV 5
SSV60
< 6
Avg
622
268
< 7 >
Avg
664
299
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 7

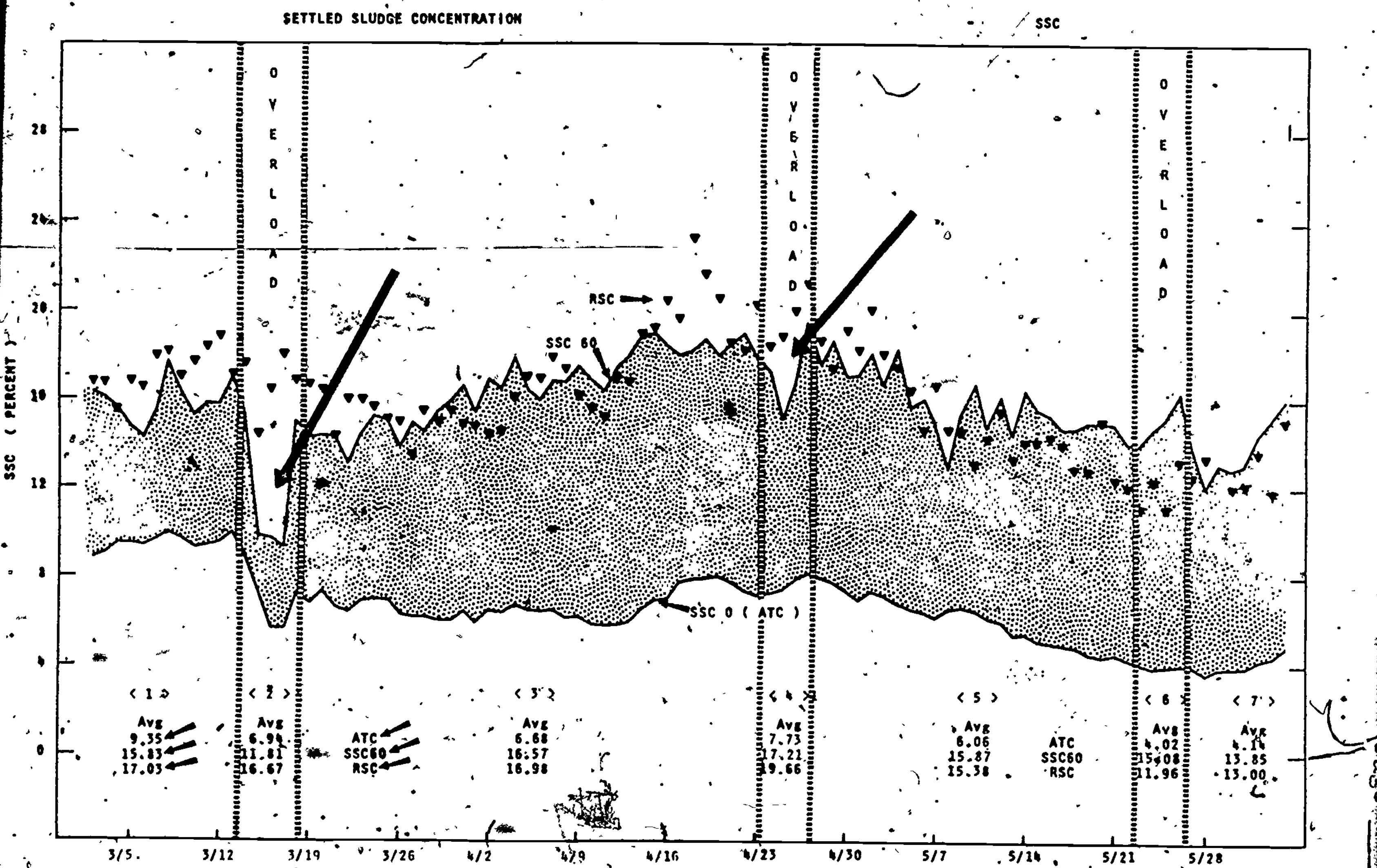

SETTLED SLUDGE CONCENTRATION
SSC
SSC (PERCENT)
OVERLOAD
OVERLOAD
OVERLOAD
RSC
SSC 60
SSC 0 (ATC)
< 1 >
Avg
9.35
15.83
17.03
< 2 >
Avg
6.94
11.81
16.67
ATC
SSC60
RSC
< 3 >
Avg
6.68
16.57
16.98
< 4 >
Avg
7.73
17.21
19.66
< 5 >
Avg
6.06
15.87
15.38
ATC
SSC60
RSC
< 6 >
Avg
4.02
15.08
11.96
< 7 >
Avg
4.14
13.85
13.00
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 8

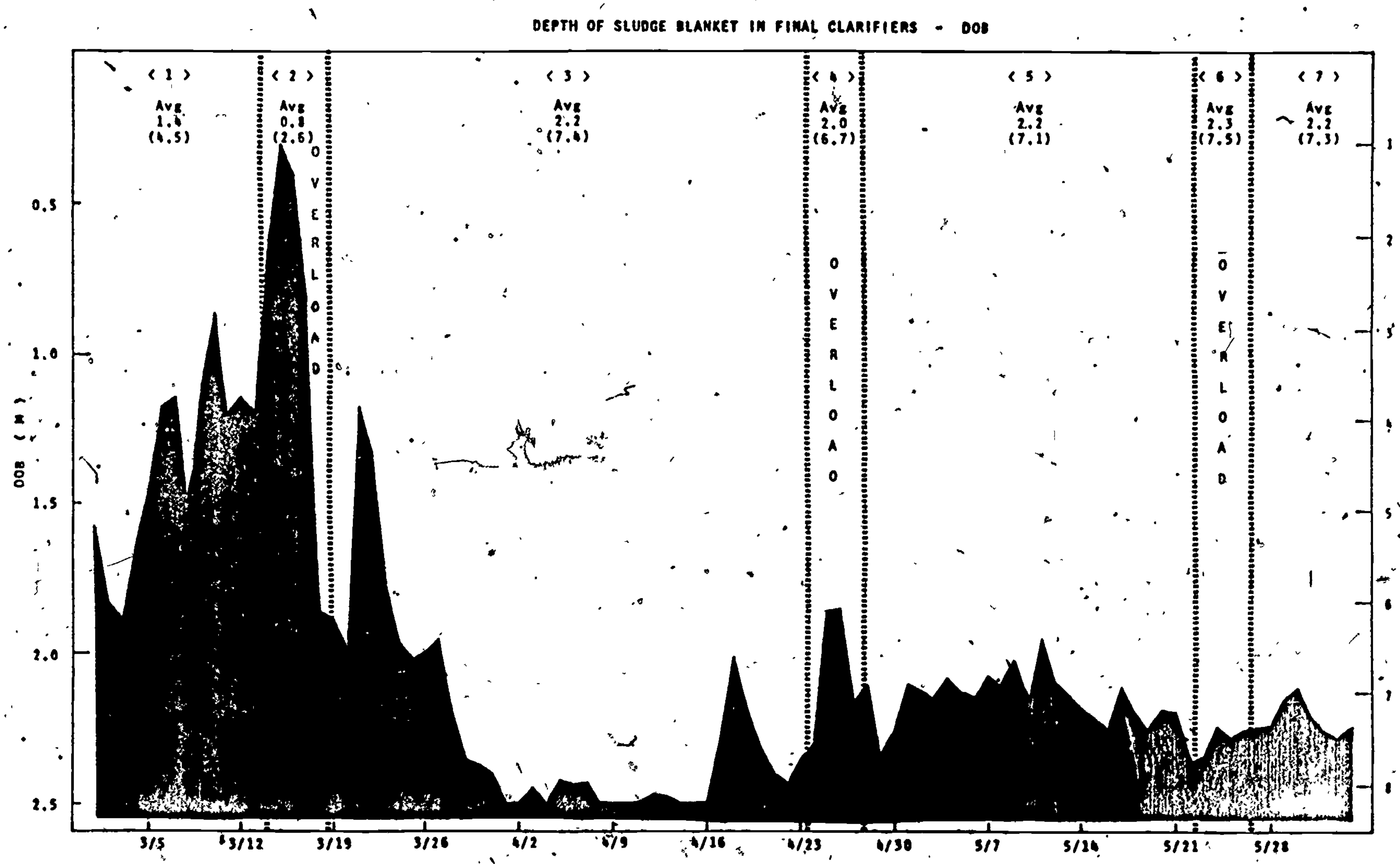

DEPTH OF SLUDGE BLANKET IN FINAL CLARIFIERS - DOB
< 1 > Avg 1.4 (4.5)
< 2 > Avg 0.8 (2.6)
OVERLOAD
< 3 > Avg 2.2 (7.4)
< 4 > Avg 2.0 (6.7)
OVERLOAD
< 5 > Avg 2.2 (7.1)
< 6 > Avg 2.3 (7.5)
OVERLOAD
< 7 > Avg 2.2 (7.3)
DOB (M)
DOB (FT)
0.5
1.0
1.5
2.0
2.5
1
2
3
4
5
6
7
8
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 9

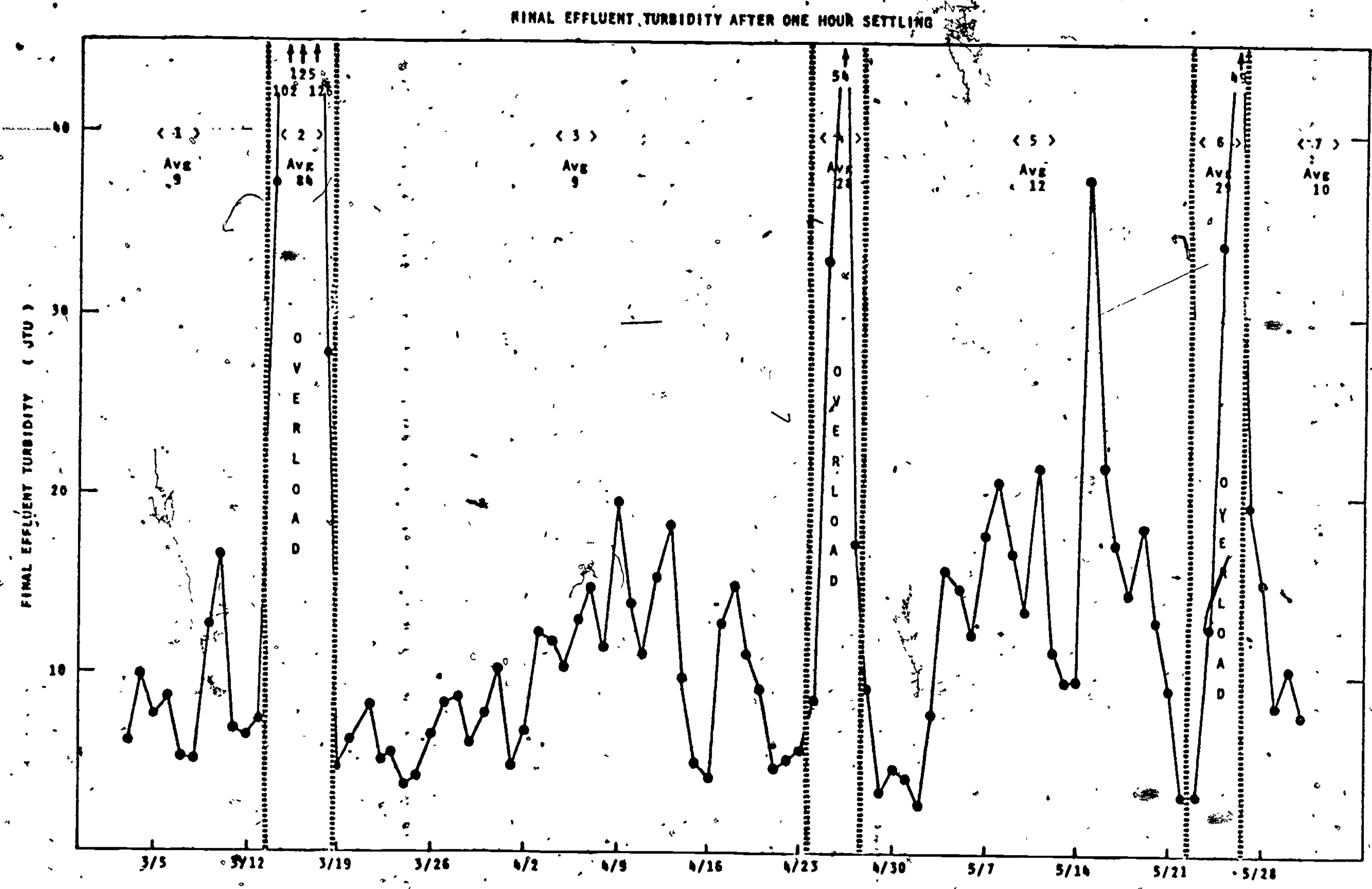

FINAL EFFLUENT TURBIDITY AFTER ONE HOUR SETTLING
FINAL EFFLUENT TURBIDITY (JTU)
< 1 > Avg 9
< 2 > Avg 84
< 3 > Avg 9
< 4 > Avg 22
< 5 > Avg 12
< 6 > Avg 29
< 7 > Avg 10
OVERLOAD
OVERLOAD
OVERLOAD
125
102
126
56
45
40
30
20
10
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 10

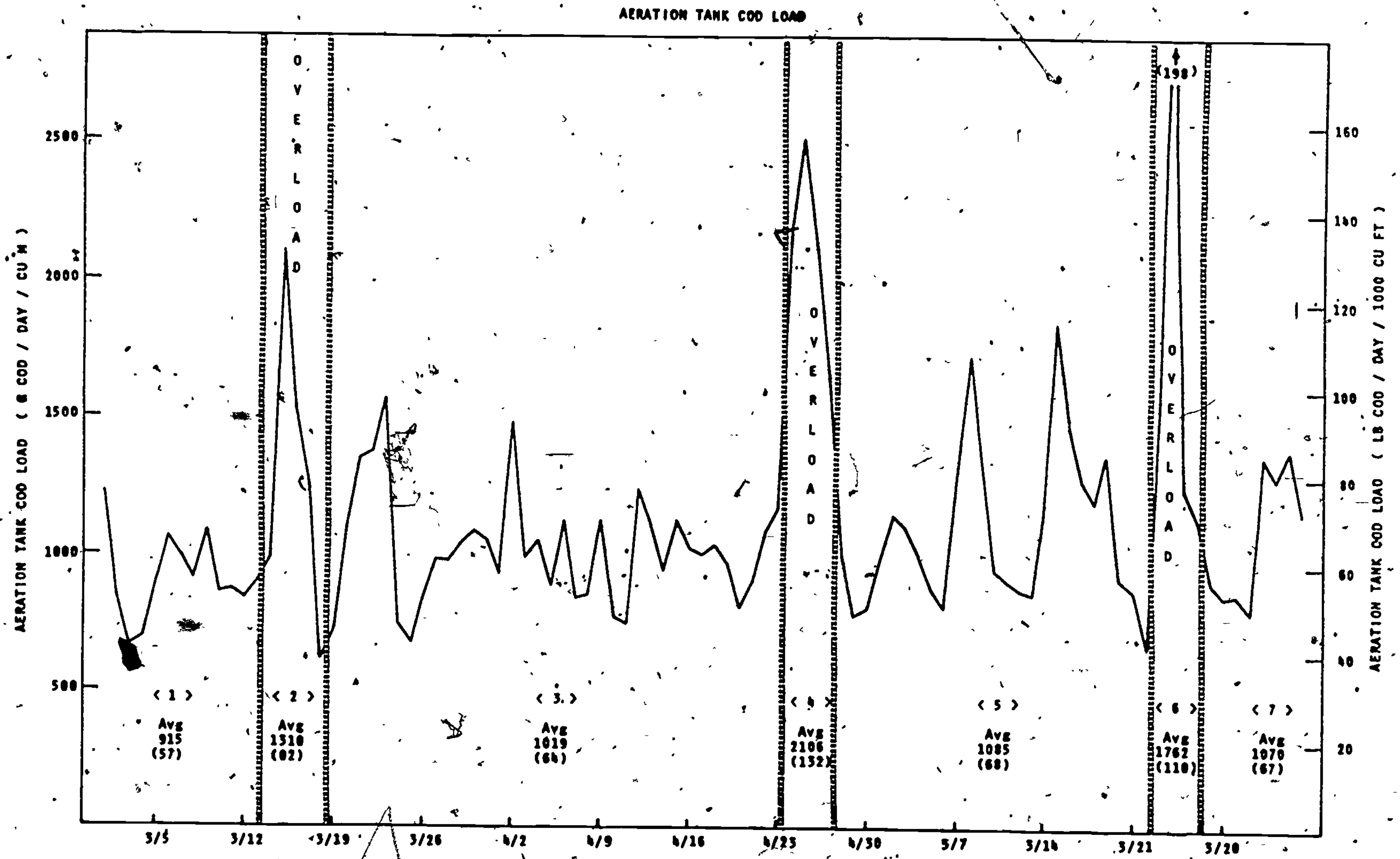

AERATION TANK COD LOAD
AERATION TANK COD LOAD (g COD / DAY / CU M)
AERATION TANK COD LOAD (LB COD / DAY / 1000 CU FT)
OVERLOAD
< 1 > Avg 915 (57)
< 2 > Avg 1310 (82)
< 3 > Avg 1019 (64)
< 4 > Avg 2106 (132)
< 5 > Avg 1085 (68)
< 6 > Avg 1762 (110)
< 7 > Avg 1070 (67)
(198)
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 11

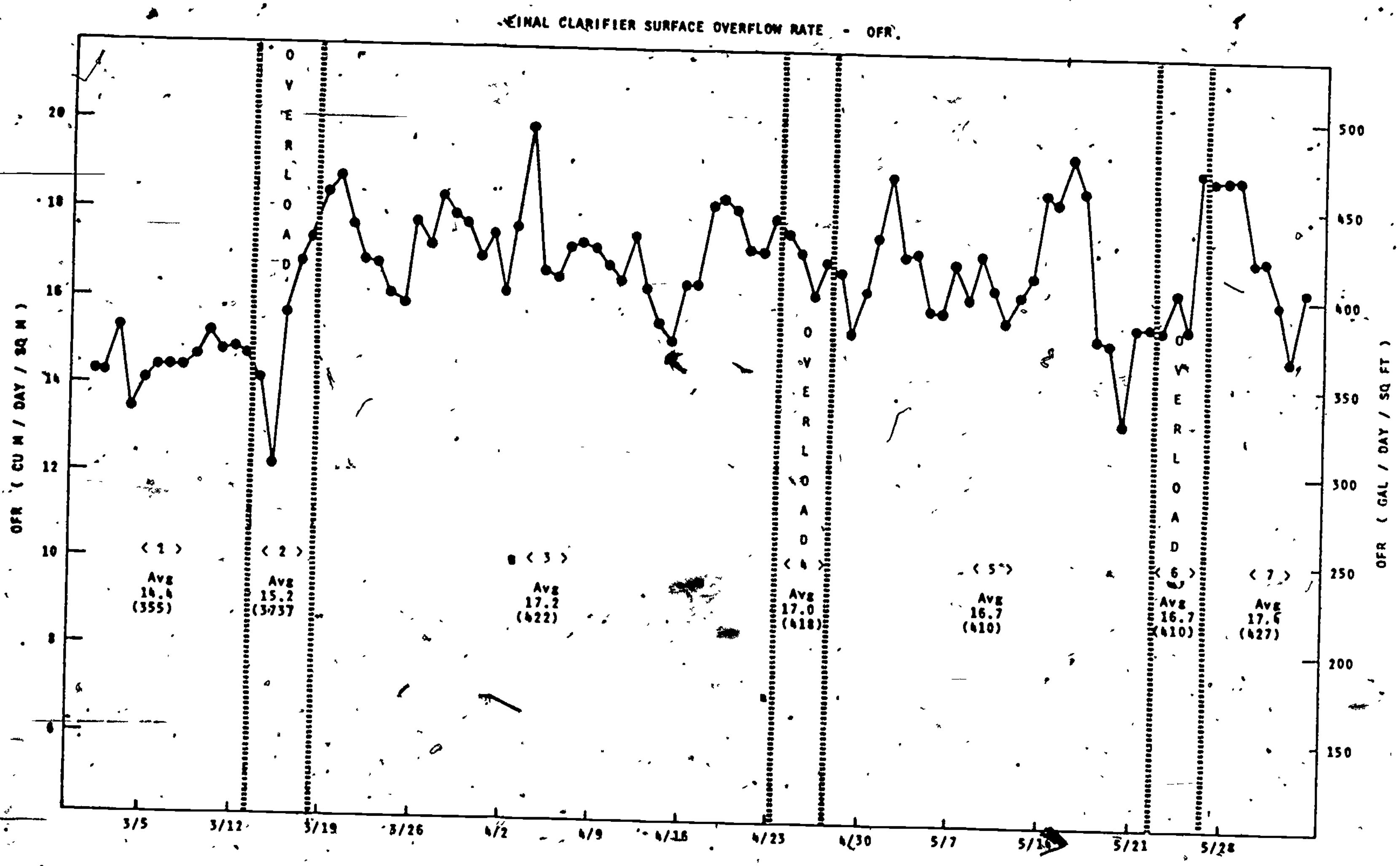

FINAL CLARIFIER SURFACE OVERFLOW RATE - OFR
OFR (CU M / DAY / SQ M)
OFR (GAL / DAY / SQ FT)
OVERLOAD
< 1 > Avg 14.4 (355)
< 2 > Avg 15.2 (373)
< 3 > Avg 17.2 (422)
< 4 > Avg 17.0 (418)
< 5 > Avg 16.7 (410)
< 6 > Avg 16.7 (410)
< 7 > Avg 17.6 (427)
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 12

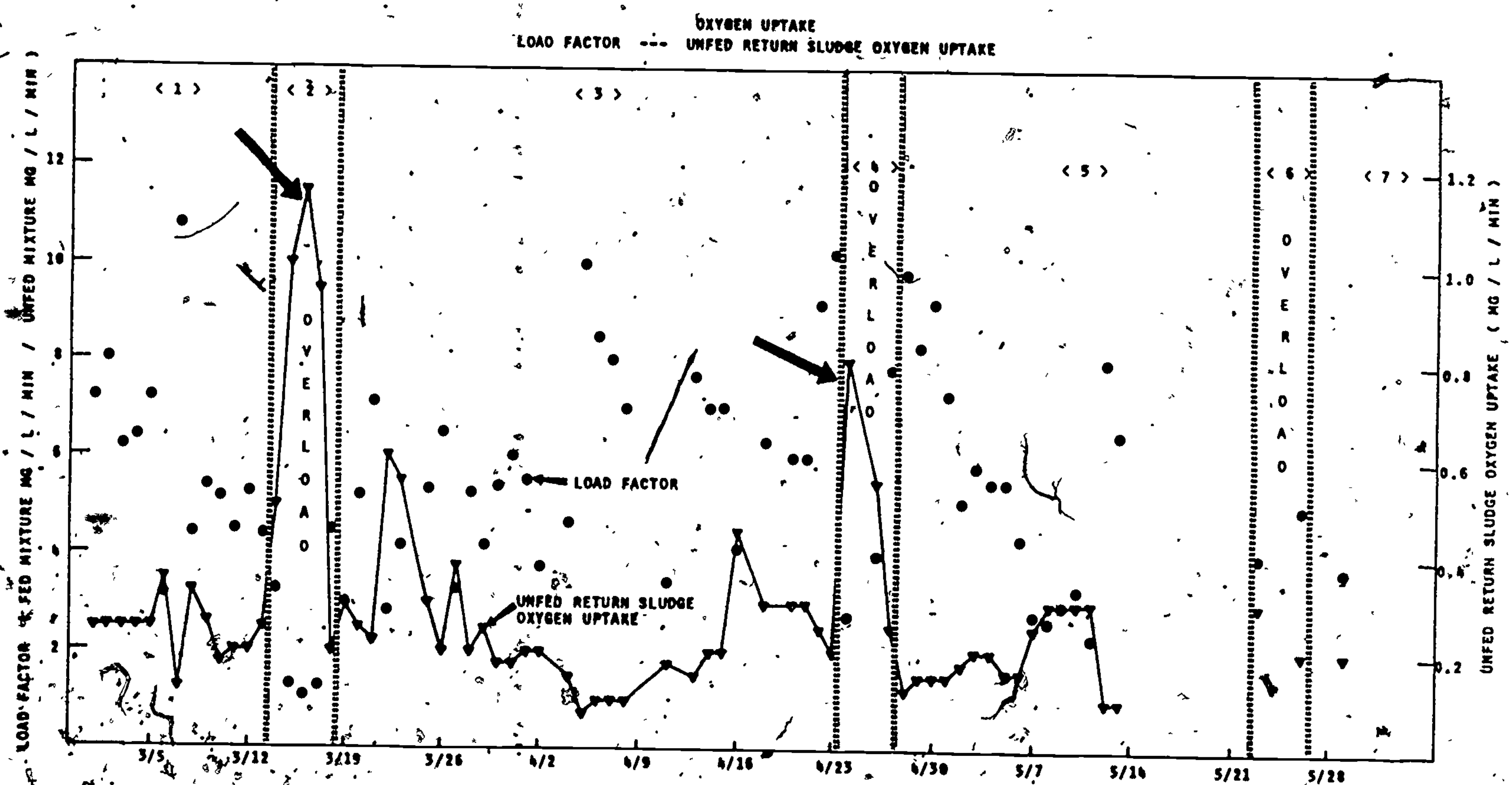
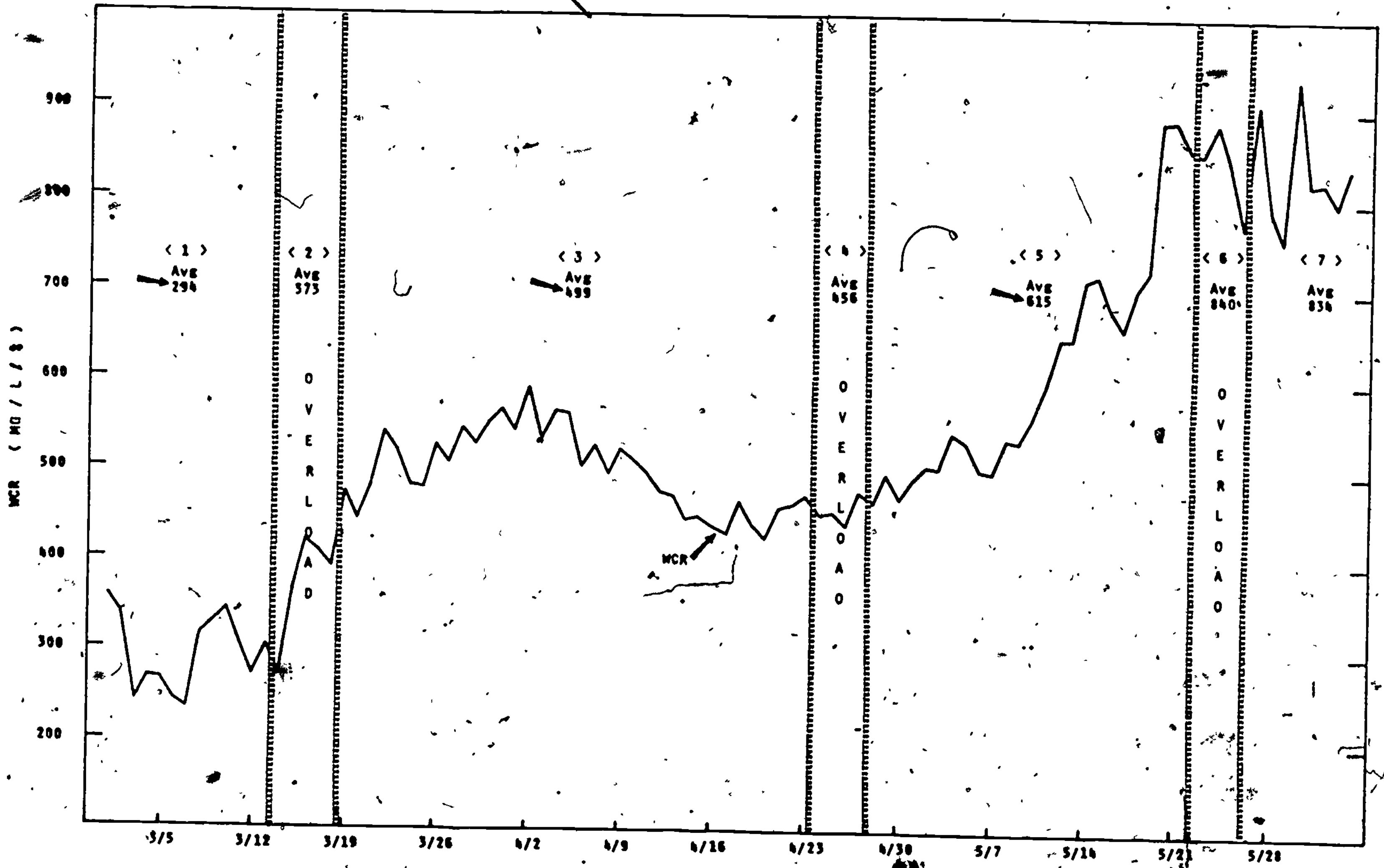

OXYGEN UPTAKE
LOAD FACTOR --- UNFED RETURN SLUDGE OXYGEN UPTAKE
LOAD FACTOR
UNFED RETURN SLUDGE
OXYGEN UPTAKE
OVERLOAD
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

FIGURE 13

WEIGHT TO CONCENTRATION RATIO - WCR



52

Figure 14

Module No:	Module Title: Advanced Activated Sludge
	Submodule Title: Oxygen Uptake
Approx. Time: 4 - 6-hours	Topic:

Objectives:

1. Perform an oxygen uptake analysis on:

   (a) Return sludge alone (diluted) - "Unfed"
   (b) Return sludge plus aeration tank influent - "Fed"

2. Plot oxygen uptake data on trend chart.

Instructional Aids:

1. Equipment as listed on following page.

Instructional Approach:

Lecture
Demonstration
Hands-on student participation

References:

1. Dissolved Oxygen Analysis, Activated Sludge Control, XT-43, USEPA, Cincinnati, Ohio, 45268.

Class Assignments:

STUDENT HANDOUT 5

OXYGEN UPTAKE WORK SHEET

UNFED MIXTURE			
Time	Temp.	D.O.	Δ D.O.
t = 0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

FED MIXTURE			
Time	Temp.	D.O.	Δ D.O.
t = 0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

Flows:

Return sludge flow = ____________ A
Aeration Tank influent = ________ B

Calculate volume of return sludge (RSV) required:

$$RSV = \frac{300 \times A}{A + B} = \frac{300 \times \_\_\_}{\_\_\_ + \_\_\_} = \_\_\_\_\_\_$$

Calculate load ratio (L.R.)

$$L.R. = \frac{\text{Fed mixture oxygen uptake}}{\text{Unfed mixture oxygen uptake}} = \frac{\_\_\_\_\_\_}{\_\_\_\_\_\_}$$

L. R. = ____________

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

The activated sludge process is a constantly changing system with interrelationships among biological, chemical, and physical characteristics. Oxygen uptake activity will show changes in process character. For example, an active sludge with an abundant available food energy will have a relatively high oxygen uptake and slow settling rate. It is appropriate, however, to learn the procedure before discussing data interpretation.

TEST PROCEDURE

Student handout 5 is a suitable data sheet for the oxygen uptake test.

These procedures and other portions of this control technique discussion are taken primarily from work done by F. J. Ludzack, deceased. Mr. Ludzack was with the National Training Center, United States Environmental Protection Agency, Cincinnati, Ohio.

The following equipment is required for the test:

1. Electronic dissolved oxygen analyzer with BOD bottle probe and agitator.
2. Magnetic stirrer and stirring bar.
3. 300 cc standard BOD bottles.
4. 100 cc and 250 cc graduated cylinders.
5. Three wide-mouth sampling containers.
6. Centrifuge.
7. Stop watch or timer.
8. An activated sludge plant with control flexibility

This test should be accomplished in a prompt, orderly fashion. For example, don't collect samples, standardize the DO meter, make volume calculations, discuss the day's work schedule, take a coffee break and then "run" the tests.

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

The DO meter should first be set up and standardized. This should be accomplished by an accepted technique using instructions furnished with the DO analyzer available.

Flow meters should then be read and the values recorded. The aeration tank influent and return sludge flow are the flow values needed. After these flow values have been recorded the sample volume calculations should be made.

Either of the following formulas may be used to determine the volume of return sludge to be added to the 300 cc BOD bottle:

Return sludge volume (cc) =

$$\frac{300 \times \text{return sludge percentage (decimal)}}{1.0 + \text{return sludge percentage (decimal)}}$$

Example

Return sludge percentage is 50%

Calculate volume of return sludge to be used in the oxygen uptake procedure.

$$\text{Return sludge volume (cc)} = \frac{300 \times 0.50}{1 + 0.50}$$

$$= \frac{150}{1.5}$$

Return sludge volume = 100 cc

The other equation which may be used:

Return sludge volume (cc) =

$$\frac{300 \times \text{return sludge flow (MGD)}}{\text{Primary effluent (MGD)} + \text{return sludge flow (MGD)}}$$

Example

Return sludge flow is 0.40 MGD

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

Primary effluent is 1.20 MGD

$$\text{Return sludge volume (cc)} = \frac{300 \times 0.40}{1.20 + 0.40}$$

$$= \frac{120}{1.60}$$

Return sludge volume = 75 cc

With the test equipment set out, the meter standardized and sample volume calculated, the samples should next be collected. Samples should be truly representative of the process stream being sampled with one exception.

1. Aeration tank influent
2. Aeration tank effluent
3. Return sludge
4. Secondary clarifier overflow

The clarifier overflow is the exception. It should be only dilution water. The return sludge sample should be aerated to "freshen" it as it has been in the clarifier for some time.

The time has arrived to perform the test procedure. In fact, two separate determinations are to be made with conclusions to be drawn from each determination and from a derived calculation using both results.

The first determination of oxygen uptake rate is run on return sludge and clarifier overflow, the "unfed" mixture. The second practice calculation determining return sludge volume (75 cc) will be used.

1. Carefully mix the freshened return sludge sample and measure the calculated volume, 75 cc. Add this to the 300 cc BOD bottle. Rinse the graduated cylinder with the clarifier overflow to transfer the remaining sludge into the BOD bottle.

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

2. Fill the BOD bottle with clarifier overflow to a point about one-quarter inch into the tapered neck.

3. Aerate the sample using an adapter to connect a clean BOD bottle to the sample bottle. Shake vigorously while transferring the sample to the empty bottle and back.

4. Insert a stirring bar and the DO probe, exercising care not to entrain air.

5. Place the test bottle with probe on the magnetic stirrer.

6. Start the BOD probe agitator.

7. Start the magnetic stirrer and adjust the speed to maintain solids suspension and distribution throughout the bottle.

8. Observe and record the initial temperature and DO, start the timer. Observe and record the DO's at exactly one minute intervals until there are at least three consistent one-minute readings for oxygen uptake. The difference between individual readings at one-minute intervals is reported as the oxygen uptake. Save a sample of the test mixture for centrifuge testing. Record the temperature of the mixture at the time the final oxygen level is read. A tenth or two centigrade rise in temperature is not significant.

This completes the unfed mixture oxygen uptake determination. The next determination is run on an identical volume of return sludge, but with aeration tank influent used to rinse the sludge from the graduated cylinder into the test bottle and to fill the test bottle into the tapered area. This is then the "fed" mixture, return sludge (75 cc for this sample) mixed with aeration tank influent. Continue the procedure as with the "unfed" mixture, steps 3 through 8.

Module No:

Topic:
Oxygen Uptake

Instructor Notes:

Instructor Outline:

Samples of the fed mixture, the unfed mixture, and aeration tank effluent should now be centrifuged. This is a rough check to give reasonable assurance a calculation error was not made in determining the volume of return sludge to be used in the tests. The three concentrations may be expected to vary somewhat. If large discrepancies are noted, check flow readings, calculations, and re-run the tests.

DATA INTERPRETATION

Data collection is a frustrating exercise if one is not able to "use" the data for some purpose. It would be most rewarding to now be able to list some magic numbers and a laundry list of exact control adjustments which should be made as these magic numbers would be determined by test procedures under various operating conditions experienced at any given activated sludge plant. Such is not the case. However, that is not to detract from the possible usefulness of the procedure as it relates to process control.

One additional calculation must be introduced, to be followed by discussion of how to use the data accumulated from the two test determinations (fed and unfed mixture oxygen uptakes) and the calculation.

The load ratio is calculated by dividing the oxygen uptake rate of the fed mixture by the oxygen uptake rate of the unfed mixture.

$$\text{L. R.} = \frac{\text{Fed oxygen uptake}}{\text{Unfed oxygen uptake}}$$

Consider the following test results:

Case I

Unfed mixture oxygen uptake = 0.4

Fed mixture oxygen uptake = 1.2

$$\text{L. R.} = \frac{1.2}{0.4}$$

L. R. = 3

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

Ludzack stated that "The best range for each plant is an individual characteristic, but conventional activated sludge commonly performs best at an L. R. of from 2 to 4, extended aeration at less than 2, high rate plants more than 4".

Three points are to be stressed. First, that "the best range for each plant is an individual characteristic". This is determined by making the oxygen uptake determinations and plotting (trend charts) the data. Allow the plant to communicate with you, the operator. Note on your trend charts what the effluent quality is along with uptake rates. Other process indicators should also be plotted, settling rates, flows, turbidity, sludge blanket depth etc. Allow the plant to tell you via trended data what changes are interrelated.

How, for example, do sludge settling rates change as oxygen uptake rates or load ratio changes?

Secondly then, don't just perform the procedure and plot the data. Use the trend charts. Notice the changes in process indicators as you make control adjustments. Ultimately, the goal is to detect process needs or pending upsets from your plotted process control test data, make control adjustments based on process need or demand, and maintain a consistent effluent quality..

The third point deals with the load ratio ranges given as "best range". Why should the suggested range for an extended aeration facility be less than for a conventional activated sludge facility? The basic difference in the extended aeration facility compared to the conventional facility is the time under aeration. The aeration tank detention time is 3 or 4 times longer in an extended aeration plant. So? Assume two facilities receive the same waste strength, same flow, therefore same total load (food). The extended aeration plant, however has larger aeration tank capacity. It has a 24-hour detention time compared to 8 hours for the other plant. If the same amount of food is going into each plant, the extended aeration facility by sheer detention time will have a more stabilized (tending

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

toward over stabilized) sludge. The critters have eaten all of the food in the wastewater and have undoubtedly entered the cannabalistic state. The result is that when the return sludge is combined with aeration tank influent the organisms will not have as high as uptake rate as the return sludge from the conventional plant.

It is worthy of restating that an appropriate load ratio should become evident as the test results are plotted (trended) along with other process parameters, to include treated effluent quality. A load ratio or range of load ratios that has characteristically resulted in acceptable effluent quality can be expected to produce the same relative quality in the future at the given facility. Lets assume that a given facility in fact performs well at a load ratio of from 2 to 4. Suppose the load ratio has gone from

$$\frac{1.2}{0.4} = 3 \text{ to}$$

$$\frac{0.5}{0.4} = 1.25$$

The small increase in the uptake rate of the fed mixture relative to the unfed mixture could be the result of:

A. Rainwater dilution of feed

B. The critters couldn't use this type of feed

C. The feed contained growth restricting components

D. Unfavorable conditions

A rerun of the test sludge with a known acceptable feed will assist in determining if the reduced uptake rate was due to the feed or to the sludge itself. If the low activity is simply a function of a reduced food concentration, there is really no problem. If, however the sludge is "sick", there's a problem. Effort should be expended to find out why and correct the situation.

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:

Now assume the load ratio which had been hovering around 3, rises to 6.5. The fed sludge really has an increased oxygen demand. You must pay special note to aeration tank dissolved oxygen levels in this type situation. Can the needed air be supplied-will the sludge be sufficiently stabilized in the time available? This situation is calling for an increase in the amount of solids returned to the aeration tank, more critters are needed because of all the food that is entering the aeration basin. Aeration tank DO may limit just how high solids concentrations can be maintained in the aerator. If DO levels disappear, you must reduce solids. Chemical additions may be required to enhance settling rates. Step feeding also will assist in decreasing peak oxygen demands.

A load ratio like this:

$$L.R. = \frac{0.1}{0.4}$$

Indicates something in the wastewater feed could be shocking or poisoning the critters. Try to identify what might be coming in to the plant. A bare minimum would be to check the pH to see if an extreme change in pH is being experienced. Plant recycle flows should be checked for their "treatability".

This is the last example. Consider a load ratio which went from:

$$L.\ R. = \frac{1.2}{0.4} = 3 \text{ to}$$

$$L.\ R. = \frac{1.3}{1.1} = 1.2$$

What is unusual about this situation is the "unfed" rate. Notice that the "fed" mixture has not changed that much (1.2 to 1.3), but the unfed has nearly tripled (0.4 to 1.1). This can present problems in that it indicates a need for more solids in the aeration tank. There is still food remaining in the sludge. It is a "young" under-oxidized return sludge

Module No:	Topic: Oxygen Uptake

Instructor Notes:	Instructor Outline:
	and settling rates are probably slowing down markedly. The problem - If the sludge won't settle how can you return more. More time under aeration is probably needed. Coagulants may be required to assist in getting the sludge to settle so it can be "moved" back to the aeration tank. Step feeding also might allow the sludge to become more stabilized.

Module No:	Module Title: Advanced Activated Sludge
	Submodule Title: Process Control
Approx. Time: 3 - 5 hours	Topic:

Objectives:

1. Given trend chart data showing settling curves, concentration curves, sludge blanket levels, oxygen uptake, process flows, and effluent quality describe process control adjustment indicated. Address

   (a) Return sludge flow
   (b) Waste sludge flow

   Discuss the trend charts addressing what each curve is indicating relative to process.

Instructional Aids:

1. Student data and trend charts.

Instructional Approach:

1. Discussion of "real world" data. Instructor acting as moderator.

References:

Class Assignments:

Module No:	Topic: Process Control

Instructor Notes:	Instructor Outline:

The relative success of this workshop hinges on the final topic. A prerequisite of the workshop is attendance at the "Intermediate Activated Sludge" workshop, and trended data from the student's facility. The instructor should if at all possible, collect student trend charts at the close of the first day of this workshop. Then make transparancies from those student trend charts. These should form the basis of discussion for this topic.

Attempt to select data representing various control methodologies i.e. F/M constant mixed liquor, etc.

The instructor should spend some time the evening before the second day attempting to "spot" significant trends etc. If pre-registration is accomplished, the instructor should consider asking for trend charts at the time of pre-registration.

Encourage those whose data is being displayed to share their interpretation and how they are or even are not able to incorporate the trend charts into process control.

The following materials are appended from which student handouts may be duplicated and transparancies produced.

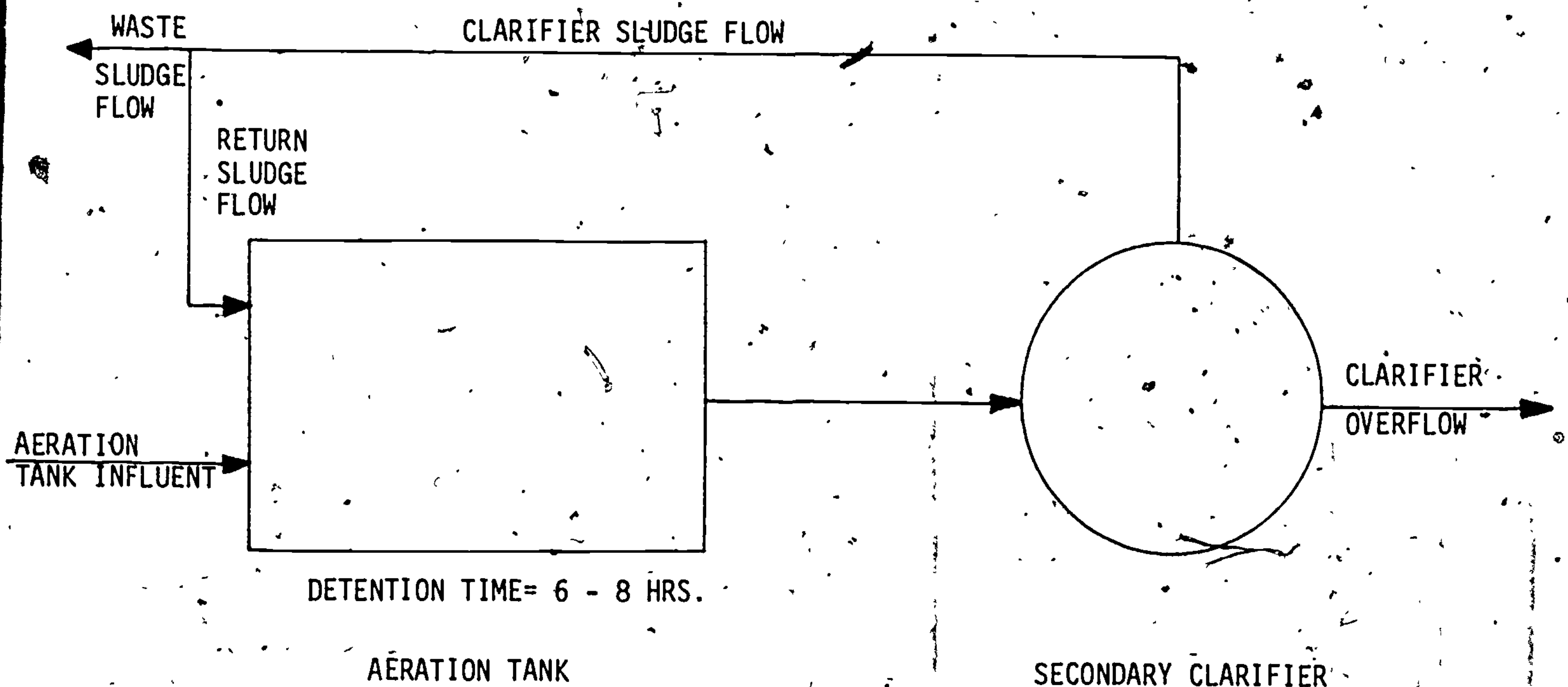


FIGURE 1
CONVENTIONAL ACTIVATED SLUDGE
PROCESS SCHEMATIC

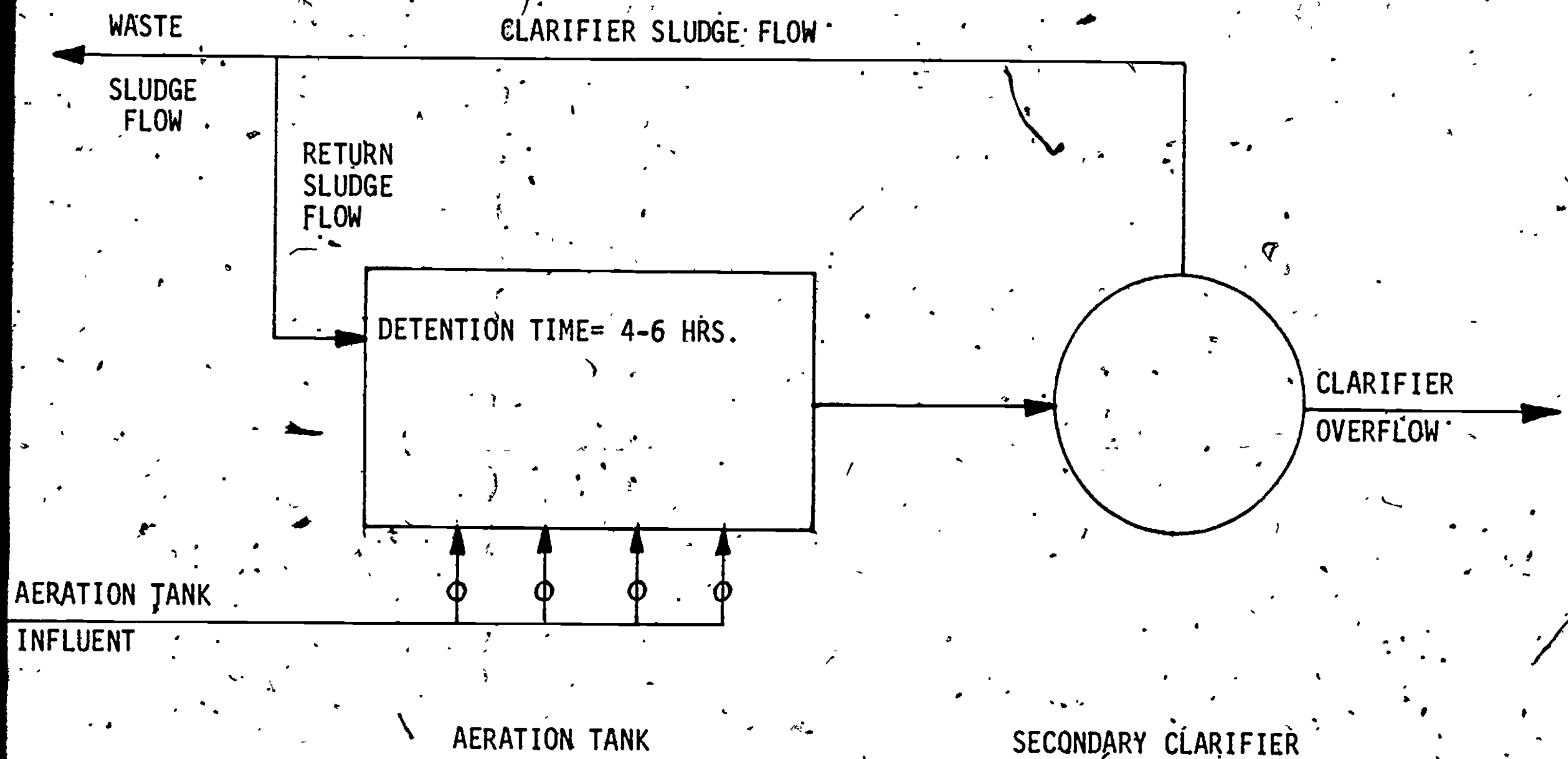


FIGURE 2
STEP-AERATION (STEP-FEED)
PROCESS SCHEMATIC

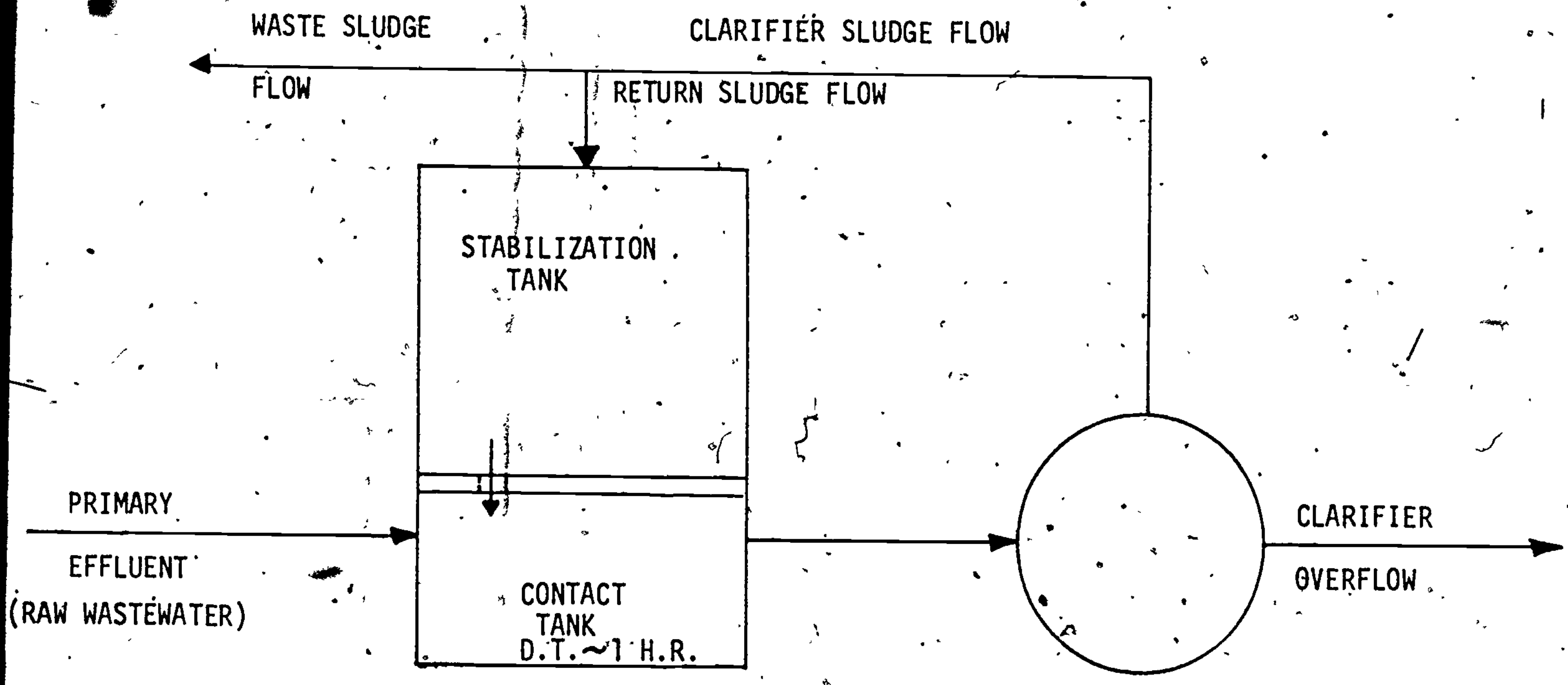
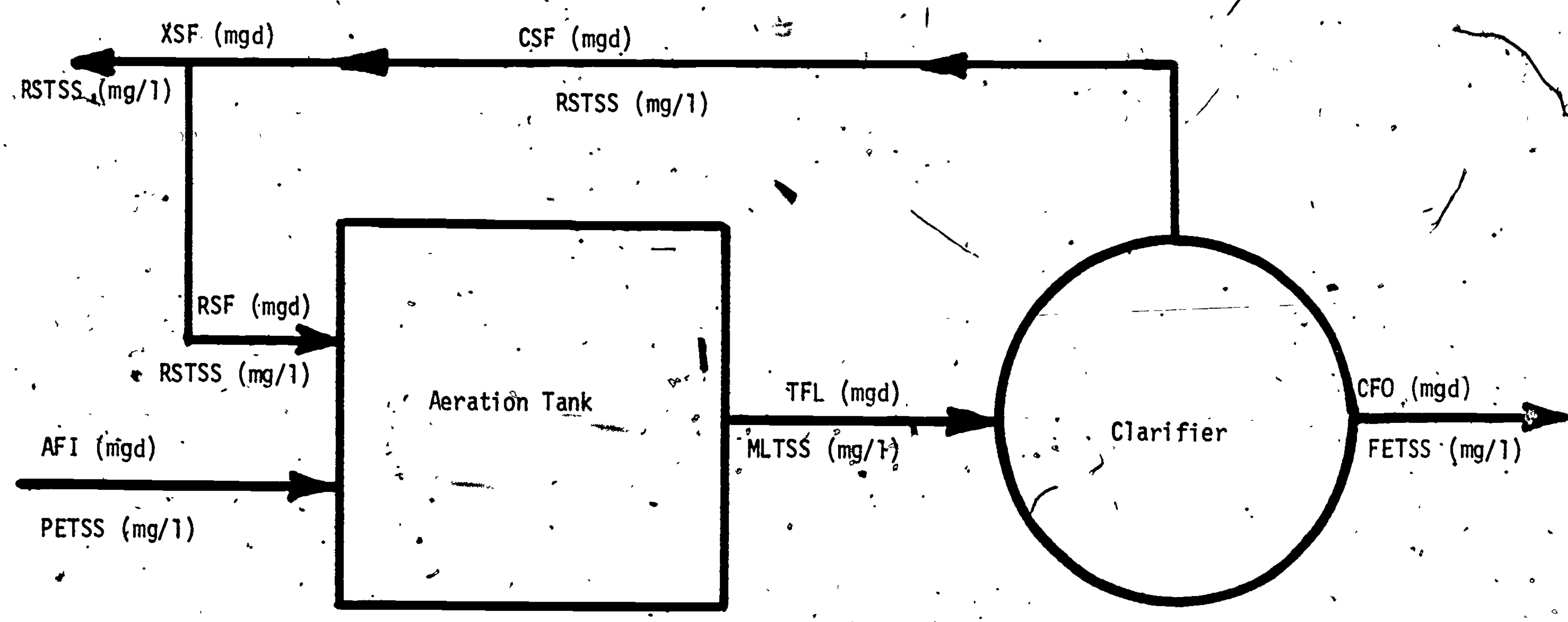


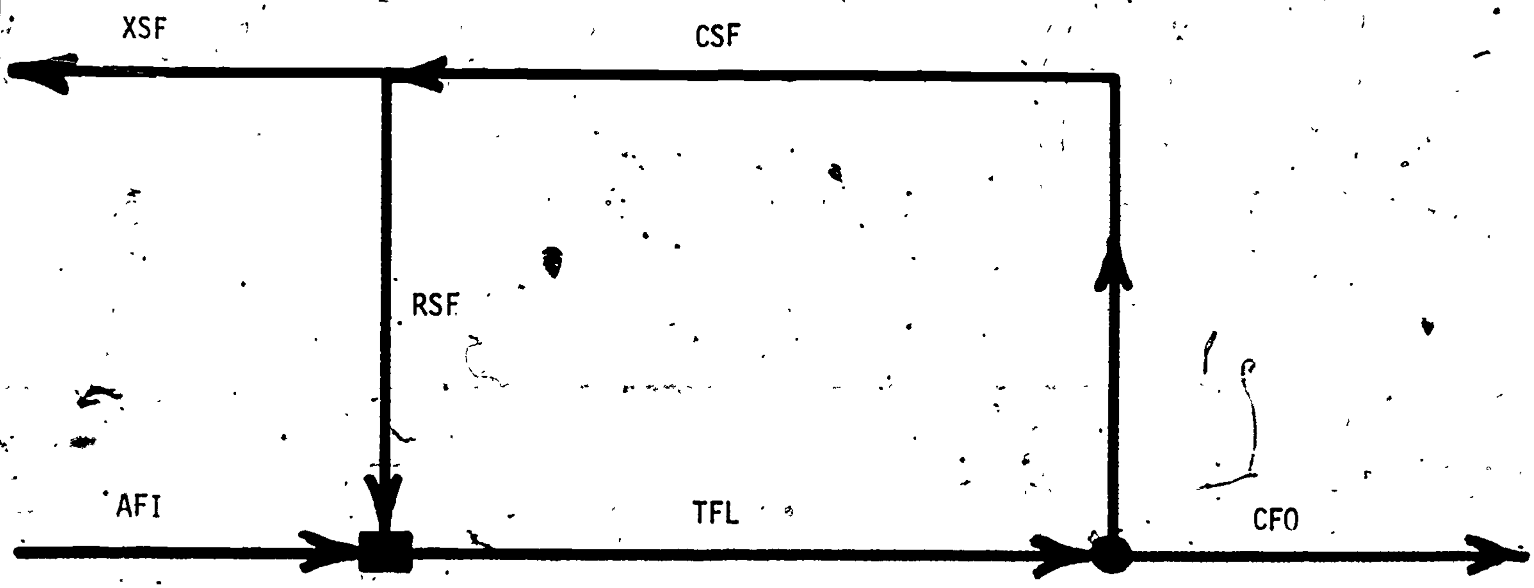
FIGURE 3
CONTACT STABILIZATION
PROCESS SCHEMATIC



CONVENTIONAL ACTIVATED SLUDGE

PROCESS SCHEMATIC

Figure 4



Flow in = Flow out

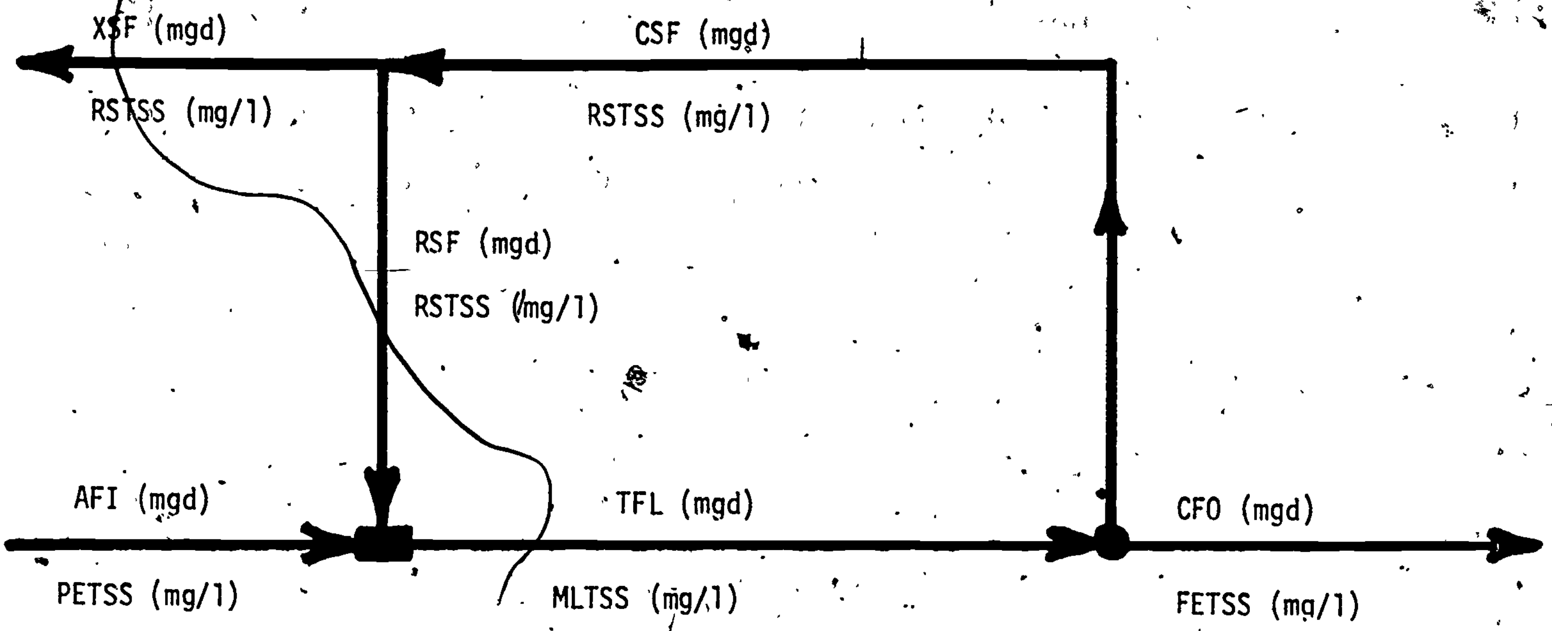
TFL = AFI + RSF

TFL = CFO + CSF

CSF = RSF + XSF

Figure 5

Flow Balance



Pounds/day = Flow (mgd) x Conc. (mg/l) x 8.34

Pounds in = Pounds out

Figure 6

MASS BALANCE

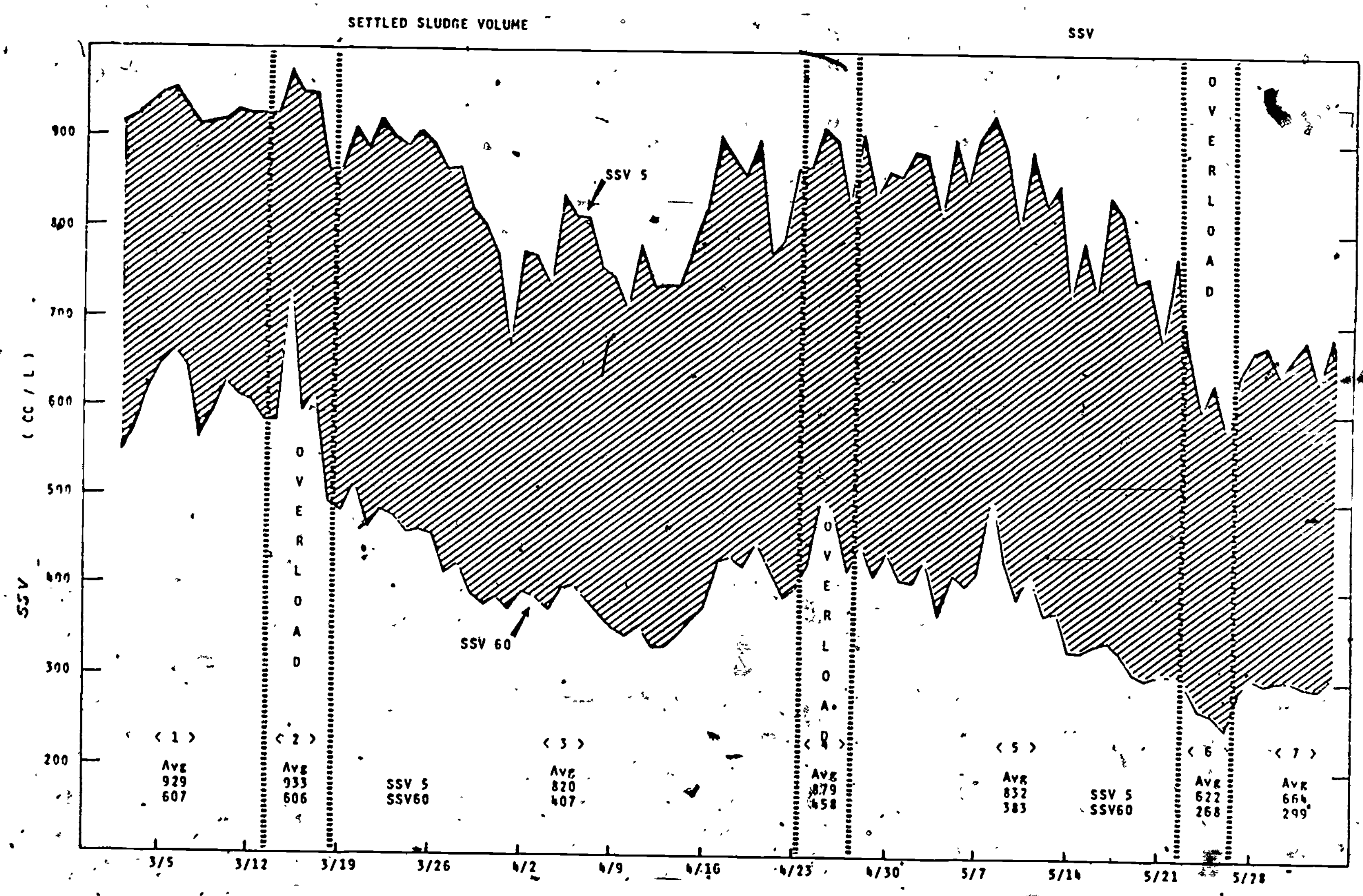

SETTLED SLUDGE VOLUME
SSV
SSV (CC/L)
900
800
700
600
500
400
300
200
SSV 5
SSV 60
OVERLOAD
OVERLOAD
OVERLOAD
< 1 > Avg 929 607
< 2 > Avg 933 606
SSV 5 SSV60
< 3 > Avg 820 407
< 4 > Avg 879 458
< 5 > Avg 832 383
SSV 5 SSV60
< 6 > Avg 622 268
< 7 > Avg 664 299
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 7

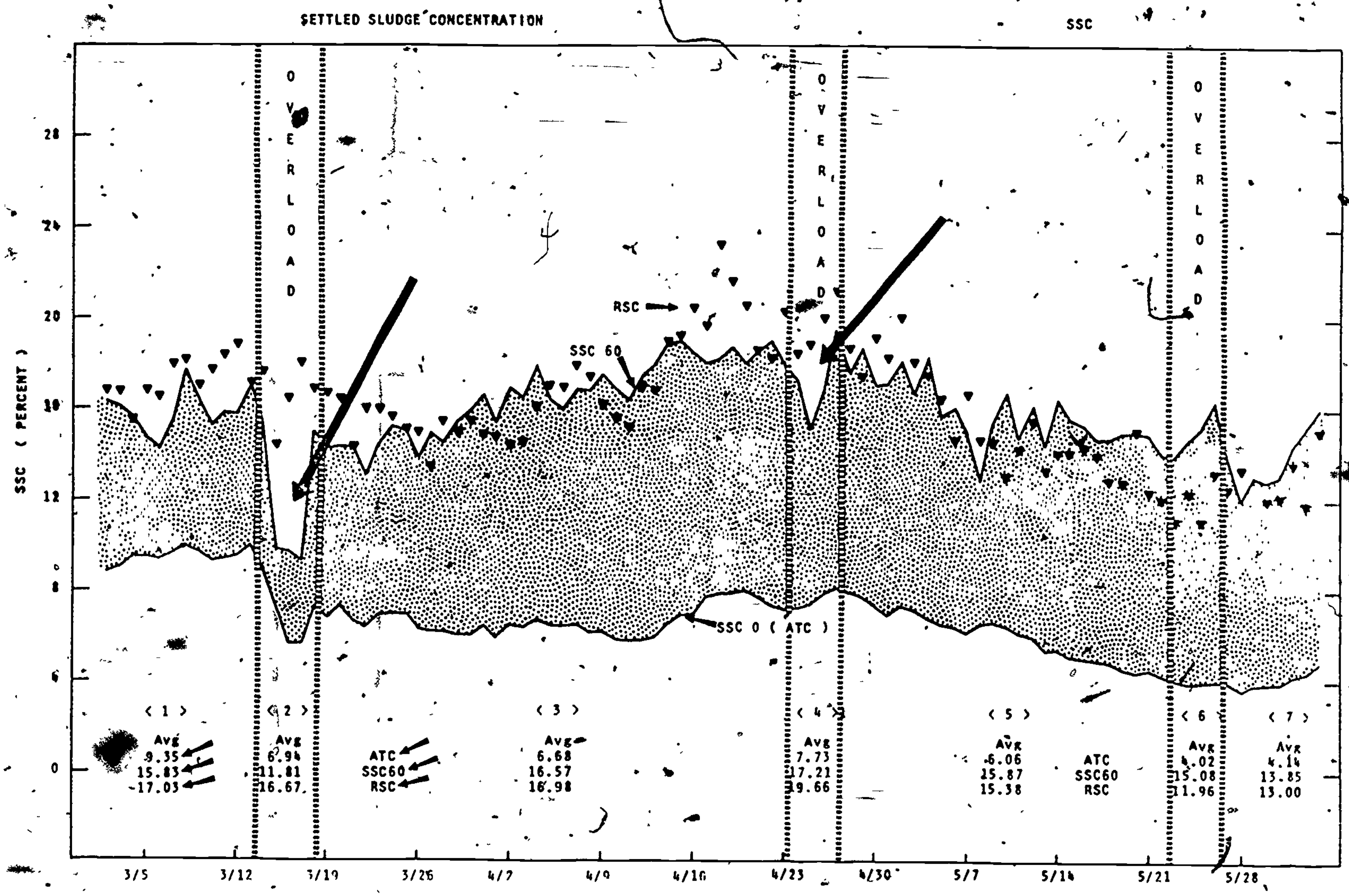

SETTLED SLUDGE CONCENTRATION
SSC
SSC (PERCENT)
OVERLOAD
OVERLOAD
OVERLOAD
RSC
SSC 60
SSC 0 (ATC)
< 1 >
Avg
9.35
15.83
17.03
< 2 >
Avg
6.94
11.81
16.67
ATC
SSC60
RSC
< 3 >
Avg
6.68
16.57
16.98
< 4 >
Avg
7.73
17.21
19.66
< 5 >
Avg
6.06
15.87
15.38
ATC
SSC60
RSC
< 6 >
Avg
4.02
15.08
11.96
< 7 >
Avg
4.14
13.85
13.00
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 8

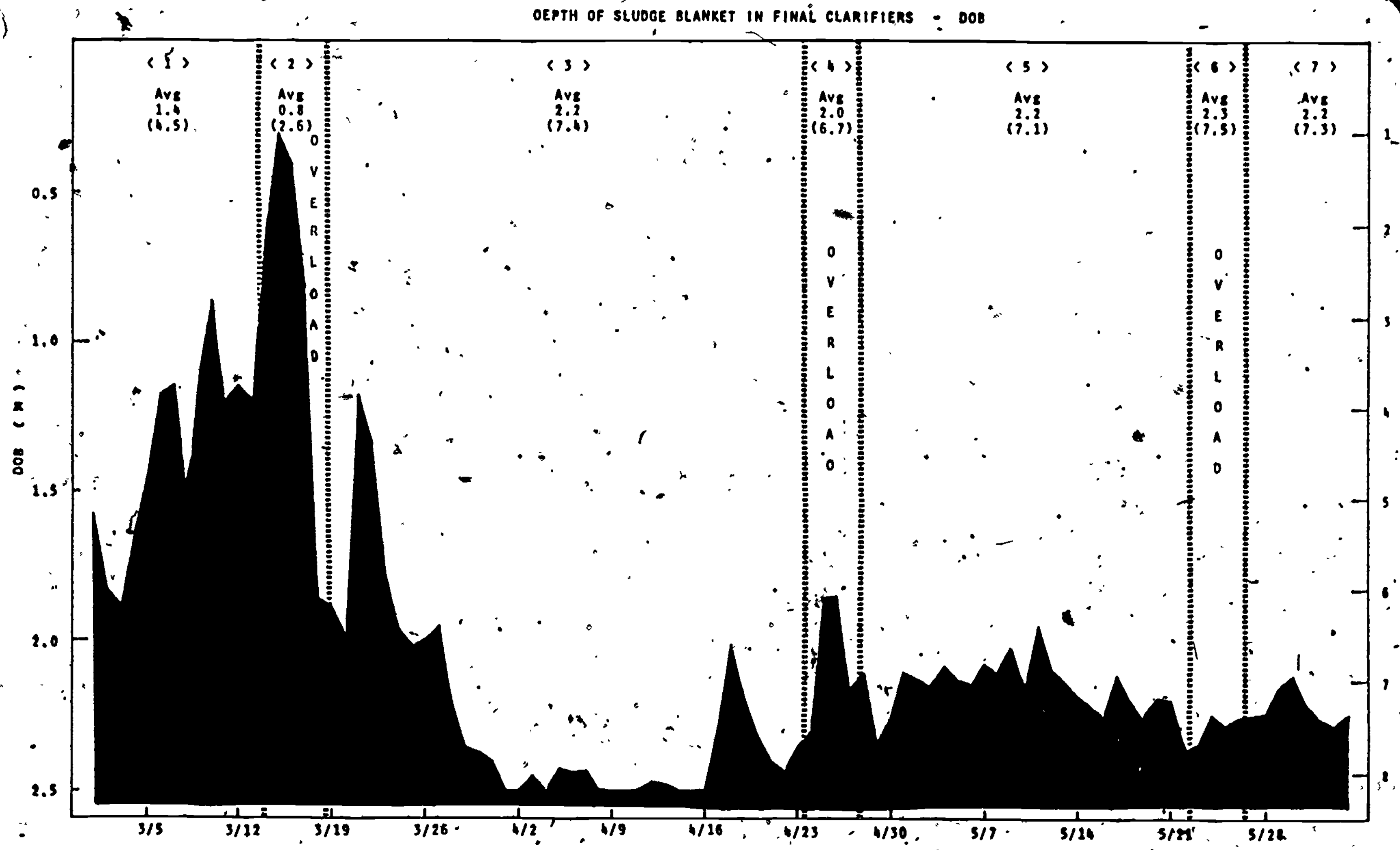

DEPTH OF SLUDGE BLANKET IN FINAL CLARIFIERS - DOB
< 1 > Avg 1.4 (4.5)
< 2 > Avg 0.8 (2.6)
OVERLOAD
< 3 > Avg 2.2 (7.4)
< 4 > Avg 2.0 (6.7)
OVERLOAD
< 5 > Avg 2.2 (7.1)
< 6 > Avg 2.3 (7.5)
OVERLOAD
< 7 > Avg 2.2 (7.3)
DOB (M)
0.5
1.0
1.5
2.0
2.5
DOB (FT)
1
2
3
4
5
6
7
8
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 9

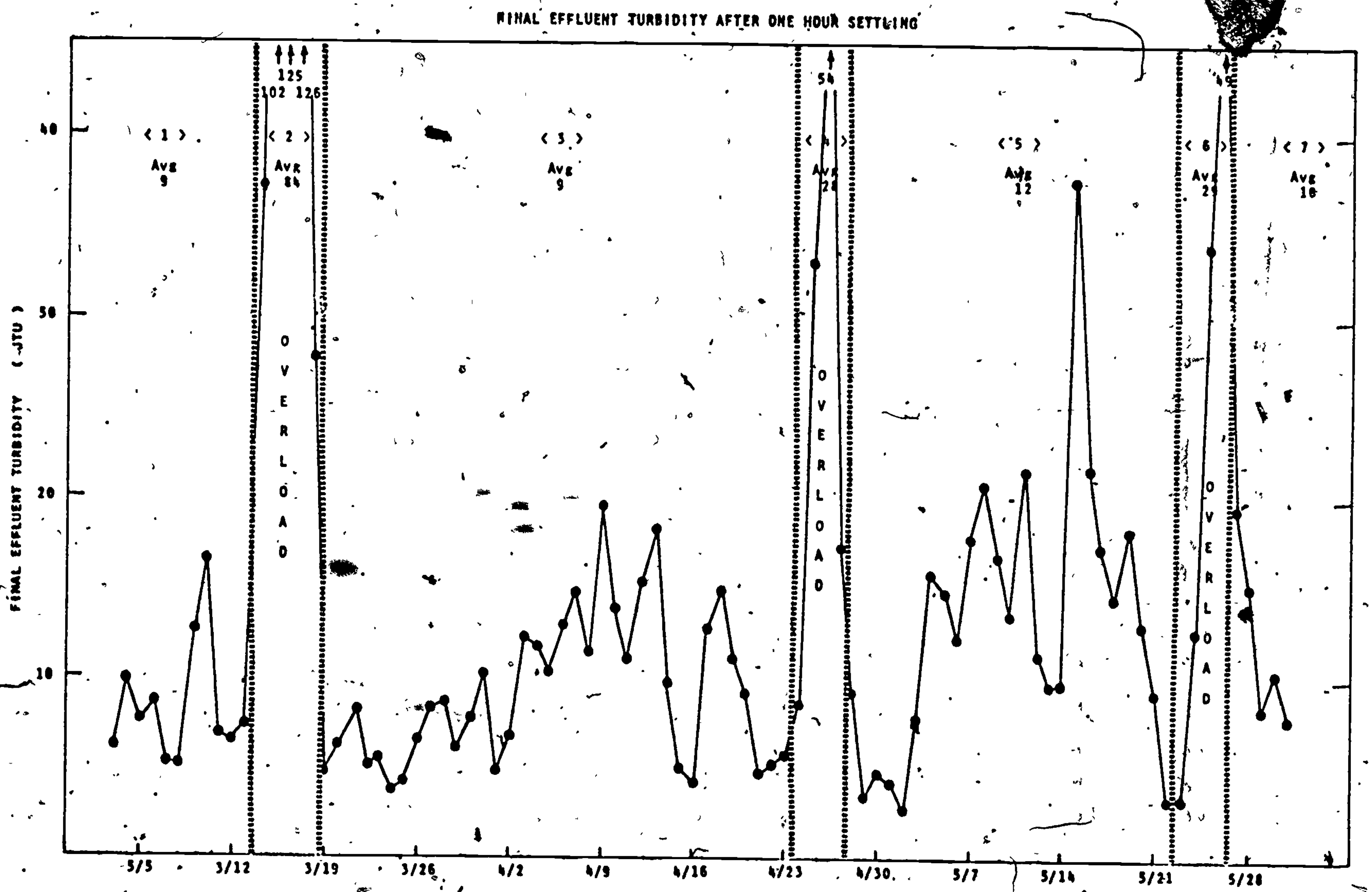

FINAL EFFLUENT TURBIDITY AFTER ONE HOUR SETTLING
FINAL EFFLUENT TURBIDITY (JTU)
< 1 >
Avg 9
< 2 >
Avg 84
102 125 126
OVERLOAD
< 3 >
Avg 9
< 4 >
Avg 24
54
OVERLOAD
< 5 >
Avg 12
< 6 >
Avg 29
49
OVERLOAD
< 7 >
Avg 10
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 10

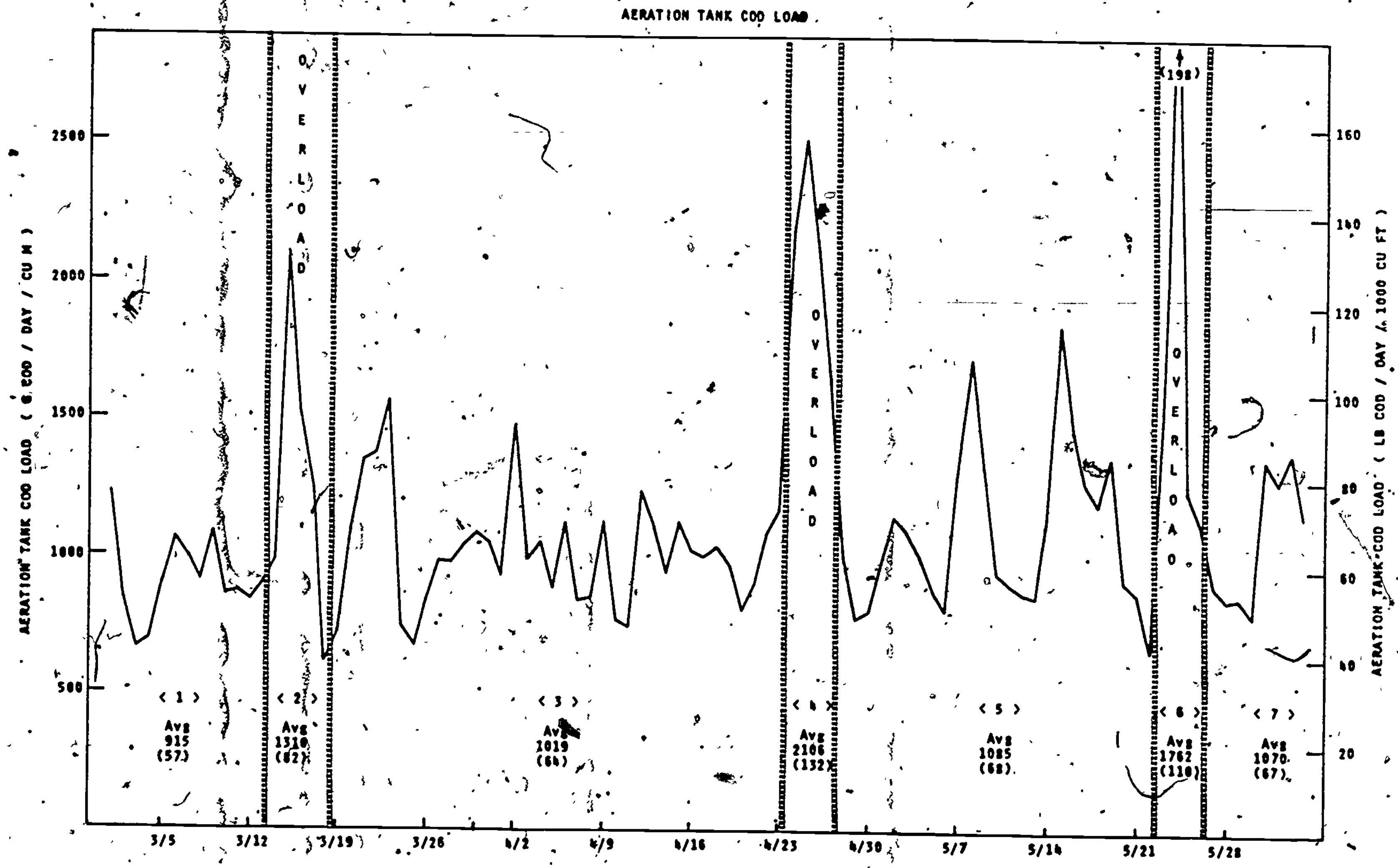

AERATION TANK COD LOAD
AERATION TANK COD LOAD (G COD / DAY / CU M)
AERATION TANK COD LOAD (LB COD / DAY / 1000 CU FT)
2500
2000
1500
1000
500
160
140
120
100
80
60
40
20
OVERLOAD
OVERLOAD
OVERLOAD
(198)
< 1 >
Avg
915
(57)
< 2 >
Avg
1310
(82)
< 3 >
Avg
1019
(64)
< 4 >
Avg
2106
(132)
< 5 >
Avg
1085
(68)
< 6 >
Avg
1762
(110)
< 7 >
Avg
1070
(67)
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 11

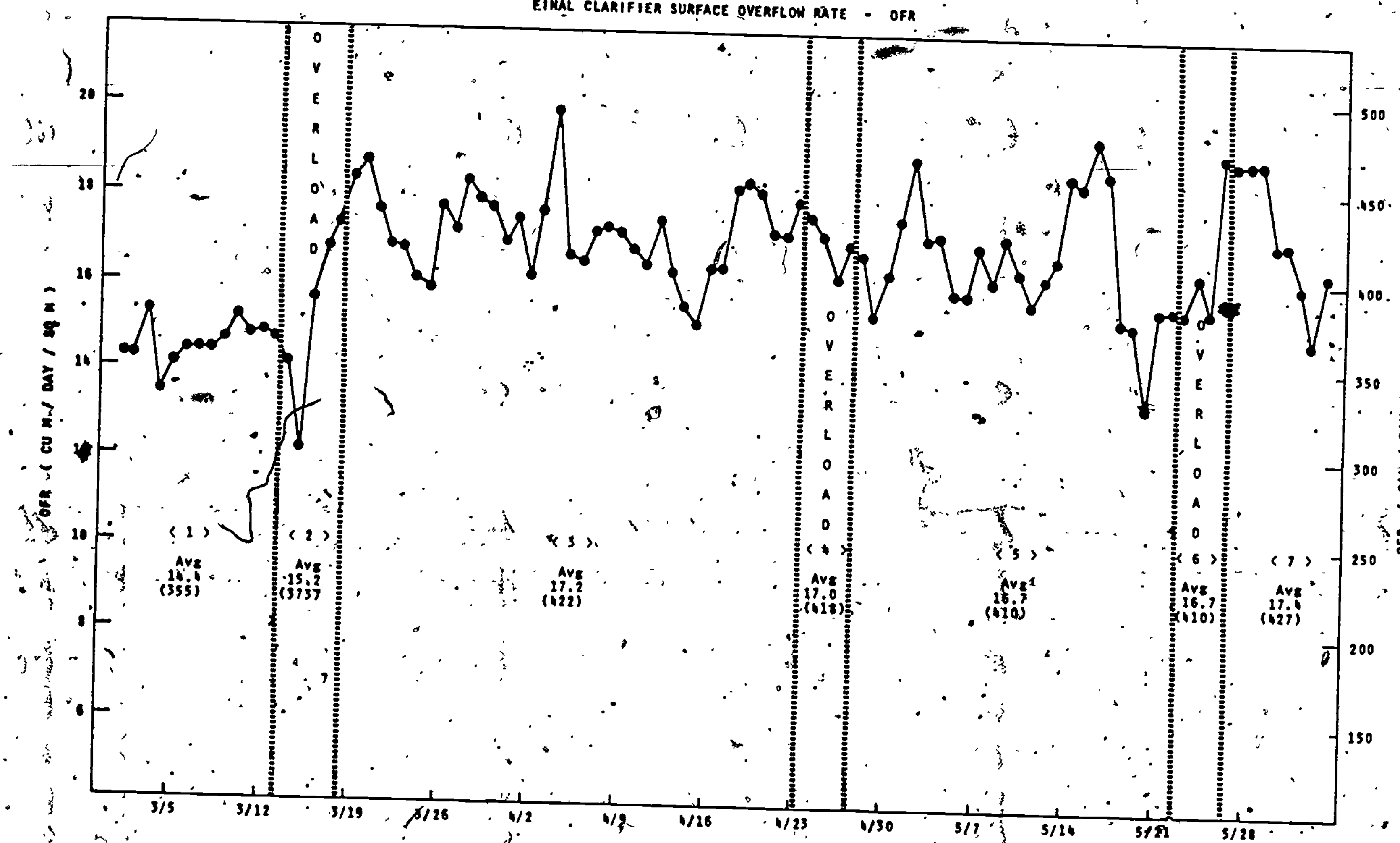

FINAL CLARIFIER SURFACE OVERFLOW RATE - OFR
OFR (CU M./ DAY / SQ M)
OFR (GAL / DAY / SQ FT)
OVERLOAD
OVERLOAD
OVERLOAD
< 1 > Avg 14.4 (355)
< 2 > Avg 15.2 (373)
< 3 > Avg 17.2 (422)
< 4 > Avg 17.0 (418)
< 5 > Avg 16.7 (410)
< 6 > Avg 16.7 (410)
< 7 > Avg 17.4 (427)
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28

Figure 12

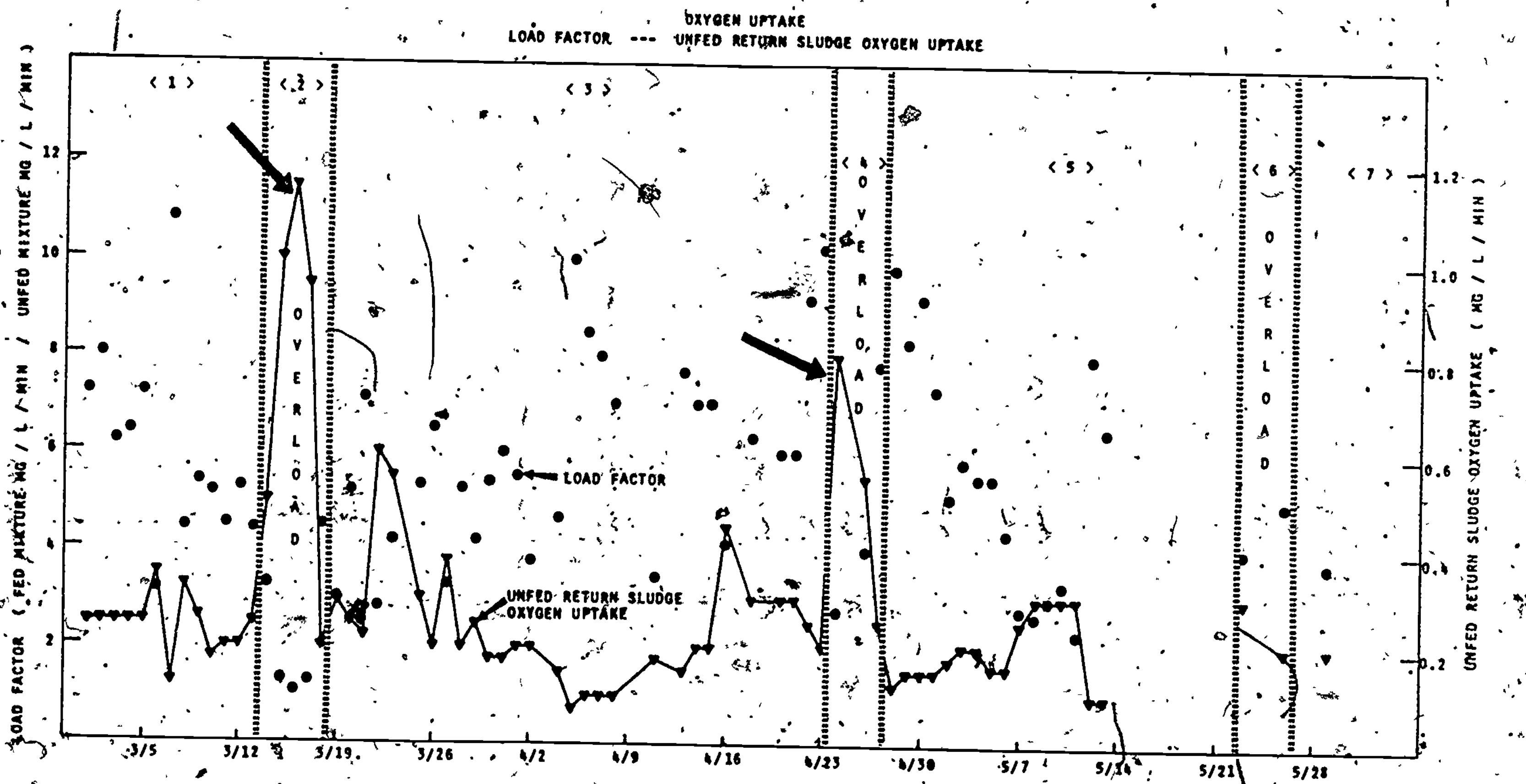

OXYGEN UPTAKE
LOAD FACTOR --- UNFED RETURN SLUDGE OXYGEN UPTAKE
LOAD FACTOR (FED MIXTURE MG / L / MIN / UNFED MIXTURE MG / L / MIN)
UNFED RETURN SLUDGE OXYGEN UPTAKE (MG / L / MIN)
< 1 >
< 2 >
< 3 >
< 4 >
< 5 >
< 6 >
< 7 >
OVERLOAD
LOAD FACTOR
UNFED RETURN SLUDGE OXYGEN UPTAKE
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
5/28
12
10
8
6
4
2
1.2
1.0
0.8
0.6
0.4
0.2

FIGURE 13

WEIGHT TO CONCENTRATION RATIO - WCR

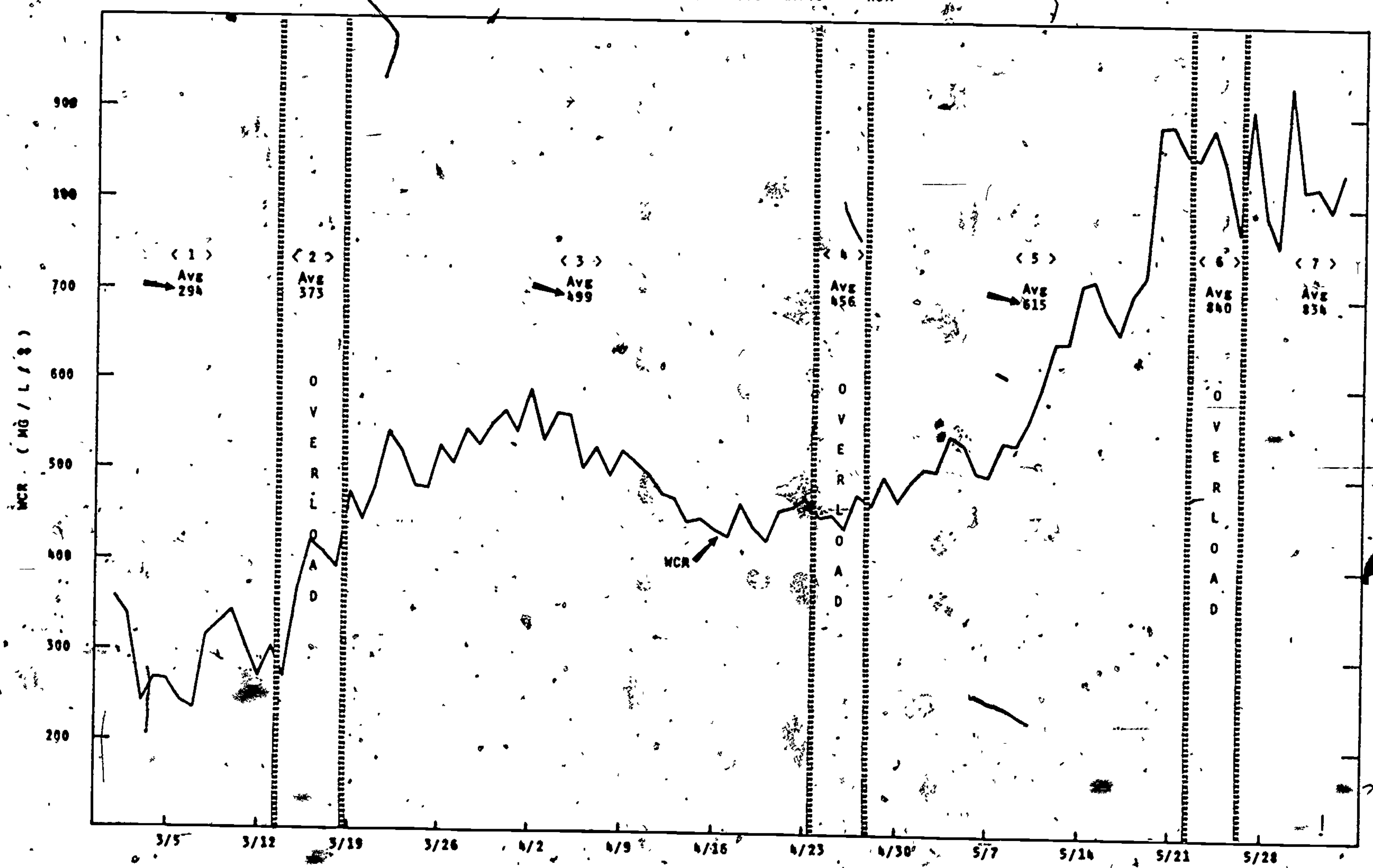


Figure 14

STUDENT HANDOUT 1

Unit Process ~~Dimensions~~

Primary Clarifiers

Number	2
Dimensions (each) 22' dia. x 9' depth	

Primary Sludge Pumps

Number	2
Capacity (each)	200 GPM

Aeration Tanks

Number	2
Dimensions (each) 32' x 64' x 14' deep	

Blowers

Number	3
Size	2 at 1,000 SCFM
	1 at 700 SCFM

Secondary Clarifiers

Number	3
Dimensions (each) 25 dia. x 9' depth	

Return Sludge Pumps

Number	2
Capacity (each)	200 GPM

STUDENT HANDOUT 2

Plant Data

Flow

Raw flow	0.6268 MGD
Primary sludge flow	0.0169 MGD
Return sludge flow	0.3140 MGD
Waste sludge flow	0.0130 MGD

BOD

Raw	366 mg/l
Primary effluent	302 mg/l
Final effluent	14 mg/l

Total Suspended Solids

Raw	460 mg/l
Primary effluent	137 mg/l
Final effluent	14 mg/l

Mixed Liquor

MLTSS	3382 mg/l
MLVSS	3138 mg/l

Return Sludge

RSTSS	8399 mg/l

Primary Sludge

PSTSS	48,157 mg/l

STUDENT HANDOUT 3

Given: Two aeration tanks, each 16' x 32' x 12'

Sewage flow BOD = 165 mg/l

Raw flow = 300,000 gallons per day

Select: F/M ratio (0.1 to 0.5)

Say 0.3

Find: Mixed liquor volatile suspended solids concentration required.

1. MLVSS = ________

Final effluent quality not acceptable. The appearance of the final clarifier indicates a higher concentration of solids would improve final effluent quality.

Select a revised F/M which would result in a higher concentration of solids and then solve for the new concentration.

2. MLVSS = ________

DATE 8/27/76 60 MINUTE DEMAND

DAY

TEST TIME 0800	TEST TIME	TEST TIME
RAW FLOW 2.65 MGD	RAW FLOW	RAW FLOW
RETURN FLOW .90 MGD	RETURN FLOW	RETURN FLOW
WASTE FLOW 0	WASTE FLOW	WASTE FLOW

TIME	SSV	SSC	TIME	SSV	SSC	TIME	SSV	SSC
0	1000		0	1000		0	1000	
5	720		5			5		
10	540		10			10		
15	450		15			15		
30	390		30			30		
45	310		45			45		
60	290		60			60		
90	—		90			90		

ATC 3.27%	ATC	ATC
RSC 14.07%	RSC	RSC
DOB 5.9'	DOB	DOB
INITIAL TURBIDITY 5.1	INITIAL TURBIDITY	INITIAL TURBIDITY
FINAL TURBIDITY 3.7	FINAL TURBIDITY	FINAL TURBIDITY

STUDENT HANDOUT 5

OXYGEN UPTAKE WORK SHEET

UNFED MIXTURE			
Time (min)	Temp.	D.O.	Δ D.O.
t = 0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

FED MIXTURE			
Time (min)	Temp.	D.O.	Δ D.O.
t = 0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

Flows:

Return sludge flow = ______________ A
Aeration Tank influent = ______________ B

Calculate volume of return sludge (RSV) required:

$$RSV = \frac{300 \times A}{A + B} = \frac{300 \times \_\_\_}{\_\_\_ + \_\_\_} = \frac{\_\_\_}{\_\_\_}$$

Calculate load ratio (L.R.)

$$L.\ R. = \frac{\text{Fed mixture oxygen uptake}}{\text{Unfed mixture oxygen uptake}} = \frac{\_\_\_}{\_\_\_}$$

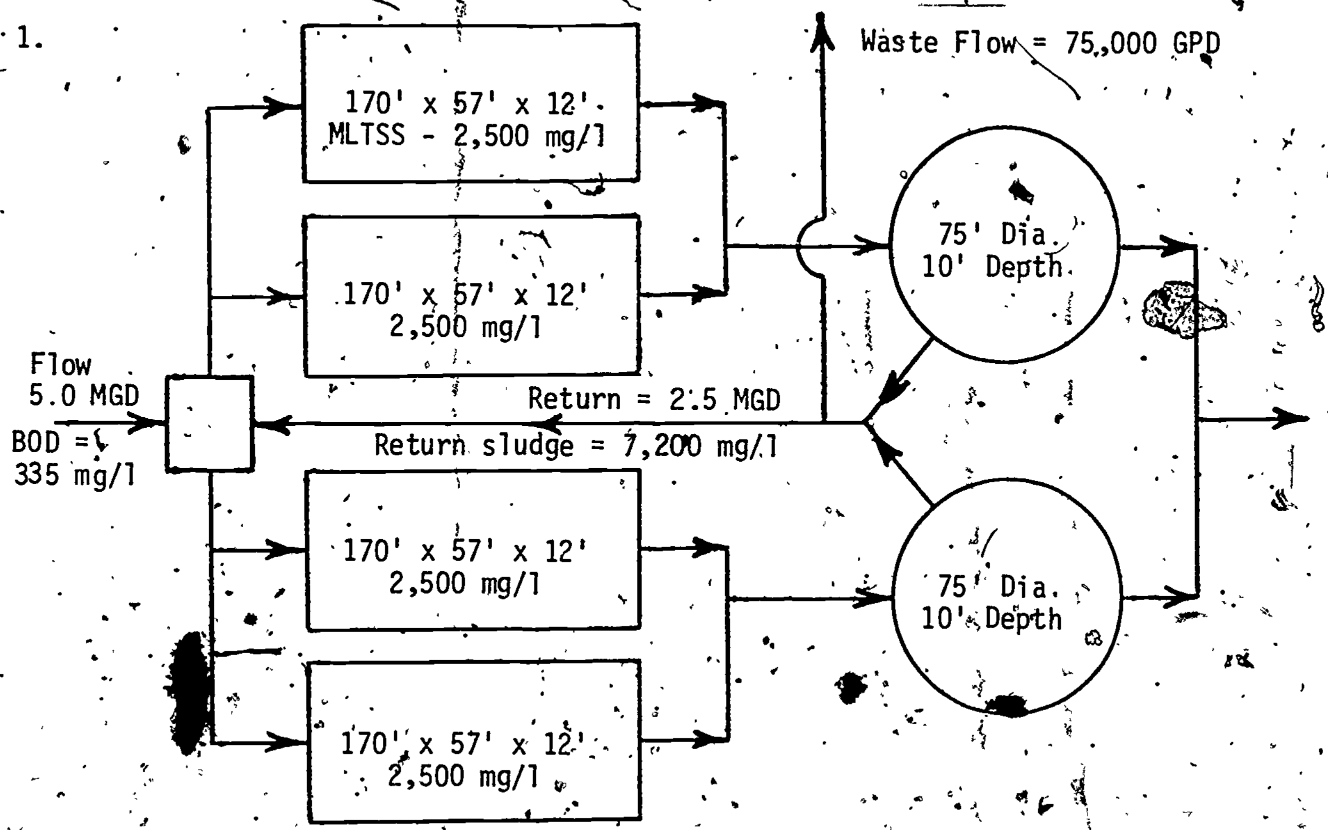
L. R. = ______________

Module No:	Module Title: Advanced Activated Sludge
Approx. Time:	Submodule Title:
	EVALUATION

Objectives:

The learner will demonstrate that he has achieved the objectives of the module by correctly answering 75% of the following questions.

1.



Calculate:

A. Aeration tank detention time at flow alone. ________

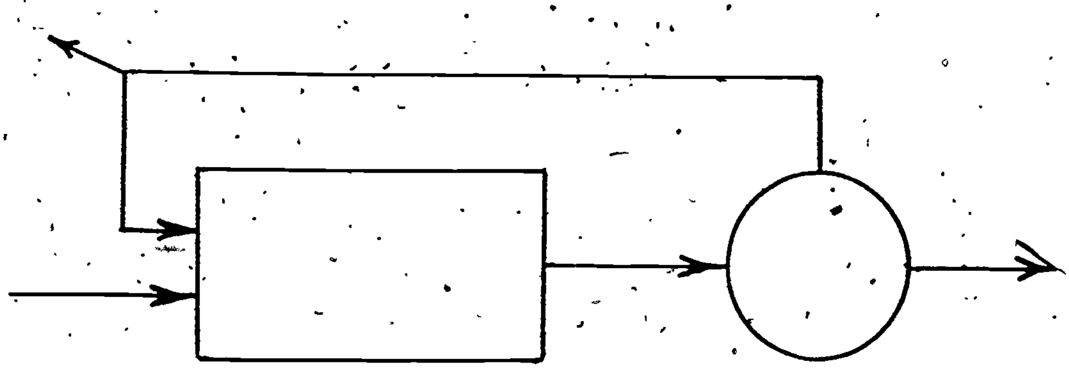
B. Aeration tank detention time at flow plus return. ________

C. BOD loading, lbs. BOD per 1000 cubic feet of aeration tank. ________

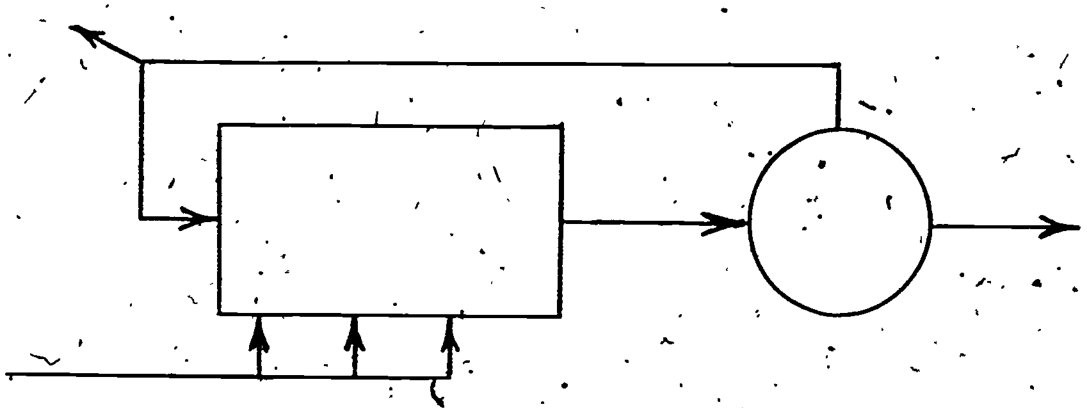
D. F/M ________

E. Clarifier Overflow Rate. ________

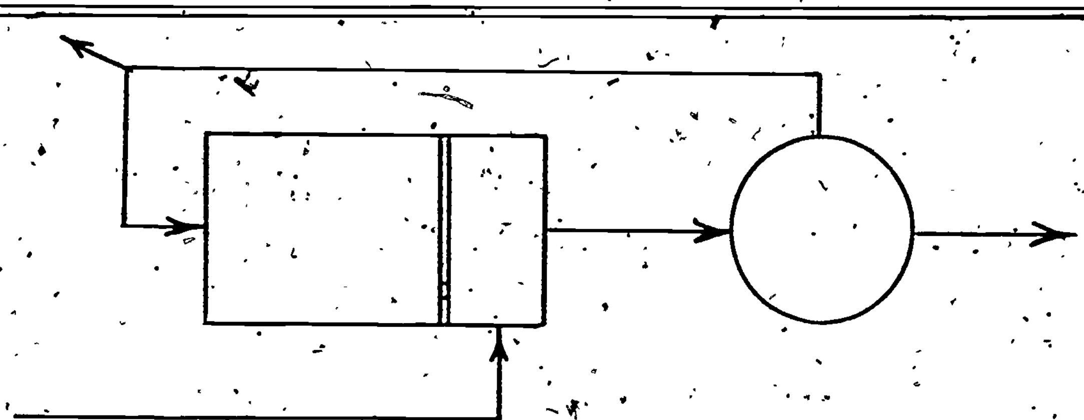
F. Sludge Age. ________



A. ______________________



B. ______________________



C. ______________________

2. Label each activated sludge schematic by the name of the process of the modification.

3. Four trend charts follow.

A. Figure A is a plot of secondary clarifier surface overflow rate. What is the probable cause of the peaks in Sections I, II, and IV.

____

B. Does the depth of sludge blanket curve, Figure B, show the identical response to the increased OFR in Sections I and IV of Figures A and B? __________. If no, what is the difference?

____

____

C. The settling characteristics were relatively poor, especially in Sections I and II of Figure C. No sludge was wasted during that period, Figure D. What is a possible explanation for zero sludge wasting during that period?

____

____

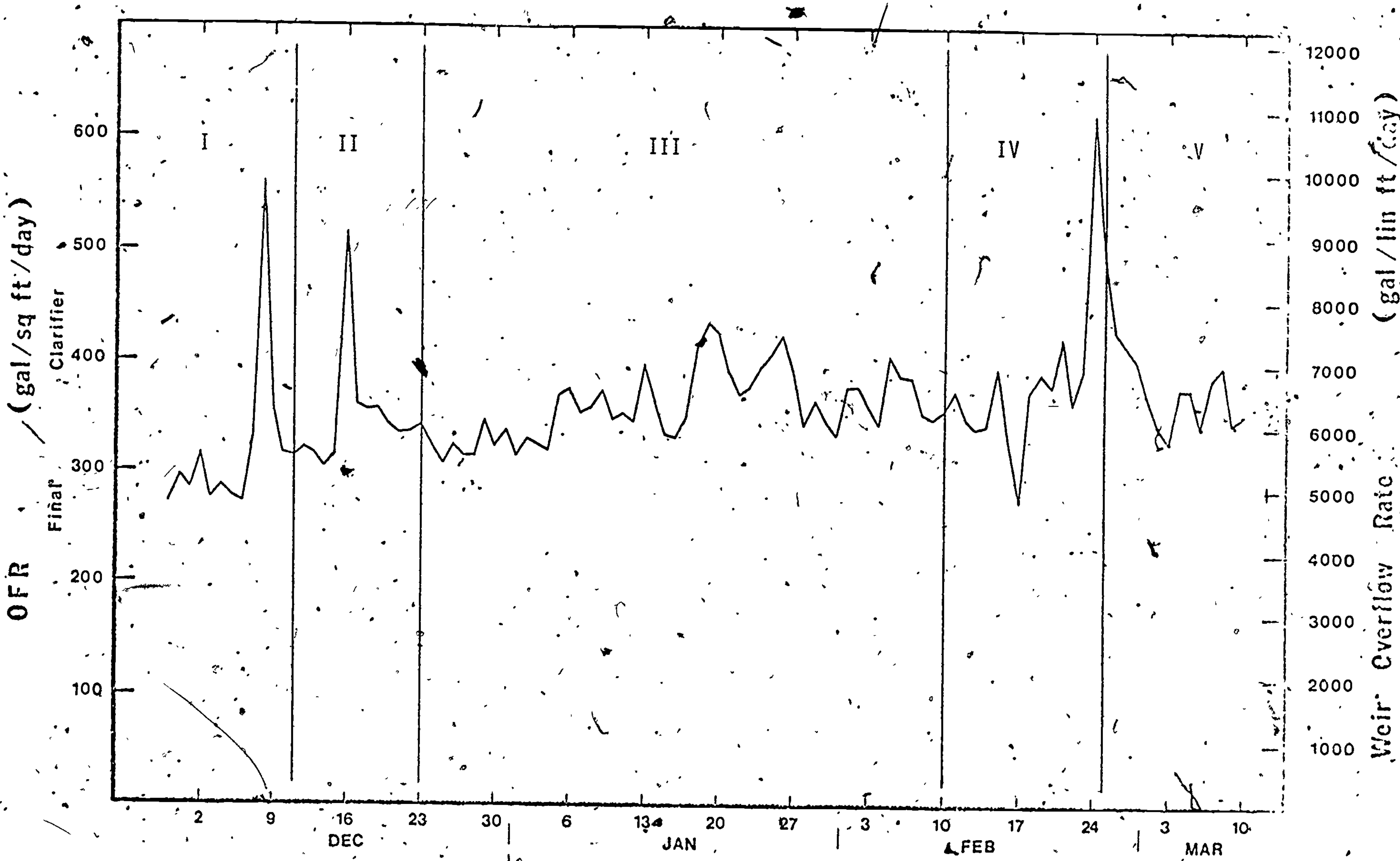
____

D. Comparing Figure C and D, Section IV, describe your interpretation of settling characteristics as a function of wasting sludge.

____

____

____



OFR Final Clarifier (gal/sq ft/day)
600
500
400
300
200
100
I
II
III
IV
V
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
Weir Overflow Rate (gal/lin ft/day)
2
9
16
23
30
6
13
20
27
3
10
17
24
3
10
DEC
JAN
FEB
MAR

Figure A

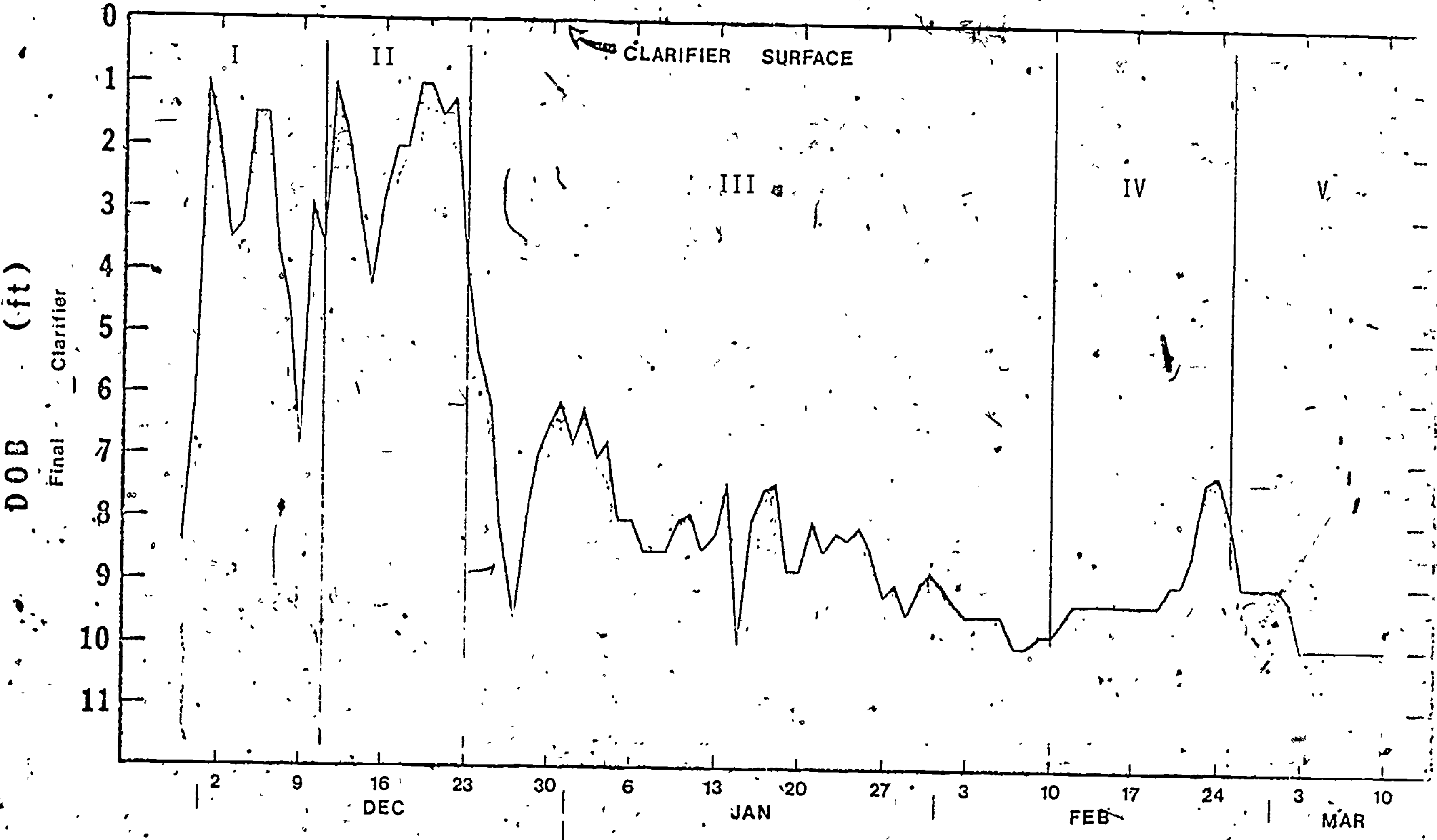
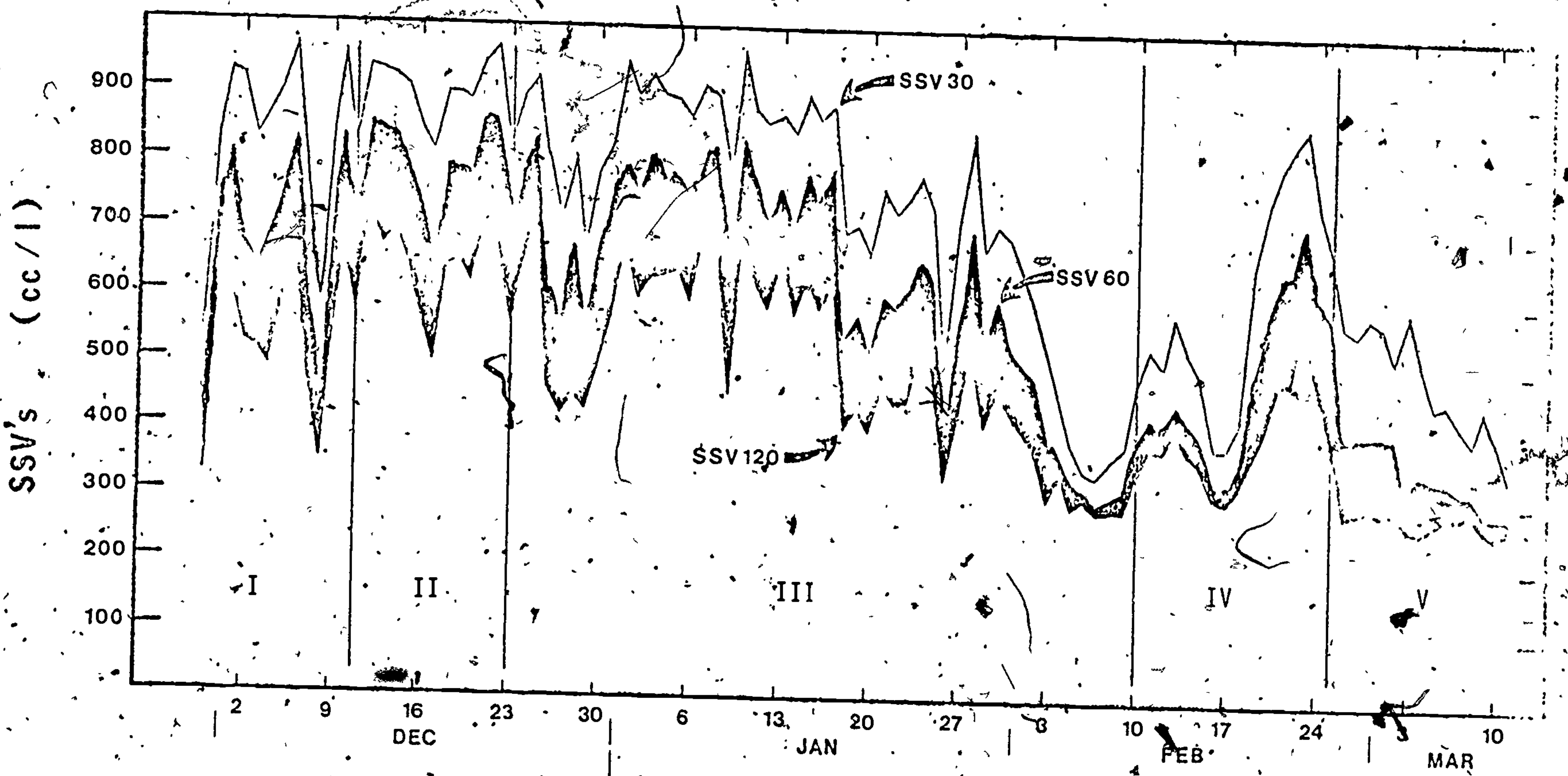

CLARIFIER SURFACE
I
II
III
IV
V
DOB (ft)
Final Clarifier
0
1
2
3
4
5
6
7
8
9
10
11
2
9
16
23
30
6
13
20
27
3
10
17
24
3
10
DEC
JAN
FEB
MAR

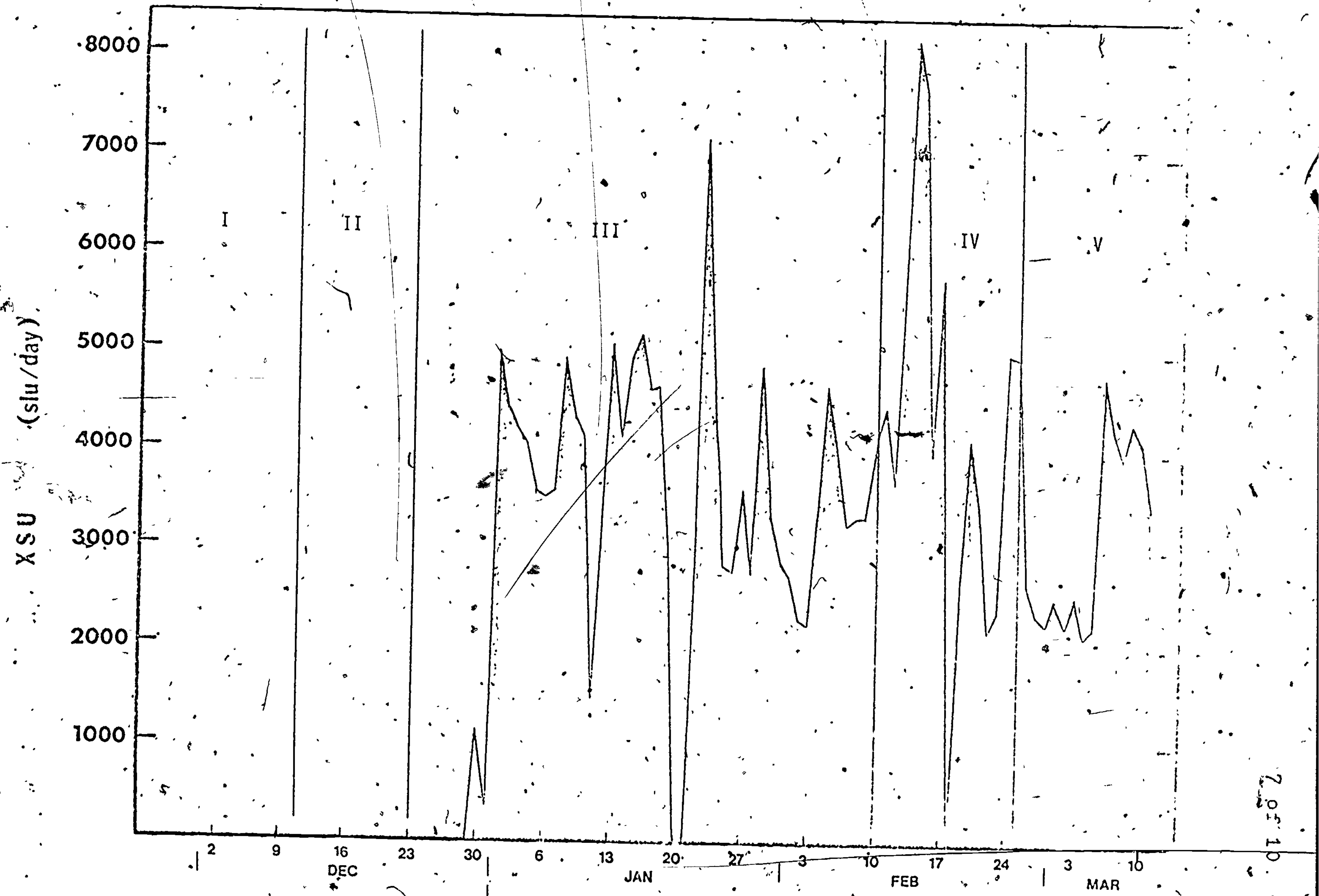
Figure B



900
800
700
600
500
400
300
200
100
SSV's (cc/l)
SSV 30
SSV 60
SSV 120
I
II
III
IV
V
2
9
16
23
30
6
13
20
27
3
10
17
24
3
10
DEC
JAN
FEB
MAR

Figure C.

7



8000
7000
6000
5000
4000
3000
2000
1000
XSU (slu/day)
I
II
III
IV
V
2
9
16
23
30
DEC
6
13
20
27
JAN
3
10
17
24
FEB
3
10
MAR

Figure D

4. An oxygen uptake analysis is run with the following data recorded:

Time (minutes)	D.O.	D.O.
0	8.6	____
1	6.4	____
2	5.1	____
3	4.6	____
4	4.0	____
5	3.4	____
6	2.8	____
7	____	____

Complete the data sheet and show the oxygen uptake rate. ____________

(Show the units).

5. A second uptake analysis is run with the following data recorded:

Time (minutes)	D.O.	D.O.
0	8.7	____
½	6.5	____
1	5.4	____
1½	4.7	____
2	4.1	____
2½	3.5	____
3	____	____

Complete this data sheet and show the oxygen uptake rate. ____________

(Show the units).

6. An aeration tank has a volume of 214,000 gallons. Mixed liquor total suspended solids concentration is 1,800 mg/l. The waste flow has been averaging 310,000 gallons per day. An increase in flow is anticipated from a new interceptor. The flow should increase to 400,000 gallons per day; BOD is expected to remain at 200 mg/l. The operator wants to control to a constant F/M ratio, maintaining the ratio that existed before the flow increase. What will be the new concentration of mixed liquor the facility will want? A.__________

What is the F/M ratio at which the facility is being controlled?

B. __________

7. What is the primary process control variable used in constant mixed liquor solids level control? __________

8. A waste treatment facility has a wide variation in the BOD load coming into the plant. Is constant MLVSS a good control methodology for this facility? __________

9. A waste treatment facility recently purchased a total organic carbon (TOC) analyzer. What control methodology are they probably going to at least attempt to incorporate? __________

10. List two disadvantages to control to a constant F/M ratio.

____

____

11. List a problem relative to control to a constant sludge age.

____

12. An activated sludge facility is utilizing return sludge flow demand methodology. Final clarifier surface overflow rates are in the range of 400 to 500 gallons per square foot per day. With no additional information, would the facility probably be controlling to a 30 minute demand time or a 90 minute demand time? __________

13. Given: RSC = 18.9%

ATC = 5.1%

SSC 90 = 14.5%

RSF = 0.4 MGD

Control to a 90 minute demand =

RSFD = RSF (RSC - ATC)/(SSC 90 - ATC)

To what level should the return sludge flow be adjusted? ______________

14. Describe the control testing and operational control methodology used at your facility.

Module No:	Topic: EVALUATION

Instructor Notes:	Instructor Outline:

1. A. 16.7 hours
   B. 11.1 hours
   C. 30 lbs. per 1000 cubic ft.
   D. 0.19
   E. 566 GPS FPD
   F. 16 days
   (Lbs. under aeration/lbs. wasted per day)
2. A. Conventional (or extended aeration)
   B. Step aeration (step-feed)
   C. Contact stabilization
3. A. Rainfall
   B. No

   Section I blanket went down, in Section IV blanket came up with the increased flow.

   C. Operator thought "aging" the sludge should increase its settling characteristic. Unfortunately it didn't appear to help in this situation.

   D. Should be some comment addressing the high waste rate and the increased settling rate which resulted in that period.

4.

0	8.6	xxx
1	6.4	2.2
2	5.1	1.3
3	4.6	0.5
4	4.0	0.6
5	3.4	0.6

Module No:	Topic: EVALUATION

Instructor Notes:

Instructor Outline:

	6	2.8	0.6
	7	___	___

Uptake = 0.6 ppm per minute

5.	0	8.7	xxx
	½	6.5	2.2
	1	5.4	1.1
	1½	4.7	0.7
	2	4.1	0.6
	2½	3.5	0.6
	3	2.9	0.6

Uptake = 1.2 ppm per minute

6. A. 2322 mg/l

   B. 0.16

7. Waste sludge flow

8. No

9. Constant F/M ratio control

10. Difficulty in obtaining a timely value for F (food or load). MLVSS not necessarily a true measure of M. Inability to make instantaneous changes in aeration tank solids concentrations.

11. What equation should be used. What value of sludge age should be selected.

12. 90 minute demand time.

13. RSFD = 0.59 MGD, however, the return flow should be changed generally a maximum of 25%. Set RSF at 0.5 MGD.

14. No set answer. Check individually and offer comment in response.