EVALUATION

OF

INFILTRATION/INFLOW PROGRAM

FINAL REPORT

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OFFICE OF WATER PROGRAM OPERATIONS

WASHINGTON, D.C. 20460

February 1981

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CHAPTER 1

OVERVIEW

PURPOSE AND SCOPE

The Environmental Protection Agency (EPA) has been funding through Construction Grants, Sewer System Evaluations and Rehabilitation for approximately seven (7) years. The specific intent of these studies and construction is to eliminate and/or reduce Infiltration/Inflow (I/I) that would be more costly to transport and treat. In general, the I/I Program would result in rehabilitated sewers and smaller treatment plants.

EPA and others involved in the Construction Grants Program have become increasingly concerned about the extensive time required to analyze sewer systems, the costs of these analyses, the costs of rehabilitating sewers and the lack of results in eliminating and/or reducing extraneous water.

EPA has taken the initiative to evaluate on a broad base the effectiveness of Sewer System Evaluation and Rehabilitation. This report summarizes the findings of sixteen (16) months of investigative work in evaluating the I/I Program. The project has been funded by EPA Headquarters Office of Water Programs, Municipal Construction Division and is intended as an "inhouse" report.

HISTORY

Sewer System Evaluation and Rehabilitation has been an important component of the EPA Construction Grants Program, since its inception in 1972. The intent of Sewer System Evaluation and Rehabilitation was to eliminate excessive infiltration/inflow from sewer systems. This would allow for the construction of smaller wastewater treatment facilities, thereby saving millions of dollars in funds alloc by Congress for municipal pollution abatement facilities.

The procedures for conducting Sewer System Evaluation and Rehabilitation were outlined in the EPA final Construction Grant Regulations, dated February 11, 1974. EPA also published, in March 1974, Guidance for Sewer System Evaluation. This brief program outline was followed by a technical bulletin entitled, "Handbook for Sewer System Evaluation and Rehabilitation", dated December 1975. The Handbook provided detailed methodology for conducting Infiltration/Inflow Analyses and Sewer System Evaluation Surveys. In addition, information on sewer line rehabilitation and costs for performing studies and rehabilitation were presented.

During the period between 1973 and 1978, EPA received evide from field experience that certain modifications to the Sewer System Evaluation Program would be beneficial. In March 1978, EPA published the, "Construction Grants Program Requirements Memorandum 78-10". This memorandum provided a technique for rapidly screening out non-excessive I/I, a simplified scope of work for I/I investigations, and a mech anism for performing sewer testing and repair concurrently.

In addition to these documents, EPA published supplemental information relating to the Infiltration/Inflow Program as follows:

- Sewer Flow Measurement-A State-of-the-Art Assessment 1975
- Economic Analysis, Root Control and Backwater Flow Control as Related to Infiltration/Inflow-1977
- Sewer Infiltration and Inflow Control Product and Equipment Guide-1977.
- Sewer System Evaluation, Rehabilitation and New Construction-A Manual of Practice-1977.

NEED FOR STUDY

The Infiltration/Inflow Program has been controversial since first implemented. In the early years, much confusion resulted from the procedures in conducting Infiltration/Inflow Analyses and Sewer System Evaluation Surveys. The general use and longevity of chemical grout for sealing sewer line joints was questioned. Many municipalities, consulting engineers and contractors indicated that the I/I Program was a principle factor in delaying the construction of sewerage works. As time progressed and projects were completed, EPA began receiving feed-back that indicated unacceptable levels of I/I were returning after sewer line rehabilitation work was completed.

As a result of these concerns, EPA has undertaken this study to evaluate the effectiveness of the Infiltration/Inflow Program.

METHODOLOGY

Information Sources

Only sewer systems in which sewer system evaluation and rehabilitation had been completed, and had been funded through the EPA Construction Grants Program, were considered for evaluation under this study. Eighteen (18) such sewer systems were selected. Reports, field data, and Plans and Specifications were available for review. These documents and other pertinent information were gathered from the following sources:

- EPA Headquarters-Names of contacts at EPA Regional Offices and general guidance,
- EPA Regional Offices-I/I Analysis Reports, Sewer System Evaluation Survey Reports, and Plans and Specifications.
- State Offices-I/I Analysis Reports, Sewer System Evaluation Survey Reports, and Plans and Specifications.
- Municipalities-Population, plant base flow, total plant flow data, rainfall data and general information concerning the sewer system,

APPROACH TO STUDY

Screening of Candidate Projects

All EPA Regional offices were contacted and asked to provide a list of projects in that respective region that had completed Sewer System Evaluation and Rehabilitation. Those regional offices which reported candidate projects were visited and the plans and files of each potential system were reviewed. Systems in which sewer line rehabilitation had been completed, and in which rehabilitation included chemical grouting of joints, were given further consideration. During the visit, EPA files were searched for projects which had completed sewer line rehabilitation including chemical grouting of joints.

The I/I Analysis Reports for these systems were summarized to include the following:

- Consulting Engineer
- Population
- Length and Size of Sewers
- Base Flow
- Infiltration
- Inflow
- Rainfall Data
- Amount of I/I to be Removed

The SSES Reports were summarized to include the following:

- Consulting Engineer
- I/I to be Removed
- Outline of Proposed Rehabilitation

The Plans and Specifications were summarized to include the following:

- Consulting Engineer
- Outline of Rehabilitation.

TABLE 1-1

NUMBER OF PROJECTS REVIEWED

AT EPA REGIONAL OR STATE OFFICES

EPA Region	No. of Projects
III	7
IV	8
V	5
IX	2
X	4

Criteria for Project Selections

During the initial stages of this study, it was anticipat that at least one sewer system from each EPA Region would be selected and that the sewer systems would be represent tive of small, medium and large communities. However, du ing the examination of EPA files it became apparent that some Regions had no completed projects involving sewer li rehabilitation using chemical grouting of joints. Also, the distribution of projects tributary to various sizes o treatment plants was limited to small plants, with a few medium size plants.

The selection of projects for this study was, therefore, limited to the following criteria:

- Separate sanitary sewer systems,
- Sewer systems that were rehabilitated by chemical grouting of joints with possibly other forms of sewer line rehabilitation including slip lining and sewer replacement, and
- Sewer systems that reported to remove significant amounts of infiltration/inflow.

Visit Communities

Each of the selected communities were visited prior to flc monitoring. During these visits the following was accompl

- Establish a working rapport with the personnel responsible for the sewer system and/or treatment plant,
- Obtain total treatment plant flow data, to the exte practicable, before and after rehabilitation,
- Establish any changes in the sewer system that woul affect the base flow,
- Locate and observe potential key flow monitoring points.
- Determine the flow measuring technique to be used a each key flow monitoring points,
- Determine the high groundwater periods and,

- Contact the community during the high groundwater period and arrange for a visit to monitor flow at the selected monitoring points.

Monitor Flows

- Manhole Selection-The general approach to selection of flow monitoring manholes was to obtain as much flow data on rehabilitated sewer reaches as possible. The basic objective was to select an adequate number of manholes for flow monitoring that would permit a comparison of flows on a reach by reach basis before and after rehabilitation. The pre-rehabilitation flow data would be that used in the SSES Report. The manhole selection process involved the following procedure:

1. Sewer Reach Selection-Manholes were selected that would allow isolation of specific rehabilitated sewer reaches. In some instances rehabilitation on several sewer reaches was performed. In these instances, an attempt was made to select manholes that would isolate these reaches.

2. Subsystem Selection-An attempt was made to select key manholes in the sewer system that would isolate each subsystem. Included in the subsystem may be all rehabilitated sewers or a portion thereof. These key manholes provide a check on data obtained from manholes in (1) above and also delineate where the infiltration/inflow in the sewer system was located.

3. Total System-The total system flow was monitored at the treatment plant or at the nearest accessible manhole to the plant. This data provided a check on the treatment plant flow meter and a record of the diurnal flow in the entire system for the monitoring period.

Flow Measuring Technique

The flows at each selected manhole were measured by one of two techniques. First, calibrated V-notch weirs were used. The flow was allowed to stabilize upstream of the weir prior to taking a direct flow reading. Generally, two to ten minutes were needed to allow stable condition to exist. In cases where flow in a sewer surcharged the weir, measurements were taken of the depth of water in the pipe and the velocity of flow. Velocity readings were taken using a mechanical-electronic velocity meter. Flows were determined in these sewers by utilizing measured data and hydraulic elements and charts.

The flow at or just prior to the treatment plant was measured using a continuous recording depth of flow measuring device in conjunction with a flume or velocity data.

COLLECT FLOW DATA

Selected Manhole Flows

The flow monitoring for each community was conducted at a time when the groundwater was normally at its seasonal high level. This, of course, varies from year to year as a direct function of the weather conditions. Flow measurements were taken during early morning hours from 1 to 6 AM depending on the normal diurnal variation of flow to the treatment plant. The flows were measured over 1 to 3 days depending on the reliability of the data collected.

Total System Flow

A flow meter was installed at or near the treatment plant in each community. The flow was continuously recorded for a 1 to 3 day period. The data was generally correlated with the treatment plant flow meter, if possible.

Flow Data Before Rehabilitation

Total Flow and rainfall data was obtained, whenever possible, from treatment plant records. Flows for each rehabilitated sewer reach were obtained from the SSES Reports.

Flow Data After Rehabilitation

Flow data was obtained, whenever possible, from treatment plant records after rehabilitation was completed. Rainfall data was also obtained.

Analyse Data

Flow data obtained during this study was analysed to determine the quantity of I/I returning in terms of high day, high week and high month. Additional flow parameters were developed to approximate infiltration and inflow.

RE-TELEVISION INSPECTION

Project Selection

An attempt was made to schedule retelevising during high groundwater conditions in as many of the study communities as was practically possible. Retelevising was performed in twelve (12) communities. The record dry winter-spring of 1979-1980 and/or short-duration, weather dependent high groundwater conditions precluded televising six (6) communities. Two systems were retelevised twice·once at normal wet season flow and then at peak flow conditions.

Sewer Reach Selection

Approximately 1,000-4,000 feet were retelevised in each system. Rehabilitated sewer reaches were selected for re-televising based on the quantity of I/I identified during the SSES. Generally, the sewer reaches with the highest I/I were selected. In some cases, adjacent non-rehabilitated sewer sections were also televised.

Total System

Total system flow during retelevising was monitored using treatment plant flow records. These were available in all except one community, where system flow was measured at a manhole adjacent to the treatment plant.

Television Inspection Data Before Rehabilitation

Television inspection data generated during the SSES phase was secured, when available, from SSES reports, TV contractors, and consulting engineers.

ANALYSIS OF COST-EFFECTIVENESS

Cost effective analyses in the SSES Reports for the study communities were summarized to include the following:

- Estimated Rehabilitation Costs
- Cost and Transporting and Treating I/I
- Least Cost Solution

The actual rehabilitation construction costs for each community were divided by the SSES T & T unit cost ($/gpd) to obtain a (gpd) minimum system I/I flow reduction necessary to cost effectively justify the rehabilitation work. This figure was compared with actual system I/I reductions achieved, based on analysis of treatment plant flow records.

CHAPTER 2

FINDINGS

FINDING #1

THE EPA INFILTRATION/INFLOW PROGRAM WAS IMPLEMENTED TO ELIMINATE EXCESSIVE I/I - GENERALLY THIS HAS NOT BEEN ACCOMPLSIHED.

BACKGROUND

Eighteen (18) municipal sewer systems that had completed EPA Step 3 Construction Grants on sewer line rehabilitation were analyzed. Sixteen (16) of the eighteen (18) sewer systems were tributary to new and/or expanded wastewater treatment facilities. The remaining two (2) communities intended to reduce I/I flows to existing secondary treatment facilities.

The Sewer System Evaluation Survey Reports for each of the sewer systems were reviewed. The Infiltration/Inflow predicted to remain in the respective sewer systems after rehabilitation were analyzed for effectiveness by three methods:

1. Comparison of the predicted I/I to remain in the entire system with the post rehabilitation high week I/I.

   Plant flow records after sewer line rehabilitation were analyzed to determine the average daily flow for the highest seven (7) consecutive days in a calendar year. The present base flow was subtracted and the difference was considered the I/I component.

   Table 2-1 lists each of the communities, the I/I predicted to remain and the high week I/I as determined above. Also shown is the % I/I reduction predicted in the SSES versus the % reduction achieved in high week I/I flow. The results indicate that in no community was the I/I reduced to the extent predicted.

2. Comparison of the predicted I/I to remain in rehabilitated subsystems with post rehabilitation flow monitoring.

   Flow monitoring was conducted on each of the eighteen (18) sewer systems. The flow monitoring was performed during the early morning hours and during the period of the year when previous plant flow records indicated the highest flows to the treatment plants. In fourteen (14) of the eighteen (18) systems groundwater was observed, either by groundwater gages or

TABLE 2-1

SUMMARY OF SYSTEM INFILTRATION/INFLOW

Community	(1) I/I Predicted (gpd)	(2) I/I Remaining (gpd)	(3) % Reduction Predicted	(4) % Reduction Achieved
Bell Buckle, TN	158,000	280,000	71%	N/A
CMSD, NC	350,000	2,100,000	83%	Increase
Mt. Holly, PA	491,000	1,010,000	60%	23%
Castle Rock, WA	185,000	400,000	82%	60%
Centralia, WA	1,830,000	3,710,000	60%	3%
Dunsmuir, CA	71,000	449,000	99%	0%
Willits, CA	688,000	3,430,000	45%	N/A
Shelton, WA	1,360,000	2,930,000	70%	Increase
New Buffalo, MI	45,000	336,000	85%	1%
Amity, PA	116,000	742,000	85%	24%
Sussex, WI	85,000	899,000	92%	7%
Conyngham, PA	230,000	418,000	92%	17%
Mason, MI	950,000	1,340,000	52%	N/A
Salem, NH	240,000	890,000	63%	N/A
Vergennes, VT	124,000	440,000	79%	N/A
Cortland, NY	7,000,000	8,370,000	39%	Increase

Notes:
1. I/I predicted to be remaining; from SSES reports.
2. Average daily I/I flow for high week, after rehabilitation; fro analysis of treatment plant flow records.
3. % Reduction predicted; taken from SSES report.
4. % Reduction achieved in high week I/I flow; from analysis of treatment plant flow records.
5. N/A-Not Available

leaks in manholes, to be above the sewer lines. In the remaining four (4) systems it was not clearly established if groundwater was above the monitored sewer lines.

Table 2-2 lists each of the communities, the I/I predicted to be remaining in selected subsystems and I/I measured in the same subsystems during this study. The data for the "SSES Predicted" column was obtained from the corresponding SSES reports for each community and in some instances, represents 100% of the rehabilitated sewer lines, while in other instances represents a major portion of the rehabilitated sewers. The "EPA Measured" column represents, in each instance, the quantity of I/I actually measured during this study and corresponds to the same sewer sections as the "Predicted" column. Also shown is the SSES "Before Rehabilitation" flow measurement for the same sewer sections and the % reduction achieved in the system high Week I/I (from analysis of treatment plant flow records). The results indicate that in no community was the I/I reduced on a subsystem basis to the extent predicted.

3. Comparison, by television inspection of predicted I/I to remain in selected sewer reaches with post rehabilitation flows.

   Twelve (12) rehabilitated sewer systems were retelevised. Approximately 1,000 to 4,000 feet were retelevised in each system. Specific sewer reaches were selected for retelevising based on the quantity of I/I identifed during SSES. Generally, the sewer reaches with the highest I/I were selected. These sewer systems were TV inspected during the period of the year when treatment plant flows were generally at the highest levels. Table 2-3 lists each of the communities, the I/I estimated or measured during SSES-TV work, the I/I to be remaining after rehabilitation and the I/I measured or estimated during this study. Also shown is the system high week I/I % reduction achieved (from analysis of plant flow records).

   The I/I in the column labeled (1) SSES-TV was either measured or estimated from a TV screen. The measured flows were generally on sewer reaches that were tested and sealed; estimated flows were derived by observing leaking joints, manholes and running service connections and estimating these flows. In many of

TABLE 2-2

SUMMARY OF FLOW MONITORING

Community	(1) SSES Predicted (gpd)	(2) EPA Measured (gpd)	(3) SSES Before (gpd)	(4) System I/I % Reduction Achieved
Bell Buckle, TN	130,850	272,700	391,850	N/A
Grifton, NC	3,372	19,500	11,240	
Winterville, NC	5,790	25,200	19,300	Increase
Ayden, NC	16,232	165,800	54,105	
Mt. Holly, PA	491,076	645,500	1,247,208	23%
Castle Rock, WA	28,200	88,200	803,300	60%
Centralia, WA	1,522,000	3,640,000	4,352,000	3%
Dunsmuir, CA	70,510	125,000	6,712,420	0%
Willits, CA	249,000	600,500	829,000	N/A
Shelton, WA	386,100	1,378,000	1,280,200	Increase
New Buffalo, MI	32,500	121,000	216,800	1%
Amity, PA	20,000	35,000	132,000	24%
Sussex, WI	17,000	227,500	239,000	7%
Conyngham, PA	45,000	62,000	564,000	17%
Mason, MI	N/A	215,000	N/A	N/A
Salem, NH	34,000	230,000	470,000	Increase
Vergennes, VT	69,000	208,000	315,100	N/A
Cortland, NY	2,810	43,000	284,800	N/A

Notes:
1. I/I predicted to be remaining in study reaches; from SSES repo
2. Returning I/I measured under this study.
3. SSES; I/I measured or estimated before rehabilitation.
4. % reduction achieved in system I/I flow for High Week flow parameter-from analysis of plant flow records.
5. N/A- Not Available

TABLE 2-3

SUMMARY OF TELEVISION INSPECTION

Community	(1) SSES-TV Flow, gpd	(2) SSES-TV Flow, gpd	(3) Re-TV Flow (gpd)	(4) System I/I % Reductio
Bell Buckle, TN	93,500	39,500	60,500	N/A
Grifton, NC	7,870	1,900	14,500	}
Winterville, NC	6,800	2,000	6,900	} Increase
Ayden, NC	13,770	0	4,500	}
Mt. Holly Springs, PA	145,000	22,500	55,000	23%
Centralia, WA	16,500	4,000	78,400	3%
Willits, CA	15,600	4,700	21,375	N/A
Shelton, WA	101,600	20,320	100,900	Increase
New Buffalo, MI	89,100	5,700	63,675	1%
Sussex, WI	157,637	792	119,800	7%
Salem, NH	31,840	0	18,500	N/A
Cortland, NY	151,125	1,739	27,000	Increase

Notes:
1. Flow estimated or measured during SSES-TV.
2. Flow predicted to be remaining after rehabilitation
3. Flow estimated during Re-TV.
4. % Reduction achieved in system high week I/I; from analysis of plant flow records.
5. N/A-Not Available

these instances, the estimated flows were increased to match flows measured at a different period during the SSES work.

The I/I in the column labeled (2) SSES-TV represents the predicted I/I to be remaining in the same sewer reaches as column (1), after sewer line rehabilitation. In most instances chemical grouting of joints and manholes or replacement of sections of sewers was to remove 100% of the Infiltration and the remaining I/I was attributed to service connections that were not rehabilitated.

The I/I in the column labeled (3) RE-TV represents the flow in the same sewer reaches as column (1) and (2) and was estimated from joints, manholes and service connections. The flow estimates are the actual estimates observed by the same individual on all twelve (12) sewer systems.

The results indicate that in all instances I/I on a reach by reach basis has not been reduced to the extent predicted.

FINDING #2

POST-REHABILITATION INFILTRATION/INFLOW ARE EXCEEDING TREATMENT PLANT DESIGN I/I FLOW COMPONENTS.

BACKGROUND

Seventeen (17) of the eighteen (18) sewer systems studied are tributary to treatment plants that have been constructed or designed under the present Construction Grants Program. The design I/I flow component represents the non-excessive I/I, and in most cases an allowance for future additional I/I as the plant approaches its design life.

Table 2-4 lists the communities, design I/I flow component and post-rehabilitation high day, high week and high month I/I. The design I/I flow component was obtained from the actual treatment plant design criteria. The post-rehabilitation high day I/I was obtained from treatment plant flow records and is the highest daily flow recorded minus the present base flow. The high week I/I represents the average of the highest seven consecutive days flows minus the present base flow. The high month I/I represents the highest average monthly flows minus the present base flow.

TABLE 2-4

SUMMARY OF PLANT FLOW DATA

Community	Design I/I Flow (gpd)	Post Rehabilitation I/I (gpd) High Day	High Week	High Month
Bell Buckle, TN	158,000	N/A	N/A	N/A
Grifton, NC				
Winterville, NC	350,000	3,260,000	2,100,000	1,010,000
Ayden, NC				
Mt. Holly, PA	506,000	1,731,000	1,010,000	520,000
Castle Rock, WA	290,000	583,000	400,000	178,000
Centralia, WA	2,500,000	4,800,000	3,710,000	2,450,000
Dunsmuir, CA	71,000	748,000	449,000	162,000
Willits, CA	1,760,000	4,760,000	3,430,000	1,890,000
Shelton, WA	2,380,000	3,930,000	2,930,000	2,050,000
New Buffalo, MI	45,000	342,000	336,000	273,000
Amity, PA	116,000	1,050,000	742,000	470,000
Sussex, WI	72,000	1,167,000	899,000	588,000
Conyngham, PA	230,000	650,000	418,000	222,000
Mason, MI	950,000	2,584,000	1,340,000	804,000
Salem, NH	450,000	1,110,000	890,000	480,000
Vergennes, VT	239,000	>750,000	>440,000	N/A
Cortland, NY	7,000,000	9,290,000	8,370,000	7,380,000

1. N/A-Not Available

The results indicate that in all cases the high day and high week I/I flows exceed the design I/I flow component. The data further shows that the high month I/I exceeds or is almost equivalent to the design I/I.

Two additional analyses were performed in order to compare the significance of the remaining I/I.

1. Determine the rate of the remaining I/I.
   Table 2-5 lists each of the communities, the remain- I/I in terms of high week and the corresponding I/I as a rate, expressed in gallons per day per inch-mile (gpd/in-mile). The high week I/I as a rate was determined by dividing the high week I/I by the actual inch-miles of sewer pipe in the respective systems, not including service laterals. Infiltration, expressed as a rate, on newly constructed sewer lines, is generally specified not to exceed from less than 100 to 500 gpd/in-mile. EPA, in its program guidance Memorandum 78-10 specified as a rapid check on determing non-excessive I/I that infiltration, as a rate, less than 1,500 gpd/in-mile including service laterals would be considered non-excessive. Without service laterals this rate would be more like 2,000 to 2,500 gpd/in-mile.

2. Determine the remaining I/I as a percent of the present base flow.
   Table 2-6 lists each of the communities, the present base flow, the remaining high week I/I and the remaining high week I/I as a percent of the base flow. The base flow was determined by an analysis of water use data, population data and dry weather flows to the treatment plant. The remaining high week I/I was derived previously, and the remaining I/I as a percent of base flow was obtained by dividing the high week I/I by the base flow.

   Many sewer and sewerage works design handbooks suggest that 100 gallons per day per capita be used for design purposes including Infiltration/Inflow. Assuming that the per capita flow component is 70 gallons per day, thus 30 gallons per day would be attributable to I/I. This recommended I/I represents approximately 43% of the base flow. Thus, the returning I/I as a percent of base flow as shown in the Table is substantially greater for all studied sewer systems, than the recommended design figure.

TABLE 2-5

REMAINING INFILTRATION/INFLOW AS A RATE

Community	Remaining I/I High Week, gpd	Remaining I/I gpd/In-Mile
Bell Buckle, TN	N/A	N/A
Grifton, NC Winterville, NC Ayden, NC	2,100,000	5,300
Mt. Holly Springs, PA	1,010,000	10,600
Castle Rock, WA	400,000	4,300
Centralia, WA	3,710,000	9,800
Dunsmuir, CA	449,000	3,000
Willits, CA	3,430,000	21,300
Shelton, WA	2,930,000	8,900
New Buffalo, MI	336,000	4,000
Amity, PA	742,000	7,700
Sussex, WI	899,000	7,000
Conyngham, PA	418,000	6,500
Mason, MI	1,340,000	5,400
Salem, NH	890,000	2,900
Vergennes, VT	>440,000	>4,000
Cortland, NY	8,370,000	15,100

1. N/A-Not Available

TABLE 2-6

REMAINING INFILTRATION/INFLOW AS % OF BASE FLOW

Community	Base Flow, gpd	Remaining I/I High Week, gpd	Remaining I/I as % of Base Flow
Bell Buckle, TN	50,000	N/A	N/A
Grifton, NC	217,000	2,100,000	285
Winterville, NC	200,000		
Ayden, NC	320,000		
Mt. Holly Springs, PA	280,000	1,010,000	360
Castle Rock, WA	212,000	400,000	189
Centralia, WA	1,000,000	3,710,000	371
Dunsmuir, CA	192,000	449,000	234
Willits, CA	425,000	3,430,000	807
Shelton, WA	1,250,000	2,930,000	234
New Buffalo, MI	200,000	336,000	168
Amity, PA	150,000	742,000	495
Sussex, WI	250,000	899,000	360
Conyngham, PA	125,000	418,000	334
Mason, MI	550,000	1,340,000	244
Salem, NH	850,000	890,000	105
Vergennes, VT	400,000	>440,000	>110
Cortland, NY	3,000,000	8,370,000	279

1. N/A-Not Available

FINDING #3

HOUSE SERVICE CONNECTIONS AND NON-REHABILITATED PIPE JOI[N]
ARE THE MAJOR SOURCES OF RETURNING I/I FROM REHABILITATE[D]
SEWER REACHES.

Background

Table 2-7 lists the communities, the source breakdown of sewer joints, service connections and manholes during the SSES-TV work and the source breakdown of sewer joints, se[r]vice connections and manholes from re-televising the same sewers during this study. The SSES-TV column, when only one number is shown, represents a measured flow from sewer reaches. In all other instances, the number of joi[nts,] service connections and/or manholes precede the flow.

Table 2-8 shows the totals of Table 2-7 where direct comparisons can be made. Not included in the table were flo[ws] that were measured during test and sealing because no usa[ble] documentation was available.

The results indicate that flow and/or number of leaks ide[ntified] as coming from pipe line joints were generally reduced as [a] result of chemical grouting or pipe line replacement. Tel[e]vision inspection during this study revealed that chemical grouting of joints was generally successful in sealing out groundwater, and most of the remaining infiltration was entering through joints that were not grouted.

The overall television inspection results indicate that pi[pe] line joint leaks were reduced in number and in flow; service connection flows increased in number and in flow and manhole leaks decreased in number yet increased in flow. House service connections are contributing the largest amounts of returning I/I, followed by pipe line joints tha[t] were not rehabilitated.

FINDING #4

REMOVAL OF EXCESSIVE INFLOW WAS APPARENTLY NOT ANY MORE SUCCESSFUL THAN INFILTRATION REMOVAL.

BACKGROUND

Table 2-9 lists each community, the inflow predicted to remain and the inflow remaining after rehabilitation. The inflow predicted to remain was obtained from the SSES repo[rt]

TABLE 2-7

SUMMARY OF TELEVISION INSPECTION

SOURCE IDENTIFICATION

SSES-TV No. - gpd			Re-TV No. - gpd		
Joints	Service Connections	Manholes	Joints	Service Connections	Manholes
93,500	Flow Gaged	0	12-34,500	6-25,500	1- 500
20- 4,600	7- 2,910	1- 300	4- 6,800	5- 7,700	0
9- 4,800	6- 2,000	0	4- 2,300	4- 4,600	0
21- 6,570	2- 4,500	2- 2,700	8- 4,500	0- 0	0
145,000	(None)	0	8-50,000	0- 0	1- 5,000
11- 8,600	13- 5,900	2- 2,000	60-45,700	39-32,700	0
15,600	Flow Gaged		1- 1,500	13-19,875	0
101,600	Flow Gaged		91-42,800	40-55,100	2- 3,000
97- 47,250	25-33,600	11- 8,250	40-11,775	45-51,150	1- 750
20- 57,456	25-88,704	2-11,477	10-23,000	11-66,800	2-30,000
6- 6,000	20-20,000	3- 1,800	4- 3,800	10-12,450	1- 2,250
62-132,405	4-18,720	0	2-3,000	12-12,000	1-12,000

TABLE 2-8

SUMMARY OF TELEVISION INSPECTION TOTALS

Joints No. - gpd		Services No. - gpd		Manho: No. -
Before	After	Before	After	Before
246-267,681	132-100,875	102-176,334	126-187,400	21-26,527

TABLE 2-9

INFLOW SUMMARY

Community	SSES-Inflow Predicted, gpd	Inflow Remaining, gpd
Bell Buckle, TN	18,000	N/A
Grifton, NC	12,000	
Winterville, NC	13,000	1,160,000 (Grifton, Winterville, Ayden combined)
Ayden, NC	40,000	
Mt. Holly, PA	16,000	721,000
Castle Rock, WA	62,000	183,000
Centralia, WA	500,000	1,090,000
Dunsmuir, CA	0	299,000
Willits, CA	150,000	1,350,000
Shelton, WA	100,000	1,000,000
New Buffalo, MA	9,000	6,000
Amity, PA	68,000	308,000
Sussex, WI	15,000	268,000
Conyngham, PA	185,000	232,000
Mason, MI	<950,000	1,244,000
Salem, NH	100,000	220,000
Vergennes, VT	<124,000	310,000
Cortland, NY	200,000	920,000

1. N/A-Not Available

TABLE 2-10

COMPARISON OF TELEVISION INSPECTION

DURING DIFFERENT GROUNDWATER CONDITIONS

Community	(1) Joints No-gpd	Services No-gpd	(2) Joints No-gpd	Services No-gpd
A	1- 800	1- 200	33-31,300	4- 1,900
B	23-2,600	15-5,000	91-42,800	40-55,100

1. System I/I Rate at: 2,600 in Community A
   2,300 in Community B

2. System I/I Rate at: 10,500 in Community A
   10,000 in Community B

TABLE 2-11

SUMMARY OF COST EFFECTIVENESS ANALYSES

Community	(1) T & T $/gpd	(2) Construction Cost, $	(3) (2) ÷ (1) gpd	(4) SSES Predicted Reduction
Bell Buckle, TN	1.31	69,731	53,000	390,000
Grifton, NC; Winterville, NC; Ayden, NC	3.04	351,034	115,000	1,730,000
Mt. Holly, PA	1.35	45,378	34,000	750,000
Castle Rock, WA	2.00	125,994	63,000	817,000
Centralia, WA	0.67	459,000	685,000	2,770,000
Shelton, WA	2.63	180,844	69,000	3,150,000
Dunsmuir, CA	1.50	673,000	448,000	7,829,000
Willits, CA	3.30	505,040	153,000	562,000
New Buffalo, MI	2.20	62,523	28,000	255,000
Sussex, WI	1.10	281,500	256,000	919,000
Amity, PA	2.60	145,958	56,000	654,000
Conyngham, PA	1.27	580,000	457,000	2,649,000
Mason, MI	0.50	721,000	1,442,000	1,550,000
Cortland, NY	0.85	869,000	1,022,000	4,500,000
Vergennes, VT	2.50	700,000	280,000	460,000
Salem, NH	1.36	57,113	42,000	410,000

1. N/A-Not Available

The inflow remaining is a calculated value. The value was derived by subtracting the average daily flow for the high week I/I from the high day I/I flow.

The derivation of the remaining inflow as described above is the only rational method that would provide a reasonable value. The methods utilized to determine inflow in all the SSES reports reviewed during this study, were based on estimates. Methods used for estimating inflow included calculating inflow to catch basins based on the area tributary to each source, estimating inflow entering holes in manhole covers, estimating inflow from illegal connections as a result of smoke testing and estimating inflow from illegal connections as a result of dye water flooding.

The methods used to estimate inflow during the SSES work were inexact and the method used to calculate inflow during this study may be questionable. Thus, it is scientifically unsound to state that inflow removal on the eighteen (18) sewer systems that were studied was or was not effective. What can be stated and documented is that in all cases, during high intensity rainfalls, that flows to the treatment plants increase dramatically in relatively short times. Thus, wet weather flows are present and at rates substantially greater than predicted to remain after rehabilitation.

More inflow than infiltration was quantified in six (6) of the eighteen (18) communities. Of these six (6) communities, calculated inflow from public inflow sources documented during SSES rainfall simulation accounted for a majority of the inflow in only three (3) communities. High day and high week flows from these three communities, which comprise one metropolitan sewer district, did not decrease after rehabilitation.

FINDING #5

THE MAJOR ELEMENTS OF THE I/I METHODOLOGY ARE IMPRECISE.

BACKGROUND

The pitfalls that have prevented successful completion of eliminating excessive I/I are as follows:

1. Flow measurements and estimates for determining I/I during the I/I Analysis and SSES work can give misleading results.

Flow gaging techniques utilized during the conduct of the above studies often are inaccurate. A host of problems are inherent in sewer systems that may result in errors up to 200% in flow determinations. These include grit and debris in sewers that affect depth of flow, cross-sectional areas of flow and velocity determinations.

Measurement of sewer flows during early morning hours is considered the best time to establish I/I flows. Caution must be taken when relying on these flow data to determine I/I. Normal domestic wastewater could be present if there is a long lag time in the sewers; especially in larger sewer systems. Thus, all the measured flow may not be I/I.

Intermittent sources that discharge to the sewers could affect flow measurements. These could include pump stations and house sump pumps.

2. Flow estimates made during television inspection can give erroneous results.

   The EPA publication, "Sewer System Evaluation Rehabilitation and New Construction", - a Manual of Practice, dated December 1977 states, "Estimates within 50% represents a handle on infiltration point quantification which can be used to establish the desirability of rehabilitation". Experience during the conduct of this study indicates that flow estimates made at point sources from a TV screen can vary by at least a factor of four.

   Television inspection work is not always performed during the high groundwater periods. Complete erroneous data will be generated if this is done. During the conduct of this study two (2) communities were televised at two different periods during what is normally considered the high groundwater period. Table 2-10 summarizes the results during these different conditions. There was a substantial difference in the number of I/I sources and flow.

3. Normalizing or pro-rating measured or estimated flows to a peak or design condition can result in erroneous data.

4. Flow measurements or estimates made during the I/I Analysis and SSES work could be dramatically different if performed in a different year as a result of changes in wet weather conditions.

5. The estimated I/I reductions made during SSES work are not realistic. They generally range from 70 to 100% and in reality achieve 0 to say 40% reductions.

6. During SSES work, the transport and treatment costs utilized in the cost effectiveness analyses are generally rough estimates.

7. Cost effectiveness analyses performed during SSES work is of questionable value, due to the imprecision that exists in quantifying the cost effective elements.

Table 2-11 Summary of Cost Effectiveness Analysis lists the following information:

- Column (1) lists the Transport and Treatment (T & T) cost per gallons per day for I/I. These costs were obtained from SSES reports and are cost estimates.

- Column (2) lists the actual rehabilitation construction costs for each project.

- Column (3) represents the gallons per day of I/I that had to be removed based on the T & T cost and actual construction costs on a direct relationship basis.

- Column (4) lists the I/I predicted to be removed as obtained from the SSES reports. These data are estimated predictions.

- Column (5) lists the high week I/I that was reduced. These data were obtained from plant flow records when available.

The data presented in this Table indicate that, in all cases, the predicted I/I reductions were not achieved. Using the "predicted" I/I it can be said that none of the cases proved cost effective. Another way of analyzing the data would be to compare Column (3) with Column (5). This comparison reveals that of the eleven (11) cases with available data, eight (8) cases were not cost effective, and three (3) cases were cost effective.

In summary, the cost effectiveness analysis utilizes estimated T & T cost, estimated I/I quantification and estimated percent I/I reductions after rehabilitation. The results can only provide ambiguous results as Table 2-11 shows.

ADDITIONAL FINDINGS

THE EXCEPTION

- Documented system I/I reductions achieved in one stu community were significantly higher than reductions achieved in any of the other study communities. Thi project was distinguished chiefly by its high % of leaking joints (versus I/I from services) documented during televising, and its high % of the system to b rehabilitated. Also, a high % of the joints took grout, and the relatively few leaking services were repaired or replaced. (See Table 2-12).

SSES DETERMINATIONS ON I/I FROM PRIVATE SOURCES

- Private inflow sources were noted as a "substantial" problem in one study community, "undetermined" in two communities, and "minor" in four communities. Only one study community undertook a thorough home plumbing inspection/illegal I/I source disconnection program. A large number of sump pumps were disconnected (fall 1979), but unusually low groundwater co ditions this spring prohibited any determination of peak flow reduction attributable to the disconnectio program.

- Infiltration from service lateral sewers was specific quantified as a non-removable % of the system infiltration (varing from 15% to 30%) in 4 communities. Replacement of service laterals on private property, at community expense, was done in 3 communities.

LEAKING SERVICE CONNECTIONS

- Services leaking at the connection to the main sewer were identified as significant sources of I/I in 6 communities. Except for communities that did major amounts of replacement or slip-lining (which includes service connection replacement), the highest rate of service connection repair done in the study communiti was 8% of the services in the system (See Table 2-12)

JOINTS REQUIRING GROUTING

- Available test and seal records for the study communities showed that the % of joints to require grouting (that is, the % of joints that failed the air test), varied widely; from over 90% to under 4%. (See Table 2-12).

CHAPTER 3

SUMMARY OF FINDINGS

PLANT FLOW RECORD ANALYSIS

The expectations of the I/I Program to eliminate excessive I/I were not achieved in any of the sewer systems evaluated during this study. The upper portions of Figures 3-1 to 3-16 graphically display the following information on the systems included in this study.

- The I/I before and after rehabilitation as presented in the SSES reports,
- The high day I/I, before and after rehabilitation, obtained from the plant flow records, when available,
- The average daily flow for the high week I/I, before and after rehabilitation, obtained from the plant flow records, when available, and
- The average daily flow for the high month I/I, before and after rehabilitation, from plant records, when available.

SSES before and after figures for infiltration and inflow are summarized in Table 3-1.

These data illustrate that the I/I reductions predicted versus that attained were seriously misjudged.

INFILTRATION/INFLOW DESIGN COMPONENT

The treatment plants encountered in this study were designed to accommodate non-excessive I/I. Thus, a specific I/I design flow was used. The findings of this study indicate that in all cases, the design I/I flow component has been exceeded by returning I/I.

HOUSE SERVICE CONNECTIONS AND NON-REHABILITATED SEWER JOINTS

Television inspection of rehabilitated sewer lines was performed during this study. The lower left portions of Figures 3-1 through 3-16 compares the pre and post rehabilitation flows and sources. The data indicate that in all cases post rehabilitation flows exceed that predicted to remain. House service connections and non-rehabilitated joints are the major sources of returning I/I.

PERCENT OF COLLECTION SYSTEM REHABILITATED

- The percent of sewers in the study communities that was rehabilitated varied widely; from 6% to 70%. (See Table 2-13).

SSES TV DOCUMENTATION OF I/I

- TV leakage documented during SSES televising reasonably accounted for measured I/I flows in only four of the 18 study communities.

- The % of I/I coming from main barrel leaks (versus I/I from services) varied from a high of 93% to a low of 20% (See Table 2-12).

- SSES TV flow estimates were used directly in the cost-effective analysis in 5 communities.

I/I RETURNING VIA NON-REHABILITATED JOINTS

- Retelevising during this study found I/I returning through non-rehabilitated joints (that had passed the air test during test and seal) to be a significant source of returning I/I (see Table 2-7).

- The joint immediately adjacent to a service connection cannot be tested or sealed internally - a heavy concentration of leaking joints adjacent to services was observed in only one of the communities retelevised under this study.

TELEVISING UNDER THIS STUDY OF NON-REHABILITATED REACHES

- Televising during this study of a total of 3,761' of selected non-rehabilitated sewers adjacent to rehabilitated sewers found a total of 78 main barrel leaks (32,775 gpd TOTAL) and 36 leaking services (49,700 gpd TOTAL).

AM9 VERSUS 3M GROUTING

- AM9 was used in all of the study communities except one. Retelevising under this study found joints grouted with AM9 to be generally sound. In the one 3M community, what leaking joints were found (10 joints leaking a total of 28,500 gpd in 2,092' of

TABLE 2-13

REHABILITATION TECHNIQUES

Community	(1) Ft. of Sewers	% SYSTEM REHABILITATED Grout	Replace	Line	Total
Bell Buckle, TN	18,400	63%	2%	-	65%
Grifton, NC	40,000	10%	-	-	10%
Winterville, NC	61,500	13%	-	-	13%
Ayden, NC	107,000	26%	2%	-	28%
Mt. Holly, PA	50,500	38%	-	-	38%
Castle Rock, WA	50,000	69%	1%	-	70%
Centralia, WA	200,000	36%	-	-	36%
Dunsmuir, CA	80,000	4%	33%	2%	39%
Willits, CA	85,000	22%	3%	34%	59%
Shelton, WA	173,000	15%	-	1%	16%
New Buffalo, MA	44,500	20%	-	-	20%
Amity, PA	51,000	10%	2%	-	12%
Sussex, WI	68,000	7%	4%	-	11%
Conyngham, PA	34,000	23%	44%	-	67%
Mason, MI	130,000	11%	12%	-	23%
Vergennes, VT	59,000	4%	33%	1%	38%
Salem, NH	160,000	19%	-	-	19%
Cortland, NY	293,000	1%	4%	1%	6%

Notes: (1) Not including service laterals.

retelevised test and seal sewers) were either at or near joints that had been grouted, footage differences between the test and seal logs and the EPA TV logs made positive identification difficult.

TEST AND SEAL QUALITY CONTROL

- As stated throughout this report, retelevising found grouted joints to be generally sound. In one community, a large number of leaking joints (91 joints leaking a total of 42,800 gpd in 2,733' of retelevised test and seal sewers) were found; no footage logs showing which joints had been grouted were available. In another community, one heavily leaking reach (26 joints leaking a total of 26,300 gpd in 302' of retelevised 12" test and seal sewer) was attributed to an equipment problem or operator error during the grouting operation.

MANHOLE REHABILITATION

- Manhole infiltration and/or inflow was quantified in the study community SSES reports at an average of 6.3% of the system I/I. The maximum SSES manhole I/I was 14% of the system I/I.

- Based on manholes observed in retelevising areas, chemical grouting appears to be an effective rehabilitation measure. Repair by cement grouting appears to be not as effective.

FREQUENCY OF PEAK FLOWS

- Analysis of before and after rehabilitation plant flow records for flow "spikes" found a wide range of peak flow frequencies in the 18 study communities.

- "Sharp" spikes associated with rainstorms were found in 8 communities. The annual frequency of rainfall associated "sharp" spikes exceeding twice the study community's base flow ranged from 3-6 per year to about 15. These spikes were generally associated with daily rainfall totals exceeding 1 inch.

- Peaks that rose and fell gradually with rainstorms were found in 3 communities.

- Peaks primarily associated with snowmelt were found in 5 communities.

- Peak flows in 1 community were more responsive to t rise and fall of a nearby river than directly with rainfall.

REHABILITATION

- There is a possibility that the replacement or rehal ilitation of old, leaky trunk sewers may actually i crease peak flows, by eliminating exfiltration durir surcharged conditions and loss of dampening via bach up sewers. In one study community, a large amount c undersized, heavily leaking trunk sewers was replace in 1976. A 40% reduction of system I/I was expected but high week I/I increased.

REDUCTION OF LONG-TERM I/I

- Based on analysis of plant flow records, % reduction achieved in long-term system I/I flow parameters (Hi 6-Months, Annual Average) were not significantly dif ferent from % reductions achieved in short term syst I/I flow parameters (High Day, High Week, High Month) See Table 2-14.

TABLE 2-14

% REDUCTION OF SYSTEM I/I FLOWS

FOR SELECTED FLOW PARAMETERS(1)

Community	High Day	High Week	High Month	High 6 Months	Annual
Bell Buckle, TN	N/A	N/A	N/A	N/A	N/A
CMSD,NC	Increase	Increase	28%	N/A	N/A
Mt. Holly, PA	N/A	23%	37%	30%	16%
Castle Rock, WA	51%	60%	N/A	N/A	N/A
Centralia, WA	Increase	3%	23%	9%	Incr
Shelton, WA	Increase	Increase	Increase	Increase	Incr
Dunsmuir, CA	1%	0%	19%	50%	50%
Willits, CA	N/A	N/A	N/A	N/A	N/A
New Buffalo, MA	2%	1%	Increase	3%	10%
Sussex, WI	Increase	7%	7%	14%	1%
Amity, PA	42%	24%	33%	N/A	N/A
Mason, MA	N/A	N/A	N/A	N/A	N/A
Cortland, NY	1%	Increase	Increase	1%	4%
Vergennes, VT	N/A	N/A	N/A	N/A	N/A
Salem, NH	N/A	N/A	N/A	N/A	N/A
Conyngham, PA	28%	17%	22%	25%	12%

Notes: (1) From analysis of available plant flow records before and rehabilitation, through March 1980.

(2) N/A-Not Applicable

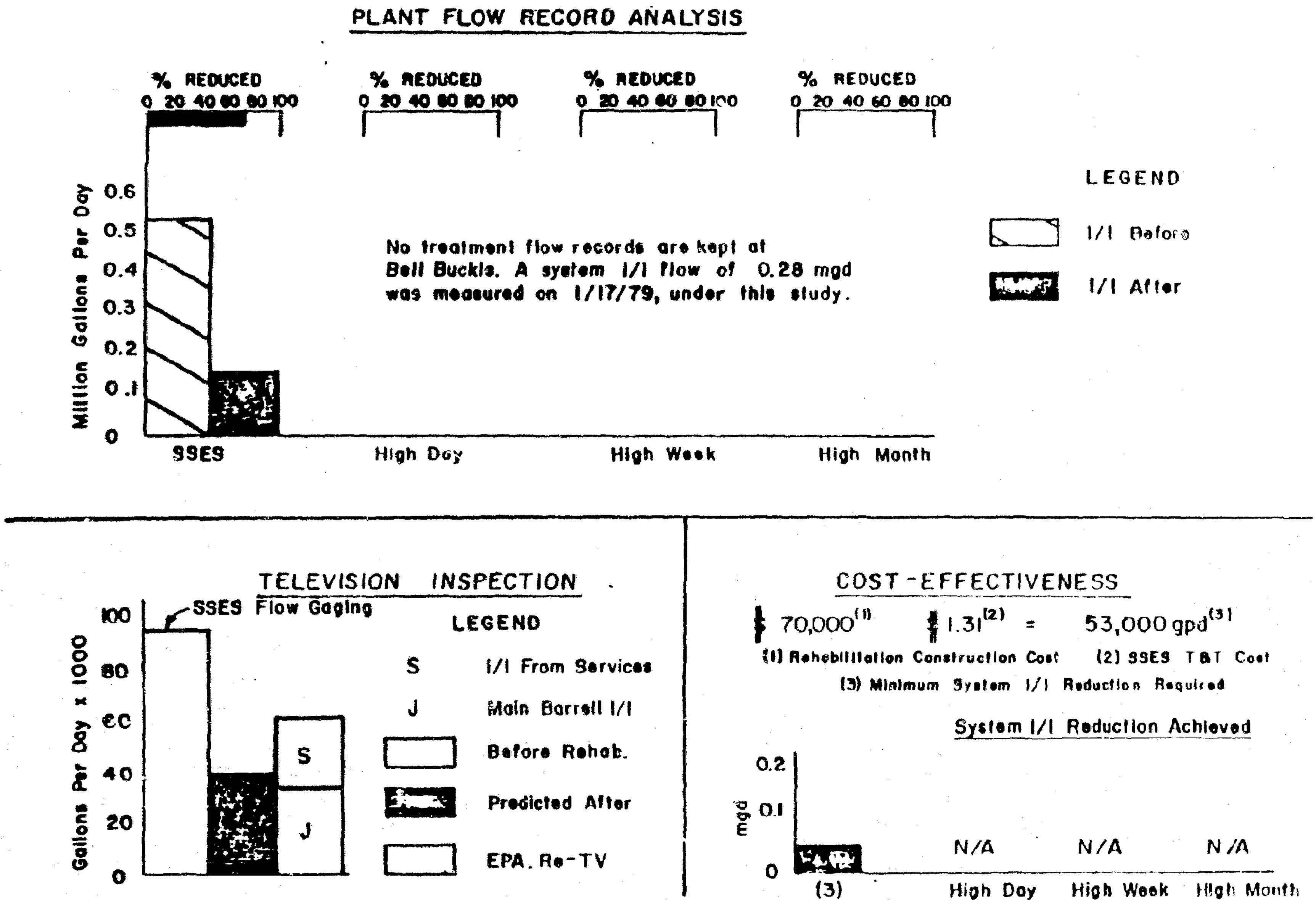


FIGURE 3-1: INFILTRATION/INFLOW DATA; BELL BUCKLE, TENNESSEE

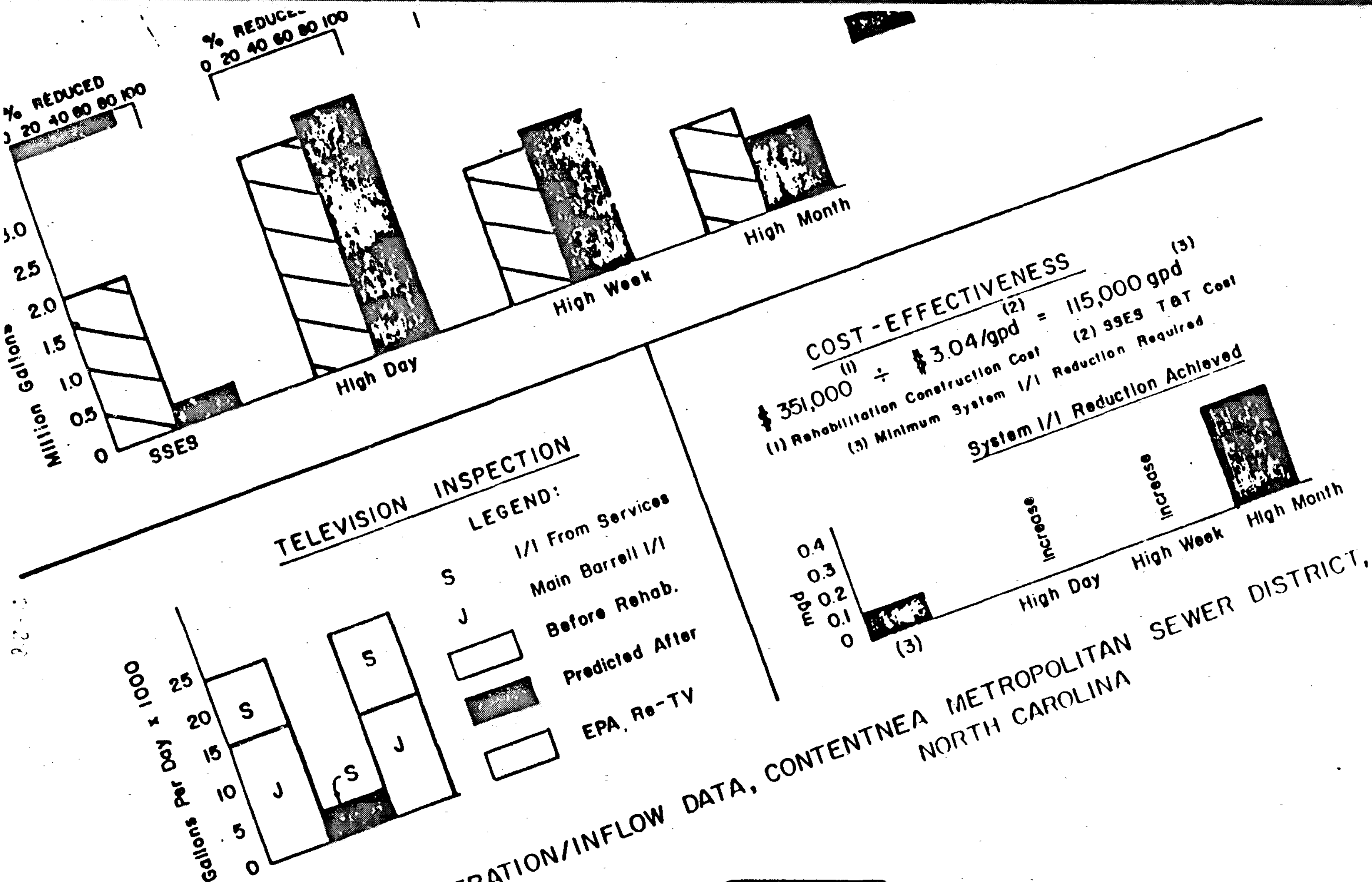
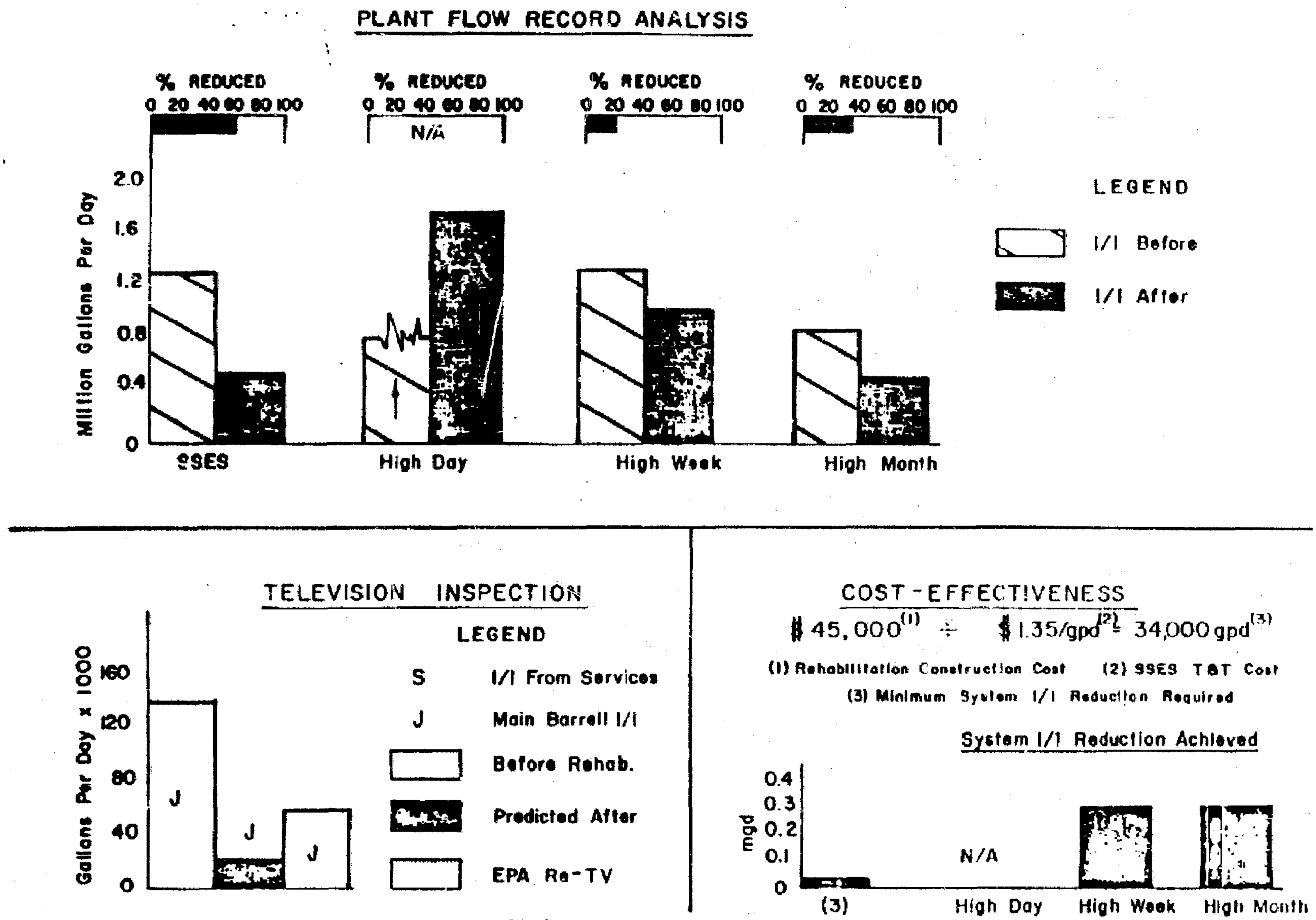


FIGURE 3-2: INFILTRATION/INFLOW DATA, CONTENTNEA METROPOLITAN SEWER DISTRICT, NORTH CAROLINA



NOTE: This TV data is from one heavily-leaking 170-foot section of cross-country sewer.

FIGURE 3-3: INFILTRATION/INFLOW DATA, MT. HOLLY SPRINGS, PENNSYLVANIA

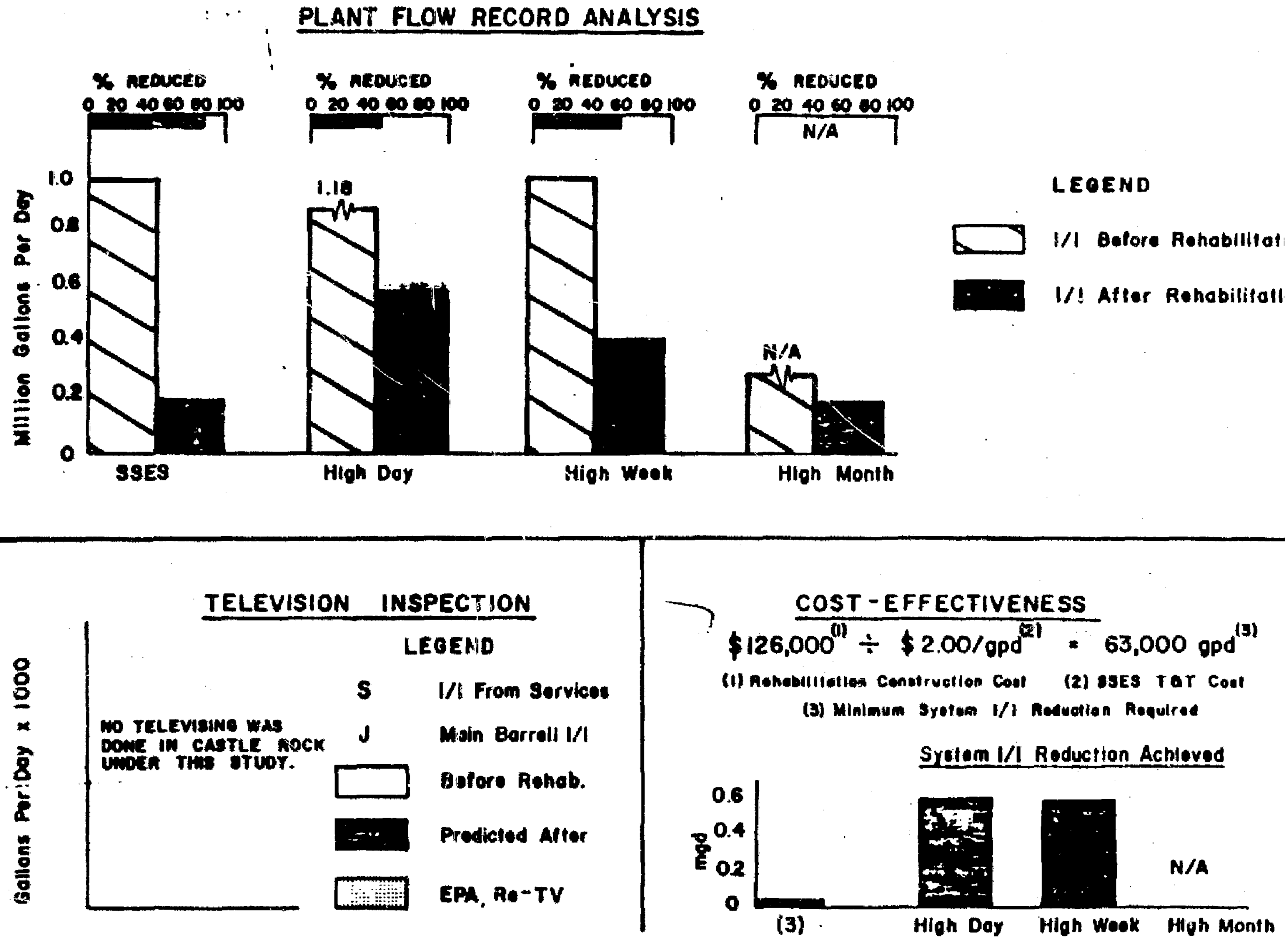


FIGURE 3-4: INFILTRATION/INFLOW DATA, CASTLE ROCK, WASHINGTON

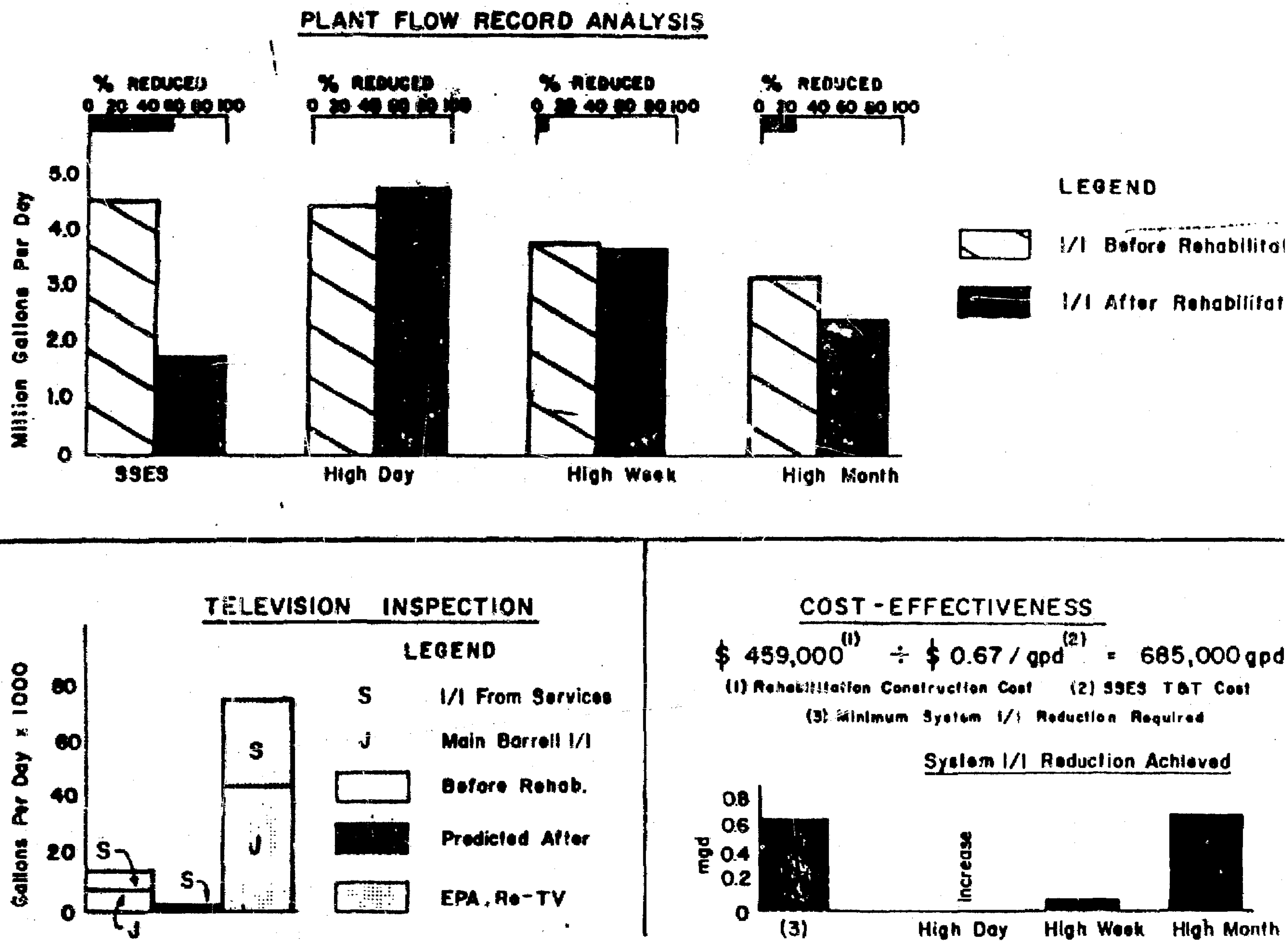


FIGURE 3-5: INFILTRATION/INFLOW DATA, CENTRALIA, WASHINGTON

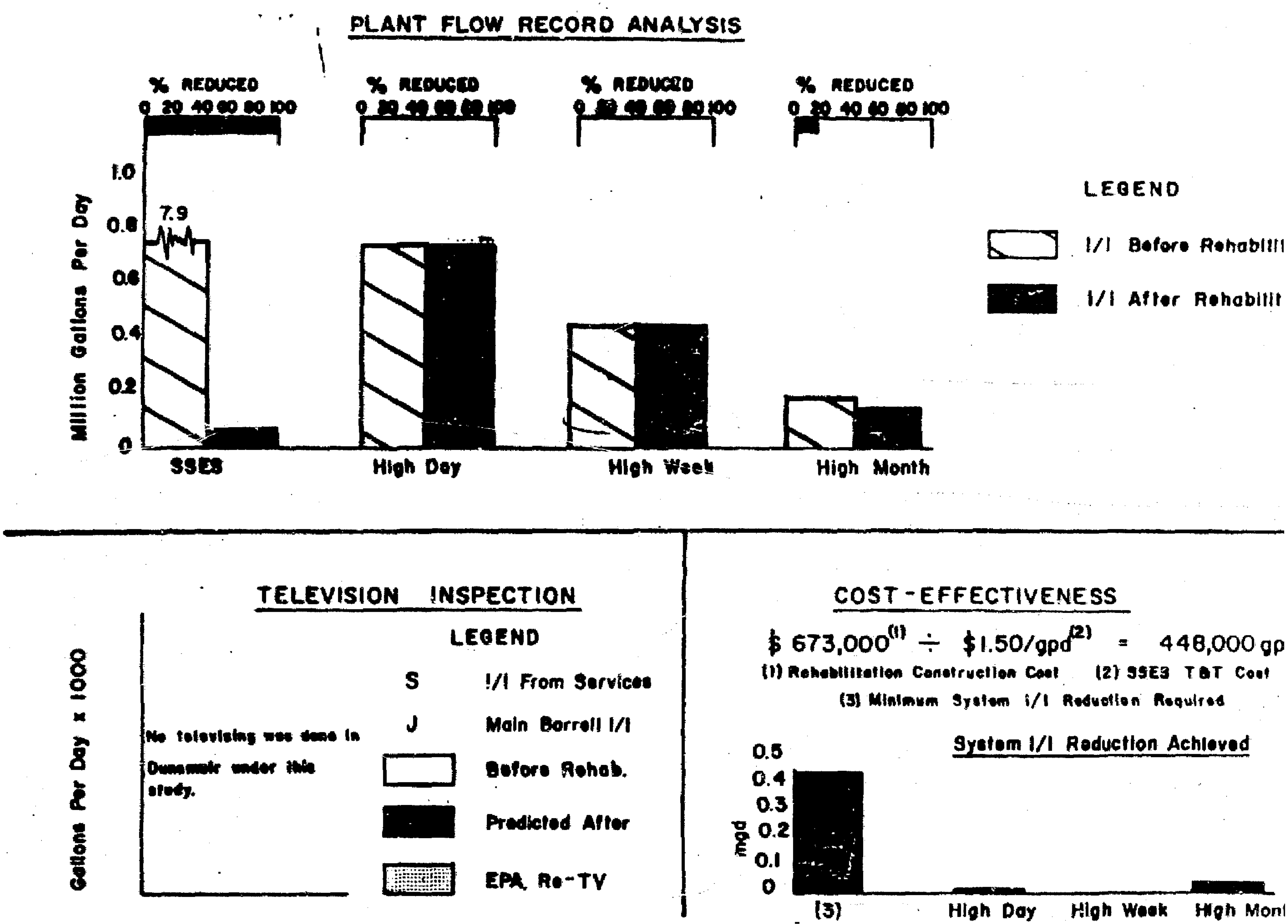


FIGURE 3-6: INFILTRATION/INFLOW DATA, DUNSMUIR, CALIFORNIA

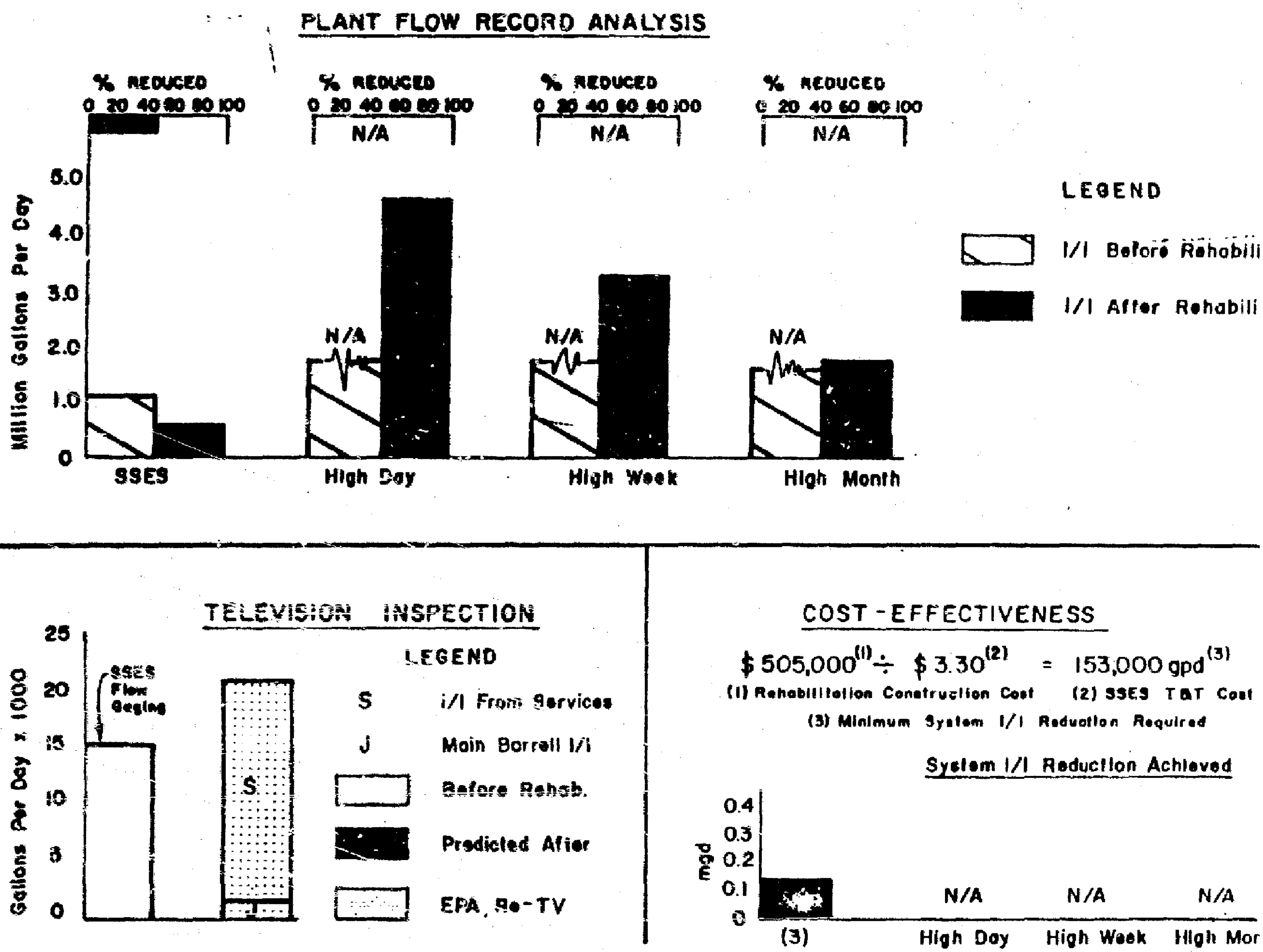


FIGURE 3-7: INFILTRATION/INFLOW DATA, WILLITS, CALIFORNIA

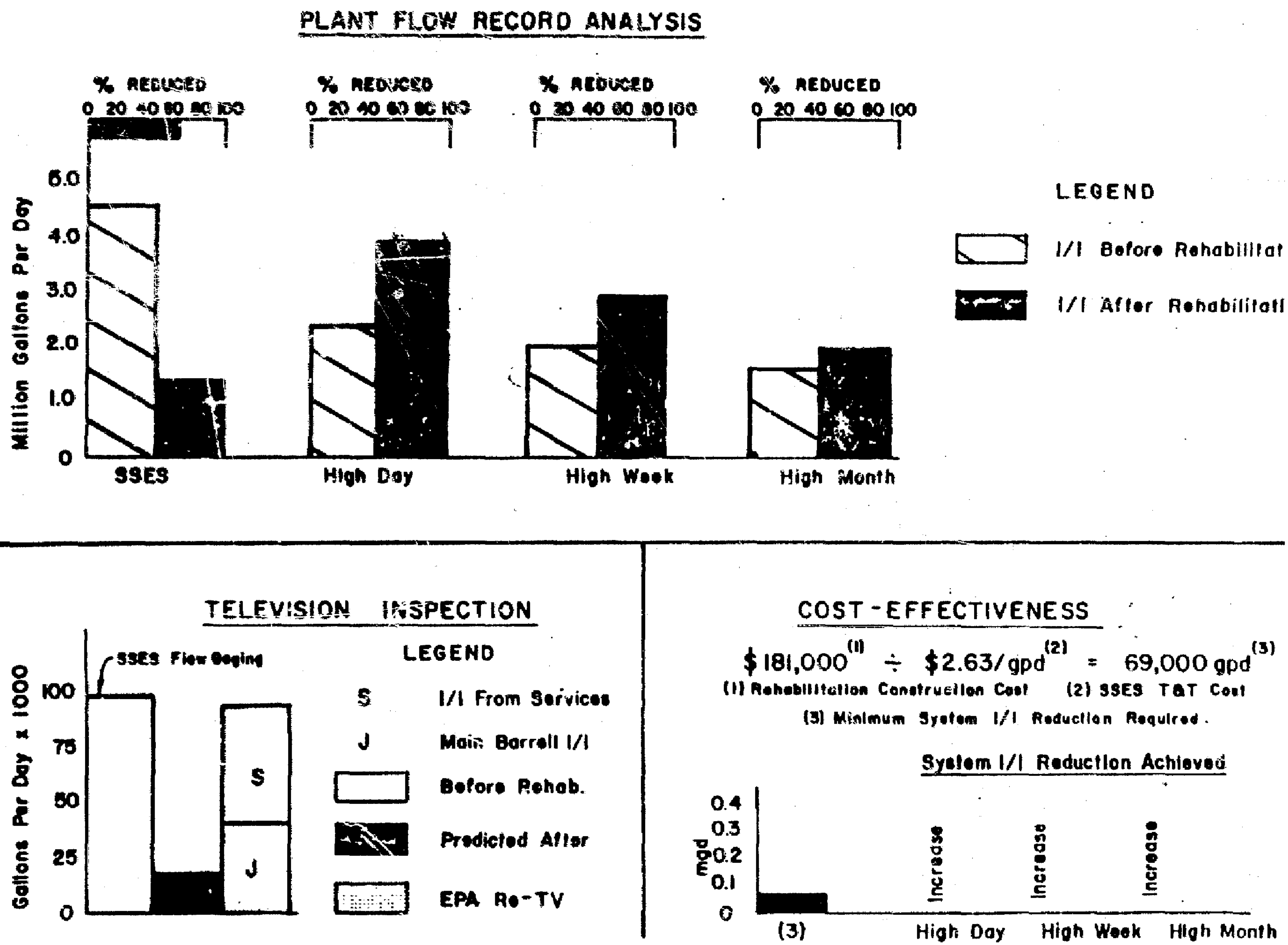


FIGURE 3-8: INFILTRATION/INFLOW DATA, SHELTON, WASHINGTON

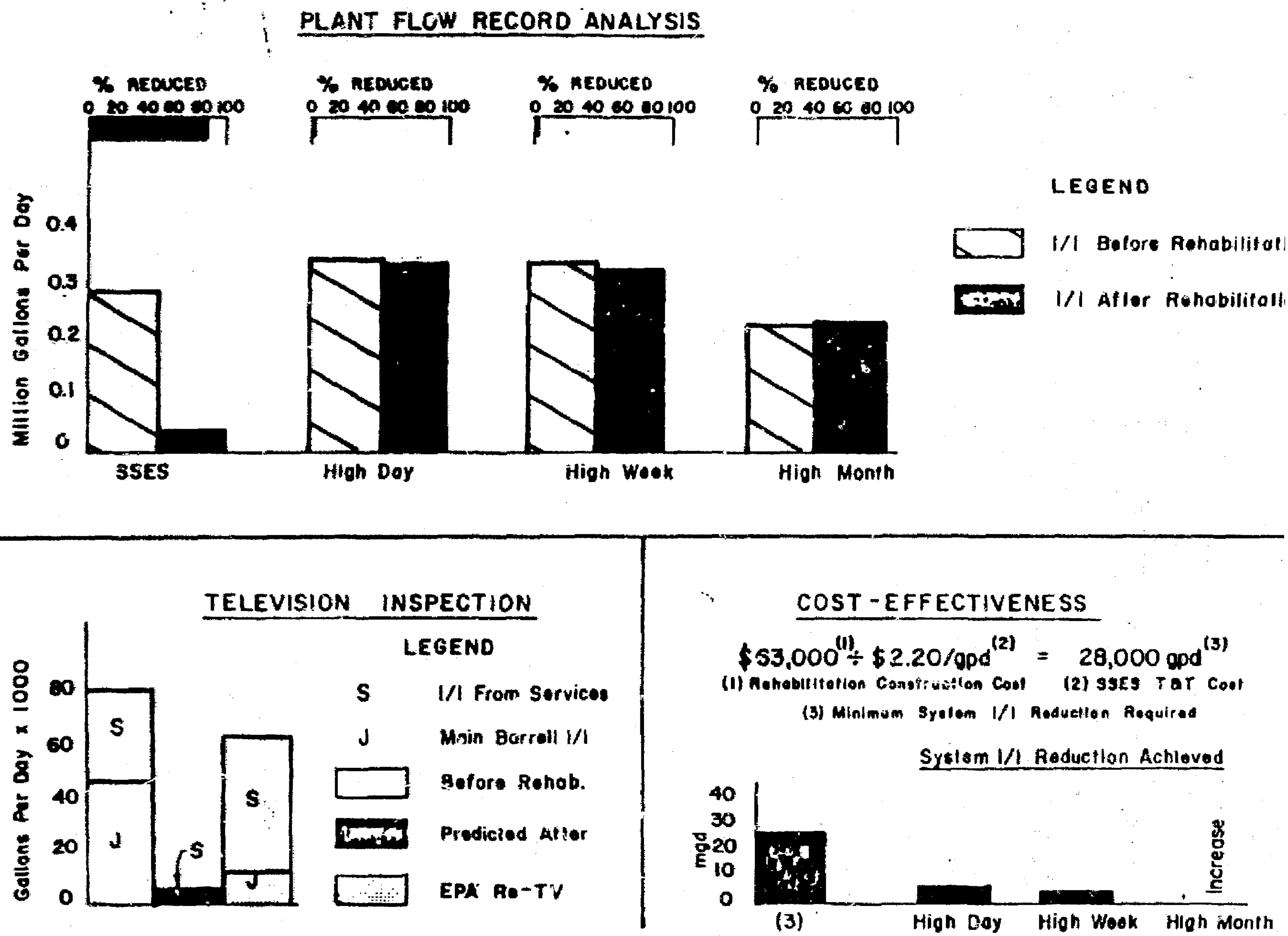


FIGURE 3-9: INFILTRATION/INFLOW DATA, NEW BUFFALO, MICHIGAN

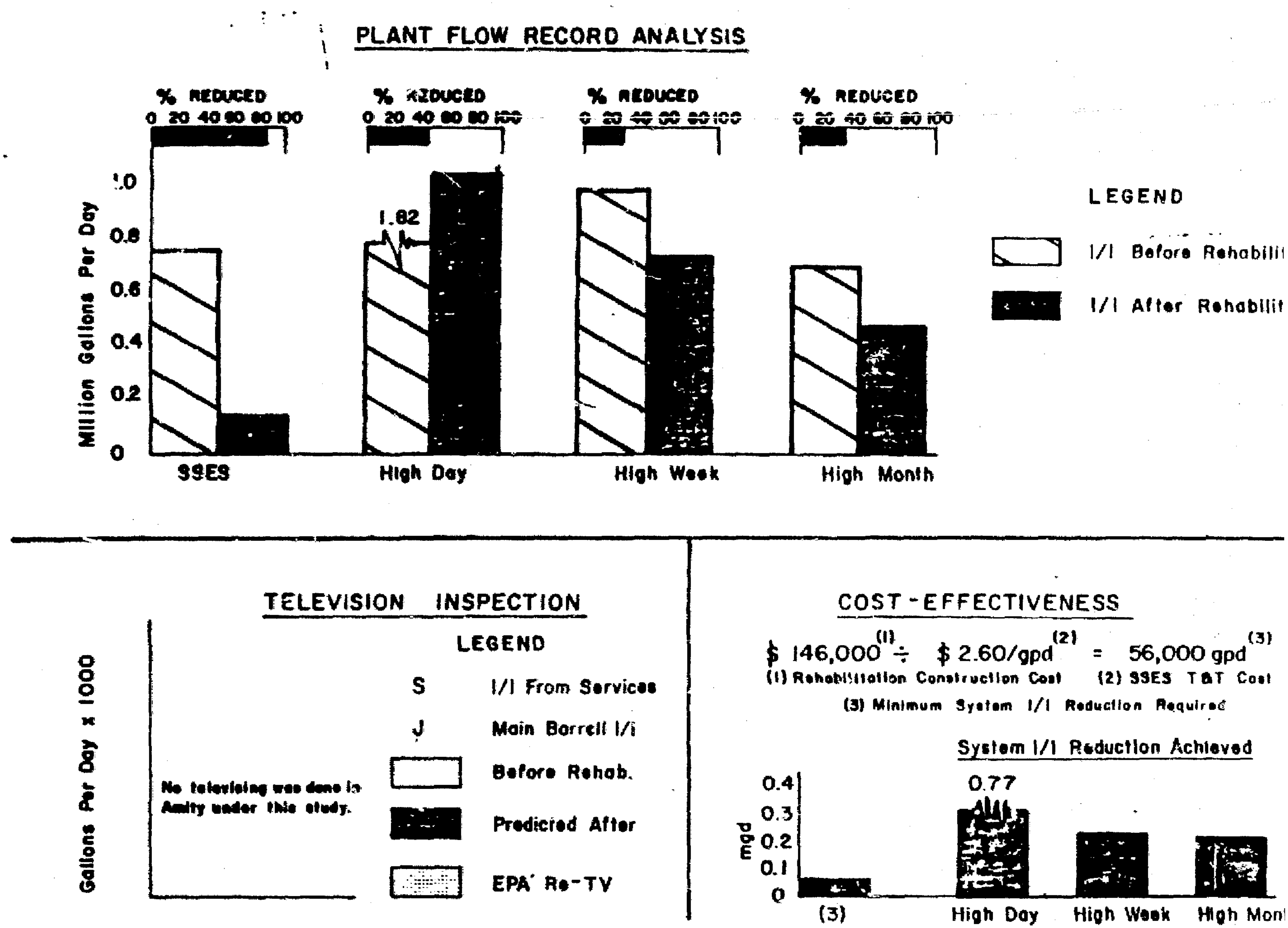


FIGURE 3-10: INFILTRATION/INFLOW DATA, AMITY TOWNSHIP, PENNSYLVANIA

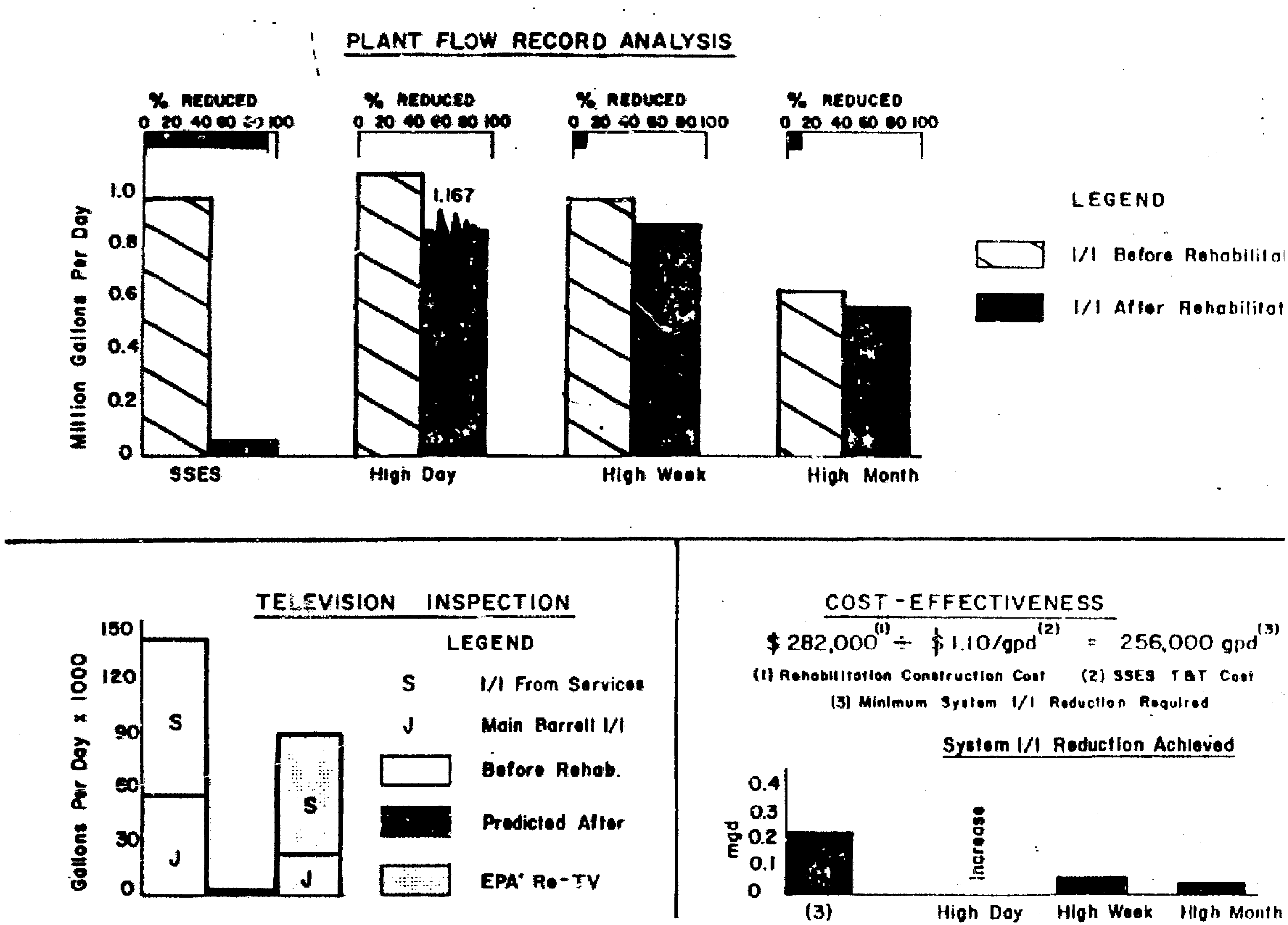


FIGURE 3-1: INFILTRATION/INFLOW DATA, SUSSEX, WISCONSIN

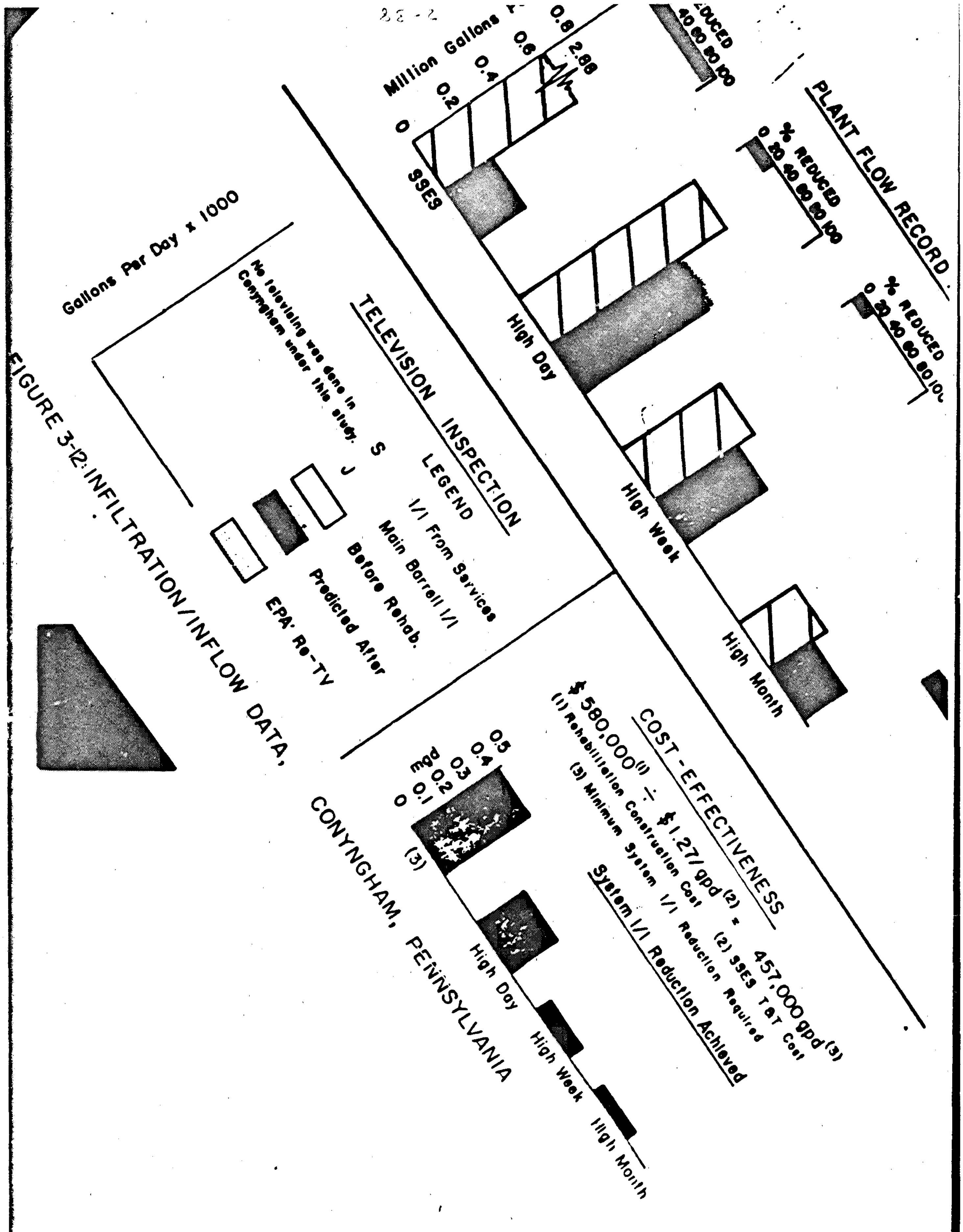


FIGURE 3-12: INFILTRATION/INFLOW DATA, CONYNGHAM, PENNSYLVANIA

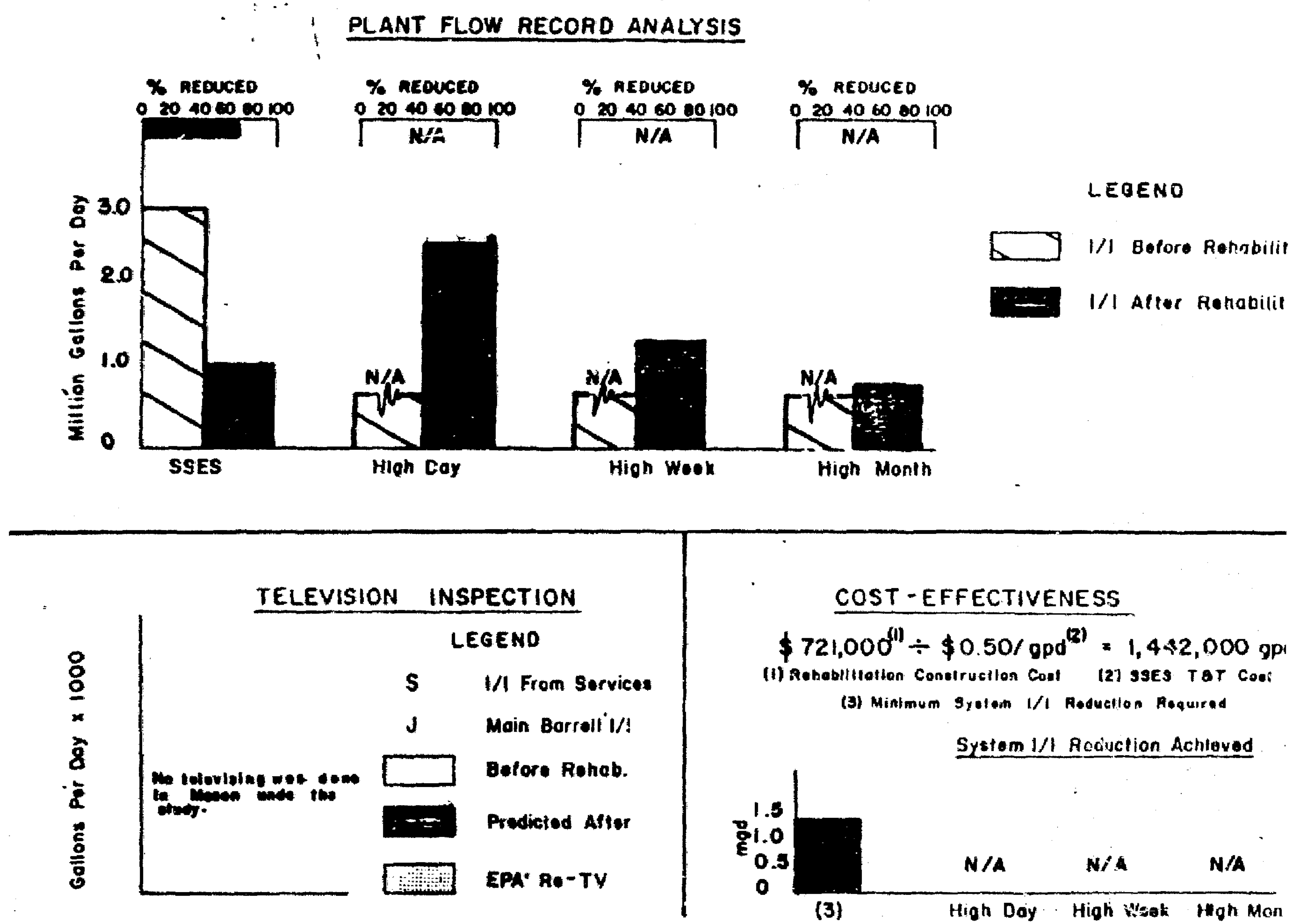


FIGURE 3-13 INFILTRATION /INFLOW DATA, MASON, MICHIGAN

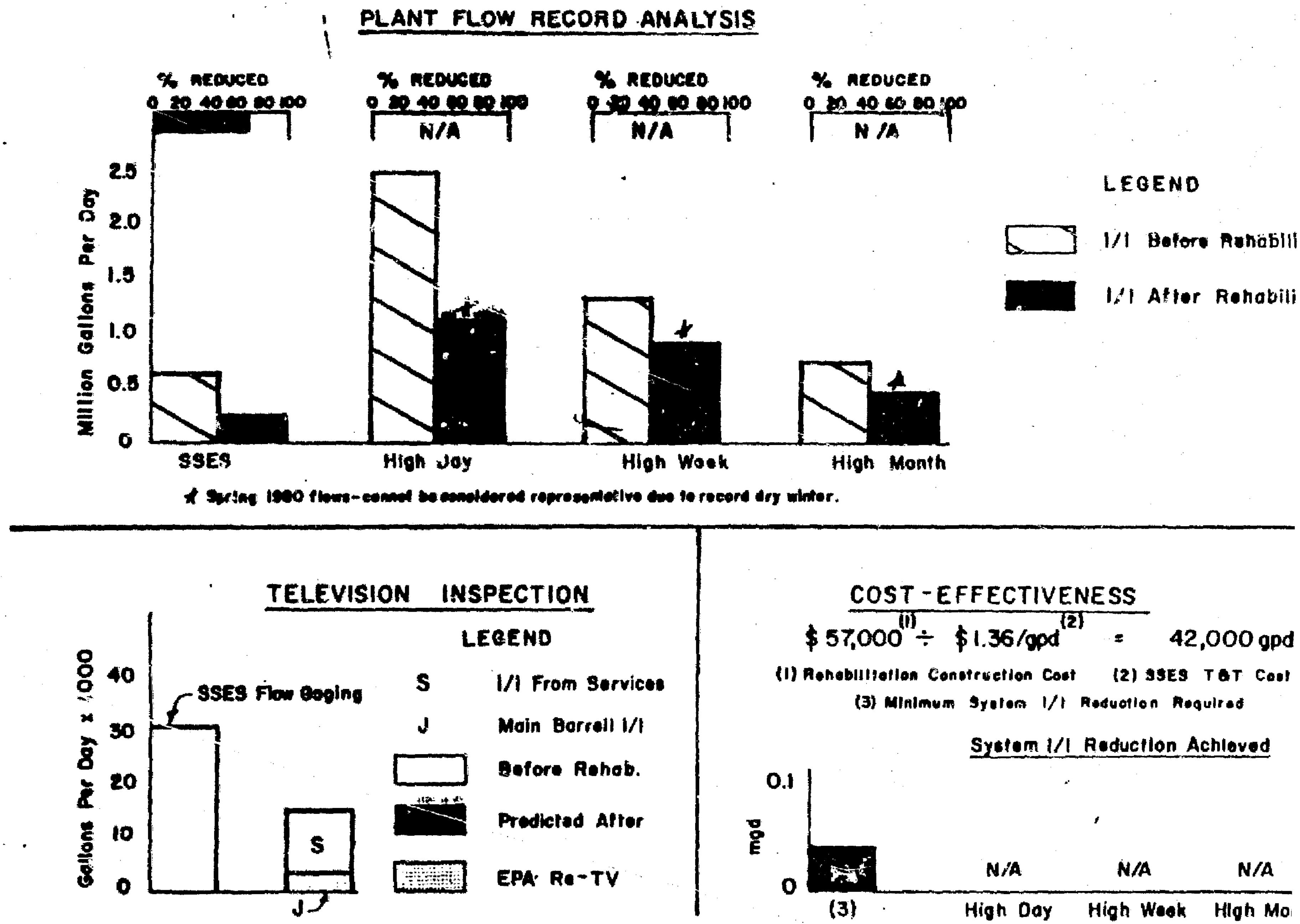


FIGURE 3-14: INFILTRATION/INFLOW DATA, SALEM, NEW HAMPSHIRE

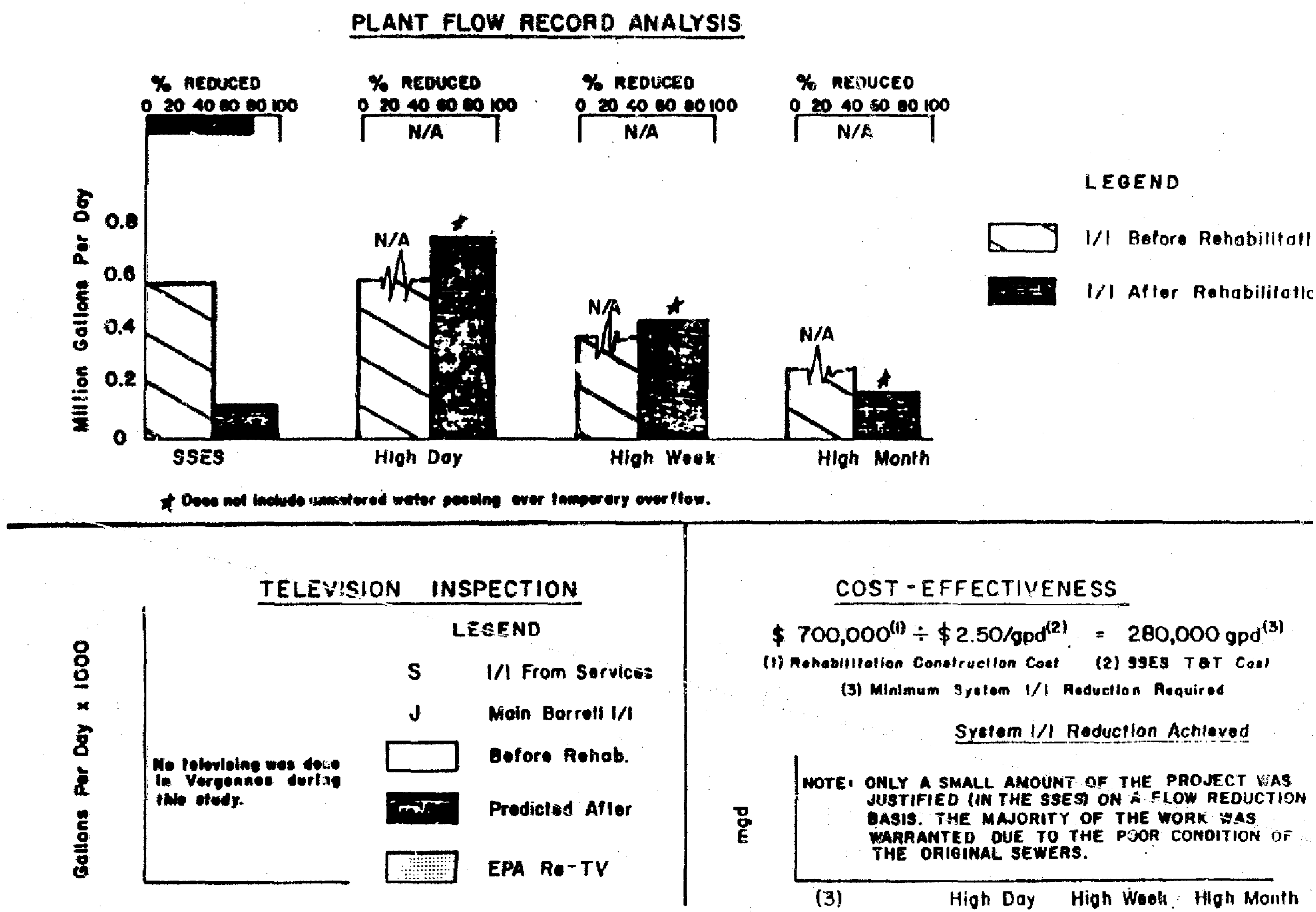


FIGURE 3-15: INFILTRATION/INFLOW DATA, VERGENNES, VERMONT

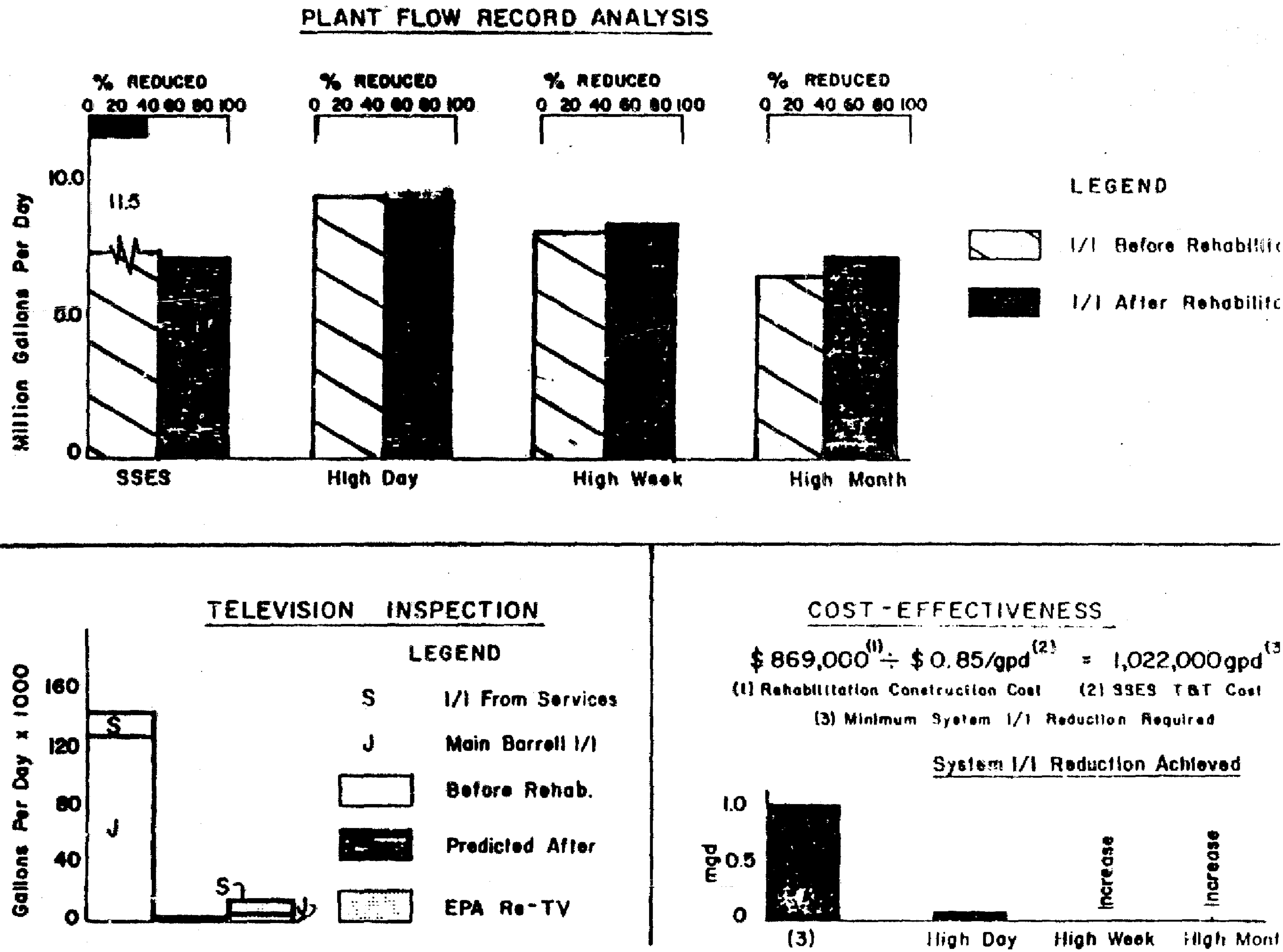


FIGURE 3-16: INFILTRATION/INFLOW DATA, CORTLAND, NEW YORK

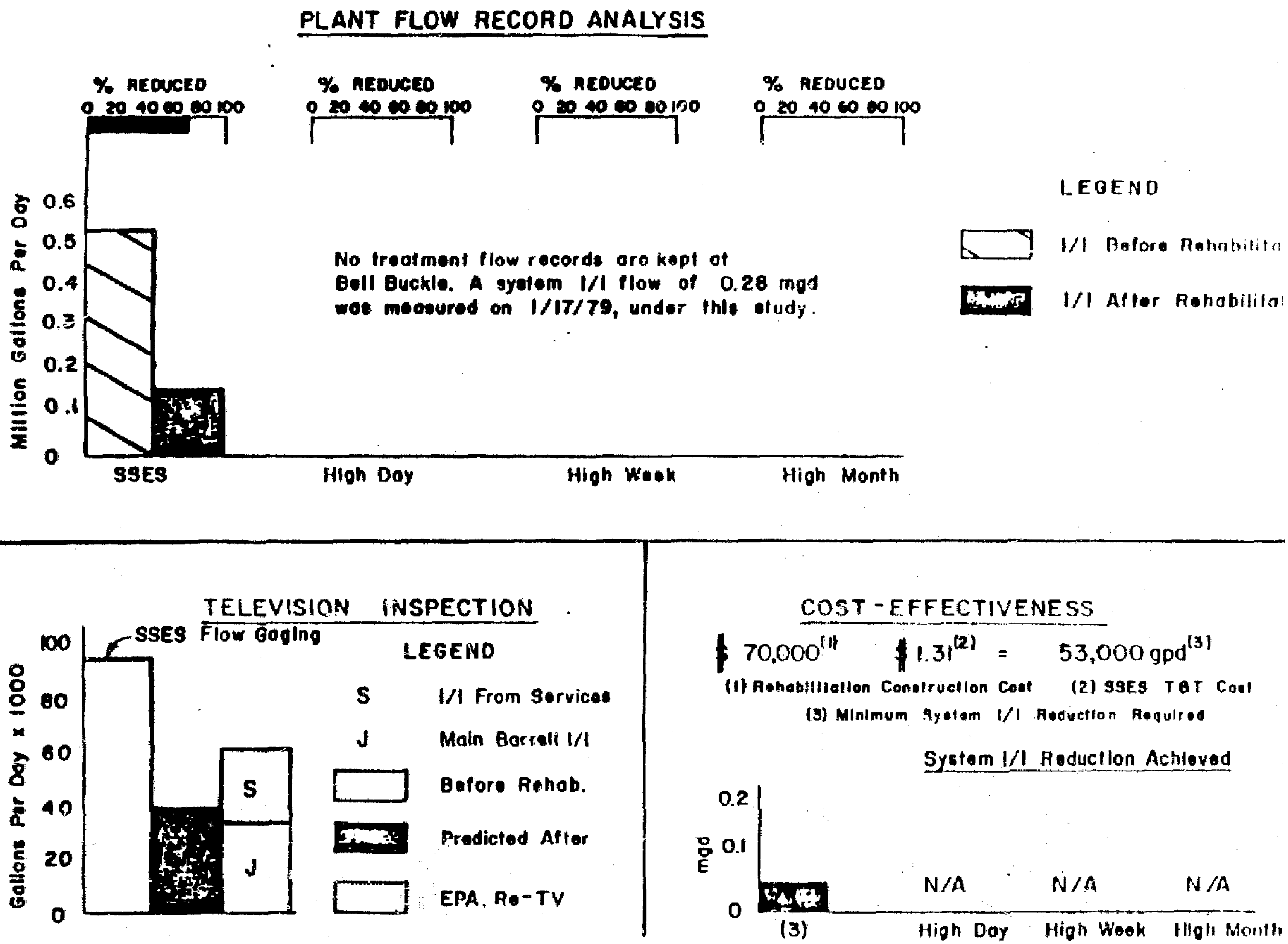


FIGURE 3-1: INFILTRATION/INFLOW DATA; BELL BUCKLE, TENNESSEE

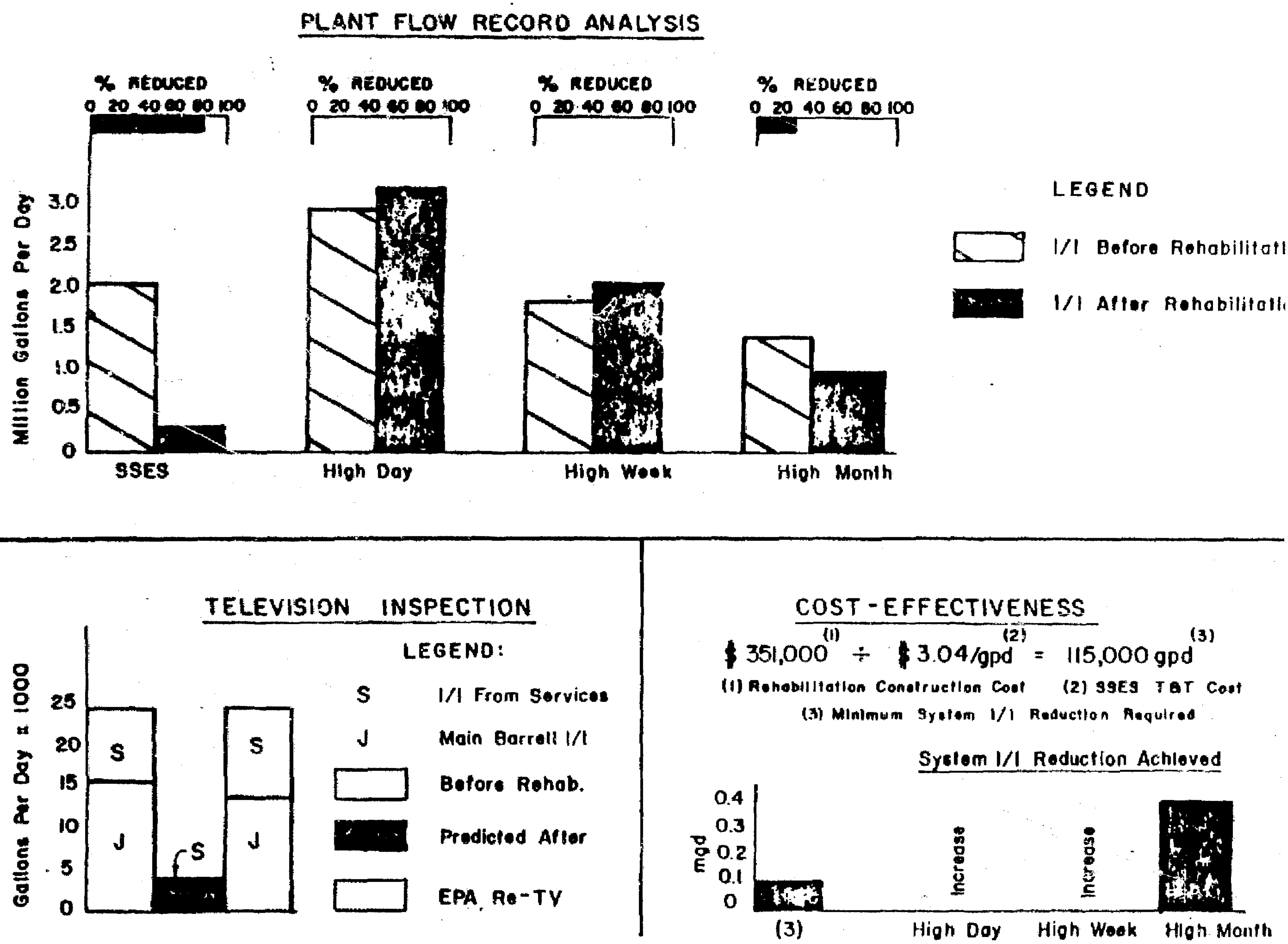
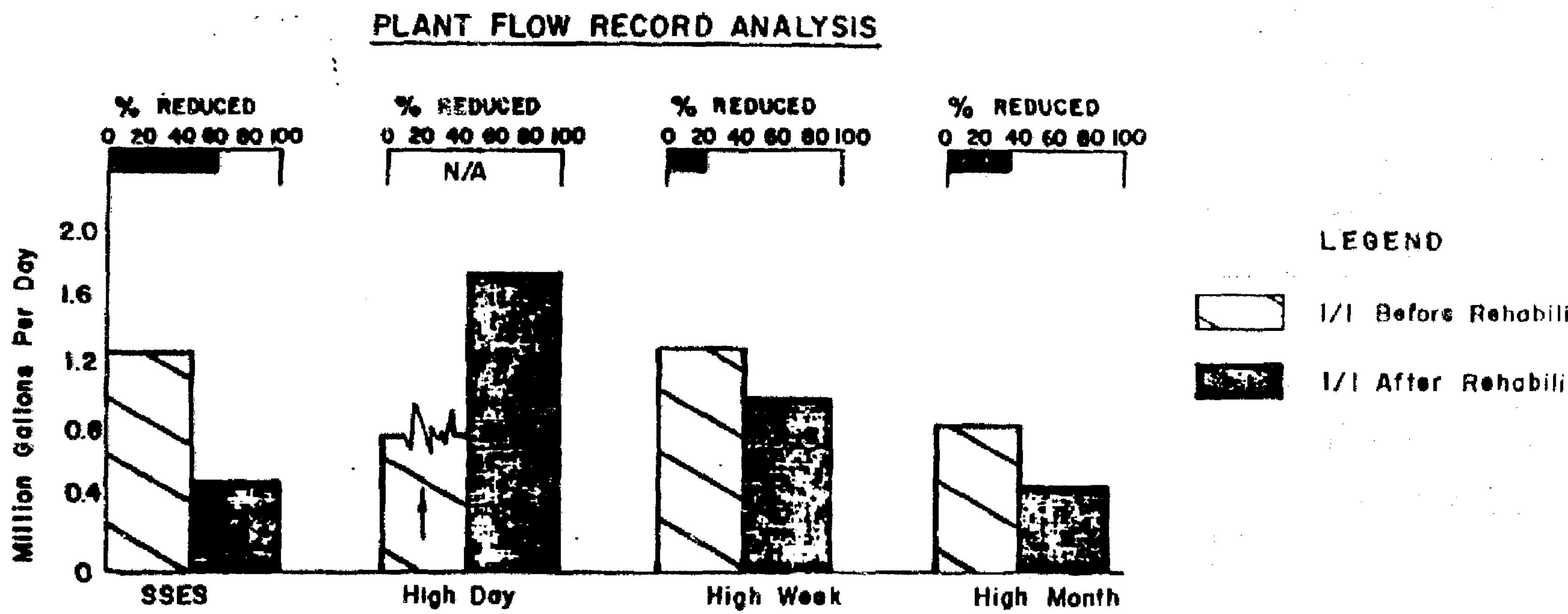
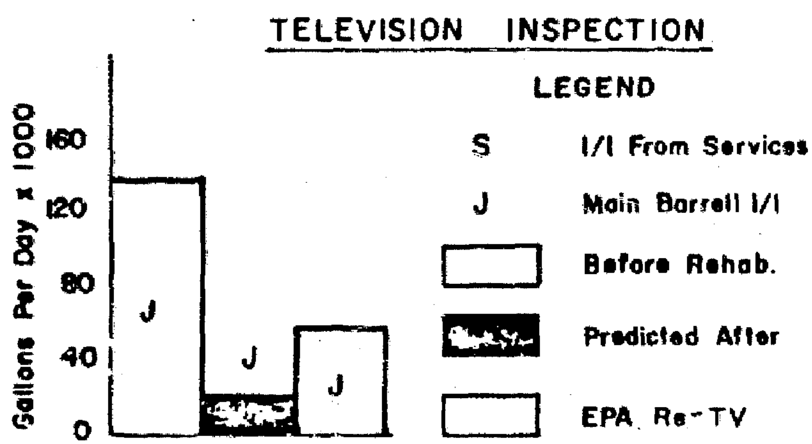


FIGURE 3-2: INFILTRATION/INFLOW DATA, CONTENTNEA METROPOLITAN SEWER DISTRICT, NORTH CAROLINA





NOTE: This TV data is from one heavily-leaking 170-foot section of cross-country sewer.

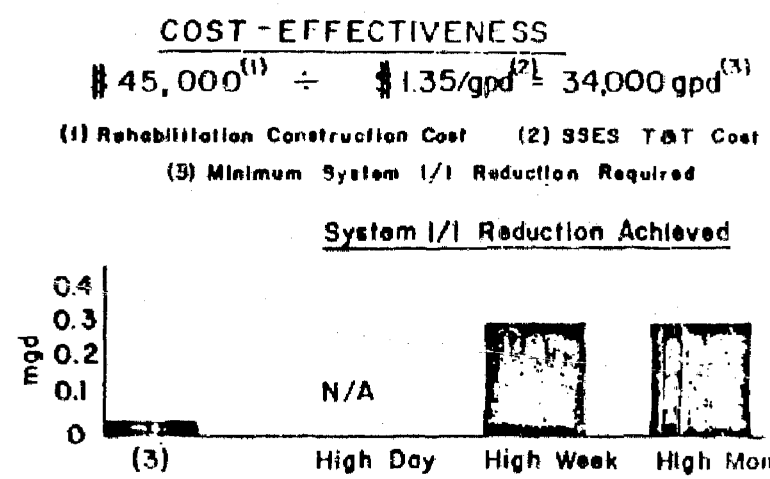


FIGURE 3.3: INFILTRATION/INFLOW DATA, MT. HOLLY SPRINGS, PENNSYLVANIA

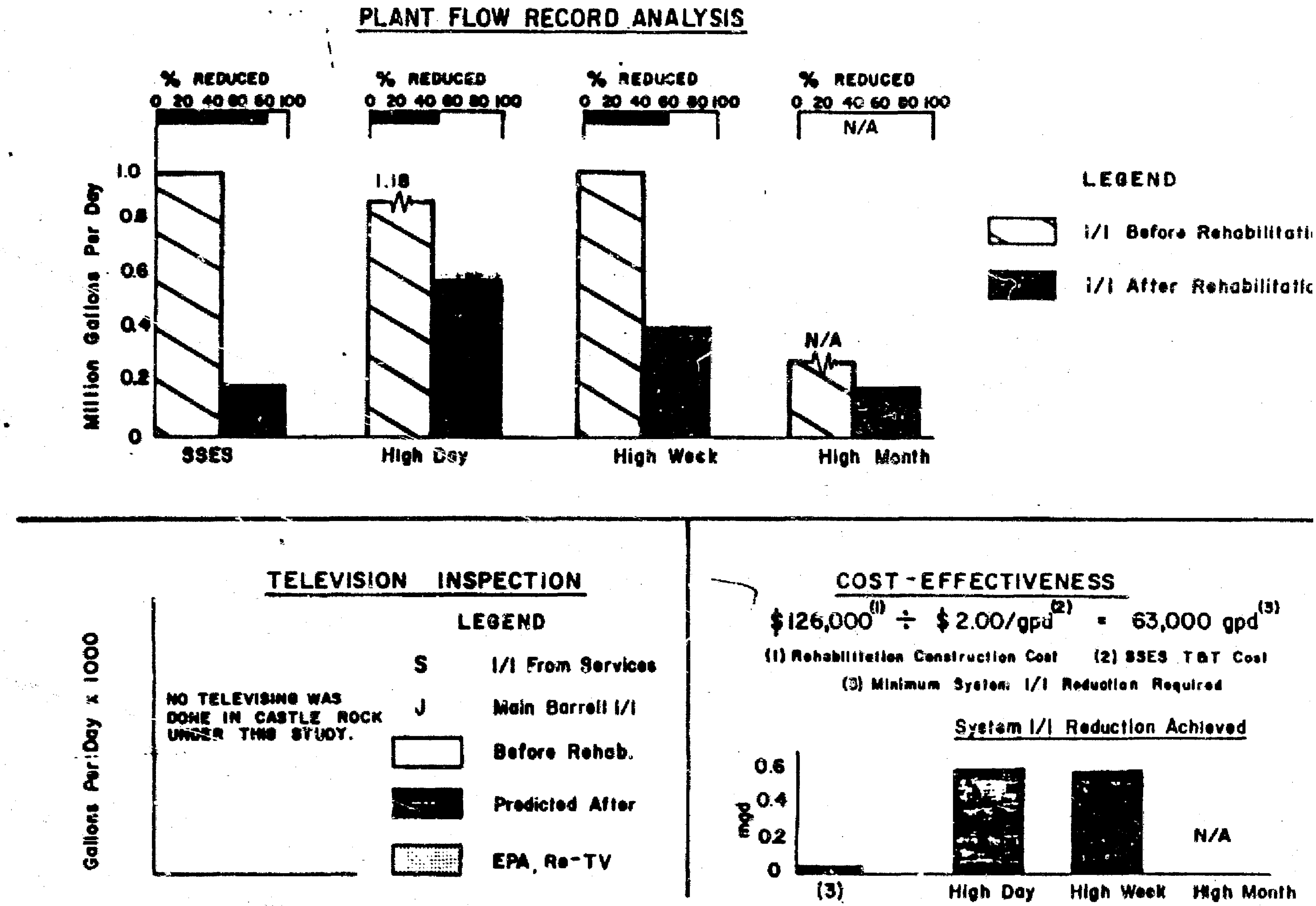


FIGURE 3-4: INFILTRATION/INFLOW DATA, CASTLE ROCK, WASHINGTON

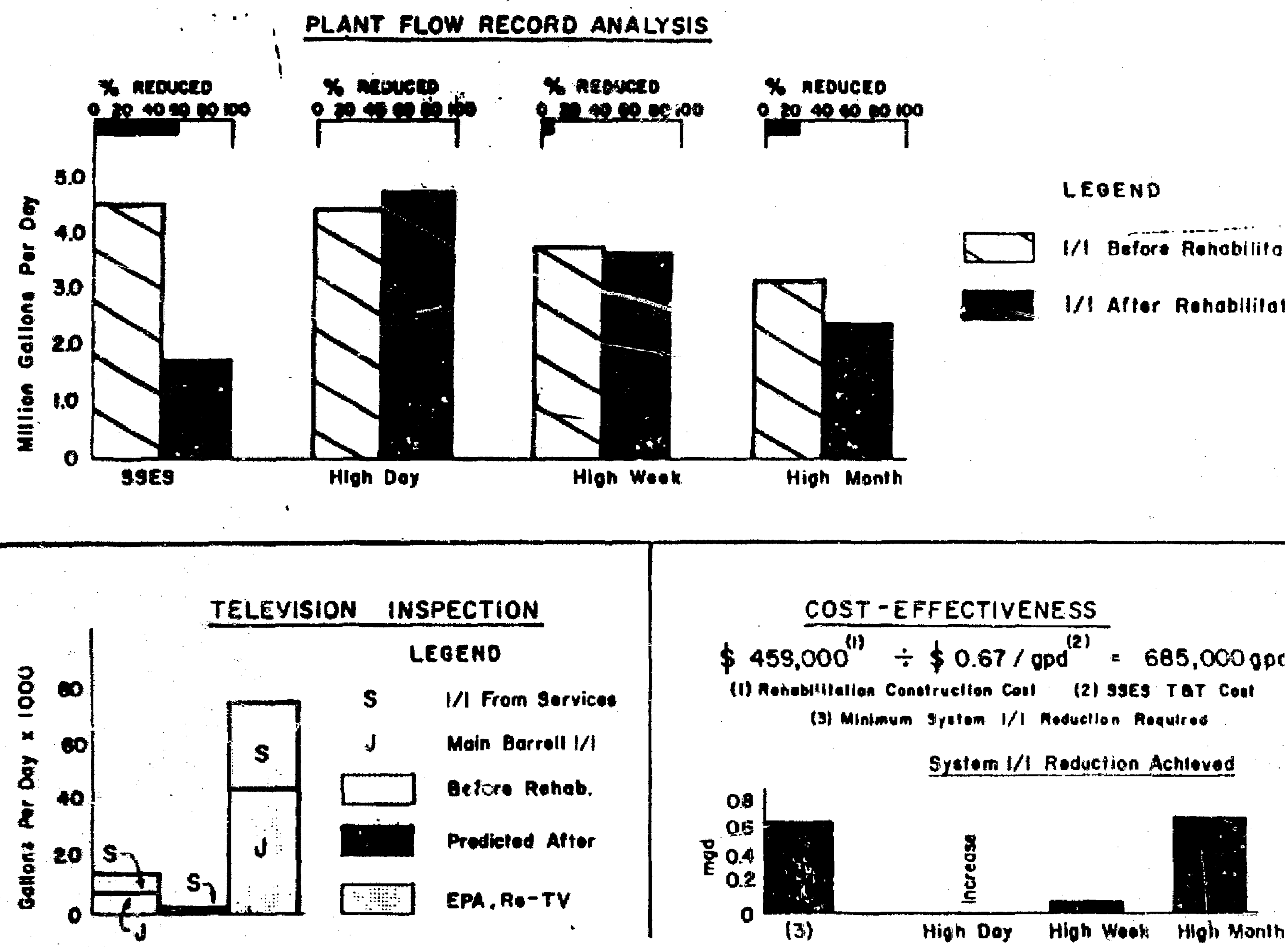


FIGURE 3-5: INFILTRATION/INFLOW DATA, CENTRALIA, WASHINGTON

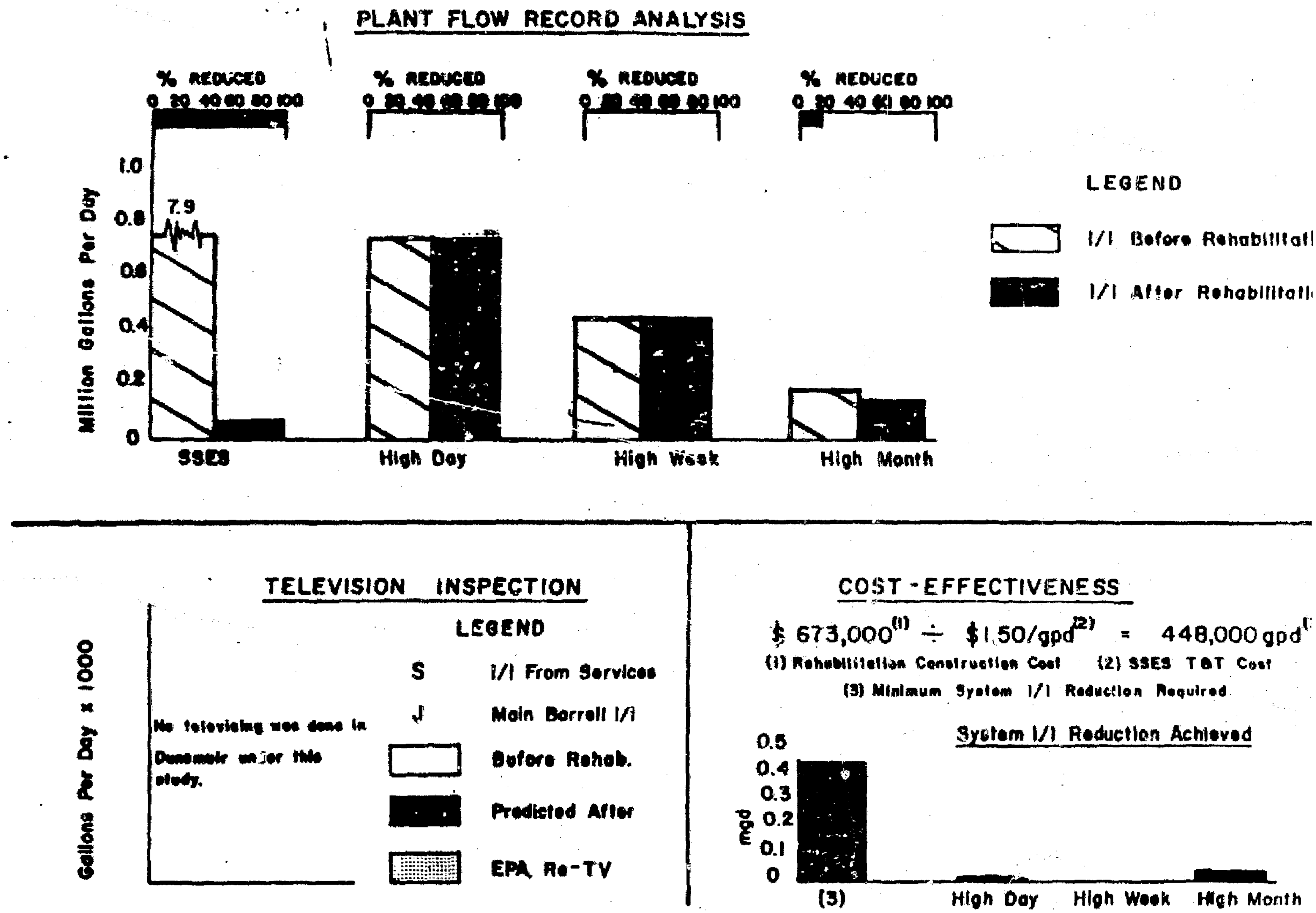


FIGURE 3-6: INFILTRATION/INFLOW DATA, DUNSMUIR, CALIFORNIA

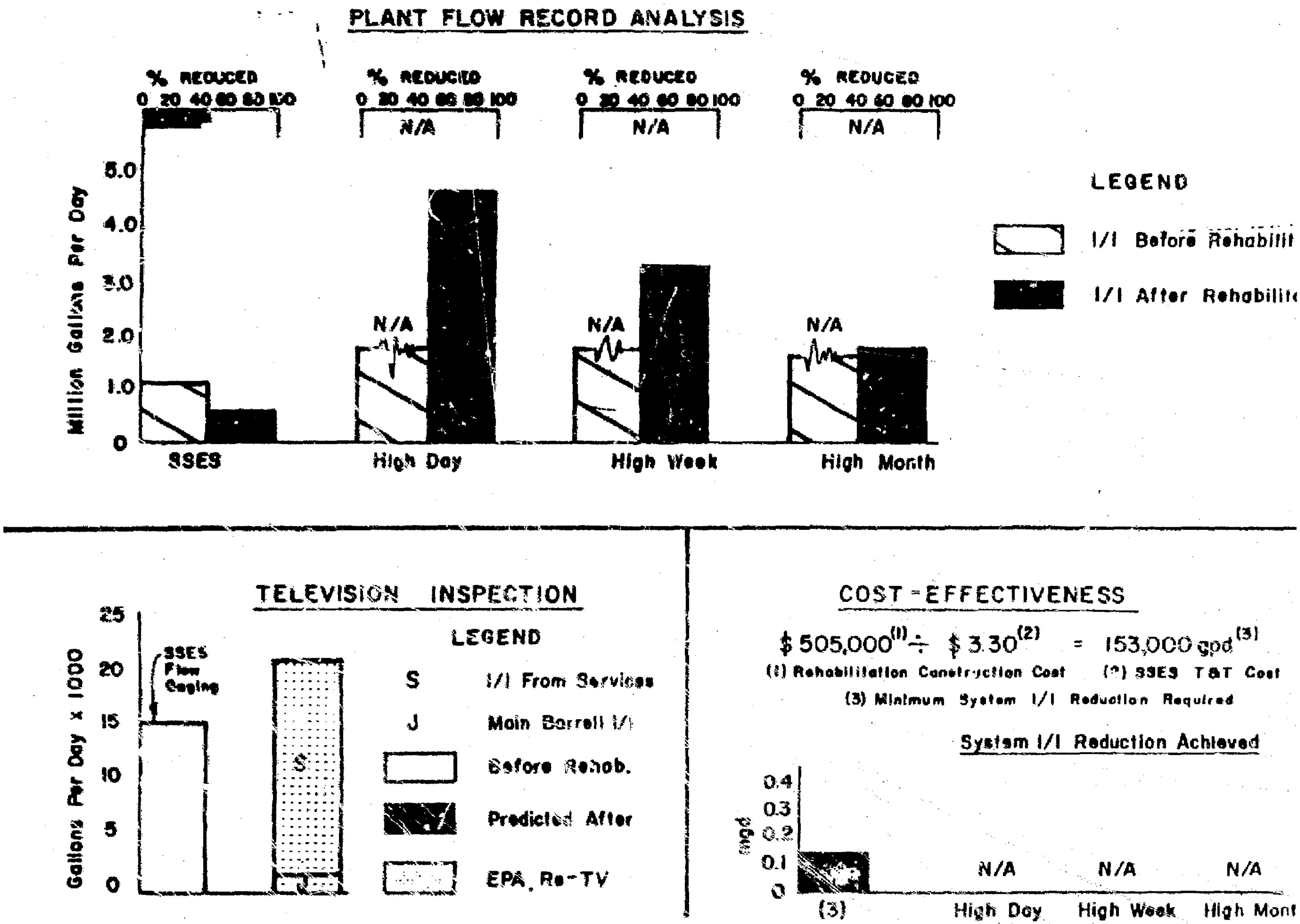


FIGURE 3-7: INFILTRATION/INFLOW DATA, WILLITS, CALIFORNIA

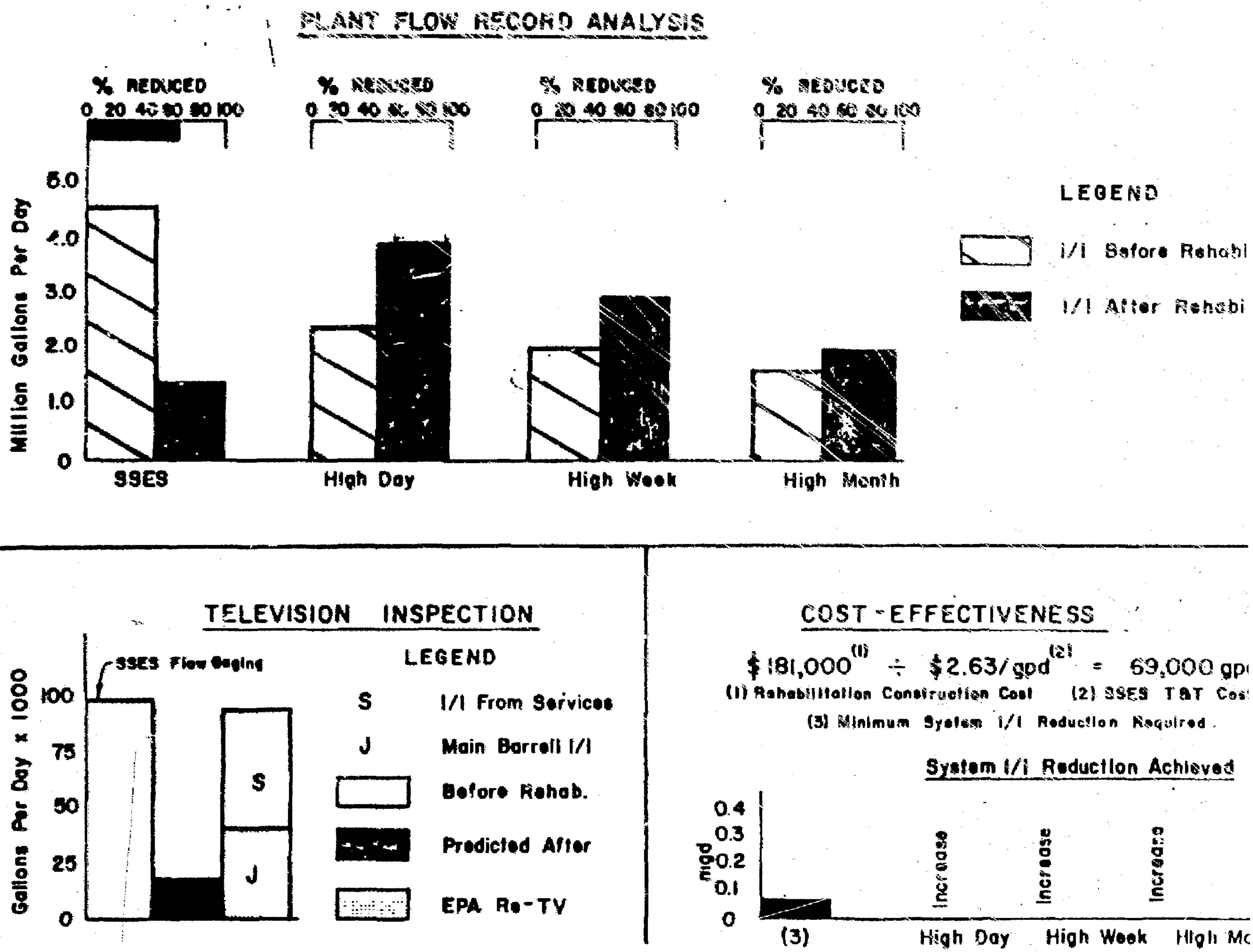


FIGURE 3-8: INFILTRATION/INFLOW DATA, SHELTON, WASHINGTON

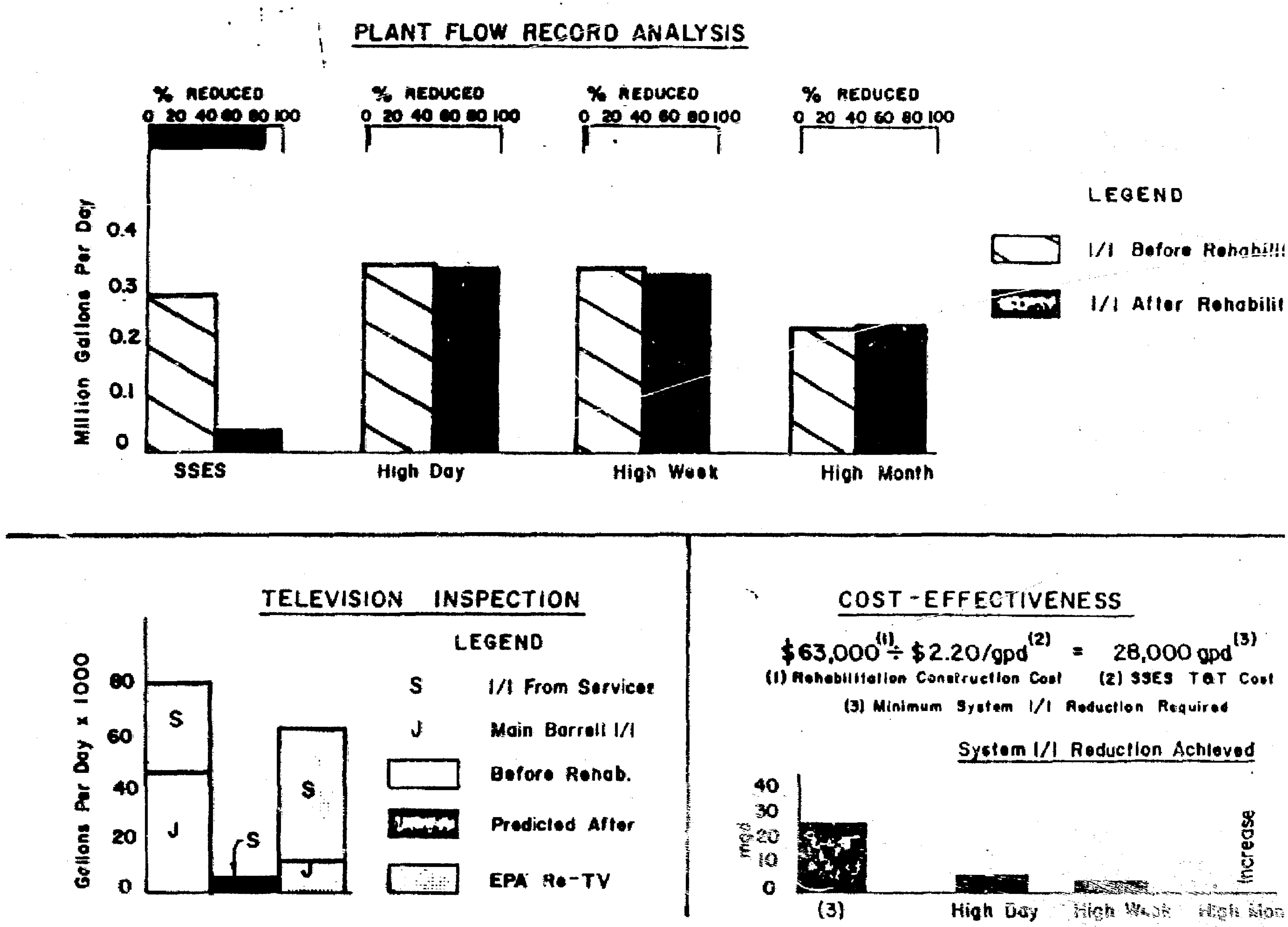


FIGURE 3-9: INFILTRATION/INFLOW DATA, NEW BUFFALO, MICHIGAN

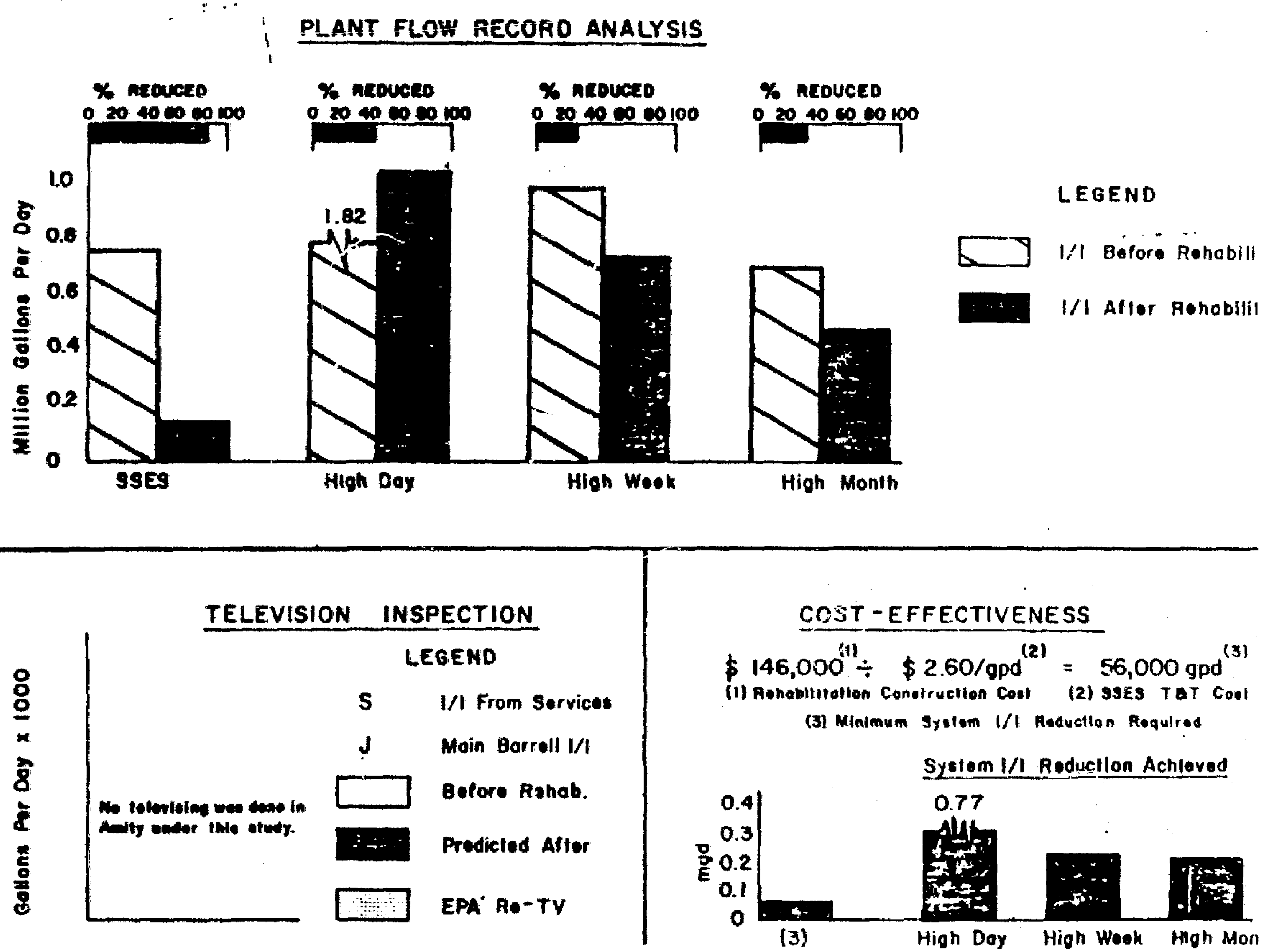


FIGURE 3-10: INFILTRATION/INFLOW DATA, AMITY TOWNSHIP, PENNSYLVANIA

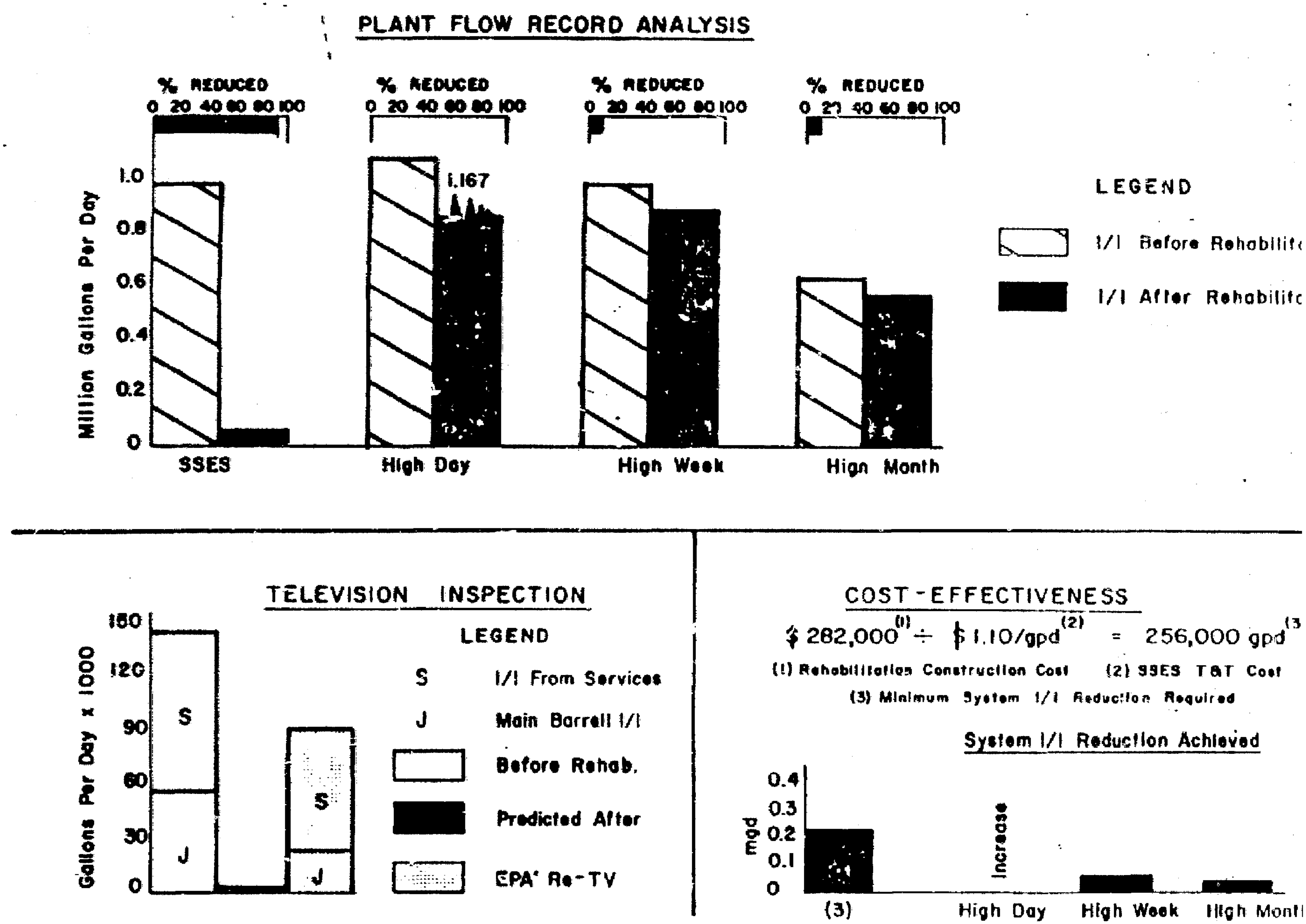


FIGURE 3-1: INFILTRATION/INFLOW DATA, SUSSEX, WISCONSIN

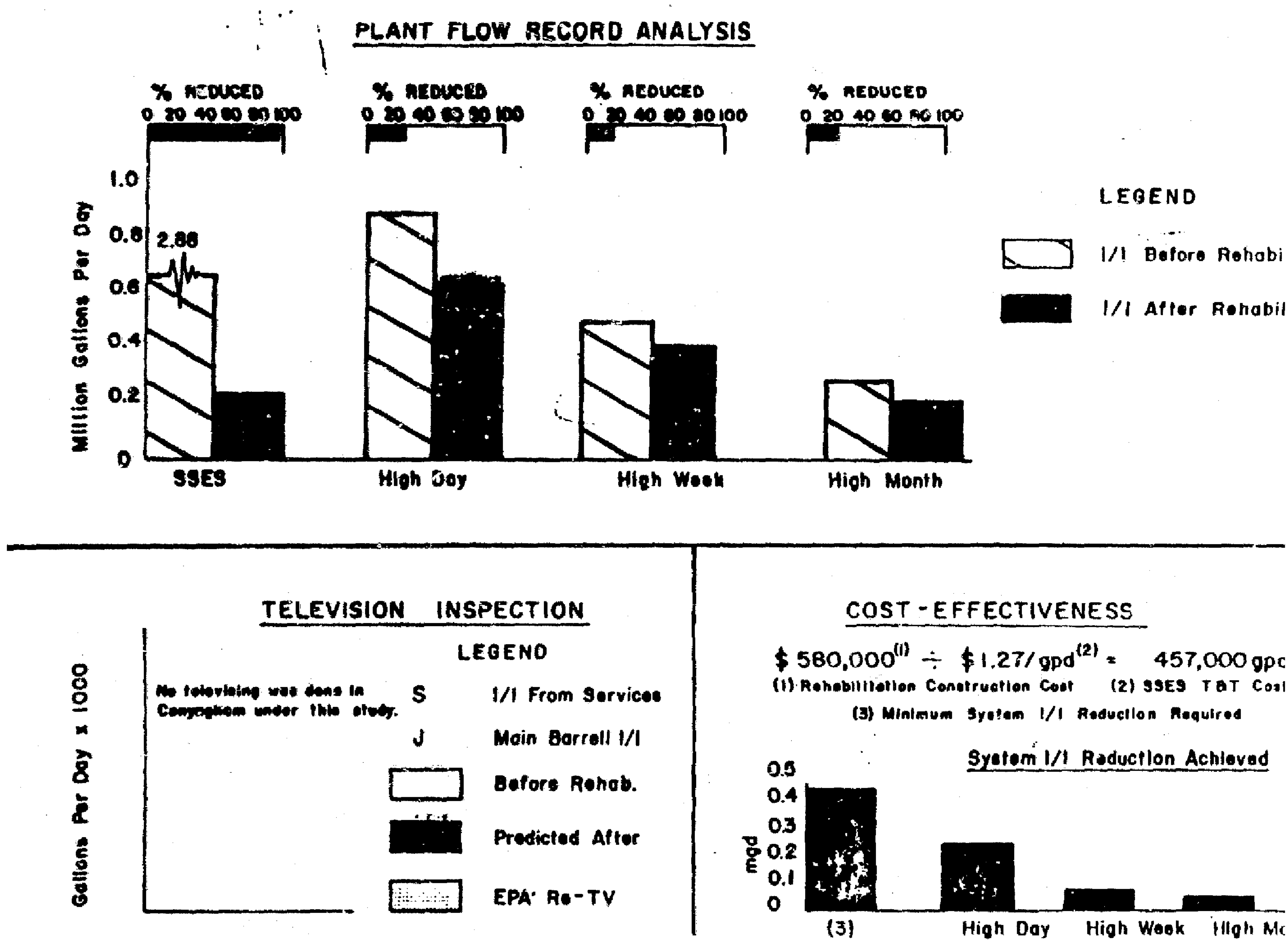


FIGURE 3-12: INFILTRATION/INFLOW DATA, CONYNGHAM, PENNSYLVANIA

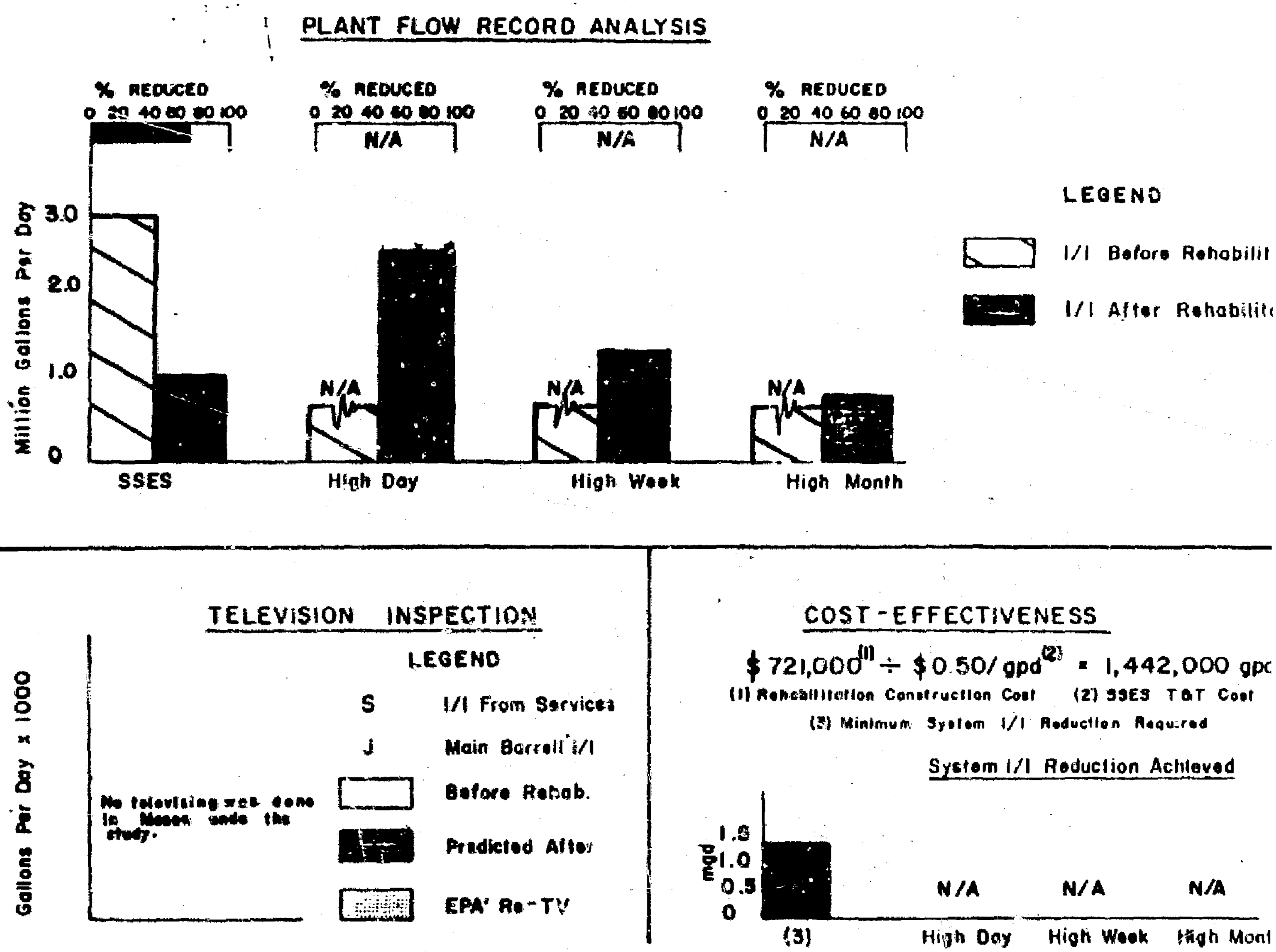


FIGURE 3-13 INFILTRATION/INFLOW DATA, MASON, MICHIGAN

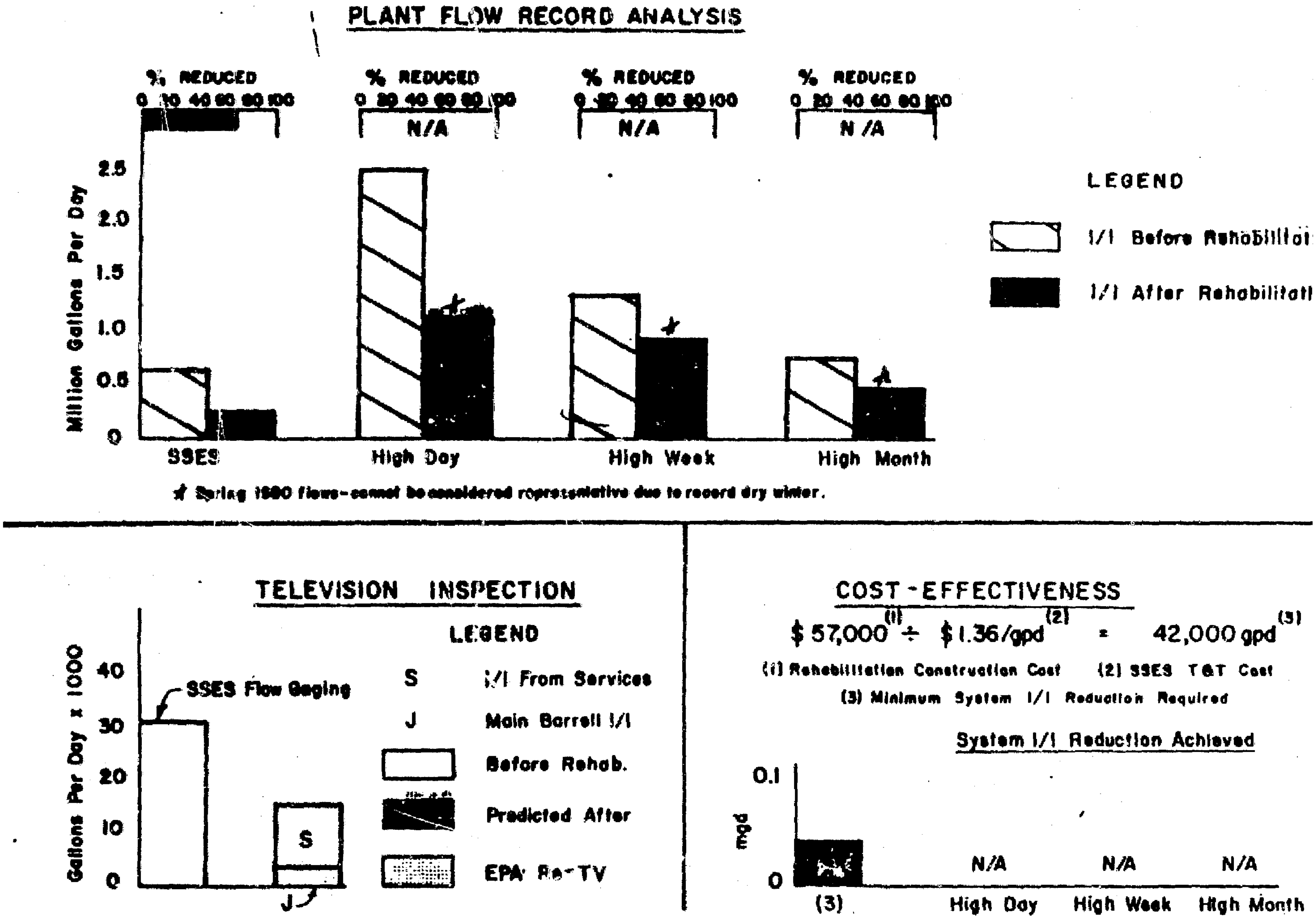


FIGURE 3-14: INFILTRATION/INFLOW DATA, SALEM, NEW HAMPSHIRE

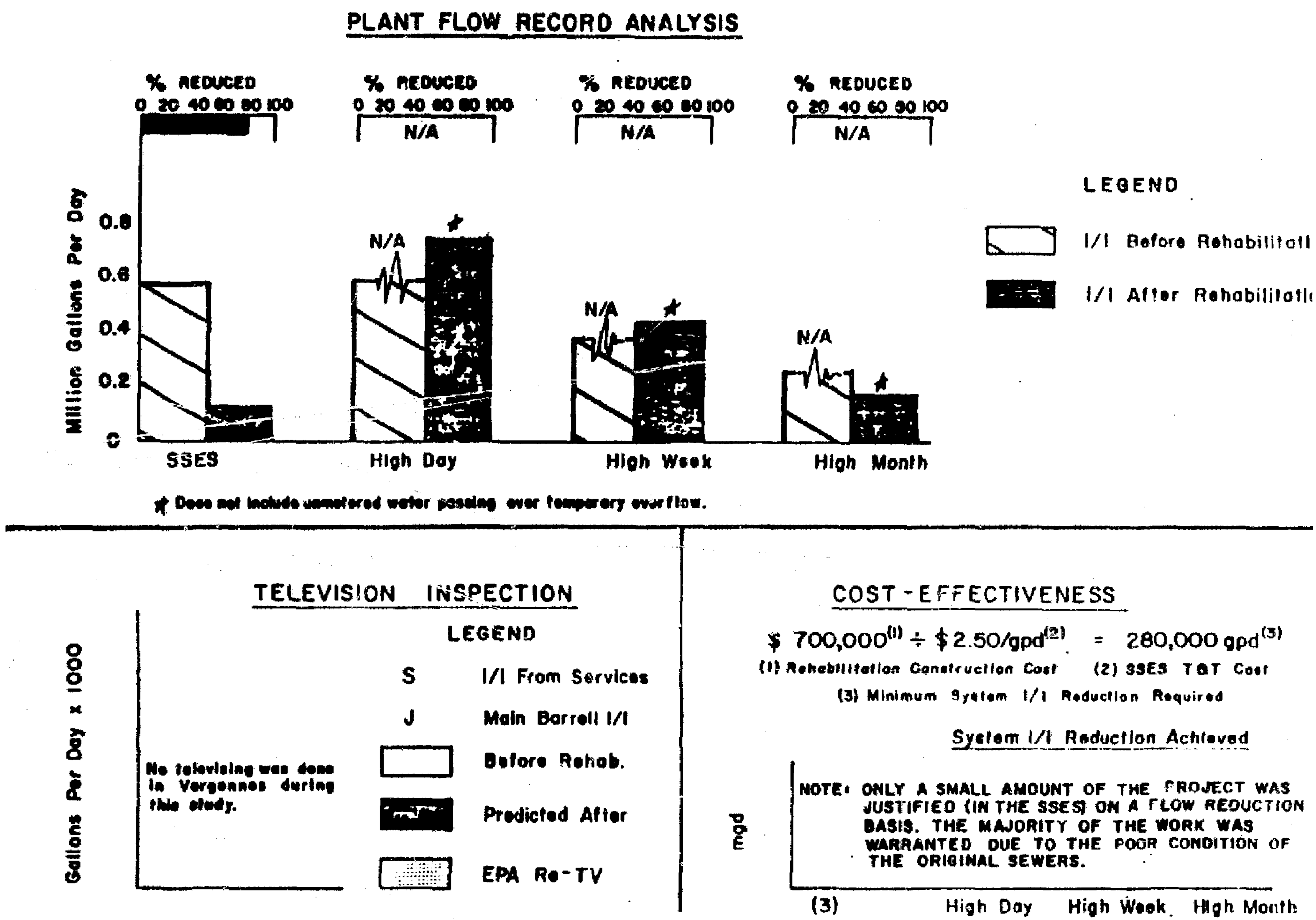
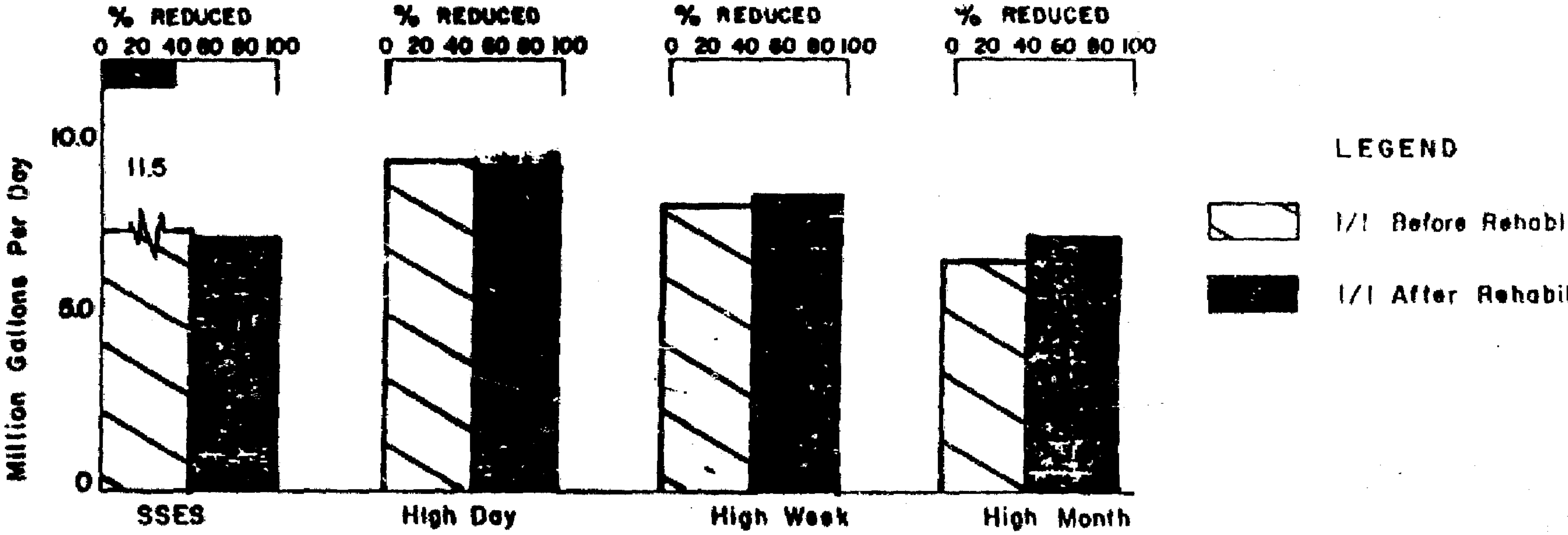
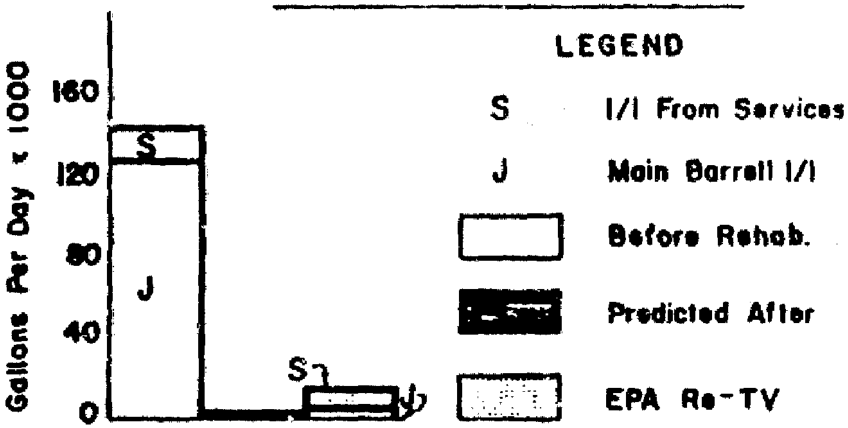


FIGURE 3-15: INFILTRATION/INFLOW DATA, VERGENNES, VERMONT

PLANT FLOW RECORD ANALYSIS



TELEVISION INSPECTION



COST-EFFECTIVENESS

$869,000[1] ÷ $0.85/gpd[2] = 1,022,000gpd

(1) Rehabilitation Construction Cost (2) SSES TBT Cost

(3) Minimum System I/I Reduction Required

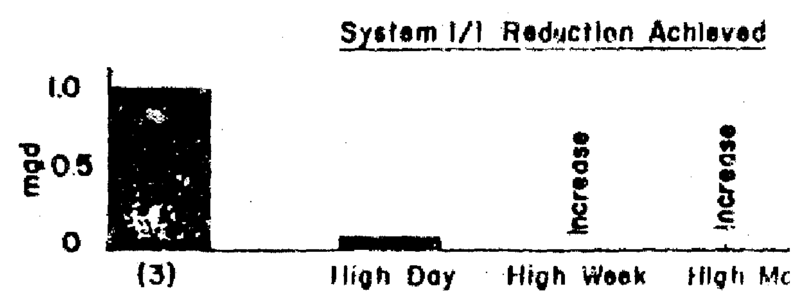


TABLE 3-1

SSES FLOW SUMMARY (1)

Community	SSES Infiltration Before Rehab	(2)	Estimated After	SSES Inflow Before Rehab	(2)	Estimat After
Bell Buckle, TN	0.466	FM	0.140	0.082	RS	0.018
Grifton, NC (3)	0.013	TV	0.004	0.122	RS	0.012
Winterville, NC (3)	0.032	TV	0.010	0.128	RS	0.013
Ayden, NC (3)	0.099	TV	0.030	0.391	RS	0.040
Mt. Holly, PA	1.241	FM	0.491	0.016	RS	0.016
Castle Rock, WA	0.847	TV	0.123	0.155	RS	0.062
Centralia, WA	4.1	FM	1.33	0.5	PR	0.5
Dunsmuir, CA	6.7	FM	0.071	1.2	RS	0
Willits, CA	1.0	FM	0.538	0.25	RS	0.15
Shelton, WA	4.41	FM	1.26	0.1	RS	0.1
New Bufflao, MA	0.240	TV	0.036	0.060	RS	0.009
Amity, PA	0.320	FM	0.048	0.450	FM	0.068
Sussex, WI	0.989	TV	0.060	0.015	RS	0.015
Conyngham, PA	0.564	FM	0.045	2.315	FM	0.185
Mason, MI	0.3	PR	N/A	2-3	PR	<1
Vergennes, VT	0.584(4)	FM	0.124(4)	0.584(4)	FM	0.124(4)
Salem, NH	0.55	FM	0.140	0.1	RS	0.1
Cortland, NY	11.0	FM	6.8	0.5	RS	0.2

Notes:
1. All flows in mgd.
2. Method used to quantify flow: TV=Televised Inspection, FM=Flow Measurement, PR=Plant Flow Record Analysis, RS=Rainfall Simulation.
3. Only part of system studied in SSES.
4. SSES figures for total I/I only.

INFLOW REMOVAL

Wet weather flows to treatment plants have not been reduced to the extent predicted following sewer line rehabilitation. Differentiation between infiltration and inflow to determine the quantity of each is an inexact exercise. Thus, the findings of this study simply state that wet weather I/I flows have not been effectively reduced.

METHODOLOGY

The major elements of the I/I methodology are imprecise. Each of the elements, namely flow monitoring, flow estimating, assumed flow reductions after rehabilitation and cost effectiveness can give erroneous results. The lower right portion of Figure 3-1 through 3-16 illustrates the amount of I/I that should have been removed cost effectively versus the actual removals.

CHAPTER 4

RECOMMENDATIONS

General

The findings of this study indicate that Sewer System Evaluation and Rehabilitation generally does not result in substantial system I/I flow reductions. The consequence of this is that returning I/I has used up all or substantial portions of the reserve capacity of new and upgraded treatment facilities and thus, shortened the plants' design lives.

I/I is not going to be removed by ignoring it. Thus, it is essential that it be evaluated in order that sewerage works can be designed and operated effectively.

In order to improve the effectiveness of Sewer System Evaluation and Rehabilitation it is necessary to make substantive changes in technical procedures utilized in evaluating I/I. These technical procedure changes must incorporate new developments and the most recent state-of-the-art technology.

The recommendations for improving the I/I Program and detailed technical procedures for accomplishing this will be presented in a separated document. This document will be prepared in accordance with the Scope of Work under this Contract.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PB95-207213

2. REPORT DATE
Feb 1981

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Technical Report - Evaluation of Infiltration/Inflow Program
Final Report

5. FUNDING NUMBERS

6. AUTHOR(S)
Gerald F Conklin, Paul W. Lewis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US EPA
Office of Water
401 M St., SW
Washington, DC 20460

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
EPA-68-01-4913

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

EPA and others involved in the Construction Grants Program have become increasingly concerned about the extensive time required to analyze sewer systems, the costs of these analyses, the costs of rehabilitating sewers and the lack of results in eliminating and/or reducing extraneous water.

EPA has taken the initiative to evaluate on a broad base the effectiveness of Sewer System Evaluation and Rehabilitation. This report summarizes the findings of sixteen (16) months of investigative work in evaluating the I/I Program. The project has been funded by EPA Headquarters Office of Water Programs, Municipal Construction Division and is intended as an "inhouse" report.

14. SUBJECT TERMS
infiltration/inflow (I/I) Program

15. NUMBER OF PAGES
82

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102