S&A/TSB-4

TECHNICAL ASSISTANCE PROJECT
GREELEY WASTEWATER TREATMENT FACILITY
GREELEY, COLORADO

JUNE - JULY, 1972

U. S. ENVIRONMENTAL PROTECTION AGENCY
SURVEILLANCE AND ANALYSIS DIVISION
TECHNICAL SUPPORT BRANCH
REGION VIII

AUGUST 1972

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I. Introduction

The Greeley Wastewater Treatment Facility has continually experienced difficulties in achieving the desired degree of treatment to meet the State's requirement of 80 percent reduction of biochemical oxygen demand - 5 day (BOD_5). The plant's main problem is organic overload. Despite the overload, modifications in the plant's facilities and in operational modes have allowed an increase in the percentage removal of BOD_5 from 40 percent in April of 1971 to the 70 percent range in April of 1972. Engineers from the Colorado State Department of Health and the Superintendent of the Greeley plant were responsible for developing the necessary modifications to improve the plant's performance.

In an effort to further improve the plant's performance, the Superintendent of the Greeley facility requested assistance from the U. S. Environmental Protection Agency - Region VIII. An assistance project was initiated at the Greeley plant on June 5, 1972. This report summarizes the findings of that project.

II. Purpose and Scope

Plans have been developed to provide for new treatment facilities at Greeley to alleviate the organic overload that exists at the present plant. These facilities are scheduled for completion in March 1973. Since future improvements have already been planned, the emphasis of this report does not deal with present plant limitations and future expansions. Only those portions of the existing facility that will be used in the future are discussed and modifications that could aid plant performance outlined. The main purpose of this report is to document the results achieved in improving plant performance by improved operation during the Federal Technical Assistance Project.

III. Description of Plant

Presently the Greeley wastewater treatment plant treats the waste from the City of Greeley plus the wastes from a large packinghouse (Monfort Packing Company). The present facilities consist of a trickling filter plant (South Plant) constructed in 1955 and an activated sludge plant (North Plant) constructed in 1965. In the past the trickling filter plant was used to treat the industrial waste and the activated sludge system was used to treat the domestic waste. Odor problems and mechanical problems forced the shut down of the trickling filter facility. During this time an attempt was made to treat all the wastes in the activated sludge plant. The gross overload on the activated sludge system reduced the plant's efficiency, resulting in a very poor quality effluent. New facilities were planned to decrease the load on the activated sludge system. Since these new facilities were not scheduled for completion until March 1973, efforts to improve the effluent quality from the Greeley plant became necessary.

The old trickling filter plant was modified and made operable to serve as a pre-treatment system for the packinghouse wastes. The filters were placed back in operation in December 1971. The pre-treated waste from the trickling filter plant was then mixed with the incoming domestic waste and treated in the activated sludge system. Pre-treatment of the packinghouse waste on the trickling filters greatly reduced the organic load on the activated sludge plant.

Figure 1 shows the various units at the Greeley facility. The activated sludge plant is located on the north side of the receiving stream (the Cache La Poudre River) and the trickling filter plant is located on the south side of the river. Sludge handling facilities (anaerobic digestors) are located on the south side of the river. All waste initially enters the plant on the south. Waste that has been pumped to the north side of the river for treatment in the activated sludge plant flows under the river to the south side for disinfection in the chlorine contact tanks prior to discharge.

Future plans call for the construction of an anaerobic, aerobic, facultative lagoon system to be built to treat the packinghouse waste and the waste activated sludge. Domestic waste will continue to be treated in the activated sludge plant. The trickling filter plant and its appurtenances are scheduled to be abandoned.

Emphasis during the technical assistance project was placed on the operation of the activated sludge facility. Therefore, units and operational controls for this portion of the facility will be described in more detail.

Incoming raw sewage and industrial waste which has been pretreated on the trickling filters are pumped to a splitter box on the north side of the river. Sewage flows by gravity from the splitter box to the two primary clarifiers. Each primary clarifier has a central sludge thickening compartment. Prior to assistance, sludge at times became too thick to pump from the primary clarifiers. Two 75 gpm piston pumps remove the sludge from the primary clarifiers and pump it to the anaerobic digestors on the south side of the river. Effluent from the primary clarifiers flows to a channel located between the two aeration basins. Gates along the channel allow settled sewage to be applied at three locations along each aeration basin. Prior to the assistance project all sewage was applied through the gate at the head end of each aeration basin. Mixed liquor from each basin flows to two final clarifiers. Clarified effluent is transported under the river to the chlorine contact basin on the south side and then is discharged to the Cache La Poudre River.

Return sludge is removed from the final clarifiers by suction type scraper arms and pumped by two centrifugal pumps through a common header back to the aeration basins. Return sludge can be added to the aeration basins at three separate locations along each

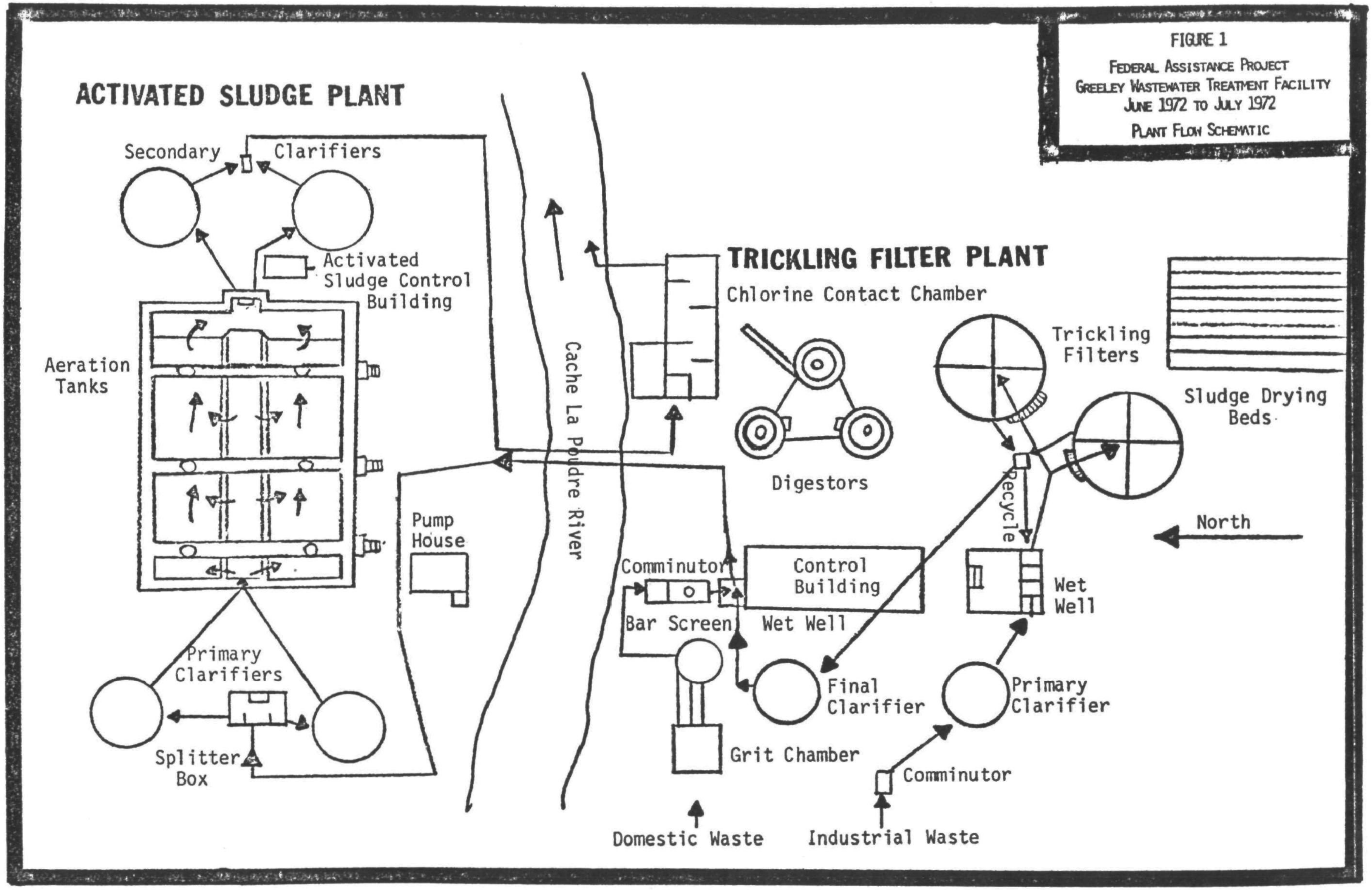
FIGURE 1
FEDERAL ASSISTANCE PROJECT
GREELEY WASTEWATER TREATMENT FACILITY
JUNE 1972 TO JULY 1972
PLANT FLOW SCHEMATIC
ACTIVATED SLUDGE PLANT
Secondary Clarifiers
Activated Sludge Control Building
Aeration Tanks
Primary Clarifiers
Splitter Box
Pump House
Cache La Poudre River
TRICKLING FILTER PLANT
Chlorine Contact Chamber
Trickling Filters
Sludge Drying Beds
Digestors
Recycle
North
Comminutor
Control Building
Bar Screen
Wet Well
Wet Well
Final Clarifier
Primary Clarifier
Grit Chamber
Comminutor
Domestic Waste
Industrial Waste

tank. Sludge is wasted from the system by partially closing the valves along the return sludge header, and thus forcing the return sludge up to the splitter box where the wasted sludge is diverted to the primary clarifiers. Measurement of waste sludge flow is accomplished by the use of v-notch weirs. Return sludge flow is measured by an in-line propeller type meter, accurate to 100 gpm. Return sludge flow rates are adjusted by opening or closing a butterfly valve. Gate valves are used to control the distribution of return sludge to each aeration basin.

The activated sludge portion of the plant was designed to achieve 80% removal at aeration basin loadings of 78 lbs. of BOD_5 per 1000 cubic feet (13,200 lbs. BOD_5 /day). Present loadings on the aeration portion of the activated sludge plant are approximately 110 lbs. BOD_5 per 1000 cubic feet of aeration basin volume (18,500 lbs. BOD_5/day) or about 140 percent above design. Present flows to the activated sludge portion of the plant are less than the average design flow rate of 7 mgd.

IV. Summary of Assistance Project

Little could be done to improve the performance of the pretreatment trickling filters due to the limited recirculation capabilities. Therefore, the major emphasis of the technical assistance project was the operation and control of the activated sludge portion of the plant.

A. Control Testing

The superintendant of the Greeley facility had initiated a program of control testing. These tests were modified slightly and used to control the plant's performance. The control tests used were dissolved oxygen tests, centrifuge tests, turbidity, settleability tests, and sludge blanket depths. These tests were conducted five times a day by plant personnel.

A dissolved oxygen meter was used to measure the oxygen concentrations of the mixed liquor in the aeration basins. Since the plant is organically overloaded, the determination of dissolved oxygen was necessary to indicate those conditions which depleted the availability of oxygen.

Centrifuge testing was used to determine rapidly the variations in solids concentrations throughout the day, as well as day to day. Tests were conducted on the mixed liquor, return sludge, and primary sludge. The centrifuge tests resulted in a percent solids determination. A correlation between percent solids by centrifuge and solids by weight was determined. The results of this correlation indicate that one percent solids from the centrifuge test on mixed liquor and return sludge was equivalent to 660 mg/l solids by weight. This factor will change as the sludge characteristics change.

Turbidity tests were conducted on the effluent from the final clarifiers to monitor improvements in performance prior to obtaining a BOD_5 test result.

Settleability tests were conducted on the mixed liquor to monitor and observe sludge settling characteristics.

Sludge blanket depth determinations were made on the final clarifiers to monitor changes in the depth of the blanket. Depth determinations were also made on the sludge in the primary clarifiers.

Results of these tests were used to perform daily calculations and to develop graphs that are used to control the activated sludge process.

B. Process Modifications

Various changes were made in the operational mode of the activated sludge portion of the Greeley facility.

Conditions as they existed prior to Federal assistance are outlined below:

All sewage was loaded at the head of each aeration basin. Return sludge was pumped to the head end port and the center port along each aeration basin. Rates for returning sludge were set at twenty-five percent of the incoming flow. A minimum of 500 gpm per pump or 1000 gpm return sludge rate had been established.

Mixed liquor concentrations were built from 300 to 500 mg/l on Monday to 900-1000 mg/l on Friday. Mixed liquor concentrations were dropping dramatically over the weekend when the waste from the packinghouse decreased.

Activated sludge was being wasted to the primary clarifiers only on Wednesday, Thursday and Friday. Mixed liquor was returned to the splitter box which directs the flow to the primaries to effect the removal of solids. No controlled wasting was performed on the weekend or on Monday or Tuesday.

Modifications that were made to the above operational mode are outlined below:

Incoming sewage was "step" loaded to the aeration basins, i.e., the sewage was loaded through each of the three gates along the aeration basin. This modification was made because of the excessive organic load on the plant. The organic overload requires an amount of oxygen greater than the plant was designed to provide. Step loading equalizes the demand for oxygen throughout the aeration basin, thus optimizing the use of oxygen. Oxygen profiles were conducted along the side of the aeration basin to determine the optimum gate settings. For example, higher dissolved oxygen values in a portion of the aeration basins indicated that more of the incoming sewage load should be applied to that section.

At the start of the project, it was decided to try and build the mixed liquor solids concentration to a maximum value. It was felt that increased solids could better handle the organic overload. As the solids concentration was increased, the effluent clarity from the final clarifiers increased. However the effluent quality as measured by the suspended solids concentration from the chlorine contact tank decreased. It was determined that a cross-connection existed between the plant effluent and mixed liquor from the aeration basins. A partially closed valve was discovered to be the source of the cross-connection. This leaky valve explains why the plant personnel had been unable to maintain a solids concentration over the weekends when the packinghouse waste was eliminated. After this valve was shut completely off, solids built rapidly in the system. It was felt that dissolved oxygen would be the critical factor controlling the amount of solids that could be maintained. However, bulking of solids from the final clarifiers proved to be the most critical factor.

Solids were wasted from the system by partially closing the valves which controlled the distribution of return sludge to the aeration basins. Flow adjustment of the desired quantity of waste sludge was relatively easy to accomplish by measuring the head on V-notch weirs. But, adjustment of the partially closed return sludge valves to obtain an even distribution of solids to each aeration basin was difficult to accomplish. Flow distribution of the return sludge to the aeration basins had to be "eye-balled" and then one-half hour after a setting was made, samples had to be collected from each aeration basin and percent concentration by centrifuge had to be determined to find if a solids imbalance due to return sludge flow differences had occurred. Each time the return flow rates were readjusted, the waste sludge flow rate changed due to the common header. Also, each time return flow rates were increased or decreased, the head on the gate valves changed, thus requiring a readjustment of the flow distribution between the two aeration basins. To correct these difficulties would require flow measuring devices (i.e., weir boxes) on the discharge return sludge ports. It would also be more desireable to have a separate line for sludge wasting which would eliminate the difficulties with a common header.

Return sludge rates were increased during the assistance project from the rate of twenty-five percent of the incoming flow to selected arbitrary rates. Rates were adjusted to the maximum return flows possible throughout most of the day. These rates were reduced at night and increased in increments in the morning as the flow increased.

During the initial portions of the assistance project and after the cross-connection was discovered, sludge was wasted to keep the final clarifiers from bulking solids. This required wasting rates of 500 to 700 gpm during the week when the packinghouse was in operation. Wasting at these rates pinpointed the bottleneck in the plant's capabilities. Waste activated sludge was pumped to the primary clarifiers which are equipped with central sludge thickening compartments. The sludge is then pumped, at a maximum rate of 150 gpm, to the anaerobic digestors on the south side of the river. The sludge produced by a high rate activated sludge process (i.e., 110 lbs. BOD_5 per 1000 cubic ft.) generally does not settle or concentrate well. It was quickly determined that the sludge thickeners could not cause thickening of the 500 to 700 gpm of waste sludge to a degree that all solids could be removed by the available 150 gpm sludge pumps. Therefore, the primary clarifiers filled with solids and effluent suspended solids from the primary clarifiers increased from less than 100 mg/l to greater than 300 mg/l. These septic solids placed an extreme overload on the aeration portion of the activated sludge system. It is doubtful that the anaerobic digestors which are already overloaded could have handled the solids that were wasted even if they could have been removed from the primary clarifiers.

After the limitation on sludge pumping and thus wasting of activated sludge was determined, an effort was made to develop a satisfactory operational mode. It was decided to continue to operate the aeration portion of the system to get optimum solids production, since a large portion of the BOD_5 in the waste is used in assimulative and endogenous respiration during cell growth. Wasting to the primaries was then optimized by monitoring the sludge blanket in the primary clarifiers. Wasting was continued until the primary clarifier blankets began to increase to the point that "bulking" of solids from the primaries would occur. In this manner, all the solids that could be handled by the system were removed. Also, all the BOD_5 that could be utilized in solids production was removed. Those solids that could not be removed by the system were lost in the effluent. This mode of operation provided the maximum degree of treatment from a grossly overloaded plant.

C. Performance Results

The performance of the North (activated sludge) plant is depicted in Figure 2 by the plot of percentage reduction of BOD_5 versus time. Prior to assistance the 7-day moving average indicates that the percent reduction of BOD_5 was approximately 65 percent. After assistance the percent reduction of BOD_5 was between 80 and 90 percent. The fluctuation in the percentage reduction of BOD_5 after assistance reflects the somewhat sporadic loss of solids that occurs. As outlined previously, the system cannot handle all of the solids and therefore some solids must be lost in the effluent. It is important to note that the efficiency of removal from the North plant is calculated on the load to that facility. In-plant loads (i.e., digestor supernatant) are discharged to the North Plant. Therefore, it is possible for the North plant to have an efficiency equal to or greater than the total plant efficiency.

Figure 3 shows the total plant performance for percent reduction of BOD_5. A gradual increase in percent reduction was occuring prior to the start of the Federal Assistance project. This increase reflects the improvement in performance of the trickling filter with the warmer summer temperatures. After the start of the Federal Assistance project, percentages of BOD_5 reduction, as indicated by the seven day moving average, increased from the 70 percent range to the 80 and 90 percent range. Again the sporadic loss of solids from the activated sludge plant prevents the development of a consistent removal pattern.

Figure 4 depicts the improvement in plant performance as measured by effluent BOD_5 concentration. The decline in effluent concentration prior to assistance is due to the increased performance of the trickling filters. The effluent BOD_5, as indicated by the seven day moving average, had decreased to approximately 105 to 110 mg/l prior to assistance. After assistance the 7-day average effluent BOD_5 concentration ranged from 28 to 90 mg/l with an average of about 60 mg/l. Thus, after Federal Assistance was initiated, the effluent BOD_5 concentration was reduced by at least 15 mg/l and as much as 82 mg/l with an average reduction of about 45 mg/l.

Figure 5 shows the pounds of BOD_5 in the effluent versus time. Again the decline of BOD_5 in the effluent prior to assistance is due to the increased performance of the trickling filters. The

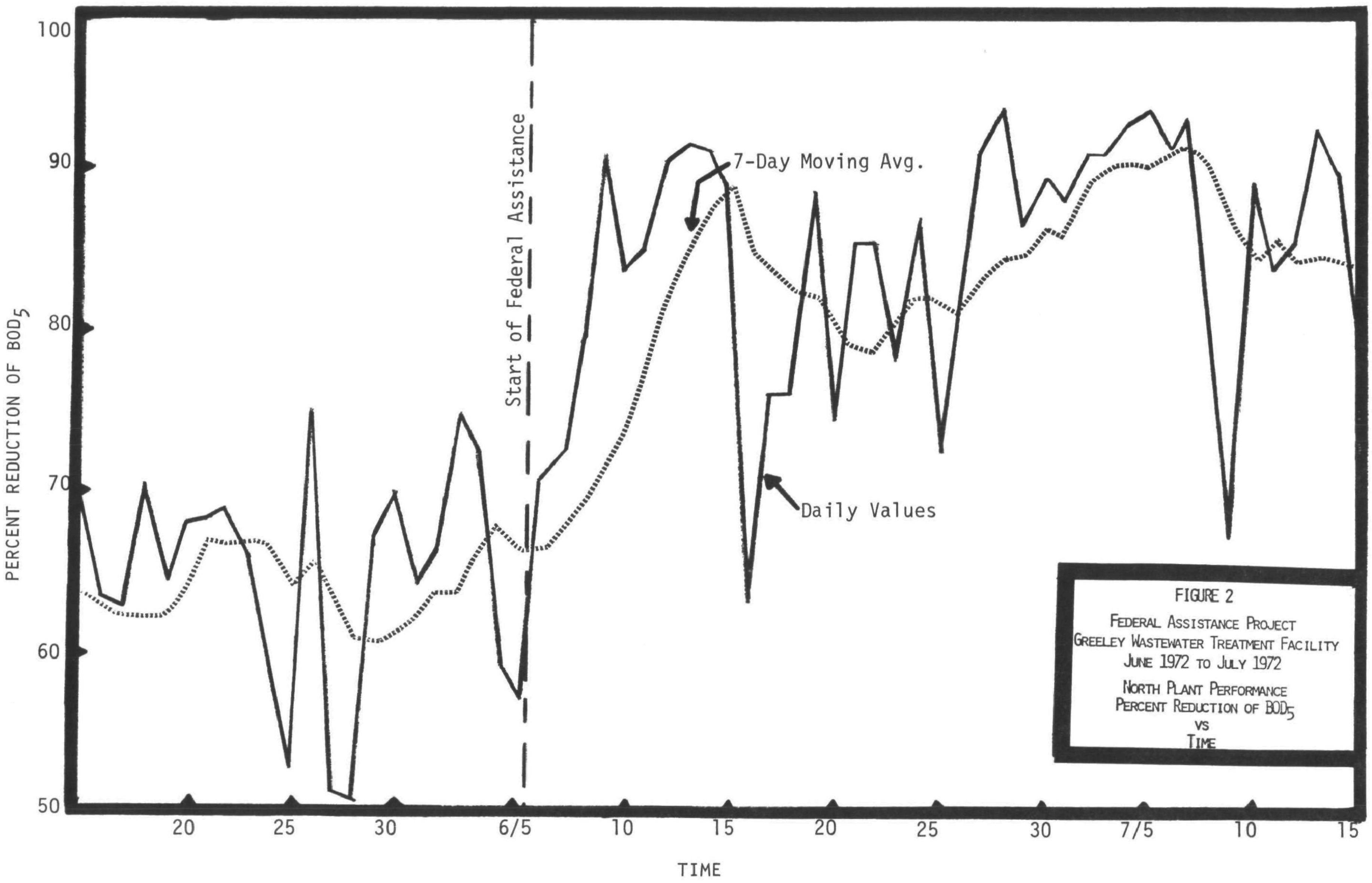

FIGURE 2

Federal Assistance Project
Greeley Wastewater Treatment Facility
June 1972 to July 1972

North Plant Performance
Percent Reduction of BOD_5
vs
Time

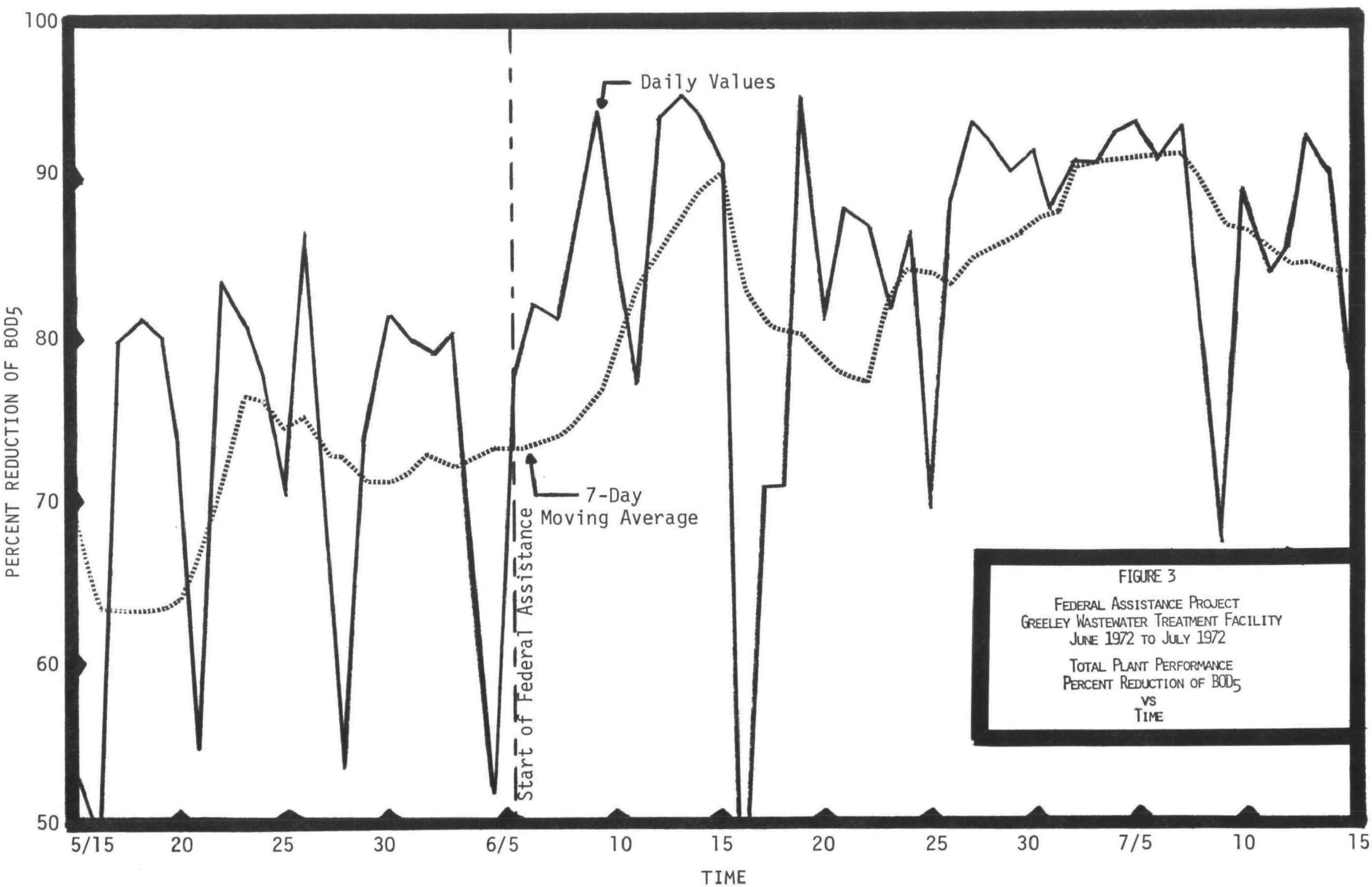

FIGURE 3

FEDERAL ASSISTANCE PROJECT
GREELEY WASTEWATER TREATMENT FACILITY
JUNE 1972 TO JULY 1972

TOTAL PLANT PERFORMANCE
PERCENT REDUCTION OF BOD_5
VS
TIME

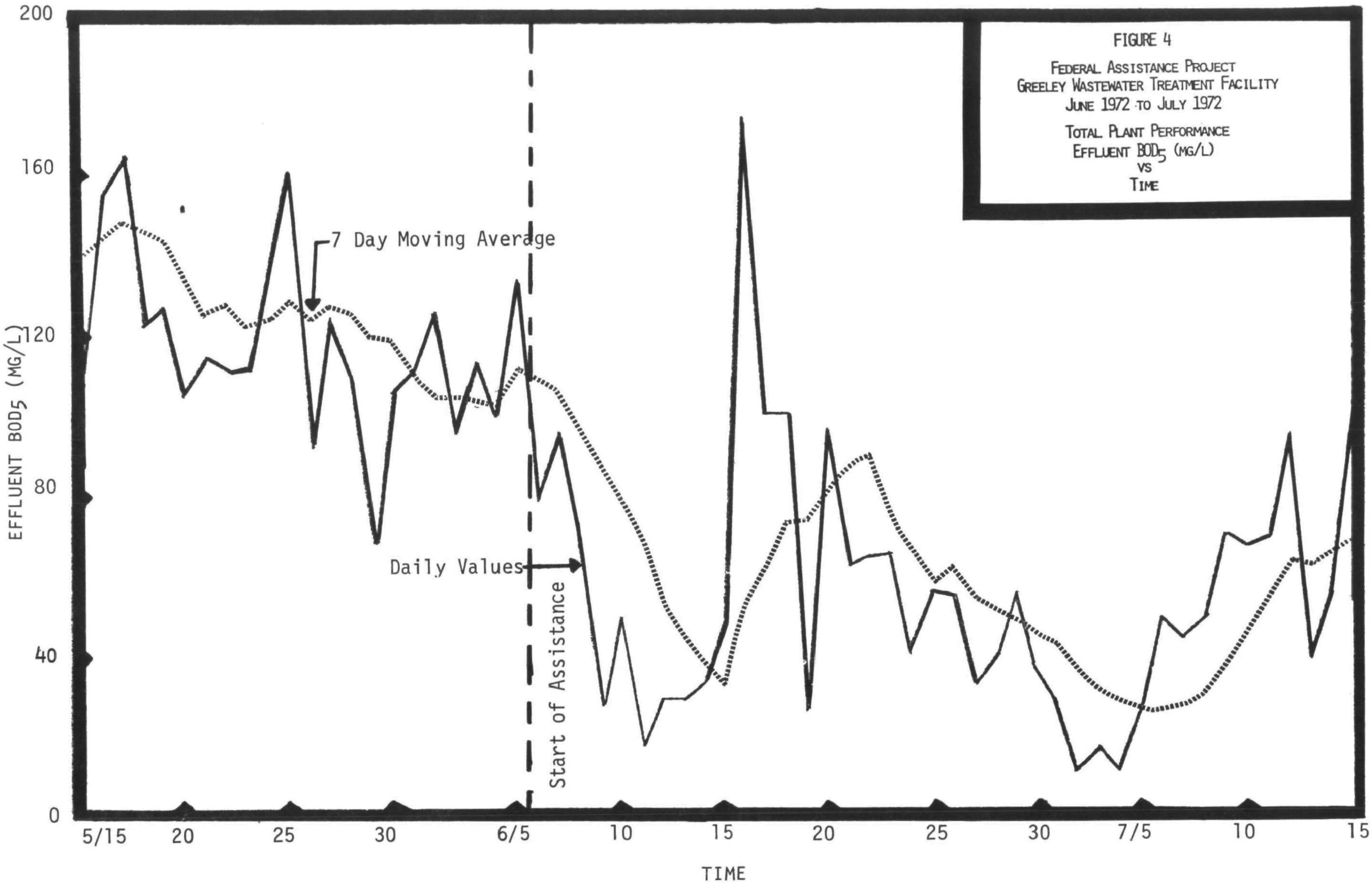

FIGURE 4
FEDERAL ASSISTANCE PROJECT
GREELEY WASTEWATER TREATMENT FACILITY
JUNE 1972 TO JULY 1972
TOTAL PLANT PERFORMANCE
EFFLUENT BOD5 (MG/L)
VS
TIME
7 Day Moving Average
Daily Values
Start of Assistance
EFFLUENT BOD5 (MG/L)
200
160
120
80
40
0
5/15
20
25
30
6/5
10
15
20
25
30
7/5
10
15
TIME

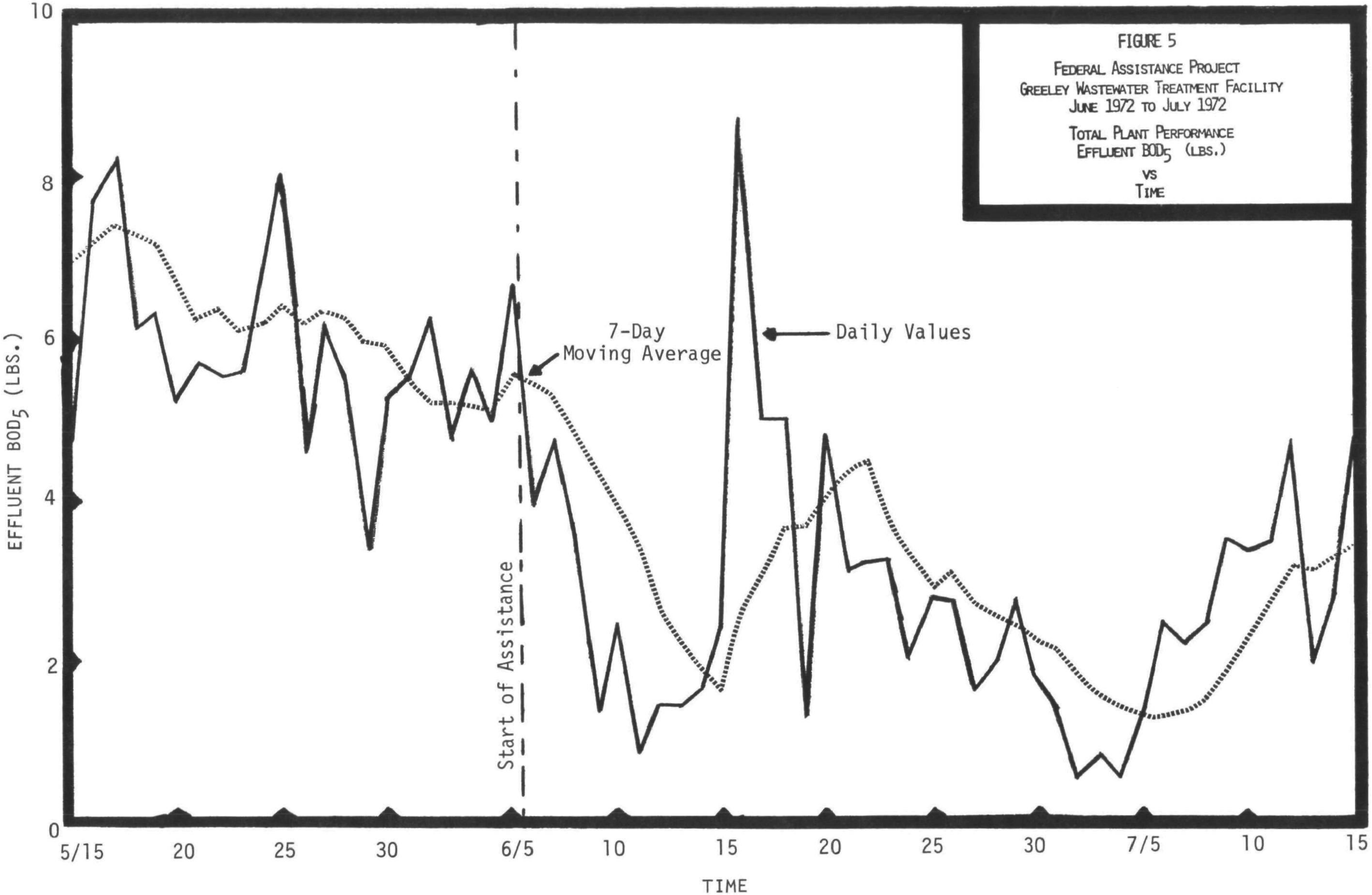
FIGURE 5
FEDERAL ASSISTANCE PROJECT
GREELEY WASTEWATER TREATMENT FACILITY
JUNE 1972 TO JULY 1972
TOTAL PLANT PERFORMANCE
EFFLUENT BOD5 (LBS.)
VS
TIME
EFFLUENT BOD5 (LBS.)
10
8
6
4
2
0
7-Day
Moving Average
Daily Values
Start of Assistance
5/15
20
25
30
6/5
10
15
20
25
30
7/5
10
15
TIME

BOD_5 in the effluent, as indicated by the seven day moving average, had decreased to between 5000 and 6000 lbs./day prior to assistance. After assistance the seven day moving average indicates a BOD_5 load in the effluent that is quite variable, but less than the effluent BOD_5 load before assistance. Data for the time period represented in Figure 5 was grouped and averaged. Prior to assistance, the average BOD_5 load discharged to the river was 6500 lbs./day. After assistance the average BOD_5 load discharged to the river was 3500 lbs./day which represents a decrease of 3000 lbs. of BOD_5 per day (population equivalent of about 15,000 people) discharged to the Cache La Poudre River.

The results outlined above indicate a definite improvement in performance of the Greeley facility. The majority of this improvement is due to the discovery of a partially opened valve which provided a cross-connection between the mixed liquor and the final effluent. Also, change of the operational mode caused an improvement in effluent quality as measured by BOD_5. Consistent effluent quality will be difficult to achieve at the Greeley plant due to the organic overload received at the plant and the plant's inability to handle sludge solids which causes sludge bulking.

V. Summary and Conclusions

Modifications to the Greeley Facility have allowed an increase in the percentage removals of BOD_5 from 40 percent in April of 1971 to the 70 percent range in April of 1972. Engineers from the Colorado State Department of Health and the Superintendent of the Greeley plant were responsible for developing the necessary modifications to improve the plant's performance. At the request of the plant Superintendent, assistance was provided by the U. S. Environmental Protection Agency. Percentage removals were increased to the 80 percent range during the course of this assistance. During certain periods, 7-day average removal efficiencies were in the 90 percent range. As a result of the improved efficiencies a reduction about 3000 lbs. of BOD per day has been removed from Greeley's effluent.

The majority of the improvement at the Greeley plant was due to the discovery of a partially opened valve which provided a cross-connection between the mixed liquor from the activated sludge plant and the final effluent. An improved operational mode for the activated sludge portion of the plant also resulted in improved effluent quality. Consistent effluent quality will be difficult to achieve at the Greeley plant due to the organic overload received at the plant and the plant's inability to handle sludge solids which causes sludge bulking or loss of solids.

Achieving optimum reduction of BOD_5 at the Greeley plant will require close control over the activated sludge portion of the facility. The plant will have to be controlled to obtain the maximum reduction of BOD_5 by assimulative and endogenous respiration and the maximum removal of solids with the present sludge handling facilities.

The majority of difficulties that presently exist at the Greeley plant should be alleviated by the addition of a new facility that is under construction. However, several areas within the plant that will continue to be used in the future should be modified or evaluated. These are:

1. Weir boxes should be placed on the return sludge ports to each aeration basin so that equal flow distribution and the resulting solids distribution can be achieved.

2. Flow control and flow measuring devices should be modified on the return sludge system so that increments of flow less than $\pm$100 gpm can be set and maintained.

3. The sludge wasting system should be a separate system to avoid the balancing problems that occur in a combined system.

4. The primary sludge pumping capabilities should be evaluated to see if they will be adequate for future needs.

VI. Recommendations

The following recommendations are made:

1. Control testing should be continued at the Greeley facility to aid in the operation of the activated sludge portion of the plant.

2. The activated sludge portion of the plant should be operated to obtain maximum solids production from the reduction of BOD_5, thus optimizing the reduction of BOD_5 as a result of cell assimulation and endogenous respiration.

3. The maximum amount of solids that can be handled by the present sludge handling system should be removed daily. This will increase solids and associated BOD_5 removals and will minimize the amount of solids that will be lost in the effluent.

4. The operational mode initiated during Federal Assistance should be continued (i.e., step loading, maximize mixed liquor concentrations, etc.).

5. Weir boxes should be placed on the return sludge ports to each aeration basin to allow for adjustment of flow distribution.

6. Return sludge flow control and measuring control should be modified to allow for the adjustments of flow less than ±100 gpm.

7. Sludge wasting (both primary and activated) should be evaluated to determine if these systems will be adequate for future needs.

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