State of Oregon

Department of Environmental Quality Guidelines

Guidelines for Making Wet-Weather and Peak Flow Projections for Sewage Treatment in Western Oregon: MMDWF, MMWWF, PDAF, and PIF

1. Scope

These guidelines describe a rainfall method for calculating current or prevailing sewage flowrates. It is a shortcut method for using published rainfall statistics to determine peak monthly and daily flows which have specific recurrence intervals, or probabilities of occurrence. The method is only applicable where precipitation strongly impacts sewage flows, as in Western Oregon. Here a consistent storm effect generally prevails in areas where rainfall totals at least 20" to 25" per year.

The guidelines propose working definitions for various flowrates employed in wastewater design, until such time as flowrate definitions may be agreed to and standardized in the field of sanitary engineering. Our working definitions are:

$MMDWF_{10}$: The Maximum Monthly Average Dry-Weather Flow with a 10% Probability of Occurrence

$MMWWF_5$: The Maximum Monthly Average Wet-Weather Flows with a 20% Probability of Occurrence

$PDAF_5$: The Peak Daily Average Flow Associated with a 5-Year Storm

PIF_5: The Peak Instantaneous Flow Attained During a 5-Year PDAF

The guidelines also give examples of four graphs which help determine flowrates of various return frequencies:

Graph #1: Average Monthly Flowrate (MGD) versus Cumulative Monthly Rainfall (inches per month)

Graph #2 Flowrate (MGD) versus 24-hour Rainfall Intensity (inches per day)

Graph #3 Flowrate (MGD) versus Probability (%)

Graph #4 Flowrate (MGD) versus Total Suspended Solids (mg/l)

Our intent here is not to dictate or limit the approach used to estimate future design flows, but rather to establish a minimum baseline for comparison. In areas where there is enough rainfall to make a significant impact on sewage flowrates, the rainfall method described here should always be presented as part of the discussion on design flow projections, including Graphs # 1, 2, and 3. Graph # 4 can sometimes help to compensate for missing flow measurements when estimating $PDAF_5$ and PIF_5, and it should also be included if used.

Baseline flowrates, estimated using this rainfall method, should be considered the minimum estimate for current flows from which to project future flowrates. Flow projections to the design year (normally 20 years out) should then reflect anticipated growth as well as can be predicted.

2. Graph # 1 (Monthly Average Flowrate versus Monthly Cumulative Rainfall)

In Western Oregon, the main cause of extreme sewage flows is rain. To estimate a flowrate, the first step is to identify the exact relationship between peak storms and peak sewage flows. This will involve drawing a graph of flowrate versus rainfall, normally based on plant records. All low-groundwater months, when storms do not contribute a proportional amount to sewage flows, would interfere with the correlation and should be excluded.

As may be seen in the attached example of Graph #1, the correlation is conveniently presented in the form of monthly average daily flows (million gallons per day) versus total monthly rainfall accumulation (inches per month). A treatment plant's Daily Monitoring Reports (DMR's) will provide both types of data. Such a graph should reflect the current impact of rainfall on sewage flows under prevailing conditions, whenever groundwater levels are high. A table describing each data point (not shown here) should also be provided to document and help validate the graph.

Data must normally be limited to the period January-May, as the groundwater level in Western Oregon tends to sink in June and stay deep until December. Data should also be limited to the most recent year to avoid growth effects that may skew or mask the flow/rainfall correlation. A few selected points from the previous year may be warranted if a correlation is not clear-cut or if unreliable data make it advisable to exclude several outliers. Approximately 5 data points is enough if they are good ones.

This approach minimizes growth effects and does not involve a statistical analysis of several years of plant flow data. If the precipitation pattern is normal and the flow data are accurate, Graph #1 will illustrate whether a consistent flowrate-rainfall relationship prevails under peak monthly flow conditions.

3. Background and Basis for Design Flowrates

At one time, annual average flow was the main parameter used for sizing sewage treatment plants. Plants were designed and rated according to their annual average capacity. This convention still continues in regions where effluent limits remain constant year-round, regardless of the season.

In Western Oregon, however, an annual-average design basis had little applicability because of wide flow variations and seasonal effluent limits. Average summer flowrate replaced annual average flowrate as the basis for design, and average dry-weather flow became established as the basis for issuing NPDES permits.

Oregon NPDES permits still designate an "Average Dry-Weather Flow" (ADWF) for each treatment plant. The ADWF is the average of daily flows over the 6-month dry-weather period, roughly May through October. This is the flowrate on which dry-weather mass loads are based.[*]

However, from the standpoint of reliability, it is implicit in the concept of a seasonal or annual average that there is a 50% chance every year for possible overload and failure of the process. To base design on average capacity implied a potential failure or sewage overflow every other year, which presented an excessive risk to the environment. In 1991, we stopped using average flows as a design basis for sewage treatment in favor of the 5-year flow, which presents only 20% probability of a failure in any given year.

In 1996, we concluded that even a 20% probability of failure presented an excessive risk in the summer. The probability of a summertime failure or sewage overflow has now been reduced to 10%, which amounts to one failure every 10 years on average. This has the effect of further reducing the potential for poor treatment or raw sewage overflows during the period of May through October. An immediate consequence is to require somewhat larger and more reliable treatment facilities than previously.[**]

The regulations adopted in 1996, which require design capacities of $MMWWF_5$ and $MMDWF_{10}$, were published in OAR 34-41-120 (13) and (14). The anticipated compliance in the winter months with capacity at the $MMWWF_5$ would be 98% (59/60 = 0.983). Compliance in the summer months with capacity at the $MMDWF_{10}$ would be 99% (119/120 = 0.991). The use of these design flowrates assures compliance with the goals of EPA's water-quality regulations, which are designed to protect the environment if the regulations are met 95% of the time.

4. Estimating Current Maximum Monthly Design Flows

$MMDWF_{10}$

The Maximum Monthly Average Dry-Weather Flow would be the monthly average flow in the rainiest summer month of high groundwater. West of the Oregon Cascades, the MMDWF almost invariably occurs in May. On Graph # 1, the 10-Year MMDWF will be the anticipated monthly flow corresponding to the monthly rainfall accumulation during May with a 10% probability of occurrence in any given year.

The US Weather Bureau publishes statistical compilations for weather stations in Oregon by month. A convenient source is the Climatological Summary No. 20, Years 1951-1980 (see attached example). The 10-year May accumulation is indicated here as the 90% value. That is, the amount which exceeds 9 out of 10 totals which have been recorded in May.

With this approach to estimating $MMDWF_{10}$, note that is not necessary to have 10 years of plant flow data. Only about 4 to 8 good sets of Monthly Flow/Cumulative Rainfall data are needed to draw Graph # 1, showing $MMDWF_{10}$ at the 90% total for May. The statistics are developed through the rainfall data rather than through a database of plant flow records.

Another source of rainfall statistics is Johnson and Dart's Variability of Precipitation in the Pacific Northwest published in 1982 by the Portland State University Department of Geography. The Oregon State Meteorologist at OSU in Corvallis has extensive additional data and can advise on specific applications.

$MMWWF_5$

The Maximum Monthly Average Wet-Weather Flow represents the highest monthly average attained during the winter period of high groundwater. West of the Cascades, high groundwater is usually not attained until January, and the MMWWF (maximum monthly wet-weather flow) occurs in January. Sometimes the period of October-December produces significant storms, but the ground is still dry. Heavy storms generally do not begin to cause a reliable or consistent infiltration response until January.

Referring to the Climatological Summary, the 5-year January accumulation is listed as the 80% value. That is, the amount of rainfall that exceeds 4 out of 5 totals that have been recorded in January. On Graph #1, this 80% January rainfall will correspond to the current 5-year MMWWF.

5. Estimating Current Peak Daily Average Flow (5-Year PDAF)

In Western Oregon, $PDAF_5$ invariably corresponds to the 5-year storm: it is the flow that will result from a 5-year storm during a period of high groundwater. For convenience we recommend the 24-hour storm period for $PDAF_5$ analysis, as plant rainfall and flow records reflect the previous 24 hours. However, other time periods such as the 6-hour storm or 48-hour storm can be considered, where such data are available, and they may be more useful than 24-hour storm data in some cases.

$PDAF_5$ will not be directly available from plant records unless a 5-year storm was recently experienced during the high groundwater period of January-April. However, it can be determined by constructing a graph that shows the relationship between daily plant flow (MGD) and daily rainfall (inches per day). An example is attached as Graph # 2. Large storms going back several years should be used to define the graph, but one must use only records where the antecedent weather for each storm was wet and groundwater levels were high. Numerous large storms will not meet these conditions and should not be used.

On Graph # 2, $PDAF_5$ will correspond to the 5-year, 24-hour storm. This storm may be roughly estimated from isopluvial maps based on Weather Bureau records such as NOAA Atlas 2, Volume X, Figure 26. If a more refined 5-year, 24-hour storm intensity is desired, several decades of local rainfall data can be ranked and analyzed for probability of recurrence.

6. Estimating Current Peak Instantaneous Flow (PIF_5)

PIF_5 Estimate Using A Diurnal Peaking Factor

PIF_5 is the peak instantaneous or peak hourly flow associated with a 5-Year PDAF. That is, the peak flow resulting from a 5-year storm during high groundwater periods. The current PIF_5 may be reflected in plant records, or can be estimated by observing the diurnal peaking factors which characterize high-flow events at the facility. It is desirable to examine actual flow charts that were recorded during high-flow days to extract a suitable peaking factor (or peak-to-average ratio).

The peaking factor will be less during heavy flows than during normal flowrates. This reflects the relatively constant supply of infiltration which occurs only when the groundwater is high. Peaking factors developed from dry-weather periods do not reflect the diminished peaking caused by infiltration, and should not be applied to the $PIF_{5.}$

PIF_5 Estimate by Extrapolation (Graph # 3)

PIF5 may also be estimated by means of a probability graph, either using logarithmic probability paper or using a computation program to generate the graph. See attached example Graph # 3, where the PIF_5 was extrapolated from a known $PDAF_5$.

Sometimes this method seems to be the most rational way to estimate the PIF_5 which would be experienced if all bottlenecks were removed from the collection system to eliminate the peak-shaving effects of surcharging and overflows. The basis for this approach is annual probability of occurrence, and assuming that wet weather prevails.

It follows from this assumption that the year of interest will feature the $MMWWF_5$, and within it a $PDAF_5$ and PIF_5. The average annual flowrate will be the average of AWWF and ADWF, both of which are available from plant records. However, during dry years, the records should be adjusted for growth to a reasonably wet year (e.g. 1995-1996), consistent with our assumption of wet weather.

These assumptions yield the following probabilities of occurrence:

> The average annual flow, the mean of summer (ADWF) and winter (AWWF) flowrates, is likely to occur 6/12 of the time or 50% probability.
>
> A peak monthly flow, $MMWWF_5$, occurs 1/12 of the time or 8.3% probability.
>
> A peak weekly flow occurs 1/52 of the time or 1.9% probability
>
> The $PDAF_5$ occurs once in 365 days or 0.27% probability.

The PIF_5 occurs once in 8,760 hours or 0.011% probability.

Graph # 3 should always be drawn as a check on estimated flowrates. Graph # 3 will show whether the various flowrates are theoretically coherent. A reasonable statistical consistency will be apparent if the estimates are realistic.

PIF and $PDAF_5$ Estimates by TSS Records (Graph # 4)

Too often upstream sewage overflows or undersized meters make peak daily flow records of PDAF and PIF unusable. Using the recorded storm intensity and plant laboratory tests for high-flow days, it may be possible to use influent solids dilution as a surrogate flow meter. This approach entails the realistic assumption of somewhat constant per-capita solids delivery from the collection system in winter and early spring, after the initial fall flush.

Provided that test documentation reflects 24-hour composite samples, and provided that low-groundwater events which would skew the curve are excluded, solids dilution can be a valid approach to determining the true peak flows which correspond to known rainfalls. The attached example Graph # 4 shows an estimated PDAF derived from a curve of dilute TSS as low as 19 mg/l. The influent sewer either choked or spilled all flows above 1.45 MGD., as shown, but the PDAF was estimated at 2.5 MGD based on TSS.

7. Projecting Current Flowrates to the Design Year

There is no standardized approach to projecting from current baseline flowrates to the future design year. The traditional method involves a mechanical application of peaking factors derived from plant records and past experience. It has the virtue of tending to overestimate future flows and to yield amply sized facilities.

This type of systematic error results from applying the same peaking factor to the stormwater contribution as to growth components, despite the fixed statistical basis of the stormwater portion. However, any error here tends to be conservative and beneficial to the environment. A more rational approach consists of summing up all anticipated loadings from all foreseeable sources, and adding them to the current baseline flowrates. This approach tends to result in less excess capacity being designed into the project.

Regardless of the approach taken, all calculations should be clearly documented and annotated, and projections should be based on current flowrates. Both methods will normally involve various adjustments in addition to growth. For example, former overflows and exfiltration from the collection system that may have to be captured in the project, less any inflow removal expected, less any infiltration removal that may be counted on, etc.

8. Documentation and Calculations

Any facility plan or engineering design report should indicate how $MMDWF_{10}$, $MMWWF_5$, $PDAF_5$, and PIF_5 were calculated. Backup data and tabulations that were used should either be included in the text, or be attached in an appendix. Graphs #1 and 2 should be included to show how the baseline flowrates were estimated. Graph # 3 should also be included to illustrate the statistical coherence of both baseline and design-year flowrates. All data points shown in the graphs should be tabulated and identified as to month, year, etc.

Lists of design criteria for sewage treatment works should always include all relevant current and future criteria projected to the design year. The list or tabulation should include as a minimum: ADWF, AWWF, $MMDWF_{10}$, $MMWWF_5$, $PDAF_5$, and PIF_5.

9. Other Flow Criteria for Design

The engineer must usually consider several additional flowrate criteria in establishing the basis of design. Standard manuals of practice list a number of these and their applications. For example: peak 8-hour flow, peak weekly flow, seasonal average flow, minimum daily and hourly flow, dry-weather and wet-weather maximum month BOD and SS loadings, etc. Also many additional flow parameters are needed for lagoon water balances and plant solids balances. Where used, all such criteria should be defined and distinguished to avoid confusion with $MMDWF_{10}$, $MMWWF_{5}$, $PDAF_{5}$, and PIF_{5}.

10. Inquiries

Inquiries about these guidelines should be directed to DEQ regional water-quality plan review engineers.

REFERENCES

Isopluvials of 5-year 24-hour Precipitation, NOAA ATLAS 2, Volume X, Figure 26 (Oregon).

Monthly Precipitation Probability for Oregon in Climatography of the United States No. 20, Climatic Summaries for Selected Sites, 1951-1980: Asheville, N.C., National Climatic Data Center, NOAA, US Department of Commerce.

Descriptive Statistics, Monthly Precipitation Data (1940-1979), in Johnson and Dart, Variability of Precipitation in the Pacific Northwest: Spatial and Temporal Characteristics: Portland, Department of Geography, Portland State University, 1982.

ATTACHMENTS

Graph # 1 Example (Average Monthly Flowrate versus Total Monthly Rainfall)

Graph # 2 Example (Daily Flowrate versus Rainfall)

Graph # 3 Example (Flowrate versus Probability)

Graph # 4 Example (Flowrate versus TSS)

Isopluvial Chart Example (Western Oregon 5-year, 24-hour storm)

Rainfall Probability Table Example (Oregon City Gauge)

DSM:QSTP4.FPR

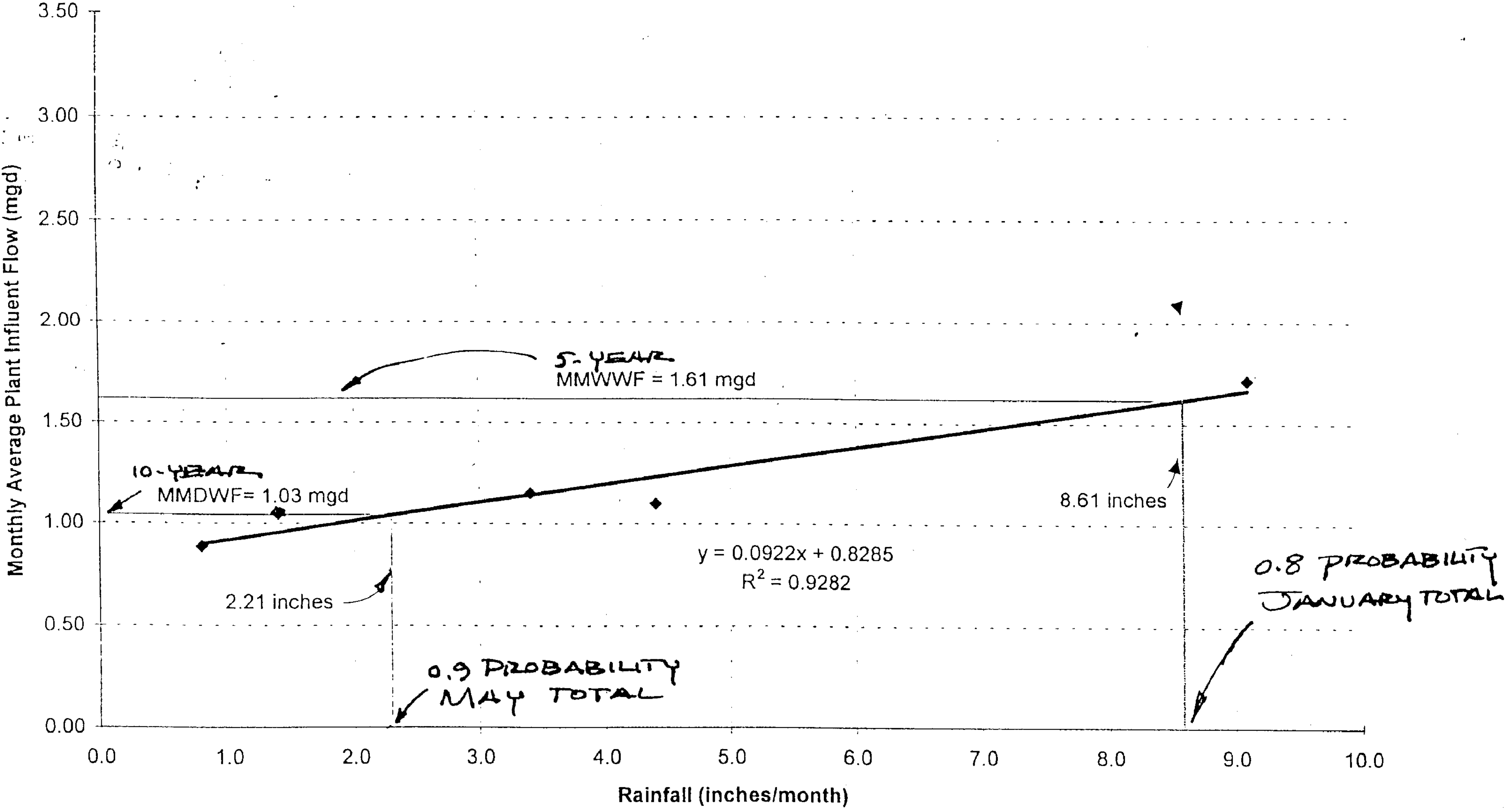
Orig. I.91

Rev. VIII.94

Rev. IV.96

Figure 1

Average Plant Flow vs. Winter Rainfall
(January - May, 1995)

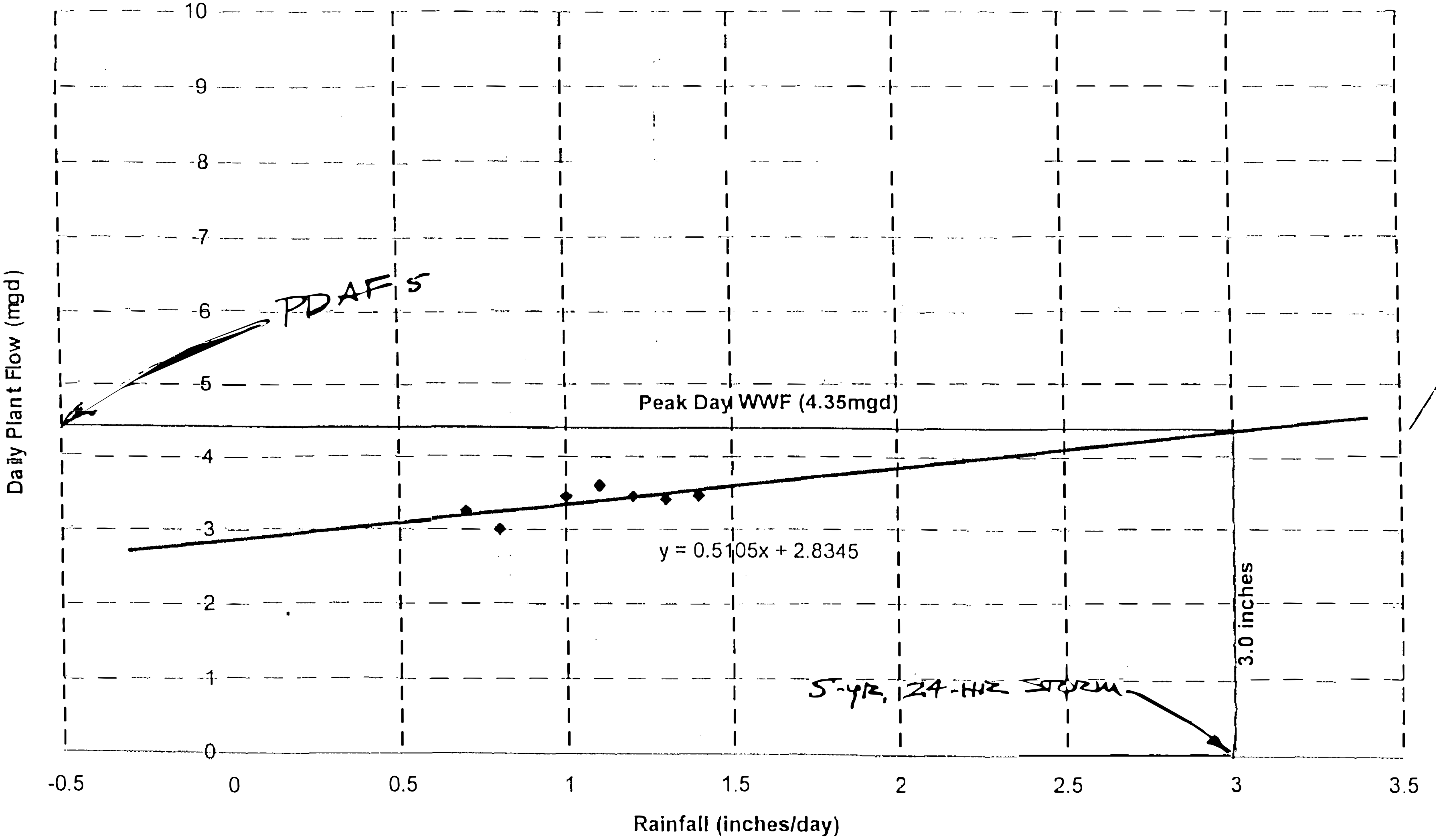


EXAMPLE
GRAPH #1

Figure 2

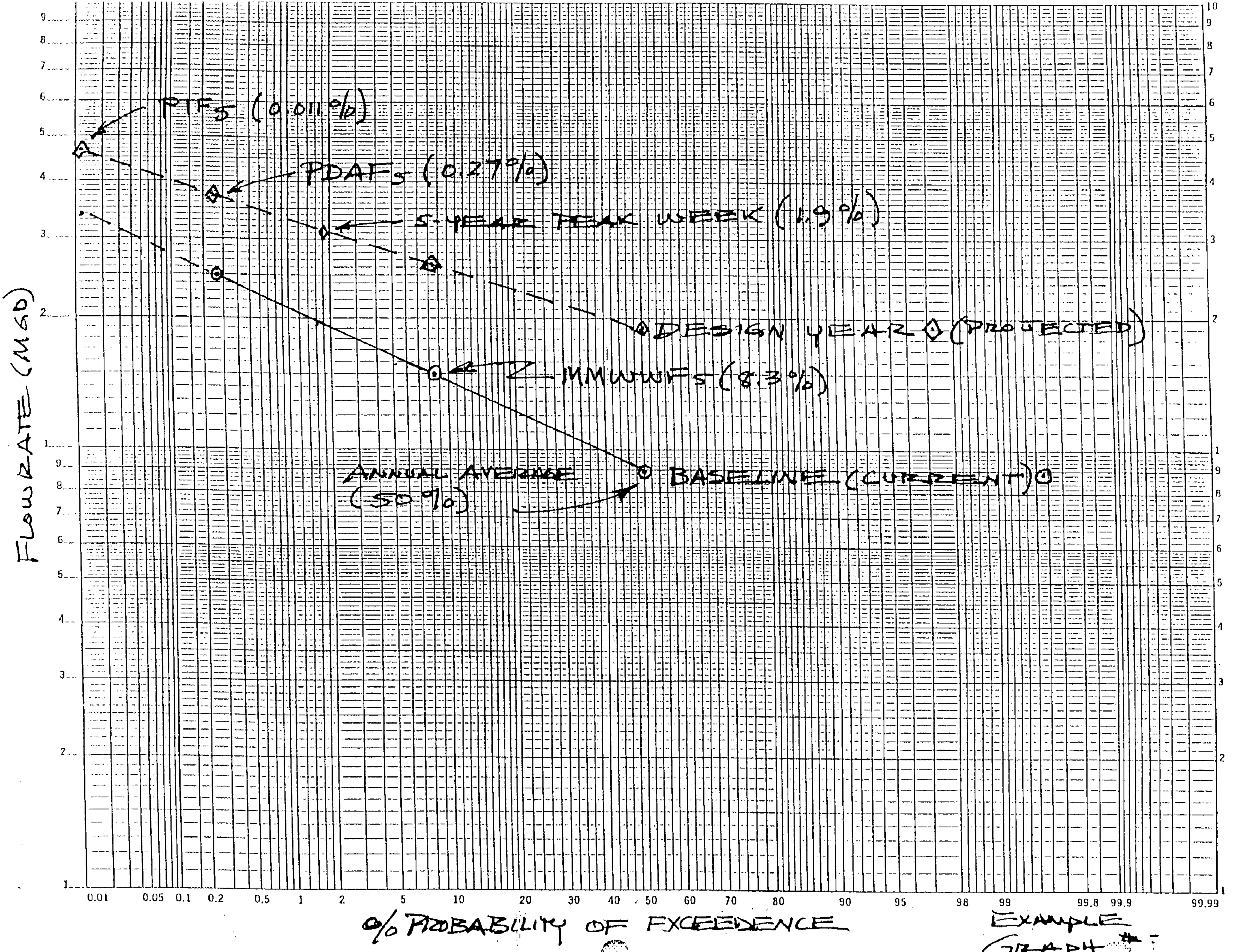
Plant Flow vs. Storm Rainfall

(Jan-May, 1992-1995)



c:\excel\reports\winston\wingrn3.xls

EXAMPLE
GRAPH #2

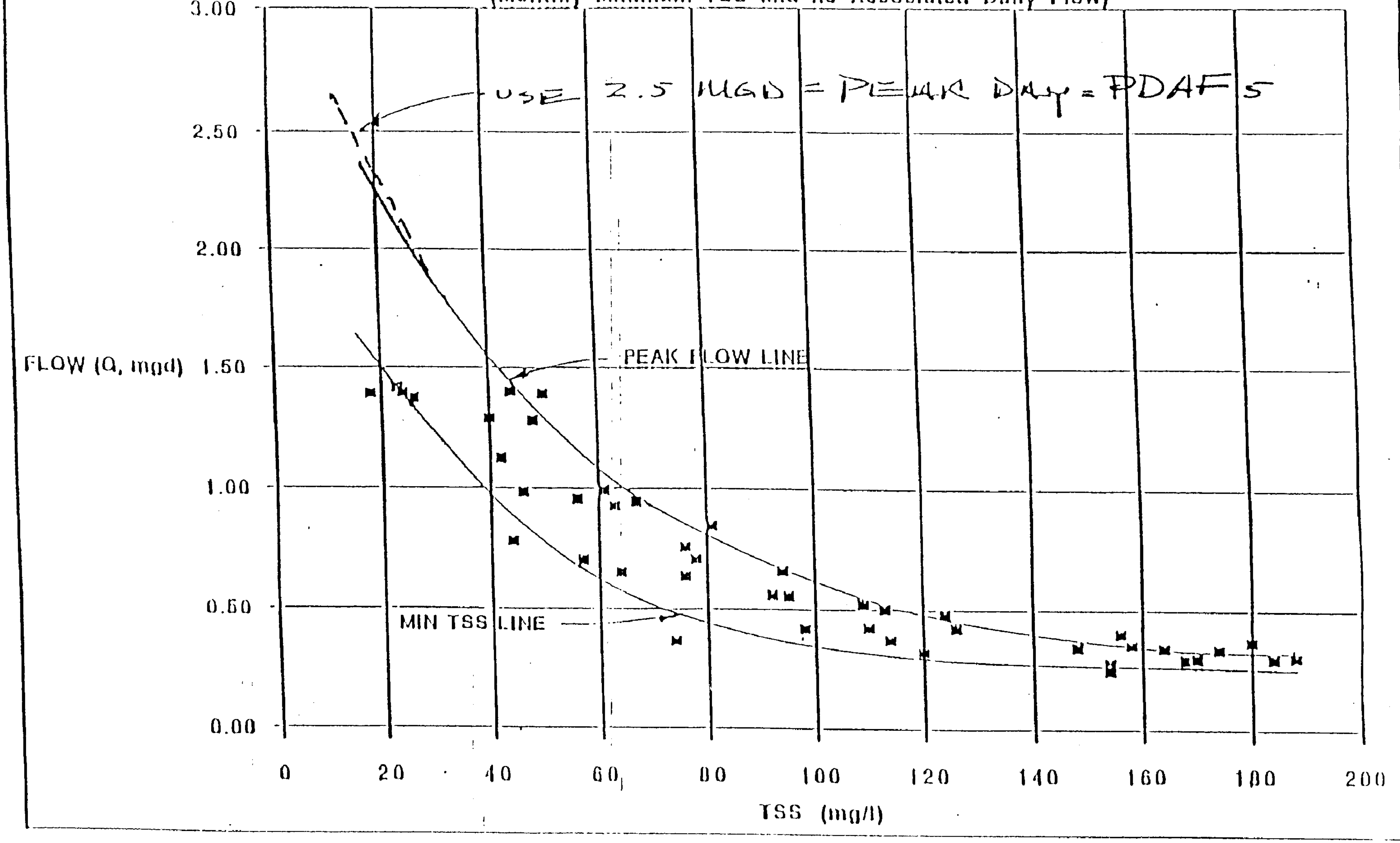


EXAMPLE GRAPH #

Flow vs TSS (Min Mo TSS, Oct,86

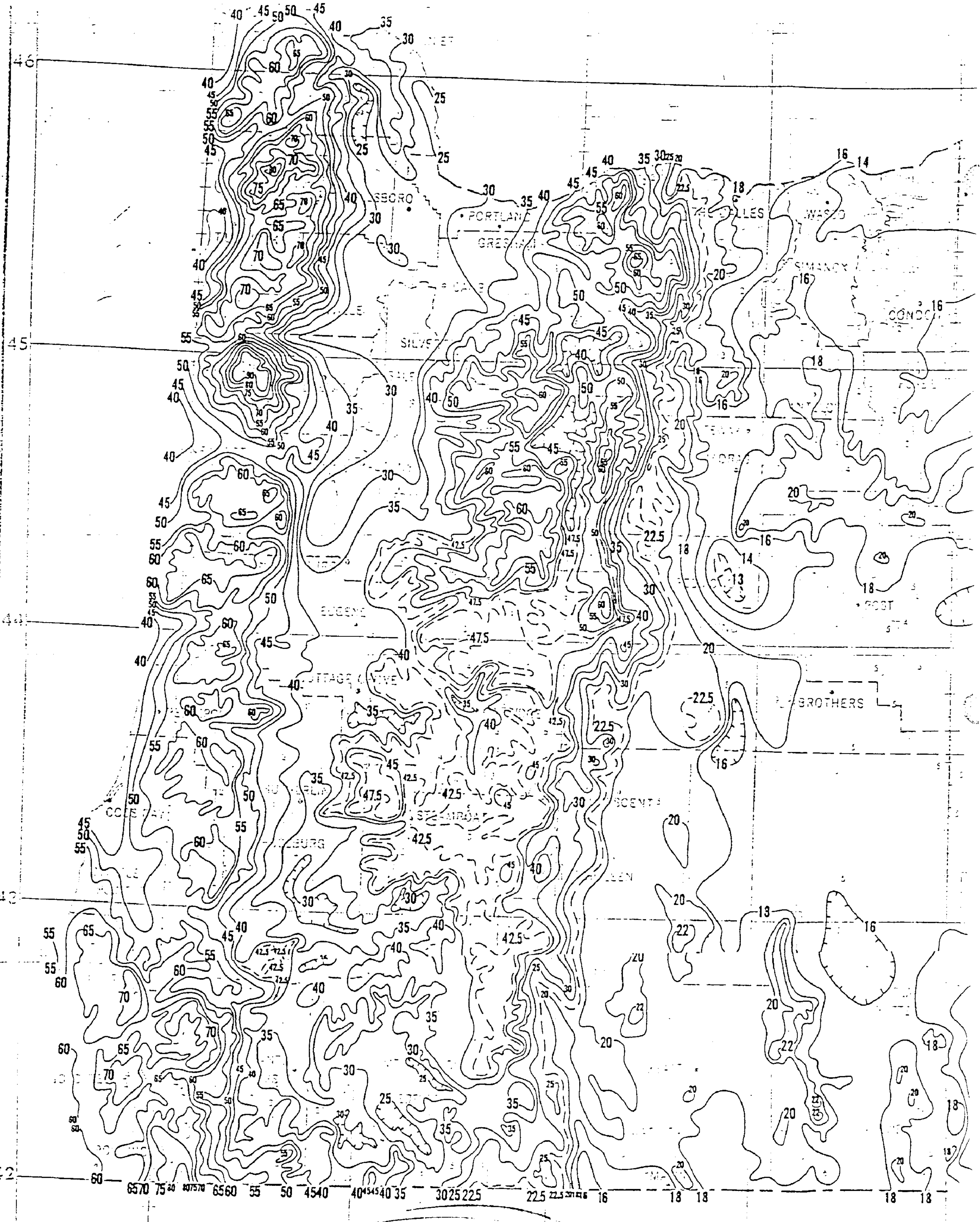
MEASURED STP FLOW vs TSS (Oct,86-Mar,90)

(Monthly Minimum TSS and Its Associated Daily Flow)



City of Oakridge

EXAMPLE
GRAPH #4
FLOWRATE VS. MIN. T.S.S.



5-YR, 24-HR
STORMS IN
TENTHS OF
AN INCH

NOAA ATLAS 2, Volume X

Prepared by U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service, Office of Hydrology

Prepared for U.S. Department of Agriculture.
Soil Conservation Service, Engineering Division

CLIMATOGRAPHY OF THE UNITED STATES NO. 20
OREGON CITY, OR

CLIMATOLOGICAL SUMMARY

PERIOD: 1951-80
ELEVATION: 167 FT

	TEMPERATURE (F)															PRECIPITATION TOTALS (INCHES)											
	MEANS			EXTREMES						MEAN NUMBER OF DAYS				DEGREE DAYS								SNOW			MEAN NUMBER OF DAYS		
										MAX		MIN															
	* DAILY MAXIMUM	* DAILY MINIMUM	* MONTHLY	RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	90 AND ABOVE	32 AND BELOW	32 AND BELOW	0 AND BELOW	* . HEATING BASE 65	* COOLING BASE 65	* MEAN	* GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	MEAN	MAXIMUM MONTHLY	YEAR	.10 OR MORE	.50 OR MORE	1.00 OR MORE
JAN	45.9	34.4	40.2	64+	58	15	9+	57	27	0	2	12	0	769	0	8.11	16.77	53	2.86	74	15	2.7	18.9	69	14	5	2
FEB	51.7	36.9	44.3	73+	68	29	13+	79	2	0	0	7	0	580	0	5.14	11.74	61	3.13	68	19	.4	5.2	62	11	3	1
MAR	55.5	38.0	46.8	77+	64	29	22	71	1	0	0	5	0	564	0	4.99	9.43	57	2.09	63	29	.7	11.2	51	12	3	1
APR	62.0	41.1	51.5	91+	57	29	28+	72	2	0	0	1	0	405	0	3.37	9.44	69	2.20	69	18	.0	.0		8	2	0
MAY	69.4	46.1	57.8	96	63	20	31+	54	1	1	0	0	0	232	9	2.64	5.80	60	1.58	63	06	.0	.0		7	1	0
JUN	75.1	51.3	63.3	99+	61	17	37+	76	3	2	0	0	0	107	56	1.87	4.48	69	1.93	69	23	.0	.0		4	1	0
JUL	82.4	54.4	68.4	107	56	19	41+	76	2	6	0	0	0	23	129	.56	2.82	74	.99	74	08	.0	.0		2	0	0
AUG	81.2	54.3	67.8	106+	77	17	41+	51	29	5	0	0	0	44	131	1.24	4.95	68	2.43	56	25	.0	.0		3	1	0
SEP	76.1	51.1	63.6	101+	58	7	33+	65	17	2	0	0	0	98	56	2.08	4.50	69	1.86	51	30	.0	.0		4	1	0
OCT	64.8	45.0	54.9	94	70	3	24+	71	28	0	0	1	0	313	0	3.79	7.69	56	2.40	55	09	.0	.0		9	2	1
NOV	53.4	39.2	46.3	73	70	2	9+	55	15	0	0	5	0	561	0	6.59	14.21	73	3.35	60	24	.2	2.0	78	12	4	2
DEC	47.5	36.1	41.8	66+	80	30	6+	64	17	0	1	8	0	719	0	8.02	14.78	64	3.22	64	22	1.2	13.6	68	14	6	2
YEAR	63.8	44.0	53.9	107	JUL 56	19	6	DEC 64	17	16	3	39	0	4415	381	48.40	16.77	JAN 53	3.35	NOV 60	24	5.2	18.9	JAN 69	100	29	9

*FROM 1951-80 NORMALS

ESTIMATED VALUE BASED ON DATA FROM SURROUNDING STATIONS

\+ ALSO ON EARLIER DATES.

DEGREE DAYS TO SELECTED BASE TEMPERATURES (F)

BASE	HEATING DEGREE DAYS												
BELOW	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
65	769	580	564	405	232	107	23	44	98	313	561	719	4415
60	614	440	409	259	113	37	0	10	30	166	411	564	3053
57	521	356	316	177	64	15	0	0	12	93	321	471	2346
55	466	305	260	129	38	8	0	0	6	58	267	409	1946
50	324	181	130	46	7	0	0	0	0	8	140	262	1098

BASE	COOLING DEGREE DAYS												
ABOVE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
55	7	5	6	24	125	257	415	397	264	55	6	0	1561
57	0	0	0	12	89	204	353	339	210	28	0	0	1235
60	0	0	0	0	45	136	264	252	138	7	0	0	842
65	0	0	0	0	9	56	129	131	56	0	0	0	381
70	0	0	0	0	0	13	43	52	12	0	0	0	120

DERIVED FROM THE 1951-80 MONTHLY NORMALS

PROBABILITY THAT THE MONTHLY PRECIPITATION WILL BE EQUAL TO OR LESS THAN THE INDICATED PRECIPITATION AMOUNT

MONTHLY PRECIPITATION (INCHES)

PROBABILITY LEVELS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
.05	2.22	1.95	2.16	.88	.90	.34	.00	.00	.14	.93	1.86	2.96
.10	2.99	2.43	2.61	1.19	1.15	.51	.00	.00	.35	1.29	2.49	3.71
.20	4.16	3.11	3.24	1.68	1.51	.78	.04	.12	.68	1.84	3.44	4.79
.30	5.18	3.68	3.75	2.11	1.82	1.04	.12	.29	.99	2.33	4.26	5.70
.40	6.18	4.23	4.23	2.54	2.12	1.30	.22	.49	1.31	2.82	5.06	6.56
.50	7.23	4.78	4.72	2.98	2.42	1.58	.34	.74	1.66	3.33	5.91	7.43
.60	8.40	5.38	5.24	3.48	2.75	1.90	.48	1.06	2.07	3.91	6.84	8.39
.70	9.77	6.08	5.83	4.07	3.14	2.28	.67	1.48	2.57	4.59	7.93	9.50
.80	11.56	6.97	6.58	4.83	3.64	2.80	.95	2.07	3.24	5.48	9.36	10.91
.90	14.37	8.33	7.73	6.04	4.42	3.62	1.41	3.11	4.34	6.89	11.59	13.09
.95	16.99	9.58	8.77	7.17	5.13	4.41	1.88	4.17	5.41	8.22	13.68	15.09

THESE VALUES WERE DETERMINED FROM THE INCOMPLETE GAMMA DISTRIBUTION.

5-YR JAN

10-YR MAY

EXAMPLE RAINFALL STATISTICS